CROSBY BROOK RESTORATION STUDY BRATTLEBORO, VT

Key Stakeholders:

VT Dept. of Environmental Conservation
VT Agency of Transportation (VTrans)
Town of Brattleboro

Funded By:

VT Agency of Transportation
Transportation Enhancement Grant
(Focus on VTrans Drainage)

NEWEA Spring Meeting
Omni Mt. Washington Resort
Bretton Woods, NH

June 9, 2015

PROJECT OVERVIEW

- CROSBY BROOK IS LOCATED IN BRATTLEBORO, VT.
- PROJECT WAS AN EXTENSION OF PRIOR WORK PERFORMED BY THE WINDHAM COUNTY CONSERVATION DISTRICT (STREAM GEOMORPHIC ASSESSMENTS)
- TRIBUTARY TO THE CONNECTICUT RIVER (NUTRIENT LOADING IS A CONCERN)
- ON THE 303(D) LIST AND IS IMPAIRED FOR SEDIMENT POLLUTION AND HABITAT ALTERATION DUE SEDIMENTATION, CHANNELIZATION AND BUFFER LOSS.
- IDENTIFIED AS A CLASS B /COLDWATER FISH HABITAT (TEMPERATURE CONCERNS)
- IMPROVE FLOW CONDITIONS, TEMPERATURE / DO AND PREVENT FURTHER DEGRADATION
- STREAM RESTORATION IS A UNIQUE COMBINATION OF PEAK FLOW CONTROLS, STORMWATER TREATMENT, GEOMORPHIC IMPROVEMENTS AND BUFFER ENHANCEMENTS

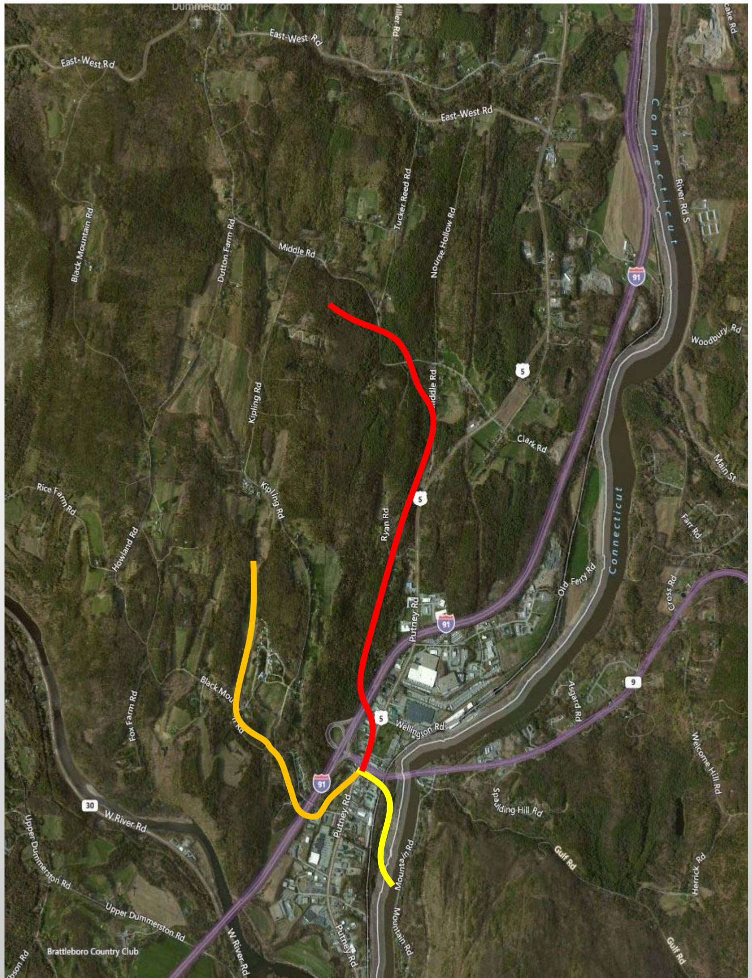
VTrans Working to Get You There

VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION

CROSBY BROOK

NORTH BRANCH

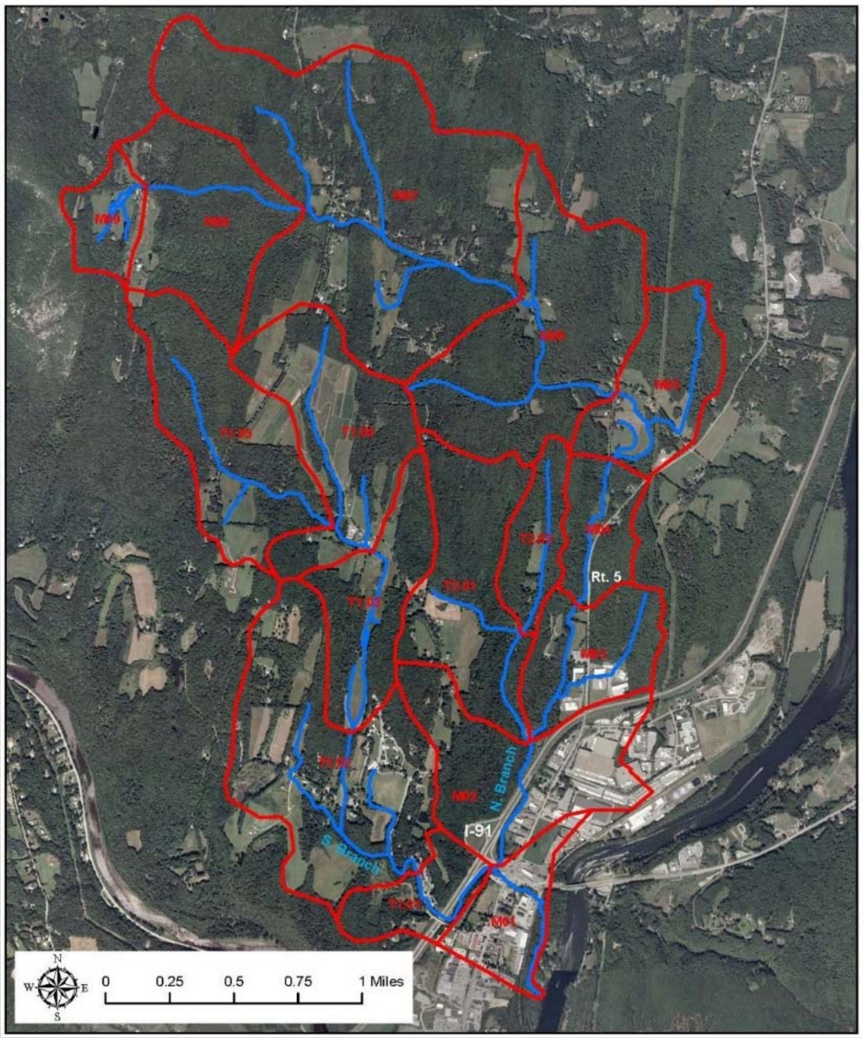
SOUTH BRANCH



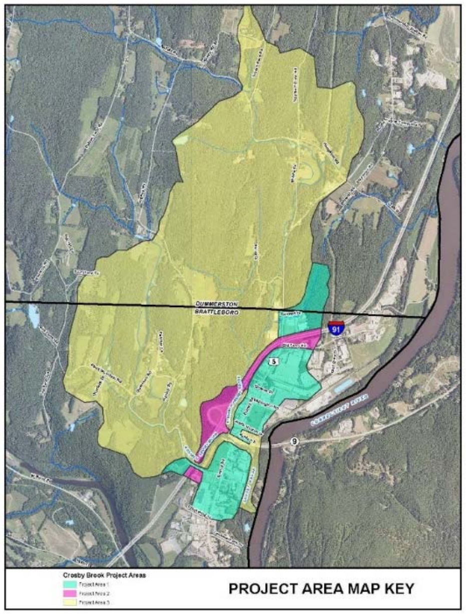
SOURCE: BING MAPS

- COLDWATER FISH HABITAT (BROOK TROUT).
- TWO SEPARATE BRANCHES;
- NORTH MAIN BRANCH IS APPROX. 4 MILES LONG;
- SOUTH MAIN BRANCH IS APPROX. 2 MILES LONG;
- THE TWO BRANCHES JOIN, TO THE WEST OF THE ROUTE 9 AND ROUTE 5 ROUND-ABOUT (EXIT 3);
- THE LAST LEG OF THE BROOK FLOWS THROUGH A BUSY URBANIZED AREA FOR APPROX. ½ MILE PRIOR TO DISCHARGE INTO THE CONNECTICUT RIVER;

CROSBY BROOK WATERSHED



- 6 SQUARE MILES;
- LOWER WATERSHED HIGHLY DEVELOPED WITH A MIX OF RESIDENTIAL AND COMMERCIAL PROPERTIES;
- STEEP UPPER WATERSHED MAINLY FORESTED WITH SOME AGRICULTURAL AND RESIDENTIAL LAND USES;
- THIS STUDY PRIMARILY FOCUSED ON A 350 ACRE HIGHLY DEVELOPED PORTION OF THE WATERSHED.
- GENERALLY HSG-B SOILS



CROSBY BROOK PROJECT AREA 1

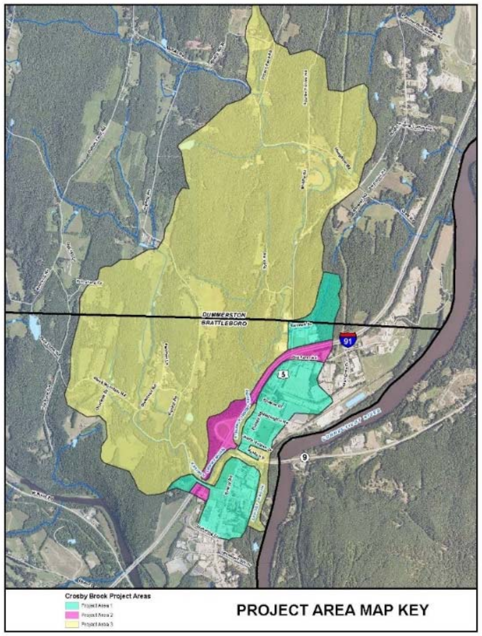
Route 5 & Route 9 – (Green Area)

- Approx. 240 acres
- Urbanized with commercial & industrial properties
- Approx. 40% impervious

- SEDIMENT LOADING FROM PARKING LOTS AND ROADWAYS
- HIGH PEAK FLOWS AND HIGH VELOCITY RUNOFF FROM LARGE IMPERVIOUS AREAS
- REQUIRES TREATMENT FOR SEDIMENT, FLOATABLES (SPILLS) AND NUTRIENTS
- IMPACTED BASEFLOW AND HIGHER RUNOFF TEMPERATURES

SOURCE: BING MAPS

CROSBY BROOK PROJECT AREA 2



Interstate Route 91 – (Pink Area)

- Approx. 110 acres
- Mainly paved roads with linear grassed areas
- Approx. 15% impervious

- SEDIMENT & SALT LOADING FROM THE HIGHWAY
- HIGH VELOCITY RUNOFF FROM LONG LINEAR IMPERVIOUS AREAS LEADS TO EROSION
- HIGHWAY DRAINAGE = MANY UNTREATED DIRECT DISCHARGES

SOURCE: BING MAPS

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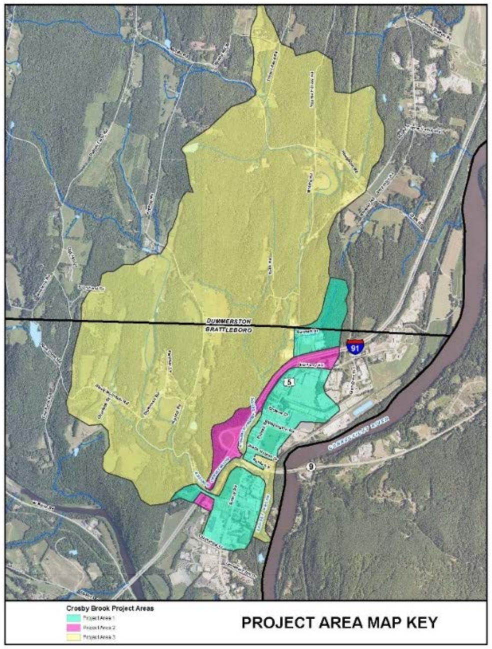
CROSBY BROOK PROJECT AREA 3



Route 9, Black Mountain Road and Middle Road – (Yellow Area)

- Approx. 750 acres
- Low density residential, meadows, agriculture and forested areas
- Less than 1% impervious but many steep slopes

- SEDIMENT LOADING FROM BANK EROSION AND MASS FAILURES
- SEDIMENT LOADING FROM STEEP GRAVEL ROADWAY DRAINAGE
- CHANNEL DEGRADATION (STREAM MORPHOLOGY)
- IMPACTS TO WILDLIFE PASSAGE AND NATURAL BUFFERS

SOURCE: BING MAPS

STP OVERVIEW

Project Goals

1. Identify potential ***stormwater treatment practices*** (STPs) for the Putney Road corridor with a target on sediment/temperature. Properly size STPs based on diverting drainage to open available space (future build-out and proposed Putney Road Master Plan).
2. Identify and size potential STPs for the Interstate Route 91 corridor with a target on retrofit projects to provide improved treatment within linear corridors.
3. Identify potential STPs in the upper watershed to minimize sedimentation, buffer loss and to stabilize the channel and banks.

- STP Identification – Location and Type
- STP Sizing – VT Stormwater Standards
- STP Selection – Ranking Process
- STP Recommendations – Most Effective

STP IDENTIFICATION

STP POTENTIAL LOCATIONS AND TYPES WERE SELECTED BASED ON AVAILABLE INFORMATION:

- FIELD REVIEWS (GEOMORPHIC ASSESSMENT & WATERSHED REVIEW)
- RESOURCE AREA REVIEWS (IDENTIFY PERMITTING)
- DETAILED PLAN REVIEWS (VTRANS AND BRATTLEBORO PLANNING)
- STPS WERE IDENTIFIED FOR EACH OF THE THREE PROJECT AREAS AND STP TYPE, SIZING AND SELECTION PROCESS WERE ALL BASED ON THE POTENTIAL POLLUTANT SOURCES AND SPECIFIC SITE CONSTRAINTS

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STP IDENTIFICATION

STP TYPES & CONSTRAINTS

STP TYPES were selected based on the potential issue and any site constraints observed during field investigations & plan reviews:

- Land use – Potential pollutants & Sources (VT SMM)
- Available Space – Existing & Future Development
- Potential Build-out
- Potential utility conflicts
- Location of bedrock
- Underlying Soils
- Shallow groundwater
- Maintenance access issues

The Vermont Stormwater Management Manual — Appendix A1

Table A.1. Land Use Matrix

STP Group	STP Design	Rural	Residential	Roads and Highways	Commercial/ High Density	Hotspots	Ultra Urban
Pond	Micropool ED	○	○	○	◗	①	●
	Wet Pond	○	○	○	◗	①	●
	Wet ED Pond	○	○	○	◗	①	●
	Multiple Pond	○	○	◗	◗	①	●
	Pocket Pond	○	◗	○	◗	●	●
Wetland	Shallow Marsh	○	○	◗	◗	①	●
	ED Wetland	○	○	◗	◗	①	●
	Pond/Wetland	○	○	◗	◗	①	●
	Gravel Wetland	○	◗	○	○	①	●
Infiltration	Infiltration Trench	◗	○	○	○	●	◗
	Shallow I-Basin	◗	○	◗	◗	●	◗
Filters	Surface Sand Filter	●	◗	○	○	②	○
	Underground SF	●	●	◗	○	○	○
	Perimeter SF	●	●	◗	○	○	○
	Organic SF	●	◗	○	○	②	○
	Bioretention	○	○	○	○	②	○
Open Channels	Dry Swale	○	◗	○	◗	②	◗
	Wet Swale	○	●	○	●	●	●
	Grass Channel	○	◗	○	◗	②	◗
Detention*	Pond/Vault	○	○	○	○	①	●

○: Yes. Good option in most cases.
◗: Depends. Suitable under certain conditions, or may be used to treat a portion of the site.
●: No. Seldom or never suitable.
①: Acceptable option, but may require a pond liner to reduce risk of groundwater contamination.
②: Acceptable option, if not designed as an exfilter. (An exfilter is a conventional stormwater filter without an underdrain system. The filtered volume ultimately infiltrates into the underlying soils.)
*: The pond/vault is not an acceptable stand-alone water quality STP.

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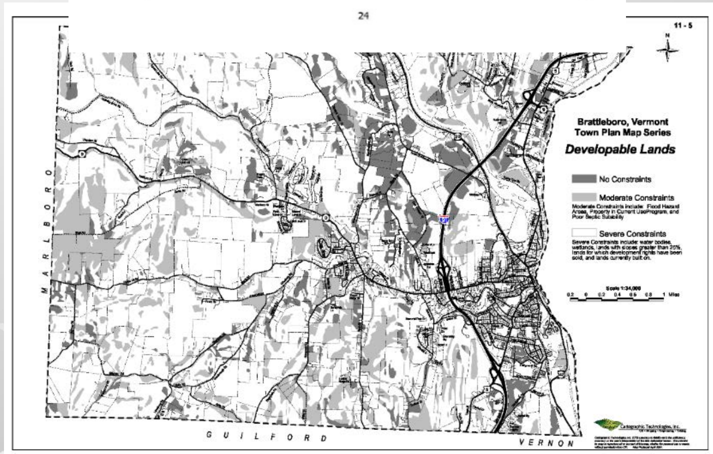

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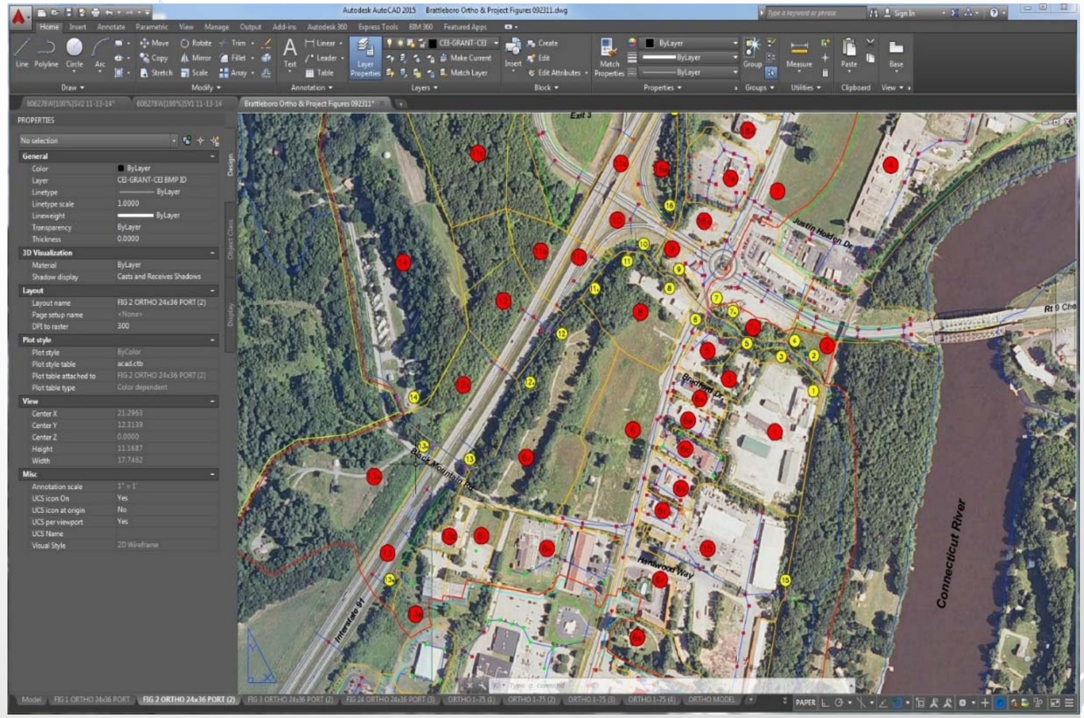
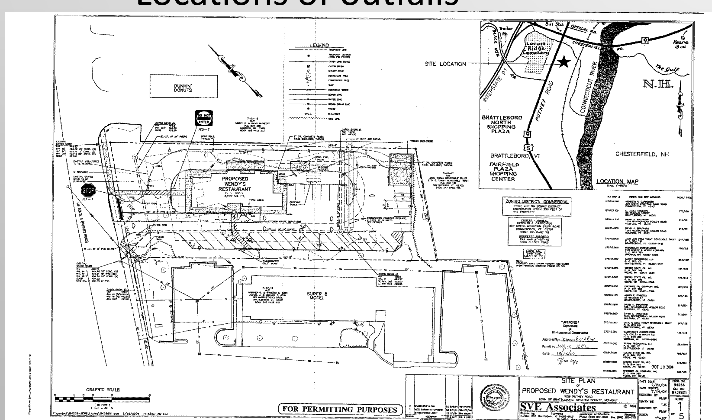
STP IDENTIFICATION

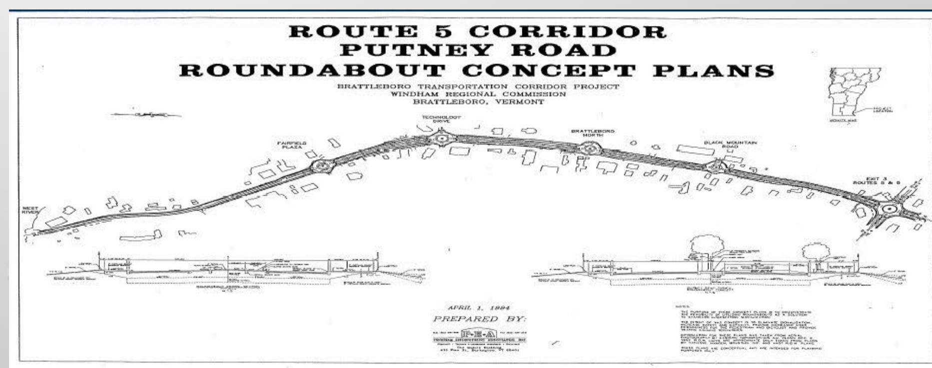
PROJECT AREAS 1 & 2



STP LOCATIONS

- Identify available space;
- Detailed subwatershed delineation (property level);
- Potential for drainage system / subwatershed to be diverted;
- Review of existing drainage interconnections;
- Locations of outfalls





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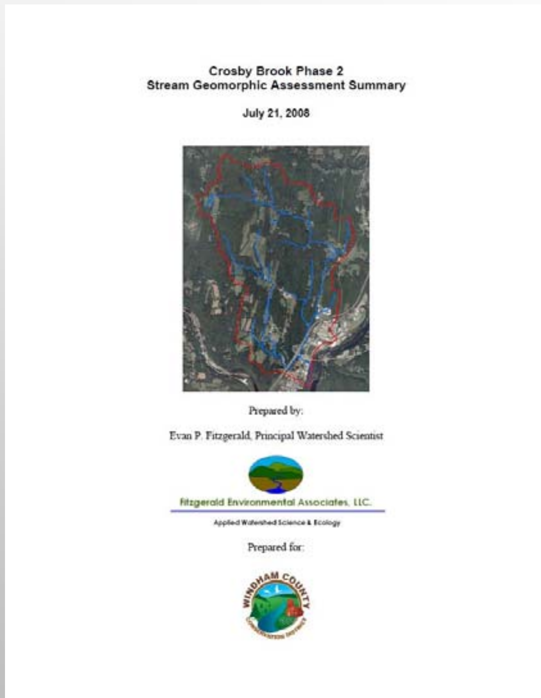
STP IDENTIFICATION

PROJECT AREA 3

CULVERT REPLACEMENTS & STABILIZATION AREAS WERE IDENTIFIED BASED ON INFORMATION FROM PREVIOUS GEOMORPHIC ASSESSMENTS


Crosby Brook Phase 2
Stream Geomorphic Assessment Summary

July 21, 2008

Prepared by:

Evan P. Fitzgerald, Principal Watershed Scientist

Fitzgerald Environmental Associates, LLC.

Applied Watershed Science & Ecology

Prepared for:

Windham County

Appendix B - Phase 2 Reach Summary Statistics

Reach/ Segment	Stream Type	Dominant Bed Material	Bedform	STD*	Reference Stream Type†	Reference Bed Material†	Reference Bedform†	RHA Score	RHA Condition	RGA Score	RGA Condition	Reach Sensitivity	CEM**	CEM** Stage
M01-A	A	Gravel	Step-Pool	No				0.70	Good	0.74	Good	High	F	I
M01-B	C	Sand	Riffle-Pool	No				0.42	Fair	0.41	Fair	Very High	F	II
M02	F	Gravel	Plane Bed	Yes	C	Gravel	Riffle-Pool	0.34	Poor	0.33	Poor	Extreme	F	II
M03	C	Gravel	Riffle-Pool	No				0.63	Fair	0.48	Fair	Very High	F	III
M04	C	Gravel	Riffle-Pool	No				0.72	Good	0.68	Good	High	F	I
M05	E	Gravel	Riffle-Pool	No				0.57	Fair	0.64	Good	High	F	IV
M06-A	C	Gravel	Riffle-Pool	No				0.71	Good	0.61	Fair	Very High	F	II
M06-B	B	Cobble	Step-Pool	No				0.73	Good	0.68	Good	Moderate	F	II
M06-C	C	Gravel	Riffle-Pool	No				0.73	Good	0.66	Good	High	F	I
T1.01	F	Gravel	Plane Bed	Yes	C	Gravel	Riffle-Pool	0.53	Fair	0.38	Fair	Extreme	F	II
T1.02-A	C	Gravel	Riffle-Pool	No				0.63	Fair	0.45	Fair	Very High	F	II
T1.02-B	F	Gravel	Step-Pool	Yes	B	Cobble	Step-Pool	0.48	Fair	0.34	Poor	Extreme	F	II
T1.02-C	A	Bedrock	Step-Pool	No				0.86	Reference	0.85	Reference	Very Low	F	I
T1.02-D	E	Sand	Riffle-Pool	No				0.62	Fair	0.60	Fair	Very High	F	II
T1.02-E	B	Gravel	Plane Bed	No				0.72	Good	0.79	Good	Moderate	F	I
T1.03	E	Sand	Dune-Ripple	No				0.62	Fair	0.61	Fair	Very High	F	II
							Mean:	0.62		0.58				
							Max:	0.86		0.85				
							Min:	0.34		0.33				

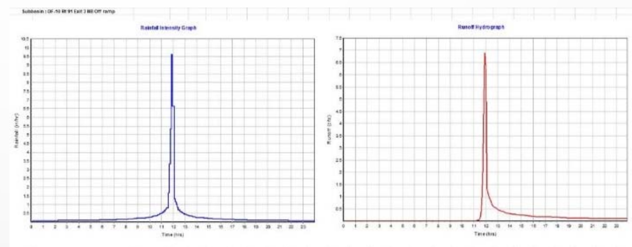
* STD = Stream Type Departure
** CEM = Channel Evolution Model
† = Assessed Reference Condition Prior to Stream Type Departure

STP SIZING
PROJECT AREAS 1 & 2

VT STORMWATER MANAGEMENT MANUAL STP SIZING STANDARDS

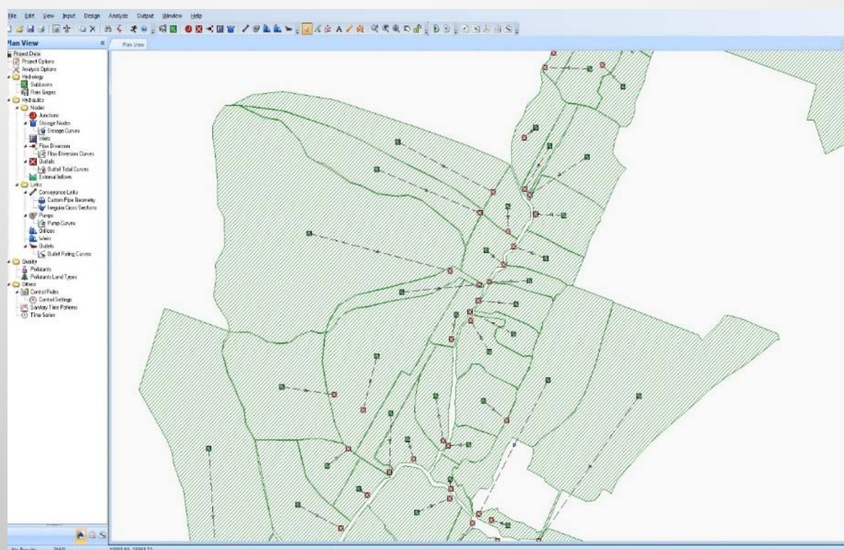
Volume Sizing for Peak Flow Attenuation
(More Extreme Storms)

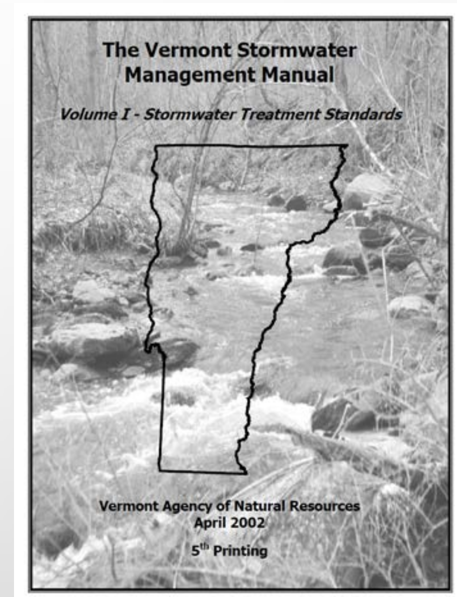
- Channel Protection ~ 1-year
- Overbank Protection ~ 10-year
- Spillway sized for 100-year



Volume Sizing for Stormwater Treatment

- Water Quality Volume
- Pre-Treatment Volume
- Recharge Volume





STP SIZING

PROJECT AREAS 1 & 2

PEAK FLOW CRITERIA

CP_V – CHANNEL PROTECTION VOLUME

OB_V – OVERBANK PROTECTION VOLUME

EXTREME STORM PRECIPITATION DATA

NY & NE (NRCC & NRCS)

Subbasin Summary

Subbasin ID	Area (acre)	Weighted Curve Number	Total Rainfall (in)	Total Runoff (in)	Total Runoff Volume (ac-in)	Peak Runoff (cfs)	**tc** (hr)	S	Ia	**Ia/P**	Channel Protection Volume, 24 Hour Storm: qu	qo/qi	T (hrs)	Vs/Vr	Vs (acre-feet)	Vs cubic feet
OF-10 Rt 91 Exit 3 NB Off ramp	2.11	54.08	2.40	0.05	0.11	0.01	**0.037**	8.49	1.70	**0.71**	400	0.04	24	0.627	0.006	260
OF-11A Rt 91 NB / S Exit 3 Off ramp	1.32	60.86	2.40	0.16	0.22	0.23	**0.032**	6.43	1.29	**0.54**	500	0.03	24	0.641	0.012	504
OF-11B Rt 91 Exit 3 SB On/Off Clover Leaf	9.29	67.37	2.40	0.33	3.03	3.65	**0.110**	4.84	0.97	**0.40**	800	0.025	24	0.647	0.163	7115
OF-11C Rt 91 Exit 3 SB Overpass	1.85	68.68	2.40	0.37	0.68	0.91	**0.061**	4.56	0.91	**0.38**	810	0.025	24	0.647	0.036	1590
OF-11D Rt 91 SB / S Exit 3	2.12	40.70	2.40	0.00	0.00	0.00	**0.058**	14.57	2.91	**1.21**	100	0.15	24	0.502	0.000	0
OF-11E Upper Watershed RT 91 Clover Leaf	8.13	30.00	2.40	0.00	0.00	0.00	**0.340**	23.33	4.67	**1.94**	80	0.16	24	0.492	0.000	0
OF-12 Rt 91 S of Exit 3	5.47	40.32	2.40	0.00	0.00	0.00	**0.059**	14.80	2.96	**1.23**	100	0.15	24	0.502	0.000	0
OF-12A Rt 91 N of Black MT Rd Overpass	4.87	49.90	2.40	0.02	0.07	0.01	**0.060**	10.04	2.01	**0.84**	200	0.08	24	0.578	0.004	153
OF-13 Rt 91 S Black Mt Rd Overpass	3.50	74.96	2.40	0.59	2.07	3.16	**0.059**	3.34	0.67	**0.28**	980	0.02	24	0.654	0.113	4909
OF-16B Rt 91 Exit 3 NB On ramp	2.44	44.42	2.40	0.00	0.00	0.00	**0.039**	12.51	2.50	**1.04**	200	0.08	24	0.578	0.000	0
OF-17 Rt 91 N Exit 3 / Steakout	1.32	58.65	2.40	0.12	0.16	0.09	**0.059**	7.05	1.41	**0.59**	400	0.04	24	0.627	0.008	367
OF-20A Rt 91 SB Exit Offramp	1.76	67.33	2.40	0.33	0.57	0.78	**0.046**	4.85	0.97	**0.40**	800	0.025	24	0.647	0.031	1342
OF-20B Upper Watershed Rt 91 Exit 3	29.54	70.00	2.40	0.41	12.05	9.18	**0.395**	4.29	0.86	**0.36**	400	0.04	24	0.627	0.630	27452
OF-22A Rt 91 N of Exit 3	1.80	73.13	2.40	0.52	0.93	1.37	**0.060**	3.67	0.73	**0.31**	950	0.02	24	0.654	0.051	2217
OF-22B Upper Watershed Rt 91	6.22	70.00	2.40	0.41	2.54	1.93	**0.395**	4.29	0.86	**0.36**	400	0.04	24	0.627	0.133	5781
OF-25A Rt 91 S of Crosby Crossing	1.58	72.25	2.40	0.49	0.77	1.10	**0.060**	3.84	0.77	**0.32**	970	0.02	24	0.654	0.042	1825
OF-25B Upper Watershed Rt 91	7.30	70.00	2.40	0.41	2.98	2.27	**0.395**	4.29	0.86	**0.36**	400	0.04	24	0.627	0.156	6786
OF-26A Rt 91 N of Crosby Cross	0.95	63.18	2.40	0.22	0.20	0.24	**0.051**	5.83	1.17	**0.49**	550	0.035	24	0.634	0.011	472
OF-27 Rt 91 N of Crosby Cross	2.39	51.10	2.40	0.02	0.05	0.01	**0.050**	9.57	1.91	**0.80**	360	0.055	24	0.608	0.003	121
OF-28A Rt 91 N Exit 3 / E Hampton	2.64	53.97	2.40	0.05	0.14	0.01	**0.052**	8.53	1.71	**0.71**	400	0.04	24	0.627	0.007	313
OF-28B Upper Watershed Rt 91	2.67	39.00	2.40	0.00	0.00	0.00	**0.429**	15.64	3.13	**1.30**	180	0.1	24	0.555	0.000	0
OF-29 Rt 91 SW of Putney Bridge	6.42	54.54	2.40	0.06	0.38	0.04	**0.046**	8.34	1.67	**0.69**	410	0.045	24	0.621	0.020	853
OF-35 Rt 91 NE of Putney Bridge	9.49	76.68	2.40	0.66	6.30	10.38	**0.038**	3.04	0.61	**0.25**	950	0.02	24	0.654	0.343	14958

Channel Protection (CP_v)	Default Criterion: CP_v = 12 hours extended detention of post-developed 1-year, 24-hour rainfall event in coldwater fish habitats (24 hr. detention in warmwater fish habitats).

Overbank Flood (Q_{p10})	Control the post-developed[2] peak discharge from the 10-year storm to 10-year pre-development[3] rates.
Extreme Storm (Q_{p100})	Control the peak discharge from the 100-year storm to 100-year pre-development rates.

STP SIZING
PROJECT AREAS 1 & 2

PEAK FLOW – BASIN VOLUMES

VT SM Manual – Peak flow basin volumes were estimated using (USDA TR-55) and Harrington methods

Then using q_O/q_i, Figure 1.6 can be used to estimate V_S/V_r. For a Type II or Type III rainfall distribution, V_S/V_r can also be calculated using the following equation:

$$V_S/V_r = 0.682 - 1.43\,(q_O/q_I) + 1.64\,(q_O/q_I)^2 - 0.804\,(q_O/q_I)^3$$

Where:
- V_S = required storage volume (acre-feet)
- V_r = runoff volume (acre-feet)
- q_O = peak outflow discharge (cfs)
- Q_I = peak inflow discharge (cfs)

The required storage volume can then be calculated by:

$$V_S = \frac{(V_S/V_r)(Q_d)(A)}{12}$$

Where:
- Q_d = the developed runoff for the design storm (inches)
- A = total drainage area (acres)

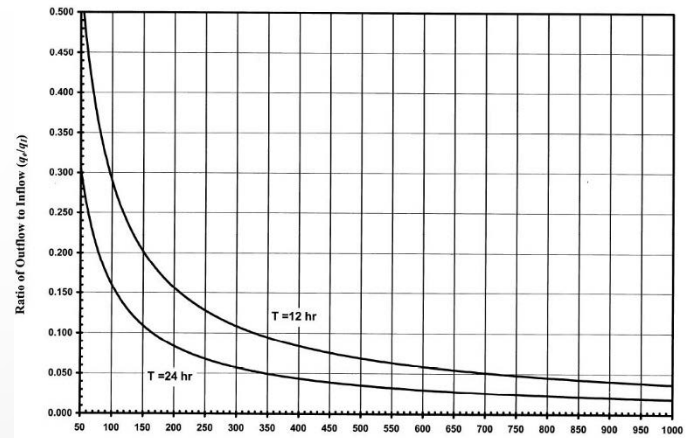


Figure 1.5 Detention Time vs. Discharge Ratios (Source: adopted from Harrington, 1987)

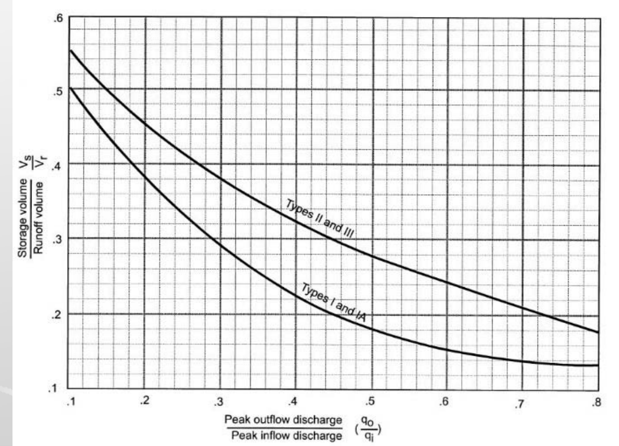


Figure 1.6 Approximate Detention Basin Routing For Rainfall Types I, IA, II, and III. (Source: NRCS, 1986)

STP SIZING

PROJECT AREAS 1 & 2

VT STANDARDS – TREATMENT STP VOLUMES

The Percent Volume Method calculation is as follows:

$$Re_v = (F)(A)(I)/12$$

Where: Re_v = Recharge volume (acre-feet)
F = Recharge factor (inches)

Hydrologic Soil Group	Recharge Factor (F)
A	0.40
B	0.25
C	0.10
D	waived

A = Site area (in acres)
I = Site imperviousness (expressed as a decimal percent)

The following equation shall be used to determine the water quality storage volume (WQ_v) (in acre-feet of storage):

$$WQ_v = \frac{(P)(R_v)(A)}{12}$$

where:

WQ_v = water quality volume (in acre-feet)
P = 90% Rainfall Event (0.9 inches across Vermont)
R_v = volumetric runoff coefficient equal to: [0.05 + 0.009(I)], where I is a whole number percent impervious cover at the site (ex. 25, not .25)
A = site area (in acres)

- Pre-treatment volume varies based on STP type
- For conceptual sizing purposes, used 10% of the water quality volume.

Subbasin Summary

Subbasin ID	Area (acre)	Imp Area	P (in)	% Imp (%)	% Imp (decimal)	Runoff Coeff (Rv)	WQv (acre-feet)	WQv (cu ft)	WQv (acre-in)
		Water Quality Volume							
OF-10 Rt 91 Exit 3 NB Off ramp	2.11	0.54	0.90	26%	25.56	0.28	0.04	1933	0.53
OF-11A Rt 91 NB / S Exit 3 Off ramp	1.32	0.49	0.90	37%	37.05	0.38	0.04	1657	0.46
OF-11B Rt 91 Exit 3 SB On/Off Clover Leaf	9.29	1.06	0.90	11%	11.41	0.15	0.11	4634	1.28
OF-11C Rt 91 Exit 3 SB Overpass	1.85	0.56	0.90	30%	30.29	0.32	0.04	1949	0.54
OF-11D Rt 91 SB / S Exit 3	2.12	0.27	0.90	13%	12.72	0.16	0.03	1141	0.31
OF-11E Upper Watershed RT 91 Clover Leaf	8.13	0	0.90	0%	0.00	0.05	0.03	1329	0.37
OF-12 Rt 91 S of Exit 3	5.47	0.69	0.90	13%	12.61	0.16	0.07	2923	0.81
OF-12A Rt 91 N of Black MT Rd Overpass	4.87	0.88	0.90	18%	18.08	0.21	0.08	3383	0.93
OF-13 Rt 91 S Black Mt Rd Overpass	3.50	2.11	0.90	60%	60.31	0.59	0.16	6776	1.87
OF-16B Rt 91 Exit 3 NB On ramp	2.44	0.38	0.90	16%	15.61	0.19	0.03	1515	0.42
OF-17 Rt 91 N Exit 3 / Steakout	1.32	0.44	0.90	33%	33.30	0.35	0.03	1510	0.42
OF-20A Rt 91 SB Exit Offramp	1.76	0.41	0.90	23%	23.33	0.26	0.03	1493	0.41
OF-20B Upper Watershed Rt 91 Exit 3	29.54	0	0.90	0%	0.00	0.05	0.11	4826	1.33
OF-22A Rt 91 N of Exit 3	1.80	0.59	0.90	33%	32.80	0.35	0.05	2029	0.56
OF-22B Upper Watershed Rt 91	6.22	0	0.90	0%	0.00	0.05	0.02	1016	0.28
OF-25A Rt 91 S of Crosby Crossing	1.58	0.48	0.90	30%	30.41	0.32	0.04	1669	0.46
OF-25B Upper Watershed Rt 91	7.30	0	0.90	0%	0.00	0.05	0.03	1193	0.33
OF-26A Rt 91 N of Crosby Cross	0.95	0.56	0.90	59%	59.02	0.58	0.04	1802	0.50
OF-27 Rt 91 N of Crosby Cross	2.39	0.49	0.90	21%	20.51	0.23	0.04	1831	0.50
OF-28A Rt 91 N Exit 3 / E Hampton	2.64	0.67	0.90	25%	25.37	0.28	0.06	2401	0.66
OF-28B Upper Watershed Rt 91	2.67	0	0.90	0%	0.00	0.05	0.01	436	0.12
OF-29 Rt 91 SW of Putney Bridge	6.42	1.69	0.90	26%	26.34	0.29	0.14	6017	1.66
OF-35 Rt 91 NE of Putney Bridge	9.49	2.78	0.90	29%	29.30	0.31	0.22	9724	2.68

STP SIZING

PROJECT AREAS 1 & 2

MODELING RESULTS

Available STP volume versus Sizing Criteria

STPv falls shy of Obv

	STP #1.1	Total Area (acre)	Treated Percent	Treated Area (acre)	12 hr- CPv Volume (cu.ft.)	Total Imp Area (acre)	Treated Imp Area (acre)	WQ Volume (cu.ft.)	Soils Group	Re Volume (cu.ft.)	Pre-Treat Volume (cu.ft.)	Sanded Area (acre)	Sand Load (cu.ft.)	24 hr -OB Volume (cu.ft.)	Assumed Weir Ht. (ft)	Peak Flow 100 yr (cfs)	Weir Length (ft)
59	OF-6D McDonalds	0.97	100%	0.965	3593	0.8	0.80	2510	B	726	290	0.00	27	7364	1.0	9.0	3
60	OF-6E KFC Taco Bell	1.00	25%	0.249	928	0.87	0.22	680	B	197	79	0.04	7	1902	1.0	2.3	1
61	OF-6F Americas Best Inn	1.83	100%	1.832	6820	1.26	1.26	4004	B	1143	457	0.15	46	13979	1.0	17.0	5
22	BO-OF-6 Current House	2.11	25%	0.528	19	0.12	0.03	175	A	44	11	0.00	0	263	1.0	0.6	0
23	BO-OF-6 New Development 1	1.26	50%	0.630	608	0.68	0.34	1103	B	309	123	0.00	9	2126	1.0	3.4	1
24	BO-OF-6 New Development 2	2.66	50%	1.328	1281	1.44	0.72	2334	A	1045	261	0.00	20	4480	1.0	7.1	2
25	BO-OF-6-Current Putney Road	2.29	60%	1.372	3791	1.80	1.08	3400	B	980	392	1.08	60	8705	1.0	11.8	4
8	BO-OF-15 Current Commercial / Indu	8.73	60%	5.236	19491	6.43	3.86	12199	A	5602	1400	0.16	191	39953	1.0	47.9	15
9	BO-OF-15 New Development 15	2.58	50%	1.289	1244	1.39	0.70	2254	A	1009	252	0.00	19	4351	1.0	6.9	2
15	OF-15 Commercial / Industrial	11.31	0%	0.000	0	7.36	0.00	0	B	0	0	0.00	0	0	1.0	0.0	0
	STP #1.1	34.73		13.43	37773	22.15	9.00	28658		11055	3267	1.43	380	83123		106.1	34

STP #1.1

	Decription	TYPE	Length	Width	Area	Area	Depth		Volume							
BMP 1	Infiltration Pond	POND	0.00	0.00		7500.00	4.50		33750						100 YR	Spillway
BMP 2	Wetpond	POND	0.00	0.00		9000.00	5.00		45000	Pre	WQv	REv	CPv	Obv	Peak	Length
BMP 3	Gravel Wetland	TRENCH	100.00	50.00		5000.00	2.00		3000	(cu.ft.)	(cu.ft.)	(cu.ft.)	(cu.ft.)	(cu.ft.)	(cfs)	(ft)
BMP 4			0.00	0.00		0.00			0	3267	28658	11055	37773	83123	106.1	34
				Total Area		Avg Depth	3.83	Volume	81750	2502%	285%	739%	216%	98%		

STPv meets REv

STPv meets WQv, CPv

STP SIZING
PROJECT AREAS 1 & 2

MODELING RESULTS

Treated areas and associated property owners:

STP #1.1	Area	Imp Area					
Subwatersheds	(acres)	(acres)					
BO-OF-6 Current House	0.528	0.03					
BO-OF-6 New Development 1	0.630	0.34					
BO-OF-6 New Development 2	1.328	0.72					
BO-OF-6-Current Putney Road	1.372	1.08					
OF-6D McDonalds	0.965	0.80					
OF-6E KFC Taco Bell	0.249	0.22					
OF-6F Americas Best Inn	1.832	1.26					
BO-OF-15 Current Commercial / Industrial	5.236	3.86					
BO-OF-15 New Development 15	1.289	0.70					
Total =	13.43	9.00					
Area Breakdown	**Area**	**Area**		**% Total Area**		**% Imp Area**	
Putney Rd	**1.37**	**1.08**	Putney Rd	10%		12%	
Other Town Roads	**0.35**	**0.35**	Other Town Roads	3%		4%	
Route 91	**0.00**	**0.00**	Route 91	0%		0%	
Total Private	**11.71**	**7.57**	Total Private	87%		84%	
					% Private		% Private
Private - Currently Developed	**8.46**	**5.82**	Current	63%	72%	65%	77%
Private - Potential Buildout	**3.25**	**1.76**	Potential Buildout	24%	28%	19%	23%

Treat a mix of public and private lands

STP SIZING

PROJECT AREAS 3

Sizing to Address Channel Erosion

<u>Main Channel STPs</u>

- Culverts should meet ~75% to 100+% of bank-full width (up / downstream effects)
- More detailed study required for final sizing – length, slope, skew, depth, etc.
- Culvert designs follow *Guidelines for the Design of Stream/Road Crossings for Passage of Aquatic Organisms in VT* prepared by the VT Department of Fish and Game
- Sizing of stabilization and natural buffers - based on field measurements and observations

Table 2. Crosby Brook Reference Reach Characteristics

Reach	Phase 2 Data	Drainage Area (sq. mi.)	Channel Length (mi)	Channel Slope (%)	Channel Width (ft.)	Sinuosity	Valley Width§ (ft.)	Confinement Ratio	Type*	Stream Type**	Bedform†
M01	Yes	5.7	0.7	1.2	28.2	1.07	150	5.3	NW	C	Riffle-Pool
M02	Yes	3.7	0.5	0.7	23.3	1.03	227	9.7	BD	C	Riffle-Pool
M03	Yes	2.8	0.6	1.1	20.6	1.07	200	9.7	BD	C	Riffle-Pool
M04	Yes	2.6	0.6	1.4	19.9	1.10	100	5.0	NW	C	Riffle-Pool
M05	Yes	2.4	0.5	0.3	19.4	1.20	400	20.7	VB	E	Riffle-Pool
M06	Yes	2.2	0.7	2.5	18.4	1.05	150	8.1	BD	C	Riffle-Pool
M07	No	1.6	1.0	3.1	16.1	1.03	*50*	3.1	SC	B	Step-Pool
M08	No	0.5	0.7	7.4							
M09	No	0.1	0.3	3.6							
T1.01	Yes	1.8	0.5	1.4							
T1.02	Yes	1.7	0.8	4.5							
T1.03	Yes	1.1	0.8	0.2							
T1.04	No	0.8	0.2	4.3							
T1.05	No	0.4	1.0	4.9							
T2.01	No	0.5	0.5	3.4							
T2.02	No	0.1	0.7	4.8							

* NW = Narrow; SC = Semi-confined; BD = Broad; VB = Very B

§ Valley Width estimated remotely for *italicized* values

** per Rosgen (1994)

† per Montgomery & Buffington (1997)

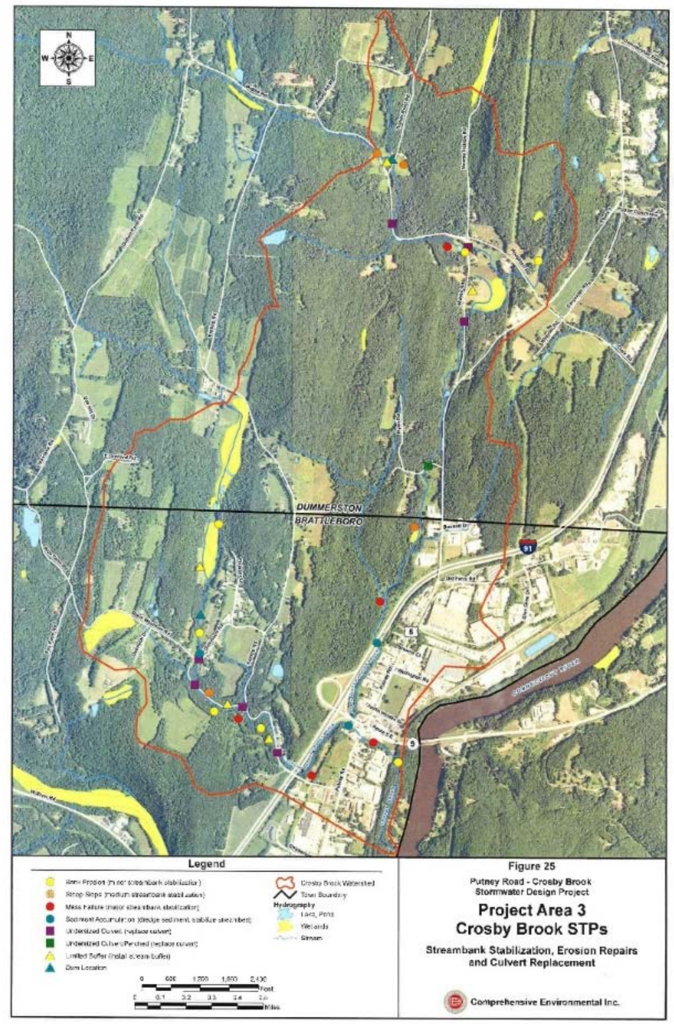
Figure 14. Mass failure in lower M01-B

STP SELECTION
PROJECT AREAS 1 & 2

Two Phased Ranking Process:

The intent was to use model results to prioritize sites based on feasibility and then rank those sites based on a more refined cost and pollutant removal estimate.

- 1^{st} phase ranked the potential STP sites based on feasibility, location and ability to meet stormwater standards.
- 2^{nd} phase ranked the STP sites based on cost-effectiveness and removal of sediment.



STP PHASE 1RANKING

PROJECT AREAS 1 & 2

- Specific criteria was used to determine feasibility of the STPs
- Each criterion was given a range of priority points based on importance

- ➢Proximity to Brook
- ➢Sediment Accumulation & Removal
- ➢Ease of Implementation
- ➢Land Use
- ➢Land Owner
- ➢STP Sizing & Standards Compliance
- ➢Maintenance Requirements
- ➢Permitting Requirements

Explanation of Ranking:

Proximity to Brook: Within 50 feet = 1 ; 51 feet - 100 feet = 2 ; 101 - 200 feet = 3 ; 201 - 300 feet = 4 ; 300+ feet = 5

Direct / Indirect Discharge: Direct = 4 ; Indirect = 2

Impervious Area %: 76% - 100% = 4 ; 51% - 75% = 3 ; 26% - 50% = 2; 0% - 25% = 1

Ease of Implementation: Easy, low number of issues = 5 ; Moderate, possible equipment maneuvering/ access issues = 3 ; Difficult, expensive equipment maneuvering/ road closures = 1

Land Owner: Town / State Owned (no easements) = 3; Private (easement needed) = 1

Land Use: Commercial / Industrial = 3.5; Commercial / Highway = 3; Industrial / Highway = 2.5; Commercial / Residential = 2.5; Residential / Highway = 1.5; Commercial = 4; Industrial = 3; Highway = 2; Residential/Forested = 1

Potential STP Storm Size: 10yr -24hr plus = 3 ; 10yr -24hr = 2 ; under 10yr -24hr = 1; No STP = 0

Potential STP Recharge: 15,000 CF plus = 5 ; 10,000 - 14,999 CF = 4 ; 5,000 - 9,999 CF = 3 ; 2,000 - 4,999 CF = 2; <2,000 CF = 1 ; No STP = 0

Sediment Removal: 250 cf plus = 6; 200 - 249 cf = 5; 150 - 199 cf = 4 ; 100 - 149 = 3; 50 - 99 = 2; 0 - 49 = 1 ; No STP = 0

STP Cost: $550,000 plus = 1; $450,000 - $549,999 = 1.5; $350,000 - $449,999 = 2 ; $250,000 - $349,999 =2.5 ; $150,000 - $249,999= 3; $125,000 - $149,999 =3.5; $75,000 - $124,999 = 4; $74,999 and less = 4.5

Permit Requirements: No Permit Needed = 3 ; Possible Permit Needed = 2 ; Definitely Permit Needed = 1

Maintenance Requirements: Low frequency, easy access, easy tasks = 3 ; Moderate frequency, access issues, several tasks = 2 ; High frequency, difficult to access w/ equipment = 1

STP PHASE 1RANKING

PROJECT AREAS 1 & 2

APPENDIX D - STP OPTIONS - COST SUMMARY TABLE

STP ID	Sub-basins Handled (Outfall I.D.)	Area	Pipe	Pipe	Structure	Structure	Pond Install	Add Excavation	Excav Cost	Added Costs	STP Const Cost ($)	Survey	Permitting	Engineering	Bid / Construction	Engineering Total Costs ($)	STP Total Costs ($)	STP Maintenance ($)	STP Total 10 yr Costs ($)
1-1	6, 6D, 6E, 6F, 15	20,500	1,200	$180,000	15	$52,500	$163,500	5,125	$3,796	$80,000	$479,796	$7,400	$0	$96,000	$72,000	$175,400	$655,196	$3,400	$689,196
1-2	6, 6H, 6I, 6J	18,250	300	$45,000	5	$17,500	$109,600	9,125	$6,759	$35,800	$214,659	$7,100	$0	$42,900	$32,200	$82,200	$296,859	$3,100	$327,859
1-3	1, 3, 5, 6, 6A, 6B, 6C, 8	14,000	950	$142,500	8	$28,000	$125,800	7,000	$5,185	$60,300	$361,785	$6,600	$5,000	$72,400	$54,300	$138,300	$500,085	$2,600	$526,085

- Conceptual costs were prepared and entered into the matrix to be used for ranking analysis
- STP sizing and pollutant reduction information was also entered into the matrix to be used for ranking analysis.
- Once criteria for each STP was compiled, the priority point scores were applied and tallied to select STPs with the highest total score

STP ID	Proximity to Brook	Direct / Indirect Discharge	Impervious Area %	Ease of Implementation	Land Owner	Land Use	Potential STP Storm Size	Potential STP Recharge	Sediment Removal	STP Costs	Permit Requirements	Maintenance Requirements / Access	Priority Points	RANK
1-1	5	2	3	3	1	4	3	4	6	1	3	3	38	1
1-4	2	4	3	5	2	4	3	3	3	3	2	3	37	2
1-2	5	2	2	5	2	2.5	3	3	3	2.5	3	2	35	3
1-8	1	4	3	5	1	4	2	4	4	2	2	2	34	4
1-6	3	2	3	3	1	4	2	3	3	3	3	3	33	5
1-7	5	2	3	1	2	3.5	3	3	4	2	3	1	32.5	6
1-10	5	2	3	1	2	3.5	1	4	4	3	2	2	32.5	7
1-3	2	4	3	3	1	3.5	2	3	4	1	2	3	31.5	8
1-13	5	2	3	1	3	3	1	4	3	1.5	3	2	31.5	9
1-9	1	4	3	5	2	3	1	2	3	2.5	1	3	30.5	10
1-11B	5	2	2	3	2	3.5	2	3	3	2	1	2	30.5	11
1-5	1	4	2	5	1	4	2	1	1	4.5	1	3	29.5	12

STP PHASE 2 RANKING

PROJECT AREAS 1 & 2

POLLUTANT LOADS & REDUCTIONS

- Simple Method
- STPs – Treatment trains (in series)

The Simple Method - Pollutant Reduction Model

Example Pollutant Loading Estimates

No.	Watershed Name	Landuse ID	Landuse	Area (acres)	Sanded?	Sanded Area (acres)	% Impervious	Runoff (in)	Pretreatment (0.1"/ Imp. acre) cf	Treatment (1"/ Imp. acre) cf	Annual Runoff (cf)	Annual TSS (lbs)	Annual TP (lbs)	Annual TN (lbs)	Annual FC (billion colonies)
1	Paved Roadway	8	Roadway/Parking Lot	1.870	Yes	1.870	80	31.2	543	5,430	211,687	6,545	7.25	18.5	102.1
2	Woods	2	Forested	1.000	No	0.000	5	3.8	18.2	182	13,966	44	0.10	1.5	1.2
3	Commercial	1	Commercial	10.550	Yes	7.130	85	33.0	3,255.2	32,552	1,264,072	26,919	25.97	233.7	1,649.9
							0	0.0	0.0	0	0	0	0.00	0.0	0.0
							0	0.0	0	0	0	0	0.00	0.0	0.0
Total				13.420		9.000			3,816	38,164	1,489,725	33,509	33.3	253.7	1,753.2

Landuse[1]	Landuse ID (used for v-lookup)	% Impervious	(C) TSS (mg/l)	(C) TP (mg/l)	(C) TN (mg/l)	*Fecal Coliform (colonies/100 mL)	Landuse
Commercial	1	85	77	0.33	2.97	4600	Commercial
Forested	2	5	51	0.11	1.78	300	Forested
Open Urban Land	3	9	51	0.11	1.74	300	Open Urban Land
Residential-High Density	4	40	100	0.4	2.2	7000	Residential-High Density
Residential-Low Density	5	10	100	0.4	2.2	7000	Residential-Low Density
Residential-Med. Density	6	30	100	0.4	2.2	7000	Residential-Med. Density
Industrial	7	75	149	0.32	3.97	2400	Industrial
Roadway/Parking Lot	8	80	172	0.55	1.4	1700	Roadway/Parking Lot
Pasture	9	5	145	0.37	5.98	300	Pasture

[1] High density residential (<1/4 acre lots); Medium density residential (1/4 to 1/2 acre lots); Low density residential (>1 acre lots); Multifamily (>[illegible] dwellings per acre)

Table A.5. STP Selection: Pollutant Removal Matrix

Practice	TSS [%]	TP [%]	TN [%]	Metals[1] [%]	Bacteria [%]	Hydrocarbons [%]
Wet Ponds	80	51	33	62	70	81[2]
Stormwater Wetlands	76	49	30	42	78[2]	85[2]
Filtering Practices	86	59	38	69	37[2]	84[2]
Infiltration Practices[3]	95[2]	80	51	99[2]	N/A	N/A
Open Channels[4]	81	34	84[2]	70	N/A	62[2]
Quantity Control Ponds[2, 5]	3	19	5	7.5	78	N/A

1. Average of zinc and copper. Only zinc for infiltration
2. Based on fewer than five data points (i.e., independent monitoring studies)
3. Includes porous pavement, which is not on the list of approved practices for Vermont. At this time, there are no known field studies that have measured sediment removal in infiltration trenches. However, it can logically be presumed that a properly operating infiltration trench will remove nearly 100% of the TSS load associated with the design treatment volume.
4. Higher removal rates for dry swales.
5. Quantity control ponds (a.k.a. dry detention basins or vaults) do not meet the WQ_v requirement and must be used in conjunction with acceptable water quality STPs.

N/A: Data not available

Removals represent median values from Winer (2000)

The Simple Method - Pollutant Reduction Model

Example Pollutant Reduction Estimates

No.	Watershed Name	BMP ID	BMP Type	BMP Drainage Area (acres)	BMP Removal Efficiency^ TSS Removal (%)	TP Removal (%)	TN Removal (%)	Fecal Coliform Removal**(%)	Quantity of Pollutant Removed Annual TSS Removed (lbs)	Annual TP Removed (lbs)	Annual TN Removed (lbs)	Annual Fecal Coliform Removed (billion colonies)	Pretreatment / Treatment
1st BMP in series													
	BMP Volume (cf) =	3,820.00	Water Quality Volume %	100%									
1	Paved Roadway	2	Plunge Pool / Forebay**	1.870	85.0%	8.0%	3.0%	12.0%	5,563	0.58	0.6	12.3	Pretreatment
2	Woods	2	Plunge Pool / Forebay**	1.000	85.0%	8.0%	3.0%	12.0%	38	0.01	0.0	0.1	Pretreatment
3	Commercial	2	Plunge Pool / Forebay**	10.550	85.0%	8.0%	3.0%	12.0%	22,882	2.08	7.0	198.0	Pretreatment
Total								BMP Total	28,482	2.67	7.6	210.4	
2nd BMP in series													
	BMP Volume (cf) =	38,200.00	Water Quality Volume %	100%									
1	Paved Roadway	7	Infiltration Basin	1.870	95.0%	80.0%	51.0%	90.0%	933	5.3	9.1	80.9	Treatment
2	Woods	7	Infiltration Basin	3.000	95.0%	80.0%	51.0%	90.0%	19	0.2	2.3	2.8	Treatment
3	Commercial	7	Infiltration Basin	1.500	95.0%	80.0%	51.0%	90.0%	545	2.7	16.4	185.8	Treatment
Total								BMP Total	1,497	8.26	27.9	269.5	
								TOTAL REMOVAL =	29,979	10.9	35.5	479.9	
								% REMOVAL =	89.5%	32.8%	14.0%	27.4%	

BMP Type	BMP ID (used for v-lookup)	TSS Removal (%)	TP Removal (%)	TN Removal (%)	Fecal Coliform Removal** (%)	Pretreatment / Treatment	BMP Type
Vegetated Swale	1	81%	34%	84%	60%	Pretreatment	Vegetated Swale
Plunge Pool / Forebay**	2	85%	8%	3%	12%	Pretreatment	Plunge Pool / Forebay**
Leaching Catch Basin**	3	95%	80%	51%	90%	Pretreatment	Leaching Catch Basin**
Wet Pond	4	80%	51%	33%	70%	Treatment	Wet Pond
Riprap Swale***	5	50%	5%	2%	5%	Pretreatment	Riprap Swale***
Raingarden	6	86%	59%	38%	37%	Treatment	Raingarden
Infiltration Basin	7	95%	80%	51%	90%	Treatment	Infiltration Basin
Infiltration Chambers**	8	95%	80%	51%	90%	Treatment	Infiltration Chambers**
Enhanced Sand Filtration****	9	86%	59%	38%	37%	Treatment	Enhanced Sand Filtration****
Gravel Wetland	10	76%	49%	30%	78%	Treatment	Gravel Wetland
Extended Detention Wetland	11	76%	49%	30%	78%	Treatment	Extended Detention Wetland

VTrans Working to Get You There

VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION

STP PHASE 2 RANKING

PROJECT AREAS 1 & 2

Use Specific Ranking Criteria:

- BMP Drainage Area
- Percent Impervious
- Land Use Types
- 10 yr. Pollutant Removal
- BMP Cost
- 10 yr. BMP Maintenance Cost

To Estimate:

$ per ton of sediment (TSS) removed

(over 10 year period)

To Select:

Top 2 BMPs per Area = Most Cost Effective

On average over a 10 year period

~ $4,000 - $5,000 per ton

APPENDIX C - STP OPTIONS - RANKING SUMMARY TABLE BY AREA

STP ID	Sub-basins Handled (Outfall I.D.)	Sub-basin Areas (acres)	Percent Impervious (%)	WQv Target (cu.ft.)	REv Target (cu.ft.)	CPv Target (cu.ft.)	OBv Target (cu.ft.)	STP Max Volume (cu.ft.)	TSS Removal (cu.ft.)	STP Total Costs ($)	STP Maintenance ($)	STP Total 10 yr Costs ($)	TSS Removal (lbs)	10 Yr TSS Removal (tons)	Cost / TSS Removal ($/ton)
1-1	6, 6D, 6E, 6F, 15	13.4	67%	28,700	11,000	38,700	83,100	81,750	340	$655,196	$3,400	$689,196	30,600	153	**$4,505**
1-4	7, 7A	7.3	56%	13,200	5,900	8,600	26,200	26,400	110	$215,259	$2,000	$235,259	9,900	50	**$4,753**

STP SELECTION

PROJECT AREA 3

Culverts with widths less than bank-full width were reviewed:

- Any undersized culverts should eventually be replaced.
- For ranking purposes, culvert projects with widths less than 33% of the bank-full channel width were selected as the highest priority to be completed under a first phase.
- Remaining undersized culverts could be replaced in 2 additional phases based on similar criteria (e.g. under 67% and remainder less than bank-full width).
- Cost estimates were preformed for the top 4:

Table 3. Summary of Stream Crossings

Reach/ Seg-ment	Road Name	Road Type	Location	Struct. Height (ft)	Stream Width (ft)	Struct. Width (ft)	Struct/ Stream Width*	Flood-plain Filled?	Stream Approach
M01-B Bridge	Railroad	Rail-road	Railroad crossing just upstream of segment break.	9.5	20.0	19.0	95%	Partially	Channelized Straight
M01-B Bridge	Route 5	Paved	Route 5 crossing.	5.4	22.0	30.0	136%	Entirely	Channelized Straight
M01-B Bridge	I-91 Ramp	Paved	I-91 Exit 3 ramp.	7.0	21.8	20.0	92%	Partially	Channelized Straight
M02 Bridge	I-91	Paved	I-91 crossing (2 lanes).	4.5	23.0	25.0	109%	Partially	Mild Bend
M03 Culvert	Ryan Rd.	Gravel	Just west of intersection with Route 5.	7.0	23.8	7.0	**29%**	Partially	Naturally Straight
M04 Culvert	Middle Rd.	Paved	Just north of intersection with Route 5.	7.0	21.0	7.0	**33%**	Partially	Channelized Straight
M05 Culvert	Middle Rd.	Paved	Just south of intersection with Houghton Rd.	7.0	16.0	7.0	**44%**	Partially	Mild Bend
M06-B Bridge	Drive-way	Gravel	Driveway stemming from Houghton Rd mid-segment.	10.6	18.0	18.5	103%	Partially	Naturally Straight
M06-B Culvert	Hough-ton Rd.	Paved	Houghton Rd crossing upper.	7.0	16.0	9.0	**56%**	Partially	Mild Bend

APPENDIX D - PROJECT AREA 3 - STP OPTIONS - COST SUMMARY

STP ID	STP Type	Location Description of STP	Road Length (ft.)	Road Width (ft.)	Road Area (sq.ft.)	Culvert Length (ft.)	Culvert Opening (ft. x ft.)	Culvert Cost ($)	No. of Structures (#)	Structure Cost ($)	STP Install ($)	STP Materials ($)	Add'l Excav / Prep/ Clearing ($)	Construction Cont. Costs (30%) ($)	**STP Const. Cost ($)**	Survey Costs ($)	Permit Costs ($)	Engineering Costs ($)	Bid / Construct Oversight ($)	Engineering Total Costs ($)	**STP Total Costs ($)**
1	Replace Culvert	Northern Fork / Ryan Rd (M03) - Install new culvert to meet min 75% stream width - Exist. Culvert = 7'x7'	50.0	25.0	1250.0	50	7 x 18	$175,000	0	$0	$3,750	$5,625	$6,250	$57,200	**$247,825**	$3,100	$8,000	$49,600	$24,800	$85,500	**$333,300**
2	Replace Culvert	Northern Fork / Middle Rd (M04) - Install new culvert to meet min 75% stream width & LCBs for paved drainage - Exist. Culvert = 7'x7'	100.0	25.0	2500.0	60	7 x 16	$210,000	2	$7,000	$7,500	$11,250	$12,500	$74,500	**$322,750**	$3,300	$8,000	$64,600	$32,300	$108,200	**$431,000**
3	Replace Culvert	Southern Fork / Black Mtn. Rd (T1.01) - Install new culvert to meet min 75% stream width LCBs for paved drainage - Exist. Culvert = 4'x4'	100.0	30.0	3000.0	75	4 x 12	$112,500	2	$7,000	$9,000	$13,500	$15,000	$47,100	**$204,100**	$3,300	$8,000	$40,800	$20,400	$72,500	**$276,600**
4	Replace Culvert	Southern Fork / Dickinson Rd (T1.02-D) - Install new culvert to meet min 75% stream width - Exist. Culvert = 3'x3'	50.0	25.0	1250.0	40	3 x 7	$60,000	0	$0	$3,750	$5,625	$6,250	$22,700	**$98,325**	$3,100	$8,000	$19,700	$9,800	$40,600	**$138,900**
						225								**Totals**	**$873,000**					**Totals**	**$1,179,800**

STP SELECTION
PROJECT AREA 3

Bank stabilization and buffer development selection:

- Based on the repair of the top 6 largest problem areas identified in the field
- Cost estimates were performed:

Figure 17. Large mass failure in upper M02

Figure 3. Bank erosion in lower M05.

Figure 9. Large landslide in lower T1.02

APPENDIX D - PROJECT AREA 3 - STP OPTIONS - COST SUMMARY

STP ID	STP Type	Location Description of STP	Slope Length (ft.)	Slope Width (ft.)	Slope Area (sq.ft.)	STP Install ($)	STP Materials ($)	Add'l Excav / Prep/ Clearing ($)	Construction Cont. Costs (30%) ($)	**STP Const. Cost ($)**	Survey Costs ($)	Permit Costs ($)	Engineering Costs ($)	Bid / Construct Oversight ($)	Engineering Total Costs ($)	**STP Total Costs ($)**
1	Stabilize Steep Slopes	Mass Slope Failure Southern Fork near Black Mtn. Rd - Repair erosion & stabilize slope	100.0	75.0	7500.0	$15,000	$22,500	$7,500	$13,500	**$58,500**	$3,900	$8,000	$11,700	$5,900	$29,500	**$88,000**
2	Streambank Stabilization	Steep Slope Failure Northern Fork near Route 91 northbound - Repair erosion & stabilize banks	100.0	30.0	3000.0	$9,000	$13,500	$3,000	$7,700	**$33,200**	$3,300	$8,000	$6,600	$3,300	$21,200	**$54,400**
3	Streambank Stabilization	Mass Slope Failure Northern Fork along Route 91 southbound right of way - Repair erosion & stabilize banks	75.0	50.0	3750.0	$11,250	$16,875	$3,750	$9,600	**$41,475**	$3,400	$8,000	$8,300	$4,100	$23,800	**$65,300**
4	Stabilize Steep Slopes	Steep Eroded Banks along Northern Fork near Pepsi - Repair erosion & stabilize slopes	50.0	50.0	2500.0	$5,000	$7,500	$2,500	$4,500	**$19,500**	$3,300	$8,000	$3,000	$2,500	$16,800	**$36,300**
5	Streambank Stabilization	Mass Slope Failure along Main Channel near Route 9 eastbound shoulder - Repair erosion & stabilize slope	150.0	30.0	4500.0	$13,500	$20,250	$4,500	$11,500	**$49,750**	$3,500	$8,000	$10,000	$5,000	$26,500	**$76,300**
6	Stabilize Steep Slopes	Mass Slope Failure Northern Fork near Houghton Rd - Repair erosion & stabilize slope	75.0	50.0	3750.0	$7,500	$11,250	$3,750	$6,800	**$29,300**	$3,400	$8,000	$5,900	$2,900	$20,200	**$49,500**
					25,000				Totals	$231,725					Totals	$369,800

STP Recommendations

Project Area 1

Project Area 1 – Routes 5 & 9

- Peak flow controls maximized based on largest potential impervious area treated. Treatment trains used to meet goals
- Located in undeveloped space that is currently available with no future plans for development
- Designed to handle both VTrans and Town drainage with minimal encroachment on future transportation enhancement / development

<u>Site 1.1 – Putney Road & Private Properties</u>

- Located on private property behind the America's Best Inn
- Re-direct runoff from an existing drainage system on Putney Road, Hardwood Way and a Private Drive
- Located away from brook – Storage pond followed by gravel wetlands for nutrient treatment / temperature reduction and good baseflow to the brook

<u>Site 1.4 – Putney Road & Route 9</u>

- Located on private property next to the old Bickford's restaurant
- Re-direct runoff from an existing drainage system on Routes 5 and 9 that discharges at the Putney Rd bridge crossing. Located closer to the brook - infiltrate

VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION

STP Recommendations
Project Area 2

Project Area 2 – Route I-91

- STPs designed to meet topography, fit linear corridors and provide treatment for the longest lengths of untreated roadway.
- Designed with shallow depths, minimal standing water and limited encroachment on safety clear zones to provide treatment and/or elimination of direct discharges.
- Based on soils / hydric conditions, designs use a mixture of Infiltration Swales, Stormwater Wetlands, Wet / Dry Swales and Sand Filters.

<u>Site 2.1 – Interstate Route 91 at Black Mtn. Rd</u>

- Located in Right of Way near Bridge Overpass
- Retrofit existing drainage systems on shoulders and medians – infiltration near stream crossing

<u>Site 2.4 – Interstate Route 91 at Exit 3</u>

- Located in Right of Way within on/off ramps
- Use low-points and large available space along the exit ramp to install larger STPs – peak flow controls
- Retrofit existing drainage systems on highway medians to provide linear STPs – treatment with filters

STP Recommendations
Project Area 3

Culvert Designs Provide:

- Roadway drainage treatment at crossings
- Proper widths
- Proper substrate material
- Proper Embedment or open bottoms
- Improved Wildlife Passage

Crosby Culvert Replacement Locations:
- Ryan Rd
- Middle Rd
- Black Mountain Rd
- Dickinson Rd

Figure 20. Perched culvert beneath Ryan Road.

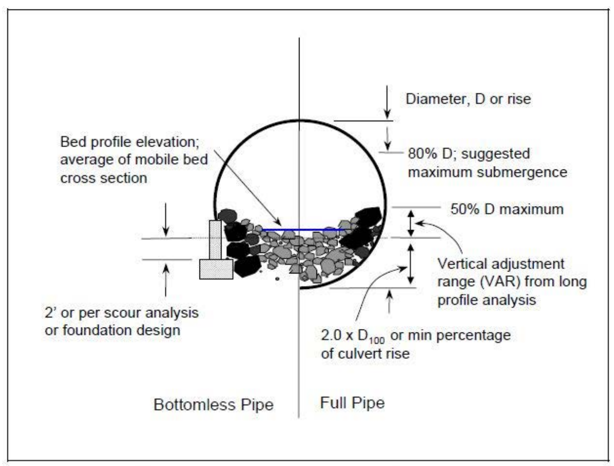
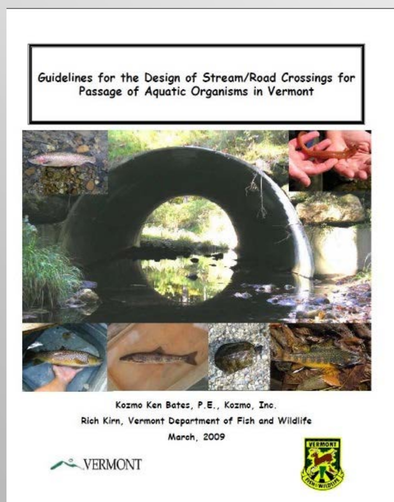


Figure 6-6. Stream simulation culvert embedment.



Guidelines for the Design of Stream/Road Crossings for Passage of Aquatic Organisms in Vermont

Kozmo Ken Bates, P.E., Kozmo, Inc.
Rich Kirn, Vermont Department of Fish and Wildlife
March, 2009

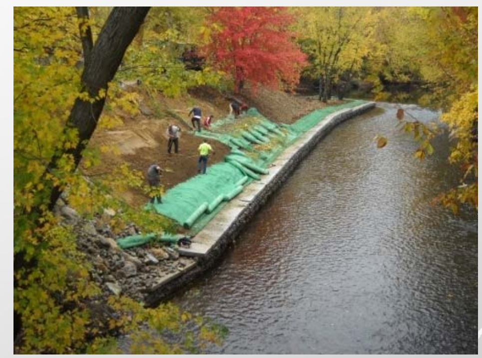
VERMONT

STP Recommendations

Project Area 3

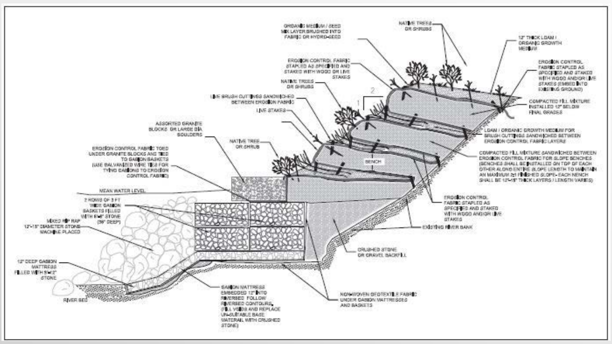
Stabilization Techniques:

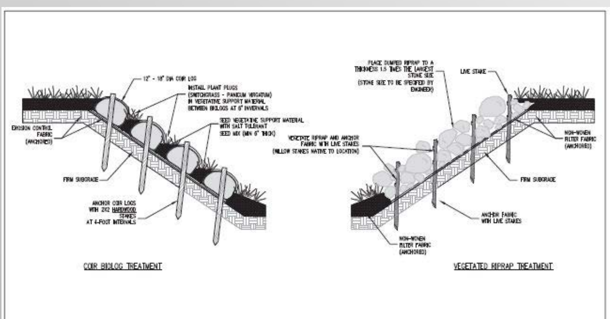
- Bio-engineered slope treatment
- Combine -riprap, vegetation, fabrics and coir logs
- Proper toe-of-slope selection
- Proper anchoring
- Proper reinforcement materials

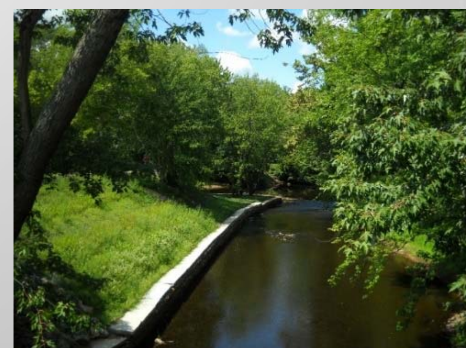


Crosby Stabilization:

- 6 locations
- 4 on the Northern Branch
- 1 on the Southern Branch
- 1 on the Main (lower) Branch

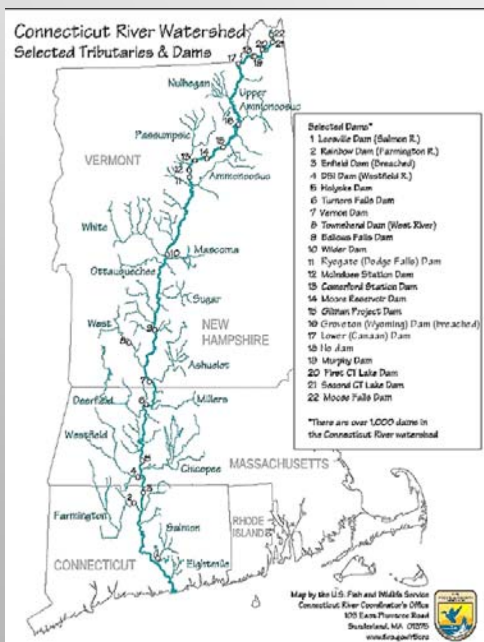






CROSBY BROOK POINTS TO PONDER

- BASED ON RECENT HISTORY, THE USE OF EXTREME STORM PRECIPITATION IS RECOMMENDED FOR STP SIZING AND CULVERT DESIGN.
- TREATMENT TRAINS – A GOOD METHOD FOR MEETING SEVERAL PROJECT TARGETS (PEAK FLOW CONTROL, NUTRIENT REMOVAL, SEDIMENT REMOVAL AND TEMPERATURE CONTROLS).
- A BLEND OF HARD STRUCTURE AND NATURALIZED TREATMENTS HAS PROVEN TO BE VERY EFFECTIVE STABILIZATION METHOD.
- ALL LEAD TO HIGHER COST PROJECTS – CROSBY BROOK 7 MILES ~ $400,000 PER MILE OF STREAM
- HOW DO YOU PRIORITIZE WHERE TO USE THE AVAILABLE LIMITED FUNDING? WHICH PROJECTS TO TARGET FIRST AND CAN YOU MEET THESE HIGHER STANDARDS?



- ACCORDING TO EPA, THERE IS APPROXIMATELY 65,000 MILES OF STREAMS AND RIVERS IN NEW ENGLAND. THERE ARE LIKELY HUNDREDS OF SMALL STREAMS THROUGH-OUT NEW ENGLAND WITH SIMILAR ISSUES AS CROSBY BROOK

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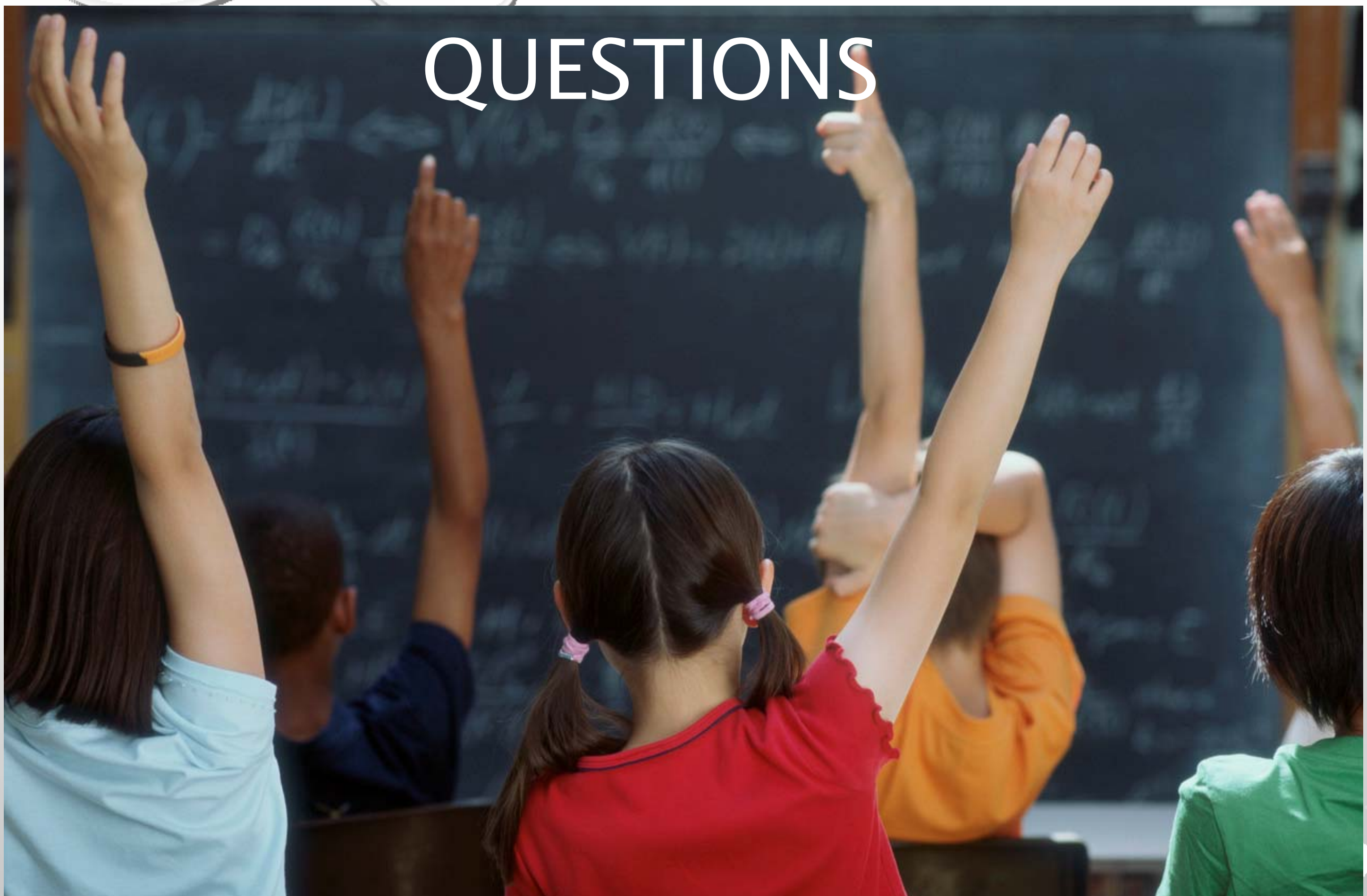
QUESTIONS



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