Bear Creek **Environmental**
297 East Bear Swamp Road, Middlesex, Vermont 05602
Phone: (802) 223-5140 / **Fax:** (802) 229-4410

Ayers Brook
River Corridor Management Plan
Brookfield, Braintree, and Randolph, Vermont

June 22, 2007

Prepared by:

Michael Blazewicz
Watershed Scientist

And

Mary Nealon
Principal/Aquatic Biologist

Prepared for:

The White River Partnership
99 Ranger Road
Rochester, VT 05767

Ayers Brook
River Corridor Management Plan
Brookfield, Braintree, and Randolph, Vermont

TABLE OF CONTENTS

1.0 PROJECT OVERVIEW 1
1.1 LOCAL PROJECT GOALS 2
1.2 STATE OF VERMONT RIVER MANAGEMENT GOALS 3
2.0 PROJECT BACKGROUND INFORMATION 5
2.1 GEOGRAPHIC SETTING 5
2.2 GEOLOGIC SETTING 11
2.3 ECOLOGICAL SETTING 12
2.4 FLOOD HISTORY 13
2.5 CHANNEL AND FLOODPLAIN MANAGEMENT HISTORY 15
2.6 PAST AND PRESENT WATER QUALITY AND BIOLOGICAL DATA 16
3.0 STREAM GEOMORPHIC ASSESSMENTS 19
3.1 PHASE 1 STREAM GEOMORPHIC ASSESSMENT RESULTS 19
3.2 PHASE 2 STREAM GEOMORPHIC ASSESSMENT RESULTS 21
4.0 WATERSHED SCALE HYDROLOGIC AND SEDIMENT MODIFIERS 23
4.1 HYDROLOGIC ALTERATIONS 23
4.2 SEDIMENT MODIFIERS 28
5.0 REACH SCALE STRESSORS 31
5.1 CHANNEL SLOPE MODIFIERS 31
5.2 BOUNDARY CONDITIONS 35
5.3 BRIDGE AND CULVERTS AS REACH SCALE STRESSORS 38
6.0 STREAM ADJUSTMENT, SENSITIVITY, AND FLUVIAL EROSION HAZARD MAPPING 40
6.1 CHANNEL EVOLUTION 40
6.2 STREAM SENSITIVITY 45
6.3 FLUVIAL EROSION HAZARD ZONES 49
6.4 RIPARIAN CORRIDOR WIDTHS FOR PROTECTION 50
7.0 REACH SCALE PROJECT IDENTIFICATION AND PRIORITIZATION 52
7.1 RESTORATION APPROACHES 52
7.2 RIVER CORRIDOR PROJECT TYPES 52
8.0 PRIORITY PROJECT IDENTIFICATION 56
8.1 RECOMMENDATIONS BY SEGMENT FOR RESTORATION AND PROTECTION 56
8.2 SPECIFIC PROJECT RECOMMENDATIONS FOR AYERS BROOK 57
9.0 PLAN IMPLEMENTATION 64
10.0 REFERENCES 65

Bear Creek **Environmental**
297 East Bear Swamp Road, Middlesex, Vermont 05602
Phone: (802) 223-5140 / **Fax:** (802) 229-4410

Ayers Brook
River Corridor Management Plan
Brookfield, Braintree, and Randolph, Vermont

Executive Summary

The Ayers Brook is a tributary to the Third Branch of the White River and defines a significant valley shared by the towns of Brookfield, Braintree, and Randolph. A multitude of resources, at the cost of private landowners and state taxpayers, have been spent on protecting property adjacent to the river by methods such as channel straightening, dredging, and streambank armoring. This River Corridor Management Plan includes 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 Ayers Brook and to shift the focus of management projects from short term control (2 year planning) to long term equilibrium and stability (50 and even 100 year planning). This plan is meant to be used as part of the local planning process. Annual review of this plan is suggested to identify where progress has been made and to pinpoint areas in need of improvement.

Beginning in 2004, fluvial geomorphic assessments of the Ayers Brook, using Vermont Department of Environmental Conservation (VDEC) protocols, were sponsored by the White River Partnership (WRP). These assessments studied the past and current condition of the river, and made predictions about how the Ayers Brook will continue to adjust in the future. 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 stream geomorphic assessments provide evidence that the Ayers Brook is undergoing active adjustment processes. Along much of the Ayers Brook mainstem, historic channel management activities, such as straightening and bank armoring, have caused incision (lowering of the elevation of the river bed) leaving the floodplain inaccessible during normal high water events. 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 channel instability. The traditional approach of attempting to control erosion employs bank armoring (rip-rap), which is common on the Ayers Brook, but has lead to further instability in the system. Also, there are many encroachments upon the river corridor mostly in the form of roads and bridges, but also some residential and commercial development. 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 over time; 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 Ayers Brook 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.

In addition to identifying restoration strategies, this Plan provides recommendations for defining a Fluvial Erosion Hazard Zone to further assist the Towns of Brookfield, Braintree, and Randolph with managing and restoring the Ayers Brook watershed. The purpose of defining these zones is to 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 hazard

Bear Creek Environmental
297 East Bear Swamp Road, Middlesex, Vermont 05602
Phone: (802) 223-5140 / Fax: (802) 229-4410

Ayers Brook
River Corridor Management Plan
Brookfield, Braintree, and Randolph, Vermont

1.0 PROJECT OVERVIEW

Bear Creek Environmental (BCE) was retained by the White River Partnership (WRP) to write a River Corridor Management Plan for the area of the Ayers Brook which flows through the Towns of Brookfield, Braintree, and Randolph, Vermont. The project has been funded by the White River Partnership as part of a grant with the New Hampshire Charitable Foundation through the Upper Connecticut River Mitigation and Enhancement Fund. Data and information for the Ayers Brook Watershed was obtained from the Vermont Department of Environmental Conservation (VDEC), the Vermont Center for Geographic Information (VCGI), the Vermont Department of Fish and Wildlife, the Vermont Mapping Program, the Towns of Randolph, Braintree, Brookfield, and Roxbury, and the WRP. 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 Ayers Brook, 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 local town plans. 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 Ayers Brook watershed, it is also important to note that the VDEC has developed a water quality improvement plan for the entire White River Basin. The White River Basin Plan was completed in November of 2002, after several years or stakeholder meetings. The White River Basin Plan describes water quality and water resource problems in the basin and recommends strategies for remediation of these problems. "The principle purpose of the plan is to improve water quality by guiding the Agency of Natural Resources in its own work and in collaborative projects with the public as well as other State and federal agencies" (Vermont Agency of Natural Resources 2002).

This River Corridor Management Plan outlines goals and strategies for restoring the Ayers Brook watershed with specific focus on the river corridor along the mainstem of the river. It provides an overview of 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 Ayers Brook River Corridor Management Plan set out by the WRP are to develop a strategy for prioritizing the various protection and restoration efforts to effectively restore Ayers Brook, created in cooperation with local landowners and community members. This goal is outlined below and addressed with general and specific strategies in sections 7.0 and 8.0 of this document.

1.1.1 Prioritize protection and restoration efforts to restore Ayers Brook

Protection and restoration efforts on Ayers Brook provide many opportunities. The Ayers Brook community is in a position to benefit from various recreational and aesthetic values of the Ayers Brook and its tributaries. The community will also benefit from unpolluted surface and groundwater. Additionally, a stable stream will benefit the community because there will be a less likelihood that damage from flood and erosion may cost landowners and taxpayers money. Addressing the problems in a systemic way is beneficial for channeling funding, programmatic, and volunteer efforts to the root sources of the problems that are affecting the Ayers Brook watershed. For these reasons, the prioritization of protection and restoration efforts is the main purpose of this River Corridor Management Plan.

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 the Ayers Brook. The state management goal is to, "manage toward, protect, and restore the equilibrium conditions of Vermont's 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. The Program seeks to conduct river corridor planning in an effort to remediate the geomorphic instability that is largely responsible for these problems in a majority of Vermont's rivers. Additionally, the Vermont River Management Program has set out to provide funding and technical assistance to facilitate an understanding of river instability and the establishment of well developed and appropriately scaled strategies to protect and restore river equilibrium (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 (Vermont Agency of Natural Resources 2006e), 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 changes in reach hydrology and sediment transport. Channel adjustment generally 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 2006e).

2.0 PROJECT BACKGROUND INFORMATION

2.1 Geographic Setting

2.1.1 Watershed Setting

Ayers Brook, located in central Vermont, is a major tributary to the Third Branch of the White River and has a watershed size of 37 square miles (Figures 1 and 2). The White River is within the Connecticut River Basin. The Ayers Brook watershed lies within the towns of Randolph, Braintree, Brookfield and Roxbury. The Ayers Brook watershed is dominated by forested land; however, most subwatersheds contain agricultural fields, cropland, or residential land as a sub-dominant land use. Forty one reaches were selected for a Phase 1 Stream Geomorphic Assessment and four reaches were selected for a Phase 2 Stream Geomorphic Assessment (Figure 2).

Geologically, the Ayers Brook watershed was historically reshaped by the advancement of late Wisconsonian ice (Larsen, et. al., 2004). Surficial deposits found in the watershed are from glacial Lake Hitchcock. As this glacial lake drained, sandy gravel deposits were left behind in the valley of the Third Branch of the White River. At the confluence of Ayers Brook and the Third Branch, a thick deposit of Lake Hitchcock sands created a large fan (Larsen, et. al., 2004). In general, the dominant soil types in the Ayers Brook watershed are therefore glacial lake deposits.

The lower reaches of Ayers Brook flow through a relatively gentle gradient valley. The upper reaches, generally within the Town of Brookfield, flow through a much steeper gradient valley. Most reaches within the watershed have a slope less than 10%. Except for the uppermost reach, the average slopes on the mainstem of Ayers Brook are all less than 1%.

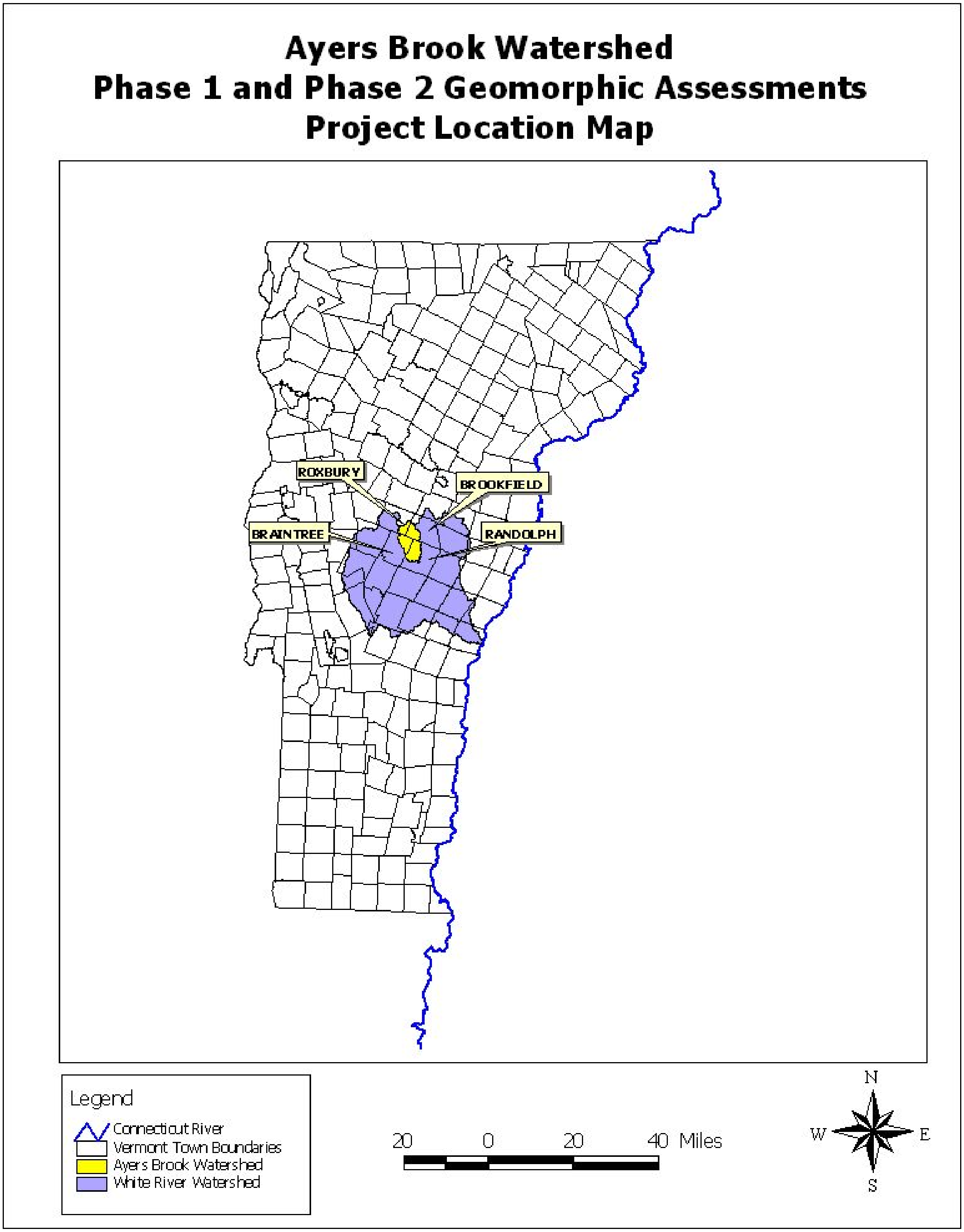

Figure 1: Project Location Map, Ayers Brook Watershed

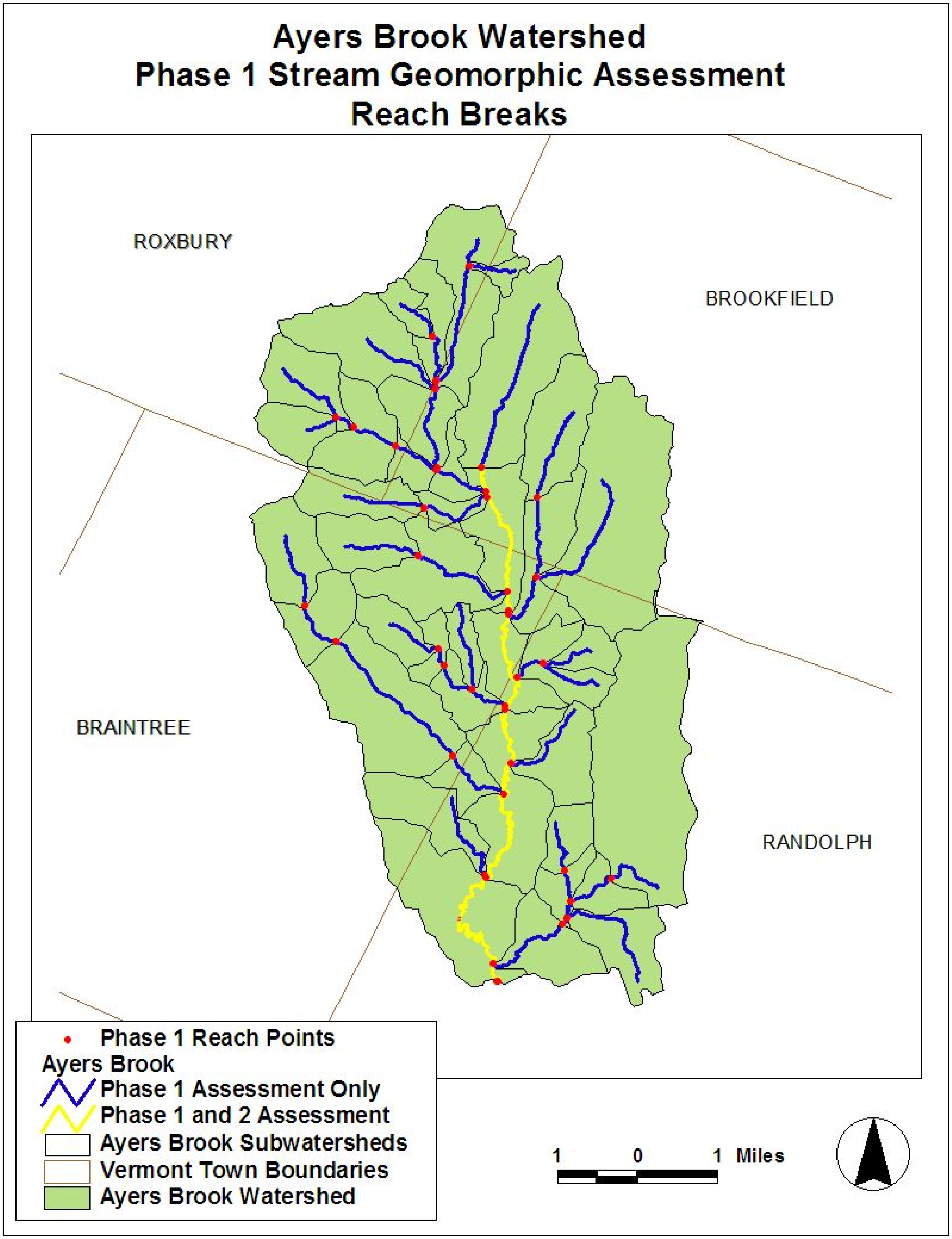

Figure 2: Overview of Study Area, Ayers Brook Watershed

2.1.2 Political Jurisdictions

The Ayers Brook watershed is predominately located in the Towns of Randolph, Braintree, and Brookfield; however, the northwest corner of the watershed is in the town of Roxbury. The Ayers Brook is located entirely within Orange County, Vermont. With the exception of Roxbury (which is a member of the Central Vermont Regional Planning Commission), the towns within the Ayers Brook watershed are members of the Two-Rivers Ottauquechee Regional Planning Commission.

There are specific water laws that govern our relationship with Ayers Brook and other rivers and streams in Vermont. According to the Vermont Institute for Government, "If it flows past or through your land, or you share a water boundary with others, it doesn't really belong to you, the way land belongs to you, or the trees. Water has a public quality to it, and you need to respect that." In the state of Vermont a Water Resources Board classifies waters and regulates the use of all public waters. The Agency of Natural Resources issues permits and appeals are heard by the Board, which has issued a body of decisions that form an important canon of water law in Vermont. The Vermont Supreme Court has also decided dozens of important cases on the water rights and responsibilities of landowners. The Army Corps of Engineers is active in enforcing the law of water in Vermont, whenever a wetland is threatened, when fill is added or removed from a stream bed, or when a project has an impact on rivers and lakes. Federal laws, including those guaranteeing clean water, also affect water use in Vermont (Vermont Institute for Government, 2001).

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 at very least 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. Randolph was chartered in 1781. 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. Ayers Brook falls into the southern green mountain biophysical range as classified by Thompson and Sorenson (2005). The area's settlement patterns, transportation and land use have historically been determined by its waterways, especially the White River and its major tributaries. The major land use patterns within the Ayers Brook watershed that exist today seem to have also followed the water courses and the hills, with forestry and logging activities on the steeper slopes and farming and settlements confined to the valleys and more moderately sloping lower elevation hills.

The land use within the watershed plays a significant 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 2004d).

As reported in the Phase 1 and 2 Stream Geomorphic Assessment (Blazewicz and Nealon 2006) the dominant watershed land cover/land use within the Ayers Brook Watershed is forest (Figure 3). Forty-five percent of the 41 subwatersheds analyzed in this study were found to have 10% or more crop or urban land use. The dominant land cover/land use within the river corridor was forest for all but three of the reaches. Fifty percent of the reaches were found to have 10% or more crop or urban land use in the river corridor.

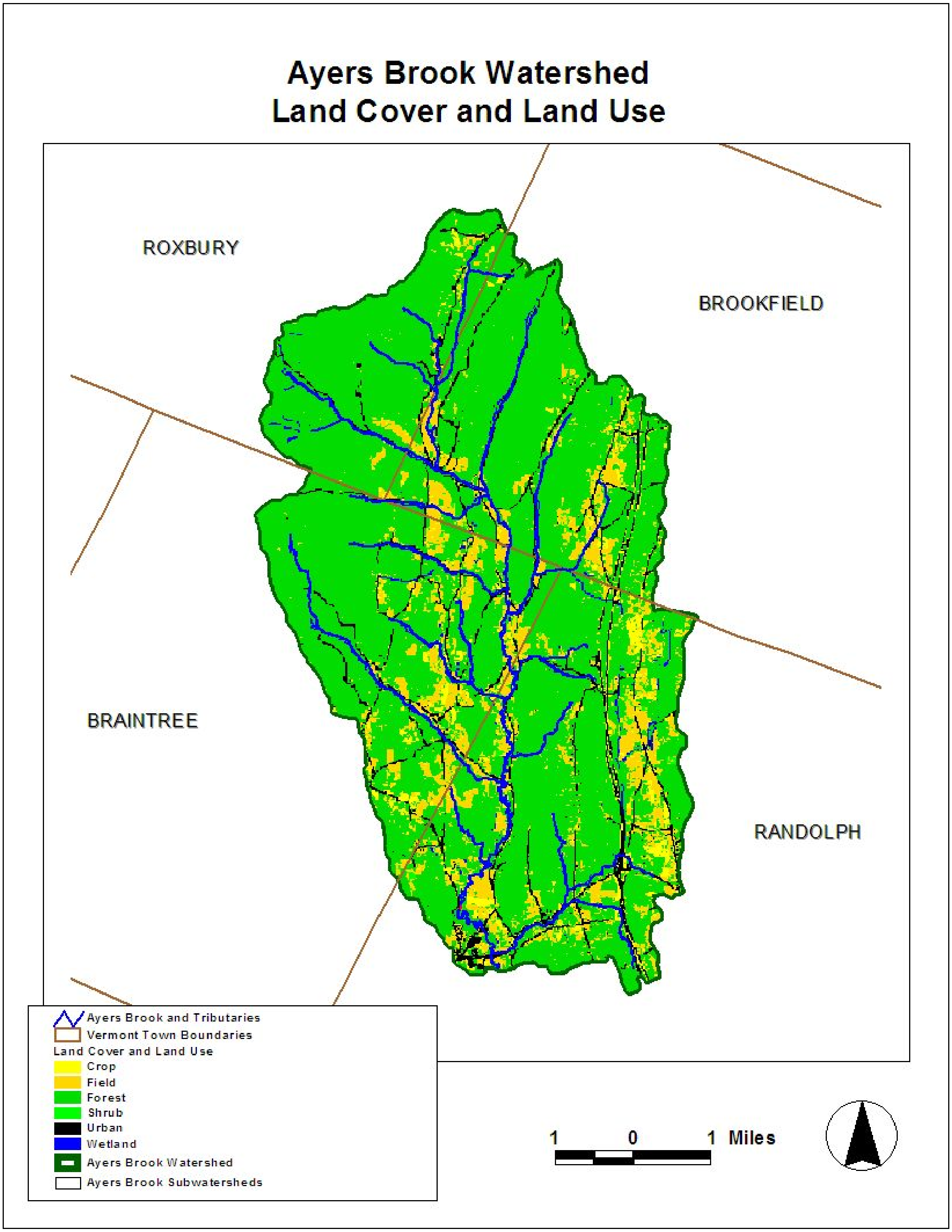

Figure 3: Ayers Brook Land Use, Land Cover Map

2.2 Geologic Setting

Geologically, this region was historically reshaped by the advancement of late Wisconsonian ice (Larsen, et. al., 2004). 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 the Wisconsin glaciation, Vermont was buried under an ice sheet up to a mile thick. During this event, the mountains and hills of the Ayers Brook watershed were softened further, stripping off the soils and earlier glacial deposits. All over the Ayers Brook 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 White River Valley. As this glacial lake drained, sandy gravel deposits were left behind in the valley of the Third Branch of the White River. At the confluence of Ayers Brook and the Third Branch, a thick deposit of Lake Hitchcock sands created a large fan deposit (Larsen, et. al., 2004) (see Figure 4). In general, due to the glacial history of the valley, the dominant soil types in the Ayers Brook watershed are glacial lake deposits and till. The upstream reaches of the mainstem, T2.04 and T2.03 had glacial till as a subdominant surficial geology while the lower two mainstem reaches (T2.02 and T2.01) had glacial lake deposits as a subdominant geology.

Figure 4: Glacial lake deposits are found in the lower reaches of the study area.

2.3 Ecological Setting

Northern hardwood forests and mixed coniferous forests cover the majority of acreage in the Ayers Brook watershed. 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 deposits, and bedrock is close to the surface in some areas. Sandy or gravelly soils derived from glacial outwash are found only locally, such as in Ayers Brook, as are soils formed in lake bed deposits (Thompson and Sorenson 2000).

2.4 Flood History

According to the Vermont Agency of Natural Resources document "Municipal Guide to Fluvial Erosion Hazard Mitigation" (2006a), "Of all the natural hazards experienced in Vermont, flooding is the most frequent, damaging, and costly." The guide documents that over the last 50 years, flood recovery has cost the state an average of $14 Million a year and that during the period of 1995-1998 alone, flood losses in Vermont totaled almost $57 Million. Of particular concern for towns and properties near streams, it notes that, "While some flood losses are caused by inundation (i.e. waters rise, fill, and damage low-lying structures), most flood losses in Vermont are caused by "fluvial erosion". Fluvial erosion is caused by rivers and streams, and can range from gradual bank erosion to catastrophic changes in river channel location and dimension during flood events."

The Municipal Guide further documents that, "Closer study of our rivers and streams reveals that Vermont's erosion hazard problems are largely due to pervasive, human-caused alteration during the past 150 to 200 years of our waterways and landscapes they drain. By end of the nineteenth century, forests had been cleared from many watersheds, resulting in major changes in watershed hydrology and sediment production. Towns and villages, the centers of commerce, grew on the banks of rivers, whose role in power generation and transportation at first outweighed flood risks. In addition, many watersheds were changed by development, agriculture, log drives, roads and railways." The legacy of this landscape manipulation is rivers and streams, such as Ayers Brook, which are unstable and prone to fluvial erosion (Vermont Agency of Natural Resources 2006a).

The town of Randolph was contacted for information regarding the flood history and channel management of the Ayers Brook watershed. According to the Joe Voci, the Public Works Director, Ayers Brook flooded south of Route 66 in Randolph in 1998 and in the mid 1970s. He recalled that houses on Route 66 where Ayers Brook crosses were damaged by floods in 1998. Linda Nissl, the Assistant Town Clerk for Randolph, also recalled that Ayers Brook flooded across Route 12 during the 1998 flood.

In Braintree, local officials did not recall of any significant flooding other than what has been recorded from the 1927 flood. Tuthill Doane, Emergency Coordinator for the town, remembered hearing that all of the houses on the right bank of Ayers Brook along Peth Road were washed out from that flood.

In order to better understand the flood history of Ayers Brook, 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. 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. The drainage area at the Ayers Brook gauge is 30.5 square miles.

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 5 below.

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

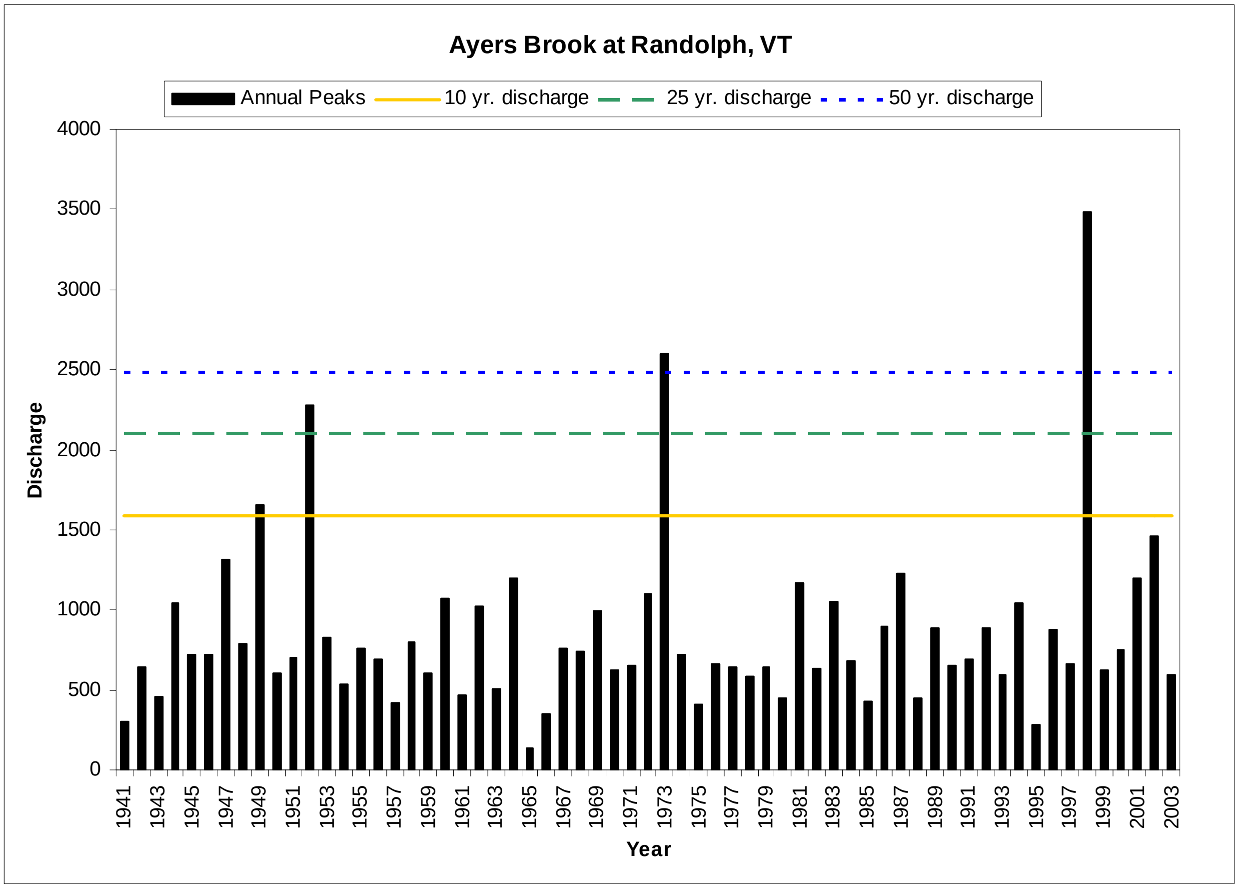

Figure 5: Flood frequency analysis for Ayers Brook.

2.5 Channel and Floodplain Management History

Historic channel management practices may have impacted the stability of Ayers Brook by increasing the energy in the channel leading to downcutting of the bed and channel adjustment. DEC River Management Engineer, Barry Cahoon, reported that gravel extraction has occurred on Ayers Brook below Route 66 (reach T2.01-A) during the past thirty years (personal communication 2006). Additionally, it is likely that there was some dredging associated with the channelization of many of the straightened sections adjacent to agriculture fields and buildings. Infrastructure and development adjacent to Ayers Brook may have also contributed to instability of the stream by restricting access to the floodplain and lateral migration. Floodplain encroachments resulted in the confinement of flows and an increase in stream power, thereby, leading to incision, erosion, and often increased flood damage.

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 Ayers Brook and its tributaries.

2.6.1 Water Quality Data

In 2001, the WRP launched a Water Quality Monitoring Program to better understand potential threats to water quality and public health. In the five years of monitoring for *E. coli*, samples taken out of Ayers Brook at Peth Road were found to be consistently quite high (Table 1). According to a 2005 Water Quality Monitoring Report issued by the White River Partnership, "The Town of Randolph was aware of a leak in a sewage pipe that ran under the River in the village as well as a problem with the sewer line that comes down Route 66 from Vermont Technical College and a failed private septic system on the Ayers Brook. In 2004 the Town was working to address all of these issues."

Table 1: *E. coli* DATA SUMMARY (WHITE RIVER PARTNERSHIP 2005)

River	Town	Site Name	Geometric Mean					
			2001	2002	2003	2004	2005	2006
Third Branch	Randolph	Ayers Brook		175	270	340	211	113
	Randolph	Adam's Brook - Randolph I-89	83	186	129	33	39	105

Sites higher than the EPA standard for recreational contact of 126 are shaded gray.

In addition to bacterial monitoring, the White River Partnership also monitored the temperature of Ayers Brook in order to assess thermal pollution. In 2002, Ayers Brook at the mouth had a 78°F Seven Day Maximum Average (SDMA). This prompted the WRP to put thermographs at the elementary school (near the mouth) and at the Menard Road crossing in 2003 and 2004. Overall it was found that the Ayers Brook warms significantly between the mouth and Menard Road (White River Partnership, 2005). In 2001 Adam's Brook had a thermograph which registered a SDMA of 79°F and exceeded 68°F 17% of the time. These temperature figures are important as agencies such as the Green Mountain National Forest are moving toward using 68°F as a threshold temperature for sustaining healthy trout populations as well. (White River Partnership, 2004)

In addition to the monitoring conducted by the WRP, the state of Vermont has recognized that the water quality of Ayers Brook is not pristine. According to the 2006 Vermont List of Impaired Waters (Vermont Agency of Natural Resources 2006g), the Ayers Brook has been listed (in Part C) as needing further study to determine whether elevated levels of Nickel and Chromium found in sediments are affecting aquatic life. In addition, from the mouth of the Brook upstream to Brookfield Gulf is considered morphologically unstable and the aquatic life and aesthetics are listed as being potentially impaired from excess sediment (Figure 6).

2.6.2 Fisheries Data

The Vermont Department of Fish and Wildlife have been surveying fish populations in the Ayers Brook and Adams Brook (a major tributary) since 1995. According to Rich Kirn, district Fisheries Biologist, the upper reaches of Ayers Brook support an abundant population of wild brook trout. Downstream, near East Braintree village, a few wild rainbow trout are also observed and populations can still be considered good in this reach. Further downstream, wild trout essentially disappear, presumably due to elevated water temperatures and habitat deficiencies. Closer to the mouth (Route 12), a few wild trout including brook, brown and rainbow trout are again found, probably due to the influence of Adams Brook. Adams Brook, in the vicinity of Route 12, was also sampled in 2006. This reach appears to support a moderate population of wild brook, brown and rainbow trout (Kirn 2007).

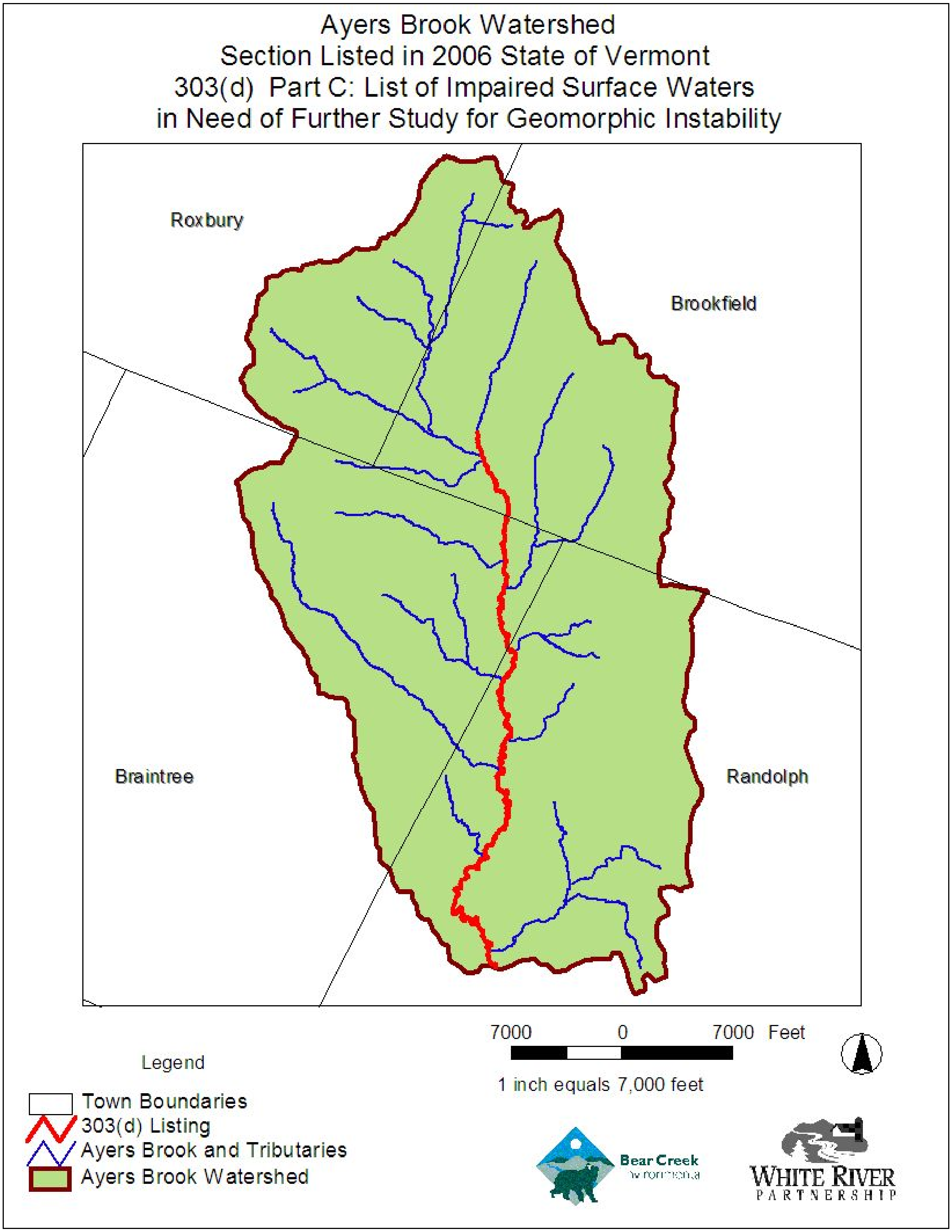

Figure 6: Ayers Brook on 303(d) (Part C) List of Priority Surface Waters in need of further assessment due to morphological instability.

3.0 STREAM GEOMORPHIC ASSESSMENTS

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 that determines what adjustment processes are taking place and predicts how the river will continue to evolve in the future. Phase three is a reach level survey and design of restoration projects.

The White River Partnership retained several consultants over several years to conduct Phase 1 & 2 geomorphic assessments and bridge and culvert assessments of the Ayers Brook. A quality assurance check and report from these data were generated by Bear Creek Environmental (Blazewicz and Nealon 2006). These data helped to pinpoint areas of concern and set the stage for the development of this River Corridor Management Plan.

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. Due to an incomplete Phase 1 data set, the overall Phase 1 analysis was evaluated for only the four mainstem reaches of Ayers Brook (T2.01-T2.04). For each parameter, the maximum impact score for the mainstem is 8 (4 reaches times impact score of 2). As shown below in Figure 7, the meander migration category (which examines lateral movement of the channel) received the highest impact rating for the watershed. The parameters channel modifications, corridor land use, average wavelength, and bank erosion also resulted in high scores.

Two reaches (T2.02 and T2.03) resulted in a Phase 1 reach condition of poor. These reaches have undergone significant channel and floodplain modifications which may have resulted in a change in planform, profile, and dimension such that the stream is no longer in balance with the flow and sediment regime of its watershed.

Streams in fair condition are likely in adjustment and experiencing major and rapid changes due to recent floodplain and channel modifications, land cover changes, and/or loss of riparian buffer. Reach T2.04 fell into this category. The other reach, T2.01, fell into the good category. This reach was thought to have experienced some degree of human-induced change within its floodplain and/or channel and was thought to be likely to be undergoing only minor adjustments. A reference reach has no significant channel or floodplain modifications and has a forested buffer, adjacent to the channel. In other words, these reaches are close to the natural condition. None of the reaches on the mainstem of Ayers Brook were found to be in reference condition. As depicted in Figure 8, the impact ratings ranged from 12 to 20, with the high impact rating reported for reach T2.02.

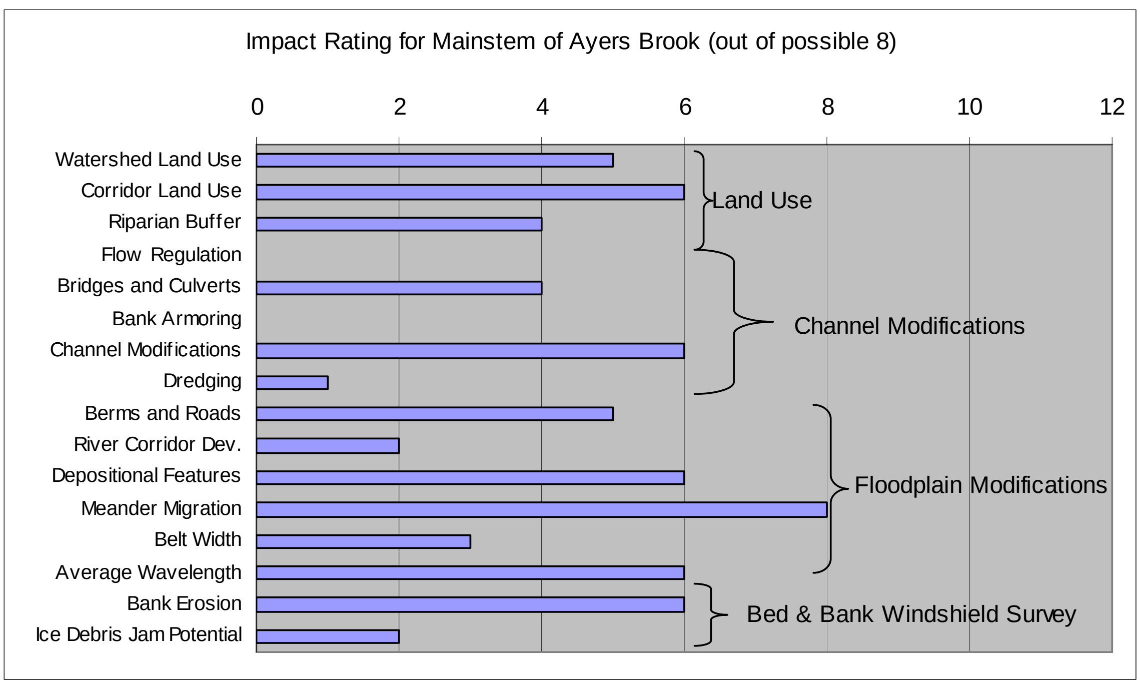

Figure 7. Impact Rating for Ayers Brook Watershed by Parameter and Category

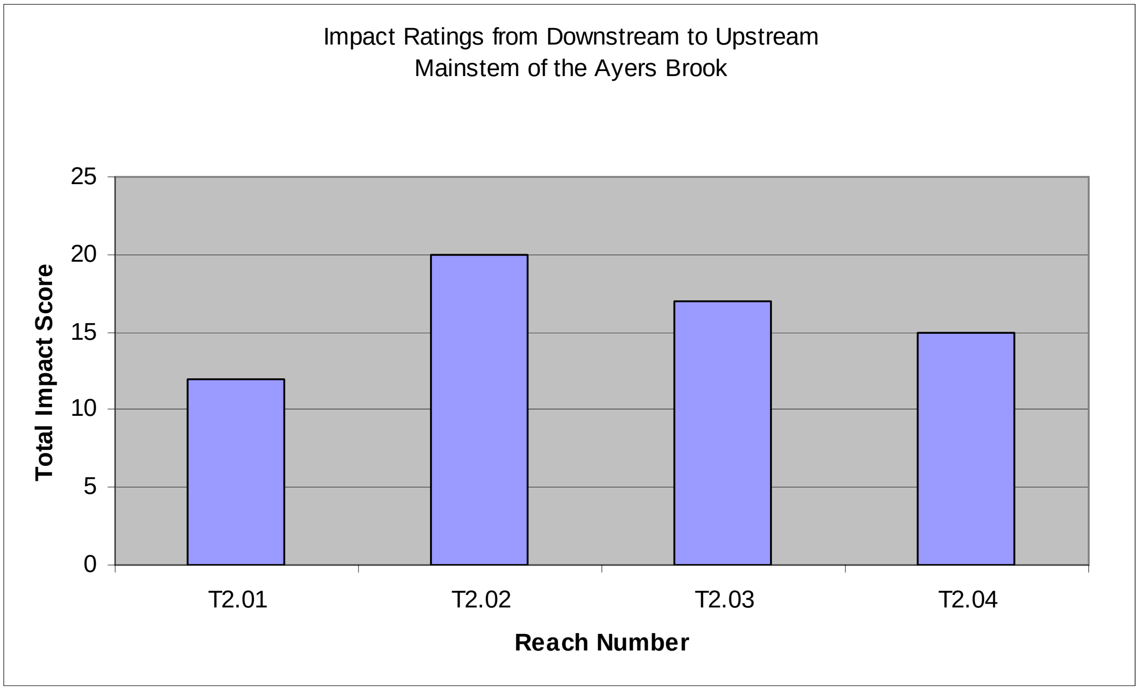

Figure 8. Impact Ratings from downstream to upstream on the main stem of the Ayers Brook.

3.2 Phase 2 Stream Geomorphic Assessment Results

A Phase 2 Stream Geomorphic Assessment of targeted reaches was conducted within the Ayers Brook watershed by a team of consultants working on behalf of the White River Partnership. A summary report of this field work was completed by Bear Creek Environmental (Blazewicz and Nealon 2006). The study included four reaches on the main stem of the Ayers Brook (T2.04, T2.03, T2.02, and T2.01). The four targeted reaches were further divided into a total of eight segments based on changes in confinement, stream type, and stage of channel evolution stage.

Information from the Phase 2 study came from the VDEC, the Vermont Mapping Program, and the Vermont Center for Geographic Information, the Towns of Braintree, Brookfield, Randolph, and Roxbury, and field data collected by the White River Partnerships consultants. The Phase 2 Rapid Stream Assessment included field observations and measurements (Figure 9) 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.

Figure 9. Kari Dolan of the Vermont DEC and Annie Bourdon of the WRP measure the cross-sectional area of the Ayers Brook during summer 2006.

The Phase 2 Rapid Geomorphic Assessment (RGA) provides information on the geomorphic condition of each segment within the study area. 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. All of the Phase 2 Ayers Brook reaches 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 Ayers Brook 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, and floodplain encroachment have occurred within this river system both on the mainstem and on the lower ends of the tributaries. In addition, much of the streambank vegetation along the Brook has been removed leading to a decrease in the resistance of the streambanks to the erosive forces of the river. These cumulative 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 10).

Figure 10. The Ayers Brook is working to create a new floodplain bench in many areas as a result of historic channel and floodplain modifications.

4.0 WATERSHED SCALE HYDROLOGIC AND SEDIMENT MODIFIERS

Degraded sites where people want to or need to resolve conflicts rarely result from stressors borne solely within a reach. Instead, streambank erosion, habitat degradation, threats to public and private investments are more likely the result of multiple stressors related to changes in flow, sediment supply, or channel and floodplain modifications outside of the affected reach. These watershed scale changes to the Ayers Brook can be examined to help determine constraints and assets to stream restoration.

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 Deforestation

The hydrologic stressor that provides a backdrop for the analysis of nearly every stream in Vermont is the deforestation which occurred primarily during the 19th century. During this time high-energy flash floods in denuded, sheep-grazed watersheds, without vegetation to slow and store precipitation, eroded and carried with them much of topsoil. While forests are once again moderating the flows in most watersheds, such as Ayers Brook, the decades of sediment accretion in the lower portion of the Ayers Brook and Third Branch of the White River may have contributed to the loss of floodplain that we see today. Although there is no data to help us map this stressor, fluvial processes may still be influenced by these large scale landscape changes that occurred a century ago (Vermont Agency of Natural Resources 2007).

4.1.2 Urbanization and Stormwater

Altered hydrology may be a significant stressor when urban land use reaches 5-10% of the watershed, as is the case with several Ayers Brook subwatersheds. Urbanization may be the predominant stressor when it reaches 20% of the watershed. The purple shading in Figure 11 symbolizes alterations to the Ayers Brook watershed that have increased the amount of impervious surfaces and reduced the capacity of the land to store water during significant rain and thaw events. Where hydrologic alterations are persistent, the impacted stream will adjust morphologically (e.g. enlarging when stormwater peaks are consistently higher) and often result in significant changes in sediment loading and channel adjustments in downstream reaches (Vermont Agency of Natural Resources 2007). In the Ayers Brook, reach T2.02 is considered to have significant hydrologic stress due to numerous stormwater outfalls that were identified during the Phase 2 survey. Additionally reach T2.01-A is considered to be significantly hydrologically stressed due to land use change in the Adams Brook tributary.

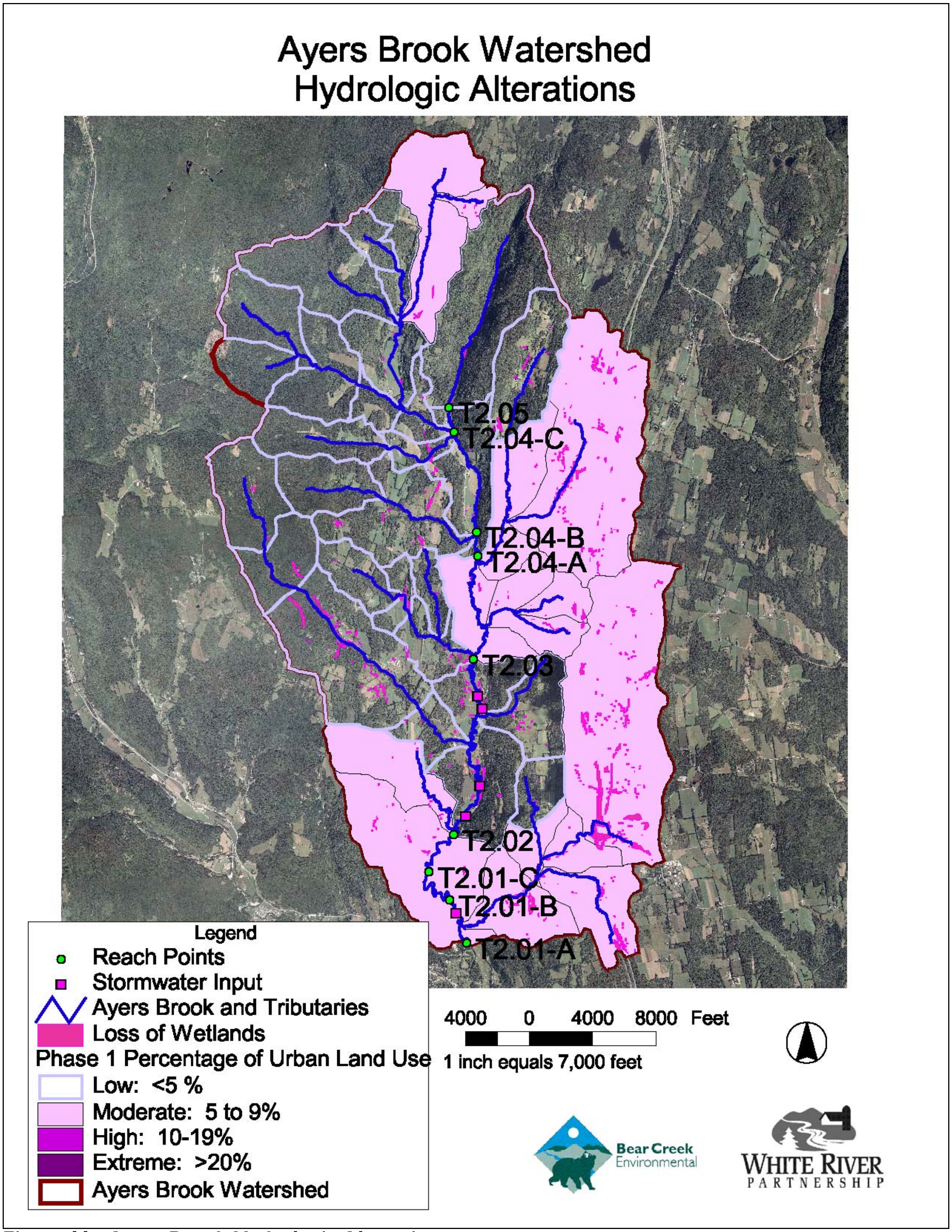

Figure 11: Ayers Brook Hydrologic Alterations

4.1.3 Roads and Ditching

According to the Vermont 911 GIS road data layer, the Ayers Brook study area has a combined total of 35 miles of improved road (not including driveways, logging roads, and or other unimproved roads). That is a density of just under 1 mile of improved road per square mile of watershed. According to Foreman and Alexander, 1998, this is not enough to significantly increase peak flows (which require about 3.2 miles/mile^2). However, runoff from the impervious surface of these road networks can transport sediment and other materials into highly erodable soils (such as are found in many Ayers Brook locations) creating gullies and transferring a significant amount of sediment into the channel, as illustrated in Figure 12. 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. Water from these road ditches tends to deposit finer sediment in streams, thereby increasing turbidity, which disrupts stream ecosystems. The increased runoff in a watershed as a result of the roads depicted in Figure 13 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).

Figure 12: Road drain emptying onto steep erodable soils off of Mason Road, T2.01-C.

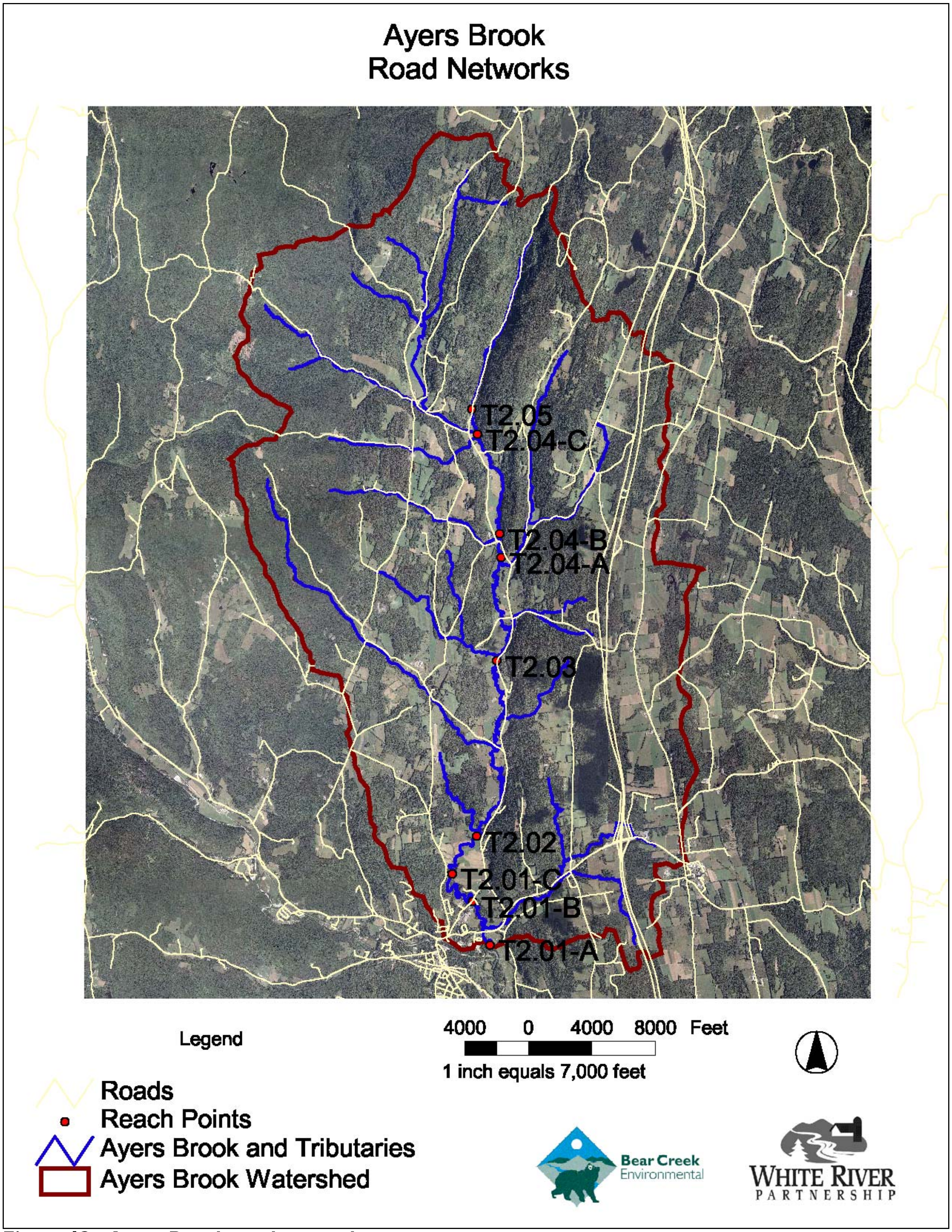

Figure 13: Ayers Brook road networks.

4.1.3 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.

During the 19th century, *drainage societies* were formed in Vermont for the purpose of building the ditch networks necessary to farm lands that were either permanently or seasonally wet. Drain tile and ditch networks were enlarged and maintained through the 20th century. In watersheds where wetlands have been lost, flood peaks may increase by as much as 80 percent (Vermont Agency of Natural Resources 2006f). Wetlands within, upstream, and downstream of urban areas are particularly valuable for flood protection. The impervious surface in urban areas greatly increases the rate and timing of runoff.

As depicted in Figure 11, it is likely that many wetlands in the Ayers Brook watershed have been either drained or filled and converted to agriculture or developed land such as a highway or road, as appears to be the case on the east side of the watershed were Interstate 89 may have disrupted many wetlands. 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 Ayers Brook watershed is a good land use goal for the surrounding communities.

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.

Sediment load modifiers are included in Figure 14. The green color coding on the map represents sediment load increases. As shown in Figure 14, avulsions, braiding, flood chutes and steep riffles are indicators that Ayers Brook has a high sediment load as a result of streambank erosion, mass failures, planform adjustment, cropland and gully erosion. Table 2 explains that sediment appears to be a significant reach stressor for all reaches except T2.04-A and T2.04-C. Specific sediment load impacts are discussed below.

Factors that Increase Sediment Load:

Unvegetated tilled cropland – is exposed to wind and water. According to the 2002 Landcover/Landuse data layer provided by the Vermont Center for Geographic Information, four and half percent of the Ayers Brook watershed (1.57 square miles) was thought to be in crop use while ten and a half percent (3.95 square miles) was classified as field (VCGI 2006).

Cleared, exposed soils from forestry, agriculture, or for development – are exposed to wind and water. Sedimentation of the Ayers Brook 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.

Accelerated bank erosion due to riparian vegetation removal and/or channel alterations – major channel widening and/or planform adjustment, which is occurring in six of the eight Phase 2 study segments, adds sediment to the river system as the river erodes its banks and bed (see Figure 14).

Mass Failure and Gully Erosion – may add major amounts of sediment disrupting channel flow and morphology of a reach.

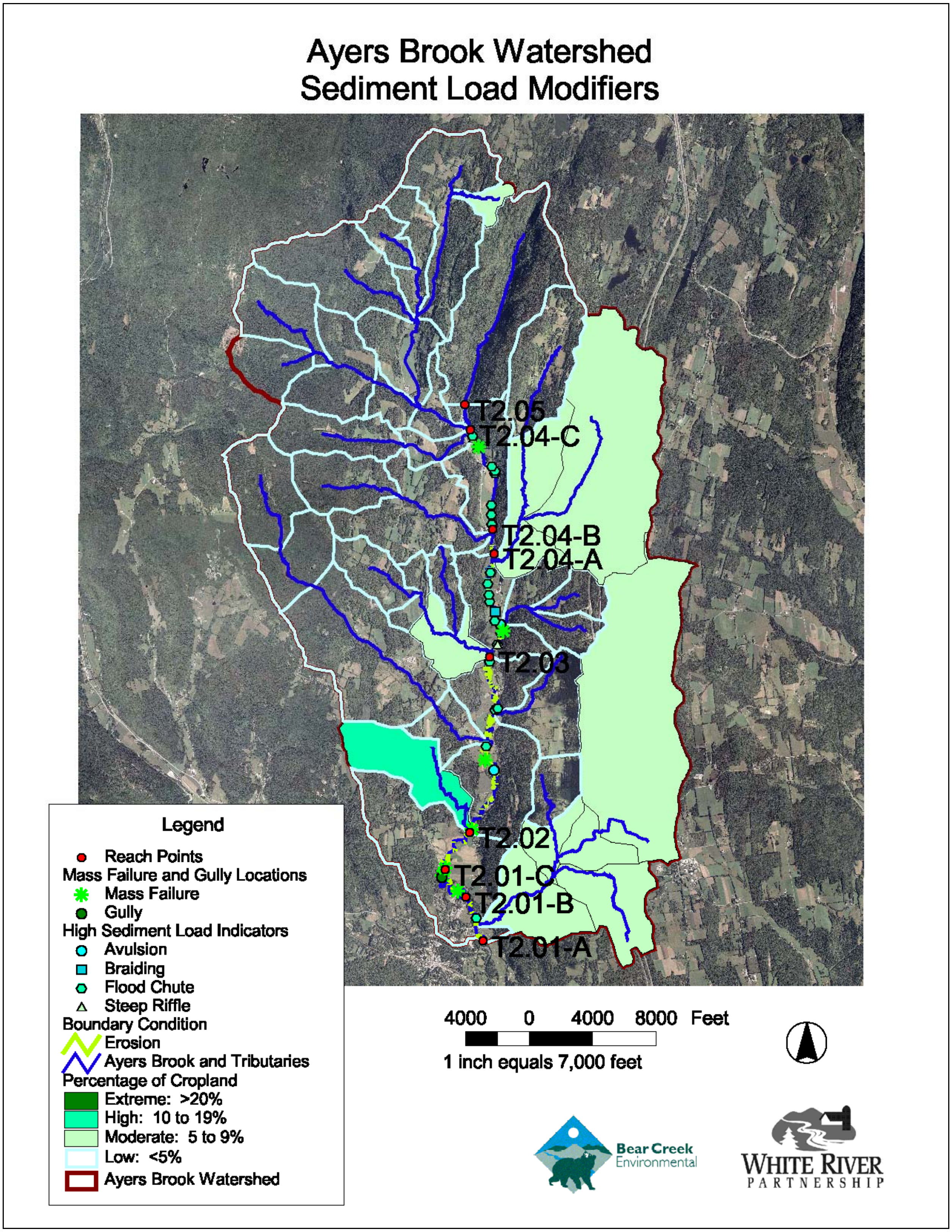

Figure 14: Ayers Brook Sediment Load Modifiers

TABLE 2: Ayers Brook Sediment Load Input Stressors	
River Segment	**Sediment Load Input**
T2.04-B	Streambank erosion, widening, mass failure.
T2.03	Streambank erosion, planform adjustment, mass failure, moderate cropland in tributary
T2.02	Streambank erosion, extreme planform adjustment, multiple mass failures
T2.01-C	Streambank erosion, widening, high percentage of cropland in tributary
T2.01-B	Streambank erosion, multiple mass failures
T2.01-A	Streambank erosion, major planform adjustment, moderate cropland in tributary

5.0 REACH SCALE STRESSORS

The previously discussed alterations to flow and sediment load at the watershed scale serve as a pretext for understanding the timing and degree to which reach-scale modifications are contributing to field observed channel adjustments. When there are modifications to the valley, floodplain, channel, and channel boundary conditions, a stream may change the way sediment is transported, sorted, stored, and distributed. The stressors that alter these conditions either increase or decrease stream power and/or increase or decrease the resistance of its boundary conditions.

5.1 Channel Slope Modifiers

Stream condition and stability is determined by a combination of many factors. Often, small impacts tend to accumulate into reach scale impairment. Figure 15 depicts some of the major reach scale stressors that are modifying the slope of Ayers Brook and are therefore increasing stream power. In Figure 15, pink and purple colors are depicting areas of increased channel slope, while green area indicate areas where the channel slope has been decreased by undersized structures. The major reach-scale channel slope modifiers are described below.

Increase Sediment Transport:

Straightened stream channels – increase the velocity of the stream and therefore its ability to transport sediment. With the exception of reach T2.01, three of the four mainstem reaches of the Ayers Brook had greater than 25% of the channel length straightened, with reaches T2.03 and T2.04 having over 40% of the channel straightened.

Stream corridor encroachments **-** 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 2005b).

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 Ayers Brook watershed,

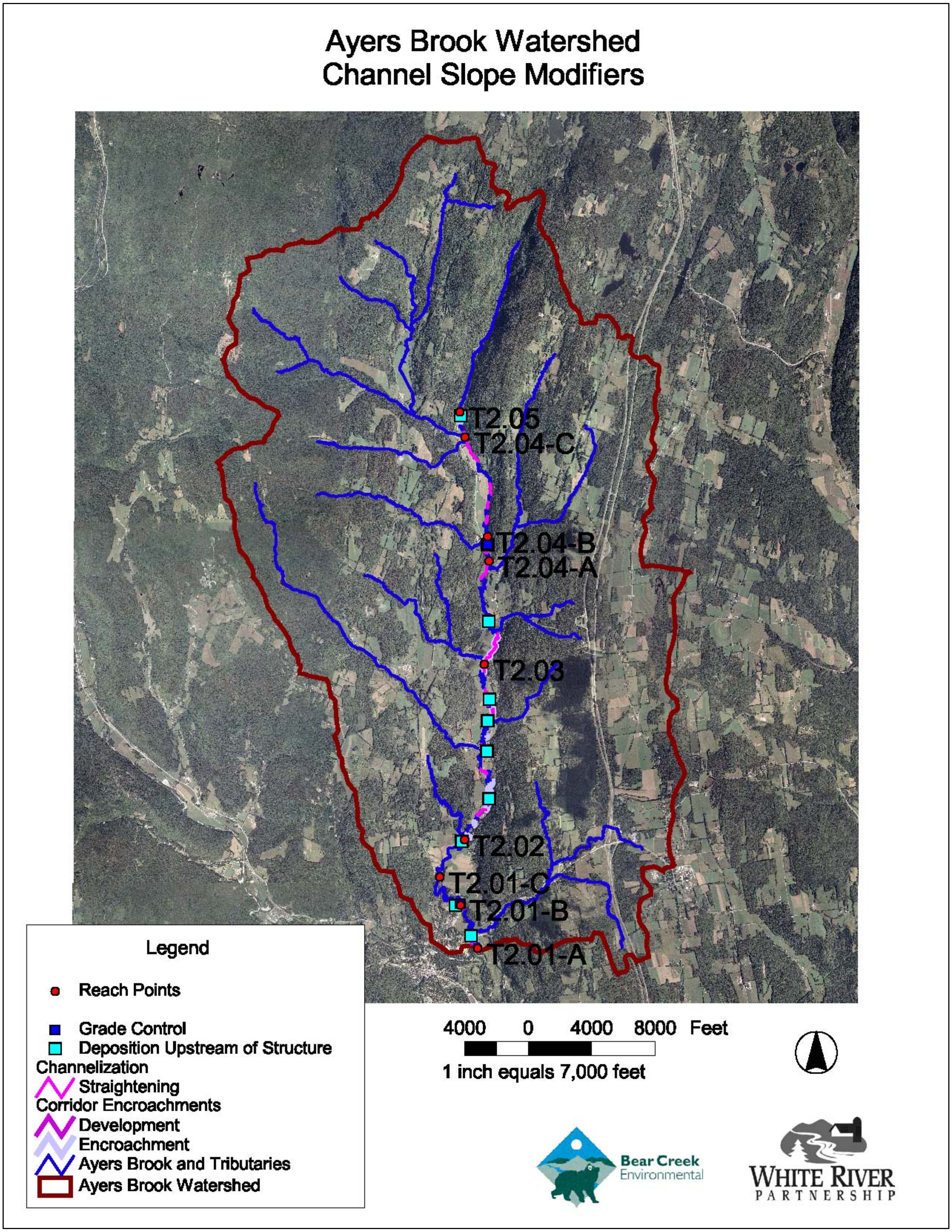

Figure 15: Ayers Brook Channel Slope Modifier Map

Route 12 is the dominant lateral constraint that has impacted the channel. Hard armoring placed in order to protect this infrastructure has led to increased instability in the system. In addition to this major road, minor roads in the watershed impact tributaries in numerous places.

Decrease Sediment Transport:

Undersized stream crossings – capture sediment in unnatural patterns, may create scour downsteam. The Phase 2 survey, found 12 undersized structures on the mainstem of Ayers Brook, as well as 5 old bridge abutments that were causing excessive degradation, aggradation, and/or scour in the river channel (Figure 16).

Overwidened channels – are unable to move sediment effectively through them. Channel widening was found to be a current adjustment process on half (4 of 8) of the Phase 2 segments.

Figure 16: Example of one of many undersized structures that are significantly disrupting sediment and water transport in Ayers Brook.

5.2 Boundary Conditions

The root networks of woody vegetation bind stream bank soils and sediment adding to the bank's resistance to erosion. Areas of active erosion and stream banks that have been armored with rip-rap, indicate a decrease in the natural roughness and boundary resistance and therefore result in an increase in stream power.

5.2.1 Riparian Vegetation

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. Of the four mainstem reaches studied, three were found to have over 75 percent of the reach with little or no buffer on one or more banks (Figure 17). These stream reaches which lack a high quality riparian buffer are at a significantly higher risk of experiencing high rates of lateral erosion (Blazewicz and Nealon 2006).

5.2.2 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. Grade controls (both natural and manmade) keep the base elevation of a river from being lowered, thereby preventing the river from incising in that location. 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

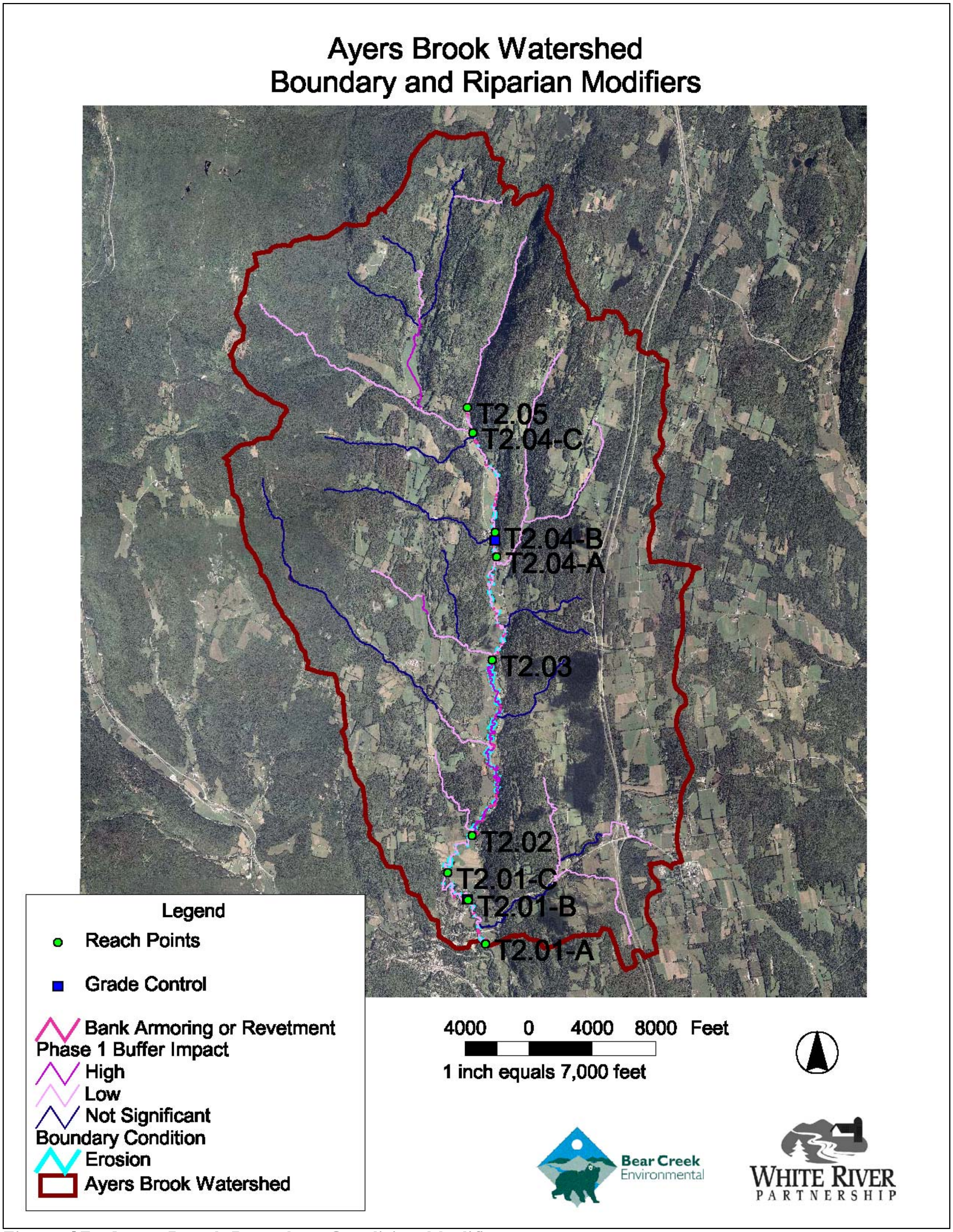

Figure 17: Ayers Brook Boundary Condition Modifiers

Overall there was a general absence of natural grade control in the Ayers Brook watershed. Exposed bedrock ledges are important natural grade controls that may be noted during a geomorphic assessment. Channel spanning ledge was recorded in three reaches in the headwaters of Ayers Brook in Brookfield and Roxbury and in one tributary reach at the southeastern end of the study area. There were no natural grade controls (waterfalls or ledge) that were observed on the Ayers Brook mainstem. Weirs and dams provide manmade grade controls. One small dam, on T2.04-S1.02 (Farnsworth Brook) was recorded within the study area. Two weirs were recorded. One weir was located on reach T2.04-A below East Braintree Village, the other is the USGS gauge weir which is found directly above the Route 12 culvert at the downsteam end of reach T2.02.

5.2.3 Lateral Constraints

Structures that encroach into the river corridor are not only threatened by the river due to channel migration and flooding, 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, such as the many roads that border Ayers Brook and its tributaries (particularly Route 12 along the mainstem) typically limit a stream's ability to dissipate energy in the floodplain. Building roads and structures in a floodplain may cause flows to concentrate in the channel during high flow events, thereby increasing the energy transferred by the stream to the channel bed. This excessive energy may cause the stream to downcut and the banks to erode. The combined response of a channel to lateral constraints may effectively turn a reference response or depositional area of a stream, such as segment T2.04-A, into a transfer reach. This may lead to an increase in sediment loading and aggradation, as well as bank erosion, in downstream reaches, such as T2.03.

Additional areas of significant floodplain encroachment observed in Ayers Brook include the lower portions of T2.03 and T2.02 and T2.05 where Route 12 is within the river corridor. Although many of these areas do not have encroachment occurring on both sides, in highly sensitive channels, such as those found in the Ayers Brook watershed, this may be enough to significantly alter the hydraulic geometry of the channel and therefore change the way sediment is transported, sorted and distributed. River Corridor Management of Ayers Brook should include proactive steps to ensure that lateral constraints are not placed within the river corridor.

5.3 Bridge and Culverts as Reach Scale Stressors

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 flow rates, 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"

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 (at least 1.2 times the bankfull width for open bottom stream crossings). The towns within the Ayers Brook watershed could establish ordinances or identify zoning requirements which would ensure adherences to proper design and installation practices for future development, especially of private crossings. It is recommended that existing crossings (major ones identified in Figure 18) be assessed using the ANR bridge and culvert protocol to provide useful information for retrofitting or replacement of these structures to ensure aquatic organism passage and improved geomorphic stability.

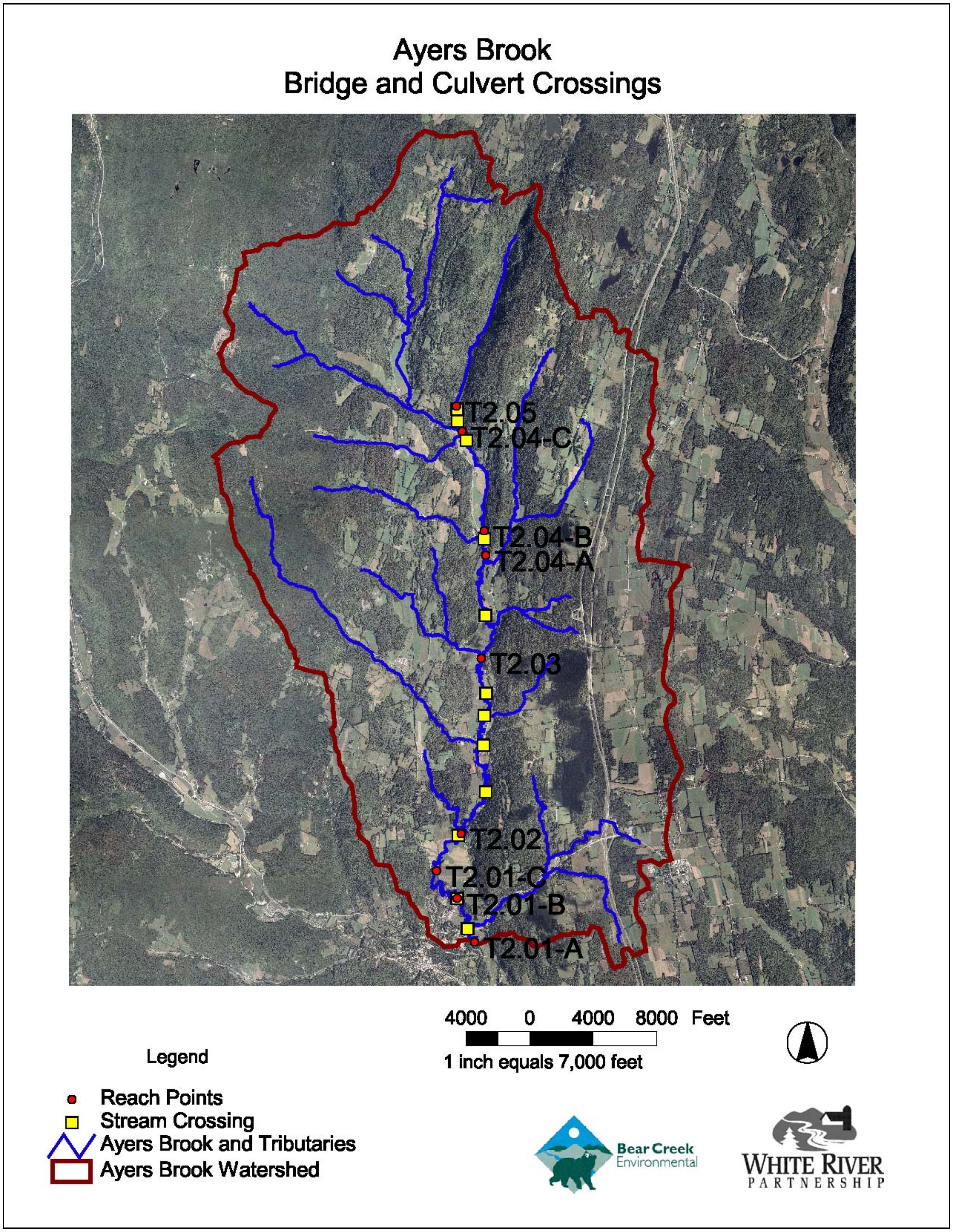

Figure 18: Ayers Brook Major Stream Crossings

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. This often leads to an increased amount of deposition of material in the stream channel. 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 19 include:

- A pre-disturbance period
- Incision – Channel degradation (as a result of straightening, floodplain encroachment, dredging, stormwater, etc.)
- Aggradation and channel widening
- The gradual formation of a stable channel with access to its floodplain at a lower elevation.

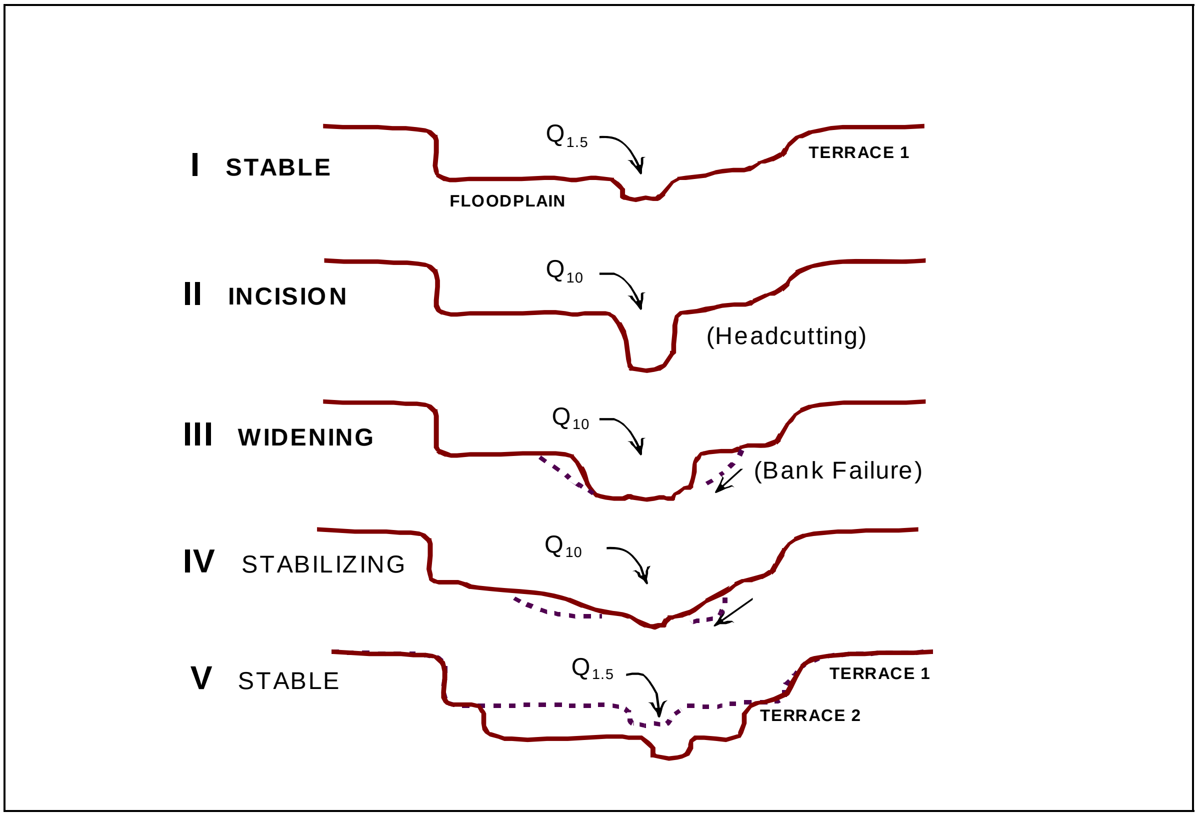

Figure 19: Typical Channel Evolution Model following incision.

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 adjustments work their way through a stream system.

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 2005a).

In addition to changes in stream channel boundary conditions and energy grades caused by straightening and lateral constraints, Vermont rivers are also reacting and undergoing adjustment due to changes in their hydrology and sediment regimes. The hydrologic regime refers to the timing, volume, and duration of flow events throughout the year and over time. The hydrologic regime may be influenced by climate, soils, geology, groundwater, watershed land cover, connectivity of the stream, riparian and floodplain network, and the valley and stream morphology. Changes to hydrologic regime due to anthropogenic alterations of the watershed and stream networks (and perhaps our climate as well) may lead to increased or decreased flows which can cause significant channel adjustment processes to ensue.

Likewise, the sediment regime of a watershed, the quantity, size, transport, sorting, and distribution of sediments, is subject to anthropogenic influences. The sediment erosion and depositional patterns which are unique to the stable stream channels, create habitat and lend to the overall stability of a channel. Significant alterations in the sediment regime due to either the removal of sediment from a channel or watershed (such as through gravel extraction) or an increased contribution of sediment due to land use practices or instream erosion, can have significant impacts on instream habitat, water quality, and stream channel stability. In particular, in a stream channel that has been straightened and incised, such as Ayers Brook, fine sediments are more likely to stay in suspension due to a lack of floodplain access during a flood. The inability of a stream to store these fine sediments has a profound effect on aquatic plant and animal life, and can cause significant export of fine sediment and nutrient enrichment problems to sensitive reaches and water bodies located downstream . The sediment regime of Ayers Brook also appears to be altered as evidenced by an increase in the storage of coarse sediment The increase in coarse sediment is attributed to an increase in sediment load (due to having little or no boundary residence) and the lower transport capacity brought about by the high width to depth ratios from channel widening. This has resulted in the growth of large unvegetated bars or an uneven distribution of coarse sediment.

The reach condition ratings of Ayers Brook 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 Ayers Brook 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 Ayers Brook watershed are undergoing a channel evolution process in response to large scale changes in its sediment, slope, and/or discharge associated with the human influences on the watershed. Table 3 below summarizes the channel evolution of each study reach and the primary adjustment processes that are occurring.

Table 3. Stream Type and Channel Evolution Stage

Segment Number	Entrenchment Ratio	Width to Depth Ratio	Reference Stream Type	Existing Stream Type	Channel Evolution Stage	Active Adjustment Process
T2.04-C	13.8	23.6	C4	C4	II	Degradation Widening
T2.04-B	4.0	48.8	C4	C4	III	**Aggradation Widening Planform**
T2.04-A	7.8	21.9	C4	C4	III	**Aggradation Planform**
T2.03	5.0	17.1	E4	C4	III	**Aggradation Planform**
T2.02	11.3	14.4	E4	C5	III	**Planform**
T2.01-C	8.2	8.7	E4	E5	III	**Aggradation Widening Planform**
T2.01-B	1.2	19.1	C4	F5	III	**Aggradation Widening**
T2.01-A	15.8	12.4	C4	C4	III	**Aggradation**

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

The mainstem of Ayers Brook is predominately in stage III of the "F-stage" channel evolution model (Vermont Agency of Natural Resources 2006a). In most segments the channel has undergone historic degradation. Many of the cross sections on study reaches were found to be incised. The incision ratio ranged form 1.2 to 2.8. Two 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 Ayers Brook 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 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.

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 2006c).

Figure 20 is a map presenting the existing stream types found in the Ayers Brook watershed. All of the Phase 2 study 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. The stream sensitivity of these reaches, generalized according to stream type and condition are depicted in Table 4 and in Figure 21.

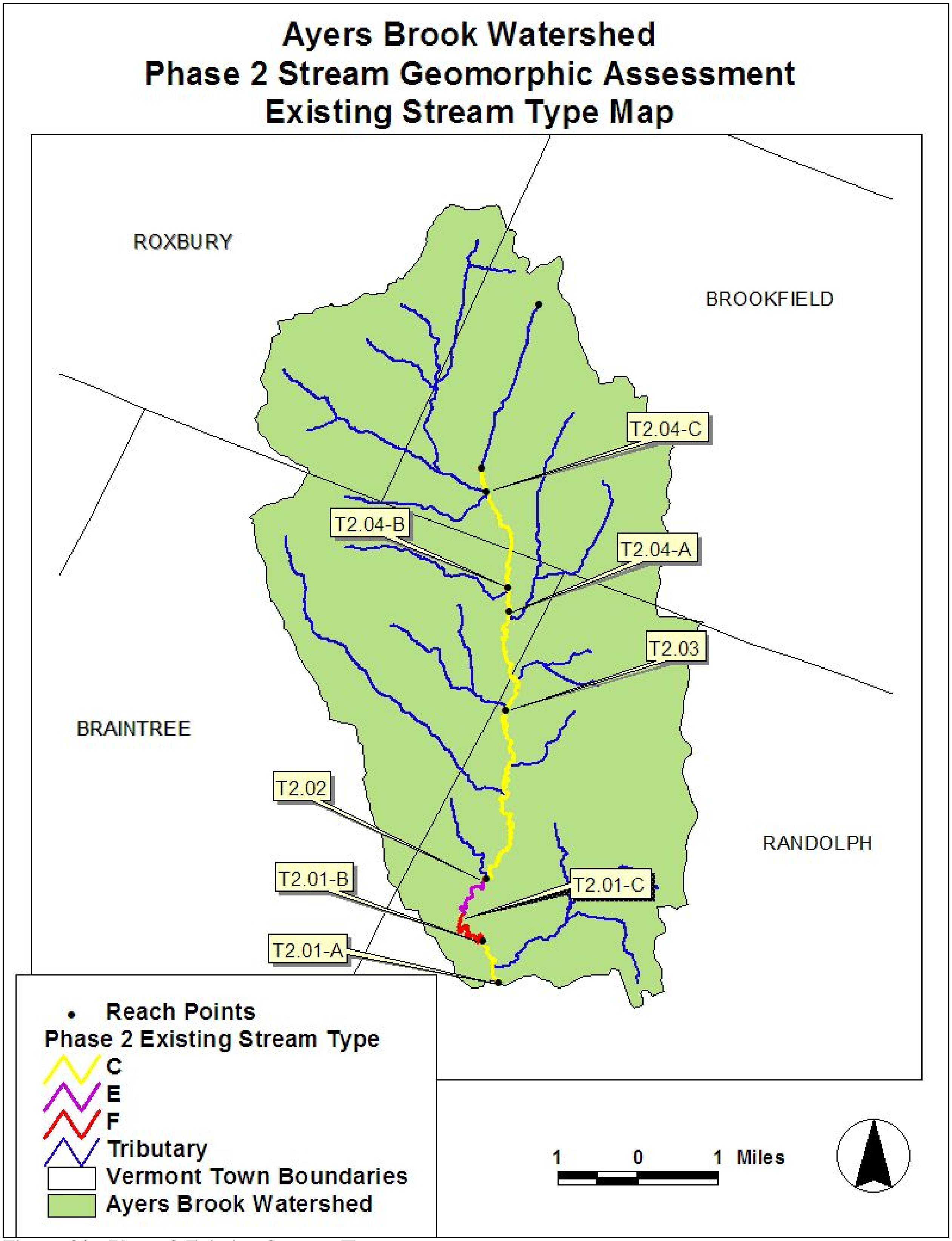

Figure 20. Phase 2 Existing Stream Types

Table 4. Stream Sensitivity for Phase 2 Reaches

Segment Number	Reference Stream Type	Existing Stream Type	Stream Type Departure	Geomorphic Condition	Sensitivity
T2.04-C	C4	C4	No	Fair	Very High
T2.04-B	C4	C4	No	Fair	Very High
T2.04-A	C4	C4	No	Fair	Very High
T2.03	E4	C4	No	Fair	Very High
T2.02	E4	C5	Yes	Fair	Very High
T2.01-C	E4	E5	No	Fair	Very High
T2.01-B	C4	F5	Yes	Fair	Extreme
T2.01-A	C4	C4	No	Fair	Very High

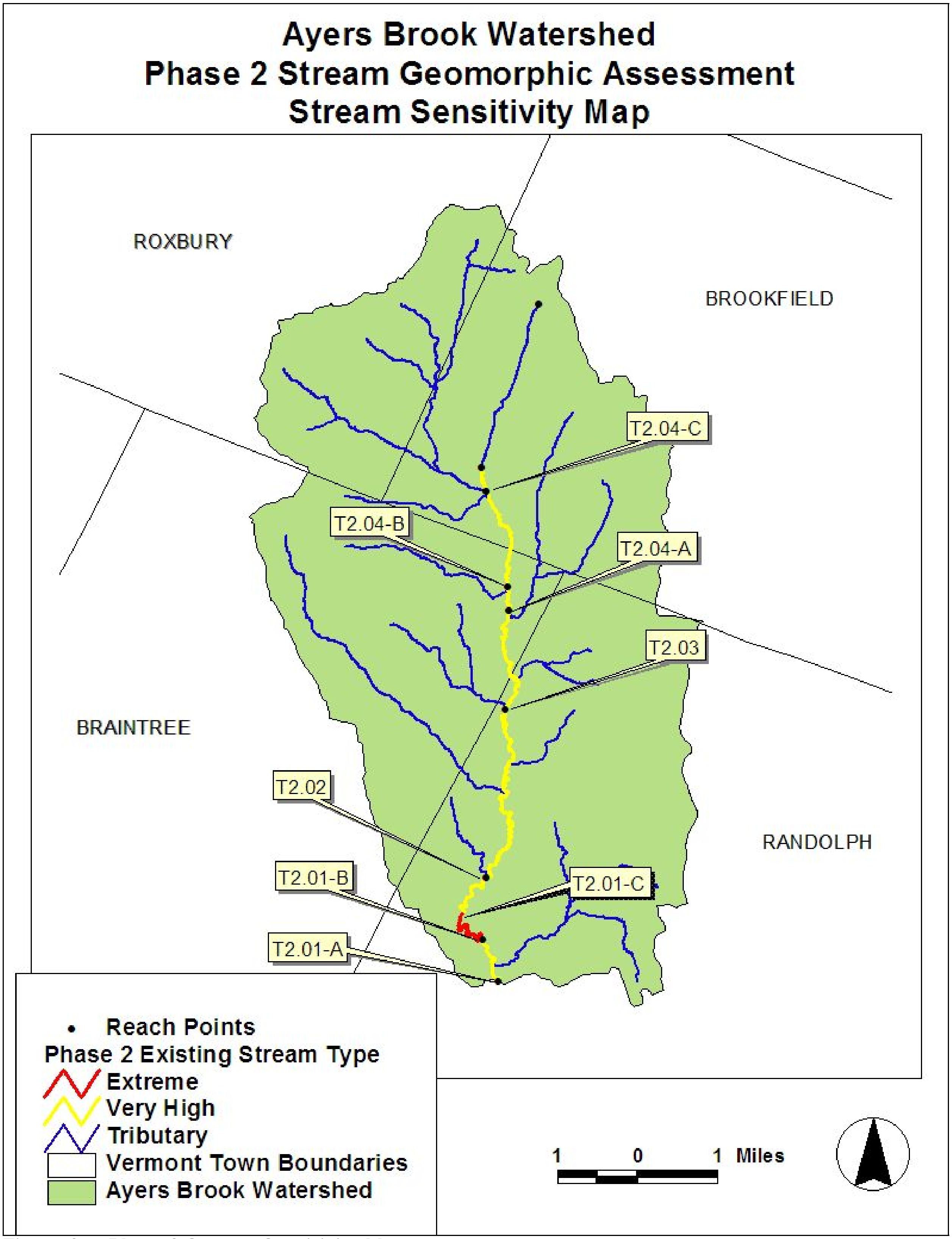

Figure 21: Phase 2 Stream Sensitivity Map

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 (2006), 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 22 represents a draft Fluvial Erosion Hazard Map for the Ayers Brook.

It should also be noted that the glacial history of the Ayers Brook has created soils along valley side slopes and river terraces that are extremely erodable. Although a Fluvial Erosion Hazard Zone may protect against hazards in the beltwidth of the river, where Ayers Brook runs up against its valley walls, there is extreme danger of landslide hazard in many locations. A discussion of landslide hazard should be included with any discussion of adoption of Fluvial Erosion Hazard Zones.

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 White River Partnership to protect and enhance riparian corridors along the Ayers Brook through the implementation of river corridor projection projects.

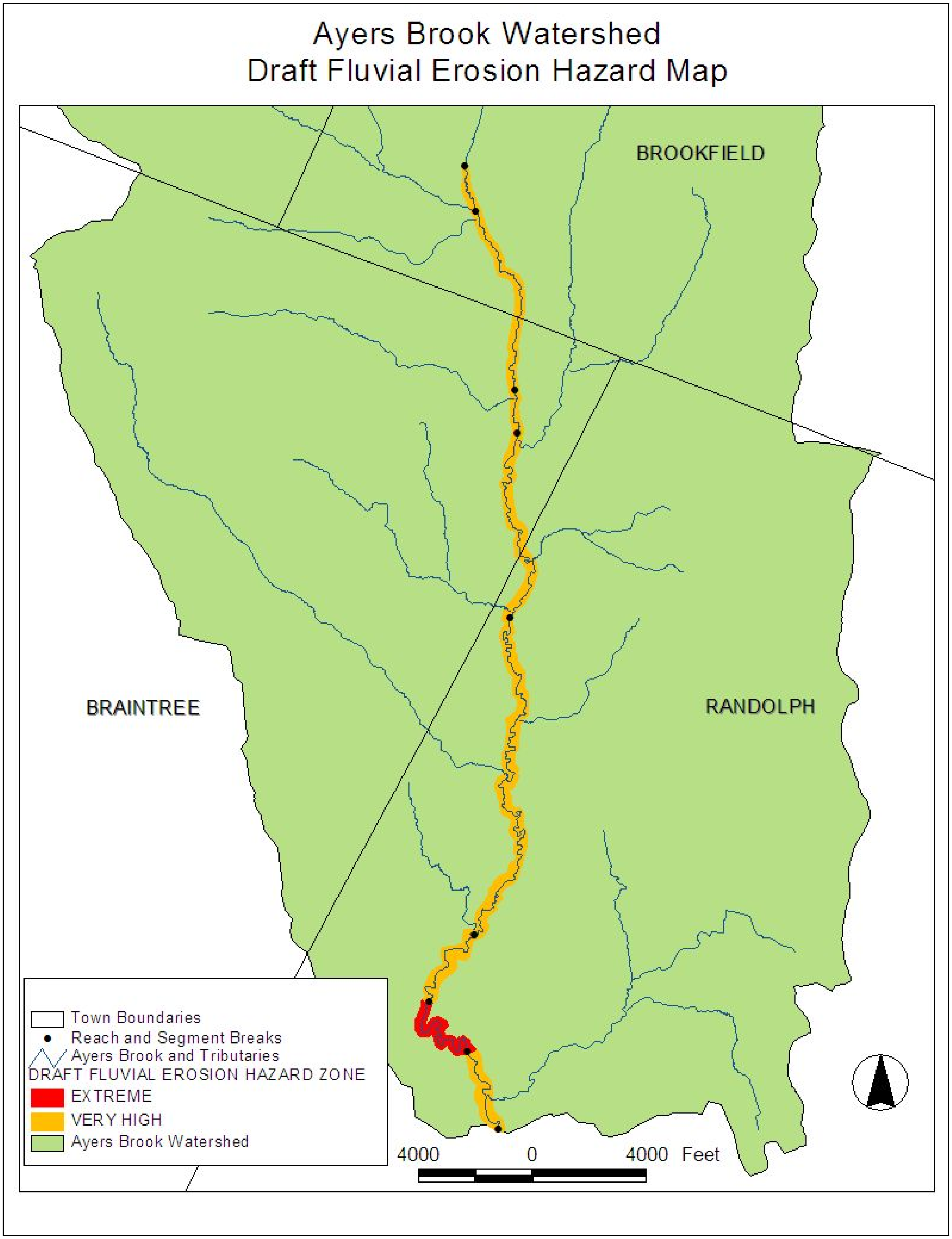

Figure 22: DRAFT Fluvial Erosion Hazard (FEH) Map for Ayers Brook.

7.0 REACH SCALE PROJECT IDENTIFICATION AND PRIORITIZATION

7.1 Restoration Approaches

The restoration of the Ayers Brook 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.

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 Ayers Brook will likely combine a variety of these project types in order to manage for systemic equilibrium. These five project types are:

Conservation Reaches – Conservation reaches are typically least disturbed and occur 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. 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 may 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 23 and in Table 5.

Table 5: Classification of River Corridor Project Types

Segment Number	Geomorphic Condition	Channel Evolution Stage	River Project Type
T2.04-C	Fair	II	Highly Unstable Reach
T2.04-B	Fair	III	Highly Unstable Reach
T2.04-A	Fair	III	Highly Unstable Reach
T2.03	Fair	III	Highly Unstable Reach
T2.02	Fair	III	Highly Unstable Reach
T2.01-C	Fair	III	Highly Unstable Reach
T2.01-B	Fair	III	Highly Unstable Reach
T2.01-A	Fair	III	Highly Unstable Reach

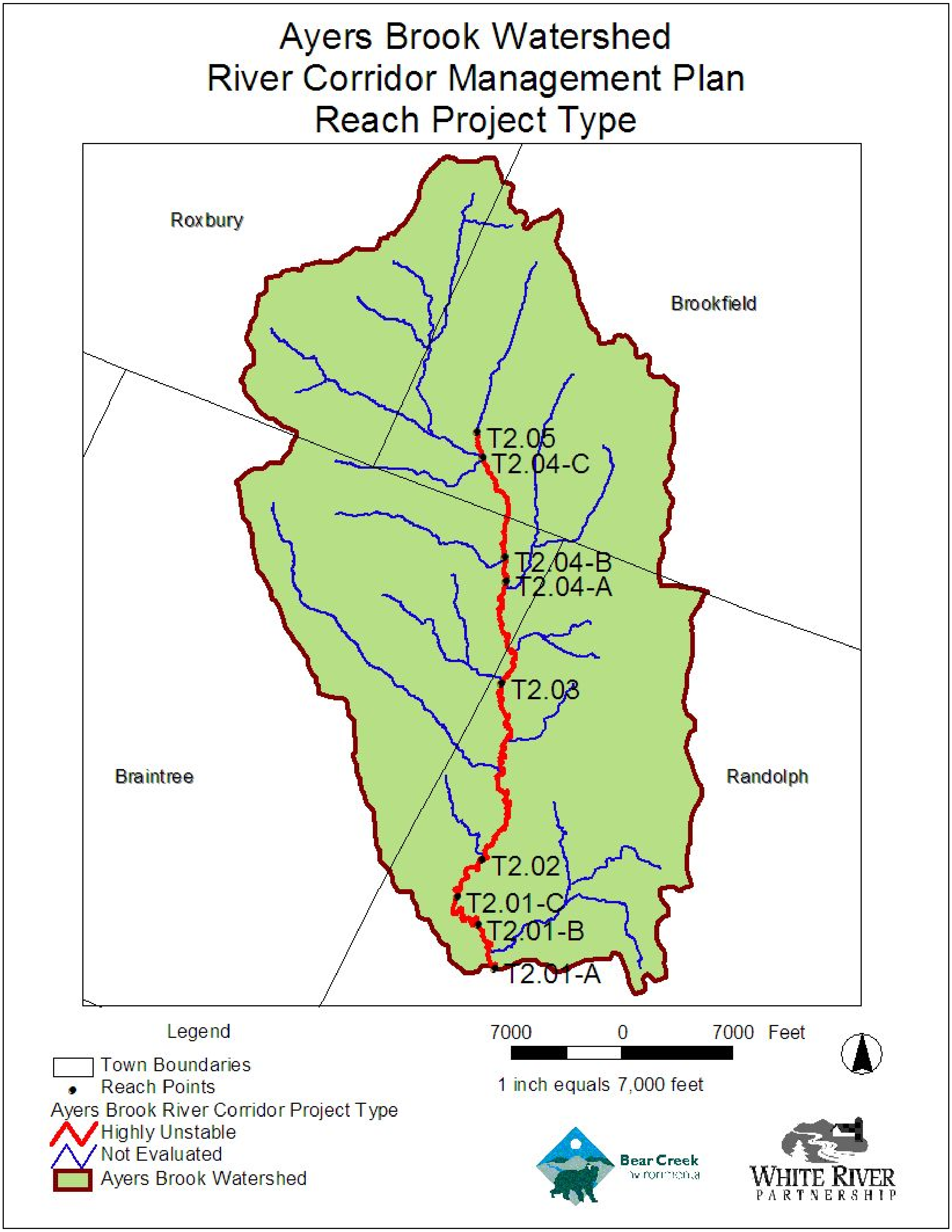

Figure 23: Ayers Brook restoration project types.

8.0 PRIORITY PROJECT IDENTIFICATION

The following priority project recommendations have been developed by Bear Creek Environmental, the White River Partnership, and the Vermont Agency of Natural Resources with assistance from the "Vermont Agency of Natural Resources River Corridor Planning Guide to Identify and Develop River Corridor Protection and Restoration Projects" (Vermont Agency of Natural Resources, 2007).

8.1 Recommendations by Segment for Restoration and Protection

The following paragraphs offer general recommendations by segment of restoration and protection of the Ayers Brook main stem. These recommendations are presented from upstream to downstream.

Reach T2.04-C: This is a transitional reach between steeper headwater reaches and the valley bottom of the Ayers Brook. Much of the riparian vegetation has been removed and it may be in danger of incising. This section would benefit from a riparian buffer restoration and river corridor protection to prevent future floodplain encroachments. There are also several undersized structures within this reach that could be removed or replaced.

Reach T2.04-B: This reach appears to be undergoing channel adjustment and is able to continue these adjustments without endangering infrastructure or buildings. It is an important reach in the upper watershed as it has the potential to store sediment and floodwaters coming from the steeper reaches above. River corridor protection should be implemented in this reach as well as possible buffer plantings and the removal or replacement of undersized structures in order to secure long term stability within this reach.

Reach T2.04-A: This segment runs through East Braintree Village. This reach has been historically straightened and armored and the upstream portion acts mostly as a transport reach. The decision to protect infrastructure within the Village may dictate that this reach be maintained to transport water and sediment in the channel it currently occupies. The Route 12 Bridge is undersized and would benefit from being made wider if the opportunity becomes available. Landowners within this reach would do well to voluntarily plant stream buffers to help keep the river shaded, and to provide habitat and streambank stability. Additionally, livestock exclusion from a farm near the downstream end of this segment is recommended.

Reach T2.03: This reach appears to be undergoing major channel adjustment and is able to continue these adjustments without significantly endangering infrastructure or buildings. Protecting the river corridor through CREP, an FEH zone, or similar program will ensure that the river has the room to meander and reestablish the ability to store floodwaters and sediment. Riparian buffer restoration could take place in association with a beltwidth protection program and should focus away from the near bank, especially on outside bends, where the brook is likely to continue to erode laterally in the near future. Several undersized structures in this reach should also be considered for removal or replacement.

Reach T2.02: This reach appears to be undergoing channel adjustment and is able to continue these adjustments without significantly endangering infrastructure or buildings. Protecting the river corridor through CREP, an FEH zone, or similar program will ensure that the river has the room to meander and reestablish the ability to store floodwaters and sediment. Riparian buffer restoration is recommended in association with a beltwidth protection program and should focus away from the near bank, especially on outside bends, where the brook is likely to continue to erode laterally in the near future. Several undersized structures in this reach should also be considered for removal or replacement.

Reach T2.01-C: This reach appears to be undergoing channel adjustment and is able to continue these adjustments without significantly endangering infrastructure or buildings. Protecting the river corridor through CREP, an FEH zone, or similar program will ensure that the river has the room to meander and reestablish the ability to store floodwaters and sediment. Riparian buffer restoration is recommended in association with a beltwidth protection program and should focus away from the near bank, especially on outside bends, where the brook is likely to continue to erode laterally in the near future. Several undersized structures in this reach should also be considered for removal or replacement.

Reach T2.01-B: This reach travels through a naturally narrowly confined valley. There is already an adequate riparian buffer through this reach. There are several mass failures within this reach indicating highly erodable valley side slopes. River corridor protection within this reach should include landslide hazard considerations.

Reach T2.01-A: This reach at the mouth of the Ayers Brook is highly dynamic. River corridor protection that prevents further encroachment could be enacted by the Town of Randolph. Stream buffer planting and the replacement of an undersized structure could also be on the town's priority for action in association with the aforementioned projects.

8.2 Specific Project Recommendations for Ayers Brook

The step-wise procedure for identifying technically feasible river corridor restoration and protection projects outlined in the Vermont Agency of Natural Resources River Corridor Planning Guide (ANR 2007) was followed by Bear Creek Environmental, the WRP and other partners to prioritize projects on the Ayers Brook main stem. Four main types of projects were identified and prioritized by reach: 1. Adoption of FEH Zones; 2. Replacement/removal of undersized structures; 3. Buffer Restoration; and 4. River Corridor Protection. A discussion of each of these types of projects is provided below and is summarized in Table 6.

Table 6: Ayers Brook River Corridor Planning Project and Strategy Summary Table

Project #	Reach	Project or Strategy Description	Technical Feasibility & Priority	Social Benefits	Land Use Conversion	Potential Partner Commitments
1	ALL	FEH Zone	Mapping, zoning, planning	Prevent Future flood damage	River Corridor Protection	ANR, Towns, WRP, Two River Ottauquechee Regional Commission
2	ALL	Replace/Remove Undersized Structures	Conduct Bridge and Culvert survey	Prevent further stream instability		ANR, Towns, VTRANS
3	ALL	Buffer Restoration	Site visits	Reduce conflicts, water quality, habitat	River Corridor Protection	WRP
4	T2.04-C	CREP/River Corridor Easement	Site visits and mapping	Flood attenuation, water quality, and wildlife	River Corridor Protection	VT Agency of Ag., ANR, US Fish and Wildlife Service, USDA, NRCS, WRP, Landowners
5	T2.04-B	CREP/River Corridor Easement	Site visits and mapping	Flood attenuation, water quality, and wildlife	River Corridor Protection	VT Agency of Ag., ANR, US Fish and Wildlife Service, USDA, NRCS, WRP, Landowners
6	T2.03	CREP/River Corridor Easement	Site visits and mapping	Flood attenuation, water quality, and wildlife	River Corridor Protection	VT Agency of Ag., ANR, US Fish and Wildlife Service, USDA, NRCS, WRP, Landowners
7	T2.02	CREP/River Corridor Easement	Site visits and mapping	Flood attenuation, water quality, and wildlife	River Corridor Protection	VT Agency of Ag., ANR, US Fish and Wildlife Service, USDA, NRCS, WRP, Landowners
8	T2.01-C	CREP/River Corridor Easement	Site visits and mapping	Flood attenuation, water quality, and wildlife	River Corridor Protection	VT Agency of Ag., ANR, US Fish and Wildlife Service, USDA, NRCS, WRP, Landowners

FEH – Fluvial Erosion Hazard; ANR – Vermont Agency of Natural Resources; WRP – White River Partnership; CREP – The Conservation Reserve Enhancement Program; USDA-United States Department of Agriculture; NRCS – Natural Resources Conservation Service; Agency of Ag – Vermont Agency of Agriculture

8.2.1 Fluvial Erosion Hazard Zones

The towns that comprise the Ayers Brook watershed would benefit from working with the VDEC 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 these towns 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 Ayers Brook communities 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.

8.2.2 Replace Remove Undersized Structures

Table 7 provides a preliminary list of undersized structures by reach that were noted during the Phase 2 assessment. These structures were all rated as high priority using criteria provided in Vermont ANR's River Corridor Planning Guide (2007). It is recommended that a bridge and culvert assessment be conducted in the near future using the ANR protocols to provide towns, state agencies, and local groups with information about structures that are causing localized instability or impeding the passage of aquatic organisms.

The towns and the Vermont Agency of Transportation could assist the recovery and further impairment of the Ayers Brook by proactively replacing undersized structures that cross the Brook and its tributaries. These municipalities could also choose to assist in the design or construction 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 undersized and/or misaligned structures.

Table 7: Project and Practices for Restoration of Ayers Brook – Remove or Replace Undersized structures

Project	Segment	Priority	Completed Independent of Other Projects	Next Steps and Other Project Notes
Remove or Replace Undersized Structures *(Note: A formal bridge and culvert using ANR protocols has not been conducted. Information provided here regarding undersized structures is tentative.)*	T2.04-C	High	Yes	Private Bridge and Rt. 12 Culvert
	T2.04-B	High	Yes	Remove or replace private bridge
	T2.04-A	High	Yes	Replace bridge in East Braintree Village if opportunity becomes available
	T2.03	High	Yes	Remove or replace undersized structures, old abutment
	T2.02	High	Yes	Remove or replace undersized structures and old abutments
	T2.01-C	High	Yes	Remove or replace undersized bridge
	T2.01-A	High	Yes	Remove or replace undersized bridge and culvert

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.

8.2.3 Buffer Restoration

Much of the main stem of the Ayers Brook has less than a 25 foot buffer along one or both banks. It is important to establish a buffer of vegetation on all reaches from a water quality and habitat standpoint. Therefore, the Ayers Brook is in great need of buffer restoration. Buffer restoration can be in the form of plantings or can be as simple as just allowing the vegetation to grow along the river. Livestock exclusion is an important component of a successful buffer restoration project. Potential buffer restoration projects should be designed to take into account the stage of channel evolution. On areas where active adjustment is occurring, it is recommended that low cost native grasses and shrubs be planted in the near bank region and more expensive tree stock that may mature and lend to long term stability be planted further back. This provides time for the trees to grow up and establish a strong root mass, should the stream migrate to the outer extent of its belt width. Higher priority should be given to tree plantings as a stand along treatment on areas that are vertically stable.

8.2.4 River Corridor Protection

Given the highly unstable nature of Ayers Brook, river corridor protection is the most important type of project that could be implemented. As summarized below in Table 8, segments T2.04-B, T2.03, T2.02, and T2.01-C are natural attenuation areas and have been given the highest priority for river corridor protection. River corridor protection comes in many forms including: river corridor easements that give the holder of the easement the channel management rights, conservation easements, recommendations in towns plans regarding land use, and/or the adoption of FEH zones. A separate discussion of FEH zones is provided in Section 8.2.3.

Federal and state programs are available to offer financial assistance for implementing conservation practices such as riparian buffer restoration, fencing of livestock from the channel, development of alternative water systems for livestock, road and ditch maintenance, wildlife enhancement projects, and point and non-point source water pollution reduction initiatives. These programs include but are not limited to: Wildlife

Habitat Incentives Program (WHIP), Conservation Reserve Enhancement Program (CREP) and the Vermont Clean and Clear Program. Additionally, land conservation through easements, or other means, may be pursued by willing landowners and appropriate project partners. WHIP is a voluntary program for conservation minded landowners who are interested in developing and improving wildlife habitat on their land (http://www.nrcs.usda.gov/programs/whip/). The goal of CREP is to improve water quality in streams and lakes by assisting agricultural landowners to voluntarily establish buffers. These buffers are important for filtering runoff by trapping sediment, fertilizers and pesticides. The farmers are compensated for the loss of productive agricultural land through incentives payments. The contracts can be either 15 or 30 years (http://www.vermontagriculture.com/CREPwebsite/Home/Home.htm). The Vermont Clean and Clear supports riparian corridor protection and restoration and river restoration projects. The Vermont River Management Program offers a river corridor easement program for riparian land parcels that have been identified using the Vermont Stream Geomorphic Assessment Protocols as being critical for achieving long term stability.

The WRP is currently working with willing landowners, the VDEC, and the Vermont Department of Agriculture and partners to implement a reach level project to improve water quality and protect the river corridor. This program is a coupling of CREP and river corridor easements funded through the Vermont Clean and Clear Action Plan.

Table 8: Project and Practices for Restoration of Ayers Brook – River Corridor Protection

Project	Segment	Priority	Completed Independent of Other Projects?	Next Steps and Other Project Notes
Protect River Corridor	T2.04-C	Highest	Yes	Could happen independent of other projects. First area of potential attenuation below Brookfield Gulf.
	T2.04-B	Highest	Yes	Could happen independently of other projects. Natural attenuation area. Important to allow for stream to naturally redevelop floodplain and attenuate flows and sediment from T2.05 and T2.04-C.
	T2.04-A	Lower*	Yes	Village of East Braintree. **(except higher priority at downstream end of segment)*
	T2.03	Highest	Yes	Natural attenuation area.
	T2.02	Highest	Yes	Natural attenuation area.
	T2.01-C	Highest	Yes	Natural attenuation area.
	T2.01-B	Lower	Yes	Narrow Valley, less attenuation asset.
	T2.01-A	High	Yes	Village of Randolph, however, undeveloped area behind school. Natural depositional area.

Prioritizing River Corridor Protection:

Higher Priority – Highly sensitive reaches critical for flow and sediment attenuation from upstream sources or sensitive reaches where there is a major departure from equilibrium conditions and threat from encroachment. Prioritize key attenuation assets at alluvial fans, below tributaries, and downstream of other large sediment sources. Evaluate these assets for storing flood flows; capturing and storing sediments, organic material, and nutrients; and reducing erosion hazards.

Lower Priority –Wooded corridor experiencing very little threat from encroachment and less sensitive reaches not playing a significant flow or sediment load attenuation role in the watershed.

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. 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 Ayers Brook community will encourage community awareness and participation in the restoration of the Ayers Brook. In order to provide additional information to fully implement the River Corridor Plan, it is recommended that the following assessments be undertaken in the near future:

1. Conduct a bridge and culvert assessment on the Ayers Brook mainstem using the ANR's protocols.

2. Phase 1 and 2 data suggests that there may be high impacts occurring in the Adams Brook. The Vermont Department of Fish and Wildlife has taken interest in this brook through is fish population monitoring program. A complete Phase 2 Assessment of the mainstem reaches of this brook may help identify other important projects in the Ayers Brook watershed that may be contributing to issues in the Third Branch of the White River.

10.0 REFERENCES

Blazewicz, M. and M. Nealon. 2006. Phase 1 and 2 Stream Geomorphic Assessment, Ayers Brook Watershed, Towns of Brookfield, Braintree, Randolph, and Roxbury, Vermont. Bear Creek Environmental, Middlesex, VT. 54 pp. plus appendices.

Forman, R. T. T. and L. E. Alexander. 1998, Roads and Their Major Ecological Effects: Annual. Rev. Ecol. Syst. 1998. 29:207–31.

Kirn, Rich. 2007. Personal memo RE: Fisheries Assessment - Ayers Brook. Roxbury, VT.

Larsen, F. D., Dunn, R. K, Springston, G. E., and Donahue, N. 2004. Surficial Geology of the Third Branch of the White River, Central Vermont. Presentation to the Geological Society of America. http://gsa.confex.com/gsa/2004NE/finalprogram/abstract_70786.htm

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

Ryan, J. 2001. Stream stability assessment of Lamoille County, Vermont. Washington, Vermont.

Thompson and Sorenson. 2005. Wetland, Woodland, Wildland: A guide to the natural communities of Vermont. Capital City Press, Montpelier, Vermont.

United States Department of Agriculture. 1986. Urban Hydrology for Small Watersheds. Soil Conservation Service, Engineering Division, Technical Release 55. Washington, D.C.

VCGI. 2006. Vermont Center for Geographic Information public database. www.vcgi.org

Vermont Agency of Natural Resources. 2002. White River Basin Plan. Waterbury, Vermont.

Vermont Agency of Natural Resources. 2005a. Riparian Buffers and Corridors: Technical Papers. Waterbury, Vermont

Vermont Agency of Natural Resources. 2005b. 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 (DRAFT). Waterbury, Vermont.

Vermont Agency of Natural Resources. 2006a. Fluvial Erosion Municipal Guide. Waterbury, Vermon

Vermont Agency of Natural Resources. 2006b. Vermont River Management Program: Overview of Program Activities and Responsibilities. Waterbury, VT. http://www.vtwaterquality.org/rivers/docs/rv_programoverview.pdf

Vermont Agency of Natural Resources. 2006c. Vermont Stream Geomorphic Assessment, Appendix C, Channel Evolution Models, Waterbury, Vermont.

Vermont Agency of Natural Resources. 2006d. Vermont Stream Geomorphic Assessment Phase 1 Handbook. Watershed Assessment Using Maps, Existing Data, and Windshield Surveys. Waterbury, Vermont

Vermont Agency of Natural Resources. 2006e. Vermont Stream Geomorphic Assessment Phase 2 Handbook. Rapid Stream Assessment, Field Protocols. Waterbury, Vermont

Vermont Agency of Natural Resources. 2006f. Wetlands: Water Storage for Flood water and Storm water. http://www.anr.state.vt.us/dec/waterq/wetlands/htm/wl_func-storage.htm

Vermont Agency of Natural Resources. 2006g. 2006 List of Priority Surface Waters. Waterbury, Vermont.

Vermont Agency of Natural Resources. 2007. River Corridor Planning Guide (Draft). Waterbury, Vermont.

Vermont Department of Fish and Wildlife. 2005. Interim Guidelines for Aquatic Organism Passage through Stream Crossing Structures in Vermont. Waterbury, Vermont.

Vermont Institute for Government. 2001. The Law of Water: An Introduction to Vermont Water Law. Berlin, Vermont.

White River Partnership. 2005. Water Quality Monitoring Report. White River Watershed, Vermont