Lake Champlain Basin Generalized Phosphorus Control Plan for the Vermont Agency of Transportation

STONE
ENVIRONMENTAL

PROJECT NO.

18-008-A

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PC

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Acknowledgements and Disclaimer

This project was undertaken by Stone Environmental, Inc. for the Vermont Agency of Transportation, with funding provided by the Agency.

The intent of this plan is to present the data collected, evaluations, analysis, designs, and cost estimates for the Vermont Agency of Transportation (VTrans). This document provides information for stormwater retrofit projects proposed to meet VTrans phosphorus management obligations in watersheds subject to a Phosphorus Control Plan (PCP) under *National Pollutant Discharge Elimination System (NPDES) General Permit 3-9007 for Stormwater Discharges form the State Transportation Separate Storm Sewer System (TS4)* (effective November 29, 2017). This plan is the regulatory document for VTrans to meet PCP obligations under General Permit 3-9007. If VTrans is included in PCPs submitted by any Municipal Separate Storm Sewer System (MS4) permittee, the information contained in this plan should supersede that information. Retrofit projects identified in this plan have not been fully assessed for feasibility or completely designed. The work completed has been done at a planning level and will be subject to change based on site conditions, permitting, budgetary constraints, and other unforeseen issues.

The still-unfolding coronavirus epidemic has, as of March of 2020, radically changed and will continue to affect both how VTrans and Vermont Agency of Natural Resources (ANR) staff members interface, and how work is completed to advance the first four-year implementation plan. VTrans and the consultant team gratefully acknowledge the flexibility provided by the ANR Stormwater Program staff during the preparation and submittal of this draft Generalized PCP.

Executive Summary

The Vermont Agency of Transportation (VTrans), through its Maintenance Bureau and Pollution Prevention and Compliance Section, is committed to maintaining compliance with a swiftly evolving variety of state and federal environmental regulations. The Vermont Agency of Natural Resources (ANR) and VTrans have worked together for several years to develop and implement permitting programs, plans, policies, and designs to comply with the Lake Champlain Phosphorus Total Maximum Daily Load (TMDL), finalized by the United States Environmental Protection Agency (EPA) on June 17, 2016.

This Generalized Phosphorus Control Plan (PCP) documents how VTrans will work towards the reduction of phosphorus (P) loading from roads, rights-of-way, and facilities under the Agency's control by over 20% within the next 20 years (by June 17, 2036). It first summarizes what VTrans has already done to develop the framework for a basin-wide PCP, and then provides a summary of how the agency intends to meet its goals.

The compliance and implementation strategy VTrans will use to achieve its target reductions across the PCP Area in the LCB will continue immediately from submittal of this Generalized PCP into development of the first four-year implementation plan. Work in progress described in this PCP continues into development of the first four-year implementation plan, specifically to refine determinations of what P reduction credit towards VTrans' target reductions can be expected from existing and planned structural stormwater treatment practices (STP)s, existing areas of localized erosion repaired in the last seven years, and areas of hydrologically connected roadway drainage systems recently improved to current standards. Existing application of non-structural practices such as street sweeping and catch basin cleaning is summarized within this document, and while future adjustments to crediting may be applied, the acres and basis for those credits is thoroughly documented in this PCP.

Prior to submittal of the first four-year implementation plan, VTrans will identify additional retrofits and improvement projects using previously compiled datasets and screening criteria enhanced with field verification. This implementation plan will focus on the Missisquoi Bay Lake segment but will opportunistically assess potential major retrofits and opportunities outside that watershed. The plan will include a combination of implementation of localized erosion and hydrologically connected road segment drainage repairs, structural STPs (both new treatment practices and retrofits to existing structural STPs), potential enhancements to non-structural control frequencies, and other projects (particularly floodplain reconnection) with the highest P cost-benefit. Through the execution of the four-year implementation plans, backed by robust tracking and accounting, VTrans expects to achieve its P reduction targets.

After completing the first four-year implementation plan with a Missisquoi Bay Lake segment focus, the focus of the TS4's PCP implementation plans will move south through the Lake Champlain basin as follows:

- 2024-2028: Focus on remaining Lake segments generally north of Main Lake (Isle La Motte, St. Albans Bay, Northeast Arm, Malletts Bay, and Shelburne Bay)
- 2028-2032: Focus on Main Lake and the Winooski River watershed
- 2032-2036: Focus on Lake segments generally south of Main Lake (Otter Creek, Port Henry, South Lake A, and South Lake B).

As envisioned in this Generalized PCP, over a third of the impervious acres anticipated to be managed with structural measures constitute maintenance-level road drainage asset repairs or localized erosion repairs. This application is anticipated to result in two-thirds of the required annual P load target reduction. In Lake segments where these measures coupled with non-structural control application did not appear sufficient to demonstrate P reduction target achievement, areas to be managed with conceptual structural STPs were estimated, preferring infiltration-based practices and those with the highest P reduction cost-benefit.

The Generalized Plan is conservative, demonstrating that VTrans may meet its target P reductions without the benefit of several innovative strategies that are progressing, but for which results are not yet available.

Correction of gullying and large areas of active erosion, as well as corrections at stormwater system outlets, remain areas of active investigation across multiple State agencies, Regional Planning Commissions and municipalities, watershed stewardship organizations, and other partners. As implementation plans are developed, VTrans expects that they will be informed by the progress and findings of the VTrans and ANR research project *Quantifying Nutrient Pollution Reductions Achieved by Erosion Remediation Projects on Vermont's Roads*, which is now underway and will be completed in 2021. VTrans also expects that major upgrades to road embankments and culverts where improvements would address both existing drainage issues and reduce vulnerability to damage from floods, where risk, vulnerability, or criticality have been identified in VTrans's Transportation Resilience Planning Tool will become a possibly substantial factor in prioritization and completion of improvements when those data become available for areas within the Lake Champlain Basin.

Natural resource restoration projects, and particularly floodplain reconnection projects, may be credited as a stormwater treatment practice in the context of the VTrans PCP if the floodplain area to be reconnected is also connected to a TS4 roadway or other VTrans-controlled contributing drainage. Preliminary evaluations of the potential for floodplain reconnection in the VTrans PCP Area will be completed as the first implementation plan is developed. However, more exhaustive evaluation of how to execute and credit floodplain reconnection where VTrans roads and facilities contribute runoff upstream of the restoration practice will be possible through application of results from Vermont's Functioning Floodplains Initiative. While the project outputs will not be complete until 2021, the initiative will develop and apply methodologies for evaluating river reach and watershed-scale restoration of stream, riparian, wetland, and floodplain function. The initiative seeks to track and publicize the natural and socio-economic assets derived from connected and naturally functioning floodplains and wetlands. These and other emerging innovative approaches represent a strong confluence of regulatory priorities, maximizing the opportunity to achieve greater benefits for all compared to a narrow focus on the reduction of P load from VTrans paved roads and facilities.

Generalized Phosphorus Control Plan, Lake Champlain Basin, Vermont Agency of Transportation

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Abbreviations

ANR	Vermont Agency of Natural Resources
BMP	Best Management Practice
DEC	Department of Environmental Conservation
DI	Drop Inlet
EPA	Environmental Protection Agency
HHC	Highly Hydrologically Connected
LHC	Low Hydrologically Connected
MATS	Maintenance Activity Tracking System
MHC	Moderately Hydrologically Connected
MRGP	Municipal Roads General Permit
MSGP	Multi-Sector General Permit
NPDES	National Pollutant Dischrage Elimintation System
PCP	Phosphorus Control Plan
REI	Road Erosion Inventory
SCI	Small Culverts Inventory
STP	Stormwater Treatment Practice
SWMP	Stormwater Management Program
TMDL	Total Maximum Daily Load
TS4	Transportation Sseparate Storm Sewer System
VTrans	Vermont Agency of Transportation

1. Introduction and Background

The Vermont Agency of Transportation (VTrans), through its Maintenance Bureau and Pollution Prevention and Compliance Section, is committed to maintaining compliance with a swiftly evolving variety of state and federal environmental regulations. The Vermont Agency of Natural Resources (ANR) and VTrans have been working together for several years to develop and implement permitting programs, plans, policies, and designs to comply with the Lake Champlain Phosphorus Total Maximum Daily Load (TMDL), finalized by the United States Environmental Protection Agency (EPA) on June 17, 2016.

This Generalized Phosphorus Control Plan (PCP) documents how VTrans will work towards the reduction of phosphorus (P) loading from roads, rights-of-way, and facilities under the Agency's control by over 20% within the next 20 years (by June 17, 2036). It first summarizes what VTrans has already done to develop the framework for a basin-wide PCP, and then provides a summary of how the agency intends to meet its goals.

1.1. VTrans Stormwater Permitting

As part of its Phase 1 Implementation Plan[1] developed in response to the Lake Champlain P TMDL, the ANR, in December 2016, issued the National Pollutant Discharge Elimination System (NPDES) General Permit 3-9007 for Stormwater Discharges from the State Transportation Separate Storm Sewer System[2] (TS4) to VTrans (effective November 27, 2017). The TS4 General Permit is the primary regulation ensuring that stormwater discharged from VTrans owned or controlled impervious surfaces is managed according to State water quality policy. It combines VTrans' compliance obligations from several permit programs, including the Municipal Separate Storm Sewer System (MS4) General Permit and its associated Flow Restoration Plan and VTrans requirements, Multi-Sector General Permit (MSGP), and Operational (post-construction) Stormwater Permit.

Section 9.2 of the TS4 General Permit requires VTrans to develop and implement a PCP, in phases, that will identify and document a suite of best management practices (BMPs) capable of achieving required reductions in the amount of P in stormwater discharges in each of 11 Lake segments, as required by the TMDL. That plan must, at minimum, estimate the area (acres or road miles) to be treated, and the extent and type of BMPs that will be implemented to meet the entire P load reduction.

VTrans is required to meet a series of interim performance milestones that first culminate in the completion this conceptual PCP for the entire TS4 within the Lake Champlain Basin (LCB) by April 1, 2020, and creation of the first of several four-year implementation plans by October 1, 2020. Below is the compliance schedule from Section 9.2.C of the permit, outlining the Agency's progress in meeting these milestones. Additional information about each of the progress submittals through and including the October 1, 2019 submittal is available at https://arcg.is/0DS4LC0 and in Appendix D.

- January 1, 2018: Submit Notice of Intent and Stormwater Management Program.

[1] https://dec.vermont.gov/watershed/restoring/champlain
[2] https://dec.vermont.gov/watershed/stormwater/transportation-general-permit

- VTrans submitted its Notice of Intent[3] and Stormwater Management Program (SWMP)[4] document, outlining its expected actions and commitments for compliance with Vermont water quality policies and regulations over the next five years, to ANR in December 2017.

- April 1, 2018: Establish the baseline P load and reductions needed.
  - VTrans first developed GIS data defining the spatial extents and geographic coverage of the TS4 within the LCB, then worked with ANR to extract draft developed lands acreages and resulting draft P base loads from ANR's existing land use-land cover dataset (Appendix A and at website above).
- October 1, 2018: Complete GIS inventory of P loading factors.
  - The GIS inventory of loading factors was developed by VTrans in consultation with ANR to first establish the baseline P load, and then to determine other factors to more accurately refine P load allocation for the TS4 across the LCB (Appendix B and at website above).
- April 1, 2019: Complete development of coefficients of loading rates.
  - VTrans and ANR considered the development of loading rate coefficients for each of the four land cover classes and associated P loading factors. Factors adjusting P loading rates by degree of hydrologic connectivity and road slope were developed only for paved roadways, distributing P base load proportionately to VTrans roadways based on each road segment's risk of contributing disproportionate P loads to surface waters (Appendix C and at website above).
- October 1, 2019: Submit progress report on VTrans.
  - The progress submittals above, as well as inventory and assessment work completed through VTrans' other commitments under the TS4 General Permit, were summarized and the groundwork laid for completion of a conceptual PCP for the entire TS4 within the LCB (Appendix D and at website above).
- April 1, 2020: Complete generalized statewide Phosphorus Control Plan.
- October 1, 2020: Submit 1st 4-year implementation plan (Phase I).
- April 1, 2021 and every 6 months thereafter (April 1st and October 1st): Submit semi-annual report on VTrans implementation.
- October 1, 2024: Submit 2nd 4-year implementation plan (Phase II).
- October 1, 2028: Submit 3rd 4-year implementation plan (Phase III).
- October 1, 2032: Submit 4th 4-year implementation plan (Phase IV).
- No later than June 17, 2036: Complete implementation of the approved PCP.

1.2. Summary of Watershed Characteristics

The P-impaired watersheds included in the VTrans PCP Area encompass the entirety of the LCB in Vermont, except for the Burlington Bay direct drainage. A summary of the VTrans PCP area by land cover type (Road/linear facility or Parcel-based facility) and type of land cover (Developed Impervious, Paved Road, Unpaved Road, and Developed Pervious) is provided in Table 1.

[3] https://anrweb.vt.gov/PubDocs/DEC/Stormwater/PublicNotice/7892-9007/TS4%20VTrans%20NOI_Final_signed.pdf
[4] https://anrweb.vt.gov/PubDocs/DEC/Stormwater/PublicNotice/7892-9007/VTrans%20Final%20SWMP%20-%20December%205%202017.pdf

Table 1. Summary of VTrans PCP Area by Land Cover Classification (acres)

Lake Segment	Linear Facilities and Right-of-Way Areas (acres)				Parcel-Based Facility Areas (acres)				Total
	Developed Impervious	Paved Roads	Unpaved Roads	Developed Pervious	Developed Impervious	Paved Roads	Unpaved Roads	Developed Pervious	
South Lake B	16.83	481.54	0.00	775.63	3.98	1.22	0.00	9.74	1,288.94
South Lake A	1.94	69.11	0.00	61.30					132.35
Port Henry	0.75	15.29	0.00	8.10					24.14
Otter Creek	57.93	1,181.20	0.00	1,445.40	43.96	42.53	0.00	269.14	3,040.16
Main Lake	65.38	1,645.12	12.30	3,029.56	41.68	36.57	0.00	223.05	5,053.66
Shelburne Bay	10.15	163.66	0.00	189.58	0.84	2.62	0.00	11.15	378.01
Burlington Bay	--	--	--	--	--	--	--	--	--
Malletts Bay	56.67	1,013.46	0.00	1,604.31	24.13	0.99	0.00	47.44	2,747.00
Northeast Arm	5.86	159.51	0.00	164.01	1.83	0.00	0.00	2.54	333.76
St. Albans Bay	9.90	187.20	0.00	321.73	5.60	0.00	0.00	1.03	525.45
Missisquoi Bay	38.18	910.14	0.00	1,167.43	28.87	26.78	0.44	115.14	2,286.97
Isle La Motte	2.29	46.93	0.00	37.56					86.78
Total	265.89	5,873.17	12.30	8,804.61	150.89	110.71	0.44	679.22	15,897.23

The portion of the Vermont P base load (2001-2010) falling within developed lands source areas as summarized in Table 3 of the 2016 P TMDL[5], as compared to the portion of those developed lands owned and controlled by VTrans, is included in Table 2. The portion of VTrans-managed developed lands by Lake segment varies from 0% in the area draining to the Burlington Bay Lake segment, where VTrans has no land subject to this TMDL, to 8.6% in the watershed draining to the St. Albans Bay Lake segment.

[5] https://ofmpub.epa.gov/waters10/attains_impaired_waters.show_tmdl_document?p_tmdl_doc_blobs_id=79000

Table 2. Summary of Total Developed Land and VTrans Developed Land Base P Loads

Lake Segment	Total Developed Lands Base P Load (mt/yr)	VTrans Base P Load (mt/yr)	Percent of Base P Load Within VTrans PCP Area
South Lake B	9.0	0.66	7.3%
South Lake A	2.3	0.09	3.9%
Port Henry	0.7	0.02	2.7%
Otter Creek	20.2	1.64	8.1%
Main Lake	35.1	2.24	6.4%
Shelburne Bay	3.4	0.17	4.9%
Burlington Bay	1.7	0.00	0.0%
Malletts Bay	17.2	1.19	6.9%
Northeast Arm	3.9	0.19	4.8%
St. Albans Bay	2.6	0.23	8.6%
Missisquoi Bay	17.0	1.19	7.0%
Isle LaMotte	0.9	0.06	7.0%
Total	114.0	7.7	6.7%

The developed lands portion of the P base loads, and target P reductions to be managed under the VTrans PCP, are summarized by Lake segment in Table 3.

Table 3. Phosphorus Base Loads and Reduction Targets by Lake Segment

	P Base Load (kg/yr)				Target P Load Reduction (kg/yr)		
Lake Segment	Linear Facilities	Parcel Facilities	Total	% Reduction Needed to Meet Allocation	Linear Facilities	Parcel Facilities	Total
South Lake B	646.16	8.49	654.66	21.10%	136.34	1.79	138.13
South Lake A	89.46		89.46	18.10%	16.19		16.19
Port Henry	18.69		18.69	7.60%	1.42		1.42
Otter Creek	1,472.19	163.72	1,635.91	15.00%	220.83	24.56	245.39
Main Lake	2,115.80	127.02	2,242.82	20.20%	427.39	25.66	453.05
Shelburne Bay	162.62	4.64	167.26	20.20%	32.85	0.94	33.79
Malletts Bay	1,153.92	36.20	1,190.12	20.50%	236.55	7.42	243.98
Northeast Arm	186.27	2.85	189.11	7.20%	13.41	0.21	13.62
St. Albans Bay	217.58	7.12	224.70	21.70%	47.21	1.55	48.76
Missisquoi Bay	1,101.05	85.96	1,187.02	34.20%	376.56	29.40	405.96
Isle La Motte	63.30		63.30	8.90%	5.63		5.63
Total	**7,227.04**	**436.00**	**7,663.04**		**1,514.40**	**91.52**	**1,605.91**

2. BMPs Considered in Plan Development

Four classes of conceptual stormwater best management practices (BMPs) were considered for development and inclusion in the Generalized Plan:

- Areas of VTrans property treated with structural stormwater BMPs
- Areas of VTrans property treated with non-structural practices
- Areas of localized erosion treated with structural BMPs
- Areas of VTrans roadway and drainage upgraded to meet standards

A process schematic illustrating the framework used to evaluate each class of practices is provided in Figure 1. The practices evaluated included both classes where design, application, treatment, and crediting for P reduction opportunities and constraints are well understood (structural stormwater treatment practices and non-structural controls), and classes where applicability and crediting—at the initiation of plan development—remained areas of active investigation and consideration by both VTrans and ANR.

Implementation plans are anticipated to include combinations of implementation of localized erosion and hydrologically connected road segment drainage repairs, structural STPs (both new treatment practices and retrofits to existing structural STPs), potential enhancements to non-structural control frequencies or extents, and other projects with the highest P cost-benefit. As each class of practices was evaluated, repairs to road drainage assets (Section 2.2) and to areas of localized erosion (Section 2.3) were found to generally be more cost-effective and to have greater co-benefits (for example, regarding flood resilience and the safety of the traveling public) compared to treatment of impervious surfaces with green stormwater infrastructure or other structural stormwater treatment practices (Section 2.1). Although not included in Figure 1, natural resource restoration projects (Section 2.4), and particularly floodplain reconnection projects, represent a critical opportunity for cost-effective P reduction and maximization of co-benefits, and will be an area of continued development and application in the implementation plans.

Details of the evaluations completed and results for each class of conceptual practices are provided in the sections below.

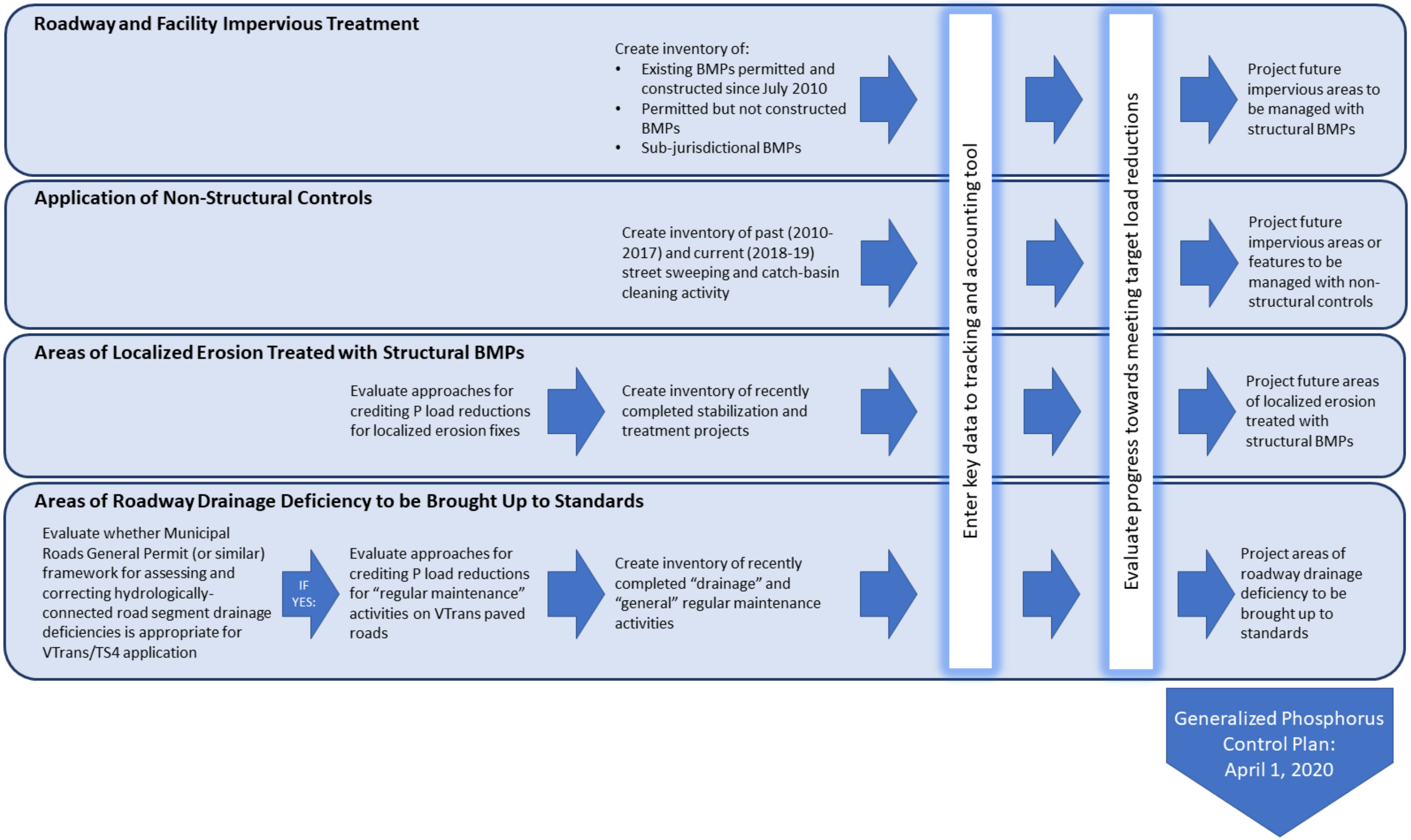

Figure 1. VTrans Generalized Phosphorus Control Plan Framework Schematic

2.1. Structural Stormwater Treatment Practices

Structural stormwater treatment practices (STPs) are one of the measures available to VTrans to meet P reduction targets in accordance with the TS4 General Permit. Structural treatment practices are intended to detain, treat, and better manage runoff from well-defined areas of impervious surface, such as roads, parking lots, or rooftops. These treatment practices range from older detention ponds managing only peak flows to dry swales, gravel wetlands, and other green stormwater infrastructure. Structural stormwater treatment practices historically have been incorporated into VTrans' asset portfolio as transportation projects improving roads and facilities implemented to comply with regulatory requirements.

In developing the Generalized PCP, enhancements to maintenance activities already being performed by VTrans that have quantifiable P reduction benefits were typically preferred over construction of new structural STPs (Sections 2.2 and 2.3). Recognizing that these improvements alone may not be sufficient to achieve the required target P reductions in all Lake segments, structural STP opportunities were evaluated to allow for adaptive management during the development and execution of the four-year implementation plans.

Existing and planned structural STPs throughout the TS4 were first evaluated to determine progress made towards meeting P reduction targets in each Lake segment. Next, a GIS desktop evaluation was completed to screen pervious areas within the VTrans right-of-way for application of conceptual structural STPs. Paved road areas potentially managed by conceptual structural STPs, and P base loads and reductions potentially creditable through construction of the conceptual STPs, were evaluated within each Lake segment, as were feasibility constraints and potential implementation costs. During the development of the first four-year implementation plan, VTrans will more closely evaluate structural STP retrofit feasibility, and will continue to determine acres managed and P reduction credit anticipated from existing and planned structural STPs.

2.1.1. Existing Structural Stormwater Management Practices

VTrans has identified upgrades and retrofits to practices implemented after the adoption of the 2002 Vermont Stormwater Management Manual design standards, including both jurisdictional and sub-jurisdictional improvements. Operational permits and plans issued by the Vermont Department of Environmental Conservation (DEC) Stormwater Program for projects permitted and constructed after July 1, 2010 were reviewed to assess and credit the additional benefit provided by these systems (Map 2). Future VTrans projects that have been issued operational stormwater permits, but which are not constructed as of January 2020, are referred to in this assessment as "planned STPs". For planned STPs, the anticipated acres managed and associated P reductions are included in projections where possible. Treatment practices planned for implementation as part of the Flow Restoration Plans are also included, both as completed (for Allen Brook) and as anticipated in future years where sufficient information existed. Many of the planned FRP projects are anticipated to be adjusted during design to increase P removal efficiency while retaining peak flow mitigation benefits.

As qualifying structural STPs were identified, the P base loads to be managed by each existing and in-process structural STPs were calculated. Phosphorus removal efficiencies and P load reduction benefits expected for existing and planned structural BMPs were calculated consistent with the structural STP types and crediting already established by ANR. VTrans projects in early development stages, such that stormwater requirements are not fully developed, should be reviewed on an annual basis and any newly identified structural STPs should be incorporated into the BMP tracking spreadsheet currently maintained by VTrans.

Nearly 160 structural STPs presently exist and another 64 are planned, which together will manage stormwater from 235.4 acres of impervious area and 814.1 acres of pervious area within the VTrans PCP Area (Figure 1 and Table 4). The majority of existing structural STPs are grass channels that manage stormwater from moderately hydrologically connected paved roads areas with less than 10% slope (Table 5). Most existing structural STPs (93%) manage stormwater from paved roads (Table 5).

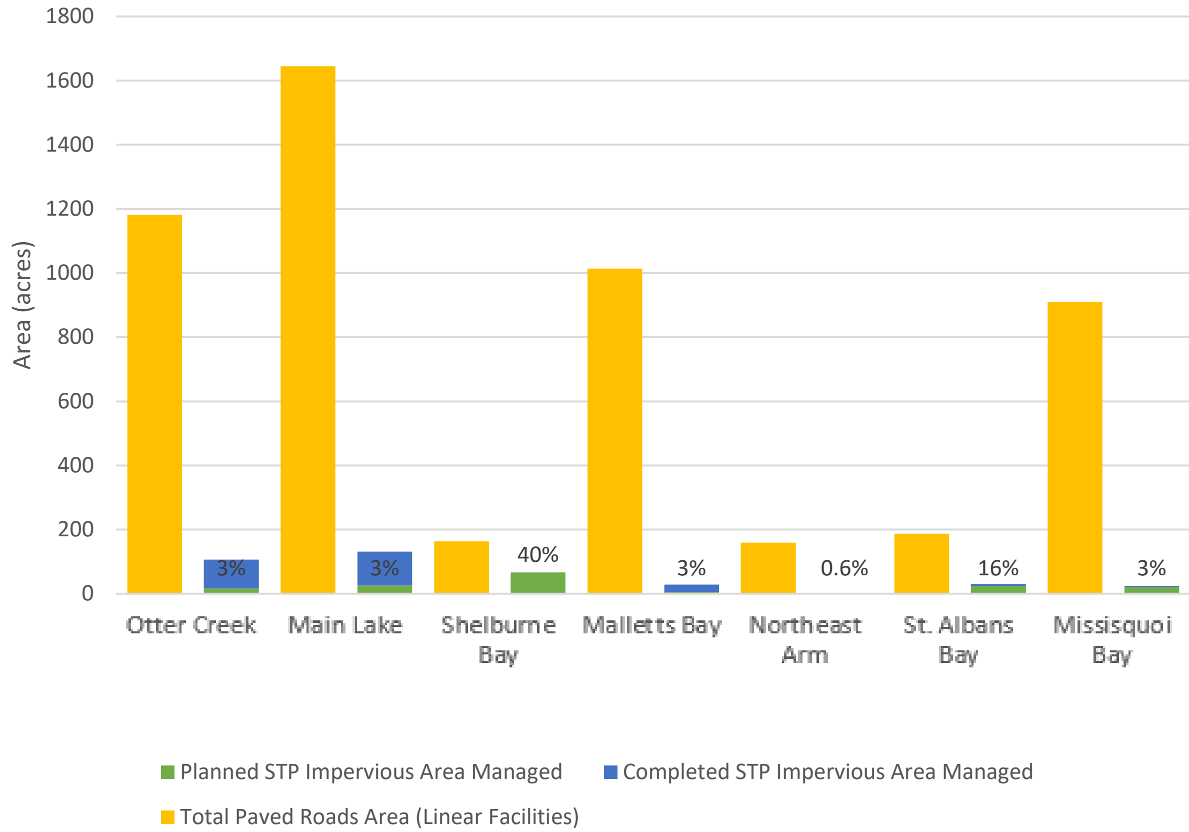

Figure 2. VTrans Impervious Areas Managed by Existing and Planned Structural STPs

Table 4. Summary of Areas Managed by Existing and Planned Structural STPs (ac)

Lake Segment	Completed STP Impervious Area Managed	Completed STP Pervious Area Managed	Planned STP Impervious Area Managed	Planned STP Pervious Area Managed
Otter Creek	17.8	90.0	16.0	28.4
Main Lake	26.3	106.0	25.4	38.7
Shelburne Bay			66.0	118.7
Malletts Bay	22.3	24.0	5.7	28.6
Northeast Arm			0.9	0.2
St. Albans Bay	5.7	8.9	24.9	302.7
Missisquoi Bay	3.8	57.5	20.7	10.5
TOTAL	75.8	286.3	159.6	527.8

Table 5.Summary of Existing and Planned Structural STPs by Land Cover Classification

Land Cover Classification	Total Structural STPs Installed
Developed Impervious	1

Paved Roads - Facilities	14
Paved Roads, 0-10% Slope, High Hydrologic Connectivity	75
Paved Roads, 0-10% Slope, Low Hydrologic Connectivity	9
Paved Roads, 0-10% Slope, Moderate Hydrologic Connectivity	122
Total	221

Table 6: Summary of Existing and Planned STPs by Practice Type

Structural STP Type	Completed	Planned	Total
Bioretention (infiltrating)	0	2	2
Disconnection	23	9	32
Dry Swale (w/ underdrain)	3	2	5
Extended Dry Detention Pond	34	11	45
Grass Channel	81	9	90
Gravel Wetland	1	22	23
Infiltration Chambers	1	0	1
Infiltration Trench	3	2	5
Median Filter	0	3	3
Reduction of existing impervious	1	0	1
Sand filter (infiltrating)	6	0	6
Sand filter (w/ underdrain)	1	0	1
Underground Detention Chamber	0	3	3
Wet pond/ Created Wetland	2	1	3
Wet Swale	1	0	1
Total	157	64	221

Phosphorus load reductions from existing and planned projects account for a small portion of the total required reduction for each Lake segment, ranging from 0.4% (Missisquoi Bay) to 30% (Shelburne Bay), with an average of 5% in Lake segments with existing structural STPs (Figure 2 and Table 7). Many existing structural STPs are either grass swales, which have low P removal efficiency, or were designed primarily to manage the one-year, 24-hour storm event in order to comply with stormwater flow TMDLs (Table 6).

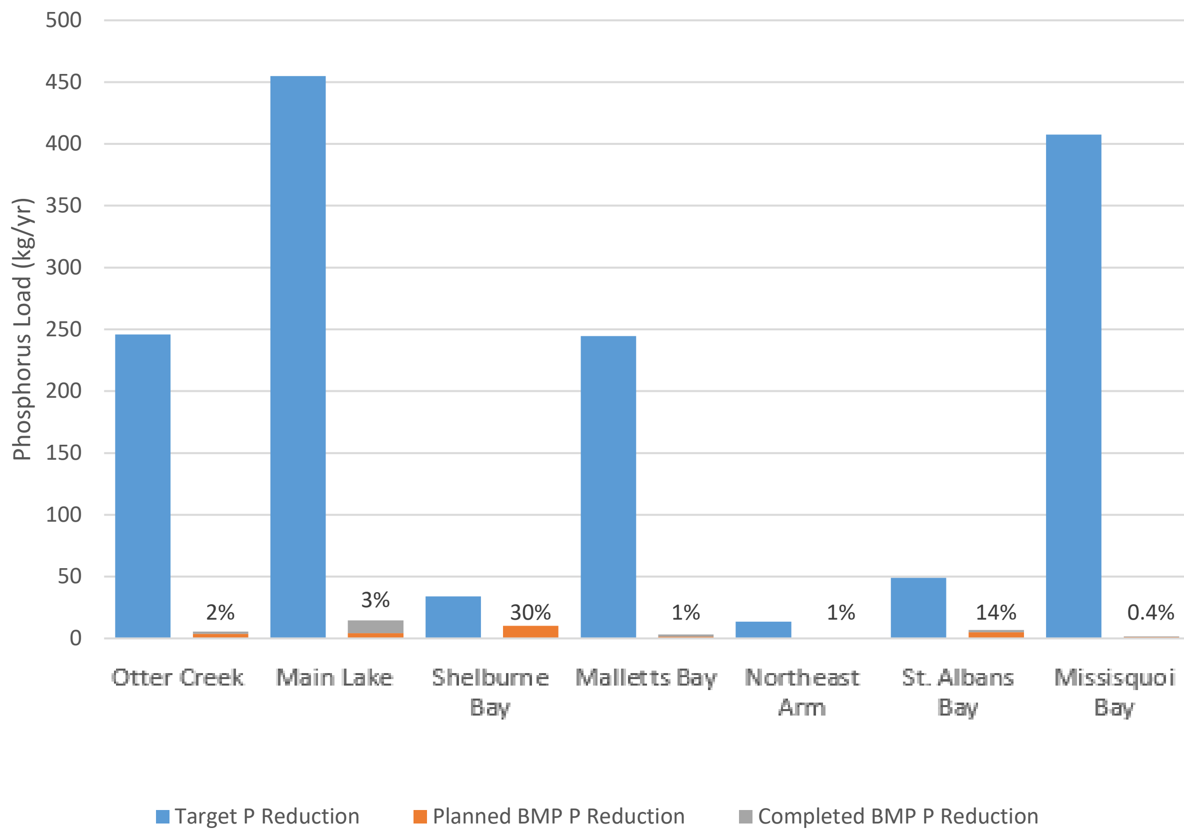

Figure 3.Phosphorus Load Reductions from Existing and Planned Structural STPs by Lake Segment

Table 7. Summary of P Load Reductions from Existing and Planned Structural STPs (kg/yr)

Lake Segment	Completed STP P Load Reduction	Planned STP P Load Reduction	Total P Load Reduction	Target P Load Reduction*	% of Total P Reduction
Otter Creek	1.8	3.8	5.6	246.0	2%
Main Lake	10.3	4.2	14.5	454.9	3%
Shelburne Bay		10.1	10.1	33.9	30%
Malletts Bay	1.9	1.4	3.3	244.6	1%
Northeast Arm		0.2	0.2	13.7	1%
St. Albans Bay	1.8	5.0	6.8	48.9	14%
Missisquoi Bay	0.5	1.1	1.6	407.5	0.4%
Total	16.28	25.83	42.11	795.91	5%

One of the most cost-effective structural STPs available to VTrans is the retrofit of replacement of existing guardrails, where removal of timber curb effectively disconnects runoff from adjacent paved roads areas, allowing unconcentrated flow of runoff into the pervious right-of-way (ROW). Several such disconnections are included in VTrans' BMP tracking table for 'structural' STPs. Where conditions are right (relatively gentle slopes and sufficient pervious area width available in the ROW), the guardrail and timber crib removal may be completed by VTrans personnel, and operation/maintenance of the resulting disconnection practice consists primarily of maintaining the guardrail (if only timber curb is removed and guardrail remains) and mowing –

all of which is part of normal VTrans operations. Opportunities for implementing disconnections through timber curb removal will be evaluated more closely in development of the first four-year implementation plan.

2.1.2. Analysis of Treatment Potential using Structural STPs

A screening analysis was conducted to determine the potential for successfully siting and implementing structural STPs to manage runoff from linear facilities within the VTrans PCP Area. Areas of developed pervious land within the VTrans right-of-way were identified using a desktop GIS analysis, and the drainage areas directing runoff to each pervious area were delineated. Suitable structural STP types were assigned to each pervious potential STP area based on physical and feasibility constraints, as well as cost considerations. Conceptual structural STP were identified by targeting pervious right-of-way areas in proximity to and downslope of large areas of VTrans paved road impervious cover. The resulting comprehensive set of potential structural STP opportunities will be further refined and prioritized based on additional feasibility and cost considerations, through field confirmation, and as the need for structural STP implementation versus other, more cost-effective measures comes into focus during the development and execution of the four-year implementation plans.

The results of this screening analysis are intended to be used only in the context of this Generalized PCP. Further refinement of structural STP siting and sizing, and careful evaluation of feasibility constraints and permitting needs, will be necessary prior to implementation. The assessment results are highly dependent on the assumptions outlined below, which will be adjusted both as the first four-year implementation plan is developed and as the implementation plans are executed.

2.1.2.1. Conceptual Structural STP Opportunity Assessment Methods

Areas of developed pervious land within the VTrans right-of-way greater than 0.1 acres and adjacent to highly hydrologically connected road segments (referred to as “STP areas”) were selected. Drainage areas adjacent to and up-slope of the STP areas were calculated using the watershed function within ArcGIS. The resulting drainage areas were categorized based on ownership (VTrans vs. non-VTrans) and surface type (impervious vs. pervious). A processing document describing the steps undertaken to derive the conceptual STP areas and their contributing drainage areas is available upon request.

The desktop GIS analysis only considered developed pervious areas adjacent to impervious roadway surfaces for conceptual STP selection. VTrans parcel-based facilities and associated impervious surfaces constitute a small portion of the total P base load (10%) and are better suited to individual assessment and application of both jurisdictional and sub-jurisdictional structural STPs.

A conceptual STP selection workflow was developed to preferentially select high-performing, low-cost STPs that align with VTrans’ needs and operation/maintenance preferences (Figure 3). Where site and soil considerations indicated that multiple STP types could be sited, P removal efficiency, cost, and maintenance impacts were considered. Conceptual STP areas that intersected with a water body or floodplain were removed from consideration as structural STPs and were instead considered as potential floodplain reconnection projects (Section 2.4). Similarly, conceptual STP areas intersecting Vermont Significant Wetlands Inventory areas were flagged as potential wetland restoration projects.

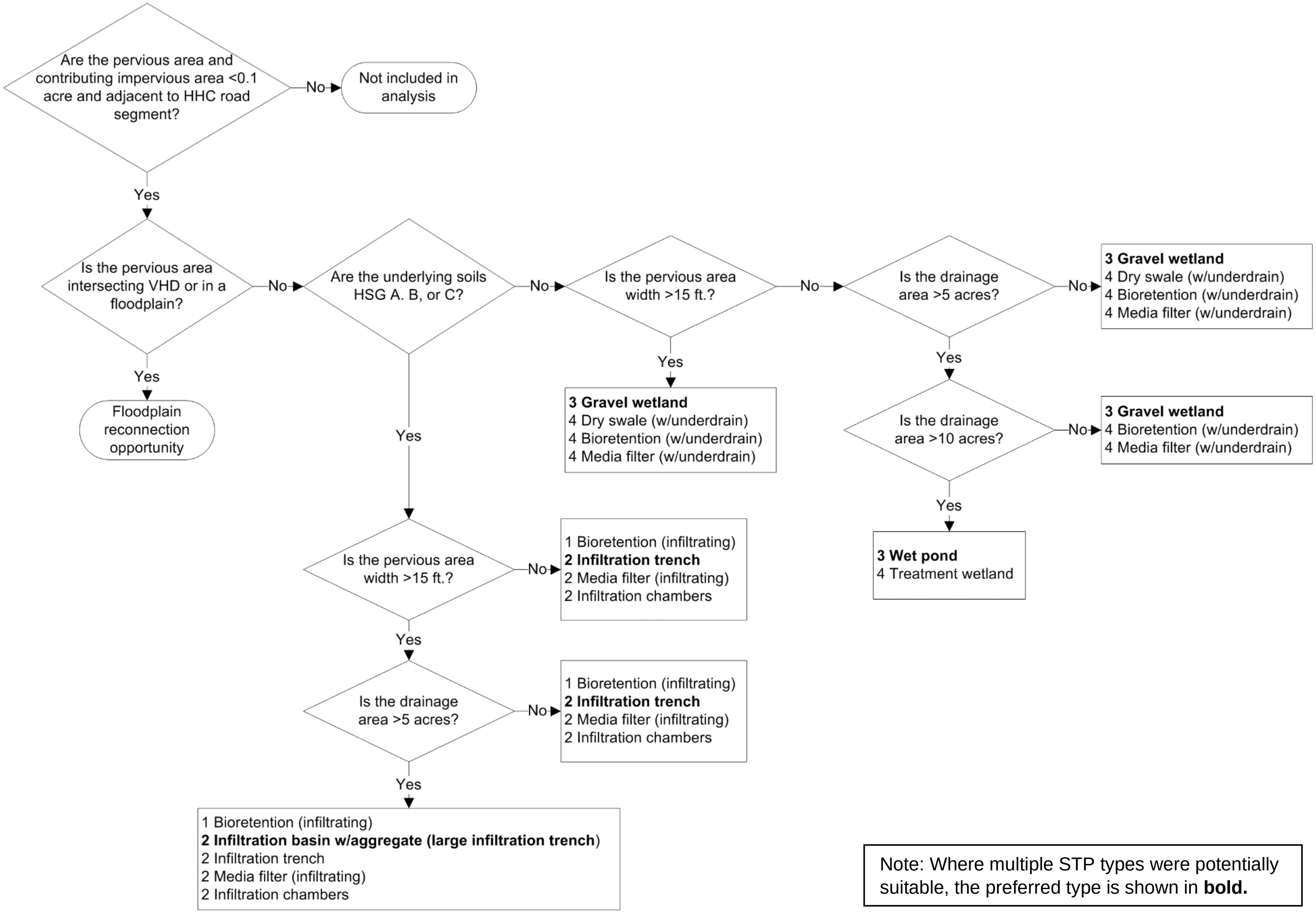

Figure 4. Conceptual STP Selection Decision Logic Flowchart

In addition to performance, implementation cost and long-term maintenance impacts are key factors when selecting structural STPs. Cost estimates per STP type were derived from 2016 Opti-Tool values[6] and refined using implementation costs for recent STP retrofit projects provided by VTrans (Table 8). Each STP unit cost includes construction cost; a 35% allowance for design, engineering, and contingency; and a cost adjustment factor of 1.2, accounting for VTrans project development processes and sometimes-complex permitting situations. In lieu of detailed evaluation of operation and maintenance costs, a maintenance factor was derived from 2016 Opti-Tool estimates of annual labor hours required to maintain each type of STP. The maintenance factor allowed normalization of STPs that may be less costly to construct but expensive to maintain (and vice versa). Once STP types were selected for each conceptual STP area, stormwater treatment volumes, P base loads, P load reductions, and estimated STP implementation costs were calculated for all conceptual STPs.

Table 8. Conceptual STP Implementation Costs and Maintenance Factors

STP Type	STP Implementation Cost ($/CF storage volume)	Maintenance Factor	Implementation and Maintenance Cost ($/CF storage volume)
Wet Pond	$7.90	0.98	$15.63
Gravel Wetland	$10.21	0.70	$17.33
Treatment Wetland	$10.21	0.70	$17.33
Infiltration Trench	$14.52	0.70	$24.65
Bioretention (infiltrating)	$17.97	0.65	$29.71
Dry Swale (infiltrating)	$17.97	0.65	$29.71
Bioretention (w/ underdrain)	$18.14	0.65	$30.00
Dry Swale (w/ underdrain)	$18.14	0.65	$30.00
Media Filter (infiltrating)	$20.85	1.00	$41.70
Media Filter (w/ underdrain)	$20.85	1.00	$41.70
Infiltration Chambers	$78.86	not included	

2.1.2.2. Conceptual Structural STPs: Potential P Reduction Benefits and Costs

Once STP types were assigned to available pervious areas, the conceptual STPs were sized to manage the water quality storm (WQv)[7] using typical design assumptions, so that P load reductions and costs could be estimated for each conceptual STP (Appendix E). Load reductions were calculated using the methodology and calculations embedded in the ANR BMP Tracking Table (3/13/2020 version)[8]. Cost estimates per conceptual STP were calculated using the implementation costs above (Table 8), and cost-benefit metrics ($/acre and $/kg P removed) were calculated.

All results of the conceptual structural STP screening assessment are accessible in a web app, available at https://bit.ly/2WULVJd. As the first four-year implementation plan is developed, refinements to STP characteristics and the STP selection workflow may be made and further prioritization will occur. In addition to the attributes used in the conceptual STP selection workflow (STP area size, drainage area size, proximity to water bodies, hydrologic connectivity of adjacent road segments, soil type, etc.), the variables outlined in Table 9 and others will be considered.

[6] https://www3.epa.gov/region1/npdes/stormwater/ma/green-infrastructure-stormwater-bmp-cost-estimation.pdf
[7] https://dec.vermont.gov/sites/dec/files/wsm/stormwater/docs/Permitinformation/2017%20VSMM_Rule_and_Design_Guidance_04172017.pdf
[8] https://dec.vermont.gov/sites/dec/files/wsm/stormwater/docs/MS4/BMPTrackingTable_03132020.xlsx

Table 9. Examples of Conceptual Structural STP Attributes for Prioritization

STP Attribute	Notes
Slope	Higher slope typically leads to higher costs
Existing STP present?	BMP retrofits typically have lower costs
Floodplain permit potentially required?	Mitigation measures can increase cost and slow project delivery
VSWI permit potentially required?	Mitigation measures can increase cost and slow project delivery
RTE or Significant Natural Community present?	Mitigation measures can increase cost and slow project delivery
High crash zone?	BMPs sited in these areas have long-term maintenance concerns
Adjacent to interstate?	BMPs sited in these areas can access Federal funding

Over 8,000 conceptual structural STPs were identified that have the potential capacity to manage stormwater from 2,821 acres of paved roads area and 4,910 acres of developed pervious area within the VTrans PCP Area (Figure 4 and Table 11). The majority of conceptual structural STPs identified were infiltration trenches and gravel wetlands (Figure 5). The inclusion of HSG C soils as potentially suitable for infiltration trenches at a low infiltration rate (0.17 inches/hour) may have resulted in an artificially high preponderance of infiltration trench STPs. This assumption will be revisited through field screening during the development of the first four-year implementation plan. Port Henry was the only Lake segment with no conceptual STP opportunities identified, with the Main Lake, Otter Creek and Malletts Bay Lake segments containing the most opportunities (Table 10).

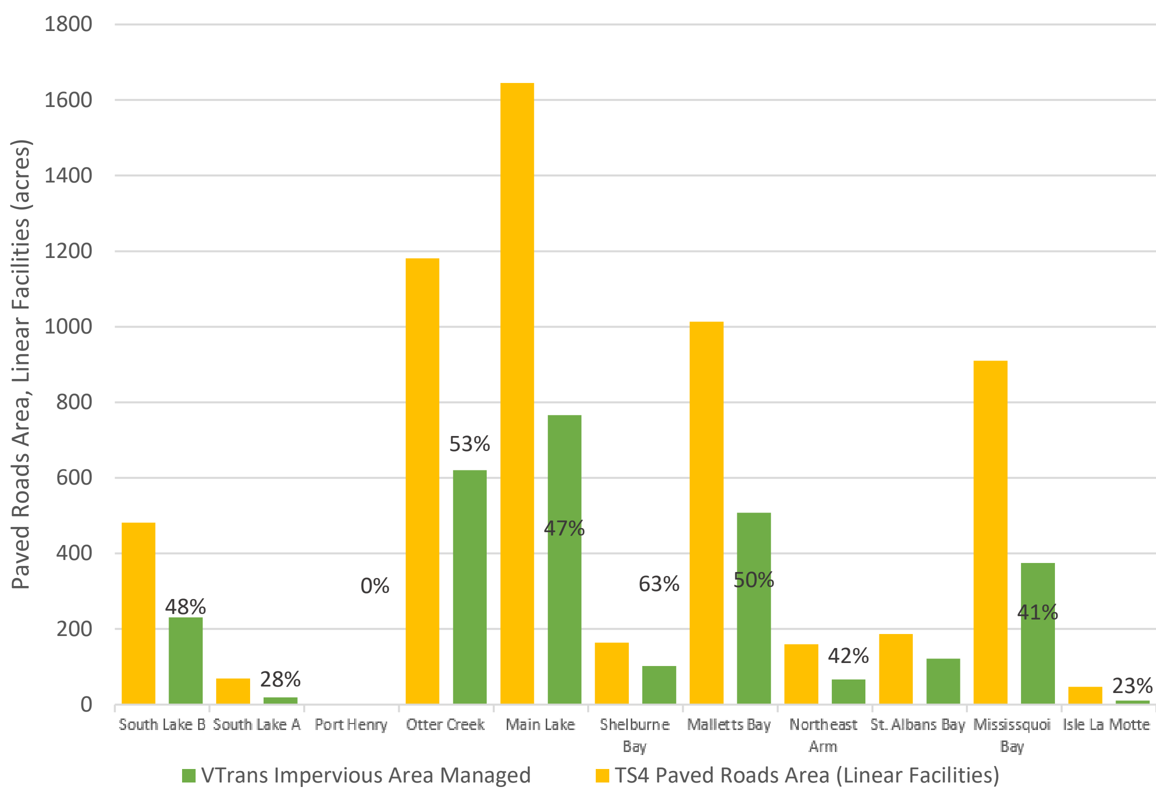

Figure 5. VTrans Paved Roads Area Potentially Managed by Conceptual Structural STPs

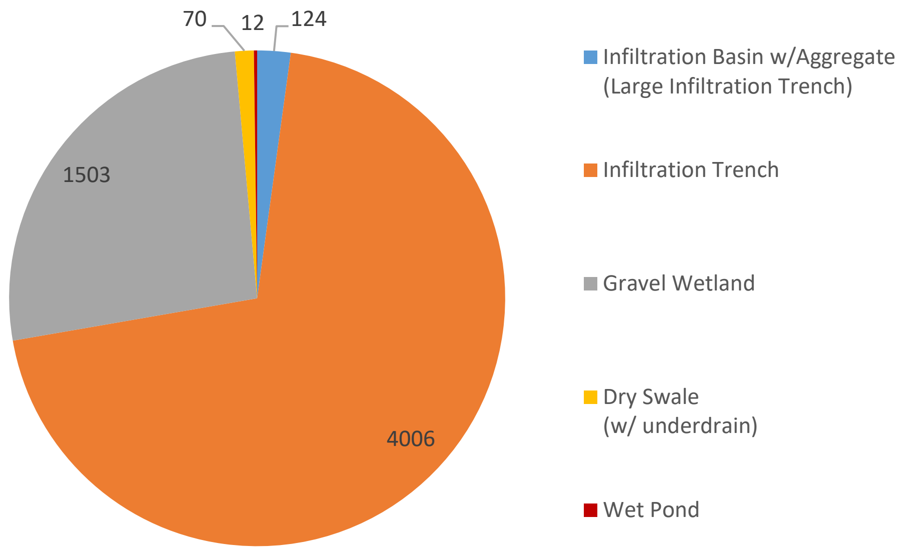

Figure 6. Conceptual Structural STPs by STP Type

Table 10. Summary of Conceptual structural STP Opportunities by Lake Segment

Lake Segment	Infiltration Basin w/Aggregate (Large Infiltration Trench)	Infiltration Trench	Gravel Wetland	Dry Swale (w/ underdrain)	Wet Pond	Floodplain Reconnection	Total
South Lake B	9	360	140	3	1	168	681
South Lake A		6	42	2		18	68
Port Henry							-
Otter Creek	27	779	360	23		473	1,662
Main Lake	36	1,066	393	8	3	780	2,286
Shelburne Bay	4	79	47			52	182
Malletts Bay	22	865	219	7	4	393	1,510
Northeast Arm	1	64	75	12		71	223
St. Albans Bay	7	119	25		2	53	206
Missisquoi Bay	18	656	190	13	2	379	1,258
Isle LaMotte		12	12	2		18	44
Total	124	4,006	1,503	70	12	2,405	8,120

Table 11. Summary of VTrans Paved Roads Area Potentially Managed by Conceptual STPs (acres)

Lake Segment	Conceptual STP Area	Developed Pervious Area Managed	Paved Roads Area Managed	Total VTrans Acres Managed	Total VTrans PCP Paved Roads Area (Linear Facilities)	Total VTrans PCP Area (Linear Facilities)	Paved Roads Area Potentially Managed (%)
South Lake B	8.3	437.6	231.2	677.1	481.5	1,274.0	48%
South Lake A	0.8	22.5	19.5	42.8	69.1	132.4	28%
Port Henry	0.0	0.0	0.0	0.0	15.3	24.1	-
Otter Creek	21.9	951.1	620.1	1,593.2	1,181.2	2,684.5	53%
Main Lake	27.7	1,516.3	766.1	2,310.1	1,645.1	4,752.4	47%
Shelburne Bay	2.6	169.1	102.4	274.1	163.7	363.4	63%
Malletts Bay	17.0	903.6	507.9	1,428.5	1,013.5	2,674.4	50%
Northeast Arm	2.5	69.6	66.3	138.5	159.5	329.4	42%
St. Albans Bay	3.1	167.8	121.7	292.6	187.2	518.8	65%
Missisquoi Bay	13.1	660.8	374.7	1,048.6	910.1	2,115.7	41%
Isle LaMotte	0.4	11.5	11.0	22.9	46.9	86.8	23%
Grand Total	97.4	4,910.0	2,821.0	7,828.4	5,873.2	14,956.0	48%

Conceptual structural STPs have the potential to manage a large portion of the P reduction target in most Lake segments, ranging from 55% (Missisquoi Bay) to 248% (Northeast Arm) (Figure 6). Nearly half of the Lake segments in the VTrans PCP Area could fully reach P reduction targets through application of the conceptual structural STPs (Table 12).

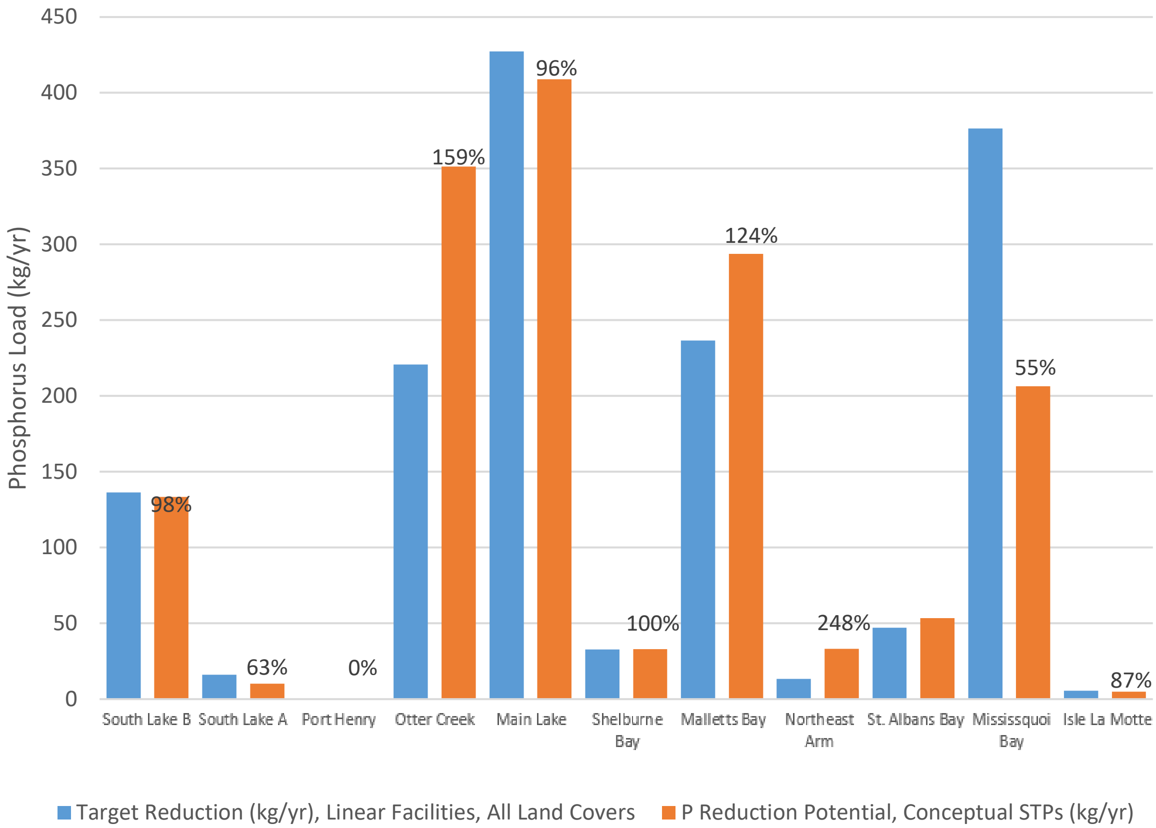

Figure 7. P Load Reductions Possible with Conceptual Structural STPs by Lake Segment

Table 12. Summary of P Reduction Possible from Conceptual Structural STPs

Lake Segment	P Reduction Possible (kg/yr)	Target Reduction (kg/yr)	Total % of Target Reduction Possible
South Lake B	133.4	136.3	98%
South Lake A	10.2	16.2	63%
Port Henry	0.0	0.0	-
Otter Creek	351.5	220.8	159%
Main Lake	409.0	427.4	96%
Shelburne Bay	32.9	32.8	100%
Malletts Bay	293.8	236.6	124%
Northeast Arm	33.2	13.4	248%
St. Albans Bay	53.5	47.2	113%
Missisquoi Bay	206.4	376.6	55%
Isle LaMotte	4.9	5.6	87%
Total	1,528.9	1,513.0	101%

Although conceptual structural STPs have the potential to manage the majority of the required P reduction targets for linear facilities in the VTrans PCP Area, the costs of using these measures alone would be prohibitive. The average cost for each conceptual structural STP type ranges from $18,900 (gravel wetlands) to $151,900 (wet ponds) with an average implementation cost of $24,000 per STP (Table 13). The total cost to implement all the conceptual structural STPs identified in this analysis would be $136,947,800, with an average cost per annual P reduction of $97,100/kg P/yr and an average cost per impervious acre managed of $50,800/acre. These costs are only associated with structural STP implementation and do not account for the life-cycle maintenance and repair costs associated with structural STPs, although these were considered in the initial STP selection process (see Section 2.1.2.1).

Table 13. Summary of Conceptual Structural STP Implementation Costs (2020 dollars)

STP Type	Total Conceptual STP Implementation Cost	Average Cost per STP	Average of Cost per kg P Load Reduced ($/kg/yr)	Average Cost per Impervious Acre Managed ($/ac)
Infiltration Basin w/Aggregate (Large Infiltration Trench)	$18,484,500	$149,100	$119,400	$58,300
Infiltration Trench	$86,394,100	$21,600	$90,900	$54,800
Gravel Wetland	$28,385,700	$18,900	$107,200	$38,900
Dry Swale (w/ underdrain)	$1,860,300	$26,600	$181,600	$64,600
Wet Pond	$1,823,300	$152,000	$183,200	$42,500
Total	$136,947,800	$24,000	$97,100	$50,800

2.2. Structural Correction of Road Drainage Deficiencies

Over the past year, a method has been developed by VTrans in coordination with ANR to assess roadway and drainage deficiencies, and to subsequently quantify P load reductions for improvements that are considered regular maintenance activities on VTrans paved roads. Examples include ditching, guardrail maintenance, or culvert or outfall repair/replacement, where these activities result in a demonstrable P load reduction or improvement in a road segment's condition. This approach is comparable to ANR's requirement for municipalities to compete Road Erosion Inventories (REI) of hydrologically connected road segments under the Municipal Roads General Permit (MRGP)[8] and as incorporated into the MS4 General Permit[9]. This requirement is not part of the TS4 General Permit. VTrans and ANR have worked during the development of this Generalized PCP to determine whether VTrans should develop and maintain a similar Road Erosion Inventory as a component of its PCP.

VTrans continues to work with ANR to more closely define standards and criteria for hydrologically connected road segments within the TS4, where an approach similar to the MRGP standards may be applied. As consensus is reached, a similar workflow may be followed as for the other classes of BMPs included in the Generalized PCP. Existing areas where roadway drainage deficiencies have been brought up to standards since July 2010 are being compiled into a desktop inventory of roadway drainage improvement projects that may be eligible for P reduction credit. Paved road acres or miles where deficiencies have been addressed will be calculated, resulting in estimates of what P load reduction credit may reasonably be granted for existing road drainage projects across the LCB.

This Generalized PCP applies the evaluation and methodology described below to estimate acres of paved roads area where existing drainage deficiencies may be brought up to standards in each Lake segment, the types of conceptual BMPs or drainage improvements that would be best suited in each application, and the P load removal credit achieved for each conceptual application.

2.2.1. Evaluation of VTrans Asset Inventories in PCP Area

The road erosion inventory, scoring, and prioritization system DEC developed for the MRGP was evaluated, acknowledging that the MRGP is targeted to gravel roads and ditches and thus does not always represent conditions within the VTrans highway network. A review of VTrans existing data sources and inventories was conducted to evaluate how existing data could be used to emulate the inventories that are being conducted on a municipal level through the REI. The following VTrans asset inventories and their associated Inventory Field Manuals were considered:

- Small Culverts Inventory (SCI) and SCI Field Manual
- Guardrail Inventory and Guardrail Field Manual (May 2107)
- Ditch/Swale Inventory and the TS4 Drainage Inventory Field Guide

The following fields within these inventories were determined to be most relevant for understanding present road drainage conditions and possible drainage deficiencies:

- SCI – Culvert Condition (Inlet, Outlet and Culvert Barrel) and Treatment
- SCI – Culvert Sediment (Inlet and Outlet)
- SCI – Culvert Erosion (Inlet and Outlet)
- SCI – Sink Hole present

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[8] https://dec.vermont.gov/sites/dec/files/wsm/stormwater/docs/Permitinformation/MunicipalRoads/sw_MRGP_RoadErosionInventory.pdf

[9] https://dec.vermont.gov/watershed/stormwater/permit-information-applications-fees/ms4-permit

- SCI – Road Settling
- SCI – Presence of Stone Pad at outlet
- Guardrail Inventory – Presence of Curb-board
- Ditch/Swale Inventory – Condition and Material

The guardrail inventory only identifies the presence of curb board and does not provide information regarding erosion or potential drainage deficiencies. Presence of curb board alone is not sufficient to determine whether the removal of curb board and the creation of a disconnection could be a suitable new water quality treatment practice (Section 2.1.2.1). Likewise, assessment of the presence of a stone pad at the culvert outlet within the SCI showed only a small number of culverts with an existing stone pad, such that stone pad presence was not useful as an indicator of either meeting a drainage standard or as indication of drainage deficiency.

The SCI and the TS4 Drainage Inventory (Swale/Ditch) were overlaid with the previously developed GIS inventory of paved road areas, P loading factors, and resulting P base loads to create a desktop inventory of areas located within highly hydrologically connected (HHC) and moderately hydrologically connected (MHC) paved road segments that, based on existing conditions reflected in the asset inventories, may be "brought up to standards" and thus be eligible for P reduction credit throughout the VTrans PCP Area.

The scoring system below (Table 14) was developed to create a unified condition assessment across various asset inventory data fields. The scoring is intended to categorize condition assessments so that segments can be identified as Meeting Standards, Partially Meeting Standards, or Not Meeting Standards based upon a standardized set of scoring criteria. The scoring system was then applied to develop prioritization for addressing identified deficiencies, based on the severity and/or number of conditions identified within any given road segment.

Table 14. Scoring System for Determining Whether Roadway Drainage Infrastructure Meets Drainage Standards

Score	Culvert Condition	Culvert Erosion	Culvert Sediment	Culvert Sink Hole	Road Settling	Swale Condition
5	Critical	Severe	Plugged	Severe	Grade	Critical
4	Poor	Moderate	Heavy	Major	--	Poor
3	Fair	Light	Moderate	Moderate	Repair	Fair
2	--	--	Light	Minor	--	Good
1	Good	None	None	None	None	Excellent
0	Unknown/Null	Unknown/Null	Unknown/Null	Unknown/Null	Unknown/Null	Unknown/Null

2.2.2. Assessment of VTrans Road Drainage Inventory Conditions

A spatial query of the asset inventories was executed using the following datasets:

- VTrans road segments by hydrologic connectivity (High, Moderate, Low)
- Key inventory conditions (Culvert Erosion and Sediment, Sink Hole, Road Settling, Swale Condition)
  - Selection of the worst case within a road segment for that inventory condition (Score 0 to 5 as identified in Table 14)
    - For example, if two culverts in one road segment each have sediment at the inlet, but one is identified as "plugged" and one is "heavy", then the ranking will be 5 for "heavy", which is the most deficient drainage scenario.

- Drainage areas within the LCB, from the determination of PCP Area and P base load by VTDEC and VTrans in March 2018 (Appendix A).

An overall road segment score was assigned using the worst ranking of any of the above conditions found within that road segment. The resulting data and scoring outputs were uploaded to a web map (available at https://bit.ly/2QIPqyy), where users may filter and export the results by Lake segment, degree of hydrologic connectivity, road slope and other criteria. These outputs are intended to be imported into an Excel spreadsheet and tabulated by highly and moderately hydrologically connected road segments within each Lake segment and SWAT drainage basin. An example of an implementation table for the Missisquoi River drainage area is included as Appendix F.

Table 15 summarizes the number of HHC road segments by worst-case ranking in each Lake segment. Of the almost 9,900 HHC paved road segments in the VTrans PCP Area, nearly 40% (3,974) had a condition ranking of 4 or 5, indicating that at least one road drainage asset within that road segment was generally in poor to critical condition.

Table 15. Roadway Drainage Infrastructure Conditions, Count of Highly Hydrologically Connected Road Segments by Lake Segment

	Swale and Culvert Conditions						
	Unknown	Best-->Worst					
Lake Segment	0	1	2	3	4	5	Total
South Lake B	1	72	185	214	100	70	642
South Lake A		9	53	43	17	14	136
Port Henry		1	6	3	3	4	17
Otter Creek	2	211	632	535	352	166	1,898
Main Lake	106	208	685	779	773	313	2,864
Shelburne Bay	7	21	92	56	26	18	220
Malletts Bay	62	89	248	464	708	218	1,789
Northeast Arm		11	29	98	109	32	279
St. Albans Bay		5	43	110	76	27	261
Missisquoi Bay		87	149	541	634	257	1,668
Isle La Motte		4	19	17	46	11	97
Total	178	718	2,141	2,860	2,844	1,130	9,871

Based on these results and the apparent significant number of opportunities to address existing road drainage, road segments with overall segment scores of 4 or 5 are proposed to be considered as "Not Meeting Standards" and thus eligible for credit for fixes that have been made since 2010 or moving forward. A more detailed segmentation of the asset inventory and assessment data into segments that "Partially Meet Standards" as established in the MRGP was not considered in the development of the Generalized PCP, though this concept may be revisited as the implementation plans are developed and executed. Presently, further prioritization is being developed by considering the number of issues located within a road segment, and by including additional prioritization data such as slope (both for the paved road segments and the adjoining swales).

Much of the VTrans road network in the LCB has some level of hydrologic connection (Table 16). The HHC road segments (linear facilities only) represent 2,537 paved road acres (43%) of the 5,873 such acres in the

TS4's PCP area in the LCB, while the MHC road segments represent 2,220 paved road acres (38%). The paved road impervious acres in the PCP Area are summarized in Table 16 and Figure 7 first by whether the areas have any mapped drainage infrastructure assets, and then by whether those areas served by drainage infrastructure 'meet' or 'do not meet' the set of standards/criteria described above. Of the 2,537 acres that are HHC in the PCP Area, 733 acres (29%) have no mapped drainage infrastructure assets, 1,027 acres (40%) "meet standards", and 778 acres (31%) "do not meet standards". The portion of the HHC road segments 'not meeting standards' ranges from 17% (South Lake A) to 43% (Isle La Motte). Similarly, of the 2,220 acres classified as MHC, 552 acres (25%) have no mapped drainage assets, 997 acres (45%) "meet standards", and 671 acres (30%) "do not meet standards". The basin-wide portion of the MHC road segments 'not meeting standards' ranges from 17% (Port Henry) to 59% (Isle La Motte).

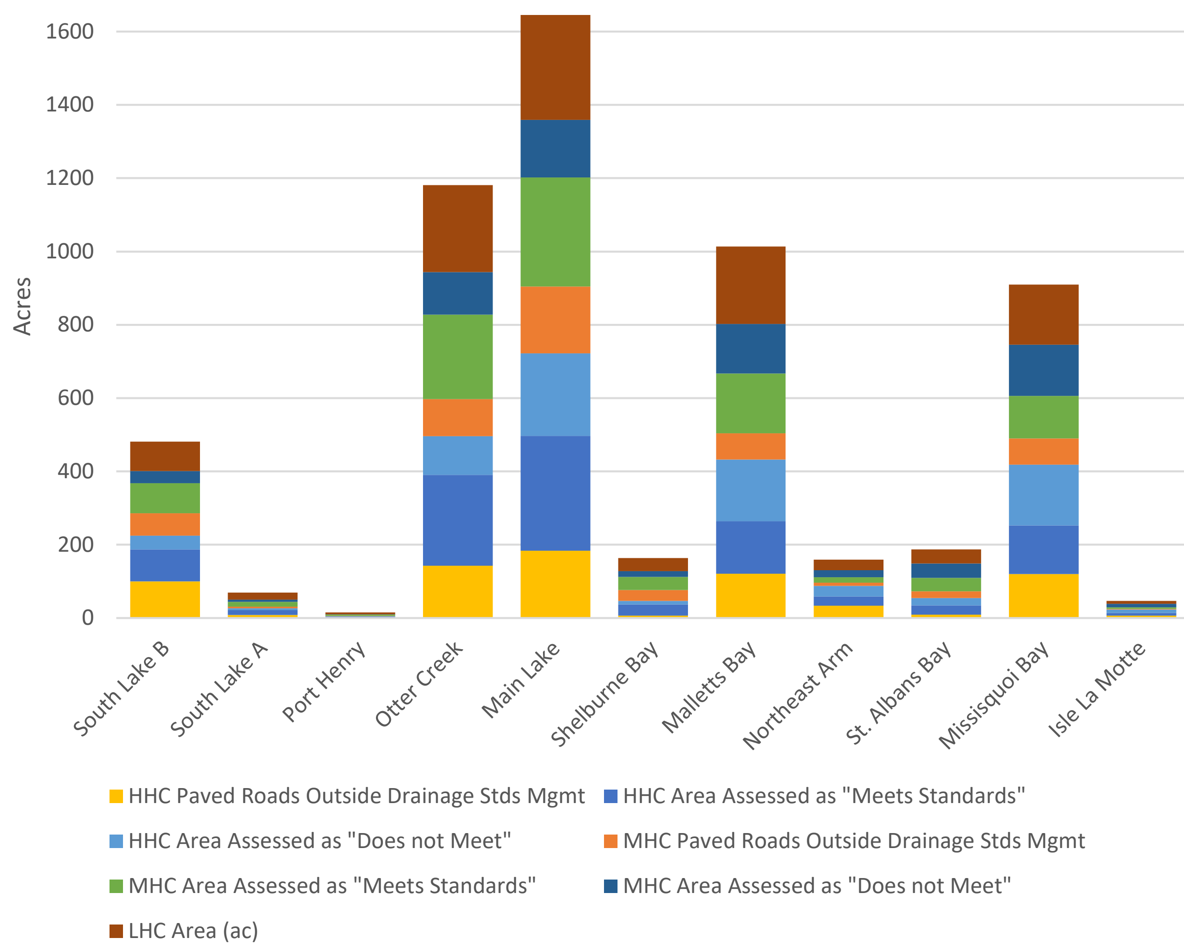


Figure 8. Linear Facilities, Paved Roads Acres by Hydrologic Connectivity and Drainage Standard

Table 16. Summary of Linear Facilities, Paved Roads Area by Hydrologic Connectivity and Asset Drainage Standards Status (acres)

Lake Segment	Total Paved Roads Area	HHC Paved Roads Outside Drainage Stds Mgmt	HHC Area Assessed as "Meets Standards"	HHC Area Assessed as "Does Not Meet"	MHC Paved Roads Outside Drainage Stds Mgmt	MHC Area Assessed as "Meets Standards"	MHC Area Assessed as "Does Not Meet"	LHC Area
South Lake B	481.54	99.62	87.42	37.70	61.05	81.86	33.66	80.23
South Lake A	69.11	8.15	13.42	5.11	4.34	13.12	5.69	19.29
Port Henry	15.29	2.08	1.78	0.93	0.87	3.36	0.89	5.38
Otter Creek	1181.20	142.57	247.67	105.55	101.13	231.12	115.64	237.51
Main Lake	1645.12	183.55	313.12	225.07	183.11	296.75	157.11	286.41
Shelburne Bay	163.66	6.83	30.50	9.77	29.46	35.63	15.82	35.65
Malletts Bay	1013.46	120.67	143.14	168.72	71.27	162.94	135.57	211.15
Northeast Arm	159.51	33.36	25.30	29.36	8.56	14.85	18.80	29.28
St. Albans Bay	187.20	9.10	25.53	20.19	18.54	36.11	39.39	38.35
Missisquoi Bay	910.14	120.37	132.54	165.16	72.11	116.25	139.07	164.65
Isle La Motte	46.93	6.93	6.28	9.99	1.52	4.89	9.16	8.16
Total	5873.17	733.23	1026.70	777.56	551.95	996.88	670.79	1116.06

The assessment returns a higher fraction of roadway areas 'not meeting standards' than what ANR staff have indicated the Road Erosion Inventories submitted by municipalities and RPCs under the MRGP program are returning (~10% or less of hydrologically connected road segments 'not meeting standards'). VTrans expects that further analysis of which TS4 criteria for meeting standards are most representative of erosion and subsequent water quality impacts, and refinement to the criteria and these assessment results, will continue as the first four-year implementation plan is developed. VTrans also acknowledges that the results received by ANR for completed REIs are necessarily incomplete, as the submittal deadline for those inventories is December 31, 2020.

Numeric P target reductions that may be expected if all paved road segments identified as having drainage deficiencies are corrected for linear facilities (roadways and rights-of-way) within the PCP Area are summarized in Table 17. The extent to which addressing all identified road drainage deficiencies on HHC and MHC road segments could be credited towards the TS4's target P reductions, assuming the same crediting schema being applied by ANR to municipal roadway drainage improvements under the MRGP is applied to the TS4's PCP, is summarized in Figure 8. In the MRGP framework, an 80% reduction credit is applied for bringing a hydrologically connected road segment fully up to standards' if its base condition when inventoried did not meet standards. A set of standards that adjusts the MRGP Road Stormwater Management Standards[11] (Part 6 of the MRGP) is in development and will be provided for ANR review when available. VTrans is also developing a ditching Standard Operating Procedure, which may be incorporated into the VTrans standards.

Table 17. Summary of P Target Reductions and Credit Possible for HHC and MHC Road Segments Not Meeting Drainage Standards

Lake Segment	Target P Reduction (Roads Portion Only, All Land Covers) (kg/yr)	HHC P Reduction Possible (kg/yr)*	MHC P Reduction Possible (kg/yr) *	HHC % of Target Reduction Possible	MHC % of Target Reduction Possible
South Lake B	136.34	32.19	18.34	24%	13%
South Lake A	16.19	5.36	4.06	33%	25%
Port Henry	1.42	0.92	0.59	65%	41%
Otter Creek	220.83	93.56	67.14	42%	30%
Main Lake	427.39	188.35	85.61	44%	20%
Shelburne Bay	32.85	7.87	8.72	24%	27%
Malletts Bay	236.55	140.52	72.77	59%	31%
Northeast Arm	13.41	23.69	9.83	177%	73%
St. Albans Bay	47.21	17.62	22.99	37%	49%
Missisquoi Bay	376.56	137.06	74.33	36%	20%
Isle La Motte	5.63	7.30	4.27	130%	76%
Total	1514.40	654.44	368.63	43%	24%

**Assuming 80% credit*

[11] https://dec.vermont.gov/sites/dec/files/wsm/stormwater/docs/Permitinformation/MunicipalRoads/sw_FinalMRGP.pdf

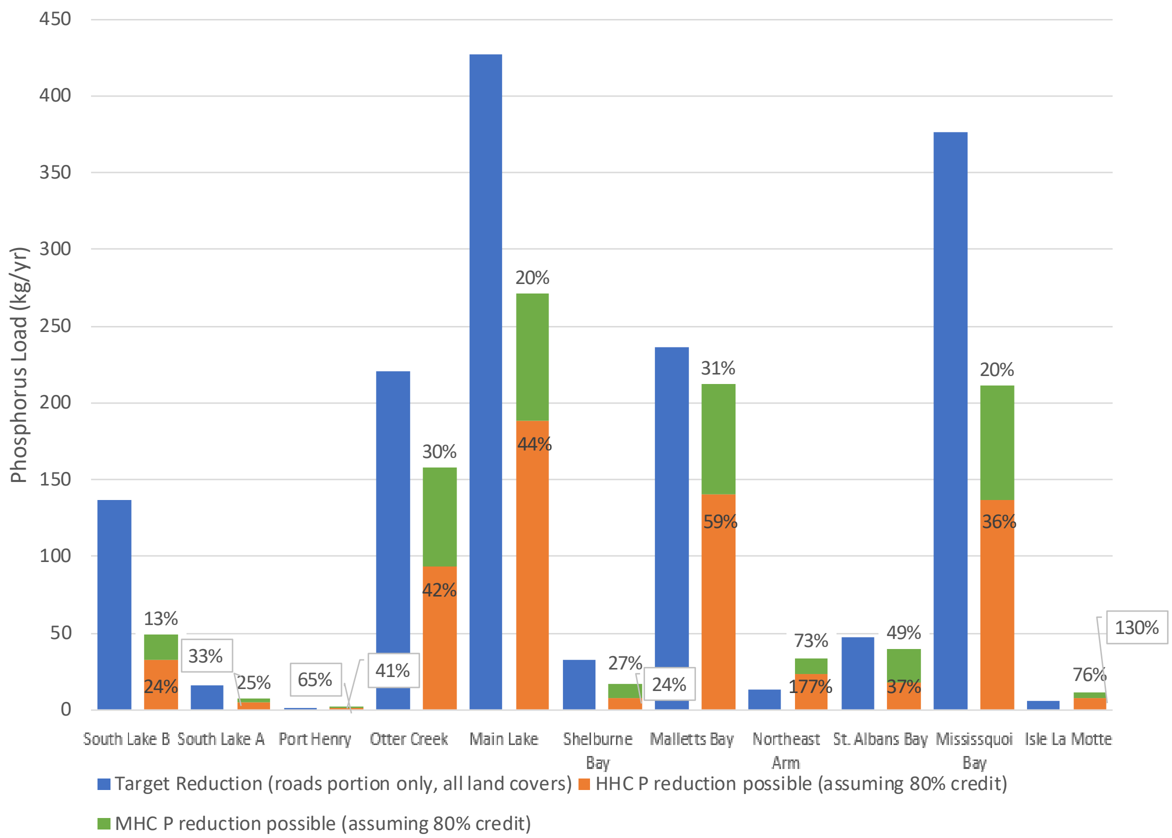


Figure 9. Linear Facilities - P Target Reductions and Credit Possible for HHC and MHC Segments Not Meeting Drainage Standards

In two cases – the Northeast Arm and Isle La Motte Lake segments, both small, low-lying drainages – correction of road drainage conditions on HHC road segments, alone, may be sufficient to meet target P reductions. Across the LCB, however, these corrections can be expected to address up to 43% of the target P reduction (range of 24% in South Lake A and Shelburne Bay, to 177% in the Northeast Arm segment). Adding the MHC road segments for correction of drainage deficiencies, and assuming correction of those drainage deficiencies is feasible and would be eligible for the same P reduction efficiency, would be sufficient to achieve and additional 24% of the target reduction across the LCB but in most cases is still not sufficient to meet the full target P reduction.

The ranking system and prioritization criteria presented above are still under consideration by both VTrans and ANR and may be adjusted as the first four-year implementation plan is developed. The following steps are being advanced in the development of this concept:

- Development of standardized conceptual BMPs and standards that a road segment should meet to be considered “brought up to standards” and receive P reduction credit.
- Confirmation of the P load reduction credit received for bringing a road segment “up to standards”.
- Refinement the prioritization system to help VTrans identify which segments should be “brought up to standards” in a given time frame.

- Identification of existing problems identified in the inventories that have been "brought up to standards" since July 2010 as indicated in the MATS database.
- Development of recommendations for refinement of the asset inventories and MATS database to facilitate tracking and P accounting during PCP implementation.

Additionally, a District Needs Map is under development by VTrans and is anticipated in 2020. As this resource comes online and is populated by District personnel, the identified needs can be spatially assessed in comparison to the road drainage standards inventory developed for the Generalized Plan. The District Needs Map will represent a valuable resource for use in developing and executing the implementation plan(s), particularly in prioritizing and addressing road drainage improvements and localized erosion fixes that can be completed by the Districts and that have distinct and creditable water quality benefits.

2.2.3. Conceptual Cost Information for Correction of Road Drainage Deficiencies

To develop preliminary cost estimates associated with standard fixes to bring road segments "up to standards", costs associated with MATS records of activities consistent with the suite of BMPs associated with correcting roadway drainage deficiencies were reviewed (Table 18).

Table 18. Implementation Cost Ranges for Repairs to Road Drainage Deficiencies

MATS Activity	Number of MATS Entries	Average Cost	Cost Range
Installing Culverts	1822	$4,995	$189 - $545,254
Maintaining Culverts (Repair or Replace)	120	$3,356	$178 - $32,888
Sink Hole Fixes	25	$2,017	$200 - $5,090
Ditching with Stone	106	$4,655	$650 - $10,628
Ditching with Mulch	89	$3,377	$101 - $9171
Ditching without Stone or Mulch	1263	$3,721	$232 - $11,206

Based on this review of standard maintenance items that would be consistent with bringing a road segment "up to standards", a range of average costs of activities that constitute significant improvements was established, using $2,000 for repairing sink holes to approximately $5,000 for ditching with stone or installing culverts. These costs were compared to the VTrans 2018 2-*Year Averaged Price List, 2011 Specifications*[11] and found to be within the same order of magnitude.

To develop an order-of-magnitude cost estimate associated with correcting roadway drainage deficiencies in the context of the Generalized PCP, the estimated per-repair costs were entered into the web app as low and high ranges to fix a structure within a segment that was identified as "not meeting standards" Therefore, a road segment with a larger number of deficient culverts or swales is estimated to have a higher implementation cost to bring the segment up to standards. This method consistently applies broad cost averages across Lake segments and paved road segments with varying degrees of repair intensity needed. Costing methodologies and assumptions described here may be refined and adjusted as the four-year implementation plans are developed and executed.

[11] https://vtrans.vermont.gov/sites/aot/files/estimating/documents/2YearEnglishAveragedPriceList11.pdf

2.3. Structural Correction of Localized Erosion Issues

Stabilization and treatment of areas of localized erosion caused by roadway runoff provides P reduction benefits while protecting VTrans infrastructure. Specific crediting mechanisms are not yet well-established for these and similar transportation-related improvements. VTrans is working with ANR to clarify and come to consensus on a P reduction crediting methodology for existing localized erosion repair projects, which then may reasonably be extended to P reduction crediting for proposed localized erosion repairs under the implementation phase of the PCP. This work will utilize the progress and findings of the VTrans and ANR research project *Quantifying Nutrient Pollution Reductions Achieved by Erosion Remediation Projects on Vermont's Roads,* which is now underway and will be completed in 2021. In this Generalized PCP, road segments with a high risk of localized erosion were identified and a conceptual P reduction credit applied as further described below.

2.3.1. Opportunities for Correction of Minor Areas of Localized Erosion

Localized erosion fixes constitute a demonstrable water quality improvement that can largely be achieved using existing VTrans maintenance practices. A desktop GIS analysis was conducted to identify road segments with risk factors for localized erosion (Appendix C). A road segment was deemed to be at risk for localized erosion if:

- if it was downslope of steep roadway, and/or
- if curb board was present, and/or
- there was evidence of a ditch upslope.

Road segments already included in the road drainage standards analysis, and improvement and crediting framework described in Section 2.2 (road segments with drainage infrastructure such as culverts), were excluded from this analysis. Thus, although paved areas with localized erosion risk exist and have been previously evaluated within paved road segments subject to the asset-based inventory and evaluation framework, those road segments are not 'double-counted' within this assessment. The exclusion results in a very conservative estimate of the acres potentially managed, and P load reduction possible, through application of maintenance-level fixes to areas of localized erosion.

Additionally, in 2017, VTrans field verified a subset of road segments that were identified as having risk factors for localized erosion (Section 2.3.2). The verification work determined that localized erosion was present 30% of the time where the GIS analysis indicates one or more risk factors are present[12]. Therefore, 30% of the acres within paved road segments with one or more localized erosion risk factors were assumed to have active erosion.

Using these criteria, 546 acres of the 5,873 total acres of paved roads in the PCP Area (9%) are outside road segments with drainage infrastructure and associated with one or more localized erosion risk factors (Table 19 and Figure 9), constituting 23% of the 2,401 paved roads acres located outside the asset-based drainage management standards framework. When the assumption of active localized erosion is factored in, the paved road area associated with active localized erosion is 164 acres, or 3% of the total TS4 paved roads area in the LCB (Table 20).

[12] See *VTrans PCP Area Characterization and Results* memo submitted by Stone to VTrans on 10/13/2017 for full results of the localized erosion GIS desktop field verification.

Table 19. Summary of Paved Roads Area with Localized Erosion Potential and No Drainage Infrastructure (acres)

Lake Segment	Paved Road Area Outside Drainage Stds Mgmt	Paved Road Area with Localized Erosion Risk				TS4 Paved Road Area with Localized Erosion Potential (%)
		Total	High HC	Moderate HC	Low HC	
South Lake B	240.9	82.6	37.3	21.4	23.9	17%
South Lake A	31.8	5.2	3.4	0.4	1.4	8%
Port Henry	8.3	0.5	0.2	0.0	0.2	3%
Otter Creek	481.2	113.9	61.3	22.2	30.3	10%
Main Lake	653.1	187.8	84.3	43.9	59.6	11%
Shelburne Bay	71.9	6.0	2.8	1.5	1.7	4%
Malletts Bay	403.1	90.8	54.3	12.0	24.6	9%
Northeast Arm	71.2	16.6	14.4	0.8	1.4	10%
St. Albans Bay	66.0	0.3	0.3	0.0	0.0	0.1%
Missisquoi Bay	357.1	37.5	19.2	7.3	11.0	4%
Isle La Motte	16.6	4.7	3.9	0.3	0.4	10%
Grand Total	2401.2	545.8	281.4	109.9	154.6	9%

Table 20. Summary of Paved Roads Area (Linear Facilities) Assumed to Contain Active Localized Erosion (acres)

Lake Segment	Paved Road Area Outside Drainage Stds Mgmt	Paved Road Area with Assumed Active Erosion				TS4 Paved Road Area with Assumed Active Localized Erosion (%)
		Total	High HC	Moderate HC	Low HC	
South Lake B	240.9	24.8	11.2	6.4	7.2	5%
South Lake A	31.8	1.6	1.0	0.1	0.4	2%
Port Henry	8.3	0.1	0.1	0.0	0.1	1%
Otter Creek	481.2	34.2	18.4	6.7	9.1	3%
Main Lake	653.1	56.4	25.3	13.2	17.9	3%
Shelburne Bay	71.9	1.8	0.8	0.5	0.5	1%
Malletts Bay	403.1	27.2	16.3	3.6	7.4	3%
Northeast Arm	71.2	5.0	4.3	0.2	0.4	3%
St. Albans Bay	66.0	0.1	0.1	0.0	0.0	0%
Missisquoi Bay	357.1	11.3	5.8	2.2	3.3	1%
Isle La Motte	16.6	1.4	1.2	0.1	0.1	3%
Grand Total	2401.2	163.8	84.4	33.0	46.4	3%

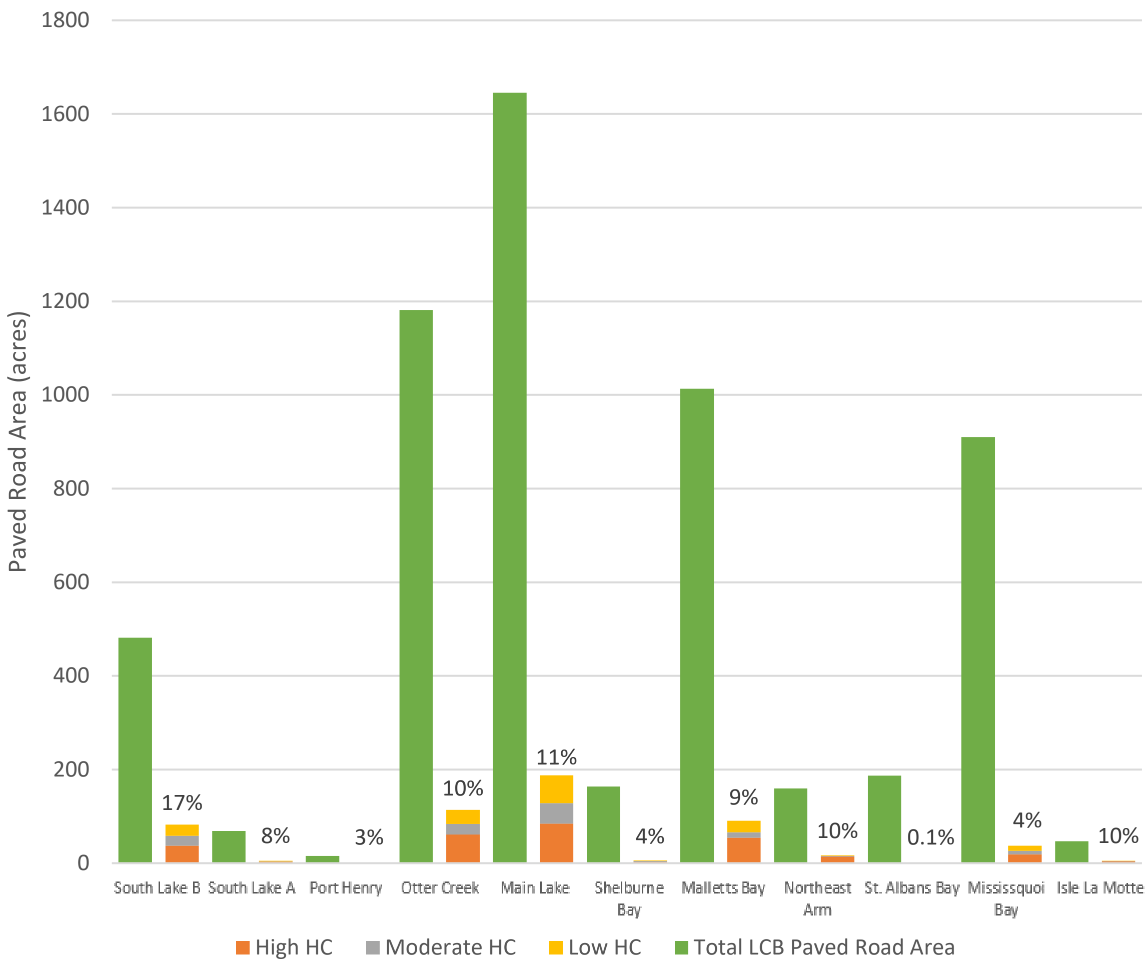


Figure 10. Paved Roads Area (Linear Facilities) with Localized Erosion Risk Outside Drainage Management Standards Area

The P reduction crediting methodology for repairs to areas of localized erosion associated with roadways remains in development and discussion between VTrans, ANR, and other partners in implementing the Lake Champlain P TMDL. A conceptual 50% P reduction credit was assumed for Generalized PCP development, following confirmation of the appropriateness of the assumption by ANR in March 2020. If all areas of localized erosion outside of paved roads areas being considered for application of drainage management standards were corrected, the resulting P load reduction of 67.8 kg/yr would account for 4% of the total P reduction required for VTrans paved roads (linear facilities only, not parcels) (Table 21). As seen in Figure 10, the Northeast Arm and Isle La Motte Lake segments have the highest proportions of P load reductions possible through applying this conceptual management practice (17% and 11%, respectively), with Missisquoi Bay and St. Albans Bay having the smallest P reduction opportunity for crediting through fixes to areas of active localized erosion (1% and 0.1%, respectively).

Table 21. Summary of Estimated P Load Reduction from Roads with Areas of Localized Erosion (kg/yr)

Lake Segment	Target P Reduction*	HHC P Reduction**	MHC P Reduction**	LHC P Reduction**	Total P Reduction**	HHC % of Target Reduction	MHC % of Target Reduction	LHC % of Target Reduction	Total % of Target Reduction
South Lake B	136.3	6.1	2.2	1.8	10.0	4%	2%	1%	7%
South Lake A	16.2	0.6	0.0	0.1	0.8	4%	0.3%	1%	5%
Port Henry	1.4	0.1	0.0	0.0	0.1	4%	0.0%	2%	6%
Otter Creek	220.8	10.1	2.4	2.3	14.8	5%	1%	1%	7%
Main Lake	427.4	13.6	4.4	4.3	22.3	3%	1%	1%	5%
Shelburne Bay	32.9	0.4	0.2	0.1	0.7	1%	1%	0.4%	2%
Malletts Bay	236.6	8.5	1.2	1.8	11.5	4%	1%	1%	5%
Northeast Arm	13.4	2.1	0.1	0.1	2.3	16%	1%	1%	17%
St. Albans Bay	47.2	0.0	0.0	0.0	0.0	0.1%	0.0%	0.0%	0.1%
Missisquoi Bay	376.6	3.0	0.7	0.8	4.6	1%	0.2%	0.2%	1%
Isle La Motte	5.6	0.5	0.0	0.0	0.6	10%	0.5%	0.5%	11%
Grand Total	1514.4	45.2	11.2	11.4	67.8	3%	1%	1%	4%

Load reductions derived from 30% of load totals based on results from field verification of desktop GIS analysis.
**Roads portion of P load only, all land covers*
***Assuming 50% P reduction credit for localized erosion fixes*

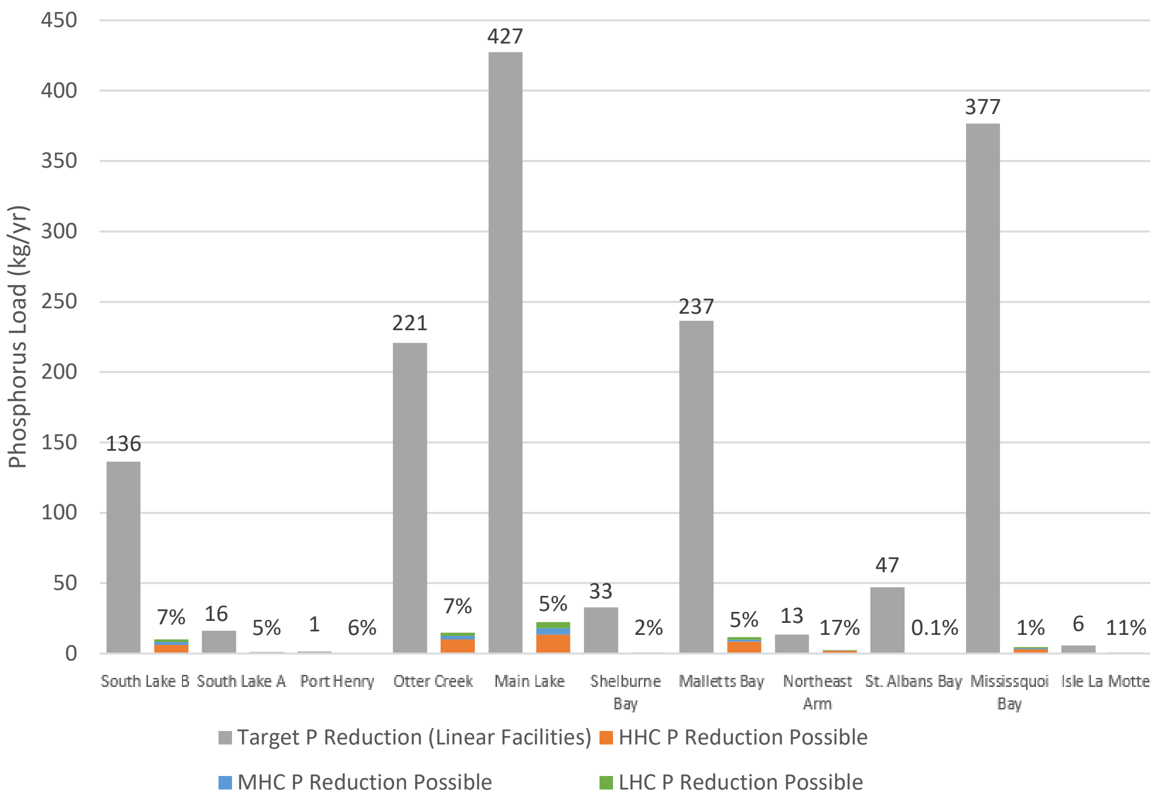


Figure 11. P Target Reductions Summary, Localized Erosion Repairs Outside Drainage Management Standards Areas

2.3.2. Conceptual Cost Information for Regular Maintenance Localized Erosion Repairs

To inform recommendations for future structural controls, a cost analysis was conducted for localized erosion corrections from field verified historic MATS records for the "Protecting Banks and Slopes" MATS activity (from 2017 and 2019 field verification efforts). The average cost (labor and materials) to correct an area of localized ranged from $358 - $22,695 with an average of $2,606. Assuming that each road segment identified with localized erosion would require one repair, the unit cost for removing 1 kg/yr of P with a localized erosion structural BMP is $47,400 (Table 22). The strongest cost-benefit for repairing areas of active localized erosion is, as expected, in HHC road segments ($36,700/kg P/yr).

Table 22. Estimated Costs and Cost Metrics for Small Localized Erosion Repairs Outside Road Drainage Standards Areas

	HHC Roads	MHC Roads	LHC Roads	Total Roads
Number of road segments with localized erosion	637	247	352	1236
Paved roads areas with active localized erosion (acres)	84.4	33.0	46.4	163.8
P load reduction possible through localized erosion fixes (kg/yr)	45.2	11.2	11.4	67.9
Total cost to correct assumed areas of active localized erosion	$1,658,800	$ 644,100	$ 917,700	$ 3,220,700
Cost per impervious acre managed ($/ac)	$ 19,700	$ 19,500	$ 19,800	$ 19,700
Cost per kg P load reduced ($/kg/yr)	$ 36,700	$ 57,400	$ 80,200	$ 47,400

2.3.3. Treatment and Correction of Minor Areas of Localized Erosion

Existing areas of localized erosion that have been repaired or managed with structural BMPs since 2010 are being identified by leveraging asset conditions tracked and maintenance activities reported in the MATS database. These data are being utilized to create a desktop inventory of localized erosion stabilization projects completed since 2010 and which may be eligible for P reduction credit. During the summer of 2019, a sub-set of localized erosion repairs identified in the MATS database completed between January 2017 and May 2019 were field verified. The field verification effort had several goals:

- Understand possible credit for correcting areas of localized erosion
- Gather information to compare the MRGP's REI framework and criteria with VTrans' inventories and maintenance activity records
- Determine applicability for VTrans roadways and erosion problem, such that "fixes" may be credited using a similar strategy between both permit and regulatory programs

Field verification of existing localized erosion repairs was completed in July-August 2019 at over 70 sites identified in the MATS database and returned the following results:

- At 38 sites, (53%) the localized erosion fix was located in good condition.
- At 11 sites, (15%) the fix was located but it was either in need of additional repair or the fix had failed.
- 19 sites (27%) were not found – either the location data were not precise, or the fix was so effective it could not be located.
- 3 records (4%) were related to planning activities rather than localized erosion fixes.

Inventory results, associated P reduction crediting, and recommendations for tracking and accounting will be developed further during creation of the Phase 1 Implementation Plan.

2.3.4. Treatment and Correction of Major Drainage Asset Deficiencies and Areas of Localized Erosion

The costs and P reduction credit opportunities for correction of maintenance-level drainage infrastructure deficiency and small-scale areas of localized erosion are relatively well-understood in the context of the Generalized PCP. Correction of gullying and large areas of active erosion, as well as corrections at stormwater system outlets, remain areas of active investigation across multiple State agencies, Regional Planning Commissions and municipalities, watershed stewardship organizations, and other partners. As implementation plans are developed, VTrans expects that they will be informed by the progress and findings of the VTrans and ANR research project *Quantifying Nutrient Pollution Reductions Achieved by Erosion Remediation Projects on Vermont's Roads*, which is now underway and will be completed in 2021. VTrans also expects that major upgrades to road embankments and culverts where improvements would address both existing drainage issues and reduce vulnerability to damage from floods, where risk, vulnerability, or criticality have been identified in VTrans's Transportation Resilience Planning Tool[13] will become a possibly substantial factor in prioritization and completion of improvements (when and as data become available in the LCB).

2.4. Natural Resource Restoration Projects

Natural resource restoration projects, and particularly floodplain reconnection projects, may be credited as a stormwater treatment practice in the context of the VTrans PCP if some portion of the floodplain area to be reconnected is also connected to a TS4 roadway or parcel-based "developed lands" contributing drainage. A crediting methodology has been developed by ANR that relates the Chesapeake Bay crediting methodology for

[13] https://vtrans.vermont.gov/planning/transportation-resilience

stream restoration projects[14] to Vermont's conditions (Appendix G). Using this method, floodplain cross-sections are created, simulations are run in HEC-RAS, the volume of reconnected floodplain is estimated, and P reduction is apportioned by the fraction of the contributing watershed that is owned and controlled by VTrans or an MS4 permittee.

A test case completed by ANR, using a floodplain reconnection project completed in the Lamoille River watershed in 2007-2008, indicates that the P load reduction, cost-effectiveness, and other co-benefits of broader application of this approach are substantial. The potential for siting floodplain reconnection projects near VTrans roadways is also substantial. The screening analysis for conceptual structural STPs (Section 2.1.2.2) indicated that roughly a quarter of the pervious right-of-way areas identified intersected the Vermont Hydrography Dataset (VHD) – a blue-line stream. As the implementation plans are developed and executed, further evaluation is warranted, possibly utilizing the screening assessment being developed through the VTrans research project described below.

VTrans is aware of at least two potential floodplain reconnection projects that will be further evaluated as the first four-year implementation plan is developed. A series of floodplain reconnection alternatives for a portion of the Lamoille Valley Rail Trail located along VT Route 36 in Fairfield in the Black Creek floodplain are now being evaluated through the VTrans-funded project *Evaluating Effectiveness of Floodplain Reconnection Sites along the Lamoille Valley Rail Trail: A Blueprint for Future Rail/River Projects,* with results expected in mid-2020. A preliminary evaluation of the potential for floodplain reconnection in the Potash Brook watershed was conducted by the South Burlington MS4 in February 2020, identifying a potential reconnection opportunity near the I-89/I-189 interchange.

VTrans also anticipates further investigation of floodplain reconnection where VTrans roads and facilities contribute runoff upstream of the restoration practice through coordination with and application of results from Vermont's Functioning Floodplains Initiative[15]. While the project outputs will not be complete until 2021, the initiative will develop and apply methodologies for evaluating river reach and watershed-scale restoration of stream, riparian, wetland, and floodplain function. The initiative seeks to garner local community support by tracking and publicizing the accumulation of the natural and socio-economic assets derived from connected and naturally functioning floodplains and wetlands, including fish and wildlife habitat, water quality, avoided damage from floods and fluvial erosion, and the storage of carbon affecting the earth's climate.

14 https://www.chesapeakebay.net/documents/Final_CBP_Approved_Stream_Restoration_Panel_report_LONG_with_appendices_A-G_02062014.pdf

15 http://www.vermontbusinessregistry.com/bidAttachments/37484/Vermont Functioning Floodplains Initiative White: Paper.pdf

2.5. Non-Structural Controls

As part of its SWMP[16], VTrans has committed to completing a robust suite of maintenance activities under Minimum Control Measure 6.F (Pollution Prevention/ Good Housekeeping for Municipal Operations). In the SWMP, VTrans has committed to conduct street sweeping on 2,000 lane miles of VTrans roads annually, conduct storm drain inspections on 20% of VTrans roads annually, and to properly dispose of materials collected per ANR guidelines during routine street sweeping and storm drain cleaning. Drop inlet (DI) or catch basin cleaning and street sweeping both result in the removal of sediment and P from impervious surfaces—and thus, are of interest in developing the Generalized PCP.

Robust information recorded in the MATS dataset was assessed to review maintenance records and quantify non-structural controls with P reduction benefits: DI cleaning and street sweeping. P reductions for both DI cleaning and street sweeping were calculated using methodology provided by ANR[17]. VTrans will incorporate applicable findings from ongoing research by USGS[18], in cooperation with the Chittenden County Regional Planning Commission, DEC, the University of Vermont, and nine Vermont municipalities, to evaluate P reductions possible through current practices, possible enhancements to those activities, and adjustments to activity frequency and equipment usage as the four-year plans are developed and executed.

Prior to 2010, non-structural controls were not consistently implemented on a significant extent of roads within the LCB as part of VTrans' annual operations. Street sweeping or DI cleaning that can be documented is therefore creditable toward the target P reductions. Review of relevant records in the MATS database was completed, determining that information from 2015 on was reliable enough to quantify lane miles and paved roads areas managed using street sweeping or DI cleaning. Detailed analysis of non-structural controls in the TS4 PCP Area is included in Appendix H.

2.5.1. Street Sweeping

VTrans elected to begin street sweeping with high-efficiency equipment on a limited basis within its MS4 areas in response to requirements within their MS4 permit in 2012. Now across the TS4, VTrans primarily uses mechanical broom sweepers for street sweeping as a regular maintenance practice, particularly along bike routes and for special events such as bike races where the road needs to be clear of debris for safety (Map 3).

Vermont DEC credits street sweeping P reductions based on frequency and type of sweeping equipment used (Table 22). VTrans regularly sweeps some sections of road more than once per year, so a spatial analysis was conducted to determine the appropriate P reduction credit to apply. Very few road segments were swept more than twice annually, and those that were swept more than twice were with a great enough frequency to qualify for the higher P reduction credit applied for monthly or weekly sweeping frequencies. Road segments swept once per year were allocated a 0.5% P reduction, and road segments swept more than once were allocated a 1% P reduction. On average, 15% of road area that is swept is swept more than once per year (Table 23).

[16] https://anrweb.vt.gov/PubDocs/DEC/Stormwater/PublicNotice/7892-9007/VTrans%20Final%20SWMP%20-%20December%205%202017.pdf

[17] https://dec.vermont.gov/sites/dec/files/wsm/stormwater/docs/MS4/Draft%20Annual%20Report%20Workbook_11_2019.xlsx

[18] https://www.ccrpcvt.org/wp-content/uploads/2018/12/CleanStreetsSweepingStudy_Sept4_update.pdf

Table 23. Street Sweeping P Reduction Factors[17]

Equipment Type	Sweeping Frequency: 2/year (spring and fall)	Monthly	Weekly	4X in the fall
Mechanical Broom	1%	3%	5%	17%
Vacuum Assisted	2%	4%	8%	17%
High Efficiency Regenerative Air-Vacuum	2%	8%	10%	17%

To determine the P base load from streets where sweeping occurred, the P load from each road segment associated with a MATS street sweeping record was calculated using the road segment area, Lake segment identification, slope, and hydrologic connectivity classification of each road segment. The total acres of VTrans roads swept per year ranged from 1,609 to 2,836, with an average of 2180 acres/year, or 37% of the total VTrans road area in the LCB. (Table 24).

Table 24. Summary of Street Sweeping Activity by Paved Roads Areas Swept (acres)

Lake Segment	2015	2016	2017	2018	2019	Average Annual Acres Swept	Total VTrans LCB Road Area (ac)	Average % Total VTrans LCB Road Area Swept
South Lake B	147.4	99.4	294.8	154.6	95.5	158.4	481.5	33%
South Lake A	46.6	18.7	59.7	61.9	22.2	41.8	69.1	61%
Port Henry	15.0	0.3	13.8	15.4	15.0	11.9	15.3	78%
Otter Creek	671.0	653.0	861.5	607.7	756.3	709.9	1181.2	60%
Main Lake	264.2	486.1	441.5	480.6	432.8	421.0	1645.1	26%
Shelburne Bay	60.8	25.2	99.8	85.5	92.1	72.7	163.7	44%
Malletts Bay	215.5	413.9	483.1	421.2	362.8	379.3	1013.5	37%
Northeast Arm	116.3	140.9	61.6	12.4	121.0	90.4	159.5	57%
St. Albans Bay	24.2	53.2	76.6	79.6	56.3	58.0	187.2	31%
Missisquoi Bay	17.1	156.7	427.7	320.0	130.8	210.4	910.1	23%
Isle La Motte	31.4	38.1	16.1	15.2	31.4	26.4	46.9	56%
Total	1609.4	2085.5	2836.0	2254.0	2116.1	2180.2	5873.2	37%

Annual P load reductions ranged from 6.3 - 11.9 kg/yr from 2015 - 2019, with an average of 8.8 kg/yr, translating to roughly 0.6% of the total required P reduction target per year from VTrans roads within the LCB (Table 25). Current street sweeping coverage and frequency accounts for a small portion of the target P reduction, ranging from 0.2% - 3.3%. Annual street sweeping costs averaged $279,200 per year, resulting in an average unit cost of $31,600 per kg P/yr (Table 26).

Table 25.Summary of Annual Sweeping P Load Reduction by Lake Segment (kg/yr)

Lake Segment	2015	2016	2017	2018	2019	Average Annual P Reduction	Target Reduction (kg/yr)*	Average Annual % P Reduction
South Lake B	0.60	0.37	1.30	0.63	0.40	0.66	136.3	0.5%
South Lake A	0.22	0.09	0.28	0.29	0.07	0.19	16.2	1.2%
Port Henry	0.07	0.00	0.03	0.07	0.03	0.04	1.4	2.8%
Otter Creek	2.64	3.00	3.66	2.29	2.42	2.80	220.8	1.3%
Main Lake	1.02	1.75	1.88	2.10	1.79	1.71	427.4	0.4%
Shelburne Bay	0.16	0.16	0.39	0.40	0.44	0.31	32.9	0.9%
Malletts Bay	0.86	1.78	1.99	1.55	0.98	1.43	236.6	0.6%
Northeast Arm	0.48	0.70	0.33	0.04	0.65	0.44	13.4	3.3%
St. Albans Bay	0.09	0.21	0.32	0.41	0.19	0.25	47.2	0.5%
Missisquoi Bay	0.09	0.98	1.64	1.15	0.65	0.90	376.6	0.2%
Isle La Motte	0.11	0.21	0.05	0.06	0.11	0.11	5.6	1.9%
Total	6.3	9.2	11.9	9.0	7.7	8.8	1514.4	0.6%

**Roads portion of P load only, all land covers*

Table 26. Average Annual Unit Costs and Cost-Effectiveness Metrics for Street Sweeping

Metric	2015	2016	2017	2018	2019	Average
Total Area Swept (acres)	1609.4	2085.5	2836.0	2116.1	2180.2	2165.4
Total P Reduction (kg/yr)	6.32	9.24	11.86	8.99	7.73	8.83
Percent of Total VTrans P Reduction Target	0.4%	0.6%	0.8%	0.6%	0.5%	0.6%
Annual Cost	$233,215	$210,775	$414,991	$362,477	$174,631	$279,218
Per-Acre Unit Cost ($/acre/year)	$145	$101	$146	$171	$80	$129
Per-kg P Load Reduction Unit Cost ($/kg/yr)	$36,906	$22,809	$34,979	$40,324	$22,579	$31,623

Current street sweeping activity frequency and coverage (38% of streets swept in the LCB per year) annually manages 0.6% of the total P load reduction required from VTrans roads. Table 27 shows the incremental increase in both P reduction credit and implementation cost that would result from sweeping 2,000 lane miles annually within the VTrans PCP Area.

Table 27. Example Projection of Increased Street Sweeping from 1,055 to 2000 Lane Miles (Ln Mi) Annually

	2015 - 2019 Annual Average	Future Projection
Lane miles swept	1055	2000
Percent of total lane miles swept in PCP Area	38%	73%
P Load Reduction (kg/yr)	8.83	17
P Load Reduction per lane mile swept (kg/yr)	0.01	0.01
Annual Cost	$279,218	$530,000
Percent of VTrans P target reduction (annual)	0.5%	1%

Street sweeping has a modest annual P reduction benefit, and it is a routine maintenance practice that enhances the safety of the traveling public. VTrans may choose to focus future street sweeping programs on sweeping highly hydrologically connected road segments, on increasing the extent and frequency of bridge washing, or to target Lake segments with the most aggressive P target reductions. Further direction of street sweeping may be included in the development of each four-year implementation plan. Results of ongoing research by USGS and others[18] evaluating reductions in nutrient and sediment loads from current street cleaning and leaf litter collection practices, and evaluating P reductions and crediting for current practice and potential enhancements, will further influence decision making regarding VTrans' street sweeping program once those findings are available in 2020.

2.5.2. Drop Inlet Cleaning

In 2012, VTrans elected to begin cleaning DIs with a vac truck in response to requirements within their MS4 permit. A large portion of DI cleaning with a vac truck occurred within VTrans' former MS4 area (Map 4). Since this activity is performed by specialty contractors rather than by VTrans personnel, it is not tracked with a specific activity code in the MATS database. Detailed assessment of individual MATS records was required to determine the areas covered by DI cleaning and thus the P reductions that could be applied. Appendix G includes details of the processes used to estimate P load reductions associated with this non-structural control.

Vermont DEC[17] allows two methods for determining P reduction credit for DI cleaning:

1. *Area-based* – This method allocates a 2% P load reduction from the P base load of streets where DI cleaning occurs (kg/yr).
2. *Volume-based* – Still under development, this method will most likely require a total P (TP) test be conducted on the material collected from cleaned DIs by vac truck so that the amount of P can be determined for the entire volume of material collected and then counted towards P load reduction[17].

The area-based methodology was applied to determine P load reductions from DI cleaning activity between 2015-2019. The paved road areas associated with DI cleaning activity were identified by spatial analysis of the MATS records compared to the VTrans PCP area. The paved road areas with cleaned DIs ranged from 27 acres in 2017 to over 480 acres in 2015 (Table 28), largely due to fluctuations in the annual funding available for VTrans to contract the specialty equipment and operators. Given the limited funding available for 2017 operations, that year was excluded from further analysis. On average, DI cleaning occurred on 339 acres (or 6%) of VTrans paved roads areas in the PCP Area. The Shelburne Bay, Main Lake, and Otter Creek Lake segments contained the highest percentage of roadway where DI cleaning was completed.

Table 28. Summary of Paved Road Areas with DI Cleaning

Lake Segment	DI Cleaning Area (ac) 2015	2016	2017	2018	2019	Annual Average	Total VTrans LCB Road Area (ac)	% Total VTrans LCB Road Area w/ DI Cleaning
South Lake B	0.00	0.00	1.01	0.67	0.00	0.17	481.5	0.03%
South Lake A	10.85	0.00	0.00	0.00	0.00	2.71	69.1	3.92%
Port Henry	0.00	0.00	0.00	0.00	0.00	0.00	15.3	-
Otter Creek	168.18	1.85	18.48	0.37	205.61	94.00	1181.2	7.96%
Main Lake	170.47	229.22	0.85	27.50	39.04	116.56	1645.1	7.09%
Shelburne Bay	20.19	8.69	1.63	5.38	64.94	24.80	163.7	15.15%
Malletts Bay	109.39	50.01	2.13	105.22	46.71	77.83	1013.5	7.68%
Northeast Arm	0.00	0.00	0.00	0.00	4.67	1.17	159.5	0.73%
St. Albans Bay	0.00	0.00	0.00	32.80	0.00	8.20	187.2	4.38%
Missisquoi Bay	3.19	24.71	0.00	21.92	1.65	12.87	910.1	1.41%
Isle La Motte	0.00	0.00	2.95	0.00	3.98	1.00	46.9	2.12%
Total	482.28	314.48	27.04	193.86	366.61	339.31	5873.2	5.78%

Notes: Averages exclude 2017, when DI cleaning received minimal budget consideration.

Annual P load reductions creditable to DI cleaning ranged from 3.16 – 8.07 kg/yr with an average of 6.17 kg/yr, translating to roughly 0.41% of the total P reduction target per year from VTrans roads within the PCP Area. As with street sweeping, DI cleaning accounts for a modest portion of the total required P reduction, ranging from 0.02% in South Lake B to 1.14% in Shelburne Bay (Table 29). Average annual DI cleaning costs were $74,398 total with a unit cost for removing one kg/yr of P with DI cleaning of $12,054 (Table 29).

Table 29. Summary of DI Cleaning P Load Reductions by Lake Segment (kg/yr)

Lake Segment	2015	2016	2017)	2018	2019	Average Annual P Reduction	Target P Reduction*	Average Annual % P Reduction
South Lake B	0.00	0.00	0.02	0.01	0.00	0.00	136.3	0.00%
South Lake A	0.17	0.00	0.00	0.00	0.00	0.04	16.2	0.27%
Port Henry	0.00	0.00	0.00	0.00	0.00	0.00	1.4	-
Otter Creek	3.03	0.03	0.51	0.01	3.78	1.71	220.8	0.77%
Main Lake	2.86	5.29	0.01	0.46	0.53	2.29	427.4	0.53%
Shelburne Bay	0.31	0.12	0.02	0.09	0.98	0.37	32.9	1.14%
Malletts Bay	1.65	1.41	0.04	1.54	0.79	1.35	236.6	0.57%
Northeast Arm	0.00	0.00	0.00	0.00	0.07	0.02	13.4	0.14%
St. Albans Bay	0.00	0.00	0.00	0.59	0.00	0.15	47.2	0.31%
Missisquoi Bay	0.05	0.38	0.00	0.46	0.03	0.23	376.6	0.06%
Isle La Motte	0.00	0.00	0.03	0.00	0.05	0.01	5.6	0.21%
Total	8.07	7.23	0.64	3.16	6.23	6.17	1514.4	0.41%

Notes: Averages exclude 2017, when DI cleaning received minimal budget consideration.
**Roads portion of P load only, all land covers*

Table 30. Average Annual Unit Costs and Cost-Effectiveness Metrics for DI Cleaning

Metric	2015	2016	2017	2018	2019	Average
Total Area with Cleaned DIs (acres)	482.28	314.48	27.04	193.86	366.61	339.31
Total P Reduction (kg/yr)	8.07	7.23	0.64	3.16	6.23	6.17
Percent of Total VTrans P Reduction Target	0.5%	0.4%	0.04%	0.2%	0.4%	0.4%
Annual Cost	$86,687	$59,956	$27,837	$84,179	$66,768	$74,398
Per-Acre Unit Cost ($/acre/year)	$180	$191	$1,029	$434	$182	$219
Per-kg P Load Reduction Unit Cost ($/kg/yr)	$10,740	$8,291	$43,381	$26,672	$10,720	$12,054

Note: Average Annual Percent of Total VTrans P Reduction Target was calculated using the total target P reduction for all VTrans impervious surface within the LCB (1611 kg/yr).
Averages exclude 2017, when DI cleaning received minimal budget consideration.

Current DI cleaning extent and frequency (covering 6% of VTrans roads in the PCP Area) are documented to annually reduce the total P load by an average of 0.4%. The incremental increase that could result from increasing the present effort to instead clean 10% of the DIs in the PCP Area annually is shown in Table 31.

Table 31. Example Projection of Increased DI Cleaning from 6% to 10% Annually

	2015 - 2019 Annual Average	Example Projection
DIs cleaned	376	804
Percent of total DIs cleaned in PCP Area	6%	10%
P load reduction (kg/yr)	6.17	13
P load reduction per acre draining to DI cleaned (kg/yr)	0.02	0.02
Annual Cost	$74,398	$159,152
Percent of VTrans P target reduction (annual)t	0.4%	1%

DI cleaning presently has a modest impact on annual P target reductions. As a routine maintenance practice, DI cleaning has additional benefits, including maintaining DI function and protecting downstream VTrans drainage infrastructure. Without increasing the number of DIs cleaned or the overall budget for DI cleaning, VTrans may choose to prioritize cleaning DIs along highly hydrologically connected road segments or to focus DI cleaning in select Lake segments with aggressive target P reductions. Adjustment to the current DI cleaning program may be considered in the development and execution of each 4-year implementation plan. As discussed above, results from ongoing research by USGS and others[18] evaluating reductions in P loads possible through DI cleaning and street cleaning practices, and evaluating P reductions and crediting for current practice and potential enhancements, will further inform VTrans' DI cleaning program once those findings are available in 2020.

3. Compliance and Implementation Strategy

The compliance and implementation strategy VTrans will use to achieve its target reductions across the PCP Area in the LCB will continue immediately from submittal of this Generalized PCP into development of the first four-year implementation plan. Work in progress described in this PCP continues into development of the first four-year implementation plan, specifically to refine determinations of what P reduction credit towards VTrans' target reductions can be expected from existing and planned structural stormwater STPs, existing areas of localized erosion repaired in the last seven years, and areas of hydrologically connected roadway drainage systems recently improved to current standards. Existing application of non-structural practices such as street sweeping and catch basin cleaning is summarized within this document, and while future adjustments to crediting may be applied, the acres and basis for those credits is thoroughly documented in this PCP.

Prior to submittal of the first four-year implementation plan, VTrans will identify additional retrofits and improvement projects using previously compiled datasets and screening criteria enhanced with field verification. This initial implementation plan will focus on the Missisquoi Bay Lake segment but will opportunistically assess potential major retrofits and opportunities outside that watershed. Field evaluations will be prioritized starting with the largest potential drainage areas and areas of impervious surface, whether on roadways or at facilities, as well as the largest areas of localized erosion associated with roadways and the highest-priority hydrologically connected road segments. As a suite of suitable practices is identified and potential constraints documented, VTrans anticipates continued coordination with ANR, especially if and as environmental resource conflicts related to wetlands and river corridors appear to be substantial.

Retrofit identification, estimation of P reduction credit possible for each retrofit, and updates to PCP tracking tools will be iterative until a suite of BMPs and practices/enhancements is identified that documents 25% net progress towards achievement of the TS4 P reduction targets across the extent of VTrans's PCP Area in the LCB.

The first four-year implementation plan will include a combination of implementation of localized erosion and hydrologically connected road segment drainage repairs, structural STPs (both new treatment practices and retrofits to existing structural STPs), potential enhancements to non-structural control frequencies, and other projects (particularly floodplain reconnection) with the highest P cost-benefit. Through the execution of the four-year implementation plans, and robust tracking and accounting, VTrans expects to achieve its P reduction targets. If and as necessary, the design and implementation schedules included with the four-year plans will include a discussion of any necessary permits or other regulatory approvals needed for implementation of the required practices.

The draft implementation schedule below provides an example of how VTrans anticipates the execution of the four-year plans will be managed. A rough schedule for how the remaining four-year plans are currently anticipated to be executed is also included. Both the schedule below and the implementation model are planning-level documents only and will be subject to revision and adjustment as the implementation plans are developed.

Year 1 of plan implementation (2021):

- Continue to advance priority retrofit designs for FRPs and other VTrans projects in development
- Begin design work for highest-priority structural stormwater practice retrofits identified
- Advance regular maintenance and non-structural control activities basin-wide
- Ensure P reduction credit documented for 2010-2020 activities and retrofits
- Develop and test systems for easy tracking and accounting of progress towards target reductions.

Years 2-3 (2022-2023):

- Deploy tracking and accounting system and apply it to track progress towards target reductions
- Continue to advance priority retrofit designs for FRPs and other VTrans projects in development
- Continue design work for highest-priority structural STP retrofits
- Advance regular maintenance and non-structural control activities basin-wide
- Begin increasing frequency of repairs to roadway drainage and areas of localized erosion
- Begin construction of structural STP retrofits and repairs to major areas of localized erosion

Year 4 (2024):

- Continue to advance priority retrofit designs for FRPs and other VTrans projects in development
- Continue design work for highest-priority structural STP retrofits
- Advance regular maintenance and non-structural control activities basin-wide
- Increase frequency of repairs to roadway drainage and areas of localized erosion
- Continue construction of structural STP retrofits and repairs to major areas of localized erosion
- Develop and submit second four-year implementation plan

After completing the first four-year implementation plan with a Missisquoi Bay Lake segment focus, the focus of the TS4's PCP implementation plans is anticipated to move south through the basin as follows:

- 2024-2028: Focus on remaining Lake segments generally north of Main Lake (Isle La Motte, St. Albans Bay, Northeast Arm, Malletts Bay, and Shelburne Bay)
- 2028-2032: Focus on Main Lake and the Winooski River watershed
- 2032-2036: Focus on Lake segments generally south of Main Lake (Otter Creek, Port Henry, South Lake A, and South Lake B).

3.1. Implementation Unit Cost Assumptions and Metrics

The unit cost estimates and cost metrics presented in Section 2 for each class of practices considered are summarized below in Table 32. While implementation plans will include varying combinations of all the practice types considered, priority for implementation is expected to be directed preferentially to practices that are both implementable and cost-effective. Maintenance-level repairs to road drainage assets along highly and moderately hydrologically connected road segments are the most cost-effective structural practices available for implementation, whether considered on a per-impervious-acre-managed basis ($15,500-$15,800/acre impervious) or on a $/kg P managed basis ($18,800-$28,200/kg P managed) (Table 32). Maintenance-level repairs to areas of localized erosion are estimated to have slightly higher costs on a $/acre impervious basis ($22,200/acre) and markedly higher costs on a $/kg P managed basis—with fixes in highly hydrologically connected road segments being the most cost-effective at $41,700/kg P managed (Table 32). Structural STPs such as infiltration trenches, gravel wetlands, and dry swales generally appear to be the least cost-effective, whether cost-effectiveness is considered in terms of impervious acres managed ($42,400-$64,600/acre) or annual P load managed ($90,800-$183,100/kg P/yr).

Table 32. Summary of Unit Costs and Cost-Effectiveness Metrics (2019 dollars)

BMP Type	$/cf storage volume	$/acre impervious managed	$/kg P managed	Assumptions and Notes
Bioretention (w/ underdrain)[1,5]	$18.14	$64,600	$181,600	
Dry Swale (w/ underdrain)[1,5]	$18.14	$64,600	$181,600	
Gravel Wetland[1,5]	$10.21	$38,800	$107,200	
Infiltration Basin w/Aggregate (Large Infiltration Trench)[1,5]	$14.52	$58,300	$119,300	
Infiltration Trench[1,5]	$14.52	$54,700	$90,800	
Wet pond/ Created Wetland[1,5]	$7.90	$42,400	$183,100	
Floodplain Reconnection[5]			$320	Drawn from Lamoille 2007-08 reconnection project
Road Drainage Repair, Maintenance Project, HHC[2,5]	n/a	$15,800	$18,800	High $/ac and $/kg applied, all Lake segments combined. Cost-effectiveness varies substantially between Lake segments and HC classes, and is affected both by P base loads and target reductions, and by number of issues identified per road segment.
Road Drainage Repair, Maintenance Project, MHC[2,5]	n/a	$15,500	$28,300	
Localized Erosion Repair, Maintenance Project, HHC[3,5]	n/a	$22,200	$41,700	Based on MATS data and average cost per fix, assumed one fix per segment, extrapolated to acre basis
Localized Erosion Repair, Maintenance Project, MHC[3,5]	n/a	$22,200	$65,100	
Localized Erosion Repair, Maintenance Project, LHC[3,5]	n/a	$22,200	$90,600	
Street Sweeping[4,5]	n/a	$130	$31,600	Based on 2015-2019 actuals; annual cost
DI Cleaning[4,5]	n/a	$190	$12,100	

1 Cost estimates for conceptual structural STPs derived from 2016 Opti-Tool values as refined using implementation costs for recent STP retrofit projects provided by VTrans (Section 2.1.2.1, Tables 8 and 13).

2 Cost estimates for road drainage asset repairs derived from 2015-2019 MATS records, related analysis, and VTrans 2018 *2-Year Averaged Price List, 2011 Specifications* (Table 18, Section 2.2.3).

3 Cost estimates for localized erosion repairs derived from 2015-2019 MATS records and related analysis (Table 22, Section 2.3.2).

4 Cost estimates for non-structural controls (street sweeping and DI cleaning) are derived from 2015-2019 MATS activity records and related analysis (Table 26 and Section 2.5.2 for street sweeping, Table 30 and Section 2.5.2 for DI cleaning). Unit costs do not consider any changes in equipment used (mechanical broom vs. vacuum assisted street sweeping), procurement methods (current practice vs. increased contracting or VTrans procurement of Vactor truck for DI cleaning), etc.

5 All cost estimates presented in this table are planning-level, conceptual costs only. Implementation cost for any class of improvements may vary substantially from these planning-level estimates, depending upon access, feasibility, environmental, and other constraints.

3.2. Implementation Model and Schedule

An implementation model was created (Table 35) to both summarize the analyses and findings described in this Generalized PCP, and to develop a draft implementation schedule that includes estimates of the area (acreage) to be treated and the extent and type of treatment strategies that will be applied to meet the entire P load reduction. The model was populated using the following assumptions:

- Existing non-structural control applications continue at present average levels of application and are credited on an annual basis.
- All structural stormwater management strategies, once constructed, are assumed to be maintained at levels sufficient to retain P management benefits and credit towards target P reductions. This includes existing and planned structural STPs, conceptual structural STPs, road drainage asset repairs, localized erosion repairs. The assumption will also apply to natural resource restoration projects, as those are potentially implemented during future implementation plan terms.
- Increased frequency and application of maintenance-level repairs to drainage assets on hydrologically connected road segments, and maintenance-level repairs to areas of localized erosion, were applied preferentially.
- Where full implementation of road drainage asset repairs and localized erosion repairs appeared insufficient to meet target P reductions, conceptual structural STPs were specified, following the selection preferences shown in Figure 3. However, the potential for management using conceptual structural STPs has not been adjusted for the likelihood of feasibility constraints and will be revisited during implementation plan development.
- Costs of operation and maintenance for existing and planned structural STPs, and for conceptual structural STPs, are not yet included in the implementation cost basis. Life-cycle and operational cost considerations for structural STPs are anticipated to be included in a future version of the model.
- The implementation model and schedule includes the opportunity for consideration of project-scale drainage asset repairs and localized erosion fixes, but does not include numeric estimates of acres managed or P load reduction possible. Such projects and credits will be applied as specific projects are identified during implementation plan development and execution.
- Similarly, the model includes the opportunity to record acres managed and P reduction credit applied for natural resource restoration projects but does not yet estimate the costs or benefits of specific floodplain reconnection or wetland restoration projects.

A draft summary of the total acres in the TS4 that are anticipated to be managed in order to meet P load reductions in the VTrans PCP Area is provided in Table 33. A chart summarizing the estimated acres to be managed by structural management strategies is provided as Figure 12. Information about the total P load managed by implementation strategy is summarized in Table 34, and a chart summarizing the estimated P load to be managed by structural management strategy is similarly provided as Figure 13.

Finally, a draft of the implementation model and schedule summarizing the acres and loads to be managed by implementation strategy over the PCP implementation term is provided in Table 35. The timing and the content of this schedule are expected to be adjusted periodically through discussions with ANR, as the implementation plans are developed and executed, and as greater detail regarding critical classes of practices such as natural resource restoration projects becomes available.

A substantial portion of the acres anticipated to be managed with structural measures constitute maintenance-level road drainage asset repairs or localized erosion repairs (1,591 acres or 35%, Table 33 and Figure 12). These structural measures together are anticipated to manage nearly two-thirds of the required annual P load reductions (1,041 kg P/yr or 63%, Table 34 and Figure 13). Of this target P reduction, 638 kg/yr (41%) is estimated to be derived from repairs to road drainage asset deficiencies within highly hydrologically connected road segments. Repairs to areas of localized erosion are currently anticipated to manage a relatively small portion of both paved road area (209 acres and 64.4 kg P/yr).

Existing and planned structural STPs are anticipated to manage 204 impervious acres, or 8% of the total impervious acres managed (963 total acres) within the PCP Area (Table 33 and Figure 12). Collectively, these existing and planned structural STPs are estimated to manage only 55.1 kg P/yr (or 3% of the total P load reduction required (Table 34 and Figure 13). These STPs represent both structural practices required for FRP implementation and STPs anticipated to be constructed on upcoming VTrans projects where operational stormwater permits are required. The model does not presently account for the increase in structural STP application that will likely accompany the lowering of the jurisdictional threshold associated with operational stormwater permit coverage to 0.5 acres of impervious cover following construction beginning in 2022.

In Lake segments where these measures coupled with non-structural control application were not sufficient to demonstrate P reduction target achievement, areas to be managed with conceptual structural STPs were estimated, preferring infiltration-based practices and following the prioritization rubric described in Section 2.1.2.1. Conceptual infiltration trench STPs are proposed to manage 743 impervious acres, or 27% of the total impervious acres managed (1,975 total acres) within the PCP Area (Table 33 and Figure 12); these conceptual STPs are estimated to provide an annual P load reduction of 499 kg P/yr, or 31% of the required target P reduction (Table 34 and Figure 13). Conceptual gravel wetlands were required in limited instances to manage 9.6 acres of impervious surface, for an estimated P load reduction of 4.8 kg P/year . No conceptual under-drained dry swales or wet ponds were required to be applied to meet target P reductions. VTrans expects these assumptions will be revisited often during development and execution of the four-year implementation plans.

The existing, planned, and proposed structural stormwater and P management strategies described above are estimated to manage a total of 2,526 impervious acres (4,818 total acres) within the VTrans PCP Area (Table 34, Table 35, and Figure 12), resulting in a cumulative P load reduction of 1,634 kg P/yr (Table 35 and Figure 13). Though non-structural controls are applied to approximately 2,500 acres of VTrans paved roads area on an annual basis (Table 33), they receive little individual P reduction credit. If current frequencies of street sweeping and DI cleaning continue through 2036, 35.2 kg P/year (1.9%) of the total P target reduction) will be managed (Table 34). Together, over the implementation term of the Vermont Lake Champlain Basin P TMDL, the structural and non-structural measures proposed in this Generalized Plan are estimated to manage 7,317 total acres and result in a total P load reduction of 1,634 kg P/year, exceeding the target P reduction of 1,606 kg P/yr (Table 35).

Table 33. Summary of Acres Managed by Strategy - VTrans Lake Champlain TS4 PCP Area

Treatment Strategy Category	Treatment Type	Land Cover Type	Acres Managed
Structural STP	Existing and Planned Structural STPs	Total Impervious	203.9
Structural STP	Existing and Planned Structural STPs	Developed Pervious	758.7
Conceptual Structural STP	Infiltration Basin w/Aggregate (Large Infiltration Trench)	Total Impervious	259.3
Conceptual Structural STP	Infiltration Basin w/Aggregate (Large Infiltration Trench)	Developed Pervious	717.2
Conceptual Structural STP	Infiltration Trench	Total Impervious	484.4
Conceptual Structural STP	Infiltration Trench	Developed Pervious	778.6
Conceptual Structural STP	Gravel Wetland	Total Impervious	9.6
Conceptual Structural STP	Gravel Wetland	Developed Pervious	11.5
Road Drainage Repair	Road Drainage Repair, Maintenance Project, HHC	Paved Roads	758.9
Road Drainage Repair	Road Drainage Repair, Maintenance Project, MHC	Paved Roads	627.2
Localized Erosion Repair	Localized Erosion Repair, Maintenance Project, HHC	Paved Roads	100.7
Localized Erosion Repair	Localized Erosion Repair, Maintenance Project, MHC	Paved Roads	43.3
Localized Erosion Repair	Localized Erosion Repair, Maintenance Project, LHC	Paved Roads	64.8
Non-Structural Control	Street Sweeping	Paved Roads	2,180.2
Non-Structural Control	DI Cleaning	Paved Roads	338.7
TOTAL IMPERVIOUS ACRES MANAGED (STRUCTURAL)			2,526.4
TOTAL ACRES MANAGED (STRUCTURAL)			4,818.1
ANNUAL ACRES MANAGED (NON-STRUCTURAL)			2,498.9

Table 34. Summary of Treatment Strategies Applied to Meet Target P Reduction

Treatment Strategy Category	Treatment Type	P Load Managed (kg/yr)
Structural STP	All Structural STPs	55.1
Conceptual Structural STP	Infiltration Basin w/Aggregate (Large Infiltration Trench)	139.2
Conceptual Structural STP	Infiltration Trench	360.2
Conceptual Structural STP	Gravel Wetland	4.8
Road Drainage Repair	Road Drainage Repair, Maintenance Project, HHC	640.1
Road Drainage Repair	Road Drainage Repair, Maintenance Project, MHC	339.1
Localized Erosion Repair	Localized Erosion Repair, Maintenance Project, HHC	42.9
Localized Erosion Repair	Localized Erosion Repair, Maintenance Project, MHC	10.7
Localized Erosion Repair	Localized Erosion Repair, Maintenance Project, LHC	10.8
Non-Structural Control	Street Sweeping	19.2
Non-Structural Control	DI Cleaning	13.0
TOTAL P REDUCTION		1,635.6

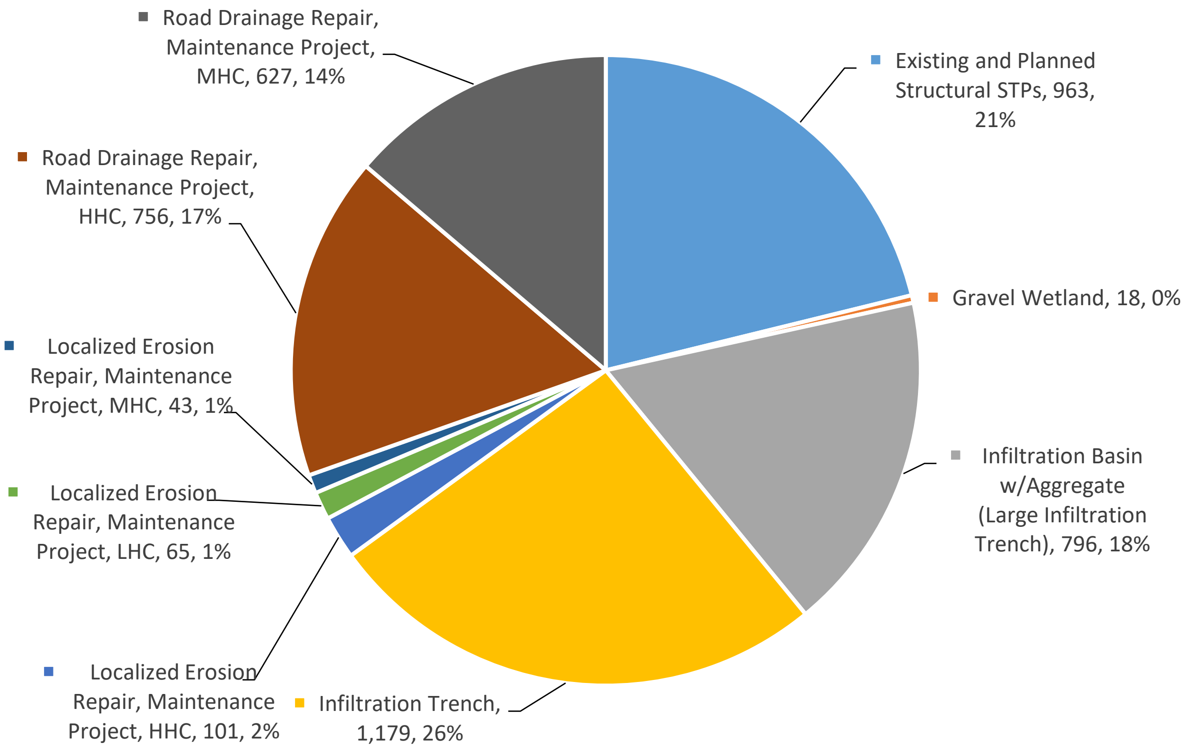


Figure 12. Summary of VTrans PCP Area Acres Managed by Structural Management Strategy

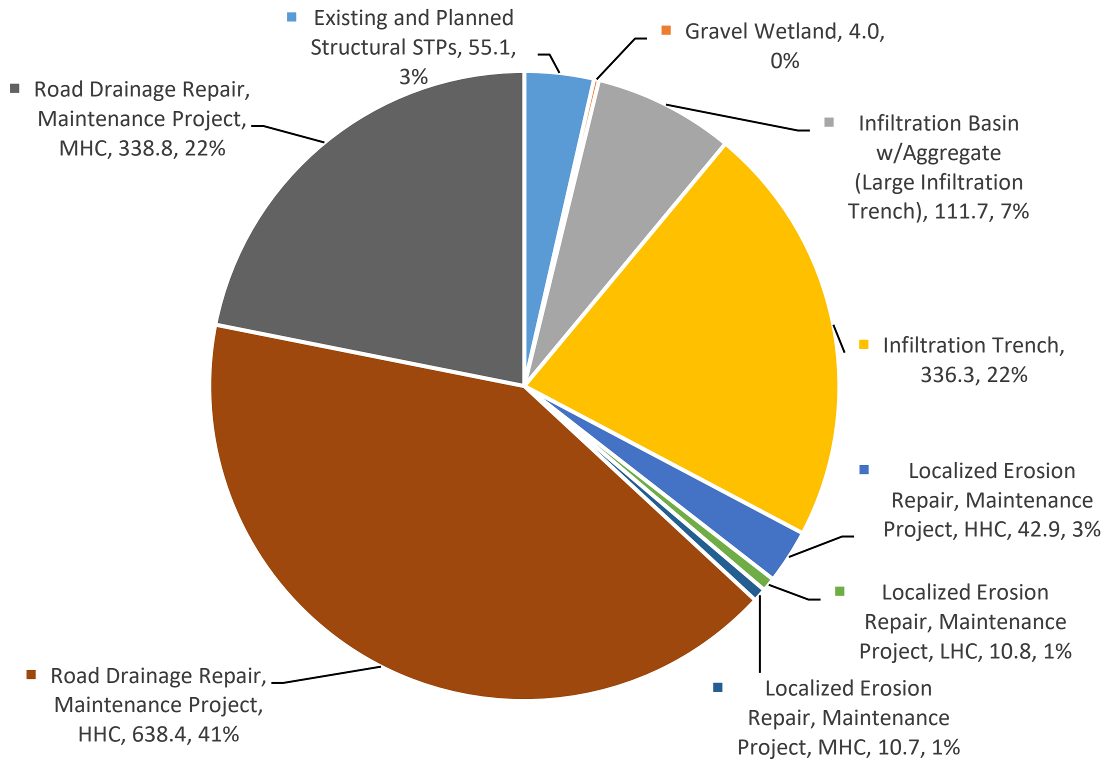


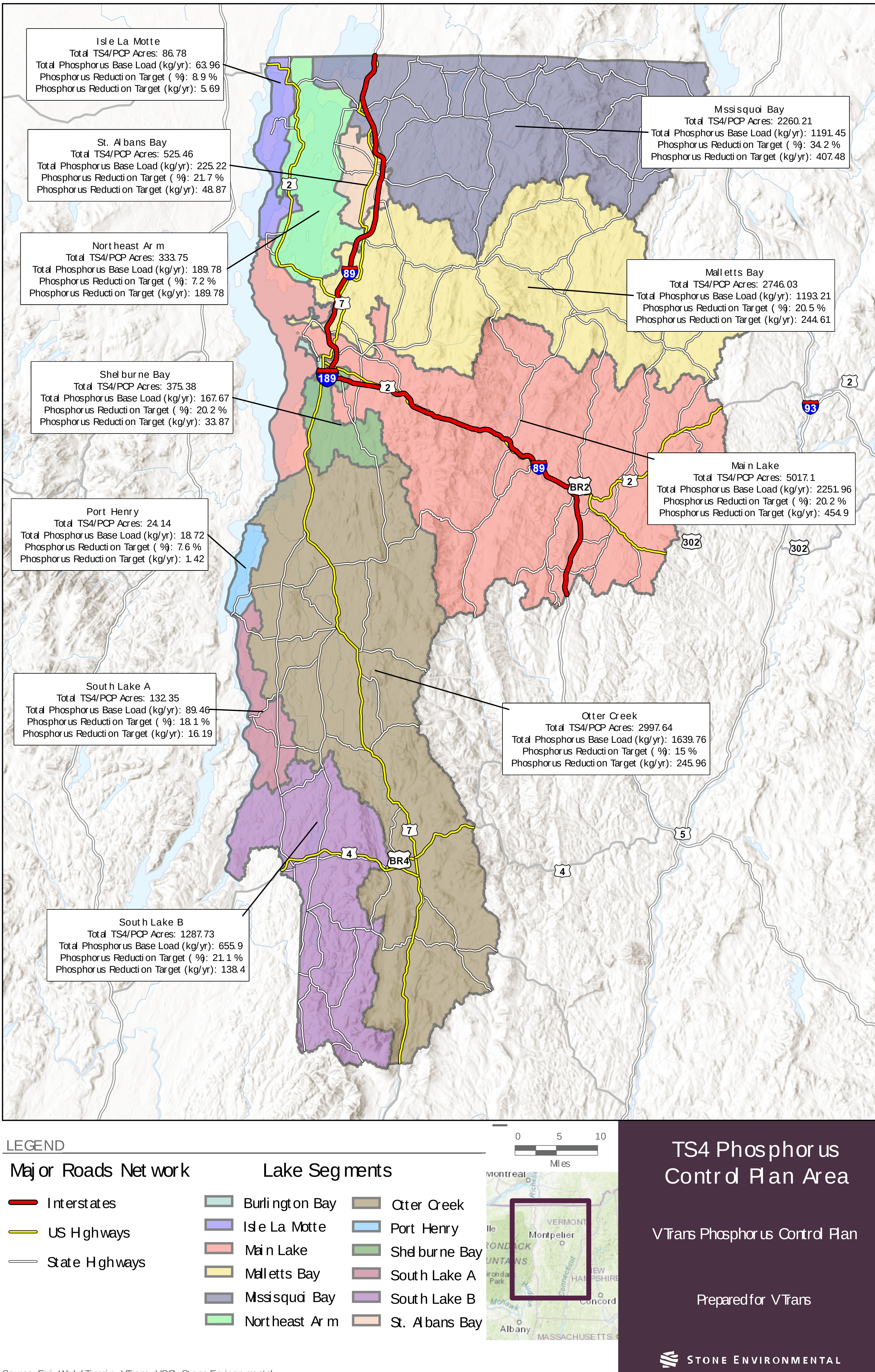
Figure 13. Summary of VTrans P Load (kg/yr) Managed by Structural Management Strategy

Table 35: Draft Generalized Implementation Schedule and Summary of Extent and Type of Measures Anticipated

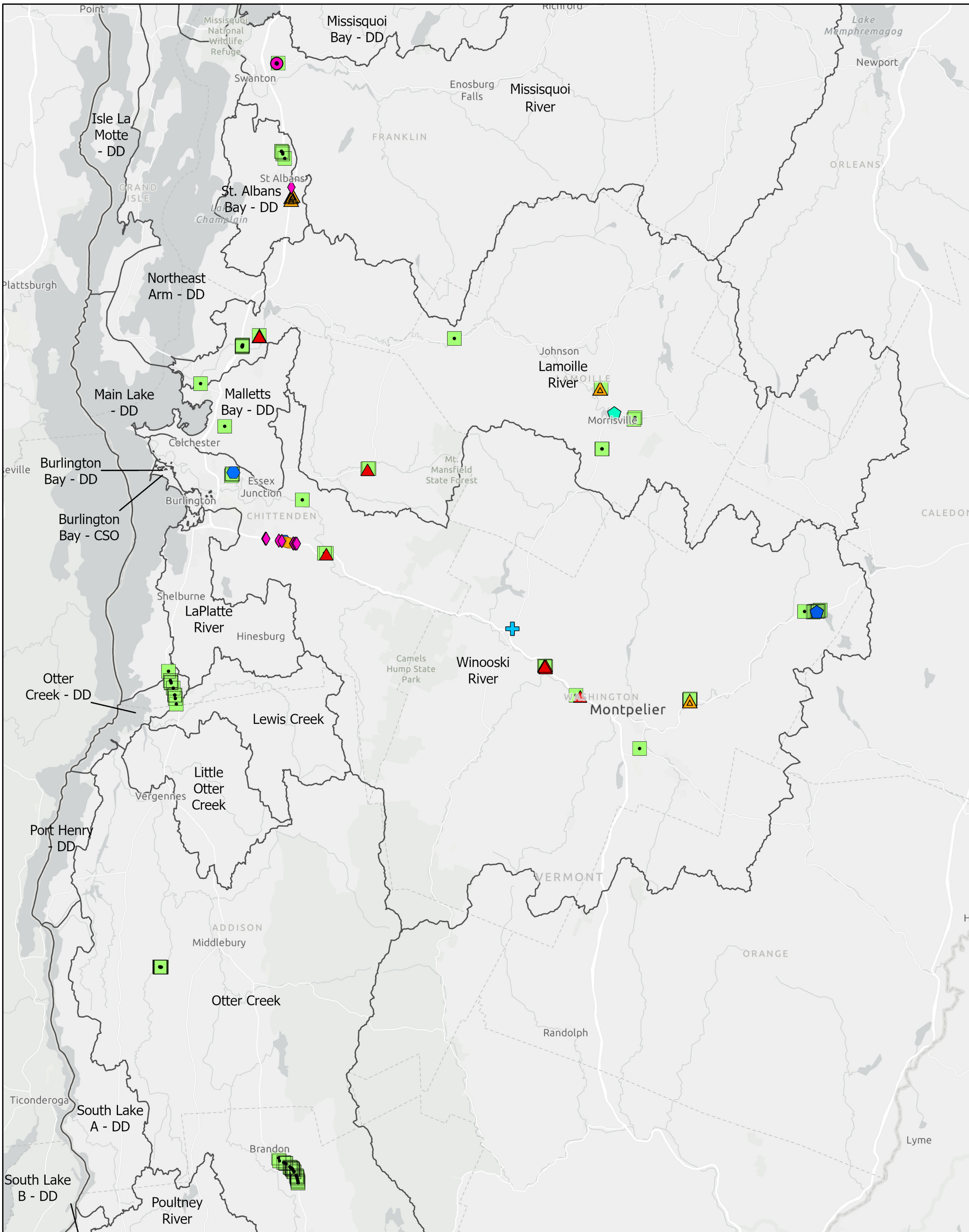
Lake Segment:	Lake Champlain Basin	Land Cover Type	PCP Area (acres)	P Base Load (kg/yr)	P Target Reduction (kg/yr)	Progress to Target P Reduction Key:
Target Reduction:	20.96%	Developed Impervious	416.78	466.78	97.85	Less than 25%
		Paved Roads	5,983.87	4,836.67	1,014.55	26%-50%
		Unpaved Roads	12.74	28.85	5.96	51%-75%
		Developed Pervious	9,483.84	2,330.74	487.56	76%-99%
		Total	15,897.23	7,663.04	1,605.91	100%+

Metric	Lake Segment	Total Acres Managed	2010-2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
				Gen PCP, 1st Imp Plan				2nd Imp Plan				3rd Imp Plan				4th Imp Plan				Complete
IMPERVIOUS ACRES MANAGED (STRUCTURAL)	South Lake B	**215.9**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.0	65.3	65.3	47.3	19.0
IMPERVIOUS ACRES MANAGED (STRUCTURAL)	South Lake A	**24.5**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	12.2	6.2	0.0
IMPERVIOUS ACRES MANAGED (STRUCTURAL)	Port Henry	**1.9**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.9	0.0	0.0	0.0
IMPERVIOUS ACRES MANAGED (STRUCTURAL)	Otter Creek	**389.4**	17.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61.7	73.3	78.9	78.9	78.9
IMPERVIOUS ACRES MANAGED (STRUCTURAL)	Main Lake	**669.7**	28.4	0.0	0.8	0.0	0.0	13.8	2.0	0.0	0.0	73.8	116.3	147.7	147.7	139.3	0.0	0.0	0.0	0.0
IMPERVIOUS ACRES MANAGED (STRUCTURAL)	Shelburne Bay	**98.1**	0.0	0.0	9.2	0.0	6.6	11.8	11.8	5.1	16.4	5.9	3.3	9.3	9.3	9.3	0.0	0.0	0.0	0.0
IMPERVIOUS ACRES MANAGED (STRUCTURAL)	Malletts Bay	**385.1**	22.3	0.0	0.0	0.0	0.0	35.8	66.2	83.1	82.1	65.2	30.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMPERVIOUS ACRES MANAGED (STRUCTURAL)	Northeast Arm	**21.3**	5.7	0.9	0.0	0.0	0.0	0.0	5.9	5.9	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMPERVIOUS ACRES MANAGED (STRUCTURAL)	St. Albans Bay	**105.6**	5.7	0.0	24.9	0.0	0.0	11.9	11.9	17.1	19.6	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMPERVIOUS ACRES MANAGED (STRUCTURAL)	Mississquoi Bay	**609.0**	3.8	0.0	38.1	76.1	191.2	153.2	96.9	49.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMPERVIOUS ACRES MANAGED (STRUCTURAL)	Isle La Motte	**6.0**	0.0	0.0	0.0	0.0	0.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IMPERVIOUS ACRES MANAGED (STRUCTURAL)	**PCP Area**	**2,526.4**	**83.7**	**0.9**	**72.9**	**76.1**	**197.9**	**229.4**	**197.6**	**161.0**	**121.0**	**159.5**	**150.0**	**157.0**	**157.0**	**230.3**	**145.6**	**156.4**	**132.3**	**97.9**
TOTAL ACRES MANAGED (STRUCTURAL)	South Lake B	**441.5**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.0	154.9	154.9	93.7	19.0
TOTAL ACRES MANAGED (STRUCTURAL)	South Lake A	**38.6**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.1	19.3	6.2	0.0
TOTAL ACRES MANAGED (STRUCTURAL)	Port Henry	**1.9**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.9	0.0	0.0	0.0
TOTAL ACRES MANAGED (STRUCTURAL)	Otter Creek	**762.0**	107.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73.9	130.2	150.1	150.1	150.1
TOTAL ACRES MANAGED (STRUCTURAL)	Main Lake	**1,343.5**	134.3	0.0	1.3	0.0	0.0	39.2	3.5	0.0	0.0	139.3	278.6	278.6	278.6	190.0	0.0	0.0	0.0	0.0
TOTAL ACRES MANAGED (STRUCTURAL)	Shelburne Bay	**223.7**	0.0	0.0	16.1	0.0	16.4	21.5	21.5	5.1	27.1	5.9	7.3	34.2	34.2	34.2	0.0	0.0	0.0	0.0
TOTAL ACRES MANAGED (STRUCTURAL)	Malletts Bay	**485.1**	46.3	0.0	0.0	0.0	0.0	35.8	66.2	83.1	120.1	103.2	30.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL ACRES MANAGED (STRUCTURAL)	Northeast Arm	**15.7**	0.0	1.0	0.0	0.0	0.0	0.0	5.9	5.9	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL ACRES MANAGED (STRUCTURAL)	St. Albans Bay	**453.2**	14.7	0.0	327.6	0.0	0.0	11.9	11.9	30.1	36.2	21.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL ACRES MANAGED (STRUCTURAL)	Mississquoi Bay	**1,046.9**	61.2	0.0	38.1	76.1	327.4	289.3	186.9	67.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL ACRES MANAGED (STRUCTURAL)	Isle La Motte	**6.0**	0.0	0.0	0.0	0.0	0.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL ACRES MANAGED (STRUCTURAL)	**PCP Area**	**4,818.1**	**364.2**	**1.0**	**383.0**	**76.1**	**343.8**	**400.7**	**298.9**	**192.0**	**186.3**	**269.4**	**316.4**	**312.9**	**312.9**	**318.0**	**299.2**	**324.2**	**250.0**	**169.0**
ANNUAL ACRES MANAGED (NON-STRUCTURAL)	South Lake B	**158.7**	158.8	158.7	158.7	158.7	158.7	158.7	158.7	158.7	158.7	158.7	158.7	158.7	158.7	158.7	158.7	158.7	158.7	158.7
ANNUAL ACRES MANAGED (NON-STRUCTURAL)	South Lake A	**44.5**	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5	44.5
ANNUAL ACRES MANAGED (NON-STRUCTURAL)	Port Henry	**11.9**	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
ANNUAL ACRES MANAGED (NON-STRUCTURAL)	Otter Creek	**804.2**	808.5	803.9	803.9	803.9	803.9	803.9	803.9	803.9	803.9	803.9	803.9	803.9	803.9	803.9	803.9	803.9	803.9	803.9
ANNUAL ACRES MANAGED (NON-STRUCTURAL)	Main Lake	**537.6**	537.8	537.6	537.6	537.6	537.6	537.6	537.6	537.6	537.6	537.6	537.6	537.6	537.6	537.6	537.6	537.6	537.6	537.6
ANNUAL ACRES MANAGED (NON-STRUCTURAL)	Shelburne Bay	**97.5**	97.9	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5
ANNUAL ACRES MANAGED (NON-STRUCTURAL)	Malletts Bay	**457.1**	457.6	457.1	457.1	457.1	457.1	457.1	457.1	457.1	457.1	457.1	457.1	457.1	457.1	457.1	457.1	457.1	457.1	457.1
ANNUAL ACRES MANAGED (NON-STRUCTURAL)	Northeast Arm	**91.6**	91.6	91.6	91.6	91.6	91.6	91.6	91.6	91.6	91.6	91.6	91.6	91.6	91.6	91.6	91.6	91.6	91.6	91.6
ANNUAL ACRES MANAGED (NON-STRUCTURAL)	St. Albans Bay	**45.8**	66.2	66.2	66.2	66.2	66.2	66.2	66.2	66.2	66.2	66.2	66.2	66.2	66.2	66.2	66.2	66.2	66.2	66.2
ANNUAL ACRES MANAGED (NON-STRUCTURAL)	Mississquoi Bay	**223.3**	223.3	223.3	223.3	223.3	223.3	223.3	223.3	223.3	223.3	223.3	223.3	223.3	223.3	223.3	223.3	223.3	223.3	223.3
ANNUAL ACRES MANAGED (NON-STRUCTURAL)	Isle La Motte	**26.8**	28.2	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7
ANNUAL ACRES MANAGED (NON-STRUCTURAL)	**PCP Area**	**2,498.9**	**2526.3**	**2518.9**	**2518.9**	**2518.9**	**2518.9**	**2518.9**	**2518.9**	**2518.9**	**2518.9**	**2518.9**	**2518.9**	**2518.9**	**2518.9**	**2518.9**	**2518.9**	**2518.9**	**2518.9**	**2518.9**
CUMULATIVE TOTAL P REDUCTION	South Lake B	140.2	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	12.9	55.1	97.2	128.1	140.2
CUMULATIVE TOTAL P REDUCTION	South Lake A	16.4	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	3.3	11.3	16.4	16.4
CUMULATIVE TOTAL P REDUCTION	Port Henry	1.6	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.8	1.6	1.6	1.6	1.6
CUMULATIVE TOTAL P REDUCTION	Otter Creek	248.3	5.8	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	48.8	96.4	147.0	197.7	248.3
CUMULATIVE TOTAL P REDUCTION	Main Lake	463.4	15.6	19.6	19.8	19.8	19.8	31.9	33.3	33.3	33.3	81.0	176.6	272.2	367.8	463.4	463.4	463.4	463.4	463.4
CUMULATIVE TOTAL P REDUCTION	Shelburne Bay	34.3	0.7	1.4	3.7	3.7	5.5	10.6	15.7	19.0	26.0	29.7	30.3	31.7	33.0	34.3	34.3	34.3	34.3	34.3
CUMULATIVE TOTAL P REDUCTION	Malletts Bay	247.9	4.6	7.2	7.2	7.2	7.2	30.8	75.8	134.8	187.7	226.6	247.9	247.9	247.9	247.9	247.9	247.9	247.9	247.9
CUMULATIVE TOTAL P REDUCTION	Northeast Arm	13.9	0.9	2.0	2.0	2.0	2.0	2.0	6.7	11.5	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9
CUMULATIVE TOTAL P REDUCTION	St. Albans Bay	49.9	2.2	2.6	7.9	7.9	7.9	16.0	24.2	32.7	42.8	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9
CUMULATIVE TOTAL P REDUCTION	Mississquoi Bay	412.1	1.6	2.8	24.5	68.1	197.1	304.3	379.6	412.1	412.1	412.1	412.1	412.1	412.1	412.1	412.1	412.1	412.1	412.1
CUMULATIVE TOTAL P REDUCTION	Isle La Motte	5.7	0.1	0.2	0.2	0.2	0.2	3.0	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
CUMULATIVE TOTAL P LOAD REDUCTION	**PCP Area**	**1,633.7**	**32.6**	**47.4**	**77.0**	**120.6**	**251.4**	**410.3**	**552.6**	**660.7**	**733.1**	**830.6**	**948.2**	**1045.1**	**1142.0**	**1290.3**	**1383.6**	**1484.3**	**1571.0**	**1633.7**

Maps



Source: Esri World Terrain, VTrans, VCGI, Stone Environmental



LEGEND

Area Treatment Practice

- Disconnection
- Dry Detention Pond
- Gravel Wetland
- Infiltration Basin
- Sand Filter
- Subsurface Infiltration
- Wet Retention Pond

Linear Treatment Practice

- Dry Swale
- Grass Swale
- Infiltration Trench
- Wet Swale

SWAT Drain Boundary

Source: Esri Basemaps, Vermont Agency of Transportation

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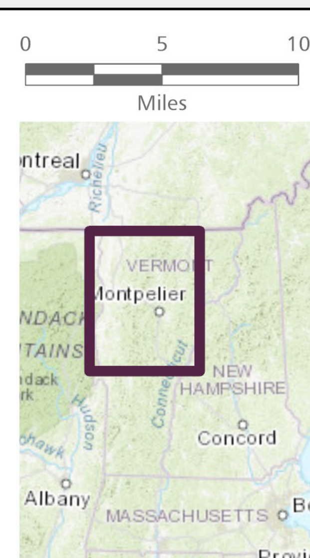
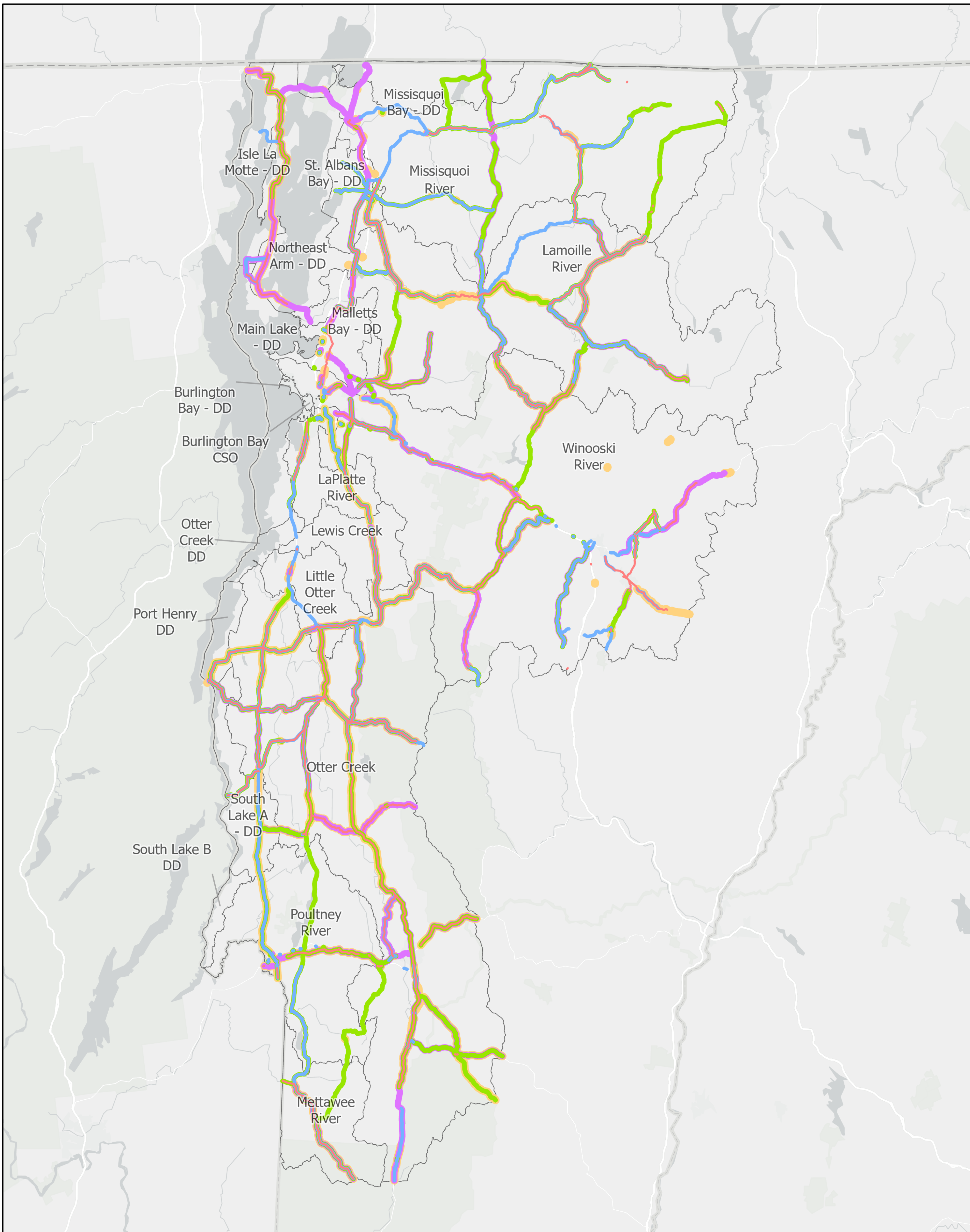


Existing VTrans Strructural BMPs

VTrans Generalized Phosphorous Control Plan

Prepared for Vermont Agency of Transportation - Stormwater Division

STONE ENVIRONMENTAL



LEGEND

SWAT Drains

MATS Sweeping of Interest by Year

- 2019
- 2018
- 2017
- 2016
- 2015

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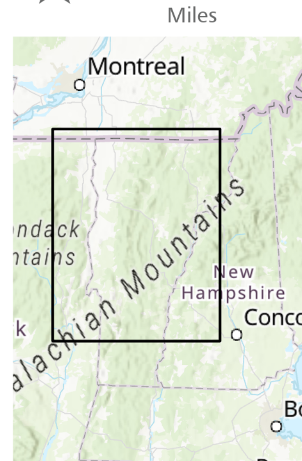

MATS Sweeping Activities of Interest: 2015-2019

VTrans Phosphorous Control Plan

Prepared for VTrans and VT DEC

STONE ENVIRONMENTAL

Source: Basemap - ESRI; MATS Sweeping Activities - VTrans

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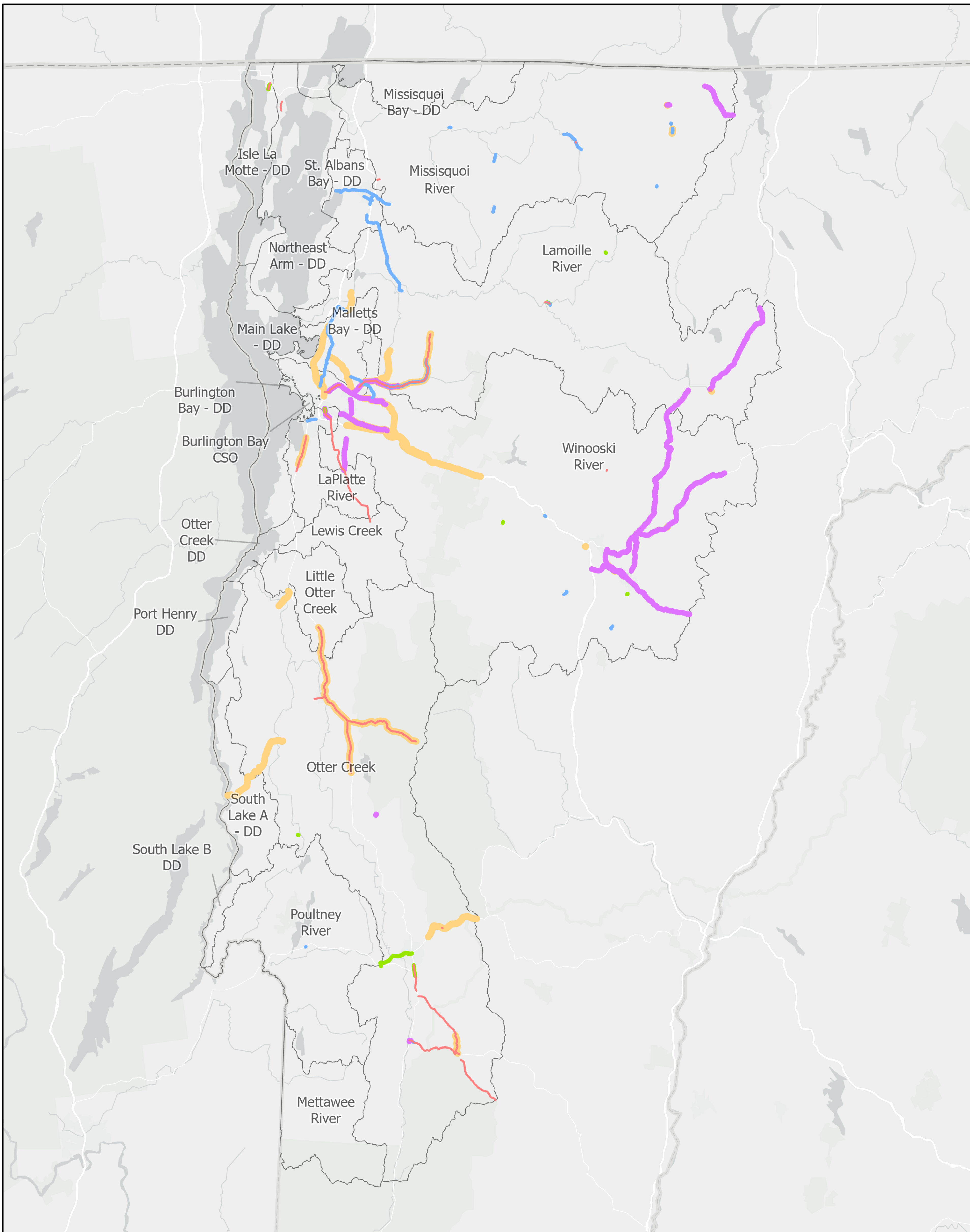
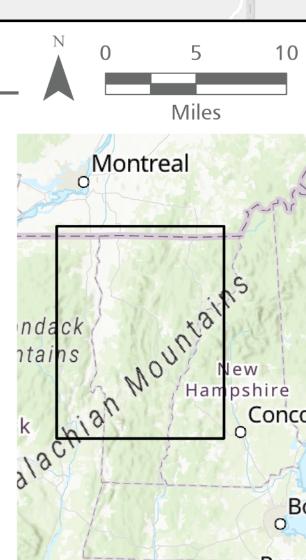


LEGEND

SWAT Drains

MATS DI Cleaning of Interest by Year

- 2019
- 2018
- 2017
- 2016
- 2015



MATS DI Cleaning Activities of Interest: 2015-2019

VTrans Phosphorous Control Plan

Prepared for VTrans and VT DEC

STONE ENVIRONMENTAL

Source: Basemap - ESRI; MATS DI Cleaning Activities - VTrans

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Appendix A: Baseline P Load and Reductions Needed, April 1 2018 Submittal

STONE ENVIRONMENTAL
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MEMO

March 27, 2018

To: Emily Schelley, VT DEC
Jenn Callahan, VTrans

From: Amy Macrellis, Katie Budreski, Gabe Bolin

Stone Project No. 16-091
Subject: VTrans PCP – Evaluation of draft phosphorus base loads and load reduction numeric targets

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The following narrative summarizes work completed by VTDEC and VTrans, as supported by Stone, to establish the baseline phosphorus load and reductions needed to comply with Lake Champlain Phosphorus Control Plan (PCP) requirements specified in Subpart 9.2.A.1 of the *National Pollutant Discharge Elimination System (NPDES) General Permit 3-9007 for Stormwater Discharges from the State Transportation Separate Storm Sewer System (TS4),* effective November 27, 2017.

In order to establish the baseline phosphorus load and reductions needed, it was first necessary to develop GIS data defining the spatial extents and geographic coverage of the TS4 within the Lake Champlain Basin (LCB). The GIS data for TS4 extents was developed by VTrans and Stone in consultation with VTDEC. The spatial extents of linear facilities were derived based on the VTrans Managing Assets for Transportation Systems (MATS) database and include VTrans owned and maintained roads within the Lake Champlain Basin (LCB). Right of way areas for linear facilities were derived using GIS data from VTrans, buffered road centerlines using minimum ROW widths and standard road class width where gaps existed within the VTrans data, and further manual edits to remove right of way areas maintained by private or municipal entities. The spatial extents for VTrans facilities, including airports, welcome centers, park and rides, gravel pits, and maintenance garages, were developed based on parcel data provided by VTrans. Stone digitized non-road impervious areas using 2011 impervious cover data from the Lake Champlain Basin Program, which was then updated and corrected using aerial imagery.

VTDEC applied the GIS datasets defining the TS4 extents within the LCB to extract draft developed lands acreages and resulting draft phosphorus base loads from VTDEC's existing developed lands dataset. The draft acreages and phosphorus base loads were broken down by lake segment, SWAT model drainage area, type of area (Road/linear facility or Parcel-based facility) and type of land use/land cover (Developed Impervious, Paved Road, Unpaved Road, and Developed Pervious). Draft phosphorus base loads and target reductions were provided in draft form by VTDEC on January 12, 2018.

1. Draft Acreages and Phosphorus Base Loads for VTrans Facilities (Parcels)

Draft acreages and phosphorus base loads for VTrans facilities (parcels) provided by VTDEC are summarized in Table 1. The table is annotated with proposed revisions to the draft acreages and resulting phosphorus base loads, as further described in the narrative below. Proposed revisions in Table 1 are highlighted.

The VTrans/Stone estimate of non-road impervious acres (259 acres) compares favorably with VTDEC's SWAT-model derived impervious acreage for the combined acreage on Parcels for Developed Impervious (151 acres) and Paved Roads (111 acres) – a total of 262 acres. VTrans/Stone generally agree that VTDEC's draft base load allocations for Developed Impervious, Paved Roads, and Developed Pervious are reasonable.

The VTDEC acreages by land use/land cover include 1.38 acres of Unpaved Road, which translates to a base load of 2.85 kg/year. In some cases, this allocation is appropriate, while in other cases, the Unpaved Road acres and allocation should be removed, as described below:

- The 1.07 acres of Unpaved Road in the Missisquoi River drainage area appears to be associated with two VTrans facilities:
    - Approximately 0.46 acres is adjacent to the Franklin County State Airport in Highgate. A section of Hemp Yard Road between Carter Hill Road and the airport is unpaved road and is included in the extents of the VTrans parcel data. This should remain within the VTrans base load allocation.
    - An additional 0.61 acres in the Missisquoi River drainage area is located on Fiddler's Elbow Road off VT Rte. 100 in Lowell, adjacent to a gravel pit that does not appear on VTrans' TS4 Industrial Activities table. While this gravel pit facility appears in VTrans's parcel data, it is owned by Dale E. Percy Inc. The unpaved road is not owned or maintained by VTrans, and so it should be removed from the VTrans acreage and phosphorus base load.
- In the LaPlatte River drainage area, 0.19 acres of unpaved roadway appears to be associated with unpaved municipal road crossings of a railroad right-of-way parcel that runs parallel to US 7 in South Burlington between that highway and Shelburne Bay. We recommend that these areas be removed from the base load allocation.
- A similar situation occurs in the Main Lake – DD drainage area, where less than 0.01 acres of unpaved road municipal road-railroad crossings and unpaved municipal roads are located within the

same railroad right-of-way parcel described above (between US 7 and Lake Champlain, but south of Shelburne Bay).

- 0.14 acres of unpaved road in the Otter Creek drainage area are associated with the Middlebury State Airport. These polygons are in the middle of the taxiway and runway, and should be classified as Paved Road.
- In the Winooski River drainage area, less than 0.01 acres of unpaved road is associated with the Waterbury Park and Ride, where the parcel boundary overlaps with Lincoln St. – however, this road is paved where it passes the park-and-ride entrance. This should either be classified as paved road or removed from VTrans's base load allocation.
- Also in the Winooski River drainage area, less than 0.01 acres of unpaved road is associated with a large, undeveloped parcel in East Montpelier, north of US 2 and near the intersection of US 2 and Coburn Rd. Coburn Rd. is unpaved, and the parcel boundary captures the curb cut. This Unpaved Road fraction should be removed from the base load, as it is more likely to be managed by the municipality. In addition, DEC's mapping shows 0.99 acres of paved road on this parcel, but current orthophotos indicate that no road is present. Historical orthophotos indicate an unpaved road or access was present through roughly 2013, but that now only pedestrian or bicycle trails remain. In this case it is not clear whether the Paved Road base allocation should be removed, or whether de-paving and a resulting land cover change should be later credited towards targets in the PCP.

2. Draft Acreages and Phosphorus Base Loads for VTrans Linear Facilities and Rights-of-Way (Roads)

Draft acreages and phosphorus base loads for VTrans linear facilities (roads) provided by VTDEC are summarized in Table 2. The table is annotated with minor proposed revisions to the draft acreages and resulting phosphorus base loads, as further described in the narrative below. Proposed revisions in Table 2 are highlighted.

2.1 Paved Roads

VTDEC's estimated impervious acreage for Paved Roads (5,904 acres) is higher than the VTrans/Stone estimate (4,830 acres). The VTrans/Stone estimate was derived by buffering road centerlines based on VTrans data and reported roadway widths. This approach, while generally accurate along the roadway, often excludes impervious area at intersections where turning lanes and the intersections themselves are often wider than the reported roadway width. The VTrans/Stone estimate is likely under-estimating the actual paved road impervious acreage. However, VTDEC's estimated impervious acreage sometimes captures portions of municipal roads that are located in the VTrans ROW, particularly at bridge crossings or running parallel to interstate highways, and in villages can misclassify developed impervious as paved road within the VTrans right-of-way. While efforts were made to exclude these non-VTrans-managed roadways, VTDEC's acreage for VTrans Paved Roads is likely an over-estimate. All parties acknowledge this uncertainty, and agree to use VTDEC's estimate of Paved Roads acres for overall consistency with other VTDEC Phase I implementation work (Municipal Roads General Permit, MS4 PCPs, etc.). It is also acknowledged that the VTDEC acreage, and thus the phosphorus base load resulting from that acreage, represents a conservative assumption and may need to be revisited periodically as progress is made towards developing and implementing the specific PCPs. The next opportunity to revisit these estimates of road-related impervious cover will be with the release of updated land use/land cover data which is now under development by the Lake Champlain Basin Program and the UVM Spatial Analysis Lab; delivery of this dataset is currently estimated to be in the fall of 2018.

In addition to the above, the method that will be used to assign the road-related phosphorus base load to various portions of the roadway based on hydrologic connectivity, slope class, or localized erosion caused by highway runoff within each lake segment remains under development.

2.2 Roadway –Related Developed Impervious

VTDEC's estimate of impervious cover within the TS4 right-of-way, which should cover only Paved Road impervious acreage, includes 266 acres of Developed Impervious area. This impervious acreage is generally associated with curb cuts, accesses, or pre-existing developed rooftops, parking, or other impervious cover located within the VTrans ROW but associated with municipal, private or other development. Figure 1 illustrates the breakdown of the draft phosphorus base load for VTrans linear facilities and developed lands within the VTrans ROW, and includes notes about the largest lake segments, draft phosphorus base loads, and target reductions. It was used in consideration of whether the Developed Impervious contribution to the phosphorus base load within the VTrans ROW was cause for substantial concern, and is offered as a visual representation of how the most substantial portions of the draft phosphorus base load and reductions required are distributed across the LCB.

Basin-wide, VTDEC's acreage and phosphorus base load estimates indicate that this developed impervious area accounts for 2.2% of the total acres (range of 1.1-4% across all drainage areas) and 4.4% of the total phosphorus base load(range of 2.6-7.1%) within the TS4 ROW. In contrast, the Paved Roads area (DEC's estimate of 4,472 acres basin-wide) accounts for 43% of the total acres (range of 26-63% across all drainage areas) and 66% of the total base load (range of 45-91%) within the TS4 ROW (Figure 1 and Table 2). These Developed Impervious areas are therefore a relatively minor portion of the overall base load allocation. VTrans' ability to directly control these areas is extremely limited – treatment or improvement of existing accesses can only be required through the 1111 permit process. However, since these Developed Impervious areas are located within the VTrans ROW, VTrans should be able to take credit for treating any incidental, directly connected curb cuts and accesses as part of stormwater improvement projects that otherwise and primarily treat Paved Road impervious. The Developed Impervious areas located within VTrans right-of-way are currently proposed to remain as part of the VTrans phosphorus base load, although this assumption may be re-visited in the future.

2.3 Unpaved Roads

VTDEC's estimate of impervious cover within the VTrans ROW also includes 25 acres of unpaved roads. However, VTrans only has records of owning and controlling two areas of unpaved road described below, both of which are located in the Winooski River drainage area. We recommend that the other areas, which are nearly all associated with municipal Unpaved Road areas crossing into VTrans ROW at intersections, be removed from the VTrans base load allocation (Table 2).

- A 150' section of Dog River Road in the Winooski River drainage area in Berlin does not appear in the GIS dataset for the PCP Area delivered to VTDEC; however, this 0.05-acre section of road is owned and maintained by VTrans and should be classified as unpaved road under VTrans linear facilities and right-of-way.
- A 12.26-acre portion of VT Rte. 65 in Brookfield, between VT Rte. 12 and the edge of the Winooski River drainage area (the unpaved portion of VT Rte. 65 continues out of the Lake Champlain basin, past I-89 and the Floating Bridge in Brookfield Village). This portion alone represents approximately half of the total Unpaved Road area within VTrans's ROW (Table 2), and represents a base load of 27.06 kg/yr.

3. Revised Baseline Phosphorus Load and Reductions Required

The draft phosphorus base loads and target reductions provided by VTDEC on January 12, 2018 were adjusted to reflect the proposed revisions discussed in Sections 1 and 2 above. Table 3 summarizes the revised phosphorus base load, and target phosphorus reductions, by lake segment.

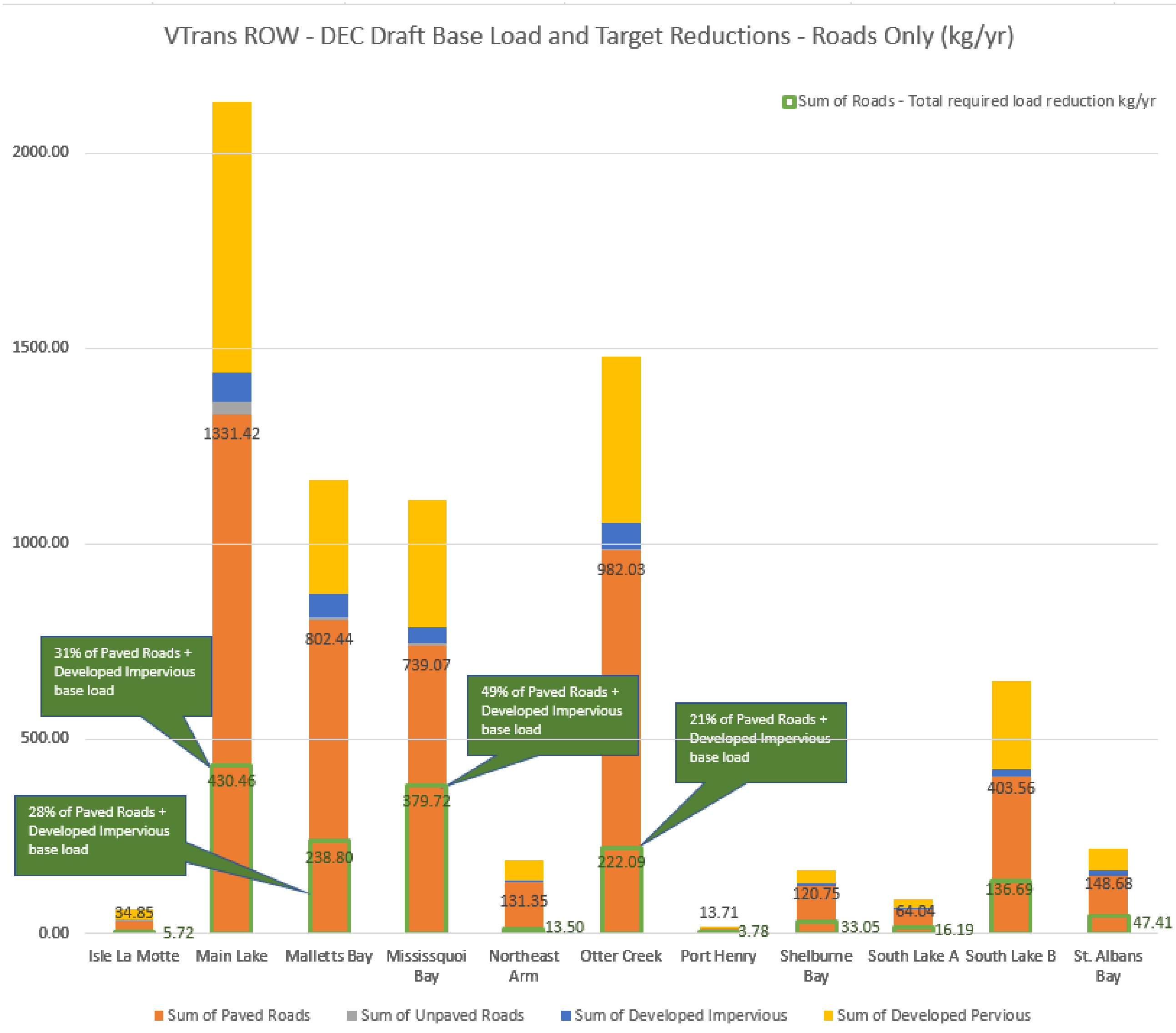

Figure 1. Summary of draft phosphorus base load for VTrans linear facilities (roads and associated ROW areas). Paved roads base loads and draft required load reductions are labeled. This figure shows the VTDEC Jan. 12 draft base loads, before corrections proposed in this memo are applied.

Table 1. Summary of Draft Acres and Phosphorus Base Loads for VTrans Facilities (Parcels)

			Area (acres)				Load (kg/yr)				
Lake Segment	SWAT_drain	Area_Type	Developed Impervious	Paved Roads	Unpaved Roads	Developed Pervious	Developed Impervious	Paved Roads	Unpaved Roads	Developed Pervious	Total
Main Lake	Main Lake - DD	Parcel	1.29	0.14	~~0.000076~~ 0.00	0.45	1.21	0.12	~~0.00016~~ 0.00	0.04	1.37
Main Lake	Winooski River	Parcel	40.39	36.43	~~0.01~~ 0.00	222.60	45.10	29.23	~~0.025~~ 0.000	51.31	~~125.67~~ 125.64
Malletts Bay	Lamoille River	Parcel	20.74	0.98	0.00	39.06	23.60	0.80	0.00	8.90	33.30
Malletts Bay	Malletts Bay - DD	Parcel	3.40	0.01	0.00	8.39	2.80	0.00	0.00	0.10	2.91
Mississquoi Bay	Mississquoi Bay - DD	Parcel	1.17	6.18	0.00	4.58	0.84	5.05	0.00	1.90	7.79
Mississquoi Bay	Mississquoi River	Parcel	27.69	20.60	~~1.05~~ 0.46	110.56	31.83	16.60	~~2.15~~ 0.95	28.83	~~79.42~~ 78.21
Northeast Arm	Northeast Arm - DD	Parcel	1.83	0.00	0.00	2.54	2.09	0.00	0.00	0.76	2.85
Otter Creek	Lewis Creek	Parcel	1.63	0.00	0.00	2.91	1.61	0.00	0.00	0.84	2.46
Otter Creek	Little Otter Creek	Parcel	1.76	0.00	0.00	0.26	2.17	0.00	0.00	0.10	2.27
Otter Creek	Otter Creek	Parcel	40.57	~~42.39~~ 42.53	~~0.14~~ 0.00	265.97	46.65	~~34.68~~ 34.79	~~0.29~~ 0.00	77.55	~~159.17~~ 158.99
Shelburne Bay	LaPlatte River	Parcel	0.84	2.62	~~0.19~~ 0.00	11.15	0.80	1.93	~~0.39~~ 0.00	1.92	~~5.03~~ 4.64
South Lake B	Poultney River	Parcel	3.98	1.22	0.00	9.74	4.66	1.02	0.00	2.81	8.49
St. Albans Bay	St. Albans Bay - DD	Parcel	5.60	0.00	0.00	1.03	6.94	0.00	0.00	0.18	7.12
Total (adjusted to reflect proposed changes)			150.89	110.71	0.46	679.22	170.30	89.55	0.95	175.25	436.04

Table 2. Summary of Draft Acres and Phosphorus Base Loads for VTrans Linear Facilities and Right-of-Way (Roads)

			Area (acres)				Load (kg/yr)				
Lake Segment	SWAT_drain	Area Type	Developed Impervious	Paved Roads	Unpaved Roads	Developed Pervious	Developed Impervious	Paved Roads	Unpaved Roads	Developed Pervious	Total
Isle La Motte	Isle La Motte - DD	Road	2.29	47.83	~~0.17~~ 0.00	37.56	1.74	34.85	~~0.33~~ 0.00	27.37	~~64.29~~ 63.96
Main Lake	Main Lake - DD	Road	1.04	19.73	~~0.14~~ 0.00	35.36	0.97	17.29	~~0.30~~ 0.00	3.35	~~21.91~~ 21.61
Main Lake	Winooski River	Road	64.34	1637.74	~~14.92~~ 12.31	2994.20	71.85	1314.13	~~32.93~~ 27.17	690.19	~~2109.1~~ 2103.34
Malletts Bay	Lamoille River	Road	49.29	854.33	~~3.34~~ 0.00	1264.60	56.08	692.11	~~6.78~~ 0.00	288.31	~~1043.28~~ 1036.49
Malletts Bay	Malletts Bay - DD	Road	7.38	163.06	~~0.55~~ 0.00	339.71	6.09	110.33	~~1.11~~ 0.00	4.09	~~121.62~~ 120.51
Missisquoi Bay	Missisquoi Bay - DD	Road	5.67	104.24	~~0.13~~ 0.00	133.22	4.05	85.21	~~0.26~~ 0.00	55.27	~~144.78~~ 144.52
Missisquoi Bay	Missisquoi River	Road	32.51	811.33	~~2.23~~ 0.00	1034.21	37.37	653.86	~~4.59~~ 0.00	269.70	~~965.52~~ 960.92
Northeast Arm	Northeast Arm - DD	Road	5.86	160.33	~~0.28~~ 0.00	164.01	6.70	131.35	~~0.58~~ 0.00	48.88	~~187.52~~ 186.93
Otter Creek	Lewis Creek	Road	3.58	37.31	~~0.22~~ 0.00	47.81	3.55	31.86	~~0.59~~ 0.00	13.87	~~49.77~~ 49.28
Otter Creek	Little Otter Creek	Road	4.75	72.65	~~0.036~~ 0.00	68.28	5.85	69.53	~~0.08~~ 0.00	24.96	~~100.42~~ 100.34
Otter Creek	Otter Creek	Road	49.06	1068.57	~~1.81~~ 0.00	1308.92	56.42	874.16	~~3.84~~ 0.00	381.66	~~1316.08~~ 1312.24
Otter Creek	Otter Creek - DD	Road	0.54	7.35	~~0.079~~ 0.00	20.40	0.59	6.48	~~0.18~~ 0.00	7.10	~~14.35~~ 14.17
Port Henry	Port Henry - DD	Road	0.75	15.33	0.00	8.10	0.93	13.71	0.00	4.08	18.72
Shelburne Bay	LaPlatte River	Road	10.15	164.23	~~0.28~~ 0.00	189.58	9.66	120.75	~~0.57~~ 0.00	32.61	~~163.6~~ 163.03
South Lake A	South Lake A - DD	Road	1.94	69.11	~~0.0035~~ 0.00	61.30	2.54	64.04	~~0.01~~ 0.00	22.87	~~89.47~~ 89.46
South Lake B	Mettawee River	Road	4.82	102.55	~~0.051~~ 0.00	87.60	5.77	84.43	~~0.12~~ 0.00	25.35	~~115.67~~ 115.55
South Lake B	Poultney River	Road	12.01	380.48	~~0.13~~ 0.00	688.04	14.04	319.13	~~0.29~~ 0.00	198.69	~~532.15~~ 531.86
St. Albans Bay	St. Albans Bay - DD	Road	9.90	187.85	~~0.18~~ 0.00	321.73	12.28	148.68	~~0.37~~ 0.00	57.14	~~218.46~~ 218.1
Total (adjusted to reflect proposed changes)			265.89	5904.03	12.31	8804.61	296.49	4771.90	27.17	2155.49	7251.04

Table 3. Revised Phosphorus Base Loads and Target Reductions

Lake Segment	Phosphorus Base Load (kg/yr)	TMDL Target	Target Phosphorus Reduction (kg/yr)
Isle La Motte	63.96	8.9%	5.69
Main Lake	2251.96	20.2%	454.90
Malletts Bay	1193.21	20.5%	244.61
Mississquoi Bay	1191.45	34.2%	407.48
Northeast Arm	189.78	7.2%	13.66
Otter Creek	1639.76	15.0%	245.96
Port Henry	18.72	7.6%	1.42
Shelburne Bay	167.67	20.2%	33.87
South Lake A	89.46	18.1%	16.19
South Lake B	655.90	21.1%	138.40
St. Albans Bay	225.22	21.7%	48.87
Total	7687.09		1611.05

Appendix B: GIS inventory of phosphorus loading factors, October 1 2018 Submittal

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MEMO

October 1, 2018

To: Emily Schelley, VT DEC
Jenn Callahan, VTrans

From: Amy Macrellis, Katie Budreski, Gabe Bolin

Stone Project No. 16-091
Subject: VTrans PCP – Submission of GIS Files of Loading Factors

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The following narrative summarizes work completed by VTDEC and VTrans, as supported by Stone, to complete a GIS inventory of phosphorus loading factors to comply with Lake Champlain Phosphorus Control Plan (PCP) requirements specified in Subpart 9.2.C. of the *National Pollutant Discharge Elimination System (NPDES) General Permit 3-9007 for Stormwater Discharges from the State Transportation Separate Storm Sewer System (TS4),* effective November 27, 2017.

The loading factors that are being considered to allocate load across the TS4 include the following:

1) Developed Impervious TS4 extents
2) Paved Road TS4 extents, further distributed by:
    a. slope class
    b. hydrologic connectivity
    c. localized erosion potential
3) Unpaved Road TS4 extents
4) Developed Pervious TS4 extents

The GIS inventory of loading factors was developed by VTrans and Stone in consultation with VTDEC to first establish baseline phosphorus load (see Memo titled *VTrans PCP – Evaluation of draft phosphorus base loads and load reduction numeric targets* submitted on March 27, 2018 to VTDEC) and next to determine other factors to refine load allocation across the Lake Champlain Basin (LCB). The spatial extents of loading factors are based on land use data compiled by VTDEC using 2011 Land Cover Data from the Lake Champlain Basin Program (LCBP), VTrans right of way data (ROW), the VTrans Managing Assets for Transportation Systems (MATS) database, VTrans parcel and facility data, VTrans Small Culverts Inventory (SCI) data, and basin-wide LiDAR-based elevation data available through VCGI.

The Lake Champlain Basin Program and the UVM Spatial Analysis Lab are completing an updated land cover dataset based on 2016 orthoimagery that may also be used to define loading factors in the PCP implementation process. The dataset is anticipated to be available in the fall of 2018.

1. GIS Inventory of Loading Factors

The GIS inventory of loading factors is being delivered as an Esri File Geodatabase (v.10.5.1) with feature classes representing loading factors within the TS4. The geodatabase can be downloaded from: https://www.dropbox.com/s/0g7f7lr8zw2h7zu/VTrans_TS4_LoadFactors_20180919.gdb.zip?dl=1.

The following sections outline the included feature classes by loading factor.

1.1 Developed Impervious

Developed impervious areas are associated with non-road VTrans properties including airports, welcome centers, park and rides, gravel pits, and maintenance garages. The full spatial extents for VTrans facilities were developed based on parcel data provided by VTrans. The impervious portions of these areas were defined using 2011 land cover data from the LCBP and provided to VTrans by VTDEC. These data will be used to allocate load across the TS4 for Developed Impervious areas and are included in the following feature class and associated attribute:

- VTrans_landuses (Attribute: LU_Class = "Developed Impervious")

Impervious areas were further refined by Stone using aerial imagery. These data may be used as a refined dataset to calculate load reduction for PCP implementation activities. The data are provided in the following feature class:

- VTrans_NonRoad_Impervious_Surface_Segment

1.2 Paved Roads

Paved roads include roads that have paved surfaces. Paved road areas were provided to VTrans by VTDEC and were defined by combining the 2011 land cover from LCBP with VTrans Right of Way (ROW) areas. These data will be used to allocate load across the TS4 for Paved Road areas and are included in the following feature class and associated attribute:

- VTrans_landuses (Attribute: LU_Class = "Paved Roads")

Two additional datasets have been developed to further refine paved road areas. First, a dataset has been developed by buffering VTrans road centerlines by widths specified in GIS data attributes and standard road class width where gaps existed within the VTrans data. These data may be used as a refined dataset to calculate load reductions for PCP implementation activities. The refined paved road area dataset is provided in the following feature class:

- VTrans_Roads_Impervious_Surface_Soil_Segment

A road centerline dataset was derived to further classify road segments by road slope class, hydrologic connectivity class, and localized erosion potential. These data will be used to further refine load for paved road areas within the TS4. This version of the VTrans road segment dataset was developed using a combination of data sources and manual editing. First, MATS roads data from VTrans was obtained. The MATS road segments were intersected with soil polygons and then divided into ~100m (or less) segments.

Each road segment was assigned hydrologic connectivity based on the following criteria with the first being the most hydrologically connected and with the last being the least hydrologically connected:

1) Intersecting NHD Stream, Pond, or VSWI Wetland (attribute: HydroBisect_Criteria) – considered as highly hydrologically connected
2) Within 100 ft of NHD Stream, Pond, or VSWI Wetland (attribute: HydroParallel_Criteria) – considered as highly hydrologically connected
3) Within River Corridor (attribute: HydroRiverCorr_Criteria) – considered as highly hydrologically connected
4) Intersecting Additional Intermittent Streams (used LiDAR-based Enhanced Hydro Network) (attribute: HydroBisectLidar3_Criteria) – considered as highly hydrologically connected
5) Within 100 ft of Additional Intermittent Streams (used LiDAR-based Enhanced Hydro Network) (attribute: HydroParallelLidar3_Criteria) – considered as moderately hydrologically connected
6) Within 50 ft of Piped Stormwater Infrastructure that is Connected to Outfalls within 500 ft of NHD or VSWI (attribute: HydroStorm_Criteria) – considered as moderately hydrologically connected
7) Within 50 ft of a culvert in the Small Culvert Inventory (SCI) (attribute: HydroSCI_Criteria_50ft) – considered as moderately hydrologically connected

If none of the above conditions applied, the road segment was considered to have low hydrologic connectivity.

An attribute was added to provide an single overall 'hydrologic connectivity ranking' called 'HydroConnectCriteria', which assigns the highest connectivity class to the road segment, when multiple criteria are met (of the seven criteria outlined above). Another attribute called 'HydroConnectClass' was included to indicate the general level of hydrologic connectivity (High, Moderate, Low).

Additional analyses were conducted to determine the potential for localized erosion with results added to the line segment, based on the following criteria:

1) Downslope & Steep ROW & Road Runoff (attribute: LE1_DownslpSteepRdRunoff)

   a. Downslope = "Yes" (Meets 2 of the following criteria)

      i. If the nearest road segment has a higher average elevation

      ii. If the nearest road segment has a higher maximum elevation

      iii. If there is 'runoff' or flow accumulation from the road

   b. Steep Slope in ROW (Meets either of the following criteria)

      i. Ave Slope in adjacent ROW > 15% and Max Slope > 40%

      ii. Ave Slope in adjacent ROW > 20% and Max Slope > 25%

   c. Road Runoff

      i. Max flow accumulation of > 5 road segment pixels (45 m2)

2) Potential Culvert Erosion (based on SCI - yes if any of the following) (attribute: LE2_CulvertErosion)

   a. Culvert condition = Light, Moderate or Severe erosion

   b. Culvert type = Concrete

   c. Separation = Minor, Moderate or Major OR Proj_End = Yes

   d. Sink Hole = Minor, Moderate, or Major

   e. Connected to DI or Elbow (Elbows (Yes); then Both In_Treat = DI and Drain_Type = Slope)

3) Presence of Curb Board (Guardrail Dataset) (attribute: LE3_CurbBoard)

4) Evidence of Ditch (upslope along road) (attribute: LE4_PotentialDitch)

   a. Downslope = "No" (Does NOT meet at least 2 of the following criteria)

      i. If the nearest road segment has a higher average elevation

      ii. If the nearest road segment has a higher maximum elevation

      iii. If there is 'runoff" or flow accumulation from the road

b. Road Runoff

i. Max flow accumulation of > 10 road segment pixels (90 m2)

Lastly, road slope was calculated based on LiDAR (attribute: Line_Slope_Mean). An attribute was added to indicate whether the slope of the road segment fell above or below 10% (attribute: SlopeClass).

The linear paved road features are provided in the following feature class:

- VTrans_MATS_PCP_RdSegments

1.3 Unpaved Road

Unpaved roads include roads that have gravel surfaces. Unpaved road areas were defined by VTDEC using the 2011 land cover data from LCBP and VTrans ROW areas. These data will be used to allocate load across the TS4 for Unpaved Road areas and are included in the following feature class and associated attribute:

- VTrans_landuses (Attribute: LU_Class = "Unpaved Roads")

1.4 Developed Pervious

Developed pervious areas include non-impervious, developed portions of both road ROW areas and VTrans parcels. The data were prepared by VTDEC using VTrans ROW, VTrans parcels, and the 2011 Land Cover from LCBP. These data will be used to allocate load across the TS4 for Developed Pervious areas and are included in the following feature class and associated attribute:

- VTrans_landuses (Attribute: LU_Class = "Developed Pervious")

2. Supplemental GIS Files

There are three GIS data layers that are included in the inventory that were used to develop the loading factor GIS files outlined above in Section 1. These supplemental GIS data layers are described below.

2.1 VTrans Parcels within the LCB

A dataset of VTrans owned or managed parcels was compiled to determine the extent of TS4 property within the Lake Champlain Basin (LCB). The data are included in the following feature class:

- VTrans_Parcels_LCB

2.2 VTrans Right of Way within the LCB

In addition to facility-based TS4 property, ROW extents were extracted for the LCB. This version of the VTrans (ROW) data was developed using a combination of data sources and manual editing. First, ROW data from VTrans was obtained. The dataset was incomplete in some areas. To supplement the VTrans

ROW dataset, the MATS road centerline data was buffered by 50 feet for interstates and 25 feet for other VTrans roads, and added to the overall ROW dataset.

We recognized that some ROW areas within the master dataset were included as 'access' areas versus areas that VTrans owns and maintains. Only ROW areas maintained and owned by VTrans are of interest for purposes of stormwater management and improvement through the TS4 permit and PCP development and implementation processes. For this reason, any ROW areas on municipally or privately owned property, with a focus on impervious surface areas, were removed from the final dataset where feasible.

The ROW data are included in the following feature class:

- VTrans_RDS_ROW_Updated_SWOnly

2.3 All VTrans-owned property within the LCB

The VTrans parcel data and ROW data were combined to represent the full extent of VTrans-owned properties – the extents of the TS4 within the LCB. The combined parcel and ROW data are included in the following feature class:

- VTrans_ROW_parcel_union

Appendix C: Development of coefficients of loading rates, April 1 2019 Submittal

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April 1, 2019

MEMO

To: Emily Schelley, VT DEC
Jenn Callahan, VTrans

From: Amy Macrellis, Barb Patterson, Jody Stryker, and Warren Rich

Stone Project No. 16-091
Subject: VTrans PCP – Submission of Coefficients for Phosphorus Loading Rates

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The following narrative summarizes the work completed by VTDEC and VTrans, as supported by Stone, to develop coefficients for phosphorus loading rates across the various transportation land uses included in the VTrans Phosphorus Control Plan (PCP) Area. Our submittal complies with the requirements specified in Subpart 9.2.C. of the *National Pollutant Discharge Elimination System (NPDES) General Permit 3-9007 for Stormwater Discharges from the State Transportation Separate Storm Sewer System (TS4),* effective November 27, 2017.

A GIS inventory of loading factors was developed by VTrans and Stone in consultation with VTDEC to first establish baseline phosphorus load[1] and next to determine other factors to refine load allocation[2]. The spatial extents of loading factors were based on land use data compiled by VTDEC using 2011 Land Cover Data from the Lake Champlain Basin Program (LCBP), VTrans right of way data (ROW), the VTrans Managing Assets for Transportation Systems (MATS) database, VTrans parcel and facility data, VTrans Small Culverts Inventory (SCI) data, and basin-wide LiDAR-based elevation data available through VCGI[2].

The allocation of P base load across the TS4 includes loading rates and factors for four transportation-related land use classes:

1. Developed Impervious TS4 extents
2. Paved Road TS4 extents, further distributed by:
    a. slope class
    b. hydrologic connectivity
    c. localized erosion potential
3. Unpaved Road TS4 extents
4. Developed Pervious TS4 extents

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[1] See technical memo titled *VTrans PCP – Evaluation of draft phosphorus base loads and load reduction numeric targets*, dated March 27, 2018
[2] See technical memo titled *VTrans PCP – Submission of GIS Files of Loading Factors*, dated October 1, 2018

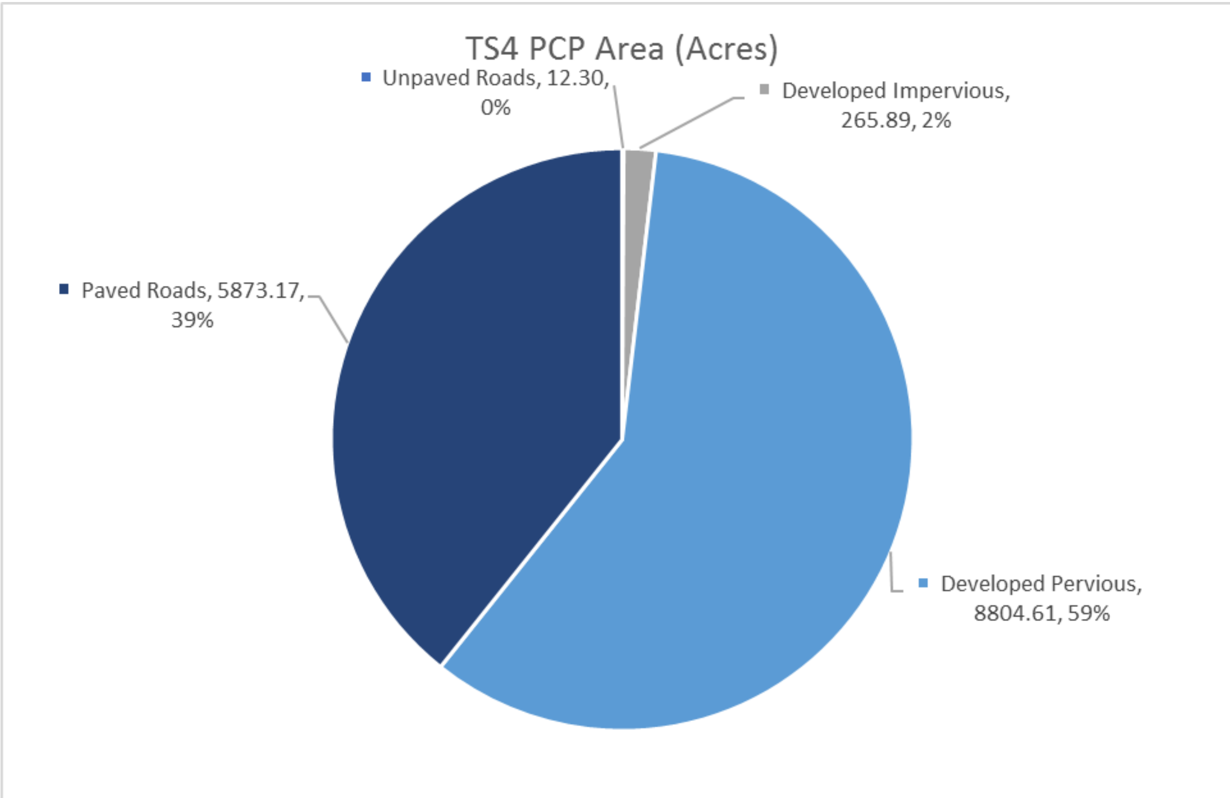
For each of the four land use classes and associated factors, VTrans and VTDEC considered the development of loading rate coefficients. The intent of the loading rate coefficients is to refine allocation of the P base load within each classification such that critical source areas – portions of the TS4 with the highest risk of contributing disproportionate P load to surface waters – were assigned a proportionately higher portion of the P base load within each Lake segment.

Following completion of the GIS inventory of loading factors, the acres and P base loads falling into each land use classification and set of loading factors were further evaluated to understand the best opportunities for coefficient development. Figure 1 summarizes the acres and P base load distribution by each of the four transportation-related land use classes across the entire Lake Champlain basin and PCP area.

Nearly 60% (8,804 acres) of the TS4 area included in the PCP is classified as developed pervious, but this area only constitutes 30% of the phosphorus base load (2,155 kg/yr). This is a substantial portion of acreage, but compared to paved roads (which, though only about 40% of the total acres, constitute 66% of the P base load) it is a relatively minor and hard to treat portion of the P base load. Substantial uncertainty remains about how improvements to developed pervious, especially related to localized erosion fixes that also treat paved road runoff, would be credited. Ultimately, the group decided to retain the localized erosion potential factors, but at this time did not elect to develop coefficients to re-distribute P base load according to risk of localized erosion. This decision may be revisited as development of the basin-wide generalized PCP and lake segment-specific PCPs proceed.

Developed impervious areas and unpaved roads both represent small portions of the TS4 Phosphorus Control Plan area, both in terms of acreage and P base load (Figure 1). Thus, no coefficients were developed to refine distribution of these portions of the P base load.

Paved roads represent the highest proportion of the P base load as discussed above and as shown in Figure 1. As demonstrated in the GIS inventory of loading factors, there is substantial variability between both slope class and level of hydrologic connectivity across the TS4 paved road network within the Lake Champlain basin. The following sections outline the methods used to develop loading coefficients for the paved roads portion of the P base load, and to assign that load to paved roads areas within each Lake segment and drainage area based on the slope class and degree of hydrologic connectivity of individual paved road segments.



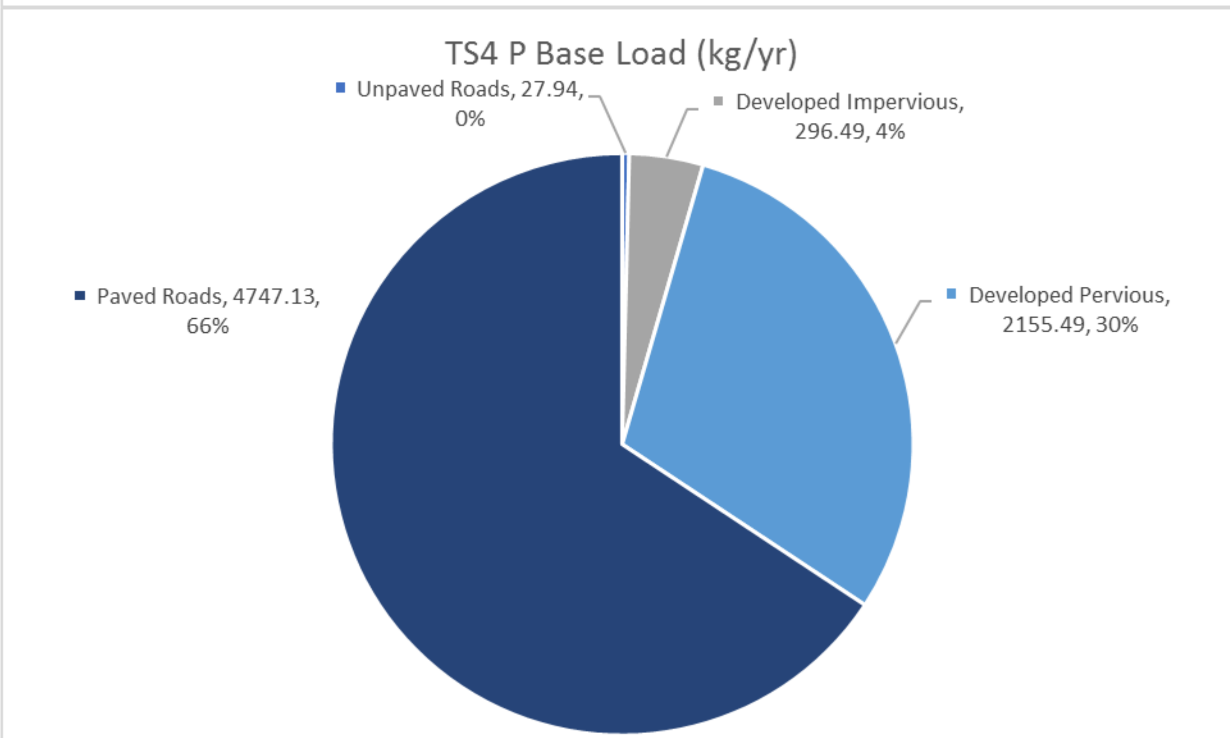


Figure 1. Summary of TS4 acres and P base load by transportation-related land use classification within the Lake Champlain Basin

1. Development of Coefficients for Paved Road P Loading Rates

As discussed in our October 1, 2018 submittal, a road centerline dataset was derived to further classify road segments by road slope class, hydrologic connectivity (HC) class, and localized erosion potential. The road slope class and HC class data, developed using the linear MATS road segment centerline dataset, were used to further refine load allocation for paved road areas within the TS4. A Microsoft Excel spreadsheet model was developed to summarize the TS4 paved roads miles and P base loads, and then to re-allocate the P base load first by roadway slope class (0 – 10% and >10%), then by high, moderate, or low degrees of hydrologic connectivity as reflected in the GIS inventory of loading factors and in frequent consultation with VTrans and VTDEC (Table 1).

The refinement of P base load assignment was completed by first converting the P loading rates from kg/acre-year to kg/mile-year to match the MATS road segment centerline dataset, then by using the Solver add-in functionality in Microsoft Excel. Solver finds an optimal (maximum or minimum) value for a formula in one cell—called the objective cell—subject to constraints, or limits, on the values of other formula cells on a worksheet. Solver works with a group of cells, called decision variables or simply variable cells, which are used in computing the formulas in the objective and constraint cells. Solver adjusts the values in the decision variable cells to satisfy the limits on constraint cells and produce the desired result for the objective cell.

Loading rates for each slope class were determined by applying Solver to each SWAT drainage basin independently. The objective function was the difference between the total load per drainage basin calculated using the solved loading rates and the TS4 paved roads base load, where the goal was that this difference be 0. This resulted in optimal slope class loading rates that ensured the resulting calculated loads matched the total paved roads P loads for each SWAT drainage basin that were agreed upon by VTrans and VTDEC in March 2018. It was expected, and proved to be true, that >10% slope segments received a higher loading rate than 0-10% slope segments.

Loading coefficients were then applied to the calculated slope class loading rates for each of three HC classes, such that slope class loading rates were multiplied by the HC-specific loading coefficient to account for the impact of connectivity. Loading coefficients were set to 1.0 originally, then optimal values were solved for by using a similar objective function as for slope class. This was done first at the Lake Champlain Basin level, such that a single set of loading coefficeints was obtained which could be applied across all Lake segments and SWAT drainage areas. The resulting coefficients were 1.30 for highly hydrologically connected road segments, 0.84 for moderately hydrologically connected segments, and 0.61 for road segments with low hydrologic connectivity. While this method resulted in equivalent paved roads P base loads at the Lake Champlain Basin level, the calculated base loads at the SWAT drainage area level did not match those agreed upon by VTrans and VTDEC in March 2018.

The Solver routine was thus run again at the SWAT drainage area level, such that a unique set of loading coefficients was obtained for each drainage basin. The result of solving for unique sets of loading coefficients at the SWAT drainage level is illustrated in a box-and-whiskers plot in Figure 2. The average results for the loading coefficients were very similar to those obtained at the Lake Champlain Basin level. An average loading rate coefficient of 1.31 was derived for the high HC class, 0.87 for the moderate HC class, and 0.63 for the low HC class, respectively. The SWAT drainage area-specific loading coefficients were similar, with limited variation across the basin (Figure 2) – and the drainage area-specific coefficients ensured that again the resulting P base load for paved roads matched the initial base load allocation for each individual SWAT drainage area.

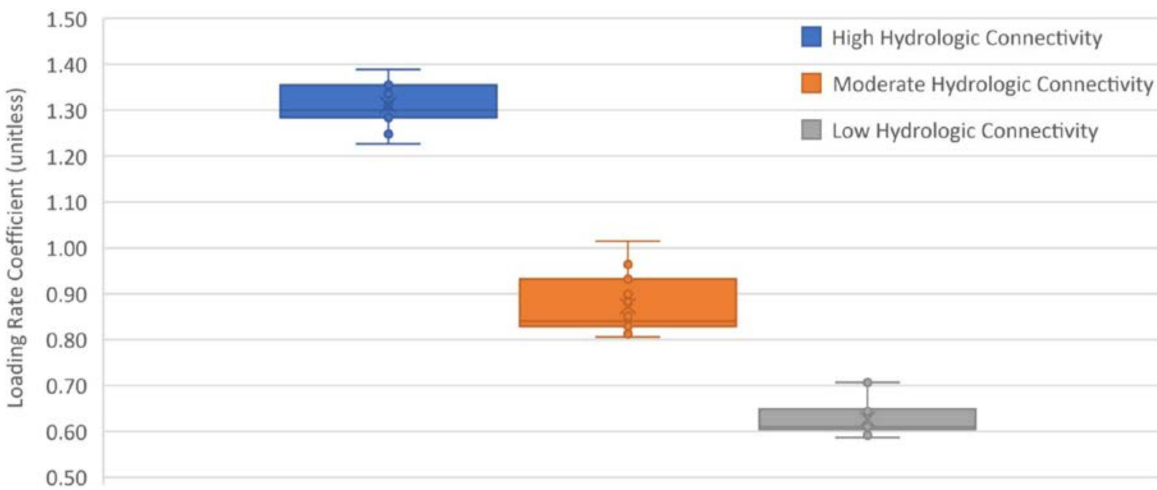


Figure 2.Comparison of paved roads P loading coefficients by SWAT drainage area and hydrologic connectivity class.

The resulting distribution of loading rates for paved roads listed in Table 1 by combined slope class and hydrologic connectivity class is summarized for all drainage areas in the TS4 PCP area using a box-and-whiskers plot in Figure 3. Developed lands P loading rates as provided by VTDEC are shown on the left-hand side of this figure, while the results of application of the paved roads loading rate coefficients are shown on the right-hand side. The resulting distribution maintains the P loading rates for paved roads in a range consistent with the loading rates for developed impervious and paved roads provided by VTDEC, and does not produce artificially low loading rates for paved roads areas that are effectively disconnected (low hydrologic connectivity) when compared to pervious land use loading rates (developed pervious and forest).

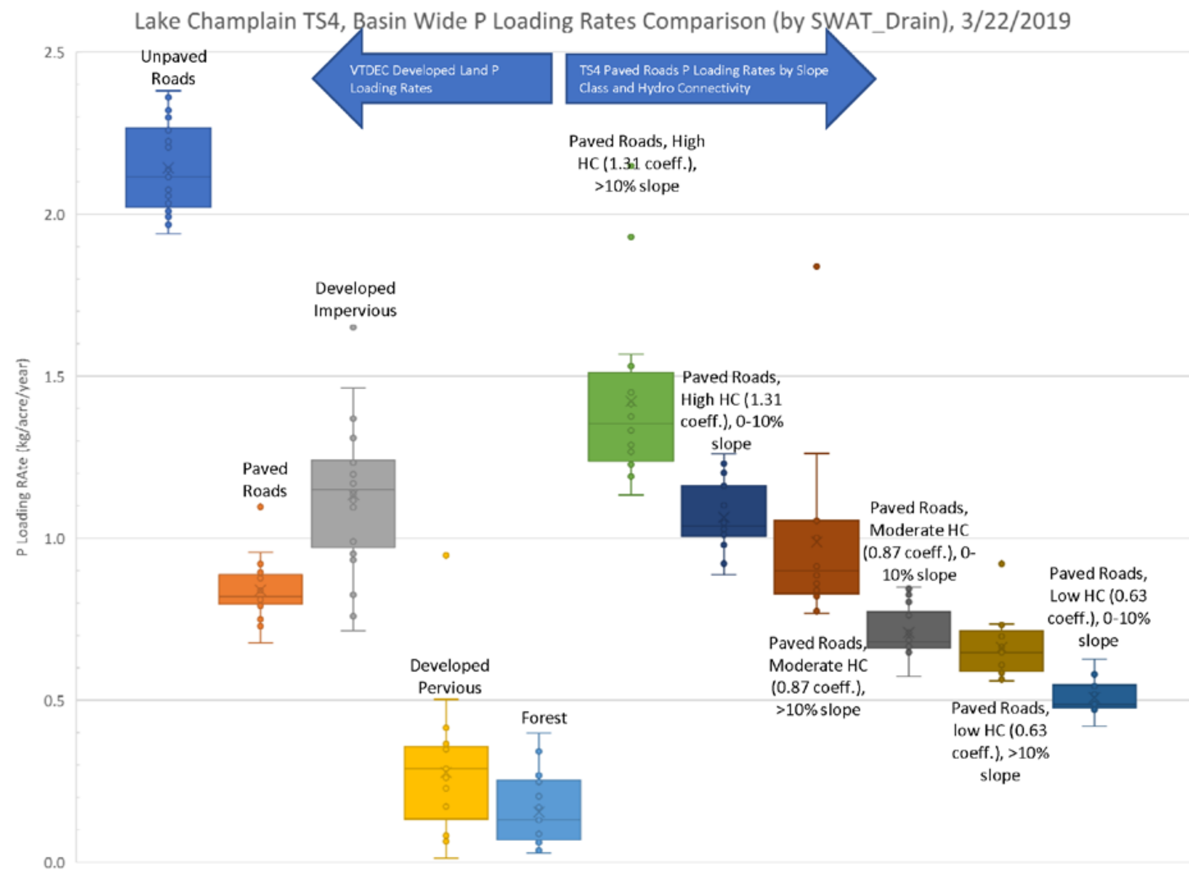


Figure 3. Comparison of VTDEC developed lands loading rates with VTrans paved roads loading rates by slope and hydrologic connectivity class.

Paired bar charts demonstrating the application of the coefficient-weighted P loading rates for paved roads on a Lake segment basis, as compared to the acreage those loading rates are applied to, are provided in Figure 4. As in Figure 3, acres and P base loads by for the entire TS4 PCP area by developed land use class are shown on the left side of each plot, while TS4 paved roads acres and P base loads only, by slope class and hydrologic connectivity class, are summarized on the right. Figure 4 demonstrates that, although relatively high loading rates are assigned to the steeply sloping road segments relative to the low-slope segments, these highest-risk portions of the TS4 road network represent a very small portion of the overall area and resulting P base load.

2. P Base Load Assignment to VTrans Linear Facilities (Paved Roads)

Once consensus was reached on the appropriate coefficients to assign to the paved roads loading rates based on slope class and hydrologic connectivity, the final loading rates from the Excel spreadsheet model, which were necessarily calculated based on the collective mileage of the linear MATS road segment dataset, were attributed to the paved road area polygon dataset originally provided by VTDEC. The MATS road segments were divided in portions ≤100 meters for assignment of loading factors and coefficients, while the VTDEC land use dataset is a polygon feature class dissolved by land use class and drainage area (SWAT drain). The VTDEC paved roads features were thus divided at the extent of each classified paved road segment, in order to assign the hydrologic connectivity and slope class attributes from each paved road line feature to the associated paved road polygon feature. The following steps were taken to complete the assignment of loading factors, rates, and coefficients from the MATS road segments feature dataset to the VTDEC paved roads polygon feature class:

1. Buffer the MATS road segment linear features by 60 feet on each side, with an end type of "FLAT" to divide each buffer at the extent of the divided road segments.
2. Intersect the 60-foot buffer polygon with areas from the VTDEC land cover dataset classified as paved road.
3. Identify and isolate areas of buffer overlap, primarily at the intersections of two or more MATS road segments, in order to remove duplicate paved road polygons.
4. Run custom Python script on overlapping, duplicate paved road areas, comparing the duplicate areas and keeping the highest HydroConnect class first, followed by the highest Slope class.
5. Merge the resulting overlap areas dataset back to the intersected paved roads dataset, with the output representing the MATS linear road segments as converted to TS4 paved road areas within the Lake Champlain basin.

2.1 Assessment of Non-VTrans Managed Paved Road Areas Within the VTrans Right-of-Way

When the paved road polygon features were created using the methodology above, approximately 48 acres classified as paved road and included in the paved roads area and base load submitted to VTDEC on March 27, 2018 were not captured. Some of these locations were a result of the buffering process and could be rectified simply. Larger areas, however, represented locations that were either misclassified as VTrans paved road areas, or areas where MATS road segments were missing from the VTrans paved road areas. The following steps were taken to analyze the discrepancies and determine whether each represented VTrans paved road areas:

1. Isolate the paved road areas located within the TS4, but which had no corresponding MATS linear feature, to a single dataset.
2. Using the VTrans managed "VT_Roads_Centerline" dataset, identify missing paved road areas which did not contain a road centerline designated as a VTrans managed road (US Highway, Interstate Highway, State Highway).
3. Isolate areas identified in Step 2 into a single dataset to retain relevant information and remove from the missing areas dataset.

4. The remaining missing areas represent portions of paved road areas managed by VTrans, but not which are not represented within the MATS road segment dataset.

The remaining paved roads areas were attributed appropriate hydrologic connectivity and slope class attributes as follows:

1. Areas smaller than 10 meters in road length were assigned the attributes of adjoining paved road areas.
2. Areas larger than 10 meters in road length were subjected to the same processing steps used to initially attribute hydrologic connectivity and slope classes to the MATS road segments.
3. The missing areas were merged with the master VTDEC paved road area polygon feature class, resulting in an updated dataset of all VTrans paved road areas containing the necessary attributes to allocate the phosphorus base load for paved roads.

The TS4 paved road area for the Lake Champlain Basin was adjusted to reflect the removal of areas which were previously misclassified. A total of 30.86 acres was removed from paved road areas within the TS4, changing the total acreage of paved road areas from the initial calculation of 5,904.02 acres to 5,873.17 acres. These changes are summarized in Table 1, and an updated version of draft acres and phosphorus base loads originally presented in Tables 1 and 2 of our March 27, 2018 submittal is included as Table 2. Changes to the paved roads acres and base loads for paved roads described in this memo are highlighted, as were changes from the acres and loads originally provided by VTDEC in January 2018.

3. Updates to the GIS Inventory of Loading Factors

Updates to the GIS inventory of loading factors are being delivered as an Esri File Geodatabase (v.10.5.1) with feature classes representing loading factors and loading rate coefficients within the TS4. The geodatabase is available at the following download link:

https://stoneenvironmentalvt-my.sharepoint.com/:u:/g/personal/amym_stone-env_com/EafG_oX7OrVFvTLc8vhvmlMBSdFLKvI437LgHQQRWsFbgQ?e=s3mIMu

Only those feature classes delivered in the October 1, 2018 submittal of the loading factors inventory associated with paved roads were updated and included in this GIS deliverable as described below.

Paved roads polygons used to allocate load across the TS4 are included in the VTrans_landuses feature class and associated attributes:

- Attribute: LU_Class_TS4 = "Paved Roads_LowSlope_HighHC"
- Attribute: LU_Class_TS4 = "Paved Roads_HighSlope_HighHC"
- Attribute: LU_Class_TS4 = "Paved Roads_LowSlope_ModHC"
- Attribute: LU_Class_TS4 = "Paved Roads_HighSlope_ModHC"
- Attribute: LU_Class_TS4 = "Paved Roads_LowSlope_LowHC"
- Attribute: LU_Class_TS4 = "Paved Roads_HighSlope_LowHC"

The VTrans_MATS_PCP_RdSegments feature class, as updated during development of the loading coefficients described in this memo, is also included.

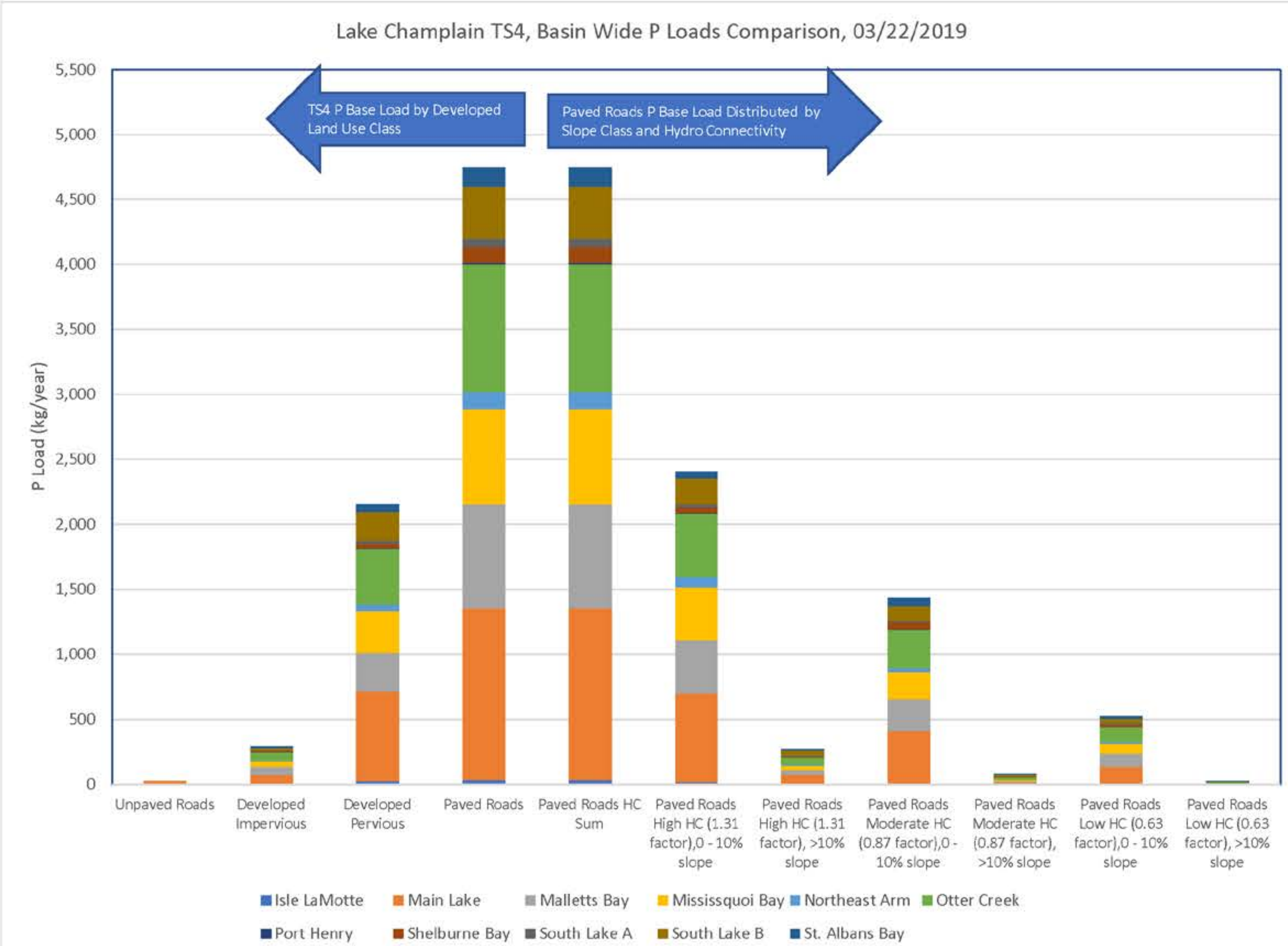
Table 1: Phosphorus Load Allocation Spreadsheet Model - Paved Roads Only

Lake Segment	Drainage Area (SWAT_Drain)	TMDL Base Loads, March 2018: TS4 Paved Roads Area (acres)	TMDL Base Loads, March 2018: TS4 Paved Roads Base Load[1] (kg/yr)	TMDL Base Loads, March 2019: TS4 Paved Roads Area (acres)	TMDL Base Loads, March 2019: TS4 Paved Roads Base Load[2] (kg/yr)	Road Slope: Slope Class (%)	Acres and Road Miles by Slope Class: Area per Slope Class (ac)	Acres and Road Miles by Slope Class: Road Miles per Slope Class (mi)	Acres and Road Miles by Slope Class: Total Road Miles (mi)	Loading Rates and Load by Slope Class: Loading Rate for Paved Roads[3] (kg/mi-yr)	Loading Rates and Load by Slope Class: Loading Rate for Paved Roads[4] (kg/ac-yr)	Loading Rates and Load by Slope Class: Load Per Slope Class (kg/yr)	Loading Rates and Load by Slope Class: Calculated TS4 Paved Roads Base Load (kg/yr)
Isle LaMotte	Isle La Motte Direct Drainage	47.83	34.85	46.93	34.19	SC 1: 0 - 10%	43.20	11.3	12.3	2.698	0.703	30.39	34.19
						SC 2: >10%	3.73	1.0		3.650	1.020	3.80	
Main Lake	Main Lake Direct Drainage	19.73	17.29	19.61	17.19	SC 1: 0 - 10%	19.59	3.8	3.8	4.522	0.876	17.15	17.19
						SC 2: >10%	0.02	0.005		6.874	1.908	0.03	
Main Lake	Winooski River	1,637.74	1,314.13	1,625.51	1,304.31	SC 1: 0 - 10%	1,543.20	346.2	365.8	3.521	0.787	1,214.26	1304.31
						SC 2: >10%	82.31	19.6		4.695	1.094	90.06	
Malletts Bay	Lamoille River	854.33	692.11	851.18	689.56	SC 1: 0 - 10%	814.64	196.6	205.8	3.338	0.805	655.67	689.56
						SC 2: >10%	36.55	9.2		3.690	0.927	33.89	
Malletts Bay	Malletts Bay Direct Drainage	163.06	110.33	162.27	109.80	SC 1: 0 - 10%	158.20	32.3	33.1	3.294	0.673	106.43	109.80
						SC 2: >10%	4.07	0.7		4.501	0.828	3.37	
Missisquoi Bay	Missisquoi Bay Direct Drainage	104.24	85.21	103.00	84.19	SC 1: 0 - 10%	97.10	28.1	29.5	2.790	0.804	78.11	84.19
						SC 2: >10%	5.90	1.4		4.411	1.031	6.08	
Missisquoi Bay	Missisquoi River	811.33	653.86	807.14	650.48	SC 1: 0 - 10%	772.05	187.4	196.2	3.294	0.799	617.00	650.48
						SC 2: >10%	35.09	8.9		3.782	0.954	33.48	
Northeast Arm	Northeast Arm Direct Drainage	160.33	131.35	159.51	130.68	SC 1: 0 - 10%	152.76	32.9	34.4	3.730	0.805	122.89	130.68
						SC 2: >10%	6.76	1.4		5.488	1.153	7.79	
Otter Creek	Lewis Creek	37.31	31.86	37.30	31.85	SC 1: 0 - 10%	36.93	9.2	9.2	3.440	0.852	31.48	31.85
						SC 2: >10%	0.36	0.1		4.323	1.005	0.37	
Otter Creek	Little Otter Creek	72.65	69.53	72.56	69.44	SC 1: 0 - 10%	68.44	14.6	15.7	4.418	0.944	64.60	69.44
						SC 2: >10%	4.12	1.1		4.340	1.174	4.83	
Otter Creek	Otter Creek	1,068.57	874.16	1,063.99	870.41	SC 1: 0 - 10%	987.01	227.9	250.9	3.498	0.807	796.13	870.41
						SC 2: >10%	76.98	23.0		3.228	0.965	74.29	
Otter Creek	Otter Creek Direct Drainage	7.35	6.48	7.35	6.49	SC 1: 0 - 10%	7.35	2.3	2.3	2.879	0.882	6.49	6.49
						SC 2: >10%	0.00	0.0			0.000	0.00	
Port Henry	Port Henry Direct Drainage	15.33	13.71	15.29	13.68	SC 1: 0 - 10%	15.09	4.1	4.2	3.295	0.886	13.36	13.68
						SC 2: >10%	0.21	0.2		1.998	1.547	0.32	
Shelburne Bay	Laplatte River	164.23	120.75	163.66	120.34	SC 1: 0 - 10%	156.66	32.1	33.4	3.520	0.720	112.86	120.34
						SC 2: >10%	7.01	1.3		5.700	1.067	7.48	
South Lake A	South Lake A Direct Drainage	69.11	64.04	69.11	64.05	SC 1: 0 - 10%	61.56	18.1	20.4	2.933	0.865	53.23	64.05
						SC 2: >10%	7.56	2.2		4.860	1.431	10.82	
South Lake B	Mettawee River	102.55	84.43	102.55	84.43	SC 1: 0 - 10%	93.24	25.3	28.3	2.991	0.810	75.54	84.43
						SC 2: >10%	9.31	3.1		2.896	0.954	8.89	
South Lake B	Poultney River	380.48	319.13	378.99	317.88	SC 1: 0 - 10%	332.30	74.9	88.2	3.584	0.806	267.84	317.88
						SC 2: >10%	46.70	13.3		3.811	1.072	50.04	
St. Albans Bay	St. Albans Bay Direct Drainage	187.85	148.68	187.20	148.16	SC 1: 0 - 10%	177.46	39.2	40.8	3.529	0.773	137.16	148.16
						SC 2: >10%	9.73	1.6		7.030	1.130	11.00	
TOTAL		**5,904.02**	**4,771.90**	**5,873.17**	**4,747.13**		**5,873.17**	**1,374.4**	**1,374.4**			**4,747.13**	**4,747.13**

Lake Segment	Slope Class	High Hydrologic Connectivity (Hydro Bisect, Hydro Parallel, River Cooridor, Hydro Intermittent Bisect): Acres (ac)	High: Miles (mi)	High: L.R.[4] (kg/mi-yr)	High: L.R.[4] (kg/ac-yr)	High: Base Load (kg/yr)	Moderate Hydrologic Connectivity (Hydro Intermittent Parallel, Hydro Storm, Hydro SCI): Acres (ac)	Moderate: Miles (mi)	Moderate: L.R.[4] (kg/mi-yr)	Moderate: L.R.[4] (kg/ac-yr)	Moderate: Base Load (kg/yr)	Low Hydrologic Connectivity (Low Hydrologic Connectivity): Acres (ac)	Low: Miles (mi)	Low: L.R.[4] (kg/mi-yr)	Low: L.R.[4] (kg/ac-yr)	Low: Base Load (kg/yr)
Isle LaMotte (Isle La Motte Direct Drainage)	SC 1: 0 - 10%	20.9	6.0	3.41	0.89	18.53	15.0	3.4	2.20	0.57	8.59	7.4	1.8	1.61	0.42	3.09
	SC 2: >10%	2.3	0.7	4.61	1.29	3.00	0.6	0.2	2.98	0.83	0.50	0.8	0.2	2.18	0.61	0.49
Main Lake (Main Lake Direct Drainage)	SC 1: 0 - 10%	3.2	0.9	6.00	1.16	3.76	15.0	2.6	4.36	0.84	12.65	1.4	0.2	2.81	0.54	0.74
	SC 2: >10%	0.0	0.0	9.12	2.53	0.00	0.02	0.005	6.63	1.84	0.03	0.0	0.0	4.27	1.18	0.00
Main Lake (Winooski River)	SC 1: 0 - 10%	665.3	151.2	4.56	1.02	677.30	600.2	130.2	2.94	0.66	394.18	277.7	64.9	2.14	0.48	132.77
	SC 2: >10%	53.2	11.7	6.07	1.42	75.29	21.8	5.5	3.92	0.91	19.89	7.3	2.4	2.85	0.66	4.88
Malletts Bay (Lamoille River)	SC 1: 0 - 10%	371.3	90.4	4.29	1.03	383.77	280.9	67.7	2.77	0.67	187.40	162.4	38.5	2.01	0.49	78.90
	SC 2: >10%	28.3	7.0	4.74	1.19	33.71	5.6	1.5	3.06	0.77	4.32	2.6	0.7	2.23	0.56	1.46
Malletts Bay (Malletts Bay Direct Drainage)	SC 1: 0 - 10%	31.1	6.3	4.51	0.92	28.69	81.0	16.5	3.34	0.68	55.27	46.1	9.6	2.33	0.48	21.90
	SC 2: >10%	1.8	0.3	6.16	1.13	2.04	2.3	0.5	4.57	0.84	1.89	0.0	0.023	3.18	0.58	0.01
Missisquoi Bay (Missisquoi Bay Direct Drainage)	SC 1: 0 - 10%	43.0	11.6	3.61	1.04	44.73	35.8	10.7	2.33	0.67	24.00	18.3	5.7	1.69	0.49	8.93
	SC 2: >10%	3.6	0.8	5.70	1.33	4.83	1.2	0.3	3.68	0.86	1.00	1.1	0.3	2.68	0.63	0.69
Missisquoi Bay (Missisquoi River)	SC 1: 0 - 10%	349.9	85.9	4.24	1.03	359.76	279.9	67.4	2.73	0.66	185.56	142.2	34.1	1.99	0.48	68.70
	SC 2: >10%	21.5	5.5	4.86	1.23	26.35	10.5	2.6	3.14	0.79	8.34	3.1	0.8	2.29	0.58	1.78
Northeast Arm (Northeast Arm Direct Drainage)	SC 1: 0 - 10%	82.4	17.8	4.57	0.99	81.33	41.7	8.9	3.00	0.65	27.01	28.7	6.3	2.19	0.47	13.51
	SC 2: >10%	5.6	1.1	6.73	1.41	7.91	0.5	0.2	4.42	0.93	0.49	0.6	0.1	3.22	0.68	0.42
Otter Creek (Lewis Creek)	SC 1: 0 - 10%	15.3	3.9	4.45	1.10	16.80	17.6	4.2	2.86	0.71	12.44	4.1	1.1	2.09	0.52	2.14
	SC 2: >10%	0.36	0.08	5.59	1.30	0.47	0.0	0.0	3.59	0.84	0.00	0.0	0.0	2.63	0.61	0.00
Otter Creek (Little Otter Creek)	SC 1: 0 - 10%	20.9	4.7	5.90	1.26	26.38	37.0	7.8	3.97	0.85	31.42	10.5	2.2	2.77	0.59	6.20
	SC 2: >10%	2.2	0.6	5.80	1.57	3.44	1.8	0.5	3.90	1.06	1.95	0.1	0.02	2.72	0.73	0.06
Otter Creek (Otter Creek)	SC 1: 0 - 10%	414.5	96.1	4.59	1.06	438.79	364.5	82.0	2.98	0.69	250.08	208.1	49.8	2.15	0.50	103.39
	SC 2: >10%	40.1	11.8	4.24	1.27	50.74	24.1	7.1	2.75	0.82	19.80	12.8	4.1	1.99	0.59	7.61
Otter Creek (Otter Creek Direct Drainage)	SC 1: 0 - 10%	2.5	0.8	3.92	1.20	3.05	2.9	0.9	2.62	0.80	2.31	1.9	0.6	1.89	0.58	1.12
	SC 2: >10%	0.0	0.0	0.00	0.00	0.00	0.0	0.0	0.00	0.00	0.00	0.0	0.0	0.00	0.00	0.00
Port Henry (Port Henry Direct Drainage)	SC 1: 0 - 10%	4.6	1.3	4.58	1.23	5.65	5.1	1.4	3.07	0.83	4.22	5.4	1.4	2.33	0.63	3.37
	SC 2: >10%	0.2	0.2	2.77	2.15	0.44	0.0	0.0	1.86	1.44	0.00	0.0	0.0	1.41	1.09	0.00
Shelburne Bay (Laplatte River)	SC 1: 0 - 10%	43.4	8.4	4.78	0.98	42.53	78.6	16.5	3.31	0.68	53.17	34.6	7.2	2.30	0.47	16.30
	SC 2: >10%	3.7	0.6	7.75	1.45	5.32	2.3	0.5	5.35	1.00	2.30	1.0	0.2	3.73	0.70	0.73
South Lake A (South Lake A Direct Drainage)	SC 1: 0 - 10%	23.1	6.9	3.95	1.17	26.94	20.2	6.0	2.59	0.76	15.41	18.2	5.2	1.89	0.56	10.13
	SC 2: >10%	3.6	1.0	6.55	1.93	6.89	2.9	0.9	4.28	1.26	3.69	1.1	0.3	3.13	0.92	0.98
South Lake B (Mettawee River)	SC 1: 0 - 10%	45.9	12.2	3.73	1.01	46.36	28.4	8.0	2.43	0.66	18.71	18.9	5.1	1.77	0.48	9.08
	SC 2: >10%	7.7	2.6	3.61	1.19	9.17	0.9	0.3	2.35	0.77	0.73	0.7	0.2	1.71	0.56	0.38
South Lake B (Poultney River)	SC 1: 0 - 10%	143.8	33.3	4.60	1.03	148.74	134.3	29.0	2.96	0.67	89.41	54.3	12.7	2.17	0.49	26.44
	SC 2: >10%	27.4	7.4	4.89	1.38	37.73	12.9	3.9	3.15	0.89	11.46	6.3	2.0	2.30	0.65	4.10
St. Albans Bay (St. Albans Bay Direct Drainage)	SC 1: 0 - 10%	50.4	11.2	4.78	1.05	52.76	90.6	20.0	3.29	0.72	65.34	36.5	8.0	2.29	0.50	18.28
	SC 2: >10%	4.5	0.8	9.53	1.53	6.82	3.4	0.5	6.56	1.05	3.60	1.9	0.3	4.56	0.73	1.36
TOTAL		2,537.5	600.8			2,680.02	2,219.6	507.5			1,517.18	1,116.1	266.1			549.93
		Average Optimized Loading Coefficient:				**1.31**	**Average Optimized Loading Coefficient:**				**0.87**	**Average Optimized Loading Coefficient:**				**0.63**

References/Notes:

1. Columns G-H - Final acres and P base load for paved roads, excluding paved roads areas on VTrans Facilities, 03-27-2018 version.
2. Columns I-J - Acres and P base load for TS4 paved roads, 3-12-2019 update to remove portions of Paved Road area not owned or controlled by VTrans (total of 30.85 ac).
3. P loading rate for paved roads is an area-weighted loading rate for each SWAT_Drain, by slope class, for paved roads only: (loading rate*acres) / total road miles.
4. P loading rate (kg/ac-yr) back-calculated by converting optimized loading rate based on road miles to acres: (kg/mi-yr) * (miles/acres) = kg/ac-yr.



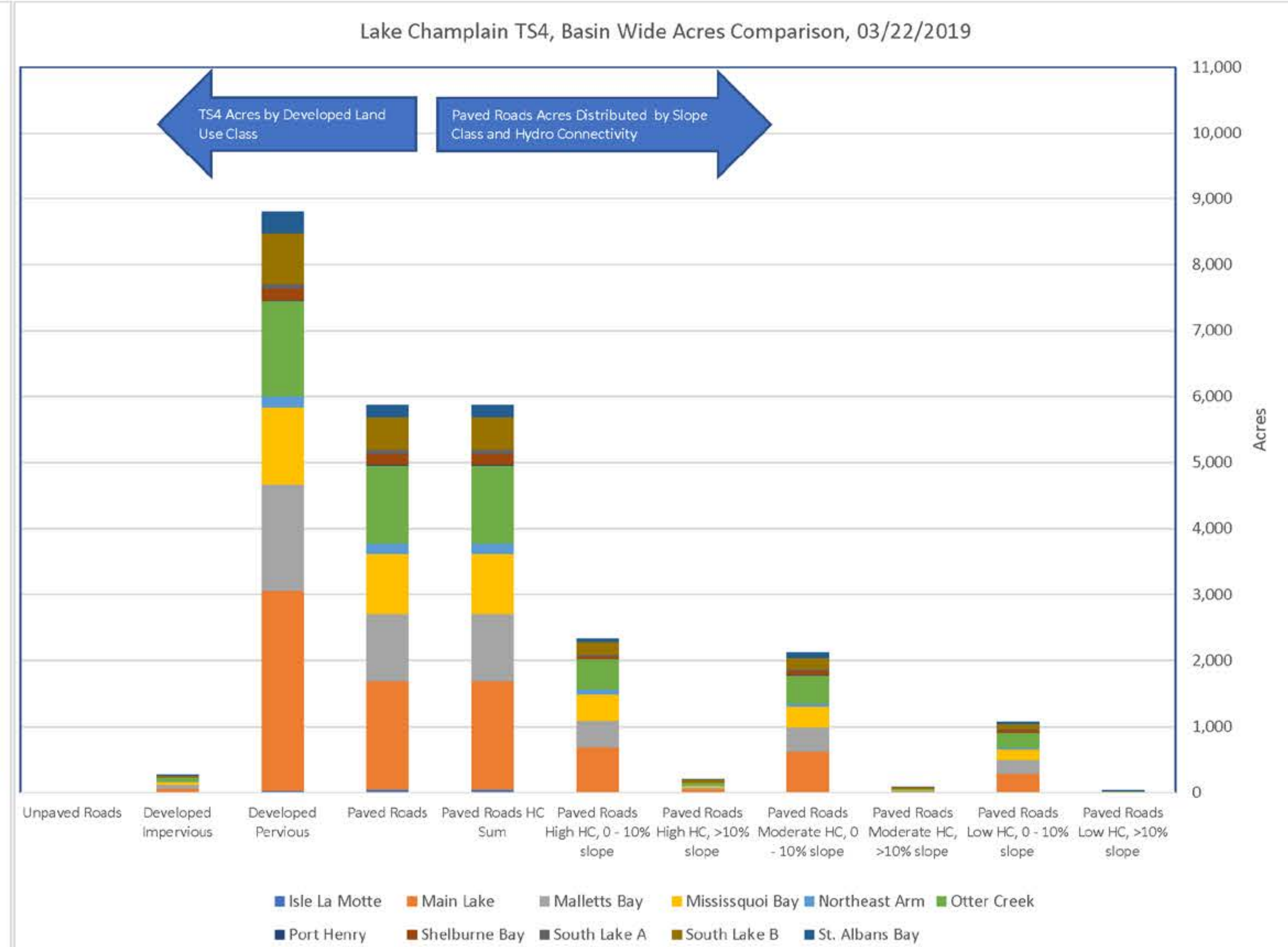


Figure 4. Summary of TS4 Acres and Phosphorus Base Loads by Lake segment

Table 2. Revised Acres and Phosphorus Base Loads for VTrans Linear Facilities and Right-of-Way (Roads)

			Area (acres)				Load (kg/yr)				
Lake Segment	SWAT_drain	Area_Type	Developed Impervious	Paved Roads	Unpaved Roads	Developed Pervious	Developed Impervious	Paved Roads	Unpaved Roads	Developed Pervious	Total
Isle La Motte	Isle La Motte - DD	Road	2.29	46.93	0.00	37.56	1.74	34.19	0.00	27.37	63.30
Main Lake	Main Lake - DD	Road	1.04	19.61	0.00	35.36	0.97	17.19	0.00	3.35	21.51
Main Lake	Winooski River	Road	64.34	1625.51	12.30	2994.20	71.85	1304.31	27.94	690.19	2094.29
Malletts Bay	Lamoille River	Road	49.29	851.18	0.00	1264.60	56.08	689.56	0.00	288.31	1033.95
Malletts Bay	Malletts Bay - DD	Road	7.38	162.27	0.00	339.71	6.09	109.80	0.00	4.09	119.98
Mississquoi Bay	Mississquoi Bay - DD	Road	5.67	103.00	0.00	133.22	4.05	84.19	0.00	55.27	143.51
Mississquoi Bay	Mississquoi River	Road	32.51	807.14	0.00	1034.21	37.37	650.48	0.00	269.70	957.54
Northeast Arm	Northeast Arm - DD	Road	5.86	159.51	0.00	164.01	6.70	130.68	0.00	48.88	186.27
Otter Creek	Lewis Creek	Road	3.58	37.30	0.00	47.81	3.55	31.85	0.00	13.87	49.27
Otter Creek	Little Otter Creek	Road	4.75	72.56	0.00	68.28	5.85	69.44	0.00	24.96	100.25
Otter Creek	Otter Creek	Road	49.06	1063.99	0.00	1308.92	56.42	870.41	0.00	381.66	1308.50
Otter Creek	Otter Creek - DD	Road	0.54	7.35	0.00	20.40	0.59	6.49	0.00	7.10	14.18
Port Henry	Port Henry - DD	Road	0.75	15.29	0.00	8.10	0.93	13.68	0.00	4.08	18.69
Shelburne Bay	LaPlatte River	Road	10.15	163.66	0.00	189.58	9.66	120.34	0.00	32.61	162.62
South Lake A	South Lake A - DD	Road	1.94	69.11	0.00	61.30	2.54	64.05	0.00	22.87	89.46
South Lake B	Mettawee River	Road	4.82	102.55	0.00	87.60	5.77	84.43	0.00	25.35	115.55
South Lake B	Poultney River	Road	12.01	378.99	0.00	688.04	14.04	317.88	0.00	198.69	530.61
St. Albans Bay	St. Albans Bay - DD	Road	9.90	187.20	0.00	321.73	12.28	148.16	0.00	57.14	217.58
Total			265.89	5873.17	12.30	8804.61	296.49	4747.13	27.94	2155.49	7227.04

Appendix D: Progress Report on Phosphorus Control Plan, October 1, 2019 submittal

STONE ENVIRONMENTAL
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October 1, 2019

MEMO

To: Emily Schelley, Vermont DEC
Jenn Callahan, VTrans

From: Amy Macrellis, Warren Rich, Barb Patterson, and Peter Lazorchak

Stone Project No. 18-008-A
Subject: VTrans PCP – Submission of Progress Report on the Phosphorus Control Plan

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The story map available at https://arcg.is/0DS4LC0 summarizes the completed by Vermont DEC and VTrans, as supported by Stone, to develop Phosphorus Control Plans for the various transportation land uses included in the VTrans Phosphorus Control Plan (PCP) Area. Our submittal complies with the requirements specified in Subpart 9.2.C. of the *National Pollutant Discharge Elimination System (NPDES) General Permit 3-9007 for Stormwater Discharges from the State Transportation Separate Storm Sewer System (TS4),* effective November 27, 2017.

Previously, a GIS inventory of loading factors was developed by VTrans and Stone in consultation with Vermont DEC to first establish baseline phosphorus load[1] and next to determine other factors to refine load allocation[2]. This inventory and supporting datasets were utilized to develop coefficients of loading rates[3] for the Paved Roads portion of the baseline phosphorus load.

The story map linked above serves as VTrans's Progress Report submittal. It documents how VTrans is developing Phosphorus Control Plans (PCPs) that will result in the reduction of phosphorus loading from roads, rights-of-way, and facilities under the Agency's control by over 20% within the next 20 years (by June 17, 2036). It first summarizes what VTrans has already done to develop the framework for a basin-wide PCP, and then provides a road-map for how the agency intends to meet its goals – beginning with the submittal of a Generalized PCP to Vermont DEC in April 2020.

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[1] See technical memo titled *VTrans PCP – Evaluation of draft phosphorus base loads and load reduction numeric targets*, dated March 27, 2018
[2] See technical memo titled *VTrans PCP – Submission of GIS Files of Loading Factors*, dated October 1, 2018
[3] See technical memo titled *VTrans PCP – Submission of Coefficients for Phosphorus Loading Rates*, dated April 1, 2019

VTrans Lake Champlain Basin Phosphorus Control Plan

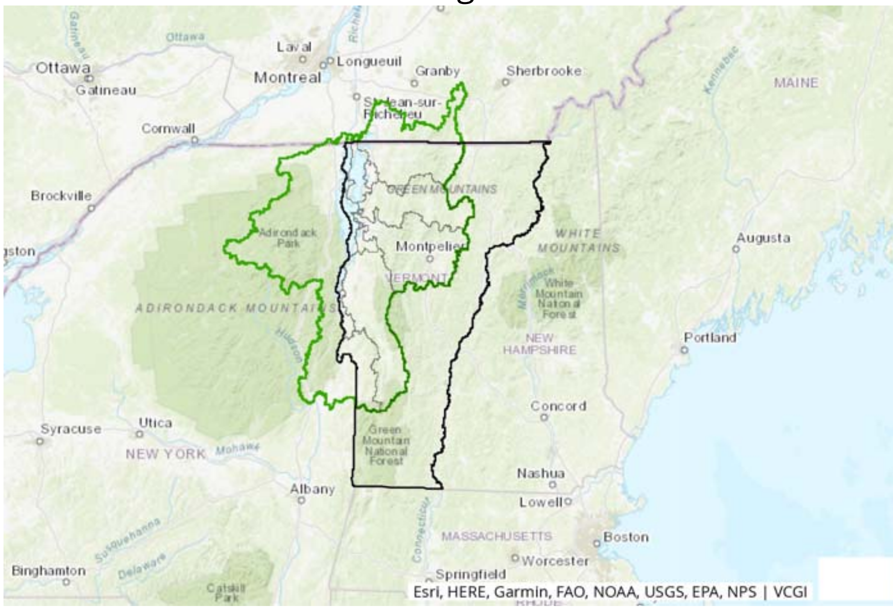
*This story was made with **Esri's Story Map Journal**.*
*Read the interactive version on the web at **https://arcg.is/0DS4LC0**.*

The Vermont Agency of Transportation (VTrans), through its **Maintenance Bureau** and **Pollution Prevention and Compliance Section**, is committed to maintaining compliance with a swiftly evolving variety of state and federal environmental regulations. The Vermont Agencies of Natural Resources (ANR) and Transportation have been working together for several years to develop and implement permitting programs, plans, policies, and designs to comply with the **Lake Champlain Phosphorus Total Maximum Daily Load (TMDL)**, finalized by the U.S. EPA on June 17, 2016.

This story map documents how VTrans is developing Phosphorus Control Plans (PCPs) that will result in the reduction of phosphorus loading from roads, rights-of-way, and facilities under the Agency's control by over 20% within the next 20 years (by June 17, 2036). It first summarizes what VTrans has already done to develop the framework for a basin-wide PCP, and then provides a road-map for how the agency intends to meet its goals – beginning with the submittal of a Generalized PCP to ANR in the spring of 2020.

[Tips for navigation: Scrolling down on left brings new panel; clicking on a map on right will provide information about that feature.]

VTrans Stormwater Permitting



Lake Segments

TS4 Extent - State of Vermont

Lake Champlain Basin Boundary

As part of its **Phase 1 Implementation Plan** developed in response to the Lake Champlain Phosphorus TMDL, the Vermont ANR, in December 2016, issued the **National Pollutant Discharge Elimination System (NPDES) General Permit 3-9007 for Stormwater Discharges from the State Transportation Separate Storm Sewer System (TS4)** to VTrans. The permit was effective November 27, 2017. The TS4 General Permit is the primary regulation ensuring that stormwater discharged from VTrans owned or controlled impervious surfaces is managed according to State water quality policy. It combines VTrans's compliance obligations from several permit programs, including the Municipal Separate Storm Sewer System (MS4) General Permit and its associated Flow Restoration Plan and Phosphorus Control Plan requirements, Multi-Sector General Permit (MSGP), and Operational (post-construction) Stormwater Permit.

TS4 Permit Requirements for Phosphorus Control Planning

Section 9.2 of the TS4 permit requires VTrans to develop and implement Phosphorus Control Plans (PCPs), in phases, that will identify and document a suite of best management practices (BMPs) that will be able to achieve reductions in the amount of phosphorus in stormwater discharges in each of 11 Lake segments, as required by the TMDL. That plan must, at minimum, estimate the area (acres or road miles) to be treated, and the extent and type of BMPs that will be implemented to meet the entire P load reduction.

VTrans is required to meet a series of interim performance milestones that first culminate in the completion of a conceptual PCP for the entire TS4 within the Lake Champlain Basin by April 1, 2020, and creation of the first of several four-year implementation plans by October 1, 2020. Below is the compliance schedule from Section 9.2.C of the permit, outlining the Agency's progress in meeting these milestones. The results of each of the milestone submittals are described below.

- **January 1, 2018: Submit NOI and SWMP. (link available only in online story)**
- **April 1, 2018: Establish the baseline phosphorus load and reductions needed. (link available only in online story)**
- **October 1, 2018: Complete GIS inventory of phosphorus loading factors. (link available only in online story)**
- **April 1, 2019: Complete development of coefficients of loading rates. (link available only in online story)**
- **October 1, 2019: Submit progress report on Phosphorus Control Plan. (link available only in online story)**
- *April 1, 2020: Complete generalized statewide Phosphorus Control Plan.*
- *October 1, 2020: Submit 1st 4-year implementation plan (Phase I).*
- *April 1, 2021 and every 6 months thereafter (April 1st and October 1st): Submit semi-*

annual report on Phosphorus Control Plan implementation.

- *October 1, 2024: Submit 2nd 4-year implementation plan (Phase II).*
- *October 1, 2028: Submit 3rd 4-year implementation plan (Phase III).*
- *October 1, 2032: Submit 4th 4-year implementation plan (Phase IV).*
- *No later than June 17, 2036 Complete implementation of the approved PCP.*

Progress submittal: TS4 Permit Notice of Intent and Stormwater Management Plan (January 1, 2018)

VERMONT AGENCY OF TRANSPORTATION TS4 STORMWATER MANAGEMENT PROGRAM (SWMP)

Attachment F Incorporation of Previously Permitted Stormwater Systems
December 5, 2017

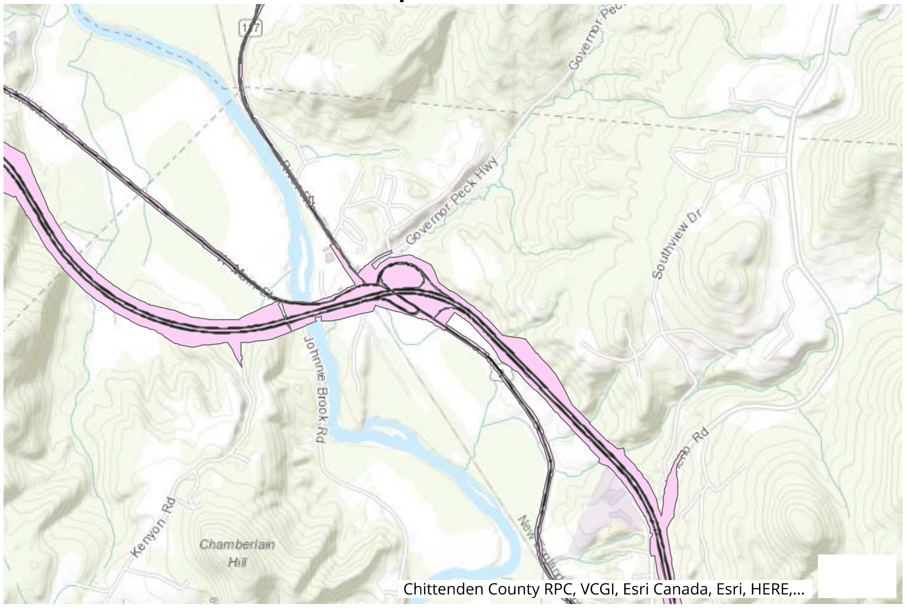
Project Name	Location	Stormwater Permit	BMP Type(s)
Alburg-Swanton Missisquoi Bay Bridge	Alburg-Swanton	6070-9010	grass/stone swales, scuppers
Barre Town HES 026-1(38) (roundabout)	Barre Town	4969-9010	catch basins, culverts, dry swale, flow splitter
Berlin STPG SGNL(40)	Berlin	7066-INDS	grass/stone swales
Bennington D1 Garage (TRANSFERRED TO VTrans)	Bennington	3361-9010	culverts, detention basins, swales
Bennington-Hoosick DPI 0146(1) C/3 &C/4	Bennington-Hoosick	3156-9010.R	vegetated/stone swales, stone check dams, sedementation trap, culverts, deten basins,
Brandon D3 Maint Garage (Arnold Rd)	Brandon	3768-9010.R	vegetated swales, detention basin
Bristol STP BRF 021-1(15)	Bristol	5221-9010	grass treatment channels, disconnection
Burke RS 0269(3) Bridge Replacement	Burke	3906-9010.R	grass/stone swales, DIs, culverts
Cabot-Danville FEGC F028-3(26) C1	Cabot-Danville	4022-INDS.R	grass channels
Cambridge BRF 027-1(4) & STP 030-2(27)	Cambridge	4765-9010	grass channels, site balancing
Cambridge BRF 030-2(12)	Cambridge	3885-9010.R	DI, stone lined swale, sheet flow
Chester BRF-F 016-1(3)	Chester	3905-9010.R	catch basins, culverts
Colchester D5 "Fort" Site Redevelopement	Colchester	6363-INDS.R	grass channels, micropool extended-detention pond, culverts
Colchester HES 0281(28)	Colchester	7427-INDS	sheet flow, grass channel
Colchester Park & Ride and Maintenance Facility	Colchester	3012-9010.R	wet detention basin, rain garden (not part of permit)
[illegible]	Cornwall	[illegible]	[illegible]

VTrans submitted its Notice of Intent and Stormwater Management Program (SWMP) document, outlining its expected actions and commitments for compliance with Vermont water quality policies and regulations over the next five years, to ANR in December 2017.

VTrans Lake Champlain Basin Phosphorus Control Plan

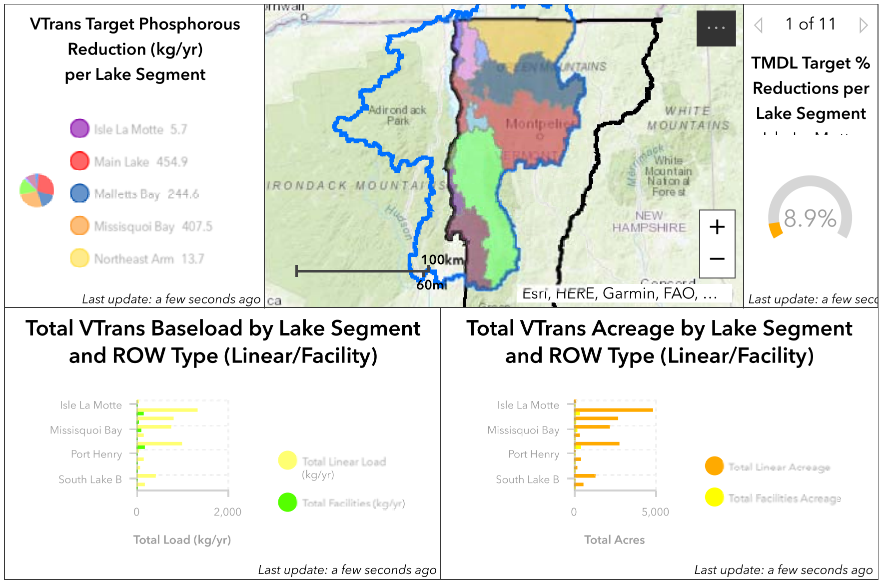
This story was made with ***Esri's Story Map Journal****.*
Read the interactive version on the web at ***https://arcg.is/0DS4LC0****.*

Progress Submittal: Establish the baseline phosphorus load and reductions needed. (April 1, 2018)



In order to establish the baseline phosphorus load and reductions needed, it was first necessary to develop GIS data defining the spatial extents and geographic coverage of the TS4 within the Lake Champlain Basin (LCB). The GIS data for TS4 extents were developed by VTrans and Stone in consultation with VTDEC. The spatial extents of linear facilities were derived based on the VTrans Managing Assets for Transportation Systems (MATS) database and include VTrans owned and maintained roads within the LCB. Right of way areas for linear facilities were derived using GIS data from VTrans, buffered road centerlines using minimum ROW widths and standard road class width where gaps existed within the VTrans data, and further manual edits to remove right of way areas maintained by private or municipal entities. The spatial extents for VTrans facilities, including airports, welcome centers, park and rides, gravel pits, and maintenance garages, were developed based on parcel data provided by VTrans. Stone digitized non-road impervious areas using 2011 impervious cover data from the Lake Champlain Basin Program, which was then updated and corrected using aerial imagery.

Base load and target reductions submittal continued



Once the extents of the TS4 within the LCB were determined, Vermont DEC extracted draft developed lands acreages and resulting draft phosphorus base loads from their existing land use-land cover dataset. The draft acreages and phosphorus base loads were broken down by lake segment, SWAT model drainage area, type of area (Road/linear facility or Parcel-based facility) and type of land use/land cover (Developed Impervious, Paved Road, Unpaved Road, and Developed Pervious).

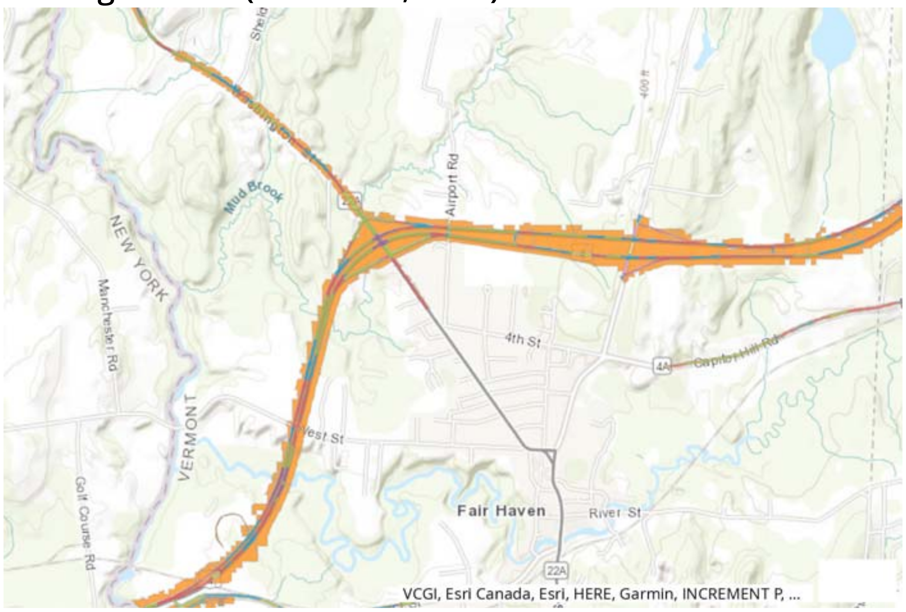
Following detailed review of the draft acreages and base loads by both VTrans and Vermont DEC, the draft phosphorus base loads and target reductions provided by Vermont were adjusted to reflect the consensus revisions. The table below summarizes the resulting VTrans phosphorus base load and target reductions by Lake segment.

Click here to view the full dashboard

Lake Segment	Phosphorus Base Load (kg/yr)	TMDL Reduction Target	Target Phosphorus Reduction (kg/yr)
Isle La Motte	63.96	8.9%	5.69
Main Lake	2,251.96	20.2%	454.90
Malletts Bay	1,193.21	20.5%	244.61
Missisquoi Bay	1,191.45	34.2%	407.48
Northeast Arm	189.78	7.2%	13.66
Otter Creek	1,639.76	15.0%	245.96
Port Henry	18.72	7.6%	1.42
Shelburne Bay	167.67	20.2%	33.87
South Lake A	89.46	18.1%	16.19
South Lake B	655.90	21.1%	138.40
St. Albans Bay	225.22	21.7%	48.87
Total	7,687.09		1,611.05

VTrans Lake Champlain Basin Phosphorus Control Plan

Progress Submittal: Complete GIS inventory of phosphorus loading factors. (October 1, 2018)



VTrans Land Use with Total Load

- 3 - Paved Roads Moderate HC - Low Slope
- 5 - Paved Roads Low HC - Low Slope
- 1 - Paved Roads High HC - Low Slope
- 2 - Paved Roads High HC - High Slope
- Developed Pervious
- 4 - Paved Roads Moderate HC - High Slope
- 6 - Paved Roads Low HC - High Slope
- Developed Impervious
- Paved Roads - Facilities
- Unpaved Roads

The GIS inventory of loading factors was developed by VTrans in consultation with Vermont DEC to first establish the **baseline phosphorus load (link available only in online story)** and then to determine other factors to more accurately refine P load allocation for the TS4 across the Lake Champlain Basin (LCB). The loading factors that were considered to allocate load across the TS4 included:

- **Developed Impervious TS4 Extents (link available only in online story)**
  - Developed impervious areas are associated with non-road VTrans properties including airports, welcome centers, park and rides, gravel pits, and maintenance garages. These data are used to allocate P baseline load across the TS4 for Developed Impervious areas.
- **Paved Road TS4 Extents (link available only in online story)**
  - Paved roads include VTrans roads that have paved surfaces. Paved road areas were initially provided to VTrans by Vermont DEC. The Vermont DEC paved roads areas were used to allocate load across the TS4 for Paved Road areas. A road centerline dataset was derived to further classify VTrans road segments and to more closely refine allocation of the P baseline load for paved road areas within the TS4. MATS roads segments from VTrans were intersected with soil polygons and then divided into ~100m (or smaller) segments, and

each of these smaller segments was classified by road slope class, hydrologic connectivity class, and localized erosion potential.

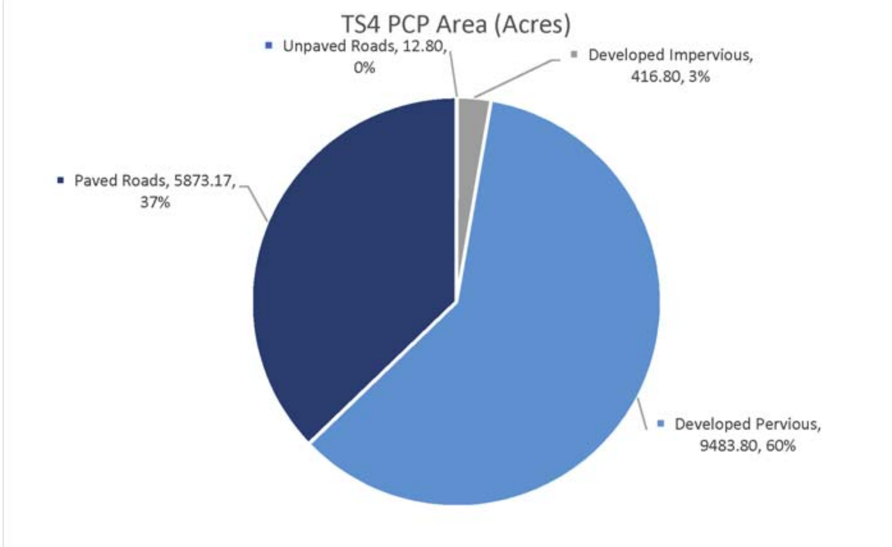
- **Slope Class (link available only in online story)**
  - Road slope was calculated based on LiDAR and classified based on whether the slope of the road segment fell above or below 10%.
- **Hydrologic Connectivity (link available only in online story)**
  - Each road segment was assigned hydrologic connectivity based on seven evaluation criteria:
    - Highly hydrologically connected: road segment intersects or is within 100 feet of an NHD Stream, Pond, or VSWI Wetland, or within a mapped River Corridor
    - Moderately hydrologically connected: Road segment intersects or is within 100 feet of additional intermittent streams (identified using a LiDAR-based Enhanced Hydrology Network); within 50 feet of piped stormwater infrastructure connected to an outfall within 500 feet of an NHD stream, pond, or VSWI wetland; or within 50 feet of any culvert in the Small Culvert Inventory (SCI)
    - Low hydrologic connectivity: If none of the above conditions applied, the road segment was considered to have low hydrologic connectivity.
- **Localized Erosion Potential (link available only in online story)**
  - The potential for localized erosion at each paved road segment was assessed and results were added to the line segment based on the following four criteria:
    - Road segment has steep slopes in the adjacent right-of way, and flow accumulation is mapped downslope of the road segment
    - Potential culvert erosion is recorded in the Small Culverts Inventory dataset
    - The guardrail inventory indicates curb board is present
    - There is evidence of a ditch upslope along the road segment.

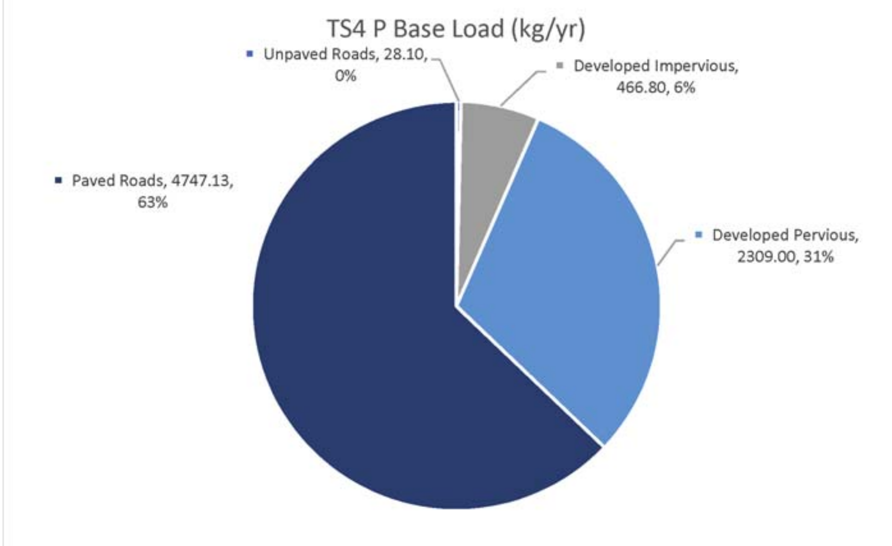
- **Unpaved Road TS4 Extents (link available only in online story)**
  - Unpaved roads include roads that have gravel surfaces. Unpaved road areas were defined by VTDEC using the 2011 land cover data from LCBP and VTrans ROW areas. These data are used to allocate the baseline P load across the TS4 for Unpaved Road areas.
- **Developed Pervious TS4 Extents (link available only in online story)**
  - Developed pervious areas include non-impervious, developed portions of both road ROW areas and VTrans parcels. The data were prepared by VTDEC using VTrans ROW, VTrans parcels, and 2011 Land Cover data. These data are used to allocate load across the TS4 for Developed Pervious areas.

VTrans Lake Champlain Basin Phosphorus Control Plan

This story was made with ***Esri's Story Map Journal****.*
Read the interactive version on the web at ***https://arcg.is/0DS4LC0****.*

Progress Submittal: Complete development of coefficients of loading rates (Subpart 9.2.A.3 - April 1, 2019)





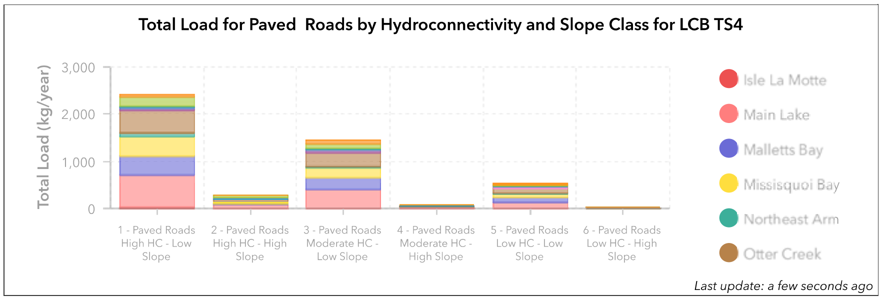
Following the development of the **GIS inventory of loading factors (link available only in online story)**, VTrans and Vermont DEC considered the development of loading rate coefficients for each of the four land use classes and associated P loading factors. The intent of the loading rate coefficients is to refine allocation of the P base load such that critical source areas – portions of the TS4 with the highest risk of contributing disproportionate P loads to surface waters – were assigned a proportionately higher portion of the P base load within each Lake segment. The chart at the right summarizes acres and P base load distribution by each of the four transportation-related land use classes across the entire Lake Champlain basin and PCP area.

60% (9,843 acres) of the TS4 area included in the PCP is classified as developed pervious, but this area only constitutes 31% of the phosphorus base load (2,309 kg/yr). This is substantial acreage, but compared to paved roads (which, though only about 40% of the total acres, constitute 63% of the P base load) it is a relatively minor and hard to treat portion of the P base load. Substantial uncertainty remains about how improvements to developed pervious, especially related to localized erosion fixes that also treat paved road runoff, would be credited. Ultimately, the localized erosion potential factors were retained, but coefficients were not developed to re-distribute P base load according to risk of localized erosion. This decision may be revisited as development of the basin-wide generalized PCP and lake segment-specific PCPs proceed.

Developed impervious areas and unpaved roads both represent small portions of the TS4 Phosphorus Control Plan area, both in terms of acreage and P base load. Thus, no coefficients were developed to refine distribution of these portions of the P base load.

Paved roads represent the highest proportion of the P base load. As demonstrated in the GIS inventory of loading factors, there is substantial variability between both slope class and level of hydrologic connectivity across the TS4 paved road network within the Lake Champlain basin. Loading coefficients were developed for the paved roads portion of the P base load, and that load was assigned to paved roads areas within each Lake segment and drainage area based on the slope class and degree of hydrologic connectivity of individual paved road segments.

Development of coefficients of loading rates continued



Click here to view the full dashboard

The paved roads inventory as refined by **road slope class, hydrologic connectivity class, and localized erosion potential (link available only in online story)** was used to further refine load allocation for paved road areas within the TS4. A spreadsheet model was developed to summarize the TS4 paved roads miles and P base loads, and then to re-allocate the P base load first by roadway slope class (0 – 10% and >10%), then by high, moderate, or low degrees of hydrologic connectivity in frequent consultation between VTrans and Vermont DEC.

Loading rates for each slope class were determined by applying the model to each SWAT drainage basin independently. This resulted in optimal slope class loading rates that ensured the resulting calculated loads matched the total paved roads P loads for each SWAT drainage basin that were agreed upon by VTrans and Vermont DEC in March 2018. The >10% slope segments received a higher loading rate than 0-10% slope segments.

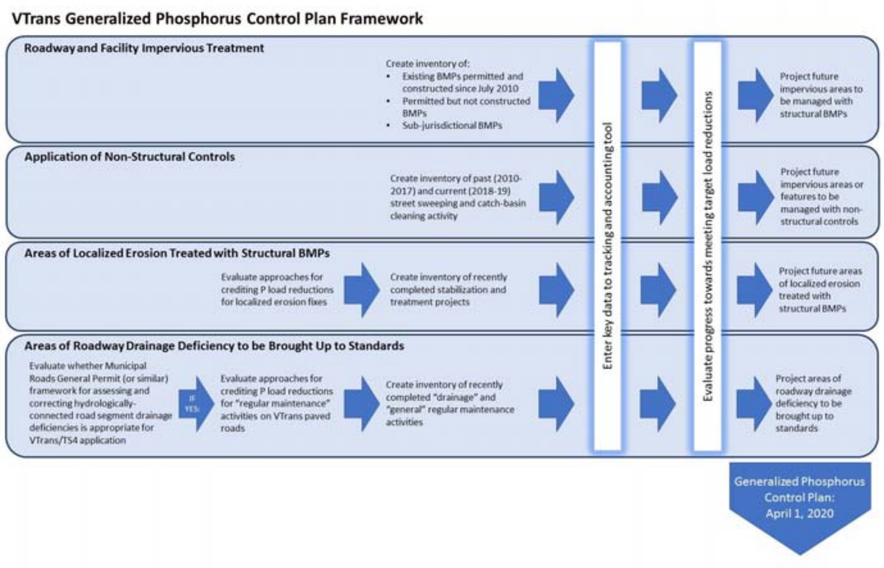
Loading coefficients were then applied to the calculated slope class loading rates for each of the three hydrologic connectivity classes, such that slope class loading rates were multiplied by the hydrologic-connectivity-class-specific loading coefficient to account for the impact of connectivity. Loading coefficients were set to 1.0 originally, then optimal values were solved for using the spreadsheet model. This was done first at the Lake Champlain Basin level, such that a single set of loading coefficients was obtained which could be applied across all Lake segments and SWAT drainage areas. While this method resulted in equivalent paved roads P base loads at the Lake Champlain Basin level, the calculated base loads at the SWAT drainage area level did not match those agreed upon by VTrans and Vermont DEC in March 2018. The model routine was thus run again at the SWAT drainage area level, such that a unique set of loading coefficients was obtained for each drainage basin. The average results for the loading coefficients were very similar to those obtained at the Lake Champlain Basin level. Average loading rate coefficients of 1.31 were derived for the high hydrologic connectivity class, 0.87 for the moderate hydrologic connectivity class, and 0.63 for the low hydrologic connectivity class, respectively.

Once consensus was reached on the appropriate coefficients to assign to the paved roads loading rates based on slope class and hydrologic connectivity, the final loading rates from the spreadsheet model, which were necessarily calculated based on the collective mileage of the linear MATS road segment dataset, were attributed to the paved road area polygon dataset originally provided by Vermont DEC.

VTrans Lake Champlain Basin Phosphorus Control Plan

*This story was made with **Esri's Story Map Journal**.*
*Read the interactive version on the web at **https://arcg.is/0DS4LC0**.*

Progress Submittal: Progress report on the Phosphorus Control Plan (October 1, 2019)

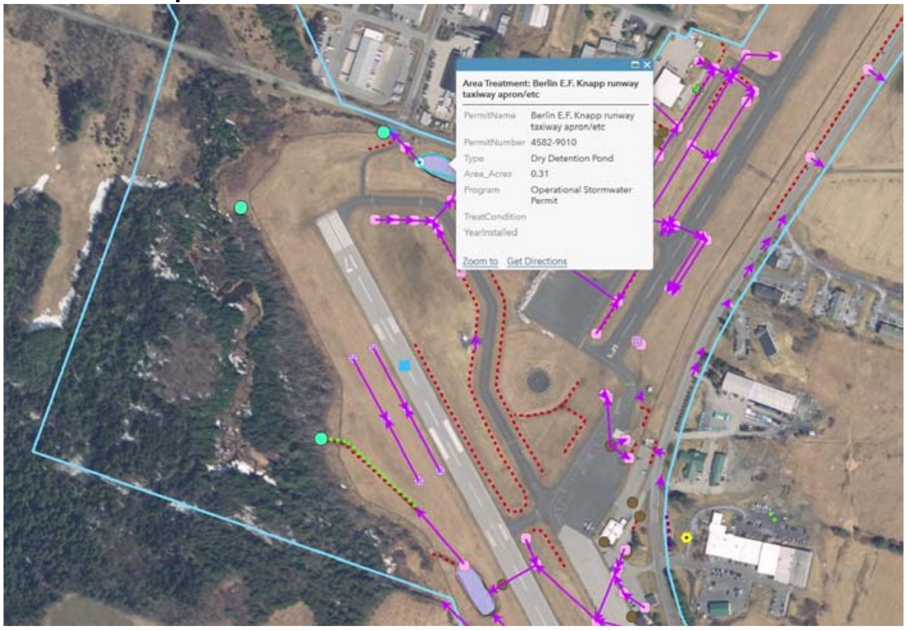


The progress submittals described above, as well as inventory and assessment work completed through VTrans' other commitments under the TS4 General Permit, lay the groundwork for completion of a conceptual PCP for the entire TS4 within the Lake Champlain Basin, as required by April 1, 2020. The generalized PCP must, at minimum, estimate the area (acres or road miles) to be treated, and the extent and type of BMPs that will be implemented to meet the entire P load reduction.

Four classes of conceptual BMPs are under consideration and development for inclusion in the Generalized PCP:

- **Areas of VTrans property treated with structural stormwater BMPs (link available only in online story)**
- **Areas of VTrans property treated with non-structural practices (link available only in online story)**
- **Areas of localized erosion treated with structural BMPs (link available only in online story)**
- **Areas of VTrans roadway and drainage upgraded to meet standards (link available only in online story)**

Areas of impervious surface treated with structural BMPs



Structural best management practices (BMPs) are intended to detain, treat, and better manage runoff from well-defined ares of impervious surface, such as roads, parking lots, or rooftops. These treatment practices range from older detention ponds managing only peak flows, to dry swales, gravel wetlands, and other **green stormwater infrastructure**.

VTrans is identifying upgrades and retrofits to practices implemented after the adoption of the 2002 Vermont Stormwater Management Manual design standards, including both jurisdictional and sub-jurisdictional improvements. Operational permits and plans issued by the Vermont DEC Stormwater Program for projects permitted after July 1, 2010 are under review to assess and credit the additional benefit provided by these systems.

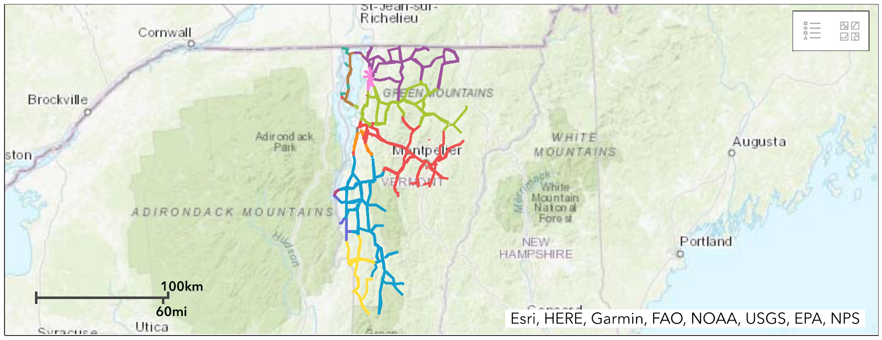
As qualifying BMPs are identified, the P base loads to be managed by each existing and in-process BMP are calculated. Next, P removal efficiencies and P load reduction benefits expected for existing and planned structural BMPs are calculated, generally consistent with **BMP types and crediting already established by DEC**. Upon completion of these updates, VTrans will have an indication of progress already made towards meeting P reduction targets in each Lake segment.

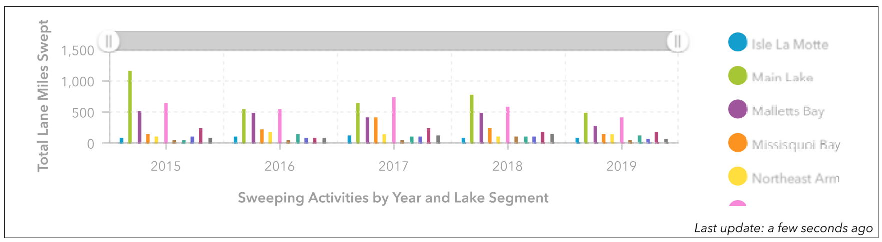
Once an indication of progress towards meeting targets already achieved is in hand, GIS analysis will be used to refine areas for application of conceptual BMPs. Large areas of highly hydrologically connected roadway and moderately connected roadway will be the primary targets for structural BMP retrofits. Structural BMP locations will be identified by targeting large, low-slope right-of-way areas in proximity and downslope of large areas of roadway impervious cover. The results of this analysis will be used to estimate acres of paved road managed with structural BMPs in each Lake segment, the types of BMPs that would be best suited in each application, and the P load removal credit achieved for each conceptual BMP application.

VTrans Lake Champlain Basin Phosphorus Control Plan

This story was made with ***Esri's Story Map Journal****.*
Read the interactive version on the web at ***https://arcg.is/0DS4LC0****.*

Areas treated with non-structural practices





As part of its **SWMP**, VTrans has committed to completing a robust suite of maintenance activities under Minimum Control Measure 6.F (Pollution Prevention/ Good Housekeeping for Municipal Operations). The ultimate goal of this control measure, as stated in Subpart 6.3.F of the **TS4 Permit**, is "preventing or reducing pollutant runoff from all VTrans' operations related to the TS4". Two of the maintenance activities, drop inlet (DI) or catch basin cleaning and street sweeping, can directly result in the removal of sediment and phosphorus from impervious surfaces—and thus, are of particular interest in developing VTrans's PCP.

It is generally not feasible to summarize VTrans' application of non-structural controls prior to July 2010 outside of areas included in operational stormwater permit drainage areas or stormwater flow-impaired watersheds, where VTrans was previously a non-traditional MS4 permittee. Exploration of maintenance records from VTrans's Managing Assets for Transportation Systems (MATS) database from 2010-July 2018 indicates that it is possible to estimate road miles swept, annual frequency of street sweeping operations, and frequency of drop inlet/catch basin cleaning for at least some VTrans Maintenance Districts within the LCB. The lack of reliable data prior to July 2010 complicates assessment of enhancements to non-structural controls implemented since then. However, the MATS data provide a baseline condition against which enhancements to equipment used or frequency of application may be measured and credited in the development and implementation of Lake-segment-specific PCPs.

Application of non-structural practices (street sweeping and DI cleaning) by Lake segment and drainage basin between 2010 and 2018 is now being summarized to the extent practicable to evaluate opportunities to improve maintenance and provide phosphorus reduction credits. VTrans will incorporate applicable findings from **ongoing research** by USGS, in cooperation with the Chittenden County Regional Planning Commission, Vermont DEC, the University of Vermont, and nine Vermont municipalities, to evaluate potential reductions in nutrient and sediment loads possible through current street cleaning practices, and possible enhancements to those activities.

Ultimately, P load reduction credits anticipated from each type and application of non-structural control on an annual basis will be developed or applied as appropriate. For the Generalized Phosphorus Control Plan, generalized recommendations will be provided by Lake segment for targeting of increased frequency of lane miles swept (2,000 lane miles annually) in line with VTrans' commitment made under the TS4 General Permit and resulting Stormwater Management Program (SWMP). Generalized recommendations will also be made for enhanced DI cleaning, consistent with VTrans' commitment to inspect 20% of DIs on an annual basis under its SWMP.

VTrans Lake Champlain Basin Phosphorus Control Plan

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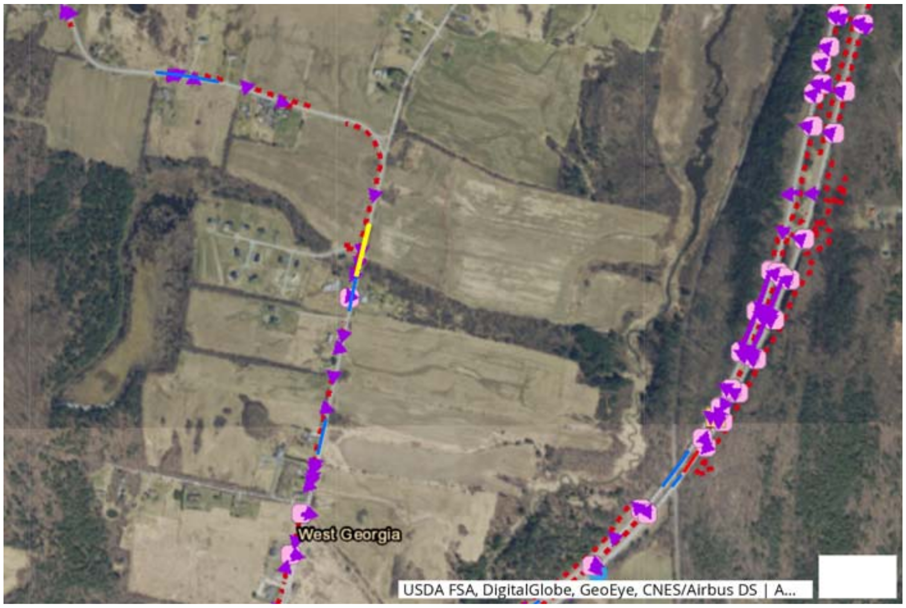
Areas of Localized Erosion Treated with Structural BMPs



Editable - Erosion Validation Segments August 2019

Editable - Erosion Area

Editable - Other Points of Interest

Editable - Erosion Validation Segments July 2019

High HydroConnectivity and High Slope

High HydroConnectivity and Low Slope

VTRC 19(2) - Candidate sites

AMP_SmallCulvertInventory

SCI Culverts

SCI DropInlets
- Unknown
- Drop Inlet
- Dry Sump
- Junction Box
- Stand Pipe

SCI Access Holes

MOB_EPWQ_TS4_Inventory

Swales

Outfall

Stabilization and treatment of areas of localized erosion caused by roadway drainage infrastructure has utility in both the VTrans PCP and in crediting for "meeting standards" under the **Municipal Roads General Permit (MRGP)**. However, specific crediting mechanisms are not well-established for these and similar transportation-related improvements. VTrans is working with Vermont DEC to clarify and come to consensus on a crediting methodology for existing localized erosion repair projects, which then may reasonably be extended to crediting for proposed localized erosion repairs under either the VTrans PCP or the MRGP implementation efforts. Crediting options being explored include NRCS or other area-based approaches, as well as alternative options. For example, the Virginia Department of Transportation has successfully utilized stream restoration and stabilization practices with phosphorus reduction credit for the stabilization of outfalls associated with their roadway network, applying the same **credits offered for stream restoration/stabilization** in the Chesapeake Bay nutrient TMDL. A similar approach could apply both for improvements to areas of localized erosion, and to correction of some areas of **existing roadway drainage deficiency (link available only in online story)**. This work will utilize the progress and findings of the VTrans and Vermont DEC research project *Quantifying Nutrient Pollution Reductions Achieved by Erosion Remediation Projects on Vermont's Roads,* which is now underway.

Existing areas of localized erosion that have been repaired or managed with structural BMPs since July 2010 are being identified by leveraging asset conditions tracked and maintenance activities reported in VTrans electronic data management systems including the MATS database, the Small Culverts Inventory (SCI), and the TS4 infrastructure and operational stormwater permits inventories. These data sources are being coupled with the **GIS inventory of areas of localized erosion (link available only in online story)** to create a desktop inventory of recently-completed localized erosion stabilization projects that may be eligible for P reduction credit.

A sub-set of localized erosion repairs identified in the MATS database and completed between January 2017 and May 2019 were field verified in the summer of 2019. The field verification effort had several goals:

- Understand possible credit for correcting areas of localized erosion with structural BMPs
- Gather information to compare the MRGP's Road Erosion Inventory framework and criteria with VTrans's inventories and maintenance activity records
- Determine applicability for VTrans roadways and erosion problem, such that "fixes" may be credited using a similar strategy between both permit and regulatory programs

Field verification of existing localized erosion repairs was attempted in July-August 2019 at over 70 sites identified in the MATS database (see map at right).

- At 38 sites (53%) a localized erosion fix was located in good condition.
- At 11 sites, (15%) a fix was located but it was either in need of additional repair or the fix had failed.
- 19 sites (27%) were not found – either the location data were not precise, or the fix was so effective it could not be located.
- 3 records (4%) were related to planning activities rather than localized erosion fixes.

Given the positive field verification results, a simple calculation was completed to evaluate the basin-wide scale and potential for P reduction resulting from repairing areas of localized erosion using structural BMPs. It appears that approximately 8% of the PCP area's paved road base load (383 kg/yr) is likely associated with active or recently-repaired localized erosion areas. If a conceptual 50% P load reduction credit was applied for these fixes over the term of PCP implementation, the associated P load reduction of 191 kg/yr constitutes roughly 19% of VTrans's total required target reduction across the LCB.

Erosion Fix, US Route 4 in Proctor, VT

In the coming months, VTrans will be using the MATS data and field verification results to extrapolate the frequency of localized erosion fixes by Lake segment, VTrans Maintenance District, and year. Localized erosion fixes constitute a demonstrable water quality improvement and should be a component of the Generalized Plan – but better prediction is needed of both acres anticipated to be treated and time domain.

As with **structural (link available only in online story)** and **non-structural BMPs (link available only in online story)**, once an indication of progress towards meeting targets already achieved is clear, GIS analysis will be used to refine areas for application of conceptual BMPs. In this assessment, large areas of hydrologically connected paved road adjacent to areas of potential localized erosion identified in the inventory will be targeted, where structural BMPs may be applied to both manage runoff from paved road areas and repair erosion problems. The results of this analysis will be used to estimate acres of paved road and localized erosion managed with structural BMPs in each Lake segment, the types of BMPs that would be best suited in each application, and the P load reduction credit achieved for each conceptual BMP application.

VTrans Lake Champlain Basin Phosphorus Control Plan

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Areas treated by improving road and drainage conditions

High HydroConnectivity and High Slope

High HydroConnectivity and Low Slope

Maintenance_Inventory_Guard

- Excellent
- Good
- Fair
- Poor
- Very Poor
- Unknown
- No Value Assigned

AMP_SmallCulvertInventory

SCI Culverts

SCI DropInlets

- Unknown
- Drop Inlet
- Dry Sump
- Junction Box
- Stand Pipe

ROW_ActiveErosionClassification_FullBasin

- <Null>
- LE1_DownSteepRdRunoff
- LE2_CulvertErosion
- LE3_CurbBoard
- LE4_PotentialDitch

SCI Access Holes

MOB_EPWQ_TS4_Inventory

Swales

Outfall

As with repairs to areas of localized erosion with **structural BMPs (link available only in online story)**, further work is underway to define approaches for quantifying or crediting P load reductions for BMPs that are considered as regular maintenance activities on VTrans paved roads. Examples include guardrail maintenance and culvert or outfall repair/replacement, where these activities result in a demonstrable P load reduction or improvement in a road segment's condition when compared to DEC's 'hydrologically-connected road segments' **inventory requirement** under the MRGP and as incorporated into the MS4 General Permit. This requirement is not part of the TS4 permit, and VTrans and DEC have not reached consensus regarding whether VTrans should develop and maintain a similar Road Erosion Inventory as a component of its PCP.

VTrans is working with Vermont DEC to more closely define standards and criteria for hydrologically connected road segments within the TS4, where an approach similar to the **MRGP standards** may be warranted. If and as consensus is reached, a similar workflow will be followed as for the other classes of BMPs described above. Existing areas where roadway drainage deficiencies have been brought up to standards since July 2010 will be compiled into a desktop inventory of roadway drainage improvement projects that may be eligible for P reduction credit. Road miles or acres where deficiencies have been addressed will be calculated, resulting in estimates of what P load reduction credit may reasonably be granted for existing projects across the LCB.

Once an indication of progress towards meeting targets already achieved is clear, GIS analysis will be used to refine areas for application of conceptual BMPs. Analysis results will estimate acres or miles where existing drainage deficiencies may be brought up to standards in each Lake segment, the types of conceptual BMPs or drainage improvements that would be best suited in each application, and the P load removal credit achieved for each conceptual application.

Appendix E: Design Basis Assumptions for Conceptual Structural STPs

BMP Type	Design Element	Design Element Code	Design Criteria	Unit	Standard Reference	Notes
Bioretention (infiltrating)						
Bioretention (infiltrating)	MS4 BMP Definition Design Storage Volume (DSV)	DSV	DSV = Ponding water storage volume and void space volumes of soil filter media. Example: DSV = (Apond x Dpond) + (Asoil x Dsoil x nsoil mix)	cubic feet	(3)	
Bioretention (infiltrating)	CF storage per SF BMP area	Dv	1.38	cf/sf		
Bioretention (infiltrating)	Bioretention soil mix media minimum depth (Dbio_soil)	Dbio_soil	2	feet	(1)	
Bioretention (infiltrating)	Pea gravel choker course depth (Dpea_gravel)	Dpea_gravel	0.25	feet	(1)	
Bioretention (infiltrating)	Stone reservoir minimum depth (Ddrain_rock)	Ddrain_rock	0.75	feet	(1)	
Bioretention (infiltrating)	Max ponding depth (Dponding)	Dponding	0.5	foot	(1)	
Bioretention (infiltrating)	Porosity of pea gravel	npea_gravel	0.32		(4)	
Bioretention (infiltrating)	Porosity of drain rock	ndrain_rock	0.40		(5)	
Bioretention (infiltrating)	Porosity of bioretention soil	nbio_soil	0.25		(12) - NY DEC porosity value	
Bioretention (infiltrating)	Pre-treatment volume	PTv			(1)	Forebay sized for 25% of WQv or other per section 4.1 of VSMM
Bioretention (infiltrating)	Treatment volume	Tv			(1)	Treatment volume, including ponding, media and pre-treatment storage, must be 75% of WQv to avoid premature bypass
Bioretention (w/ underdrain)						
Bioretention (w/ underdrain)	MS4 BMP Definition Design Storage Volume (DSV)	DSV	DSV = Ponding water storage volume and void space volumes of soil filter media. Example: DSV = (Apond x Dpond) + (Asoil x Dsoil x nsoil mix)	cubic feet	(3)	Same calculation as infiltrative bioretention. Sizing of underdrained facilities should be increased for poorly drained soils.
Bioretention (w/ underdrain)	CF storage per SF BMP area	Dv	1.38	cf/sf		
Bioretention (w/ underdrain)	Bioretention soil mix media minimum depth (Dbio_soil)	Dbio_soil	2	feet	(1)	
Bioretention (w/ underdrain)	Pea gravel choker course depth (Dpea_gravel)	Dpea_gravel	0.25	feet	(1)	
Bioretention (w/ underdrain)	Stone reservoir minimum depth	Ddrain_rock	0.75	feet	(1)	
Bioretention (w/ underdrain)	Ponding depth	Dponding	0.5	foot	(1)	
Bioretention (w/ underdrain)	Porosity of pea gravel	npea_gravel	0.32		(4)	
Bioretention (w/ underdrain)	Porosity of drain rock	ndrain_rock	0.40		(5)	
Bioretention (w/ underdrain)	Porosity of bioretention soil	nbio_soil	0.25		(12) - NY DEC porosity value	
Gravel Wetland						A liner is required if underlying soils have an infiltration rate >0.05 inches per hour.
Gravel Wetland	MS4 BMP Definition Design Storage Volume (DSV)	DSV	DSV = pretreatment volume + ponding volume + void space volume of gravel ISR. DSV = (A pretreatment x DpreTreatment)+ (A wetland x Dponding)+ (AISR x Dgravel x ngravel) Pretreatment	cubic feet	(3)	
Gravel Wetland	Minimum Length (L)	L	15	feet	(1)	Minimum length to width ratio of 1:1 (L:W) for each treatment cell, with a minimum flow path (L) within the gravel substrate of 15 feet.
Gravel Wetland	CF storage per SF BMP area	Dv	2.03	cf/sf		
Gravel Wetland	Ponding depth above gravel (Dponding)	Dponding	1	feet	(2)	(3:1 side slopes and 0.5 feet freeboard)
Gravel Wetland	Topsoil depth (Dtsoil)	Dtsoil	0.33	feet	(2)	
Gravel Wetland	3/4" stone depth (Dstone)	Dstone	0.33	feet	(2)	
Gravel Wetland	Gravel treatment area depth (Dgravel)	Dgravel	2	feet	(2)	
Gravel Wetland	Porosity of topsoil (ntsoil)	ntsoil	0.32		(12) - NY DEC porosity value	topsoil per reference (2), but used bioretention soil porosity for estimation purposes due to high variability of topsoi porosity
Gravel Wetland	Porosity of 3/4" stone	nstone	0.38		(5)	3/8 in crushed stone per reference (2)
Gravel Wetland	Porosity of gravel (ngravel)	ngravel	0.40		(5)	1.5 in crushed stone per reference (2)
Gravel Wetland	Pre-treatment volume	PTv			(1)	At least 10% of the WQV shall be provided in a sediment forebay if used for pre-treatment.
Gravel Wetland	Treatment volume	Tv			(1)	The remaining 90% of the WQV shall be provided through a combination of one or more basins or chambers filled with a minimum 24-inch gravel layer
Infiltration Chambers						Max longitudinal slope is 1%
Infiltration Chambers	MS4 BMP Definition Design Storage Volume (DSV)	DSV	DSV = void space volumes of stone and sand layers. DSV = (Atrench x Dstone x nstone)+ (Atrench x Dsand x nsand)	cubic feet	(3)	
Infiltration Chambers	CF storage per SF BMP area	Dv	2.90	cf/sf		
Infiltration Chambers	Chamber depth	Dchamber	2.5	feet	(8)	
Infiltration Chambers	Gravel cover depth min	DgravelC	0.5	feet	(1)	
Infiltration Chambers	Gravel foundation depth min	DgravelF	0.5	feet	(1)	
Infiltration Chambers	Porosity of gravel	ngravel	0.40		(5)	
Infiltration Basin						Max longitudinal slope is 1%

BMP Type	Design Element	Design Element Code	Design Criteria	Unit	Standard Reference	Notes
Infiltration Basin	MS4 BMP Definition Design Storage Volume (DSV)	DSV	DSV = Water volume of storage structure before bypass. Example for rectangular vegetated basin. DSV = (L x W x D)	cubic feet	(3)	MS4 BMP tracking table and performance curve definitions assume surface ponding only - no stone reservoir.
Infiltration Basin	CF storage per SF BMP area	Dv	2.00	cf/sf		
Infiltration Basin	Ponding depth (Dponding)	Dponding	2	feet	(1)	
Infiltration Trench						- Suggested DMA<5ac for this technology (VSMM) - Max longitudinal slope is 1%
Infiltration Trench	MS4 BMP Definition Design Storage Volume (DSV)	DSV	DSV = void space volumes of stone and sand layers. DSV = (Atrench x Dstone x nstone)+ (Atrench x Dsand x nsand)	cubic feet	(3)	
Infiltration Trench	CF storage per SF BMP area	Dv	2.60	cf/sf		
Infiltration Trench	Ponding depth above gravel (Dponding)	Dponding	1	feet	(1)	
Infiltration Trench	Stone reservoir max depth (Dstone)	Dstone	4	feet	(1)	
Infiltration Trench	Porosity of stone (nstone)	nstone	0.40		(5)	
Infiltration Trench	Pre-treatment volume	PTv			(1)	- If the infiltration rate is ≤2 inches per hour, then the min PTv is 25% of WQv - If the infiltration rate is >2 inches per hour, then the min PTv is 50% of WQV
Porous Pavement						- Assumed porous asphalt rather than concrete. - Permeable pavements shall be sited on slopes less than 5%. - Permeable pavements should only be used to manage precipitation that falls directly on the permeable pavement area to protect the surface from clogging
Porous Pavement	MS4 BMP Definition Design Storage Volume (DSV)	DSV	DSV = void space volumes of stone and sand layers. DSV = (Atrench x Dstone x nstone)+ (Atrench x Dsand x nsand)	cubic feet	(3)	
Porous Pavement	CF storage per SF BMP area	Dv	0.96	cf/sf		
Porous Pavement	Choking course depth (Dchoking)	Dchoking	0.5	feet	(1)	
Porous Pavement	Base course depth (Dbase)	Dbase	2	foot	(1)	Minimum depth is 0.5ft
Porous Pavement	Porosity of choking course (nchoking)	nchoking	0.32		(4)	Assumed similar to pea gravel
Porous Pavement	Porosity of base course (nbase)	nbase	0.40		(5)	
Permeable Pavers						- Assumed paver bricks, no underdrain - Permeable pavements shall be sited on slopes less than 5%. - Permeable pavements should only be used to manage precipitation that falls directly on the permeable pavement area to protect the surface from clogging
Permeable Pavers	MS4 BMP Definition Design Storage Volume (DSV)	DSV	DSV = void space volumes of stone and sand layers. DSV = (Atrench x Dstone x nstone)+ (Atrench x Dsand x nsand)	cubic feet	(3)	Difference between porous asphalt and permeable paver is choking course/beddign course depth and material
Permeable Pavers	CF storage per SF BMP area	Dv	0.83	cf/sf		
Permeable Pavers	Stone bedding course depth (Dbedding)	Dbedding	0.17	feet	(7)	
Permeable Pavers	Base course depth (Dbase)	Dbase	2	foot	(7)	Minimum depth is 0.5ft
Permeable Pavers	Porosity of bedding stone layer (nbedding)	nbedding	0.20		(10)	Assumed ASTm No. 8 stone
Permeable Pavers	Porosity of base course (nbase)	nbase	0.40		(5)	
Dry Swale (infiltrating)						Max longitudinal slope is 6%
Dry Swale (infiltrating)	MS4 BMP Definition Design Storage Volume (DSV)	DSV	DSV = Water volume of storage structure before bypass. Example for linear trapazoidal vegetated swale. DSV = (L x ((Wbottom+Wtop@Dmax)/2) x D)	cubic feet	(3)	
Dry Swale (infiltrating)	Minimum width (W)	W	2	feet	(1)	Width of reservoir only, ponding can be trapezoidal above
Dry Swale (infiltrating)	CF storage per SF BMP area	Dv	2.10	cf/sf		
Dry Swale (infiltrating)	Filter bed minimum depth (Dfilter)	Dfilter	2	feet	(1)	
Dry Swale (infiltrating)	Stone reservoir minimum depth (Dstone)	Dstone	1	foot	(1)	
Dry Swale (infiltrating)	Max ponding depth (Dponding)	Dponding	1	foot	(1)	
Dry Swale (infiltrating)	Porosity of stone (nstone)	nstone	0.4		(5)	
Dry Swale (infiltrating)	Porosity of filter bed	nfilter	0.35		(9)	VSMM specified sand or bioretention soil, assumed sand here. Porosity is based on average of coarse sand range from .26-.43
Dry Swale (infiltrating)	Pre-treatment volume	PTv			(1)	Forebay sized for 10% of WQv or other per section 4.1 of VSMM
Dry Swale (infiltrating)	Treatment volume	Tv			(1)	Treatment volume, including ponding, media and pre-treatment storage, must be 75% of WQv to avoid premature bypass
Dry Swale (w/ underdrain)						Max longitudinal slope is 6%
Dry Swale (w/ underdrain)	MS4 BMP Definition Design Storage Volume (DSV)	DSV	DSV = Ponding water storage volume and void space volume of soil filter media. DSV = (Abed x Dponding)+ (Abed x Dsoil x nsoil)	cubic feet	(3)	Currently, this is the same calculation as infiltrative dry swales. Sizing of underdrained facilities should be increased for those sites on poorly draining soils.
Dry Swale (w/ underdrain)	Minimum width (W)	W	2	feet	(1)	Width of reservoir only, ponding can be trapezoidal above
Dry Swale (w/ underdrain)	CF storage per SF BMP area	Dv	2.10	cf/sf		

BMP Type	Design Element	Design Element Code	Design Criteria	Unit	Standard Reference	Notes
Dry Swale (w/ underdrain)	Filter bed minimum depth (Dfilter)	Dfilter	2	feet	(1)	
Dry Swale (w/ underdrain)	Stone reservoir minimum depth (Dstone)	Dstone	1	foot	(1)	
Dry Swale (w/ underdrain)	Max ponding depth (Dponding)	Dponding	1	foot	(1)	
Dry Swale (w/ underdrain)	Porosity of stone (nstone)	nstone	0.4		(5)	
Dry Swale (w/ underdrain)	Porosity of filter bed	nfilter	0.35		(9)	VSMM specified sand or bioretention soil, assumed sand here. Porosity is based on average of coarse sand range from .26-.43
Dry Swale (w/ underdrain)	Pre-treatment volume	PTv			(1)	Forebay sized for 10% of WQv or other per section 4.1 of VSMM
Dry Swale (w/ underdrain)	Treatment volume	Tv			(1)	Treatment volume, including ponding, media and pre-treatment storage, must be 75% of WQv to avoid premature bypass
Wet Pond						- BMP Type is Wet Pond/ Created Wetland in BMP Tracking Sreadsheet - Max slope of 10%
Wet Pond	MS4 BMP Definition Design Storage Volume (DSV)	DSV	DSV= Pemanant pool volume prior to high flow bypass DSV=Apond x Dpond	cubic feet		- does not include pretreatment volume - The minimum flow path length to practice width ratio is 3:1.
Wet Pond	CF storage per SF BMP area	Dv	4	cf/sf		
Wet Pond	Min ponding depth (Dponding)	Dponding	4	feet	(1)	
Wet Pond	Pre-treatment volume	PTv			(1)	Forebay sized for 10% of WQv or other per section 4.1 of VSMM. If winter traction sanding is prevalent in the contributing drainage area, the forebay size may be increased to 25% of the WQV to accommodate additional sediment loading.
Wet Pond	Treatment volume	Tv			(1)	At least 25% of the WQV shall be provided in “deep water zones” with a depth equal to or greater than 4 feet, but not more than 8 feet. As required above, at least 10% of the WQV shall be provided in a sediment forebay or other pretreatment practice. The remaining 65% of the WQV shall be provided in some combination of shallow permanent pool with depth less than four feet
Treatment Wetland						A liner is required if underlying soils have an infiltration rate >0.05 inches per hour.
Treatment Wetland	MS4 BMP Definition Design Storage Volume (DSV)	DSV	DSV = Ponding water storage volume and void space volume of soil filter media. DSV = (Abed x Dponding)+ (Abed x Dsoil x nsoil)	cubic feet	(3)	Minimum length to width ratio of 2:1 (L:W)
Treatment Wetland	CF storage per SF BMP area	Dv	4	cf/sf		
Treatment Wetland	Max ponding depth (Dponding)	Dponding	4	feet	(1)	
Treatment Wetland	Pre-treatment volume	PTv				Forebay sized for 10% of WQv or other per section 4.1 of VSMM
Treatment Wetland	Treatment volume	Tv				- Minimum 35% of the WQV storage shall be at design depth of less than 6 inches. A minimum of 65% of the WQV storage shall be at design depth of less than 18 inches. - At least 25% of the WQV storage shall be provided in deep water zones at design depths greater than 4 feet. - The remaining WQV shall be provided through a combination of shallow permanent pool with depth less than 4 feet
Media Filter (infiltrating)						Sites with contributing area imperviousness greater than 75%, and sites with high sediment loading (such as aggressive use of traction sand for de-icing), may require more aggressive sedimentation pre-treatment techniques.
Media Filter	MS4 BMP Definition Design Storage Volume (DSV)	DSV	DSV = void space volumes of stone and sand layers. DSV = (A_{trench} x D_{stone} x n_{stone})+ (A_{trench} x D_{sand} x n_{sand})	cubic feet	(3)	
Media Filter	CF storage per SF BMP area	Dv	1.04	cf/sf		
Media Filter	Topsoil depth (Dtsoil)	Dtsoil	0.88	feet	(2)	Typical detail specified 50:50 native soil, but called "topsoil" for consistency with other BMP assumptions. Also, averged soil depth across parabolic layer, 9" at lowest point and 12" at highest depth along the sides of the parabola.
Media Filter	Sand depth (Dsand)	Dsand	2	feet	(2)	
Media Filter	Porosity of topsoil (ntsoil)	ntsoil	0.32		(12) - NY DEC porosity value	Reference (2) specified 50:50 native soil:sand, however used used bioretention soil porosity for estimation purposes due to high variability of native soil porosity
Media Filter	Porosity of sand	nsand	0.38		(9)	Porosity based on average for range of fine sand range from 0.29-0.46
Media Filter	Pre-treatment volume	PTv				

BMP Type	Design Element	Design Element Code	Design Criteria	Unit	Standard Reference	Notes
Media Filter	Treatment volume	Tv				A storage volume of at least 75% of the design TV, including the volume over the top of the filter media and the volume in the sediment forebay as well as within the filter media is required
Media Filter (w/ underdrain)						- Currently, this is the same calculation as infiltrative media filters. Sizing of underdrained facilities should be increased for those sites on poorly draining soils. - Sites with contributing area imperviousness greater than 75%, and sites with high sediment loading (such as aggressive use of traction sand for de-icing), may require more aggressive sedimentation pre-treatment techniques.
Media Filter (w/ underdrain)	MS4 BMP Definition Design Storage Volume (DSV)	DSV	DSV = Ponding water storage volume and void space volume of soil filter media. DSV = (Abed x Dponding)+ (A_{bed} x D_{soil} x n_{soil})	cubic feet	(3)	
Media Filter	CF storage per SF BMP area	Dv	1.04	cf/sf		
Media Filter	Topsoil depth (Dtsoil)	Dtsoil	0.88	feet	(2)	Typical detail specified 50:50 native soil, but called "topsoil" for consistency with other BMP assumptions. Also, averged soil depth across parabolic layer, 9" at lowest point and 12" at highest depth along the sides of the parabola.
Media Filter	Sand depth (Dsand)	Dsand	2	feet	(2)	
Media Filter	Porosity of topsoil (ntsoil)	ntsoil	0.32		(12) - NY DEC porosity value	Reference (2) specified 50:50 native soil:sand, however used used bioretention soil porosity for estimation purposes due to high variability of native soil porosity
Media Filter	Porosity of sand	nsand	0.38		(9)	Porosity based on average for range of fine sand range from 0.29-0.46
Media Filter	Pre-treatment volume	PTv				
Media Filter	Treatment volume	Tv				A storage volume of at least 75% of the design TV, including the volume over the top of the filter media and the volume in the sediment forebay as well as within the filter media is required

References

(1) 2017 Vermont Stormwater Management Manual Rule and Design Guidance. Vermont Agency of Natural Resources, July 2017.
(2) Allen Brook FRP Typical Details, Vtrans 2018
(3) Nov 2019 MS4 BMP Tracking Table
(4) https://www.utoledo.edu/nsm/lec/research/errl/pdfs/Memo_2.pdf
(5) https://www.stormtech.com/download_files/pdf/techsheet1.pdf
(6) https://www.sanjuanco.com/DocumentCenter/View/1609/Bio-Retention-Rain-Gardens-PDF
(7) Great streets manual http://greatstreetsbtv.com/ - Appendix A, reference detail SW-01B
(8) Assumed SC-740 Chambers
(9) https://www.geotechdata.info/parameter/soil-porosity.html
(10) https://www.wgpaver.com/wp-content/uploads/2012/05/PICP_Base_Construction1.pdf
(11)
(12) GI Exchange Modelling Memo

Appendix F: Road Erosion Inventory Implementation Table, Example for the Missisquoi River Drainage Area

Segment ID	SWAT Drain	MRGP Slope Class	Length (m)	Hydroconnect Class	Total Number of Swales and Culverts	Total Structures Not Meeting Standards	Date of Most Recent Culvert Inspection	Culvert Condition	Culvert Sediment	Culvert Erosion	Culvert Sink Hole	Culvert Road Settling	Swale Condition	Status	Priority
400	Missisquoi River	>10%	44	High	1	1	11/3/2016	Does Not Meet	Meets	Meets	Meets	Does Not Meet	N/A	Does Not Meet	Very High
1284	Missisquoi River	>10%	69	High	2	1	7/31/2019	Meets	Meets	Does Not Meet	Meets	Meets	Meets	Does Not Meet	Very High
1285	Missisquoi River	>10%	109	High	2	1	7/31/2019	Meets	Meets	Does Not Meet	Meets	Meets	Meets	Does Not Meet	Very High
1336	Missisquoi River	>10%	119	High	3	1	7/31/2019	Meets	Meets	Meets	Meets	Does Not Meet	N/A	Does Not Meet	Very High
2027	Missisquoi River	>10%	50	High	1	1	9/2/2019	Does Not Meet	Meets	Meets	Meets	Meets	N/A	Does Not Meet	Very High
2028	Missisquoi River	>10%	75	High	2	2	9/2/2019	Does Not Meet	Meets	Does Not Meet	Meets	Meets	Does Not Meet	Does Not Meet	Very High
19637	Missisquoi River	>10%	26	High	2	1	9/2/2019	Meets	Meets	Meets	Meets	Meets	Does Not Meet	Does Not Meet	Very High
19639	Missisquoi River	>10%	102	High	4	3	9/2/2019	Does Not Meet	Meets	Meets	Meets	Meets	Does Not Meet	Does Not Meet	Very High
19743	Missisquoi River	>10%	72	High	2	1	9/2/2019	Does Not Meet	Does Not Meet	Meets	Meets	Meets	N/A	Does Not Meet	Very High
30935	Missisquoi River	>10%	127	High	4	2	10/8/2018	Does Not Meet	Does Not Meet	Meets	Meets	Meets	Meets	Does Not Meet	Very High
32375	Missisquoi River	>10%	103	High	1	1	6/26/2018	Meets	Does Not Meet	Meets	Meets	Meets	N/A	Does Not Meet	Very High
32401	Missisquoi River	>10%	103	High	1	1	7/11/2018	Meets	Meets	Does Not Meet	Meets	Does Not Meet	N/A	Does Not Meet	Very High
32417	Missisquoi River	>10%	24	High	1	1	6/26/2018	Does Not Meet	Meets	Does Not Meet	Meets	Meets	N/A	Does Not Meet	Very High
32438	Missisquoi River	>10%	18	High	1	1		N/A	N/A	N/A	N/A	N/A	Does Not Meet	Does Not Meet	Very High
32443	Missisquoi River	>10%	61	High	1	1	10/29/2018	Does Not Meet	Meets	Meets	Meets	Meets	N/A	Does Not Meet	Very High
32505	Missisquoi River	>10%	61	High	1	1		N/A	N/A	N/A	N/A	N/A	Does Not Meet	Does Not Meet	Very High
32539	Missisquoi River	>10%	60	High	1	1	6/18/2018	Meets	Meets	Does Not Meet	Meets	Meets	N/A	Does Not Meet	Very High
32635	Missisquoi River	>10%	56	High	1	1	6/18/2018	Does Not Meet	Meets	Does Not Meet	Meets	Meets	N/A	Does Not Meet	Very High
33304	Missisquoi River	>10%	74	High	5	4	10/2/2019	Does Not Meet	Does Not Meet	Does Not Meet	Meets	Meets	Does Not Meet	Does Not Meet	Very High
33306	Missisquoi River	>10%	30	High	4	1	10/2/2019	Meets	Does Not Meet	Meets	Meets	Meets	N/A	Does Not Meet	Very High
33398	Missisquoi River	>10%	55	High	3	2	10/2/2013	Meets	Does Not Meet	Meets	Meets	Meets	Meets	Does Not Meet	Very High
33623	Missisquoi River	>10%	89	High	5	1	10/10/2019	Does Not Meet	Meets	Meets	Meets	Meets	Meets	Does Not Meet	Very High
36235	Missisquoi River	>10%	72	High	1	1	10/31/2016	Meets	Does Not Meet	Meets	Meets	Meets	N/A	Does Not Meet	Very High
36824	Missisquoi River	>10%	61	High	2	1	10/2/2019	Does Not Meet	Meets	Meets	Meets	Meets	N/A	Does Not Meet	Very High
37028	Missisquoi River	>10%	71	High	2	1	7/16/2013	Meets	Does Not Meet	Meets	Meets	Meets	Meets	Does Not Meet	Very High
37045	Missisquoi River	>10%	88	High	3	1	7/16/2013	Does Not Meet	Meets	Meets	Meets	Meets	N/A	Does Not Meet	Very High
37070	Missisquoi River	>10%	106	High	1	1	11/14/2016	Meets	Meets	Does Not Meet	Meets	Meets	N/A	Does Not Meet	Very High
37489	Missisquoi River	>10%	85	High	2	1	9/20/2017	Does Not Meet	Meets	Does Not Meet	Meets	Meets	Meets	Does Not Meet	Very High
38104	Missisquoi River	>10%	101	High	1	1	8/24/2016	Does Not Meet	Meets	Meets	Meets	Meets	N/A	Does Not Meet	Very High
513	Missisquoi River	8-10%	106	High	2	1		N/A	N/A	N/A	N/A	N/A	Does Not Meet	Does Not Meet	High
579	Missisquoi River	8-10%	65	High	2	1	10/25/2016	Meets	Does Not Meet	Meets	Meets	Meets	Meets	Does Not Meet	High
1423	Missisquoi River	8-10%	82	High	1	1	8/22/2016	Does Not Meet	Meets	Meets	Meets	Meets	N/A	Does Not Meet	High
1424	Missisquoi River	8-10%	109	High	3	2	4/16/2019	Does Not Meet	Does Not Meet	Meets	Meets	Meets	N/A	Does Not Meet	High
1425	Missisquoi River	8-10%	55	High	1	1	6/14/2015	Does Not Meet	Meets	Meets	Meets	Meets	N/A	Does Not Meet	High
19504	Missisquoi River	8-10%	53	High	2	1	9/8/2019	Meets	Meets	Meets	Meets	Meets	Does Not Meet	Does Not Meet	High
19534	Missisquoi River	8-10%	98	High	2	1	7/8/2013	Does Not Meet	Meets	Meets	Meets	Meets	N/A	Does Not Meet	High
19620	Missisquoi River	8-10%	28	High	2	2	9/4/2019	Does Not Meet	Meets	Meets	Meets	Meets	Does Not Meet	Does Not Meet	High
19635	Missisquoi River	8-10%	7	High	1	1		N/A	N/A	N/A	N/A	N/A	Does Not Meet	Does Not Meet	High
19636	Missisquoi River	8-10%	126	High	3	3	9/2/2019	Meets	Meets	Does Not Meet	Meets	Meets	Does Not Meet	Does Not Meet	High
19638	Missisquoi River	8-10%	104	High	3	2	9/2/2019	Meets	Meets	Meets	Meets	Meets	Does Not Meet	Does Not Meet	High
19648	Missisquoi River	8-10%	38	High	1	1	9/4/2019	Does Not Meet	Meets	Does Not Meet	Meets	Meets	N/A	Does Not Meet	High

Segment ID	SWAT Drain	MRGP Slope Class	Length (m)	Hydroconnect Class	Total Number of Swales and Culverts	Total Structures Not Meeting Standards	Date of Most Recent Culvert Inspection	Culvert Condition	Culvert Sediment	Culvert Erosion	Culvert Sink Hole	Culvert Road Settling	Swale Condition	Status	Priority
19649	Missisquoi River	8-10%	100	High	1	1	7/31/2013	Meets	Does Not Meet	Meets	Meets	Meets	N/A	Does Not Meet	High
19651	Missisquoi River	8-10%	10	High	3	1	7/31/2013	Does Not Meet	Meets	Meets	Meets	Meets	Meets	Does Not Meet	High
19656	Missisquoi River	8-10%	76	High	2	2		N/A	N/A	N/A	N/A	N/A	Does Not Meet	Does Not Meet	High
19703	Missisquoi River	8-10%	33	High	4	1	9/4/2019	Does Not Meet	Meets	Meets	Meets	Meets	Meets	Does Not Meet	High
19820	Missisquoi River	8-10%	85	High	4	1	11/4/2013	Meets	Meets	Meets	Meets	Meets	Does Not Meet	Does Not Meet	High
30943	Missisquoi River	8-10%	78	High	1	1		N/A	N/A	N/A	N/A	N/A	Does Not Meet	Does Not Meet	High
30945	Missisquoi River	8-10%	131	High	4	3	10/29/2018	Meets	Does Not Meet	Meets	Meets	Meets	Meets	Does Not Meet	High
30946	Missisquoi River	8-10%	3	High	1	1		N/A	N/A	N/A	N/A	N/A	Does Not Meet	Does Not Meet	High
30962	Missisquoi River	8-10%	49	High	2	2	10/29/2018	Does Not Meet	Meets	Does Not Meet	Meets	Meets	Does Not Meet	Does Not Meet	High
32341	Missisquoi River	8-10%	66	High	1	1		N/A	N/A	N/A	N/A	N/A	Does Not Meet	Does Not Meet	High
32398	Missisquoi River	8-10%	101	High	2	2	7/11/2018	Meets	Does Not Meet	Meets	Meets	Meets	N/A	Does Not Meet	High
32439	Missisquoi River	8-10%	76	High	2	1	9/26/2018	Meets	Meets	Meets	Meets	Meets	Does Not Meet	Does Not Meet	High
32463	Missisquoi River	8-10%	0	High	1	1		N/A	N/A	N/A	N/A	N/A	Does Not Meet	Does Not Meet	High
32584	Missisquoi River	8-10%	48	High	1	1	6/18/2018	Meets	Does Not Meet	Meets	Meets	Meets	N/A	Does Not Meet	High
32603	Missisquoi River	8-10%	102	High	3	3	6/25/2018	Meets	Does Not Meet	Does Not Meet	Meets	Meets	Does Not Meet	Does Not Meet	High
32616	Missisquoi River	8-10%	53	High	3	3	10/13/2013	Does Not Meet	Meets	Meets	Meets	Meets	Does Not Meet	Does Not Meet	High
32681	Missisquoi River	8-10%	69	High	3	3	9/2/2013	Does Not Meet	Meets	Does Not Meet	Meets	Meets	Does Not Meet	Does Not Meet	High
32860	Missisquoi River	8-10%	69	High	2	1	8/11/2013	Meets	Does Not Meet	Meets	Meets	Meets	Meets	Does Not Meet	High
32879	Missisquoi River	8-10%	89	High	2	1	12/1/2016	Does Not Meet	Meets	Meets	Meets	Meets	N/A	Does Not Meet	High
32899	Missisquoi River	8-10%	35	High	1	1	8/21/2013	Does Not Meet	Meets	Meets	Meets	Meets	N/A	Does Not Meet	High
32927	Missisquoi River	8-10%	46	High	3	2	6/20/2017	Does Not Meet	Meets	Meets	Meets	Meets	Meets	Does Not Meet	High
32938	Missisquoi River	8-10%	126	High	1	1	11/6/2016	Does Not Meet	Meets	Meets	Meets	Meets	N/A	Does Not Meet	High
32954	Missisquoi River	8-10%	103	High	1	1	10/2/2019	Does Not Meet	Does Not Meet	Meets	Meets	Meets	N/A	Does Not Meet	High
33123	Missisquoi River	8-10%	102	High	2	2	11/7/2016	Does Not Meet	Does Not Meet	Meets	Meets	Meets	Does Not Meet	Does Not Meet	High
33124	Missisquoi River	8-10%	12	High	1	1		N/A	N/A	N/A	N/A	N/A	Does Not Meet	Does Not Meet	High
33198	Missisquoi River	8-10%	81	High	1	1	11/7/2016	Does Not Meet	Meets	Does Not Meet	Meets	Meets	N/A	Does Not Meet	High
33350	Missisquoi River	8-10%	101	High	3	2	9/23/2019	Does Not Meet	Meets	Does Not Meet	Meets	Meets	Meets	Does Not Meet	High
33376	Missisquoi River	8-10%	108	High	2	1	6/11/2018	Meets	Does Not Meet	Meets	Meets	Meets	Meets	Does Not Meet	High
33407	Missisquoi River	8-10%	60	High	1	1	6/11/2018	Meets	Does Not Meet	Meets	Meets	Meets	N/A	Does Not Meet	High
33416	Missisquoi River	8-10%	67	High	1	1	6/11/2018	Does Not Meet	Meets	Meets	Meets	Meets	N/A	Does Not Meet	High
33579	Missisquoi River	8-10%	59	High	2	1		N/A	N/A	N/A	N/A	N/A	Does Not Meet	Does Not Meet	High
33588	Missisquoi River	8-10%	66	High	1	1		N/A	N/A	N/A	N/A	N/A	Does Not Meet	Does Not Meet	High
36055	Missisquoi River	8-10%	59	High	3	1	9/4/2013	Meets	Meets	Meets	Meets	Meets	Does Not Meet	Does Not Meet	High
36172	Missisquoi River	8-10%	78	High	2	1	6/11/2017	Meets	Meets	Does Not Meet	Meets	Meets	Meets	Does Not Meet	High
36858	Missisquoi River	8-10%	35	High	2	1	7/17/2013	Meets	Does Not Meet	Meets	Meets	Meets	Meets	Does Not Meet	High
37053	Missisquoi River	8-10%	101	High	3	2	11/9/2016	Does Not Meet	Meets	Does Not Meet	Meets	Meets	Meets	Does Not Meet	High
37233	Missisquoi River	8-10%	103	High	5	1	8/1/2016	Meets	Does Not Meet	Meets	Meets	Meets	Meets	Does Not Meet	High
37305	Missisquoi River	8-10%	103	High	2	1	9/13/2017	Does Not Meet	Meets	Meets	Meets	Meets	N/A	Does Not Meet	High
37324	Missisquoi River	8-10%	124	High	1	1	9/14/2017	Does Not Meet	Meets	Meets	Meets	Meets	N/A	Does Not Meet	High
37328	Missisquoi River	8-10%	97	High	1	1	9/14/2017	Does Not Meet	Meets	Meets	Meets	Meets	N/A	Does Not Meet	High
37371	Missisquoi River	8-10%	120	High	4	1	9/13/2017	Does Not Meet	Meets	Meets	Meets	Meets	Meets	Does Not Meet	High

Appendix G: ANR Standard Operating Procedure for Crediting Floodplain Reconnection Projects (DRAFT)

Crediting Stream Restoration for Phosphorus Reductions

February 4, 2020

VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION
WATERSHED
MANAGEMENT DIVISION
RIVERS PROGRAM

VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION
WATERSHED
MANAGEMENT DIVISION
STORMWATER PROGRAM

1

1

TMDL review

Wasteload Allocation

- Wastewater discharge
- Stormwater from developed lands
- Treated CSOs (Burlington Main facility)
- Agriculture production areas (farmsteads)

Load Allocation

- Forested land
- Agricultural land
- Stream channel instability/erosion

Phosphorus load from **BOTH** need to be reduced to meet the TMDL

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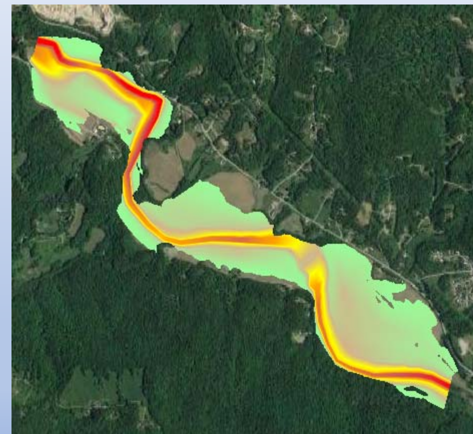
Crediting Stream Projects

- ~~Stream Bank Erosion~~ → Reductions included in the Load Allocation
- Floodplain Reconnection:

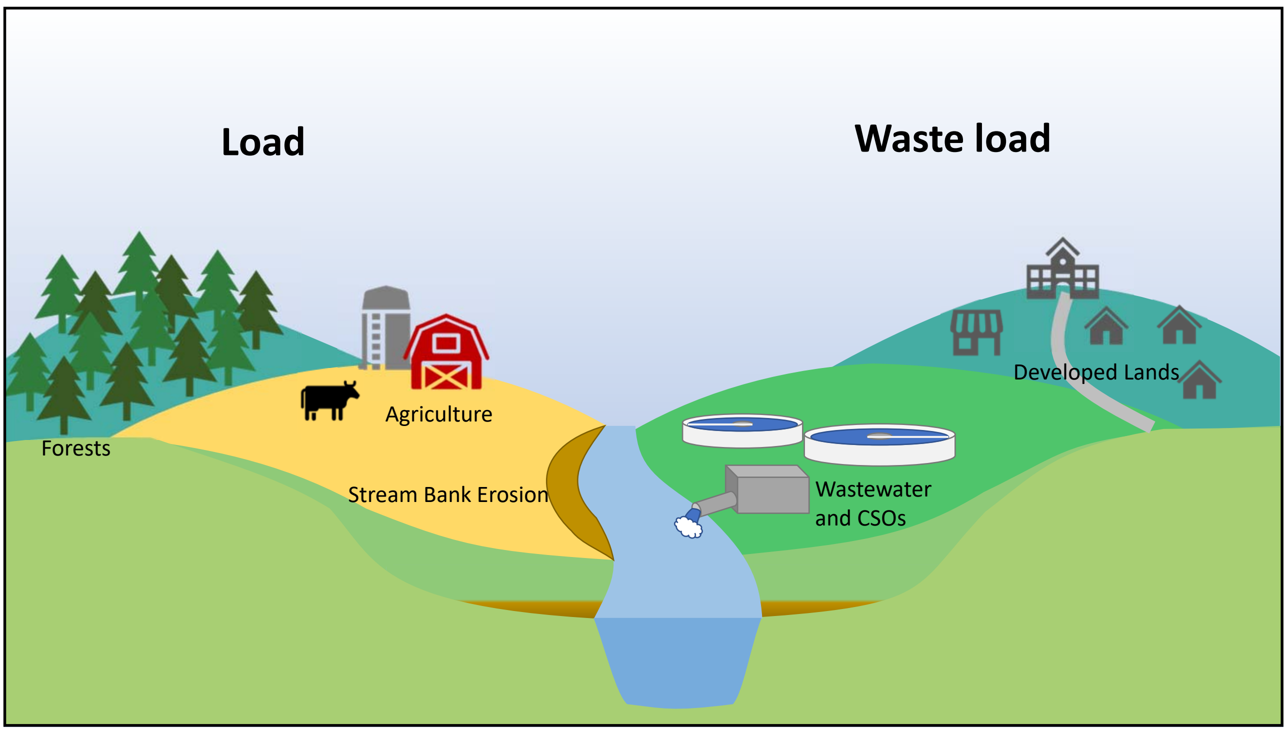
  Increase deposition and adsorption of phosphorus by increasing floodplain storage.



Stream power lbs/ft/s

3

3



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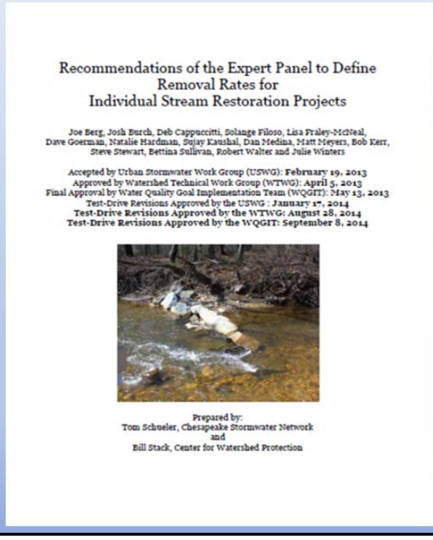
Proposed Method for Crediting Floodplain Reconnection

Expert panel formed to define removal rates for stream restoration


Recommendations of the Expert Panel to Define
Removal Rates for
Individual Stream Restoration Projects

Joe Berg, Josh Burch, Deb Cappuccitti, Solange Filoso, Lisa Fraley-McNeal,
Dave Goerman, Natalie Hardman, Sujay Kaushal, Dan Medina, Matt Meyers, Bob Kerr,
Steve Stewart, Bettina Sullivan, Robert Walter and Julie Winters

Accepted by Urban Stormwater Work Group (USWG): **February 19, 2013**
Approved by Watershed Technical Work Group (WTWG): **April 5, 2013**
Final Approval by Water Quality Goal Implementation Team (WQGIT): **May 13, 2013**
Test-Drive Revisions Approved by the USWG : **January 17, 2014**
Test-Drive Revisions Approved by the WTWG: August 28, 2014
Test-Drive Revisions Approved by the WQGIT: September 8, 2014

Prepared by:
Tom Schueler, Chesapeake Stormwater Network
and
Bill Stack, Center for Watershed Protection

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Credit for floodplain reconnection volume

- Calculate volume of runoff that accesses the floodplain on an annual basis before and after reconnection
- Estimate load of TP in reconnected volume by multiplying total pollutant load times the ratio of floodplain runoff to total runoff
- Compute percent of floodplain load that is removed by deposition

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6

$$TP_{removed} = (Q_{AfterReconnect} - Q_{BeforeRonnect}) \times TP_{export} \times TP_{efficiency}$$

$TP_{removed}$ = Phosphorus removed annually due to floodplain reconnection (kg/yr)

$Q_{AfterReconnect} = \frac{Annual\ peak\ flow\ volume\ that\ accesses\ floodplain\ \mathbf{after}\ reconnection}{Total\ annual\ peak\ flow\ volume}$ (dimensionless)

$Q_{BeforeReconnect} = \frac{Annual\ peak\ flow\ volume\ that\ accesses floodplain\ \mathbf{before}\ reconnection}{Total\ annual\ peak\ flow\ volume}$ (dimensionless)

TP_{export} = Annual TP export from one or more sources (kg/yr)

$TP_{efficiency}$ = TP removal efficiency for floodplain (dimensionless)

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Required data and sources

Inputs	Data source
Flow data	Streamstats
Topographic data	LiDAR
Estimate of surface roughness	Professional judgement/literature
Land cover	Existing GIS layers
Export Coefficients	TMDL Modeling
Floodplain efficiency	Default Chesapeake Bay value/best available data

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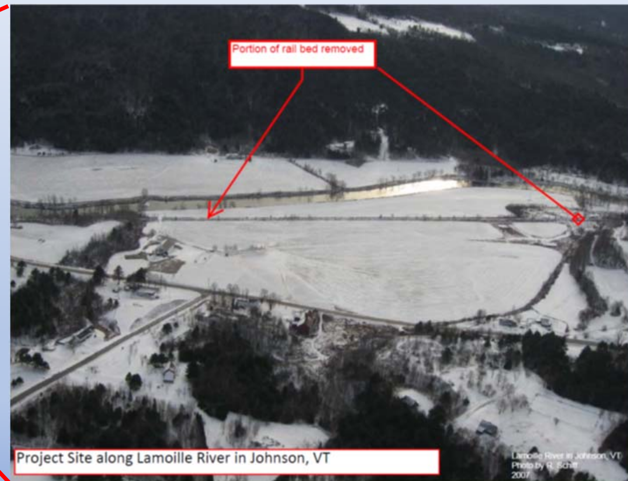
Site Location: Lamoille River, Johnson VT

~70 Acres



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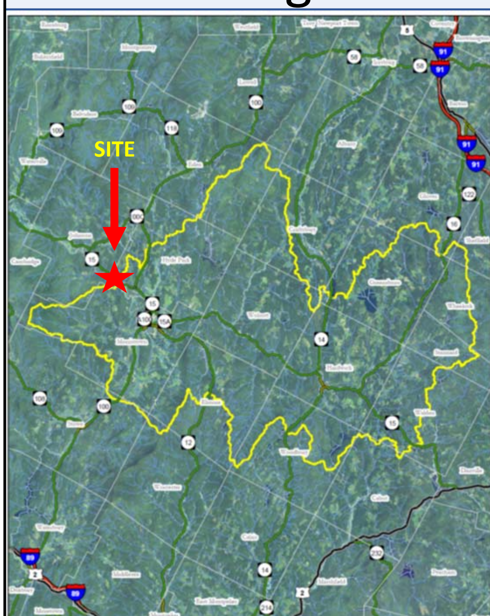
Contributing Watershed



- 190,474 Acres (298 mi^2)

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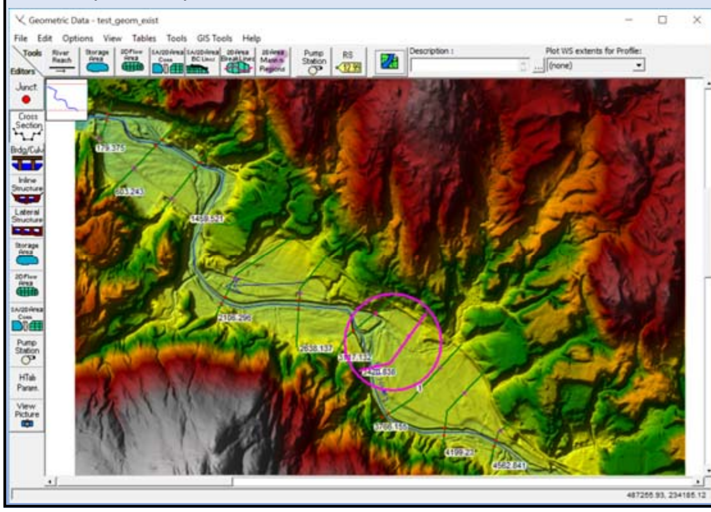
Modeling

Army Corps of Engineers Hydrologic Engineering Center's (HEC) River Analysis System (RAS)



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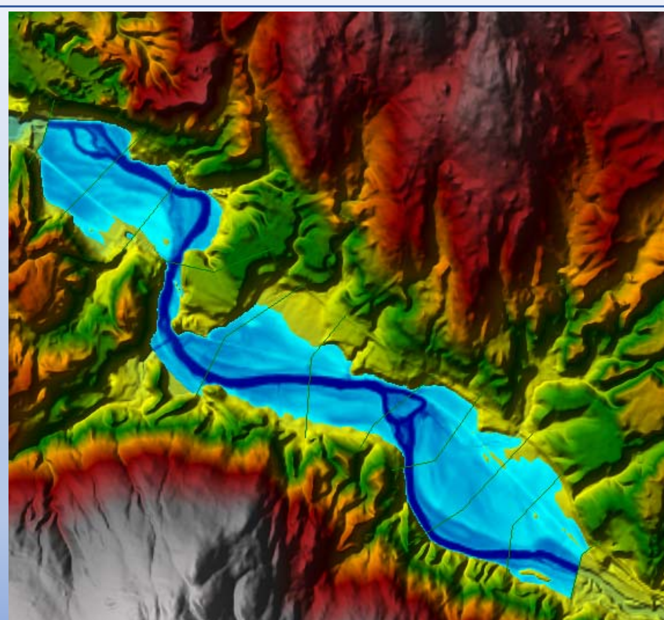
10-Year Flood - Proposed



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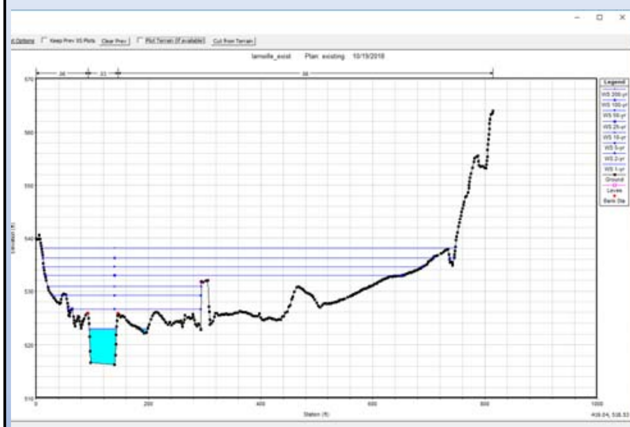
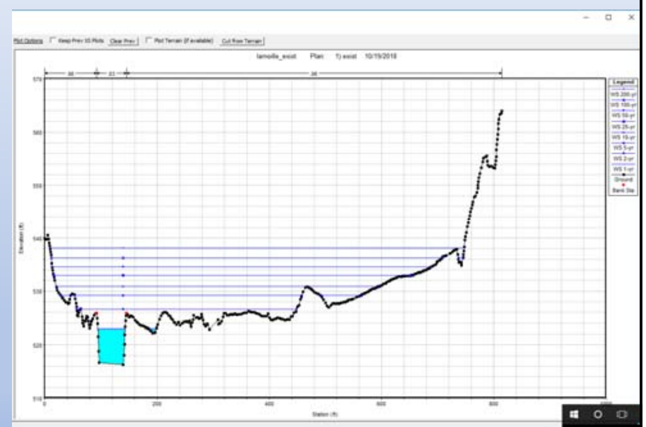
Hydrologic Data: Lamoille River

Existing Condition: Berm	Proposed Conditions: Berm Removed
~20-year storm accesses floodplain	2-year storm accesses floodplain





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Calculations

Credit Calculation				Existing Conditions				Proposed Conditions			
Return Period	Discharge (cfs)	Probability of Event	Integration of Discharge (cfs)	Total Runoff (Ac-ft)	Floodplain Runoff (Ac-ft)	Integration of Total Runoff (Ac-ft)	Integration of Floodplain Runoff (Ac-ft)	Total Runoff (Ac-ft)	Floodplain Runoff (Ac-ft)	Integration of Total Runoff (Ac-ft)	Integration of Floodplain Runoff (Ac-ft)
1	480	1		47	3.64			47.29	3.92		
2	1,240	0.5	430.00	90.45	27.68	34.36	7.83	94.63	32.34	35.48	9.07
5	1,860	0.2	465.00	137.94	61.49	34.26	13.38	153.16	77.85	37.17	16.53
10	2,340	0.1	210.00	172.62	87.32	15.53	7.44	197.08	113.56	17.51	9.57
25	3,050	0.04	161.70	241.66	147.07	12.43	7.03	256.89	163.69	13.62	8.32
50	3,630	0.02	66.80	298.92	197.25	5.41	3.44	306.67	205.88	5.64	3.70
100	4,260	0.01	39.45	361.62	251.94	3.30	2.25	363.12	253.82	3.35	2.30
200	5,910	0.005	25.43	426.76	306.51	1.97	1.40	428.52	308.78	1.98	1.41
			1,398			107.26	42.76			114.74	50.88

Existing conditions: % of annual flood flow that accesses the floodplain	39.87%
Proposed conditions: % of annual flood flow that accesses the floodplain	44.34%
Percent increase due to reconnection	4.47%
Floodplain Efficiency Data Source: Chesapeake Bay Protocol	30.00%
Reconnected floodplain efficiency	1.34%

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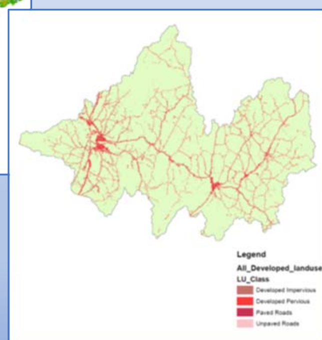
Contributing Load (kg/yr)

All Land Uses (SWAT Inputs)

Developed Lands

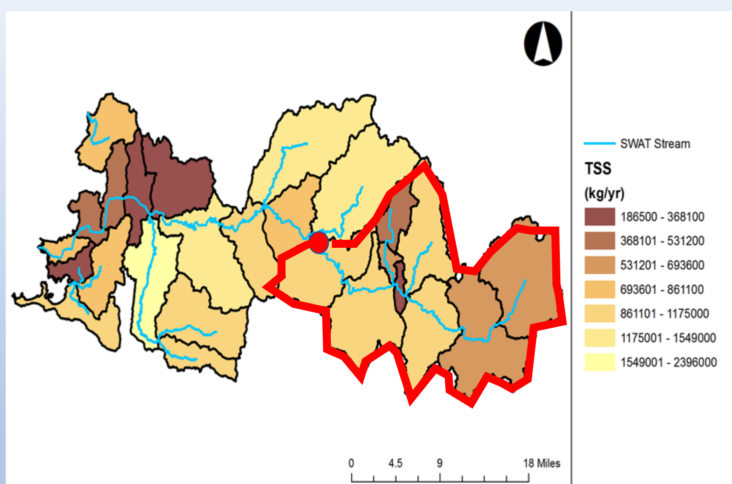


- Contributing areas from GIS
- Multiply by loading rates from TMDL to get load

15

15

Streambank Load (kg/yr)



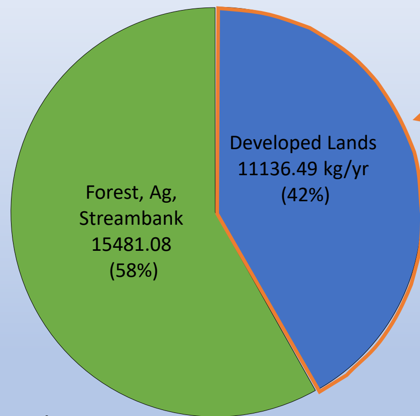
$$\frac{Stream\ km\ upstream\ of\ site\ location}{Total\ stream\ km}$$ * Total Stream Bank Loading = Stream Bank Load to Project

16

16

TP Loading (kg/yr)

Loading sources upstream of floodplain reconnection



Reductions to the developed load is creditable to the MS4

Total Load: 26,617.60 kg/yr

17

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Results (Total Project)

$$(Q_{AfterReconnect} - Q_{BeforeRonnect}) \times TP_{export} \times TP_{efficiency} = TP_{removed}$$

4.47% x 26,617 (kg/yr) x 30% = 357 kg/yr (total removed)

- % Increased annual flood volume: 4.47%
- Assumed Floodplain Efficiency: 30%
- Reconnected floodplain efficiency: 1.34%
- Total TP loading from upstream: 26,617 kgs/yr

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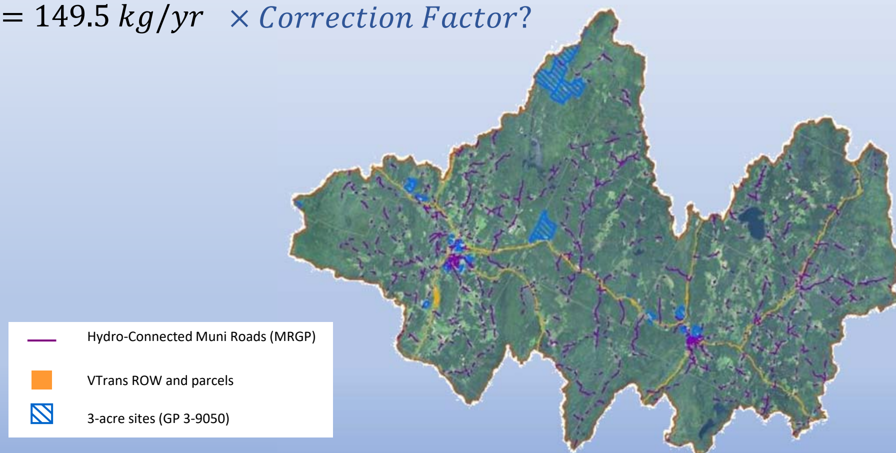
Results (Developed Lands)

$$Total\ P\ Reduction \times \frac{Developed\ Lands\ Load}{Total\ P\ Load} = Developed\ Lands\ Credit$$

$$357\ kg/yr \times 41.9\% = 149.5\ kg/yr \quad \times Correction\ Factor?$$



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Cost Comparison to Stormwater BMPs

Average Stormwater Treatment: $26,000-$95,000 per kg/yr TP

Average Road Erosion Remediation: $14,000 - $67,000 per kg/yr TP

source: 2019 Vermont Clean Water Performance Report, 25th – 75th Percentile

Average floodplain reconnection: $321/kg/yr TP

source: 2007/2008 Lamoille Valley floodplain reconnections

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Summary

- For a proposed floodplain reconnection site, the methodology quantifies how much of the annual TP load from upstream sources would be captured
    - The reductions can be attributed to specific sources
- Costs/benefits suggest relatively high return on investment (ROI)
    - Not just nutrient retention, also habitat, flood resilience
    - Additional tracking of BMP costs would help support comparisons
- Applicability to Wetlands?

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Appendix H: Non-Structural Controls Memo

STONE ENVIRONMENTAL

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MEMO

March 18, 2020

To: Emily Schelley, VT DEC
Jenn Callahan, VTrans

From: Polly Crocker, Amy Macrellis, Warren Rich, Stone Environmental Inc.

Stone Project No. 18-008-A
Subject: VTrans PCP Task 4 – Estimate Areas to be Treated with Non-Structural Practices

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The purpose of this memo is to summarize the baseline condition and potential phosphorus (P) reductions of non-structural controls implemented by the Vermont Agency of Transportation (VTrans) from 2010-2019 and recommend possible future enhancements to those activities with cost estimates for further P reduction for compliance with the Transportation Separate Storm Sewer System (TS4) permit[1]. The Stone Environmental (Stone) team leveraged the VTrans Maintenance Activity Tracking System (MATS) dataset to review maintenance records and quantify the two existing non-structural controls that reduce P: street sweeping and drop inlet (DI)/catch basin cleaning activities (note: for purpose of all PCP analysis DI and catch basins are synonymous and will be referred to as "DI").

P reductions for both DI cleaning and street sweeping were calculated using methodology provided by the Vermont Department of Environmental Conservation (DEC)[2]. VTrans will incorporate applicable findings from ongoing research by USGS[3], in cooperation with the Chittenden County Regional Planning Commission, DEC, the University of Vermont, and nine Vermont municipalities, to evaluate potential reductions in nutrient and sediment loads possible through current street cleaning practices, and possible enhancements to those activities.

Prior to 2010, these non-structural controls were not consistently implemented on a significant extent of roads within the Lake Champlain Basin (LCB) as part of VTrans' annual operations. Therefore, any street sweeping or DI cleaning included in the PCP can count toward the annual P reduction crediting. Upon initial review of the MATS data it was determined that data collected prior to 2015 was sporadic

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[1] https://dec.vermont.gov/watershed/stormwater/transportation-general-permit
[2] ANR. (2019) "Draft MS4 Annual Report for Calendar Year 2019" Dec 11, 2019. https://dec.vermont.gov/sites/dec/files/wsm/stormwater/docs/MS4/Draft%20Annual%20Report%20Workbook_11_2019.xlsx
[3] https://www.ccrpcvt.org/wp-content/uploads/2018/12/CleanStreetsSweepingStudy_Sept4_update.pdf

and unreliable, as maintenance crews were getting used to the new maintenance tracking system. Therefore, the general approach for each of the non-structural controls was to analyze data from 2015-2019 to create a baseline of non-structural BMP activities from which average annual P reductions and operational cost could be derived. The baseline, potential P reductions and recommendations for future implementation of each non-structural activity is outlined below.

1. DI Cleaning

VTrans elected to begin cleaning DIs with a vac truck in response to requirements within their Municipal Separate Storm Sewer System (MS4) permit. Therefore, a large portion of DI cleaning with a vac truck happened within VTrans' MS4 area (Figure 1). Additionally, most of the DI cleaning work is contracted out to a vendor with the specialized equipment required and is therefore somewhat limited in scale.

DI cleaning MATS data posed a unique challenge because there is currently no specific activity code for DI cleaning in the MATS database. The activity code "Stormwater Drainage Work" encompasses several activities, including DI cleaning. It was also discovered the DI cleaning can be broken into two categories: 1) clearing debris off the top of a DI so that water can flow into the structure (this activity typically indicates that material is merely being brushed aside and not hauled away) and 2) using a vac truck to vacuum out debris from a DI and hauling it away for disposal. It was determined that the latter DI cleaning would result in P reduction and therefore the data presented in this memo is for vac truck-assisted DI cleaning only.

It should be noted that the baseline estimates presented below may be conservative. Because there is not a specific activity code for DI cleaning, the only way to determine if the Stormwater Drainage Work MATS record was for DI cleaning was if the language included in the comments for that MATS record contained references to DIs. Therefore, blank comments and comments that didn't reference DIs may have been unnecessarily excluded. Refer to Appendix A: Processing Document - MATS Stormwater Drainage Work Baseline Data Analysis for the methods used to create the MATS baseline data set for estimating P reductions of DI Cleaning discussed below.

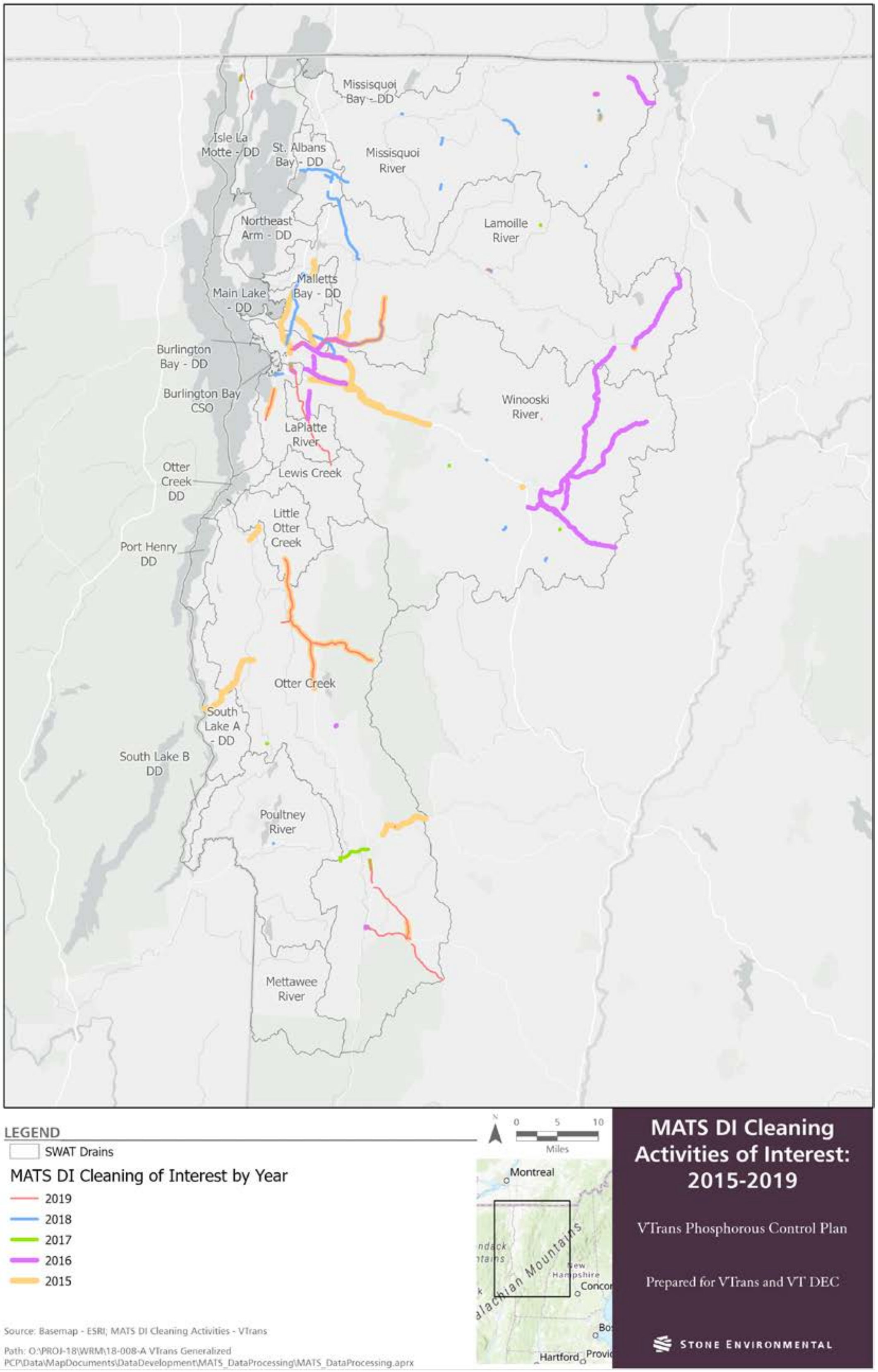

Figure 1. VTrans DI cleaning extent 2015-2019

1.1 DI Cleaning Baseline Analysis

DI Cleaning was analyzed by Soil and Water Assessment Tool (SWAT) drainage area (which is how P reductions will be credited) as well as VTrans District (which is how VTrans manages its maintenance activities). The total number of DIs cleaned per year was somewhat sporadic, ranging from 86 in 2017 to 469 in 2015. Discussions with VTrans staff brought to light that this is largely because of budgeting fluctuations. On average 376 of the 8038 DIs (or 5%) in the LCB area were cleaned each year with a vac truck. Proportional to the total number of DIs per SWAT drainage area, the Isle La Motte – Direct Drainage, LaPlatte River and Malletts Bay – Direct Drainage and Missisquoi River were the SWAT drainage areas with the highest percentage of DIs cleaned (Table 1).

During years with a healthy DI cleaning budget (2015, 2016, 2108, and 2019), annual totals ranged 330-469; whereas the year with a lack of DI cleaning budget (2017) was below 90 per year (Figure 2). Looking at only the volume of DIs cleaned, most DI cleaning occurred in the LaPlatte, Otter Creek and Winooski River SWAT drainage areas which translates to Districts three, five and eight (Table 2, Figure 3).

It should be noted that vac trucks often cross SWAT drainage area boundaries while cleaning DIs. Each MATS record is associated with the SWAT drainage area that represented the majority of cleaned DIs for that record. This results in less precise location data for cleaned DI totals but allows for seamless cost analysis because DI cleaning costs are associated with individual MATS records (see cost analysis below).

Table 1. Total cleaned DIs by SWAT drainage area

SWAT Drainage Area	2015	2016	2017	2018	2019	Grand Total	Average DIs Cleaned Annually	Total # of DIs per SWAT Drain	Average % of DIs Cleaned
Isle La Motte - DD	0	0	1	0	21	22	5	41	13%
Lamoille River	64	14	17	76	27	198	45	1129	4%
LaPlatte River	126	34	1	4	116	281	70	525	13%
Malletts Bay - DD	37	0	0	58	0	95	24	225	11%
Missisquoi River	48	7	0	97	2	154	39	554	7%
Northeast Arm - DD	0	0	0	0	21	21	5	161	3%
Otter Creek	57	8	65	1	108	239	43	1060	4%
Poultney River	0	0	0	2	0	2	1	519	<1%
South Lake A - DD	2	0	0	0	0	2	1	20	3%
St. Albans Bay - DD	0	0	0	37	0	37	9	212	4%
Winooski River	135	258	2	110	35	540	135	3365	4%
Grand Total	469	321	86	385	330	1591	376	8038	5%

Note: Averages are for years with healthy DI cleaning budgets (2015, 2016, 2018, 2019)

Table 2. Total cleaned DIs by district

District	2015	2016	2017	2018	2019	Grand Total	Average DIs Cleaned Annually
3	18	8	65	3	84	178	28
4	0	0	0	29	0	29	7
5	398	236	2	194	184	1014	253
7	5	70	1	1	7	84	21
8	0	0	18	129	55	202	46
9	48	7	0	29	0	84	21
Grand Total	469	321	86	385	330	1591	376

Note: Averages are for years with healthy DI cleaning budgets (2015, 2016, 2018, 2019)

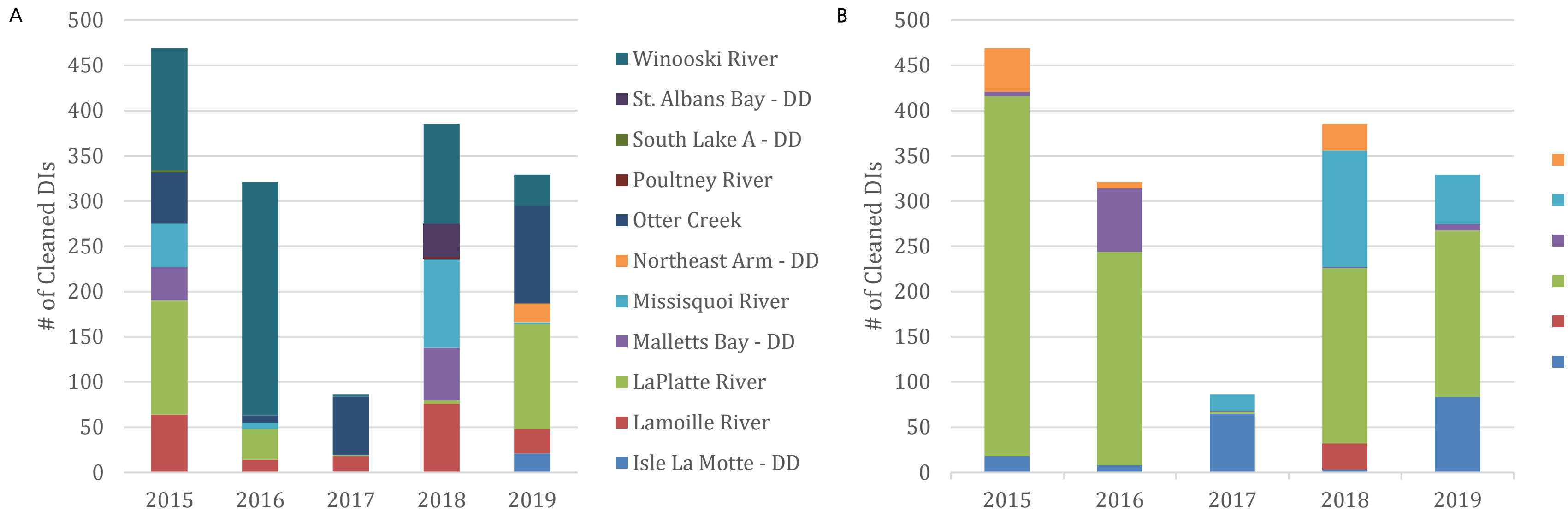

Figure 2. Annual DI cleaning by A) SWAT drainage area, and B) district

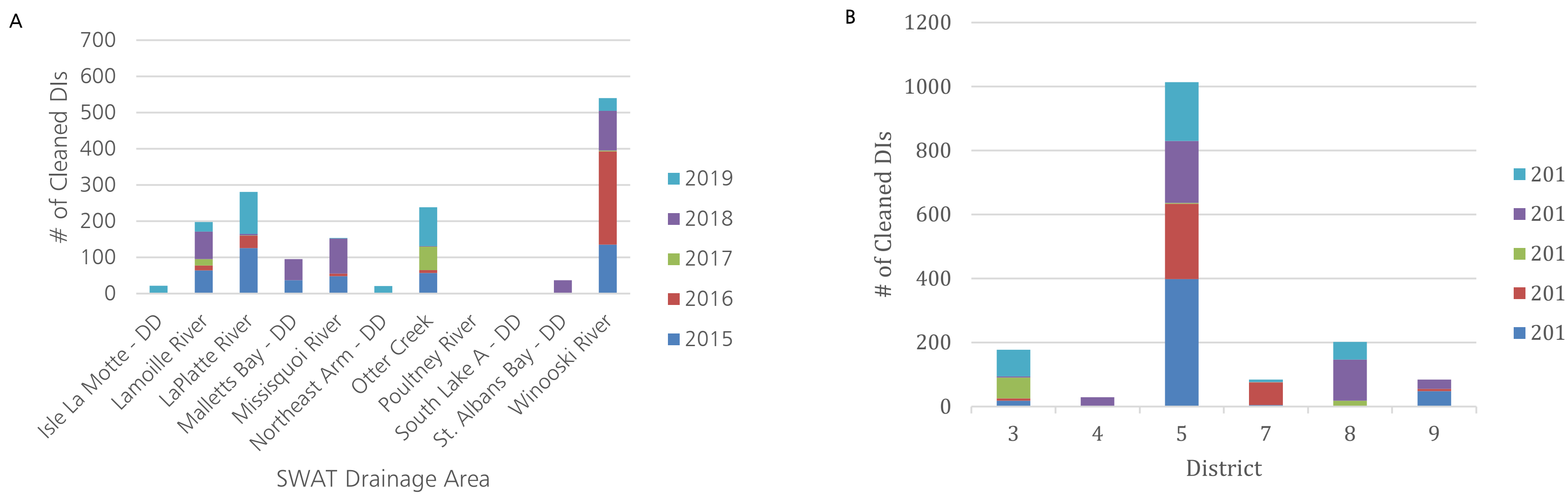

Figure 3. Total cleaned DIs by A) SWAT drainage area, and B) district

DIs are cleaned throughout the year, with a spike of activity later in the year that corresponds to the rainy season (Figure 4).

Figure 4. Total number of DIs cleaned per month 2015-2019

To inform recommendations for future non-structural controls, a cost analysis was conducted for DI cleaning activities from 2015-2019. Total annual costs ranged from $27,837-$86,687 per year, averaging $74,398 (Table 3). The average cost to clean a single DI varied widely between SWAT drainage areas ($81-$851) and was much more consistent across District boundaries ($167-$285). This would be expected due to the data phenomenon outlined above (vac trucks crossing SWAT drainage areas) and Districts sharing a similar contracting mechanism for vac truck work (re: low variability across jurisdictional boundaries). On average, the cost to clean a DI was $198 from 2015-2019 (Table 4).

Costs correlated with where the DI cleaning occurred, with the highest costs attributed to the LaPlatte, Otter Creek and Winooski River SWAT drainage areas, which again correspond to Districts three, five and eight (Figure 5, Figure 6).

Table 3. Annual DI cleaning costs by SWAT drainage area

SWAT Drainage Area	2015	2016	2017	2018	2019	Grand Total	Average Annual $	Average DIs Cleaned Annually	Average $ per DI
Isle La Motte - DD	$ -	$ -	$ 4,056	$ -	$ 1,711	$ 5,767	$ 428	5	$ 81
Lamoille River	$10,695	$ 276	$ 8,740	$19,501	$13,145	$ 52,358	$10,904	45	$ 241
LaPlatte River	$17,737	$ 6,679	$ 3,468	$ 2,766	$23,133	$ 53,782	$12,579	70	$ 180
Malletts Bay - DD	$ 5,893	$ -	$ -	$10,847	$ -	$ 16,739	$ 4,185	24	$ 176
Missisquoi River	$11,178	$ 1,093	$ -	$13,577	$ 2,613	$ 28,461	$ 7,115	39	$ 185
Northeast Arm - DD	$ -	$ -	$ -	$ -	$ 4,529	$ 4,529	$ 1,132	5	$ 216
Otter Creek	$11,293	$10,000	$ 6,968	$ 871	$17,011	$ 46,145	$ 9,794	43	$ 226
Poultney River	$ -	$ -	$ -	$ 386	$ -	$ 386	$ 97	1	$ 193
South Lake A - DD	$ 1,701	$ -	$ -	$ -	$ -	$ 1,701	$ 425	1	$ 851
St. Albans Bay - DD	$ -	$ -	$ -	$18,154	$ -	$ 18,154	$ 4,539	9	$ 491
Winooski River	$28,190	$41,908	$ 4,605	$18,076	$ 4,626	$ 97,406	$23,200	135	$ 172
Grand Total	$86,687	$59,956	$27,837	$84,179	$66,768	$ 325,428	$74,398	376	$ 198

Note: Averages are for years with healthy DI cleaning budgets (2015, 2016, 2018, 2019)

Table 4. Annual DI cleaning costs by District

District	2015	2016	2017	2018	2019	Grand Total	Average Annual $	Average DIs Cleaned Annually	Average $ per DI
3	$ 4,569	$10,000	$ 6,968	$ 1,258	$ 7,463	$ 30,258	$ 5,822	28	$ 207
4	$ -	$ -	$ -	$ 4,844	$ -	$ 4,844	$ 1,211	7	$ 167
5	$64,962	$39,573	$ 4,180	$37,330	$41,464	$ 187,508	$45,832	253	$ 181
7	$ 5,978	$ 9,290	$ 3,893	$ 2,205	$ 6,156	$ 27,522	$ 5,907	21	$ 285
8	$ -	$ -	$12,796	$36,199	$11,686	$ 60,681	$11,971	46	$ 260
9	$11,178	$ 1,093	$ -	$ 2,344	$ -	$ 14,615	$ 3,654	21	$ 174
Grand Total	$86,687	$59,956	$27,837	$84,179	$66,768	$ 325,428	$74,398	376	$ 198

Note: Averages are for years with healthy DI cleaning budgets (2015, 2016, 2018, 2019)

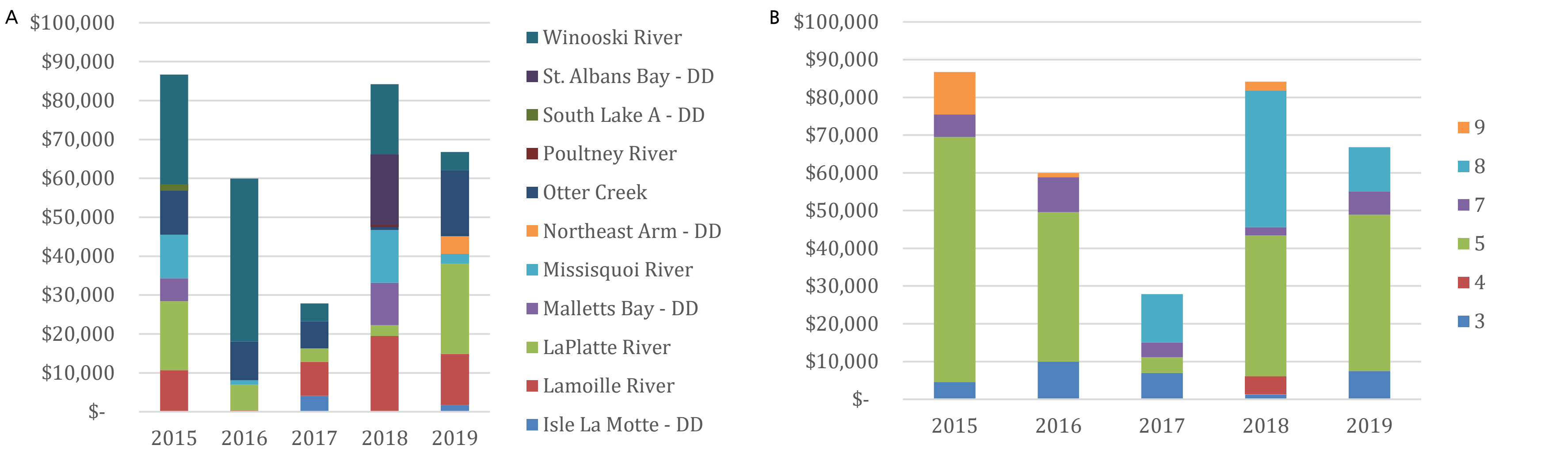

Figure 5. Annual DI cleaning costs by A) SWAT drainage area, and B) district

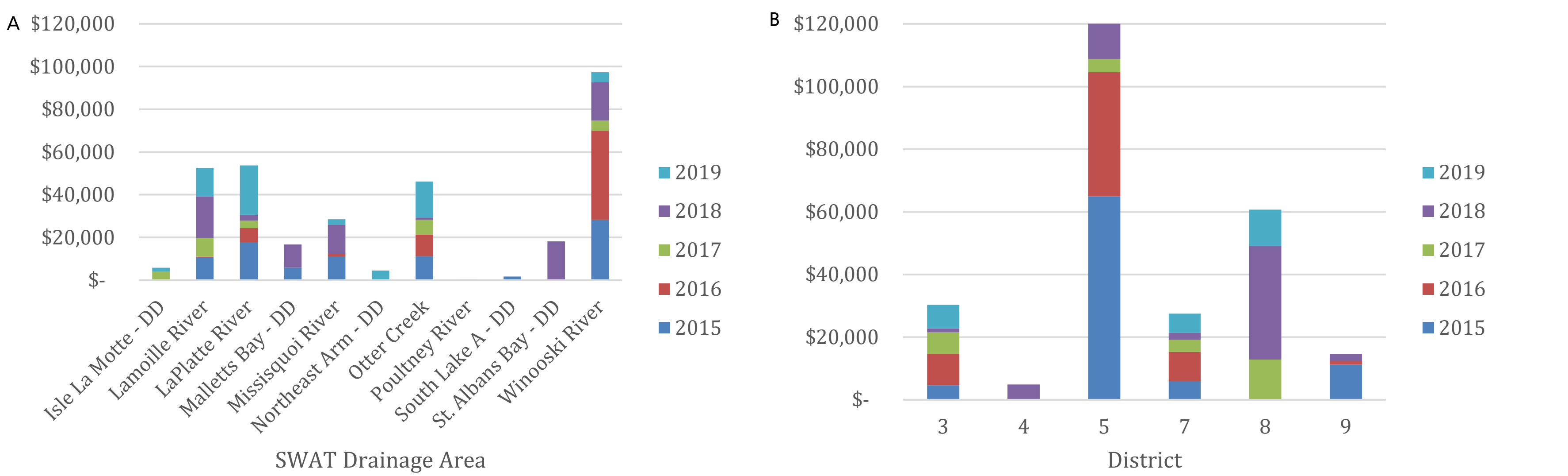

Figure 6. Total DI cleaning costs by A) SWAT drainage area, and B) district

1.2 DI Cleaning Baseline P Load Reduction Credits

The DEC provides two methods for P reduction calculation from DI cleaning:

1. *Area-based* – This method allocates a 2% reduction in P from the P load of streets where DI cleaning occurs (kg/yr).
2. *Volumetric-based* – Still under development, this method will most likely require a total P (TP) test be conducted on the material collected from cleaned DIs by vac truck so that the amount of P can be determined for the entire volume of material collected and then counted towards P load reduction[2].

Samples were not taken from the cleaned DI material from 2015-2019 and TP per volume cannot be determined. Therefore, Stone used the area-based methodology to determine P reductions from 2015-2019. To determine the P load from streets where DI cleaning occurred, the P load from each road segment associated with a DI cleaning MATS record was calculated using the road segment area, SWAT drainage area, slope, and hydrologic class of each road segment (Table 5, Table 6).

Because there are multiple road segments per MATS DI cleaning record and the linear nature of the activity, there were some instances where one MATS record included road segments from multiple SWAT drainage areas (as described above). Therefore, the P loads and associated reduction credits are distributed slightly differently across the SWAT drainage areas than the rest of the data analyzed in this memo (where all data associated with a MATS record as attributed to the single SWAT drainage area that made up the majority of road segments attributed to that MATS record). For example, the Little Otter Creek SWAT drainage area appears in the data analyzed below because there was one MATS record that was previously only associated with the Otter Creek SWAT drainage area, but when broken up into road segments to calculate P load it was discovered the DI cleaning crew also drove through and worked in the Little Otter Creek SWAT drainage area on that trip. Refer to Appendix A: Processing Document - MATS Stormwater Drainage Work Baseline Data Analysis for more detail.

Table 5. Acres of road where DI cleaning occurred by SWAT Drainage Area

SWAT Drainage Area	2015	2016	2017	2018	2019	Annual Average
Isle La Motte - DD	0.0	0.0	2.9	0.0	4.0	1.0
Lamoille River	62.2	44.0	2.1	60.9	40.7	52.0
LaPlatte River	20.2	8.7	1.6	5.4	64.9	24.8
Lewis Creek	0.0	0.0	0.0	0.0	2.0	0.5
Little Otter Creek	12.3	0.0	0.0	0.0	12.3	6.1
Malletts Bay - DD	47.2	6.0	0.0	44.3	6.0	25.8
Missisquoi River	3.2	24.7	0.0	21.9	1.7	12.9
Northeast Arm - DD	0.0	0.0	0.0	0.0	4.7	1.2
Otter Creek	155.9	1.9	18.5	0.4	191.3	87.4
Poultney River	0.0	0.0	1.0	0.7	0.0	0.2
South Lake A - DD	10.8	0.0	0.0	0.0	0.0	2.7
St. Albans Bay - DD	0.0	0.0	0.0	32.8	0.0	8.2
Winooski River	170.5	229.2	0.8	27.5	39.0	116.6
Grand Total	482.3	314.5	27.0	193.9	366.6	339.3

Note: Averages are for years with healthy DI cleaning budgets (2015, 2016, 2018, 2019)

Table 6. Annual P load from roads where DI cleaning occurs (kg/ac) by SWAT drainage area

SWAT Drainage Area	2015	2016	2017	2018	2019	Annual Average
Isle La Motte - DD	0.00	0.00	1.74	0.00	2.33	0.58
Lamoille River	51.01	66.03	2.02	47.53	34.87	49.86
LaPlatte River	15.64	5.94	1.11	4.42	48.94	18.74
Lewis Creek	0.00	0.00	0.00	0.00	1.74	0.43
Little Otter Creek	11.82	0.00	0.00	0.00	11.82	5.91
Malletts Bay - DD	31.60	4.53	0.00	29.55	4.53	17.55
Missisquoi River	2.36	18.94	0.00	23.25	1.40	11.48
Northeast Arm - DD	0.00	0.00	0.00	0.00	3.68	0.92
Otter Creek	139.46	1.43	25.48	0.39	175.50	79.20
Poultney River	0.00	0.00	1.05	0.58	0.00	0.15
South Lake A - DD	8.66	0.00	0.00	0.00	0.00	2.17
St. Albans Bay - DD	0.00	0.00	0.00	29.31	0.00	7.33
Winooski River	143.03	264.72	0.68	22.77	26.61	114.28
Grand Total	403.58	361.59	32.08	157.81	311.41	308.60

Note: Averages are for years with healthy DI cleaning budgets (2015, 2016, 2018, 2019)

Annual P load reductions ranged from 0.64 – 8.07 kg/yr with an average of 6.17 kg/yr, which translates to roughly 0.43% of the total required P reduction per year from VTrans roads within the LCB (Figure 7). P load reductions largely corresponded to where DI cleaning happened, although the distribution differed slightly due to the data manipulation discussion above, with the highest P reductions occurring within the Lamoille, Otter Creek and Winooski River SWAT drainage areas (Figure 8). Compared to the total P reduction target of each SWAT drainage area, current DI cleaning regimes account for a relatively small portion of annual P reduction, ranging from 0.003% - 1.43% (Table 7). Looking back at the cost data presented in Section 1.1, the unit cost for removing one kg/yr of P with DI cleaning is $12,054 (Table 8).

Table 7. Annual P load reduction (kg/yr) from DI cleaning activities by SWAT drainage area

SWAT Drainage Area	2015		2016		2017		2018		2019		Average Annual P Red (kg/yr)	Total Target P Red (kg/yr)	Average Annual Percent of Total P Red
	P Red (kg/yr)	Percent of Total P Red	P Red (kg/yr)	Percent of Total P Red	P Red (kg/yr)	Percent of Total P Red	P Red (kg/yr)	Percent of Total P Red	P Red (kg/yr)	Percent of Total P Red			
Isle La Motte - DD	0.00	-	0.00	-	0.03	1.14%	0.00	-	0.05	1.53%	0.01	5.63	0.21%
Lamoille River	1.02	0.72%	1.32	0.93%	0.04	0.03%	0.95	0.67%	0.70	0.49%	1.00	211.96	0.47%
LaPlatte River	0.31	1.29%	0.12	0.49%	0.02	0.09%	0.09	0.36%	0.98	4.03%	0.37	32.85	1.14%
Lewis Creek	0.00	-	0.00	-	0.00	-	0.00	-	0.03	0.73%	0.01	7.39	0.12%
Little Otter Creek	0.24	2.27%	0.00	-	0.00	-	0.00	-	0.24	2.27%	0.12	15.04	0.79%
Malletts Bay - DD	0.63	2.81%	0.09	0.40%	0.00	-	0.59	2.63%	0.09	0.40%	0.35	24.60	1.43%
Missisquoi River	0.05	0.02%	0.38	0.17%	0.00	-	0.46	0.21%	0.03	0.01%	0.23	327.48	0.07%
Northeast Arm - DD	0.00	-	0.00	-	0.00	-	0.00	-	0.07	0.78%	0.02	13.41	0.14%
Otter Creek	2.79	2.14%	0.03	0.02%	0.51	0.39%	0.01	0.01%	3.51	2.69%	1.58	196.27	0.81%
Poultney River	0.00	-	0.00	-	0.02	0.03%	0.01	0.02%	0.00	-	0.00	111.96	0.00%
South Lake A - DD	0.17	1.49%	0.00	-	0.00	-	0.00	-	0.00	-	0.04	16.19	0.27%
St. Albans Bay - DD	0.00	-	0.00	-	0.00	-	0.59	1.82%	0.00	-	0.15	47.21	0.31%
Winooski River	2.86	1.09%	5.29	2.01%	0.01	0.01%	0.46	0.17%	0.53	0.20%	2.29	423.05	0.54%
Grand Total	8.07	0.86%	7.23	0.77%	0.64	0.07%	3.16	0.33%	6.23	0.66%	6.17	1433.04	0.43%

Notes: - Red = reduction

- Total Target P Reduction is only for SWAT drainage areas which contained roads where DI cleaning occurred. The total target P reduction for all VTrans roads within the LCB is 1514 kg/yr.

- Averages are for years with healthy DI cleaning budgets (2015, 2016, 2018, 2019)

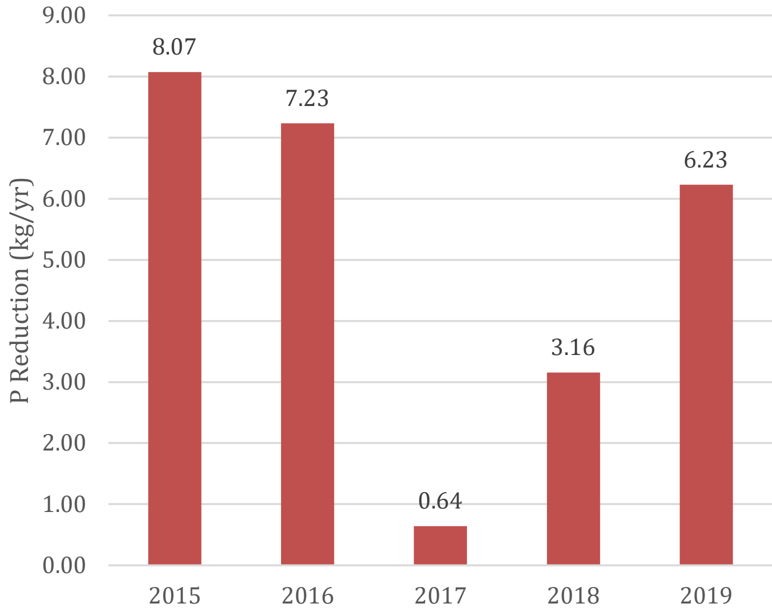

Figure 7. Total P reduction (kg/yr) from streets where DI cleaning occurred 2015-2019

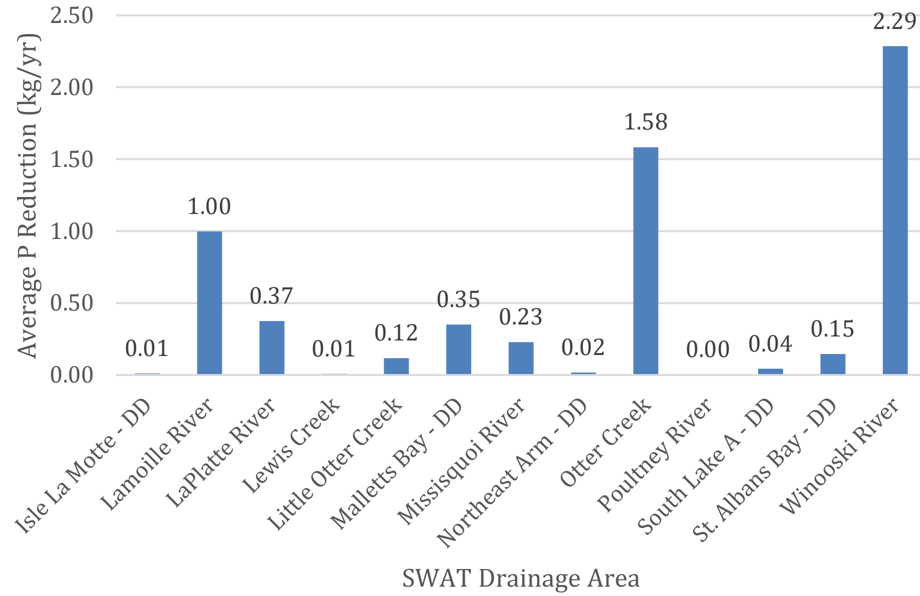

Figure 8. Average annual P reduction (kg/yr) from streets where DI cleaning occurred 2015-2019 by SWAT drainage area

Table 8. Average annual unit cost for removing one kg/yr of P with DI cleaning

	2015	2016	2017	2018	2019	Average
Total P Red (kg/yr)	8.07	7.23	0.64	3.16	6.23	6.17
Percent of Total VTrans P Reduction Target	0.5%	0.4%	0.04%	0.2%	0.4%	0.4%
Total Cost	$ 86,687	$ 59,956	$ 27,837	$ 84,179	$ 66,768	$ 74,398
P Red Unit Cost ($/kg/yr)	$10,740	$ 8,291	$43,381	$26,672	$10,720	$ 12,054

Note: - Average Annual Percent of Total VTrans P Reduction Target was calculated using the total target P reduction for all VTrans roads within the LCB (1514 kg/yr).
- Averages are for years with healthy DI cleaning budgets (2015, 2016, 2018, 2019)

1.3 Recommendations for Future DI Cleaning Non-Structural Controls

1.3.1 MATS Tracking Improvements

Better tracking will lead to more accurate calculations and potentially greater P reduction estimates; here are a few suggestions for better tracking of street DI cleaning in MATS:

1. Create an activity code for DI Cleaning with vac truck.
2. In order to use the more precise volumetric approach to account for P reductions, begin tracking the volume of material captured and removed per MATS record.
3. Inconsistencies in data entry were identified during this analysis and re-training staff at a regular interval (suggest bi-annually, or as updates to the system are made) may be beneficial to reduce errors.
4. Many DI cleaning MATS records used one MATS record for two different geographic locations. It would be ideal if a truck moves to a different area, a new MATS record be created so area-based P reductions can be calculated more accurately.
5. A field indicating whether or not a vacuum truck was used to clean DIs would be helpful in determining potential credit allocated to each MATS entry.
6. If possible, relating the MATS records to the VTrans Small Culvert Inventory asset would be helpful to provide better spatial context, as well as in tracking changes in DI conditions as a result of a MATS activity.

1.3.2 Extent & Frequency of DI Cleaning

It was determined that current DI cleaning regimes (5% of total DIs in the LCB cleaned per year) could annually reduce the total P required from VTrans roads within the LCB by 0.4% on average. Table 9 shows the incremental increase that would result from doubling ongoing DI cleaning efforts to clean 10% of all DIs in the LCB in a year.

Table 9. Example projections of increased DI cleaning, from 5% of Dis cleaned annually to 10%

	2015 - 2019 Annual Average	Example Projection
DIs cleaned	376	804
Percent of Total DIs in LCB	5%	10%
P Red (kg/yr)	6.17	13
P Red per Cleaned DI (kg/yr/DI)	0.02	0.02
Cost	$74,398	$159,152

Percent of Total VTrans P Red Target	0.4%	1%

DI cleaning presently has a relatively small impact on annual P reductions. As a routine maintenance practice, DI cleaning has additional benefits, including maintaining DI function and protecting downstream VTrans drainage infrastructure. Without increasing the number of DIs cleaned or the overall budget for DI cleaning, VTrans could see increased P reduction benefits from implementing an approach that prioritizes cleaning DIs along highly hydrologically connected road segments. DI sweeping could also be focused in Lake segments with the highest P reduction targets (Table 10).

Further analysis of where to focus DI cleaning efforts will be included in the development of each 4-year Implementation Plan. For example, if structural BMPs have been identified within a 4-year Implementation Plan and marginal P reductions are still required, focused DI cleaning within the planning area could close the P reduction gap. As discussed above, results from ongoing research by USGS and others[3] evaluating reductions in nutrient and sediment loads possible through DI cleaning and street cleaning practices, and evaluating P reductions and crediting for current practice and potential enhancements, will further influence decision making regarding VTrans' DI cleaning program once those findings are available in 2020.

Table 10. Comparison of DI cleaning metrics by SWAT drainage area

SWAT Drainage Area	Average DIs Cleaned Annually	Average Annual P Red (kg/yr)	Total Target P Red (kg/yr)	Average Annual Percent of Total P Red
Isle La Motte - DD	5	0.01	5.63	0.21%
Lamoille River	45	1.00	211.96	0.47%
LaPlatte River	70	0.37	32.85	1.14%
Lewis Creek	N/A	0.01	7.39	0.12%
Little Otter Creek	N/A	0.12	15.04	0.79%
Malletts Bay - DD	24	0.35	24.60	1.43%
Missisquoi River	39	0.23	327.48	0.07%
Northeast Arm - DD	5	0.02	13.41	0.14%
Otter Creek	43	1.58	196.27	0.81%
Poultney River	1	0.00	111.96	0.003%
South Lake A - DD	1	0.04	16.19	0.27%
St. Albans Bay - DD	9	0.15	47.21	0.31%
Winooski River	135	2.29	423.05	0.54%
Grand Total	376	6.17	1433.04	0.43%

Notes: - Red = reduction
- Total Target P Reduction is only for SWAT drainage areas which contained roads where DI cleaning occurred. The total target P reduction for all VTrans roads within the LCB is 1514 kg/yr.
- Averages are for years with healthy DI cleaning budgets (2015, 2016, 2018, 2019)
- Lewis Creek and Little Otter Creek do not have number of DIs cleaned because of the data phenomenon described in the above section that results from vac trucks driving across SWAT drainage areas.

1.3.3 DI Cleaning P Reduction Calculation Methodology

The area-based methodology for calculation P reductions from DI cleaning could be underestimating the actual P reductions from streets where DI cleaning. There are two particular instances where this could be happening:

1. when multiple DIs are located along a road segment, and
2. if a DI has been cleaned multiple times in one year.

In both cases, the prescribed 2% P reduction may underestimate the P load removed. Conducting a pilot study to test the volumetric-based methodology or partnering with other municipalities or agencies similarly exploring this methodology, would help determine if there are P reduction benefits that outweigh the expense of lab testing material collected from cleaned DIs.

2. Sweeping

VTrans elected to begin street sweeping with high-efficiency equipment on a limited basis within its MS4 areas in response to requirements within their MS4 permit in 2012. Now across the TS4, VTrans primarily uses mechanical broom sweepers for street sweeping as a regular maintenance practice, particularly along bike routes and for special events such as bike races where the road needs to be clear of debris for safety (Figure 9). A mechanical broom sweeper primarily pushes dirt and debris aside to clear the road, and often does not collect material to be removed. Therefore, current VTrans sweeping provides the least amount of P removal compared to other sweeping methods such as vacuum assisted and high efficiency regenerative air-vacuum sweeping. The analysis presented in this section sets a baseline for street sweeping which can inform future VTrans non-structural P reduction regimes in the Lake Champlain Basin.

The baseline sweeping values presented below are conservative estimates. A subset of MATS sweeping records (roughly 30%) were excluded from the analysis due to irregularities. Refer to Appendix B: Processing Document - MATS Sweeping Baseline Data Analysis for the methods used to create the MATS baseline data set for estimating P reductions of sweeping discussed below.

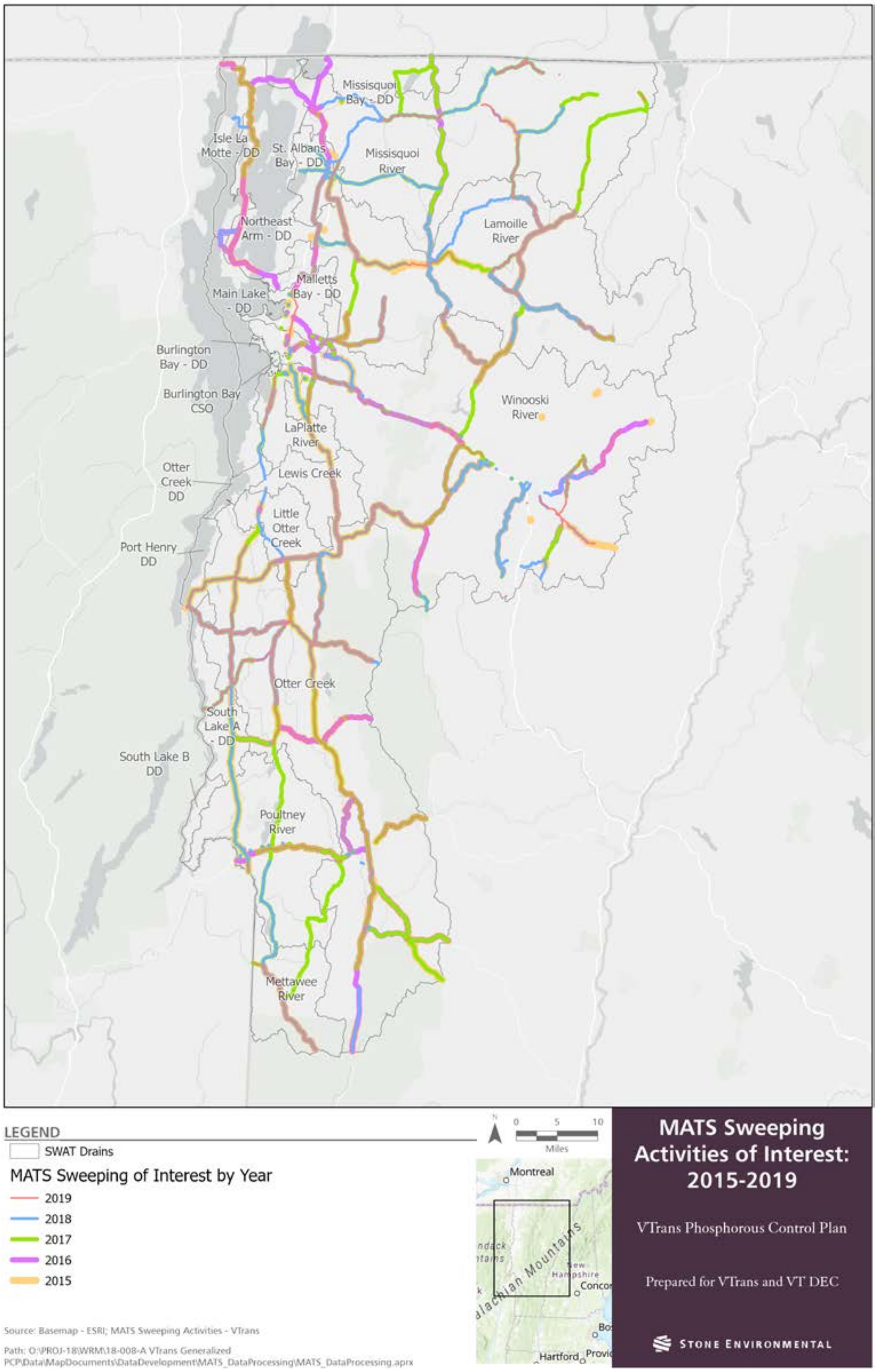

Figure 9. VTrans sweeping extent within the LCB, 2015-2019 (Note that there are overlapping areas of sweeping)

2.1 Sweeping Baseline Analysis

Sweeping was analyzed by SWAT drainage area (which is how P reductions will be credited) as well as VTrans District (which is how VTrans manages its maintenance activities). The total lane miles (Ln Mi) [4] swept per year ranged from 739 to 1430, with an average of 1055/year (Table 11, Table 12).

Table 11. Total lane miles swept by SWAT drainage area

SWAT Drainage Area	2015	2016	2017	2018	2019	Grand Total	Average Ln Mi Swept Annually
Isle La Motte - DD	0	0	0	6	0	6	1
Lamoille River	106	127	254	194	106	787	157
LaPlatte River	22	8	25	65	33	154	31
Lewis Creek	0.2	0	29	0	0	30	6
Little Otter Creek	32	28	6	59	21	146	29
Main Lake - DD	0.0	0	5	0	0	5	1
Malletts Bay - DD	2	18	4	2	0	26	5
Mettawee River	26	20	34	26	29	135	27
Missisquoi Bay - DD	0.2	0	14	0	0	14	3
Missisquoi River	5	96	175	94	63	433	87
Northeast Arm - DD	65	119	39	11	89	322	64
Otter Creek	265	258	422	236	273	1454	291
Port Henry - DD	0	0	0	27	0	27	5
Poultney River	31	29	94	33	21	209	42
South Lake A - DD	60	69	69	50	0	248	50
St. Albans Bay - DD	1	72	77	94	24	268	54
Winooski River	125	250	185	188	264	1012	202
Grand Total	739	1095	1430	1085	924	5274	1055

[4] A lane mile equals 12' by 1 mile, or one single lane of a roadway. It includes passing lanes, two lanes, truck lanes, etc.

Table 12. Total lane miles swept by District

District	2015	2016	2017	2018	2019	Grand Total	Average Ln Mi Swept Annually
1	36	44	35	45	29	188	38
3	203	200	336	104	175	1018	204
4	1	1	9	18	1	30	6
5	269	410	489	461	368	1995	399
7	23	36	30	53	63	204	41
8	208	405	465	404	287	1769	354
9	0	0	67	0	2	69	14
Grand Total	739	1095	1430	1085	924	5274	1055

The most sweeping occurred in Lamoille River, Otter Creek and Winooski SWAT drainage areas (the largest of the SWAT drainage areas with more roads for sweeping) which translates to Districts five and eight (Figure 11, Figure 12). Sweeping occurred most frequently in the spring and summer, which corresponds with when sweepers can get back out to clear debris post-snowmelt (Figure 10).

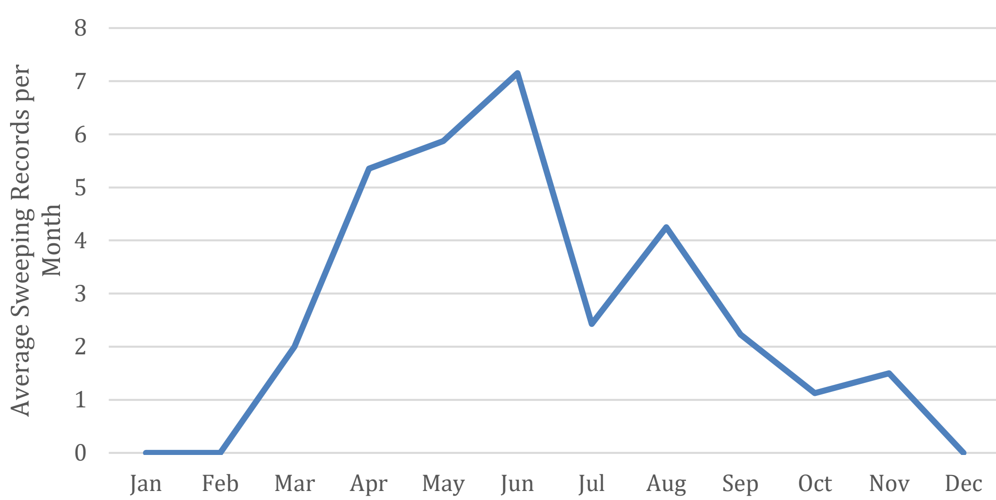

Figure 10. Average monthly frequency of sweeping.

From 2015-2019 an average of 38% (1055 Ln Mi) of the 2749 mi in the LCB were swept per year. However, these totals include re-sweeping the same stretches of road multiple times, as can easily be seen in Table 13 where the percent of LCB swept per SWAT drainage area exceeds 100%. It should also be noted that sweepers often cross SWAT drainage area boundaries while sweeping. Each MATS record is associated with the SWAT drainage area that represented the majority of swept lane miles for that record. This results in less precise location data for lane mile totals but allows for seamless cost analysis because sweeping costs are associated with individual MATS records.

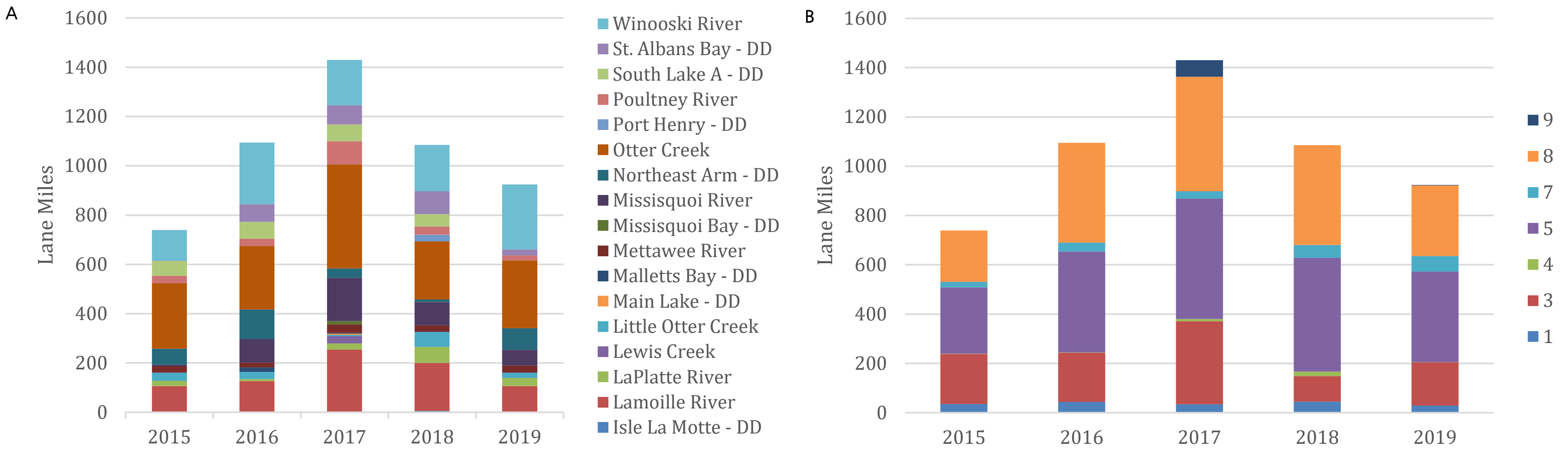

Figure 11. Annual sweeping by A) SWAT drainage area, and B) district

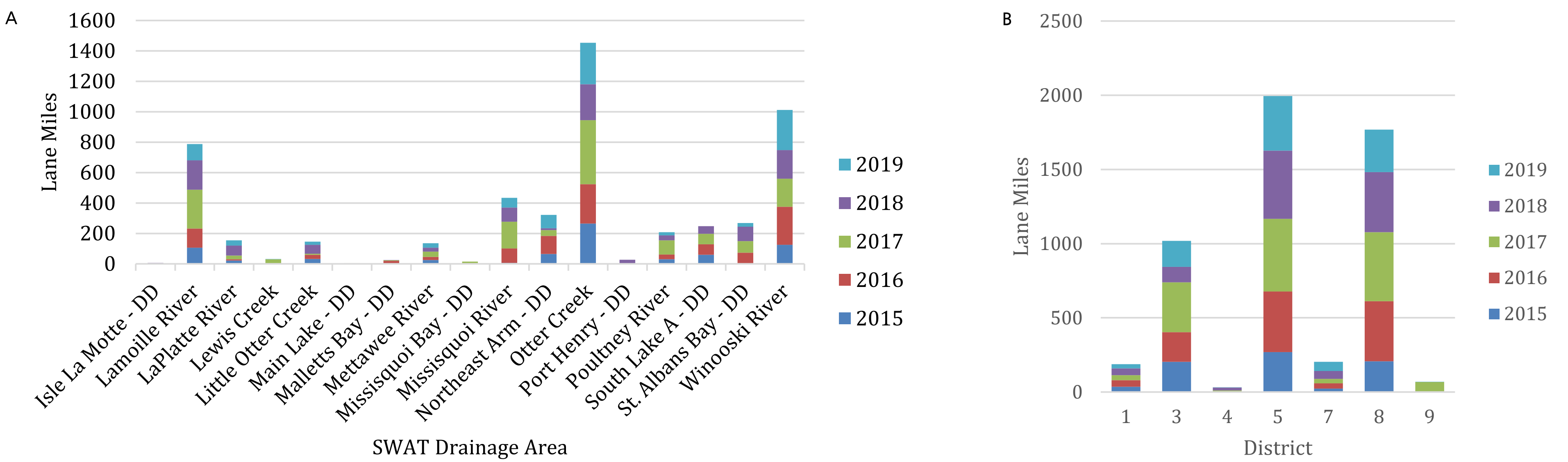

Figure 12. Total sweeping by A) SWAT drainage area, and B) district

Table 13. Annual lane miles swept by SWAT drainage area from 2015-2019

SWAT Drainage Area	2015		2016		2017		2018		2019				
	Sweeping (Ln Mi)	% LCB Swept	Sweeping (Ln Mi)	% LCB Swept	Sweeping (Ln Mi)	% LCB Swept	Sweeping (Ln Mi)	% LCB Swept	Sweeping (Ln Mi)	% LCB Swept	Average Annual Sweeping (Ln Mi)	Total Ln Mi in LCB	% LCB Swept on Average
Isle La Motte - DD	0	-	0	-	0	-	6	26%	0	-6%	1	25	5%
Lamoille River	106	26%	127	31%	254	62%	194	47%	106	26%	157	412	38%
LaPlatte River	22	33%	8	13%	25	37%	65	98%	33	50%	31	67	46%
Lewis Creek	0.2	1%	0	-	29	160%	0	-	0.1	1%	6	18	32%
Little Otter Creek	32	102%	28	90%	6	18%	59	189%	21	66%	29	31	93%
Main Lake - DD	0	-	0	-	5	59%	0	-	0	-	1	8	12%
Malletts Bay - DD	2	3%	18	27%	4	6%	2	3%	0	-	5	66	8%
Mettawee River	26	45%	20	35%	34	60%	26	46%	29	52%	27	57	48%
Missisquoi Bay - DD	0	-	0	-	14	23%	0	-	0	-	3	59	5%
Missisquoi River	5	3%	96	49%	175	89%	94	48%	63	32%	87	196	44%
Northeast Arm - DD	65	94%	119	173%	39	56%	11	16%	89	129%	64	69	93%
Otter Creek	265	53%	258	51%	422	84%	236	47%	273	54%	291	502	58%
Port Henry - DD	0	-	0	-	0	-	27	317%	0	-	5	8	63%
Poultney River	31	18%	29	17%	94	53%	33	19%	21	12%	42	176	24%
South Lake A - DD	60	147%	69	168%	69	169%	50	123%	0	-	50	41	121%
St. Albans Bay - DD	1	1%	72	88%	77	95%	94	115%	24	30%	54	82	66%
Winooski River	125	17%	250	34%	185	25%	188	26%	264	36%	202	732	28%
Grand Total	739	27%	1095	40%	1430	52%	1085	39%	924	34%	1055	2749	38%

To inform recommendations for future sweeping activities, a cost analysis was conducted for sweeping from 2015-2019. Total annual costs ranged from $174,631 to $414,991 per year, averaging $279,218 (Table 14). The average annual cost to sweep varied widely between districts, from $3,157 to $172,361, with an average of $39,888 (Table 15). This variability is likely attributed to different districts having varying equipment (rent vs. own) and the data phenomenon discussed above (sweepers crossing SWAT drainage areas, but MATS record data only being associated with one SWAT drainage area). On average, it cost $265 to sweep one lane mile from 2015-2019.

As would be expected, costs correlated with where sweeping occurred, with the highest costs attributed to the Lamoille River, Otter Creek, and Winooski River SWAT drainage areas, which again correspond to Districts five and eight (Figure 13, Figure 14).

Table 14. Annual sweeping costs by SWAT drainage area

SWAT Drainage Area	2015	2016	2017	2018	2019	Grand Total	Average Annual $	Average Ln Mi Swept Annually	Average $ per Ln Mi
Isle La Motte - DD	$ -	$ -	$ -	$ 567	$ -	$ 567	$ 113	1	$ 90
Lamoille River	$ 21,615	$ 21,022	$ 39,799	$ 30,791	$ 9,963	$ 123,190	$ 24,638	157	$ 156
LaPlatte River	$ 14,254	$ 9,192	$ 43,641	$ 28,418	$ 14,025	$ 109,530	$ 21,906	31	$ 711
Lewis Creek	$ 614	$ -	$ 6,125	$ -	$ 2,265	$ 9,005	$ 1,801	6	$ 303
Little Otter Creek	$ 3,018	$ 10,902	$ 5,568	$ 5,553	$ 12,455	$ 37,497	$ 7,499	29	$ 257
Main Lake - DD	$ -	$ -	$ 2,272	$ -	$ -	$ 2,272	$ 454	1	$ 505
Malletts Bay - DD	$ 10,757	$ 11,689	$ 27,545	$ 13,490	$ -	$ 63,480	$ 12,696	5	$ 2,475
Mettawee River	$ 1,761	$ 2,194	$ 3,323	$ 1,022	$ 2,556	$ 10,856	$ 2,171	27	$ 80
Missisquoi Bay - DD	$ 561	$ -	$ 406	$ -	$ -	$ 967	$ 193	3	$ 69
Missisquoi River	$ 41,786	$ 8,830	$ 10,902	$ 8,114	$ 20,624	$ 90,256	$ 18,051	87	$ 208
Northeast Arm - DD	$ 3,859	$ 4,451	$ 2,215	$ 567	$ 4,685	$ 15,776	$ 3,155	64	$ 49
Otter Creek	$ 37,751	$ 55,803	$ 80,606	$ 49,798	$ 27,608	$ 251,567	$ 50,313	291	$ 173
Port Henry - DD	$ -	$ -	$ -	$ 856	$ -	$ 856	$ 171	5	$ 32
Poultney River	$ 10,493	$ 20,250	$ 29,813	$ 31,592	$ 11,122	$ 103,269	$ 20,654	42	$ 495
South Lake A - DD	$ 1,856	$ 4,628	$ 2,706	$ 2,318	$ -	$ 11,508	$ 2,302	50	$ 46
St. Albans Bay - DD	$ 10,864	$ 3,308	$ 4,004	$ 3,611	$ 1,966	$ 23,752	$ 4,750	54	$ 89
Winooski River	$ 74,026	$ 58,504	$ 156,067	$ 185,781	$ 67,362	$ 541,741	$108,348	202	$ 535
Grand Total	$ 233,215	$ 210,775	$ 414,991	$ 362,477	$ 174,631	$ 1,396,089	$279,218	1055	$ 265

Table 15. Annual sweeping costs by District

District	2015	2016	2017	2018	2019	Grand Total	Average Annual $	Average Ln Mi Swept Annually	Average $ per Ln Mi
1	$ 2,736	$ 4,389	$ 4,059	$ 2,045	$ 2,556	$ 15,784	$ 3,157	38	$ 84
3	$ 33,026	$ 50,666	$ 78,737	$ 64,872	$ 23,249	$ 250,550	$ 50,110	204	$ 246
4	$ 2,249	$ 1,371	$ 3,784	$ 6,184	$ 4,482	$ 18,071	$ 3,614	6	$ 600
5	$ 100,164	$ 120,655	$ 288,319	$ 255,105	$ 97,562	$ 861,806	$172,361	399	$ 432
7	$ 14,453	$ 12,287	$ 9,973	$ 14,197	$ 8,436	$ 59,347	$ 11,869	41	$ 290
8	$ 80,586	$ 21,408	$ 26,193	$ 20,074	$ 23,938	$ 172,198	$ 34,440	354	$ 97
9	$ -	$ -	$ 3,926	$ -	$ 14,408	$ 18,334	$ 3,667	14	$ 264
Grand Total	$ 233,215	$ 210,775	$ 414,991	$ 362,477	$ 174,631	$ 1,396,089	$279,218	1055	$ 265

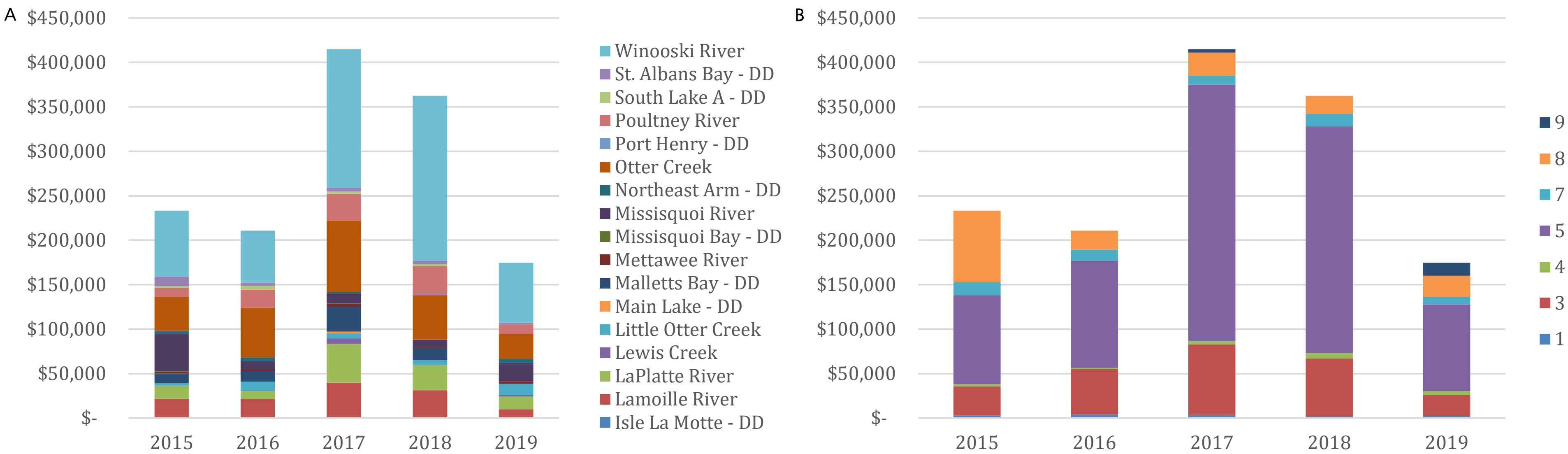

Figure 13. Annual sweeping costs by A) SWAT drainage area, and B) district

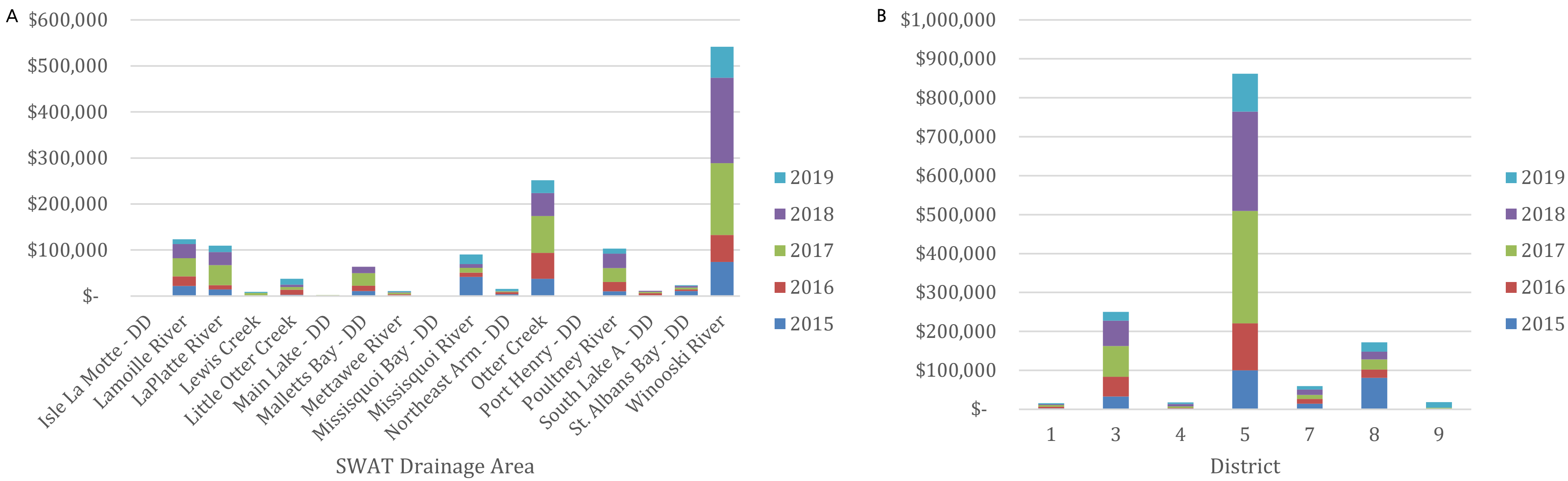

Figure 14. Total sweeping costs by a) SWAT drainage area, and B) district

2.2 Sweeping Baseline P Load Reduction Credits

The DEC credits sweeping based on frequency and type of sweeping equipment used (Table 16). As mentioned previously in Section 2.1, VTrans did sweep some sections of road more than once so a spatial analysis was conducted to determine which appropriate potential P reduction credits could be applied. Preliminary results indicated that very few road segments were swept more than twice and those that were swept more than twice were with not enough regularity to gain larger P reduction credits (re: monthly or weekly). Therefore, road segments that were swept once per year were allocated a 0.5% P reduction and road segments that were visited more than once were allocated a 1% P reduction.

Table 16. P reduction factors[5]

	Sweeping Frequency			
Equipment Type	2/year (spring and fall)	Monthly	Weekly	4X in the fall
Mechanical Broom	1%	3%	5%	17%
Vacuum Assisted	2%	4%	8%	17%
High Efficiency Regenerative Air-Vacuum	2%	8%	10%	17%

To determine the P load from streets where sweeping occurred, the P load from each road segment associated with a sweeping MATS record was calculated using the road segment area, SWAT drainage area, slope, and hydrologic class of each road segment (Table 17, Table 18). Because there are multiple road segments per MATS sweeping record and the linear nature of the activity, there were some instances where one MATS record included road segments from multiple SWAT drainage areas. Therefore, the P load reduction credits are distributed slightly differently across the SWAT drainage areas than the rest of the data analyzed in this memo (where all data associated with a MATS record as attributed to the single SWAT drainage area that made up the majority of road segments attributed to that MATS record). For example, the Otter Creek - DD SWAT drainage area appears in the data analyzed below because there was one MATS record that was previously only associated with the LaPlatte River SWAT drainage area, but when broken up into road segments to calculate P load it was discovered the sweeping crew also drove through and worked in the Otter

[5] MS4 Operational Tracking and Accounting Interim SOP (https://dec.vermont.gov/sites/dec/files/wsm/stormwater/docs/MS4/MS4%20Operational%20Tracking%20and%20Accounting%20SOPs_excerpt_08062019.pdf)

Creek - DD SWAT drainage area on that trip. Refer to Appendix B: Processing Document - MATS Sweeping Baseline Data Analysis for more detail.

Table 17. Acres of road where sweeping occurred by SWAT Drainage Area

SWAT Drainage Area	2015 Acres Swept			2016 Acres Swept			2017 Acres Swept			2018 Acres Swept			2019 Acres Swept			Average Annual Acres Swept
	Once	> Once	Total	Once	> Once	Total	Once	> Once	Total	Once	> Once	Total	Once	> Once	Total	
Isle La Motte - DD	31.4	0.0	31.4	6.7	31.4	38.1	16.1	0.0	16.1	15.2	0.0	15.2	30.3	1.2	31.4	26.4
Lamoille River	201.9	6.9	208.8	299.7	65.0	364.6	441.6	25.1	466.7	389.8	19.3	409.2	312.0	13.7	325.7	355.0
LaPlatte River	54.9	5.9	60.8	8.7	16.5	25.2	55.4	44.4	99.8	62.4	23.1	85.5	44.5	47.6	92.1	72.7
Lewis Creek	25.3	0.8	26.1	23.6	0.0	23.6	23.5	2.3	25.8	28.5	0.0	28.5	24.0	0.0	24.0	25.6
Little Otter Creek	32.8	6.7	39.5	33.6	1.5	35.1	27.3	3.4	30.7	39.5	21.2	60.7	28.0	11.2	39.2	41.0
Main Lake - DD	0.0	0.0	0.0	4.7	0.0	4.7	10.2	0.0	10.2	19.2	0.0	19.2	1.6	0.0	1.6	7.1
Malletts Bay - DD	6.7	0.0	6.7	34.8	14.4	49.2	14.9	1.5	16.4	12.0	0.0	12.0	37.1	0.0	37.1	24.3
Mettawee River	51.2	0.0	51.2	51.2	0.0	51.2	83.5	6.6	90.1	59.5	0.0	59.5	57.1	0.4	57.5	61.9
Missisquoi Bay - DD	0.5	0.0	0.5	27.6	12.0	39.5	38.4	0.0	38.4	6.7	0.0	6.7	0.0	0.0	0.0	17.0
Missisquoi River	9.5	7.2	16.6	56.6	60.5	117.1	375.0	14.2	389.3	275.1	38.2	313.2	75.2	55.6	130.8	193.4
Northeast Arm - DD	116.0	0.3	116.3	21.1	119.8	140.9	40.5	21.1	61.6	9.3	3.1	12.4	79.4	41.6	121.0	90.4
Otter Creek	564.6	40.8	605.4	497.8	96.5	594.3	698.9	106.1	805.0	379.9	131.3	511.1	615.2	77.8	693.1	641.8
Otter Creek - DD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	0.0	7.3	0.0	0.0	0.0	1.5
Port Henry - DD	15.0	0.0	15.0	0.3	0.0	0.3	13.8	0.0	13.8	0.3	15.1	15.4	15.0	0.0	15.0	11.9
Poultney River	95.2	1.0	96.2	47.7	0.5	48.2	204.2	0.5	204.7	95.1	0.0	95.1	38.0	0.0	38.0	96.4
South Lake A - DD	46.6	0.0	46.6	18.7	0.0	18.7	59.7	0.0	59.7	61.6	0.3	61.9	11.3	10.8	22.2	41.8
St. Albans Bay - DD	24.2	0.0	24.2	52.9	0.4	53.2	75.5	1.1	76.6	38.9	40.7	79.6	28.4	27.9	56.3	58.0
Winooski River	247.7	16.5	264.2	413.7	67.7	481.4	339.3	92.0	431.3	396.3	65.1	461.4	342.2	89.0	431.2	413.9
Grand Total	1523.4	86.1	1609.4	1599.4	486.2	2085.5	2517.7	318.3	2836.0	1896.5	357.4	2254.0	1739.3	376.8	2116.1	2180.2

Table 18. Annual P load from roads where sweeping occurred (kg/ac), based on frequency of sweeping by SWAT drainage area

SWAT Drainage Area	2015 P Load by Sweeping Frequency (kg/ac)			2016 P Load by Sweeping Frequency (kg/ac			2017 P Load by Sweeping Frequency (kg/ac)			2018 P Load by Sweeping Frequency (kg/ac)			2019 P Load by Sweeping Frequency (kg/ac)			Average Annual P Load (kg/ac)
	Once	> Once	Total	Once	> Once	Total	Once	> Once	Total	Once	> Once	Total	Once	> Once	Total	
Isle La Motte - DD	21.7	0.0	21.7	4.7	18.6	23.2	10.6	0.0	10.6	12.2	0.0	12.2	20.7	1.1	21.7	17.9
Lamoille River	153.5	6.6	160.1	238.5	37.5	276.0	355.6	14.8	370.4	290.9	6.7	297.6	171.7	5.5	177.3	256.3
LaPlatte River	26.3	3.2	29.5	5.9	12.6	18.5	31.3	22.9	54.2	45.1	17.7	62.8	19.3	33.9	53.2	43.6
Lewis Creek	21.2	0.6	21.8	20.4	0.0	20.4	10.3	1.5	11.8	13.3	0.0	13.3	10.5	0.0	10.5	15.6
Little Otter Creek	32.0	7.0	38.9	31.7	1.3	33.0	20.0	1.7	21.7	18.2	10.8	29.1	14.1	5.5	19.6	28.5
Main Lake - DD	0.0	0.0	0.0	4.3	0.0	4.3	4.2	0.0	4.2	16.8	0.0	16.8	0.7	0.0	0.7	5.2
Malletts Bay - DD	4.5	0.0	4.5	22.5	9.7	32.2	9.9	1.4	11.3	6.3	0.0	6.3	12.8	0.0	12.8	13.4
Mettawee River	42.7	0.0	42.7	33.7	0.0	33.7	67.7	5.5	73.1	48.4	0.0	48.4	47.7	0.4	48.1	49.2
Missisquoi Bay - DD	0.5	0.0	0.5	25.3	9.6	34.9	30.7	0.0	30.7	4.7	0.0	4.7	0.0	0.0	0.0	14.2
Missisquoi River	8.4	4.1	12.5	50.7	50.3	101.0	274.1	11.8	285.9	168.2	28.1	196.2	43.3	43.1	86.4	136.4
Northeast Arm - DD	94.3	0.3	94.7	17.2	61.0	78.2	28.9	18.6	47.5	7.2	0.9	8.0	61.5	34.2	95.8	64.8
Otter Creek	412.0	23.5	435.5	383.4	81.0	464.4	515.9	89.2	605.1	256.5	70.9	327.5	377.1	36.1	413.2	449.1
Otter Creek - DD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	0.0	6.5	0.0	0.0	0.0	1.3
Port Henry - DD	13.3	0.0	13.3	0.2	0.0	0.2	6.4	0.0	6.4	0.2	6.7	7.0	6.7	0.0	6.7	6.7
Poultney River	75.8	1.0	76.8	40.2	0.4	40.6	179.2	0.6	179.8	77.0	0.0	77.0	31.6	0.0	31.6	81.2
South Lake A - DD	43.0	0.0	43.0	18.1	0.0	18.1	56.0	0.0	56.0	57.5	0.2	57.7	6.0	4.3	10.3	37.0
St. Albans Bay - DD	18.7	0.0	18.7	41.1	0.2	41.3	62.8	0.9	63.7	29.8	26.3	56.1	11.0	13.6	24.6	40.9
Winooski River	186.7	8.2	195.0	258.1	44.0	302.1	245.7	62.9	308.6	322.2	40.0	362.2	235.4	60.7	296.1	292.8
Grand Total	1155	55	1209	1196	326	1522	1909	232	2141	1381	208	1589	1070	238	1308	1554

To accurately account for potential P load reductions, P load from roads where street sweeping occurred was broken into P load from streets swept once and streets swept more than once (Figure 15). On average, 15% of swept road segments were swept more than once annually, which accounted for 4% of the P load.

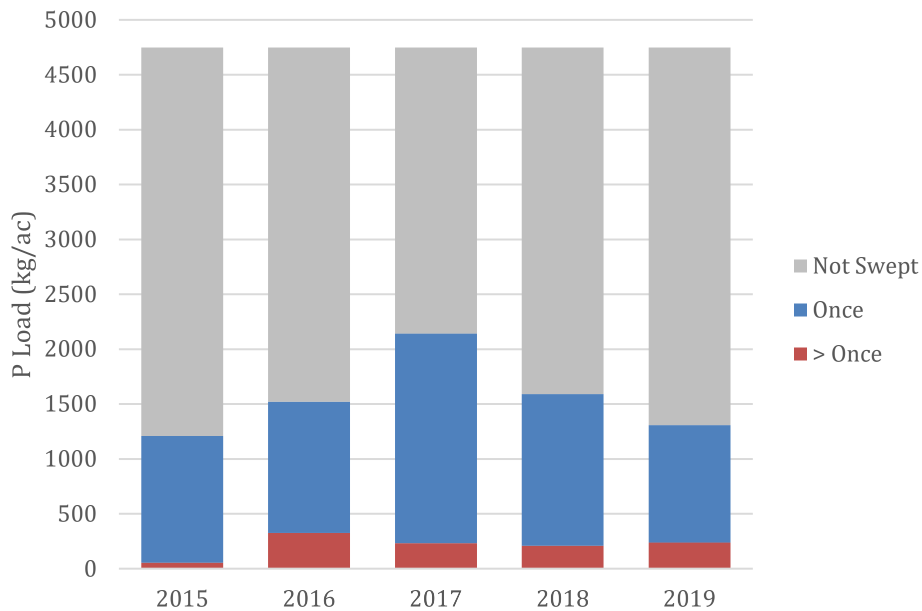

Figure 15. Annual P load from roads where sweeping occurred (kg/ac) by frequency of sweeping

Annual P load reductions ranged from 6.32- 11.86 kg/yr, with an average of 8.83 kg/yr, which translates to roughly 0.6% of the total required P reduction target per year from VTrans roads within the LCB (Figure 16). P load reductions corresponded to where sweeping happened and as would be expected and the highest P reductions occurred within the Lamoille River, Otter Creek and Winooski SWAT drainage areas (Figure 17). Compared to the total P reduction target of each SWAT drainage area, current sweeping regimes account for a relatively small portion of the annual P reduction, ranging from 0.3% - 3.3% (Table 19). Higher percentages of total P reduction targets were typically found in smaller SWAT drainage areas with relatively low P loads. Looking back at the cost data presented in Section 2.1, the unit cost for removing one kg/yr of P with sweeping is $31,623 (Table 20).

Table 19. Annual P load reduction (kg/yr) from sweeping by SWAT drainage area

SWAT Drainage Area	2015		2016		2017		2018		2019		Average Annual P Red	Total Target P Red (kg/yr)	Average Annual Percent P Red
	P Red (kg/yr)	Percent of Total P Red	P Red (kg/yr)	Percent of Total P Red	P Red (kg/yr)	Percent of Total P Red	P Red (kg/yr)	Percent of Total P Red	P Red (kg/yr)	Percent of Total P Red			
Isle La Motte - DD	0.11	4%	0.21	7%	0.05	2%	0.06	2%	0.11	4%	0.11	5.63	1.9%
Lamoille River	0.83	1%	1.57	1%	1.93	1%	1.52	1%	0.91	1%	1.35	211.96	0.6%
LaPlatte River	0.16	1%	0.16	1%	0.39	2%	0.40	2%	0.44	2%	0.31	32.85	0.9%
Lewis Creek	0.11	2%	0.10	2%	0.07	1%	0.07	1%	0.05	1%	0.08	7.39	1.1%
Little Otter Creek	0.23	2%	0.17	2%	0.12	1%	0.20	2%	0.13	1%	0.17	15.04	1.1%
Main Lake - DD	0.00	-	0.02	1%	0.02	1%	0.08	2%	0.00	0%	0.03	4.34	0.6%
Malletts Bay - DD	0.02	0.1%	0.21	1%	0.06	0.3%	0.03	0.1%	0.06	0%	0.08	24.60	0.3%
Mettawee River	0.21	1%	0.17	1%	0.39	2%	0.24	1%	0.24	1%	0.25	24.38	1.0%
Missisquoi Bay - DD	0.00	0%	0.22	1%	0.15	1%	0.02	0.1%	0.00	0%	0.08	49.08	0.2%
Missisquoi River	0.08	0%	0.76	0%	1.49	1%	1.12	1%	0.65	0%	0.82	327.48	0.3%
Northeast Arm - DD	0.48	5%	0.70	7%	0.33	4%	0.04	0.5%	0.65	7%	0.44	13.41	3.3%
Otter Creek	2.29	2%	2.73	2%	3.47	3%	1.99	2%	2.25	2%	2.55	196.27	1.3%
Otter Creek - DD	0.00	-	0.00	-	0.00	-	0.03	3%	0.00	0%	0.01	2.13	0.3%
Port Henry - DD	0.07	6%	0.00	-	0.03	3%	0.07	7%	0.03	3%	0.04	1.42	2.8%
Poultney River	0.39	1%	0.20	0.3%	0.90	1%	0.38	1%	0.16	0%	0.41	111.96	0.4%
South Lake A - DD	0.22	2%	0.09	1%	0.28	2%	0.29	2%	0.07	1%	0.19	16.19	1.2%
St. Albans Bay - DD	0.09	0.3%	0.21	1%	0.32	1%	0.41	1%	0.19	1%	0.25	47.21	0.5%
Winooski River	1.02	0.4%	1.73	1%	1.86	1%	2.01	1%	1.78	1%	1.68	423.05	0.4%
Grand Total	6.32	0.6%	9.24	0.9%	11.86	1.2%	8.99	0.9%	7.73	0.8%	8.83	1514.4	0.6%

Notes: - Red = reduction

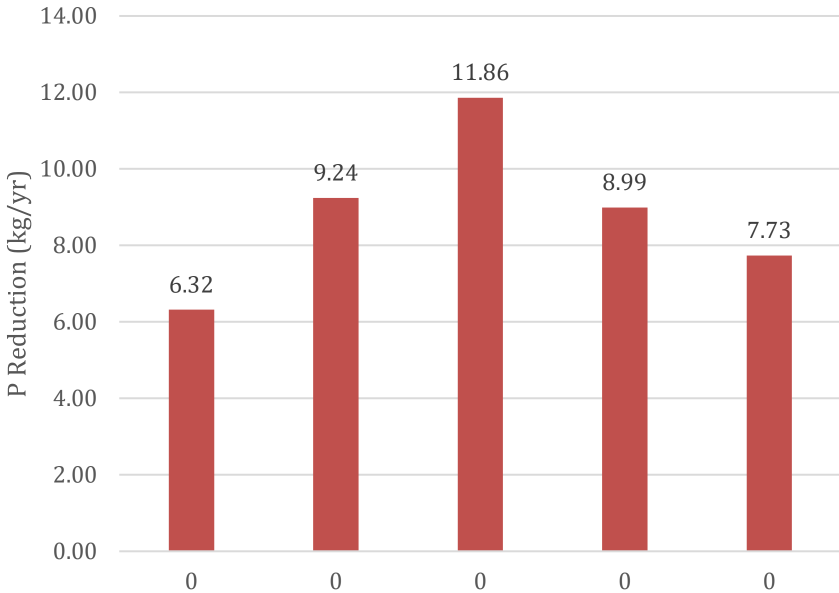

Figure 16. Total P reduction (kg/yr) from roads where sweeping occurred 2015-2019

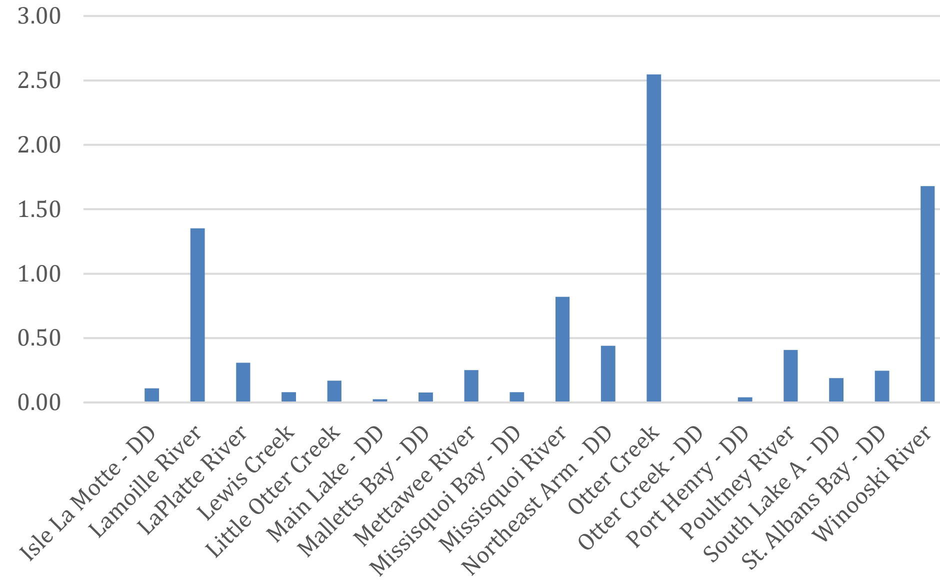

Figure 17. Average annual P reduction (kg/yr) from roads where sweeping occurred by SWAT drainage area

Table 20. Average annual unit cost for removing one kg/yr of P with sweeping

	2015	2016	2017	2018	2019	Average
Total P Red (kg/yr)	6.32	9.24	11.86	8.99	7.73	8.83
Percent of Total VTrans P Reduction Target	0.4%	0.6%	0.7%	0.6%	0.5%	0.5%
Total Cost	$ 233,215	$ 210,775	$ 414,991	$ 362,477	$ 174,631	$ 279,218
P Red Unit Cost ($/kg/yr)	$ 36,906	$ 22,809	$ 34,979	$ 40,324	$ 22,579	$ 31,623

Note: Average Annual Percent of Total VTrans P Reduction Target was calculated using the total target P reduction for all VTrans roads within the LCB (1514 kg/yr).

2.3 Recommendations for Future Street Sweeping Non-Structural Controls

2.3.1 MATS Tracking Improvements

Better tracking will lead to more accurate calculations and greater P reduction estimates; here are a few suggestions for better tracking of street sweeping in MATS:

1. Many sweeping MATS records used a single MATS record for two different geographic sweeping locations. It would be ideal if a truck moves to a different area, a new MATS record be created so P reductions can be calculated more accurately.
2. The length of the MATS record and the Accomplishment value should be more relevant to one another, to aid in determining the potential credit for the linear area swept.
3. It would be helpful to indicate the number of lanes swept per MATS record to better understand when the length and Accomplishment values do not match.
4. A field indicating the type of sweeping that occurred (i.e. broom vs. vac truck) would be helpful in determining potential credit allocated to each MATS entry.

2.3.2 Extent & Frequency of Street Sweeping

It was determined that current sweeping regimes (38% of streets wept in the LCB per year) could annually reduce the total P required from VTrans roads within the LCB by 0.5% on average. Table 21 shows the incremental increase that would result from almost doubling existing street sweeping efforts from roughly 1,000 to 2,000 Ln Mi in a year.

Table 21. Example projection of increased street sweeping from 1,055 to 2000 Ln Mi annually

	2015 - 2019 Annual Average	Future Projection
Ln Mi Swept	1055	2000
Percent of Total Ln Mi in LCB	38%	73%
P Red (kg/yr)	8.83	17
P Red per Ln Mi Swept (kg/yr/Ln Mi)	0.01	0.01
Cost	$279,218	$530,000
Percent of Total VTrans P Red Target	0.5%	1%

Street sweeping has a modest annual P reduction benefit at this time, and it is a routine maintenance practice that enhances the safety of the traveling public. VTrans could see increased P reduction benefits from a sweeping approach that focuses, for instance, on preferentially sweeping highly hydrologically connected road segments, increasing the extent and frequency of bridge washing, or targets Lake segments with the most aggressive P target reductions. For example, the Missisquoi Bay Lake segment (Missisquoi Bay – DD and Missisquoi River) has some of the highest P load reduction targets, but some of the lowest annual P reductions from sweeping (Table 22).

Further analysis of where sweeping efforts could be focused will be included in the development of each 4-year Implementation Plan. Results of ongoing research by USGS and others[3] evaluating reductions in nutrient and sediment loads from current street cleaning and leaf litter collection practices, and evaluating P reductions and crediting for current practice and potential enhancements, will further influence decision making regarding VTrans' street sweeping program once those findings are available in 2020.

Table 22. Comparison of street sweeping metrics by SWAT drainage area

SWAT Drainage Area	Average Ln Mi Swept Annually	Average Annual P Red (kg/yr)	Total Target P Red (kg/yr)	Average Annual Percent P Red
Isle La Motte - DD	1	0.11	5.63	1.9%
Lamoille River	157	1.35	211.96	0.6%
LaPlatte River	31	0.31	32.85	0.9%
Lewis Creek	6	0.08	7.39	1.1%
Little Otter Creek	29	0.17	15.04	1.1%
Main Lake - DD	1	0.03	4.34	0.6%
Malletts Bay - DD	5	0.08	24.60	0.3%
Mettawee River	27	0.25	24.38	1.0%
Missisquoi Bay - DD	3	0.08	49.08	0.2%
Missisquoi River	87	0.82	327.48	0.3%
Northeast Arm - DD	64	0.44	13.41	3.3%
Otter Creek	291	2.55	196.27	1.3%
Otter Creek - DD	N/A	0.01	2.13	0.3%
Port Henry - DD	5	0.04	1.42	2.8%
Poultney River	42	0.41	111.96	0.4%
South Lake A - DD	50	0.19	16.19	1.2%
St. Albans Bay - DD	54	0.25	47.21	0.5%
Winooski River	202	1.68	423.05	0.4%
Grand Total	1055	8.83	1514.40	0.6%

Notes: - Red = reduction

- Otter Creek - DD does not have average Ln Mi swept annual because of the data phenomenon described in the above sections that results from sweeping trucks driving across SWAT drainage areas.