New Jersey Highlands Water Protection and Planning Council

Stream Corridor Guidance

Part 2: Protection and Restoration Planning

Release Date: January 2014

Abstract

This Stream Corridor Protection and Restoration Planning document is intended to be used by technical planning and science professionals. It provides a framework for identifying, prioritizing and implementing protection and restoration projects for either general planning purposes or mitigation planning related to a specific proposed project. This document is part two of a two-part series of technical Stream Corridor Guidance documents provided by the Highlands Council for use by municipalities. Part I, the Functional Value Assessment Methodology, is a separate document that provides the foundational data on which this document should build.

Although this document is intended primarily for use by municipalities within the Highlands Region (and grant funding is available to support associated work for municipalities that are conforming with the Highlands Regional Master Plan) the principles, strategies and methods outlined within are applicable to any municipality and may be of interest to other stakeholders.

Highlands Council
New Jersey

100 North Road (Route 513) | Chester, NJ 07930-2322 | (908)879 6737 | www.highlands.state.nj.us

Statutory Platform, Purpose and Funding

Through the passage of the New Jersey Highlands Water Protection and Planning Act in 2004, the NJ Highlands Water Protection and Planning Council (the Highlands Council) was created and charged with developing a Regional Master Plan (RMP). Adopted in 2008, the RMP serves as the guiding document for the long-term protection and restoration of the region's critical resources. In accordance with Objectives 1D4h and 1D4i of the RMP, the Highlands Council has developed Stream Corridor Guidance documents.* They are presented in two parts:

Part I: Functional Value Assessment Methodology (FVAM)
Part II: Protection and Restoration Planning

These technical documents are intended to be used by planning and science professionals within a municipality to first assess the integrity of Highlands streams, rivers and riparian areas within a jurisdiction and then develop targeted protection and restoration plans based on the findings of the assessment.

Part I, the FVAM, is a tool for collecting and analyzing stream corridor data. Part II, provides a framework for identifying, prioritizing and implementing protection and restoration projects for either general planning purposes or mitigation planning related to a specific proposed project.

Funding to support this work within a municipality is provided through the Highlands Plan Conformance process. Municipalities with approved Plan Conformance Petitions are eligible for grant funding to cover the reasonable expenses of planning activities associated with the Conformance process and should contact their Highlands Council Municipal Liaison for additional information.

** Copies of the Highlands Regional Master Plan are available in most municipal offices and can be obtained by contacting the Highlands Council office.*

List of Preparers

This document was prepared by the following firm(s)/individual(s) with project management from Highlands Council technical staff.

Paul Cooper
Princeton Hydro, LLC
1108 Old York Road, Suite 1
P.O. Box 720
Ringoes, New Jersey 08551
908.237.5660
www.princetonhydro.com

Table of Contents

1.0 Introduction

The New Jersey Highlands (Highlands) is an area without equal in the state as an important natural and cultural resource. The environmental resources of the region are a notable feature of the Highlands. The geology of the region is defined by relatively high gradients that have limited development in contrast to much of the remainder of the state. In addition, the rolling topography of the Highlands has also led to high stream and lake density with associated wetlands and riparian forests, accounting for nearly 40% of the region. This mix of factors provides the conditions, including large contiguous tracts of land, that are vital to maintaining unique and important aquatic and related habitats that support rare biological communities and a range of state and federally listed threatened and endangered species.

While overall lightly developed compared to the rest of the state, the Highlands Region contains mineral resources that played a strong role in the early industrial development of the area, particularly the mining and production of iron harking back to the colonial era. Of course, harnessing hydropower was an important component of the industrialization process such that valley bottoms and riparian corridors tend to exhibit some of the highest levels of development in the region, a pattern that made full use of the density of high-gradient streams. This industrial development was accompanied by the construction of urban centers and transportation systems nestled within the same stream and river valleys. Agricultural development also took advantage of riparian areas relying on the rich floodplain soils and abundant water. While the environmental and cultural value of the region is undeniable, perhaps the greatest resource of the Highlands is water. Besides contributing to the formation and sustenance of the streams and rivers that embody the region and have driven historic development patterns, the Highlands is dotted by a number of large drinking-water reservoirs that service the water needs of urbanized northern and central New Jersey municipalities that are located outside the region. Much of the Highlands lies within the watersheds of these reservoirs, which are fed by numerous tributaries and headwaters.

It is clear that streams, rivers, and riparian corridors are crucial to the character of the Highlands. They not only support a diverse range of plants, animals, and habitat types, but also provide a wide range of environmental services and serve as the nodes of industrial, transportation, residential, and agricultural development. In addition, these areas directly convey and supply the consumptive water demands for a majority of New Jersey residents. In light of these qualities and demands on the aquatic resources of the Highlands, it is absolutely critical to develop and apply proper planning and management to protect, preserve, and rehabilitate the streams, rivers, and riparian corridors of the New Jersey Highlands.

1.1 The Value of Stream Corridors

This document, Stream Corridor Management Planning Guidance, is designed to preserve the various services and functions provided by stream corridors in the region. Stream corridors are extremely important areas in any environment because of the intersection of myriad features and functions they provide, as well as the inherent dynamics of these systems. Stream corridors represent the confluence of upland environments with tributary networks, often support wetlands and floodplains, and in many cases are highly developed due to cultural needs including transportation, water power, and consumptive water use for residential, industrial, and agricultural purposes. Stream corridors often provide a unique mix of habitats, and like other ecotones or edge habitats are important areas for wildlife including many rare species specifically adapted for the dynamic conditions of riparian corridors. The Highlands Regional Master Plan is exemplary in documenting and explaining the value of stream corridors.

The dynamic nature of riparian corridors is related to the processes involved in channel morphology and stream channel alignment, namely hydraulic forces and sediment transportation that lead to natural movement of stream channels within the meander belt, an important concept in defining the extent of the riparian corridor. The dynamism of stream channels and riparian corridors has led to the alteration of the corridors as a result of both natural and anthropogenic processes. Historical alterations have typically focused on improving drainage for agricultural and developed lands; straightening and otherwise altering channel alignment and geometry to improve flow velocity, depth, and other features to improve navigability; armoring banks to protect development and infrastructure; and the removal of native riparian plant communities for farming and residential/industrial development. These efforts to improve riparian corridors for anthropogenic uses has consequently led to the major loss of environmental function and deterioration of these systems, often contrary to the intended purpose of the alteration. This is manifested primarily in extensive and severe erosion partnered with sediment accretion, streambank encroachment, loss of habitat and impaired habitat quality, channel incision, invasive vegetation colonization, increased hydraulic and pollutant loading, water quality impairments, warming, and a host of other issues.

1.2 The Need for Stream Corridor Protection

This guidance document is intended to directly address the changes in riparian corridor integrity throughout the Highlands in an effort to protect and preserve natural functions where appropriate, and to mitigate impairments in degraded areas. It is important to note that modern efforts to manage and otherwise protect streams, rivers, and wetlands date back decades, usually with a strict focus on protection of the resource proper. One of the regulatory vehicles to protect these resources was to implement a buffer, literally a space between the resource and any disturbance or activity deemed harmful to the resource; the concept of buffers remains an important component of various laws and regulations. There has, however, been an evolution in the treatment of these buffers; while buffers were formerly viewed as merely a means to protect the stream, there is increasing recognition that the buffers themselves, now defined as stream or riparian corridors, are equally important as environmental resources and can be the primary determinant of stream quality. This guidance document was developed to assist municipalities and stakeholders in better understanding the role of riparian corridors and their importance in the environment and in meeting the water demand needs of the region.

1.3 Regulatory Considerations

In particular, this effort will focus on the protection and enhancement of five functional values, four of which were listed in the Stormwater Management Rules (N.J.A.C. 7:8-5.5(h) for Special Water Resource Protection Areas (SWRPA). The Highlands Open Water Buffer, is an important concept in the Highlands Regional Master Plan (RMP), which establishes a 300-foot buffer on all mapped open waters in the Highlands. There is a variety of regulatory protections applied to the riparian corridors of the Highlands, all of which act to preserve key functions. The protections include: The Highlands Act, the Stormwater Management Rules, the Flood Hazard Area Rules (N.J.A.C. 7:13), and the Freshwater Wetland Rules (N.J.A.C. 7:7), as well as other rules, regulations, and technical guidance, including planning documents such as the Highlands Regional Master Plan. A common theme throughout these regulations is preventing or limiting the expansion of development into these areas with an appropriate acquiescence for existing development, and preserving or improving natural functions, both biological and hydraulic. This guidance document will focus five functional values:

- Habitat Quality
- Nonpoint (NPS) Pollution Reduction
- Temperature Moderation
- Channel Integrity
- Public Uses

While these functional values may seem broad and limited in number, they are important keystones to corridor protection and each exhibits multiple facets touching on chemical, physical, and biological components mirroring the complex ecology of these corridors, as well as accounting for anthropogenic uses of these corridors, which as noted, are important residential, commercial, and agricultural centers in the Highlands.

1.4 Development of Stream Corridor Protection and Restoration Planning Guidance

The purpose of this document is to provide technical guidance for use by municipalities and their professionals (as well as stakeholders) during Plan Conformance, to develop and implement municipal-wide or subwatershed-based Stream Corridor Protection/Restoration Plans. This guidance document is intended to directly address the changes in riparian corridor integrity throughout the Highlands Region in an effort to protect and preserve natural functions where appropriate, and to mitigate impairments in degraded areas.

Much of this guidance will be based on existing sources. As discussed in detail in the annotated bibliography in Appendix A, the amount of guidance for corridor planning and protection is voluminous. There are several reasons for this large quantity of material, which varies considerably in tone, scope, and most importantly applicability, which is rooted in varied perspectives of corridor protection and tailoring a specific approach for a region. Thus, selecting the appropriate method to use or to build from can be a challenging task. After a review of many different approaches, many of which are variations on common themes, the general approach outlined by the River Management Program of the Vermont Agency of Natural Resources (Kline, M., 2010) was selected as the best method upon which to base this document. This approach was selected because of the similarities between the Highlands and Vermont including scale, geological and climatic conditions, the extent and type of land development and stream encroachments, and generalized fluvial patterns. The River Management Program has developed a large set of resources including technical manuals for developing and implementing corridor protection schemes that are ideally suited for application in the Highlands. As with the Functional Value Assessment Methodology, permission was granted for the use of the Vermont materials.

The Vermont guidance follows the basic outline of many of the modern corridor protection documents and is based upon a scientifically-sound assessment of the stream corridor followed by a decision making process that ranks and prioritizes areas of concern based on the results of the analysis and then develops a series of project recommendations. This includes a defined scheme of project implementation ordination, which starts with the simplest projects and advances towards larger, more costly, and ultimately more complex schemes. The guidance also touches on other equally important areas such as building consensus in the community to develop the public will to advance projects in a meaningful way and to achieve in-the-ground results.

The overall philosophy of the guidance represents a paradigm shift in traditional riparian corridor and river channel management, away from the highly engineered approach highlighted by straightening and bank armoring to restoring the systems to a point reflective of the natural dynamics of the system. Ultimately, this highly engineered approach has failed and has exacerbated many of the problems that it was originally intended to solve. In particular, the channelization of rivers has led to increased hydraulic energy in the systems leading to severe erosion. Encroachment into the floodplain has had similar impacts including increased pollutant loading and loss of riparian habitats. This approach is a losing one since it defies the natural dynamics and energies of the system, resulting in repeated losses to infrastructure, degradation of the corridor, and massive spending on projects that will likely fail.

The central tenet of the Vermont guidance is the concept of dynamic equilibrium, which runs counter to old approaches and works within the framework of fluvial systems. Dynamic equilibrium is a concept of river channel equilibrium in which the pattern, profile, and dimension are stable over time within the valley type, geology, and soils of the watershed, balancing the dual functions of rivers – the transport of water and sediment. Despite the stability of pattern, profile, and dimension, the dynamic portion of this equilibrium equation is that the channel will continue to exhibit lateral migration within the meander belt with roughly equal natural erosion and deposition processes. This represents a natural state of river systems under natural conditions. Managing towards equilibrium conditions therefore represents a sustainable approach to corridor management as well as restoring the five functional values of riparian corridors: Habitat Quality, Nonpoint (NPS) Pollution Reduction, Temperature Moderation, Channel Integrity, and Public Uses.

In some senses, the idea of dynamic equilibrium also expands the definition of corridors based on natural river functions. As such, this plan focuses on the identification of stressors and their alleviation. Moreover, in a stream that is highly developed, stressors can be relieved even if the ultimate goal of restoring dynamic equilibrium is untenable.

1.5 Building on the Functional Value Assessment Methodology

This Stream Corridor Protection and Restoration Planning document builds upon the **Functional Value Assessment Methodology (FVAM) (Part I of the Stream Corridor Guidance documents**). This document very much relies on the evaluation of streams and stream corridors to guide management of the systems by relying on the impact ratings of the evaluation to identify specific stressors and departures from reference conditions (i.e., the term "reference conditions" refers to the expected pattern, profile and dimension of a stream channel if there were no anthropogenic influences. Stated differently, they are the "natural conditions" of a stream in a given valley type). This will build on the results of the desktop analysis, field work, and other analyses presented in the FVAM. The FVAM and this document should be viewed as a single document.

The FVAM was designed to assess holistic corridor function yet explicitly score each of the functional values to guide management actions, be it preservation, restoration, or no action; from a technical sense, the FVAM also provides a standardized and repeatable assessment methodology. In addition to the technical discussions of evaluating stream corridors, the FVAM also introduces important management concepts and specific components to be included in stream corridor protection and restoration planning.

The first use of the Stream Corridor guidance documents is to protect the stream corridor by ensuring that any proposed project demonstrate that there would be no net loss of functional value associated with the proposed activities (in accordance with the Highlands Regional Master Plan Objective 1D4e and 1D4h). This holds any development activity to high standards in preserving the function of riparian corridors. It also stipulates that any loss of riparian functional value must be mitigated. As such, this application of the Highlands Regional Master Plan and the ability to quantify and therefore preserve functional values is extremely important in limiting degradation to the corridors on a project-specific basis.

The second use of this document focuses on a more generalized assessment of stream corridors in the Region with the objective of assessing current conditions and using these findings to identify impairments and prioritizing reaches for protection or rehabilitation. This is a more expansive use of this document and factors in wider watershed influences and past perturbations that shape the current landscape. Additionally, this type of assessment provides baseline data that can be used to measure changes in the functional values over time as a function of watershed land use, restoration project implementation, or development activity thus triggering the appropriate management actions.

Besides the two general uses of this document discussed above (i.e., ensuring no net loss of functional values and prioritizing stream reaches for restoration), this document will also explore establishing goals and supporting tasks, identifying restoration projects and practices, identifying responsible parties, finding sources of financial and technical assistance, and developing a schedule of implementation. Scale is an important consideration in addressing all these components and this document supports stakeholders in the management of stream corridors as a whole within the Highlands for both specific reaches and projects.

1.6 Using this Document

The purpose of this document is to provide technical guidance for use by shareholders and municipalities and their consultants during Plan Conformance, and to develop and implement municipality-wide or subwatershed-based Stream Corridor Management (Protection/ Restoration) Plans. This guidance document is intended to directly address the changes in riparian corridor integrity throughout the Highlands Region in an effort to protect and preserve natural functions where appropriate, and to mitigate impairments in degraded areas. Key elements of the individual stream corridor management plans will be to identify areas where existing development, disturbances or land uses are within Highlands Open Waters buffers and have reduced or impaired the functional values of those buffers; and to identify opportunities for restoration of those areas. This technical guidance document can be viewed as a "cook book" or "blueprint" that identifies the "what" and "how" of preparing a successful stream corridor management plan and then implementing that plan using an adaptive management approach.

This document is organized as follows:

1) **Introduction** – discusses the value of stream corridors and the need for protection;

2) **Goals** – description of regional and watershed goals as well as reach and site specific goals;

3) **Identifying and Selecting Projects** – discusses specific project types, for example, planting stream buffers, stabilizing stream banks, removing berms and structures, watershed management, etc. ;

4) **Project Prioritization** – describes how allocation of resources (time, money, and effort), requires a system to prioritize projects, and the precursor to prioritization is a feasibility analysis that examines both technical and social feasibility aspects;

5) **Financial/Technical Assistance** – discusses briefly Highlands Council grant funding as part of Plan Conformance and lists potentially available US Environmental Protection Agency grants;

6) **Implementation** – provides tables for proposed short-tem, medium-term, and long-term implementation schedules; and

7) **References** – including Appendix A, which is an annotated bibliography pertaining to the preparation of stream corridor management planning guidance.

2.0 Regional Stream Corridor Protection Goals

The overall goal of this document is to provide a planning framework to identify and develop stream corridor protection and restoration projects. The key to meeting this goal in the Highlands is through reliance on the functional values. The functional values provide metrics to assess stream and stream corridor conditions, prioritize projects, and then evaluate the success of implementation.

2.1 Dynamic Equilibrium, Meander Belt, and Departure from Reference Conditions

The form and function of rivers, streams, and the river corridor as a whole is dependent on the movement of both water and sediment and when these factors equilibrate a river system is said to be in a state of dynamic equilibrium. A number of factors affect this equilibrium including channel slope and sediment size (as demonstrated in Lane's Balance in Figure 1), but a system in equilibrium will maintain a constant channel type (using the Rosgen Classification of Natural Rivers) defined by a narrow range of parameters like sinuosity, slope, and substrate type, as well as meeting flow and sediment transport requirements. Stated differently, over time the channel will maintain pattern, profile, and channel dimensions, defined as:

- Pattern: the basic shape of the river in plan view, with stable meander geometry or shape and derived metrics
- Profile: The sectional view of a river depicting slope
- Channel Dimension: Width, depth, bankfull depth, entrenchment, and other related metrics

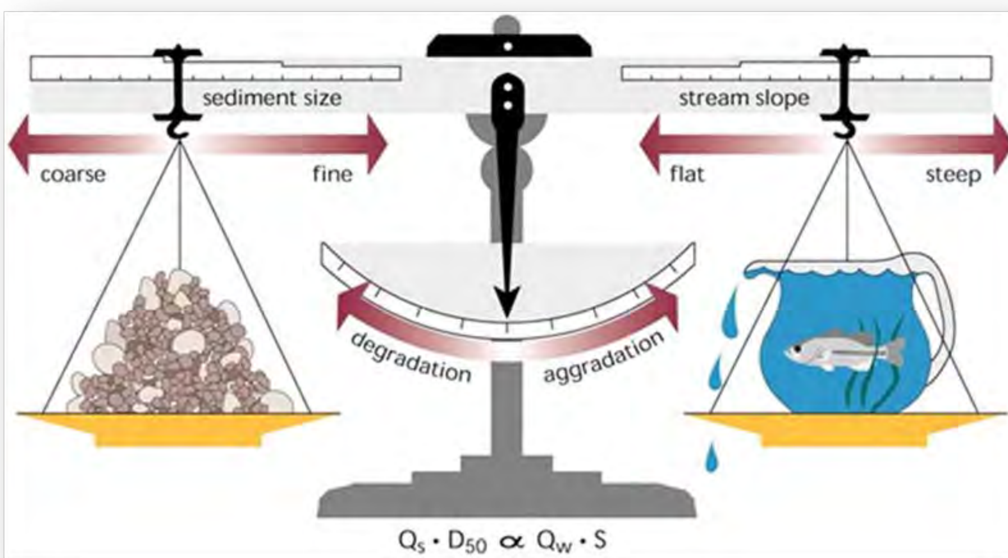

Figure 1: Lane's Balance http://www.nrcs.usda.gov/wps/portal/nrcs/detail/il/home/?cid=nrcs141p2_031337

While this represents a state of equilibrium, the river corridor remains dynamic and continues to evolve and will exhibit changes in channel alignment over time, particularly a lateral and downstream migration of the channel. While the channel may change location, it is stable in pattern, profile, and dimension because there is a balance in processes. For instance, bed erosion in a certain part of the channel is counteracted by depositional processes elsewhere under stable flow and sediment transport regimes such that channel dimensions, pattern, and profile will not change and access to the floodplain will be maintained. The continued movement of the channel also introduces the concept of the meander belt. The **meander belt** is the corridor in which the channel will naturally migrate back and forth over time to accommodate equilibrium conditions (Figure 2). The meander belt width is dependent upon various watershed features and stream type, but valley walls are primarily responsible for confinement. Man-made confinements like levees, elevated roadways and bridges, bank armoring, and other structures and developments in the meander belt can limit the natural channel migration processes and cause disequilibrium in the system.

Figure 2: Meander Belt

The concept of the meander belt (described in previous paragraph), which is related to the Channel Integrity functional value, raises two very important management considerations. First, encroachment in the meander belt of any form, which would naturally lead to a loss of functional value of the riparian corridor, is a losing proposition, especially in regards to the placement of structures. Within the meander belt, the channel continues to be active, migrating over time through erosion and sedimentation processes, and flooding is periodic and frequent, meaning that any structure is at risk. The loss of functional value in the stream corridor will also exacerbate these issues, especially when the structures serve as confinements. The second consideration is that the meander belt width, like the floodplain, is reach specific and on larger systems or streams with very low confinement and broad valleys, the meander belt may exceed the fixed buffer width of 300 feet. Alternatively, the meander belt width on smaller streams with greater confinement, may not meet the limits of the fixed 300 foot buffer.

Disequilibrium occurs when there are modifications to hydraulic loading (increased water inputs), sediment supply, channel slope, boundary conditions, and riparian modifiers. These modifications are also called stressors. Stressors can result from a loss of functional value and contribute to further loss of functional value. For instance, increased hydraulic loading occurs as a result of poor stormwater management within the riparian corridor and the watershed at large, which results in a loss of habitat quality. This however, results in loss of channel integrity with channel erosion, incision, and other channel modifications, which in turn can lead to habitat disruptions in-channel and in the riparian corridor. This type of feedback loop is common in riverine impairments and again highlights the need for management and protection. These relationships are very complex, but specific impairments are best documented and ultimately explained in the execution of the FVAM.

Disequilibrium in these systems can also be discussed in other terms including the notion of departure from reference conditions and adjustment. To repeat from earlier in this document, the term "reference condition" refers to the expected pattern, profile and dimension of a stream channel if there were no anthropogenic influences; it is a system in equilibrium. A stream corridor system subject to a variety of stressors is usually not in equilibrium and is thereby exhibiting a departure from reference conditions. This is an important concept in the FVAM and the scoring of impact ratings is a reflection of departure from reference conditions, an idealized scenario given the watershed characteristics in which a stream is in dynamic equilibrium with high functional value. River systems experiencing a departure from reference conditions or subject to a variety of stressors are also said to be in adjustment, which means that the stream is seeking a return to a state of dynamic equilibrium given the new hydraulic regime, sediment supply, or boundary conditions. A river in adjustment will therefore show changes in pattern, profile, and stream dimensions until a state of equilibrium is reached.

The attempted rehabilitation of rivers to reference conditions is an ideal scenario, but one that is hard to attain given the pervasive changes throughout the watersheds of the region, particularly in alterations of hydrology, usually increased loading due to increased impervious coverage, and sediment loading, usually increased through erosion and untreated stormwater, but sometimes includes sediment starvation as a result of on-line impoundments. In any case, while the systems should be managed as close to reference conditions as possible, it is more important to manage towards dynamic equilibrium under altered conditions or modified equilibrium.

Dynamic Equilibrium

Stream corridors exhibit a dynamic form of stability, known as dynamic equilibrium. Dynamic equilibrium refers to the ability of system to persist within a range of conditions. Maintaining this balance requires the presence of a series of self-correcting mechanisms or negative feedback loops. A disturbance to the stream ecosystem triggers a response from these self-correcting mechanisms allowing maintenance of the dynamic equilibrium.

Disturbances result from both naturally occurring and human-induced events. Climatic factors often play a role in naturally occurring disturbances and generally involve below- or above-normal precipitation and concomitant runoff. Human-induced disturbances often relate to changing land use patterns associated with development activities within the watershed.

While many stream ecosystems can tolerate fairly significant disturbances and maintain dynamic equilibrium, threshold levels exist. When thresholds are exceeded, the system becomes unstable. As the ecosystem adjusts over time, it moves towards a new dynamic equilibrium that may be different than the one that existed prior to the disturbance. In some instances, disturbances alter the system to such an extent that it cannot recover unless the cause of the disturbance is removed or actions are taken to restore stream functions.

Source: http://www.fishfriendlyfarming.org/definitions.html#Dynamicequilibrium

Ultimately, planning stream and corridor protection measures must incorporate the following goals:

- Manage to a state of dynamic equilibrium (see text box above for definition).
- Recognize that a channel in dynamic equilibrium maintains an active and evolving channel alignment.
- Apply generalized buffer and corridor management strategies throughout the meander belt, which is the pathway in which channels will migrate over time, and may include an expansion (or reduction) of management beyond the 300 foot buffers.
- Use the FVAM to identify stressors, loss of functional value, departure from reference conditions, and adjustment processes.
- Management towards modified dynamic equilibrium that incorporates systemic changes to hydrology and sediment loading while being mindful of reference conditions.

2.2 Reach and Site Specific Goals

While regional goals are valuable for a consistent approach in the Highlands, ultimately the FVAM surveys and individual projects are conducted on a reach or site specific basis. The goals on this level therefore need to be ascertained as potential projects are identified or as reaches are selected for evaluation and therefore are developed in light of the evaluation. In reality, this process is more akin to setting objectives.

The use of this document and the accompanying FVAM to evaluate projects will allow for consistent data collection and review by the Highlands Council. While the goal is to maintain functional values of the buffer and therefore protect related environmental features, the specific objectives of the review are to document the functional value of the buffer at the initiation of the project, ensure that the project design results in no net loss of functional value, and evaluate the project upon completion to assess if there has been any degradation of functional value. Project monitoring to assess success should recognize that revegetation requires time especially with trees, and lack of full growth does not reflect a reduction in value. If however, a loss of functional value is demonstrated even with that caveat, the losses are easily identified and plans can be made to mitigate the loss, a process referred to as adaptive management. Therefore:

- Use the FVAM for any Highlands Open Waters Buffer (HOWB) evaluation related to project implementation.
- Allow for Highlands consistency review of the existing conditions and plans for the maintenance or improvement of corridor functional values.
- Use the initial characterization to monitor and evaluate the project after completion and employ adaptive management to correct any loss of functional value.

Region-wide evaluation will of course identify a number of opportunities for project implementation independent of any imminent regulated activity requiring a permit. These types of projects will focus on protection, but most will likely be mitigation or restoration projects addressing specific deficiencies in corridor functional values. The FVAM will be the ultimate arbiter of specific project objectives and will clearly identify the stressors and impairments in functional value. That however is mostly a technical objective and other considerations must be made. Any projects therefore will have to satisfy all permit requirements, landowner needs, grant and funding requirements, goals of stakeholder groups including the public, and compliance with local planning initiatives. Goals of specific projects must also dovetail with watershed goals. Goals and objectives for projects identified in the regional corridor assessments include:

- Specific stressors and impairments in functional value identified in the FVAM assessment will inform the selection of appropriate management to protect or improve the functional value of the riparian corridor.
- Satisfy Highlands Council Consistency reviews
- Satisfy applicable local goals including landowner, funding source, and local and regional planning objectives.

3.0 Identifying and Selecting Projects

The identification of projects is the heart of this document and the foundation for all subsequent actions. The project identification is wholly dependent on the completion of the FVAM. The FVAM was designed to clearly score the conditions of each of the five stream corridor functional values and the scores are then used to assign a condition category. This type of classification fulfills two uses: first, it provides an easily understood context of the functional value in a numeric format; the first time this type of assessment was developed in a numeric format for SWRPA determinations, and second it can be used in project prioritization. Ultimately, the scoring and the condition category will drive the selection process and the specific impairments in functional value will drive the project selection. While this section will focus on the identification and selection of projects, the prioritization of projects will be covered in Section 4.0. For instance, ranking projects on score alone is not sufficient to prioritize projects because some projects with very high scores are natural candidates for protection, which is a priority action, whereas project implementation at some very poor scoring sites may simply be infeasible.

The FVAM was laid out to assess each of the functional values separately and each of the functional values is divided into separate parameters. These parameters in turn are evaluated through a number of metrics. Table 1 below summarizes the assessment and shows how specific metrics relate to each of the functional values. It is also interesting to note that many of the metrics are repeated between parameters and functional values. This shows that the functional values and the descendent components represent different facets of a complex, interlinked system that are not easily separated and a loss of any functional value usually results in a cascade of other losses.

Table 1: FVAM Summary

FVAM Summary	
Parameter	**Metrics**
Watershed	
Watershed Characteristics	Geology, Runoff, Erodibility, Land Use/Land Cover
Channel Integrity	
General Instability	Dams, Bridges, Stormwater Inputs, Encroachment, Armoring
Degradation	Channel Dimensions, Bank Slope, Particle Size, Headcuts
Aggradation	Sediment Bars, Embeddedness, Braiding
Widening	Width-Depth Ratio, Sediment Bars, Bank Erosion
Re-Alignment	Sinuosity, Bank Erosion, Flood Chutes/Channel Avulsion
Habitat	
Available Data	Water Quality Standards Classification
Channel Modifiers	Dams/Weirs, Bridges/Culverts
In-Stream Features	Pool Condition, Bed Substrate, Vegetative Material
Banks	Bank Vegetation, Channel Shading, Buffer Width
Riparian Area	Wildlife Habitat, Plant Community, Floodplain Connectivity
Water Quality	
Existing Data	Water Quality Standards, NJPDES Discharges, 303(d) Listing
Flow Modifiers	Dams/Weirs, Stormwater Inputs
Banks	Bank Erosion
Riparian Area	Buffer Width, Wetlands, Flooplain Connectivity
Temperature Moderation	
Existing Data	NJPDES Discharges, 303(d) Listing
Flow Modifiers	Dams/Weirs, Stormwater Inputs
Banks	Bank Vegetation, Channel Shading
Riparian Area	Buffer Width, Wetlands
Public Use	
Public Use	Existing Public Use, Potential Public Use

Utilizing the Vermont approach, there are nine general project classes that can be implemented to address a range of stressors, departures from reference conditions, and most importantly loss of stream corridor functional value. A rough approach for prioritization is provided in Section 4 for the project classes with the generally less complex and therefore more feasible actions given a higher priority, which tends to encourage wide implementation of projects as a whole. Less complex projects are given priority in this scheme, but the ranking does not necessarily reflect the efficacy of the projects; indeed protecting river corridors, the first project class, is preferable to actions requiring project design and construction because they simply preserve the outstanding resources rather than mitigating damages. Even the most successful restoration efforts rarely, if ever, restore the full measure of lost functional values, and thus protection deserves greater importance than active restoration or mitigation. This reflects the state of stream corridors in the Highlands as a whole, and while there are undoubtedly many impairments of stream corridors throughout the region, there remains a large number of undisturbed sites, which contributes to the high environmental quality of the region overall.

Sections 3.1 through 3.9 discuss nine general management pathways that follow the general prioritization philosophy of this document. Discussion of each of the functional values will also be provided as appropriate within the project classes. In addition to selecting the project class, specific project types will also be discussed. Many of the choices throughout the dichotomous key will be informed by the results of the FVAM and general site familiarity. Once completed, the key will provide the general management direction for the site, which may consist of multiple actions. **Please refer to Appendix B for a simplified key.**

3.1 Protect River Corridors

Protecting rivers corridors is the simplest way to preserve the environmental function of these features. Protection will preserve existing features, arrest continued degradation of functional values in the corridor (unless originating outside of the corridor), and limit extensive rehabilitation needed on more degraded sites. In addition to land use planning, zoning, and the provision of local ordinances, river corridor protection, for the most part, will involve either establishing corridor easements or purchase of the property for conservation. Protecting river corridors addresses all the functional values and maintains habitat quality, temperature moderation in a well vegetated corridor, high water quality through pollution mitigation in the corridor, and channel integrity within a stable channel and a preserved meander belt free of encroachment. Riparian areas with high Native Mean Coefficients of Conservatism help to identify areas worthy of protection. Protecting river corridors is also a natural fit for enhancing public use, but intensity of use should be inversely proportional to the quality.

1. **Land Cover:** Is the stream corridor largely undeveloped, consisting primarily of forest or wetland land cover with few encroachments?
   Yes: Proceed to Step 2: Channel Constraint.
   No: Proceed to Step 4: Native Perennial Riparian Vegetation. Developed stream corridors are subject to a loss of corridor functional value and thus lack the basic criteria for preservation. Protection still may be warranted to satisfy public use values or if the restoration requirements are minimal.

---

2. **Channel Constraints:** Is the channel largely unconstrained (i.e., not armored or bermed) and if not actively managed could the channel maintain or adjust to equilibrium conditions? The ability to maintain or adjust to channel equilibrium is determined by optimal to good channel integrity scores.
   Yes: Enact corridor protection plan (pursuant Highlands Council approved scope of work) and then proceed to Step 3: Channel Equilibrium.
   No: Proceed to Step 4: Native Perennial Riparian Vegetation.

3.2 Plant Stream Buffers

Planting stream buffers is not only one of the most basic riparian corridor restoration techniques, but it is also one of the most efficacious and least costly management techniques available. While simple, it does require some level of sophistication in the selection of plant materials and it is important to select the appropriate plants for the condition with special care given to soil moisture conditions as riparian corridors can run the gamut from herbaceous wetlands to upland forests. Dependence on reference conditions at preserved streams can be valuable for selecting the appropriate plant palette. Planting buffers most directly addresses habitat quality especially the banks and riparian area parameters. However, these benefits extend to other values. Dense growth of riparian vegetation, especially of trees, directly shades the channel thus moderating temperatures, while herbaceous layers and shrubs may help to mitigate NPS pollution through settling, uptake, and stabilization of the soils. Plants also maintain channel integrity by increasing general stability and limiting widening and erosion.

The Riparian Plant Community parameter provides quantitative metrics – total number of species, number of natives, total mean C (mean coefficient of conservatism), native mean C (mean coefficient of conservatism for native plants), and plant stewardship index (PSI), which should be applied to assess the development and monitor the success of restoration or mitigation projects. For example, good to optimal Native Mean C values (3.5 or greater) serve as a natural performance standard for habitat restoration and enhancement projects. The application of PSI to projects that impact riparian zones can be used to not only assess the quality of the community to be impacted but can be used to determine whether the impacts to the riparian zone community can realistically be compensated through mitigation efforts. PSI can also be used to establish a performance standard for a mitigation project or even to determine an appropriate mitigation ratio. Lastly, PSI can be used to determine whether the impacts to a riparian zone can be realistically or adequately mitigated. For example, sites with high PSI scores tend to be extremely conservative and thus difficult if not impossible to successfully replicate or restore. In those cases where it may not be feasible to compensate for impacts to a high quality riparian zone, PSI can be used to guide an alternative analysis or as the basis to recommend higher mitigation ratios.

Some consideration must also be made for areas of non-native invasive growth as this is a serious problem throughout the region. In some cases, especially where there are mono-cultures of particular species such as Phragmites, the non-native vegetation should be eradicated and replaced with native vegetation. Eradication must be weighed against the potential harm in removal operations, especially where the non-native species are a minor part of the flora.

3. **Channel Equilibrium:** Is the stream channel at or near equilibrium in terms of depth, slope, and floodplain relationship as indicated by good to optimal Channel Integrity Conditions?

Yes: Proceed to Step 4: Native Perennial Riparian Vegetation.

No: Proceed to Step 8: Degradation. While buffer planting is a part of almost every restoration project, it is generally the last step. Ensure that a buffer of native perennial riparian vegetation is provided in all restoration projects where possible.

---

4. **Native Perennial Riparian Vegetation**: Is there native perennial riparian vegetation on both sides of the stream with good to optimal Riparian Plant Community scores?

   Yes: Proceed to Step 5: Re-alignment.

   No: Plant stream buffer with native vegetation and then proceed to Step 5: Re-alignment.

3.3 Stabilize Stream Banks

Bank stabilization has come to represent the classic depiction of stream management and more lately stream restoration. Of course, many corridor impairments are related to over-aggressive or misplaced stabilization projects that have altered stream hydraulics resulting in increased stream power, erosion, or flooding; these effects are often manifested at some distance downstream rather than immediately adjacent to the project. Regardless, bank stabilization remains a very important tool in river restoration. Stabilization is used in two capacities: to speed geomorphic processes in attaining equilibrium; and to protect infrastructure. While this document is primarily focused on reversing the impacts related to stream encroachment, the reality remains that protection of structures, especially infrastructure such as roads, rail lines, and sanitary sewer, is a necessity and must be accomplished through stabilization. While undesirable, this can still be accomplished responsibly with proper design to limit the impacts of this approach.

Bank stabilization projects are implemented to increase channel integrity. This also leads to improvements in habitat quality, specifically in-stream habitat, and can be brought about directly by inclusion of certain preferred habitat elements such as rootwad revetments that enhance complexity or indirectly by limiting further deterioration of stream substrates. Stabilizing banks also increases bank habitat quality and if planted with woody vegetation can aid in temperature moderation. Water quality benefits are less easily attributable, but stable banks will certainly reduce suspended solids loading, which can impact aquatic organism respiration. Various stabilization techniques can be selected and include the following:

- Bank grading and soil wraps
- Boulder toe placement
- Brush mattress
- Live fascines
- Rootwad revetments
- Longitudinal peaked stone toe protection
- Riprap

- Gabion baskets

In addition to these direct bank stabilization measures, in-stream measures can also be implemented to deflect flow from the banks and decrease the erosive forces. These types of techniques, including boulder placement, bendway weirs, rock vane, and J-hook vanes, are all used in conjunction with other stabilization practices, and revegetation of the slopes is essential.

5. **Re-alignment**: Is the channel undergoing lateral movement by eroding either bank as indicated by fair to poor channel integrity re-alignment scores?
   Yes: Proceed to Step 6: Proximity to Structures.
   No: Proceed to Step 8: Degradation.

---

6. **Proximity to Structures**: Is the eroding bank within 50 feet of a structure or other infrastructure including roadways?
   Yes: Stabilize stream bank to stop lateral migration and where possible encourage the growth of woody buffer, then proceed to Step 8: Degradation.
   No: Proceed to Step 7: Sedimentation.

---

7. **Sedimentation**: Is the reach affected by an increase in sediment supply or is the reach highly sensitive and subject to extreme natural deposition? This is determined by fair to poor scores for the watershed assessment, especially soil runoff, soil erodibility, and land use/land cover. Also indicated by fair to poor channel integrity aggradation and high channel sensitivity.
   Yes: Proceed to Step 27: Decrease in Stream Power.
   No: Stabilize the stream banks or employ flow deflection structures to halt lateral movement and maintain long term stability. Do not constrain downstream channel migration and allow for revegetation. Proceed to Step 8: Degradation.

3.4 Arrest Head Cuts

Head cuts occur as an incision of the stream bed typically starting as nick point or some other scour feature. These are typically identified by near vertical features in the stream bed and once created migrate upstream. Arresting head cuts, or providing in-stream grade control, rank among the most complex in-stream restoration techniques. There are a number of grade control devices, many of which are variations on a theme. Some common ones include engineered rock riffles, cross vanes, log sills, or in extremely steep systems step-pools, a series of linked vanes or other structures. Important design considerations of these types of systems include limiting the slope and the hydraulic jump in order to foster fish passage and limit scour. It is also important to build these types of structures in compression to use stream power to stabilize the structure and furthermore to extend the structure well into the bank to prevent circumvention by over-bank flows. These types of structures, as with other restoration techniques, are subject to failure when improperly engineered or installed. In-stream stabilization measures such as arresting head cuts are geared prominently towards improving channel integrity. Secondary benefits include improved in-stream habitat, which particularly fish tend to gravitate towards and a reduction in bed load mobility.

8. **Degradation**: Is the stream bed actively eroding? Have head cuts been identified?
   Yes: Proceed to Step 9: Floodplain Abandonment.
   No: Proceed to Step 10: Presence of Berm(s).

---

9. **Floodplain Abandonment**: Is the stream in the process of abandoning a functioning floodplain as indicated by fair to poor channel integrity bank height ratio and headcut scores.
   Yes: If no natural grade control exists within a meander wavelength upstream of the headcut (as determined by examining approximately 14 bank full widths), construct one of the grade controls discussed above. Proceed to Step 10: Presence of Berm(s).
   No: Proceed to Step 10: Presence of Berm(s).

3.5 Remove Berms

Berms are artificial constrictions or confinements within the stream corridor that prevent or hinder normal stream migration, lead to stream entrenchment, and loss of floodplain connectivity. These stressors may lead to a major loss of corridor functional value, particularly riparian habitat quality and often to channel instability. Berm removal can alleviate many of these stressors and restore channel integrity and habitat quality functionality. The actual implementation of these removal projects is relatively straightforward from a construction standpoint, but caution must be exercised to evaluate the effect of reconnecting the floodplain as other structures may have been constructed beyond the berm.

10. **Presence of Berm(s)**: Is there a berm or abandoned levee, road, or railroad embankment adjacent to the surveyed reach?
    Yes: Proceed to Step 11: Floodplain Disconnection.
    No: Proceed to Step 13: Flow Constriction.

---

11. **Floodplain Disconnection**: Is the berm causing disconnection of the stream and floodplain?
    Yes: Proceed to Step 12: Infrastructure Flood Risk.
    No: If no, it is assumed that the stream is deeply incised or the berm sufficiently distant from the stream that berm removal would not contribute to increased floodplain connectivity; proceed to Step 13: Infrastructure Flood Risk. In case of severe incision, projects to restore incised reaches would need to be considered in Step 19:

Stream Power. Further information regarding evaluation of incised reaches can be found in the Restore Incised Reach discussion below.

---

12. **Infrastructure Flood Risk**: Are there developments, land uses, or structures within the river corridor that would be placed at risk by normal flooding cycles?
    Yes: Proceed to Step 13: Flow Constriction.
    No: Remove Berms and proceed to Step 13: Flow Constriction.

3.6 Remove or Replace Structures

Structures in this case refers to structures sited in or otherwise crossing the channel including bridges, culverts, dams, weirs, abutments, and other similar structures. There has been a major push in the last decade throughout the Mid-Atlantic and New England to remove these types of structures. This effort is born of increased understanding of the impact that these systems have on the environment and from a more practical perspective the liability issues. While certainly many structures continue to serve a useful purpose, there are a vast number of structures that are abandoned, failing, or have otherwise outlived their utility. This is especially true of dams, many of which date back to the colonial era or through the industrial age, and provided the water power needed to sustain the economy. Most dams in the region are classified as run-of-river dams, weirs, or low head dams in which the river surface or stage is effectively raised, forming an impoundment behind the structure, and the river discharges over the top of the structure. There are a variety of impairments associated with these dams including thermal loading, reduced water quality often signified by eutrophication of the impoundment, aggradation and sedimentation in the impoundment, potential degradation downstream related to sediment starvation, a complete shift in habitat quality, blockage of fish and other aquatic organism passage, alteration of stream hydraulics, potential for increased flooding, and other associated issues. While dams represent the most severe case, abutments, culverts, and bridges can also cause similar impacts although usually of a decreased scale and most often manifested during high flow events. Thus, removing these structures can directly improve water quality, thermal moderation, habitat quality, and channel integrity. Additionally, many of these remnant dams have been incorporated as public spaces and thus also fulfill public use demands.

Removal of structures, especially dams, is technically challenging. The technical challenges range from logistics to managing sediment. Sediment management is an important consideration as the removal of a dam has the potential to release a large amount of sediment downstream, which can lead to a loss of habitat quality through sedimentation and increased flooding. In fact, the concept of legacy sediment has gained strength over the years and theorizes that the floodplains of most dammed river systems are significantly built-up with fine sediments and that much of the increase in erosion and related phenomena are a result of streams in adjustment cutting new channels through these soft sediments. Removal of dams may also mean resizing and realigning channels through the former impoundment as well as ensuring that downstream flooding is not exacerbated by removal. For the most part, this concern tends to be overstated as these low head dams provide little in terms of flood storage. Besides design and implementation, permitting burdens are also high.

On the political front, it tends to be the flooding issue that is most contentious. There is a mistaken belief that all dams provide flood attenuation; this is simply not true and most dams actually contribute to it by actively raising the river stage. Another common concern is that removing dams will destroy a fishing hotspot, as fish tend to stack on the downstream face of dams since they cannot pass upstream, or that the reduction in depth upon dam removal will leave fish stranded. These again are misplaced concerns as riverine fish are adapted for the hydraulics of moving systems and will thrive under more natural regimes. There are also other concerns including the loss of historic structures, which generally require an evaluation of their historic worth, and the loss of aesthetic value in the structure itself, the impoundment, or even the sound of falling water. Despite these numerous reservations, dam and structure removal projects are becoming much more common and as a whole are afforded the support of the regulatory and permitting agencies.

13. **Flow Constriction**: Are there bridges, culverts, abutments, dams, weirs, or other structures that span or otherwise significantly constrain vertical and lateral movement of the channel or result in floodplain constriction?
    Yes: Proceed to Step 14: Sediment Deposition Upstream of Structure.
    No: Proceed to Step 18: Increase in Stream Power.

---

14. **Sediment Deposition Upstream of Structure**: Is there significant sediment deposition upstream of the structure or within the impoundment that would erode or mobilize upon removal? This can be determined from fair to poor scores in the channel integrity aggradation.
    Yes: Proceed to Step 15: Flooding Risk Due to Modification.
    No: Proceed to Step 17: Structure Condition.

---

15. **Flood Risk Due to Structure Modification**: Are there developments or land uses with the stream corridor that would be significantly affected by channel bed elevation changes or bank instability due to changes in sediment erosion/deposition upon removal?
    Yes: Proceed to Step 18: Increase in Stream Power. Further evaluation of structures may be needed while considering restoring incised reaches; structure removal may still be viable with consideration for property protection and channel bed stabilization.
    No: Proceed to Step 16: Sediment Mobilization.

---

16. **Sediment Mobilization**: Is sediment mobilization from the impoundment likely to cause significant downstream channel adjustment inconsistent with equilibrium conditions? This may involve assessing reaches downstream using the FVAM and evaluating aggradation/degradation as well as general instability.

    Yes: Modify the structure to reduce its adverse impacts. Implement a sediment management plan, which will involve partial or complete removal of the sediment, place in-channel grade controls, or otherwise stabilize the sediment and encourage floodplain restoration and functionality. Modifications are only desirable if the structure is functional and active. Proceed to Step 18: Increase in Stream Power.

    No: Remove or modify/replace the structure and then proceed to Step 18: Increase in Stream Power.

---

17. **Structure Condition**: Is the structure derelict or nonfunctional?

    Yes: Remove the structure and implement proper grade control and bank stabilization as needed. Proceed to Step 18: Increase in Stream Power.

    No: Proceed to Step 18: Increase Stream Power.

3.7 Restore Incised Reach

Channel incision, the downcutting of the channel, is caused by a number of factors. The two primary factors causing incision include an increase in stream power or modified sediment delivery. Increased stream power can occur as a result of increased flow through the system as a result of an active discharge or poor stormwater management, an increase in channel slope caused by channel straightening or bank armoring that prevents lateral migration, or by flood plain encroachment causing flow constriction. Reduced sediment supply is almost always related to sediment capture in impoundments. The end result of incision is severe loss of bank stability, reduced in-stream habitat quality, and water quality impairments.

The correction of incised reaches is complicated and often necessitates several different management practices working in concert and includes practices discussed above such as removing structures and arresting head cuts through grade control. One practice is to reconfigure the channel alignment and dimensions to reduce stream power and achieve a state of equilibrium; in some cases this might include closing a flood chute or recent channel avulsion and realigning the stream in its original course. Reducing discharge is accomplished through better stormwater management and restoring riparian buffer functionality. Sediment supply regime can be restored through the removal of upstream impoundments. A fairly common approach is restoring floodplain connectivity, which usually requires excavation of a new floodplain bench and removal of the material, paired with bank stabilization, grade control, and buffer planting. Finally, the last approach is a passive one; the protection of the stream corridor and meander belt allowing the system to equilibrate on its own.

18. **Increase in Stream Power**: Is the channel steeper or straightened, indicated by fair to poor bank armoring/channel straightening or sinuosity scores, or fair to poor bank height ratio, resulting in increased stream power and sediment transport capacity?
    Yes: Proceed to Step 19: Cause of Increased Stream Power.
    No: Proceed to Step 27: Decrease in Stream Power.

---

19. **Cause of Increased Stream Power**: Is the increase in stream power the result of significantly reduced sediment supply or increased peak flows? Increased peak flow can be ascertained by examining impervious cover rating in the watershed assessment. Sediment starvation would be indicated by an upstream impoundment. Increase in stream power not related to peak flow increases would include localized channel modification (i.e. increased slope through channelization and bank armoring).
    Yes: Proceed to Step 20: Watershed Modifications.
    No: Proceed to Step 21: Recent Channel Equilibrium.

---

20. **Watershed Modification**: Can watershed input stressors be reduced within 5 years as a result of project implementation upstream?
    Yes: Proceed to Step 21: Recent Channel Equilibrium.
    No: Proceed to Watershed Management discussion below.

---

21. **Recent Equilibrium Channel**: Is it possible to restore the stream to a recently abandoned channel in equilibrium?
    Yes: If no other constraints are present, restore the incised channel to the abandoned channel. The project will incorporate elements of bed and bank stabilization, grade control, corridor restoration, and removing berms or other constrictions. Then proceed to Step 27: Decrease in Stream Power.
    No: Proceed to Step 22: Permanent Constraints.

---

22. **Permanent Constraints**: Is there active infrastructure and permanent constraints in proximity to the channel?
    Yes: Proceed to Step 23: Channel Armoring.
    No: Proceed to Step 24: Constraints to Floodplain Restoration.

---

23. **Channel Armoring**: Are the bed and banks completely armored such that erosion has been halted?

Yes: Pursue high priority river corridor protection at downstream reach to attenuate flow and sediment transported through the channelized reach. Then proceed to Watershed Management discussion below.

No: Implement incision restoration practices as described above. Corridor protection practices should be implemented downstream to attenuate flow and sediment transport. Then proceed to Watershed Management discussion below.

---

24. **Constraints to Floodplain Restoration**: Are there current land use constraints, flow and sediment load alterations, or project feasibility concerns that would inhibit or prohibit active restoration of floodplain connectivity and channel migration in the meander belt?

    Yes: Proceed to Step 25: Corridor Protection.

    No: Proceed to Step 26: Rapid Equilibrium.

---

25. **Corridor Protection**: Can corridor protection be implemented to allow for passive adjustment to equilibrium?

    Yes: Implement river corridor protection to allow for passive restoration and channel adjustments to proceed to equilibrium conditions.

    No: Defer further actions until such projects are feasible, which may occur after further deterioration and unsustainable losses or a change in ownership or liability. Proceed to Watershed Management discussion below.

---

26. **Rapid Equilibrium**: If there are no encroachments to the channel or floodplain, would the stream quickly equilibrate to a geometry that results in a reduction in stream power? Rapid equilibration is more likely in high sediment supply environments, which can be determined by a lack of upstream impoundments or other in-channel encroachment and in systems subject to erosion upstream or where bed and bank materials are highly erodible.

    Yes: Allow for passive restoration of incised reach through corridor protection and then pursue corridor protection.

    No: Actively restore the incised reach through channel realignment with correct sinuosity and by excavating a new floodplain to reconnect with the current bed elevation to create new equilibrium conditions.

3.8 Restore Aggraded Reach

The restoration of aggraded reaches is the last corridor-specific project group; further actions are generalized measures to be implemented within the watershed and outside of the HOWB or the meander belt in larger systems. Aggraded reaches are the mirror opposite of incised reaches, characterized by reduced stream power or increased sediment supply. Aggraded reaches also share spatial and evolutionary relationships with incised reaches. Sedimentation is common downstream of incised reaches, particularly if there is a reduction in stream or valley slope and eroded materials are deposited. From a channel evolution perspective, a period of aggradation typically follows incision; specifically the stream incises until stream power is reduced or a stable bed is reached, such as bedrock, which is then followed by lateral erosion and stream widening, until the system is so over-widened that sediment is accumulated. Stream aggradation primarily impacts in-stream habitat quality and results in thermal impairments and reduced water quality. An over-widened stream may also result from poor bank stability and thus channel integrity is also affected.

Restoration of these aggraded reaches focuses on improving sediment transport through in-stream encroachments, removal of dams and weirs to increase stream power, or inducing constriction through reconstructing and stabilizing banks. New bank construction often involves excavation of the channel and reuse of the material to form the new banks.

27. **Decrease in Stream Power**: Is the decrease in stream power the result of increased sediment supply or decreased peak flows? Sediment supply can again be inferred by soil erodibility and land use factors; decrease of peak flows is unlikely unless there has been a significant consumptive surface water withdrawal.
    Yes: Proceed to Step 28: Watershed Stressors.
    No: Proceed to Step 29: Backwater or Impoundments.

---

28. **Watershed Stressors**: Can watershed stressors, such as increased sediment supply, be significantly managed within 5 years?
    Yes: Proceed to Step 29: Backwaters and Impoundments.
    No: Proceed to Watershed Management discussion below.

---

29. **Backwater or Impoundments**: Is sediment deposition the result of backwater conditions or impoundment as the result of artificial floodplain or channel constrictions such as bridges or dams?
    Yes: Proceed to Step 30: Increased Sediment Transport.
    No: Proceed to Step 31: Channel Over-widening.

---

30. **Increased Sediment Transport**: Is it feasible to increase sediment transport through the dammed or constricted reach?
    Yes: Restore the reach by modifying or removing the constrictions in the channel or floodplain to increase sediment transport or otherwise attain equilibrium. Follow up by implementing watershed management and proceed to Watershed Management discussion below.

No: Protect the river corridor in these areas to minimize any additional stressors, especially when plans to modify the channel and stream corridor upstream and downstream are untenable or infeasible. Proceed to Watershed Management discussion below.

---

31. **Channel Over-widening**: Is floodplain connectivity maintained and sediment generated within the reach leading to over-widening of the channel? Optimal to good channel integrity, floodplain encroachment ratio, and bank height ratio indicate adequate floodplain connectivity, while fair to poor channel integrity width-depth ratios indicate an over-widened channel.

Yes: Restore the reach by addressing stressors that have caused over-widening. This will likely require reducing channel dimensions and stabilizing the banks through general stabilization and flow deflection techniques as well as riparian protection and buffer planting.

No: Protect the river corridor in these areas to minimize any additional stressors, especially when plans to modify the channel and stream corridor upstream and downstream are untenable or infeasible. Proceed to Watershed Management discussion below.

3.9 Watershed Management

Watershed management is beyond the scope of this document, yet wider implementation of environmental conservation practices is crucial to ensure the success of efforts within the stream corridor. This is true because many of the stressors that result in the loss of functional value of the stream corridors arise outside the corridor. In particular, this is true of alterations in hydrologic loading attributable mostly to increased impervious coverage and runoff, increased sediment loading due to changes in land use/land cover and increased soil erosion, and increased pollutant loading especially of nutrients that contribute to stream eutrophication. The value of implementing these types of watershed projects is also consistent with the preceding project identification flow.

Regulatory protections exist for watersheds as a whole, yet protections for uplands lag at this point relative to waterbodies and wetlands. Certainly the Stormwater Management Rules continue to be a prime driver in the management of watersheds for the reduction of peak flows, solids, and NPS pollutants, but there are a host of other regulations that are also important including many local ordinances that focus on steep slopes, stormwater management, zoning, and other environmental performance factors. The Highlands Regional Master Plan also outlines many of these elements, and conformance with that document will provide benefits throughout the watershed that result in improvements in corridor function.

The following list examines some watershed management techniques:

- Stormwater Management
    - Detention Basins and Wet Ponds
    - Bioretention Systems
    - Infiltration Systems Water Quality Swales
    - Manufactured Treatment Devices
- Cultural Best Management Practices (BMPs)
    - Fertilizer Use
    - Yard and Pet Waste
    - Waterfowl Control
    - Road Salt Application
    - Water Conservation
    - Septic Management
    - BMP Maintenance
- Invasive Species Management
- Agricultural BMPs
    - Manure Management
    - Conservation Tillage
    - Livestock Fencing
    - Pasture Management
- Open Space Preservation

4.0 Project Prioritization

Due to the nature of corridor impairments and assessing them via the five functional values in the Highlands, a concerted effort should be made to address each project, the realities of allocating resources, time, money, and effort, requires a system to prioritize projects.

The following sections explore approaches for feasibility, prioritization, and scale.

4.1 Feasibility

Technical feasibility includes the four following tests, all of which require affirmation to prove technical feasibility.

1. The project or activity contributes to and accommodates stream equilibrium conditions. Stated differently, the project should preserve or improve the stream corridor functional values.
2. The project design results in a reduction in material transport from the watershed, increased flow, and increased storage of sediment in the river and floodplains. This of course is a reference to long-term objectives on a watershed basis; reach or even project level goals may deviate. For instance, the objective of restoring aggraded reaches is to encourage increased sediment transport through the reach, but this fits in the framework of decreasing net transport in degrading or actively eroding reaches upstream that contribute to accretion. In other words, there should be a net increase in functional value on a watershed scale.
3. Upon project completion there is small risk of failure due to unmitigated constraints or channel adjustment processes. This is a very important consideration and unfortunately many restoration projects do fail due to an incomplete understanding of the dynamics of river systems. This also points to not relying too strongly on meeting reference conditions, but rather working within the framework of modified equilibrium.
4. The project will not contribute to instability or significant sediment accretion or generalized loss of functional value in reaches upstream or downstream of the project site.

Technical feasibility for development projects is somewhat different and must comply with state regulations including the Highlands Preservation Area Rules at N.J.A.C. 7:38; Stormwater Management rules at N.J.A.C. 7:8 (Special Water Resource Protection Areas– 300' buffers adjacent to all C-1 waters and their upstream tributaries in same HUC14 subwatershed); Flood Hazard rules at N.J.A.C. 7:13; and New Jersey Freshwater Wetland rules at N.J.A.C. 7:7. As such, any development project must not result in any loss of corridor functional value.

Local benefit may be assessed using the following four considerations.

1. The project results in tangible local benefits. This would include increased public access, restoration of diadromous fishery runs, visible project demonstration, and reduced erosional risks. Of course, the project would also have to meet other local goals including planning initiatives. This assessment overlaps with technical feasibility.
2. Municipalities, landowners, and other project stakeholders are committed to land use conversion and have formally agreed to the changes. While this is the second test, simple access is usually the first significant barrier to project implementation. This is especially true in areas where there is little public land.
3. The costs of design, permitting, and implementation are reasonable given the overall gains in equilibrium, functional value, and other local benefits. Cost ultimately tends to be the real decider of feasibility and there is no escaping that protection and restoration activities are expensive given the scale of the undertaking, the need for technical expertise, and construction and materials costs. Because of NJDEP permitting requirements and requisite Highlands Council Consistency Determination reviews, all proposed stream corridor projects should be reviewed early in the project formulation process to limit future complications.
4. Stakeholders are committed to project support and management. Within the Highlands, cultivating these types of relationships should be relatively easy. Besides municipalities, stakeholders such as watershed groups are extremely active in these types of activities.

4.2 Prioritization

Following project feasibility determinations, selected projects can be prioritized. Assessing feasibility thereby automatically discounts a number of projects. Project prioritization roughly follows the project identification scheme outlined in Section 3.0. The general scheme for prioritization seeks to first protect and preserve functional values of stream corridors. Restoration actions then follow after protection actions and priority generally decreases with increasing project complexity. This type of scheme therefore seeks to maintain the functional values of stream corridors through protection rather than restoration reacting to impairments. It is also expected that the general feasibility of projects will follow a similar pattern. The following section explores assessing the priority of various project groups.

1. **Protect River Corridors**
   <u>Higher</u>: Highly sensitive reaches critical for flow and sediment attenuation, or sensitive reaches where there is a major departure from equilibrium conditions due to the threat of encroachment are important to protect. Prioritizing these types of projects has an outsized influence on protecting areas downstream. In addition, this type of project involves resources that are particularly sensitive to change or are under threat and would benefit from immediate protection. This is echoed in the site's Native Mean C Riparian Plant Community index, with good to optimal values (3.5 or greater) identifying high quality plant communities. Stream sensitivity is rated with the FVAM channel integrity assessment.

Lower: Wooded corridors with little threat from encroachment, with low sensitivity, and not significantly contributing to flow or sediment attenuation are lower priority. In a sense, these types of reaches are already more robust and resistant to adjustment or impairment and because they are well vegetated their functional value is presumed high. These types of systems already enjoy a de-facto protection and thus are rated lower. It should be noted though that these types of projects offer ideal opportunities for expanding public access and thus might rate higher in terms of feasibility.

2. **Plant Stream Buffers**
   Higher: Priority is given to revegetation projects on relatively geomorphically stable reaches. Planting buffers is important in regaining functional value, especially for habitat quality, thermal moderation, and water quality. Trees and other woody plants are favored for increasing bank stability. Creating fair (2.5 – 3.4) Native Mean C Riparian Plant Community values should be targeted in these areas. It should be noted that establishing a community with a good to optimal (3.5 or greater) Native Mean C Riparian Plant Community has not been documented.
   Lower: Stream reaches exhibiting a higher degree of sensitivity are less well suited for stand-alone buffer planting projects as the sites are at higher risk of failure. That said, buffer planting should be incorporated in conjunction with other restoration activities, especially those addressing channel integrity where there has been significant work to stabilize or move the channel and banks.

3. **Stabilize Stream Banks**
   Higher: Streams that are overall relatively stable and where bank stabilization measures could slow channel migration and allow revegetation of the banks are given priority. Higher priority would also be assessed for projects that are impacting sensitive downstream reaches or where there is a need to protect active and functional infrastructure or other encroachments.
   Lower: Highly sensitive project sites that are at risk for project failure are assessed a lower priority.

4. **Arrest Head Cuts**
   Higher: The placement of grade controls are a priority where incision will lead to a loss of floodplain connectivity or place structures at risk.
   Lower: Reaches with natural grade controls within a meander wavelength upstream of the nick point or where there is high bed load deposition (coarser materials such as gravel and larger) are more likely to naturally recover and achieve equilibrium.

5. **Remove Berms**
   Higher: Removal of berms that would allow floodplain connectivity and lateral channel migration, in situations where the berm is directly responsible for reach incision, or where

there is no increased risk to structures from flooding or erosion after removal have high priority. These types of projects are linked by the high potential for significant increases in functional value and relatively low risk.

Lower: Projects that have less clear potential for functional value improvements are ranked lower. This includes reaches where the berms are well vegetated by trees and removal would cause major habitat disruptions or where removing the berms would not help to counteract channel incision.

6. **Remove or Replace Structures**

   Higher: Highest priority is given to derelict and non-functional structures. This is especially true where the structures are in an advanced state of disrepair and represent a significant liability. Structures that are causing major sediment accretion upstream and degradation downstream or structures that may cause channel avulsion during flood events are also given preference. In some cases restoration of diadromous fish migration is also given very high priority especially if it coincides with state or federal management plans.

   Lower: Lower priority is assessed to more complex projects that would require significant channel creation or realignment or where the risk of changes in equilibrium conditions upstream or downstream is deemed too high. Removal of structures that would contribute little to affecting lower erosion hazards are also lower ranked.

7. **Restore Incised Reaches**

   Higher: Implementation of projects that can take advantage of certain corridor conditions, such as restoration of recently avulsed channels or where there are few encroachments allowing for the creation of new floodplain benches, is favored.

   Lower: Highly developed reaches where allowing natural channel migration within the meander belt is impractical or where mitigation requires bank armoring or other similar methods are ranked low. Similarly, projects where many of the stressors that cause the impairments are located outside of the reach or outside of the riparian corridor with a low chance of reaching equilibrium conditions are also rated low; these types of projects are considered higher risk. There may be however a strong imperative to protect infrastructure when incision is also accompanied by extreme bank instability.

8. **Restore Aggraded Reaches**

   Higher: Priority is assigned to projects that address aggradation as a result of localized conditions.

   Lower: Projects in which aggradation is driven by conditions outside the reach, especially on a watershed scale, are given a lower priority.

4.3 Scale

The idea of scale is an important concept in assessing priority. The scale hierarchy starts at the site level, progresses to a reach, followed by the watershed or subwatershed scale, and finally the

Highlands Region. While stream corridor protection programs should be applied evenly throughout the Highlands Region, smaller scale implementation of related projects on a watershed scale is more natural. It also offers a variety of benefits and increased feasibility. First, while municipalities or private landowners are often primary project sponsors, it tends to be watershed groups that are the most vocal proponents and do the most to initiate projects, although administration duties and execution usually fall to other parties. As such, projects are often focused on the watershed scale and this requires prioritization on that scale as well. Following the same philosophy of weighting easier-to-implement projects higher with a focus on protection first and restoration second, rural watersheds should probably receive priority as they are less prone to the higher level of corridor impairment and loss of functional value than more urbanized watersheds.

Grouping projects together along a single stream or within a watershed is more effective on a large scale than spatially disparate and discrete projects. This is because individual sites and reaches are all connected within a single stream or tributary network by the common passage of flow and sediment. Thus, upstream projects designed to improve functional values and achieve dynamic equilibrium will decrease stressors on downstream projects and lead to better long-term success.

5.0 Sources of Financial and Technical Assistance

Identifying and securing technical and financial assistance is a key step in project success. Funding in particular is the key limiter in project implementation, but implementing a technically sound plan and project design is critical for ensuring a real improvement in the functional values. Both financial and technical responsibilities were discussed above and identifying these opportunities will be expanded in the following sections.

5.1 Financial Assistance

As previously discussed, the Highlands Council can appropriate funds to a conforming municipality for preparation of a stream corridor protection/restoration plan. To be eligible to a municipality must first submit a draft scope of work. That scope of work is reviewed by Highlands Council Staff and the request, if valid and appropriate, is finalized in accordance with the Plan Conformance Grant Agreement.

There are also a large number of grant or low-interest loan opportunities available from both public and private sectors. Private sector grants tend to be somewhat smaller than public grants and may be more difficult to research. Public sector grants may offer larger award amounts, higher prominence, and when viewed collectively cover a wider array of project areas. However, even with the diversity of available grants, grant amounts are finite and competition for grants can be fierce. Larger organizations, both private and public (like municipalities), may have specialized staff that research grant opportunities and prepare grant submission packages. Even the grant application process may require a consultant who provides either a technical scope of work or handles the entirety of the application preparation. In any case, grant opportunities will need to be explored as they arise across the board.

Most grant funding opportunities germane to this document are likely to originate at either the US Environmental Protection Agency (EPA) or New Jersey Department of Environmental Protection (NJDEP). EPA grants that may be applicable to stream corridor protection projects include the following:

- Clean Water State Revolving Fund: These are low-interest loans that can be used to fund NPS control programs and watershed management projects. As a loan, this would often require a governmental sponsor to assume the debt.
- Environmental Education Grants: While focused primarily on education and outreach these grants must also meet environmental priorities as well. Several ways this grant could be used in the context of this document would be to train volunteers to perform the FVAM assessment or to use a demonstration project as an educational tool for further expansion in the Highlands. There are of course other avenues that could be and should be explored.

- Environmental Justice Grants: Environmental Justice Small Grants Program seeks to fund grassroots organizations in partnerships (sometimes with government agencies). One of the top priorities is protecting water resources.
- Five Star Restoration Programs: These are relatively modest grants aimed at community-based restoration projects.
- Section 319 Grants and Nonpoint Source Mini-grants: The 319 grants are probably the most well-known and among the best funded grants for addressing NPS impairments, which is directly related to functional impairments in stream corridors. While a Federal grant, this is administered by the State. Formerly, these grants could be used in a variety of ways, including the development of protection plans, but now the focus is on implementation projects and could directly be used for any likely identified project discussed in the SCMPG.

Other federal agencies that maintain grant programs include the National Oceanic and Atmospheric Administration (NOAA), United States Department of Agricultural (USDA) and especially the Natural Resources Conservation Service (NRCS) section of the USDA, the United States Fish and Wildlife Service (USFWS), and the United States Geological Survey (USGS). More information about these topics can be found at:
http://water.epa.gov/grants_funding/shedfund/federal.cfm
http://www.grants.gov/

The state also maintains a number of grant opportunities. While most of these are administered through the NJDEP, the Department of Agriculture also provides funding opportunities. More information can be found at the New Jersey Grants website, http://www.nj.gov/nj/gov/njgov/grants.html. A brief summary follows.

- Endangered Species – Conserve Wildlife Matching Grant: This grant is open to nonprofit organizations and may be applied to river corridors as they host a number of rare communities; these grants are quite small however.
- Green Acres Programs: The Green Acres Program is designed to acquire lands for recreation and conservation purposes and directly addresses the top priority of the SCMPG, the protection of functional values in stream corridors through acquisition. The Green Acres program carries a high match burden at 50%, but this program has been extremely successful throughout the state. As of early 2013, nearly $15 million in the funding cycle has yet to be distributed.
- Nonpoint Source Pollution Control and Management Implementation Grants: Synonymous with the Section 319 grants; as mentioned above this is a federal loan program administered by the state.
- Soil and Water Conservation Grants: While targeted on active farms, implementing farm BMPs within riparian corridors or meander belts can help sustain or mitigate functional value impacts.

In addition, grants for restoration projects are issued by the New Jersey Freshwater Wetlands Mitigation Council (NJDEP Division of Land Use Regulation). The Mitigation Council is responsible for the governance of the Wetlands Mitigation Bank, which serves as a repository for land donations and monetary contributions collected as a result of freshwater/state open water impacts that cannot be mitigated for on-site, off-site, or at an existing wetland mitigation bank. As such, the Mitigation Council is responsible for the disbursement of funds to purchase land for the enhancement or restoration of degraded freshwater wetlands, to actively enhance or restore degraded freshwater wetlands on any public lands, and to preserve freshwater wetlands and critical transition areas. Eligible applicants include municipalities and nonprofit organizations. More information can be found at: http://www.state.nj.us/dep/landuse/mitigate.html.

5.2 Technical Assistance

The technical requirements of the different components of this plan vary considerably from the FVAM through design, construction, and monitoring. Most technical demands, especially the FVAM assessment, project design, and even permitting, will be shouldered by hired consultants with an expertise in ecology, water resources management, and engineering. These consultants will also provide other services at need, such as preparing grant submissions, performing additional biological and civil surveys, construction oversight, and others. Contractors may also need to be hired if the implementation projects require earthmoving equipment or other specialized practices. In any case, much of the technical assistance needed to execute any single project is provided by the people hired and ultimately will hinge on their project experience, familiarity with regulatory and engineering requirements, and their ability to adapt to new management paradigms discussed in this document. But there is still much in terms of project development, planning, administration, management, restoration philosophy, restoration design, and other related components that can be gleaned from a number of sources. These sources can vary considerably but include nonprofit organizations like watershed groups, academics and academic institutions, and governmental organizations from the municipal to the federal level. Besides directly interfacing with these groups, there is also a very expansive set of published literature on these topics.

Relatively few agencies will offer true technical assistance and work closely in the design or implementation process and instead primarily function in an advisory or oversight role. A major exception is the North Jersey RC&D which works with the County Soil Conservation Districts and other agencies to promote conservation projects including land conservation, water management, and environmental enhancement all of which are directly applicable to preserving and protecting stream corridor functional values. The New Jersey Water Supply Authority is another public agency that promotes similar projects, although their goal is more narrowly focused on the protection of water quality and water quantity within the Raritan Basin (and some other portions of New Jersey) specifically to continue to meet consumptive demand needs. In any case, they also promote projects seeking to preserve the functions of stream corridors. The Rutgers Cooperative Extension is another very valuable resource for technical assistance with county offices located throughout the Highlands. The Extension is often a primary resource for agricultural matters, but they also maintain a number of programs and projects related to environmental and natural resources as well as fisheries. The New Jersey Department of Agriculture also supports conservation practices, although these are usually directly related to agricultural operations.

Other agencies that will on occasion render direct technical assistance, usually when working on a defined project of interest, include the EPA, NJDEP, United State Army Corps of Engineers (USACE), USDA NRCS, and the USFWS.

Technical literature resources include:

- NJStormwater.org and the excellent NJ Stormwater BMP Manual – www.njstormwater.org
- The River Network – www.rivernetwork.org
- Association of New Jersey Environmental Commissions – www.anjec.org
- Green Values Stormwater Toolbox – http://greenvalues.cnt.org/
- Center for Invasive Species and Ecosystem Health – www.invasive.org
- New Jersey NRCS Programs – www.nj.nrcs.usda.gov/programs/
- USEPA Handbook for Developing Watershed Plans to Restore and Protect Our Waters
- University of Georgia A Review of the Scientific Literature on Riparian Buffer Width, Extent, and Vegetation
- USEPA Center for Watershed Protection Urban Subwatershed Restoration Manual No. 1, 2, 10, 11
- Rosgen Applied River Morphology
- USEPA Rapid Bioassessment Protocols for Use in Streams and Wadable Rivers
- Bowman's Hill Wildflower Preserve Plant Stewardship Index Program
- The Nature Conservancy The Active River Area: A Conservation Framework for Protecting Rivers and Streams
- Shields et al. Design for Stream Restoration
- USACE Channel Restoration Design for Meandering Rivers
- Milone & MacBroom Guidelines for Naturalized River Channel Design and Bank Stabilization

6.0 Schedule of Implementation

Project implementation is facilitated by setting an implementation schedule. This is done primarily to maintain momentum and working towards a deadline can be beneficial in maintaining progress. The implementation schedule also works to define the various project components, thus presenting a clearer picture of the entire operation. As with other areas covered in this document, creating an implementation schedule is scale dependent. As a regional initiative, a generalized schedule is necessary for the implementation of stream corridor protection and restoration throughout the Highlands, yet it will also be necessary to create implementation schedules for each associated project. In addition to spatial scale considerations, it may be easier to break down schedule along different time scales as well. While the implementation schedule is important, it must also remain fluid to account for real world concerns and delays and be designed upfront with sufficient time to allow task completion.

The complexity and the sheer scale of a stream corridor protection program means that many activities will be occurring simultaneously, a situation that should be encouraged. The practical goal of this document is the implementation of projects and as projects are identified and roughly prioritized they should be implemented. In other words, project implementation need not be delayed because the FVAM evaluations have not been completed on a regional basis, this only creates an artificial bottleneck. The following tables show a proposed implementation schedule for a stream corridor protection program (Tables 2, 3, and 4).

Table 2: Short Term Implementation Schedule

Short Term Implementation (0 to 4 years)	
Activity	**Description**
Planning	Begin a general prioritization of watersheds and streams to initiate FVAM surveys, especially those where protection measures would feature prominently. Start to firm up schedules, design a record keeping protocol, and assess how the program and projects will be administered.
Outreach	Ramp up efforts to effectively communicate message of corridor protection throughout the Highlands. Identify and interface with stakeholders, and build proram support. Identify project sponsors.
Technical Assistance	Identify and contact parties to provide the technical assistance to initiate FVAM surveys
Secure Funding	Investigate funding including grant oppurtunities and the use of public funds, low interest loans, or other financial vehicles.
FVAM Assessments	Initiate the regional FVAM assessments. Areas with defined project sponsors or with other perceived priority will be surveyed first. Continue to seek project funding, sponsors, and consultants to address the remaining areas.
Project Selection	Using the FVAM results, run through the project selection matrix in the SCPG and determine project priority
Project Implementation	Once projects are selected and prioritized, high priority projects should be implemented. At the early stage of program adoption this will probably be mostly protection projects, those revolving around land or rights acquisitions. Some of the simpler restoration activities, like buffer planting could be implemented. More complex projects should initiate design concepts.

Table 3: Medium Term Implementation Schedule

Medium Term Implementation Schedule (4 to 8 years)	
Activity	**Description**
FVAM Assessments	Continue the FVAM surveys. Ideally, at the end of this period at least 50% of the Highlands should be surveyed. At a minimum seek to complete FVAM Phase I throughout the region
Project Implementation	This time frame is defined primarily by project implementation. High priority projects should at least be initiated if not completed and low and medium priority projects started.
Outreach	Outreach activities are continued as an integral component of the SCPG. While education and participation is still the primary message relaying implementation success should become more prominent. GIS maps indicating FVAM survey progress and results will be very effective in communicating this information.
Maintenance	Maintenance activities should be fully incorporated into any implementation projects and otherwise adopted for existing BMPs.
Monitoring	Routine monitoring should now be fully integrated into completed projects to document changes in functional value. This data should be freely available and effectively communicated to stakeholders. If declines in functional value are documented, implement adaptive management.

Table 4: Long Term Implementation Schedule

Long Term Implementation Schedule (8 years and beyond)	
Activity	**Description**
FVAM Assessments	FVAM assessments should be largely completed regionally by this time. Any oustanding areas should be given high priority at the expiration of this stage. An important component of natural resource protection is evaluation, and a second round of regional assessments should be initiated.
Project Implementation	Projects should continue to be implemented during this time. In particular, very complex projects or simpler and lower priority projects will be implemented. As the FVAM assessments are completed new projects will be identified. Project implementation will of course be a constant as long as this program is maintained. Over time however the cumulative effect of project implementation should result in decreased corridor function loss and more projects will shift to protection or simpler mitigation.
Outreach	Maintain outreach effort and promote project success.
Maintenance	If designed and implemented correctly, project maintenance hopefully will be minimal after an initial stabilization and revegetation phase and maintenance requirements should be modest as sustainability must be a project goal.
Monitoring	Monitoring efforts will be continue through this period as mandated by permit conditions. On a more general scale monitoring will begin to blend with repeated FVAM assessments.

6.1 Project Implementation

The project implementation schedule needs to be determined for each project and is largely independent of larger regional implementation schedule, although it shares many of the same steps. Most projects, once seriously initiated, tend to be implemented within about three years. This number can vary considerably, but certainly there can be long delays between project steps, especially in securing funding, conducting additional field work as needed, permit review and approval, and starting construction, even while the actual design and construction is relatively short. As mentioned above, setting a realistic schedule is important as it both pushes the project ahead yet avoids the frustrations of missed deadlines due to both foreseeable and unforeseeable events. The various projects components that should be considered are summarized in Table 5.

Table 5: Project Implementation Schedule

Project Implementation (0 to 3 years)	
Activity	**Description**
FVAM Assessments	Complete an FVAM assessment on the selected site or project reach. Use the results to identify and prioritize the project.
Technical Assistance	Secure a project sponsor and design consultant. Develop initial costs and concepts
Secure Funding	Apply for grants or secure other funding. Many grants are only awarded once per year and application review may last six months or more. Schedule appropriately.
Design and Permitting	With funding and technical assistance secured, the project can go to design and permitting. Design may require additional fieldwork, such as a land survey or hydrologic monitoring, that could take up to a year. The design process and permitting, especially if multiple iterations are required, could also take up to a year.
Implementation	Once the proper permits are secured, the design can be constructed. This may require bidding out the construction. While most projects, even fairly complex ones, can be finished within several months, there are often permit conditions that limit the initiation of construction to certains times of year to avoid impacts to migrating, spawning, or hibernating species.
Monitoring	Monitoring is a crucial part of project implementation. At a minimum the FVAM assessment should be conducted again to determine the change in corridor functional value. This should be assessed probably after at least a growing season to allow a period of revegetation or to gather hydrology data over the course of a year. Permits may stipulate increased monitoring burdens, sometimes over the course of several years. The monitoring program will be determined in conjunction with the regulators in an approved quality assurance project plan (QAPP).

7.0 References

Highlands Water Protection and Planning Council. 2008. *Highlands Regional Master Plan*. Highlands Council. Chester, NJ.

Kline, M. 2010. *Vermont ANR A Guide to River Corridor Easements*. Vermont Agency of Natural Resources. Waterbury, VT.

Kline, M. 2010. *Vermont ANR River Corridor Planning Guide: to Identify and Develop River Corridor Protection and Restoration Projects, 2nd ed.* Vermont Agency of Natural Resources. Waterbury, VT.

Kline, M., C. Alexander, S. Pytlik, S. Jaquith, and S. Pomeroy. 2007. *Vermont Stream Geomorphic Assessment Protocol Handbooks and Appendices*. Vermont Agency of Natural Resources. Waterbury, VT.

Kline, M. and K. Dolan. 2008. *Vermont ANR River Corridor Protection Guide: Fluvial Geomorphic-Based Methodology to Reduce Flood Hazards and Protect Water Quality*. Vermont Agency of Natural Resources. Waterbury, VT.

NJDEP. 2007. *Administrative Order No. 2007-01: Special Water Resource Protection Area Functional Value Analysis*. New Jersey Department of Environmental Protection. Trenton, NJ.

Princeton Hydro. 2013. *New Jersey Highlands Region Stream Corridor Guidance Part I - Functional Value Assessment Methodology*. New Jersey Highlands Council. Chester, NJ.

Rosgen, D. 1996. *Applied River Morphology*. Wildland Hydrology. Pagosa Springs, CO.

Schiff, R., M. Kline, and J. Clark. 2008. *Vermont ANR Reach Habitat Assessment*. Prepared by Milone & MacBroom, Inc. for Vermont Agency of Natural Resources. Waterbury, VT.

USEPA. 2008. *Handbook for Developing Watershed Plans to Restore and Protect our Waters*. U.S Environmental Protection Agency, Office of Water, Nonpoint Source Control Branch. Washington, D.C.

Appendix A:
Annotated Bibliography

Literature Review and Annotated Bibliography

Guidance concerning rivers conservation, riparian corridor restoration, and watershed management, as well as other related subject matter, is both abundant and diverse. The reason for this diversity is that there is no universally appropriate method for implementing watershed and riparian corridor restoration plans. This is to be expected given that the discipline of river and riparian restoration practices are still evolving. As a result, there is active experimentation to discover the best solutions and management practices. Furthermore authors of these guidance documents tend to tailor the reports and methodologies for the predominant conditions or the range of conditions applicable to their selected geographic area. Additionally, from a more practical perspective, the diversity can be explained by divergent perceptions, opinions and ultimately different goals. For instance, the goals of an agency tasked with protecting stream bank infrastructure is more likely to favor stream armoring techniques as opposed to an organization interested in promoting habitat quality in the floodplain that would favor planting and "softer" bioengineering solutions. Despite these differences, there are unifying principles behind much of the published guidance. Some of the core ideas promote a characterization phase of variable intensity, objectively assessing collected data, setting data supported goals, building consensus and support, identifying a chain of events and supporting resources, and implementing projects collectively agreed upon to protect various functional values and resources deemed important.

The objective of this task was to develop Stream Corridor Protection guidance for the New Jersey Highlands by selecting the best framework and components from the existing literature. The successful completion of this task greatly relies on conducting a thorough review of available literature and then selecting the appropriate guidance from those plans that share basic similarities with the New Jersey Highlands study area; scale, dominant geologic and climatic conditions, the extent and type of land development and encroachment issues, and general fluvial patterns. The advantage of performing a literature review for this project is that the fundamental goals of this plan have been identified in general in the Highlands Water Protection and Planning Act (N.J.S.A. 13:20-1 et seq.) and expanded upon in the Highlands Water Protection and Planning Rules (N.J.A.C. 7:38) and the Highlands Regional Master Plan and supporting documentation.

Legislation and regulation, including the New Jersey Stormwater Management Rules (N.J.A.C. 7:8) and the Flood Hazard Area Rules (N.J.A.C. 7:13), explicitly defines and seeks to preserve the functional values for all Category-1 streams through the establishment of a Special Water Resource Protection Area (SWRPA). Protection of the functions and services provided by the SWRPA's 300 foot riparian buffer encompasses habitat quality (both in the riparian corridor and within the channel), the mitigation of nonpoint source (NPS) pollutant loading, the moderation of water temperatures, and maintenance of channel integrity. While there are a variety of other functions provided by riparian corridors these are amongst the chief services and represent a good cross-section of the range of biological, hydrologic/hydraulic, and water quality functions provided by riparian corridors.

Besides the preservation of ecological and hydraulic function, the preservation of existing development and infrastructure must also be factored into the equation. While future development in these sensitive and valuable habitats is largely limited due to the Highlands Act and supporting rules and regulations, the reality of the situation in the Highlands, and throughout New Jersey as a whole, is that riparian corridors tend to be highly developed or prone to encroachment and disturbance. This is because historically riparian corridors provided numerous natural resources and functions required by developing communities. Among the most important of these values were hydropower, transportation, and water for consumptive uses in industrial processes, in agriculture, and for potable supplies. This trend of developing these corridors has left a highly visible print in the corridors, much of it related to attempts to improve flow capacity and drainage, impoundment, or protecting against flooding. All of these efforts have led to a loss of the primary environmental functions of these corridors. However, any guidance document must account for the protection of existing structural resources in riparian corridors and the management of the waterways and floodplains that is consistent with the four primary functional values listed above.

The above summarizes the crux of this task. Preparation of this Stream Corridor Protection guidance for the New Jersey Highlands must take into consideration riparian corridor and stream management challenges for the region given the area's variable development patterns ranging from relatively dense riverside communities to undisturbed, pristine forests and wetlands. The following annotated bibliography provides a synopsis of the published plans and guides that appear to be most consistent with the goals and objectives of the Highlands Council. Many of the reports summarized below have particular utility in the development of Stream Corridor Protection guidance for the New Jersey Highlands. The materials are therefore presented and reviewed not in alphabetical order, but rather in their apparent application in the preparation of the Stream Corridor Protection guidance document.

Vermont ANR River Corridor Planning Guide

Kline, M. 2010. *Vermont ANR River Corridor Planning Guide: to Identify and Develop River Corridor Protection and Restoration Projects, 2nd ed.* Vermont Agency of Natural Resources. Waterbury, VT.

This document serves as the primary basis for the development of the corridor protection guidance document. This planning guide is particularly well suited for use in developing the Highlands guidance because of the many similarities between the Highlands and Vermont. The most important consideration is the geological similarity of the Highlands to Vermont, characterized largely by relatively high relief and high gradients, creating rather energetic stream systems. Development patterns are also similar ranging from forested headlands and agricultural areas, often pastures and hayfields, to developed valley bottoms initially settled for the advent of colonial industry. Aside from the physical similarities, which marks this as a suitable template, the Vermont document is comprehensive, expansive, and compatible with the defined goals of the Highlands Council. The primary theme of the document is managing river and river corridors towards dynamic equilibrium conditions, which can be thought of as the set of fluvial geomorphic conditions that preserve certain characteristics of stream shaping processes that results in stable channel patterns while the actual channel may continue to show predictable movements within a defined corridor. In other words, equilibrium management recognizes that stream systems are dynamic and will, even under equilibrium, exhibit channel movement within the meander belt and systematic erosion and deposition. This is in contrast to earlier management practices in which attempts were made to lock channels in place, which in the long haul has proven ineffective, costly, prone to failure, and responsible for the poor shape of the rivers in the area. The objective of this type of management approach therefore is to work within dynamic systems to maintain stable patterns, profiles, and other stream metrics, and to avoid the types of management practices, such as straightening, bank armoring, and development encroachment in the floodplain, that contribute to alterations in hydraulics and other functions that ultimately lead to severe erosion, deposition, flooding, and other problems that represent a loss of environmental services as well as damage to real property and infrastructure.

The Vermont approach relies strongly on a scientific approach to river and corridor characterization, performed at a reach scale, which is two pronged. The first phase is largely a desktop exercise utilizing existing data sources to gather basic information about a river system. Some of the most important sources of data include topographic maps, aerial photographs, and USGS steam flow statistics. The second phase is an in-situ study and assessment of fluvial geomorphic quality, habitat value, land use, and other important features. These assessments will be discussed in greater detail elsewhere. These characterization phases provide a great quantity of data which is subsequently used to perform a variety of analyses, specifically a departure analysis and stressor identification. Departure analysis models the departure of a stream system from a theoretical reference condition. Reference conditions are modeled based upon numerous watershed characteristics, particularly valley type and slope as well as geology and soils; reference conditions are also considered to represent equilibrium conditions and therefore function as the restoration targets. Observed departure is assumed to be caused by various stressors and constraints that have resulted in an alteration in the system and a loss of function. This type of analysis, which identifies impairments, their causes, and management goals encourages and facilitates the planning aspects of corridor management. The most important components of the planning development phase are the identification of restoration projects and the prioritization of these projects and tasks. This includes a prioritization schedule that is based on a chronological implementation basis rather than project importance. This represents a departure from some restoration schemes, which may highlight high end projects of high severity or technical complexity, and is a more holistic approach to management which is consistent with the goals of the Highlands Act. Typically, restoration activities have focused primarily on a fix, for example the armoring of a severely eroded bank or the removal of failing in-stream structure. Instead, this approach starts at the beginning and advocates river corridor protection measures followed by management of increasing complexity to address different components of degraded systems. This philosophy and the project prioritization is important in managing to equilibrium conditions and corresponds to the protection afforded to the SWRPAs within the Highlands.

Building on the characterization exercises for the system and the identification and prioritization of projects, this guide then discusses project development. This is an accounting of the practical aspect of project implementation including developing set goals and objectives for the projects, the reach and the watershed, building the political will and landowner cooperation that is imperative for these projects, and considering costs and benefits, both social and economic. Finally, monitoring is discussed as a tool for tracking progress and being able to apply adaptive management practices to ensure project success.

As stated above, this document seems to be a nearly ideal template upon which to base the Highlands corridor protection guidance, however the Highlands guidance will be changed as necessary to better manage the Highlands corridors due to the unique conditions of this region. One area that will be slightly reworked in the Highlands is the management of stream corridors to equilibrium conditions. While management to equilibrium conditions is the still the top priority to restore the four functional values deemed vital for riparian corridors, these equilibrium conditions will not always align with the modeled reference conditions. While this is touched on in the Vermont document attaining reference conditions in a heavily developed watershed or corridor is simply not possible due to the alteration of the hydrology and hydraulics in a watershed with high impervious coverage or where vital infrastructure requires protection. Stated somewhat differently, and more elegantly, the guidance suggests assigning a modified stream reference in cases where relief of stressors is impractical. The relief of many stressors is going to be very difficult in the Highlands without a concerted effort throughout the watershed to change hydrology, which while a worthy goal, is to some extent impractical given that as little as 10% impervious surface can significantly alter watershed hydrology. Instead, the management objective will be to promote equilibrium conditions given *existing* hydrology and other constraints that caused instability in stream geomorphic setting throughout the region.

Handbook for Developing Watershed Plans to Restore and Protect our Waters

USEPA. 2008. *Handbook for Developing Watershed Plans to Restore and Protect our Waters.* U.S Environmental Protection Agency, Office of Water, Nonpoint Source Control Branch. Washington, D.C.

This Environmental Protection Agency (EPA) developed handbook is an extensive and extremely broad guidance for the development of watershed plans. While the focus is on a watershed plans, the protection of riparian corridors is only slightly more narrowly focused, and many of the conservation and restoration elements of watershed plans by necessity focus on the riparian corridor as the most crucial element in the preservation of water quality in watersheds. As mentioned above, the handbook is extremely broad and covers a vast array of topics related to the process in exhaustive detail. As with the Vermont corridor guide, this document follows a similar outline with the characterization of a watershed, followed by analysis, project identification, implementation, and ultimately monitoring. This plan differs slightly from the Vermont guidance and focuses slightly less attention on the actual specific methods of the characterization, instead delving more thoroughly into the process of characterization, and covers some of the implementation details, such as the preparation of work plans and milestones in somewhat greater detail. The main thrust of the handbook is a concentration on nine elements considered imperative for the development of successful watershed plans. The nine elements include: the identification of impairments and pollutant sources, an estimate of NPS reduction from management measures, a description of NPS management measures and implementation sites, an estimate of the amount of technical and financial assistance required, information and education of the public and their inclusion in plan development, a schedule for implementing projects, a description of measurable milestones, developing criteria to determine load reductions and achievement of water quality and other standards, and monitoring to evaluate implementation effectiveness. Ultimately, this handbook should serve as a useful reference guide in the implementation and development of corridor protection guides, especially in completing the detail-oriented parts of the plan that deal with technical administration of the project. It also provides insight into the process from a federal perspective and satisfying some of the requirements listed in this plan could be valuable for seeking funding for project implementation from federal authorities, especially the EPA.

A Review of the Scientific Literature on Riparian Buffer Width, Extent, and Vegetation

Wenger, S. 1999. *A Review of the Scientific Literature on Riparian Buffer Width, Extent and Vegetation.* University of Georgia, Office of Public Service & Outreach, Institute of Ecology. Athens, Georgia.

As the title suggests, this is a scientific review of existing literature dealing with the various benefits of riparian buffers. More specifically, this paper examines the various functions and services provided in riparian corridors including all four of the core functional values expounded by the Highlands Council, and examines the effect of corridor extent and quality on different functions of the corridor. This paper reviews this information in order to establish legally defensible corridor widths based on the best scientific evidence. While establishing a legally defensible buffer width has already been established in New Jersey through different regulatory vehicles, the detailed examination of buffer functions is important for better understanding the importance of the resource. Specifically, this enhanced knowledge can be used in designing buffer restoration projects, prioritizing these projects, and communicating the benefit of buffer conservation and enhancement important to build community involvement. The review examines various buffer functions such as sediment impacts including mitigation, erosion, deposition, channel stability, nutrient mitigation for primary nutrients phosphorus and nitrogen and various other contaminants, aquatic habitat quality including allochthonous carbon inputs, temperature and light, and terrestrial habitat quality including the effect on flooding. These functions are then summarized in various riparian buffer guidelines. This includes several models for calculating buffer widths that incorporates hydraulics, hydrology, geomorphic factors, topography, and additional characteristics. These models could potentially be very important in the recommendation of expanded buffers in certain areas to enhance various buffer functions. In addition to the establishment of buffers, other management options are explored including decreasing impervious areas, managing pollutants, and reengineering buffer crossings.

Vermont ANR A Guide to River Corridor Easements

Kline, M. 2010. *Vermont ANR A Guide to River Corridor Easements.* Vermont Agency of Natural Resources. Waterbury, VT.

This guide is a product of the VT River Management Program and therefore functions as a companion piece to the Corridor Planning Guide and other associated documents. As the name suggests it explores the use of river corridor easements, which is considered an avoidance strategy, one designed to minimize conflicts between fluvial processes and development. These easements are generally a deed transfer of streamside lands to be preserved in a natural state for perpetuity. The purchase of river corridor easements is consistent with the management of a river to equilibrium conditions in that easements provide the undeveloped corridor in which natural fluvial processes can occur without damaging structures. While the main advantage of corridor easements is in allowing natural processes to dominate, there is a distinct economic advantage to their purchase. It is estimated that in Vermont over a 50 year period the purchase of an easement could save at least 70% of comparable maintenance costs in maintaining a river in disequilibrium or unstable conditions through extensive bank armoring or other related methods, meaning that in time the purchase pays for itself. Another economic benefit, one that directly benefits developers, is that money paid out in the purchase of easements can be used to push proposed or existing development out of the corridor thus avoiding future damage to these structures. In addition, there are other indirect benefits of such purchases as in the avoidance of damage downstream due to restored functionality in the easement.

The selection or identification of sites suitable for easement acquisition, as well as the prioritization of such sites, is based on the geomorphic and corridor assessments discussed in the Corridor Planning Guide. The acquisition of easements in reaches characterized as attenuation reaches is most important, namely because these areas exhibit functional hydraulics that provide benefits such as the storage of water and sediments. Other characteristics to rank projects include the lack of existing constraints, proposed and future development in the corridor that could be prevented with an easement, and protecting downstream areas from erosion and deposition. This guide also includes model easement language that addresses in a legal context the transfer of rights.

Vermont ANR River Corridor Protection Guide: Fluvial Geomorphic-Based Methodology to Reduce Flood Hazards and Protect Water Quality

Kline, M. and K. Dolan. 2008. *Vermont ANR River Corridor Protection Guide: Fluvial Geomorphic-Based Methodology to Reduce Flood Hazards and Protect Water Quality*. Vermont Agency of Natural Resources. Waterbury, VT.

The Corridor Protection Guide is a partner to the Corridor Planning Guide and is in effect an introduction to the management concepts and fluvial geomorphology of rivers expounded in the Planning Guide. As with the Planning Guide, the Protection Guide discusses managing towards stable systems exhibiting equilibrium conditions where certain geomorphic characteristics, such as pattern and profile, remain stable while the river remains dynamic within the meander belt.

This means that appropriate channel geometry is maintained through the stable transport of water and sediment within the system. This document also defines the concept of the meander belt, which is a corridor drawn between roughly parallel lines that a river channel will migrate through over time. While buffers drawn from a defined bed and bank are an important management aspect of preserving functionality in riparian corridors, simple buffers are not sufficient unless protection is granted within the meander belt, which should also be buffered. In effect this provides an area where channel adjustments can occur naturally. Defining these corridors is accomplished in a number of ways. As with other papers cited in this document, the proposed geomorphic assessments, particularly the Phase I methods, can be used to determine these corridors. Defining floodplains is also an important concept in this paper, and making use of the National Flood Insurance Program (NFIP) Special Flood Hazard Area (SFHA) maps. However, there are certainly limitations to the SFHA maps because they do not account for erosion processes and also consider the channel to be static. Additionally, many of the maps lack elevation data and are developed using "approximate" methods. A technical method of evaluating and defining meander belts is then explored using both Phase I, desktop analysis, and Phase II, in-situ, methods. Using the Phase II methods stream sensitivity can be deduced, which in part relies on channel evolution models. Finally, river corridor planning is explored briefly including prioritization of projects, defining Fluvial Erosion Hazard areas which can be a zoning overlay that considers full meander belts and appropriate buffers expanding on the SFHA maps, and the implementing river corridor easements as discussed in the easement section.

Vermont ANR Reach Habitat Assessment

Schiff, R., M. Kline, and J. Clark. 2008. *Vermont ANR Reach Habitat Assessment.* Prepared by Milone & MacBroom, Inc. for Vermont Agency of Natural Resources. Waterbury, VT.

The Reach Habitat Assessment (RHA) is a considerable expansion and refinement of some earlier methodologies referenced in guidance documents. This is a highly technical document that is a walk-through of the assessment methodology. This document focuses, as the name suggests, on the assessment of in-stream habitat quality, primarily focused on habitat for the benthic infauna, but also useful in considering habitat quality for other aquatic organisms including fish. Habitat assessments are useful in tying together fluvial processes, which are largely responsible for the quality of the habitat, and biological utilization. This protocol basically mirrors the form of EPA Rapid Bioassessment Protocols (RBP). The RBP is really the de-facto standard for this type of methodology and enjoys very large adoption in modified forms by many regulatory agencies throughout the country. This methodology explores several different parameters than what is typically included for RBP. The coarse categories explored include woody debris, substrate, scour/deposition features, channel morphology, hydrology, and other similar parameters. Much of the document is spent explaining these parameters and assigning the appropriate scoring. Also of great utility is that a number of different data sheets were developed that correspond to different stream types. Because this methodology in many respects is a product of fluvial processes in the river different stream types will exhibit widely different characteristics that need to be evaluated respective of their own stream type. For example, substrate type and sediment transport will vary widely between streams of different gradient and the preponderance of a finer grained material in a low gradient stream is not necessarily an indication of poorer habitat quality than a coarse grained, high gradient stream.

The results of a pilot study correlating total and component scoring from the RHA against ecological and geomorphic parameters, including indices of biotic integrity and channel evolution stage, are explored in detail. This methodology will probably be adopted with little overall change.

Vermont ANR Stream Geomorphic Assessment Protocols

Kline, M., C. Alexander, S. Pytlik, S. Jaquith, and S. Pomeroy. 2007. *Vermont Stream Geomorphic Assessment Protocol Handbooks and Appendices.* Vermont Agency of Natural Resources. Waterbury, VT.

The Stream Geomorphic Assessment will be the backbone of the geomorphic assessment methodology being developed for the Highlands. The term fluvial geomorphology refers to the shaping of riverine systems in the landscape, and as such evaluates process, form, and function, and is primarily concerned with the transport of water and sediment. All of these factors are highly inter-related and are complex. By studying and assessing river geomorphology, a detailed condition of the river can be assigned. Imbalances in hydrology, hydraulics, and sediment transport caused by a variety of stressors including increased stormwater runoff, channel straightening, floodplain encroachment, and other factors will be reflected in the geomorphic characteristics of river. Channel evolution theory indicates that river systems will continue to be highly unstable or at disequilibrium while undergoing channel evolution until a stable state is reached that is consistent with altered hydrology and sediment transport regimes. In the context of riparian corridor protection, establishing the geomorphic characteristics of a reach is important in understanding impairments in river function and in formalizing management goals.

The geomorphic methodology discussed in this document and other companion pieces is a two-pronged approach. Phase I Watershed Assessment, as described above, is basically a desktop exercise that uses existing data sources to collect basic data about a watershed and reach. This information is used to provide an overview of the physical characteristics of a watershed. Information reviewed in this context includes USGS topographic maps, aerial photographs, databases, and local knowledge. It is also important to consider that NJDEP and the Highlands Council maintain outstanding GIS (geographic information system) databases that cover numerous topics including waterbodies, water quality, anti-degradation policy, biological data, topography, soils, land use/ land cover (LU/LC), and a wide variety of others that would be extremely helpful. In the end a Phase I assessment is conducted to provide stream reference typing, an impact rating, a provisional geomorphic condition evaluation that describes reach condition, channel adjustment process, and reach sensitivity, a like-reach evaluation that groups similar reaches, and a variety of watershed maps. A large portion of the Phase I handbook is predicated on using various GIS modules unique to Vermont, which will not transfer to use in New Jersey, but the items examined can still be found, accomplished, and stored, albeit from a different source or in a different format. Since the geomorphic assessments are a data intensive process pulling from many different sources the establishment of a quality insurance program is recommended prior to beginning data collection. Simple exercises such as delineating the catchment and determining valley width, valley slope, sinuosity, confinement, and other parameters can be easily measured using topographic maps. Delineation of reaches is also discussed and where to identify natural reach or segment breaks. Similarly, large constraints can also be identified at this time including some crossings, large-scale straightening, impoundment, and other such features can be identified. The watershed at large can also be more closely examined and soils, geology, and development levels can be populated that would indicate potential hydrology and other properties. Using all this data certain analyses can be performed to characterize reaches. One of the primary uses of the Phase I assessment is also assigning reference type based on the valley and geology characteristics that will to some extent serve as a management objective. This Phase will likely be largely adopted as it stands, however it seems that conducting a windshield survey in the first phase of the assessment is unnecessary due to the quality of available data and the intensity of stream surveys in the following phase.

Phase II Rapid Stream Assessment builds upon the results developed in Phase I, providing both confirmation and expanding the characterization of the stream. This phase is primarily an intensive field survey, and survey efforts should focus on areas of concern identified in Phase I. The goal of the Rapid Stream Assessment is to characterize existing stream type (based primarily of the Rosgen Classification of Natural Rivers), a geomorphic condition evaluation examining reach condition, channel adjustment process, and reach sensitivity, a stream habitat assessment as described in the Reach Habitat Assessment, and updated maps and accompanying photographs. As with Phase I work a quality assurance plan should be completed to specify methods and data handling procedures. Much of this work is simply inventorying data about the river including corridor encroachments, depositional features, substrates, bank and buffer features, beaver dams, impoundments, grade controls, crossings, outfalls, and all other similar features. The next step, and proceeding steps, involves the measurement of geomorphic characteristics of a river, which are the base of the geomorphic evaluation. This includes measuring things like floodprone width, bankfull width, thalweg location, cross-sections, longitudinal profiles, substrate particle size, and other parameters. These simple measurements can be used to calculate derived metrics such as width to depth ratios, incision ratios, slope, and others to characterize stream type. Stream banks and buffer conditions are evaluated next by examining bank slopes, buffer quality, land use in the riparian corridor, and bank armoring. Flow modifiers are inventoried including springs, adjacent wetlands, debris jams, flow regulation including water withdrawals, and stormwater inputs. Bed forms are also investigated including bars, pools, sediment storage, avulsions and flood chutes, crossings, and head cuts. Finally, this information is used to perform the actual Rapid Geomorphic Assessment which evaluates, based on the collected data, departure from reference condition, channel evolution sequence, reach sensitivity, channel adjustment processes, and general stream condition. In reviewing this methodology, most of the assessments are useful and will be incorporated for Highlands guidance. However, there are certain assessments and rankings that will be dropped or significantly modified to better describe the range of conditions encountered in the Highlands.

Vermont ANR Technical Guidance for Determining Floodway Limits

VTANR. 2009. *Technical Guidance for Determining Floodway Limits Pursuant to Act 250 Criterion 1(D).* Vermont Agency of Natural Resources.

As the title suggests, this document largely is an interpretation of existing legislation regarding the delineation of floodway limits, and explicitly explores the Vermont ANR Floodway

Procedure. The Technical Guidance deals with not only inundation, but fluvial erosion hazard (FEH) within the floodway. The inundation floodway, as determined primarily by the base flood elevation, is to ensure that there is no development or change in land use that would result in a rise in flood elevations as calculated by hydraulic models; this is also called a "no-rise" standard. Development in the flood fringe, the floodplain area outside of the inundation floodway is also discussed. Of greater interest is the FEH floodway determination. As discussed above, the National Flood Insurance Program does little to address erosion and channel stability concerns, and establishing a FEH floodway through geomorphic assessment of a river corridor is important. As with almost all other documents reviewed in this exercise, the concept of the meander belt is the driving factor behind this effort. First, the meander centerline of a channel is calculated and channel width is measured. After this a belt width or erosion floodway shall be established parallel to the meander centerline based on stream type. In low sensitivity streams, including those with boulder or bedrock substrate, the belt width is relatively confined and narrow, but with increasing sensitivity the belt width increases to a minimum of six stream widths in highly or extremely sensitive reaches, but confinements and floodplain features can also modify the belt width. Stream sensitivity refers to the erosional potential of a stream, as defined in the Stream Geomorphic Assessment handbook, and streams which show high sensitivity are most likely to be unstable and show the greatest degree of migration through a meander belt thus requiring greater protection through expansion of the belt width. In the end, this paper covers familiar ground, but couches the identification of floodways in terms of hydraulic assessment in a legal and regulatory context that would be important for maintaining functional values in the Highlands riparian corridors.

Urban Subwatershed Restoration Manual No. 10 - Unified Stream Assessment: A User's Manual

Kitchell, A. and T. Schueler. 2005. *Urban Subwatershed Restoration Manual No. 10 - Unified Stream Assessment: A User's Manual.* Prepared by Center for Watershed Protection for U.S. Environmental Protection Agency, Office of Water Management. Washington, D.C.

This is the tenth manual in a series of eleven which serves as a compendium for the volumes of information regarding watershed restoration. The tenth manual is a description of the Unified Stream Assessment (USA) methodology which is designed to evaluate buffer conditions and identify restoration opportunities. As with many of these assessment tools the Rapid Bioassessment Protocol (Barbour, et al., 1999) is one of the main methodologies upon which this method is based, but also includes components from other methods. This method examines eight specific impact assessments including: outfalls, severe bank erosion, impacted buffers, utilities in stream corridors, stream crossings, channel modification, trash and debris, and miscellaneous impacts. This information is then distilled into a reach level assessment. Like some of the source materials that this is drawn from, ultimately the various impact assessments are entered into an additive scoring system. The simplicity of this approach encourages its use and allows for a direct comparison of various reaches in aggregate or by each impairment category. Generally, this approach does not offer anything new that is not discussed in the other documents, however the area in which it is most useful is the description of the impairments. While the Stream Geomorphic Assessments cover the same areas in detail, this manual is both more simplistic in the assessment methods, but covers each in probably greater detail with extensive photographs that could be valuable in illustrating certain points. This manual is likely to serve primarily as a complement to other more technical approaches suitable for the Highlands assessments.

Urban Subwatershed Restoration Manual No. 11 - Unified Subwatershed and Site Reconnaissance: A User's Manual

Wright, T., C. Swann, K. Cappiella, and T. Schueler. 2005. *Urban Subwatershed Restoration Manual No. 11 - Unified Subwatershed and Site Reconnaissance: A User's Manual.* Prepared by Center for Watershed Protection for U.S. Environmental Protection Agency, Office of Water Management. Washington, D.C.

This manual is the next and last in the Urban Subwatershed Restoration Manual series. Like manual 10 it is primarily an assessment methodology. It differs in that it focuses on upland areas in urban watersheds. The Unified Subwatershed and Site Reconnaissance (USSR) represents a significant difference from the other reviewed materials and really leaves behind the concept of corridor assessment. With that said, it still follows the same basic outline of other assessment methodologies in developing an inventory of potential stressors leading to a loss of functional value in riparian corridors or watersheds on the whole. The USSR is composed of four main components: neighborhood source assessment (NSA), hotspot source investigation (HSI), pervious area assessment (PAA), and streets and storm drains (SSD). Collectively, these assessments are used to quantify pollutant and hydraulic loading in the watershed, in an effort to develop projects to mitigate these impacts. Like the other reviewed methods this consists of both desktop analysis and field work, leading to the creation of maps, simple analyses, and a compilation of data. While generally simple, the methods described are thorough. This method could actually be quite valuable and should be considered for incorporation in this plan. In general, most of the riparian corridor assessments generally assume a more or less naturalized corridor that while exhibiting encroachment within the floodplain or certain channel alterations urban encroachments are generally poorly examined. While much of the Highlands is still rural and relatively natural, there are certainly areas that are highly developed in valley bottoms. Incorporating this method for urbanized uplands could be valuable. While the geomorphic properties of the stream should still be assessed using the Phase II methodology, other functions of riparian corridors, such as nutrient mitigation, could be examined in a cursory way through the adoption of a modification of such a method for the Highlands.

Applied River Morphology

Rosgen, D. 1996. *Applied River Morphology.* Wildland Hydrology. Pagosa Springs, CO.

This is the base text used in the Rosgen method. This text, and the approach in general, has been controversial. In general the approach has been relatively widely adopted, however some critics claim it is lacking in substance with too much concentration on form over function. According to Rosgen, improper application of the methods are usually to blame for failures in associated projects. In any case, it is a widely adopted text and at least portions of it have been almost universally adopted in most technical geomorphic assessments. Generally, the Rosgen method advocates an approach of basic rivers management that shares many of the themes found in the Vermont guidance, namely that stable rivers systems exist in dynamic equilibrium and it is important to design management programs to reach this state of equilibrium. The biggest innovation in the approach, and the part that is most widely adopted, is the classification of natural river systems. This classification scheme groups river systems according to a variety of morphological features, one that all river systems can be fit into along the continuum of the classification scheme. One of the key ideas is that valley types and topographic features are important driving factors in the form of a river, setting up the hydraulics and sediment transport functions that result in a given form. Much of the text concentrates on the description of these forms. Other portions of the book examine stream condition, departure and sensitivity, channel evolution, the verification of field data, and finally applications of the method.

Parts of this approach are liberally used in the Vermont guidance and thus this text will be an invaluable asset in completing that approach. The geomorphic assessments rely heavily on characterizing river type per the Rosgen classification scheme, identifying reference conditions which again will be based strongly on the identification of Rosgen valley types and the resultant stream form, and finally conducting departure and sensitivity analyses which are based on examining differences in existing and reference conditions by river type. This text explains in detail the methods to identify river types and will be a primary text in the development of assessment methodologies.

Rapid Bioassessment Protocols for use in Streams and Wadable Rivers

Barbour, M., J. Gerritsen, B. Snyder, and J. Stribling. 1999. *Rapid Bioassessment Protocols for use in Streams and Wadable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. 2nd ed.* U.S. Environmental Protection Agency, Office of Water. Washington, D.C.

The Rapid Bioassessment Protocols (RBP) is a huge compendium of data covering the biological assessment of various aquatic taxa. This document has had an unusual effect on the community of users both by advocating the adoption of universal practices that have proven to be both robust and relatively easy to implement and by encouraging the adoption of local variations that are consistent with the field conditions. In practice variations of the RBPs are seemingly in use by most of the states. As the full title of the document reveals, the RBP focuses mainly on biological sampling in wadable rivers for periphyton (attached benthic algae), benthic macroinvertebrates (stream insects and other aquatic invertebrates), and fish. It covers a number of robust field methods for each of these disciplines, and also covers data analysis approaches. Both the field methods and the data analysis, including the development of indices of biotic integrity, are widely adopted by NJDEP either directly or in a modified format.

For the Highlands project, the RBP have been adopted in a modified form for the in-stream habitat assessment, called the visual habitat assessment in the RBP. While not directly related to geomorphic assessments, additional components of the RBP should be considered for inclusion in the protection guidance in the interest of preserving and defining the resources of the riparian functional values in a second tier evaluation. For instance, the implementation of certain restoration projects may require significant in-stream work that could temporarily cause habitat disturbances. If a suspected threatened or endangered species is known to inhabit the reach in question, field surveys will need to be conducted to verify these suspicions. In another scenario the discharge of pollutants into a waterway may require the investigation on the impacts to biota. While this aspect of project development should be covered by regulatory authorities especially through the permitting process, the acknowledgement of this eventuality should be made explicit.

Plant Stewardship Index

BHWP. *Plant Stewardship Index Program.* Bowman's Hill Wildflower Preserve. New Hope, PA.

The Plant Stewardship Index, or PSI, is an index promoted by Bowman's Hill Wildflower Preserve to assess the quality of plant communities. This approach will be the primary method utilized in assessing the quality of riparian plant communities. The PSI, which is a modification of the Floristic Quality Assessment (FQA) developed by Swink and Wilhelm, focuses on describing the "naturalness" of the examined site as well as how land use practices have affected the plant community. Ultimately the PSI describes the sensitivity and overall quality of the plant community in an area, which in turn is related to site disturbance. High quality plant communities are characterized by specialist species with strict habitat requirements, also called conservative species, which show high sensitivity to disturbance. These plants therefore are only found in undisturbed environments. On the other hand, disturbed sites are generally colonized primarily by generalist species which are disturbance-tolerant, and frequently these plants are non-native invasive species. The PSI, as well as the FQA, consists of a desktop analysis based on current and historic aerial photographs and field surveys. Sites that have the potential to be relatively natural are surveyed in more depth in the field. All plants are then identified along survey transects per a given methodology and assigned coefficients of conservatism. Specialist plants are assigned higher coefficients, up to 10, while strict generalists and non-native plants are assigned a 0 coefficient. A community mean is then calculated for both the entire plant community and the native community and both a PSI and FQA are calculated, the difference between the scores indicating the effect of non-native vegetation. It is important to note that density or coverage is not a factor in PSI calculations, merely presence or absence. The PSI will be very useful for characterizing plant community quality and by proxy functionality in the riparian corridor. Disturbed sites and poorly functioning buffers should be characterized by low scores, while high quality sites will have higher scores. Buffer impairment in plant communities is likely to be caused by two distinct, although not unrelated stressors. Buffers can be impaired by anthropogenic land disturbances, such as paving and other impervious features, maintained lawn space, or agricultural uses, or by fluvial processes in which frequent channel migration or severe flooding, often the result of anthropogenic effects, can maintain the site in a permanently disturbed state. The PSI will be a very valuable tool for assessing buffer habitat quality.

Functional Value Assessment Guidance

NJDEP. 2007. *Administrative Order No. 2007-01: Special Water Resource Protection Area Functional Value Analysis.* New Jersey Department of Environmental Protection. Trenton, NJ.

The Functional Value Assessment Guidance published through administrative order is a clarification of N.J.A.C. 7:8-5.5(h), a clause of what is commonly referenced as the Stormwater Rules. The rule, which calls for the preservation of the functional value and overall condition of the Special Water Resource Protection Area (SWRPA), or the 300 foot buffer, did not specify a method to assess these values in the SWRPA and this guidance is designed to provide that methodology. This guidance is meant to clarify the legality of proposed development in the SWRPA according to its impact on the defined functional values of the riparian buffer; under most circumstances no activities will be permitted that impair the existing functional value of the SWRPA. This guidance defines four functional habitat values, namely habitat, nonpoint source pollution reduction, temperature moderation, and channel integrity. For each of these values it provides an assessment methodology for current conditions, assessing future conditions, and a standard stating what is considered a loss of functional value. It goes on to discuss the analysis in terms of potential development, and ultimately the minimization and mitigation of functional value loss in cases of unavoidable disturbance, for instance road development or structural repair.

While the functional value guidance provides a good starting point in the definition of functional values, the standards against which to judge potential loss of functional value, and what the result of a loss of functional value means for development in the SWRPA, the actual assessment methodology is still fairly vague. The Highlands Stream Protection Guidance seeks to build upon the functional value guidance by establishing a firm assessment methodology with a defined and repeatable set of protocols to be used throughout the Highlands. Ultimately, both desktop and field components will point to empirical data collected in a scientific manner and evaluated in an objective fashion that will produce defensible and definitive statements of functional values and provide the framework upon which to measure future conditions.

The Active River Area: A Conservation Framework for Protecting Rivers and Streams

Smith, M, R. Schiff, A. Olivero, and J. MacBroom. *The Active River Area: A Conservation Framework for Protecting Rivers and Streams*. The Nature Conservancy. Boston, MA.

Like most of the other reviewed documents, this approach concentrates on the concept of a dynamic river system that exhibits channel migration, but broadens the spatial context somewhat. Where some approaches mostly focus on protecting and preserving within the meander belt, this approach is expanded to include not only the meander belt, but low and high floodplains and other features throughout the tributary network. In some respects, this more closely mirrors some of the fluvial erosion hazard floodways in the expansion of an active river corridor. Defining the active river area is important in this concept and looks at material contribution areas, the meander belt, floodplains, terraces (also sometimes called abandoned floodplains), and riparian wetlands. The physical, chemical, and biological functions and services of each of these areas are described in detail, which is a restatement of functional values. The delineation of the active river area is model based, relying strongly on LU/LC and soils data, and the inclusion of not only adjacent wet areas with defined or theoretical flow paths as well as materials contribution areas, areas that are sources of bed materials and solids generally, is a definite departure from pure topographic and hydraulics models, and places this approach in a wider watershed context. The use of models is a beginning step in this approach and field geomorphic assessments, including the Vermont methods, are also included. A literature review of various river restoration techniques is given in this document, which in fact served as a source of some of the studies reviewed by this document.

There is certainly some useful restoration language in this guide that can be fitted into the framework of the Vermont guidance. This plan in fact fills in some of the gaps in the actual restoration techniques outlined only broadly in the Vermont plans. First, this plan discusses that management of the active river area needs to be conducted in concert with general freshwater protections and conservation strategies with a basic goal of preserving or enhancing the hydrologic regime, which is the root cause of most river impairments. The plan begins to focus on channel evolution models and the effects on the various components of the active river area, and stressor identification which is then used to explore restoration techniques. What is especially useful, and definitely warrants inclusion in the Highlands guidance, is the exploration of restoration approaches. Restoration approaches consist of "no action" by allowing natural processes to occur over time, passive approaches that remove or reduce stressors without direct intervention in the river area, and active approaches including bioengineering and structural measures. The design of active restoration measures can be analog designs that copy reference areas or analytical methods involving modeling. An analytical approach is likely to be most prominent in the Highlands as analog methods have shortcomings in the use of reference conditions as described above. Only analytical methods will address existing conditions that have caused impairments, although natural reaches should still guide general forms. Following this is an excellent table of various restoration techniques to address a large number of impairments as well as sources that show their design and implementation that should be added wholesale to this project.

Urban Subwatershed Restoration Manual No. 1 – An Integrated Framework to Restore Small Urban Subwatersheds

Schueler, T. 2005. *Urban Subwatershed Restoration Manual No. 1 - An Integrated Framework to Restore Small Urban Subwatersheds.* Prepared by Center for Watershed Protection for U.S. Environmental Protection Agency, Office of Water Management. Washington, D.C.

This manual is the first in the Center for Watershed Protection series for Urban Subwatershed Restoration. This manual serves as a basic introduction to the series focusing on the rough framework and methods described in detail throughout the rest of the series. This manual is probably most useful as an introduction to stakeholders, landowners, and other interested parties to explain the concepts of watershed and riparian corridor restoration. While basic, it covers all the highlights of the process, including the process of organization to affect positive change in watersheds, the alteration of watersheds and their impact on stream function, a review of restoration practices, developing goals for restoration, and explaining the general framework of restoration programs from start to finish. This document is ultimately of little use for this project, except as stated above, as an introduction to people becoming initially involved in such endeavors that would serve as useful introductory guide.

Urban Subwatershed Restoration Manual No. 2 – Methods to Develop Restoration Plans for Small Urban Watersheds

Schueler, T. and A. Kitchell. 2005. *Urban Subwatershed Restoration Manual No. 2 - Methods to Develop Restoration Plans for Small Urban Watersheds.* Prepared by Center for Watershed Protection for U.S. Environmental Protection Agency, Office of Water Management. Washington, D.C.

This manual is the follow up to the first manual in the series and describes the steps necessary to assemble a watershed protection plan. In fact, this manual describes 32 desktop analyses, field assessments, and stakeholder involvement methods used in the process. While this covers the same ground discussed in the first manual it does so in a more detailed fashion and looks at developing goals, screening priority subwatersheds, evaluating restoration potential, investigating restoration projects, assembling watershed plans, determining if goals are met by the plan, implementing the plan, measuring improvements over time, and scoping and budgeting a restoration plan. Overall, this document is somewhat similar to the EPA guidance, but the topics are covered in more detail and in a more cohesive fashion in other documents. Overall, this manual will be of limited utility although some of the multitudinous checklists could potentially be used.

Design for Stream Restoration

Shields, F., R. Copeland, P. Klingeman, M. Doyle, and A. Simon. 2003. *Design for Stream Restoration.* Journal of Hydraulic Engineering. 575-584.

This paper is technical design guidance for channel rehabilitation projects. It explores some of the main topics of concern in engineering channel restoration and balancing design goals between natural fluvial geomorphic processes and ensuring channel stability in urbanized corridors to protect existing development and infrastructure. Again, this paper discusses the concepts of dynamic equilibrium of river channels and introduces a different term to describe this concept, dynamism. The recommended engineering approaches focus on hybrid methods and uses geomorphic assessments, empirical tools, and simple one-dimensional hydraulic modeling in the development of design criteria. Like other engineering approaches, the statement of design objectives early in the project is crucial. Much of the design will be based on channel-forming flows (Q_{cf}) or dominant flow. This flow can be derived in several fashions including defining the effective flow, which is the flow that cumulatively (combining frequency and sediment transport capacity) moves the most sediment and thus is primarily responsible for much of the channel shaping, the bank full discharge which is often assumed to be the effective flow, and the return interval discharge, which in this area is generally assumed to be on a 1 to 2 year return interval. With the identification of the Q_{cf}, the design criteria of width, slope, depth, meander geometry, and channel alignment can be calculated in combination with sediment influx and bed material composition. While all of these parameters can be modeled using a number of different models, reference conditions can also be important in influencing design decisions, especially for meander geometry and channel alignment. An important caveat is that reference conditions, either calculated or measured at an analog, must show no significant deviation in hydrology and other conditions from the stream, which is frequently hard to match in urbanized settings. In such a case modeled data will be more important in developing a design. This recognition of departure from reference conditions is an important consideration and one that must be highlighted in the Highlands guidance to avoid developing designs and projects based on reference conditions that do not adequately address existing hydrology.

Channel Restoration Design for Meandering Rivers

Soar, P. and C. Thorne. 2001. *Channel Restoration Design for Meandering Rivers.* US Army Corps of Engineers, Coastal and Hydraulics Laboratory. Washington, D.C.

Channel Restoration Design for Meandering Rivers is a voluminous engineering manual of a highly technical nature. It provides exactly what the title promises and reflects its status as a document and engineering philosophy meant to counteract the historic channelization of river systems throughout the United States. More importantly this document deals with restoration in meandering systems thus approximating a restoration of at least some natural fluvial processes to river systems. The Army Corps of Engineers is the primary environmental engineering arm of the United States government and is also an important regulator and reviewer of restoration design plans, and this manual reflects that position. Like other documents, this one briefly hits upon some of the functional values and environmental services of riparian systems, as well as their assessment, but this is primarily geared towards the engineering of channels. It largely ignores corridors other than placing a focus on bank stability and the utility of floodplains as storage features for sediment and water. The use of this document is largely limited in the development of the Highland guidance because it reflects the end game of design and does not focus strongly on corridor concerns in a broader context. With that said, this guide will be referenced as a primary resource in the engineering and implementation of engineered projects.

Guidelines for Naturalized River Channel Design and Bank Stabilization

Schiff, R., J. MacBroom, and J. Armstrong Bonin, 2007, *Guidelines for Naturalized River Channel Design and Bank Stabilization*. Prepared by Milone & MacBroom, Inc. for the New Hampshire Department of Environmental Services and the New Hampshire Department of Transportation, Concord, N.H.

This document is another that focuses heavily on the engineering aspects of river corridor management and covers much of the same ground as the other manuals with a basic tenet of returning rivers to a natural regime. Basic points are reiterated about the process including the selection of appropriate design methods, identifying constraints and stressors, and the social acceptance of projects. It also expands a little on some of the design philosophies in use and examines unnatural rigid designs, typically responsible for many problems associated with channelization, semi-natural form designs, which incorporate natural processes where possible but maintains other more highly engineered aspects to promote bank stability, and natural process designs. These different design approaches also fall within different project types which include routine projects, moderate projects, and comprehensive projects. The document then goes on to explore topics such as project planning and data requirements, which mirror much of the Phase I efforts, hydraulics and hydrology data, biological sampling, problem identification, and setting goals and objectives. This document also discusses in somewhat more detail some different aspects of projects including permitting and adequate monitoring, both pre and post implementation. This guide contains a good table linking project designs to impairments in the corridor. Design criteria are also explored which discusses the use of reference reaches, empirical data, and modeling. This document serves as a sort of bridge between some of the most technical engineering works and the planning level guidance while still providing technical engineering strategies. This will serve as a reference in the intersection of these areas within the guidance.

Appendix B:
Simplified Dichotomous Key

Protect River Corridors

1. **Land Cover:** Is the stream corridor largely undeveloped, consisting primarily of forest or wetland land cover with few encroachments?
   Yes: Proceed to Step 2: Channel Constraint.
   No: Proceed to Step 4: Native Perennial Riparian Vegetation.

2. **Channel Constraints:** Is the channel largely unconstrained (i.e. armored or bermed) and if not actively managed could the channel maintain or adjust to equilibrium conditions? The ability to maintain or adjust to channel equilibrium is determined by optimal to good channel integrity scores.
   Yes: Enact corridor protection plan and then proceed to Step 3: Channel Equilibrium.
   No: Proceed to Step 4: Native Perennial Riparian Vegetation.

Plant Stream Buffers

3. **Channel Equilibrium:** Is the stream channel at or near equilibrium in terms of depth, slope, and floodplain relationship as indicated by good to optimal Channel Integrity Conditions?
   Yes: Proceed to Step 4: Native Perennial Riparian Vegetation.
   No: Proceed to Step 8: Degradation.

4. **Native Perennial Riparian Vegetation:** Is there native perennial riparian vegetation on both sides of the stream with good to optimal Riparian Plant Community scores?
   Yes: Proceed to Step 5: Re-alignment.
   No: Plant stream buffer with native vegetation and then proceed to Step 5: Re-alignment.

Stabilize Stream Banks

5. **Re-alignment:** Is the channel undergoing lateral movement by eroding either bank as indicated by fair to poor channel integrity re-alignment scores?
   Yes: Proceed to Step 6: Proximity to Structures.
   No: Proceed to Step 8: Degradation.

6. **Proximity to Structures**: Is the eroding bank within 50 feet of a structure or other infrastructure including roadways?
   Yes: Stabilize stream bank to stop lateral migration and where possible encourage the growth of woody buffer, then proceed to Step 8: Degradation.
   No: Proceed to Step 7: Sedimentation.

7. **Sedimentation:** Is the reach affected by an increase in sediment supply or is the reach highly sensitive and subject to extreme natural deposition? This is determined by fair to poor scores for the watershed assessment, especially soil runoff, soil erodibility, and land use/land cover. Also indicated by fair to poor channel integrity aggradation and high channel sensitivity.
   Yes: Proceed to Step 27: Decrease in Stream Power.
   No: Stabilize the stream banks or employ flow deflection structures to halt lateral movement and maintain long-term stability. Do not constrain downstream channel migration and allow for revegetation. Proceed to Step 8: Degradation.

Arrest Head Cuts

8. **Degradation:** Is the stream bed actively eroding? Have head cuts been identified?
   Yes: Proceed to Step 9: Floodplain Abandonment.
   No: Proceed to Step 10: Presence of Berm(s).

9. **Floodplain Abandonment:** Is the stream in the process of abandoning a functioning floodplain as indicated by fair to poor channel integrity bank height ratio and headcut score?
   Yes: If no natural grade control exists within a meander wavelength upstream of the headcut (as determined by examining approximately 14 bank full widths), construct one of the grade controls discussed above. Proceed to Step 10: Presence of Berm(s).
   No: Proceed to Step 10: Presence of Berm(s).

Remove Berms

10. **Presence of Berm(s):** Is there a berm or abandoned levee, road, or railroad embankment adjacent to the surveyed reach?
   Yes: Proceed to Step 11: Floodplain Disconnection.
   No: Proceed to Step 13: Flow Constriction.

11. **Floodplain Disconnection:** Is the berm causing disconnection of the stream and floodplain?
   Yes: Proceed to Step 12: Infrastructure Flood Risk.
   No: If no, it is assumed that the stream is deeply incised or the berm sufficiently distant from the stream that berm removal would not contribute to increased floodplain connectivity; proceed to Step 13: Infrastructure Flood Risk. In case of severe incision, projects to restore incised reaches would need to be considered in Step 19: Stream Power. Further information regarding evaluation of incised reaches can be found in the Restore Incised Reach discussion below.

12. **Infrastructure Flood Risk:** Are there developments, land uses, or structures within the river corridor that would be placed at risk by normal flooding cycles?
Yes: Proceed to Step 13: Flow Constriction.
No: Remove Berms and proceed to Step 13: Flow Constriction.

Remove or Replace Structures

13. **Flow Constriction:** Are there bridges, culverts, abutments, dams, weirs, or other structures that span or otherwise significantly constrain vertical and lateral movement of the channel or result in floodplain constriction?
Yes: Proceed to Step 14: Sediment Deposition Upstream of Structure.
No: Proceed to Step 18: Increase in Stream Power.

14. **Sediment Deposition Upstream of Structure:** Is there significant sediment deposition upstream of the structure or within the impoundment that would erode or mobilize upon removal? This can be determined from fair to poor scores in the channel integrity aggradation.
Yes: Proceed to Step 15: Flooding Risk Due to Modification.
No: Proceed to Step 17: Structure Condition.

15. **Flood Risk Due to Structure Modification:** Are there developments or land uses with the stream corridor that would be significantly affected by channel bed elevation changes or bank instability due to changes in sediment erosion/deposition upon removal?
Yes: Proceed to Step 18: Increase in Stream Power. Further evaluation of structures may be needed while considering restoring incised reaches; structure removal may still be viable with consideration for property protection and channel bed stabilization.
No: Proceed to Step 16: Sediment Mobilization.

16. **Sediment Mobilization:** Is sediment mobilization from the impoundment likely to cause significant downstream channel adjustment inconsistent with equilibrium conditions? This may involve assessing reaches downstream using the FVAM and evaluating aggradation/degradation as well as general instability.
Yes: Modify the structure to reduce its adverse impacts. Implement a sediment management plan, which will involve partial or complete removal of the sediment, place in-channel grade controls, or otherwise stabilize the sediment and encourage floodplain restoration and functionality. Modifications are only desirable if the structure is functional and active. Proceed to Step 18: Increase in Stream Power.
No: Remove or modify/replace the structure and then proceed to Step 18: Increase in Stream Power.

17. **Structure Condition:** Is the structure derelict or nonfunctional?
    Yes: Remove the structure and implement proper grade control and bank stabilization as needed. Proceed to Step 18: Increase in Stream Power.
    No: Proceed to Step 18: Increase Stream Power.

Restore Incised Reach

18. **Increase in Stream Power:** Is the channel steeper or straightened, indicated by fair to poor bank armoring/channel straightening or sinuosity scores, or fair to poor bank height ratio, resulting in increased stream power and sediment transport capacity?
    Yes: Proceed to Step 19: Cause of Increased Stream Power.
    No: Proceed to Step 27: Decrease in Stream Power.

19. **Cause of Increased Stream Power:** Is the increase in stream power the result of significantly reduced sediment supply or increased peak flows? Increased peak flow can be ascertained by examining impervious cover rating in the watershed assessment. Sediment starvation would be indicated by an upstream impoundment. Increase in stream power not related to peak flow increases would include localized channel modification (i.e. increased slope through channelization and bank armoring).
    Yes: Proceed to Step 20: Watershed Modifications.
    No: Proceed to Step 21: Recent Channel Equilibrium.

20. **Watershed Modification:** Can watershed input stressors be reduced within 5 years as a result of project implementation upstream?
    Yes: Proceed to Step 21: Recent Channel Equilibrium.
    No: Proceed back to Section 3.9 Watershed Management of main text.

21. **Recent Equilibrium Channel:** Is it possible to restore the stream to a recently abandoned channel in equilibrium?
    Yes: If no other constraints are present, restore the incised channel to the abandoned channel. The project will incorporate elements of bed and bank stabilization, grade control, corridor restoration, and removing berms or other constrictions. Then proceed to Step 27: Decrease in Stream Power.
    No: Proceed to Step 22: Permanent Constraints.

22. **Permanent Constraints:** Is there active infrastructure and permanent constraints in proximity to the channel?
    Yes: Proceed to Step 23: Channel Armoring.
    No: Proceed to Step 24: Constraints to Floodplain Restoration.

23. **Channel Armoring:** Are the bed and banks completely armored such that erosion has been halted?

Yes: Pursue high priority river corridor protection at downstream reach to attenuate flow and sediment transported through the channelized reach. Then proceed to Watershed Management, Section 3.9 of main text.

No: Implement incision restoration practices as described above. Corridor protection practices should be implemented downstream to attenuate flow and sediment transport. Then proceed to Watershed Management, Section 3.9 of main text.

24. **Constraints to Floodplain Restoration:** Are there current land use constraints, flow and sediment load alterations, or project feasibility concerns that would inhibit or prohibit active restoration of floodplain connectivity and channel migration in the meander belt?

Yes: Proceed to Step 25: Corridor Protection.

No: Proceed to Step 26: Rapid Equilibrium.

25. **Corridor Protection:** Can corridor protection be implemented to allow for passive adjustment to equilibrium?

Yes: Implement river corridor protection to allow for passive restoration and channel adjustments to proceed to equilibrium conditions.

No: Defer further actions until such projects are feasible, which may occur after further deterioration and unsustainable losses or a change in ownership or liability. Proceed to Watershed Management, Section 3.9 of main text.

26. **Rapid Equilibrium:** If there are no encroachments to the channel or floodplain, would the stream quickly equilibrate to a geometry that results in a reduction in stream power? Rapid equilibration is more likely in high sediment supply environments, which can be determined by a lack of upstream impoundments or other in-channel encroachment and in systems subject to erosion upstream or where bed and bank materials are highly erodible.

Yes: Allow for passive restoration of incised reach through corridor protection and then pursue corridor protection.

No: Actively restore the incised reach through channel realignment with correct sinuosity and by excavating a new floodplain to reconnect with the current bed elevation to create new equilibrium conditions.

Restore Aggraded Reach

27. **Decrease in Stream Power:** Is the decrease in stream power the result of increased sediment supply or decreased peak flows? Sediment supply can again be inferred by soil erodibility and land use factors; decrease of peak flows is unlikely unless there has been a significant consumptive surface water withdrawal.
    Yes: Proceed to Step 28: Watershed Stressors.
    No: Proceed to Step 29: Backwater or Impoundments.

28. **Watershed Stressors:** Can watershed stressors, such as increased sediment supply, be significantly managed within 5 years?
    Yes: Proceed to Step 29: Backwaters and Impoundments.
    No: Proceed to Watershed Management, Section 3.9 of main text.

29. **Backwater or Impoundments:** Is sediment deposition the result of backwater conditions or impoundment as the result of artificial floodplain or channel constrictions such as bridges or dams?
    Yes: Proceed to Step 30: Increased Sediment Transport.
    No: Proceed to Step 31: Channel Over-widening.

30. **Increased Sediment Transport:** Is it feasible to increase sediment transport through the dammed or constricted reach?
    Yes: Restore the reach by modifying or removing the constrictions in the channel or floodplain to increase sediment transport or otherwise attain equilibrium. Follow up by implementing watershed management and proceed to Watershed Management discussion, Section 3.9 of main text.
    No: Protect the river corridor in these areas to minimize any additional stressors, especially when plans to modify the channel and stream corridor upstream and downstream are untenable or infeasible. Proceed to Watershed Management discussion, Section 3.9 of main text.

31. **Channel Over-widening:** Is floodplain connectivity maintained and sediment generated within the reach leading to over-widening of the channel? Optimal to good channel integrity, floodplain encroachment ratio, and bank height ratio indicate adequate floodplain connectivity, while fair to poor channel integrity width-depth ratios indicate an over-widened channel.
    Yes: Restore the reach by addressing stressors that have caused over-widening. This will likely require reducing channel dimensions and stabilizing the banks through general stabilization and flow deflection techniques as well as riparian protection and buffer planting.

No: Protect the river corridor in these areas to minimize any additional stressors, especially when plans to modify the channel and stream corridor upstream and downstream are untenable or infeasible. Proceed to Watershed Management discussion, Section 3.9 of main text.