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A River Might Run Through It Again: Criteria for Consideration of Dam Removal and Interim Lessons from California

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ABSTRACT / Resource managers are increasingly being challenged by stakeholder groups to consider dam removal as a policy option and as a tool for watershed management. As more dam owners face high maintenance costs, and rivers as spawning grounds for anadromous fish become increasingly valuable, dam removal may provide the greatest net benefit to society. This article reviews the impact of Endangered Species Act listings for anadromous fish and recent shifts in the Federal Energy Regulatory Commission's hydropower benefit-costs analysis and discusses their implications for dam removal in California. We propose evaluative criteria for consideration of dam removal and apply them to two case studies: the Daguerre and Englebright Dams on the Yuba River and the Scott and Van Horne Dams on the South Eel River, California.

This paper addresses the policy implications of the recent interest in dam removal as a tool for aquatic habitat restoration. The pace of removal has increased over the past decade as public officials and citizen watershed groups have performed economic and ecological analyses that demonstrate, under certain circumstances, that removal may result in positive net benefits to society. Worldwide, the public is becoming aware that the benefits of dams have been routinely exaggerated and the costs have been frequently underestimated (Reisner 1986, Fearnside 1999, Pottinger 1998), and policy-makers are increasingly considering dam removal as a policy option (Babbitt 1999, Mann and Plummer 2000). We review recent developments in dam licensing and Endangered Species Act regulations, propose evaluative criteria for consideration of dam removal as a watershed management tool, and apply these criteria to case studies in two California watersheds.

Dams provide significant benefits to society, such as flood control and hydropower, but they have severely degraded aquatic ecosystems (NRC 1992). A watershed-based approach to ecosystem management has been endorsed by at least 18 federal agencies, and this has resulted in a greater role for community-based stakeholder participation in shaping management strategies (McGinnis and others 1999). The federal procedure for licensing dams now requires that environmental impacts be considered so that mitigation costs may now exceed the future benefits of the dam (Black and others 1998). If dam removal is to be considered a viable tool in watershed management, resource managers must be able to respond with an objective process for making management decisions. Today, public discussions of the merits of maintaining a dam must be weighed not just against modification but also against removal. Even if dam removal is ruled out as an alternative, consideration of removal promotes stakeholder discussion of incorporating environmental values into river and dam management. It is the logical next step as policy-makers struggle to match policy to public opinion.

KEY WORDS: Salmon; Anadromous fish; Watershed management; Dam management; Dam removal; Endangered Species Act; Dam hazard

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The Ticking Clock in River Ecosystems

The U.S. Army Corps of Engineers National Inventory of Dams (NID) has cataloged roughly 75,000 dams over 1.8 m tall in the United State (Table 1), whereas the National Research Council estimates that the total number of dams of all sizes is closer to 2.5 million (NRC 1992). Most of these dams were built before environmental considerations were incorporated in project decision-making. Some of these dams would not be built today because their environmental costs exceed their benefits.

Dams can degrade aquatic habitat by altering river ecosystems to the detriment of anadromous fish and other organisms. Dams change water flow, channel morphology, microhabitat, water temperature, dissolved oxygen levels, nutrient loads, sediment loads,

Table 1. Primary purposes of dams in the United States

Purpose	Percent	Number
Recreation	35.7	26,817
Fire and farm ponds	16.7	12,532
Flood control	14.6	10,971
Irrigation	9.6	7,223
Water supply	9.7	7,293
Tailings and debris	9.0	6,756
Hydroelectric	3.0	2,259
Undetermined	1.5	1,110
Navigation	0.3	226
Total	100.0	75,137

Source: U.S. Army Corps of Engineers (1996).

and debris loads, and block access to miles of natural spawning habitat for anadromous fish (Kanehl and others 1997, NRC 1992, NMFS 1998). In a few unusual cases, dams have created habitat for threatened species or their prey, but overall, dams have resulted in widespread and significant damage to aquatic ecosystems (Schmidt and others 1998, NRC 1992). In California dams block 90% of the historical spawning habitat of chinook salmon and steelhead and have contributed to the decline of every anadromous species in the state, including the extinction of three species of salmonids, chum, pink and sockeye salmon (Friends of the River 1999, Wolf and Zuckermann 1999).

Dams often benefit nonnative fish species at the expense of native species. By decreasing downstream water temperatures, dams have created many important trout fisheries in river reaches that were formerly too warm. For instance, Schmidt and others (1998) have documented that nonnative trout below the Glen Canyon Dam are outcompeting native fish for resources when niches overlap. Meffe (1984) has also shown that changes in water flow due to river management can benefit nonnative fish, such as the mosquitofish (*Gambusia affinis*) that outcompete flood-adapted native fish in the Southwest in the absence of predam flooding events. By documenting freshwater and anadromous fish survivorship and fecundity before and after dam construction, Penaz and others (1999) and Zhong and Power (1996) have shown that dams and reservoirs substantially change the composition of fish communities in river ecosystems to the detriment of rare or vulnerable species.

The issue of time is central to both technical and ecological considerations for dam removal. According to the Association of State Dam Safety Officials, the average life expectancy of a dam is 50 years because that is the point at which concrete begins to deteriorate (ASDSO 2000, NRC 1992). Over 30% of U.S. dams identified on the NID are > 50 years old, and by 2020 that figure is estimated to reach 80% (ASDSO 2000). Dam owners are facing substantial repairs, modification, and maintenance to continue to meet safety and environmental standards. At the same time, hundreds of dams used for hydropower generation across the nation are facing relicensing from the Federal Energy Regulatory Commission (FERC). In 1986 Congress directed the FERC to incorporate environmental, recreational, and other factors into its relicensing process. This relicensing process is an opportunity for the public to consider the costs of maintaining hydropower dams against the benefits of restoring an aquatic ecosystem.

Time is also a critical issue for the recovery of anadromous fish runs and the restoration of riverine ecosystems. The anadromous fish in each run are genetically distinct from the fish in a neighboring run and uniquely adapted to their particular stream (Dittman and others 1995, Courtenay and others 1997, Hasler and Wisby 1951). Hatcheries built to mitigate dam impacts erode the genetic integrity of these runs by releasing fish that outcompete and interbreed with wild populations (Noakes and others 2000). Faulty construction of fish ladders and the stress of passing turbines and sluiceways increase mortality of both adults and juveniles (NMFS 1998). Due to genetic erosion, direct mortality, and widespread habitat loss, numerous distinct anadromous fish populations are declining rapidly. Timely recovery efforts are critical because of the high extinction risk associated with small populations and the uncertainty inherent in the recovery process.

New Developments: Extinctions and Relicensing

The National Marine Fisheries Service (NMFS) and the FERC face the challenge and the responsibility of complementary mandates: defining critical habitat toward the recovery of anadromous fish and evaluating dams for decommissioning based in part on ecological criteria. The federal government has assigned NMFS, a division of the National Oceanic and Atmospheric Administration (NOAA), responsibility for implementing the Endangered Species Act (ESA) for anadromous fish. NMFS has assigned each run of steelhead, chinook salmon, and coho salmon in California to the category of endangered, threatened, candidate, or listing not warranted (NOAA 2000c) (Table 2). NMFS recently designated critical habitat for 19 runs in California and the Northwest (NOAA 2000a).

One goal of designating critical habitat is to clarify when consultation under section 7 of the ESA is required to determine if a proposed action should take

Table 2. California salmon runs listed under the Endangered Species Act

Species	Chinook salmon	Coho salmon	Steelhead
Endangered	1	0	1
Threatened	2	2	3
Proposed threatened	0	0	1
Candidate for listing	1	0	1
Listing not warranted	1	0	0

Source: NOAA (2000b).

place that could compromise a listed species (NMFS 1999). NMFS's definition of critical habitat is ambiguous on whether dams block access to critical habitat and therefore should be considered for removal as part of a recovery plan. One of their criteria for critical habitat is "habitats that are protected from disturbance or are representative of the historical geographical and ecological distributions of the species" (NOAA 2000a). This definition suggests that spawning grounds that are now unavailable to anadromous fish because of dams should be classified as critical habitat. However, they also specify that "unoccupied areas are not to be included in critical habitat unless the present range would be inadequate to ensure the conservation of the species," and they identify dams as the "upstream extent" of critical habitat for most runs including those on the Yuba and Eel Rivers (NOAA 2000a). NMFS states its willingness to consider areas above dams as part of critical habitat "if future analyses reveal that these areas are essential for the species' conservation or could contribute to expedited recovery" (NOAA 2000a). This transfers the burden of proof to the public (specifically commercial fishing and environmental advocates) and insulates dams from the review of projects impacting listed species as mandated by the ESA. It is understandable that NMFS is reluctant to declare critical habitat above dams because of the likely political and legal backlash from dam owners and users. However, NMFS has been legally mandated responsibility for defining critical habitat. By shifting the burden of proving that critical habitat exists above a dam, NMFS abdicates its regulatory responsibility. Local organizations generally lack the resources to launch such a research-intensive, politics-laden project, and thus the relationship between dams and critical habitat is unlikely to be addressed adequately and comprehensively.

Even if a dam is determined to be a threat to critical habitat, a review of economic impacts may preclude any consideration of removal. The ESA prohibits the consideration of economic impacts in the listing process but does require analysis of economic impacts when designating critical habitat and reviewing proposed projects. As long as the species is not at immediate risk of extirpation due to the project, if the cost of removal is too great, the dam is protected from the ESA (NOAA 2000a).

Critical habitat designation (including or excluding dams) is also important in the revised FERC relicensing process. The FERC is an independent federal commission that has jurisdiction over almost all nonfederally owned hydropower dams: approximately 2600 dams with 1633 licenses (about 617 licenses, or 1000 dams, are exempted because the projects are so small; Black and others 1998). These licenses are issued for 30–50 years, and their renewal provides an opportunity for public input on public resources.

FERC was originally established to promote hydropower development, but it is now constrained by NEPA and the Electric Power Consumers Act (EPCA), which mandated FERC include environmental benefits in relicensing. These benefits include protection of fish and wildlife, recreation, water supply, and flood control. EPCA also mandated construction of fish ladders on dams lacking them at the time of relicensing (Black and others 1998). FERC must solicit and consider comments on dam relicensing from public agencies, such as the U.S. Fish and Wildlife Service, NMFS, and state wildlife agencies. This "equal consideration" mandate has forced FERC to consult with public agencies responsible for resource management, giving them a powerful tool for informing public discussion of river management (American Rivers 1996, Black and others 1998). EPCA also provides an opportunity for public interest and environmental groups to address concerns about river management through motions of intervention (American Rivers 1996, Friends of the River 2001).

Nationwide, 550 dam licenses are coming up for renewal before 2010, creating the opportunity to address environmental concerns on the rivers affected (Table 3). Although FERC has improved its licensing proceedings, many have attacked the commission and its staff for using poorly designed and inconsistent analyses (Black and others 1998, Hydropower Reform Coalition 1999, Freeman 1996). Freeman (1996) demonstrated that FERC's Draft Environmental Impact Statement (DEIS) in favor of relicensing the Edwards Dam failed to consider nonpower values, in effect contravening the ECPA's "equal consideration" mandate and FERC's own stated policy. The DEIS recommended relicensing with fish passage (in its 160-year history the Edwards Dam had never operated a fish ladder). A coalition of fishing and environmental advocacy groups

Table 3. High hazard dams, dam removals, and dams licenses expiring over the next 10 years

Dams	California	Nation
Total number of dams	1395	75,000–2.5M?
High hazard dams	392	9280
Dams removed 1912–1999	48	467
FERC licenses expiring 1993–2010	51	419
Number of dams covered by expiring licenses	212	Not available

Sources: American Rivers and others (1999), ASDSO (2000), Black and others (1998), Friends of the River (2001), NRC (1992).

Table 4. Dam ownership

Ownership	Percent
Private	58
Local government	17
State government	5
Federal government	3
Public utilities	2
Undetermined	15

Source: ASDSO (2000)

sued, demonstrating that a majority of the fish runs would be unable to use the ladders. The FERC's cost-benefit analysis combines dollar values for a dam's economic benefits with qualitative description of environmental and recreational benefits lost. Freeman attacked this methodology as "totally at odds with all credible, modern welfare economics theory of which I am aware. It is further at odds even with the recommendation of the electric power industry, as well as my understanding of FERC's own stated policy" (Freeman 1996). The final environmental impact statement recommended removal based on the fact that constructing fish passage for the only three fish species that could negotiate it would still cost 1.7 times more than retiring and removing the dam.

The order to remove the Edwards Dam against the will of its owners has realigned the relationships between dam owners, federal and state agencies, and environmental groups. The full implications of EPCA are becoming clear. Quantifying economic benefits and qualitatively appraising the value of environmental benefits does not fulfill the EPCA. Computing dollar values of wild rivers is problematic because there is no conventional market to set prices, but advances in economics over the past 20 years have made it possible to assign appropriate figures (Wegge and others 1996, Braden and Kim 1998). The hydropower industry is concerned about the precedent of the Edwards Dam removal and is currently pushing a bill in Congress that would require resource agencies to submit their opinions on improved river management to FERC according to an accelerated time line. This bill would significantly curtail the ability of already-overextended agencies, like the U.S. Fish and Wildlife Service, to contribute to the discussion in a meaningful way (Carville 2000).

In the United States, the focus of debate over dams is shifting westward as larger projects built later come up for relicensing (American Rivers 1996). Advocacy groups emboldened by the implications of the ESA and changes in FERC's relicensing process are conducting their own research into the economics of dam removal, and insisting that California policy-makers give full consideration to the benefits of dam removal as a watershed management option.

The Problems in California: Danger and Opportunity

California has over 1395 dams, and their original purposes, ownership, size, environmental impact, state of repair, and current usefulness vary widely (Tables 3 and 4). Dam building started early with the state's gold rush in 1849, but California is now second only to Wisconsin with 47 dams removed (American Rivers and others 1999). California was the first state to create systems for large, interbasin water transfers with urban areas dependent on water imports from distant watersheds (Reisner 1986, Pincetl 1999).

More than 22 million Californians and a $27 billion agricultural industry depend on water passing through the Sacramento Bay Delta, and conflict over water use among urban, environmental, and agricultural interests resulted in the creation of a federal-state watershed stakeholder program called CalFed. After years of "water fights" in the state, CalFed is providing a forum where opposing views can be voiced, and it claims to be undertaking the largest and most inclusive environmental restoration program in the United States (CalFed 2000).

The most recent river restoration initiative, the removal of four dams on Butte Creek, a tributary of the Sacramento River, may be a sign that collaboration is possible. The Sacramento River was historically host to 700,000 salmon, but extensive dam construction in the 1920s led to dramatic decline. Butte Creek, a tributary of the Sacramento River, hosted less than 500 returning fish during the 1987–92 drought, and its spring-run chinook were listed as threatened under California's Endangered Species Act and were candidates for the federal ESA. When the drought was over, state biologists counted 7500 juveniles outmigrating, and they realized that targeted habitat restoration in Butte Creek had great potential. The threat of a federal listing under the ESA provoked intense negotiations among diverse stakeholders: water districts, agricultural users, commercial fishermen, and state and federal agencies. This led to a $9.13 million project that removed four dams and protected fish from being pumped into agricultural irrigation systems. It restored 40 km of riverine habitat blocked for 80 years, and local farmers benefited from habitat restoration because their water supplies were no longer threatened by environmental regulatory action. The spring-run in 1998 consisted of over 20,000 adult chinook. A full array of benefits was reaped from this effort because other environmental restoration activities—such as fish screens on water diversion and habitat improvement—were packaged with dam removal (American Rivers and others 1999).

As with dam controversies around the country, the greatest obstacle—after politics—lies in the lack of robust data on impacts and alternatives. The accuracy of cost benefit analyses can never be better than the quality of information used to create them. In several watersheds, well-organized stakeholders are coaxing state and federal officials to consider dam removal to restore impaired aquatic ecosystems. Advocates are insisting that policy-makers compare dam removal benefits with the cost of maintaining the policy status quo, and that performing cost benefit analyses will demonstrate the positive net benefits of removal. To address this information need, river advocacy groups in California are working to pass a bill that would instruct the California State Secretary of Resources to:

1. Conduct a statewide inventory to identify abandoned, obsolete, or poorly functioning dams that could be modified or removed to restore fish habitat and migration, river ecosystems, and enhance public safety.
2. Conduct studies to determine the cost and feasibility of modifying or removing dams, and to identify alternative methods that could be used to replace the beneficial functions (if any) of such dams.
3. Establish the Dam Decommission Fund in the State Treasury and authorize the expenditure of monies from the fund, on the appropriation by the Legislature (Friends of the River 1999).

Dams within the Central Valley Project or the State Water Project system, plus those providing essential flood control, water supply, or hydroelectric benefits, are specifically excluded from consideration in this bill, except where recommended structural and operational modifications to such facilities would aid in the restoration of salmon and steelhead fisheries and their habitat.

Evaluative Criteria for Dam Removal

In light of these developments, resource managers need objective, evaluative criteria for assessing dams proposed for removal. This section will suggest criteria for policy-makers to consider when evaluating a dam for removal, relicensing, or modification. Our criteria are written to address some dam-related issues, such as anadromous fish that are unique to California and the Northwest. However, these criteria may easily be adapted to other regions of the United States and beyond. Given the highly contextual and locally specific nature of dams and rivers, it is not possible to create a simple formula for using these criteria or to establish priority among criteria. Ours act as a checklist to ensure that all of the major issues associated with dam removal are considered. We recommend that the watershed be the fundamental unit of analysis for evaluating dam removal. For example, removing one dam will provide no benefit to anadromous fish populations if there is an additional dam downstream blocking access to upstream spawning habitat and degrading water quality for aquatic organisms. Table 5 outlines key ecological, functional, safety, and political questions to be addressed in the decommissioning process.

We view ecological criteria for dam removal as critical. The widespread degradation of anadromous fish habitat is the primary political force driving consideration of dam removal in the coastal states of the United States. Dams are the most significant factor contributing to the environmental degradation of watershed integrity in California (Moyle and Randall 1998). A qualitative analysis of ecological costs (and benefits, should they exist) of each dam would help evaluate and prioritize dams for removal. The first step in considering dam removal is to establish to what extent the dam is degrading habitat quality and quantity. Good water quality for steelhead and other threatened species is correlated with cool water temperatures, neutral pH, high dissolved oxygen and nutrients, and low turbidity. Salmon require slow, low-grade flows, vegetation cover, and habitat heterogeneity, including pools and riffles, runs and glides for protection and spawning (Kanehl and others 1997, Busby and others 1996, NMFS 1998). If one or more of these critical habitat characteristics has been compromised by the dam, then mitigation for habitat loss could include dam removal. Data that determine the nature and extent of habitat degradation caused by a dam may be limited or nonexistent. The dam decommissioning process must evaluate if these

Table 5. Evaluative criteria for dam removal

Ecological criteria	Is the dam currently degrading habitat quality and quantity?	• Does the dam slow or alter natural flow patterns temporally or spatially? • Does the dam increase the temperature of the water? • Does it cause changes in natural nutrient load? • Does it cause changes in natural sediment load? • Does the dam result in the release of oxygen-deprived water, suffocating organisms? • Does the dam obstruct access to spawning grounds for threatened and endangered fish? • Does the dam cause immediate death to organisms: do turbines kill fish and do fish ladders, if present, stun and stress fish, making them more vulnerable to predators? • Is the dam contributing to the degradation of wetlands by reducing available freshwater and leading to saltwater intrusion? • Are data for the above impacts on habitat quality available for this dam? If not, are they obtainable at an acceptable cost and over a reasonable time?
	Will the removal of the dam restore habitat quality and quantity?	• Will dam removal renew access to spawning grounds for threatened and endangered fish? • Will dam removal restore natural flow patterns, channel morphology, water temperature, nutrient and sediment load? • Would dam removal impact sensitive or endangered species that benefit from habitat alterations brought about by the dam and reservoir? • Can dam removal be accomplished safely so as to minimize harm to aquatic organisms? • Can potentially contaminated sediment be removed safely and can we identify and manage the uncertainty associated with sediment removal? • Are there other dams, diversions or activities in the watershed that could compromise fish recovery and habitat restoration despite removal of this dam? • Are data for predicting the effectiveness of dam removal available? If not, are they obtainable at an acceptable cost and over a reasonable time?
Dam function and safety	Is the dam still fulfilling its original intended function?	• How much longer is the dam expected to be functional? What are the existing benefits to society? i.e., kilowatts of electricity, flood control, recreation. • Do the costs associated with operating and maintaining the facility outweigh costs of enforcing laws for safe fish passage and human safety? • If the dam provides critical flood control, are there alternatives? • If the dam still provides hydroelectric power, how much does it provide, and are there alternatives? • Could water storage and diversion be reconfigured if they are affected by dam removal?
	Does the dam pose a current or potential safety hazard to human lives and property?	• Is the dam inspected regularly? • Has maintenance been deferred? • Was the dam built to “low hazard” specifications but due to development now needs to be upgraded to “high hazard”? • Would dam failure result in a significant loss of life, property, and/or services? • What are the expenses associated with dam maintenance now and in the future?

Table 5. (continued)

		● What are the expenses associated with dam maintenance now and in the future? ● What are the expenses associated with potential emergency removal and potential dam and downstream repair costs resulting from failure?
Political process	Is there stakeholder support for dam removal?	● Are there local economic opportunities tied to dam removal? ● Are there advocacy organizations in support of dam removal? ● Are regulatory agencies addressing or recommending dam removal? ● Who are the principal opponents to dam removal and what is their political capacity to block consideration of removal? Can their interests, such electricity generation or reservoir-based-recreation, be shifted elsewhere within the watershed?
	Would the Endangered Species Act play a role in dam removal?	● Would dam removal reduce the economic and/or regulatory burden of the agencies responsible for enforcing the ESA?
	Is funding available?	● Would the dam owner absorb the costs of removal? ● Would costs of removal be shared within the watershed? ● Would organizations such as CalFed or other divisions of the state or federal government contribute to removal costs?

data are obtainable at an acceptable cost, time scale, and level of uncertainty. Quantifying acceptable cost is a political decision. Quantifying acceptable time and uncertainty involves weighing the risk of further habitat degradation due to delay or inaction against the risk of degradation due to acting on inadequate data.

It is equally important to evaluate if the removal of the dam would in fact result in the restoration of habitat quality and quantity. Factors to consider include renewed access to spawning grounds, restoration of natural flow patterns, stream morphology and microhabitat, and sediment and nutrient load. Successful restoration will require careful research and planning to ensure that the dam removal itself does not cause irreparable ecological damage (Shuman 1995). There must be a plan to safely remove or release sediments, including those contaminated by toxics, so that they do not further degrade the aquatic system. The potential expense and uncertainty surrounding sediment management may be so great as to make full removal prohibitively expensive (Task Committee on Guidelines for Retirement of Dams and Hydroelectric Facilities 1997). Determining the quantity and type of sediment and how it will affect habitat health is critical to ensuring that ecosystem benefits outweigh the potential damage caused by unwise sediment management. Table 6 provides an overview of the relative merits of various sediment management strategies.

The next set of criteria involve the questions and costs associated with dam function and safety. If the dam is no longer fulfilling its original function, there are likely to be fewer political and economic obstacles to removal. If the dam is still providing services, such as flood control, hydropower, or water storage, then stakeholders need to evaluate how much longer the dam is expected to provide these services and balance the benefits to society with the ecological and maintenance costs over time. In many cases, when these services can be shifted to other reservoirs, the decision to remove a problematic dam has gained stakeholder support (American Rivers and others 1999). Stakeholders also need to evaluate if the services provided by the dam are significant enough to outweigh environmental costs. Thirty-one percent of dams in the United States were built for recreation and 8% for disposing of debris from now-obsolete mining sites (Table 1). We suggest that dams that are ecologically damaging and were built solely for recreation or debris should be targeted for ecological and economic cost-benefit analysis. A tiny minority of these kinds of dams in this country have been scrutinized in light of scientific, economic, and political developments.

Dam safety is an important evaluative criterion because potential dam failure is another factor capable of catalyzing dam removal. There is little agreement over who is responsible for the upkeep of many dams, and

Table 6. Relative advantages of sediment management alternatives

Approach	Definition	Advantages	Disadvantages
River erosion	Allow the river to naturally erode sediments from the reservoir	• Costs of removal are spread over longer time frame • Allows river to reach equilibrium naturally	• Generally, largest risks of impacts • Stability for removal stage requires study • Long deconstruction period
Mechanized removal	Removal of sediment form the reservoir by hydraulic or mechanical dredging or conventional excavation for long-term storage at an appropriate disposal site	• Low risk after deconstruction • Minimal long-term impacts • Low maintenance costs	• Large up-front construction costs • Construction impacts • Difficult to remove all reservoir sediment
Stabilization	Modify the project facilities (partially breached dam) and design appropriate protection against erosion to store sediments in the reservoir over the long term	• Minimize disposal site considerations	• Long-term channel/overbank maintenance costs • Intermediate construction impacts

Source: Task Committee on Guidelines for Retirement of Dams and Hydroelectric Facilities (1997).

there are limited funds for inspection. Evaluative criteria for dam removal must address the risks and costs associated with the potential failure of a particular dam such as loss of human life and property, environmental damage, sudden release of sediments with toxics, and sudden loss of services to community.

The last set of criteria addresses the social and political processes associated with dam removal. Dam removal is unlikely to proceed without strong support among stakeholders. If local or regional communities will benefit economically from dam removal, they may view the decommissioning process as an investment in their future. For example, the Pacific Coast Federation of Fishermen's Associations (PCFFA) has formed a coalition of commercial fisherman to lobby for the review and decommissioning of several hundred of California's hydropower dams. More than 75% of the nation's $152 billion/year fishing industry depends on the health of the inshore or nearshore environment. Rivers are the nursery grounds for most of the fish caught in U.S. waters, and commercial fishermen are advocating dam removal because their livelihood and the health of their communities are at stake (PCFFA 2000). Other local economic opportunities potentially associated with dam removal include tourist dollars from river recreation and the jobs created and sustained by deconstruction and restoration.

Because dam removal is a political process, evaluative criteria should also address the political capacity of stakeholder organizations in the watershed and the political will of relevant regulatory agencies (Rhoades and others 1999). Through research and education, advocacy groups pressure public agencies to consider dam removal. Communication and cooperation between advocacy groups, local communities, and government agencies is crucial to the dam decommissioning process. Dam removal could also reduce the financial and regulatory burden on NMFS and USFWS if this would prevent or potentially remove a species from listing under the ESA. Members of the public presently enjoy reservoir-based recreation, and they often form groups to resist consideration of dam removal proposals. River restoration advocates have responded by proposing that this form of recreation be managed on a watershed basis by concentrating it in neighboring reservoirs. Organizations opposed to dam removal must be factored into the decommissioning process.

The final criterion addresses funding availability. Given the potential environmental benefits of decommissioning, the physical removal of the dam structure is not an expensive process, but managing sediment and compensating for hydropower loss can be. In considering a dam for removal, it is important to plan who will bear the costs. The ASDSO and the American Society of Civil Engineers assert that the lack of funds to maintain dams is a serious national problem (ASDSO 2000). Dam maintenance is the responsibility of the owners, but many private owners with insufficient access to capital have deferred it.

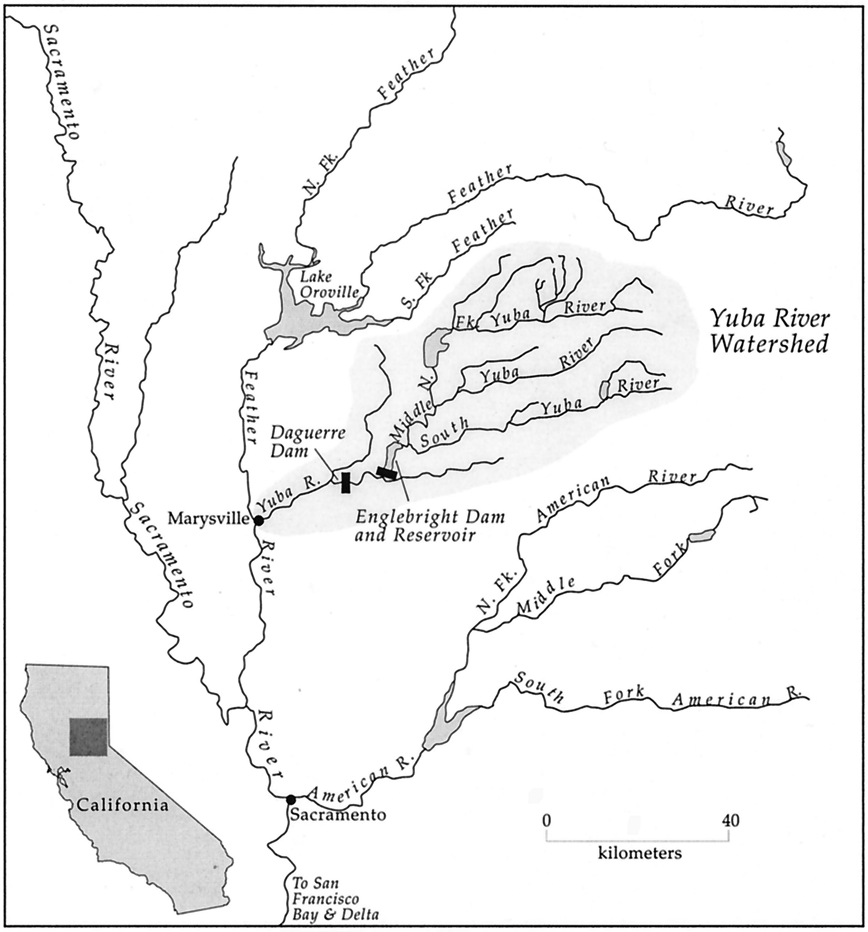

Figure 1. Yuba River watershed. (Cartography by John E. Isom.)

This crisis may cloak an opportunity: Facing prohibitive maintenance expenses, owners may recognize that it is simply cheaper to abandon or decommission a dam than replace it. The Hydropower Reform Coalition (1999) believes that electricity deregulation will result in the termination of subsidies to some hydropower facilities, resulting in further dam abandonment. This does not necessarily result in dam removal, because owners may choose to forgo needed repairs to the facility and leave the dam in place. Environmental advocates (see Hydropower Reform Coalition 1999) insist that dam owners must be held accountable for dam removal. Owners have profited, in some cases immensely, from a public good, and the licensing agency must ensure that the burden of deconstruction not be shifted onto the taxpaying public.

Case Studies

The Yuba River: Daguerre and Englebright Dams

Europeans began settling in the Yuba River watershed northeast of Sacramento during a later phase of the California gold rush in the 18th century (Figure 1) Its slopes were subject to hydraulic monitors, similar to giant gravity-fed fire hoses, which dissolved entire hillsides to sluice them for gold particles. The river ran thick with mud and rocks washing downstream, resulting in deadly floods in Yuba City and Marysville in the 1860s and 1870s, and eventually leading to a ban on use of monitors in 1884 (Kelley 1959). So much mining debris was created, however, that the region has had to build numerous dams to capture the sediment and prevent it from further congesting the stream channel in the Sacramento Valley. The Yuba is the third largest tributary to the Sacramento River, the most important river to California's economy.

The Daguerre Dam was built by the California Debris Commission on the Yuba near Marysville in 1906 as a catchment basin for mining debris. The 6.4-m-high dam is no longer able to fulfill its original purpose, however, because it has been completely filled with sediment for several years. More significantly, it blocks roughly 40% of the salmon and steelhead migration up the Yuba annually. Fish ladders along the side of the dam are so poorly designed that salmon often flop out of them and die on dry land (Rose 2000). Englebright Dam, located about 24 km upstream of the Daguerre, was built in 1941 for debris containment, hydroelectric power generation, and recreation. At 81 m tall, it was built without any provision for fish passage, completely blocking access to historical spawning habitat. In addition, altered stream flows below the dam disrupt instream spawning habitat for the anadromous fish that do negotiate the Daguerre (Rose 2000).

In 1998 CalFed issued a multivolume Ecosystem Restoration Program Plan, identifying numerous opportunities for restoring ecosystem health to the region's rivers and including consideration of removal of Daguerre and Englebright Dams (CalFed 2000). Since then, CalFed has recommended the removal of the Daguerre, although formal studies and a work plan have not yet begun. CalFed chose the Yuba River Watershed for possible restoration activities because the spring- and fall-run salmon have been extirpated from most of the other tributaries to the Sacramento River, and the Yuba holds the most promise for restoring habitat and preventing or forestalling an ESA listing. Removal of these dams could conceivably triple or quadruple the entire amount of spawning habitat available in the Sacramento River watershed. The consequences of listing these fish would have huge implications for water supply in other parts of the Bay-Delta region because NMFS could require dam operators to follow a flow release schedule to favor salmon spawning, and this could put commercial fishermen and farmers out of business and curtail water delivery to Los Angeles (Reisner 1998). If these dams were removed, salmon could access their historic spawning habitat above the dam, and NMFS would not impose a flow release schedule. Consideration of dam removal makes more sense as a policy option because of the economic and social costs associated with a "no action" alternative (Rose 2000).

The South Yuba River Citizen's League (SYRCL) was founded in 1983 to educate and advocate on behalf of wild river and wilderness issues in the region, and its staff submitted to CalFed a proposal to study the benefits and costs of removing the Englebright Dam. Their proposal to remove this dam is much more controversial than the Daguerre plan because the Englebright provides hydropower, reservoir-based recreation, and increased property values. Even though CalFed chose to place the study in the context of a broader public process, SYRCL was successful in spurring CalFed to actively consider the removal of these dams. In 1999 CalFed initiated the Upper Yuba River Studies Program, which will evaluate stakeholder-developed options (ranging from no action to dam removal) in light of seven issues: sediment transport and storage, flood protection, water quality, water supply and hydropower generation, social values, economics, and fisheries habitat (UYRSP 2000). These studies will provide most of the scientific information called for by the criteria proposed in this article.

The quantity of the mercury in the Englebright reservoir's sediments is a wild card in this case. Mercury was used extensively in 19th century placer mining, and losses to the river were as high as 30% (Hunerlach and others 1999). Mercury in sediment progressively methylates or "dissolves" in the relatively warm and calm waters of a reservoir, making it available for bioaccumulation in fish as a potent neurotoxin (May and others 1999). Those favoring retaining the dam suggest that the Englebright dam protects the health of the downstream river by blocking mercury, but this argument does not address the escalating problem of mercury exposure. The threat of mercury exposure could trigger consideration of reservoir draw down to prevent further methylation. One of the three sediment management alternatives in Table 6 would then be much more appropriate than leaving the mercury in the reservoir to methylate. When the mercury studies are completed, the discussion of removing Englebright dam may be substantially reconfigured. This issue illustrates that the cost of "no action" may turn out to be greater than dam removal.

The regulatory action of NMFS will also play a critical role in shaping the decision to remove the Englebright dam. There does not appear to be any biological justification for excluding the above-dam habitat from designation as critical to salmon recovery. In this case, to apply the ESA, NMFS should designate habitat above the dam as critical and force the dam owners to resolve the issue of fish access. The dam's height of 81 m poses significant costs and engineering challenges to constructing a fish passage structure, however, and it may prove to be cheaper to remove the dam than to spend millions of dollars on a fish ladder, one that may prove to be inadequate. In any event, EPCA's reform of FERC's decision-making process will require the construction of fish ladders when the Englebright's hydro permit comes up for relicensing in 2012, but it is not clear whether salmon will still exist in this watershed at that time.

The Yuba County Water Agency, PG&E, and an association of houseboat owners on Englebright Lake have been the most vocal opponents of dam removal. They maintain that removing the Englebright would increase peak flood flows and increase the risk to downstream levees, reduce water supply, further degrade downstream habitat, and result in the loss of private property rights and hydropower generation. The water agency claims that the steelhead runs are the best in the state and that fish would be placed at greater risk by removing the dam (Wilson 1998).

PG&E has claimed that it would lose $278 million if the Englebright were removed (although they do not specify a time frame). The value of the reservoir to power generation is roughly $10 million per year (LAKE 2000). The value of recreation has been suggested to be $94 million (Levy 2000), although this figure is disputed and does not reflect recreational benefits of removal (Rose 2000). Sediment removal has been estimated at roughly $80 million. Breaching the dam is estimated at only $5 million (Levy 2000). The cost of removing a dam is often a small part of the overall price tag of a project (see American River and others 1999).

CalFed, Federal fish recovery legislation, and state water bonds are all potential sources for funding removal, although environmental advocates insist that those who have profited from the dam should bear the full price of restoring the river to health (Levy 2000). Until the potential benefits of making available above-dam habitat to salmon and the costs of resolving the mercury issue are quantified, and NMFS's decides to fully implement critical habitat designation, there are too many uncertainties to predict whether this dam will be removed. Regardless of how the data will resolve uncertainties in this case, dam removal will be considered in the final analysis only if the associated costs can be reconfigured within the watershed or subsidized by the general public. For example, it might be cheaper to buy out the property owners on the lake and move the houseboats to another reservoir than to allow years of litigation to further compromise fish populations. Stakeholders outside of the watershed such as commercial fishermen and urban water districts are hoping that those within the watershed can resolve the issue successfully.

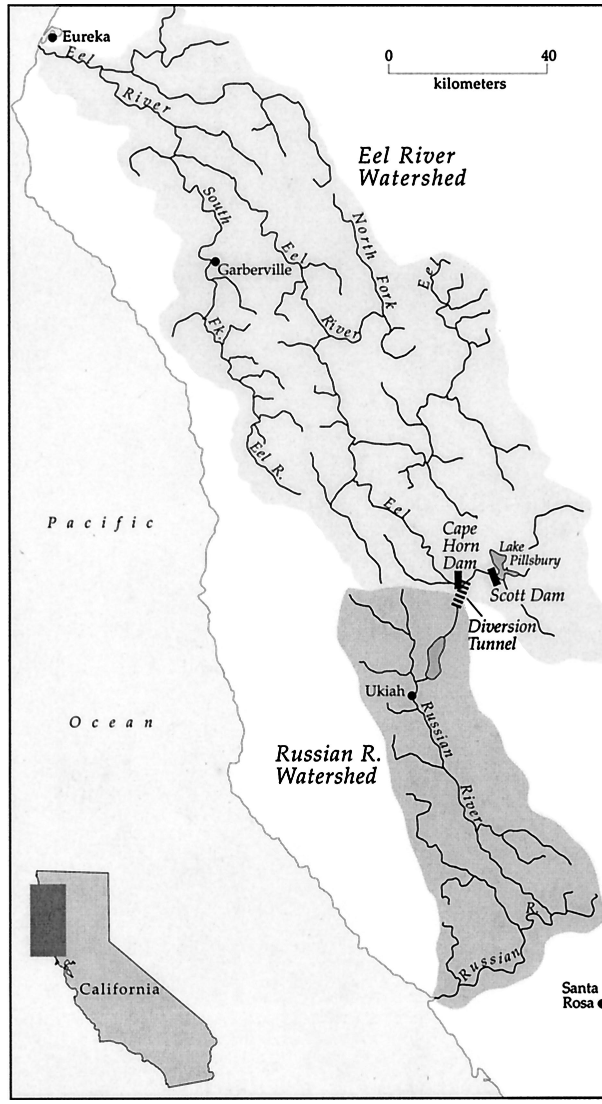

Figure 2. Russian River and Eel River watersheds. (Cartography by John E. Isom.)

The Upper Eel River: Scott Dam and Cape Horn Dam

The damming and diversion of the upper Eel River illustrates California's history of inter-basin water transfer and contention over water rights, and how this contention drives contemporary discussions of dam removal in this watershed. The Potter Valley Project (PVP) includes Cape Horn Dam, Scott Dam, and a diversion tunnel that diverts 90% of the water from the headwaters of the Eel River into the Russian River and down to Sonoma County (Figure 2). Cape Horn Dam was built in 1908 and created Van Arsdale reservoir. This reservoir filled up with sediment almost immediately and Scott Dam was built 13 years later to create Lake Pillsbury and provide greater storage capacity for the PVP. PG&E bought the project in 1930 and still uses Scott Dam to produce hydropower. Seventy years later, this diversion is providing Sonoma County with $40 million in free water every year, and the facility continues to contribute to the dramatic decline of anadromous fish in the Eel watershed (Friends of the Eel River 2000a).

The Eel River once supported half a million chinook salmon, coho salmon, and steelhead, but today is host to less than 30,000. Scott Dam is 39 m high and does not have a fish ladder, thus blocking access to 250–300 km of prime salmon spawning habitat in tributaries upstream of the dam (Friends of the Eel River 2000b). Most of the watershed downstream has been highly degraded by poor logging and mining practices. Thus, the headwaters of the Upper Eel River are critical to salmon recovery in the watershed because they represent the most intact and highest-quality spawning habitat.

The reduction in flow volume due to the diversion of Eel River water is itself detrimental to anadromous fish. Cape Horn Dam, 20 km downstream of Scott dam, is 9.5 m high and does have a fish ladder. However, the number of fish ascending the ladder have dropped from over 6000 in 1945 to only 5 today. This decline is due to low flows that prevent the fish with enough muscle to reach the headwaters from ascending the river. California Fish and Game extract eggs from the few fish that do return and raise them in hatcheries until they are large enough to survive the introduced, carnivorous squawfish that thrive in the water below the dams. These hatchery-raised fish tend to outcompete and reduce genetic diversity in the remaining populations of wild salmon and may help spread pathogens (Noakes and others 2000).

Removal of the PVP could potentially result in great economic benefit through the restoration of the salmon fishery. The Eel River remains the third-largest producer of chinook and coho salmon and the second largest producer of steelhead in California, and the loss of fishery income to Humboldt County due to the PVP is estimated at $4 billion (Friends of the Eel River 2000a). The return of a productive fishery has the potential to give a sizable return on taxpayer spending for dam removal and restoration.

Dam removal on the Eel River will require extensive channel work to restore the shady pool/riffle conditions important for spawning fish downstream of the dams. As with most dam removal projects, the question of how to manage sediment trapped behind the dams will likely be the biggest challenge in the removal process. In several cases, dam removal has had devastating impacts on already threatened species and sensitive habitat because sediment was not properly managed (Brauner and others 1997, American Rivers and others 1999). In this case, dredging may be the best option for safe dam removal.

Both dams in the PVP are only partially fulfilling their originally intended purpose, and the legality of this purpose is itself questionable. A coalition of local and regional advocacy organizations has embarked on a citizen action suit, arguing that the PVP was constructed illegally in 1908 and represents a breach of the public trust. They point out that development interests in Sonoma, Marin, and Mendocino Counties are benefiting from this project at the expense of the people and natural ecosystems along the Eel River. Residents in the Potter Valley have never had to develop their own water resources because it has always been subsidized by free Eel River water, but they could do so with ponds, off-stream storage, and cisterns (Friends of the Eel River 2000a).

The strongest opposition to decommissioning the PVP comes from development interests in Marin and Sonoma Counties, who have joined forces to purchase the project to ensure that they continue to receive free water from the Eel River. However, stakeholder arguments for decommissioning the PVP are strengthened by the loss of function and safety hazards associated with the dams. PG&E is interested in selling the project because the dam no longer produces profitable electricity, in part because downstream water users refuse to subsidize it by paying for Eel River water use. Both dams pose serious safety concerns. The dams sit directly on fault lines and were not built to withstand seismic activity, and the diversion tunnel has been subject to regular repairs over the last few years (Nadananda 2000).

There is considerable agency support for decommissioning the PVP. During the FERC relicensing process that began in 1968 and was completed in 1983, the U.S. Fish and Wildlife Service wrote to FERC, “Decommissioning the project and eliminating the out of basin diversion would have the greatest benefit, of all potential alternatives, to anadromous salmonids in the Eel River” (Friends of the River 2000b). On February 4, 2000, the California Public Utilities Commission ruled that PG&E must prepare an environmental impact report on the PVP before it is sold. This provided an opportunity for river advocacy organizations to intervene, and it prevented PG&E from selling off its dams, reservoirs, and plants to a corporation outside of California and beyond the jurisdiction of California law. Several weeks later the California State Supreme Court ruled that any FERC-licensed hydro project must comply with the California Environmental Quality Act and other local and county plans. This ruling allowed advocacy organizations to launch a legal campaign to ensure that FERC adheres to laws such as the National Environmental Policy Act, the ESA, and the Federal Wild and Scenic Rivers Act. They hope that upholding the law will leave FERC with no choice but to recommend decommissioning the PVP based on environmental impacts (Friends of the River 2000a).

Any discussion of the future of the PVP must take into account the costs and benefits and *who* benefits from maintaining the dams and weigh this with the costs and benefits of decommissioning the facility. Factors that should be considered include potential economic benefit of restored fisheries, ecological benefits, safety-related costs, recreational benefits and losses, and costs of physical deconstruction and restoration.

Like the Edwards Dam, the PVP will be a test case for the FERC. The commission's decision will demonstrate its seriousness in applying EPCA's "equal consideration" criteria to an application for license renewal. If FERC mandates fish habitat restoration, continued operation of the PVP may be too expensive for any owner. Returning the diverted water to the Eel River would also challenge the immutability of other interbasin water transfers and strengthen people's sovereignty over resource management in their own watershed.

Conclusions and Recommendations

Based on the above criteria and case studies, we make the following policy recommendations:

1. Public agencies that have adopted watershed-based ecosystem management should include analysis of the potential benefits of removing dams as a routine matter of policy. Virtually all U.S. dams were built prior to the passage of national environmental laws, but public resource managers now have sophisticated tools for evaluating their impacts. A small yet unknown number of the 75,000 dams in the United States could be removed with measurable economic and ecological benefits to society. Public agencies should develop objective and transparent criteria-based processes to make decisions about watershed management, including evaluation of dam and fish passage repair or removal.
2. The NMFS should elaborate its own criteria for designating historical habitat now blocked by dams as "critical" under the ESA. To address the significant impact dams continue to have on threatened anadromous fish, NMFS needs to reevaluate how they define critical habitat relative to dams and how they assign costs. Public interest groups should not allow NMFS to hide behind the ambiguity of its policy. NMFS should spell out what conditions should trigger studies of designating "critical" above-dam habitat for anadromous fish and should state clearly who is responsible for these studies. The ESA itself may not provide sufficient clarity to guide public agencies in considering the impact of dams, and this issue may have to be resolved in the courts.
3. Congress should resist private industry initiatives that would weaken the essential reforms of EPCA and serve to restrict social and environmental considerations in the FERC relicensing process. The current system is slow and somewhat cumbersome, but hydropower dams can have devastating and permanent environmental impacts on public resources.
4. We concur with the Hydropower Reform Coalition that Congress should establish a national dam decommissioning fund financed by dam owners. Those who have profited from public resource use should bear the financial cost of restoring any habitat they may have degraded.
5. States should pass laws like California's SB 1540 to inventory obsolete, abandoned, and malfunctioning dams. Watershed management policies depend on accurate and ecologically informed knowledge of their resources to make sound decisions. Some dams may be located at the lower end of a watershed on streams with major fish runs. These dams should be identified and targeted for fish passage improvement if not removal.
6. Local resource management agencies and watershed councils should investigate fully the opportunities for removing nonessential dams (i.e., abandoned dams, dams that exist only for reservoir-based recreation opportunities).

Dam removal, when it provides a net benefit to society, is a logical policy option for watershed councils. Individual dams may confer benefits that outweigh their costs, but if public agencies analyze an entire watershed, it may be possible to demonstrate that the removal of an individual dam will result in a net positive benefit to society. The health of a watershed could be improved if the services provided by a network of dams can be reconfigured to make one expendable. This kind of negotiation relies heavily on active and responsible stakeholder participation. The threat of ESA listing consequences to a watershed—and distant stakeholders—may be great enough to overcome the resistance of recalcitrant stakeholders.

Removing hazardous dams that degrade the environment clearly provides direct benefits for both human communities and natural ecosystems. But dam removal can also have a larger impact on environmental management as a symbol of ecological restoration. The high profile, high-energy work that goes into dismantling a dam and restoring a river can catalyze further efforts to improve the environment. Dam removal gives people the opportunity to become educated about the effect of logging practices and water diversion on their river and the potential rapid recovery of salmon populations provides hope as well as an immediate return on their investment. Successful dam removal also calls into question other environmentally damaging institutions in our society as people come to see that dams are not a permanent part of our landscape.

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