Bear Creek Environmental

West Branch of the Ompompanoosuc River
River Corridor Management Plan
Strafford, Vermont

October 30, 2006

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Executive Summary

The West Branch of the Ompompanoosuc River (West Branch) in Strafford defines the town's landscape. A multitude of resources have been spent on protecting property adjacent to the river and restoring the natural characteristics of the river. This River Corridor Management Plan makes recommendations to restore stable channel conditions by providing a structure for identifying and prioritizing river restoration and corridor protection project opportunities and for developing effective approaches. An overriding objective is to reduce the need for maintenance of traditional channel management applications along the West Branch, and shift the focus of management projects from short term control to long term equilibrium and stability. This plan is meant to be used as part of the local planning process and may be incorporated into Strafford's town plan. Annual review of this plan is suggested to identify where progress has been made and to pinpoint areas in need of improvement.

The major goals for the West Branch of the Ompompanoosuc River Corridor Management Plan are to: improve the riverine recreational opportunities; improve public access to the river; improve aquatic habitat; reduce flood and erosion hazard; and restore riparian corridor functions.

Beginning in 2004, fluvial geomorphic assessments of the West Branch, using Vermont Department of Environmental Conservation (VDEC) protocols, were conducted by the Strafford Conservation Commission (SCC) and Bear Creek Environmental (BCE). These assessments studied the condition of the river, and made predictions about how the West Branch will continue to evolve. The results provided by the assessments are useful in determining management strategies that will help people make good decisions about land use within the river corridor.

These assessments showed that the West Branch of the Ompompanoosuc is undergoing active adjustment processes. On the majority of the West Branch, historic incision has lowered the elevation of the river bed leaving the floodplain inaccessible. As a result, high flows that would normally access the floodplain are contained within the channel; thereby causing extensive bank erosion, channel widening, lateral migration, loss of aquatic habitat, and general channel instability. The traditional approach of attempting to control erosion employs bank armoring (rip-rap), which is common on the West Branch, but has lead to further instability in the system. Also, there are many encroachments upon the river corridor in the form of residential and commercial development, as well as roads. The result is a decreased amount of area that is capable of reestablishing equilibrium through lateral channel migration and the creation of a lower floodplain. It is important to protect the few areas that still have the space for the river to move; otherwise, management of the river will become increasingly difficult and expensive.

This report considers the stage of channel evolution, sensitivity, condition, and major adjustment process for each section, or reach, of the West Branch in order to determine management strategies. The results are management approaches that are appropriate for each section rather than a uniform plan for the entire river. The four major project types identified for the West Branch of the Ompompanoosuc River are:

- conservation reaches,
- high recovery reaches,
- moderately unstable reaches, and
- highly unstable reaches.

The project types help to define restoration strategies which range from a do-nothing approach to actively attempting to restore in-channel equilibrium.

In addition to identifying restoration strategies, this plan provides recommendations for defining a Fluvial Erosion Hazard zone to further assist the Town of Strafford with managing and restoring the West Branch of the Ompompanoosuc River watershed. The purpose of defining these zones is minimize property loss and damage due to fluvial erosion; prohibit land uses and development in fluvial erosion hazards areas that pose a danger to health and safety; and discourage the acquisition of property that is unsuited for the intended purposes due to fluvial erosion hazards.

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1.0 PROJECT OVERVIEW

Bear Creek Environmental (BCE) was retained by the Strafford Conservation Commission (SCC) to write a corridor management plan for the area of the West Branch of the Ompompanoosuc River (West Branch), which flows through the Town of Strafford, Vermont. The project has been funded through a grant by the Upper Valley Community Foundation. Data and information for the West Branch Watershed within the Town of Strafford was obtained from the Vermont Department of Environmental Conservation (VDEC), the Vermont Center for Geographic Information (VCGI 2003), and the SCC. Phase 1 and 2 Stream Geomorphic Assessments conducted under the direction of the SCC (Nealon and Blazewicz 2004; Blazewicz and Nealon 2006) were used as the basis for developing the river corridor management plan. A glossary of stream geomorphic assessment terms is included in the appendix of this report to assist the reader. These definitions, which were adopted by Fischenich (2000), are from Appendix Q of the Vermont Agency of Natural Resources' Stream Geomorphic Handbook (2004).

This River Corridor Management Plan provides recommendations to restore stable channel conditions by providing a structure for identifying and prioritizing river restoration and corridor protection project opportunities and developing effective approaches. An overriding objective is to reduce the need for maintenance of traditional channel management applications along the West Branch, and shift the focus of management projects from short term control to long term equilibrium and stability. This plan is meant to be used as part of the local planning process and may be incorporated into Strafford's town plan. Annual review of this plan is suggested to identify where progress has been made and to pinpoint areas in need of improvement.

While this document is specific for the Strafford community, it is also important to note that the VDEC is currently developing a Basin Plan for the entire Ompompanoosuc River. The Ompompanoosuc River Basin Plan will summarize natural resource information, current and past water quality assessments, and efforts at the state and local level to protect and restore water quality. The Basin Plan will identify and prioritize state and local water quality issues, develop strategies for solving water quality problems, and implement on-the-ground protection and restoration projects. The purpose of the Basin Plan is to guide state and local efforts, and to serve as a resource document for the Ompompanoosuc watershed. The draft Basin Plan is scheduled for completion in late 2006. For the West Branch of the Ompompanoosuc watershed, the Basin Plan will rely heavily on the information contained in this River Corridor Management Plan.

This River Corridor Management Plan outlines the goals for the West Branch of the Ompompanoosuc River in the Town of Strafford, the current condition of the river and its tributaries, results of field assessments, prioritization of restoration opportunities, and strategies for implementing corridor protection and restoration.

1.1 Local Project Goals

The main goals for the West Branch of the Ompompanoosuc River set out by the SCC are to increase its value as a recreational resource, improve public access to the river and streams, improve aquatic habitat, reduce flood and erosion hazard and restore river corridor function. The goals are outlined below and addressed with general and specific strategies in sections 7.0 and 8.0 of this document.

1.1.1 Increase the Recreational Value of the West Branch

The Strafford community benefits from various recreational values of the West Branch and its tributaries. From the Upper Village downstream to Rices Mill, the West Branch is noted as a class II enjoyable paddle by American Whitewater. Many Strafford residents enjoy paddling the West Branch during high water in the spring time.

The SCC has a new Trails Committee that would like to develop a walking and/or bike trail between the two villages along the river, most likely just outside the FEH zone. Ideally this trail will be lined with trees that the SCC will purchase or donate to the effort.

1.1.2 Improve Public Access

Currently, access to the river is limited to several public lands. The Robert Murray Recreational Field in South Strafford Village provides riverfront access from the village. There is access to a nice swimming hole in the river behind the Robert Murray Recreation Field. There is also a favorite swimming spot in the Upper Village. Strafford residents, especially its young residents, would like access maintained at least in these spots, and improved elsewhere if possible.

Old City Falls and its ravine, a unique natural and historical area, are also owned by the Town. Residents enjoy use of the picnic area at the Old City Falls parking lot and hiking trails that go down to the falls. Since this is a publicly owned area, there is easy access to this beautiful waterfall.

The Strafford Area Lions Club sponsors and maintains a 0.4 mile bicycle and pedestrian path between the Varney ballfield and Our Lady of the Peace Chapel in South Strafford. The path provides a picnic area and access to the West Branch (Strafford Planning Commission 2003).

Improved public access would enhance the value of the river as an educational and recreational resource for uses such as fishing and swimming, which is an objective for many in town. Greater public access may encourage people to spend more time in close proximity to the river, thus resulting in a greater appreciation and recognition of its value to the community.

1.1.3 Improve Aquatic Habitat

The West Branch and its tributaries are part of the great Connecticut River basin. Long ago the Connecticut River hosted one of North America's southern-most salmon runs. Salmon once ascended the mainstem Connecticut River to its very headwaters (as far north as Beechers Falls, Vermont, nearly 400 miles upstream from the river mouth at Long Island Sound) and entered all major tributaries not blocked by natural barriers such as waterfalls (Connecticut River Atlantic Salmon Commission 1998). Experimental stocking of Atlantic Salmon fry in the West Branch has been discontinued. The West Branch in Strafford was stocked with 400 brook trout from the Vermont Department of Fish and Wildlife in May 2006.

Steve Fiske, Aquatic Biologist, VTDEC, Biomonitoring Aquatic Studies Section, has been studying the effects of the Elizabeth Copper Mine on the West Branch of the Ompompanoosuc for several years. On the main stem of the West Branch, above Tyson Road bridge, biological sampling results indicate the stream is in very good biological health. Downstream, in the area of the Elizabeth Mine, however, Fiske reports that the stream consistently is found to be in poor biological health (Fiske 2006).

1.1.4 Reduce Flood and Erosion Hazards

Encroachment of corridors from development can be both damaging to the river as well as to property. The Town of Strafford recognized these concerns and addressed them by adopting a Flood Hazard Zoning Ordinance on March 6, 1990 (Amended in 1993). The purpose of these regulations were to, "promote the public health, safety, and general welfare, to prevent increases in flooding caused by the uncontrolled development of lands in areas of special flood hazard, and to minimize losses due to floods." The areas to which the regulations apply are designated as special flood hazard areas on the Town's Official Flood Hazard Area Map.

Sound floodplain ordinances will prevent some unnecessary loss, but inundation maps are not updated frequently enough to reflect the changes in inundation hazard areas that come about as rivers undergo channel adjustment. Nor do inundation maps identify areas of erosion hazards. This River Corridor Management plan identifies fluvial erosion hazard (FEH) areas and provides guidance on reducing erosion hazards.

1.1.5 Restore River Corridor Functions

The reference stream type for much of the main stem of the West Branch Ompompanoosuc between the Strafford/Thetford town lines is an "E" channel as defined according to the Rosgen stream classification system (Rosgen 1996). "E" type stream channels are highly dependent upon vegetation for stability. For this reason, it is recommended that the establishment and protection of vegetated buffers be high priority in restoration planning and design work. 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.

Additionally, effective protection of river corridors will allow flood flows to be handled by the river system. As mentioned earlier, allowing for a buffer of native vegetation will enhance the river's capacity to manage the flood flow and reduce downstream erosion. Floodplains also can act as sinks for nutrients and sediment that would otherwise continue downstream and impact receiving waters. Encroachment of floodplains from development can be both damaging to the river as well as to property.

1.2 State of Vermont River Management Goals

The State of Vermont's River Management Program has set out several goals and objectives that are supportive of the local initiative in Strafford. The state management goal is to, "manage toward, protect, and restore the equilibrium conditions of Vermont rivers by resolving conflicts between human investments and river dynamics in the most economically and ecologically sustainable manner." The objectives of the Program are to include fluvial erosion hazard mitigation and sediment and nutrient load reduction as well as aquatic and riparian habitat protection and restoration. River corridor planning will be conducted in an effort to remediate the geomorphic instability that is largely responsible for these problems in a majority of Vermont's rivers. The Vermont River Management Program will 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 (Vermont River Management Program, personnel communication, 2006).

1.2.1 Fluvial Geomorphology and its Application to River Management

Geomorphic stability is defined as, "The ability of a stream, over time and in the present climate, to transport the flow **and** sediment of its watershed in such a manner that it maintains its dimension, pattern, and profile without aggrading (building up) or degrading (eroding down) its channel bed materials" (Rosgen 1996).

Fluvial geomorphic science explains the physical river processes and forms that occur in different landforms and geologic and climatic settings. In applying fluvial geomorphic science, it is assumed that:

- Although rivers are dynamic, with a form or geometry that is ever changing through erosion and depositional processes, there is a central tendency of form and process that has a predictable relationship with surrounding and watershed land forms and which may undergo significant change naturally with climate changes over time;
- Human-related physical change to river channels, floodplains, and watersheds often mimic and/or change the rate of natural physical processes;
- A scientifically sound river corridor management program can be based in part on regional channel evolution models that help predict how an altered river channel may return to a former channel form (or type) when significant

disturbances end, or how the channel may adjust to develop a new form (or type) if the disturbances continue; and

- The distribution and condition of stream types, especially those indicative of reach and watershed scale adjustments, influence erosion and flood hazard risk levels and aquatic habitat quantity and quality.

In the Vermont Stream Geomorphic Assessment Protocols, the term "in adjustment" is used to describe a river that is undergoing change in its channel form and/or fluvial processes outside the range of natural variability. The fluvial processes typically affected in river reaches that are "in adjustment" are those associated with reach hydrology and sediment transport. Channel adjustment typically involves erosion, but the terms are not synonymous. The processes of erosion and sediment deposition are ongoing and often result in changes in channel form and fluvial processes that are well within the range of natural variability. Fluvial geomorphic assessments help us understand whether the observed channel changes (such as eroding banks) are indicative of a river adjustment process, and if so, to what extent and over what period of time the adjustment will occur. With this knowledge river managers can weigh the long-term costs and risks associated with different human activities, including channel and floodplain encroachments or land use conversions at the watershed scale and manage river systems for geomorphic stability. (Vermont Agency of Natural Resources 2006a)

2.0 PROJECT BACKGROUND INFORMATION

2.1 Geographic Setting

2.1.1 Watershed Setting

The West Branch has a watershed size of 40.2 square miles measured from a point just downstream of the Strafford/Thetford town line. The West Branch within the Town of Strafford is a subwatershed of the Ompompanoosuc River (Figure 1). The Ompompanoosuc River is a tributary to the Connecticut River which drains south into Long Island Sound.

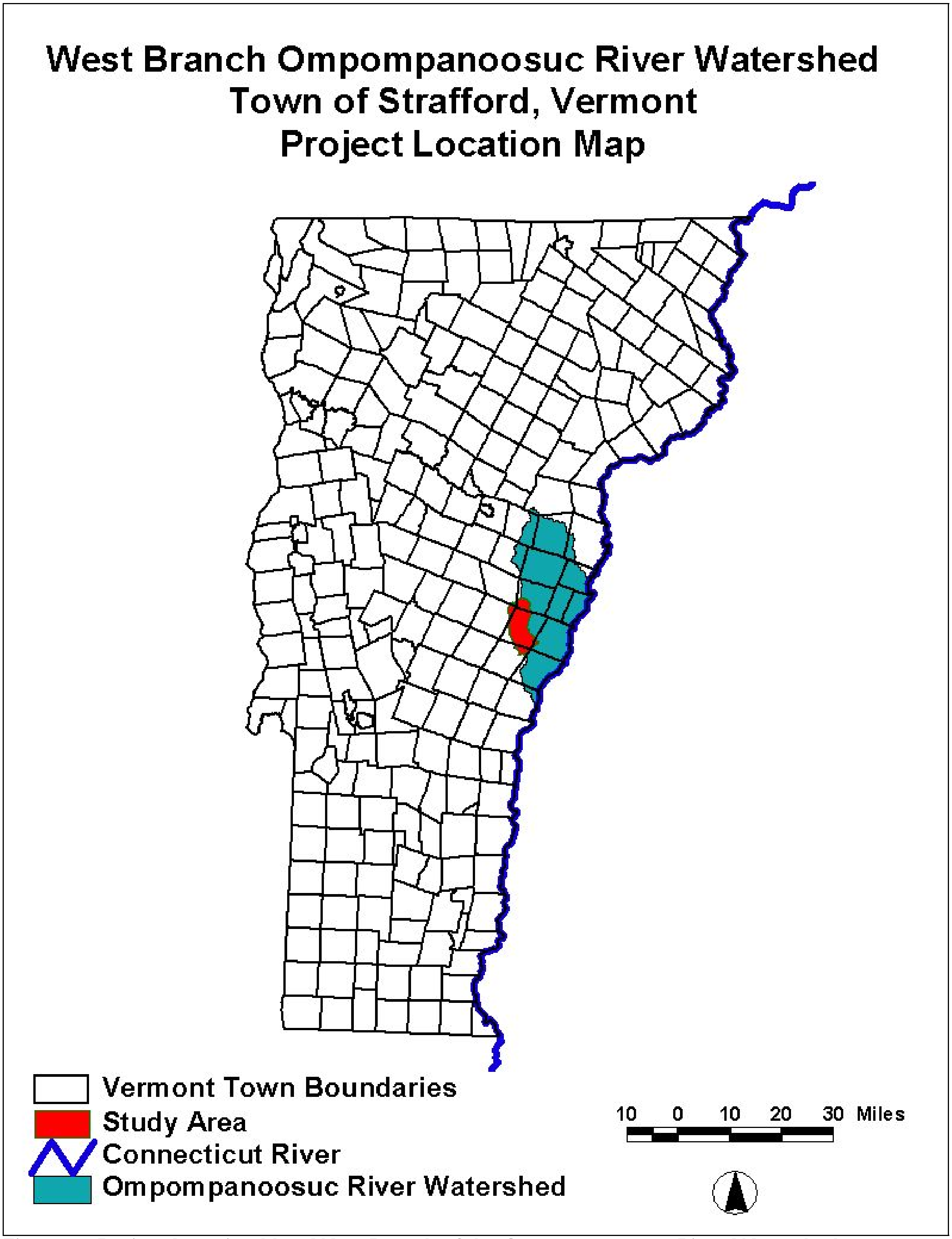

Figure 1: Project Location Map, West Branch of the Ompompanoosuc River Watershed

The highest elevations in the West Branch are the hills in the north of the watershed. Hawkins Mountain, at 2360 feet above sea level, is the highest point. At its confluence with the Ompompanoosuc River, the elevation is 550 feet above sea level.

2.1.2 Political Jurisdictions

The West Branch watershed is predominately located in the Town of Strafford. The headwaters extend into the surrounding towns of Vershire, Chelsea, Tunbridge, and Sharon. The towns within the West Branch watershed are members of the Two-Rivers Ottauquechee Regional Planning Commission. The lowest reaches of the West Branch drain from the hillsides of Thetford. The watershed is predominately within Orange County; however a small portion of the southern portion lies in Windsor County. The West Branch is located entirely within the State of Vermont.

2.1.3 Land Use History and Current Condition

According to natural history scientists at the Vermont Department of Fish and Wildlife, Native Americans inhabited Vermont for 8,000 years prior to European Settlement. Their impact on the landscape, however, is thought to have been minimal, except along the shores of some of the larger lakes and more fertile river valleys. (Thompson and Sorenson 2005).

European settlement of the region began in the mid to late 1700s. Strafford was chartered on August 12, 1761. Land clearing for agriculture and wood products increased dramatically around 1800 and approximately 80 percent of Vermont's land area was cleared of forests by 1900. The "sweet" soils of the Northern Vermont Piedmont are derived from calcium-rich bedrock, a factor leading to heavy early agricultural use in the region. (Thompson and Sorenson 2005). Strafford's settlement patterns, transportation and land use have historically been determined by its waterways. The earliest settlement, "Old City," was located at Old City Falls, along Old City Brook. Later settlement of Strafford Village and South Strafford Village were both along the river valley bottom.

The major land use patterns have also followed the water courses and the hills between forestry on the steeper slopes with farming and settlements confined to the valleys. Human use of these resources and associated livestock, first sheep then dairy cattle and later horse and alpaca, have determined the appearance of the land.

Although much of the forest has now regenerated, the structure and species composition of presettlement forests has surely been altered. The Northern Vermont Piedmont remains a region with numerous small farms, forestlands mostly managed for timber production, and a dense network of roads and settlements that leave few large areas of unmanaged land. (Thompson and Sorenson 2005).

Increasingly since the mid 1960's, recreation, summer camps, summer residences, and new year-round residents have built new homes in the community. A few farms still operate in the community, although increasingly agricultural land is being utilized for recreational livestock production (such as horse and alpaca). For the purposes of property valuation, the State of Vermont lists 21 working farms in Strafford. Dairy farms now number only six. Just over 2,500 acres of land in Strafford, is devoted to hay and corn or permanent pasture (Strafford Planning Commission 2003).

The land use within the watershed plays a role in the hydrology of the receiving waters, and is therefore useful in understanding the impacts that are seen today. 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 are increasing peak discharges and runoff by reducing infiltration and travel time (United States Department of Agriculture 1986). The land use/land cover within the stream corridor itself is also an important parameter to evaluate. This land use/land cover plays an influential role in the sediment deposition and erosion which occurs during annual flood events (Vermont Agency of Natural Resources 2004b).

As reported in the Phase 1 Assessment (Nealon and Blazewicz 2004) the dominant watershed land cover/land use within the West Branch Watershed in Strafford is forest. Only four of the forty subwatersheds assessed had high impact ratings for land use due to agricultural and/or development. However, thirty-six of the forty reaches were measured to have 10% or more of the river corridor in crop or developed land use.

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. Twenty-one of the stream reaches studied in the Phase 1 Assessment were found to have over 75 percent of the reach with little or no buffer on one or more banks. These stream reaches which lack a high quality riparian buffer are at a significantly higher risk of experiencing high rates of lateral erosion (Nealon and Blazewicz 2004).

2.2 Geologic Setting

The West Branch watershed is located within the Northern Vermont Piedmont, or New England uplands, physiographic region of Vermont. The geologic formation where the West Branch watershed is located is a plateau-like landscape that rises gradually inland from the sea (Van Diver, 1987). The rocks of the Northern Vermont Piedmont originated as marine sediments laid down during the Devonian and Silurian Periods. These were later metamorphosed into schists, phyllites, and crystalline limestones during the Acadian Orogeny. These metamorphic rocks of the Northern Vermont Piedmont are generally calcareous (Thompson and Sorenson 2005).

Between 18,000 and 20,000 years ago, Vermont was covered by the most recent of several glacial advances that occurred during the Pleistocene. During this, the Wisconsin glaciation, Vermont was buried under an ice sheet up to a mile thick. During this event, the mountains and hills of the West Branch watershed were softened further, stripping off the soils and earlier glacial deposits. All over the West Branch a thin layer of rocks and boulders was laid down under the ice. The rocks and boulders found in the Valley's soil are largely a product of this glacial deposition.

As the glaciers retreated, numerous lakes formed between the ice and the high ground. In the Connecticut River basin the very large glacial Lake Hitchcock was formed; it extended all the way up the Connecticut River Valley with fingers reaching up into the Ompompanoosuc River Valley. The shorelines of these lakes were often the receiving area for copious fine sediments shed from the melting ice and surrounding barren landscape. These glacio-lacustrine deposits, as they are known, are often prone to unpredictable shifting and shearing. Near the Strafford/Thetford town line glacial clay deposits begin to appear, evident by the large massive streambank failures that occur when they fail (Figure 2).

Figure 2: Glacial lake deposits are found in the lower reaches of the study area.

Except for the valley floors, Strafford is generally quite steep with slopes greater than 15% and rather shallow soils (Strafford Planning Commission 2003). The dominant surficial geology of the West Branch consists of alluvium, unsorted glacial till, and several ice contact deposits. The reaches characterized as "E" channels within the West Branch study area have alluvium, till, and ice contact as the dominant geologic material. Alluvium soils are frequently flooded, however are only slight to moderately erodable. Ice contact soils, which are formed in lakes, ponds, or streams in contact with glacial ice, are infrequently flooded, however have severe erodibility. The majority of the A and B type channels have till as the dominant geologic materials. These soils are rarely flooded and have very severe erodibility.

No alluvial fans were identified within the study area. Grade control structures such as ledge and dams were noted during the geomorphic assessment. Channel spanning ledge was noted in eight of the forty reaches. Ledge acts as a grade control by keeping the base elevation of a river from being lowered, thus preventing the river from incising in that location.

2.3 Ecological Setting

Northern hardwood forests and mixed coniferous forests cover the majority of acreage in the West Branch watershed. According to the Strafford Town Plan, more than 9,000 acres are mixed coniferous-broadleaf, another 8,000 acres are hardwoods, and about 3,500 acres are in pine and hemlock (Strafford Planning Commission 2003). The climate of these forests is cool-temperate and moist. Summers are warm and winters may be severely cold. Average annual temperatures range from 37° to 52°F. Annual precipitation ranges from 35 to 50 inches in most areas and is distributed more or less evenly throughout the year. Average annual snowfall is about 100 inches. Growing season length averages 100 to 110 days. Northern hardwood forests are typically characterized by soils that are neither extremely dry nor extremely wet. Soil moisture varies with parent material, topography, and depth to a restricting layer. Soils are mostly developed from glacial till, and bedrock is close to the surface in some areas. Sandy or gravelly soils derived from glacial outwash are found only locally, as are soils formed in lake bed deposits (Thompson and Sorenson 2000).

According to the Strafford Town Plan, there are 17 acres of wetlands in the town of Strafford. In 2003, the forests of Strafford were said to have in excess of 2,230 acres of deer wintering yards, principally contained in the three wildlife management areas, Podunk, Clover Hill, and Kibling Hill. There has only been one officially recognized rare and endangered botanical species in Strafford, it is located in a parcel that has been preserved by the Upper Valley Land Trust in the Taylor Valley.

2.4 Flood History

There are no USGS stream gauges within the West Branch of the Ompompanoosuc watershed. In order to better understand the flood history, long term data from the U.S. Department of the Interior, U.S. Geological Survey (USGS) gauge on Ayers Brook at Randolph, VT (gauge #01142500) was obtained. The Ayers Brook gauge was selected for a number of reasons. These reasons are as follows: 1. The Ayers Brook gauge is in close proximity to the West Branch watershed; 2. the stream flow of Ayers Brook is unregulated; and 3. the drainage area at the Ayers Brook gauge is 30.5 square miles, which is similar to the drainage area of the West Branch watershed at the Strafford/Thetford line. Sixty-four years of record are available for the Ayers Brook gauge at Randolph, VT. The gauge provides a continuous record of flow from 1940 through the present. Flow data from the gauge on the Ompompanoosuc River at Union Village, VT could not be used for the flood frequency analysis because peak discharge is influenced by flow regulation.

The long term record for Ayers Brook shows a 10 year discharge occurred in water year[1] 1949 and between a 25 and 50 year discharge occurred in 1952. During water years 1973 and 1998, the peak discharge exceeded the projected 50 year discharge. A graph of the flood frequency analysis is provided in Figure 3 below. The only anecdotal evidence available to BCE at the time of this report was from the Strafford selectboard. Selectboard members told the SCC that a bridge on Old City Falls road washed out in 1973, thus supporting the peak discharge record at the Ayers Brook gauge (personal communication with Sally Mansur).

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

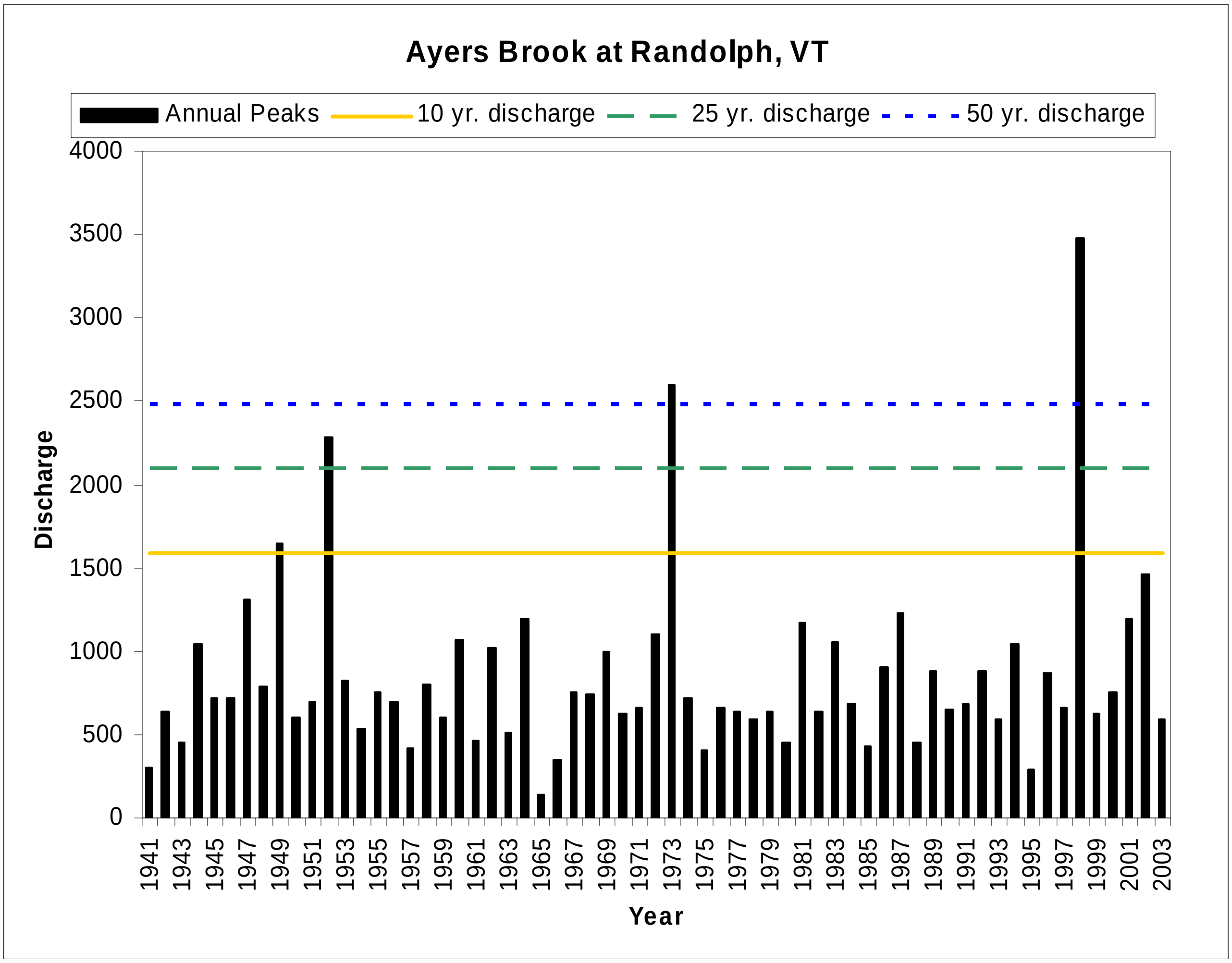

Figure 3: Flood frequency analysis for USGS 01142500 Ayers Brook at Randolph Vermont. Peak streamflow data from 1940 through 2003 were used in the analysis.

2.5 Channel and Floodplain Management History

Natural and anthropogenic impacts may alter the delicate 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 West Branch Ompompanoosuc watershed include:

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

These anthropogenic practices have altered the delicate balance between water and sediment discharges within the West Branch watershed. Channel morphologic responses to these practices contribute to channel adjustment that may further create unstable channels. The most common adjustment processes observed in the West Branch watershed are widening and planform migration as a result of historic degradation within the channel. 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 is the channel 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.

2.6 Past and Present Water Quality and Biological Data

The following sections are meant to provide a current summary of the ecological and chemical health of the West Branch and its tributaries.

2.6.1 Water Quality Data

The lower West Branch, below the Elizabeth Mine is listed on the State of Vermont 2004 303(d) Impaired Waters list. The listing is due to aesthetic and aquatic life impairment from heavy metals in the river due to the mining activities at the Elizabeth Mine. The West Branch upstream of the mine site is listed under Part C, "Waters in Need of Further Assessment". The section the Upper Village down to South Strafford Village is listed as being possibly impaired for aesthetics and aquatic life due to geomorphic instability. Further assessment, including information generated by the Phase 1 and 2 and River Corridor Management Plan will assist in informing the 2006 303(d) list.

2.6.2 Benthic Macroinvertebrate Data

Vermont DEC Aquatic Biologist Steve Fiske has been monitoring the health of benthic macroinvertebrates[2] in the lower reaches of the West Branch for several years in order to determine impacts of the Elizabeth Copper Mine on the health of the river. The control site for these studies is located near the Strafford/Thetford town line just upstream of the Tyson Road Bridge. In 2005, this site was rated at the upper end of very good with higher density, richness and EPT numbers then seen in recent years at the site. These results are typically a signal of benign enrichment, however the Bio Index at the reach was very low and EPT/EPT&c high, indicating that any enrichment stress at the reach has not altered the community composition (Fiske, 2006).

2.6.3 Fisheries Data

Very little data exists for the health of fish populations in the West Branch. In 2001, a fish community evaluation of the West Branch was conducted by the Agency of Natural Resources to document impacts from the drainage of the defunct Elizabeth Copper Mine on the fish community. According to Rich Kirn, District Fisheries Biologist, "All

[2] Freshwater benthic macroinvertebrates are animals without backbones that are larger than ½ millimeter (the size of a pencil dot). These animals live on rocks, logs, sediment, debris and aquatic plants during some period in their life. The benthos include crustaceans such as crayfish, mollusks such as clams and snails, aquatic worms and the immature forms of aquatic insects such as stonefly and mayfly nymphs.

West Branch sites {both upstream and downstream of the copper mine} were rated as having a low quality (brook trout) fisheries. The acid mine drainage study provided evidence that the length of the river in non-compliance with the Vermont Class B water quality standards for the fish community due to the impact of the mine is limited to, less than 1.4 miles downstream of the confluence." (Langdon 2002)

State Fisheries biologists from the Vermont DEC sampled Old City Brook in August of 2002. The brook contained an excellent community assemblage of brook trout, slimy sculpin and blacknosed dace in the brook according to DEC records for this sampling event.

3.0 STREAM GEOMORPHIC ASSESSMENT

The Vermont Agency of Natural Resources has developed protocols for conducting geomorphologic assessments of rivers. Various trainings have been held to provide consultants and regional planning commissions with the knowledge necessary to make accurate and consistent assessments of Vermont's rivers.

The stream geomorphic assessments are divided into three phases. The phase one assessment is a rough analysis of the condition of the stream using aerial photographs, maps, and preliminary field data collection. The phase two assessment is a more detailed analysis of the stream by determining what adjustment processes are taking place and predicts how the river will continue to evolve in the future. Phase three is the identification and implementation of restoration projects.

Bear Creek Environmental was retained by the Strafford Conservation Commission to conduct Phase 1 & 2 geomorphic assessments and bridge and culvert assessments of the West Branch of the Ompompanoosuc River (Nealon and Blazewicz 2004, Nealon 2005, Blazewicz and Nealon 2006). These Phase 1 and 2 assessments were funded through a grant from the Upper Valley Community Foundation. These data helped to pinpoint areas of concern and set the stage for restoration work needed within the watershed.

3.1 Phase 1 Stream Geomorphic Assessment Results

The Phase 1 geomorphic assessment evaluates parameters that may cause channel adjustment. These parameters are grouped into four major categories: land use, instream modifications, floodplain modifications, and bed and bank windshield survey. On the West Branch, fourteen of the reaches had high impact ratings for channel modifications; these reaches were mostly on the main stem and near the mouths of the tributaries (Figure 4). The West Branch also had high impact scores for berms and roads, channel migration, and bank erosion. Figure 5 shows a general trend of decreasing impact rating (i.e. improved geomorphic stability) upstream of reach M11 and downstream of M06 on the mainstem.

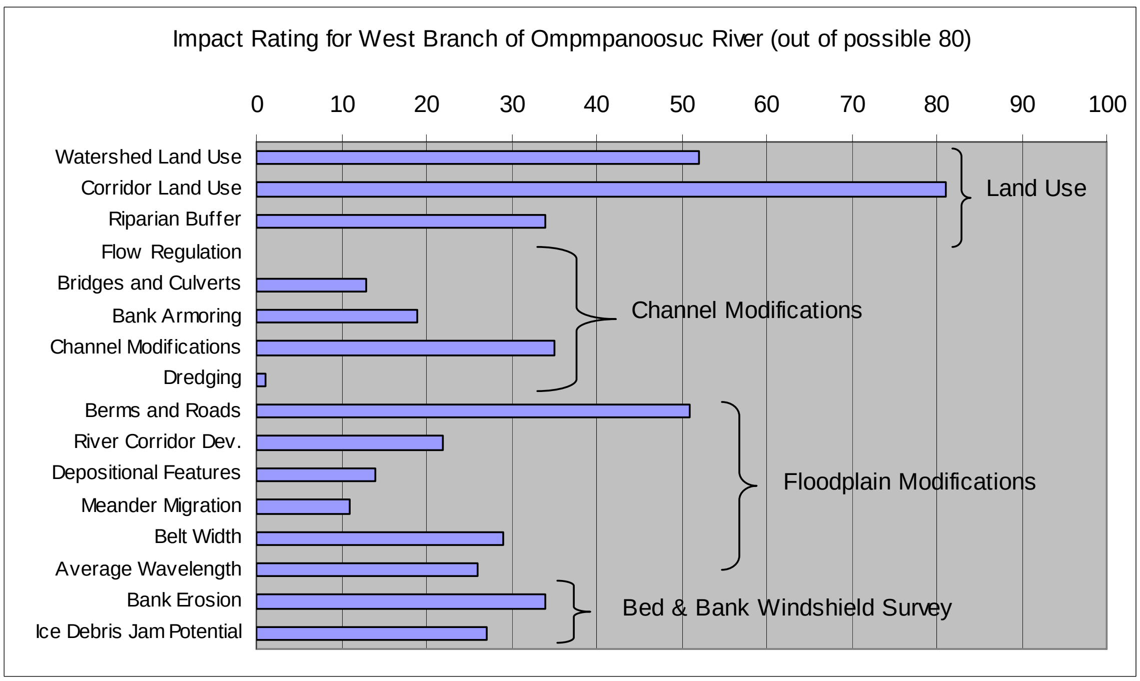

Figure 4. Impact Rating for West Branch Ompompanoosuc River Watershed by Parameter and Category

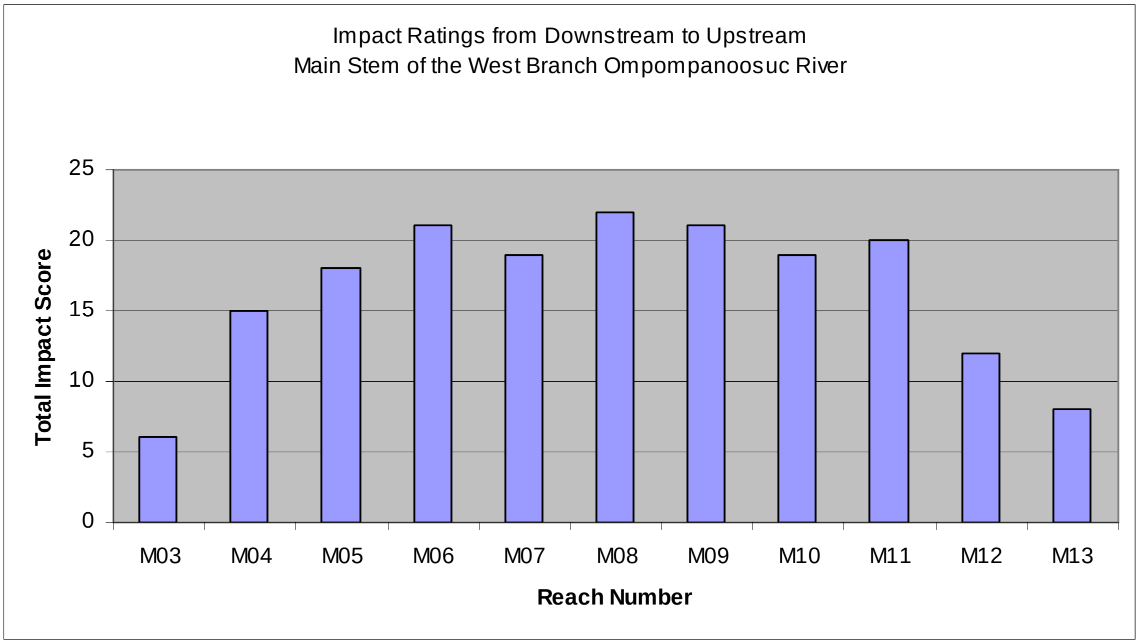

Figure 5. Impact Ratings from downstream to upstream on the main stem of the West Branch of the Ompompanoosuc River

3.2 Phase 2 Stream Geomorphic Assessment Results

A Phase 2 Stream Geomorphic Assessment of targeted reaches was conducted within the West Branch watershed by Bear Creek Environmental in 2005 (Blazewicz and Nealon 2006). The study included ten reaches on the main stem of the West Branch River and the six lowest reaches of six tributaries. The sixteen targeted reaches were further divided into 22 segments based on changes in confinement, stream type and stage of channel evolution stage.

Information from the study came from the VDEC, the Vermont Mapping Program, and the Vermont Center for Geographic Information, the Town of Strafford, and field data collected by Bear Creek Environmental. The Phase 2 Rapid Stream Assessment included field observations and measurements that are used to verify the Phase 1 stream geomorphic data, to provide field evidence of channel adjustment processes, and rate the health and condition of the riparian corridor and aquatic habitat. The channel dimensions were measured within each of the segments using a tape and measuring rod as shown in Figure 6. The collection and synthesis of the Phase 2 information can be used in watershed planning, for the establishment of erosion hazard zones, and for the identification of watershed improvement projects.

Figure 6. Ben Copans of the Vermont DEC measures the cross-sectional area of the Upper West Branch during summer 2005.

The Phase 2 Rapid Geomorphic Assessment (RGA) provides information on the geomorphic condition of each segment within the study area (Figure 7 and Table 1). The condition rating relates to the degree of adjustment a channel is undergoing. A channel in "Reference" condition is not undergoing significant adjustment. "Good" condition indicates some minor adjustments are occurring. The majority of Strafford streams fall into the "Fair" geomorphic condition rating indicating major active adjustments are occurring. In the worst scenario a "Poor" rating indicates extreme geomorphic adjustment Many of the tributaries and the main stem of the West Branch in Strafford are experiencing high rates of bank erosion. The bank erosion has been accelerated due to land use activities and channel and floodplain modifications. Significant channel straightening, bank armoring, berming, and floodplain encroachment have occurred within this river system both on the mainstem and on the lower ends of the tributaries. These impacts have resulted in the loss of natural energy dissipation of the river system via meandering and flooding the fields along the river. Over time, the river has down cut into the streambed resulting in loss of floodplain access and increased energy within the channel. The increased energy within the channel has lead to severe bank erosion and subsequent channel widening. Along much of the main stem, the river channel is currently migrating laterally to recreate a new floodplain at a lower elevation to dissipate the energy and to become more stable (see Figure 8).

The disturbance and removal of the riparian vegetation in Strafford has decreased the resistance of the streambanks to the erosive forces of the river. Rates of lateral adjustment are influenced by the presence and condition of riparian vegetation. As the river works toward a more stable equilibrium, the Strafford Community has the opportunity to reestablish floodplain, improve riparian vegetation and protect the river from further encroachments.

Table 1. Phase 2 Geomorphic Condition for West Branch Ompompanoosuc

Segment Number	Existing Stream Type	RGA Score	Reach Condition
M03	B3c	0.71	Good – Minor Adjustments
M04	B3c	0.50	Fair – Major Adjustments
M05	B4c	0.38	Fair – Major Adjustments
M06	C5	0.40	Fair – Major Adjustments
M07	C5	0.49	Fair – Major Adjustments
M08	C4	0.41	Fair – Major Adjustments
M09-A	E4	0.58	Fair – Major Adjustments
M09-B	E4	0.63	Fair – Major Adjustments
M10	C4	0.45	Fair – Major Adjustments
M11-A	E4b	0.84	Good – Minor Adjustments
M11-C	E4	0.58	Fair – Major Adjustments
M12	C3b	0.71	Good – Minor Adjustments

Table 1. Phase 2 Geomorphic Condition for West Branch Ompompanoosuc			
Segment Number	**Existing Stream Type**	**RGA Score**	**Reach Condition**
T2.01-A	G3	0.48	Fair – Major Adjustments
T2.01-B	C4b	0.63	Fair – Major Adjustments
T3.01-A	E4b	0.59	Fair – Major Adjustments
T3.01-B	G3	0.50	Fair – Major Adjustments
T4.01-A	G4	0.53	Fair – Major Adjustments
T4.01-B	E4b	0.58	Fair – Major Adjustments
T5.01	E4b	0.48	Fair – Major Adjustments
T6.01	C4b	0.68	Good – Minor Adjustments
T7.01	B3	0.56	Fair – Major Adjustments

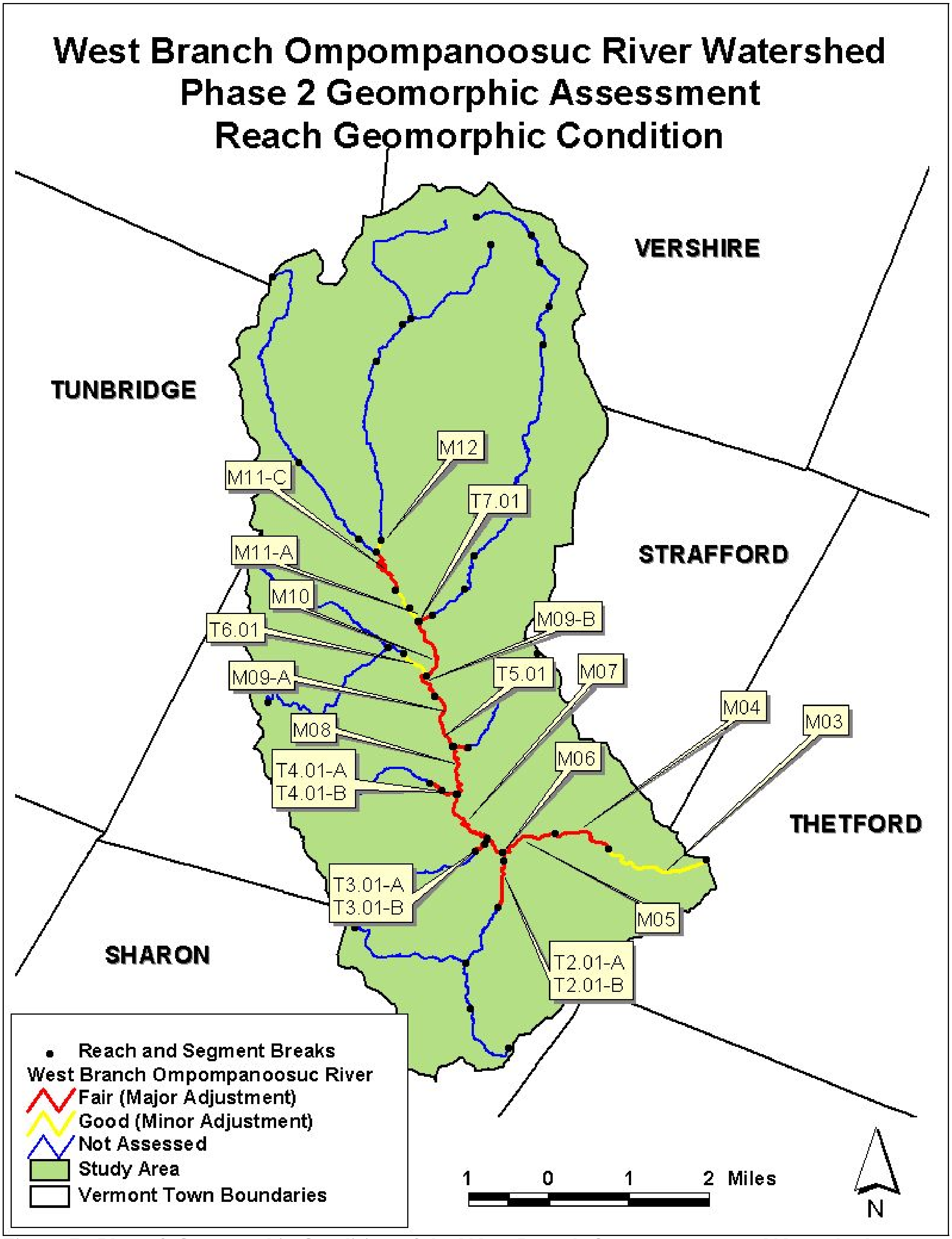

Figure 7: Phase 2 Geomorphic Condition of the West Branch Ompompanoosuc Watershed

Figure 8. The West Branch is working to create a new floodplain bench in many areas.

4.0 WATERSHED SCALE HYDROLOGIC AND SEDIMENT MODIFIERS

Changes to the West Branch watershed have resulted in changes to the volume and timing of runoff as it makes its way down into the stream channels. Changes in land use have also affected the amount and sources of sediment that enter the river system.

4.1 Hydrologic Alterations

Hydrology refers to the study of water as it moves over (and within) the land. Channel shape and pattern develops over time in relationship to climatic and landscape conditions. Abrupt changes to the landscape or the amount and velocity of water as it moves into a stream will have significant effects on the characteristics of the stream channel.

4.1.1 Land uses and wetland loss

During rain storms and snow melt events, the amount of water running over the surface of the land increases, and in severe storms, flooding may result. Many wetlands, particularly floodplain wetlands, have the capacity to temporarily store flood waters, during high runoff events. As flood waters recede, the water is released slowly from the wetland soils. By holding back some of the flood waters and slowing the rate that water re-enters the stream channel, wetlands can reduce the severity of downstream flooding and erosion.

In watersheds where wetlands have been lost, flood peaks may increase by as much as 80 percent (Vermont Agency of Natural Resources 2006b). Wetlands within and upstream of urban areas are particularly valuable for flood protection. The impervious surface in urban areas greatly increases the rate and timing of runoff.

Although data are lacking, it is likely that many wetlands in Strafford have been either drained or filled and put to use – usually for agriculture. Loss of wetlands and an increase in clearing and impervious surfaces (roads, driveways, rooftops, parking lots, etc.) leads to changes in the hydrology of this watershed and therefore affects the flood hazard, geomorphology, and habitat of the streams. Protection of existing wetlands in the West Branch watershed is a good land use goal for the Town of Strafford.

4.1.2 Roads

According to the Vermont 911 GIS road data layer, the West Branch of the Ompompanoosuc River study area has a combined total of 89 miles of improved road (not including driveways, logging roads, and or other unimproved roads). That is a density of 2.2 miles of improved road per square mile of watershed. Although runoff from the impervious surface of these road networks can transport sediment and other materials into streams, in mountainous and hilly terrain the greater culprit seems to be the ditches along the roads that intercept slow moving groundwater and convert it to fast-moving surface water. The increased runoff in a watershed as a result of these roads may increase the rates and extent of erosion, reduce groundwater recharge rates, alter river channel morphology, and increase downstream flooding as well as flood frequency (Forman and Alexander 1998).

4.2 Sediment Modifiers

From a geomorphic perspective, researchers and land managers are increasingly interested in the response of erosion and sedimentation to changes occurring on watershed hillslopes or in stream channels. Managers need to predict how land use will alter erosion and sedimentation rates and the relative importance of different sediment sources in order to assign priorities for erosion control. They also must anticipate where sediment will be deposited, how long it will be stored, and how it will be re-mobilized.

Common modifiers of sediment load and transport in the West Branch study area are:

Increase Sediment Load:

Unvegetated tilled cropland – is exposed to wind and water. Nine percent of the Town of Strafford (2,541 acres) was thought to be in hay/crop/farm use in 1995 (Strafford Planning Commission 2003).

Cleared, exposed soils from forestry, agriculture, or for development – are exposed to wind and water. Sedimentation of the West Branch can be limited if such clearing is followed by measures that minimize erosion and encourage regeneration of vegetation on the site.

Sanding of town roads and storage of sand – increases the amount of fine sediment that may run off of the landscape. At the time of this plan, the Town of Strafford has voted to relocate the town sand storage yard and is working to implement this project.

Accelerated bank erosion due to riparian vegetation removal and/or channel alterations – major channel adjustment, which is occurring in seventeen of twenty-one reaches, adds sediment to the river system as the river erodes its banks and bed.

Decrease Sediment Load (and therefore increases bank erosion and channel migration):

Gravel extraction from the river channel – decreases available sediment that river needs to move thus making it sediment deficient and causing erosion or scour downstream. Gravel extraction in the West Branch watershed has been limited to only one permit in 2005.

Increase Sediment Transport:

Straightened stream channels – increase the velocity of the stream and therefore its ability to transport sediment. Seven of the ten main stem reaches included in this River Corridor Management Plan had greater than 30% of the channel length straightened.

Stormwater ditches - increase the velocity of water and therefore its ability to transport sediment. Twenty-eight stormwater inputs were found during the Phase 2 geomorphic assessment.

Decrease Sediment Transport:

Undersized stream crossings – capture sediment in unnatural patterns, may create scour downsteam. The 2004 Bridge and Culvert survey of public stream crossings identified 39 undersized structures in the West Branch watershed.

Overwidened channels – are unable to move sediment effectively through them. Channel widening was found to be a current adjustment process on half of the Phase 2 reaches.

5.0 REACH SCALE STRESSORS

Stream condition and stability is determined by a combination of many factors. Often, small impacts tend to accumulate into reach scale impairment. The maps in the Appendix depict some of the major impacts that are occurring within the study area. The maps are laid out from upstream to downstream starting near the intersection of Taylor Valley Road and the Justin Morrill Highway.

5.1 Vertical Constraints

Grade controls are critically important features in maintaining bed elevation and overall channel stability, and in determining upstream migration of many aquatic organisms, primarily fish. By definition, grade controls must extend across the entire bankfull channel from bank to bank in order to function as true controls. Natural and man-made features which may serve as grade controls include:

***Waterfall* -** Bedrock that extends across the channel and forms a vertical, or near vertical, drop in the channel bed

Ledge - Bedrock that extends across the channel and forms no noticeable drop in the channel bed, or only a gradual drop in the channel bed
Dam - High cross-channel structures
Weir - At-grade or low cross-channel structures

There were only four grade control features found in the West Branch study area. These features were all located in the upstream portion of the stream. Channel spanning ledge was found below the Upper Village in reach M09-A just upstream of Eastburn Drive. Above the Upper Village, at reach M10, the remnants of an old dam still span the channel of the West Branch providing grade control. In the tributaries, grade control was found at the upstream end of Brook Road Brook (T6.01). Channel spanning ledge was also found on Old City Falls Brook (T7.01) upstream from the Justin Morrill Highway bridge.

5.2 Lateral Constraints

Though we often associate floodplains with large rivers, over time, even streams in semi-confined valleys will have created a certain amount of floodplain. In addition to providing floodwater storage and attenuation, a floodplain is often the space (or river corridor) through which stream channels meander over time, undergoing planform adjustment and thereby slope adjustment. The availability of space for slope adjustment is critical to the stream in reaching equilibrium with the size and quantity of sediment produced in the watershed. A stream cut off from its floodplain may have less room to meander and be forced into a higher gradient form. If this higher gradient translates into stream power that can move even larger particles in the stream bed, the channel may begin to degrade (or incise), cutting down into its streambed and initiating the channel evolution process (Vermont Agency of Natural Resources 2005a).

Berms and roads, and the hardened embankments often used to protect them, limit the lateral adjustments of the stream within the corridor and may contribute to onset of vertical adjustments within the channel. Developed land, including highways, roads, and railroads, in close proximity to the stream may be a clue that the stream bank has been bermed to protect the infrastructure and investments. In the West Branch watershed, there are several dominant lateral constraints that have impacted the channel. Route 132 and the Justin Morrill Highway both have, in areas, considerably limited the area within which the West Branch is able to adjust laterally. Hard armoring placed in order to protect this infrastructure has led to increased instability in the system. In addition to these two major roads, minor roads in the watershed impact tributaries in numerous places.

Structures that encroach into the river corridor are not only threatened by the river, but the armoring and berming of the river banks often deemed necessary to protect these investments may pose a threat to downstream areas, by limiting slope adjustments and increasing flood velocities and stream power of the confined stream. Floodplain encroachments typically concentrate flow in the channel during floods, increasing the stress of flood flows on the channel bed and banks. They can also effectively turn a response or depositional stream into a transfer stream, which may lead to an increase in sediment loading and aggradation, as well as bank erosion, in downstream reaches.

5.3 Bridge and Culverts

Stream crossings can disrupt the sediment transport and/or the movement of fish and wildlife within a stream reach. Forman and Alexander (1998) summarize bridge and culvert impacts on stream morphology and hydrology. They write that, "Streams may be altered for considerable distances both upstream and down-stream of bridges…. The fixed stream (or river) location at a bridge or culvert reduces both the amount and variability of stream migration across a floodplain. Therefore, stream ecosystems have altered flowrates, pool-riffle sequences, and scour, which typically reduce habitat-forming debris and aquatic organisms."

Furthermore, the Vermont Department of Fish and Wildlife (2005) states, "The biological consequences of improper culvert installation to aquatic communities are many, and may include:

- direct loss of aquatic habitat
- loss of resident aquatic populations (by preventing recolonization of upstream habitat after catastrophic events, such as floods or toxic discharges)
- loss of access to critical spawning, rearing, feeding or refuge habitat for aquatic organisms
- altered aquatic community structure (e.g. species composition, distribution)

- altered genetic composition of aquatic populations"

Bear Creek Environmental was retained by the Strafford Conservation Commission (SCC) to conduct a Bridge and Culvert Assessment of the West Branch of the Ompompanoosuc River watershed limited to the Town of Strafford. The Vermont Agency of Natural Resources Bridge and Culvert Assessment and Survey Protocols (dated April 2004) were used to conduct a rapid assessment of stream crossings. The study relied on volunteers from the SCC to assist with the field data collection. The objective of the study was to red-flag structures that are potential barriers to fish and wildlife movement and/or are flood or erosions hazards. A total of 39 bridges and culverts within the Town of Strafford were surveyed during September 2004. The stream crossings included 28 bridges and 10 culverts on state and town roads and one private bridge within reach M07 (Nealon 2005). All of the structures surveyed were red flagged by the VDEC's database as being geomorphologically incompatible due to flood and/or erosion hazards. Eleven of these structures were designated Priority I structures. Bridges and culverts with channel widths of approximately 50 percent of the bankfull width or less, which were significantly impeding natural sediment transport were placed in Category 1. Structures which block aquatic organism passage were also generally placed in the Priority 1 category. Therefore, the Priority 1 category contains structures that have highest priority for replacement due to geomorphic incompatibility and aquatic organism passage (see Figure 9 or map of priority structures).

Long term stability of stream channels and structures is more likely when the geomorphic context and sediment transport needs of a stream channel are given consideration when designing new and rehabilitating existing structures. The Town of Strafford could establish ordinances or identify zoning requirements which would ensure adherences to proper siting and design practices for future development, especially on private crossings.

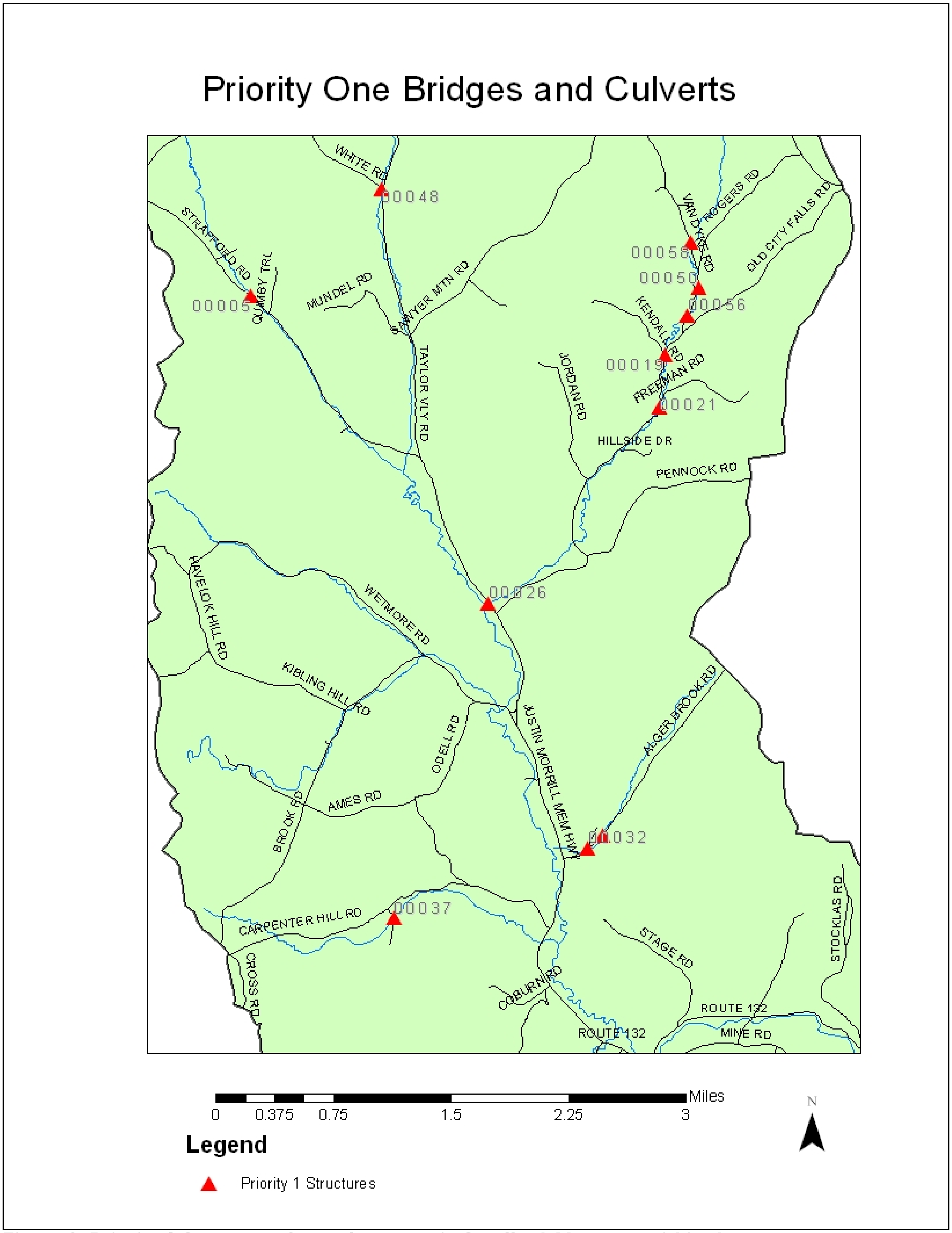

Figure 9: Priority 1 Structures for replacement in Strafford, Vermont within the Ompompanoosuc River

6.0 Stream Adjustment, Sensitivity, and Fluvial Erosion Hazard Mapping

6.1 Channel Evolution

The stability of a stream channel is based on maintaining a certain flow of water, shape and slope of the channel, and sediment load. When any of these change significantly, the river channel must change, typically resulting in erosion of the stream bed or banks. Between the 1700's and the 1800's, the building of roads and railroads within the floodplains, deforestation, and moving streams to accommodate agricultural fields and villages resulted in unstable river channels. Even in recent decades, large-scale channelization practices have been employed to reclaim damaged lands after large flood events. The 1970's and 1980's were also a period of extensive gravel mining in many Vermont streams. Post-flood channel straightening and gravel mining of point bars have the effect of steepening stream channels. A steep channel in a relatively flat valley may initiate a bed degradation, or downcutting process. Once a stream begins to degrade, it will typically erode its way through an evolution process until it has created a new floodplain at a lower elevation in the landscape. The common stages of channel evolution, as depicted in Figure 10 include:

- A pre-disturbance period
- Incision – Channel degradation
- Aggradation and channel widening
- The gradual formation of a stable channel with access to its floodplain at a lower elevation.

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 eroding sediments from otherwise stable streambeds. These bed sediments will move into and clog reaches downstream leading to lateral scour and erosion of the streambanks. 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.

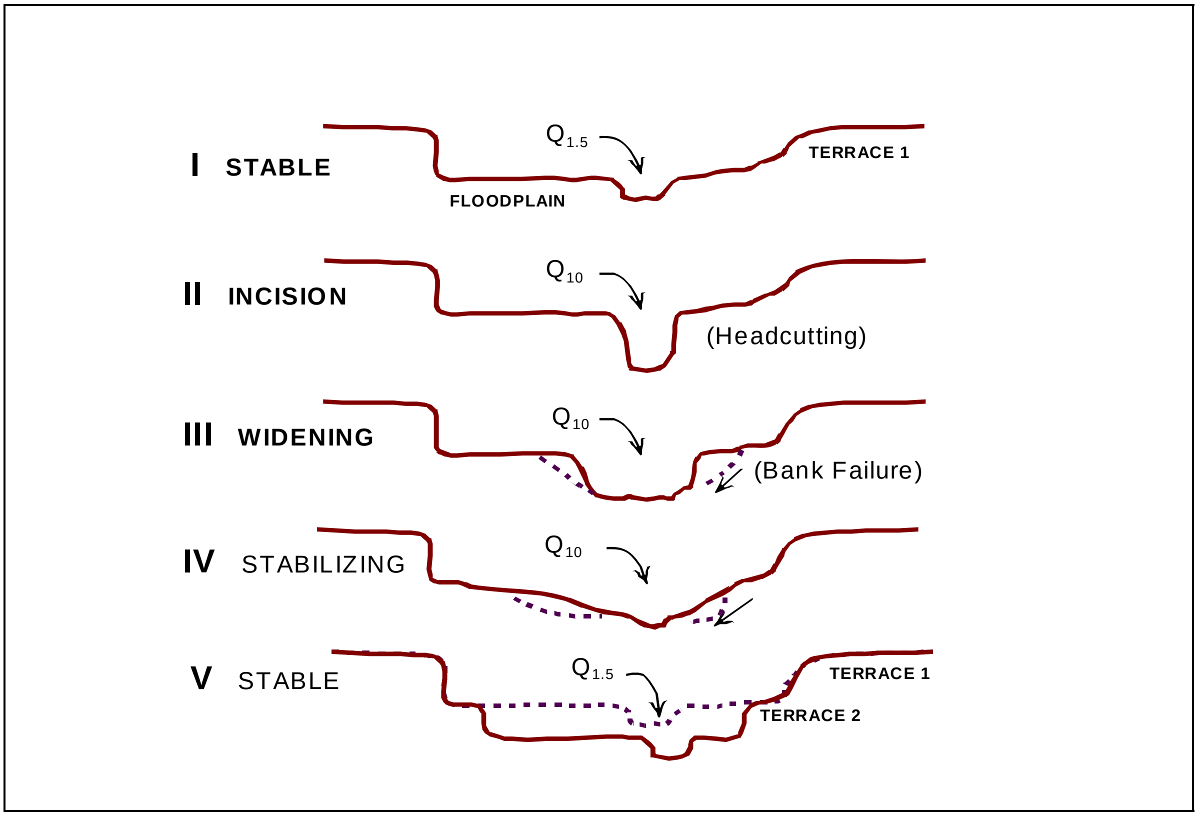

Figure 10: Typical Channel Evolution Model following incision.

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. Landowners and government agencies have repeatedly armored and bermed reaches of Vermont's rivers to contain floodwaters in channels. These efforts have proven to be temporary fixes at best, and in some cases have lead to disastrous property losses and natural resource degradation. A more effective solution is to limit encroachments within the riparian corridor and maintain a buffer of woody vegetation between the stream and adjacent land uses. Maintaining vegetated riparian corridors and offsetting development limits the conflict between property investments and the natural processes of flooding and channel migration that occurs gradually over time. Given room, a channel can adjust its shape and slope to changes in flow and sediment load. In general, the space provided by an established riparian corridor allows the river or stream system to be more resilient to watershed changes, thereby protecting the fish, wildlife, and humans that depend on Vermont's rivers and streams (Vermont Agency of Natural Resources 2005d).

The reach condition ratings of West Branch indicate that many of the reaches are actively, or have historically, undergone a process of minor or major geomorphic adjustment. The most common adjustment processes in the West Branch are widening and planform migration as a result of historic degradation within the channel. 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 is the channel 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.

Most of the reaches studied in the West Branch of the Ompompanoosuc 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 2 below summarizes the channel evolution of each study reach and the primary adjustment processes that are occurring.

Table 2. Stream Type and Channel Evolution Stage

Segment Number	Incision Ratio	Width to Depth Ratio	Reference Stream Type	Existing Stream Type	Channel Evolution Stage	Major Active Adjustment Process
M03	1.0	24.8	B	B3c	I	None
M04	1.8	24.8	C	B3c	III	**Aggradation** Planform Widening
M05	2.6	21.3	C	B4c	III	**Aggradation** **Widening** **Planform**
M06	1.8	11.7	E	C5	IV	**Aggradation** **Widening** **Planform**
M07	1.3	18.5	E	C5	III	**Aggradation** **Widening** **Planform**

Table 2. Stream Type and Channel Evolution Stage

Segment Number	Incision Ratio	Width to Depth Ratio	Reference Stream Type	Existing Stream Type	Channel Evolution Stage	Major Active Adjustment Process
M08	1.4	13.0	E	C4	III	**Aggradation** **Widening** **Planform**
M09-A	1.3	8.7	E	E4	III	**Aggradation** **Planform**
M09-B	1.1	9.0	E	E4	IId	Aggradation Planform
M10	1.9	12.5	E	C4	III	**Aggradation** **Widening** Planform
M11-A	1.0	10.0	E	E4b	I	None
M11-C	1.3	10.8	E	E4	III	Aggradation Widening **Planform**
M12	1.0	12.0	C	C3b	I	None
T2.01-A	2.4	8.9	C	G3	II	**Aggradation** Widening Planform
T2.01-B	1.0	15.5	C	C4b	IId	**Aggradation** Widening Planform
T3.01-A	1.0	7.4	E	E4b	IV	Aggradation Widening **Planform**
T3.01-B	2.3	10.1	E	G3	II	**Widening**
T4.01-A	2.0	5.8	E	G4	II	**Widening** Planform
T4.01-B	1.6	9.3	E	E4b	III	Aggradation Widening Planform
T5.01	2.0	7.8	C	E4b	II	**Aggradation** Widening Planform
T6.01	1.2	10.9	C	C4b	IV	Planform
T7.01	1.7	23.0	C	B3	III	**Aggradation**

Red bold lettering - denotes extreme adjustment process
Bold Black lettering – denotes major adjustment process
Black lettering (no bold) – denotes minor adjustment process

The West Branch and the lower reaches of its tributaries are predominately between stages II and IV of the "F-stage" channel evolution model (Vermont Agency of Natural Resources 2005b; Vermont Agency of Natural Resources 2004). In many reaches the channel has undergone historic degradation. Many of the cross sections of study reaches were found to be incised. The incision ratio ranged form 1.0 to 2.6. Five of the segments were found to have a bankfull elevation that was at least one mean bankfull depth lower than the top of the low bank indicating a high level of bed degradation. Along many of the main stem reaches and near the mouths of the tributaries, 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. Aggradation in the West Branch study area seems to be a combination of endogenous sources of sediment that are brought into the system as the stream widens and erodes its banks to reestablish a new floodplain as well as from exogenous processes such as erosion and runoff from gravel roads and land clearing that bring sediment into the stream channel. Unvegetated mid channel bars, point bars in "E" type channels, side bars and impending neck cutoffs confirm the channel is undergoing extensive lateral migration.

Several segments within the West Branch study area fell into another channel evolution model. The "D-stage" channel evolution model applies to reaches where there may have been some minor historic incision; however, the more dominant active adjustment process is aggradation, which then in turn leads to channel widening and planform adjustment. This evolution is occurring in reaches M09-B and T2.01-B where aggradation is a major channel adjustment process. In the IId stage, a stream channel becomes extremely depositional. Lateral migration is extensive as the stream shifts through different channels and flood chutes and actively erodes its outside banks. Eventually, if the sediment supply stabilizes, the channel width will begin to narrow through the development of large bar features, which will eventually recolonize with shrubs and trees. A riffle-pool sequence will redevelop as the stream reconnects with a floodplain. Both segments M09-B and T2.01-B appear to be in the IId stage.

6.2 Stream Sensitivity

Sensitivity refers to the likelihood that a stream will respond to a watershed or local disturbance or stressor, such as; floodplain encroachment, channel straightening or armoring, changes in sediment or flow inputs, and/or disturbance of riparian vegetation. Assigning a sensitivity rating to a stream is done with the assumption that some streams, due to their setting and location within the watershed, are more likely to be in an episodic, rapid, and/or measurable state of change or adjustment. A stream's inherent sensitivity may be heightened when human activities alter the setting characteristics that influence a stream's natural adjustment rate including: boundary conditions; sediment and flow regimes; and the degree of confinement within the valley. Streams that are currently in adjustment, especially those undergoing degradation or aggradation, may become acutely sensitive (Vermont Agency of Natural Resources 2005a).

Figure 11 is a map presenting the existing stream types found in the West Branch watershed. Most of the reaches are Rosgen (1996) "E" or "C" channels by reference. E and C channels have wide valleys and moderate to gentle gradients. The difference between E and C channels is largely due to the difference in the shape of the channel. E channels have very low width to depth ratios and are highly sinuous by reference. This means that E channels are narrow and deep and have a long channel length relative to the valley length. C channels are typically wider and shallower and have moderate to high width to depth ratios and sinuosity. B channels have moderate to steep slopes and have narrower valleys than E or C channels. The stream sensitivity of these reaches, generalized according to stream type and condition are depicted in Table 3 and in Figure 12.

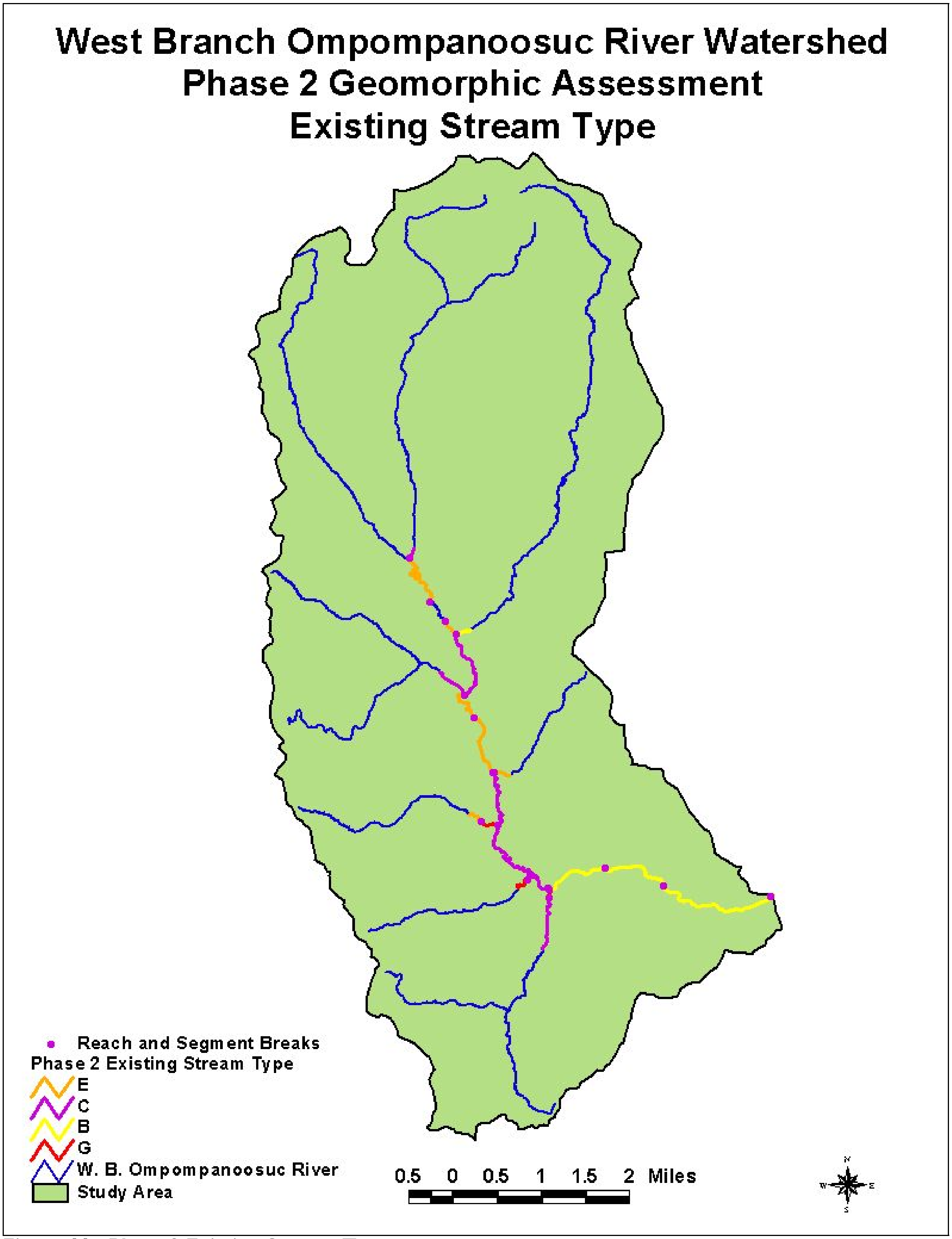

Figure 11. Phase 2 Existing Stream Types

Table 3. Stream Sensitivity for Phase 2 Reaches					
Segment Number	**Reference Stream Type**	**Existing Stream Type**	**Stream Type Departure**	**Geomorphic Condition**	**Sensitivity**
M03	B3c	B3c	No	Good	Moderate
M04	C4	B3c	Yes	Fair	High
M05	C4	B4c	Yes	Fair	High
M06	E5	C5	Yes	Fair	Very High
M07	E5	C5	Yes	Fair	Very High
M08	E4	C4	Yes	Fair	Very High
M09-A	E4	E4	No	Fair	Very High
M09-B	E4	E4	No	Fair	Very High
M10	E4	C4	Yes	Fair	Very High
M11-A	E4b	E4b	No	Good	High
M11-C	E4	E4	No	Fair	Very High
M12	C3b	C3b	No	Good	Moderate
T2.01-A	C4b	G3	Yes	Fair	Extreme
T2.01-B	C4b	C4b	No	Fair	Very High
T3.01-A	E4b	E4b	No	Fair	Very High
T3.01-B	E4b	G3	Yes	Fair	Extreme
T4.01-A	E4b	G4	Yes	Fair	Extreme
T4.01-B	E4b	E4b	No	Fair	Very High
T5.01	C4	E4b	Yes	Fair	Very High
T6.01	C4b	C4b	No	Good	High
T7.01	C3b	B3	Yes	Fair	High

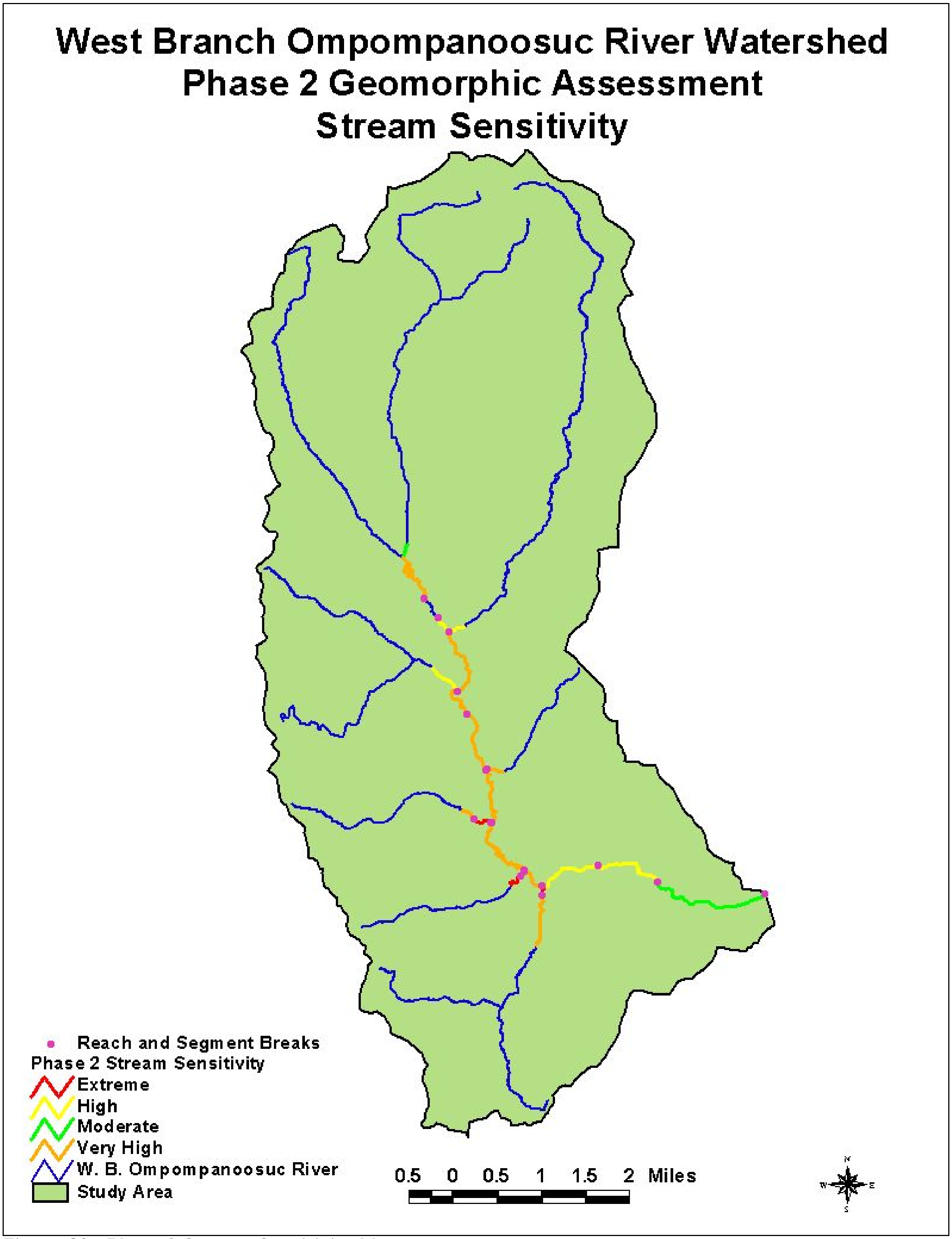

Figure 12: Phase 2 Stream Sensitivity Map

6.3 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 predominate 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 Zones is to prevent increases in fluvial erosion resulting from uncontrolled development in identified fluvial erosion hazard areas; minimize property loss and damage due to fluvial erosion; prohibit land uses and development in fluvial erosion hazards areas that pose a danger to health and safety; and discourage the acquisition of property that is unsuited for the intended purposes due to fluvial erosion hazards.

The basis of a Fluvial Erosion Hazard Zone is a defined river corridor which includes lands adjacent to and including the course of a river. 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, defined through VDEC Geomorphic Assessments (2004), 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. Figure 13 represents a draft Fluvial Erosion Hazard Map for the Town of Strafford.

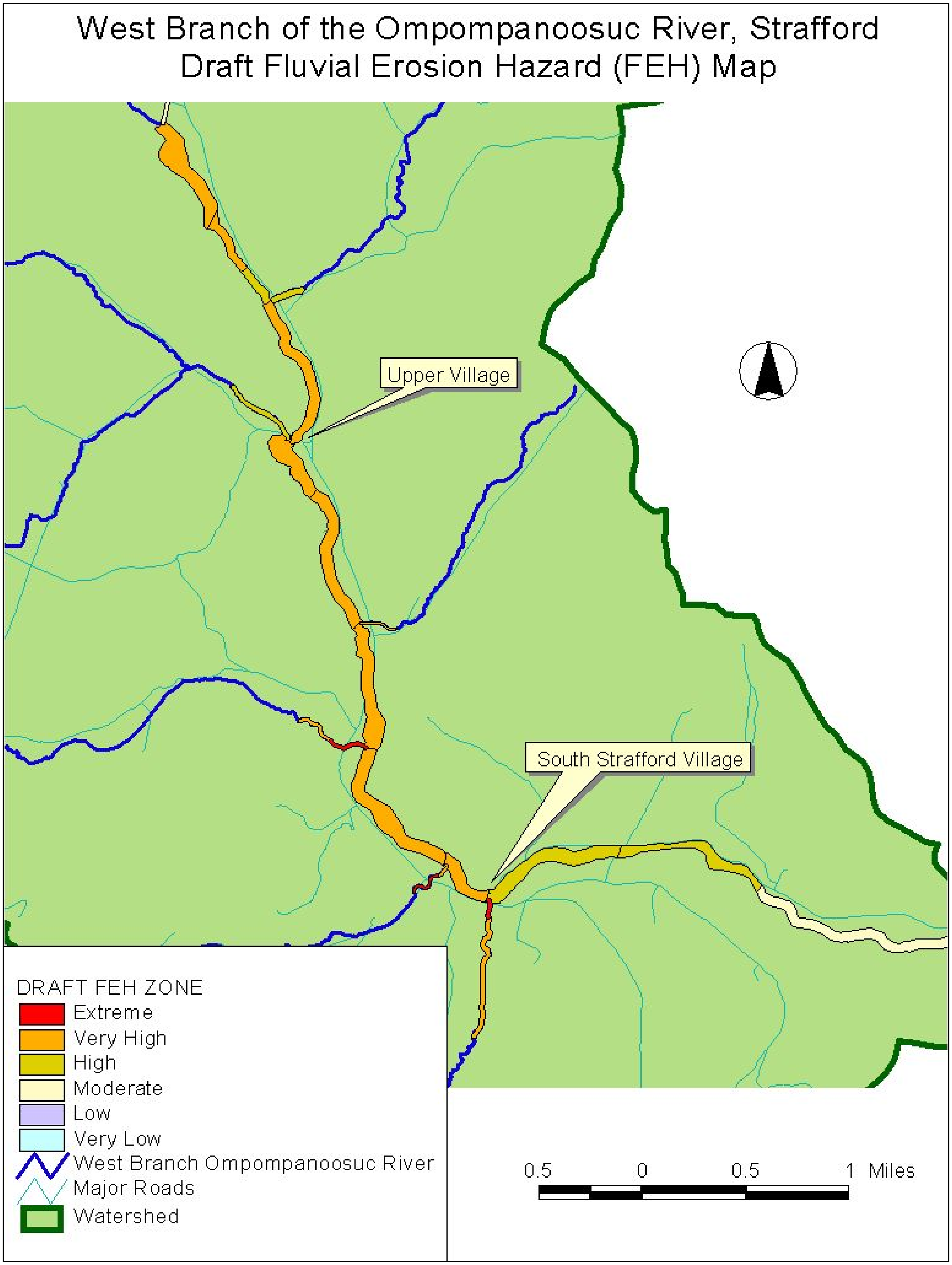

Figure 13: DRAFT Fluvial Erosion Hazard (FEH) Map for Strafford, VT.

6.4 Riparian Corridor Widths for Protection

It is important to note that the area deserving consideration for conservation, restoration, or protection from encroachment may extend beyond FEH zones. For example, riparian buffers measuring back from the top of an existing stream bank may extend beyond an FEH zone in order to capture some of the other ecological and water quality benefits of buffers above and beyond the erosion hazard risk that is outlined in the FEH zone. Riparian landowners are encouraged to work on a voluntary basis with the Strafford Conservation Commission to protect and enhance riparian corridors along the West Branch through the implementation of river corridor projection projects.

7.0 REACH SCALE PROJECT IDENTIFICATION AND PRIORITIZATION

7.1 Restoration Approaches

The restoration of the West Branch may focus on one or a combination of the following strategic approaches.

Active Geomorphic: This approach seeks to restore or manage rivers to a geomorphic state of dynamic equilibrium through an **active** approach that may include human-constructed meanders, floodplains, and bank stabilization techniques. This approach tends to have high upfront cost. Typically, the active approach involves the design and construction of a management application or river channel restoration project in an attempt to achieve stability in a relatively short period of time. This approach may involve restoring sections of river to their reference condition or may involve recognizing new valley conditions imposed by human constraints and working within those constraints. Active riparian buffer revegetation and long-term protection of a river corridor is essential to this alternative.

Passive Geomorphic: A **passive** geomorphic approach is targeted at allowing rivers to return to a state of dynamic equilibrium by removing constraints from a river corridor thereby allowing the river, utilizing its own energy and watershed inputs to re-establish its meanders, floodplains, and self maintaining, sustainable equilibrium condition over an extended time period. This approach is typically less expensive, however, may take much longer to achieve desired results. Active riparian buffer revegetation and long-term protection of a river corridor is also essential to this alternative. (Vermont Agency of Natural Resources 2005c)

7.2 River Corridor Project Types

The State of Vermont River Management Program has outlined five project types to further identify opportunities and address major issues on a reach level. River restoration within the West Branch will likely combine a variety of these project types in order to manage for systemic equilibrium. These five project types are:

Conservation Reaches - least disturbed, where river structure and function and vegetation associations are relatively intact. Remnant or refuge reaches would provide a good base to work out from, into more degraded reaches in the watershed.

High Recovery Reaches. These reaches show signs or potential for self-adjustment, in a manner that fits the present-day setting and stream type. Management efforts that work with the current tendencies of the river could achieve quick and visible success. High Recovery Reaches are those undergoing lateral adjustments, where minimally invasive approaches to increase bank stability will accelerate recovery while meeting the concerns of the landowner.

Moderately Unstable Reaches - Moderately unstable reaches may be defined as over-widened with only localized vertical instability and have a reasonable potential to recover. An active geomorphic approach would require an invasive management strategy (consisting of changes to dimension and some bed form restoration). In most cases, restoration of moderately unstable reaches is best done where watershed deposition and transport stressors have been evaluated and have either been treated or deemed to pose only minor risk to the stability of the project.

Incising Reaches - These are very high priority river reaches which are sensitive to disturbance, and where adjustments may trigger off-site responses (There were no incising reaches found in the Phase 2 assessment; however, they may exist within the watershed). These projects involve a pro-active management strategy. If action is not taken at these sites, the adjustments set in motion may lead to watershed-scale changes that would be uncontrollable without inordinate, impractical expense. The key example is the management of nick points (incision) or bed level instability. If incision issues are not addressed, significant upstream and downstream instability could develop.

Highly Unstable Reaches - typically involve large scale vertical adjustments where the river/floodplain relationship is significantly different from that of equilibrium conditions. An active geomorphic approach would require an invasive management strategy (consisting of changes to dimension, pattern, and profile). Highly unstable reaches have a natural recovery potential considered in terms of decades (10-50 yrs.) and are found to be high-sediment source and/or accumulation zones. Given the costs and risks associated with actively restoring vertically unstable reaches, highly unstable reaches may be ideal candidates for a passive geomorphic approach. Physical intervention in highly-unstable reaches is often expensive with an uncertain outcome. In most cases, restoration is best done once upstream (and in some cases, downstream) sites have been dealt with and watershed-wide sediment and vegetation management plans have been implemented.

Based on Phase 2 Geomorphic Assessment results, classification of river corridor project types have been identified in Figure 14 and in Table 4.

Table 4: Classification of River Corridor Project Types		
Segment Number	**Stream Condition**	**River Project Type**
M03	Good	Conservation Reach
M04	Fair	Highly Unstable Reach
M05	Fair	Highly Unstable Reach
M06	Fair	Highly Unstable Reach
M07	Fair	Highly Unstable Reach
M08	Fair	Highly Unstable Reach
M09-A	Fair	Highly Unstable Reach
M09-B	Fair	Moderately Unstable Reach
M10	Fair	Highly Unstable Reach
M11-A	Good	Conservation Reach
M11-C	Fair	Highly Unstable Reach
M12	Good	Moderately Unstable Reach
T2.01-A	Fair	Highly Unstable Reach
T2.01-B	Fair	Moderately Unstable Reach
T3.01-A	Fair	High Recovery Reach
T3.01-B	Fair	Highly Unstable Reach
T4.01-A	Fair	Highly Unstable Reach
T4.01-B	Fair	Highly Unstable Reach
T5.01	Fair	Highly Unstable Reach
T6.01	Good	High Recovery Reach
T7.01	Fair	Highly Unstable Reach

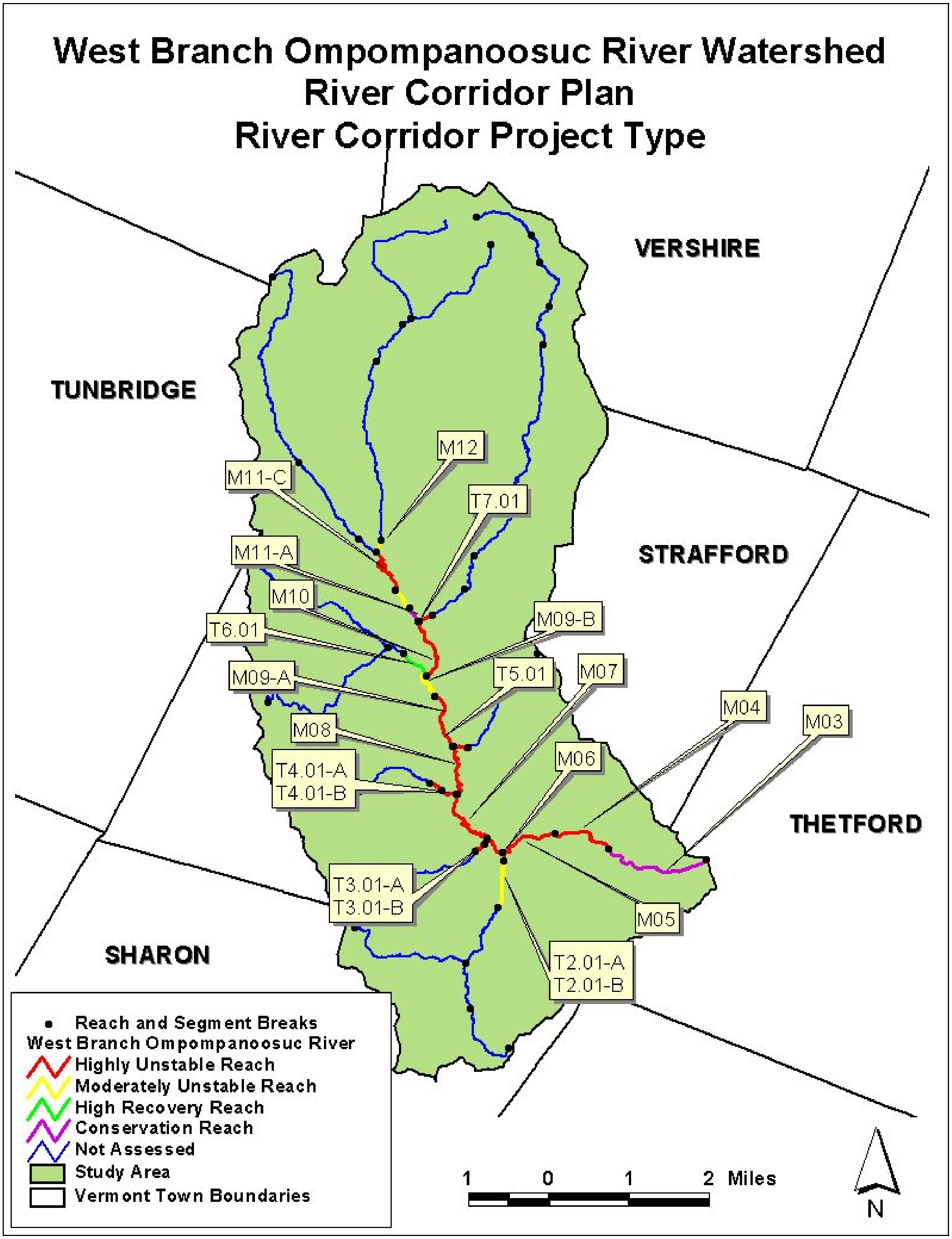

Figure 14: Restoration project types.

7.3 Specific Project Strategies

The following sections provide information on the six river corridor project types defined by the VDEC. Each project type includes a table outlining major strategies that may be employed at specific reaches. Following the table are general recommendations for action adopted from the VDEC worksheet, "Using geomorphic assessment data to guide the development of River Corridor Management Plans to achieve: Fluvial Erosion Hazard (FEH) Mitigation; Sediment and Nutrient Load Reduction; ecological-based River Corridor Conservation".

7.3.1 Conservation Reaches

Conservation reaches are generally in stable geomorphic condition and need little restoration work. In Strafford, only two conservation reaches were identified on the mainstem. These reaches typically have a healthy riparian buffer (see Figure 15) which lend to their stability. Conserving a riparian corridor along these reaches is good policy. General strategies for restoration may include the following:

- IMPLEMENT FEH ZONES
- PROTECT RIVER CORRIDOR
- REPLACE UNDERSIZED STRUCTURES IF NECESSARY

Figure 15: Reach M03, has a healthy riparian buffer that provides an opportunity for conservation.

7.3.2 High Recovery Reaches

High recovery reaches are generally in good to fair geomorphic condition and exhibit expected channel dimensions, profile, and patterns (Figure 16). These reaches may have already undergone significant adjustment or may be prevented from undergoing a major adjustment process through proactive work. Restoration of these reaches is best approached with a passive or light active approach to restoration. General strategies for returning these river segments to health may include the following:

- PLANT RIPARIAN BUFFERS
- IMPLEMENT FEH ZONES
- PROTECT RIVER CORRIDOR
- REPLACE UNDERSIZED STRUCTURES IF NECESSARY
- ATTENUATE STORMWATER IF NECESSARY
- TREAT STREAMBANK FAILURE THROUGH MINIMALLY INVASIVE APPROACHES IF THERE IS A THREAT TO PROPERTY OR INFRASTURE.
- CONDUCT PHASE 3 (IF NECESSARY)

Figure 16: Reach T2.01-B, Downer Forest Brook, is an exemplary high recovery reach.

7.3.3 Moderately Unstable Reaches

Moderately unstable reaches may not have expected channel dimensions, patterns, or profile (see Figure 17). Moderately unstable reaches are best approached through conducting alternatives analysis in order to determine the best strategy for restoration. General strategies for implementation may include the following:

- IMPLEMENT FEH ZONES
- PROTECT RIVER CORRIDOR
- REPLACE UNDESIZED STRUCTURES
- PLANT RIPARIAN BUFFERS
- ATTENUATE STORMWATER IF NECESSARY
- CONDUCT A PHASE 3 ASSESSMENT AND ALTERNATIVES ANALYSIS

Figure 17: Reach M12, which begins at the confluence of Tunbridge Brook, is moderately unstable.

7.3.4 Highly Unstable Reaches

Restoration of highly unstable reaches is best approached with caution. These reaches are often severely incised, aggrading, or exhibiting major planform or widening processes (see Figure 18). Passive restoration techniques are preferred, as active geomorphic restoration of unstable reaches is often very expensive and unsuccessful. The very dynamic nature of these streams lends to the challenge of active restoration. The best technique may be to relieve the stream of obvious stressors such as undersized structures or other impairments to sediment transport and then to look for opportunities to develop a new floodplain. General strategies that are appropriate for these river segments are to:

- IMPLEMENT FEH ZONES
- PROTECT RIVER CORRIDOR
- REPLACE UNDERSIZED STRUCTURES
- PLANT RIPARIAN BUFFERS (SET AWAY FROM THE TOP OF BANK)
- ATTENUATE STORMWATER IF NECESSARY

Figure 18: M07 is a highly unstable reach that is undergoing major geomorphic adjustment.

8.0 PRIORITY PROJECT IDENTIFICATION

8.1 General Recommendations for Project Prioritization

The following topics have been prepared by the Mike Kline (ANR) to help guide communities in prioritizing river restoration projects.

Prioritizing River Corridor Protection:
Higher Priority – Give higher priority for river corridor protection for highly sensitive reaches that are critical for attenuating floodwaters and sediment (from upstream to downstream) or sensitive reaches where there is a major departure from equilibrium conditions and development is threatening the stream corridor.

Lower Priority – Wooded corridors experiencing very little threat from encroachment and less sensitive reaches not playing a significant role in storing floodwaters and sediment in the watershed may be given lower priority for river corridor protection.

Prioritizing River Buffer Planting:
Higher Priority – It is important to establish a buffer of vegetation on all reaches from a water quality and habitat standpoint. From a stream stability standpoint, give higher priority to tree planting, as a stand alone treatment or in combination with stream bank stabilization, on those sensitive reaches that are vertically stable.

Lower Priority – Give lower priority to tree planting, as a stand alone treatment or in combination with streambank stabilization, on those reaches, while exhibiting stable conditions, are extremely sensitive due to their watershed location. On areas where active adjustment is occurring, use low cost native grasses and shrubs in the near bank region and more expensive tree stock that may mature and lend to long term stability should the stream migrate to the outer extent of its belt width.

Prioritizing Streambank Stabilization:
Higher Priority - *Give* priority to geomorphically stable reaches where stabilization would slow down lateral movement enough to allow for the re-establishment of a riparian buffer. Also give priority to areas where human-placed structures are at high risk and not taking action may result in increased erosion risk to lands that may otherwise have the opportunity to establish a riparian buffer.

Lower Priority - A lower priority may be given to reaches where there is no conflict with the erosion process and the increase in sediment to downstream reaches may contribute beneficially to the floodplain development process.

Prioritizing the Arresting of Streambed Incision:
Higher Priority - Reaches where the bed lowering process will lead to a significant loss of floodplain and/or human-placed structures if a channel evolution process were to be initiated may be given high priority for arresting streambed incision.

Lower Priority – Reaches where natural grade controls exist upstream of the nickpoint and where the reach is sensitive to high bed load deposition and the nickpoints are a result of meander cutoffs and braiding may be given lower priority for arresting migrating nickpoints. In these instances floodplain reconnection may be a relatively rapid process.

Prioritizing Berm Removal:
Higher Priority – Reaches where a significant (>50%) portion of the river corridor would become accessible to the stream for meander redevelopment and/or floodplain access, if the berm were removed, may be given higher priority. Berm removal is also of higher priority if the berm constitutes the predominate reason why the reach is incised and/or human structures would not be at greater risk to flood inundation or erosion if the berm were removed.

Lower Priority – Berms vegetated with mature trees may be given lower priority for removal. The removal of such berms may cause major land disruption and habitat impacts, and the benefits to the channel are less certain. Berm removal as a stand alone treatment on reaches that would be severely incised even if the berm were removed may also be of lower priority.

Prioritizing the Removal or Replacement of Structures:
Higher Priority – Those structures which are derelict (i.e., no longer serving as stream crossing or flow control structure), which contribute to a significant increase in erosion

hazard due to a constriction-related disruption of sediment transport in the system (i.e., major aggradation upstream and/or degradation downstream of the constriction) and/or are likely to result in an avulsion of the channel during a storm event due to blockage or alignment issues may be given higher priority for the removal or replacement of structures.

Lower Priority – Those structures which, if removed, would result in little change in level of erosion hazard at the site and the removal would potentially result in the need for restoration of the channel due to changes in stream conditions and/or sediment transport may be given lower priority.

Prioritizing Restoration of Incised Reaches:
Higher Priority – Give higher priority to restoration of incised reaches where it is possible, due to the lack of encroachment, to either passively or actively restore some degree of floodplain function at a lower elevation. This may include the rare, but important, opportunities to restore the river from a recent channel avulsion that has disconnected from the former floodplain.

Lower Priority – Reaches with little to no opportunity to restore meanders and floodplain and the restoration would mainly involve placing structures to minimize erosion hazards, ensure sediment transport, and improve habitat may be given lower priority for restoration. Also of lower priority is the active restoration of reaches that incised due to changes in the hydrologic and sediment regimes of the watershed.

Prioritizing Restoration of Aggraded Reaches:
Higher Priority – Reaches aggrading and widening at a localized scale due to bank erosion are more likely to benefit from active restoration.

Lower Priority – Active restoration of reaches that are aggrading due to changes in the hydrologic and sediment regimes of the watershed may be of lower priority.

8.2 Specific Project Recommendations for Strafford

Specific project recommendations are made in Table 5 and Figure 19. The following paragraphs offer further explanation for management of the West Branch.

<u>Reach M12:</u> This is a transitional reach between steeper headwater reaches and the valley bottom of the West Branch. It has been historically straightened and seems to have accepted this new channel. The long term stability of this channel may be assisted in the long term if the existing riparian buffer were widened and protected. - *See Prioritizing Buffer Planting.*

<u>Reach M11-C:</u> This reach is undergoing major adjustments and may be left to develop its own course. Historic channel straightening and armoring in this reach has only prolonged the channel evolution process. The best approach is to protect a wide corridor around this reach and to prevent further disturbance of the corridor. – *See Prioritizing River Corridor Protection*

Reach M11-B: This reach appears to have retained floodplain access and sediment storage due in part to the work of beavers. No active restoration work is recommended for this reach. *– See Prioritizing River Corridor Protection*

Reach M11-A: This seems to be a stable reach. Long term stability may be encouraged by preventing further encroachment and encouraging buffer regeneration. *– See Prioritizing River Corridor Protection*

Reach M10: Due to historic channel straightening this reach has become highly unstable. Left untouched, the reach will continue to widen and undergo planform adjustment. Because of its proximity above the Upper Village, this reach may be considered for an alternatives analysis to determine if an active geomorphic restoration project in portions of this reach may benefit the watershed. *– See Prioritizing Restoration of Incised Reaches*

Reach M09-B: This reach is likely being impacted by channel straightening and loss of floodplain in Reach M10. Past channel stabilization projects have failed due to instability upstream. The channel is likely to continue to actively adjust in this reach and may be allowed to do so. Access to floodplain will assist long term stability at this site and therefore the berm on the left bank may be considered for removal. *– See Prioritization of Berm Removal*

Reach M09-A: Historic channel management in this reach has caused it to incise and become highly unstable. Limited benefit to upstream and downstream reaches would be realized by conducting an expensive active geomorphic approach at this time. It is best to allow this reach to continue to adjust and to protect the river corridor through this reach in order to allow for future adjustment. *– See Prioritizing River Corridor Protection*

Reach M08: Historic channel management in this reach has also caused it to incise and become highly unstable. Some benefits to the reach and surrounding property may be realized by replacing the undersized bridge on the Justin Morrill Highway that crosses this reach. Replacing this bridge may help reduce localized adjustment. The rest of the reach would benefit by protecting the river corridor through this reach in order to allow for future adjustment. *– See Prioritizing River Corridor Protection and Prioritizing Structure Replacement*

Reach M07: This is a highly active reach that is undergoing major adjustments. Protection of the river corridor in order to continue to allow the stream to adjust through this section is recommended. A private bridge could be replaced in order to ensure future access for the landowner while improving sediment and water transport in the area of the structure. *– See Prioritizing River Corridor Protection and Prioritizing Structure Replacement*

Reach M06: This reach has been impacted by historic floodplain encroachment. An alternatives analysis in this reach may show that increasing floodplain (while maintaining and possibly enhancing land use expectations for the community) in this reach may contribute to stability through the village. *– See Prioritization of Incised Reaches*

Reach M05: This reach is an incised channel that has lost access to much of its floodplain. Removal of the town sand storage facility is recommended. A floodplain redevelopment project may be investigated in association with this relocation project as the reach would benefit from improved floodplain access. *– See Prioritization of Incised Reaches*

Reach M04: This reach is fairly stable. If an opportunity arises, the community may want to investigate replacing the Tyson Road Bridge, as it is undersized and causing localized instability. *– See Prioritization of Structure Replacement*

Reach M03: The river corridor along this reach may be protected from encroachment and the stream allowed to maintain its dynamic stability. *– See Prioritizing River Corridor Protection*

Reach T7.01 (Old City Brook): No further encroachment of the river corridor would benefit the stream. *– See Prioritizing River Corridor Protection*

Reach T6.01 (Brook Road Brook): This reach would benefit from an agriculture assistance program such as the Conservation Reserve Enhancement Program (CREP) in order to minimize the impacts from farming on this reach. *– See Prioritizing River Corridor Protection*

Reach T5.01 (Alger Brook): This reach may be allowed to adjust naturally. The stream corridor would benefit from protection. *– See Prioritizing River Corridor Protection*

Reach T4.01 (Carpenter Hill Brook): This reach would also benefit from an agriculture assistance program such as CREP in order to minimize the impacts from farming on this reach. The lower part of this reach (segment A) would benefit from being allowed to adjust naturally. The stream corridor could also be protected for maximum long term protection. *– See Prioritizing River Corridor Protection*

Reach T3.01 (Route 132 Brook): This reach may be maintained in its current configuration through the village in order to reduce flooding to existing property owners. The lower portion of the reach (Segment A) may be allowed to adjust naturally. It is important to limit further encroachment of the stream corridor. *– See Prioritizing River Corridor Protection*

Reach T2.01 (Downer Forest Brook): The upper portion of the brook would benefit from protection from development in the stream corridor, and adjacent, highly unstable valley walls. The lower portion (segment A) may be maintained in its current configuration through the village. *– See Prioritizing River Corridor Protection*

Table 5: Prioritization of River Corridor Project Types

Project ID Number	Segment Number	River Project Type	Specific Strategy					Project Description (including Potential Constraints and/or Opportunities)	Priority
			River Corridor Protection	Replace Undersized Structure(s)	Develop New Floodplain and Plant Buffer	Plant Riparian Buffer	Other		
1	M12	MU	√			√		Maintain and expand existing buffer for long term stability	L
2	M11-C	HU	√					This reach is redeveloping floodplain; Recommend allowing river to adjust naturally. Protection of the river corridor through this reach would be beneficial to encourage long term stability.	L
3	M11-A	CR	√	√		√	Protect and enhance existing buffer	Although a few houses are within the river corridor, this reach has a fairly healthy buffer. An undersized bridge in this reach could be removed.	**M**
4	M10	HU	√	√	√			This reach suffers from historic straightening. Landowners may want to consider an alternatives analysis for floodplain redevelopment project. Attenuation of floodwaters and sediment in this reach may reduce pressure on the stream as it passes through the Upper Village.	**H**
5	M09-B	MU	√			√	Remove berm	A berm on the left bank downstream of the Brook Road bridge may prevent the stream from accessing its floodplain. This reach is also likely being impacted by increased sediment transport in reach M10 which is leading to excessive sediment deposition in this reach.	**H**

Table 5: Prioritization of River Corridor Project Types

Project ID Number	Segment Number	River Project Type	Specific Strategy					Project Description (including Potential Constraints and/or Opportunities)	Priority
			River Corridor Protection	Replace Undersized Structure(s)	Develop New Floodplain and Plant Buffer	Plant Riparian Buffer	Other		
6	M09-A	HU	√					Historic photographs show this reach has been greatly straightened. Limited existing infrastructure to protect, therefore consider letting the channel adjust on its own.	L
7	M08	HU	√	√				Replace bridge over Justin Morrill Highway to remove channel and floodplain constriction.	**M**
8	M07	HU	√	√				Replace undersized private bridge to allow future access for private landowner. Landowner recognizes river's movement and has voluntarily planted floodway to help create roughness during high flows.	**M**
9	M06	HU	√		√			Landowners may consider determining the feasibility of a project in this area. Remove high spot at bend in river next to soccer field to create floodplain and help reduce flood hazard through village. Existing recreational use of this small area would need to be discontinued.	**H**
10	M05	HU	√		√			Relocate town sand storage. Landowners may consider a floodplain redevelopment project at this site. Also consider floodplain project at beginning of rec path; existing land use, existing stream conditions, and public connection make this a good project.	**H**

Table 5: Prioritization of River Corridor Project Types									
Project ID Number	Segment Number	River Project Type	Specific Strategy					Project Description (including Potential Constraints and/or Opportunities)	Priority
			River Corridor Protection	Replace Undersized Structure(s)	Develop New Floodplain and Plant Buffer	Plant Riparian Buffer	Other		
11	M04	HU	√	√				Consider replacing undersized bridges on this reach in order to improve sediment transport and reduce potential flood hazard.	L
12	M03	CR	√				Preserve existing buffer	The entire reach is well forested, conservation of the corridor will provide for long-term benefits to the river.	**M**
13	T7.01	HU	√					This reach would best be maintained as a transport reach to protect existing infrastructure.	L
14	T6.01	HR	√	√		√	Remove berm at lower end; Livestock exclusion	This reach would benefit from a CREP project that would exclude livestock from the stream, locate an alternative watering source, and plant a riparian buffer. Also there are berms at the lower end that could be removed to improve floodplain access.	**H**
15	T5.01	HU	√					This reach is highly incised. Existing land use is pasture and field. Recommend allowing to adjust naturally.	L
16	T4.01-B	HU	√				Livestock exclusion	This reach would benefit from a CREP project that would exclude livestock from the stream, locate an alternative watering source, and plant a riparian buffer.	**H**
17	T4.01-A	HU	√					This reach is highly incised. Existing land use is field. Recommend allowing to adjust naturally.	L

Table 5: Prioritization of River Corridor Project Types

Project ID Number	Segment Number	River Project Type	Specific Strategy					Project Description (including Potential Constraints and/or Opportunities)	Priority
			River Corridor Protection	Replace Undersized Structure(s)	Develop New Floodplain and Plant Buffer	Plant Riparian Buffer	Other		
18	T3.01-B	HU	√			√		This reach is best maintained as a transport reach in order to protect existing infrastructure through South Strafford Village. Voluntary buffer planting from local landowners could be encouraged.	L
19	T3.01-A	HR	√					This reach is highly incised. Existing land use is field. Recommend allowing to adjust naturally.	L
20	T2.01-B	MU	√					The corridor around this reach is a good opportunity to be protected. Land use in the surrounding subwatershed could be encouraged be very careful to not concentrate stormwater towards the very unstable valley walls of this reach.	L
21	T2.01-A	HU	√			√		This reach has been historically straightened and will likely be maintained in its current configuration to protect property in the Village of South Strafford. Voluntary buffer enhancement could be encouraged.	L

River Corridor Project Type:
CR = Conservation Reach
HR = High Recovery Reach
MU = Moderately Unstable Reach
HU = Highly Unstable Reach
Priority Ranking:
H = Higher
M = Medium
L = Lower

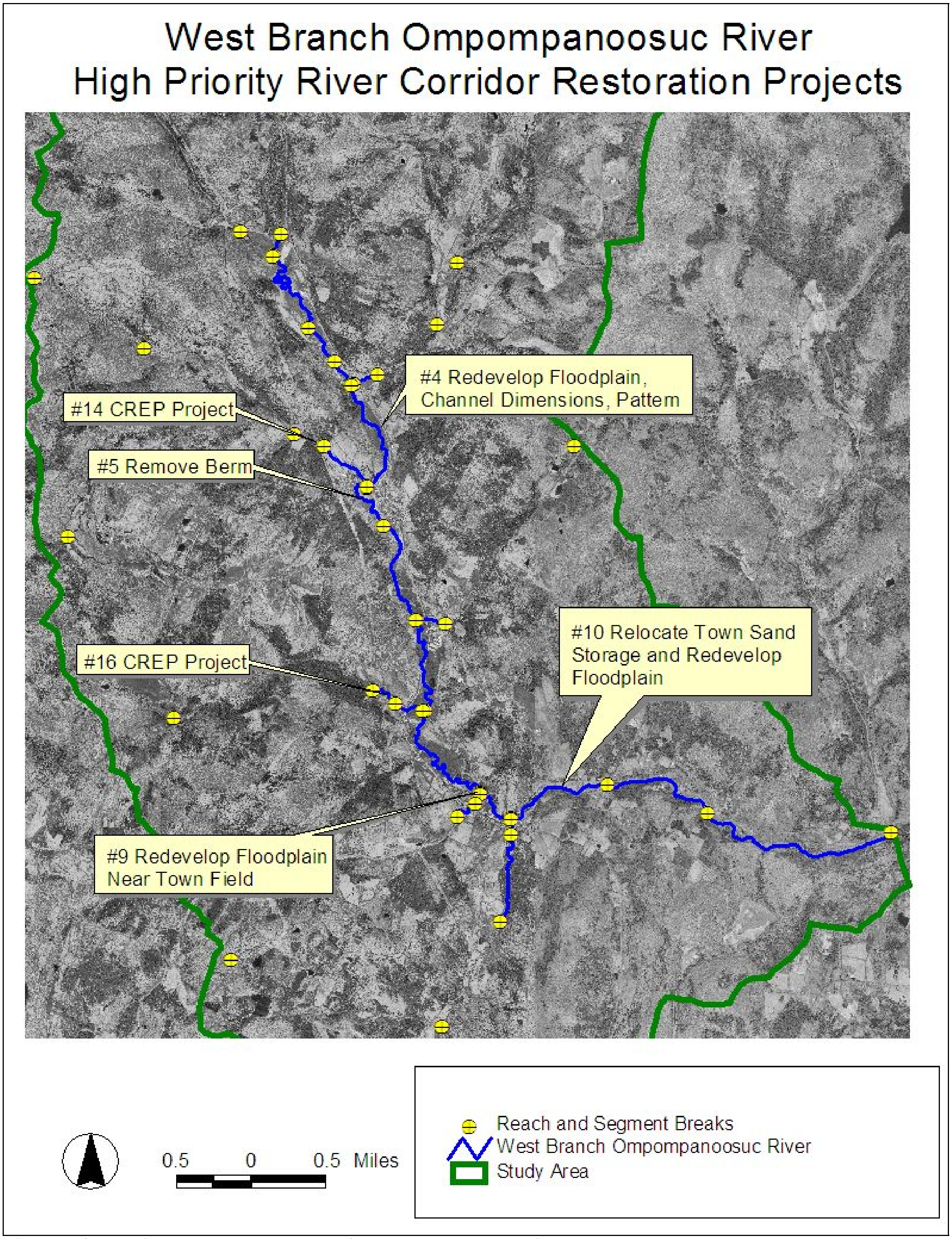

Figure 19: Project study area map of recommended projects.

9.0 PLAN IMPLEMENTATION

Implementation of this River Corridor Management Plan will require participation of the town, state, federal, and local organizations and most importantly local landowners.

9.1 Public Review and Revision of River Corridor Management Plan

River Corridor protection is best accomplished at a community level. While specific landowners may have key roles in restoring certain pieces of the river, the entire watershed is subject to the quality of stewardship provided to the land by each and every landowner, whether they live next to the river or up on the ridgeline. Review and continuing revision of this River Corridor Management Plan by the Strafford community will encourage community awareness and participation in the restoration of the West Branch of the Ompompanoosuc.

9.2 Develop and Adopt a River Corridor Overlay District and FEH Zone

The Town of Strafford would benefit from continuing to work with the River Management Section and the Two Rivers Ottauquechee Regional Planning Commission in a public planning process to review the role of a River Corridor Overlay District in town planning and to develop a draft ordinance for public review. Incorporation of FEH maps in the town planning process may also make Strafford eligible for additional incentives, including priority for State restoration, flood recovery, and community development funding. More importantly, however, adoption of an FEH zone will transition the Strafford community from a reactionary role in river management to a proactive role that recognizes the dynamic nature of river systems and plans accordingly in order to minimize future flood damage, minimize maintenance and repair costs of infrastructure, and maximize the health of the fishery and water quality.

9.3 Proceed with Conservation / Restoration Projects

The Strafford Conservation Commission has a great opportunity to work closely with the VDEC and river scientists to continue to develop and implement restoration and conservation projects in the West Branch watershed based on the recommendations of this plan.

9.4 Address Undersized Structures

The Town of Strafford would assist the recovery and further impairment of the West Branch by proactively replacing undersized structures in the watershed. With the assistance of the Bridge and Culvert survey, the Town could begin to work towards replacing all Priority I structures in the watershed. The Town of Strafford may also choose to assist in the design review of new private and public structures in order to prevent future geomorphic and aquatic life impairment, as well as possible flood hazards that may result from poorly suited structures.

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