Vermont Agency of Natural Resources
River Corridor Planning Guide

to Identify and Develop
River Corridor Protection and Restoration Projects

River Management Program
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Author's Note: This is the second edition of this Guide, and it remains a work in progress. We continue to learn everyday, how to implement a science-based river corridor protection and restoration program at the state level of government. The work is both challenging and rewarding. If you would like to see and read a few corridor plans developed using the first edition of this Guide go to: https://anrnode.anr.state.vt.us/ssl/sga/finalReports.cfm

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Vermont ANR River Corridor Planning Guide: Identifying and Developing River Corridor Protection and Restoration Projects

1.0 Introduction

River corridor planning is conducted in Vermont to address the river instability that is largely responsible for erosion conflicts, increased sediment and nutrient loading, and a reduction in river habitat. The Vermont River Management Program (RMP) has developed this Guide to facilitate an understanding of river channel adjustments and the establishment of well developed and appropriately scaled projects and strategies to protect and restore river equilibrium. This corridor planning guide provides the:

- river science and societal benefits of managing streams toward equilibrium conditions;
- methods for assessing and mapping stream geomorphic conditions;
- methods for creating strategies to address different channel and watershed stressors;
- methods for identifying and prioritizing river corridor protection and restoration projects; and
- methods for examining project feasibility and negotiating management alternatives.

This is a technical guide. It is primarily directed toward river scientists, planners, and engineers engaged in finding economically and ecologically sustainable solutions to the conflicts between human investments and river dynamics. Throughout the document, the RMP provides scientific background and references that may also help interested lay people, i.e., those within watershed associations and river stakeholder organizations who wish to increase their understanding of watershed science and how to pursue meaningful river projects.

River corridor planning is recommended as a component of watershed planning and is structured to achieve specific river management goals and objectives (see text below). Through technical support of project identification and development, the RMP hopes to engage, support, and cost share project implementation with its partners. This cooperation will support a common understanding of current stream and watershed conditions and a more unified commitment to the benefits derived from a fluvial process-based program.

The goal of this River Corridor Planning Guide is to assist the State and its partners in managing toward, protecting, and restoring 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.

The objectives include:

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

1.2 What are Fluvial Geomorphic Equilibrium Conditions?

Fluvial geomorphic equilibrium is the condition in which a persistent stream and floodplain morphology is created by the dynamic processes associated with the inputs of water, sediment, and woody debris from the watershed. Fluvial processes derive within a consistent climate and are influenced by topographic and geologic boundary conditions. When achieved at a watershed scale, equilibrium conditions are associated with minimal erosion, watershed storage of organic material and nutrients, and aquatic and riparian habitat diversity.

Equilibrium: a Balance between Fluvial Process and Channel Form

The physical attributes of a stream channel are composed of watershed inputs, which are water, sediment and organic debris. The discharge regimes (i.e., runoff volume, rate, and duration) of these input materials into the stream channel, both laterally and longitudinally, are influenced by the characteristics of the valley within which the river is located, including valley width and slope, bedrock and surficial geology, soils, and vegetation. Collectively, the fluvial processes associated with water, sediment, and debris runoff determine the shape or morphology of the river and floodplain, including: dimension (channel width and depth), pattern (meander planform), profile (channel slope), and bed forms (scour and deposition features). Persistent channel morphology is developed and maintained over time by the channel forming flow and the sediment produced by the watershed. The channel forming flow, also called the bankfull flow, is approximately the average annual high water event, which, by virtue of its frequency, does the greatest amount of "work" on the channel and floodplain and transports the greatest volume of sediment over time.

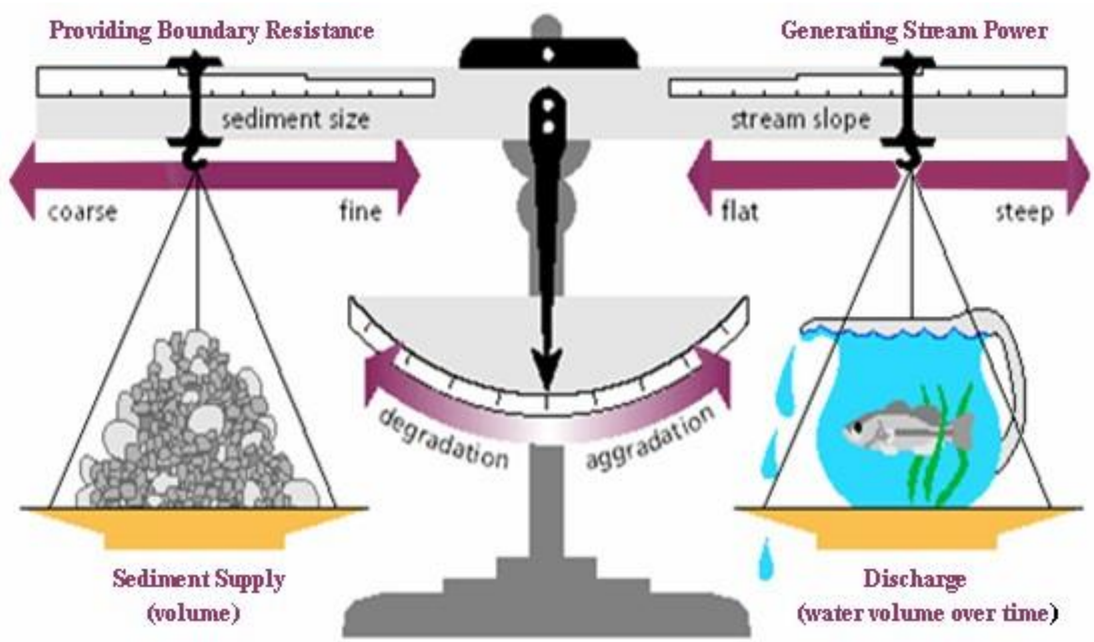


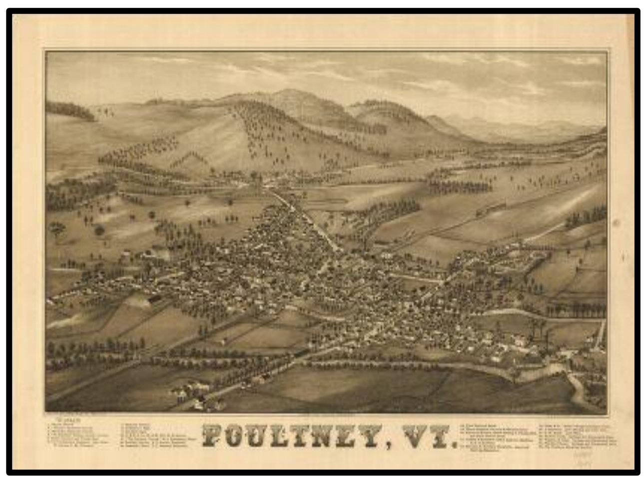
Figure 1 Lane's Balance of: Sediment Supply & Sediment Size with Slope & Discharge (Lane, E.W. 1955. "The Importance of Fluvial Morphology in Hydraulic Engineering." In Proceedings of the American Society of Civil Engineers 81(745): 1-17.) Reproduced by permission of the American Society of Civil Engineers.

Figure 1 illustrates how water volume, sediment volume, sediment particle size, and the slope of a river channel are naturally balanced (Lane, 1955). 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. For example, rapid urbanization of a watershed has been shown to increase peak runoff such that a river channel receives a greater volume of water more frequently. The diagram above illustrates that an increase in the river's water volume would tip the scale downward on the right. The river will respond by degrading until either the volume and/or size of sediment (along the channel boundaries) increases enough to bring the scale (river channel) back into balance.

It is the physical imperative of a stream channel to undergo adjustments until it reaches equilibrium, and becomes in balance with its watershed inputs. Using the fundamental equation offered by Lane, one can begin to understand how different land uses or management activities “tip the balance.” Land use patterns, especially those within or adjacent to riparian corridors, which significantly alter the runoff patterns of water and/or sediment, will elicit a channel adjustment process. When these processes change the relationship of the river with its floodplain (by aggrading or degrading the channel bed), it becomes increasingly difficult to plan for, as well as expensive to maintain, those land uses.

Streams in equilibrium may still erode their banks, migrate over time across their valleys, and periodically experience small-scale lateral and/or vertical adjustments. Even with these changes, a stream will remain in equilibrium as long as the channel form (dimension, pattern, and profile) is consistent with the processes inherent in the runoff and inputs of water, sediment, and organic debris at a given point in the watershed continuum (from highlands to lowlands).

Climate change, geologic events, and major storms affect the flow of water, sediment, and debris and change the shape of river channels. Natural adjustments in river channel and floodplain geometry occur continually until dynamic equilibrium is reestablished. These adjustments, however, have been greatly altered during the past two centuries in Vermont by human-imposed changes to the depth and slope of rivers related to intensive watershed and riparian land uses. Nearly every Vermont watershed has streams “in adjustment” from the following sequence of events:



Deforestation – led to dramatic increases in the volume of water and sediment runoff (McGrory Klyza and Trombulak, 1999). Channels aggraded and floodplains were buried by a meter or more of sediment, much of it glacial lake sediments that had yet eroded from higher on the valley perimeter. As watersheds reforested, channels eroded back down through these materials, but terraces, inaccessi- ble to the rivers, remain as a legacy to statewide deforestation.

Snagging & ditching – clearing boulders, beavers, and woody debris to increase channel efficiency and sluice logs from headwaters to village mill sites. Extensive ditching was conducted to drain wet soils for agriculture. Many pristine-looking mountain streams in Vermont contain only a fraction of their former channel roughness and resistance, and store far less sediment and debris.

Villages, farms, roads, and railroads – early settlements led to the first attempts to channelize rivers and streams, resulting in increased channel slope, stream bed degradation (incision), and floodplain encroachments. Drainage Societies were started over 100 years ago to straighten and channelize streams to accommodate farms and early settlements. These channel works have been periodically maintained through gravel removal, realignment, channel armoring, and extensive flood remediation projects.

Mills, dams, and diversions – led to alterations in the amount and rate of water and sediment runoff. While dozens of dams are in place in each Vermont watershed today, historically there were hundreds. The small mill ponds of yesteryear have been replaced by larger dams used for hydroelectric generation and impoundments for flood control.

Gravel removal – advocated as a way to maintain straighter, deeper channels and control flooding. Large-scale gravel mining resulted in bed degradation, head cutting, channel over-widening, and severe bank erosion. The interstate highways, state roads, and thousands of miles of dirt roads in Vermont were built on materials commercially extracted from the State's rivers.

Encroachments, stormwater, and urbanization – have resulted in increased impervious surfaces and ditching to support economic development. Land use conversions have increased the rate and volume of water relative to sediment runoff, thereby contributing to channel incision and enlargement. Development and use of lands previously occupied by river meanders or inundated during floods has created unrealistic and unsustainable human expectations in the absence of continuous or periodic channel management activities.

The cumulative effect of these human-related stressors has been varying degrees of vertical channel adjustment. Vermont streams are still evolving from significant channel bed degradation and loss of floodplain function. Channel incision, and the anthropogenic stressors that have accelerated the channel down-cutting process, are being documented by river scientists worldwide. Simon and Rinaldi (2006) described channel incision as the "quintessential feature of dis-equilibriated fluvial systems."

Rivers are in a constant balancing act between the energy they produce and the work that must be done to convey the runoff of sediment and debris produced in their watersheds. The slope and depth of a river dictate how much transporting energy it contains. For example, a wide and shallow river will have less energy than one that is narrow and deep, resulting in a lower capacity to move sediment. During large runoff events, the widened river channel may aggrade, filling with gravel. On the other hand, a steep or high gradient river will have more energy than one of lower gradient, resulting in a greater capacity to move sediment. River channels that have become significantly steeper will often degrade, eroding bed and banks, then widening and aggrading until the meanders and floodplains necessary to expend the excess energy have been established. Balance or equilibrium is achieved through adjustment of channel dimensions and longitudinal slope, and channel elevation relative to the floodplain.

When a natural stream achieves an equilibrium depth and slope, the channel geometry is primarily maintained by the boundary conditions established by coarse sediment on the bed and/or the soil cohesiveness and soil binding attributes of vegetative root systems on the banks. When these stabilizing influences are disturbed, the resistance of the bed and bank to the erosive power of the stream is largely diminished. Grade control structures and rip-rap have been used on streams to replace boulder steps, cobble riffles, and the deep, soil binding roots of trees and shrubs. These structures work but are not self-maintaining or replenishing like the boundary materials of naturally stable streams, and thus, must be periodically maintained. Human-placed boundary conditions may work for many years where the channel and floodplain geometry are in equilibrium. When the stream is undergoing large-scale longitudinal slope adjustments and planform changes, however, human-engineered structural con- straints may initiate other deleterious channel adjustments or fail during the next flood.

Floodplain Access and Channel Evolution

When stream channels contain significantly greater flows, the increase in stream power must be resisted by the channel boundary materials. Depending on the type of channel boundary, the effects of disconnecting a channel from its floodplain may be varied. Channel evolution models (CEMs) published by Schumm (1969 and 1984), Thorne, Hey, and Newson (1997), and Simon and Rinaldi (2006) help to explain a stream channel's response to losing its floodplain. *Figure 2* shows the response at the channel cross section. Channel evolution may also result in profound physical adjustments upstream and downstream from the site of alteration, in the form of bed degradation (head cuts) migrating upstream through the system, and bed aggradation, in the form of sedimentation, occurring downstream.

It is important to recognize the temporal aspect of channel response to change. Fluvial systems are energized by episodic events. Channel adjustment in response to land use practices or floodplain encroachments may begin immediately and persist for decades, depending on the sensitivity and morphology of the affected stream, the magnitude of alteration, and the frequency of high flow events. The channel evolution stages related to channel incision (bed degradation) and widening might occur within a few months to a few years; but stages associated with plan form adjustment and floodplain redevelopment might not reach completion for decades.

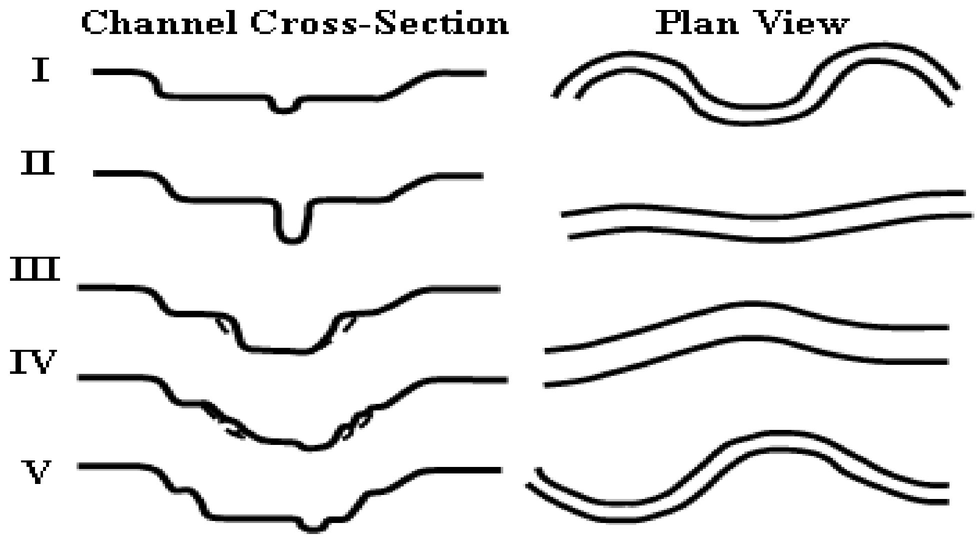


Figure 2 Channel Evolution Process showing channel down-cutting or incision in Stage II, widening through Stages III and IV, and floodplain re-establishment in Stage V. Stages I and V represent equilibrium conditions. Plan view shows straightening and meander redevelopment. Channel evolution is a flood-driven process that typically takes place over decades.

Of the many surface water management deficiencies of the 20th century, the failure to understand, protect and preserve the access of rivers to their floodplains has directly resulted in some of the most intractable conflicts between human investments and river system dynamics being experienced today. Over the last century, many miles of Vermont's rivers have been subjected to channel management practices such as armoring, dredging, gravel mining and channelization, for the purpose of containing high flows in the channel and to protect human investments built in the historic floodplains. Following, and in support of the land drainage and damming practices started during the 19th century, structural controls and loss of floodplain access are largely responsible for stream disequilibrium in Vermont today.

1.3 Why Manage Toward Equilibrium Conditions

Stream geomorphic assessments completed in Vermont are telling a recurring story – traditional land use patterns, river management, and flood recovery efforts have led to the straightening, steepening, and a down-cutting of rivers. Since European settlement, repeated channel dredging, snagging, berming and armoring have led to a widespread loss of flood plain function (*Figure 3*). The increased power of larger floods, contained within the channel, has led to higher rates of bed and bank erosion. The millions spent annually in Vermont to keep rivers straightened and static in the landscape, has become unsustainable leading to ever-increasing erosion hazards and flood losses. River management has become a vicious cycle where flood recovery and structural constraints have led to increased encroachments and land use investment where rivers formerly meandered and accessed their floodplains. Inevitably, and often decades later, a large flood occurs and the cycle repeats itself.

If this cycle is not broken, land-based enterprises will suffer economically because, in addition to erosion hazards, channelization leads to a loss of sediment storage and a net export of life-giving soil and nutrient from a watershed. Despite the barriers placed in their way, it is the physical imperative of rivers that have down cut and lost access to their floodplains, to erode their banks until new floodplains are formed. During the early stages of this channel evolution process, floods remain within deepened channels, and have much more power to erode and carry away anything that enters them. Without floodplains and meanders, it is often the lakes and reservoirs that are the first quiet waters in which rivers deposit the eroded soil and nutrient. This process helps to explain the increasing enrichment and algae along the shores and bays of Lake Champlain.

Under natural conditions, periodic flood-related disturbances create and maintain the tremendous habitat diversity within aquatic and riparian ecosystems (Allen, 1995). Disruption of flood cycles and the widespread physical manipulation of rivers are major factors in the decline of aquatic ecosystems worldwide (Abramovitz, 1996). Despite the success in treating wastewater discharges, the challenge remains to develop alternatives to maintaining channelized streams for flood and erosion control, and protect existing functional riparian corridors from degradation and loss. Human channel works, and the energized, sediment transport-dominated conditions they create, degrade habitat by continually removing the structure and complexity in river ecosystems. The physical watershed processes that create and maintain stream, flood- plain, and riparian habitat have been altered over a vast ma- jority of the Vermont landscape.

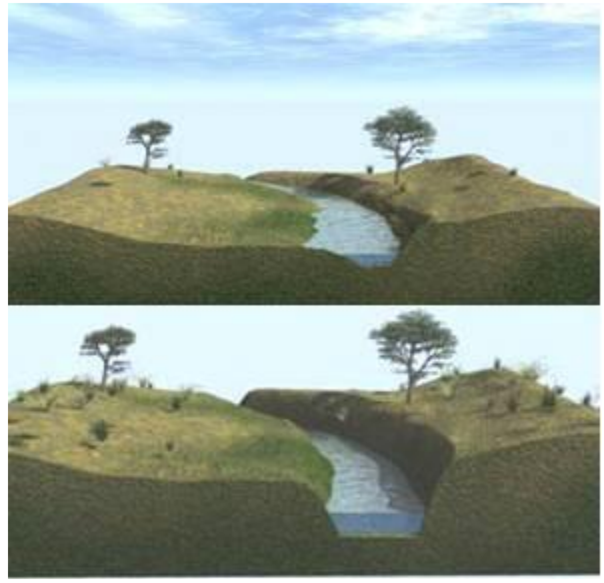


Figure 3 Loss of critical flood prone width when a river undergoes channel down-cutting.

Vermont river assessments to date show significant losses in the flood and sediment attenuation and organic and nutrient retention where rivers have been straightened and lack access to floodplain. The profound degradation of these ecological services has resulted in an increase in fluvial erosion hazards (i.e., flood damage), an upward trend in sediment, soil, and nutrient export from Vermont watersheds, and a downward spiral of the social, economic, and ecological sustainability of riparian ecosystems.

The goal of managing toward, protecting, and restoring the fluvial geomorphic equilibrium condition of Vermont rivers is to resolve conflicts between human investments and river dynamics in the most economically and ecologically sustainable manner, thereby enabling the State and its partners to achieve multiple objectives:

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

While it is encouraging that multiple objectives may be achieved through a single management paradigm, any effort to restore stream equilibrium conditions must recognize the land use investments within river corridors and the livelihoods which may depend on those uses. State and federal initiatives should mitigate, find replacement value, or compensate for the short-term costs associated with the long-term societal benefits of river corridor lands conservation. Where there is neither the will nor the means to recognize these current investments, the cost of post-flood remediation and property protection will remain high in perpetuity. Changing land use expectations may take generations to accomplish. The long term challenge is to have more predictable investments with less erosion and healthier aquatic ecosystems, while minimizing short term economic losses along the way. In reality, the social, economic, and ecological return for implementing river corridor management practices that work toward equilibrium at the watershed scale will be largely enjoyed by generations to come.

1.4 How Will Vermont Manage Toward Equilibrium Conditions

In order to manage toward and restore stream equilibrium, there must be an analysis and understanding of:

- Reference conditions, i.e., what are the equilibrium conditions for a particular stream reach?
- Existing conditions, i.e., how far has the reach departed from equilibrium? , i.e., (stage of channel evolution and current adjustment phase)
- Stressors, i.e., what natural or anthropogenic factors are likely to be causing dis-equilibrium?
- Management Alternatives, i.e., what strategic protection and restoration activities would reduce stressors and be compatible with or accelerate the river's adjustment back to equilibrium?

"Reference" condition is the fluvial processes and geomorphology that would persist given the climate, geology, and vegetative characteristics of a given valley. Understanding reference makes it possible to evaluate the watershed and reach-scale stressors which explain departure from reference and predict the sensitivity of "existing" conditions. Stressors are those changes in the forces which maintain balance (*see Figure 1*) and elicit stages of channel adjustment as it evolves or returns to equilibrium conditions (*see Figure 2*). Mapping the departure and sensitivity of reaches in the context of vertical and lateral channel constraints (which may impede adjustments) throughout the stream network can explain the type and rate of channel evolution processes underway, and how adopting certain management strategies may accommodate, preserve, or restore equilibrium conditions over time.

1.4.1 Stream Geomorphic Assessment

The Vermont ANR Stream Geomorphic Assessment protocols help river planners and managers take the first steps in applying channel form, adjustment process, and channel evolution data. The protocols provide a method for assigning a geomorphic and physical habitat condition to stream reaches. The term "departure from reference" is used synonymously with stream geomorphic condition.

The degree of departure is captured by the following set of terms:

At or Near Equilibrium – a stream reach in reference and good condition that:

- Is in or near a dynamic equilibrium which involves localized change to its shape or location while maintaining the fluvial processes and functions of its watershed over time and within the range of natural variability; and
- Provides high quality aquatic and riparian habitat with persistent bed features and channel forms that experience periodic disturbance as a result of erosion, deposition, and woody debris.

In Adjustment – a stream reach in fair condition that:

- Has experienced changes in channel form and fluvial processes outside the expected range of natural variability; may be poised for additional major adjustments with future flooding or changes in watershed inputs that would change the stream type; and
- Provides aquatic and riparian habitat that may lack certain bed features, cover types, and connectivity due to obstructions and/or increases/decreases in the rate of erosion and deposition-related processes.

Active Adjustment and Stream Type Departure – a stream reach in poor condition that:

- Is experiencing adjustment outside the expected range of natural variability; is exhibiting a new stream type (fluvial processes and morphology); is expected to continue undergoing major adjustments, either evolving back to the historic reference stream type or to a new stream type consistent with watershed inputs
- Provides aquatic and riparian habitat that lacks certain bed features, cover types and connectivity due to obstructions and substantial increases/decreases in the rate of erosion and deposition-related processes. Habitat features may be frequently disturbed beyond the range of many species' adaptability.

Geomorphic condition helps with the prioritization of protection and restoration projects at the watershed scale. Data queries of reach conditions upstream and downstream of project locations may be invaluable to solving issues related to watershed hydrology, changes in sediment supply, and large scale channel adjustments.

Every stream changes in time. Geomorphic assessments include the assignment of stream sensitivity ratings to acknowledge that some streams, due to their setting and location within the watershed, are more likely to be in an episodic, rapid, and/or measurable state of change or adjustment. A stream's inherent sensitivity may be heightened by human activities. The parameters used in the ANR Stream Geomorphic Assessment Protocols to rate sensitivity include:

- the erodibility of the channel boundary materials
- sediment and flow regimes (volume and runoff characteristics)
- the confinement and slope of the valley
- the degree of departure from reference conditions observed both in the study reach and in adjacent reaches

Streams that are adjusting vertically, i.e., degradation or aggradation, may become acutely sensitive. Defining sensitivity has value in communicating the "rate of change" associated with adjustment and channel evolution processes. For instance, a reach rated as highly sensitive due to relatively large loadings of small-sized sediment would potentially exhibit a more rapid adjustment rate than another reach of the same type but rated as having a low to moderate sensitivity. Understanding the sensitivity of a reach can inform how the stream might react to different river management alternatives.

1.4.2 Physical Habitat Assessment

Managing toward stream equilibrium conditions is critically important to aquatic and riparian ecosystem sustainability. Addressing the stressors which alter the fluvial processes and geomorphology of a stream network may restore the physical attributes of aquatic life cycle requirements, such as critical shelter, foraging, and reproductive habitat components within different stream types. The Vermont ANR Reach Habitat Assessment (RHA) data are used to explain how adverse impacts or the loss of these components may degrade ecosystem health. Key life cycle requirements provide a basis for categorical bio-physical stressor evaluations.

The fluvial geomorphic-based RHA is conducted to understand and explain how adverse impacts to physical processes limit the development and maintenance of critical habitat components and reduce habitat diversity. The following key physical attributes provide a basis for categorical bio-physical stressor evaluations, threat analysis, and remediation strategies:

- **Hydrologic Regime** – the timing, volume, and duration of flow events throughout the year and over time, which may be influenced by the climate, soils, geology, groundwater, watershed land cover, connectivity of the stream, riparian, and floodplain network, and valley and stream morphology.
- **Sediment Regime** – the size, quantity, sorting, and distribution of sediments, which may differ between stream types due to their proximity to different sediment sources, their hydrologic regime, their stream, riparian and floodplain connectivity, and valley and stream morphology.
- **Large Wood and Organics Regime** – the diversity, quantity, and physical retention of organic material available for biological uptake and physical refugia (moderating the expenditure of energy), which may be influenced by the primary productivity within the stream channel and riparian zone, watershed and floodplain connectivity, the hydrologic regime, and the stream and valley morphology.
- **Temperature Regime** – the daily and seasonal instream water temperatures influenced by climate, riparian canopy, hydrologic regime (particularly groundwater components), and valley and stream morphology and aspect.
- **Stream, Riparian, and Floodplain Connectivity** – the unimpeded movement of materials (water, sediment, and organic material) and organisms both longitudinally up and down the watershed and vertically between the stream channel and its riparian area and floodplain.

Resource managers require biological data (response indicators) to determine impairments and directly monitor the effectiveness of management practices. They also require an evaluation of ecosystem stressors to understand the cause of the impairment and devise and implement effective watershed management plans. The same physical stressors which alter equilibrium conditions degrade ecological processes and lead to biological stress. The ANR stream reach habitat assessment protocols (Schiff et al., 2008) will guide effective management strategies to eliminate or reduce human stressors of the physical stream environment.

1.4.3 Project Identification and Development

River managers and conservation organizations have traditionally treated symptoms of erosion rather than address the underlying problems which may be causing stream disequilibrium. This planning process is intended to improve and streamline the watershed and reach-scale analyses required to implement projects which are at least part of a more comprehensive set of treatments and strategies to restore stream equilibrium. The project identification is preceded by the analysis and mapping of physical stressors and natural or human constraints. Project development is broken down into technical and social components of project feasibility.

Stressor Identification

To effectively address disequilibrium at different scales, it is imperative to examine watershed and reach-scale stressors and explain the departure (from reference) and sensitivity of existing conditions. Mapping the departure and sensitivity of reaches in the context of vertical and lateral channel constraints throughout the stream network can explain the type and rate of channel evolution processes underway, and how adopting certain management practices can accommodate, preserve, or restore equilibrium conditions over time.

Degraded sites where people want or need to resolve conflicts rarely result from stressors borne solely within the reach. The erosion, the physical habitat degradation, the threat to public and private investments are more likely the result of multiple stressors related to changes in flow, sediment supply, or channel and floodplain modifications outside the affected reach. This Guide will suggest methods for mapping and analyzing the following set of watershed and reach scale stressors:

Watershed Stressors

- ***Hydrologic Alterations* -** deforestation; urban land use; storm water inputs; diversions, dams, and dam operations; wetland loss; and road and ditch networks

- ***Sediment Load Alterations* -** Hydrologic alterations; crop land uses; bed and bank erosion; upstream/downstream sediment regime changes; mass wasting sites; and gullies.

Channel Stressors

- ***Channel Slope Modifiers* -** straightening and channelization; grade controls; stream crossings and channel constrictions; and river corridor encroachments

- ***Channel Depth Modifiers* -** berms and road/railroad embankments; delta and backwater deposits; and gravel mining and bar scalping (many of these factors affect channel/flood plain connectivity)

- ***Boundary Condition and Riparian Modifiers* -** riparian vegetation; bank armoring and active bank erosion; grade controls; and historic snagging and windrowing.

Managing toward equilibrium conditions and successfully implementing projects at the local scale will require consideration of watershed-scale changes. The physical condition of Vermont rivers is the result of over 200 years of channel and watershed manipulation, deforestation, and floods. Nearly every contemporary management decision should be made in this context and weigh alternatives based on larger spatial and temporal considerations. The stressor ID process should strive to explain cumulative impacts. In so doing, the corridor plan may set priorities for treating the multiple stressors that have altered the geometry and physical characteristics of streams.

By mapping stressors, an analysis of which stressors are eliciting a physical response may be conducted. A list of stressors affecting each reach may then be developed to understand cumulative and potentially counter-balancing forces. Human activities or conservation practices may then be applied to alleviate identified stressors or work in concert with natural forces driving a river reach toward equilibrium.

Constraints to Sediment Transport and Attenuation

Natural and human-imposed features which require specific attention in the project identification process are the vertical and lateral constraints which affect 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 affect on existing channel form and process is the first step. The feasibility of removing constraints (either actively or passively) then becomes a central part of the project identification and development process.

Defining and protecting the meander belt width corridor that will accommodate equilibrium conditions may be the most important objective in any river restoration project.

In nearly every Vermont watershed, there will be 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 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.

Hydrologic changes and the constraints associated with channelization, designed to increase water and sediment transport, have so pervasively altered fluvial processes, that river corridor planning will need to identify counterbalancing measures. The protection of “key attenuation assets” would be one such measure. Attenuation areas are riparian floodplains, wetlands, and vegetation, connected to geomorphically sensitive streams, which store flood flows and sediments and reduce the transport of organic material and nutrients from the watershed. The removal of constraints and protection of key attenuation assets are particularly important in reducing flood and fluvial erosion hazards and providing for water quality and habitat improvement.

1.4.4 Project Identification

The physical laws which govern channel evolution dictate that, in time and without human intervention, rivers will self-adjust to equilibrium conditions. Appropriate and well-timed actions, however, may accelerate the proc- ess. This Guide may be used to identify and promote projects recognizing that the state and federal sponsored, “on-the-ground” restoration work happening at any given time is minor compared with the effort that will be required by private individuals and local communities to make land use decisions and conserve corridors along Vermont rivers and streams.

Projects demonstrate to private riparian landowners, their neighbors and communities, the benefits that may be accrued from geomorphically stable river systems. These projects may spur other projects, but perhaps more importantly, they begin to define a new societal relationship with rivers. In this relationship, the benefits of channelization and watershed alteration are critically reviewed, and long-term impacts are given as much or more consideration than the short-term gain or the resolution of an immediate conflict. As the public embraces a sustainable river management paradigm, the resources necessary to support meaningful landowner and municipal incentives for river corridor protection will increase and river and watershed restoration will greatly accelerate.

River protection and restoration programs are established primarily to complete “projects” which meet specific goals and objectives. Traditionally this means tangible actions on the ground. This Guide offers a step-wise procedure for analyzing data to identify and prioritize the following actions:

1. Protecting river corridors
2. Planting stream buffers
3. Stabilizing stream banks
4. Arresting head cuts and nick points
5. Removing berms and other constraints to flood and sediment load attenuation
6. Removing/replacing/retrofitting structures (e.g. undersized culverts, constrictions, low dams)
7. Restoring incised reaches
8. Restoring aggraded reaches

The first set of actions (1- 6) may be more readily pursued without an extensive alternatives analysis. The last two actions, restoring vertically unstable streams (incised or aggrading), may require channel management practices, corridor land use changes, more extensive feasibility analyses, landowner negotiations, and time.

The centerpiece of Vermont’s river restoration program is the recognition and initiative to protect river corridors. A key component of any restoration project may be the long-term protection of river corridor lands that will accommodate the fluvial processes associated with equilibrium conditions. River corridors include a meander belt width area and are promoted to include:

- farming and forestry practices but with a wooded buffer to create more stable and sustainable channel boundaries

- only those channel or floodplain structures that accommodate the river in establishing and maintaining the dimension, pattern, profile and floodplain access associated with its equilibrium condition.

The River Management Program has published a River Corridor Protection Guide (Kline and Dolan, 2008), which describes in detail how corridors are designed and introduces corridor protection programs, that have been developed to date. While advocating larger scale, conflict avoidance strategies, corridor plans will also identify opportunities to:

- restore river reaches that are unstable due to localized stressors
- implement restoration practices which may pose little risk of being incompatible with equilibrium conditions at any scale and provide some immediate relief to a landowner
- resolve enduring or intractable conflicts using natural channel design techniques which may create a static channel but in a form that provides water quality and habitat benefits. The challenge is defining the

words “enduring” and “intractable” and expanding the project to mitigate any fluvial process changes creating disequilibrium elsewhere.

The list of projects produced for each assessed reach may be prioritized for implementation at both the reach scale and within watershed strategies. There is a critical interplay between listing projects in the context of alleviating physical stressors, determining whether projects are feasible from a natural and human constraint standpoint, and setting priorities for protection and restoration projects.

1.4.5 Implementing Projects and Watershed Strategies

The restoration projects and strategies identified through this planning process are those deemed necessary and desirable for managing river systems toward their equilibrium conditions. Projects are discrete practices or a combination of practices put in place through landowner agreements to protect and/or restore a reach of river. Strategies are planning activities or prescriptions centered on a particular stressor (e.g., hydrologic modification) which will prioritize a set of future projects or practices. Methods are provided in this Guide for prioritizing projects within strategies for:

- Drainage and storm water management
- Gully and erosion control
- Floodplain and river corridor protection
- Buffer establishment and protection
- Bridge and culvert retrofits and replacements
- Reach-scale river corridor protection projects
- Reach-scale river corridor restoration projects


Encroachments on a straightened and incised channel that must now be maintained as a channelized river, transferring its erosive energy and sediment load to downstream reaches.

The Vermont River Management Program will directly or indirectly support the funding of projects appropriately identified in this corridor planning process. The RMP will also seek incentives for communities and organizations which adopt strategies consistent with the goals and objectives of the Program.

In general, and with concern over the costs to society when physical river imperatives are ignored, the Vermont River Management Program will promote and support projects and strategies to minimize the need for structural measures which constrain equilibrium conditions. The RMP is applying science and partnering with state and federal resource agencies to focus on the sources of sediment-related surface water impairments. These sources are the land use conversions, investments, and expectations within river corridors which result in:

- inundation and erosion conflicts with river dynamics
- the application and maintenance of structural measures to resolve those conflicts
- the spiraling economic and environmental costs associated with fluvial erosion hazard mitigation.

In the long term, conflicts must be resolved at the watershed and river corridor scales, and secondarily, at individual erosion sites. From a geomorphic standpoint, this means recognizing that rivers transport and deposit sediment; natural stability and balance in the river system will depend on the river’s opportunity to build and access a floodplain and create depositional features such as point bars, steps, and riffles to evenly distribute its energy and sediment load in a sustainable manner.

These fundamental concepts provide the basis for Vermont to implement a river restoration program that promotes an avoidance strategy to design and protect river corridors that accommodate stream deposition, meander and floodplain processes.

1.4.6 Feasibility Analysis

This guide separates project feasibility into two categories. The first test of project feasibility derives from whether a project is technically sound and maximizes the restoration and protection of river equilibrium. The second test is about landowner acceptability, reasonable costs and other human-related constraints. It is at this stage, that river corridor planning must be recognized as a dynamic process. What is not "technically" or "socially" feasible one year may become more feasible once other stressors or constraints are alleviated. Watershed coordinators and river managers should periodically update project feasibility and reset priorities accordingly.

From a technical standpoint, project feasibility is ranked based on the following evaluative criteria:

- Does the overall project or activity contribute to and accommodate the stream equilibrium conditions?
- Does the project alternative chosen, at least in the long-term, result in an overall reduction in transport of materials from the watershed, increasing flow, sediment, and organic material storage in the river and its floodplains?
- If the project is completed, is it likely to fail because of unmitigated constraints or anticipated channel adjustment processes in the river reach or in the watershed?
- Will the project lead or contribute to instability in upstream or downstream reaches?

The systemic nature of channel adjustments often creates a seemingly insurmountable challenge to developing a restoration plan. How to conceive discrete projects when watershed processes are either totally out-of-balance or in such major transition that there is little hope of predicting a channel form compatible with the outcome of such large scale adjustments? Never-the-less, project proponents should consider fluvial processes that extend upstream and downstream of the reach they may be working. These considerations may be expressed in corridor plans by describing a specific project alternative as:

- designed in a manner where the channel is not expected to be static and where fluvial processes may continue to evolve within the reach while larger scale adjustments either play out or become resolved;
- accommodating the existing and anticipated hydrologic and sediment regimes and designed to create and/or maintain a channel and floodplain morphology compatible with equilibrium conditions;
- a significant alteration of the sediment regime such that offsite (typically downstream) mitigation practices are required to allow for and attenuate the transferred sediment load—thereby reducing the conflicts with other landowners; or
- unfeasible, at present, due to major watershed adjustments currently underway (e.g. alteration of hydrology due to urbanization)

On the human and social values side of the equation, project developers will document the feasibility of each project or activity in terms of land use constraints, landowner / municipal / stakeholder support, cost estimates, and regulatory requirements. Considerations include:

- Will the project result in tangible social benefits, e.g., fisheries restoration, fluvial erosion hazards reduction, or serve as a highly visible public demonstration project?
- What level of land use conversion would be necessary or feasible? Are the town and/or landowners committed, and have they formally agreed to adopt the necessary changes?
- What are the potential costs of design, permitting, and implementation, and are they reasonable given the overall gains in equilibrium and other social benefits achieved?

- What commitments to project support and management will be required of different stakeholders, and is the required level of commitment available?

Project development involves negotiating with landowners. There is an art to changing a technically-derived alternative, which creates conflict with other values and/or has unreasonable costs, into a practical and desirable set of practices that is supported by the landowner and still, overall, meets the objectives of the restoration plan. This guide will lay out a process for enhancing the social and technical feasibility of projects and provides negotiating tips to help the project developer. For instance, project feasibility may be particularly enhanced with appropriate and well-timed incentives to support land use change.

1.4 Development of the Local Planning Process

Vermont is fortunate to have organizations formed around the premise that citizen involvement can make a difference toward the health, use, and enjoyment of local waters. These groups have learned to work in cooperation with towns and other regional entities such as Natural Resource Conservation Districts and Regional Planning Agencies. While this river corridor planning program is focused on achieving the State's river management goal (see Introduction, Section 1.0), the ANR must join locally-based river partnerships if the State is to succeed. Likewise, local partnership groups benefit from participating in a standardized process that has been implemented in other watersheds throughout Vermont. Partnerships are strengthened when state and federal project funding is made available for both corridor planning and the maintenance of local capacity to get projects developed and implemented.

1.4.1 Forming a Corridor Planning Team

Ideally, a river corridor planning project begins with the formation of a steering committee or corridor planning team. Members of the team would generally include:

- Local Watershed Group
- Municipal Conservation Commissioners
- Natural Resource Conservation District
- Regional Planning Commission
- RMP Regional Scientist
- DEC Watershed Coordinator

The administrative, technical, advocacy, landowner-liaison, and overall coordinating roles are represented in this team; however, different planning efforts may greatly benefit from the inclusion of municipal, state, federal program representatives, specific user groups, and conservation organizations. Having a small core team, with affiliates brought in as needed, is probably the most efficient model. The composition of the planning team may also need to shift as the program evolves from assessment to implementation or shifts from one geographic area to another. A planning team will be most successful when the people involved take ownership of the data and planning outcomes. Such commitment will be vital for getting action on the hardest piece of the process—river corridor protection and restoration.

1.4.2. Identifying Project Goals and Objectives

The river corridor planning team will seek to identify and integrate the goals and objectives of planning outcomes for the watershed. The State's goal of managing toward stream equilibrium condition is often compatible with more localized goals; indeed, the team should seek as much local input as possible, keeping in mind any special needs and considerations for the watershed and its municipalities. In some cases, the team may need to take special care to identify and communicate common ground between various partners.

2.0 Writing Executive Summaries

River corridor plans are detailed technical documents and require an executive summary to distill key points and recommendations. Following are tips for writing an executive summary:

- Keep in mind how the plan will be used and who the audience will likely be. Think about what policy makers would want to know and act upon without wading through the entire analysis;
- Be concise and organized, including key points and leaving other details within the body of the plan;
- Summarize the appropriate and strategic next steps for the watershed; and
- Acknowledge partner organizations involved thus far in the planning process, as well as consultants, volunteers, or local officials who may have participated in the geomorphic assessment.

Give a brief overview of the watershed, orienting readers to the location and size of the watershed, and provide a general map showing the watershed location relative to political landmarks (e.g. roads, town boundaries) (*Figure 4*). Explain how and/or why this watershed was chosen for study and corridor plan development, providing a context and background for the project (e.g., events, local concerns, past or geographically adjacent studies that may have lead to the current corridor plan).

Often, corridor plans have focused on a subset of reaches within a given watershed. Discuss how and why reaches in the current plan were chosen, and describe where they are located within the watershed. Designing a map that shows the planning reaches—with clear reach break labels—will be the best way to convey the location of the project area. This map can be combined with the general location map described above, but avoid compromising clarity and usability.

Present state and local river management goals and objectives. Local goals may be articulated by a variety of sources, such as Town Plans or the mission statements of watershed groups. Strive to describe the convergence of goals and objectives in terms that will be easily understood by readers with a range of exposures to river science and floodplain issues. Highlight corridor protection and restoration strategies and projects identified as high priorities in the corridor plan.

River corridor plans represent a snapshot of an ongoing and strategic restoration and protection program for a set of river reaches. Emphasize the locally driven process that has been established to review priority "next steps."

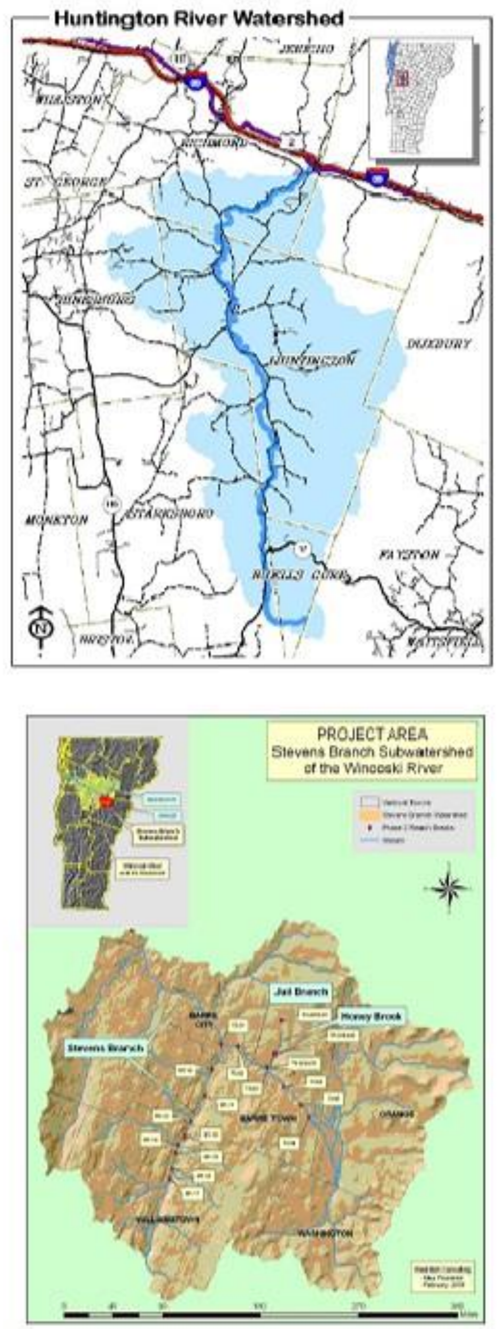


Figure 4 Examples of general watershed and reach location maps. These maps may be combined or presented separately. The upper map shows the Huntington River watershed location. The lower map combines watershed and reach location data. Note that an inset map is used in both examples to further orient the viewer. Map credits: Arrowwood Environmental (top); and Redstart Forestry and Consulting (bottom).

3.0 Background Watershed Information

River corridor plans should take a comprehensive look at the watershed from geographic, geologic, geomorphic, hydrologic, and ecologic perspectives. In many cases, the Corridor Plan may be the first such integration of these data for a given watershed. Including the information described in Sections 3.1 through 3.5 will provide great insight into the watershed and its sensitivity to various human stressors.

3.1 Geographic Setting

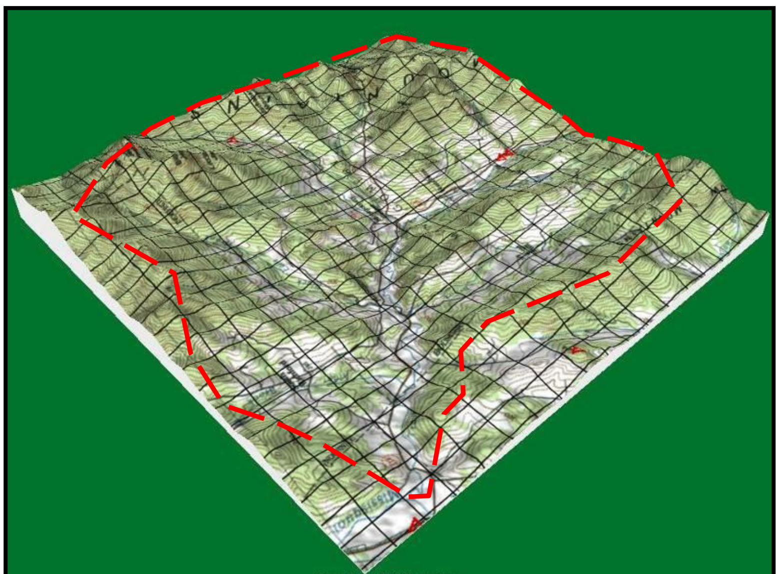
Provide a description of the regional geographic setting of the study area, which sets an important context for interpreting fluvial geomorphic conditions. Characterization of the watershed, i.e., physiographic features, general land use, and land use trends, which influence the volume and duration of runoff events will factor into every discussion about the equilibrium conditions and the management objectives for different study reaches. Political boundaries are also important to note. Towns play an important role in managing different infrastructure, and not all towns administer these activities in the same way. Towns are also key partners in project implementation.

This section should include:

- A description of the watershed and its topographic relief. Note the size of watershed in square miles and acres, and the vertical drop of the mainstem in feet.
- Describe any prominent hills or mountain ranges
- Note the larger river basin within which the river corridor is located.
- Identify the county and towns in which the study area is located.
- Use the Phase 1 SGA data (Step 4.1) as well as any local information obtained to note any pertinent trends in land use, e.g. increases in forested or developed land.
- Note population changes in the study area.

Include a location map that shows the following information:

- Phase 1 & 2 reach and segment breaks
- Watershed boundaries
- County and town boundaries
- Large bodies of water, lakes ponds
- Mapped Wetlands

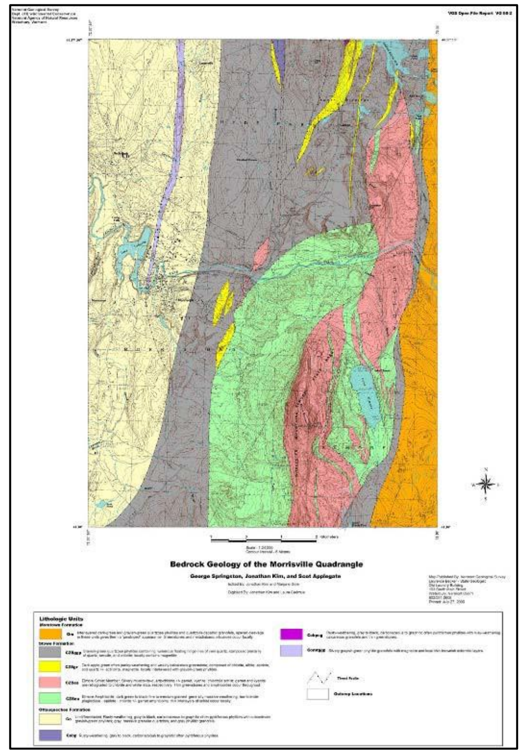


Trout River watershed draining to the Missisquoi River in northern Vermont delineated on a 3-dimensional map, developed with readily available computer mapping software.

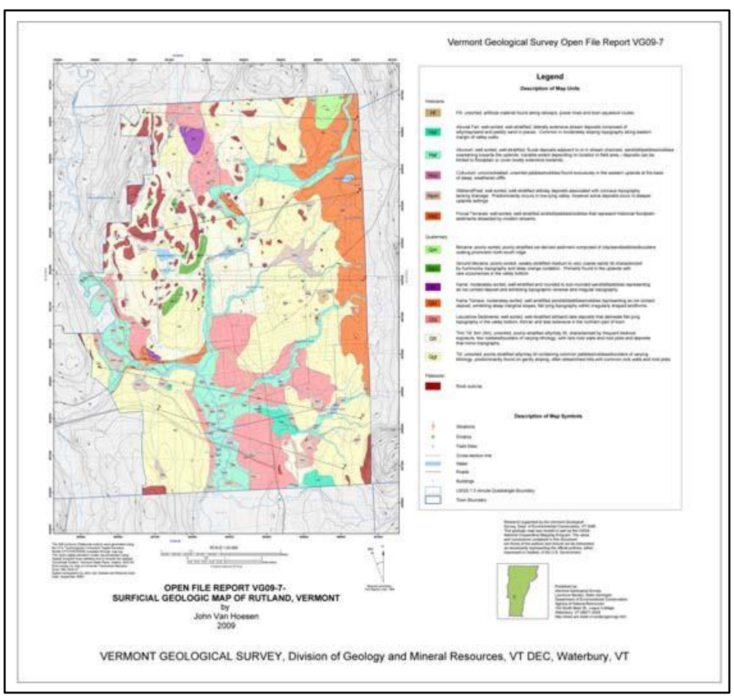
3.2 Geologic setting

Understanding the geologic setting is critical to every aspect of fluvial geomorphology. Provide an overview of the geologic setting to help explain what type of river channels may form and how sensitive streams will be to changes within the landscape. Understanding the geology of the watershed will also help interpret features on the landscape, as it may have been difficult to determine the age and composition of landform features during the Phase 2 field work. Within this section of the corridor plan describe the:

- glacial history of the watershed, noting any important glacial features within the study area such as remnant lacustrine or fluvial terraces, deltas, or moraines;
- type of bedrock as well as outcrop locations that serve as grade controls within the watershed;
- dominant types of surficial geology as well as their dominant characteristics such as erodibility, cohesiveness and permeability; and
- dominant pedology, using summaries of the NRCS soils survey (Phase 1, Step 3 results), or other local soil surveys to describe the unique properties of the soils present within the study area. Interesting items to note will include the parent material, hydrologic group and depth to water table.



There are many resources available to determine the geologic history of Vermont. The Vermont Geologic Survey maintains a wealth of information on their website found at: http://www.anr.state.vt.us/dec/geo/vgs.htm.



Many bedrock and surficial geology maps are available from the Vermont Geologic Survey. The map above, shows the bedrock geology of the Morrisville, Vermont. The Lamoille River can be seen flowing across several different geologic formations. To the left is a surficial geology map of Rutland, Vermont, showing the extent of alluvium in the valleys of the Otter Creek and its tributaries.

3.3 Fluvial Geomorphic Setting

Describe the fluvial geomorphic setting of the watershed to help identify reference channel and floodplain conditions along different river reaches. Certain physical characteristics, taken together, illustrate the river's natural variation in dimension (channel width and depth), pattern (meander planform), profile (channel slope), and bed forms (scour and deposition features). The fluvial geomorphic setting can then be used to determine the natural processes within the watershed that would be associated with equilibrium condition (e.g., sediment regime). Identifying reference condition also allows for reach by reach comparison with existing geomorphic conditions.

In the corridor plan, describe the fluvial geomorphic setting of the watershed as a whole, identifying any major tributaries and specifically addressing the assessed river reaches. Discuss the physical attributes used to distinguish the assessed reaches, such as valley confinement, slope, sinuosity, dominant bed material, and bed form. Be sure to provide relevant definitions, such as "reach," if not done so already. Sometimes it is helpful to include a glossary of terms as an appendix.

3.3.1 Description and mapped location of the assessed reaches

If not already included in the Executive Summary, be sure to map the locations of the assessed river reaches, with clear reach break labels (see *Figure 4*). Provide a table to describe where the reaches are located and how many river miles are included, e.g.:

Reach ID	Reach Length	Narrative Reach location Description

3.3.2 Longitudinal profile, alluvial fans, and natural grade controls

Provide a longitudinal profile (*Figure* 5) and highlight any features that are characteristic or distinctive in the watershed, including alluvial fans, natural grade controls, and significant changes in valley slope and confinement. Be sure to provide relevant definitions and describe the geomorphic significance of these features.

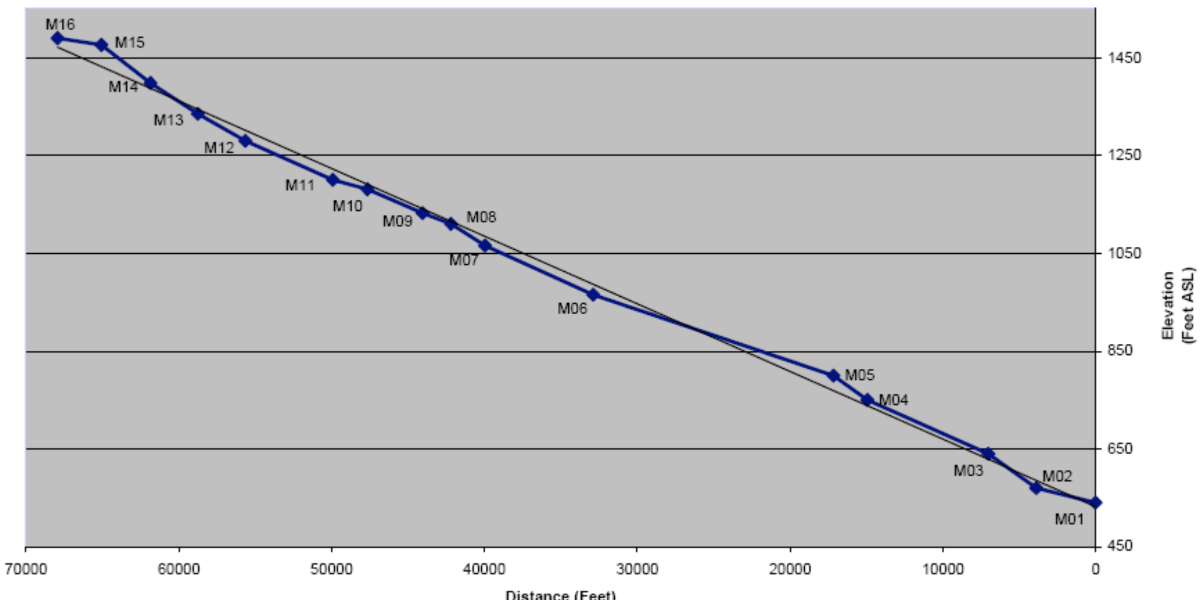


Figure 5 Example of a longitudinal profile from Mill River: River Corridor Management Plan by Round River Design, February 2009.

3.3.3 Valley and reference stream types

Present the Phase 1 stream and valley type data for the assessed reaches. Provide the reference stream types using Rosgen and Montgomery-Buffington stream type classifications and include valley type and slope (*Table 1*).

Table 1 from Vermont Stream Geomorphic Assessment Handbook, Phase 1, VT ANR, 2007

Reference Stream Type	Confinement (Valley Type)	Valley Slope
A	Narrowly confined (NC)	Very Steep > 6.5%
A	Confined (NC)	Very Steep 4.0 - 6.5%
B	Confined or Semi-confined (NC, SC)	Steep 3.0 - 4.0 %
B	Confined or Semi-confined or Narrow (NC, SC, NW)	Mod. - Steep 2.0 – 3.0 %
C or E	Unconfined (NW, BD, VB)	Mod. - Gentle < 2.0 %
D	Unconfined (NW, BD, VB)	Mod. - Gentle < 4.0 %

Provide Phase 1 reach morphology statistics for the assessed reaches (*Table 2*), and discuss why reference stream type is important in the interpretation of Phase 2 existing geomorphic conditions.

Table 2 Example of Phase 1 reach summary statistics table. River Corridor Plan: Moon Brook Watershed, Bear Creek Environmental, March 2008.

Table 1. Moon Brook Watershed Phase 1 reference reach data

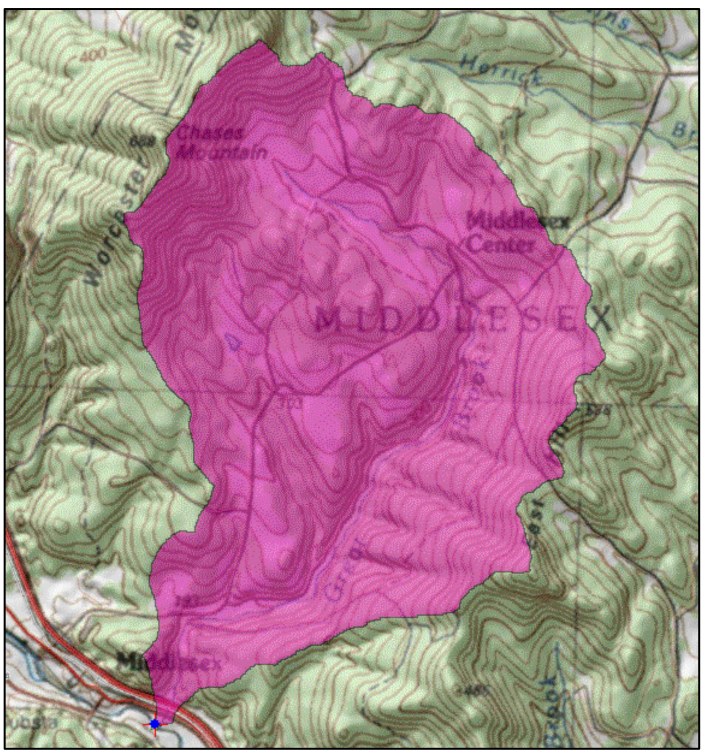
Reach ID	Drainage Area (Sq mi)	Valley Type	Channel Width (ft^2)	Channel Slope (%)	Sinuosity	Reference Stream Type	Channel Bedform
M22-S1.01-s1.03-s1.01	0.64	Broad	10.7	2.40	1.06	C	Plane Bed
M22-S1.01-s1.03-s1.02	0.08	Narrowly Confined	4.3	15.28	1.04	A	Cascade
M22-S1.01-S1.04	1.62	Very Broad	16.2	1.33	1.36	C	Riffle-Pool
M22-S1.01-S1.06	1.00	Very Broad	13.1	2.33	1.21	E	Riffle-Pool
M22-S1.01-S1.07	0.82	Semi Confined	12.0	5.43	1.13	C	Riffle-Pool
M22-S1.02	5.43	Very Broad	27.6	0.42	1.11	E	Dune-Ripple
M22-S1.02-s1.01	1.81	Very Broad	17.0	2.38	1.21	C	Plane Bed
M22-S1.02-s1.02	1.65	Very Broad	16.3	0.92	1.15	C	Dune-Ripple
M22-S1.02-s1.03	0.67	Semi Confined	11.0	4.18	1.12	B	Step-Pool
M22-S1.03	3.10	Very Broad	21.6	1.04	1.25	E	Riffle-Pool
M22-S1.05	1.97	Very Broad	17.6	1.40	1.11	E	Riffle-Pool
M22-S1.07	1.64	Very Broad	16.3	3.03	1.07	E	Riffle-Pool
M22-S1.08	0.33	Semi Confined	8.1	19.53	1.11	A	Cascade

3.4 Hydrology

Note the location of any nearby flow gages maintained by the USGS. If a nearby flow gage exists include a plot of the annual peak flows for the recorded time and note the bankfull (1-2 year), 5, 10, 50, and 100 year flood flows published for the gage site.

Provide a table with each flood year and the frequency value associated with any flood greater or equal to the 5 year frequency. An understanding of the flood history is important to a proper interpretation of channel condition, adjustments processes, and stream sensitivity. Use local resources such as flow gages, Town Reports, local officials and residents to understand the extent, magnitude and effect of all major floods within the study area, especially those within the recent past.

Use the Web-based USGS StreamStats application at http://water.usgs.gov/osw/streamstats/Vermont.html to obtain and analyze stream flow statistics, basin characteristics, and descriptive information for both USGS data-collection stations and ungaged sites (Figure 6 below). StreamStats may also be used to identify the physical and climatic characteristics of the drainage basin (basin characteristics) and the influence of human activities, such as dams and water withdrawals, on stream flow upstream from study reaches to understand some of the mechanisms that control hydrology.



Parameter	Value
Area in square miles	8.84
Percent of area covered by lakes and ponds	0.0397
Mean annual precipitation, in inches	43.7
Percent of area with elevation > 1200 ft	52

Statistic	Flow (ft^3/s)	90-Percent Prediction Interval	
		Minimum	Maximum
PK2	308	161	591
PK5	459	242	869
PK10	570	298	1090
PK25	739	384	1420
PK50	877	449	1710
PK100	1020	513	2040
PK500	1410	657	3010

Figure 6. StreamStats Application outputs watershed delineation (program automated), estimated flows at different return frequencies for an ungaged watershed, and basin characteristics.

3.5 Ecological Setting

The ecological setting encompasses biophysical features in the landscape, as well as the plant and animal communities associated with these features. Documenting the location and condition of any unique habitat or community that exists in the watershed can help prioritize restoration and conservation strategies. The publication "Wetland, Woodland, and Wildland; a Guide to Natural Communities in Vermont" by Thompson and Sorenson (2000) provides a good overview of Vermont's natural communities.

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3.5.1 Distribution of instream, riparian and wetland habitats

The distribution of instream, riparian, and wetland habitats plays a role in shaping the ecological setting of a watershed. The Reach Habitat Assessment (RHA) (Schiff et al., 2008) can be used to collect detailed information on the types and quality of instream and riparian habitat. When RHA assessments have been completed, create a table showing reach habitat condition broken out by different habitat components, e.g., instream cover types and riparian habitat. Highlighting important habitat assets and deficiencies such as presence/absence of pools, undercut banks, refuge areas, and large woody debris can help inform restoration and conservation strategies.

3.5.2 Aquatic life

The DEC Biomonitoring and Aquatic Studies Section (BASS) has collected macroinvertebrate and fish data and evaluated the biological integrity of wadeable streams throughout Vermont. Find out if biomonitoring has been conducted within the study reaches at: www.watershedmanagement.vt.gov/bass/htm/bs_fish.htm. Contact DEC biologists to get reports on the conditions of aquatic life, and specifically inquire as to whether any physical or chemical stressors have been indicated by the data. District Fisheries Biologists with the Vermont Fish and Wildlife Department (http://www.vtfishandwildlife.com/) also collect instream and aquatic life data.
Agency evaluations of aquatic life communities may or may not be congruent with the physical habitat and stream geomorphic data and conditions. Where physical and biological data tell a similar story, they may co-support a set of selected management strategies. Incongruent data may be common, however. Non-physical stressors may explain biological impacts when physical features would suggest the presence of healthy aquatic communities. Likewise, biomonitoring methods (e.g., assessment of local-scale conditions) may explain why good aquatic communities exist where SGA and RHA data, more representative of the large-scale physical conditions, suggest there may be significant biological impacts. Report on these differences when they are found.

Biomonitoring and fisheries assessments offer a way to monitor the success of corridor plan implementation over time. After Phase 2 stream geomorphic and reach habitat assessments are completed, inquire as to whether biomonitoring data exists at or near cross-sections that represent the geomorphic and habitat conditions of specific reaches of interest. If not, pursue the collection of biological data in key locations so that a long-term monitoring and assessment regime might be established.

3.5.3 Unique plant and animal communities

Unique plant and animal communities are often associated with instream and riparian ecosystems. Presence of unique plant and animal communities and species of special concern (e.g., brook trout), either historic or present, can help identify priority areas for conservation or restoration. Specific locations of threatened and endangered organisms are sensitive information, but general information can be obtained from the Vermont Fish and Wildlife's Non-game and Natural Heritage Program (http://www.vtfishandwildlife.com/wildlife_nongame.cfm). This information may not only help inform restoration and conservation strategies, but it also may help identify possible funding sources for conservation efforts as presence of threatened and endangered species or communities can create eligibility for some grant programs.

4.0 Methods

A River Corridor Plan represents a synthesis of physical data collected for the study reaches. With any scientifically based endeavor, it is important to document the methods used for conducting a study to ensure credibility and repeatability. This section of the guide covers important considerations to take into account when documenting the methods used for conducting stream geomorphic and habitat assessments and quality assurance / quality control (QA/QC) of the resulting data.

4.1 Fluvial Geomorphic and Habitat Assessment protocols

The Vermont Agency of Natural Resources Stream Geomorphic Assessment Protocols (VT ANR SGA Protocols) form the technical foundation for river corridor plans. Additional information from other types of watershed studies can also be incorporated into a River Corridor Plan. It is important to be aware that there have been several versions of the VT ANR SGA and Reach Habitat (RHA) protocols. It is important to make note of what year the assessment data were collected, what version of the protocols was utilized for data collection, and to include appropriate citations for the protocols.

4.1.1 Phase 1 and Phase 2 Assessments

A River Corridor Plan should contain a brief synopsis of the of the Phase 1 and Phase 2 Vermont Stream Geomorphic Assessment protocols and how the analysis of data as outlined in Sections 5 and 6 of this Guide support departure analysis, stressor identification, and potential project identification. Focus should be given to explaining the assessment process and the types of data collected. The Vermont Agency of Natural Resources Stream Geomorphic and Reach Habitat Assessment protocols should be cited using the following format:

Kline, M., C. Alexander, S. Pytlik, S. Jaquith and S. Pomeroy. 2007. Vermont Stream Geomorphic Assessment Protocol Handbooks and Appendices. Published at: www.watershedmanagement.vt.gov/rivers.htm. Vermont Agency of Natural Resources, Montpelier, VT

Schiff, R., M. Kline, J. Clark. 2008. The Vermont Reach Habitat Assessment Protocol. Prepared by Milone and MacBroom, Inc. for the Vermont Agency of Natural Resources, Waterbury, VT. Published at: http://www.watershedmanagement.vt.gov/rivers.htm

4.1.2 Other assessments completed and/or data acquired

River Corridor Plans should take advantage of previous river studies or other physical data collected prior to the development of stream geomorphic assessment protocols as well as any other studies conducted in the study area that are relevant to the river corridor planning process. Historic studies can lend perspective to how stressors and adjustment processes may have changed over time. Watershed natural resource inventories, biological surveys, and water quality monitoring data may help identify areas key to ecological function and diversity as well as potential sources of ecosystem stressors. Make note of whether bridges and culverts were assessed using the Phase 2 protocols outlined in Appendix G of the SGA Handbooks. When using information from previous studies, make sure that the proper citation is included in the report to allow potential users of the River Corridor Plan to locate the original information if desired.

4.2 QA/QC summary report

Adherence to a Quality Assurance/Quality Control protocol is extremely important for insuring that a dataset is both accurate and complete. Quality Assurance Protocols are outlined in both the Phase 1 and Phase 2 VT ANR SGA Protocols (Kline et al., 2009). These protocols include a data review process to identify data inconsistencies and gaps. A River Corridor Plan should include a summary and documentation of the data QA process.

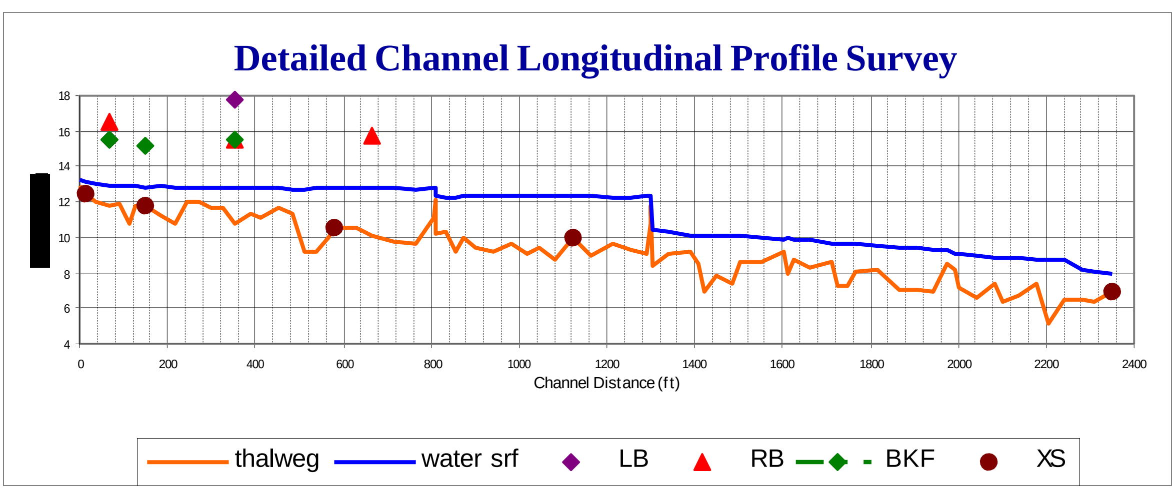
4.2.1 Location and QA status of data

All Phase 1 and Phase 2 data collected is recorded in an on-line database called the Vermont Stream Geomorphic Assessment Data Management System (DMS) (https://anrnode.anr.state.vt.us/ssl/sga/security/frmLogin.cfm). The DMS has automated quality assurance checks to identify data inconsistencies and gaps. In addition to the automated quality assurance checks, the data receives thorough review by the data collector and State River Scientists who oversee the collection of the data. This review process involves a written dialogue between the assessor and the scientist identifying and resolving any uncertainties in the dataset. This dialogue should be included as an appendix in a River Corridor Plan. The data in the DMS displays as either "provisional" or "complete". Data labeled as "provisional" have one or more quality assurance concerns in need of review. Data labeled as complete are considered to have passed all quality assurance protocols.

4.2.2 Parameters not evaluated and data use qualifications

Occasionally, some assessment parameters are not evaluated for a reach due to a variety of constraints such as landowner access limitations or significant beaver dam influence. In these situations, information that can be observed from the river channel such as riparian buffer conditions, flow modifiers, and depositional features may be recorded, but a cross section may not have been completed. In these instances it is important to make note of what parameters were not evaluated and why to avoid confusion over gaps in the dataset.

It is important to note that the Phase 1 and Phase 2 SGA Protocols are "rapid assessment" protocols. Their intention is to characterize the physical conditions and adjustment processes shaping a reach of river and to help identify and guide restoration and conservation efforts towards a condition of dynamic equilibrium. The information is not intended as a substitute for more detailed longitudinal and cross sectional survey work that would be necessary for any in-stream engineering work associated with restoration project design, hydrologic and hydraulic modeling, or bridge and culvert design projects.



5.0 Departure Analysis and Stressor Identification

In this section of the Guide, information will be provided on how to prepare Phase 1 and Phase 2 stream geomorphic data and maps to describe the types and extent of physical modification and change within the assessed portions of a watershed. The assessor will characterize these modifications as stressors of stream equilibrium and gain an understanding of the significance of physical processes underway within the stream network.

The GIS data layers created during the Phase 1 and updated during Phase 2 assessments using the Stream Geomorphic Assessment Tool (SGAT) and SGAT feature index tools (FIT) will be essential to creating the planning maps described below. The Agency of Natural Resources has developed data exports and mapping routines within its web-based river data management system (DMS), which should greatly facilitate the production of these maps. Detailed instructions for using of the DMS map serve program and tailoring maps to individual planning needs are available online at: http://www.watershedmanagement.vt.gov/rivers.htm.

The first part of this Section lays out the development of stressors maps. Stressors are described and mapped based on whether they are acting at the watershed or reach-scale to influence channel adjustments. The second part of the Section will describe the development of synthesis maps to show departures from equilibrium condi- tions within the stream network at the watershed scale. Mapping fluvial process departures and stream sensitivity in combination with physical constraints to flow and sediment attenuation will be used to predict the location and rate of future channel adjustments in the stream network. Synthesis maps will be particularly useful in understand- ing the priority and technical feasibility of river corridor protection and restoration projects.

5.1 Departure Analysis

The purpose of the following protocol is to help facilitate a common application of stream geomorphic data showing the departure of stream reaches from reference or equilibrium conditions. The fluvial processes associated with hydrologic, sediment, and large wood regimes may be changed due to natural events, but from a river management perspective, it is the human-caused stressors that are of interest.

Human modification of the natural runoff regimes within a watershed may profoundly affect the equilibrium conditions of sensitive stream reaches. For example, consider an alluvial, riffle-pool stream with adequate flood plain in a wooded riparian corridor. Such a stream, though in equilibrium at present, may completely unravel with significant increases or decreases in flow and/or sediment load at the watershed scale. Should reach-scale stressors, such as stream bank vegetation removal, also occur, any ongoing watershed modification will greatly affect the rate of recovery and the feasibility of restoring the reach.

Departure analyses for hydrologic and sediment regimes help explain the stage and rate of channel evolution at individual river segments and reaches, and whether changes to watershed inputs have been so modified and/or constrained that a new management target, other than the natural reference condition, may be reasonable in combination with appropriate mitigation strategies. Methods for evaluating departure maps in conjuncture with the stressor and sensitivity maps will be described in Section 6.0 for the identification of technically feasible projects.

Mapping protocols for depicting hydrologic and sediment load alterations are provided in the Mapping Appendix. Parameters are grouped on maps to assist the evaluation of hydrology or sediment load changes as significant stressors affecting reach stability. The pertinence of each selected parameter as a watershed or reach-scale stressor is also discussed. Several data may be transformed as "counts per stream mile" to provide a means of comparing data between reaches of different lengths or watershed size. Lengths of other stressors may be repre- sented as a percentage of the reach. These types of data conversions are completed and incorporated in mapping data tables available for export from the DMS. It may not be necessary or desirable to show all parameters listed in a table on a map. The structure of the mapping protocol tables is such that, where FIT data is noted and available, this data will be prioritized for use on the map to show the location of the stressor. When both Phase 1 and

Phase 2 data are available, the assessor is encouraged to use the data that provides the best information for the overall project. For example, for a watershed-wide project where Phase 2 data is available for only a few reaches, it maybe better to show the Phase 1 data. Example tables are provided for recording stressor evaluations.

5.1.1 Hydrologic Regime Stressors

The hydrologic regime may be defined as the timing, volume, and duration of flow events throughout the year and over time. Hydrologic regime may be influenced by climate, soils, geology, groundwater, watershed land cover, connectivity of the stream, riparian, and floodplain network, and valley and stream morphology. 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 interacts with reach-scale physical forms and is affected by reach-scale physical modifications (e.g., bridges modify channel and floodplain hydraulics).

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

The Vermont Stream Geomorphic Assessment Protocols do not describe methods for directly and empirically assessing the hydrological modifications within a watershed. Models for analyzing departures of the hydrologic regime for streams with long-term gauging data (>40-50 yrs) are available. For watersheds with no flow record, the assessor must rely on surrogate data and information on human activities which are known to modify the timing, volume, and duration of flow. The Mapping Appendix to this Guide provides directions for developing Land Use\Land Cover and Hydrologic Alterations maps using the data and mapping techniques described for each stressor type. A description of each map and its use in evaluating stressors are provided below.

The magnitude and extent of hydrologic regime departures are evaluated by examining the land use and flow-related stressors, as well as sediment regime departures which indicate the typical channel responses to hydrologic stressors. Use a Stressor Identification Table (*Figure 7*) to indicate which reaches may be in adjustment or significantly influenced by modifications of the hydrological regime. The project identification process described in Section 6 will factor the significance of hydrologic regime departures and the importance of addressing this watershed scale stressor before implementing reach-scale channel restoration projects.

	Watershed Input Stressors		Reach Modification Stressors	
River Segment (name and number)	Hydrologic	Sediment Load	Stream Power	Boundary Resistance
List all assessed reaches in hydrological order	Increased flows (provide detail)			

Figure 7 Example of River Stressors Identification Table indicating where hydrologic stressors are likely causing or contributing to channel adjustment and a departure from equilibrium conditions.

Deforestation

A hydrologic stressor which provides a backdrop for the departure analysis of nearly every stream and river in Vermont is the deforestation which occurred primarily during the 19th century. Unlike the changes wrought by early dams, the channel adjustments underway today may still be strongly linked to deforestation. High energy flash floods in denuded, sheep-grazed watersheds, with little vegetation to slow and store precipitation, eroded and carried with them much of the soils and sediment that built up and became weathered on the surface of the catchment. While forests are once again moderating the flows in most Vermont watersheds, the decades of sediment accretion in the lower valleys is one of the main reasons why so many streams and rivers have lost access to their historic floodplains. This accretion of sediment is more than a meter thick and in some valleys nearly two meters thick. Initially, the channels aggraded or rode upward with the sediment accretion. Over the past 50 years many rivers have been in the process of eroding back down to the elevation they were before deforestation, aided by channelization and dredging operations, which increased their slope and energy. At this lower elevation, the process of creating new floodplains has begun but, in most river systems, is nowhere near complete.

This process does not include a mapped representation of the deforestation "stressor," but interpretation of departure and sensitivity maps should take into consideration that fluvial processes may still be modified and channels may still be under adjustment due to deforestation-reforestation effects. The stress associated with other channel and watershed modifications may be magnified by the legacy of these large scale land cover changes.

Hydrologic Alterations Map

The Hydrologic Alterations Map shows site specific stressors where flow volume is either increased or decreased. In general, this map is used as a way to red flag hydrologically stressed reaches (*Figure 8*). Should protection and restoration designs necessitate a more precise quantification of hydro-modifications, the assessor may wish to consult the DEC Stormwater and River Management, Flow Protection sections where gauging and/or modeling studies may be available. For some urban and village areas, the Stormwater Section may have stormwater outfall maps available. The RMP Flow Protection Section has very detailed flow studies for large water withdrawals, and hydroelectric and flood control dams.

Stormwater

Perhaps the most contemporary issue associated with hydrologic modification is the conversion of land to an impervious surface (i.e., urbanization) and the discharge of concentrated runoff to streams. By increasing the peak flows during flood events, stormwater discharges increase stream power which may lead to bed and bank erosion (Doyle et al., 2000). Stormwater inputs show specific locations where runoff has become concentrated and mapped as a discharge to the stream. Data sources and mapping techniques are described in the Mapping Appendix.

Evaluation: Streams under major adjustment, primarily due to stormwater impacts, are in the process of "re-sizing" to match the cross-section of the new, larger, and typically more frequent channel-forming flow. On the stressor identification table, using descriptors such as moderate, high, and extreme, indicate each reach which is likely to undergo adjustment due to the increased stream power associated with stormwater inputs. Factor in the size of the watershed. If the watershed at the reach break is greater than 15 square miles, reduce the significance of the stormwater inputs as a stream equilibrium stressor.

Dams and Diversions

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 wood regimes, and the likelihood for channel enlargement. While some streams and rivers are still hydrologically affected by dams and hydroelectric facilities, the regulation and diversion of stream flow is less extensive. Diversions, impoundments, and the mode of flow regulation are mapped and indicated. This component of the Hydrologic Alterations Map (*Figure 8*) will also inform the analysis of sediment loading at the watershed scale.

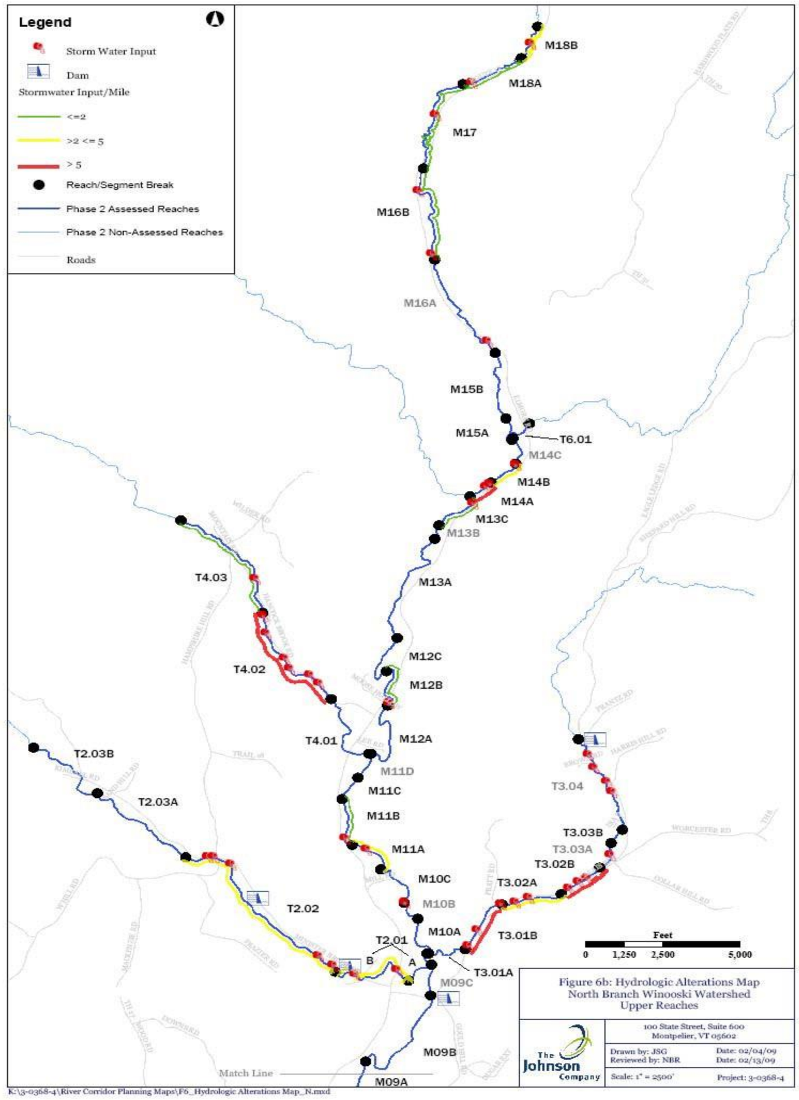


Figure 8 Example of a Hydrologic Alterations Map from the North Branch of the Winooski. Map Credits: The Johnson Company.

Evaluation: Altered hydrology may be a significant stressor in reaches which are either bypassed by a diversion penstock or lie between a "store-and-release" flood control dam and the input of the next major tributary (or the point where the watershed size has increased by at least 10%). Many Vermont hydroelectric facilities, which have impoundments to store-and-release water, have been in existence for over 50 years. While the initial response of the river to the decrease in stream power may still be evident, the channel may have adjusted and is now relatively quiescent because the facility "shaves-off" both the highest peak flows and the highest sediment discharges. Run-of-the-river hydro-facilities, while affecting diversion or bypass flows and influencing the sediment regime (see below), do not significantly affect the hydrologic regime. Indicate in the Stressor ID Table a "significant" hydrologic stressor for reaches that have a "large" store-and-release impoundment or diversion within the reach. The influence of large flow regulations should be considered for all reaches downstream to the next major tributary confluence.

Land Use\Land Cover Map

The Land Use\Land Cover Map depicts watershed areas where flow volume may be increased due to the concentration of runoff and a decrease in the infiltration associated with certain soils and native vegetation (*Figure 10*).

Urbanization

Urban land use results in the conversion of pervious to impervious land cover and an increased drainage density. These conversions may significantly alter the hydrologic regime and result in major channel adjustments. The biological integrity of many smaller urban streams has been impaired due to hydrologic-related stressors. Recent studies in Burlington and St. Albans show that major channel adjustment and biological impacts are associated with 5% impervious cover (Fitzgerald, 2007). The percent of urban land use within a sub-watershed is mapped to show where land development may be at densities sufficient to alter the hydrology of the watershed. The Land Use/Land Cover Map will also inform the analysis of sediment loading at the watershed scale, because of the large scale gully erosion that is commonly associated urban land use (see Sediment Load Indicator Mapping pro- tocol below). Sub-watershed polygons are used to indicate local urbanization and the stream reach line indicates the cumulative upstream urbanization (further described in the Mapping Appendix).

Evaluation: Altered hydrology may be a significant stressor when urban land use reaches 5-10% of the watershed (depending on the percentage of the urban land use that is actually impervious cover) and may be the predominant stressor when it reaches 20% of the watershed. On the stressor identification table, using descriptors such as moderate, high, and extreme, indicate each reach which is likely to undergo adjustment due to the stress associated with urbanization, impervious cover and stormwater impacts.

Ditching

During the 19th century, drainage societies were formed in Vermont for the purpose of building the ditch networks necessary to farm lands that were either permanently or seasonally wet. Drain tile and ditch networks were enlarged and maintained through the 20th century. Wetland scientists are beginning to assess the loss of wetlands by mapping hydric soils (i.e., soils formed under wet conditions) with current land use / land cover data. Wetland loss leads to a reduction in hydrologic attenuation and to an increase in runoff rates and peak discharge volumes.

Modern forestry and logging regulations in Vermont have largely diminished the practice of deforesting a watershed to the point where the hydrologic regime is significantly affected. There may be instances, however, where the field observer encounters small streams that appear hydrologicaly affected by logging operations. These modifications may be associated with the manner and timing in which skid trails and truck roads were laid out and used and have become the equivalent of the ditch networks constructed in farm fields or those associated with rural road networks and stormwater modifications.

The rural road networks, unlike major highways and transportation infrastructure, do not get mapped as urban land use and are not under the purview of the Stormwater Section. As more and more houses are built in the Vermont countryside, there is an increasing demand for back roads that serve passenger cars year round. To ac- complish this, towns are investing more and more in road ditching, often with little attention or investment in con- trols which can moderate the effects of those ditches on watershed hydrology. At this time, there are no drainage network data specifically analyzed during either Phase 1 or Phase 2 assessments. Road and ditch networks, as indicated by the density of roads, effectively intercept and concentrate runoff leading to an increase in runoff rates and peak discharge volumes. Sub-watershed polygons are shaded to indicate the densities of roads.

Evaluation: The mapping of NWI (existing) wetlands with hydric soils on a map with urban and crop land uses, creates an opportunity to see the extent to which historic wetlands may no longer be fully functioning as wetlands, and what land uses conversions may have led to their partial or complete drainage. The loss of wetlands may be extensive and their drainage leads to the same hydrologic impacts as stormwater. The increased stream power from larger peak discharges may initiate or contribute to channel adjustments. Mapping road densities captures the potentially significant hydrologic modification and stress related to road networks. While some researchers are beginning to see correlations between road densities and channel adjustments, there are no broadly accepted analytical methods for interpreting this data in lieu of flow measurements in watersheds with and without extensive road ditch networks. If a channel in a small watershed is under adjustment and signs of concentrated flow (e.g., gullies) and artificial drainage systems are identified, then hydrologic modification may be significant and should be factored into alternatives analysis and watershed restoration strategies.

5.1.2 Sediment Regime Stressors

The sediment regime may be defined as the quantity, size, transport, sorting, and distribution of sediments. The sediment regime may be influenced by the proximity of sediment sources, the hydrologic regime, and valley, floodplain and stream morphology. Understanding changes in sediment regime at the reach and watershed scales is critical to the evaluation of stream adjustments and sensitivity. The sediment erosion and deposition patterns, unique to the equilibrium conditions of a stream reach, create habitat. In all but the most dynamic areas (e.g., alluvial fans), they provide for relatively stable bed forms and bank conditions.

In evaluating the significance of sediment regime departures with respect to water quality, aquatic habitat, and erosion hazard objectives, it is important to distinguish between wash load and bed load sediments. During high flows, when sediment transport typically takes place, small sediments become suspended in the water column. These wash load materials are easily transported and typically deposit under the lowest velocity conditions, which exist on floodplains and the inside of meander bendways at the recession of a flood. When these features are missing or disconnected from the active channel, wash load materials may stay in transport until the low velocity conditions are encountered (e.g., Lake Champlain). This departure has particular significance to water quality and habitat management as the unequal distribution of fine sediment has a profound effect on aquatic plant and animal life. Fine-grained wash load materials typically have the highest concentrations of organic material and nutrients.

Bed load is comprised of larger sediments, which move and roll along the bed of the stream during floods. Coarser-grained materials stay resting on a streambed until flows of sufficient depth, slope, and velocity produce the power necessary to pick them up and move them. Bed load materials will continue to move (bounce) down the channel until they encounter conditions of lower stream power. When the power is no longer sufficient to move a particle, it will deposit and rest back on the streambed. The fact that it takes greater energy or stream power to move different sized sediment particles results in the differential transport and sorting of bed materials. Where channel depth and slope remain relatively constant along the longitudinal profile sequences of depositional features (bed forms) become equally distributed. When these patterns are disrupted, there are direct impacts to existing aquatic habitat, and the lack of equal distribution and sorting may result in abrupt changes in depth and slope leading to vertical instability, channel evolution processes, and a host of undesirable erosion hazard and water quality impacts.

The sediment regime, therefore, is sensitive to changes in stream power. Stream Power is a function of mean water depth, slope and velocity:

$$\omega = (\gamma * Q * S) / W = \gamma * d * u * S = \tau * u$$

Where:
ω = stream power
γ = density of water
Q = discharge-stream flow
S = slope
W = width
d = mean depth
u = velocity
τ = shear stress

The first step in conducting a sediment regime departure analysis is to review Phase 1/ Phase 2 stream geomorphic assessment data that pertains to stream power parameters. The mapping protocols and evaluation techniques have been organized to address the factors moderating stream power. As shown in *Figure 9*, these factors exist at the watershed scale and at the reach scales. Human-wrought changes to the controlling factors may be thought of as the stressors that lead to changes in stream power and sediment regime. There is a hierarchy, where stream flow and sediment supply characteristics are primary controlling factors influencing hydraulic geometry and stream power. Addressing alterations to watershed inputs (e.g., stormwater) then becomes paramount over many types of reach-scale remediation projects in watersheds experiencing systemic disequilibrium.

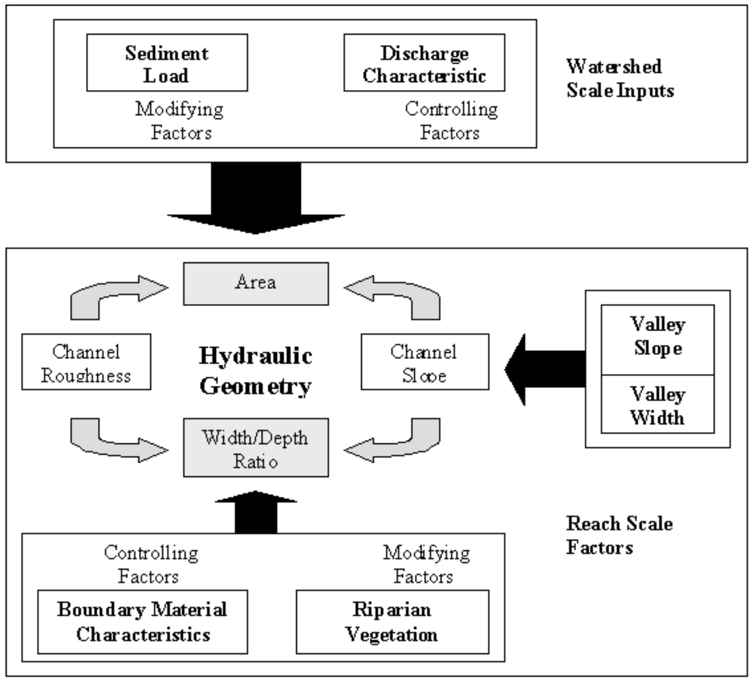


Figure 9 Diagram explaining the watershed and reach-scale controlling and modifying factors affecting the hydraulic geometry and fluvial processes of a stream. (Modified from McCrae, 1991**)**

Hydrology and Sediment Regime

Sediment regime modifiers at the watershed scale are often closely linked to those associated with the hydrologic regime. As discussed in the previous section, significant changes to the hydrologic regime will result in changes to the channel cross-section. The concentration of runoff (see Stormwater Inputs and Ditching), especially in erodible soils, creates new channels and gullies, and may result in significant new sediment inputs to the stream. The increased depth, seen in most stormwater-impacted channels, results in an increase in stream power that acts on both the bed and banks and enlarges the channel. Increased channel depth means that the channel will continue to have the power to entrain and transport sediment into and through the stream network until flow depth is decreased at the completion of the channel evolution process. Therefore, sediment regime modifications are closely linked with hydrologic regime modification. Particularly, noteworthy is the alteration of sediment regime below large impoundments. Reaches below impoundments may be "starved" of sediment and have often become incised as a result. The data and maps used to analyze hydrology should also inform the evaluation of stressors associated with sediment load and transport.

Watershed-Scale Erosion

Human-induced changes to the sediment regime that occur at the watershed scale, such as those associated with land use change, may either result in an increase or decrease the sediment load. For instance, an urbanizing watershed may see an increase in load as the land surface is disturbed during construction and a decrease in sediment load when impervious surfaces, grade controls, and stone lined ditches significantly reduce the normal sheet and rill erosion of a landform.

Use the Land Use/Land Cover Map, in conjuncture with historic land use data, to evaluate whether recent or on-going urbanization has significantly changed the sediment load. Urban land use change has been extensively studied in most cities. Contact the city or regional planning agencies or the ANR Stormwater Section to inquire whether hydrologic and sediment load characteristics have been modeled over the urbanizing time period.

While erosion is typically evaluated on a site-by-site basis, the cumulative effect of erosion at the watershed scale may be significant in terms of sediment load. The Vermont protocol, due to time and expense, does not call for the direct measure of sediment load. Published methods for quantitatively measuring sediment are available. Protocols for producing a Land Use/Land Cover and Sediment Load Indicators maps (see Mapping Appendix) include instruction for indicating multiple gullies and mass wasting sites, the extent of bank erosion, and sub-watersheds with a high percentage of cropland. The magnitude, frequency, and cumulative effect of these sources, as evidenced by the depositional features shown on the map, may strongly suggest which reaches are under adjustment due to the stress associated with sediment load modifications.

Land Use\Land Cover Map

The Land Use\Land Cover Map, created to evaluate hydrological modifications, may also be used to depict watershed areas where an increase in sediment production may be expected due to land uses involving the ongoing exposure of soils to stormwater runoff.

Exposed Soils

When perennial vegetation is removed and soils are exposed they are susceptible to erosion. Urban land use, as discussed above, results in surface erosion, especially during the construction phase where large areas of soil and other surface materials are exposed to rain storms. Additionally, tilled cropland, depending on type of soils and the agricultural practices used, may be highly susceptible to surface erosion. The fine grained soil materials eroded from the surface may embed in aquatic habitats and/or carry nutrients to receiving waters, while the courser grained materials, mobilized when surface runoff concentrates into rills and gullies, contributes to an in- crease in bed sediment load and may result in significant channel adjustment. The percentage of cropped land use is mapped to show where expanses of land may have exposed soils and contribute significantly larger sediment loads. Sub-watershed polygons are used to indicate local crop land percentage and the stream reach line indicate the cumulative upstream crop land percentage (*Figure 10)*.

> **Evaluation:** Altered sediment load may be a significant stressor when crop land use reaches 5-10% of the watershed and may be the predominant stressor when it reaches 20% of the watershed. On the stressor identification table, using descriptors such as moderate, high, and extreme, indicate each reach which is likely to undergo adjustment due to the stress associated with crop land use, exposed soils, and surface erosion.

Sediment Load Indicators Map

In addition to the use of hydrology and land use/land cover data in an evaluation of sediment regime, there are other Phase 2 data which may provide important evidence of sediment load at different locations within the watershed. A map showing the type and quantity of erosion and deposition features may support a qualitative evaluation of where sediment load is increasing or decreasing. Used with information pertaining to channel modifications, and the soils, geology, and valley characteristics of a watershed, the assessor may use the sediment load indicators map to evaluate channel adjustments, stream sensitivity, and the degree to which project design and configuration may be subject to constraints associated with sediment regime.

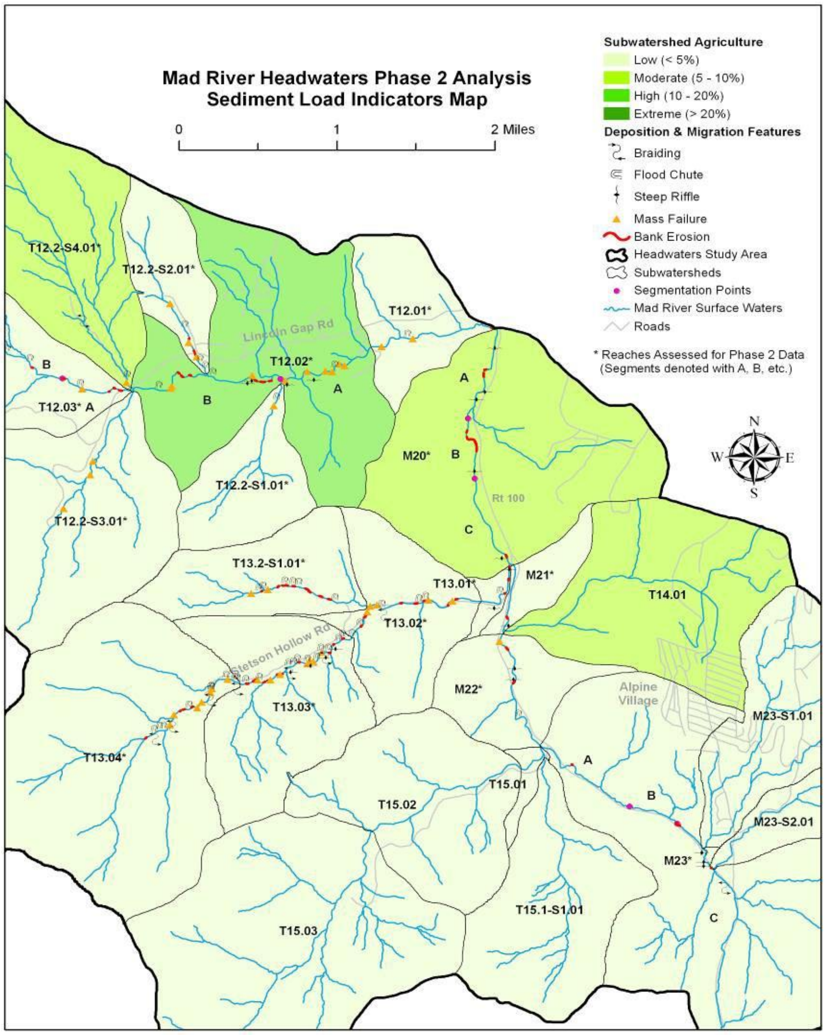


Figure 10 Example of a Sediment Load Indicators Map, Headwaters of the Mad River. Map Credits: Fitzgerald Environmental L.L.C.

Erosion and Deposition Features

Streams in an equilibrium state exhibit erosion and deposition processes. In good measure, these processes are essential ecologically—providing habitat features such as feeding and reproductive cover for aquatic organisms. When larger scale disequilibrium occurs, the degree and rate of erosion may significantly overwhelm the sediment transport capacity of a stream reach and depositional processes, detrimental to geomorphic stability and aquatic ecosystems, may occur. The purpose of this analysis is to look at the cumulative impact of erosion and subsequent deposition at the watershed scale.

Bank erosion, mass wasting sites, and gullies, including known locations on either right or left bank, are mapped and assessed as potentially large sources of fine and coarse sediments contributing to the suspended and bed loads of streams Much of Vermont was covered by glacial lakes to elevations tens of feet higher than the current valley floors. When streams erode into the high glacial lacustrine deposits (valley-side terraces) left behind, sediment loads increase and downstream channel adjustments may ensue. Another large-scale process elevating sediment loads occurs when stream beds incise and the base elevation of tributary streams down-cut to match the receiving stream. This is a process identified as tributary rejuvenation.

Steep riffles, mid-channel bars, delta bars, flood chutes, avulsions, and braiding are the deposition and planform features which often indicate of a high sediment load. The presence of deposits and channel bifurcations do not necessarily explain the source of sediment, but are common features when the transport capacity of the channel has been exceeded.

Evaluation: Use the River Stressor Identification Table (*Figure 11*) started during the evaluation of hydrologic regime stressors to indicate which reaches may be in adjustment, or significantly influenced from an equilibrium standpoint, by modifications of the sediment load coming from upstream and in-reach sources. For instance, where the sediment load and land use maps indicate a large number of sediment sources, then downstream reaches, if unconstrained, are likely to be aggrading. Also consult the departure and sensitivity maps, described below, to evaluate whether the current vertical channel adjustments (i.e., aggradation and degradation) within the stream network may be contributing to increases or decreases in sediment load. Mapping sediment regime departure provides a method for understanding where tributaries may be contributing a significant increase in sediment load. Increased sediment load may be a significant and noted stressor where upstream reaches are actively incising and widening, as observed on the departure and sensitivity maps.

	Watershed-Scale Stressors		Reach-Scale Stressors	
River Segment (name and number)	Hydrologic	Sediment Load	Stream Power	Boundary Resistance
List all assessed reaches in hydrological order		Increased load (provide detail)		

Figure 11 Example of River Stressors Identification Table indicating where sediment load stressors are causing or contributing to channel adjustment and a departure from equilibrium conditions.

Reach-Scale Sediment Regime Stressors

The just completed evaluation of flow and sediment load modifications at the watershed scale serves as a pretext for understanding the timing and degree to which reach-scale modifications are contributing to field observed channel adjustments. Referring to *Figure* 9, there are modifications to the valley, floodplain, and channel, as well as boundary conditions, at the reach scale that can change the hydraulic geometry and therefore change the way sediment is transported, sorted and distributed. Phase 1 and Phase 2 assessments provide semi-quantitative datasets for examining stressors and their effects on sediment regime when the channel hydraulic geometry of the channel is modified.

Table 3 sorts reach scale stressors into categories. Reach stressors affect either the stream power or the resistance to stream power, afforded by the channel boundary conditions. These categories are further subdivided into components of the hydraulic geometry, i.e., stream power into modifiers of slope and depth; and boundary resistance into those stressors affecting the streambed and stream banks. Finally, stressors are sorted as to whether they increase or decrease stream power and/or increase or decrease boundary conditions. By categorizing reach-scale stressors, it becomes easier to determine why a reach is under adjustment and what types of management activities will be complementary to the equilibrium process.

Table 3 Reach-scale sediment regime stressors.

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

For example, channel straightening, as an observed reach-scale stressor, may result in bed and bank erosion stemming from a measurable loss in floodplain access (i.e., increased incision), and play a significant role in temporarily enhancing sediment transport capacity as a result of the increased slope and depth at flood stage. If there is also a significant increase in sediment load from upstream, and the straightened reach is armored to arrest the erosion/deposition process, then the enhanced transport capacity would likely result in stress to reaches downstream of the channelization. Instead of storing some of the increased load, the straightened, armored transport reach is now conveying sediment. In this example, the reach-scale stressors are working in tandem with watershed-scale stressors to cumulatively affect equilibrium conditions throughout the stream network (Brookes, 1988; Huggett, 2003, Brierley and Fryirs, 2005).

The following section outlines the assessment parameters that may be important in depicting how equilibrium has been affected within a reach and the stressors that are most likely to be causing change. The Channel Slope and Depth Modifier Maps will be used to determine whether stream power has been significantly increased or decreased. The Channel Boundary and Riparian Modifiers Map will be used to explain whether the resistance to stream power has been increased or decreased.

Channel Slope Modifiers Map

The Channel Slope Modifiers Map includes those stressors that directly or indirectly lead to slope increases and those modifications that often result in a channel slope decrease (*Figure 12*).

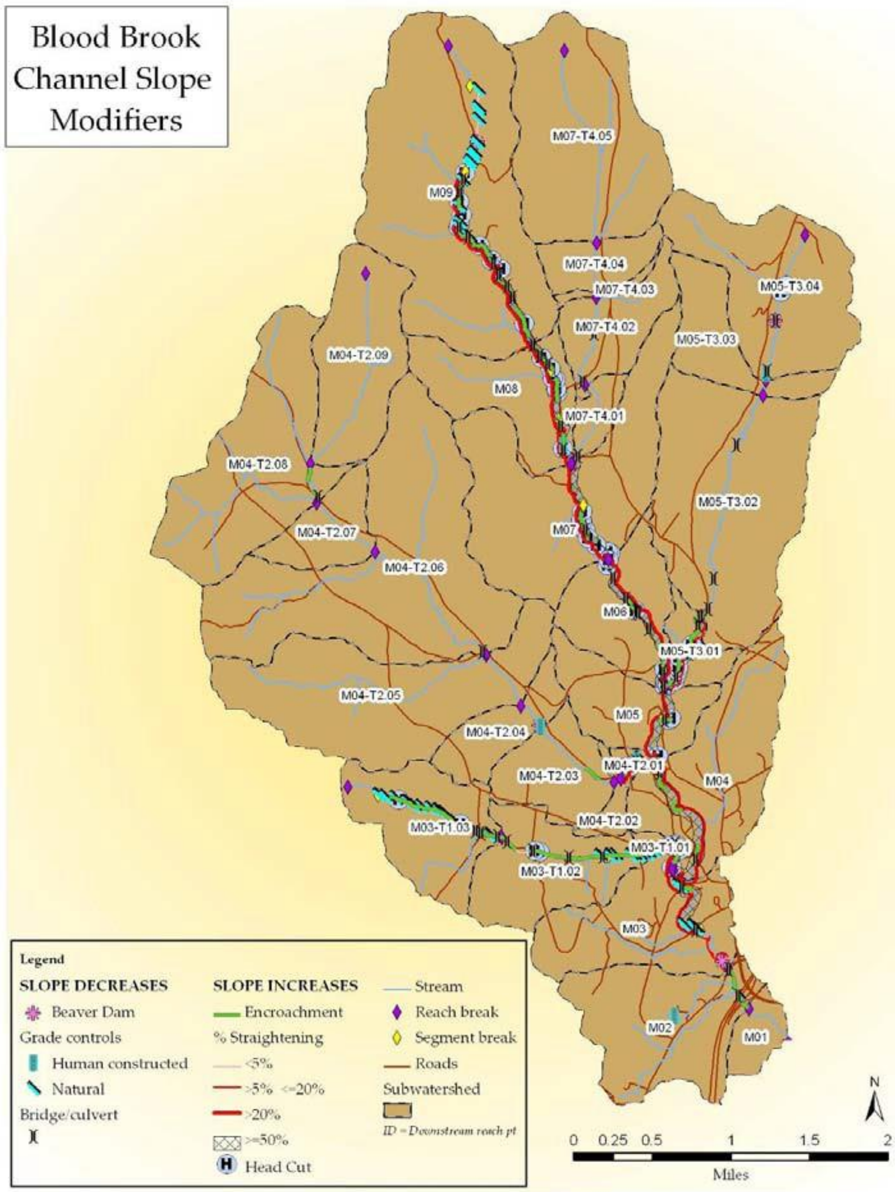


Figure 12 Example of a Channel Slope Modifiers Map, Blood Brook.
Map Credits: Redstart Forestry and Consulting.

Slope Increases

The historic manipulation and current maintenance of channel planform geometry during times of post flood recovery and in support of land uses incompatible with stream meandering led to significant increases in channel slope. Straightening and channelization of alluvial channels in Vermont watersheds generally ranges between 25 and 75% of the total stream length, with some valley bottom streams having been ditched and straightened their entire length. The increases in slope have been large enough to initiate bed erosion, incision, and subsequent stages of channel evolution.

Those reaches which have been straightened and channelized are mapped to show where the slope of the channel has been increased. The location of existing head cuts are also shown on this map to aid in the analysis of any channel adjustments associated with increases in slope and stream power.   The Channel Slope Modifiers Map should also depict river corridor encroachments such as roads and developments within the river corridor, which may indirectly lead to an increased channel slope as a result of the structural measures used to protect them.

Slope Decreases

Channel and floodplain constrictions often reduce the slope of a stream because they lead to an aggradation of sediment in the backwater zone they create during floods. The elevated bed near the constriction more nearly matches the bed elevation upstream, thereby reducing the overall slope of the channel. It is not uncommon to look at an orthophoto or topographic map and see one or more torturous meanders formed above a constriction, which may be natural (e.g., a bedrock gorge), or human structures such as undersized bridges and culverts. The location of stream crossings, dams, and weirs are mapped to indicate the presence of grade controls and channel constrictions which back-up flood flows and/or raise the elevation of the channel bed.

Evaluation: slope-related stressors affect hydraulic geometry, initiate or contribute to channel adjustments, and may be used to predict a sequence of stream responses. *Table 4* (below) attempts to explain the channel adjustments that typically occur in response to changes in stream power as a stream regains equilibrium. In the Stressor ID Table under the reach-scale stressor columns, indicate whether stream power has been increased or decreased as a result of increases or decreases in channel slope. For instance, if a reach has been significantly straightened and is experiencing head-cutting and/or lack depositional features (due to excessive scour – see Sediment Load Indicators Map), then note an "increase in stream power from increase in channel slope." Where dams and constrictions have resulted in a significant increase in upstream depositional process and high amplitude meandering, note a "decrease in stream power from decrease in channel slope."

Channel Depth Modifier Map

The Channel Depth Modifiers Map includes those stressors that directly or indirectly lead to depth increases and those modifications that may result in decreases of the channel depth (*Figure 13*).

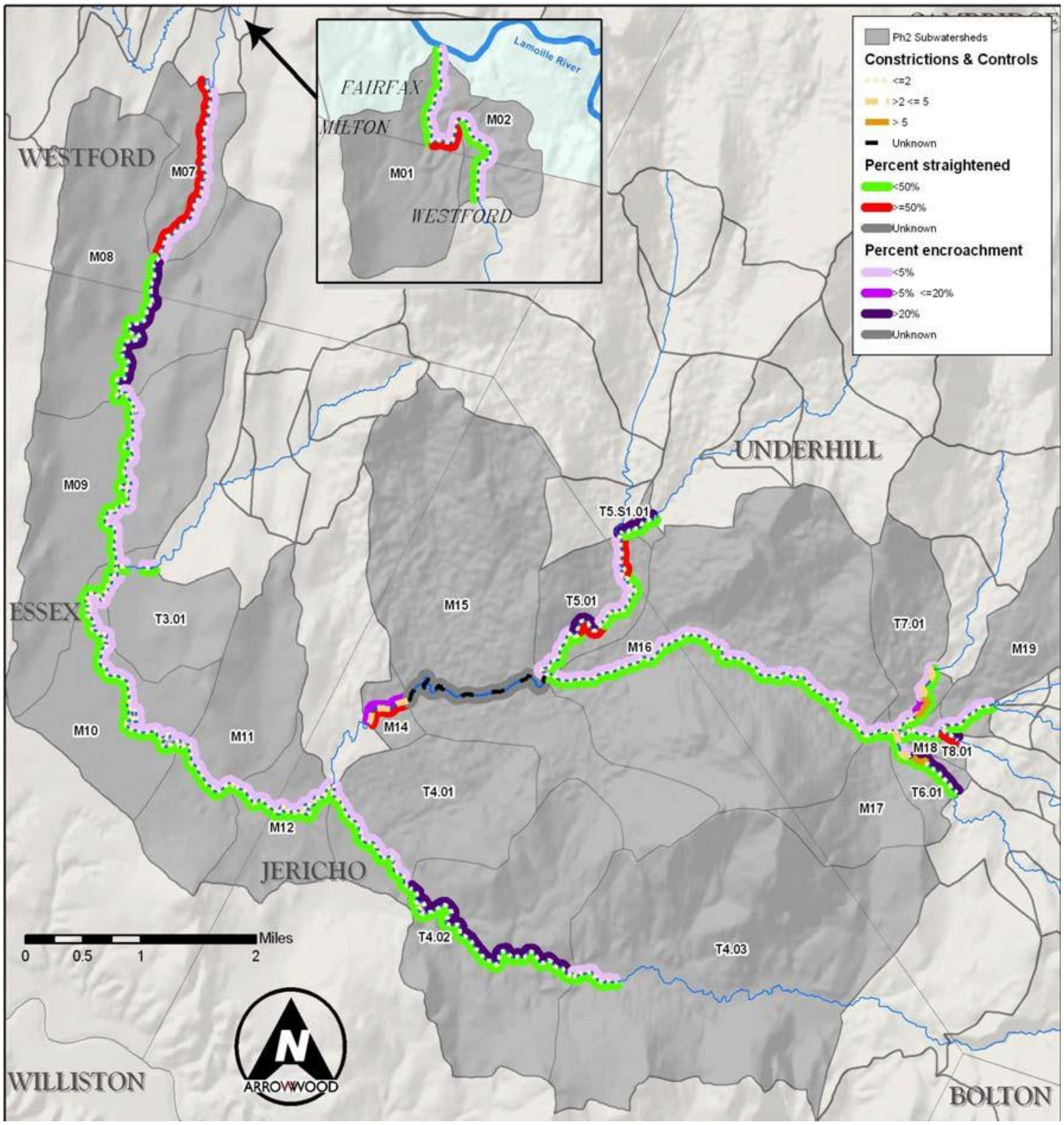


Figure 13 Example of a Channel Depth Modifier Map, Browns River. Map Credits: Arrowwood Environmental

Increases in Depth

The lowering of stream beds and the raising of floodplains have, either singularly or in combination, resulted in an increase in overall channel depth. Historic deforestation and subsequent hill-slope erosion significantly raised the floodplain elevations of many Vermont headwater valleys. This condition coupled with channel incision or dredging activities has profoundly increased the depth of many Vermont stream channels. Channel depths have also been increased as a result of the floodplain fills associated with roads and other river corridor encroachments. Channel enlargement and deepening have occurred where urbanization and stormwater have altered watershed hydrology. Significant increases in channel depth have increased stream power enough to initiate bed erosion, incision, and subsequent stages of channel evolution.

The Channel Depth Modifier Map should show which reaches have been dredged, as well as the location of berms, elevated roads, and railroads within the river corridor which have increased the depth of flood flows. Roads and railroads may also be added by using the data available through VCGI (Vermont Center for Geographic Information). If a road is not elevated (as observed in the field), then it would not be included as a feature modifying channel depth. Storm water outfalls are also indicated to note where significant increases in peak discharge during floods may result in an increase in flow depths and stream power.

Decreases in Depth

Stream channel depth may be significantly decreased when the width of the bankfull channel is increased. Channel widths may be significantly increased during dredging and gravel mining operations, or when depositional processes lead to erosion of the stream banks. A decrease in depth reduces stream power and the ability of the stream to transport bed load sediments. A reduction in depth may result in an increase in channel slope, i.e., channel avulsion, and/or a redevelopment of depositional features such as new floodplain when a channel evolves from Stage III to Stage IV. In either case, areas of shallow depth are associated with more sensitive and dynamic reaches.

Map delta and backwater deposits to indicate areas with a higher probability of more shallow depths during moderate flows due to a wider channel and the mid-channel deposits. Stream power is typically lower in delta and backwater areas. Gravel mining and bar scalping activities also increase the potential for more shallow depths during flood flows due to the over-widening of the channel that often results from dredging, gravel mining and bar scalping.

Evaluation: depth-related stressors affect hydraulic geometry, initiate or contribute to channel adjustments, and may be used to predict a sequence of stream responses. *Table 4* (below) attempts to explain the channel adjustments that typically occur in response to changes in stream power as a stream regains equilibrium. In the Stressor ID Table under the reach-scale stressor columns, indicate whether stream power has been increased or decreased as a result of increases or decreases in channel depth modifiers. For instance, if a reach has been significantly deepened due to floodplain fills, hy- drologic stress, or any subsequent incision process, note an “increase in stream power from increase in channel depth.” Channel dredging may result in an increase in depth, or in a significant decrease in channel depth, depending on whether the channel was mechanically over-widened. Note the change in stream power from an increase or decrease in channel depth.

Boundary Conditions and Riparian Modifiers Map

The Boundary Conditions and Riparian Modifiers Map includes those stressors that directly or indirectly lead to increases or decreases in the boundary resistance of the channel (*Figure 14*).

Increased Boundary Resistance

The resistance of the channel boundary materials to the shear stress and stream power exerted, will, in large part, determine whether the channel will undergo adjustment. Riparian vegetation are self-maintaining materials resistant to erosion. The size and cohesion of inorganic bed and bank materials (e.g., clay, sand, gravels, cobbles, etc.) also determines boundary resistance. Human-placed bed and bank armoring should be thought of as mostly effective, but temporary unless maintained.

Riparian vegetation and bank cohesiveness are mapped to indicating areas with little or no woody (or natural) vegetation. The root networks of woody vegetation bind stream bank soils and sediment adding to the bank’s resistance to erosion. Herbaceous plants in lower gradient, meadow streams serve the same function. The map will show where buffers are lacking, thereby indicating a stressor on the boundary resistance function of buffer vegetation. To interpret where boundary resistance is enhanced by riparian vegetation, look for those stream segments which are not indicated as having "little or no buffer." Data are also mapped to evaluate the boundary resistance as a function of the cohesiveness of the lower bank materials. Finally, the resistance of channel beds to erosion may be evaluated by mapping both natural and man-made grade controls and the presence of course bed substrate materials. Man-made grade controls other than dams may indicate that the stream bed is sensitive to erosion.

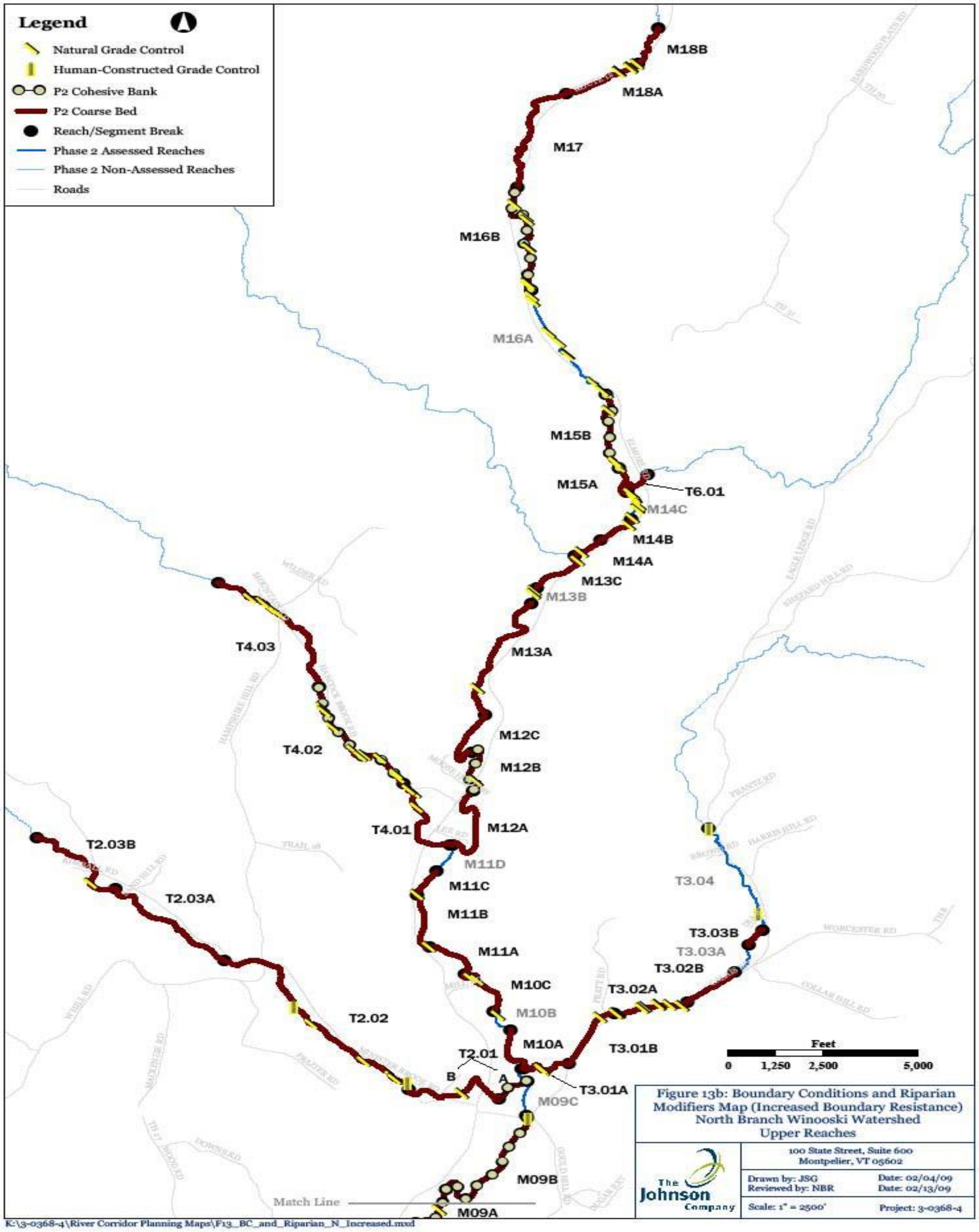


Figure 14 Example of a Boundary Conditions and Riparian Modifiers Map. Map Credits: The Johnson Company.

Decreased Boundary Resistance

When deep-rooted and perennial vegetation is removed and/or the coarser materials of the stream bed are disrupted or removed, the boundary resistance is decreased, and bed or bank erosion typically ensues. Bank armoring while temporarily increasing bank boundary resistance is indicative of where either stream power has been increased and bank resistance has been reduced. A decrease in boundary resistance may, in and of itself, be the stressor that initiates a channel evolution process. Streams with a naturally low width-depth ratio, such as equilibrium E channels, may undergo major channel adjustment when riparian vegetation is removed.

Areas of active bank erosion and bank armoring are mapped to indicate where the stream power produced in the channel has been or is still overcoming the boundary resistance of the streambank materials. Extensive bank armoring may increase stream power by reducing the natural roughness of the channel. The data for erosion and bank armoring should be shown on maps as separate parameters. Historic snagging and windrowing areas are indicated where woody debris and bed substrate were removed or dredged from the stream bed. These practices reduce the roughness and resistance of the stream bed to erosion.

Evaluation: boundary stressors affect hydraulic geometry, initiate or contribute to channel adjustments, and may be used to predict a sequence of stream responses. *Table 4* attempts to explain the channel adjustments that typically occur in response to changes in stream power and boundary resistance as a stream regains equilibrium. Under the reach-scale stressor columns, for reaches where appropriate, indicate whether boundary resistance has been increased or decreased. For reaches where boundary resistance has been maintained through the protection of riparian vegetation, or the maintenance of artificial bed and bank hardening, indicate an "increase in boundary resistance due to natural/artificial materials" in the Stressor ID Table. Where vegetation removal or stream bed dredging have resulted in a significant decrease in boundary resistance, indicate a "decrease in boundary resistance" in the Stressor ID Table.

Table 4 Typical channel response to a change in stream power and boundary resistance.*

	→ Sequence of Adjustments →		
Stream power increased over boundary resistance threshold	Erosion occurs on the bed and banks; depth may initially increase until the bed coarsens and excess stream power begins eroding and steepening stream banks and widening the channel.	Depth decreases as the channel widens in response to mid-channel deposition.	Slope decreases as the channel lengthens around growing depositional features and stream power is decreased. Reduced slope may facilitate increased stability of boundary conditions as described below.
Stream power decreased below sediment transport threshold	Deposition ensues and bed becomes more fine grained, flows are concentrated on banks, and the channel further widens.	Slope decreases as the channel lengthens around growing depositional features. Meander extensions may become extreme; channel avulsions and meander cutoffs then lead to shortened channels and head cutting. Interceding periods of increased slope enhance sediment transport by initiating the processes described above under increased stream power.	Eventually, fine sediment features become conducive to revegetation. Bank resistance and a moderated channel slope, contributing to the redevelopment of a narrower, deeper channel, and the stream power necessary to transport sediment load.

* These adjustments will occur or play out differently if there are also watershed-scale stressors such as an increased sediment supply from upstream, new reach stressors are introduced mid-process, or the reach is located in an extremely sensitive, high-deposition zone such as an alluvial fan. Channel adjustments that move the stream toward equilibrium (channel evolution) typically occur over long periods of time in response to one or more large flow events (i.e., floods). Like a pendulum, adjustments may swing through the idealized state, even stagnating at different equilibrium stream types, until dampening back to an equilibrium consistent with its setting and watershed inputs.

In evaluating the influence of stream power-related stressors on the channel adjustments described in *Table 4*, it is important to remember boundary resistance factors which affect equilibrium conditions and govern how a stream will respond. Modifications to the boundary conditions of the stream may affect channel adjustments as follows:

- If bed resistance is significantly increased over the bank resistance and/or the bank resistance is reduced, the banks will erode and the bed may aggrade. Lateral erosion may lead to a wider or lower gradient channel which will result in a decrease in steam power.
- If bank resistance is significantly increased, and/or bed resistance is reduced, then bed erosion deepens the channel. The deepened channel results in an increase in steam power. If scour continues, bank materials and/or armoring may become undermined and the channel widening process begins.
- If bed and bank materials are both resistant or have been made resistant to the stream power produced by the slope and depth of the channel then (for some period of time) erosion and deposition processes are transferred to downstream reaches.

5.1.3 Constraints to Sediment Transport and Attenuation

Successful river corridor restoration and protection projects require an understanding of where a stream reach is in the channel evolution process and how rapidly one might expect the channel to evolve back to equilibrium conditions. This analysis can not be isolated to the project reach. An analysis of departure and sensitivity must be conducted over larger reach and watershed scales. Whether a project works with or against the physical processes at play in a watershed is primarily determined by examining the source, volumes, and attenuation of flood flows and sediment loads from one reach to the next within the stream network. For instance, when an increased sediment load is transported through the network to the sensitive reach, where conflicts with human investments are creating a management expectation, little success can be expected unless the restoration design accommodates the increased load or finds a way to attenuate the load upstream and/or downstream.

Within a reach, the principals of stream equilibrium dictate that stream power and sediment will tend to distribute evenly over time (Leopold, 1994). Changes or modifications to watershed inputs and hydraulic geometry create disequilibrium and lead to an uneven distribution of stream power and sediment. Large channel adjustments observed as dramatic erosion and deposition may be the result of this uneven distribution and may continue until equilibrium is achieved. This principal should not be considered an absolute rule governing the behavior of all reaches within a watershed. Certain reaches will, by nature, be either transport dominant or deficient, and/or the temporal scale at which the distribution of energy and sediment becomes equilibrated is lengthened considerably as compared to other reaches. In the short term, an alluvial

Sediment Deposition and Transport Modifiers

Causes of **increased** transport capacity:

- Hard-armored channelized reaches
- Channelized and straightened reaches
- Berming and straightening
- Channel incision and entrenchment
- Increased storm flows (Urban land use >10%)
- Reduced sediment supplies (below dams and undersized culverts)

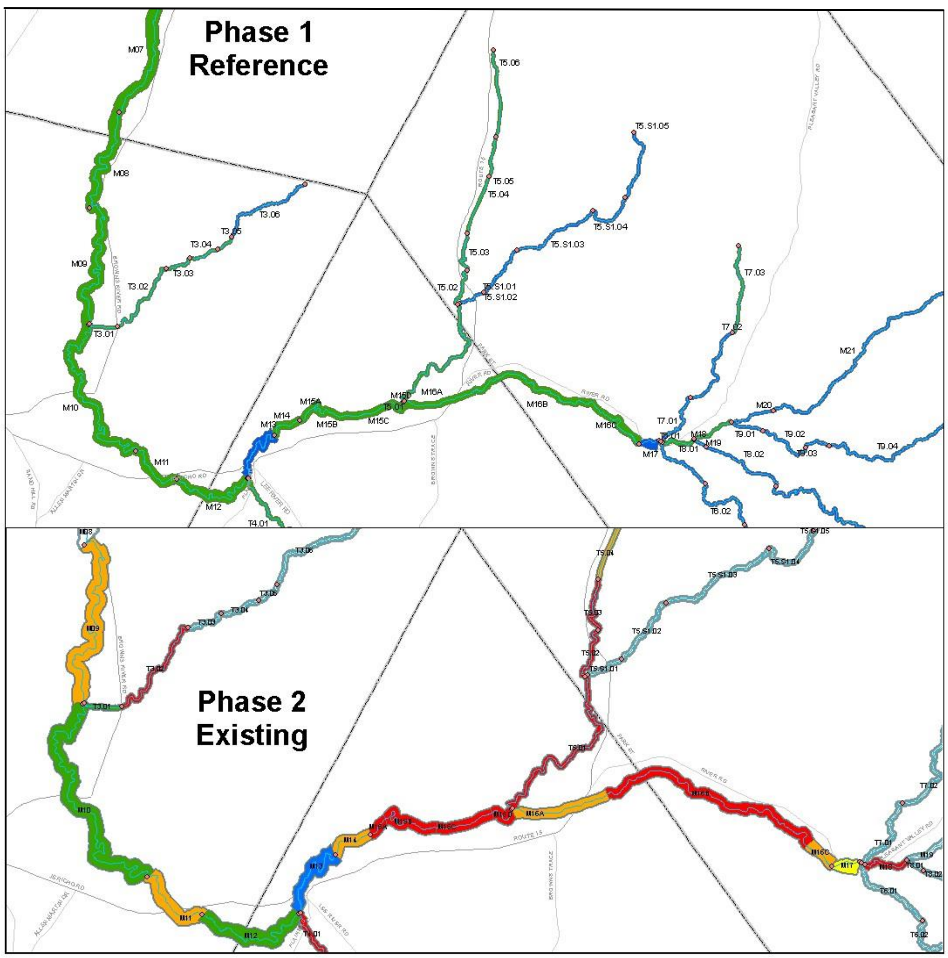
Causes of **decreased** transport capacity:

- In-stream dams and weirs
- Undersized bridges and culverts
- Removal of riparian vegetation
- Channel aggradation and/or braiding
- Decreased storm flows (flow diversions)
- Increases in sediment supply
- Gravel mining and bar scalping

fan reach may be classified as transport deficient (characterized by depositional processes). During dryer climates, when sediment production is lower, the same reach may switch to a transport mode, and begin eroding the accumulated sediment.

Rarely is a stream reach, and the character of its transport processes, ever affected by just a single stressor. Analyzing multiple and overlapping stressors is complicated and requires the use of watershed maps that depict existing and ongoing changes in hydraulic geometry as compared with reference conditions. "Sediment Regime Departure Maps" are therefore suggested as a way to examine these changes and understand the natural and human structures that govern the evolution of a channel back to equilibrium conditions. In combination with the stressor maps, particularly the Sediment Load Indicators Map, sediment regime departure maps are extremely useful in preliminary project identification because specific strategies may be devised to deal with reach and watershed stressors, which have been targeted as contributing to the departure.

Table 5 describes how, in different stream types, the stages of channel evolution, incision, and aggradation may translate into modification of the sediment regime. It is important to note that, the sediment regimes described in *Table 5* attempt to characterize the source and fate of both fine and course sediment loads (i.e., wash and bed sediment loads).



Sediment Regime Departure Maps for the Browns River, Vermont showing the conversion of stream reaches from a regime conducive to fine sediment deposition to those that are more transport dominated.

Table 5 Sediment regime types - color coding and descriptions

Sediment Regime	Narrative Description
Transport	Steeper bedrock and boulder/cobble cascade and step-pool stream types; typically in more confined valleys, do not supply appreciable quantities of sediments to downstream reaches on an annual basis; little or no mass wasting; storage of fine sediment is negligible due to high transport capacity derived from both the high gradient and/or natural entrenchment of the channel.
Confined Source and Transport	Cobble step pool and steep plane bed streams; confining valley walls, comprised of erodible tills, glacial lacustrine, glacial fluvial, or alluvial materials; mass wasting and landslides common and may be triggered by valley rejuvenation processes; storage of coarse or fine sediment is limited due to high transport capacity derived from both the gradient and entrenchment of the channel. Look for streams in narrow valleys where dams, culverts, encroachment (roads, houses, etc.), and subsequent channel management may trigger incision, rejuvenation, and mass wasting processes.
Unconfined Source and Transport	Sand, gravel, or cobble plane bed streams; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to entrenchment or incision and associated bed form changes; these streams are not a significant sediment supply due to boundary resistance such as bank armoring, but may begin to experience erosion and supply both coarse and fine sediment when bank failure leads to channel widening; storage of coarse or fine sediment is negligible due to high transport capacity derived from the deep incision and little or no floodplain access. Look for straightened, incised or entrenched streams in unconfined valleys, which may have been bermed and extensively armored and are in Stage II or early Stage III of channel evolution.
Fine Source and Transport & Coarse Deposition	Sand, gravel, or cobble streams with variable bed forms; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to vertical profile and associated bed form changes; these streams supply both coarse and fine sediments due to little or no boundary resistance; storage of fine sediment is lost or severely limited as a result of channel incision and little or no floodplain access; an increase in coarse sediment storage occurs due to a high coarse sediment load coupled with the lower transport capacity that results from a lower gradient and/or channel depth. Look for historically straightened, incised, or entrenched streams in unconfined valleys, having little or no boundary resistance, increased bank erosion, and large unvegetated bars. These streams are typically in late Stage III and Stage IV of channel evolution.
Coarse Equilibrium (in = out) & Fine Deposition	Sand, gravel, or cobble streams with equilibrium bed forms; at least one side of the channel is unconfined by valley walls; these streams transport and deposit coarse sediment in equilibrium (stream power—produce as a result of channel gradient and hydraulic radius—is balanced by the sediment load, sediment size, and channel boundary resistance); and store a relatively large volume of fine sediment due to the access of high frequency (annual) floods to the floodplain. Look for unconfined streams, which are not incised or entrenched, have boundary resistance (woody buffers), minimal bank erosion, and vegetated bars. These streams are Stage I, late Stage IV, and Stage V.
Deposition	Silt, Sand, gravel, or cobble streams with variable and braided bed forms; at least one side of the channel is unconfined by valley walls; may represent a stream type departure due to changes in slope and/or depth resulting in the predominance of transient depositional features; storage of fine and coarse sediment frequently exceeds transport**. Floodplains are accessed during high frequency (annual) floods. Look for unconfined streams, which are not incised or entrenched, have become significantly over-widened, and if high rates of bank erosion are present, it is offset by the vertical growth of unvegetated bars. These regimes may be located at zones of naturally high deposition (e.g., active alluvial fans, deltas, or upstream of bedrock controls), or may exist due to impoundment and other backwater conditions above weirs, dams and other constrictions.

** Use of the "Deposition" regime characterization may be rare, but valuable as a planning tool, where the reach is storing far more than it is transporting during some defined planning period. The extreme example would be that of an impounded reach where all of the course and a great percentage of the fine sediments are being deposited, rather than transported downstream. This man-made condition may change, thereby changing the sediment regime, but is not likely over the period at which the corridor plan will be used.

The sediment regime of a stream is significantly influenced by the slope, width and depth of the channel and the relationship of the bankfull channel to the adjacent floodplain. The stage of channel evolution, as documented for each field assessed river segment (or reach), integrates channel dimension factors, and is therefore a primary indicator of the existing sediment regime type. *Table 6* describes in more detail how the stages of channel evolution and other parameters may be used to evaluate a sediment regime for each stream reach. Criteria are provided in columns from left to right, in the order of relative importance. The reach data will typically match all the criteria provided in the columns for a regime type, but, outliers exist, and the assessor should document the conditions which led them to select a regime type that may be extraordinary.

Table 6 Additional data for characterizing existing sediment regime using Phase 2 data.

Sediment Regime	Delimiting criteria related to sediment supply, transport, and storage	Stage of Channel Evolution Geomorphic Condition	Common Existing Stream Type	Natural Valley Type
Transport	Bedrock gorge = yes	Stage I or V Good-Ref	A1, A2, B1, B2 G1,G2, G3 F1, F2, F3	NC, SC, NW
	Incision ratio < 1.3	Stage I or V Good-Ref	A3, B3, B4	NC, SC, NW
Confined Source and Transport	Incision ratio > 1.3	Stage II-IV Fair-Good	A3, B3*	NC, SC, NW
	Incision ratio > 1.3	Stage II-IV Fair-Good	A4, A5 B4*, B5*	Any Type
Unconfined Source & Transport	Bank armor > 50% Straightening > 50% W/d < 30 Incision ratio > 1.3	Stage II - III Poor-Fair	G3, G4, G5 F3, F4, F5	NW, BD, VB
		Stage II - III Poor-Fair	E3, E4, E5 C3, C4, C5 B3c, B4c, B5c	NW, BD, VB
Fine Source & Transport and Coarse Deposition	Bank armor < 50% W/d > 30** Incision ratio > 1.3	Stage II-IV Poor-Fair	E3, E4, E5 C3, C4, C5 B3c, B4c, B5c F3, F4, F5	NW, BD, VB
	Bank armor < 50% Incision ratio > 1.3	Stage II-IV Poor-Fair	D3, D4, D5	NW, BD, VB
Coarse Equilibrium (in = out) & Fine Deposition	Incision ratio < 1.3	Stage I -V Fair-Good-Ref	D3, D4, D5	NW, BD, VB
	W/d < 30 Incision ratio < 1.3	Stage I -V Fair-Good-Ref	C2, C3, E3	NW, BD, VB
	W/d < 30 Incision ratio < 1.3	Stage I -V Fair-Good-Ref	C4, C5 E4, E5	NW, BD, VB
Deposition	Incision ratio = 1.0 Backwater from downstream constriction, weir, dam, etc.	Stage IId	C4, C5, C6	BD, VB
	Incision ratio = 1.0 Active alluvial fan	Stage IId	D3, D4, D5	BD, VB

* B streams with the slope of a C stream, or a Bc stream type, in an unconfined valley setting (NW, BD, VB) should be classified as having a sediment regime as either "unconfined source and transport" or a "fine source and transport & course deposition" depending on other delimiting criteria.

** Depositional Features may include multiple channel avulsions and multiple chute cut-offs

Sediment Regime Departure Map

The Sediment Regime Departure Map is perhaps the single most useful tool for evaluating how channel adjustments in one reach may be affecting adjustments and equilibrium conditions of another. A full description of the construction of these maps is provided in the Mapping Appendix. Looking at sediment regimes and sediment regime departures at a watershed scale is critical to meeting the primary goal of corridor planning, that of managing a stream system toward a more equal distribution of sediment and energy (i.e., equilibrium conditions). When evaluated in the context of natural and human constraints, the assessor may identify priorities for restoring transport and sediment attenuation processes.

Two maps are created, one for the most probable reference sediment regime types, using Phase 1 data, and a second for the existing condition using Phase 2 data. Mapping reference conditions primarily relies on use of the Phase 1 valley type and valley slope to designate a sediment regime. Existing conditions are based on the degree of incision, the stage of channel evolution, the existing stream type, and certain channel modifiers.

To examine anticipated channel adjustments and the potential for restoration, the assessor then maps documented channel constraints as overlays on the Sediment Regime Departure Maps. These natural or human-constructed features represent both lateral and vertical constraint to channel adjustment. Place natural constraints on the reference sediment regime map (Phase 1 data) and place both natural and human constraints on the existing sediment regime map (Phase 2 data).

Natural and human constructed grade controls may be important vertical constraints, reducing the energy gradient (slope) of the stream, and confining the migration of upstream head-cutting or the flow of certain sediment sizes in the downstream direction. Lateral constraints include human-made constrictions and corridor encroachments. One of the greatest challenges in the river corridor planning process will be to figure out which human invest- ments, at the present time, represent long-term constraints (perhaps as immutable as a rock gorge). In the pre- liminary project identification process (Section 6), only documented structural investments will be mapped as lat- eral constraints. Parcel boundaries are also added to Sediment Regime Departure Maps, because these political boundaries may lead to other constraints and/or constrain the design of a given protection or restoration project. It is very desirable to know, from the very start, where one landownership ends and another begins.

Evaluation: An understanding of departure is aided by making a side-by-side comparison of existing versus reference sediment regimes. For watersheds, which have been significantly modified, the first observation is the degree to which portions of the watershed have changed with respect to sediment transport. Special attention should be given to the loss of storage (or deposition) process. Watersheds which have lost attenuation or sediment storage areas, due to human-related constraints, are generally more sensitive to erosion hazards, transport greater quantities of sediment and nutrient to receiving waters, and lack the sediment and large wood storage and distribution processes that create and maintain habitat.

Constraints: Natural or human constructed features may be very resistant to erosion and explain the likely extent to which erosion and depositional processes will play out laterally and longitudinally within the watershed. For instance, if head cuts were mapped (located on field sketches) in a reach, which has departed from a storage regime to a transport regime, the expectation would be that, the higher channel energy in the transport reach would be favorable to a rapid upstream movement of the head cut or incision process. If a grade control exists (e.g., bedrock ledge) within the reach, then the threat of the incision process moving past the grade control and threatening further upstream reaches would be minimal. In another example, these constraints may not be governing, but rather the cause of sediment regime change, such as the significant increase in storage or natural depositional process that often occurs just upstream of bedrock gorges.

Locating vertical and lateral constraints on the sediment regime maps provides an opportunity to begin looking for locations where it may be possible to mitigate channel adjustments or extreme modifications to sediment transport capacity. For instance, finding opportunities to even out the distribution of stream power and sediment load within a stream network often involves looking for reaches or segments with little or no lateral constraints where larger flows and sediment loads may be attenuated. Working with landowners to restore and protect these places within the river corridor as "attenuation assets" may be the best way to reduce erosion hazards to downstream landowners and increase sediment storage and habitat values. Consideration of lateral constraints in project planning will be further discussed in Section 6. In general, developed land represents a constraint in the re-establishment of meanders and floodplain for the attenuation of flood flows and sediment deposition.

In most cases, the sensitivity of reaches downstream of the human-constrained reach will increase as the sediment load is transferred and then deposits when the transport capacity is exceeded. In some cases, due to constraints, which alter flow and sediment inputs or permanently alter channel hydraulic geometry, an alternatives analysis may show that the only way to achieve equilibrium conditions is by establishing a "modified" reference channel/floodplain condition. Restoration and protection designs must consider and accommodate permanent constraints impinged on the river network, which have changed fluvial processes at a larger scale.

Transport and Attenuation: Many channels that once had floodplain access, where erosion and deposition processes were in balance, have become incised and more powerful during and in response to flood events. Until bank erosion significantly widens the channel, these reaches will not only have more capacity to transport sediment from upstream, but also may generate more sediment and increase the load to downstream reaches. In this scenario it is interesting to look down the stream network to find the reach where transport capacity is reduced and sediment deposition is accentuated. This reduction in transport capacity may be due to a natural change in hydraulic geometry (e.g., at an alluvial fan or a bedrock valley constriction) or due to some manmade stressor such as an undersized culvert. In some cases, it is not a slope reduction, but rather a sediment capacity issue—where the load under transport simply becomes too great for the channel to transport. Once aggradation begins, it can proceed rapidly until widening leads to a further reduction in transport capacity. In this process, deposition leads to channel avulsions, tremendous erosion, and often substantial flood damage.

To interpret sediment regime departure, the assessor should carefully examine stream bed erosion and deposition, as well as the constraints on these processes. To place all of this data on the Departure Map would clutter and obscure other information. Therefore, other stressor maps produced in this Section, in particular the Sediment Load Indicators and Channel Slope Modifiers maps, which show important sediment regime characteristics, should be closely consulted. Some erosion and deposition processes are part of the natural signature of dynamic equilibrium conditions that occur in certain valley locations (e.g., alluvial fans), but others represent the outcomes of the cause-and-effect relationship between sediment regime departures and the vertical adjustments that often result. For instance, the reach with multiple bar features and channel bifurcations, indicative of significant bed aggradation, may be seen below a set of upstream reaches that had been converted from storage to transport regimes. Likewise, a confluence reach with large delta bars may warrant consideration of whether the tributary sediment load has increased significantly beyond the receiving waters transport capacity.

Use the following guidelines, definitions, and interpretations of the Sediment Regime Departure Map to characterize river segments and reaches in the Departure Analysis Table as shown in *Figure 16.*

Constraints: In the columns provided, indicate whether the reach is vertically or laterally constrained and whether the constraint is "natural" or "human" constructed.

Transport: Place an "X" in the appropriate column to indicate whether the segment is a transport-type stream naturally or has been converted to a transport stream due to human-placed constraints.

Attenuation: Place an "X" in the appropriate column to indicate whether the segment is a high deposition zone naturally (e.g., alluvial fans and deltas), is experiencing a significant increase in sediment deposition, and/or would be an attenuation asset to allow future deposition to occur.

	Constraints		Transport		Attenuation (storage)		
River Segment (name and number)	Vertical	Lateral	Natural	Converted	Natural	Increased	Asset

Figure 16 Example of Departure Analysis Table indicating where river segments are constrained from adjustment, converted to transport streams, and/or have existing or future potential as a place to attenuate sediment load.

The utility of the Departure Analysis Table is where an assessor is prioritizing reaches for river corridor easements. An ideal reach for easement acquisition may be the first laterally unconstrained reach experiencing increased deposition (attenuation) below a string of reaches that were converted to transport dominated systems as a result of straightening and encroachment. The reach was not necessarily a location where a naturally high degree of sediment storage would otherwise take place, but was categorized as the ideal attenuation asset because of opportunity to mitigate the sediment regime departures upstream.

With a new perspective on sediment deposition and transport processes throughout the stream network, use the Stressor Maps and the Sediment Regime Departure Map to re-evaluate sediment load, stream power and boundary resistance modifications. Examine the likelihood and degree to which a sediment regime departure in the reach is creating imbalances in upstream or downstream reaches. Adjust any interpretations made on the River Stressors Identification Tables to incorporate changes discovered in the analysis of sediment regime departure, i.e. increases or decreases in sediment load. In this way, the success of a river management practice targeted at reach-scale stressors may be weighed against the types of channel adjustments that may be underway due to watershed and network scale stressors.

Stream Sensitivity Map

Stream Sensitivity Maps help synthesize a great deal of information by identifying the degree or likelihood that vertical and lateral adjustments (erosion) will occur, as driven by natural and/or human-induced fluvial processes (*Figure 17*). The Phase 2 stream sensitivity rating is depicted on a map for each field assessed river segment (or reach) as described in the Mapping Appendix. Sensitivity is assigned 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. This approach is intended to capture: 1) the inherent sensitivity of the stream; and 2) whether that sensitivity is heightened due to major adjustments that may be ongoing in the stream segment. For instance, when the stream is in fair or poor geomorphic condition as a result of major channel adjustments, the sensitivity rating may be increased significantly (*Table 7*).

Table 7 Stream sensitivity ratings and color coding based on stream type and condition

	Sensitivity Ratings		
Existing Geomorphic Stream Type*	**Reference or Good Condition**	**Fair-Poor Condition in Major Adjustment**	**Poor Condition and represents a Stream Type Departure**
A1, A2, B1, B2,	Very Low	Very Low	Low
C1, C2	Very Low	Low	Moderate
G1,G2	Low	Moderate	High
F1, F2	Low	Moderate	High
B3, B4, B5	Moderate	High	High
B3c, C3, E3	Moderate	High	High
C4, C5, B4c,B5c	High	Very High	Very High
A3, A4, A5, G3, F3	High	Very High	Extreme
G4, G5, F4, F5	Very High	Very High	Extreme
D3, D4, D5	Extreme	Extreme	Extreme
C6, E4,E5,E6	High	Extreme	Extreme

* Geomorphic stream types from the Rosgen (1996) Classification System

A second overlay on the Sensitivity Maps documents the current vertical channel adjustment within the reach, including major degradation or aggradation adjustments. The priority of implementing the projects identified in Section 6 of this Guide will be concerned with whether or not the stream channel is undergoing vertical adjustments. For instance, the decision to prioritize the placement of grade controls in a stream channel over other management actions may be influenced by whether the channel is actively degrading. In one example, hydrologic alterations and the need for stormwater controls may be essential for resolving the most significant stressor in the watershed, but the construction of weirs at head cut locations may preserve critical floodplain functions while the primary issue is being resolved.

Evaluation: Certain geomorphic stream types are inherently more sensitive than others, responding readily through lateral and/or vertical adjustments to high flow events and/or influxes of sediment. Other geomorphic stream types may undergo far less adjustment in response to the same watershed inputs. In general, streams receiving a large supply of sediment, having a limited capacity to transport that sediment, and flowing through finer-grained, non-cohesive materials are inherently more sensitive to adjustment and likely to experience channel evolution processes than streams with a lower sediment supply, higher transport capacity and flowing through cohesive or coarse-grained materials (Montgomery and Buffington, 1997). The geometry and roughness of the stream channel and floodplain (i.e., the width, depth, slope, sediment sizes, and floodplain relations) dictate the velocity of flow, how much erosive power is produced, and whether the stream has the competence to transport the sediment delivered from upstream (Leopold, 1994). If the energy produced by the depth and slope of the water is either too little or too great in relation to the sediment available for transport, the stream may be out of equilibrium and channel adjustments are likely to occur, especially during flood conditions (Lane, 1955). To interpret stream sensitivity, the assessor should carefully examine the watershed and reach-scale stressors that affect sensitivity. To place all of this data on the Sensitivity Map would clutter and obscure important information. Therefore, other stressor maps produced in this Section should be closely consulted.

The stream sensitivity analysis will be used to moderate the conclusions one might make with respect to transport and deposition processes occurring in different parts of a watershed. A few examples:

- The departure maps show a couple incised reaches in similar settings. Both reaches may be similarly sensitive, but one reach may be actively degrading and the second may be in the process of aggrading. In this example, the first reach may be prioritized for more immediate action to address reach scale stressors.

- The departure maps show a couple incised reaches but in different geologic settings—one cut into an alluvial material, and a second incised into a more cohesive, glacial-lacustrine material, and both in the process of widening and aggrading. The alluvial material will heighten the sensitivity of the stream, thereby tipping the alternatives analysis toward a more active restoration of the floodplain feature in materials that would otherwise erode rapidly causing instability downstream.

- The departure maps show a couple of aggrading reaches. The reaches are in different settings, however, the first being in an alluvial fan or delta area of extreme sensitivity, the second in a higher gradient setting and indicated as having a lower sensitivity rating. Concern for aggradation in the first reach, unless there are major conflicts, is moderated by the fact that this process is expected in the reach ("natural" attenuation reach) and there is little that should or might successfully be done to try and change the process. Aggradation in the second reach, however, may be of great concern and efforts to address the reach and watershed stressors would be prioritized.

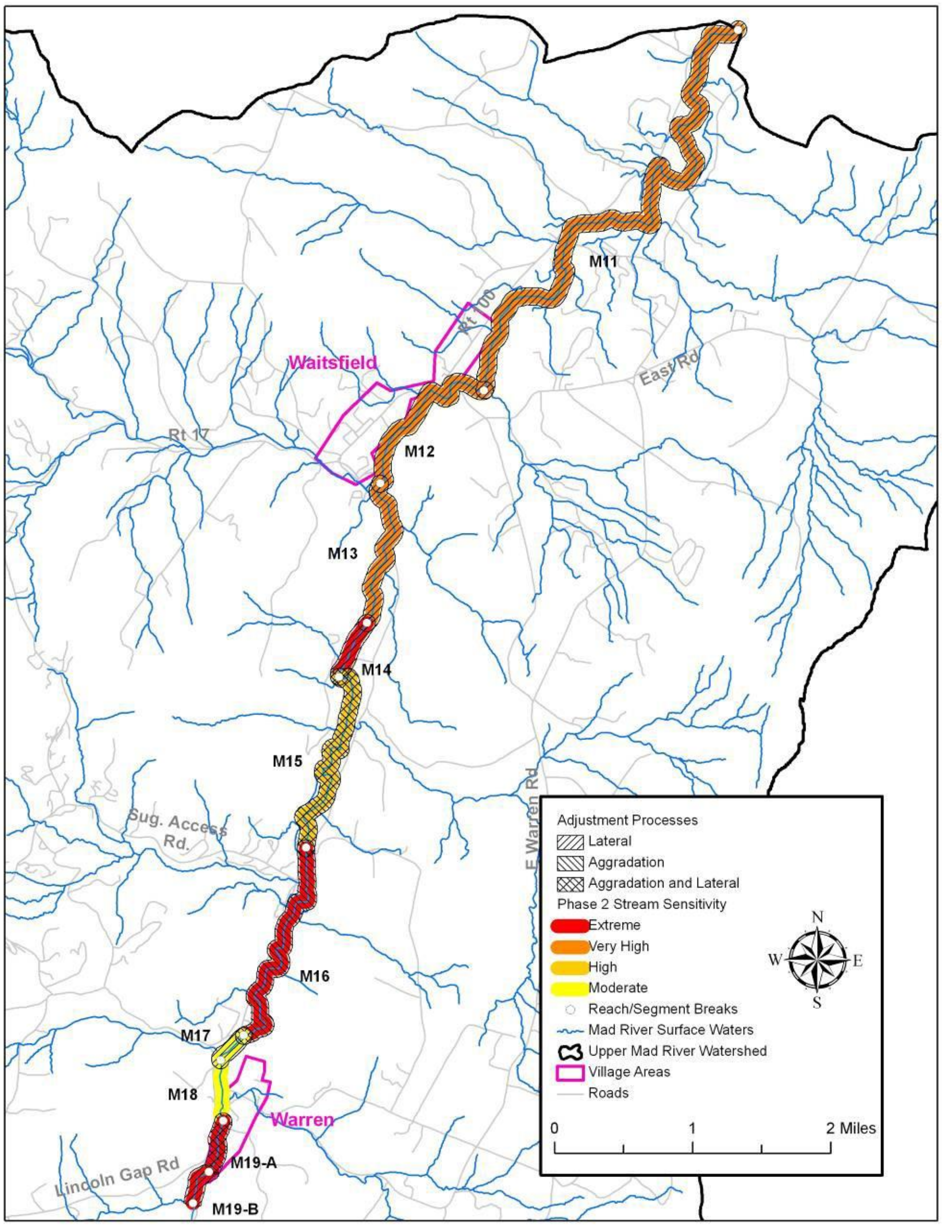


Figure 17 Example of a Stream Sensitivity Map, Upper Mad River. Map Credits: Fitzgerald Environmental LCC.

As discussed earlier, channel adjustments and the evolution process moves forward, typically, as a result of high flow events. This is the case because stream slopes and depths are at their greatest during flood conditions, and the stream power necessary to overcome the resistance of the boundary materials is achieved. Erosion and sediment transport increase as the floodwaters rise. As a flood recedes and/or the transport capacity is exceeded, sediments deposit, flows divert around the deposits, and bank erosion may result. Streams with less resistant boundaries and having a limited transport capacity (either naturally or as a result of a transport limiting stressor) tend to be more sensitive and subject to a higher rate of adjustment. This may be viewed as a concern on some adjusting reaches (e.g., the incising reach) and as a positive mitigating factor on another reach.

For example, the highly sensitive reach which just went through an avulsion during one flood occurrence, may have such a high bed load and undergo adjustments so rapidly because of the limited transport capacity in the reach as a whole, that within one or two additional flood events (if no constraints exist) the channel evolves back to its equilibrium channel geometry. In this case, where head cutting in the avulsion channel may have been of initial concern, the alternatives analysis would not necessarily prescribe grade controls and bank stabilization, but concentrate on corridor protection and eventual reestablishment of riparian vegetation.

In the examples above, consideration is given to the condition the stream is evolving to, whether the current adjustment processes are moving the channel form away from (in the case of head-cutting) or toward this condition, and how long is the process anticipated to take. The alternatives considered and the feasibility of those management alternatives will depend on the costs and benefits of intervening and/or accommodating the channel evolution process underway within appropriate and effective spatial and temporal contexts. From a restoration standpoint, passive rather than active restoration using river corridor protection is often more feasible because of the high level of risk associated with stream reaches adjusting due to multiple stressors. There are situations, however, where an active restoration approach will create such social and environmental benefits as to overcome the costs and risks of construction.

Stream sensitivity ratings also provide a basis for fluvial erosion hazard (FEH) classification because major vertical or lateral channel adjustments are known to result in extensive erosion of adjacent lands causing damage to private property and public infrastructure. The mapped corridor depicting sensitivity, created for planning purposed here, **should not be used** in place of the FEH maps developed by the Vermont Fluvial Erosion Hazard Program. The FEH maps, while using the same scientific basis for sensitivity, are refined based on meander belt width considerations as well as other geomorphic and hazard considerations. This and other distinctions between corridor types are described in the Vermont ANR Guide to River Corridor Protection (Kline and Dolan, 2008).

6.0 Preliminary Project Identification And Prioritization

River restoration projects designed without consideration of the underlying physical processes causing channel instability are subject to a high rate of failure. To maximize their effectiveness, river corridor protection and restoration projects should be designed as part of an overall program to create equilibrium conditions at the reach and watershed scale. This may be achieved by using the maps and tables developed in Section 5 to establish an equilibrium reference and developing projects to accommodate fluvial processes, and resultant channel and floodplain forms, on a reach-by-reach basis.

While restoration projects and strategies may take years to put in place at the watershed scale (as further discussed in Section 7), there are often more feasible restoration and protection projects that may be pursued in the interim. This Section is structured as a step-wise procedure for identifying projects which would be consistent with the goal of managing a stream toward its equilibrium condition. The first subsections of the procedure identify pro- jects which may be more readily pursued without an extensive alternatives analysis. The last two subsections identify restoration alternatives for vertically unstable streams (incised or aggrading) that may require channel management practices, corridor land use changes, more in-depth feasibility analyses, landowner negotiations, and time.

This step-wise procedure is a data analysis technique for identifying the following actions:

1. Protecting River Corridors
2. Planting Stream Buffers
3. Stabilizing Stream Banks
4. Arresting head cuts and nick points
5. Removing Berms and other constraints to flood and sediment load attenuation
6. Removing/Replacing Structures (e.g. undersized culverts, constrictions, low dams)
7. Restoring Incised Reaches
8. Restoring Aggraded Reaches

Using a Projects and Practices Table similar to the example in *Figure 18*, the assessor creates a preliminary list of projects for each assessed reach, and:

- the priority of each project from a reach and watershed perspective;
- whether the project may be completed independent of or in conjuncture with other practices, and
- the next project development steps that should be subsequently conducted.

River Segment (name and number)	Project	Reach Priority	Watershed Priority	Completed Independent of other Practices	Next Steps and other Project Notes

Figure 18 Example of a Projects and Practices Table used throughout the step-wise project identification process as a "first-cut" worksheet to catalogue projects for each reach.

Questions concerning pre- and post-project conditions, potential land use conflicts, and landowner agreements would be examples of the "next steps" to list for each identified project. Research into other significant constraints such as funding, permits, or the need for land use conversion, may be noted. For vertically unstable reaches, especially those experiencing a major departure from equilibrium conditions, conducting a more thorough analysis of alternatives, further studying the influence of watershed-scale stressors, completing detailed surveys, and running hydraulic models may also be logical next steps. Much of this detail may come to light later in the project development process and it would not be efficient to ascertain all "next steps" with each entry into the worksheet. The object is to get through the step-wise analysis, and make notations where necessary to keep track of the ideas, questions, and concerns as they arise.

Restoration projects identified in the following step-wise procedure may be effective as stand alone projects or become more feasible as part of a more comprehensive set of restoration practices. For example, a project to restore an incised reach may involve replacing undersized structures, removing berms, arresting head cuts, stabilizing and planting stream banks, and protecting the river corridor. The alternatives for restoring the stream channel and floodplain in this example may include active, passive, or a combination of approaches:

- **Active Geomorphic**: Restore or manage rivers to a geomorphic state of dynamic equilibrium through an active approach that may include the removal or reduction of human-placed constraints or the construction of meanders, floodplains, and bank stabilization techniques. Typically, the active approach involves the design and construction of a management application or river channel restoration such that dynamic equilibrium is achieved in a relatively short period of time. The approach may involve restoring the reach to its reference condition or to an equilibrium state consistent with new valley conditions as imposed by human constraints. Active riparian buffer revegetation and long-term protection of a river corridor is essential to this alternative.
- **Passive Geomorphic**: Allow rivers to return to a state of dynamic equilibrium through a passive approach that involves the removal of constraints from a river corridor thereby allowing the river, utilizing its own energy and watershed inputs, to re-establish its meanders, floodplains, and self maintaining equilibrium condition over an extended time period. Active riparian buffer revegetation and long-term protection of a river corridor is essential to this alternative.
- **Active-Passive Combination:** Use a sequenced combination of active and passive approaches to accommodate the varying constraints that typically occur along a project reach.

Prioritizing projects begins with questions of technical feasibility, i.e., the restoration of equilibrium conditions based primarily on stream departure and sensitivity. Section 7 explains the prioritization of restoration projects and strategies from a social feasibility standpoint, including landowner involvement and overall project costs. Also discussed is the documentation of social benefits that may be accrued by implementing a particular project or strategy. For instance, biological data may strongly suggest that restoring fluvial processes and physical habitat components in a particular reach may result in a healthier age class distribution within the population of a threatened species. Flood damage data may help to prioritize the replacement of an undersized culvert that has repeatedly failed due to sediment discontinuity through the structure.

Evaluating project feasibility in the order suggested above is a significant break with past practice. Restoration programs have traditionally started the project prioritization process using social benefit cues, and then, with very little attention to larger scale fluvial processes, such programs have gone on to explore the technical feasibility of the desired project. At the end of the step-wise procedure below, the priority restoration projects listed for each reach should be viable from a fluvial geomorphic equilibrium standpoint, and as such will engender the social benefits listed as objectives in this planning process—water quality, habitat, and hazard mitigation. Further prioritization of specific sites to maximize social benefits may then be used to increase landowner and stakeholder involvement.

Step-Wise Procedure for Identifying Technically Feasible River Corridor Restoration and Protection Projects

The following step-wise procedure is intended to provide a logical sequence for the critical questions that will arise when pursuing a geomorphic-based restoration program at the watershed scale. The questions are purposely kept simple and direct and the assessor should not look for specific language that will cover all the unique circumstances they will encounter. Any attempt to cover or eventually capture all possible contingencies and outliers would make this guidance far too dense and inaccessible. Also, project descriptors, those suggested as write-ins to the Project and Practices Table, are kept general in the step-wise procedure. The assessor should add key de- tails to the table, in the project description column, such as the location of the project within the reach

The River Stressors Identification and Departure Analysis tables generated in Section 5 will be invaluable references throughout the project identification process. Used in conjunction with the maps listed in each Section, these tables will not only help to identify the types of encroachments or practices that may be constraining fluvial processes within a reach, but they will allow the assessor to more quickly answer questions related to upstream and downstream effects. Another useful tip may be to go through the entire step-wise procedure for all assessed reaches, listing projects, and making preliminary notes with respect to priority. Then once all reaches have been evaluated, go back and give further consideration to priority, whether projects may be done independently or in conjunction with one another, and what next steps should be pursued in project development.

6.1 Protect River Corridors

Maps:

- Channel Slope Modifiers – channelization, channel constrictions and encroachments
- Boundary Conditions and Riparian Modifiers – erosion and woody buffers
- Sediment Regime Departure Map - head cuts and stage of channel evolution
- Stream Sensitivity – current adjustments

Evaluation: For each assessed reach, add "protect river corridor" to the project table based on answers to the following questions.

1. Is the corridor of the river largely undeveloped?
   Yes: Proceed to Step 2.
   No: Proceed to Step 4, Stream Buffer Evaluation.
2. Is the channel largely unconstrained (i.e., armored and bermed), and were it not actively managed in the near term (20-30 years), the channel could maintain itself or adjust to an equilibrium condition?
   Yes: Proceed to Step 3
   No: Proceed to Step 4, Stream Buffer Evaluation. Further evaluation of river corridor protection needs and opportunities will be included as part of the analysis for restoring incised and aggraded reaches, beginning at Step 28.
3. Seek to protect the river corridor and go on to Stream Buffer Evaluation, Step 4.

Prioritizing River Corridor Protection:

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

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

6.2 Plant Stream Buffers

Maps:
- Channel Slope Modifiers – channelization, channel constrictions and encroachments
- Boundary Conditions and Riparian Modifiers – erosion and woody buffers
- Sediment Regime Departure Map - head cuts and stage of channel evolution

Evaluation: For each assessed reach, add "plant/create stream buffers" to the project table based on answers to the following questions.

4. Is the stream channel at or near equilibrium or modified equilibrium, in terms of depth, slope, and floodplain relationship (channel evolution Stage I or near Stage V)?
   Yes: Proceed to Step 5.
   No: Create stream buffer, setting aside/protecting a buffer area, where in consideration of ongoing channel adjustments, natural regeneration may occur or limited planting may be conducted. Ideally buffer creation is done as part of the overall corridor protection or restoration plan identified in later steps. Proceed to Step 7, steam bank evaluation. Important: In settings where a woody buffer is lacking due to animal grazing, exclusion practices such as fencing should also be listed as part of the project.
5. Is there perennial riparian vegetation on both sides of the stream?
   Yes: Proceed to Step 7, steam bank evaluation.
   No: Proceed to Step 6
6. Plant stream buffer with native woody vegetation. Proceed to Step 7, stream bank evaluation.

Prioritizing Buffer Planting:

Higher Priority – It is important to establish a buffer of native vegetation on all reaches from a water quality and habitat standpoint. From a stream stability standpoint, give high priority to tree planting, as a stand alone treatment or in combination with stream bank stabilization, on those sensitive reaches that are vertically stable.

Lower Priority - Give lower priority to tree planting, as a stand alone treatment or in combination with stream bank stabilization, on reaches which are extremely sensitive due to their watershed location (e.g., braided channels, where rapid and continuous planform change is anticipated). **Reminders:** Buffer re-establishment may be pursued using either high or low cost designs. The "cadillac" buffer design involves planting a high density of large, purchased trees that typically require care and maintenance until they become well established. At the other end of the price range is a design that involves a passive approach, where native plants are given the opportunity to seed in over time, augmented by inexpensive bare-root plantings. The cadillac buffer is not advised as a stand alone project on vertically unstable reaches, either incised or aggrading, where rapid meander and floodplain development is likely to erode the planted trees and shrubs. Inexpensive buffer re-establishment may be ideal is such situations, where immediate water quality benefits may be accrued and landowners are willing to set back their land uses from the stream bank. If a project involves the "active" restoration of equilibrium conditions, restore a buffer of native woody vegetation throughout the entire width of the protected belt width corridor. If a specific restoration project is not planned or is based more on a passive approach, use low cost native grasses and shrubs in the near bank region and more expensive native tree stock that may mature and strengthen the banks when the stream has eroded to the outer extent of the delineated belt width.

6.3 Stabilize Stream Banks

Maps:

- Sediment Load Indicators – increased sediment supply, alluvial fans, and deltas
- Channel Slope Modifiers – channel constrictions and encroachments
- Boundary Conditions and Riparian Modifiers – erosion and woody buffers
- Sediment Regime Departure Map - head cuts and stage of channel evolution
- Stream Sensitivity Map – active aggradation\

Evaluation: For each assessed reach, add "stabilize stream banks" to the project table based on answers to the following questions.

7. Is the stream channel at or near equilibrium, in terms of depth, slope, and floodplain relationship (channel evolution Stage I or near Stage V)?
   Yes: Proceed to Step 8
   No: Proceed to Step 13, head cut evaluation.
8. Is the channel undergoing lateral movement by eroding of the right or left bank?
   Yes: Proceed to Step 9.
   No: Proceed to Step 13, head cut evaluation.
9. Is the eroding stream bank within 50 feet of a building or improved road?
   Yes: proceed to Step 10.
   No: Proceed to Step 11.
10. Stabilize stream bank to stop the lateral erosion and maintain the opportunity for a woody buffer (may require toe armoring). Proceed to Step 13, head cut evaluation.
11. Is the reach being affected by a significant increase in sediment supply or is the reach highly sensitive due to its location in the watershed where very high to extreme depositional processes occur naturally?
    Yes: Proceed to Step 12.
    No: Stabilize steam bank and/or plant buffer to arrest the lateral movement of the channel and achieve long term bank stability. Designs should not constrain down-valley channel migration (e.g., rip-rapping entire bend ways) or eliminate the opportunity for native vegetation to play the dominant role in stream bank stability in the future. Proceed to Step 13, head cut evaluation.
12. Streams where naturally high deposition processes occur will be further evaluated as aggrading reaches, starting at Step 41, proceed to Step 13, head cut evaluation.

Prioritizing stream bank stabilization:

Higher Priority – As a stand alone treatment on geomorphically stable reaches (i.e., those which have not significantly departure in from the dimension, pattern, and profile of the equilibrium condition) where the added boundary resistance would slow down the lateral movement of the channel over a long enough period of time to allow for the re-establishment of bank vegetation. In this scenario, priority consideration may be given to laterally-unstable, upstream reaches which are contributing sediment to sensitive, downstream reaches. Priority is also given to stabilizing banks on laterally unstable reaches where human-placed structures are at high risk and not taking action may result in increased risk of erosion, to not only the structure, but lands that would provide the opportunity to establish a buffer.

Lower Priority – Highly to extremely sensitive reaches where the sediment supply is naturally high (i.e., at alluvial fans or active deltas areas) and the bank stabilization would be at risk to failure due to the depositional processes that are ongoing. The lowest priority might be given to those reaches where there is no conflict with the erosion process, and the increase in sediment supply to downstream reaches would contribute beneficially to a floodplain redevelopment process.

6.4 Arrest Head Cuts

Maps:

- Channel Slope Modifiers – Grade controls, channel constrictions, and encroachments
- Sediment Regime Departure Map - head cuts and stage of channel evolution
- Stream Sensitivity Map – active degradation

Evaluation: For each assessed reach, add "arrest head cuts" to the project table based on answers to the following questions.

13. Is the stream bed actively eroding? Have head cuts been identified within the reach?
    Yes: Proceed to Step 14.
    No: Proceed to Step 16, berm evaluation.
14. Is the stream in the process of abandoning a functioning floodplain?
    Yes: Proceed to Step 15. Important: Answering this question in the affirmative means that the bed erosion and sediment transported out of the reach is happening and will continue to happen at a greater rate that the process of sediment accretion on the bed from sources upstream or within the reach (i.e., in some high bed load systems, head cuts "wash out" relatively quickly).
    No: Proceed to Step 16, berm evaluation. Note: It is assumed in this step that the stream is already deeply incised (IR > 1.4). Further evaluation of head cuts will be included under a more detailed analysis for restoring incised reaches, Step 28.
15. If no natural grade controls exist within one meander wavelength (14 x Wbkf) upstream of the head cut that would serve to arrest the channel incision process, then consider constructing one or more weirs to arrest head cuts. Proceed to Step 14, berm evaluation.

Arresting of head cuts:

Higher Priority – Reaches where the bed-lowering process will lead to extensive loss of floodplain and/or human-placed structures if a channel evolution process were to be initiated.

Lower Priority – Reaches where natural grade controls exist within a meander wavelength upstream or where the reach is sensitive to high bed load deposition, and the head cuts are the result of meander cut-offs and braiding; i.e., floodplain reconnection would be a relatively rapid process.

6.5 Remove Berms

Maps:

- Channel Slope Modifiers – river corridor encroachments
- Channel Depth Modifiers – berms including elevated roads and railroads

Evaluation: For each assessed reach, add "remove berms" to the project table based on the answers to the following questions.

16. Is there a berm, stream sediment windrow, or abandoned levee, road, or rail embankment adjacent to the reach?
    Yes: Proceed to Step 17.
    No: Proceed to Step 20, structures evaluation.
17. Is the stream denied access to a floodplain because of the berms?
    Yes: Proceed to Step 18.
    No: Proceed to Step 20, structures evaluation.
    Note: By answering no, it is assumed that the stream is deeply incised (IR > 1.4), and that berm removal would not by itself significantly improve floodplain access. Further evaluation of berms will be included under a more detailed analysis for restoring incised reaches, Step 28.
18. Are there developments or land uses within the river corridor that would become threatened by more frequent flooding?
    Yes: Proceed to Step 19.
    No: Remove berms. Proceed to Step 20, structures evaluation.
19. End evaluation of berms and proceed to Step 20, structures evaluation.
    Note: Further evaluation of berms will be included under a more detailed alternatives analysis for restoring incised reaches, Step 28.

Prioritizing berm removal:

Higher Priority – 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. *or* 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 Priority – Berms which are vegetated with mature trees, the removal would cause major land disruption and habitat impacts, and the benefits to attainment of equilibrium conditions are less certain. *or* Berm removal as a stand alone treatment where the stream would be deeply incised even if the berm were removed.

6.6 Remove or Replace Structures

Maps:

- Channel Slope Modifiers – Grade controls, channel constrictions, and encroachments
- Sediment Regime Departure Map - head cuts and stage of channel evolution
- Stream Sensitivity Map – active degradation

Evaluation: For each assessed reach, add "remove / replace structures" to the project table based on the answers to the following questions.

20. Are there bridges, culverts, abutments, dams, weirs, or other structures that span or otherwise significantly constrain the vertical and lateral movement of the stream channel and/or result in a significant constriction of the floodplain within the reach?
    Yes: Proceed to Step 21.
    No: Proceed to Step 28, evaluation of incised reaches.
21. Is there significant sediment deposition upstream of the structure that would erode if the structure were removed?
    Yes: Proceed to Step 22.
    No: Proceed to Step 26.
22. Are there developments or land uses within the river corridor that would be significantly affected by channel bed elevation changes or bank instability brought about by changes in sediment erosion / deposition processes if the structure were replaced or removed.
    Yes: Proceed to Step 23.
    No: Proceed to Step 24.
23. End evaluation of structures and proceed to Step 28, evaluation of incised reaches. Note: Further evaluation of structures may be included under a more detailed analysis for restoring incised reaches. Structure removal or replacement may still be a viable project with consideration of property protection and channel bed stabilization.
24. Is the erosion of sediment from above the structure likely to create a significant channel adjustment in a downstream reach that would be inconsistent with the equilibrium conditions or the channel evolution processes underway in the downstream reach?
    Yes: Proceed to Step 25.
    No: Replace the structure. Proceed to Step 28, evaluation of incised reaches.
25. Replace the structure and either remove the sediment or place grade control structure(s) to partially retain sediment and/or encourage floodplain restoration and redevelopment. Proceed to Step 28, evaluation of incised reaches.
26. Is the structure derelict and/or nonfunctional?
    Yes: Proceed to Step 27.
    No: Replace the structure. Proceed to Step 28, evaluation of incised reaches.
27. Remove the structure (with grade control if necessary to protect against head cuts). Proceed to Step 28, evaluation of incised reaches.

Prioritizing structure removal or replacement:

Higher Priority – Those structures which are derelict, i.e., no longer serving as a stream crossing or flow control structure. *or* Those structures contributing to a significant increase in erosion hazard due to a constriction-related disruption in sediment continuity (i.e., major aggradation upstream and/or degradation downstream of the constriction). *or* Those structures which are likely to result in an avulsion of the channel during a storm event due to blockage or alignment issues.

Lower Priority – Those structures which, if removed, would result in little change in level of erosion hazard at the site and the removal would potentially result in the need for restoration of the bed profile and/or result in changes to the sediment regime that would potentially contribute to new or greater departures from equilibrium conditions within upstream or downstream reaches.

6.7 Restore Incised Reach

Maps:
- Hydrologic Alterations – increased peak flows
- Sediment Load Indicators – rejuvenating tributaries
- Channel Slope Modifiers – channelization, channel constrictions and encroachments
- Channel Depth Modifiers – decreased sediment supplies, berms, backwater areas
- Boundary Conditions and Riparian Modifiers – erosion and woody buffers
- Sediment Regime Departure Map - stage of channel evolution
- Stream Sensitivity Map – active degradation

Evaluation: For each assessed reach, add "restore incised reach" and/or "protect river corridor" to the project table based on the answers to the following questions.

28. Is the channel significantly steeper (straightened) and/or deeper (incised) as to result in greater stream power and sediment transport capacity?
    Yes: Proceed to Step 29.
    No: Proceed to Step 41, evaluation of aggraded reaches.
29. Is the increase in stream power the result of significantly reduced sediment supply or increased peak flows?
    Yes: Proceed to Step 30.
    No: Proceed to Step 31.
30. Watershed input stressors can be reduced in the near term (5 years). Note: Restoration projects are designed based on the discharge and sediment loads anticipated when upstream projects or watershed strategies are completed.
    Yes: Proceed to Step 31.
    No: Proceed to Section 6.10, Watershed Strategies.
31. Is it possible to restore the stream to a recently abandoned channel with equilibrium depth and/or slope?
    Yes: and no other obvious constraints are present: Proceed to Step 32.
    No: Proceed to Step 33.
32. Restore incised reach to abandoned channel to reduce stream power. Bed, bank, and riparian restoration should be included as a part of the project. Constrictions or other hydraulic changes that may have led to the avulsion should also be addressed. Go on to Step 41, evaluating aggraded reaches.
33. Are there buildings, improved roads and/or other permanent constraints within the corridor that exist on both sides and in close proximity to the stream channel?
    Yes: Proceed to Step 34.
    No: Proceed to Step 36.
34. Is there complete armoring of the bed and/or banks, such that erosion is not occurring?
    Yes: Proceed to Step 35.
    No: Pursue high priority river corridor protection at downstream reach to attenuate flow and sediment transported through the channelized reach and restore incised reach with bed forms and/or floodplain features in equilibrium with higher stream power of the channelized reach. Proceed to Section 6.10, Watershed Strategies.
    Note: The feasibility of incised reach restoration, in human-confined settings, will increase as erosion conflicts increase.
35. Pursue high priority river corridor protection at a downstream reach to attenuate flow and sediment transported through the channelized reach. Proceed to Section 6.10 , Watershed Strategies.
36. Are there current corridor land use constraints, flow and sediment load alterations, or project feasibility issues which would inhibit the active geomorphic restoration of a flood plain and meanders?
    Yes: Proceed to Step 37.
    No: Proceed to Step 39.

Unsure: Indicate potential restoration / protection project, list additional information gathering as next steps, and proceed to Step 41, evaluating aggraded reaches.

37. Are landowners willing to consider corridor protection to allow for a passive flood plain and meander redevelopment?

    Yes: Proceed to Step 38.

    No: Defer action on restoring incised reach until restoration and protection opportunities exist. Proceed to Section 6.10, Watershed Strategies.

38. Pursue high priority river corridor protection to accommodate passive flood plain and meander redevelopment.
39. In the absence of any channel or flood plain encroachments (including berming), would the stream quickly equilibrate (i.e., high sediment supply) to a geometry that results in a reduction in stream power and transport capacity?

    Yes: Proceed to Step 40.

    No: Remove encroachments if present, and, if feasible, restore incised reach with new meanders and/or floodplain in relation to the current elevation of the channel bed, and ensure long-term viability of the project through river corridor protection.

40. Pursue removal of encroachments and restore incised reach through river corridor protection to accommodate passive flood plain and meander redevelopment.

Prioritizing restoration of incised reaches:

Higher Priority – The rare, but important opportunities to restore the river from a recent avulsion channel that is rapidly becoming disconnected from the former floodplain to a pre-avulsion channel that has floodplain connection. *or* Those reaches where it is still possible, due to lack of encroachment, to either passively or actively restore some degree of floodplain function at a lower elevation.

Lower Priority – Reaches with little to no opportunity to restore meanders and floodplain and the restoration would mainly involve placing structures to minimize erosion hazards, ensure sediment transport, and improve instream and riparian habitat in a mostly channelized reach. *or* Active restoration of reaches where the alteration of hydrologic and/or sediment regimes, at the watershed scale, are the predominant stressors that are driving channel adjustment and a departure from equilibrium conditions.

6.8 Restore Aggraded Reach

Maps:
- Hydrologic Alterations – increased peak flows
- Sediment Load Indicators – increased sediment supply, alluvial fans, and deltas
- Channel Slope Modifiers – channelization, channel constrictions and encroachments
- Channel Depth Modifiers – decreased sediment supplies, berms, backwater areas
- Boundary Conditions and Riparian Modifiers – erosion and woody buffers
- Sediment Regime Departure Map - stage of channel evolution
- Stream Sensitivity Map – active degradation

Evaluation: For each assessed reach, add "restore aggraded reach" to the project table based on the answers to the following questions. At this stage in the project identification process, it is assumed that the channel is experiencing a significant reduction in hydraulic capacity (backwater and other slope reductions) and/or has become more shallow as to result in less stream power and sediment transport capacity?

41. Is the decrease in stream power the result of significantly increased sediment supply or decreased peak flows?
    Yes: Proceed to Step 42.
    No: Proceed to Step 43.
42. Watershed input stressors can be reduced in the near term (5 years). Note: Restoration projects would be designed based on the discharge and sediment loads anticipated with the completion of watershed BMPs.
    Yes: Proceed to Step 43.
    No: Proceed to Section 6.10, Watershed Strategies.
43. Is sediment discontinuity primarily the result of backwater conditions created by an artificial constriction of the channel or floodplain?
    Yes: Proceed to Step 44.
    No: Proceed to Step 46.
44. Is it feasible to increase sediment transport through the dammed or constricted reach?
    Yes: Proceed to Step 45.
    No: Proceed to Step 48.
45. Restore aggraded reach by removing, retrofitting, or replacing structure(s) and/or adding structures within the restored channel and/or floodplain to either increase sediment transport or to restore equilibrium sediment transport processes. Proceed to Section 6.10, Watershed Strategies.
46. Does the stream have access to a floodplain (at Stage I or near-Stage V of channel evolution) and sediment, generated from within the reach, is leading to a over-widened channel?
    Yes: Proceed to Step 47.
    No: Proceed to Step 48.
47. Restore aggraded reach and protect river corridor to address the issues that are likely to have led to channel over-widening (i.e., lack of integrity to the boundary conditions and riparian vegetation) and place structure(s) to restore the equilibrium width-depth ratio. Proceed to Section 6.10, Watershed Strategies.
48. Protect river corridor to minimize or avoid future conflicts in high deposition zones, i.e., at alluvial fans, deltas, or extreme aggradation areas associated with intractable channel management issues, e.g. when upstream reaches have been permanently modified into a sediment transport regime or when downstream channel constriction(s) are irremovable. Proceed to Section 6.10, Watershed Strategies.

Restoring aggraded reaches:
Higher Priority – Reaches aggrading and widening at a localized scale due to bank erosion.
Lower Priority - Active restoration of reaches where the alteration of hydrologic and/or sediment regimes, at the watershed scale, are the predominant stressors that are driving channel adjustment and a departure from equilibrium conditions.

6.9 Watershed Strategies

Watershed strategies may address changes in the hydrologic and sediment regimes that are driving stream instability, or reach scale stressors that directly or indirectly alter hydraulic geometry and stream equilibrium conditions. For certain watersheds, the percentage of impervious cover in urban areas, drainage ditching, and/or exposed soils in agricultural settings is so high, an emphasis must be placed on water and sediment input stressors before restoration strategies may be truly successful. At a minimum, some attention toward the planning and management of flows alterations (i.e., stormwater) and soil erosion is prudent even where these land use/land cover conditions are not predominant. This Section is a partial reference to those environmental programs that regulate or provide technical assistance in addressing watershed land use-related stressors. Another set of strate- gies involve corridor planning at the municipal level, which is covered here in greater depth. Methods for enhanc- ing local corridor protection and restoration efforts will be explained. Finally, strategies for prioritizing and addressing reach-scale stressors will be described.

This Section provides references and guidance for developing Watershed Strategies, involving government agencies, watershed organizations, and multiple landowners to address stressors that may prevail throughout an entire watershed, such as:

- Drainage and storm water management
- Gully and erosion control
- Floodplain and river corridor planning and protection
- Buffer establishment and protection
- Bridge and culvert retrofits and replacements
- Reach-scale river corridor protection projects
- Reach-scale river corridor restoration projects

While high priority town and watershed-based strategies are being pursued, implementing priority reach-scale projects may be an important way to keep stakeholder organizations and agencies engaged in the watershed.

The River Stressor Identification Table (constructed in Section 5) may indicate the recurrence of stressors and suggest that town-based or watershed strategies would be the most cost effective method for programmatically addressing stream instability. Commercial and residential developments, stream crossings, and other land use encroachment are often the predominate stressors leading to changes in stream power and a loss in channel boundary resistance. While river corridor protection initiatives (e.g., securing corridor easements) may be warranted as high priority projects, working through the town planning and zoning process to limit future encroachment and avoid the placement of undersized crossing structures may be strategies highly recommended in the river corridor plan as they may address both current and future river and floodplain modifications.

Using the Stressor ID and the Projects and Practices tables, begin prioritizing strategies and projects in a Summary Table. Use the guidance on strategy development provided below and the information on social feasibility detailed in Section 7 to devise an Interim Corridor Plan.

6.9.1 Drainage and Stormwater Management

The timing, volume, and duration of flow events in a watershed may explain significant adjustments and observed disequilibrium in a stream channel network. Changes in the composition of land use and land cover over time are often the root of hydrologic modification. The concentration of runoff—stormwater discharges—from lands either cleared to accommodate development, and associated impervious cover, or drained to create drier conditions for agriculture or unpaved road networks is the primary driver in Vermont watersheds, where land use change has been linked to channel instability. When the Hydrologic Modifications and the Land use/Land Cover maps strongly suggest that stormwater inputs are a primary stressor, list “drainage and stormwater management” as a very high priority strategy in the River Corridor Plan.

The cumulative impacts of hydrologic changes, in both time and space, has a tempering effect on the pace at which any specific project within a stormwater-based strategy may result in stream equilibrium conditions. This is true in part, because of the interconnectedness of hydrologic and sediment regime modifications described above in Section 5. Better structural attenuation of storm flows may be achieved, and the channel may remain unstable for some time while the sediment regime adjusts to the morphological changes and channel evolution brought about by increased stormwater discharges. These concerns should not be a reason to displace stormwater management from the top of a list of important restoration strategies, as it may temper the success of all others.

The Vermont DEC and the U.S. EPA have expanded stormwater programs in recent years to address water quality/quantity stressors associated with the stormwater runoff from developments. Performance standards are established for stormwater treatments in a state permit program, under authority delegated from EPA to the State of Vermont. For those watersheds under very high to extreme stress from hydrologic modification, i.e., where water quality standards and aquatic life criteria are not being met, the Stormwater and Planning Sections of the DEC Watershed Management Division are developing and implementing stormwater remediation plans based on runoff detention and channel protection. This guide will not attempt to outline these state planning and permit programs, which are explained on the Department web page: http://www.watershedmanagement.vt.gov/stormwater.htm. Effective im- plementation of state and federal stormwater programs, should be identified in the Corridor Plan as a part of the strategy for drainage and stormwater management.

Hydrologic stressors that may not be captured by Stormwater Programs often stem from the changes in runoff that occur with small or otherwise non-jurisdictional developments, or when land uses and dispersed development are made possible through the construction of drainage networks. Outlining components of a strategy to address these runoff alterations is complicated and should be broken down into plans that:

- reduce sources, or minimize the extent to which precipitation becomes concentrated by human activity;
- increase storage, in both natural and human constructed features within the watershed; and
- decrease transport, by creating opportunities for the dispersal of runoff that has become concentrated.

Rural residential developments and associated road networks, agricultural drainage networks, and silvicultural roads, landings, and skid trials are all potential sources of concentrated runoff that change the timing, volume, and duration of flow in a receiving stream. Reducing these sources largely involves avoidance strategies that start with education and outreach. The proponents of river corridor protection and restoration can bring together ex- perts in stormwater, low impact development, and best management practices with landowners, contractors, and municipal planners to reduce existing and/or avoid new modifications to watershed hydrology.

The Vermont League of Cities and Towns (VLCT) has developed model ordinances and provides technical assistance to towns to plan for and promote low impact development. The following VLCT link is a resource for getting started: http://resources.vlct.org/u/o_LID-secured.pdf. State natural resource, land use, and transportation agencies all have programs to assist landowners and communities with the design and implementation of stormwater BMPs. In addition to the DEC Stormwater Program listed above, the following State program links provide a wealth of information on the technical and financial assistance available:

Vtrans/St. Michael College Local Roads Program: http://personalweb.smcvt.edu/vermontlocalroads/
VTANR Better Back Roads Program: vtransengineering.vermont.gov/sections/environmental/betterbackroads
Agency of Agricultural Water Quality Program: http://www.vermontagriculture.com/ARMES/awq/AWQ.html
Department of Forest, Parks & Recreation Watershed Program: http://www.vtfpr.org/watershed/index.cfm
Department of Fish and Wildlife Habitat Conservation Programs: http://www.vtfishandwildlife.com/index.cfm
VTANR Ecosystem Restoration Program: http://www.watershedmanagement.vt.gov/erp.htm

Many of these state programs are paralleled at the federal level at the EPA, USFWS, and the USDA. Information is available, ranging from how to design road ditch turnouts or rain gardens to improve infiltration, to the availability of grants to restore wetlands and floodplains that may increase storage of precipitation and runoff. Work with the resource agency staff to create priority subshed projects under a "drainage and stormwater management" strategy that are focused on reducing stormwater sources and increasing the storage and dispersal of runoff.

Documented stormwater impairment of surface water quality sets in motion the full remediation dictates of the Clean Water Act. Creating a separate action plan within this corridor planning process is unnecessary. The focus here is to address the hydrologic modifications threatening physical and biological conditions of other waters before they reach the impairment threshold.

Almost any corridor protection and restoration activity identified in a corridor planning exercise could have design aspects that help achieve a stormwater management strategy. A great example is the protection and restoration of riparian vegetation, wetlands and adjacent floodplains. When these features are present and interconnected on the landscape, they directly influence stream hydraulic geometry and provide for the channel form and processes associated with equilibrium conditions. They are also critical as stormwater storage and recharge areas, and their protection helps to avoid the land uses that may generate concentrated runoff. These projects should be sought at every opportunity. In other words creating a list of priority projects under a stormwater strategy may overlap with projects listed under other strategies, and visa-versa.

Prioritizing projects compiled into a watershed wide stormwater strategy should consider the factors which drive the sensitivity of streams and stream hydrology. In addition to sub-watershed land use/land cover, the hydrologic regime may be influenced by climate, soils, geology, and groundwater; the connectivity of the stream, riparian, and floodplain network; and valley and stream morphology. Listing high priority drainage and stormwater projects should be guided by which reaches or sub-sheds: 1) have hydrologic modifications listed as a likely contributor to stream disequilibrium; 2) possess highly sensitive watershed characteristics; and 3) have multiple or rare but critical opportunities to reduce sources and/or increase the storage and dispersal of runoff.

6.9.2 Gully and Erosion Control

A "gully and erosion control" strategy may become a priority when the hydrologic regime has been significantly modified and/or when changes in the size and quantity of mobilized sediments through the watershed are seen as contributing to stream instability. Outlining components of a strategy to address sediment runoff should be broken down into plans and projects that:

- reduce sources, or minimize the extent to which surfaces become exposed to runoff and erosive forces
- increase and maintain storage, in natural features within the watershed, and
- decrease transport, by creating opportunities for the deposition of mobilized sediments.

When the volume of concentrated runoff creates an erosive power greater than the ground surface can withstand, rills and gullies will form. Gullies the size of ravines may be created where ditches or stormwater outfalls are day lighted in highly erodible settings. These may be significant but avoidable sediment sources through the proper planning and remediation of stormwater discharges. The issue is particularly difficult, however, in agricultural settings where extensive tiling and ditching were conducted to dry out and plow Vermont's poorly drained soils. The feasibility of developing stormwater treatment systems for the single agricultural enterprise is far more challenging than the same type of projects in an urban municipality. The programs listed above that assist in the development of drainage and stormwater management strategies, also assist with BMPs designed to avoid and correct stormwater-related erosion. Gullies are so much easier to stop before they get started. Damage to adjacent properties may become severe and the costs of engineering and treating a large gully are substantial.

The Sediment Load Indicator Map shows gullies and mass wasting sites identified during Phase 2 assessments. This data may inform the priority of projects in a sediment reduction strategy, but there is often an outstanding assessment need. Where land use and/or instream depositional features indicate a sediment stressor, the erosion within and at the outlets of drainage and stormwater ditches should be evaluated. These features may be outside the Phase 2 corridor and represent a new but worthwhile assessment effort as a precursor to the prioritization of erosion control BMPs. This is especially true in those situations where a mass wasting site has been triggered by the concentration of runoff and saturation of strata at the top of the feature, rather than slope failure resulting from the river impinging on and eroding the toe of the feature. The Vermont Geological Survey may offer technical assistance to further investigate mass failures: http://www.anr.state.vt.us/DEC/GEO/vgs.htm.

Construction-related erosion is managed by the State under a general permit issued for stormwater runoff at construction sites by the DEC, see: http://www.watershedmanagement.vt.gov/stormwater.htm. Guidance and funding are provided by the Local Roads and Better Back Roads programs (listed above) for the protection of road side ditches from excessive erosion. Stone lined ditches with turnouts are much less likely to blow out during a large rainfall event, which can save towns hundreds of thousands of dollars in road embankment repairs.

Where the Land Use/Land Cover Map shows sub-watersheds with a high cropland percentage, priority agricultural BMPs may be indicated in an erosion control strategy, i.e., not plowing flood chutes and areas where runoff concentrates, tilling soils along the contour to reduce the concentration of stormwater, and cover cropping to minimize exposure during fallow periods. Fencing livestock out of sensitive areas at sensitive times may also reduce erosion. The Natural Resource and Agriculture agencies have published guidance for farm ditch maintenance with the aim of reducing erosion. Prioritizing projects to promote best management practices on farms may yield results as landowners recognize an immediate benefit from protecting the soils on which their livelihoods depend. Contact the local Natural Resource Conservation District at http://www.vacd.org/ or the Agency of Agriculture Water Quality Program (listed above) to initiate or support this work.

For many reaches, where a departure in sediment regime is identified as the greatest stressor on stream stability, the predominant source of sediment is the upstream channel bed and bank erosion associated with channel evolution and rejuvenation. Similar to the interconnectedness of stormwater strategies with projects designed to address modifications to channel and floodplain hydraulics, an erosion strategy to reduce sediment loading is incrementally achieved each time reach-scale equilibrium is protected and/or restored. Listing high priority erosion control projects should be guided by which reaches or sub-sheds: 1) have sediment load modification listed as a likely contributor to stream disequilibrium; 2) are stressed by hydrologic modifications in highly sensitive watersheds; and 3) have multiple or rare but critical opportunities to reduce new erosion and increase sediment storage in floodplain features. In addition to the Sediment Load and Land Use maps already mentioned, the Sediment Regime Departure Map and RHA data pertaining to scour and deposition features may also be useful in this exercise, because the transport, fate, and impact of wash load and bed load-sized sediments may be factored into the prioritization of projects.

6.9.3 Floodplain and River Corridor Planning and Protection

Limiting structure and fill encroachments into river corridors and onto floodplains may be by far the most cost effective and expedient strategy adopted as part of a river corridor plan. Keeping people and their investments backed away from flooding rivers is fundamental toward the attainment of equilibrium conditions, because:

- watershed inputs may be reduced because less impervious surface and/or exposed soils are created near the river and there is a greater opportunity for using nonstructural treatments to attenuate watershed inputs (i.e., stormwater and sediment loads) generated outside the corridor;
- channelization works are not required, saving money and minimizing the degree to which river slopes are increased by channel straightening practices;
- berms, floodplain fills, and the need for emergency dredging are not required, saving money and minimizing the degree to which river depths are increased; and
- bank armoring and the removal of riparian vegetation are less essential practices, saving money and minimizing the degree to which channel boundary resistance is altered.

A floodplain and river corridor protection strategy is based primarily on municipal action, i.e., town planning and zoning. The state, however, does play a role in land use regulation, defining the floodway under criterion 1(D) for Act 250 jurisdictional developments. The River Management Program bases floodway delineation on both inundation and erosion hazards, using National Flood Insurance Program (NFIP) maps and State fluvial erosion hazard (FEH) zones. The RMP has published numerous papers on the policy and application of flood hazard avoidance programs, available at http://www.anr.state.vt.us/dec/waterq/rivers.htm. In particular, a fact sheet has been prepared to help differentiate between inundation and erosion hazard programs, and a River Corridor Protection Guide (Kline and Dolan, 2008) is available, which details the State's fluvial geomorphic-based river corridor delineation process and contrasts floodplain and buffer protections with corridor setbacks:
Fact Sheet: http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_NFIPFEHFactSheet.pdf
Guide: www.watershedmanagement.vt.gov/rivers/docs/rv_RiverCorridorProtectionGuide.pdf

Outlining a protection strategy primarily involves listing the priority of towns within which to begin the outreach and promotion of local ordinance adoption. The River Management Program, the VLCT, and Regional Planning Commissions (RPCs at http://www.vpic.info/rpcs/) are using the answers to the following questions to help their respective programs prioritize flood hazard planning assistance to municipalities:

Local Regulations:

- Does the town have (or are they working toward) a Town Plan and or Zoning?
- If no zoning, do they have other stand alone ordinances such as NFIP or Junk Yard?
- Does the town participate in the NFIP program?
- Is there an active NFIP Map Modernization Effort in the county?
- Does the Local Hazard Mitigation Plan need updating by 2010?

Social Considerations:

- Has the Selectboard or Planning Commission expressed an interest in FEH and/or the NFIP?
- Is the town currently updating or anticipate updating its Town Plan or Zoning within 8 months?
- Is the town currently updating or anticipate updating other applicable ordinances within 8 months?

Technical And Other Considerations:

- Is there town-wide quality assured Phase 1/2 data available for unconfined streams and rivers?
- Has there been significant flood damage in recent years?
- Was the flood damage primarily from inundation or erosion hazards?
- Is FEH map and/or updated NFIP map development underway?

In addition to this information, evaluate the Sediment Regime Departure and Sensitivity maps to help decide priorities. For instance, a town with miles of straightened, vertically unstable streams in unconfined settings may be a higher priority for FEH zoning than a town with a handful of unstable streams flowing in areas less accessible to development.

The RMP provides technical assistance through its NFIP Map Modernization and FEH programs. Model language for town plans and zones are provided at the following links:

- Flood hazards: http://www.watershedmanagement.vt.gov/rivers/htm/rv_floodhazard.htm
- Fluvial erosion hazards: http://www.watershedmanagement.vt.gov/rivers/docs/rv_municipalguide.pdf

The RMP Floodplain Management Program has developed four model ordinances—each progressively more protective against inundation and erosion hazards. Each model (*Table 8*) is prefaced with a two page introduction.

Table 8 DEC Model Flood Hazard Area Regulations (available through the flood hazards link above)

	Primary Focus	NFIP Compliant?	Use	Address Erosion Hazards?	Cumulative Benefits / Cost for Town	VT DEC Recommended
1.0	NFIP Minimum	Yes		No	Low	No
2.0	Inundation Hazard	Yes	Stand Alone	No	High	Yes
3.0	Inundation and Erosion Hazard	Yes	Zoning Attachment	Yes	Moderate	Highly
4.0	Flood Hazard	Yes	Zoning Attachment	Yes	High	Highly

The Municipal Guide to Fluvial Erosion Hazard Mitigation (see above link) contains a wealth of information for towns wishing to learn about erosion hazards and how the FEH Program may assist them. DEC watershed coordinators (see list at: http://www.watershedmanagement.vt.gov/planning.htm), RMP scientists and floodplain managers, and regional planners, are available and work together to attend Planning Commission and Selectboard sponsored meetings to explain local erosion hazards and the town options for dealing with them singularly or in combination with other flood hazards mitigation plans.

The Vermont River Corridor Protection Guide contains a technical appendix detailing the "final" design of river corridors and FEH zones. In developing work plans under this strategy, it is important to keep in mind that the corridor produced during the Phase 1 process may never have been significantly adjusted using the Phase 2 assessment data. Once a town has decided to move forward with corridor protection, this analysis need to happen, and a design-level corridor is developed to meet both technical and socially feasibility tests. The Corridor Protection Guide also lays out criteria for creating simple setback provisions for small streams (typically in steep, confined settings), where meander belt-based FEH zones have not been designed. Creating a conservative top-of-bank setback recommendation for small streams that largely accommodate equilibrium channel geometry, when combined with FEH zones, allows towns to mitigate erosion hazards town wide, rather than single out only those areas where Phase 2 work was completed. The Corridor Protection Guide carefully lays out an argument for why towns would want to use FEH zones where available, rather than pursue simple minimum "buffer" setbacks for all streams, as was traditionally recommended.

6.9.4 Buffer Establishment and Protection

When streams and rivers have the space to develop and maintain the dimension, pattern, and profile associated with equilibrium, they become more naturally stable. It is the establishment and protection of vegetated buffers that represents the most cost effective strategy for maintaining this natural stability and its water quality and aquatic habitat benefits. The VT ANR has developed buffer guidance and technical papers, which provide a wealth of information on the environmental and social functions and values of vegetated buffers.

Guidance: http://www.anr.state.vt.us/site/html/buff/BufferGuidanceFINAL-0905.pdf

Technical Papers:
www.watershedmanagement.vt.gov/rivers/docs/Educational%20Resources/rv_RiparianBuffers&Corridors TechnicalPapers.pdf

The creation of new or enhanced buffers is almost always a worthwhile practice when objectives are clearly specified. Other physical departures and stressors may be present, but a buffer practice, properly designed and executed, will provide benefits. This Guide spells out the development of a buffer strategy to restore and protect stream stability and aquatic habitat functions. While these actions may help to partially or wholly achieve goals related to water quality, wildlife habitat, and aesthetics, the full restoration of other buffer functions may require further technical considerations.

Designing a buffer involves deciding how wide it needs to be, what vegetation is desired, and how the vegetation will get established. Numerous manuals on buffer design are available. Information and other references are included in the Technical Papers cited above. The VT DEC published "Native Vegetation for Lakeshores, Streamsides, and Wetland Buffers" (Kashanski, 1994), which is an excellent source on information on what vegetation will thrive in the different soil and climatic settings of Vermont.

Ideally, the buffer project will include a formal mechanism for protecting the area that is being set aside. First and foremost, good fences make good neighbors. On lands where livestock are grazing, a wooded vegetated buffer depends on a well maintained fence. Other land uses should be permanently setback from the streambank as well. When land uses involve substantial investments, great care must be made to distinguish between protecting the river corridor and providing for a buffer setback area. As a companion to this Guide, the River Corridor Protection Guide (Kline and Dolan, 2008) treats this subject in detail. A buffer strategy should be coordinated with a river corridor protection strategy, and ideally carried out in tandem. A landowner may not take kindly to establishing a buffer to achieve certain stream bank stability and habitat objectives and find out a short time later that a much greater setback is required to accommodate the geometry of a stable equilibrium channel, especially if investments were made during the interim period.

Section 6.2 of the Step-Wise Procedure provides criteria for identifying and prioritizing potential buffer projects. In creating a watershed wide strategy for buffer establishment and protection, perhaps the highest priority is protecting those buffers that exist, as well as protecting the riparian areas where, at least in the future, there would be an opportunity to restore buffers before streamsides become developed. Setting aside and protecting buffers is an outcome that may be accomplished through the corridor protection strategies outlined in Sections 6.10.3 and 6.10.6 for municipal zoning and corridor easements, respectively. Buffer protection agreements are also a part of several state and federal agricultural programs which require the active reestablishment of riparian vegetation. If protecting buffer zones in state and municipal regulation is not feasible in the near-term, it may be desirable to strategically target the most sensitive and/or threatened areas and work directly with landowners to set-aside and protect these areas from land-use conversions that would eliminate riparian vegetation and/or preclude buffer establishment in the future.

The following steps may be useful in prioritizing projects in a buffer strategy:

- List all reaches in a Projects and Strategy Summary Table (*Figure 20*) which have been identified as opportunities for planting or creating a buffer;
- Separate out and create a separate list of those buffer projects which would very likely be subsumed within and designed as part of a larger corridor protection and/or restoration project in the near future;
- Of those remaining as potential stand-alone buffer projects, separate them again into two lists, those in reaches likely to undergo planform change and those that are less likely to so;
- For both lists, prioritize projects based on
    - highest to lowest stream sensitivity
    - adjacency to land uses and features which contribute higher runoff and sediment
    - opportunity to increase buffer connectivity and improve fish and/or wildlife habitat

Sensitivity to planform (*Table 9*) change is not a show stopper with respect to buffer establishment; rather, it should be a tempering factor on the degree to which active buffer planting is pursued. The process of separating reaches by planform stability should be informed by the Sediment Regime Departure Maps. The yellow, red, and purple coded streams (moderately to deeply incised or rapidly aggrading and little of no boundary resistance) are those where one would expect significant planform change during flood events, and are not good candidates for active and aggressive planting of expensive woody plant stock. The other color-coded sediment regimes on the map represent streams which are less likely to undergo significant planform change. The orange-coded streams (incised and mostly armored) are those where, although departed from natural equilibrium, the pattern of the stream is being largely controlled and woody buffer vegetation could be established with less concern for erosion.

The remaining sediment regimes (blue and green-coded) may be closer to equilibrium for their respective valley confinements and, while sensitive to planform change, are likely to remain in equilibrium and maintain natural stability if native woody vegetation can become established.

Table 9 Planform Sensitivity Table.

Sediment Regime	Planform Sensitivity	Buffer Project
Transport	Medium sensitivity – more naturally armored, buffer vegetation plays minor to moderate role in boundary resistance.	Larger tree plantings
Confined Source And Transport	High Sensitivity – scour occurring below the root zone, vegetation providing little resistance, mass wasting of trees	Fast shrub and small bare root trees
Unconfined Source and Transport	Low – Medium Sensitivity – planform structurally constrained and/or scour occurring below root zone.	Larger tree plantings on stabilized segments
Fine Source / Transport & Coarse Deposition	High Sensitivity – highly erodible bank materials, significant planform change, and scour occurs below the root zone.	Fast shrub and small bare root trees
Coarse Equilibrium & Fine Deposition	Medium Sensitivity - highly erodible bank materials, minor to moderate planform change.	Fast shrub and larger tree plantings offset from bank
Deposition	High Sensitivity - highly erodible bank materials, moderate to extreme planform change.	Fast shrub and small bare root trees

Where reaches have been assessed as sensitive to planform change and/or mass wasting processes are likely to ensue from the occurrence of scour far below the depth of root growth, buffer projects should anticipate a dynamic bank line and a significant loss of planted material to erosion. Fast growing shrubs and inexpensive bare root shrubs and trees may be most cost effective materials to use, and some reliance on natural regeneration may also be warranted. If an area has not been used to graze animals, there may be some current regeneration that would indicate the success of a passive approach to buffer re-establishment. A reach evolving to equilibrium where plantings and regeneration have occurred over time, in all likelihood enough stabilizing vegetation will have survived to provide resistance to erosion.

Water quality and habitat are additional factors used to help prioritize buffer projects from a resource restoration standpoint. Riparian areas adjacent to steep sloping lands or where swales create more concentrated flows into the stream, may be especially important priorities for reestablishing year round, riparian buffer vegetation. Rather than impede streambank erosion, this buffer vegetation is reducing the overland erosion of soils and nutrients that could impair water quality and aquatic habitat. Some buffers serve the additional habitat function of reducing thermal radiation and temperature increases that impact fish and other organisms. The development of priorities within this strategy may also be influenced by available RHA data that indicates habitat deficiencies and stressors associated with loss of woody cover and riparian vegetation.

The willingness of landowners to commit the space to establish and maintain a riparian buffer is, of course, one of the most important criteria to use in ordering the priority of projects within a buffer strategy. Stating this last in a discussion about priority setting is done to emphasize that technically defining where, why and how a buffer project would be pursued, is an exercise that should not be overlooked in one's eagerness to start working with the willing landowner. Those pursuing this strategy will also want to understand the landowner's motivation for allowing buffer establishment on their land. This provides insight as to whether they will maintain the buffer over time.

Several state and federal agencies have buffer programs. The following provide design and funding support for buffer projects:

- Vermont DEC Watershed Management Division and River Management Programs (several funding programs) at http://www.watershedmanagement.vt.gov/wqdhome.htm
- Vermont Agency of Agriculture, Food, and Markets, CREP (Conservation Reserve Enhancement Program) at http://www.vermontagriculture.com/ARMES/CREPwebsite/Home/Home.htm
- USFWS Lake Champlain Fish And Wildlife Resources Office, Partners for Fish and Wildlife Program at 802 872-0629 http://www.fws.gov/partners/
- U.S.D.A. Natural Resource Conservation Service, buffer practice available through several Farm Bill Programs at http://www.vt.nrcs.usda.gov/programs/

The staff of these programs in Vermont have years of experience working together on riparian buffer project, often conducting joint site visits and sharing in the design, funding, and implementation of projects. They have also worked over the years to establish an ongoing capacity in watersheds to carry out buffer projects. This includes training watershed coordinators, starting nurseries and/or making annual plant orders to support multiple projects in any given year. Vermont Natural Resource Conservation Districts (http://www.vacd.org/), typically have active buffer programs. The Lamoille NRCD and Nature Center has a notable program called "Trees for Streams" http://www.lcnrcd.com/.

6.9.5 Road-Stream Crossing Retrofits and Replacements

Bridges and culverts improperly sized, typed, and/or placed at a stream crossing often modify natural channel dimensions and disrupt hydrology and sediment / debris transport. Excessive upstream aggradation and downstream channel incision are observed above and below poorly designed crossing structures, indicating some degree of sediment discontinuity. Structures which are incompatible with stream geomorphology (i.e., they deviate from the natural channel width, slope, and alignment) either fail due to excessive erosion around the structure and/or lead to reach scale disequilibrium.

When culverts are improperly sized, fish and other aquatic organisms may not be able to move freely throughout previously accessible parts of a watershed. A loss of watershed connectivity and blockage of aquatic organism passage (AOP) can have the following negative impacts on aquatic communities:

- Loss of resident populations by preventing recolonization of upstream habitats after catastrophic events, such as floods or toxic discharges;
- Partial or complete loss of populations of migrant species due to blocked access to critical spawning, rearing, feeding or refuge habitats;
- Altered aquatic community structure (e.g. species composition, distribution)
- Reduced genetic fitness of aquatic populations that allow communities to survive changing or extreme conditions.

The bridge and culvert "Datasets" area of the Vermont SGA data management system has "Failure Mode" reports as well as an "AOP and Geomorphic Compatibility" reports. These coupled with data reports from the Vtrans-sponsored Online Bridge and Culvert Inventory Tool (VOBCIT) provide a wealth of information useful in ranking structures and creating a strategy for road-stream crossing retrofits and replacements.

VANR SGA / DMS: https://anrnode.anr.state.vt.us/ssl/sga/security/frmLogin.cfm
Vtrans VOBCIT:
http://apps.vtrans.vermont.gov/BridgeAndCulvert/Login.aspx?ReturnUrl=%2fbridgeandculvert%2freportselection.aspx

The VT ANR has produced a wealth of information regarding the evaluation of road crossings. Two key documents that lay out the methodology and criteria used to rank structures include the culvert geomorphic compatibility screening tool: http://www.vtwaterquality.org/rivers/docs/rv_VTCulvertGCScreenTool.pdf, and the AOP screening tool: http://www.vtwaterquality.org/rivers/docs/rv_VTAOPScreeningTool.pdf. These methods along with Vtrans data, which indicates the age and physical condition of the structure, can be used to develop a strategy for stream crossing retrofits and replacements that meets environmental, social, and economic priorities.

Structures are owned by state and federal governments, municipalities, or private entities. They all require maintenance and eventual replacement. Structure owners should be involved in the process of developing a crossings strategy within river corridor plans. For State structures, points of contact are the Vtrans District Engineers, the RMP Regional Scientists and Stream Alteration Engineers, and the District Fisheries Biologists. Each year, these professionals work on critical structures lists, which increasingly involves the consideration of AOP and geomorphic compatibility. The Vermont Fish and Wildlife Department published *"Guidelines for the Design of Stream/Road Crossings for Passage of Aquatic Organisms in Vermont,"* which are used by the State agencies to minimize the impacts of stream crossings.

Replacing undersized culverts and achieving AOP is a significant restoration activity. Similar to dam removals, government agencies and non-government organization, involved with aquatic habitat restoration, provide both funding and technical assistance. In addition to the agencies named above, a crossing retrofit and replacement strategy may be of great interest to the U.S. Fish and Wildlife Service, Partners for Fish and Wildlife Program, the USDA Natural Resource Conservation Service, Wildlife Habitat Incentives Program (WHIP), and organizations like Trout Unlimited.

6.9.6 Reach-scale River Corridor Protection Projects

For decades, channel works designed to keep rivers static and contained in the landscape were used to resolve any and all conflicts between rivers and people. The need to stop erosion, wherever it occurs, *even when few investments* are at risk, is a notion deeply ingrained in our society, especially for those invested in riparian lands. River corridor protection, in the form of an easement, represents a feasible alternative to channel management. Easements have been designed to augment municipal FEH zoning ordinances. Zoning may avoid future encroachment and minimize fluvial erosion hazards, but does not restrict channelization practices.

Floodplains, as the "pressure relief valves" of a watershed, are being nurtured in the public mindset as a new type of community asset. Obtaining an easement to protect rather than stop the erosion process and allow floodplains to reestablish is a valuable restoration tool. Landowners may divest from areas where repetitive losses are anticipated, while soils, property, and infrastructure in the watershed are protected at lower, long-term costs.

Giving rivers space, protecting floodplains, and using limited public resources to preserve selected corridors where the river may erode and deposit, is becoming part of a shared local, state, and federal commitment to enhancing watershed storage. Wherever feasible, the capture and storage of water, sediment, and debris in natural floodplain features will reduce flood hazards and promote the ecological health of our rivers.

One of the primary objectives in creating a river corridor protection strategy is to identify the key flood and sediment attenuation areas, where human land uses may be in constant conflict with the channel evolution of particularly dynamic and sensitive stream reaches. Key attenuation reaches are prime candidates for the acquisition of river corridor easements (see Section 5.1.3).

Securing a river corridor easement may be the most viable river management alternative where: 1) the sediment deposition process is dominating and/or is critical to the development and maintenance of equilibrium channel forms (i.e., stable meanders, river beds and banks); 2) channel and corridor constraints do not currently limit meander and channel slope adjustments; 3) existing and future proposed activities have been identified that would constrain or otherwise threaten the attainment of equilibrium conditions; and 4) protecting the erosion/deposition process in the easement area may help minimize the erosion hazards to downstream areas (*Figure 19*).

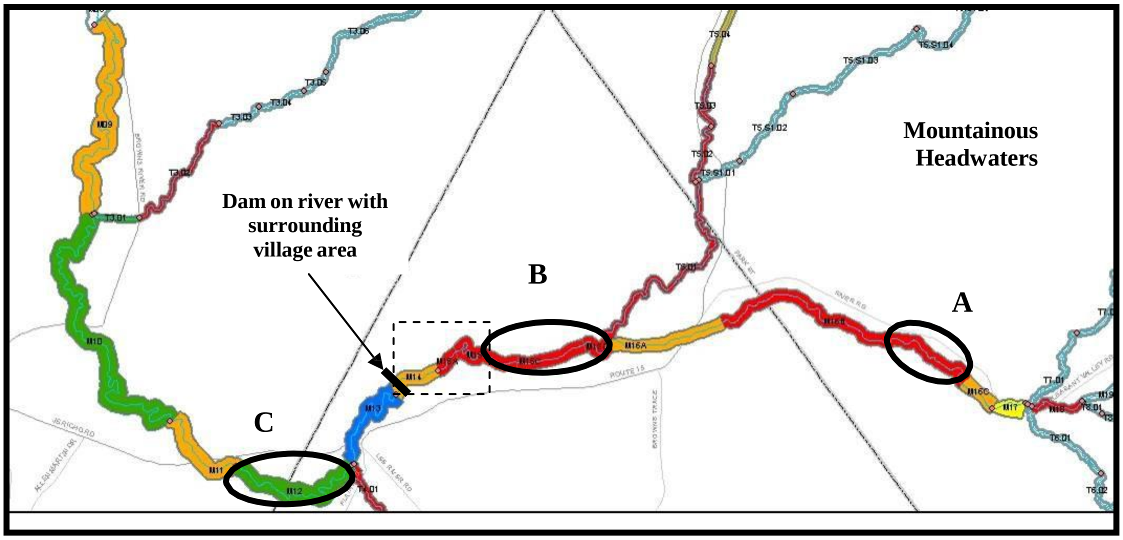


Figure 19 Three priority sediment attenuation areas that are good candidates for river corridor easements. Reach A is a naturally sensitive reach, where headwater sediments are deposited; Reach B is at the tail end of a string of unstable reaches (red) where allowing deposition and flood storage provide some flood mitigation for the downstream village; and Reach C has aggradation occurring (green) in a delta area below a confluence.

Attenuation reaches are high priorities for protection within watersheds, because they are critical to the capture and storage of water, sediment, nutrients, and organic material. Functioning attenuation reaches serve to reduce excess erosion, reduce the fine sediment and nutrient loading that otherwise impairs water quality, and retain the coarser sediment and organic debris important as cover habitats to aquatic organisms.

The River Management Program has prepared *A Guide to River Corridor Easements* which may be obtained from:
www.watershedmanagement.vt.gov/rivers/docs/rv_RiverCorridorEasementGuide.pdf. Appendix B of the Easement Guide offers a set of Ranking Criteria that may be used by river corridor and easement project planners to identify and prioritize easement projects. This process focuses on the stream equilibrium and erosion hazard reduction at the watershed scale, and breaks down the ranking process to coincide with three different stages in the development of a corridor protection strategy:

Stage I provides a technical ranking of priority easement projects on river segments identified in the corridor planning process, and occurs prior to easement project scoping, considering:

- Sediment regime departure (as per Section 5.1.3);
- Active adjustment processes;
- Opportunities to increase storage by mitigating or reducing human-imposed sediment transport; and
- Land use factors, i.e., existing and potential constraints to the attainment of equilibrium conditions.

Stage II provides for the ranking of easement projects based on size and estimated cost per acre. This Stage assumes that there has been limited contact with the landowner, and would be used to support priorities for easement scoping. Stage III is a final ranking used to order easement projects based on a range of project benefits that are determined through the project scoping phase and landowner negotiations. After this Stage, easement projects may be prioritized for implementation. Stage III considers:

- Project type, including public or private ownership and whether an easement is donated or purchased;
- Other partner contributions to the project (financial, cost-share, or in-kind);
- Potential for active restoration components;
- Proximity to other permanently protected/restored features or relevant public assets; and
- Level of structural maintenance required within the easement area

The *Guide to River Corridor Easements* contains an easement template with model language for achieving the purposes of corridor protection (Appendix A). It also contains a step-wise procedure, through which a team, established to oversee the development of a corridor protection strategy, may work through the design process and implement priority easement projects (Appendix C).

A number of regional and local land trusts have become active in river corridor protection by accepting easement donations or working with the River Management Program and other partners to purchase river corridor easements. The Vermont Land Trust and the Vermont River Conservancy have partnered with the RMP to develop both stand-alone and incorporated corridor easement templates. River corridor provisions incorporated into larger easement projects, with other conservation objectives, are being developed in partnership with state and federal agricultural agencies and the Vermont Housing and Conservation Board (VHCB).

Vermont River Conservancy: http://www.vermontriverconservancy.org/index.html
Vermont Land Trust: http://www.vlt.org/
Vermont Housing and Conservation Board: http://www.vhcb.org/

6.9.7 Reach-scale River Corridor Restoration Projects

River restoration strategies have become increasingly popular as practitioners, riparian stakeholders, and watershed organizations seek alternative methods for resolving human-river conflicts. New restoration techniques have provided opportunities for achieving more immediate water quality and habitat benefits. This guidance is geared toward developing a restoration strategy where actions are in concert with the natural channel adjustments, hydrology, and sediment regime associated with stream equilibrium. This guidance cautions against restoration projects intended to resolve human-river conflicts using techniques such as bioengineering and natural channel design, but where landowner constraints severely limit fluvial processes and future channel adjustments. River management agencies in Vermont have learned through experience that trying to keep dynamic systems static in the landscape under the guise of restoration often results in a lose-lose situation. A successful restoration strategy embraces the idea of dynamic equilibrium and only uses the design and construction techniques associated with "natural channel design" to accelerate or nudge the channel evolution process.

Some desirable projects, not fitting the above definition but still referred to as restoration, do involve active intervention of active channel adjustment processes. For instance, the use of fish-friendly, cross-channel weirs to arrest an active head-cut may call to question the use of "restoration" as a project moniker. On the other hand, it may be very consistent with an overall restoration strategy to categorize such a project as a positive intervention to protect active floodplain function. Arresting head-cuts is difficult, because it involves trying to stop an ongoing channel evolution process with a man-made structure, and therefore, it creates a significant challenge from a maintenance standpoint. Not all head-cuts should or can be stopped, but in some cases, doing so may be deemed exceedingly worthwhile because major erosion is avoided and upstream floodplain function is protected that would otherwise be lost for a very long time period.

Another exception involves projects that might be more correctly referred to as enhancements rather than restoration, where often the existence of physical constraints preclude the attainment of the natural dynamic equilibrium. In-channel and riparian habitat enhancements exemplify this type of "restoration" project. This guidance places a lower priority on enhancement projects. Vermont River Management does support, however, those habitat enhancements that do not impede stream equilibrium in the long run, especially when they are coupled with river corridor protection. These projects can be important in developing a constituency for rivers and river restoration work.

Creating a restoration strategy involves setting priorities for the most timely and cost effective activities that are consistent with the goals and objectives on the overall corridor plan. The following order of priority objectives is suggested in creating a restoration strategy:

1. Actively restoring and protecting floodplain function
2. Removing constraints to the natural sediment and hydrological regimes
3. Maintaining the equilibrium dimensions, pattern, and slope of the existing channel
4. Reconstructing the channel dimensions, pattern, and slope associated with equilibrium conditions
5. Enhancing the channel and floodplain features in a reach being maintained as modified stream type

A restoration strategy is created by sorting and prioritizing reach-specific projects under these five objectives. Reach-specific restoration projects, identified in Sections 6.3 through 6.8, include: stabilizing streambanks; arresting head-cuts and nick-points; removing berms and other constraints to flood and sediment load attenuation; removing/replacing structures (e.g. undersized culverts, constrictions, low dams); restoring incised reaches; and restoring aggraded reaches. In a restoration strategy, managing streams toward equilibrium conditions is factored with socio-economic considerations, i.e., those elaborated on in Section 7.

Removing structures and landforms that constrain or obstruct fluvial processes and restoring and maintaining vertical connectivity between a channel and adjacent floodplains and horizontal connectivity between upstream and downstream are the mainstays and highest restoration priorities of the Vermont River Management Program. Every opportunity to couple active restoration with river corridor protection is pursued. Where large funding is required to complete a restoration project, and adjacent landowners accrue substantial benefits form the work, corridor protection may be identified as an essential component of the project.

A highly successful restoration strategy is one which seeks funding and technical support of local restoration projects that are part of a larger river corridor protection initiative. For instance floodplain restoration projects, riverbed and bank stabilization within village centers, bridge and culvert work at common road washout areas and fish blocks, and property relocation when offered and implemented as incentives to achieve the larger objective of corridor protection. A key aspect of this strategy is the collaboration and consistency with state, federal, municipal, and non-profit programs. Under this approach, landowners and towns seeking to resolve their river conflicts get consistent guidance and support for corridor protection and working towards natural equilibrium.

Before and after channel restoration on the White River in Granville, Vermont

6.10 Reporting Technically Feasible Projects and Strategies

This Section describes the initial development of a River Corridor Plan and suggests the types of summary information will be useful in moving toward meaningful river corridor protection and restoration work. River Corridor Plans should express a priority for different strategies and projects, which is based on both social and environmental costs and benefits. Priority setting may be guided by the set of feasibility tests outlined in Section 6.10.2. River Corridor Plans, at least when first published, may not contain great detail on reach-scale projects, but should prioritize general strategies and projects within strategies to direct the planning and design work to follow.

6.10.1 The Interim River Corridor Plan

The planning activities outlined in Sections 5 and 6 provide a strong basis for reporting technically feasible projects and strategies (i.e., projects consistent with managing toward equilibrium conditions) and a first cut at the social feasibility of different action alternatives. An Interim River Corridor Plan may be presented to the public at this stage, which would include for each assessed reach the:

- Reach condition, based on regime departures and sensitivity, and used to evaluate the large scale changes in a stream network associated with the equal distribution of energy, i.e., given the existing and future constraints on the system, where are erosion and deposition processes most likely to occur and where is there the greatest potential for change and/or conflict with human investments;
- Stressors, or modifications to equilibrium conditions, which help to explain why a reach or segment of river is under adjustment and at a particular stage of the channel evolution process;
- Constraints, natural and human-placed, which will modify how and where the physical adjustments in the stream network will play out, and how the lack of change and channel evolution in one location may affect the fluvial processes and change in another reach;
- Attenuation assets, existing and potential, which tell where sediment deposition is occurring, and where, if sediment deposition could occur, a reduction in systemic stress and erosion could be achieved;
- Prioritized strategies and projects that would work to alleviate stressors at the watershed or reach-scales, maximize flood flow and sediment attenuation, and, at least in the long-term, contributes to the restoration of equilibrium conditions.

Introducing an Interim Plan to landowners and other stakeholders at this stage is advisable; however, there are qualifiers that should be made. For instance, the lists of constraints are primarily those which are easily observed on maps, orthophotos, and during field assessments. Other constraints surely exist, especially economically important land uses. The identification of attenuation assets has been largely academic to this point, and will become more focused during the exploration of other constraints. The list of projects and strategies includes those which are only generally described and are still largely unknown with respect to social feasibility. Much input and consensus from landowners and communities will be required if they are to move forward. Framing this information correctly at this juncture may make the difference in successfully engaging people during the project development phase. Participants need to know that their input will matter.

Use of a Project and Strategy Summary Table (*Figure 20*) is recommended to organize and compile information in one place and begin evaluating the technical and social feasibility of projects or strategies. The Summary Table builds and expands on the Projects and Practices Table, used as a worksheet throughout the step-wise procedure. In particular, the Summary Table provides a method for logically grouping practices into comprehensive reach-scale projects or grouping projects under comprehensive strategies within the watershed. Different ways to organize and list projects and strategies on copies of the Summary Table may include:

- Watershed Strategies: e.g., town planning & zoning, culvert upgrading, buffer planting programs
- Projects by Strategy Type: e.g., buffer planting projects listed in order of priority (overall feasibility)
- Reach-scale Projects: e.g., projects listed in order of priority and representing a suite of practices combined to address multiple stressors while working with individual riparian landowners

The development of reach scale projects is taken up in Section 7.0. This breakdown is made recognizing that reach-scale project development may be a component of an overall watershed strategy in an Interim River Corridor Plan, and that initiating and enhancing the technical and social feasibility of projects with individual landowners requires much more precision than is normally included in river corridor plans. Getting high priority strategies underway, on the other hand, requires working with organizations and agencies that are vested in a broader set of public concerns and familiar with the adaptive management required to resolve conflicts between human investments and the dynamics of rivers. Finding agreement on the order, synergy, and coordination of different strategies within a restoration program leads to a much greater comfort level with and commitment to the time, energy and resources required in the development of individual projects with landowners.

_____River Name_________Corridor Planning

Project and Strategy Summary Table

Project #	**Reach/Segment Condition**	**Site Description including Stressors and Constraints**	**Project or Strategy Description**
1			
2			
3			
4			
5			

Project #	**Technical Feasibility & Priority**	**Other Social Benefits**	**Costs**	**Land Use Conversion & Landowner Commitment**	**Potential Partner Commitments**
1					
2					
3					
4					
5					

Figure 20 Example of a Project and Strategy Summary Table. Assessor may wish to assemble the table as one long table with each row containing all the desired columns stretched out on a legal sized page with a landscape orientation.

6.9.2 Feasibility Tests

The step-wise procedure outlined in this Section is designed to identify projects which meet the following four *technical feasibility* tests:

1. The overall project or activity contributes to and accommodates stream equilibrium conditions.
2. The project alternative chosen, at least in the long-term, results in an overall reduction in material transport from the watershed, increasing flow, sediment, and organic material storage in the river and its floodplains.
3. If the project is completed, there is little likelihood that it will fail because of unmitigated constraints or anticipated channel adjustment processes in the river reach or in the watershed.
4. The project will not lead or contribute to instability in upstream or downstream reaches.

The *social feasibility* of watershed strategies and projects may be judged by evaluating landowner and stakeholder involvement, project costs, and the accrual of both public and individual benefits. These tests should be applied:

1. The project results in tangible social benefits, e.g., fisheries restoration, fluvial erosion hazards reduction, or serve as a highly visible public demonstration project.
2. Municipalities and/or landowners are committed to any necessary land use conversions and have formally agreed to the changes.
3. The potential costs of design, permitting, and implementation are reasonable given the overall gains in equilibrium and other social benefits achieved.
4. Stakeholders are available and committed to the required level of project support and management.

These same sets of tests may be applied when prioritizing watershed strategies. For instance an avoidance strategy that promotes corridor protection, or projects that involve the removal of channel and corridor constraints (e.g., berms and other floodplain fills), are among the most feasible from a technical and social standpoint. This is typically true because there are greater gains with fewer risks and at smaller costs. Projects involving the placement of bed or bank armor, or those that otherwise attempt to modify vertical channel adjustments, would be less feasible due to their higher costs and the uncertainty associated of unmitigated watershed stressors. The suggestions in the step-wise procedure, for placing higher and lower priority on different projects, are based primarily on their technical feasibility and costs.

The Summary Table (*Figure 20*) has a column for noting technical, social, and overall feasibility under the priority ranking of each strategy or project. At the completion of planning activities outlined up to and through Section 6, the assessor may not have succinct or comprehensive evaluations for all feasibility tests, and priorities will change, but this is an iterative process. As information becomes available, projects and strategies may be further documented in the Summary Table. Partners and stakeholders in river corridor planning are encouraged to select high priority projects and strategies, pursue the social and landowner feasibility questions, and implement the most technically feasible alternatives that best satisfy these concerns.

7.0 Project Development

This Section of the River Corridor Planning Guide will focus on readying projects and strategies for implementation. At the end of the project identification process, the planning team may have dozens of potential projects to work on. Through prioritizing projects and strategies, and enhancing social feasibility, the planning team will become proficient with analyzing alternatives based on the rate and extent of restoration activities that may be pursued in any given year of the corridor planning process.

A type of alternative analysis that became common, as a requirement for federally funded and regulated programs, was the examination of alternatives including a "do nothing" alternative and various proposals for development. A preferred alternative was chosen based on which project configuration would achieve the goals of the developer, while having the least environmental impact. An alternatives analysis becomes less and less meaningful when there is consensus for a detailed set of goals and objectives. In a river corridor protection and restoration program, a preferred alternative is being chosen based on which project configuration would most accommodate equilibrium conditions and provide benefits for the landowner and community. Throughout the project development process, alternatives related to project extent, timing, and configuration may be considered. The preferred alternative is derived as an outgrowth of negotiations to develop the most technically and socially feasible project.

One of the first decisions in creating an effective project development and implementation program, is how to phase different types of projects. Pursuing the most feasible projects makes sense, but in the beginning there may be less knowledge on the social feasibility of projects and therefore less certainty on exactly where and in what order projects should be developed. It is recommended that, in any given year, the planning team would want to work on a mix of projects and strategies: one or two "low hanging fruit;" a project or two involving more negotiation and conceptual design; and the development of at least one key strategy. These activities often require different technical capacities. Having a mix will reduce the burden on agencies and consultants who will be working to assist planning teams in multiple watersheds. Developing key strategies, such as municipal erosion hazard zoning, may be a lengthy process. While it is tempting to steer clear of the politics often associated with municipal actions, they are among the most effective in meeting the plan's objectives, and often the only way to reduce stressors at the watershed scale.

This Section offers an overview of reach specific project development, including ways to enhance and document the social feasibility of projects. There are tips for deciding on active and passive restoration alternatives and to what extent project proponents should seek the protection of a new attenuation area as an off-set or mitigation for measures that achieve property protection, but contribute to disequilibrium in the stream. The Section describes the use of landowner and municipal incentives in an iterative process to promote a sustainable community relationship with the river and its tributaries.

7.1 Reach Specific Project Development

The *Project and Strategy Summary Table* (Section 6) is used to track progress throughout the assessed watershed. It can serve as a quick reference for any one interested in learning the status of projects and planning further project development activity. Resource agencies and organizations may consult the *Summary Table* to evaluate whether proposals seeking their review, funding and/or assistance, have been deemed technically and socially feasible within the river corridor planning process. The *Summary Table is* the heart of the River Corridor Plan.

When reaches have been culled out of the *Summary Table* for a focused effort to develop more difficult projects (i.e., multiple stressors, constraints and attenuation opportunities), the project developer should be tasked with creating and maintaining a "project packet" for each project the team feels should be moved forward to the next step of project development and ultimately project implementation. Project summary packets should provide a narrative summary of the project, document the feasibility of each project or activity in terms of land use constraints, landowner/municipal/stakeholder support, restoration and protection activities required, project development and implementation cost estimates and regulatory requirements. The project summary should also document landowner contacts and participation throughout the planning process. These narratives should follow an outline established with reference to the column headings in the *Summary Table*. The following are useful tips in creating an effective narrative summary of a project or strategy:

- Reference the River Stressor Identification, Departure Analysis, Projects and Practices, and Project and Strategy Summary tables produced in early stages of the planning process;
- Embed key photographs in the text which show specific stressors, constraints, and proposed project locations (labels and arrows may be added to digital photos);
- Provide a plan view map (ideally a digital orthophoto) which should include the geomorphic river reach , landowner information (when available), known constraints, acreage, boundaries of any corridors for consideration of corridor easement or other practices where a specific area of land is to be considered for that practice, and relevant Phase 2 data;
- Provide a second plan view map to show any conceptual or preliminary designs which are under discussion or have been agreed to by the landowner(s);
- Under the project or strategy description, make note of not only technically feasible practices and strategies for which there is agreement, but practices which have been put on the table and evaluated as not feasible (from a water quality restoration and protection standpoint);
- Document the funding, technical assistance, volunteer efforts, and regulatory reviews offered by various agencies and partners; and
- Complete a narrative of "next steps" to keep the project progressing.

Packets should also include a "Project Ranking Table" which will be based on the following screening or evaluation criteria:

- Does the overall project or activity contribute to and accommodate the stream equilibrium conditions?
- Does the project alternative or management activity chosen result in an overall reduction of sediment/nutrient production from within the river corridor and increase in sediment and nutrient storage in the watershed?
- If the project is completed, is there likelihood that it will fail because of unmitigated constraints or anticipated channel adjustment processes in the river reach or in the watershed?
- Will the project or management activity lead to or contribute to instability in upstream or downstream reaches?

Additional secondary considerations will include:

- What is the cost and feasibility of the recommended (set of) practices?
- How will the practices maximize the restoration and protection of river equilibrium and minimize fluvial erosion hazards within the river corridor?
- What are the potential costs and feasibility of design and permitting?
- What level of landowner participation has been obtained and what level is land use conversion would be necessary or feasible?
- What commitments to project support and management will be required of staff, and is the required level of commitment available?
- Are partners available to share (functionally and/or financially) in achieving the project objective?

These narratives should be kept up over time. It is not unusual for river corridor projects and strategies to take years to complete. New project coordinators, steering committee members, and project partners will benefit from complete and up-to-date project narratives.

Based on the ranking criteria and project development costs, the "steering committee" or project team, would select which of the identified projects will be developed further under Corridor Planning Tasks. Types of corridor planning projects may fall under three categories: Management Alternatives; Project Design, Permitting and Contract Development; and River Corridor Easement Development. The type of project is determined based on the project development effort and strategies laid out in the project packets. An individual project may fall within one type or may include elements of all corridor planning approaches.

Negotiating Management Alternatives

During the project screening and priority setting process, the project developer acts as liaison between landowners, local town officials, and federal, state and regional agricultural and environmental program staff to develop and advocate river corridor protection and restoration projects. The project developer would:

- contact and conduct one-on-one meetings with landowners within the project reaches to discuss results from Phase 2 stream geomorphic assessment (SGA) and the potential projects identified from the assessment;
- document the feasibility (constraints, preliminary costs, and benefits) of different alternatives with the landowner(s) to maximize the achievement of river corridor goals and objectives;
- identify opportunities for leveraged funding, provide information on various funding programs available to landowners for corridor protection and restoration projects, and prepare and submit qualifying projects through the appropriate funding program application or sign-up process; and
- secure landowner commitments, in the form of a letter that shows their intent to move forward with a selected project alternative (as conceptually designed) and documents their understanding of project goals and objectives.

Project Design, Permitting, and Contract Development

The project developer evaluates and advances these projects to appropriate levels of readiness for implementation. The project developer would:

- conduct appropriate site specific assessment to serve as a basis of project design (surveys will generally follow the SGA Phase 3 Protocols);
- produce maps and/or conceptual design drawings as necessary to support the alternatives analysis, be applicable for public representations of the project, and create a basis for landowner commitments (maps and drawing will demonstrate how the selected alternative is supportive of the project objectives, and will maintain, restore, or accommodate the evolution of the fluvial dynamic equilibrium condition);
- Provide preliminary conceptual project description to regulators, including site visits, to submit, on behalf of the project sponsor, permit applications, and to respond to regulatory questions and requests for additional information until all regulatory requirements are satisfied; or until such time as the project sponsor may provide alternative directives; and
- produce maps and/or final designs drawings adequate for regulatory considerations and suitable for construction contracts; prepare contract specifications and other contract documents for project implementation.

River Corridor Easement Development

A Guide to River Corridor Easements, Appendix C, lays out specific scoping and easement development tasks. An overview of this work includes:

- prioritize reaches and parcels for corridor easement development based on the feasibility analysis, the role of the stream segment(s) or reach as "key attenuation assets" within the watershed; and other criteria as determine during the scoping meeting;
- produce a technically complete river corridor base map which includes, at a minimum, land parcel information and the fluvial erosion hazard corridor;
- contact and conduct one-on-one meetings with landowners along the selected reaches to discuss results from the assessment and the potential stakeholder interest in the purchase of certain easements within the river corridor;
- work with the landowners, local entities, and other stakeholders to modify/expand the river corridor base map to include other land-based resources into the corridor such as wetlands, existing buffers, and natural heritage sites;
- document the project feasibility (constraints, preliminary costs, and benefits) using the appropriate land appraisal methods to maximize the achievement of river corridor goals and objectives;
- identify opportunities for leveraged funding, provide information on various funding programs available to landowners for the purchase of development and river channel management rights with the river corridor, and prepare and submit qualifying projects through the appropriate funding program application or sign-up process; and
- develop easements and stewardship plans and secure landowner commitments, in the form of a "purchase and sales" or a signed "options agreement."

7.2 Enhancing the Social Feasibility of Projects

This sub-section is concerned with increasing public acceptance and stakeholder involvement in river corridor protection and restoration. Citizen watershed groups and their partners, having sponsored the geomorphic assessment and project identification components of the planning process, are now challenged to work with other agencies and professionals to bring a science-based "story of the river" to watershed communities in a manner that will foster consensus for project and strategy development.

In some cases, finding consensus will be very easy. For instance, there are constraints causing river channel disequilibrium that are also causing hardship to landowners or towns. Agreement to remove these constraints would be swift in coming, and the work to remove them could proceed once funding and permits are in hand.

For most river projects and strategies, however, consensus will either be slower to come or evolve through education and compromise. This sub-section will discuss ways to enhance the social aspects of project feasibility and thereby improve consensus. There is an art to "managing toward equilibrium" which requires patience and latitude without compromising the stated objectives of the river corridor planning process.

There is no single formula—the social science literature is burgeoning with theories and methods for building constituencies for action. Many are extremely helpful when applied. There is agreement, however, that the changes required for sustaining environmental conservation come more readily through a bottom-up or grassroots initiative, as compared with approaches borne solely from a top-down directive. The engineering-centered paradigm of river management now coming to an end, replete with unsustainable results, is a clear example of a failed top-down approach (Hillman and Brierley, 2005).

It is difficult work building negotiation and coordination skills into an organization that has the staying power to adaptively manage and implement river corridor plans. Coordinators must learn to take advantage of the nearly constant procession of river management fads without falling prey to what is often their single-minded purpose. A sustainable approach must be developed where river equilibrium-based goals are linked with measures that maintain capacity for economic production and asset protection, along with social, recreation, and cultural values.

7.2.1 Increasing and refining project goals and objectives

Thus far the technical process for identifying potential river corridor projects has been guided by the management goal to "protect and restore the fluvial geomorphic equilibrium condition of Vermont rivers" which engenders a vision to broadly achieve fluvial erosion hazard mitigation; sediment and nutrient load reduction; and aquatic and riparian habitat restoration. Adopting an expansive view of the time and space over which this goal may be achieved, creates room for a consensus building process to potentially expand or refine the objectives of local projects or strategies.

This step in the corridor planning process may be viewed as a socio-economic fact finding mission and is largely completed during the landowner discussions and efforts to involve key partners and stakeholders (as discussed below). The river equilibrium goal and objectives provide a catalyst for local participation. Any local public discourse about river management priorities leads to expressions of concern for flooding, erosion, water quality, and the health of aquatic ecosystems. Once the science is made plain, and there is an understanding and agreement that, on the whole, an equilibrium-based approach is a sustainable way to reduce hazards and enhance water quality and habitat, then people can begin to work toward maximizing its application. An effective way to gain this understanding and agreement is to get local landowner and stakeholder participation in the gathering of social, economic, and environmental data specific to their river corridor and watershed. The following methods for documenting societal benefits and concerns may prove useful in getting people to appreciate their interests and wanting to take part in developing a consensus for how, when, and where projects will be implemented.

1. *Flooding and erosion hazards, areas of repeated flood damages, and essential land uses* – are all terms that riparian landowners and town officials will be familiar with. Have people identify these areas within the river corridor on a map and talk about whether they represent an:
   - economic asset: a constraint to flow and sediment attenuation that must be protected;
   - attenuation asset: an opportunity to protect and restore flood flow and sediment storage; or
   - potential attenuation asset: based on landowner needs and stakeholder willingness to pay.

   The more hazard areas and land use constraints are documented the more opportunities may be found to meet landowner needs and resolve conflicts. For instance, emergency management officials, river engineers, road foremen, and selectboards have records and information about lands and infrastructure that have failed, and sometimes repeatedly, during floods due to erosion or inundation. Paying for land use conversions or buy outs in these areas and protecting the corridor may be both a warranted and welcomed set of alternatives. Try to gain a more in-depth understanding from landowners as to why particular river corridor areas are important to the bottom line of their business. Is the current land use and channel management immutable in their minds because that is the way it has always been, or, for instance, is it a vital and irreplaceable component of the animal feed production on their farm?

   The information gained during landowner discussions and research into flood damage records may be used to update the Project and Strategy Summary Table. In the "Site Description" column add new information pertaining to land use constraints. Then, use the "Other Social Benefits" column to document the potential reduction in flood hazard accrued from the project as a benefit to riparian and downstream landowners (when mitigating upstream constraints), or the community as a whole from bearing the cost of repeated damage to local and state-owned infrastructure.

2. *Aquatic life and fisheries habitat, fish passage, and wildlife corridors* – are increasingly understood throughout society as vital to the survival of fish and wildlife species which sustain and enrich peoples'

lives. Request that landowners and other interested individuals help identify specific areas where the restoration of habitat and habitat continuity would likely result in measurable benefits. Fish and wildlife professionals, especially in resource agencies such as the Vermont Fish and Wildlife Department, have long records of river-specific data that may be consulted. Outdoor guiding professionals and angling associations also have a tremendous knowledge base and concern for habitat protection and restoration.

When documenting the reach-specific social benefits associated with fish and wildlife habitat, it will be particularly helpful to have summaries and maps of the data collected during Rapid Habitat Assessments and Bridge and Culvert Assessments both completed in tandem with the collection of fluvial geomorphic data. These data will show where particular habitat components may be missing, where there may be impediments to fish and wildlife movement, and where the restoration and protection of equilibrium conditions may make a difference. For instance, maps showing undersized-culvert locations that impede fish passage coupled with data showing a severe reduction in fish populations above the structures; with geomorphic data showing the lack of sediment continuity through the structures; and the input of local angling club members as to the accessibility of waters above the culverts, provide a strong argument that the social benefits accrued from replacing or retrofitting those culverts will substantiate project costs. The information gained during this research may be used to update the Project and Strategy Summary Table. Use the "Other Social Benefits" column to document the specific societal benefits that may be accrued from the project with respect to aquatic and riparian habitat restoration and protection.

3. *Healthy and productive soils* – are the cornerstone of a sustainable agriculture. People not only want to keep soil from eroding away, but have endeavored to maintain soil structure, including its organic, inorganic and nutrient composition. Throughout the 19th and 20th centuries, and with respect to watershed processes, mechanized farming and industrialization favored the use of engineered structures to drain fields, enhance and divert runoff, and retain the usability of soils. Natural soil regeneration processes, including stream meandering and annual flooding, created too much uncertainty for the Vermont farm struggling to compete with other regions growing crops with more favorable soils and climate. The reliance on deterministic practices to promote drainage and at the same time stem the loss of soil from tilled lands and denuded stream banks, however, is proving to be counterproductive. The streams that have been straightened, dredged, bermed, and armored to control erosion and mitigate flood damage, without respect for watershed process, channel incision, and the imperatives of channel evolution, are now experiencing the greatest erosion and soil loss.

The decades that often intervene between major floods have given people the misperception that channelization projects have actually worked (see Alternatives for River Corridor Management, VT River Management Program, 2006). Meanwhile, significant soil loss and degeneration have resulted in watersheds where the streams and rivers have been repeatedly separated form their floodplains and/or where the storage of water, sediment, and nutrient has been significantly diminished.

Soil and nutrient conservation are a large impetus for Vermont's river corridor protection and restoration programs. Reducing our reliance on structural controls, embracing some uncertainty, and promoting practices, which will largely benefit future generations, present a very great challenge to the consensus building process. There will be landowners and community members, however, who express great concern for sustainability and desire assistance to break free from rather than perpetuate the vicious cycle where greater and greater structural (erosion) control and encroachment lead to flood losses and economic disparity (i.e., those who may afford the increasing cost of bank armoring send the erosion problem to their downstream neighbor).

Building local consensus for maximizing river and floodplain equilibrium within a watershed, as a way to reduce the probability of soil loss along any given reach of river, may gain momentum if sought one project at a time. Work to document "prime soil protection" as a specific social benefit accrued from a project by focusing on soil quality and the potential threats to those soils. Most importantly, ask landowners where their best soils are and whether they have specific concerns for losing prime soils to dramatic adjustments of the river (e.g., channel avulsions). Research the availability of soil maps and document prime agricultural soils with the help of soil scientists and the Natural Resource Conservation Service.

The information gained during this research may be used to update the *Project and Strategy Summary Table*. Use the "Other Social Benefits" column to document the specific societal benefits that may be accrued from different types of projects which promote soil protection, including those that:

- protect existing equilibrium conditions where floodplains and/or adjacent terraces are comprised of prime soils (where bank and buffer treatments may make sense);
- increase the certainty of soil protection outside the meander belt width by actively or passively restoring equilibrium within the meander belt width (where active restoration may involve the relocation of prime soils out of the belt width to accommodate floodplain processes); and
- protect soils through traditional channelization practices, but as part of a larger project where the loss of attenuation is more than offset by the restoration and protection of equilibrium conditions in other parts of the stream network.

Start with landowner and stakeholder meetings to find out about the specific benefits that may be accrued from any given project. Use information gained through other professional organizations and agencies to substantiate and bolster the local interest. If landowners are the last to know about project proposals there will be less chance they will join any consensus that may have formed without them. If landowners and local communities take ownership of project goals and objectives, it will be sustained by the knowledge that project benefits out-weigh project costs. The challenge is to strike a balance between landowner and community interests and between the interests of current and future generations.

7.2.2 Negotiating Land Use Conversions and Landowner Agreements

Riparian landowners become involved in the river corridor planning process during the river assessments and at initial public meetings. Some landowners are interested and come forward seeking more information or help in resolving a river-related issue on their property. Others may be more skeptical or express frustration that the flooding or erosion problems that threaten their property are not being resolved. These first interactions are not always positive, but they are opportunities to engage the people who ultimately have to "sign-on" to the idea of restoring and protecting the river. The following guide points are offered as a set of reminders on some of the proven methods for getting landowners involved, negotiating land use conversions, and formalizing agreements to restore equilibrium conditions in the river system.

Seek out interested landowners: The interaction between project coordinators and landowners during public meetings often demonstrate where the "iron is hot" in terms of project development. Follow up on these conversations. Have a scoping meeting with the planning team to look at all the social and scientific data collected to date to develop a strategy for priority projects, based in part on landowner receptivity. The momentum of the restoration program hinges on the mix of projects and strategies selected for further development. The program will benefit from the early success of implementing projects where:

- change causes no harm – i.e., the practices and protections put in place do not require any significant change in land use and are cash neutral or financially beneficial to the landowner; or
- everyone desires change – i.e., land use conversions and cost sharing may be involved but the practices and protections put in place resolve a long-standing conflict where previous efforts have failed.

Projects implemented early on will create confidence in the community that the corridor plan will result in action. Picking away at the easier projects keeps the community's interest while work continues on the harder projects.

Involve all legal parties: Do not assume that the parcel map obtained in the Town Clerks Office, tells the whole story about who has an interest in the lands along the river. Certainly, of primary concern is the person or persons who own the land—make sure people who own even the smallest sliver of land in the river corridor, as well as adjacent upstream and downstream landowners, are included on the list of interested parties. Find out whether the landowner resides on the parcel and whether other persons currently use the land under lease agreement. Do not assume a lease-holder can represent the interests of a landowner. Through town records, state and federal conservation programs, and local and state-wide land trusts, find out whether rights-of-way and conservation easements have been granted on lands within the river corridor. Learn about the nature of those easements and whether a signed management plan has been put in place. Finding out mid-way or toward the end of project negotiations that others have a significant legal interest in lands within the scope of the proposal, has too often been a show-stopper and the cause of ill-spent time and resources.

Know who you are talking to: It helps to know the history of a landowner's relationship with the river. Find out whether there have been river projects undertaken in the recent past? Have they been successful? Talk with state and federal resource agencies to find out if landowners have signed-on to certain practices directly or indirectly related to the river and/or riparian lands. Talk with the Natural Resource Conservation District staff and those of other watershed groups who may have knowledge and experience in working with landowners in a local watershed. Being prepared to acknowledge and empathize with a landowner's experience is one way to ease the tension or uncertainty that typically exists when people are just learning each other's intentions. Also, get to know the neighborhood. A gathering of all interested parties at the onset may create the desired synergy or be a recipe for disaster. If possible find and enlist the help of a community member who has experience in moderating the differences and enjoys the trust of all parties.

Build trust with landowners: The most successful local river restoration and protection programs are those where partnerships of resource agencies and local community organizations have the trust of riparian landowners and stakeholders. This means generally that people are secure in the knowledge that others are not intentionally working against their interests. Ideally, the river corridor planning effort has been sponsored by a well established and locally successful organization, whose staff or volunteer members are now prepared to assist with any on-site negotiations with landowners. The trust building process with landowners may also be accelerated by scheduling a meeting with them, at their convenience, and including a resource professional with whom they have already worked with and trust. During the first conversation(s):

- Review the assessment findings and discuss the significant social values, documented above, and how they affect both the landowner and other stakeholders in the community;
- Find commonality with the landowner's interests (note: this often leads directly to discussing solutions, some engendering an immediate agreement, while others, in isolation, are inconsistent with a plan for restoring the river—don't be too eager to say yes or win favor from a landowner);
- Show a willingness to act on any simple, technically feasible stream projects that will demonstrate mutual interests and help build the familiarity it may take to negotiate the more complex projects; and
- Speak in a respectful manner, do not use technical jargon, and always remember to listen!

Be a cooperative negotiator: This guide point assumes that the project developer is engaging a landowner over a more complex project where a solution is not so apparent. The goal is to negotiate a win-win solution, where both individual and public goals are achieved and neither side is exploited. The following methods of negotiation may help:

- Make at least a credible offer to restore and protect the river corridor in a manner that will reasonably protect the valued assets of the landowner. This may not be immediately acceptable to the landowner but will give them the sense that an agreement is achievable. (Note: It is not always possible to be the first one to make an offer, so it is important from the very beginning that the landowner is aware that an offer on their part must be credible in terms of meeting the public's river restoration goals.)
- Assume a landowner's aversion to risk-taking and frame the project proposal in terms of the landowner's potential gain rather than as an effort to avoid loss. Concessions from the initial proposal should be characterized as a further gain for the landowner.

- Do not use offensive negotiation tactics (e.g., threats, intolerance, and ultimatums) and point them out when the landowner is using them. This will either immediately improve the relationship or be a good reason to take your leave until there can be a more respectful and pleasant exchange.
- Be assertive on substantive issues. This avoids being exploited and shows that being cooperative is beneficial to all sides. (Note: A relationship can be poisoned when people are assertive over non-substantive issues.)
- Strive for a cooperative approach where both the public and private landowner interests are satisfied with as little costs as possible. Resolve issues and do not get bogged down in initial positions or bottom lines. Use "what" and "how" rather "why" questions which put people on the defensive.
- Use brainstorming techniques to discuss all possible options supportive of both public and private interests. Examine solutions from the other person's point of view and integrate options to get a workable restoration plan.

These methods are summarized from "*Negotiation and Settlement Advocacy: A Book of Readings*" (Wiggins and Lowry, 1997). Related coursework and guides to successful negotiations are available. Planning team members, working directly with landowners, should be trained in these concepts. Hiring a consultant skilled in negotiations may also be worth considering.

Create opportunities to say yes: For the landowner who has investments within the river corridor or derives economic gain from land uses in conflict with the processes of an adjusting river, it may be a challenge to explore management alternatives that accommodate equilibrium conditions. Either tangible incentives will need to be offered or a series of "horse trades" may be necessary to make such a project possible. More often, the landowner wants the river managed to protect the status quo. Have an idea of how much concession to make and/or how much reciprocity to seek. The objective is to come out of the negotiation with a project that protects their interest and yet, in the end, will significantly protect and restore the river. To achieve a win-win situation, a landowner may need to see an offer that provides some:

- channel management to protect certain structures or land uses they deem essential; and/or
- financial compensation that allows them to shift their economic reliance away from the certain land uses within the river corridor.

Channel management often means some form of streambank revetment to try and stop the lateral movement of a channel that is threatening an investment. There are situations where bed and bank armoring are neutral with respect to restoring equilibrium, but these are exceptions. On the other hand, some channel or floodplain management practices protect both the landowner's assets and the fluvial processes of the stream. The removal of obstructions, for instance, old berms or undersized culverts that divert flood flows in the "wrong" direction, may produce win-win situations.

Configuring a project to help a landowner with channelization practices may only be supportable from a restoration standpoint, if those practices are limited in extent and are more than mitigated by other corridor protection and restoration measures in the reach. For example, it may be possible to say "yes" to rip-rapping a stream bank to protect a structure or a farm field, where the landowner agrees to forgo channelization practices or encroachments on the remaining length of river corridor through their property.

Making these decisions and saying "yes" may take time. Once a landowner makes their needs known, request the time necessary to consider the costs and benefits of perpetuating certain constraints and the degree to which they are offset over different spatial and temporal scales. If every step forward is matched by a step backward, then restoration is not really being achieved.

*Be prepared to say **no**:* If a cost-benefit analysis shows that costs far outweigh the benefits, or a proposal is not technically feasibility, find a respectful way of saying "no." If any of these questions are answered affirmatively, the project proposal should not be deemed technically feasible and would not be consistent with a plan to restore the river:

1. The overall project or activity results in greater constraint on stream equilibrium conditions than existed prior to the project;
2. The project alternative chosen, in the long-term, results in an increase in sediment and nutrient production from within the river corridor and a decrease in sediment and nutrient storage in the watershed (i.e., floodplain access is restricted, channel and floodplain roughness/vegetation are reduced , or streams are converted and maintain in a transport regime);
3. If the project is completed, there is a high likelihood that it will fail because of unmitigated constraints or anticipated channel adjustment processes in the river reach or in the watershed;
4. The project will lead or contribute to disequilibrium in upstream or downstream reaches.

By saying no, there is an opportunity to start working toward a more acceptable project configuration. The key to making this shift, is being able to explain why the proposal or request was turned down (i.e., why it failed one of the above tests and why this created an unacceptable cost burden from a public interest standpoint). Make a counter-proposal that would be technically feasible and supportive of at least part of the interests engendered in the landowner's first proposal. Ask them to consider the proposal and an opportunity to return again if the negotiations seem stalled or negative at this point.

Bring in the other stakeholders: Some projects are not feasible without the involvement of more than one landowner. Multiple landowner negotiations can be tricky and involve building a network of trust and keeping it. Designing an acceptable project with a larger landowner and getting the endorsement of town officials is usually a successful strategy in getting adjoining landowners and other community members to participate. Be careful not to walk into ongoing disagreements between landowners completely unaware. River restoration may then be- come part of the disagreement.

Restoration and protection projects typically involve several parties playing multiple roles, including funding, technical design, local river interest advocacy, and project implementation. These are local organizations, state and federal resource agencies, or non-profits, some of whom require formal or even legal documentation and agreement to carry-out or be involved with certain project components. Once the landowner verbally agrees to a project, explain the roles that other parties and stakeholders that may play a role in carrying out the project. Try to set up opportunities for introductions and for each stakeholder to explain their role. Take cues from the landowner as to how they would prefer to meet and interact with other stakeholders. The trust that is being established with the landowner may depend on whether these interactions are too much, too little, or too late in the process.

Get firm agreements based on preliminary designs: Many river restoration programs have wasted time and energy pursuing projects based on vague concepts and hand shakes. No matter how committed the project planning team may be, or how much time and money has been spent preparing, if a landowner learns a crucial detail late in the process which changes the deal for them, they may back away from the agreement. Be up front about project costs, whether the landowner will have to share in those costs, and whether binding agreements will be required. Once a project alternative is chosen, create a preliminary design sheet that shows the project configuration on a property map. Be prepared to walk the land and drive in stakes to show the placement of structures and the extent of river corridor lands involved in the project. Invest enough time in the preliminary design to ensure the landowner knows what they are signing on to. This does not mean engineered designs, but it does mean a detailed plan view (bird's-eye) drawing with locations of project components in relation to landforms and landowner investments.

There should be a paper trail of landowner agreements. Project summaries and preliminary designs, initialed by the landowner; provide the basis for moving forward. Funding agencies are eager to support good restoration and protection projects where the landowners have literally signed-on. The landowner's signature can give the project planning team the confidence they need to continue spending time and resources, applying for funds, and further developing the project. Many projects will involve some form of legal agreement for expending public funds to purchase land use conversions or perpetual easements. These legal arrangements should be disclosed early in the project development process. Organizations and agencies typically have standard agreements or model easements which can be shared. Make sure the landowner understands every line of these agreements, and do not implement a project without them.

Use the *Project and Strategy Summary Table* to document the status of land use conversions and landowner agreements achieved through this step. After landowner negotiations, there will most likely be a need to go back and revise the description of constraints and the project configurations around which agreements are being made.

7.2.3 Minimizing Project Costs

An accurate accounting of project costs and benefits may not be possible for years or decades after the original project proponents and landowners have moved on. Assessed benefits of a large-scale river restoration program completed on the lower Winooski River in Williston, Vermont after the 1927 flood were studied 25 and 50 years after the practices were put in place. The avoided costs and accrued benefits, more clearly seen today, could not have been calculated with certainty prior to the work. Project partners must gain a comfort level with the qualitative nature and future contingencies associated with a cost-benefit analysis, and, based on experience, use the information to look at alternatives, generate agreements, and implement projects in phases, if necessary.

Use the *Project and Strategy Summary Table* to indicate whether a project has a high, neutral, or low cost-benefit ratio. The socially feasibility of a project is enhanced when costs are low relative to benefits.

To increase feasibility, the project developer must put effort into both parts of the cost-benefit equation. Lower project costs by minimizing the inclusion and/or maintenance of:

- Structural channel constraints or floodplain encroachments, especially in dynamic stream locations
- Active restoration techniques which require engineering, permitting, materials, and construction
- Viable agricultural lands, especially those not essential for accommodating equilibrium conditions
- Professional staff time, using volunteer assistance where possible

Increase project benefits by maximizing the:

- Specific data and/or tangible evidence available to show that erosion hazards are being avoided and valued assets are being restored and protected
- The protection of downstream properties by increasing flow and sediment attenuation in the project reach and removal of derelict channel constraints;
- Restoration and protection of floodplains to store sediment and nutrients
- Demonstration value of a project that could be a broadly applicable in a restoration program

In deciding a cost-benefit ratio for a proposed alternative, the project developer should think about different spatial, temporal and social scales, i.e. the cost-benefit considerations of the:

- Stream vs. river; or single meander bend way vs. an entire river reach or multi-reach
- Current generation and/or future generations
- Landowner, neighbors, the community as a whole, and/or the people of the State

For instance, the project which includes armoring of a single bank on larger stream to protect a barn yard, as well as a half mile corridor protection easement surrounding a confluence delta area (key attenuation asset), may have a low cost-benefit ratio. The key expenses, including the limited structural controls and the cost of the easement, are outweighed by a larger stream segment not requiring structural controls in the present or future, and the benefits to the landowner, neighbors and the community. The landowner gets assistance with an immediate conflict (loss of barnyard), remuneration from the selling of channel management rights in the easement, and the saved expenses from fighting channel adjustments at a confluence area. The reduction of channelization practices benefits downstream landowners and communities, who otherwise would have had to cope with (structurally control) the erosion hazards that result when larger quantities of sediment are transported, i.e. those not attenuated at the confluence upstream. The reduction of channelization practices means better wildlife and water quality—enjoyed for generations to come.

7.2.4 Involving Key Partners and Stakeholders

The planning team or steering committee which has been sponsoring the river corridor planning process may include several agencies and organizations with the experience and resources necessary to develop and implement river restoration and protection projects. If not, the feasibility of projects may increase significantly once they have been recruited and/or notified. Project development and implementation may require individuals from the following agencies and organizations to technically or functional support a project:

- Local and regional commissions: Local planning and conservation entities may have technical roles such as map development, but largely serve in administrative support roles, providing project management services and maintaining contacts with municipal officials and landowners;
- Conservation organizations: Including local and regional land trusts (and some state and federal agencies) which have the expertise to develop river corridor protection projects, i.e., obtaining and holding lands or easements;
- Technical agencies: State and federal environmental science and engineering programs which provide technical review and design support for restoration projects;
- Restoration and protection programs: Public agency funding and private foundation programs that provide financial support and cost share dollars to fund project development and/or implementation;
- Watershed and sporting organizations: These local and regional non-profit groups may provide a large range of technical and functional support roles including funding, technical assistance, and project management; a key role may be organizing the volunteer labor of local people interested in the social benefits of projects, e.g., water quality, fish, wildlife, and aesthetics; and
- Local, state, and federal authorities: Including regulatory programs which must review and permit the active restoration components of a project.

Knowing the ins-and-outs of various programs and the existence of local entities involved with watershed issues may save a great deal of resources and time while developing a project. Enhancing the technical and social feasibility of river restoration may be thought of as a long passageway, and these agencies and organizations may have much experience in opening the doors along the way. Take advantage of this experience.

Be wary of having "too many cooks in the kitchen." If resources are spent managing the team instead of managing the project, the river corridor planning program may falter. Be especially mindful not to have the entire steering committee working separately with landowners. Use the Project and Strategy Summary Table to list the agencies and organizations that will be involved with a project or strategy and the time and/or resources they have committed. Each of these commitments enhances the social feasibility of the project or strategy.

8.0 Monitoring Progress

Monitoring should be conducted to show the success or failure of projects and to monitor the progress of the protection and restoration program as a whole. It is important to start a monitoring program before projects and strategies are completed; an overall monitory strategy should be outlined in the corridor plan and detailed in each project design. Several monitoring suggestions will be made in this Section related to the goals and objectives of a corridor plan as described on Page 1. Other monitoring requirements may come about as part of project grants or regulatory requirements.

8.1 Monitoring Program Progress

The objectives of corridor planning include: fluvial erosion hazard mitigation; sediment and nutrient load reduction; and aquatic and riparian habitat protection and restoration. Periodic geomorphic and reach habitat assessments (Phase 2), targeted on certain geomorphically sensitive reaches, will enable the corridor planning team to determine whether the goal of managing toward equilibrium is being achieved. Data collected to complete a corridor plan provides a baseline. Data collected every 5-10 years after the baseline is established, or following major flood events, will enable program tracking. Physical change and the channel evolution process can take a long time to play out; be patient, and make sure to maintain a narrative in monitoring reports that explains the positive or negative trends that are observed. As a reach evolves to a more naturally stable morphology and woody bank vegetation takes hold, the rate of erosion should lower, a higher retention of fine sediments and nutrients on new floodplains should increase, channel bed features (scour and depositional areas) should become more prevalent and persistent, woody debris retention should increase, energy dissipation should result in lower flood velocities both within the reach and downstream, and the biological communities should begin to reach their potential.

Data collected to establish the social feasibility of projects and strategies create another baseline for the overall program. If extra care is taken to gather and organize information on the human side of the equation, a meaningful story will unfold over time. How much and how frequently are towns seeking funds for flood recovery, are capital expenditures on river-related infrastructure and revetments going down? Are people observing more wildlife in the river corridor, is the fishing better? Are there greater quantities of "poor man's fertilizer" on local farms (fines and nutrients brought in by the river)? Are attitudes changing about the river, do people perceive as much conflict?

Simple bar graphs depicting the number of projects completed within each strategy along with maps showing their location are very well received by stakeholders in a protection and restoration program. For instance if the program team has placed an emphasis on buffer establishment and river corridor easements, maps showing reaches where buffer and easement projects have been implemented, attract the interest of community members as well as those agencies and organizations which have funded the projects, especially when kept up over time.

If conducting a restoration strategy focused on the removal of channel and floodplain constraints, be sure to track lateral and longitudinal connectivity at a watershed scale. Use a sediment regime departure map as a base to indicate fluvial process-based changes in river management, i.e., map transport reaches locked in place (due to long-term constraints) vs. those now free to evolve into storage reaches (due to the long-term resolution of river-human conflicts).

8.2 Project Monitoring

Projects that contribute significantly to the protection and restoration of equilibrium conditions, are difficult to monitor and produce tangible results within short time frames. For instance, obtaining an easement on a reach assessed as a key attenuation asset may be the highest priority project identified in the corridor plan. However, unless a major flood comes along to energize the stream system, the adjustments that lead to floodplain formation may take decades to play out. Clean Water Act programs, which were largely based on projects to attain chemical and biological integrity through the control of pollution discharges, are struggling with the time frames involved with attaining physical integrity. Surrogate measures need to be devised and agreed to by all stakeholders and funding agencies. For easements, the monitoring strategy may track acres conserved, the cost per acre, the success of the buffer plantings, and the dollar amount of channel management practices deferred now that land use expectation have been modified.

The success and failure of active restoration projects is somewhat easier—there are things to measure before and after a project. Too often, however, monitoring is an after-thought and people miss the opportunity to collect data before a project goes into the ground. Phase 3 assessment data, collected to help with project design, can be used as a pre-project baseline of the physical condition. Do an as-built survey, return every other year to survey for a couple iterations, then shift to a longer interval. If projects are to include habitat features, or enable processes that create habitat in the near-term, seek the assistance of biologists to collect macroinvertebrate and fish data before and after the project. This is especially true for culvert replacement and dam removal projects. Improving longitudinal connectivity for both the sediment regime and the biological community can show immediate and significant results with upstream and downstream monitoring.

Many active restoration projects involve moving dirt. How much and what kind? Is this material being moved out of an erosive area and/or enabling floodplain function and greater sediment storage? What is the weight of nutrients such as phosphorus that is being set aside and/or collected? The VRMP removed a large levee along a river and worked with its consultants to monitor the fine sediment accumulation occurring on floodplains being accessed by the river for the first time in 150 years. In two years time, 1.3 metric tones of Total phosphorus were captured with the sediment on 3 of the 7 floodplain areas opened up by the project (Schiff et al., 2010).

Remember, agencies and organizations that fund protection and restoration projects have to show results too. A program with good monitoring reports is much more welcome at the funding trough.

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