# 3

# Dam Removal Decisions

A DETERMINATION to keep or remove a dam needs to account for complex social, economic, and environmental interactions. This chapter presents a framework of steps and indicators to help decision makers assemble data and analyses that will assist them with this often difficult and contentious determination. The framework will help clarify multiple goals and objectives, identify the issues of greatest concern to a variety of stakeholders, and structure data collection and analyses. For owners or communities that decide to remove a dam, the chapter includes a discussion of post-removal monitoring and adaptive management to help them ensure that the original goals are achieved. The chapter begins with an introduction to the method used over the last 50 years to decide whether to build dams: benefit–cost analysis.

## THE ECONOMICS OF DAM REMOVAL

Every existing dam was originally constructed for some explicit economic purpose. Many of the earliest small dams in the United States provided waterpower to mills and other industrial facilities. Some of these dams later were adapted to low-head hydroelectric generation, and many new hydroelectric dams were constructed. Medium-sized dams often were designed to provide a reliable supply of water for urban and/or agricultural uses. Other dams were constructed to provide storage for flood peaks, thus reducing the hazards to human life and flood-related property damage. Farmers have long used small dams to store water for livestock watering and fire suppression. By the last third of the twentieth century,





property values in suburban housing developments frequently were enhanced by the creation of artificial "real estate lakes."

Because each dam had a known cost and economic purpose at the time of its construction, it is reasonable to assume that some type of financial or economic analysis justified each. For older dams, this justification likely was limited to a simple, nondiscounted comparison of construction cost to anticipated economic benefit. Only the costs and benefits affecting the dam owner would have been considered. Before the mid-twentieth century, dams were single-purpose projects. Even where multiple services were provided (e.g., a hydroelectric dam that also reduced downstream flood discharge), the dam was likely to be justified based on the primary purpose. The external costs of construction, including environmental costs, typically were omitted from the economic analysis or ignored entirely.

In 1936, the Congress authorized the U.S. Army Corps of Engineers to construct dams and other improvements for reducing flood hazards. The Flood Control Act (FCA) of 1936 (P.L. 74-738) contained a highly significant provision, little noticed at the time, stating that the policy of the United States was to construct improvements for the purpose of flood control where the "benefits to whomsoever they may accrue are in excess of the estimated costs" (FCA ch. 688, §1,49 Stat. 1570). This statement set into motion an investigation of the economics of dam building that culminated in the 1950 publication of the first formal procedures for benefit–cost analysis of water resource projects (U.S. Federal Inter-Agency River Basin Committee, 1950). These procedures were revised, elaborated on, and redesigned a number of times in subsequent decades.

Beginning as informal guidance, the benefit–cost procedures became formal guidance for all federal agencies involved in water resource development and ultimately were published as federal regulations in the late 1970s. In 1983, the regulations were rescinded and the procedures returned to their original status as informal guidance, known as the Principles and Guidelines. Over the years, however, the existence of written procedures or guidance had a profound effect on the design and evaluation of large federal dams, and, eventually, on the accepted framework for the evaluation of most dam proposals, both within and outside of government.

In particular, benefit–cost analysis practice came to incorporate a number of features:

- Even when motivated by a single issue, dams normally are designed and analyzed as multipurpose projects.

- For a dam to be economically feasible, the expected present value of the beneficial effects needs to exceed the expected present value of the adverse effects.
- Beneficial effects are to include the incremental value of all goods and services produced by the project as well as any beneficial external effects.
- Adverse effects are to include the costs of planning, designing, constructing, and operating the dam and reservoir, as well as any adverse external effects.
- The beneficial effects of each project's purpose are expected to exceed the allocated adverse effects of that purpose; otherwise, the project needs to be reformulated to eliminate that purpose.
- For each project, alternative structural and nonstructural solutions are to be defined and analyzed, so that the most economically efficient strategy is selected.

It is the nature of water resource development that the beneficial effects derive mostly from the known purposes of the project. Accordingly, they tend to be economic goods and services (e.g., water supply, electric energy, flood protection), which can be predicted and evaluated in monetary terms. Adverse effects also include some easily quantified components (e.g., construction and operating costs). But every water resource project has potentially large adverse external effects, such as the loss of habitat, fish passage disruption, destruction of wetlands, loss of wild river recreational opportunities, population movements, traffic congestion, and so on.

The stereotypical analysis produces three types of impacts: monetized benefits, monetized construction and operating costs, and nonmonetized (possibly nonquantitative) external costs. Not surprisingly, benefit–cost analyses of dam projects have been widely criticized for focusing on the quantitative effects while ignoring or minimizing nonquantitative external costs.

Additional considerations in assessing the financial aspects of a possible dam removal are the questions of who will benefit and who will pay. The distribution of costs and benefits among private individuals or companies and the public taxpayer is a pivotal issue for some removal decisions. An effective decision-making process exposes the true sources of financing and true sinks of additional costs before the decision is made. There is also a geographical aspect to costs and benefits; those who bear the costs seldom are in the same location as those who benefit. The entire



general community may benefit from a dam removal, whereas most of the cost may be born by the owner of the dam and the owners of property on the shore of the reservoir that will be eliminated. Alternatively, the general community may pay the bill for dam removal, but the benefits may be enjoyed only by a dam owner who escapes financial and legal responsibility for the structure, and by property owners near the dam site that is eventually changed in some way by the removal.

## INFORMED DECISION MAKING

Credible dam removal decisions take into account administrative, political, social, and environmental issues as well as factors emphasized in economic analyses. An informative general review of decision-making processes for dam removal is provided in *Dam Removal: A Citizen's Guide to Restoring Rivers* (River Alliance of Wisconsin and Trout Unlimited, 2000). However, much of this document focuses on how to remove a dam after the decision to remove it has been made. This section presents general guidance to help decision makers approach a decision to keep or remove a dam.

The process (Figure 3.1) begins with a clear identification and definition of goals and objectives. The articulation of these goals and objectives provides the framework within which the advisability of dam removal can be evaluated. Ideally, the procedure allows decision makers to compare the ecological, economic, and social outcomes of keeping or removing the structure. In addition, if a decision is made to remove the structure, the process will provide a foundation for continued monitoring and management corrections to ensure that the objectives are achieved.

This general method for reaching decisions about dam removal involves four basic steps:

**Step 1:** Define the goals and objectives

**Step 2:** Identify major issues of concern

**Step 3:** Data collection and assessment

**Step 4:** Decision making

If a decision is reached to remove the dam, two more steps are added:

**Step 5:** Dam removal

**Step 6:** Data collection, assessment, and monitoring

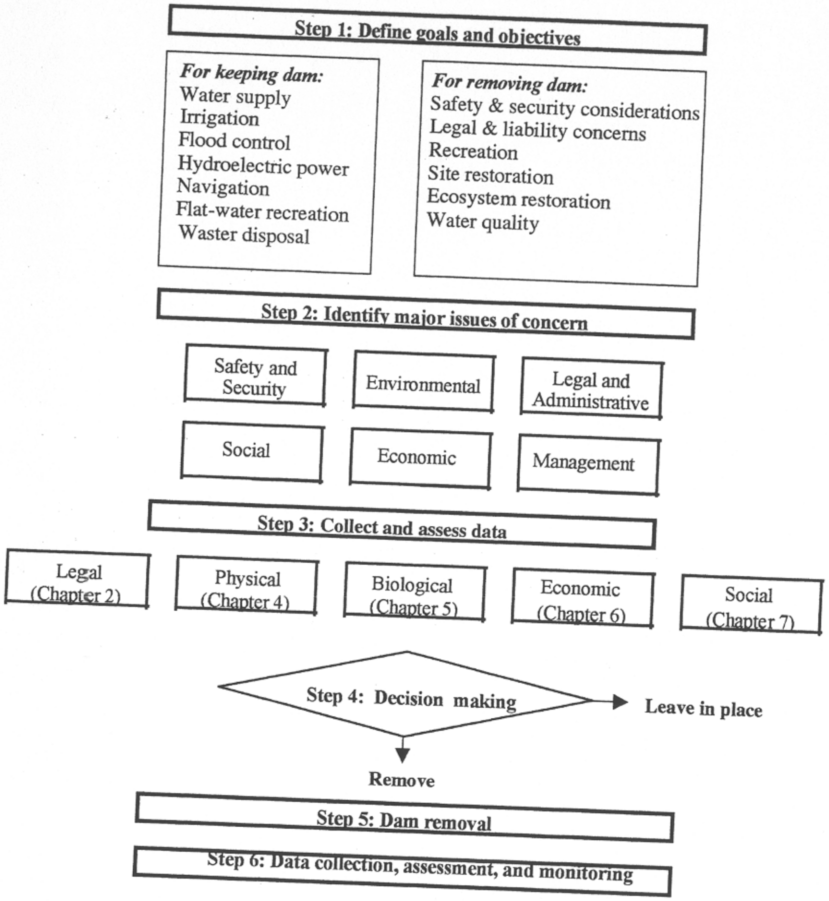


**Figure 3.1** A general method for dam removal decisions

## Step 1: Define the Goals and Objectives

To establish a basis for a dam removal decision, the goals and objectives for either removing a dam or leaving it in place need to be defined clearly. A stakeholder group needs to be assembled to help identify issues, concerns, and goals. Two key questions need to be addressed:

- Is the dam meeting its legally or socially defined original purpose and need?
- Have additional issues or needs arisen that need to be added to the list of goals?



### Is the Dam Meeting Its Legally or Socially Defined Original Purpose and Need?

The first question challenges decision makers to evaluate the original purpose and need for the dam and determine whether the structure still meets its stated objectives. The typical reasons for dam construction, discussed in Chapter 1, are summarized below:

- **Recreation** is a significant by-product of many reservoirs created for other primary purposes. Flat-water recreation on reservoirs is common in the southeastern, midwestern, and Plains states.
- **Fire and farm ponds** are common in rural areas and are built primarily to impound water for livestock, agricultural, or fire-fighting uses. These ponds also serve as important recreational areas.
- **Flood control** is a major function of large, multipurpose dams in all parts of the nation, but especially in the East and Midwest. Medium-sized and large dams are used for flood control because large volumes of storage are required to capture potentially hazardous runoff and store it for subsequent gradual release.
- **Water supplies** for urban, domestic, and industrial use are obtained from systems made possible by dams. These dams range from small, run-of-river structures that divert stream flow into distribution systems to medium-sized and large structures that create reservoirs for temporary storage.
- **Irrigation** is made possible by dams. In the plains and western states, where rainfall is not consistent enough for the production of crops, low dams commonly are used to divert water for crop irrigation. Medium-sized and large dams create storage reservoirs in the upper portions of watersheds, filling them from runoff and snowmelt in winter and spring and releasing water for downstream diversions into lateral distribution systems during the growing season.
- **Waste disposal** is made possible by the construction and maintenance of dams that create holding ponds for use in several activities, particularly mining and industrial animal husbandry.
- **Waterpower** was the primary reason for the construction of many of the older dams in the United States. The advent of steam power made many of these structures obsolete for their original intended purpose, but many were refitted for other pur-

poses, including the production of electricity or have remained in place for aesthetic, cultural, or other reasons.

- **Electricity** is produced from dams of all sizes, ranging from low diversion works to large storage structures.
- **Navigation** on the nation's inland rivers depends on lock and dam systems that maintain pools of water deep enough to accommodate boat and barge traffic. Small dams raise water elevations, with boat and barge passage to and from different levels provided by locks adjacent to the dams. In upper reaches of watersheds, large storage dams impound reservoirs that release water to sustain the downstream pools.

### Have Additional Issues or Needs Arisen That Need To Be Added to the List of Goals?

Societal preferences may have changed and additional objectives may have emerged since the dam was constructed. Accordingly, the second question requires decision makers to determine if these additional concerns have called into question the need for the dam. The typical reasons for dam removals, discussed in Chapter 1, are summarized below:

- **Dam safety and security** is a major issue in the consideration of possible removal. Dam failures can inundate downstream areas with unexpected floods and disastrous results. Dams installed 50 or 100 years ago at moderate cost now require substantial investments that are often several times the initial construction price simply to return the structures to safe, up-to-date operating condition. In many cases, if the owner is an individual or small business, removal is the only reasonable, economical alternative. In light of the potential for terrorist acts, security of dams and reservoirs also must be considered.
- **Liability concerns** can prompt action by dam owners, who may choose to remove a dam to eliminate their own potential liability. Turbulence downstream from small, run-of-river dams can be deadly traps for boaters and canoeists. People fishing from dams and related structures risk serious injury or drowning. The liability of a dam owner in the case of an injury or death is unclear, but some owners prefer to avoid the risk by removing the structure. The threat of liability for injury to life or property following a dam collapse gives dam owners an economic incentive to repair unsafe dams or remove them, and removal may be cheaper than repair.



- **Recreation** can be used as a reason to support or oppose dam removal. Dams and their reservoirs make possible flat-water recreation, and dam removal, in addition to eliminating the reservoir, may enhance recreational opportunities downstream. For example, white-water boating in canyon rivers is enhanced by flows that are more natural. In flatland streams, canoeists and boaters seek continuous, uninterrupted lengths of river. Sport fishing, especially for trout in eastern and midwestern streams, benefits from rivers without subdivision by dams. However, some dams support trout fisheries that would not exist without the coldwater releases from reservoirs, and reservoirs often provide habitat for largemouth bass, a fish prized by anglers.
- **Site restoration** may be a benefit of a dam removal if the site where the dam is constructed is of historic, cultural, religious, or environmental importance. Often the dam site itself may be at issue, but the area below the waters of its reservoir also might be restored to support a newly designed ecosystem. The removal of dams also can contribute to the restoration of aquatic habitats downstream. Because dams artificially trap sediment and modify flow regimes, the reaches of rivers downstream are significantly altered from their original natural condition. The removal of dams may restore the movement of sediment in such systems as well as return the water to more natural temperatures.
- **Ecosystem restoration** is a possible benefit of dam removal. In addition to the obvious restoration of a river course inundated by reservoir waters, the river reaches downstream from a dam also can be restored to a more natural condition. The principal dam removal efforts to date have involved dams that fragmented streams and blocked spawning runs of anadromous fish, such as salmon and shad.

These questions address connections in the social, environmental, administrative, and political arenas. The definition of the overall goals and outcomes to be achieved by either retaining or removing the structure strengthens the decision-making process. After answering these questions, decision makers can (if there is sufficient justification) proceed to Step 2 of the evaluation process.

## Step 2: Identify Major Issues of Concern

Once the goals have been established for either leaving a dam in place or removing it, the major controversies and specific issues of concern to various stakeholders need to be identified. This review needs to be accomplished in an open and transparent process, using the expertise and values of a wide array of people and institutions. The review needs to include the views of the owner of the dam and owners of land adjacent to the reservoir and along the downstream channel, as well as owners of water rights in the watershed. Local government agencies, along with state and federal regulatory agencies for water uses (consumptive and nonconsumptive), power, environmental quality, and fish and wildlife need to be part of the review as well. Nongovernmental organizations and groups advocating conservation, preservation, and economic development also are logical participants. Public sessions can provide a venue for input from individual citizens. The case of Rindge Dam (Box 3.1) is a useful example of the scientific, economic, and social complexity of dam decisions.

The widest possible involvement of stakeholders in the identification of issues is a key to success in reaching a sound decision about dam removal. At times, it may seem that an expeditious process is one that involves few participants. But agencies, organizations, and individuals with divergent opinions and viewpoints can reach compromise positions and innovative solutions most easily if they are all part of the decision-making process from the beginning, and if they are invited to participate rather than having to force their way into the process at a later stage. The early involvement of a wide range of participants also reveals potential problems when there is still ample time to address them, which is preferable to having the problems surface later in the process when there may be pressure to adhere to a schedule.

The types of issues that are likely to be raised, as illustrated in Figure 3.1, are safety and security, environmental, legal and administrative, social and economic, financial, and management issues. Clearly not all of these issues are contentious at any individual site, but the list below provides a good starting point for community discussions.

### Safety and Security Issues

Identify safety and security issues associated with keeping or removing the existing structure. Questions to address include the following:



- Is there a significant potential for loss of life, injury, and property damage if the dam should fail or be removed?
- Is the dam vulnerable to failure because of either aging or inadequate maintenance?
- Is the dam vulnerable to acts of terrorism?

### Environmental Issues

Identify environmental issues associated with keeping or removing the existing structure. Depending on the site, questions to address include the following:

- Will removal of the structure help to enhance the recovery of threatened or endangered species?
- Will removal of the structure lead to changes in unwanted invasive species or perhaps restore native species?
- Are there likely to be problems associated with contaminated sediments currently contained behind the dam if the dam is removed?
- Will removing the dam cause sediment to help build beaches?
- Will dam removal lead to a net gain or loss in wetland area?
- Have so many other changes occurred in addition to the dam that removal of the dam will not achieve the desired ecosystem restoration goals?
- What is the relationship of the dam and its removal to other parts of the watershed?
- How will drinking water supplies be affected?
- How will groundwater tables be affected?

### Legal and Administrative Issues

Evaluate concerns and needs from a legal and process perspective. Questions that might be addressed include the following:

- Are there existing or potential conflicts with laws and regulations (e.g., Clean Water Act, Endangered Species Act) designed to protect natural systems?
- Are there existing or potential conflicts with laws and regulations (e.g., National Historic Preservation Act, tribal water rights) designed to protect social, historical, or cultural values?

**Box 3.1** The Debate over Rindge Dam in Malibu, California

Rindge Dam in Malibu, California, was built in the 1920s by the Rindge family for use as an agricultural reservoir but was filled with sediment and nonfunctional by the 1950s. Today, in addition to no longer providing any water storage, the dam also blocks endangered steelhead trout from much of their habitat in the upper tributaries of Malibu Creek and contributes to erosion problems downstream on Malibu beaches. The dam currently is owned by the California Parks and Recreation Department and surrounded by state park lands. The decision-making process governing any future dam removal has been federalized because of the intervention of the U.S. Congress. A congressionally authorized study by the U.S. Army Corps of Engineers' Los Angeles District is under way to evaluate alternative means, including removal, of addressing the dam's presumed adverse impacts on the capability of the endangered steelhead trout to spawn in the upper reaches of the Malibu Creek watershed. The state of California is participating in this study.

Courtesy of Sarah Baish

The idea of removing Rindge Dam is not without controversy. Several homeowners in the Malibu Creek watershed whose homes are located in close proximity to the dam have expressed opposition to removal based on concerns about increased flood risk, and some members of the Rindge family oppose removal on historic preservation grounds. Malibu residents who have built expensive homes downstream of Rindge Dam in the Malibu Creek watershed, including Hollywood celebrities and some residents who have resorted to the courts for relief, apparently fear increased flood and mudslide risks because of removing the dam. On the other side of the debate, local conservation groups concerned about the survival of the steelhead support removal of Rindge Dam; these groups include California Trout, the Sierra Club's Malibu Group, American Rivers, and the Resource Conservation District of the Santa Monica Mountains. These groups, along with the U.S. Fish & Wildlife Service, California State Coastal Conservancy, Las Virgenes Municipal Water District, California Department of Fish & Game, National Marine Fisheries Service, and National Park Service, have created the Steelhead Recovery Task Force to investigate solutions and coordinate efforts.



- How does the existing structure fit into the overall management of the river system?
- Are there existing contracts for water supply and delivery?

## Social Issues

Identify social issues associated with the existing project as well as those associated with removal. Examples of questions that might be addressed include the following:

- Are there changes in the types of, and access to, recreational opportunities?
- Are there effects on local and regional populations in terms of economic stability (or lack thereof), displacement, water supply, and loss of access to traditional use areas?
- Are there direct and indirect effects on the cultural relationships of the peoples to the landscape?
- Are there impacts related to changing regional and local economics?
- Are there direct and indirect impacts related to any necessary service that was provided by the dam, and how will this service be replaced?
- How will dam removal affect aesthetic property values in the area?

## Economic Issues

Identify economic issues associated with the dam removal project. Examples of questions to be asked include the following:

- What is the cost of maintaining the dam versus the cost of other alternatives?
- Who is financially responsible for the dam and for any damage that might occur if the dam were breached? What are the potential costs (estimate) of any repair and annual maintenance of the existing facility?
- What is the status of the repayment on the debt for the project? Has it met the financial criteria defined in its authorization language?
- Are there financial criteria that must be met or maintained if the project is funded with international or public funds?
- Is the dam providing a service that will need to be replaced by some alternative, and what is its cost?

- What are the costs of alternative measures to mitigate for project impacts?
- What are the costs to provide additional security measures?
- How will property values be affected?

### Management Issues

Identify the management issues associated with the dam and water control. Examples of questions to be addressed include the following:

- How does the existing structure fit into the overall management plan for the river system? Is it a critical element to meeting any legal agreements and providing a service to the local economy such as flood control, water supply, power production, irrigation, fire protection, or recreation?
- Do the operations fit into a broader context of river basin control?
- What is the source of funding for removal or restoration efforts?

From this series of questions, a suite of potentially contentious issues can be identified. This will help the decision makers and the public assess whether the dam should be considered for removal, what alternatives exist, and whether the process should move to Step 3, Data Collection and Assessment.

## Step 3: Data Collection and Assessment

If, after the completion of Step 2, decision makers determine that there is reason and technical support to warrant further review, then data collecting and assessment need to be initiated.

The Heinz Center panel undertook two tasks to help decision makers better understand their choices. First, the panel developed a list of measurable indicators to support the decision-making process outlined in this chapter (Table 3.1). The dam owner, interest groups, scientists, engineers, and the public can use these indicators to gauge the potential outcomes of either keeping or removing an existing dam. To be of greatest use, such outcomes need to be forecast for various lengths of time into the future. The consideration of other rivers and streams that are similar to the one in question and can be used as points of reference, both with and without a dam, may be helpful in forecasting potential outcomes.



Second, the panel collected data and resources from scientific studies and previous dam removal projects that may be useful to decision makers. The remaining chapters of this report present information on the effects of dams, typical consequences of their removal, and, where possible, guidance for making site-specific forecasts of the consequences of dam removal. The qualitative descriptions and technical references included in these chapters are the best available resources for those seeking to gain an understanding of the consequences of decisions to remove or keep a dam.

If funding is available, The Heinz Center may prepare a handbook for communities offering more detailed guidance for site-specific evaluation. The Center would identify two communities that are currently considering the removal of a dam. A somewhat expanded panel would work jointly with community decisionmakers and the concerned public to identify key issues. With technical assistance from either a local university or state agency, the panel would assemble the relevant site-specific information using the indicators in Table 3.1. The goal would be to assist the two communities, but also to prepare a handbook for other communities to use.

Note that the present report does not include advice on evaluating dam safety. Handbooks on this aspect of the decision-making process are already available. Key sources of information include *Safety of Existing Dams* (National Research Council, 1983); *Safety of Dams: Flood and Earthquake Criteria* (National Research Council, 1985); and *Safety Evaluation of Existing Dams* (U.S. Bureau of Reclamation, 1980).

A fair amount of current and historical information is available from existing data collections, including some available free or at nominal cost from the World Wide Web. Web sources as well as traditional data sources are cited throughout each of the subsequent chapters. Geographic information (data displayed on maps) can be particularly helpful to decision makers; sources of geographic data and reliable base maps are listed in Appendix A.

## Step 4: Decision Making

Once the data have been assembled, the scientific and economic assessments have been conducted with public input, and the legal review is completed, all the information needs to be forwarded to the ultimate

**Table 3.1** Key Indicators for Making Dam Removal Decisions[a]

| Potential Outcome Issue | Indicator |
|---|---|
| Physical | |
| River network segmentation | Length of free-flowing river |
| Watershed fragmentation | Percentage of watershed accessible to outlet of the river |
| Downstream hydrology | Flood frequency for bank-full discharge |
| | Measures for 100-year flood: magnitude, frequency, and duration |
| | Annual peak flow: magnitude, frequency, duration, and timing |
| | Diurnal flow variation |
| Downstream sediment system | Annual sediment yield |
| | Timing of maximum sediment yield |
| | Annual suspended load |
| | Annual bedload |
| | Mean particle size for bed and bank materials |
| Downstream channel geomorphology | Width of active channel |
| | Dominant channel pattern (single thread, braided, compound) |
| | Degree of channel sinuosity |
| | Frequency of islands, bars, beaches |
| | Spacing and frequency of pools and riffles or rapids |
| | Dominant channel process (aggradation or degradation) |
| Floodplain geomorphology | Degree of connection between floodplain and active channel |
| | Frequency of floodplain inundation |
| | Depth of floodplain inundation at various return intervals |
| | Areal extent of the annual and 100-year floodplain |

*(continued)*



**Table 3.1** *(Continued)*

| Potential Outcome Issue | Indicator |
|---|---|
| Physical (continued) | |
| Reservoir geomorphology | Rate of sedimentation and sediment storage |
| | Rate of erosion and sediment loss |
| | Areal extent of delta wetland surface |
| | Length of shoreline |
| | Frequency and length of beaches, bluffs |
| Upstream geomorphology | Distance of upstream deposition or erosion |
| | Area subject to backwater flooding |
| Chemical | |
| Water quality | Turbidity |
| | Temperature |
| | PH (acidity or alkalinity) |
| | Levels of dissolved oxygen |
| | Concentrations of nutrients, toxins, heavy metals, radionuclides, herbicides, pesticides, and fuels |
| Sediment quality (reservoir area and downstream) | Organic content |
| | PH (acidity or alkalinity) |
| | Concentrations of nutrients, toxins, heavy metals, radionuclides, herbicides, pesticides, and fuels |
| Air quality | Pollution from boats |
| | Pollution from land-based vehicles |
| Ecological | |
| Aquatic ecosystems | Areal extent of aquatic ecosystems |
| | Productivity: primary, secondary, tertiary |
| | Diversity of species |
| Riparian ecosystems | Areal extent of riparian ecosystems |
| | Biomass of riparian vegetation |
| | Diversity of plant species |
| | Dominant plant species |
| | Number and extent of native, introduced, and endangered species |

*(continued)*

**Table 3.1** *(Continued)*

| Potential Outcome Issue | Indicator |
|---|---|
| Ecological (continued) | |
| Fishes | Number and extent of native, introduced, and endangered species |
| Birds | Number and extent of native, introduced, and endangered species |
| | Connectivity and size of avian habitats |
| Terrestrial animals | Number and extent of native, introduced, and endangered species |
| Economic | |
| Dam-site economics | Income generated to the dam owner |
| | Relicensing costs |
| | Maintenance costs |
| | Operating costs and restrictions |
| | Required upgrading and refitting costs |
| | Removal costs |
| River reach | Value of urban/industrial water supply |
| | Value of irrigation water supply |
| | Value of navigation services |
| | Value of flood protection |
| | Value of hydropower production |
| | Value of waste disposal |
| | Local and regional recreation values for whitewater boating activities, flat-water boating activities, fishing, swimming, and shoreline recreation |
| | Property value gains or losses for reservoir shoreline and river banks downstream |
| Regional economic values | Number of jobs |
| | Value of water transportation or replacement |
| | Required additional investment for infrastructure: levees, channelization, bridges, locks, navigation equipment, canals, fish passage systems |

*(continued)*



**Table 3.1** *(Continued)*

| Potential Outcome Issue | Indicator |
|---|---|
| Social | |
| Safety and security | Dam structural safety and security |
| | Potential for loss of life, injury, and property damage |
| | Public water supply vulnerability |
| | Vulnerability to failure from natural or human-induced causes |
| | Downstream implications of loss of dam |
| | Perceptions of safety of the reach |
| | Perceptions of safety of the reservoir |
| Aesthetic and cultural values | Aesthetic and historical values of the reservoir |
| | Aesthetic and historical values of the free-flowing river |
| | Religious values associated with the river and its landscape |
| | Historical value of the dam and associated structures |
| | Historical value of structures in and near the river |
| Non-majority considerations | Tribal sovereignty and rights |
| | Rights of minority populations, environmental justice |
| | Rights of future generations, intergenerational equity |
| | Animal and environmental rights |

[a] Ideally, one would measure or estimate today's conditions and forecast conditions one year, five years, and a decade or more into the future

decision makers at the appropriate level. The ultimate decision whether or not to remove a dam is likely to balance the following concerns:

- Safety, security, and water management requirements
- Economics of maintaining the dam versus dam removal or other alternatives (i.e., alteration of the dam, change in operations)
- Ecological need and potential gains
- Societal considerations

toring program. Therefore, monitoring needs to be identified directly and included in a dam removal budget. Data sharing and coordination of efforts among resource agencies, academia, and public and private researchers can reduce costs significantly.

## CONCLUSIONS AND RECOMMENDATIONS

- **Conclusion:** Dam removal is a site-specific issue. The issue is complex because of competing values and competing regulatory issues, and therefore dam removal decisions require careful planning and review. To be effective and credible to managers, decision makers, and the public, a removal project needs to be informed by science, including social, economic, and environmental data. Sometimes the best available science is not enough, and additional investigations are needed. Decisions about dam removal take place in specific economic and social contexts that also need to be taken into account. Decision-making processes for dam removal are most effective when they are well organized, open, and inclusive of all the people in the affected communities.
- **Recommendation:** The panel recommends that participants in public decision making use a multistep process, beginning with the establishment of goals as a basis for the process, and including the identification of the full range of interests and concerns of those likely to be involved, the assessment of potential outcomes, and informed and open decision making.

1. Identify the goals and objectives of the dam removal project.
2. Identify the major issues of concern.
3. Gather and assess the data.
4. Decide whether to keep or remove the dam.

If a decision is made to remove a dam, then the following steps may apply:

5. Dam removal
6. Data Collection, Assessment, and Monitoring

- **Conclusion:** The assessment of potential outcomes of dam retention or removal requires measurable indicators that can be used to measure the present environmental, economic, and social conditions associated with the dam and to monitor future changes.



- **Recommendation:** The panel recommends that assessment of potential outcomes of a decision to retain or remove a dam include the evaluation of as many indicators as are applicable to the situation, with the assessments conducted for short-, medium-, and long-term periods, and for the "with dam" as well as "without dam" alternatives. The panel developed a list of measurable indicators (Table 3.1) that can be used to support the decision-making process.