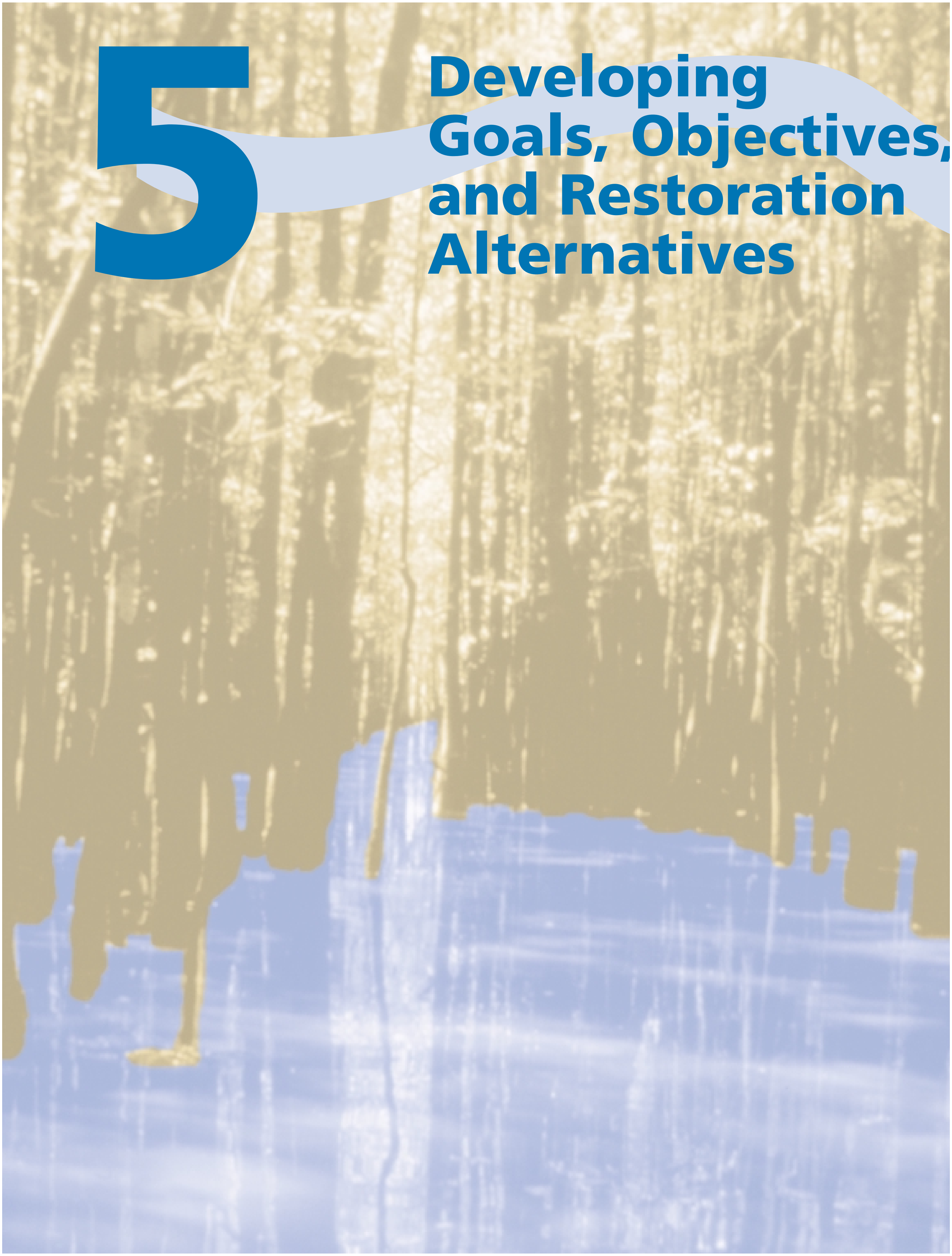

5 Developing Goals, Objectives, and Restoration Alternatives

5.A Developing Restoration Goals and Objectives

- *How are restoration goals and objectives defined?*
- *How do you describe desired future conditions for the stream corridor and surrounding natural systems?*
- *What is the appropriate spatial scale for the stream corridor restoration?*
- *What institutional or legal issues are likely to be encountered during a restoration?*
- *What are the means to alter or remove the anthropogenic changes that caused the need for the restoration (i.e., passive restoration)?*

5.B Alternative Selection and Design

- *How does a restoration effort target solutions to treat causes of impairment and not just symptoms?*
- *What are important factors to consider when selecting among various restoration alternatives?*
- *What role does spatial scale, economics, and risk play in helping to select the best restoration alternative?*
- *Who makes the decisions?*
- *When is active restoration needed?*
- *When are passive restoration methods appropriate?Chapter 6: Implement, Monitor, Evaluate, and Adapt*

5 Developing Goals, Objectives, and Restoration Alternatives

Once the basic organizational steps have been completed and the problems/opportunities associated with the stream corridor have been identified, the next two stages of the restoration plan development process can be initiated. These two stages, the development of restoration goals and objectives and alternative selection and design, require input from all partners. The advisory group should work in collaboration with the decision maker(s) and technical teams.

During the objective development, alternative selection, and design stages, it is important that continuity be maintained among the fundamental steps of the restoration process. In other words, planners must work to ensure a logical flow and relationship between problem and opportunity statements, restoration goals and objectives, and design.

Remember that the restoration planning process can be as complex as the stream corridor to be restored. A project might involve a large number of landowners and decision makers. It might also be fairly simple, allowing planning through a streamlined process. In either case, proper planning will lead to success.

Proper planning in the beginning of the restoration process will save time and money for the life of the project. This is *often accomplished by managing the causes rather than the symptoms.*

This chapter is divided into two sections that describe the basic steps of defining goals and objectives, selecting alternatives, and designing restoration measures.

Section 5.A: Developing Restoration Goals and Objectives

Restoration objectives are essential for guiding the development and implementation of restoration efforts and for establishing a means to measure progress and evaluate success. This section outlines some of the major considerations that need to be taken into account in developing restoration goals and objectives for a restoration plan.

Although active restorations that include the installation of designed measures are common, the "no action" or passive alternative might be more ecologically desirable, depending on the specific goals and time frame of the plan.

Section 5.B: Alternative Selection and Design

The selection of restoration alternatives is a complex process that is intended to address the identified problems/opportunities and accomplish restoration goals and objectives. Some of the important factors to consider in designing restoration measures, as well as some of the supporting analysis that facilitates alternative selection, are discussed.

5.A Developing Restoration Goals and Objectives

Developing goals and objectives for a stream corridor restoration effort follows problem/opportunity identification and analysis. The goals development process should mark the integration of the results of the assessment of existing and desired stream corridor structure and functions with important political, economic, social, and cultural values. This section presents and explains some of the fundamental components of the goal and objective development process.

Components of the Goal and Objective Development Process

- Define the desired future condition.
- Identify scale considerations.
- Identify restoration constraints and issues.
- Define goals and objectives.

Defining Desired Future Stream Corridor Conditions

The development of goals and objectives should begin with a rough outline, as discussed in Chapter 4, and with the definition of the *desired future condition* of the stream corridor and surrounding landscape (**Figure 5.1**). The desired future condition should represent the common vision of all participants. This clear, conceptual picture is necessary to serve both as a foundation for more specific goals and objectives and as a target toward which implementation strategies can be directed.

The vision statement should be consistent with the overall ecological goal of restoring stream corridor structure and functions and bringing the system as close to a state of dynamic equilibrium or proper functioning condition as possible.

The development of this vision statement should be seen as an opportunity for participants to articulate an ambitious ecological vision. This vision will ultimately be integrated with important social, political, economic, and cultural values.

Identifying Scale Considerations

In developing stream corridor restoration goals and objectives it is important to consider and address the issue of scale. The scale of stream corridor restoration efforts can vary greatly, from working on a short reach to managing a large river basin corridor. As discussed

Figure 5.1: Example of future conditions. *The desired future condition should represent the common vision of all participants.*

CASE STUDY Chesapeake Bay Program

A unique partnership that spanned across all scales of the Chesapeake Bay watershed was formed in 1983. The Chesapeake Bay Agreement was signed that year by the District of Columbia, the state of Maryland, the Commonwealths of Pennsylvania and Virginia, the Chesapeake Bay Commission (a tri-state legislative body), and the federal government represented by the Environmental Protection Agency to coordinate and direct the restoration of the Chesapeake Bay. Recognizing that local cooperation would be vital in implementing any efforts, the Executive Committee created the Local Government Advisory Committee (LGAC) in 1987. The LGAC acts as a conduit to communicate current efforts in the Program to the local level, as well as a platform for local governments to voice their perceptions, ideas, and concerns. The Land Growth and Stewardship Subcommittee was formed in 1994 to encourage actions that reduce the impacts of growth on the Bay and address other issues related to population growth and expansion in the region.

***Figure 5.2*: Chesapeake Bay.** *The Chesapeake Bay is a unique estuarine ecosystem protected through interagency cooperation.*
Source: C. Zabawa.

*The Chesapeake Bay was the first estuary targeted for restoration in the 1970s. Based on the scientific data collected during that time, the agreement targeted 40 percent reductions in nutrients, nitrogen, and phosphorus by the year 2000. The committee has been instrumental in moving up the tributaries of the bay and improving agricultural practices, removing nutrients, and educating the millions of residents about their role in improving the quality of the bay. Success has been marked by reduction in nutrients and an increase in populations of striped bass and other species (**Figure 5.2**). Recent fish kills in the watershed rivers, however, are reminders that maintaining the health of the Chesapeake Bay is a continuing challenge.*

Success at the local level is key to the success of the overall program. Chesapeake Bay Communities' Making the Connection *catalogs some of the local initiatives to restore local environments and improve the condition of the bay. In Lancaster County, Pennsylvania, for example, a Stream Team was formed to preserve and restore the local streams. Its primary role is to coordinate restoration efforts involving local landowners, volunteers, and available programs. In one case, the Stream Team was able to arrange materials for a local fishing group and a farmer to fence a pasture stream and plant trees. With continuous efforts such as this, the Chesapeake Bay will become cleaner one tributary at a time.*

previously, it is important to recognize, however, that the functions of a specific streambank or reach ecosystem are not performed in isolation and are linked to associated ecosystems in the surrounding landscape. As a result, goals and objectives should recognize the stream corridor and its surrounding landscape.

The Landscape Scale

Technical considerations in stream corridor restoration usually encompass the landscape scale as well as the stream corridor scale. These considerations may include political, economic, historical, and/or cultural values; natural resource management concerns; and biodiversity (Landin 1995). The following are some important issues relevant to the landscape scale.

Regional Economic and Natural Resource Management Considerations

Regional economic priorities and natural resource objectives should be identified and evaluated with respect to their likely influence on the restoration effort. It is important that restoration goals and objectives reflect a clear understanding of the concerns of the people living in the region and the immediate area, as well as the priorities of resource agencies responsible for managing lands within the restoration target area and providing support for the initiative (**Figure 5.3**).

In many highly developed areas, restoration may be driven largely by a general recognition that stream corridors provide the most satisfactory opportunities to repair and preserve natural environments in the midst of increasingly dense human occupation. In wildland areas, stream corridor restoration might be pursued as part of an overall ecosystem management program or to address the requirements of a particular endangered species.

Land Use Considerations

As discussed in Chapter 2, many of the characteristics and functions of the stream corridor are controlled by hydrologic and geomorphic conditions in the watershed, particularly as they influence streamflow regime, sediment movement, and inputs of nutrients and pollutants (Brinson et al. 1995).

As introduced in Chapter 3, changes in land use and increases in development are a concern, particularly because they can cause rapid changes in the delivery of storm water to the stream system, thereby changing the basic hydrologic patterns that determine stream configuration and plant community distribution (**Figure 5.4**). In addition, future development can influence what the stream corridor will be expected to accomplish in terms of processing or storing floodwaters or nutrients, or with respect to providing wildlife habitat or recreation opportunities.

REVERSE

Review Chapters 2 and 3.

Figure 5.3: Western stream—landscape scale. *Developing goals and objectives requires the consideration of important social, economic, ecological, and natural resource factors at the landscape scale.*

Figure 5.4: Urban stream corridor. *Population growth and land use trends, such as urbanization, should be considered when developing restoration goals and objectives.*

Landscape concerns pertinent to developing goals and objectives for stream corridor restoration should also include an assessment of land use and projected development trends in the watershed. By making an effort to accommodate predictable future land use and development patterns, degradation of stream corridor conditions can be prevented or reduced.

Biodiversity Considerations

The continuity that corridors provide among different areas and ecosystem types has often been cited as a major tool for maintaining regional biodiversity because it facilitates animal movement (particularly for large mammals) and prevents isolation of plant and animal populations. However, there has been some dispute over the effectiveness of corridors to accomplish these objectives and over the creation of inappropriate corridors having adverse consequences (Knopf 1986, Noss 1987, Simberloff and Cox 1987, Mann and Plummer 1995).

Where corridor restoration is intended to result in establishing connectivity on a landscape scale, management objectives and options should reflect natural patterns of plant community distribution and should be built to provide as much biodiversity as possible. In many instances, however, the driving force behind restoration is the protection of certain threatened, endangered, game, or other specially targeted species. In these cases a balance must be struck. A portion of the overall restoration plan can be directed toward the life requirements of the targeted species, but on the whole the goal should be a diverse community (**Figure 5.5**).

The Stream Corridor Scale

Each stream corridor targeted for restoration is unique. A project goal of restoring multiple ecological functions might encompass the channel systems, the active floodplain, and possibly adjacent hill slopes or other buffer areas that have the potential to directly and indirectly influence the stream or protect it from surrounding land uses (Sedell et al. 1990). A wide corridor is

Figure 5.5: Animal population dynamics. *Restoration plans may target species, but biodiversity should be the basic goal of restoration.*

most likely to include a range of biotic community types and to perform many of the stream functions (floodwater and sediment storage, nutrient processing, fish and wildlife habitat, and others) that the restoration effort is intended to restore. In many cases, however, it will not be possible to reestablish the original corridor width, and restoration will be focused on a narrower strip of land directly adjacent to the channel.

Where narrow corridors are established through urban or agricultural landscapes, certain functions might be restored (e.g., stream shading), while others might not (e.g., wildlife movement). In particular, very narrow corridors, such as western riparian areas, may function largely as edge habitat and will favor unique and sometimes opportunistic plant and animal species. In some situations, creating a large amount of edge habitat might be detrimental to species that require large forested habitat or are highly vulnerable to predation or nest parasitism and disturbances.

The corridor configuration and restoration options depend to a large extent on the pattern of land ownership and use at the stream corridor scale. Corridors that traverse agricultural land may involve the interests of many individual landowners with varying levels of commitment to or interest in the restoration initiative.

Often, landowners will not be inclined to remove acreage from production or alter land use practices without incentive. In urban settings, citizen groups may have a strong voice in the objectives and layout of the corridor. On large public land holdings, management agencies might be able to commit to the establishment and management of stream corridors and their watersheds, but the incorporation of competing interests (timber, grazing, mining, recreation) that are not always consistent with the objectives of the restoration plan can be difficult. In most cases, the final configuration of the corridor should balance multiple and often conflicting objectives, including optimizing ecological structure and function and accommodating the diverse needs of landowners and other participants.

The Reach Scale

A reach is the fundamental unit for design and management of the stream corridor. In establishing goals and objectives, each reach must be evaluated with regard to its landscape and individual characteristics, as well as their influence on stream corridor function and integrity. For example, steep slopes adjacent to a channel reach must be considered where they contribute potentially significant amounts of runoff, subsurface flow, sediment, woody debris, or other inputs. Another reach might be particularly active with respect to channel migration and might warrant expanding the corridor relative to other reaches to accommodate local stream dynamics.

Identifying Restoration Constraints and Issues

Once participants have reached consensus on the desired future condition and examined scale considerations, attention should be given to identifying *restoration constraints and issues*. This process is important in that it helps identify limitations associated with establishing specific restoration goals and objectives. Moreover, it provides the information that will be needed when integrating ecological, social, political, and economic values.

Due to the innumerable potential challenges involved in identifying all of the constraints and issues, it is often help-

FAST FORWARD

Preview Chapter 6's Adaptive Management section.

ful to rely on the services of the interdisciplinary technical teams. Team members support one another and provide critical expertise and the experience necessary to investigate potential constraints. The following are some of the restoration constraints and issues, both technical and nontechnical, that should be considered in defining restoration goals and objectives.

Technical Constraints

Technical constraints include the availability of data and restoration technologies. In terms of data availability, it is important that the technical team begin by compiling and analyzing data available on stream corridor structure and functions. Analyzing these data will enable the identification of information gaps and should allow the restoration effort to proceed, even though all of the information might not be at hand. It should be noted that there is usually a wealth of technical information available either in published sources or in public agency offices as unpublished source material.

In addition to data availability, a second technical constraint might involve the tools or techniques used to analyze or collect stream corridor data. Some restoration techniques and methodologies are not complete and might not be sufficient to conduct the restoration effort. It is also generally known that technology transfer and dissemination associated with available techniques are far behind the existing information base, and field personnel might not readily have access to needed information. It is important that the technical teams are up-to-date with restoration technology and are prepared to modify implemented plans through adaptive management as necessary.

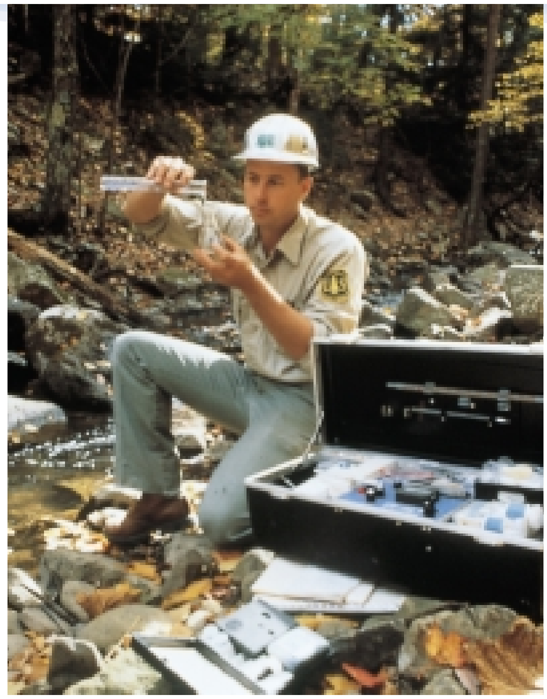

Figure 5.6: Field sampling. *Collecting the right kinds of data with the proper quality control and translating that data into information useful for making decisions is a challenge.*

Quality Assurance, Quality Control

The success of a stream corridor restoration plan depends on the following:

- Efficient and accurate use of existing data and information.
- Reliable collection of new data that are needed, recognizing the required level of precision and accuracy (**Figure 5.6**).
- Interpretation of the meaning of the data, including translating the data into information that can be used to make planning decisions.
- A locally led, voluntary approach.

The concept of quality assurance or quality control is not new. When time, materials, or money are to be expended, results should be as reliable and efficiently derived as possible. Provisions for quality control or quality assurance can be built into the restoration plan, especially if a large number of contractors, volunteers, and other people not directly under the control of the planners are involved (Averett and Schroder 1993).

Many standards, conventions, and protocols exist to ensure the quality or reliability of information used for planning a restoration (Knott et al. 1992), including the following:

- Sampling
- Field analytical equipment
- Laboratory testing equipment
- Standard procedures
- Training
- Calibrations
- Documentation
- Reviews
- Delegations of authority
- Inspections

The quality of work and the restoration actions can be ensured through the following (Shampine et al. 1992, Stanley et al. 1992, Knott et al. 1993):

- Training to ensure that all persons fully understand what is expected of them.
- Products that are produced on time and that meet the plan's goals and objectives.
- Established procedures for remedial actions or adaptive management, which means being able to make adjustments as monitoring results are analyzed.

Nontechnical Constraints

Nontechnical constraints consist of financial, political, institutional, legal and regulatory, social, and cultural constraints, as well as current and future land and water use conflicts. Any one of these has the potential to alter, postpone, or even stop a restoration initiative. As a result, it is important that the advisory group and decision maker consider appointing a technical team to investigate these issues prior to defining restoration goals and objectives.

Contained below is a brief discussion of some of the nontechnical issues that can play a role in restoration initiatives. Although many general examples and case studies offer experience on addressing nontechnical constraints, the nuances of each issue can vary by initiative.

Land and Water Use Conflicts

Land and water use conflicts are frequently a problem, especially in the western United States. The historical, social, and cultural aspects of grazing, mining, logging, water resources development and use, and unrestricted use of public land are emotional issues that require coordination and education so that local and regional citizens understand what is being proposed in the restoration initiative and what will be accomplished.

Financial Issues

Planning, design, implementation, and other aspects of the restoration initiative must stay within a budget. Since most restoration efforts involve public agencies, the institutional, legal, and regulatory protocols and bureaucracies can delay restoration and increase costs. It is extremely important to recognize these problems early to keep the initiative on schedule and preclude or at least minimize cost overruns.

In some cases, funds might be insufficient to accomplish restoration. The means to undertake the initiative can often be obtained by seeking out and working with a broad variety of cost- and work-sharing partners; seeking out and working with volunteers to perform

Permits

Federal, state, or local permits might be required for some types of stream restoration activities. Some states, such as California, require permits for any activity in a streambed. Placement of dredged or fill material in waters of the United States requires a Clean Water Act (CWA) Section 404 permit from the US Army Corps of Engineers or, when the program has been delegated, from the state. The CWA requires the application of the Section 404(b)(1) guidelines issued by the Environmental Protection Agency in determining whether discharge should be allowed. A permit issued under Section 10 of the Rivers and Harbors Act of 1899 might also be required for activities that change the course, condition, location, or capacity of navigable waters.

Activities that could trigger the need for a CWA Section 404 permit include, but are not limited to, re-creation of gravel beds, sand bars, and riffle and pool habitats; wetland restoration; placement of tree root masses; and placement of revetment on channel banks. CWA Section 404 requires that a state or tribe (one or both as appropriate) certify that an activity requiring a Section 404 permit is consistent with the state's or tribe's water quality standards. Given the variety of actions covered by the CWA, as well as jurisdiction issues, it is vital to contact the Corps of Engineers Regulatory Branch and appropriate state officials early in the planning process to determine the conditions triggering the need for permits as well as how to best integrate permit compliance needs into the planning and design of the restoration initiative. Chances are that a well-thought-out planning and design process will address most, if not all, the information needs for evaluation or certification of permit applications. Federal issuance of a permit triggers the need for compliance with the National Environmental Policy Act (see National Environmental Policy Act Considerations*).*

***Figure 5.7: Field volunteers.** Volunteers assisting in the restoration effort can be an effective way to combat financial constraints.*
Source: C . Zabawa.

various levels of field work, as well as to serve as knowledgeable experts for the effort; costing the initiative in phases that are affordable; and other creative approaches (**Figure 5.7**). Logistical support by a local sponsor or community in the form of labor, boats, and other equipment should not be overlooked.

Not all restorations are complex or costly. Some might be as simple as a slight change in the way that resources are managed in and along the stream corridor, involving only minor costs. Other restorations, however, may require substantial funds because of the complexity and extent of measures needed to achieve the planned restoration goals.

National Environmental Policy Act Considerations

The National Environmental Policy Act (NEPA) of 1969 established the nation's policy to protect and restore the environment and the federal responsibility to use "all practicable means and measures ... to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social and economic and other requirements of present and future generations of Americans." NEPA focuses on major federal actions with the potential to significantly affect the human environment. The Council on Environmental Quality's regulations implementing NEPA require the federal agency taking action to develop alternatives to a proposed action, to analyze and compare the impacts of each alternative and the proposed action, and to keep the public informed and involved throughout the project planning and implementation. Although NEPA does not mandate environmentally sound decisions, it has established a decision-making process that ultimately encourages better, wiser, and fully informed decisions.

When considering restoration of a stream corridor, it is important to determine early on whether a federal action will occur. Federal actions that might be associated with a stream corridor restoration initiative include, but are by no means limited to, a decision to provide federal funds for a restoration initiative, a decision to significantly alter operation and maintenance of federal facilities on a river system, or the need for a federal permit (e.g., a Clean Water Act Section 404 permit for placement of dredged or fill material in waters of the United States).

In addition, many states have environmental impact analysis statutes patterned along the same lines as NEPA. Consultation with state and local agencies should occur early and often throughout the process of developing a stream corridor restoration initiative. Jointly prepared federal and state environmental documentation is routine in some states and is encouraged.

The federal requirement to comply with NEPA should be integrated with the planning approach for developing a restoration plan. When multiple federal actions are required to fully implement a restoration initiative, the identity of the lead federal agency(s) and cooperating agencies should be established. This will facilitate agency adoption of the NEPA document for subsequent decision making.

Institutional and Legal Issues

Each restoration effort has its own unique set of regulatory requirements, which can range from almost no requirements to a full range of local, county, state, and federal permits. Properly planned restoration efforts should meet or exceed the intent of both federal and non-federal requirements. Restoration planners should contact the appropriate local, state, and federal agencies and involve them early in the process to avoid conflicts with these legal requirements.

Typical institutional and legal requirements cover a wide range of issues. Locally, restoration planners must be concerned with zoning permits and state and county water quality permits. Most federally sponsored and/or funded initiatives require compliance with the National Environmental Policy Act and the Endangered Species Act. Initiatives that receive federal support must comply with the National Historic Preservation Act and the Wild and Scenic Rivers Act. Permits might also be required from the US Army Corps of

Example Goals and Objectives

The following is an excerpt from of a restoration plan used for restoration of Wheaton Branch, a severely degraded urban stream in Maryland. The ***goal*** *of the project was to control storm water flows and improve water quality.*

OBJECTIVES	ALTERNATIVES
(1) Remove urban pollutants	Upstream pond retrofit
(2) Stabilize channel bundles	Install a double-wing deflector, imbricated riprap, and brush
(3) Control hydrologic regime retrofit	Upstream storm water management pond
(4) Recolonize stream community	Fish reintroduction

Adapted from Center for Watershed Protection 1995.

Engineers under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899.

Defining Restoration Goals

Restoration goals should be defined by the decision maker(s) with the consensus of the advisory group and input from the interdisciplinary technical team(s) and other participants. As noted earlier, these goals should be an integration of two important groups of factors:

- Desired future condition (ecological reference condition).
- Social, political, and economic values.

Considering Desired Future Condition

As discussed earlier, the desired ecological future condition of the stream corridor is frequently based on predevelopment conditions or some commonly accepted idea of how the natural stream corridors looked and functioned. Consequently, it represents the ideal situation for restoration, whether or not this reference condition is attainable. This ideal situation has been given the term "potential," and it may be described as the highest ecological status an area can attain, given no political, social, or economic constraints (Prichard et al. 1993). When applied to the initiative, however, this statement might require modification to provide realistic and more specific goals for restoration.

Factoring In Constraints and Issues

In addition to the desired future ecological condition, definition of restoration goals must also include other considerations. These other factors include the important political, social, and economic values as well as issues of scale. When these considerations are factored into the analysis, realistic project goals can be identified. The goals provide the overall purpose for the restoration effort and are based on a stream corridor's capability or its ideal ecological condition.

Defining Primary and Secondary Restoration Goals

The identification of realistic goals is a key ingredient for restoration success since it sets the framework for adaptive management within a realistic set of expectations. Unrealistic restoration goals create unrealistic expectations and potential disenchantment among stakeholders when those expectations are unfulfilled.

In defining realistic restoration goals, it might be helpful to divide these goals into two separate, yet connected, categories—primary and secondary.

Primary Restoration Goals

Primary goals should follow from the problem/opportunity identification and analysis, incorporate the participants' vision of the desired future condition, and reflect a recognition of project constraints and issues such as spatial scale, needs found in baseline data collection, practical aspects of budget and human resources requirements, and special requirements for certain target or endangered species. Primary goals are usually the ones that initiated the project, and they may focus on issues such as bank stabilization, sediment management, upland soil and water conservation, flood control, improved aquatic and terrestrial habitat, and aesthetics.

Secondary Restoration Goals

Secondary goals should be developed to either directly or indirectly support the primary goals of the restoration effort. For example, hiring displaced forestry workers to install conservation practices in a forested watershed or region could serve the secondary goal of revitalizing a locally depressed economy, while also contributing to the primary goal of improving biodiversity in the restoration area.

Defining Restoration Objectives

Objectives give direction to the general approach, design, and implementation of the restoration effort. *Restoration objectives* should support the goals and also flow directly from problem/opportunity identification and analysis.

Cultural Resource Considerations and the National Historic Preservation Act

Restoration objectives should be defined in terms of the same conditions identified in the problem analysis and should specifically state which impaired stream corridor condition(s) will be moved toward which particular reference level or desired condition(s). The reference conditions provide a gauge against which to measure the success of the restoration effort; restoration objectives should therefore identify both impaired stream corridor conditions and a quantitative measure of what constitutes unimpaired (restored) conditions. Restoration objectives expressed in terms of measurable stream corridor conditions provide the basis for monitoring the success of the project in meeting condition objectives for the stream corridor.

Concepts Useful in Defining Restoration Goals and Objectives

Value*: Social/economic values associated with a change from one set of conditions to another. Often, these values are not economic values, but rather amenity values such as improved water quality, improved habitat for native aquatic or riparian species, or improved recreational experiences. Because stream corridor restoration often requires a monetary investment, the benefits of restoration need to be considered not only in terms of restoration costs, but also in terms of values gained or enhanced.*

Tolerance*: Acceptable levels of change in conditions in the corridor. Two levels of tolerance are suggested:*

(1) Variable "management" tolerance that is responsive to social concerns for selected areas.

(2) Absolute "resource" tolerance or minimal acceptable permanent resource damage.

Stream corridors in need of restoration usually (but not always) exceed these tolerances.

Vulnerability*: How susceptible a stream's present condition is to further deterioration if no new restoration actions are implemented. It can be conceptualized as the ease with which the system might move away from dynamic equilibrium. For example, an alpine stream threatened by a headcut induced by a poorly placed culvert might be extremely vulnerable to subsequent incision. Conversely, a forested stream that has sluiced to bedrock because large woody debris was lost from the system might be much less vulnerable to further deterioration.*

Responsiveness*: How readily or efficiently restoration actions will achieve improved stream corridor conditions. It can be conceptualized as the ease with which the system can be moved toward dynamic equilibrium. For example, a rangeland stream that has become excessively wide and shallow might respond very rapidly to grazing management by establishing a more natural cross section that is substantially narrower and deeper. On the other hand, an agricultural stream that has deeply incised following channelization might not readily reestablish grade or channel pattern in response to improved watershed or riparian vegetation conditions.*

Self-Sustainability*: The degree to which the restored stream can be expected to continue to maintain its restored (but dynamic) condition. The creation or establishment of dynamic equilibrium should always be a goal. However, it might be that intensive short-term maintenance is necessary to ensure weeds and exotic vegetation do not get a foothold. The short-term and longer-term goals and objectives to ensure sustainability need to be carefully considered relative to funding, proximity of the site to population concentrations, and caretakers.*

CASE STUDY

Restoration of the Elwha River Ecosystem

The construction of numerous hydropower projects fueled the economic growth of the Pacific Northwest during the early 1900s. With the seemingly inexhaustible supply of anadromous salmonids, little care was taken to reduce or mitigate the consequent impacts to these fish (Hoffman and Winter 1996). Two hydropower dams built on the Elwha River, on Washington's Olympic Peninsula, were no exception.

The 108 ft. high Elwha Dam (**Figure 5.8**) was built from 1910–13 about five miles from the river mouth. Although state law required a fishway, one was not built. As a result, salmon and steelhead populations immediately declined, some to extinction, and remaining populations have been confined to the lower five miles ever since. The 210 ft. high Glines Canyon Dam (**Figure 5.9**) was built from 1925–27 about eight miles upstream of the first dam, also without fish passage facilities. Glines was licensed for a period of 50 years in 1925 while the Elwha Dam has never been licensed.

In 1968, the project owner filed a license application for Elwha Dam and filed a relicense application for the Glines Canyon Dam in 1973. The Federal Energy Regulatory Commission (FERC) did not actively pursue the licensing of these two projects until the early 1980s when federal and state agencies, the Lower Elwha Klallam Tribe (Tribe), and environmental groups filed petitions with FERC to intervene in the licensing proceeding. The option of dam removal to restore the decimated fish runs was raised in most of these petitions, and FERC addressed dam removal in a draft environmental impact statement (EIS). Nonetheless, it was apparent that disagreements remained over numerous issues, and that litigation could take a decade or more.

Congressional representatives offered to broker a solution. In October 1992, President George Bush signed Public Law 102-495 (the Elwha River Ecosystem and Fisheries Restoration Act; the Elwha Act), which is a negotiated settlement involving all parties to the FERC proceeding. The Elwha Act voids

Figure 5.8: Elwha Dam. Fish passages were not constructed when the dam was built in 1910–1913.

FERC's authority to issue long-term licenses for either dam, and it confers upon the Secretary of the Interior the authority to remove both dams if that action is needed to fully restore the Elwha River ecosystem and native anadromous fisheries. In a report to the Congress (DOI et al. 1994), the Secretary concluded that dam removal was necessary to meet the goal of the Elwha Act. Subsequently, Interior completed the EIS process FERC had begun but using the new standard of full ecosystem restoration rather than "balancing" competing uses as FERC is required to do (NPS 1995).

Interior analyzed various ways to remove the dams and manage the 18 million cubic yards (mcy) of sediments that have accumulated in the two reservoirs since dam construction. The preferred alternative for the Glines Canyon Dam is to spill the reservoir water over successive notches constructed in the concrete gravity-arch section, allowing layers of the dam to be removed with a crane under dry conditions (NPS 1996). Standard diamond wire-saw cutting and blasting techniques are planned. Much of the dam, including the left and right side concrete abutments and spillway, will be retained to allow for the interpretation of this historic structure.

The foundation of the Elwha Dam failed during reservoir filling in 1912, flooding downstream areas such as the Tribe's reservation at the mouth of the river. A combination of blasted rock, fir mattresses, and other fill was used to plug the leak (NPS 1996). To avoid a similar failure during removal, the reservoir will be partially drained and the river diverted into a channel constructed through the bedrock footing of the left abutment. This will allow the fill material and original dam structure to be removed under dry conditions. Following removal of this material, the river will be diverted back to its historic location and the bedrock channel refilled. Since the Elwha Dam was built in an area that is religiously and culturally important to the Tribe, all structures will be removed.

The 18 mcy of accumulated sediment consists of about 9.2 mcy of silt and clay (<0.075 mm), 6.2 mcy of sand (0.075-<5 mm), 2.0 mcy of gravel (5-<75 mm), and .25 mcy of cobbles (75-<300 mm). The coarse material (i.e., sand and larger) is considered a resource that is lacking in the river below the dams, the release of which will help restore the size and function of a more natural and dynamic river channel, estuary, and nearshore marine areas. The silt- and clay-sized particles are also reduced in the lower river, but resuspension of this material may cause the loss of aquatic life and adversely affect water users downstream for the approximately two to three years this process is expected to last (NPS 1996). Nevertheless, the preferred alternative incorporates the natural erosive and transport capacity of the river to move this material downstream, although roughly half of the fine and coarse materials will remain in the newly dewatered reservoir areas. Water quality and fisheries mitigation actions are planned to reduce the impacts of sediment releases during and following dam removal. Revegetation actions will be implemented on the previously logged slopes for stabilization purposes and to accelerate the achievement of old-growth characteristics. The old reservoir bottoms will be allowed to revegetate naturally; “greenup” should occur within three to five years.

(a)

(b)

Figure 5.9: Glines Canyon Dam. (a) Before removal and (b) simulation after removal.

Following the removal of both dams, the salmon and steelhead runs are expected to total about 390,000 fish, compared to about 12,000 to 20,000 (primarily hatchery) fish. These fish will provide over 800,000 pounds of carcass biomass (NPS 1995). About 13,000 pounds of this biomass is marine-derived nitrogen and phosphorous, the benefits of which will cascade throughout the aquatic and terrestrial ecosystem. The vast majority of wildlife species are expected to benefit from the restoration of this food resource and the recovery of over 700 acres of important lowland habitat. Restoration of the fish runs will also support the federal government’s trust responsibility to the Tribe for its treaty-reserved harvest rights. More wetlands will be recovered than will be lost from draining the reservoirs.

As in the case of restoration goals, it is imperative that restoration objectives be realistic for the restoration area and be measurable. Objectives must therefore be based on the site's expected capability and not necessarily on its unaltered natural potential. It is much more useful to have realistic objectives reflecting stream corridor conditions that are both achievable and measurable than to have vague, idealistic objectives reflecting conditions that are neither.

For example, an overall restoration goal might be to improve fish habitat. Several supporting objectives might include the following:

- Improve water temperature by providing shade plants.
- Construct an instream structure to provide a pool as a sediment trap.
- Work with local landowners to encourage near-stream conservation efforts.

If these objectives were to be used as success criteria, however, they would require more specific, measurable wording. For example, the first objective could be written to state that buttonbush planted along streambanks exhibit a 50 percent survival rate after three growing seasons and are not less than 5 feet in height. This vegetative cover results in a net reduction in water temperature within the stream. It should be noted that this issue of success or evaluation criteria is critical to stream corridor restoration. This is explored in more detail in Chapters 6 and 9.

5.B Alternative Selection and Design

The selection of technically feasible alternatives and subsequent design are intended to solve the identified problems, realize restoration opportunities, and accomplish restoration goals and objectives. Alternatives range from making minor modifications and letting nature work to total reconstruction of the physical setting. An efficient approach is to conceptualize, evaluate, and select general solutions or overall strategies before developing specific alternatives.

This section focuses on some of the general issues and considerations that should be taken into account in the selection and design of stream corridor *restoration alternatives*. It sets the stage for the more detailed presentation of restoration design in Chapter 8 of this document.

Important Factors to Consider in Designing Restoration Alternatives

The design of restoration alternatives is a challenging process. In developing alternatives, special consideration should be given to managing causes as opposed to treating symptoms, tailoring restoration design to the appropriate scale (landscape/corridor/stream/reach), and other scale-related issues.

Managing Causes vs. Treating Symptoms

When developing restoration alternatives, three questions regarding the factors that influence conditions in the stream corridor must be addressed. These are critical questions in determining whether a passive, nonstructural alternative is appropriate or whether a more active restoration alternative is needed.

FAST FORWARD
Preview Chapter 8's restoration design section

Alternative Selection and Design Considerations

Supporting Analyses for Selecting Alternatives

- *Feasibility study*
- *Cost-effectiveness analysis*
- *Risk assessment*
- *Environmental impact analysis*

Factors to Consider in Alternative Design

- *Managing causes vs. treating symptoms*
- *Landscape/Watershed vs. corridor reach*
- *Other spatial and temporal considerations*

1. What have been the implications of past management activities in the stream corridor (a cause-effects analysis)?
2. What are the realistic opportunities for eliminating, modifying, mitigating, or managing these activities?
3. What would be the response of impaired conditions in the corridor if these activities could be eliminated, modified, mitigated, or managed?

If the causes of impairment can realistically be eliminated, complete ecosystem restoration to a natural or unaltered condition might be a feasible objective and the focus of the restoration activity will be clear. If the causes of impairment cannot realistically be eliminated, it is critical to identify what options exist to manage either the causes or symptoms of altered conditions and what effect, if any, those management options might have on the subject conditions.

If it is not feasible to manage the cause(s) of impaired conditions, then mitigating the impacts of disturbance(s) is an alternative method of implementing sustainable stream corridor restoration. By choosing mitigation, the focus of the restoration effort might then be on addressing only the symptoms of impaired conditions.

When disturbance cannot be fully eliminated, a logical planning process must be used to develop alternative management options. For example, in analyzing bank erosion, one conclusion might be that accelerated watershed sediment delivery has produced lateral instability in the stream system, but modification of land-use patterns causing the problem is not a feasible management op-

Figure 5.10: Streambank erosion. *In designing alternatives for bank erosion it is important to assess the feasibility of addressing the cause of the problem (e.g., modify land uses) or treating the symptom (e.g., install bank-erosion control structures).*

tion at this time (**Figure 5.10**). It might therefore still be possible to develop a channel erosion condition objective and to identify treatments such as engineered or soil-bioengineered bank erosion control structures, but it will not be possible to return the stream corridor to its predisturbance condition. Other resource implications of increased watershed sediment delivery will persist (e.g., altered substrate conditions, modified riffle-pool structure, and impaired water quality).

It is important to note that in treating causes, a danger always remains that in treating one symptom of impairment, another unwanted change in stream corridor conditions will be triggered. To continue with the erosion example, bank hardening in one location might interfere with sedimentation processes critical to floodplain and riparian habitats, or it might simply transfer lateral instabilities from one location in a stream reach to some other location.

Core Elements of Restoration Alternatives

At a minimum, alternatives should contain a management summary of proposed activities, including an overview of the following elements:

- *Detailed site description containing relevant discussion of all variables having a bearing on that alternative.*
- *Identification and quantification of existing stream corridor conditions.*
- *Analysis of the various causes of impairment and the effect of management activities on these impaired conditions and causes in the past.*
- *Statement of specific restoration objectives, expressed in terms of measurable stream corridor conditions and ranked in priority order.*
- *Preliminary design alternatives and feasibility analysis.*
- *Cost-effectiveness analysis for each treatment or alternative.*
- *Assessment of project risks.*
- *Appropriate cultural and environmental clearances.*
- *Monitoring plan linked to stream corridor conditions.*
- *Anticipated maintenance needs and schedule.*
- *Alternative schedule and budget.*
- *Provision to make adjustments per adaptive management.*

Landscape/Watershed vs. Corridor/Reach

The design and selection of alternatives should address the following relationships:

- Reach to stream
- Stream to corridor
- Corridor to landscape
- Landscape to region

Characterizing those relationships requires a good inventory and analysis of conditions and functions on all levels including stream structure (both vertical and horizontal) and human activities within the watershed.

The restoration design should include innovative solutions to prevent or mitigate, to the extent possible, negative impacts on the stream corridor from upstream land uses. Land use activities within a watershed may vary widely within generalized descriptions of urban, agricultural, recreation, etc. For example, urban residential land use could comprise neighborhoods of manicured lawns, exotic plants, and roof runoff directed to nearby storm sewers. Or residential use might be composed of neighborhoods with native cover types, overhead canopy, and roof runoff flowing to wetland gardens. Restoration

REVERSE

Review Chapter 1's Dynamic Equilibrium section.

design should address the storm water flows, pollutants, and sediment loadings from these different land uses that could impact the stream corridor.

Since it is usually not possible to remove the human activities that disturb stream corridors, where seemingly detrimental activities like gravel mining, damming, and road crossings are present in the watershed or in the stream corridor itself, restoration design should provide the best possible solutions for maintaining optimum stream corridor functions while meeting economic and social objectives (**Figure 5.11**).

Other Time and Space Considerations

Restoration design flexibility is critical to long-term success and achievement of dynamic equilibrium. Beyond the stream corridor is an entire landscape that functions in much the same way as the corridor. When designing and choosing alternatives, it is important to consider the effect of the restoration on the entire landscape. A wide, connected, and diverse stream corridor will enhance the functions of the landscape as well as those of the corridor. Connectivity and width also increase the resiliency of the stream corridor to landscape perturbations and stress, whether induced naturally or by humans.

***Figure 5.11*: Stream buffers in agricultural areas.** *It is not possible to remove human activity from the corridor. Design alternatives should provide the best possible way of achieving the desired goals without negating the activity.*

Alternatives should also be relatively elastic, although time and physical boundaries might not be so flexible. As discussed in Chapter 1, dynamic equilibrium requires that the restoration design be allowed an opportunity to mold itself to the changing conditions of the corridor over time and to the disturbances that are a part of the natural environment. Alternatives should be weighed against one another by considering how they might react to increasing land pressures, climate changes, and natural perturbations. Structure should be planned to provide necessary functions at each phase of the corridor's development.

A possible restoration design concept is Forman and Godron's (1986) "string of lights." Over time, the variations among landscape elements mean that some provide more opportunities for desired functions than others. A stream corridor connection provides a pathway through the landscape matrix such that it can be thought of as a string of lights in which some turn on and burn brightly for a time, while others fade away for a short time (**Figure 5.14**). As the string between these lights, the stream corridor is critical to the long-term stability of landscape functions. Alternatives could therefore fit the metaphor of a string of lights to sustain the corridor through time.

Supporting Analyses for Selecting Restoration Alternatives

Once the restoration alternatives have been defined, the next step is to evaluate all the feasible alternatives and management options. In conducting this evaluation it is important to apply several different screening criteria that allow the consideration of a diverse number of factors. In general, the application of the following supporting analytical approaches ensures the selection of the best alternative or group of alternatives for the restoration initiative:

- Cost-effectiveness and incremental cost analysis
- Evaluation of benefits
- Risk assessment
- Environmental impact analysis

Figure 5.14: "String of lights." *Patches along the stream corridor provide habitat in an agricultural setting.*
Source: C. Zabawa.

Cost-Effectiveness and Incremental Cost Analyses

In its National Strategy for the Restoration of Aquatic Ecosystems, the National Research Council (NRC) states that, in lieu of benefit-cost analysis, the evaluation and ranking of restoration alternatives should be based on a framework of incremental cost analysis: "Continually questioning the value of additional elements of a restoration by asking whether the actions are 'worth' their added cost is the most practical way to decide how much restoration is enough" (NRC 1992). As an example, the Council cites the approach where "a justifiable level [of output] is chosen in recognition of the incremental costs of increasing [output] levels and as part of a negotiation process with affected interests and other federal agencies" (NRC 1992).

As described below, cost-effectiveness analysis is performed to identify the least-cost solution for each possible level of nonmonetary output under consideration. Subsequent incremental cost analysis reveals the increases in cost that accompany increases in the level of output, asking the question "As we increase the scale of this project, is each subsequent level of additional output worth its additional cost?"

Data Requirements: Solutions, Costs, and Outputs

Cost-effectiveness and incremental cost analyses may be used for any scale of planning problem, ranging from local, site-specific problems to problems at the more extensive watershed and ecosystem scales. Regardless of the problem-solving scale, three types of data must be obtained before conducting the analyses: a list of solutions and, for each solution, estimates of its ecosystem or other nonmonetary effects (outputs) and estimates of its economic effects (costs).

The term "solutions" is used here to refer generally to techniques for

CASE STUDY

Meander Reconstruction on the J. Bar S. Winter Feeding Area

January 1, 1997, was an eventful time for Asotin Creek, Washington, residents. In a period of less than a year, two large flood events occurred, causing extreme damage at numerous sites throughout the watershed.

The ordinary high flow (often referred to as channel forming or bankfull flow) is the natural size channel a river will seek, over time. Asotin Creek's flows exceeded the ordinary high flow 10 times at Asotin and Headgate parks.

*One impacted site is on the South Fork of Asotin Creek. This site, referred to as the J. Bar S. winter feeding site (**Figure 5.12**) and owned by Jake and Dan Schlee, received floods more than 10 times the ordinary high flow. Previous to January 1, the stream was located over a hundred feet away from the haysheds and feeding area. When large amounts of rock, cobble, and gravel collapsed into the right side of the stream corridor, the entire channel was directed toward the winter feeding area and hayshed. This redirection of flood flows undermined and eroded away thousands of tons of valuable topsoil and property, threatening the loss of the hayshed and corral. Fences and alternative water sources were destroyed. The challenges for stream restoration at this site were numerous because of the potential bridge constriction at the bottom, excessive downcutting, and limited area within which to work (**Figure 5.13**).*

The Asotin County Conservation District put an interdisciplinary team together in the spring of 1997 to develop a plan and alternative for the J. Bar S. site. An innovative approach referred to as meander reconstruction was proposed by the interdisciplinary team to correct the problem and restore some natural capabilities of the stream. It was accepted by the landowners and Asotin County Conservation District. Some natural capabilities are the dissipation of flood energy over floodplains and maintenance of a stable ordinary high flow channel.

***Figure 5.12: The J. Bar S. winter feeding area.** This area received floods more than 10 times the ordinary high flow.*

Additional benefits to the approach would be to reestablish proper alignment with the bridge and restore fish habitat. This alternative was installed within the last 2 weeks of September 1997. Care was used to move young steelhead out of the old channel while the new meandering channel was built. Other practices on site such as alternative water sources and fencing are soon to follow.

The meander reconstruction was designed to address both the landowners' concerns and stream processes. Although on-site stream restoration cannot resolve problems higher up in the watershed, it can address immediate concerns regarding fish habitat and streambank stability. Numerous pools with woody debris were introduced to enhance salmon rearing and resting habitat. The pools were designed and set to a scour pattern unique to this stream type. This meander reconstruction is the first of its kind in the state of Washington.

Figure 5.13: South Fork of Asotin Creek restoration site. *(a) Before reconstruction and (b) after reconstruction.*

*The principal funding for this project was provided by the Bonneville Power Administration (BPA) (**Table 5.1**). The BPA funds are used to help implement the Asotin Creek Model Watershed Plan, which is part of the Northwest Power Planning Council's "Strategy for Salmon." The moneys for funding by BPA are generated from power rate payers in the Northwest. The purpose for funding is to improve the fish habitat component of the "Strategy for Salmon," which is one of the four elements referred to as the four H's—harvest management, hatcheries and their practices, survival at hydroelectric dams, and fish habitat improvement.*

Table 5.1: Project costs for J. Bar S. winter feeding area meander reconstruction and upstream revetments.

Projects	Costs
Reconstruction meanders	$10,200
Upstream revetments	$2,800
Fencing	$400
Riparian/streambank plantings and potential operation and maintenance *(to be completed)*	$3,500

Note: Original estimate in April 1997 was $26,600

The Instream Flow Incremental Methodology

*The Instream Flow Incremental Methodology (IFIM) is designed for river system management. IFIM is composed of models linked to describe the spatial and temporal habitat features of a given river (***Figure 5.15***). It uses hydrologic analyses to describe, evaluate, and compare water use throughout a river system to understand the limits of water supply. Its organizational framework is useful for evaluating and formulating alternative water management options. Ultimately, the goal of any IFIM application is to ensure the preservation or enhancement of fish and wildlife resources. Emphasis is placed on displaying data from several years to understand variability in both water supply and habitat.*

IFIM is meant to be implemented in five sequential phases—problem identification, study planning, study implementation, alternatives analysis, and problem resolution. Each phase must precede the remaining phases, though iteration is necessary for complex projects.

Problem Identification

The first phase has two parts—a legal-institutional analysis and a physical analysis. The legal-institutional analysis identifies all affected or interested parties, their concerns, information needs, relative influence or power, and the potential decision process (e.g., brokered or arbitrated). The physical analysis determines the physical location and geographic extent of probable physical and chemical changes to the system and the aquatic resources

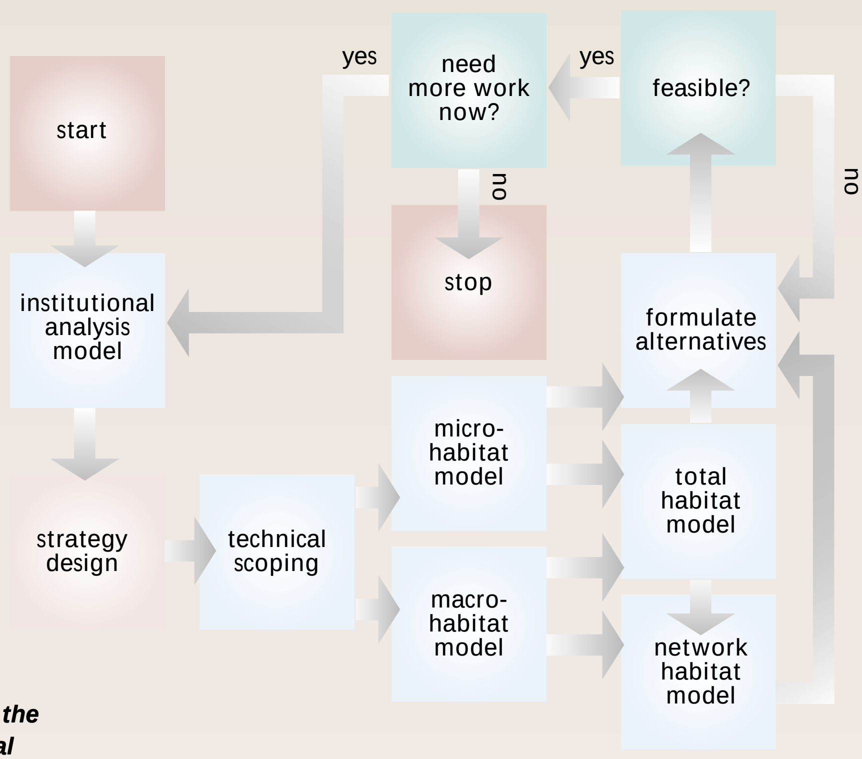

Figure 5.15: Overview of the instream flow incremental methodology. *IFIM describes the spatial and temporal habitat features of a given river.*

of greatest concern, along with their respective management objectives.

Study Planning

The study planning phase identifies information needed to address project concerns, information already available, information that must be obtained, and data and information collection methods. Study planning should result in a concise, written plan that documents all aspects of project execution and costs. It should also identify pertinent temporal and spatial scales of evaluation.

Hydrologic information chosen to represent the baseline or reference condition should be reexamined in detail during this phase to ensure that biological reference conditions are adequate to evaluate critical life history phases of fish populations.

Study Implementation

The third phase consists of several sequential activities—data collection, model calibration, predictive simulation, and synthesis of results. Data are collected for physical and chemical water quality, habitat suitability, population analysis, and hydrologic analysis. IFIM relies heavily on models because they can be used to evaluate new projects or new operations of existing projects. Model calibration and quality assurance are key during this phase to obtain reliable estimates of the total habitat available for each life stage of each species over time.

Alternatives Analysis

The alternatives analysis phase compares all alternatives, including a preferred alternative and other alternatives, with the baseline condition and can lead to new alternatives that meet the multiple objectives of the involved parties. Alternatives are examined for:

- *Effectiveness: Are objectives sustainable?*
- *Physical feasibility: Are water supply limits exceeded?*
- *Risk: How often does the biological system collapse?*
- *Economics: What are the costs and benefits?*

Problem Resolution

This final phase includes selection of the preferred alternative, appropriate mitigation measures, and a monitoring plan. Because biological and economic values differ, data and models are incomplete or imperfect, opinions differ, and the future is uncertain, IFIM relies heavily on professional judgment by interdisciplinary teams to reach a negotiated solution with some balance among conflicting social values.

A monitoring plan is necessary to ensure compliance with the agreed-upon flow management rules and mitigation measures. Post-project monitoring and evaluation should be considered when appropriate and should be mandatory when channel form will respond strongly to the selected new flow and sediment transport conditions.

For More Information on IFIM

The earliest and best documented application of IFIM involved a large hydroelectric project on the Terror River in Alaska (Lamb 1984, Olive and Lamb 1984). Another application involved a Section 404 permit on the James River, Missouri (Cavendish and Duncan 1986). Nehring and Anderson (1993) discuss the habitat bottleneck hypothesis. Stalnaker et al. (1996) discuss the temporal aspects of instream habitats and the identification of potential physical habitat bottlenecks. Relations between habitat variability and population dynamics are described by Bovee et al. (1994). Thomas and Bovee (1993) discuss habitat suitability criteria. IFIM has been used widely by state and federal agencies (Reiser et al. 1989, Armour and Taylor 1991). Additional references and information on available training can currently be obtained from the Internet at http://www.mesc.nbs.gov/rsm/IFIM.html.

accomplishing planning objectives. For example, if faced with a planning objective to “Increase waterfowl habitat in the Blue River Watershed,” a solution might be to “Construct and install 50 nesting boxes in the Blue River riparian zone.” Solutions may be individual management measures (for example, clear a channel, plant vegetation, construct a levee, or install nesting boxes), plans (various combinations of management measures), or programs (various combinations of plans, perhaps at the landscape scale).

Cost estimates for a solution should include both financial implementation costs and economic opportunity costs. Implementation costs are direct financial outlays, such as costs for design, real estate acquisition, construction, operation and maintenance, and monitoring. The opportunity costs of a solution are any current benefits available with the existing state of the watershed that would be foregone if the solution were implemented. For example, restoration of a river ecosystem might require that some navigation benefits derived from an existing river channel be given up to achieve the desired restoration. It is important that the opportunity costs of foregone benefits be accounted for and brought to the table to inform the decision-making process.

The level to which a solution accomplishes a planning objective is measured by the solution’s output estimate. Historically, environmental outputs have been expressed as changes in populations (waterfowl and fish counts, for example) and in physical dimensions (acres of wetlands, for example). In recent years, output estimates have been derived through a variety of environmental models such as the U.S. Fish and Wildlife Service’s Habitat Evaluation Procedures (HEP), which summarize habitat quality and quantity for specific species in units called “habitat units.” Models for ecological communities and ecosystems are in the early stages of development and application and might be more useful at the watershed scale.

Cost-Effectiveness Analysis

In *cost-effectiveness analysis,* solutions that are not rational (from a production perspective) are identified and can be screened out from inclusion in subsequent incremental cost analysis.

Cost-effectiveness screening is fairly straightforward when monetary values are easily assigned. The “output” or nonmonetary benefits of restoration actions are more difficult to evaluate. These benefits may include changes in intangible values of habitat, aesthetics, nongame species populations, and others. The ultimate goal, however, is to be able to weigh objectively all of the benefits of the restoration against its costs.

There are two rules for cost-effectiveness screening. These rules state that solutions should be identified as inefficient in production, and thus not cost-effective, if (1) the same level of output could be produced by another solution at less cost or (2) a greater level of output could be produced by another solution at the same or less cost.

For example, look at the range of solutions in **Figure 5.16**. Applying Rule 1, Solution C is identified as inefficient in production: why spend $3,600 for 100 units of output when 100 units can be obtained for $2,600 with Solution B, a savings of $1,000? In this example, Solution C could also be screened out by the application of Rule 2: why settle for 100 units of output with Solution C when 20 additional units can be provided by Solution E at the same cost? Also by applying Rule 2, Solution D is screened out: why spend $4,500 for 110

Solution	Units of Output	Total Cost ($)
No action	0	0
A	80	2,000
B	100	2,600
C	100	3,600
D	110	4,500
E	120	3,600
F	140	7,000

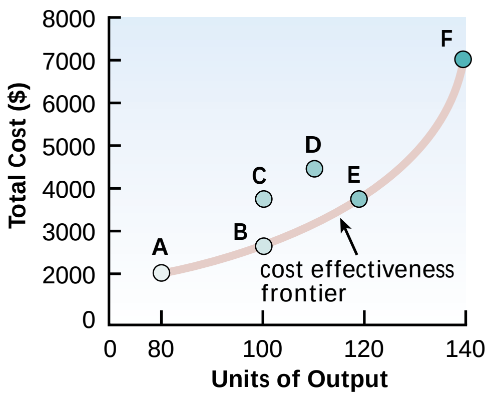

*Figure 5.16: **Cost effectiveness frontier.** This graph plots the solutions' total cost (vertical axis) against their output levels (horizontal axis).*

units when 10 more units could be produced by E for $900 less cost?

Figure 5.16 shows the "cost-effectiveness frontier" for the solutions listed in the table. This graph, which plots the solutions' total cost (vertical axis) against their output levels (horizontal axis), graphically depicts the two screening rules. The cost-effective solutions delineate the cost-effectiveness frontier. Any solutions lying inside the frontier (above and to the left), such as C and D, are not cost-effective and should not be included in subsequent incremental cost analysis.

Incremental Cost Analysis

Incremental cost analysis is intended to provide additional information to support a decision about the desired level of investment. The analysis is an investigation of how the costs of extra units of output increase as the output level increases. Whereas total cost and total output information for each solution is needed for cost-effectiveness analysis, incremental cost analysis requires data showing the difference in cost (incremental cost) and the difference in output (incremental output) between each solution and the next-larger solution.

Continuing with the previous example, the incremental cost and incremental output associated with each solution are shown in **Figure 5.17**. Solution A would provide 80 units of output at a cost of $2,000, or $25 per unit. Solution B would provide an additional 20 units of output (100 – 80) at an additional cost of $600 ($2,600 – $2,000). The incremental cost per unit (incremental cost divided by incremental output) for the additional 20 units B provides over A is, therefore, $30. Similar computations can be made for solutions E and F. Solutions C and D have been deleted from the analysis because they were previously identified as inefficient in production.

As shown in **Figure 5.17,** the incremental cost per unit is measured on the vertical axis; both total output and incremental output can be measured on the horizontal axis. The distance from the origin to the end of each bar indicates total output provided by the corresponding solution. The width of the bar associated with each solution identifies the incremental amount of output that would be provided over the previous, smaller-scaled solution; for example, Solution E provides 20 more units of output than Solution B . The height of the bar illustrates the cost per unit of that additional output; for example, those 20 additional units obtainable through Solution E cost $50 each.

Solution	Level of Output		Cost ($)		
	Total Output	Incremental Output	Total Cost	Incremental Cost	Incremental Cost Incremental Output
No action	0	0	0	0	0
A	80	80	2,000	2,000	25
B	100	20	2,600	600	30
E	120	20	3,600	1,000	50
F	140	20	7,000	3,400	170

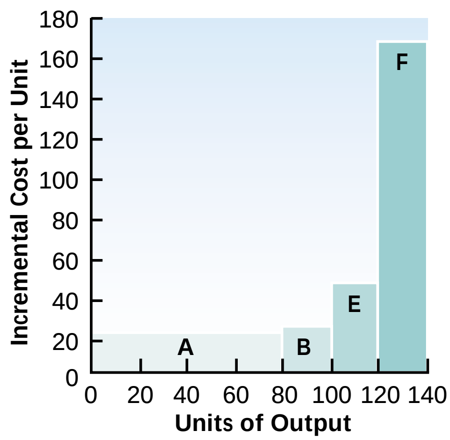

Figure 5.17: Incremental cost and output display. *This graph plots the cost per unit (vertical axis) against the total output and incremental output (horizontal axis).*

Decision Making—”Is It Worth It?”

The table in Figure 5.17 presents cost and output information for the range of cost-effective solutions under consideration in a format that facilitates the investment decision of which (if any) solution should be implemented. This decision process begins with the decision of whether it is “worth it” to implement Solution A.

Figure 5.17 shows Solution A provides 80 units of output at a cost of $25 each. If it is decided that these units of output are worth $25 each, the question becomes “Should the level of output be increased?” To answer this question, look at Solution B, which provides 20 more units than Solution A. These 20 additional units cost $30 each. “Are they worth it?” If “yes,” look to the next larger solution, E, which provides 20 more units than B at $50 each, again asking “Are they worth it?” If it is decided that E’s additional output is worth its additional cost, look to F, which provides 20 more units than E at a cost of $170 each.

Cost-effectiveness and incremental cost analyses will not result in the identification of an “optimal” solution as is the case with cost-benefit analysis. However, they do provide information that decision makers can use to facilitate and support the selection of a single solution. Selection may also be guided by decision guidelines such as output “targets” (legislative requirements or regulatory standards, for example), minimum and maximum output thresholds, maximum cost thresholds, sharp breakpoints in the cost-effectiveness or incremental cost curves, and levels of uncertainty associated with the data.

In addition, the analyses are not intended to eliminate potential solutions from consideration, but rather to present the available information on costs and outputs in a format to facilitate plan selection and communicate the decision process. A solution identified as "inefficient in production" in cost-effectiveness analysis might still be desirable; the analysis is intended to make the other options and the associated trade-offs explicit. Reasons for selecting "off the cost-effectiveness curve" might include considerations that were not captured in the output model being used, or uncertainty present in cost and output estimates. Where such issues exist, it is important that they be explicitly introduced to the decision process. After all, the purpose of conducting cost-effectiveness and incremental cost analyses is to provide more, and hopefully better, information to support decisions about investments in environmental (or other nonmonetary) resources.

Evaluation of Benefits

Cost-effectiveness and incremental cost analyses are but one approach for evaluating restoration projects. More broadly defined approaches, sometimes referred to as benefit maximization, fall into three categories (USEPA 1995a):

1. Prioritized benefits are ranked by preference or priority, such as best, next best, and worst. Available information might be limited to qualitative descriptions of benefits, but might be sufficient.
2. Quantifiable benefits can be counted but not priced. If benefits are quantifiable on some common scale (e.g., percent removal of fine sediment as an index of spawning substrate improvement), a cost per unit of benefits that identifies the most efficient producer of benefits can be devised (similar to the previously described cost effectiveness and incremental cost analyses).
3. Nonmonetary benefits can be described in monetary terms. For example, when restoration provides better fish habitat than point source controls would provide, the monetary value of improved fish habitat (e.g., economic benefits of better fishing) needs to be described. Assigning a monetary value to game or commercial species might be relatively easy; other benefits of improved habitat quality (e.g., improved aesthetics) are not as easily determined, and some (e.g., improved biodiversity) cannot be quantified monetarily. Each benefit must, therefore, be analyzed differently.

Key considerations in evaluating benefits include timing, scale, and value. The short-term and long-term benefits of each project must be measured. In addition, potential benefits and costs must be considered with respect to results on a local level versus a watershed level. Finally, there are several ways to value the environment based on human use and appreciation. Commercial fish values can be calculated, recreational or sportfishing values can be estimated by evaluating the costs of travel and expenditures, some aesthetic and improved flood control values can be estimated through changes in real estate value, and social values (such as wildlife, aesthetics, and biodiversity) can be estimated by surveying people to determine their willingness to pay.

Risk Assessment

Stream-corridor restoration involves a certain amount of risk that, regardless of the treatment chosen, restoration efforts will fail. To the extent possible, an identification of these risks for each alternative under consideration is a useful tool for analysis by the decision maker. A thorough risk assessment is particularly important for those large-scale restoration efforts which involve significant outlays of labor and money or where a significant risk to human life or property would occur downstream should the restoration fail.

A primary source of risk is the uncertainty associated with the quality of data used in problem analysis or restoration design. Data uncertainty results from errors in data collection and analysis, external influences on resource variables, and random error associated with certain statistical procedures (e.g., regression analysis). Data uncertainty is usually handled by application of statistical procedures to select confidence intervals that estimate the quality of the data used for analysis and design.

The first source of risk is the possibility that design conditions will be exceeded by natural variability before the project is established. For example, if a channel is designed to pass a 50-year flood on the active floodplain, but it takes 5 years to establish riparian vegetation on that floodplain, there is a certain risk that the 50-year flood will be exceeded during the 5 years it takes to establish natural riparian conditions on the floodplain. A similar situation would exist where a revegetation treatment requires a certain amount of moisture for vegetation establishment and assumes the worst drought of record does not occur during the establishment period. This kind of risk is readily amenable to statistical analysis using the binomial distribution and is presented in several existing reports on hydrologic risk (e.g., Van Haveren 1986).

Environmental Impact Analysis

The fact that the impetus behind any stream corridor restoration initiative is recovery or rehabilitation does not necessarily mean that the proposal is without adverse effects or public controversy. Short-term and long-term adverse impacts might result. For example, implementation activity such as earthwork involving heavy equipment might temporarily increase sedimentation or soil compaction. Furthermore, restoration of one habitat type is probably at the expense of another habitat type; for example, recreating habitat to benefit fish might come at the expense of habitat used by birds.

Some alternatives, such as total exclusion to an area, might be well defined scientifically but have little social acceptability. Notwithstanding the environmental impacts and trade-offs, both fish and birds have active constituencies that must be involved and whose concerns must be acknowledged. Therefore, careful environmental impact analysis considers the potential short- and long-term direct, indirect, and cumulative impacts, together with full public involvement and disclosure of both the impacts and possible mitigating measures. This is no less important for an initiative to restore a stream corridor than for any other type of related activity.