Channel Management
and
River Corridor Protection Plan

Walloomsac River and Roaring Branch, Bennington County, Vermont

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Prepared for:

Town of Bennington, Vermont

and

Bennington County Conservation District

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PARISH geomorphic

Executive Summary

The Roaring Branch and Walloomsac River in Bennington County, Vermont have historically presented extreme challenges related to erosion and flooding for the Town of Bennington and surrounding communities. To begin addressing these concerns, an assessment of the Walloomsac River watershed was conducted to determine the major conditions, both natural and human-related, that control river form and function in this watershed. The assessment concluded that the river system is in a state that has greatly departed from a stable condition and will therefore remain dynamic and pose a threat of further erosion and property damage during flood events.

This Channel Management and River Corridor Protection Plan (Corridor Plan) was prepared to further examine the locations, types, and sources of stream channel instability along the Roaring Branch and Walloomsac River in order to develop management options throughout the corridor that will address these areas of instability. Historic manipulation of in-stream sediments through practices such as dredging and channelization, in association with artificial constraints (such as roads and berms) which influence natural river processes, are the primary factors causing the instability of these rivers. This river system contains a large supply of coarse sediment, primarily in the form of boulders, cobble, and gravel, and the presence of the numerous stream-side berms magnifies stream energy and prevents the river from accessing its floodplain under higher flows. This, in turn, has led to accelerated rates of change in the channel form and has exacerbated the river's erosive tendencies.

In this Corridor Plan, a series of management measures are presented to guide the decision-making process related to mitigating fluvial erosion hazards in the river corridor. Two site-specific projects of floodplain reconnection and bank stabilization/aggraded reach restoration were presented as conceptual solutions that may be applied to any area in the corridor experiencing similar problems. The actual implementation of watershed-scale restoration activities (e.g., corridor protection, berm removal, and bridge maintenance) will require considerable stakeholder involvement - so all interested parties must understand the potential value accrued in making short-term sacrifices in order to achieve sustainable erosion and flood hazard mitigation.

The corridor protection efforts must focus on the protection of floodplain areas where sediment can be stored and flow energy can be dissipated, which will reduce in-stream sediment loading and erosion hazards along the Roaring Branch and the Walloomsac River. Many opportunities still exist in the watershed for re-establishing a stream to floodplain connection. If development is allowed to encroach into these areas, many of the highest priority restoration sites in the watershed could be permanently lost.

The protection and restoration measures presented in this Corridor Plan should be implemented in order to achieve a holistic restoration of the Roaring Branch and Walloomsac watersheds. Projects were ranked and prioritized based on their likelihood of achieving equilibrium of the river system (leading to channel stability), costs, technical requirements, and anticipated societal acceptance. The highest priority restoration actions may be implemented over the next one to five years in an incremental fashion; lower priority management measures can be addressed as resources become available. The implementation of corridor protection and the process-based restoration measures will eventually reduce or minimize the need to pursue "maintenance-type" solutions, such as channel dredging, so that sustainable, long-term solutions can be realized and in the end, become more effective.

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Acronyms and Abbreviations

ANR	Agency of Natural Resources
BCCD	Bennington County Conservation District
cms	cubic meters per second
FEH	Fluvial Erosion Hazard
FEMA	Federal Emergency Management Agency
FIT	Feature Indexing Tool
ft	feet
LiDAR	Light Detection and Ranging
N	Newton (derived into a mass of one kilogram at a rate of one meter per second squared)
NFIP	National Flood Insurance Program
NRCS	Natural Resource Conservation Service
RMP	River Management Program
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

1.0 Introduction

A Phase 2 geomorphic assessment was conducted on the Roaring Branch and portions of the Walloomsac River in Bennington County, Vermont during the summer and fall of 2006. Stemming from the Phase 2 geomorphic assessment is the development of a River Corridor Protection and Channel Management Plan (Corridor Plan). The Phase 2 assessment provides a detailed analysis of stream type, stage of channel evolution, geomorphic condition, and habitat condition of the river. Details of the findings of this assessment are presented in the Phase 2 Assessment Report (Gomez and Sullivan and Parish Geomorphic, 2007).

To supplement the Phase 2 field assessment and this Corridor Plan, additional geospatial data were collected in the spring of 2007. LiDAR (Light Detection and Ranging) data were collected along the Walloomsac and Roaring Branch in the Towns of Bennington and Woodford. The data allowed for a more detailed analysis of the topography of the study area including floodplains and the channel bed. The LiDAR data are relied on for identification of potential restoration projects and will be a valuable tool for implementation of this Corridor Protection and Channel Management Plan (note: cross-sectional data were obtained every 100 meters using the LiDAR data set for several reaches of the Roaring Branch and Walloomsac River, and are contained in Appendix E).

Funding for this project was provided through a grant from the Vermont River Management Program (RMP). Project partners include the Vermont Agency of Natural Resources (ANR) River Management Program, the Bennington County Conservation District (BCCD), Bennington County Regional Commission, and the Towns of Bennington and Woodford, VT.

1.1 Goals and Objectives

The State of Vermont has initiated an effort to identify and develop river corridor protection plans and restoration projects in river systems through the state. The primary goal of this Corridor Plan is to mitigate fluvial erosion hazards along Roaring Branch and Walloomsac River in order to increase property and infrastructure protection. By striving to achieve this goal, the additional goals of establishing natural river and sediment regime stability and restoring the ecological functions and economic values of the river system can be achieved.

The specific objectives of this plan are to:

- Summarize the watershed and reach-specific fluvial erosion hazards documented in the Phase 2 assessment;
- Describe the existing and potential restoration and mitigation assets in the watershed;
- Present protection and restoration recommendations that would mitigate the flooding and erosion hazards presented by the current condition of the river system; and
- Provide a roadmap for further development of the plan.

It should be noted that in this plan, the scale of the project does not permit a full alternatives analysis at all potential remediation and management sites along the reaches of the Roaring Branch and Walloomsac River. The management measures presented here, however, can be applied to areas along the river with similar problems (e.g., bridges). The River Management Program has committed to assisting the town with final designs and implementation of the limited sites for which alternatives have been developed, as well as with funding to move forward with further management planning and design work, as the town moves forward with the adoption of a river corridor protection plan.

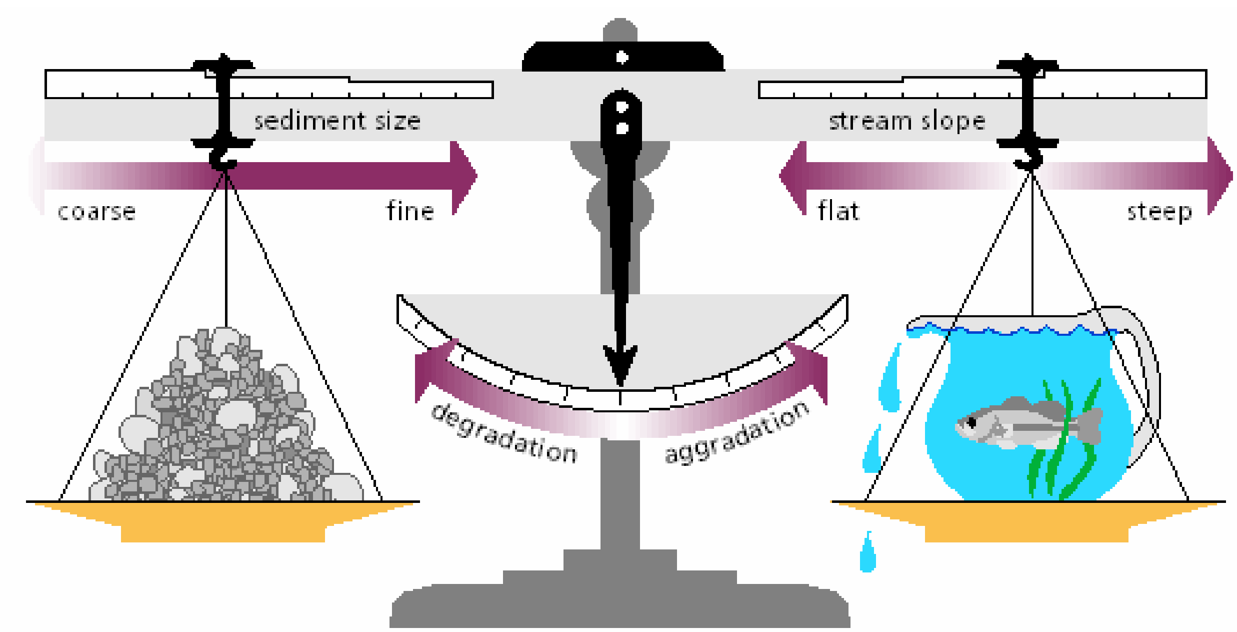
1.2 Management Towards Equilibrium Conditions

The overarching goal of the River Management Program is to manage toward, protect, and restore the fluvial geomorphic equilibrium condition of Vermont rivers by resolving conflicts between human investments and river dynamics in the most economically and ecologically sustainable manner. Fluvial geomorphic equilibrium is the condition in which a persistent stream and floodplain morphology is created by the dynamic fluvial processes associated with the inputs of water, sediment, and woody debris from the watershed (ANR, 2007). When considering management alternatives presented in this Corridor Plan, this concept is essential to understand because it is the physical imperative of a stream channel to undergo adjustments until it reaches equilibrium, and becomes in balance with its watershed inputs.

Figure 1-1 shows "Lane's Diagram", which illustrates how water volume, sediment volume, sediment particle size, and the slope of a river channel are naturally balanced (Lane, 1955 in ANR, 2007). If the balance is tipped the channel responds by either aggrading (building up sediment on the channel bed) or degrading (scouring down the channel bed). A change in any one of these factors will cause adjustments of the other variables until the river system comes back into equilibrium (ANR, 2007).

In the River Corridor Planning Guide (ANR, 2007), the River Management Program provides scientific background and references that may help to understand geomorphic processes and watershed science. Readers may want to refer to this document for additional information.

Figure 1-1: Lane's Balance of Sediment Supply and Sediment Size with Slope and Discharge.



2.0 Geomorphic Setting

The Walloomsac River watershed has a total drainage area of 156 square miles, most of which are located in southwestern Vermont (see Figure 2-1). The mainstem Walloomsac River originates in the Town of Bennington at the confluence of South Stream and Barney Brook, and flows generally northwest 16.4 miles to the Hoosic River in New York State. The Walloomsac River flows through residential, commercial, and agricultural areas of Bennington. The drainage area of the Roaring Branch is approximately 41 square miles. The Roaring Branch begins in the Town of Woodford at the point where City Stream joins Bolles Brook (two high gradient streams originating from the Green Mountains) and flows west through Woodford Hollow along the face of a glacial delta.

Evidence from historic topographical maps and aerial photographs indicates that the current location of the Roaring Branch below Route 9 to the confluence with the Walloomsac was altered between 1898 and 1942. According to the 1898 topographical map, the Roaring Branch confluences with the Walloomsac just east (and upstream) of the Town of Bennington (Figure 2-2). The 1942 aerial photographs show the channel at this time to be relocated north of Bennington center in its current location. It is not known whether the river was relocated by man or by natural adjustment, but it is important to note that the river has occupied it present location for fewer than 100 years. Since that time, the Roaring Branch and the Walloomsac have undergone a history of significant alteration and control in response to large flood events and severe erosion.

The Phase 2 geomorphic assessment was conducted during September and October 2006 on the Roaring Branch and portions of the Walloomsac River. A total of 11.3 river miles on the Walloomsac River and Roaring Branch were assessed using Vermont's Phase 2 assessment protocols (Figure 2-3). The Phase 2 study area included four reaches (M06T3.04 to M06T3.01) encompassing the entire length of the Roaring Branch (4.6 miles) and five reaches (M06 to M02) on the Walloomsac River totaling 6.7 river miles. The Phase 2 field efforts consisted of identifying bankfull features and collecting field measurements of channel dimensions, impacts, shoreline and riparian conditions, floodplain encroachments and modifications, and substrate characterization. The measurements were collected to determine the stream reach type, condition, and sensitivity. More detailed information about the geomorphic setting of the Walloomsac River and Roaring Branch, including recent flood history, is discussed in the Phase 2 Assessment Report (Gomez and Sullivan and Parish Geomorphic, 2007).

The Roaring Branch, as it travels through Bennington, transitions from a single thread channel with a few flood chutes to a multiple thread river that flows through reworked glaciofluvial outwash composed of very coarse sediment. The Roaring Branch (and the upstream reach of the Walloomsac) is currently reworking vast sediment deposits that were deposited in typical alluvial fan formation under previous climatic conditions, likely the end of the Pleistocene epoch period when the flow regime was influenced by glacial melt water.

The Walloomsac River is generally a single thread channel with a few islands and flood chutes. There are several flow obstructions such as dams and weirs and several bridges also cross the river. Reach M06 begins where the Roaring Branch joins the Walloomsac River in Bennington. The upstream reach of the Walloomsac River flows through glacial outwash like the Roaring Branch does. At the transition from Reach M06 to M05, the surficial geology becomes recent alluvium. At the transition from Reach M03 to M02 there is also an injection of glacial outwash where Paran Creek joins the Walloomsac. The geology of the surrounding area is primarily till with bedrock outcrops.

Since the valley has been inhabited, the Walloomsac River and Roaring Branch have been impacted by human disturbances. A vast network of berms have been constructed along the Roaring Branch and upper reaches of the Walloomsac River and several dams, weirs, and bridges have also been constructed which have constricted flow and altered the valley. In particular, Reach M06 has experienced severe encroachment and incision from bridge constrictions, berms, and bank hardening. The most significant impact downstream of M06 is a 16-foot high dam at the downstream end of Reach M04 which impounds the entire reach (about 2,400 feet).

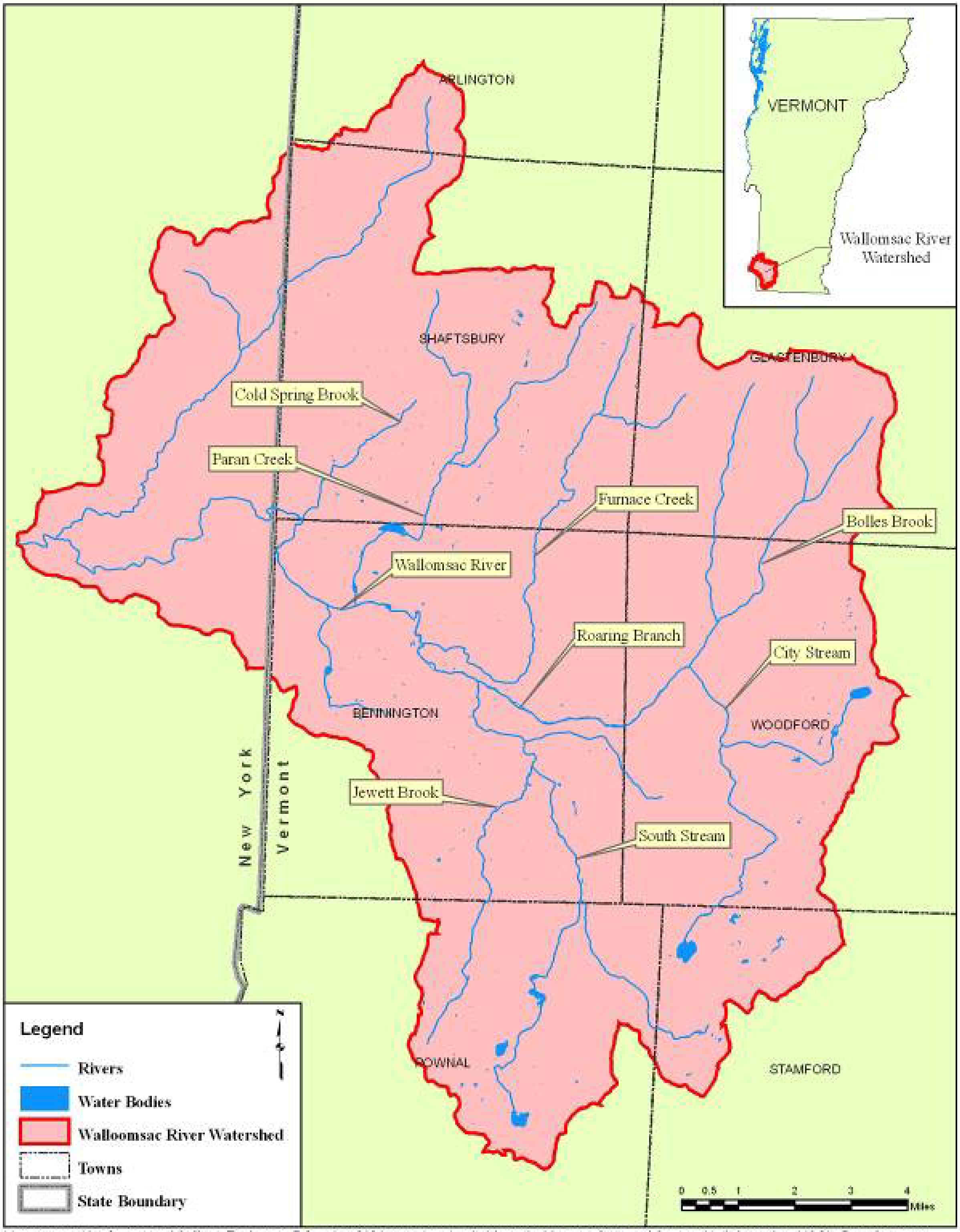
Large scale channel relocations, such as that which occurred on the Roaring Branch between 1898 and 1942, typically take many years to stabilize, unless they are carefully planned and natural channel design concepts are incorporated. It is realistic to assume that an imbalance with regards to flow and sediment transport existed in the Roaring Branch system in the decades following the relocation. The nature of the surficial geology through which the Roaring Branch flows is such that there is a large quantity of sediment to be manipulated. Subsequent to the channel relocation, many factors have prohibited equilibrium conditions (i.e., a natural and stable reference condition) from ever establishing in the river including: the removal of sediment from the river by dredging and channelization works in the 1930s, 1950s, and periodic maintenance through the 1990s; the implementation of control works such as floodwalls and berms; bridge constrictions; and encroachment from development. The dynamic nature of the lower reaches of the Roaring Branch is directly related to a historic shift in location within the valley and subsequent anthropogenic manipulation of sediment and artificial control on the natural planform of the river.

The extent of historic manipulation of the Roaring Branch further complicates the definition of stream reference conditions, particularly in the lower reaches. There, the absence of a historic reference condition means one must predict the channel condition that was likely to form were it allowed to stabilize without anthropogenic manipulation and control, given the geology, flow regime, topography and natural controls. Although the historic condition (last 100 years) of the lower reaches of the Roaring Branch appear to be multi-thread, we believe the reference condition would be that of a single-thread channel, with meso-scale bed forms of riffles and pools in the lower reaches and possibly steps and pools as seen in some parts of the upper reaches where the gradient is fairly high.

The equilibrium of flow and sediment transport of these reaches remains unbalanced to the present day. This imbalance continues to cause the river to shift its planform and create multiple channels under larger flood events in attempts to regain equilibrium between flow and sediment load. This process should be expected to continue, and any further dredging, channelization, or encroachment into the river corridor—without due consideration of natural adjustment processes—will exacerbate the rate of change and the potential for further damage.

Since the USGS gage on the Walloomsac River has been in place, there have been significant floods in the basin, however, none approaching the 100-year magnitude. Since flood events of lesser magnitude have caused damage to the town, damage to flood control works, and loss of life, it is important to implement a River Corridor Protection and Channel Management Plan to attenuate the possible impacts of higher magnitude floods which are likely to occur in the future. Watershed and reach-scale alterations to the river and the floodplains are discussed in more detail in the following section.

Figure 2-1: Walloomsac River Watershed.



Map prepared by Gomez and Sullivan Engineers, P.C. using GIS layers downloaded from the Vermont Center of Geographic Information (VCGI), Data Sources; Rivers & Water Bodies – USGS DLG; Walloomsac River Watershed - USGS HUC10 Basins; State & Town Boundaries - BNDHASH.

Figure 2-2: M06T3.01 and M06T3.02 Existing and Historic (1898) Channels.

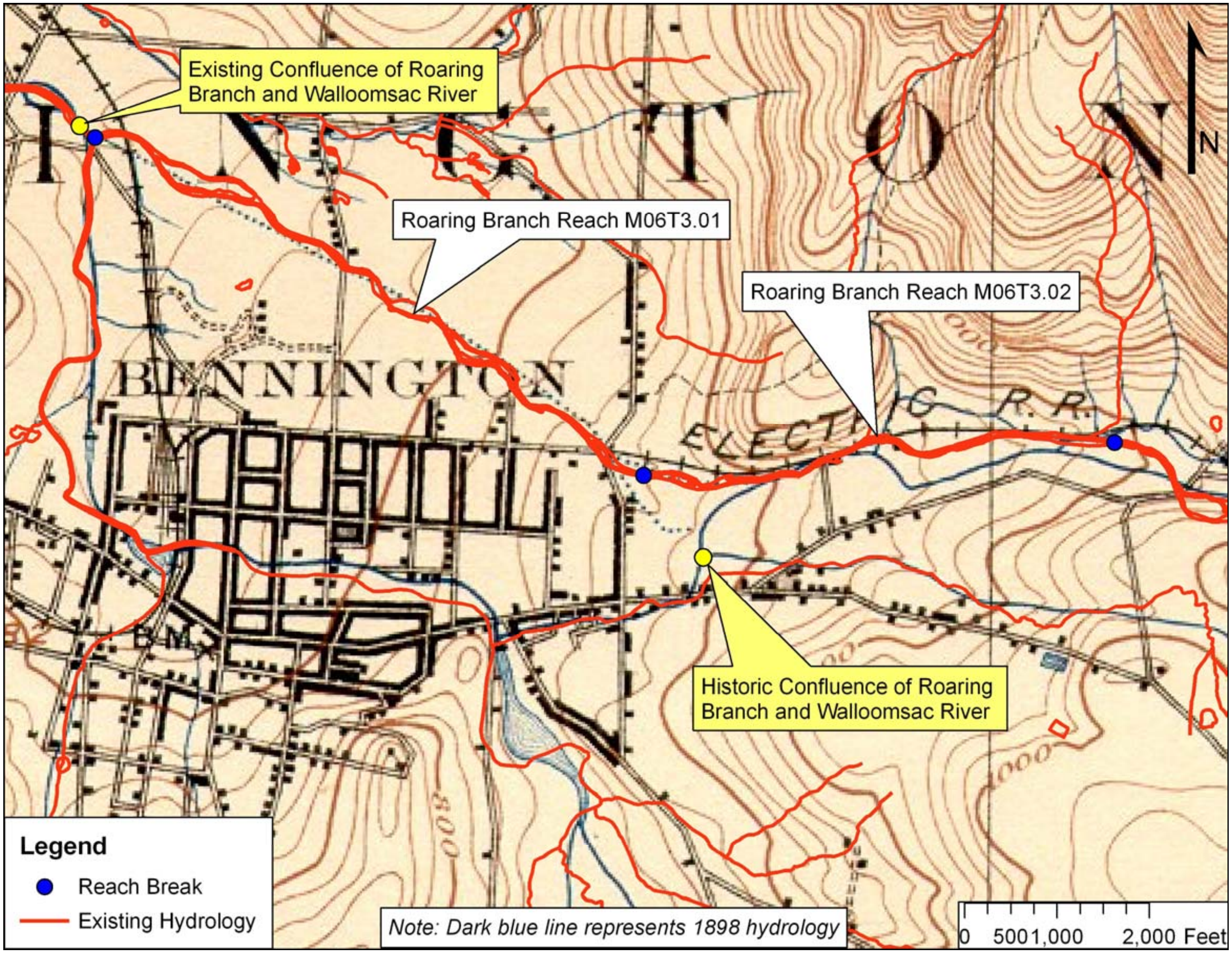
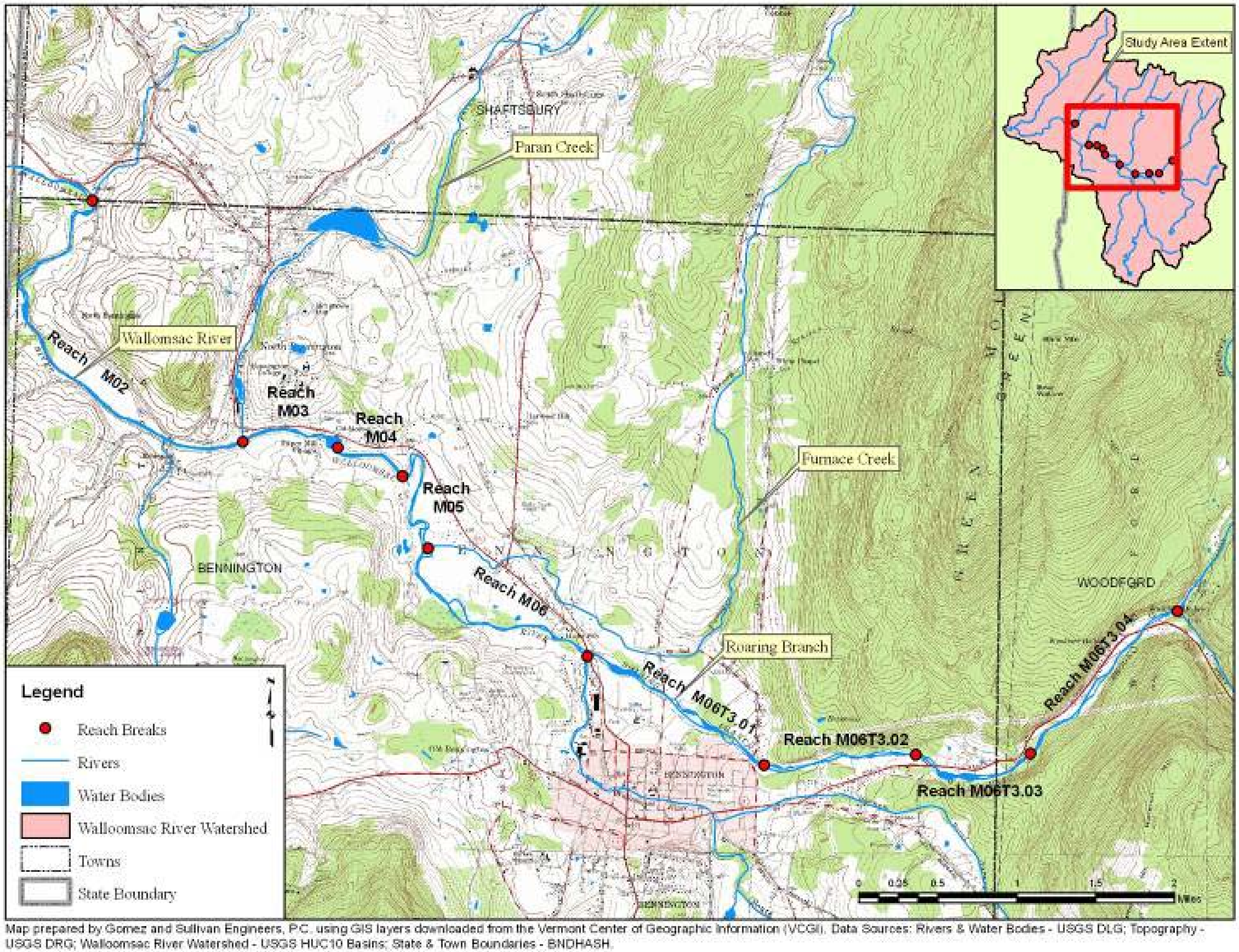


Figure 2-3: Walloomsac River and Roaring Branch - Phase 2 Assessment Study Reaches.



3.0 Threats/Fluvial Erosion Hazards

In this section, the locations, types, and sources of stream channel instability along the Roaring Branch and Walloomsac River are identified. How these areas of instability may lead to fluvial erosions hazards is an important factor when considering improvements, mitigation, and restoration options for the corridor.

3.1 Watershed and Reach Scale Stressors

In the upper reaches of the Walloomsac River watershed, the valley is naturally confined. However, the development of transportation infrastructure, such as Route 9 along City Stream and a railroad bed along Bolles Brook have resulted in further confinement of the valleys, reducing the available floodplain for the streams and ultimately leading to increased stream power and sediment transport. This, subsequently, has resulted in coarse sediment deposition downstream in the Roaring Branch. Historically, these upstream confinement issues have lead to the development of an alluvial fan in Woodford and Bennington composed of very coarse substrate. The current path of Roaring Branch travels through this fan and the result is a highly dynamic channel.

3.1.1 Hydrology and Sediment Load

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

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

During the 19th and early 20th centuries, the hydrologic modifications associated with mill dams and diversions extended to the very headwaters of Vermont rivers. Dam networks to support mill operations numbered in the hundreds, and unlike the beaver ponds they replaced, these impoundments and the intervening channels were maintained (drained, dredged, and snagged) to support the efficient transport of materials, primarily water and wood. These activities would have led to more frequent large discharges, a disruption of the sediment and large woody debris regimes, and the likelihood for channel enlargement. While some larger rivers are still hydrologically affected by dams and hydroelectric facilities, the current regulation and diversion of stream flow is less extensive (ANR, 2007).

Hydrologic regime stressors for the Walloomsac system include increased runoff from urbanization. The major urbanized center in the watershed is Bennington. With an increase in impermeable surfaces following urbanization, water is delivered to the system more rapidly and with less attenuation.

The sediment regime may be defined as the quantity, size, transport, sorting, and distribution of sediments. The sediment regime may be influenced by the proximity of sediment sources, the hydrologic regime, and valley, floodplain, and stream morphology. Understanding changes in sediment regime at the reach and watershed scale is critical to the evaluation of stream adjustments and sensitivity. The dynamic nature of the lower reaches of the Roaring Branch is directly related to a historic shift in location within the valley and subsequent anthropogenic manipulation of sediment and artificial control on the natural planform of the river.

Sediment regime stressors include historic dredging, which changes the amount of sediment readily available to be transported downstream. As evidenced by Figure 3-1, dredging on the Roaring Branch has occurred probably since European colonization of the river valley. Once a widespread commercial activity in Vermont's rivers, gravel removal is now restricted to maximum annual volumes for landowners' use and for the maintenance or restoration of stream channel stability. The 1986 Rivers Act only prohibited commercial gravel mining activities in rivers and streams.

3.1.2 Encroachments, Channelization, and Levees

Natural and human-imposed features which require specific attention in the project identification process are the vertical and lateral constraints which influence channel adjustments and flow attenuation. Natural constraints, such as bedrock valley walls, cascades, and waterfalls are mapped and considered as immutable components of the background or reference geomorphological condition. Human constraints vary in their degree of permanence. Mapping and evaluating their effect on existing channel form and process was the first step in this process. Evaluating the feasibility of removing constraints (either actively or passively) then becomes a central part of the project identification and development process.

In nearly every Vermont watershed, there is a need to reduce or remove constraints to the lateral adjustment of the stream channel. This is especially true where streams are not only under adjustment from current and large-scale historic land use/land cover changes but have also been straightened and channelized over extended portions of the watershed response (or deposition) zones. Restoration projects have traditionally attempted to resolve conflicts by "fixing"—and often re-fixing—the location of the channel. Inevitably, when the restoration planner ignores the channel evolution process, the energy of a large flood brings another round of traditional channel works perpetuating the conflicts at the restoration site or exacerbating the conflicts somewhere downstream (ANR, 2007).

The Roaring Branch in particular has been heavily encroached upon over the years. The Roaring Branch is more naturally confined than the Walloomsac River due to the more mountainous terrain through which it flows. However, the Roaring Branch has been further confined by roads, urban development, and the construction of levees to contain flood flows. Moreover, the channel has been redirected and excavated for sediment multiple times throughout the past century. The confined nature of these channels frequently causes them to behave as incised channels as they no longer have access to their floodplains. This results in higher flood velocities and shear stresses which results in a more mobile bed and more destructive capabilities during floods.

Along the Roaring Branch, reach M06T3.04 has been confined by the presence of Route 9 and berms. The channel downstream of the Route 9 bridge within this reach appears to have been channelized and is fairly straight, consisting of a single thread. Berms are located along river right and old channels cut through the floodplain along river left. The left side of the river is confined by a steep valley wall, but movement of the channel in this area is evident. Reach M06T3.03 has been confined by the presence of Route 9 as well as by berms located on the floodplain that concentrate flood flows and limit the sediment storage and attenuation function within this reach. Extensive berming on both banks and floodplain areas continues throughout Reach M06T3.02, which flows in a westerly direction. The channel breaks away from Route 9 further downstream, and the left bank and floodplain is bermed to protect the developments along Route 9. Reach M06T3.01 flows through a more developed area of Bennington and features five bridges within the reach. Extensive berming is present on both sides of the river (Figure 3-2). The United States Army Corps of Engineers (USACE) constructed a local protection project throughout the reach that consists of a flood wall on the left side of the river upstream and downstream of the Brooklyn Bridge and an engineered levee, also on the left side of the river. The right floodplain contains a network of berms consisting of dredged material from the river, which are intended to protect the residential and other development on the river right. An extensive levee project was also completed by the Natural Resource Conservation Service (NRCS) after the 1987 floods on the right bank between the Brooklyn Bridge and Park Street (personal communication, B. Cahoon, ANR).

Along the Walloomsac River, berms are present on the right bank of Reach M06B. Terraces and areas of the left bank appear to be built up with non-native fill material along the golf course, which is actively eroding. The left bank of Reach M05 is bermed and built up further to protect the residential properties along Silk Road. The downstream portions of the reach feature a tortuous meander bend, built-up banks on both sides, and confinement by road development. Reach M03 flows parallel to Route 67A from the Paper Mill Dam to the confluence with Paran Creek. The right bank is confined by a road and there are a few houses along the river in the upper portion of the reach. The land use on river left is largely agricultural, the left bank is high, and the river is entrenched.

The extent of berming throughout the Phase 2 study area was evaluated using the LiDAR data set. Reach-specific figures showing berm locations and heights are presented in Appendix A. The extensive berm network along reach M06T3.01 of the Roaring Branch is shown in Figure 3-2.

3.1.3 Bridges and Sediment Discontinuity

The Walloomsac River and the Roaring Branch are traversed by several bridges. In many cases, these bridges cause a sediment discontinuity (that is, sediment which is normally transported by the river can not pass through the bridge opening). This can result in a high rate of deposition immediately upstream of the bridge. Several examples of this occur along the Roaring Branch, in particular.

The channel constrictions at the bridges (Brooklyn, Park Street, and Route 7) in Reach M06T3.01 are causing large amounts of sediment deposition throughout the reach. These areas of deposition are currently being degraded as evidenced by headcutting through the coarse alluvial material. This cycle of deposition and degradation is expected to continue, and is reset during larger flood events that re-deposit significant amounts of cobble and boulders in these regions. The channel also contains substantial amounts of large woody debris and bank erosion, and the reshaping of island formations within the channel is apparent.

These three bridges were evaluated using LiDAR data to examine the amount of sediment deposition upstream and downstream of each bridge. An example of the river bed cross-sections analyzed at the Park Street bridge is shown in Figure 3-3. These areas will be examined in more detail in Section 5. Longitudinal and cross-sectional bed elevation profile graphs and locations for the three bridges are presented in Appendix B.

In addition to existing bridges, an old bridge constriction has caused sediment accumulation in the Roaring Branch as well. Just upstream of the Route 9 bridge in Reach M06T3.03, remnants of an old bridge in the channel may have contributed to the massive depositional area upstream of the current bridge (Figure 3-4). Mid-channel bars, vegetated islands and steep riffles are prevalent upstream of the Route 9 bridge in this area.

On the Walloomsac River, a significant channel avulsion has recently occurred in the vicinity of the Route 279 bridge in Reach M05. It is not known whether the bridge construction influenced this event, but the presence of an extreme amount of woody debris in the area indicates the possibility that a debris jam may have caused or contributed to the cut-off. Avulsions typically result in a large influx of sediment to the reach as the river cuts a new path through undisturbed sediment.

3.1.4 Channel Incision and Loss of Attenuation

According to channel evolution models as described by ANR 2007, rivers will down-cut thereby removing their connection to the floodplain. This process has two main implications. The first implication is that all the flood waters become concentrated into a narrower channel, consequently increasing the velocity, shear stress, and sediment transport capacity associated with the flow. The second implication is the loss of sediment storage as flood flows are no longer able to deposit sediment onto the floodplain (ANR, 2007).

The extensive berming and flood protection structures along the Roaring Branch have contributed to a loss of river-floodplain connection, thereby increasing stream power. This has resulted in areas of channel incision through both down-cutting of the bed and build-up of the floodplain with artificially high banks and berms. Some of these banks are starting to severely erode, such as the right bank upstream of Park Street in Bennington (Figure 3-5). The levee rebuilt on Roaring Branch in 1987 is beginning to show signs of deterioration through bank undercutting and channel downcutting.

Road development encroachment has also effectively constrained portions of the Walloomsac River and the Roaring Branch, leading to further incision. Reach M03 on the Walloomsac River is incised, with high banks that cut-off access of the river to its floodplain in this area. An upstream dam may be sediment-starving the reach and contributing to the incision. To compensate for the lack of sediment, the river has eroded not only the banks but also the bed in order to regain a more normal sediment transport rate. As a result, the river has down-cut, removing access to the floodplain. This further exacerbates the problem as high flood flows remain concentrated in the channel with no attenuation of flow on the floodplain.

3.2 Sensitivity Analysis and Fluvial Erosion Hazard Mapping

The Vermont RMP rates sensitivity on a six-part scale: very low, low, moderate, high, very high, and extreme. Braided rivers with cobble, gravel, or sandy banks are considered extremely sensitive even under reference conditions as they are characterized by frequent shifts in channel position.

Fluvial erosion hazard (FEH) mapping is based on identifying the degree or likelihood that vertical and lateral adjustments (erosion) associated with fluvial processes (natural and/or human-induced) can be anticipated, and may occur as to justify certain fluvial erosion hazard ratings indicating different levels of risk to investments and infrastructure within the river corridor.

Phase 2 geomorphic assessment data provides the basis for FEH map development. Phase 2 assessments enable FEH mapping by identifying the sensitivity of each reach of a stream. Some streams, due to their setting or physical characteristics, are inherently sensitive and are more likely to experience rapid adjustment in channel dimension and location. In addition, the inherent sensitivity of a stream may be heightened by human alterations of the channel or watershed.

The Vermont Fluvial Erosion Hazard Risk Assessment and Mapping Methodology outlines the following steps in the identification and mapping of fluvial erosion hazard types and corridors for a segment of stream:

1. Conduct remote sensing and field assessments at the stream segment level, utilizing ANR protocols, to determine the existing and reference geomorphic stream type and the presence of ongoing channel adjustment processes;
2. Assign a stream sensitivity rating based on whether the assessed reach is in reference condition, experiencing major adjustment, or represents a departure from the reference or equilibrium geomorphic stream type that would exist in the absence of human stressors;
3. Assign and map fluvial erosion hazard types based on the stream sensitivity rating; and
4. Develop an FEH river corridor based on belts widths, valley confinement, and sensitivity characteristics.

The most sensitive reaches in the watershed are on the Roaring Branch with sensitivity ratings ranging from high to extreme (Table 3-1). The channel type, adjustment processes, and sensitivity of the study reaches are further discussed in the Phase 2 Assessment Report.

Table 3-1: Reach Sensitivities and Fluvial Erosion Hazard Rating.

Stream Segment	Sensitivity	Existing Stream Type	Natural Valley Type	Departure from Equilibrium	FEH Rating	
M06T3.04	High	C3b	Broad	Major Adjustment	HI	6
M06T3.03	Extreme	D3b	Very Broad	Major Adjustment	EX	10
M06T3.02	Extreme	D3b	Very Broad	Stream Type Departure	EX	10
M06T3.01	Extreme	D3	Very Broad	Stream Type Departure	EX	10
M06b	Very High	F3/C3	Very Broad	Major Adjustment	VH	8
M06a	High	C4	Very Broad	Major Adjustment	HI	7
M05	Very High	C4	Very Broad	Major Adjustment	VH	7
M04*	High	C5	Broad	Reference	HI	7
M03	Extreme	F4	Broad	Stream Type Departure	EX	9
M02	Extreme	F3	Broad	Stream Type Departure	EX	8

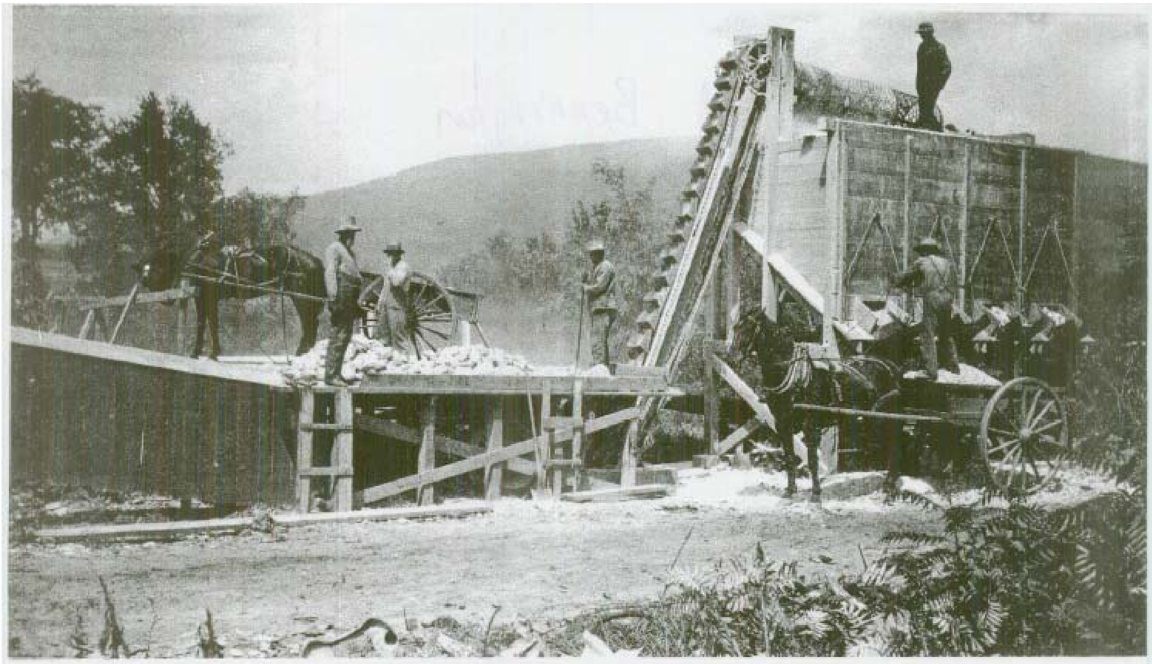
*For Reach M04, which is impounded, the reference stream type (C) was used for the sensitivity rating.

The FEH zone was developed based upon the Phase 2 data and modified to reflect the geomorphic conditions (i.e., important potential floodplain areas that are currently undeveloped) and administrative boundaries. The FEH zone was modified by the VT RMP and the Bennington County Regional Commission and is still considered preliminary. Figures showing the FEH zone for each Phase 2 study reach along the Roaring Branch and Walloomsac River are shown in Appendix C.

FEH maps should be used to advise existing and future land use investments and infrastructure development within river corridors. The Bennington County Regional Commission, with technical assistance from the RMP, will support municipalities in generating fluvial erosion hazard maps and advise local boards in the development of flood hazard mitigation strategies for consideration and adoption by the town, as detailed further in Section 5.3.

The FEH overlay district is an important way to limit encroachment along rivers. FEH zone boundaries from the final, science-based FEH map can be translated directly into boundaries of a FEH overlay district, or can be used as a guide for the development of a FEH overlay district that meets the specific needs of town (ANR Municipal Guide).

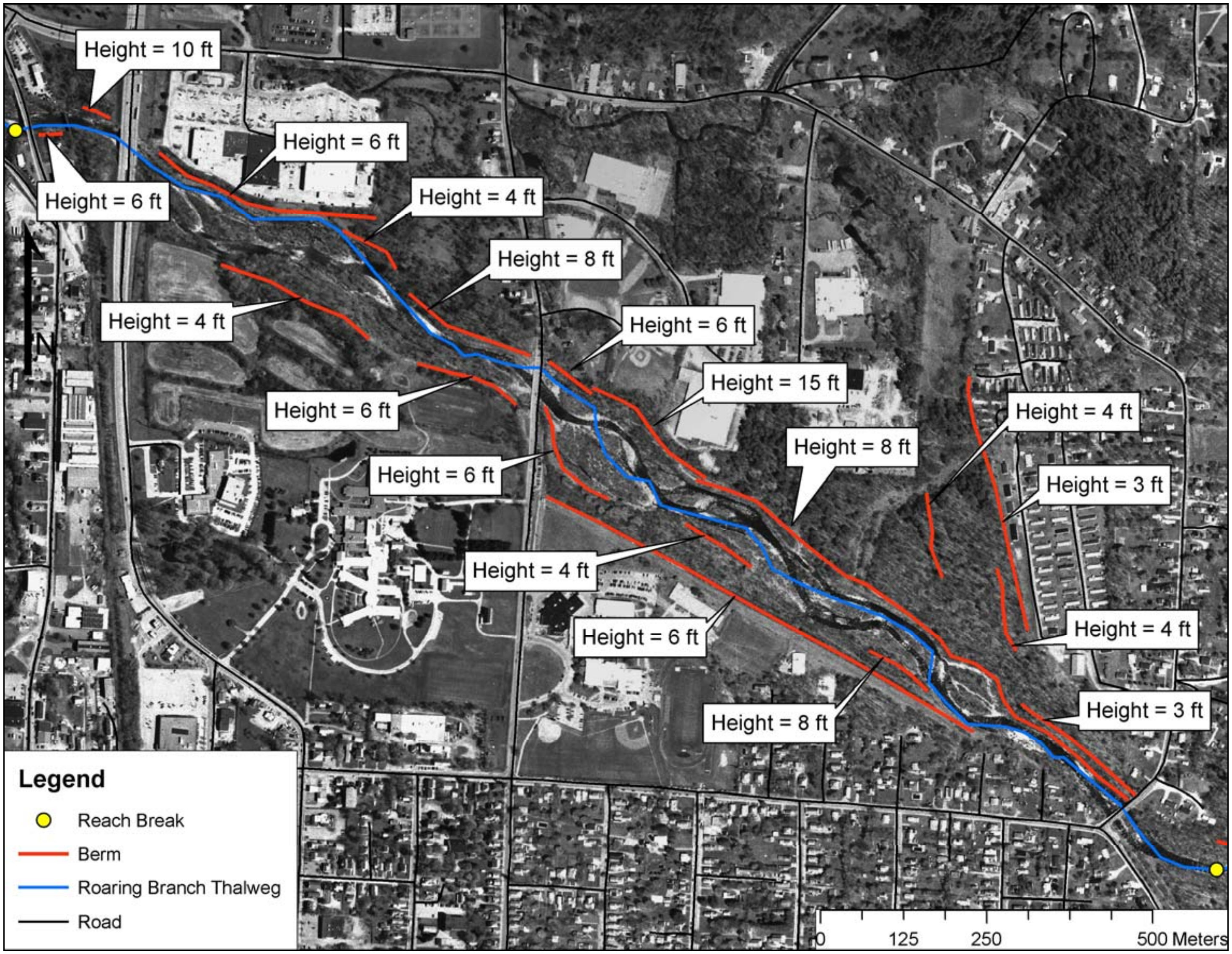
Figure 3-1: Historic Dredging on the Roaring Branch.



10-11. Gravel sorting. *This is probably the water-powered gravel operation that for many years drew rocks from the Roaring Branch at Park Street. Cylindrical sorter, at top, deposited stones of different sizes into the bins.*

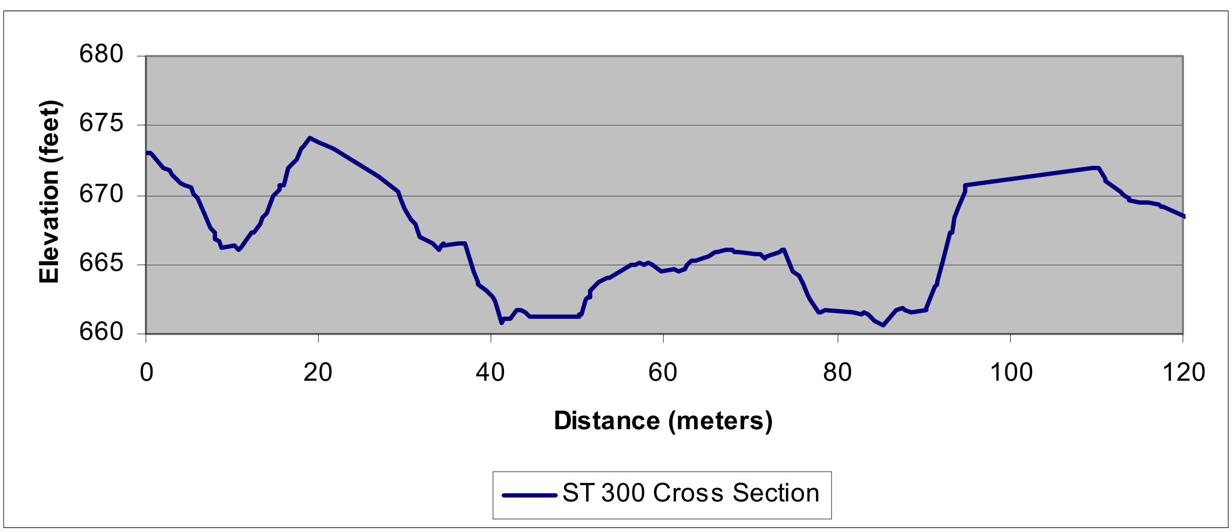
Source: Resch, 1975. Date of photo uncertain.

Figure 3-2: Berm Network along Roaring Branch Reach M06T3-01.



Note: Berm heights are approximate and were obtained from LiDAR data.

Figure 3-3: Park Street Bridge and Typical Channel Cross-Section.



Station 300 – Note dual thalweg. Additional cross-sections located in Appendix B. X-axis in meters.

Figure 3-4: Sediment Deposition Upstream of Old Route 9 Bridge.

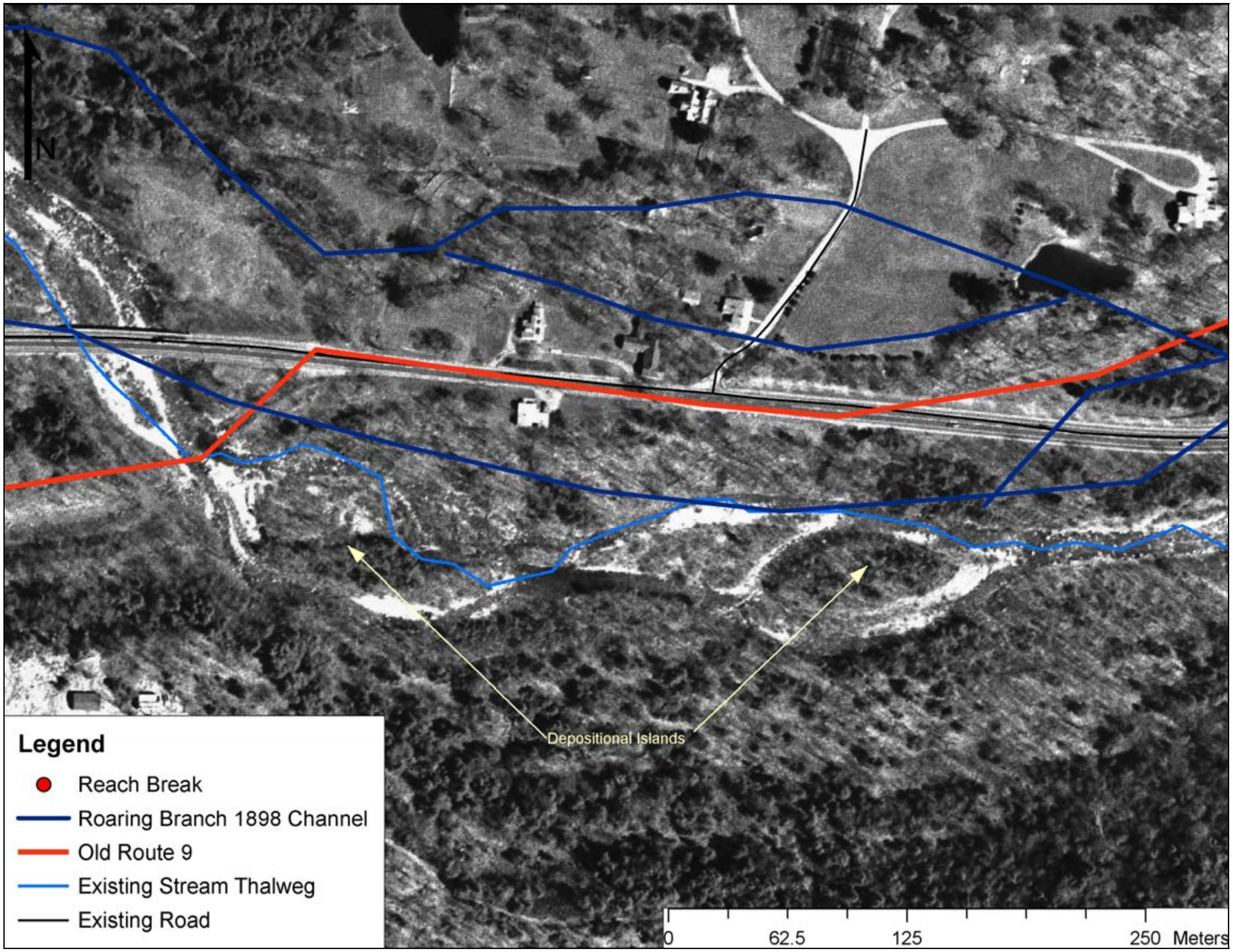


Figure 3-5: Bank Erosion Upstream of Park Street.

Date of Photo: 9/19/2006, facing upstream.

4.0 Existing and Potential Restoration and Mitigation Assets

Attenuation assets consist of river-accessible, vegetated floodplains and wetlands that store flood flows, capture sediments, and store rather than mobilize and transport organic material and nutrients from the watershed. Key attenuation assets are particularly important in reducing flood and fluvial erosion hazards as well as providing for water quality and habitat improvement (ANR, 2006).

In this section of the Plan, existing and potential areas for sediment and flood flow attenuation along the Roaring Branch and Walloomsac River are identified and described. Existing and potential areas were evaluated by examining property ownership and determining the potential of each specific area for achieving immediate sediment storage and long-term sediment storage. These areas were identified through collaboration with the RMP, Town of Bennington, BCCD and the Bennington County Regional Commission. The town can use the potential and existing areas as the various stages of the Plan are implemented. Figures 4-1 and 4-2 show an overview of the properties along the Roaring Branch and Walloomsac River respectively. Existing and potential restoration assets are described further below.

4.1 Existing Assets

An existing attenuation asset is defined as an area that presents an opportunity to protect and restore flood flow and sediment storage. Existing assets in the Walloomsac corridor were identified and primarily include town- and state-owned properties along the river that may not yet be fully utilized. Although the specific assets may not currently have a river-to-floodplain connection, they were still considered existing assets due to property ownership and relative lack of development. Figures 4-1 and 4-2 show properties along the Roaring Branch and Walloomsac River, respectively, that may serve as existing or potential attenuation assets.

Starting upstream along the Roaring Branch in Reach M06T3.04 (not shown in the Figure), an old floodplain is still active as evidenced by flood chutes and old channel scars in floodplain. Similarly, in Reach M06T3.03, there are areas of old channels and floodplain access along state-owned, undeveloped land adjacent to river for flood flow and sediment storage.

There is also town property just upstream of the Route 9 bridge on river left. This may be an option for attenuation in the form of a high-flow settling pond. However, the angle of the river approach here combined with the downward slope of the adjacent land would likely rule out this area for attenuation consideration.

In reach M06T3.02, there is an existing floodplain attenuation asset on river left, labeled on Figure 4-1 as CVPS (Central Vermont Public Service Corporation) property. Although this area is the location of the new Route 279 eastern approach, the design calls for no further encroachment into the river corridor. At this site, there is potential for utilizing the left floodplain. In the area of the new Route 279 bridge, this may be a good attenuation asset because the property is now state-owned.

Just upstream of this site on river left is a privately owned parcel of land currently being used as a mobile home park. Public safety issues have arisen for this site after it was damaged during the flooding of 1987. The town may want to pursue property acquisition in this area to get the residents out of this unsafe area.

Perhaps the most promising locations of existing and potential floodplain attenuation assets along the Roaring Branch are in Reach M06T3.01. There is an area of town-owned property on the river right, which is isolated from the channel by berms up to 12 feet high. There are various berm-like structures throughout this property, with another berm running parallel to the mobile homes off of Bell Street. The area downstream of Brooklyn Bridge on river right near the trailer park is also an excellent candidate for attenuation. A restoration opportunity involving offset berm construction may be feasible here.

Another open area along the Roaring Branch in this reach is on river left just upstream of the Route 7 bridge. This area is the state veterans' home and consists of open field that currently allows floodplain access in areas. These fields have potential for additional attenuation areas; however, there are currently berms located along the river banks. Cross-sections through three potential restoration areas ("Route 9", "Town Garage", and "Veterans' Home") are shown in Appendix D.

4.2 Potential Assets

Potential assets along the Roaring Branch and Walloomsac River consist of properties in private ownership that currently are not developed and could serve as areas for floodplain reconnection. Any property adjacent to the river within the FEH zone should be considered a potential asset. At this stage of Corridor Plan development, private landowner cooperation and land values have not been fully examined; however, several high-value properties with respect to watershed restoration have been identified (Figures 4-1 and 4-2). When additional properties are identified as part of the implementation of the plan, the town and state can further pursue agreements with the property owners for utilization of the floodplain assets.

As described in Section 3.2, the FEH zone was developed based upon the degree or likelihood of stream adjustments associated with fluvial processes occurring, and indicates the different levels of risk to investments and infrastructure within the river corridor. Using the FEH maps and related stream sensitivities (e.g., extreme, very high, etc.), potential assets can be pinpointed and prioritized.

Along the Roaring Branch in Reach M06T3.03, several parcels of land may serve as high-priority potential assets (Figure 4-1). In particular, the Campbell properties, located on river right in the area of the Route 9 bridge, may serve as potential asset areas, although the lands are privately held and have some residential development. Downstream of the Route 9 crossing, the old floodplain on river right (in Campbell ownership) is isolated from the river channel by the presence of several berms. This area appears to be a high terrace, so any floodplain reconnection here would require major bank alterations.

In Reach M06A on the Walloomsac River, there are two separate parcels of land under private ownership (Brady properties) that have potential for floodplain reconnection (Figure 4-2).

Figure 4-1: Properties Along the Roaring Branch Identified as Existing or Potential Attenuation Assets.

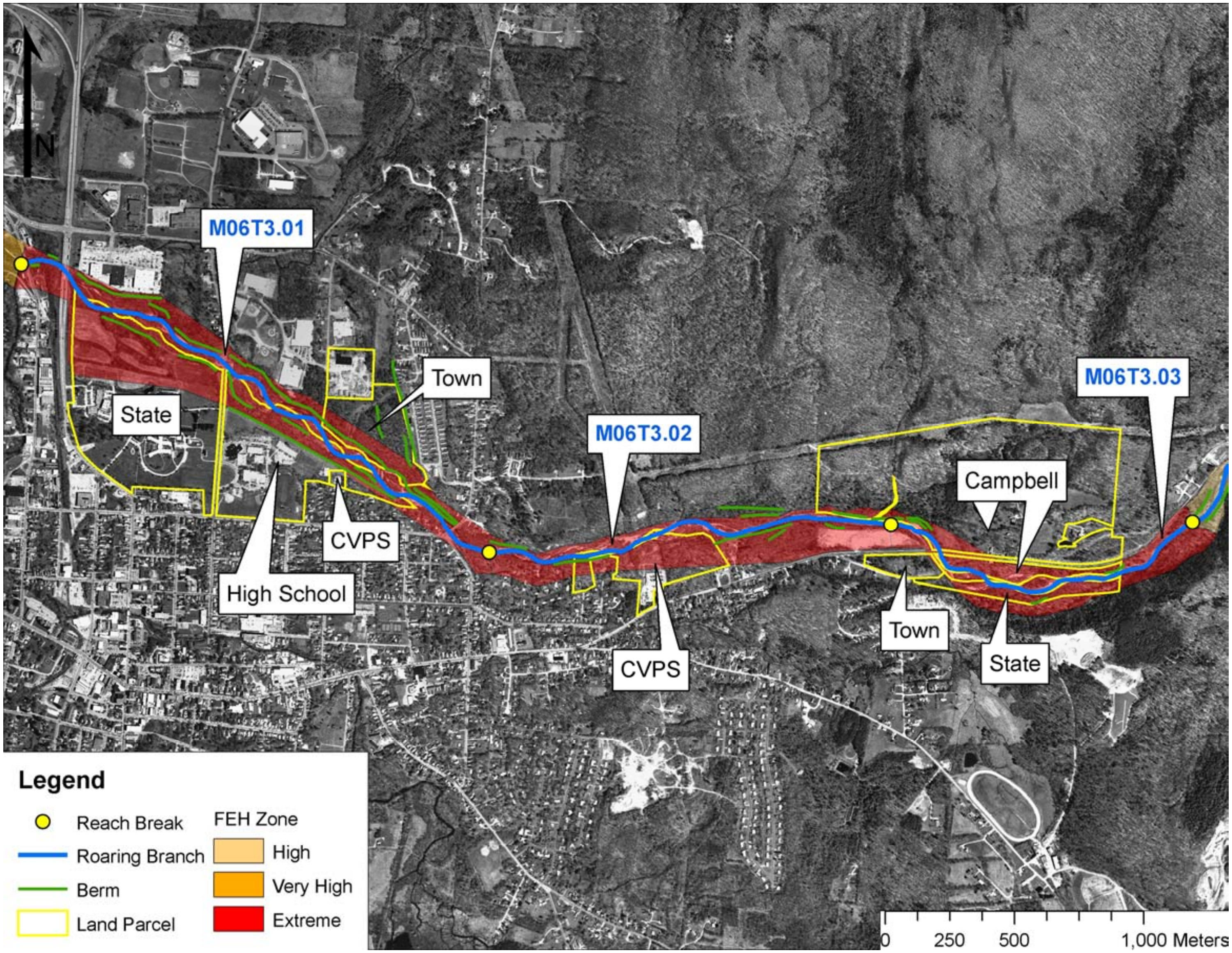
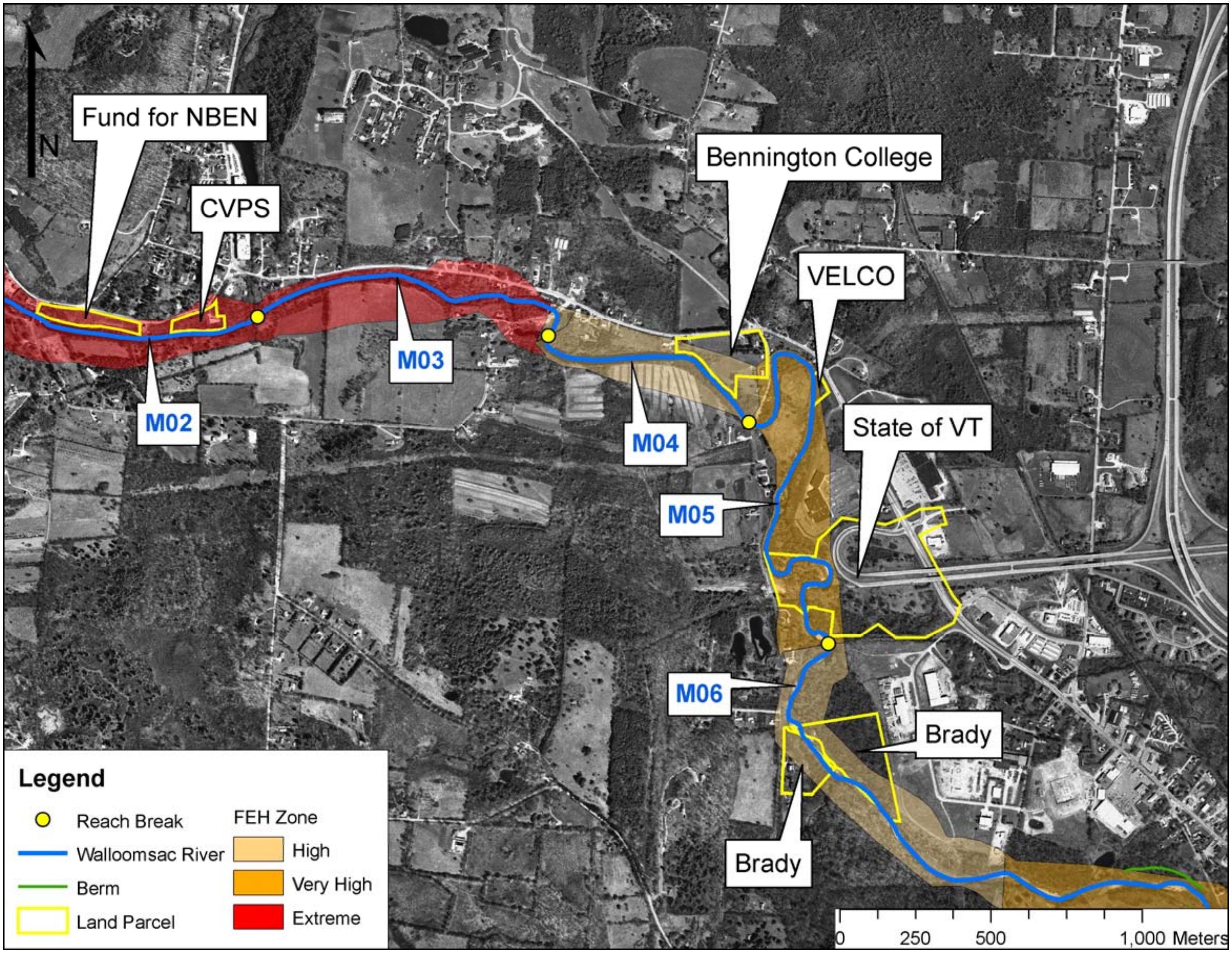


Figure 4-2: Properties Along the Walloomsac River Identified as Existing or Potential Attenuation Assets.



5.0 Management Alternatives

River management and restoration projects must be designed to work with the underlying physical processes occurring on both the watershed and the reach scales. Management plans and restoration projects that do not are subject to a high rate of failure. River corridor protection and restoration projects are incorporated into an overall program to create equilibrium conditions at the reach and watershed scales to maximize the effectiveness of the management plan. The planning of projects must also consider the long-term maintenance required, land-ownership issues, zoning restrictions, and municipal, state, and federal laws.

A major impediment to the full utilization of floodplain areas along the Roaring Branch in particular is the presence of berms. Some berms serve to protect houses and others areas are simply remnants of old dredging activities throughout the system. The network of berms along the channel and in the floodplain has been examined through the use of LiDAR data. Figures were developed showing the location, extent, and height of each berm. The next section will examine options for addressing areas where potential floodplain access is available, but blocked by the presence of berms adjacent to the channel. It is not feasible (economically or socially) to remove certain flood control structures, such as the levee north of Mt. Anthony School and the flood wall along County Road.

The extensive berm network along the Roaring Branch, and to a much lesser extent the Walloomsac River, was verified by the LiDAR data analysis. Figure 3-2 shows an example of the location and heights of berms along the Roaring Branch in reach M06T3.01. The berm network on additional stream reaches is presented in Appendix A.

5.1 Prioritization Hierarchy

While restoration projects and strategies can take many years to put in place on a watershed scale, there are often more feasible restoration and protection projects that can be pursued in the short-term. The prioritization of projects based on reach and watershed scale channel equilibrium, social benefit, cost, and likelihood of success is a necessary step in the planning process.

The goal of the prioritization hierarchy is to link river reaches or abutting properties to specific restoration actions. The hierarchy also relates the relative importance of each action to the management goals for the reach and watershed scales, and identifies where the project can occur independently or needs to be completed in conjunction with other work in the watershed in order to be most effective.

The primary steps in developing a restoration prioritization hierarchy are the following:

1. Identification of the reach sensitivity and the reach and watershed scale stressors that limit adjustment towards equilibrium.
2. Formation of a generalized list of restoration actions on a reach-by-reach basis that address identified reach and watershed scale stressors. This list can be used as a planning guide for existing and potential restoration assets and for the evaluation of unforeseen projects or properties that may develop in the future.
3. Identification of existing and potential assets (properties and reaches) where restoration activities are more socially feasible because of land ownership and/or current management and zoning.
4. A comparative assessment of the technical feasibility, social benefits, and relative cost comparisons for each of the options.

5. Formulation of a restoration hierarchy to be used as a management tool to guide the planning of identified restoration projects and to evaluate the suitability and feasibility of unforeseen projects and opportunities that will arise in the future.

5.1.1 Sensitivity and Reach and Watershed Scale Stressors

The Phase 2 report completed a stream type departure and sensitivity analysis for all reaches in the project area of the Roaring Branch and Walloomsac Rivers (Gomez and Sullivan and Parish Geomorphic, 2007). The Phase 2 work also assessed stream adjustment processes and stressors on a reach-by-reach basis. Feature Indexing Tool (FIT) data collected for the work are used to decipher which reaches are subject to different watershed and reach scale stressors. Table 5-1, based on the data collected and the analysis for the Phase 2 report summarizes the sensitivities as well as reach and watershed scale stressors for each reach. Reach scale stressor maps were re-created showing stream feature data (erosion, migration, etc.) collected during the Phase 2 geomorphic assessment and are provided in Appendix F.

Table 5-1: River Stressor Identification Table.

River	Reach ID	Stream Sensitivity	Watershed Scale Stressors		Reach Scale Stressors	
			Hydrologic	Sediment Load	Stream Power	Boundary Resistance
Roaring Branch	M06T3.04	High		Increased because of upstream confinement and degradation	Increased stream power due to confinement and berms	Decreased due to loss of floodplain connection
Roaring Branch	M06T3.03	Extreme		Increased because of upstream confinement and degradation	Increased stream power due to confinement and berms – Decreased stream power upstream of bridges	Decreased due to loss of floodplain connection and bank erosion
Roaring Branch	M06T3.02	Extreme	Increased flood flows from watershed development and drainage	Increased because of upstream confinement and degradation	Increased stream power due to localized headcuts and berms	Decreased due to loss of floodplain connection and bank erosion
Roaring Branch	M06T3.01	Extreme	Increased flood flows from watershed development and drainage	Increased because of upstream confinement and degradation	Increased stream power due to confinement and berms – Decreased stream power upstream of bridges	Decreased due to loss of floodplain connection and bank erosion

Table 5-1: River Stressor Identification Table (Continued).

River	Reach ID	Stream Sensitivity	Watershed Scale Stressors		Reach Scale Stressors	
			Hydrologic	Sediment Load	Stream Power	Boundary Resistance
Walloomsac	M06B	High	Increased flood flows from watershed development and drainage	Increased because of upstream confinement and degradation	Increased stream power due to incision and berms	Decreased due to loss of floodplain connection and bank erosion
Walloomsac	M06A	High	Increased flood flows from watershed development and drainage	Increased because of upstream confinement and degradation	Increased stream power due to incision	Decreased due to loss of floodplain connection and bank erosion
Walloomsac	M05	Very High	Increased flood flows from watershed development and drainage	Increased because of upstream confinement and degradation	Increased stream power due to incision	Decreased due to loss of floodplain connection and bank erosion
Walloomsac	M04	High	Increased flood flows from watershed development and drainage		Decreased stream power due to reduction in slope – Paper Mill Dam	
Walloomsac	M03	Extreme	Increased flood flows from watershed development and drainage	Decreased because of upstream Paper Mill Dam	Increased stream power due to incision	Decreased due to loss of floodplain connection
Walloomsac	M02	Extreme	Increased flood flows from watershed development and drainage	Decreased because of upstream Paper Mill Dam	Increased stream power due to incision	Decreased due to loss of floodplain connection

5.1.2 Restoration Actions

Restoration actions define the process-based goal of restoration projects. Some projects may need to address several different restoration actions to be sustainable at a particular site. There are typically many different ways to go about achieving each of the restoration actions. Some require engineered installations and others require less structured methods. All will need varying degrees of an alternatives analysis before specific alternatives can be selected. Specific restoration actions typically include:

1. Protecting river corridors to prevent further impact and future development. This can be done by enacting zoning laws, conservation easements, or by buying out personal property. Removal of structures from hazardous areas can be an effective approach when it is feasible. FEMA-funded home buyouts, for instance, were a successful mitigation activity after several of Vermont's destructive floods in the 1990s. While removal or relocation is effective, it is generally far too costly to be applied at a broad scale. In addition, many large structures, particularly transportation infrastructure or public facilities, are rarely feasible to remove or relocate (ANR Municipal Guide).
2. Planting of channel banks and floodplain corridors. Increase boundary resistance of corridors by planting vegetation and/or limiting access.
3. Stabilization of channel banks. Stabilization of banks to protect infrastructure and property may sometimes be necessary, but it is often done in a way that is contrary to restoration principals. Bank stabilization should only be considered as a tool for restoration if it addresses either reach scale or watershed scale stressors. Bank stabilization can be undertaken if the restoration of the site requires establishing or maintaining appropriate channel geometry, if excessive sediment input is a reach stressor, or if the badly eroding bank won't support the growth of vegetation required to increase boundary roughness. Only those bank stabilization measures that are a part of larger channel management projects to protect public infrastructure should be considered.
4. Arresting headcuts or channel grade adjustments. Bed degradation tends to occur in locations where the banks have been hardened or the river has been channelized by controls. This degradation can migrate upstream causing additional bank and bed failure and an influx of sediment into the system. It is important to note here that within the Roaring Branch system, several areas were identified as "steep riffles" located at the downstream ends of large in-stream depositional bars. Theses areas are different from headcuts, where the channel bed is actively cutting down in relation to the floodplain. Typically, steep riffles are located in aggrading reaches and headcuts are located in degrading reaches. The two therefore require different restoration actions and should not be managed in the same manner.
5. Removing berms or levees to allow flood and sediment attenuation. Higher priority areas include reaches where a significant (>50%) portion of the river (belt width) corridor would become accessible to the stream for meander development and/or lateral floodplain access if the berm were to be removed, where the berm constitutes the predominate reason why the reach is incised, or where human structures would not be under greater risk to flood inundation or erosion hazard if the berm were removed. Lower priorities would be berms which are vegetated with mature trees because their removal would cause major land disruption and habitat impacts, and the benefits to attainment of equilibrium conditions are less certain.
6. Removing or replacing structures such as undersized culverts, bridges, and dams.
7. Restoring incised or degraded reaches to reconnect sediment and flood flows with the floodplain surface. This typically involves building up the channel bed and/or lowering the floodplain surface.
8. Restoring avulsing or aggrading reaches by increasing sediment transport capacity. This can be done by adjusting the channel shape and configuration using natural channel design principals.

Each river reach has a unique sensitivity and set of reach and watershed scale stressors. Once these factors are identified, specific river restoration actions that address the stressors can be assigned to each reach. Table 5-2 summarizes the primary restoration actions for each reach in the project area. Restoration actions not listed for a reach may still be appropriate for localized areas within the reach or for the reach as a whole at some time in the future after adjustment occurs. This list highlights the restoration actions that will most directly address the current reach and watershed scale stressors identified in Table 5-1.

Table 5-2: River Restoration Actions.

River	Reach ID	Restoration Action
Roaring Branch	M06T3.04	Protecting river corridors – limiting further encroachment of the road on the stream channel.
		Removing berms or levees not needed to protect infrastructure to allow flood and sediment attenuation.
		Stabilizing channel banks so shrubs and trees can establish.
		Planting of channel banks and floodplain corridors to increase boundary resistance.
Roaring Branch	M06T3.03	Protecting river corridors – acquisition of property adjacent to channel to prevent future development.
		Removing berms or levees not needed to protect infrastructure to allow flood and sediment attenuation.
		Stabilizing channel banks so shrubs and trees can establish.
		Planting of channel banks and floodplain corridors to increase boundary resistance.
		Removing or replacing structures such as undersized culverts, bridges and dams
		Restoring avulsing or aggrading reaches upstream of Route 9 bridge to increase sediment transport competence and capacity.
Roaring Branch	M06T3.02	Protecting river corridors – acquisition of property adjacent to channel to prevent future development.
		Removing berms or levees not needed to protect infrastructure to allow flood and sediment attenuation. Consider areas of partial berm removal to activate historic flood chutes on the floodplain.
		Stabilizing channel banks so shrubs and trees can establish.
		Arresting localized headcuts and knick points to prevent the migration of bed degradation and excessive additions of sediment.
		Planting of channel banks and floodplain corridors to increase boundary resistance.
Roaring Branch	M06T3.01	Protecting river corridors – acquisition of property adjacent to channel to prevent future development.
		Removing berms or levees not needed to protect infrastructure to allow flood and sediment attenuation. Consider areas of partial berm removal to activate historic flood chutes on the floodplain.
		Stabilizing channel banks so shrubs and trees can establish.
		Arresting localized headcuts and knick points to prevent the migration of bed degradation and excessive additions of sediment.
		Planting of channel banks and floodplain corridors to increase boundary resistance.
		Removing or replacing structures such as undersized culverts and bridges.
		Restoring avulsing or aggrading reaches upstream of Brooklyn Street bridge to increase sediment transport competence and capacity.
		Restoring avulsing or aggrading reaches upstream of Park Street bridge to increase sediment transport competence and capacity.
		Restoring avulsing or aggrading reaches upstream of Route 7 bridge to increase sediment transport competence and capacity.

Table 5-2: River Stressor Identification Table (Continued).

River	Reach ID	Restoration Action
Walloomsac	M06B	Protecting river corridors – acquisition of property adjacent to channel to prevent future development.
		Removing berms or levees not needed to protect infrastructure to allow flood and sediment attenuation.
		Stabilizing channel banks so shrubs and trees can establish.
		Arresting localized headcuts and knick points to prevent the migration of bed degradation and excessive additions of sediment.
		Planting of channel banks and floodplain corridors to increase boundary resistance.
		Restoring incised or degraded reaches to reconnect flood flows with the floodplain.
Walloomsac	M06A	Protecting river corridors – acquisition of property adjacent to channel to prevent future development.
		Stabilizing channel banks so shrubs and trees can establish.
		Planting of channel banks and floodplain corridors to increase boundary resistance.
		Restoring incised or degraded reaches to reconnect flood flows with the floodplain.
Walloomsac	M05	Protecting river corridors – acquisition of property adjacent to channel to prevent future development.
		Stabilizing channel banks so shrubs and trees can establish.
		Planting of channel banks and floodplain corridors to increase boundary resistance.
		Restoring incised or degraded reaches to reconnect flood flows with the floodplain.
Walloomsac	M04	Removing or replacing structures such as undersized culverts, bridges and dams.
Walloomsac	M03	Protecting river corridors – acquisition of property adjacent to channel to prevent future development.
		Stabilizing channel banks so shrubs and trees can establish.
		Planting of channel banks and floodplain corridors to increase boundary resistance.
		Restoring incised or degraded reaches to reconnect flood flows with the floodplain.
Walloomsac	M02	Protecting river corridors – acquisition of property adjacent to channel to prevent future development.
		Stabilizing channel banks so shrubs and trees can establish.
		Planting of channel banks and floodplain corridors to increase boundary resistance.
		Restoring incised or degraded reaches to reconnect flood flows with the floodplain.
		Removing or replacing structures such as undersized culverts, bridges and dams.

Note: Specific locations for reach-specific restoration actions are presented in Table 5-3. Only those bank stabilization measures that are a part of larger channel management projects to protect public infrastructure should be considered.

5.1.3 Project Identification and Prioritization Hierarchy

A representative sample of possible restoration projects were selected for this report. Projects were selected based on the existing and potential assets identified in Section 4.0, the location of berms as identified by the LiDAR survey, and upon geospatial data collected during the Phase 2 report (Gomez and Sullivan and Parish Geomorphic, 2007). The geospatial data included identification of eroding banks, headcuts, and other indicators of channel instability and adjustment. A total of 31 projects were identified for this report. The projects cover a full spectrum of project types and are listed on a reach-by-reach basis in Table 5-3.

Each project was then ranked as high, medium, or low using the following criteria:

- Watershed Priority – How important is the project to establishing equilibrium conditions on a watershed scale?
- Reach Priority – How important is the project to establishing equilibrium in the vicinity of the project?
- Technical Requirements – How technically demanding will the project be?
- Relative Cost Comparison – High is greater than $200,000, Low is less than $100,000, and Medium is between $100,000 and $200,000.
- Typical Societal Acceptance – How willing, typically, are the public, municipality, and/or private landowners to participate in or undertake the project?

A restoration hierarchy was then established by weighting the projects that were highest in ranking for the following order of criteria stated above:

1. Watershed Priority
2. Reach Priority
3. Technical Requirements
4. Cost

The criterion of Typical Societal Acceptance was used to adjust the results of the prioritization hierarchy as completed by the above method. The priority of each project is presented in Table 5-3.

The Roaring Branch and the Walloomsac River have presented extreme challenges through history for the Town of Bennington. The Phase 2 assessment concluded that the river is currently in a state that has greatly departed from a stable condition and will therefore remain dynamic and pose a threat of further erosion and damage to property during flood events. Historic manipulation of in-stream sediments and artificial constraints on natural planform adjustment are the primary reason for the instability. The river system contains a large sediment supply and the presence of the numerous berms has only resulted in constraining stream energy, which in turn has led to accelerated rates of change in channel form. As such, projects that are located in the upper reaches of the Roaring Branch that address channel encroachment and sediment and flow attenuation have ranked high on the priority list. Other projects located lower in the watershed may not have as much of an impact on the watershed scale so they have been ranked lower; even though the degraded condition may be having a more severe effect on stability and habitat condition of localized area.

Table 5-3: Project Identification and Restoration Hierarchy.

River	Reach	Priority	Project	Asset Type	Reach Priority	Watershed Priority	Requires Other Action	Cost	Technical Requirement	Social Acceptance	Next Steps or Project Notes
Roaring Branch	M06T3.04	1	Berm removal - reach wide initiative.	Undeter-mined	High	High	No	Low	Medium	Medium	Will require additional assessment and design
Roaring Branch	M06T3.03	11	Campbell Property - upstream of Route 9. Protecting river corridors – acquisition of property on North bank.	Potential	Medium	High	Yes	Low	Low	Low	Will require removal of berms to be effective
		14	Removing berms or levees not needed to protect infrastructure to allow flood and sediment attenuation.	Potential	Medium	High	No	Low	Medium	Medium	Removal of berms on property, will require additional assessment and design
		9	Campbell Property - downstream of Route 9. Bank Stabilization - Right Bank immediately downstream of Route 9 bridge (as part of a larger restoration project).	Potential	High	Medium	No	Low	Medium	High	
		30	Town Property - upstream of Route 9. Off channel sediment detention area.	Existing Potential	Low	Medium	No	High	High	Medium	Will require additional assessment and design
		2	Berm removal - reach wide initiative.	Undeter-mined	High	High	No	Low	Medium	Medium	Will require additional assessment and design
Roaring Branch	M06T3.02	12	Private Property - Mobile Homes off Smith Way. Protecting river corridors – acquisition of properties on South bank that are currently constructed in active flood chutes.	Undeter-mined	Medium	High	Yes	Low	Low	Low	Will require removal of berms to be effective
		15	Removing berms or levees not needed to protect infrastructure to allow flood and sediment attenuation.	Undeter-mined	Medium	High	No	Low	Medium	Medium	Will require additional assessment and design
		18	Arrest headcuts - in channel works.	Existing	High	Medium	No	Low	Medium	High	Headcut along bank armor installed after 1987 floods is destabilizing bank and bed

Roaring Branch	M06T3.02 (Cont.)	16	Central Vermont Public Service Corporation (CVPS). Removing berms or levees not needed to protect infrastructure to allow flood and sediment attenuation.	Existing	Medium	High	No	Low	Medium	Medium	Will require that Route 279 bridge extension is designed not to encroach onto the floodplain
		3	Berm removal - reach wide initiative.	Undeter-mined	High	High	No	Low	Medium	Medium	Will require additional assessment and design
		19	Arrest headcut on South bank / Utility Building.	Existing	High	Medium	No	Low	Medium	High	Headcut along bank armor is destabilizing bank and bed
Roaring Branch	M06T3.01	4	Town Garage Property. Removing berms or levees not needed to protect infrastructure to allow flood and sediment attenuation.	Potential	High	High	No	Medium	Medium	Medium	Will require additional assessment and design
		5	May require the additional construction of new berms offset from the channel and along the boundaries of the corridor to protect infrastructure to the north of the corridor.	Potential	High	High	No	Medium	Medium	Medium	Will require additional assessment and design
		6	High School Property. Removing berms or levees not needed to protect infrastructure to allow flood and sediment attenuation - berm along High School should remain to protect infrastructure.	Potential	High	High	No	Low	Medium	Medium	Will require additional assessment and design
		7	State Property. Removing berms or levees not needed to protect infrastructure to allow flood and sediment attenuation.	Potential	High	High	No	Medium	Medium	Medium	Will require additional assessment and design
		8	May require additional construction of new berms offset from the channel to protect infrastructure to the south of the corridor.	Potential	High	High	No	Medium	Medium	Medium	Will require additional assessment and design

Roaring Branch	M06T3.01 (Cont.)	20	NRCS Flood Berm - North Bank. Arrest headcuts - in channel works.	Existing	High	Medium	No	Medium	Medium	High	Headcut along bank armor installed after 1987 floods is destabilizing berm and bed
		21	Brooklyn Bridge. Arrest headcuts through depositional material.	Existing	High	Medium	No	Low	Medium	High	
		25	Restore aggraded river channel upstream of bridge.	Existing	Medium	Medium	No	Medium	High	Medium	
		22	Park Street bridge. Bank Stabilization upstream of bridge.	Existing	High	Medium	No	Low	Medium	High	
		26	Restore aggraded river channel upstream of bridge.	Existing	Medium	Medium	No	Medium	High	Medium	
		27	Route 7 bridge. Restore aggraded river channel upstream of bridge.	Existing	Medium	Medium	No	Medium	High	Medium	
		29	Remove or Replace Bridge Structures.	Existing	High	High	Yes	High	High	Low	Will require additional assessment and design, and require addressing existing degradation and aggradation at bridges
Walloo msac	M06B	23	Upstream of Golf Course. Arrest headcuts downstream of RB confluence.	Existing	High	Medium	No	Low	Medium	High	
		17	Restore incised river channel.	Existing	Medium	Medium	No	High	High	Medium	
Walloo msac	M06A	13	Brady Property. Protecting river corridors – acquisition of property on both banks.	Potential	Medium	High	No	Medium	Low	Low	
		28	Restore incised river channel.	Potential	Medium	Medium	No	High	High	Medium	
Walloo msac	M05	24	Restore aggraded river channel under Route 279 bridge.	Existing	High	Medium	No	Medium	Medium	Medium	
Walloo msac	M04	10	Remove or Replace Paper Mill Dam.	Existing	High	High	Yes	High	High	Low	Will require additional assessment and design
Walloo msac	M02	31	Remove weir.	Existing	Medium	Low	No	Low	Medium	Low	Will require additional assessment and design

Note: Reach scale stressors maps showing stream feature data (Appendix F) should be used to note locations of Projects presented above.

5.1.4 Schedule and Costs for Implementation of Restoration

All of the selected projects for this report are valuable projects with respect to managing and implementing a holistic restoration of the Roaring Branch and Walloomsac watersheds. Relative costs of each project are presented in Table 5-3. If a project has a low ranking priority, it is still worthy of consideration at any time in the near future. It is also worth noting that some projects have two or more restoration actions needed to restore the site. In some cases, the prioritization for each action may be widely spread. The prioritization hierarchy is not a marching order of projects meant to be taken one before or after the other. It is in fact a relative scale to help managers understand whether the project under consideration falls near the top, middle, or bottom of the 31 projects presented for this analysis.

The high-priority restoration actions should be implemented over the next one to five years in an incremental fashion—particularly those located in areas identified as existing or potential assets. High priority erosion sites, for example, can be addressed immediately upon funding availability. Additionally, lower priority and undetermined asset areas can be addressed at a later time given resource availability. The implementation of process-based restoration solutions will eventually reduce or minimize the need to pursue short-term and "maintenance-type" solutions.

5.1.5 Selected Priority Restoration Options

Two of the prioritized projects were selected for conceptual development for this report. They included berm removal at the town garage property and bank stabilization on the north bank upstream of the Park Street bridge, discussed in more detail in the following sections.

5.1.5.1 Floodplain Reconnection – Town Garage Property

The town garage property is located on the north bank of the Roaring Branch on reach M06T3.01. The property is shown as an existing asset on Figure 4-1 in Section 4.0 of this report. The project scored a rank of 4 in the prioritization hierarchy for contributing to overall equilibrium at the reach and watershed scales. The town garage property is a 34-acre parcel located on the historic floodplain of the Roaring Branch. A large riverside berm separates the floodplain surface from the river channel. The berm concentrates flood flows in the channel, increasing stream power and sediment transport, and eliminating the flood flow and sediment attenuation potential of the parcel. The parcel is generally forested with smaller trees and has very little in the way of underbrush.

The goal of restoration at this site is to remove berms or levees not needed for the protection of infrastructure to allow flood and sediment attenuation which is consistent with the identified process-based restoration actions for the reach, while still allowing for future development of this site for town purposes. Figure 5-1 shows the berm locations for this property as identified from the LiDAR survey. This project would involve the removal of approximately 1,800 feet of the berm located immediately adjacent to the stream down to the historic floodplain elevation. In addition, the construction of a new berm offset from the right bank is recommended. The new berm may be required to protect homes and existing and future infrastructure from water that accesses the new floodplain surface. The conceptual location of the new berm is shown in Figure 5-1; however this particular berm reconfiguration concept may be adjusted in response to future development plans for the property and still allow for restoration of the floodplain.

Modifications to channel and floodplain configuration would primarily involve removal of the streamside berm. Minor adjustments to channel grade and shape may be beneficial as well. Figure 5-2 shows the cross-section at station 2 both in the existing and the proposed, or post-restoration, condition. Notice the addition of the offset berm while still allowing for future property development behind the berm. Additional cross-sections through this potential restoration area are shown in Appendix D.

A comparative hydraulic analysis was conducted to demonstrate the effectiveness of berm removal on decreasing stream power, shear stress, and energy in the channel during flood events. Existing versus post-restoration hydraulics are presented in Figures 5-3 and 5-4 for cross-section 2 (ST2) and cross-section 4 (ST4), respectively. Both areas demonstrate a significant decrease in stream power and shear stress from the existing to post-restoration conditions. Under berm removal conditions, at flows around 50 cubic meters per second (1,765 cubic feet per second), the river will spill over the new bank into the floodplain and thus decrease stream power and shear stress, at the same time allowing for sediment storage out of the channel.

It should be emphasized that any berm removal or reconfiguration project should not be undertaken without assessment and design to ensure that the resulting floodplain access will not cause a higher potential for flooding and erosion hazards. Any such project would require detailed and engineered designs and a stream alteration permit.

5.1.5.2 Restoration of Aggrading Reach and Bank Stabilization – Upstream of Park Street Bridge

The Park Street bridge constricts the corridor of the Roaring Branch and has caused considerable aggradation of gravel, cobble, and boulder-sized material upstream of the bridge. The accumulated sediments have formed a large mid-channel bar and have forced the thalweg (deepest part of the channel) to move toward the margins of the channel and form a split path around the bar under flood conditions. The primary channel is now on the north bank and is rapidly eroding the bank. The eroding bank at this site is actually an old berm made primarily of dredged river material, so it is a very tall bank with respect to the much lower historic floodplain elevation.

The erosion is threatening the stability of the flood control berm adjacent to the baseball diamonds in reach M06T3.01. The erosion was documented in the local newspaper in the spring of 2005 and has been a highly visible problem site for some time. A picture of the bank erosion is shown in Figure 3-5 of this report. Figure 5-5 shows the location of the bank erosion as identified during the Phase 2 assessment. The project did not score high at number 22 in the prioritization hierarchy for contributing to the overall equilibrium at the reach and watershed scales. It is however a highly visible, easily accessible site and does potentially pose a threat to infrastructure and the walking trail. As a rule, bank stabilization projects should be approached with caution, as the practice may cause relocation of the erosion hazards downstream. In addition, it is the rare case that bank stabilization projects rank high on the priority list for addressing watershed and reach scale stressors. This report does recognize, however, that bank stabilization is sometimes required for the protection of infrastructure. Therefore, an alternative method for stabilizing banks is a valuable example for inclusion in this report. Bank stabilization upstream of Park Street should only be performed in conjunction with the restoration of the aggrading reach as described below.

The goal of restoration at this site would be consistent with the identified process-based restoration actions for the reach, primarily to restore aggrading and avulsing conditions, and to increase boundary resistance required to maintain a thalweg away from the toe of the bank towards the center of the channel. The project would involve the stabilization of approximately 260 feet of eroding bank. In addition, the project should also include the relocation and reconstruction of approximately 1,000 feet of a single-thread channel capable of transporting sediment through the site. Figure 5-6 shows existing and conceptual cross-sections upstream of the Park Street bridge. Adjustment of the channel grade will also be necessary to mitigate the aggraded condition of the reach.

Bank Stabilization

Traditional methods of riprap on failing slopes prohibit the growth of vegetation and eventually make for a hydraulically smooth surface in comparison with the natural banks around it. Boundary resistance can be increased by using a vegetated protection stone treatment. Vegetated protection stone is sized and placed like riprap, except the void spaces between the rocks are filled with topsoil and planted with shrubs. In addition, increased bank resistance can be realized if the rock treatment is only used at the toe of the bank, or up to the appropriate height on the bank where bio-engineering slope stabilization techniques can be implemented. A wide variety of biodegradable fabric is available and each has a unique tensile strength and longevity. Depending upon the bio-engineering slope stabilization method selected, the treatment can start either lower or higher on the bank. Ultimately, the shear stresses and the flow duration of the design storm will be understood so that the treatment type and the appropriate elevation to start the treatment can be selected. In many, but not all cases, bio-engineered banks start at or above the bankfull level. Figure 5-7 shows typical details for a vegetated stone toe treatment with a bioengineered upper bank.

In some cases, the bank is eroded so far into the floodplain or is so steep that bank revetment of this type is not feasible. Vegetated rock buttresses are a viable restoration option in this scenario. The primary difference between a buttress and revetment is that a buttress is structurally designed to "stand" by itself, and is not "lain" upon and existing bank. More detailed surveying and a geotechnical assessment will be required to determine if the Park Street bridge site will require a revetment or buttress type treatment.

Restoration of Aggraded Reach

The LiDAR data was used to conceptually lay out the design considerations for restoring channel alignment channel cross-section at the Park Street bridge. A sediment transport analysis utilizing existing topography, the reach grade, channel bed grade at the site, sediment material size, and the upstream source conditions was completed to determine competent channel geometry for the site. A conceptual cross-section of restored channel through the Park Street bridge is presented in Figure 5-8. The width of the restored channel should range between 90 and 100 feet and have a bankfull depth of 5 to 6 feet. The conceptual cross-sections upstream of the bridge were designed to be consistent with a single thread reference channel width which would promote effective sediment transport through the bridge opening. The LiDAR data also provided channel slopes through the project area which allowed for an estimate of the upstream extent of the depositional features influenced by the bridge. Conceptual profile adjustments are shown in Figure 5-9. The channel should be reconstructed at a grade consistent with the upstream and downstream reaches of river, which is approximately 2%. The profile indicates aggradation between cross-sections 100 and 400. The bridge is approximately located at station 250. Channel reconstruction plans should be completed by an engineer experienced with bridge hydraulics and sediment transport in gravel bed rivers. Any such project would require engineered designs and a stream alteration permit.

5.2 Maintenance Alternatives

Maintenance of channel sediments may be required to alleviate short-term pressures or risks to infrastructure from the accumulation of sediment. For example, sediment transport capacity is reduced because of constriction caused by the bridges the Roaring Branch. This causes a cycle of accumulation of large amounts of sediment that is eventually followed by degradation through the sediments. The discontinuity in sediment flow creates an unstable and dynamic setting that can threaten bridge stability and cause worry among managers. Historic dredging has also exacerbated sediment discontinuity and prevented the channel from evolving into an efficient and stable channel form.

5.2.1 Sediment and Debris Management

The U.S. Army Corp of Engineers has in the past performed dredging operations on portions of the Roaring Branch. In 1951, they performed snagging and clearing with the intent of improving the flow capacity of the channel. The work consisted of excavating accumulated gravel and boulders from about 3,000 feet of channel (USACE 1995). The sediment was then deposited at four critical locations on the left bank of the Roaring Branch to form earthen dikes. As part of this work, the Army Corps suggested that tree removal take place from islands in the Roaring Branch. This type of channel maintenance has been discouraged by the Vermont River Management Program.

Once a widespread commercial activity in Vermont's rivers, gravel removal is now restricted to maximum annual volumes for landowners' use and for the maintenance or restoration of stream channel stability. The 1986 Rivers Act resulted only in the prohibition of commercial gravel mining activities in rivers and streams. Since that date, gravel excavation has continued to be routinely approved for the purpose of property protection wherever it is determined that removal will provide the intended relief and will not significantly contribute to increased system instability.

Historic dredging has enlarged the flow area in the channel, which has reduced the stream power and the ability of the river to move sediment downstream. Large amounts of sediment have accumulated in bar features and in the river bed in these areas. Accumulated in-stream sediments have forced the channel to erode into the channel margins, further threatening infrastructure and flood protection structures.

5.2.2 Vertical and Lateral Alignment of River and Bridges

Maintenance dredging of aggraded reaches can likely be completed without destabilizing any particular reach in this system. It is clear that the sediment deposition around bridges in the Roaring Branch in particular is of major concern to the Town of Bennington due to potential public safety issues. Floodplain restoration is an important management practice that may alleviate the need for maintenance dredging. There may be several instances of channel maintenance during the time which it will take to restore sufficient upstream sediment attenuation (as presented in Section 5.1.5.1) to fully alleviate accumulation at the bridges. Even though floodplain attenuation opportunities should be pursued to address watershed-scale sediment loading, the maintenance around bridges may warrant a higher priority in the short-term.

One likely scenario for this type of channel maintenance is around bridges where local accumulation of sediment is threatening the stability or flow capacity of the structure. The dredging of sediments for bridge maintenance should not be undertaken without assessment and design to ensure that the resulting channel grade and cross-section configuration are efficient at transporting sediment through the dredged reach. Excessive or unplanned dredging can leave a channel configuration that heightens the uncertainty of future adjustments thereby increasing the risk to the structure. This level of design and planning would differentiate the work from dredging operations that have occurred in the past and have led to degraded conditions in the river. Existing profile and cross-sections through Brooklyn Bridge, Park Street bridge and Vermont Route 7 bridge are contained in Appendix B to assist the town if maintenance is determined by bridge engineers to be required. Dredging plans should be completed by an engineer experienced with bridge hydraulics and sediment transport in gravel bed rivers, and the designs should take into consideration any underground utility structures such as water or sewer main pipes.

Section 5.1.5.2 presents a conceptual plan for addressing the aggradation of material above the Park Street bridge. This type of design could also be applied to the other bridges along the Roaring Branch and Walloomsac River with the preferred implementation schedule of starting upstream at the Route 9 bridge and working downstream from there.

5.3 Corridor Protection

The Phase 2 assessment on the Roaring Branch and the Walloomsac River verified that the various bank protective structures, designed to protect investments in the corridor, are not sustainable in the long-term and are beginning to fail in places. The Roaring Branch in Bennington is particularly sensitive to fluvial erosion hazards due to residential and commercial encroachments, and past channelization and dredging practices. Corridor protection, instituted by the town, is important for maintaining the undeveloped space along river. Limiting development in this corridor will prevent flood damage and allow for increased opportunities for floodplain reconnection and sediment attenuation.

A protective zone around the river corridor should be pursued in combination with the structural management measures presented above. According to the RMP, "without corridor protection, and local efforts to limit encroachments, the system will remain in an unending and escalating cycle of flood disaster and recovery that will create more and more hazards, degrade water quality, and result in an expensive program to resolve conflicts with channelization practices."

In addition to corridor protection, perpetual easements, which include the purchase of channel and riparian vegetation management rights within river corridors, can be an important conservation tool along the Roaring Branch and Walloomsac River (ANR, 2006). Targeted areas for potential land acquisition to supplement corridor protection were detailed above in Section 4.

5.3.1 Town Planning and Zoning

Because towns have the ability to regulate land use, their planning and zoning practices can be effective in mitigating flood and erosion hazards by encouraging development in appropriate areas and preventing investment in hazardous areas. A logical starting point for developing protective zoning around a river corridor is with the FEH (Fluvial Erosion Hazard) mapping process.

The FEH corridor was developed using calculated belt widths and channel widths, definition of valley walls and meander centerlines, and other field data documenting any unique characteristics associated with stream reach sensitivity (as detailed above in Section 3.2). Using the fluvial erosion hazard map, the Towns of Bennington and Woodford should institute restrictions on development related to the sensitivity of the stream. One way of protecting the river corridor is to institute an FEH overlay district, based on the FEH maps developed during the Phase 2 assessment (Appendix C).

An FEH overlay district is an additional zoning requirement placed on a specific geographic area (in this case the FEH zone) without changing the underlying zoning. The degree of protection afforded by an FEH overlay district depends upon the exact wording, but could include limits on structures, land use activities, or even vegetative condition. Limiting development within an overlay district based on the boundaries of a FEH map has two major functions. First, it will prevent development in hazardous areas, reducing costly flood losses. Second, it will prevent further river corridor encroachment that increases overall fluvial erosion hazards and even impedes a river's natural tendency to adjust toward a more stable, equilibrium condition (ANR Municipal Guide).

The FEH risk assessment and mapping process provides a sound scientific and technical basis for determining the boundaries of an FEH overlay district. Because overlay district boundaries do not shift as a river channel changes position, this approach can provide a consistent, easy-to-administer tool for mitigating fluvial erosion hazards over a wide geographic area. In the long-term, this option will do the best job of minimizing human/river conflicts and limiting losses caused by fluvial erosion. Model FEH overlay district language developed by the RMP is available (ANR Municipal Guide).

Another potential planning and zoning tool that towns can use to protect river corridors is to implement minimum setbacks or stream buffers. Setbacks establish a distance perpendicular to a stream in which certain standards are established regarding land use. Stream buffers are naturally vegetated zones adjacent to a stream which are established or managed to protect the stream from human disturbances. Setbacks are generally tied to the location of a stream, however, and can lead to confusion and conflict as a stream channel location changes over time (ANR Municipal Guide).

5.3.2 Flood Ordinances

Opportunities exist for towns to participate in the National Flood Insurance Program (NFIP) to minimize encroachment in river corridors. For instance, towns can adopt floodplain regulations more restrictive than the minimum required for participation in the NFIP (such activities may also make a town eligible for additional benefits like discounted flood insurance). The NFIP is a program administered by the Federal Emergency Management Agency (FEMA) that allows property owners in participating communities to purchase flood insurance as a protection against flood losses. In exchange the state and local community must enact floodplain management regulations that reduce the possibility of future flood damage. If a community adopts and enforces a floodplain management ordinance to reduce future flood risk to new construction in floodplains, the federal government will make flood insurance available within the community as a financial protection against flood losses. This insurance is designed to provide an insurance alternative to disaster assistance to reduce the escalating costs of repairing damage to buildings and their contents caused by floods.

While participation in the NFIP is one important element of a town's efforts to mitigate flood hazards, supplemental tools to address the fluvial erosion component of flood damage, such as additional zoning restrictions to encourage or mandate avoidance strategies are essential.

When assessing the impacts of new development in Vermont, developers must go through the Act 250 permitting process which regulates and controls the utilization and usages of lands and the environment to ensure that the only usages that will be permitted are not unduly detrimental to the environment. When considering development adjacent to rivers and streams, for the purposes of Act 250 Criterion 1(D), the floodway limit shall be determined in consideration of inundation hazards as delineated by NFIP maps and in consideration of fluvial erosion hazards.

5.3.3 Municipal and State Enforcement

Once the towns adopt a corridor protection and channel management plan, then what? In terms of implementation, the State of Vermont is committed as a financial and technical assistance partner to ensure the recommendations detailed in the plan are seen to fruition. The most important partner to consider when implementing this plan, however, is the affected public. Riparian landowners and others involved with implementation of new land use regulations or ordinances related to fluvial erosion hazard zones, or other similar land use restrictions need to be educated about how the new zoning will apply to their lands. Education is an important first step before any enforcement is considered.

There must be a system in place to verify that the various protective zoning and flood ordinances being considered are complied with. On a local level, the town zoning officer can utilize existing authority to ensure compliance with new zoning regulations. Vermont's Act 250 can also be an effective compliance tool in achieving compliance with the new zoning regulations. The Natural Resources Board's enforcement program ensures compliance with Act 250. Act 250 enforcement investigations are handled by the district coordinators and Environmental Enforcement Officers throughout the State. The Act 250 permitting process related to development in floodways and adjacent to streams and shorelines is detailed below.

Before granting a permit, the district commission shall find that the subdivision or development: (1) Will not result in undue water or air pollution.

> *D) Floodways. A permit will be granted whenever it is demonstrated by the applicant that, in addition to all other applicable criteria:*
>
> > *(i) the development or subdivision of lands within a floodway will not restrict or divert the flow of flood waters, and endanger the health, safety and welfare of the public or of riparian owners during flooding; and*
> >
> > *(ii) the development or subdivision of lands within a floodway fringe will not significantly increase the peak discharge of the river or stream within or downstream from the area of development and endanger the health, safety, or welfare of the public or riparian owners during flooding.*
>
> *(E) Streams. A permit will be granted whenever it is demonstrated by the applicant that, in addition to all other applicable criteria, the development or subdivision of lands on or adjacent to the banks of a stream will, whenever feasible, maintain the natural condition of the stream, and will not endanger the health, safety, or welfare of the public or of adjoining landowners.*
>
> *(F) Shorelines. A permit will be granted whenever it is demonstrated by the applicant that, in addition to all other criteria, the development or subdivision of shorelines must of necessity be located on a shoreline in order to fulfill the purpose of the development or subdivision, and the development or subdivision will, insofar as possible and reasonable in light of its purpose:*
>
> > *(i) retain the shoreline and the waters in their natural condition,*
> > *(ii) allow continued access to the waters and the recreational opportunities provided by the waters,*
> > *(iii) retain or provide vegetation which will screen the development or subdivision from the waters, and*
> > *(iv) stabilize the bank from erosion, as necessary, with vegetation cover.*

Source: Act 250 Statute, Title 10: Conservation and Development, Chapter 151: State Land Use and Development Plans, § 6086.

Figure 5-1: Conceptual Berm Removal and Offset Project along the Roaring Branch.

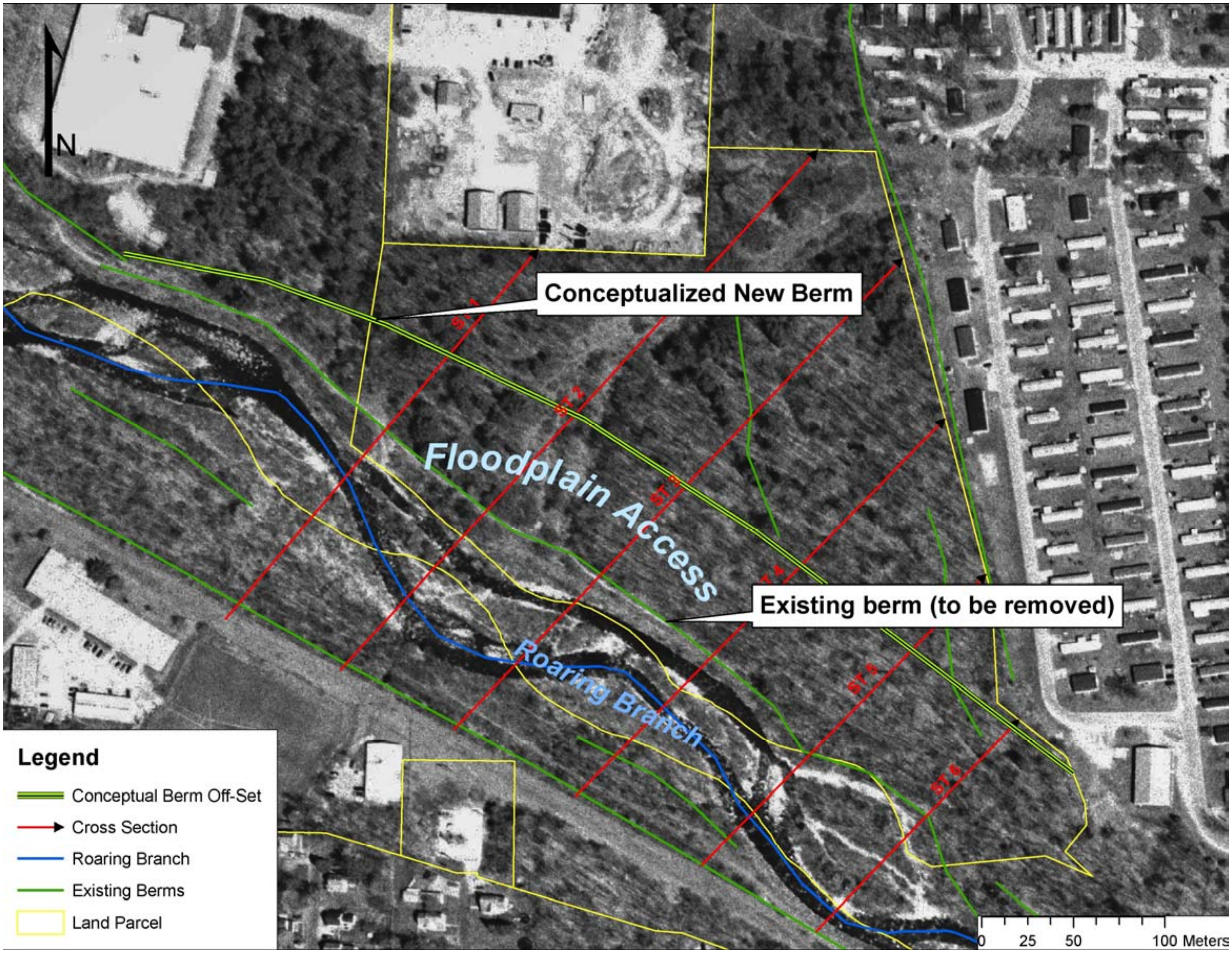
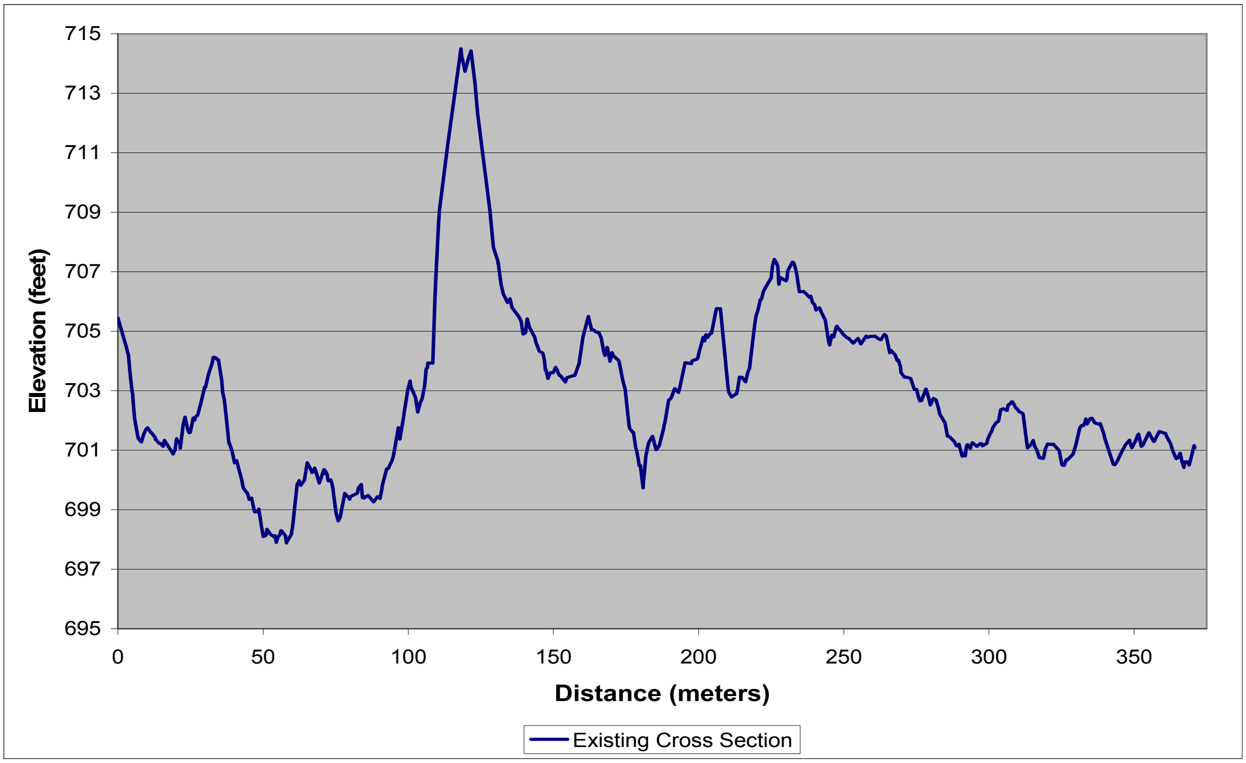
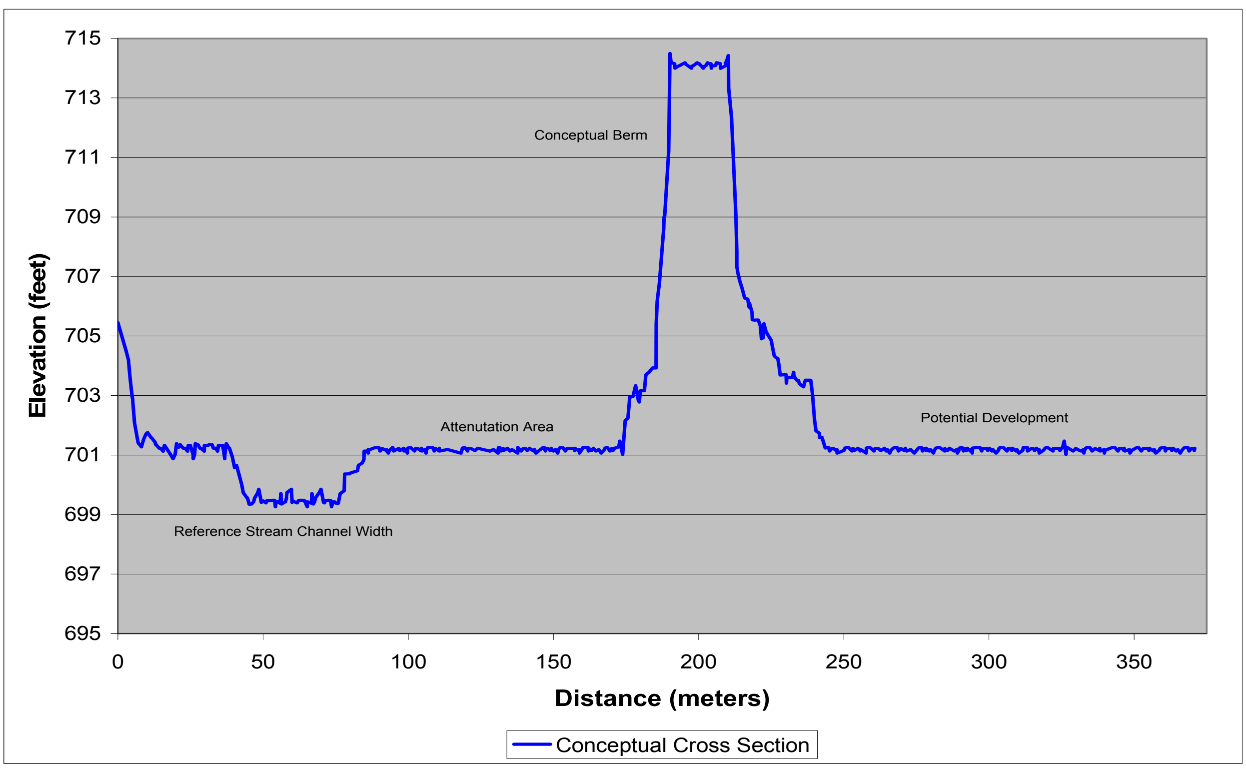


Figure 5-2: Town Garage Land – Conceptual Cross-Section through ST 2 after Berm Offset.





Note: X-axis in meters.

Figure 5-3: Hydraulics Comparison for ST 2 with and without Riverside Berm.

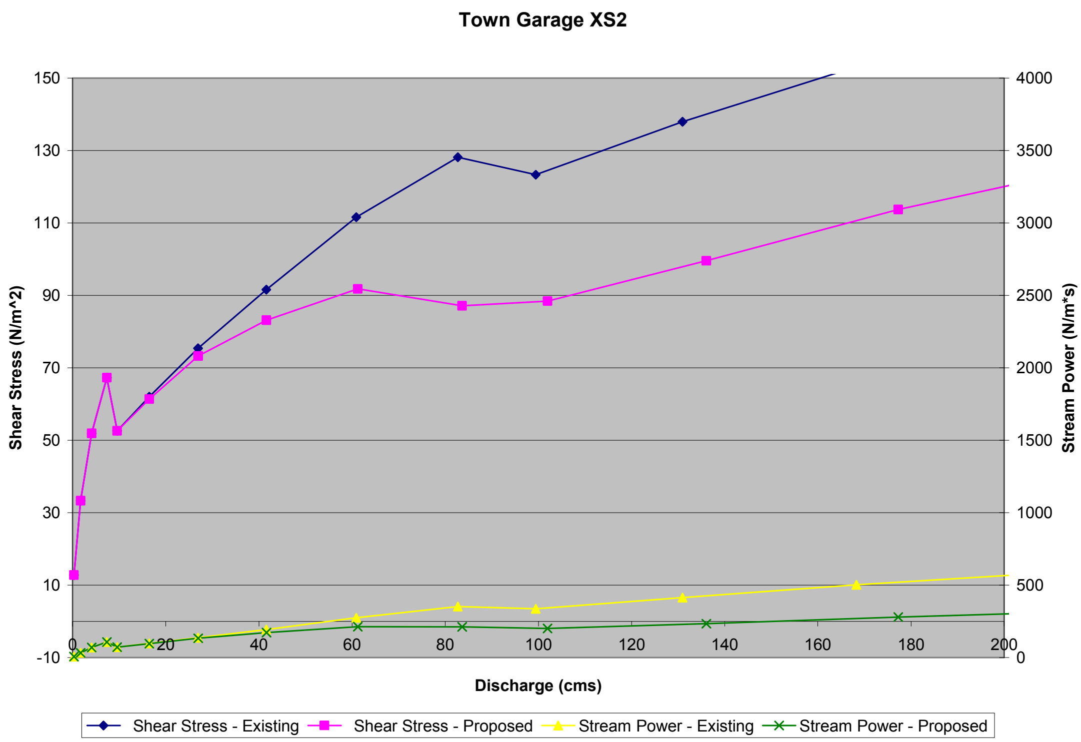


Figure 5-4: Hydraulics Comparison for ST 4 with and without Riverside Berm.

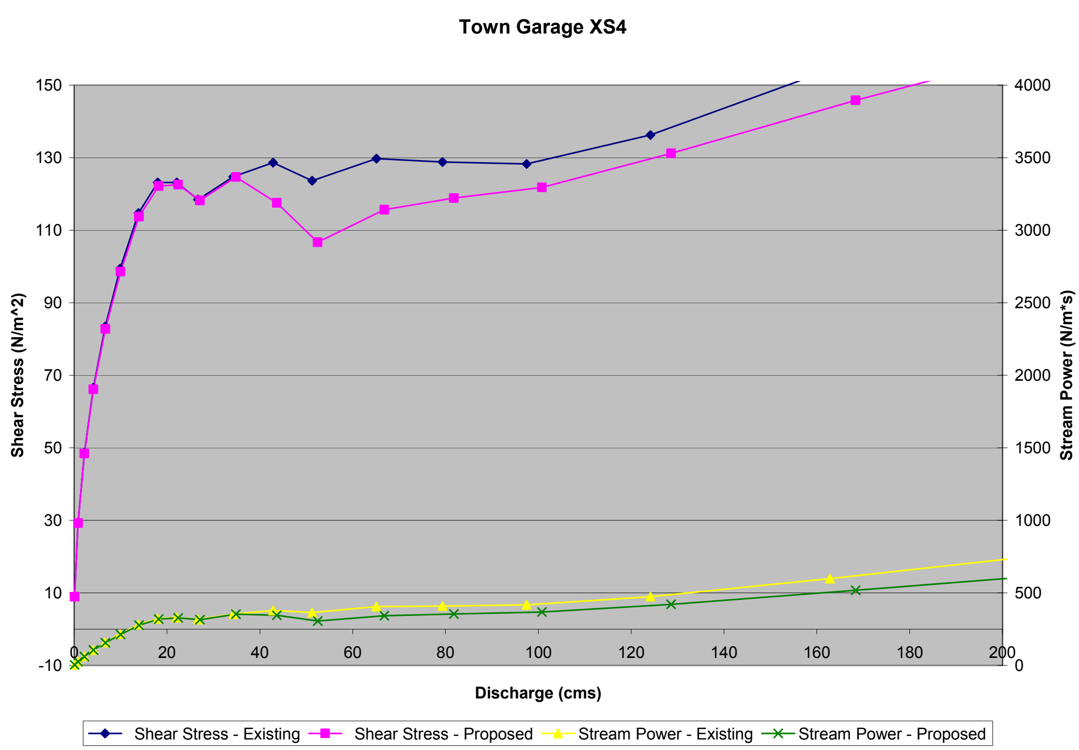


Figure 5-5: Eroding Bank Upstream of Park Street Bridge.

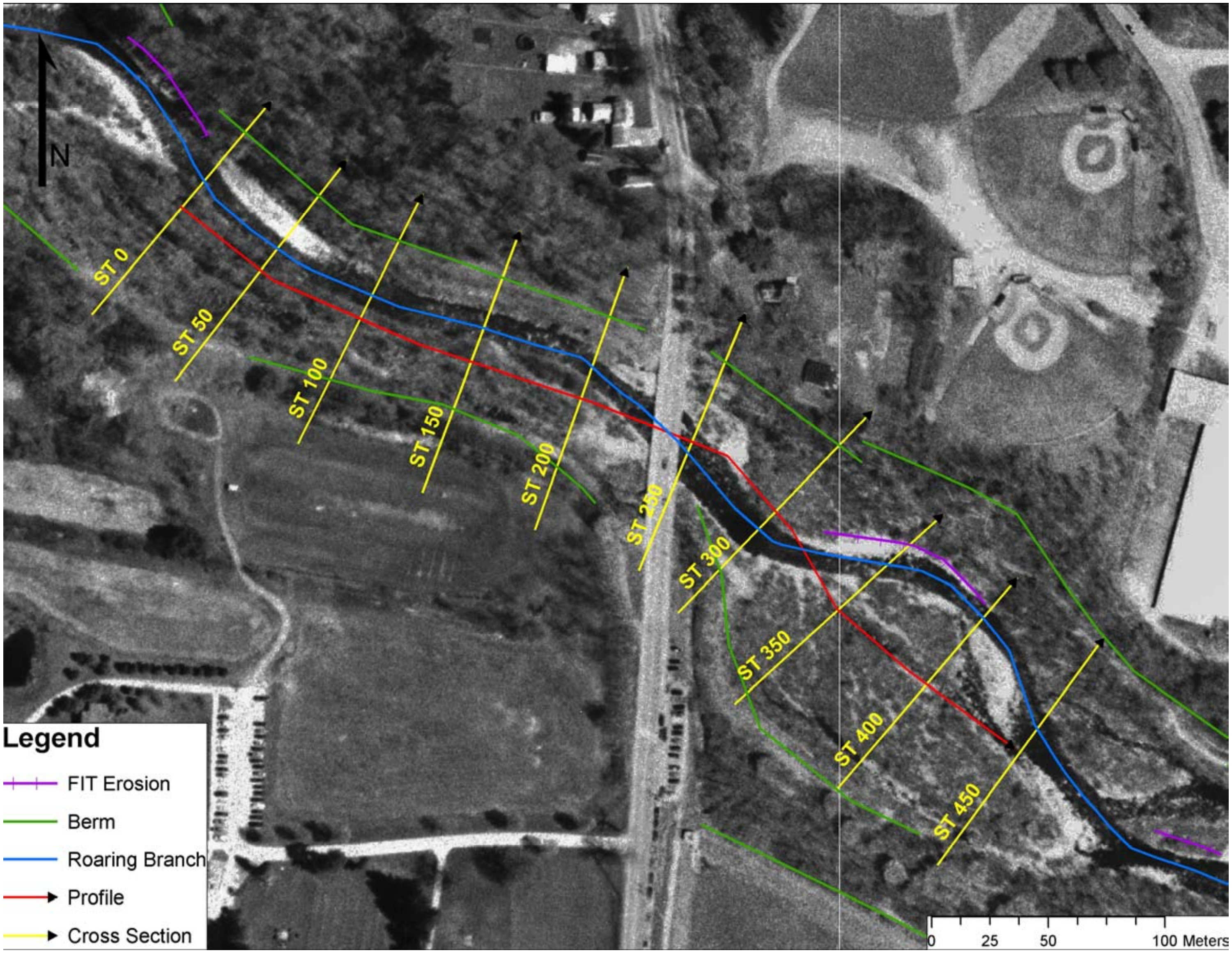
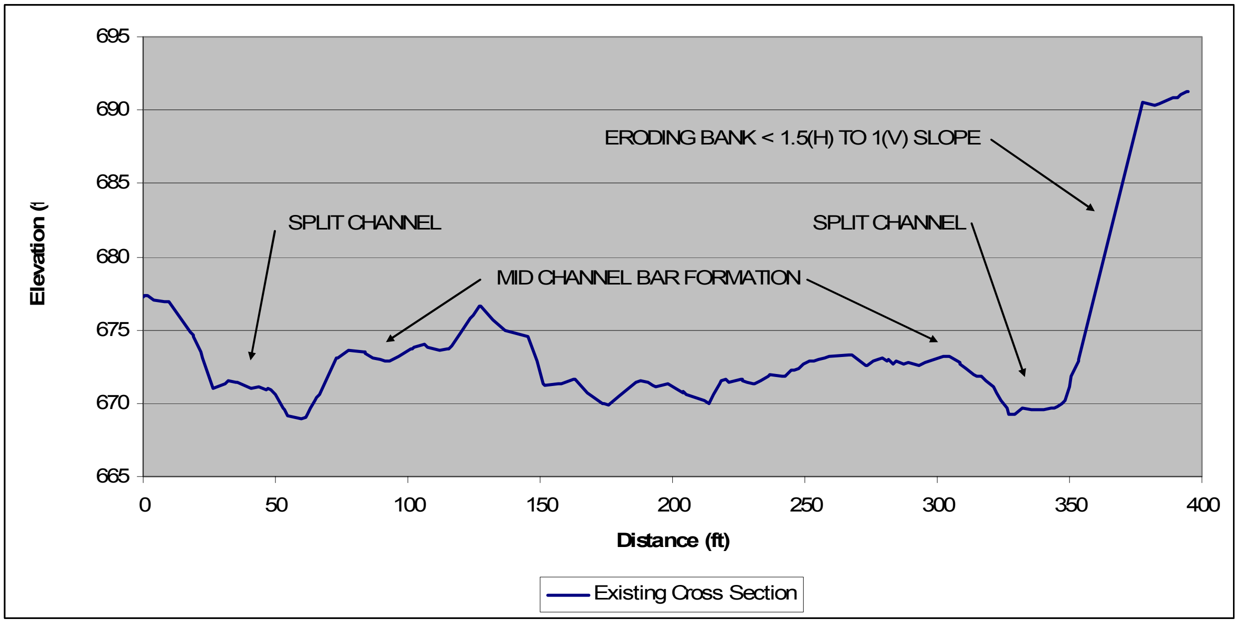
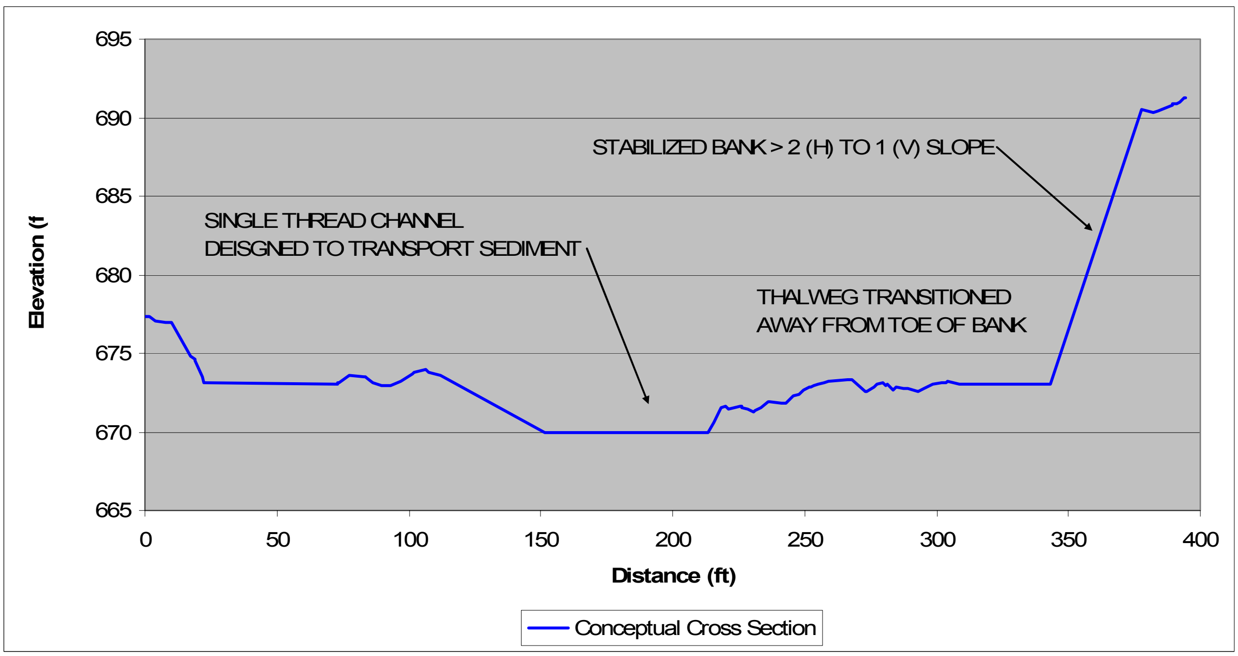


Figure 5-6: Bank Stabilization Upstream of Park Street Bridge - Concept Cross-Section ST 400.





Note: This conceptual cross-section can be applied to the areas upstream and downstream of Park Street bridge to facilitate sediment transport through the bridge opening.

Figure 5-7: Vegetated Protection Stone Toe Treatment with Bioengineered Slope Protection.

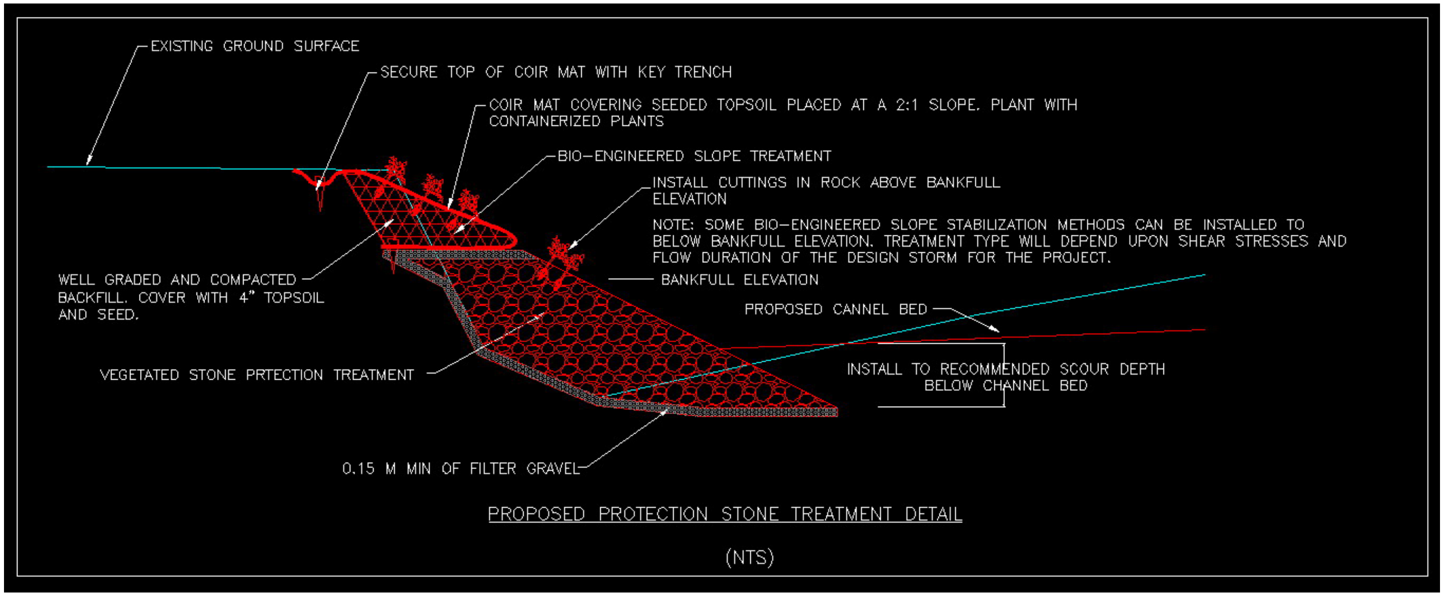
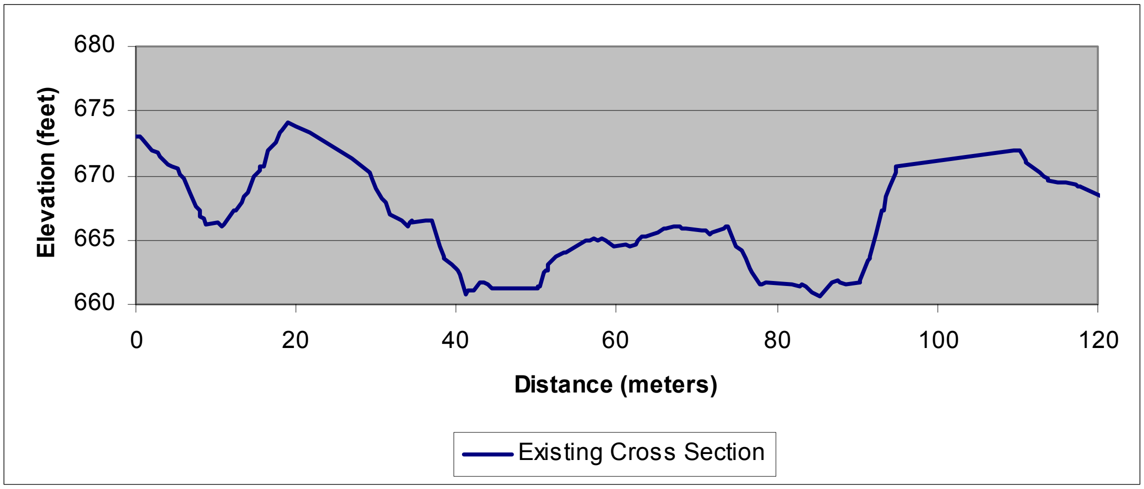
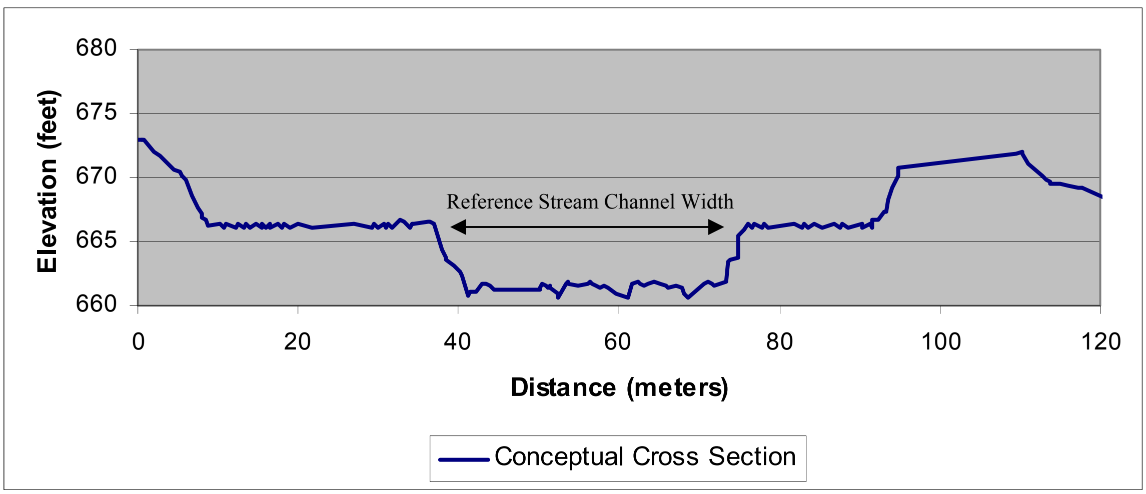


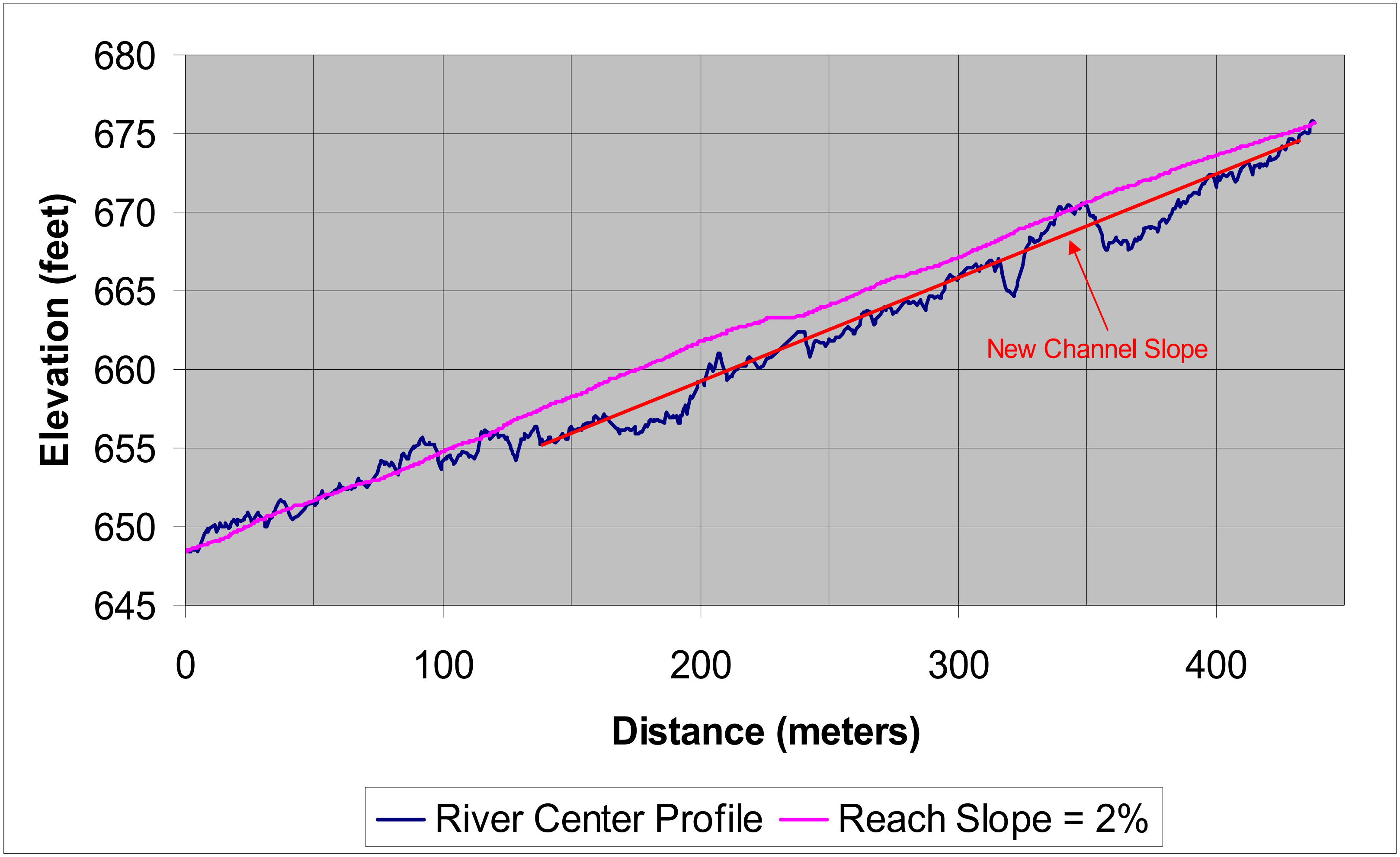
Figure 5-8: Park Street Bridge – Existing and Conceptual Cross-Section upstream of Bridge Opening (Station 300).





Note: X-axis in meters. See also Figure 5-5.

Figure 5-9: Existing and Conceptual Slope of Stream Channel through the Park Street Bridge.



Note: The LiDAR data provided channel slopes through the project area which allowed for an estimate of the upstream extent of the depositional features influenced by the bridge. Conceptual profile adjustments are shown in red above.

6.0 Conclusions

A fluvial geomorphic assessment of the Walloomsac River watershed identified the major geological and human conditions that control river processes and morphology. The Roaring Branch and Walloomsac rivers have historically presented extreme challenges related to erosion and flooding for the Town of Bennington. The Phase 2 assessment concluded that the river is in a state that has greatly departed from a stable condition and will therefore remain dynamic and pose a threat of further erosion and damage to property during flood events.

In this Corridor Plan, the locations, types, and sources of stream channel instability along the Roaring Branch and Walloomsac River are identified and considered during development of management options throughout the corridor. Historic manipulation of in-stream sediments and artificial constraints on natural planform adjustment are the primary reason for the instability. The river system contains a large sediment supply and the presence of the numerous berms has only resulted in constraining stream energy, which in turn has led to accelerated rates of change in channel form.

In this plan, a series of management measures are presented to guide the decision-making process related to mitigating fluvial erosion hazards in the corridor. Two specific projects of floodplain reconnection and bank stabilization/restoration of aggraded reach were presented as conceptual solutions that may be applied to problems areas anywhere in the corridor. The actual implementation of watershed-scale restoration activities (e.g., corridor protection, berm removal, and bridge maintenance) will require considerable stakeholder involvement, so all interested parties understand the potential value accrued in making short-term sacrifices in order to achieve sustainable erosion and flood hazard mitigation.

The corridor protection efforts must focus on the protection of floodplain assets where sediment can be stored and flow energy dissipated, thereby reducing sediment loading and erosion hazards along the Roaring Branch and the Walloomsac River. Many opportunities still exist in the watershed for creating attenuation areas. If development is allowed to encroach into these areas, many of the highest priority restoration sites in the watershed could be permanently lost.

All of the selected projects for this report are valuable projects with respect to managing and implementing a holistic restoration of the Roaring Branch and Walloomsac watersheds. If a project has a low ranking priority, it is still worthy of consideration at any time in the near future. It is also worth noting that some projects have two or more restoration actions needed to restore the site. In some cases, the prioritization for each action may be widely spread. The prioritization hierarchy is not a marching order of projects meant to be taken one before or after the other. It is simply a relative scale to help managers understand whether the project under consideration falls near the top, middle or bottom of the 31 projects presented for this analysis.

The high priority restoration actions should be implemented over the next one to five years in an incremental fashion—particularly those identified as potential attenuation assets. High-priority erosion sites, for example, can be addressed immediately upon funding availability. Lower priority and undetermined asset areas can then be addressed given resource availability. The implementation of process-based restoration solutions will eventually reduce or minimize the need to pursue short-term and "maintenance-type" solutions.

7.0 References

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Appendix A: Berms within the Walloomsac River Corridor

Appendix B: Bed Profiles and Cross-Sections through Roaring Branch Bridges

Appendix C: Fluvial Erosion Hazard Zone Maps

Appendix D: Cross-Sections through Potential Roaring Branch Restoration Areas

Appendix E: Reach-Specific Cross-Sections

Appendix F: Reach Scale Stressor Maps