Winhall River Watershed Corridor Plan

Winhall, Jamaica, & Londonderry, Vermont

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1.0 EXECUTIVE SUMMARY

A stream geomorphic assessment of the Winhall River was conducted by Bear Creek Environmental, LLC (BCE) under the direction of the Windham Regional Commission (WRC) and the Vermont Agency of Natural Resources (VANR) during the summer and fall of 2013. Funding for the project was provided through the State of Vermont Ecosystem Restoration Program. A planning strategy based on fluvial geomorphic science (see glossary at end of report for associated definitions) was chosen because it provides a holistic, watershed-scale approach to identifying the stressors on river ecosystem health. The stream geomorphic assessment data can be used by resource managers, community watershed groups, municipalities and others to identify how changes to land-use alter the physical processes and habitat of rivers.

The towns of Winhall, Jamaica, and Londonderry experienced major flooding in August 2011 as a result of Tropical Storm Irene (TSI) and subsequent damage and destruction of infrastructure. As part of the long term plan to mitigate the impact of flooding, the Windham Regional Commission secured state funding to complete a Phase 2 stream geomorphic assessment of the Winhall River watershed. The stream geomorphic assessment data will be used to help focus stream restoration and protection activities within the watershed and assist the towns with flood resiliency planning.

The Winhall River was divided into eleven reaches for the assessment. The study encompassed approximately 13 miles of stream channel, and was helpful in identifying major stressors to geomorphic stability in the Winhall River watershed. The primary problem relating to geomorphic stability and habitat condition in the watershed is channel straightening and corridor encroachment associated with the existence of roads. In some cases, this encroachment has limited floodplain access and has caused moderate to extreme channel degradation (lowering of the bed) resulting in sediment build up, channel widening, and planform adjustment (lateral movement). There are approximately 5.4 miles, or about 65 percent, of the Winhall River in the study area, that run parallel to Rt. 30. In some places, the high road embankment is restricting floodplain access. Mass failures are also common along the Winhall River and are contributing sediment to the channel.

Significant impacts to the Winhall River watershed have occurred not only historically, but also recently during post-Irene recovery efforts. Post Irene stream work, which often involved excavating the channel and creating berms along its banks, in many places did more damage to the streams than the storm itself. TSI has emphasized the importance of adequately planning for emergency situations, as well as regulating post-emergency recovery efforts.

A list of 34 potential restoration and conservation projects was developed during project identification. Types of projects include: river corridor protection through easements, improving riparian buffers, bridge and culvert replacements, stream clean-up, berm removal, and arresting of headcuts. Detailed surveys for active restoration projects may be required at some point in the near future for project design and permitting.

2.0 LOCAL PLANNING PROGRAM OVERVIEW

There are many scientific terms used in this river corridor plan, and the reader is encouraged to refer to the glossary at the end of the document. Important terms that are in the glossary are shown in italics the first time they are used in the text.

2.1 Overview

This project focuses on the Winhall River watershed in Winhall, Jamaica, and Londonderry, Vermont. The main stem of the Winhall River, Red Brook, and an Unnamed Tributary to the Winhall River were assessed using the Vermont Agency of Natural Resources Phase 2 Stream Geomorphic Assessment protocol during the summer and fall of 2013 for a total of 13 river miles. The Vermont Rivers Program has developed state-of-the-art Stream Geomorphic Assessment (SGA) protocols that utilize the science of *fluvial geomorphology* (fluvial = water, geo = earth, and morphology = the study of structure or form). Fluvial geomorphology focuses on the processes and pressures operating on river systems. The Vermont protocol includes three phases:

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

2.2 River Corridor Planning Team

The river corridor planning team for the Winhall River watershed is comprised of Bear Creek Environmental (BCE), the Windham Regional Commission (WRC), and the Vermont Agency of Natural Resources (VANR). The 2013 study was funded through The State of Vermont Ecosystem Restoration Program under contract to the Windham Regional Commission. Shannon Pytlik from the Vermont River Management Program of VANR provided a quality control/assurance review of the stream geomorphic assessment data.

2.3 Local Project Objectives

The stream geomorphic assessment data are useful to resource managers, community watershed groups, municipalities and others for identifying how changes to land-use alter the physical processes and *habitat* of rivers. Characterizing stream type, identifying stressors in the watershed, and assessing the health of aquatic habitat and the riparian corridor are essential for the preparation of an effective and long-term river corridor plan. The Windham Regional Commission and project partners, in collaboration with towns and other organizations, have the opportunity to address and mitigate major watershed stressors through the design and implementation of r*estoration* and protection projects outlined in this corridor plan.

The Water Quality Management Plan (WQMP) for Basin 11 (West River, Williams River, and Saxtons River) (Vermont Agency of Natural Resources, 2008a) specifies the goal of proactively managing streams through identification and prioritization of stream restoration projects that will bring channels back to equilibrium conditions. Specifically, the WQMP includes recommendations to conduct Phase 2 geomorphic assessments in the Winhall River watershed. According to the Plan, two of the main impacts in this basin are thermal modification and sediment inputs to the streams as a result of human activities, such as river corridor encroachment. River corridor encroachments can lead to a lack of high quality *riparian buffers*, bank erosion, excessive sediment, flow alterations, and storm water runoff.

2.4 Goals of the Vermont River Management Program

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

3.0 BACKGROUND WATERSHED INFORMATION

3.1 Geographic Setting

3.1.1 Watershed Description

The Winhall River is a tributary to the West River, one of the major rivers in Vermont that drains into the Connecticut River (Figure 3.1). The 18-mile long stream drains approximately 60 square miles of land. Generally flowing from west to east, the Winhall River originates in eastern Sunderland, Vermont, and flows through the towns of Stratton, Winhall, Jamaica, and Londonderry, Vermont where it empties into the West River. From its source in the *headwaters* of the Green Mountains, the Winhall River flows south through Stratton and into a confined valley in Winhall. Here the Winhall River continues south along the Long Trail and then heads east down the mountainside to the valley floor where it generally flows through a broad valley until it reaches the confluence of the West River. As the river flows from Stratton to the West River, the Winhall River is influenced by several tributaries.

3.1.2 Political Jurisdictions

The Winhall River watershed is located in the following towns:

- Town of Winhall (Bennington County)
- Town of Sunderland (Bennington County)

- Town of Peru (Bennington County)
- Town of Landgrove (Bennington County)
- Town of Stratton (Windham County)
- Town of Jamaica (Windham County)
- Town of Londonderry (Windham County).

The 2013 Phase 2 assessments focused on the river channel and *riparian corridor* within Londonderry, Jamaica and Winhall.

3.1.3 Land-Use

A land cover layer (2002) was obtained from the Vermont Center for Geographic Information (VCGI) to present land-use within the Winhall River watershed for the river corridor plan. The 2002 land cover data indicates that the watershed is 80% forested, 8% urban, and 6% agricultural (Figure 3.2). While the Winhall River watershed is dominated by forested land, developed and agricultural land are sub-dominant land-uses. Developed areas are concentrated along roads in Bondville, a village within the town of Winhall, and in the vicinity of the Bromley Mountain Ski Resort in the town of Peru.

3.2 Geologic Setting

The Winhall River flows through a gentle *gradient* valley, except for two upstream reaches. Most of the main stem has a channel slope between one and two percent. The most upper reach of the Winhall River originates in Sunderland, where the valley slope is gentle with a slope of 1.8 percent. The valley gradient then increases to moderate (between 2 and 4 percent slope) as the river flows north through Stratton and into Winhall where it drops to gentle (less than two percent) as it turns east. This gentle gradient persists downstream through the towns of Winhall, Jamaica, and into Londonderry where it empties into the West River. The two tributaries assessed in this study, Red Brook and an Unnamed Tributary, flow through a moderate valley (2.5 percent) and a gentle to moderate valley (1 to 3 percent), respectively.

The Winhall River watershed is located in the Green Mountain physiographic region, which is characterized by a large anticline or upfold that extends from southern to northern Vermont. The watershed is located within the Green Mountain massif, which is dominated by Precambrian metamorphic gnesiss. The upper part of the watershed (in Stratton and Sunderland) is dominated by a variety of types of gnesiss including the following: granitic and granodioritic, trondjemite, and granodiorite gneiss with pegmatite (Bedrock Geologic Map of Vermont, USGS, 2011). The remaining part of the watershed is also Precambrian gneiss with a trondhjemite gneiss dominant (light gray to whitish gray fine grained biotite trondhjemite gneiss with abundant magnetite).

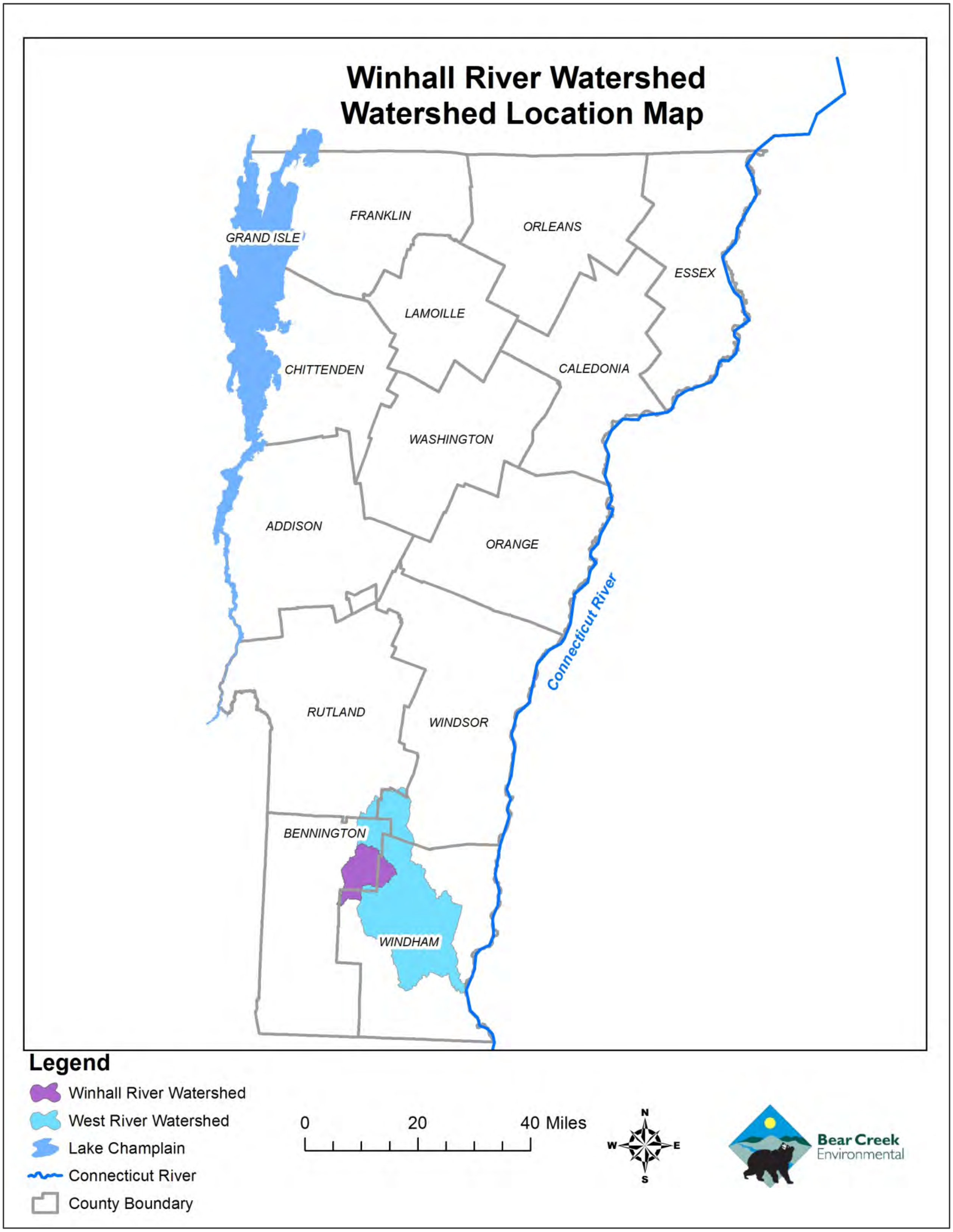


Figure 3.1. Watershed Location Map for Winhall River watershed.

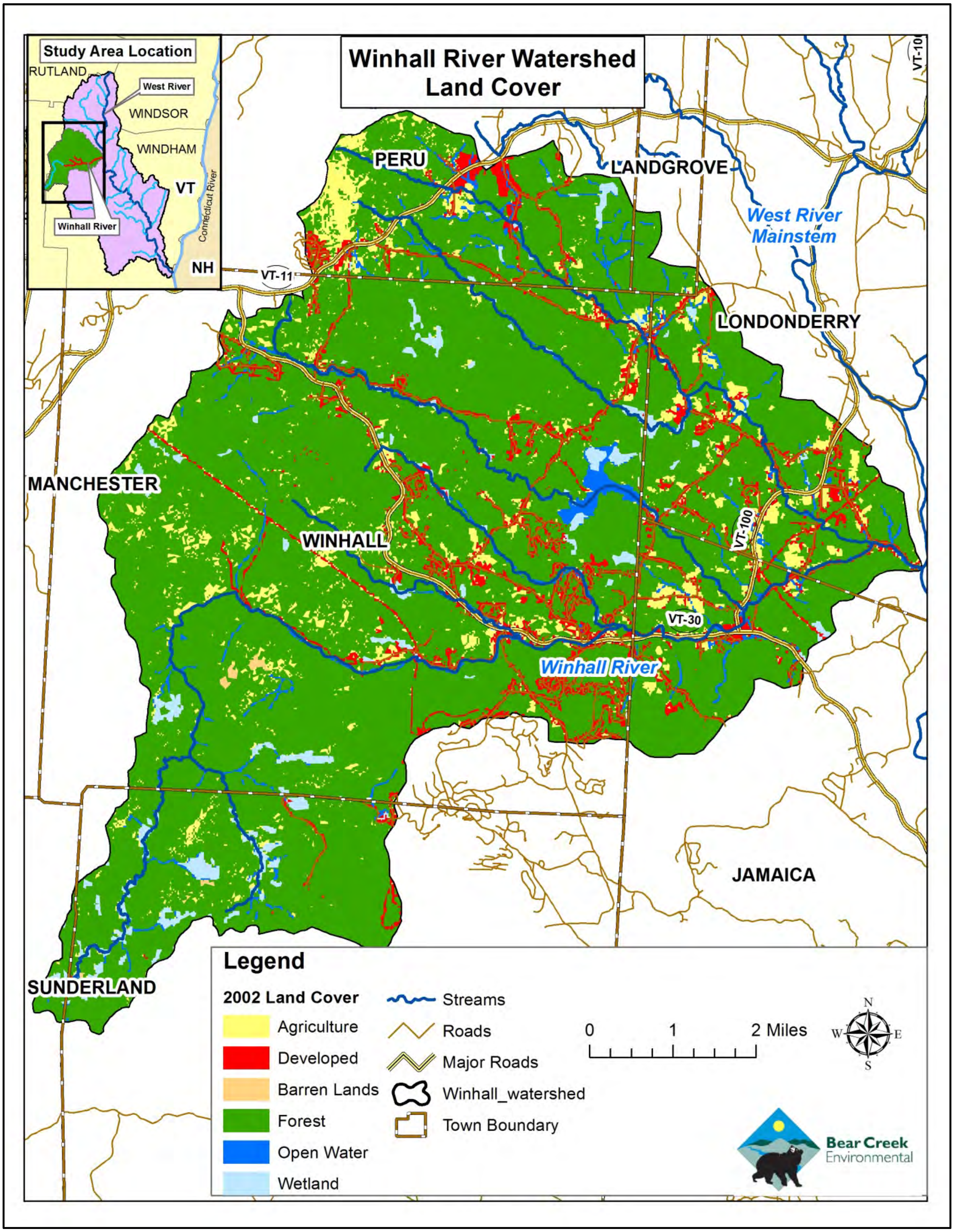


Figure 3.2. Land Cover Map for the Winhall River watershed.

3.3 Geomorphic Setting

A Phase 1 assessment of the Winhall River watershed was completed in 2007 as part of the West River study conducted by Michael Batcher, consultant to the Windham County Natural Resources Conservation District. The Phase 1 assessment included breaking the watershed into thirty *reaches*. Each reach represents a similar section of the stream based on physical attributes such as valley confinement, slope, sinuosity, bed material, dominant *bedform*, land-use, and other hydrologic characteristics. Each point in Figure 3.3 represents the downstream end of the reach. This report summarizes the 2013 Phase 2 study of the Winhall River and two tributaries (Red Brook and an Unnamed Tributary). The combined length of the eleven stream reaches assessed during the Phase 2 study is approximately 13 miles (Figure 3.4).

3.4 Hydrology

In late August 0f 2011, Vermont was hit hard by Tropical Storm Irene (TSI). Heavy rain totaled over seven inches in areas over the course of one day. This immense downpour caused raging floodwaters to tear through Vermont's streams, devastating people and infrastructure throughout central and southern Vermont. In some areas, TSI flooding approached historic flood levels, while in other areas, the storm greatly exceeded them. Over 500 miles of state roads were damaged as a result of TSI, in addition to over 2000 segments of municipal roads. In total, approximately 500 bridges were damaged or destroyed, as well as almost 1,000 culverts. Approximately 1,500 residences were significantly damaged or destroyed as a result of flooding, as well as state, municipal, and commercial buildings (VANR 2012b). The Winhall River was impacted by flooding from Tropical Storm Irene as well as instream channel work following the flood. Three bridges suffered significant damage or were completely destroyed as a result of high streamflows from TSI, and roads washed out in numerous locations (Windham Regional Commission 2013). Pages 1 and 2 in Appendix A show Irene-related damage within the study area. Studying the flood history of the Winhall River can aid in the understanding of flood damage during TSI and possible flood risks for the future.

In order to better understand the flood history of the Winhall River, long-term data from the U.S. Department of the Interior, U.S. Geological Survey (USGS), were obtained (USGS 2014). There are no USGS *gaging stations* in the Winhall River watershed, but peak flow data from two nearby stations were reviewed. The station on the Saxton's River at Saxton's River, Vermont has a drainage area of 72.2 square miles, and the station on a tributary to a West River tributary near Jamaica, Vermont has a drainage area of 0.9 square miles. The Winhall River watershed has a drainage area of 60 square miles and is a good match for the Saxton's River gage in terms of watershed size. The tributary to the West River near Jamaica provides a comparison for the Winhall River tributaries included in this Phase 2 assessment. The peak flow data show the magnitude of difference in stream flows as a result of Tropical Storm Irene in August 2011. Figure 3.5 shows a map of the locations of these two stations in relation to the Winhall River watershed.

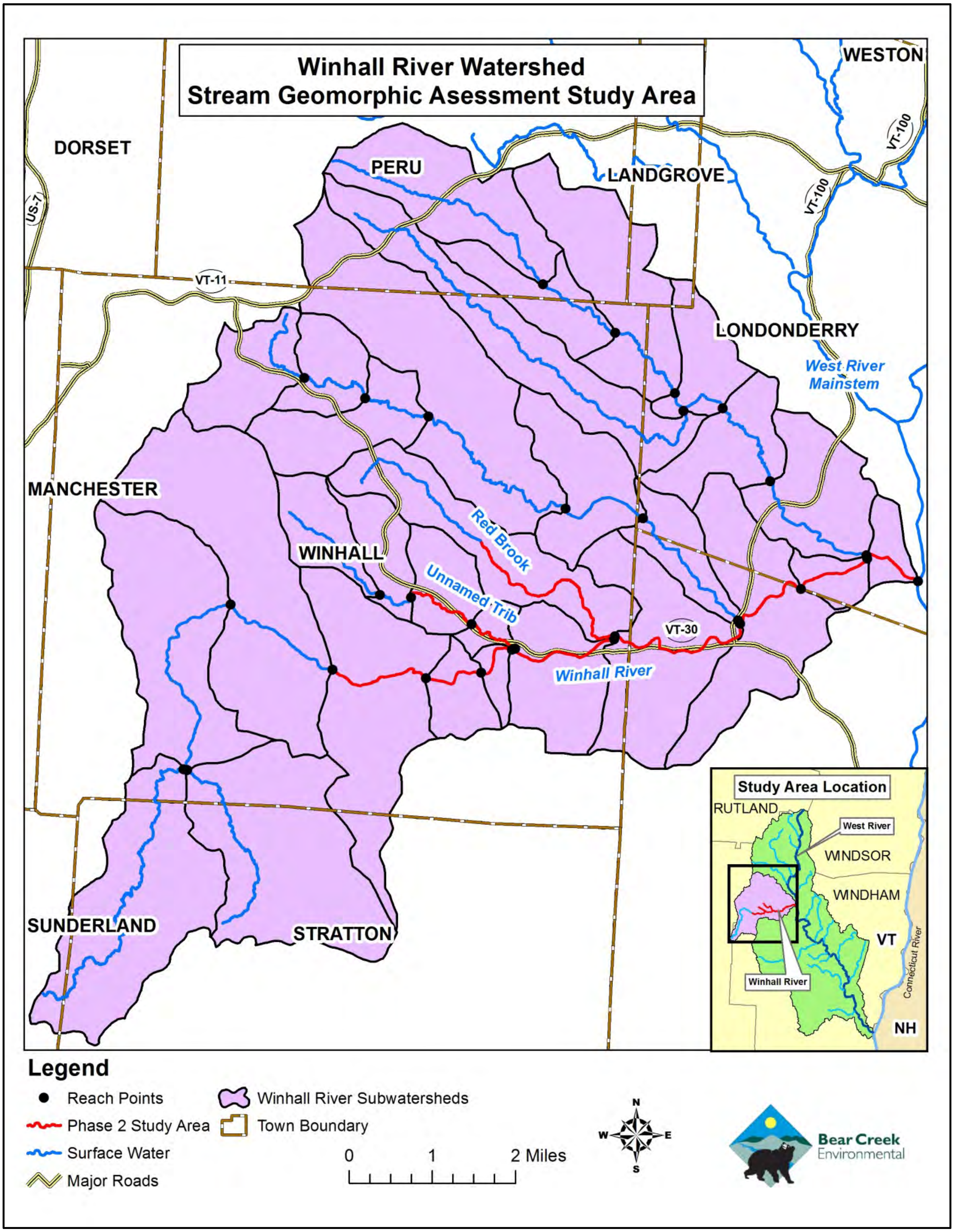
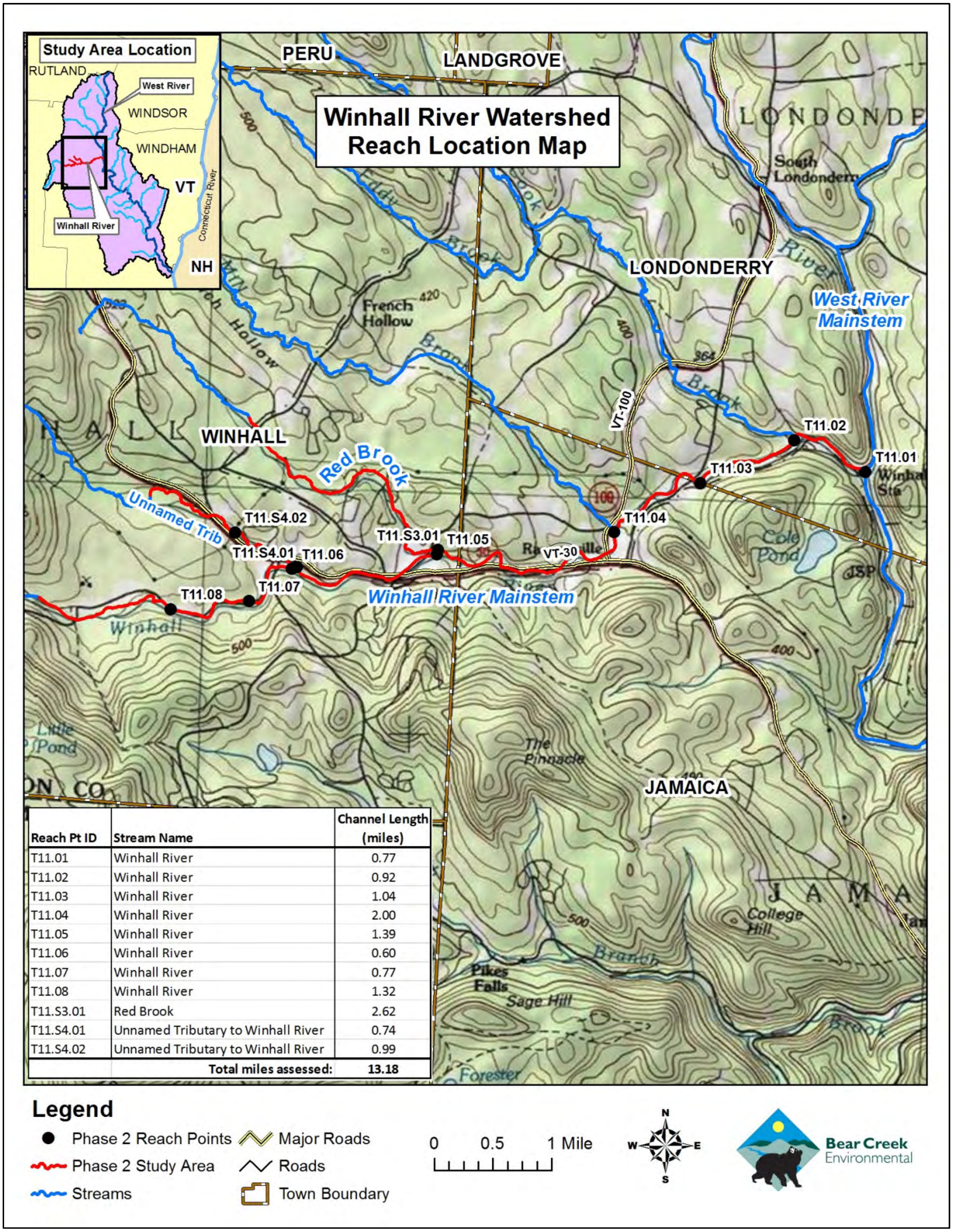


Figure 3.3. Winhall River Stream Geomorphic Assessment Study Area



Reach Pt ID	Stream Name	Channel Length (miles)
T11.01	Winhall River	0.77
T11.02	Winhall River	0.92
T11.03	Winhall River	1.04
T11.04	Winhall River	2.00
T11.05	Winhall River	1.39
T11.06	Winhall River	0.60
T11.07	Winhall River	0.77
T11.08	Winhall River	1.32
T11.S3.01	Red Brook	2.62
T11.S4.01	Unnamed Tributary to Winhall River	0.74
T11.S4.02	Unnamed Tributary to Winhall River	0.99
	Total miles assessed:	13.18

Figure 3.4. Reach Location Map for Winhall River watershed.

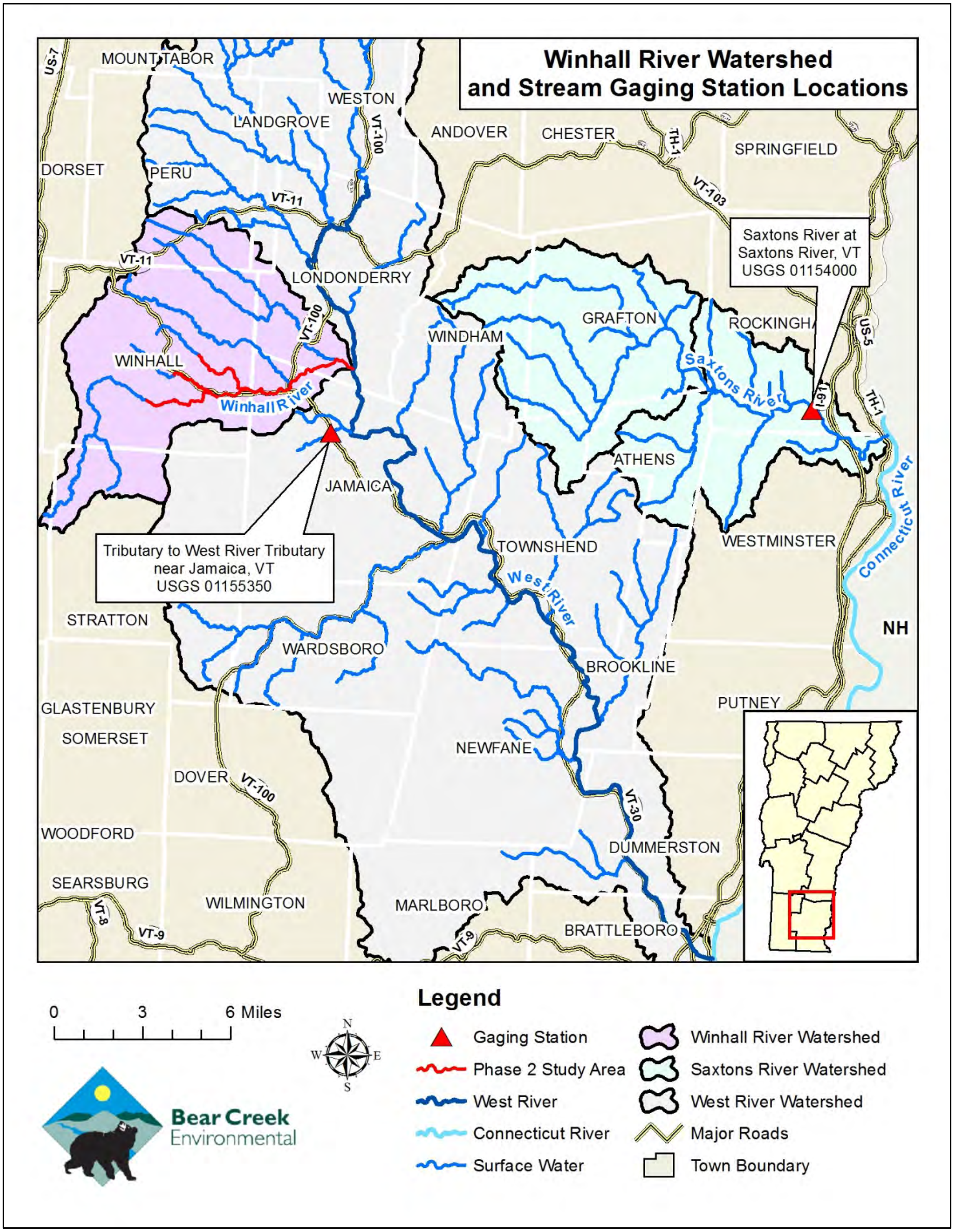


Figure 3.5. Gaging station locations in relation to study area.

Peak discharge records are available for the Tributary to the West Branch Tributary near Jamaica, Vermont from 1964 through 1978 and 1999 through 2012 (Figure 3.5) (USGS 2014). Flood events higher than the 50 year recurrence interval did not occur in this watershed as it did in 1973. However in August of 2011, Tropical Storm Irene resulted in an increase of approximately five times the peak streamflow from the previous water year.

Also, peak discharge records are available for the Saxtons River at Saxtons River, Vermont from 1941 through 1982 and 2002 through 2012 (Figure 3.7) (USGS 2014). Tropical Storm Irene resulted in peak streamflow higher than the 100 year recurrence interval, which approached the 500 year return interval. This peak streamflow value is the highest on record for the Saxtons River at Saxtons River, VT gaging station.

For Tropical Storm Irene, flood levels for many areas in Vermont equaled or approached the historic flood of 1927 (Vermont Agency of Natural Resources, 2012b). In the aftermath of TSI, emergency flood recovery work involved stream channel excavation where infrastructure damage occurred. Throughout central and southern Vermont, stream channels were dug out, and channel materials piled on the banks in a process known as *windrowing.* This and other channel work has impacted aquatic habitat in the Winhall River, and has created geomorphic instability that puts the stream channel at an elevated risk of causing significant damage to infrastructure during large storms in the future.

Of all the natural hazards experienced in Vermont, flooding is the most frequent, damaging, and costly. During the period of 1995-1998 alone, flood losses in Vermont totaled nearly $57 Million (Vermont Agency of Natural Resources, 2010b). The Vermont Agency of Administration (2012) states that over 733 million dollars has been estimated in funding resources for Tropical Storm Irene recovery. 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 (Vermont Agency of Natural Resources, 2010b). The VANR (2010b) attribute the high cost and frequency of fluvial erosion in Vermont to its geography (mountainous setting with narrow valleys and extreme climate) and past land-use practices (forest clearing).

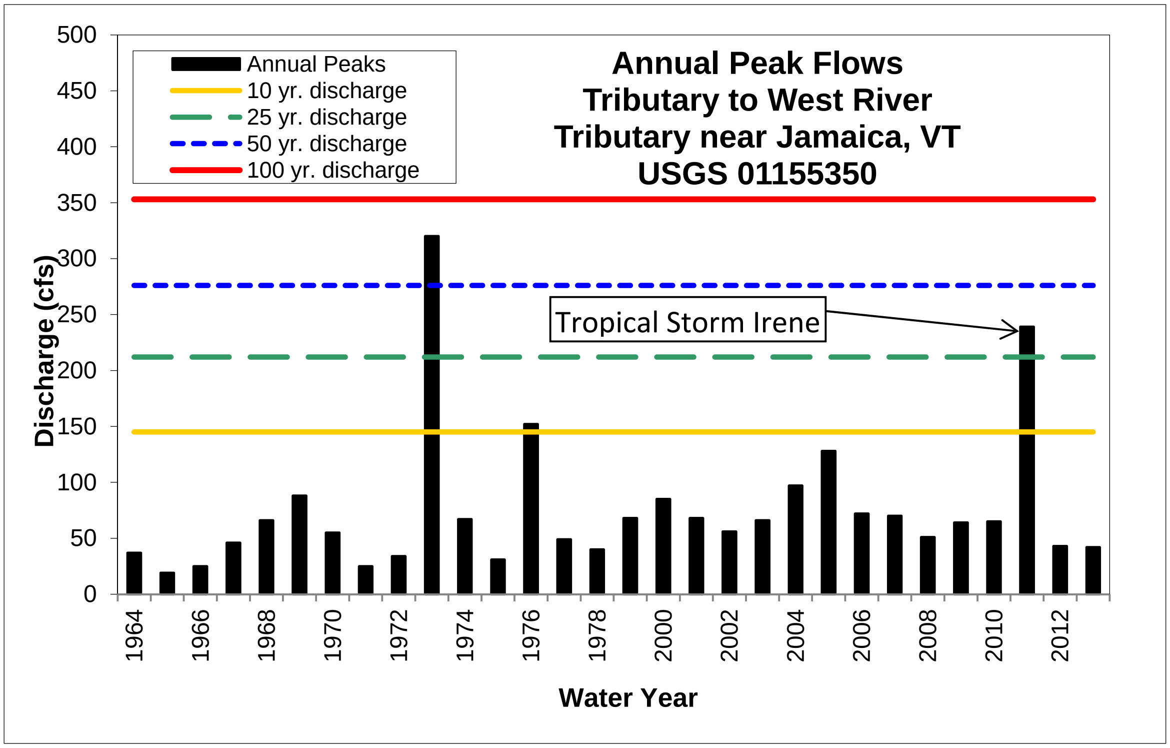


Figure 3.6. Annual Peak Flows for the Tributary to West River Tributary near Jamaica, Vermont.

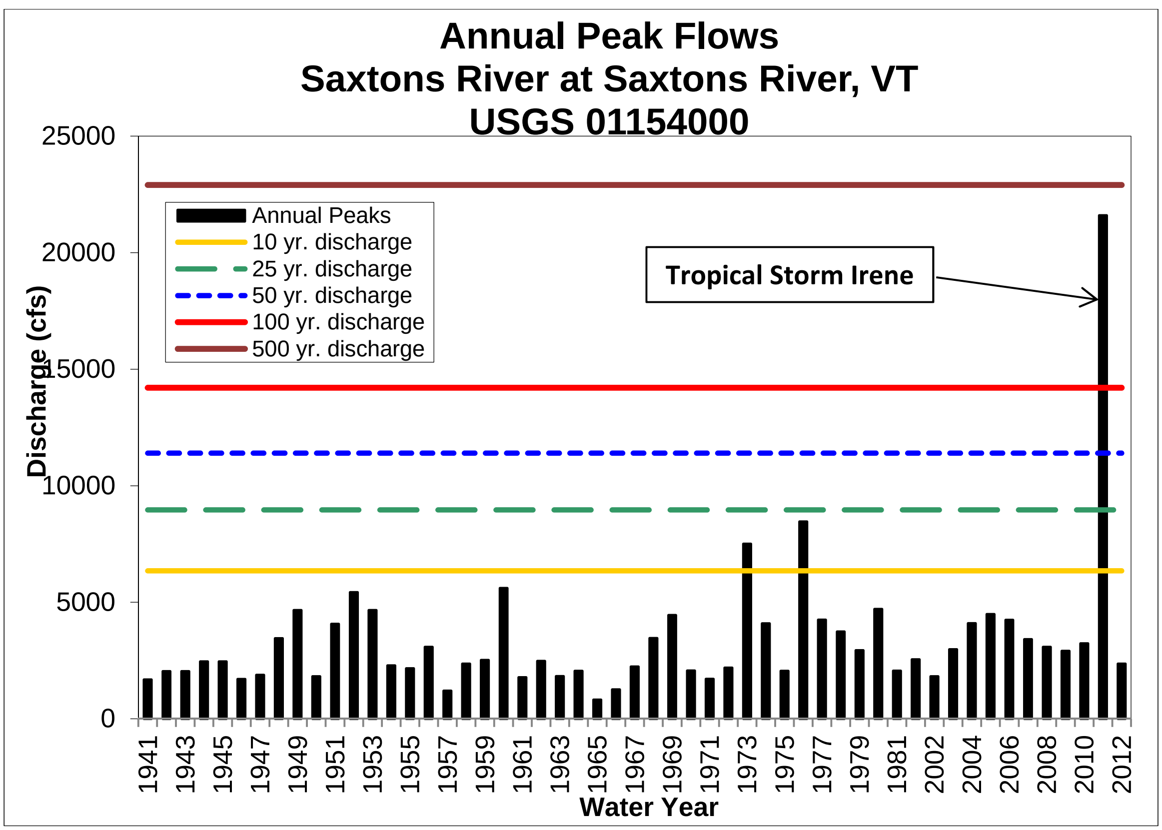


Figure 3.7. Annual Peak Flows for the Saxtons River at Saxtons River, Vermont.

3.5 Ecological Setting

The Winhall River watershed lies within the Southern Green Mountains biophysical region. This region is characterized by Thompson and Sorenson (2000) as being a combination of high peaks, high plateau, and dramatic escarpment on the western border while the eastern side is low foothills. The climate is cool during the summer months and the elevation leads to a high average annual precipitation (Thompson and Sorenson, 2000). The typical zonation of forests types can be found in this biophysical region. From the lower slopes to the summits, Northern Hardwood Forest change to Montane Yellow Birch-Red Spruce Forest, to Montane Spruce-Fir Forest, and finally to Subalpine Krummholz at the tree lines (Thompson and Sorenson, 2000).

The Vermont Significant Wetland Inventory (VSWI) GIS layer provides important information about the distribution of wetland habitat within the Winhall River watershed (Appendix A, page 3). There are numerous wetlands within the watershed according to the VSWI layer with the most wetlands located in the southwestern section of the watershed.

According to Thompson and Sorenson (2000), the Southern Green Mountains contain excellent wild habitat remaining in Vermont. Mammals found here include black bear, white-tailed deer, bobcat, fisher, beaver, and red squirrel. Bird species that nest in high elevations include blackpoll warblers, Swainson's thrush, and the rare Bicknells' thrush (Thompson and Sorenson, 2000).

Deer wintering areas are present in the watershed with deer wintering areas overlapping with the river corridor in reaches T11.04 and T11.06 through T11.08 on the mainstem and T11.S4.02 on the Unnamed Tributary (Appendix A, page 3). The major public land covering most of the watershed is the Green Mountain National Forest. Core habitat is abundant in the Winhall River watershed as shown on page 3 of Appendix A and represents those areas that are at least 100 meters from a zone of human disturbance.

4.0 METHODS

A summary of the Phase 1, Phase 2, and Bridge and *Culvert* methodologies is provided in the following sections.

4.1 Phase 1 Methodology

The Phase 1 assessment followed procedures specified in the Vermont Stream Geomorphic Assessment Phase 1 Handbook (Vermont Agency of Natural Resources, 2007), and used version 4.59 of the Stream Geomorphic Assessment Tool (SGAT). SGAT is an ArcView extension. Phase 1, the remote sensing phase, involves the collection of data from topographic maps and aerial photographs, from existing studies, and from very limited field studies, called "windshield surveys". The Phase 1 assessment provides an overview of the general physical nature of the watershed. As part of the Phase 1 study, stream reaches are determined based on geomorphic characteristics such as: valley confinement, valley slope, geologic materials, and tributary influence.

4.2 Phase 2 Methodology

The Phase 2 assessment of the Winhall River watershed followed procedures specified in the Vermont Stream Geomorphic Assessment (SGA) Phase 2 Handbook (Vermont Agency of Natural Resources, 2009b), and used version 10.0 of the SGAT Geographic Information System (GIS) extension to index impacts within each reach.

The geomorphic condition for each Phase 2 reach is determined using the Rapid Geomorphic Assessment (RGA) protocol, and is based on the degree of departure of the channel from its reference stream type (Vermont Agency of Natural Resources, 2009b). The study used the 2008 Rapid Habitat Assessment (RHA) protocol (Vermont Agency of Natural Resources, 2008a; Milone and MacBroom, Inc., 2008).

The RHA is used to evaluate the physical components of a stream (channel bed, banks, and riparian vegetation) and how the physical condition of the stream affects aquatic life. The RHA results can be used to compare physical habitat condition between sites, streams, or watersheds, and they can also serve as a management tool in watershed planning.

RHA and RGA field forms were completed for the Phase 2 reaches. The appropriate RHA and RGA forms were selected based on segment characteristics and scored according to the data collected from the field assessment. A segment score and corresponding condition were determined for both the RHA and the RGA. Additionally for the RGA, major geomorphic processes were identified, the stage of channel evolution was determined, and a stream sensitivity rating was assigned.

To assure a high level of confidence in the Phase 2 SGA data, strict quality assurance/quality control (QA/QC) procedures were followed by BCE. These procedures involved a thorough in-house review of all data, which took place during January 2014. The Project Team conducted the assessment according to the approved Quality Assurance procedures specified in the Phase 2 handbook. Shannon Pytlik of the State of Vermont Watershed Management Division conducted a QA/QC review of the data collected by Bear Creek Environmental (BCE) for the Winhall River watershed during March 2014.

4.3 Bridge and Culvert Methodology

Bridge assessments were conducted by BCE on all public and private crossings within the selected Phase 2 reaches. The Agency of Natural Resources Bridge and Culvert protocols (Vermont Agency of Natural Resources, 2009a) were followed. Latitude and Longitude at each of the structures was determined using a MobileMapper 100 GPS unit. The assessment included photo documentation of the inlet, outlet, upstream, and downstream of each of the structures.

The Vermont Culvert Geomorphic Compatibility Screening Tool (Milone and MacBroom, Inc. 2008) was used to determine geomorphic compatibility for each bridge. Bridges are not typically screened for geomorphic compatibility in the VTANR protocol because they are usually more robust and have less impact on stream channel function than culverts. Bridges also do not have potential to become perched above the water surface, because the bottom of the structure is natural substrate. Bridges in this study were screened using the geomorphic compatibility tool that was modified by BCE to exclude the slope parameter. Tables 1 and 2 in Appendix B explain how each bridge was scored using the Screening Tool. The compatibility rating is based on four criteria: structure width in relation to bankfull channel width, sediment continuity, river approach angle, and erosion & armoring and the ratings span the following range:

- Fully Compatible
- Mostly Compatible
- Partially Compatible
- Mostly incompatible
- Fully Incompatible

All culverts were evaluated for Aquatic Organism Passage (AOP) using the Vermont Culvert Aquatic Organism Passage Screening Tool (Milone and MacBroom, 2009). Tables 3 through 5 in Appendix B explain how each culvert was scored using the screening tool. The screening guide has the four following categories:

- Full AOP for all organisms
- Reduced AOP for all aquatic organisms
- No AOP for all aquatic organisms except adult salmonids
- No AOP for all aquatic organisms

5.0 RESULTS

5.1 Condition and Departure Analysis

5.1.1 Stream Types

Reference stream types are based on the valley type, geology and climate of a region and describe what the channel would look like in the absence of human-related changes to the channel, floodplain, valley width, and/or watershed. Table 1 shows the typical characteristics used to determine reference stream types (Vermont Agency of Natural Resources, 2009b). Reference reach typing was based on both the Rosgen (1996) and the Montgomery and Buffington (1997) classification systems. Stream and valley characteristics including valley confinement, and slope were determined from digital United States Geological Survey (USGS) topographic maps (Table 2).

Table 1. Reference Stream Type

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

Table 2 lists the reference stream types for assessed reaches in the Winhall River watershed. Most reaches assessed for Phase 2 in the Winhall River watershed are “C” channels by reference. Reference “C” channels have unconfined valleys with moderate to gentle valley slopes and moderate to high width to depth ratios and sinuosity. The confinement is Broad or Very Broad for all reaches, except one (T11.02) which is Semi-confined. All reaches have a reference bedform of *riffle-pool* except for T11.08, which is *braided*. The reference reach characteristics were refined during the Phase 2 Assessment.

During the Phase 2 assessment, the eleven assessed reaches were broken into 26 segments based on detailed field observations. A segment is distinct in one or more of the following parameters: degree of floodplain encroachment or channel alteration, *grade control* occurrence (e.g. ledge), channel dimensions, channel sinuosity and slope, *riparian buffer* and corridor conditions, and degree of flow regulation. The most downstream segment within a reach is labeled “A”, the second from the reach point is “B, etc. (i.e. T11.02-A is the most downstream segment on Reach T11.02) (Figures 4.1 and 4.2). Of the 26 segments, four were not assessed: one segment was an impounded pond, two segments lacked property access, and one segment was upstream of the study area.

The existing stream type is based on channel dimensions measured during the Phase 2 assessment. A map of the reference and existing stream type for each assessed reach/segment is included on page 4 of Appendix A. Some of the segments in the 2013 assessment have the same reference and existing stream type. However, the existing stream type differs from the reference stream type in ten of the assessed segments. This indicates that a stream type departure has taken place in those areas. A stream type departure occurs when the channel dimensions deviate so far from the reference condition that the existing stream type is no longer the reference stream type. These stream type departures represent a significant change in floodplain access and stability. Watersheds which have lost attenuation or sediment storage areas due to human related constraints are generally more sensitive to erosion hazards, transport greater quantities of sediment and nutrients to receiving waters, and lack the sediment storage and distribution processes that create and maintain habitat (Vermont Agency of Natural Resources, 2009b).

Table 2: Geomorphic Setting of 2013 Assessed Reaches

Stream	Reach ID	Reference Stream Type	Reference Confinement	Valley Slope (%)	Bedform
Winhall River	T11.01	C	Broad	0.69	Riffle-Pool
	T11.02	B	Semi-confined	1.5	Riffle-Pool
	T11.03	C	Very Broad	1.2	Riffle-Pool
	T11.04	C	Very Broad	1.7	Riffle-Pool
	T11.05	C	Very Broad	1.0	Riffle-Pool
	T11.06	C	Very Broad	1.6	Riffle-Pool
	T11.07	C	Broad	1.3	Riffle-Pool
	T11.08	C	Very Broad	1.3	Braided
Red Brook	T11.S3.01	C	Very Broad	2.5	Riffle-Pool
Unnamed Tributary	T11.S4.01	E	Very Broad	1.2	Riffle-Pool
	T11.S4.02	C	Very Broad	2.5	Riffle-Pool

Figure 4.1. Reach and segment locations for the Winhall River watershed in Jamaica and Londonderry, Vermont.

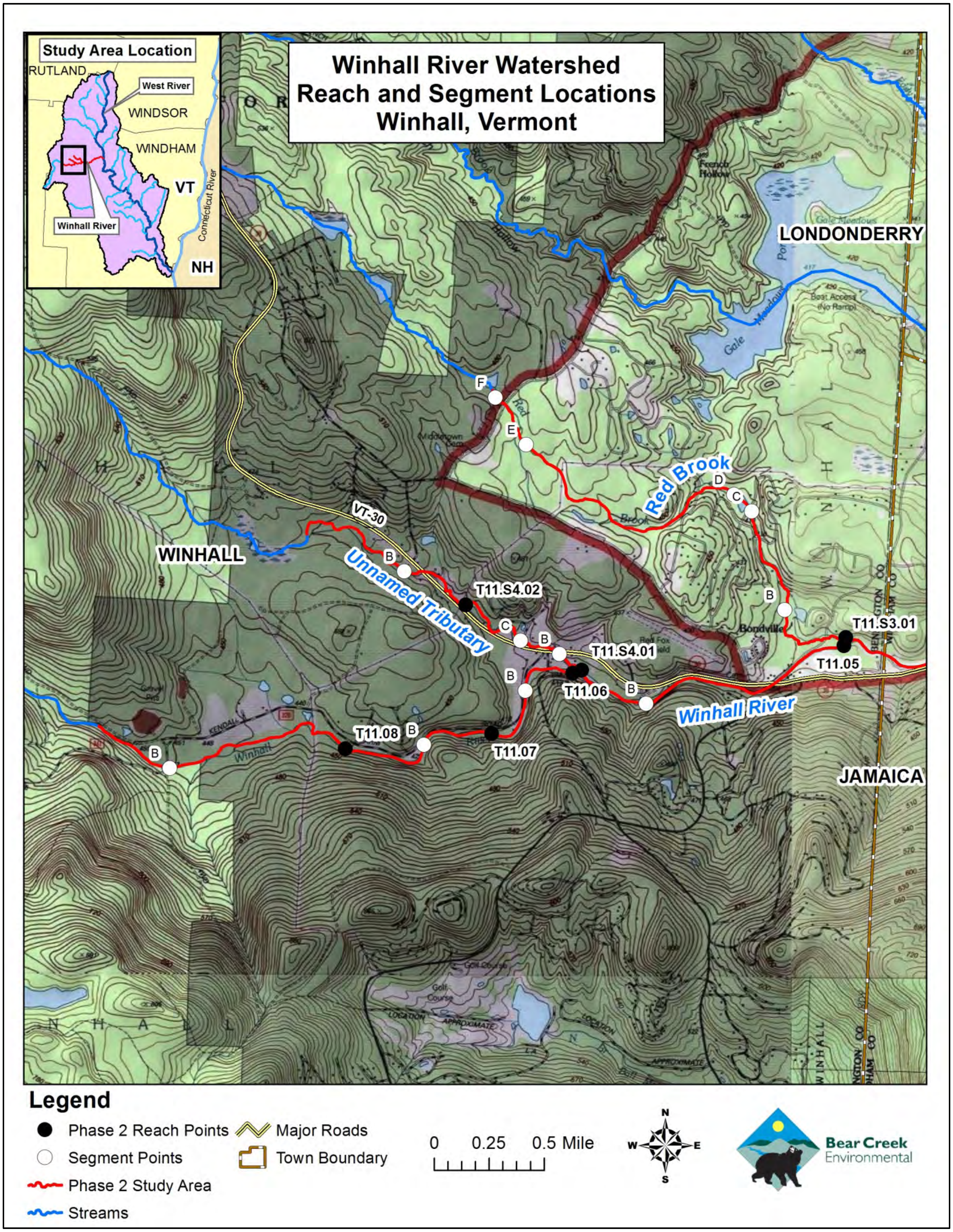


Figure 4.2. Reach and segment locations for the Winhall River watershed in Winhall, Vermont

5.1.2 Geomorphic Condition

The stream condition is determined using the scores on the rapid assessment field forms, and is defined in terms of departure from the reference condition. There are four categories to describe the condition (reference, good, fair and poor). These ratings are defined below.

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

A map of the existing geomorphic condition for each segment is depicted on page 5 of Appendix A. Geomorphic condition is determined based on the degree (if any) of channel degradation, aggradation, widening and planform adjustment. Degradation is the term used to describe the process whereby the stream bed lowers in elevation through erosion, or scour, of bed material. Aggradation is a term used to describe the raising of the bed elevation through an accumulation of sediment. The planform of a channel is its shape as seen from the air. Planform change can be the result of a straightened course imposed on the river through different channel management activities, or a channel response to other *adjustment processes* such as aggradation and widening. Channel widening is a result of channel degradation or sediment build-up in the channel. In both situations the stream's energy is concentrated into both banks.

Within the Winhall River watershed, five of twenty one assessed segments are in "poor" geomorphic condition, fourteen are in "fair" condition, and two are in "good" condition. No segment is in "reference" geomorphic condition. Four segments were not assessed due to such constraints as bedrock gorges, impoundment, and no property access. The current geomorphic conditions in the assessed segments are a result of several factors. Corridor encroachments are common along the river, including Vermont Route 30, which runs along the mainstem and Unnamed Tributary. Town roads and buildings also abound within the river corridor. Some of these encroachments are causing changes in valley types. Following Tropical Storm Irene, areas within the Winhall River watershed were windrowed and their channels excavated in an attempt to protect infrastructure from future flooding. This windrowing, in combination with other factors such as corridor encroachments, has caused the Winhall River to lose access to its floodplain in many areas. Mass failures, erosion, and aggradation were all exacerbated by TSI, and are contributing to the unstable geomorphic condition of many assessment reaches.

5.1.3 Habitat Condition

The habitat condition for each segment within the Winhall River watershed 2013 study area is presented on page 5 of Appendix A. Seven segments in the study are in "good" habitat condition and are located in areas where the stream channel flows away from major roads and into forested areas (T1.08-A and B; T11.S3.01-A through E; T11.S4.02-B). These segments have minimal to no corridor encroachments, allowing for high quality vegetated banks and buffers. The segments in "good" condition have high amounts of large woody debris in the channel, many *pools*, and good canopy cover; all of which provide habitat for aquatic life. Fourteen segments are in “fair” habitat condition (T11.01-A through T11.07-B; T11.S4.01-B; T11.S4.02-A). Segments are in “fair” habitat condition mainly as a result of corridor encroachments, poor bank and buffer vegetation, erosion and revetments, channel straightening, and windrowing. Many of the segments in “fair” habitat condition exhibit a habitat stream type departure to a *plane bed*, featureless channel.

The map on page 5 in Appendix A includes both the geomorphic and habitat condition maps side by side. Overall, the habitat and geomorphic conditions were similar, implying that the ecological health of the Winhall River watershed is related to the geomorphic condition of the stream.

As shown in Table 1 (Appendix A, pages 8 through 10), many of the segments have high width to depth ratios. This can be attributed to the geomorphic process of channel widening. The aggradation as a result of the increased flows from TSI in 2011 has likely led to the high width to depth ratios observed in the assessed reaches. A high width to depth ratio indicates that the channel is relatively wide and shallow. Wide, shallow channels tend to have a reduced number of deep pools, canopy cover in the center of the stream, undercut banks, and sometimes a higher water temperature (Foster, Stein, & Jones, 2001). These factors can contribute to a lower habitat score.

5.1.4 Sediment Regime

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

- Channelization and bank armoring
- Removal of woody riparian vegetation
- Floodplain encroachments
- Undersized stream crossings
- Post-Irene channel work

These anthropogenic practices have altered the balance between water and sediment discharges within the Winhall River watershed. The sediment regime is the quantity, size, transport, sorting, and distribution of sediments. The sediment regime may be influenced by the proximity of sediment sources, the hydrologic characteristics of the region, and the valley, floodplain, and stream morphology (ANR, 2010a). Sediment can be supplied to the river through bank erosion, large flooding events, and stormwater inputs. A sediment regime map depicting the reference and existing sediment regimes can be found on page 6 of Appendix A. Reference and existing sediment regimes were derived from the Agency of Natural Resources Data Management System according to the sediment regime criteria established by the Vermont Agency of Natural Resources (2010a).

Of the 25 segments in the study area, 23 have a reference sediment regime of Coarse Equilibrium & Fine Deposition (*Equilibrium*). *Equilibrium* channels are unconfined on at least one side, and they transport and deposit sediment in equilibrium, wherein the stream power is balanced by the sediment load, sediment size, and boundary resistance. Two segments have transport as their dominant reference sediment regime. *Transport* channels are typically in confined valleys, and do not supply appreciable quantities of sediment to downstream reaches. These channels have confining valley walls with limited sediment storage capacity due to both channel slope and entrenchment (Vermont Agency of Natural Resources, 2010a).

Changes in hydrology (such as development and agriculture within the riparian corridor) and sediment storage within the watershed have altered the reference sediment regime types for many segments in the Winhall River watershed. The majority of the segments have undergone a transformation from a reference sediment regime of Coarse Equilibrium & Fine Transport or Transport to a departure sediment regime (Appendix A, page 6). Tropical Storm Irene, as well as post-flood channel work, further altered the sediment regimes in the study reaches. The analysis of sediment regimes at the watershed level is useful for summarizing the stressors affecting geomorphic condition of river channels. Sediment regime mapping provides a context for understanding the sediment transport and channel evolution processes.

5.1.5 Channel Evolution Model

Channel morphologic responses to these anthropogenic practices and changes in sediment regimes contribute to channel adjustment that may further create unstable channels. All three adjustment processes, aggradation, widening and planform migration as a result of active and historic degradation and recent channel work are present within the Winhall River watershed. In many areas, the placement of VT Route 30 has significantly changed the river's valley width, floodplain access, and its ability to meander. The floods that came through the area during TSI in August, 2011 have resulted in significant aggradation and planform change within many reaches, and post-TSI channel work has exacerbated these impacts in some areas.

The reach condition ratings of the Winhall River watershed indicate that most of the reaches/segments are actively or have historically undergone a process of major geomorphic adjustment. Many of the reaches studied in the Winhall River watershed are undergoing a channel evolution process in response to large scale changes in its sediment, slope, and/or discharge associated with the human influences on the watershed and impacts from flooding.

The “F” stage channel evolution model (Vermont Agency of Natural Resources, 2009b; Vermont Agency of Natural Resources, 2004) is helpful for explaining the channel adjustment processes underway in the Winhall River watershed. The “F” stage channel evolution model is used to understand the process that occurs when a stream degrades (*incises*).

The common stages of the “F” channel evolution stage, as depicted in Figure 5.2 include:

- Stable (F-1) - a pre-disturbance period
- Incision (F-II) – channel degradation (head cutting)
- Widening (F-III) – bank failure
- Stabilizing (F-IV) – channel narrows through sediment build up and moves laterally building juvenile floodplain
- Stable (F-V) - gradual formation of a stable channel with access to its floodplain at a lower elevation

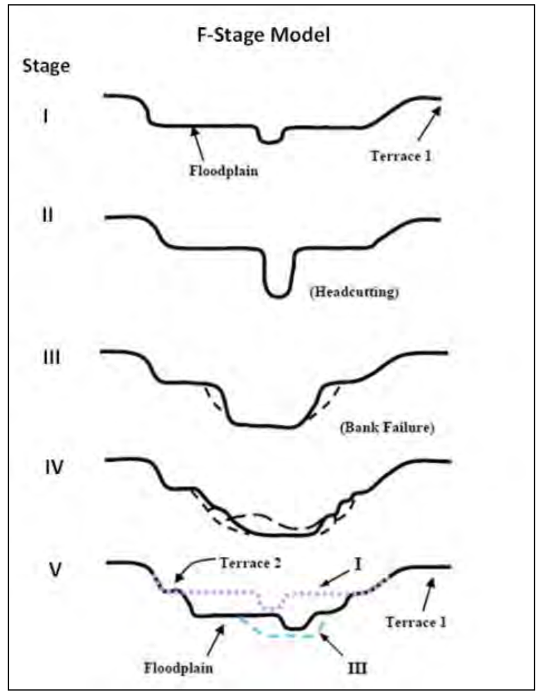


Figure 5.1 Typical channel evolution models for F-Stage (Vermont Agency of Natural Resources, 2009b)

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

The channel evolution stage for each Phase 2 segment was determined based on field data and observations. A summary of the channel evolution stage by segment is provided on pages 8 through 10 of Appendix A. Three segments on Red Brook (T11.S3.01-A, D, and E) are in stage I of the "F-stage" channel evolution model, indicating that they have not undergone a channel incision process. Three segments on the Winhall River mainstem are currently in stage "F-II", T11.05-A, T11.06-A, and T11.07-A. These segments have incised but not widened, likely due to boundary conditions limiting lateral channel movement.

Ten of twenty one assessed segments are in stage III of the "F-stage" channel evolution model. Most of these segments have undergone severe historic incision. The placement of VT Route 30 likely led to this incision and the subsequent loss of floodplain access, which has been exacerbated by TSI and post-TSI channel work in some areas. In stage F-III, the entrenched channel begins to widen and migrate laterally through bank erosion caused by the increased stream power.

Five segments have moved into stage IV of the "F-stage" channel evolution model. This means that the channel has stabilized itself by changes in its migration pattern and building a new floodplain at a lower elevation. Some of these segments are highly depositional and have become braided with many large *bar* features including transverse (*diagonal*) bars. This buildup of sediment has led to channel widening and planform adjustment.

5.2 Reach/Segment Descriptions

A description of each segment is provided in this section along with a list of recommendations for restoration and protection strategies. The segments are listed from downstream to upstream. Phase 2 Segment Summary Reports from the Agency of Natural Resources' Data Management System, which contain all the data for the Phase 2 steps, can be found at the following link: https://anrweb.vt.gov/DEC/SGA/projects/phase2/dataEntry.aspx?pid=120.

Proposed project locations are provided on maps in Appendix C. Further recommended project detail tables and photos are also provided in Appendix C. The Phase 2 stream geomorphic assessment provides a picture of the condition of the channel and the adjustment process occurring; however, it is not a comprehensive study for determining site specific actions. The Phase 2 study provides a foundation for project development, and additional work is recommended to further develop these projects.

Winhall River

T11.01

The most downstream reach on the Winhall River was not split into segments during assessment. The reach begins at the confluence with the West River and continues upstream for 4,000 feet to the reach break. The stream channel flows through a broad valley as it enters the West River. This reach is an *alluvial fan,* which occurs as the channel slope drops to meet the West River, creating a depositional area. Corridor encroachments throughout the reach, including Winhall Station Road, are limiting floodplain access in many areas. Residential development has impacted buffers greatly, particularly on the southern side of the river. Erosion is frequent along the south bank in areas where the riparian buffer is lacking. The channel underwent extreme historic incision as well as minor recent incision, as evidenced by glacial till present in the streambed. Aggradation is a major process that is currently occurring as the channel forms large bars and steep riffles. The channel is also widening and adjusting planform slightly through large flood chutes. Due to these processes, reach T11.01 is in **fair** geomorphic condition. The reach is also in in **fair** habitat condition due to its impacted buffers, eroding banks, and lack of large woody debris (LWD).

Figure 5.2. Stream crossing at the upstream end of T11.01.

T11.01 Data Summary		**Reference**	**Existing**
	Confinement	Broad	Broad
Length: 4,066 ft	Stream Type	C	B
Drainage Area: 60 sq. mi.	Entrenchment Ratio	> 2.2	1.5
Evolution Stage: F-III	Incision Ratio	< 1.2	2.5
Sensitivity: High	Dominant Bed Material	Cobble	Cobble
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Encroachments, Poor Buffers, Poor Bank Vegetation, Erosion**		

T11.02

This reach was split into two segments during the assessment due to the presence of a bedrock gorge. Overall, the reach has a semi-confined valley and runs along Cohen Road in Londonderry, VT between the TH52 and Goodaleville Road stream crossings.

T11.02-A

This segment begins just upstream of the TH52 bridge and continues upstream almost 4,400 feet to where a bedrock gorge begins. Characterized by a semi-confined valley and a riffle-pool bedform, the segment has historically incised slightly, but the presence of several grade controls upstream is limiting the channel's vertical adjustment. T11.02-A has an "F" stream type, which indicates that it has very little floodplain access. Several mass failures are present along the northern valley wall, and stormwater inputs from Cohen Road abound on the southern river bank. Major aggradation is currently occurring in the segment, creating large diagonal bars with steep riffles. Planform adjustment is evidenced by several flood chutes throughout the segment. Overall, it is in **fair** geomorphic condition. Habitat condition is also **fair** due to impacted buffers along Cohen Road and lacking bank vegetation.

Figure 5.4. One of many mass failures present in T11.01-A.

T11.02-A Data Summary		Reference	Existing
Length: 4,378 ft	Confinement	Semi-confined	Semi-confined
Drainage Area: 46 sq. mi.	Stream Type	B	F
Evolution Stage: F-IV	Entrenchment Ratio	1.4-2.2	1.1
Sensitivity: Very High	Incision Ratio	< 1.2	1.3
	Dominant Bed Material	Cobble	Cobble
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Poor Buffers, Stormwater Inputs, Mass Failures, Poor Bank Vegetation**		

T11.02-B

This segment is located within a bedrock gorge in a narrowly confined valley. Several bedrock grade controls are present in the segment, which prevent stream channel adjustment. The segment begins approximately 1,000 feet downstream of the Cohen Road stream crossing and continues upstream 500 feet to the reach break. T11.01-B was not fully assessed due to the presence of the bedrock gorge. Administrative judgment was used to determine reference and existing stream type, bed material, and bedform. Overall, the segment is in good geomorphic condition due to the stability of the bedrock grade controls.

Figure 5.6. T11.02-B is located within a bedrock gorge.

T11.02-B Data Summary	***NOT ASSESSED**	**Reference**	**Existing**
	Confinement	Narrowly Confined	Narrowly Confined
Length: 505 ft	Stream Type	F	F
Drainage Area: 46 sq. mi.	Entrenchment Ratio	< 1.4	N/A
Evolution Stage: N/A	Incision Ratio	< 1.2	N/A
Sensitivity: N/A	Dominant Bed Material	Bedrock	Bedrock
	Dominant Bedform	Bedrock	Bedrock
Major Stressors:	**None**		

T11.03
This reach was split into three segments to account for changes in reference confinement and channel dimensions.

T11.03-A
This segment flows through a very broad valley from just below the Goodaleville Road crossing to 1,500 feet upstream where the valley narrows. It is characterized by extensive straightening with windrowing along Goodaleville Road. The channel was historically straightened along the road, but windrowed post-TSI likely to protect the road. Extreme historic incision has caused a stream type departure and loss of floodplain access in T11.03-A. Bank revetments are nearly continuous along the southern bank of the river and also present along the north bank. Widening has occurred in the segment and rip rap is limiting further widening in some areas. Channel alterations have caused the river to lose its riffle-pool bedform in this segment in exchange for a plane bed, featureless channel. Many diagonal bars are present in this reach. Historic and recent channel alterations have created geomorphic instability in T11.03-A, placing it in **poor** geomorphic condition. The loss of bedform in this segment, as well as a lack of LWD, and poor banks and buffers have placed T11.08-A in **fair** habitat condition.

Figure 5.7. T11.03-A was windrowed extensively post-Irene.

T11.03-A Data Summary		**Reference**	**Existing**
Length: 2,758 ft Drainage Area: 45 sq. mi. Evolution Stage: F-III Sensitivity: Extreme	Confinement	Very Broad	Very Broad
	Stream Type	C	F
	Entrenchment Ratio	> 2.2	1.4
	Incision Ratio	< 1.2	1.9
	Dominant Bed Material	Cobble	Cobble
	Dominant Bedform	Riffle-Pool	Plane Bed
Major Stressors:	**Windrowing, Channel Straightening, Revetments, Erosion, Mass Failure, Poor Buffers, Stormwater Inputs**		

T11.03-B

This segment is located along Goodaleville Road where the river valley narrows. The majority of the segment was historically straightened along the road, and a portion was recently windrowed post-Irene. The high incision ratio in T11.03-B alludes to major historic incision. Despite this incision, the segment overall has intact floodplain access. These alterations have, however, caused a riffle-pool reference bedform to be converted to plane bed. Erosion abounds along both banks, as does rip rap along Goodaleville Road. One mass failure is present along the north bank of the river. Several diagonal bars with steep riffles indicate that the segment has majorly aggraded. Due to the aforementioned impacts and processes, T11.03-B is in **fair** geomorphic condition. The segment lacks a diversity of bed features and does not provide good cover for aquatic biota. Coupled with historic and recent channel alterations as well as impacted buffers, T11.03-B is in **fair** habitat condition.

Figure 5.8. A featureless plane bed channel dominates in T11.03-B.

T11.03-B Data Summary		**Reference**	**Existing**
Length: 1,277 ft Drainage Area: 45 sq. mi. Evolution Stage: F-III Sensitivity: High	Confinement	Narrow	Narrow
	Stream Type	C	C
	Entrenchment Ratio	> 2.2	2.7
	Incision Ratio	< 1.2	1.8
	Dominant Bed Material	Cobble	Cobble
	Dominant Bedform	Riffle-Pool	Plane Bed
Major Stressors:	**Windrowing, Channel Straightening, Revetments, Erosion, Mass Failure, Stormwater Inputs**		

T11.03-C

This segment begins where the Winhall River flows away from Goodaleville Road and ends 1,500 feet upstream just above the confluence of Mill Brook with the Winhall. T11.03-C flows through a very broad valley and the river corridor is encroached upon by Goodaleville Road only at the most downstream end of the segment. Erosion is common on both sides of the river, and a high width to depth ratio indicates that the channel has widened significantly. Segment T11.03-C is undergoing active planform adjustment and moving laterally through multiple flood chutes. A juvenile floodplain is being built via very large bars. Channel incision occurred historically, but floodplain connectivity remains. Gravel mining was noted where the Winhall River approaches Goodaleville Road. Overall, T11.03-C is in **poor** geomorphic condition due to the adjustments that have occurred and are currently occurring in the segment. Habitat conditions are better in this segment than the rest of the reach, but T11.03-C is still in the **fair** category due to impacted bank and buffer vegetation, channel morphology, and hydrologic characteristics.

Figure 5.9 The Winhall River is building a juvenile floodplain through large bars in T11.03-C.

T11.03-C Data Summary		**Reference**	**Existing**
Length: 1,473 ft Drainage Area: 45 sq. mi. Evolution Stage: F-IV Sensitivity: High	Confinement	Very Broad	Very Broad
	Stream Type	C	C
	Entrenchment Ratio	> 2.2	8.1
	Incision Ratio	< 1.2	1.5
	Dominant Bed Material	Cobble	Cobble
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Erosion, Poor Buffers, Mass Failure, Gravel Mining, Channel Straightening, Encroachments**		

T11.04

This reach was not split into any segments during assessment. T11.04 begins just downstream of the Route 100 stream crossing and continues upstream to just above the confluence of a major tributary, Red Brook, with the Winhall River. The channel flows through a very broad valley by reference, but due to the presence of Vermont Route 30 encroaching upon the river corridor, the existing valley type is broad. T11.04 has a dominant bedform of braided, with riffle-pool subdominant. The channel was historically straightened along Rt. 30, which led to historic incision. Recent channel work post-Irene involved channel windrowing in some areas of the reach. Rip rap is abundant where the river flows along Rt. 30, and seven mass failures are present throughout the reach. Bank erosion is severe and buffers have been majorly impacted. Aggradation is extreme in this reach, with huge bars creating a braided channel throughout. Widening and planform adjustment are major processes, as evidenced by abundant bank erosion and numerous flood chutes. The channel is currently building a juvenile floodplain through its very large bars. Due to these factors, reach T11.04 is in **poor** geomorphic condition. The braided nature of the channel has created abundant refuge areas for fish, but the impacted banks and buffers and channel alterations have created **fair** habitat conditions in this reach.

Figure 5.10. One of seven large mass failures in T11.04.

T11.04 Data Summary			Reference	Existing
Length:	10,578 ft	Confinement	Very Broad	Broad
Drainage Area:	31 sq. mi.	Stream Type	C	C
Evolution Stage:	F-III	Entrenchment Ratio	> 2.2	8.1
Sensitivity:	High	Incision Ratio	< 1.2	1.5
		Dominant Bed Material	Cobble	Cobble
		Dominant Bedform	Riffle-Pool	Braided
Major Stressors:		**Encroachments, Revetments, Mass Failures, Erosion, Channel Straightening, Windrowing, Poor Bank Vegetation, Poor Buffers**		

T11.05

This reach was split into two segments during assessment primarily due to channel dimensions and depositional features. The reach begins just upstream of the confluence of Red Brook and the Winhall River and extends upstream to just above where Tributary 4 to the Winhall River meets the river.

T11.05-A

This segment begins at the reach break and continues upstream just over 5,300 feet to where Rt. 30 is no longer a corridor encroachment and the valley width increases. T11.05-A was historically straightened along VT Rt. 30 for almost its entire length, and portions of the channel were windrowed post-TSI, creating berms. Bank armoring is common in areas where the river flows directly along Rt. 30, as are impacted buffers. Erosion is common along both banks of T11.05-A. The historic and recent channel straightening has led to extreme channel incision, causing a stream type departure and greatly reducing floodplain access in this segment. The reference bedform of riffle-pool has also been lost and converted to plane bed. Bedrock in the stream channel is limiting further bed degradation and incision. Aggradation is limited in this segment, as is widening due to boundary conditions. Overall, T11.05-A is in **fair** geomorphic condition. The loss of channel bedform, lack of woody debris, and impacted banks and buffers have caused this segment to be in **fair** habitat condition.

Figure 5.11. Bedrock is limiting further incision throughout T11.05-A.

T11.05-A Data Summary		**Reference**	**Existing**
Length: 5,355 ft Drainage Area: 26 sq. mi. Evolution Stage: F-II Sensitivity: Very High	Confinement	Very Broad	Broad
	Stream Type	C	F
	Entrenchment Ratio	1.4 – 2.2	1.3
	Incision Ratio	< 1.2	2.0
	Dominant Bed Material	Cobble	Cobble
	Dominant Bedform	Riffle-Pool	Plane Bed
Major Stressors:	**Encroachment, Revetments, Channel Straightening, Windrowing, Erosion, Poor Buffers**		

T11.05-B

This segment begins where the river flows away from Rt. 30 and the existing valley type changes to very broad. T11.05-B is characterized by a riffle-pool bedform and unconfined valley. The channel exhibits minor incision, which is likely historic, and has not been straightened extensively. One small headcut is present in this segment. Despite the minor incision, T11.05-B has good floodplain access overall. Major aggradation is currently occurring in T11.05-B and large bars are beginning to form a juvenile floodplain. The stream channel has widened, and is beginning to move laterally without impediment from bank armoring and revetments. Due to the channel adjustments occurring in T11.05-B, it is in **fair** geomorphic condition. Unstable river banks with extensive erosion, as well as impacted riparian buffers, are also creating **fair** habitat conditions in this segment.

Figure 5.12. T11.05-B is undergoing major aggradation, but has good floodplain access.

T11.05-B Data Summary		Reference	Existing
Length: 1,989 ft Drainage Area: 26 sq. mi. Evolution Stage: F-III Sensitivity: Very High	Confinement	Very Broad	Very Broad
	Stream Type	C	C
	Entrenchment Ratio	> 2.2	3.0
	Incision Ratio	< 1.2	1.5
	Dominant Bed Material	Cobble	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Erosion, Mass Failure, Poor Buffers**		

T11.06

This reach was split into two segments to account for changes in channel confinement, substrate size, and channel dimensions. Kendall Farm Road is a corridor encroachment throughout most of the reach.

T11.06-A

The downstream segment in T11.06 begins behind Homestead Landscaping just below the stream crossing at Lower Taylor Hill Road. This segment has a very broad valley by reference, however due to the presence of VT Rt. 30 and Kendall Farm Rd in the river corridor, the existing valley is broad. T11.06-A was historically straightened along Kendall Farm Rd and recently straightened and windrowed extensively after Tropical Storm Irene. These channel alterations have caused a loss of riffle-pool bedform and conversion to plane bed. A stream type departure has occurred in T11.06-A due to historic incision and floodplain access has largely been lost. It appears that aggradation occurred in this segment during TSI, but it was excavated to create large berms during post-flood channel work. T11.06-A is in **fair** geomorphic condition due to extensive channel alteration that has led to loss of floodplain access and bedform. The segment is also in **fair** habitat condition due to the aforementioned factors, as well as a lack of LWD and poor riparian buffers.

Figure 5.13. T11.06-A was windrowed extensively during post-TSI channel work and has lost its bedform.

M3.03-A Data Summary		Reference	Existing
Length: 1,535ft Drainage Area: 21 sq. mi. Evolution Stage: F-II Sensitivity: High	Confinement	Very Broad	Broad
	Stream Type	C	B_c
	Entrenchment Ratio	> 2.2	1.5
	Incision Ratio	< 1.2	2.2
	Dominant Bed Material	Gravel	Cobble
	Dominant Bedform	Riffle-Pool	Plane Bed
Major Stressors:	**Channel Straightening, Windrowing, Encroachments, Poor Buffers, Poor Bank Vegetation**		

T11.06-B

This segment begins where the river valley narrows and bedrock appears on the streambed. T11.06-B was historically straightened along Kendall Farm Road and historically incised down to bedrock. Recent windrowing and berming post-TSI have further entrenched the stream channel in this segment and severely limited floodplain access, causing a stream type departure. The presence of one large bedrock grade control spanning almost the entire segment is limiting further channel incision. The placement of Kendall Farm Road has also caused a broad river valley by reference to become semi-confined. Erosion is present along both banks, and the eastern bank in particular may be susceptible to severe erosion in the future due to increased stream power in this segment. T11.06-B is in **fair** geomorphic condition due to the aforementioned details. The bedrock in the stream channel has created large pools and refuge areas, however overall, this segment is in **fair** habitat condition due to the lack of LWD, loss of bedform, and poor bank and buffer vegetation.

Figure 5.14. The stream channel in T11.06-B has incised to bedrock and lost its riffle-pool bedform.

T11.06-B Data Summary		**Reference**	**Existing**
Length: 1,640 ft Drainage Area: 21 sq. mi. Evolution Stage: F-III Sensitivity: Very High	Confinement	Broad	Semi-Confined
	Stream Type	C	F
	Entrenchment Ratio	> 2.2	1.2
	Incision Ratio	< 1.2	2.7
	Dominant Bed Material	Gravel	Cobble
	Dominant Bedform	Riffle-Pool	Plane Bed
Major Stressors:	**Channel Straightening, Windrowing, Encroachments, Erosion, Poor Buffers**		

T11.07

This reach was split into two segments during assessment to account for changes in channel dimensions, depositional features, and planform. T11.07 flows through a broad valley by reference; however the placement of Kendall Farm Road has created a narrow valley throughout the reach.

T11.07-A

This segment begins above the bedrock in T11.06-B and ends just downstream of Rocky Dell Road. The Winhall River was historically straightened along Kendall Farm Road for almost the entirety of T11.07-A. A stretch of the river that runs directly along the road was windrowed post-Irene, and bank revetments are common along the road. Historic incision has led to a stream type departure in this segment and has limited floodplain access. A weir is present in T11.07-A, which acts as a grade control and a withdrawal to a snowmaking pond owned by Stratton Mountain. The snowmaking withdrawal is likely impacting the sediment dynamics in this segment. Widening is currently occurring in this segment as evidenced through bank erosion and a high width to depth ratio at the cross section. Due to these historic and recent changes in the channel morphology, T11.07-A is in **fair** geomorphic condition. A lack of LWD and poor river banks and buffers in this segment have created **fair** habitat conditions as well.

Figure 5.15. A weir in T11.07-A is impacting sediment transport throughout the segment.

T11.07-A Data Summary		Reference	Existing
Length: 1,824 ft Drainage Area: 21 sq. mi. Evolution Stage: F-II Sensitivity: High	Confinement	Broad	Narrow
	Stream Type	C	B_c
	Entrenchment Ratio	> 2.2	1.8
	Incision Ratio	< 1.2	1.6
	Dominant Bed Material	Cobble	Cobble
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Encroachment, Channel Straightening, Flow Withdrawal, Revetments, Erosion, Poor Bank Vegetation**		

T11.07-B

This segment begins just downstream of Rocky Dell Road and continues upstream to just above Hunker Road.T11.07-B overall has good floodplain access and has only experienced minor historic incision due to straightening along Kendall Farm Road. Bank erosion abounds in T11.07-B and one very large mass failure is present along the valley wall. A berm exists in the area with the mass failure, but its origin is unknown and it may be natural piling of sediment. T11.07-B is very aggradational, with bars and sedimented riffles common. The riparian buffer along the north bank of the stream has been impacted due to Kendall Farm Road and agricultural fields that abut the river. Overall, T11.07-B is in **fair** geomorphic condition due to historic incision and recent aggradation. This segment's habitat condition is also **fair** due to poor bank and buffer conditions and changes in channel morphology.

Figure 5.16. The Winhall River has good floodplain access in T11.07-B.

T11.07-B Data Summary		**Reference**	**Existing**
	Confinement	Broad	Narrow
Length: 2,258 ft	Stream Type	C	C
Drainage Area: 21 sq. mi.	Entrenchment Ratio	> 2.2	2.7
Evolution Stage: F-III	Incision Ratio	< 1.2	1.4
Sensitivity: High	Dominant Bed Material	Cobble	Cobble
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Encroachments, Channel Straightening, Erosion, Mass Failure**		

T11.08

This reach was split into two segments during assessment to account for changes in planform, depositional features, and valley width.

T11.08-A

This segment begins just upstream of Hunker Road and continues to just below the stream crossing at Lightfoot Camp Road. T11.08-A is characterized by the presence of an *alluvial fan*, which exists due to a decrease in channel slope and increase in valley width. The river is *braided* throughout this segment, and several different threads of the channel exist even under low flow conditions. Nine channel avulsions were noted during assessment, as were numerous flood chutes. The braided nature of this segment was likely exacerbated during TSI. It appears that a major aggradation and a large debris jam formed during the flood, causing the river to abandon its channel and cut several new ones in the floodplain. Bank erosion abounds in the new channels formed due to the braiding. Riparian buffers are impacted mostly as a result of agricultural activities in the northern side of the river corridor. The channel has incised in this segment, but floodplain access remains intact. Because of the major aggradation and changes in channel planform that have occurred in T11.08-A, the segment is in **poor** geomorphic condition. The formation of multiple channels has created bed features that provide habitat for aquatic biota. LWD is common in this segment, providing increased cover for these organisms. Due to these factors, T11.08-A is in **good** habitat condition.

Figure 5.17. Braiding is common in T11.08-A due to the presence of an alluvial fan.

T11.08-A Data Summary		**Reference**	**Existing**
Length: 4,921 ft	Confinement	Very Broad	Very Broad
Drainage Area: 20 sq. mi.	Stream Type	C	C
Evolution Stage: F-IV	Entrenchment Ratio	> 2.2	6.8
Sensitivity: Very High	Incision Ratio	< 1.2	1.7
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Braided	Braided
Major Stressors:	**Erosion, Encroachments, Channel Straightening**		

T11.08-B

This segment begins just below the Lightfoot Camp Road stream crossing and continues upstream to past the cul-de-sac on Kendall Farm Road. T11.08-B flows through a very broad valley by reference that has been altered to a narrow valley due to the presence of Kendall Farm Road. The segment is characterized by a riffle-pool bedform and extensive historic and recent channel berming and windrowing. The placement of Kendall Farm Road and aforementioned berms led to historic channel incision and a stream type departure. The channel is widening and changing planform as evidenced by bank erosion and multiple flood chutes. There is a wetland across the road from the river that was likely historically accessed by the stream, but the road now impedes this access. Due to historic incision and current lateral adjustments, T11.08-B is in in **fair** geomorphic condition. Despite this, there is good instream cover and refuge for organisms, placing the segment in **good** habitat condition.

Figure 5.18. T11.08-B historically incised, forming a "B" channel with limited floodplain access.

M3.06-B Data Summary		**Reference**	**Existing**
Length: 2,031 ft Drainage Area: 20 sq. mi. Evolution Stage: F-III Sensitivity: Very High	Confinement	Very Broad	Narrow
	Stream Type	C	B_c
	Entrenchment Ratio	> 2.2	1.4
	Incision Ratio	< 1.2	1.6
	Dominant Bed Material	Cobble	Cobble
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Encroachments, Channel Straightening, Windrowing, Stormwater Inputs**		

Red Brook

<u>T11.S3.01</u>

Red Brook is a major tributary to the Winhall River that enters the river in reach T11.04. The first reach on Red Brook flows through a very broad valley by reference. Assessment was conducted from its confluence with the Winhall River upstream to just above the stream crossing at Winhall Hollow Road. The reach was split into five segments during assessment to account for changes in channel planform, channel dimensions, and depositional features.

T11.S3.01-A

This segment begins at the mouth of the brook and continues upstream to about 1,800 feet above the culvert at River Road. This reach is an alluvial fan, which has formed as the channel slope drops and river valley widens to meet the Winhall River valley. T11.S3.01-A flows through a beaver meadow, with several intact and breached beaver dams present. The alluvial fan and beaver activity have led to major aggradation and planform adjustment in this segment. Flood chutes and channel avulsions are common in T11.S3.01-A. Bank erosion is present in areas where there are active flood chutes. A culvert under River Road has created a major channel constriction, and the stream has significantly aggraded above the structure and scoured below it. There is also a channel avulsion directly upstream of the structure, which could put it at an elevated risk of being undermined during future high flow events. Due to the aggradation and planform adjustment occurring in T11.S3.01-A, it has been placed in **fair** geomorphic condition. However, the beaver dams create a diversity of bed features and supply LWD to the channel, creating **good** habitat conditions.

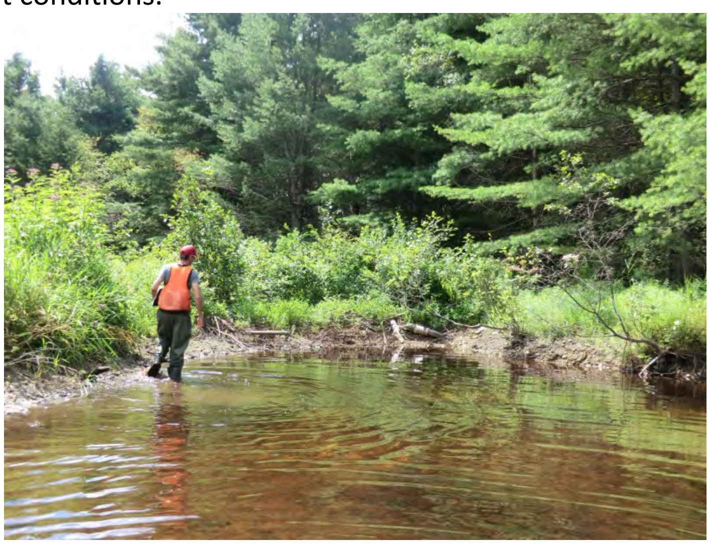


Figure 5.19. One of many beaver dams present in T11.S3.01-A.

T11.S3.01-A Data Summary		**Reference**	**Existing**
	Confinement	Very Broad	Very Broad
Length: 2,309 ft	Stream Type	E	E
Drainage Area 2.5 sq. mi.	Entrenchment Ratio	> 2.2	16.7
Evolution Stage: F-I	Incision Ratio	< 1.2	1.0
Sensitivity: Extreme	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Channel Constriction**		

T11.S3.01-B

This segment begins about 1,800 feet upstream of the River Road stream crossing and ends just below the upstream-most crossing at Raspberry Hill Road. Directly upstream of this reach is an on-stream pond at Strattonwald Recreation Club. Despite the presence of the pond, severe incision was not observed in T11.S3.01-B. Typically, an on-stream pond disrupts sediment transport regimes, and the section of river downstream of it can become sediment starved. This is not the case for T11.S3.01-B. Aggradation is major in this segment, and the source of which is unknown. There are abundant bars in this segment, which could have formed during TSI. Also, numerous debris jams are present, which have formed flood chutes and channel avulsions. These were also likely formed during Irene. Erosion is present on both banks in T11.S3.01-B. The downstream-most Raspberry Hill Road crossing is undersized and causing significant aggradation above and scour below the structure. Overall, the segment is in **fair** geomorphic condition due to channel aggradation, planform adjustment, and slight historic incision. Debris jams provide LWD to the stream for aquatic organism cover, as do undercut banks and plunge pools. These and other features create **good** habitat conditions in T11.S3.01-B.

Figure 5.20. T11.S3.01-B has good floodplain access and good cover for aquatic biota.

T11.S3.01-B Data Summary		**Reference**	**Existing**
	Confinement	Very Broad	Very Broad
Length: 2,726 ft	Stream Type	C	C_b
Drainage Area: 2.5 sq. mi.	Entrenchment Ratio	> 2.2	2.3
Evolution Stage: F-IV	Incision Ratio	< 1.2	1.4
Sensitivity: Very High	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Channel Constriction, Erosion, On-stream Pond Upstream**		

T11.S3.01-C

This segment is an on-stream pond located at Strattonwald Recreation Club. The segment begins at the upstream-most Raspberry Hill Road crossing and continues upstream for 600 feet. A small run of the river dam is present at the downstream end of the segment, impounding the water behind it. The dam also acts as a grade control for the stream, and likely poses a significant barrier to aquatic organism passage (AOP). There is a large overflow outlet for the small dam and two small culverts. There is no riparian buffer surrounding the pond, which is used for recreation purposes.

Figure 5.21. T11.S3.01-C is an on-stream pond used for recreation.

Figure 5.22. The dam at the pond outlet likely poses an AOP barrier.

T11.S3.01-D

This segment is located above the on-stream pond at Strattonwald Recreation Club and ends approximately 1,100 feet below the Winhall Hollow Road crossing. T11.S3.01-D is characterized by good floodplain access and well forested buffers. This segment flows through the woods, but development encroaches on the river corridor in a few locations. This development also impacts the riparian buffers in areas and contributes stormwater to the stream via gullies. Frequent debris jams have caused channel avulsions and created flood chutes. Where avulsions and flood chutes are not present, the stream channel appears to be very stable and has mossy cobbles and boulders on the bed. There is very little bank erosion present in this segment. T11.S3.01-D is in **good** geomorphic condition due to its lack of incision and erosion and overall channel stability. The segment is also in **good** habitat condition due to abundant LWD, plunge pools, and well vegetated banks and buffers.

Figure 5.23. Debris jams are common in T11.S3.01-D and are causing planform adjustment.

T11.S3.01-D Data Summary		**Reference**	**Existing**
	Confinement	Very Broad	Very Broad
Length: 6,578 ft	Stream Type	C	C
Drainage Area: 2.5 sq. mi.	Entrenchment Ratio	> 2.2	3.7
Evolution Stage: F-I	Incision Ratio	< 1.2	1.0
Sensitivity: High	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Channel Constriction, Stormwater Inputs**		

T11S3.01-E

This segment begins 1,100 feet below the stream crossing at Winhall Hollow Road and ends just upstream of the crossing. T11.S3.01-E is characterized as a wetland that has evidence of past and possibly current beaver activity. There is one intact beaver dam in this segment and ten debris jams, which are creating flood chutes and channel avulsions and spreading out flow throughout the wetland complex. There is almost no bank erosion present in this segment, and no channel incision. Minor aggradation has occurred in T11.S3.01-E as a result of its low slope and beaver dam/debris jams. Red Brook retains its reference bedform of ripple-dune in this segment Overall, the stream channel is stable throughout the wetland, and is in **good** geomorphic condition. A variety of streambed features are present in the wetland, LWD is abundant, and undercut banks create good cover for aquatic biota. For these reasons, T11.S3.01-E is also in **good** habitat condition.

Figure 5.24. T11.S3.01-E flows through a wetland complex.

T11.S3.01-E Data Summary		**Reference**	**Existing**
Length: 1,427 ft Drainage Area: 2.5 sq. mi. Evolution Stage: F-I Sensitivity: High	Confinement	Very Broad	Very Broad
	Stream Type	E	E
	Entrenchment Ratio	> 2.2	32.0
	Incision Ratio	< 1.2	1.0
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Dune-Ripple	Dune-Ripple
Major Stressors:	**Channel Constriction**		

Tributary 4 to the Winhall River

<u>T11.S4.01</u>

This reach was split into three segments during assessment because of property access and lack of landowner permission.

T11.S4.01-A

This segment begins just above the confluence with the Winhall River and continues upstream to just below the VT Rt. 30 stream crossing. It was not fully assessed due to limited property access on the north side of the stream. Administrative judgment was used to determine reference and existing stream type, bed material, and bedform. Overall, the segment was placed in fair geomorphic condition based on extensive straightening and stream conditions observed from the segment break.

Figure 5.25. T11.S4.01-A has a reference riffle-pool bedform but has likely been converted to plane bed due to channel straightening.

T11.S4.01-A Data Summary	*NOT ASSESSED	Reference	Existing
Length: 702 ft Drainage Area: 3 sq. mi. Evolution Stage: N/A Sensitivity: N/A	Confinement	Very Broad	Very Broad
	Stream Type	E	E
	Entrenchment Ratio	< 1.4	N/A
	Incision Ratio	< 1.2	N/A
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Plane Bed
Major Stressors:	**Channel Straightening, Poor Buffers, Encroachments**		

T11.S4.01-B

This segment begins just downstream of the Rt. 30 culvert and continues upstream approximately 1,000 feet to just above the stream crossing at Stratton View Road. The entirety of the segment is encroached upon by Rt. 30 and areas have been historically straightened due to its presence. Bank armoring is present around both stream crossings in T11.S4.01-B, which are also channel constrictions. The channel has undergone historic incision and is actively widening. In areas that have widened, aggradation is common. The channel is surrounded by wetlands, which can be accessed in bankfull events. A stream type departure has occurred due to channel incision and widening. Tributary 4 has also lost its reference bedform of riffle-pool in this segment, which has been replaced by a featureless plane bed channel. Due to these impacts, T11.S4.01-B is in **fair** geomorphic condition. The lack of diverse bed features and impacted banks and buffers place this segment in **fair** habitat condition.

Figure 5.26. T11.S4.01-B is actively widening and aggrading.

T11.S4.01-B Data Summary		**Reference**	**Existing**
Length: 1,095 ft Drainage Area: 3 sq. mi. Evolution Stage: F-III Sensitivity: Very High	Confinement	Very Broad	Very Broad
	Stream Type	E	C
	Entrenchment Ratio	> 2.2	11.2
	Incision Ratio	< 1.2	1.6
	Dominant Bed Material	Gravel	Gravel
	Dominant Bedform	Riffle-Pool	Plane Bed
Major Stressors:	**Encroachments, Bank Erosion, Channel Straightening, Channel Constrictions, Poor Buffers**		

T11.S4.01-C

This segment begins just above the stream crossing at Stratton View Road and continues upstream to the reach break near Goslings Way. It was not fully assessed due to limited property access on the both sides of the stream. Administrative judgment was used to determine reference and existing stream type, bed material, and bedform. Overall, the segment was rated as fair geomorphic condition due to various impacts, such as extensive corridor encroachments, and conditions observed immediately upstream and downstream of the segment.

Figure 5.27. T11.S4.01-C was not assessed due to limited property access.

T11.S4.01-C Data Summary		*NOT ASSESSED	Reference	Existing
		Confinement	Very Broad	Very Broad
Length:	2,110 ft	Stream Type	E	C
Drainage Area:	3 sq. mi.	Entrenchment Ratio	< 1.4	N/A
Evolution Stage:	N/A	Incision Ratio	< 1.2	N/A
Sensitivity:	N/A	Dominant Bed Material	Gravel	Gravel
		Dominant Bedform	Riffle-Pool	Plane Bed
Major Stressors:		**Encroachments, Poor Buffers**		

T11.S4.02

This reach was split into two segments during assessment to account for changes in channel dimensions and valley width.

T11.S4.02-A

This segment begins just downstream of Goslings Way and ends approximately 500 feet above the Rt. 30 stream crossing. The majority of T11.S4.02-A was historically straightened along Rt. 30, which likely caused extreme historic channel degradation and a stream type departure. Extensive bank revetments are limiting channel widening, though they have been undermined in some areas. Widening has occurred in locations that are not riprapped, as has aggradation and planform adjustment via flood chutes. Development and Rt. 30 encroach upon the river corridor for the majority of T11.S4.02-A. Erosion is frequent along both banks. Tributary 4 has lost its riffle-pool bedform, which has been converted to plane bed. Overall, the segment is in **poor** geomorphic condition due to all of these factors. T11.S4.02-A is in **fair** habitat condition due to its lack of bed features, woody debris, bank and buffer vegetation, and overall cover for aquatic organisms.

Figure 5.28. A riffle-pool bedform has been converted to featureless plane bed in T11.S4.02-A.

M3.08-C Data Summary		Reference	Existing
	Confinement	Very Broad	Very Broad
Length: 1,988 ft	Stream Type	C_b	B
Drainage Area: 2.7 sq. mi.	Entrenchment Ratio	> 2.2	1.6
Evolution Stage: F-III	Incision Ratio	< 1.2	2.5
Sensitivity: High	Dominant Bed Material	Cobble	Gravel
	Dominant Bedform	Riffle-Pool	Plane Bed
Major Stressors:	**Channel Straightening, Encroachments, Erosion, Revetments, Poor Buffers, Stormwater Inputs, Channel Constriction**		

T11.S4.02-B

This segment begins approximately 500 feet upstream of the Rt. 30 culvert and continues upstream to where the stream begins flowing directly south and farther away from the road. T11.S4.02-B is not impacted by Rt. 30 as a corridor encroachment as the downstream reaches are. Development is minimal within the corridor, as is channel straightening, and adjacent wetlands abound. Erosion is common, though not extensive, on both banks and there is one mass failure present in this segment. The channel does not appear to be incised; however, aggradation and planform adjustment are occurring. A large amount of fine sediments was noted in this segment, the source of which could be eroding banks and logging activities. There is moss on the stream banks and in the channel in areas, indicating a stable channel. Despite this, the segment is in **fair** geomorphic condition due to the planform changes and aggradation that is occurring. Habitat conditions in T11.S4.02-B are **good** as a result of abundant LWD and cover for aquatic biota and well forested banks and buffers.

Figure 5.29. A variety of bed features and forested buffers create good habitat conditions in T11.S4.02-B.

T11.S4.02-B Data Summary		Reference	Existing
Length: 3,254 ft Drainage Area: 2.7 sq. mi. Evolution Stage: F-IV Sensitivity: High	Confinement	Narrow	Narrow
	Stream Type	C_b	C_b
	Entrenchment Ratio	> 2.2	6.3
	Incision Ratio	< 1.2	1.0
	Dominant Bed Material	Cobble	Cobble
	Dominant Bedform	Riffle-Pool	Riffle-Pool
Major Stressors:	**Increased Sediment Inputs**		

5.3 Stream Crossings

Tables 7 and 8 in Appendix B summarize the data collected for the assessed structures within the Phase 2 study area. The maps on pages 6 and 7 in Appendix B show the location and geomorphic compatibility rating of each structure. Of the 16 bridges and culverts assessed, none were determined to be fully incompatible, one was “mostly incompatible,” eleven were “partially compatible,” and four were “mostly compatible.” This information can be used by municipalities and the Vermont Agency of Transportation to prioritize bridge and culvert replacements. Information from the Phase 2 stream geomorphic assessment and bridge and culvert assessments can be used to inform Winhall, Jamaica, and Londonderry of which stream crossings are contributing to localized instability.

Stream crossings recommended for replacement are in reaches/segments T11.04, T11.06-A, T11.08-B, on the Winhall River, all segments on Red Brook, and T11.S4.01-B, T11.S4.02-A, and T11.S4.02-B on Tributary 4 to the Winhall. The following parameters factored into the recommendations and their priority for replacement: flood damage, geomorphic compatibility, and condition of structure. All structures on the Winhall are bridges, while all structures on Red Brook and Tributary 4 are culverts with one exception.

<u>Winhall River Structures</u>

The downstream-most crossing recommended for replacement is a Rt. 30 bridge in reach T11.04 in Jamaica, as pictured in Figure 5.30. The bridge is a bankfull channel constriction and has poor alignment. A pier in the center of the structure is causing aggradation within and above it. One cell of the bridge is plugged with sediment. This structure is recommended for replacement with a low priority.

A bridge on Lower Taylor Hill Road in T11.06-A (Figure 5.31) has also been recommended for replacement at a low priority. This bridge was closed to traffic at the time of assessment and had scour around its footers, wingwalls, and abutments. It is a channel constriction because of riprap placed within the structure. The streambed has scoured through the structure.

The final stream crossing structure recommended for replacement on the Winhall River is located in segment T11.08-B on Lightfoot Camp Road and is shown in Figure 5.32. This bridge is a channel constriction due to the placement of riprap within the structure. There is also a flood chute that enters the river immediately upstream of the structure, which could pose a risk to it during high flow events. It is recommended for replacement with a low priority.

Figure 5.30. Rt. 30 bridge with aggradation and alignment problems in T11.04.

Figure 5.31. Lower Taylor Hill Rd bridge was closed at the time of assessment.

Figure 5.32. Channel constriction on Lightfoot Camp Road

Red Brook

The downstream-most structure recommended for replacement on Red Brook is a culvert under River Road in T11.S3.01-A, as shown in Figure 5.33. This culvert is significantly undersized and is causing severe aggradation directly upstream and scour downstream. There is a channel avulsion directly upstream of the structure, which could put it at an elevated risk of being undermined during high flow events. It is recommended for replacement with a high priority.

In the next segment upstream, T11.S3.01-B, a culvert under Raspberry Hill Road is recommended for replacement at a moderate priority. There are two culverts present at the crossing; one has a rusted out bottom, and the other carries all of the baseflow. The structure is a significant channel constriction and road runoff is undermining the headwall on the upstream end. Significant aggradation is present above the structure and scour below. The crossing is pictured below in Figure 5.34.

In segment T11.S3.01-D, the culvert under Cranberry Hill Road (Figure 5.35) is recommended for replacement at a high priority. This structure is significantly undersized, and the streambed has aggraded above it and scoured below it. Woody debris is partially obstructing the culvert, which was overtopped during TSI.

A culvert under Winhall Hollow Road in segment T11.S3.01-E has been recommended for replacement with a high priority. This structure is severely undersized and is not well aligned with the channel. The streambed has scoured below the structure and aggraded above it. Bank scour both above and below the culvert are present (Figure 5.36).

Figure 5.33. A culvert under River Road in T11.S3.01-A is very undersized.

Figure 5.34. One culvert captures all baseflow and the other is rusting out at Raspberry Hill in T11.S3.01-B.

Figure 5.35. The culvert on Red Brook under Cranberry Hill Rd is full of woody debris.

Figure 5.36. The culvert under Winhall Hollow Rd is not well aligned.

Tributary 4 to the Winhall River

The downstream-most structure recommended for replacement on Tributary 4 is a culvert under Rt. 30 in T11.S4.01-B, as seen in Figure 5.37. The culvert is undersized and in poor condition (bottom is rusting out at inlet and outlet). There is a small drop at the outlet, which could be creating a barrier for AOP.

A second structure in T11.S4.01-B has been recommended for replacement with a high priority. Three pipes are present at this structure under Stratton View Road, but it is still a significant channel constriction. The bottom of one pipe is completely rusted out, and woody debris and sediment are causing blockage. Baseflow is captured by one of three pipes. Figure 5.38 shows this stream crossing.

Lastly, a culvert under Rt. 30 in segment T11.S4.02-A has been recommended for replacement with a low priority (Figure 5.39). The culvert is undersized, but is in good condition. Baffles are present throughout the structure and there is a drop of 0.4 feet at the outlet. The structure's alignment with the channel is poor. Deposition is present above the structure and scour below.

Figure 5.37. The bottom of the culvert under Rt. 30 in T11.S4.01-B is rusting out.

Figure 5.38. One of three culverts under Stratton View Rd in T11.S4.01-B is rusted out.

Figure 5.39. The culvert under Rt. 30 has a small drop at the outlet and baffles throughout.

6.0 PRELIMINARY PROJECT IDENTIFICATION AND PRIORITIZATION

6.1 Reach Level and Site Specific Opportunities

The stream reaches evaluated in this study present a variety of planning and management strategies which can be classified under one of the following categories: Active Geomorphic Restoration and Passive Geomorphic Restoration.

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

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

6.1.1 Project Identification

Winhall River Mainstem

Reach T11.01
(Refer to Appendix C, Map 1 and Table 1)

1. **Passive Restoration** by planting native trees and shrubs species along the south bank of the river.

Reach T11.02
(Refer to Appendix C, Map 1 and Table 1)

2. **Active Restoration** by stabilizing a gully, which is delivering stormwater and sediment from Cohen Road directly into the river.

Reach T11.03
(Refer to Appendix C, Map 2 and Table 2)

3. **Active Restoration** by removing intact abutments from a bridge destroyed during TSI, which are causing channel constriction;
4. **Passive Restoration** by planting native trees and shrubs in an area where the riparian buffer is lacking;
5. **Passive Restoration** by planting trees and shrubs at a location where the riparian buffer is impacted by a lawn and the landowner is interested in conservation/restoration work;

6. **Active Restoration** by returning post-TSI windrowed material to the channel where floodplain access has been reduced;
7. **Passive Restoration** by protecting the river corridor in an area where the channel has good floodplain access and well forested buffers;
8. **Passive Restoration** by planting trees and shrubs along a field to restore the riparian buffer.

Reach T11.04

(Refer to Appendix C, Map 3 and Table 3)

9. **Passive Restoration** by planting native tree and shrub species in an area along the north bank of the river where the buffer is lacking;
10. **Passive Restoration** by planting trees and shrubs in a similar, but smaller, area;
11. **Active Restoration** by removing a historic berm that is restricting floodplain access.

Reach T11.05

(Refer to Appendix C, Map 4 and Table 4)

12A. **Active Restoration** by moving back the River Road embankment (rebuilt after TSI) that is encroaching upon the river and creating a pinch point;

12B. **Active & Passive Restoration** by returning material that was windrowed post-TSI to the stream channel and planting trees and shrubs along the south bank;

13. **Passive Restoration** by conducting plantings along the river where a landowner's lawn has impacted the riparian buffer;
14. **Active Restoration** by arresting a small headcut that is moving upstream and cleaning up a trash pile on the north bank of the river.

Reach T11.06

(Refer to Appendix C, Map 5 and Table 5)

15. **Active Restoration** by returning windrowed material to the stream channel and removing a berm on the south bank, to create floodplain access along a bend in the Winhall River in segment A;
16. **Active Restoration** by returning windrowed material to the channel and investigating the removal of a berm that is restricting floodplain access on the north side of the river in segment B;

Reach T11.07

(Refer to Appendix C, Map 5 and Table 5)

17. **Passive Restoration** by protecting the river corridor in an area with good riparian buffers and floodplain access;
18. **Active Restoration** by removing a berm where no infrastructure is present and investigating a gully delivering stormwater and sediment to the river.

Reach T11.08

(Refer to Appendix C, Map 6, and Table 6)

19. **Passive Restoration** by protecting the river corridor in an area where the river is undergoing extensive planform adjustment, has good habitat, and good riparian buffers;
20. **Active Restoration** by investigating options to remove a historic berm that is limiting floodplain access and to lower a trail that has caused the river to lose access to adjacent wetlands.

Red Brook

Reach T11.S3.01

(Refer to Appendix C, Maps 7 and 8 and Tables 7 and 8)

21. **Active Restoration** by replacing the undersized culvert on River Road that was overtopped during TSI and is causing aggradation and scour problems in the channel;
22. **Passive & Active Restoration** by protecting the river corridor in an area where the brook flows through a beaver meadow/wetland complex and is actively adjusting planform, and investigating the source of a large iron seep flowing into the brook;
23. **Active Restoration** by replacing the culvert under Raspberry Hill Road, which is undersized and rusting;
24. **Active Restoration** by conducting an alternatives analysis for dam removal at Strattonwald Recreation Club pond, which is creating a barrier to AOP;
25. **Active Restoration** by replacing the undersized culvert at Cranberry Hill Road;
26. **Active Restoration** by determining the cause of two gullies delivering sediment to the brook and remediating them;
27. **Passive Restoration** by protecting the river corridor in an area where the brook has excellent floodplain access, well forested buffers, and good habitat conditions;
28. **Active Restoration** by replacing the undersized culvert under Winhall Hollow Road.

Unnamed Tributary 4 to the Winhall River

Reach T11.S4.01

(Refer to Appendix C, Map 9 and Table 9)

29. **Active Restoration** by replacing the rusting and undersized culvert under Rt. 30;
30. **Active Restoration** by replacing the culvert under Stratton View Road, which is also rusting and undersized.

Reach T11.S4.02

(Refer to Appendix C, Map 9 and Table 9)

31. **Passive Restoration** by planting native tree and shrub species along the stream banks in two areas lacking riparian buffers;
32. **Active Restoration** by removing a destroyed footbridge that has fallen into the channel and created a large debris jam;
33. **Passive Restoration** by protecting the river corridor where the stream has good floodplain access and good habitat;
34. **Passive Restoration** by planting trees and shrubs in a small area at the top of the reach where the buffer has been impacted by a homeowner’s lawn.

6.1.2 Program Descriptions

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

- ANR River Corridor Easement Program (RCE)
- Ecosystem Restoration Program (formerly called Clean & Clear)
- Conservation Reserve Enhance Program (CREP)
- Trees for Streams (TFS)
- Environmental Quality Incentives Program (EQIP)
- Wildlife Habitat Incentives Program (WHIP)
- Wetland Reserve Program (WRP)
- Connecticut River Watershed Council (CRWC)

River Corridor Easement

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

- Easements are in perpetuity, meaning the agreement stays with the land forever.
- A onetime payment is received by the landowner for transferal of channel management rights to a second party (a land trust).
- Transferal of channel management rights means that the landowner would no longer be able to rock line river banks or remove gravel for personal use.
- A RCE requires a minimum 50 foot buffer that floats with the river. No active land-use is allowed within the buffer. The buffer can be actively planted or allowed to revegetate passively.
- The easement does not take away the agricultural land-use rights, so the landowner could continue to crop or pasture the farm land mapped outside of the buffer, yet within the corridor, for as long as the river allows.

Ecosystem Restoration Program

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

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

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

Trees for Streams
Programs offered by the US Fish and Wildlife Service or through State funding to work with local partners and landowners to restore native streamside vegetation along river banks.

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

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

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

Connecticut River Watershed Council
Restoration, protection, and enhancement of the river, wetlands, and shore lands within the Connecticut River watershed are supported by funds from the Connecticut River Watershed Council (CRWC). Typical projects include guiding development, preventing erosion, restoring stream passage, and making sure hydropower and industrial permits are aligned to protect natural heritage for future generations.

6.2 Watershed-Level Opportunities

There are a number of watershed-level opportunities available to improve the geomorphic stability and water quality of the Winhall River watershed. Watershed opportunities include the development and adoption of River Corridors and improved stormwater treatment.

River Corridors
The purpose of defining river corridors is to prevent increases in man-made conflicts that can result from development in identified river corridor areas; minimize property loss and damage due to fluvial erosion; and prohibit land-uses and development in river corridors that pose a danger to health and safety. The basis of a river corridor is a defined area which includes the course of a river and its adjacent lands. The width of the corridor is defined by the lateral extent of the river meanders, called the meander belt width, which is governed by valley landforms, *surficial geology*, and the length and slope requirements of the river channel. The width of the corridor is also governed by the stream type and *sensitivity* of the stream. River corridors, as defined by the Vermont Agency of Natural Resources (2008b), are intended to provide landowners, land-use planners, and river managers with a meander belt width which would accommodate the meanders and slope of a balanced or equilibrium channel, which when achieved, would serve to maximize channel stability and minimize fluvial erosion hazards. Information collected during the Phase 2 Assessment including reach sensitivity, reach condition, and stream type is used to develop these zones. The development of river corridor overlay districts on the municipal level are recommended by the Vermont River Management Program (2010b) to improve stream stability, reduce flood losses, and enhance public safety. Additional information about river corridors is available at (http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_vtfehqa.pdf).

Stormwater Management
Stormwater runoff rates are of particular concern in urbanized and agricultural watersheds because stormwater runs off from impervious surfaces rather than naturally infiltrating the soil. The cumulative effect of the increased frequency, volume, and rate of stormwater runoff results in increases in wash-off pollutant loading to streams and destabilization of stream channels. Improving stormwater management and construction practices in the Winhall River watershed is recommended to reduce siltation of critical aquatic habitat and improve geomorphic stability. An added benefit of stormwater management is the reduction of peak flows in the channel.

6.3 Next Steps

There are many opportunities to restore the Winhall River watershed to a more stable condition. Types of reach and site level projects that have been identified in this plan include returning excavated material to the stream channel, removing berms, arresting headcuts, planting in the riparian zone, protecting the river corridor, and replacing stream crossing structures. These projects combine in a strategy to recover from Tropical Storm Irene and post-flood channel work through improving flood resiliency in the watershed. Further, the development and implementation of river corridors is recommended to restrict future development within the river corridor, minimize damage to infrastructure during flood events, and save money on flood recovery.

Specific steps recommended following this study are as follows:

- Outreach to private landowners and the public about the plan and potential restoration and protection opportunities.
- Meetings held with project partners and landowners to prioritize projects and discuss implementation.
- Apply to funding sources for implementation grants.
- Phase 3 stream survey work where applicable for restoration projects.
- Implementation of priority projects with project partners and landowners.

For additional information about river corridors or project development, please contact the Vermont River Management Program or the Windham Regional Commission.

7.0 LIST OF ACRONYMS AND GLOSSARY OF TERMS

List of Acronyms

BCE – Bear Creek Environmental, LLC
CREP – Conservation Reserve Enhancement Program
CRWC – Connecticut River Watershed Council
EQIP – Environmental Quality Incentives Program
ERP – Ecosystem Restoration Program
GIS – Geographic Information System
NWI – National Wetlands Inventory
QA/QC – quality assurance/quality control
RCE – ANR River Corridor Easement Program
RHA- Rapid Habitat Assessment
RGA-Rapid Geomorphic Assessment
SGA – Stream Geomorphic Assessment
SGAT – Stream Geomorphic Assessment Tool
TFS – Trees for Streams
US ACOE – United States Army Corps of Engineers
USGS – United States Geological Survey
VANR – Vermont Agency of Natural Resources
VTDEC – Vermont Department of Environmental Conservation
VDFW _ Vermont Department of Fish and Wildlife
WHIP – Wildlife Habitat Incentives Program
WRC – Windham Regional Commission
WRP – Wetland Reserve Program

Glossary of Terms

Adapted from:
Restoration Terms, by Craig Fischenich, February, 2000, USAE Research and Development Center, Environmental Laboratory, 3909 Halls Ferry Rd., Vicksburg, MS 39180
And
Vermont Stream Geomorphic Assessment Handbook, Appendix Q, 2009, VT Agency of Natural Resources, Waterbury, VT.
http://www.vtwaterquality.org/rivers/docs/assessmenthandbooks/rv_apxqglossary.pdf

Adjustment Process – type of change that is underway due to natural causes or human activity that has or will result in a change to the valley, floodplain, and/or channel condition (e.g., vertical, lateral, or channel plan form adjustment processes).

Aggradation - A progressive buildup or rising of the channel bed and floodplain due to sediment deposition. The geologic process by which streambeds are raised in elevation and floodplains are formed. Aggradation indicates that the stream discharge and/or bed load characteristics are changing. Opposite of degradation.

Alluvial Fan – A fan-shaped accumulation of alluvium (alluvial soils) deposited at the mouth of a ravine or at the juncture of a tributary stream with the main stem where there is an abrupt change in slope.

Alluvial Soils – Soil deposits from rivers.

Alluvium – A general term for detrital deposits made by streams on riverbeds, floodplains, and alluvial fans.

Avulsion – A change in channel course that occurs when a stream suddenly breaks through its banks, typically bisecting an overextended meander arc.

Bank Stability – The ability of a stream bank to counteract erosion or gravity forces.

Bankfull Channel Depth - The maximum depth of a channel within a riffle segment when flowing at a bankfull discharge.

Bankfull Channel Width - The top surface width of a stream channel when flowing at a bankfull discharge.

Bankfull Discharge - The stream discharge corresponding to the water stage that overtops the natural banks. This flow occurs, on average, about once every 1 to 2 years and given its frequency and magnitude is responsible for the shaping of most stream or river channels.

Bar – An accumulation of alluvium (usually gravel or sand) caused by a decrease in sediment transport capacity on the inside of meander bends or in the center of an over wide channel.

Berms – Mounds of dirt, earth, gravel or other fill built parallel to the stream banks designed to keep flood flows from entering the adjacent floodplain.

Bifurcated Channel – a river channel that has split into two branches as a result of planform adjustment (i.e. split flow due to island).

Cascade – River bed form where the channel is very steep with narrow confinement. There are often large boulders and bedrock with waterfalls.

Channelization – The process of changing (usually straightening) the natural path of a waterway.

Culvert – A buried pipe that allows flows to pass under a road.

Degradation – (1) A progressive lowering of the channel bed due to scour. Degradation is an indicator that the stream's discharge and/or sediment load is changing. The opposite of aggradation. (2) A decrease in value for a designated use.

Delta Bar – A deposit of sediment where a tributary enters the main stem of a river.

Depositional Features – Types of sediment deposition and storage areas in a channel (e.g. mid-channel bars, point bars, side bars, diagonal bars, delta bars, and islands).

Diagonal Bar – Type of depositional feature perpendicular to the bank that is formed from excess sedimentation and within the channel and from the development of steep riffles.

Drainage Basin – The total area of land from which water drains into a specific river.

Dredging – Removing material (usually sediments) from wetlands or waterways, usually to make them deeper or wider.

Erosion – The wearing away of rock or soil by the gradual detachment of soil or rock fragments by water, wind, ice, and other mechanical, chemical, or biological forces.

Floodplain – Land built of sediment that is regularly covered with water as a result of the flooding of a nearby stream.

Floodprone Width – the wetted width of the channel when the water level is twice the maximum bankfull depth. For most channels this is associated with less than a 50 year return period (Rosgen, 1996).

Fluvial Geomorphology – the physics of flowing water, sediments, and other products of watersheds in relation to various land forms.

Gaging Station – A particular site in a stream, lake, reservoir, etc., where hydrologic data are obtained.

Grade Control - A fixed feature on the streambed that controls the bed elevation at that point, effectively fixing the bed elevation from potential incision; typically bedrock, dams or culverts.

Gradient – Vertical drop per unit of horizontal distance.

Habitat – The local environment in which organisms normally grow and live.

Headwater – Referring to the source of a stream or river.

Head Cut – Sudden change in elevation or knickpoint at the leading edge of a gully

Incised River – A river that erodes its channel by the process of degradation to a lower base level than existed previously or is consistent with the current hydrology.

Islands – Mid-channel bars that are above the average water level and have established woody vegetation.

Lacustrine Soils- Soil deposits from lakes.

Meander - The winding of a stream channel, usually in an erodible alluvial valley. A series of sine-generated curves characterized by curved flow and alternating banks and shoals.

Meander Migration – The change of course or movement of a channel. The movement of a channel over time is natural in most alluvial systems. The rate of movement may be increased if the stream is out of balance with its watershed inputs.

Meander Belt Width – The horizontal distance between the opposite outside banks of fully developed meanders determined by extending two lines (one on each side of the channel) parallel to the valley from the lateral extent of each meander bend along both sides of the channel.

Meander Wavelength - The lineal distance downvalley between two corresponding points of successive meanders of the same phase.

Meander Wavelength Ratio – The meander wavelength divided by the bankfull channel width.

Meander Width Ratio – The meander belt width divided by the bankfull channel width.

Mid-Channel Bar – Sediment deposits (bar) located in the channel away from the banks, generally found in areas where the channel runs straight. Mid-channel bars caused by recent channel instability are unvegetated.

Planform - The channel shape as if observed from the air. Changes in planform often involve shifts in large amount of sediment, bank erosion, or the migration of the channel.

Plane Bed – Channel lacks discrete bed features (such as pools, riffles, and point bars) and may have long stretches of featureless bed.

Point Bar –The convex side of a meander bend that is built up due to sediment deposition.

Pool -- A habitat feature (section of stream) that is characterized by deep, low-velocity water and a smooth surface.

Reach - Section of river with similar characteristics such as slope, confinement (valley width), and tributary influence.

Restoration – The return of an ecosystem to a close approximation of its condition prior to disturbance.

Riffle - A habitat feature (section of stream) that is characterized by shallow, fast-moving water broken by the presence of rocks and boulders.

Riffle-pool - Channel has undulating bed that defines a sequence of riffles, runs, pools, and point bars. Occurs in moderate to low gradient and moderately sinuous channels, generally in unconfined valleys with well-established floodplains.

Riparian Buffer – The width of naturally vegetated land adjacent to the stream between the top of the bank and the edge of other land-uses. A buffer is largely undisturbed and consists of the trees, shrubs, groundcover plants, duff layer, and naturally uneven ground surface.

Riparian Corridor – Lands defined by the lateral extent of a stream's meanders necessary to maintain a stable stream dimension, pattern, profile, and sediment regime.

Segment – A relatively homogeneous section of stream contained within a reach that has the same reference stream characteristics but is distinct from other segments in the reach.

Sensitivity – The valley, floodplain and/or channel condition's likelihood to change due to natural causes and/or anticipated human activity.

Side Bar – Unvegetated sediment deposits located along the margins or the channel in locations other than the inside of channel meander bends.

Step-Pool – Characterized by longitudinal steps formed by large particles (boulder/cobbles) organized into discrete channel-spanning accumulations that separate pools, which contain smaller sized materials. Often associated with steep channels in confined valleys.

Steep Riffle – Associated with aggradation where sediment has dropped out to form a steep face of sediment on the downstream side.

Surficial Sediment/Geology – Sediment that lies on top of bedrock.

Tributary – A stream that flows into another stream, river, or lake.

Tributary Rejuvenation – As the bed of the main stem is lowered, head cuts (incision) begin at the mouth of the tributary and move upstream.

Urban Runoff – Storm water from city streets and gutters that usually carries a great deal of litter and organic and bacterial wastes into the receiving waters.

8.0 REFERENCES

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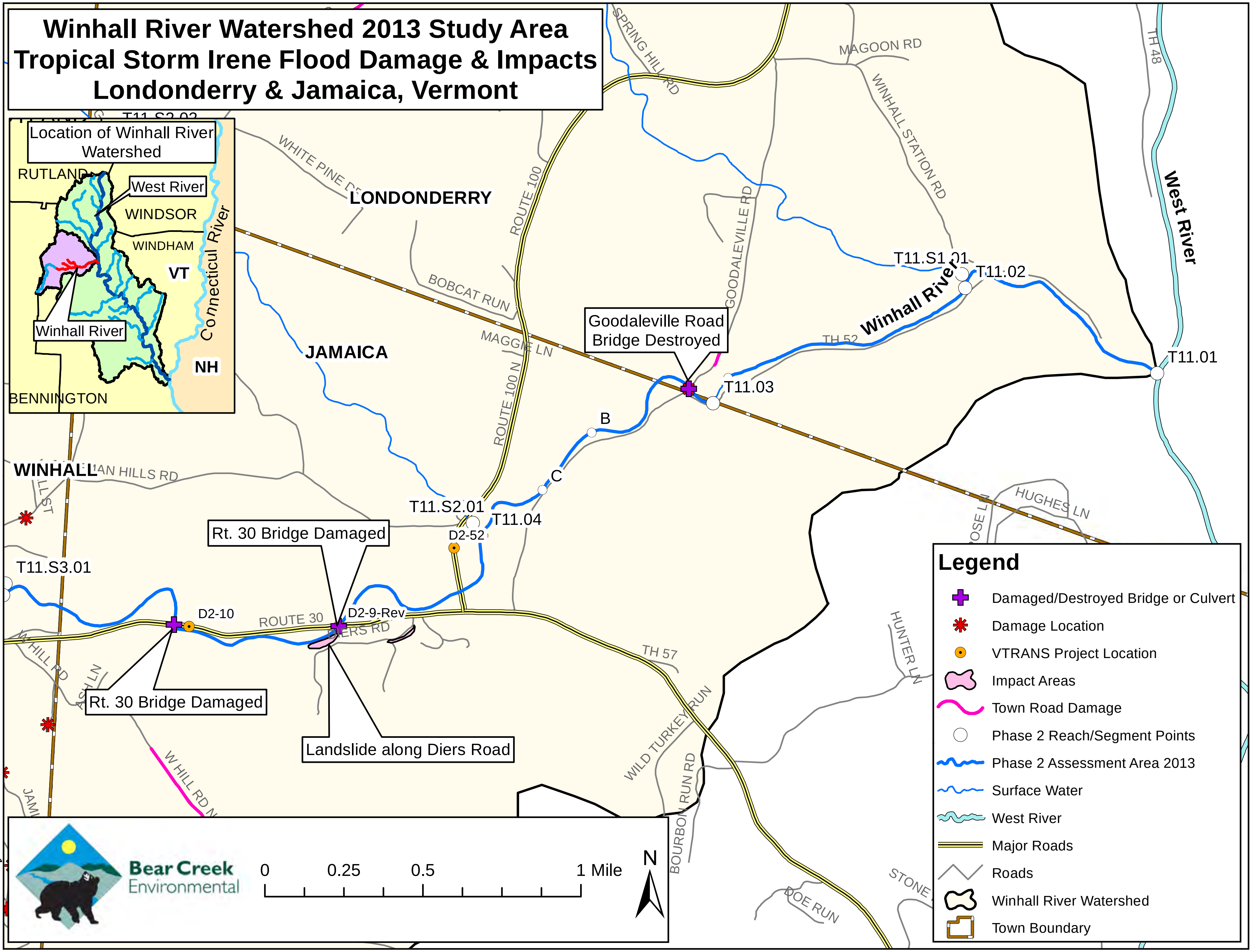
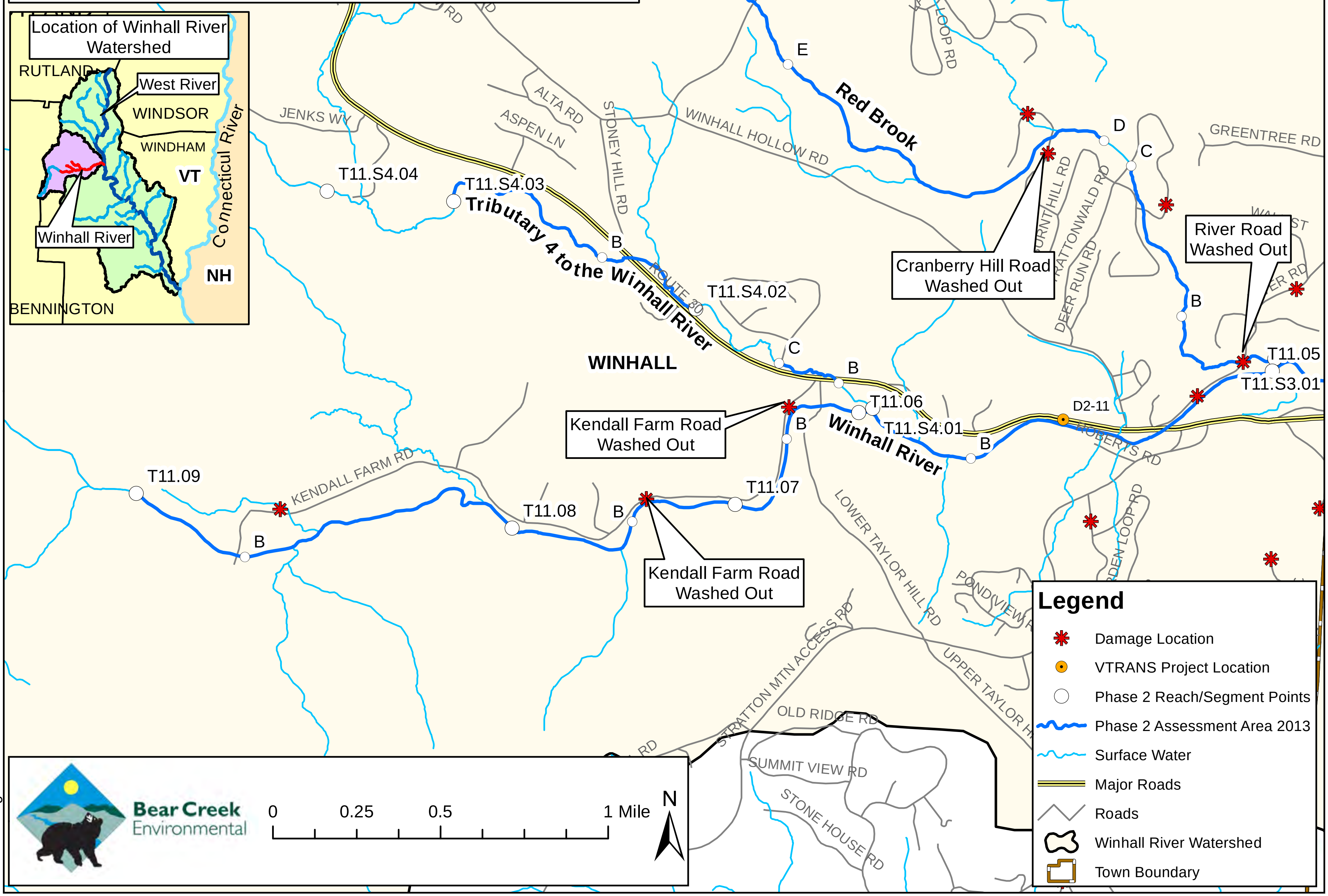
APPENDIX A

Maps

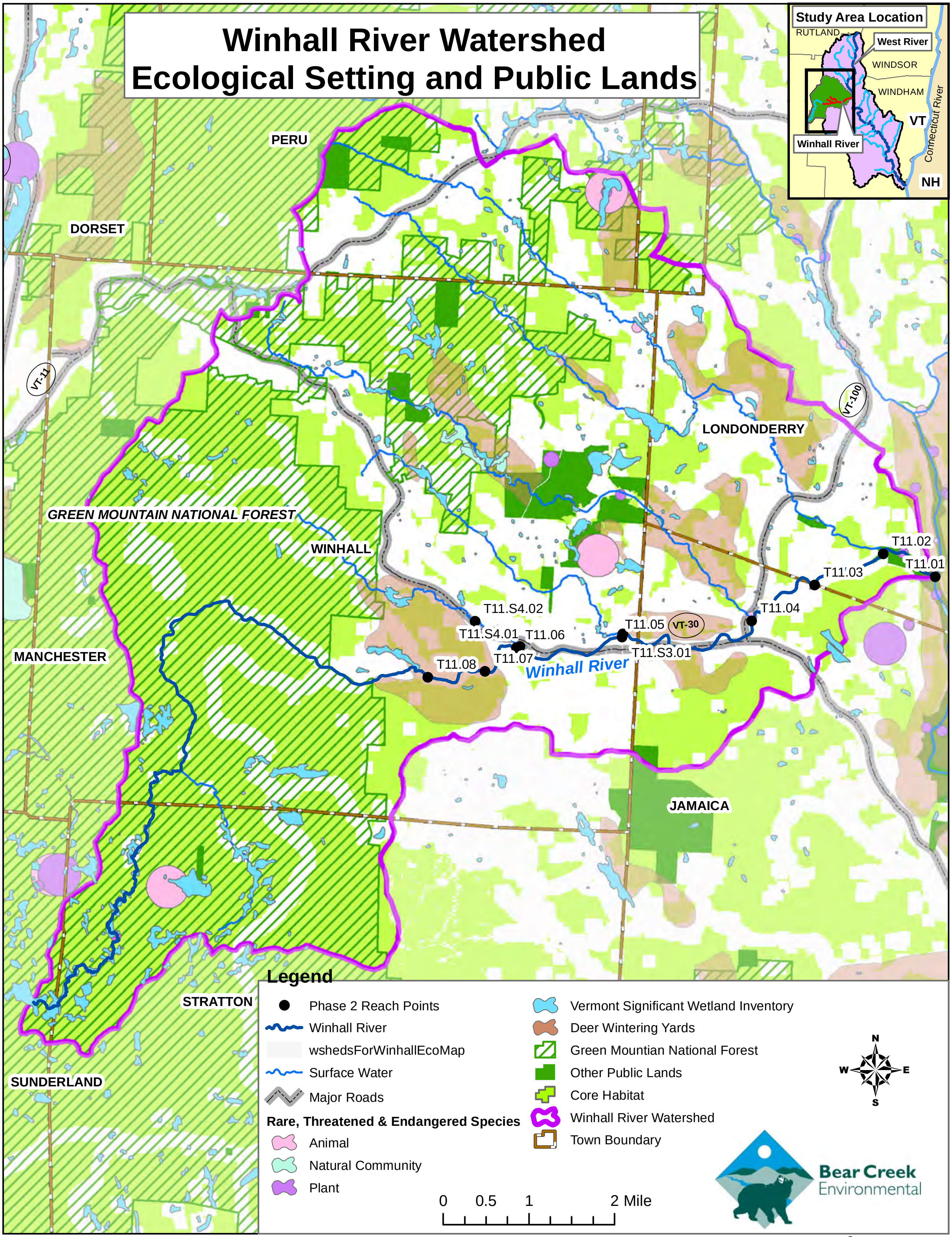


Data provided by the Windham Regional Commission and Vermont Agency of Transportation. Road damage data are not comprehensive and reflect information collected during a time of crisis.

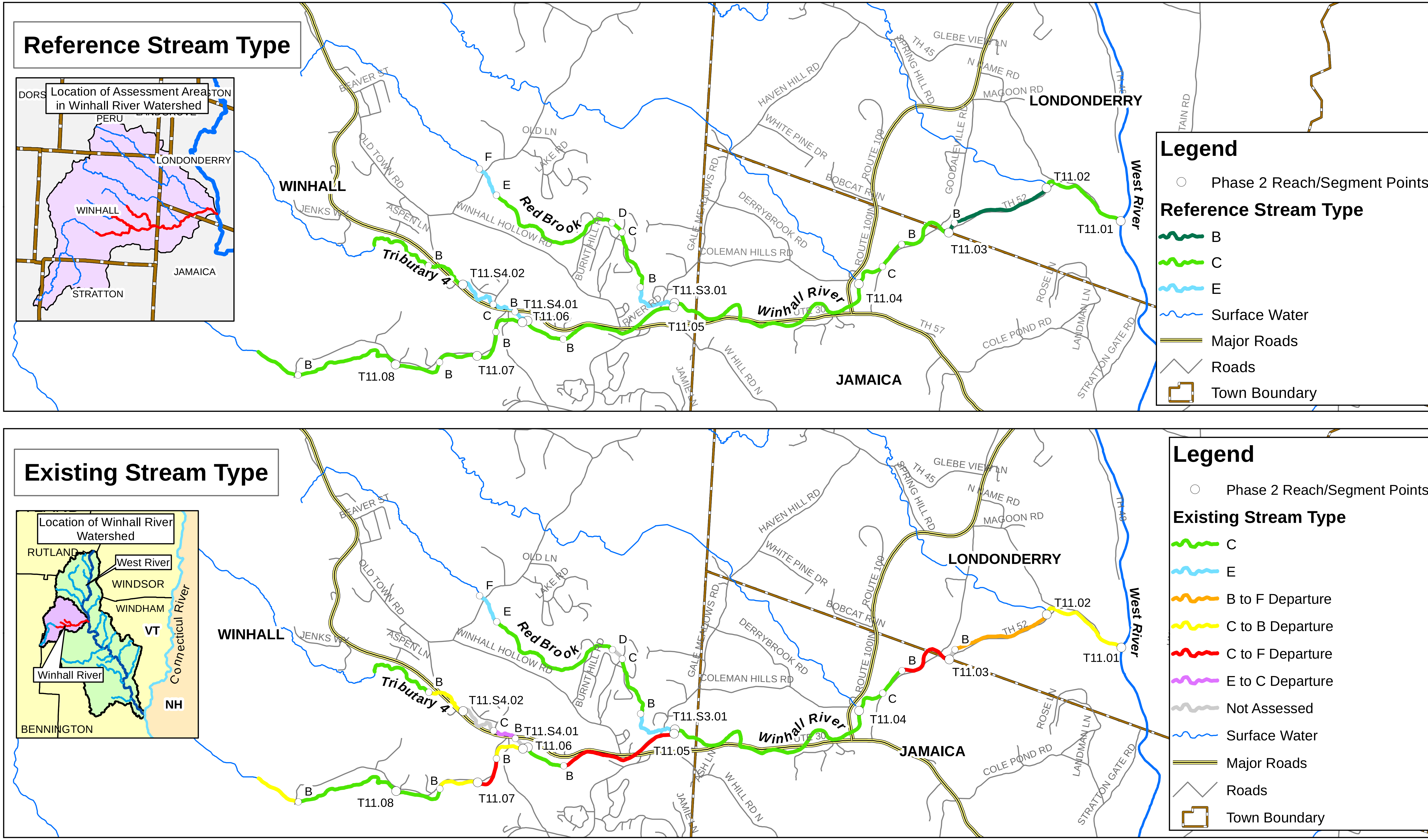
Winhall River Watershed 2013 Study Area
Tropical Storm Irene Flood Damage & Impacts
Winhall, Vermont



Data provided by the Windham Regional Commission and Vermont Agency of Transportation. Road damage data are not comprehensive and reflect information collected during a time of crisis.



Winhall River Watershed
Ecological Setting and Public Lands
Study Area Location
RUTLAND
West River
WINDSOR
WINDHAM
VT
Connecticut River
Winhall River
NH
PERU
DORSET
VT-11
VT-100
LONDONDERRY
GREEN MOUNTAIN NATIONAL FOREST
WINHALL
T11.02
T11.01
T11.03
T11.04
T11.S4.02
T11.05
VT-30
T11.S4.01
T11.06
T11.S3.01
T11.08
T11.07
Winhall River
MANCHESTER
JAMAICA
STRATTON
SUNDERLAND
Legend
Phase 2 Reach Points
Winhall River
wshedsForWinhallEcoMap
Surface Water
Major Roads
Rare, Threatened & Endangered Species
Animal
Natural Community
Plant
Vermont Significant Wetland Inventory
Deer Wintering Yards
Green Mountian National Forest
Other Public Lands
Core Habitat
Winhall River Watershed
Town Boundary
N
W
E
S
0
0.5
1
2 Mile
Bear Creek Environmental

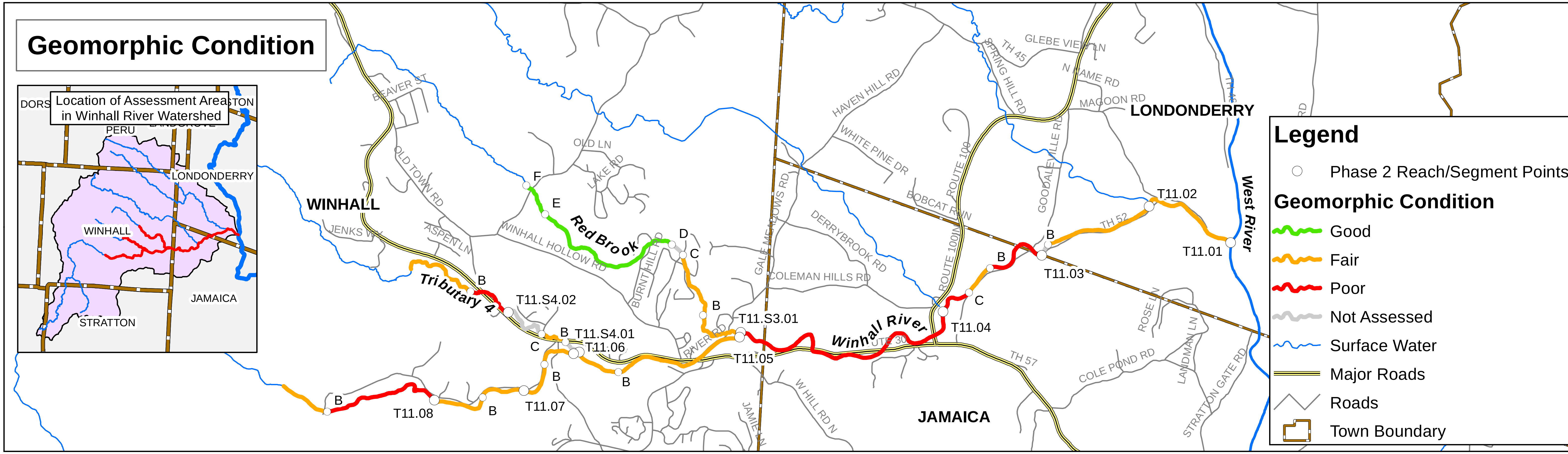


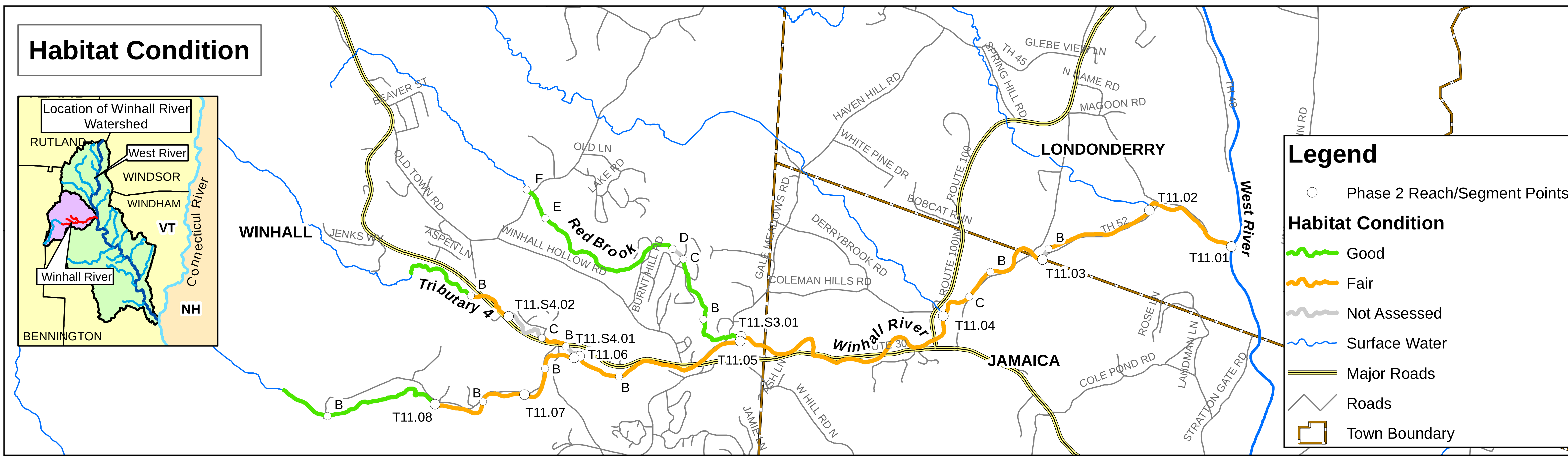
Winhall River, Red Brook, & Tributary 4
Stream Type - Winhall, Jamaica, & Londonderry, Vermont

N S W E

0 0.5 1 2 Miles

Bear Creek Environmental

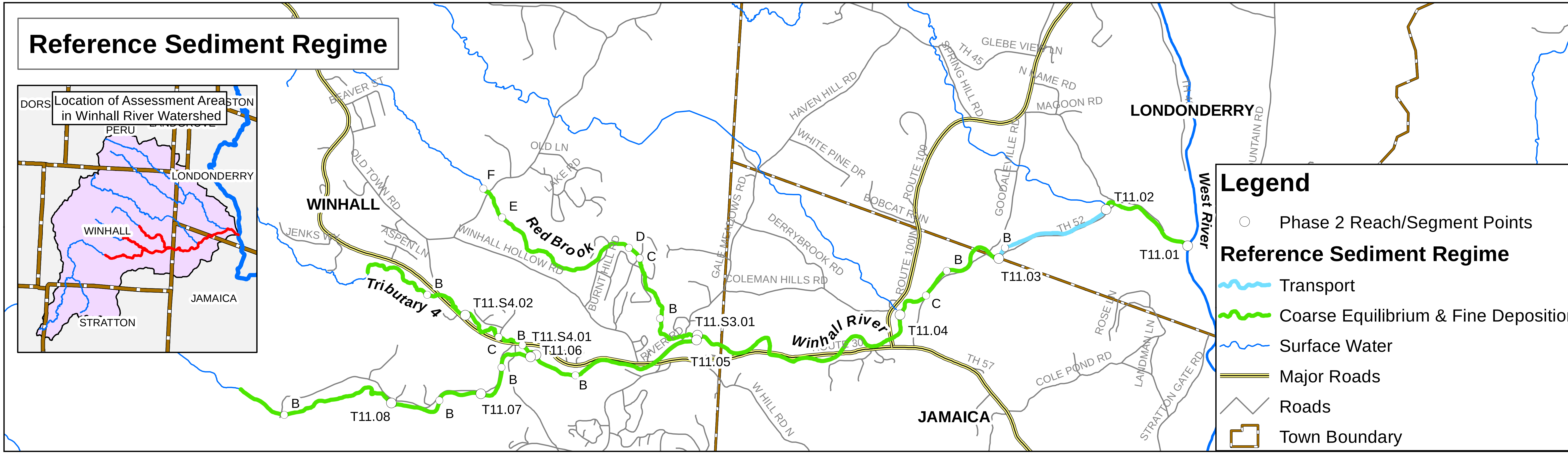


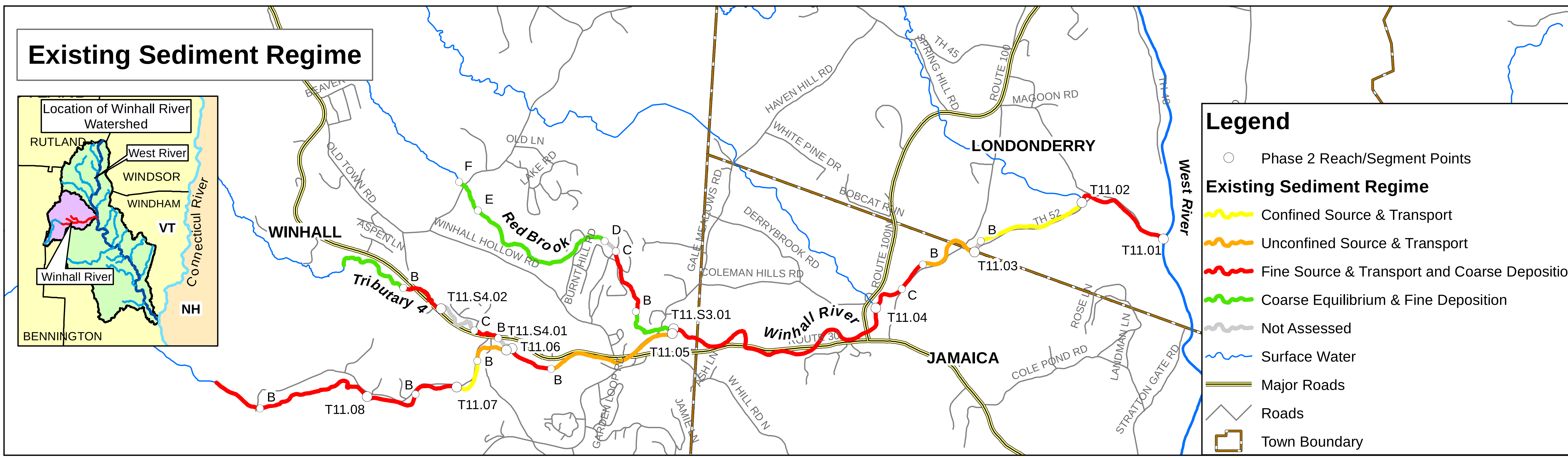


Winhall River, Red Brook, & Tributary 4
Stream Condition - Winhall, Jamaica, & Londonderry, Vermont

0 0.5 1 2 Miles

Bear Creek Environmental





Winhall River, Red Brook, & Tributary 4
Sediment Regime - Winhall, Jamaica, & Londonderry, Vermont

0 0.5 1 2 Miles

Bear Creek Environmental

Winhall River, Red Brook, & Tributary 4 Stream Sensitivity
Winhall, Jamaica, & Londonderry, Vermont

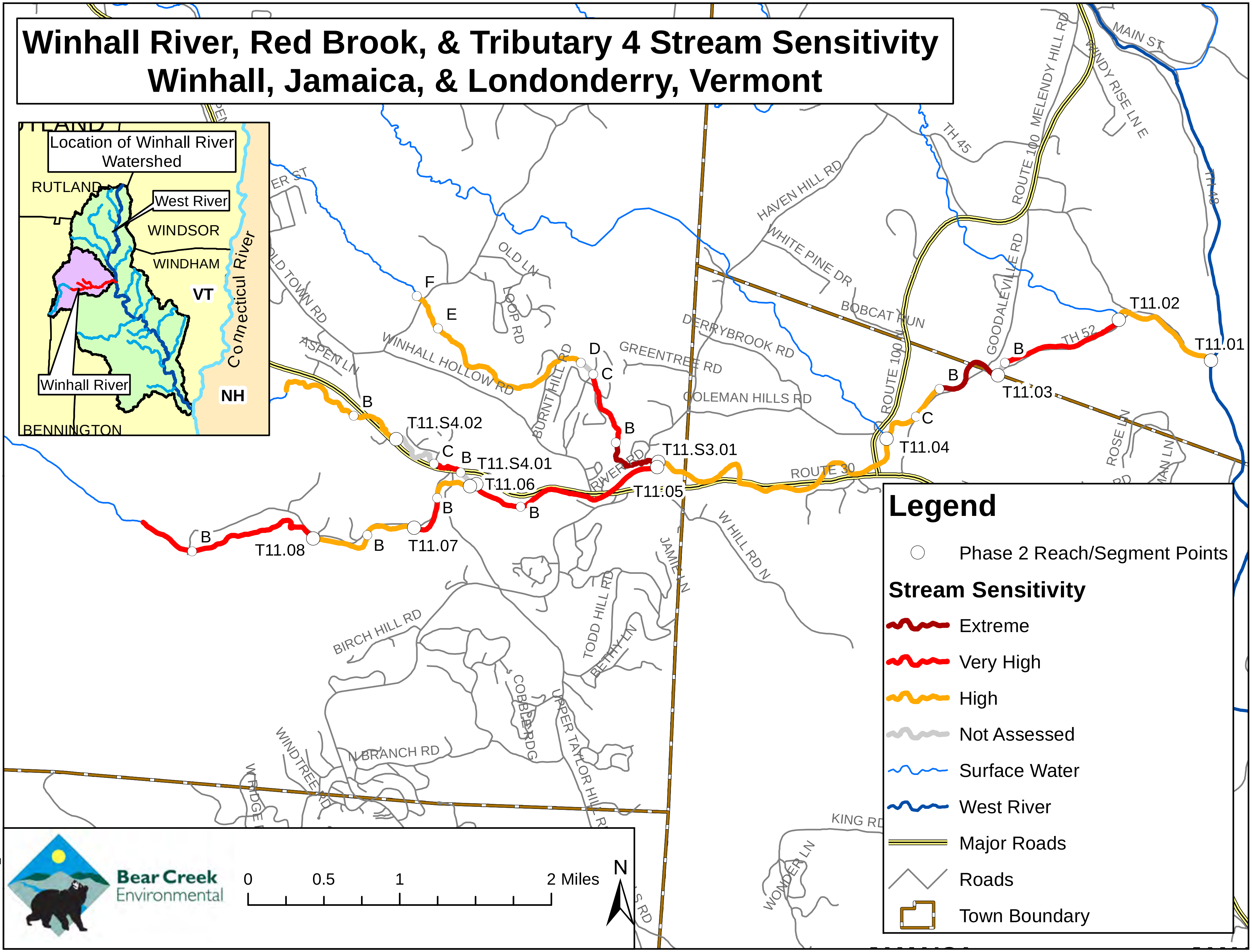


Table 1. Stream Type and Channel Evolution Stage Summary Winhall River Watershed							
Segment Number	**Entrenchment Ratio**	**Width to Depth Ratio**	**Reference Stream Type**	**Incision Ratio**	**Existing Stream Type**	**Channel Evolution Stage**	**Active Adjustment Process**
Winhall River Mainstem							
T11.01	1.5	33.6	C	2.5	B	F-III	**Incision** **Aggradation** **Widening** **Planform**
T11.02-A	1.1	58.8	B	1.3	F	F-IV	Incision **Aggradation** **Widening** **Planform**
T11.02-B	*Not Assessed - Bedrock Gorge*						
T11.03-A	1.4	34.2	C	1.9	F	F-III	**Incision** **Aggradation** **Widening** **Planform**
T11.03-B	2.7	36.0	C	1.8	C	F-III	**Incision** **Aggradation** **Widening** Planform
T11.03-C	8.1	53.0	C	1.5	C	F-IV	**Incision** **Aggradation** **Widening** **Planform**
T11.04	8.1	53.0	C	1.5	C	F-III	**Incision** **Aggradation** **Widening** **Planform**
T11.05-A	1.3	17.8	C	2.0	F	F-II	**Incision** Aggradation **Widening** Planform
T11.05-B	3.0	39.0	C	1.5	C	F-III	**Incision** **Aggradation** **Widening** **Planform**
T11.06-A	1.5	26.1	C	3.0	B_c	F-II	**Incision** Aggradation **Widening** Planform

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

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

Table 1. Stream Type and Channel Evolution Stage Summary Winhall River Watershed							
Segment Number	**Entrenchment Ratio**	**Width to Depth Ratio**	**Reference Stream Type**	**Incision Ratio**	**Existing Stream Type**	**Channel Evolution Stage**	**Active Adjustment Process**
T11.06-B	1.2	22.6	C	2.7	F	F-III	**Incision** Aggradation Widening Planform
T11.07-A	1.8	31.0	C	1.6	B_c	F-II	**Incision** **Aggradation** **Widening** Planform
T11.07-B	2.7	29.4	C	1.4	C	F-III	**Incision** **Aggradation** **Widening** Planform
T11.08-A	6.8	36.1	C	1.7	C	F-IV	**Incision** **Aggradation** **Widening** **Planform**
T11.08-B	1.4	34.3	C	2.6	B_c	F-III	**Incision** Aggradation **Widening** Planform
Red Brook							
T11.S3.01-A	16.7	10.8	E	1.0	E	F-I	Incision **Aggradation** Widening **Planform**
T11.S3.01-B	2.3	19.5	C	1.4	C_b	F-IV	**Incision** **Aggradation** Widening **Planform**
T11.S3.01-C	*Not Assessed - Impounded*						
T11.S3.01-D	3.7	15.0	C	1.0	C	F-I	Aggradation **Planform**
T11.S3.01-E	32.0	6.7	E	1.0	E	F-I	Aggradation **Planform**

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

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

Table 1. Stream Type and Channel Evolution Stage Summary Winhall River Watershed							
Segment Number	**Entrenchment Ratio**	**Width to Depth Ratio**	**Reference Stream Type**	**Incision Ratio**	**Existing Stream Type**	**Channel Evolution Stage**	**Active Adjustment Process**
Tributary 4 to Winhall River							
T11.S4.01-A	*Not Assessed - No Property Access*						
T11.S4.01-B	11.2	16.0	E	1.6	C	F-III	**Incision** **Aggradation** **Widening** **Planform**
T11.S4.01-C	*Not Assessed - No Property Access*						
T11.S4.02-A	1.6	13.0	C_b	2.5	B	F-III	**Incision** **Aggradation** **Widening** **Planform**
T11.S4.02-B	6.3	14.5	C_b	1.0	C_b	F-IV	**Aggradation** Widening **Planform**

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

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

APPENDIX B

Bridge & Culvert Assessment Data

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

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

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

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

Table 5. Aquatic Organism Passage (AOP) Coarse Screen Tool (Milone & MacBroom, 2009)						
VT Aquatic Organism Passage Coarse Screen	**Full AOP**	**Reduced AOP**	**No AOP**			
Updated 2/25/2008	**for all aquatic organisms**	**for all aquatic organisms**	**for all aquatic organisms except adult salmonids**		**for all aquatic organisms including adult salmonids**	
AOP Function Variables / Values	**Green (if all are true)**	**Gray (if any are true)**	**Orange**		**Red**	
Culvert outlet invert type	at grade **OR** backwatered	cascade	free fall **AND**		free fall **AND**	
Outlet drop (ft)	= 0		> 0 , < 1 ft **OR**		≥ 1 ft **OR**	
Downstream pool present			= yes	(= yes **AND**	= no **OR**	(= yes **AND**
Downstream pool entrance depth / outlet drop			n/m	≥ 1)	n/a	< 1) **OR**
Water depth in culvert at outlet (ft)					< 0.3 ft	
Number of culverts at crossing	1	> 1				
Structure opening partially obstructed	= none	≠ none				
Sediment throughout structure	yes	no				

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

Table 6. Winhall River Watershed Bridge Assessment (2013)
Geomorphic Compatibility

Reach/ Segment Number	Town	Road Name	Structure ID[1]	Percent Bankfull Channel Constriction Width[2]	Phase 2 Notes	Scoring						Priority for Replacement
						% Bankfull Width[3]	Sediment Continuity	Approach Angle	Erosion & Armoring	Total Score	Geomorphic Compatibility	
T11.01	Londonderry	TH52	100052000013101	87/79.1 = 110	Not a channel constriction. No problems due to bridge noted. Side bars and pool are not a result of the bridge. The crossing is a one lane bridge for cars in the campground.	4	4	3 Mild Bend	2	**13**	Mostly Compatible	Not recommended for replacement
T11.04	Jamaica	Route 100	200013008113092	78/59.5 = 131	Deposition and scour above. Not a channel constriction but a floodprone constriction. Bridge in good condition and no problems noticed.	5	4	2 Channelized Straight	3	**14**	Mostly Compatible	Not recommended for replacement
T11.04	Jamaica	Route 30	200015004013092	90/59.5 = 151	Not a channel constriction but a floodprone constriction. Deposition above and below. Scour above and below. Diagonal bar is present on left side throughout structure.	5	4	0 Sharp Bend	0	**9**	Partially Compatible	Not recommended for replacement
T11.04	Jamaica	Route 30	200015004213092	48/59.5 = 81	Pier in center of bridge with sediment built up underneath one side of bridge. Built up sediment is causing steep riffle upstream of structure and channel is constricted between pier and right abutment.	3	3	0 Sharp Bend	0	**6**	Mostly Incompatible	Low (Abundant aggradation between abutment and pier; geomorphic incompatibility)
T11.05-A	Winhall	Route 30	200015004302162	90/54.9 = 164	Not a channel constriction but a floodprone constriction. Constriction width is smaller than span due to piers. Scour above and below with abundant scour of abutments. Glacial till exposed in bed below. Riprap likely installed after TSI.	5	4	3 Mild Bend	2	**14**	Mostly Compatible	Not recommended for replacement
T11.S4.02-B	Winhall	Private Driveway	700000000002163	16/20.2 = 79	Newer arch structure. Deposition above and below. Scour above. Poorly aligned.	3	4	0 Sharp Bend	3	**10**	Partially Compatible	Not recommended for replacement (New structure; on private property)
T11.06-A	Winhall	Lower Taylor Hill Road	100216001702161	55/50.2 = 110	Bridge closed down at time of assessment. Deposition and scour above. Channel dredged upstream of bridge with large pool above and below bridge. Constriction width is smaller than span due to riprap.	4	2	3 Mild Bend	0	**9**	Partially Compatible	Low (Sufficient size, scour around footers, wingwalls, and abutments; closed)
T11.08-B	Winhall	Lightfoot Camp Road	200000000702161	36/49.2 = 73	Scour below. Constriction width is smaller than span due to riprap. Floodchute upstream of structure on southern side hits roadway approach and enters the stream channel just upstream of bridge.	2	4	5 Naturally Straight	2	**13**	Mostly Compatible	Low (Riprap constricting channel)

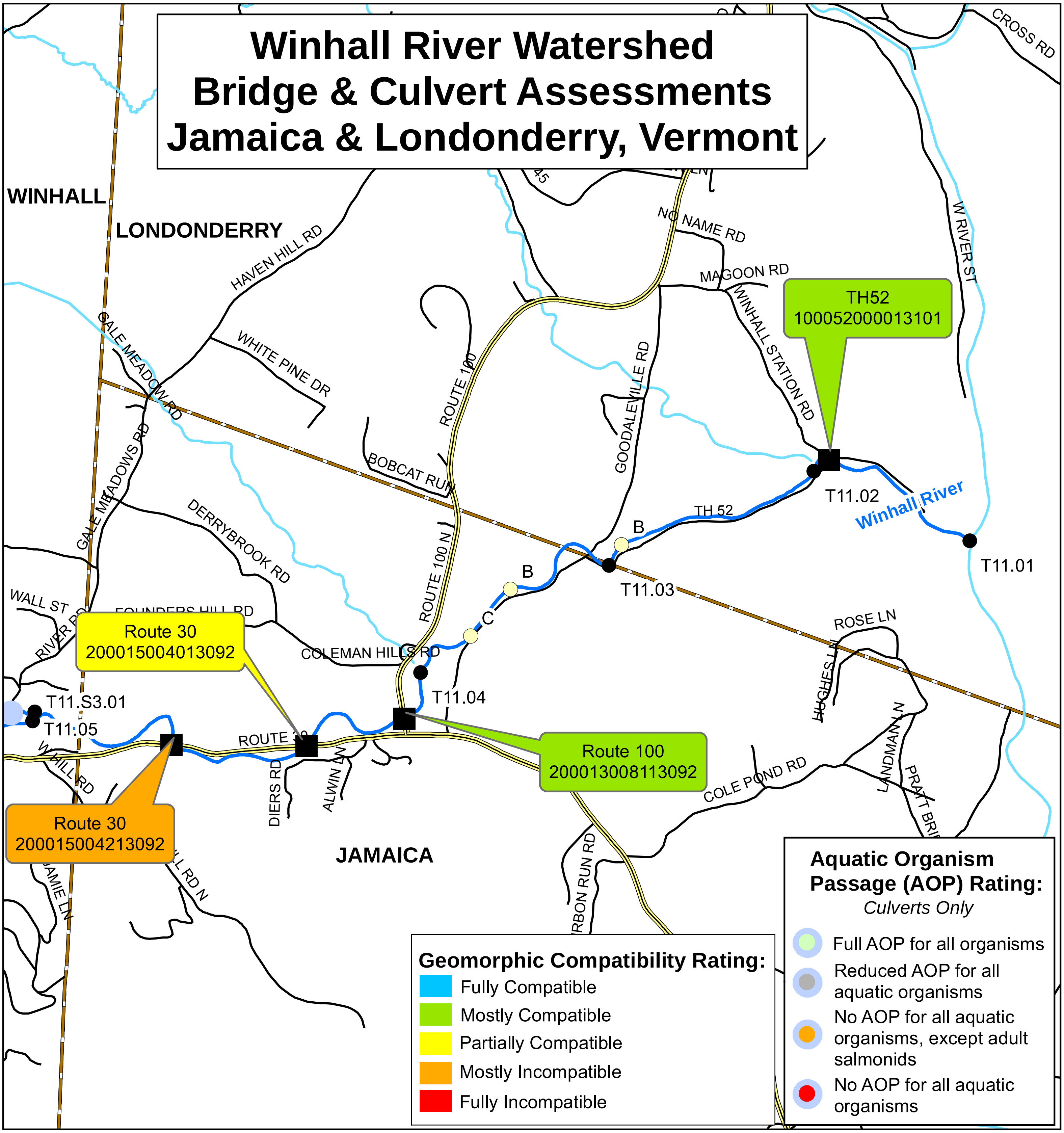
[1]The structure ID is the identification number provided by the 2010 "TransStructures_TRANSTRUC" shapefile from the Vermont Center for Geographic Information, unless no number was available. In this case, the SGAID is provided.
[2]Percent Bankfull Channel Width percentages are calculated based on the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

Table 7. Winhall River Watershed Culvert Assessment (2013)
Geomorphic Compatibility and Aquatic Organism Passage (AOP)

Reach/ Segment Number	Town	Road Name	Structure Type and ID[1]	Percent Bankfull Channel Width[2]	Phase 2 Notes	Scoring (Geomorphic Compatibility - Milone & MacBroom, 2008; AOP – Milone & MacBroom, 2009)								Priority for Replacement
						% Bankfull Width	Sediment Continuity	Slope	Approach Angle	Erosion & Armoring	Total Score	Geomorphic Compatibility	AOP	
T11.S3.01-A	Winhall	River Road	990013001602161	7/19.5 = 36	Significantly undersized steel corrugated culvert. Deposition above and scour below with deep pool. Avulsion, island and steep riffle upstream. No material throughout.	1	1	5	3 Mild Bend	2	**12**	Partially Compatible	Reduced AOP	High (Significantly undersized with large scour pool)
T11.S3.01-B	Winhall	Raspberry Hill Road	700027029502163	10/19.5 = 51	Two culverts at crossing, each 5 feet wide. One culvert, which is slightly higher than the other has a rusted out bottom. Other culvert takes up 100% of the baseflow. Road runoff is undermining culvert headwall on upstream end.	2	2	5	5 Naturally Straight	1	**15**	Partially Compatible	Reduced AOP	Moderate (Undersized, headwall undermined)
T11.S3.01-C	Winhall	Raspberry Hill Road	700027029002163	10/19.5 = 51	Scour below. Concrete dam that is 5.5 feet high with two culverts encased in concrete, each 5 feet wide. Large overflow structure present with deteriorated concrete flooring and cracked wingwall. Outlet drop of 1 foot at culverts creating potential fish passage issue.	2	5	2	5 Naturally Straight	1	**15**	Partially Compatible	No AOP Including Adult Salmonids	Low (Pond outlet; dam present; not recommended for replacement unless dam also replaced)
T11.S3.01-D	Winhall	Cranberry Hill Road	700050041202163	6/19.5 = 31	Significantly undersized culvert with abundant large woody debris. Considerable deposition and widening above culvert. Water overtopped culvert during TSI and downstream residence is in danger of flooding if culvert is plugged.	1	4	5	3 Mild Bend	1	**14**	Partially Compatible	Reduced AOP	High (Significantly undersized; overtopped during TSI)
T11.S3.01-E	Winhall	Winhall Hollow Road	400002000402161	6/19.5 = 31	Significantly undersized culvert with alignment issue. Appears to have had serious downstream scour during TSI. Deposition and scour above also. Slightly perched with outlet drop of 0.1 feet.	1	2	5	3 Mild Bend	0	**11**	Partially Compatible	Reduced AOP	High (Significantly undersized and alignment)
T11.S4.01-B	Winhall	Route 30	300015004502161	11.5/21 = 54	Culvert is undersized and in poor condition with rotting at inlet and outlet. Outlet drop causing potential fish passage issue. Small amount of gravel/sand within structure but mostly no material throughout.	2	4	5	3 Mild Bend	0	**14**	Partially Compatible	No AOP Including Adult Salmonids	High (Poor condition; undersized with no AOP)
T11.S4.01-B	Winhall	Stratton View Road	100000000302161	12/21 = 57	Three culverts at crossing. Deposition and scour below with large scour pool (>3 feet deep). One pipe in poor condition and rotted out. Woody debris and sediment causing blockage. Flow only coming out of center culvert at time of assessment.	2	4	5	2 Channelized Straight	0	**13**	Partially Compatible	Reduced AOP	High (Each culvert significantly undersized; one in poor condition)
T11.S4.02-A	Winhall	Route 30	300015004602161	11.5/20 = 57	Undersized but in good condition. Baffles throughout structure. Culvert outlet is perched by 0.4 feet; partially backwatered due to baffles. Deposition above and below and scour above.	2	4	5	0 Sharp Bend	1	**12**	Partially Compatible	Reduced AOP	Low (Undersized but still in good condition)

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

Winhall River Watershed
Bridge & Culvert Assessments
Jamaica & Londonderry, Vermont



Legend

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

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

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

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

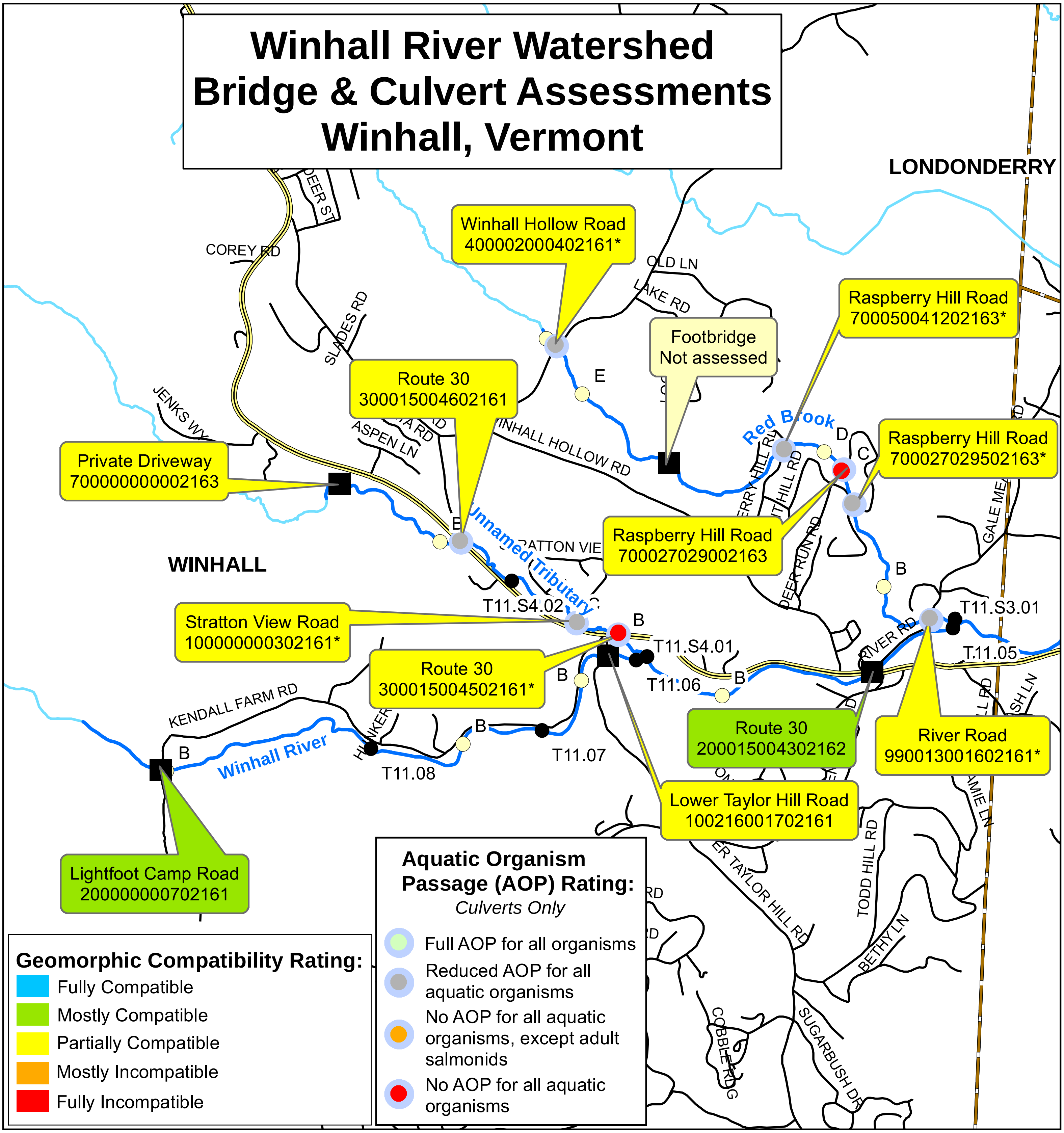
*Structure is recommended for replacement.

0 0.25 0.5 Miles

N W E S

Bear Creek Environmental

Winhall River Watershed Bridge & Culvert Assessments Winhall, Vermont



Legend

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

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

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

0 0.25 0.5 Miles

N W E S

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

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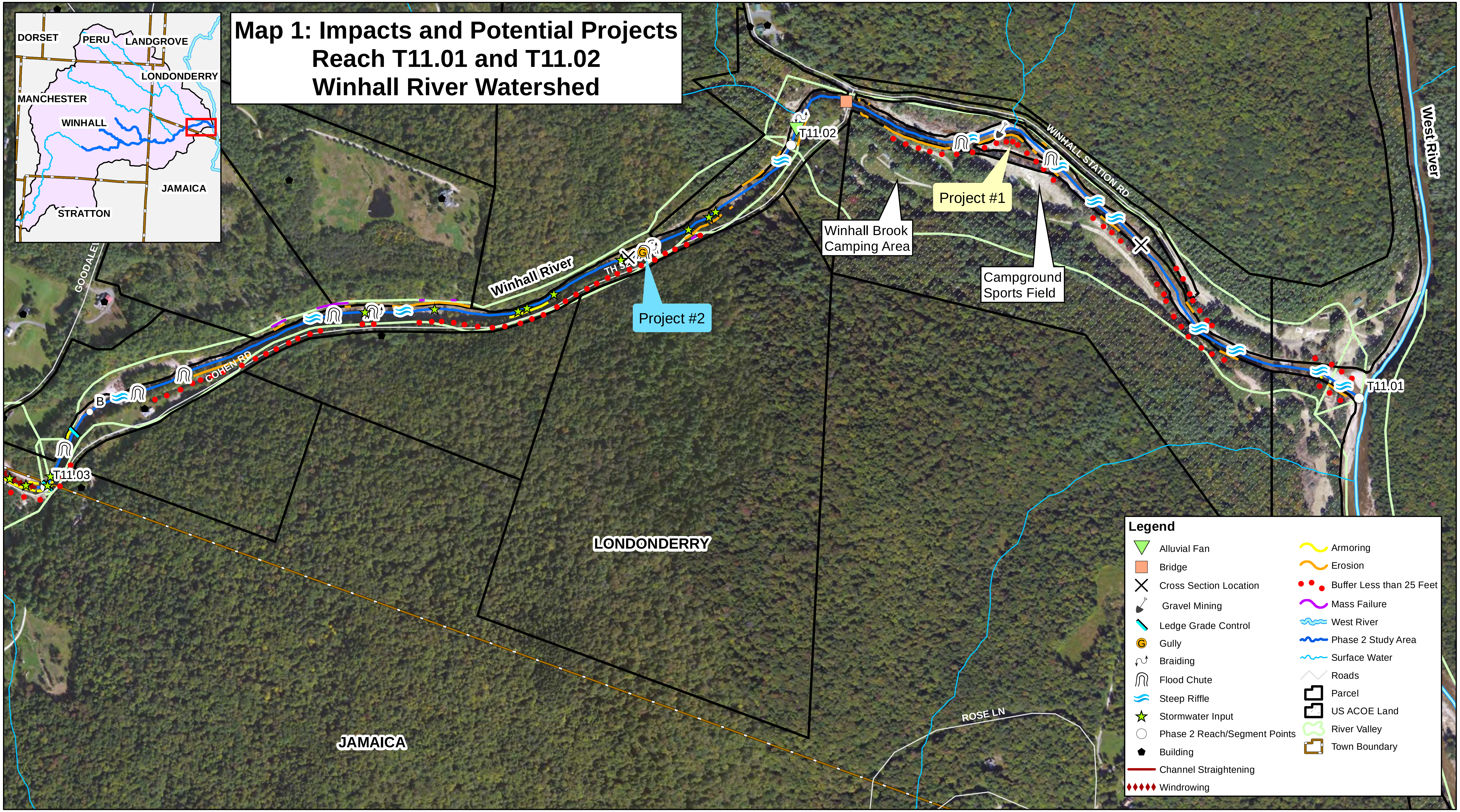
*Structure is recommended for replacement.

APPENDIX C

Potential Project Locations & Descriptions



Background is World Imagery

Projects:

1. Streamside Plantings
2. Stabilize/Remediate Gully

Project Priority:

- Low
- Moderate
- High

N

0 500 1,000 2,000 Feet

1 inch = 500 feet

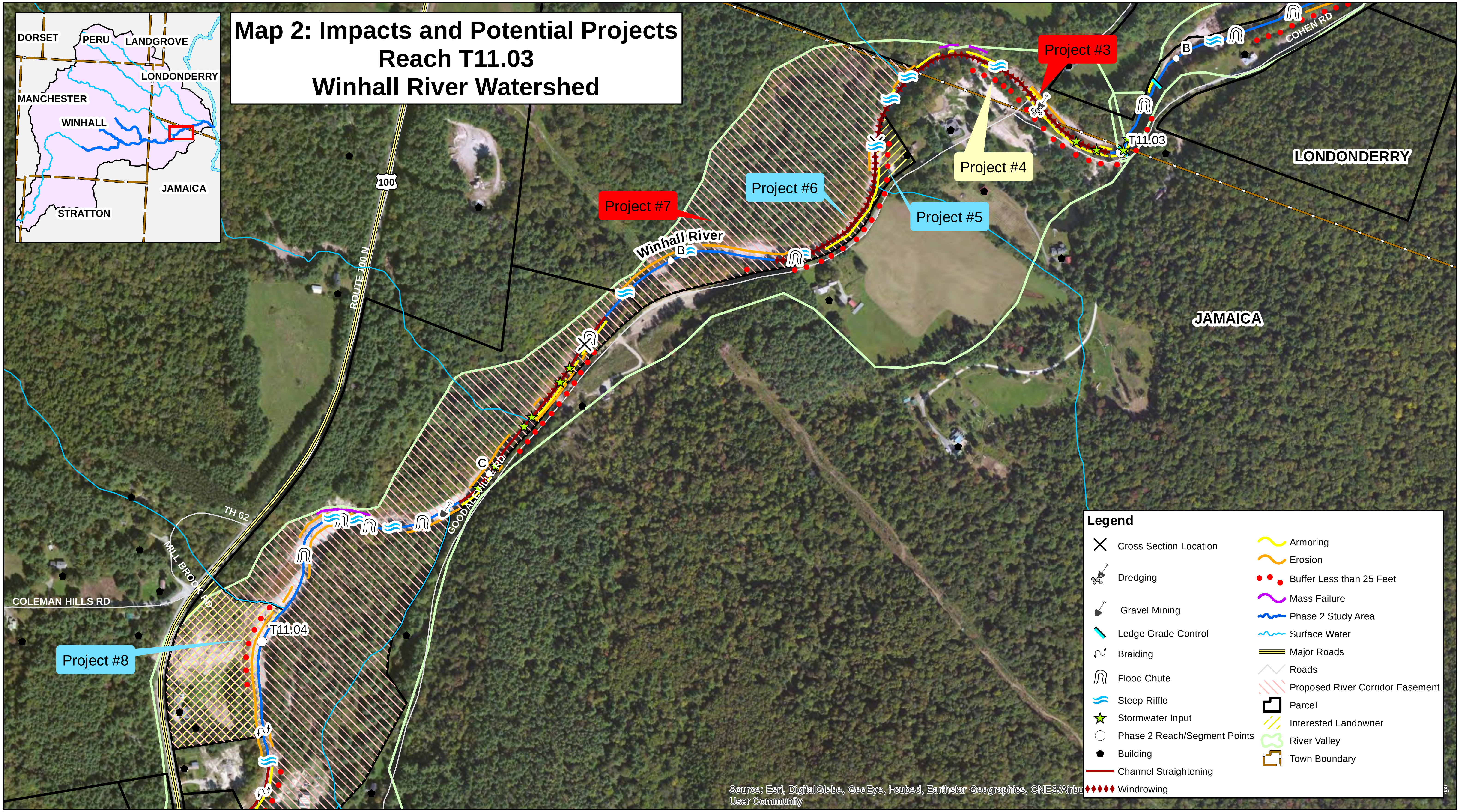
Bear Creek Environmental

Table 1. Winhall River Main Stem Map 1: T11.01 and T11.02 Site Level Opportunities for Restoration and Protection Londonderry, Vermont						
Project # Segment	**Type of Project**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Benefits**	**Potential Partners/ Programs**
Project #1 T11.01	Passive Restoration	Buffer is lacking on the south side of the river due to the Winhall Brook Camping Area. There is a recreational field with no buffer at the site.	**Streamside Plantings**	Low Priority (campground sports field at site)	Improved habitat and water quality	US ACOE TFS
Project #2 T11.02-A	Active Restoration	A gully is present along the south side of the river that is delivering sediment from Cohen Road. There are several locations in this segment where overland flow from the road appears to enter the river.	**Stabilize/ Remediate Gully; Improve Stormwater Infrastructure**	Moderate Priority	Improved geomorphic stability, water quality, and habitat	WRC, VANR, CRWC, Town of Londonderry

Photos of Proposed Project Locations – Map 1

(No photo for Project #1)

Project #2 – Stabilize/ Remediate Gully; Improve Stormwater Infrastructure



Background is World Imagery

Projects:

3. Remove Old Bridge Abutments
4. Streamside Plantings
5. Streamside Plantings
6. Return Windrowed Material to Channel
7. River Corridor Easement
8. Streamside Plantings

Project Priority:

- Low
- Moderate
- High

N

0 | 375 | 750 | 1,500 Feet

1 inch = 400 feet

Bear Creek Environmental

Table 2. Winhall River Main Stem Map 2: T11.03 Site Level Opportunities for Restoration and Protection Londonderry & Jamaica, Vermont						
Project # Segment	**Type of Project**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Benefits**	**Potential Partners/ Programs**
Project #3 T11.03-A	Active Restoration	A bridge on Goodaleville Road was destroyed during TSI. The bridge abutments remain in place and are creating a channel constriction in this location.	**Remove Old Bridge Abutments**	High Priority (Bridge is no longer in existence, but may be replaced in the future)	Improved geomorphic stability	WRC, VANR, CRWC, Town of Jamaica
Project #4 T11.03-A	Passive Restoration	Riparian buffer is lacking along the south side of the river.	**Streamside Plantings**	Low Priority (Small area for planting)	Improved habitat and water quality	Landowners, WRC, CRWC TFS
Project #5 T11.03-A	Passive Restoration	Riparian buffer is lacking along east side of river due to homeowner's lawn.	**Streamside Plantings**	Moderate Priority (Interested landowner but small area)	Improved habitat and water quality	Landowner, WRC, CRWC TFS
Project #6 T11.03-A	Active Restoration	Channel was windrowed and excavated post-TSI and floodplain access has been lost in this area.	**Return Windrowed Material to Channel**	Moderate Priority	Improved geomorphic stability and habitat; attenuation of floodwaters and sediment	Landowners, WRC, VANR, CRWC, Town of Jamaica
Project #7 T11.03-A through C, T11.04	Passive Restoration	The river has well forested buffers for the majority of this area and some floodplain access. It is also undergoing active planform adjustment.	**River Corridor Easement**	High Priority (Landowner interest & important flood water attenuation area)	Improved geomorphic stability and habitat; attenuation of floodwaters and sediment	Landowners, WRC, VANR, CRWC RCE
Project #8 T11.03-C & T11.04	Passive Restoration	Riparian buffer is lacking on the western bank of the Winhall. The bank is actively eroding and contributing sediment to the river.	**Streamside Plantings**	Moderate Priority	Improved habitat and water quality	Landowners, WRC, VANR, CRWC TFS

Photos of Proposed Project Locations – Map 2
(No photo for Project #4)

Project #3 – Remove Old Bridge Abutments

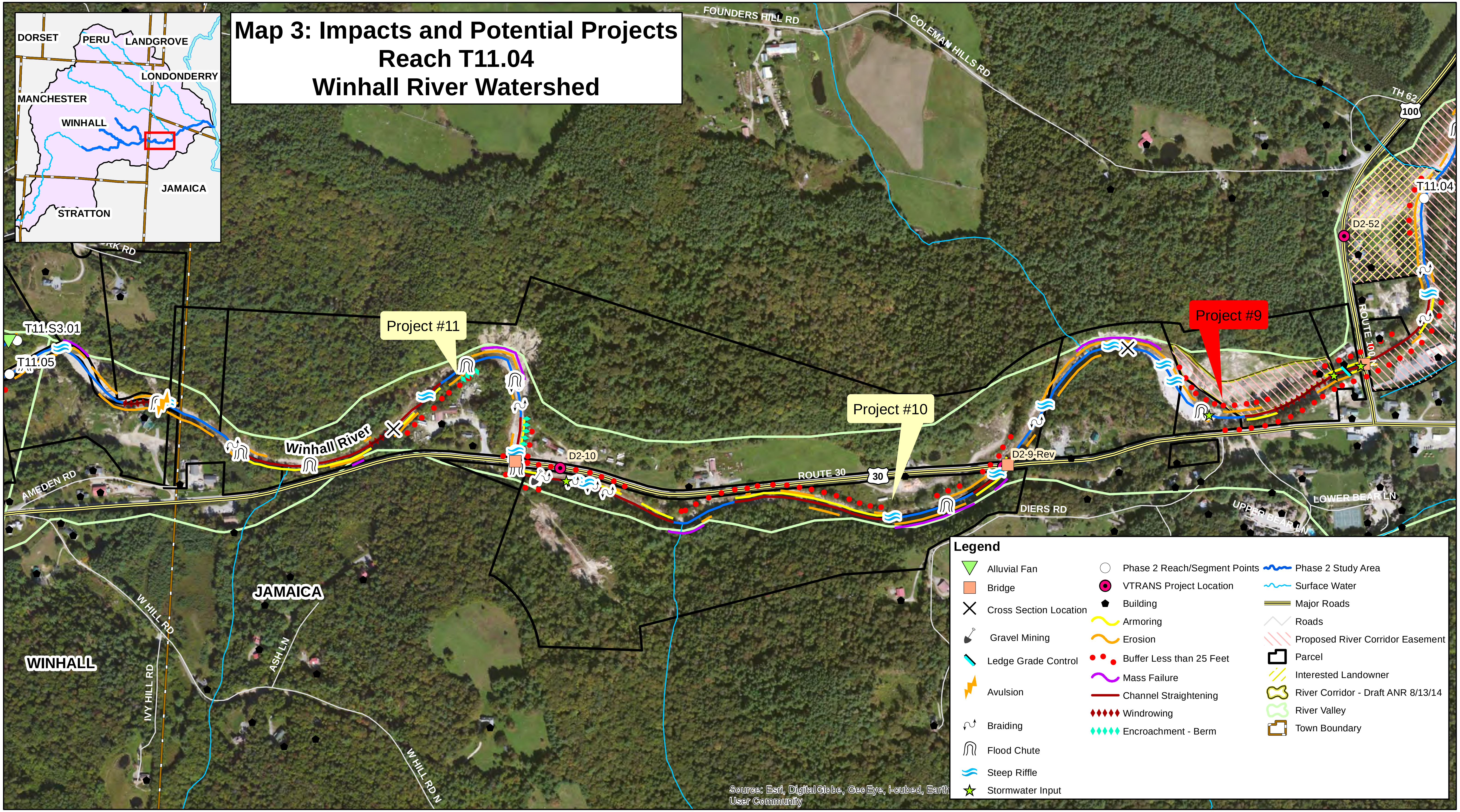
Project #5 – Streamside Plantings

Project #6 – Return Windrowed Material to Channel

Project #7 – River Corridor Easement

Project #8 – Streamside Plantings

Map 3: Impacts and Potential Projects
Reach T11.04
Winhall River Watershed



Background is World Imagery

Projects:

9. Streamside Plantings & River Corridor Easement
10. Streamside Plantings
11. Remove Berm

Project Priority:

- Low
- Moderate
- High

N

0 500 1,000 2,000 Feet

1 inch = 500 feet

Bear Creek Environmental

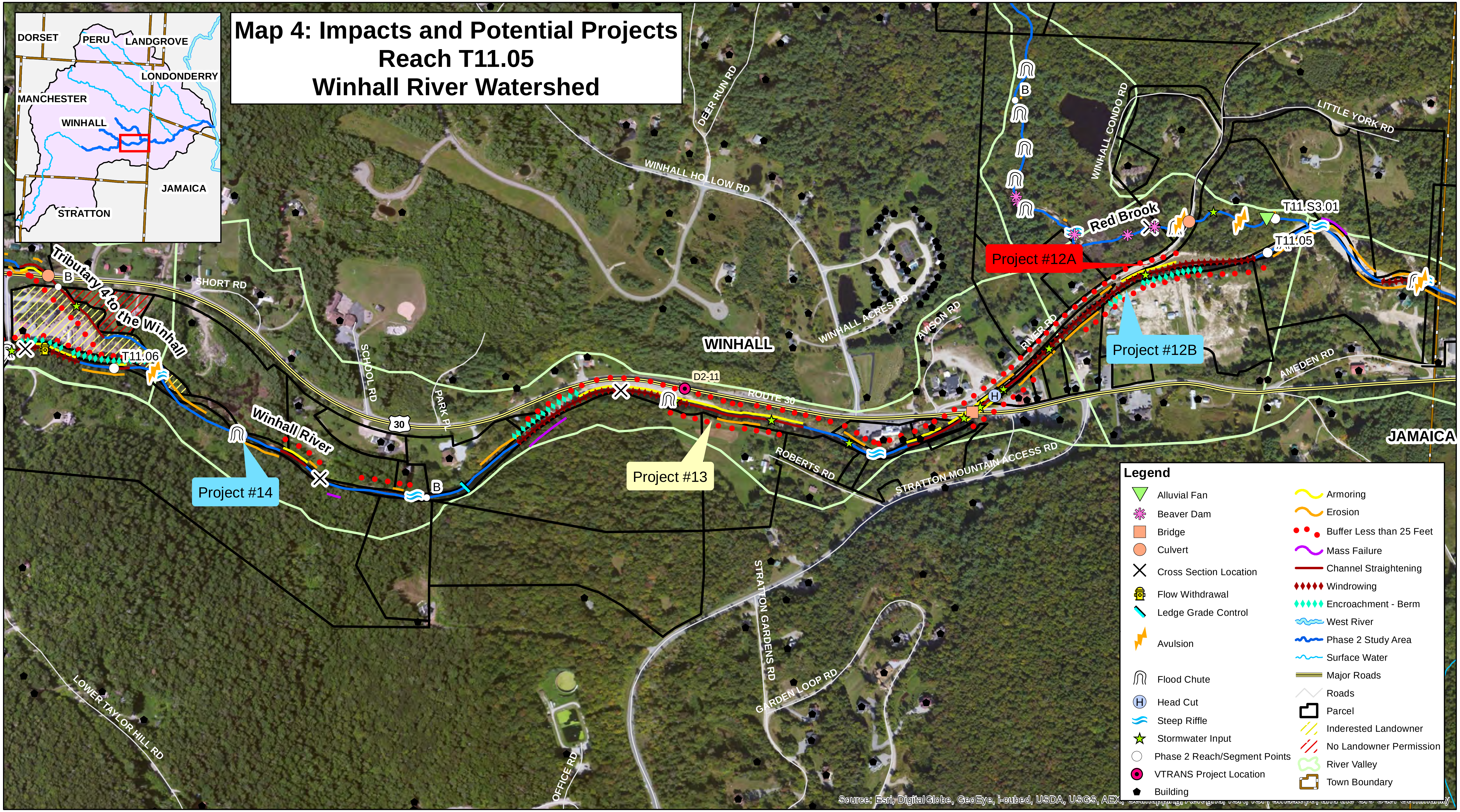
Table 3. Winhall River Main Stem Map 3: T11.04 Site Level Opportunities for Restoration and Protection Jamaica & Winhall, Vermont						
Project # Segment	**Type of Project**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Benefits**	**Potential Partners/Programs**
Project #9 T11.04	Passive Restoration	Riparian buffer is lacking along field on north side of river. This area has good floodplain access and the river is actively adjusting.	**Streamside Plantings & River Corridor Easement**	High Priority	Improved habitat, water quality, and geomorphic stability	Landowners, WRC, VANR, CRWC TFS, RCE
Project #10 T11.04	Passive Restoration	Area along northern bank lacks adequate buffer width. Canopy cover is reduced.	**Streamside Plantings**	Low Priority (Small area)	Improved habitat and water quality	Landowners, WRC, VANR, CRWC TFS
Project #11 T11.04	Active Restoration	Historic four-foot berm is present along the south side of the stream and is restricting floodplain access.	**Berm Removal**	Low Priority (Berm is short-lived)	Improved geomorphic stability, habitat, and water quality, attenuation of floodwaters and sediment	Landowners, WRC, VANR, CRWC

Photos of Proposed Project Locations – Map 3

Project #9 – Streamside Plantings & River Corridor Easement

Project #10 – Streamside Plantings

Project #11 – Berm Removal



Background is World Imagery

Projects:

12A. Pull back River Road Embankment to Reduce Encroachment
12B. Return Windrowed Material to Channel & Streamside Plantings
13. Streamside Plantings
14. Arrest Headcut & Clean Up Trash on Banks

Project Priority:

- Low
- Moderate
- High

N

0 500 1,000 2,000 Feet

1 inch = 500 feet

Bear Creek Environmental

Table 4. Winhall River Main Stem Map 4: T11.05 Site Level Opportunities for Restoration and Protection Winhall, Vermont						
Project # Segment	**Type of Project**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Benefits**	**Potential Partners/ Programs**
Project #12A T11.05-A	Active Restoration	River Road washed out during Irene, and was rebuilt with an embankment that significantly encroaches upon the river and creates a pinch point in the channel. Pulling this embankment back would give the river more room and disperse energy more during high flows.	**Pull Back River Road Embankment to Reduce Encroachment**	High Priority	Improved geomorphic stability	Town of Winhall, WRC, VANR
Project #12B T11.05-A	Active & Passive Restoration	Channel was windrowed post-TSI, creating a two-foot berm along the southern bank of the river. Berm is protecting fairgrounds, which were damaged during Irene. Riparian buffer is also lacking in the same location.	**Return Windrowed Material to Channel & Streamside Plantings**	Moderate Priority (High bank, property damaged during Irene)	Improved geomorphic stability, habitat, and water quality; attenuation of floodwaters and sediment	Landowners, WRC, VANR, CRWC, Town of Winhall TFS
Project #13 T11.05-A	Passive Restoration	The riparian buffer is lacking on the south side of the river due to a homeowner's lawn.	**Streamside Plantings**	Low Priority (The bank is high in this location)	Improved habitat and water quality	Landowners, WRC, VANR, CRWC, TFS
Project #14 T11.05-B	Active Restoration	The stream channel in T11.05-B is actively degrading via one small headcut. At the same location, there is trash piled on the north bank of the river.	**Arrest Headcut & Clean Up Trash on Banks**	Moderate Priority	Improved geomorphic stability, habitat, and water quality	Landowners, WRC, VANR, CRWC

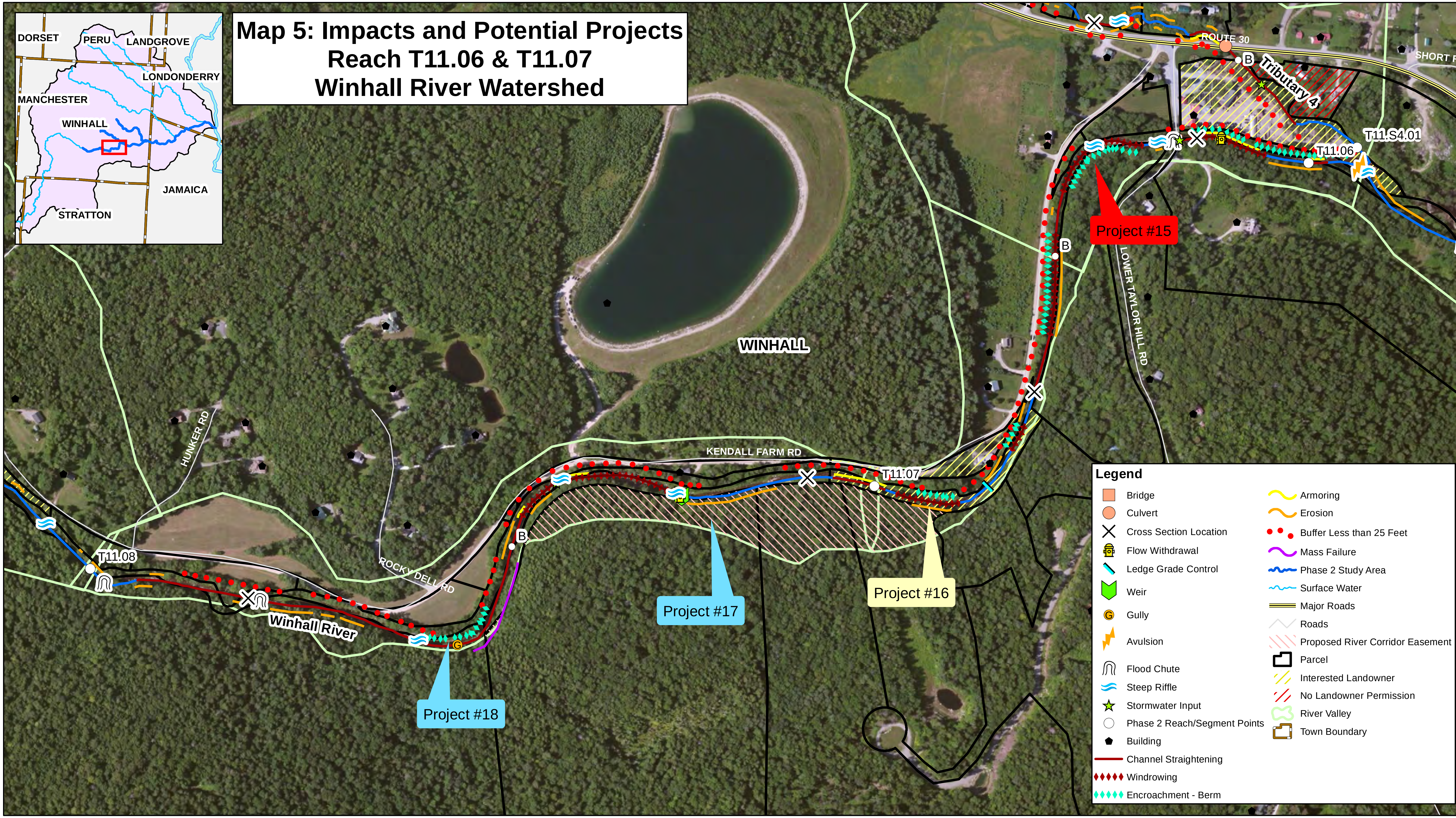
Photos of Proposed Project Locations – Map 4

(No photo of Project #13)

Project #12A – Pull Back River Road Embankment to Reduce Encroachment

Project #12B – Return Windrowed Material to Channel & Streamside Plantings

Project #14 – Arrest Headcut & Clean Up Trash on Banks



Projects:

15. Return Windrowed Material to Channel & Remove Berm
16. Return Windrowed Material to Channel & Remove Berm
17. River Corridor Easement
18. Remove Berm & Investigate Gully

Project Priority:

- Low
- Moderate
- High

N

0 375 750 1,500 Feet

1 inch = 400 feet

Background is World Imagery

Bear Creek Environmental

Table 5. Winhall River Main Stem Map 5: T11.06 & T11.07 Site Level Opportunities for Restoration and Protection Winhall, Vermont						
Project # Segment	**Type of Project**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Benefits**	**Potential Partners/ Programs**
Project #15 T11.06-A	Active Restoration	The channel was windrowed post-TSI, lowering the streambed and creating a one-foot berm along the inside of a large bend. Floodplain access has been lost along this bend, which is well forested and free of infrastructure/buildings.	**Return Windrowed Material to Channel & Remove Berm**	High Priority	Improved geomorphic stability and habitat; attenuation of floodwaters and sediment	Landowners, WRC, VANR, CRWC
Project #16 T11.06-B	Active Restoration	This section of the river was windrowed post-TSI, creating a four-foot berm along the north bank. This berm was created to protect a nearby house from flood waters.	**Return Windrowed Material to Channel & Remove Berm**	Low Priority (Landowner interest, but berm is protecting house)	Improved geomorphic stability and habitat	Landowners, WRC, VANR, CRWC
Project #17 T11.07-A	Passive Restoration	The Winhall River has well forested buffers in this area and some floodplain access.	**River Corridor Easement**	Moderate Priority	Improved habitat and water quality; attenuation of floodwaters and sediment	Landowners, WRC, VANR, CRWC RCE
Project #18 T11.07-B	Active Restoration	A berm exists on the north bank of the Winhall where no infrastructure is present – only an agricultural field. The river could likely access this floodplain if the berm were not present. A gully exists on the south bank and is contributing sediment to the river. The source of the gully is unknown.	**Remove Berm & Investigate Gully**	Moderate Priority	Improved geomorphic stability, habitat, and water quality; attenuation of floodwaters and sediment	Landowners, WRC, VANR, CRWC

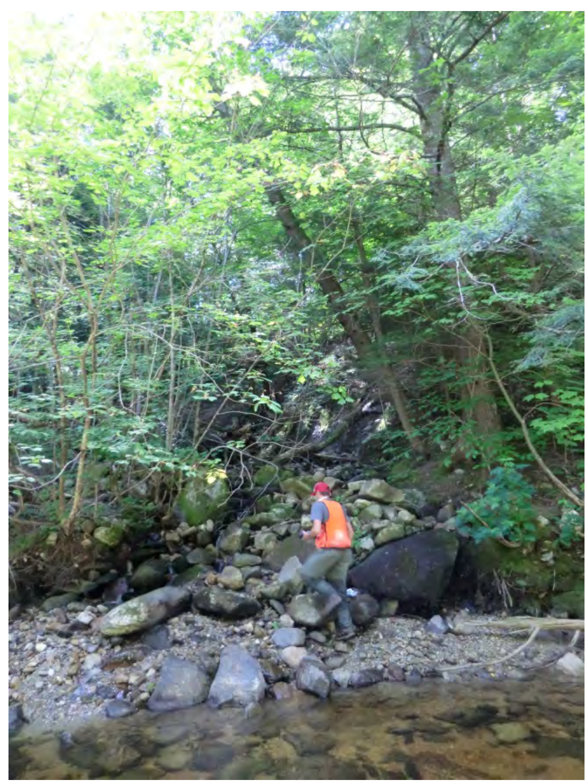
Photos of Proposed Project Locations – Map 5

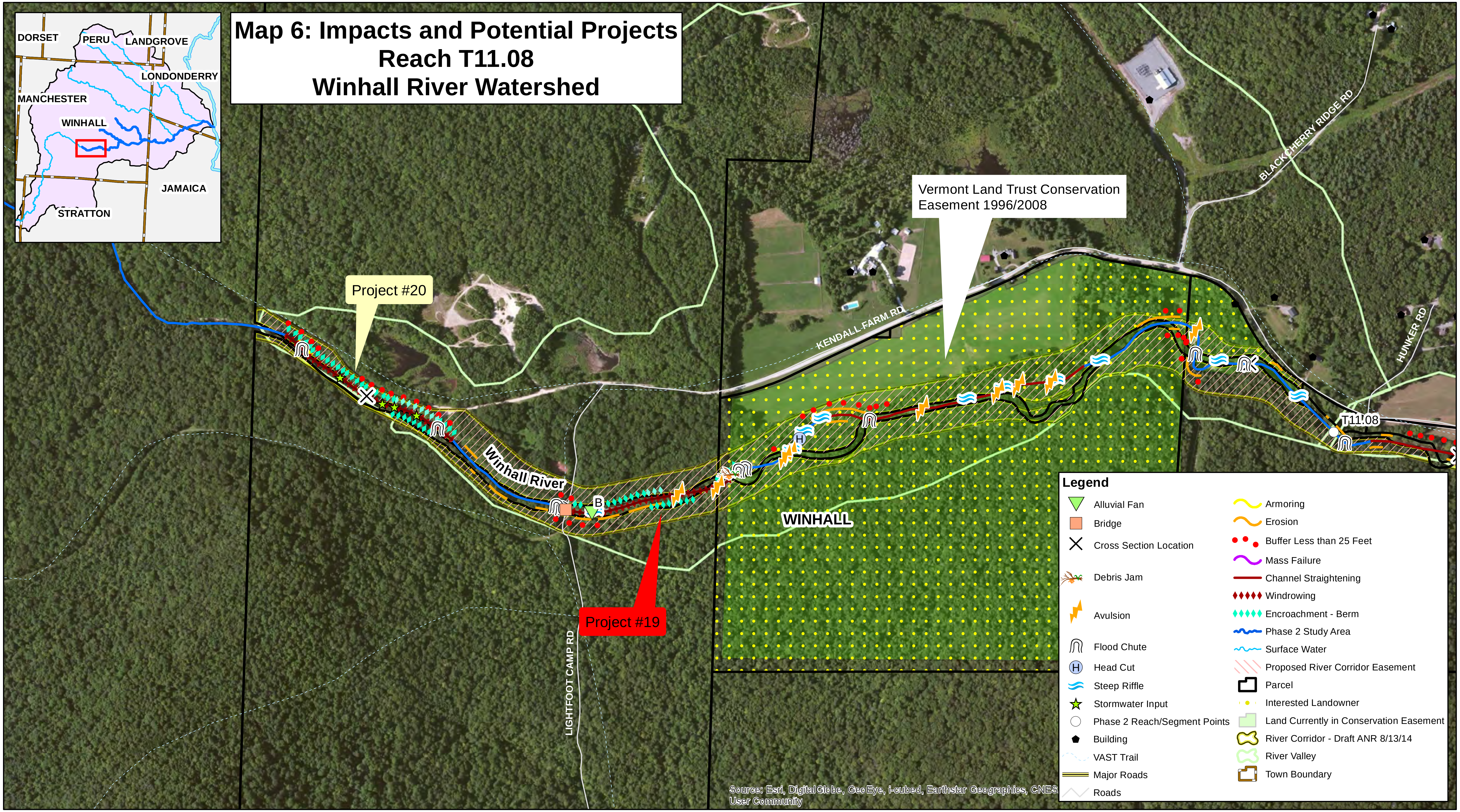
Project #15 – Return Windrowed Material to Channel & Remove Berm

Project #16 – Return Windrowed Material to Channel & Remove Berm

Project #17 – River Corridor Easement

Project #18 – Remove Berm & Investigate Gully





Background is World Imagery

Projects:

19. River Corridor Easement
20. Investigate Berm Removal & Lowering Road

Project Priority:

- Low
- Moderate
- High

N

0 500 1,000 2,000 Feet

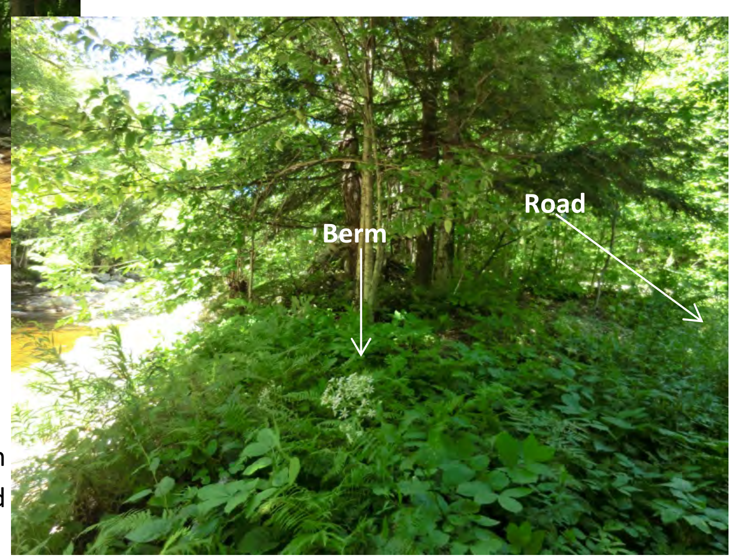
1 inch = 500 feet

Bear Creek Environmental

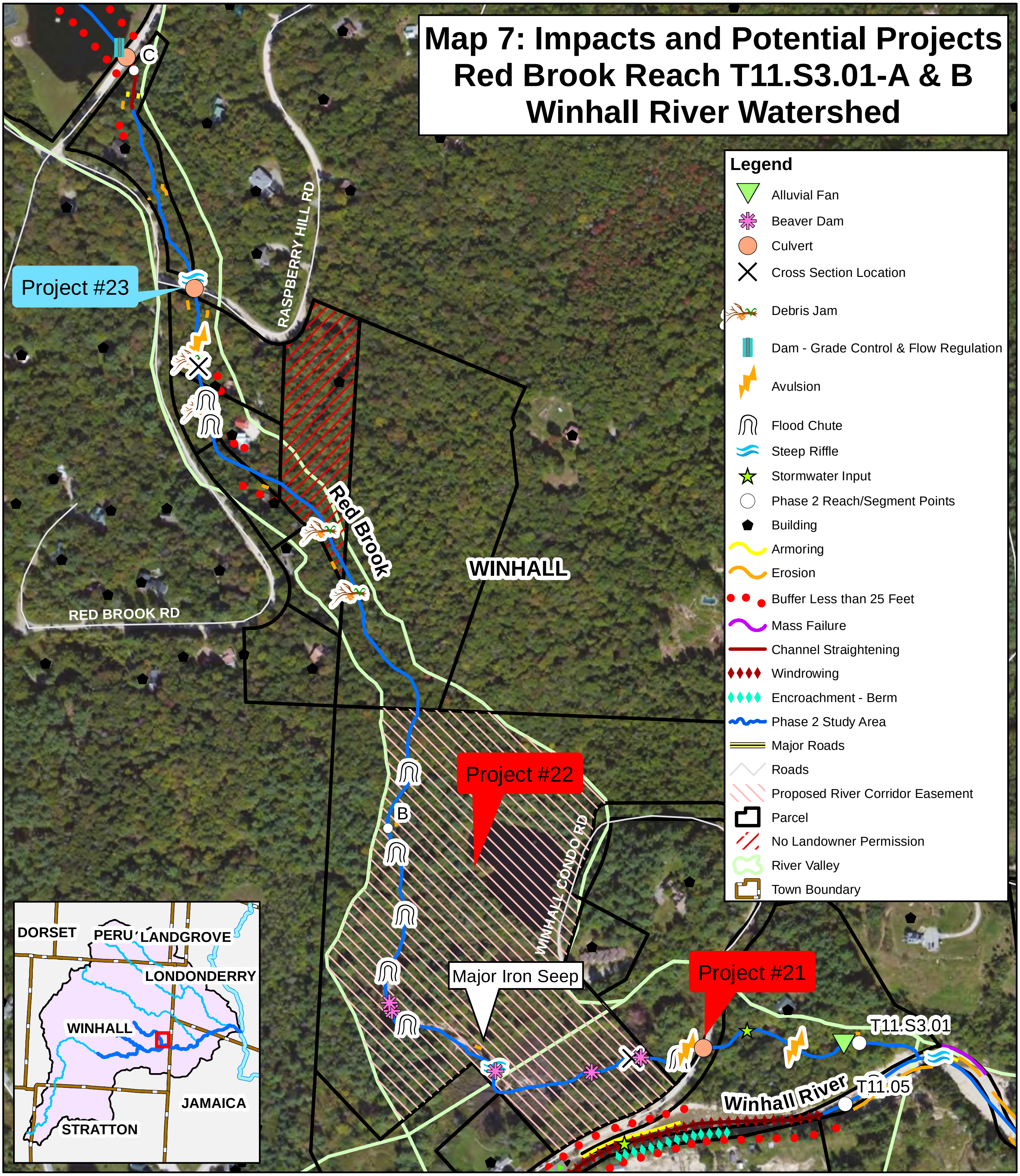
Table 6. Winhall River Main Stem Map 6: T11.08 Site Level Opportunities for Restoration and Protection Winhall, Vermont						
Project # Segment	**Type of Project**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Benefits**	**Potential Partners/ Programs**
Project #19 T11.08-A & B	Passive Restoration	This section of the Winhall River is undergoing extreme planform adjustment via several channel avulsions and flood chutes. It is braided and will continue to adjust into the future. Riparian buffers are well forested and habitat conditions are good.	**River Corridor Easement**	High Priority (River is actively adjusting, has good floodplain access, and landowner interest)	Improved habitat and water quality; attenuation of floodwaters and sediment	Landowners, WRC, VANR, CRWC, Town of Winhall RCE
Project #20 T11.08-B	Active Restoration	The extension of Kendall Farm Road has caused the river to lose access to once-adjacent wetlands. A historic berm along the road has furthered this segment's loss of floodplain access. Access to this wetland could provide important flood water & sediment attenuation.	**Investigate Berm Removal & Lowering Road**	Low Priority	Improved geomorphic stability, habitat, and water quality; attenuation of floodwaters and sediment	Green Mountain National Forest, WRC, VANR, CRWC, Town of Winhall

Photos of Proposed Project Locations – Map 6

Project #19 – River Corridor Easement



Project #20 – Investigate Berm Removal & Lowering Road



Background is World Imagery

Projects:

21. Replace Culvert
22. River Corridor Easement & Investigate Iron Seep
23. Replace Culvert

Project Priority:

- Low
- Moderate
- High

N

0 125 250 500 Feet

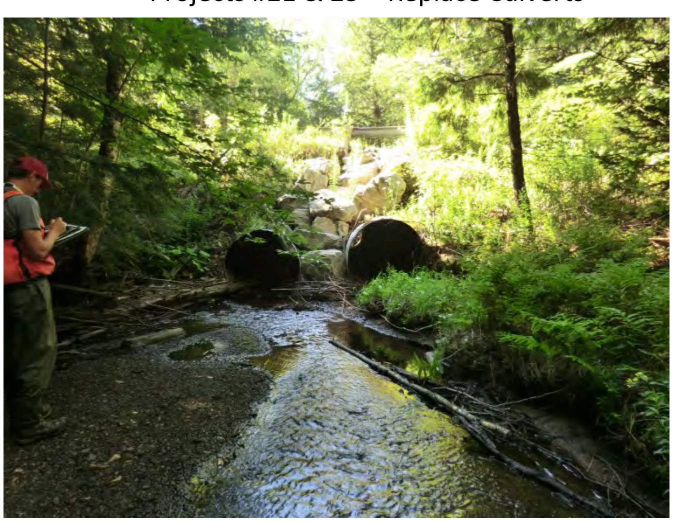
1 inch = 400 feet

Bear Creek Environmental

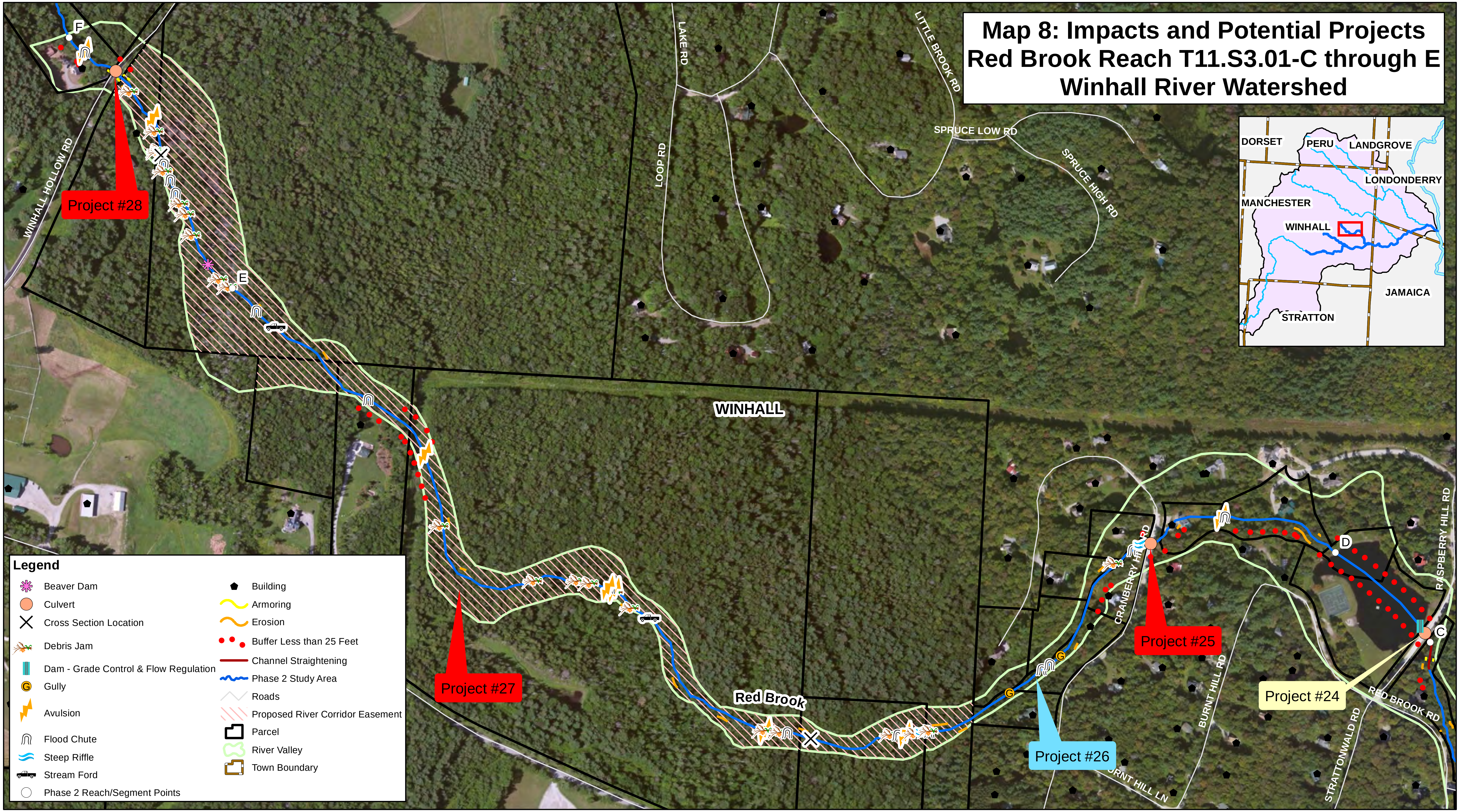
Table 7. Red Brook Map 7: T11.S3.01-A & B Site Level Opportunities for Restoration and Protection Winhall, Vermont						
Project # Segment	**Type of Project**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Benefits**	**Potential Partners/ Programs**
Project #21 T11.S3.01-A	Active Restoration	The culvert under River Rd is severely undersized & has major deposition above & scour below. Channel avulsion is present just upstream of the structure & may put it at risk of undermining during high flows.	**Replace Culvert**	High Priority	Improved geomorphic stability and habitat; improved AOP	Landowners, WRC, VANR, CRWC, Town of Winhall
Project #22 T11.S3.01-A & B	Passive & Active Restoration	This portion of the brook is a beaver meadow and wetland complex. The channel is actively adjusting planform. There is a large iron seep present on the north bank of the brook, the source of which is unknown.	**River Corridor Easement & Investigate Iron Seep**	High Priority	Improved habitat and water quality; attenuation of floodwaters and sediment	Landowners, VANR, CRWC, WRC RCE
Project #23 T11.S3.01-B	Active Restoration	The culvert at Raspberry Hill Road is undersized with major aggradation above and scour below. One of two pipes has a rusted out bottom.	**Replace Culvert**	Moderate Priority	Improved geomorphic stability and habitat	Landowners, WRC, VANR, CRWC, Town of Winhall

Photos of Proposed Project Locations – Map 7

Projects #21 & 23 – Replace Culverts



Project #22 – River Corridor Easement & Investigate Iron Seep



Projects:

24. Investigate Dam & Culvert Replacement
25. Culvert Replacement
26. Investigate/ Remediate Gullies
27. River Corridor Easement
28. Culvert Replacement

Project Priority:

- Low
- Moderate
- High

N

0 400 800 1,600 Feet

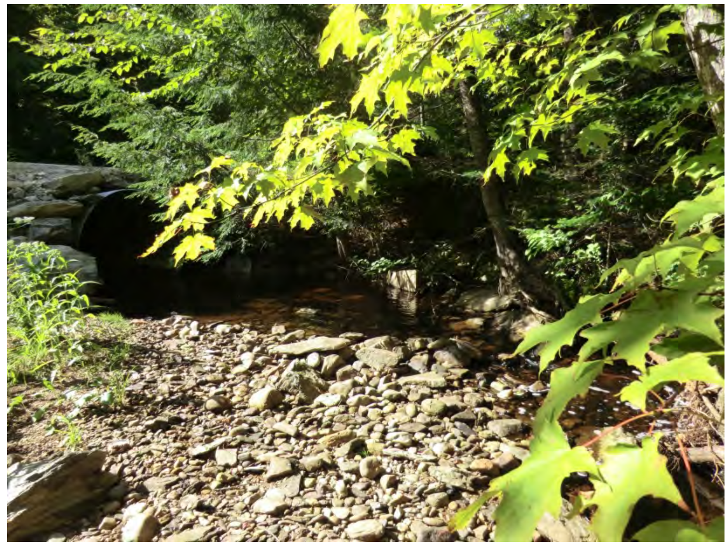
1 inch = 400 feet

Bear Creek Environmental

Table 8. Red Brook Map 8: T11.S3.01-C through E Site Level Opportunities for Restoration and Protection Winhall, Vermont						
Project # Segment	**Type of Project**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Benefits**	**Potential Partners/ Programs**
Project #24 T11.S3.01-C	Active Restoration	The dam outlet and culvert at the on-stream pond on Red Brook are creating a barrier for aquatic organism passage.	**Alternatives Analysis of Dam Removal**	Low Priority	Improved habitat, geomorphic stability, and AOP	Landowners, WRC, VANR, CRWC, Town of Winhall
Project #25 T11.S3.01-D	Active Restoration	The culvert under Cranberry Hill Road is undersized and was likely overtopped during Irene.	**Culvert Replacement**	High Priority	Improved geomorphic stability, habitat, and AOP	Landowners, WRC, VANR, CRWC, Town of Winhall
Project #26 T11.S3.01-D	Active Restoration	There are two gullies coming off of the valley walls from landowner's lawns and contributing sediment to the brook.	**Investigate/ Remediate Gullies**	Moderate Priority	Improved geomorphic stability, water quality, and habitat	Landowners, WRC, VANR, CRWC
Project #27 T11.S3.01-D & E	Passive Restoration	In this area, the brook is undergoing major planform adjustment. It has good floodplain access and well forested buffers.	**River Corridor Easement**	High Priority	Improved water quality and habitat; attenuation of floodwaters and sediment	Landowners, WRC, VANR, CRWC RCE
Project #28 T11.S3.01-E	Active Restoration	The culvert under Winhall Hollow Road is undersized and is not well aligned with the channel. It is also slightly perched (0.1 feet).	**Culvert Replacement**	High Priority	Improved geomorphic stability, habitat, and AOP	Landowners, WRC, VANR, CRWC, Town of Winhall

Photos of Proposed Project Locations – Map 8

Project #24 – Investigate Dam & Culvert Replacement

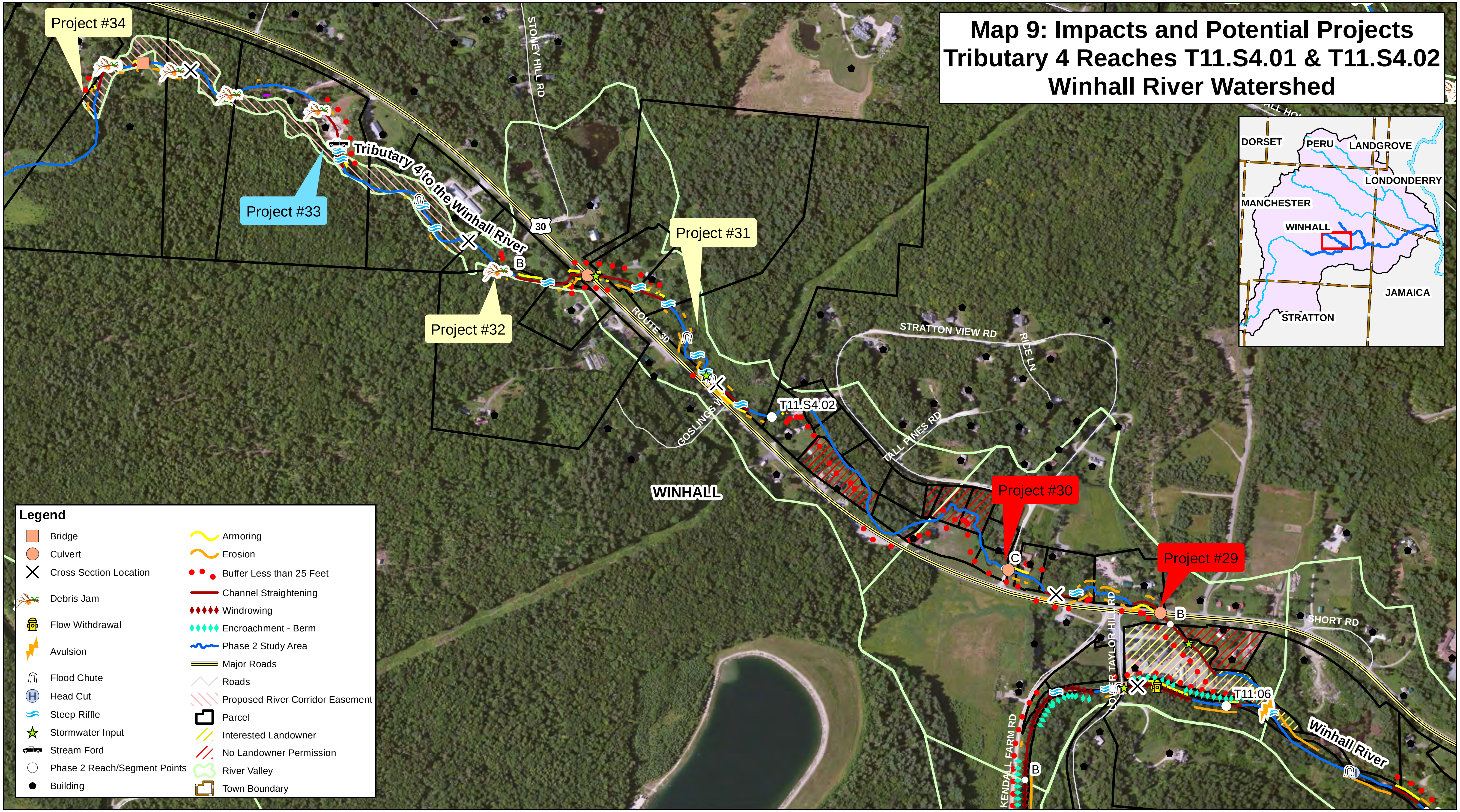


Project #25 –Culvert Replacement

Project #26 – Investigate/ Remediate Gullies

Project #27 – River Corridor Easement

Project #28 –Culvert Replacement



Background is World Imagery

Projects:

29. Culvert Replacement
30. Culvert Replacement
31. Streamside Plantings
32. Remove Destroyed Footbridge
33. River Corridor Easement
34. Streamside Plantings

Project Priority:

- Low
- Moderate
- High

N

0 500 1,000 2,000 Feet

1 inch = 500 feet

Bear Creek Environmental

Table 9. Tributary 4 to the Winhall River Map 8: T11.S4.01 & T11.S4.02 Site Level Opportunities for Restoration and Protection Winhall, Vermont						
Project # Segment	**Type of Project**	**Site Description Including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility and Priority**	**Benefits**	**Potential Partners/ Programs**
Project #29 T11.S4.01-B	Active Restoration	The culvert under VT Rt. 30 is undersized, rusting out, and likely poses a barrier to AOP.	**Culvert Replacement**	High Priority	Improved geomorphic stability, AOP, and habitat	Landowners, WRC, VANR, CRWC, VTrans, Town of Winhall
Project #30 T11.S4.01-B	Active Restoration	The culvert under Stratton View Road is undersized and rusting.	**Culvert Replacement**	High Priority	Improved geomorphic stability, AOP, and habitat	Landowners, WRC, VANR, CRWC, Town of Winhall
Project #31 T11.S4.01-C & T11.S4.02-A	Passive Restoration	Riparian buffer is poor in more than one location in this area.	**Streamside Plantings**	Low Priority (No landowner permission)	Improved water quality and habitat	Landowners, WRC, VANR, CRWC TFS
Project #32 T11.S4.02-B	Active Restoration	An old footbridge has collapsed and fallen into the river, creating a large debris jam.	**Remove Destroyed Footbridge**	Low Priority	Improved geomorphic stability and habitat	Landowners, WRC, VANR, CRWC
Project #33 T11.S4.02-B	Passive Restoration	This area of the stream has good floodplain access and well forested buffers. It is undergoing planform adjustment.	**River Corridor Easement**	Moderate Priority	Improved geomorphic stability, water quality, and habitat; attenuation of floodwaters and sediment	Landowners, WRC, VANR, CRWC RCE
Project #34 T11.S4.02-B	Passive Restoration	Riparian buffer is poor on west bank due to lawn.	**Streamside Plantings**	Low Priority (Small planting area)	Improved water quality and habitat	Landowners, WRC, VANR, CRWC TFS

Photos of Proposed Project Locations – Map 9


Project #29 – Culvert Replacement


Project #30 – Culvert Replacement


Project #31 – Streamside Plantings


Project #32 – Remove Destroyed Footbridge


Project #33 – River Corridor Easement


Project #34 – Streamside Plantings