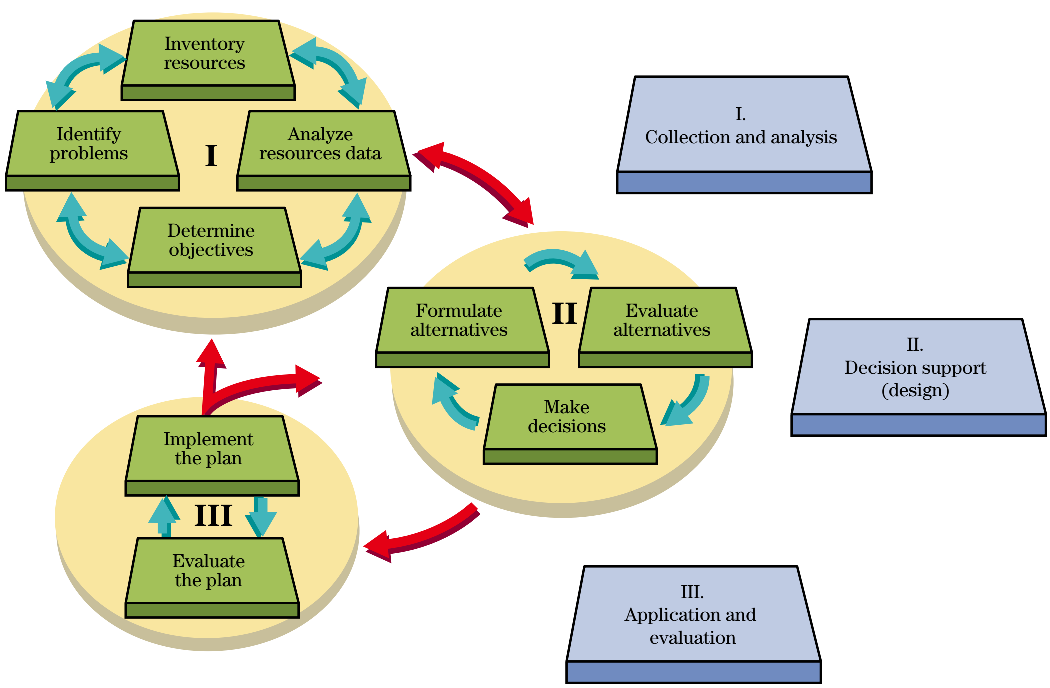
United States
Department of
Agriculture

**Natural
Resources
Conservation
Service**

**Part 654 Stream Restoration Design
National Engineering Handbook**

Chapter 4 Stream Restoration Design Process



Issued August 2007

Cover illustration: Design of solutions for stream problems is a part of the restoration planning process. Designs translate the desired changes into the stream and riparian zone. Changes to the design may cause goals and objectives to be reevaluated, as the planning process may be iterative.

Advisory Note

Techniques and approaches contained in this handbook are not all-inclusive, nor universally applicable. Designing stream restorations requires appropriate training and experience, especially to identify conditions where various approaches, tools, and techniques are most applicable, as well as their limitations for design. Note also that product names are included only to show type and availability and do not constitute endorsement for their specific use.

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654.0401 Purpose

The purpose of this chapter is to provide an overview of the process for designing stream restoration solutions. The design process is integrated with the overall planning process. To design a solution means to fit it into the landscape, into the stream system, so that the result meets the goals and objectives of the plan. Solutions may range from no action to management and simple removal of perturbations, to site-specific practices, to riparian corridor and watershed-scale restoration systems.

Often, solutions to stream problems (fig. 4–1) are suggested at the time that they are identified, such as: "My streambank is eroding. We need to put rock riprap on it." It could be that the problem merits that response. It could also be that the nature of the bank erosion problem is more complex and may be related to a general instability of the stream system. An interdisciplinary, onsite analysis is critical to the development and success of any designed solution or system.

The design of a solution to a stream problem must address the goals and objectives developed from the planning process. Once a solution is agreed upon, the design process determines the feasibility of the solution and whether goals or objectives must be revised or whether a different designed solution should be pursued. A cookbook design procedure is not recommended since each project and each design will have differing goals and objectives, physical or biological constraints, and jurisdictional requirements and constraints.

This chapter provides an integration of the conservation planning process (CPP) with stream restoration design concepts and provides the foundation for using the tools and procedures in the following chapters. Note that design of stream restoration solutions may include a wide range of design elements, from management practices to structural practices, the selection of which depends on the nature of each individual project.

654.0402 Introduction

Planning actions to fix stream problems can be a complex process. This is due to the interactions between possibly many stakeholders: people who affect or are affected by the stream problems and any potential solutions. How streams are supposed to look and function are ideals that vary from one person to another. Philosophies and approaches to stream restoration abound: restore to what conditions or functions?

This chapter overviews the process for developing designs to solve stream problems. There are many steps in the overall process (NEH654.02). Some steps may be accomplished quickly, while others may require lengthy analysis, data gathering (NEH654.03), or discussion with stakeholders, depending on the magnitude and complexity of the problems, as well as constraints posed by boundary conditions, funding, attitudes, or local requirements (fig. 4–2). Problems that are localized and involve only a single land user may be planned and designed rapidly. Designs must also address environmental and ecological factors, as well as satisfy the immediate stream restoration need. Streams in urban areas present unique challenges for restoration (fig. 4–3).

Figure 4–1 Severe bank erosion along the Connecticut River eroded cornfield and resulted in excessive sediment in the river

Appropriate and effective stream solutions can only be designed when the goals and objectives of the planned solutions are clear, realistic, and adequately formulated. NEH654.02 focuses on the importance of identifying the goals and objectives of any proposed stream action that will drive the design approaches. It also expands on the concept of risk associated with stream solutions—the risk of failure of the implemented design elements, the risk of creating ecological imbalances, as well as the risk of not achieving the intended results.

The importance of collecting the right information to assess the nature of the temporal, physical, and biological nature of the problem are addressed in NEH654.03. The information collected will also facilitate the design process and form the basis for making assessments of the overall success of the project after implementation.

This chapter introduces an overall design procedure, which is an integral part of the planning process for stream design. The purposes of stream designs can range from simply conveying water to restoring self-sustaining ecological functions and values to the stream corridor. The design process may be iterative, in that the initial design may require cycling back through some of the planning steps, making decisions, possibly modifying goals and objectives, and redesigning alternatives. Stream designs may include a variety of solutions ranging from upland watershed and riparian area management practices that may be needed, large-scale reconstructions of entire stream reaches, localized applications that can involve earth materials, live and inert plant materials, and manufactured materials.

Figure 4–2 How streams are supposed to look and function are ideals that vary from one person to another.

Figure 4–3 Lined channels may be necessary, based on boundary constraints, drainage needs (discharge capacity), and maintenance costs.

654.0403 The CPP for stream design

The design and management of streams must address the myriad of resource concerns, as well as client objectives, to support near- and instream stabilization activities in a sustained manner. In general, prescribing the treatment for a stream is based on the site or reach conditions including historic and reference stream corridor information and objectives of the decision-making client, as well as stakeholders who influence the client. This important issue was first addressed in NEH654.02.

Stream restoration is defined here as one or more conservation practices used to overcome resource impairments and accomplished the identified purposes based on client objectives for a conservation management unit (CMU) containing, in whole or part, the stream corridor needing treatment.

A stream corridor includes the stream and extends in cross section from the channel's bankfull level towards the upland (perpendicular to the direction of streamflow) to a point on the landscape where channel-related surface and/or soil moisture no longer influence the plant community. Figure 4–4 illustrates an idealized cross section of a stream corridor (modified from Stanford and Ward 1992).

This description encompasses moisture influenced land on both sides of a channel. The length of a stream corridor is typically a sinuous band that follows both sides of the channel from the headwaters to the mouth of the stream system. Depending on channel conditions (stream order, channel evolution model (CEM) stage, bankfull width, degree of incision, and flood plain characteristics), the width of this longitudinal band fluctuates with corresponding influences on the kind and composition of riparian vegetation within the band. In mountainous areas, changing elevations along the stream corridor determine riparian community composition because of the varying cold-hardiness capacity of individual plants. Also in effect are cross-sectional variations in microclimate and soils, which influence the kind and mix of riparian species. Stream corridor soils are typically not a single soil series, but a complex of named soil series and taxadjuncts. Taxadjuncts are soils closely associated with a named series that differ somewhat in one or more soil characteristics, which may further complicate the planning process.

Table 4–1 lists and figure 4–5 illustrates the steps in the Natural Resources Conservation Service (NRCS) CPP. This was described in NEH654.02. Detailed information about each of these steps is provided in the NRCS National Planning Procedures Handbook (NPPH) (USDA NRCS 2003b). These steps are applied for each CMU on a client's planning unit. An important aspect of the planning process is how the proposed stream restoration practice(s) will interact and work compatibly with other practices in the resource management system (RMS) to address all pertinent resource concerns in achieving resource quality criteria (refer to Section III of the local NRCS Field Office Technical Guide (FOTG), available for each county at *http://www.nrcs.usda.gov/Technical/efotg/*).

Figure 4–4 Cross-sectional view of a generalized stream corridor segment. Biota may reside in all dimensions (riparian, inchannel, hyporheic and/or ground water zone). Inundation and desiccation of the blue shaded area occurs as the amplitude of the discharge increases and decreases under a natural flow regime. Sd designates sediment deposition sites, and Se is a site of bank erosion. The solid line is the thalweg, and the broken lines indicate the different directions of flow and materials among inchannel, hyporheic, and ground water zones.

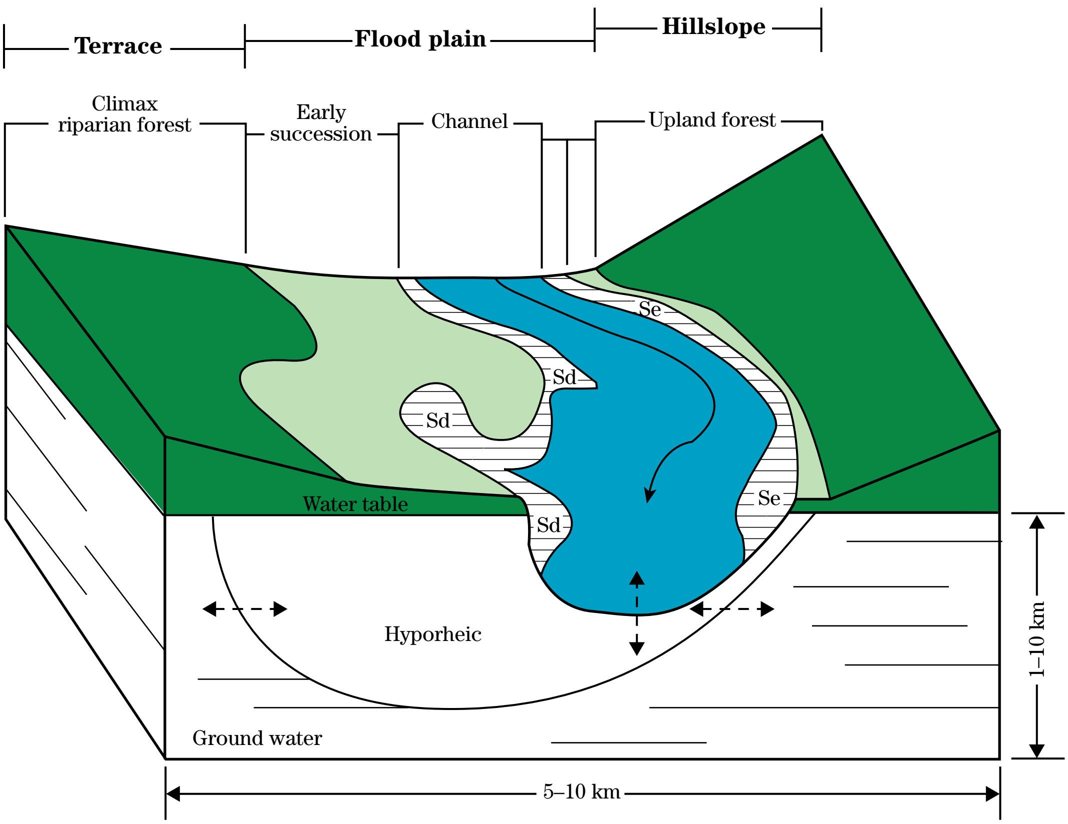


Table 4–1 Steps in the NRCS CPP

Steps	Planning activity	Level	Potential iterations
1	Identify problems and opportunities	I	
2	Determine objectives		
3	Inventory resources		
4	Analyze resource data		
5	Formulate alternatives	II	
6	Evaluate alternatives		
7	Make decisions		
8	Implement the plan	III	
9	Evaluate the plan		

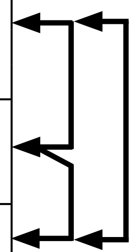
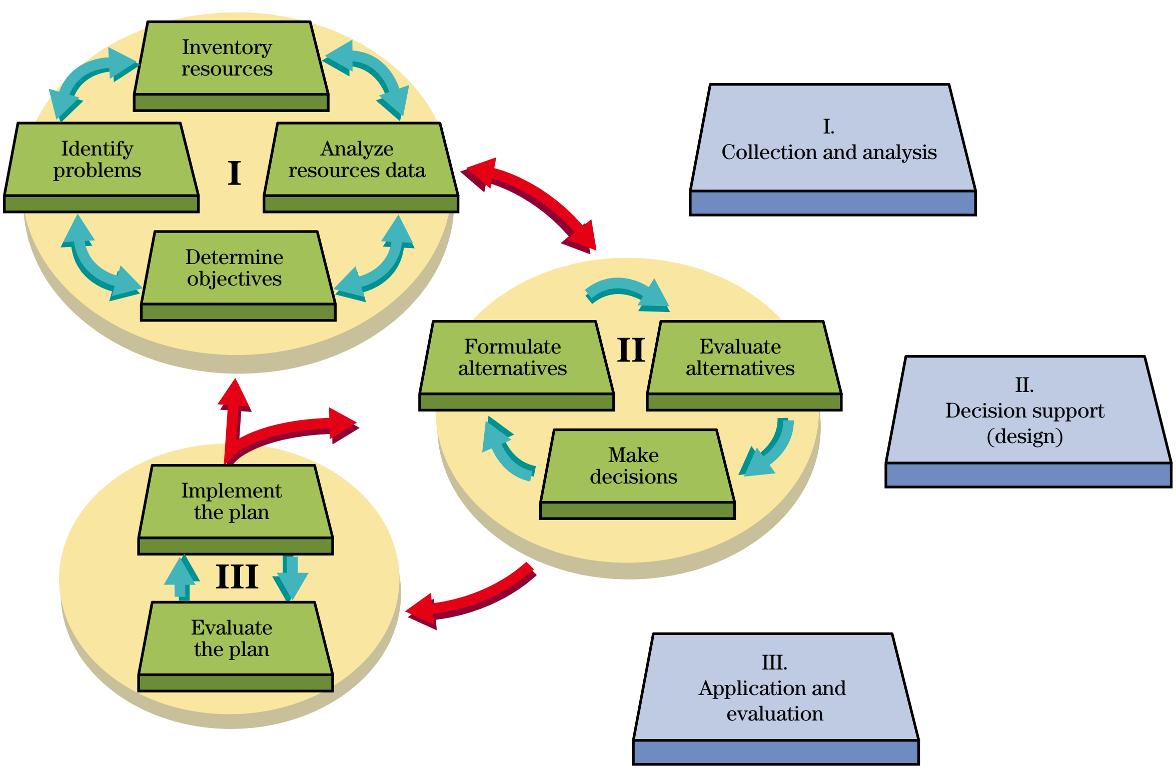


Figure 4–5 NRCS CPP showing the dynamic interaction between the steps



654.0404 Designing solutions for the stream corridor

While an array of suitable practices is available for most stream corridor conditions, client objectives usually focus treatments to a more limited range. Planning site problems, however, typically exceed the client's focus and, more than likely, are symptomatic of larger area and watershed concerns (habitat fragmentation or an imbalance in sediment transport).

Table 4–2 describes the interplay of stream restoration with three common client problem/objective scenarios. While all objectives are justifiable management options, multiple resource concerns and ecological functions are usually only addressed with example objective C.

(a) Landscape context for restoration

Once site problems and client objectives have been evaluated (NPPH planning steps 1 through 4), potential treatment and restoration activities can be considered. From a context viewpoint, an important first step is to recognize the site-level landscape settings or zones on the CMU/stream corridor that influence the selection of potential practices. Figure 4–6 (adapted from Hoag et al. 2001) illustrates an idealized, conceptual cross section of a stream and one side of the stream's riparian area. Not all of these zones will exist in all streams and rivers. Table 4–3 provides more detail on applicable landscape zones, descriptions of each zone, and an overview of correlated practices.

Because of the strong physical and ecological interaction of streams with their flood plain and adjacent corridors, a CMU should be delineated to encompass the stream corridor, which includes the streambed, banks, and riparian areas. These landscape components strongly interact and are best planned as a whole to optimize desired effects and meet client and ecological objectives.

Tables 4–4, 4–5, and 4–6 provide information on selection of NRCS Conservation Practice Standards and their considerations and effects related to landscape zones in and along the stream. Table 4–4 focuses on accelerated erosion, sediment, and site instability, whereas tables 4–5 and 4–6 focus on habitat and biodiversity and production and land use, respectively. Each zone depicted in these tables has particular characteristics and correlated practices. Practices can be reviewed and studied by referring to section IV of the FOTG. From a biotic perspective, the plant community potential is an important ecological reference in thinking about restoration and triggering site-level planning questions:

- Is the reference plant community (or a successional stage of it) present?
- Are the site's landscape zones in a physical condition to mutually sustain the reference community or stages?
- Are watershed-level landscapes in a physical and biotic condition to sustain site-level stream corridor recovery or restoration?

(b) Selecting conservation practices for stream restoration

With an understanding of the planning process and stream corridor landscape settings, the planner is ready to match site impairments, landscape zones, and client objectives with conservation practices (idealized in fig. 4–7). Tables 4–4, 4–5, and 4–6 provide information for use by the planner in choosing appropriate treatments and vegetation types. An important strategy when using the table is to match existing problems in each impairment category with coinciding conservation practices suited to the particular landscape zone or zones making up the CMU. An assumption is that once impairments are recognized, the client's objective is to remedy problems by using a system of conservation practices (fig. 4–8).

Selection of some practices at the beginning of tables 4–4, 4–5, and 4–6 will influence or curtail the selection and extent of others listed later. For example, a client wants to improve forage resources in the overbank and transitional zone, but has eroding banks and overbank zones lacking protective ground cover. Treatment of the bank and overbank zones (using rock, mulching, and/or specialized vegetation) to control bank or surface erosion will necessarily restrict the use and extent of forage establishment practices. In this situation, the bank and overbank zones may require livestock exclusion temporarily or permanently, with a corresponding revision of the site's prescribed grazing management.

Table 4–2 Relationship of stream restoration components with client problems and objectives

Example problems/client objectives	Channel/riparian/watershed characteristics	Desired outcome/effects
A. Erosion and sediment control (streambank erosion, channel aggradation, channel degradation, concentrated flow and scour erosion, sheet and rill erosion)	• Excessive bank recession rates • Instream bar formation • Incised channels that are deepening, then widening • Lack of vegetative cover on banks, flood-prone zones and riparian areas, allowing concentrated flow, sheet, rill, and scour erosion • Concentrated-flow gullies from adjacent areas and land uses • Overall watershed cover has less native perennial cover, more impervious areas or more direct flow paths, which are unbuffered	• Return to normal reference bank recession rates and point bar dynamics • Incised channels are stabilized and flood-prone areas are reestablished. This occurs at a lower elevation than preincisement conditions • Aggressive herbaceous plants substantially reduce surface erosion and hinder the invasion of weeds, but they can impede successional progression to the desirable plant community • Woody plants bind streambank soils and in adjacent flood-prone areas, increase surface roughness, which can reduce scour erosion • Buffers and associated practices in adjacent uplands can slow runoff, reducing stress to streambanks and channel degradation processes
B. Production and use of stream and streamside vegetation (game fish, livestock forage, forest products)	• Channel banks and bed are modified and maintained to favor specific game fish • Streamside herbaceous plants, woody plants or a combination consistent with the client's operation and marketing capability are grown to satisfy economic requirements	• Production and utilization goals are achieved when fish and vegetation products reach desired biomass, size, or quality • Aquatic and plant community succession is retarded/managed (or completely supplanted by a production community) to maintain the desired operational condition
C. Restoration of ecological functions (creation of a successional stage which can be maintained or allowed to succeed to a desired plant community)	• Herbaceous plants, woody plants or a combination consistent with desired successional stage or progression to the reference reach plant community	• Functions such as site-soil stability, vertical and spatial habitat, and nutrient cycling are achieved when vegetation reaches the desired successional condition • Domestic use for recreation, grazing, timber harvesting, or other exploitation is excluded or sufficiently restricted so that the desired successional stage is reached and maintained

Figure 4–6 Conceptual cross section of a riparian area with landscape zones for planning restorations

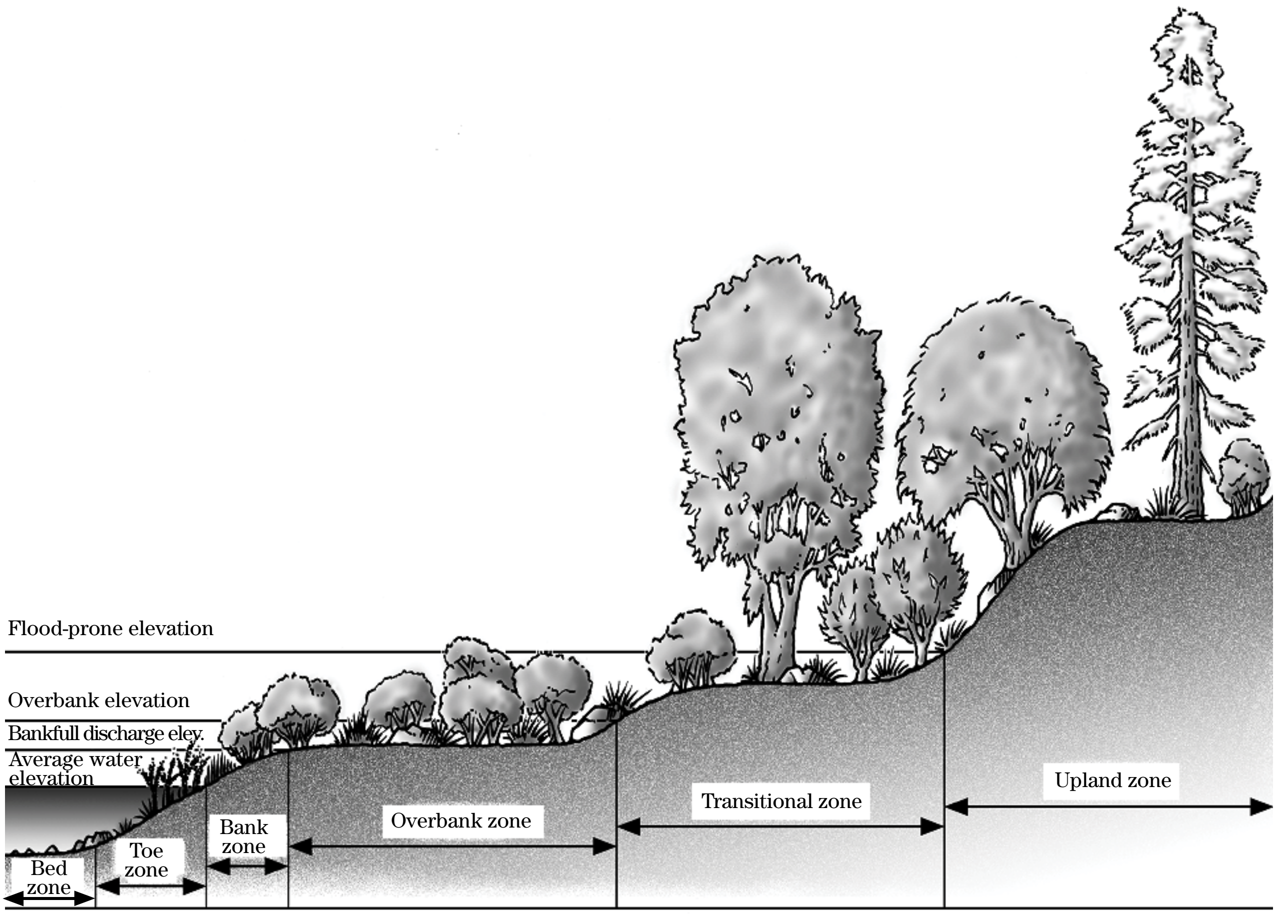


Table 4–3 Description of riparian landscape zones for stream corridor design and management

Definitions and descriptions of landscape zones	Potential RMS conservation practices*
Bed zone—The bottom of the channel that can consist of a variety of bed materials. Vegetation may consist of periphyton (diatoms, algae, phytoflagellates attached to substrate material), phytoplankton (suspended in the water column), and macrophytes (vascular and nonvascular plants), depending on bed material, pool, riffle, run proportions, and flow rate	Channel Stabilization (584)*, Clearing and Snagging (326), Fish Passage (396), Open Channel (582), Stream Crossing (578), Stream Habitat Improvement and Management (395)
Toe zone—The portion of the bank that is between the average water level and the upper edge of the bottom of the channel. This zone has the highest stress because of frequent exposure to wave wash, channel-forming currents, ice and debris movement, and wet-dry and freeze-thaw cycles. Vegetation is generally herbaceous emergent aquatic species, tolerant of long periods of inundation	Channel Stabilization (584), Clearing and Snagging (326), Fish Passage (396), Streambank and Shoreline Protection (580), Stream Crossing (578), Stream Habitat Improvement and Management (395)
Bank zone—The area above the toe zone located between the average water level and the bankfull discharge elevation. (The bankfull discharge elevation, in natural streams, is the elevation at which water fills the channel without overflowing onto the flood plain.) This zone is exposed periodically to wave wash, erosive river currents, ice and debris movement, and traffic by animals or humans. Vegetation may be herbaceous or woody and is typically characterized by flexible stems and rhizomatous root systems. Plants are periodically submerged	Channel Stabilization (584), Channel Bank Vegetation (322), Streambank and Shoreline Protection (580), Stream Crossing (578), Stream Habitat Improvement and Management (395), Use Exclusion (472)
Overbank zone—The area located above the bankfull discharge elevation continuing upslope to an elevation equal to two-thirds of the flood-prone depth. Vegetation may consist of some proportion of herbaceous plants, shrubs and trees, depending on the plant community potential of the site	Critical Area Planting (342), Early Successional Habitat Development/ Management (647), Fence (382), Filter Strip (393), Forest Stand Improvement (666), Irrigation System (441/442/443), Mulching (484), Nutrient Management (590), Pasture and Hay Planting (512), Pest Management (595), Prescribed Grazing (528), Range Planting (550), Recreation Area Improvement (562), Restoration and Management of Declining Habitats (643), Riparian Forest Buffer (391), Riparian Herbaceous Cover (390), Stream Crossing (578), Use Exclusion (472), Watering Facility (614), Wetland Wildlife Habitat Management (644)
Transitional zone—One or more levels of terraces located between the overbank zone and the flood-prone width elevation. On forest potential sites, vegetation is usually larger shrub and tree species with a shrub/ herbaceous understory. On herbaceous potential sites, a combination of overbank and upland herbaceous vegetation is usually present in some proportion, as well as other herbaceous species intolerant of upland (dryer) or overbank conditions (wetter)	
Upland zone—The area above the transitional zone. This area is seldom influenced by stream/riparian soil moisture	Various practices, section IV of the local FOTG consisting of 150+ practices

*NRCS National Conservation Practice Standard codes, Specific information for these practice standards is available at the following Web site: *http://www.nrcs.usda.gov/technical/Standards/nhcp.html*

Table 4–4 NRCS Conservation Practice Standards selection for accelerated erosion, sediment, and site instability. Guidance is shown using impairment category and landscape zone, with notes on considerations and effects. Impairments and practices[1/] are listed in general order of consideration for use in formulating a resource management system.

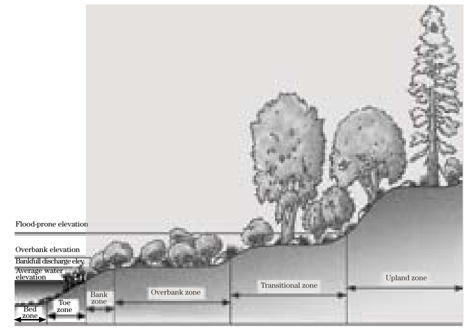
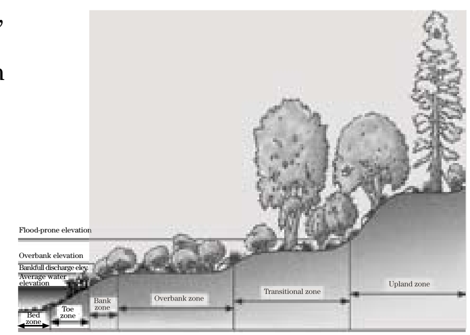
Impairment	Landscape zones	Primary NRCS Conservation Practice Standards	Considerations and effects: accelerated erosion, sediment, and site instability	Landscape zones
Unbalanced channel sediment transport and deposition; unstable channel bed and/or gradient[2/]	Bed, toe	Open Channel (582)	Various techniques including channel meander reconstruction at a site will reconfigure the bed and bank topography and influence the extent of overbank and transitional zones and related soil moisture and the selection of vegetation species	
		Channel Stabilization (584)	Measures to support balance and stability will reduce risk of bank recession and damage to overbank zone vegetation	
		Clearing and Snagging (326)	Where practical, restore native vegetation to all bank, overbank and transitional areas disturbed by use, ingress, or egress of obstruction removal equipment	
Accelerated bank erosion and instability[2/]	Bank, toe	Channel Bank Vegetation (322)	In the overbank zone nearest the stream, use the same or similar riparian area plant species as channel bank vegetation to provide additional support to controlling bank erosion	
		Streambank and Shoreline Protection (580)	See notes for Channel Bank Vegetation (322), which is the vegetation component of this practice	
		Clearing and Snagging (326)	Restore vegetation (native species where practical) to all bank, overbank and transitional areas disturbed by use, ingress and egress of obstruction removal equipment	

Table 4–4 NRCS Conservation Practice Standards selection for accelerated erosion, sediment, and site instability. Guidance is shown using impairment category and landscape zone, with notes on considerations and effects. Impairments and practices[1/] are listed in general order of consideration for use in formulating a resource management system—Continued

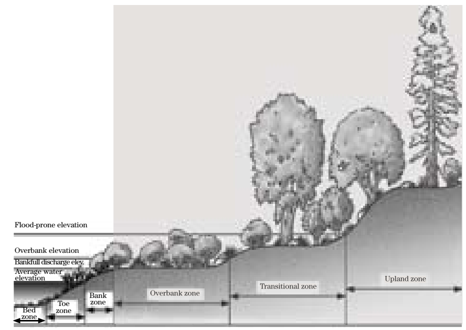
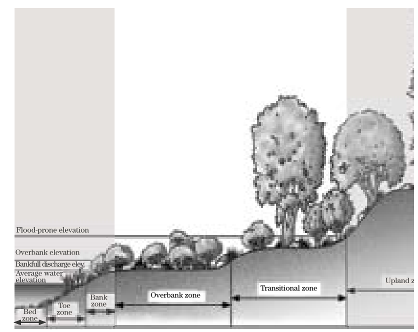
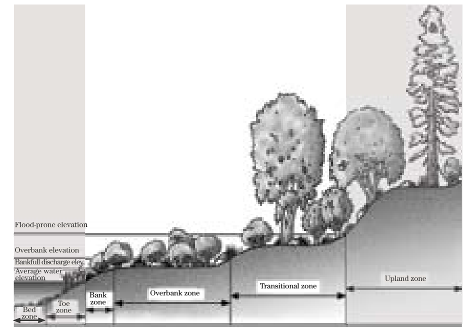
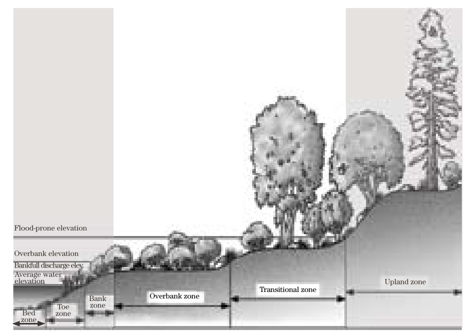
Impairment	Landscape zones	Primary NRCS Conservation Practice Standards	Considerations and effects: accelerated erosion, sediment, and site instability	Landscape zones
Excessive damage by animals, people or vehicles (soil compaction and rutting, loss of protective ground cover) and associated liability and health concerns	Bed, toe, bank,	Use Exclusion (472) Fence (382)	Use Exclusion by use of a fence or other means may be sufficient in restoring the desired vigor and density of the site's vegetation to mitigate damage. Use Exclusion is also used to protect new plantings and accelerate their establishment period	
Accelerated or potential high-rate surface erosion from sheet, rill, ephemeral, or flood scour erosion processes	Overbank and transitional	Critical Area Planting (342)	Introduced plant species and cultivars are usually chosen over native plant species because of improved vigor or establishment density. Flood scour may require additional, shrubby plantings of sufficient height and width (perpendicular to flow) placed strategically to slow out-of-bank flows	
		Mulching (484)	Mulch materials can accelerate establishment of riparian area erosion control plantings by suppressing weed growth, moderating soil temperature, and conserving soil moisture. Seeding can be incorporated into and applied concurrently with some mulching techniques (hydroseeding)	

Table 4–4 NRCS Conservation Practice Standards selection for accelerated erosion, sediment, and site instability. Guidance is shown using impairment category and landscape zone, with notes on considerations and effects. Impairments and practices[1/] are listed in general order of consideration for use in formulating a resource management system—Continued

Impairment	Landscape zones	Primary NRCS Conservation Practice Standards	Considerations and effects: accelerated erosion, sediment, and site instability	Landscape zones
Overgrazing	Overbank and transitional	Prescribed Grazing (528)	Prescribed grazing controls the timing, duration and intensity of domestic animals, while maintaining some use of existing forage. Based on the degree of damage to riparian and bank vegetation, use exclusion and livestock deferment may be needed for several years before grazing can resume	
Excessive sediment and/or other pollutants in runoff reaching the channel	Overbank and transitional	Filter Strip (393)	Introduced herbaceous species filter sediment in runoff reaching and passing through the strip. In areas with forest potential, filter strips are used as zone 3 of a riparian forest buffer to filter and slow upland runoff	
		Riparian Forest Buffer (391)	Tree and shrub species further slow upland runoff and aid in the infiltration of pollutant-laden water. Uptake and microbial processes break down nitrates and pesticides. Riparian forest buffers are not intended to withstand unabated upland runoff. Native woody species may not be of sufficient vigor or establish quickly enough for some pollutant loadings	

1/ NRCS National Conservation Practice Standard codes, *http://www.nrcs.usda.gov/technical/Standards/nhcp.html*
2/ The feasibility of site-level versus watershed-level treatment needs to be assessed during the planning process to determine if the erosion problems are due to local conditions or are the result of stream instability in multiple reaches or over a wide area.

Table 4–5 NRCS Conservation Practice Standards selection for unsuited or insufficient habitat and biodiversity. Guidance is shown using impairment category and landscape zone, with notes on considerations and effects. Impairments and practices[1/] are listed in general order of consideration for use in formulating a resource management system.

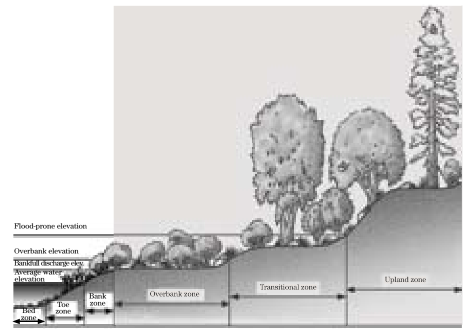
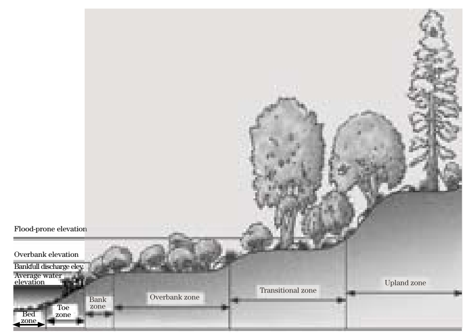
Impairment	Landscape zones	Primary NRCS Conservation Practice Standards	Considerations and effects: unsuited or insufficient habitat and biodiversity	Landscape zones
Unsuited instream physical habitat (lack of pools, large and fine woody debris, channel depth)	Bed, toe, and bank	Stream Habitat Improvement and Management (395)	Measures applied instream for aquatic species habitat can be enhanced with supporting shade, detritus, and debris from adjacent bank and overbank vegetation. The needs of aquatic species using this practice must be coordinated closely with Channel Bank Vegetation (322), Riparian Forest Buffer (391) (if forest potential) and Riparian Herbaceous Cover (390) (if herbaceous only potential)	
Unsuited near-stream habitat (lack of spatial and vertical structure)	Bank and toe	Channel Bank Vegetation (322)	All practices dealing with vegetation must be coordinated to provide needed habitat for the wildlife species of concern in the bank, overbank, and transitional zones	

Table 4–5 NRCS Conservation Practice Standards selection for unsuited or insufficient habitat and biodiversity. Guidance is shown using impairment category and landscape zone, with notes on considerations and effects. Impairments and practices[1/] are listed in general order of consideration for use in formulating a resource management system—Continued

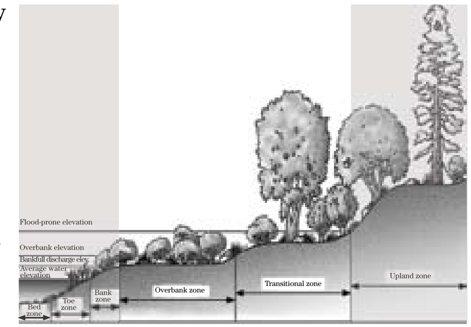
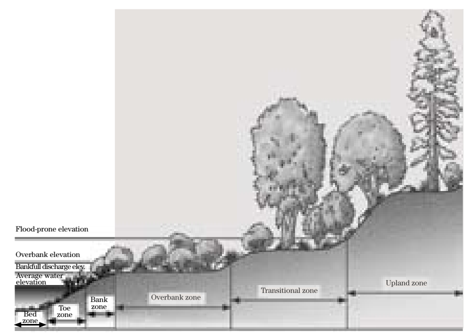
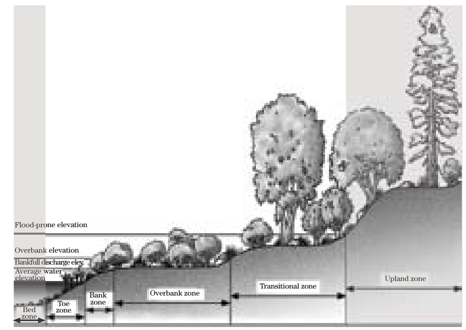
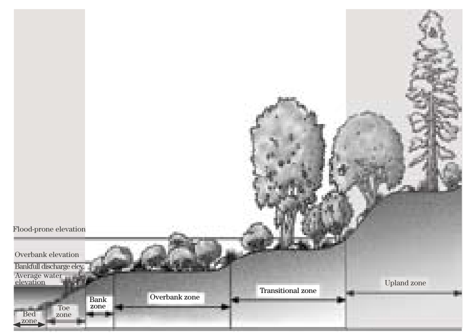
Impairment	Landscape zones	Primary NRCS Conservation Practice Standards	Considerations and effects: unsuited or insufficient habitat and biodiversity	Landscape zones
Unsuited near stream habitat (lack of spatial and vertical structure)	Overbank and transitional	Riparian Forest Buffer (391) Riparian Herbaceous Cover (390)	Depending on the site's plant community potential for forest or herbaceous, Riparian Forest Buffer (391) and Riparian Herbaceous Cover (390) are used singly, but not together	
		Wetland Wildlife Habitat Management (644)	Wetland Wildlife Habitat Management (644) is used on those areas within the overbank and transitional zones that are wetland in nature	
		Prescribed Grazing (528)	For sites grazed by livestock, use Prescribing Grazing (528) to enhance and maintain desired habitat structure. As a general rule for all practices, native plant species are chosen or favored over introduced species	
Obstructions or channel configurations affecting flow capacity or fish passage	Bed, toe, and bank	Clearing and Snagging (326)	Restore vegetation (native species where practical) to all bank, overbank and transitional areas disturbed by use, ingress or egress of obstruction removal equipment	
		Fish Passage (396)	Consider the quality of stream corridor habitat upstream of obstructions before applying Fish Passage (396)	
		Open Channel (582)	Various techniques including channel meander reconstruction at a site will reconfigure the bed and bank topography and influence the overbank extent, soil moisture and vegetation species	

Table 4–5 NRCS Conservation Practice Standards selection for unsuited or insufficient habitat and biodiversity. Guidance is shown using impairment category and landscape zone, with notes on considerations and effects. Impairments and practices[1/] are listed in general order of consideration for use in formulating a resource management system—Continued

Impairment	Landscape zones	Primary NRCS Conservation Practice Standards	Considerations and effects: unsuited or insufficient habitat and biodiversity	Landscape zones
Lack of early successional habitat for target wildlife	Bank, toe, overbank, and transitional	Early Successional Habitat Development/ Management (647)	Coordinate plant selection and management of Channel Bank Vegetation (322), Riparian Forest Buffer (391), Riparian Herbaceous Cover (390), and/or Wetland Wildlife Habitat Management (644) to coincide with specifications developed for Early Successional Habitat Development/ Management (647). For sites grazed by livestock, use Prescribed Grazing (528) to enhance and maintain early successional habitat. Field Border (386) can be used at the edge of adjacent upland cropland nearest to the transitional zone to ease movement into and along agricultural land	
Presence of rare or declining native plant communities and impacted wildlife	Bank, overbank, and transitional	Restoration and Management of Declining Habitats (643)	Coordinate specifications and supporting management of all instream and near-stream practices to coincide with specifications developed for Restoration and Management of Declining Habitats (643). Rare and declining sites may need temporary or permanent Use Exclusion (472) to buffer from intensive land use and management. Field Border (386) can be used at the edge of adjacent upland cropland nearest to the transitional zone to ease movement into and along agricultural land	

1/ NRCS National Conservation Practice Standard codes. Specific information for these codes is available at the following Web site: *http://www.nrcs.usda.gov/technical/Standards/nhcp.html.*

Table 4–6 NRCS Conservation Practice Standards selection for unsuited or insufficient production/land use. Guidance is shown using impairment category and landscape zone, with notes on considerations and effects. Impairments and practices[1/] are listed in general order of consideration for use in formulating a resource management system.

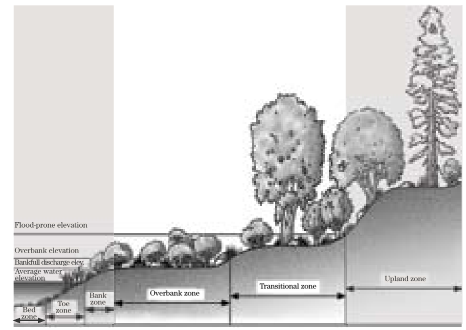
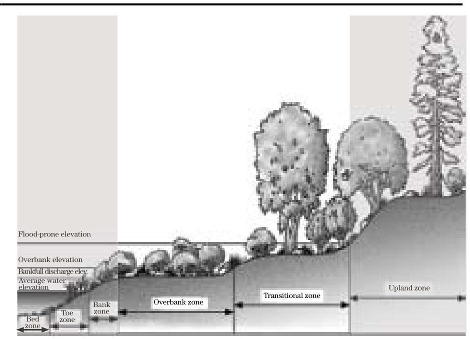
Impairment	**Landscape zones**	**Primary NRCS Conservation Practice Standards**	**Considerations and effects: unsuited or insufficient production/land use**	**Landscape zones**
Insufficient forage quantity and quality for livestock	Overbank and transitional	Pasture and Hay Planting (512) Range Planting (550), (528) Prescribed Grazing (328) Silvopasture Establishment (381) Forest Stand Improvement (666)	Plant species are chosen and managed for their forage quality and quantity attributes insofar as compatible with site erosion and sediment control, instability improvement, and habitat improvement. For sites with a combined forage and wood production use, Silvopasture (381) and Forest Stand Improvement (666) are used to manipulate the tree or tall shrub overstory to maintain production of forage cultivars in the understory. For native understory species, only Forest Stand Improvement (666) is used to manipulate the tree or tall shrub overstory. To reduce the risk of erosion, sediment, instability and lack of habitat, the area devoted to forage production may need to be reduced particularly in the overbank zone by Use Exclusion (472), Fence (382) or a modification to Prescribed Grazing (328)	
Under or overstocked forest stands for wood products	Overbank and transitional	Riparian Forest Buffer (391) Forest Stand Improvement (666)	Tree and shrub species are chosen and managed for their wood quality and quantity attributes insofar as compatible with site erosion and sediment control, instability improvement, and habitat improvement. To reduce the risk of erosion, sediment, instability and lack of habitat, the area devoted to wood harvesting may need to be reduced particularly in the overbank zone. Certain techniques (directional felling and skidding) could be used for harvesting in the overbank zone on a periodic basis to maintain vigor of overstory and understory species	

Table 4–6 NRCS Conservation Practice Standards selection for unsuited or insufficient production/land use. Guidance is shown using impairment category and landscape zone, with notes on considerations and effects. Impairments and practices[1/] are listed in general order of consideration for use in formulating a resource management system—Continued

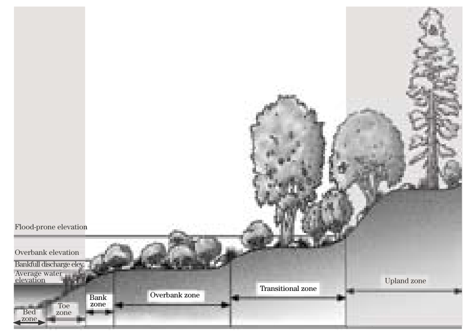
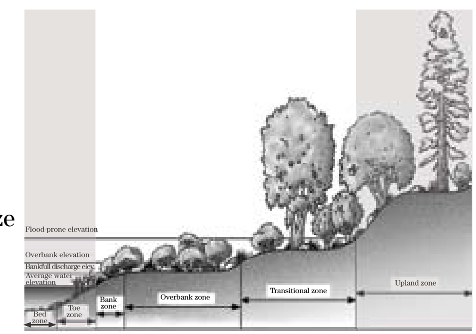
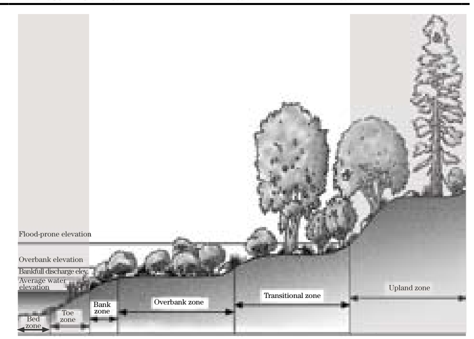
Impairment	Landscape zones	Primary NRCS Conservation Practice Standards	Considerations and effects: unsuited or insufficient production/land use	Landscape zones
Unimproved recreational opportunities	Bank, overbank, and transitional	Recreation Area Improvement (562) Stream Habitat Improvement and Management (395)	Vegetation is established and/or manipulated to enhance specific recreational uses suited to the site and compatible with site erosion and sediment control, instability improvement, and habitat improvement Recreation structures, land grading, and trails may be concurrently applied with vegetation management. Manipulation of bank and overbank conditions for recreation purposes can be detrimental if not tied to and compatible with a geomorphic/hydraulic analysis at bankfull and flood stages	
Insufficient moisture for desired plant communities	Bank, overbank, and transitional	Irrigation System Microirrigation (441) Sprinkler (442) Surface and Subsurface (443)	A suitable irrigation system with associated practices (Pipeline (430), Irrigation Water Conveyance (428)) can be installed to overcome moisture-deficit conditions detrimental to plant growth and establishment. Irrigation is particularly effective on overbank and transitional zones on incised channel reaches, but it can be costly. To minimize costs, select plant materials that, when well established, can reach their site potential size using available amounts and timing of natural precipitation	
Insufficient nutrients for desired plant communities	Bank, overbank, and transitional	Nutrient Management (590)	Meeting nutritional requirements for existing or new plantings can accelerate their growth, establishment, and function. This is particularly the case with nonnative herbaceous species. Addition of nutrients must be carefully balanced with the nutrient loading at the site and any incoming nutrients in surface and subsurface flows. Nutrition becomes less important as plants and onsite nutrient cycling become well established	

Table 4–6 NRCS Conservation Practice Standards selection for unsuited or insufficient production/land use. Guidance is shown using impairment category and landscape zone, with notes on considerations and effects. Impairments and practices[1/] are listed in general order of consideration for use in formulating a resource management system—Continued

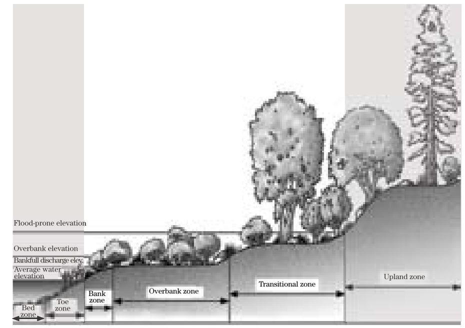
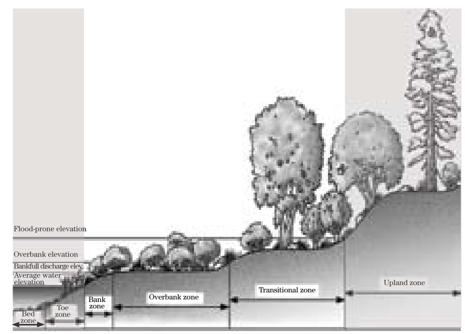
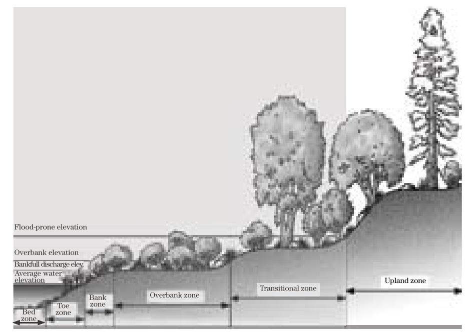
Impairment	**Landscape zones**	**Primary NRCS Conservation Practice Standards**	**Considerations and effects: unsuited or insufficient production/land use**	**Landscape zones**
Presence of pests	Bank, overbank, and transitional	Pest Management (595)	A first and foremost step in pest management is selection of plant materials that help achieve desired site conditions and resist local pests. If pests become problematic (weeds, insects, diseases, animals, and other organisms including invasive and noninvasive species), sufficient control helps assure continued function of existing plantings and establishment of new plantings. A variety of control methods are available including cultural, biological, and chemical which must be matched to the problem, the site, and the vegetation. In all cases, pest management design includes an environmental risk analysis to assure that additional problems are not caused (excess pesticides in surface or ground waters)	
Lack of or need for a conveyance structure or travel way across a channel to facilitate land management	Bank, overbank, and transitional	Stream Crossing (578)	Crossings are located where the streambed is stable or where grade control can be provided to create a stable condition. Crossings are typically not placed in shaded conditions if the stream corridor is grazed and there is a potential for livestock loafing in the stream. Stream crossings allow for the passage of water, fish and other aquatic animals within the channel during all seasons of the year. Restore vegetation (native species where practical) as soon after construction as possible to all bank, overbank and transitional areas disturbed by use, ingress or egress of construction equipment)	

Table 4–6 NRCS Conservation Practice Standards selection for unsuited or insufficient production/land use. Guidance is shown using impairment category and landscape zone, with notes on considerations and effects. Impairments and practices[1/] are listed in general order of consideration for use in formulating a resource management system—Continued

Impairment	Landscape zones	Primary NRCS Conservation Practice Standards	Considerations and effects: unsuited or insufficient production/land use	Landscape zones
Point source and nonpoint source pollution, water diversions, flow modifications caused by structures (dams), hydrologic modifications caused by urbanization and other changed land uses	Upland	Nutrient Management (590) Residue and Tillage Management (329, 344, 345, 346), Conservation Crop Rotation (328) Conservation Cover (327) Filter Strip (393) Terrace (600) Water and Sediment Control Basin (638) Waste Treatment and Storage (313, 359. 367, 629, 633, 635) Sediment Basin (350) Subsurface Drain (606) Surface Drainage (606, 607, 608) Constructed Wetland (656) – and others	Protection of watershed areas that contribute water, sediment, and chemicals to the stream may be required to reach the restoration goals of the project. Watershed land use and cover, conservation treatments, and the amount of land converted to urban or suburban uses can have significant effects on runoff to the stream, both in terms of lag times and peak flows	

1/ NRCS National Conservation Practice Standard codes. Specific information for these codes is available at the following Web site: *http://www.nrcs.usda.gov/technical/Standards/nhcp.html*

Figure 4–7 The planner is cautioned to clearly understand the degree and extent of impairments (both onsite and offsite), applicable landscape zones within the CMU, and specific client objectives before considering the selection of conservation practices and vegetation types.

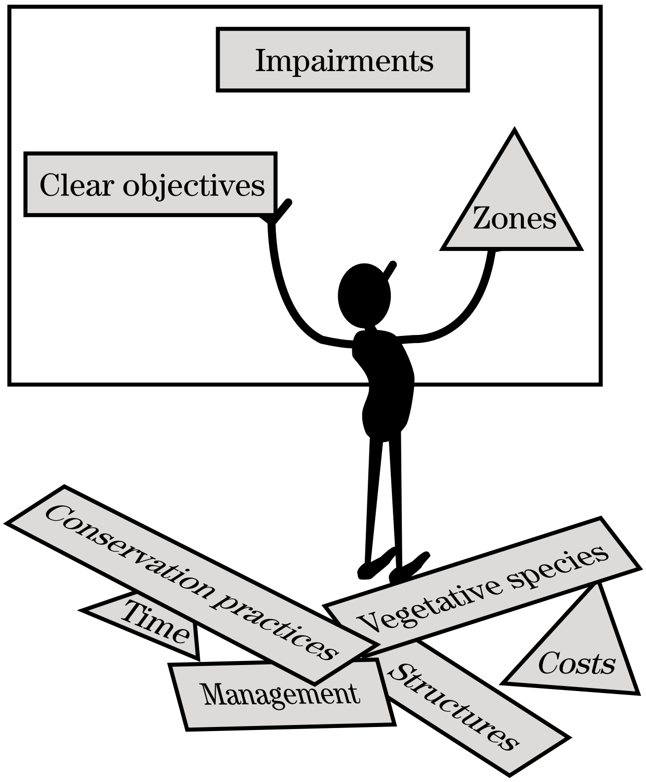
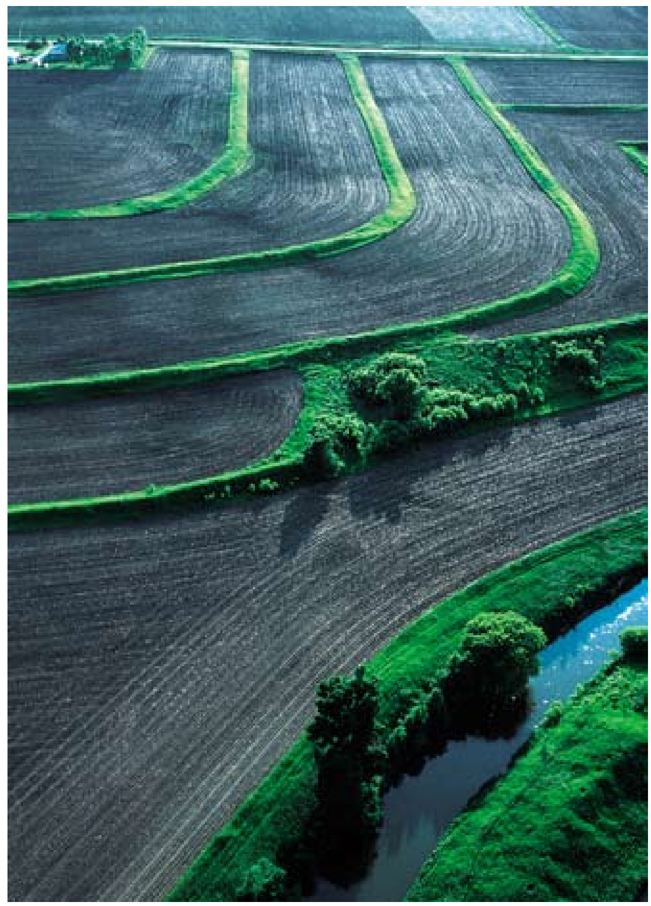


Figure 4–8 Terraces, conservation tillage, and conservation buffers form a system to treat the watershed and protect the stream (Woodbury County in northwestern IA)



(c) Formulating a resource management system for stream restoration

After studying table 4–3 and the applicable conservation practice standards in the FOTG, the planner will have a preliminary idea of the conservation practices that can address site problems and client objectives. Some practices will be either selected or eliminated, based on degree of effect, cost, duplication of outcome (mulching in place of critical area planting for erosion control), or perhaps a change in the client's objectives during the formulation process. This stage of planning (steps 5, 6, and 7) is an iterative phase of the process that must be accomplished with the client. The product of this stage is a plan for the CMU, listing the practices and their locations, types of structures and vegetation, and management requirements. Although more thorough information about certain practices (design options, costs, materials) is sometimes needed by the client to make informed decisions, preparing detailed or preliminary specifications or designs for any practice is not the intent of this phase of planning.

A critical strategy in formulating an RMS for a stream corridor CMU is the interplay between candidate practices in achieving desired conditions. The scenario below illustrates two RMSs developed for a stream corridor-grazing situation. Note how the characteristics of plant materials affect RMS formulation.

Example 1: Streambank erosion control using an RMS that emphasizes management elements for the designed solution

Given benchmark conditions: A CMU at one edge of a farm has a third order stream with fairly wide overbank and transitional zones. Channel banks have accelerated erosion, and the overbank zone has periodic scour erosion; both can be controlled by vegetative means. The client wishes to graze livestock on the entire stream corridor/riparian CMU (both sides of the channel) and use the stream as a water source. Livestock cross the channel at many locations, causing soil compaction and additional bank erosion.

- *RMS Option A*—The Channel Bank Vegetation (322) standard specifies that suitable erosion control plants with low palatability will be used in the bank zone. Pasture and Hay Planting (512) specifies the establishment of forage species with fibrous root systems in the overbank zone. Specifications for Prescribed Grazing (528) identify certain plants in the overbank zone as key forage species that are closely monitored to maintain protection against flood scour erosion. Also, incidental use and trampling damage of bank zone vegetation is monitored, and the livestock are removed immediately when any degradation or loss of vigor is detected. A Stream Crossing (578) in the form of a rock ford is installed to concentrate livestock movement across the channel (livestock choose the ford because of ease of crossing).
- *RMS Option B*—Both Channel Bank Vegetation (322) and Critical Area Planting (342) specify that suitable erosion control plants with low palatability will be used in the bank and overbank zones, respectively. Livestock Use Exclusion (472) is installed in the form of a Fence (382) between the overbank and transitional zones on both sides of the channel. A gated and fenced Stream Crossing (578) is installed to allow ready access to the far side of the CMU and periodic grazing of the bank and overbank zones. Livestock periodically graze the bank and overbank zones for short periods with close monitoring to maintain erosion control (a requirement in the Prescribed Grazing (528) specifications). Because access to water is variable, a Watering Facility (614) is developed within the transitional zone on the far side of the channel. This also improves use of forage on both sides of the stream.

Summary: Both RMSs meet quality criteria and client objectives for livestock grazing. RMS option B affords the greatest assurance that resource concerns and practice purposes will be met, but likely at a higher investment in installation costs and management time. Additional fencing in this option can impact certain types of wildlife and pose a periodic maintenance chore if fences are damaged by floods. RMS option A may require additional monitoring to maintain desired conditions.

Other situations and examples exist for stream/riparian CMUs with cropland, wood production, recreation, or other intensive land uses. Obviously, those sites with little or no demands for crops, wood, forage, or recreation will have the fewest planning constraints and interplay between practices. However, streams and associated riparian areas are typically landscapes with favorable moisture and potential for exploitation. Intensive use of such landscapes will remain the rule, rather than the exception. Planners will need to think through each scenario using the process and techniques presented in this section to formulate sustainable RMSs. Consultation with specialists for complex situations is advised.

Example 2: Streambank erosion control using an RMS that emphasizes a combination of vegetation and structural design elements

Given benchmark conditions: Severe streambank erosion is attacking stream banks in a suburban area, with damage to utilities, loss of land, and degraded habitat. The stream is enlarged, excessive sediment yield, and loss of property and utility services are concerns. In some locations, sewer pipes and gas lines are in imminent danger of collapse. The site constraints are such that relocation of these utilities is not possible. The streambed appears to be stable with no active incision.

- *RMS options*—The objectives are to solve the bank erosion problem, protect the utilities (water and sewer lines) and property, and retain flow-carrying capacities. Measures that are considered include Streambank and Shoreline protection (580) and Channel Bank Vegetation (322). It would be necessary to confirm that the bed is indeed stable. If it is not, some grade control may be necessary. The emphasis will be on protecting the streambank from future undercutting and collapse, so that the toe will be stabilized with rock riprap or gabions. The design will focus on the slope stability that can be achieved with the least impact on land (backyards and easement areas) and result in a stable bank condition. Soil bioengineering will be used to establish woody vegetation that will protect the bank from the erosion of flowing water and also knit together the bank with roots. Where riparian infrastructure is in imminent danger, harder structures such as gabions, sheetpile, and ACBs will be considered. Final design of the solution will depend on hydraulic analyses for the site.

Example 3: Streambank erosion control using an RMS that emphasizes a reliance on vegetative design elements

Given benchmark conditions: Streambank erosion is present along a long stretch of an outside meander bend. This erosion is impacting a farm in a rural area. At one point, a dirt farm road is in jeopardy. No utilities or riparian infrastructure is threatened. The streambed appears to be stable with no active incision. Minimal funds are available for any work.

- *RMS options*—The objectives are to solve the bank erosion problem. The dirt road itself may be relocated. Measures that are considered include Streambank and Shoreline Protection (580) and Channel Bank Vegetation (322). The design may focus on soil bioengineering practices including vertical bundles, live stakes and vegetated stream barbs. All of these techniques, once designed, could be constructed without construction equipment. A site assessment would need to be made to see if Livestock Use Exclusion (472) in the form of a Fence (382) between the overbank and transitional zones on the bank would also reduce some of the stress.

Example 4: Streambank erosion control using an RMS that emphasizes a complete reconstruction of a natural stream channel

Given benchmark conditions: A natural channel was straightened and widened to provide flood control benefits to rural farmland. Historically, the stream had supported healthy populations of fish which are now considered to be threatened. This old channelization of the stream has resulted in a loss of habitat and impacts to the threatened fish species. Riparian land use has now changed such that the original flood control purposes of the project are no longer an issue.

- *RMS options*—The objectives are to restore the stream so that it will support a population of the target fish species. A healthy stream corridor is necessary to achieve this goal and to solve the bank erosion problem. Measures that are considered include Streambank and Shoreline Protection (580), Channel Bank Vegetation (322), Channel Stabilization (584), Open Channel (582), Restoration and Management of Declining Habitats (643), Riparian Forest Buffer (391), and Stream Habitat Improvement and Management (395). The design may focus on a complete recreation of the stream channel. This will involve determining a stable planform, section, and profile of the stream. Techniques which serve to stabilize the grade and protect the banks in targeted areas may be necessary. Instream and edge habitat features, such as soil bioengineering practices including vertical bundles, live stakes, and vegetated stream barbs, may also be used. The analysis, design, and construction effort for such a project may be significant.

(d) Specifications and designs at the conservation practice level

After examining the RMS alternatives and associated practices with the planner, the client makes decisions about the CMU. With a definitive plan of what will occur, the preliminary specifications and designs for stream corridor restoration can be formulated. This is the start of NPPH planning step 8, Implement the Plan. Individual conservation practice standard criteria contained in the local FOTG will guide the planner in:

- location, extent, design specifications, and operation of physical structures
- plant species selection, layout, and spacing
- site preparation and planting techniques
- site management to progress to and maintain desired site conditions

Generic specifications and designs will not be presented here because of the wide array of ecological regions, site conditions, implementation techniques, and plant materials. However, the considerations and effects column in tables 4–4, 4–5, and 4–6 provides important considerations for developing specifications and designs. The planner is advised to carefully study the tables and local FOTG practice standard criteria. During the development of detailed specifications and designs, the planner and client may decide to modify the original RMS. This is a normal iteration of the planning process.

654.0405 Evaluating success of stream restoration designs

The main purpose for evaluating the restoration treatment (planning step 9 in table 4–1) is to determine if desired future conditions are being achieved at the expected level and rate. In the NRCS CPP, desired conditions in relation to existing benchmark conditions are first established and documented in planning step 4 and later used in step 6 to evaluate alternative RMSs. During treatment evaluation, two basic questions are answered:

- Have practices been installed as planned?

  This is answered by examining the plan, implementation schedule, designs in planning steps 7 and 8 (table 4–1), and confirming that practices have been installed. Plans are subject to change and modification, so it is important to verify that practices have actually been applied when and where specified.

- Are desired future conditions being achieved at the specified level and timing?

  The desired conditions were originally specified during planning step 4 and used again in step 6 to evaluate the expected performance of RMS options and, ultimately, help the client choose the best one. To respond to this question, conditions may be measured on an absolute basis (tons of sediment passing a reference point, presence or absence of instream bars, soil loss calculated in scour areas), on an interpretive basis (some kind of index score based on habitat components), or using modeling where before and after values for model variables compared.

The specific measurements and techniques used in planning steps 3 and 4 (table 4–1) are again remeasured during the step 9 evaluation. The results of the evaluation or progress towards success can be expressed in terms of yes or no or as a percentage of improvement. The following examples illustrate two cases of treatment evaluation.

Case 1

Given: Bank erosion has a recession rate of about 0.5 foot per year. Site and upstream conditions have remained constant during the past 10 years. The RMS was developed based on determination that bank erosion is controllable at the site, using primarily Channel Bank Vegetation (322) and Riparian Forest Buffer (391). The recession rate is determined to be of an accelerated nature (above and beyond natural, geologic erosion for the stream type). The desired condition is no evidence of bank recession within 10 years of the last applied RMS practice.

Evaluation: RMS practices have all been applied, with the last practice installed 10 years ago. There is no visual evidence of bank recession. The evaluation indicates yes, the RMS is successful.

Case 2

Given: The client owns a significant part of an upstream watershed. The Agricultural Nonpoint Source Pollution Model (AGNPS) has been used to estimate sediment production at the lowest downstream point of the client's stream system. The stream corridor CMU is continuous along both sides of the stream system and excludes agricultural and other intensive land uses to 150 feet on each side of the stream (perpendicular to streamflow) as measured from the bankfull level. The desired condition is a 70 percent reduction of annual sediment within 10 years of the last applied RMS practice.

Evaluation: RMS practices which include riparian vegetation establishment have all been applied, with the last practice installed 10 years ago. Conditions have been reassessed, and the model rerun. Results indicate there has been only a 30 percent decrease in annual sediment. The evaluation indicates the RMS is not yet successful. If the planner and client are dissatisfied with the evaluation outcome, they can decide to reassess the efficacy of the RMS, reset the target or threshold for success, increase the allowable response time, or use a more exacting model (if available) to improve the sediment yield estimate.

The evaluation procedure presented above is based on the assumption that desired future conditions have been well established during the planning process. If this is not the case, land and water treatment evaluation may require the development of a special strategy in consultation with interdisciplinary specialists to determine the effects of applied RMSs. A challenge with a retroactive approach is re-creating pretreatment conditions and estimates of measurements.

654.0406 Conclusion

The process for designing stream restoration solutions is an integral part of the CPP. Solutions may result in simple designs that may only require changes in management and removal of disturbance factors. However, depending on the complexity of the problem, a solution that integrates both management and structural approaches may be needed. Structural approaches may include design elements that integrate soil materials, plants, large woody material, concrete, rock, steel, or other materials. In either case, the focus should be on solving the stated problems, as well as conserving and restoring natural resources to the extent possible. Local conditions determine what kinds of data are needed for preliminary and detailed designs, and the design process will vary according to the types and number of design elements, complexity of the project, and degree of risk involved, as described in NEH654.02.

The best design will be one that results in minimal maintenance and is also self-sustaining. This may not always be possible, depending on the specific goals and objectives and overall constraints, especially in areas with impaired watersheds, rigid constraints of land ownership, or jurisdictional requirements.

The following chapters provide more detailed information on the use and applicability of various tools for analyzing and designing stream restorations. Some are well entrenched in scientific research and experience, while others reflect the state of the art.