UPPER WHITE RIVER CORRIDOR PLAN

WHITE RIVER PARTNERSHIP

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We at Redstart have felt honored to be part of this collaborative and cooperative effort. We hope that this report can serve as a component of a natural resource stewardship model that supports a sustainable, enriched and enjoyable world for present and future communities. Special thanks to the trail-blazing and persevering Upper River Stream Team, including Richard and Alvina Harvey, Tom and Sandy Pierce, Marvin Harvey, Walt Wells, Norm Arsenault, Beth and Bob Kennison, Royce Gage, and others who have come before and will come after, as well as Mary Russ, Executive Director of the White River Partnership. Dan McKinley, Stream Team member and Green Mountain Forest Fisheries Biologist, has worn so many hats on Upper White projects over the years that it would be difficult to fully estimate all his contributions; thank you. Kari Dolan, Gretchen Alexander, Staci Pomeroy, Mike Kline, Sacha Pealer, Shannon Hill Pytlik, Leslie Fernandes, Andrew Tomczak, Frederick Nicholson, and Lauren Moore of the River Management Program have offered invaluable support, assistance and encouragement along the way. Chris Casey, Holly Knox, and other members of the USDA Forest Service Rochester Ranger District, Green Mountain and Finger Lakes National Forests, have offered a model for thorough and conscientious work in their analysis of the Upper White watershed and have been extremely helpful in exchanges of that information. George Springston of Norwich University provided valuable field time and information on the geology of the watershed. Pete Fellows, Chuck Wise, Sally Mansur Hull and Kevin Geiger of Two Rivers-Ottauquecheee Regional Commission have provided a wealth of varied and sundry support and information. Mark McEathron and Chris Moore of Vermont Land Trust provided helpful background information. Consultants Lisa Godfrey, Evan Fitzgerald of Fitzgerald Associates, and Mary Nealon and Mike Blazewicz of Bear Creek Environmental Associates provided helpful interactions and examples for communicating much of the science involved. Our thanks are also extended to others who have helped along the way and may have been inadvertently omitted here.

EXECUTIVE SUMMARY

The White River is one of the last free-flowing rivers in Vermont and is noted for its tremendous natural beauty, significant fisheries and wildlife habitat, vital natural resources, ecologic integrity, and recreational values. In the spring of 2006 the White River Partnership (WRP), as part of a project funded by the Vermont Department of Environmental Conservation (VTDEC) River Corridor Grant Program, initiated development of a community-based river corridor management plan for the upper White River (including portions of the river in Stockbridge, Pittsfield, Rochester, Hancock, and Granvillle).

For more than a decade, the WRP has been an active partner and coordinator in developing and implementing community-based projects. The Upper River Stream Team, a volunteer group of the WRP, has been very active in the upper White River watershed, frequently in conjunction with Green Mountain National Forest personnel and other cooperators. After nearly a decade of experience implementing an impressive number of projects, these groups identified a need to coordinate efforts in a more comprehensive plan that assesses overall watershed dynamics in conjunction with smaller scale problems in order to increase the effectiveness of these efforts. In 2004, a decision was made to initiate the Upper River Stream Team Pilot Project, which has evolved into the development of an Upper White Corridor Planning Project.

The draft of this corridor plan, presented here, is designed to integrate information from previous stream assessments and preliminary corridor planning. By assessing underlying causes of channel instability and encouraging the stream's return to equilibrium conditions, management efforts can be directed toward long-term solutions that help curb escalating costs and efforts directed toward resolving conflicts with ongoing stream processes. These efforts can help reduce flood and erosion hazards along the river corridor, improve water quality and aquatic habitat, and enhance recreational opportunities along and in the river.

The results of Phase 1 and Phase 2 geomorphic assessments of the White River conducted by Shannon Hill in 2001 (under WRP and the Vermont Department of Environmental Conservation River Management Program) and Lisa Godfrey in 2003-2004, respectively, are summarized in this report. In addition, the report is informed by a more detailed planform analysis of the upper White mainstem conducted by VTDEC River Management Program personnel in 2004. The results are analyzed through the use of stressor, departure, and sensitivity analysis maps to integrate the findings in a more understandable and intuitive manner.

Results in brief indicate that:

- Portions of the White River included in the Corridor Planning Project, under equilibrium conditions, would provide flow, sediment, and nutrient storage and attenuation in all assessed stream reaches (reaches are portions of the stream with similar characteristics in terms of channel geometry, valley, and floodplain settings)

- Due primarily to historical downcutting of the streambed, the majority of these stream reaches have lost access to historical floodplains, and all included reaches are now functioning primarily as transport reaches that transfer flow, sediment, and nutrient loads to downstream portions of the river. Sediment loads are being deposited primarily when they become too great for the power of the stream to transport further, as there are few constrictions in the Upper White that reduce stream power sufficiently to accelerate deposition

- All portions of the stream channel in the Upper White Project area have been significantly channelized, with indications that 78% to 100% of each reach has been historically straightened

- Loss of access to floodplain means greater flows are now contained within the channel at high flow events; channelization means the stream now diffuses less of its power through meander patterns

- All assessed reaches in the Project area are at a stage of channel evolution marked primarily by overwidening and lateral migration of the stream, due to increased stream power and erosive boundary materials

- Traditional channel management at this stage has usually entailed further channelization, dredging or bar scalping, and often hard armoring of banks for stabilization. In the Upper White, these approaches will tend to aggravate both upstream and downstream impacts of increased stream power and increased sediment loads. In addition, the evolution of the channel as it attempts to reestablish equilibrium is likely to entail further widening and lateral migration, increasing the susceptibility of some of these projects to failure and escalating costs for installation and maintenance

- Stream sensitivity indicates the rate at which the river will return to a dynamic equilibrium, given its own energy and watershed inputs. All but one reach in the Project area were classed as highly to extremely sensitive, indicating the likelihood of relatively rapid channel evolutions. For this reason, most reaches in the Project area are good candidates for passive geomorphic restoration. This approach would reduce costs for project implementation in comparison with approaches such as continued channelization or armoring, but will require an emphasis on protection of the river corridor to reduce conflicts between land use and stream evolution processes.

- One of the most important aspects of restoration work along the Upper White will be identification of areas where the river can be allowed to regain floodplain access for attenuation of flow and sediment loads. Opportunities exist in all reaches of the Project area, although road encroachment and development constraints limit opportunities in the village areas of Rochester, Hancock and Granville. Limiting further development in floodplain and riparian corridor areas will avert future conflicts with inevitable river dynamics.

- The White River valley is extensively farmed, and some of the more challenging aspects of restoration will involve development of fair and equitable solutions to allowing floodplain access and protection of key attenuation assets in areas of high value agricultural lands.

- Vegetated stream buffers will be important to the success of most restoration activities on the Upper White, where bank materials are highly erodible. Planting activities can be completed independent of many other projects, but should focus on low-cost approaches using smaller stock in most areas of the Upper White due to lateral bank instability in areas where buffers are not already established.

- The increased stream power, increased sediment load, and erosive boundary materials along the Upper White mean that primary flood hazards are more likely to come from channel avulsions and severe erosion rather than high water inundation. Although all towns in the Project area have stand-alone floodplain ordinances (based primarily on flood inundation levels) or have incorporated such ordinances into zoning regulations, fluvial erosion hazard mapping is recommended as a means to further reduce conflicts and protect valuable assets.

2.0 INTRODUCTION

Vermont's rivers and streams have a long history of being utilized and impacted by humans. Due in part to the long-term processes resulting from this history of interaction with human uses, we often find ourselves in an escalating cycle that requires an increasing level of investment to rebuild and/or protect property and livelihoods from damage caused by weather events or by erosion and nutrient loading on ecosystems and recreational resources. With increasing recognition of this situation, and informed with data from geomorphic assessments, communities have the opportunity to reduce conflict with the river by practicing river management that favors an equilibrium between the power of moving water and the transport and storage of sediment that is held within that water (VT DEC-RMP 2003). Understanding the balance of these forces at a watershed scale, and the fact that occurrences in any portion of a watercourse are linked to processes unfolding in other parts of the watershed over intervals of both space and time, are critical to successful implementation of such an approach. The time and thought that go into this work can contribute to transforming the efforts of perpetual frustrated attempts at control, with often unanticipated consequences, to those of enjoyment of enhanced, vital resources.

2.1 PROJECT OVERVIEW

In the spring of 2006 the White River Partnership (WRP), as part of a project funded by the Vermont Department of Environmental Conservation River Corridor Grant Program, initiated development of a community-based river corridor management plan for the upper White River. For more than a decade, the WRP has been an active partner and coordinator in developing and implementing community-based projects with numerous cooperators[1] throughout the watershed, including numerous stream restoration projects, community outreach, riparian buffer restoration, stream assessments, and preliminary corridor planning. The Upper River Stream Team has been a very active volunteer group of the WRP, helping to implement an impressive number of projects in the Upper White River (hereafter Upper White) watershed, frequently in conjunction with Green Mountain National Forest personnel who have also been very active in river management and restoration projects in this area.

[1] In addition to numerous citizen participants, many of whom are active in local WRP 'Stream Teams', the White River Partnership 'Mission, History, and Principles' page on their website (http://www.whiteriverpartnership.org/index_files/page0001.htm) lists the following partners who had been involved as of 2002: Green Mountain National Forest, National Wildlife Refuge System, Partners for Fish and Wildlife, USDA Forest Service, USDA Natural Resources Conservation Service, Vermont Agency of Natural Resources, Two Rivers-Ottauquechee Regional Commission, Vermont Institute of Natural Science, Trout Unlimited, National Wildlife Federation, U.S. Department of the Interior Fish & Wildlife Service, Connecticut River Joint Commissions, and the U.S. Environmental Protection Agency.

The following excerpt is from the White River Partnership website (http://www.whiteriverpartnership.org/), and serves to summarize many of the key issues of concern in the Upper White watershed:

> Our River Heritage
>
> The White River is one of the last free-flowing rivers in Vermont. From its headwaters in the Green Mountains, it travels 56 miles through a variety of landscapes to its confluence with the Connecticut River. The combination of forest, agricultural fields, farms and historic towns make the watershed one of the most picturesque in New England. But it is more than just a pretty picture, the White River is of great economic and ecologic importance to the region providing many opportunities for fishing, wildlife viewing, boating, tubing, hunting and swimming. The White is also important in the Connecticut River Salmon Restoration Program, a Special Focus Area of the Conte National Fish & Wildlife Refuge, a National Showcase Watershed…and the main stem is the longest undammed tributary to the Connecticut River.
>
> While the White is still known for its trout fishing and scenic beauty, the watershed faces many challenges. Local communities are increasingly concerned about issues like riverbank erosion, water quality problems, wildlife and habitat loss, sedimentation, the decline of native fisheries, flood damage and limited public access.

In 2004, a series of forums were held to develop the background for the Upper River Stream Team Pilot Project (notes from final session are included as Appendix 1). Following the conclusion of this pilot effort, the WRP determined that a river corridor plan for the Upper white would be a beneficial next step. The Upper White Corridor Planning Project (hereafter "the Project") area includes eight mainstem 'reaches' (sections of river with similar slope and valley setting) comprising roughly 19 miles of the river chosen for inclusion through this planning process and based largely on the same concerns summarized above. The primary goal of the Project was to cooperate with local landowners and community members to develop a community-based river corridor management plan for the Upper White that includes a strategy for prioritizing protection and restoration efforts. Many of these cooperators have been involved with restoration efforts in the watershed for more than a decade, and based on previous experience have expressed a desire to incorporate a process that will optimize the benefits and minimize the costs of future projects by including upstream and downstream dynamics in the planning process.

The Vermont Agency of Natural Resources (VTANR) River Management Program has been developing the framework for a process to facilitate such a prioritization strategy (VTANR 2007). The goal of the River Management Program is to manage toward, protect, and restore the equilibrium conditions of Vermont rivers by resolving conflicts between human investments and river dynamics in the most economically and ecologically sustainable manner. The objectives include:

1. fluvial erosion hazard mitigation;
2. sediment and nutrient load reduction; and
3. aquatic and riparian habitat protection and restoration

3.0 BACKGROUND INFORMATION

3.1 GEOGRAPHIC SETTING

3.1.1 Watershed description

The White River is located within the Connecticut River basin. The full basin of the White encompasses roughly 710 square miles ranging from roughly 3500 ft in elevation along the spine of the Green Mountains at the western flank of the basin to approximately 600 ft at the confluence with the Connecticut River on the eastern edge of the basin. The Upper White mainstem (the Project area) comprises roughly 24 miles of stream extending from the headwaters of the White River, in Ripton, to a downstream terminus just above the confluence with the Tweed River in Stockbridge. From the confluence with the Tweed at the downstream end of the Project area, the White River mainstem enters its 'middle' portion and is joined by the Third Branch before entering the 'lower' section of the mainstem (where it is joined by the Second and First Branches), on its way to emptying into the Connecticut River at White River Junction (Fig. 1).

3.1.2 Political jurisdictions

Project reaches on the Upper White mainstem are located in the towns of Stockbridge, Pittsfield, Rochester, Hancock, and Granvillle (Fig. 1). The drainage basin for these reaches also includes small portions of the towns of Bethel, Braintree, Chittenden, Goshen, and Ripton. The mainstem in this area lies primarily in Windsor and Addison counties, with a small portion in Rutland county; the basin also includes a very small area in Orange county (Fig. 1 inset).

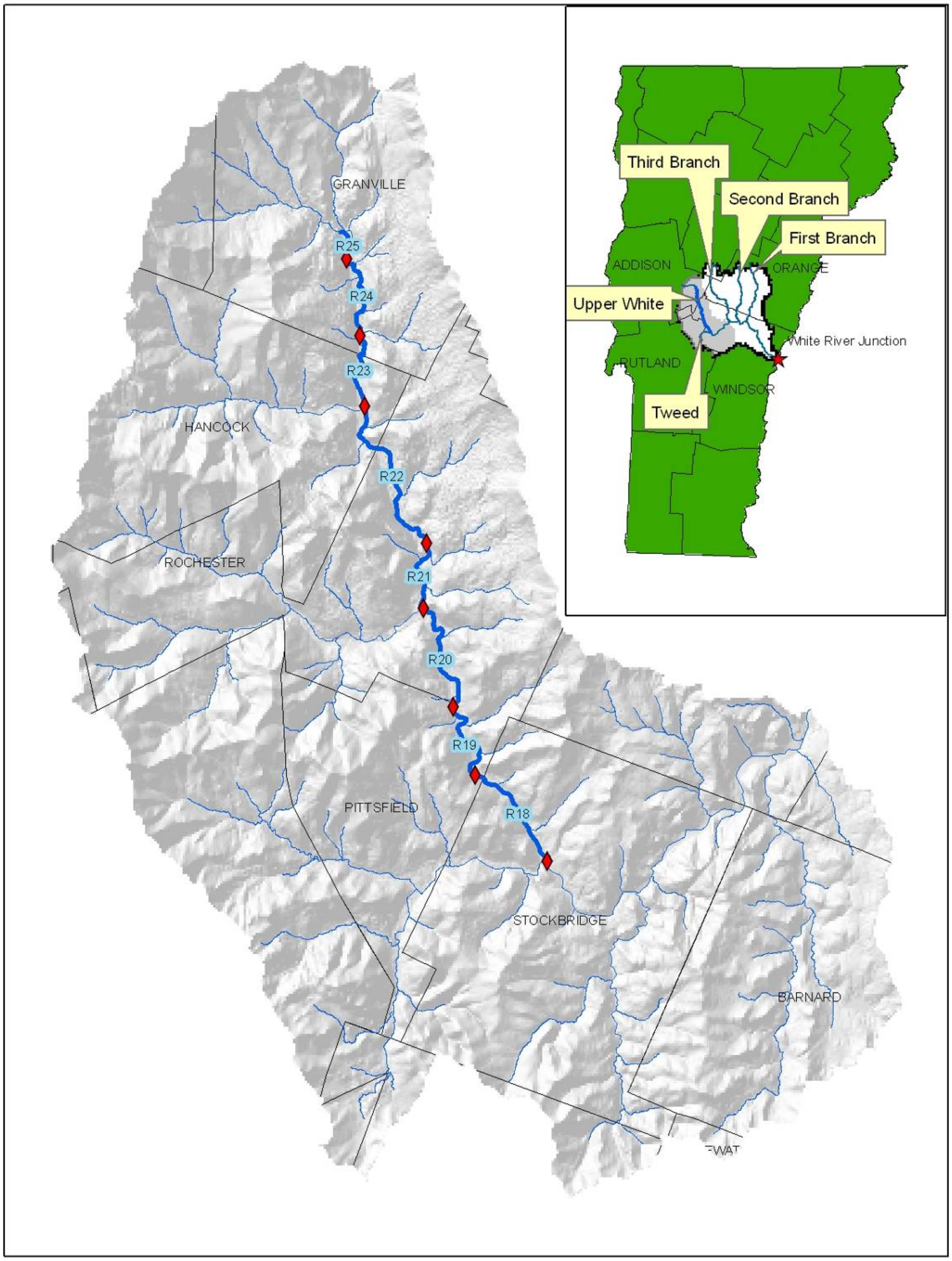


Figure 1. Eight mainstem reaches included in the Upper White River Corridor Planning process depicted in relationship to the drainage basin of the upper and middle White River mainstem. Inset shows the location of this area in terms of the entire White River drainage basin.

3.1.3 Land use history and current general characteristics

An excellent background treatment and analysis of the Upper White River has been prepared by the USDA Forest Service, pertinent points of which are briefly summarized at the following location on the world wide web:
(http://www.fs.fed.us/r9/gmfl/green_mountain/resource_management/soil_water_air/water/index.htm).

Current historical research indicates a long period of Native American use of this area, with the White River likely providing an important travel route between the Connecticut River and points north and west. Low population densities and primarily non-intensive land use, however, likely created minimal impacts on the landscape. With the arrival of European immigrants, land-use and settlement patterns after the late 1700's had a more dramatic affect on the landscape and hydrology. "Land clearing, logging, altered stream channels, intensive agricultural practices, home building, and the establishment of road systems created the "classic" Vermont landscape of open hillsides, rural homesteads and stream-side roads and mills…" (USDA-FS 2001). Current forest species and age distributions indicate that the watershed likely experienced extensive areas of deforestation, with accompanying changes in hydrology including higher peak flows and direct runoff discharges, lower minimum flows, and significant inputs of sediment. These trends appear to have peaked around 1920, with a reduction in peak flows and higher minimum flows gradually returning as the watershed was reforested through the 20th century (USDA-FS 2001). The higher peak flows through aggraded sediment inputs, in particular, were likely contributors to a high degree of historical incision noted in the Upper White corridor during the data collection for the current Project.

Farming and wood products dominated the economy during the last century and continue to be important parts of the economy and culture today. Log drives along the river corridor have been documented, and 'snagging' of the channel in the past along with current land uses has likely contributed to a scarcity of large woody debris along the mainstem. Most of the lands west of the Upper White are under the jurisdiction of the Green Mountain National Forest. Scenic and recreational values are important socially and economically throughout the watershed. Most lands east of the Upper White are wooded, and are owned by private individuals; forest management and harvesting is practiced by many. Livestock grazing and diverse farms occupy private lands along floodplains and terraces of the White River. Lower elevations along the main stem of the White River and tributaries are used for primary and secondary home sites. The area east of Route 100 to the Braintree Ridge has an extensive gravel road system accessing private homes.

3.2 GEOLOGIC SETTING

The Upper White River corridor basin is bounded by the Green Mountains to the west and the Braintree ridge to the east, and ranges from roughly 750 ft. elevation along the River to approximately 3500 ft at the highest elevations of the Greens and 3000 ft on the Braintree ridge. These mountains were originally in the bottom of the Iapetus Ocean and were pushed upward when continents collided in the Taconic Orogeny (Thompson and Sorenson 2000). The primarily acidic metamorphic mudstones that comprise the bulk of the bedrock geology have remained very resistant to erosion over time. There are numerous inclusions of calcareous bedrock however, evident in much of the Upper White corridor area. Additionally, slivers of oceanic crust and deep mantle layers were forced upward to form local concentrations of talc and other unusual, localized formations, particularly along the eastern flank of the Green Mountains.

More recently, glaciation moved from northeast to southwest through this region, exposing bedrock at high elevations but widely depositing glacial till at mid and lower elevations. Ridgetops and sideslopes formed from loose or compacted glacial till, weathering to well drained, loamy soils. Upper sideslopes are often steep, shallow, and highly erosive. Soils on mid-to-lower sideslopes tend to be deep, frequently accompanied by an underlying hardpan that limits the occurrence of mass wasting and gully formation. Mid-to-lower slope soils vary in erodibility depending on the slope, wetness, and amount of organic matter. Basin characteristics for the Upper White corridor, however, include very steep valley walls on both sides for all reaches included in the Project area. With glacial outwash deposits forming parent materials, stream processes over time have created alluvial deposits that comprise the bulk of the valley bottom and floodplains. While the soil formations in these lowest elevations are generally considered of low erosive potential due to gentle slopes, the materials are highly erodible and can be a significant source of sediment from unstable stream banks. Table 1 provides a summary of the corridor soil properties and valley side slopes at a reach scale.

Table 1. Upper White River geology and soils summary

Reach ID	Geologic materials			Valley side slopes		Soil Properties		
	Dominant	% Dom	Sub-Dominant	Left	Right	Hydrologic Group	%	Erodibility
R18	Alluvial	43	Ice-Contact	Extremely Steep	Extremely Steep	B*	82	Moderate
R19	Till	49	Ice-Contact	Extremely Steep	Extremely Steep	B*	77	Severe
R20	Alluvial	49	Ice-Contact	Extremely Steep	Extremely Steep	B*	76	Moderate
R21	Alluvial	33	Ice-Contact	Extremely Steep	Extremely Steep	B*	70	Severe
R22	Alluvial	60	Till	Extremely Steep	Extremely Steep	B*	82	Moderate
R23	Alluvial	79	Till	Extremely Steep	Extremely Steep	B*	80	Slight
R24	Alluvial	71	Till	Extremely Steep	Extremely Steep	B*	60	Slight
R25	Alluvial	57	Ice-Contact	Extremely Steep	Extremely Steep	B*	57	Slight

* Primarily, moderately well drained

3.3 GEOMORPHIC SETTING

For the purpose of geomorphic assessment and corridor planning, the Upper White has been divided into 'reaches,' eight of which fall within the scope of this plan. A reach is a similar sections of stream; this determination is primarily based on physical attributes such as valley confinement, slope, sinuosity, dominant bed material, and bed form, as well as predicted morphology based on hydrologic characteristics and drainage basin size. The eight reaches chosen for inclusion in the Project comprise approximately19 stream miles located between Stockbridge on the downstream end and Granville on the upstream end (Fig. 1), draining some 91,715 acres (143.3 sq. mi.). The relationship of the stream channel to its valley setting is fairly similar throughout this Project area, making this section of river relatively homogenous. Using remote sensing analysis, the Phase 1 assessment conducted for the Upper White concluded that 'reference type' for all included reaches was a C type, riffle-pool system (Rosgen 1994) dominated by gravel substrates. This channel type is typically found in unconfined valleys, noted for its meandering nature, and uses floodplains to dissipate energy during flood events. Currently, the river in the Project area has no natural grade controls such as waterfalls or ledge outcrops, although some limited areas of bedrock outcrop are located along the banks and valley walls.

Table 2 briefly summarizes the Phase 1 characterization of these reaches. Further detailed descriptions of the reaches, with associated Phase I and II observations, are found in Section 6 of this report along with maps depicting Phase 2 segment delineations.

Table 2. Upper White River Phase 1 reference reach summary statistics

Reach ID	Drainage Area (sq mi)	Valley width (ft)	Valley Type	Channel width (ft)	Channel Slope (%)	Sinuosity	Reference Stream Type	Channel Bedform
R18	143.31	888	Broad	116.4	0.13	1.06	C	Riffle-Pool
R19	136.5	1136	Broad	114	0.18	1.25	C	Riffle-Pool
R20	128.49	1286	Very Broad	111	0.22	1.19	C	Riffle-Pool
R21	79.66	923	Very Broad	89.9	0.36	1.09	C	Riffle-Pool
R22	71.23	1153	Very Broad	85.6	0.23	1.17	C	Riffle-Pool
R23	34.4	871	Very Broad	62.1	0.41	1.19	C	Riffle-Pool
R24	27.79	1201	Very Broad	56.6	0.21	1.23	C	Riffle-Pool
R25	22.01	1155	Very Broad	51	0.57	1.06	C	Riffle-Pool

3.4 HYDROLOGY

3.4.1 Upper White River StreamStats

The United States Geological Survey (USGS) administers a StreamStats in Vermont website, which is designed to help compute streamflow and drainage basin characteristics for ungaged sites (application description: http://water.usgs.gov/osw/streamstats/ssinfo.html; Vermont state application: http://water.usgs.gov/osw/streamstats/Vermont.html). Basic characteristics for the Upper White drainage basin are summarized in the following report:

*Streamflow Statistics Report**

Date: Thu Apr 26 2007 10:52:22
Site Location: Vermont
Latitude: 43.7768
Longitude: -72.7532
Drainage Area: 143 mi2

Peak Flow Basin Characteristics			
100% Statewide Peak Flow (143 mi2)			
Parameter	**Value**	**Min**	**Max**
Drainage Area (square miles)	143	0.211	850
Percent Lakes and Ponds (percent)	0.0646	0	6.86
Percentage of Basin Above 1200 ft (percent)	89.2	0	100
Geographic Factor (dimensionless)	155900.9	-87	296194

Streamflow Statistics					
Statistic	**Flow (ft^3/s)**	**Prediction Error (percent)**	**Equivalent years of record**	**90-Percent Prediction Interval**	
				Minimum	**Maximum**
Q2	4180	42	1.4	2170	8040
Q5	6120	40	2.3	3230	11600
Q10	7570	41	3.2	3960	14500
Q25	9610	42	4.6	4990	18500
Q50	11200	43	5.5	5750	21900
Q100	12900	44	6.3	6470	25800
Q500	17300	49	7.6	8070	37000

*These are peak flow statistics, where Qx = x-Year Peak Flood, i.e.: Maximum instantaneous flow that occurs on average once in x years

Figure 2. USGS StreamStats basin characteristics and statistics reports for the Upper White drainage basin.

There are no continuous record stream gages in the Upper White drainage basin. The nearest gage of this type is downstream on the mainstem White at Bethel, and has a limited track record, spanning years 1932-1955. A gage on Ayers Brook in Randolph, a tributary of the White located approximately 20 miles east of the Upper White in a parallel valley, has a longer continuous record spanning the years from 1941- 2003, but monitors a much smaller drainage basin (30 sq. mi.). Figure 3 (VTANR 2006, Appendix L) indicates that the 50year-flood peak discharge was exceeded on Ayers Brook in 1973 and 1998, while the 25-year-flood level was exceeded in 1952.

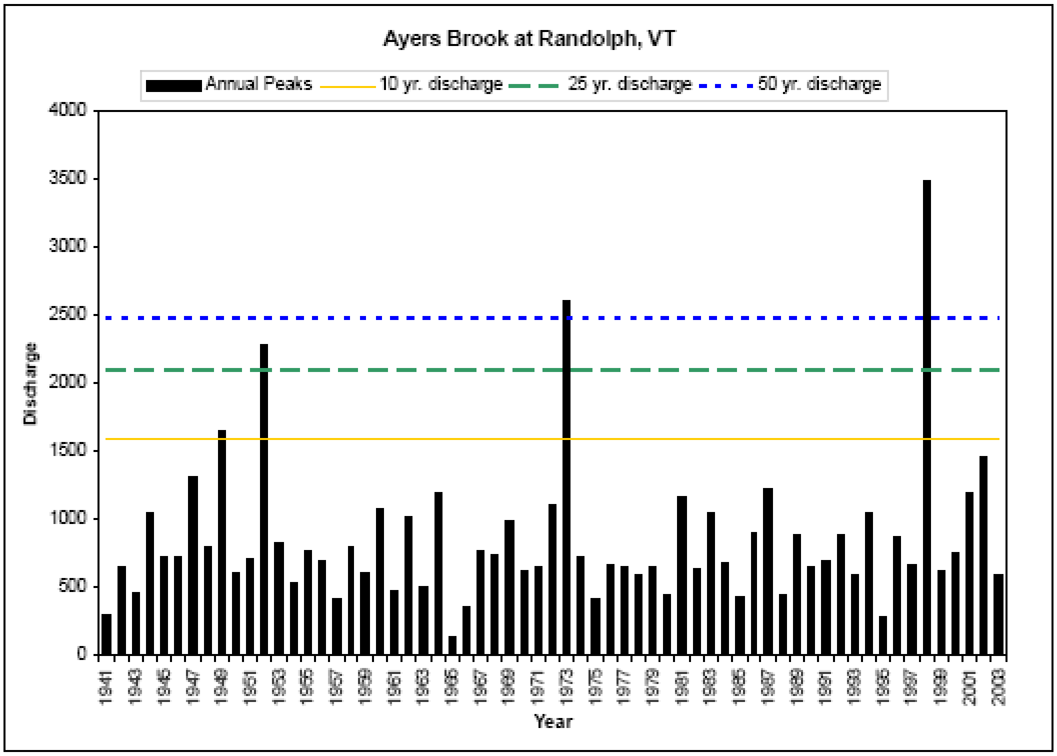


Figure 3. Annual and flood-level peak streamflows at the USGS continuous record stream gage on Ayers Brook. (Water years run from Oct. 1 – Sept. 30).

Further downstream on the mainstem of the White, the USGS gage at West Hartford has a continuous record spanning 1912-2005, but monitors a drainage basin (including the Upper White) of 630 sq. mi., nearly 4.5 times the size of the Upper White basin. Figure 4 indicates that the 500-year flood-level was exceeded at West Hartford in 1927, while peak discharges approached or exceeded the 25-year-flood level in both 1936 and 1938. The 10-year-flood level was exceeded in 1973, with peak discharges in excess of the 10-year- flood level in 1922, 1976, 1987, 1998, and 2002. Noticeable is the fact that the 10-year- flood level was not exceeded in 2000, a year when the Upper White did experience flooding (USDA-FS 2001).

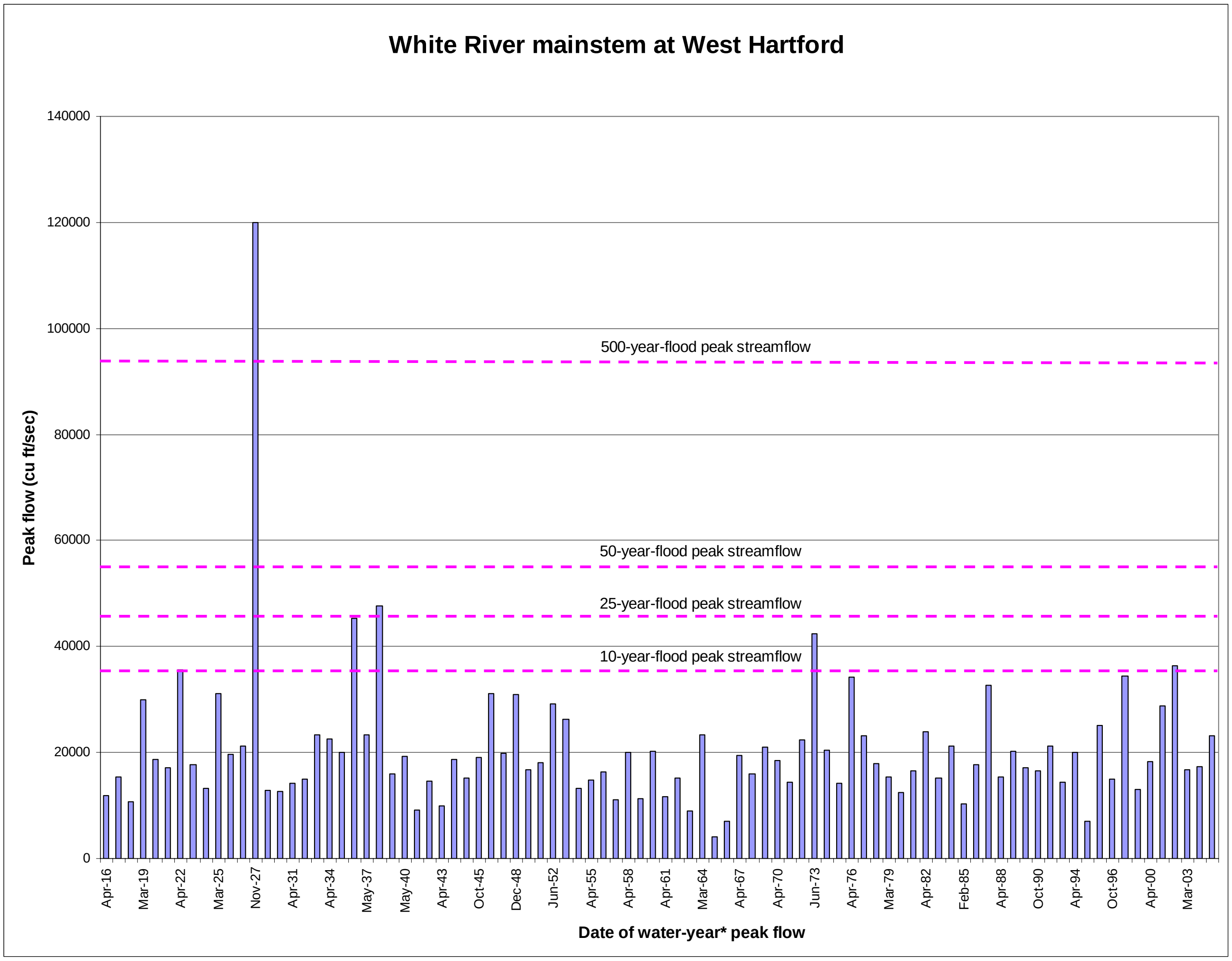


Figure 4. Annual and flood-level peak streamflows at the USGS continuous record stream gage on the mainstem of the White River at West Hartford. (*Water years run from Oct. 1 – Sept. 30).

While these statistics give a general sense of peak flows in the river based on the drainage basin characteristics, it is also important to recognize the impact of changes in hydrology over time, as further discussed in Section 4.1 of this report.

3.4.2 Upper White flood history

As partially noted in the previous discussion, major floods occurred in the Upper White basin in 1830 (USDA-FS 2001) and 1927 (Johnson 1928), with floods of lesser extent occurring in 1973, 1998 and 2000 (USDA-FS 2001). As was the case in much of central Vermont during floods in the 1970s, dredging and channelization occurred in response to these events during that time period in particular (USDA-FS 2001).

The flood of 1927 caused extensive damage to the railroad bed and many dams; this flood is hence largely responsible for the fact that the mainstem of the White River is today the largest undammed tributary of the Connecticut. Although some railroad bridges in the Upper White remained on their abutments, the White River Railroad between Bethel and Rochester was put out of business by the loss of a large portion of its roadbed, and all highway bridges between Rochester and White River Junction were taken out by the river in the November flood (Johnson 1928). Bridges in Granville and Hancock also sustained substantial damage or went out, and virtually all developed waterpower and hydroelectric dams were destroyed (Johnson 1928).

3.5 ECOLOGICAL SETTING

The White River, as a largely flee-flowing river, is important for Atlantic salmon restoration in the Connecticut River Basin's Anadromous Fish Restoration Program. The watershed also hosts a native resident fish community that includes such species as brook trout, Slimy sculpin and Blacknose dace along with naturalized Rainbow and Brown trout important to popular and economically important sport fisheries (USDA-FS 2001). State and Federal fisheries biologists have observed declines in the trout and salmon fisheries or recorded low fish abundance in specific reaches of the White River, including the Upper White.

Wetland habitats are sparsely distributed in the watershed largely due to the geological setting (contributing primarily well and moderately drained settings), and are not well documented. Several dragonflies and damsels are considered sensitive species for USDA Forest Service Region 9 (which includes the Upper White area) but have not been surveyed in wetland and riparian areas within the Project area (USDA-FS 2001).

Riparian habitat has been heavily influenced by human habitation in the last two hundred years, with intensive agriculture and development largely occupying what would likely be floodplain forest habitats. The numerous inclusions of calcareous bedrock in the area contribute to potential habitat for a number of uncommon or rare species, and support a good number of butternut (a Region 9 sensitive species) within the riparian corridor of the Upper White (although the large majority are declining due to the presence of butternut canker).

4.0 METHODS

4.1 STREAM GEOMORPHIC ASSESSMENT

In an effort to provide a sound basis for decision-making and project prioritization and implementation, the Vermont Agency of Natural Resources (VTANR) has developed protocols for conducting geomorphic assessments of rivers. The results of these assessments provide the scientific background to inform planning in a manner that incorporates an overall view of watershed dynamics as well as the reach-scale dynamics that have been a primary focal point of project planning in the past. Incorporating upstream and downstream dynamics in the planning process can help increase the effectiveness of implemented projects by addressing the sources of river instability that are largely responsible for erosion conflicts, increased sediment and nutrient loading, and reduced river habitat quality (VTANR 2007). Trainings have been held to provide consultants, regional planning commissions, and watershed groups with the knowledge and tools necessary to make accurate and consistent assessments of Vermont's rivers.

The stream geomorphic assessments are divided into three phases. A Phase 1 assessment is a preliminary analysis of the condition of the stream through remotely sensed data such as aerial photographs, maps, and 'windshield survey' data collection. Phase 2 involves rapid assessment fieldwork to inform a more detailed analysis of what adjustment processes are taking place and predicting how the river will continue to evolve in the future. Phase 3 involves detailed fieldwork for the identification and implementation of management and restoration projects.

The White River Partnership hired Shannon Hill to conduct a Phase 1 Stream Geomorphic Assessment (SGA) of the White River mainstem watershed in 2001, and a Phase 2 SGA for the Upper White was conducted primarily by Lisa Godfrey during 2003 and 2004. VTDEC River Management Program personnel conducted a more detailed planform analysis of the upper White (analyzing the meander patterns of the stream in its valley setting) in 2004 (VTDEC-RMP2004; Appendix 9). As previously noted, the USDA Forest Service has completed a landscape-scale watershed analysis for the Upper White, which was utilized extensively for background and auxiliary information (USDA-FS 2000, USDA-FS 2001).

Vermont Agency of Natural Resources (VTANR) River Management Program personnel transferred Phase 1 data and Phase 2 stream channel cross-section data to the most current version of the VTANR Stream Geomorphic Assessment (SGA) Database (https://anrnode.anr.state.vt.us/ssl/sga/security/frmLogin.cfm). Redstart Consulting transferred Phase 2 field data into the SGA Database. Phase 1 data were updated, where appropriate, using the field data from the Phase 2 assessment; these changes are tracked and documented within the SGA Database. Spatial data for bank erosion, grade control structures, bank revetments, beaver dams, debris jams, depositional features, and other important features were documented within all segments and entered by Redstart into the spatial component of the statewide data base (the Feature Indexing Tool, FIT) via the Stream Geomorphic Assessment Tool (SGAT) ArcView extension, which permits geographic information systems implementation of the data.

4.2 QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance/quality control (QA/QC) checks were initially conducted by Redstart utilizing the QA/QC tools developed by VTANR and implemented through the SGA Database in January 2007 (https://anrnode.anr.state.vt.us/ssl/sga/security/frmLogin.cfm). Data were submitted to VTANR for QA/QC review in January 2007, and VTANR completed an initial QA check in February 2007. Redstart and VTANR each completed subsequent QA checks in February and March 2007, with final checks completed at the end of March 2007. QA/QC reports are included as Appendix 2, and detail connections and amendments made in linking the Phase 1 and 2 data. Data collection methods, along with brief rationales regarding the methodology, can be found in the SGA Protocols (VTANR 2006).

It should be noted that under the protocols in place at the time of Phase 2 data collection (2003-2004), no data was collected concerning parameters for: a) old abutment widths and associated, potential constriction-related geomorphic problems (there are three old abutments within the Project area); b) grade control heights (there are no natural grade controls in the Project area, but a series of small weirs were placed in a restoration effort in the Granville section of the stream); and c) tributary rejuvenation. Tributary rejuvenation occurs when the mainstem of a stream has experienced significant downcutting, with headcutting subsequently observed moving back up a tributary from the confluence as the tributary tries to lower its bed to match the elevation of the mainstem. With a good deal of historical downcutting observed on the mainstem of the Upper White, tributary rejuvenation is probable but undocumented in much of the Project area.

5.0 RESULTS

The following sections summarize Phase I and II SGA analysis for the Upper White River. Stressor, departure, and sensitivity maps are presented as a means to integrate the data that has been collected and show the interplay of watershed and reach-scale dynamics. In addition, these maps should assist in identifying practical restoration and protection actions that can move the river towards a healthy equilibrium (VTANR 2007). Alterations to watershed-scale hydrologic and sediment regimes can profoundly influence reach-scale dynamics, and if not considered adequately can undermine protection and restoration efforts at the reach level (VTANR 2007). Section 4.1 summarizes watershed-scale stressors on the geomorphic and habitat conditions of the stream, and Section 4.2 characterizes reach-scale stressors. Reach scale data from Phase 1 are included as summary sheets in Appendix 3. Reach/segment scale data from Phase 2 fieldwork are included as summary sheets in Appendix 4. Comparative reach/segment summaries and channel geometry data are found in Appendix 5. Channel cross sections are included in Appendix 6.

5.1 DEPARTURE ANALYSIS

5.1.1 Hydrologic regime stressors

The hydrologic regime involves the timing, volume, and duration of flow events throughout the year and over time; as addressed in this section, the regime is characterized by the input and manipulation of water at the watershed scale. When the hydrologic regime has been significantly changed, stream channels will respond by undergoing a series of channel adjustments. 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 (VTANR 2007).

The Upper White drainage basin today is primarily forested (Table 3; Figure 5). Although watershed analysis conducted by the USDA Forest Service (2001) indicates that fine sediment inputs from road systems within the basin are problematic, land developed for residential, urban, and transportation infrastructure comprises roughly 3% of the landuse in the basin, and intensively cultivated crop lands account for another 3.5% of the watershed landcover (Table 3). Analysis of hydric soils overlaid with current crop and developed land uses (Figure 5) indicates some loss of wetland attenuation of precipitation inputs, although wetland extent is relatively small in the basin due to the glacial and geologic history.

Many of the roads and crop lands have been ditched over time, contributing to intensified inputs to the stream, but the primarily historical nature of downcutting in the stream channel observed in the Upper White is likely related to historical deforestation in the watershed. Historical clearing (late 18th and 19th centuries) in the Upper White watershed initially contributed to higher runoff of both water and sediment, which accrued in the valley. Additionally, removal of large woody debris from stream channels, likely related to use of the stream for log drives and agricultural uses, combined with road developments to change the rainfall-runoff regime in such a way that water inputs intensified through deposited sediments, and the watershed's hydrologic regime became more "flashy". While this situation tended to diminish with reforestation of the watershed, the channel of the Upper White River mainstem exhibits a high degree of historical downcutting as indicated by Phase 2 collection of data informing this Project. This downcutting has been sufficient to limit access to the historical floodplain throughout much of the Upper White, meaning that high volume flows are now contained within the channel and smaller precipitation events can generate levels of geomorphic impact previously associated with more extreme precipitation events. Under these conditions, thunderstorms, mid-winter rains, and snow melt events can cause significant hydrologic impacts.

Table 3. Upper White River watershed landcover/landuse (UVM-SAL 2002)

BROADLEAF FOREST (generally deciduous)	61.9%
CONIFEROUS FOREST (generally evergreen)	15.8%
MIXED CONIFEROUS-BROADLEAF FOREST	10.2%
WATER	4.3%
ROW CROPS (not including orchards and berries)	3.5%
TRANSPORTATION, COMMUNICATION AND UTILITIES	1.5%
RESIDENTIAL	1.2%
HAY/ROTATION/PERMANENT PASTURE	1.0%
FORESTED WETLAND	0.4%
COMMERCIAL, SERVICES AND INSTITUTIONAL	<0.1%
INDUSTRIAL	<0.1%
OUTDOOR AND OTHER URBAN AND BUILT-UP LAND	<0.1%
ORCHARDS, BUSH FRUITS, VINEYARDS AND ORNAMENTAL HORTICULTURE	<0.1%
OTHER AGRICULTURAL LAND	<0.1%
NON-FORESTED WETLAND	<0.1%
BARREN LAND	<0.1%

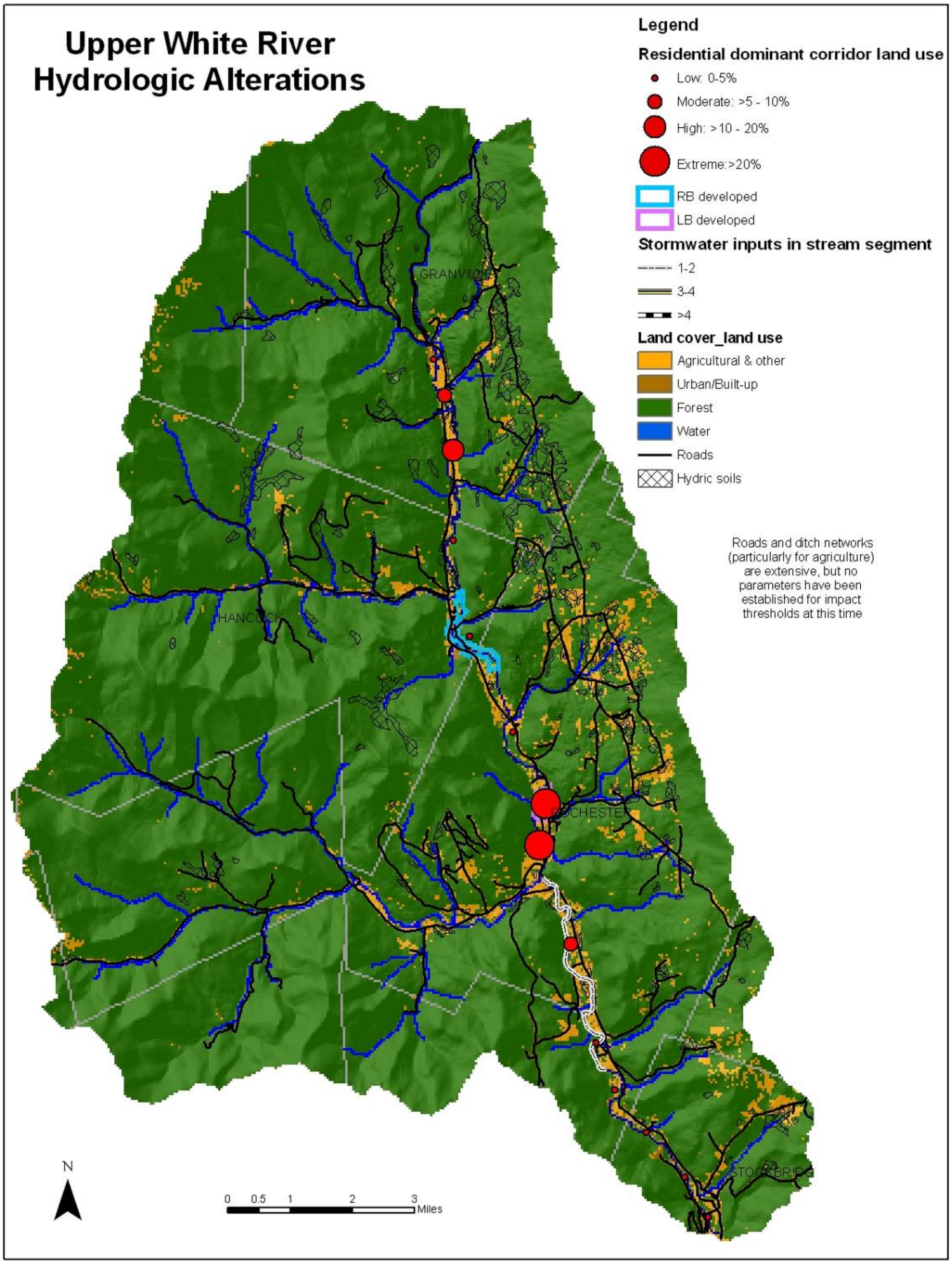


Figure 5. Watershed-scale stressors: Hydrologic alterations map for the Upper White River Corridor Project planning area.

5.1.2 Sediment regime stressors

The following description of issues related to the sediment regime is taken from the most current 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. Sediment erosion and deposition patterns, unique to the equilibrium conditions of a stream reach, create habitat. Generally, these patterns provide for relatively stable bed forms and bank conditions….
>
> …During high flows, when sediment transport typically takes place, small sediments become suspended in the water column. These wash load materials are easily transported and typically deposit under the lowest velocity conditions, which exist on floodplains and the inside of meander bendways at the recession of a flood. When these features are missing or disconnected from the active channel, wash load materials may stay in transport until the low velocity conditions are encountered….This … unequal distribution of fine sediment has a profound effect on aquatic plant and animal life. Fine-grained wash load materials typically have the highest concentrations of organic material and nutrients.
>
> Bed load is comprised of larger sediments, which move and roll along the bed of the stream during floods…. The fact that it takes greater energy or stream power to move different sized sediment particles results in the differential transport and sorting of bed materials….When these patterns are disrupted, there are direct impacts to existing aquatic habitat, and the lack of equal distribution and sorting may result in abrupt changes in depth and slope leading to vertical instability, channel evolution processes, and a host of undesirable erosion hazard and water quality impacts.

Sedimentation and associated degradation of aquatic habitat have consistently been identified as primary issues of concern in the Upper White River (USDA-FS 2000; USDA-FS 2001; VTANR 2002; WRP 1996). At the watershed scale, erosive materials present in upper sideslopes of steep valley walls, alluvial soils on exposed streambanks, and bed materials lacking any natural grade controls in the Upper White River (see Secs. 2.2 and 2.3 of this report) contribute to a characteristically a high sediment-load system. Figure 6 characterizes watershed-scale distribution of sediment load indicators in the Upper White mainstem and drainage basin related to these processes.

Geomorphic instability related to the downcutting (and loss of floodplain access) of the mainstem Upper White have resulted in adjustment processes that are manifested largely in redistribution of the sediment loads noted above as the stream tries to regain equilibrium and establish a new floodplain. Additional stressors in this system can include sheet and gully erosion on exposed soils of tilled croplands in the river corridor in particular, where the extensive ditching system can transport these materials easily in runoff events. On lower elevation sideslopes, underlying hardpan tends to limit the occurrence of mass wasting and gully formation (none were identified in 2003-2004 fieldwork), but additional stressors can rapidly alter this situation.

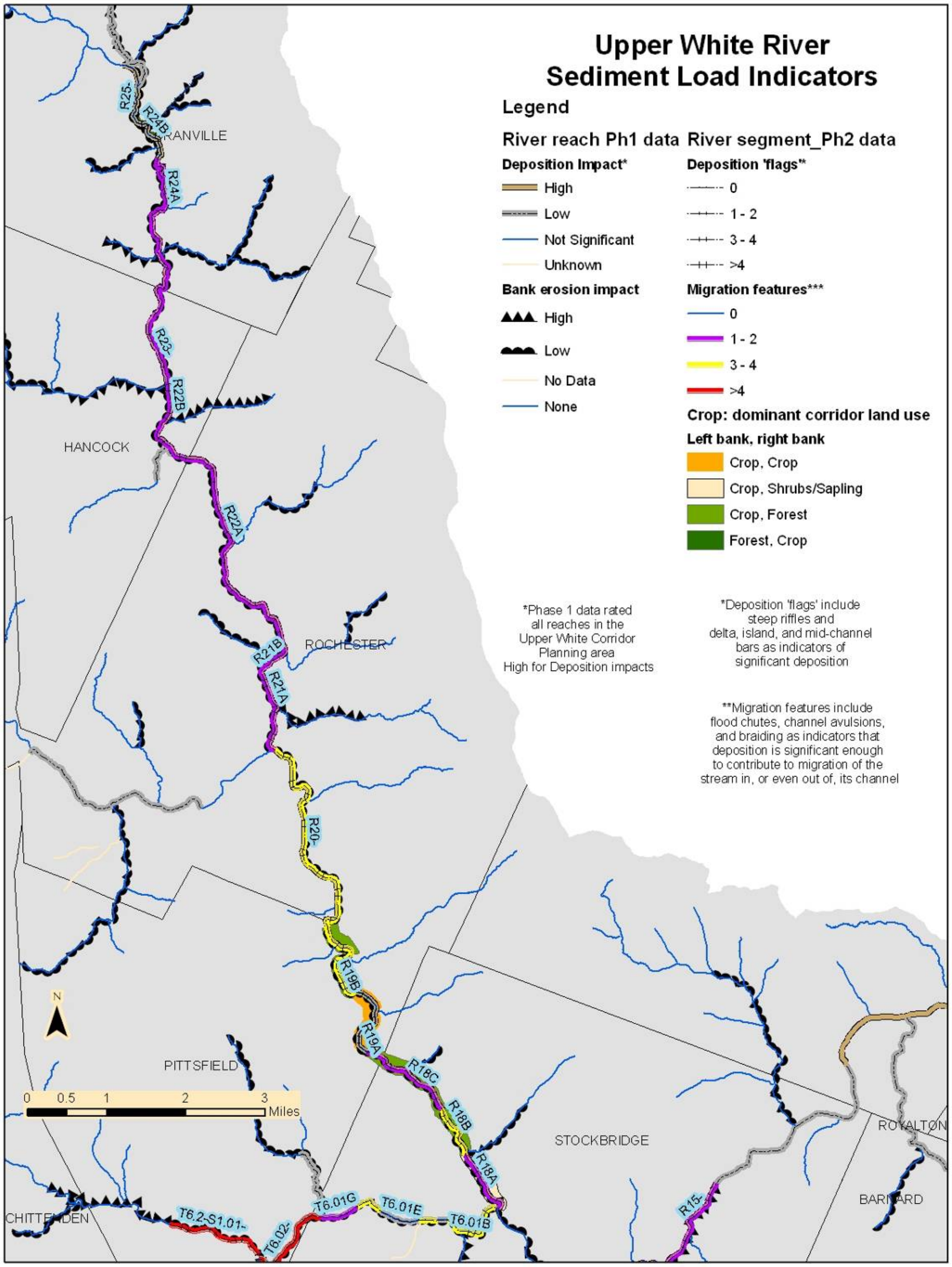


Figure 6. Watershed-scale stressors: Sediment-load indicators map for the Upper White River Corridor Project planning area.

5.1.3 Reach scale sediment regime stressors

Watershed scale stressors form a hierarchical pretext for understanding the timing and degree to which reach-scale modifications are contributing to field observed channel adjustments (VTANR 2007). Modifications to the valley, floodplain, and channel, as well as boundary (bank and bed) conditions, at the reach scale can change the hydraulic geometry, and thus change the way sediment is transported, sorted and distributed (Table 4). Phase 1 and Phase 2 assessments provide semi-quantitative data-sets for examining stressors and their effects on sediment regime when channel hydraulic geometry is modified.

Channel Slope and Depth Modifier Maps (Sections 5.1.4 and 5.1.5, respectively) can be used to determine whether stream power has been significantly increased or decreased. A Channel Boundary and Riparian Modifiers Map (Section 5.1.6) can help explain whether the resistance to stream power has been increased or decreased. The primary hydrologic and sediment stressors in each segment of the Upper White are identified in Table 5.

Table 4. Reach level stressors: relationship of energy grade and boundary conditions in sediment transport regime (VTANR 2007).

		Sediment Transport Increases	**Sediment Transport Decreases**
	Stream power as a function of:	**Stressors that lead to an Increase in Power**	**Stressors that lead to an Decrease in Power**
Energy Grade	**Slope**	• Channel straightening, • River corridor encroachments, • Localized reduction of sediment supply below grade controls or channel constrictions	• Upstream of dams, weirs, • Upstream of channel/floodplain constrictions, such as bridges and culverts
Energy Grade	**Depth**	• Dredging and Berming, • Localized flow increases below stormwater and other outfalls	• Gravel mining, bar scalping, • Localized increases of sediment supply occurring at confluences and backwater areas
Boundary Conditions	**Resistance to power by the:**	**Stressors that lead to an Decrease in Resistance**	**Stressors that lead to an Increase in Resistance**
Boundary Conditions	**Channel Bed**	Snagging, dredging, and windrowing	Grade controls and bed armoring
Boundary Conditions	**Stream Bank and Riparian**	Removal of bank and riparian vegetation (influences sediment supply more directly than transport processes)	Bank armoring (influences sediment supply more directly than transport processes)

Table 5. Upper White River Stressors Identification table indicating some of the hydrologic and sediment load stressors that are likely causing or contributing to channel adjustment and a departure from equilibrium conditions.

UW_River Stressors Identification Table	**Watershed Input Stressors**		**Reach Modification Stressors**	
River Segment	Hydrologic	Sediment Load	Stream Power	Boundary Resistance
R18A	Increased flows Roads and ditching (Left corridor dominant: crop) Wetland loss: Moderate (subshed: crop) P1*: 9% urban (Moderate)	Increased load P1*: Deposition impact: High P2: Left corridor dominant: crop Deposition: Moderate Migration : Moderate Erosion: <30% (Moderate)	Increased stream power: slope P1* Straightening: 20% 2004 Planform analysis* currently straightened: 60% Increased stream power: depth P1* Berm Impact: High Decreased stream power: depth P1* Deposition impact: High	Decreased bank resistance Erosion: Moderate (<30%) Increased bank resistance Bank armoring: Moderate (<30%)
R18B	Increased flows Ditching (Left corridor dominant: crop) P1*: 9% urban (Moderate)	Increased load P1*: Deposition impact: High P2: Left corridor dominant: crop Deposition impact: High Migration impact: High Erosion: <30% (moderate)	Increased stream power: slope P1* Straightening: 20% 2004 Planform analysis* currently straightened: 60% Increased stream power: depth P1* Berm Impact: High Decreased stream power: depth P1* Deposition impact: High P2 Backwaters: High	Decreased bank resistance Erosion: Moderate (<30%) Increased bank resistance Bank armoring: Moderate (<30%)

* Although listings in this table are by stream segment, Phase 1 and 2004 Planform analysis assessments shown are on an overall reach basis; 2004 planform analysis maps can be found in Appendix 9.

UW_River Stressors Identification Table	**Watershed Input Stressors**		**Reach Modification Stressors**	
River Segment	Hydrologic	Sediment Load	Stream Power	Boundary Resistance
R18C	Increased flows Ditching (L corridor dominant: crop) P1*: 9% urban (Moderate)	Increased load P1*: Deposition impact: High P2: L corridor dominant: crop Deposition: High Migration: Moderate Erosion: <30% (Moderate)	Increased stream power: slope P1* Straightening: 20% 2004 Planform analysis* currently straightened: 60% Increased stream power: depth P1* Berm Impact: High Decreased stream power: depth P1* Deposition impact High	Decreased bank resistance Erosion: Moderate (<30%) Increased bank resistance Bank armoring: moderate (<30%)
R19A		Increased load P1*: Deposition impact: High P2: Deposition: Moderate Erosion: <30% (Moderate)	Increased stream power: slope P1* Straightening: 21% 2004 Planform analysis* currently straightened: 66% Increased stream power: depth P1 Berm Impact: High Decreased stream power: depth P1* Deposition impact: High P2 Backwaters: High	Decreased bank resistance Erosion: Moderate (<30%) Increased bank resistance Bank armoring: Moderate (<30%)
R19B	Increased flows Ditching (L corridor dominant: crop)	Increased load P1*: Deposition impact: High P2: L corridor dominant: crop Deposition: High Migration: High Erosion: <30% (Moderate)	Increased stream power: slope P1* Straightening: 21% 2004 Planform analysis* currently straightened: 66% Increased stream power: depth P1* Berm Impact: High Decreased stream power: depth P1* Deposition impact: High P2 Backwaters: High	Decreased bank resistance Erosion: Moderate (<30%) Increased bank resistance Bank armoring: Moderate (<30%)

* Although listings in this table are by stream segment, Phase 1 and 2004 Planform analysis assessments shown are on an overall reach basis

UW_River Stressors Identification Table	**Watershed Input Stressors**		**Reach Modification Stressors**	
River Segment	Hydrologic	Sediment Load	Stream Power	Boundary Resistance
R20-0	Increased flows P1*: 8% urban (Moderate) Wetland loss: Moderate (corridor: residential/crop)	Increased load P1*: Deposition impact: High P2: Deposition High Migration: High Erosion: <30% (Moderate)	Increased stream power: slope P1* Straightening: 42% 2004 Planform analysis* currently straightened: 76% Increased stream power: depth P1* Berm Impact: High Decreased stream power: depth P1* Deposition impact: High P2 Backwaters: High	Decreased bank resistance Dominant buffer LB: 5-25 ft Erosion: Moderate (<30%) Increased bank resistance Bank armoring: Moderate (<30%)
R21A	Increased flows P1*: 39% urban (Extreme); Development Impact: High	Increased load P1*: Deposition impact: High P2: Deposition High; Migration: Moderate Erosion: <30% (Moderate)	Increased stream power: slope P1* Straightening: 55% Encroachment: High 2004 Planform analysis* currently straightened: 72% Increased stream power: depth P1* Berm Impact: High Decreased stream power: depth P1* Deposition impact: High	Decreased bank resistance Dom buffer LB: 5-25 Erosion: Moderate (<30%) Increased bank resistance Bank armoring: Moderate (<30%)
R21B	Increased flows P1*: 39% urban (Extreme); Development Impact: High Roads and ditching (L corridor dominant: residential)	Increased load P1*: Deposition impact: High P2: Deposition: Moderate Migration: Moderate Erosion: <30% (moderate)	Increased stream power: slope P1* Straightening: 55% 2004 Planform analysis* currently straightened: 72% Increased stream power: depth P1* Berm Impact: High Decreased stream power: depth P1* Deposition impact: High	Decreased bank resistance Dominant buffer LB: 5-25 ft Erosion: Moderate Increased bank resistance Bank armoring: Moderate

* Although listings in this table are by stream segment, Phase 1 and 2004 Planform analysis assessments shown are on an overall reach basis

UW_River Stressors Identification Table	**Watershed Input Stressors**		**Reach Modification Stressors**	
River Segment	Hydrologic	Sediment Load	Stream Power	Boundary Resistance
R22A	Increased flows P1*: 6% urban (Moderate) Wetland loss: Moderate (subshed: crop)	Increased load P1*: Deposition impact: High P2: Deposition: Moderate Migration: Moderate Erosion: <30% (Moderate)	Increased stream power: slope P1* Straightening: 41% 2004 Planform analysis* currently straightened: 83% Increased stream power: depth P1* Berm Impact: High Decreased stream power: depth P1* Deposition impact: High	Decreased bank resistance Erosion: Moderate Increased bank resistance Bank armoring: Moderate
R22B	Increased flows P1*: 6% urban (Moderate) Wetland loss: Moderate (subshed: crop) Roads and ditching (R corridor dominant, L subdominant: residential)	Increased load P1*: Deposition impact:High P2: Deposition: High Migration: Moderate Erosion: <30% (Moderate)	Increased stream power: slope P1* Straightening: 41% 2004 Planform analysis* currently straightened: 83% Increased stream power: depth P1* Berm Impact: High Decreased stream power: depth P1* Deposition impact: High	Decreased bank resistance Erosion: Moderate Increased bank resistance Bank armoring: Moderate
R23-0	Increased flows Wetland loss: Moderate (corridor: crop)	Increased load P1*: Dep_impact:High P2: Deposition: Moderate Migration: Moderate Erosion: <30% (Moderate)	Increased stream power: slope P1* Straightening: 35% 2004 Planform analysis* currently straightened: 62% Decreased stream power: depth P1* Deposition impact: High	Decreased bank resistance Erosion: Moderate Increased bank resistance Bank armoring: Moderate

* Although listings in this table are by stream segment, Phase 1 and 2004 Planform analysis assessments shown are on an overall reach basis

UW_River Stressors Identification Table	Watershed Input Stressors		Reach Modification Stressors	
River Segment	Hydrologic	Sediment Load	Stream Power	Boundary Resistance
R24A		Increased load P1*: Deposition impact: High P2: Deposition: Moderate Migration: Moderate Erosion: <30% (Moderate)	Increased stream power: slope P1* Straightening: 24% 2004 Planform analysis* currently straightened: 64% Decreased stream power: depth P1* Deposition impact: High	Decreased bank resistance Erosion: Moderate Increased bank resistance Bank armoring: Moderate
R24B	Increased flows Ditching (R corridor subdominant: residential) Wetland loss: moderate (corridor: residential)	Increased load P1*: Dep_impact:High P2: R corr dom: crop Deposition: High Erosion: <30% (Moderate)	Increased stream power: slope P1* Straightening: 24% 2004 Planform analysis* currently straightened: 64% Decreased stream power: depth P1* Deposition impact: High	Decreased bank resistance Erosion: Moderate Increased bank resistance Bank armoring: Moderate
R25-0	Increased flows Phase 1*: 9% urban (Moderate); Development Impact: High Roads and ditching (R corridor subdomiant: industrial) Wetland loss: Moderate (corridor: roads/residential)	Increased load Phase 1*: Deposition impact: High P2: Deposition: moderate Erosion: <30% (Moderate)	Increased stream power: slope P1* Straightening: 44% Encroachment: high 2004 Planform analysis* currently straightened: 65% Increased stream power: depth P1* Berm Impact: High Decreased stream power: slope Weirs (human placed) Decreased stream power: depth P1* Deposition impact: High	Decreased bank resistance Erosion: Moderate Increased bank resistance Bank armoring: Moderate

* Although listings in this table are by stream segment, Phase 1 and 2004 Planform analysis assessments shown are on an overall reach basis

5.1.4 Channel slope modifiers

Results for the Upper White River indicate that primary stressors include extensive straightening of the channel, along with road and development encroachment (Fig. 8). Phase 1 analysis indicated 22% to 55% of total reach length having been straightened in each reach, while a more detailed planform analysis indicated 78-100% of each reach straightened historically and 60-83% of each reach still showing straightened patterns in 2004 (VTDEC-RMP 2004; Appendix 9). Channel straightening can result in bed and bank erosion stemming from a measurable loss in floodplain access (i.e., increased incision), and play a significant role in enhancing sediment transport capacity as a result of the increased slope and depth at flood stage. With a significant increase in sediment load from upstream, the enhanced transport capacity has also resulted in stress to reaches downstream: instead of storing some of the increased load, the straightened reaches are now conveying sediment. Roads and developments within the river corridor indirectly lead to an increased channel slope when structural measures are used to protect those encroachments.

It is also important to note that no natural grade controls exist in the Project area. Phase 2 data collection indicated that the majority of bridges were adequately sized to permit transport of both water and sediment, with only minor deposition due to channel constrictions and few problems related to geomorphic incompatibility of theses structures with stream processes. Under protocols in place at the time of data collection, however, these issues were not assessed for three old abutments in and along the river.

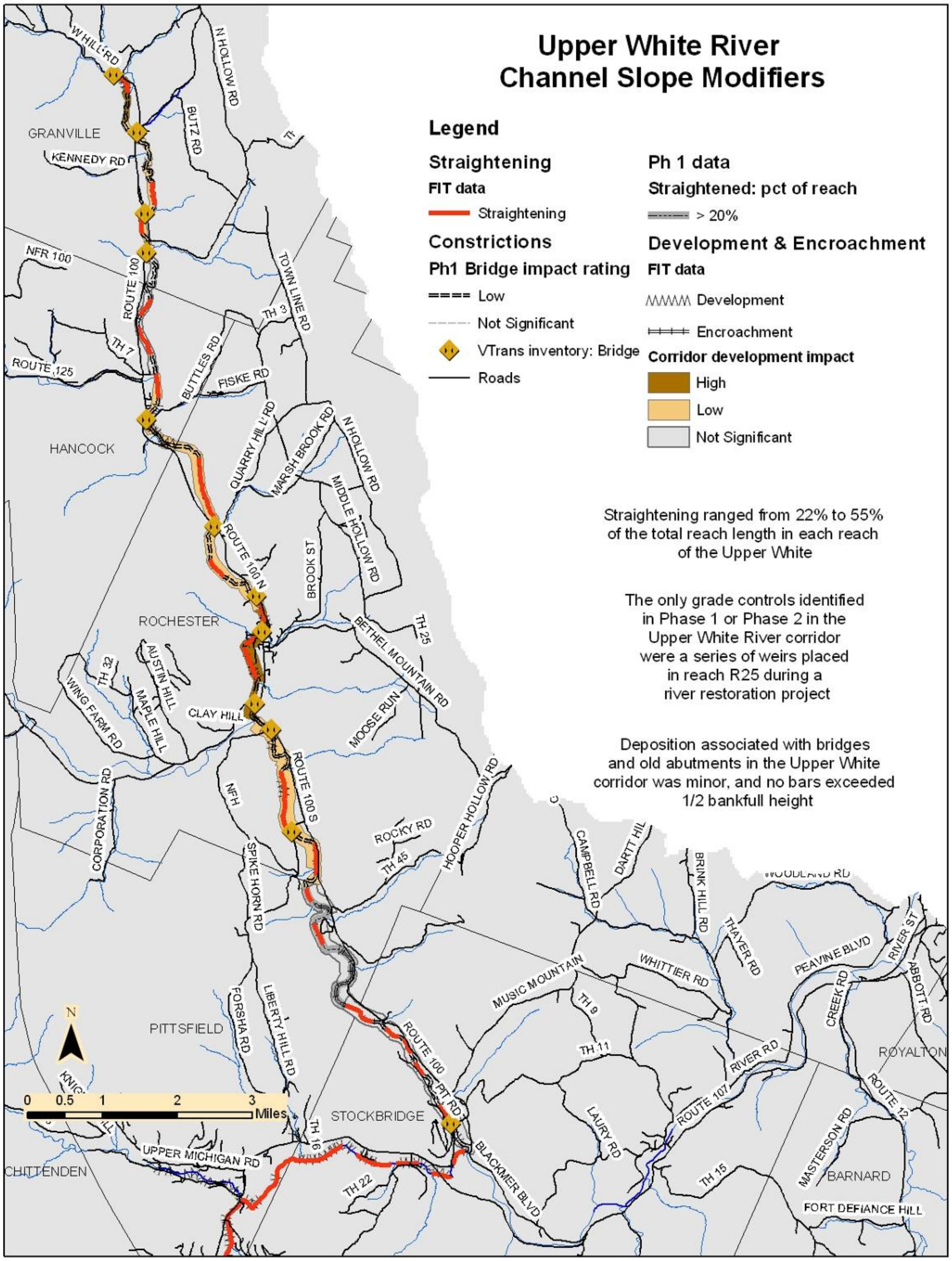


Figure 7. Reach-scale stressors: Channel slope modifiers map for the Upper White River Corridor Project planning area.

5.1.5 Channel depth modifiers

Phase 1 data collection indicated a high impact of berms in several reaches of the Upper White, and the high degree of road encroachment in particular has served to reduce the effective width of the valley and floodplain (Figure 9). Berms and elevated roads within the river corridor increase the depth of flood flows, and thus also increase stream power.

Significant deposition, particularly delta and backwater deposits, create the potential for more shallow depths during moderate flows due to the mid-channel deposits and the wider channel that results from the backwater conditions. Stream power is reduced in delta and backwater areas, leading to further deposition. Bar scalping has been practiced throughout the Upper White, and also contributes to the potential for more shallow depths during high flows due to the over-widened channel that typically results from dredging, gravel mining and bar scalping. Stream dynamics related to this practice are complex, however, and it is also important to recognize that headcutting up and downstream of bar scalping sites has contributed to channel downcutting in flood flows on the Upper White, which lacks any natural grade controls and primarily has relatively fine-grained bed sediments (see Appendix 7 for more information on bar scalping impacts). This has reduced access to historical floodplain, increasing sediment transport increased until the stream can no longer carry its sediment load.

Stormwater inputs documented in Phase 2 fieldwork were limited, but it should be noted that new ditching and culverts have been installed along Route 100 (which parallels the Upper White along most of its length - see Fig. 8) in the northern portion of the Project area since the fieldwork was done. Cumulatively, direct stormwater inputs to the stream can significantly increase peak discharge during floods, which typically results in an increase in flow depths and stream power.

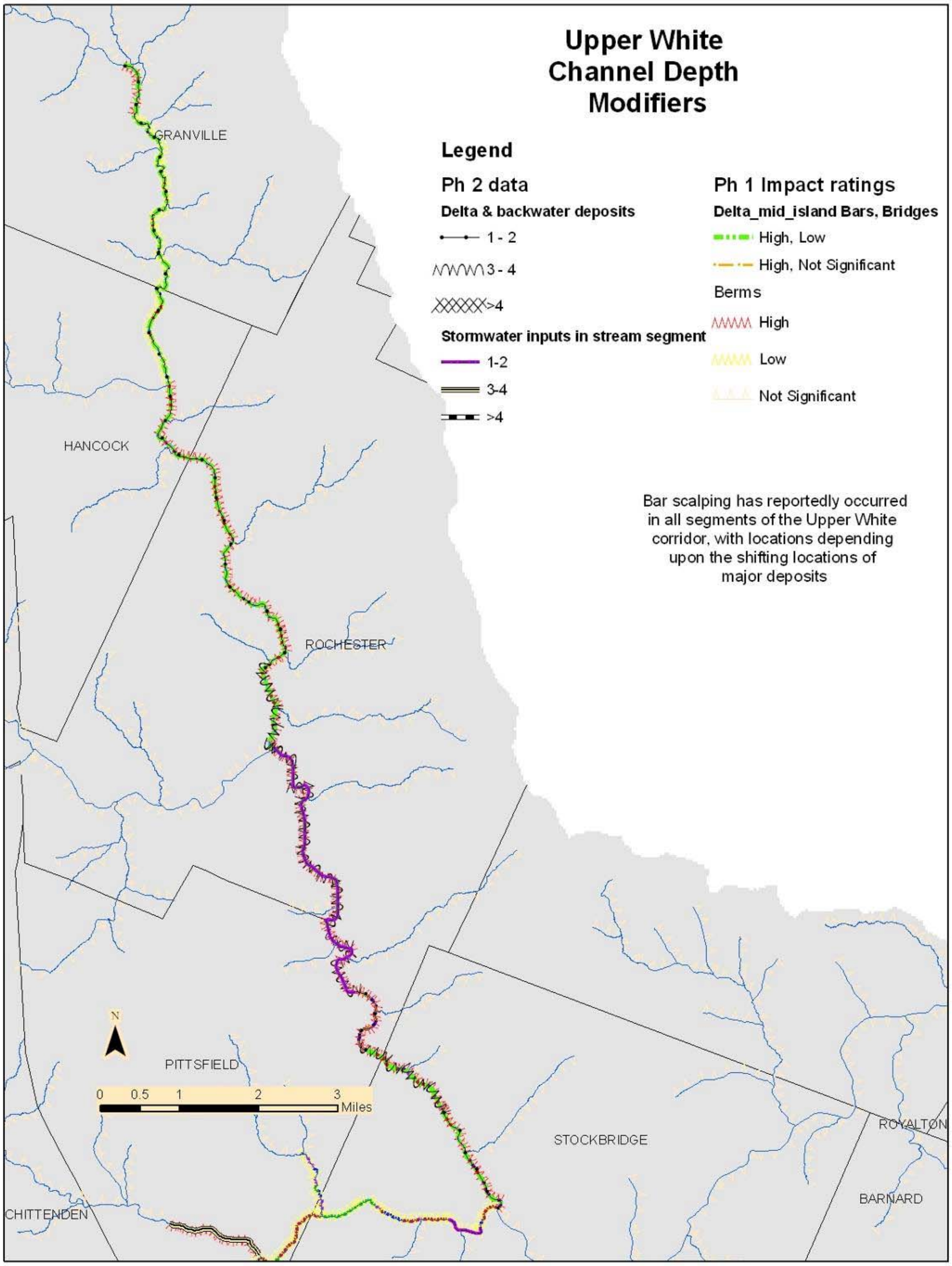


Figure 8. Reach-scale stressors: Channel slope modifiers map for the Upper White River Corridor Project planning area.

5.1.6 Boundary condition and riparian modifiers

Stream boundaries include bed and banks, and are also affected by the state of buffer vegetation in the riparian corridor in particular. Root systems from woody vegetation (and to a lesser extent, herbaceous vegetation) help bind stream bank soils.

Bed materials were gravel dominated in all reaches, and no natural grade controls exist in the Project area. A series of weirs were installed in the Granville area (Reach 25) in a stream restoration project in 2004, indicative of the sensitive nature of these relatively small-grained bed materials. In addition, historical log drives have been documented in the Upper White and there are strong indications that the stream has been "snagged" historically (USDA-FS 2001), removing woody debris and reducing sediment storage and channel roughness throughout the Project area.

With highly erosive alluvial materials present along the banks of the Upper White, bank erosion and fine sediment deposition have been an ongoing concern for infrastructure and property protection as well as habitat quality impacts (see USDA-FS 2001; WRP 1996). Phase 1 data, however, rated all reaches within the Project area Low for erosion impacts (Fig. 10), and Phase 2 data collection indicated that all segments within the study area exhibited bank erosion on less than 10% of the stream segment length (Appendix 4). Bank armoring was noted on less than 20% of the segment length in all segments in Phase 2 with the exception of segment 18B in Stockbridge (24%), where log vanes placed in stabilization efforts (Peavine and Timberhawk Meadow) accounted for much of the revetment length.

Phase 2 data indicated that dominant stream buffer widths were greater than 25 ft in all reaches of the Project area except those in Rochester south of the village (reaches 20 and 21; Fig. 10), likely contributing to the surprisingly low (in light of the bank materials present and extensive lack of floodplain access for the stream) amounts of erosion recorded. It is clear that the presence of wooded buffers greatly aids the stability of the banks in the Project area.

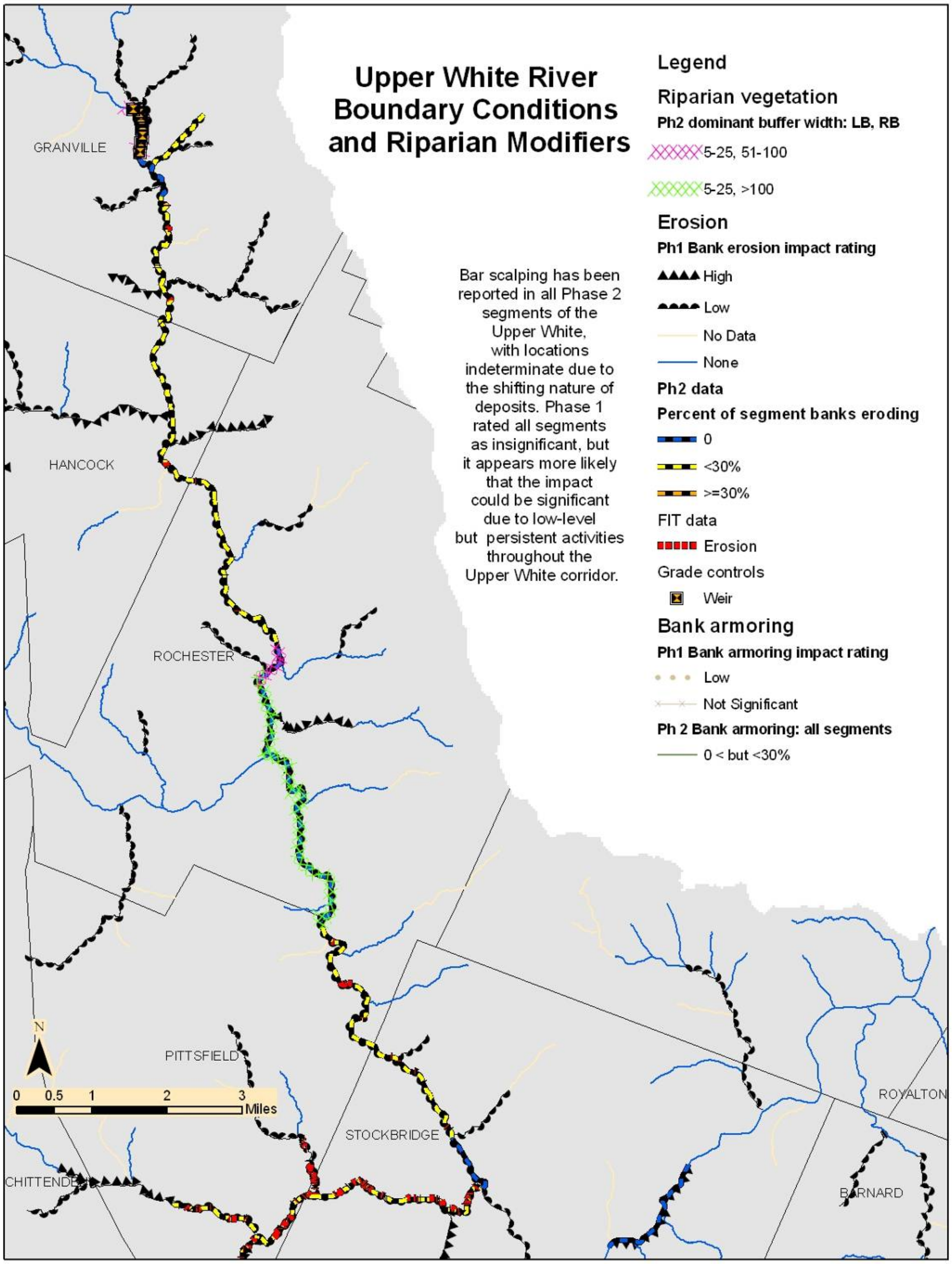


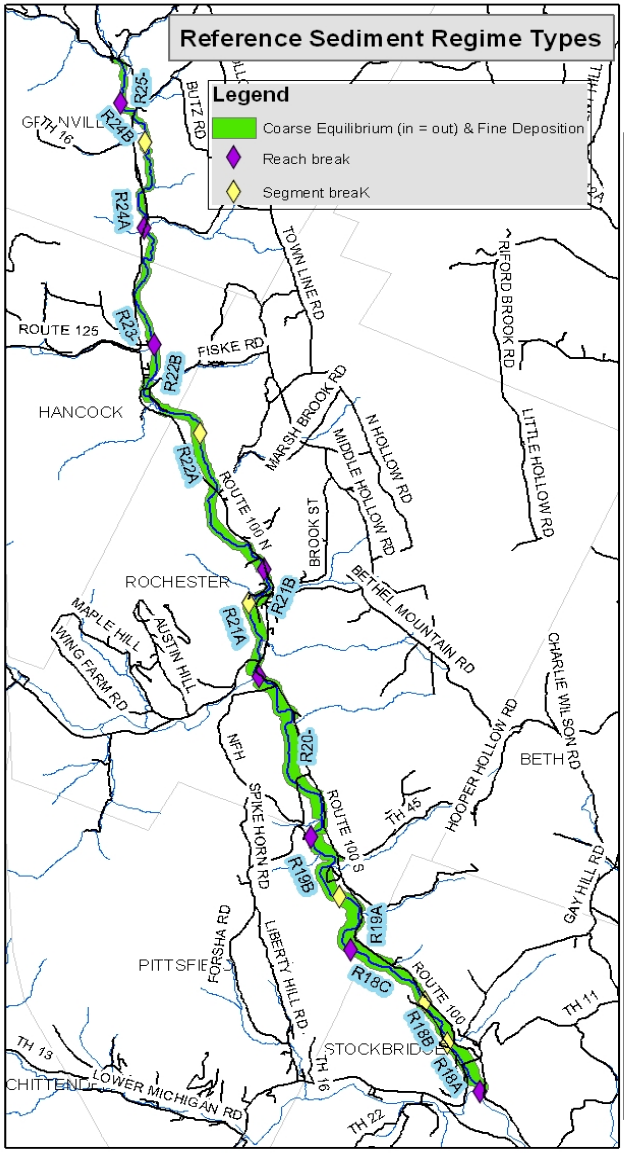
Figure 9. Reach-scale stressors: Boundary conditions and riparian modifiers map for the Upper White River Corridor Project planning area.

5.1.7 Sediment regime departure, constraints to sediment transport, and attenuation

Within a reach, the principals of stream equilibrium dictate that stream power and sediment will tend to distribute evenly over time (Leopold 1994). Changes or modifications to watershed inputs and hydraulic geometry create disequilibrium and lead to an uneven distribution of power and sediment. Whether a project works with or against the physical processes at play in a watershed is primarily determined by examining the source, volumes, and attenuation of flood flows and sediment loads from one reach to the next within the stream network. If increasing loads are transported through the network to a sensitive reach, where conflicts with human investments are creating a management expectation, little success can be expected unless the restoration design accommodates the increased load or finds a way to attenuate the loads upstream (VTANR 2007).

Phase 1 designated 'reference type' for all reaches in the Project area was a C type, riffle-pool system (Rosgen 1994) dominated by gravel substrates. This channel type is typically found in unconfined valleys, characterized by a meandering nature, and uses floodplains for sediment storage and dissipation of steam power. Under reference conditions, the sediment regime of the Upper White would be one in which all reaches would provide for coarse particle equilibrium (in = out: stream power, which is produced as a result of channel gradient and hydraulic radius—is balanced by the sediment load, sediment size, and channel boundary resistance) and fine sediment deposition at annual flood flows.

The Upper White area has no natural grade controls, however, and as noted above has erosive materials on both bed and banks. Thus, Phase 2 measurements indicated a high degree of historical incision (downcutting) throughout the Project area, which has limited access of the river to historical floodplains in most reaches, in conjunction with extensive straightening and channelization that have served to increase stream power. The existing sediment regime has thus been converted to one in which reaches of the Upper White function as transport reaches, with coarse deposition occurring when stream power is reduced or sediment load exceeds the carrying capacity of the stream (Fig. 11). All but one of these reaches have been converted to 'Fine Source and Transport & Coarse Deposition' reaches (Table 5). The one exception, reach R21 in Rochester village, was identified as an 'Unconfined Source and Transport' sediment regime type (transferring the bulk of its sediment further downstream), primarily because of a low channel width/depth ratio largely related to bank armoring and infrastructure protection along with maintenance of the stream channel along the valley wall over time.



Upper White River Sediment Regime Departure

The map on the left is based primarily on the relationship of the river to its valley type and valley slope. This Phase 1 assessment identified all of the reaches in the Upper White River valley as gravel bottom, C type streams (Rosgen classification). These reference type streams utilize access to their floodplains as a primary means to store sediment and nutrients within the watershed, and the reference sediment regime is generally a'Coarse Equilibrium (in = out) & Fine Deposition' type.

Due to changes in hydrology (likely largely related to historic deforestation and reforestation of the watershed) and sediment storage and transport within the watershed, exisiting stream types and dynamics identified in Phase 2 rapid field assessments (map at right) indicate that all but one reach within the Upper White River corridor have been converted to 'Fine Source and Transport & Coarse Deposition' sediment regimes.This means that most sediment entering the stream is either being transported through without being deposited,or is being dropped out when the load reaches a point the river cannot carry (or at any channel constrictions such as abutments and delta bars from tribs). Reach R21 in Rochester village was identified as an 'Unconfined Source and Transport' sediment regime type, transferring the bulk of its sediment further downstream.

With much of the stream channel in the Upper White incised sufficiently to prevent access to historical floodplains, efforts of the river to re-establish equilibrium will cause widening channels and lateral migration until it is able to rebalance the power of the water in the channel with the amount of sediment being moved.
Hence, it will be important to identify areas where sediment and nutrients can be stored within the Upper White.

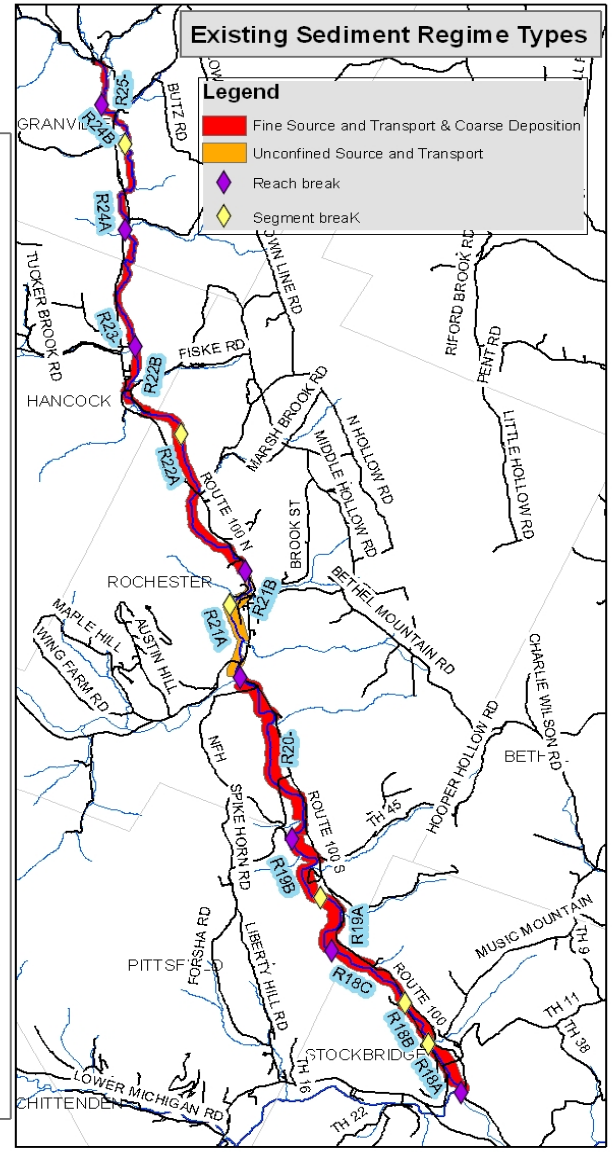


Figure 10. Sediment regime departure of the Upper White River.

Table 6. Applicable sediment regime criteria (VTANR 2007) and Upper White existing sediment regimes.

Sediment Regime	Stage of Channel Evolution Geomorphic Condition	Common Existing Stream Type	Delimiting criteria related to Sediment supply, transport, and storage	Natural Valley Type
Unconfined Source and Transport	Stage II - III Fair-Poor	G3, G4, G5 F3, F4, F5	Bank armor > 50% Straightening > 50% W/d ≤ 30	NW, BD, VB
	Stage II - III Fair-Poor	E3, E4, E5 C3, C4, C5	Bank armor > 50% Straightening > 50% W/d ≤ 30 Incision ratio ≥ 1.4	NW, BD, VB
Fine Source and Transport & Coarse Deposition	Stage III-IV Fair-Poor	E3, E4, E5 C3, C4, C5 F3, F4, F5	Bank armor < 50% W/d > 30 Incision ratio ≥ 1.4	NW, BD, VB
	Stage III-IV Fair-Poor	D3, D4, D5	Bank armor < 50% Incision ratio ≥ 1.4	NW, BD, VB
Coarse Equilibrium (in = out) & Fine Deposition	Stage I or V Good-Ref	D3, D4, D5	Incision ratio < 1.4	NW, BD, VB
	Stage I or V Good-Ref	C2, C3, E3	W/d < 30 Incision ratio < 1.4	NW, BD, VB
	Stage I or V Good-Ref	C4, C5 E4, E5	W/d > 30 Incision ratio < 1.4	NW, BD, VB
Upper White	All segments: Channel Evolution Stage III, Bank armor <25%			
Reach 18 Straightened: 60% (Historic: 91%)*	R18A: Fair R18B: Poor R18C: Poor	C4 B4 F4	Incision ratio 1.3 W/d 27.7 Incision ratio 2.6 W/d 84.7 Incision ratio 2.2 W/d 37.4	BD BD BD
Reach 19 Straightened: 66% (Historic: 88%)*	R19A: Fair R19B: Poor	B4 F4	Incision ratio 1.3 W/d 34.7 Incision ratio 1.6 W/d 54.2	BD BD
Reach 20 Straightened: 76% (Historic: 95%)*	Fair	C4	Incision ratio 1.5 W/d 41.8	BD
Reach 21 Straightened: 72% (Historic: 78%)*	R21A: Fair R21B: Fair	C4 C4	Incision ratio 1.6 W/d 26.4 Incision ratio 1.1 W/d 16.1	BD NW
Reach 22 Straightened: 83% (Historic: 100%)*	R22A: Poor R22B: Fair	F4 B4	Incision ratio 2.0 W/d 45.9 Incision ratio 1.9 W/d 30.8	BD BD
Reach 23 Straightened: 62% (Historic: 88%)*	Poor	F4	Incision ratio 4.0 W/d 38.5	VB
Reach 24 Straightened: 64% (Historic: 100%)*	R24A: Poor R24B: Fair	F4 B4	Incision ratio 2.7 W/d 36.7 Incision ratio 1.6 W/d 20.0	VB VB
Reach 25 Straightened: 65% (Historic: 100%)*	Poor	F4	Incision ratio 2.1 W/d 56.7	VB

* Straightening figures from 2004 River Management Program planform analysis (Appendix 9)

Phase 2 work assessed all reaches of the Upper White as being at Stage III of channel evolution (Table 5). Schumm (1977 and 1984) has described five stages of channel evolution (F-stage model) for reaches such as those found in the Project area, where the stream has a bed and banks that are sufficiently erodible to be shaped by the stream over time, paraphrased from the SGA protocols (VTANR 2006, Appendix C) as follows:

I. Stable – in regime, reference to good condition. Insignificant to minimal adjustment; planform is moderate to highly sinuous.
II. Incision – Fair to poor condition, major to extreme channel degradation. High flow events are contained in the channel, and channel slope is typically increased.
III. Widening/Migration – Fair to poor condition, major to extreme widening and aggradation.
IV. Stabilizing – Fair to good condition, major reducing to minor aggradation, widening and planform adjustments
V. Stable – In regime, reference to good condition. Insignificant to minimal adjustment.

Under the existing sediment regime, which includes limited floodplain access and increased stream power, erosion, widening, and lateral migration are likely to increase and deposition is primarily occurring in the Upper White when sediment load exceeds carrying capacity, or when channel geometry changes sufficiently to decrease stream power. At high flows on the Upper White this occurs primarily at channel constrictions and meanders, and with natural lateral constraints largely absent in the Upper White, the most significant channel constrictions in the Project area according to Phase 2 data are the Brandon Mountain Rd bridge south of Rochester Village (segment R21A) and delta bars at the mouths of tributaries entering the mainstem. Rapid deposition also appears to have occurred at overwidened channels resulting from bar scalping, where wider, shallower channel geometry has decreased stream power sufficiently to facilitate sediment deposition and rapid refilling of pools and excavations (see Appendix 7).

The combination of increased stream power and sediment transport along with erosive materials on both bed and banks and lack of natural grade controls raise the following issues on the Upper White:

a) both bed and banks are susceptible to further erosion as part of a process of channel evolution as the stream attempts to regain equilibrium;

b) maintenance of banks through continued channelization increases the likelihood of further bed incision (including potential headcuts, none of which were identified in Phase 2 work) that would further limit access to floodplain and initiate further channel adjustments

c) lack of access to floodplain and extensive channel straightening means that the bulk of sediment deposition impacts is being transferred to downstream reaches;

d) deposition is occurring whenever stream power is reduced, and will likely continue to accumulate quickly in these areas (building on the further decrease of stream power caused by that deposition), increasing the likelihood of channel avulsions in the highly erodible materials along the river corridor;

e) lack of access to floodplains and meanders for sediment storage means that nutrients are being transported downstream and out of the Upper White watershed

f) deposition of fine sediments is amplified at lower flows in overwidenened channels, with potential negative habitat quality impacts for White River fisheries in particular (USDA-FS 2001)

The primary lateral constraints to stream processes identified in both Phase 1 and Phase 2 work on the Upper White are road and development encroachment in the river corridor, along with maintenance of highly-valued agricultural resources along the river corridor. Given the existing sediment transport regime and stage of channel evolution of reaches in the Project area, likely entailing increased erosion and widening as the river attempts to reestablish equilibrium with the increased stream power, restoration of floodplain access would be a critical component in re-establishing a reference sediment regime. Identification of “attenuation assets” to accommodate high flows and sediment deposition would include areas where the river can be allowed to reestablish meanders (rather than being channelized) as well access the floodplain (which can help nutrient retention, as evidenced by the fertility of alluvial soils). These assets occur in virtually all reaches of the Upper White, with limited opportunities likely in stream segments R21B and R22B (Rochester and Hancock villages) due to road and development encroachments (Table 6). It should be noted, however, that similarly limited opportunities have still been utilized for attenuation assets in the Granville area, where constructed wetlands were created in a channel avulsion created by 1998 flooding on some of the small area of available lands in Reach R25 south of the Bowl Mill (pers. comm., Dan McKinley, USDA-FS District Fisheries Biologist – Rochester Ranger District, April 11, 2007).

Table 7. Upper White Departure Analysis Table indicating where river segments are constrained from adjustment, converted to transport streams, and/or have existing or future potential as a place to attenuate sediment load.

UW_Departure Analysis Table	**Constraints**		**Transport**		**Attenuation (storage)**		
River Segment (name and number)	Vertical	Lateral	Natural	Converted	Natural	Increased	Asset
R18A		Human: Roads, agriculture		X	X	X	X
R18B		Human: Roads, agriculture		X	X	X	X
R18C		Human: Roads, agriculture		X	X	X	X
R19A		Human: Roads, agriculture		X	X	X	X
R19B		Human: Ag, golf course		X	X	X	X
R20		Human: Roads, agriculture		X	X	X	X
R21A		Human: Bridge, development, ag		X	X	X	X
R21B		Human: Roads, development		X	X	X	
R22A		Human: Roads, agriculture		X	X	X	X
R22B		Human: Roads, development, ag		X	X	X	limited
R23		Human: Roads, agriculture		X	X	X	X
R24A		Human: Roads, development, ag		X	X		X
R24B		Human: Roads, development, ag		X	X		X
R25	Human: Weirs	Human: Roads, development		X	X	X	limited

5.2 SENSITIVITY ANALYSIS

The preceding departure analysis identifies the watershed and reach scale stressors that help explain the sediment regime departure currently existing in all reaches of the Upper White. Designing stream corridor protection and restoration projects that are compatible with channel evolution processes, and prioritizing them at the watershed scale, also requires an understanding of stream sensitivity.

Sensitivity refers to the likelihood that a stream will respond to a watershed or local disturbance or stressor, and an indication as to the potential rate of channel evolution (VTANR 2006, Phase 2 Step 7.7; VTANR 2007 Sec. 5.2). While every stream changes in time, a sensitivity rating indicates that that some streams, due to their setting and location within the watershed, are more likely to be in an episodic, rapid, and/or measurable state of change or adjustment (VTANR 2006, Phase 3 Step 6.2).

Alteration of sediment and flow regimes that have converted all Upper White reaches to transport reaches, combined with fine-grained and erosive boundary conditions and high levels of current aggradation in most reaches, have led to conditions in which all but one stream segment (R19A, at Tupper) are highly to extremely sensitive (Fig. 11). Stream type departures (indicating a change from the reference C type channels indicated by Phase 1 analysis for all Upper White reaches), were indicated for 10 of 14 river segments assessed in Phase 2, converting these streams to B (moderately entrenched) and F (highly entrenched) stream types. This is indicative of the loss of floodplain access that is contributing to elevated stream sensitivity.

Although the lack of floodplain access has currently converted the Upper White to a transport regime, the high sediment load and high sensitivity of the reaches, along with relatively limited constraints within the corridor at present, indicates good possibilities for success of passive geomorphic projects, which would allow the river to utilize its own energy and watershed inputs to re-establish its meanders, floodplains, and self maintaining equilibrium conditions over time.

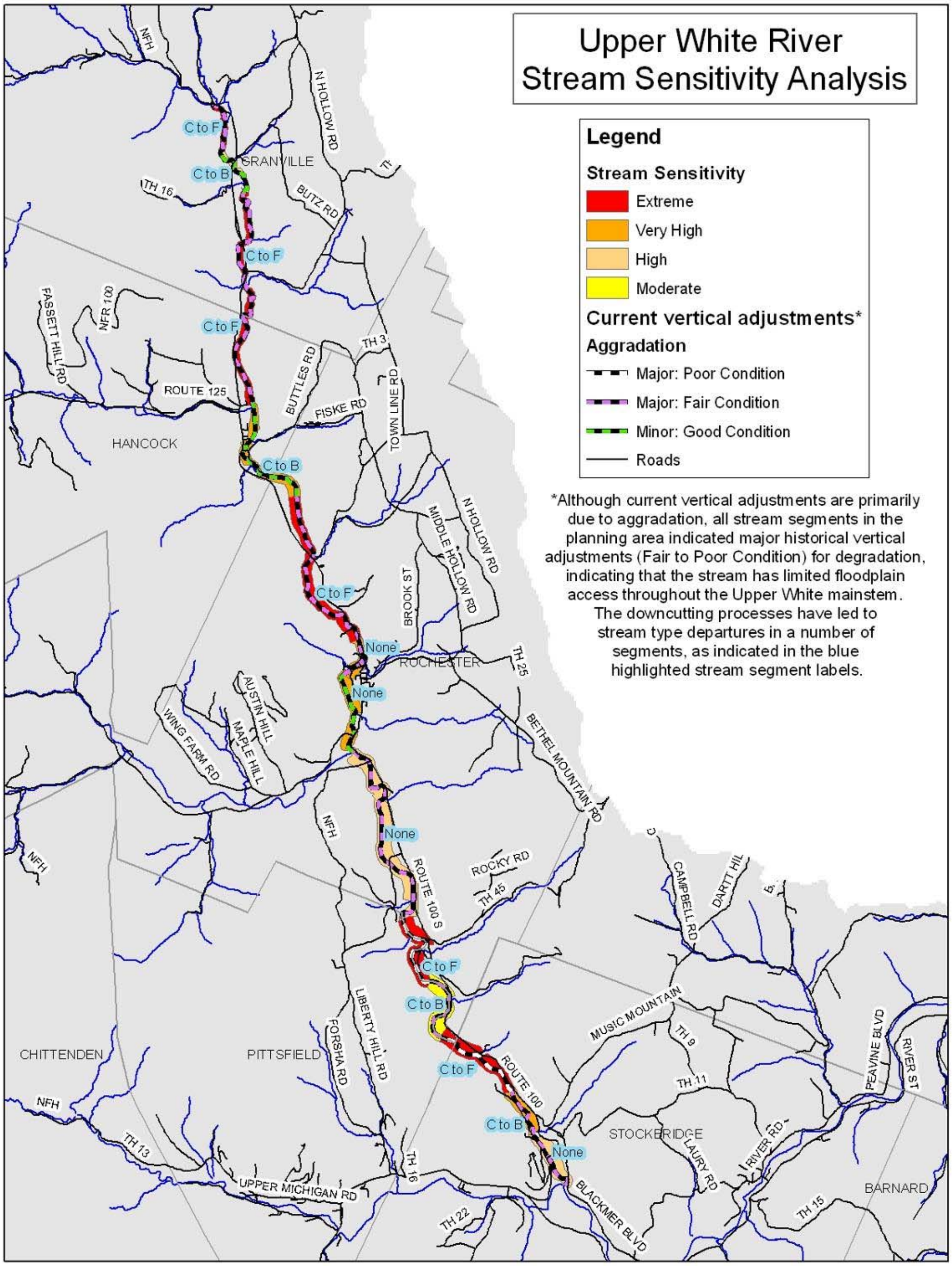


Figure 11. Sensitivity analysis: Stream sensitivity and current adjustment map for the Upper White River Corridor Project planning area.

6.0 PRELIMINARY PROJECT IDENTIFICATION

The preceding departure and sensitivity analysis provides the watershed and reach scale background to inform prioritization and selection of projects in a manner that maximizes their effectiveness and reduces the likelihood of failure, specifically by assessing the underlying causes of channel instability. With the information from these maps and tables, a step-wise process has been conducted to identify the following actions, in order of priority, in a manner designed to facilitate restoration of the stream to equilibrium conditions (VTANR 2007):

Step 6.1. Protecting River Corridors
Step 6.2. Planting Stream Buffers
Step 6.3. Stabilizing Stream Banks
Step 6.4. Arresting head cuts and nick points
Step 6.5. Removing Berms and other constraints to flood and sediment load attenuation
Step 6.6. Removing/Replacing Structures (e.g. undersized culverts, constrictions, low dams)
Step 6.7. Restoring Incised Reaches
Step 6.8. Restoring Aggraded Reaches

As indicated in Section 5.2 of this report, the high to extreme sensitivity of the majority of the reaches in the Upper White Project area indicates that passive geomorphic projects, particularly given the high sediment load of the Upper White and the rapidity of channel evolutions evidenced in the past, is generally an appropriate management alternative in the Project area. This places a very high priority, throughout the Project area, on the first two items identified in the stepwise procedure. The third item, stabilization of stream banks, is generally not recommended due to vertical instability in all reaches and continuing widening in channel evolution processes, increasing the likelihood of failure of such efforts as well as escalating maintenance costs. This recommendation clearly needs to be carefully assessed in regards to site specific recommendations and critical infrastructure. It should be recognized, however, that the current conversion of all Upper White reach sediment regimes to transport types will mean that further armoring of banks or bed will aggravate downstream deposition impacts.

Bed materials are sensitive to erosion, and although no headcuts were documented in Phase 2 (and the bed has been stabilized to some degree in the Granville area by the installation of weirs in a previous restoration project), the deeply incised nature of the Upper White makes Step 4 an item to be regularly assessed, as further downcutting of the channel will initiate further channel adjustments and delay establishment of equilibrium conditions.

6.1 REACH DESCRIPTIONS

With these overarching considerations, preliminary project identification for the Upper White River is presented on a reach by reach basis in the following pages. “Left bank” and “right bank” in the reach descriptions are referenced looking downstream. Reach maps include a “belt-width corridor” drawn on either side of the stream. The width of this corridor is based on over 30 years of research and data collected from hundreds of streams around the world, and approximates the extent of lateral adjustments likely to occur over time in a meandering stream type (VTANR 2006, Appendix H). “Human investments within the belt width inevitably result in structural constraints placed on the channel adjustment process to protect those investments and address associated threats to public safety. These threats will be largely avoided by recognizing the hazards created by development, incompatible with channel adjustments, within the critical belt width” (VTANR 2006 Phase 2 Handbook, p.17). White River Partnership and USDA Forest Service (Green Mountain National Forest) project areas along the river are also indicated on the maps.

6.1.1 Preliminary project identification: Reach R18 – Tweed River confluence to Tupper

Reach R18 is the furthest downstream reach within the Project area, extending roughly 15,000 ft (2.8 mi) from just above the confluence of the Tweed River in Stockbridge to the village of Tupper on the Pittsfield/Rochester border at its northern end (Fig. 12). The reach was divided into three segments for Phase 2 assessment, due to changes in planform and slope in segment R18B, a more sinuous section of the stream located between two extensively channelized segments up and downstream. Phase 1 assessment noted 52% of the reach as straightened while planform analysis indicated 91% straightened historically. Although the river corridor is relatively undeveloped, there is road encroachment along nearly 50% of the reach, with several areas of riprapped banks noted in Phase 2. Stream type departures were noted in both upstream segments (Fig. 11), with a highly entrenched F type stream in segment R18C at the head of the reach and a moderately entrenched B type stream in segment B. R18A did not show a stream type departure, indicating that the stream regains access to floodplain in this section of the reach. An old abutment (which is also across from a delta bar at the base of a gravel pit) below Olmstead Rd in segment 18C was not assessed for channel constriction in the 2003-2004 Phase 2 assessment.

The confluence of the Tweed River at the tail end of reach 18 exhibits significant sediment loading from that tributary, and delta bar formation at the confluence of these streams serves to significantly decrease stream power and thus increase deposition just upstream. The position of this reach at the downstream end of Upper White reaches that have all been converted to transport reaches makes the floodplain in this area a key attenuation asset, but the stream channel is subject to a high likelihood for further channel evolution due to upstream watershed inputs. Projects to address historical channel incision in this area are thus currently a lower priority from a watershed perspective, but protection of the river corridor and establishment and maintenance of buffer vegetation are high priorities; this area could be a good candidate for passive restoration due to the extreme to high sensitivity of the reach. White River Partnership conducted a project in this reach that included bank stabilization with rock and log vanes in order to aid establishment of buffer plantings along 800 ft of the stream at Timberhawk Meadow, along with placement of instream structures to improve fish habitat. The USDA Forest Service also implemented a project near the Peavine Interpretive site, where fish habitat improvements were made among rock revetments in a 1000 ft section of stabilized banks. The Peavine Preservation Trail Committee (http://peavinetrail.org/index.php) and Forest Service have been investigating maintenance of the old White River Railroad railbed as a multi-use recreational trail (primarily along segment R18C) as well.

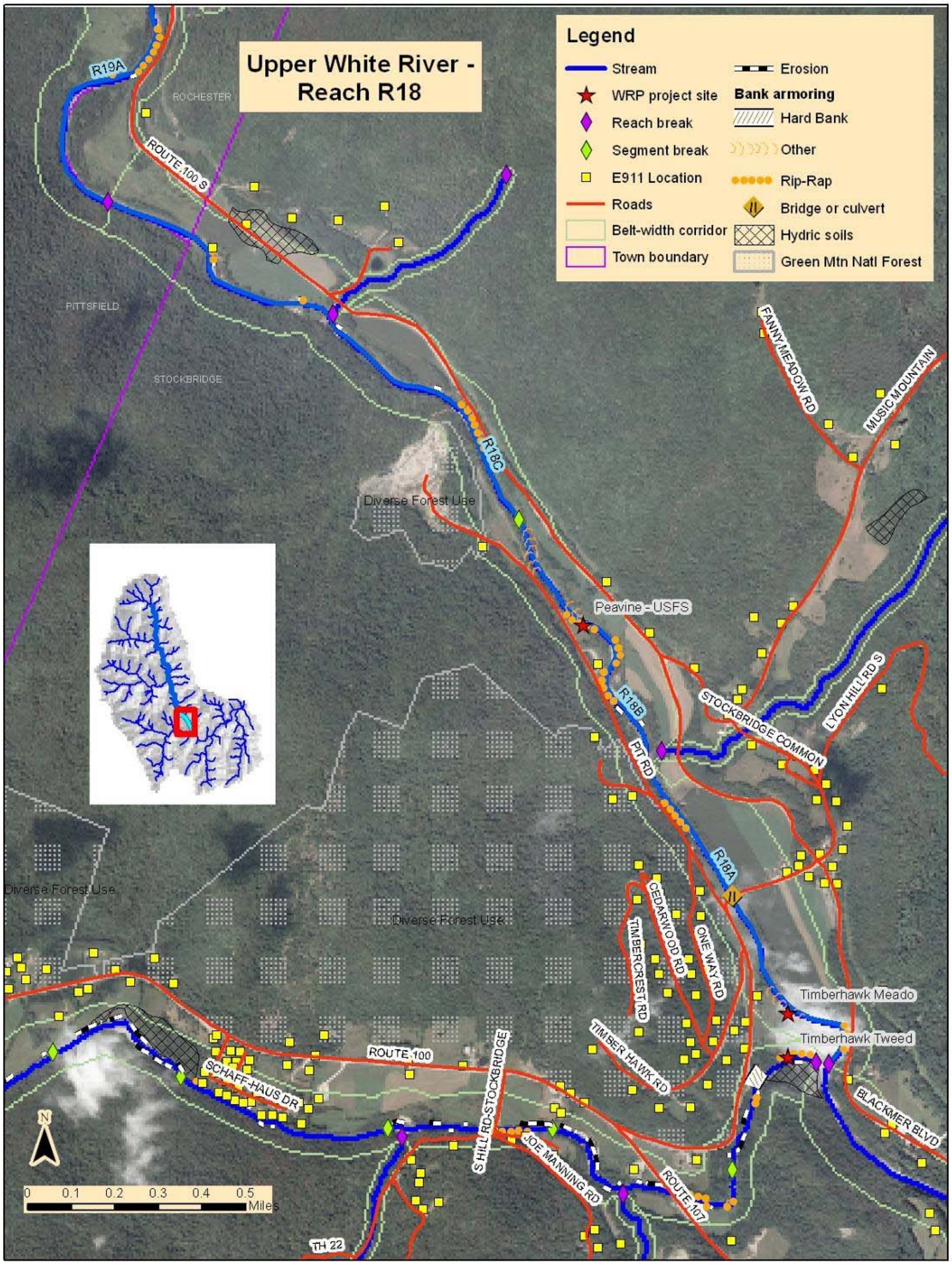


Figure 12. Upper White River reach R18 (2003 National Agricultural Imagery Program aerial photography background).

Table 8. Upper White River Reach R18 Projects and Practices Table used throughout the step-wise project identification process to catalogue projects, indicate a priority for each project, and list the next steps suggested in developing the project.

River Segment (step #)	Project	Reach Priority	Watershed Priority	Completed Independent of other Practices	Next Steps and other Project Notes
R18A (6.1)	Protect river corridor	High	High	Y	Rd encroachment – not sensitive
R18A (6.2)	Plant/fence	High	Low	Y	Crop land dom LB – low cost because reach aggrading
R18A (6.7)	Protect river corridor at downstream reach	Low	High	N	Out of project area
R18A (6.8)	Protect river corridor	High	Low	Y	Driven by upstream
R18B (6.1)	Protect river corridor	High	High	Y	
R18B (6.2)	Plant stream buffer	Low	High	Y	Vertically unstable
R18B (6.7)	Protect river corridor at downstream reach	Low	High	Y	Out of project area
R18C (6.2)	Plant stream buffer	Low	Low	Y	Low cost – extremely sensitive reach
R18C (6.6)	Remove structure	?	?	Y	Lacking constriction/ problems data
R18C (6.7)	Protect river corridor	High	High	Y	Landowner contact- passive

6.1.2 Preliminary project identification: Reach R19 – Tupper to White River Golf Club and Liberty Hill Farm

Reach R19 includes approximately 12,280 ft (2.3 mi) of the Upper White extending from Tupper, on the downstream end, to the White River Golf Club below the Liberty Hill Farm home farm on the upstream end (Fig. 13). The reach was segmented for Phase 2 assessment primarily on the basis of a change in channel dimensions, with the downstream segment (R19A) exhibiting a much lower width to depth ratio, largely due to a deeper channel in terms of both maximum and mean depths. This section of the river is notable as having some of the better quality pools in the Upper White at this point in time, habitat that is largely degraded in the Project area according to Phase 2 data and local reports Appendix 1; USDA-FS 2001). Bedrock outcroppings along the banks within the reach are also notable.

Planform analysis in 2004 indicated 88% of the reach was historically channelized, with straightening primarily designed to maintain the stream along the valley wall and maintain infrastructure encroachments. Initiation of meander patterns was noted in 22% of the reach at that time, although none of the reach had achieved full meander expression (Appendix 9). Stream type departures were noted in Phase 2 assessment of both segments of the reach, with the downstream portion (R19A) typed as a C to B change (moderately entrenched) and the upstream segment (R19B) exhibiting a C to F change (highly entrenched); both departures indicate a current lack of access to floodplain. R19A, along the bedrock-protected terraces at Tupper, is the only reach in the Project area to be denoted as moderately sensitive, indicating the likelihood of slower rates of change and geomorphic adjustment processes in this segment. For these reasons, this is one of the limited portions of the Project area where investigation of active or combined active/passive restoration (particularly old flood chute access to restore floodplain function at the downstream end of the reach) may be warranted.

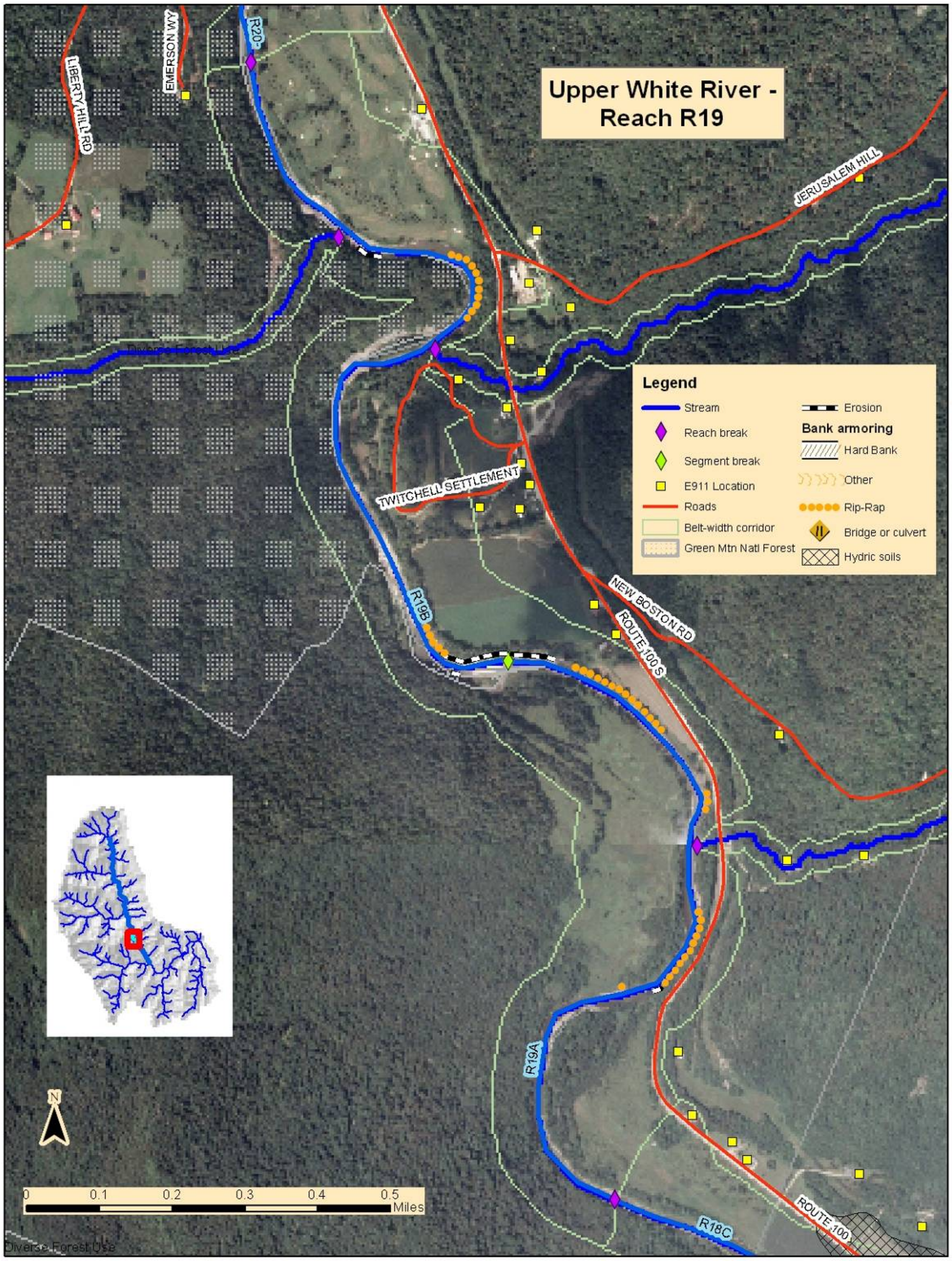


Figure 13. Upper White River reach R19 (2003 National Agricultural Imagery Program aerial photography background).

Table 9. Upper White River Reach R19 Projects and Practices Table used throughout the step-wise project identification process to catalogue projects, indicate a priority for each project, and list the next steps suggested in developing the project.

River Segment (step #)	**Project**	**Reach Priority**	**Watershed Priority**	**Completed Independent of other Practices**	**Next Steps and other Project Notes**
R19A (6.1)	Protect river corridor	High	High	Y	Landowner contact-passive
R19A (6.2)	Plant stream buffer	Low	Low	Y	Mostly good - infill
R19A (6.7)	Potential restoration/ protection project	High	High	Y	Information gathering – landowner interest for active meander/ floodplain restoration
R19A (6.8)	Protect river corridor	High	High	Y	Minimize conflicts
R19B (6.2)	Plant stream buffer	High	Low	Y	Low cost – Vertically unstable (aggrading)
R19B (6.7)	Restore to abandoned channel	High	High	N	At Twitchell Settlement?
R19B (6.7)	Potential restoration/ protection project	Low	Low		Golf course and crop land
R19B (6.8)	Protect river corridor	High	High	N	Minimize conflicts

6.1.3 Preliminary project identification: Reach R20 – White River Golf Club to the West Branch confluence

Reach R20 covers roughly 13,750 ft (3 mi) of the Upper White extending from the White River Golf Club below Emerson Way to the mouth of the West Branch just south of the main village of Rochester (Fig. 14). The reach was not segmented for Phase 2 assessment, indicating relatively homogenous conditions through this section of the Upper White. With significant development and encroachment in the next reach upstream, R21 in Rochester village, reach R20 represents the first relatively unfettered access to floodplain in the Upper White Project area due to stream type departures (indicating loss of floodplain access) related to historical downcutting in all mainstem reaches upstream of R21. As in most of the Upper White, however, there is significant agricultural investment in the corridor of this reach. The access to floodplain is notable, as gravel ramping and sediment deposition have been witnessed on some of the fields in the reach and numerous deposition features are present along the stream channel. An incision ratio (a measure of the height of the recently abandoned floodplain ('high bank') divided by the maximum depth of the stream) of 1.5 in the reach indicates that the recently abandoned floodplain is at a level that further downcutting of the stream could quickly restrict floodplain access and initiate a new round of channel adjustments.

Planform analysis of the Upper White indicated 95% of Reach R20 as historically straightened, with 76% of the reach still exhibiting a straightened planform in 2004. Full meander expression was evident in 19% of the reach in 2004, however, second only to Reach R25 on the Upper White in terms of length of the reach exhibiting equilibrium meander patterns (Channel evolution stage 4-5) (Appendix 9).

High stream sensitivity was noted in Reach R20 Phase 2 assessment, and the reach was one of four stream segments (R20-0, R21A and R21B in Rochester, and R25-0 in Granville) in the Project area with dominant buffer widths of less than 25 ft noted on one or the other of the banks. Ample buffer establishment will be an important component of any sort project implementation in this reach. Previous White River Partnership projects in this reach have included cooperation on installation of a 250 ft tree revetment for bank stabilization in preparation for a buffer fencing and planting project at Liberty Hill Farm, as well as stabilization and flood chute closure to facilitate buffer establishment along a half mile stretch of the river at the Harvey Farm.

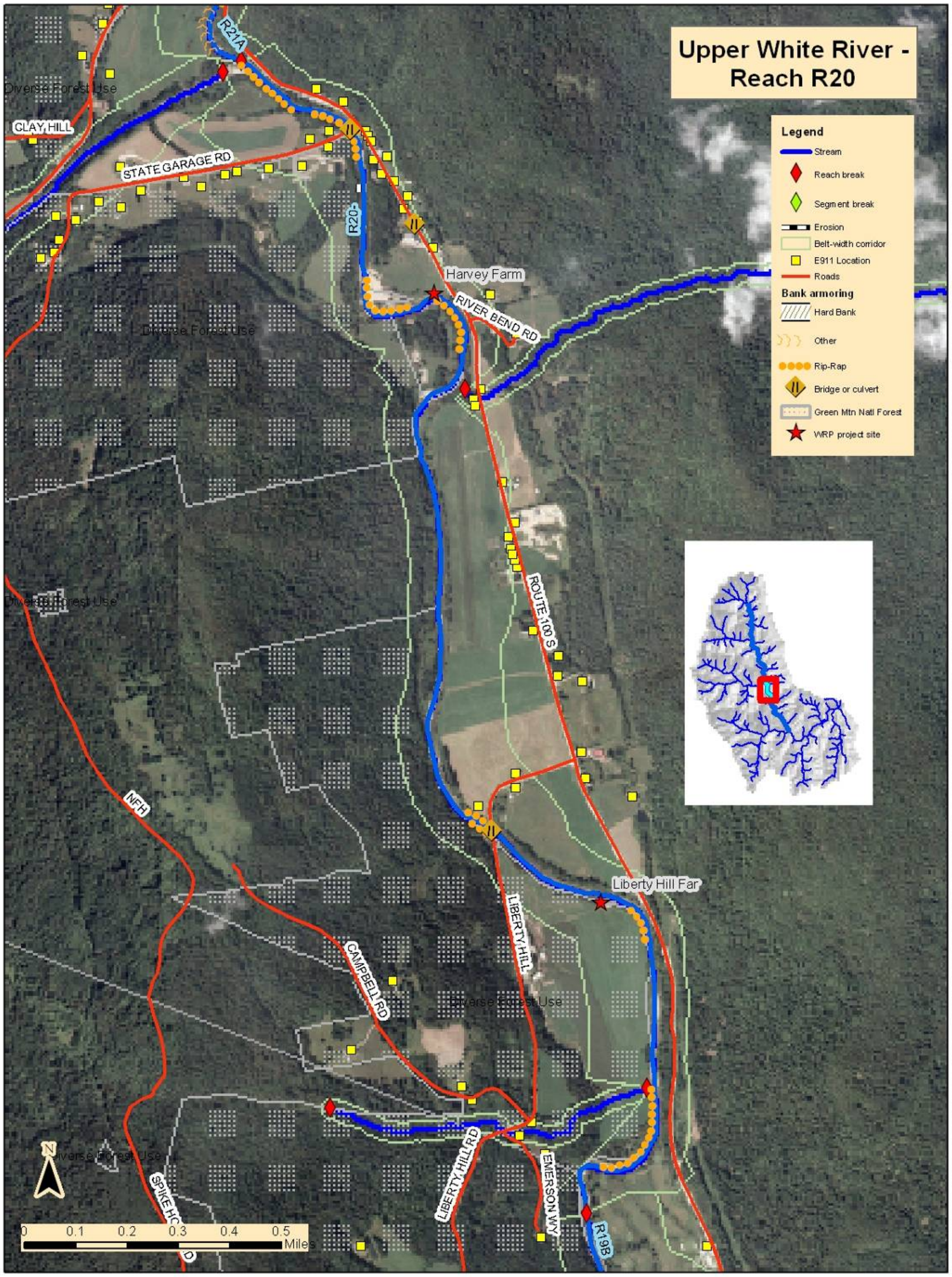


Figure 14. Upper White River reach R20 (2003 National Agricultural Imagery Program aerial photography background).

Table 10. Upper White River Reach R20 Projects and Practices Table used throughout the step-wise project identification process to catalogue projects, indicate a priority for each project, and list the next steps suggested in developing the project.

River Segment (step #)	Project	Reach Priority	Watershed Priority	Completed Independent of other Practices	Next Steps and other Project Notes
R20-0 (6.1)	Protect river corridor	High	High	Y	Landowner contacts-attenuation asset
R20-0 (6.2)	Plant stream buffer	High	High	Y	Mixed cost
R20-0 (6.7)	Potential restoration/ protection project	High	High	Y	Information gathering – landowner contacts for active meander/ floodplain restoration
R20-0 (6.8)	Protect river corridor	High	High	Y	Watershed scale drivers

6.1.4 Preliminary project identification: Reach R21 – West Branch confluence to 900 ft south of Bean's Bridge

Reach R21 includes approximately 9400 ft (1.8 mi) of the river including the concentrated development in Rochester village; school and recreation playing fields occupy much of the floodplain in the central portion of the reach. The reach was segmented for Phase 2 assessment primarily based on differences in corridor encroachment, with the upstream segment (R21B) dominated by residential corridor land use on the left bank in Rochester village. No stream type departures were noted in Phase 2 assessment, indicating that the stream type remains a C channel with access to the floodplain in both segments. An incision ratio of 1.6 was noted in the downstream segment (R21A) however, indicating that the access to floodplain may be growing more limited in this portion of the reach. Channel straightening was indicated in 55% of the reach in Phase 1 assessment, while more detailed planform analysis indicated that 78% of the reach was straightened historically and 22% is naturally confined (Appendix 9). These facts combine with a low width to depth ratio for the stream channel to make this reach an unconfined source and transport reach with limited opportunity for coarse deposition (Fig. 10 and Table 6). Both segments were classed as very highly sensitive to watershed changes in the Phase 2 assessment, and the left bank in both segments were identified with a dominant buffer width of less than 25 ft. Stability of the reach would thus benefit from adequate buffer establishment, and this would be an important component of any project implementation.

Road encroachment was assessed along 34% of this reach in Phase 1 analysis, in addition to development in 20% of the floodplain. These encroachments will likely limit opportunities for flow and sediment load attenuation, and past White River Partnership projects in this reach (one in segment R21A, three in the upstream segment R21B) have primarily dealt at least in part with bank stabilization, with efforts included to incorporate vegetated buffer establishment and fish habitat improvements into project design.

The Brandon Mountain Road (Rte. 73) bridge at the downstream end of R21A was one of the only bridges with signs of geomorphic incompatibility due to channel constriction (deposition upstream of the bridge and scour downstream) noted in Phase 2 assessment. An old bridge abutment just upstream of Woodlawn Cemetery was not measured or assessed for constriction-related problems in the 2003-2004 Phase 2 assessment.

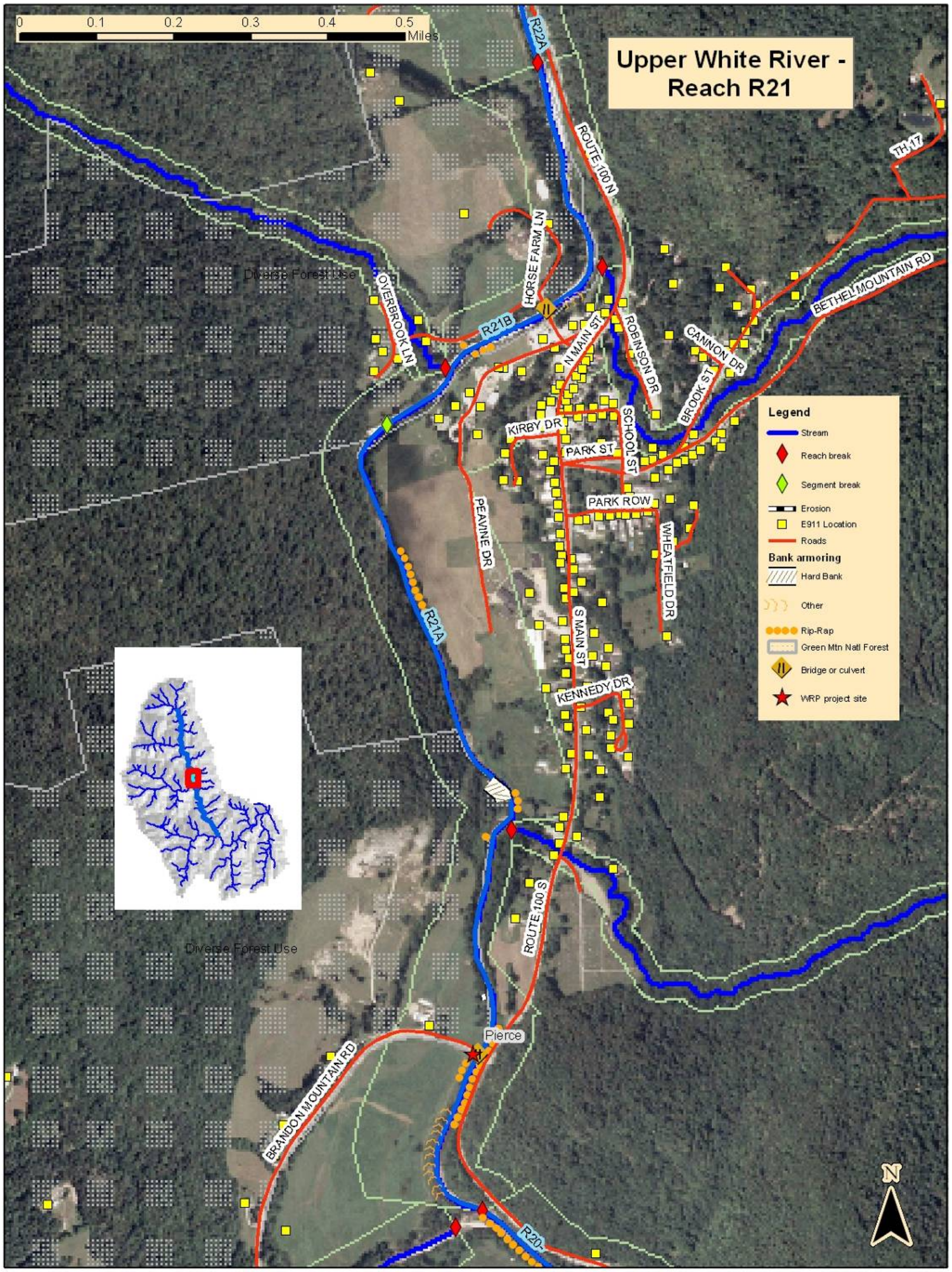


Figure 15. Upper White River reach R21 (2003 National Agricultural Imagery Program aerial photography background).

Table 11. Upper White River Reach R21 Projects and Practices Table used throughout the step-wise project identification process to catalogue projects, indicate a priority for each project, and list the next steps suggested in developing the project.

River Segment (step #)	Project	Reach Priority	Watershed Priority	Completed Independent of other Practices	Next Steps and other Project Notes
R21A (6.1)	Protect river corridor	High	High	Y	Landowner contact-attenuation asset
R21A (6.2)	Plant stream buffer	High	Low	Y	Sensitive reach – constriction at bridge
R21A (6.6)	Replace structure	High	High	Y	VTrans
R21A (6.6)	Remove structure	?	?	Y	Lacking constriction/ problems data
R21A (6.7)	Protect river corridor	High	High	N	Landowner contact-passive; may need to defer
R21B (6.1)	Plant stream buffer	High	Low	Y	Mixed cost
R21B (6.7)	Protect river corridor at downstream reach; restore incised reach with bedforms and floodplain features	Low	Low	N	Opportunities may be limited – above horse farm?
R21B (6.8)	Protect river corridor	Low	High	Y	Minimize conflicts with increasing deposition

6.1.5 Preliminary project identification: Reach R22 – Bean's Bridge to Hancock Cemetery

Reach R22 is comprised of almost 22,000 ft (4.2 mi) of the Upper White channel (3. 5 mi of valley length) extending from just south of Bean's Bridge Rd. to just upstream of the Hancock Cemetery, east of the Rte. 100/ Rte. 125 junction in Hancock (Fig. 16). The reach was segmented for Phase 2 assessment based on changes in planform and slope, with the downstream segment (R22A) indicating extensive channel straightening, likely due in large part to maintenance of the stream against the valley wall in order to farm high-value agricultural lands in the river corridor. Phase 1 assessment indicated channel straightening along 42% of the reach overall, and more detailed planform analysis indicated that 100% of the reach was straightened historically with only 17% of the reach significantly re-establishing meander patterns in 2004 (Appendix 9). Residential use was noted as the dominant corridor land use on the right bank of the upstream segment in the village of Hancock, and the dominant vegetated buffer width was noted as less than 50 ft on the right bank in the upstream segment and the left bank of the downstream segment.

Stream type departures indicating loss of floodplain access were noted in both segments, with the downstream segment (R22A) assessed as a highly entrenched F-type stream in Phase 2 and the upstream segment a moderately entrenched B type stream. The downstream segment was noted in Phase 2 work as extremely sensitive to watershed impacts, while the upstream segment was classified as very highly sensitive. Both segments are experiencing major widening adjustments in particular, and five previous projects implemented by the White River Partnership and associated cooperators in this reach have included buffer establishment and fish habitat enhancement along with more traditional bank stabilization techniques.

The White River Partnership offices are housed at the USDA Forest Service Rochester Ranger District Headquarters in this reach (Fig. 16). The Vermont Land Trust has also been active in land conservation efforts within this reach, working to conserve the former Martin Farms property that borders more than 2 miles of river channel in the Upper White. These efforts have included continued monitoring of easements as well as transfer of properties with river frontage to the Forest Service and the Town of Hancock (Taylor Meadow has been developed for housing: http://www.rherald.com/news/2003/1113/Front_Page/f02.html). Although flow and sediment attenuation opportunities may be limited in the upstream segment of this reach due to development and encroachment constraints, these land ownership and easement configurations may offer greater flexibility in working within those constraints. The reach is located at a point in the watershed where significant project implementation addressing watershed dynamics has occurred upstream, and efforts in this area could yield high benefits in terms of easing downstream impacts from flow and sediment transfer, increasing the effectiveness of projects implemented further downstream. Recommendations for any active floodplain or meander restoration would primarily be focused on accessing flood chutes.

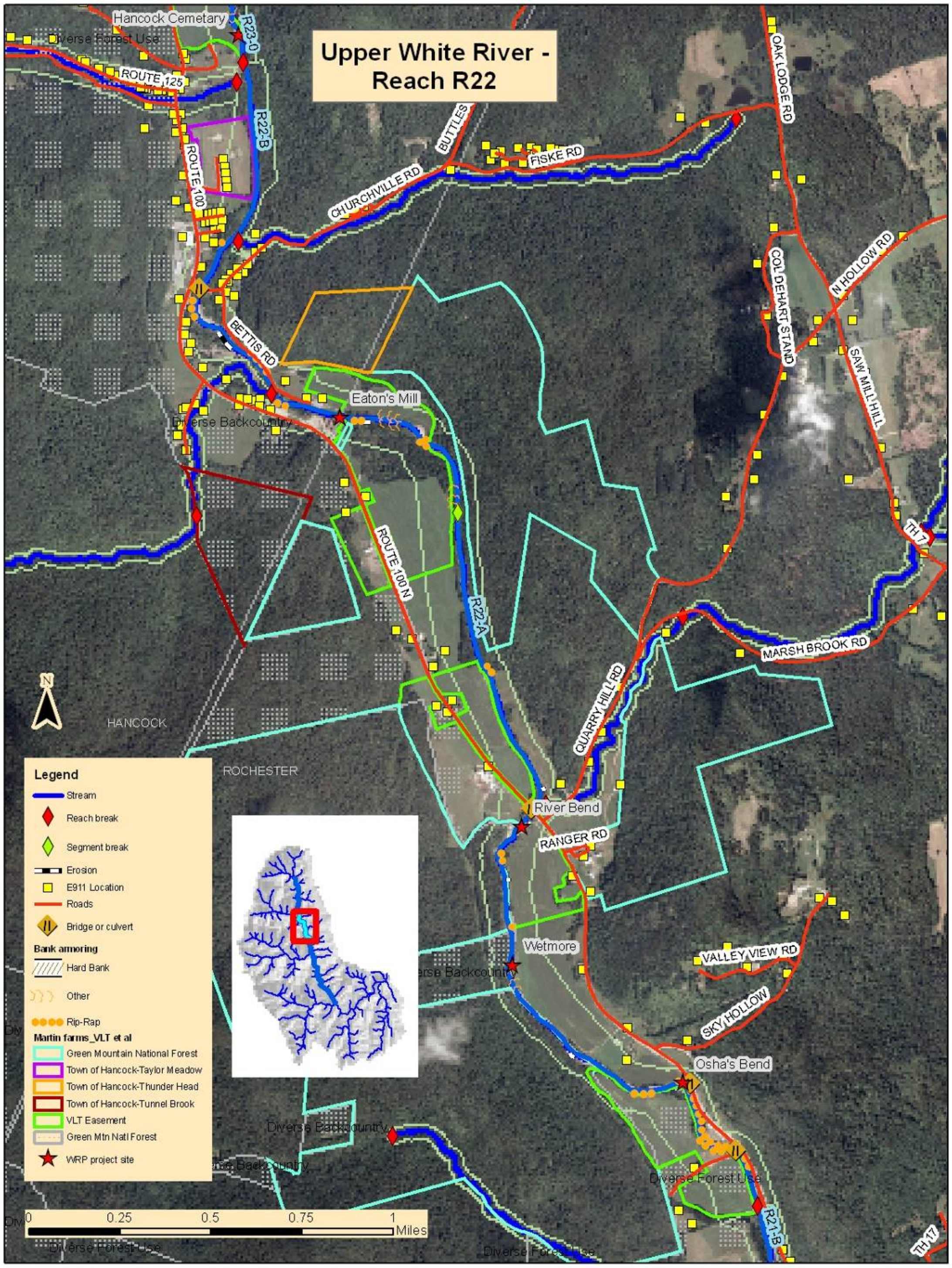


Figure 16. Upper White River reach R22 (2003 National Agricultural Imagery Program aerial photography background).

Table 12. Upper White River Reach R22 Projects and Practices Table used throughout the step-wise project identification process to catalogue projects, indicate a priority for each project, and list the next steps suggested in developing the project.

River Segment (step #)	**Project**	**Reach Priority**	**Watershed Priority**	**Completed Independent of other Practices**	**Next Steps and other Project Notes**
R22A (6.1)	Protect river corridor	High	High	Y	Attenuation asset for high erosion tribs
R22A (6.2)	Plant stream buffer (fencing also?)	High	High	Y	Low cost – extremely sensitive reach
R22A (6.6)	Replace structure	High	Low	Y	VTrans? May transport more sediment to next
R22A (6.7)	Potential restoration/ protection project	High	High	Y	Information gathering – interest for active meander/ floodplain restoration
R22A (6.8)	Protect river corridor	High	High	Y	Minimize conflicts with increasing dep
R22B (6.2)	Plant stream buffer	Low	Low	Y	Mostly good - infill
R22B (6.7)	Potential restoration/ protection project	High	High	Y	Information gathering – interest for active meander/ floodplain restoration – tail end of segment
R22B (6.8)	Protect river corridor	High	High	Y	Minimize conflicts with increasing deposition

6.1.6 Preliminary project identification: Reach R23 – Hancock Cemetery to Thatcher Brook confluence

Reach R23 covers roughly 10,200 ft (1.9 mi) of the Upper White channel extending from just downstream of the Hancock Cemetery to a Rte. 100 bridge near the mouth of Thatcher Brook, located roughly 0.4 mi north of the Hancock/Granville border and about 800 ft south of the Rte. 100/Buffalo Farm Rd. junction (Fig. 17). The reach was not segmented for Phase 2 assessment. Phase 1 assessment indicated that 36% of the reach as straightened, primarily to maintain the position of the channel in relationship to agricultural lands and encroachment from Rte.100. Planform analysis indicated 12% of the reach as naturally confined, with the remaining 88% historically straightened; 26% of the reach was expressing various stages of meander development in 2004 (Appendix 9).

Stream type departure was indicated for the reach, with a current highly entrenched F type stream indicating loss of the floodplain access typical of a C type stream. The reach was assessed as extremely sensitive to watershed changes, and the channel is currently undergoing major widening adjustments. Dominant buffer width through the reach was noted as less than 50 ft on the right bank during Phase 2 assessment, and subdominant buffer widths of less than 25 ft were noted on both banks. Due to the extreme sensitivity of the reach, adequate buffer establishment will be important to any sort of project implementation within the reach but should likely focus on relatively low cost approaches due to lateral instability within the reach.

The Vermont Land Trust monitors conservation easements on the Hancock North portion of the former Martin Farms in reach R23, and the Forest Service and White River Partnership have been major cooperators on restoration projects within the reach. One of these projects helped the Town of Hancock stabilize banks and place fish habitat enhancement structures near the Hancock Cemetery at the downstream end of the reach. A Forest Service-designed project placed log revetments and restored large woody debris to the river channel in the Hancock Overlook area of the Hancock North Conservation Easement area (former Martin Farms) to assist in sediment storage and help attenuate high flows. White River Partnership has also increased buffer plantings within the reach.

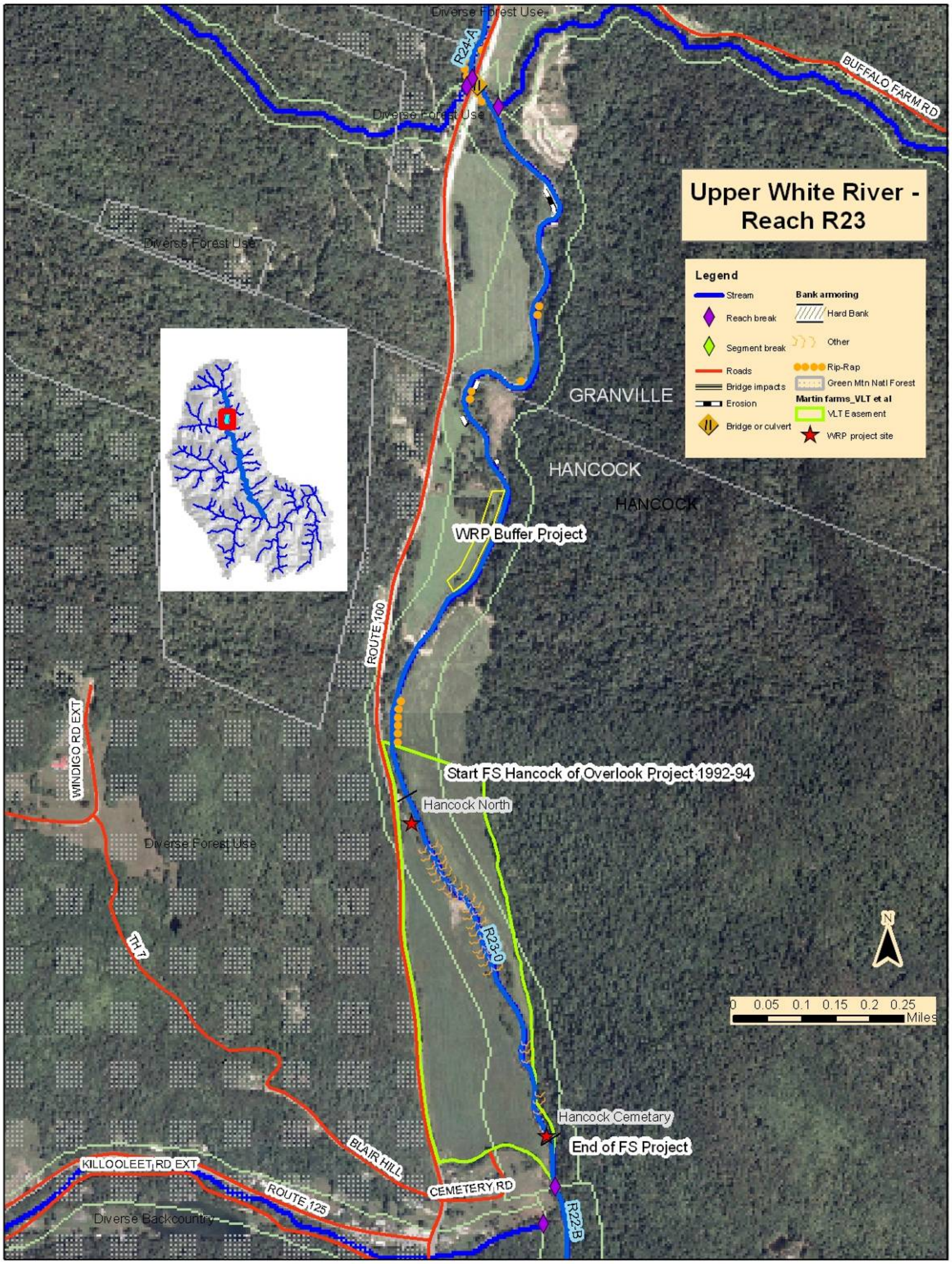


Figure 17. Upper White River reach R23 (2003 National Agricultural Imagery Program aerial photography background).

Table 13. Upper White River Reach R23 Projects and Practices Table used throughout the step-wise project identification process to catalogue projects, indicate a priority for each project, and list the next steps suggested in developing the project.

River Segment (step #)	Project	Reach Priority	Watershed Priority	Completed Independent of other Practices	Next Steps and other Project Notes
R23-0 (6.1)	Protect river corridor	High	High	Y	Attenuation asset
R23-0 (6.2)	Plant stream buffer (fencing also?)	High	High	Y	Low cost – extremely sensitive reach; Hancock North esp.
R23-0 (6.6)	Remove structure	?	?	Y	Lacking constriction/ problems data
R23-0 (6.7)	Protect river corridor	High	High	Y	Landowner contact-passive
R23-0 (6.7)	Protect river corridor	High	High	Y	Minimize conflicts with increasing deposition

6.1.7 Preliminary project identification: Reach R24 – Thatcher Brook confluence to below Elmwood Cemetery

Reach R24 extends roughly 12,110 ft (2.3 mi) from the Rte 100 bridge south of Buffalo Farm Rd., near the mouth of Thatcher Brook, to a location below Elmwood Cemetery (midway between Lower Granville and Granville) that was the site of channel avulsions that occurred during flooding of the Upper White in 1998 (Fig. 18).

Reach R24 indicated a relatively low degree of channel straightening in comparison with other Upper White reaches, with 25% indicated by Phase 1 analysis and planform analysis in 2004 indicating the highest percentage of combined stages of meander redevelopment on the Upper White (36%) after 100% of the reach being straightened historically(Appendix 9). The reach was segmented for Phase 2 assessment based on changes in planform and slope, with extensive channel straightening in the downstream segment (R24A) to maintain the stream against the valley wall and away from agricultural fields. The river corridor is relatively undeveloped in this reach, although agricultural lands occupy much of the riparian area and a subdominant residential corridor landuse was noted in the upstream segment (R24B) in the area of Lower Granville.

Stream type departures were noted in Phase 2 assessment of both segments of reach R24, with reference C type streams now assessed as a highly entrenched F type in downstream segment R24A and a moderately entrenched B type stream in R24B. Segment R24A was assessed as extremely sensitive to watershed changes, while R24A was noted as highly sensitive.

Flooding in 1998 created channel avulsions in the upstream portions of the reach in particular, which were utilized for constructed wetlands that have now established regenerating shrub and floodplain forest conditions which are reportedly providing significant wildlife habitat benefits in particular (pers. comm., Dan McKinley, USDA-FS Rochester Ranger District Fisheries Biologist, April 11, 2007). In addition, a major oxbow just downstream of the Bagley project rock vanes and start point of a Forest Service large woody debris project, both indicated in Fig. 18, indicates other major shifts in location of the river channel in this reach as well.

Although no alluvial fans were noted in Phase 1 or 2 assessment of the Upper White, it is conceivable that the presence of a compound or combined, multiple alluvial fans in this area are masked by location within a relatively narrow valley and the presence of development and agricultural fields in the Lower Granville and Granville areas at the northern end of this reach and extending into reach R25. Alluvial fans consist of thick sediment deposits in areas where the slope of a stream becomes gentler and stream flow velocity decreases. Due to the decrease in stream power, the stream's ability to carry sediment is reduced and the sediment load drops out and is deposited across the channel bed, and sometimes the adjacent floodplain, in the shape of a fan. Alluvial fans may be very unstable, and multiple channels are commonly found within them. Clark Brook and Albee Brook carry sediments from steep valley walls on either side of the valley in Reach R24, and three tributary streams converge with the White River mainstem in Granville in R25, the next reach upstream (Fig. 19).

Alluvial fans are naturally high bed load systems subject to a relatively high degree of channel movement in response to watershed inputs, and the naturally high degree of channel instability at the upper end of this reach and into Reach R25 make this area a particularly valuable attenuation asset with a high priority for protection as a means to mitigate high flow inputs and provide critical sediment storage that would contribute significantly to facilitating equilibrium conditions in downstream reaches. Adequate vegetated buffers are vital for enhancing channel and boundary stability in such a situation, and subdominant buffer widths of less than 50 ft were noted on both banks of both segments of reach R24 in Phase 2 assessment.

Previous projects in Reach R24 include the constructed wetlands noted above as well as installation of rock vanes for flow attenuation, erosion control, and enhancement of fish habitat at the upstream end of the reach. A 2004 Forest Service restored large woody debris to the channel (to enhance flow and sediment attenuation) just downstream of these rock vanes, and the White River Partnership was planting stream buffer trees at Short Hills Ski Club, just south of the Forest Service 2004 project, as this document was being prepared in the spring of 2007.

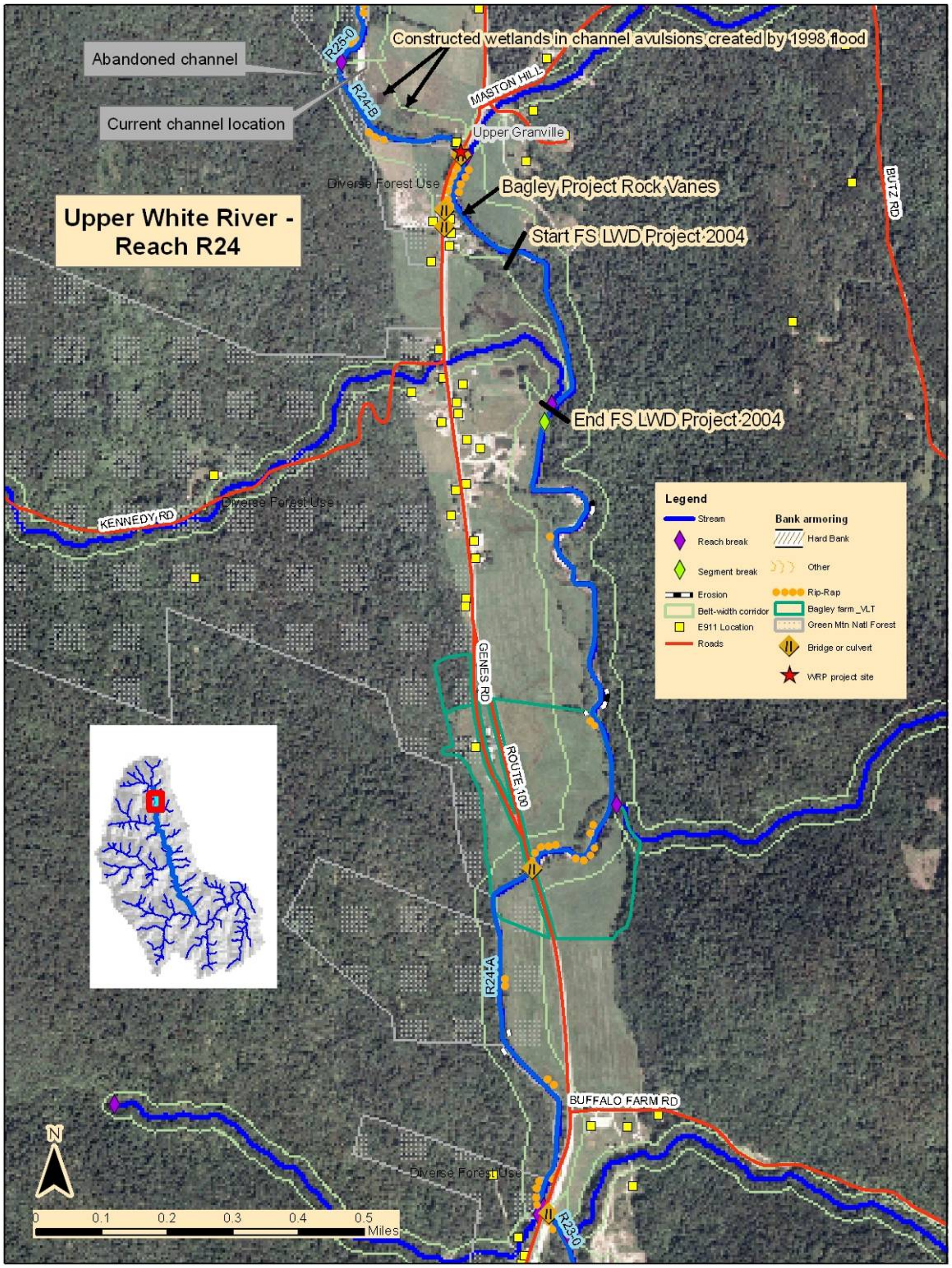


Figure 18. Upper White River reach R24 (2003 National Agricultural Imagery Program aerial photography background).

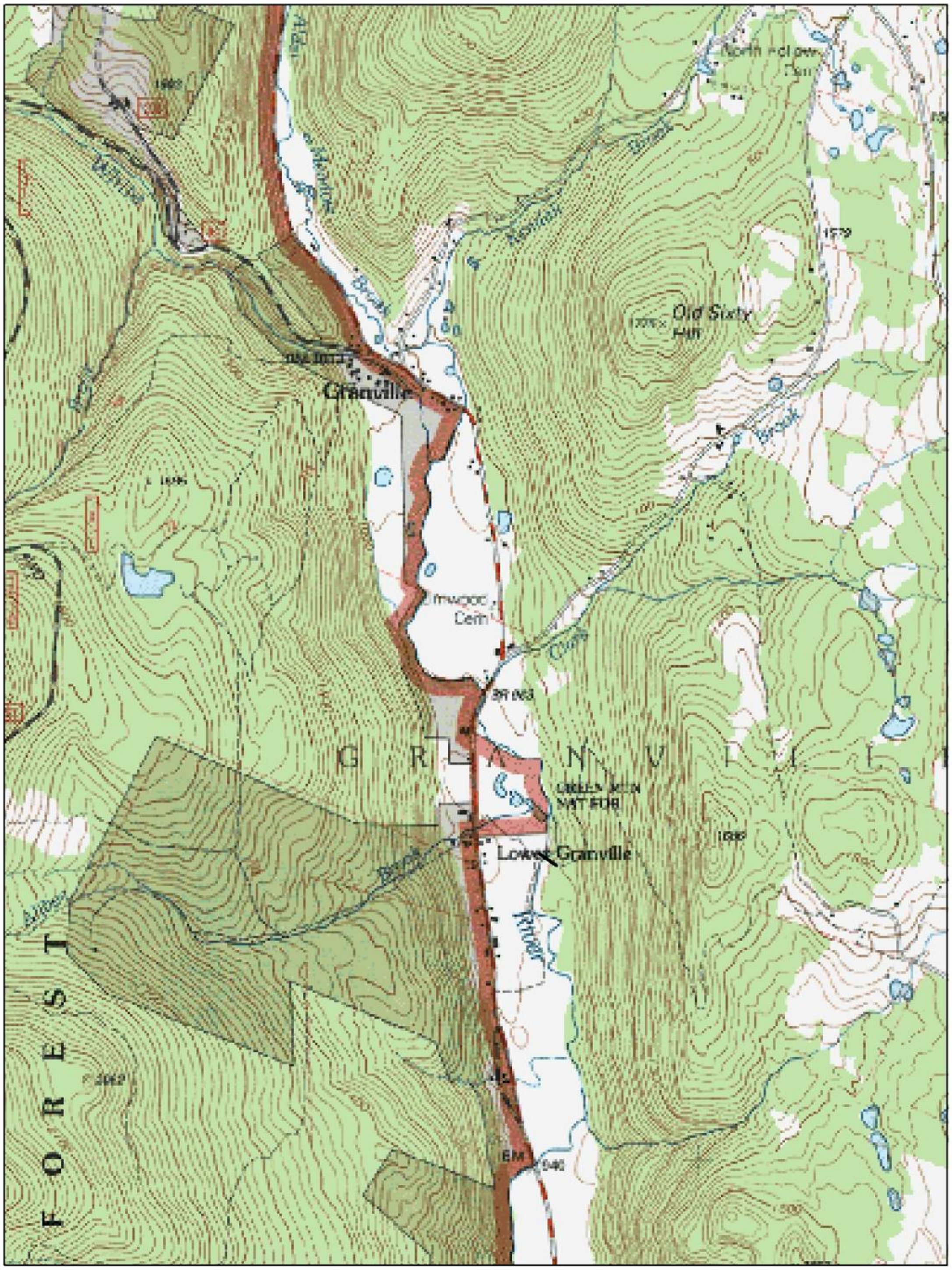


Figure 19. Although no alluvial fans were identified in Phase 1 or Phase 2 assessment of the Upper White, the confluence of several streams at the base of steep valley walls in a relatively narrow valley setting suggest that the presence of a combined fan, or several fans, may be masked by development and agricultural lands in the upstream portion of reach R24 and reach R25 near Lower Granville and Granville.

Table 14. Upper White River Reach R24 Projects and Practices Table used throughout the step-wise project identification process to catalogue projects, indicate a priority for each project, and list the next steps suggested in developing the project.

River Segment (step #)	**Project**	**Reach Priority**	**Watershed Priority**	**Completed Independent of other Practices**	**Next Steps and other Project Notes**
R24A (6.1)	Protect river corridor	High	High	Y	Widening
R24A (6.2)	Plant stream buffer (fencing also?)	High	High	Y	Low cost – extremely sensitive reach; Short Hills being planted this spring; could still use more south of there
R24A (6.7)	Potential restoration/ protection project	High	High	Y	Information gathering –allow rip rap failure; passive meander/ floodplain restoration
R24A (6.8)	Protect river corridor	High	High	Y	Minimize conflicts with increasing deposition

River Segment (step #)	Project	Reach Priority	Watershed Priority	Completed Independent of other Practices	Next Steps and other Project Notes
R24B (6.1)	Protect river corridor	High	High	Y	Site of bowl mill project, Bagley rock vanes, FS 2004 LWD project
R24B (6.2)	Plant stream buffer	Low	High	Y	Infill by bowl mill project and elsewhere?
R24B (6.6)	Remove structure	Low	Low	Y	Old bridge abutment w/ no problems listed
R24B (6.7)	Restore incised reach to abandoned channel	High	High	N	Below 2004 FS LWD project and above Short Hills – oxbow wetland
R24A (6.1)	Protect river corridor	High	High	Y	Widening

6.1.8 Preliminary project identification: Reach R25 – Elmwood Cemetery to Granville

Reach R25 consists of roughly 4,000 ft (0.8 mi) of the White River mainstem extending from just west of Elmwood Cemetery to the village of Granville (Fig. 20). The reach was not segmented for Phase 2 assessment. Subdominant corridor landuse in the right bank corridor was noted as industrial due to the presence of the Bowl Mill. Phase 1 assessment noted 44% of the reach as straightened, largely due to the development encroachments along the river. Planform analysis in 2004 indicated 100% of the reach as historically straightened, but also noted the highest percentage of full meander expression (35% of the reach) of any reach within the Upper White Corridor Planning Project area at that time.

Stream type departure from a reference C type stream to a highly entrenched F type stream was indicated in Phase 2 assessment, indicating loss of floodplain access, and the reach was classified as extremely sensitive to watershed changes. Rock weirs have been installed along much of the reach to limit further bed degradation and thus help limit further disconnection of the stream floodplain access. Although it is difficult to assess with certainty whether the combination of increased stream power and protection of the bed has increased pressure on bank boundaries, it is notable that active widening scores were very low (indicating major adjustments) for this parameter in the Phase 2 assessment (Appendix 5).

Although no alluvial fans were noted in Phase 1 or Phase 2 assessment of the Upper White mainstem within the Project area, it is conceivable that the presence of alluvial fans may be masked in this area (see discussion in Reach R24 description within this report). Regardless of whether there are actually a fan or fans present, this reach appears to be naturally subject to high hydrologic and sediment inputs, with attendant channel instability, due to its position in the watershed (Fig. 19). A channel avulsion is clearly visible at the tail end of the reach and into the beginning of Reach R24 (Fig. 20), and flood impacts in 1998 were significant in this portion of the stream.

Vegetated buffers were noted as dominantly less than 25 ft on the left bank and subdominantly less than 25 ft on the right bank within the reach, and bank canopy was noted as less than 25% coverage in the reach during Phase 2 assessment. Adequate buffer establishment and maintenance would greatly enhance boundary stability and habitat value in such an active portion of the Upper White, although opportunities are limited by current development patterns within the village in particular.

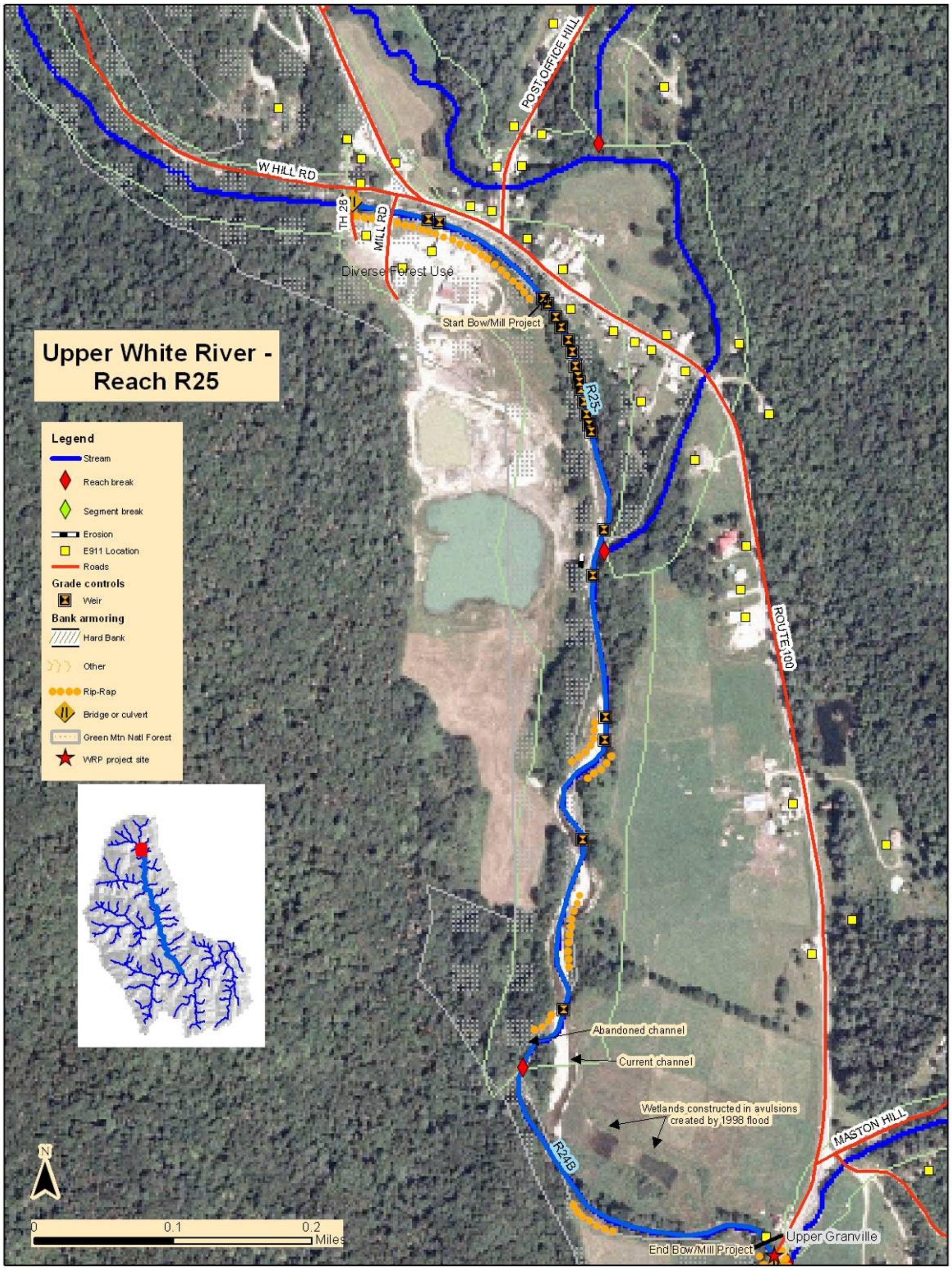


Figure 20. Upper White River reach R25 (2003 National Agricultural Imagery Program aerial photography background).

Table 15. Upper White River Reach R25 Projects and Practices Table used throughout the step-wise project identification process to catalogue projects, indicate a priority for each project, and list the next steps suggested in developing the project.

River Segment (step #)	**Project**	**Reach Priority**	**Watershed Priority**	**Completed Independent of other Practices**	**Next Steps and other Project Notes**
R25-0 (6.1)	Protect river corridor	High	High	Y	
R25-0 (6.2)	Plant stream buffer	Low	High	Y	Infill above bowl mill project?
R25-0 (6.7)	Restore incised reach to abandoned channel	High	High	N	Above bowl mill project?
R25-0 (6.8)	Protect river corridor	High	High	Y	Minimize conflicts with increasing deposition

6.2 PROJECT PRIORITIZATION

Due to its location in the overall White River basin and its geologic setting, the Upper White corridor overall tends to be highly sensitive and responsive to changes in watershed inputs. Passive geomorphic restoration projects, which leverage these inputs and the river's own energy to facilitate a return to equilibrium conditions, are thus recommended for prioritization due to the likelihood of rapid stream evolution (see Section 7 of this report for further discussion). In addition, the lower investments associated with this approach are fitting considering an inherent degree of uncertainty in the success of engineered approaches in a highly active system.

Sediment regime departure analysis (see esp. Sec. 5.1.7 of this report) indicates that reach R20, south of Rochester village, is the first area of the Upper White (moving downstream) in which access to historical floodplain still exists. Sediment load indicators signify that this area is also currently where sediment loads begin to significantly exceed the river's capacity to transport these loads, causing these loads to drop out and deposit in considerable quantities. Areas of deposition in this area and further downstream would thus be best able to capitalize on current stream dynamics and watershed inputs to facilitate stream evolution to equilibrium conditions.

Detailed planform analysis of the Upper White conducted by River Management Program personnel in 2004 has indicated a number of areas of meander development in the Project area (Appendix 9). Meanders are beginning to reestablish in the upstream portions of the Project area, particularly in reaches R23 and R24 in northern Hancock and Granville, and projects to augment this process would be beneficial in terms of overall watershed dynamics. However, the stream is entrenched in much of this area and project implementation in this area would likely require active approaches to meander and floodplain restoration, with associated higher costs for implementation. This is also a highly active portion of the river (see discussion in Sec. 6.1 of this report), increasing the possibility for failure of implemented projects due to flooding impacts in particular.

With these considerations in mind, Table 16 lists potential projects in the Upper White corridor in order of recommended priority. It is important to bear in mind that buffer establishment and augmentation would be an important component of any of these projects due to the composition of boundary materials in the Upper White.
The prioritization should be considered preliminary and will need to be adjusted based on further information and community interest. Maps of the potential project areas follow the table and are referenced in the table.

Table 16. Potential project prioritization for the Upper White Corridor Planning Project

Upper White River Corridor Planning Prioritized Project and Strategy Summary								
Project #	**Reach/Segment Condition-Sensitivity**	**Site Description including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility & Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion & Landowner Commitment**	**Potential Partner Commitments**
1	R20-0 Fair – High (Both downstream and upstream potential project sites) (Figs. 21 & 22)	First real access to floodplain below Granville; extensive historical straightening; gravel ramping and heavy sediment deposition evident; constraints of armoring to protect Rte 100 on one side and ag fields on the other	Passive; Protect corridor, buffer establishment and augmentation	Feasible; still has floodplain access; some buffer already; high watershed priority	High educational/ demonstration value, community leaders	Easement transactions, CREP programs or other compensation	Buffer establishment; ag land likely involved in floodplain access	R20-0 Fair – High (Both downstream and upstream potential project sites)

Upper White River Corridor Planning Prioritized Project and Strategy Summary								
Project #	**Reach/Segment Condition-Sensitivity**	**Site Description including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility & Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion & Landowner Commitment**	**Potential Partner Commitments**
2	R18-B Poor – Very high (Fig. 23)	Straightened historically; constrained on right bank by road encroachment; crop land on left bank; high deposition	Passive; Augment/ establish buffers, protect corridor, refrain from maintenance of riprap	Feasible; moderately entrenched, high deposition; some buffer already; high priority	augments possible Peavine Trail vistas, Rte 100 sound buffer	Planting stock, easement transactions	Buffer establishment	
3	R18-A Fair – High (Fig. 24)	Straightened historically, meanders reestablishing in lower third of segment; constrained on right bank by road and development encroachment; crop land on left bank; deposition building at Tweed	Passive; Augment buffers, protect corridor, refrain from further riprap on RB	Feasible; still has floodplain access; some buffer already; high priority and may increase if development pressure	“gateway” visual corridor to Upper White; augments possible Peavine Trail vistas, Rte 100 sound buffer	Planting stock, easement transactions	Ag lands likely to be impacted by floodplain access and meander reestablishment	

Upper White River Corridor Planning Prioritized Project and Strategy Summary								
Project #	**Reach/Segment Condition-Sensitivity**	**Site Description including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility & Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion & Landowner Commitment**	**Potential Partner Commitments**
4	R18-C Poor – Extreme (Fig. 25)	Straightened historically; beginning to meander in upper portion; naturally confined at lower end	Passive; Augment buffers, protect corridor	Feasible, already evolving; only moderately high priority because highly entrenched	augments possible Peavine Trail vistas, Rte 100 sound buffer	Planting stock at upper end, easement transactions	Widen buffer; refrain from riprap	
5	R23-0 Poor – Extreme (Fig. 26)	Straightened to maintain against valley wall; naturally confined just upstream, with full meander expression above the confined section; Hancock Cemetery downstream	Passive; Protect corridor, meander and floodplain access reestablishment; buffer augmentation, plus establishment on downstream end	Highly entrenched; high priority in watershed dynamics, but may be lower priority if active restoration required; assessment of buffer establishment, and infill if necessary, is high priority	Hancock Overlook interpretive signage	Easement transactions, CREP programs or other compensation; planting stock if necessary	Ag lands likely to be impacted by floodplain access and meander reestablishment	

Upper White River Corridor Planning Prioritized Project and Strategy Summary								
Project #	**Reach/Segment Condition-Sensitivity**	**Site Description including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility & Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion & Landowner Commitment**	**Potential Partner Commitments**
6	R22-A&B Poor – Extreme (A) Fair – Very high (B) (Fig. 27)	Straightened to maintain against valley wall for ag lands and road encroachment; beginning to meander just upstream; moderately entrenched on upstream end	Passive; Protect corridor, meander and floodplain access reestablishment; buffer augmentation, plus establishment on downstream end	Moderately entrenched; high priority in watershed dynamics, but may be lower priority if any active restoration required	Close to WRP offices & Ranger station, educational/ demonstration value	Easement transactions, CREP programs or other compensation; planting stock at lower end,	Ag lands likely to be impacted by floodplain access and meander reestablishment	
7	R22-A Poor – Extreme (Fig. 28)	Straightened, but beginning to meander on downstream end; primary constraint is ag lands; highly entrenched	Passive/active; Protect corridor, meander and floodplain access reestablishment; buffer establishment and augmentation	Highly entrenched; high priority in watershed dynamics, but may be lower priority if active restoration required	Close to WRP offices & Ranger station, educational/ demonstration value	Active restoration may be needed to restore floodplain access	Ag lands likely to be impacted by floodplain access and meander reestablishment	

Upper White River Corridor Planning Prioritized Project and Strategy Summary								
Project #	**Reach/Segment Condition-Sensitivity**	**Site Description including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility & Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion & Landowner Commitment**	**Potential Partner Commitments**
8	R19-A&B Poor – Extreme (Fig. 29)	Straightened along valley wall and then across valley on border of segments 19-A & 19-B below New Boston Rd; riprapped upstream to protect ag; Rte 100 encroachment downstream	Augment buffers; protect corridor; might require some active floodplain restoration; high deposition	Highly entrenched; high priority in watershed dynamics, but lower priority in terms of costs		Higher costs associated with need for active restoration	Ag land likely involved in floodplain restoration	
9	R19-B Poor – Extreme (Fig. 29)	Straightened across valley and then along valley wall at Twitchell; encroachment from Rte 100 and Twitchell Settlement Rd; naturally confined above	Protect corridor; might require some active floodplain restoration; high deposition	Highly entrenched; high priority in watershed dynamics, but lower priority in terms of costs		Higher costs associated with need for active restoration; impacts of flooding on fill may be problematic	Clean up may be required before restoration	

Upper White River Corridor Planning Prioritized Project and Strategy Summary								
Project #	**Reach/Segment Condition-Sensitivity**	**Site Description including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility & Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion & Landowner Commitment**	**Potential Partner Commitments**
10	R19-A Fair – Moderate (Fig. 30)	Straightened historically; beginning to meander in midsection; Rte 100 encroachment on LB; bedrock protected terraces	Might require some active restoration	Feasible; moderately entrenched, but only moderate sensitivity; lower priority		Higher costs associated with possible need for active floodplain restoration		
11	R21-A&B Good – Very high (A) Fair – Very high (B) (Fig. 31)	Straightened; playing fields and ag lands; development encroachments (incl. Water treatment) on upstream end; armoring on downstream end	Passive/active; Protect corridor, meander reestablishment; buffer establishment and augmentation	Feasible; still has floodplain access; high watershed priority but lower priority in terms of costs	educational/ demonstration value	Some active restoration may be needed to accommodate encroachments on upstream end	Impacts to playing fields, ag land	

Upper White River Corridor Planning Prioritized Project and Strategy Summary								
Project #	**Reach/Segment Condition-Sensitivity**	**Site Description including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility & Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion & Landowner Commitment**	**Potential Partner Commitments**
12	R24-A&B Poor – Extreme (A) Fair – High (B) (Fig. 32)	Straightened across valley and then along valley wall for maintenance of ag lands and bridge passage; meanders already reestablishing on upstream end	Passive/active; Protect corridor, meander reestablishment; buffer establishment and augmentation; evaluate feasibility of bridge relocation on replacement schedule (long term)	Highly to moderately entrenched; high priority in watershed dynamics, but lower priority in terms of costs; may require active floodplain restoration and evaluation of bridge siting/maintenance issues	Land trust engagement in stream restoration as part of overall land conservation picture; possible VTrans demonstration project in conjunction with replacement	Higher costs associated with need for active floodplain/ meander restoration; bridge relocation would be expensive; buffer establishment/ planting costs, easement transactions	Buffer establishment; ag land likely impacted by floodplain/ meander restoration; bridge relocation would likely require extensive evaluation	

Upper White River Corridor Planning Prioritized Project and Strategy Summary								
Project #	**Reach/Segment Condition-Sensitivity**	**Site Description including Stressors and Constraints**	**Project or Strategy Description**	**Technical Feasibility & Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion & Landowner Commitment**	**Potential Partner Commitments**
13	R24-B Fair – High (Fig. 33)	Straightened across valley and then along valley wall for protection of road and development encroachments; meanders already reestablishing further upstream and downstream	Passive/active; Protect corridor, access old flood chute/ oxbow for meander reestablishment; tricky due to upstream development encroachments	Feasibility questionable; high priority in watershed dynamics, but lower priority in terms of costs; Active approach likely required to accommodate development on upstream end		Higher costs associated with need for active approach to access oxbow; Easement transactions		

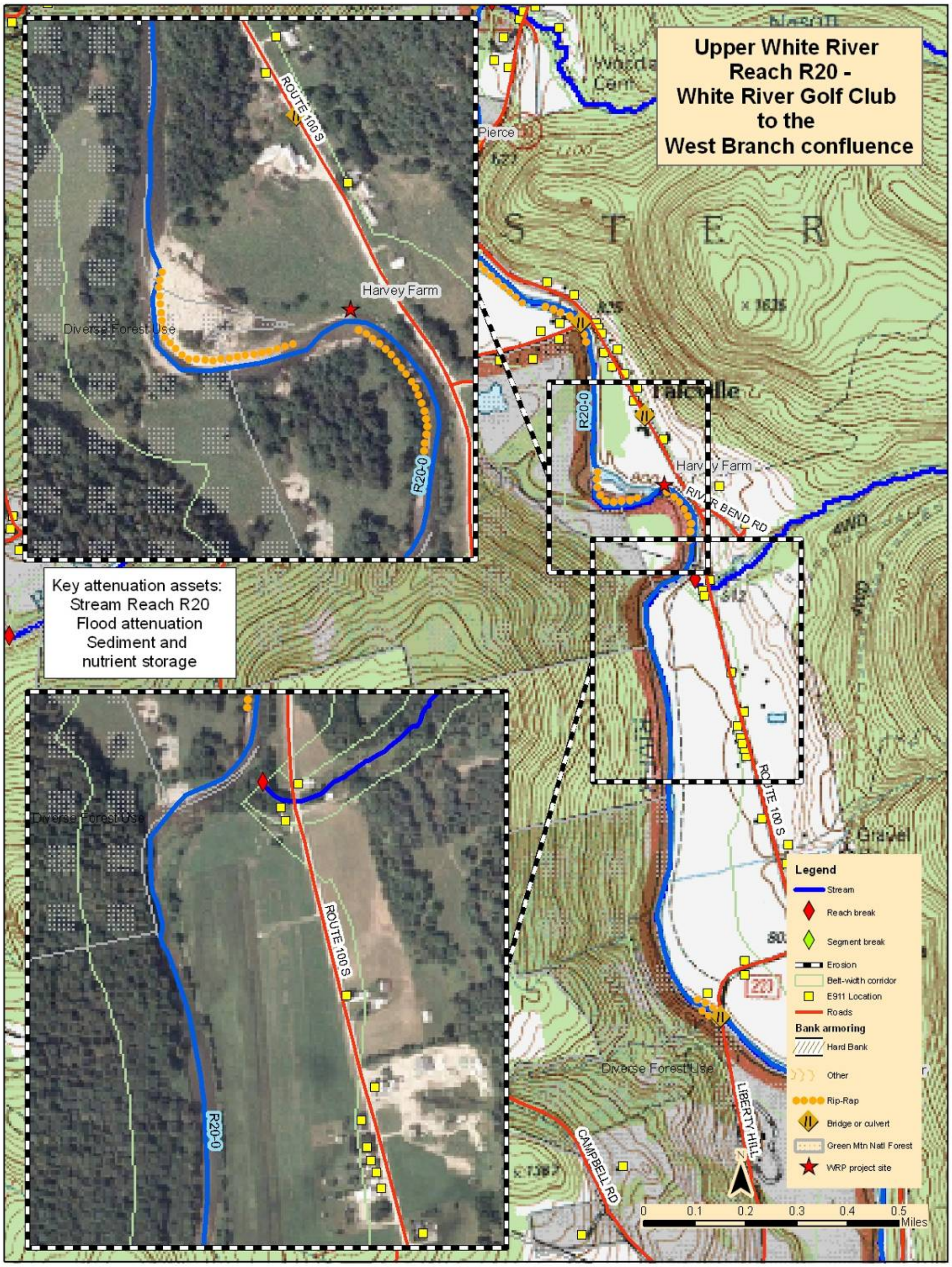


Figure 21. Project prioritization: Reach 20-0 upstream

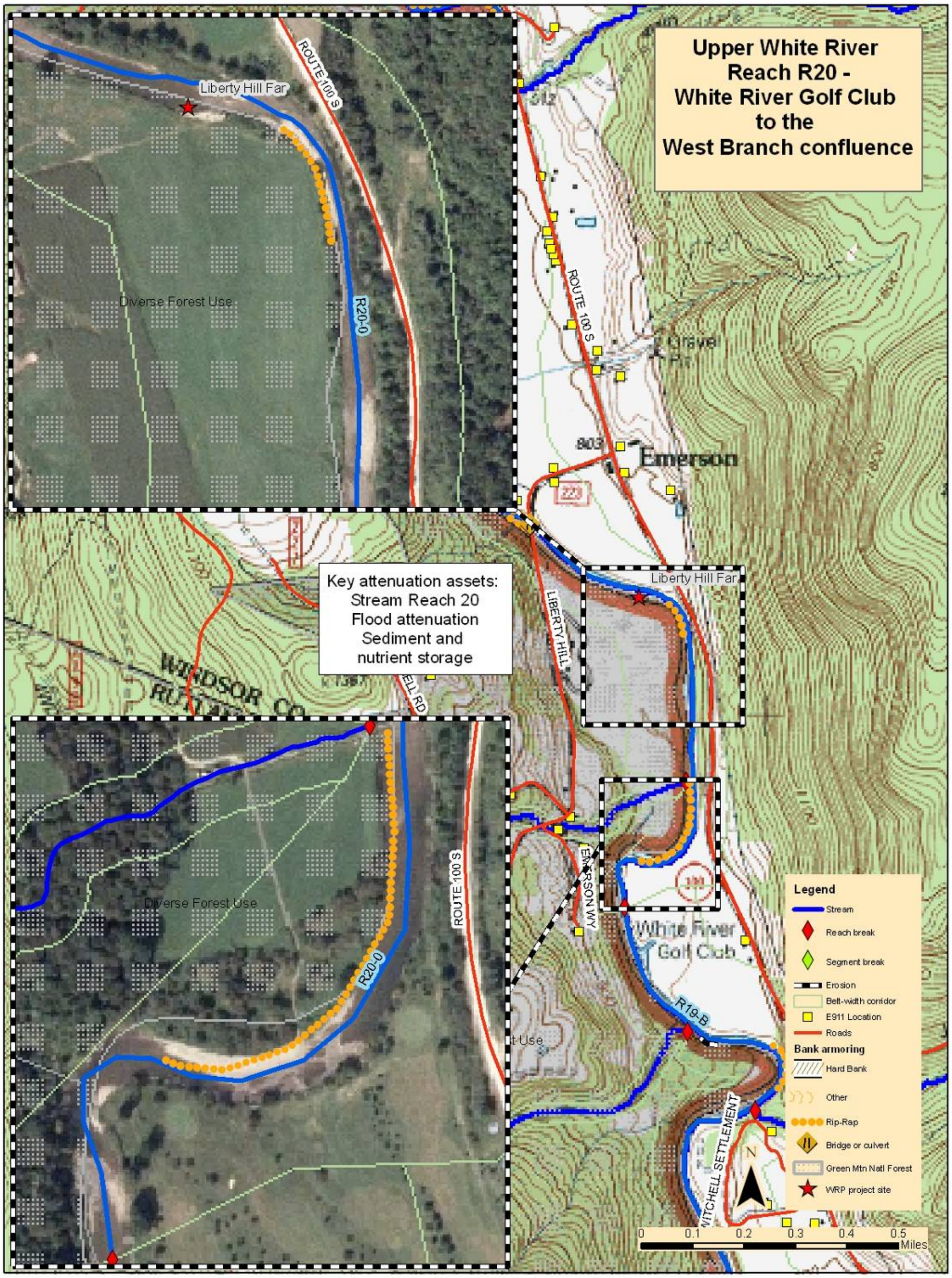


Figure22. Project prioritization: Reach 20-0 downstream

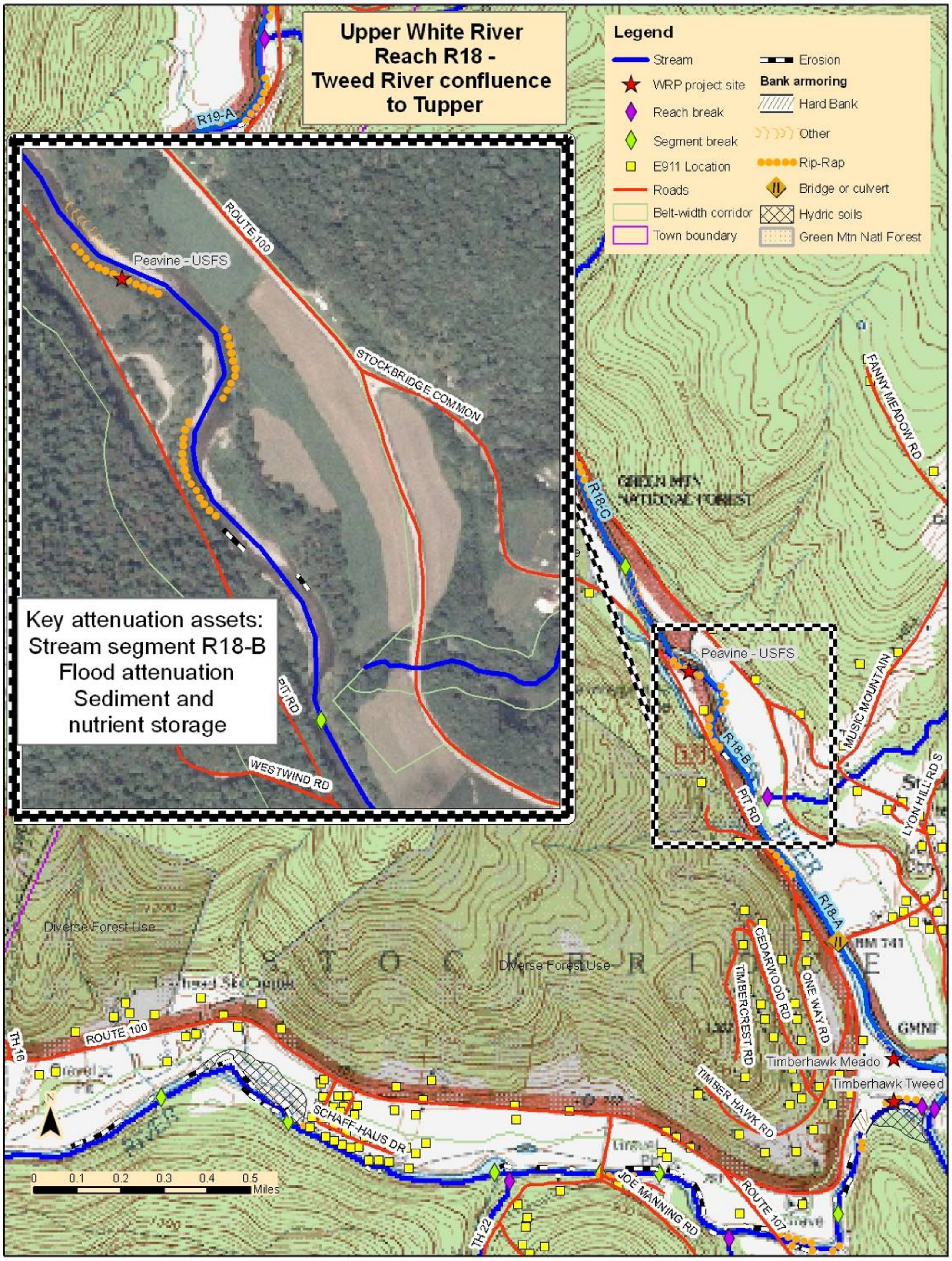


Figure23. Project prioritization: Reach R18-B

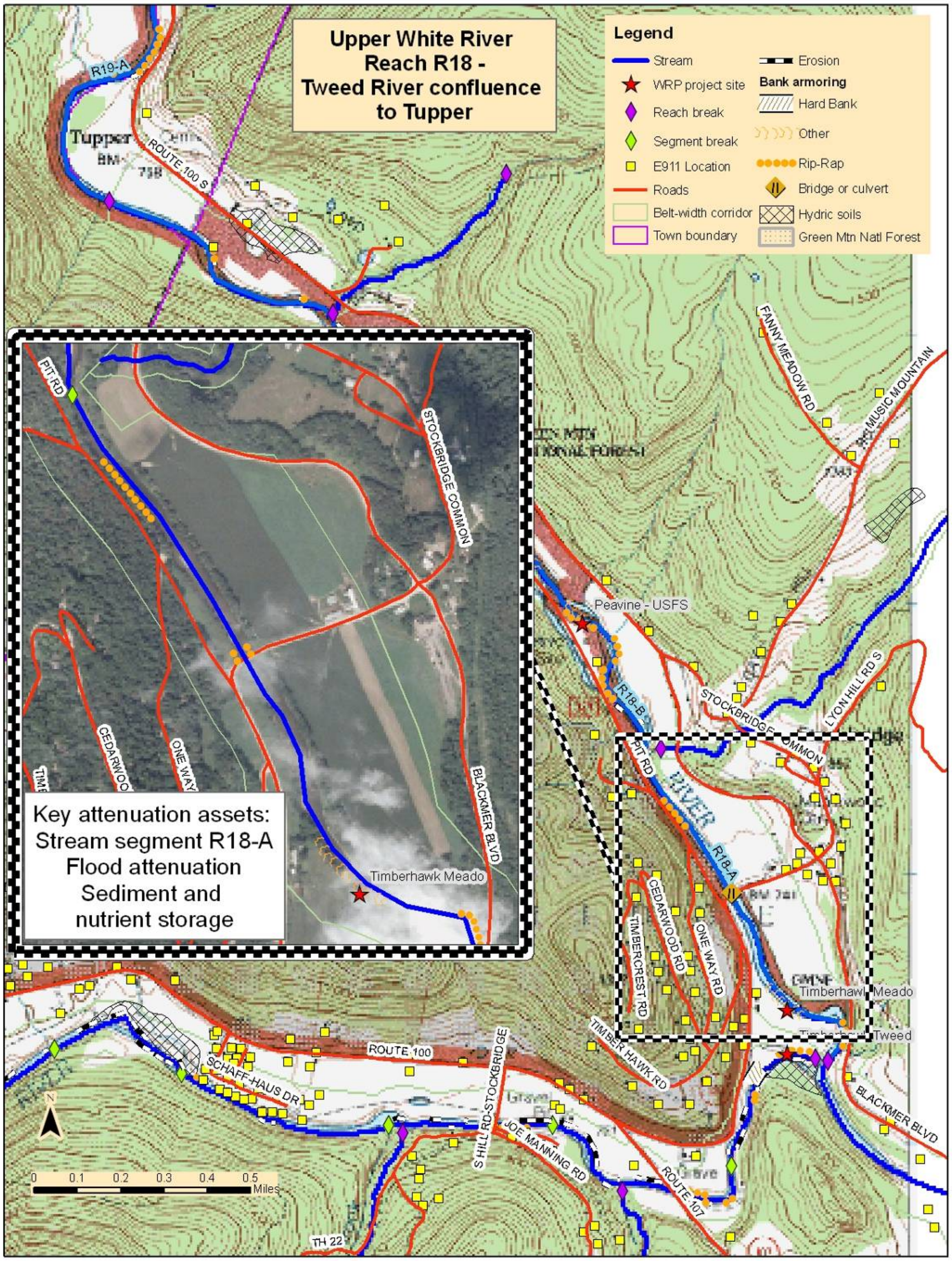


Figure 24. Project prioritization: Reach R18-A

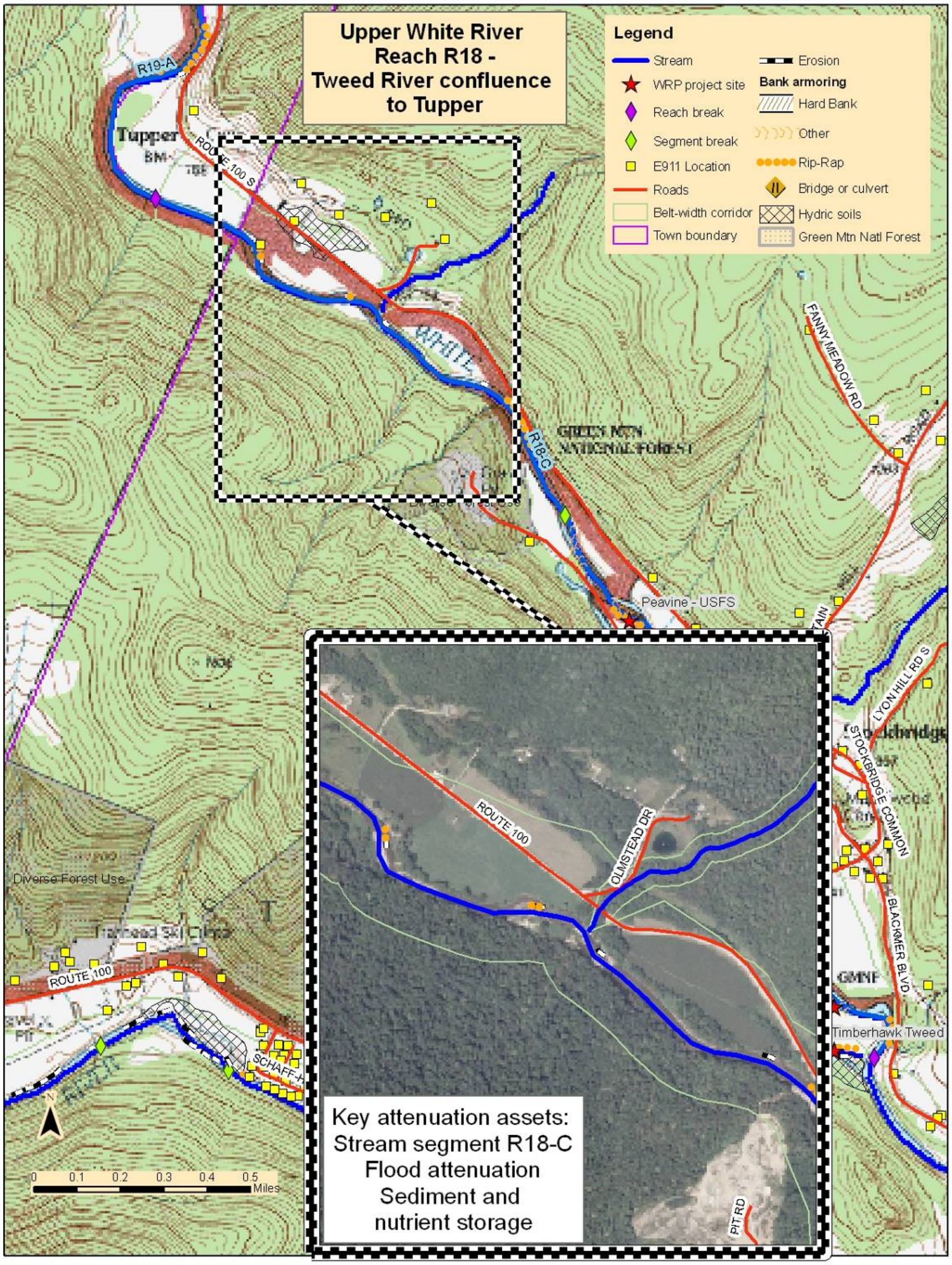


Figure 25. Project prioritization: Reach R18-C

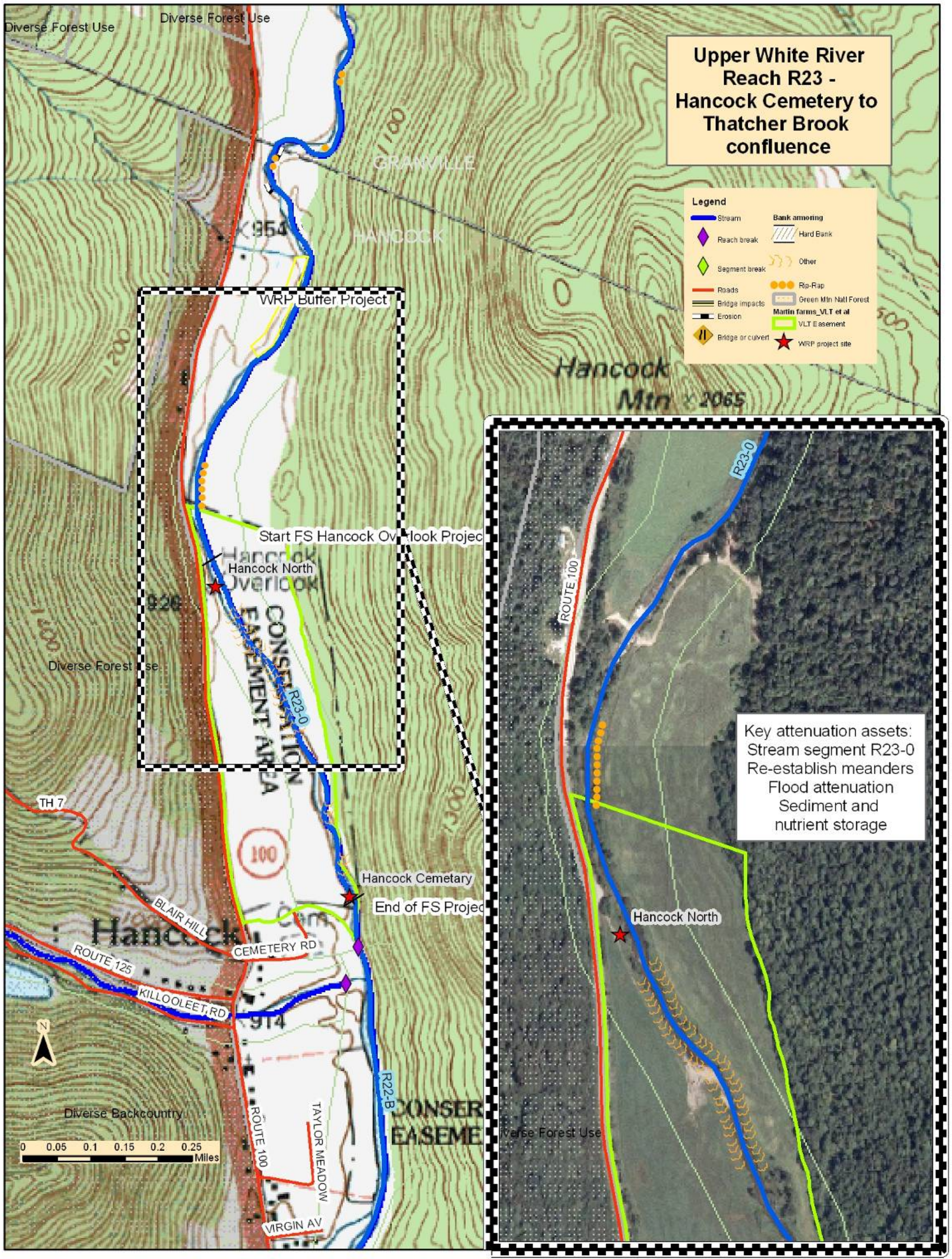


Figure 26. Project prioritization: Reach R23-0

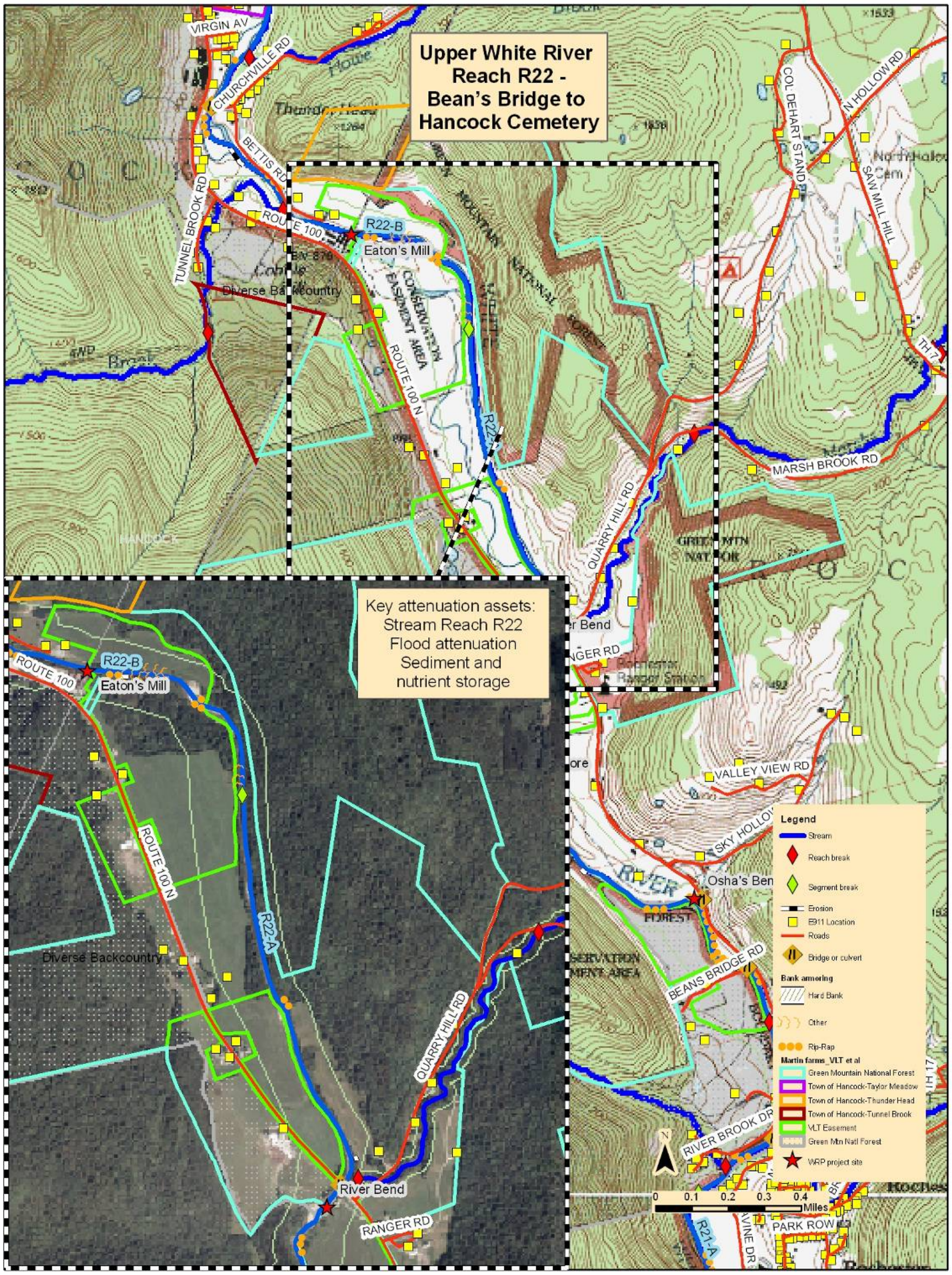


Figure 27. Project prioritization: Reach R22-A&B

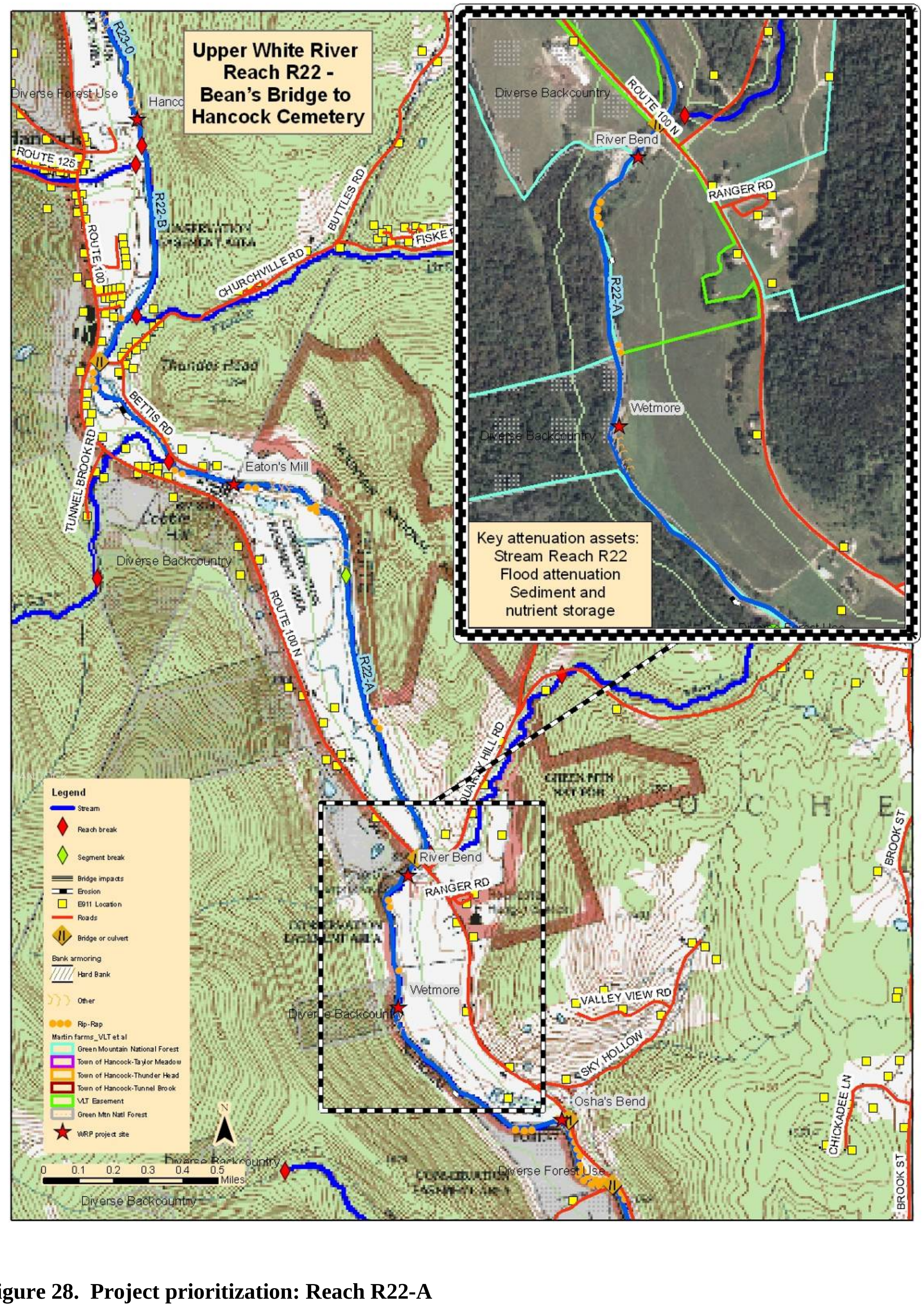


Figure 28. Project prioritization: Reach R22-A

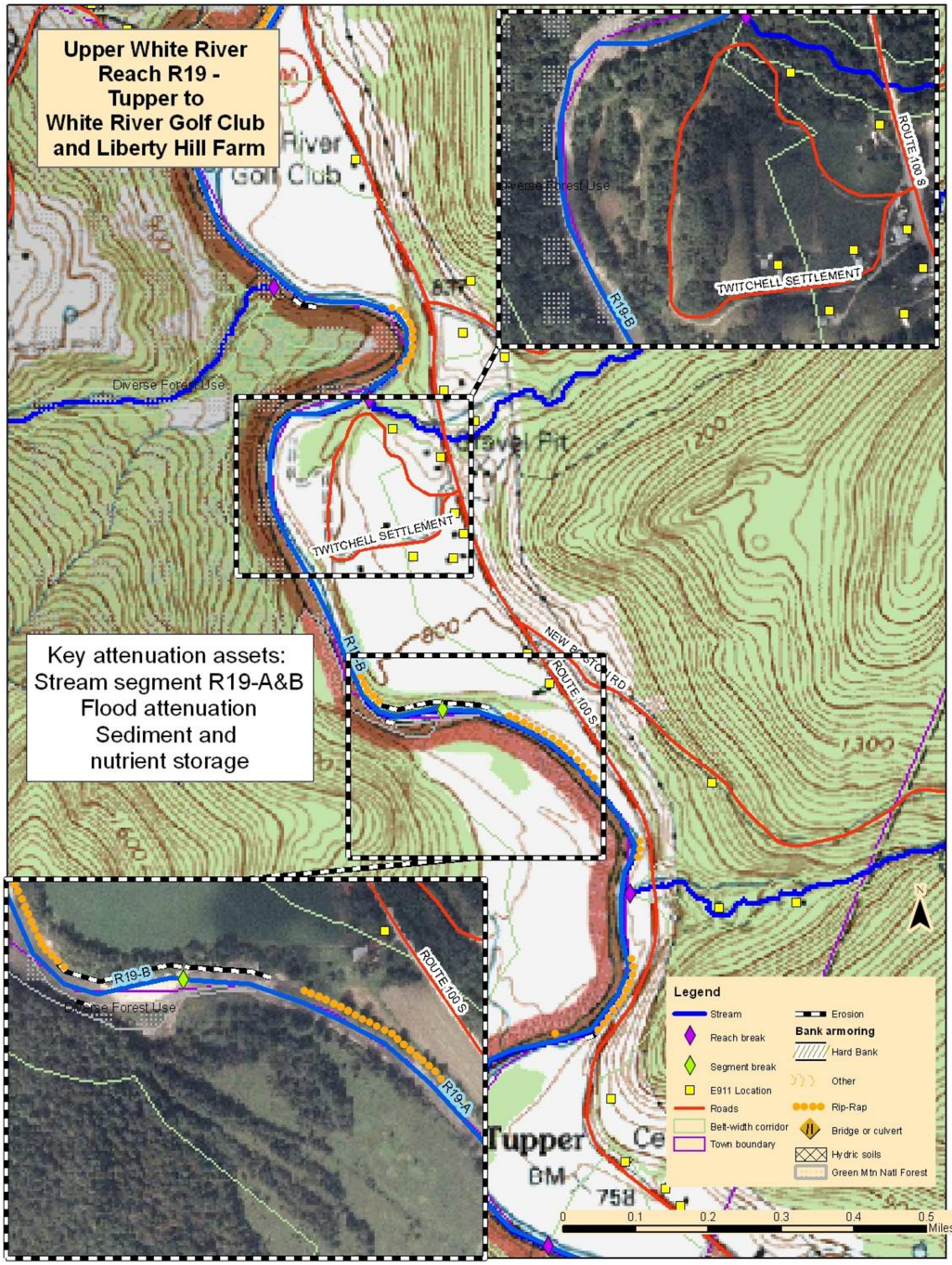


Figure 29. Project prioritization: Reach R19-A&B

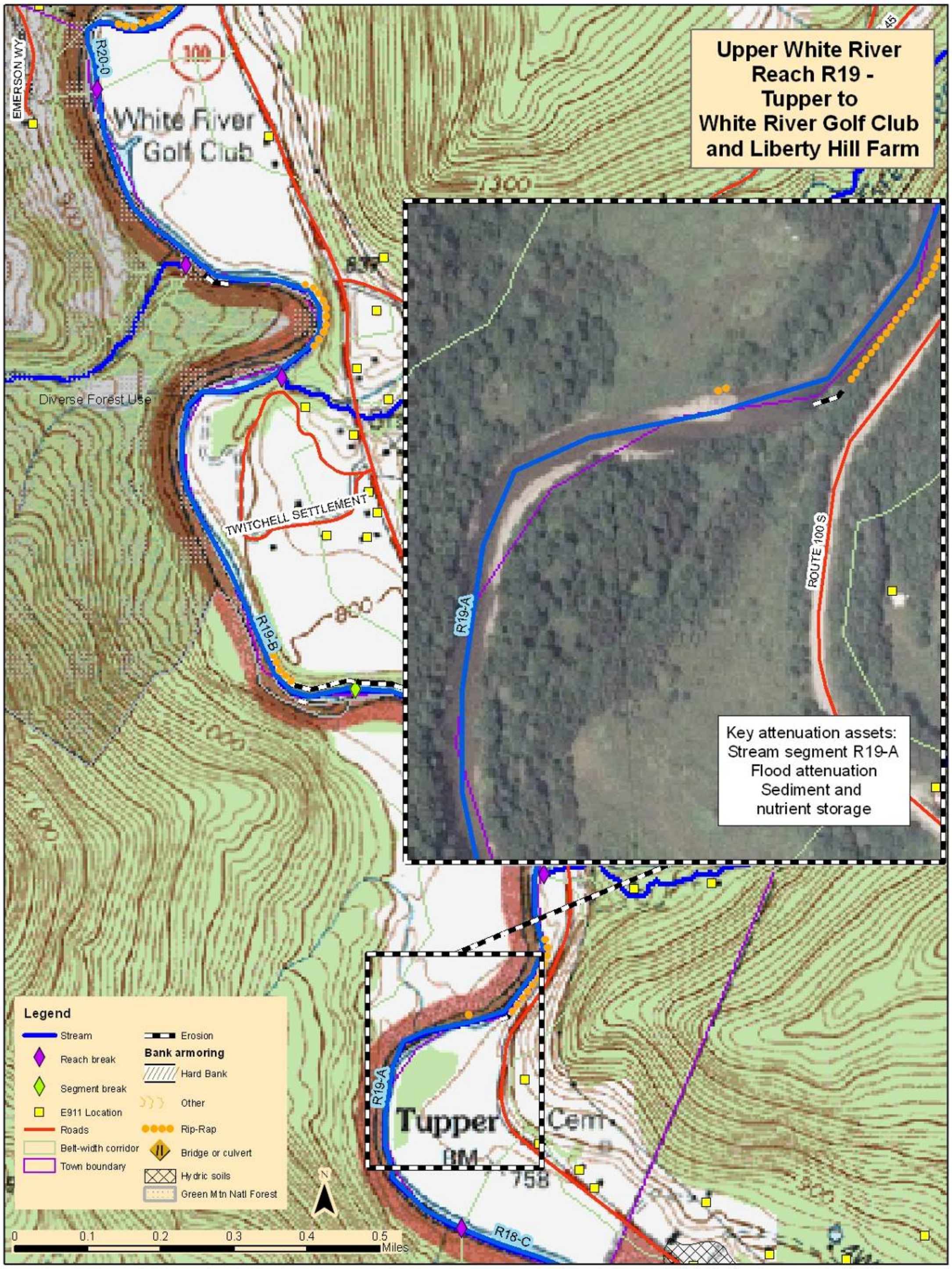


Figure 30. Project prioritization: Reach R19-A

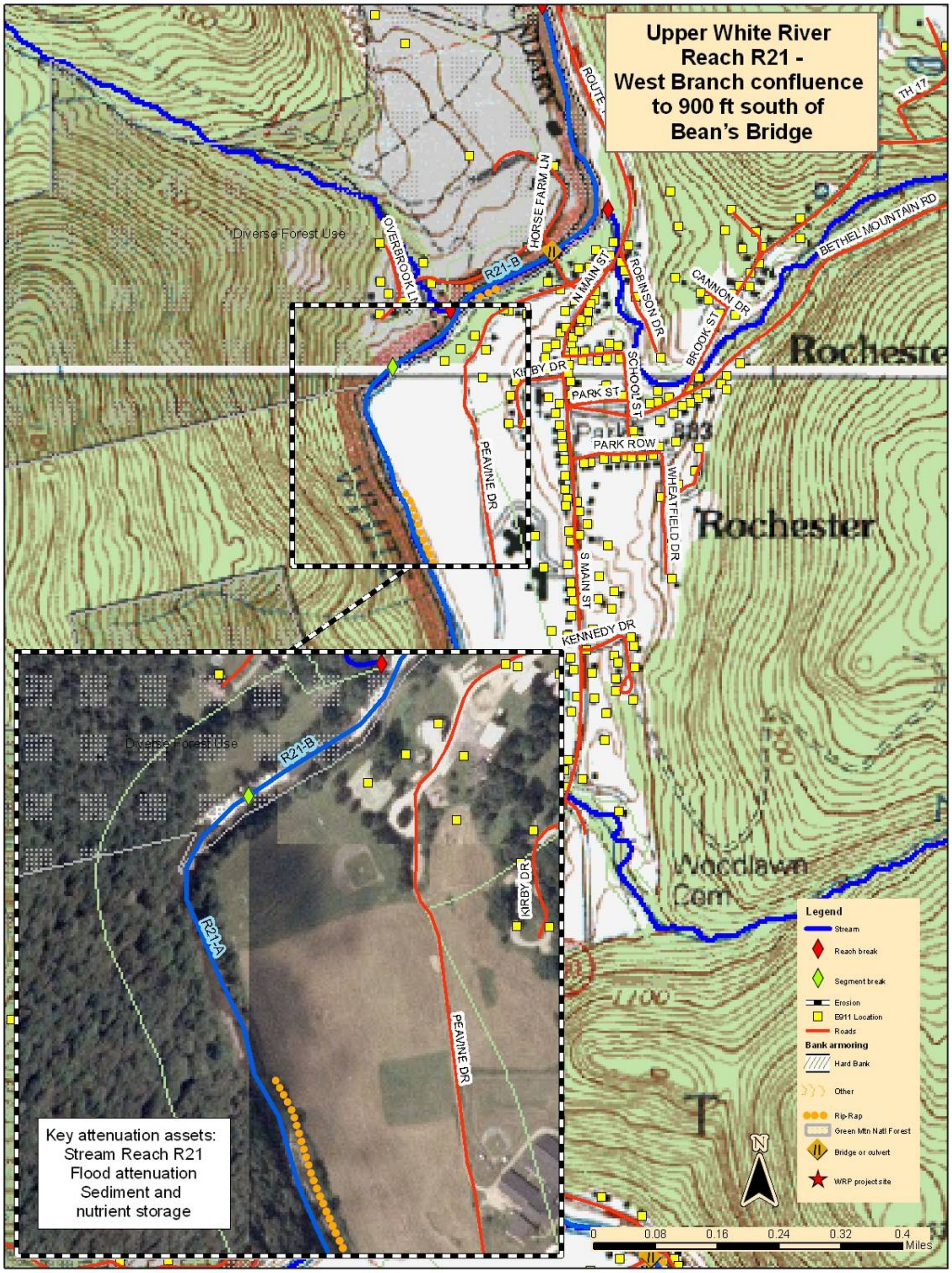


Figure 31. Project prioritization: Reach R21-A&B

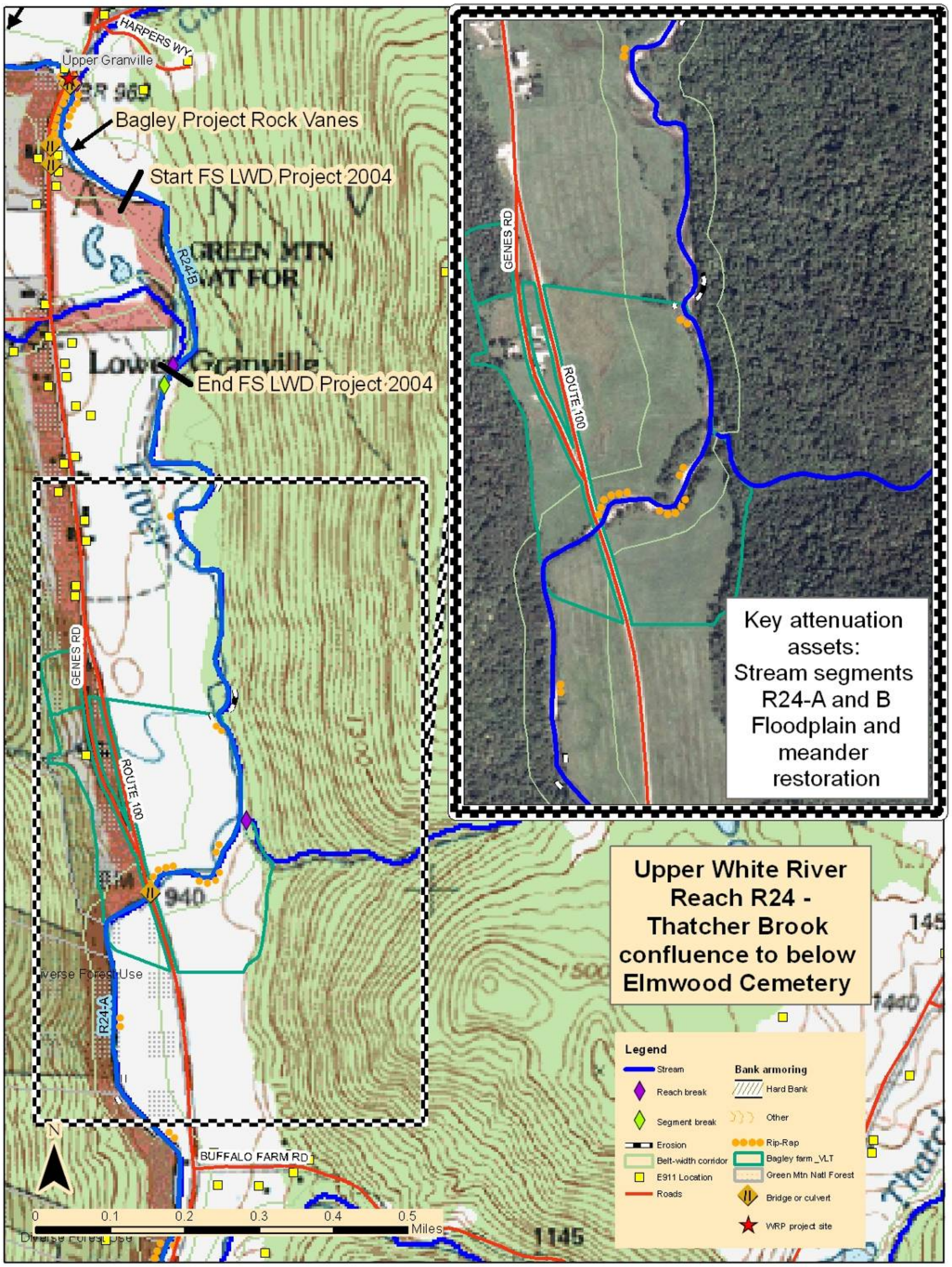


Figure 32. Project prioritization: Reach R24-A&B

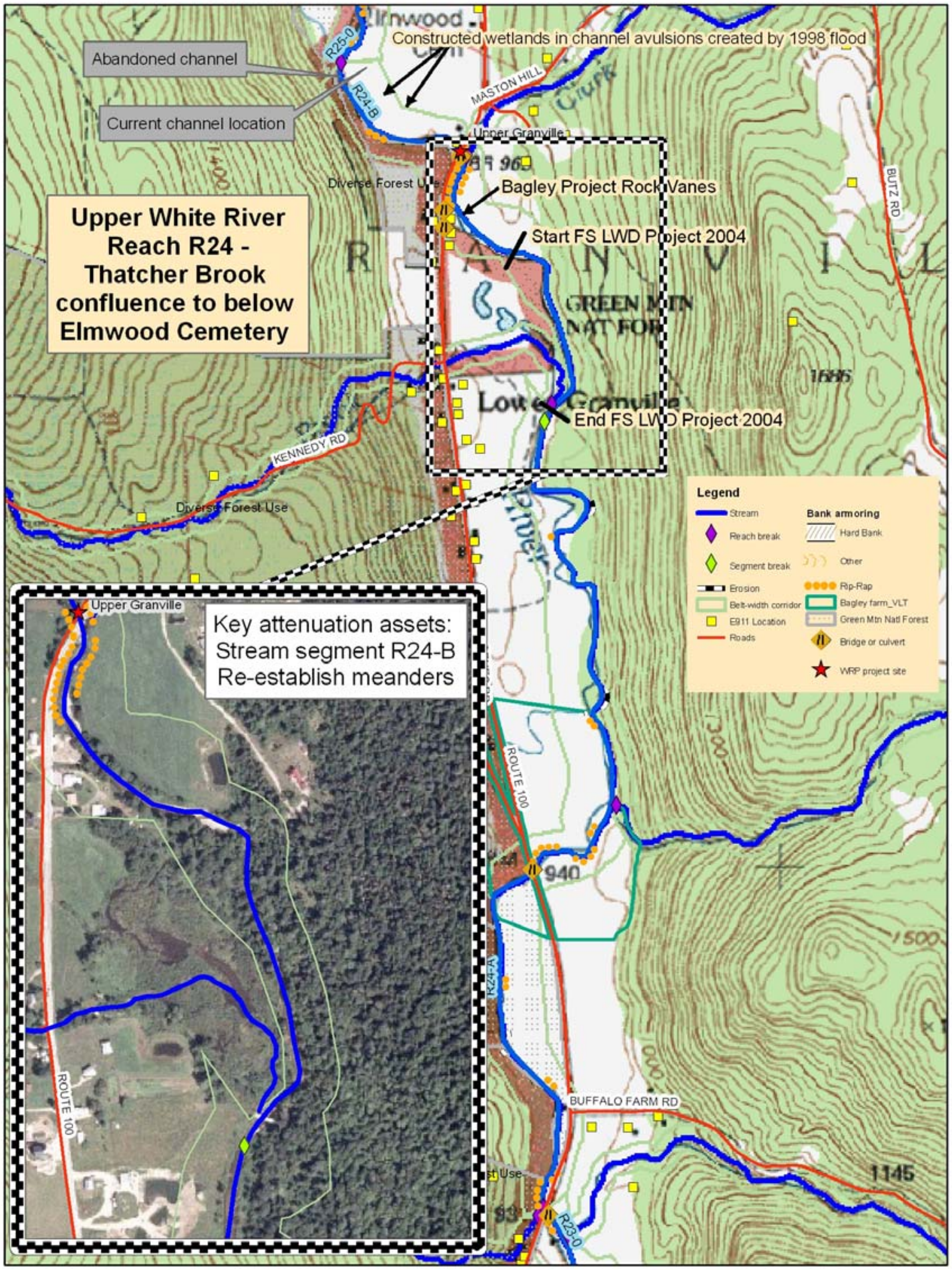


Figure 33. Project prioritization: Reach R24-B

7.0 PROJECT AND PROGRAM RECOMMENDATIONS

7.1 STATE AND MUNICIPAL ACTIONS

Several strategies can be used by state agencies and municipalities to reduce human conflicts with the river. The first strategy, planning and zoning to minimize future encroachment, includes tools such as corridor-based zoning ordinances, participation in the National Flood Insurance Program, and fluvial erosion hazard mapping.

The National Flood Insurance Program (NFIP) was created by Congress through the National Flood Insurance Act of 1968. It enables property owners in participating communities to purchase insurance protection against flood related losses. The insurance provides an alternative to disaster assistance by covering damage repairs to buildings and their contents. Participation in the NFIP is based on an agreement between the Federal Government and local communities that states the Federal Government will make flood insurance available if a community adopts and enforces a floodplain management ordinance to reduce flood risks to new construction in Special Flood Hazard Areas (SFHA). The SFHAs and other risk premium zones that affect participating communities are depicted on Flood Insurance Rate Maps. The Mitigation Division within the Federal Emergency Management Agency manages the NFIP, and oversees the floodplain management and mapping components of the Program (http://www.fema.gov/business/nfip/). Within the Upper White Project area, Stockbridge and Rochester have incorporated floodplain regulations into zoning regulations; Hancock, Granville and Pittsfield have stand alone floodplain ordinances.

Fluvial erosion hazard (FEH) mapping uses the geomorphic data collected in Phases I and II to rate the erosion hazards in the zone along the river based on the predicted movement of the river (http://www.anr.state.vt.us/cleanandclear/rivstrm.htm).
It is recommended that FEH mapping be completed for the Upper White and that it be made available to the towns in the Project Area. In each town, corridor-based municipal zoning ordinances can be considered as a means to limit encroachment and landuse conflicts within the FEH zones identified.

7.2 STORMWATER MANAGEMENT

The Project Area is predominately rural at the present time and is characterized by farming, forestry, and dispersed residential land uses. Although typically considered an urban issue, stormwater management should be considered for rural areas because hydrology and sediment regimes can be altered by road construction and maintenance. State and municipal permitting and guidelines have been developed for managing roadwork and can be emphasized by communities in the Project Area to encourage good water quality and reduce downstream geomorphic impacts. In addition, the Vermont Better Backroads Program offers assistance to towns, including on-site technical assistance, project funds for addressing erosion problems, and a manual of cost-effective procedures for reducing the impact of roads on water resources. Grants are also available to towns through the Vermont Better Backroads Program to inventory roads and develop budgets to fix road erosion problems (http://www.anr.state.vt.us/cleanandclear/bbroads.htm).

7.3 INDIVIDUAL OR MULTIPLE LANDOWNER INITIATIVES

This plan encourages coordination of landowner and municipal efforts to approach restoration with an eye to watershed scale dynamics. While previous efforts have often focused on individual properties within the river corridor, it is important to expand this focus to incorporate upstream and downstream impacts in project consideration. The White River Partnership has played a critical role in coordinating restoration efforts, and this Project aims to facilitate such coordination in a way that can help landowners understand the part their properties play within the context of the watershed.

7.3.1 Short-term

The following short-term actions are recommended in this preliminary draft of an Upper White Corridor Plan:

- Review of the draft plan by riverside landowners, the Upper White Stream Team and White River Partnership, USDA Forest Service, VT DEC River Management Program, and other interested parties

In April and May of 2007, Upper White Stream Team members provided preliminary input for a draft of the Upper White Corridor Plan. In late May 2007, the White River Partnership will hold a potluck event to seek review and input for the draft Corridor Plan, discuss the status of previous projects in the Upper White corridor, and observe stream dynamics modeled with a portable flume table supplied by the VT DEC River Management Program. Prospective project partners and landowners will be engaged on the basis of input from the meeting.

- Landowner and community outreach:

On the basis of community input from the introduction potluck, a minimum of 10 site visits will be scheduled to discuss input and project ideas with landowners along the river

- Draft revision to incorporate feedback and site visit information:

Following completion of the site visits, original draft project identification will be revised to incorporate information regarding likely projects to be implemented and those that may need to be deferred

- Incorporate revisions and prepare Corridor Plan for public presentation

Adjustments to the draft will be reviewed in conjunction with White River Partnership and VT DEC River Management Program personnel to focus on the most promising projects consistent with return of the Upper White to equilibrium conditions. At that juncture, public presentation of the Upper White Corridor Plan will be used to facilitate active community engagement

7.3.2 Long-term

With the bulk of the Upper White Project area in Stage III of channel evolution, indications are that the Upper White is overwidening and starting to migrate laterally in efforts to reestablish functional floodplains. This is likely to aggravate erosion problems in particular, and situations are likely to arise calling for bank stabilization and channelization as short-term remedies. Restoration plans should be consistent with the objective of returning streams to dynamic equilibrium, while taking into account human and capital constraints. In some cases, land use conflicts along the river corridor (such as roads or industry) may make reinforcing current stream banks a priority. However, the critical issues for long-term stability in the Upper White will involve identifying and protecting key attenuation assets that allow for floodplain access and reestablishment of river meander patterns to facilitate diffusion of stream power under high flow conditions as well as sediment and nutrient storage within the watershed. An alternative analysis of four restoration and protection plans is listed below:

- **No action** allows the stream to return to its dynamic equilibrium with no human aid or involvement. This strategy does not resolve, but postpones existing land use conflicts, which may increase costs and limit management options in the future. For this reason, a no action management plan is recommended only in regions where conflicts are few to none.
- **Continued channelization** involves the sustained maintenance of historically straightened streams by means of dredging, berming, and bank armoring. This alternative locks the stream into its current or historic planform and meander geometry. High construction costs, long-term maintenance, and ecological impacts make this alternative preferred only where land use conflict is high and conversions are highly unlikely.
- **Active restoration** attempts to restore rivers to a geomorphic state of dynamic equilibrium using human constructed meanders, flood plains, and stabilized banks. These types of projects are designed to work within human constraints and, when possible, restore rivers to reference conditions. Active restoration plans tend to have high upfront costs and achieve bank stability in a relatively short time period.
- **Passive restoration** allows the stream to return to a natural equilibrium primarily by the removal of human restraints within the river corridor. Over an extended time, the stream will regain meanders and access to its floodplain by use of its own energy and watershed input. Active buffer re-vegetation is essential to this approach, along with long term protection of the river corridor. This alternative is

less expensive than active restoration, but often requires a longer time period to achieve equilibrium conditions.

7.4 PROJECT RECOMMENDATIONS - GENERAL

A passive restoration approach is recommended for the majority of the Upper White Project area due to low cost, moderate land-use conflicts, and high to extreme stream sensitivity (indicating the rate at which the river will return to dynamic equilibrium, given its own energy and watershed inputs). The primary goal would be regaining access to floodplains and reestablishment of stream meander geometry, both intended as a means of diffusing stream power and permitting greater nutrient and sediment storage within the watershed. Active restoration may be appropriate in conjunction with passive restoration in limited circumstances, particularly when human constraints present strong limitations to floodplain or meander access on certain portions of properties that may provide these benefits elsewhere. A no-action alternative may also be considered in segments that are heavily buffered, although most reaches require some protection and buffer revegetation that would be provided by a passive restoration approach. Continued channelization is typically discouraged due to high costs and ecologic impact, but is likely in areas of existing development and road encroachment where restoration opportunities are limited. It is important to identify other key attenuation assets (see Table 7) when opting for continued channelization techniques, so that flood plain access can be insured elsewhere within the watershed while preserving critical functions of nutrient and storage sediment within the watershed.

Reaches of the Upper White are currently all working as transport reaches, with high sediment and water flows. Given the consistent stream dynamic between reaches, it is recommended that restoration efforts begin within the uppermost reaches. This approach will not only improve the immediate reaches, but increase the likelihood of successful project implementation in downstream reaches of the Upper White (and further downstream as well). Numerous projects have already been implemented in the upstream reaches of the Project area, and it is highly recommended that documentation of these projects and their status be compiled to assist with further prioritization.

The White River valley is extensively farmed, and some of the more challenging aspects of restoration will involve development of fair and equitable solutions to allowing floodplain access and protection of key attenuation assets in areas of high value agricultural lands. Appendix 8 lists a number of resources for programs designed to accommodate and compensate the investments in these areas, as well as other avenues for investigating conservation easements and other arrangements for interested landowners.

8.0 ASSESSMENT AND MONITORING RECOMMENDATIONS

8.1 RECOMMENDATIONS FOR FUTRUE STREAM GEOMORPHIC AND PHYSICAL HABITAT ASSESSMENTS

Phase 1 assessment of the White River mainstem included many of the tributaries, as well as several more reaches of the mainstem, upstream of the Upper White Project area. That assessment notably rated several tributaries (Nason Brook, Howe Brook) high for deposition impacts in particular (Fig. 6). Of particular note was the Hancock Branch, which may offer some areas for potential flow and sediment attenuation within that drainage basin and could be earmarked for future assessments due to potential impacts on the success of project implementation downstream.

Phase 2 assessment protocols did not include assessment of tributary rejuvenation (migration of bed erosion up a tributary, in an effort to match a lowered elevation if the stream below the tributary has incised) at the time of assessment of the Upper White. This parameter would be particularly important to assess for tributaries, such as those mentioned in the previous paragraph, which stand to contribute significant sediment loads and/or be at risk of losing access to floodplain in the tributary watershed, which would initiate further channel adjustments and aggravate downstream impacts.

8.2 RECOMMENDATIONS FOR MONITORING OF ASSESSED REACHES AND IMPLEMENTED PROJECTS

It is estimated that as many as 25 projects have been implemented in the Upper White corridor in the past decade (pers. comms., WRP Upper Stream Team, April 11, 2007). Some documentation of these projects exists (pers. comm.., Mary Russ WRP Executive director, May 2007). It is highly recommended that this documentation be compiled and elaborated, both for its value to understanding the lessons learned in these projects and their contributions to restoring equilibrium conditions, as well as the value of maintaining and enhancing the remarkable vitality and engagement of the broad group of collaborators who have been so active in this area.

The reach maps in Section 6 of this report show locations of many of these projects, and the White River Partnership has created a Geographic Information System (GIS) layer of these projects. Further recommendations would include the ability to hyperlink documentation of project implementation to these spatial locations to facilitate future analysis.

Due to the erodibilty of boundary materials in the Project area and the potential aggravation of loss of floodplain access if further incision were to occur, it is recommended that any new stormwater inputs along the Upper White mainstem, including culvert replacements and new ditching along Rte. 100 since Phase 2 assessment was completed, be monitored at least annually until vegetation is well established in the areas of these inputs. It will be particularly important to identify any nickpoints or headcutting in relation to these inputs and assess the need to arrest downcutting processes quickly.

It is further recommended that periodic Upper White Corridor Plan updates be made, preferably at least every five years. The White River Partnership appears well situated to continue coordinating such efforts provided funding is available. These updates could include:

- Assessment of management strategies in light of project implementation and further geomorphic assessments

- Identification of additional reach and watershed scale management options

- Updates on financial and technical resources available to riparian landowners

- Public outreach and education concerning these efforts

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Appendix 1. White River Partnership Upper Stream Team Pilot Project Background

Appendix 2. QA/QC Reports

Appendix 3. Phase I Reach Summary Reports

Appendix 4. Phase II Reach Summary Reports

Appendix 5. Reach Summary Statistics and Channel Geometry Data

Appendix 6. Plots of Channel Cross Sections

Appendix 7. Further Information on Bar Scalping Impacts

Appendix 8. Further Resources for Project Implementation

Appendix 9. Planform Analysis of the Upper White River (VT DEC-RMP 2004)