MOREHOUSE BROOK FLOW RESTORATION PLAN

Stone Project ID: 13-239

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This project was performed by Stone Environmental, Inc. and Aldrich + Elliott, PC under contract with the City of Winooski.

DISCLAIMER

The intent of this document is to present the data, evaluations, alternatives, preliminary designs and opinions of probable costs needed to support the development of a flow restoration plan for Morehouse Brook, as required by the National Pollutant Discharge Elimination System (NPDES) General Permit 3-9014 (VTDEC 2012) for stormwater discharges to impaired waters from municipal separate storm sewer systems (MS4). The presented plan is in draft form and, at this time, the MS4s are not bound in any way to the proposed BMP list.

EXECUTIVE SUMMARY

Stone Environmental, Inc., and partner Aldrich + Elliott, PC (A+E), were retained by the City of Winooski to develop a Flow Restoration Plan (FRP) for Morehouse Brook. The FRP was developed in accordance with the MS4 General Permit (3-9014), subpart IV.C.1. The purpose of the FRP is to serve as a planning tool for the MS4 entities in the Morehouse Brook watershed (the City of Winooski and the Town of Colchester) to implement stormwater Best Management Practices (BMPs) in an effort to return Morehouse Brook to its attainment condition.

In developing the FRP, an assessment was completed to determine to what extent current stormwater controls have reduced high flows (e.g., flows occurring less than 0.3% of the time) from the pre-2002 conditions as required by the *Total Maximum Daily Load [TMDL] to Address Biological Impairment in Morehouse Brook* (VTDEC 2007). The Best Management Practice Decision Support System (BMP DSS), a GIS-based hydrologic model used to assess the impacts of various BMP scenarios while developing the TMDL, was used to evaluate the impact of current stormwater controls on high flows in Morehouse Brook.

According to the review completed under this contract, Morehouse Brook is much closer to meeting its attainment condition than it was when the TMDL was prepared, largely as a result of the diversion structure installed in the Malletts Bay Ave. storm sewer (sometimes referred to as the Brookside Diversion), which diverts storm flow from more than 65 acres of the watershed directly to the Winooski River. Other practices implemented since preparation of the TMDL include improved BMPs in the Highland Industrial Park, as well as several smaller BMPs implemented by the City of Winooski within their right-of-way.

In addition, as part of this review, a comprehensive evaluation was completed of the future growth allocation contained in the TMDL. This is important because the TMDL requires reductions from currently developed areas that are equal to the future impacts of new impervious surfaces that are not subject to State of Vermont stormwater permitting requirements (and therefore are considered “non-jurisdictional”). The TMDL currently assumes 10 acres of future growth in non-jurisdictional impervious surfaces. Using recent land use trends, our analysis shows that a net increase of less than one acre is a more reasonable estimate of non-jurisdictional impervious surface likely to be constructed between 2010 and 2025.

A suite of potential BMPs and retrofit projects were identified as part of FRP development, including:

- Two stormwater infiltration basins in Landry Park;
- Green stormwater infrastructure (GSI) practices in the neighborhoods along and to the west of North St. (e.g., Dufresne Dr., Brisson Ct., Cedar St.);
- A retrofit of the existing detention pond servicing the Pine Grove neighborhood; and
- A new bioretention area to the west of Brisson Ct.

Sketch plans were developed for each of the potential BMPs and retrofit projects and presented to the MS4s. The infiltration basins in Landry Park and GSI practices within the City’s existing right-of-way (ROW) along Brisson Ct. and southern Cedar St. were prioritized for implementation. These projects could be accomplished wholly within land already owned by the City, and were determined to be sufficient to meet the high-flow target when assessed with the BMP DSS model. A 30% engineering design and planning level cost estimate was prepared for the infiltration basins, while a spreadsheet cost calculator was used to estimate the cost of the GSI practices. The two centralized practices were not pursued further.

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1. BACKGROUND

Morehouse Brook drains a small, highly urbanized 234-acre watershed that straddles the town boundary between the City of Winooski and the Town of Colchester. The majority of the Morehouse Brook watershed is located in the City of Winooski, with a small portion in the Town of Colchester (Figure 1).

The entire stream and its tributaries are Class B waters designated as cold water fish habitat pursuant to the Vermont Water Quality Standards (WQS). Land use in the Morehouse Brook watershed is 88% developed land, 1% open land and 11% forested.

The stream generally flows in an east-west direction to the Winooski River (Figure 1). The lower stream channel, below (west of) Mallets Bay Avenue, has a relatively steep gradient confined within steep valley walls. This section of the stream is characterized by several mass failures of the stream bank, which are contributing large amounts of fine sediment in the stream channel near the mouth. The stream channel to the east of Mallets Bay Avenue is less steep and somewhat less affected by erosion.

Morehouse Brook is currently on Part D of the State of Vermont's 303(d) List of Impaired Waters indicating that it has a completed total maximum daily load (TMDL) that has been approved by the U.S. Environmental Protection Agency (EPA). The pollutants identified as responsible for the impairment in Morehouse Brook are stormwater runoff and erosion. The TMDL, which was developed and approved in 2007, identifies needed changes in watershed hydrology – a reduction in stormwater high flows and an increase in baseflow – to restore water quality. The flow targets are the basis for the flow restoration plan (FRP).

The FRP identifies the scope and scale of the best management practice (BMP) retrofits of existing impervious surface that, when implemented, are projected to meet the flow targets established in the TMDL and ultimately, to attain compliance with the Class B WQS. In addition, the Municipal Separate Storm Sewer System (MS4) general permit (issued December 5, 2012) outlines the following components of an FRP: identification of required controls, a construction and design schedule, a financial plan, regulatory analysis of any additional authorities needed to implement the FRP including support from the Vermont Department of Environmental Conservation (VT DEC), and any third party(ies) that have responsibility for implementing the FRP.

The two MS4s with impervious cover contributing to stormwater high flows in Morehouse Brook – the City of Winooski and the Town of Colchester – have agreed to prepare a joint FRP for the watershed, with flow-target allocation based on the relative share of impervious cover in the watershed, based on 2010 imagery (Table 1).

Table 1: Summary of Impervious Cover in the Morehouse Brook Watershed.

Jurisdiction	2010 Impervious Area (ac) [1]	Fraction of Watershed Area (%)
City of Winooski [2]	27.83	90.7%
Town of Colchester	2.85	9.3%
TOTAL	30.68	100.0%

[1] *Sourced from ESRI's "World Imagery" basemap. Imagery date: 08/28/2010.*

[2] *City of Winooski impervious area does not include area within the City diverted to the Winooski River as a result of the Malletts Bay Ave. diversion structure*

Figure 1. Morehouse Brook watershed boundaries

In considering the flow regime in Morehouse Brook, it is important to understand that the watershed boundary indicated in Figure 1 does not include a significant area within the City of Winooski that historically drained to Morehouse Brook, but has since been diverted to the Winooski River. In 2004, the City was awarded a 319 grant that, among other improvements, funded the construction of a diversion structure in the large-diameter storm sewer at the intersection of Malletts Bay Avenue and Morehouse Drive. The diversion structure was designed to utilize excess capacity as temporary in-pipe storage and to attenuate peak storm flows in Morehouse Brook by shunting flows during storm events up to the 2-year, 24-hour event (2.2 inches of rain in 24 hours) directly to the Winooski River. This area is identified in Figure 2, but has not been considered as part of the FRP because it was installed prior to the development of the Morehouse Brook TMDL.

1.1. TMDL Flow Targets

In developing the TMDLs for waters that were determined to be impaired by stormwater runoff, VT DEC chose to use flow as a surrogate. Flow was used as a surrogate because the impacts on streams of increased stormwater flows resulting from urbanization are cumulative and include multiple stressors. Using flow was thought to integrate the effects of multiple stressors all related to stormwater runoff. In general, the basis for the TMDL flow targets was a comparison of modeled flow duration curves (FDCs) between the impaired watershed and attainment watersheds with similar hydrologic characteristics where the WQS are currently met. In the case of Morehouse Brook, there was only one attainment stream with similar hydrologic characteristics. For this watershed, a modified approach was used to develop a range of attainment flows, which produced a more conservative target than simply using the flow of the single attainment stream as the target.

A FDC displays the percentage of time that a flow equals or exceeds a certain value, with low or baseflow represented by the 95th percentile ($Q_{95\%}$) of the curve and stormwater high flows at the 0.3% exceedance interval ($Q_{0.3\%}$). The FDC for the Morehouse Brook and its attainment watershed were compared to determine the percent change (e.g., reduction in high flows and increase in base flows) required from current conditions; the percent change was codified in the TMDL document, and is presented in Table 2 below.

Table 2: TMDL Flow Restoration Targets, with and without Future Growth Allocations.

Flow Target	High Flow ($Q_{0.3\%}$) Reduction Target (%) [1]	Low Flow ($Q_{95\%}$) Increase Target (%) [2]
TMDL Targets	-54.0%	15.0%
TMDL Targets with 10 acres of non-jurisdictional future growth	-65.3%	15.0%

[1] *The high flow reduction target is negative (-), indicating there needs to be a reduction in high flow from the baseline condition*

[2] *The low flow target is positive (+), indicating there needs to be an increase in low flow from the baseline condition; the low flow target is not actionable under the TMDL, but is included because improving base flow in the watershed is also a water quality goal*

The high flow target ($Q_{0.3\%}$) was determined to be relatively equivalent to the 1-year design storm flow, and therefore BMPs sized to manage the channel protection volume (CP_v) as described in the 2002 Vermont Stormwater Management Manual were optimal for sizing BMPs to achieve the required high-flow reductions.

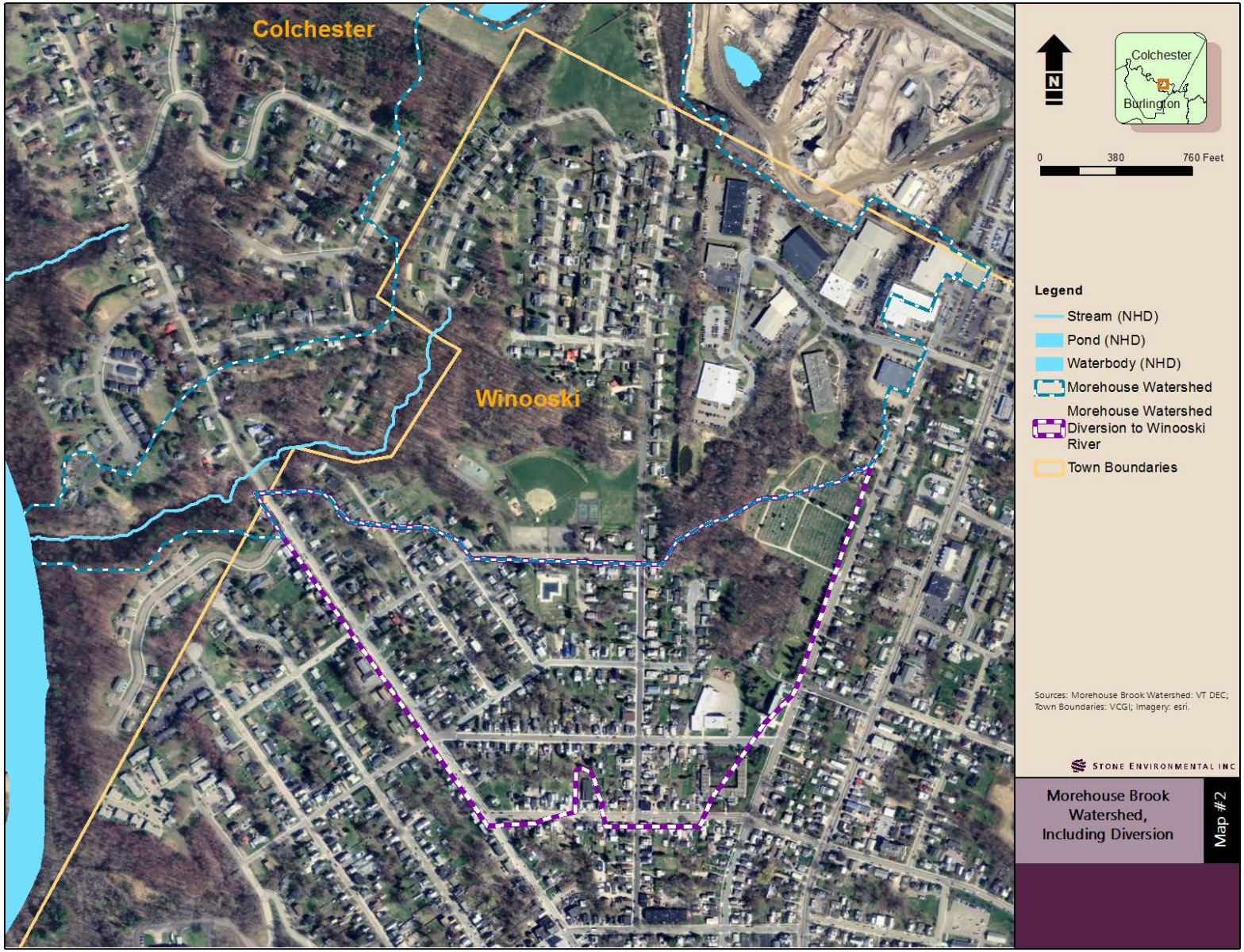

Figure 2. Pre-2004 Morehouse Brook watershed boundaries

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1.2. Future Growth

VT DEC added a future growth allocation to the TMDL flow targets to account for non-jurisdictional (e.g., not subject to state regulation and therefore unlikely to be managed by a BMP) impervious area that could reasonably be estimated to be constructed in the Morehouse Brook watershed during the next 10-15 years while the TMDL is implemented. New, non-jurisdictional impervious surfaces are typically created as a part of smaller projects – such as the construction of a single family home – that are not part of a common plan of development and therefore do not rise to the state regulatory threshold of one acre of post-construction impervious cover. The future growth allocation in the TMDL assumes that no local zoning or land use regulations would be in place that require stormwater management for smaller projects. The Morehouse Brook TMDL assumes that 10 acres of non-jurisdictional impervious surface will be created.

In order to incorporate the future growth estimate into the flow restoration target, 10 acres was added to the watershed's existing impervious cover to simulate projected watershed conditions when the TMDL is fully implemented. With the projected non-jurisdictional growth of 10 acres of impervious surface, the high flow target reduction was changed by -11.3% and the low flow target was unchanged (Table 2).

As a result, the reduction in peak flows required to account for future growth is 17.3% of the total flow reduction required. Given this and existing land use and development patterns in the Morehouse Brook watershed, a careful re-examination of the allocation was completed. Impervious areas that existed in the Morehouse Brook watershed in 2004[1] and in 2010[2] were manually digitized; these years were selected because high quality aerial imagery was readily available. Each parcel in the watershed was categorized in one of three ways:

- Parcels that are less than one acre in size;
- Parcels that are greater than one acre but currently contain less than one acre of impervious surface; and
- Parcels that are greater than one acre and currently have more than one acre of impervious surface.

A summary of impervious cover by parcel type and by municipality, for both 2004 and 2010, is presented in Table 3, below. Roads were not included in this analysis, consistent with the impervious cover analysis conducted by the Chittenden County Regional Planning Commission (CCRPC) during the development of the TMDL. Further, it was assumed that any new roads in this watershed would likely be for access to large future developments on larger parcels. Also, any new road expansions or sidewalk additions are likely to put the impervious area threshold on any roadway parcel over one acre. In either case, the net result would be that the road project would be subject to state stormwater standards.

As shown in Table 3, there was an increase of approximately 0.32 acres of impervious cover in the Morehouse Brook watershed between 2004 and 2010, which equates to an increase of 0.15% per year. More specifically, this net increase includes the construction of approximately 0.56 acres of impervious cover as well as the removal of 0.25 acres of impervious surface; a significant number of residential swimming pools were

[1] Orthophotos downloaded from the VT Center for Geographic Information (VCGI). Imagery shot from 8 May to 12 May, 2004.

[2] Sourced from ESRI's "World Imagery" basemap. Imagery date: 8/28/2010.

decommissioned during the evaluation period. Although the pool itself was considered pervious, the removal of surrounding patio areas accounts for much of the removed impervious surfaces.

The watershed-specific impervious area growth rate (0.15% per year) was applied to impervious areas within the Morehouse Brook watershed to estimate the acreage of non-jurisdictional impervious growth potential using the following equation:

$$\text{Non-jurisdictional impervious acres} = \text{2010 impervious acres} * ((1 + \%\ \text{change per year})^{\#\ \text{years}})$$

$$= 30.68\ \text{acres} * (1 + 0.15)^{15}) = 31.38\ \text{acres or } \underline{0.70\ \text{acres increase between 2010 and 2025}}$$

Table 3: Summary of Impervious Cover by Parcel Type

	Parcel Type	Parcel Count	Total Parcels	Percent of Parcels	2004 Impervious Area (ac)	2010 Impervious Area (ac)	Area Change (ac)	Percent Change
Winooski	Less than one acre	142	159	89.3%	9.78	9.86	0.08	
	>1 acre with <1 acre impervious	9	159	5.7%	2.54	2.71	0.17	
	>1 acre with >1 acre impervious	8	159	5.0%	15.23	15.27	0.03	
	SUBTOTAL				27.55	27.83	0.28	1.0%
Colchester	Less than one acre	48	59	81.4%	1.98	1.99	0.01	
	>1 acre with <1 acre impervious	11	59	18.6%	0.83	0.86	0.03	
	>1 acre with >1 acre impervious	0	59	0.0%	0.00	0.00	0.00	
	SUBTOTAL				2.81	2.85	0.04	1.5%
Watershed-wide	TOTAL				30.36	30.68	0.32	1.1%

This estimate is conservative because it does not consider whether each parcel could actually add more impervious area given site and/or zoning constraints, nor were parcels within the watershed that are already subject to a state stormwater permit identified. Even with these conservative assumptions, it was estimated that a net increase of less than one acre of non-jurisdictional impervious cover could reasonably be estimated to be constructed between 2010 and 2025.

Based on this analysis, a future growth allocation of one acre was carried through the VTBMPDSS model assessment and identification of required controls. Reducing the estimated future growth in non-jurisdictional impervious surface to one acre changed the high flow target reduction; the specific impact of the proposed reduction in future growth is presented in Section 2.

2. VTBMPDSS MODEL ASSESSMENT

The VTBMPDSS model is a continuous hydrological simulation model that estimates the effect of land use changes and stormwater BMPs on streamflow. This model was applied to the Morehouse Brook watershed to predict progress toward the TMDL flow targets based on proposed BMP implementation scenarios. The most important inputs to the model for this study are the GIS layers of land use, impervious cover, and soil, as well as the locations, configuration, and connections of the BMPs themselves. The VTBMPDSS model is used to predict stormwater high flows and baseflows at the watershed outlet for a base condition (pre-2002) and then a future BMP implementation condition. VT DEC requires the use of the model to document compliance with the TMDL flow restoration targets. VT DEC established both a base and a credit (existing conditions) model scenarios to determine the remaining high flow reduction needed under the flow restoration plan. As described below, the Base and Credit Scenarios were updated to correct errors, add BMPs constructed since the VTBMPDSS was last updated, and make minor subwatershed boundary adjustments.

The Base Scenario establishes watershed conditions and flows against which the 2007 Morehouse Brook TMDL flow restoration targets are applied. The original Base Scenario uses impervious cover data extracted from QuickBird high-resolution satellite imagery, and includes stormwater BMPs installed prior to the issuance of the 2002 Vermont Stormwater Management Manual, when only large storms (i.e. 10-year storm events) required flow reduction. In coordination with VT DEC, an updated Base Scenario was developed to reflect lessons learned in modeling other watersheds, including resampling the land use and slope layers that define how runoff is generated in the model, and updating soils data for Landry Park based on the results of field investigationVT DEC also adjusted a number of subwatershed boundaries within the model as better information became available. Taken together, these adjustments to the VTBMPDSS Base Scenario resulted in updated flow restoration targets presented in Table 4, below.

Table 4: Updated Base Scenario Flow Restoration Targets, With and Without Updated Future Growth Allocations.

Flow Target	High Flow ($Q_{0.3\%}$) Target (%) [1]	Low Flow ($Q_{95\%}$) Target (%) [2]
Updated Targets	-52.3%	15.0%
Updated Targets with 1 acre of non-jurisdictional future growth	-53.4%	15.0%

[1] *The high flow reduction target is negative (-), indicating there needs to be a reduction in high glow from the baseline condition*

[2] *The low flow target is positive (+), indicating there needs to be an increase in low flow from the baseline condition; the low flow target is not actionable under the TMDL, but is included because improving base flow in the watershed is also a water quality goal*

The Credit Scenario represents current conditions and includes changes in the watershed that have occurred since the time of the Base Scenario's creation. The suite of BMPs installed as part of the Highland Industrial Park Stormwater Mitigation Project (6727-INDS.A1) were incorporated into VTBMPDSS, replacing the pre-2002 controls at this site considered under the Base Scenario. In addition, the North Street rain gardens constructed by the City Department of Public Works were added to the Credit Scenario.

The Flow Restoration Scenario represents the retrofits needed to sufficiently manage high flows in order to achieve the flow restoration target in the TMDL. In addition, as discussed in Section 1.2, the future growth allocation was revisited and an updated assumption about potential growth in non-jurisdictional impervious surfaces was incorporated into the Flow Restoration Scenario. The Flow Restoration Scenario is discussed in more detail in Section 3.

3. IDENTIFICATION OF REQUIRED CONTROLS

In 2015, field studies were performed throughout the Morehouse Brook watershed to identify and evaluate existing BMPs that were candidates for retrofits, as well as potential locations for new BMPs. Each site was reviewed to determine its ability to meet the CP_v criteria of the 2002 Vermont Stormwater Management Manual. This criterion was utilized as part of the FRP evaluation since the 1-year, 24-hour storm event is a close approximation to the storm event associated with the $Q_{0.3\%}$ flow. The CP_v criterion requires 12-hours of detention for cold water fish habitats, such as Morehouse Brook.

Table 5, below, lists the candidate BMP sites, provides general information about each BMP, and highlights practices that were modeled as part of the FRP. Additional information for each BMP considered in the initial evaluation is provided in Appendix A. While some field work was performed as part of identifying these candidate sites, no detailed hydrologic analysis, property research, engineering, or other studies were performed, and thus unidentified constraints may exist that prevent certain sites from being utilized in the FRP.

Table 5: Summary of BMPs Considered in Developing the Morehouse Brook FRP.

BMP ID	Permit Number, if applicable	Site Name	BMP Type	Included in FRP?	Notes
WIN-1		North St, Brisson Ct, Cedar St, Dufrense Dr.	Infiltration	Y	Treatment of Brisson Ct and southern Cedar St included as part of the FRP; other areas are believed to drain to WIN-4 and therefore determined to be lower priority
WIN-2		Pine Grove Terr, north	Infiltration	N	Area drains to WIN-4 and therefore determined to be lower priority
WIN-3		Pine Grove Terr, south	Infiltration	N	Area drains to WIN-4 and therefore determined to be lower priority
WIN-4	1-0576	Pinegrove Development Associates	Wet pond	N	Permittee is Pinegrove Development Associates and has not been maintained for some time; some areas of public ROW drain to this facility which will need to be considered as part of future management scenarios
WIN-5		Landry Park, east	Infiltration	Y	Treating runoff from eastern parking lot and tennis courts
WIN-6		Landry Park, west	Infiltration	Y	Treating runoff from western parking lot
WIN-7	2-0628, 6727-INDS	Highland Industrial Park	Wet pond, infiltration	Y	Significant improvements were made to the Industrial Park's stormwater management facilities in 2013; these improvements are reflected in the existing condition (post-2002) model; no additional measures are included as part of the FRP
COL-1		Young St	Infiltration	N	Fire service turnaround requirements and steep slopes make retrofits challenging
COL-2		Malletts Bay Ave	Infiltration	N	Very limited space available for practice

Based an initial evaluation of the BMP opportunities, and discussions with the City of Winooski and Town of Colchester on BMP implementation feasibility, a preferred Flow Restoration Scenario was selected that meets the revised TMDL high flow reduction target (Table 6). The restoration scenario includes GSI retrofits in the municipal right-of-way along Brisson Ct. and southern Cedar St., and two infiltration areas to manage runoff from the parking lots at Landry Park. Concept designs for each of the BMPs included in the Flow Restoration Scenario are included in Appendix B, and were used in developing the initial cost estimates discussed further in Section 5. Basic soil testing (e.g., hand-augered test pits) was also conducted for the Landry Park sites and is included as Appendix C.

Table 6: VTBMPDSS Model Runs Summary for Proposed FRP Scenario.

VTBMPDSS Run	Scenario Description	Area (sq. mi)	Flow (cfs)		% change vs base	
			High (Q0.3%)	Low (Q95%)	High Flow (Q0.3%)	Low Flow (Q95%)
Original (TMDL) models	Attainment flow		3.179	0.092		
	DEC Base (2002)	0.4094	6.910	0.080		
Updated Models	Attainment flow		3.179	0.092		
	FRP Base	0.3662	6.670	0.070		
	FRP Credit	0.2581	3.310	0.080	-50.4%	14.3%
	WIN-5/6	0.2581	3.130	0.080	-53.1%	14.3%
	WIN-5/6 + WIN-1	0.2581	3.080	0.080	-53.8%	14.3%

4. DESIGN AND CONSTRUCTION SCHEDULE

The 2012 MS4 permit requires that this FRP include a design and construction schedule for the stormwater BMPs that have "been identified by the permittee[s] as necessary to achieve the flow restoration targets." The schedule must provide for implementation of the BMPs as soon as possible, but no later than 20 years from the effective date of MS4 permit, which is December 5, 2012--meaning that the BMPs must be implemented by the end of 2032. The BMPs included in this FRP will require permitting and design work prior to construction, and will have varying costs. Given the limited nature of the BMPs identified as necessary to achieve the high flow target, and barring any unforeseen complications, it is anticipated the implementation of the BMPs will be completed within eight years from receipt of approval of this FRP from VT DEC. An eight year planning horizon was selected in order to provide an opportunity for the City of Winooski and the Town of Colchester to account for these projects in their respective long-range (e.g., 5-year) capital budgets.

5. FINANCIAL PLAN

The 2012 MS4 permit also requires that this FRP include a financing plan that estimates the costs for implementing the FRP and describes a strategy for financing the FRP. Costs for implementing the BMPs have been calculated based on the memorandum from Tetra Tech, Inc. dated October 30, 2007. These rates use a 2000 base year and have been updated to account for inflation to the year 2022, using a 2.5% inflation rate. The 2022 year was chosen, assuming that the VT DEC will approve this FRP in early 2017. The costs are calculated based on the following equation:

total cost = installation cost (I) + land cost (L) + fixed cost (F)

Where:

I = $6/cf of infiltration, inflated at 2.5% to year 2022 = $10.40/cf

L = $0 as it is not anticipated that property will be required to be purchased

F = project-specific estimate of design/permitting costs

The anticipated costs associated with implementing each BMP identified in Section 4 are presented below in Table 7.

Table 7: Proposed BMP Cost Estimates.

BMP ID	Site Name	Infiltration Volume (cf)	I ($)	F ($)	Total Cost ($)
WIN-1	Brisson Ct; southern Cedar St	5,449	$56,650	$11,500	$68,150
WIN-5 [1]	Landry Park, east	3,479	$36,200	$5,450	$41,650
WIN-6 [1]	Landry Park, west	2,378	$24,750	$3,700	$28,450
TOTAL					**$138,250**

[1] *Does not include any costs associated with parking lot reconstruction which may be needed to promote drainage to BMPs*

6. REGULATORY ANALYSIS

As part of this FRP, no retrofits are being proposed for the site with an expired State operational stormwater permit (WIN-4, Pinegrove Development Associates). Further, it is projected that sufficient retrofit opportunities exist within existing municipal landholdings – Landry Park and road right-of-ways – to achieve the flow targets without having to consider retrofit projects on private land. Although the City of Winooski will ultimately need to determine if the Pinegrove Development pond is eligible for a Residual Designation Authority permit from the State or whether the facility will need to be adopted by the City under its MS4, that decision does not need to be made as part of this FRP.

APPENDICES

APPENDIX A: CONSIDERED FLOW REDUCTION BMPS

ID#: WIN-1

Name: North Street, Brisson and Pine Grove

Concept Description:
Wide, flat street w/ room for on-street parking. A number of roof leaders discharge onto driveways. Opportunities for traffic-calming bump-outs to manage road runoff. Some yards appear amenable to residential-scale rain gardens.

Notes/Feasibility:
Willingness of landowners to install rain gardens is unknown; there may be some resistance to repurposing of on-street parking for stormwater treatment

GENERAL SITE INFORMATION

Site Contact Info:	City of Winooski
Ownership:	Public/private
Land Use Type:	Road/SFRs
Existing BMP on Site?	No
Is site a hotspot?	No
Sources/pollutants:	Road runoff
Soils:	HSG A

SIZING INFORMATION

Drainage Area (ac):	City input needed
Impervious Area (ac):	"
Practice Area Available (ft^2):	"
Existing Head Available?	Yes

RETROFIT DETAILS

Project Candidate:	Yes
Retrofit of new or existing BMP:	New
Proposed Retrofit Practice 1:	Traffic-calming bump-out
Proposed Retrofit Practice 2:	
Non-Structural Controls:	Downspout disconnection
Maintenance Burden:	low

Benefits:		Conflicts:	
Storage	No	Soils	No
Water quality	Yes	Access	Maybe
Recharge	Yes	Land Use	Maybe
Demonstration	Yes	Utilities	Maybe
Repair	No	Wetlands	No

Date: 07/14/15 Assessed by: JSM/CG

ID#: WIN-2

Name: Pine Grove Terr, west of Cedar St

Concept Description:
Wide, flat street w/ room for on-street parking. A number of roof leaders discharge onto driveways. Opportunities for traffic-calming bump-outs to manage road runoff. In addition, existing green space between sidewalk and road could be repurposed as a "green gutter".

Notes/Feasibility:
Utilities in this neighborhood are buried and may limit some options in the ROW

GENERAL SITE INFORMATION

Site Contact Info:	City of Winooski
Ownership:	Public/private
Land Use Type:	Road/SFRs
Existing BMP on Site?	No
Is site a hotspot?	No
Sources/pollutants:	Road runoff
Soils:	HSG A

SIZING INFORMATION

Drainage Area (ac):	City input needed
Impervious Area (ac):	"
Practice Area Available (ft^2):	"
Existing Head Available?	Yes

RETROFIT DETAILS

Project Candidate:	Yes
Retrofit of new or existing BMP:	New
Proposed Retrofit Practice 1:	Green street/green gutter
Proposed Retrofit Practice 2:	
Non-Structural Controls:	Downspout disconnection
Maintenance Burden:	Medium

Benefits:		Conflicts:	
Storage	No	Soils	No
Water quality	Yes	Access	No
Recharge	Yes	Land Use	Maybe
Demonstration	Yes	Utilities	Maybe
Repair	No	Wetlands	No

Date: 07/14/15

Assessed by: JSM/CG

ID#: WIN-3

Name: End of Pine Grove Terrace

Concept Description:
End of Pine Grove Terrace has odd-shaped "cul-de-sac"; existing storm pond is beyond berm on right-side pf photo. Significant erosion was evident below the storm drain outfall that drains cul-de-sac. The cul-de-sac could be reconfigured to reduce the impervious area and create space for storage.

Notes/Feasibility:
Any space that could be created here might may be more efficient to use for pond expansion (see WIN-4, which receives runoff from ~30 acres).

GENERAL SITE INFORMATION

Site Contact Info:	City of Winooski
Ownership:	Public/private
Land Use Type:	Road/SFRs
Existing BMP on Site?	No
Is site a hotspot?	No
Sources/pollutants:	Road runoff/yard waste
Soils:	HSG A

SIZING INFORMATION (measured from GIS)

Drainage Area (ac):	~1 ac to outfall
Impervious Area (%):	50%
Practice Area Available (ft²):	1500 sf
Existing Head Available?	Yes

RETROFIT DETAILS

Project Candidate:	Maybe
Retrofit of new or existing BMP:	New
Proposed Retrofit Practice 1:	Infiltration area
Proposed Retrofit Practice 2:	
Non-Structural Controls:	Impervious cover removal
Maintenance Burden:	Medium

Benefits:		Conflicts:	
Storage	No	Soils	No
Water quality	Yes	Access	No
Recharge	Yes	Land Use	Maybe
Demonstration	Yes	Utilities	Maybe
Repair	No	Wetlands	No

Date: 07/14/15 Assessed by: JSM/CG

ID#: WIN-4

Name: Pine Grove Pond

Concept Description:
Retrofit existing, pre-2002 pond to increase detention time and better manage peak flows. Pond appears to have received limited maintenance; outlet was not viewed during initial site visit.

Notes/Feasibility:
As noted on WIN-3, due to space constraints expansion of pond could preclude construction of infiltration practice at the end of Pine Grove Terr

GENERAL SITE INFORMATION

Site Contact Info:	City of Winooski
Ownership:	Public/private
Land Use Type:	Road/SFRs
Existing BMP on Site?	Yes
Is site a hotspot?	No
Sources/pollutants:	Road runoff/yard waste
Soils:	HSG A

SIZING INFORMATION (measured from GIS)

Drainage Area (ac):	~30 ac
Impervious Area (%):	30%
Practice Area Available (ft²):	6000 sf, incl. existing pond
Existing Head Available?	Yes

RETROFIT DETAILS

Project Candidate:	Yes
Retrofit of new or existing BMP:	Existing
Proposed Retrofit Practice 1:	Pond improvements
Proposed Retrofit Practice 2:	
Non-Structural Controls:	Downspout disconnection
Maintenance Burden:	Low

Benefits:		Conflicts:	
Storage	Yes	Soils	No
Water quality	Yes	Access	No
Recharge	No	Land Use	Maybe
Demonstration	No	Utilities	Maybe
Repair	Yes	Wetlands	Maybe

Date: 07/14/15

Assessed by: JSM/CG

ID#: WIN-5

Name: Landry Park Tennis Courts

Concept Description:
There is considerable rill erosion on the slope to the south of the tennis courts, which appears to be attributable to runoff from the courts. In addition, a portion of the parking lot drains to the north and east. A bioswale could be constructed at the toe of the court-side slope to convey runoff to the corner of the parking lot, where an infiltration basin could be constructed in place of several existing parking spots.

Notes/Feasibility:
Existing dumpster should be relocated. Parking could be reconfigured and/or a paved swale added to encourage additional area to drain to the north and east.

GENERAL SITE INFORMATION

Site Contact Info:	City of Winooski
Ownership:	Public
Land Use Type:	Parking lot/Landry Park
Existing BMP on Site?	No
Is site a hotspot?	No
Sources/pollutants:	Athletic fields
Soils:	HSG A

SIZING INFORMATION (measured from GIS)

Drainage Area (ac):	0.75 ac
Impervious Area (%):	50%
Practice Area Available (ft^2):	1500 sf
Existing Head Available?	Some

RETROFIT DETAILS

Project Candidate:	Maybe
Retrofit of new or existing BMP:	New
Proposed Retrofit Practice 1:	Infiltration area
Proposed Retrofit Practice 2:	Bioswale
Non-Structural Controls:	Impervious cover removal
Maintenance Burden:	Medium

Benefits:		Conflicts:	
Storage	No	Soils	No
Water quality	Yes	Access	No
Recharge	Yes	Land Use	Yes
Demonstration	Yes	Utilities	Maybe
Repair	No	Wetlands	No

Date: 07/14/15 Assessed by: JSM/CG

ID#: WIN-6

Name: Landry Park parking lot

Concept Description:
Western half of the parking lot at Landry Park drains to DI that is currently failed (e.g., collapsed). Soils surrounding the parking lot are HSG A; if parking lot is to be redone, consideration should be given to grading the lot to shed water toward adjacent green space and disconnect it from the storm drain system. There is also space off the northwest corner of the lot where an infiltration area could be established. Some potential for larger practice to north/west of lot near skate park; will required detailed review of existing infrastructure mapping.

Notes/Feasibility:
Although it is clear the City needs to take action to address the failed DI, it is not clear how extensive the renovation may be. Storm sewer maps indicate that Industrial Park pond drains to sewer line that passes thru/under park.

GENERAL SITE INFORMATION

Site Contact Info:	City of Winooski
Ownership:	Public
Land Use Type:	Parking lot/Landry Park
Existing BMP on Site?	No
Is site a hotspot?	No
Sources/pollutants:	Athletic fields
Soils:	HSG A

SIZING INFORMATION (measured from GIS)

Drainage Area (ac):	~0.5 ac
Impervious Area (%):	90%
Practice Area Available (ft²):	1500 sf
Existing Head Available?	Some

RETROFIT DETAILS

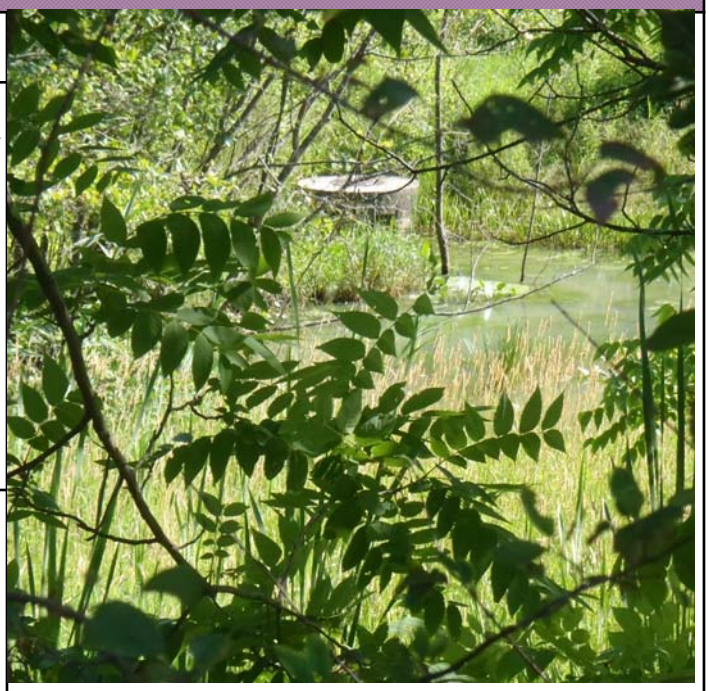
Project Candidate:	Maybe
Retrofit of new or existing BMP:	New
Proposed Retrofit Practice 1:	Infiltration area
Proposed Retrofit Practice 2:	
Non-Structural Controls:	
Maintenance Burden:	Medium

Benefits:		Conflicts:	
Storage	No	Soils	No
Water quality	Yes	Access	No
Recharge	Yes	Land Use	Yes
Demonstration	No	Utilities	Maybe
Repair	Yes	Wetlands	No

Date: 07/14/15 Assessed by: JSM/CG

ID#: WIN-7

Name: Highland Industrial Park Pond



Concept Description:
Retrofit existing pond to increase detention time and better manage peak flows. Pond appears to have received limited maintenance; outlet was not viewed during initial site visit.

Notes/Feasibility:
Numerous upgrades have been implemented within the industrial park. It will be important o understand the detention time and the impact that the overall system currently has on flows at the watershed outlet

GENERAL SITE INFORMATION

Site Contact Info:	Highland Industrial Park
Ownership:	Private
Land Use Type:	Commercial/industrial
Existing BMP on Site?	Yes
Is site a hotspot?	No
Sources/pollutants:	Road runoff
Soils:	HSG A

SIZING INFORMATION (measured from GIS)

Drainage Area (ac):	25 ac
Impervious Area (%):	75%
Practice Area Available (ft^2):	??
Existing Head Available?	Yes

RETROFIT DETAILS

Project Candidate:	Maybe
Retrofit of new or existing BMP:	Existing
Proposed Retrofit Practice 1:	Pond improvements
Proposed Retrofit Practice 2:	
Non-Structural Controls:	
Maintenance Burden:	Low

Benefits:		Conflicts:	
Storage	Yes	Soils	No
Water quality	Yes	Access	No
Recharge	No	Land Use	No
Demonstration	No	Utilities	No
Repair	??	Wetlands	??

Date: 07/14/15 Assessed by: JSM/CG

ID#: COL-1

Name: Young Street

Concept Description:
Cul-de-sac at the south west end of Young St has two DIs. Significant erosion was evident below the storm drain outfall connected to these structures. The cul-de-sac could be reconfigured to reduce the impervious area and create space for storage/infiltration. This area is mapped as having highly infiltrative soils.

Notes/Feasibility:
Need to understand Colchester requirements for cul-de-sac layout to determine area eligible for practice; may be able to cover next set of Dis to the north on Young St to increase drainage area

GENERAL SITE INFORMATION

Site Contact Info:	Town of Colchester
Ownership:	Public/private
Land Use Type:	Road/SFRs
Existing BMP on Site?	No
Is site a hotspot?	No
Sources/pollutants:	Road runoff, yard waste
Soils:	HSG A

SIZING INFORMATION

Drainage Area (ac):	~1 ac
Impervious Area (ac):	50%
Practice Area Available (ft²):	~2000 sf
Existing Head Available?	Yes

RETROFIT DETAILS

Project Candidate:	Yes
Retrofit of new or existing BMP:	New
Proposed Retrofit Practice 1:	Infiltration area
Proposed Retrofit Practice 2:	
Non-Structural Controls:	Impervious cover removal
Maintenance Burden:	Medium

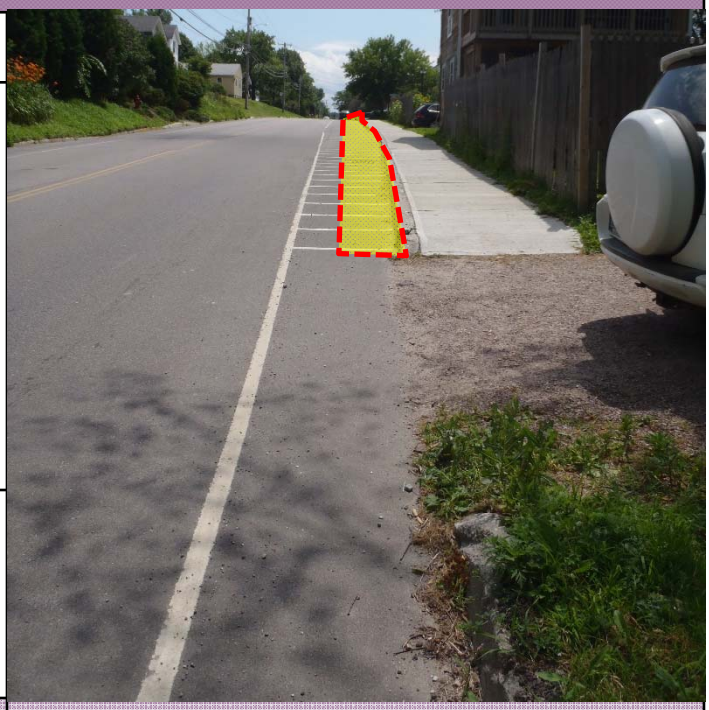
Benefits:		Conflicts:	
Storage	Yes	Soils	No
Water quality	Yes	Access	No
Recharge	Yes	Land Use	Maybe
Demonstration	Yes	Utilities	Maybe
Repair	Yes	Wetlands	No

Date: 07/14/15

Assessed by: JSM/CG

ID#: COL-2

Name: Malletts Bay Ave



Concept Description:
Near where Malletts Bay Ave crosses over Morehouse Brook, there is a swath of unused pavement that is neither available for parking or as part of the travel lane. This area could be depaved and a green gutter installed.

Notes/Feasibility:
There is considerable bike traffic along Malletts Bay Ave and care would need to be taken to ensure that enough room remains for both bikes and cars to travel safely.

GENERAL SITE INFORMATION

Site Contact Info:	Town of Colchester
Ownership:	Public
Land Use Type:	Road
Existing BMP on Site?	No
Is site a hotspot?	No
Sources/pollutants:	Road runoff, yard waste
Soils:	HSG A

SIZING INFORMATION

Drainage Area (ac):	~0.25 ac
Impervious Area (ac):	100%
Practice Area Available (ft²):	~300 sf
Existing Head Available?	Yes

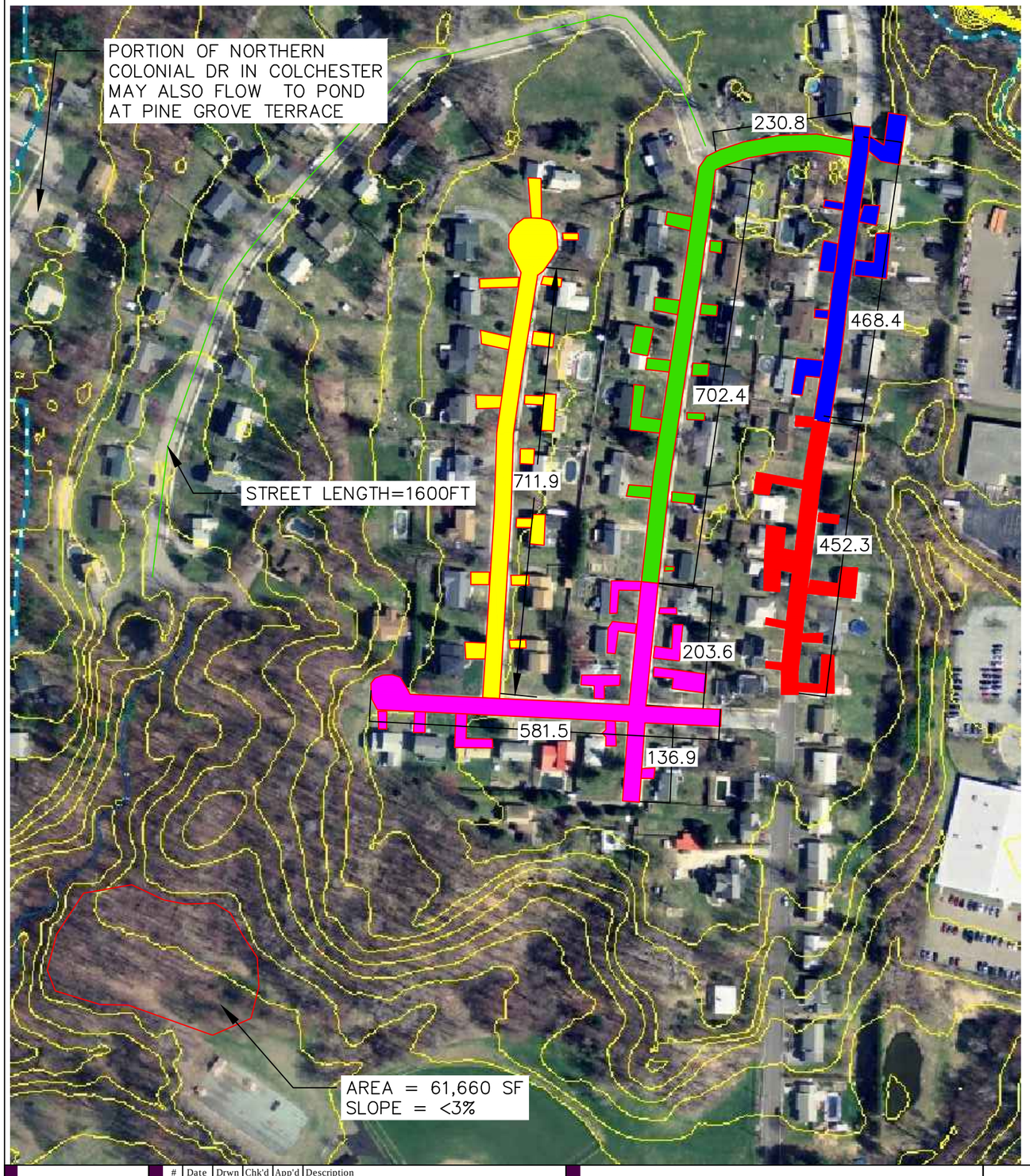
RETROFIT DETAILS

Project Candidate:	Yes
Retrofit of new or existing BMP:	New
Proposed Retrofit Practice 1:	Green street/gutter
Proposed Retrofit Practice 2:	
Non-Structural Controls:	Impervious cover removal
Maintenance Burden:	Medium

Benefits:		Conflicts:	
Storage	No	Soils	No
Water quality	Yes	Access	No
Recharge	Yes	Land Use	Maybe
Demonstration	Yes	Utilities	Maybe
Repair	No	Wetlands	No

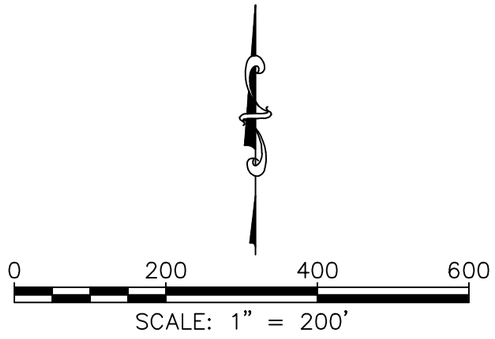
Date: 07/14/15 Assessed by: JSM/CG

APPENDIX B: FLOW RESTORATION SCENARIO BMP CONCEPT DESIGNS



DRAINAGE	IMPERVIOUS AREA (SF) [1]	DESTINATION	TOTAL BMP FOOTPRINT (SF)	TOTAL LENGTH OF BUMPOUT [2]	GREEN GUTTER POTENTAL (SF) [3]
YELLOW (DUFRESNE DR)	41,600	POND AT PINE GROVE TERRACE	5,283	881	1,422
PINK (BRISSON CT & SOUTHERN CEDAR ST)	42,903	WEST TO MOREHOUSE BROOK DIRECT	5,449	908	1,566
GREEN (CEDAR ST)	39,288	POND AT PINE GROVE TERRACE	4,990	832	1,404
BLUE (UPPER NORTH ST)	24,231	EAST TO INDUSTRIAL PARK SYSTEM	3,077	513	NONE
RED (NORTH ST)	24,615	EAST TO INDUSTRIAL PARK SYSTEM	3,126	521	NONE

[1] INCLUDES: STREET, ROOFS, DRIVES, SIDEWALKS [2] 6' WIDTH [3] 2' WIDTH



WIN-1 & WIN-2
NORTH , BRISSON, PINE GROVE, CEDAR, DUFRENSE STREETS

DRAWING CREDITS
Drawn On: 12/28/2015
Drawn By: CAG
Checked On:
Checked By:
Project No.: 13-239

REVISIONS

#	Date	Drwn	Chk'd	App'd	Description

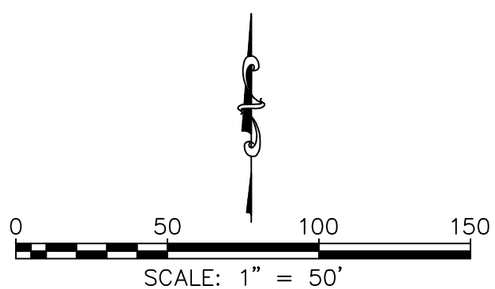
DRAWING SCALE
File:

STONE ENVIRONMENTAL
535 Stone Cutters Way / Montpelier / VT / 05602 / USA
802.229.4541 / info@stone-env.com / www.stone-env.com

MOREHOUSE BRROK
FLOW REDUCTION ALTERNATIVES
WIN-1 AND WIN-2
WINOOSKI VT

FIGURE NO. 1

DRAINAGE	IMPERVIOUS AREA (SF)	DESTINATION	TOTAL BMP FOOTPRINT (SF)
TENNIS COURT & EAST PARKING LOT	27,392	CATCH BASINS	3,479
WEST PARKLING LOT	18,727	CATCH BASINS	2,378



DRAWING CREDITS
Drawn On: 12/28/2015
Drawn By: CAG
Checked On:
Checked By:
Project No.: 13-239

REVISIONS

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MOREHOUSE BRROK
FLOW REDUCTION ALTERNATIVES
WIN-5 AND WIN-6
WINOOSKI VT

FIGURE NO.
3

APPENDIX C: LANDRY PARK SOIL TEST RESULTS

Morehouse Brook Watershed Flow Restoration Plan Development, Winooski, Vermont – Hand Auger Soil Test Logs

Soils investigation in Landry Park conducted by Amy Macrellis of Stone Environmental, Inc. on April 28, 2016. No others were present during the investigation. The area of primary focus was the area of soils located north of the tennis court and in the outfield of the baseball diamond, where the Chittenden County Soil Survey shows the soils mapped as "fill material". Overall, the structure and redoximorphic features in the soil profiles evaluated were not indicative of recent fill. It appears that material was generally removed, rather than filled in, during construction of the park.

Auger Test Hole AH-1 (northeast of tennis court)

0" – 8"	Very dark brown (7.5YR 2.5/2) fine sandy loam, weak granular structure, friable consistence, moist. Topsoil with robust grass cover.
8" – 14"	Olive brown (2.5Y 4/3) loamy very fine sand, weak subangular blocky structure, friable consistence, moist.
14" – 30"	Light olive brown (2.5Y 5/3) silt loam, moderate platy structure, firm consistence, moist. Few medium distinct mottles at 24", wet at 30".

No bedrock to depth. Seasonal high groundwater indicators at 24". Structure and redoximorphic features in this soil profile are not indicative of recent fill.

Auger Test Hole AH-2 (just outside NW corner of ball field)

0" – 5"	Dark brown (7.5YR 3/2) very fine sandy loam, weak granular structure, loose consistence, moist. Topsoil.
5" – 9"	Dark grayish brown (2.5Y 4/2) very fine sandy loam, weak subangular blocky structure, friable consistence, moist.
9" – 14"	Olive brown (2.5Y 4/4) very fine sandy loam, weak subangular blocky structure, friable consistence, moist.
14" – 26"	Dark grayish brown (2.5Y 4/2) silt loam, moderate platy, firm consistence, dry. Very hard digging at 20". Few medium faint mottles at 22".

No bedrock to depth. Seasonal high groundwater indicators at 22". Structure and redoximorphic features in this soil profile are not indicative of recent fill.

Auger Test Hole AH-3 (middle of center field in the ballfield)

0" – 6"	Brown (7.5YR 5/2) loamy very fine sand, no discernable structure, friable consistence, moist. No topsoil at this location.
6" – 11"	Brown (7.5YR 4/2) loamy very fine sand, no discernable structure, friable consistence, moist.
11" – 30"	Yellowish brown (10YR 5/4) loamy very fine sand, fining downward to very fine sandy loam at 30", weak subangular blocky structure, friable consistence, moist. Many medium prominent mottles at 18" but easy digging to bottom of horizon.
30" – 36"	Yellowish brown (10YR 5/4) very fine sandy loam, moderate platy structure, firm consistence, moist. Many medium prominent mottles throughout.

No bedrock to depth. Seasonal high groundwater indicators at 18". Structure and redoximorphic features in this soil profile are not indicative of recent fill.

Auger Test Hole AH-4 (20 feet north of parking lot, between east crabapple tree and tennis court)

0" – 6"	Brown (7.5YR 5/2) loamy gravelly sand, no discernable structure, friable consistence, moist. No topsoil at this location.
6" – 18"	Yellowish brown (10YR 5/4) gravelly sand, no discernable structure, friable consistence, moist.
18" – 24"	Light olive brown (2.5Y 5/3) loamy gravelly fine sand, friable consistence, moist. Likely fill material – fragments of plastic bags and jumbled pieces of wood and roots. Some redoximorphic features in this horizon but it's not clear if these are any indication of seasonal high groundwater.
24" – 36"	Light olive brown (2.5Y 5/3) loamy very fine sand, friable consistence, moist. May be fill; still a few organic fragments to 36".
36" – 52"	Light olive brown (2.5Y 5/3) loamy very fine sand, friable consistence, moist. Firm consistence from 36-42"; many medium distinct mottles at 36". Soil texture does not change, but sand is wet and mottles are prominent at 52".

No bedrock to depth. Seasonal high groundwater indicators at 36".