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ENVIRONMENTAL ASSESSMENT

Assessing Societal Impacts When Planning Restoration of Large Alluvial Rivers: A Case Study of the Sacramento River Project, California

GREGORY H. GOLET*
MICHAEL D. ROBERTS
RYAN A. LUSTER
GREGG WERNER
The Nature Conservancy
Northern Central Valley Office
Chico, California 95928, USA

ERIC W. LARSEN
Department of Geology
University of California
Davis, California 95616, USA

RON UNGER
EDAW, Sacramento, California 95814, USA

GREGORY G. WHITE
Archaeological Research Program
California State University
Chico, California 95929, USA

ABSTRACT / Studies have shown that ecological restoration projects are more likely to gain public support if they simultaneously increase important human services that natural resources provide to people. River restoration projects have the potential to influence many of the societal functions (e.g., flood control, water quality) that rivers provide, yet most projects fail to consider this in a comprehensive manner. Most river restoration projects also fail to take into account opportunities for revitalization of large-scale river processes, focusing instead on opportunities presented at individual parcels. In an effort to avoid these pitfalls while planning restoration of the Sacramento River, we conducted a set of coordinated studies to evaluate societal impacts of alternative restoration actions over a large geographic area. Our studies were designed to identify restoration actions that offer benefits to both society and the ecosystem and to meet the information needs of agency planning teams focusing on the area. We worked with local partners and public stakeholders to design and implement studies that assessed the effects of alternative restoration actions on flooding and erosion patterns, socioeconomics, cultural resources, and public access and recreation. We found that by explicitly and scientifically melding societal and ecosystem perspectives, it was possible to identify restoration actions that simultaneously improve both ecosystem health and the services (e.g., flood protection and recreation) that the Sacramento River and its floodplain provide to people. Further, we found that by directly engaging with local stakeholders to formulate, implement, and interpret the studies, we were able to develop a high level of trust that ultimately translated into widespread support for the project.

The aquatic biodiversity of North American rivers is in dire straits. Extinction rates in the continent's freshwater ecosystems are as high as those in tropical forests (Ricciardi and Rasmussen 1999). Centuries of extractive uses have left rivers in the developed world in a degraded condition—denuded of their forests, disconnected from their floodplains, and severely altered in both their flow and sediment regimes (Dynesius and Nilsson 1994; Richter and others 1997).

KEY WORDS: Floodplain; Resource management planning; River restoration; Sacramento River; Societal impacts; Stakeholder

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*Author to whom correspondence should be addressed; *email:* ggolet@tnc.org

If we are to avert further aquatic extinctions and ecosystem degradation, river restoration must be implemented soon, and on a large scale.

Restoring the underlying physical processes and natural flow regimes that have shaped rivers over the millennia will help sustain aquatic biodiversity (Gore and Shields 1995; Stanford and others 1996; Poff and others 1997). However, it is unlikely that most rivers will ever be completely returned to their natural states. Floodplains will continue to be managed to maximize economic prosperity, river flow patterns will be regulated to protect important human infrastructure (e.g., bridges, roads, floodplain farmlands), and large quantities of water will continue to be appropriated for agriculture and drinking. River restoration will necessarily entail a delicate balancing act—ideally by enhancing natural ecosystem processes without compromising important human services that rivers provide.

Although there are numerous general discussions of how to balance human and biodiversity needs in riverine systems (e.g., Gleick 1998; Baron and others 2002; Richter and others 2003), there are few examples of how to advance river restoration in specific situations amid local skepticism or misunderstanding (but see Rhoads and others 1999; Whalen and others 2002; Postel and Richter 2003). To be effective, river restorationists need access to more information about the specific issues that arise during public involvement and more examples of ways in which stakeholders have been positively engaged in restoration planning. Additionally, as river restorationists are increasingly adopting a watershed approach when planning restoration projects (Stanford and others 1996; Ward and others 2001), the demand for comprehensive, large-scale assessments is greater than ever before. Finally, the need to develop appropriate tools for addressing stakeholder concerns cannot be underestimated, as large-scale restoration projects typically require broad-based and local support before funds are awarded for their implementation.

We have been involved with restoration of the Sacramento River since 1988, working with partners to balance human and biodiversity needs. This approach has helped us deal with heterogeneous and, at times, stubborn opposition and build a collective vision for restoration of the river. Drawing on these experiences, in this article, we (1) discuss those issues that were of greatest concern to local stakeholders, (2) describe the studies that were performed to address these issues (3) identify stakeholder reactions to the studies and how they were addressed to build trust and advance restoration planning (4) examine remaining uncertainties that should be addressed through additional investigations and (5) provide guidance on integrating stakeholders into river restoration science and planning studies.

Background

The Sacramento River is the largest and most important river in California. The river drains approximately 6.2 million hectares of the northern Central Valley and supplies ~80% of the freshwater flowing into the Sacramento–San Joaquin Bay-Delta (California State Lands Commission 1993). Historically, the river was lined by approximately 324,000 ha of riparian habitat; however, over 95% of this habitat has been lost to logging, agriculture, urban development, and flood control and power generation projects (Katibah 1984). Two-thirds of the linear extent of the river's banks have been modified and confined by levees and riprap (bank revetment), and Shasta Dam has degraded the remaining natural habitats by restricting flow regimes that promote riparian habitat succession and regeneration (Kondolf and others 2000).

Cumulatively, these changes have greatly stressed the natural communities and species associated with the Sacramento River. The loss and degradation of riparian habitat has diminished the river's ability to support viable wildlife populations and encouraged the invasion and proliferation of non-native invasive species. At-risk special-status taxa in the region include diverse species of fish [e.g., Sacramento splittail (*Pogonichthys macrolepidotus*), green sturgeon (*Acipenser medirostris*), chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*Oncorhynchus mykiss*)], birds [e.g., Western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), Swainson's hawk (*Buteo swainsoni*), bank swallow (*Riparia riparia*)], mammals {e.g., western mastiff bat (*Eumops perotis*)], Yuma myotis (*Myotis yumanensis*)], and insects [e.g., valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*)] (CALFED 2000a).

A History of Planning Efforts

In 1986, state and federal agencies and nongovernment organizations began to implement management programs aimed at improving the health of the river. The California legislature passed Senate Bill 1086, which called for the formation of the Upper Sacramento River Fisheries and Riparian Habitat Council, and in 1989, by the authority provided under the Endangered Species Act, the US Fish and Wildlife Service (USFWS) Sacramento River National Wildlife Refuge (the Refuge) was established. The CALFED Bay-Delta Program has furthered these efforts. CALFED's 30-year mission is ''to develop and implement a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta System'' (CALFED 2000b). At a more local level, four other major government agency planning efforts similarly seek to balance human use with ecosystem heath and restoration on the Sacramento River. Key attributes of each are presented in Table 1.

To advance these planning efforts, The Nature Conservancy (TNC), in 1988, launched the Sacramento River Project (the Project). Key Project partners include the Sacramento River Conservation Area Forum, the USFWS, the US Army Corps of Engineers

Table 1. Key attributes of major natural resource planning efforts in the Sacramento River Project Area that seek to balance human use and ecosystem conservation/restoration

Planning effort	Geographic focus area	Total area[a]	Resource management goals	Associated documents	Completion date
CALFED[b] Bay Delta Program	Sacramento and San Joaquin Valleys, San Francisco Bay Delta, and Southern California	>23 million ha	• Water supply reliability • Levee system integrity • Water quality • Ecosystem restoration	CALFED 2000b, 2001	2030 (2008 for completion of stage 1)
US Army Corps of Engineers Sacramento and San Joaquin River Basins Comprehensive Study[c,d]	Entire Sacramento and San Joaquin River Basins	>10 million ha	• Flood management • Ecosystem restoration	US Army Corps of Engineers 2002, 2003	None specified
US Fish and Wildlife Service Sacramento River National Wildlife Refuge (the Refuge) Comprehensive Conservation Plan	124-km stretch of the Sacramento River between Red Bluff and Princeton	~3666 ha at 22 units under fee title[e], ~463 ha under conservation easement	• Long-term conservation of fish, wildlife, plants, and their habitats • Compatible wildlife-dependent recreation • Cultural resource preservation	US Fish and Wildlife Service 1997	Finalized June 2005
California Department of Fish and Game Sacramento River Wildlife Area Comprehensive Management Plan	113-km stretch of the Sacramento River between Corning and Colusa	~1467 ha at 13 units under fee title	• Protect and enhance habitat for wildlife species • Provide public with compatible wildlife-related recreation.	California Department of Fish and Game 2002	Finalized April 2004
California Department of Parks and Recreation Bidwell-Sacramento River State Park General Plan	Bidwell–Sacramento River State Park	~97 ha	• Protection and long-term management of cultural and natural resources • Compatible recreation	California Department of Parks and Recreation 1991	2006

Note: The studies profiled in this article were designed to provide information for these efforts.
[a]As of June 2003.
[b]For further information, see http://calwater.ca.gov.
[c]For further information, see http://www.compstudy.org/index.html.
[d]Of particular relevance to conservation and restoration planning efforts in the Sacramento River Project area is the current Hamilton City Flood Damage Reduction and Ecosystem Restoration Feasibility Study. Additional information on this project of the USACE Comprehensive Study can be found at http://www.compstudy.org/hamilton.html.
[e]The Refuge has the specific goal of conserving 7284 ha of floodplain habitats in fee title.

(USACE), the California Department of Fish and Game (DFG), the California Department of Parks and Recreation (DPR), and the California Department of Water Resources (DWR). The main goal of the Project is to develop and implement a ''single blueprint'' for the restoration and management on the main stem of the Sacramento River, so that different efforts along the river collectively support a unified vision for the future and do not work at odds with one another. Our strategies include the following: (1) conserving flood-prone lands, giving priority to those that contain and/or border remnant riparian habitats (~5424 ha thus far acquired in fee title), (2) revegetating land with native trees, shrubs, and understory species (~1457 ha thus far replanted, ~1228 ha planned), and (3) restoring natural river processes (Golet and others 2003).

TNC's Sacramento River Project Area

The Nature Conservancy has focused restoration efforts on the meandering reach of the Sacramento River, between the towns of Red Bluff and Colusa (~161 river km, inset in Figure 1), because this area presents unparalleled opportunities for restoration of geomorphic processes and natural habitats. Although this stretch of the river is severely compromised relative to its historical condition, much of the degradation is reversible. Farms (as opposed to cities) have replaced floodplain forests, and levees, where present, are often set back from the river by appreciable distances. In some areas, bank revetment is absent and the natural processes of bank erosion and point-bar deposition are still intact. This meandering reach is very different from the reaches upstream that are confined by resistant geologic formations and the reaches downstream that are completely confined by revetted levees. For more through geomorphic descriptions of the Sacramento River, see Buer and others (1989) and Singer and Dunne (2001, 2004).

Increasing the Scale of Planning to Identify Opportunities for Simultaneously Improving Ecosystem Health and Societal Condition

Although restoring natural riverine processes is most effectively achieved by planning at large scales (Stanford and others 1996; Harper and others 1999), the vast majority of river restoration projects are planned and implemented on one small section of a river at a time (Gore and Shields 1995). Such piecemeal planning often leads to projects that are both uncoordinated and ineffectual. In an effort to avoid these pitfalls, we initiated studies that focused on large geographic areas and that met some of the central information needs of the agencies that were developing management plans for river. In addition, we looked for focal areas where we could advance restoration through large-scale, on-the-ground projects, where we could offer technical information to characterize project feasibility. One such focal area was found near the town of Hamilton City, where we worked with stakeholders to comprehensively assess a suite of proposed actions aimed at improving management of the river over a 13-km reach (Figure 1).

Hamilton City (estimated population: 2,500) and the adjoining agricultural lands have been threatened by floodwaters of the Sacramento River several times in the past decade. All that currently protects these areas from flooding during high water events is an old (circa 1904), degraded private levee (the ''J'' levee) (Figure 1). The ''J'' levee was not constructed to meet any formal engineering standards and is largely composed of silty sand soils (US Army Corps of Engineers 2003). The USACE estimates that the ''J'' levee has only a 66% probability of containing a 10-year flood, and this probability assumes significant flood-fighting activities. In fact, extensive flood fighting was necessary and the town was evacuated in 1974, 1983, 1986, 1995, 1997, and 1998. Locals have attempted to persuade the USACE to repair and reengineer the levee, but they have never been able to meet required cost/benefit ratios. Despite this, locals initiated fund-raising efforts, including levee festivals (Bernardini 2002), to generate the required local cost share match in hopes that a future feasibility study would someday produce a project design that would qualify for federal participation.

In 2000, a diverse group of stakeholders (including farmers, conservationists, and citizens from the local community) came together to form the Hamilton City Working Group (hereafter the ''Working Group''). The group recognized that a project to fix the ''J'' levee problem would only be supported if it offered multiple benefits and was the product of coordinated planning. One of the Working Group's main objectives was to develop recommendations for restoration of the Hamilton City area for the Army Corps of Engineer's Comprehensive Study team (see Table 1).

Alternative solutions to the ''J'' levee problem had the potential to affect the ecosystem of the Sacramento River in profoundly different ways. We were interested in exploring solutions that could reconnect floodplain lands owned by several conservation groups with the natural processes of flooding, erosion, and sediment deposition. A significant ''J''

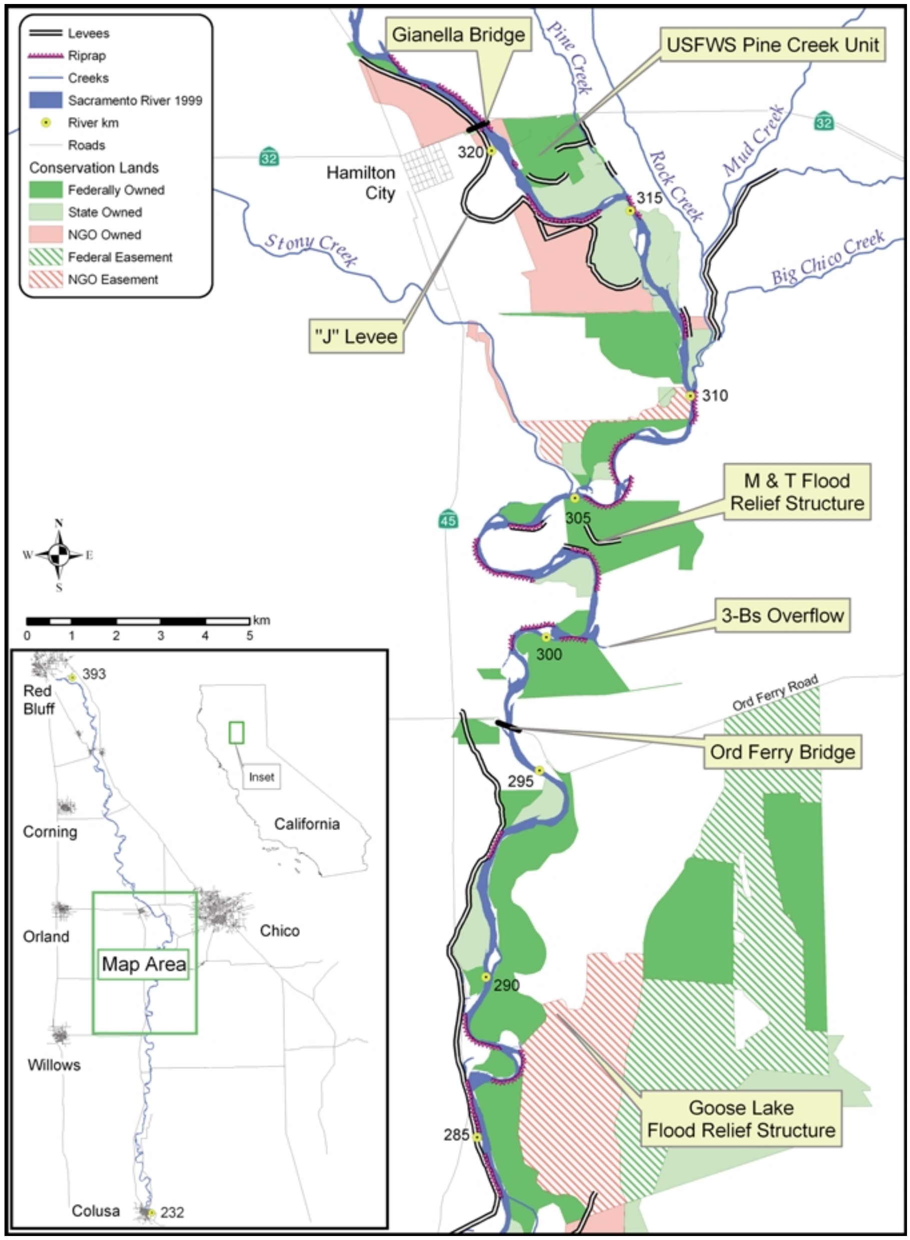

Figure 1. Existing levees, riprap, and conservation land ownership patterns in the vicinity of Hamilton City on the Sacramento River, California, USA. Inset map shows the Sacramento River Project area and the location of the Project area within California.

levee setback in the vicinity of Hamilton City could help revitalize the Sacramento River ecosystem, reduce flooding impacts on the local community, and better protect agricultural lands from flooding, thus creating a highly desirable, multiple-benefit situation for Hamilton City, local agricultural interests, and the conservation community.

Forming partnerships to design multiple-benefit projects is frequently referred to in concept, but infrequently implemented on the ground. We view the collaborative and science-based process of addressing Hamilton City's problem with the ''J'' levee as a model for increasing the scope, scale, and effectiveness of restoration on the Sacramento River.

Profiles of Component Studies for Hamilton City and the Larger Project Area

We conducted five studies to forecast societal impacts of a set of potential river restoration activities.

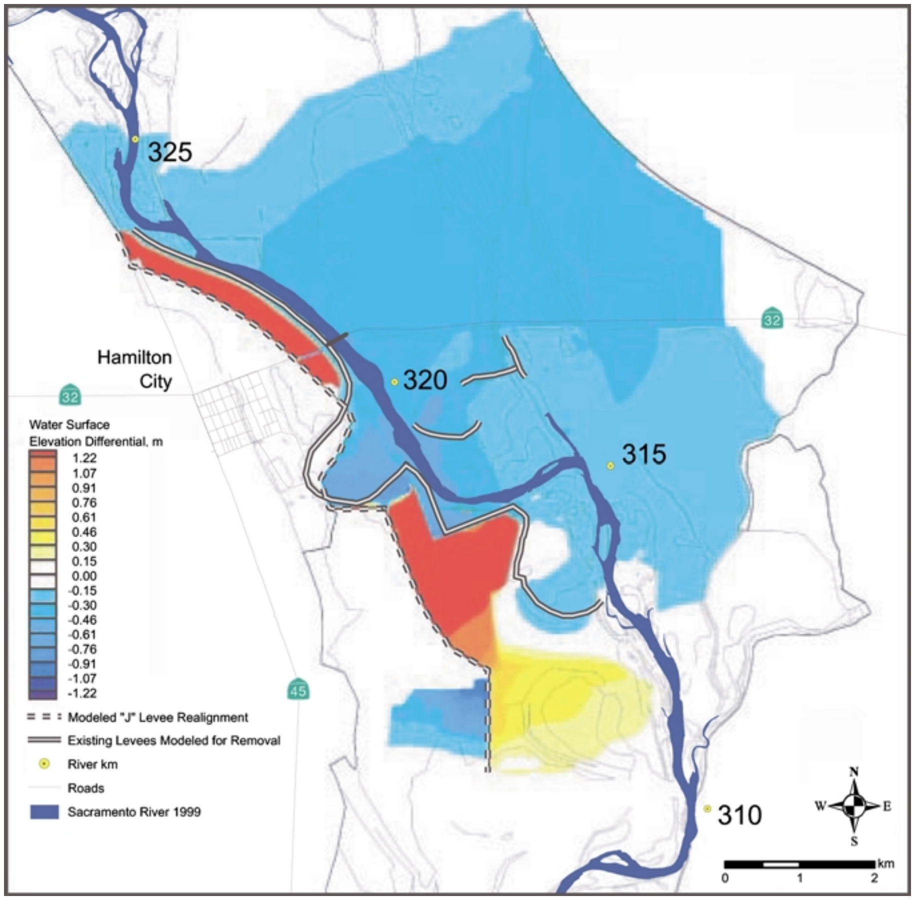

Figure 2. Two-dimensional hydraulic modeling output for Sacramento River water surface elevation differential derived by comparing existing conditions to a scenario that includes a setback ''J'' levee and the removal of several small levees on the USFWS's Pine Creek Unit. [Modified and reprinted from Ayres Associates (2002) with permission.]

The studies focused on flood and erosion patterns, socioeconomics, cultural resources, and public access and recreation. Impacts of these types are important to consider, as they influence the extent to which natural riverine processes and habitats might be restored while maintaining the important societal benefits that river systems provide to local communities. In the following, we present the rationale for, and major findings of, these studies. We also report how stakeholders reacted to the information derived and the ways in which the information was applied to ongoing planning efforts. Most of the studies focused at the scale of the entire Sacramento River Project area (~161 river km); however, some were specific to the ''J'' levee focal area (~13 river km).

Hydraulic Modeling of Flood Impacts

Rationale. Landowners in the Hamilton City area, many of whom are farmers, expressed concern [through the Working Group and area newspapers (Sutton 2001; Hacking 2003)] that habitat restoration activities on neighboring conservation lands might exacerbate problems of flooding on their properties. These worries were shared by public agencies responsible for maintaining travel corridors and associated infrastructure (e.g., roads and bridges), as well as important Sacramento River Flood Control Project (FCP) features such as levees and weirs (US Army Corps of Engineers 2002, 2003).

Methods. To address these questions, we contracted with a consulting firm to calibrate and run a two-dimensional hydraulic model (RMA-2V; US Army Corps of Engineers 1997) for the Hamilton City area (river km 312–325). The model quantified the effects that proposed land-use changes (replacement of agricultural lands with native vegetation plantings), altered levee alignments, and removal of small private levees would have on floodwater surface elevation, velocity, and flow patterns. As the output of the modeling is dependent on both the accurate characterization of existing conditions and detailed forecasting of future conditions, we worked with the consulting firm, researchers, agency representatives, and stakeholder groups to derive appropriate input parameters. Most importantly, local landowners actively participated in all meetings during the calibration exercise by supplying aerial photography and personal observation records from a recent flood event and by reviewing preliminary model output.

Because different types of riparian vegetation (e.g., forest, grassland) impede the passage of floodwaters to varying degrees (Mount 1995), we needed to supply the hydraulic modelers with a map depicting future land-cover patterns at the restoration area. To generate the map, we applied a simple model that relates plant community types to physical site characteristics such as soil stratigraphy and depth to groundwater (The Nature Conservancy 2003). We defined other input parameters, including the alignment of the setback ''J'' levee and the removal of levees on the USFWS Pine Creek Unit (Figure 2) by working with local stakeholders and agency representatives.

Results. The analysis predicted that by setting back the ''J'' levee, removing private levees on the Refuge's Pine Creek Unit, and revegetating the landscape with appropriate native communities, significant improvements can be made in both flood damage reduction and ecosystem restoration. Hydraulic changes predicted to result from the proposed levee setback are also expected to be beneficial to human infrastructure in the area. The model predicted a reduction in water surface elevation both in the main river channel and on the Highway 32 floodplain area (Figure 2). A localized area of water surface elevations increase (0.15–0.61 m) is predicted, but only for one parcel (owned by TNC). Some changes in velocity are expected due to changes in vegetation density; however, no significant increase in floodplain erosion is expected. These results suggest that conservation lands can be utilized as floodplain storage and conveyance areas, thereby reducing flood pressure on neighboring private lands. Further results of the hydraulic modeling are detailed in Ayres Associates (2002).

Reactions and Applications. Although controversial at first, the assessments of flood impacts were eventually well received by stakeholders, especially after they saw that their input and personal observations were directly incorporated into the model. Essentially, we did not finalize the calibration process until stakeholders were satisfied that the model accurately predicted the flow patterns they had witnessed during their years of observation on the river. Stakeholder acceptance of the modeling results was also bolstered by our willingness to model the magnitudes of flooding in which they most interested.

Information from both the hydraulic modeling study and the geomorphic modeling study (discussed later) was shared with the USACE and incorporated into the Hamilton City Feasibility Study to help solve the existing flooding problem (Table 1). In fact, the Feasibility Study team selected a scenario for ''J'' levee realignment within their final report (US Army Corps of Engineers 2004) that closely approximates the stakeholder-preferred alternative that was developed and evaluated during the course of our studies (compare setback levee alignments in Figures 2 and 3). Importantly, this scenario will reconnect an estimated 731 ha of floodplain habitat to the river and restore natural processes of flooding and sediment deposition over a 13-km reach, in one of the largest levee setback projects ever undertaken on the Sacramento River.

Geomorphic Modeling of Meander Migration

Rationale. Meandering rivers often have their banks lined with rock revetment (riprap) to protect bridges, levees, and other infrastructure from erosion (Mount 1995). In the Hamilton City area, >90% of the outer bends of the river are lined. However, riprap is highly detrimental to the ecological health of rivers (National Research Council 2002), including the Sacramento (DeHaven 2000). Riprap prevents active lateral channel migration, or meandering, which is essential in maintaining the structure of riparian landscapes (Bravard and Gilvear 1996) and the proper functioning of river ecosystems (Malanson 1993). Yet, on modern river systems it is often difficult to identify locations where riprap can be removed to restore ecosystem function without impacting human infrastructure. Conservation lands might offer locations where riprap can be removed. Before such decisions are made, however, it is prudent to evaluate the effects that such actions will have on nearby erosion patterns.

Methods. To address the issue of riprap removal in the context of the restoration of the Sacramento River, we applied a meander migration model that predicts migration patterns on alluvial rivers (Johannesson and Parker 1989; Larsen 1995). The migration model is based on physical algorithms for flow and sediment flux—two of the main driving forces of meander migration. The model accommodates changes in input parameters, such as flow regime or bank stabilization measures, and unlike previous models, it effectively integrates the effects of local morphology and upstream conditions (Larsen and Greco 2002).

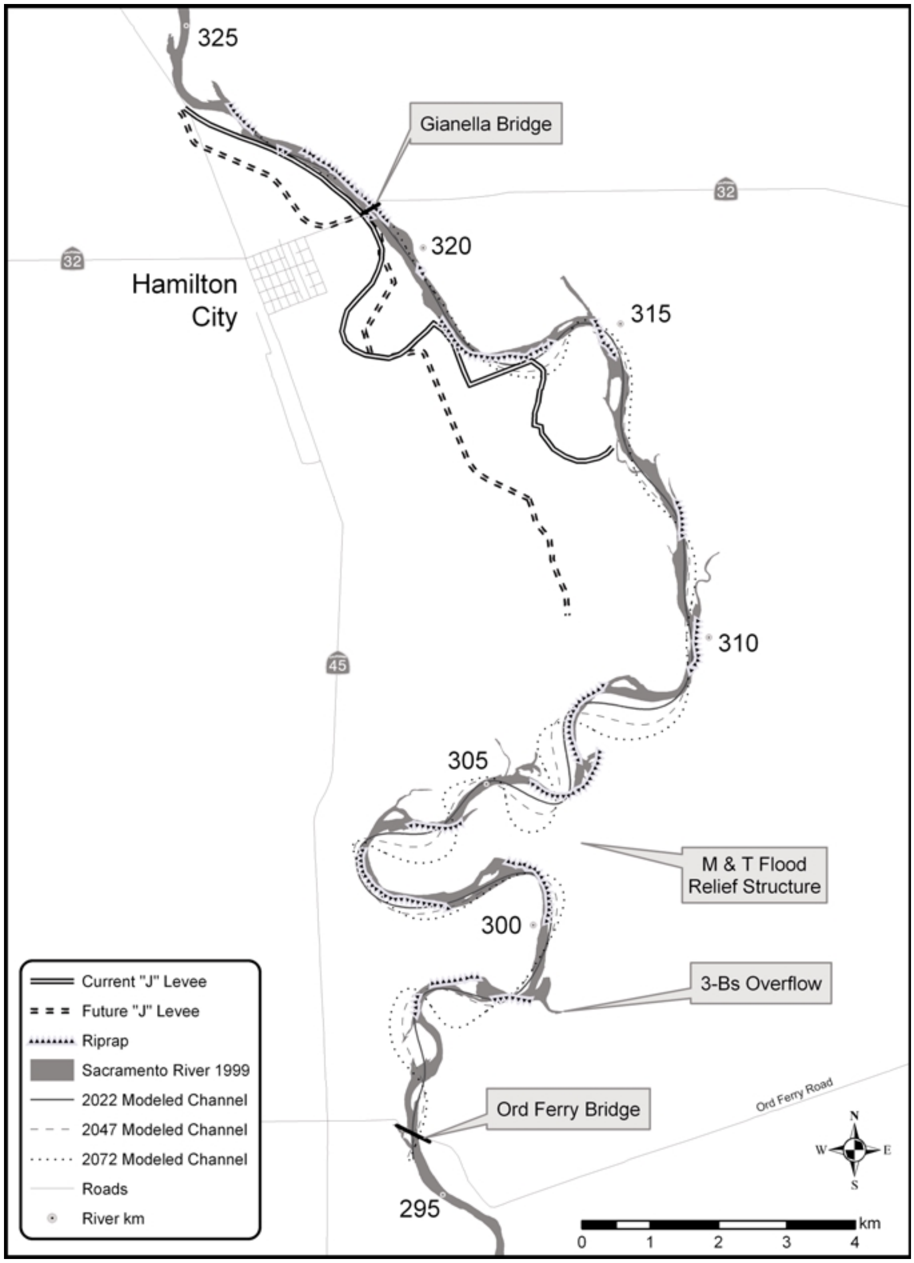

Figure 3. Future predictions of channel location modeled based on a scenario of all riprap being removed. Other scenarios (including a stakeholder preferred alternative) were also modeled. Depicted are the current and future (as determined by the US Army Corps of Engineers) alignments of the ''J'' levee. The setback depicted would reconnect ~731 ha of floodplain habitat to the river and produce significant benefits in terms of flood damage reduction and ecosystem restoration. [Modified and reprinted from Larsen and others (2002) with permission.]

More specifically, we predicted migration patterns that would result under several different riprap removal scenarios in the vicinity of Hamilton City. We modeled this reach of the river because we wanted to explore the potential to remove riprap on conservation lands in the vicinity of Hamilton City and needed to determine whether this would endanger local infrastructure, including the Gianella Bridge and several overflow structures of the FCP (Figure 3). The modeling exercise forecasted meander patterns in three 25-year time steps to simulate meander patterns 75 years into the future.

As with the hydraulic modeling study, we worked closely with stakeholders and agency partners to define appropriate locations for potential restoration actions. Locations selected for riprap removal were based on expert opinion of where revetment might be able to be removed to permit erosion and limited meander without causing harm to local infrastructure. Geomorphic modeling was then used to predict the outcome of these removals.

Results. Our analysis suggested that the flood control infrastructure is not likely to be damaged in the foreseeable future from the removal of riprap (Figure 3). Specifically, partial removal of riprap in the Hamilton City area is unlikely to lead to major changes in channel alignment over the next 75 years, nor is it expected to impact either the Gianella Bridge or a setback ''J'' levee. Additional results are detailed in Larsen and others (2002).

Reactions and Applications. The geomorphic modeling study did not receive the same amount of attention as the hydraulic modeling study. This was likely due to the fact that riprap removal did not end up being included in the USACE's Hamilton City ''J'' levee setback project plan. It was left out of the plan because its inclusion caused an increase in the cost of the project that was not offset by sufficient benefit (as determined by the USACE). Removal of bank protection on the Sacramento River is a contentious issue that is currently being discussed in other forums.

In addition to hydraulic modeling, geomorphic analyses are proving to be useful for addressing stakeholder concerns and advancing river restoration projects, as shown by our studies and those conducted elsewhere. For example, in the Midwest, where farmers were concerned that lateral migration of meander bends would remove precious topsoil and threaten fields, restorationists conducted a detailed geographic information system (GIS)-based analysis of channel change using historical aerial photography. The analysis showed that past rates of lateral movement toward adjacent farmland were negligible, as the direction of meander bend movement was downstream along the riparian axis (Rhodes and others 1999). Although our approach of using a mathematical migration model to investigate meander migration was more sophisticated, both approaches were successful, in that they helped stakeholders visualize likely future channel changes.

Socioeconomic Assessment

Rationale. Changes in land-use patterns associated with habitat protection and restoration have the potential to affect local and regional economies in complex ways (Sutherland 2002), but these concerns are rarely considered quantitatively. In reaction to TNC and its partner's efforts to restore agricultural lands along the Sacramento River, agricultural advocacy groups worried that there would be losses of revenues to the local taxing agencies and the local economy with the conversion of land from agriculture to habitat (Sutton 2001; Hacking 2003). To address these concerns, we initiated a socioeconomic assessment to quantify potential third-party impacts (both positive and negative) to counties, landowners, and the general public that might result from acquiring and restoring lands in the Project area.

Methods. The socioeconomic assessment evaluated impacts on all four counties (1.8 million total hectares) that border the Project area. It built upon two previous studies of similar focus that were limited to Butte County (Adams and Gallo 1999, 2001). Prior to conducting the technical analyses, a future condition scenario was defined based on habitat restoration goals defined by a series of meetings with stakeholders. The scenario assumed that riparian vegetation would expand by ~45% (to 12,140 ha) over a 30-year period, so that, in total, 71% of the area along the river would be in riparian habitat. The remainder (29%) was assumed to remain in agriculture or other uses. Of the land to be converted to riparian habitat, ~48% was already in conservation ownership, and the remainder was privately owned agricultural land that would be purchased from willing sellers.

The analysis estimated changes in regional economic activity and fiscal conditions and changes in resource costs and benefits. These effects were estimated by analyzing changes in spending for agriculture, recreation, and habitat restoration using IMPLAN, a regional economic software model that describes flows from producers to intermediate and final consumers using a series of economic multipliers (Rickman and Schwer 1993; Miller and Blair 1985). The fiscal study modeled how restoration would change revenue flows to the counties, estimating changes in property tax revenues, federal revenue sharing payments, state in-lieu payments, and Williamson Act subvention payments.

Results. Overall, the socioeconomic assessment suggested that adverse impacts of the modeled acquisition and restoration program would be relatively minor and localized. It was also noted that it should be possible to partially offset these impacts through state and federal in-lieu payments and by further developing sustainable recreational opportunities. Results of the assessment are summarized below in terms of effects on agricultural resources, recreation spending, site monitoring, the regional economy, and county revenues (fiscal effects). Percentage changes are reported relative to the year 2000.

Agricultural Resources Effects: The principal effect of establishing a riparian corridor along the river would be a reduction in agricultural production and associated reductions in farmer income and agricultural jobs. The economic losses to the agricultural sector would increase gradually as land is taken out of production over a 30-year period, such that by 2030, annual losses could be as much as $11.5 million. Although this is a substantial amount, it is relatively small (~1%) when taken in the context of the combined annual value of agricultural production in the four-county economy.

Recreation Spending Effects: The increase in riparian habitats along the river would improve conditions for fish and wildlife and cause increases in recreation-related spending. With a doubling of anadromous fish populations by the end of the 30-year period (a CALFED goal), recreation-related spending would increase by $948,400 annually in the four-county area. Additional significant revenue increases would likely occur from other recreational activities (e.g., wildlife observation, hunting), but these were not predicted because of a lack of available data to quantify these relationships.

Site-Monitoring Effects: During the 30-year time frame, a riparian adaptive management research and monitoring program would be in place. The program would assess vegetation and wildlife populations to monitor the status of targets of restoration efforts. The program would stimulate local spending for salaries and equipment estimated at $187,800 annually.

Regional Economic Effects: The changes in agricultural production anticipated by 2030 would have direct, indirect, and induced effects on the economy. The total losses are estimated to be 228 jobs and $7.5 million in personal income. The loss in jobs represents less than 0.15% of the four-county total employment base, and the reduction in personal income is 0.09% of the four county average.

Fiscal Effects: The analysis suggested that there would be minimal impacts on county revenues relative to nonrestoration conditions. Three counties would experience a minor decrease (<1%) in revenues as property taxes are replaced by in-lieu payments from the state and revenue sharing from the federal government, and the remaining is expected to see a minor increase. Additional results from the socioeconomic assessment are presented in Jones and Stokes (2003).

Reactions and Applications. Although widely recognized as generating much useful information, the socioeconomic study was met with criticism from both the conservation community and opponents of conservation. A common criticism was that the study was deficient in quantifying the full range of economic outcomes expected to result from the modeled land-use changes. Additional outcomes (e.g., economic returns from increased ecosystem services) could have been estimated; however, doing so would have increased the uncertainty of the results, as quantitative relationships for effects not included in the study are ill-defined (Jones and Stokes 2003). In retrospect, more attention could have been given in stakeholder meetings to discussing the advantages and disadvantages of including additional elements in the analysis. Doing so would have enabled stakeholders to better define what they wanted from the study in terms of how it balanced uncertainty and comprehensiveness.

Although assessments of socioeconomic impacts are typically not as comprehensive as is desired, they might be useful in identifying strategies that can effectively minimize costs and maximize benefits associated with changing land management practices. For example, this study demonstrated that there is great potential to offset the relatively small (when viewed on a county-wide basis) agricultural production losses that are expected to occur as a result of land use changes by promoting recreation-related spending (Jones and Stokes 2003). One strategy to accomplish this is to expand public access and recreation-related facilities along the river (EDAW 2003). A similar result was found in an economic analysis of the Colorado River, where local, state, and federal agencies were seen as having great potential to improve the local recreation-based economy by increasing access to riparian corridors and updating and expanding existing recreational facilities and infrastructure (Bayley 1995).

Public Recreation Access Study

Rationale. Recreational opportunities are consistently identified as one of the most important parameters in defining quality of life for Americans (Cordell and others 1999). Yet, prior to our conducting this study, there was no centralized location to obtain public access and recreation information for the Sacramento River. Stakeholders were unsatisfied with the situation and felt it was being made worse by conservation entities, such as TNC, that were purchasing private agricultural land (often with public funds) and keeping it closed to the public (Ellena 2000). We thus conducted a study to characterize current public access and recreation use patterns along the river and to identify opportunities for improvements.

Methods. The study focused on the entire Project area and was coordinated with USFWS, DFG, and other public and private land management entities. In addition to characterizing existing public access opportunities and needs, the study identified how changes in land management patterns were expected to influence public recreation and access opportunities in the context of ongoing management planning efforts (Table 1). Information was gathered from available demographic data, previous and ongoing recreation and access studies (listed in EDAW 2003), site visits, interviews with land and facility managers, selected interest group representatives, and public scoping meetings.

Results. Our study confirmed that many of the sites in conservation ownership were closed to the public (e.g., those that are actively being restored or that are part of the Refuge). However, this has changed, as the USFWS has recently finalized it's management plan (Table 1), which identifies a broad range of permissible recreational activities and permits access to 79% of Refuge lands (USFWS personal communication). Increased opportunities for recreation have been welcomed along the river. Regional trends indicate a continued interest in the traditional recreational activities of boating, fishing and hunting, and suggest that nonconsumptive recreational pursuits such as bird watching, nature observation, and hiking will increase by 65% over the next 40 years (California Department of Water Resources 1982; California Department of Parks and Recreation 1998; Cordell and others 1999). Additional results of the public recreation access study are detailed in EDAW (2003).

Reactions and Applications. This study was received well by all stakeholders, although many saw the effort as long overdue. The study made a number of general and specific recommendations for improving public access and recreational opportunities and their associated management and infrastructure in the Project area (see Appendix A). These recommendations have been instrumental in developing management plans for those public agencies that manage lands along the river (Table 1). Importantly, however, the study also confirmed that public knowledge of existing recreation opportunities along the river was limited by a lack of readily accessible, centrally located information. To improve the situation, DWR recently partnered with the Geographic Information Center at California State University, Chico to produce a popular new website dedicated to this very purpose (http://www.sacramentoriver.org).

As awareness of the Sacramento River corridor has grown, the river has become an increasingly popular recreation destination. Continued conservation and restoration along the river will likely draw even more people to this area, as Californians indicate that natural areas are highly sought after as recreational settings (California Department of Parks and Recreation 1998). Moreover, as the population in the region grows, demand for public recreational opportunities are expected to increase (Cordell and others 1999). Continuing with and building upon efforts to increase compatible public recreation opportunities along the Sacramento River is important to achieve successful, community-supported restoration of the dynamic river ecosystem as well as benefiting the region's economic and social well-being. Increases in recreational activities such as wildlife viewing, hunting, and fishing often translate to increases in support for conservation actions (Theodori and others 1998).

Cultural Resource Study

Rationale. Archaeological sites, with their historic, cultural, and educational value, should be protected from land management activities that can lead to their degradation. Because rivers and floodplains are typically rich in natural resources (e.g., fish and game), they often harbor significant archaeological sites. It is understandable therefore that significant legal mandates exist to ensure that care is taken when planning management activities (including restoration) on floodplain lands (King 1998; King 2000). To fulfill such a mandate for a close agency partner (USFWS), we conducted a comprehensive archaeological overview of the entire Project area.

Methods. We synthesized all available information for the entire Project area, surveyed and mapped archaeological sites on 4654 ha of the Refuge, and established the significance of all known sites. Significance was determined by evaluating individual resources present at a site relative to the nature, extent, and distribution of archaeological resources at other sites across the region. Assessments of significance are needed to determine whether or not sites are placed on the National Register of Historic Places of the National Historic Preservation Act (King 2000). We also provided administration and coordination recommendations for management activities that have the potential to affect cultural resources. Activities included in the cultural resource study are further detailed in Appendix B.

Results. The results of this and previous studies (listed in White 2003) demonstrate that the Project area hosts a number of significant archaeological sites with high research potential. Our study identified 51 previously conducted cultural resource surveys that collectively documented 104 archaeological sites. In addition, our study established 46 new sites. The majority of documented sites are concentrated in close proximity to the Sacramento River and along the banks of the major tributaries in the region. Throughout the span of cultural use, occupation sites probably clustered along areas of high elevation on the floodplain. This and previous surveys suggest that archaeological resources are more likely to be found on sites that have floodplain soils than those that have basin soils.

Importantly, three archaeological sites in the Project area are considered eligible for the National Register of Historic Places in that they ''have yielded or may be likely to yield, information important in prehistory or history'' (Criterion [d], *Federal Register*, Vol. 65, No. 239, pp: 77,728–77,729). These sites are important for a variety of reasons, including the potential they have to provide valuable information on changing environmental conditions that prehistoric populations faced. Such changes could be documented through analysis of food resource remains and by conducting plant macrofossil and zooarchaeological studies (Brown 2002).

Reactions and Applications. Reactions to the cultural resources study by stakeholders were uniformly positive. The study findings did not result in new restrictions placed on private landowners, and those management entities that need to consider impacts to cultural resources before proceeding with management operations now have the information they need to guide management actions. In fact, information gathered in the cultural resources study was directly incorporated into the USFWS's Comprehensive Conservation Plan for the Refuge (Table 1) to assist the USFWS in meeting cultural resource inventory mandates as specified in Sections 106 and 110 of the National Historic Preservation Act (King 2000). The study was also used to inform the USACE Hamilton City Feasibility Study (Table 1).

Any efforts to develop facilities for recreation or other human uses should be considered in the context of the impacts that they might have to important cultural resources (King 1998; Balsom 1999; King 2000). Restoration activities should also be viewed in this context. On the Sacramento River, restoration activities now include recontouring natural distributary channels, an activity that has obvious potential to impact cultural resource sites. Only by making detailed assessments of archaeological resources can adverse impacts to archaeological sites be avoided.

Discussion

River management issues have always been highly contentious in California (Kelly 1989; Mount 1995), and as human populations continue to grow, we can expect them to become even more so in the future (Gleick 1998; Baron and others 2002). Water and floodplain management decisions face intense scrutiny, such that typically only those restoration projects that provide demonstrable benefits to society, as well as the ecosystem, are supported. Our effort to develop a restoration project that offered benefits to both the ecosystem and society was advanced by a series of studies that predicted the outcomes of proposed restoration actions. The particular topics we studied (flooding, meander migration, socioeconomics, public recreation and access, and cultural resources) represent typical issues of concern to stakeholders involved in restoration projects on large alluvial rivers where restoration involves shifting land-use patterns. Our experiences have shown that successful river restoration requires getting the technical detail ''right''; however, just as important is communication of the science and transparency. Perhaps even more important is inclusiveness and stakeholder involvement.

Using Science to Achieve Multiple Benefits in River Restoration Projects

The Sacramento River Hamilton City ''J'' levee project provides a good example of what it takes to advance a large-scale river restoration project for a lowland alluvial river in the face of stakeholder opposition. Ultimately, what allowed this project to move forward, when others have not, is the fact that it is virtually certain to provide increased flood protection to a local community that currently faces high flood risks. Without a direct and easy-to-understand tie to improving human conditions, groups that are opposed on principle to replacing agricultural lands with habitat are often successful in eroding local support for projects to the point that restoration funding programs are unwilling to allocate funds for implementation. Restorationists, therefore, need to look for opportunities for ecosystem revitalization that can go hand in hand with projects that have as a central goal the betterment of some aspect of societal condition.

The results of our studies conducted on the Sacramento River support an emerging paradigm shift in river management. Increasingly, on lowland alluvial rivers where agriculture has encroached on floodplain habitats, managers are recognizing, and researchers are documenting, that providing rivers with greater connections to their historical floodplains can simultaneously revitalize impaired ecosystems and improve flood damage protection (Nienhuis and Leuven 2001; Larsen and Greco 2002). Hydrodynamic models, such as those used in this study, are being used to identify such opportunities.

In the Central Valley, this paradigm shift is supported by an increased awareness of the potential that rivers have to damage floodplain infrastructure. In 1997, flooding associated with a winter storm killed 6 people and drove 120,000 Central Valley citizens from their homes (Leavenworth 2004a), and future catastrophic flood impacts are possible (California Department of Water Resources 2005). In recognition of this, flood management discussions between the US Army Corps of Engineers and the US Fish and Wildlife Service have begun, with the goal of developing projects that can meet the dual challenges of improving flood control and reviving ecological health. These projects are focusing less on riprap and channelization as river management tools, and more on setting back levees and restoring habitat (Leavenworth 2004b), similar to what is planned for the Sacramento River near Hamilton City.

A similar willingness to reconsider river management strategies is evident elsewhere. Following two large flood events when huge impacts were narrowly averted (250,000 people were evacuated in 1993 and 1995) on the Rhine and Meuse rivers in western Europe, multinational discussions ensued to develop alternative river management strategies (Nienhuis and Leuven 2001). Resulting projects included setting levees back on channelized sections of the Rhine to retain floodwaters in upstream floodplain storage areas and to retard river discharge, imitating the historical situation as much as possible (Nienhuis and Leuven 2001).

Restoration projects on the Sacramento River might also offer benefits to society in the form of increased recreational opportunities and associated economic inputs. However, expectations of positive change along these lines have done less to earn stakeholder support than have expectations of gains in flood protection. In part, this might be because there is less of an assurance that the economic benefits of recreation will come, as projects sold to communities on economic grounds have not always provided the anticipated benefits (e.g., damming the Feather River to form Lake Oroville; Gascoyne 2001). Nonetheless, as different outcomes will resonate with different stakeholders, we suggest analyzing and communicating restoration benefits in the most comprehensive manner possible.

Future Research Needs

Several steps could be taken to improve the quality of the information derived from these studies. As with all modeling, the accuracy with which input parameters are defined limits the quality of the information that the models produce. Hydraulic modeling studies could more accurately forecast anticipated changes in flood patterns with better definition of natural vegetation communities occurring on the landscape and with more accurate floodplain roughness coefficients for each vegetation type. Similarly, geomorphic modeling could be improved by applying finer-scale mapping of land-use coverages, as floodplain lands that are managed differently (e.g., as orchards vs. natural habitat) have significantly different rates of erosion (Micheli and others 2003). Geomorphic modeling could also be improved by developing the capability to address the effects of a variable hydrograph on meander migration patterns, as current modeling approaches (Larsen 1995; Imran and others 1999; Larsen and others 2002) predict meander migration by assuming constant rates of flow.

Better quantification needs to be made of how restoration affects recreational activity and flood damage expenditures to improve existing socioecomic models. Additional studies could be conducted to better describe the economic value citizens derive from protecting, restoring, and maintaining wildlife habitats (Jones and Stokes 2003), as well as the wider range of ecosystem services that healthy rivers provide to society (Daily 1997; Wilson and Carpenter 1999). To aid in offsetting any adverse economic impacts of lost farm revenues, updated, comprehensive surveys of recreationists should be conducted. These would increase our understanding of the importance of existing and potential future recreational opportunities to the local communities, and help in the formation of development strategies (EDAW 2003).

Incorporating Stakeholders in Restoration Planning

Data analysis and model building are important activities for restorationists seeking to identify and advance multiple-benefit river restoration projects. However, because watershed management is largely a social process (Rhoads and others 1999), it is imperative that restorationists also dedicate themselves to interacting with stakeholders. Although a multitude of stakeholder groups (e.g., local, state, and federal government agencies and nongovernmental organizations) might need to be coordinated when planning river restoration, special attention should be paid to working with local citizen stakeholders who live and work in the communities that will be affected by project activities. Fostering productive partnerships with locals might be time-consuming and challenging; however, much can be gained by doing so. Such partnerships force restorationists to focus on community values in addition to science and technical analyses, which behavioral research has shown can lead to better decision-making (Gregory and others 1993). Also, local support is often required before funds are awarded to restoration projects.

Restorationists might experience a certain level of mistrust in the early stages of the stakeholder engagement process. Citizens who are strong supporters of private property rights can be hostile to outside intervention on land management issues (Reading and others 1994) and often discount or ignore scientific information if they perceive the bearer of this information as an untrustworthy outsider (Rhoads and others 1999). For these reasons, we recommend that restorationists integrate with the place-based social worlds of local communities. In a practical sense, this points to the need to strike a balance between directing efforts to advancing scientific studies and interacting more with stakeholders. Although both are important, ultimately it might be more the acts of engagement than the information produced from the studies that leads groups opposed to conservation activities to reconsider their viewpoints.

In the case of the Sacramento River, we found that including stakeholder input in the early phases of the project development was extremely beneficial. It allowed stakeholders to develop a sense of ownership of the process [as was also noted by Shindler and Cheek (1999)] and permitted flexibility in study design and focus. Directly involving stakeholders early in the planning stages both demystified the planning process and increased trust. Although partnering with citizen stakeholders increased uncertainty, time, and cost spent on the project at the initial stages, doing so in an effective manner and early on was essential to moving the project forward.

The key to developing a restoration project that was well received by locals was a lengthy process of directly engaging stakeholders in the formation of technical studies and the evaluation of results. Although a willingness to accept stakeholder input will not guarantee project support, it will help develop trust, a prerequisite to establishing effective partnerships. For example, we saw a local landowner's appreciation of the hydraulic modeling results increase when he observed that his flood photos were incorporated into the analyses. Simple acts of inclusion such as this can help foster a sense of trust and a belief that the planning process is fair, which helps promote conservation (Sullivan and others 1996; Peterson and Horton 1995).

Stakeholder involvement should not be a coercive process in which particular values are intrinsically privileged relative to others (Rhoads and others 1999). True collaborations with shared power are needed, as they rightfully confer some sense of control over the decision-making process to stakeholders (Brook and others 2003; Wondolleck and Yaffee 2000). In the Hamilton City project, local citizen stakeholders exercised control over the project in numerous ways, including selecting the magnitude of the flood events to be modeled in the hydraulic analysis, choosing the sites to be modeled for riprap removal, and, perhaps most significantly, recommending alternative alignments for a setback ''J'' levee.

Being involved in the scenario creation process allowed stakeholders to test future conditions that represented their values in a scientific risk assessment process. In so doing, it helped generate a sense of shared ownership in the products of the studies. As noted by others (Keeney 1992; Failing and others 2004), what is ultimately deemed as acceptable by stakeholders is strongly influenced by their understanding of the nature of the alternatives. It follows then that much can be gained by allowing stakeholders to define alternative future states that are the subject of analyses, as was recently demonstrated in planning efforts focusing on the Willamette River (Baker and others 2004). Our experiences confirm that the requirement to go through a stakeholder process should not preclude conducting analyses at the level of sophistication warranted by the problem (Failing and others 2004). In fact, we found that having stakeholders help guide rigorous studies was an effective way to shift the focus of discussions from the positions of individual participants to the alternative restoration scenarios.

Having local stakeholders become advocates for conservation can be extremely beneficial, as we found when local community members stepped forth at key times as spokespersons. In our project, a local landowner even traveled across the country to speak to US Congress and Senate staff to help build broad-based partisan support for the project. Although such a high level of commitment might not be possible for all projects, it is worth noting that individual citizens can do much to advance conservation when they act as representatives of their communities.

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Appendix A

General and Specific Recommendations for Improving Public Access and Recreational Opportunities, Management, and Infrastructure in the Sacramento River Project Area, California.[1]

General Recommendations

- Improve the condition of boat ramps and other access points
- Provide more outreach, including brochures, kiosks, and visitor center(s)
- Provide maps and signage to assist in finding river

[1] For further details, see EDAW (2003)

access and services and to reduce trespassing
- Increase the number of facilities and amenities such as trails, picnicking, and camping facilities, especially in the southern portion of the study area
- Minimize conflicts between different recreational uses (e.g., hunting vs. hiking)
- Increase coordination and resource sharing among management entities, local landowners, and other stakeholders

Specific Recommendations

- Establish a ''Pine Creek Preserve'' near the ''J'' levee setback area with a public nature center and a dynamic river research center: Over 1538 ha of conservation land is currently held by government agencies and nonprofit organizations in the Pine Creek/Hamilton City area (see Figure 1). Included in this area is a complex matrix of habitat types, including riparian forest, grassland, and riverine wetland habitat, as well as a set of current and future horticultural restoration sites. The area offers tremendous research potential, as well as great opportunities for high-quality wildlife-compatible recreational experiences. A concept plan and figure representing a hypothetical ''Pine Creek Preserve'' is provided in EDAW (2003).
- Establish facilities to support multiday boating trips on the river: No comprehensive assessment has been made of the recreational facility and access needs of boaters (e.g., kayakers, canoeists) wishing to take multiday trips down the river. Completing such an assessment and filling unmet needs should be a priority, as it would greatly enhance recreational experiences available on the river.
- Improve public information outreach: The Sacramento River Conservation Area Forum is encouraged to spearhead an effort to widely communicate information on recreation access opportunities to the public. The effort could include development of a river signage program, updated maps and guides, and a public recreation access website (http://www.sacramentoriver).
- Establish a formalized management coordination committee: The private, local, state, and federal landowner groups and agencies that manage land with public access opportunities should share resources and expertise and develop strategies to address a variety of issues (e.g., coordination of maintenance and law enforcement activities, development of a shared GIS database).

Appendix B

Components of the Cultural Resources Study of Floodplain Lands of the Sacramento River Project Area, California.[2]

1. Overview of the paleoenvironment, prehistory, Native American cultures, history of contact, and postcontact change in the study area
2. Review of documents included in the California Historical Resources Information System housed at the California Office of Historic Preservation
3. Archaeological survey of selected Units of the Sacramento River National Wildlife Refuge (conducted to assist USFWS in meeting cultural resource inventory mandates as specified in Sections 106 and 110 of the National Historic Preservation Act)
4. Characterization of previously identified and newly discovered cultural resources within the Project area. Includes information on resource location, age, composition, function, cultural affiliation, status, integrity, eligibility for the National Register of Historic Places (NRHP), management concerns, and opportunities for immediate or long-term mitigation
5. Review of curation facilities required to further identify and evaluate cultural materials collected from the project area, including ethnographic, historical, and archaeological items
6. Development of research priorities for the study area; includes identification of pertinent historical, prehistoric and geoarchaeological research themes, and their relevance to specific cultural resources in the project area
7. Summary management plan including recommendations for future investigations, public interpretation of archaeological and paleoenvironmental findings, and administration and coordination for future actions which may affect cultural resources

[2]For further details, see White (2003).