

# Upper Mad River Corridor Plan

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Prepared by:

Evan P. Fitzgerald, Principal  
Fitzgerald Environmental Associates, LLC.



and

Lisa C. Godfrey, LLC.  
Consulting Geomorphologist

Prepared for:

Friends of the Mad River  
Waitsfield, Vermont

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## 1.0 Executive Summary

The Mad River encompasses multiple, diverse natural communities from the headwaters in Warren to its confluence with the Winooski River, and represents natural resource of extraordinary value to the inhabitants of its watershed. The river, with its many recreational uses such as fishing and boating, and its supply of clean water for drinking and agriculture, provides tremendous natural capital and ecosystem services to residents within the valley and beyond. In addition, its value as a cultural and historical resource provides a common thread among valley residents, as noted by Brian Shupe on the Friends of the Mad River website:

*Encompassing a diverse community of farms, forests and villages, the entire Mad River Valley serves as the ultimate expression of this River's remarkable character. The Mad River's role in shaping the Valley's landscape is obvious. Equally profound is its subtle influence on the spirit and emotions of the Valley's inhabitants. This influence is reflected in the history of our community and can be heard in the voices of our neighbors.*

Like many alluvial rivers in Vermont, the Mad River has an exceptional flood history dating back to the first settlements in its corridor in the late 1700's. Since the settling of the valley over 220 years ago, the river has swept away bridges, mills, and homes during large and infrequent flood events. The large floods of this century, including the 1927 flood, those of the 1970's, and the recent event in 1998, have served to remind valley residents of its volatile nature. Recent floods on the Mad River have brought to light the legacy of previous land uses and channel management activities. Historical deforestation of hillslopes in the watershed delivered large amounts of sediment to the river channel in the 18<sup>th</sup> and 19<sup>th</sup> centuries. Channel management (e.g., straightening, dredging, and bank armoring) during the middle part of the 20<sup>th</sup> century increased the channel's flood flow capacity and decreased its access to floodplain areas, leading to the present-day river conditions with degraded biotic habitat and increased erosion hazards.

The Friends of the Mad River (FMR) recognize that the protection and restoration of this great resource not only benefits the ecological health of the river and surrounding watershed, but also reduces the extent to which the river poses hazards to valley residents. With this in mind, FMR sought funding from the Vermont Agency of Natural Resources (VTANR) to develop a River Corridor Plan (RCP) for the Mad River in the towns of Waitsfield and Warren. The goal of the RCP is to facilitate restoration and protection activities with the following objectives: (a) to improve the long-term stability of the Mad River; (b) to reduce sediment and nutrient pollution loading to the Mad River and therefore Lake Champlain; (c) to over time reduce landowner vulnerability and infrastructure damage from flood and erosion hazards.

The RCP was developed using previously collected data (Field, 2007) as a basis for the identification of watershed stressors and potential restoration projects to mitigate those stressors. Phase 1 Stream Geomorphic Assessments (SGA) were completed by dividing

the streams in the Mad River watershed into many different “reaches” of similar setting, and collecting remotely-sensed data. Phase 2 assessments involving more detailed reach-specific field observations were completed on a total of 21 reaches during 2006. The RCP encompasses 10 reaches on the Mad River in the towns of Waitsfield and Warren. The following is a summary of findings of the stressor and project identification effort:

- With the exception of three reaches found in narrow, bedrock controlled settings, the Mad River has been historically altered, and in many areas, “locked in place” through channel straightening and dredging, application of bank armoring, and removal of stream bank vegetation.
- All of the alluvial reaches of the study area are going through a predictable pattern of aggradation and lateral adjustments (stage III or IV of channel evolution). These adjustments have resulted from the legacy effect of sediments transported to the channel from hillslope deforestation associated with human settlement of the valley, *and* modern-day channel management practices (i.e., straightening and armoring) that were temporarily effective at reducing property damage caused by flooding and bank erosion.
- Review of historic aerial photography and topography mapping indicates that the Mad River channel occupied a much wider corridor prior to the large floods that occurred in 1927 and 1938. This is especially true in the wide alluvial valleys found in Reaches M11, M12, M13, and M15. In addition, prior to the flood events of the 1970’s, two large meanders existed in Reach M11, which have since been abandoned. Channel management practices likely implemented following these events resulted in a straightened channel at these two sites.
- The above-described channel management practices have resulted in a simplified channel form that is effective at transporting flood flows, but provides only limited habitat for aquatic biota. Six of the 9 study reaches were assessed as having “fair” habitat, while only 3 reaches were assessed as “good”.
- The results of a structure analysis indicate that only 15 percent of the assessed bridges and culverts (on the 21 previously assessed reaches) are adequately sized to accommodate stream equilibrium conditions. Many of these structures are causing additional sediment loading through bank erosion, and are in need of replacement.
- The stressor identification and sensitivity analysis revealed that historic and current alterations to the hydrologic and sediment regimes have resulted in many river miles being converted to effective transporters of sediment to downstream areas, rather than depositional areas expected under reference conditions. The supply of sediment to the valley reaches is further exacerbated by excess stormwater runoff caused by increased impervious cover in the tributary watersheds, resulting in channel enlargement and failure of side slopes. In

addition, historic wetland loss has reduced floodwater attenuation at the watershed scale.

- Watershed-level approaches to restoration of dynamic equilibrium conditions were evaluated, including an analysis of the Fluvial Erosion Hazard corridor for Waitsfield, the above-described analysis of structure data, and qualitative assessments of alterations to the hydrologic and sediment regimes. Four watershed-level approaches were prioritized for action based on their compatibility with a corridor approach to restoration and immediacy of possible action.
- Site level approaches to restoration of dynamic equilibrium conditions were evaluated in detail at the reach-scale using a step-wise procedure developed by VTANR. This resulted in the identification of 23 unique projects for the study area. Ten projects that do not require further study to pursue (i.e., passive approach), and 6 projects requiring further study (i.e., active restoration approach) were prioritized for implementation for FMR and its partnering organizations.

In addition to identifying stressors to stream stability and potential restoration projects, an analysis of Fluvial Erosion Hazard (FEH) risks was completed for the Town of Waitsfield. An FEH corridor was created for Waitsfield by the Vermont Department of Conservation River Management Program (RMP) using their SGAT program. The FEH analysis included calculations of land area, land use, and current developments within the FEH corridor that would be at risk from erosion as well as implications of current town zoning within the corridor area. Results of the FEH analysis will be shared with the Waitsfield Planning Commission.

The RCP project also included an extensive landowner outreach effort. Riparian landowners were identified and contacted in an effort to share information from the SGA projects as well as to learn landowner observations of the river. The outreach effort continues with public meetings planned for 2008.

## 2.0 Introduction

### 2.1 Project Overview

Friends of the Mad River (FMR) have received funding from the Vermont Department of Environmental Conservation (DEC) to develop a River Corridor Plan (RCP). The primary purpose of the River Corridor Management Plan is to reduce sediment and nutrient pollution loading into the Mad River and ultimately Lake Champlain, reduce property loss and infrastructure damage from flooding and erosion, and improve aquatic habitat. The current planning effort includes approximately 12 miles of the Mad River from the Lincoln Brook confluence upstream of Warren Village to about 3 miles south of Waitsfield Village and several tributaries.

FMR hired consultants to complete geomorphic (or physical) assessments in this area using standard protocols developed by the DEC. Phase 1 Stream Geomorphic Assessments (SGA) were completed, dividing the streams in the Mad River watershed into many different “reaches” of similar setting. For example, the main stem of the Mad River has 23 separate reaches from the Winooski River up through the town of Warren. Phase 2 assessments have been completed on a total of 21 of those reaches. Field Geology Services completed the Phase 1 and 2 SGAs in 2006 (Field, 2007). The consultants were also asked to evaluate the data to determine the causes of channel instability.

FMR hired Fitzgerald Environmental Associates, LLC and Lisa C Godfrey, LLC as consulting geomorphologists to complete the corridor planning tasks. Tasks involved in compiling the Mad River Corridor Plan for Waitsfield and Warren included: 1) completion of Bridge and Culvert Assessments for structures not yet assessed and analysis of all structure data; 2) identification of riparian landowners and outreach; 3) analysis of the Fluvial Erosion Hazard zone in the Town of Waitsfield; and 4) identification and prioritization of potential stream restoration projects.

### 2.1 Corridor Planning Goals and Objectives

Stream restoration and protection projects are most successful when they are planned with consideration for the reach and watershed stressors and physical processes causing channel instability and adjustments. The VTANR River Corridor Planning Guide provides a science-based method for identifying stressors to channel stability and restoration projects to address them at the appropriate scale (VTDEC, 2007).

The goal of the River Corridor Plan (RCP) was to develop projects with the following objectives: (a) to improve the long-term stability of the Mad River; (b) to reduce sediment and nutrient pollution loading of the Mad River and therefore Lake Champlain; (c) to reduce over time landowner vulnerability and infrastructure damage from flood hazards. FMR intends to use this plan for project implementation and stakeholder outreach to work towards achieving long-term stream channel stability.

The overall goal of the River Management Program (RMP) 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,” (VTANR, 2007) achieved through:

- Fluvial erosion hazard mitigation
- Sediment and nutrient load reduction, and
- Aquatic and riparian protection and restoration

## 2.2 Stream Corridor Planning Tasks

### 2.2.1 Data Collection and Analysis

#### **Bridge & Culvert Data**

Bridge and Culvert Assessments were completed for structures on all reaches with Phase 2 data. This included reaches M11-M19 on the Mad River mainstem, Clay Brook, Rice Brook, and Pine Brook. The RMP Bridge and Culvert Assessment Protocols (VTDEC, 2006) were used to complete the assessments and data entered into the DMS. Structures were evaluated based on problems noted during the assessments and according to RMP recommendations.

### 2.2.2 Landowner Identification and Outreach

Landowners along the study area were identified using the parcel information from the towns of Waitsfield and Warren overlaid on orthophoto maps with the stream corridor. A letter was sent to high priority landowners describing the Corridor Planning process and inviting them to participate. Letters were followed with phone calls to individual landowners to schedule meetings between landowners, the consultants, and FMR when available. Meetings were held with interested landowners where information was shared about the project and stream assessment data and landowners were asked to share their knowledge of the stream over time. Packets of information including a map, reach condition details, and ANR publications were prepared for each landowner and discussed at the meetings. Information about the river gained from these meetings was included in this Plan.

### 2.2.3 FEH Analysis for Waitsfield

A separate component of the corridor planning effort involved the analysis of the Fluvial Erosion Hazard (FEH) zone of the Mad River within the project area. Using Phase 1 data previously developed by Field Geology Services (Field, 2007), Kari Dolan of the DEC developed an FEH corridor following the DEC FEH approach (VTDEC, 2007). The FEH corridor is determined by the inherent sensitivity of the reach to adjustments (i.e., lateral migration) and the current condition of reach stability as determined through Phase 2 field surveys. The corridor can be used by municipalities to develop protection strategies that will reduce property loss and infrastructure damage from flooding and long-term bank erosion.

Using the FEH corridor developed by DEC, we analyzed the implications of an FEH Overlay District within the Town of Waitsfield. The purpose of this analysis was to provide the Town, FMR and DEC with a summary of the built and natural capital within the corridor, and highlight opportunities for corridor protection. The analysis also assessed the Town's planning and zoning in the context of development patterns and other protected parcels within the corridor (e.g., town-owned parcels and conserved lands). Finally, the analysis compared the FEH overlay with the FEMA mapping for the 100-year floodplain and the Waitsfield stream setback ordinance for an example river reach. The complete results of the FEH analysis are provided in Appendix 1.

## 2.2.4 Potential Project and Stressor Identification

A stressor identification analysis was completed following the RMP approach (VTANR, 2007). This approach uses Phase 1 and 2 data to develop watershed and reach-scale mapping of natural and built features that influence river stability. A step-wise procedure (VTANR, 2007) has been developed by RMP to identify projects that would be compatible with geomorphic adjustments and managing the stream toward equilibrium conditions. We used the step-wise procedure and the Planning Guide to identify potential stream restoration projects compatible with RMP goals. Please refer to the RMP Corridor Planning Guide for more detailed information at:

[http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv\\_restoration.htm](http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv_restoration.htm)

Types of projects include:

- Protecting river corridors from channel management and future encroachment,
- Planting stream buffers with woody vegetation,
- Stabilizing stream banks if it will achieve the stated goals,
- Arresting channel erosion such as head cuts and nick points,
- Removing berms and other barriers to geomorphic processes,
- Removing or replacing structures following RMP and F&W recommendations,
- Restoring incised reaches through "passive" or "active" measures, and
- Restoring aggraded reaches.

Corridor protection and conservation is an effective tool for stream restoration. Protecting stream corridors helps avoid future conflicts between streams and human investments while allowing streams room to establish their desired dynamic equilibrium. Vegetated buffers, whether planted or allowed to reestablish, protect water quality, stabilize banks, and provide riparian habitat. Protecting the river corridor and allowing the stream to recreate its own equilibrium geometry can be more cost effective in the long-term than attempting to impose a calculated stream geometry in the short-term.

Planting stream buffers helps protect water quality, stabilize banks, and provide riparian habitat. Riparian or stream bank vegetation is important to stream stability because of its ability to slow flood flows and its quality as a binder of stream bank soils. While thick bushy riparian vegetation slows flood flows above ground its root systems help bind the soil below ground making it more resistant to the erosive energy of the flood flows.

Stabilizing eroding stream channels with hard armoring such as rock riprap or log revetments can be occasionally useful as a temporary measure while woody vegetation is established. The extent to which this approach is successful depends on the natural characteristics of the channel and the degree of channel instability. This method can have negative upstream and downstream effects, mainly increased erosion rates, which should be considered.

Undersized crossing structures (bridges and culverts) can aggravate channel instability by preventing the steady, uninterrupted passage of both channel flow (water) and bed material (sands and gravels). An interruption of flow and bed materials causes changes in the erosive energy of the flow leading to channel erosion and possibly crossing structure instability. Replacing undersized crossing structures with structures that allow for flow and sediment passage is highly successful in restoring channel stability.

Encouraging land uses that are compatible with healthy well-functioning riparian and floodplain areas can be an effective tool for restoring streams. Floodplains perform the critical function of storing floodwaters during times of extreme flow events. By providing a storage area for floodwaters floodplains provide for the dispersion of the tremendous erosive energy of flood flows, energy that is otherwise spent eroding the bed and banks of the river channel. Any development within the floodplain inherently diminishes its ability to store flood flows and is therefore ideally avoided.

Avoiding development in floodplains also reduces the need to “lock the river in place”. The meandering nature of rivers is driven by the ever-present erosive energy of the flow. Healthy rivers, with vigorous riparian vegetation and well functioning floodplain display low rates of erosion and this erosion is a necessary natural process which allows the river to distribute energy evenly throughout the channel over time. Maintaining land uses along the river corridor that do not bring about the need to “lock the river in place” allows natural processes to minimize erosion rates.

Analyzing the desired time frame for results can help determine if a “passive” or “hands-off” approach to channel restoration is feasible, or if a more “active” approach for more immediate results is desired. Examples of “active” restoration projects include constructed meander bends, constructed or lowered floodplain areas, bank stabilization measures, constructed grade controls, or constructed habitat structures. The chosen approaches for restoring a given stretch of river will depend on the characteristics of the river and the nature of the instability demonstrated.

### 3.0 Background

The following information serves as a brief introduction to the scientific background of the study area with respect to its physical forms, land use history, hydrology, and ecosystems. Further, more detailed information can be found in the references cited throughout this section.

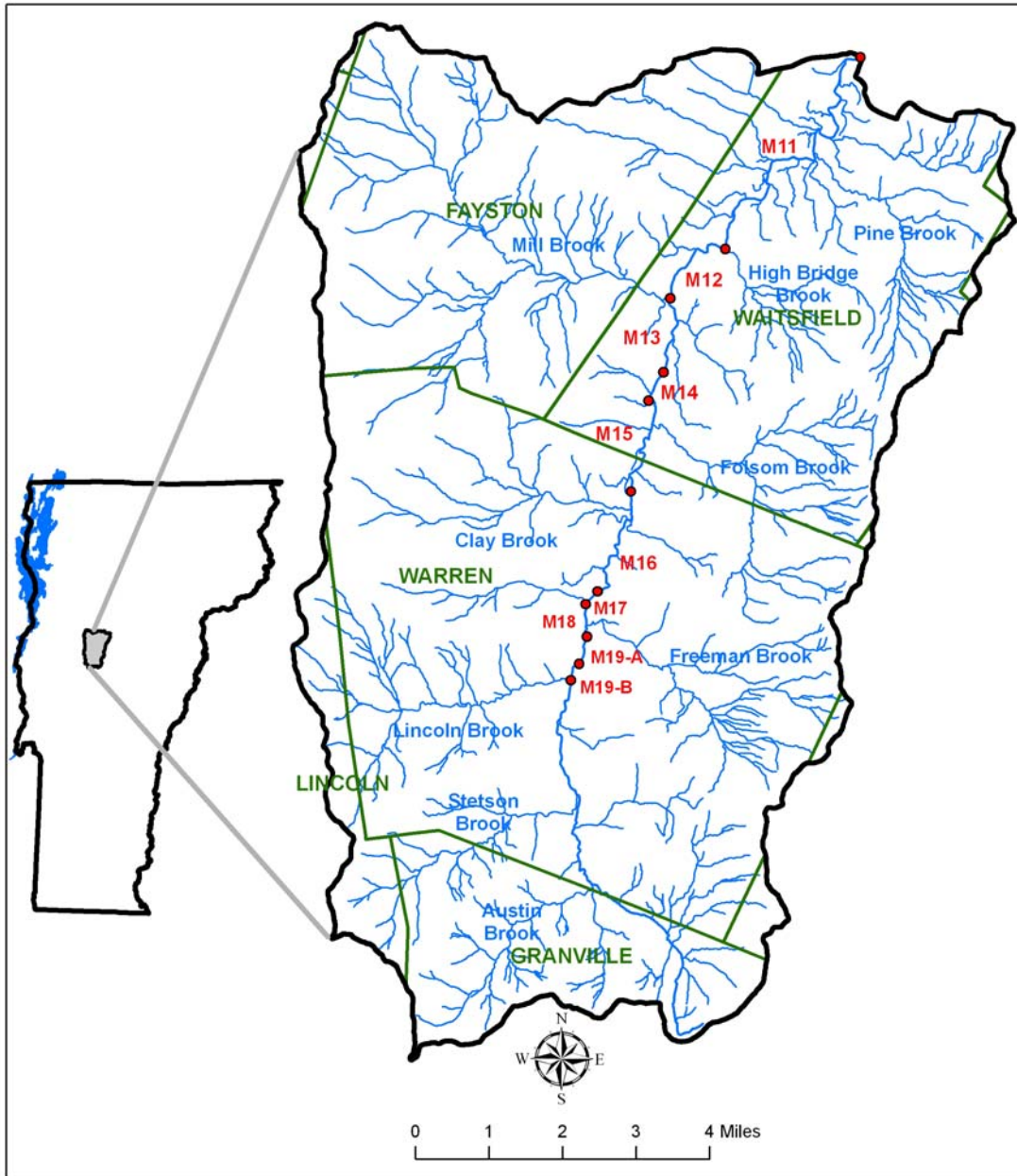


Figure 3.1. Upper Mad River watershed, town boundaries, and study reaches.

### 3.1 Geographic Setting and Land Use

The Mad River drains a 144 square mile watershed spanning the towns of Duxbury, Fayston, Moretown, Waitsfield, Warren, and Granville. The Mad River is a tributary to the Winooski River, eventually draining to Lake Champlain. The Upper Mad River watershed, which was the study area for the RCP, encompasses the towns of Waitsfield, Fayston, Warren, Granville, and Lincoln (Figure 3.1). This area has a wide range of topographic relief, from an elevation of 650 feet in northern Waitsfield to over 4,000 feet on Lincoln Peak.

Prior to the forest clearing associated with human settlement, logging and farming, the watershed would have been a mixture of deciduous forest on the valley floors, coniferous forest along the mountain spines, and a mixture of both along the slopes. Deforestation and grazing, largely from sheep farms, likely left over 90 percent of the watershed devoid of trees at one time or another (Albers, 1998). This landscape change had a tremendous impact on waterways like the Mad River. Exposed soils on steep slopes eroded and was carried to the valley floors where it aggraded on river bottoms; a legacy that still influences the way Vermont's rivers are managed today.

As Vermont's farmers began to move to the Midwest in search of more productive farmland in the mid to late 1800's, the deciduous forests along the mountain slopes began to recover (Albers, 1998). Throughout the early and mid 1900's, as more family farms found on marginal lands were given up, the forests continued to recover. Today, approximately 80 percent of the Upper Mad River watershed is covered by forest. With the increasing tourism sector in the state, and the need for hardwood lumber for second-homes, forestry has replaced agriculture in the rural hill slopes of the valley. Only 11 percent of the watershed is occupied by agricultural lands today, much of this along the Mad River on the valley floor. Residential land use occupies nearly 4 percent of the watershed, reflecting the expansion of development and second-homes associated with the ski industry.

### 3.2 Geologic Setting

The Mad River watershed is found in the Northern Green Mountain Biophysical Region (Thompson and Sorenson, 2000). The bedrock of this region dates back to the Cambrian and Ordovician time, but was metamorphosed during the geologic events that formed the Taconic Mountains. The metamorphic rocks present in today's Northern Green Mountains include schists, phyllites, gneisses, and quartzites (Field, 2007).

During the Wisconsin glaciation, glaciers a mile in thickness extended across New England, reaching their maximum extents approximately 20,000 years ago. This glacial event left the Northern Green Mountains with a physical imprint that is evident today. In the Mad River watershed, features such as kame terrace deposits (i.e., Lincoln gravel pit) moraines and outwash areas (i.e., Irasville area), and lake sediments represent the dynamic nature with which glaciers shaped the landscape. However, most of the surficial geology of the Mad River watershed is dominated by glacial tills. The resultant soils are

dominated by rocky tills in the sloped areas. On the valley floors, fine sandy loams and silty loams associated with recent alluvium provide good to excellent soils for agriculture.

### 3.3 Geomorphic Setting

The river reaches encompassed in the RCP are found from the northern part of Waitsfield south to the Warren Village Area (Figure 3.1). These reaches were defined as part of the Phase 1 and 2 assessments carried out by Field Geology Services during 2006 (Field, 2007). The drainage area of the study area, measured at Reach M11, is 95.9 square miles.

Reaches M11 through M16 are generally found in a wide alluvial valley dominated by agriculture and, in the vicinity of Irasville and the Waitsfield Village, a mixture of residential and commercial land uses. The gravel and sand soils on the valley floor comprise the alluvium deposited by the migration of the Mad River across this wide valley over thousands of years. Channel slopes range from 0.3 to 0.5 percent across these reaches, and most areas exhibit C-type channel geometry with riffle-pool bedform and gravel-dominated substrates (Table 3.1). The one exception is Reach M14, which, despite its low-gradient channel (0.4 percent slope), is found in a confined valley with B-type channel geometry. Numerous natural grade controls are found throughout the valley where the bedrock protrudes through the alluvium.

**Table 3.1 Upper Mad River Reference Stream Characteristics**

Reach	Watershed	Channel	Channel	Channel	Sinuosity	Valley	Stream	Bedform <sup>†</sup>
	Area (sq. mi.)	Length (mi.)	Slope (%)	Width (ft.)		Type	Type*	
M11	95.9	4.4	0.3	99.7	1.21	Very Broad	C	Riffle-Pool
M12	77.8	1.4	0.3	89.8	1.03	Broad	C	Riffle-Pool
M13	57.3	1.1	0.3	77.1	1.00	Very Broad	C	Riffle-Pool
M14	55.3	0.4	0.4	75.7	1.00	Semi-Confined	B	Riffle-Pool
M15	54.7	1.6	0.5	75.3	1.16	Very Broad	C	Riffle-Pool
M16	45.6	1.8	0.4	68.7	1.17	Broad	C	Riffle-Pool
M17	37.1	0.3	3.0	62	1.02	Narrowly-Confined	B	Step-Pool
M18	34.5	0.5	1.4	59.8	1.05	Narrowly-Confined	B	Riffle-Pool
M19	27.6	0.7	1.3	53.5	1.03	Narrow	C	Riffle-Pool

\* per Rosgen (1994)

† per Montgomery and Buffington (1997)

Reaches M17 through M19 are found in steeper terrain with narrower valley settings than those areas downstream. Reaches M17 and M18 are located downstream of and within the lower Warren Village area, respectively. Both reaches are found in bedrock-

controlled gorges with narrowly confined valley settings. B-type channel geometry with step-pool and riffle-pool bedform are the reference conditions for these reaches. Reach M19 is located above the Warren Crib Dam through the upper part of the Warren Village. This reach is less confined than M17 and M18, but still has abundant natural grade controls throughout. Under reference conditions we would expect the channel to have C-type geometry with riffle-pool bedform.

### 3.4 Hydrology and Flood History

The USGS has maintained a streamflow gauging station on the lower Mad River since 1928. The station is located north of the Village of Moretown, and records the river stage at 15-minute intervals. A hydrograph of the annual peak streamflow values compiled by Field Geology Services is provided below in Figure 3.2.

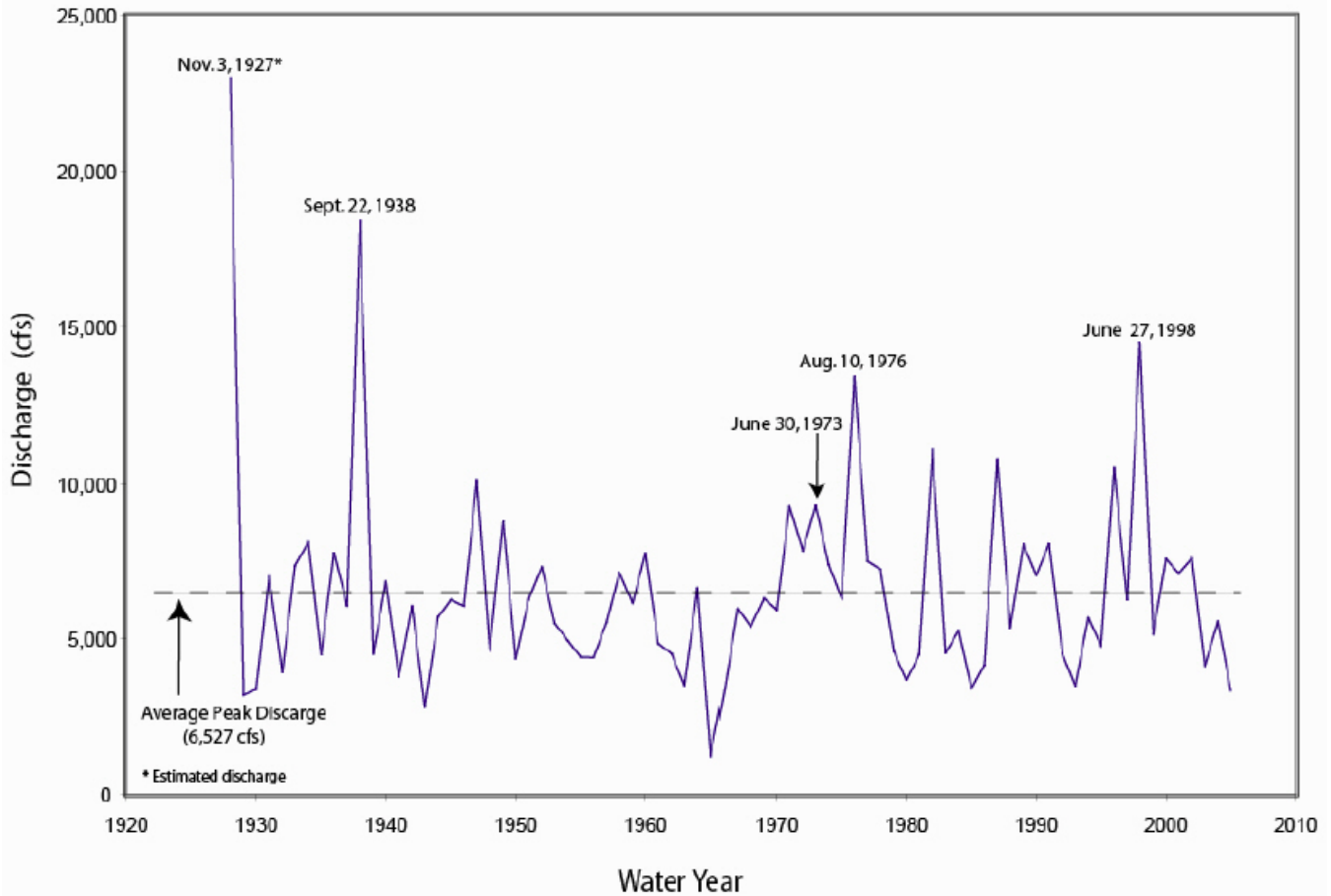


Figure 3.2 Annual Peak Discharges at USGS gauge from 1927 through 2005 (from Field, 2007)

The largest flood measured on the Mad River since the installation of the gauging station was in 1938. During this event, extensive damage occurred throughout the valley, including the destruction of a covered bridge spanning Old Route 100 at the current location of the Lareau Farm (Schenk personal communication, 2007). Prior to that, the

1927 flood, which caused massive damage across northern and central Vermont, had an estimated discharge of 23,000 cubic feet at the gauging station.

In more recent times, two floods in the 1970's also caused extensive damage and led to increased channel management efforts (e.g., bank armoring and channel straightening) on the Mad River. The flood of 1973 caused extensive damage to infrastructure and agricultural lands in the lower watershed, and the recovery effort included bank armoring to arrest the resulting erosion. Three years later, the 1976 flood was of greater magnitude than the 1973 event, and resulted in significantly more areas of bank erosion and channel incision, likely due to the increased containment of flows within the channel following post-1973 bank armoring. The most recent large flood event occurred in 1998, which was the second largest ever recorded at the gauging station. The structural damage caused by this event was concentrated in the headwaters areas around Warren, where numerous homes were destroyed by the flooding of the narrow valley through the Village.

### 3.5 Ecological Setting

An extensive natural heritage survey was recently conducted by Arrowwood Environmental in the Towns of Waitsfield and Fayston (Arrowwood, 2007). The study encompassed only half of the RCP study area, however the general findings are applicable to the entire Mad River watershed. Wetlands, wildlife habitats, and rare communities were all mapped as part of the survey. Within the survey area, nearly 1000 acres of wetlands were identified (versus 200 acres previously mapped through the National Wetlands Inventory), highlighting the importance and lack of accurate mapping of this landcover type in the basin. Two of the four large wetland complexes (wetlands with more than one community type) noted in the area are found along Shepard Brook and an unnamed tributary north of Pine Brook. No rare, threatened, or endangered species were noted in the survey area.

The study noted the high degree of fragmentation and disturbance of floodplain forests within the basin due mainly to historical clearing for agriculture. In addition, because of the recurring natural disturbance typical of these ecosystems (i.e., spring floods), they tend to be more susceptible to invasive species. Japanese knotweed (*Polygonum cuspidatum*) is particularly problematic along the banks and gravel bars of the Mad River, often colonizing new areas via propagules carried downstream during flood events. Two significant tracts of undisturbed floodplain forest were noted in the study area with mature forests and limited invasive species (Arrowwood, 2007), and these areas were recommended for further study as potential conservation sites. Due to the diverse ecological functions and recreation opportunities provided by floodplain forests, their value for conservation is generally very high.

The fishery of the Mad River watershed varies significantly along the channel network, depending on the channel gradient, bed substrate, streambank vegetation, and other factors. In the upper headwaters area above Warren Village, excellent habitat conditions support healthy wild brook trout (*Salvelinus fontinalis*) populations. Below Warren, where the channel gradient decreases and scour and depositional features are better

formed, wild brook and rainbow trout (*Onchorynchus mykiss*) are present, as are brown trout (*Salmo trutta*) in lesser numbers. Below Waitsfield Village, all trout populations diminish in density, likely due to the degradation of physical habitat and elevated water temperatures. A fisheries summary of the watershed, including further information on non-trout species and other stocking and monitoring activities, is included in Appendix 3.

## 4.0 Methods and Data QA/QC

The Vermont River Management Program (RMP) has invested many person-years of effort into developing a state-of-the-art system of stream geomorphic assessment (SGA) protocols. The SGA protocols are intended to be used by resource managers, community watershed groups, municipalities and others to identify how changes to land use affect hydro-geomorphic processes at the landscape and reach scale, and how these changes alter the physical structure and biotic habitat of streams in Vermont. The SGA protocols have become a key tool in the prioritization of restoration projects that will 1) reduce sediment and nutrient loading to downstream receiving waters such as Lake Champlain, 2) reduce the risk of property damage from flooding and erosion, and 3) enhance the quality of instream biotic habitat. The protocols are based on defensible scientific principles and have been tested widely in many watersheds throughout the state. Data collected for the Mad River watershed using the protocols forms the basis for the stressor identification and project prioritization carried out for the RCP. A description of the SGA methods follows, while methods used in the stressor and project identification are found in sections 5.0 and 6.0.

The SGA protocols include three phases (VTDEC, 2006). Phase 1 assessments employ remote sensing techniques, along with limited field verification, to identify background conditions in the watershed. The Phase 1 approach results in watershed-scale data about the landscape (e.g., soils and land cover) and the stream channel (e.g., slope and form), providing a basis for understanding the natural and human-impacted conditions within the watershed. The Phase 2 approach builds upon Phase 1 data through the collection of reach-specific data about the current physical conditions. Characterization of reach conditions utilizes a suite of quantitative (e.g., channel geometry, pebble counts) and qualitative (e.g., pool-riffle habitat) measurements to calculate two indices: Rapid Geomorphic Assessment (RGA) Score and Rapid Habitat Assessment (RHA) score. Using the RGA scores in conjunction with knowledge about the background or “reference” conditions, a sensitivity rating is developed to describe the degree to which the channel will adjust to human impacts in the future. Phase 3 surveys involve the collection of detailed, reach-scale survey data for use in project development and monitoring.

Phase 1 and 2 data for the Mad River watershed were collected by Field Geology Services in 2006 and were summarized in a final report submitted to FMR (Field, 2007). The Phase 1 data were collected for the entire Mad River watershed for a total of 116 reaches, including 23 mainstem reaches, 77 reaches on major named tributaries, and 16 reaches on unnamed tributaries. During the 2006 field season, 19 selected reaches were

assessed using the Phase 2 approach, including 10 reaches on the mainstem. All major human impacts and natural features noted during the Phase 2 surveys were indexed in a GIS using the Feature Indexing Tool (FIT; VTDEC, 2006). In addition, a Phase 3 assessment was carried out on Reach M13 to develop options and recommendations for passive and active restoration projects in the upper reach. Details of the assessment and results are found in the final report (Field, 2007), and were considered in the project identification process for the RCP.

RMP staff shared responsibility with Field Geology Services for the Quality Assurance and Control (QA/QC) of the Phase 1 and 2 datasets. The DMS database for Phase 2 reaches was finalized in January, 2007. However, ongoing review of the data by RMP staff and the Project Team in 2007 led to revisions for stream type, RGA score, and sensitivity for reaches M15, M17, and M18. Revisions made by Kari Dolan of RMP are noted in the DMS.

## 5.0 Stressor Identification and Departure Analysis

### 5.1 Hydrologic Regime Stressors

The following description of the hydrologic regime of a watershed, and the general response to watershed-scale land use changes and stressors is included from the most recent version of the VTANR River Corridor Planning Guide (VTANR, 2007).

The hydrologic regime may be defined as the timing, volume, and duration of flow events throughout the year and over time. The hydrologic regime may be influenced by climate, soils, geology, groundwater, watershed land cover, connectivity of the stream, riparian, and floodplain network, and valley and stream morphology. The hydrologic regime, as addressed in this section, is characterized by the input and manipulation of water at the watershed scale and should not be confused with channel and floodplain “hydraulics,” which describes how the energy of flowing water affects reach-scale physical forms and is affected by reach-scale physical modifications (e.g., bridges modify channel and floodplain hydraulics).

When the hydrologic regime has been significantly changed, stream channels will respond by undergoing a series of channel adjustments. Where hydrologic modifications are persistent, the impacted stream will adjust morphologically (e.g., enlarging when stormwater peaks are consistently higher) and often result in significant changes in sediment loading and channel adjustments in downstream reaches.

The land cover within Mad River watershed is dominated by natural vegetation following the recovery of forest cover in the mid-1900s. Today, approximately 80 percent of the upper watershed from Moretown to the headwaters in Granville Notch is covered by a mixture of deciduous and coniferous forest (Table 5.1). A moderate amount of agricultural land still occupies the watershed, mostly in the alluvial valley associated with the historic (and current) floodplain.

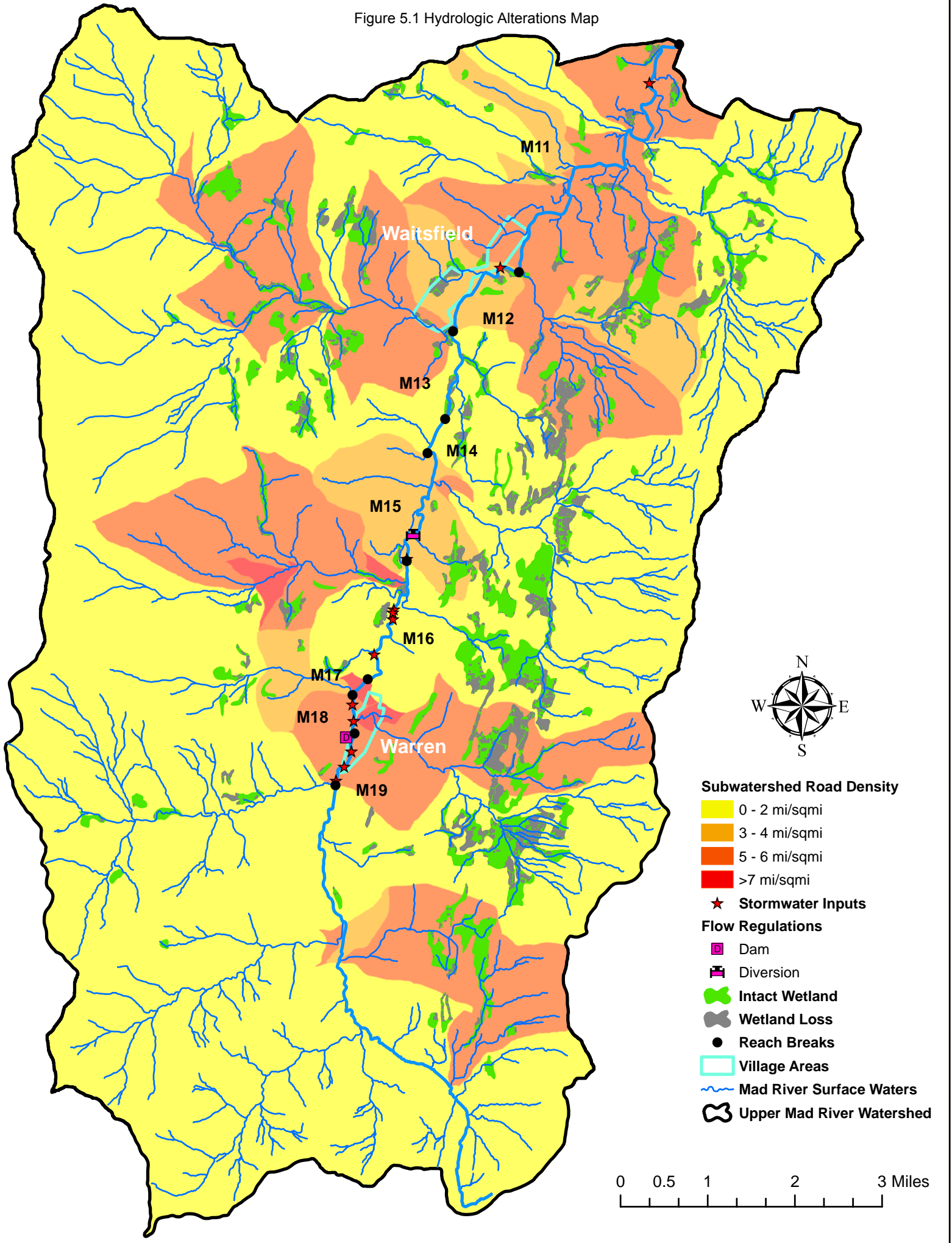
**Table 5.1 Upper Mad River  
Watershed Land Cover<sup>†</sup>**

<b>Land Cover Type</b>	<b>Percent Cover</b>
Forested	80.2%
Agriculture	11.1%
Barren Land	0.1%
Water & Wetland	2.6%
Residential	3.7%
Commercial/Industrial	0.2%
Transportation	2.2%

<sup>†</sup> UVM Spatial Analysis Data (SAL, 2005)

The current day stressors to the hydrologic regime have been mapped using the variables extracted from the Phase 2 field assessments (indexed using FIT), watershed-scale loss of wetlands, and the road density at the subwatershed scale (Figure 5.1). An analysis of the percent impervious cover of the Mad River watershed was completed using methods

Figure 5.1 Hydrologic Alterations Map



specific to Vermont from Fitzgerald (2007). Percent impervious cover and road density at the subwatershed scale in the Mad River watershed was analyzed for strength of correlation. The analysis revealed that in the Mad River watershed road density is positively correlated with percent impervious cover (Figure 5.2), and that a road density of approximately 4 miles per square mile corresponds to 5 percent impervious cover. This level of impervious cover is associated with decline of channel stability and biotic integrity in watersheds in Chittenden County (Fitzgerald, 2007). A total of four classes of road density were mapped in Figure 5.1 to depict the relative impact of the road network and impervious cover on the hydrologic regime. Wetland loss was mapped as the area where hydric soils intersect with urban or agricultural land uses in the watershed, with the remaining areas assumed to be intact wetland (the majority found in forested conditions). This approach allows for the interpretation of loss of hydrologic attenuation of surface runoff at the reach and watershed scale. In addition, stormwater outfalls and flow regulations mapped during the 2006 Phase 2 assessments are included to depict areas of increased stormflows and areas of decreased baseflows, respectively. A summary of the local (reach-scale) and upslope impacts to the hydrologic regime for each mainstem reach based on Figure 5.1 is provided in Table 5.4 at the end of this section.

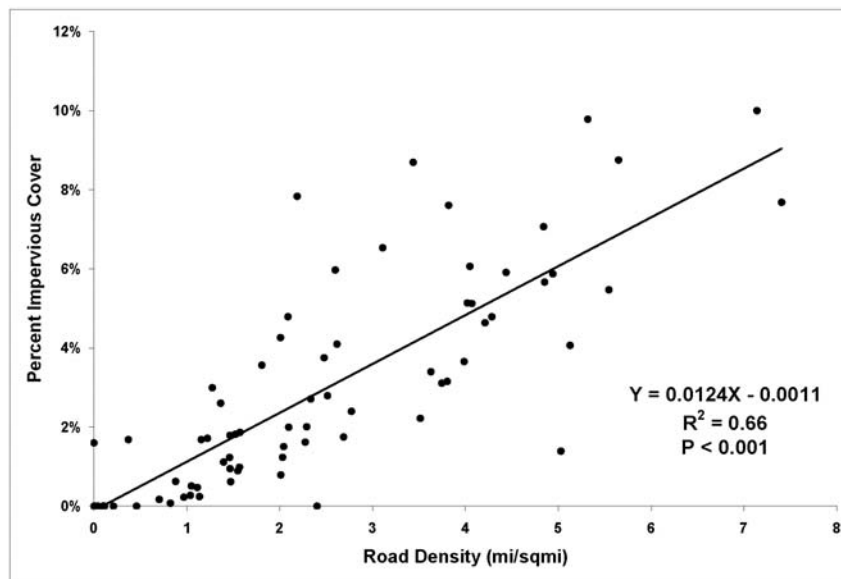


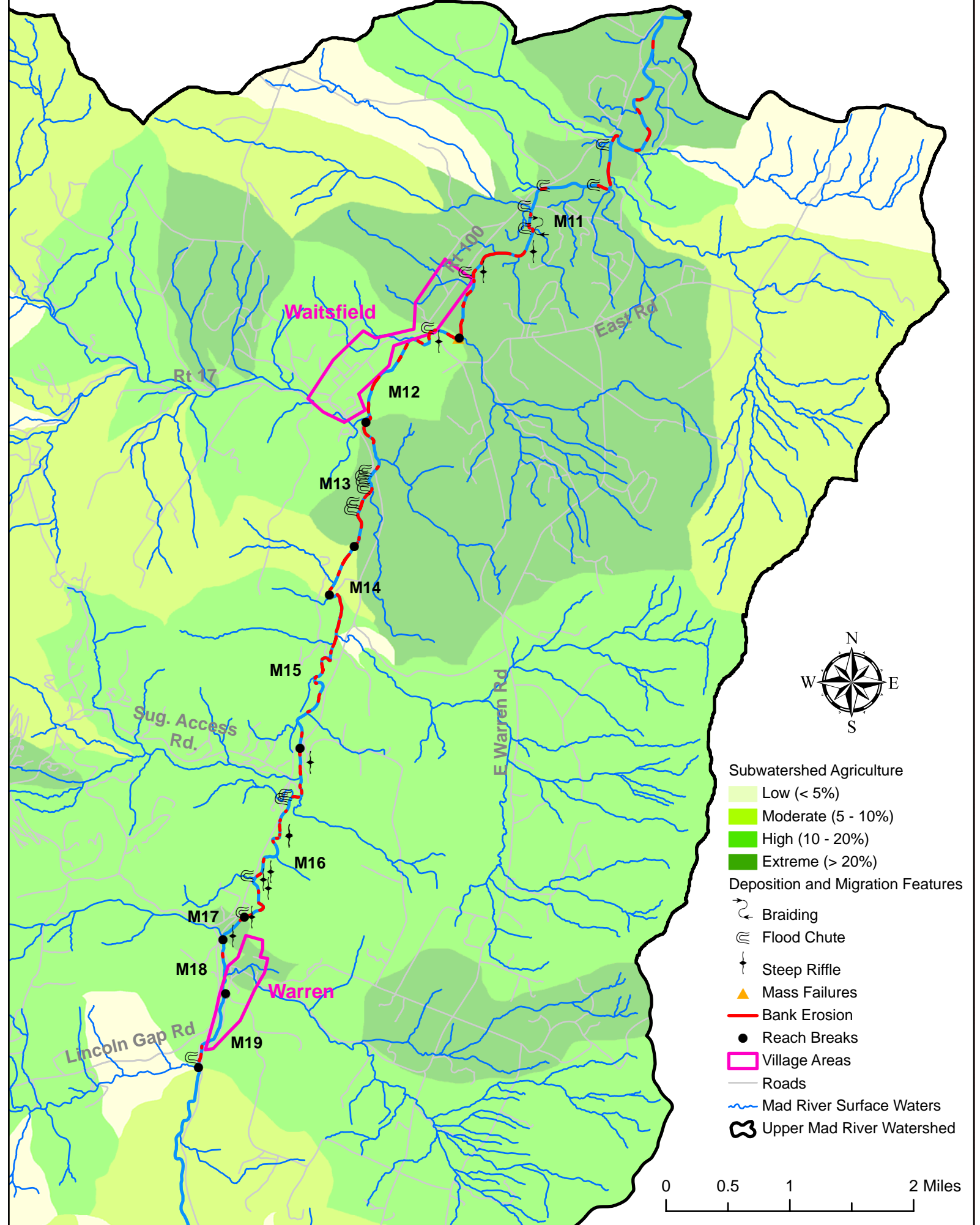
Figure 5.2 Correlation between road density and percent impervious cover for the Upper Mad River Watershed

## 5.2 Sediment Regime Stressors

The following description of the sediment regime of a watershed, and the general response to watershed-scale land use changes and stressors is included from the most recent version of the VTANR River Corridor Planning Guide (VTANR, 2007).

The sediment regime may be defined as the quantity, size, transport, sorting, and distribution of sediments. The sediment regime may be influenced by the proximity of sediment sources, the hydrologic regime, and valley, floodplain and stream morphology. Understanding changes in sediment regime at the reach and watershed scales is critical to the evaluation of stream adjustments and sensitivity. The sediment

Figure 5.3 Sediment Load Indicators Map



- Subwatershed Agriculture**
- Low (< 5%)
  - Moderate (5 - 10%)
  - High (10 - 20%)
  - Extreme (> 20%)
- Deposition and Migration Features**
- Braiding
  - Flood Chute
  - Steep Riffle
  - Mass Failures
  - Bank Erosion
  - Reach Breaks
  - Village Areas
  - Roads
  - Mad River Surface Waters
  - Upper Mad River Watershed

0 0.5 1 2 Miles

erosion and deposition patterns, unique to the equilibrium conditions of a stream reach, create habitat. In all but the most dynamic areas (e.g., alluvial fans), they provide for relatively stable bed forms and bank conditions.

The current day stressors to the sediment regime have been mapped using the variables extracted from the Phase 2 field assessments, and the percent of agriculture within each subwatershed (Figure 5.3). Four classes of percent agriculture were mapped to depict the relative impact of sediment delivery from agricultural lands at the reach and watershed scales. In addition, depositional and migration features mapped during the 2006 Phase 2 assessments are included to depict areas of increased vertical and lateral channel adjustments due to aggradation. Mass failures and bank erosion depict where sediment delivery from the channel boundaries is occurring. A summary of the local and upslope impacts to sediment loading for each mainstem reach based on Figure 5.3 is provided in Table 5.4 at the end of section 5.0.

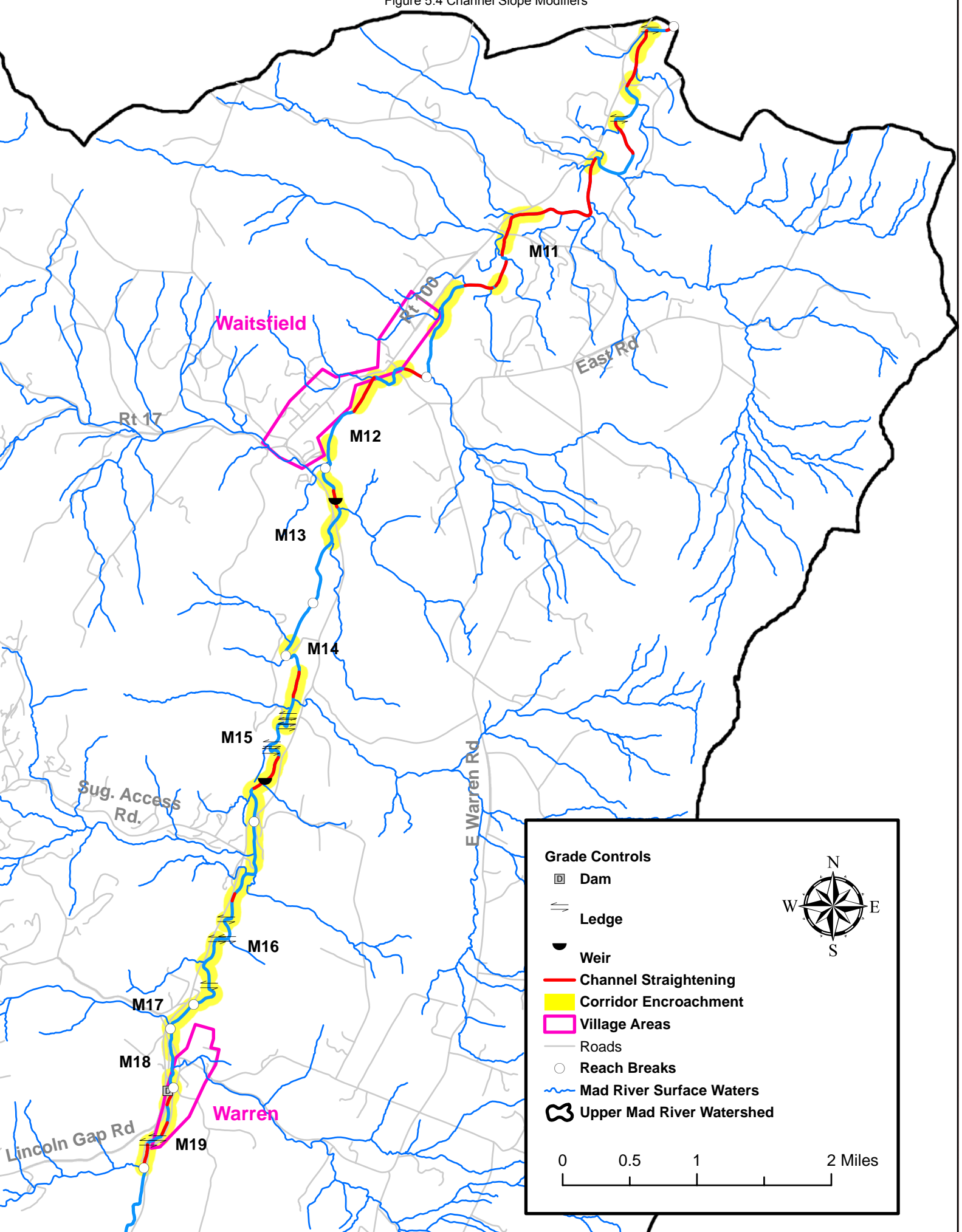
### 5.3 Channel Slope and Depth Modifiers

Many of Vermont's alluvial rivers have been historically manipulated and straightened to maintain an unnaturally steep slope in a state of sediment transport, allowing for a short term sense of security from flooding and subsequent encroachment of infrastructure in the floodplain. Over time, alluvial rivers seek to redevelop a sinuous planform through the deposition of sediments in unconfined valleys. Following flood events when alluvial rivers have become energized enough to transport large amounts of coarse sediment into depositional zones of the watershed, lateral channel migration ensues and further channel straightening is required to protect infrastructure found in the floodplain. Straightening and channelization typically ranges between 25 and 75 percent of the total river channel length in Vermont (VTANR, 2007).

In addition to historic alterations to channel slope in Vermont's alluvial rivers, the lowering of stream beds (e.g., dredging) and the raising of floodplains (e.g., berming) have resulted in an increase in channel depth (VTANR, 2007). Channel depths have typically been increased through the encroachment on the floodplain by roads and railroads and subsequent filling and armoring required to construct and maintain this infrastructure. Increases in impervious cover have also led to the deepening and eventual widening of channels throughout urbanized areas of Vermont (Fitzgerald, 2007).

Alterations to channel slope and depth in the Upper Mad River watershed have been mapped using the variables extracted from the Phase 2 field assessments (Figures 5.4 and 5.5). Channel straightening mapped during the 2006 Phase 1 and 2 assessments are included to depict areas of increased channel slope. Based on the results of the Phase 1 analysis, approximately 15 percent of the channel length for reaches M11 through M19 has been straightened. Corridor encroachment data highlights where roads and development have reduced the floodplain area, typically resulting in increased stream power and channel deepening. Additional data showing the location of natural channel features (e.g., ledges) and channel modifications (e.g., weirs, dredging) depict areas that have a resistance or propensity for channel change, respectively. A summary of the local and upslope impacts to channel depth and slope for each reach is provided in Table 5.4.

Figure 5.4 Channel Slope Modifiers



**Grade Controls**

▣ Dam

≡ Ledge

⌒ Weir

— Channel Straightening

■ Corridor Encroachment

▭ Village Areas

— Roads

○ Reach Breaks

~ Mad River Surface Waters

⊕ Upper Mad River Watershed

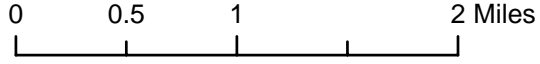
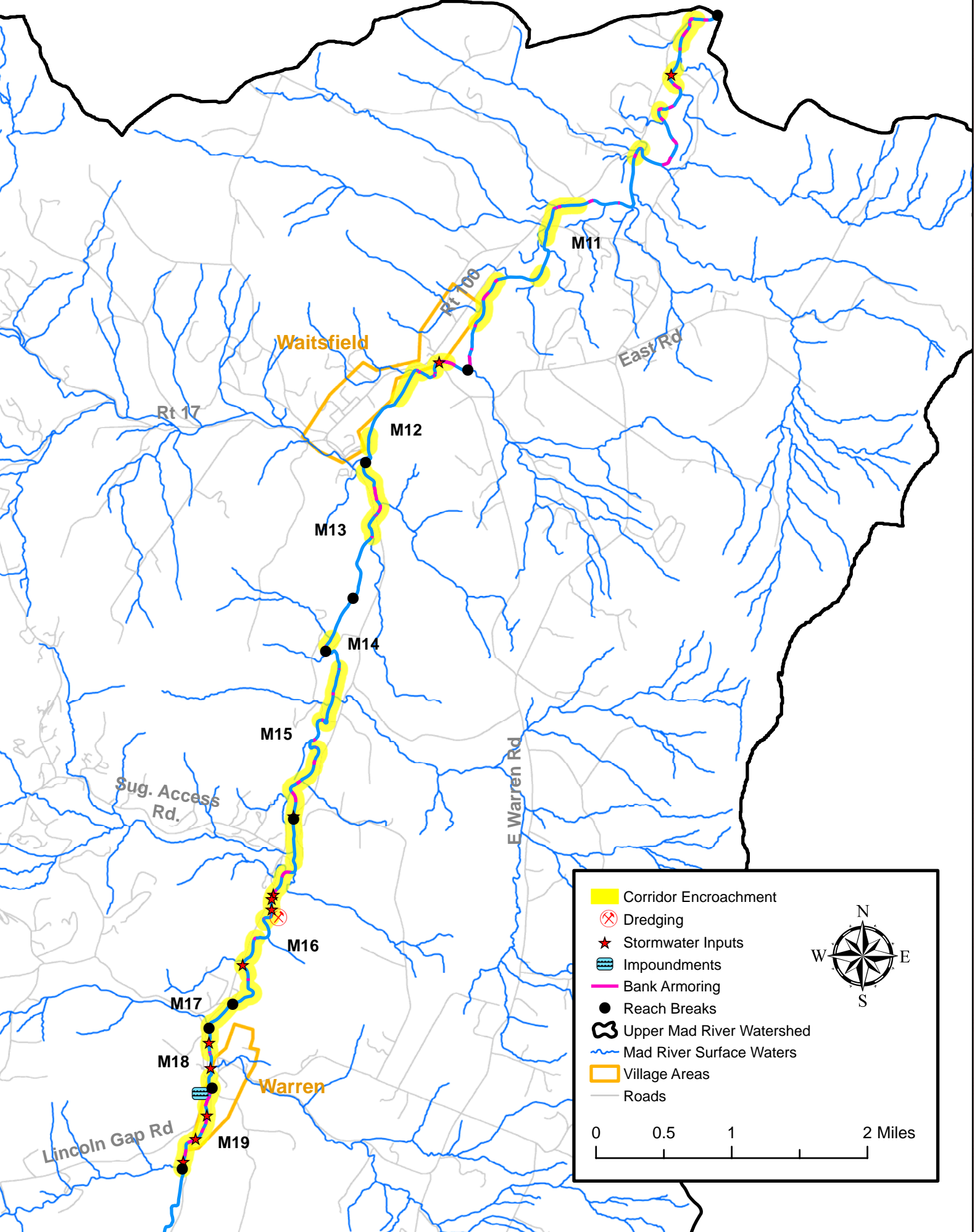


Figure 5.5 Channel Depth Modifiers



## 5.4 Modifications to Channel Boundary and Riparian Conditions

The boundary conditions of a river encompass the bed and bank substrate, and the vegetation and root material found along the riverbank. Human alterations to the river boundary conditions are often made to increase the resistance of the banks and bed to reduce lateral and vertical adjustments. In addition, the removal of riparian vegetation can cause a decrease in boundary resistance, and lead to increased lateral migration. Other natural and human-installed features within the channel, such as bedrock ledges and dams, affect boundary resistance in an upstream and downstream direction by controlling the vertical adjustment processes.

In the Upper Mad River watershed, a majority of the reaches not found in bedrock-controlled settings have non-cohesive bank materials consisting of sand, gravel and to a lesser extent, cobbles and boulders. Numerous natural grade controls exist along the channel network in the form of bedrock ledges, especially in the reaches upstream of Waitsfield. Two weirs located in reaches M13 and M15, and the Warren crib dam (M19) act as grade controls.

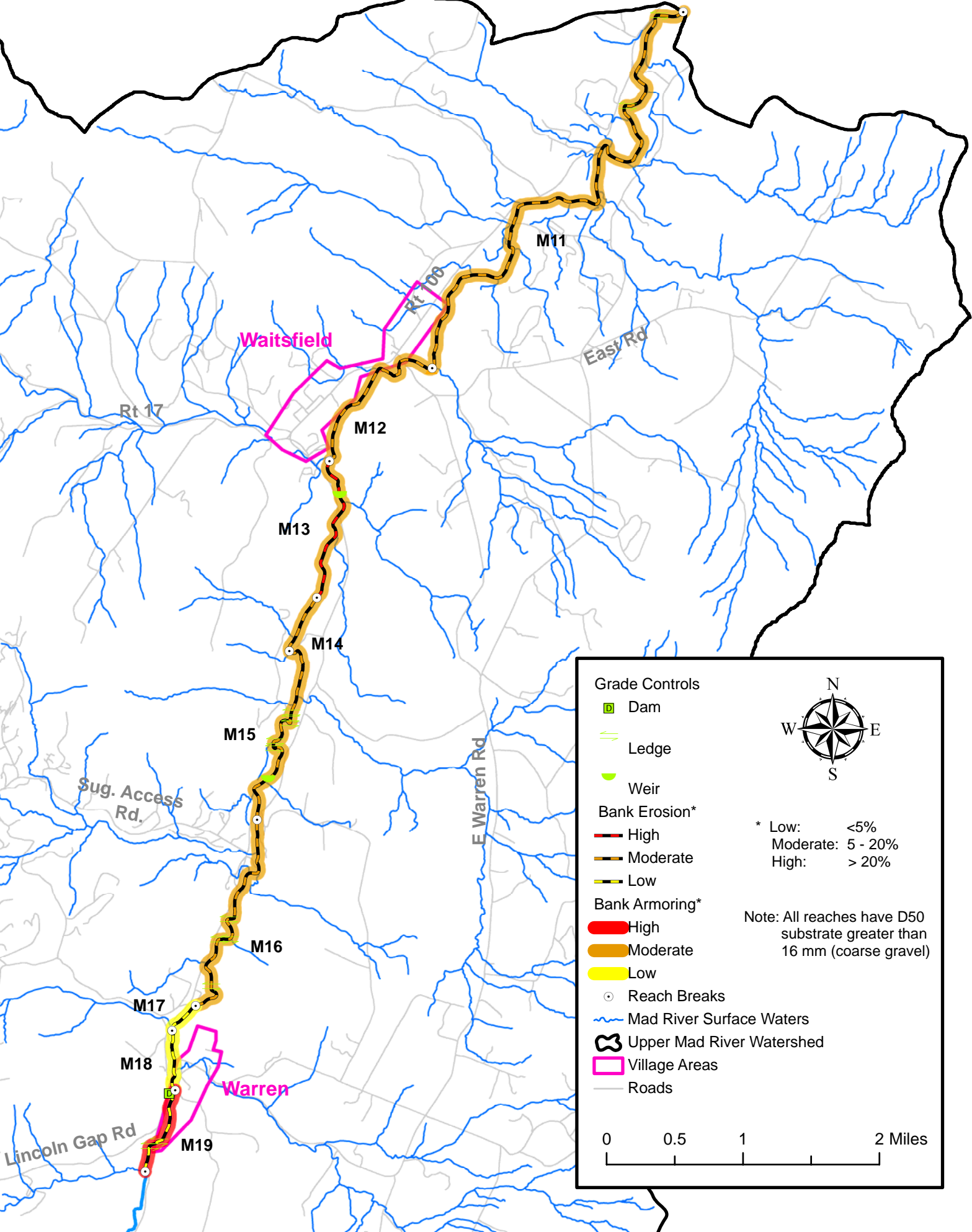
Alterations to the channel boundary conditions and riparian areas in the Upper Mad River watershed have been mapped using the variables extracted from the Phase 2 field assessments (Figure 5.6). Relative bank armoring (e.g., rip-rap) highlights areas of increased resistance to lateral migration, whereas relative bank erosion highlights reaches where significant lateral adjustments are found. Additional data showing the location of natural channel features (e.g., ledges) and channel modifications (e.g., weirs) depict areas that have a resistance or propensity for channel change, respectively. A summary of the local impacts to channel boundary conditions, including impacts to riparian vegetation, for each mainstem reach based on Figure 5.6 is provided in Table 5.4 at the end of section 5.0.

## 5.5 Sediment Regime Analysis

Many years of research has shown that alluvial river channels in wide valleys will adjust their geometry and planform to accommodate changes in the discharge and sediment loading from the upslope watershed (Dunne and Leopold, 1978). This concept was summarized by Lane (1955) to show that stream power and sediment (size and distribution) will seek a dynamic equilibrium condition in the absence of anthropogenic disturbance or catastrophic natural storm events. Slight changes from one year to another, such as variation in rainfall amounts (and a resulting variation in discharge), may cause subtle changes in channel form. However, the shape and profile of a river is typically stable under reference watershed conditions, and predictable given knowledge about 1) the geologic conditions of the watershed and corridor, 2) the topography of the watershed, and 3) the regional climate.

Analysis of a watershed's sediment regime is a useful approach for summarizing the reach and watershed-scale stressors (described previously in Section 5.0) affecting the equilibrium conditions of river channels. Sediment regime mapping provides a context

Figure 5.6 Boundary and Riparian Conditions



<b>Grade Controls</b>		
Dam		
Ledge		
Weir		
<b>Bank Erosion*</b>		
High		
Moderate		
Low		
<b>Bank Armoring*</b>		
High		
Moderate		
Low		
Reach Breaks		
Mad River Surface Waters		
Upper Mad River Watershed		
Village Areas		
Roads		

\* Low: <5%  
 Moderate: 5 - 20%  
 High: > 20%

Note: All reaches have D50 substrate greater than 16 mm (coarse gravel)

for understanding the sediment transport and channel evolution processes (Schumm, 1977) which govern changes in geometry and planform for river channels in a state of disequilibrium. The VTANR River Corridor Planning Guide (2007) outlines a methodology for understanding the reference and altered sediment regimes of reaches according to data collected during the Phase 2 field assessments. The sediment regime types used in this analysis are summarized below in table 5.2.

Table 5.2 Sediment Regime Types (VTANR, 2007)

<b>Regime</b>	<b>Narrative Description</b>
<b><i>Transport</i></b>	Steeper bedrock and boulder/cobble cascade and step-pool stream types; typically in more confined valleys, do not supply appreciable quantities of sediments to downstream reaches on an annual basis; little or no mass wasting; storage of fine sediment is negligible due to high transport capacity derived from both the high gradient and/or natural entrenchment of the channel.
<b><i>Confined Source and Transport</i></b>	Cobble step pool and steep plane bed streams; confining valley walls, comprised of erodible tills, glacial lacustrine, glacial fluvial, or alluvial materials; mass wasting and landslides common and may be triggered by valley rejuvenation processes; storage of coarse or fine sediment is limited due to high transport capacity derived from both the gradient and entrenchment of the channel. Look for streams in narrow valleys where dams, culverts, encroachment (roads, houses, etc.), and subsequent channel management may trigger incision, rejuvenation, and mass wasting processes.
<b><i>Unconfined Source and Transport</i></b>	Sand, gravel, or cobble plane bed streams; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to entrenchment or incision and associated bed form changes; these streams are not a significant sediment supply due to boundary resistance such as bank armoring, but may begin to experience erosion and supply both coarse and fine sediment when bank failure leads to channel widening; storage of coarse or fine sediment is negligible due to high transport capacity derived from the deep incision and little or no floodplain access. Look for straightened, incised or entrenched streams in unconfined valleys, which may have been bermed and extensively armored and are in Stage II or early Stage III of channel evolution.
<b><i>Fine Source and Transport &amp; Coarse Deposition</i></b>	Sand, gravel, or cobble streams with variable bed forms; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to vertical profile and associated bed form changes; these streams supply both coarse and fine sediments due to little or no boundary resistance; storage of fine sediment is lost or severely limited as a result of channel incision and little or no floodplain access; an increase in coarse sediment storage occurs due to a high coarse sediment load coupled with the lower transport capacity that results from a lower gradient and/or channel depth. Look for historically straightened, incised, or entrenched streams in unconfined valleys, having little or no boundary resistance, increased bank erosion, and large unvegetated bars. These streams are typically in late Stage III and Stage IV of channel evolution.
<b><i>Coarse Equilibrium (in = out) &amp; Fine Deposition</i></b>	Sand, gravel, or cobble streams with equilibrium bed forms; at least one side of the channel is unconfined by valley walls; these streams transport and deposit coarse sediment in equilibrium (stream power—produce as a result of channel gradient and hydraulic radius—is balanced by the sediment load, sediment size, and channel boundary resistance); storage of fine sediment as a result of floodplain access for high frequency (annual) floods. Look for unconfined streams, which are not incised or entrenched, have boundary resistance (woody buffers), minimal bank erosion, and vegetated bars. These streams are Stage I, late Stage IV, and Stage V of channel evolution.

The reference and existing sediment regime types have been mapped using data from the 2006 Phase 1 and 2 assessments. In some cases, data for reaches that were re-evaluated in the field in 2007 by the Project Team were adjusted using best professional judgment (with oversight from ANR staff). Figures 5.7 and 5.8 summarize the sediment regime types for reference and existing conditions for reaches M11 through M19. The analysis of sediment regime types reveals that the mainstem channel of the Mad River has experienced many areas of departures from the reference regime conditions. All of the reaches with slopes less than 2 percent are assumed to have been coarse-bottomed

Figure 5.7 Reference Sediment Regimes

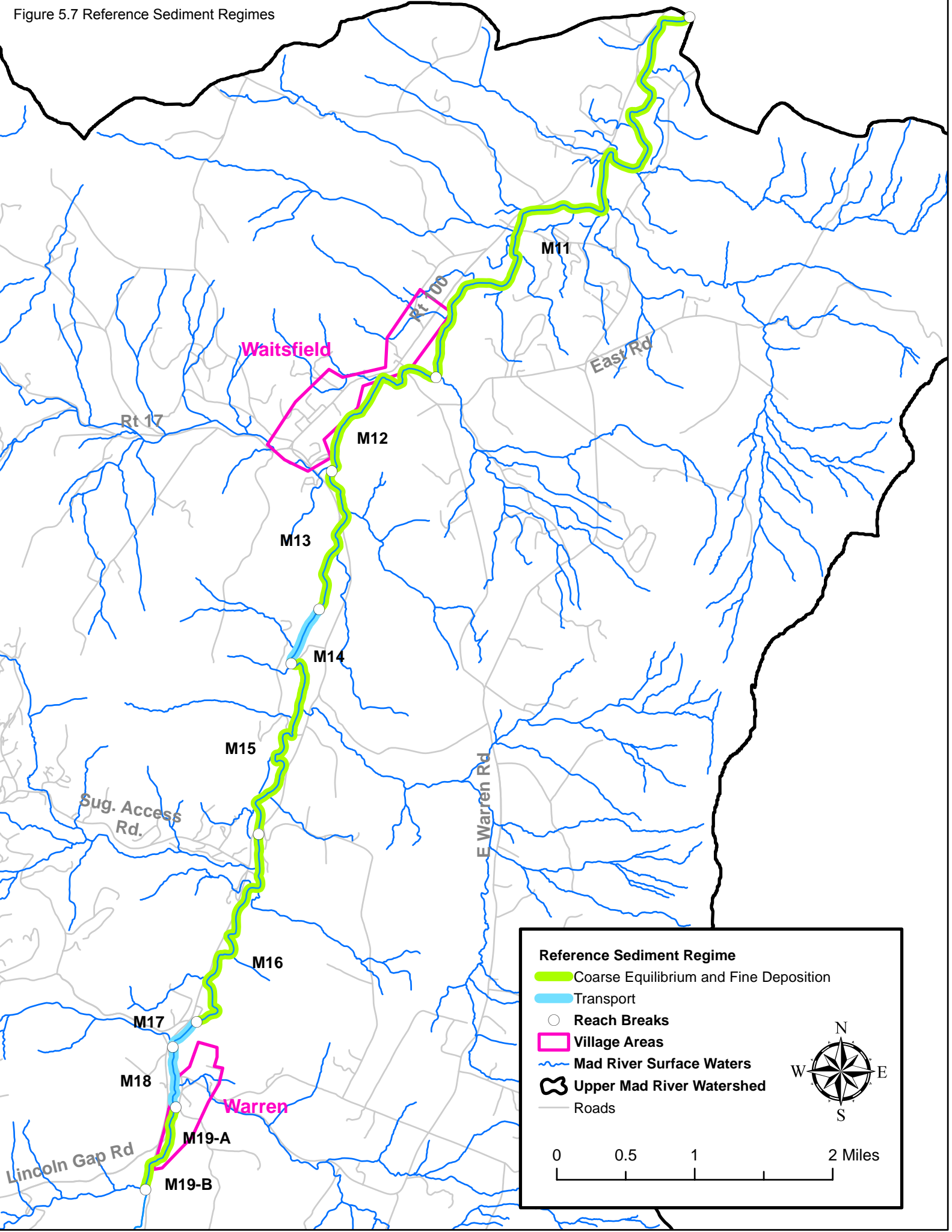
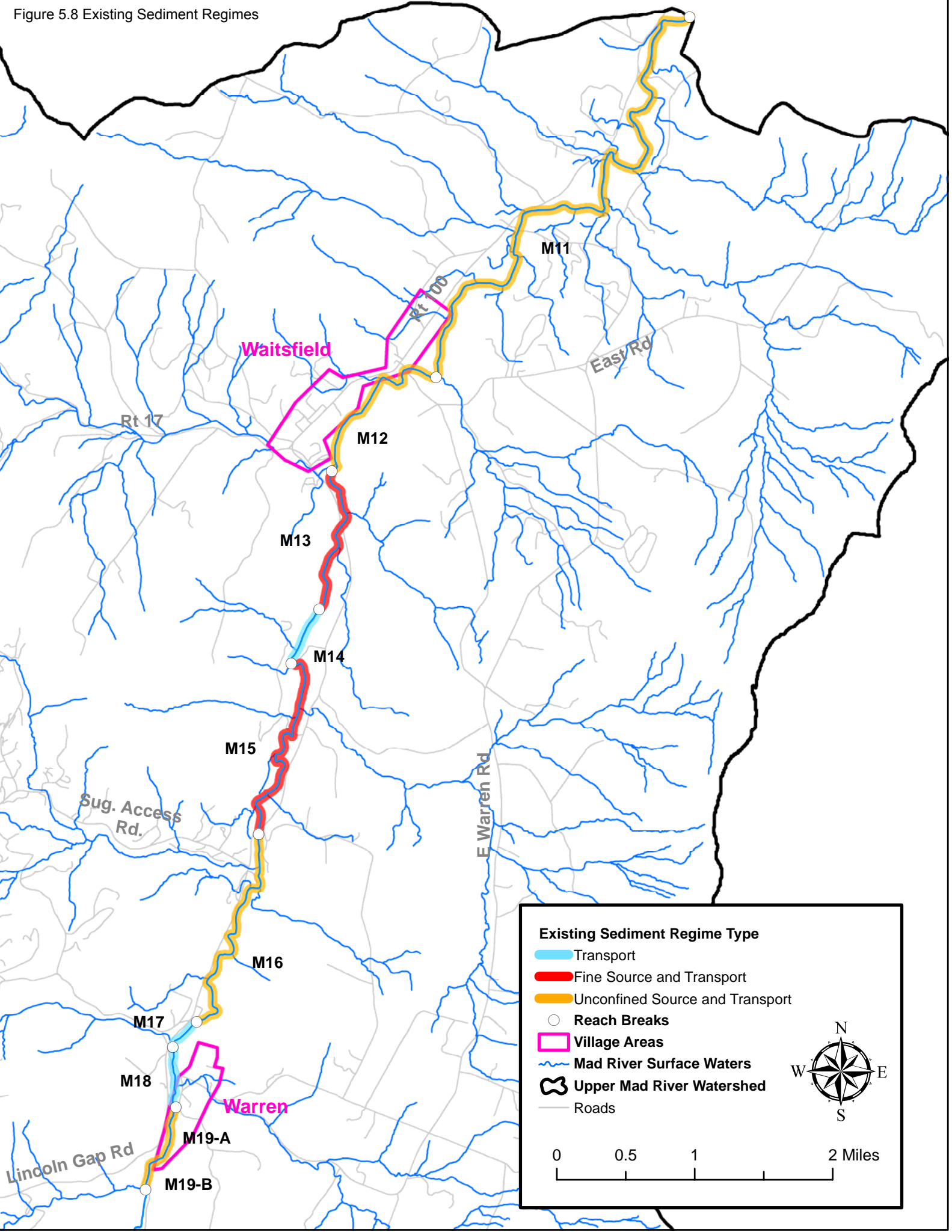


Figure 5.8 Existing Sediment Regimes



**Existing Sediment Regime Type**

- █ Transport
- █ Fine Source and Transport
- █ Unconfined Source and Transport
- Reach Breaks
- ▭ Village Areas
- ~ Mad River Surface Waters
- ⊞ Upper Mad River Watershed
- Roads



0 0.5 1 2 Miles

streams in equilibrium, where there was a balance between sediment transport and supply. Reaches M11, M12, M13, M15, M16 and M19 are characterized by this regime under reference conditions, but have all experienced a departure to source and transport regimes due to channel evolution processes brought on by human impacts (see Figure 5.9). Reaches M14, M17 and M18 have confinement and channel slope characteristics that support sediment transport channels. None of the transport reaches have experienced a sediment regime departure from reference conditions. Table 5.3 summarizes both the departure of sediment regime conditions based on the transport and storage capacity, as well as the constraints to: 1) the connectivity of the adjustment processes along the channel network, and 2) the redevelopment of equilibrium conditions in the reach. The summary of transport regimes (transport versus storage) indicates whether the regime is naturally dominated by sediment transport processes, or whether it has been converted to this state due to human constraints (with a resulting attenuation decrease). The flow and sediment attenuation summary indicates where streams have an inherent tendency to store sediment (natural), where sediment deposition is increasing, and whether the reach has potential for future sediment deposition (asset).

Table 5.3 Upper Mad River Departure Analysis Summary

River Segment	Constraints		Transport		Floodplain Sediment and Flow Attenuation (Storage)		
	Vertical	Lateral	Natural	Converted	Natural	Increased	Asset
M11	Ledges (N);	Agriculture Roads (H)		X	X		X
M12		Development; Roads (H)		X	X		
M13		Development; Roads (H)		X	X	X	X
M14			X			X	
M15	Ledges (N); Weir (H)	Development; Pond (H)		X	X	X	X
M16	Ledges (N);	Development; Roads (H)		X	X		X
M17		Roads (H)	X			X	
M18		Development; Roads (H)	X				
M19-A	Dam (H); Ledges (N)	Development; Roads (H)		X	X	X	
M19-B	Ledges (N);	Development; Roads (H)		X	X		

N = Natural  
 H = Human Constructed

## 5.6 Stream Sensitivity Analysis

The following description of the sensitivity of various stream types to changes in sediment and flow regimes, boundary conditions and channel morphology, is included from the most recent version of the VTANR River Corridor Planning Guide (VTANR, 2007).

Certain geomorphic stream types are inherently more sensitive than others, responding readily through lateral and/or vertical adjustments to high flow events and/or influxes of sediment. Other geomorphic stream types may undergo far less adjustment in response to the same watershed inputs. In general, streams receiving a large supply of sediment, having a limited capacity to transport that sediment, and flowing through finer-grained, non-cohesive materials are inherently more sensitive to adjustment and likely to experience channel evolution processes than streams with a lower sediment supply, higher transport capacity and flowing through cohesive or coarse-grained materials (Montgomery and Buffington, 1997). The geometry and roughness of the stream channel and floodplain (i.e., the width, depth, slope, sediment sizes, and floodplain relations) dictate the velocity of flow, how much erosive power is produced, and whether the stream has the competence to transport the sediment delivered from upstream (Leopold, 1994). If the energy produced by the depth and slope of the water is either too little or too great in relation to the sediment available for transport, the stream may be out of equilibrium and channel adjustments are likely to occur, especially during flood conditions (Lane, 1955).

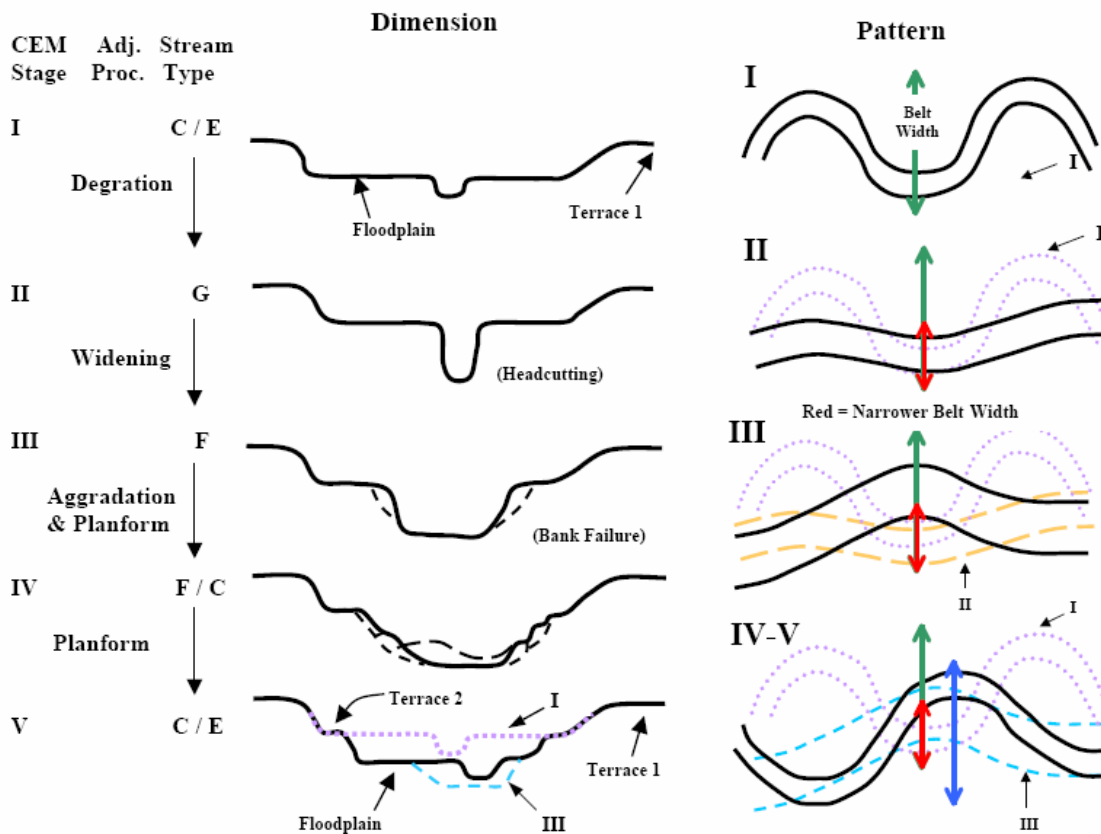


Figure 5.9 Typical channel evolution processes observed in rivers of VT (modified from Schumm, 1977)

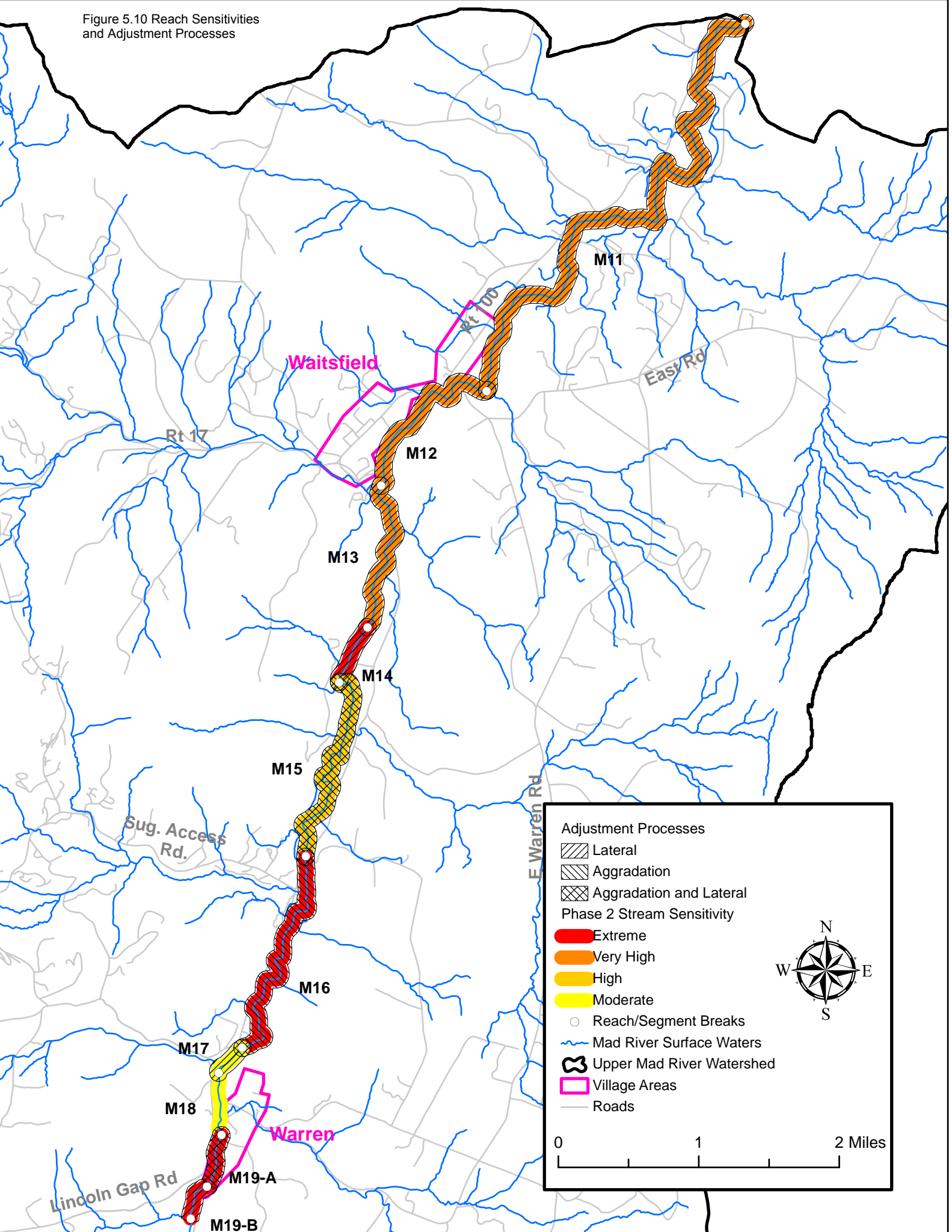
The methods outlined in the Corridor Planning Guide have been used to describe the stream sensitivities of the mainstem reaches of the Mad River. Using the stream geometry and substrate data (Rosgen, 1994) and overall geomorphic stability (RGA score) as determined during the 2006 field surveys, stream sensitivity ratings have been assigned to each reach. In addition, the active adjustment processes described during the field effort have been summarized. An adjustment process was considered “active” if it received a score in the fair to poor range during the RGA scoring process. Figure 5.10 summarizes the current stream sensitivities and adjustment processes for the Mad River.

Due to the inherent propensity of meandering, gravel bed channels to adjust in response to impacts, 9 out of 10 reaches (11 segments total) have a stream sensitivity rating of very high or above. Many of the mainstem reaches have gone through the initial stages of channel evolution (stage II; incision) and are beginning to aggrade coarse gravel and cobble substrate (stage III) and redevelop the sinuosity (stage IV) lost due to historic straightening (see Figure 5.9). Typically, channel stability and habitat conditions decline during the latter stages of channel evolution as the morphology and planform adjust to accommodate the new sediment and hydrologic regimes. This is the case along the entire mainstem channel network, as fair geomorphic conditions were reported for 9 of the 10 reaches, and aggradation and lateral adjustments are occurring throughout.

Four reaches have experienced a departure of channel morphology from reference conditions (see Figure 5.11 for further description of the Rosgen classification system), resulting in a stream sensitivity rating of extreme:

- Reach M14 is a low-gradient channel (0.4% slope) found in a confined valley setting. Under reference conditions, this reach would have B-type channel geometry despite a low slope ( $B_c$ ), and sediment transport processes due to the narrow confinement. During the 1998 flood, this reach experienced severe channel widening (Field, 2007), resulting in an F-type channel in an entrenched setting (entrenchment ratio = 1.1).
- Reach M16 is a low-gradient channel (0.5% slope) found in an unconfined valley setting. Under reference conditions, this reach would have C-type channel geometry and an equilibrium sediment regime where the supply of coarse sediment is equal to the transport capacity. However, excessive channel incision has led to an entrenched channel with F-type geometry, particularly in the upper section of the reach. This reach is beginning to experience aggradation associated with stage III of channel evolution, and will be highly susceptible to planform changes over the next few decades.
- Segment M19-A is a moderate-gradient channel (0.9% slope) found in a narrow valley setting. Under reference conditions, this reach would have C-type channel geometry and a combination of transport and depositional processes. This reach has undergone a departure in form to an F-type channel due to the floodplain encroachment and bank armoring around the Warren village.

Figure 5.10 Reach Sensitivities and Adjustment Processes



**Adjustment Processes**

- Lateral
- Aggradation
- Aggradation and Lateral

**Phase 2 Stream Sensitivity**

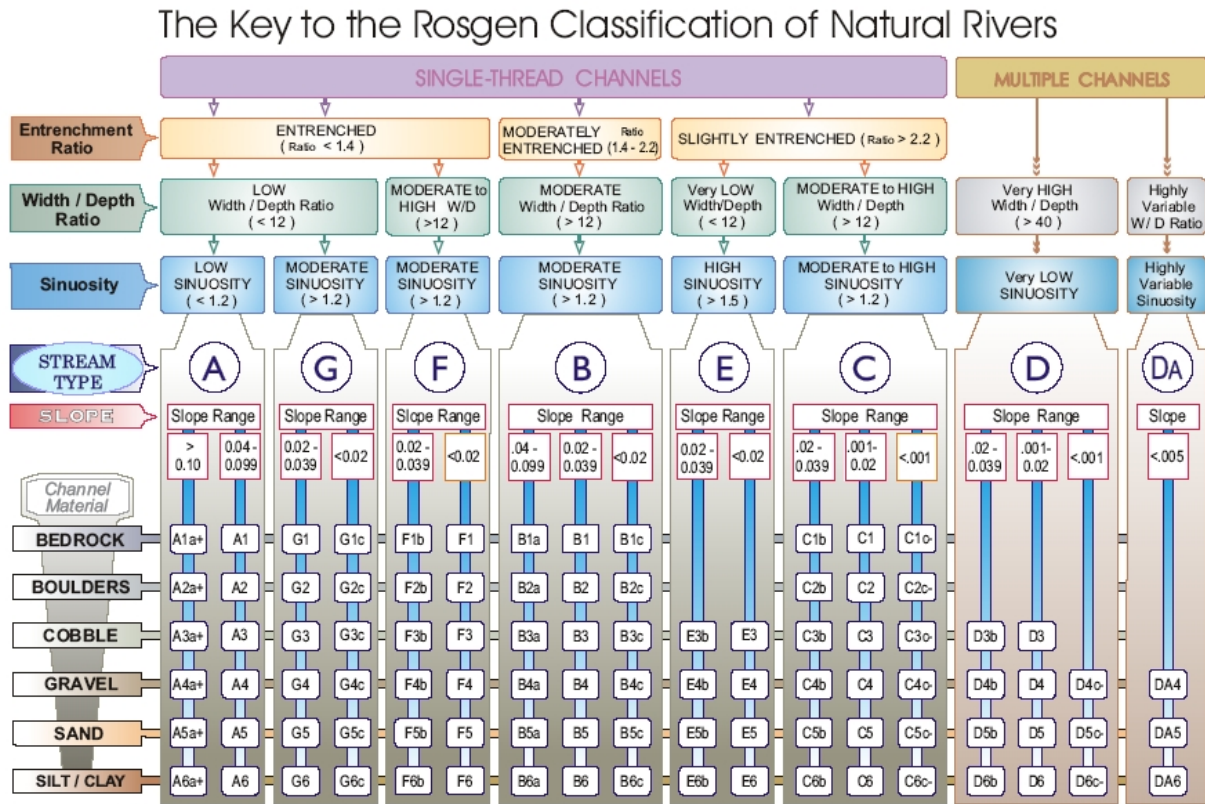
- Extreme
- Very High
- High
- Moderate

- Reach/Segment Breaks
- Mad River Surface Waters
- Upper Mad River Watershed
- Village Areas
- Roads

0 1 2 Miles

- Segment M19-B is also moderate-gradient channel (1.3% slope) found in a narrow valley setting. Under reference conditions, this reach would also have C-type channel geometry and a combination of transport and depositional processes. This reach has undergone a departure in form to an F-type channel due to the floodplain encroachment from Route 100 and associated bank armoring.

Reaches M17 and M18 have the lowest sensitivities of all the reaches analyzed (moderate). Both reaches have fair geomorphic stability, but because they are found in a bedrock gorge downstream of the Warren Crib Dam, they are less prone to vertical and lateral adjustment processes.



KEY to the ROSGEN CLASSIFICATION of NATURAL RIVERS. As a function of the "continuum of physical variables" within stream reaches, values of **Entrenchment** and **Sinuosity** ratios can vary by +/- 0.2 units; while values for **Width / Depth** ratios can vary by +/- 2.0 units.

Figure 5.11 The Rosgen (1994) classification of streams based on channel morphology. Key parameters for classification include 1) the entrenchment ratio (floodprone width / bankfull channel width), 2) width to depth ratio (bankfull width / mean channel depth), and 3) channel sinuosity (channel length / straight-line valley length). Entrenched channels are typically dominated by sediment transport processes, whereas slightly entrenched channels (C and E types) have sediment transport and depositional processes.

Table 5.4. River Stressors Identification Table summarizing watershed and reach-scale stressors impacting dynamic equilibrium conditions

River Segment (CEM;RGA <sup>†</sup> )	Regime Stressors		Reach-Scale Stressors	
	Hydrologic	Sediment	Stream Power	Boundary Resistance
M11 (III;Fair)	<p><i>Increased Flows</i></p> <ul style="list-style-type: none"> <li>• High local and upslope road density &amp; TIA*</li> <li>• High local wetland loss</li> <li>• Minor stormwater inputs</li> </ul>	<p><i>Increased Load</i></p> <ul style="list-style-type: none"> <li>• Very high (&gt;25%) cropland in local/upslope drainages</li> <li>• Moderate bank erosion (5-20%)</li> <li>• Abundant depositional and migration features</li> <li>• Lateral channel adjustments</li> </ul>	<p><i>Increase</i></p> <ul style="list-style-type: none"> <li>• Very high channel straightening impact (57%)</li> <li>• High Berm/Road Impact (30%)</li> </ul> <p><i>Decrease</i></p> <ul style="list-style-type: none"> <li>• Abundant depositional and migration features</li> </ul>	<p><i>Increase</i></p> <ul style="list-style-type: none"> <li>• Moderate Bank Armoring (5-20%)</li> <li>• Multiple grade controls</li> </ul> <p><i>Decrease</i></p> <ul style="list-style-type: none"> <li>• Moderate Bank Erosion (5-20%)</li> <li>• Reduced riparian vegetation</li> </ul>
M12 (III;Fair)	<p><i>Increased Flows</i></p> <ul style="list-style-type: none"> <li>• High local and upslope road density &amp; TIA*</li> <li>• High local wetland loss</li> <li>• Minor stormwater inputs</li> </ul>	<p><i>Increased Load</i></p> <ul style="list-style-type: none"> <li>• High cropland (15-20%) in local/upslope drainages</li> <li>• Moderate bank erosion (5-20%)</li> <li>• Moderate depositional and migration features</li> <li>• One large mass failure</li> <li>• Lateral channel adjustments</li> </ul>	<p><i>Increase</i></p> <ul style="list-style-type: none"> <li>• High channel straightening impact (32%)</li> <li>• High Berm/Road Impact (30%)</li> <li>• High Corridor Development Impact (30%)</li> </ul> <p><i>Decrease</i></p> <ul style="list-style-type: none"> <li>• Moderate depositional and migration features</li> </ul>	<p><i>Increase</i></p> <ul style="list-style-type: none"> <li>• Moderate Bank Armoring (5-20%)</li> </ul> <p><i>Decrease</i></p> <ul style="list-style-type: none"> <li>• Moderate Bank Erosion (5-20%)</li> <li>• Reduced riparian vegetation</li> </ul>
M13 (III;Fair)	<p><i>Increased Flows</i></p> <ul style="list-style-type: none"> <li>• Moderate local and upslope road density &amp; TIA*</li> <li>• High local wetland loss</li> </ul>	<p><i>Increased Load</i></p> <ul style="list-style-type: none"> <li>• High cropland (15-20%) in local/upslope drainages</li> <li>• High bank erosion (&gt;20%)</li> <li>• Abundant depositional and migration features</li> <li>• Lateral channel adjustments</li> </ul>	<p><i>Increase</i></p> <ul style="list-style-type: none"> <li>• High Berm/Road Impact (47%)</li> </ul> <p><i>Decrease</i></p> <ul style="list-style-type: none"> <li>• Abundant depositional and migration features</li> </ul>	<p><i>Increase</i></p> <ul style="list-style-type: none"> <li>• Moderate Bank Armoring (5-20%)</li> </ul> <p><i>Decrease</i></p> <ul style="list-style-type: none"> <li>• Moderate Bank Erosion (5-20%)</li> <li>• Reduced riparian vegetation</li> </ul>
M14 (IV;Fair)		<p><i>Increased Load</i></p> <ul style="list-style-type: none"> <li>• Moderate bank erosion (5-20%)</li> <li>• Lateral channel adjustments</li> </ul>		<p><i>Increase</i></p> <ul style="list-style-type: none"> <li>• Moderate Bank Armoring (5-20%)</li> </ul> <p><i>Decrease</i></p> <ul style="list-style-type: none"> <li>• Moderate Bank Erosion</li> </ul>

River Segment (CEM;RGA <sup>†</sup> )	Regime Stressors		Reach-Scale Stressors	
	Hydrologic	Sediment	Stream Power	Boundary Resistance
				(5-20%)
M15 (IV;Fair)	<i>Increased Flows</i> <ul style="list-style-type: none"> <li>High local and upslope road density and TIA*</li> <li>High local wetland loss</li> </ul> <i>Decreased Flows</i> <ul style="list-style-type: none"> <li>Flow Diversion</li> </ul>	<i>Increased Load</i> <ul style="list-style-type: none"> <li>High cropland (15-20%) in local/upslope drainages</li> <li>Moderate bank erosion (5-20%)</li> <li>Lateral and aggradational channel adjustments</li> </ul>	<i>Increase</i> <ul style="list-style-type: none"> <li>High channel straightening impact (31%)</li> <li>High Berm/Road Impact (55%)</li> </ul> <i>Decrease</i> <ul style="list-style-type: none"> <li>Moderate depositional and migration features</li> </ul>	<i>Increase</i> <ul style="list-style-type: none"> <li>Moderate Bank Armoring (5-20%)</li> <li>Abundant grade controls</li> </ul> <i>Decrease</i> <ul style="list-style-type: none"> <li>Moderate Bank Erosion (5-20%)</li> <li>Reduced riparian vegetation</li> </ul>
M16 (III;Fair)	<i>Increased Flows</i> <ul style="list-style-type: none"> <li>Very high local and upslope road density/TIA*</li> <li>High local wetland loss</li> <li>Major stormwater inputs</li> </ul>	<i>Increased Load</i> <ul style="list-style-type: none"> <li>Mod. cropland (5-15%) in local/upslope drainages</li> <li>Moderate bank erosion (5-20%)</li> <li>Abundant depositional and migration features</li> <li>High aggradation</li> </ul>	<i>Increase</i> <ul style="list-style-type: none"> <li>Very High Berm/Road Impact (78%)</li> <li>Historic dredging</li> </ul> <i>Decrease</i> <ul style="list-style-type: none"> <li>Abundant depositional and migration features</li> </ul>	<i>Increase</i> <ul style="list-style-type: none"> <li>Moderate Bank Armoring (5-20%)</li> <li>Multiple grade controls</li> </ul> <i>Decrease</i> <ul style="list-style-type: none"> <li>Moderate Bank Erosion (5-20%)</li> <li>Reduced riparian vegetation</li> </ul>
M17 (IV;Fair)	<i>Increased Flows</i> <ul style="list-style-type: none"> <li>Very high local and upslope road density/TIA*</li> <li>Moderate local wetland loss</li> </ul>	<i>Increased Load</i> <ul style="list-style-type: none"> <li>Very high (&gt;25%) cropland in local/upslope drainages</li> </ul>	<i>Increase</i> <ul style="list-style-type: none"> <li>Very High Berm/Road Impact (91%)</li> </ul>	<i>Increase</i> <ul style="list-style-type: none"> <li>Abundant bedrock grade controls</li> </ul>
M18 (IV;Fair)	<i>Increased Flows</i> <ul style="list-style-type: none"> <li>Very high local and upslope road density/TIA*</li> <li>High local wetland loss</li> <li>Major stormwater inputs</li> </ul>	<i>Increased Load</i> <ul style="list-style-type: none"> <li>High cropland (15-20%) in local/upslope drainages</li> </ul>	<i>Increase</i> <ul style="list-style-type: none"> <li>High Berm/Road Impact (51%)</li> <li>High Corridor Development Impact (48%)</li> </ul>	<i>Increase</i> <ul style="list-style-type: none"> <li>Abundant bedrock grade controls</li> </ul>
M19-A (III;Fair)	<i>Increased Flows</i> <ul style="list-style-type: none"> <li>Very high local road density/TIA*</li> <li>Moderate local wetland loss</li> </ul>	<i>Increased Load</i> <ul style="list-style-type: none"> <li>Moderate cropland (5-15%) in local/upslope drainages</li> <li>Lateral and aggradational channel adjustments</li> </ul>	<i>Increase</i> <ul style="list-style-type: none"> <li>Very high channel straightening impact (56%)</li> <li>Very high Berm/Road Impact (69%)</li> </ul>	<i>Increase</i> <ul style="list-style-type: none"> <li>High Bank Armoring (&gt;20%)</li> <li>Multiple grade controls</li> </ul> <i>Decrease</i>

River Segment (CEM;RGA <sup>†</sup> )	Regime Stressors		Reach-Scale Stressors	
	Hydrologic	Sediment	Stream Power	Boundary Resistance
	<i>Decreased Flows</i> <ul style="list-style-type: none"> <li>Warren Crib Dam</li> </ul>		<ul style="list-style-type: none"> <li>High Corridor Development Impact (42%)</li> </ul> <i>Decrease</i> <ul style="list-style-type: none"> <li>Warren Crib Dam</li> </ul>	<ul style="list-style-type: none"> <li>Reduced riparian vegetation</li> </ul>
M19-B (III;Fair)	<i>Increased Flows</i> <ul style="list-style-type: none"> <li>Very high local road density/TIA*</li> <li>Moderate local wetland loss</li> </ul>	<i>Increased Load</i> <ul style="list-style-type: none"> <li>Moderate cropland (5-15%) in local/upslope drainages</li> <li>Lateral channel adjustments</li> </ul>	<i>Increase</i> <ul style="list-style-type: none"> <li>Very high channel straightening impact (61%)</li> <li>Very high Berm/Road Impact (67%)</li> <li>High Corridor Development Impact (28%)</li> </ul>	<i>Increase</i> <ul style="list-style-type: none"> <li>High Bank Armoring (&gt;20%)</li> <li>Multiple grade controls</li> </ul> <i>Decrease</i> <ul style="list-style-type: none"> <li>Reduced riparian vegetation</li> </ul>

\*Total Impervious Area

Note: local scale for wetland loss and road density/TIA includes the corridor and the adjacent subwatersheds draining directly to the reach

† Channel evolution stage (F model for all reaches) and Rapid Geomorphic Assessment categorical score

## 6.0 Preliminary Project Identification

The Corridor Planning Guideline prescribes a process for identifying restoration and protection project opportunities, the results of that process are presented in the following two sections 1) broader, watershed level opportunities and 2) more localized, reach or site level opportunities.

### 6.1 Watershed Level Opportunities

#### 6.1.1 Stormwater

Fitzgerald (2007) shows correlations between road density, impervious surface coverage and decline of channel stability and biotic integrity. In the Mad River study area (Reach M11-M19), Areas with these high levels of road density were centered around Waitsfield Village and up Route 17 to Mad River Glen area, up Clay brook in the Sugarbush Ski area, in the Warren Village area, and in the headwaters near Alpine Village (Figure 5.1).

Increased stormwater runoff can increase peak flood flows and the erosive power of the streams. Stormwater runoff over dirt roads and exposed soil during development or over farm fields can also add significant sediment inputs to the streams. Clay Brook for example, has high road density and high sediment inputs to the Mad River. Some sediment was from instream sources such as mass bank failures in the lower portion of Clay Brook.

With increasing development, more driveways and roads are funneling sediment and runoff to streams more quickly. Sediment from roads and driveways can be addressed with improved ditches, limiting future driveway lengths in sensitive areas, and other methods. The Better Back Roads program can provide assistance. Increased development also increases sediment loads through erosion of bare soils exposed during construction. While erosion control measures are required, enforcement of their effective use is difficult.

Towns can use local planning to improve development standards and enact local stormwater control standards and guidelines for stormwater treatment or mitigation. Such local planning efforts are important to control and monitor stormwater and development effects on local natural resources. By planning proactively, towns can reduce long-term costs and risks associated with stormwater runoff. Options that municipalities could consider at the local scale which reflect the local, rural development patterns and the sensitivity of waterbodies to stormwater runoff (especially in mountainous areas like the Mad River valley) would include:

- Requiring stormwater controls for development projects which are not large enough in scale to fall under state regulatory permits (less than 1 acre impervious cover), but likely have a measurable impact on adjacent waterbodies.
- Incorporating more rigorous requirements for stormwater control of new development in headwaters areas. Recent research in Vermont has shown that physical and biotic conditions in small watersheds (< 5 square miles in area) are impacted by very low levels of impervious cover (as low as 5 percent; Fitzgerald, 2007)

- Encouraging Low Impact Development (LID) by offering development density incentives for those projects which result in reduced footprints of impervious cover.

Loss of wetlands also increases stormwater runoff by altering hydrology, increasing peak flows by eliminating the uptake of runoff by the wetlands. Figure 5.1 highlights wetland losses in the Mad River watershed. While class 1 and 2 wetlands are now protected, class 3 wetlands remain unprotected and filling can occur. Opportunities to restore degraded wetlands and to protect vulnerable functioning wetlands in the watershed should be explored. Town planning can be used to increase protections for local wetlands of all classes as an important step in protecting these natural resources and aiding in stormwater control.

### 6.1.2 Agriculture

Figure 5.3 shows alterations to the sediment load of the Mad River study area. Agriculture is a main factor affecting sediment, as the practices tend to lead toward increased soil erosion. Many of the subwatersheds had high to very high percentages of agricultural land use. The watershed area around reaches M11, M12, M13 had greater than 20 percent of agricultural land use. Reaches M15 through M19 had 10 to 20 percent agricultural land use. Improving soil conservation practices can help moderate effects of agriculture on the streams. Such soil conservation practices can include cover-cropping practices on flood prone fields and stream buffer re-establishment, which provides sediment filtration for runoff from fields and farmyards. NRCS has more information on soil conservation. For more information on the VT NRCS and its programs, visit their website at: [www.vt.nrcs.usda.gov/](http://www.vt.nrcs.usda.gov/).

### 6.1.3 Planning and Zoning to Limit Corridor Encroachment

Nine of the ten reaches within the study area are extremely sensitive to stressors and as such have a high propensity to migrate both vertically and laterally, potentially damaging public and private investments. As depicted in Figure 5.4, encroachments from berms, roads and development into the corridor are found along most of the stream length of the study area. All study reaches except for M14 and M17 have a high or very high berm/road encroachment impact. Development within the corridor is high in reaches M12 (30%), M18 (48%), M19A (42%), and M19B (28%). Preventing the placement of future investments in potential erosion hazard areas is very important, even if additional restoration activities are needed. Protecting the corridor can prevent erosion related losses and the need for future channel management activities.

Towns can reduce future flood recovery and infrastructure maintenance costs and increase public safety by limiting development in areas adjacent to rivers with a high potential for vertical and lateral adjustment. The Fluvial Erosion Hazard Corridor delineated as part of this study identifies those areas and can be used in the creation of zoning overlay districts that limit future encroachment into them. Avoiding future conflicts between the streams and investments by utilizing zoning to prevent encroachment will reduce future costs and risks and increase safety for area residents as well as those downstream.

Please see Appendix 1 for a Fluvial Erosion Hazard zone analysis for the Town of Waitsfield completed as part of this project.

### 6.1.4 Stream Crossings

Throughout Vermont, undersized bridges and poorly aligned culverts prevent critical sediment and woody debris transport processes and fish and wildlife migration resulting in channel instability loss or damage to infrastructure and personal property, increased flooding and decreased fish and wildlife population health. Many bridges and culverts in the Mad River watershed are currently undersized and causing various problems such as upstream deposition, excessive erosion, downstream bed degradation, wildlife passage problems, etc. As such structures come up for replacement, resizing them to accommodate the flow and sediment loads of the streams and placing them in proper alignment with stream channels is recommended.

Generally speaking, to accommodate sediment transport processes structures should span the bankfull width of the channel. Several states have adopted guidelines for designing structures to allow for fish passage (including Washington, California, Massachusetts), most of these guidelines prescribe a structure width of 1.0 – 1.5 times the bankfull channel width. Streams undergoing significant adjustments may require larger structures than streams in an equilibrium state, (contact the Vermont River Management Program for further technical assistance). Towns can adopt bridge and culvert standards for appropriate crossing width. Adopting such standards can help with pre-disaster mitigation planning and can help towns receive state incentives for taking a proactive approach.

Table 6.1 shows structures assessed during Bridge and Culvert Assessments in the Mad River watershed in 2006 and 2007. Only 5 structures meet the recommended 1.0 times stream width: The Tremblay Road bridge in reach M11, Route 100 structures in reaches M13, M19, and T9.01, as well as a bridge for a path over Rice Brook in reach T9.3S2.01. Structures with signs of significant problems include (marked with a “\*” in the table below):

- The Covered Bridge in Waitsfield in reach M12,
- The Covered Bridge in Warren in segment M19A,
- Both culverts on Ronk Road in reach T5.02,
- A culvert on Common Road in reach T6.1S1.01,
- A culvert for Golf Course Rd in reach T9.03,
- A culvert for Inferno Road in reach T9.04,
- All four culverts on Clay Brook in the ski area,
- A culvert for Privet Drive in reach T9.2-S1.01,
- All four culverts in reach T9.3S1.01 in the golf course area,
- Three culverts in reach T9.3S2.01 on the Sugarbush Access Road, Village Road, and West Drive.

These structures should be replaced and resized according to the RMP recommendations as well as redesigned to eliminate current problems. All additional structures not meeting the recommended minimum width of 1.0 times the stream channel width should be resized as they are up for replacement.

Table 6.1 Stream Crossings in Waitsfield and Warren

Reach/ Structure Type	Road	Road Type	Stream	Location	Struct Height	Struct Span	Stream Width	% Span/ Stream Width	Floodplain Filled	Stream Approach	Comments
M11 Bridge	Meadow Rd	Gravel	Mad River	Just east of route 100	19.4	71	83	<b>86</b>	Not Significant	Naturally Straight	Bedrock right bank upstream, in, and downstream of structure.
M11 Bridge	Tremblay Rd	Paved	Mad River	About 300 feet east of route 100.	17.2	131	83	158	Partially	Channelized Straight	Vane present.
*M12 Bridge	E Warren Rd	Gravel	Mad River	Waitsfield, E. Warren Rd. passing over the Mad River, Reach M12.	21	105	117	<b>90</b>	Partially	Sharp Bend	Covered Bridge. Storm input, left bank. Downstream left bank had high erosion, large mid-channel bar. Pool downstream, steep riffle upstream.
M13 Bridge	Route 100	Paved	Mad River	Just north of Flatbread Lareau Farm	18	164	117	140	Partially	Mild Bend	Diagonal bar downstream. Left side blocked by sediment vane structures.
M15 Bridge	Butternut Hill Rd	Gravel	Mad River	1/4 miles west of Route 100	22	58	95	61	Not Significant	Naturally Straight	Bedrock present on both banks, so the location is stable and the constriction pre-existing. In the 1998 flood, the river flowed over the road to the west, this capability should be preserved.
M15 Bridge	Route 100	Paved	Mad River	1/4 mile north of Sugarbush Access Rd.	12	108	95	<b>114</b>	Partially	Naturally Straight	Slight diagonal riffle upstream and old concrete abutments are deteriorating, stepped footers.
M17 Bridge	Main St	Paved	Mad River	At the north end of town	34	48	60	80	Not Significant	Naturally Straight	Over gorge, so constriction formed by bedrock, not bridge. Storm input left bank upstream, stepped footers.
*M19A Bridge	Covered Bridge Rd	Paved	Mad River	At the south end of town	18	40	61	<b>66</b>	Not Significant	Channelized Straight	Covered Bridge. Pool downstream. New concrete abutments have added to constriction.
M19B Bridge	Route 100	Paved	Mad River	Just south of Lincoln Gap Rd. at intersection with Main St.	31	157	61	257	Not Significant	Mild Bend	2 Storm Input drop basins, steep riffle upstream, stepped footers. The structure width is at the widest point, down at the channel, the width of the riprap fill is much narrower, narrower than bankfull.
T5.02 Bridge	North Rd	Gravel	Pine Brook	North Road bridge passing over Pine Brook reach T5.02A	9	27	38	<b>71</b>	Not Significant	Mild Bend	Old covered bridge, Stone abutments with concrete additions. Storm input, upstream end blocked by sediment.
*T5.02 Culvert	Ronk Rd	Gravel	Trib to Pine Brook	At intersection with privet trail.	3.5	3.5	15.5	<b>23</b>	Not Significant	Naturally Straight	Road was washed out from a previous high water incident. Outflow a free fall, pool downstream, steep riffle upstream. Upstream end blocked by sediment.
*T5.02 Culvert	Ronk Rd	Gravel	Trib to Pine Brook	At intersection with Floodwoods Rd.	5.6	6.3	14.33	<b>44</b>	Entirely	Naturally Straight	Local forester says that stream gets really low mid- late summer. Outflow a free fall, pool downstream, steep riffle upstream. Upstream end blocked by

Reach/ Structure Type	Road	Road Type	Stream	Location	Struct Height	Struct Span	Stream Width	% Span/ Stream Width	Floodplain Filled	Stream Approach	Comments
											wood debris.
*T6.1- S1.01 Culvert	Common Rd	Gravel	High Bridge Brook Trib	Crossing of Common Road.	4.7	4.7	25	<b>19</b>	Partially	Mild Bend	High degree of deposition of fine gravel upstream and within structure. Sharp change in slope below road. Note: Channel width is probably not representative of width in the section of reach assessed. It is probably much lower ~8-10 feet. Outflow a free fall.
T9.01 Bridge	Route 100	Paved	Clay Brook	At Sug. Access Rd us of conf w/ mainstem	10.5	56	38	147	Partially	Channelized Straight	Large amount of riprap (intact) along left bank upstream along Sugarbush Access Rd. Structure has adequate capacity, no problems.
*T9.03 Culvert	Golf Course Rd	Paved	Clay Brook	After a sharp rt turn, at the base of a hill.	8	13	22	<b>59</b>	Entirely	Naturally Straight	Rice Brook merges just up from the inlet. Outflow a free fall, pool downstream,, steep riffle upstream.
*T9.04 Culvert	Inferno Rd	Paved	Clay Brook	At the base of hill near intersection w/ Sugarbush Access Rd.	6.5	6	21	<b>29</b>	Entirely	Naturally Straight	About 50 feet from inlet there is a water trap that diverts water into a small waterfall, see picture. Outflow a cascade, pool downstream, steep riffle upstream.
*T9.04 Culvert	Unnamed Access Road	Gravel	Clay Brook	Sugarbush S ski slope upper crossing on gravel access road to slope.	5.5	7.4	23	<b>32</b>	Partially	Naturally Straight	Outflow a free fall, pool downstream, sediment obstructing upstream end.
*T9.04 Culvert	Ski Slope Area	Trail	Clay Brook	Sugarbush S ski slope, near lower lifts to lodge.	10	10	23	<b>43</b>	Entirely	Channelized Straight	Huge culvert under ski area difficult to access, downstream measurements are estimates. Outflow a cascade, pool downstream.
*T9.04 Culvert	Ski Slope Area	NA	Clay Brook	Sugarbush S ski slope middle crossing.	5.8	8.4	23	<b>37</b>	Entirely	Naturally Straight	Outflow a free fall. Pool downstream.
*T9.04 Culvert	Ski Slope Area	NA	Clay Brook	Sugarbush S ski slope (lower crossing)	4	4	23	<b>17</b>	Partially	Mild Bend	A large pool is present at the upstream end of the culvert, likely for water withdrawal. Outflow a cascade.
T9.2-S1.01 Culvert	Sugarbush Access Rd	Paved	Trib to Clay Brook	Down hill near the Alpine Options sign.	6	6	5.33	<b>113</b>	Entirely	Mild Bend	Was lined, but not recently. There is a culvert 50 feet up stream. Outflow a free fall, pool downstream, steep riffle upstream.
T9.2-S1.01 Culvert	Eurich Pond Rd	Gravel	Trib to Clay Brook	At the Southface sign.	3.5	3.5	3	<b>117</b>	Entirely	Channelized Straight	Bottom is rusting out. There is a culvert 50 feet downstream. Outflow at grade, pool downstream, steep riffle upstream.
*T9.2- Culvert	Privet	Gravel	Trib to Clay Brook	At Alpine Options	2.8	2.8	5.33	<b>53</b>	Entirely	Mild Bend	Has a culvert 50 feet upstream. Outflow at grade,

Reach/ Structure Type	Road	Road Type	Stream	Location	Struct Height	Struct Span	Stream Width	% Span/ Stream Width	Floodplain Filled	Stream Approach	Comments
S1.01 Culvert	Drive		Clay Brook	sign.							pool downstream, steep riffle upstream. Upstream end blocked by wood debris.
*T9.3- S1.01 Culvert	Golf Course Path	Paved	Clay Brook Trib	Lower Sugarbush golf course crossing	4	4	12.6	32	Entirely	Mild Bend	Tributary enters just upstream of culvert too steep to access the downstream end. Outflow a cascade. Steep riffle upstream.
*T9.3- S1.01 Culvert	Golf Course Path	Paved	Clay Brook Trib	Middle of the Sugarbush golf course crossing	2	2	12.6	16	Entirely	Sharp Bend	Dam to impound for pond with 2 culverts stacked vertically downstream of dam and under grade control. Stream appeared moved by dam and culverts from its natural location. Outflow a cascade. Upstream end blocked by deformation.
*T9.3- S1.01 Culvert	Golf Course access Rd	Gravel	Clay Brook Trib	Upper Sugarbush golf course	3.7	7.9	12.6	63	Entirely	Mild Bend	Structure concrete box that is breaking up. Upstream end blocked by deformation. Water enters the culvert, then flows through cracks in the floor and exits below the culvert, undermining the downstream end. See photos. Outflow a free fall.
*T9.3- S1.01 Culvert	Sugarbush Access Rd	Paved	Clay Brook Trib	Near Golf Course Rd.	2.5	2.5	12.6	20	Entirely	Sharp Bend	Outflow a free fall, pool downstream. Upstream end blocked by sediment.
*T9.3- S2.01 Culvert	Sugarbush Access Rd	Paved	Rice Brook	Just before Warren House Rest.	7.5	10	16.66	60	Entirely	Mild Bend	Culvert is baffled and has sediment throughout. A beaver dam noted was not made by beavers, but looks similar, no pond at the dam. Outflow at grade, pool downstream, steep riffle upstream.
*T9.3- S2.01 Culvert	Village Rd	Paved	Rice Brook	At intersect w/ Mountainside Dr.	5	5	15	33	Entirely	Mild Bend	Found one small dead Brook Trout. Outflow a cascade, pool downstream, steep riffle upstream, sediment obstructing upstream end.
T9.3-S2.01 Bridge	Sugarbush Path	Trail	Rice Brook	Near parking area N. of lodge on Village Rd.	11	36	16.5	218	Partially	Channelized Straight	This is a path.
T9.3-S2.01 Bridge	Sugarbush Path	Trail	Rice Brook	Near parking area just north of new lodge on Village Rd.	7	14	16.5	85	Partially	Mild Bend	
T9.3-S2.01 Bridge	Trail	Trail	Rice Brook	Behind last condo in Castlerock	5	13	16.5	79	Partially	Mild Bend	Bridge for trail behind condos.
*T9.3- S2.01 Culvert	West Dr	Gravel	Rice Brook	~500' West of West Drive bend, on trail to slopes	2.4	4.6	16.5	28	Partially	Naturally Straight	Incision downstream of culvert caused scour, resulting in a perched culvert. Outflow a cascade. Upstream end blocked by sediment.

The following photographs illustrate examples of structure condition in the study area:



Figure 6.1 Concrete box culvert on T9.3S1.01 for a golf course path. The floor is broken and the stream flows through the cracks and emerges beneath the culvert.



Figure 6.2 Culverts under part of the golf course on T9.3S1.01. A dam is seen on the left then 2 small culverts on right that travel under the golf course.



Figure 6.3 Concrete culverts on T9.3S2.01 for a path. Significant sediment has been trapped upstream and the downstream end is perched above the channel bed.



Figure 6.4 A bridge on T9.3S2.01 for a path with sediment deposition upstream.



Figure 6.5 A dam and culvert on T9.04 adjacent to the ski area. The photo on the left is an upstream view with a dam and pond. The right photo shows the downstream view with a pool and riprap.

## 6.2 Site Level Opportunities

The projects outlined in Table 6.2 meet the criteria for geomorphically compatible projects as outlined in Step 6: Preliminary Project Identification (VTANR, 2007) that could lead the channel to a dynamic geomorphic equilibrium. The listed projects are prioritized based on the benefit to geomorphic stability, technical feasibility, and also considered the site size and location in the watershed. For example, undeveloped floodplain areas downstream of building and road constraints are high priority areas for corridor protection to attenuate flow and sediment transported through the channelized areas. Detailed narratives with project background information and maps follow Table 6.2.

It is important to note that the projects opportunities listed in Table 6.2 were identified through an unbiased, scientifically-defensible approach (step-wise procedure; VTANR, 2007) using the best available data about the watershed and channel conditions. The projects are initially presented in this section without significant knowledge of social constraints to project implementation. A prioritized list of projects, which incorporates information about social constraints gathered during meetings with riparian landowners, is provided in Section 7.0 of this report.

Table 6.2: Mad River Corridor Planning Project and Strategy Summary Table, Reaches M11-M19

<b>Project #, Stream Type, Evolution Stage, RGA, RHA</b>	<b>Site Description and Importance, Including Stressors and Constraints</b>	<b>Project or Strategy Description</b>	<b>Technical Feasibility and Priority</b>	<b>Other Social Benefits (All projects are aimed at achieving RMP goals)</b>	<b>Potential Partners and Costs</b>	<b>Land Use Conversion</b>
<b>M11-1 C III Fair Fair</b>	Along reach 57% straightened, incised (1.8), currently widening. Some parcels already conserved/protected.	Protect stream corridor to allow for flow and sediment attenuation and to improve water and habitat quality. Also to avoid encroachment into the corridor and future expense of protecting those investments.	Feasibility depends on willingness of landowners to cooperate. High priority due to stream sensitivity, extensive straightening, and potential for further encroachment.	Habitat benefits, recreation, hunting, clean water.	RMP, VLT Relatively low cost for corridor acquisition or easement acquisition, or dev. & mgmt. rights	Corridor land use was hay and some crop area.
<b>M11-2</b>	2 areas identified: 1) Old oxbow area, which was connected as recently as 1962 (possibly 1972); 2) upstream of Pine Rd bridge near farm on LB.	Restore incised reach through recapture of abandoned channel areas and/or stream corridor protection. Further study necessary to investigate active channel recapture.	Feasibility depends on willingness of landowners to cooperate. High priority due to presence of abandoned channel areas and relatively little encroachment.	Reduce bank erosion pressure and velocities downstream, improved habitat diversity.	Moderate costs involve corridor easement, recapture of abandoned channel areas. RMP, VLT, Town of Waitsfield.	Wooded oxbow area, some hay and shrubs in other areas.
<b>M11-3</b>	Meadow Road Bridge- currently undersized and only 86% of the bankfull width.	Replace Structure as it is up for replacement.	No major problems were associated with this structure so lower priority.	Reduced flood/erosion risks.	WHIP, Better Back Roads, Town of Waitsfield	None, as bridge already exists.
<b>M12-1 C III Fair Fair</b>	Area upstream of Waitsfield Village near the ball field and straightened section. Also upstream encompassing the M13 reach break. Moderately incised (1.6) and currently widening with bank erosion and bar	Protect stream corridor to allow for passive restoration of the reach and to reduce encroachment. Investigate potential for recapture of meander to west of ball field or possibly to the east, with the backwater at the	High priority due to stream sensitivity, extensive straightening, and potential for further encroachment (this assumes the ball field can move if	Reduce pressure and erosion on LB near residences and Rt 100. Attenuate sediment upstream rather than allowing it	Relatively low cost for easements or corridor purchase. RMP, VLT, Town of Waitsfield, Waitsfield Couples Club.	Ball field- recreation, hay, forest & residential in upstream portion of reach. Potential for

Project #, Stream Type, Evolution Stage, RGA, RHA	Site Description and Importance, Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits (All projects are aimed at achieving RMP goals)	Potential Partners and Costs	Land Use Conversion
	aggradation (esp. at constrictions). 32% straightened.	downstream left bend. In areas with building and road constraints, restore the channel with bed forms and floodplain features in equilibrium with the higher stream power.	necessary); the upstream more wooded part may be a lower priority if development pressure is low.	to transport to the Covered Bridge area.		dev. w/in corridor at upstream end.
<b>M12-2</b>	A breached dam with old abutment on the left bank downstream of the ball field with levee extending onto the floodplain. This should be done in conjunction with corridor protection of M12 and M11 if sediment is allowed to move downstream. Covered Bridge in Waitsfield Village	Remove the dam and widen the levee. Assess the volume of sediment and potential consequences of removing the sediment or allowing it to move downstream. Also assess if grade controls might be necessary to protect against head cutting of the channel. Investigate options for widening the constriction at the Covered Bridge.	High priority because dam is derelict and interrupting sediment transport. Not feasible due to investments in the floodplain and previous work addressing the dam.	Sediment from this area could assist channel evolution downstream.	High if sediment must be removed and if investments must be moved. Town of Waitsfield, RMP.	Just upstream of Village area & covered Br.
<b>M13-1 C III Fair Fair</b>	Some straightening, bank armoring, and confinement by Rt 100. Moderately incised (1.6) and actively widening w/ bank erosion, poorly vegetated buffer. High potential for planform adjustment noted, especially at Lareau Farm area. Some planting has been done, but many trees killed by deer and dry conditions.	Protect stream corridor to allow for passive flood plain and meander redevelopment already underway. Possibly implement an inexpensive corridor planting program due to the poor vegetation.	High priority corridor protection. Protecting the corridor and planting were also the preferred options found in the Field Geology Report (Field, 2007)	Trails, wildlife habitat, improved instream habitat, reduced erosion/flood risks.	Relatively low cost for plant material and easements or corridor purchase. RMP, VLT, Town of Waitsfield, NRCS.	Some hay, parts of corridor are forested.

<b>Project #, Stream Type, Evolution Stage, RGA, RHA</b>	<b>Site Description and Importance, Including Stressors and Constraints</b>	<b>Project or Strategy Description</b>	<b>Technical Feasibility and Priority</b>	<b>Other Social Benefits (All projects are aimed at achieving RMP goals)</b>	<b>Potential Partners and Costs</b>	<b>Land Use Conversion</b>
	Previous owner of current Town parcel may have removed all topsoil.					
<b>M13-2</b>	The area downstream of the swim hole to just downstream of the M13 reach break. In the swim hole area with road constraints, past work constructed stabilization and habitat improvement features.	Protect the stream corridor to allow for sediment and flow attenuation. Possibly implement a corridor planting program due to the poor vegetation.	High priority due to location at the Mill Brook confluence and downstream of the swim hole area which is confined due to the road and upstream of M12 which is a transport reach.	Reduce bank erosion pressure and velocities downstream, improved habitat diversity.	Relatively low cost for plant material and easements or corridor purchase. RMP, VLT, Town of Waitsfield, NRCS.	Right bank terrace appeared to be hay/pasture.
<b>M14-1 Bc to F departure IV Fair Good</b>	Bedrock left bank, possible gorge; semi-confined, but appears to be forming "modern" floodplain area with alluvial benches along channel edges.	Protect stream corridor to allow for continued adjustment and to improve water and habitat quality.	Lower priority due to presence of woody vegetation and perceived lack of development pressure (steep slopes).	Possible area for trails.	Relatively low cost for easement or corridor purchase. RMP, VLT, Town of Waitsfield.	Corridor wooded, except for upper most part where a house sits on the RB (possible area for planting, likely stable due to BR)
<b>M15-1 C IV Good Fair</b>	Some channel straightening, armoring, and encroachment from Rt 100. Adjacent snowmaking pond and withdrawal. "Fair" RGA condition with bedrock providing some vertical and lateral control. Moderately incised (1.4). M15 is taking	Protect stream corridor at the Kingsbury parcel to allow for adjustment, sediment attenuation and to moderate effects from upstream (M16 and Clay Brook) A buffer planting program could help establish buffer away from eroding banks and	Higher priority due to stream sensitivity and also to help compensate for increased stream power from M16. Options mainly on the right bank due to the snowmaking pond on	Reduce bank erosion pressure and velocities downstream, improved habitat diversity.	Relatively low cost. RMP, VLT, Town of Waitsfield, Yestermorrow, MRVPD.	Hay and residential, pond on left bank.

Project #, Stream Type, Evolution Stage, RGA, RHA	Site Description and Importance, Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits (All projects are aimed at achieving RMP goals)	Potential Partners and Costs	Land Use Conversion
	the hit from Clay Bk entering the system just upstream of a confined area of M16. Clay Brook had incision and multiple MFs, sediment is passing through the confined area of M16 and is deposited in M15.	provide stability as the channel migrates.	the left bank.			
<b>M15-2</b>	From the snowmaking pond through the Punch Bowl area down to the confined area of M14. Area is currently aggrading and migrating, but providing valuable sediment attenuation downstream of significant sediment inputs from Clay Brook and the fairly constricted areas in M16 and adjacent to the snowmaking pond, and upstream of the confined M14 reach.	Corridor protection to allow this site to continue to function as an attenuation area. Bedrock grade control at the Punch Bowl with large bars and migration. Stabilize stream banks at Punch Bowl only if preserving the site is desired. This would increase the priority of protecting attenuation assets downstream (M13). RB adjacent to the house had riprap.	High priority to protect the corridor here to help moderate effects of upstream sediment inputs and ski area alterations. Punch Bowl would likely have pools at bedrock areas. Feasibility depends on landowner willingness.	Could preserve public access to the Punch Bowl. Reduce bank erosion pressure and velocities downstream, improved habitat diversity.	RMP, Sugarbush, VLT, Town of Waitsfield.	Hay, shrub-forest, residential
<b>M15-3</b>	Adjacent to the snowmaking pond, a diversion weir is in the channel with a flume and water withdrawal. Some riprap present.	Remove the snowmaking pond, or improve the withdrawal area to reduce sediment build-up and annual dredging. Study alternatives to the weir for filling and monitoring for the snowmaking pond. Remove riprap opposite the	Contingent on corridor protection and landowner willingness to participate.	Reduce sediment buildup and need for dredging at the weir, reduce pressure on opposite banks, improve habitat diversity.	Unsure of costs associated with water withdrawals and associated flow-monitoring equipment. Further investigation needed.	Appeared to be hay, some residential

Project #, Stream Type, Evolution Stage, RGA, RHA	Site Description and Importance, Including Stressors and Constraints	Project or Strategy Description	Technical Feasibility and Priority	Other Social Benefits (All projects are aimed at achieving RMP goals)	Potential Partners and Costs	Land Use Conversion
		snowmaking pond to reduce pressure and chance of avulsion into the pond. Possibly gain/recreate some floodplain on the right bank adjacent to the snowmaking pond and/or on the left bank just downstream of the Rt 100 bridge.				
<b>M15-4</b>	Warren Trestle Bridge has sediment deposition upstream, stepped footers and deteriorating abutments.	Replace structure with an appropriately sized bridge.	The Town of Warren and VTRANS have been working to find a larger trestle bridge and have apparently located one.	Keeping the trestle style will preserve that icon of the valley.	David Hoyne at VTRANS, Town of Warren	None, bridge already exists.
<b>M16-1 C-F departure III Fair Fair</b>	Channel experienced a stream type departure of C to F (incision 2.1, entrenchment 1.2) and has lost floodplain access. Altered by channel straightening and bank armoring, and constriction from Rt. 100, increasing stream power. Some riprap being undermined. Area upstream of Riverside Park is heavily armored on left bank.	Protect corridor in the vicinity of Riverside Park to allow for channel adjustment and sediment attenuation. Depositional reach currently has limited sediment attenuation areas, which exacerbates sediment deposition problems in downstream reach at Snowmaking Pond.	Feasibility depends on willingness of landowners to cooperate. High priority as this is one of the few areas until M15 where sediment attenuation is possible.	Improved biotic habitat and reduced sediment loading of Mad River watershed to Winooski and Champlain Basins. Reduced risk of future structural damage.	Town of Warren, RMP, MRCP. Cost of corridor acquisition or easement acquisition. Or dev. & mgmt. rights	Limit structural development of Riverside park.
<b>M16-2 C-F departure</b>	Channel experienced a departure of C to F (incision 2.1, entrenchment 1.2) and	Protect corridor in the upper reach to allow for channel adjustment and sediment	Feasibility depends on willingness of landowners to	Improved biotic habitat and reduced sediment	RMP, MRCP. Cost of corridor acquisition or	Convert low-intensity agricultural

<b>Project #, Stream Type, Evolution Stage, RGA, RHA</b>	<b>Site Description and Importance, Including Stressors and Constraints</b>	<b>Project or Strategy Description</b>	<b>Technical Feasibility and Priority</b>	<b>Other Social Benefits (All projects are aimed at achieving RMP goals)</b>	<b>Potential Partners and Costs</b>	<b>Land Use Conversion</b>
<b>III Fair Fair</b>	has lost floodplain access. Armoring in upper reach along Rodger's parcel.	attenuation. Remove bank armoring on left bank where future meanders will not impact Route 100.	cooperate. High priority because attenuation areas are limited in reach.	loading of Mad River watershed to Winooski and Champlain Basins.	easement acquisition. Or dev. & mgmt. rights	lands to forest.
<b>M16-3 C-F departure III Fair Fair</b>	Channel experienced a departure of C to F (incision 2.1, entrenchment 1.2) and has lost floodplain access. Altered by channel straightening and bank armoring, and constriction from Rt 100, increasing stream power. Some riprap being undermined.	In areas without building and road constraints, restore incised section of reach through "active" restoration of bed forms and/or floodplain features in equilibrium with channel bed elevation and increased stream power. Protect the stream corridor and plant buffer vegetation in conjunction with restoration projects.	Medium – high priority as there is no recently abandoned floodplain, but there are some potential areas where floodplain could be lowered. Appears to have been depositional reach in past.	Improved biotic habitat and reduced sediment loading of Mad River watershed to Winooski and Champlain Basins.	RMP Relatively high to excavate new floodplain. Additional costs in corridor easements/acquisition & plantings	Convert low-intensity agricultural lands to forest.
<b>M17-1 B to F departure IV Fair Good</b>	Reach is in a bedrock gorge with some aggradation observed. Wooded buffer is greater than 100 feet. 50 Feet of riprap was on the left bank at the Bradley Brook confluence.	Protect stream corridor to prevent encroachment and buffer clearing.	Low priority for corridor protection due to the wooded corridor and unlikely encroachment pressure.	Maintained buffer for input of LWD and shading for biotic habitat.	RMP, MRCP Cost of corridor acquisition or easement acquisition.	Largely forested corridor.
<b>M18-1 Ba I Fair Good</b>	Reach in a rock gorge downstream of the Warren Crib Dam and confined by bedrock banks. Channel adjustment is unlikely due to bedrock. Some of the	Protect the woody vegetation in the corridor to prevent further clearing. Possibly plant buffer in area just downstream of M19 reach break.	Low-Medium priority for protection because current encroachment has not impacted channel stability (due to bedrock controls).	Preserves wooded setting of the village. Maintained buffer for input of LWD and	Town of Warren. Low cost to implement policy.	Residential, Warren Village. No "conversion" would be needed - only

<b>Project #, Stream Type, Evolution Stage, RGA, RHA</b>	<b>Site Description and Importance, Including Stressors and Constraints</b>	<b>Project or Strategy Description</b>	<b>Technical Feasibility and Priority</b>	<b>Other Social Benefits (All projects are aimed at achieving RMP goals)</b>	<b>Potential Partners and Costs</b>	<b>Land Use Conversion</b>
	Warren Village development encroaches into the corridor.			shading for biotic habitat.		new develop. limited.
<b>M19A-1 C-F departure III Fair Fair</b>	Stream corridor included residential development, roads, and low buffer width. A departure from C to F had occurred and the channel lacks floodplain access (incision 2.01). May have been a B type before the crib dam.	Adopt a no filling or cutting in the stream corridor policy to prevent further encroachments.	High feasibility. High priority due to current level of fill and development.	Maintained buffer for input of LWD and shading for biotic habitat. Reduced property damage.	Town of Warren. Low cost to implement policy.	Residential, Warren Village. No "conversion" would be needed - only new develop. limited.
<b>M19A-2 C-F departure III Fair Fair</b>	This segment has been straightened and partially armored and is influenced by sedimentation upstream of the Crib Dam. Channel is aggrading and attempting to widen but hindered by riprap application.	Remove Crib Dam. Investigate whether allowing some of the coarse gravel sediment to move downstream would cause negative impacts to infrastructure or channel adjustments downstream.	High priority due to the structure being non-essential. Recommended to be done in conjunction with corridor protection of sediment attenuation areas downstream (i.e., reach M16).	Improved biotic habitat and fish migration. Reduced flood/erosion risks. Improvement of incision in downstream reaches (M16)	High cost, especially if sediment needs to be removed. Town of Warren, RMP, USCOE	Possibly controversial due to age of dam/historical nature. Some residential properties and lawns may be reconfigured for new channel dimensions.
<b>M19A-3</b>	Covered Bridge north of Warren Village. Channel is aggrading and attempting to widen but hindered by riprap application.	Replace covered bridge or widen the bridge footings to accommodate the equilibrium channel width.	High priority if crib dam removed due to bed changes and potential increased adjustments.	Improved biotic habitat. Reduced flood/erosion risks. Improvement of incision in downstream reaches (M16)	VTAOT, Town of Warren	Possibly controversial due to historic significance of bridge. No major land use conversion required.

<b>Project #, Stream Type, Evolution Stage, RGA, RHA</b>	<b>Site Description and Importance, Including Stressors and Constraints</b>	<b>Project or Strategy Description</b>	<b>Technical Feasibility and Priority</b>	<b>Other Social Benefits (All projects are aimed at achieving RMP goals)</b>	<b>Potential Partners and Costs</b>	<b>Land Use Conversion</b>
<b>M19A-4</b>	Stream corridor included residential development, roads, and low buffer width. Project area is upper segment from bedrock controls down to riprap on left bank - length approx. 500 feet.	High priority corridor protection in upper segment. Prevent further structural development and plant woody buffer.	Difficult due to numerous small parcels and existing encroachments.	Improved biotic habitat. Reduced flood/erosion risks.	Low - cost of plant materials and volunteers. Town of Warren, RMP, FMR, Landowners	Some lawns and yards would be converted to woody buffer.
<b>M19B-1 C-F III Fair Fair</b>	Upstream of Rt 100 - Channel is overwidened and confined by Route 100. The channel is incised (IR=2.8) and has riprap preventing bank erosion and transferring power downstream. Two bedrock ledges control the grade at the downstream end.	Restore the incised reach through protecting the corridor on the left bank if possible and recreate some floodplain on the left bank, either through floodplain lowering or installation of sediment trapping grade control structures to attenuate flow and sediment.	Medium high priority as constraints and constrictions exist with limited options from this area downstream past the snowmaking pond. This is the last area before Warren Village to reduce velocities or attenuate some sediment.	Improved biotic habitat. Reduced flood/erosion risks.	High cost to lower floodplain. RMP	Current Bobbin mill and access road would likely require relocation, unless benefits can be gained from the small terrace areas downstream on left bank
<b>M19B-2</b>	The Rt 100 bridge at the downstream end has a wide span at the roadbed, however large amounts of riprap fill the channel and floodplain sides in a trapezoid shape.	Widen rip rapped banks to reduce flood flow constriction and sediment discontinuity.	Requires coordinating with VTRANS. Moderate costs associated with rock removal.	Reduced erosion pressure on banks upstream of bridge.	VTRANS, VTAOT. Cost of Equipment and stabilization materials.	Not significant.

Abbreviations:

RB/LB: Right Bank/Left Bank (facing downstream)

MF: Mass Failure

## 6.2.1 Potential Project Summaries

The following list of potential projects details those outlined in Table 6.2, in order of reach (beginning downstream) and project number. The narratives include background scientific information about the reach and site-specific mapping.

### Reach M11

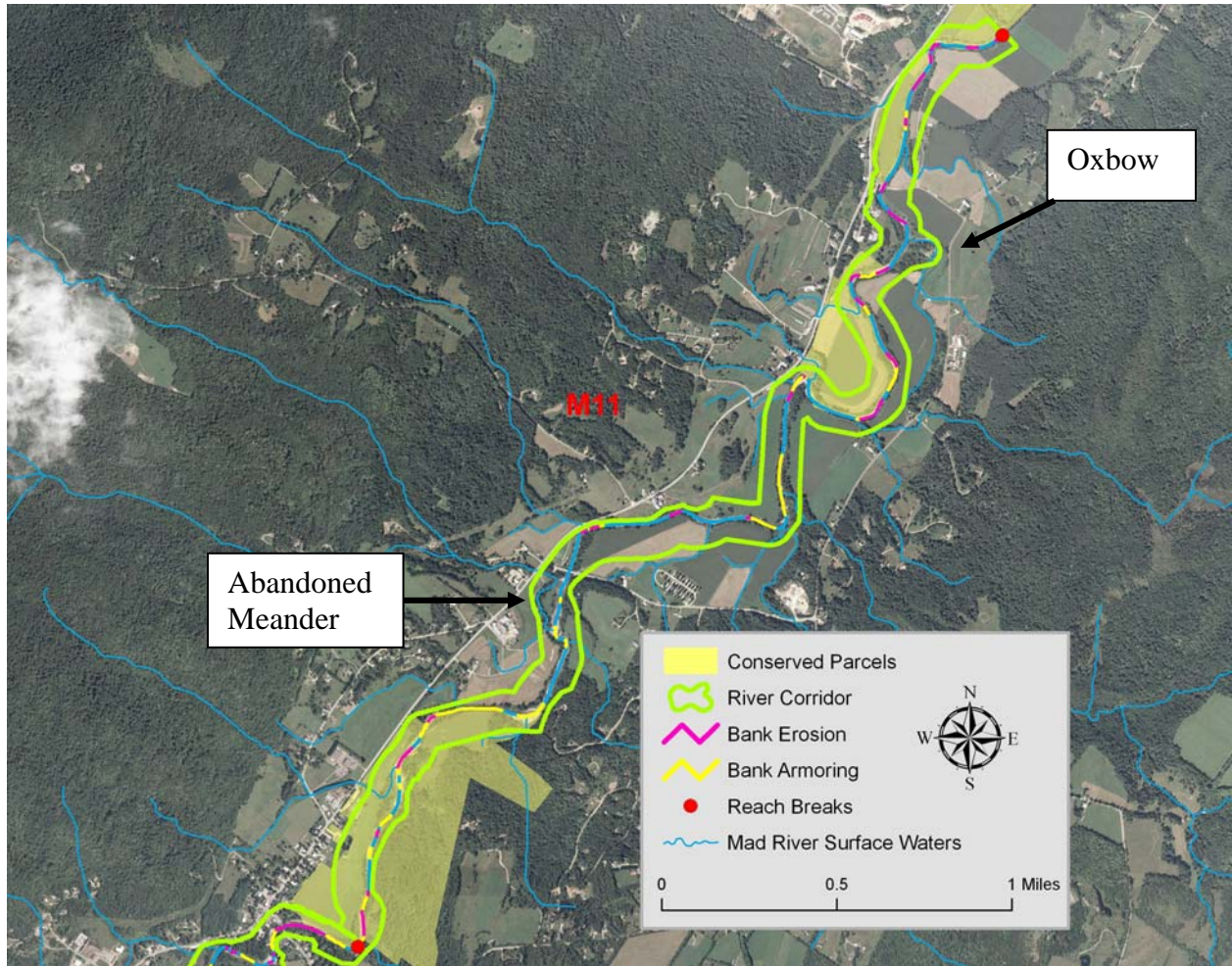


Figure 6.6 Map showing reach M11 with the corridor, areas of bank armoring and areas of bank erosion.

The river corridor appeared largely undeveloped, especially the downstream end. Adjustment to equilibrium conditions in the near term (30 years) is possible, especially if riprap were removed. This reach was mainly affected by straightening, (57% of the reach), and lack of buffer vegetation (Field, 2007). The channel was incised, (incision ratio 1.8), with floodplain access limited to higher discharges. The current channel adjustment process appeared to be widening. Lateral channel movement is evidenced by bank erosion but has been limited by riprap bank armoring (Figure 6.6). Sediment supply did not appear to be significantly reduced, in fact sediment in the reach appeared to be increased after the 1998 flood. Sediment accumulation was noted at bends and constrictions, with the straightened areas transporting sediment. Japanese

knotweed was also noted as the main bank vegetation type, doing little to help stabilize banks. Some buildings and sections of road were in close proximity to the channel. Riprap was noted on approximately 10% of the channel length, but did not completely armor the bed and banks. Agriculture was the main land use in the riparian area.

### **M11-1 Protect Stream Corridor**

Protect the stream corridor to allow for flow and sediment attenuation and to improve water and habitat quality. Protecting the corridor can also help to avoid encroachment into the corridor and future expense of protecting those investments. Planting expensive bank vegetation is not recommended due to bank instability, erosion, and channel adjustments. Planting away from the banks at the outer edges of the corridor is a possibility.

In areas without infrastructure or land use constraints, restore the incised reach passively through river corridor protection to accommodate passive floodplain and meander redevelopment. Pursue the removal of encroachments and/or riprap where they exist to enhance the adjustment to geomorphic equilibrium.

### **M11-2 Restore Incised Reach Through Recapture of Abandoned Channel Areas, Protect Stream Corridor**

Two areas with abandoned channels were identified in reach M11 with the potential for recapture as a restoration tool to reduce stream power: the Oxbow, and the abandoned meander at the Tremblay Road Bridge area (Figure 6.6). Protecting the corridor in these areas in conjunction with abandoned channel recapture is recommended. If recapture of the abandoned channels is not possible, protecting the corridor as a stand-alone project will allow the channel to migrate into these areas in the long-term.

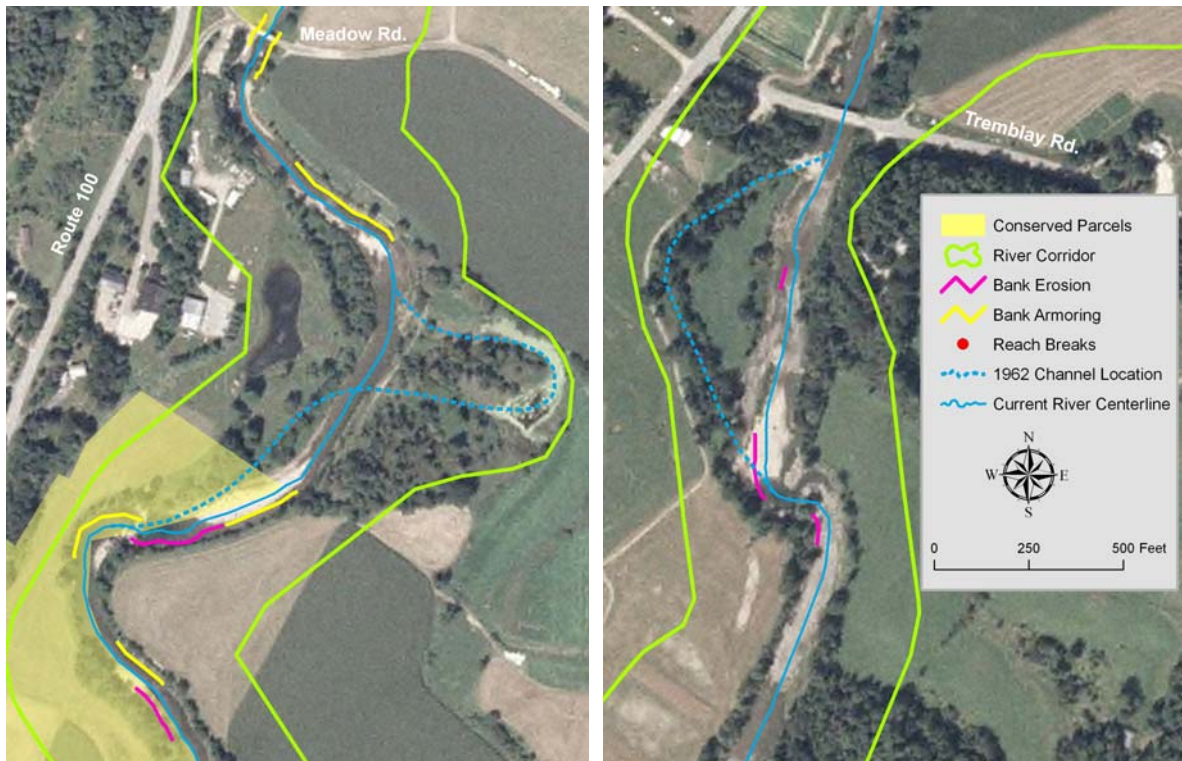


Figure 6.7 Oxbow area in Reach M11.

Figure 6.8 Abandoned meander area in M11.

The Oxbow area (Figure 6.7) was toward the downstream end of the reach, on the right bank just upstream of the Meadow Road Bridge. Aerial photos show this area was connected to the main channel as recently as 1962 (possibly 1972).



Figure 6.9 Looking west at the Oxbow area from North Road with the channel in the distance beyond the trees. Note the water in the oxbow.

The area between the oxbow and the channel was wooded. The only obvious land use constraint to channel reconnection was a recreation path between the current channel and the oxbow. The path would need to be rerouted to the east of the oxbow.

A pond and possible old meander scars were on the left bank in this area. Some small hay fields were in the pond area. Protecting the corridor here is recommended to allow for any future channel migration back into the area.

The second potential channel recapture area was just upstream of the Tremblay Road Bridge (Figure 6.8). Just upstream of the bridge, an abandoned meander was on the west side of the river, with a small hay field separating it from the river. Access to this small field appeared difficult, having to cross a tributary. The abandoned meander had standing water and appeared to have a channel bed at a higher elevation than the current bed, although no measurements were taken. Recapturing this meander through opening up the upstream plug, or allowing the stream to eventually recapture it, could allow for reduced velocities and sediment attenuation in the area.



Figure 6.10 Looking upstream, the main channel is to the left with an abandoned meander on the far right, essentially following the tree line.

The abandoned meander would reenter the channel just upstream of the bridge. Pressure appeared to be on the right bank in this area already, signaled by thalweg location and riprap present on the bank. Pressure on this bank could be increased by recapture of this meander bend.

### **M11-3 Replace Structures**

Two bridges cross reach M11 and are highlighted in Table 6.1. The Meadow Road Bridge is currently undersized and only 86% of the bankfull width. Current RMP recommendations call for structures to be at least 1.0 times bankfull width. In this case, the Meadow Road Bridge would need to be at least 83 feet wide to meet these recommendations. No other problems were associated with this structure at the time of assessment, so resizing this bridge as it is up for replacement is recommended.

### **Reach M12**

The river corridor was largely undeveloped, except for the downstream portion in Waitsfield Village. The channel appeared incised (incision ratio 1.6) and currently widening, lacking access to floodplain except in large floods (Field, 2007). The upstream portion of the reach was more confined, leaving the lower portion adjacent to the ball field as the best opportunity for channel migration in this reach. The channel may adjust to equilibrium conditions in the near term (30 years), but may take longer due to high sediment transport capacity (Field, 2007) resulting from channel straightening. Protect the stream corridor to allow for channel adjustment and return to a meandering planform, but other activities are also recommended. Because the reach is undergoing adjustments, planting stream buffers is recommended only in conjunction with the overall restoration plan.



Figure 6.11 Straightened section of M12 between the ball field and Waitsfield Village.

### **M12-1 Protect Stream Corridor**

Due to straightening in the reach (Figures 6.11, 6.12), especially near the ball field, attenuation areas were almost absent and stream power was increased. Sediment moves downstream where it is deposited upstream of the old dam and covered bridge. If attenuation areas could be found or created upstream, such as at the recreation fields, pressure and sediment accumulation could be reduced at the covered bridge.

As seen in 1921 topographic maps and digitized over current orthophotos (Figure 6.12), the channel had been to the west of the ball field. The ball field is an important community asset, however it may need to be relocated if the channel migrates, or if it were possible to recapture the old meander to the west of the field. This area would be an important sediment attenuation asset to reduce pressures at the historical covered bridge if it were allowed to meander and function geomorphically. While ball fields are important for the community, a better use of this area in the long run would be as an attenuation area for the Mad River. The town is encouraged to look for alternative locations for the ball fields so that geomorphic function can be restored to this area.

Investigate the possibility for recapture of the old channel to the west of the ball fields. Another old meander scar is upstream of the covered bridge and dam abutment on the right bank. This old meander could be recaptured to decrease slope and allow for sediment attenuation. The current land use around the old meander appeared to be woody/shrubby vegetation, so no change of land use would be necessary for this meander recapture. Protecting the corridor is an important step as this old meander is contained within the corridor.

If active meander recapture is not possible, protect the corridor to allow for passive restoration, with consideration for protection of the few buildings existing in the corridor. The sediment supply appears high enough for passive restoration to be effective, but actively capturing the meander to the west of the ball field and the meander upstream of the covered bridge may be used to provide more immediate results.

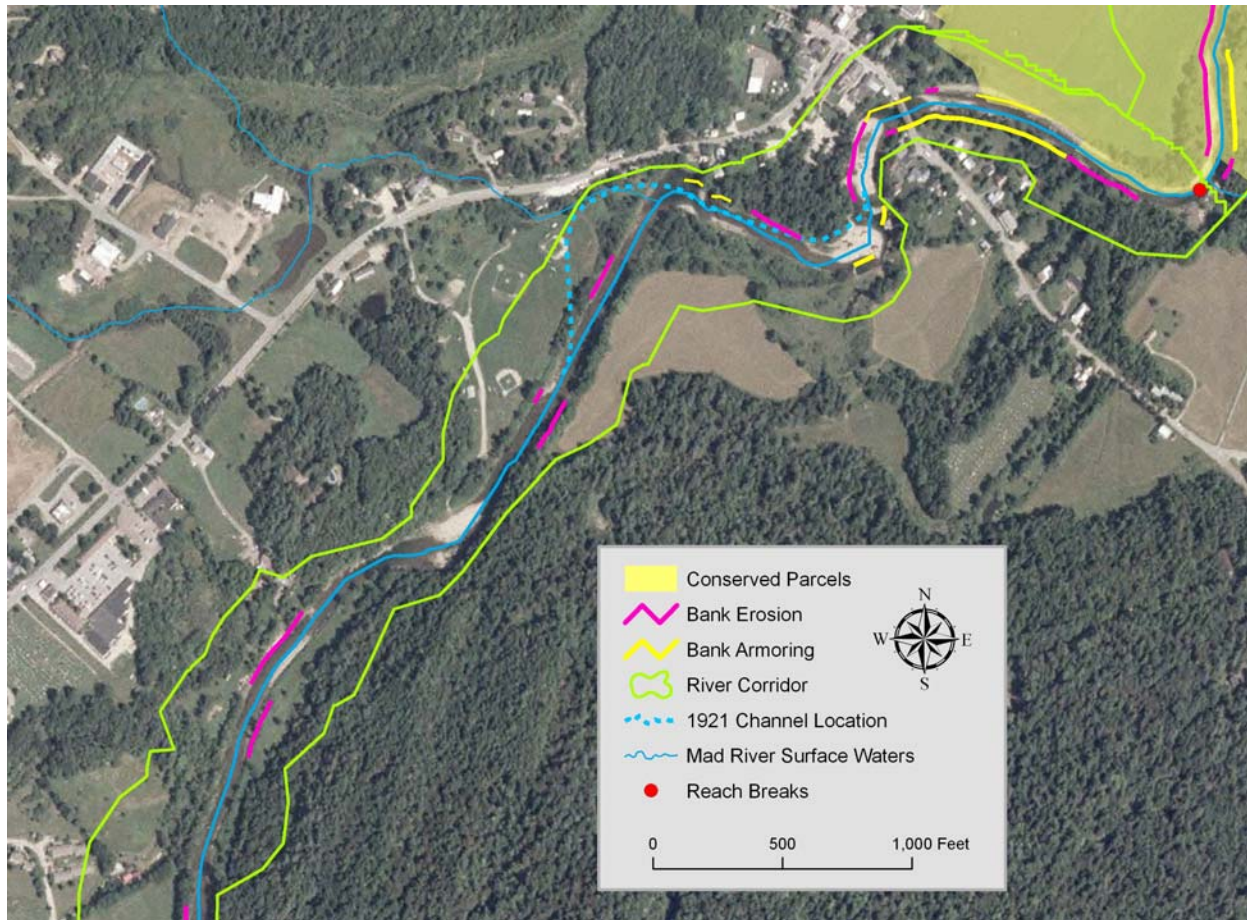


Figure 6.12 Lower portion of reach M12 with apparent channel straightening upstream of Waitsfield Village.

### **M12-2 Remove Dam and Levee, Investigate Options for Covered Bridge**

An abutment for a derelict dam on the left bank upstream of the Waitsfield covered bridge constricts the channel (with bedrock on the right bank). A levee extends from the dam abutment to the west across the floodplain to protect development in the floodplain at the south end of the village. Most of the dam has been removed, however an abutment and the levee remain on the left bank. Additional relief in this area could come from removing the dam abutment and widening the levee opening adjacent to the abutment to allow for some floodplain access while still protecting the floodplain development in Waitsfield Village. Sediment upstream of the dam could erode and increase channel adjustment downstream, but that would not be inconsistent with the adjustments in M11 (incised, now widening) and could assist in moving that reach toward equilibrium.

Given the previous work to address the dam, and the heavy floodplain development in Waitsfield Village, the dam abutment and levee are likely to persist in order to protect the investments in the village. Additionally, an historical covered bridge spans the channel just downstream of the dam and levee. The covered bridge sits on a bedrock outcrop on the left bank and stone abutment on the right bank. Widening the bridge may not be feasible due to the bedrock left bank and a house in close proximity to the bank on the right. Therefore this constriction is likely to persist as well but investigating options is recommended. Mitigating the effects of these two channel

constrictions by allowing sediment deposition and channel migration upstream as well as downstream can be achieved through corridor protection and removing as many encroachments as possible in the area.



Figure 6.13 Photo looking upstream at the dam abutment on the right and a bedrock outcrop on the left and extreme sediment build up.

### **Reach M13**

Reach M13 appeared incised (incision ratio 1.6) and currently widening with much bank erosion (Field, 2007). The river corridor was largely undeveloped, but Route 100 encroached into the corridor as well as some buildings (Lareau Farm), and agricultural fields. The channel is likely to continue adjustment due to a high sediment load and inputs from upstream, and the high potential for planform adjustment noted (Field, 2007). The bridge for Route 100 is likely to persist in its current location, therefore the riprap on the left bank at the Lareau Farm house directing the river toward the bridge is likely to persist. Removal of this riprap is likely not feasible in the foreseeable future due to the need to retain the Route 100 crossing. In addition to directing the stream toward the bridge, the riprap also protects the historical Lareau Farm house.

#### **M13-1 Protect Stream Corridor**

Protect stream corridor to allow for passive flood plain and meander redevelopment already underway as seen in Figures 6.14 and 6.15. Corridor protection is recommended with high priority areas being at the Mill Brook confluence and upstream of the Route 100 bridge (Lareau Farm) due to aggradation and channel migration observed in those areas (Field, 2007). Protecting the corridor and planting were also the preferred options found in the Field 2007 Report.

Possibly implement an inexpensive corridor-planting program due to the poor vegetation. Poor buffer vegetation accounts for some of the bank instability (Field, 2007) but because the channel is undergoing adjustments, expensive buffer revegetation procedures are not recommended. Inexpensive buffer re-establishment methods include protecting the corridor, planting small,

bare-root plantings near the channel and possibly planting more and larger trees toward the outer edges of the corridor. This ideally will allow the trees time to mature before the channel migrates to the outer edges of the corridor.

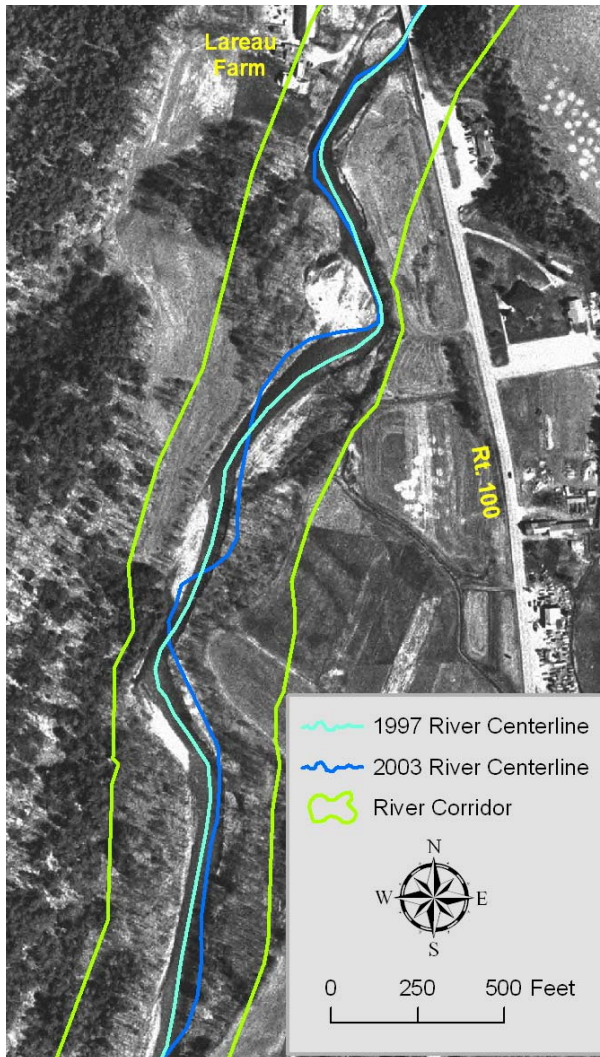


Figure 6.14 1997 orthophoto with stream centerlines.

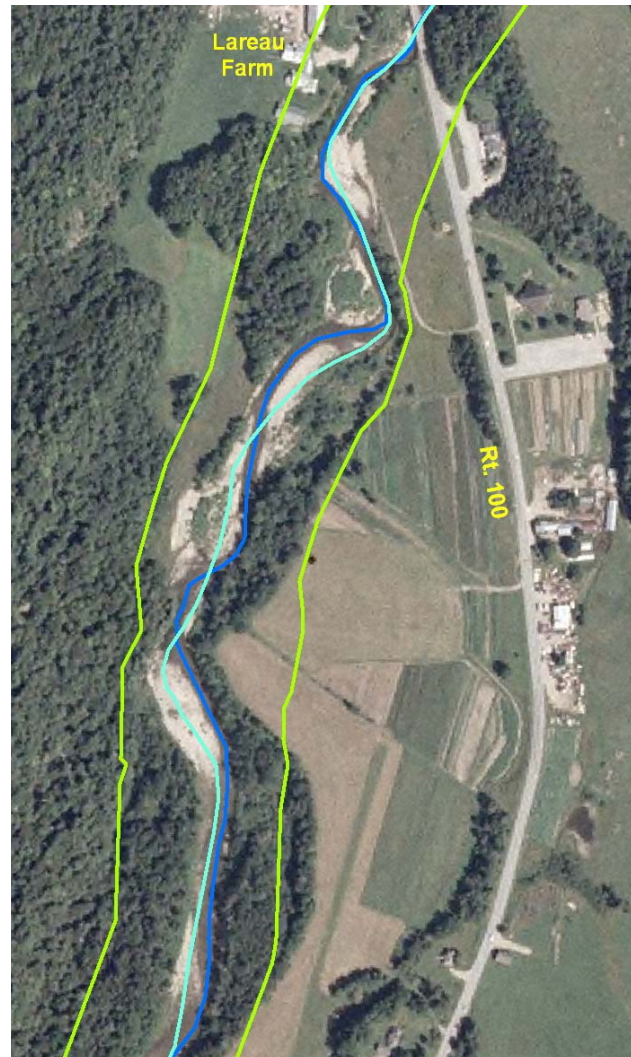


Figure 6.15 2003 orthophoto with stream centerlines.

### **M13-2 Protect Stream Corridor**

Protect the stream corridor to allow for sediment and flow attenuation in the area downstream of the swim hole and upstream of the M12 reach break. In the swim hole area with road constraints, past work included the construction of bank stabilization and habitat improvement features. Downstream of these constraints and bank armoring, the channel is migrating laterally as evidenced by eroding banks on outside meander bends and bar development (Figure 6.16).

River corridor protection is recommended as a high priority here to compensate for the channelized sections along the road and swim hole area and to allow for passive flood plain and meander redevelopment. Also, due to its location upstream of M12, which is a transport reach, this area is of high priority for sediment attenuation.



Figure 6.16 Bars and migration in reach M13 downstream of the Lareau Swim Hole.

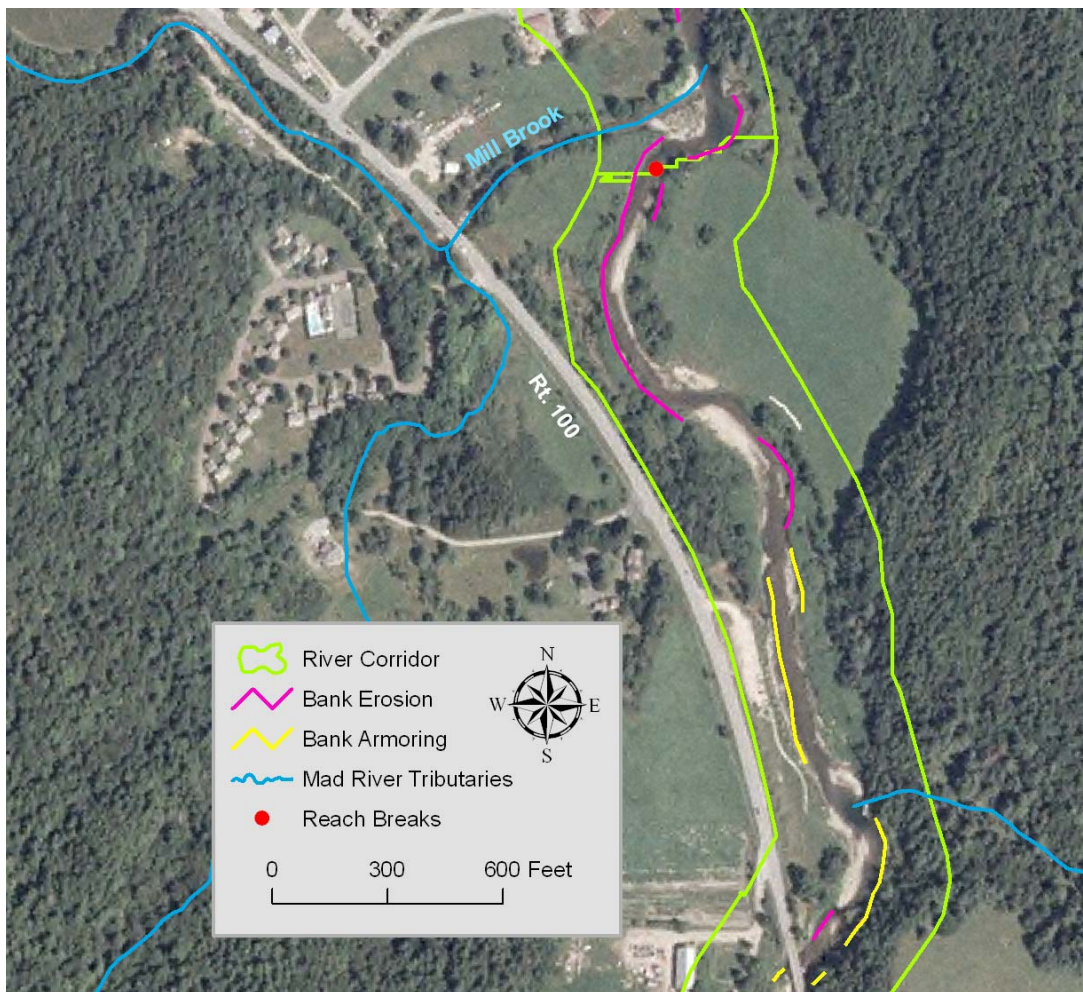


Figure 6.17 Lareau Swim Hole site map.

## Reach M14

A floodplain terrace had evolved but was washed away in the 1998 flood. Now the channel appears much wider without a floodplain area (departure from B<sub>c</sub> to F; Figure 6.18). Some fine sediment, mid-channel bars, and diagonal riffles were starting to form. The sediment regime appeared to be mostly transport with slow aggradation that will eventually rebuild the terrace. Although the channel geometry of this reach indicates a stream type departure (STD), there is little evidence that this reach will be susceptible to significant adjustments. Its setting in a confined valley will limit severe vertical and lateral adjustments.



Figure 6.18 View of Reach M14 looking downstream.

### M14-1 Protect Stream Corridor

Protect the stream corridor along the reach to allow for continued adjustment and to improve water and habitat quality. This project is a lower priority due to the presence of woody vegetation and the perceived lack of development pressure in the corridor due to steep slopes (Figure 6.19).

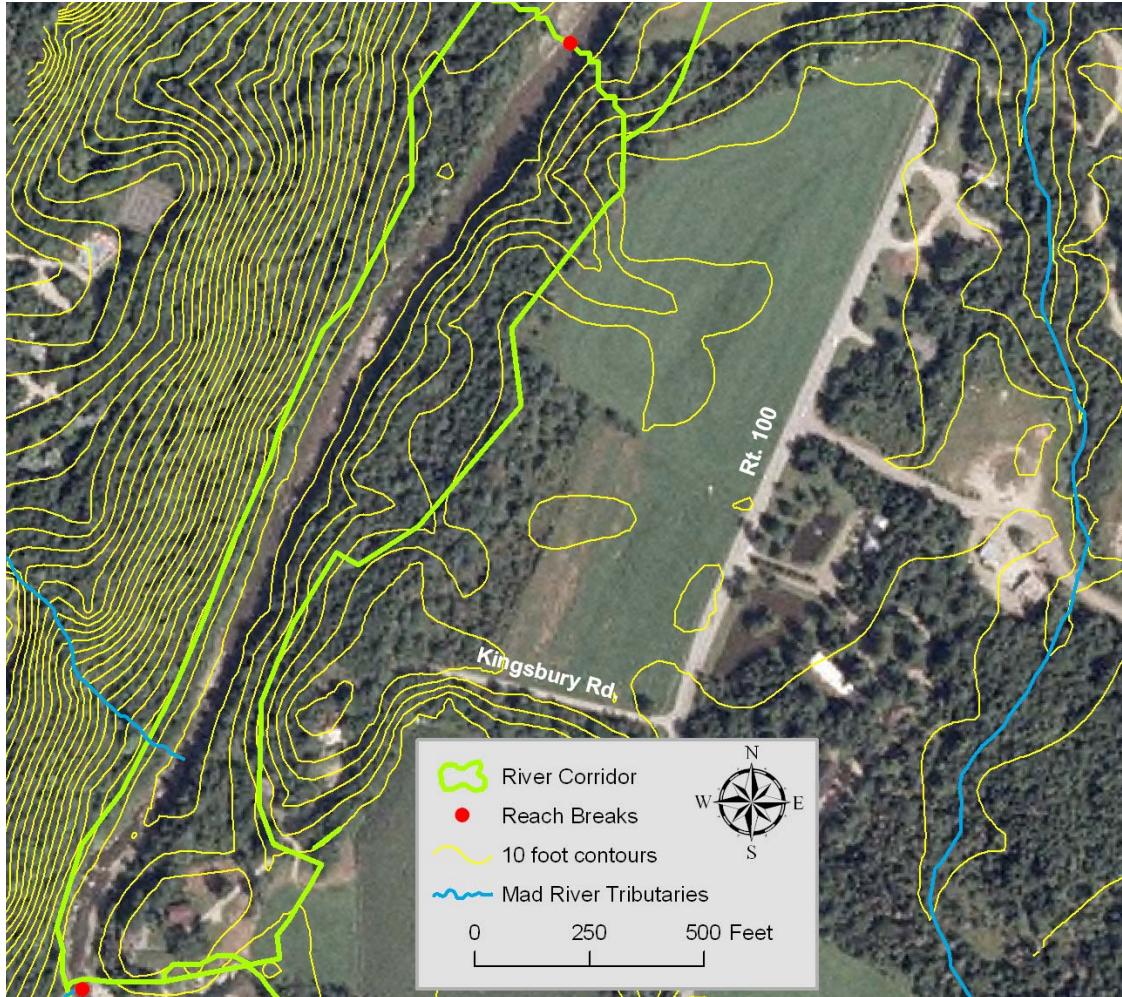


Figure 6.19 Reach M14 map with topographic lines showing the steep slopes in the corridor and confined nature of the channel in this reach.

## Reach M15

Reach M15 is the first potential area to attenuate high sediment loads produced in Clay Brook. Clay Brook enters the Mad River toward the downstream end of reach M16, which then flows through a fairly confined area, then under the Warren Trestle Bridge and in to reach M15. In the 1998 flood, the area downstream of the Warren Trestle Bridge flooded. A bulldozer “cleaned out” the channel and riprap was placed on the right bank. Knotweed is colonizing the left bank.

Upstream, Clay Brook is affected by large increases in sediment and runoff from development and ski area activities and has multiple mass failures in its downstream sections adding to the sediment load. Reach M15 would be the natural sediment attenuation area, however confinement by the snowmaking pond and dredging for the flume interrupt channel processes here. The pond receives groundwater running off of the hill, which would otherwise flow into the river. Waitsfield is concerned about the pond breaching or being captured by the channel, as it did in the 1998 flood.

Removal of the snowmaking pond would help move the channel toward equilibrium and allow for moderation of effects from upstream including attenuation of the excess sediment. If removal of the pond is not feasible, the value and importance of other potential attenuation areas along M15 is increased.

### M15-1 Protect Stream Corridor

Protect stream corridor at the Kingsbury Parcel to allow for adjustment, sediment attenuation and to moderate effects from upstream (M16 and Clay Brook). A buffer planting program could help establish buffer away from eroding banks and provide stability as the channel migrates.

Please see Appendix 2 for more detailed description of proposed project for the Kingsbury Parcel.

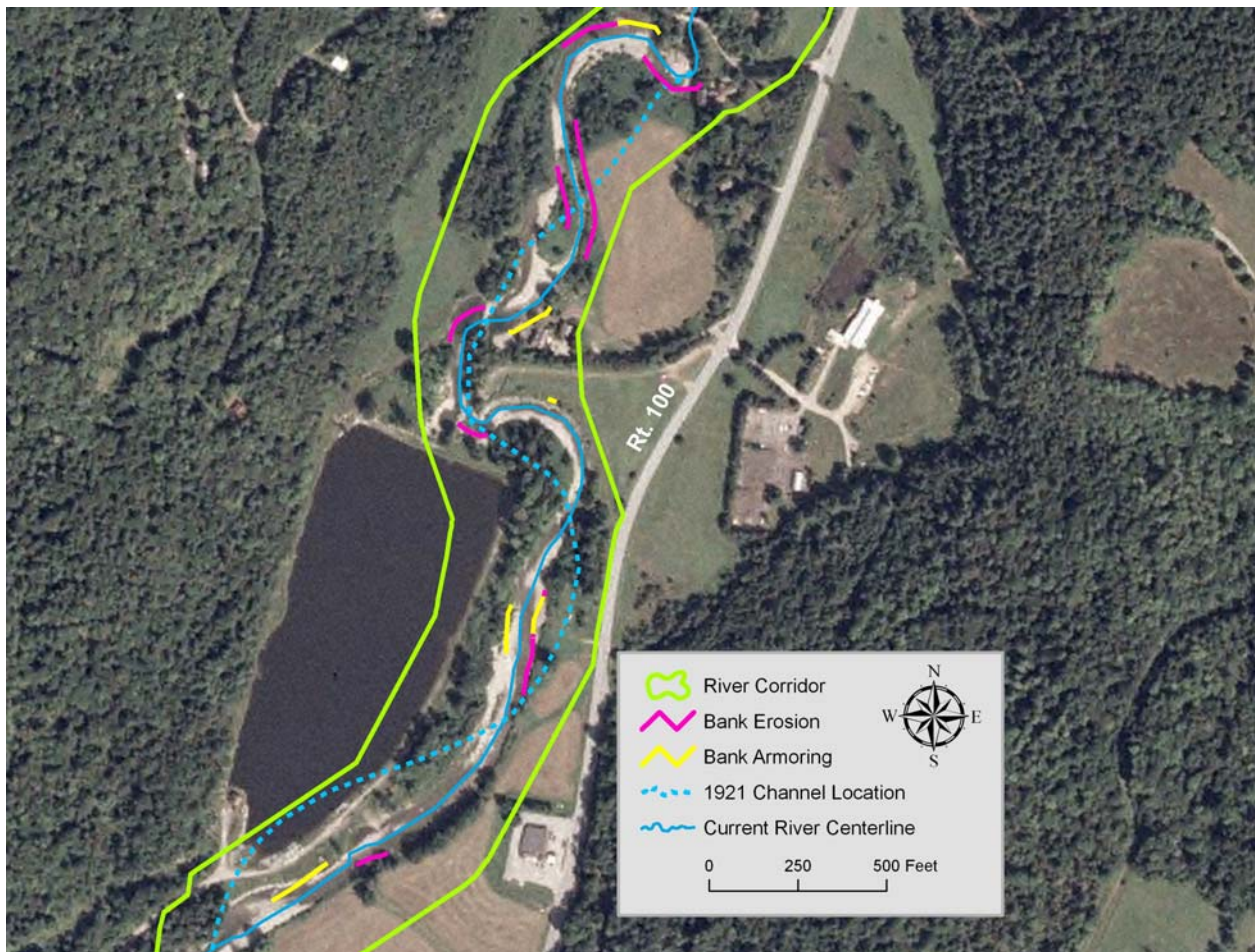


Figure 6.20 Corridor in the area adjacent to the snowmaking pond and the Punch Bowl. Note the large gravel bars and channel migration/straightening since 1921.

### M15-2 Protect Stream Corridor

This corridor protection project focuses on the area from the snowmaking pond downstream through the Punch Bowl to the confined area of M14. This area is currently aggrading and migrating where it is not confined (Figure 6.20). A bedrock grade control is at the Punch Bowl

with large gravel bars and migration. It is providing valuable sediment attenuation downstream of the significant sediment inputs from Clay Brook and the fairly constricted areas in M16 and adjacent to the snowmaking pond, and upstream of the confined M14 reach. Some riprap was present on the east side of the river to protect the house.

Corridor protection is recommended as a high priority to allow this site to continue to function as an attenuation area. Stabilize stream banks at Punch Bowl only if preserving the site in its current state as a public swim hole is desired. This would increase the priority of protecting attenuation assets downstream (M13). Stabilizing the stream banks is not recommended and may not be necessary to preserve pools as the bedrock at the Punch Bowl will likely continue to provide pool areas.

### **M15-3 Remove Diversion Weir, Rip-rap, Recreate Floodplain**



Figure 6.21 Bar forming adjacent to the snowmaking pond as the channel attempts to adjust. Dredging of the bar and sediment limit the adjustment ability of the channel here.

Full restoration of channel equilibrium in this reach requires the removal of the snowmaking pond to allow for lateral channel adjustments and geomorphic function. This is not likely feasible in the short-term, however improvement of the withdrawal area to reduce sediment build-up and annual dredging may be feasible in the short-term. Pursue removal of riprap opposite the snowmaking pond to reduce pressure and chance of avulsion into the pond. Possibly gain/recreate some floodplain on the right bank adjacent to the snowmaking pond and/or on the left bank just downstream of the Route 100 Bridge. If the weir were removed, bar development on the left bank would likely continue (Figure 6.21), inducing channel migration to the right bank.

Study alternatives to the weir for filling and monitoring for the snowmaking pond. The weir has a limited life span and, recognizing that, combined with the negative impacts on stream geomorphology, an alternative approach to filling the pond should be ready to implement when the current weir fails or is damaged by a flood event.

## M15-4 Replace Structures



Figure 6.22 Warren Trestle Bridge

The Warren Trestle Bridge at the Route 100 crossing was up for replacement. Warren wanted to preserve the trestle style, as it is an icon of the valley and acts as a traffic-calming device. VTRANS has apparently located a larger trestle structure.

Replace trestle bridge with a similar one having a greater span to preserve the character while improving sediment continuity and lessening the constraint is recommended.

## Reach M16

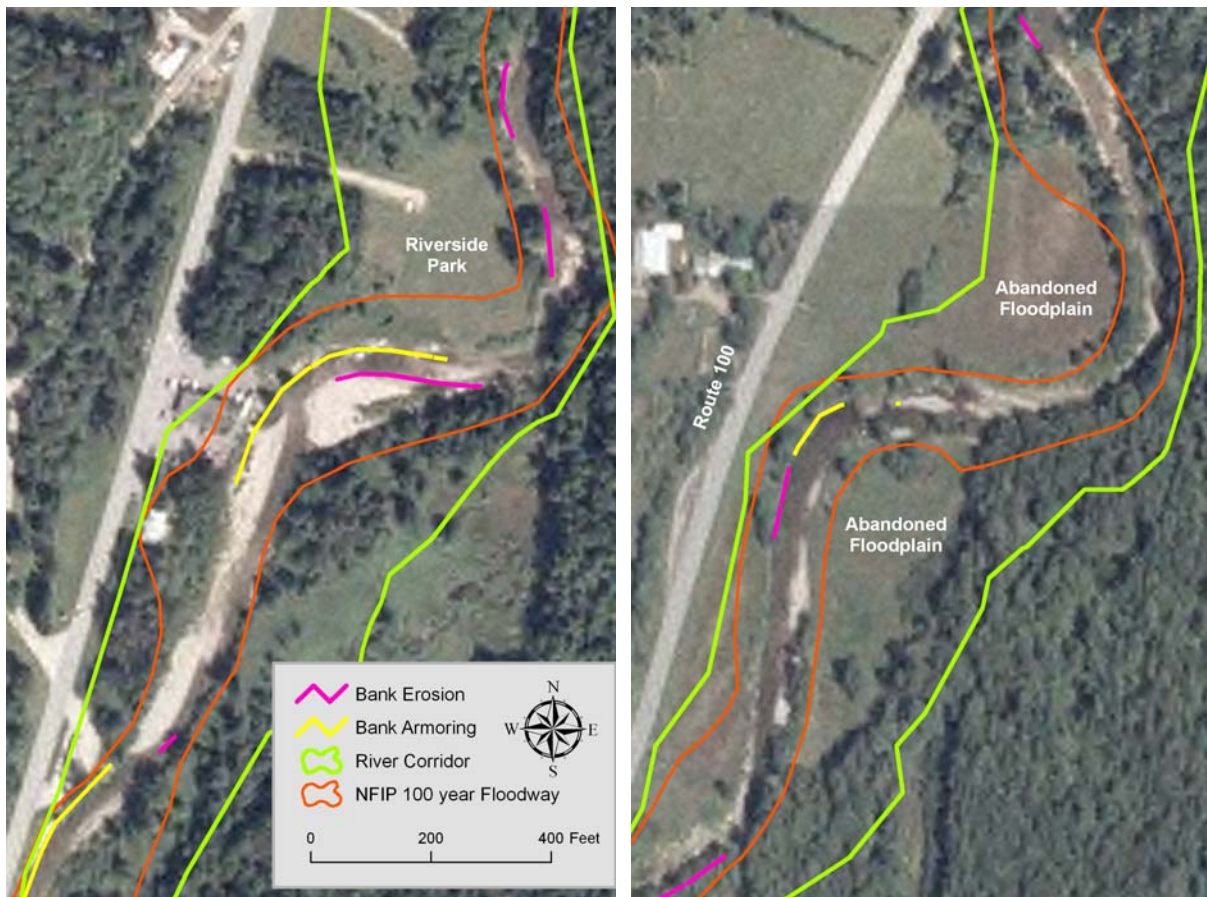
Reach M16 is the first of a series of depositional reaches found downstream of the steep, bedrock-controlled channels within the Warren Gorge. Due to the unconfined valley setting, we would expect this reach to have depositional processes and a meandering planform. However, historic channel management activities (channel straightening and dredging) and the maintenance of bank armoring to protect the road have impacted the reach. In addition, Route 100 acts as an artificial valley wall in some locations, further constricting the flood flows into the channel. The reach has some areas of severe channel incision where the geometry has departed from reference channel conditions. In the upper reach, where the cross-section was taken, measurements indicate a stream type departure from C to F-type geometry (Field, 2007), indicating the channel incision and entrenchment typical of stage II of the channel evolution.

Given the confinement and slope of upstream reaches (M18 and up), there appeared to be an unusually high amount of sediment stored above M16. This is likely a function of the channel widening that occurred in the 1998 flood and the resulting reduction in stream power. This sediment will likely begin to move downstream in subsequent high flow events, entering areas

such as M16 and initiating stage III-IV (widening, aggradation, and lateral migration) of channel evolution in the incised reach. Protection of the corridor in this reach to allow for future lateral adjustments is imperative.

### M16-1 Protect Stream Corridor at Riverside Park

Figure 6.23 depicts the river corridor and NFIP 100 year floodway for Riverside Park in the lower reach. Earthwork and filling in the southern portion of the park was completed following the 1998 flood to convert this area into a community park. Much of the southern and eastern part of the park is at bankfull elevation, and the 100-year floodplain encompasses nearly half of the park area. The town of Warren is contemplating the installation of permanent structures in the park, however this may be unwise due to the value of this area as a floodplain and the high potential for the structures to be damaged during floods. Riprap on the left bank at the upstream end of the park increases streamflow velocities and power. While the park is an important community asset, it is one of the few areas of this reach where the channel has the opportunity to meander, access the floodplain, and attenuate sediment and reduce its energy. The installation of permanent structures in the park would require more protection in the future in the form of bank armoring, which would decrease sediment attenuation at the site.



Figures 6.23 and 6.24 Potential sediment attenuation assets at Riverside Park (left) and in upper M16 (right).

### **M16-2 Protect Stream Corridor**

Figure 6.24 depicts the river corridor and NFIP 100 year floodway in the upper reach. The corridor of the upper reach is currently undeveloped, and has a mixture forested banks and hay fields in the adjacent floodplains. Channel incision has disconnected the floodplain from the bankfull channel, leaving deeply entrenched meanders with moderate bank erosion. Removal of the left bank armoring in this reach (where the channel would not endanger the adjacent road) and protection of the corridor through a conservation easement would allow this area to be an important sediment attenuation asset into the future (Figure 6.24).

### **M16-3 Active Restoration of Incised Reach**

In the two meanders where channel incision has resulted in a disconnection of the floodplain, an active restoration approach could be employed to reconnect the floodplain. Although there is little evidence of a “recently abandoned floodplain” (high terraces likely date back to the 1800’s), lowering of the floodplain along the inside bends would advance the channel evolution processes already underway. This would provide an attenuation zone for the high sediment supply from upstream reaches. This active approach would need to be done in conjunction with the corridor protection approach outlined in project M16-2. Ideally, this project would also be carried out in conjunction with the removal of the Warren Crib Dam. The presence of the dam, and the discontinuity in the headwaters sediment regime that it creates, is exacerbating the problem of channel incision in upper M16.

### **Reach M17**

Reach M17 is found in a bedrock-controlled setting within a confined valley downstream of the Town of Warren. The valley side slopes range between 15 and 30 percent, which has precluded any development within the stream corridor. There is a woody buffer of greater than 100 feet for the entire reach with the exception of a short section along Route 100 in the upper reach (Figure 6.25). This reach is not likely to migrate laterally due to the bedrock constraints. There is currently a large amount of coarse sediment stored in this reach. The channel experienced widening during the 1998 flood event, which has increased the wetted perimeter and decreased stream power. This has caused the formation of large sediment bars upstream of bedrock constrictions. This exposed sediment will continue to migrate downstream during channel forming events until the former equilibrium width is regained.

### **M17-1 Protect Stream Corridor**

Protection of the stream corridor would prevent future encroachment and buffer clearing along the channel. In the context of the entire study area, corridor protection is a lower priority for this reach because development pressures are unlikely.

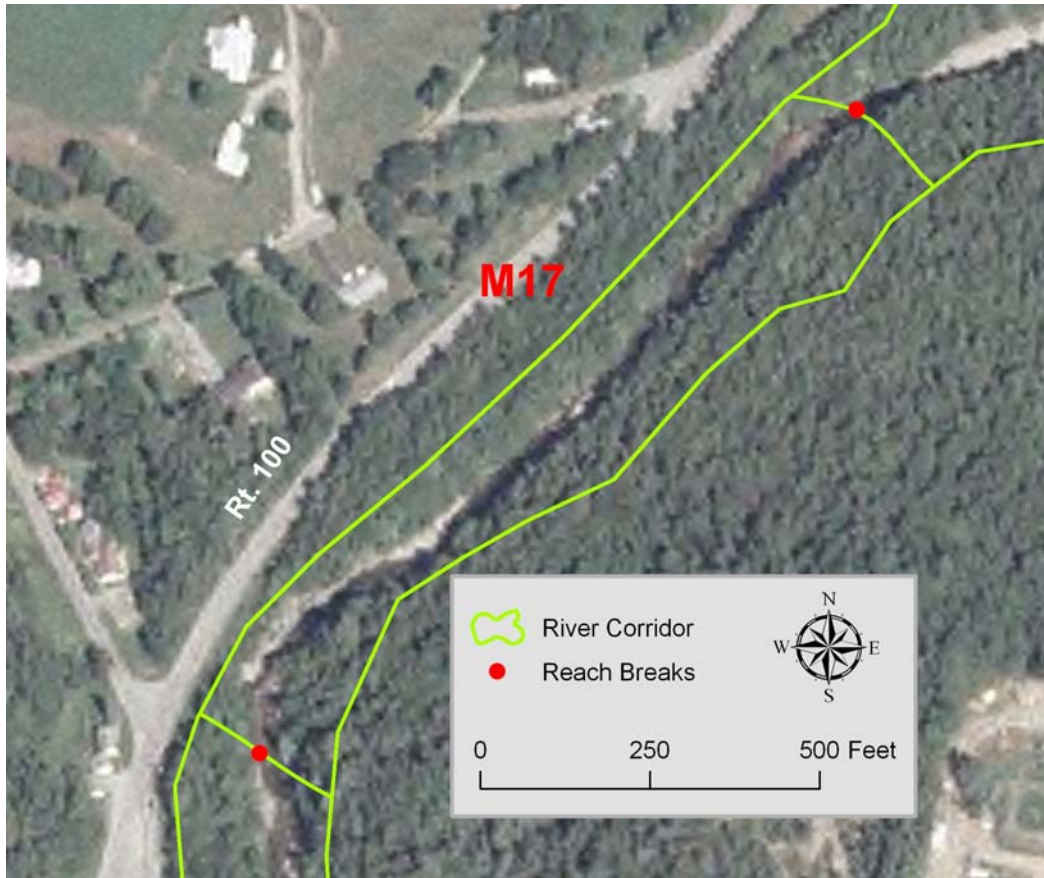


Figure 6.25 Forested river corridor of Reach M17.

## Reach M18

Similar to Reach M17, M18 is found in a bedrock-controlled setting within a confined valley (Figure 6.26). Despite the surrounding developed land in Warren, there is a woody buffer of greater than 50 feet for the entire reach and many areas with buffer greater than 100 feet. This reach is not likely to migrate laterally due to the bedrock constraints and grade controls. Development has encroached upon on the corridor in the middle and lower sections, however this has not impacted the physical stability of the reach. Only limited amount of bank erosion and armoring were noted during the field surveys (Field, 2007).

### M18-1 Protect Stream Corridor

Protection of the stream corridor in Warren would prevent further encroachment, and would limit the clearing of the woody vegetation lining the channel (Figure 6.27). The current protection afforded streams by the Warren buffer regulations is limited to 50 feet for the vegetated zone and 100 feet for structures (Warren, 2006). Protection of the existing woody buffer will benefit the biotic habitat through the input of coarse particulate organic matter, and the maintenance of shade during the warm summer months. It is recommended that the Town of Warren consider the adoption of a stream corridor policy for the entire reach that would prevent further filling (i.e., earthwork) and removal of woody vegetation within the corridor. This approach is a low cost alternative that the Town could promote among riparian landowners.



Figure 6.26 Bedrock gorge in lower M18.

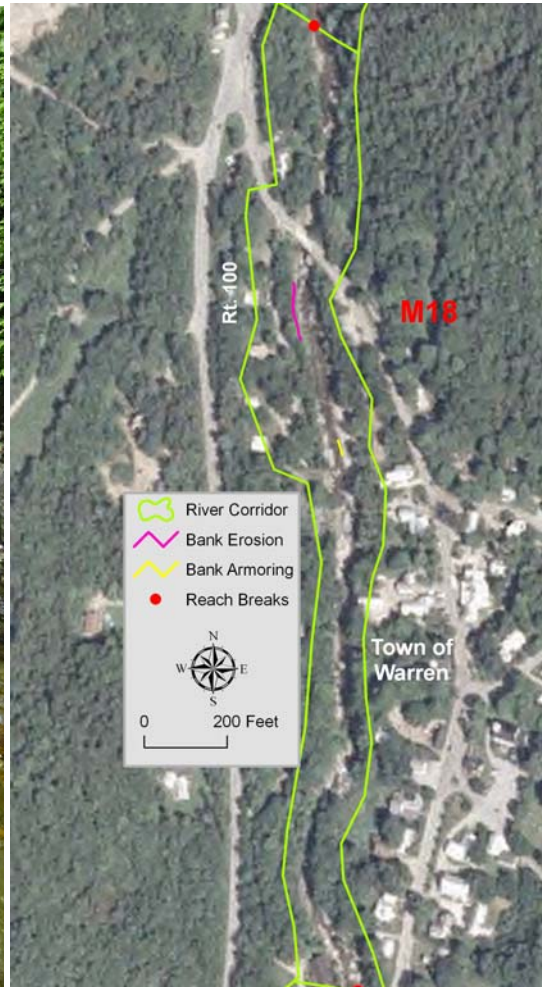


Figure 6.27 Reach M18 site location map.

## Reach M19

This 0.7-mile section of the Mad River stretches from the confluence with Lincoln Brook down to the Warren Crib Dam. The river corridor in this reach has been encroached upon by Route 100 and numerous residential properties throughout Warren Village. The encroachment of Route 100 into the corridor acts as an artificial valley wall in the upper reach, thereby reducing the width of the floodplain area. The Warren Crib Dam has caused aggradation of gravel in the lower reach, which is leading to channel widening. The widening has put the human infrastructure in the corridor at risk to flooding and erosion hazards, as occurred during the 1998 flood event. Due to a change in channel characteristics near the Route 100 crossing, this reach was further subdivided into two segments during the 2006 field surveys. These two segments are described below.

### Segment M19A

Segment A stretches from the Warren Crib Dam up to approximately 300 feet downstream of the Route 100 Bridge (Figure 6.28). The natural conditions of this section of the river have been

significantly altered by the presence of the dam and the lack of woody vegetation along the banks. The impoundment behind the dam has filled with gravel, and creates a backwater effect throughout much river segment. These conditions have led to a simplified channel with very little habitat for aquatic biota (i.e., pools are filled with gravel). In addition, the lack of woody vegetation along the stream banks causes an increase in water temperatures during the warm summer months, which negatively affects biota. The channel in Segment A is predicted to continue widening over time due to the deposition of gravel behind the dam. Over time, and during larger flow events, this may cause an increase in bank erosion, putting some of the infrastructure along the channel at risk. The overall sensitivity of this area to future or ongoing disturbances is very high. Restoration opportunities analyzed as part of the project identification effort are highlighted below.

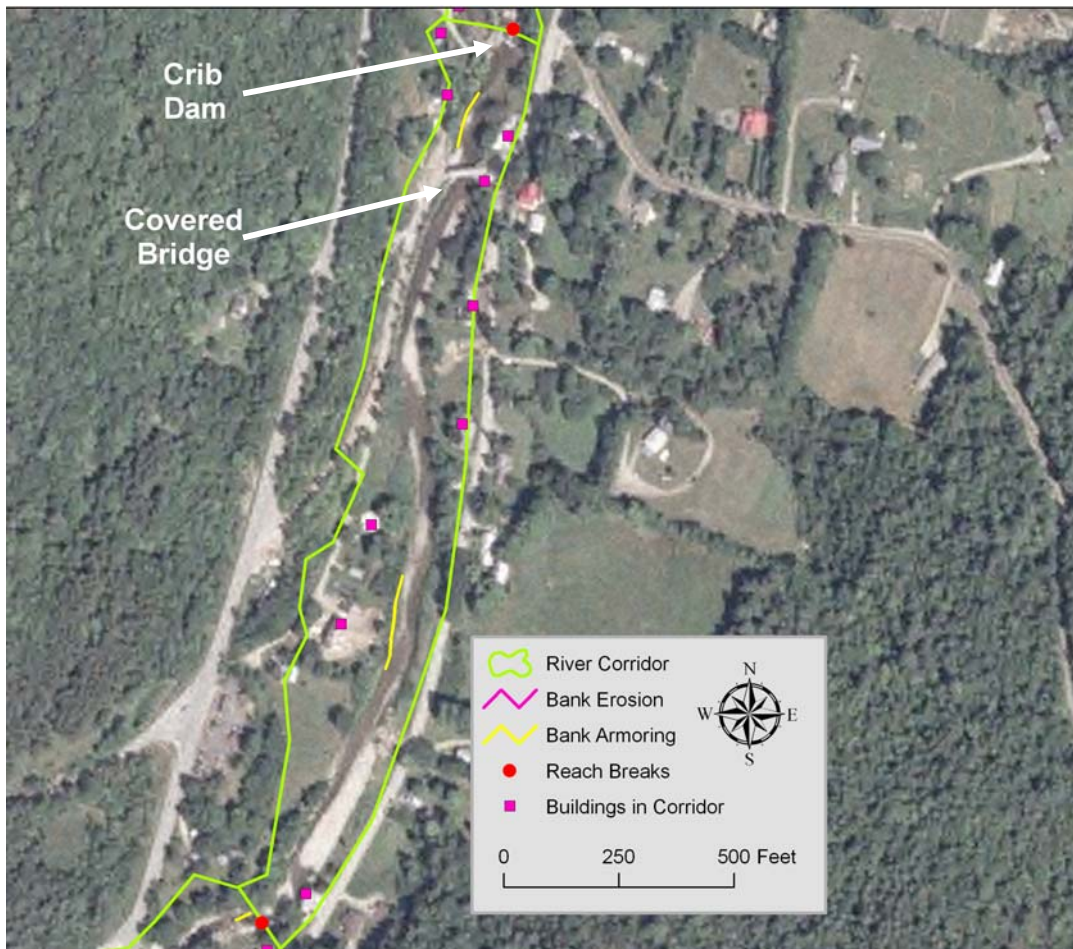


Figure 6.28 Site location map for Segment M19A.

### **M19A-1 Adopt Stream Corridor Policy for Entire Segment (Town of Warren)**

There are nine properties that have homes or businesses within the stream corridor of this segment. Many of these in the lower segment are homes that have been protected from erosion hazards by extensive bank armoring. Recognizing the importance of the continued protection of these structures, implementation of a corridor protection strategy that includes the removal of

armoring to accommodate river equilibrium conditions is not feasible in this setting. However, the Town of Warren could adopt a stream corridor policy for the entire segment that would prevent further filling (i.e., earthwork) and removal of woody vegetation within the corridor. If the Warren Crib Dam is not removed in the near future (see discussion below), further channel widening may continue in the upper half of Segment A. This may put some properties at greater risk of flood and erosion hazards, despite their location outside of the NFIP 100 year floodway (as occurred in the 1998 flood). The adoption of a policy preventing further development and building within the corridor would help avoid costly infrastructure damage in areas not protected by the Warren Flood Hazard Overlay (FHO) District and buffer ordinance.

### **M19A-2 Remove Warren Crib Dam**

The Warren Crib Dam is a non-essential structure causing 1) a discontinuity in the Upper Mad River sediment regime, 2) a discontinuity in Upper Mad River native fish migration patterns, 3) aggradation of coarse gravel upstream of the dam leading to poor biotic habitat conditions and increased bank erosion (Figure 6.29), and 4) an increased risk of flooding and erosion hazards for riparian properties, as occurred during the 1998 flood event. While the structure may be an important icon for the Town, there is no scientific management basis for maintaining it in the long term. Removal of the dam would alleviate flood and erosion hazards (thereby affording the covered bridge increased protection), and improve habitat conditions in an area where little to no biotic habitat exists. Furthermore, downstream reach M16, which has lost access to its floodplain due to channel incision, would benefit from the dam removal by increasing the sediment supplied to this reach from headwaters reaches.



Figure 6.29 Aggradation of coarse gravel behind the Warren Crib Dam.

### **M19A-3 Widening of Covered Bridge Footings Span**

The Covered Bridge footings currently constrict the bankfull width of the channel to nearly half its size (channel width = 61 feet, bridge width = 36 feet). This has caused increased aggradation of coarse gravel upstream. In addition, the hydraulic constriction during high flow events increases the risk of flooding upstream of and around the structure (as occurred during the 1998

flood). The Town of Warren has begun to look at the possibility of shifting the location of the western footing to reinforce the bridge stability (Barry Simpson, personal communication 2007). It is recommended that the feasibility of widening the bridge footings span be further studied in conjunction with the potential for removal of the Crib Dam. Removal of the Dam would likely require an active restoration and or channel management approach in the areas upstream of the structure, including the riverbed below the bridge. Therefore, the two would need to be studied in tandem.

#### **M19A-4 Stream Corridor Protection and Buffer Plantings - Upper Segment**

In addition to the segment-wide approach to protecting the stream corridor (M19A-1), the upper segment is a candidate for a more specific and intensive protection approach. There is a 500-foot stretch of river from the bedrock grade controls down to the left bank riprap where little structural encroachment is found (Figure 6.28). In this area woody bank vegetation is absent, exacerbating the poor habitat conditions in the segment (e.g., by causing an increase in water temperatures during the warm summer months). At a minimum it is recommended that the Town of Warren consider limiting further structural development in this area, and that woody buffer plantings be considered to improve biotic habitat.

#### **Segment M19B**

Segment B stretches from approximately 300 feet downstream of the Route 100 Bridge up to the confluence with Lincoln Brook (Figure 6.31). This short segment is found in a narrower valley than the downstream segment. In addition, Route 100 parallels the river above the crossing, resulting in a reduced valley width and floodplain area. The reduced floodplain in this area has led to channel incision, as flood flows of higher magnitude have been contained within the banks of the channel.



Figure 6.30 Bank erosion above Route 100 bridge.

Areas of bank erosion, with freshly exposed banks and fallen trees (Figure 6.30), were noted adjacent gravel bars (Field, 2007). Hard bank armoring installed following the 1998 flood is preventing further erosion from undercutting the Bobbin Mill on the left bank. Like in the downstream segment, the channel in Segment B is predicted to continue widening over time as the incised channel leads to increased bank erosion. The overall sensitivity of this area to future or ongoing disturbances is very high.

#### **M19B-1 Restoration of Incised Reach**

An active approach to restoring floodplain access in the area immediately upstream of the Route 100 Bridge on the left bank should be considered. Given the constraints of the upstream portion of the segment (Bobbin Mill protected on left bank by riprap), this approach would be limited to a 500-foot area where channel incision and bank erosion is most severe. Increasing floodplain

access could be achieved through 1) the excavation of the left bank to a lower elevation, or 2) the installation of grade control structures (e.g., weirs) to raise the bed elevation over time through a natural process of aggradation. Increased floodplain access in this segment would take pressure off of the downstream segment in Warren Village through the attenuation of flood waters (e.g. reduction of flood volumes and velocities) and coarse sediment supplied from upstream reaches. A detailed hydraulic and feasibility study would be needed to determine how increased floodplain access would impact the Bobbin Mill structure upslope, and whether the long-term protection of this structure with bank armoring is compatible with an active restoration approach. In addition, a long-term corridor protection strategy with riparian property owners along the segment would also be required to ensure the success of this strategy.



Figure 6.31 Site location map for Segment M19B.

### **M19B-2 Reduce Constriction Width at Route 100 Bridge**

The Route 100 Bridge and abutments are adequately sized to accommodate the equilibrium width of the channel (channel width = 61 feet, bridge width = 157 feet). However, a large amount of rock riprap was placed at the base of both footings following the 1998 flood. This has caused the constriction to be less than the equilibrium channel width, and is likely resulting in increased erosive energy downstream of the bridge during high flow events.

## 7.0 Next Steps - Projects Prioritized for Action by FMR

The following are prioritized lists of restoration projects identified in Section 6.0. Watershed level projects are prioritized in section 7.1 according to compatibility with a corridor approach to geomorphic restoration and immediacy of possible action. Site-specific projects are prioritized in section 7.2 at the watershed scale for implementation by FMR and its partnering organizations. The site level list is divided into two groups: 1) projects which *do not require* further study for FMR to pursue implementation, and are generally passive by nature (i.e., conservation based); 2) projects which *will require* further study prior to implementation. Details for site level projects can be referenced in Table 6.2.

### 7.1 Watershed Level Prioritizations

1. Pursue FEH overlay district implementation for the Town of Waitsfield. Complete a similar analysis for the Town of Warren to analyze the implications of an overlay district for Warren.
2. Advocate for the adoption of stream crossings sized according to RMP recommendations and Fish & Wildlife Spring 2008 recommendations when they are available. Adoption of such a policy could be pursued at the town level.
3. Analyze build-out scenarios for towns in the watershed to determine potential road and development densities and related effects on stormwater runoff. A Municipal Planning Grant could provide funding for such studies. Advocate for town-level policies that protect stream ecosystems from road and development stormwater runoff in rural areas, especially those sites that do not fall under state regulations (i.e., developments under the 1 acre impervious surface threshold).
4. Through municipal adoption of riparian buffer protection standards in land use regulations, advocate for woody buffers and restoration of important floodplain forest communities. Refer to Arrowwood Natural Heritage Inventory 2007 for specific site descriptions, and to the VT ANR Buffer Guidance 2005 for setback recommendations.

### 7.2 Site Level Prioritizations

#### 7.2.1 Projects Ready to Pursue Implementation (Passive Restoration)

1. M13-1: Secure conservation easements and channel management rights on all parcels south of Route 100 crossing, including the Moreland Parcel. Develop a long-term planting program for the entire corridor that will accommodate further lateral adjustments.

2. M15-1: Pursue the Kingsbury parcel river corridor and buffer protection plan as outlined in the recommendations provided in Appendix 1.
3. M11-2: Secure conservation easements and channel management rights for the Neill parcel (oxbow) and Stormcrest parcel (abandoned channel).
4. M16-1: Advocate for the long-term protection of Riverside Park in Warren as a sediment and floodflow attenuation asset by prohibiting further structural development (including bank armoring).
5. M16-2: Secure conservation easements and channel management rights for the Rodgers parcel meanders in upper reach.
6. M18-1 and M19-1: Advocate for further buffer and development protection for the entire corridor in the Town of Warren to avoid further clearing and encroachment.
7. M13-2: Secure conservation easements and channel management rights for the Lee parcel (right bank downstream of Lareau swimming hole).
8. M11-1: Pursue conservation easements and channel management rights for the remaining parcels not currently protected or identified in M11-2 (reach-wide approach).
9. M15-2: Pursue corridor protection and channel management rights at the reach-scale. Priority parcels include the area upstream of the Punch Bowl on the east side, the Punch Bowl, and downstream around Butternut Hill Drive. Develop a long-term planting program for the entire reach corridor that will accommodate further lateral adjustments.
10. M12-1: Advocate for sustainable management of the Waitsfield Couples Club parcel (recreational fields) by prohibiting further structural development (including bank armoring) and securing the long-term channel management rights. Explore possibilities for field relocation in the future given flood damage or channel avulsion.

### 7.2.2 Projects Requiring Further Study (Active Restoration)

1. M16-3: Restore incised reach at Rodgers parcel through the lowering of floodplain, removal of bank armoring, and corridor plantings. Ideally, this project would be completed in tandem with project M19A-2 (below).
2. M19A-2: Advocate for the removal of the Warren Crib Dam to restore the connectivity of the sediment regime and fish passage. Completion of this project would help ensure the long-term success of project M16-3.
3. M19B-1: Restore incised reach between Lincoln Brook and Route 100 through the lowering of floodplain or installation of grade control structures. This project would be completed in tandem with project M19B-2 (below).

4. M19B-2: Widen the span beneath the Route 100 Bridge by reducing/removing the bank armoring on the right bank.
5. M19A-3: Widen the Warren Covered Bridge span through the replacement and/or reinforcement of the western footing.
6. M15-3: Investigate options for future relocation of the snowmaking weir and intake infrastructure in the event of failure.

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## Acronym List

DMS – Data Management System (Developed by the DEC)  
FEH – Fluvial Erosion Hazard zone or corridor  
FIT – Feature Indexing Tool in SGAT for data input  
FMR – Friends of the Mad River  
GIS – Geographic Information System  
GPS – Global Positioning System  
LWD – Large Woody Debris  
MF – Mass Failure (stream banks)  
RCP – River Corridor Plan  
RGA – Rapid Geomorphic Assessment  
RHA – Rapid Habitat Assessment  
RMP – River Management Program  
SGA - Stream Geomorphic Assessment  
SGAT – Stream Geomorphic Assessment Tool  
VT ANR DEC – Vermont Agency of Natural Resources Department of Environmental Conservation

## Glossary of Terms

**Aggradation** - The build up of sediment in a streambed.

**Avulsion** – A change in a river’s course; a section of channel that has moved laterally from its bed to create another segment of channel some distance from the previous bed location.

**Bankfull width** - The width of the channel at a height corresponding to the level of stream flow that would overtop the natural banks in a reference stream system, occurring on average 1.5 to 2 years.

**Bankfull maximum depth** – The depth of the channel from the bankfull elevation to the thalweg (see below).

**Confinement** – Referring to the ratio of valley width to channel width. Unconfined channels (confinement of 4 or greater) flow through broader valleys and typically have higher sinuosity and area for floodplain. Confined channels (confinement of less than 4) typically flow through narrower valleys.

**Debris jam** - A collection of large woody debris that has lodged in a stream channel and spans the channel from bank to bank.

**Degradation or incision** - Down cutting of the streambed by erosion of bed material.

**Embedded** – Larger bed substrate particles (gravels, cobbles, boulders) surrounded by fine sediment, reducing the oxygen in the substrata and the ability of organisms to retreat into the substrata for cover.

**Entrenched** - A state where a channel has lowered significantly and floodwaters can no longer overtop the banks and access the floodplain.

**Flood chute** - A small side channel crossing the inside of a meander bend where flood waters will bypass the main channel, taking a shorter route through the chute.

**Floodprone width** - The area outward from the channel that is at an elevation that could be inundated by a flood, measured in Phase 2 SGA as at an elevation of 2 times the bankfull maximum depth.

**Grade control** – A fixed surface on the streambed that controls the bed elevation at that point, effectively fixing the bed elevation from potential incision, typically bedrock or culverts.

**Head-cut** – A sharp change in slope, almost vertical, where the streambed is being eroded from downstream to upstream.

**High gradient streams** - Typically found in steep, narrow valleys, these streams have steep slopes and are usually fast moving with many riffles or steps and low sinuosity.

**Impervious surface** – A hard surface, such as concrete or a rooftop, which prevents water from infiltrating the soil.

**In Regime** – Referring to a stream that is in an equilibrium state, one that would be expected given the stream setting.

**Large woody debris** - Pieces of wood in the active channel (within the bankfull width) usually from trees falling into the channel and with minimum dimensions of 12 inches in diameter (at one end) by 6 feet long.

**Low gradient streams** – Typically found in wide valleys, these streams have shallow slopes and are usually slow and meandering.

**Meander** – A bend in a stream, or referring to the way a stream winds down its valley.

**Sinuosity** - The level of bends or turns in a stream, calculated by dividing the stream length by the valley length.

**Thalweg** – Deepest point along the length of the stream, as if the deepest point of all cross sections were connected. The thalweg of a meandering channel typically alternates from right to left bank connecting pools.

**Width/depth Ratio** – The ratio of channel bankfull width to the average bankfull depth. An indicator of channel widening or aggradation.

**Windrowing** - Digging material from the channel bed and piling it on the bank, creating berms.

## List of Resources/Links:

- River Corridor Planning Guide from ANR River Management Program - [http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv\\_rivercorridorguide.pdf](http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_rivercorridorguide.pdf)
- Flood hazard management information from ANR River Management Program - [http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv\\_floodhazard.htm](http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv_floodhazard.htm)
- Alternatives for River Corridor Management (RMP paper) - [http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv\\_managementAlternatives.pdf](http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_managementAlternatives.pdf)
- Municipal Guide to Fluvial Erosion Hazard (from RMP) – [http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv\\_municipalguide.pdf](http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_municipalguide.pdf)
- ANR Buffer Guidance – <http://www.anr.state.vt.us/site/html/buff/BufferGuidanceFINAL-120905.pdf>

## Mad River Corridor Plan: Kingsbury Property Recommendations

The Kingsbury property consists of two parcels, one larger parcel just north of the Warren Trestle Bridge on the right bank of the river (looking downstream), opposite the Sugarbush Snowmaking pond. The other, smaller parcel is to the north, separated by Mac's gas station and convenience store. The larger parcel currently has a hay field, house, and barn with a few trees along the riverbank. Somewhat thicker treed buffers are in two places: at the sharp meander bend and just downstream of the bridge. Additional trees were planted at the very top of the bank and are beginning to fill out. Several hundred feet of riprap was installed along the southern edge of the property where the river was migrating toward the field. Riprap is also present along the snowmaking pond and is highlighted in the accompanying map. Riprap artificially stabilizes stream banks and tends to increase stream power and therefore increase the potential for erosion on opposite banks downstream. Given this tendency and the location of rip rap shown on the map, increased erosion would be expected downstream of the riprap sites on the other side of the river. In this area, the snowmaking pond also constricts the channel and its meanders, so more pressure could be expected on the right bank opposite the pond. Additionally, this area is downstream of a fairly confined section of stream upstream of the Warren Trestle bridge and is therefore a natural "attenuation" zone; meaning that it is an area where the river would naturally want to deposit sediment and meander.



Photos showing thin buffer vegetation on left and extent of riprap on right at the Kingsbury property.

From the river's perspective, the best restoration actions would be to remove the riprap, thereby allowing the river to create a meander bend towards the center of the property and dissipate its erosive energy. Additionally, planting trees in the recommended buffer and removing development potential from the Fluvial Erosion Hazard (FEH) zone would be an essential part of such a plan. However, due to the extent of the riprap and the very large size of the rocks in place, its removal is not financially feasible. With that in mind, the following additional actions are recommended for the Kingsbury site.

As shown in the accompanying map, areas outlined in dark green with a patterned interior represent areas where large-tree plantings are recommended. These areas were identified using meander centerlines and a meander radius to create a curve that estimates a planform the river

would be moving toward if riprap were not present. A corridor protection approach allows the river to migrate wherever it wants within the corridor area. In this approach, we have used the corridor to identify where buffer vegetation should be maintained and we have highlighted, based on current meander indicators in the river, where the meander bends are most likely to form in the future. In these areas, we are recommending planting large caliper native trees. The goal is to allow the trees to become established so that in the long-term, when the riprap eventually fails, these large trees will provide stability to the bank and be a source of woody debris to the stream. Because the bank is stabilized by the riprap, the investment in large planting stock is warranted because the trees are protected from short-term erosion and will have time to become established for many years before the riprap eventually fails.

The remainder of the recommended buffer is highlighted in green on the accompanying map. Plant the recommended buffer in tree/shrub vegetation and discontinue mowing activities. By focusing large, native tree plantings in the areas where the river is most likely to meander the farm can have flexibility to plant some permaculture crops in the remainder of the buffer. Additionally, without the riprap to provide some bank stability, planting less expensive trees and shrubs could be more financially responsible in the green shaded areas.

A 50-foot wide vegetated buffer is recommended along the tributary that crosses the property from under Route 100. This tributary has been straightened in the past and will likely meander in the future (channel slope ~2%). Providing the 50-foot buffer on either side of the channel (measured outward from the top of bank) will allow for this future meandering as well as provide habitat. The tributary appears incised and could benefit from lowering some floodplain area within that buffer. Such a project would be feasible due to the small nature of the tributary as well as the current lack of woody vegetation in the buffer. This would create a floodplain area for refuge from high flows for fish. It would also reduce the sediment input into the Mad River from this area as it eventually creates the floodplain. More specific project development for this tributary could be pursued through a project development grant through the VTANR Clean and Clear Program.

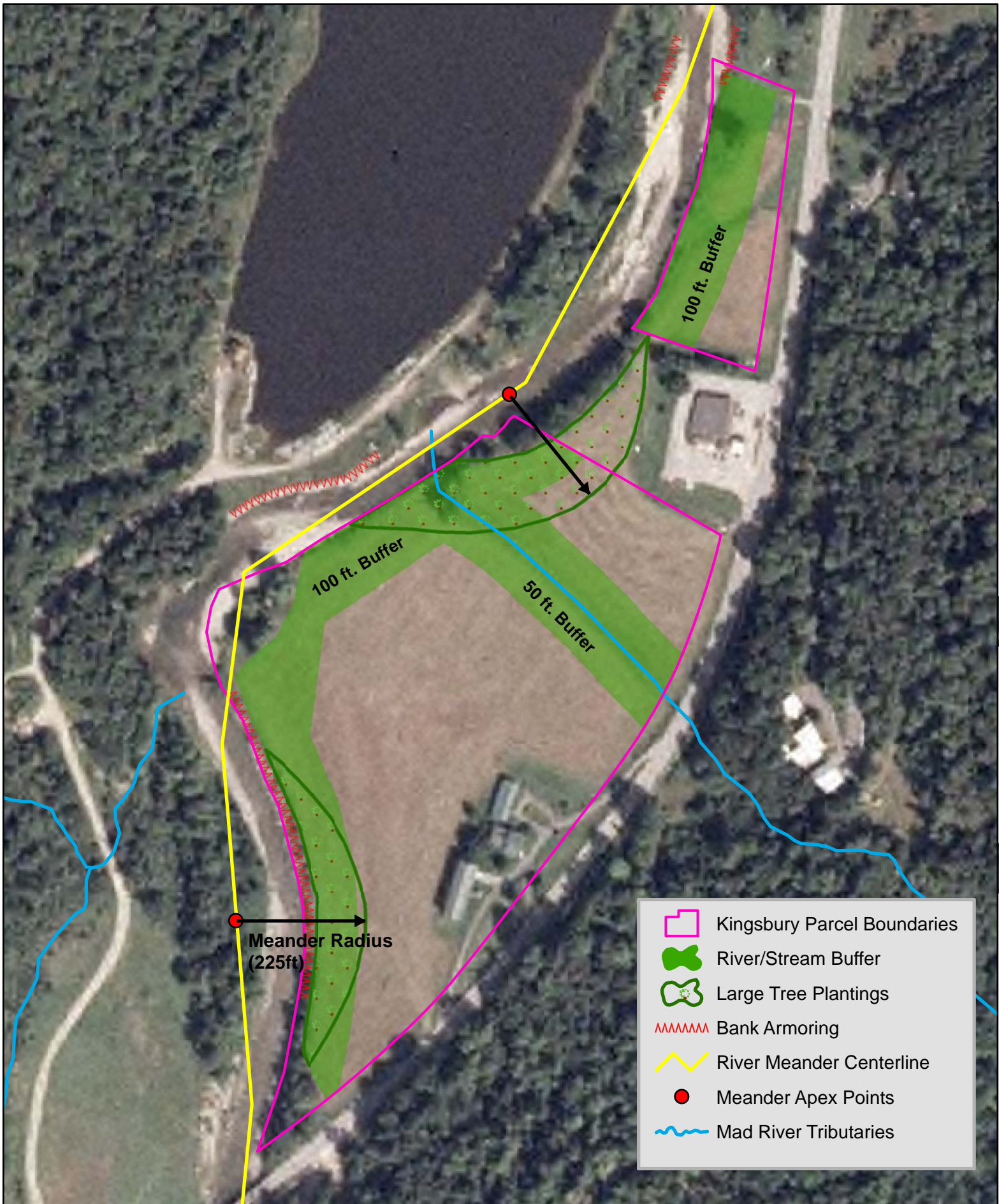









Photos showing the tributary incised on the left and lacking woody buffer vegetation on the right.

These buffer areas were developed using a combination of the DEC's buffer guidance and the Mad River FEH zone. The DEC recommends a minimum of 100 feet of woody vegetation as a

buffer for rivers such as the Mad River, and 50 foot buffers for small streams such as the tributary. For the Mad River, this buffer encompassed the FEH zone everywhere except at the sharp meander bend, where the buffer was extended to the east to accommodate the FEH zone. (For more information, see the buffer guidance and the draft FEH analysis prepared as part of this project). The areas where large-tree plantings are recommended are only best estimates at the radius and location of future meander bends based on current meanders, meander centerlines, and channel size. These areas do not represent the only possible future locations for the stream, but are an estimate of the areas likely to experience the most pressure in the near future. Trees planted in these areas should be large, native species. Ideally, this planting type would be continued throughout the recommended buffer. But to allow flexibility to the farm, the most sensitive areas are highlighted and the remainder of the buffer can include more perennial shrubs such as blueberries if necessary.

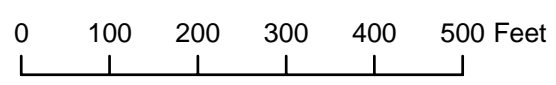
Due to the expanse of riprap along the mainstem at the southern end of the property, the trees will take decades before they are large enough to reach over and shade the channel. Additionally, it will be many years before the riprap fails and trees fall in to provide woody debris habitat. To improve the habitat along the barren stretch of riprap in the short-term, placing some habitat structures is also recommended. More specific project development for habitat enhancements could be pursued through a project development grant through the VTANR Clean and Clear Program.



-  Kingsbury Parcel Boundaries
-  River/Stream Buffer
-  Large Tree Plantings
-  Bank Armoring
-  River Meander Centerline
-  Meander Apex Points
-  Mad River Tributaries



## Kingsbury Parcel Buffer Planting Plan



Prepared by:  
 Fitzgerald Environmental Associates, LLC.  
 and Lisa C. Godfrey  
 For:  
 Friends of the Mad River



## **Mad River Fluvial Erosion Hazard Corridor Analysis**

**January 24, 2008**

### **Introduction**

Friends of the Mad River (FMR) received funding from the Vermont Department of Environmental Conservation (DEC) to develop a River Corridor Management Plan (RCP) for the Mad River in the towns of Waitsfield and Warren, Vermont. Fitzgerald Environmental Associates, LLC. (FEA) and Lisa Godfrey, consulting geomorphologist, were retained by FMR to develop the RCP based on previously collected data, a summary analysis of watershed stressors, and an assessment of the social constraints to restoration in the watershed. The purpose of the RCP is to develop strategies that will help: 1) reduce sediment and nutrient pollution loading into the Mad River and ultimately Lake Champlain, 2) reduce property loss and infrastructure damage from flooding, and 3) improve aquatic habitat functions. The project extends for about 12 miles of the Mad River from the Lincoln Brook confluence upstream of Warren Village to about 3 miles south of Waitsfield Village.

One component of the RCP is an analysis of the Fluvial Erosion Hazard (FEH) zone of the Mad River within the project area. Using Stream Geomorphic Assessment (SGA) Phase 1 data previously developed by Field Geology Services (FGS, 2007), Kari Dolan of the DEC developed an FEH corridor and reach-specific ratings using the Stream Geomorphic Assessment Tool (SGAT) and the DEC FEH approach (VTDEC, 2007). The FEH corridor is determined by the inherent sensitivity of the reach to adjustments (i.e., lateral migration) and the current condition of reach stability as determined through an extensive SGA Phase 2 field survey. The reach-specific ratings, as outlined in Table 1, determine the corridor width needed to accommodate fluvial geomorphic equilibrium conditions. The corridor may then be used by municipalities to develop strategies that will reduce property loss and infrastructure damage from flooding. Further background information about the FEH approach is provided the DEC publication “Municipal Guide to Fluvial Erosion Hazard Mitigation” (VTDEC, 2007).

FEA has used the FEH corridor developed by DEC to analyze the implications of an “FEH overlay” within the Town of Waitsfield. The purpose of this analysis is to provide the Town, FMR and DEC with a summary of the built and natural capital within the corridor, and highlight opportunities for corridor protection. The analysis also assesses the Town’s planning and zoning in the context of development patterns and other protected parcels within the corridor (e.g., town-owned parcels and conserved lands). Finally, the analysis compares the FEH overlay with the FEMA mapping for the 100 year floodplain and the Waitsfield stream setback ordinance for an example river reach. The methods used in this analysis, a summary of the results, and recommendations for further actions are provided below.

**Table 1. FEH Ratings and Corridor Widths Based on Typical Setting and Impact**

Sensitivity Rating	Corridor Width in Relation to Reference Channel Width	Typical Setting & Impact
Very Low	Equal	Steep, bedrock-bottomed stream with no impacts
Low	Equal	Steep, bedrock-bottomed stream with limited human impacts
Moderate	Four (4) channel widths	Moderate gradient stream with limited human impacts
High	Six (6) channel widths	Low to moderate gradient stream with moderate human impacts
Very High	Six (6) channel widths	Low to moderate gradient stream with high human impacts
Extreme	Six (6) channel widths	Severe departure from reference conditions

## Methods

The FEH data developed by DEC was used in conjunction with additional GIS data layers to analyze the built and natural capital in the FEH corridor. Most of the GIS data are available through the Vermont Center for Geographic Information (VCGI), while others were obtained through the Central Vermont Regional Planning Commission (CVRPC). A summary of the GIS data utilized in the analysis is provided below in Table 2.

**Table 2. GIS Data Utilized in Waitsfield FEH Corridor Analysis**

Data Layer	Description	Source
FEH Corridor	Corridor based on FEH approach described in Introduction.	VTDEC
Waitsfield Town Zoning	Zoning Districts adopted by Town for future growth.	CVRPC (developed by Town)
Waitsfield Town Parcels	Parcels boundaries and property owners (current as of 2006).	CVRPC (developed by Town)
Buildings	E-911 structure locations for State of Vermont.	VCGI
Wetland Boundaries	National Wetland Inventory (NWI) data for Class I wetlands for State of Vermont.	VCGI
Wetland Soils	Hydric soils mapped by NRCS for State of Vermont.	VCGI

Waitsfield Town Zoning Districts were summarized based on the area (acreage) and percent coverage of the FEH corridor. The Town Parcel data have been used to identify areas where Town-owned land constitutes a protected zone where no additional future development will occur. Although this may not always be the case for every Town-

owned parcel (i.e., school property where school building could expand), many of Town-owned parcels in the FEH corridor are likely protected from future structural development. In addition, the Mad River Conservation Partnership (MRCP) database was used to identify areas conserved by the Town, the Vermont Land Trust and the MRCP. Building locations from the state database were used to identify the number and type of properties in the FEH corridor. Wetlands mapping was included in the analysis to represent areas within the FEH corridor where land is unsuitable for structural development. Collectively these data layers were analyzed to determine the overall barriers to implementation of an FEH zoning ordinance for the Town of Waitsfield.

ArcGIS software was used to summarize the land cover and zoning acreages within the FEH corridor at the reach-scale. A reach-scale approach to analyzing and managing fluvial erosion hazards is imperative given the varying sensitivities to adjustment exhibited by different stream types under the influence of human impacts. Data are summarized according to the stream reaches developed during the original Phase 1 analysis. A summary of the reaches and their locations is provided in Table 3.

**Table 3. SGA Reach Locations**

<b>SGA Reach</b>	<b>Location</b>
M11	High Bridge Brook confluence near Bridge St. downstream to Shepard Brook confluence
M12	Mill Brook confluence near Lareau Park downstream to High Bridge Brook confluence near Bridge St.
M13	Ketcham parcel downstream to Mill Brook confluence near Lareau Park
M14	FitzGibbons parcel at end of Kingsbury Rd. downstream to Ketcham parcel.
M15	Route 100 bridge crossing downstream to FitzGibbons parcel at end of Kingsbury Rd.

Data summaries and mapping are provided in an Attachment to this report. Table 4 summarizes Phase 2 stream channel characteristics for the study reaches, and is included on page 1 of the Attachment. Data summaries for the FEH corridor analysis are provided in Tables 5 and 6 on page 2. A map depicting the FEH corridor for the Town of Waitsfield and reach sensitivities is provided on page 3 of the Attachment. A map of the Town's zoning districts and the FEH corridor is provided on page 4. Mapping of the human and natural assets highlighted for protection is included on pages 5 and 6 of the Attachment. Finally, a map comparing river corridor and buffer protection alternatives for a highly sensitive and actively adjusting reach is provided on page 7 of the Attachment.

Below is reach-based summary of 1) the current channel conditions and stream sensitivity ratings, 2) the current protection assets and liabilities in the FEH corridor, and 3) the opportunities for property protection as implicated by an FEH district overlay. Following the narrative summaries are recommendations for further actions that the Town, FMR,

and DEC could pursue to reduce property loss and damage from flooding and erosion along the Mad River.

## Results

### Reach Summaries

#### *Reach M11 (Very High Sensitivity)*

##### *Reach Description*

Reach M11 is a long reach (4.4 miles) located in the north-central part of Waitsfield from the confluence of High Bridge Brook near the Covered Bridge downstream to the confluence with Shepard Brook approximately 0.5 miles south of the town border with Moretown. The reach is found in a wide, alluvial valley and has an expansive historic floodplain. This section of the Mad River is surrounded by agricultural land use, and has been severely manipulated through channel straightening (72% of reach was straightened) and bank armoring. Human impacts to this reach have resulted in an incised (i.e., deepened) channel with fewer meanders and degraded habitat conditions for aquatic biota. The reach is beginning to show signs of channel widening (stage III of channel evolution; Schumm, 1977), a process that typically follows channel straightening and incision. Due to the current vertical channel adjustments and the predicted lateral adjustments to follow, this reach has a very high sensitivity to watershed and riparian-scale impacts. As such, it has been designated an FEH corridor width equal to six times the reference channel width, or 582 feet.

##### *Current Zoning and Protection Assets and Liabilities*

- **Town Zoning:** The FEH corridor for Reach M11 is found almost entirely within the Agricultural-Residential District. One small area of Historic Village Residential zoning (less than 1 acre) occupies the FEH corridor in the upper reach near the lower village (see Tables 5 and 6 in the Attachment).
- **Town-Owned and MRCP Parcels:** Three small parcels owned by the Town are located in the FEH corridor on the east side of Main Street, including the Elementary School parcel, the Cemetery parcel, and the Fire Department Parcel. Three structures are located on these parcels, however none are found within the FEH corridor. Together these parcels, although Town-owned and protected from future development, offer little in the way of protection assets due to their small size (representing less than 1% of the FEH corridor for reach M11). Three large parcels have been conserved by the MRCP in this reach, including the Tuner parcel, the Woliner/Neill Parcel, and the Flemer parcel. Combined, these protected parcels occupy 104 acres within the FEH corridor, representing 37% of the entire corridor for the reach.

- **Wetlands:** Wetlands represent 3.4% (~10 acres) of the FEH corridor for this reach. Most of the wetland areas are located in the lower reach in agricultural settings. An extensive wetland area is located on the left bank downstream of the Meadow Road crossing. This wetland area is found among hay and crop fields on the Turner Farm parcel. Other large areas of disconnected wetlands are found upstream of the Meadow Road crossing on the Neill Farm parcel. One additional small wetland area is found within the over-widened river channel just upstream of the Tremblay Road crossing within the Stormcrest Limited Partnership parcel.
- **Buildings:** There are five buildings located within the FEH corridor in reach M11. In the lower reach, three buildings are found on the left bank upstream of the Meadow Road crossing. One is an open-air “public gathering” structure associated with the parking lot and public access to the Mad River Path. Two other commercial structures are located to the south on the North Branch Condominium Association parcel. A second open-air “public gathering” structure (picnic area) is located in the left corridor off Tremblay Road. One house (Carnright parcel) is located in the upper reach in between the river and Route 100.

#### *Opportunities for Protection*

A majority of the parcels found within the FEH corridor for reach M11 are large and used for agricultural purposes. The Neill, Spaulding, Kenyon and Compere Trust parcels occupy a large fraction of the corridor and most of these appear to have well-established agricultural uses. An FEH overlay would prevent the further development or encroachment of existing buildings on the stream. Two non-agricultural parcels which appear to have potential for future development are highlighted below for Reach M11.

- The North Branch Condominium Association parcel, located upstream of the Meadow Road crossing, already has two commercial buildings located in the FEH corridor. An FEH overlay district would prevent future build-out of this site, thereby avoiding additional property losses in this parcel in the event of lateral channel migration (see Figure 1).
- The Stormcrest Parcel, located upstream of the Tremblay Road crossing, is found in an area of active lateral channel migration. The FEH overlay district would prevent residential development in the corridor of this parcel, thereby avoiding property losses due to additional lateral channel migration.



Figure 1. Parcels (white) found in FEH corridor (green), and conserved parcels (yellow) in lower Reach M11.

### *Reach M12 (Very High Sensitivity)*

#### *Reach Description*

Reach M12 is a 1.4 mile reach located in the center of Waitsfield from the confluence of Mill Brook downstream to the confluence with High Bridge Brook. The reach is found in a broad valley, however the floodplain is only accessed during large flood events due to channel incision. This reach has been highly modified (32% of reach was straightened) and has a high degree of development in the corridor. The reach shows signs of channel widening (stage III of channel evolution) and has some areas of severe aggradation and enlarged bars. Due to the current vertical channel adjustments and the predicted lateral adjustments to follow, this reach has a very high sensitivity to watershed and riparian-scale impacts. It has been designated an FEH corridor width equal to six times the reference channel width, or 538 feet.

#### *Current Zoning and Protection Assets and Liabilities*

- **Town Zoning:** Approximately one-half of the FEH corridor for Reach M12 is occupied by the Agricultural-Residential District, with 34% found within the Irasville Commercial District and lesser amounts in the Commercial and Village Districts (see Tables 5 and 6 in the Attachment).
- **Town-Owned Parcels:** One large parcel owned by the Town (and conserved through the MRCP) is located in the FEH corridor on the east side of river in

the upper reach. This parcel extends upslope and to the east, providing protection against future development for 15% of the of the entire FEH corridor for the reach.

- **Wetlands:** Wetlands represent 18.4% (~13 acres) of the FEH corridor for this reach. Most of the wetland areas are located in the lower reach along the right bank above and below the Bridge Street Crossing. One additional small wetland area is found along the north bank of Mill Brook near the confluence with the Mad River, just downstream of the reach break with M13..
- **Buildings:** There are 6 buildings located within the FEH corridor in reach M12. In the lower reach, one house is found along the left bank (downslope of the levee) upstream of the Bridge Street crossing. In the upper reach, 4 commercial buildings are found on the left bank on Fiddler's Green within the Irasville Commercial District. One house is located in the parcel downstream of the Fiddler's Green on the left bank.

#### *Opportunities for Protection*

Accounting for the wetland areas and the large Town-owned parcel, approximately 34% of the FEH corridor for this reach is already unsuitable for development. The dense residential and commercial land use around the Historic Village District is partially protected from flood hazards by the levee along the left bank. This levee has also helped focus the erosive pressures of the river towards the right bank, where bedrock outcrops have controlled lateral migration to the east. The parcels that would benefit most from the FEH corridor protection are those on the left bank immediately upstream of the Covered Bridge, where the low bank height to floodplain and continued bank erosion pose real threats to structures. The Smith parcel on the right bank in the lower reach, while located within the Agricultural-Residential District, contains a large portion of wetlands unsuitable for development.

In addition to the parcels located around Fiddler's Green in the upper reach, three other parcels on the left bank appear to have potential for future development given their location in the Irasville Commercial District. These areas are highlighted below and depicted in Figure 2.



Figure 2. Parcels (white) found in FEH corridor (green) in upper Reach M12.

- The Waitsfield Couple's Club parcel (ball fields), located in between the straightened section of the river and Route 100, has one building located in the FEH corridor. An FEH overlay district would allow the continued use of this parcel for recreational purposes, but would prevent any additional build-out of this site that would decrease the current setback from the river.
- With FEH implementation, the commercial buildings at Fiddler's Green would be prevented from causing development that would reduce the current setback from the river. Any additional structures would also be prohibited in this zone.

### *Reach M13 (Very High Sensitivity)*

#### *Reach Description*

Reach M13 is a 1.1 mile reach located in the central part of Waitsfield from the Ketcham Parcel downstream to the confluence with Mill Brook. Like reach M11, this reach is found in a very broad valley. Due to severe channel incision the floodplain is only accessed during extreme flow events. The reach shows signs of severe channel widening (stage III of channel evolution) and aggradation, and many areas of planform change suggesting lateral migrations typical of stage IV of channel evolution. Due to the current lateral adjustments, this reach has a very high sensitivity to watershed and riparian-scale impacts. It has been designated an FEH corridor width equal to six times the reference channel width, or 462 feet.

### *Current Zoning and Protection Assets and Liabilities*

- **Town Zoning:** 56% of the FEH corridor for Reach M13 is occupied by the Commercial-Lodging District, with the remaining 44 % occupied by the Agricultural-Residential District (see Tables 5 and 6 in the Attachment). Despite nearly half of the corridor being occupied by the Commercial-Lodging District, only a small fraction of this area is developed (2 buildings) due to the town-owned parcels and wetlands located here.
- **Town-Owned and MRCP Parcels:** Four Town-owned parcels are located in the FEH corridor in the lower reach. These parcel encompass the riparian areas around the confluence with Mill Brook, the restored channel at Lareau Park, and an area in between the river and Route 100. These parcels provide protection against future development for 27% of the of the entire FEH corridor for the reach.
- **Wetlands:** Wetlands represent 35% (~21 acres) of the FEH corridor for this reach. The wetland areas are located throughout reach above and below the Route 100 crossing, with a majority of the upper corridor being occupied by wetlands. The analysis of wetlands for this reach accounted for the intersection of NWI (Class I wetlands) and NRCS (hydric soils) mapped areas, providing an accurate total of land acreage unsuitable for development.
- **Buildings:** There are 3 buildings located within the FEH corridor in reach M13. On the Town-owned Lareau Park land there is a wooden bathroom (outhouse style) that is protected from flooding and erosion hazards by the berms constructed during the park construction and channel design. On the left bank upstream of the Route 100 crossing, the Lareau Farm (American Flatbread) includes 2 buildings found within the fringe of the FEH corridor.

### *Opportunities for Protection*

Accounting for the wetland areas and the large Town-owned parcel, approximately 57% of the FEH corridor for this reach is already unsuitable for development (overlapping wetlands and town-owned parcels removed from total acreage). Three areas of the corridor, including a total of six parcels that are not Town-owned, are highlighted below and depicted in Figure 3.

- The Lee parcel is a large tract located on the right bank east of the restored channel at Lareau Farm. It is located within the Commercial-Lodging District and contains approximately 600 feet of river frontage along an area prone to lateral adjustment. The FEH overlay district would prevent additional residential or commercial development in the corridor of this parcel.
- The Lareau Farm and Connell parcels on the left bank upstream of Route 100 both contain extensive areas in the floodplain. Both landowners have expressed an interest in working with FMR and DEC to protect the corridor.

- The Moreland, Gaylord and Ketcham parcels all have areas in the FEH corridor on the right bank upstream of Route 100. The Moreland parcel is a landlocked parcel that is within the wetlands associated with the floodplain. The Ketcham parcel occupies most of the corridor in the upper reach, with some land not suitable for development due to wetlands. The Gaylord parcel occupies a small area of the corridor that also appears to have some land that is unsuitable for development.

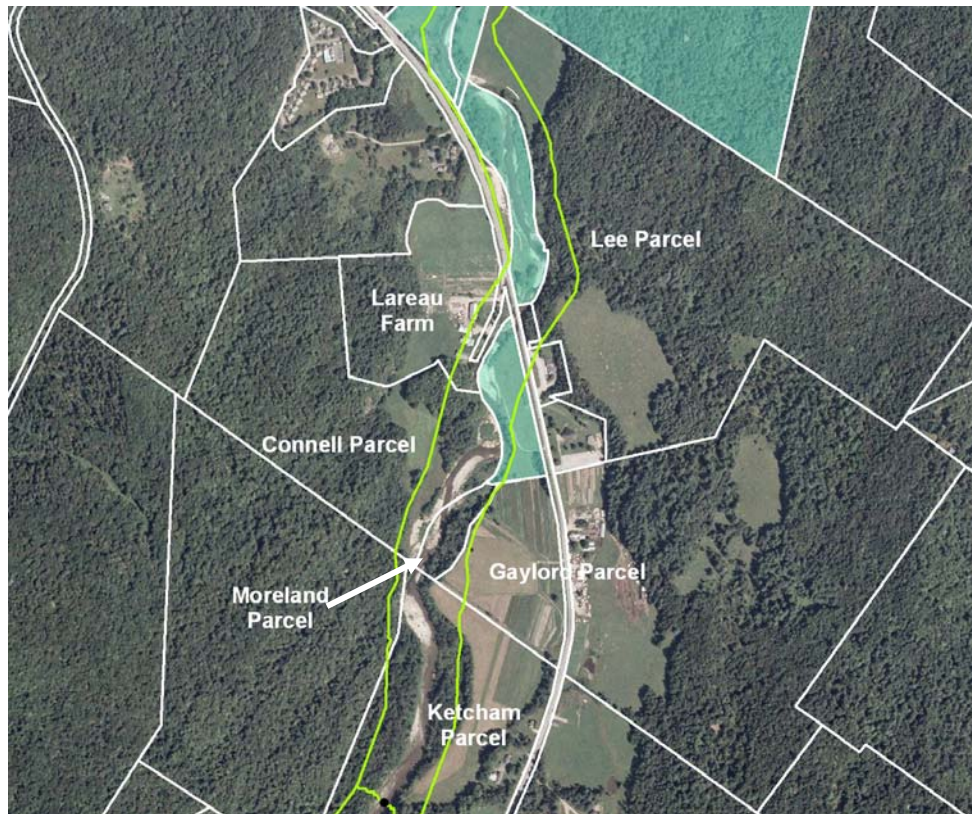


Figure 3. Private (white) and Town-owned or MRCP-conserved (blue shaded) parcels found in FEH corridor (green) for Reach M13.

### *Reach M14 (Extreme Sensitivity)*

#### *Reach Description*

Reach M14 is a 0.4 mile reach located in the southwestern part of Waitsfield from the FitzGibbons parcel downstream to the Ketcham parcel. This short reach is found in a confined valley setting. Due to channel widening that occurred during the 1998 flood, a departure from the reference stream type (B-type) was noted during the Phase 2 assessment. The channel is currently showing signs of aggradation following the widening phase, and due to the current adjustments and the stream type departure the reach has been designated an extreme sensitivity to watershed and riparian-scale impacts. It has been designated an FEH corridor width equal to six times the reference channel width, or 454 feet. Two important points should be noted with respect to the M14 FEH corridor. First, the middle section of the corridor was edited

during the FEH analysis to be narrower than the standard width based on the true width of the valley. This revision is part of the general FEH approach, and was done to accurately reflect the true corridor that is prone to long-term lateral channel adjustments. Secondly, although the sensitivity rating is extreme, this is a conservative estimate based on the stream type departure and the channel may actually be less prone to “extreme” adjustments because of the confined valley setting.

#### *Current Zoning and Protection Assets and Liabilities*

- **Town Zoning:** The entire FEH corridor for Reach M14 is occupied by the Agricultural-Residential District (see Tables 5 and 6 in the Attachment). With the exception of one residential property in the upper reach, much of the land in the FEH corridor is likely not suitable for either use (see below).
- **Town-Owned Parcels:** One Town-owned parcel occupies 25% of the FEH corridor in the middle of the reach. This parcel has been contemplated for possible wastewater treatment disposal by the Town of Waitsfield, and it is unlikely that any buildings associated with this activity would be in danger of erosion hazards on the high terrace of the right bank.
- **Wetlands:** There are no mapped wetlands in the FEH corridor for this reach.
- **Buildings:** There is one house found in the upper part of the FEH corridor, located on the right bank at the end of Kingsbury Road (FitzGibbons property). The house is situated approximately 20 to 25 feet above the channel location on a high terrace, making this property effectively out of the danger area for erosion hazards

#### *Opportunities for Protection*

Figure 4 depicts the confined valley setting in which this reach is found. Although the reach has been designated with an extreme sensitivity, no significant corridor protection opportunities have been noted since neither current nor future development within the corridor is likely to be threatened by erosion hazards.



Figure 4. Private (white) and Town-owned (blue shaded) parcels found in the M14 FEH corridor (green). Note the steep valley side slopes as depicted by yellow 5 foot contour intervals.

### *Reach M15 (High Sensitivity)*

#### *Reach Description*

Reach M15 is a 1.6 mile reach that crosses the Waitsfield-Warren border just east of the Sugarbush snowmaking pond. The section of the channel found within the Waitsfield town limits is 1.1 miles long. Like the reaches downstream of M14, this reach is found in a very broad alluvial valley. The channel is currently showing signs of planform change and redevelopment of sinuosity (stage IV of channel evolution), however it was assessed as having good geomorphic stability. Due to the observed channel conditions, it has been designated with a high sensitivity, translating to an FEH corridor width equal to six times the reference channel width, or 452 feet.

#### *Current Zoning and Protection Assets and Liabilities*

- **Town Zoning:** As in reach M14, the entire FEH corridor for Reach M15 is occupied by the Agricultural-Residential District (see Tables 5 and 6 in the Attachment). However, the corridor of this reach has significant encroachment

of residential properties and documented areas of property loss due to bank erosion (see discussion below).

- **Town-Owned Parcels:** There are no town parcels in the corridor of this reach.
- **Wetlands:** Wetlands represent 8% (~4 acres) of the FEH corridor within the Town limits of Waitsfield. The wetland areas are located at two areas in the corridor: 1) a large area (~2.5 acres) on the left bank in the lower reach just upstream of the reach break; 2) an area mostly contiguous with the current channel in the upper reach just downstream of the so-called “punch-bowl” swimming hole.
- **Buildings:** There are eight houses found within the FEH corridor limits of this reach. Two houses are located on the right bank near the confluence of Folsom Brook and the mainstem. Both of these properties are in danger of property damage due to channel migration and are discussed below as opportunities for protection. Two other houses are located on Butternut Hill Road. The house on the right bank is also susceptible to damage from flooding and erosion and is also discussed below. Similarly, the house downstream of the “punch-bowl” is included in the discussion due to its susceptibility to future erosion.

#### *Opportunities for Protection*

Three areas of this reach, including a total of five parcels that are not Town-owned (Figure 5), are highlighted below as protection opportunities.

- The Lavanaway parcel and another unidentifiable parcel immediately to the north (no information included in the Waitsfield parcel data) are in severe danger of additional property loss due to continued bank erosion. The right bank in this area migrated approximately 50 feet to the east during the 1998 flood, and the foundation of one building was subsequently undermined (Figure 6).
- The Roberts and Marble parcels, located near the Butternut Hill Road bridge, are found in the FEH corridor. While the house on the Roberts parcel is situated on a bedrock outcrop and may not be at risk, the foundation of the Marble’s house forms part of the right bank upstream of the bridge. The FEH overlay district would prevent additional structural encroachment on the channel in this parcel.
- The Jarecki parcel is found in an area of active lateral channel migration. Aggradation of coarse sediment following the 1998 flood is causing changes in channel planform that put this parcel at risk for further loss due to erosion.

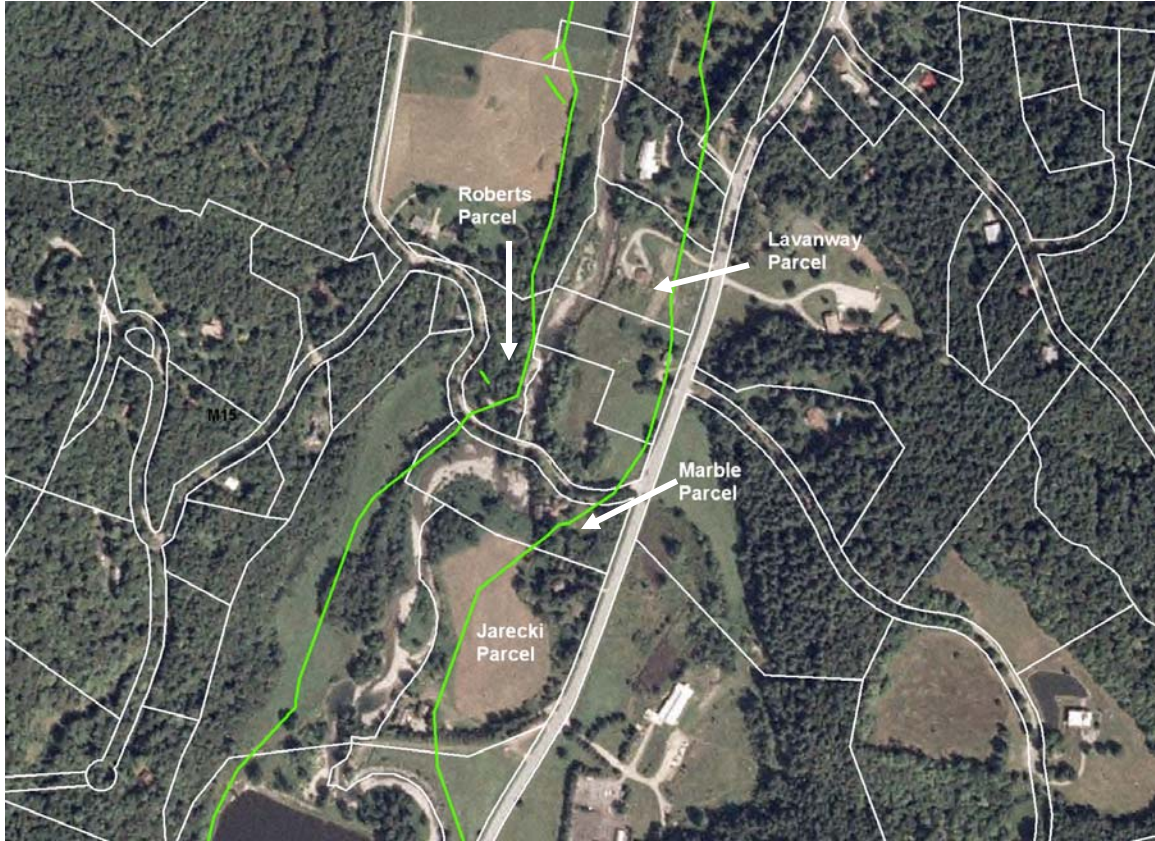


Figure 5. Private (white) parcels found in FEH corridor (green) for Reach M15.



Figure 6. Eroding bank undermining foundation in Reach M15 (FGS, 2007).

## **Comparison of Riparian Property Protection Approaches**

In order to compare the protection afforded the Mad River by different policies, the corridor of Reach M13 was analyzed using the following data: 1) the NFIP 100 year floodway (provisional data; VTDEC, 2007); 2) the protection provided by Waitsfield's stream buffer regulations; 3) the FEH corridor; 4) the land topography (slope) within the FEH corridor. The Town of Waitsfield's zoning bylaws currently provide some protection to the Mad River corridor through the conditional use regulation of additional buildings within the Flood Hazard Area Overlay (FHO) District, as well as the stream buffer setback (Section 3.12; Waitsfield, 2007). However, areas within the FEH corridor that may be suitable for development (based on topography, soils, lack of wetlands, etc.) are afforded no protection from the above-mentioned zoning ordinances.

Reach M13 was chosen to illustrate the additional corridor protection that would be provided by a FEH overlay. The channel in this reach underwent extreme lateral movement during and following the 1998 flood, which is easily visible from the Route 100 crossing upstream of Lareau swim hole. Due to the channel adjustments currently underway, the channel in this area is predicted to continue its lateral movement, and its meanders will likely occupy much of the FEH corridor in the future. A map comparing river corridor and buffer protection alternatives for this area is provided on page 7 of the Attachment. Some key observations from this mapping analysis are provided below:

- The FHO District in this reach is restricted to a narrow width due to historic channel enlargement, which has allowed the channel to accommodate large flood events without floodflows spilling into the wide, historic floodplain. The FHO District provides virtually no corridor protection in this reach, and severely underestimates the width required to accommodate current and future channel adjustments.
- The town stream buffer setback is limited to 50 feet for much of this reach, as the average grade of riparian lands along the channel is less than 8%.
- Three areas within the FEH corridor that are not protected by the FHO District or the stream setback are highlighted on the map. These areas appear to have no wetland or topography limitations, making them suitable for development under the conditions of the Commercial-Lodging or Agricultural-Residential Zones. These areas include: 1) a 1 acre portion of a Town-owned parcel in between Route 100 and the river, 2) a 1 acre portion of the Connell parcel to the west of the river, and 3) a 1.8 acre area spanning the Gaylord and Ketchum parcels to the east of the river.

## **Conclusions and Recommendations**

The FEH analysis has provided a means to assess the Waitsfield Town Zoning and natural and built capital within the Mad River corridor. In addition, the protection

provided to the river corridor by current Town bylaws has been assessed and compared with the protection provided by the FEH corridor. Based on the results of the analysis, conclusions and recommendations for further action are provided below.

- The majority of the FEH Corridor is found within the Agricultural-Residential Zoning District (86.4%), with lesser amounts found in the Commercial Districts (11.8%) and Historic Village Districts (1.7%). A summary of the zoned districts in the FEH corridor is provided in Table 5 on page 2 of the Attachment.
- A total of 23 houses and businesses are found within the FEH corridor, with 6 of these found along Reach M12 in the Historic Village and Irasville area.
- 28% of the FEH corridor in Waitsfield has been protected from future development through purchase by the Town or the Mad River Conservation Partnership. Wetlands occupy approximately 10% of the FEH corridor in the Town. Taken together, nearly 40% of the FEH corridor in the Town of Waitsfield is currently protected from further human development. However, many reaches undergoing severe adjustments have areas unprotected from and suitable for development in the corridor, such as Reach M13.
- The section of channel with an extreme sensitivity rating (Reach M14) is found in an area of steep topography that precludes further development or encroachment.
- Given the high propensity for future lateral channel adjustments observed in Reaches M11, M13 and M15, an FEH overlay in these areas would present an important opportunity to protect the corridor from further development.
- It is recommended that the Town of Waitsfield work with VTDEC to consider the implementation of a FEH Overlay District in the Zoning Bylaws. Such an overlay district would help reduce the risk of future property damage through the prevention of further development in the FEH corridor, and would help protect the aquatic habitat of the Mad River.

## **References:**

FGS (Field Geology Services), 2007, Fluvial Geomorphology Assessment of the Mad River Watershed, Vermont. Prepared for Friends of the Mad River, Waitsfield, Vermont.

Schumm, S. A., 1977, The Fluvial System, John Wiley and Sons, New York.

VTDEC (Vermont Department of Environmental Conservation), 2006, Stream geomorphic assessment handbook - Phase 1 & 2 Protocols, Vermont Agency of Natural Resources Publication.

VTDEC (Vermont Department of Environmental Conservation), 2007, Municipal Guide to Fluvial Erosion Hazard Mitigation. Vermont Agency of Natural Resources Publication.

VTDEC (Vermont Department of Environmental Conservation), 2007, Preliminary Digital Flood Insurance Rate Map for Washington County, VT

Waitsfield (Town of Waitsfield, Vermont), 2005, Waitsfield Zoning Bylaws – Adopted May 2, 2005. Available at: <http://www.waitsfieldvt.us> Accessed November, 2007

**ATTACHMENT**

**Table 4. Phase 2 Data for Waitsfield Study Reaches**

<b>Reach</b>	<b>Stream Type**</b>	<b>Dominant Bed Material</b>	<b>Bedform†</b>	<b>RHA Score</b>	<b>RHA Condition</b>	<b>RGA Score</b>	<b>RGA Condition</b>	<b>Reach Sensitivity</b>	<b>CEM*</b>	<b>CEM* Stage</b>
M11	C	Gravel	Riffle-Pool	0.45	Fair	0.56	Fair	Very High	F	III
M12	C	Gravel	Riffle-Pool	0.53	Fair	0.58	Fair	Very High	F	III
M13	C	Gravel	Riffle-Pool	0.48	Fair	0.51	Fair	Very High	F	III
M14	F	Gravel	Riffle-Pool	0.75	Good	0.56	Fair	Extreme	F	IV
M15	C	Cobble	Riffle-Pool	0.57	Fair	0.64	Fair	High	F	IV

\* CEM = Channel Evolution Model

\*\* per Rosgen (1994)

† per Montgomery & Buffington (1997)

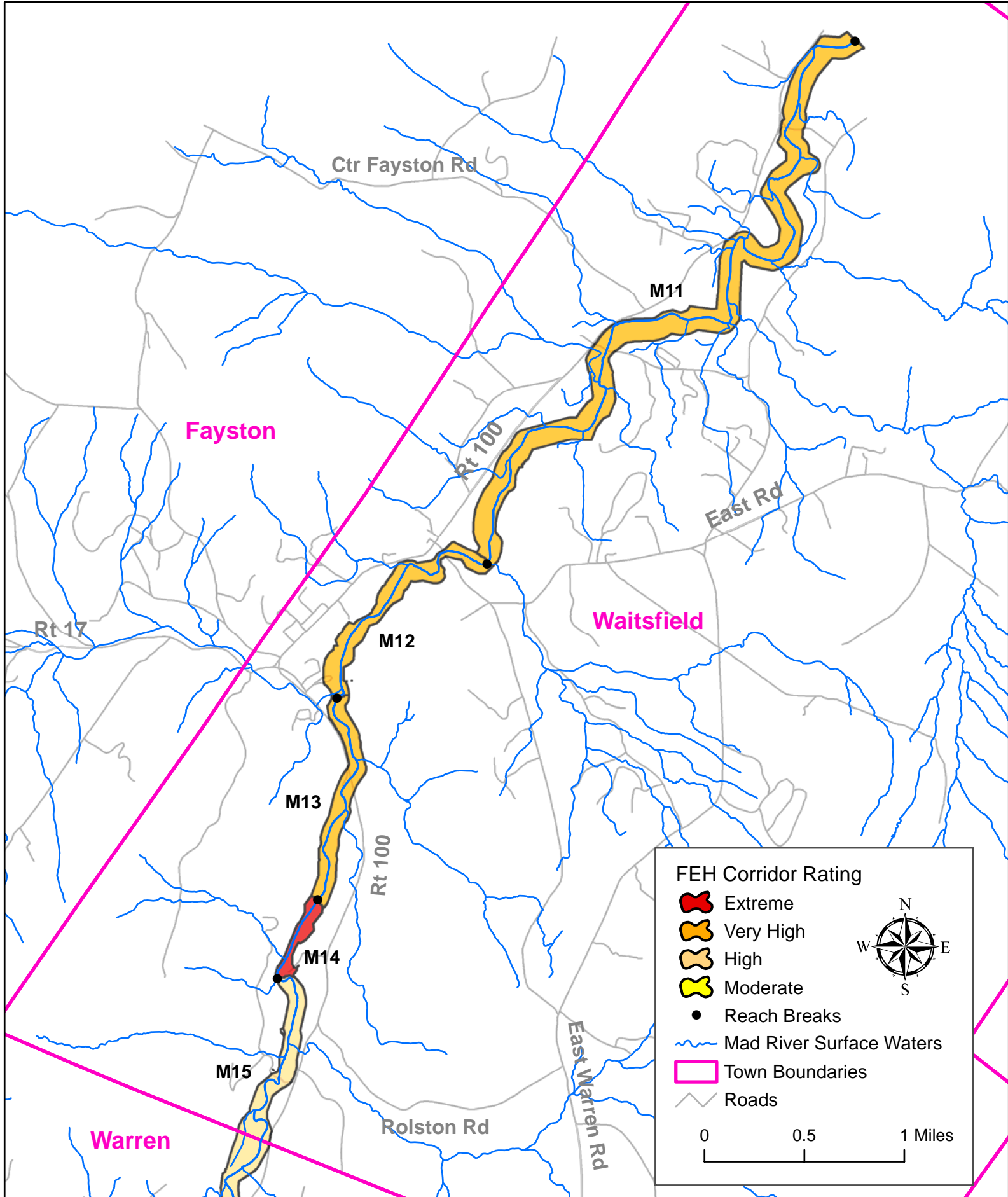
**Table 5. Summary of Town Zoning, Wetlands and Built Infrastructure in the Fluvial Erosion Hazard (FEH) Corridor of the Mad River in Waitsfield, VT**

Reach	FEH Rating	Reach Location	Waitsfield Zoning District					Town-Owned & MRCP* Lands (acres)	Wetlands (acres)	Structures		
			Agricultural-Residential (acres)	Commercial Lodging (acres)	Irasville Commercial (acres)	Historic Village (acres)	Historic Village Residential (acres)			Residential (#)	Commercial (#)	Public (#)
M11	Very High	High Bridge Bk to Shepard Bk	287.9	--	--	--	0.7	106.1	9.8	1	2	2
M12	Very High	Mill Bk to High Bridge Bk	37.2	0.9	23.2	0.4	7.4	11.1	12.7	2	4	--
M13	Very High	Ketcham Parcel to Mill Bk	26.9	33.8	--	--	--	16.6	21.3	--	2	1
M14	Extreme	FitzGibbons parcel to Ketcham parcel	18.3	--	--	--	--	4.7	0.0	1	--	--
M15	High	Rt 100 Bridge to FitzGibbons parcel	53.3	--	--	--	--	0.0	4.1	8	--	--
Percent of Total FEH Zone Land:			86.4%	7.1%	4.7%	0.1%	1.6%	28.3%	9.8%			

\* Lands conserved by the Mad River Conservation Partnership

**Table 6. Percent of Total FEH Corridor Occupied by Zoning Type, Town-Owned Lands and Wetlands**

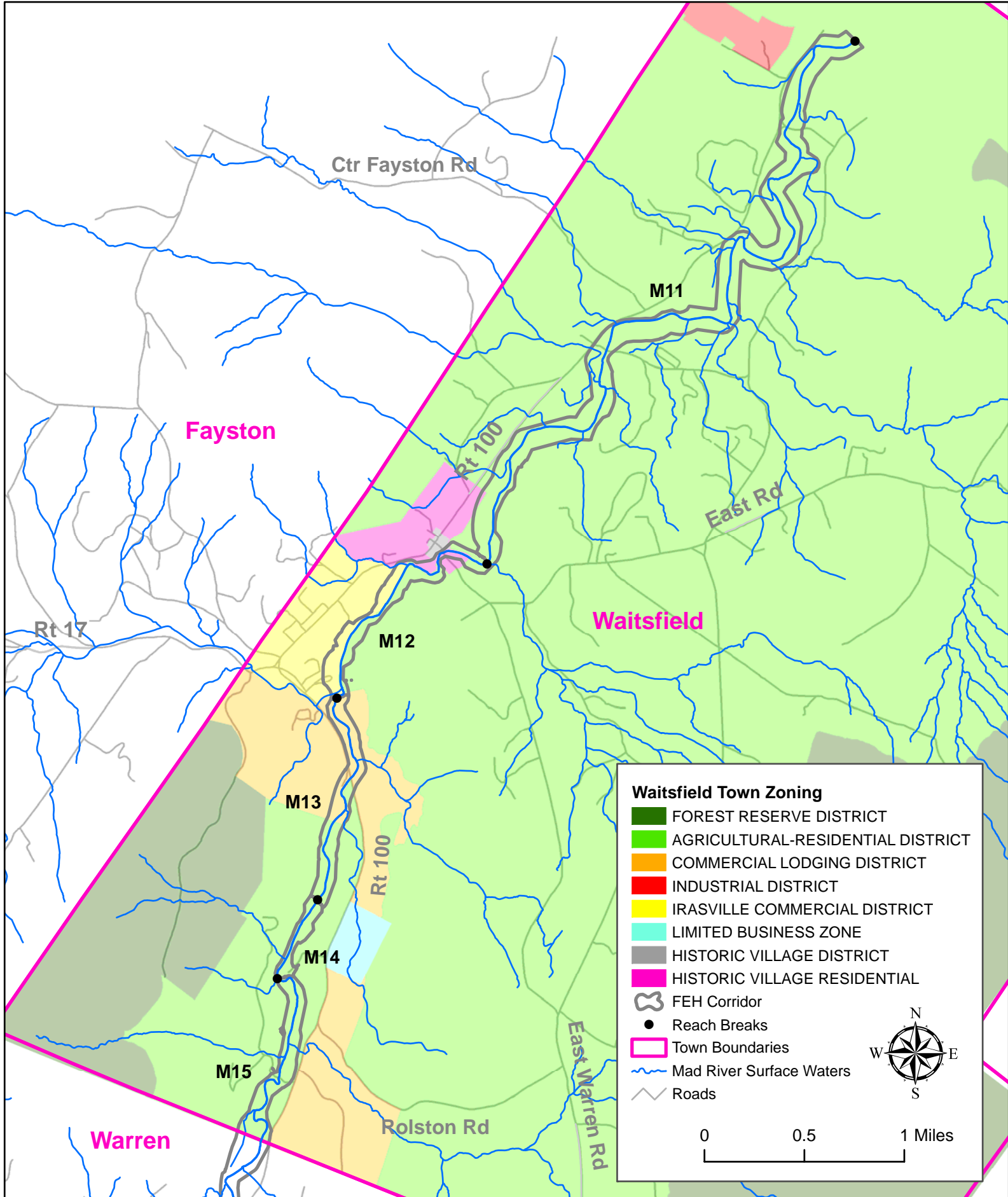
Reach	FEH Rating	Reach Location	Waitsfield Zoning District					Town-Owned & MRCP Lands	Wetlands
			Agricultural-Residential	Commercial Lodging	Irasville Commercial	Historic Village	Historic Village Residential		
M11	Very High	High Bridge Bk to Shepard Bk	99.8%	--	--	--	0.2%	36.8%	3.4%
M12	Very High	Mill Bk to High Bridge Bk	53.8%	1.3%	33.6%	0.6%	10.7%	16.0%	18.4%
M13	Very High	Ketcham Parcel to Mill Bk	44.2%	55.8%	--	--	--	27.3%	35.0%
M14	Extreme	FitzGibbons parcel to Ketcham parcel	100.0%	--	--	--	--	25.5%	0.0%
M15	Moderate	Rt 100 Bridge to FitzGibbons parcel	100.0%	--	--	--	--	0.0%	7.7%



**Mad River Fluvial Erosion Hazard Zone (FEH)  
for the Town of Waitsfield, VT**



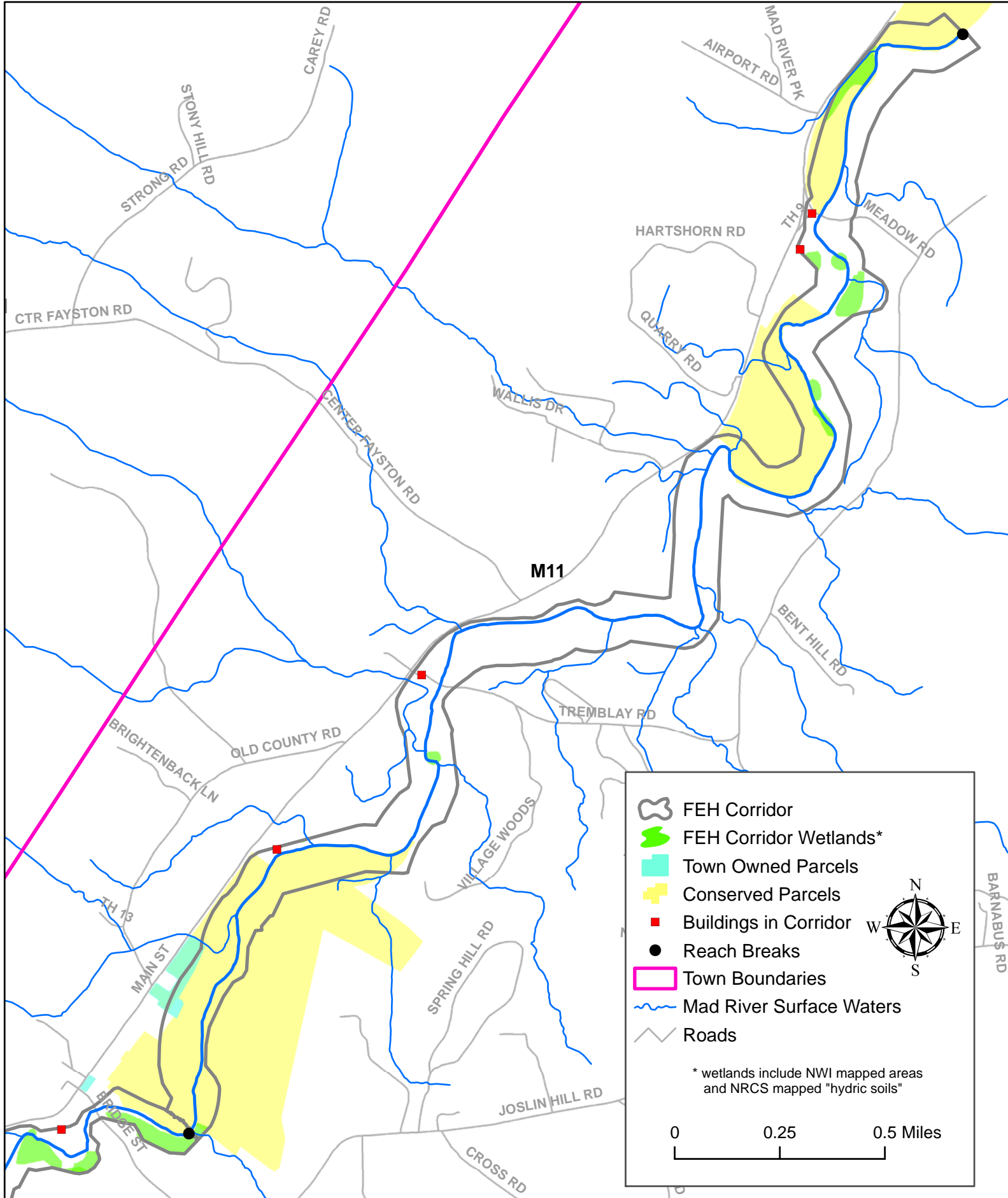
Fitzgerald Environmental Associates, LLC.  
www.fitzgeraldenvironmental.com



**Mad River Fluvial Erosion Hazard Zone (FEH)  
and Waitsfield Town Zoning**

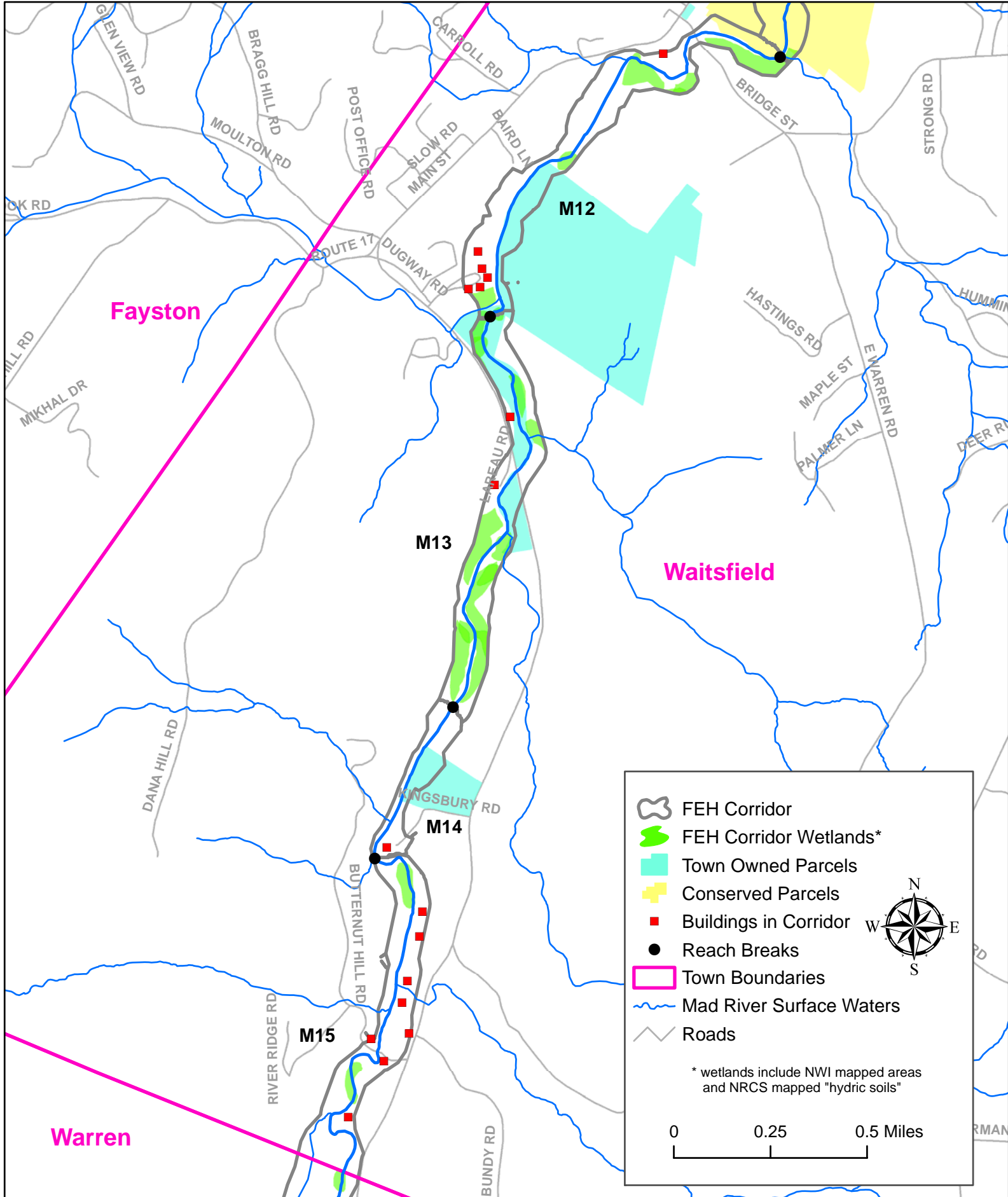


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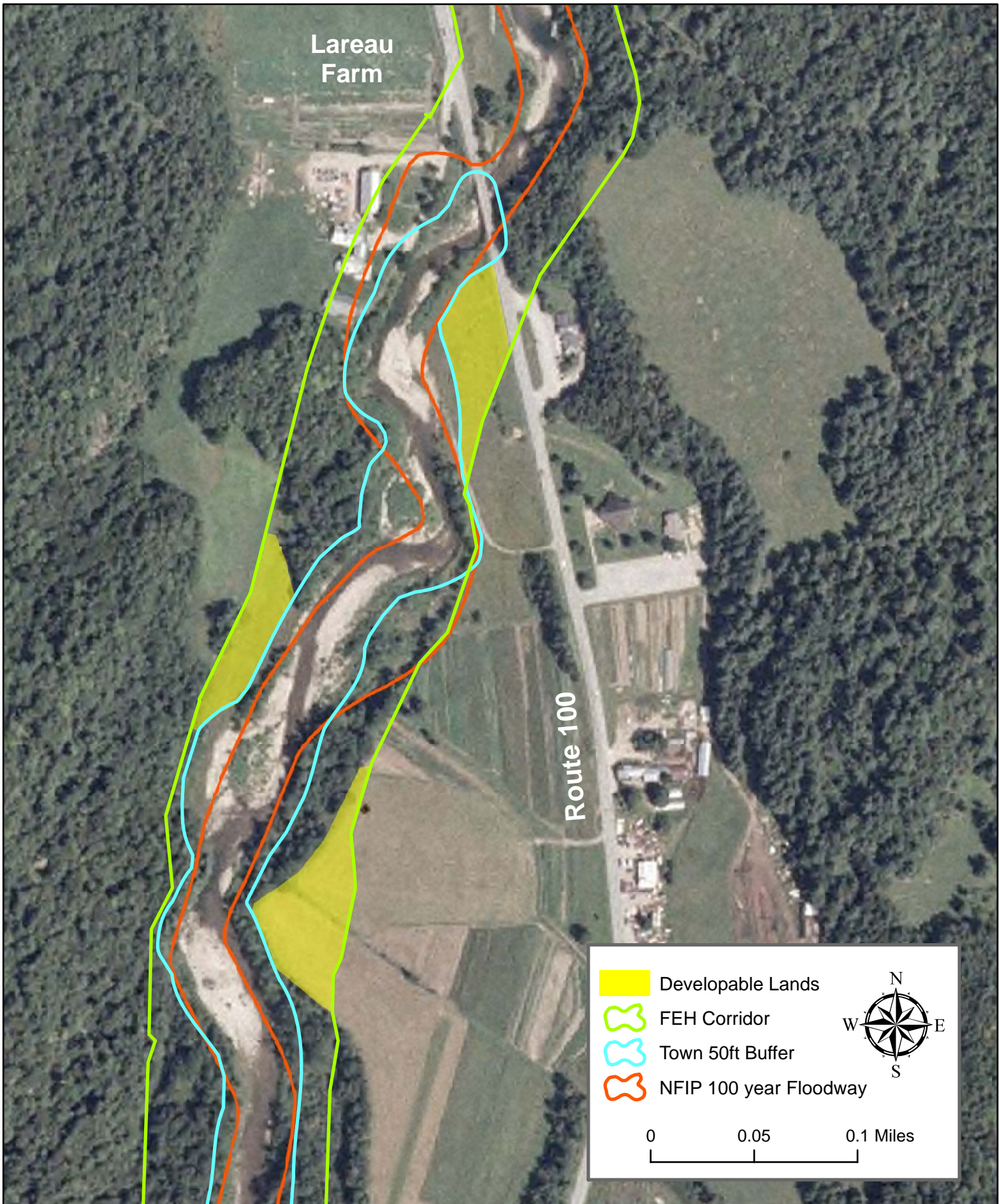
**Mad River Fluvial Erosion Hazard Zone (FEH)  
with Buildings, Wetlands & Conserved Lands  
(Reaches M11 & M12)**





**Mad River Fluvial Erosion Hazard Zone (FEH) with Buildings, Wetlands & Conserved Lands (Reaches M12 - M15)**





**Mad River Reach M13:  
Comparison of River Corridor and  
Buffer Protection Alternatives**



Fitzgerald Environmental Associates, LLC.  
316 River Road  
Colchester, VT 05446  
tel/fax. 802.419.0808  
evan@fitzgeraldenvironmental.com



## State of Vermont

## AGENCY OF NATURAL RESOURCES

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Department of Fish and Wildlife  
Department of Forest, Parks and Recreation  
Department of Environmental Conservation

DEPARTMENT OF FISH AND WILDLIFE  
District Fisheries Office  
3902 Roxbury Road  
Roxbury, Vermont 05669  
(802) 485-7566

**TO: Evan Fitzgerald, Fitzgerald Environmental Associates**

**FROM: Michael Humling; District Fisheries Biologist**

**DATE: Jan 3, 2008**

**SUBJECT: Mad River Watershed Fisheries Summary**

As in many Vermont streams, fish habitat in the Mad River mainstem varies considerably from headwaters to mouth. Above Warren Village, the river can generally be described as having excellent trout habitat. Stream and riparian conditions are typical of most Vermont upland streams, with intact forested riparian areas, steep gradients, rocky substrates, and cold, clean water. The upper Mad River and most of its upland tributaries support wild, self-sustaining trout populations. Brook trout dominate in the highest reaches and exist downstream to at least Warren Village, where wild rainbow begin to become more numerous.

Between Warren and Waitsfield villages, the gradient decreases and the river becomes wider with more riffles, bars, and occasional deeper holes. Wild brook and rainbow trout populations are present in good numbers, though in slightly lower densities than upstream. Wild brown trout can also be found below Warren, but are less abundant than brook or rainbow trout. In addition to trout, a number of non-game species can be found in the middle and upper reaches. These include blacknose dace, longnose dace, creek chub, white sucker, longnose sucker, and slimy sculpin.

Below Waitsfield Village, the river is wider and flatter with a high proportion of fine substrates and poorer riparian vegetation condition. With several possible exceptions, wild trout populations are low to non-existent downstream. Due to the cumulative effects of insufficient riparian shading and wide, shallow flows, instream summer water temperatures regularly exceed trout tolerance limits.

Vermont Fish & Wildlife historically stocked much of the Mad River Watershed, including a number of tributaries with fry and catchable size brook, rainbow, and brown trout. Currently the Mad River above Warren Village and all of its tributaries are managed as wild trout fisheries. Wild trout populations are considered to be sufficient to support existing recreational fishing pressure and thus no fish are stocked. From below Warren Village to the mouth, hatchery-reared brook, rainbow, and brown trout are stocked to support recreational fisheries.

Several regular trout index reaches throughout the Mad River mainstem and amongst its smaller tributaries have been historically sampled to monitor fish populations and assess changes in management techniques. In addition to these, Vermont Fish & Wildlife has been conducting annual trout population monitoring at nine sites on four upper Mad River tributaries. These include Clay, Rice, Slide and Chase

brooks, all of which are in the vicinity of Sugarbush Ski Area. Population monitoring in these brooks has occurred since 1987 with the objective of evaluating effects of local development and snowmaking.