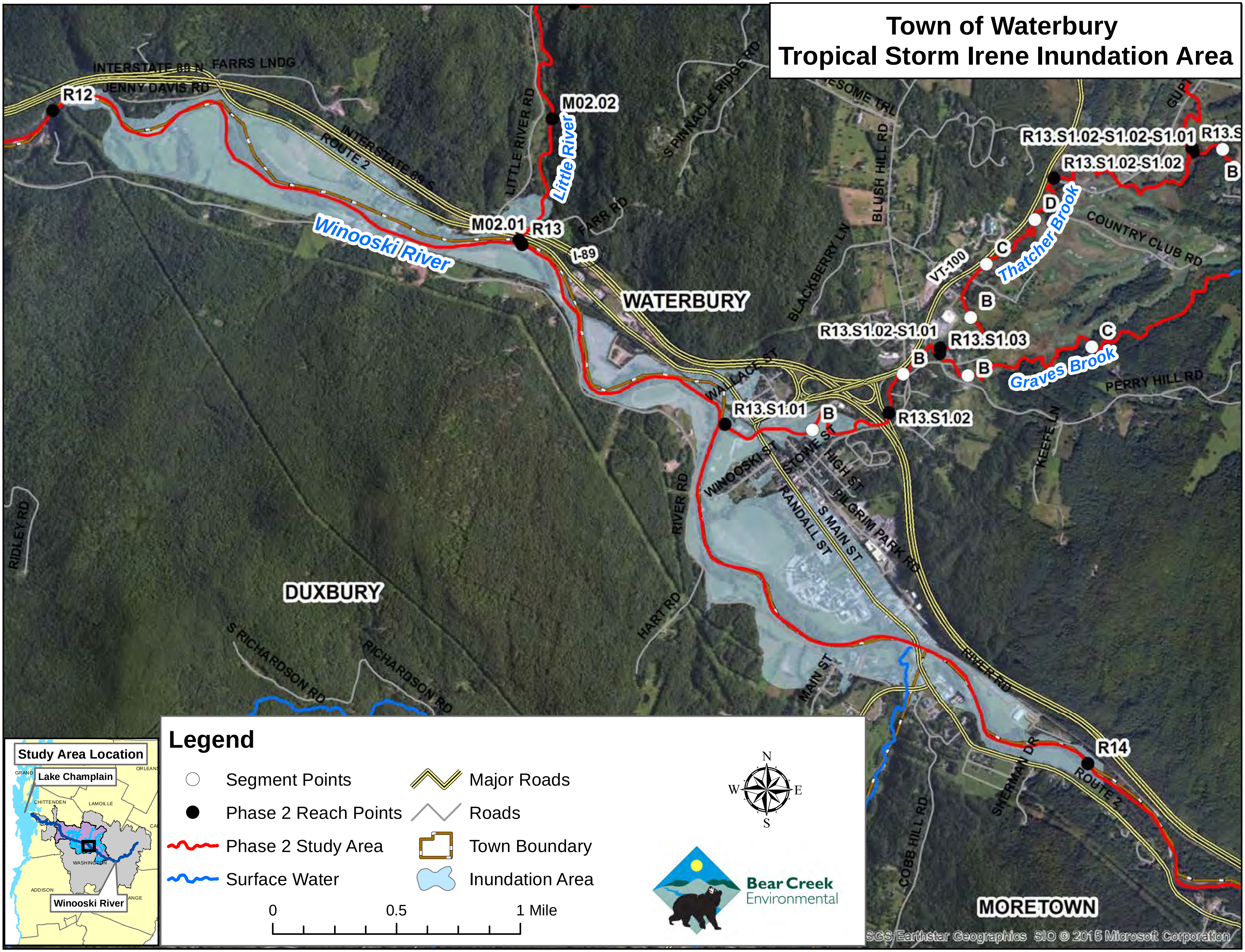
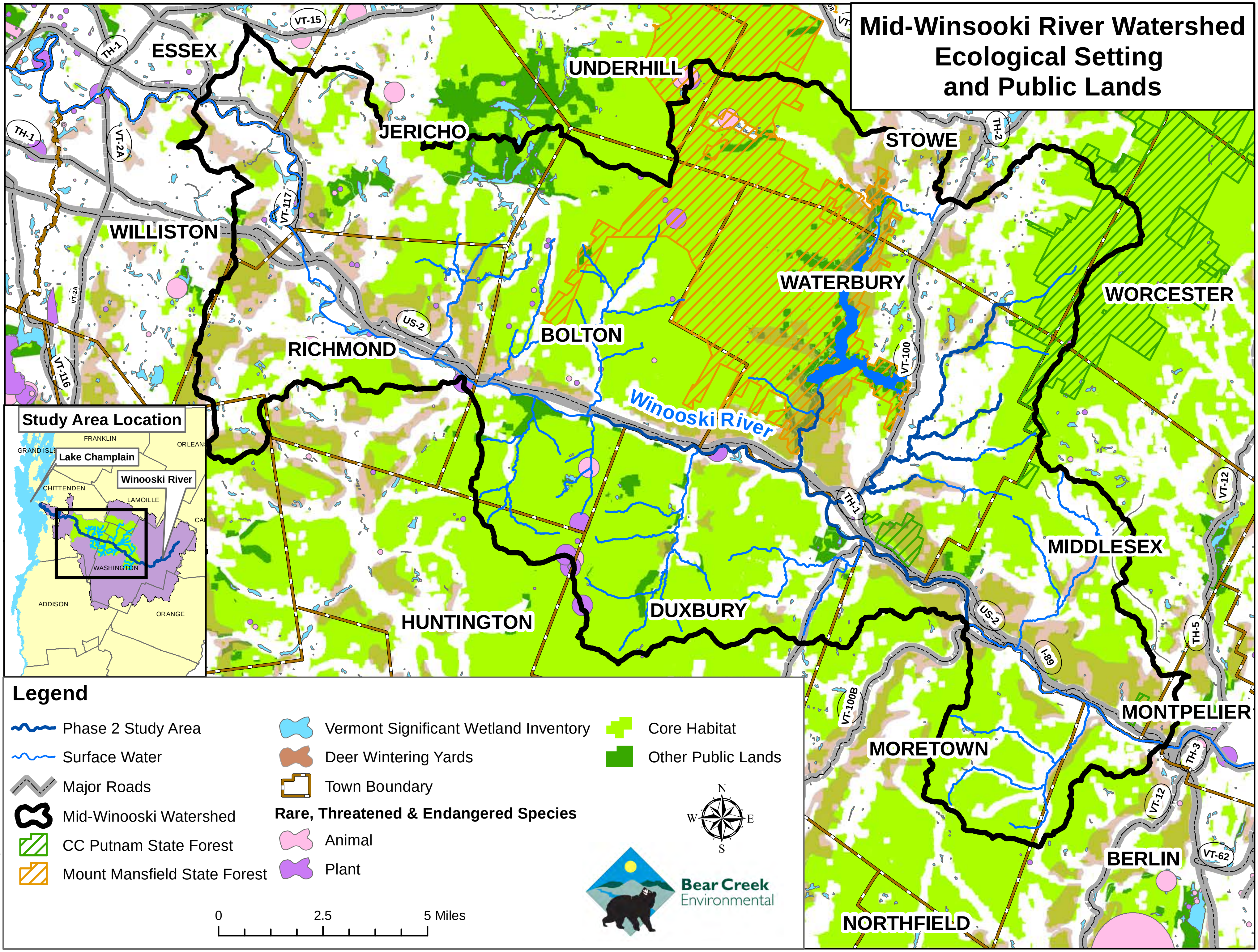
APPENDIX A

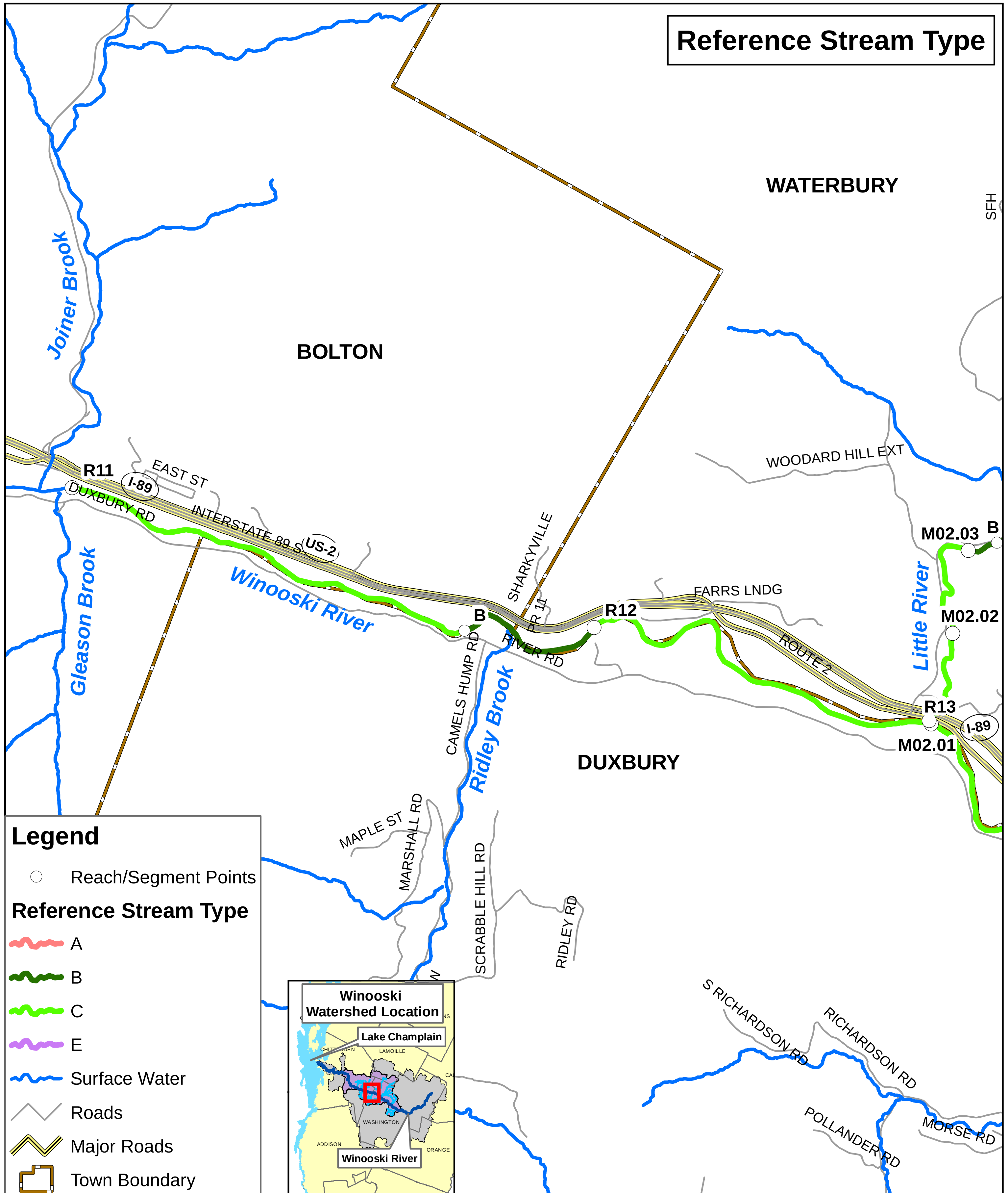
Maps

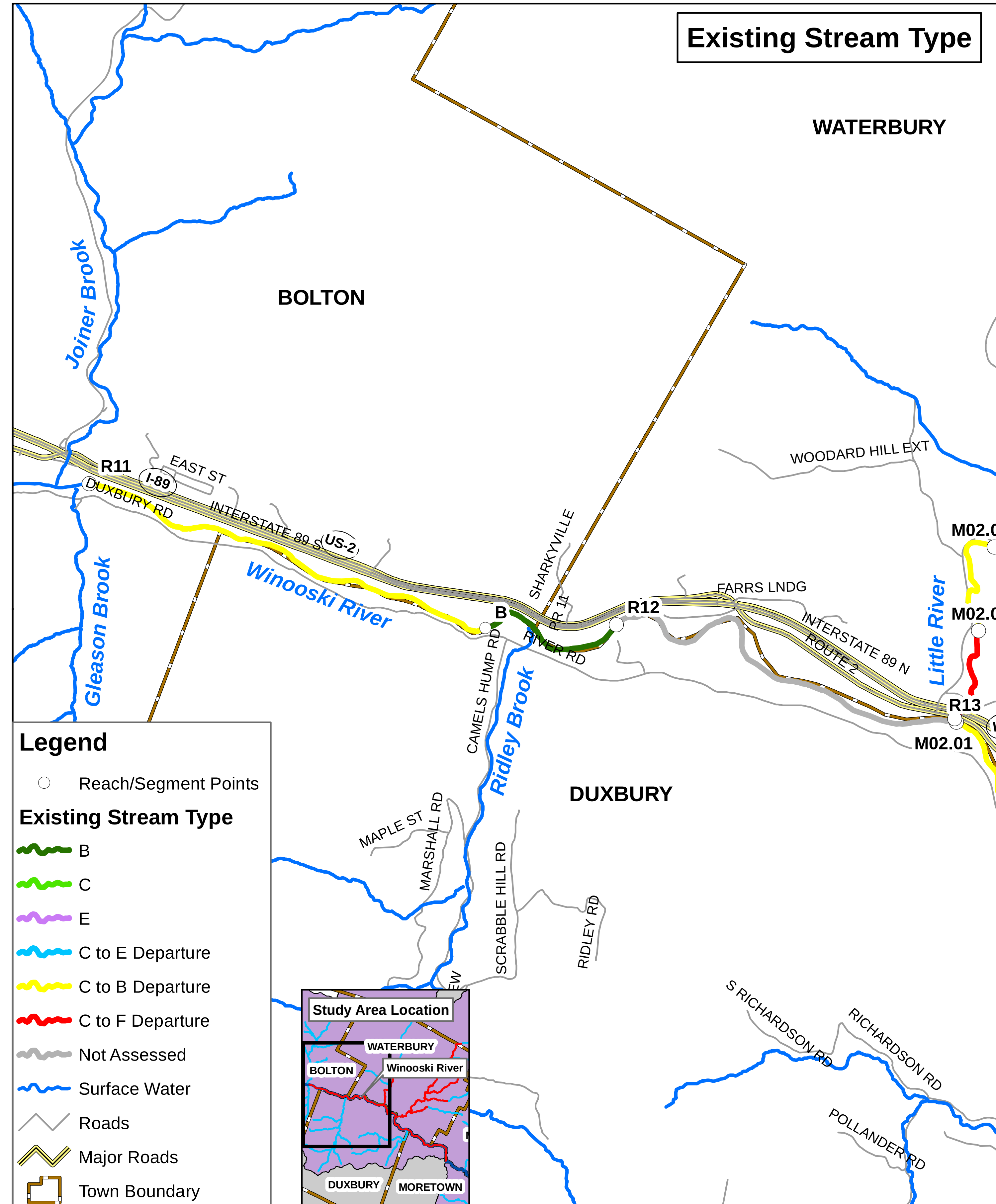
Town of Waterbury
Tropical Storm Irene Inundation Area





Mid-Winsooki River Watershed
Ecological Setting
and Public Lands
ESSEX
UNDERHILL
JERICHO
STOWE
WILLISTON
WATERBURY
WORCESTER
RICHMOND
BOLTON
Winooski River
MIDDLESEX
HUNTINGTON
DUXBURY
MONTPELIER
MORETOWN
BERLIN
NORTHFIELD
VT-15
TH-1
VT-2A
VT-117
US-2
VT-116
VT-100
TH-2
VT-12
TH-5
I-89
TH-3
VT-62
VT-100B
Study Area Location
Lake Champlain
Winooski River
FRANKLIN
GRAND ISLE
ORLEANS
CHITTENDEN
LAMOILLE
WASHINGTON
ADDISON
ORANGE
Legend
Phase 2 Study Area
Surface Water
Major Roads
Mid-Winooski Watershed
CC Putnam State Forest
Mount Mansfield State Forest
Vermont Significant Wetland Inventory
Deer Wintering Yards
Town Boundary
Rare, Threatened & Endangered Species
Animal
Plant
Core Habitat
Other Public Lands
N
W
E
S
0
2.5
5 Miles
Bear Creek Environmental

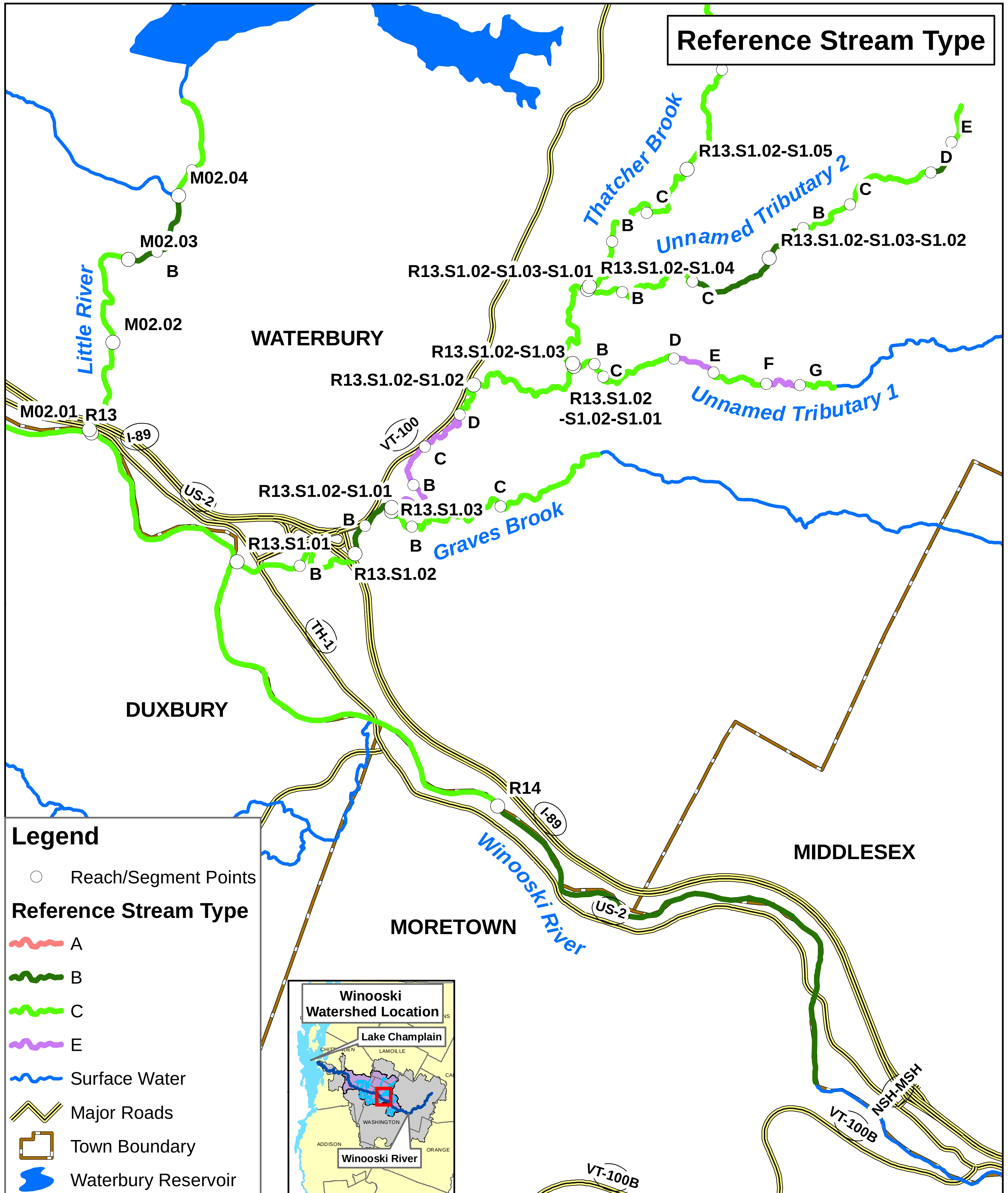


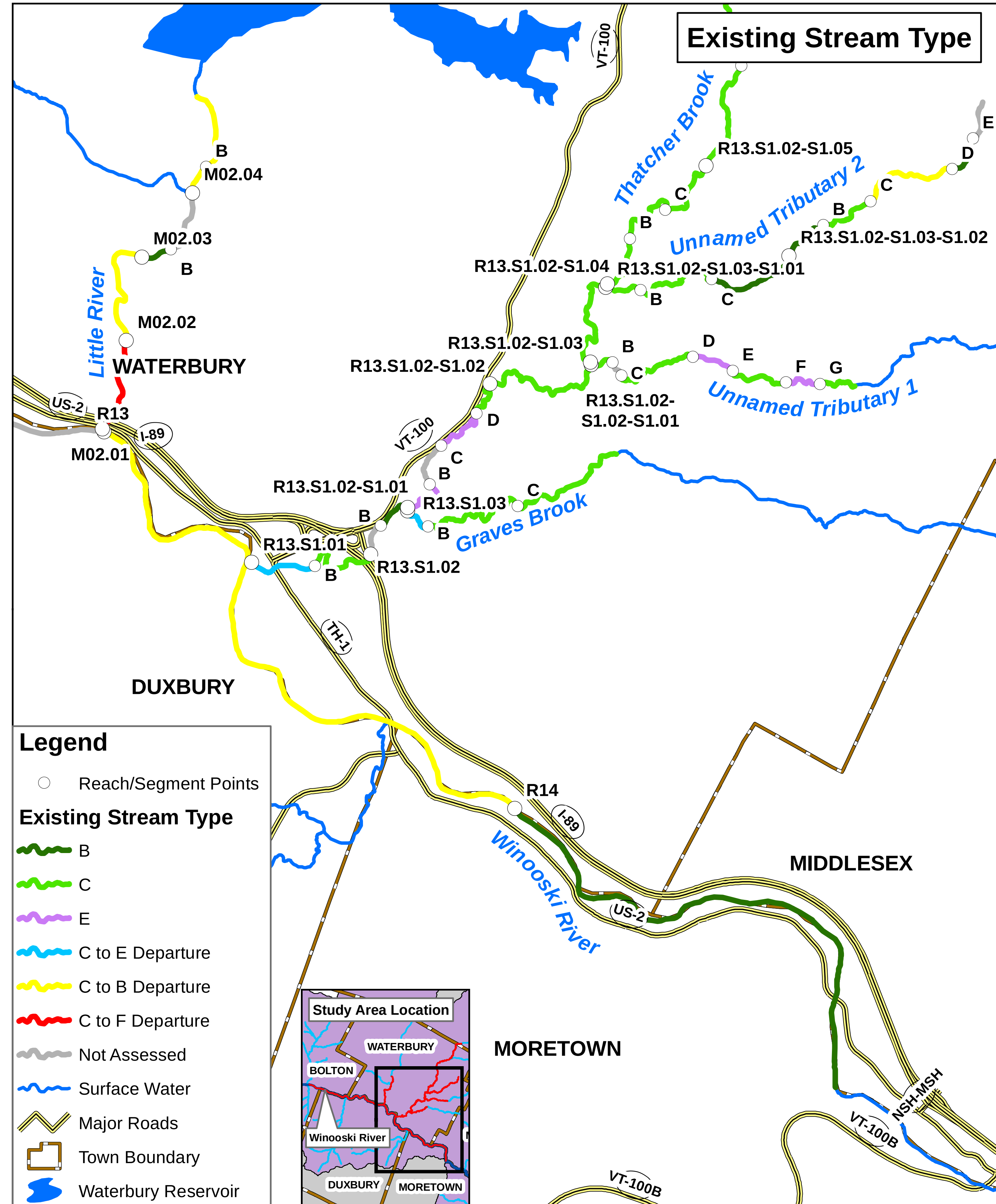


Winooski River
Stream Type - Duxbury, Waterbury,
& Bolton, Vermont

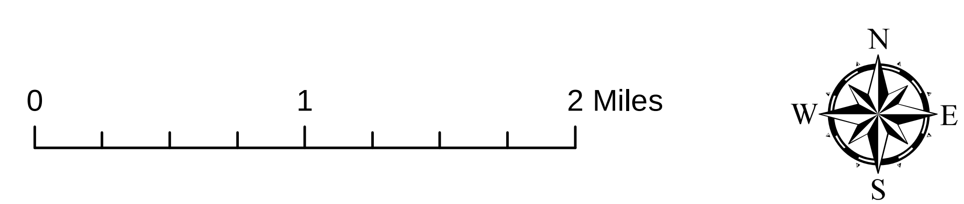
0 1 2 Miles

Bear Creek Environmental

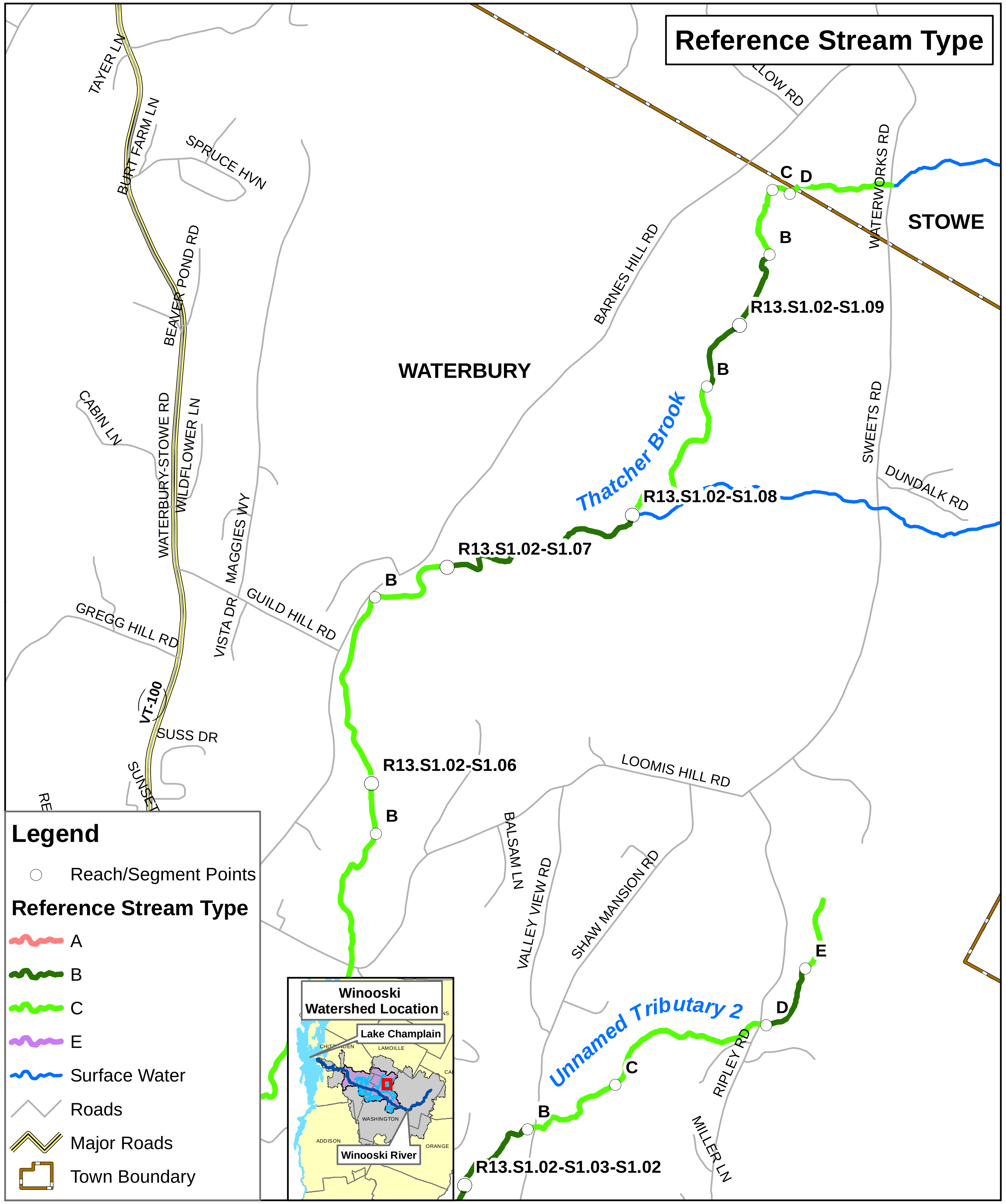


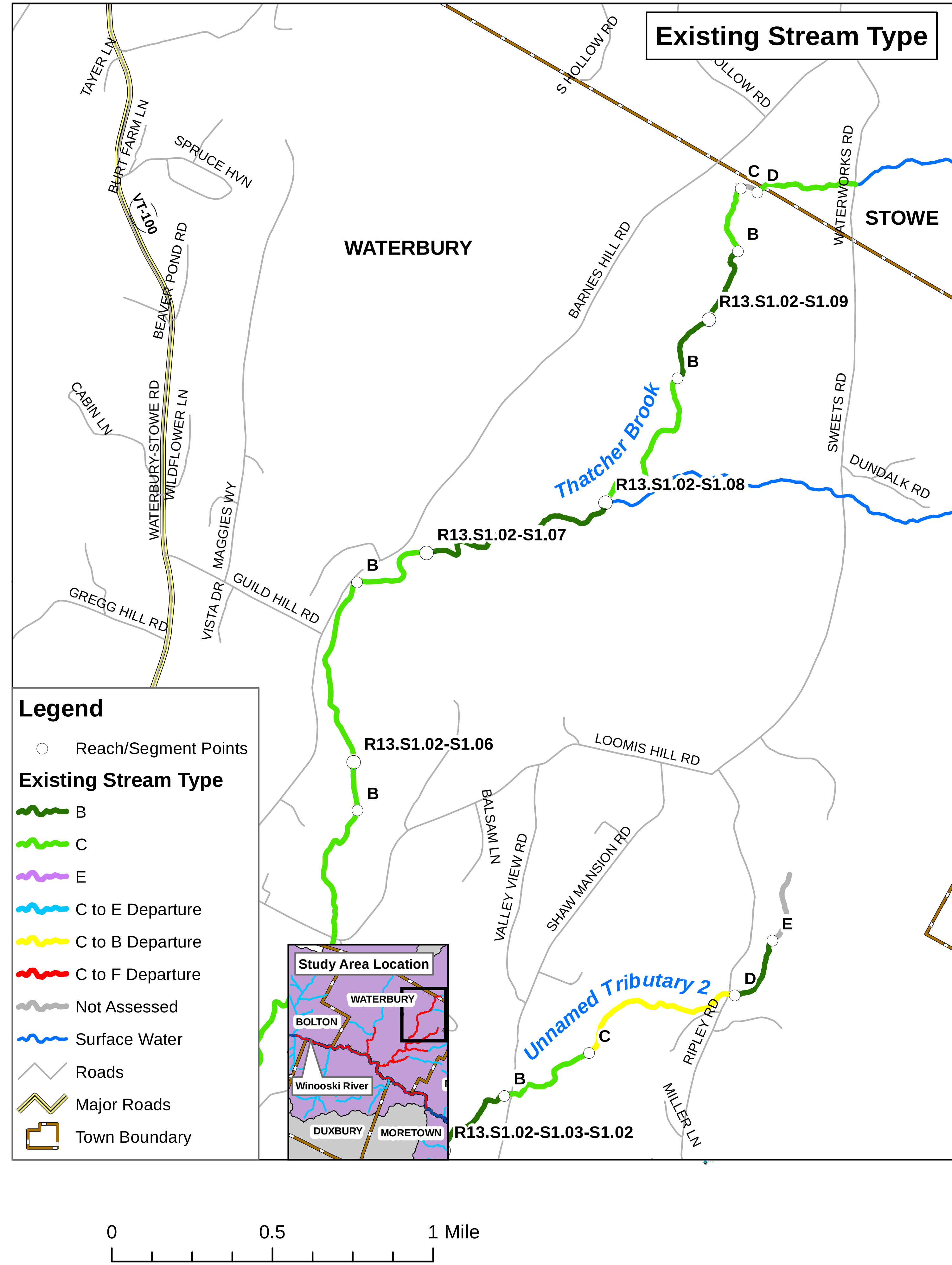


Winooski River, Little River, Thatcher Brook, Graves Brook, Unnamed Tributary 1, & Unnamed Tributary 2 Stream Type - Duxbury, Waterbury, Moretown, and Middlesex, Vermont

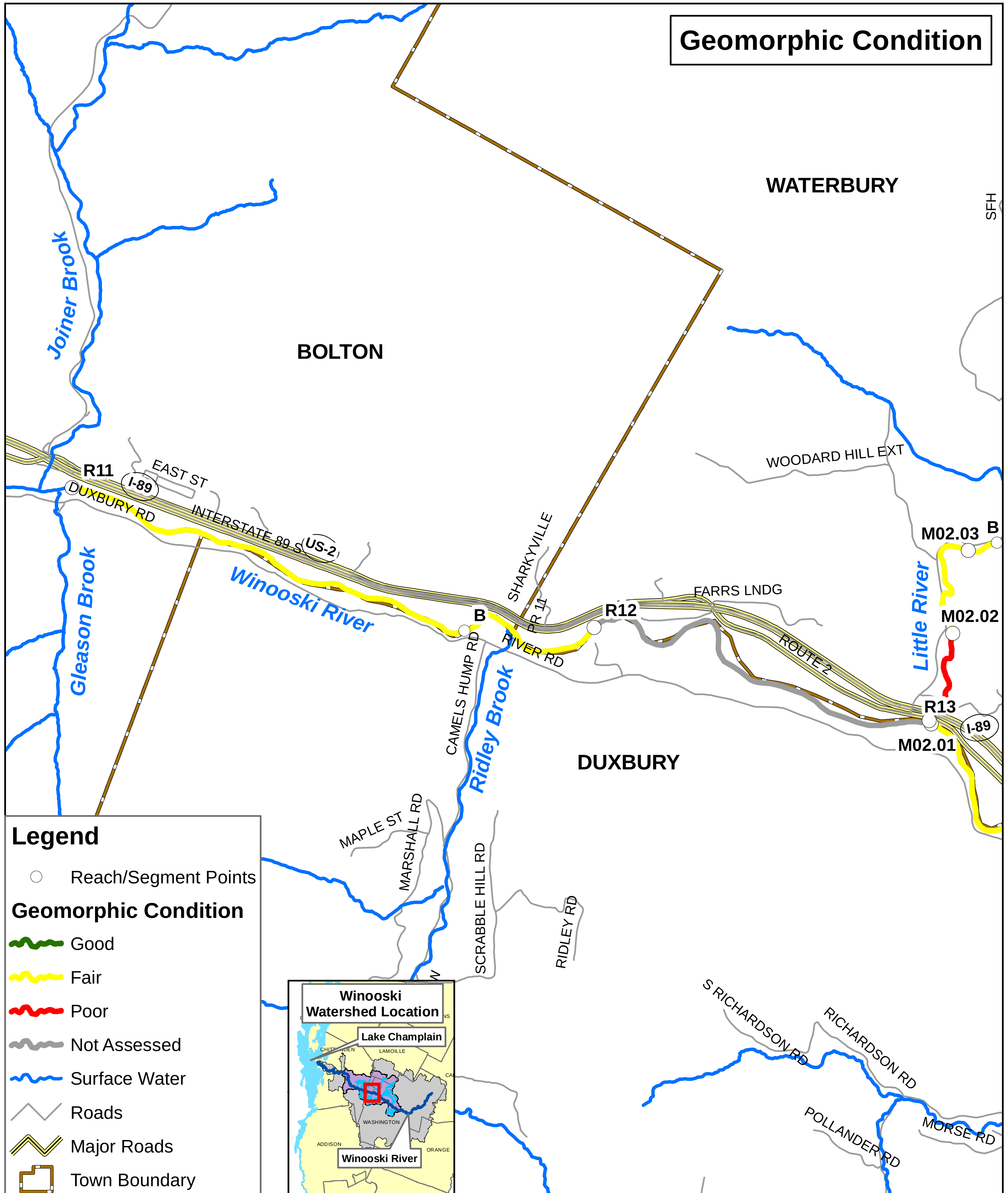


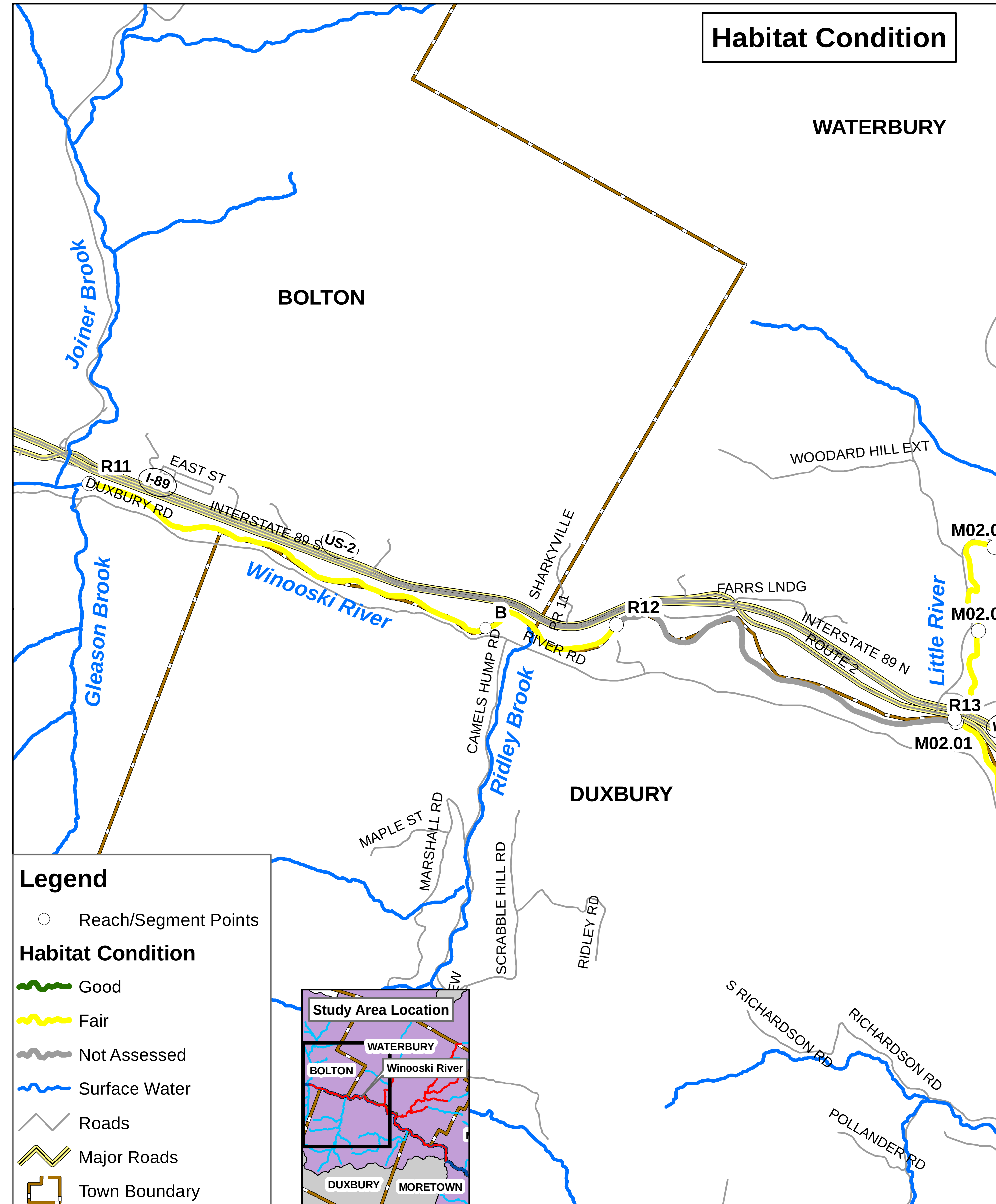
Bear Creek Environmental





Thatcher Brook
Stream Type - Waterbury & Stowe, Vermont

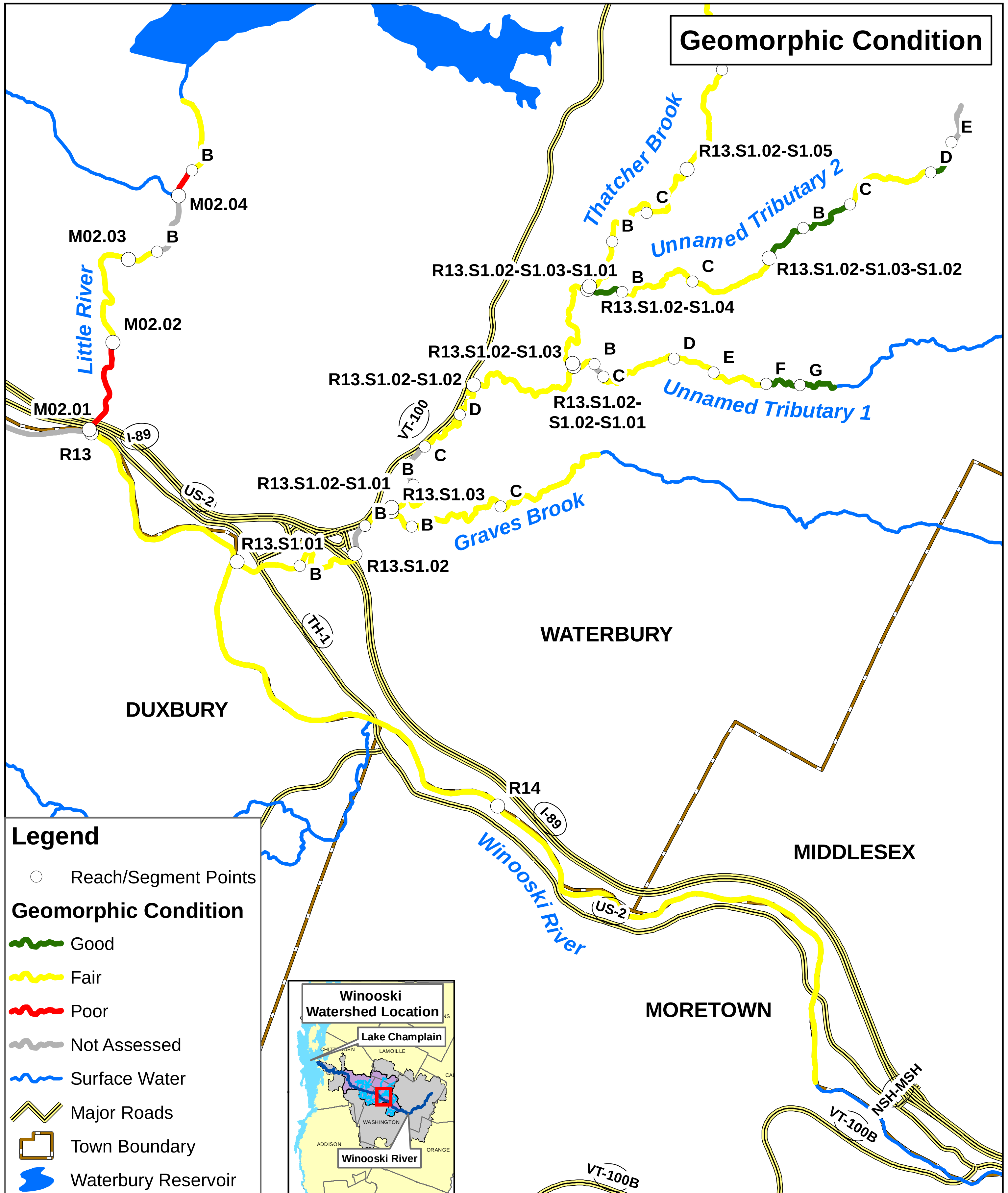


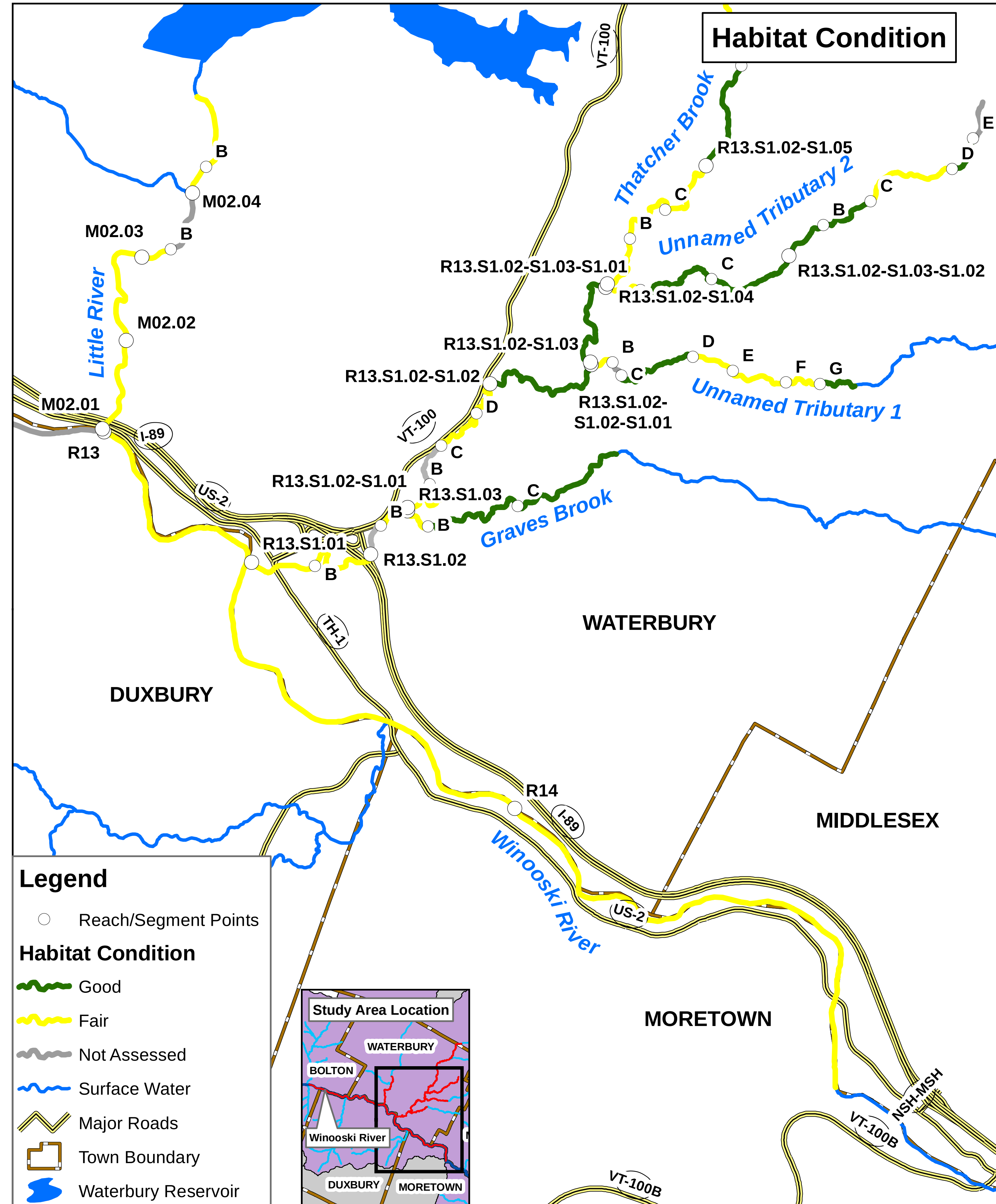


Winooski River
Stream Condition - Duxbury, Waterbury, & Bolton, Vermont

0 1 2 Miles

Bear Creek Environmental



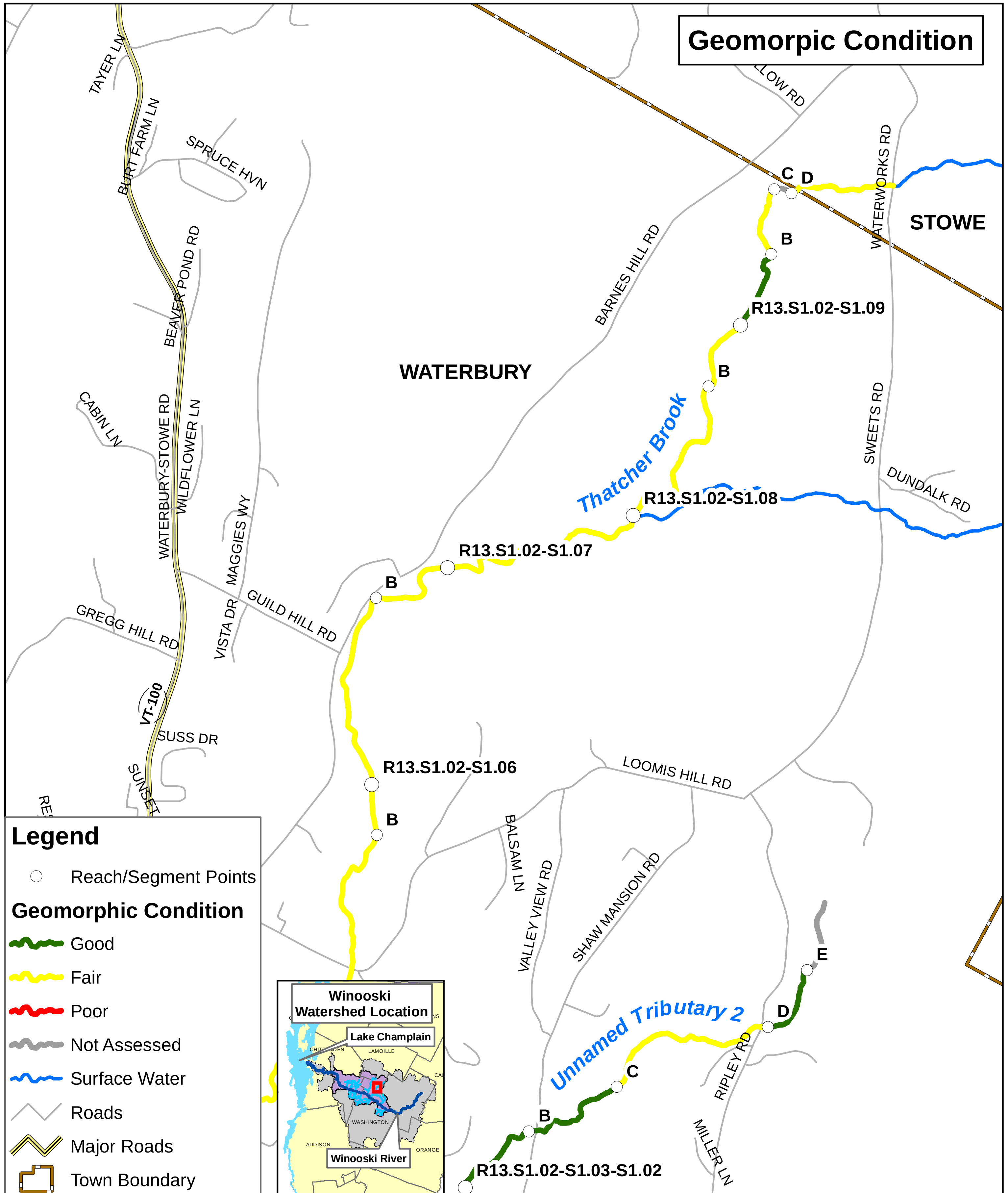


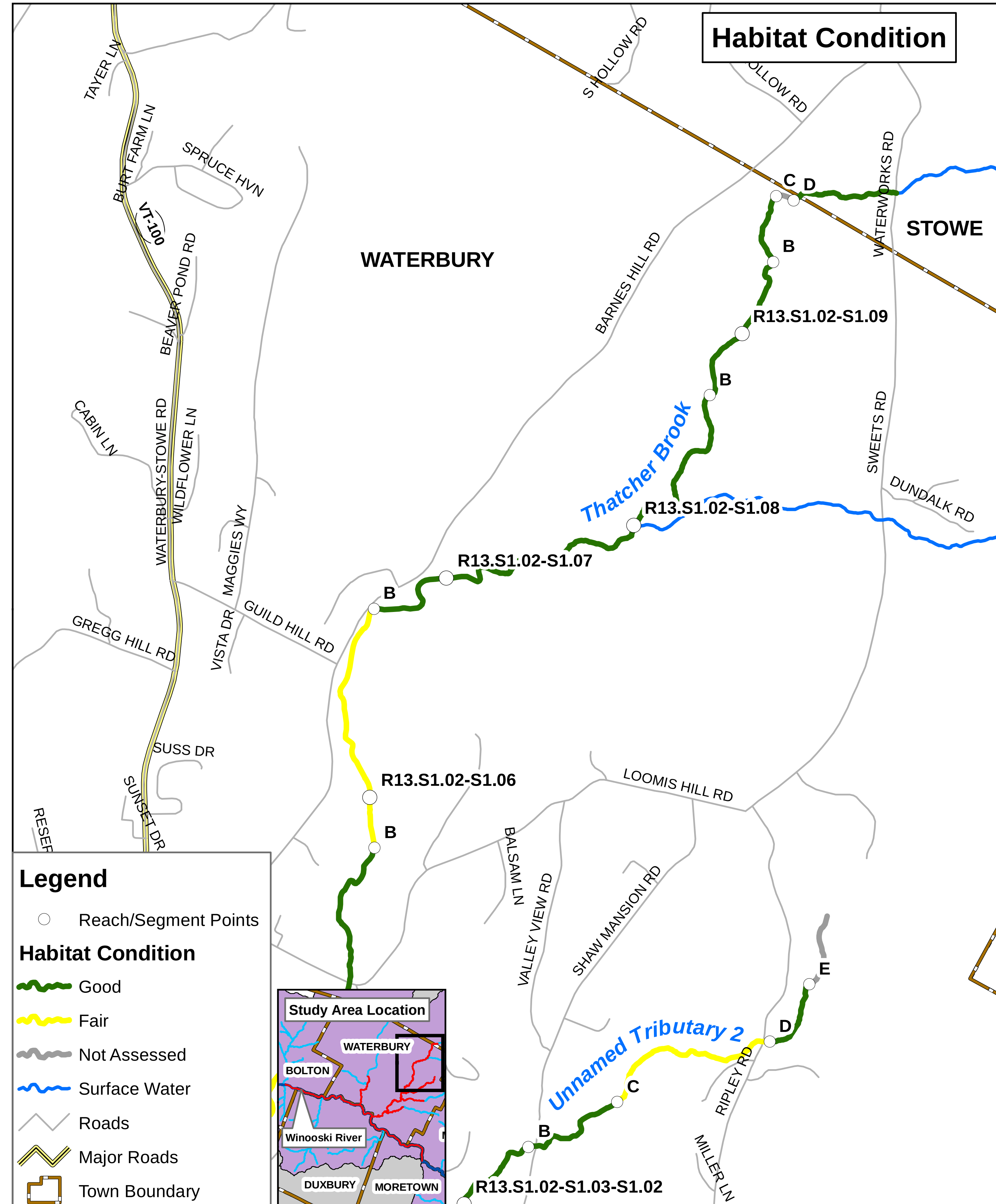
Winooski River, Little River, Thatcher Brook, Graves Brook, Unnamed Tributary 1, & Unnamed Tributary 2 Stream Condition - Duxbury, Waterbury, Moretown, and Middlesex, Vermont

0 1 2 Miles

N S W E

Bear Creek Environmental

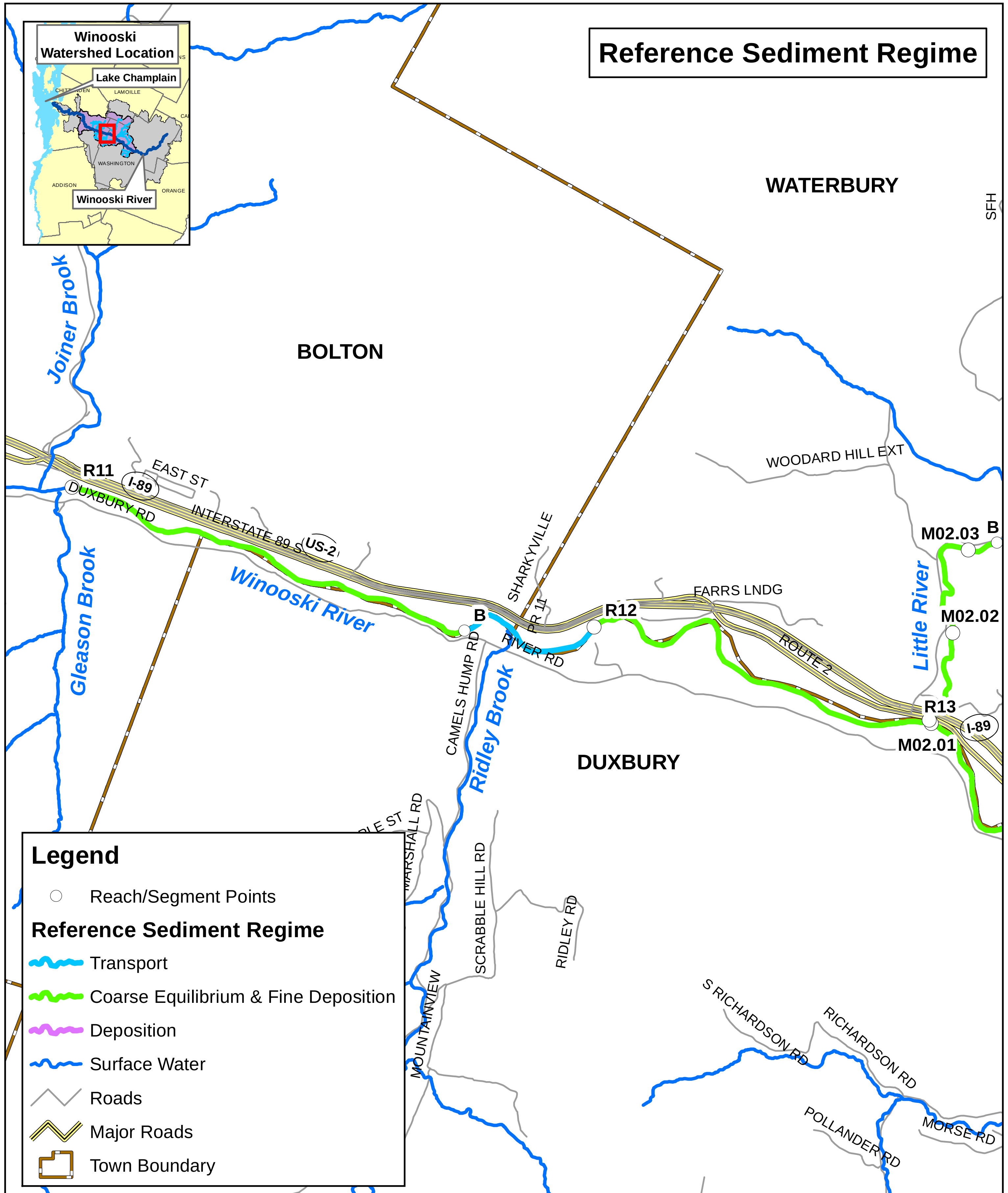


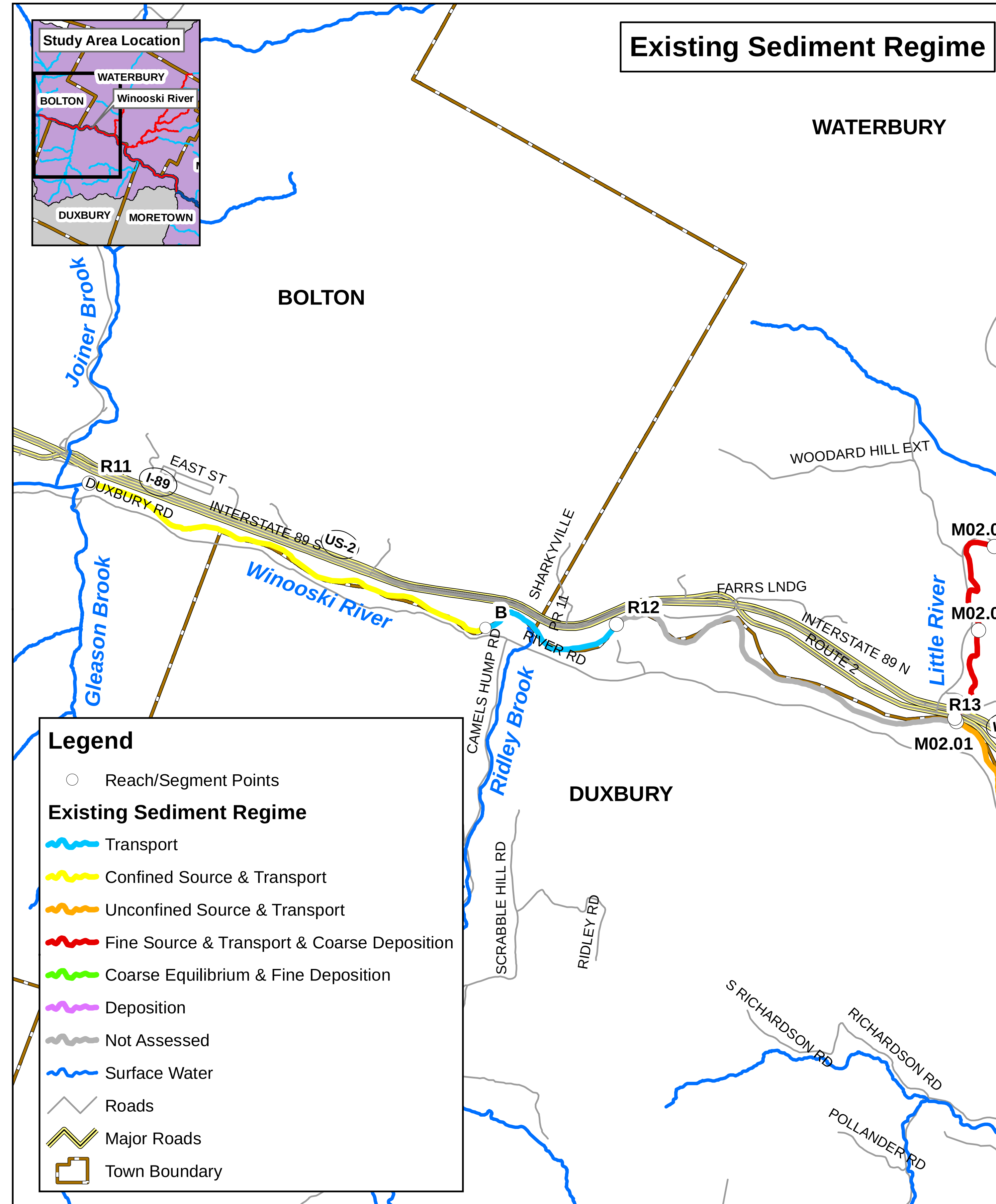


Thatcher Brook
Stream Condition - Waterbury & Stowe, Vermont

0 0.5 1 Mile

Bear Creek Environmental

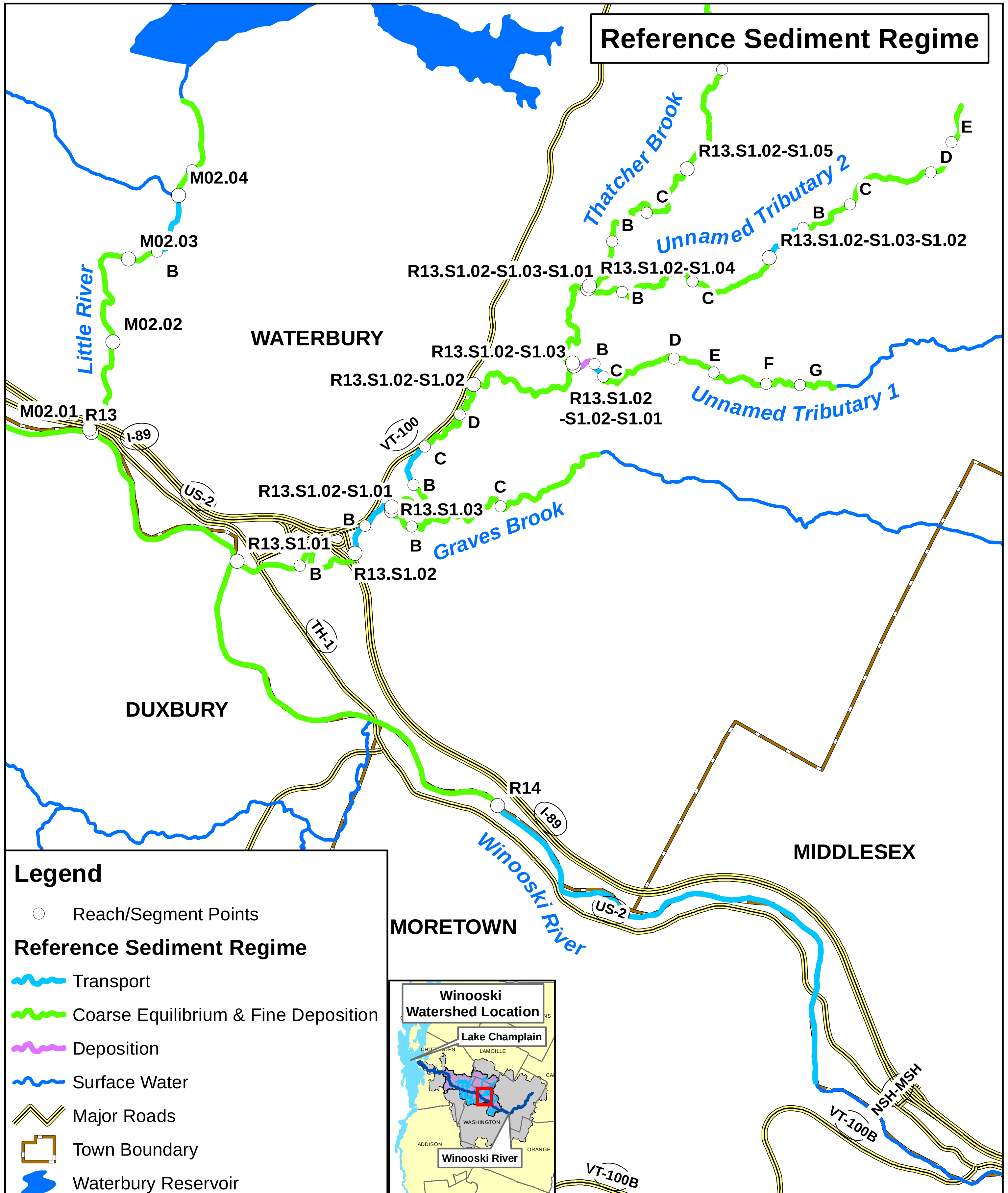


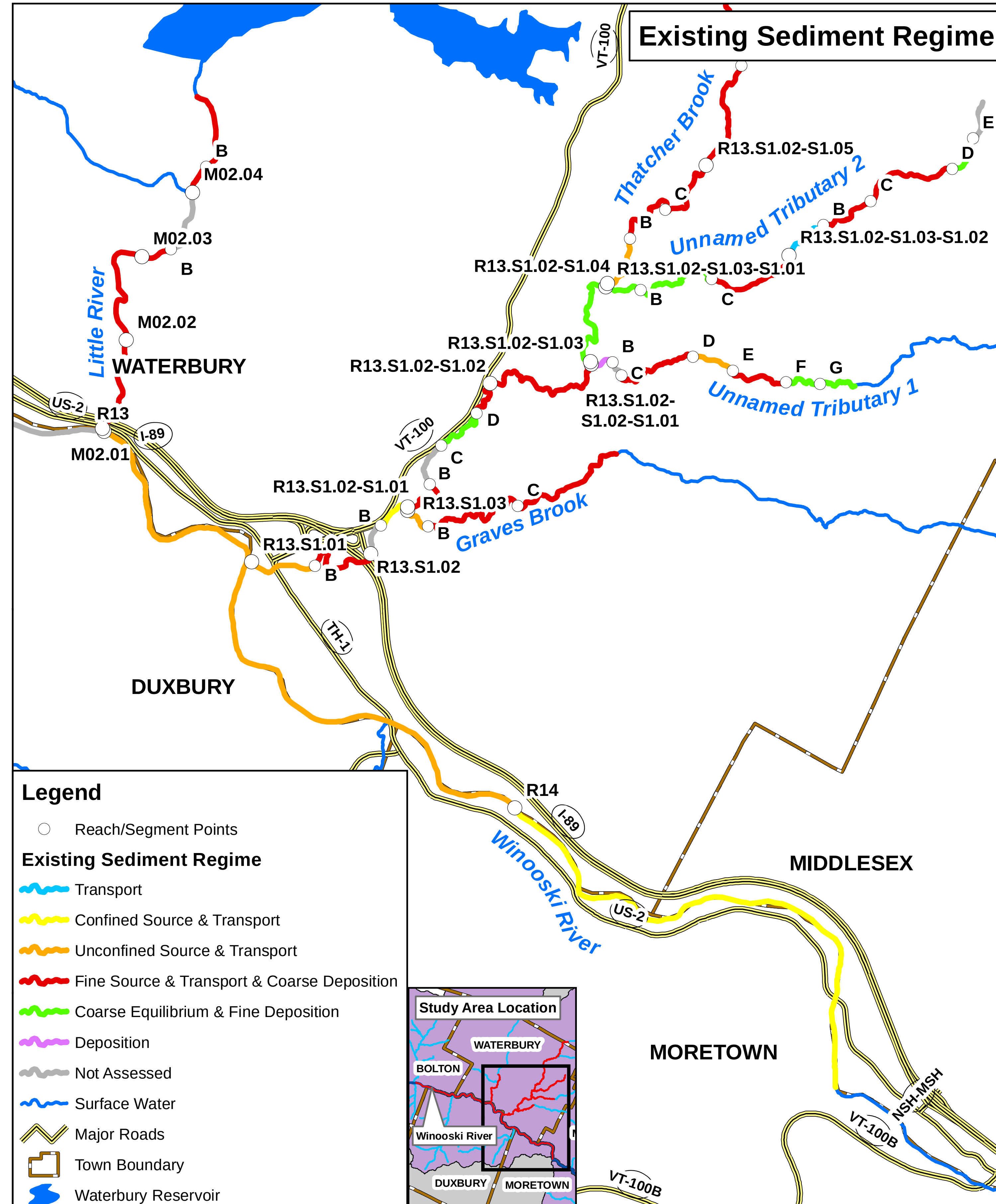


Winooski River
Sediment Regime - Duxbury, Waterbury, & Bolton, Vermont

0 1 2 Miles

Bear Creek Environmental

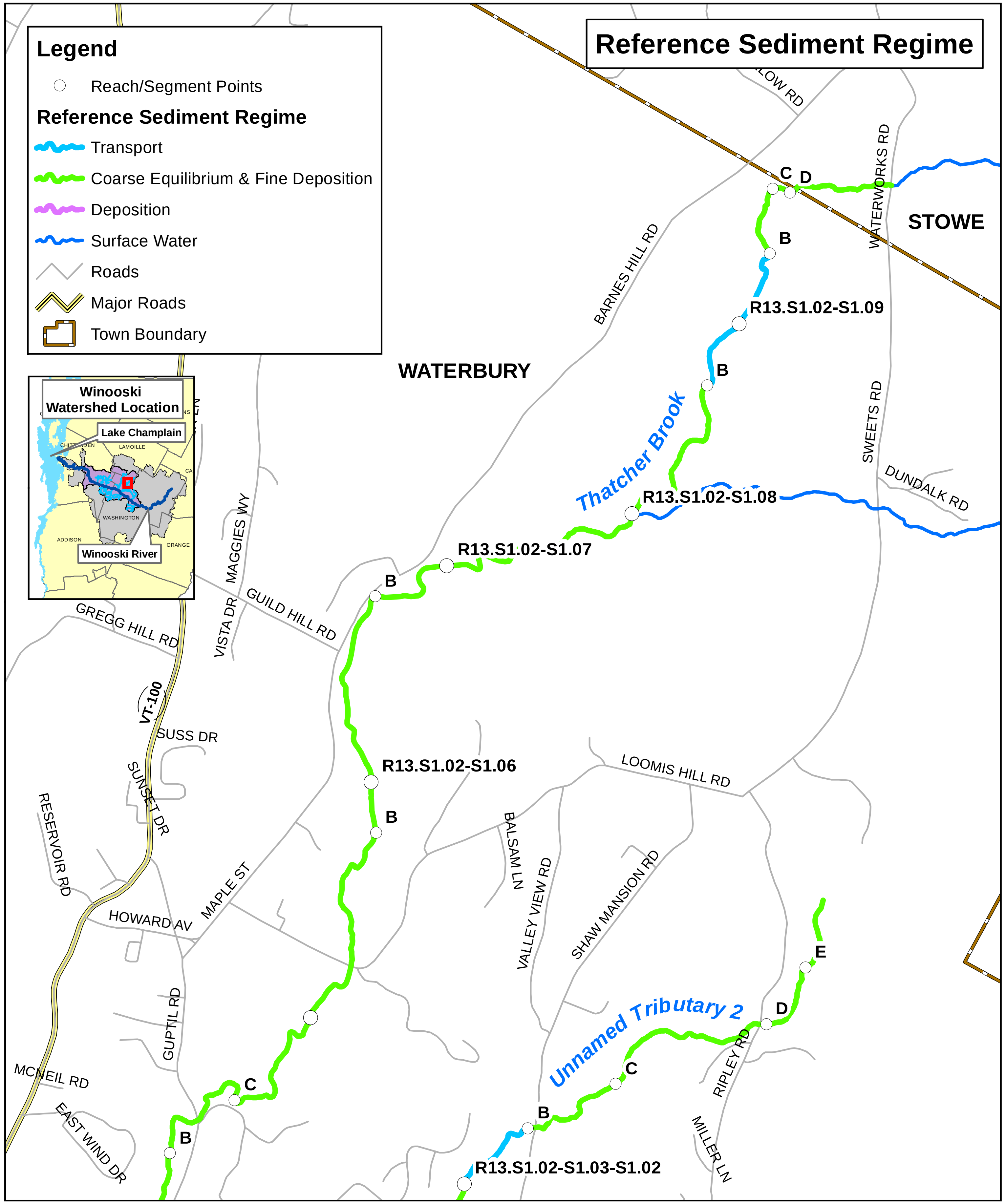


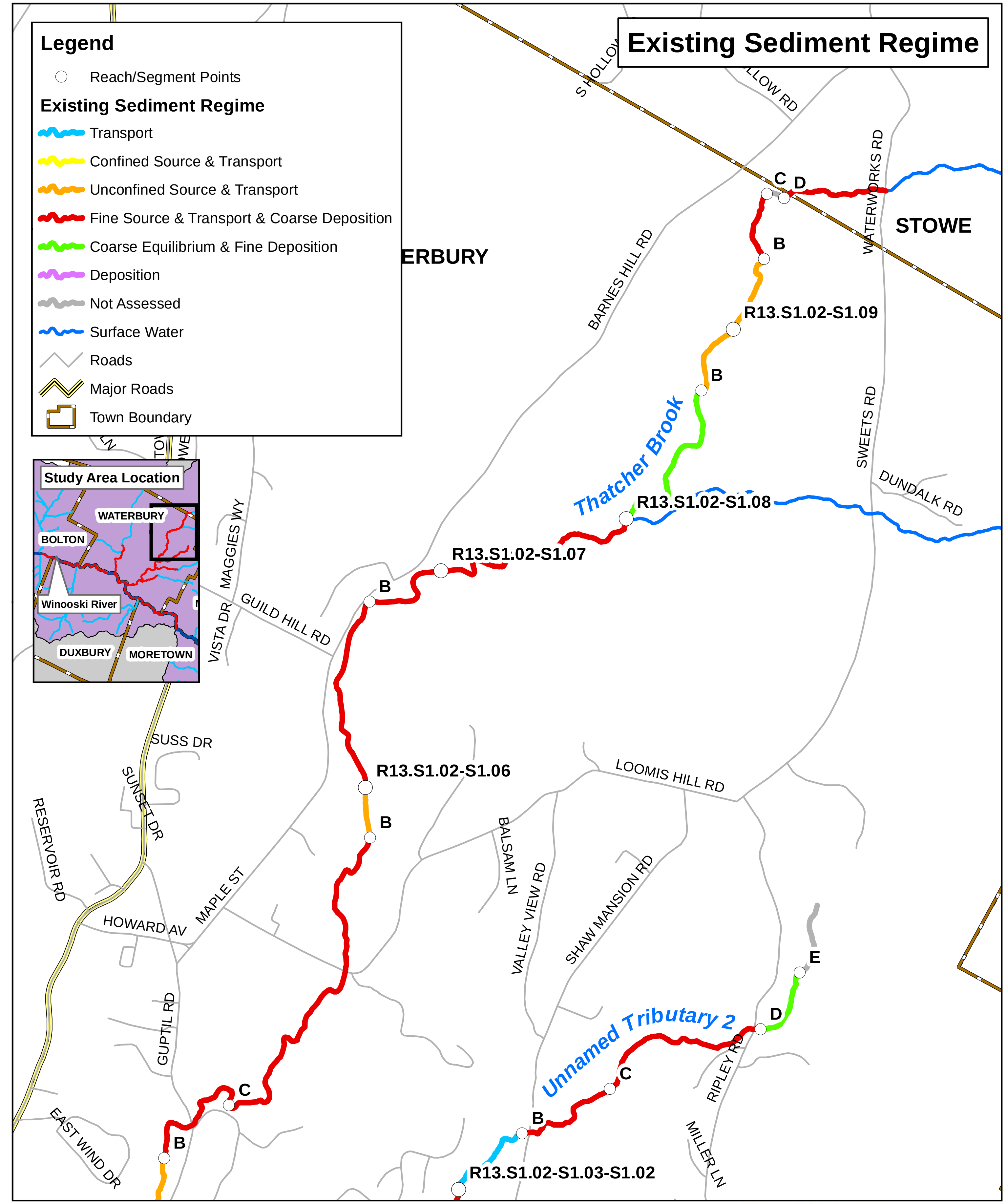


Winooski River, Little River, Thatcher Brook, Graves Brook, Unnamed Tributary 1, & Unnamed Tributary 2 Sediment Regime - Duxbury, Waterbury, Moretown, and Middlesex, Vermont

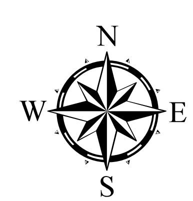
0 1 2 Miles

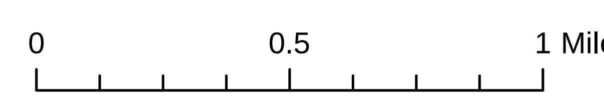
Bear Creek Environmental





Thatcher Brook
Sediment Regime - Waterbury & Stowe, Vermont





Bear Creek Environmental

Table 1. Stream Type and Channel Evolution Stage Summary Mid-Winooski River Watershed							
Segment Number	**Entrenchment Ratio**	**Width to Depth Ratio**	**Reference Stream Type**	**Incision Ratio**	**Existing Stream Type**	**Channel Evolution Stage**	**Active Adjustment Process**
Winooski River Mainstem							
R11-A	1.8	49.8	C	1.4	B_c	F-III	**Incision** Aggradation **Widening** **Planform**
R11-B	1.3	43.3	B_c	1.0	B_c	F-III	Aggradation **Widening** Planform
R13	1.9	31.8	C	1.7	B_c	F-III	**Incision** Aggradation **Widening** Planform
R14	2.2	27.9	B_c	1.5	B_c	F-II	**Incision** Aggradation Widening Planform
Little River							
M2.01	1.0	41.2	C	3.3	F	F-III	**Incision** **Aggradation** **Widening** **Planform**
M2.02	1.5	38.0	C	1.6	B_c	F-III	**Incision** **Aggradation** **Widening** **Planform**
M2.03-A	2.1	26.9	B_c	1.5	B_c	F-IV	**Incision** **Aggradation** Widening **Planform**
M2.04-A	1.9	67.3	C	1.9	B_c	F-III	**Incision** **Aggradation** **Widening** **Planform**
M2.04-B	1.5	46.7	C	4.2	B_c	F-III	**Incision** Aggradation **Widening** Planform

	F Stream Type	B Stream Type	C Stream Type	E Stream Type
Entrenchment Ratio	< 1.4	1.4 – 2.2	> 2.2	> 2.2
Width to Depth Ratio	> 12	> 12	> 12	< 12

Bold Red lettering – denotes severe adjustment process
Bold Black lettering – denotes major adjustment process
Black lettering (no bold) – denotes minor adjustment process
Red denotes severe incision ratio (≥2.0)
Blue denotes moderate incision ratio (1.4 – <2.0)
Green denotes no incision to minor incision (<1.4)
Orange denotes a stream type departure

Table 1. Stream Type and Channel Evolution Stage Summary Mid-Winooski River Watershed							
Segment Number	**Entrenchment Ratio**	**Width to Depth Ratio**	**Reference Stream Type**	**Incision Ratio**	**Existing Stream Type**	**Channel Evolution Stage**	**Active Adjustment Process**
Graves Brook							
R13.S1.01-A	3.4	8.5	C	1.8	E	F-II	**Incision** Aggradation **Widening** **Planform**
R13.S1.01-B	3.5	16.1	C	1.6	C	F-III	**Incision** **Aggradation** Widening **Planform**
R13.S1.02-B	1.4	15.2	B_c	3.5	B_c	F-II	**Incision** Aggradation Widening Planform
R13.S1.03-A	9.6	8.2	C	1.6	E	F-II	**Incision** **Aggradation** Widening **Planform**
R13.S1.03-B	6.9	17.9	C	1.4	C	F-IV	Incision **Aggradation** **Widening** **Planform**
R13.S1.03-C	12.2	13.3	C	1.4	C	F-III	**Incision** **Aggradation** **Widening** **Planform**
Thatcher Brook							
R13.S1.02-S1.01-A	14.4	12.3	E	1.5	E	F-III	Incision **Aggradation** **Widening** **Planform**
R13.S1.02-S1.01-C	13.9	12.2	E	1.0	E	D-IIc	**Aggradation** **Widening** Planform
R13.S1.02-S1.01-D	6.9	14.6	C	1.5	C	F-III	Incision **Aggradation** **Widening** **Planform**

	F Stream Type	B Stream Type	C Stream Type	E Stream Type
Entrenchment Ratio	< 1.4	1.4 – 2.2	> 2.2	> 2.2
Width to Depth Ratio	> 12	> 12	> 12	< 12

Bold Red lettering – denotes severe adjustment process
Bold Black lettering – denotes major adjustment process
Black lettering (no bold) – denotes minor adjustment process
Red denotes severe incision ratio (≥2.0)
Blue denotes moderate incision ratio (1.4 – <2.0)
Green denotes no incision to minor incision (<1.4)
Orange denotes a stream type departure

Table 1. Stream Type and Channel Evolution Stage Summary
Mid-Winooski River Watershed

Segment Number	Entrenchment Ratio	Width to Depth Ratio	Reference Stream Type	Incision Ratio	Existing Stream Type	Channel Evolution Stage	Active Adjustment Process
R13.S1.02-S1.02	18.1	15.9	C	1.3	C	F-III	Incision **Aggradation** **Widening** **Planform**
R13.S1.02-S1.03	16.4	15.0	C	1.0	C	D-IIc	Incision **Aggradation** Widening Planform
R13.S1.02-S1.04-A	11.9	11.2	C	1.5	C	F-III	Incision **Aggradation** **Widening** **Planform**
R13.S1.02-S1.04-B	8.5	13.9	C	1.8	C	F-III	**Incision** Aggradation **Widening** **Planform**
R13.S1.02-S1.04-C	4.1	30.9	C	1.5	C	F-IV	Incision **Aggradation** **Widening** **Planform**
R13.S1.02-S1.05-A	3.8	17.1	C	1.7	C	F-IV	**Incision** **Aggradation** **Widening** **Planform**
R13.S1.02-S1.05-B	6.7	12.6	C	1.6	C	F-II	**Incision** Aggradation Widening Planform
R13.S1.02-S1.06-A	3.5	21.5	C_b	1.5	C_b	F-III	**Incision** **Aggradation** **Widening** **Planform**
R13.S1.02-S1.06-B	3.0	26.3	C_b	1.6	C_b	F-III	**Incision** Aggradation Widening **Planform**
R13.S1.02-S1.07	1.3	21.6	B	1.9	B	F-III	**Incision** Aggradation Widening **Planform**

	F Stream Type	B Stream Type	C Stream Type	E Stream Type
Entrenchment Ratio	< 1.4	1.4 – 2.2	> 2.2	> 2.2
Width to Depth Ratio	> 12	> 12	> 12	< 12

Bold Red lettering – denotes severe adjustment process
Bold Black lettering – denotes major adjustment process
Black lettering (no bold) – denotes minor adjustment process
Red denotes severe incision ratio (≥2.0)
Blue denotes moderate incision ratio (1.4 – <2.0)
Green denotes no incision to minor incision (<1.4)
Orange denotes a stream type departure

Table 1. Stream Type and Channel Evolution Stage Summary
Mid-Winooski River Watershed

Segment Number	Entrenchment Ratio	Width to Depth Ratio	Reference Stream Type	Incision Ratio	Existing Stream Type	Channel Evolution Stage	Active Adjustment Process
R13.S1.02-S1.08-A	3.7	19.1	C_b	1.5	C_b	F-II	**Incision** Aggradation Widening **Planform**
R13.S1.02-S1.08-B	1.6	16.0	B	2.1	B	F-II	**Incision** Aggradation Widening Planform
R13.S1.02-S1.09-A	2.1	15.1	B	1.7	B	F-II	**Incision** Widening Planform
R13.S1.02-S1.09-B	4.2	11.7	C	1.4	C	F-IV	Incision **Aggradation** Widening **Planform**
R13.S1.02-S1.09-D	5.8	15.2	C	1.3	C	F-IV	Incision **Aggradation** Widening **Planform**
Unnamed Tributary 1 to Thatcher Brook							
R13.S1.02-S1.02-S1.01-A	5.3	17.1	C	1.8	C	F-III	**Incision** Aggradation Widening Planform
R13.S1.02-S1.02-S1.01-C	3.2	18.0	C	2.0	C	F-IV	**Incision** **Aggradation** Planform
R13.S1.02-S1.02-S1.01-D	3.1	7.2	E	2.0	E	F-II	**Incision** Aggradation Planform
R13.S1.02-S1.02-S1.01-E	3.4	18.7	C	1.4	C	F-III	Incision Aggradation Widening Planform
R13.S1.02-S1.02-S1.01-F	8.1	8.6	E	1.2	E	F-II	Incision Aggradation Planform
R13.S1.02-S1.02-S1.01-G	4.2	12.0	C_b	1.0	C_b	F-I	Planform

	F Stream Type	B Stream Type	C Stream Type	E Stream Type
Entrenchment Ratio	< 1.4	1.4 – 2.2	> 2.2	> 2.2
Width to Depth Ratio	> 12	> 12	> 12	< 12

Bold Red lettering – denotes severe adjustment process
Bold Black lettering – denotes major adjustment process
Black lettering (no bold) – denotes minor adjustment process
Red denotes severe incision ratio (≥2.0)
Blue denotes moderate incision ratio (1.4 – <2.0)
Green denotes no incision to minor incision (<1.4)
Orange denotes a stream type departure

Table 1. Stream Type and Channel Evolution Stage Summary Mid-Winooski River Watershed							
Segment Number	**Entrenchment Ratio**	**Width to Depth Ratio**	**Reference Stream Type**	**Incision Ratio**	**Existing Stream Type**	**Channel Evolution Stage**	**Active Adjustment Process**
Unnamed Tributary 2 to Thatcher Brook							
R13.S1.02-S1.03-S1.01-A	12.1	16.8	C	1.0	C	F-I	**Aggradation** Widening Planform
R13.S1.02-S1.03-S1.01-B	4.1	15.8	C	1.0	C	D-IIc	**Aggradation Planform**
R13.S1.02-S1.03-S1.01-C	2.0	21.4	B	1.5	B	F-IV	**Incision Aggradation Planform**
R13.S1.02-S1.03-S1.02-A	1.5	14.8	B	1.0	B	F-I	Aggradation
R13.S1.02-S1.03-S1.02-B	5.0	10.0	C_b	1.7	C_b	F-II	**Incision** Aggradation Planform
R13.S1.02-S1.03-S1.02-C	1.9	15.6	C_b	2.0	B	F-II	**Incision** Aggradation Planform
R13.S1.02-S1.03-S1.02-D	1.8	10.6	B	1.2	B	F-II	Aggradation Planform

	F Stream Type	B Stream Type	C Stream Type	E Stream Type
Entrenchment Ratio	< 1.4	1.4 – 2.2	> 2.2	> 2.2
Width to Depth Ratio	> 12	> 12	> 12	< 12

Bold Red lettering – denotes severe adjustment process
Bold Black lettering – denotes major adjustment process
Black lettering (no bold) – denotes minor adjustment process
Red denotes severe incision ratio (≥2.0)
Blue denotes moderate incision ratio (1.4 – <2.0)
Green denotes no incision to minor incision (<1.4)
Orange denotes a stream type departure

APPENDIX B

Bridge & Culvert Assessment Data

Table 1. Scoring Table (Vermont Culvert Geomorphic Compatibility Screen Tool, adapted by BCE for bridges)				
Score	**% Bankfull Width**	**Sediment Continuity**	**Approach Angle**	**Erosion and Armoring**
5	%BFW ≥ 120	No upstream deposition or downstream bed scour	Naturally Straight	No erosion **or** armoring
4	100 ≤ %BFW < 120	**Either** upstream deposition **or** downstream bed scour, **without** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	n/a	No erosion **and** intact armoring, **or** low upstream **or** downstream erosion **without** armoring
3	75 ≤ %BFW < 100	**Either** upstream deposition **or** downstream bed scour, **with** either upstream deposits taller than 0.5 bankfull height **or** high downstream banks	Mild bend	Low upstream **or** downstream erosion **with** armoring
2	50 ≤ %BFW < 75	**Both** upstream deposition **and** downstream bed scour, **without** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	Channelized Straight	Low upstream **and** downstream erosion
1	30 ≤ %BFW < 50	**Both** upstream deposition **and** downstream bed scour, **with** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	n/a	Severe upstream **or** downstream erosion
0	%BFW < 30	**Both** upstream deposition **and** downstream bed scour, **with** upstream deposits taller than 0.5 bankfull height **and** high downstream banks	Sharp Bend	Severe upstream **and** downstream erosion, **or** failing armoring upstream **or** downstream

Table 2. Compatibility Rating Results (Vermont Culvert Geomorphic Compatibility Screen Tool, adapted by BCE for bridges)			
Category Name	**Screen Score**	**Threshold Conditions**	**Description of Structure-channel Geomorphic Compatibility**
Fully Compatible	16<GC≤20	n/a	Structure fully compatible with natural channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. A similar structure is recommended when replacement is needed.
Mostly Compatible	12<GC≤16	n/a	Structure mostly compatible with current channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. Minor design adjustments recommended when replacement is needed to make fully compatible.
Partially Compatible	8<GC≤12	n/a	Structure compatible with either current form or process, but not both. Compatibility likely short term. There is a moderate risk of structure failure and replacement may be needed. Re-design suggested to improve geomorphic compatibility.
Mostly Incompatible	4<GC≤8	% Bankfull Width + Approach Angle scores ≤ 2	Structure mostly incompatible with current form and process, with a moderate to high risk of structure failure. Re-design and replacement planning should be initiated to improve geomorphic compatibility.
Fully Incompatible	0≤GC≤4	% Bankfull Width + Approach Angle scores ≤ 2 **AND** Sediment Continuity + Erosion and Armoring scores ≤ 2	Structure fully incompatible with channel and high risk of failure. Re-design and replacement should be performed as soon as possible to improve geomorphic compatibility.

Milone & MacBroom, Inc., 2008

Table 3. Scoring Table Vermont Culvert Geomorphic Compatibility Screen Tool (Milone & MacBroom, 2008)					
Score	**% Bankfull Width**	**Sediment Continuity**	**Slope**	**Approach Angle**	**Erosion and Armoring**
5	%BFW ≥ 120	No upstream deposition or downstream bed scour	Structure slope equal to channel slope, and no break in valley slope	Naturally Straight	No erosion **or** armoring
4	100 ≤ %BFW < 120	**Either** upstream deposition **or** downstream bed scour, **without** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	n/a	n/a	No erosion **and** intact armoring, **or** low upstream **or** downstream erosion **without** armoring
3	75 ≤ %BFW < 100	**Either** upstream deposition **or** downstream bed scour, **with** either upstream deposits taller than 0.5 bankfull height **or** high downstream banks	Structure slope equal channel slope, with local break in valley slope	Mild bend	Low upstream **or** downstream erosion **with** armoring
2	50 ≤ %BFW < 75	**Both** upstream deposition **and** downstream bed scour, **without** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	Structure slope higher or lower than channel slope, and no break in valley slope	Channelized Straight	Low upstream **and** downstream erosion
1	30 ≤ %BFW < 50	**Both** upstream deposition **and** downstream bed scour, **with** upstream deposits taller than 0.5 bankfull height **or** high downstream banks	n/a	n/a	Severe upstream **or** downstream erosion
0	%BFW < 30	**Both** upstream deposition **and** downstream bed scour, **with** upstream deposits taller than 0.5 bankfull height **and** high downstream banks	Structure slope higher or lower than channel slope, with local break in valley slope	Sharp Bend	Severe upstream **and** downstream erosion, **or** failing armoring upstream **or** downstream

Table 4. Geomorphic Compatibility Rating Results Vermont Culvert Geomorphic Compatibility Screen Tool (Milone & MacBroom, 2008)			
Category Name	**Screen Score**	**Threshold Conditions**	**Description of Structure-channel Geomorphic Compatibility**
Fully Compatible	20<GC≤25	n/a	Structure fully compatible with natural channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. A similar structure is recommended when replacement is needed.
Mostly Compatible	15<GC≤20	n/a	Structure mostly compatible with current channel form and process. There is a low risk of failure. No replacement anticipated over the lifetime of the structure. Minor design adjustments recommended when replacement is needed to make fully compatible.
Partially Compatible	10<GC≤15	n/a	Structure compatible with either current form or process, but not both. Compatibility likely short term. There is a moderate risk of structure failure and replacement may be needed. Re-design suggested to improve geomorphic compatibility.
Mostly Incompatible	5<GC≤10	% Bankfull Width + Approach Angle scores ≤ 2	Structure mostly incompatible with current form and process, with a moderate to high risk of structure failure. Re-design and replacement planning should be initiated to improve geomorphic compatibility.
Fully Incompatible	0≤GC≤5	% Bankfull Width + Approach Angle scores ≤ 2 **AND** Sediment Continuity + Erosion and Armoring scores ≤ 2	Structure fully incompatible with channel and high risk of failure. Re-design and replacement should be performed as soon as possible to improve geomorphic compatibility.

Table 5. Aquatic Organism Passage (AOP) Coarse Screen Tool
(Milone & MacBroom, 2009)

VT Aquatic Organism Passage Coarse Screen	Full AOP	Reduced AOP	No AOP			
Updated 2/25/2008	**for all aquatic organisms**	**for all aquatic organisms**	**for all aquatic organisms except adult salmonids**		**for all aquatic organisms including adult salmonids**	
AOP Function Variables / Values	**Green (if all are true)**	**Gray (if any are true)**	**Orange**		**Red**	
Culvert outlet invert type	at grade **OR** backwatered	cascade	free fall **AND**		free fall **AND**	
Outlet drop (ft)	= 0		> 0 , < 1 ft **OR**		≥ 1 ft **OR**	
Downstream pool present			= yes	(= yes **AND**	= no **OR**	(= yes **AND**
Downstream pool entrance depth / outlet drop			n/m	≥ 1)	n/a	< 1) **OR**
Water depth in culvert at outlet (ft)					< 0.3 ft	
Number of culverts at crossing	1	> 1				
Structure opening partially obstructed	= none	≠ none				
Sediment throughout structure	yes	no				

Notes:
Assessment completed during low flows
Outlet drop = invert of structure to water surface
Pool present variable is used alone if pool depths are not measured
n/m = not measured
n/a = not applicable

Table 6. Town of Waterbury Bridge Assessment (2009/2014) Geomorphic Compatibility													
Reach/ Segment Number	Town	Road Name	Structure ID[1]	Percent Bankfull Channel Constriction Width[2]	Phase 2 Notes	Scoring							Priority for Replacement
						% Bankfull Width[3]	Sediment Continuity	Approach Angle	Erosion & Armoring	Total Score	Geomorphic Compatibility	
R11-B	Bolton	Railroad	200000000104012	450/253.8 = 177	Very old railroad bridge. Scour around piers, reinforced with failing riprap. One pier is built onto bedrock. Bridge decking is very rusty.	5	2	3 Mild Bend	2	**12**	Partially Compatible	Moderate (Poor condition, scour)
R12	Waterbury /Duxbury	VAST Trail	700000000012183	240/250.9 = 96	Cable suspension bridge on VAST Trail. Bridge is built on top of the river banks and does not appear to be impacting the river.	3	5	0 Sharp Bend	1	**9**	Partially Compatible	Not recommended for replacement (Not impacting river)
R13	Waterbury /Duxbury	Railroad	200000000012182	450/234.5 = 192	Old railroad bridge constructed in 1926. I-beams rusted, piers cracked, scour around piers. Significant deposition between piers and an island at the outlet.	5	2	3 Mild Bend	0	**10**	Partially Compatible	Moderate (Poor condition)
R13	Waterbury /Duxbury	Route 2	200013004812182	279/234.5 = 119	New structure in good condition and not a channel constriction. Bridge is curved horizontally and does not go straight across the river.	4	5	2 Channelized Straight	0	**11**	Partially Compatible	Not recommended for replacement (Newly constructed)
R13	Waterbury /Duxbury	Winooski Street	101218003112181	207/23.45 = 88	Bridge was damaged and overtopped during Tropical Storm Irene. The right side approach was washed out during TSI. Bedrock along left bank.	3	4	2 Channelized Straight	2	**11**	Partially Compatible	Moderate (Damaged and overtopped during TSI)
R14	Moretown/ Middlesex	Route 2	200284005012122	285/229.6 = 124	New bridge in good condition. Left side abutment built into bedrock. Bald eagle sighted at time of assessment.	5	5	2 Channelized Straight	2	**14**	Mostly Compatible	Not recommended for replacement (Newly constructed)
M2-04-B	Waterbury	Trail	700000000112183	75/105.3 = 71	Bridge appears to have been used by cars at one time but is now blocked off. Current use most likely snowmobiles; connects into VAST trail. Fair condition. Decking is old and worn. Large pool below bridge due to bend in channel. Left abutment built into bedrock.	2	5	3 Mild Bend	0	**10**	Partially Compatible	Low (Slightly undersized; deteriorating decking)
R13.S1.01-A	Waterbury	North Main Street[4]	200013004712182	37/47.9 = 77	Bridge on US Route 2 (North Main Street) at Union Street intersection (brook flows under both roads); railroad bridge crosses above the road	3	3	3 Mild Bend	0	**9**	Partially Compatible	Low (Slightly undersized with failing armoring)
R13.S1.01-A	Waterbury	Armory Drive[4]	101218003312181	51/47.9 = 106	Bridge has minimal issues	4	5	2 Channelized Straight	0	**11**	Partially Compatible	Not recommended for replacement (Bridge span is wider than bankfull width; minimal problems)
R13.S1.02-B	Waterbury	Stowe Street[4]	101218003612181	42/47 = 89	None	3	4	3 Mild Bend	0	**10**	Partially Compatible	Low (Slightly undersized)
R13.S1.02-S1.01-B	Waterbury	Private Drive[4]	700423000012183	60/43.5 = 137	Bridge decking is wooden boards over steel I-beams; 6x6" post is acting as a pier; scour around abutments and wing walls	5	3	5 Naturally Straight	0	**13**	Mostly Compatible	Moderate (Bridge is not a channel constriction but has abutment and wing wall scour)
R13.S1.02-S1.01-B	Waterbury	Laurel Lane[4]	101218001612181	62/43.5 = 142	Beams are rusty and bridge appears to be fairly old; scour around abutments	5	4	2 Channelized Straight	0	**11**	Partially Compatible	Moderate (Bridge is not a channel constriction but has abutment scour)

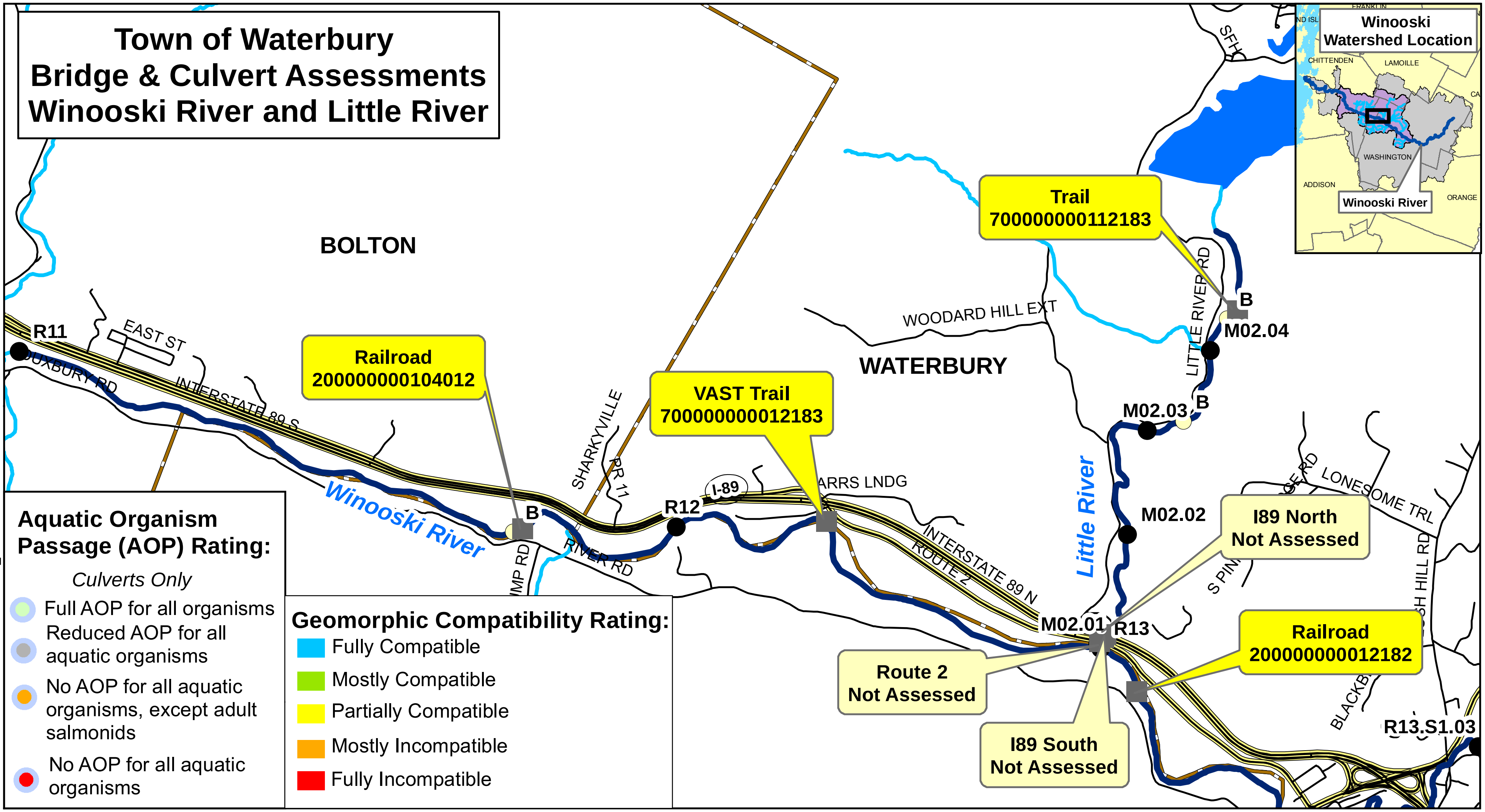
Table 6. Town of Waterbury Bridge Assessment (2009/2014)
Geomorphic Compatibility

Reach/ Segment Number	Town	Road Name	Structure ID[1]	Percent Bankfull Channel Constriction Width[2]	Phase 2 Notes	Scoring: % Bankfull Width[3]	Scoring: Sediment Continuity	Scoring: Approach Angle	Scoring: Erosion & Armoring	Scoring: Total Score	Scoring: Geomorphic Compatibility	Priority for Replacement
R13.S1.01-S1.01-D	Waterbury	Guptil Road[4]	101218000512181	63/43.5 = 144	Bridge appears to be fairly new and has minimal issues	5	3	0 Sharp Bend	3	**11**	Partially Compatible	Not recommended for replacement (Bridge is in good condition)
R13.S1.02-S1.02	Waterbury	Guptil Road[4]	101218000312181	45/41.2 = 109	Streambed scour around abutments. Not a channel constriction	4	1	3 Mild Bend	0	**8**	Mostly Incompatible	Low (Not a channel constriction)
R13.S1.02-S1.03	Waterbury	Guptil Road[4]	101218000412181	78/36.6 = 213	Structure is not a channel constriction; aggradation is typical in this reach and not excessive in vicinity of bridge	5	3	2 Channelized Straight	3	**13**	Mostly Compatible	Not recommended for replacement (Bridge has minimal impacts)
R13.S1.02-S1.04-B	Waterbury	Guptil Road[4]	101218000212181	52/32.5 = 160	Bridge is well sized and has minimal issues	5	2	3 Mild Bend	0	**10**	Partially Compatible	Not recommended for replacement (Bridge has minimal impacts)
R13.S1.02-S1.04-C	Waterbury	Trail[4]	700000000612183	30/32.5 = 92	Although stream does not appear directly manipulated, channel avulsion just downstream of structure makes stream appear channelized straight. Left abutment slumping toward brook	3	3	2 Channelized Straight	2	**10**	Partially Compatible	Moderate (Left abutment slumping)
R13.S1.02-S1.05-A	Waterbury	Loomis Hill Road[4]	101218001412181	36/31.4 = 114	Not a channel constriction and few issues	4	3	3 Mild Bend	0	**10**	Partially Compatible	Low (Not a channel constriction)
R13.S1.02-S1.09-D	Stowe	Waterworks Road	990056001508081	13/20.7 = 63	Structure in good condition but very low clearance (3.7 feet). Heavily choked with sediment. Dam upstream of bridge regulates flow and channel dry at low flow.	2	4	2 Channelized Straight	2	**10**	Partially Compatible	Moderate (Undersized; low clearance)
R13.S1.02-S1.02-S1.01-D	Waterbury	Trail to Green Mountain Garlic	700000000212183	18.5/20.6 = 90	Poor condition: failing abutments and rusted I-beams. Bridge is falling into river. Trail is used to access pasture/crop fields across river. Scour below.	3	4	2 Channelized Straight	0	**9**	Partially Compatible	Moderate (Poor condition but not very undersized)
R13.S1.02-S1.02-S1.01-G	Waterbury	VAST Trail	700000000312183	11/20.6 = 53	Bridge appeared to be part of VAST Trail network. Poor condition and unsafe: half of left abutment has fallen into river. Right abutment is also falling and decking is collapsing. Deposition above and below.	2	2	3 Mild Bend	2	**9**	Partially Compatible	**High** (Poor condition and unsafe for travel)
R13.S1.02-S1.03-S1.01-A	Waterbury	Guptil Road	990001000112181	16.5/18.7 = 88	Poor condition; armor failing; low clearance. Significant sediment built up under bridge obstructing flow. Scour below also.	3	4	2 Channelized Straight	0	**9**	Partially Compatible	**High** (Poor condition and low clearance)
R13.S1.02-S1.03-S1.01-B	Waterbury	Harvey Farm Road	400000000112181	16/18.7 = 86	Bridge in good condition overall and relatively new structure. Deposition below. Poor channel alignment.	3	5	0 Sharp Bend	1	**9**	Partially Compatible	Low (Slightly undersized; poor alignment)

[1]The structure ID is the identification number provided by the 2010 "TransStructures_TRANSTRUC" shapefile from the Vermont Center for Geographic Information, unless no number was available. In this case, the SGAID is provided.
[2]Percent Bankfull Channel Width percentages are calculated based on the reference channel width for each reach. The percentage is calculated by dividing the present constriction width by the reference channel width.
[3]The % bankfull width is based on the constriction calculation.
[4]Structure was assessed in 2009. All other structures assessed in 2014.

Table 7. Town of Waterbury Culvert Assessment (2014) Geomorphic Compatibility and Aquatic Organism Passage (AOP)														
Reach/ Segment Number	**Road Name**	**Structure Type and ID[1]**	**Percent Bankfull Channel Width[2]**	**Phase 2 Notes**	**Scoring** (Geomorphic Compatibility - Milone & MacBroom, 2008; AOP – Milone & MacBroom, 2009)									**Priority for Replacement**
					% Bankfull Width	**Sediment Continuity**	**Slope**	**Approach Angle**	**Erosion & Armoring**	**Total Score**	**Geomorphic Compatibility**	**AOP**		
R13.S1.03-A	Lincoln Street	700019024312183	9/20.6 = 44	Elliptical culvert. If blocked stream could flood nearby homes, road, and park and ride. Extensive riprap falling into streambed. Significantly undersized. Poor alignment.	1	4	5	2 Channelized Straight	0	**12**	Partially Compatible	Reduced AOP		**High** (Significantly undersized)
R13.S1.02-S1.09-B	Private Drive	100000000212181	NA	Three culverts. Two in main channel (each 4 feet wide) one in side channel (4 feet wide). Downstream of wetland complex therefore not really applicable for bankfull assessment. Deposition and scour below.	NA	4	5	3 Mild Bend	0	**12**	Partially Compatible	No AOP Including Adult Salmonids		**High** (No AOP)
R13.S1.02-S1.02-S1.01-C	Twin Peaks Road	700055032412183	11.1/20.6 = 54	Culvert height at outlet is 5.2 feet with 1.8 feet of sediment in pipe at outlet. Culvert completely backwatered with a slope that is too low. Deposition above and below.	2	4	2	3 Mild Bend	0	**11**	Partially Compatible	Full AOP		Moderate (Undersized, low slope)
R13.S1.02-S1.02-S1.01-F	Perry Hill Road	700004008712183	12.9/20.6 = 63	Bottom of culvert is rusty, but overall good condition. Slope lower than channel slope.	2	5	2	3 Mild Bend	0	**12**	Partially Compatible	Reduced AOP		Moderate (Undersized, low slope)
R13.S1.02-S1.03-S1.02-B	Shaw Mansion Road	100000000512181	7/17 = 41	Culvert bottom rusted. Headwall failing and scour around culvert. Aggradation above and large scour pool below.	1	2	2	3 Mild Bend	0	**8**	Mostly Incompatible	Reduced AOP		**High** (Significantly undersized, scour and deposition)
R13.S1.02-S1.03-S1.02-C	Ripley Road	100000000612181	6.5/17 = 38	Culvert bottom rusted. Four foot high cascade over riprap causing a potential AOP barrier. Deposition above and scour below.	1	3	2	5 Naturally Straight	0	**11**	Partially Compatible	Reduced AOP		**High** (Significantly undersized; cascade potential AOP issue)
R13.S1.02-S1.03-S1.02-E	Private Trail	700000000412183	NA	Culvert located at outlet of human-made pond in wetland therefore not applicable for bankfull assessment. Stream channel begins below culvert. Scour below.	NA	5	5	2 Channelized Straight	4	**16**	Mostly Compatible	Reduced AOP		Low (Pond outlet pipe)
R13.S1.02-S1.03-S1.02-E	Private Trail	700000000512183	3.5/17 = 21	Double culvert, one 1.5 feet wide and one 2 feet wide due to being slightly crushed.	0	5	2	5 Naturally Straight	4	**16**	Mostly Compatible	Reduced AOP		Moderate (Significantly undersized, low slope)

[1]The structure ID is the identification number provided by the 2010 "TransStructures_TRANSTRUC" shapefile from the Vermont Center for Geographic Information, unless no number was available. In this case the SGAID is provided.
[2]Percent Bankfull Channel Width percentages are calculated based on the reference channel width for each reach. The percentage is calculated by dividing the culvert width by the reference channel width.



Legend

- Bridge
- Culvert
- Segment Point
- Phase 2 Reach Point
- Phase 2 Study Area
- Surface Water
- Roads
- Major Roads
- Town Boundary

The ID numbers are provided by the 2010 "TransStructures_TRANSTRUC"shapefile from the Vermont Center for Geographic Information, unless no number was available. The SgaID (State of Vermont Data Management System) was used if no "TransStructures_TRANSTRUC" information was available.

Geomorphic Compatibility Rating for bridges is adapted from the Vermont Culvert Geomorphic Compatibility Screening Tool (Milone and MacBroom, Inc. 2008).

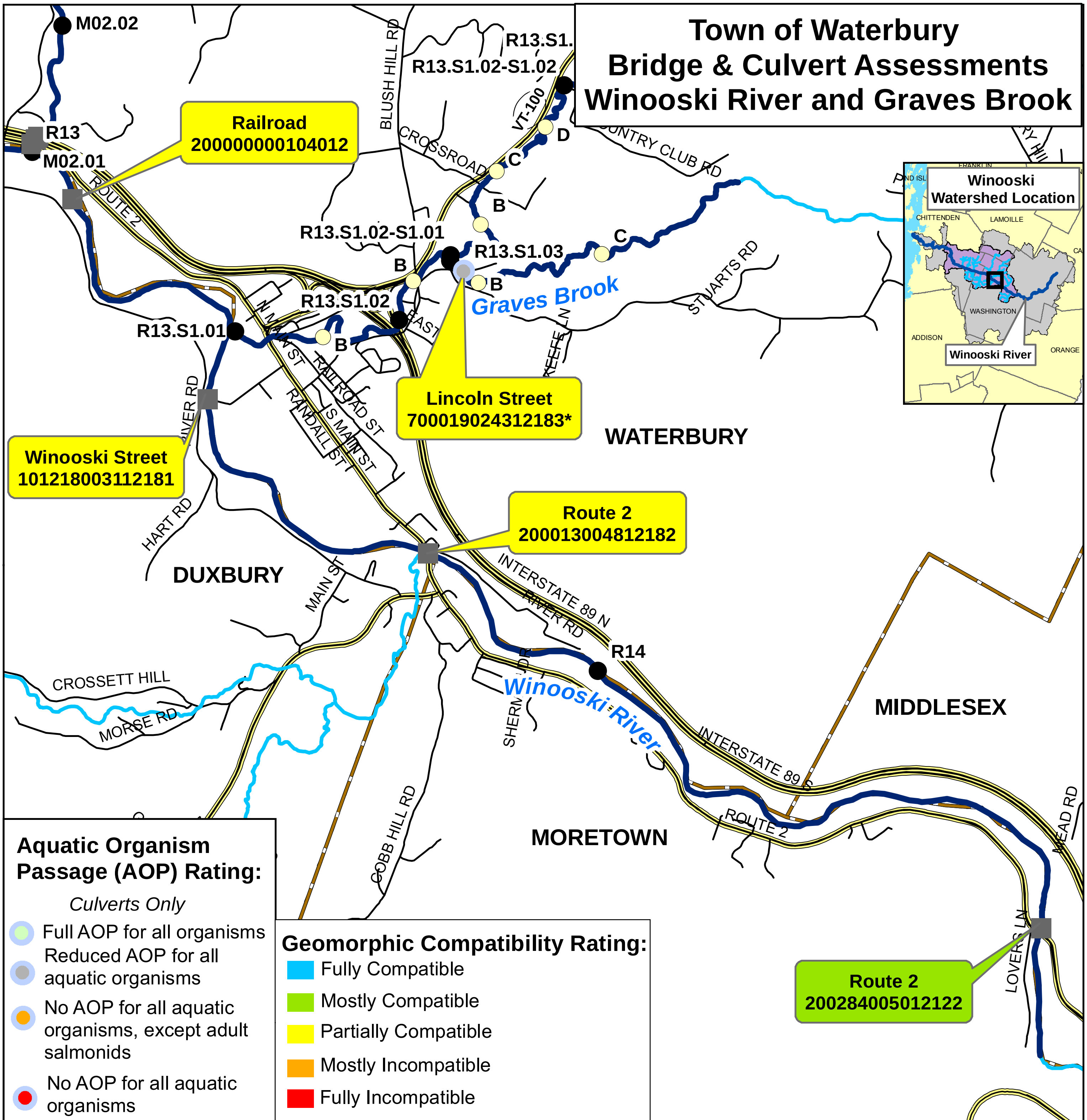
Aquatic Organism Passage Rating for culverts is from the Vermont Culvert Aquatic Organism Passage Screening Tool (Milone and MacBroom, 2009).

*Structure is recommended for replacement.

N W E S

0 0.5 1 Mile

Bear Creek Environmental



Legend

- Bridge
- Culvert
- Segment Point
- Phase 2 Reach Point
- Phase 2 Study Area
- Surface Water
- Roads
- Major Roads
- Town Boundary

The ID numbers are provided by the 2010 "TransStructures_TRANSTRUC"shapefile from the Vermont Center for Geographic Information, unless no number was available. The SgaID (State of Vermont Data Management System) was used if no "TransStructures_TRANSTRUC" information was available.

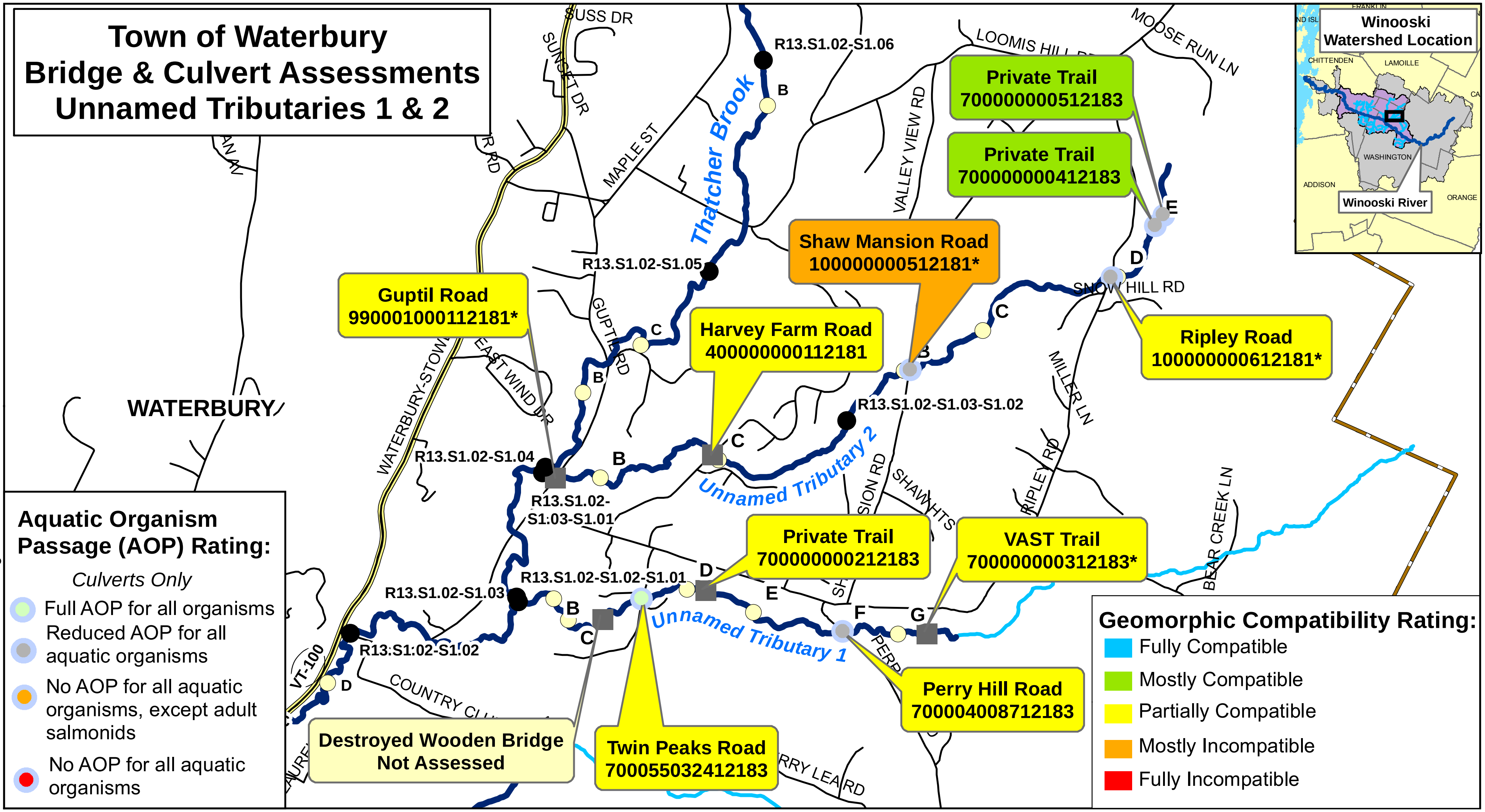
Geomorphic Compatibility Rating for bridges is adapted from the Vermont Culvert Geomorphic Compatibility Screening Tool (Milone and MacBroom, Inc. 2008).

Aquatic Organism Passage Rating for culverts is from the Vermont Culvert Aquatic Organism Passage Screening Tool (Milone and MacBroom, 2009).

*Structure is recommended for replacement.

0 0.5 1 Mile

Bear Creek Environmental



Legend

- Bridge
- Culvert
- Segment Point
- Phase 2 Reach Point
- Town Boundary
- Phase 2 Study Area
- Surface Water
- Roads
- Major Roads

The ID numbers are provided by the 2010 "TransStructures_TRANSTRUC"shapefile from the Vermont Center for Geographic Information, unless no number was available. The SgaID (State of Vermont Data Management System) was used if no "TransStructures_TRANSTRUC" information was available.

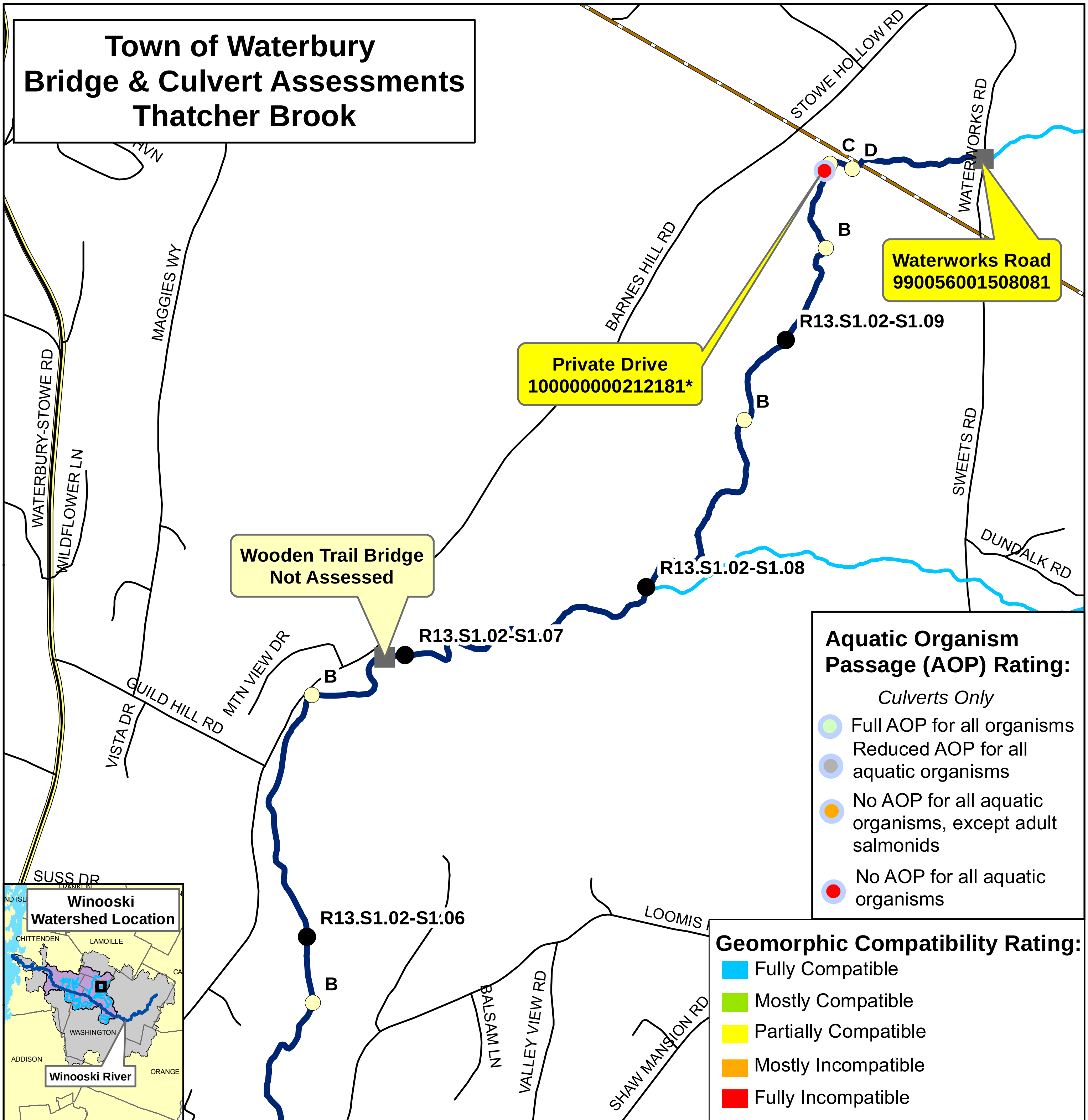
Geomorphic Compatibility Rating for bridges is adapted from the Vermont Culvert Geomorphic Compatibility Screening Tool (Milone and MacBroom, Inc. 2008).

Aquatic Organism Passage Rating for culverts is from the Vermont Culvert Aquatic Organism Passage Screening Tool (Milone and MacBroom, 2009).

*Structure is recommended for replacement.

0 0.5 1 Mile

Bear Creek Environmental



Legend

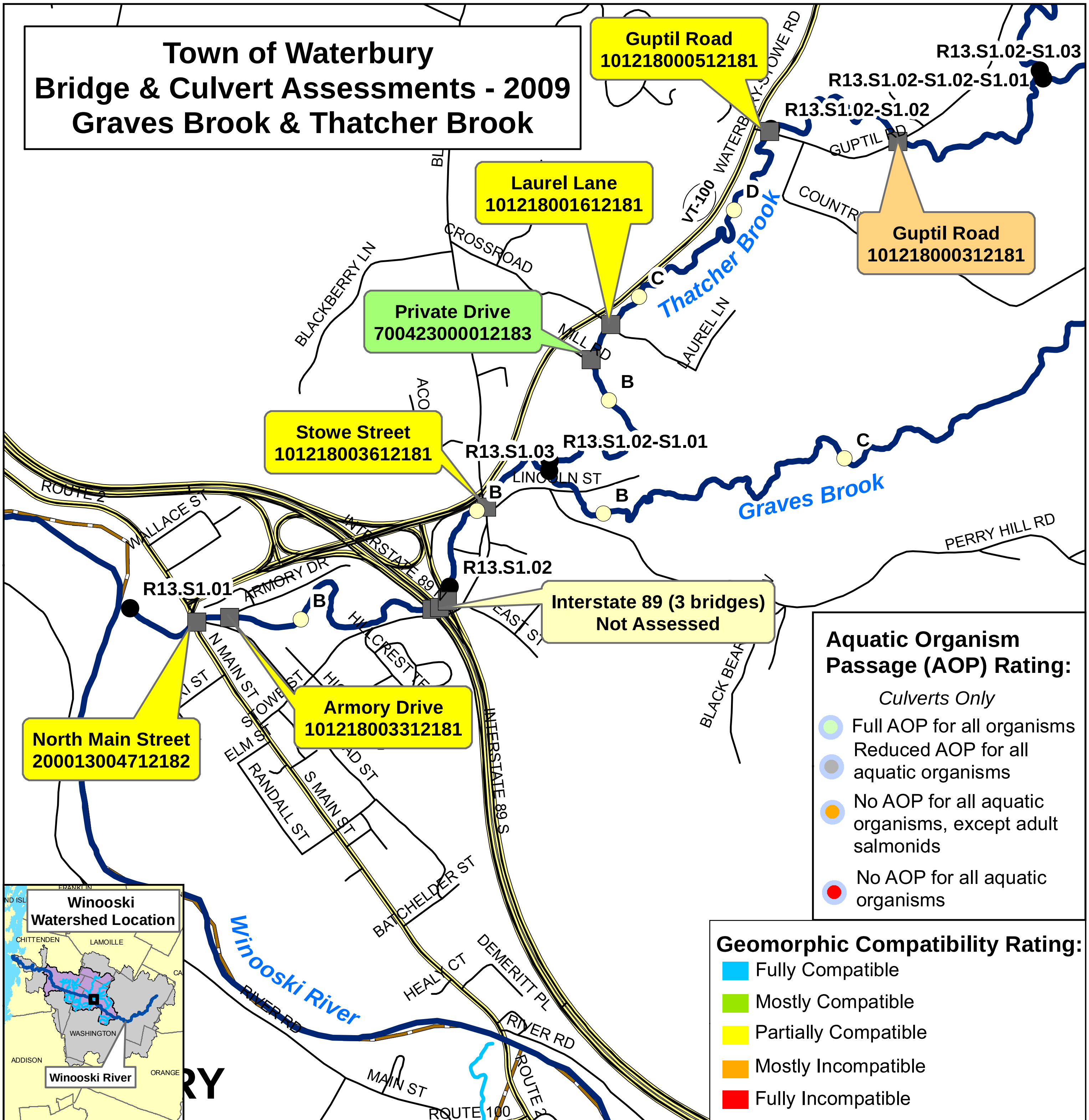
- Bridge
- Culvert
- Segment Point
- Phase 2 Reach Point
- Phase 2 Study Area
- Surface Water
- Roads
- Major Roads
- Town Boundary

The ID numbers are provided by the 2010 “TransStructures_TRANSTRUC”shapefile from the Vermont Center for Geographic Information, unless no number was available. The SgaID (State of Vermont Data Management System) was used if no “TransStructures_TRANSTRUC” information was available.

Geomorphic Compatibility Rating for bridges is adapted from the Vermont Culvert Geomorphic Compatibility Screening Tool (Milone and MacBroom, Inc. 2008).

Aquatic Organism Passage Rating for culverts is from the Vermont Culvert Aquatic Organism Passage Screening Tool (Milone and MacBroom, 2009).

*Structure is recommended for replacement.



Legend

- Bridge
- Segment Point
- Phase 2 Reach Point
- Phase 2 Study Area
- Surface Water
- Roads
- Major Roads
- Town Boundary

The ID numbers are provided by the 2010 “TransStructures_TRANSTRUC”shapefile from the Vermont Center for Geographic Information, unless no number was available. The SgaID (State of Vermont Data Management System) was used if no “TransStructures_TRANSTRUC” information was available.

Geomorphic Compatibility Rating for bridges is adapted from the Vermont Culvert Geomorphic Compatibility Screening Tool (Milone and MacBroom, Inc. 2008).

Aquatic Organism Passage Rating for culverts is from the Vermont Culvert Aquatic Organism Passage Screening Tool (Milone and MacBroom, 2009).

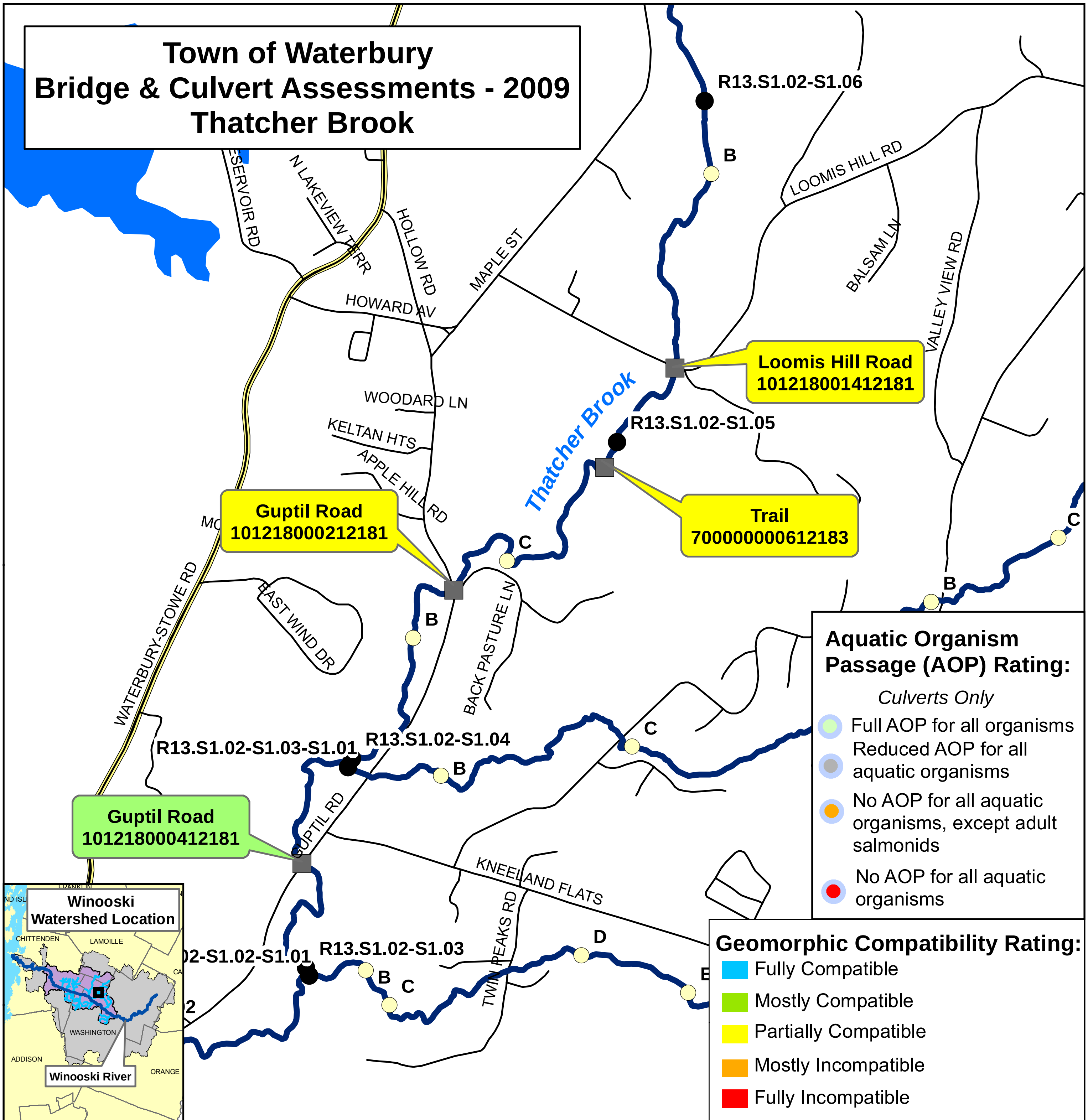
*Structure is recommended for replacement.

N W E S

0 0.25 0.5 Mile

Bear Creek Environmental

Town of Waterbury
Bridge & Culvert Assessments - 2009
Thatcher Brook



Legend

- Bridge
- Segment Point
- Phase 2 Reach Point
- Phase 2 Study Area
- Surface Water
- Roads
- Major Roads
- Town Boundary

The ID numbers are provided by the 2010 "TransStructures_TRANSTRUC"shapefile from the Vermont Center for Geographic Information, unless no number was available. The SgaID (State of Vermont Data Management System) was used if no "TransStructures_TRANSTRUC" information was available.

Geomorphic Compatibility Rating for bridges is adapted from the Vermont Culvert Geomorphic Compatibility Screening Tool (Milone and MacBroom, Inc. 2008).

Aquatic Organism Passage Rating for culverts is from the Vermont Culvert Aquatic Organism Passage Screening Tool (Milone and MacBroom, 2009).

*Structure is recommended for replacement.

N W E S

0 0.25 0.5 Mile

Bear Creek Environmental

APPENDIX C

Post-Flood Update

POST-FLOOD UPDATE SECTION

1.0 INTRODUCTION

In late August of 2011, Vermont was hit hard by Tropical Storm Irene (TSI). Heavy rain totaled over seven inches in areas over the course of one day. The immense downpours caused raging floodwaters to tear through Vermont's streams, devastating people and infrastructure throughout central and southern Vermont. In some areas, TSI flooding approached historic flood levels, while in other areas, the storm greatly exceeded them. Over 500 miles of state roads were damaged as a result of TSI, in addition to over 2000 segments of municipal roads. In total, approximately 500 bridges were damaged or destroyed, as well as almost 1,000 culverts. Approximately 1,500 residences were significantly damaged or destroyed as a result of flooding, as well as state, municipal, and commercial buildings (VANR 2012).
Flooding associated with Tropical Storm Irene (TSI) in late August 2011 greatly impacted Waterbury, Vermont. Due to very high stream flows from TSI, the channels of Graves and Thatcher Brook may have experienced major changes. In order to observe any changes in channel geometry, Bear Creek Environmental (BCE) looked at pre-TSI geomorphic data and aerial imagery and compared it to post TSI measurements and observations.

2.0 PRE- AND POST-TSI CHANNEL CONDITIONS

Phase 2 Stream Geomorphic Assessment data were collected on the lower reaches of Graves Brook and Thatcher Brook in 2009 by Redstart Consulting under contract with the Central Vermont Regional Planning Commission (CVRPC). Bear Creek Environmental, LLC (BCE) and the Central Vermont Regional Planning Commission resurveyed cross sections during 2014 that had been measured by Redstart Consulting in 2009 to assess whether there were major changes in channel geometry due to flooding or post TSI floodworks (i.e. stream channel modification). Wherever possible, BCE placed cross sections at the same locations as in 2009. In addition, BCE conducted a review of aerial imagery to determine visible changes in channel course between 2009 and 2013 – pre- and post-Irene.

National Agricultural Inventory Project (NAIP) 2009 imagery data were used to digitize the pre-TSI stream channel location for lower Graves Brook and Thatcher Brook. The digitized stream layer from 2009 was then overlain on Vermont Center for Geographic Information imagery from spring 2013 in ArcGIS to observe changes from 2009 to 2013. Figures 1 and 2 below show examples of changes observed along Thatcher Brook between 2009 and 2013. The results of the comparison of channel planform from 2009 and 2013 showed two areas where the channel had avulsed in the following segments: R13.S1.02-S1.04-A and R13.S1.02-S1.05-A (Figure 3). Google Earth Imagery dated 12/30/2011 was observed to pinpoint when the channel avulsions may have occurred. In both locations, Google Earth Imagery revealed that these avulsions occurred between 2009 and the end of 2011, most likely during TSI. Meander migrations occurred in 18 locations along the channel meanders between 2009 and 2013.

Figure 1. Side by side comparison of a location along Thatcher Brook where meander migration (purple dots) occurred likely as a result of TSI (2009 imagery on left, 2013 on right).

Figure 2. Side by side comparison of a location along Thatcher Brook where channel avulsion occurred as a result of TSI (2009 imagery on left, 2013 on right).

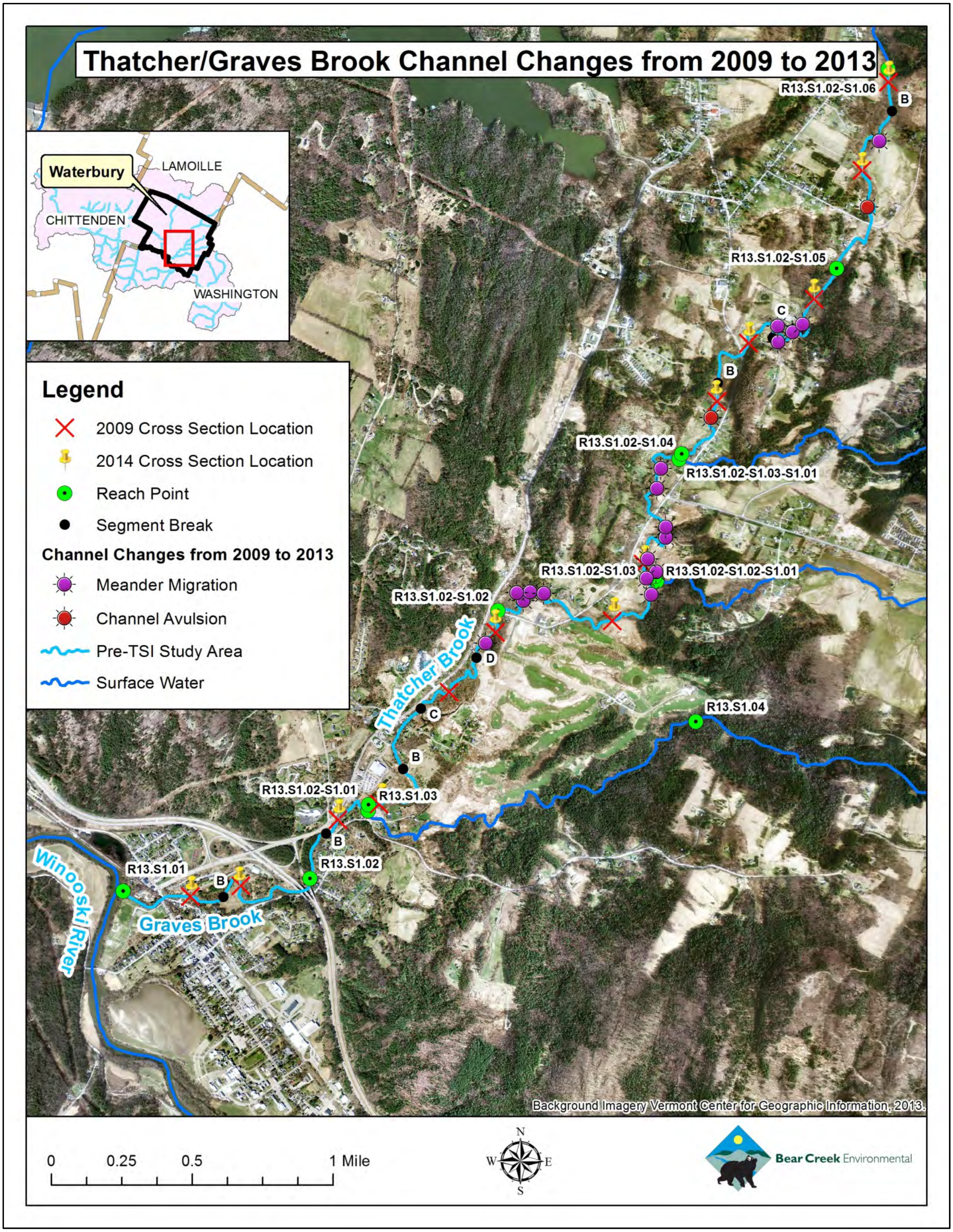


Figure 3. Channel changes in Thatcher and Graves Brook from 2009 to 2013.

Thatcher Brook flows through extensive wetland complexes in Waterbury Center as it meanders toward the confluence with Graves Brook just northeast of Waterbury Village. This area is extremely important for the attenuation of floodwaters and sediment and likely alleviates flooding and fluvial erosion downstream in the densely populated village. Figures 4 and 5 show wetlands along Thatcher Brook storing floodwaters during a high flow event in April of 2014.

Figure 4. Floodwater attenuation in wetlands along Thatcher Brook.

Figure 5. Water disperses energy out onto the floodplain in many areas along Thatcher Brook.

During the 2009 stream geomorphic assessment of Thatcher and Graves Brook, a total of thirteen cross sections within fifteen segments was measured by Redstart Consulting. BCE resurveyed twelve of these thirteen cross sections in 2014. A cross section was not measured in segment R13.S1.02-S1.01-C in 2014 due an impoundment created by a beaver dam within the vicinity of the 2009 cross section location. No cross sections were measured within segments R13.S1.02-A and R13.S1.02-S1.01-B in either 2009 or 2014, because these segments are classified as bedrock gorges. The following graphs and tables display both similarities and differences between the 2009 and 2014 cross sections. Parameters in the tables explain the changes, if any, in the morphology of the stream channels. Some parameters are more significant indicators of adjustment than others. For instance, a greater incision ratio in 2014 suggests that the channel has cut down into its bed. An increase in the width to depth ratio is an indication that the channel may have widened.

Graves Brook

R13.S1.01-A

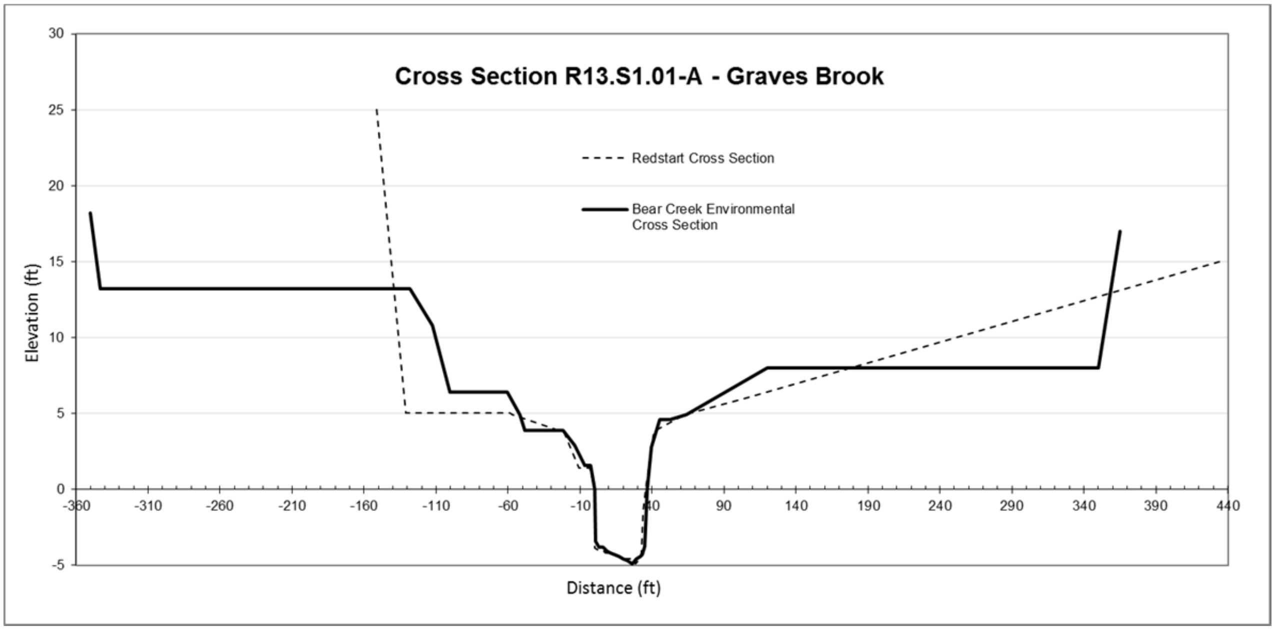


Figure 6. 2009 and 2014 Cross sections done by Redstart and BCE, respectively in Segment R13.S1.01-A.

Table 1: Comparison of 2009 and 2014 Cross Sections at R13.S1.01-A					
River Scientist Team	**Cross Sectional Area**	**Bankfull Width**	**W/D Ratio**	**Entrenchment Ratio**	**Incision Ratio**
Redstart (2009)	146.8	35.3	8.5	3.39	1.8
BCE (2014)	151.4	36.6	8.8	3.17	1.8
Percent change	3.1%	3.7%	3.5%	-6.5%	0%
Comments: Cross sections very similar. No significant change due to TSI. Left valley wall differs due to 2014 cross section extending to railroad bed. 2009 cross section ended at road. Bedform in 2014 was more of a run and not a riffle.					

Figure 7. Cross section R13.S1.01-A in 2009 (left) and in 2014 (right)

R13.S1.01-B

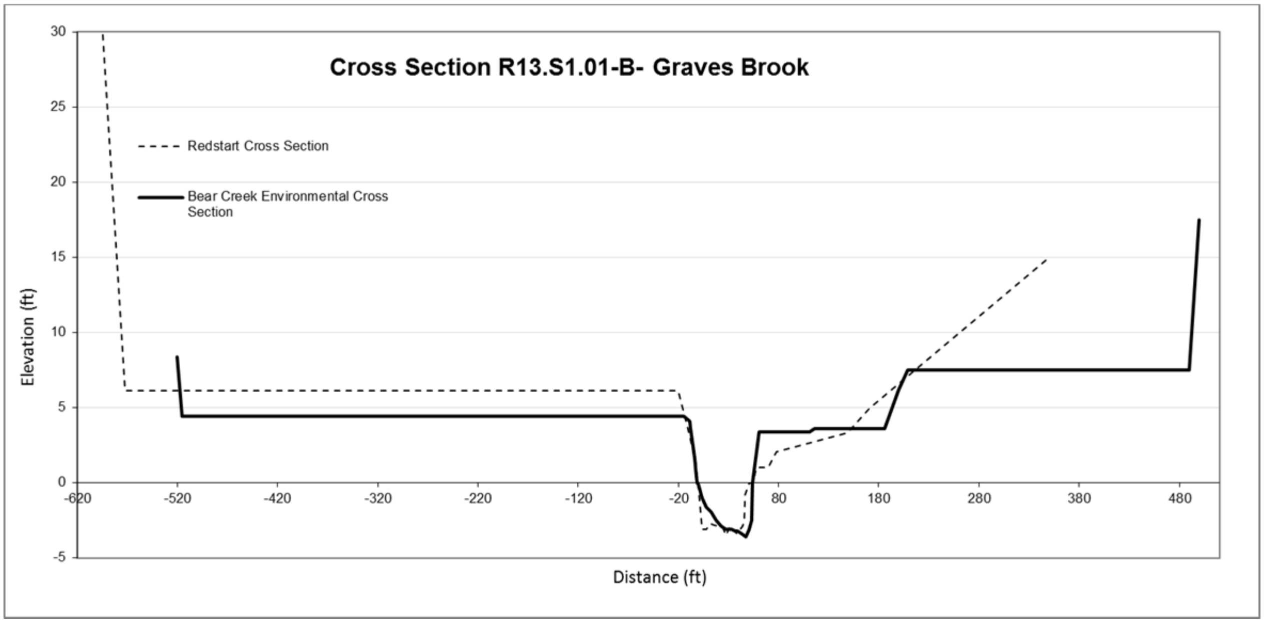


Figure 8. 2009 and 2014 Cross sections done by Redstart and BCE, respectively in Segment R13.S1.01-B.

Table 2: Comparison of 2009 and 2014 Cross Sections at R13.S1.01-B					
River Scientist Team	**Cross Sectional Area**	**Bankfull Width**	**W/D Ratio**	**Entrenchment Ratio**	**Incision Ratio**
Redstart (2009)	135	50.8	19.1	2.96	1.6
BCE (2014)	138	54.3	21.4	2.27	1.9
Percent change	2.2%	6.9%	12.0%	-23.3%	18.8%
Comments: 2009 cross section location is now a pool. 2014 cross section was surveyed just upstream (about 35 feet) of 2009 cross section location, which may account for the difference in left terrace elevation. Channel has slightly widened. No more undercut on left bank and left bank has slumped. More aggradational in 2014 possibly due to TSI (See Figure 9).					

Figure 9. Cross section R13.S1.01-B in 2009 (left) and in 2014 (right)

R13.S1.02-B

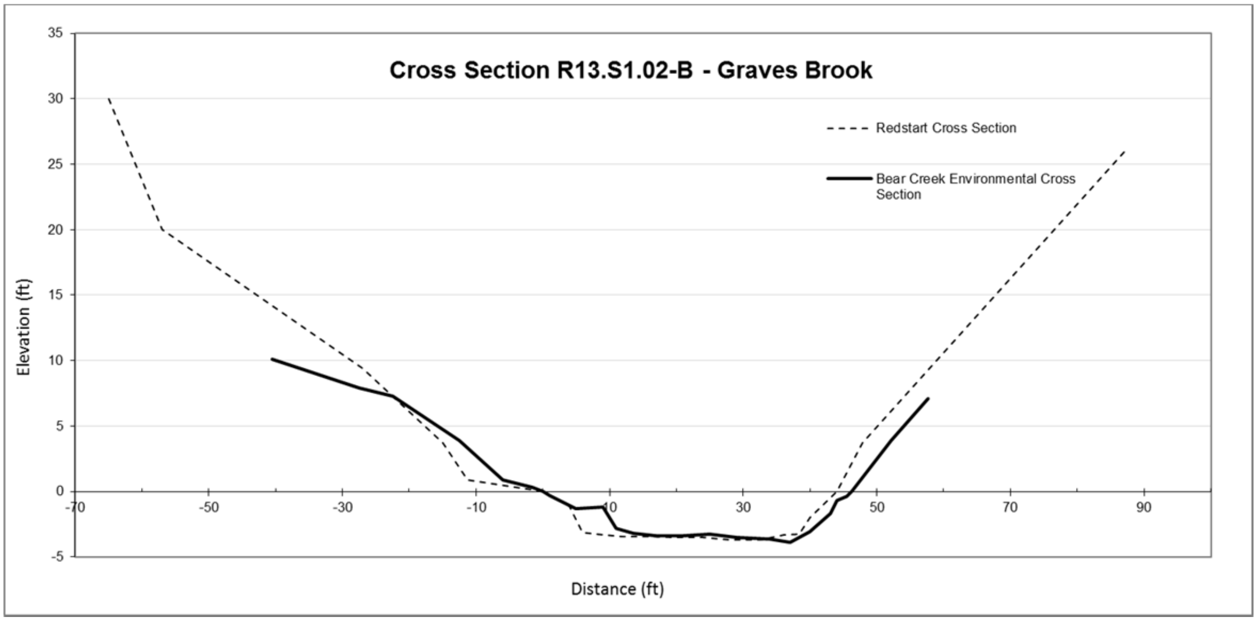


Figure 10. 2009 & 2014 Cross sections done by Redstart and BCE, respectively in Segment R13.S1.02-B.

Table 3: Comparison of 2009 and 2014 Cross Sections at R13.S1.02-B					
River Scientist Team	**Cross Sectional Area**	**Bankfull Width**	**W/D Ratio**	**Entrenchment Ratio**	**Incision Ratio**
Redstart (2009)	127.6	44.0	15.2	1.43	3.5
BCE (2014)	120.9	46.2	17.7	1.40	3.0
Percent change	-5.3%	5.0%	16.4%	-2.1%	-14.3%
Comments: Cross sections very similar from 2009 to 2014. Channel may have widened based on increased w/d ratio.					

Figure 11. Cross section R13.S1.02-B in 2009 (left) and in 2014 (right)

Thatcher Brook

R13.S1.02-S1.01-A

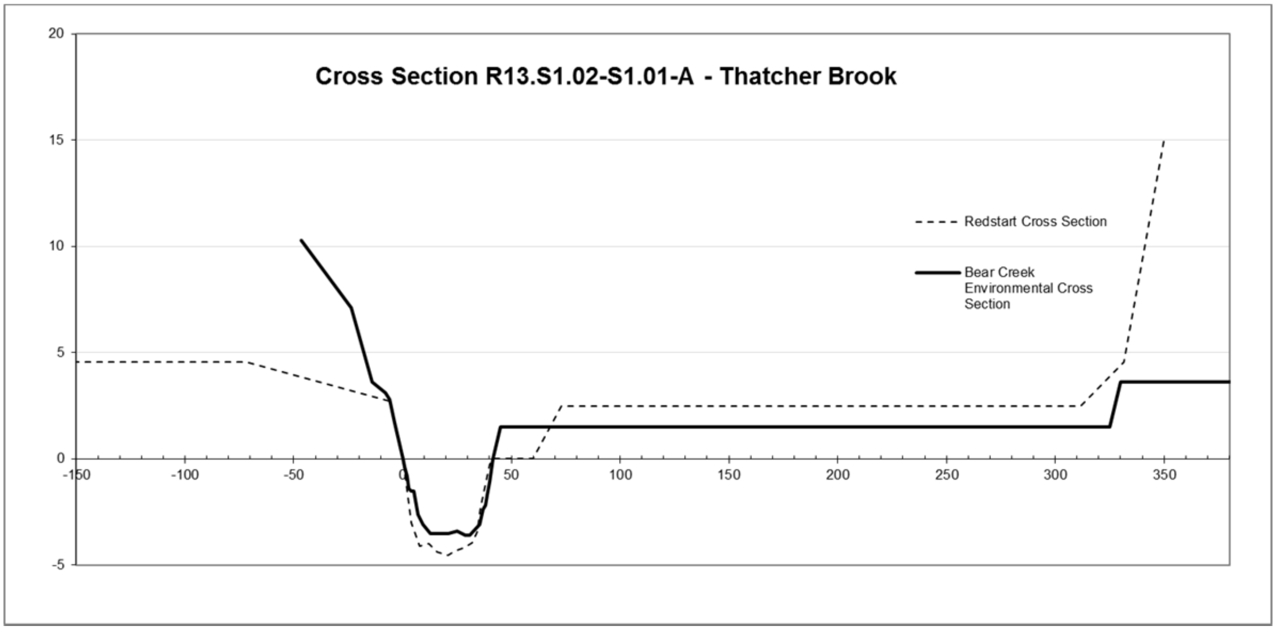


Figure 12. 2009 and 2014 Cross sections done by Redstart and BCE in Segment R13.S1.02-S1.01-A.

Table 4: Comparison of 2009 and 2014 Cross Sections at R13.S1.02-S1.01-A					
River Scientist Team	**Cross Sectional Area**	**Bankfull Width**	**W/D Ratio**	**Entrenchment Ratio**	**Incision Ratio**
Redstart (2009)	141.2	41.6	12.3	9.7	1.55
BCE (2014)	116.4	41.6	14.9	8.3	1.42
Percent change	-17.6%	0%	21.1%	-14.4%	-8.4%
Comments: Cross sectional area for 2014 was lower than 2009, but consistent with upstream cross sectional areas. Cross section in 2014 was measured just 45 feet upstream of 2009 cross section due to bank slump in 2009 location (indicating channel widening). This resulted in different valley widths. Bankfull width in 2014 cross section was the same as 2009 cross section. Width to depth ratio in 2014 showed "C" stream type.					

Figure 13. Cross section R13.S1.02-S1.01-A in 2009 (left) and in 2014 (right)

R13.S1.02-S1.01-D

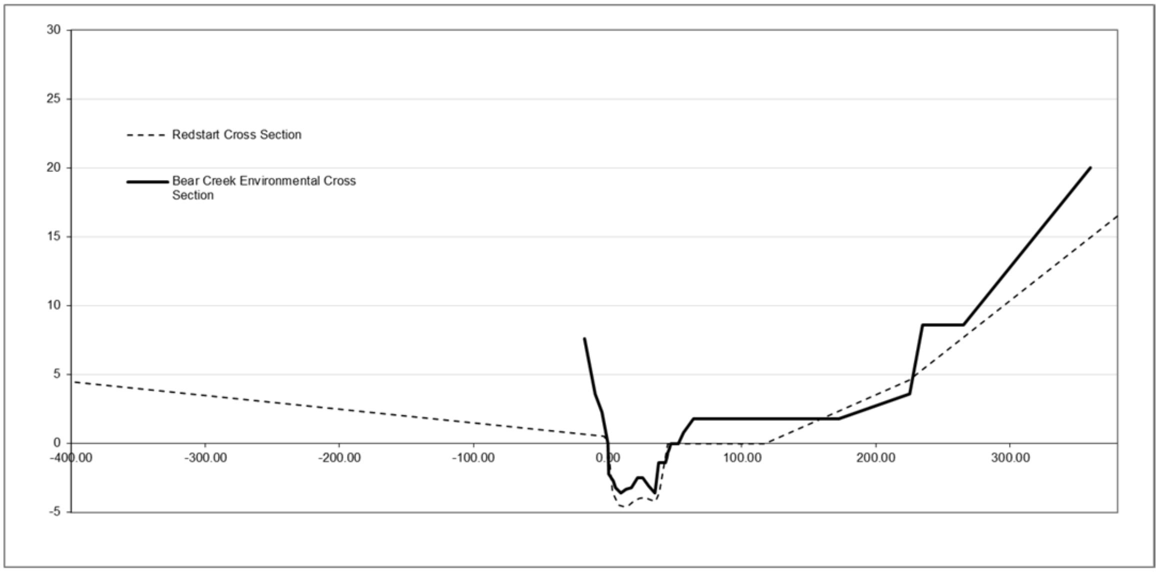


Figure 14. 2009 and 2014 Cross sections done by Redstart and BCE, respectively in Segment R13.S1.02-S1.01-D.

Table 5: Comparison of 2009 and 2014 Cross Sections at R13.S1.02-S1.01-D					
River Scientist Team	**Cross Sectional Area**	**Bankfull Width**	**W/D Ratio**	**Entrenchment Ratio**	**Incision Ratio**
Redstart (2009)	95.9	37.4	14.6	6.9	1.5
BCE (2014)	121.7	47.1	18.3	5.0	1.5
Percent change	26.9%	25.9%	25.3%	-27.5%	0%
Comments: Cross sectional area was higher in 2014 than 2009. The 2014 cross section was measured just upstream (about 20 feet) of the 2009 cross section due to channel changes. The fallen tree and large pool were present in the 2009 location (Figure 15). Channel may have experienced widening based on increased w/d ratio.					


Figure 15. Looking upstream at cross section R13.S1.02-S1.01-D in 2009 (left) and 2014 (right).

R13.S1.02-S1.02

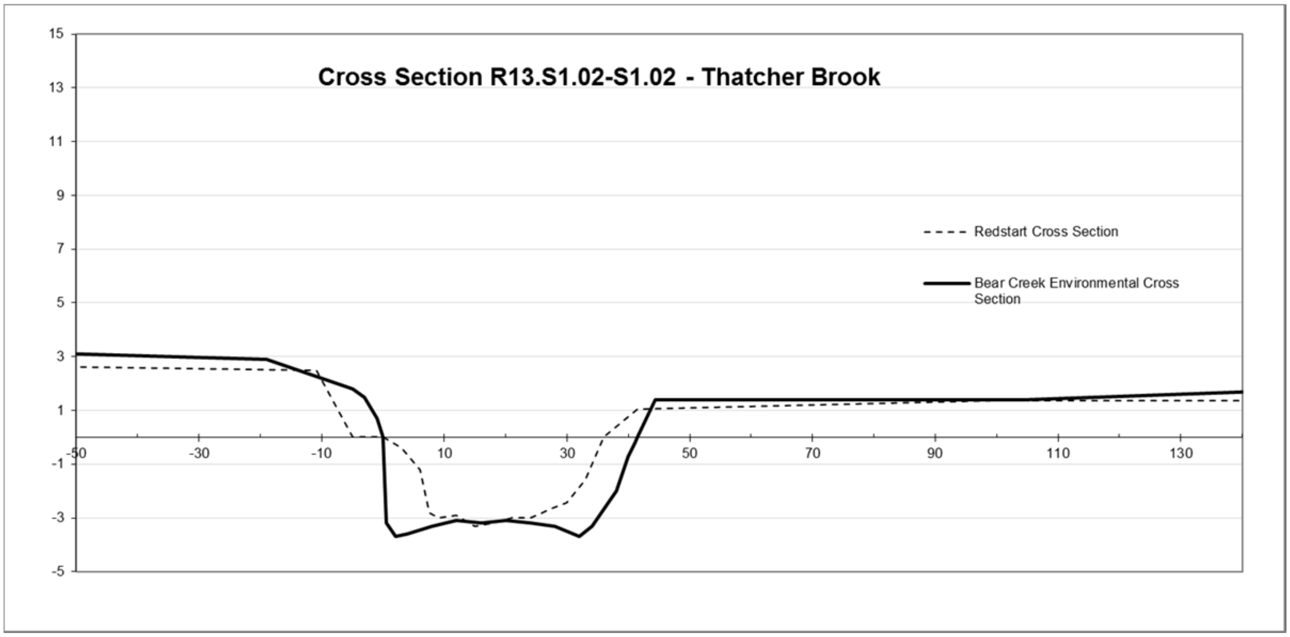


Figure 16. 2009 & 2014 Cross sections done by Redstart and BCE, respectively in Segment R13.S1.02-S1.02.

Table 6: Comparison of 2009 and 2014 Cross Sections at R13.S1.02-S1.02					
River Scientist Team	**Cross Sectional Area**	**Bankfull Width**	**W/D Ratio**	**Entrenchment Ratio**	**Incision Ratio**
Redstart (2009)	81.2	36	15.9	18.1	1.3
BCE (2014)	125.5	41.4	13.7	12.8	1.4
Percent change	54.6%	15.0%	-13.8%	-29.3%	7.7%
Comments: Cross sectional area for 2014 was higher than 2009. Depositional features in 2014 were larger than in 2009, and new debris noted in channel in 2014; both most likely due to TSI (See Figure 17). Both teams noted that bankfull was hard to find in the field. Redstart used a "low new bench" for determining the bankfull elevation, while Bear Creek used the tree line. This likely accounts for differences in the bankfull cross sectional areas measured.					

Figure 17. Cross section R13.S1.02-S1.02 in 2009 (left) and 2014 (right).

R13.S1.02-S1.03

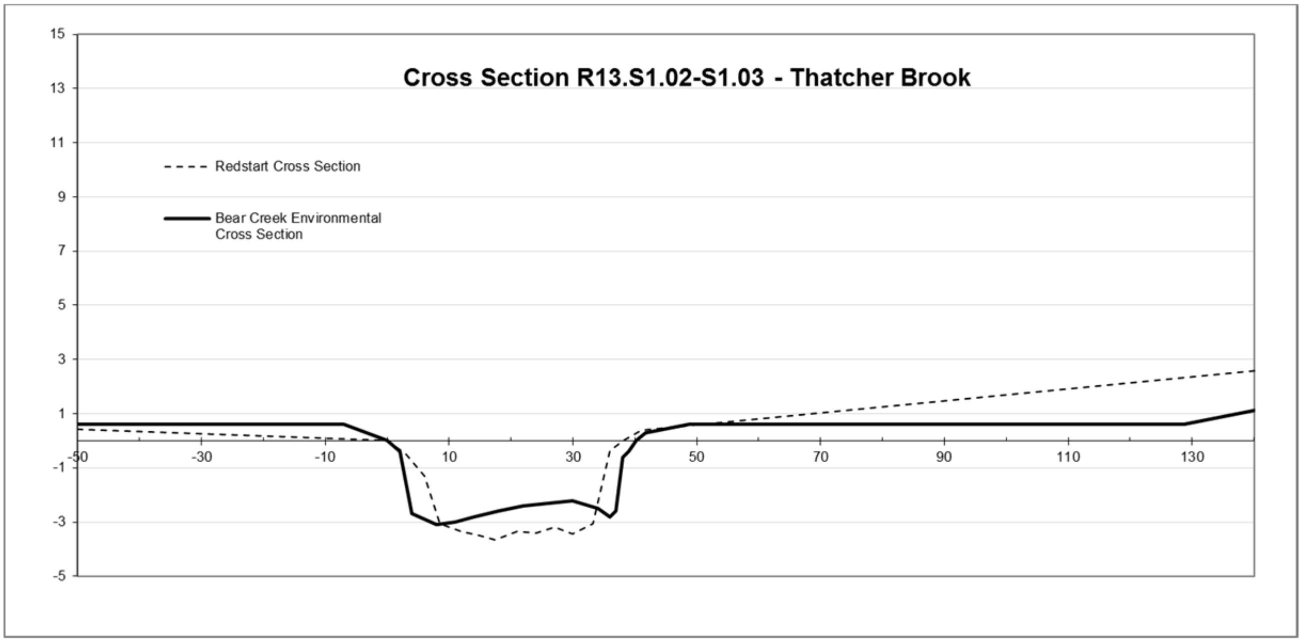


Figure 18. 2009 and 2014 Cross sections done by Redstart and BCE, respectively in Segment R13.S1.02-S1.03.

Table 7: Comparison of 2009 and 2014 Cross Sections at R13.S1.02-S1.03					
River Scientist Team	**Cross Sectional Area**	**Bankfull Width**	**W/D Ratio**	**Entrenchment Ratio**	**Incision Ratio**
Redstart (2009)	97.1	38.2	15.0	16.5	1.0
BCE (2014)	91.9	40.2	17.6	14.3	1.1
Percent change	-5.4%	5.2%	17.3%	-13.3%	10%
Comments: 2014 cross section was surveyed just downstream (about 40 feet) of 2009 cross section due to new beaver dam. Channel still has good floodplain access. More aggradational than in 2009 (Figure 19).					

Figure 19. Cross section R13.S1.02-S1.03 in 2009 (left) where there is now a beaver dam and in 2014 (right) – more aggradational.

R13.S1.02-S1.04-A

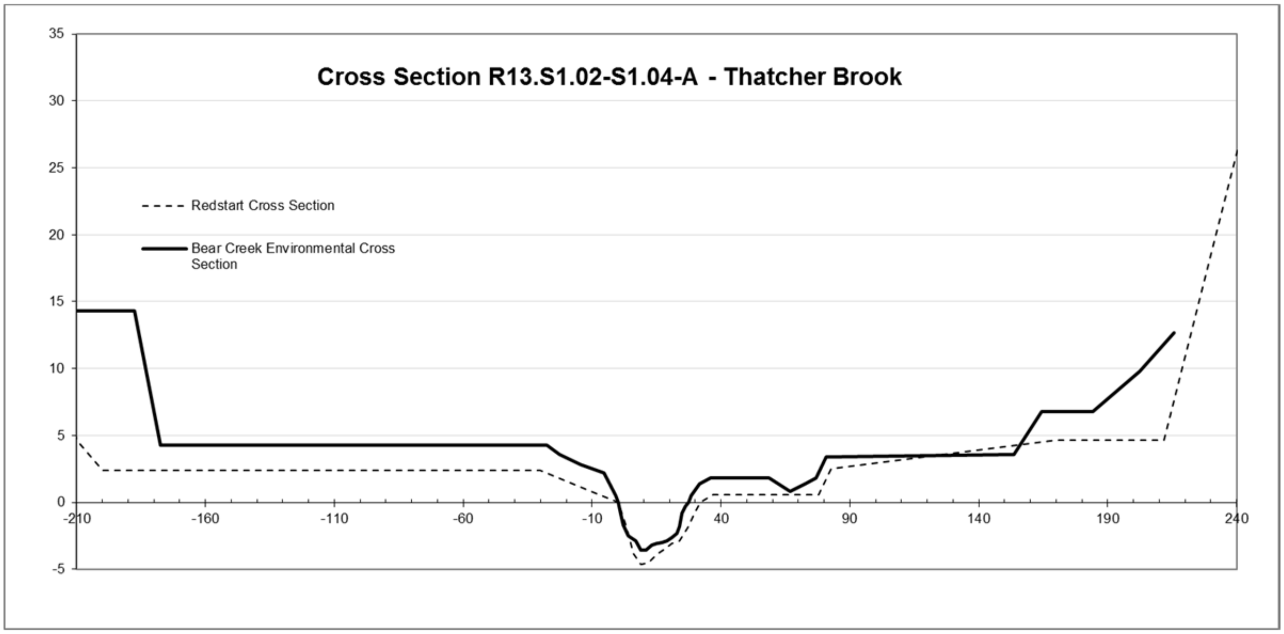


Figure 20. 2009 and 2014 Cross sections measured by Redstart and BCE, respectively in Segment R13.S1.02-S1.04-A.

Table 8: Comparison of 2009 and 2014 Cross Sections at R13.S1.02-S1.04-A					
River Scientist Team	**Cross Sectional Area**	**Bankfull Width**	**W/D Ratio**	**Entrenchment Ratio**	**Incision Ratio**
Redstart (2009)	91.4	31.9	11.1	11.9	1.5
BCE (2014)	67.4	27.3	11.1	6.5	1.9
Percent change	-26.3%	-14.4%	0%	-45.4%	21.1%
Comments: Cross sectional area lower in 2014 than 2009, but consistent with upstream cross sectional areas measured in 2014.					


Figure 21. Cross section R13.S1.02-S1.04-A in 2009 (left) and 2014 (right).

R13.S1.02-S1.04-B

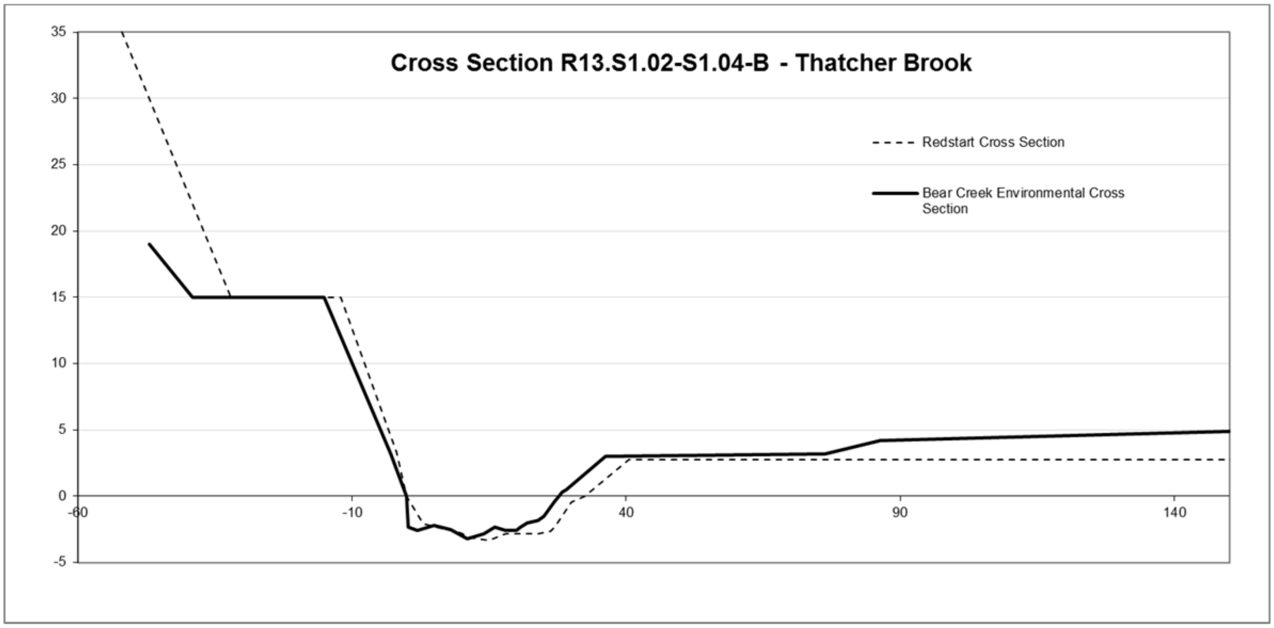


Figure 22. 2009 and 2014 Cross sections done by Redstart and BCE, respectively in Segment R13.S1.02-S1.04-B.

Table 9: Comparison of 2009 and 2014 Cross Sections at R13.S1.02-S1.04-B					
River Scientist Team	**Cross Sectional Area**	**Bankfull Width**	**W/D Ratio**	**Entrenchment Ratio**	**Incision Ratio**
Redstart (2009)	74.8	32.5	14.1	8.5	1.8
BCE (2014)	63.7	27.8	12.1	2.9	1.9
Percent change	-14.8%	-14.5%	-14.2%	-65.9%	5.6%
Comments: Cross sections similar. No significant changes from TSI except for some fallen debris from left bank.					

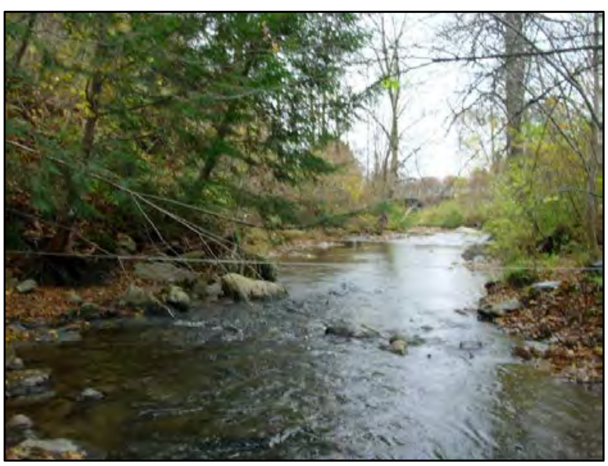
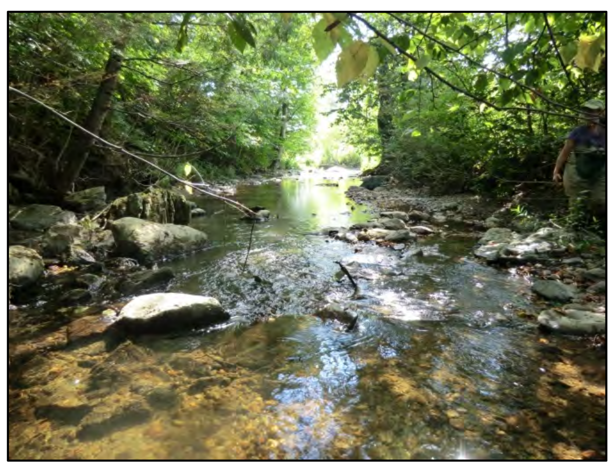



Figure 23. Cross section R13.S1.02-S1.04-B in 2009 (left) and 2014 (right).

R13.S1.02-S1.04-C

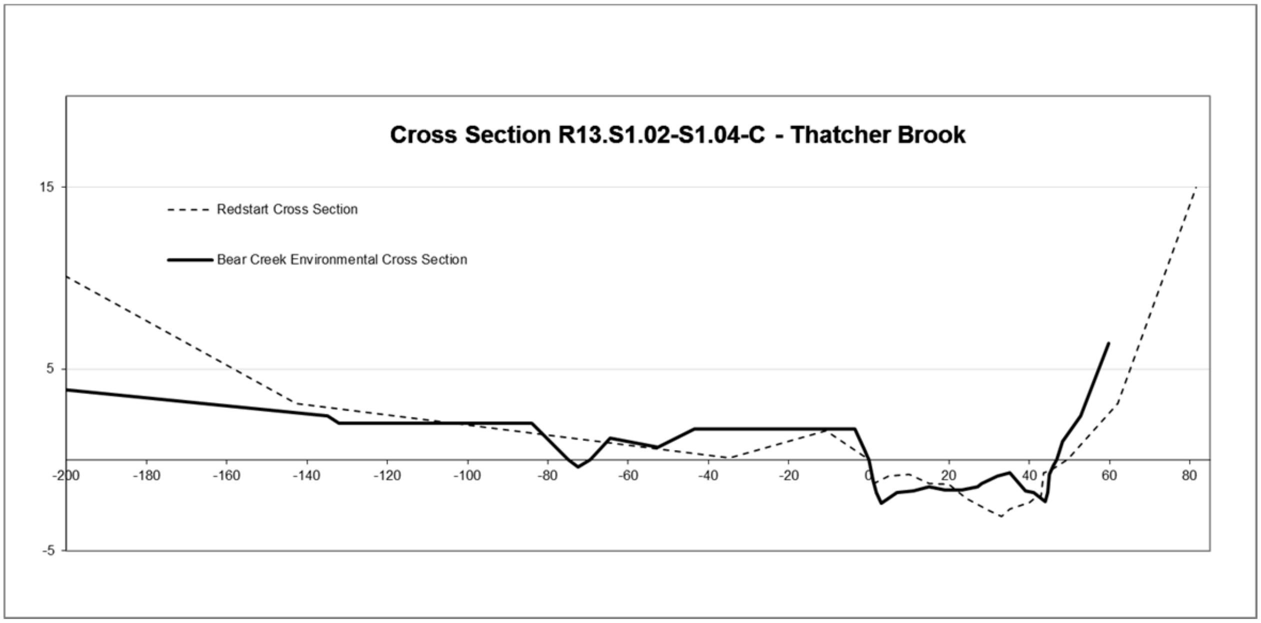


Figure 24. 2009 and 2014 Cross sections done by Redstart and BCE, respectively in Segment R13.S1.02-S1.04-C.

Table 10: Comparison of 2009 and 2014 Cross Sections at R13.S1.02-S1.04-C					
River Scientist Team	**Cross Sectional Area**	**Bankfull Width**	**W/D Ratio**	**Entrenchment Ratio**	**Incision Ratio**
Redstart (2009)	79.0	49.4	30.9	4.1	1.5
BCE (2014)	71.5	52.3	38.3	3.6	1.7
Percent change	-9.5%	5.9%	23.9%	-12.2%	13.3%
Comments: Left side of channel deeper in 2014. Flood chute observed in left floodplain in 2014. Bar shifted from left to right in channel.					

Figure 25. Cross section R13.S1.02-S1.04-C in 2009 (left) and 2014 (right).

R13.S1.02-S1.05-A

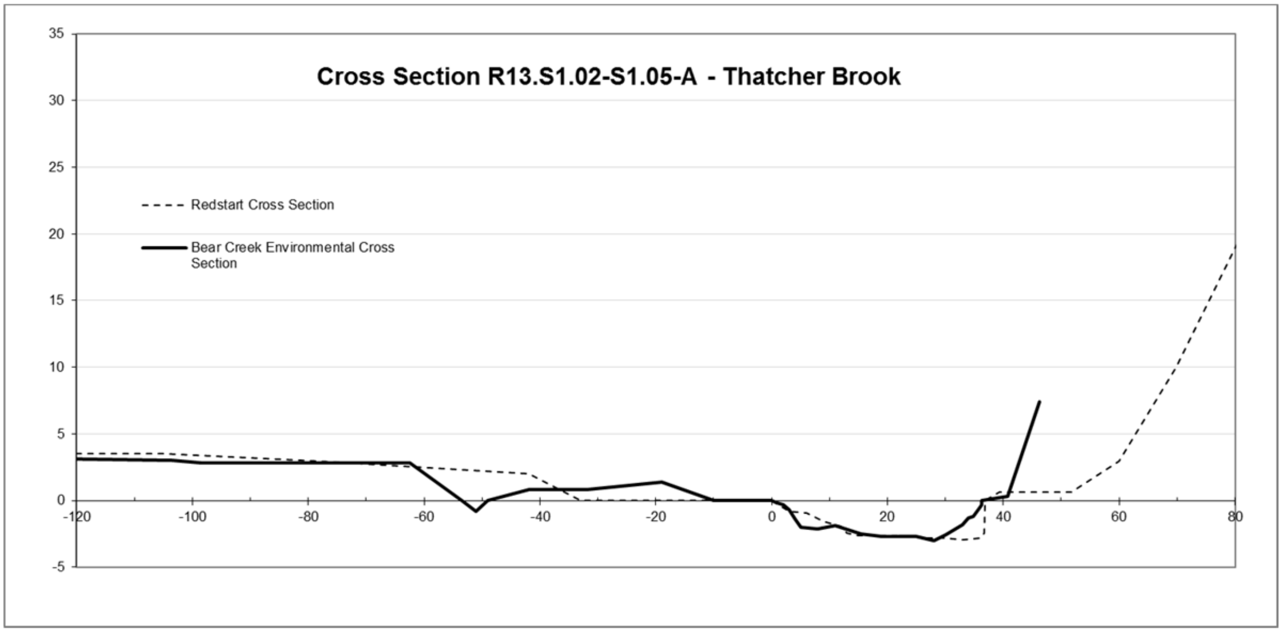


Figure 26. 2009 and 2014 Cross sections done by Redstart and BCE, respectively in Segment R13.S1.02-S1.05-A.

Table 11: Comparison of 2009 and 2014 Cross Sections at R13.S1.02-S1.05-A					
River Scientist Team	**Cross Sectional Area**	**Bankfull Width**	**W/D Ratio**	**Entrenchment Ratio**	**Incision Ratio**
Redstart (2009)	79.3	36.8	17.1	3.8	1.7
BCE (2014)	77.1	40.8	21.6	3.5	2.0
Percent change	-2.8%	10.9%	26.3%	-7.9%	15%
Comments: Cross sections were similar in 2009 and 2014. Flood chute observed in 2014 in left floodplain. 2014 cross section measured slightly downstream of 2009 cross section affecting the valley width. More aggradational and slightly wider in 2014 than 2009.					

Figure 27. Cross section R13.S1.02-S1.05-A in 2009 (left) and 2014 (right)-more aggradational.

R13.S1.02-S1.05-B

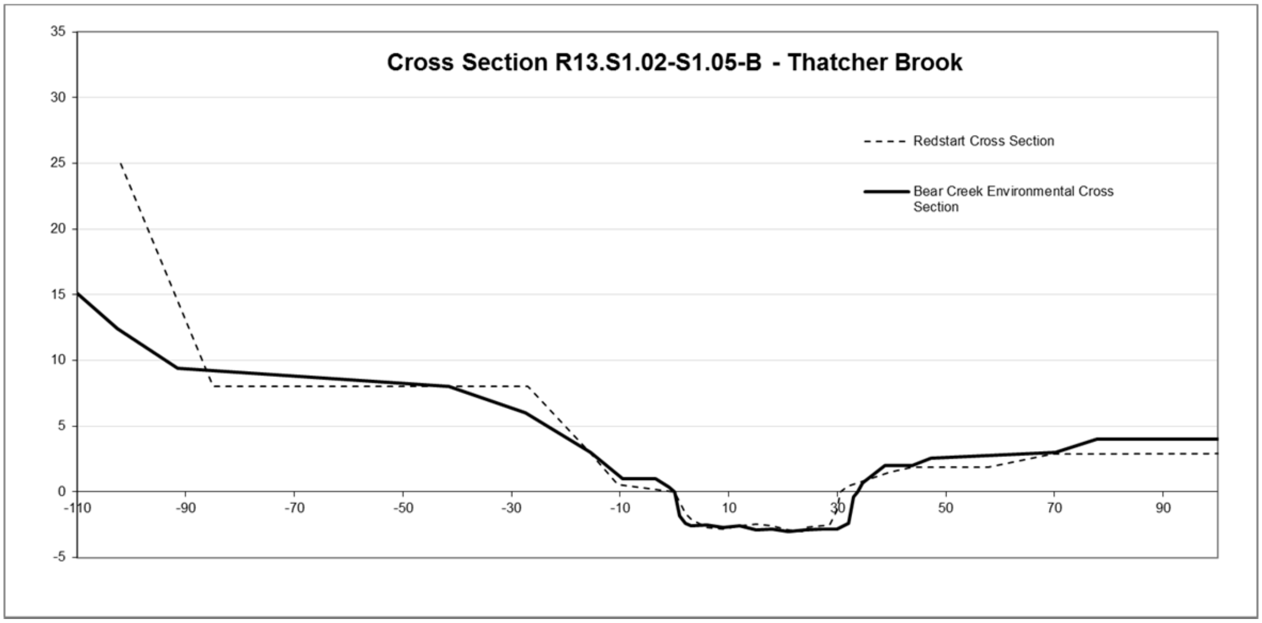


Figure 28. 2009 and 2014 Cross sections done by Redstart and BCE, respectively in Segment R13.S1.02-S1.05-B.

Table 12: Comparison of 2009 and 2014 Cross Sections at R13.S1.02-S1.05-B					
River Scientist Team	**Cross Sectional Area**	**Bankfull Width**	**W/D Ratio**	**Entrenchment Ratio**	**Incision Ratio**
Redstart (2009)	74.3	30.5	12.5	6.7	1.6
BCE (2014)	86.9	33.7	13.1	2.5	1.9
Percent change	17%	10.5%	4.8%	-62.7%	15.8%
Comments: Cross sections were similar in 2009 and 2014. More aggradational in 2014 than in 2009 most likely due to TSI (See Figure 29).					

Figure 29. Cross section in Segment R13.S1.02-S1.05-B in 2009 (left) and 2014 (right).

3.0 CONCLUSION

The orthophoto review and cross section analyses are useful in determining if channel dimensions were altered by flooding and to indicate where the channel has changed its planform over time. These analyses will help to inform restoration and protection alternatives in the river corridor plan. Channel avulsions observed from the orthophoto analysis were most likely a direct result of Tropical Storm Irene (TSI). Meander migrations between 2009 and 2013 were also most likely accelerated by the increased flows and aggradation from the floodwaters of TSI. The cross section surveys suggest that in general, the influence of TSI on Thatcher and lower Graves Brook was limited to localized areas of increased aggradation and some widening. Channel degradation has not appeared to have been increased as a result of TSI. The cross section surveys from 2009 to 2014 differed somewhat, but overall they were rather consistent and did not show any major change aside from increased aggradation and localized widening.

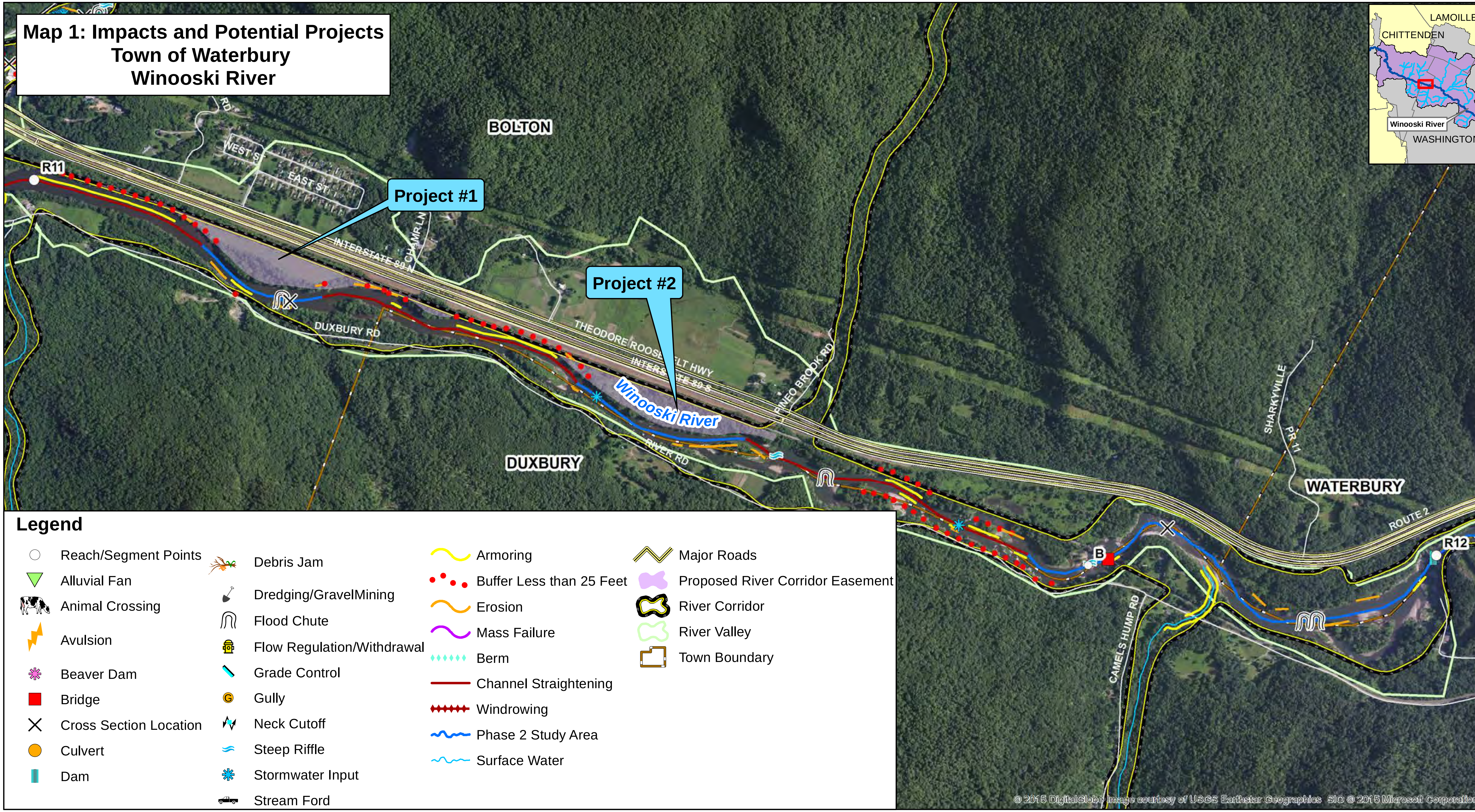
Thatcher and Graves Brook overall have very good floodplain access and extensive adjacent wetlands. During Tropical Storm Irene, it is likely that a large amount of floodwaters and sediment accessed these floodplains and adjacent wetlands, reducing the energy within the stream channels of Thatcher Brook and Graves Brook. This storage of floodwaters and reduction of in-channel energy during TSI caused a reduction in erosive forces that could have caused the stream channels to downcut, widen, aggrade, and change planform much more drastically than was observed if these floodplains and wetlands had not been intact. This post-flood study has demonstrated the immense importance of accessible floodplains and adjacent wetlands in mitigating stream impacts and adjustment during high flow events. It is critically important to protect and preserve the floodplains and wetlands along Thatcher and Graves Brook to retain their floodwater and sediment attenuation capacities.

4.0 REFERENCES

Vermont Agency of Natural Resources. 2012. Climate Change Team. Tropical Storm Irene. Accessed January 7, 2013 and available at http://www.anr.state.vt.us/anr/climatechange/irenebythenumbers.html.

APPENDIX D

Potential Project Locations & Descriptions



Background is Bing Imagery

Projects:

1. River Corridor or Conservation Easement
2. River Corridor or Conservation Easement

Project Priority:

- Low
- Moderate
- High

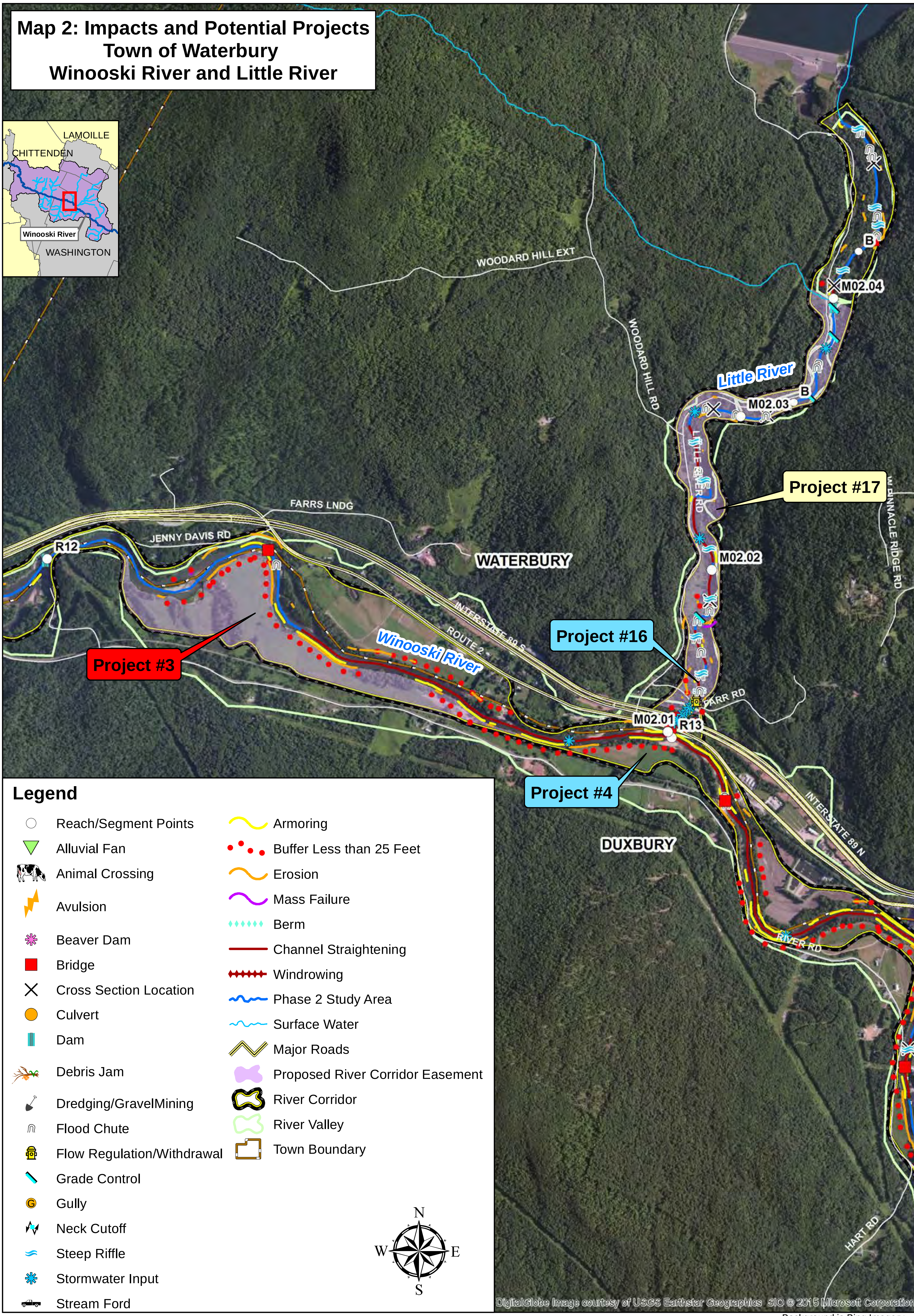
N W E S

0 1,000 2,000 Feet

1 inch = 1,000 feet

Bear Creek Environmental

Map 2: Impacts and Potential Projects
Town of Waterbury
Winooski River and Little River



Background is Bing Imagery

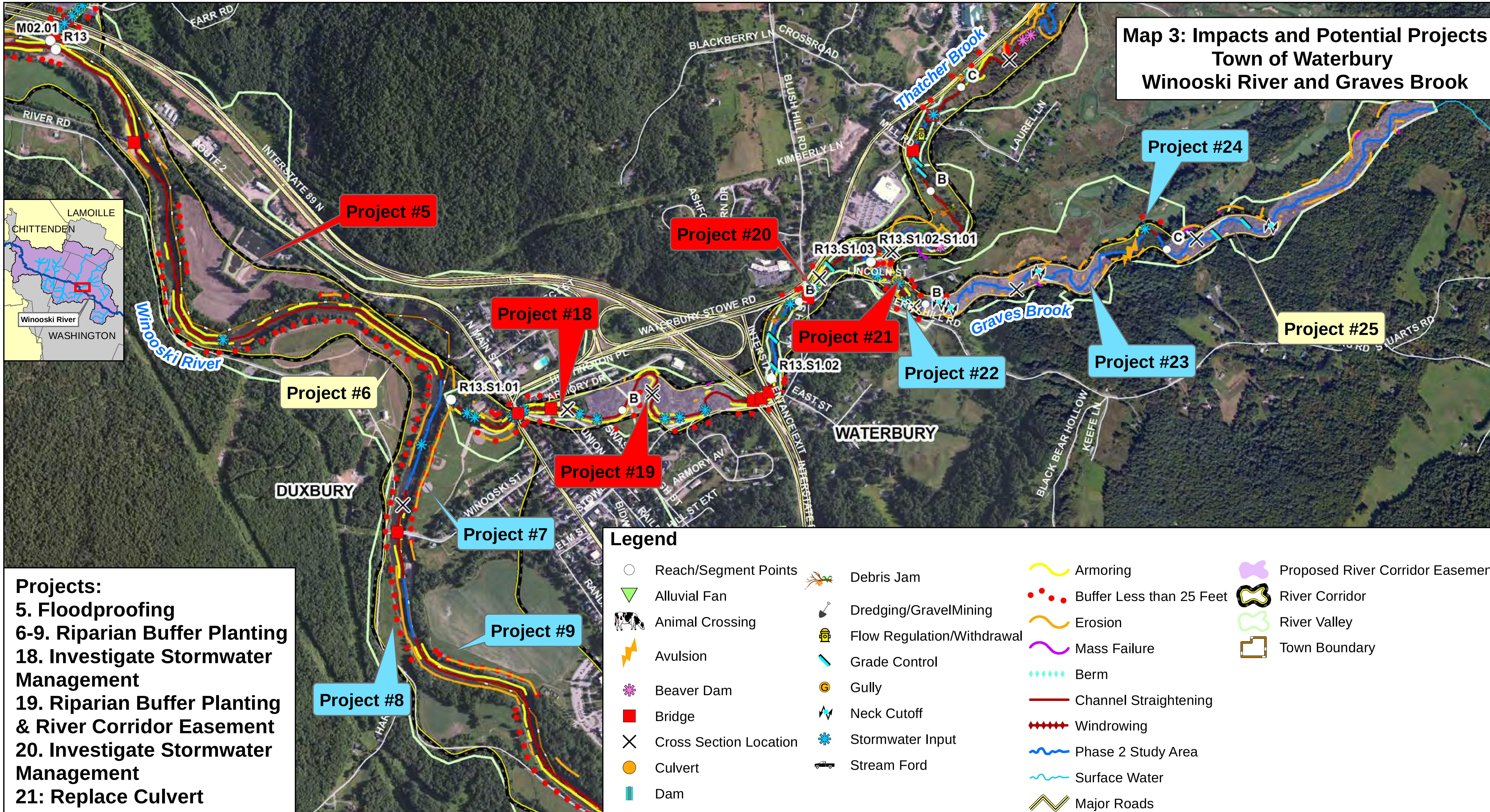
Projects:
3. Riparian Buffer Planting & River Corridor Easement
4. Riparian Buffer Planting
16. Create Floodplain
17. River Corridor or Conservation Easement (Eastern Side)

Project Priority:
Low
Moderate
High

0 1,500 3,000 Feet

Bear Creek Environmental

Map 3: Impacts and Potential Projects
Town of Waterbury
Winooski River and Graves Brook

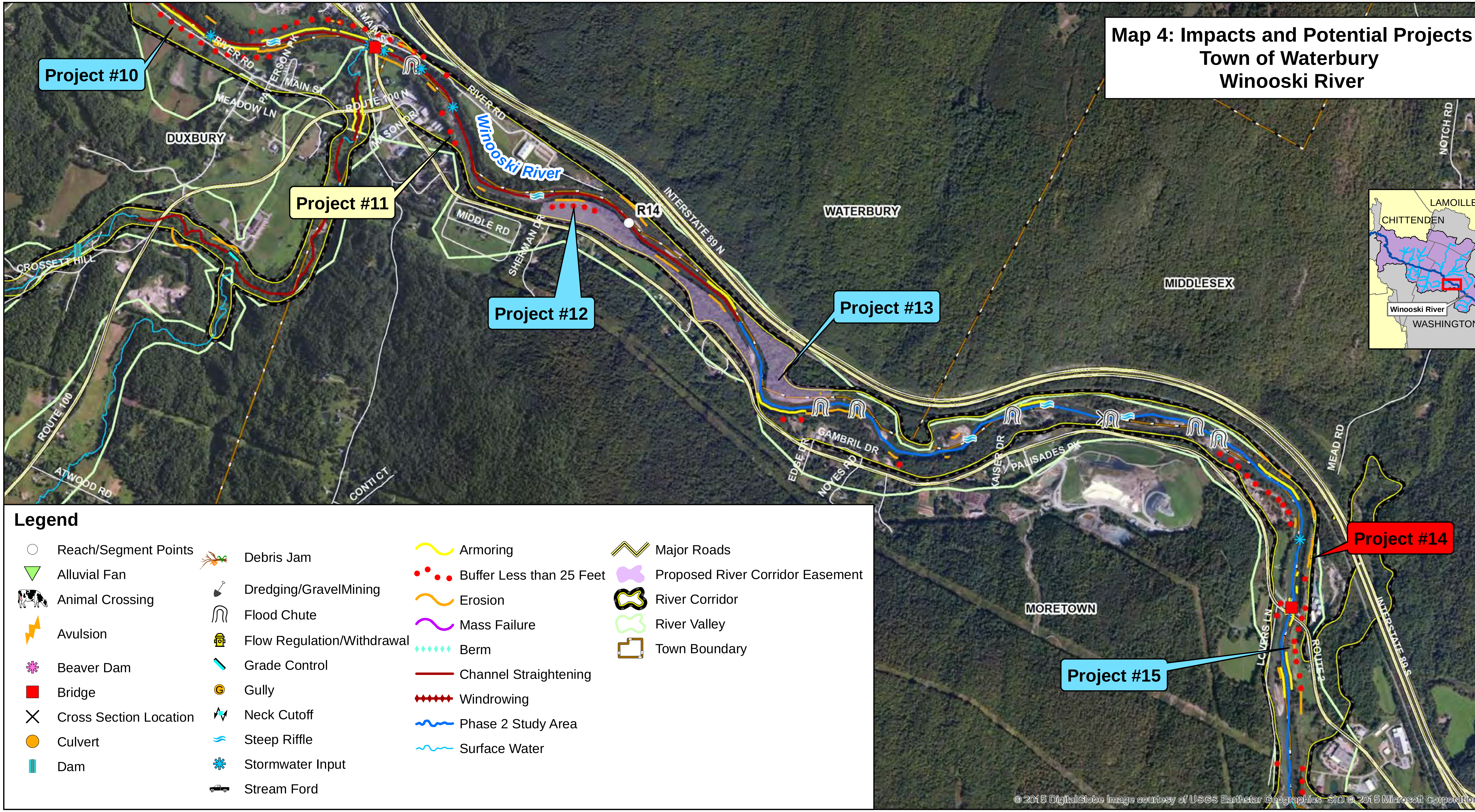


Projects:
5. Floodproofing
6-9. Riparian Buffer Planting
18. Investigate Stormwater Management
19. Riparian Buffer Planting & River Corridor Easement
20. Investigate Stormwater Management
21: Replace Culvert
22. Riparian Buffer Planting
23. River Corridor or Conservation Easement
24. Riparian Buffer Planting
25. River Corridor or Conservation Easement

Project Priority:
- Low
- Moderate
- High

Background is Bing Imagery

Bear Creek Environmental



Background is Bing Imagery

Projects:

10. Lower or Relocate Road

11. & 12. Riparian Buffer Planting

13. River Corridor or Conservation Easement

14. Relocate Storage of Gravel and Sand

15. Riparian Buffer Planting

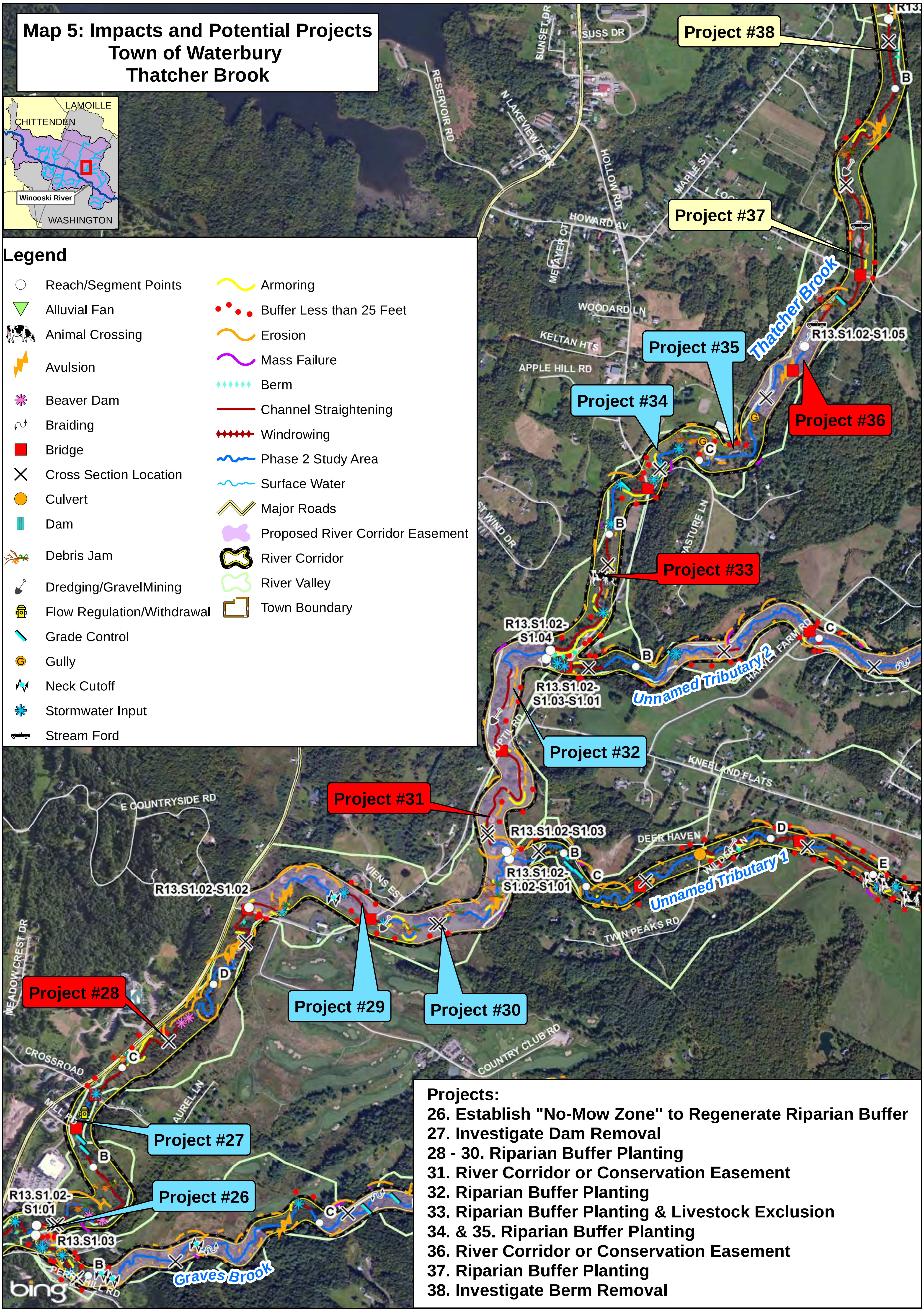
Project Priority:

- Low
- Moderate
- High

N W E S

0 1,300 2,600 Feet

Bear Creek Environmental



Background is Bing Imagery

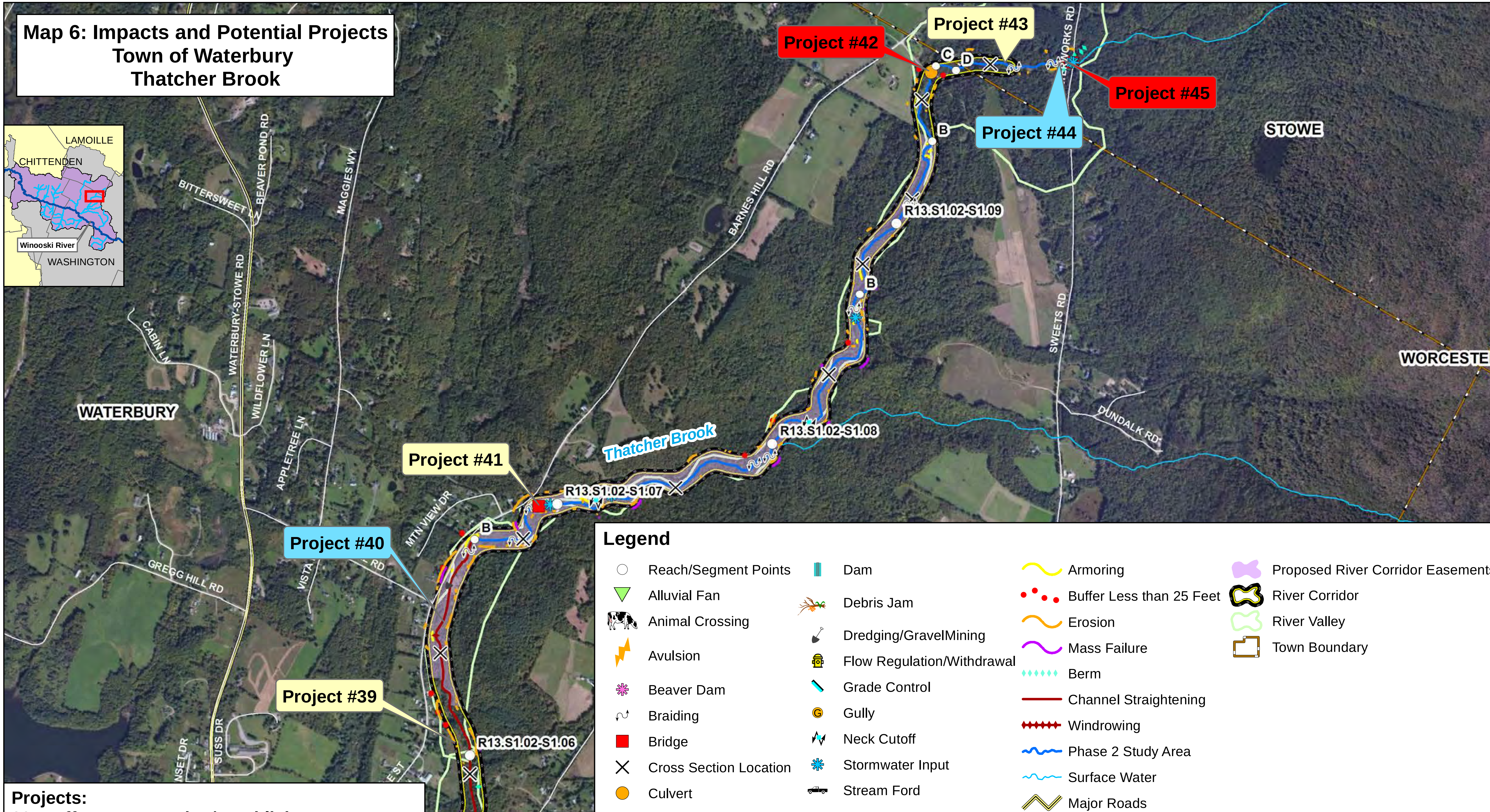
Project Priority:
- Low
- Moderate
- High

0 1,000 2,000 Feet

1 inch = 1,000 feet

Bear Creek Environmental

Map 6: Impacts and Potential Projects
Town of Waterbury
Thatcher Brook



Legend

- Reach/Segment Points
- Alluvial Fan
- Animal Crossing
- Avulsion
- Beaver Dam
- Braiding
- Bridge
- Cross Section Location
- Culvert
- Dam
- Debris Jam
- Dredging/GravelMining
- Flow Regulation/Withdrawal
- Grade Control
- Gully
- Neck Cutoff
- Stormwater Input
- Stream Ford
- Armoring
- Buffer Less than 25 Feet
- Erosion
- Mass Failure
- Berm
- Channel Straightening
- Windrowing
- Phase 2 Study Area
- Surface Water
- Major Roads
- Proposed River Corridor Easements
- River Corridor
- River Valley
- Town Boundary

Projects:

39. Buffer Regeneration/Establish No-Mow Zone
40. Riparian Corridor or Conservation Easement
41. Remove Old Wooden Bridge
42. Replace Culvert
43. Remove Old Wooden Bridge
44. Return or Remove Windrowed Material
45. Restore Streamflow

Project Priority:

- Low
- Moderate
- High

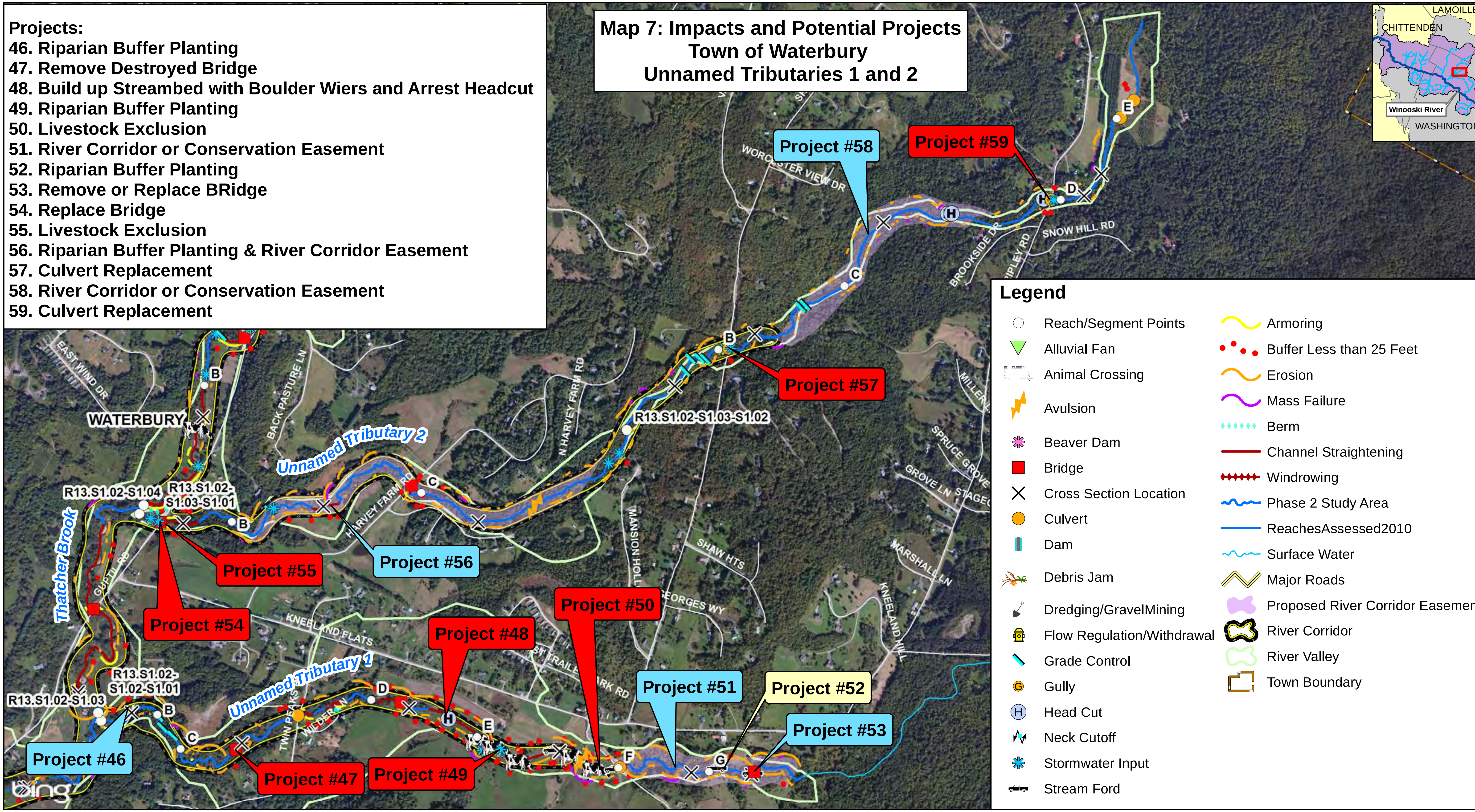
N
W E
S

0 1,250 2,500 Feet

1 inch = 1,250 feet

Background is Bing Imagery

Bear Creek Environmental



Background is Bing Imagery

Project Priority:
- Low
- Moderate
- High

N W E S

0 1,000 2,000 Feet

1 inch = 1,000 feet

Bear Creek Environmental

Mid-Winooski River Watershed - Waterbury Area - Restoration & Protection Projects
Waterbury, Vermont
Central Vermont Regional Planning Commission
May 1, 2015

Legend

● Effective ◒ Limited ○ Ineffective

Project Number Segment	Project Category	Project Type	Stream Name	Town	Project Location	Priority	OBJECTIVES: Improves or Protects Habitat[1]	Improves Water Quality[2]	Improves Long-term Channel Stability[3]	Protects Infrastructure, and Property[4]	Comments
Project #1 R11-A (Refer to Map 1)	Floodplain Improvement and Conservation	River Corridor or Conservation Easement	Winooski River	Bolton	On northern bank of river approximately 3,000 feet upstream of Joiner Brook confluence	Moderate	●	◒	●	◒	A 13 acre parcel is located on the inside of a slight meander bend between the river and the railroad/I-89. About half of the parcel has well-formed floodplain forest, while half is mowed for some purpose - likely agriculture. Project may be eligible for CREP.
Project #2 R11-A (Refer to Map 1)	Floodplain Improvement and Conservation	River Corridor or Conservation Easement	Winooski River	Bolton	On northern bank of river across river from 6097 River Road	Moderate	●	◒	●	◒	A 12.3 acre parcel on an inside bend has a well forested buffer - silver maple floodplain forest.
Project #3 R12 (Refer to Map 2)	Floodplain Improvement and Conservation	Riparian Buffer Planting and River Corridor Easement	Winooski River	Duxbury	Just upstream of Bolton Falls Dam on southern bank of the river	**High**	●	●	●	◒	Agricultural fields exist along the river and riparian buffer is lacking for about 4,500 feet. This is an important area for floodwater and sediment storage due to dam backwatering. One of two landowners indicated project interest. Project may be eligible for CREP.
Project #4 R12 & R13 (Refer to Map 2)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Winooski River	Duxbury	Just across Winooski River from confluence of Little River	Moderate	●	●	●	◒	Buffer is lacking on southern bank due to agricultural fields. Project could be eligible for CREP.
Project #5 R13 (Refer to Map 3)	Public Safety Improvement	Floodproofing	Winooski River	Waterbury	At the Waterbury Wastewater Treatment Facility	**High**	◒	●	○	●	The Waterbury Wastewater Treatment Facility is located in between the Winooski River and the New England Central Railroad/Route 2. It sustained major damage due to inundation during Irene. The facility could be floodproofed to reduce future damages and prevent future discharges of wastewater to the river.
Project #6 R13 (Refer to Map 3)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Winooski River	Duxbury	At the Harvey Farm on River Road just northwest of Waterbury Village	Low	◒	◒	◒	○	Riparian buffer is lacking for about 2,500 feet due to the presence of agricultural fields at the Harvey Farm. The bank is high in this location and land use conflicts may present challenges for implementation. This is the location of a proposed floodplain creation project (CVRPC and Milone & MacBroom).
Project #7 R13 (Refer to Map 3)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Winooski River	Waterbury	At Rowe Fields	Moderate	◒	●	◒	○	Buffer is lacking on east bank of river for about 1,500 feet due to town recreational fields. Town could designate a wider "no mow" zone, but land use conflicts may present challenges for implementation.
Project #8 R13 (Refer to Map 3)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Winooski River	Duxbury	On western bank just upstream of Winooski Street bridge	Moderate	◒	●	●	○	1,000 foot stretch is lacking riparian buffer, likely due to an agricultural field. The bank is eroding. Project could be eligible for CREP.
Project #9 R13 (Refer to Map 3)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Winooski River	Waterbury	On eastern bank at state-owned Randall Meadow	Moderate	◒	●	●	○	Buffer is lacking for approximately 1,300 feet due to presence of agricultural field. State-owned land.

[1] Enhances or protects aquatic or riparian habitat
[2] Reduces sedimentation and phosphorus levels
[3] Moves the channel toward equilibrium where the water and sediment are in balance
[4] Reduces risk of flooding and erosion hazard

Mid-Winooski River Watershed - Waterbury Area - Restoration & Protection Projects
Waterbury, Vermont
Central Vermont Regional Planning Commission
May 1, 2015

Legend

● Effective ◒ Limited ○ Ineffective

Project Number Segment	Project Category	Project Type	Stream Name	Town	Project Location	Priority	OBJECTIVES: Improves or Protects Habitat[1]	Improves Water Quality[2]	Improves Long-term Channel Stability[3]	Protects Infrastructure, and Property[4]	Comments
Project #10 R13 (Refer to Map 4)	Floodplain Improvement and Conservation	Lower or Relocate Road	Winooski River	Duxbury	River Road across the river from the state office complex	Moderate	Limited	Ineffective	Effective	Effective	Town of Duxbury raised River Road after Irene to prevent future inundation, but cut off large undeveloped floodplain. Lowering the dirt road or relocating it farther away from the river against the valley wall would reconnect the floodplain.
Project #11 R13 (Refer to Map 4)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Winooski River	Moretown	Just south of Extra Room Storage facility	Low	Effective	Effective	Limited	Ineffective	Buffer is lacking on west bank of river for about 200 feet due to landowner's lawn. This would be a small planting area and the bank is not currently eroding, making it a low priority project.
Project #12 R13 (Refer to Map 4)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Winooski River	Moretown	On southern bank of river just downstream of reach break between R13 and R14	Moderate	Effective	Effective	Limited	Ineffective	Buffer is lacking for 800 feet due to corn field. Project could be eligible for CREP.
Project #13 R14 (Refer to Map 4)	Floodplain Improvement and Conservation	River Corridor or Conservation Easement	Winooski River	Moretown	On both banks of river in vicinity of 1327 Route 2	Moderate	Effective	Limited	Limited	Limited	The river has good floodplain access in this area, most of which is well forested. A section of this area is a corn field, which may be eligible for CREP. One of three landowners is interested in projects.
Project #14 R14 (Refer to Map 4)	Floodplain Improvement and Conservation	Relocate Storage of Gravel and Sand	Winooski River	Middlesex	At VTrans Middlesex Garage	**High**	Effective	Effective	Ineffective	Limited	Large gravel and sand piles are stored on eastern bank of the Winooski River. These piles are likely contributing sediment to the river during rain and snowmelt events and could be claimed by the river during flooding.
Project #15 R14 (Refer to Map 4)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Winooski River	Middlesex	Just upstream of Route 2 Bridge near VTrans garage on eastern bank	Moderate	Effective	Effective	Limited	Ineffective	Buffer is lacking on eastern bank for nearly 1,300 feet due to the presence of a corn field. Project may be eligible for CREP.
Project #16 M2.01 (Refer to Map 2)	Floodplain Improvement and Conservation	Create Floodplain	Little River	Waterbury	On western bank of river approximately 350 feet upstream of former Farr Road crossing	Moderate	Limited	Limited	Effective	Effective	This section has incised and lost floodplain access. Two parcels (one 3 acres and one 2 acres) on the western bank of the river. High banks with abundant erosion. Dwellings outside of river corridor. Further investigation is needed.
Project #17 M2.01, M2.02, M2.02-A, and M2.03-B (Refer to Map 2)	Floodplain Improvement and Conservation	River Corridor or Conservation Easement	Little River	Waterbury	Eastern side of river corridor throughout segments	Low	Limited	Limited	Effective	Limited	One large forested tract of land (276 acres) on eastern side of river. Land on western side and some on eastern side already protected as part of Mount Mansfield State Forest.
Project #18 R13.S1.01-A & B (Refer to Map 3)	Stream Channel Improvement and Restoration	Investigate Stormwater Management	Graves Brook	Waterbury	From the mouth of Graves Brook to the I-89 bridges	**High**	Effective	Effective	Effective	Ineffective	There are at least 14 stormwater inputs to Graves Brook in reach one. The Winooski River Basin Plan identifies Graves Brook as an impaired surface water due to sedimentation from surrounding development. Stormwater inputs add flow and sediment to the channel during precipitation/ snowmelt. Project would involve investigating and improving stormwater management on Lower Graves Brook.

[1] Enhances or protects aquatic or riparian habitat
[2] Reduces sedimentation and phosphorus levels
[3] Moves the channel toward equilibrium where the water and sediment are in balance
[4] Reduces risk of flooding and erosion hazard

Mid-Winooski River Watershed - Waterbury Area - Restoration & Protection Projects
Waterbury, Vermont
Central Vermont Regional Planning Commission
May 1, 2015

Legend

● Effective ◓ Limited ○ Ineffective

Project Number Segment	Project Category	Project Type	Stream Name	Town	Project Location	Priority	OBJECTIVES: Improves or Protects Habitat[1]	OBJECTIVES: Improves Water Quality[2]	OBJECTIVES: Improves Long-term Channel Stability[3]	OBJECTIVES: Protects Infrastructure, and Property[4]	Comments
Project #19 R13.S1.01-B (Refer to Map 3)	Floodplain Improvement and Conservation	Riparian Buffer Planting and River Corridor Easement	Graves Brook	Waterbury	Southern bank on inside of bend between Armory Road and I-89 bridges	**High**	●	●	◓	○	Buffer is lacking for almost 400 feet on southern bank of brook. Landowner is interested in planting and conservation projects.
Project #20 R13.S1.01-B (Refer to Map 3)	Stream Channel Improvement and Restoration	Investigate Stormwater Management	Graves Brook	Waterbury	From just below Stowe Street Bridge to confluence of Thatcher Brook	**High**	●	●	◓	○	There are at least 7 stormwater inputs in this short stretch of Graves Brook. Investigating stormwater management and improvement could reduce sediment loading to the Brook.
Project #21 R13.S1.03-A (Refer to Map 3)	Structure Replacement/ Removal	Replace Culvert	Graves Brook	Waterbury	At Lincoln Street crossing	**High**	◓	○	●	●	Structure is significantly undersized and has poor alignment. Riprap is falling into streambed. If culvert gets blocked, stream could flood nearby homes, road, and park and ride.
Project #22 R13.S1.03-A (Refer to Map 3)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Graves Brook	Waterbury	Just upstream of Lincoln Street crossing on southern bank.	Moderate	●	●	◓	◓	Buffer is minimal on southern bank due to landowner's lawns. Some trees are present, but planting more in buffer would help to stabilize bank. Homes are nearby that could be threatened by further bank erosion.
Project #23 R13.S1.03-B (Refer to Map 3)	Floodplain Improvement and Conservation	River Corridor or Conservation Easement	Graves Brook	Waterbury	Both southern and northern sides of channel along segment approximately 2,700 feet upstream of segment break.	Moderate	●	◓	●	○	101 acre parcel potentially vulnerable to future river corridor development. Areas of beaver dam impoundment that could be protected as wetlands.
Project #24 R13.S1.03-B (Refer to Map 3)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Graves Brook	Waterbury	At edge of golf course green on northern bank at upstream end of segment	Moderate	●	●	●	○	No buffer for approximately 200 feet in vicinity of golf course green. Riprap has been placed at downstream end to protect stream bank. Channel is undergoing major adjustment.
Project #25 R13.S1.03-C (Refer to Map 3)	Floodplain Improvement and Conservation	River Corridor or Conservation Easement	Graves Brook	Waterbury	Both southern and northern sides of channel along length of segment.	Low	●	◓	●	○	One large forested parcel (330 acres) with no development currently in corridor for segment.
Project #26 R13.S1.02-S1.01-A (Refer to Map 5)	Floodplain Improvement and Conservation	Establish "No Mow Zone" to Regenerate Riparian Buffer	Thatcher Brook	Waterbury	At the Waterbury Park and Ride	Moderate	●	●	◓	◓	A short stretch on the southern bank of Thatcher Brook is lacking a buffer due to mowing around the park and ride. A "no mow" zone could be established to allow buffer regeneration.
Project #27 R13.S1.02-S1.01-B (Refer to Map 5)	Structure Replacement/ Removal	Investigate Dam Removal	Thatcher Brook	Waterbury	Historic Dams at Mill Road	Moderate	●	○	◓	◓	Two historic dams exist that may be creating a barrier for aquatic organism passage. The lower dam has been breached, but the upper one is fully intact. Removing the dams could improve habitat connectivity, but degree of current AOP is uncertain. More investigation needed.
Project #28 R13.S1.02-S1.01-C (Refer to Map 5)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Thatcher Brook	Waterbury	At 1320 Route 100	**High**	●	●	●	◓	Riparian buffer is lacking along northern bank for about 200 feet due to a landowner's lawn. Landowner indicated interest in potential projects and is concerned about bank erosion on their property. Planting a buffer could help stabilize the bank.

[1] Enhances or protects aquatic or riparian habitat
[2] Reduces sedimentation and phosphorus levels
[3] Moves the channel toward equilibrium where the water and sediment are in balance
[4] Reduces risk of flooding and erosion hazard

Mid-Winooski River Watershed - Waterbury Area - Restoration & Protection Projects
Waterbury, Vermont
Central Vermont Regional Planning Commission
May 1, 2015

Legend

● Effective ◓ Limited ○ Ineffective

Project Number Segment	Project Category	Project Type	Stream Name	Town	Project Location	Priority	OBJECTIVES: Improves or Protects Habitat[1]	Improves Water Quality[2]	Improves Long-term Channel Stability[3]	Protects Infrastructure, and Property[4]	Comments
Project #29 R13.S1.02-S1.02 (Refer to Map 5)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Thatcher Brook	Waterbury	Just downstream of upstream Guptil Road Bridge on north bank	Moderate	●	●	◓	○	Riparian buffer is lacking for about 450 feet along the north side of Thatcher Brook due to what appears to be a crop field. Project could be eligible for CREP.
Project #30 R13.S1.02-S1.02 (Refer to Map 5)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Thatcher Brook	Waterbury	On pasture land north of golf course	Moderate	●	●	◓	○	About 250 feet on the south bank are lacking a riparian buffer. Land use is unknown.
Project #31 R13.S1.02-S1.02 & R13.S1.02-S1.03 (Refer to Map 5)	Floodplain Improvement and Conservation	River Corridor or Conservation Easement	Thatcher Brook	Waterbury	Between the lower Guptil Road Bridge and confluence of Unnamed Tributary 2 to Thatcher Brook	**High**	●	●	●	◓	This section of the brook is extremely dynamic and contains abundant adjacent wetlands. It is very important for the storage of floodwaters and sediment and is currently undeveloped. Several large parcels.
Project #32 R13.S1.02-S1.03 (Refer to Map 5)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Thatcher Brook	Waterbury	Directly west of the intersection of Kneeland Flats Road and Guptil Road	Moderate	●	●	◓	○	About 250 feet on the east bank of the brook are lacking adequate riparian vegetation. This area appears to be used as both a residential lawn and an agricultural field. Project may be eligible for CREP.
Project #33 R13.S1.02-S1.04-A (Refer to Map 5)	Floodplain Improvement and Conservation	Riparian Buffer Planting and Livestock Exclusion	Thatcher Brook	Waterbury	Along western bank upstream of confluence with Unnamed Tributary 2 at 1211 Guptil Road	**High**	●	●	●	◓	Lack of buffer along pasture and horse crossing in this section. Abundant armoring preventing widening in places. Channel is widening where riprap is not located. Project may be eligible for CREP.
Project #34 R13.S1.02-S1.04-B (Refer to Map 5)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Thatcher Brook	Waterbury	Along western bank upstream of Guptil Road Bridge at 1526 Guptil Road	Moderate	●	◓	●	◓	Lack of buffer along lawn/pasture along northwestern bank. Channel is widening where armoring is not in place. Project may be eligible for CREP.
Project #35 R13.S1.02-S1.04-C (Refer to Map 5)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Thatcher Brook	Waterbury	Along northern bank at 1530 Guptil Road	Moderate	●	◓	●	◓	Lack of buffer along lawn/pasture on northern side of channel. Channel is adjusting and building new floodplain.
Project #36 R13.S1.02-S1.04-C & R13-S1.02-S1.05-A (Refer to Map 5)	Floodplain Improvement and Conservation	River Corridor or Conservation Easement	Thatcher Brook	Waterbury	Eastern side of parcels at 1842 Guptil Road and 116 Maple Street	**High**	●	○	●	○	Two parcels 70 acres in total of well forested riparian corridors.
Project #37 R13.S1.02-S1.05-A (Refer to Map 5)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Thatcher Brook	Waterbury	Approximately 1,500 feet upstream of Loomis Hill Road Bridge	Low	●	◓	●	◓	Lack of buffer in some locations along agricultural fields. Channel in major adjustment. Possible CREP project.
Project #38 R13.S1.02-S1.05-B (Refer to Map 5)	Stream Channel Improvement and Restoration	Investigate Berm Removal	Thatcher Brook	Waterbury	Approximately 2,700 feet upstream of Loomis Hill Road Bridge	Low	●	○	●	○	Historic berm most likely caused by previous windrowing preventing floodplain access on eastern bank. Well forested and removal of berm would not cause flood risks.

[1] Enhances or protects aquatic or riparian habitat
[2] Reduces sedimentation and phosphorus levels
[3] Moves the channel toward equilibrium where the water and sediment are in balance
[4] Reduces risk of flooding and erosion hazard

Mid-Winooski River Watershed - Waterbury Area - Restoration & Protection Projects
Waterbury, Vermont
Central Vermont Regional Planning Commission
May 1, 2015

Legend

● Effective ◓ Limited ○ Ineffective

Project Number Segment	Project Category	Project Type	Stream Name	Town	Project Location	Priority	OBJECTIVES: Improves or Protects Habitat[1]	Improves Water Quality[2]	Improves Long-term Channel Stability[3]	Protects Infrastructure, and Property[4]	Comments
Project #39 R13.S1.02-S1.06-A (Refer to Map 6)	Floodplain Improvement and Conservation	Buffer regeneration/Establish no mow zone	Thatcher Brook	Waterbury	At downstream end of reach in between stream and 646 Maple Street	Low	●	◓	●	○	13 acre parcel with former hay field/pasture. Buffer is currently regenerating and stream would benefit from further removal of vegetation.
Project #40 R13.S1.02-S1.06-A & B, R13.S1.02-S1.07, R13.S1.02-S1.08-A & B, R13.S1.02-S1.09-A (Refer to Map 6)	Floodplain Improvement and Conservation	River Corridor or Conservation Easement	Thatcher Brook	Waterbury	From across 901 Maple Street to just above segment break for R13.S1.02-S1.09-B at 1842 Barnes Hill Road.	Moderate	●	◓	●	○	Nine landowners along a stretch of Thatcher Brook 2.5 miles long. One parcel is landlocked with 8 acres and another town owned lot is 12 acres. All other parcels are large (85-308 acres). Well forested buffer for the most part.
Project #41 R13.S1.02-S1.06-B (Refer to Map 6)	Structure Replacement/ Removal	Remove Bridge	Thatcher Brook	Waterbury	Across from 371 Barnes Hill Road	Low	◓	○	◓	○	Old wooden trail bridge with no abutments. Low clearance and in unstable condition.
Project #42 R13.S1.02-S1.09-B (Refer to Map 6)	Structure Replacement/ Removal	Replace Culvert	Thatcher Brook	Waterbury	At private drive crossing near 1930 Barnes Hill Road	**High**	●	◓	●	●	Flow downstream of wetland is split into two channels that go through three culverts. Culverts are very undersized and there is no aquatic organism passage. Beaver dam upstream. Replace with adequately sized structure with no freefall drop.
Project #43 R13.S1.02-S1.09-D (Refer to Map 6)	Structure Replacement/ Removal	Remove Bridge	Thatcher Brook	Waterbury	Approximately 900 feet downstream of Waterworks Road crossing	**Low**	◓	○	◓	○	Old wooden trail bridge with no abutments. Low clearance and in unstable condition.
Project #44 R13.S1.02-S1.09-D (Refer to Map 6)	Stream Channel Improvement and Restoration	Return or Remove Windrowed Material/Remove berm	Thatcher Brook	Waterbury	Just downstream of Waterworks Road Bridge on southern bank	Moderate	◓	○	●	○	Material was windrowed and piled on southern bank creating a berm. The berm is not protecting anything on the southern bank. Remove material from berm to reestablish floodplain connection. Channel is undergoing major adjustment.
Project #45 R13.S1.02-S1.09-D (Refer to Map 6)	Stream Channel Improvement and Restoration	Restore flow to stream channel	Thatcher Brook	Waterbury	In vicinity of Waterworks Road crossing	**High**	●	●	○	○	Lack of flow during times of water withdrawal are leaving the stream bed dry.
Project #46 R13.S1.02-S1.02-S1.01-A (Refer to Map 7)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Unnamed Tributary 1 to Thatcher Brook	Waterbury	On northern bank just upstream of confluence with Thatcher Brook	Moderate	●	●	◓	○	Riparian buffer is lacking for about 250 feet on the northern side of the stream due to the presence of a field and walking path. Project may be eligible for CREP. Alternatively, a "no mow" zone could be established and allow for natural buffer regeneration. Project could continue along the edge of the field, which also borders R13.S1.02-S1.03 of Thatcher Brook.
Project #47 R13.S1.02-S1.02-S1.01-C (Refer to Map 7)	Structure Replacement/ Removal	Remove Destroyed Bridge	Unnamed Tributary 1 to Thatcher Brook	Waterbury	On VAST trail about 900 feet downstream of culvert under Twin Peaks Road	**High**	●	◓	●	◓	There is a destroyed snowmobile bridge (iron and wood) causing sediment and debris accumulation in the stream channel. The bridge could affect water quality and channel stability, and could wash downstream and cause damage to infrastructure/property if not removed.

[1] Enhances or protects aquatic or riparian habitat
[2] Reduces sedimentation and phosphorus levels
[3] Moves the channel toward equilibrium where the water and sediment are in balance
[4] Reduces risk of flooding and erosion hazard

Mid-Winooski River Watershed - Waterbury Area - Restoration & Protection Projects
Waterbury, Vermont
Central Vermont Regional Planning Commission
May 1, 2015

Legend

● Effective ◓ Limited ○ Ineffective

Project Number Segment	Project Category	Project Type	Stream Name	Town	Project Location	Priority	OBJECTIVES: Improves or Protects Habitat[1]	Improves Water Quality[2]	Improves Long-term Channel Stability[3]	Protects Infrastructure, and Property[4]	Comments
Project #48 R13.S1.02-S1.02-S1.01-D (Refer to Map 7)	Stream Channel Improvement and Restoration	Build Up Streambed with Boulder Weirs and Arrest Headcut	Unnamed Tributary 1 to Thatcher Brook	Waterbury	At Green Mountain Garlic Farm	**High**	◓	◓	●	◓	Stream channel is cutting down to glacial till and threatens good floodplain access upstream. Landowners indicated that they wanted help with the bank erosion and channel downcutting.
Project #49 R13.S1.02-S1.02-S1.01-D & E (Refer to Map 7)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Unnamed Tributary 1 to Thatcher Brook	Waterbury	On both banks from about 900 feet upstream of Twin Peaks Road crossing to Perry Hill Road Crossing	**High**	●	●	●	○	Riparian buffer is lacking on both banks for all of segments C and D due to crop fields and pasture land. Banks are unstable due to lacking vegetation. Project may be eligible for CREP. Landowner interest in projects is present.
Project #50 R13.S1.02-S1.02-S1.01-E (Refer to Map 7)	Stream Channel Improvement and Restoration	Livestock Exclusion	Unnamed Tributary 1 to Thatcher Brook	Waterbury	For about 1,500 feet of stream channel immediately downstream of Perry Hill Road crossing	**High**	●	●	●	○	Grazing animals have access to the stream throughout all of segment E, which is causing geomorphic instability and water quality problems. There are at least 8 locations where animals can cross/ access the stream. Algae growth in the channel is abundant below this section (but not above), suggesting that agricultural practices here could be causing nutrient enrichment.
Project #51 R13.S1.02-S1.02-S1.01-F & G (Refer to Map 7)	Floodplain Improvement and Conservation	River Corridor or Conservation Easement	Unnamed Tributary 1 to Thatcher Brook	Waterbury	Upstream of Perry Hill Road crossing	Moderate	●	◓	●	◓	This section of the brook is largely undisturbed and is an important area for floodwater and sediment storage. A section of this area is a wetland complex. Mostly forested land. Parcels are not very large, but one landowner is interested in projects.
Project #52 R13.S1.02-S1.02-S1.01-G (Refer to Map 7)	Floodplain Improvement and Conservation	Riparian Buffer Planting	Unnamed Tributary 1 to Thatcher Brook	Waterbury	About 1,300 feet upstream of Perry Hill Road crossing	Low	●	●	◓	○	Riparian buffer is lacking on northern bank for approximately 150 feet due to an agricultural field. Project may be eligible for CREP, but is a small planting area.
Project #53 R13.S1.02-S1.02-S1.01-G (Refer to Map 7)	Structure Replacement/ Removal	Remove or Replace Bridge	Unnamed Tributary 1 to Thatcher Brook	Waterbury	On VAST trail about 1,800 feet upstream of Perry Hill Road crossing	Moderate	◓	○	●	●	A snowmobile bridge on the VAST trail is in poor condition and is partially collapsing. The bridge is a safety issue if it is currently in use, and if it is not in use, it should be removed as it is undersized and failing.
Project #54 R13.S1.02-S1.03-S1.01-A (Refer to Map 7)	Structure Replacement/ Removal	Replace Bridge	Unnamed Tributary 2 to Thatcher Brook	Waterbury	Bridge on Guptil Road almost 800 feet northeast of intersection with Kneeland Flats Road	**High**	◓	○	●	●	Bridge is slightly undersized and is in poor condition. Riprap around the bridge has all fallen into the stream and a large amount of sediment has accumulated beneath the bridge, causing it to have a very low clearance. It could be easily overtopped and damaged during high flows.
Project #55 R13.S1.02-S1.03-S1.01-A (Refer to Map 7)	Stream Channel Improvement and Restoration	Livestock Exclusion	Unnamed Tributary 2 to Thatcher Brook	Waterbury	Just upstream of Guptil Road Bridge	**High**	●	●	●	○	Upstream of the Guptil Road Bridge, there is pasture land for cows, which appear to have free access to the stream. Excluding these cows would eliminate localized geomorphic instability and improve water quality.

[1] Enhances or protects aquatic or riparian habitat
[2] Reduces sedimentation and phosphorus levels
[3] Moves the channel toward equilibrium where the water and sediment are in balance
[4] Reduces risk of flooding and erosion hazard

Mid-Winooski River Watershed - Waterbury Area - Restoration & Protection Projects
Waterbury, Vermont
Central Vermont Regional Planning Commission
May 1, 2015

Legend

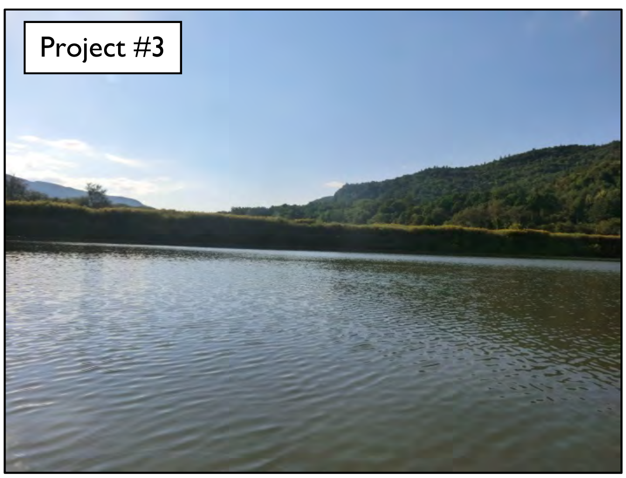
● Effective ◓ Limited ○ Ineffective

Project Number Segment	Project Category	Project Type	Stream Name	Town	Project Location	Priority	OBJECTIVES: Improves or Protects Habitat[1]	Improves Water Quality[2]	Improves Long-term Channel Stability[3]	Protects Infrastructure, and Property[4]	Comments
Project #56 R13.S1.02-S1.03-S1.01-B & C (Refer to Map 7)	Floodplain Improvement and Conservation	Riparian Buffer Planting and River Corridor Easement	Unnamed Tributary 2 to Thatcher Brook	Waterbury	Between Guptil Road and Harvey Farm Road	Moderate	●	●	●	◓	Riparian buffer is lacking on south bank for 325 feet due to an agricultural field. Aside from this, the stream is undisturbed and has good floodplain access here. It is undergoing major adjustment. One large parcel. Project may be eligible for CREP.
Project #57 R13.S1.02-S1.03-S1.02-C (Refer to Map 7)	Structure Replacement/ Removal	Culvert Replacement	Unnamed Tributary 2 to Thatcher Brook	Waterbury	Culvert under Shaw Mansion Road	**High**	●	◓	●	●	This culvert is significantly undersized and rusty. The culvert was washed out during Irene, causing road damage, and could wash out again due to its very small size.
Project #58 R13.S1.02-S1.03-S1.02-B & C (Refer to Map 7)	Floodplain Improvement and Conservation	River Corridor or Conservation Easement	Unnamed Tributary 2 to Thatcher Brook	Waterbury	Between Shaw Mansion Road and Ripley Road	Moderate	●	◓	◓	◓	One large parcel (55 acres) is suggested for river corridor or conservation easement. There is no development present in the parcel and the stream is actively adjusting in this area.
Project #59 R13.S1.02-S1.03-S1.02-C (Refer to Map 7)	Structure Replacement/ Removal	Culvert Replacement	Unnamed Tributary 2 to Thatcher Brook	Waterbury	Culvert under Ripley Road	**High**	●	◓	●	●	This culvert is severely undersized and creates a barrier to aquatic organism passage due to the drop at its outlet.

[1] Enhances or protects aquatic or riparian habitat
[2] Reduces sedimentation and phosphorus levels
[3] Moves the channel toward equilibrium where the water and sediment are in balance
[4] Reduces risk of flooding and erosion hazard


Project #1


Project #2


Project #3


Project #4

No photo for Project #5


Project #6

No photo for Project #7


Project #8


Project #9

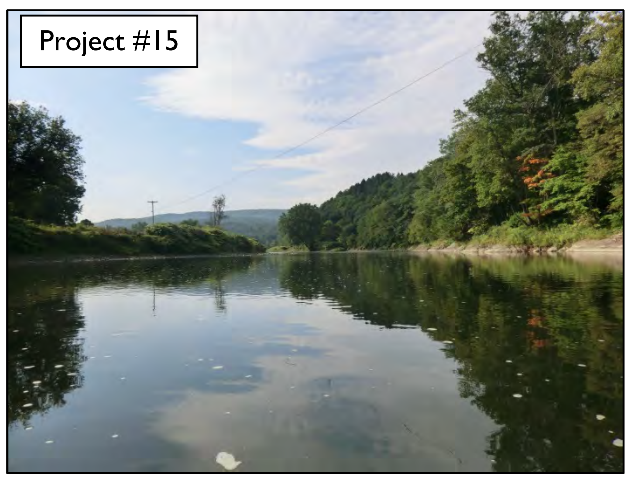

Project #10


Project #11


Project #12


Project #13


Project #14


Project #15


Project #16


Project #17


Project #18


Project #19

No photo for Project #20


Project #21


Project #22


Project #23


Project #24


Project #25

No photo for Project #29


Project #26


Project #30


Project #27


Project #31

No photo for Project #28

No photo for Project #32


Project #33


Project #34


Projects #35


Project #36


Project #37


Project #38


Project #39


Project #40


Project #41


Project #42


Project #43


Project #44


Project #45


Project #46


Project #47


Project #48


Project #49


Project #50


Project #51


Project #52


Project #53


Project #54


Project #55


Project #56


Project #57


Project #58


Project #59