Neshobe River in Rutland County Corridor Plan

Brandon, Vermont

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Acknowledgments

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This report is dedicated to property owners who were gravely impacted by high flow conditions in the Neshobe River as a result of tropical storm Irene on August 28 and 29, 2011. We offer our support and best wishes during this difficult time.

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1.0 EXECUTIVE SUMMARY

The River Corridor Planning effort is sponsored by the Rutland Natural Resources Conservation District (RNRCD) with funding provided through a grant from the Agency of Natural Resources. The Vermont Department of Environmental Conservation (DEC) River Management Program provided technical expertise and shared quality control/quality assurance responsibilities with Bear Creek Environmental, LLC (BCE). The River Corridor Plan (RCP) followed the Vermont Agency of Natural Resources River Corridor Planning Guide. Information for the RCP came from the DEC, the Vermont Center for Geographic Information (VCGI), and field data collected by Rutland Regional Planning Commission (RRPC) and Round River Design (RRD).

The primary objective of the RCP is to use stream geomorphic assessment data to identify and prioritize river corridor protection and restoration projects within the Neshobe River watershed, primarily in the Town of Brandon. A planning strategy based on fluvial geomorphic science (see glossary at end of report for associated definitions) was chosen because it provides a holistic, watershed-scale approach to identifying the stressors on river ecosystem health. The stream geomorphic assessment data can be used by resource managers, community watershed groups, municipalities and others to identify how changes to land use alter the physical processes and habitat of rivers. The Vermont Stream Geomorphic Assessment Protocol includes three phases:

1. Phase 1- Remote sensing and cursory field assessment;
2. Phase 2 – Rapid habitat and rapid geomorphic assessment to provide field data to characterize the current physical condition of a river; and
3. Phase 3 – Detailed survey information for designing "active" channel management projects.

A Phase 1 Stream Geomorphic Assessment following Agency of Natural Resources Protocols was completed for the Neshobe River watershed within Rutland County by the Rutland Regional Planning Commission (RRPC) during summer 2007. The upper portion of the Neshobe River watershed within Addison County received a Phase 1 Stream Geomorphic Assessment in 2004/2005. The Addison County Regional Planning Commission sponsored the Phase 1 study of the Neshobe River and major tributaries and BCE conducted the assessment. During Phase 1, the Neshobe River Watershed was divided into 24 reaches, encompassing roughly 19 miles of river channel.

In the fall of 2007, a Phase 2 Stream Geomorphic Assessment following Agency of Natural Resources Protocols was completed for the main stem of the Neshobe River by RRPC and Round River Design (RRD) with approximately 13 miles of river assessed. Bridge and culvert data collected during the Phase 2 assessment were used to identify structures that have the potential to fail because of channel adjustments, are having a geomorphic impact on the stream, or are impeding aquatic organism passage. BCE used the stream geomorphic and habitat data collected during 2007 to develop the corridor plan for the Neshobe River watershed within Brandon.

The major problems in the Neshobe River watershed include channel straightening associated with the construction of roads and development as well as the placement of berms. In some cases, alteration of stream channels and floodplains has caused moderate channel degradation resulting in sediment build up, channel widening and planform adjustment. The downstream end of the Neshobe River has seen increased sedimentation from the upstream reaches. The Brandon dam, located above Route 7 (Center Street), disrupts natural sediment transport within the Neshobe River. High quality streamside buffers are lacking along the Neshobe River causing unstable streambanks and increased erosion. Despite these problems, there are areas with high quality forested buffers and significant wetlands that are worthy of conservation.

As the river works toward a more stable equilibrium, the community of Brandon has the opportunity to provide long-term protection to the river corridor and wetlands and encourage the reestablishment of floodplain vegetation and healthy instream habitat. At the reach and site level, potential restoration and protection projects that would be compatible with geomorphic adjustments and managing the stream toward equilibrium conditions were identified. A list of 13 potential restoration and conservation projects was developed during project identification. Types of projects include: river corridor and wetland protection through easements and conservation efforts, improving riparian buffers, reducing farm field runoff, evaluation of berm removal, mass failure remediation, bridge replacement, and dam removal.

2.0 LOCAL PLANNING PROGRAM OVERVIEW

2.1 River Corridor Planning Team

The river corridor planning team for the Neshobe River watershed is comprised of the Rutland Natural Resources Conservation District, Rutland Regional Planning Commission, the Agency of Natural Resources, Round River Design, Bear Creek Environmental, LLC, local municipalities and landowners. This planning effort is sponsored by the Rutland Natural Resources Conservation District. Funding for the project is provided through a grant from the Vermont Department of Environmental Conservation. Shannon Pytlik and Ethan Swift of the Vermont Agency of Natural Resources (VANR) provided technical guidance for this project.

2.2 Goals and Objectives of the Project

The primary objective of the River Corridor Management Plan is to use the Phase 1 and 2 Stream Geomorphic Assessment data to identify and prioritize river corridor protection and restoration projects within the Neshobe River Watershed. The State of Vermont's River Management Program has set out several goals and objectives that are supportive of the local initiative in the Neshobe River Watershed. The state management goal is to, "manage toward, protect, and restore the fluvial geomorphic equilibrium condition of Vermont rivers by resolving conflicts between human investments and river dynamics in the most economically and ecologically sustainable manner" (Vermont Agency of Natural Resources, 2009a). The objectives of the Program include fluvial erosion hazard mitigation and sediment and nutrient load reduction, as well as aquatic and riparian habitat protection and restoration. The Program seeks to conduct river corridor planning in an effort to remediate the geomorphic instability that is largely responsible for problems in a majority of Vermont's rivers. Additionally, the Vermont River Management Program has set out to provide funding and technical assistance to facilitate an understanding of river instability and the establishment of well developed and appropriately scaled strategies to protect and restore river equilibrium.

3.0 BACKGROUND WATERSHED INFORMATION

3.1 Geographic Setting

3.1.1 Watershed Description

The Neshobe River, a major tributary to the Otter Creek, flows southwesterly from the headwaters in Goshen into Brandon adjacent to Route 73 (Figure 3.1). Most of the reaches within the main stem of the Neshobe River within the Town of Goshen are high gradient, confined systems.

The Neshobe River within the Town of Brandon undergoes a dramatic change in character as it flows from the Goshen town line to the Otter Creek. Starting at the northeastern side of Brandon, the Neshobe River has a steep, narrowly confined channel (Figure 3.2). Northeast of Forest Dale, the Neshobe River is a step/pool system with multiple ledge grade controls that are preventing the channel from incising. In the Village of Forest Dale, the channel gradient transitions from steep to a moderate slope (Figure 3.3). Floodplain encroachment and channel straightening have influenced the geomorphic stability and habitat quality of this section that flows through the Village of Forest Dale. Southwest of the Village of Forest Dale, the valley slope flattens further (Figure 3.4). Historic straightening and the lack of a riparian buffer are evident adjacent to agricultural fields and the Neshobe Golf Club. In the center of Brandon, the Neshobe River once again has a spectacular transformation as it cascades over two falls (Figure 3.5) before continuing through a gentle gradient valley to its confluence with the Otter Creek. The drainage at the mouth of the Neshobe River is 20.3 square miles.

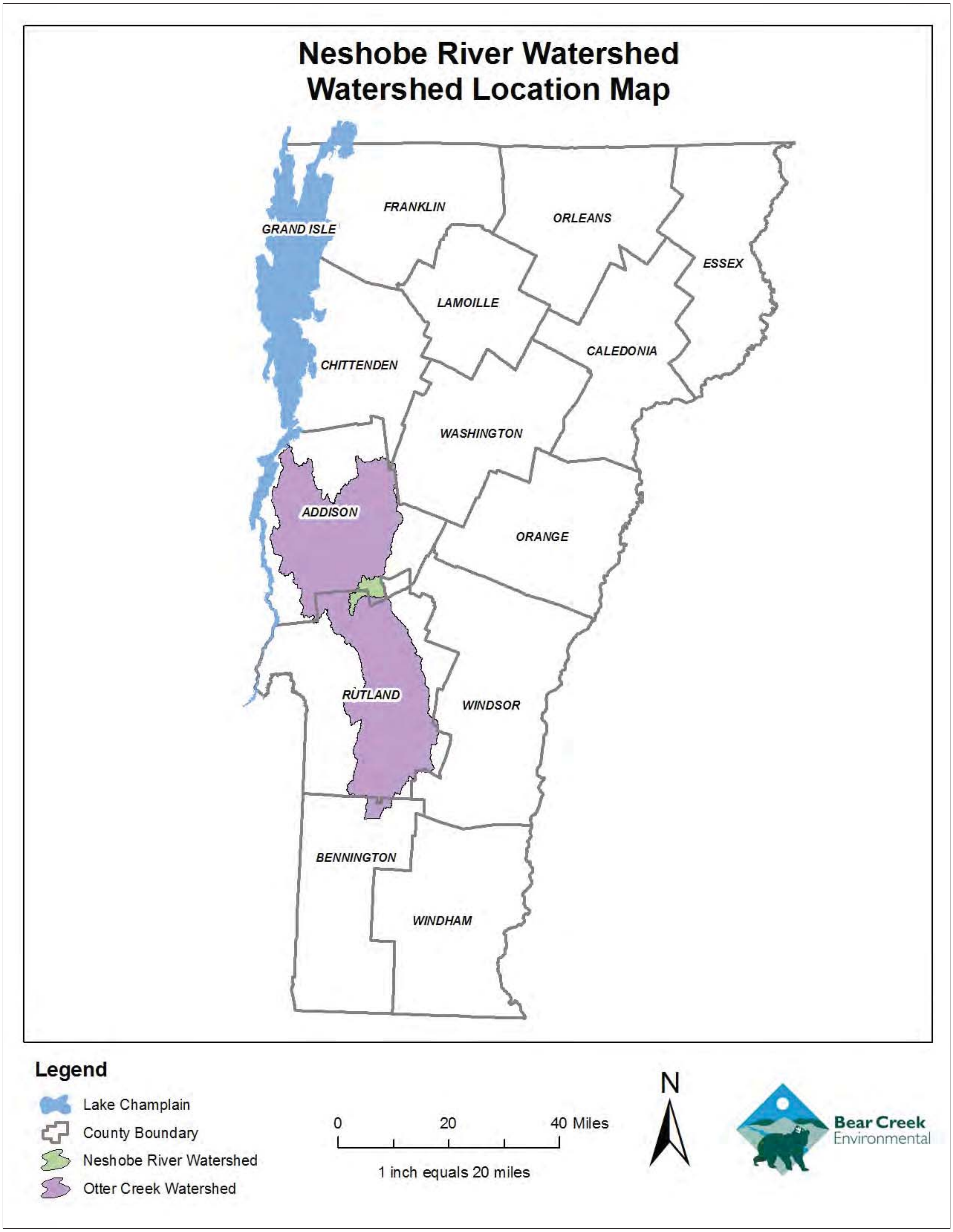

Figure 3.1. Watershed Location Map for Neshobe River Watershed

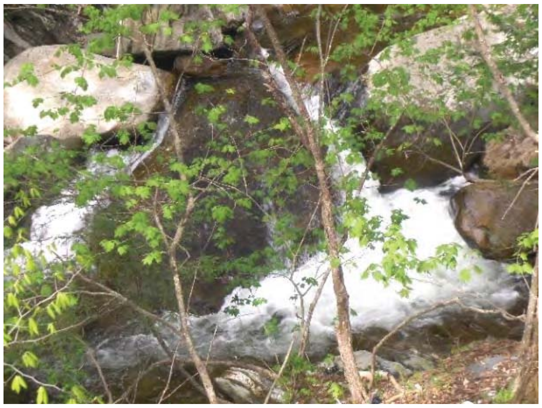

Figure 3.2. Narrowly confined channel (BCE, 5/7/2010)

Figure 3.3. Transition to moderate slope (BCE, 5/7/2010)

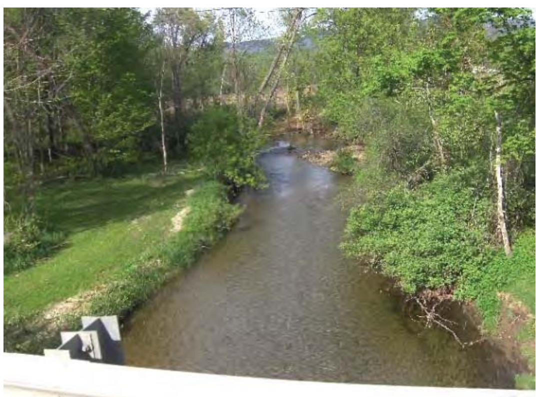

Figure 3.4. West of Town Farm Road (BCE, 5/7/2010)

Figure 3.5. Waterfall at former Mill Dam (BCE, 5/7/2010)

3.1.2 Political Jurisdictions

The Neshobe River and its major tributaries flow through the towns of Goshen and Brandon. The Neshobe River watershed falls under the jurisdiction of the RRPC and the Addison County Regional Planning Commission. This project focused on only those reaches within Rutland County and the Town of Brandon.

3.1.3 Land Use

Geographic Information System (GIS) data from 2001 was obtained from the Vermont Center for Geographic Information (VCGI) to analyze land use within the Neshobe River watershed. The majority of the Neshobe River watershed is forested (Figure 3.6). The land use breakdown for the watershed is 76 percent forest, 10 percent agriculture, 6 percent developed and urban land, 5 percent wetland and 3 percent shrub/scrub. The most concentrated areas of development in the watershed are within the lower portion of the watershed in the village center of Brandon. Agricultural lands are prevalent within the lower and middle portions of the watershed including the Neshobe River corridor.

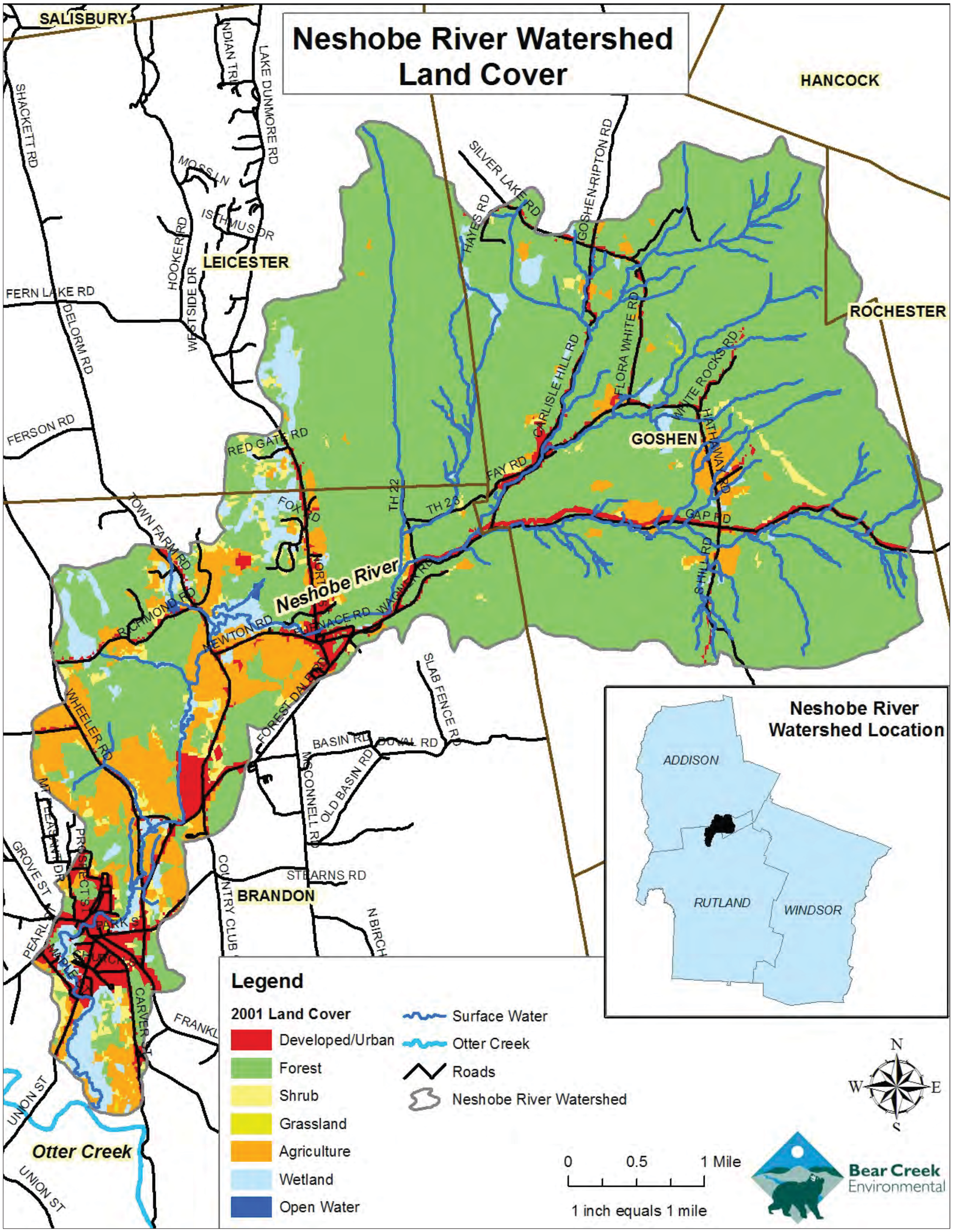

Figure 3.6. Land Cover and Land Use Map for the Neshobe River Watershed

3.2 Geologic Setting

The upper portion of the Neshobe River watershed in Goshen lies within the Northern Green Mountains physiographic region and transitions to the Champlain Valley about one-quarter mile southwest of the Goshen/Brandon town line. The Green Mountains were uplifted during the Taconic orogeny about 455 million years ago (Doolan, 1996). The portion of the watershed in the Green Mountains physiographic province primarily consists of the Pinnacle Formation, which is comprised of schistose greywacke (Doll, 1961). Heading east into the Champlain Valley province, the bedrock geology transitions to quartzite and dolomite (Doll, 1961).

The Green Mountains and adjacent valleys have been covered with ice during historic glacial periods. The last large ice sheet, the Laurentide Ice Sheet, covered all of New England and advanced up over the Green Mountains. Glacial striations in the bedrock of the Green Mountains show that the glacier moved from northwest to southeast (Wright, 2003). As the climate warmed, the glacier slowly retreated and valleys such as the Champlain Valley were left behind (Wright, 2003).

Natural Resource Conservation Service (NRCS) soils information for the Neshobe River watershed was acquired from the Vermont Center for Geographic Information. The dominant surficial geology of the Neshobe River watershed consists of alluvium, lacustrine deposits, outwash (ice-contact), and glacial till. Lacustrine deposits, outwash (ice-contact deposits), and glacial till are subdominant within the watershed.

3.3 Geomorphic Setting

A Phase 1 Stream Geomorphic Assessment was conducted on 24 reaches of the main stem of the Neshobe River its major tributaries (North Branch of Neshobe River and Gould Brook) (Figure 3.7). The Phase 2 study of the Neshobe River watershed focused on the 15 reaches on the main stem. One reach (M10) was excluded from both Phase 1 and Phase 2 since it was too short (170 feet) of a section to warrant assessment. This short reach is a result of two Phase 1 projects being combined to form one Phase 1 project for the entire Neshobe River watershed.

The combined length of the stream reaches assessed during the Phase 2 study is approximately 13 miles (Figure 3.8). Ten of the assessed reaches are located within the Town of Brandon, which are described in this report. Each reach represents a similar section of the stream based on physical attributes such as valley confinement, slope, sinuosity, bed material, dominant bedform, land use, and other hydrologic characteristics. Each point represents the downstream end of the reach.

Reference stream types are based on the valley type, geology and climate of a region and describe what the channel would look like in the absence of human-related changes to the channel, floodplain, and/or watershed. Stream and valley characteristics including valley confinement, and slope were determined from digital USGS topographic maps. The reference reach characteristics were refined during the windshield survey and Phase 2

Assessment. Reference reach typing was based on both the Rosgen (1996) and the Montgomery and Buffington (1997) classification systems. Table 1 shows the typical characteristics used to determine reference stream types (Vermont Agency of Natural Resources, 2009a).

Table 1: Reference Stream Type

Stream Type	Confinement	Valley Slope	Bed Form
A	Narrowly Confined	Very steep > 6.5 %	Cascade
A	Confined	Very steep 4.0 - 6.5 %	Step-Pool
B	Confined or Semi-confined	Steep 3.0 – 4.0 %	Step-Pool
B	Confined, Semi-confined or Narrow	Moderate to Steep 2.0 – 3.0 %	Plane Bed
C or E	Unconfined (Narrow, Broad or Very Broad)	Moderate to Gentle <2.0 %	Riffle-Pool or Dune-Ripple
D	Unconfined (Narrow, Broad or Very Broad)	Moderate to Gentle <4.0 %	Braided Channel

Table 2 lists the reference stream types for assessed reaches within Brandon in the Neshobe River watershed. Reaches assessed for Phase 2 from the mouth to just upstream of Town Farm Road (M01-M05) are "E" channels by reference (Figure 3.9). In general, "E" channels are very sinuous, have unconfined valleys with moderate to gentle slopes and a low width to depth ratio. The next two reaches upstream (M06 and M07) are "C" channels by reference. Similar to "E" channels, reference "C" channels have unconfined valleys with moderate to gentle valley slopes and moderate to high width to depth ratios and sinuosity. Most of the remaining length of the main stem within the Town of Brandon is a "C" channel by reference. Two sections within M08 and M09 (M08-A and M09-A) and reach M11 are "B" channels by reference. "B" channels have moderate to steep slopes and have narrower valleys than "C" channels.

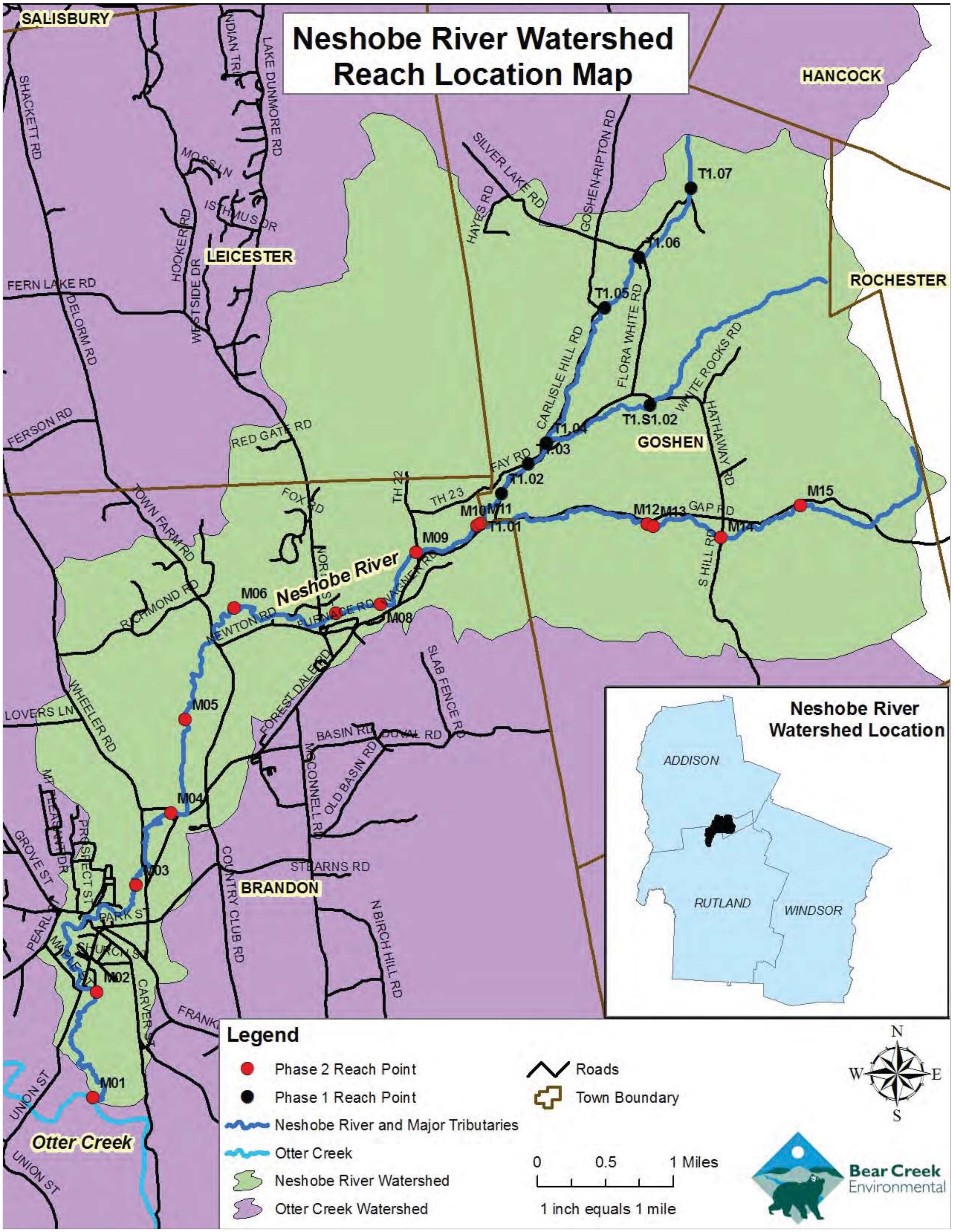

Figure 3.7 Neshobe River Watershed Reach Location Map

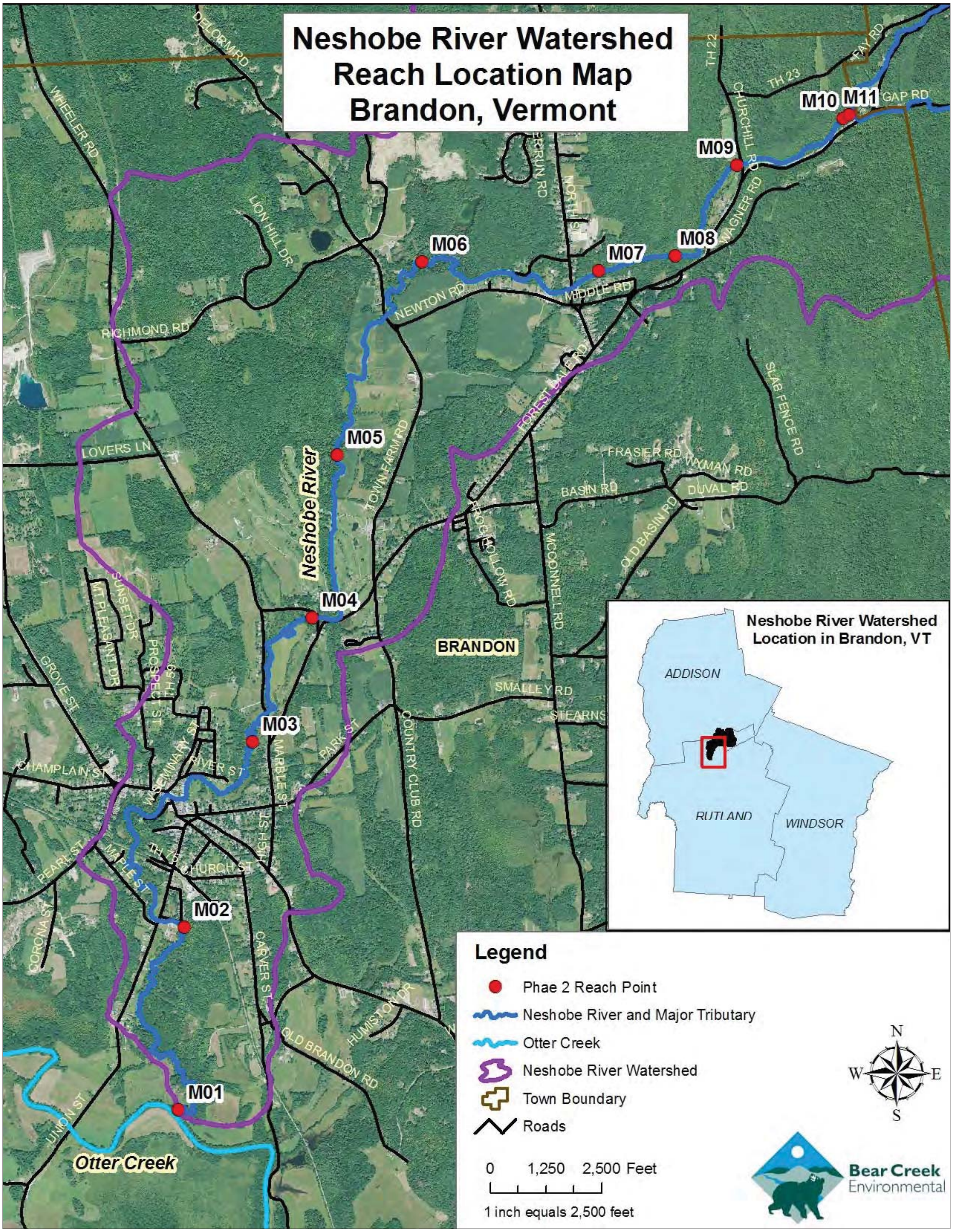

Figure 3.8 Neshobe River watershed Reach Location Map for Phase 2 Reaches

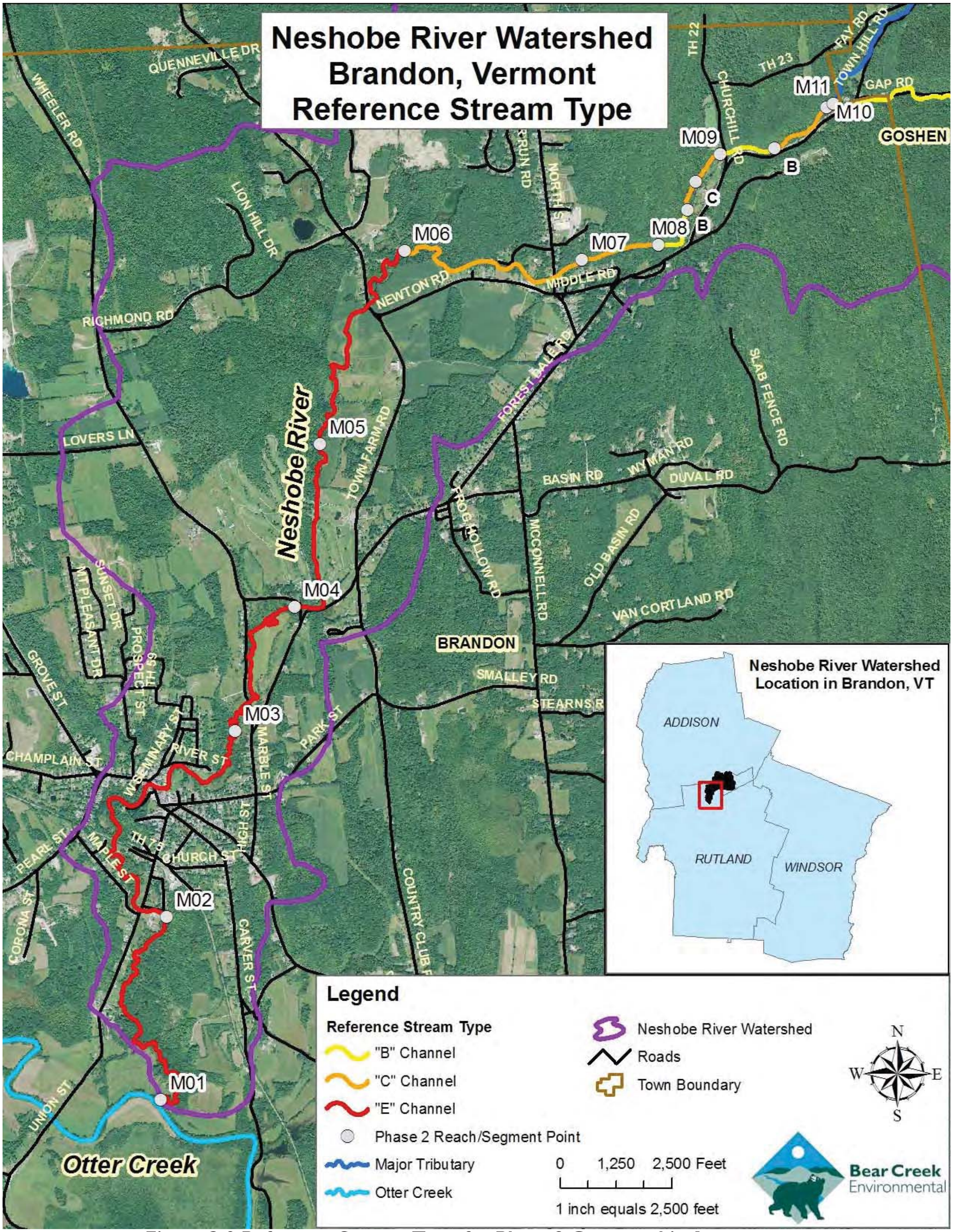

Figure 3.9 Reference Stream Type for Phase 2 Geomorphic Assessments

Table 2: Geomorphic Setting of Assessed Reaches					
Stream	**Reach ID**	**Reference Stream Type**	**Confinement[1]**	**Valley Slope**	**Bedform**
Neshobe River	M01	E	Very Broad	0.10	Dune-Ripple
	M02	E	Very Broad	0.54	Riffle-Pool
	M03	E	Very Broad	1.12	Riffle-Pool
	M04	E	Very Broad	1.27	Riffle-Pool
	M05	E	Very Broad	0.30	Riffle-Pool
	M06	C	Very Broad	2.53	Riffle-Pool
	M07	C	Broad	3.40	Plane Bed
	M08	C	Very Broad	3.62	Riffle-Pool
	M09	C	Narrowly Confined	5.36	Plane Bed
	M11	B	Semi-Confined	5.45	Step-Pool

3.4 Hydrology

In order to better understand the flood history of the Neshobe River Watershed, long term peak discharge data from the U.S. Department of the Interior, U.S. Geological Survey (USGS) gauge on the Otter Creek at Rutland, VT was obtained. The gauge provides a continuous record of flow from 1929 through the present. The drainage area at the Otter Creek gauge is 307 square miles. The long term record shows peak discharges between a ten year and 25 year recurrence interval occurred during water years[1] 1947, 1949, 1973, 1976, 1977, and 1987 as shown below in Figure 3.10. A flood less frequent than the 50 year discharge occurred during water year 1938. These USGS peak discharge flow values for each year do not account for the effects of flow regulations and diversions. (USGS, 2009)

Of all the natural hazards experienced in Vermont, flooding is the most frequent, damaging, and costly. Over the last 50 years, flood recovery has cost Vermonters an average of 14 Million dollars a year. During the period of 1995-1998 alone, flood losses in Vermont totaled nearly $57 Million. While some flood losses are caused by inundation (i.e. waters rise, fill, and damage low-lying structures), most flood losses in Vermont are caused by "fluvial erosion". Fluvial erosion is erosion caused by rivers and streams, and can range from gradual bank erosion to catastrophic changes in river channel location and dimension during flood events (Vermont Agency of Natural Resources, 2006).

[1] A water year is the twelve month period from October 1 through September 30.

Closer study of our rivers and streams reveals that Vermont's erosion hazard problems are largely due to pervasive, human-caused alteration during the past 150 to 200 years of our waterways and landscapes they drain. By end of the nineteenth century, forests had been cleared from many watersheds, resulting in major changes in watershed hydrology and sediment production. Towns and villages, the centers of commerce, grew on the banks of rivers. Benefits of power generation and transportation initially outweighed flood risks. In addition, many watersheds were changed by development, agriculture, log drives, roads and railways. This landscape manipulation has led to streams that are unstable and prone to fluvial erosion (Vermont Agency of Natural Resources, 2006).

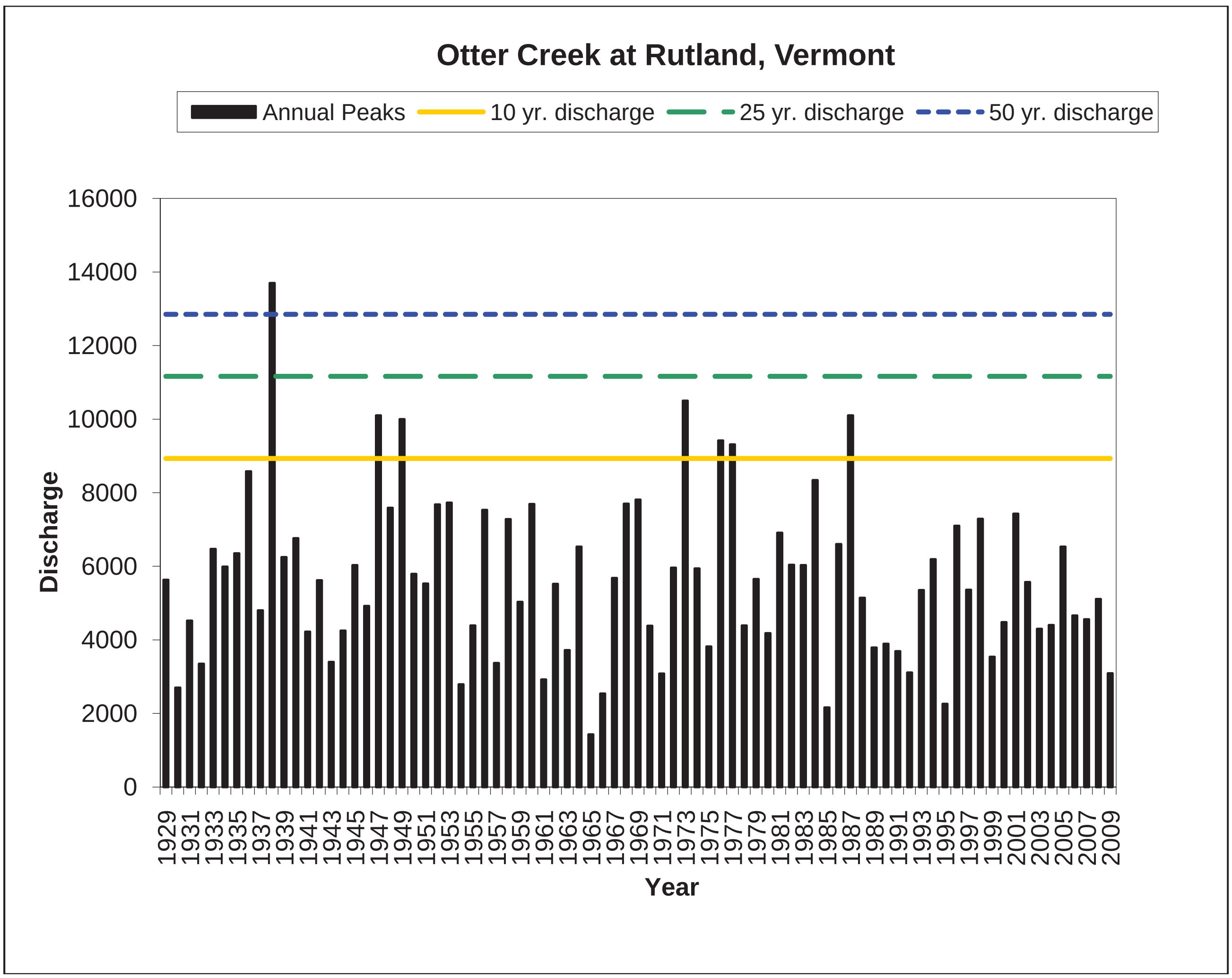

Figure 3.10. Flood frequency analysis for the Otter Creek at Rutland, Vermont

3.5 Ecological Setting

The Neshobe River watershed is made up of two biophysical regions which characterize the ecological setting (Figure 3.11). The upper portion of the Neshobe River watershed, which is mostly in Addison County, is within the Northern Green Mountains biophysical region. This region is characterized by Thompson and Sorenson (2000) as having high elevations and cool summers. The Green Mountains have a strong influence on the weather resulting in an abundance of precipitation in the form of both rain and snow. Based on Vermont StreamStats (USGS, 2011), precipitation at the base of the upper portion of the Neshobe River watershed (near the Rutland County/Addison County line) averages 49 inches annually. Approximately 95 percent of the upper watershed (drainage area of 10 square miles) has elevations greater than 1200 feet. Conserved lands in the upper watershed include the Green Mountain National Forest and the northern tip of the Brandon Town Forest. Deer wintering area have been identified by the Vermont Department of Fish and Wildlife within the corridors of the North Branch of the Neshobe River and Gould Brook.

The lower Neshobe River watershed in Rutland County lies within the Champlain Valley biophysical region. The Champlain valley is low, warm and comparatively dry and is referred to as the "banana belt" by Vermonters (Thompson and Sorenson, 2000). In contrast to the upper watershed, only about 58 percent of the lower watershed has elevations of greater than 1200 feet (USGS, 2011). Annual precipitation averages 44.4 inches. Lake Champlain is the predominant aquatic feature within the Champlain Valley. The Lake is fed by several major rivers including Otter Creek. The Vermont Significant Wetlands layer indicates there are palustrine wetlands in a number of locations within the lower Neshobe River watershed. According to Thompson and Sorenson (2000), the Champlain Valley provides excellent habitat for a variety of migrating waterfowl. The open fields provide habitat for unusual birds, such as the barn owl and upland sandpiper. White-tailed deer, gray squirrel, wild turkey and a variety of songbirds use the forests for breeding habitat. The Eastern timber rattlesnake, five-lined skink, and spiny softshell turtle are three rare reptiles that reside in the Champlain valley.

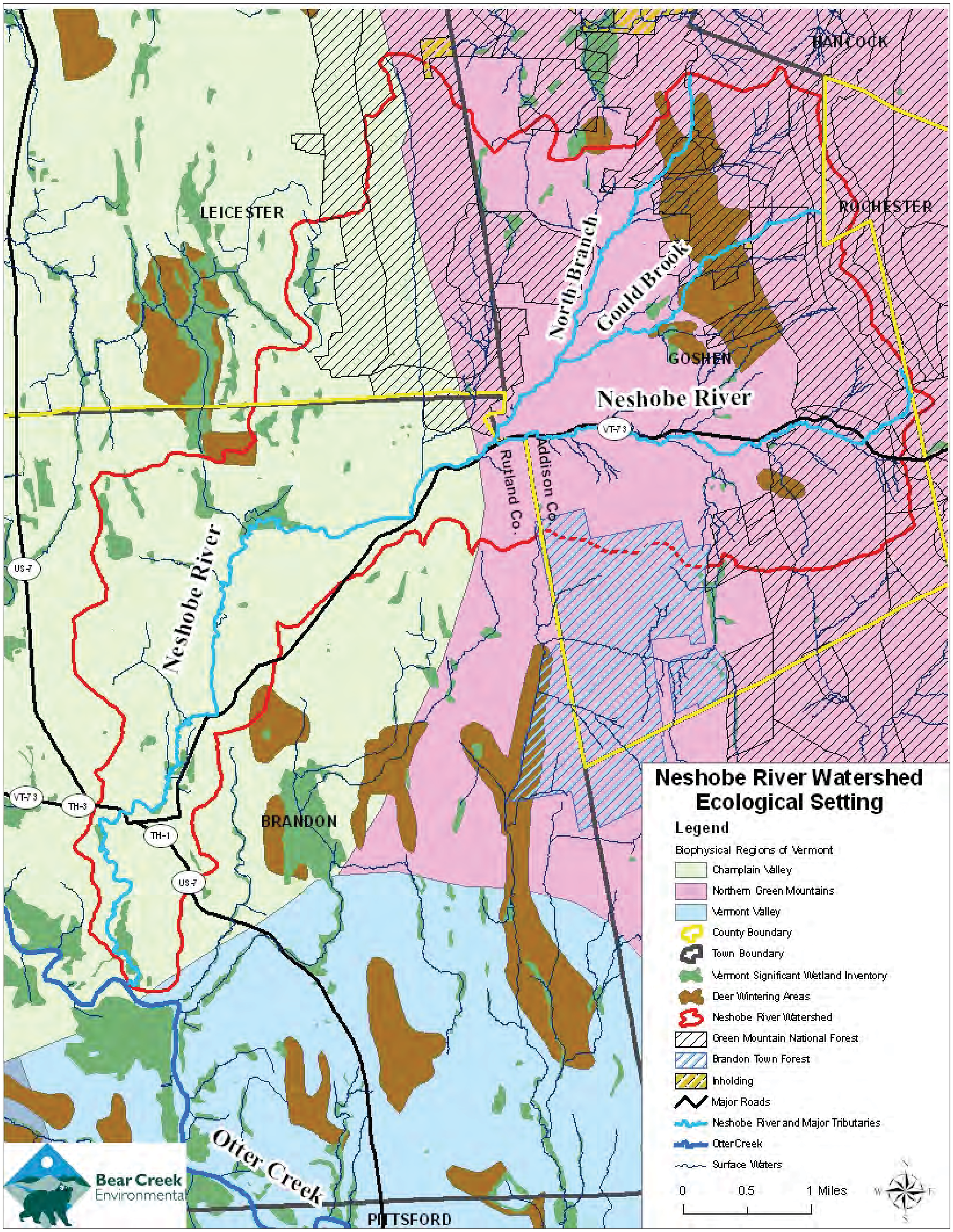

Figure 3.11 Ecological Setting of the Neshobe River

4.0 METHODS

4.1 Phase 1 Methodology

A Stream Geomorphic Assessment process is divided into three phases, based on VANR protocols. Phase 1, the remote sensing phase, involves the collection of data from topographic maps and aerial photographs, from existing studies, and from very limited field studies called "windshield surveys" (Vermont Agency of Natural Resources, 2007). The Phase 1 assessment provides an overview of the general physical nature of the watershed. A Phase 1 Assessment of the Neshobe River watershed was completed by the Rutland Regional Planning Commission (RRPC) during summer 2007.

4.2 Phase 2 Methodology

The Phase 2 assessment of the Neshobe River watershed followed procedures specified in the Vermont Stream Geomorphic Assessment Handbook Phase 2 (Vermont Agency of Natural Resources, 2009a). All assessment data were recorded on the Agency of Natural Resources Phase 2 data sheets, and were entered in to the VANR Stream Geomorphic Assessment Data Management System (DMS). The Phase 1 database was updated using the field data from the Phase 2 assessment in fall of 2007.

The parameters and protocols used for undertaking the Phase 2 assessment are outlined in the Phase 2 Handbook (Vermont Agency of Natural Resources, 2009a). The entire length of each Phase 2 reach was walked to determine segment breaks. Bank erosion, grade control structures, bank revetments, debris jams, depositional features, stormwater inputs, flood chutes, valley walls and other important features were mapped within all segments. The Stream Geomorphic Assessment Tool (SGAT) was used to index features that were mapped during the Phase 2 assessment. SGAT is an ArcView extension.

4.3 Bridge and Culvert

A bridge and culvert inventory and assessment was conducted in 2009 on the Stone Mill Dam Road Bridge to determine if the stream crossing was contributing to localized streambank erosion, sedimentation, and reduced fish passage. No other stream crossings on the main stem within the Town of Brandon were assessed. The Agency of Natural Resources Bridge and Culvert protocols (Vermont Agency of Natural Resources, 2009b) were followed.

4.4 River Corridor Plan

The Vermont Agency of Natural Resources River Corridor Planning Guide (2010) was followed to generate a series of stressor maps, which are included in Appendix B. The stressor maps were created using indexed data from the Phase 1 and Phase 2 Stream Geomorphic Assessments along with existing data available from VCGI, including roads, buildings and driveways. The stressor maps were then used to identify potential project locations that have few constraints to channel adjustment.

4.5 Quality Control/Quality Assurance Procedures

To assure a high level of confidence in the Phase 1 and 2 Stream Geomorphic Assessment data, strict quality assurance/quality control (QA/QC) procedures were followed. These procedures involved automated and manual QC checks with the DEC River Management Program.

All the Phase 2 data were entered into the DMS and the Phase 1 data were updated. The Phase 1 DMS and ArcView shapefiles were updated based on the Phase 2 field assessment work during the Phase 2 QA/QC process. The DMS and the ArcView shapefiles for the Neshobe River Phase 2 study were submitted to Shannon Pytlik of the VANR for a Quality Assurance review in July of 2009.

5.0 RESULTS

5.1 Phase 2 Results

Rapid Geomorphic Assessment

During the Phase 2 assessment, ten reaches in the Neshobe River watershed in Brandon were broken into 13 segments based on detailed field observations. The existing stream types for each assessed reach/segment are included in Figure 5.1. Detailed segment summary data are provided in Appendix A.

There are a few segments where the existing stream type differs from the reference stream type or a stream type departure has taken place. A stream type departure occurs when the channel dimensions deviate so far from the reference condition that the existing stream type is no longer the reference stream type. In reach M07, a stream type departure from a reference “Cb” channel to a “B” channel has occurred. A stream type departure also occurred in the M09-B where a “B” channel was formally a “Cb” channel before the placement of berms to protect Forest Dale Road.

These stream type departures represent a significant change in floodplain access and stability. Watersheds which have lost attenuation or sediment storage areas due to human related constraints are generally more sensitive to erosion hazards, transport greater quantities of sediment and nutrients to receiving waters, and lack the sediment storage and distribution processes that create and maintain habitat (Vermont Agency of Natural Resources, 2010).

Functioning floodplains play a crucial role in providing long term stability to a river system. Natural and anthropogenic impacts may alter the equilibrium of sediment and discharge in natural stream systems and set in motion a series of morphological responses (aggradation, degradation, and widening and/or planform adjustment) as the channel tries to reestablish a dynamic equilibrium. Small to moderate changes in slope, discharge, and/or sediment supply can alter the size of transported sediment as well as the geometry of the channel; while large changes can transform reach level channel types (Ryan 2001). Human-induced practices that have contributed to stream instability within the Neshobe River watershed include:

- Forest clearing
- Channelization and bank armoring
- Removal of woody riparian vegetation
- Floodplain encroachments
- Poor road maintenance and installation of infrastructure
- Loss of wetlands

These anthropogenic practices have altered the balance between water and sediment discharges within the Neshobe River watershed. Channel morphologic responses to these practices contribute to channel adjustment that may further create unstable channels. All three adjustment processes, aggradation, widening and planform migration as a result of historic degradation within the channel are common in the Neshobe River watershed. Degradation is the term used to describe the process whereby the stream bed lowers in elevation through erosion, or scour, of bed material. Aggradation is a term used to describe the raising of the bed elevation through an accumulation of sediment. The planform of a channel is its shape as seen from the air. Planform change can be the result of a straightened course imposed on the river through different channel management activities, or a channel response to other adjustment processes such as aggradation and widening. Channel widening occurs when stream flows are contained in a channel as a result of degradation or floodplain encroachment or when sediments overwhelm the stream channel and the erosive energy is concentrated into both banks.

The existing geomorphic condition is depicted in Figure 5.2. Geomorphic condition is determined based on the degree (if any) of channel degradation, aggradation, widening and planform adjustment. Except for three reaches/segments, the assessed segments and reaches in the Neshobe River watershed in Brandon were found to be in "fair" geomorphic condition. The other three assessed reaches were in "good" geomorphic condition. Many of the reaches studied in the Neshobe River watershed are undergoing a channel evolution process in response to large scale changes in its sediment, slope, and/or discharge associated with the human influences on the watershed. Table 3 below summarizes the channel evolution of each study reach and the primary adjustment processes that are occurring.

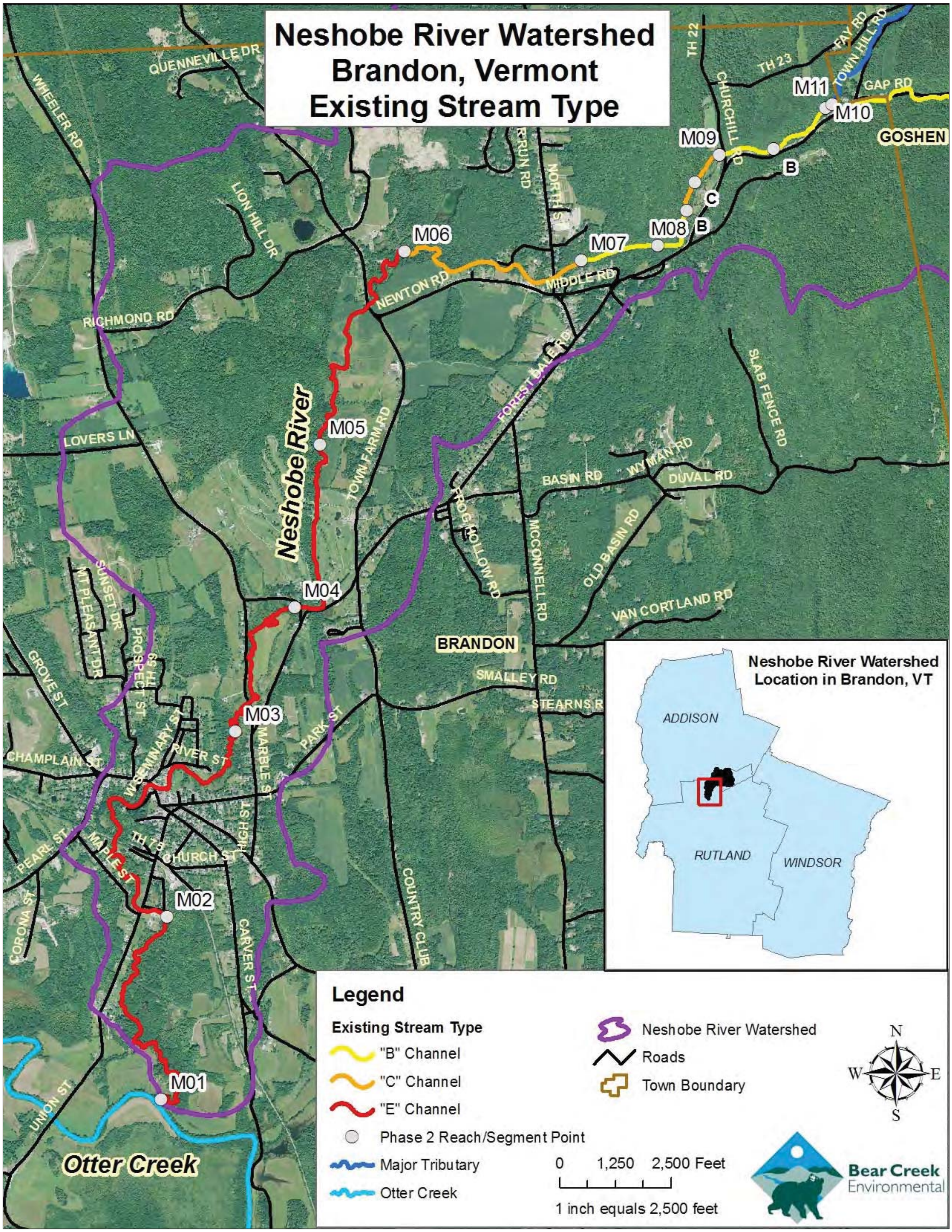

Figure 5.1 Existing stream types of the Neshobe River Watershed

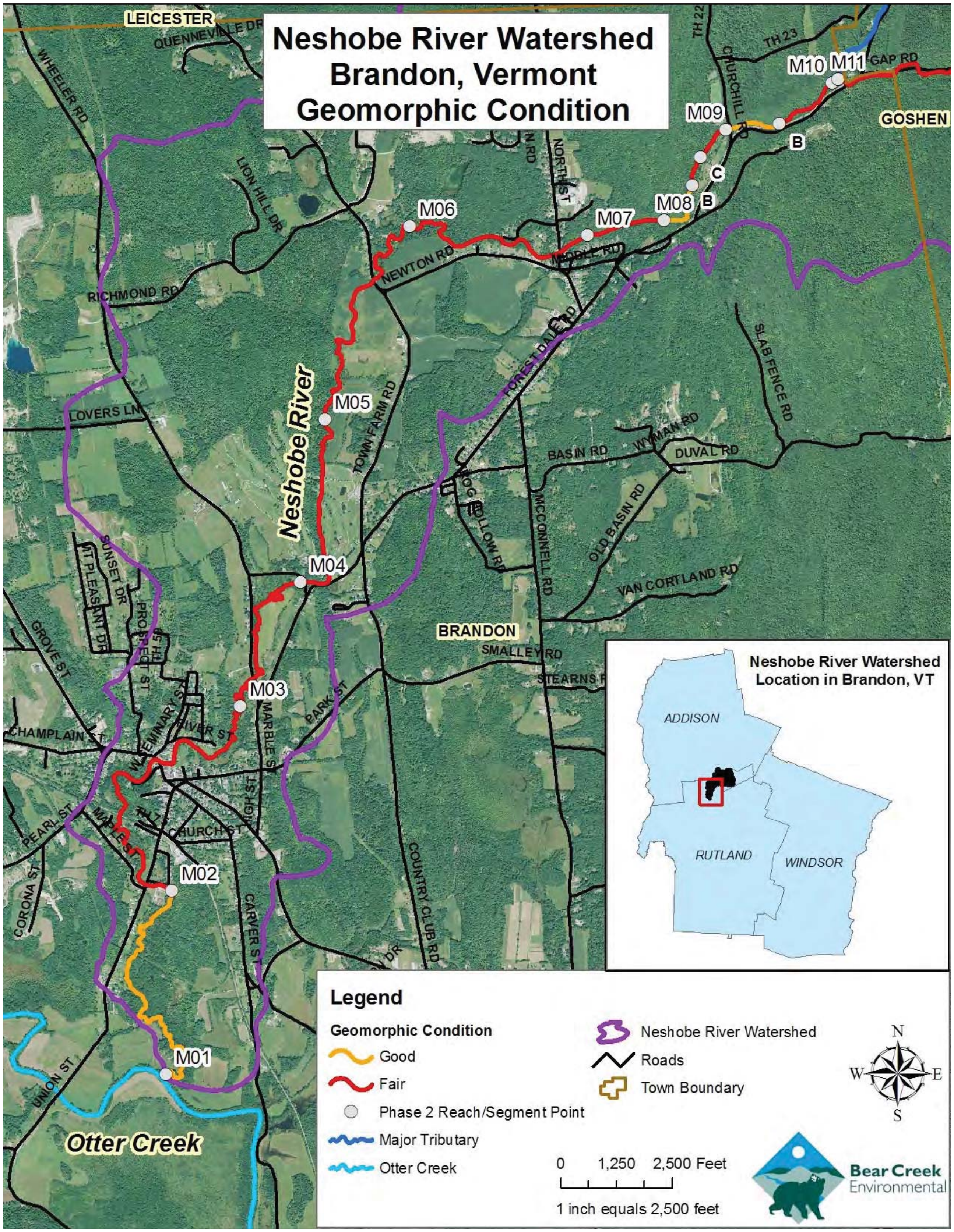

Figure 5.2. Phase 2 Geomorphic Condition of the Neshobe River Watershed

Table 3. Stream Type and Channel Evolution Stage

Segment Number	Entr. Ratio	Width to Depth Ratio	Reference Stream Type	Incision Ratio	Existing Stream Type	Channel Evolution Stage	Active Adjustment Process
Neshobe River							
M01	19.7	7.08	E5	1.00	E5	F-I	Aggradation Planform
M02	13.1	7.69	E4	1.10	E5	F-III	Aggradation Widening Planform
M03	35.4	8.33	E4	1.00	E5	F-IV	**Aggradation** Widening **Planform**
M04	10.5	8.60	E4	1.38	E5	F-III	Aggradation Widening Planform
M05	57.9	8.97	E4	1.00	E4	F-IV	**Aggradation** Widening **Planform**
M06	7.41	17.75	C4	1.00	C4	F-IV	Aggradation Widening **Planform**
M07	1.79	18.22	C3b	1.70	B3	F-II	Widening Planform
M08-A	1.46	18.31	B3	1.00	B3	F-I	Aggradation Widening Planform
M08-B	2.79	27.88	C4b	1.33	C4b	F-IV	Aggradation Widening Planform
M08-C	4.90	15.12	C4b	1.43	C4b	F-IV	Aggradation Widening Planform
M09-A	1.44	13.13	B3	1.00	B3	F-I	Aggradation Widening Planform
M09-B	1.65	23.39	C3b	1.66	B3	F-III	Aggradation **Widening** Planform
M11	2.41	13.11	B3a	1.41	B3a	F-III	Aggradation Widening Planform

Bold Black lettering – denotes adjustment process in the fair range
Black lettering (no bold) – denotes adjustment process in the good range
Blue denotes moderate incision ratio
Green denotes a stream type departure

The "F" stage channel evolution model (Vermont Agency of Natural Resources, 2009a) is helpful for explaining the channel adjustment processes underway in the Ompompanoosuc River watershed. The "F" stage channel evolution model (i.e. Schumm Channel Evolution Model) is used to understand the process that occurs when a stream degrades (incises). The common stages of the "F" channel evolution stage, as depicted in Figure 3.1 include:

- Stable (F-I) - a pre-disturbance period
- Incision (F-II) – channel degradation (head cutting)
- Widening (F-III) – bank failure
- Stabilizing (F-IV) – channel narrows through sediment build up and moves laterally building juvenile floodplain
- Stable (F-V) - gradual formation of a stable channel with access to its floodplain at a lower elevation

When stream channels are altered through straightening, it can set this evolution process into motion and cause adjustment processes to occur. The bed erosion that occurs when a meandering river is straightened in its valley is a problem that translates to other sections of the stream. Localized incision will travel upstream and into tributaries, thereby eroding sediments from otherwise stable streambeds. These bed sediments will move into and clog reaches downstream, leading to lateral scour and erosion of the stream banks. Channel evolution processes may take decades to play out. Even landowners that have maintained wooded areas along their stream and riverbanks may have experienced eroding banks as stream channel slopes adjust to match the valley slopes. It is difficult for streams to attain a new equilibrium where the placement of roads and other infrastructure has resulted in little or no valley space for the stream to access or to create a floodplain.

Channel equilibrium can be assessed by looking at the regimes of sediment transport within the watershed. The analysis of sediment regimes at the watershed scale is useful for summarizing the stressors affecting the equilibrium condition of river channels. Sediment regime mapping provides a context for understanding the sediment transport and channel evolution processes which govern changes in geometry and planform for river channels in a state of disequilibrium.

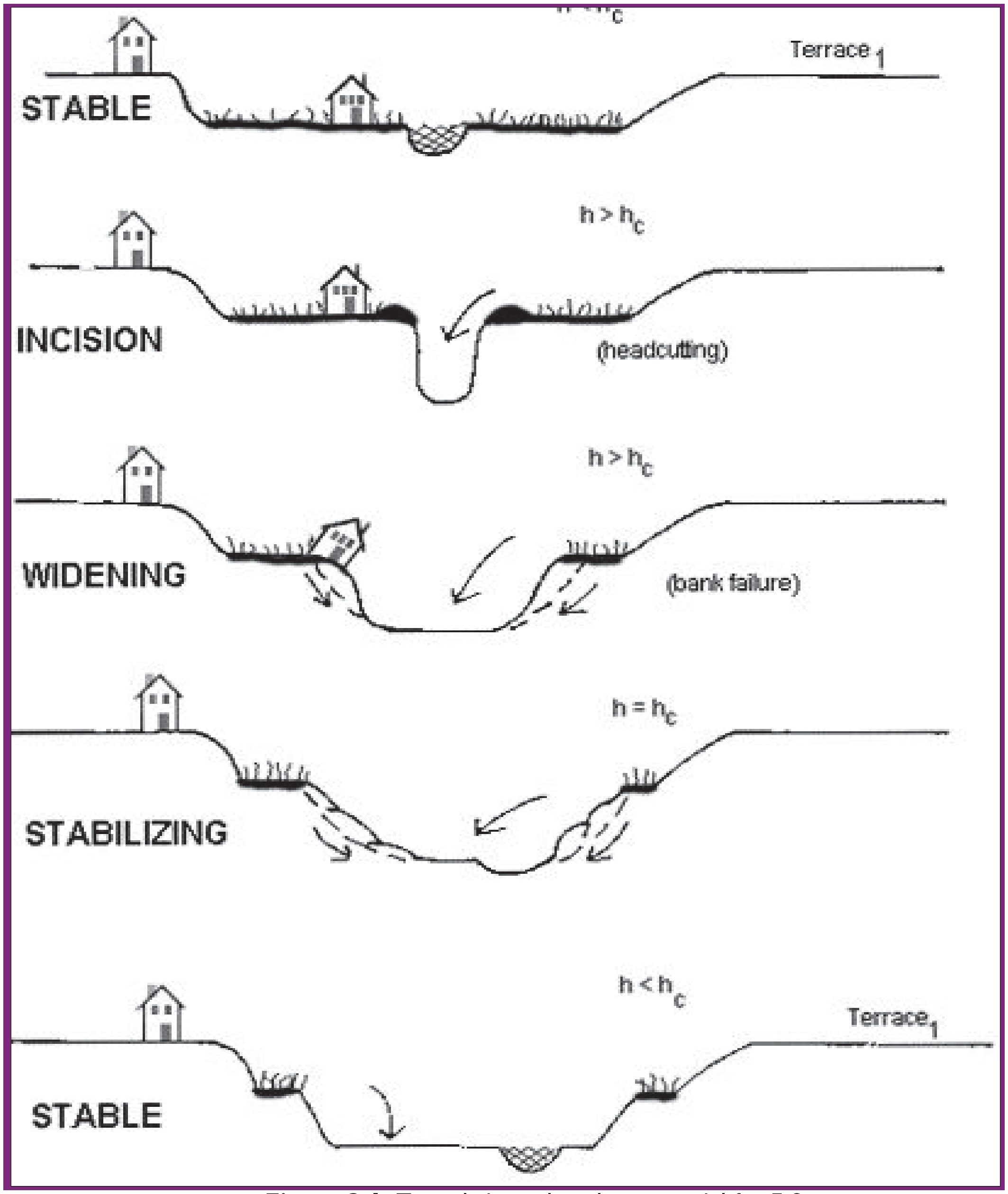

Figure 3.1. Typical channel evolution model for F-Stage
(used by permission of Mike Kline, VANR)

In terms of the VANR channel evolution model, the Neshobe River is predominately at stage III or IV of the "F-stage" channel evolution model. In about half the reaches the channel has undergone historic degradation. Many of the cross sections on Phase 2 study reaches were found to be incised, with four reaches/segments having moderate (1.4-1.7) incision ratios. Along many of the segments, the system is actively adjusting to this lower bed elevation by moving laterally and widening in order to create a new floodplain at a lower elevation. This widening and planform adjustment is leading to another adjustment process, aggradation. Both aggradation and widening are minor in most segments, scoring in the good range. Planform adjustment scored in the good range with the exception of three reaches/segments. Aggradation in the Neshobe River study area seems to be a combination of endogenous sediment that is created as the stream widens and erodes its banks to reestablish a new floodplain as well as from exogenous sources such as gravel roads and land clearing. Unvegetated mid-channel bars, point bars, side bars, and flood chutes confirm the Neshobe River is undergoing extensive lateral migration. Three reaches/segments were found to be in stage I of the "F-stage" channel evolution model, indicating the bed had not incised. Segments M08-A and M09-A have not incised historically due to the natural grade controls.

Two reaches/segments have experienced stream type departures. Both M07 and M09-B have gone from "Cb" reference stream types to "B" channels. The stream type departure in M09-B is likely due to channel alteration and the placement of berms to protect Forest Dale Road.

HABITAT EVALUATION

Table 4 below shows a comparison of the habitat condition based on the Rapid Habitat Assessment (RHA) and the geomorphic condition based on the Rapid Geomorphic Assessment (RGA). The stream condition is determined using the scores on the RGA and RHA field forms, and is defined in terms of departure from the reference condition. There are four categories to describe the condition (reference, good, fair and poor). These ratings are defined below.

- Reference – no departure
- Good – minor departure
- Fair – major departure
- Poor – severe departure

For five of the ten assessed reaches (M02-M06), both the RHA and the RGA resulted in a "fair" rating. Two segments (M08-A and M09-A) had a rating of "good" for both the RHA and the RGA. Reach M01 had a rating of "fair" for habitat but "good" for geomorphic condition, and five reaches/segments (M07, M08-B, M08-C, M09-B and M11) had a rating of "good" for habitat but "fair" for geomorphic condition. Two reaches/segments in particular (M07 and M09-B) that had been straightened or had floodplain alterations have plane bed bedforms that lack diversity in habitat features. These reaches/segments along with some others had major intrusion into their river corridor from roads or berms, and many segments had inadequate riparian buffers due to historic and/or recent land clearing. Overall, the RHA score was similar to the RGA score, implying that the ecological health of the Neshobe River is closely related to the geomorphic condition of the stream.

Table 4. Comparison of RHA and RGA for Phase 2 Reaches

Segment Number	Score RHA	Score RGA	Rating RHA	Rating RGA
M01	0.52	0.74	Fair	Good
M02	0.49	0.61	Fair	Fair

Table 4. Comparison of RHA and RGA for Phase 2 Reaches				
Segment Number	**Score RHA**	**Score RGA**	**Rating RHA**	**Rating RGA**
M03	0.51	0.60	Fair	Fair
M04	0.50	0.61	Fair	Fair
M05	0.55	0.61	Fair	Fair
M06	0.51	0.61	Fair	Fair
M07	0.77	0.63	Good	Fair
M08-A	0.83	0.76	Good	Good
M08-B	0.77	0.59	Good	Fair
M08-C	0.79	0.59	Good	Fair
M09-A	0.74	0.71	Good	Good
M09-B	0.73	0.54	Good	Fair
M11	0.69	0.54	Good	Fair

5.2 Bridge and Culvert Assessment

There are a total of 13 bridge crossings on the Neshobe River in Brandon (Figure 5.4). Eight of these stream crossings are on public roads and one in Reach M02 is at a railroad crossing. A bridge and culvert assessment using the VANR protocol was conducted of the Stone Mill Dam Road Bridge by Round River Design. The geomorphic compatibility and AOP screening tools, photographs and Phase 2 constriction notes were used to prioritize structures for replacement/retrofit. A list of resources for towns regarding funding, planning and design for replacement and retrofit of stream crossings is available on the Vermont River Management and the Vermont Department of Fish and Wildlife's web sites: http://www.vtwaterquality.org/rivers/htm/rv_EducationalResources.htm
http://www.vtfishandwildlife.com/library.cfm?libbase_=Reports_and_Documents).

Table 5 summarizes the data collected for bridges within the Phase 2 study reach. The final column of Table 5 includes a prioritization of structures for replacement or retrofit based on two criteria: structure width in relation to bankfull channel width and notes from the Phase 2 study.

One of three priorities for replacement was assigned (low, moderate or high). The following criteria explain the priority level assigned to each structure:

High Priority: Structures with spans of approximately 50 percent of the bankfull width or less, which are significantly impeding natural sediment transport.

Moderate Priority: Structures with spans less than 50 percent that are not causing significant geomorphic instability and structures with spans greater than 50 percent that are causing instability.

Low Priority: Stream crossing structures that are not included in either of the two categories above.

The spans and clearance of all the structures were re-measured by Shannon Pytlik and Ethan Swift on May 11, 2011. The Wheeler Road Bridge was noted to have undermined abutments and there is a concern that the structure may be undersized. Keith Arlund stated in a recent select board meeting on March 14, 2011 that "the town had been advised in 2009 that the cement abutments were not in good shape…" This Wheeler Street structure has been given a high priority for replacement based on the abutments being undermined and the low percent bankfull width relative to the reference channel width. Additional field work is recommended to provide a measured bankfull width to adequately design the span of the bridge for replacement.

Two bridges with a span of greater than 50 percent of the bankfull channel that are causing geomorphic instability were identified as moderate priority for replacement/retrofit. One of these bridges is located on Reach M06 at North Street has a span that is 56 percent of the bankfull channel width. The other bridge is at Churchill Road in M09-A, and has a span of 78 percent the bankfull channel width. Both bridges have scour and deposition problems that were noted in the field. Five bridges (foot path, railroad bridge, Union Street, Stone Mill Dam Road, and covered bridge at Neshobe Golf Course) were assigned a low priority for replacement due to having a span between 50 percent and100 percent of the bankfull width, and did not appear to be causing significant geomorphic instability. Five bridges on the Neshobe River in Brandon (Route 7, 2 Golf Course Bridges, Town Farm Road, and Forest Dale Road) have structure spans greater than or equal to 100 percent of the bankfull channel width and are, therefore, not recommended for replacement due to width.

Table 5
Neshobe River Watershed
Stream Crossing Summary

Reach/ Segment Number	Road Name	Structure Type	Percent Bankfull Channel Width	Phase 2 Constriction Notes	Priority for Replacement or Retrofit
M02	Route 7 (Center Street)	Bridge	149[1]	Deposition above; scour around abutments; 12 foot clearance	NR[2]
M02	Footpath	Bridge	81[1]	Scour below; 11 foot clearance	Low
M02	Railroad	Bridge	354[1]	Downstream erosion and failing riprap; beaver dam nearby; 11 foot clearance	Low
M02	Union Street	Bridge	81[1]	Low erosion both upstream and downstream; intact armoring; 7.5 foot clearance	Low

Table 5
Neshobe River Watershed
Stream Crossing Summary

Reach/ Segment Number	Road Name	Structure Type	Percent Bankfull Channel Width	Phase 2 Constriction Notes	Priority for Replacement or Retrofit
M03	Wheeler Road	Bridge	61[4]	Abutments are undermined[3]; 6.1 foot clearance	High
M04	Stone Mill Dam Road	Bridge	71[1]	Deposition above; 12 foot clearance	Low
M04	Golf Course Crossing	Bridge	97[1]	None; 7 foot clearance	NR
M04	Golf Course Crossing	Bridge	108[1]	Deposition below; 8.7 foot clearance	NR
M04	Covered Bridge at Neshobe Golf Club	Bridge	97[1]	None; 7 foot clearance	Low
M05	Town Farm Road	Bridge	221[1]	Some deposition in structure and downstream; intact armoring upstream and downstream; 12.8 foot clearance	NR
M06	North Street	Bridge	56[1]	Sediment on side of channel upstream and downstream; failing armoring upstream and intact armoring downstream; 9.7 foot clearance	Moderate
M09-A	Churchill Road	Bridge	78[1]	Deposition above; some erosion downstream; intact armoring upstream; downstream scour of footers of structure; 12 foot clearance; decking is deteriorated	Moderate
M11	Forest Dale Road	Bridge	220[1]	Alignment; 12 foot clearance	NR

[1]Percent bankfull width measured in the field during Phase 2 Assessment
[2] NR = Not recommended for replacement at this time due to geomorphic instability
[3] Field notes from May 11, 2011 taken by Ethan Swift and Shannon Pytlik
[4] Bankfull channel width measured on August 16, 2011by Mary Nealon and Shannon Pytlik

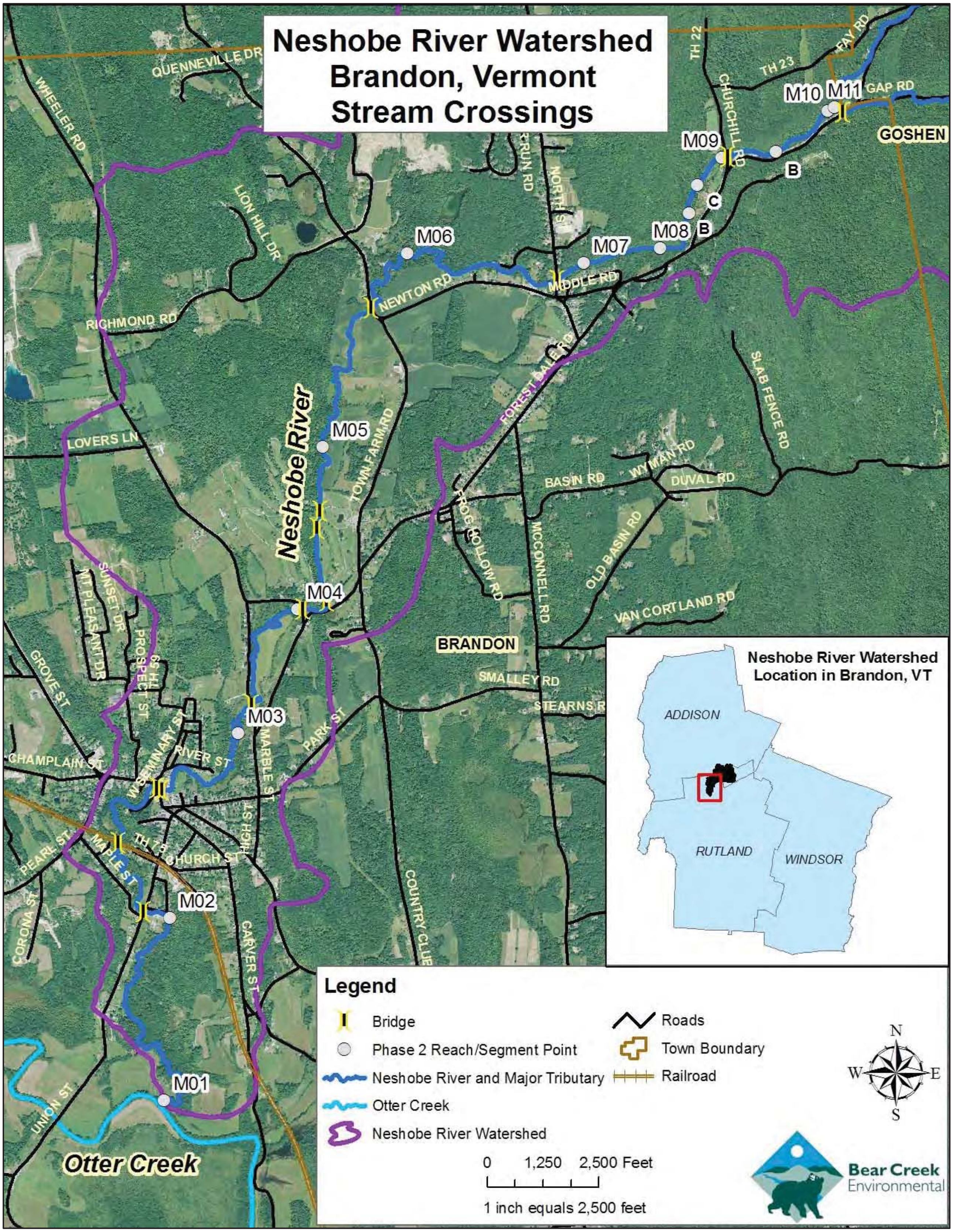

Figure 5.4. Stream Crossings within the Neshobe River Watershed

6.0 Stressor, Departure and Sensitivity Analysis

Stressor, departure and sensitivity maps are presented here as a means of displaying the effects of all significant physical processes occurring within the Neshobe River watershed that were observed during the Phase 1 and Phase 2 Stream Geomorphic Assessments. These maps also provide an indication of the degree to which the channel adjustment processes within the watershed have been altered at both the watershed scale and the reach scale. The analysis of existing and historic departures from equilibrium conditions along a stream network allows for the prediction of future alterations within the watershed. This is helpful in developing and prioritizing potential protection and restoration projects.

6.1 Stressor Identification

6.1.1 Hydrologic Regime Stressors

The hydrologic regime is the timing, volume, and duration of flow events throughout the year and over time and is characterized by the input and manipulation of water at the watershed scale. When the hydrologic regime has been significantly changed, stream channels will respond by undergoing a series of channel adjustments. The land use within the watershed plays a role in the hydrology of the receiving waters. The percentage of urban and cropland development within the watershed are factors which change a watershed's response to precipitation. The most common effects of urban and cropland development is increasing peak discharges and runoff by reducing infiltration and travel time (United States Department of Agriculture, 1986).

The dominant watershed land cover/land use within the Neshobe River watershed is forest. The impact rating for watershed land cover/land use was low (between 2% and 10% is crop and/or urban). Analysis of hydric soils located where current land uses are agricultural or urban indicates some loss of wetland attenuation (Appendix B, Page 1).

The Neshobe River watershed has a moderate network of roads as shown in Appendix B, Page 1. Extensive road networks can contribute significantly to increased flows within a river resulting both from increased runoff and stormwater ditching. According to Foreman and Alexander (1998), increased peak flows in streams may be evident at road densities of 3.2 miles/ square mile. Subwatersheds with road densities of greater than 3.2 miles/ square mile account for about 7.6 percent of the Neshobe River watershed. The highest road density within the watershed is found in subwatershed of Reach M02 (village center of Brandon), where development is denser.

6.1.2 Sediment Regime Stressors

The sediment regime is the quantity, size, transport, sorting and distribution of sediments. The sediment regime may be influenced by the proximity of sediment sources, the hydrologic regime, and the specific morphology of the valley, floodplain, and stream. The Sediment Load Indicators Map (Appendix B, Page 2) shows the distribution of sediment load indicators such as bank erosion, depositional features, channel migration features, and mass failures in the study area.

Bank erosion and mass failures contribute significant sediment inputs within the Neshobe River watershed. Bank erosion is defined as "an area of raw and barren soils where the vegetation does not have the ability to hold the soil and/or the soil has slumped or fallen into the channel". Mass failures can occur when "a perennial stream erodes into or undercuts a high erodible landform, such as glacial lacustrine terrace" (Vermont Agency of Natural Resources, 2009a). Bank erosion mapped during the Phase 2 study totals approximately 18 percent on both the east and west banks of the 10 reaches assessed in Brandon. Three mass wasting sites were mapped in Brandon during the Phase 2 assessment. The total length of mass failures on the Neshobe River Phase 2 reaches in Brandon is about 303 feet.

Depositional features per mile are mapped to show areas of deposition and planform adjustment. Steep riffles, mid-channel bars, delta bars, flood chutes, avulsions and braiding are parameters included in the depositional features' map layer. This layer does not necessarily explain the sources of sediment, but these depositional and channel bifurcation features are common in areas where the sediment transport capacity of the channel has been exceeded (Vermont Agency of Natural Resources, 2010). Channel migration features (avulsions and flood chutes) are included on the map to show areas of significant planform adjustment. Eighty percent of the Phase 2 segments assessed have a high number (greater than 5) of depositional features per mile. The most downstream reach (M01) is the only reach with a moderate (between 2 and 5) number of depositional features per mile. The reach upstream from M01 (near village center of Brandon) was the only reach with a low (less than 2) number of depositional features per mile.

The bank erosion and the prevalence of mass failures illustrate the Neshobe River is providing a source of sediment input. This is resulting in the channel being overwhelmed by sediment and exceeding the sediment transport capability as observed by the numerous depositional features per mile.

6.1.3 Channel Modifiers

Channel straightening, floodplain encroachment, and berms and roads can increase the slope of a channel resulting in increased stream power. Increases in stream power (shown in red or orange on Page 3 of Appendix B) can initiate streambed erosion resulting in incision. The most extensive areas of channel straightening and floodplain encroachment (both development and adjacent berms and roads) along the Neshobe River are in the upper portion of reach M01 and reach M02 where development is extensive. All other reaches, except for Reach M05, have been straightened to accommodate the placement of the roads. The majority of the channel straightening within the Neshobe River watershed is associated with roads that run parallel to the stream. The extensive areas with increases in stream power due to channel and floodplain alteration explain the channel adjustment that is occurring within the watershed.

Grade controls (waterfalls and ledge) and natural and manmade dams and constrictions (such bridges and culverts) constrict flows or raise the bed elevation. Backwater conditions and sediment deposition typically reduce channel slope and stream power (Vermont Agency of Natural Resources, 2010). Localized areas where slope decreases are expected in the Neshobe River watershed are shown in blue and green in Appendix B, Page 3.

6.1.4 Boundary Conditions and Riparian Modifiers

The resistance of the channel boundary materials is important for understanding the sensitivity of a channel and for predicting when a channel will undergo adjustment from stressors in the watershed. There are a number of factors that can result in decreased boundary condition. One of the most important factors is the quality of the riparian buffer. Riparian buffers provide many benefits. Some of these benefits are protecting and enhancing water quality, providing fish and wildlife habitat, providing streamside shading, and providing root structure to prevent bank erosion. Woody vegetation is essential for holding the bank soils to provide resistance to streambank erosion. There are many locations along the Neshobe River where there is little or no buffer as defined by buffers less than 25 feet in width (Appendix B, Page 4). Many of these areas are in close proximity to roads or developed areas and are not suitable for buffer plantings. Other areas are along agricultural fields that may be suitable for planting if the stream channel has not undergone historic incision. These stream reaches which lack a high quality riparian buffer are at a significantly higher risk of experiencing high rates of lateral erosion.

Parameters which are indicative of a decrease in boundary condition are shown in yellow and orange on Page 4 of Appendix B. While bank armoring may temporarily increase the boundary condition, it is indicative of where the stream power has resulted in bank erosion or widening of the channel. Extensive bank armoring may increase the stream power, resulting in downstream bank erosion. Areas where woody debris, bed substrate and plant material were removed from the channel also result in decreased boundary condition.

Important factors that result in an increase in boundary condition are included on Page 4 of Appendix B with aqua colored symbols. Natural and man-made grade controls increase the resistance of the bed to erosion. There were several locations where man-made and natural grade controls (ledge) are present in M07 and M08. The cohesiveness of the lower bank materials is another factor that was considered in evaluating boundary resistance. Cohesive bank material can increase the boundary condition. About three-quarters of the reaches/segments that were assessed for Phase 2 in Brandon had cohesive material on the lower bank.

6.2 Departure Analysis

River corridor restoration and protection projects that are successful depend on a thorough understanding of the sources, volumes, and attenuation of flood flows and sediment loads within the stream network. If increased loads are transported through the network to a sensitive reach, where conflicts with human investments are creating a management expectation, little success can be expected unless the restoration design accommodates the increased sediment load or finds a way to attenuate the loads upstream. Modifications in watershed inputs in the form of peak flows or increased sediment can result in an imbalance of stream power and sediment in the channel. Changes in the shape of the channel may also lead to disequilibrium. Large channel adjustments, such as severe erosion and excessive deposition, are a result of this imbalance, and often continue until the channel reaches a state of equilibrium. (Vermont Agency of Natural Resources, 2010)

The analysis of sediment regimes at the watershed scale is useful for summarizing the stressors affecting the equilibrium condition of river channels. Sediment regime mapping provides a context for understanding the sediment transport and channel evolution processes which govern changes in geometry and planform for river channels in a state of disequilibrium. Sediment Regime Maps have been prepared to show departure from reference conditions due to human alterations.

The reference sediment regime map (Appendix B, Page 5) shows the Phase 1 reference stream sediment conditions for each reach within the stream network. In the reference condition, streams use available floodplain access as a means to store sediment within the watershed. Ten out of the 13 reaches/segments of the Phase 2 study area in Brandon have a reference sediment regime of Coarse Equilibrium & Fine Deposition (*Equilibrium*). *Equilibrium* channels are unconfined on at least one side, and they transport and deposit sediment in equilibrium, wherein the stream power is balanced by the sediment load, sediment size, and channel boundary resistance. The remaining three reaches/segments (M08-A, M09-A, M11) have *Transport* as their reference sediment regime. *Transport* channels are steep, dominated by bedrock and boulder/cobble substrates, and are typically in confined valleys. Transport channels do not supply appreciable quantities of sediments to downstream reaches (Vermont Agency of Natural Resources, 2010). These channels have confining valleys walls with limited sediment storage capacity due to both channel slope and entrenchment (Vermont Agency of Natural Resources, 2010).

Changes in hydrology (such as development and agriculture within the riparian corridor) and sediment storage within the watershed have altered the reference sediment regime types for some reach segments. All departures were derived from the DMS according to the sediment regime criteria established by the Vermont Agency of Natural Resources (2010). Existing sediment regimes have not been established for reaches that were not assessed during the phase 2 stream geomorphic assessment. Three reaches/segments that were *Coarse Equilibrium (in=out) & Fine Deposition* or *Confined Source* by reference have been converted to *Fine Source and Transport & Coarse Deposition* sediment regimes based on the Phase 2 Stream Geomorphic Assessment data (Appendix B, Page 6). This means that most fine sediment entering the stream is transported through without being deposited as a result of channel incision and reduced floodplain access. Additionally, coarse sediment storage is increased due to increased load along with lower transport capacity. Three reaches/segments that were *Transport* by reference were converted to *Confined Source and Transport*. These channels have confining valleys walls with limited sediment storage capacity due to both channel slope and entrenchment (Vermont Agency of Natural Resources, 2010). Channel management practices such as straightening and encroachment has resulted in the change in sediment regime.

The existing sediment regime for the Neshobe River watershed includes reduced floodplain access, increased stream power, reduced boundary resistance, and lateral constraints, such as roads, at various locations throughout the stream network. Watersheds which have lost attenuation or sediment storage areas, due to human related constraints, are generally more sensitive to erosion hazards, transport greater quantities of sediment and nutrients to receiving waters, and lack the sediment storage and distribution processes that create and maintain habitat (Vermont Agency of Natural Resources, 2010).

6.3 Sensitivity Analysis

Sensitivity ratings were assigned using the River Corridor Planning Guide Management Program (Vermont Agency of Natural Resources, 2010). Stream sensitivity refers to the likelihood that a stream will respond to a watershed or local disturbance or stressor. Human activities such as: floodplain encroachment, channel straightening or armoring, changes in sediment or flow inputs, and/or disturbance of riparian vegetation may alter the natural adjustment rate of the channel. Streams that are actively adjusting through a lowering of the bed (degradation) or building up of the bed through sediment deposition (aggradation) are likely to have a heightened sensitivity (Vermont Agency of Natural Resources, 2009a). Stream sensitivity is assigned based on the existing stream type and condition. For a particular stream type, a segment in "reference" or "good" condition has a lower sensitivity than a reach in "fair" condition. The highest sensitivity is assigned for segments in "poor" condition and reaches which have undergone a stream type departure.

There are many variables that are contributing to the sensitivity of the reaches in the Neshobe River watershed. Many reaches/segments contain numerous bedrock grade controls, which decreases the stream's sensitivity to vertical adjustments. In some reaches, the lack of bedrock decrease the resistance to lateral and vertical adjustments; thereby, making the channel more sensitive. Additionally, bank vegetation and roots which hold the soil are lacking especially in areas where there is little or no buffer. Reaches that are lacking high quality riparian vegetation are more sensitive to channel adjustment.

The location and slope of a stream also affects its morphology and sensitivity. Streams that are transporting sediment through the channel are less sensitive than streams that are storing and responding to sediment. Flow regime and floodplain constrictions may be affecting the sensitivity of the Neshobe River watershed. Changes in land use and land cover that increase impervious cover, peak discharges, and/or the frequency of high flows will heighten a stream's sensitivity to change and adjustment. Confinement becomes a significant sensitivity concern when structures such as roads, railroads, and berms significantly change the confinement ratio, reduce or restrict a stream's access to floodplain, and result in higher stream power during flood stage.

Page 7 in Appendix B is a map presenting the stream sensitivity, generalized according to stream type and condition as per the VANR protocol, and current adjustments for each reach segment in the Neshobe River watershed. Many of the reaches received a sensitivity of extreme due to their stream type and condition. Reaches with a stream type of "E" in fair condition (M02, M03, M04, and M05) have an extreme sensitivity. Since M01 was found to be in good condition, its sensitivity is high. Two cobble dominated reaches/segments (M07 and M09-B) have undergone a stream type departure from a reference "Cb" channel to a "B" channel. This has resulted in a change in sensitivity from moderate to high in M07 and M09-B (Appendix B, Page 7). These stream type departures are attributed to historic incision and floodplain encroachment. Reaches with aggradation or degradation in the fair or poor range are displayed on the corridor where they were found to be actively occurring and not evaluated as historic. Aggradation in the fair or poor range is a current active process for just two reaches: M03 and M05. No reaches/segments were found to have degradation as an active process. All degradation is historic.

7.0 REACH DESCRIPTIONS

A description of each reach/segment is provided in this section along with general recommendations for restoration and protection strategies. The reaches are listed from downstream to upstream. Further details about project types for each reach will be discussed in Section 7.3.

Reach M01

Reach M01 begins at the mouth of the Neshobe and continues until just below the Union Street crossing. It is a sand dominated "E" type lowland stream with numerous oxbows within the floodplain (Figure 7.1). The dominant bedform is dune-ripple. Towards the lower end of the reach, there are abundant wetlands. The incision and width to depth ratios have remained low most likely due to the increased sediment input from upstream in the watershed. Since this reach has excellent floodplain access, it is an important sediment attenuation reach.

The west side of the river corridor is dominated by residential land use with a dominant buffer width less than 25 feet, while the east side is dominated by forest with a well vegetated buffer. The RHA resulted in a "fair" score due to the lack of favorable substrate on the bed, bank conditions and sediment deposition. The RGA was scored "good" with aggradation and planform adjustment falling in the good range. The channel evolution stage is F-I, meaning that the reach has not incised, has access to its floodplain, and is in stable condition.

Figure 7.1. Sand dominated "E" channel in Reach M01 (Round River Design, 6/24/09)

Reach M02

Reach M02 is 1.7 miles long and contains numerous grade controls including a dam (Figure 7.2), a weir, bedrock grade controls, and a waterfall. Downstream of the waterfall in downtown Brandon, the channel slope decreases and the valley opens up. The channel is slightly incised in Reach M02, but there is still adequate floodplain access except for a few locations. Reach M02 is a sand dominated "E" channel with riffle-pool as its dominant bedform. There is a berm in this reach approximately 300 feet long located just downstream of the Center Street crossing. There are four bridges that cross the Neshobe River in Reach M02 (Union Street, Route 7, Footpath, and a Railroad crossing). None of the bridges have a high priority for replacement at this time.

Approximately 30 percent of Reach M02 is influenced by road encroachment and development. The dominant buffer on both sides is greater than 100 feet, but there are areas where the buffer width is less than 25 feet. In many of the areas that lack a high quality buffer, bank erosion is resulting in widening of the stream channel. The area adjacent to the Brandon wastewater treatment facility (Figure 7.3) is an example of an area that is experiencing significant erosion and lacks woody vegetation in the buffer.

Figure 7.2. Dam and waterfall in downtown Brandon on Reach M02 (BCE, 5/7/2010)

Figure 7.3. Lack of buffer and bank erosion in the vicinity of the wastewater treatment plant (BCE, 5/7/2010)

The RHA rated in the "fair" category due mostly to bank and buffer conditions and lack of favorable substrate. Reach M02 is slightly incised and there is evidence of widening, aggradation, and planform adjustment. An RGA score of "fair" was based on historic incision, widening, aggradation, and planform change all falling within the good category. The channel evolution stage is F-III, indicating that the reach has incised and is widening, but has not yet built a juvenile floodplain.

Reach M03

Reach M03 is just under one mile in length and is also a sand dominated "E" channel. It has not incised and is in stage F-IV of the channel evolution model because of aggradation and planform adjustment in the fair range. The Neshobe River flows through a very flat and wide valley in reach M03, and significant historic channel straightening has occurred along approximately 70 percent of the channel length. Excessive sediment deposition in the reach may have prevented or reversed the incision process. Approximately 40 percent of the length of M03 is encroached upon by a road on the west side and there is also considerable development within the corridor (25 percent) (Figure 7.4). A small percentage (8 percent) of the eastern side in the upper part of the reach has a buffer less than 25 feet. There is one stream crossing within reach M03 at Wheeler Road. The Wheeler Road Bridge has been identified as a high priority for replacement due to the abutments being undermined and the concern the structure is undersized.

Both the RGA and the RHA were scored as "fair". The habitat condition is primarily a result of poor bank conditions and riparian areas. The RGA scored "fair" due in part to the excessive sediment deposition as seen through the presence of numerous mid-channel, point and side bars. Planform adjustment as evidenced by one channel avulsion and four flood chutes led to the "fair" RGA score as well.

Figure 7.4. Development within river corridor and channel straightening in Reach M03 (BCE, 5/7/2010)

Reach M04

Reach M04 begins at the Stone Mill Dam Road crossing and continues through the Neshobe Golf Club for approximately one mile. Significant historic channel straightening has occurred in Reach M04 along Forest Dale Road and the golf course (Figures 7.5 and 7.6). The stream type of Reach M04 is "E" that was gravel dominated by reference but is now sand dominated. The greens-keeper at the golf course informed Round River Design personnel that the river floods onto the golf course approximately 2 to 3 times each year. The buffer along the east bank has been radically altered due to the golf course with 50 percent of the length having a buffer less than 25 feet. Forty percent of the east bank is also armored with riprap, thereby decreasing the streambank's ability to absorb energy and causing increased stream power. The increased stream power can cause more pronounced downstream erosion.

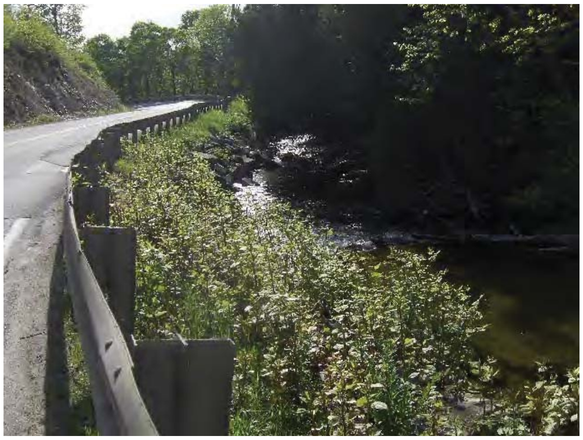

Figure 7.5. Encroachment of Forest Dale Road and channel straightening in Reach M04 (BCE, 5/7/2010)

Figure 7.6. Neshobe Golf Club within river corridor in Reach M04 (BCE, 5/7/2010)

There are three bedrock grade controls, and there is an improved path in the river corridor for approximately 40 percent of the stream length. Four bridge crossings are located within Reach M04 (Stone Hill Dam Road, Covered Bridge at Neshobe Golf Club, and two more bridges at Neshobe Golf Club). All bridges in reach M04 are either a low priority for replacement or are not recommended for replacement at this time.

The RGA and RHA both resulted in "fair" condition. The east bank and buffer conditions as well as sediment conditions contributed to the "fair" RHA condition. Historic incision (ratio of 1.38) has resulted in channel widening, aggradation and planform adjustment. Sedimentation from upstream may be keeping incision low.

Reach M05

Reach M05 is 1.2 miles long and flows through agricultural land with crop as the dominant land use on both sides of the river corridor (Figure 7.7). Gravel is the dominant substrate in this "E" channel that contains mostly riffle-pool bedforms. The dominant buffer width on both sides is 26-50 feet and approximately 30 percent of the length has a buffer width less than 25 feet in width (Figure 7.8).

Figure 7.7. Agricultural field within corridor of Neshobe River in Reach M05 (BCE, 5/7/10)

Figure 7.8. No buffer near Town Farm Road Bridge in Reach M05 (BCE, 5/7/10)

There is a mass failure approximately 150 feet long on the western bank of Reach M05 that is contributing sediment to the reach. Soft sediments underfoot and numerous depositional features including mid-channel bars, point bars, side bars, and diagonal bars indicate aggradation is occurring in this reach. Islands and flood chutes as well as historic oxbows are evidence of planform adjustment within Reach M05. Eight debris jams and one beaver dam were also present in Reach M05.

The RHA and the RGA both scored as "fair". The habitat quality was degraded due to excess sediment in the bed compromising available substrate. Bank stability, bank vegetative protection, and lack of vegetation in the river corridor also contributed to the "fair" habitat condition. Based on the Phase 2 cross section, Reach M05 did not historically incise. The "fair" RGA condition was due to slight widening and significant aggradation and planform adjustment. Sediments deposited in this reach from upstream may have prevented or reversed incision. The channel evolution stage is F-IV due to the extensive aggradation and planform adjustment.

Reach M06

Reach M06 is approximately one mile long and begins about ½ mile upstream of the Town Farm Road Bridge and continues until 700 feet upstream of the North Street Bridge. The channel has been extensively straightened and bermed (50 percent of the reach length) for development and the placement of Newton Road. It is in this reach that the stream type changes from "E" to a gravel dominated "C" channel (Figure 7.9). There is one stream crossing at North Street Bridge where the structure has caused both downstream and upstream deposition.

Figure 7.9 Gravel dominated "C" channel of Reach M06 (Round River Design, 6/17/09)

The dominant buffer width on the south side is less than 25 feet. On the north side, the dominant buffer width is 51-100 feet and subdominant is less than 25 feet. There are some agricultural fields bordering Reach M06 and recent flood waters have scoured the fields in some locations (Figure 7.10).

Figure 7.10. Drainage off of agricultural field to Reach M06 (Round River Design, 6/17/09)

Figure 7.11. Large point bar in Reach M06 (Round River Design, 6/17/09)

Channel alteration within Reach M06 has resulted in aggradation and planform adjustment, and the channel is now in stage F-IV of the channel evolution model. There has been no historic incision in this reach. Although aggradation was scored in the good category, there are many mid-channel and point bars, some of which are very large (Figure 7.11). The presence of six flood chutes supports the scoring of planform adjustment in the fair range. . Channel alteration in M06 has contributed to the low "fair" score for both the RGA and the RHA. The RHA also scored "fair" because of bank and buffer conditions, sediment deposition and substrate cover.

Reach M07

Reach M07 is 1,776 feet long and begins just upstream of the North Street Bridge. It continues through a broad valley until the channel becomes narrowly confined and the slope becomes steeper. There are two bedrock grade controls within Reach M07. On the northern side, there is a mass failure about 80 feet long contributing sediment to the reach. Approximately 40 percent of the reach by length is bermed on the south side and the entire reach has been straightened (Figure 7.12). The channel alteration has led to a chain of events including historic incision (ratio of 1.70) The channel alteration has caused a stream type departure from a reference cobble dominated "Cb" to a "B" channel in stage F-II of channel evolution.

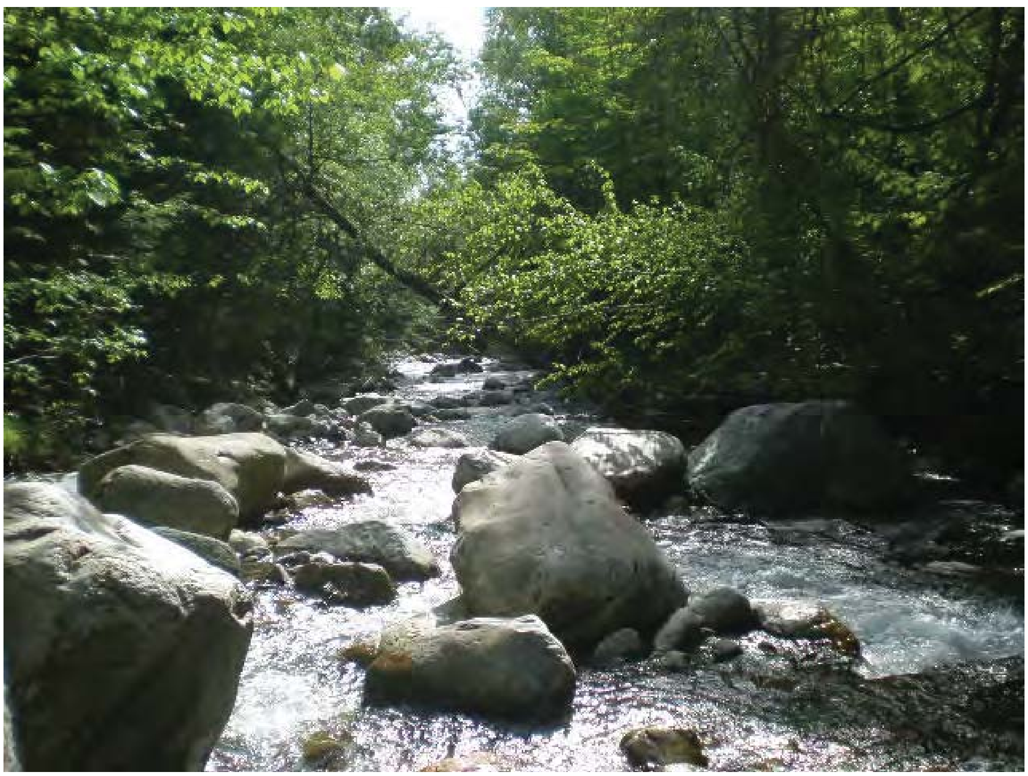

Figure 7.12. Cobble dominated straightened "B" channel of Reach M07 (Round River Design, 6/8/09)

In contrast to downstream reaches, the RHA in Reach M07 was scored as "good" due to favorable substrate and less sediment deposition. The RGA was scored as "fair" due to incision in the fair range and widening and planform adjustment in the good range.

Reach M08

Reach M08 was divided into three segments based on differences in valley widths. The downstream segment, M08-A is narrowly confined and contains many bedrock grade controls and bedrock along the banks preventing incision and widening (Figure 7.13). The bedrock along the banks is acting as a channel constriction as well. From field observations of old terraces, it appears that there was significant historic aggradation that has since been worn down to bedrock, but the channel has not incised from reference (Round River Design, 2009). The stream type is a cobble dominated "B" channel in a step-pool system. Since it has not incised, the channel is in stage F-I of the channel evolution model. The segment begins where the channel becomes narrowly confined and continues for approximately 1,300 feet until the valley opens up. A berm that begins in upper section of Reach M07, continues into Segment M08-A for 300 feet.

Figure 7.13. Bedrock on banks and grade controls in Segment M08-A (Round River Design, 6/8/09)

Dominant buffer widths are greater than 100 feet on both sides of the stream. Forest is the dominant land use within both sides of the corridor and trees are the dominant vegetation for the banks and buffers.

The RGA and the RHA were both scored as "good". The geomorphic condition is due to the stability of the channel through the presence of bedrock and lack of incision. High quality pools and a well vegetated riparian zone contributed to the "good" habitat condition in segment M08-A.

Segment M08-B begins where the valley gets wide and slope decreases again and continues for approximately 700 feet until the confluence with Hollow Brook. The segment has been straightened along the entire length (Figure 7.14), which has lead to channel incision through historic sediments that were most likely here from either post glaciation or 1800s land clearing. This historic incision has led to aggradation, widening and planform adjustment as the channel builds a new floodplain. The channel is in stage F-IV since there is a juvenile floodplain. The RGA scored in the "fair" range. The stream type is "Cb" and dominated by gravel and planebed bedform. The banks and buffers are well vegetated with trees and the riparian corridor is dominated by shrubs/saplings and forested land. The RHA scored "good" as a result of high quality pools and stable and well vegetated banks and riparian corridor.

Figure 7.14. Straightened channel in Segment M08-B with well vegetated banks and buffers (BCE, 5/7/10)

Segment M08-C begins where the valley slope decreases and valley becomes wider just upstream of the confluence with Hollow Brook. The segment continues for 869 feet until just downstream of the Churchill Road Bridge. As in the downstream segment M08-B, the river has incised through historic aggradation down to bedrock from either 1800s land clearing or post glaciation (Figure 7.15). There are bedrock grade controls present in this segment. Although the dominant bedform is planebed in this gravel dominated "Cb" channel, there are also some step-pool features (Figure 7.16). The entire length of the segment has been straightened which has led to moderate incision (ratio of 1.43) and subsequent aggradation, widening and planform adjustment as it builds a new floodplain.

Most of the segment is in stage F-IV of the channel evolution model, but the upper 200 feet is in stage F-III. Buffer widths are of low quality in segment M08-C with the dominant width less than 25 feet on the west side and 26-50 feet on the east side.

Figure 7.15. Historic aggradation on floodplain of M08-C (Round River Design, 6/8/09)

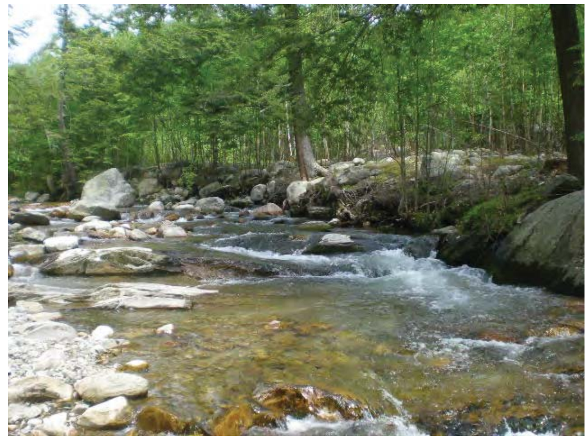

Figure 7.16. Step-pool features in Segment M08-C (Round River Design, 6/8/09)

The RHA scored "good" in Segment M08-C due to nice pools and high quality stream banks. However, the RGA scored "fair" as a result of moderate incision and subsequent aggradation, widening and planform adjustment. Five flood chutes and one island are evidence of the planform adjustment.

Reach M09

Reach M09 was divided into two segments based on valley width and channel dimensions. The downstream segment, M09-A, has a slightly narrower valley than the upstream segment, M09-B. Segment M09-A begins just upstream of the Churchill Road Bridge and continues for ¼ mile until the slope decreases and valley widens. The channel in M09-A is narrowly confined and runs along Forest Dale Road on the south side for 80 percent of its length. The channel has been entirely straightened for the placement of Forest Dale Road. Aside from the road, the river corridor is well forested and banks and buffers contain mixed trees. Bedrock grade controls and bedrock along valley walls are present. The bedrock along the valley walls is creating a channel and floodprone constriction. Another channel and floodprone constriction is being caused by the bridge at Churchill Road. Sediment deposition both upstream and downstream has resulted from the bridge. Aside from some minor sediment deposition and widening, segment M09-A is relatively healthy.

Segment M09-A has not incised most likely due to the resistant bedrock. The stream type is a cobble dominated "B" stream in a step-pool system (Figure 7.17). The channel evolution stage is F-I since there has been no degradation. Both the RHA and RGA scored "good". Pools and well vegetated banks and buffers contributed to the "good" habitat condition. The lack of incision and planform adjustment has led to the "good" geomorphic condition.

Figure 7.17. Typical channel of Segment M09-A (Round River Design, 6/8/09)

The remaining 1,600 feet in Reach M09 contains the slightly wider valley of Segment M09-B. The segment begins where the valley gets wider and continues until just downstream of the confluence with the North Branch Neshobe River. Segment M09-B is another cobble dominated "B" channel, but its main difference from Segment M09-A is that it has incised (ratio of 1.66) (Figure 7.18). There are numerous flood chutes that have been cut off by the placement of a berm that is about 280 feet long to protect the adjacent road. Forest Dale Road encroaches upon the southern corridor for approximately 80 percent of the segment's length. Without the berm and road, Segment M09-B would be a "C" channel by reference. There has been a stream type departure from a "C" to a "B" caused by the road encroachment.

Segment M09-B has a higher width to depth ratio than downstream segments/reaches. There is one bedrock grade control and five bedrock constrictions. A mass failure (70' wide x 30' high) on the northern bank is contributing sediment to the channel. The northern buffer is in great condition with a well forested buffer greater than 100 feet in width. The southern buffer is predominantly 51-100 feet wide and the subdominant width is greater than 100 feet.

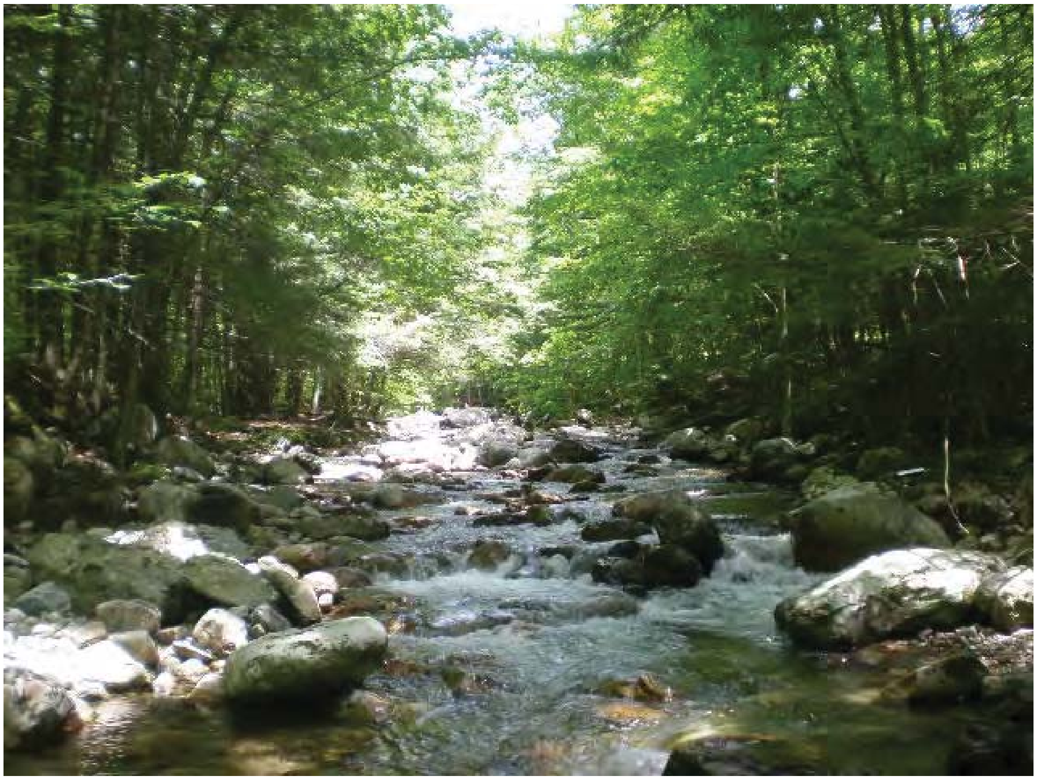

Figure 7.18. Typical channel of Segment M09-B (Round River Design, 6/8/09)

The RHA scored "good" as a result of pool variability and substrate and well vegetated banks and riparian zones. However, the RGA scored "fair" due to incision, resulting in a stream type departure and extensive widening. The channel is in stage F-III of the channel evolution model since it has gone through incision and is currently widening and undergoing planform adjustment.

Reach M11

Reach M11 begins at the confluence with the North Branch Neshobe River and continues along Gap Road for approximately 1.5 miles into the Town of Goshen. Gap Road runs parallel to the Neshobe River for approximately 75 percent of Reach M11 by length, but it is uncertain whether the road was placed in the floodplain or built into the hillside. The Neshobe River in Reach M11 flows through a semi-confined valley below a dam and there is evidence of incision most likely due to sediment retention of the dam. Reach M11 contains four stream crossings, which are all floodprone constrictions and three are channel constrictions. Only one of these crossings, on Forest Dale Road, is located within the Town of Brandon. The northern side of the Neshobe River has a dominant buffer width of less than 25 feet due to Gap Road, with the subdominant width 26-50 feet. The southern side has a buffer width greater than 100 feet with no subdominant buffer width.

The stream type in Reach M11 is a cobble dominated "Ba" with a step-pool bedform (Figure 7.19). Near bank and buffer vegetation on both sides is comprised predominantly of deciduous trees and coniferous trees are subdominant. The RHA scored "good" while the RGA scored "fair" in Reach M11. Although the riparian zone on the northern side is narrow, others factors such as bank vegetation and good pool quality contributed to the "good" habitat condition. The "fair" RGA score was mostly due to the moderate historic incision (ratio of 1.41). Aggradation, widening, and planform adjustment scored in the good range.

Figure 7.19. Step-pool "B" channel of Reach M11 along Gap Road (Round River Design, 6/5/09)

8.0 PRELIMINARY PROJECT IDENTIFICATION AND PRIORITIZATION

The departure and sensitivity analyses presented in Section 6.0 of this report provide beneficial background for selecting potential projects that will effectively help the channel return to equilibrium conditions by assessing limiting factors and by identifying underlying causes of channel instability. The stream reaches evaluated in this study present a variety of planning and management strategies which can be classified under one of the following categories: Active Geomorphic Restoration, Passive Geomorphic Restoration, and Conservation.

Active Geomorphic Restoration implies the management of rivers to a state of geomorphic equilibrium through active, physical alteration of the channel and/or floodplain. Often this approach involves the removal or reduction of human constructed constraints or the construction of meanders, floodplains or stable banks. Active riparian buffer revegetation and long-term protection of a river corridor is essential to this alternative.

Passive Geomorphic Restoration allows rivers to return to a state of geomorphic equilibrium by removing factors adversely impacting the river and subsequently using the river's own energy and watershed inputs to re-establish its meanders, floodplains and equilibrium conditions. In many cases, passive restoration projects may require varying degrees of active measures to achieve the ideal results. Active riparian buffer revegetation and long-term protection of a river corridor is also essential to this alternative.

There are a number of programs available for river restoration and protection. These programs are as follows:

- ANR River Corridor Easement Program (RCE)
- Clean and Clear (C&C)
- Conservation Reserve Enhance Program (CREP)
- Trees for Streams (TFS)
- Environmental Quality Incentives Program (EQUIP)
- Wildlife Habitat Incentives Program (WHIP)
- Wetland Reserve Program (WRP)

River Corridor Easement (RCE)

The River Corridor Easement is designed to promote the long term physical stability of the river by allowing the river to achieve a state of equilibrium (where sediment and water loads are in balance). River corridor easements are vital for a passive geomorphic restoration approach and can also be used for conserving rivers that are in good condition (equilibrium). Rivers that are in equilibrium have access to their floodplains and therefore experience less erosion and negative impacts from flooding events. Corridor easements are a high priority for reaches that are not in equilibrium; these channels are experiencing channel adjustments, which are causing conflicts with current/future land-use expectations. Providing an easement on these reaches reduces the conflict and provides a long term solution to sediment storage and flood water attenuation needs.

- Easements are in perpetuity, meaning the agreement stays with the land forever.
- A onetime payment is received by the landowner for transferal of channel management rights to a second party (a land trust).
- Transferal of channel management rights means that the landowner would no longer be able to rock line river banks or remove gravel for personal use.

- A RCE requires a minimum 50 foot buffer that floats with the river. No active land use is allowed within the buffer. The buffer can be actively planted or allowed to revegetate passively.
- The easement does not take away the agricultural land use rights, so the landowner could continue to crop or pasture the farm land mapped outside of the buffer, yet within the corridor, for as long as the river allows.

Clean and Clear

Clean and Clear is a Vermont program designed to improve water quality by addressing one or more of the following areas: stream stability, protecting against flood hazards, enhancing in-stream and riparian habitat, reducing stormwater runoff, restoring riparian wetlands, enhance the environmental and economic sustainability of agricultural lands. Funding is available for project identification, project development and project implementation. Vermont municipalities, local or regional governmental agencies, and non-profit organizations, and citizens groups are eligible to receive funding.

Conservation Reserve Enhancement Program

The USDA Farm Service administers a program called the Conservation Reserve Enhancement Program that helps agricultural producers to take farmland out of production in sensitive areas, such as river corridors. This helps to improve water quality and restore wildlife habitat.

- CREP can be either a 15 or 30 year contract to plant trees.
- 90% of the practice costs are covered with the remaining 10% either resting with the participants or could be paid by the US Partners for Fish and Wildlife. Examples of the practice costs include fencing, watering facilities, and trees. There are some costs that are capped, but generally all the practice costs can be paid through the program.
- To provide additional incentives to enroll in CREP, the program offers upfront and annual rental payments for the land where agricultural production is lost during the contract period.

Trees for Streams

Programs offered by the US Fish and Wildlife Service to work with local partners and landowners to restore native streamside vegetation along river banks.

Environmental Quality Incentives Program

EQUIP is a voluntary program available through the Natural Resources Conservation Service (NRCS) that provides financial and technical assistance to implement conservation practices to meet local environmental regulations. Owners of land in agricultural or forest production are eligible for the program. Contracts with landowners can be up to ten years in length.

Wildlife Habitat Incentives Program

WHIP is a voluntary program offered to landowners to improve wildlife habitat on their land. Owners of agricultural land, nonindustrial private forest land, and Native American land are eligible. Technical assistance and up to 75 percent cost-share is available to improve fish and wildlife habitat.

Wetland Reserve Program

WRP is a voluntary program offered by NRCS to landowners to protect, restore and enhance wetlands on their property. NRCS provides technical assistance and financial support for projects that establish long-term conservation and wildlife practices and protection.

8.1Watershed-Level Opportunities

Fluvial Erosion Hazard Zones

Of all types of natural hazards experienced in Vermont, flash flooding represents the most frequent disaster mode and has resulted in by far the greatest magnitude of damage suffered by private property and public infrastructure. While inundation-related flood loss is a significant component of flood disasters, the predominant mode of damage is associated with the dynamic, and oftentimes catastrophic, physical adjustment of stream channel dimensions and location during storm events due to bed and bank erosion, debris and ice jams, structural failures, flow diversion, or flow modification by man-made structures. These channel adjustments and their devastating consequences have frequently been documented wherein such adjustments are related to historic channel management activities, floodplain encroachments, adjacent land use practices and/or changes to watershed hydrology associated with land use and drainage.

The purpose of defining Fluvial Erosion Hazard (FEH) Zones is to prevent increases in man-made conflicts that can result from development in identified fluvial erosion hazard areas; minimize property loss and damage due to fluvial erosion; and prohibit land uses and development in fluvial erosion hazard areas that pose a danger to health and safety.
The basis of a Fluvial Erosion Hazard Zone is a defined river corridor which includes the course of a river and its adjacent lands. The width of the corridor is defined by the lateral extent of the river meanders, called the meander belt width, which is governed by valley landforms, surficial geology, and the length and slope requirements of the river channel. The width of the corridor is also governed by the stream type and sensitivity of the stream. River corridors, as defined by the Vermont Agency of Natural Resources (2008), are intended to provide landowners, land use planners, and river managers with a meander belt width which would accommodate the meanders and slope of a balanced or equilibrium channel, which when achieved, would serve to maximize channel stability and minimize fluvial erosion hazards. Information collected during the Phase 2 Assessment including reach sensitivity, reach condition, and stream type is used to develop these zones.

FEH zones have been developed by Shannon Pytlik of the Vermont River Management Program for the Neshobe River. A FEH zoning analysis has been completed by BCE and is included in Appendix C. Appendix C includes: 1) a complete summary of the methods used to develop FEH zones, 2) a summary table comparing the stream channel sensitivity assigned to each corridor with the degree of protection afforded by wetlands and conserved lands within the corridor, and 3) maps depicting the FEH corridors, sensitivity ratings, and other aspects related to corridor protection. The FEH zoning analysis is intended to provide information to local officials and the Brandon community about how different river corridor protection strategies compare in terms of hazard mitigation, water quality protection and land use. At the reach scale, land cover (conserved lands, wetlands) and town zoning districts (residential, commercial, industrial) are summarized to understand corridor assets and liabilities.

STORMWATER

Stormwater runoff rates are of particular concern in urbanized and agricultural watersheds because stormwater runs off from impervious surfaces rather than naturally infiltrating the soil. The cumulative effect of the increased frequency, volume, and rate of stormwater runoff results in increases in wash-off pollutant loading to streams and destabilization of stream channels. Improved stormwater management within the Neshobe River watershed is recommended to minimize the effects of stormwater.

8.2 Site Level Opportunities

Site specific projects were identified using the criteria outlined by the VANR in Chapter 6 – Preliminary Identification and Prioritization (Vermont Agency of Natural Resources 2010). This planning guide is intended to aid in the development of projects that protect and restore river equilibrium. Table 6, located at the end of Section 7, provides information for each project, including the project strategy, technical feasibility, priority and general cost. Maps of the potential projects sites are included in Appendix D. A total of 13 projects were identified to promote the restoration or protection of channel stability and aquatic habitat in the Neshobe River watershed. The projects are broken down by category and are described below. These projects include: 5 passive restoration (river corridor and wetland protection, streamside and buffer plantings); 7 active restoration (three analyses for berm removal projects, two mass failure remediation projects, a bridge replacement, and one dam removal project); and an alternatives analysis to evaluate options for channel and/or floodplain management in the vicinity of the Brandon WWTF.

Potential Project #1 – Protect the River Corridor and Significant Wetlands in Reach M01. This lower reach on the Neshobe River has excellent floodplain access and is an important sediment and flood attenuation asset (Figure 7.20). There is a significant wetland within and to the east of the river corridor. There are four riparian landowners that have parcels of 15 acres or greater. The project strategy is to work with the three landowners to protect the river corridor and significant wetlands using conservation easements, CREP, and/or the WRP.

Potential Project #2 – Alternatives Analysis near Wastewater Treatment Facility (WWTF) Within Reach M02. The stream bank along the Neshobe River at the WWTF off of Union Street is actively eroding and lacks vegetation. The property is owned by the Town of Brandon. The channel is currently locked in place in this location with the Union Street Bridge at the upper end of the site, Barlow Avenue to the north, and the WWTF and access drive to the south. In addition, residential lots along Barlow Avenue and an access drive to the east of the WWTF on property owned by OMYA may pose additional lateral constraints. During late 2010, the Town of Brandon moved forward with the temporary action of armoring the streambank to protect the WWTF power pole. An alternatives analysis is recommended for this area adjacent to the WWTF to consider possibilities for channel and/or floodplain management in this area. The project could range from a community planting project to providing ways for the river to have additional space to migrate.

Figure 7.20. Newly riprapped section of Neshobe River adjacent to WWTF (Photo by Ethan Swift)

Potential Project #3 – Dam Removal in Reach M02. According to the Brandon Town Plan (adopted 5/18/09), the Brandon dam (Figure 7.21) is publicly owned, but is no longer serves a commercial use. An alternatives analysis is recommended to assess options for removing the dam to possibly improve aquatic organism passage and/or sediment continuity.

There are two dams near Center Street that are included in the statewide GIS layer for dams. There is information available from the Vermont Dam Safety Section for the upper dam; however, the lower dam no longer appears to exist. The upper dam is a timber and stone masonry structure founded on ledge. The remains of a sloping plank facing are visible on the upstream side. A masonry and concrete intake structure is located at the left end. The pond is mostly silted in and has little effective storage.

Figure 7.21. Dam on Neshobe River in downtown Brandon (BCE, 5/25/2011)

Based on an inspection report completed by Robert Finucane, P.E., Assistant Dam Safety Engineer with the VANR in 1996, the upper dam is in poor condition and continues to disintegrate under normal water conditions. Additional sections of the timber crest reinforcement have failed and been washed downstream since the inspection of 1982. "The spill way crest has lost stones. The penstock pipe was displaced from the sluiceway four to five years ago, according to local observers. Some of the sluiceway stonework has collapsed. Large areas of the plank upstream structure which were still in place in 1982 are now missing. It should be noted that a major failure of the dam could occur under ice jam or high water conditions. The dam is in a weakened condition and is vulnerable to further failure and higher failure rate. "

According to Steve Bushman in the Vermont Dam Safety Program, the dam is due for a more current safety inspection, tentatively planned for 2011. Current dam safety information will be useful for considering different alternatives for dam removal. While the dam currently does not serve a purpose, removal would be a challenge given the close proximity of development and possible channel adjustments upstream that could steepen the slope. In the absence of intervention, the upper dam may eventually fail.

On the downstream side of Route 7, there appears to be remnants of an aqueduct or mill apparatus. A berm was mapped during the Phase 2 assessment from about 150 feet to about 450 feet below Route 7, which may have been formally associated with the lower dam. As part of the alternatives analysis for the removal of the upper dam, removal of the formal mill remnants below Route 7 should be considered.

Potential Project #4- Replace the Wheeler Street Bridge. The Town of Brandon has received a structures' grant to replace the Wheeler Street Bridge. The cement abutments are being undermined and are in poor condition. Ethan Swift has suggested that the size of the bridge be increased, as the current size may be contributing to flooding issues (Minutes from March 14, 2011 Brandon Select board Meeting). It is recommended that one or two additional cross sections be measured within Reach M03 to provide additional information for the design of the new bridge. The replacement bridge should be designed to meet the following requirements of the Stream Alteration General Permit in terms of structure span and alignment:

1. Scour protection of erosion treatments do not reduce the channel cross section;
2. There is no channel realignment;
3. There is no roadway realignment;
4. The replacement structure provides a span length 1.2 times the bankfull width or greater.

Potential Project #5- Protect River Corridor and Significant Wetlands, Buffer Restoration in Reach M03. Reach M03 offer opportunities for river corridor protection in the form of river corridor easements and/or CREP. A significant wetland is adjacent to Forest Dale Road that may warrant additional protection in the form of an easement. There is one large parcel (>15 acres) that includes about one-half mile of riverfront property on both sides of the channel. Smaller parcels could be added to the project development within this section, following the buy-in of the larger parcel owners. There is good floodplain access, which makes this area important for flood and sediment attenuation and appropriate for stream side plantings. Buffer plantings are recommended along the field of the upper parcel that is bounded by Forest Dale Road, Stone Mill Dam Road, and Wheeler Road. The landowner who owns the large parcel on the east side of the river may be eligible for CREP.

Potential Project #6- Remediate Mass Failure in Reach M03. A mass failure located on the west bank adjacent to Wheeler Road is contributing sediment to the Neshobe River and is undermining Wheeler Road (Figures 7.22 and 7.23). A project to divert the flow away from the mass failure or improve the stability of the mass failure is recommended.

Figure 7.22. George Springston (Vermont Geological Survey) and Keith Arlund (Brandon Town Manger) examine the mass failure on Wheeler Rd (BCE, 5/25/2011)

Figure 7.23. Mass Failure (unstable valley wall of the Neshobe River) located adjacent to Wheeler Rd (BCE, 5/25/2011)

Potential Project #7 – Riparian Buffer Improvements in Neshobe Golf Club in Reach M04. The buffer along the east bank of the Neshobe Golf Club property has been significantly disturbed (Figure 7.24). Buffer restoration is recommended for this stretch of river, recognizing there will be land use constraints.

Figure 7.24. Lack of buffer along Neshobe River at Neshobe Golf Club (BCE, 5/7/10)

Potential Project #8 – River Corridor and Wetland Protection and Streamside Plantings in M04 through M06. Reaches M04, M05 and M06 offer a myriad of river restoration and protection opportunities with all riparian properties being at least 15 acres in size. There is also a significant wetland that is at the top of Reach M05 and at the bottom of Reach M06 that warrants consideration for additional protection beyond federal and state regulations. There are a number of farms in this stretch of the river along Town Farm Road that may qualify for CREP. Corridor easements are an additional option for corridor protection. Riparian buffers are lacking along much of Reach M05 on both sides (Figure 7.25). Phase 2 data indicates this reach is not incised. For this reason, buffer plantings within this reach are a high priority. There are some agricultural fields bordering Reach M06 and recent flood waters have scoured the fields in some locations causing sediment from farm fields to enter the channel (Figure 7.26). It is recommended that an analysis for reducing farm runoff to Reach M06 be conducted. CREP is one possible program that could be used to increase buffer widths to reduce runoff and sedimentation along Newton Road.

Figure 7.25. Lack of buffer along agricultural fields in Reach M05 (BCE, 5/7/10)

Figure 7.26. Drainage off of agricultural field to Reach M06 (Round River Design, 6/17/09)

Potential Project #9- Remediate Mass Failure in Reach M05. A mass failure located upstream of Town Farm Road is threatening water quality and the town water main by contributing excessive sediment to the Neshobe River. An alternatives analysis is recommended to evaluate options for remediating the mass failure. The Act 250 guidance contains a slope stability assessment that could be used to determine where the stable slope would end up and how that related to existing encroachments. Possible options for the site that has been suggested by Shannon Pytlik include:

1. Conserving the belt width on the opposite side and trying to deflect the flow away from the bank; and

2. Buying out the landowner and moving the road.

Potential Project #10 – Alternatives analysis for berm removal in Reach M06. There is a berm approximately 2,400 feet long in Reach M06. There are potential threats to infrastructure (e.g. houses along Newton Road), if the berm were to be removed. Additional surveys and alternative analyses are recommended to determine the viability and success associated with this potential project.

Potential Project #11 - Alternatives analysis for berm removal in Reach/Segments M07 and M08-A. A berm approximately 1,100 feet long is located in upper M07 and lower M08-A. As in Project #9, an analysis to research the alternatives to the berm should be conducted.

Potential Project #12 – River Corridor Protection and Streamside Plantings (upper end) of M08. The river corridor in M08 is made up of only two parcels. Much of M08 has high quality buffers; however, Phase 2 notes suggest there are narrow buffers near the upper end of the reach (southwest of Churchill Road).

Potential Project #13 - Alternatives analysis for berm removal in Segment M09-B. A berm approximately 280 feet in length is located in Segment M09-B to protect Forest Dale Road from flooding. As in other berms within the watershed, an analysis to research the alternatives to the berm should be conducted.

Table 6. Neshobe River Watershed
Site Level Opportunities for Restoration and Protection
Brandon, Vermont

Project # Segment	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#1 From confluence with Otter Creek to just downstream of Union Street M01	Passive Restoration	Great floodplain access on downstream end. Significant wetland within and to the east of river corridor. Four landowners with parcels 15 acres or greater. This reach is an important attenuation asset.	Protect river corridor and wetlands through easements , FEH zoning and/or CREP; no new structures in corridor or wetland	High priority	Conserve sediment and flood attenuation of wetlands	Cost of easement	The lower Neshobe is dominated by wetland and floodplain land features. Currently the area is of marginal use and is largely undevelopable. Historical and current land use is marginal agriculture land for pasture and row cropping.	VANR, RNRCD, Town of Brandon, landowners , CREP, land trust, WRP
#2 Wastewater Treatment Plant off of Union Street M02	Passive or Active Restoration	Unstable streambank actively eroding at the wastewater treatment plant. The Union Street Bridge, Barlow Avenue to the North, and the WWTF and access drive to the south are current lateral constraints for the river. Residential lots to the north of the WWTF along Barlow Ave. and an access road on land owned by Imerys Pigment Inc may pose additional lateral constraints.	Conduct an alternatives analysis to consider options for channel and/or floodplain management in vicinity of WWTF. Project could range from a community project to providing additional room for the river to migrate.	High priority; Existing lateral constraints may limit possible project opportunities.	Improved water quality and habitat within reach. High profile project since owned by Town and visible from Union Street. Opportunity for community involvement in project.	Cost depends on project selected	The Town of Brandon has moved forward with the temporary action of armoring the streambank to protect the WWTF power pole.	VANR, RNRCD, Town of Brandon,

Table 6. Neshobe River Watershed
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#3 Neshobe River Dam M02	Active Restoration	A dam with a waterfall directly downstream is located in the Village of Brandon.	Remove upper dam and associated channel constrictions. Consider removal of mill apparatus/berms in vicinity of former lower dam.	Moderate priority; the upper dam is close to development, which would make dam removal a challenge.	Improved habitat and geomorphic stability and Aquatic Organism Passage (AOP).	High cost of removal	The dam is in poor condition, and is vulnerable to further deterioration. There is a high degree of encroachments upstream of the dam that needs to be considered if the dam were to be removed.	Town of Brandon, VANR, RNRCD
#4 Replace Wheeler Street Bridge M03	Active Restoration	The abutments are in poor condition and the span is less than the reference bankfull channel width; additional cross sections measurements are recommended to confirm the actual bankfull channel width to determine an adequate span for the replacement structure.	Design structure based on the guidelines set forth in the Stream Alteration General Permit	High priority	Improved localized geomorphic stability and structural integrity	Brandon has received a structure's grant		Town of Brandon
#5 From upstream of Marble street to just downstream of Stone Mill Dam Road crossing M03	Passive Restoration	Upper end of reach M02 and lower end of reach M03 have good floodplain access. Significant wetland next to Forest Dale Road. One large parcel (>15 acres) with riverfront property on both sides of channel. Lack of adequate buffer in upper M03 along farm fields.	Protect river corridor and wetlands through easements, FEH zoning and/or CREP. Buffer plantings along field in upper parcel possibly through CREP program.	High priority	Conserve sediment and flood attenuation of wetlands; Improved habitat and water quality	Cost of easement and plantings		VANR, RNRCD, Town of Brandon, landowners, CREP, land trust

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#6 Remediate Mass Failure adjacent to Wheeler Road M03	Active Restoration	A mass failure on the west bank of the Neshobe River adjacent to Wheeler Road is contributing sediment	Remediate mass failure by improving slope and vegetation and/or diverting flow away from the bank	High priority; mass failure is undermining Wheeler Road	Improved habitat and water quality	High cost of instream work and possibly removal and transport of material from site		Town of Brandon, VANR
#7 Neshobe Golf Club M04	Passive Restoration	Buffer along east bank at Neshobe Golf Club is disturbed and is commonly <25 feet wide.	Restore buffer by planting on stream bank and in buffer taking land use constraints of golf course into account.	Moderate priority	Improved habitat and water quality	Cost of plantings		VANR, RNRCD, Town of Brandon, Neshobe Golf Club
#8 Farm fields off of Town Farm Road and Newton Road and wetland north of Newton Road M04 and M06	Passive Restoration	Areas in need of buffer improvement in upper M04 and throughout much of M05. Many farms along river with lack of buffer. Significant wetland in upper M05 and lower M06 that should be protected beyond federal and state regulations. Agricultural fields bordering stream get scoured by flood waters and then sediment and farm runoff enters the stream from the field.	Protect river corridor and wetland through easement, FEH zoning and/or CREP. Streamside plantings along farm fields as part of possible CREP project. No new structures in corridor or wetland; Agricultural to forested. Conduct analysis to evaluate solutions for reducing farm runoff from agricultural field adjacent to stream. Consider improved buffer strips to reduce sedimentation.	High priority	Conserve sediment and flood attenuation of wetland; Improved habitat and water quality	Cost of corridor easement or CREP and for mitigation of farm field erosion		VANR, RNRCD, Town of Brandon, landowners, CREP, land trust
#9 Mass failure upstream of Town Farm Road M05	Active Restoration	A mass failure located upstream of the Town Farm Road is contributing sediment and is threatening water quality and the town water main	Remediate mass failure by improving slope and vegetation and/or diverting flow away from the bank; consider conserving the belt width on the opposite side or buying out the landowner and moving the road.	Moderate priority	Improve water quality and habitat and reduce threat to water main	High cost		Town of Brandon, ANR

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#10 Between stream channel and Newton Road behind development M06	Active Restoration	A 2,400 foot berm is located along Newton Street behind development to protect area from flooding.	Evaluate different alternatives to improve floodplain access through berm removal.	Moderate priority; the berm is likely protecting development and land use constraints may limit removal.	Improved habitat and geomorphic stability	Cost of analysis and possible berm removal		Town of Brandon, VANR, RNRCD
#11 Approximately 1,600 feet upstream of North Street crossing M07 and M08-A	Active Restoration	A 1,100 foot berm is located along stream within forested area.	Evaluate different alternatives to improve floodplain access through berm removal.	Moderate priority	Improved habitat and geomorphic stability	Cost of analysis and possible berm removal		Town of Brandon, VANR, RNRCD
#12 Southwest of Churchill Road crossing M08	Passive Restoration	Upper end of reach M08 has narrow buffers. The lower to mid portion of M08 is forested along the stream channel. The river corridor is comprised of only two parcels.	Protect river corridor through easements, FEH zoning, and/or CREP. Buffer plantings along field in upper part. No new structures in corridor or wetland of reach.	Moderate priority; reach is not a targeted attenuation asset.	Sediment and flood attenuation; improved habitat and water quality	Cost of easement and plantings		VANR, RNRCD, Town of Brandon, landowners, CREP, land trust
#13 Along Forest Dale Road M09-B	Active Restoration	A 280 foot berm is located along stream to protect Forest Dale Road from flooding.	Evaluate different alternatives to improve floodplain access through berm removal.	Low priority; berm is short and there is very little room between road and berm for additional floodplain access.	Improved habitat and geomorphic stability	Cost of analysis and possible berm removal		Town of Brandon, VANR, RNRCD

8.3 Next Steps

There are many opportunities to restore the Neshobe River to a stable condition. Types of reach level and site level projects that have been identified in this plan include river corridor and wetland protection, streamside plantings, evaluating berm removal, and farm field runoff. On the watershed level, the development and implementation of fluvial erosion hazard zones is recommended to avoid conflicts regarding land use and to save money spent on flood damage and river maintenance. The Town of Brandon could pursue the opportunity to work with the RNRCD and the Vermont River Management Program to adopt fluvial erosion hazard zoning for the land surrounding the Neshobe River watershed in Brandon. This zoning could be included in the pre-disaster mitigation plan (PDM), the Town Plan and/or a zoning ordinance. The following are recommendations for next steps:

1. Outreach to private landowners and the public about the plan and potential restoration and protection opportunities to be completed by the State, Rutland County Regional Planning Commission, and/or RNRCD.
2. Town, State, and RNRCD representatives meet to discuss the various restoration and protection opportunities and set priorities for action.
3. Meetings to be held with additional partners (Rutland Natural Resources Conservation District, Department of Agriculture, Natural Resources Conservation Service, Vermont Agency of Transportation, etc.) to discuss implementation of priority projects.
4. Summary and prioritization of potential projects.
5. Implementation of priority projects with project partners and landowners.

For additional information about fluvial erosion hazard (FEH) zones or project development, please contact the RNRCD or the Vermont River Management Program:

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