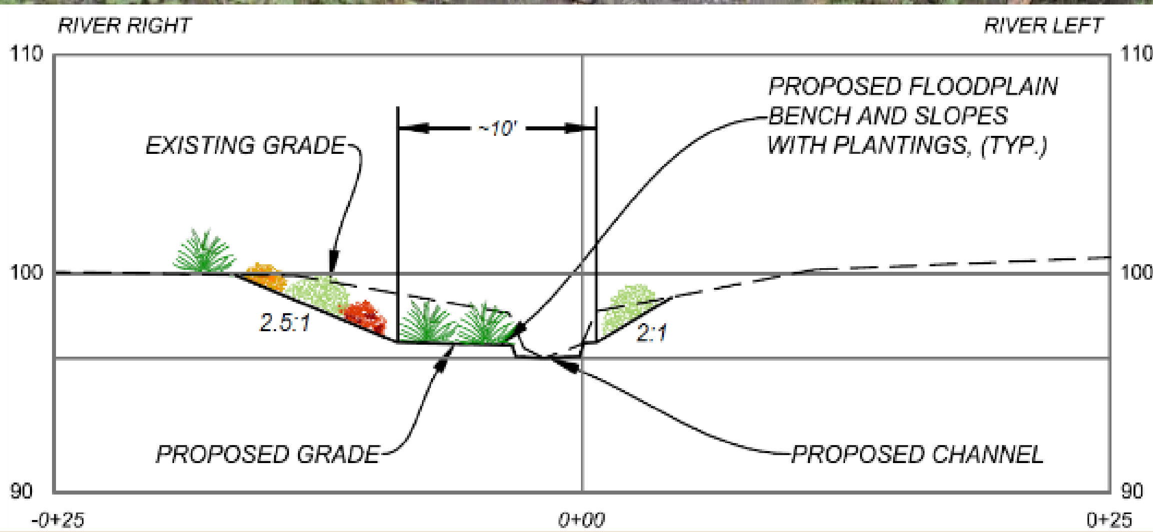
Stormwater Master Plan
Town of Hardwick, Vermont



PROJECT NO.

16-138

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Cover: Present condition of a roadside channel adjacent to Buffalo Storage and VT Rte. 14 (top), and concept plan for a natural channel design to address the site's erosion and sediment transport issues (bottom).

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Acknowledgements

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1. Introduction

Water knows no political boundaries, and thus evaluations of water quality tend to be undertaken within watershed boundaries and involve land areas in multiple towns. From a water quality perspective, it would be ideal to manage water resources along watershed lines—but the reality is that many decisions, particularly those about land use, are made at the level of towns or individual sites.

A Stormwater Master Plan is responsive to existing landscape characteristics across all watersheds within local political bounds. It connects land use, stormwater management, floodplain management, river management, and public infrastructure needs to more effectively address all of the issues which contribute to water quality impairment or improvement. Within this Plan, localized stormwater problems are examined at a larger scale (e.g., throughout the town core) to determine their relative contributions and aid in setting priorities for addressing challenges related to stormwater runoff. As adjoining municipalities also take increasingly comprehensive views of stormwater management issues and planning, these plans are one-stop resources that can improve coordination and increase opportunities for collaboration in meeting watershed-related needs across political boundaries.

1.1. Project Background

As precipitation falls on an undisturbed, natural landscape and moves through the hydrologic cycle, it flows through a complex system of vegetation, soil, groundwater, and surface water. Natural events have shaped these components over time to create a system that can efficiently handle stormwater through evaporation, transpiration, infiltration, and runoff. Alterations to the landscape change the way it responds to precipitation events. Management of land use, rainfall, storm runoff, and surface water (streams and lakes) are interrelated, and the management practices chosen all influence water quality and stream health.

Watersheds are interconnected networks in which a change at any location can carry throughout the system. There are many factors that influence exactly how stormwater runoff from a particular site will affect other areas of the watershed. The degree and type of impact varies from location to location, but it can be significant relative to other sources of pollution. Stormwater runoff affects water quality, water quantity, habitat and biological resources, public health, and the aesthetic

What is a watershed? A watershed is any area of land in which all water runoff from its surface flows to the same drainage point. Watersheds are sometimes referred to as drainage areas. Watersheds are important because they are the basic unit of analysis for all surface water management. They come in all shapes and sizes, and are defined based on the intended study area.

appearance of the receiving water. Stormwater controls, in contrast, are typically conceived and implemented on a project-by-project basis. These projects are analyzed for their individual stormwater impacts, not in the context of their impact on an interconnected hydrologic and hydraulic system. It is well documented, however, that the cumulative effects of individual land surface changes dramatically influence flooding conditions and contribute to water quality degradation (NRC 2009).

Watershed management practices have direct impacts on water quality in local creeks and streams (such as Cooper Brook), as well as downstream waterbodies (the Lamoille River and, ultimately, Lake Champlain). Any decisions that affect land use have stormwater management ramifications and, in turn, impact all downstream water resources.

Vermont's streams, rivers and lakes are vital economic resources. The quality of local receiving waters affects both economic interests and quality of life in the surrounding areas. Throughout the Lamoille River basin, the local economy depends, in part, on the revenue gained from outdoor activities enjoyed in and on the water. Protecting the quality of surface waters is one of the most important commitments communities can make to protect the economic interests of residents.

Taken together, these elements emphasize the need for a holistic planning effort that considers the interconnected nature of land use, stormwater management, and river management in order to achieve overall watershed goals.

1.2. Project Goals

The ultimate objective of this stormwater master planning project is to support the Town in improving stormwater management, by providing a list of high priority water resource concerns and conceptual solutions that will support the development and implementation of future restoration projects in an efficient and targeted manner.

This Stormwater Master Plan first incorporates information from existing plans and datasets to create a single, town-specific resource to guide future stormwater management activities. The resulting stormwater management planning information and resources are included in Section 2 of this report.

This Stormwater Master Plan also:

- Provides a means for comparing anticipated benefits of individual stormwater improvement projects;
- Provides recommendations to address stormwater problems, including a prioritized list of problem areas that can assist the Town in directing resources to high priority projects; and
- Presents conceptual solutions for stormwater management measures in select high priority problem areas.

1.3. General Descriptions – Planning Area and the Lamoille River

The Town of Hardwick is located in Caledonia County in the Northeast Kingdom of Vermont. The Town has a total area of 38.6 square miles and as of the 2010 census, the population of Hardwick was 3,010 (US Census Bureau 2017). The Lamoille River flows into town from the northeast, and flows out of town into neighboring Wolcott. The areas of interest for this plan include Hardwick's village center in the vicinity of State Routes 14 and 15 and the Lamoille River, and the East Hardwick village area (Figure 1).

The Lamoille River watershed encompasses a watershed area of 706 square miles, and drains portions of Caledonia, Chittenden, Franklin, Lamoille, Orleans, and Washington counties in northern Vermont. The river begins in its headwaters located in Glover, and flows approximately 84 miles through 34 towns to Mallets Bay in Lake Champlain (VTDEC, 2017). The Lamoille River flows southeast from Greensboro and enters Hardwick from the northeast, before flowing west northwest into Wolcott. Within Hardwick, the Lamoille River is considered to be 'altered' as water level fluctuations occur due to the Hardwick Lake Dam (VTDEC, 2016).

2. Existing Plans and Data

Numerous and varied groups and individuals have invested considerable effort in evaluating different components of Hardwick's water, wastewater, and stormwater infrastructure; water resources; and the important interface between water resources and local land use decisions. At times these evaluations followed watershed boundaries, and at other times they have followed political boundaries. The following sections identify these evaluations and highlight information most relevant to Hardwick and most relevant to developing a list of strategic, prioritized projects that could be undertaken to improve water quality and increase resilience to future flooding.

2.1. Watershed-Based Assessments

The ongoing assessments described below are generally led by the State of Vermont's Agency of Natural Resources (ANR). These include basin planning efforts, stream geomorphic assessment and in-stream water quality assessment work, and TMDL development, each of which are briefly described below where applicable information is available for Hardwick.

2.1.1. Tactical Basin Planning

The main goal of tactical basin planning is to guide ANR in its own work and in collaborative projects with the public, municipalities, and other state and federal agencies. The basin plans have a five-year scope. The Town of Hardwick is located in the Lamoille River Basin (Basin #7), where a plan was adopted in December 2016 by the Agency of Natural Resources. The central component of this Tactical Basin Plan is an implementation table with targeted actions to protect high quality waters and to address identified water quality issues identified. One of the top priority actions stated in the plan was to 'develop a stormwater master plan for the Village of Hardwick and identify priority projects for mitigating runoff' (Item B4, Table 26 of the plan) (VTDEC, 2016).

2.1.2. Other Vermont ANR-Sponsored Programs

Additional ANR-based data sources reviewed prior to the start of field visits for the purpose of locating potential stormwater problem areas (Section 3) included:

- Stream Geomorphic Assessments: Recorded in the Vermont ANR Natural Resources Atlas Geomorphic Assessment Viewer (http://anrmaps.vermont.gov/websites/anra5/?LayerTheme=1)
- Water Quality Monitoring Data: Available through the Vermont Integrated Watershed Information System (IWIS), the VTDEC-Watershed Management Division's online data portal for water quality information, at https://anrweb.vt.gov/DEC/IWIS/.

2.2. Town-Wide Assessments and Programs

In addition to the watershed-based assessments, a number of assessments and datasets are developed on a municipality-by-municipality basis. These are important to fold into any effort to develop a list of strategic, prioritized projects that could be undertaken to improve water quality in and around Hardwick. These include direct feedback from the Town, work by the Vermont Agency of Transportation and Vermont Department of Environmental Conservation, and past and current planning initiatives.

- Direct Input from Town Staff: Meetings with Town staff resulted in the identification of several areas of concern and priority project opportunities that were further assessed in the field and included in the stormwater opportunity prioritization and implementation matrix (Table 2).

- Vermont Agency of Transportation-Sponsored Programs: The agency's online bridge and culvert inventory (available at https://www.vtculverts.org/) was reviewed prior to field screening and evaluation of potential stormwater problem areas (Section 3). Much of the planning area is served by closed-system stormwater infrastructure, which was mapped by Vermont DEC (see below).

- Vermont DEC-Sponsored Programs: Detailed stormwater infrastructure mapping and state-issued post-construction stormwater permitting records were examined in order to identify additional stormwater management opportunities. The infrastructure mapping data represent an important supplement to VTrans' online bridge and culvert inventories and were invaluable during evaluations of existing problem areas and retrofit opportunities (Section 3 and as further described below).

A stormwater infrastructure mapping project completed by the VTDEC Ecosystem Restoration Program for the Hardwick (VTDEC, 2012) and East Hardwick (VTDEC, 2017) village areas identified potential locations for stormwater retrofit sites among priority drainage areas. The identified potential retrofits included:

- Two bioretention areas and an extended detention basin were proposed to treat a portion of the runoff from Hazen Union High School parking lot and upland drainage area.

- In East Hardwick, a swirl separator and outfall stabilization were proposed to treat runoff from Main Street and Brickhouse Road.

In addition, the age, style, size, and upkeep of existing facilities permitted by DEC – particularly facilities constructed prior to 2002 – may make them candidates for improvement to enhance stormwater management capabilities. Post-construction stormwater management permits for the planning area (as available from the ANR Atlas at http://anrmaps.vermont.gov/websites/anra5/, "Stormwater Permits – Issued" data layer) were reviewed during field screening of potential stormwater problem areas (Section 3) and development of potential implementation projects (Section 4).

3. Stormwater Problem Areas

One of the goals of this plan is to “develop a prioritized list of stormwater problem areas that can assist the Town in directing resources to high priority projects.” To achieve this goal, a thorough effort was made to identify existing problem areas, and then to evaluate existing conditions and potential solutions.

3.1. Identification and Initial Evaluation of Problem Areas

The first task was to identify the location and nature of existing drainage problems and stormwater management concerns, and to gather field data for further analysis where appropriate. The approach to identifying potential problem areas included the following elements:

- Reviewing existing plans and data, as described in Section 2, and noting the location of any concerns related to stormwater
- Engagement with Town, CCNRCD, and State of Vermont staff
- Targeted site visits to verify problem areas during the fall of 2016
- Documentation (with photos) of existing problem areas

A “problem area data sheet” was developed and used as a guide to ensure that consistent information was collected as site visits were completed. A total of 21 potential problem areas were identified and geo-located (Figure 2, Appendix A). The data sheets for all of the problem areas identified in Hardwick are provided in Appendix B of this report.

3.2. Initial Screening Evaluation of Problem Areas

Working from the list of potential problem areas, Stone staff visited each potential problem area to directly observe the site. Where an unresolved problem was found, photos were taken of any areas of active erosion or observable impact, and observations were recorded regarding the source or cause.

Each problem area was given an initial score with the intent of: 1) generally assessing the severity of existing problems, 2) removing low priority problem areas from the dataset, and 3) providing general guidance on the relative order in which the problems should be addressed when considered across the project area. Scores were assigned as described in Table 1.

The problem areas identified during this initial evaluation were carried forward through a more detailed examination and prioritization process as described in Section 4.

Table 1. Scoring Criteria for Preliminary Evaluation of Stormwater Problem Areas.

Level	Classification
1	Outside of project scope, or infeasible to remedy due to project size.
2	Stable, but problem could escalate with future change in surrounding land use.
3	Limited erosion and/or drainage problems are present; issues may be readily addressed.
4	Moderate erosion and/or drainage problems are present; issues may be readily addressed.
5	Significant erosion and/or drainage problems are present; issues may be readily addressed.
6	Strategic retrofit opportunity.

4. Prioritization of Stormwater Management Opportunities and Implementation Matrix

Stone completed a field screening that identified 21 stormwater management opportunities in Hardwick during the fall of 2016, with additional field confirmation in 2017 (Section 3). The locations of the opportunities are shown on Figure 2 (Appendix A), and the nature of each identified problem and potential opportunity is summarized in Table 2.

During and following the field screening, Stone recorded observations about each site which were used in the implementation matrix (Table 2) to develop a score for each opportunity relative to several criteria:

- **Existing environmental concerns** – a score was assigned based on the type(s) of problems present, with 1 point added for each of the following concerns presented by the site's current condition: water quality concerns; infrastructure vulnerability; localized drainage issues/flooding; streambank or in-stream erosion; and overbank flooding. Although sites were generally anticipated to receive between 1 and 3 points, the maximum score a site could receive was 5.

- **Environmental priority** – relative environmental impact on nearest receiving water (e.g., proximity, location) and how "active" the problem area was during the site visit, with 1 being the smallest impact and 5 being the greatest impact.

- **Constructability** – relative ease with which a project could be implemented, including whether the recommended practice(s) could be constructed on publicly-owned land or with a willing landowner-partner, existing access to the site, and the amount of additional assessment and engineering design work that would be required to move the project to implementation. The maximum score a site could receive was 3, indicating a project that should move quickly and easily to implementation.

- **Ease of operation** – including the amount and frequency of maintenance likely to be required and whether maintenance activities would be straightforward to complete. The maximum score a site can receive is 3, indicating a project with infrequent maintenance needs that are easily completed.

The type of ownership of each project location, an initial indication of project cost, and the amount of additional engineering likely needed for implementation are also presented in the matrix (Table 2). These measures are not included in the score tabulated for each potential project, but are provided to give additional context for project prioritization.

Estimated annual phosphorus loads to be removed by the proposed improvements on an annual basis (lbs/year) are also included in the table for problem areas that were ultimately advanced to restoration plan, design-build, or concept (30%) design, where applicable. Estimated total phosphorus base loads (lbs/year) were calculated using the Simple Method approach, based on phosphorus loading rates for developed lands and transportation developed by Vermont DEC in 2015 as an interim procedure to guide applicants in meeting phosphorus "Net Zero" requirements for projects that would potentially discharge phosphorus to Lake Champlain before the P TMDL was in place (VT DEC, 2015). The average annual pollutant (phosphorus) concentrations provided in the guidance are 0.441 mg/L for developed lands, 0.237 mg/L for paved roads, and 0.618 mg/L for unpaved roads. The developed lands concentration of 0.441 mg/L was applied for most systems in the project area, consistent with DEC guidance for systems that include driveways, access drives, and other transportation surfaces within larger development projects (e.g., residential and commercial developments). The estimated total phosphorus load to be removed by proposed improvements on an annual basis (lbs/year) was calculated based on the estimated total phosphorus base load, annual runoff volume anticipated to be captured by proposed BMPs, and percent pollutant removal efficiencies for the proposed BMP types, as included in the Lake Champlain BMP Scenario Tool (VT DEC, 2017).

Finally, in the three right-most columns, the matrix indicates the projects selected for development of a restoration plan, as well as sites that were advanced to preliminary design or design-build. These projects were selected in consultation with the Town, CCNRCD, and representatives from VT DEC.

Table 2. Stormwater Opportunity Prioritization and Implementation Matrix

Site ID	Site Name	Need	Proposed Approach	Web Soil Survey Mapped HSG	Existing Environmental Concerns	Environmental Priority (scale 1-5)	Constructability (scale 1-3)	Ease of Operation (scale 1-3)	Implementation Score	Potential Phosphorus Load Reduction	Project Type	Estimated Implementation Cost	Green Infrastructure Opportunity (Y or N)	Need for Additional Engineering	Develop Restoration Plan?	Prepare Preliminary Design?
CB-01	Fire Station	Retrofit opportunity	Capture and reuse roof runoff from the fire station with a cistern.	NR (Urban) Adams / Nicholville	2	1	3	3	9		C	L	N	L		
CB-02	North of 582 Mackville Rd.	Over-steepened embankment leading to the stream comprised of very small stone, shows signs of rill erosion.	The embankments should be stabilized using large stone at the toe of slope. If possible, the slopes should be constructed to be more gently sloping. This issue is also present at the intersection of Mackville Road and Carey Road - the same approach is applicable at that location.	A	3	2	2	3	10		D	L	N	L		
CB-03, CB-04	Spruce Drive at Mackville Road	A ditch draining building lots on Spruce Drive is in need of erosion prevention. The fire hydrant access on Mackville Road shows evidence of slumping and is eroding into the roadside ditch.	Install erosion prevention measures and/or water quality BMPs (bioswale) in the exisitng ditch following completion of construction activities for expansion of the mobile home park, At the hydrant, add stone to the toe of slope to stabilize the bank, and level the area used to access the hydrant.	NR (Urban) Adams / Nicholville	2	3	3	2	10	7.1 (CB-03), N/A (CB-04)	D	L	Y (partial)	L	Yes	
CB-05	Buffalo Storage	A ditch that conveys runoff and stream flow from roughly 111 acres of drainage is actively eroding and transporting large sediment loads directly to the Copper Brook.	Construct a revised stream channel sized to accommodate the 1.5 year storm event, and floodplain benches to accommodate flows for larger storm events. Side slopes will be graded between 2:1 and 3:1 up to existing grade and benches and slopes will be planted with native vegetation. Additional construction includes a pool and step on the upstream end to serve as a sediment forebay and upsizing the downstream exit culvert.	NR (Urban) Adams / Nicholville	4	5	2	1	12	47.1	B/C	M	N	H		Yes
CB-06	Poulin Lumber	Retrofit opportunity	It appears that roughly 3 acres of impervious surface is currently unmanaged and primarily drains to a single catch basin near the corner of Union Street and Wolcott Street. If the soils prove permeable, installing an infiltration basin with sediment forebay would reduce sediment transport and runoff currently directed to the confluence of the Copper Brook and the Lamoille River. There are site constraints caused by the close proximity of the railroad right-of-way.	NR (Urban) Adams / Nicholville	3	3	2	2	10		A	MH	Y (partial)	H		
CB-07	Corner of Spring and Granite Streets	Retrofit opportunity - A drainage system conveying runoff from an 8.6-acre area (Spring, Summer, and Dewey Streets) outfalls into Cooper Brook just northwest of the intersection of Spring and Granite Streets.	Existing green space east of the intersection could be utilized for stormwater volume capture and water quality treatment. Any stormwater treatment retrofit practices would be located in the brook's 100-year floodplain - so sub-surface chambers would likely be required for volume retention.	Sheepscot gravelly very fine sandy loam	4	3	1	1	9		D	MH	Y (partial)	H		
LR-01	Corner of Wolcott St. and W. Church St.	Retrofit Opportunity - The existing "trash can" style outlet cover does not protect against backwater when the river rises, causing the closed drainage system to back up.	Replace the existing "trash can" style outlet cover with a "duck bill" outlet structure or similar device. This location could be used as a demonstration, as there are many similar situations along the river.	NR (Urban) Adams / Nicholville	3	4	3	3	13	N/A	C	L	N	L	Yes (design-build)	

Site ID	Site Name	Need	Proposed Approach	Web Soil Survey Mapped HSG	Existing Environmental Concerns	Environmental Priority (scale 1-5)	Constructability (scale 1-3)	Ease of Operation (scale 1-3)	Implementation Score	Potential Phosphorus Load Reduction	Project Type	Estimated Implementation Cost	Green Infrastructure Opportunity (Y or N)	Need for Additional Engineering	Develop Restoration Plan?	Prepare Preliminary Design?
LR-02	Elm Street	Retrofit opportunity	There is opportunity to utilize green space between sidewalks and the roadway for treatment should the Town wish to implement further treatment in the neighborhood. However, this area already drains to the bioretention system at LR-03.	NR (Urban) Adams / Nicholville	2	2	2	2	8		D	M	Y (partial)	M		
LR-03	Bioretention	Existing bioretention area has not been maintained.	Complete practice maintenance, including sediment and weed removal. Consider replacement of original plantings with vegetation more easily maintained by Town staff. Create simple operations and maintenance plan and train local staff to ensure sustainable maintenance. Consider practice restoration only if maintenance and inspection uncover performance issues.	NR (Urban) Adams / Nicholville	3	3	2	2	10	14.8	C	L	Y - Existing	M	Yes	
LR-04	Tops/Rite Aid	Much of, if not all of the stormwater from the site appears to drain to the south edge of the paved area, transporting sediment and creating ponding.	A section of pavement at south edge appears to be unused. If soils are suitable for infiltration, excavating existing paved surface and installing infiltration basin with sediment forebay would reduce runoff from the site and provide treatment. Infiltration is not allowed if practice is within Zone I WHPA.	NR (Urban) Adams / Nicholville	3	4	3	2	12	2.6	A	MH	Y (partial)- no infiltration in Zone I	H	Yes	
LR-05	Lower Prospect Street at Wolcott Street	Roof runoff from the barn and surface runoff from Lower Prospect Street and Hillside Street is causing Lower Prospect Street to actively erode into the intersection of Hillside Street, Lower Prospect Street, and Wolcott Street.	Roof runoff could be captured with gutters and carried to ditches, an infiltration basin, a bioretention area, a cistern, etc. Ditches could also be established on Hillside Street to assist in reducing the amount of runoff that may be contributing to the erosion issue at the intersection.	NR (Urban) Adams / Nicholville	3	3	1	2	9		D	MH	N	H		
LR-06	Hazen Union School (Hardwick Trails)	Retrofit opportunity	Route runoff from the parking lot and uphill area to existing green space to allow for filtration. Install a small sediment basin outside wetland buffer to reduce sediment transport from paved parking and gravel access road/parking. Improve existing gravel parking with underdrained permeable paver/grass-pave system with daylight to buffer area.	A/D	2	2	3	3	10	0.2	C	L	Y (partial)	L	Yes (design-build)	
LR-07	Hazen Union School (Parking and Tennis Courts)	Retrofit opportunity	There is an existing stormwater retrofit present at this location that prevents clogging of the catch-basin. A paved swale along the driveway conveys runoff from the parking lot to a grass swale and the catch basin riser. The paved swale may be converted to a gravel wetland to treat runoff from the parking lot without substantially impacting adjacent recreational uses.	NR (Urban) Adams / Nicholville	3	3	3	2	11	2.3	C	M	N	H		Yes
LR-08	Wright Farm Road	Retrofit opportunity	Route runoff from VT Route 15 to the existing green space and install an infiltration basin with sediment bay that can be easily cleaned/maintained (pending soil investigations).	B/D	3	4	2	2	11		C	M	Y (partial)	M		
LR-09	GRACE	Retrofit opportunities	Two green strips exist between the buildings of Hardwick Village Market, GRACE, and Brochu Auto Service. These strips can be used for linear bioretention areas to capture,	NR (Urban) Adams / Nicholville	4	4	2	2	12	0.5	A	M	Y (partial)	M	Yes	

Site ID	Site Name	Need	Proposed Approach	Web Soil Survey Mapped HSG	Existing Environmental Concerns	Environmental Priority (scale 1-5)	Constructability (scale 1-3)	Ease of Operation (scale 1-3)	Implementation Score	Potential Phosphorus Load Reduction	Project Type	Estimated Implementation Cost	Green Infrastructure Opportunity (Y or N)	Need for Additional Engineering	Develop Restoration Plan?	Prepare Preliminary Design?
			treat, and infiltrate runoff from Mill Street, parking areas, and roofs.													
LR-10	Positive Pie and Yummy Wok park	Retrofit opportunity	Promote infiltration and reestablish plantings within the existing park.	NR (Urban) Adams / Nicholville	1	4	2	2	9		A	L	Y (partial)	L		
LR-11	Hardwick Elementary School	Retrofit opportunity	There is a vegetated green strip between Hardwick Elementary School and Saint Norbert's Catholic Church. Install a linear bioretention area at that location. This could be implemented in conjunction with a repaving/regrading project. Parking lot reconstruction was completed in summer/fall 2017; parking is now graded to the closed drainage system and treatment in the green space is no longer feasible.	NR (Urban) Adams / Nicholville	3	4	3	3	13		A	MH	Y (partial)	M		
LR-12	VT 14/15	Retrofit opportunity	A substantial amount of sediment collects at the northern portion of an existing parking area. Installation of a swirl separator is planned in this area in conjunction with sidewalk project on South Main St. in 2017 (the practice was installed in the summer of 2017). Regular maintenance of this practice will be critical to its ongoing performance and success.	NR (Urban) Adams / Nicholville	4	5	3	2	14		C	H	N	H		
LR-13	Hardwick Veterinary Clinic	Retrofit opportunity	Vegetated green strip between the southern clinic parking lot and the Lamoille River north bank could be enhanced with additional plantings to slow down and evapotranspire runoff.	NR (Urban) Adams / Nicholville	1	3	2	3	9		A	L	Y (plantings only)	L		
LR-14	East Hardwick	Moderate erosion exists at the Main Street bridge over the Lamoille River, as well as the east edge of church street. The most significant erosion is present at the southeast and northwest corners of the bridge. Erosion is caused by high velocity over-land flow and active outlet scour at storm drains.	A variety of practices could be established at the northwest corner to alleviate ongoing erosion. Installation of a step-pool conveyance system, stone lined swale, swirl separator, or a combination of practices are all potentially viable options. At the southeast corner, the bank should be stabilized using large stone that will hold against high velocity flows. Even larger stone may be used at the toe of slope to help weight down and anchor the bank. Stone splash pads should be established at storm drain outlets. Proper embankment stabilization may require adjusting or removing the existing concrete retaining wall at the top of the embankment.	NR (Urban) Adams / Nicholville	4	5	1	2	12	8.2	D	MH	N	L	Yes	
NB-01	Carey Road at Dix Road	Moderate erosion along the north edge of Dix Road caused by steep roadway grading, a shoulder berm, turnouts, and cross culverts with elevated outlets.	Regrade the roadway to promote sheet flow and stabilize culvert outlets by installing stone splash pads.	A	1	2	3	3	9		C	L	Y - A Soils	L		

Project Type "key":		Estimated Implementation Cost "key":		Need for Additional Engineering "key":	
A	Private property	**L**	less than $20,000	L	Project can be implemented without formal engineering
B	State property or right-of-way	**M**	$20-$50,000	M	Project requires some amount of engineering design to ensure proper sizing
C	Public property (town-owned land or right-of-way)	**MH**	$50-$100,000	H	Project requires full engineering
D	Hybrid; part public land, part private land	**H**	more than $100,000		

Potential Phosphorus Load Reduction (lbs./year) was calculated only for projects advanced to restoration plan, design-build, or concept design, and as applicable to the specific retrofit or improvement proposed.

5. Conceptual Solutions for High Priority Stormwater Problems and Opportunities

Initially, the prioritization of all of the identified problem areas and opportunities (Section 4) resulted in 14 of the identified problem areas being assigned an implementation score of 10 or higher. In consultation with CCNRCD, Town staff, and Vermont DEC staff, this list was further narrowed to five projects for development of restoration plans. Two additional sites were chosen for design build, due to their relative ease of implementation, lower need for additional engineering, and lower cost. Finally, two sites were advanced to concept design, with selection based largely on size of the treatment opportunity, as well as property owner/stakeholder interest and concurrence of State agencies' staff that the concepts were worthy of advancement.

The five opportunities advanced to restoration plan development (Appendix C) were:

- CB-03, CB-04, Mackville Road
- LR-03, Community Recreation Park (Corner of Cottage Street and Cherry Street)
- LR-04, Tops/Rite-Aid Parking lot
- LR-09, Hardwick Village Market / GRACE / Brochu Auto Service Parking Areas
- LR-14, Main Street Bridge, East Hardwick

The two locations chosen for design build (Appendix D) were:

- LR-01, West Church Street Bridge
- LR-06, Hazen Union School / Hardwick Trails Access

The two opportunities advanced to concept design (Appendix E) were:

- CB-05, Buffalo Storage
- LR-07, Hazen Union School (Parking and Tennis Courts)

5.1. Concept Designs

5.1.1. CB-05, Buffalo Storage

The Buffalo Storage site includes a first order unnamed tributary to Cooper Brook that runs generally north to south, parallel to Route 14, and directly adjacent to the Buffalo Storage facility (see CB-05 PADS in Appendix B, and conceptual design plans in Appendix D). The existing channel is essentially serving as a drainage ditch that conveys roughly 111 acres of drainage from lands that have been steadily developed over time. The channel is actively transporting large sediment loads directly to Cooper Brook. This portion of the channel is also subject to regular ditching and re-shaping by either the Town or VTrans, roughly once every 2-4 years. It is suspected that the channel is in adjustment due to the increased impervious area upstream, meaning that the channel is adjusting its cross sectional area to accommodate the increase in flows and stream power conveyed during storm events. The severity of sediment transport and active erosion can be observed in the photo below.

For conceptual design at this site, Stone considered Schumm's Channel Evolution Model (CEM; USDA 2012). The CEM provides a predictable sequence of changes a stream can undergo after disturbances such as channel straightening, increase in peak discharges, or decrease in sediment load (see figure in Appendix D). The changes can include increases or decreases in the width/depth ratio of the channel and alterations in the floodplain (USDA 2012). Field investigations performed by Stone indicate that the channel is currently in stage II, where the channel is incising and not reaching its floodplains during large storm events. Stream power is being expended on erosion of the channel bed and banks during these events.

The proposed restoration is based on accelerating the channel evolution process and bringing the channel to stage V of the CEM, where a new 'inset' floodplain exists and channel bed and banks have re-stabilized. Restoration includes a revised stream channel sized to accommodate the 1.5 year storm event, floodplain benches to accommodate flows for larger storm events (i.e. the 2 through 100 year events), side slopes graded between 2:1 and 3:1 up to existing grade, and planting of native vegetation along benches and slopes. Also proposed is a pool and step on the upstream end to serve as a sediment forebay, and upsizing of the downstream existing culvert. The end result is lower channel velocities, higher channel roughness, less sediment transport, a significant increase in channel conveyance and increased storm resiliency during storm events. It is estimated that restoration will contribute to a total suspended solids load reduction of 47,130 lbs./year and a phosphorus load reduction of 47.1 lbs/yr.

A site visit and meeting to review priority projects across the planning area with the VTDEC Watershed Planner, VTDEC Rivers Program, and VTDEC Wetlands Program staff, and Stone was arranged by CCNRCD staff on September 8, 2017. The Buffalo Storage site and its constraints were discussed, as well as the potential application of a step pool storm conveyance or "regenerative stream conveyance" as a treatment solution. Following the meeting, Stone staff provided additional information regarding the regenerative stream conveyance concept. Rivers Program staff indicated on October 2, 2017 that they were willing to explore a "regenerative step-pool project" at this location as a demonstration, provided that Program staff concerns regarding floodplain connection, stream dredging, upstream stormwater inputs, maintenance, and potential Flood Hazard Area and River Corridor impacts could be addressed during later design phases. On November 7, 2017, representatives from Stone, CCNRCD, and VTDEC Watershed Management, Rivers Program, and Wetlands Program staff met with the Buffalo Storage ownership to consider site issues and the evolving retrofit concept. Existing conditions and maintenance of the current channel were discussed, as were potential implementation options. Concerns and constraints discussed included the sediment load conveyed to Cooper Brook, the potential for implementation practices to increase surface water elevations during flood events, coordination with VTrans regarding activity in the highway right-of-way, and encroachment of construction towards Buffalo Storage property and landscaping. Finally, on November 14, 2017, Stone and CCNRCD staff met with representatives from VTrans (District Office and MOB), DEC Rivers Program, and the property owner to discuss the site, potential solutions, and VTrans's specific concerns regarding work in the right-of-way, maintenance, and other relevant design aspects. As of the end of the November 14 site meeting, all parties agreed to move forward with development of the concept design.

An opinion of probable cost for implementation of the proposed restoration design at the Buffalo Storage site is provided in Table 3 below. The estimate assumes re-use of any on-site suitable rock material found during excavation for step and pool construction. Unit costs are based on Vermont Agency of Transportation (VTrans) 5 year average unit prices, ranging from July 2012 to June 2017 (http://vtrans.vermont.gov/sites/aot/files/estimating/documents/5YearEnglishAveragedPriceList11.pdf), and adjusted based on recent stream restoration construction projects implemented in 2017 and managed by Stone staff.

Table 3. Buffalo Storage – Opinion of Probable Cost – 30% Design

	Item	Unit Price	Unit	Design Quantity	Total Cost
1	Clearing and Grubbing	$2,000	LS	1	$2,000
2	Excavation, Including Haul Away	$50	CY	211	$10,550
3	Construct Step & Pool (Sediment Forebay)	$6,000	EA	1	$6,000
4	Fine Grading	$3,000	LS	1	$3,000
5	Culvert Pipe	$8,000	LS	1	$8,000
6	Plantings	$6,000	LS	1	$6,000
7	Erosion Control Matting	$10	SY	800	$8,000
8	Seed	$100	Lb	10	$1,000
9	Erosion Controls	$5,000	LS	1	$5,000
				Total Construction Cost	***$49,550***
				Mobilization – 10% of Construction Cost	*$4,955*
				Survey Stake Out – 5% of Construction Cost	*$2,478*
				Final Design – 30% of Construction Cost	*$14,865*
				Construction Oversight – 5% of Construction Cost	*$2,478*
				Contingency – 25 % of Construction Cost	*$12,388*
				Total Estimated Project Implementation Cost:	***$86,635***

5.1.2. LR-07, Hazen Union School (Parking Lot and Tennis Court)

The Hazen Union campus includes a large school building with approximately 2 acres of rooftop area, tennis courts, parking lot and associated access roads and driveways, and a large athletic field. The school building rooftops are largely connected to drywells and thus effectively disconnected. The tennis court drains to grass swales or to the parking lot. The total drainage area associated with the parking lot and tennis court is 3.44 acres, with 1.64 acres of impervious cover. The paved parking lot drains to two catch-basins that are connected by closed drainage to a paved swale that runs along the driveway entrance to the school, which conveys runoff from the parking lot to another grass swale and eventually to a catch basin and riser (see LR-07 PADS in Appendix B, and conceptual design plans in Appendix D). Due to poorly draining soils, presence of bedrock, and a shallow seasonal high groundwater table, this area of the recreational fields is wet throughout the entire year. The existing paved swale provides conveyance but no water quality treatment or peak flow control of stormwater runoff.

The proposed design for this site includes conversion of the paved swale to a gravel wetland that will treat runoff from the parking lot and a small portion of the tennis courts, and allow flow through to the downstream grass swale. The wetland will consist of a treatment cell approximately 7' wide by 80' long, with substrate comprised of a 2' layer of ¾" double washed crushed stone on the bottom, followed by a 4" choker course of pea gravel, and finally an 8" layer of wetland soils at the top of the substrate (see plans in Appendix D). Water will be stored in the pore spaces of the gravel in the treatment cell, and will be conveyed to a manhole outlet structure via a perforated PVC piping system buried in the bottom gravel layer. Freeboard above the wetland soil layer provides for approximately 18-24" of storage during high flow events, which is defined by side berms at slopes of 1 vertical to 2 horizontal. The design also includes a forebay to trap incoming sediment, and the outlet manhole structure has a trash rack to contain larger debris, in addition to a standard outlet and an overflow outlet to allow bypass during high flow events.

The proposed design will accommodate 100% of the water quality volume for a 1" storm event (approximately 3,500 cubic feet), will provide water quality treatment including sediment and phosphorous removal and provide for storage and velocity reduction of runoff during storm events. It is estimated that gravel wetland BMP installation will contribute to a phosphorus load reduction of 2.25 lbs/yr from the existing impervious cover.

Stone and CCNRCD staff met with the VTDEC Watershed Planner, as well as representatives from VT DEC Wetlands and Rivers Program staff, on September 8, 2017, and with the DEC Watershed Planner. Stone and CCNRCD staff met separately with the Hazen Union School facilities manager on November 7, 2017 to consider the proposed concept and to discuss potential constraints. All parties agreed to move forward with development of the conceptual design.

An opinion of probable cost for implementation of the gravel wetland is included in Table 4. Similar to Buffalo Storage, this estimate assumes re-use of any on-site suitable rock material found during excavation to be used for berm construction, and also references VTrans 5-year average unit prices.

Table 4. Hazen Union School (Rec. Fields) – Opinion of Probable Cost – 30% Design

	Item	Unit Price	Unit	Design Quantity	Total Cost
1	Clearing and Grubbing	$2,000	LS	1	$2,000
2	Excavation, Including Haul Away	$50	CY	125	$6,250
3	3/4" Dense Graded Double Washed Crushed Stone	$35	CY	42	$1,470
4	3/8" Double Washed Pea Stone	$40	CY	7	$280
5	Wetland Soil	$35	CY	14	$490
6	Stone Fill, Type II	$45	CY	7	$315
7	Precast Reinforced Concrete Manhole with Cast Iron Grate and Trash Rack	$10,000	EA	1	$10,000
8	6" Perforated PVC Pipe	$25	LF	100	$2,500
9	Erosion Control Matting	$10	SY	200	$2,000
10	Seed	$100	LB	5	$500
11	Erosion Controls	$2,500	LS	1	$2,500
				Total Construction Cost	***$28,305***
				Mobilization – 10% of Construction Cost	*$2,831*
				Survey Stake Out – 5% of Construction Cost	*$1,415*
				Final Design – 20% of Construction Cost	*$5,661*
				Construction Oversite – 5% of Construction Cost	*$1,415*
				Contingency – 25 % of Construction Cost	*$7,076*
				Total Estimated Project Implementation Cost:	***$46,703***

6. Next Steps

This document represents an extensive effort to identify and evaluate potential stormwater problem areas throughout the more densely developed areas of Hardwick. Several high priority potential stormwater improvement projects, including conceptual solutions, were identified in Section 5 that CCNRCD or the Town could pursue directly, or could work with partners to pursue funding to address.

Beyond addressing the specific problem areas identified in this plan, there are often opportunities to improve management of stormwater runoff that arise as part of routine municipal projects, such as the substantial reconstruction of a road surface or intersection. Grant funds may be available to cover the incremental cost of addressing stormwater runoff as part of such projects, if stormwater management is considered early enough in the design process and does not exceed regulatory thresholds for state stormwater permits. Any party choosing to advance one of these priority projects will likely need to consult on a case-by-case basis with the VT DEC Stormwater Program to determine whether or not a specific project will be subject to state jurisdiction.

Regardless, it is often significantly more cost-effective and efficient to incorporate stormwater management measures into a planned municipal project as compared to the construction of a “stand alone” stormwater management retrofit. The swirl separator installed near the corner of VT Routes 14 and 15 in the summer and fall of 2017 during construction of the Hardwick Village Sidewalks improvements is a prime example of how to take strategic advantage of such opportunities.

7. References

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Appendix A. Maps

Appendix B. Problem Area Data Sheets

Appendix C. Restoration Plans

Appendix D. Design Build Plans

Appendix E. Concept Designs for Priority Stormwater Problem Areas

Appendix F. Batch Input File for VTDEC Tracking