Multi-Objective Approaches to Floodplain Management on a Watershed Basis

Natural Floodplain Functions and Societal Values

REVISED DRAFT
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In Memory of

Andy Lee

Whose Vision For A Wise And Proactive Floodplain Management
Was Only Exceeded By
His Love Of Family, Friends And Colleagues

Andy Lee (center bottom row) and DWR Floodplain Management Branch with
ASFPM Tom Lee Award for Excellence for Pro-Active Floodplain Management Program (Summer 2000)

PREFACE

In October of 1997 the California Department of Water Resources was awarded an EPA Wetlands Protection Development Grant to develop strategies and procedures that will encourage local governments to implement a multi-objective approach to floodplain management on a watershed basis. This federal-state cost-shared study has three distinct components. The Governor's Office of Planning and Research and the California Department of Water Resources have already completed the first--the addition of a separate floodplain management optional element to the State General Plan Guidelines (Appendix C) in November of 1998. The objective of this appendix is to assist local agencies identify flood prone areas within their communities and make appropriate land use decisions for those areas.

The second and most complex component is the development of an economic framework for estimating the benefits and costs of multi-objective floodplain management proposals. The framework addresses a growing concern among floodplain management officials that, for a variety of technical and institutional reasons, economic analyses tend to favor the selection of single-purpose "flood control" solutions rather than multi-purpose proposals that are more likely to include environmental benefits. This framework will enhance traditional benefit/cost analysis by incorporating (1) methods for valuing natural floodplain environmental and societal benefits and (2) recommendations on how to achieve a watershed perspective. It will also address other concerns regarding the economic analysis for floodplain management proposals, such as how to assign benefits for structures removed from floodplains. Four reports have been prepared for this component.

- *Ecosystem Valuation Methods*. Traditionally, economists have been reluctant to assign dollar values to ecosystem resources. However, ecosystems provide a wide range of services that are useful to society. If these services can be identified and quantified, then it may be possible to assign dollar values to them. This report summarizes the advantages and disadvantages of several methods, including those that rely upon revealed willingness to pay (market prices), imputed willingness to pay (circumstantial evidence), and expressed willingness to pay (surveys). In addition, the use of estimated values developed by other studies (benefit transfers) is also discussed.

- *Natural Floodplain Functions and Societal Values*. Natural floodplains perform a multitude of complex and interrelated functions, which not only provide basic biological support but also provide valuable goods and services to society. This report identifies these functions and their associated societal values and provides monetary examples from other studies. These examples illustrate some of the methods discussed in the *Ecosystem Evaluation Methods* report.

- *Middle Creek Ecosystem Restoration Project Case Study: Benefit and Cost Analysis*. A case study was conducted for the US Army Corps of Engineers proposed Middle Creek habitat restoration project at the north end of Clear Lake in the coastal ranges of northern California. On-site benefits of the restoration project would include restored aquatic, wetland and riparian habitats as well as removing human uses within the floodplain, which are subject to an increasing flood threat. The project is also expected to significantly increase water quality within Clear Lake, which should result in increased recreation. The Corps' Sacramento District has recently completed a feasibility study recommending that this project be implemented.

- *Benefit and Cost Analysis Framework*. Beginning with the Galloway report in 1994, there has been a growing concern among floodplain management officials that economic analyses were favoring single-purpose, structural "flood control" projects. This report presents a comprehensive framework that illustrates (a) how multiple benefits (including environmental) can be incorporated into the analysis, (b) how to address the spatial distribution of benefits and costs within a watershed, and (c) how to account for the different distribution of benefits and costs over time. This framework is then compared to current Corps and Federal Emergency Management Agency benefit/cost guidelines and practices. The report also recommends how the findings of the EPA Study can be adapted to meet current Corps and FEMA planning requirements.

The third study component is the preparation of a NFIP workshop entitled “Comprehensive Floodplain Management: Promoting Wise Uses of Floodplains” which will present proactive floodplain management strategies which incorporate multi-objective and watershed planning principles. This workshop will (1) review existing NFIP regulations and recommend No Adverse Impact strategies developed by the Association of State Floodplain Managers and (2) show how the economics tools developed in the second study component can be applied to multi-objective floodplain management projects. The audience for this workshop will include floodplain administrators; local building/planning/public works staffs, local public officials and stakeholders. Work for this workshop and its related materials will be ready by the summer of 2005.

Two advisory committees have assisted with this study. The California Interagency Floodplain Management Coordination Group, which is composed of representatives from federal, state and local agencies, is providing overall coordination and advice. In addition, a multi-disciplinary advisory committee of scholars from the University of California’s Centers for Water and Wildlife Resources at Davis provided early input into the study.

In addition to the economics reports described above, the following appendices will also be available:

Appendix A:	California General Plan Guidelines (Floodplain Management)
Appendix B:	Habitat Restoration Cost Database
Appendix C:	Economic Evaluation of Ecosystem Resources: Hamilton City Flood Damage Reduction and Ecosystem Restoration Feasibility Study and Colusa Basin Watershed Management Plan Feasibility Study
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INTRODUCTION

Nationally, there is an increasing focus upon ecosystem restoration, which strives to either restore the structure and functions of damaged ecosystems or protect existing functioning ecosystems from future losses.[1] Billions of dollars are being invested in ecosystem restoration. Within the field of floodplain management, ecosystem restoration is becoming increasingly important with the emphasis upon *multi-objective* floodplain management. Rather than just focusing upon "flood control" to protect lives and property, proactive floodplain management strives to consider multiple objective alternatives in order to determine the best overall strategy for any given location.

A critical part of the evaluation process is the economic analysis, particularly the analysis of benefits and costs: does a proposed project's benefits exceed its costs over the expected life of the project? For some objectives, such as flood damage reduction, the economic evaluation is relatively straightforward, requiring the analysis of hydrologic, hydraulic and economic data. However, for ecosystem restoration, the economic evaluation is much more difficult. How can one possibly place a dollar value on ecosystem resources?

Traditionally, many economists have been reluctant to assign dollar values to ecosystem resources. This reluctance has been further institutionalized by the Corps, which requires a cost-effectiveness/ incremental-cost approach (i.e., changes in cost per acre or habitat

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[1] Ecosystems are biological communities combined with the physical and chemical environment with which they interact (National Research Council).

unit over different sized plans) to evaluating ecosystem outputs.[2] But, this reliance upon only cost-effectiveness has its limitations as well, especially when analyzing multi-objective projects that may affect different types of ecosystems. For example, how can one decide between implementing a riparian restoration project costing cost $3,000 per acre versus a wetland restoration project costing $5,000 per acre or achieving a $*x* increase in flood damage reduction benefits but a reduction in *y* units of ecosystem restoration (or, vice versa). Without some common form of measurement of benefits these decisions are difficult. However, if dollar values could somehow be assigned to the *outputs* associated with ecosystems, then additional information would be available upon which a decision could be made.

Although it is difficult to conceptualize how one might place an economic value upon them, ecosystems do perform a multitude of complex and interrelated functions, which not only provide basic biological support but also provide valuable goods and services to society. The purpose of this paper is to identify goods and services that might be attributable to naturally functioning floodplains. If these can be identified and measured, then these goods and services can be valued using one or more of the methods discussed in the report *Ecosystem Valuation Methods*.

ECOSYSTEM STRUCTURE, FUNCTIONS AND SERVICES

An emerging theme in the literature focuses upon the interrelationships among ecosystem structure, functions, and services.[3] Ecosystem structure includes all of an ecosystem's complex physical and socioeconomic characteristics. Ecosystem functions exist in the

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[2] Federal agencies involved in land and water resources planning are required to follow the *Principles & Guidelines*. For projects that have environmental quality effects, the *P&G* state (Chapter III) that "During the course of the EQ evaluation, the planner should be aware that contributions or effects that can be measured in monetary terms are to be monetized and included in the NED account." The Bureau seems to have taken this statement at face-value and it is amenable to placing monetary values on ecosystem benefits. The Corps, on the other hand, strictly requires a cost-effectiveness/incremental-cost analysis.

[3] See for example, National Research Council: Cole, et al,; Environmental Law Institute; and Northeast-Midwest Institute/NOAA.

absence of society and normally are part of the self-sustaining properties of an ecosystem. Many of these functions result in services that have value to humans.

For example, The Corps' of Engineers Institute for Water Resources is currently researching methods for improving environmental benefits analysis, initially focusing upon the identification and measurement of physical ecosystem processes and outputs:

> Function is what the community-habitat complex "does" when energized and structure is its material form. Function is quantified from measurements of process dynamics. Ecosystem functions require driving force such as the energy in solar radiation, chemical reactions, and gravity. Structure is the spatial arrangement of materials in an ecosystem at any one time and sequentially through time. Biomass production is function, for example, and standing-crop biomass is its material form. Physical mass and its distribution in its various forms are measures of structure. Energy forces often drive ecosystem function through interactions with structure, such as when water mass and gravity interact to create the hydraulic energy so important in riverine ecosystems. An artificial equivalent of ecosystem structure is the human infrastructure that facilitates the delivery of energy and materials needed by society.[4]

Table 1 provides examples of riverine and coastal floodplain ecosystem services, functions and structures identified by the IWR.

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[4] USACE, IWR, *Draft White Paper On Improving Environmental Benefit Assessment* (June 2001).

Table 1: Ecosystem Structure, Function and Services

Ecosystem Structure	Ecosystem Function	Ecosystem Services
Carbon dioxide; biomass, water area	Thermodynamics; carbon cycle	Climate regulation
Vegetation, floodplain & barrier islands	Wind, wave & flood alteration	Disturbance regulation
Lakes, ponds, aquifers, ice, biomass	Water retention and delivery	Water supply
Particle size, root mass, debris dams	Soil and sediment movement	Control sedimentation
Biomass, sediment, humus	Material trapping; decomposition	Waste treatment
Species composition and diversity	Predation, disease, competition	Biological pest control
Biomass, air, water, species diversity	Plant and animal production	Food production
Wood, humus, clay, shell	Production of raw materials	Raw materials
Global species richness	Diversification and life support	Genetic information
Water, wildlife composition, topography	Water flow; life process	Recreation/esthetics
Source: Working Draft "White Paper on Improving Environmental Benefits Analysis", June 2001		

Source: USACE, Institute for Water Resources, *Draft White Paper Improving Environmental Benefit Analysis.*

Ecosystems provide both *biocentric* and *anthropocentric* types of services. [5] Biocentric (or biological) services are those that benefit the plants and animals inhabiting the ecosystem. Anthropocentric services are those that directly benefit humans, such as the maintenance of water supply quantity and quality, soil and air quality, flood water storage, recreation, etc. Other human services include the maintenance of genetic information over time as well as the intrinsic values that we associate with ecosystems. This latter group of human services is considerably more difficult to quantify and value compared to the first group. The valuation methods discussed in *Ecosystem Valuation Methods* can best be applied to the first group of human related services, although some methods (such as contingent valuation) may be applicable for the second group of human services. None of these valuation methods can be applied to an ecosystem's biological services, although tools are available that attempt to measure the physical outputs of ecosystems, such as habitat evaluation procedures (discussed below).

Figure 1 hypothesizes what the relationship of these types of services might look like since nobody really knows what the total value of any ecosystem is or the relative size of its biological or human services. The focus of this paper is upon those human services that

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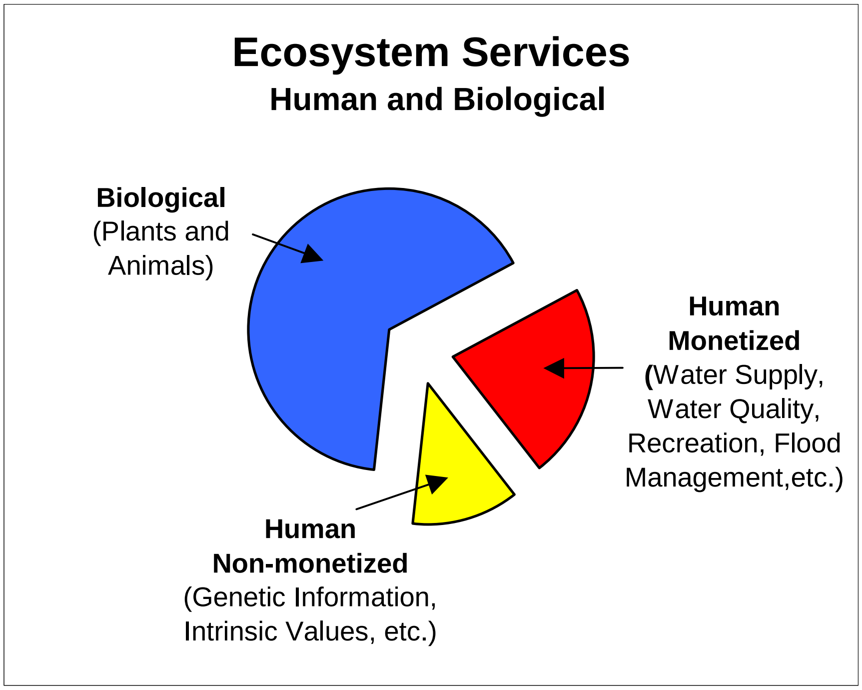
[5] See Cole, et al..

can be monetized. Figure 1 would indicate that whatever values are derived for human services, these should not be considered as the"total" value of that ecosystem's services.

Figure 1: Ecosystem Services



MEASURING ECOSYSTEM SERVICES

To successfully place monetary values on ecosystem services, it is essential to be able to first measure the physical outputs from those ecosystems, or more importantly, the *changes* in those outputs caused by proposed projects or programs. Unfortunately, measuring ecosystem outputs and their relationships to human services can be even more difficult than placing monetary values on them.

Biological Services

Traditionally, several types of indicators have been used to measure biological outputs from ecosystems. Some of the more common ones include:

- Number of acres: This measure indicates the number of acres within an ecosystem along with a qualitative description of its habitats (for example, *x* acres of aquatic, *y* acres of riparian, and *z* acres of upland habitats). The presence of threatened or endangered species or other species of special concern can also be noted. This measure is the least rigorous of all the measures since it provides no assessment of the habitat quality.

- Habitat species index: These indices measure the performance of specific species within a habitat. An example of a species based index is the Habitat Evaluation Procedure, which interprets the effects of environmental change through a species-based habitat suitability index (HSI) developed for about 150 individual fish and wildlife species. HEP uses a simple multiplication of impacted area (in acres) and HSI to calculate habitat units. Limitations of HSIs include their focus upon (a) individual species rather than communities of species and (b) animals rather than plant species.

- Community-based habitat indices: These indices measure relative community performance based on species diversity, composition and other community attributes to assess the effect of habitat change. They usually reference unaltered natural ecosystems (real or abstract concept of an ideal one) to determine a maximum index value and derive a reduced index value attributable to habitat alteration from ecosystem conversion, pollution and other human impact. Examples of community-based indices include wetland valuation assessment, index of biotic integrity, wildlife community habitat evaluation, and riverine community habitat assessment and restoration concept. These models place complete reliance on one or more structural and functional attributes of the natural community as an indicator of ecosystem performance. However, some human services (such as water supply, water treatment, flood damage and recreation) may have little to do with biological process and outputs.

- Species diversity indices: These indices measure species richness (number of species) and relative abundance. Although there are indices that measure richness and abundance, species richness indices are the most common because of problems in measuring the numbers of individual species. As with any index, species richness is not perfect. For example, it cannot measure the dependency of ecosystem function on any single species or group of species.

All of these indices have their own advantages and disadvantages, and there is a lack of agreement among the scientists as to which is the best to use. However, any attempt to monetize human ecosystem services should always include one or more of these types of biological output measures.

Human Services

Commonly cited examples of floodplain and wetland services include flood conveyance and storage, erosion control, pollution prevention and control, fish and shellfish production, water supply, recreation, food production, education and research, historic, archaeological values, open space and aesthetic values, timber production, and habitat for waterfowl and other wildlife. However, even for these more traditional services that are relatively easier to assign monetary values, significant difficulties are still likely to be encountered establishing the relationships among ecosystem structures, functions, and ultimately, human services. These difficulties arise because of the incomplete scientific understanding of ecological functions and the complex production relationships linking them to human uses. Even when there is at least a partial understanding of these relationships, obtaining the necessary data (such as changes in water quality and availability, soil quality, recreation, etc.) can be time consuming and expensive. Other human services exist for which it is very difficult, if not impossible, to measure the service outputs, such as the continuation of genetic information or the intrinsic values humans place upon ecosystems.

FLOODPLAIN ECOSYSTEMS

The focus of this paper is upon natural floodplain functions and values. Naturally functioning floodplains provide many goods and services that have value for humans.

What Is A Floodplain?

Floodplains are incredibly complex ecosystems, which are constantly changing in response to physical and social influences. Because of this complexity, there are several definitions of “floodplain”, including:

- Any area susceptible to inundation by floodwater from any source.[6]
- The lowland adjacent to a river, lake or ocean. [7]
- That portion of a river valley, adjacent to the river channel, which is built of sediments during the present regimen of the stream and which is covered with water when the river overflows its banks at flood stage.[8]
- The land adjacent to a channel at the elevation of the bank full discharge, which is inundated on the average of about two out of three years. The floor of stream valleys, which can be inundated by very small to very large floods.

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[6] California Office of Planning and Research, California General Plan Guidelines, Appendix C: Floodplain Management, November 1998

[7] Floodplain Management Association website (http://floodplain.org/p-basics.htm)

[8] American Geological Institute, *Dictionary of Geological Terms*, 1962, pg. 186.

The size of any particular floodplain is not fixed. Rather, it is determined by the frequency and amount of water flowing through it. For example, the 10-year floodplain can be inundated by the 1 in10 year flood and the 100-year floodplain by the 1 in 100 year flood. The 100-year flood is an important institutional definition, because protection from this size of flood is the minimum level of protection for a community seeking inclusion in the National Flood Insurance Program, which is administered by the Federal Emergency Management Agency. Although most often associated with riverine ecosystems, floodplains also occur along the coast, lakes and within alluvial fans.

Floodplain Habitats

Floodplains typically contain several major types of habitats. For the purposes of this study, the following have been identified:

- Aquatic: Areas that have standing or moving water at some time during the year, such as rivers, streams, lakes, etc.

- Riparian: Areas that border rivers, streams and creeks and typically include the channel banks and over bank areas.

- Wetlands: Special aquatic areas which often develop in transitional zones between aquatic and riparian habitats. Wetlands are either permanently or seasonally wet and support specially adapted vegetation and wildlife. To regulate human activities in wetlands, federal and State agencies have developed specific–and sometimes confusing–definitions and methods for wetland identification.

- Uplands: Although not part of a floodplain, uplands are integrally linked with floodplains. Upland habitats extend beyond the riparian habitats up to the top of the ridges separating watersheds. Human activities in the uplands can have profound effects in downstream floodplains. For example, increasing upland urbanization increases the amount of runoff and decreases the timing needed for its discharge to the floodplain.

> Addressing uplands issues is a critical aspect of floodplain management because it ensures that a watershed approach is used in developing solutions for local flood problems.

All of these habitats, along with their underlying physical, chemical and biological processes, make up the structure of floodplains. Figure 1 provides a conceptual illustration of these habitats and how they overlap one another.

Natural Floodplain Functions and Human Services

Naturally functioning floodplains provide significant biological and human services. For example, the National Wildlife Federation offers a concise description of floodplain functions:

> As a Nation, we are only beginning to realize the extent of harm that is caused by the wholesale alteration of one of nature's essential ecosystems. Serving their natural functions, floodplains are vast absorptive reservoirs of floodwaters; they are Earth's primary filter and dissolver of waterborne contaminants; their coastal marshes and riverine wetlands provide the creative essentials for countless forms of life; and left to themselves, floodplains and the life they generate offer enjoyment and recreation.[9]

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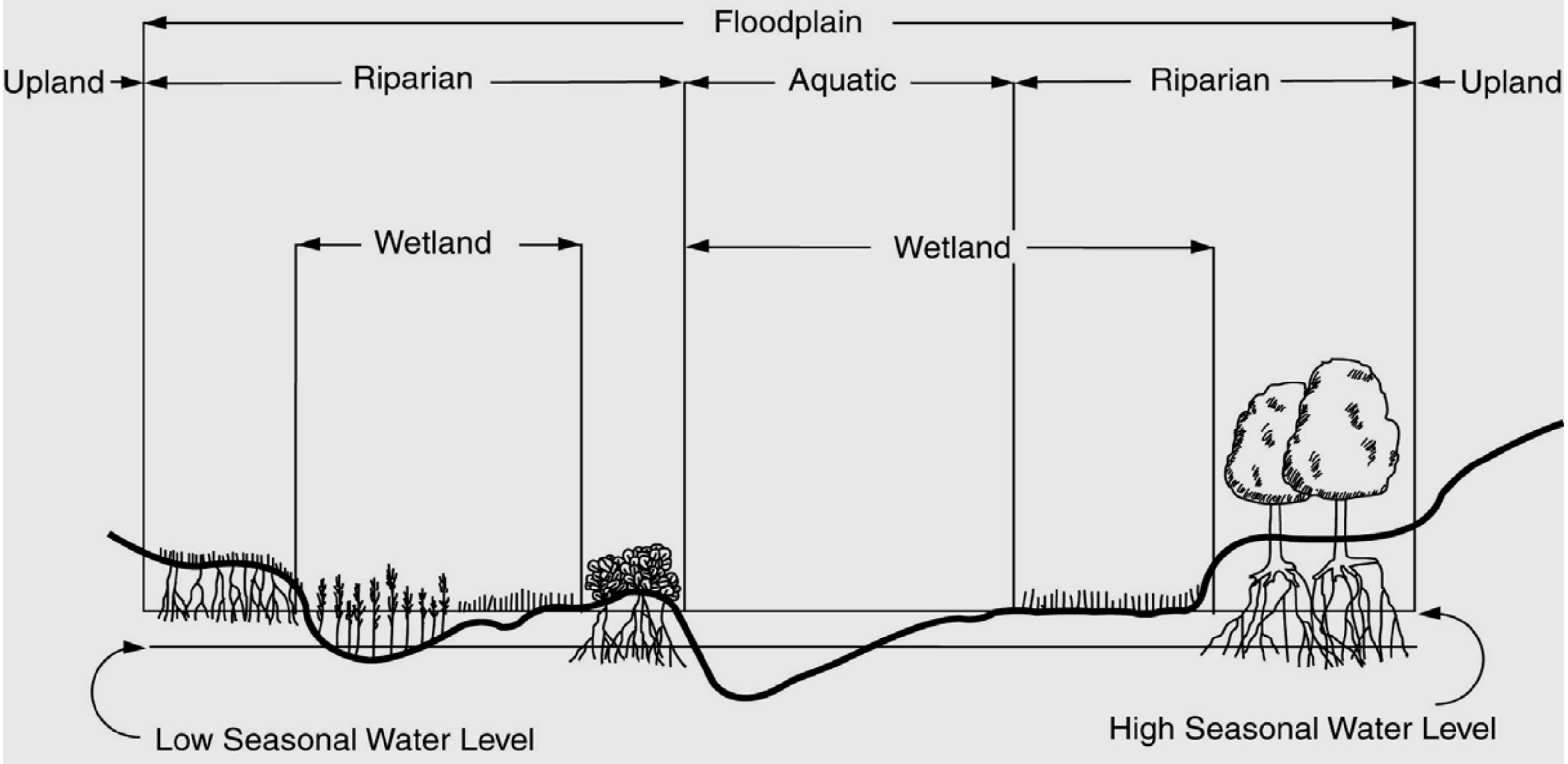
[9] National Wildlife Federation, *Higher Ground: A Report on Voluntary Property Buyouts in the Nation's Floodplains*, July 1998 (pg.11).

Figure 2: Floodplain Habitats

Figure 1. Floodplain Habitats



Adapted from: US Environmental Protection Agency, US Department of Interior, US Fish and Wildlife Service, <u>Biological Report 85 (7.24): The Ecology of Stream and Riverine Habitats of the Great Basin Region</u>, September 1989, Pg.6.

The Sacramento and San Joaquin River Basins Comprehensive Study provide a more detailed description of historical riverine floodplain functions in California's Central Valley's river systems:

> Along with the flood flow passage element, the main channel provides conveyance for water supply and limited navigation. The river system's physical functions include sediment transport, sediment deposition, and erosion processes from instream flows. The river processes function dynamically to establish areas for plant communities through sediment deposition and erosion while eliminating some established communities. The river meandering process leads to successional changes to result in a dynamic balance of successional communities within the ecosystem. The resultant community mosaic maximizes biological diversity in the system.
>
> There were other important ecological interactions between the floodplain and channel, such as shading, food, and large woody debris provided by floodplain vegetation. During prolonged inundation salmon and other fish would feed within the inundated floodplain. This interaction illustrates the important migrations and interchanges of organisms, nutrients, and carbon that occurred frequently in the flood system before 1850. Even along rivers where floodplain inundation was typically brief, interactions could be nonetheless important for recharging the alluvial water table, dispersing seeds of riparian plants, and increasing soil moisture on surfaces elevated above water tables contributed to maintenance of floodplain aquatic habitats, such as side channels, ox bow lakes, and phreatic channels.
>
> Floodplain soils and vegetation can also improve water quality in rivers by filtering sediments from runoff and because of chemical reactions in the floodplain alluvium that can remove nitrogen (and other constituents) from agricultural or urban runoff. These same areas also provide habitat for water birds, resident, and migratory species.[10]

Thus, floodplains perform a multitude of complex functions that provide basic ecological support within the floodplain as well as valuable goods and services to society. The types of functions performed, as well as their intensity, will vary among floodplains because of their different locations, water sources, hydrology, soils and habitats and other structural

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[10] Sacramento-San Joaquin River Basins Comprehensive Study, *Administrative Draft Interim Report*, January 1999 (pgs. 4-1 and 4-2).

characteristics. The specific location of a floodplain within the watershed (and proximity of human activities) will determine the nature and extent of functions and output of goods and services that have value to society.[11]

> Streams and wetlands throughout the Santa Margarita watershed tend to perform hydrogeomorphic functions to differing degrees depending upon their type and landscape position. For instance, first order streams high in the drainage are rocky and steep and have little ability to retain water. Functions performed within these channels are limited. The lower reach of the sixth order Santa Margarita River consists of a broad and complex network with extensive wetlands, and it provides a full suite of hydrogeomorphic functions.[12] , [13]

Floodplain functions may also differ among the different habitats within them. For example:

- Aquatic Habitats: Provide areas for breeding and feeding as well as shelter for fish and shellfish species, many of which are listed by the State and federal governments as rare, threatened or endangered. Many fish species (such as, salmon and trout) and shellfish (such as, clams and lobsters) are commercially important. Aquatic habitats also support recreational activities, such as boating, fishing and swimming.

- Riparian: Important sources of food, water, shelter and breeding areas for wildlife; they can provide water quality protection through storm runoff filtering and stream shading; they can improve bank stability of streams; and they can add aesthetic value to landscapes. Riparian zones are also important for providing habitat connectivity along rivers and streams. However, riparian zones can also provide habitat for organisms

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[11] Paul Scodari, *Measuring the Benefits from Federal Wetland Programs*, 1997, pgs. 49 - 53.

[12] L.C. Lee & Associates, Inc., *A Preliminary Framework for Assessing the Functions of Waters of the U.S., Including Wetlands in the Santa Margarita Watershed, Riverside and San Diego Counties, California*, July 1994, pg. 17.

[13] Streams are often classified according to their *stream order*. A first-order stream has no tributaries; when two first-order streams join, they create a second-order stream. When two second-order streams join, they create a third-order stream, and so on.

that are health and economic pests to the human community, such as mosquitoes.

- Wetlands: Perform many valuable functions, including flood protection, filtering of sediments and pollutants, erosion protection and water storage. Wetlands provide critical habitat for threatened and endangered species.

- Uplands: Are often very biologically diverse because of the wide range of vegetation types that can be found in uplands (such as grasslands, oak woodlands, and coniferous forests). Besides providing valuable plant and animal habitat, uplands also reduce soil erosion, filter storm water runoff, and increase percolation into ground water aquifers, all of which help reduce discharges to downstream floodplains.

At the risk of oversimplification, Table 2 illustrates the major floodplain functions and their associated services that have values for humans. The values of these services can be measured by the methods discussed in *Ecosystem Valuation Methods*. This table is very general and provides no specific information on the location, intensity or timing of the functions within a floodplain.

Table 1: Natural Floodplain Functions, Human Services and Values

Natural Floodplain Functions	Human Services and Values
Maintain Natural Channel Processes	
Maintain natural dynamic channel processes and equilibrium	All of below
Manage Flows	
Conduit for water, nutrients and organisms	Protection of life and property • Avoided structure and content losses • Avoided crop losses • Avoided income losses • Avoided damage to public infrastructure and services • Avoided emergency response and recovery costs • Avoided flood insurance administration costs • Avoided hospitalization and related health care costs • Avoided physical, financial and emotional disruption of lives • Avoided loss of life Avoided flood/sediment control infrastructure costs Value of flow-related goods and services • Recreational boating • Commercial navigation Avoided habitat enhancement/replacement costs
Spread and retain surface and subsurface water	
Moderate speed, force, depth and timing of flows	
Maintain base flows	
Reduce frequency and duration of low surface flows	
Maintain sediment balance	
Maintain connectivity between channel and floodplain	
Maintain Water Supply	
Increase surface water storage	Value of goods and services produced with additional water supplies
Promote groundwater recharge and storage	• Agricultural • Municipal and industrial • Environmental Avoided water supply infrastructure costs Avoided habitat enhancement/replacement costs

Natural Floodplain Functions	Human Services and Values
Maintain Water Quality	
Filter nutrients and impurities from runoff	Value of goods and services produced with improved water quality • Agricultural • Municipal and industrial • Environmental Avoided water treatment infrastructure costs Avoided damage to plumbing, fixtures and appliances Avoided habitat enhancement/replacement costs
Process organic wastes	
Moderate water temperature fluctuations	
Maintain Soil Quality	
Detention of particulates, compounds and elements	Value of goods and services produced with improved soil quality Avoided soil treatment costs Avoided habitat enhancement/replacement costs
Maintain Air Quality	
Carbon sequestration (removal of atmospheric carbon by vegetation)	Value of goods and services produced with improved air quality Improved property values Value of improved health and comfort Avoided damage caused by poor air quality Avoided habitat enhancement/replacement costs
Vegetation humidifies atmosphere and moderates air temperatures	
Maintain Plant and Animal Habitats	
Maintain characteristic and diverse plant and animal communities	Value of goods and services associated with habitats • Natural products • Aquaculture • Recreation • Hunting and fishing (sport and commercial) • Open space/aesthetics • Environmental studies • Cultural resources Improved property values Enhanced economic development Preservation values (existence, option and bequest) Avoided habitat enhancement/replacement costs
Provide habitat interspersion and connectivity	
Provide breeding and feeding grounds	
Protect habitat for species of special concern	
Maintain ecological succession	

EXAMPLES OF MONETIZED FLOODPLAIN HUMAN SERVICES

The literature contains many examples of studies that quantify and monetize floodplain functions and associated human services. Some of these are summarized below for the functions and services identified in Table 2.

Maintain Natural Channel Processes. The most basic function of a floodplain is the maintenance of naturally dynamic channel processes and equilibrium.[14] The million-dollar question of course is: What is meant by equilibrium? A good definition can be found in the "living river" strategy that has been adopted for the Napa River located north of the San Francisco Bay:

> A "living" Napa River and its tributaries is a river system with structure, function and diversity. It has physical, chemical, and biological components that function together to produce complex, diverse communities of people, plants, and animals. The health of the entire watershed, from the smallest headwater trickle on the slopes of Mt. St. Helena to the broad expanse of the [San Francisco Bay] estuary, is the summation of natural and human activities in the basin and how they affect certain undeniable physical processes common to all river systems. A "living" Napa River system functions properly when it conveys variable flows and stores water in the floodplain, balances sediment input with sediment transport, provides good quality fish and wildlife habitat, maintains good water quality and quantity, and lends itself to recreation and aesthetic values. A "living" Napa River conveys equilibrium and harmony with all that it touches and resonates this through the human and natural environment.[15]

Another more technical definition of equilibrium is:

> As early as the 1940s and 1950s, fluvial geo-morphologists began describing both rivers and landscapes as ecological systems with many interacting variables. Interrelated river system variables include the size of the watershed; the amount and size of sediment transported in the river channel; the channel shape, size, slope, and roughness (trees, bushes, rocks, streambed forms, stream-bank surface, floodplain obstructions, channel bends, etc.); and the amount and frequency of flow discharges. A stream in equilibrium is a stream in which these variables are in balance with each other and is sometimes described as being a graded system.

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[14] An interesting and opposing view was suggested by Mr. Thomas Ruby of the Washington State Department of Ecology at an Economics Valuation workshop held in Olympia, WA (April 1999). Rather than tending towards equilibrium, Mr. Ruby suggested a "chaos theory" in which an ecosystem never really recovers from the number and magnitude of natural and human-induced shocks. In response to this, Mr. Mark Cocke of the Davis office of the Natural Resources Conservation Services suggested that "resiliency" might be a more appropriate term than "equilibrium".

[15] Community Coalition for a Napa River Flood Management Plan, *Goals and Objectives For A "Living" Napa River System (DRAFT)*, July 1992, pg.3.

> A condition of equilibrium does not mean a steady state or condition at any one particular stream flow because the variables change among stream reaches and over time; the dynamic equilibrium of a channel represents the average condition of a river during its relatively recent history...Under conditions of dynamic equilibrium, the stream's energy is such that the sediment loads entering a stream reach are equal to those leaving it. Over its long-term evolution, a river or stream will attempt to transport the sediment delivered to it with the available runoff. [16]

Although these definitions are specific to riverine systems, they also have applicability to other aquatic systems (such as lakes) as well because all have complex physical, chemical and biological components that must function together. Because of its complexity, it is not realistic to ascribe any specific services to this function. At a minimum, its services include all of those discussed below.

Manage Flows. Rivers do not naturally maintain a channel big enough to carry the largest flow. As noted by Leopold, the "...river channel is large enough to accommodate all the water coming from the drainage area only in the relatively frequent event. The flat area bordering most channels - the floodplain - must flood to some extent on the average every other year."[17] Thus, floodplains provide a place for water to spread over and flow through, thereby moderating the speed, force, depth and timing of flows. Specifically, floodplains manage flows by providing:

- Increased area to spread water
- Resistance to flows provided by vegetation
- Absorption of water into the soil [18]
- Transpiration from vegetation
- Percolation into aquifers
- Slow discharge back to the river

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[16] Anne L. Riley, *Restoring Streams in Cities: A Guide for Planners, Policymakers, and Citizens*, 1998, pages 125-126.

[17] As quoted in *Community Coalition for a Napa River Flood Management Plan, Goals and Objectives For A "Living" Napa River System* (DRAFT), July 1992, pg. 9.

[18] For example, a one-acre wetland will hold 330,000 gallons of water if flooded to a depth of one foot. Environmental Law Institute, *Our National Wetland Heritage: A Protection Guide*, 1996, pg.5.

An example of the monetization of flow management benefits is provided by the Washington State Department of Ecology:

> ...the dollar per-acre values of wetlands systems for flood protection in two Western Washington communities currently experiencing frequent flooding, Lynnwood and Renton. We do this via a variant of the alternative/substitute cost method. Cost estimates for engineered hydrologic enhancements to wetlands currently providing flood protection are used to establish proxies for the value of the flood protection these same wetlands provide. A simple "ratio analysis" scheme is employed, making the method easily transferable to other communities which, like Lynnwood and Renton, are seeking ways to enhance flood protection their remaining wetlands provide. The proxy values we estimate are in the range of tens of thousands per acre in current dollars. The analysis suggests that communities are likely to pay an increasingly high price for flood protection if they allow their remaining natural systems capable of attenuating flood flows to become further compromised in their ability to do so.[19]

Other studies include:

> In two cost/benefit studies of the Charles River basin in Massachusetts, the United States Army Corps of Engineers determined that existing wetlands in the floodplain provided greater net flood control benefits than an expensive, proposed system of dams and reservoirs to protect Boston. In a study released in 1971, the Corps estimated that, if the 3,400 hectares (approximately 8,400 acres) of floodplain wetlands in the basin were drained, flood damages would increase by $647,000 per year. By these estimates, the amount of flood damage averted per wetland acre is $80 per year. However, the Corps reassessed the flood damage potential in the Charles River region in 1976 and increased its estimate to $17,000,000 per year in wetland flood control benefits...Under this revised estimate each wetland acre would provide $2,042 in flood control annually. Because the latter study captures more of the value of property development over time and likely corrects for some uncertainty in the earlier analysis, the $2,042/acre estimate is the more reliable for application in California.[20]
>
> A study by the Massachusetts Water Resources Commission on the Neponist River indicated that the loss of 10 percent of the wetlands along that river would result in flood stage increases of one and a half feet, and the loss of 50 percent of the wetlands would increase the flood stage by three feet. The Minnesota Department of Natural Resources has computed that it costs $300 to replace each acre-foot of flood water storage lost in the state. (In other words, if development eliminates a one-acre wetland that naturally

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[19] Thomas Leschine, et al., Washington State Department of Ecology, *The Economic Value of Wetlands: Wetlands Role in Flood Protection in Western Washington*, October 1997, pg. 1. Estimated values range up to $51,000 per acre in avoided flood protection costs.

[20] Jeff Allen, et al, *The Value of California Wetlands: An Analysis of Their Economic B*enefits, August 1992, pg.5.

> holds a depth of 12 inches of water during a storm, the replacement cost would be $300).[21]

The Washington Department of Natural Resources estimates that in the Puget Sound area, forestlands have decreased by about 9 percent since the 1980s. As a result, the replacement costs of this habitat are immense:

> The loss of these forests comes at considerable economic and environmental costs. It's estimated that it will cost $2.4 billion to build a storm water system equivalent to that previously provided by trees. Those trees also would have absorbed 35 million pounds of air pollutants each year. Loss of forests contributes to loss and degradation of habitat for fish and wildlife, and to diminished water quality in streams and rivers.[22]

In Napa County, a flood damage reduction project is currently underway which, among other things, reconnects the Napa River to its floodplain south (downstream) of Napa. The cost of this project is about $250 million, but it's estimated to save about $1.6 billion in flood damage over the next century without the project.[23]

Related to flow management is the maintenance of sediment balance provided by floodplains, particularly wetland areas:

- Wetlands stabilize the banks and beds of drainage ditches, creeks, small streams, seeps and springs, and oceans, reducing erosion and sedimentation in adjacent waters.

- When wetlands reduce flows and the velocity of floodwaters, they reduce erosion and allow floodwaters to drop their sediment.

- Wetland vegetation filters and holds sediment that would otherwise enter lakes, rivers, ponds, and the oceans.

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[21] Environmental Law Institute, *Our National Wetland Heritage: A Protection Guide*, 1996, pg. 5.

[22] Washington State Department of Natural Resources, *Our Changing Nature: Natural Resource Trends in Washington State*, 1998, pg. 26.

[23] Jim Morrison, *National Wildlife*, vol. 43 no. 2, "How Much is Clean Water Worth?"; Feb/Mar 2005.

- Un-retarded sediment may result in rapid filling of lakes and reservoirs and the destruction of fish habitats.

> A 1987 study in Louisiana found that the loss of one mile of coastal wetlands would increase hurricane damage by $63,676 in 1980 dollars...Additionally, wetlands filter sediments from waters flowing through them; when wetlands are destroyed, sediments collect downstream along stream and river beds. For instance, wetland loss near the Port of Redwood City, California is believed responsible for damage of shipping channels; a recent dredging project there cost the USACE approximately $2.3 million.[24]

Maintain Water Supply: In addition to flow management, floodplains maintain water supplies by providing opportunities for improved surface and groundwater storage. Floodplains also maintain the frequency and duration of low surface flows (as well as river base flows) by slowly releasing water stored during high water events. Most of the water supply functions are performed in the aquatic/wetland, riparian and over bank floodplain areas, although upland areas can also provide increased surface water storage and groundwater recharge opportunities. A properly managed upland can also provide very important storage (in soil), retardation of flow, slow release (maintenance of flow), etc. Water supplies have significant value for society, including contributing to the increase in the production and consumption of goods or services or reductions in their production costs. Naturally functioning floodplains may also enhance societal values through the avoidance of water supply infrastructure costs (capital and O&M), which can be substantial.

Water supply costs vary greatly from one source to another. For example, “typical” development costs for the following types of water supply options in California are:[25]

- Groundwater/conjunctive use: $150 - $500 per acre-foot
- Brackish groundwater recovery: $500 - $1,000 per acre-foot
- Water recycling: $250 - $1,000 per acre-foot

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[24] Jeff Allen, et al. *The Value of California Wetlands: An Analysis of Their Economic Benefits*, August 1992, pg.s 6

[25] California Department of Water Resources, *The California Water Plan Update: Bulletin 160-98*, Volume 1, November 1998.

- New reservoirs: $250 - $1,500 per acre-foot
- Sea water desalination: up to $2,000 per acre-foot

Often, the supply source is located away from the service area, thus transportation costs are incurred. For the California State Water Project, transportation costs (capital and O&M) are over $170 per acre-foot to deliver water from the Sacramento-San Joaquin Delta to the metropolitan Los Angeles area.[26] Once within the service area, additional local storage, delivery and treatment costs are incurred before final delivery to the water users (some or all of these may still be necessary from wetland water sources depending upon the location of the wetland compared to the area of final use).

Other studies have also focused upon the avoided costs of water supplies:

> A set of studies of Massachusetts's wetlands areas found that a high percentage of municipal wells were located in or adjacent to wetlands. The water supply value of wetlands may be calculated as the difference between the cost of water from wetland wells and the next cheapest alternative source. The 1975 study of the Charles River region concluded that an average acre of wetlands could supply water at a savings of $2,800 per year compared to other water sources...A more recent study estimated that an average acre of wetlands could provide 100,000 gallons per day at a rate of $16.56 per day less than water procured from the local district. This savings translates to $6,044 in annual water supply per wetland acre.[27]

Maintain Water Quality. Floodplain vegetation and soils (especially those associated with wetlands) serve as water filters, intercepting surface water runoff before it reaches the lake, stream or river.   The filtering process is accomplished by:

- Riparian vegetation trapping nutrients and toxic substances which are attached to sediment particles
- Vegetation and microorganisms consuming many of the nutrients and toxics which are dissolved in surface runoff or in soil water
- Woody vegetation removing nitrogen from ground water

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[26] California Department of Water Resources, *Management of The California State Water Project, Bulletin 132-96*, November 1996, pg 364.

[27] Jeff Allen, et al. *The Value of California Wetlands: An Analysis of Their Economic Benefits*, August 1992, pg. 6.

- Reducing the toxicity of viruses and bacteria, including fecal coliform found in municipal sewage

The literature contains numerous examples illustrating the water quality benefits of wetlands, many also focusing upon avoided costs:

> A study of Tinicum Marsh in Pennsylvania revealed significant reductions in BOD (biochemical oxygen demand), phosphorous, and nitrogen within three to five hours in samples taken from heavily polluted waters flowing through a 512-acre marsh. A study of the effects of a wetland adjacent to Lake Wingra in Wisconsin indicated that 200-300 kilograms per year of phosphorous now entering the lake would have been trapped, had not 300 wetland acres been destroyed by development. A number of investigators now are studying the use of man-made or natural wetlands as tertiary treatment facilities for domestic, industrial, and storm water wastes.[28]
>
> In 1974, a Louisiana research team calculated that tidal wetlands in that state provided $2,500 worth of water treatment benefits per acre each year...A 1978 Michigan study estimated that an average acre of wetlands along the shores of the Great Lakes could provide over $2,500 [1965 dollars] worth of water quality improvement annually...Finally, a Massachusetts study calculated the costs of a tertiary waste treatment plant to substitute for natural waste assimilation by wetlands in the Charles River Basin. An acre of marsh was found to substitute for capital costs of $85 plus $1,475 in maintenance and operation costs.[29]
>
> The wetlands of Congaree Bottomland swamp in South Carolina provide valuable water quality functions such as sediment, toxicant and excess nutrient removal. The least cost substitute for the water quality services provided would be a water treatment plant costing $5 million...Boulder, Colorado, reduced potential wastewater treatment costs significantly by deciding to restore Boulder Creek rather than construct a nitrification tower. Discharge effluent at the wastewater treatment plant met water quality standards, however, further down stream, ammonia concentrations exceeded the allowable level. Downstream the creek had been previously channelized and degraded. Through re-vegetation, terracing, construction of aeration structures, and other improvements, the stream was restored. The natural functions of the stream would then cool and re-aerate the water to convert the ammonia. Restoration of Boulder Creek would also improve wildlife habitat, particularly fisheries.[30]

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[28] Environmental Law Institute, *Our National Wetland Heritage, A Protection Guide* (1996), pg 6.

[29] Jeff Allen, et al. *The Value of California Wetlands: An Analysis of Their Economic Benefits*, August 1992, pg. 7.

[30] National Park Service, *Economic Impacts of Protecting Rivers, Trails and Greenway Corridors*, 1995, pgs. 8-7 and 8-8.

In California, the County of Clear Lake estimates that the Middle Creek Ecosystem Restoration Project (which would restore about 1,200 acres of historic wetlands) could potentially remove up to 40 percent of the phosphorous entering Clear Lake from Middle and Scotts Creeks (which combined account for 71 percent of the total phosphorous entering the lake). This improvement in water quality is expected to have significant economic benefits in terms of increased tourism and recreation around the entire lake.[31] .

Several years ago New York City discovered the value of protecting the watershed where its drinking water supplies originated from:

> New York City discovered how valuable these [ecosystem] services were 15 years ago when a combination of unbridled development and failing septic systems in the Catskills began degrading the quality of the water that served Queens, Brooklyn and other boroughs. By 1992, the U.S. Environmental Protection Agency (EPA) warned that unless water quality improved, it would require the city to build a filtration plant, estimated to cost between $6 and $8 billion and between $350 and $400 million a year to operate….Instead, the city rolled the dice with nature in a historic experiment. Rather than building a filtration plant, officials decided to restore the health of the Catskills watershed, so it would do the job naturally. What's this ecosystem worth to the city of New York? So far, $1.3 billion. That's what the city has committed to build sewage treatment plants upstate and to protect the watershed through a variety of incentive programs and land purchases. It's a lot of money. But it's a fraction of the cost of the filtration plant—a plant, city officials note, that wouldn't work as tirelessly or efficiently as nature.[32]

Maintain Soil Quality. As flood flows spread out over a floodplain, nutrient rich sediments can be deposited which improve soil quality for human (agricultural) and environmental purposes. A good example is the Cosumnes River Preserve south of Sacramento, where over 1,000 acres have been planted in organic rice and pasture and are subject to seasonal flooding. Deposition from the silt-rich floodwaters provides significant benefits for

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[31] Thomas Smythe, *Overview of Middle Creek Ecosystem Restoration Project*, pg. 2. This project was selected for further analysis as a case study (see *Middle Creek Ecosystem Restoration Project Case Study: Benefit and Cost Analysis*).

[32] Jim Morrison, *National Wildlife*, vol. 43 no. 2, "How Much is Clean Water Worth?"; Feb/Mar 2005.

the soil and the crops grown. Another soil quality value includes avoided habitat enhancement/replacement costs, because of the reliance of habitat upon good soil quality.

Maintain Air Quality. Vegetation on floodplains can improve air quality in a number of ways, as described by the National Park Service:

> Plants cleanse the air through the process of photosynthesis, which removes carbon dioxide from the air and returns oxygen. Specifically, plants control air pollution through oxygenation and dilution. Oxygenation refers to the introduction of excess oxygen into the atmosphere. The ability of plants to introduce excess oxygen into oxygen-deficit air serves to readjust the balance. Plants also act as cleansers by absorbing pollutants directly into their leaves and assimilating them.) Vegetation can absorb ozone, sulfur dioxide, carbon monoxide, and airborne particles of heavy metals.[33]

The National Park Service has cited studies of improved air quality provided by vegetation, including:[34]

- In 1991, trees in the city of Chicago, Illinois (with 11 percent tree cover) removed an estimated 17 tons of carbon monoxide, 93 tons of sulfur dioxide, 98 tons of nitrogen dioxide, and 210 tons of ozone. The value of this pollution removal was estimated to be about $1 million per year.
- Recent studies indicate that a single rural tree can intercept up to 50 pounds of particulates per year. In one study, it was determined that planting a half million trees in Tucson, Arizona, would reduce airborne particulates by 6,500 tons per year, with an annual value of about $1.5 million.
- Reductions in pollutant concentrations downwind have been recorded, as in one Ohio study where reductions in particulate concentrations of 19 percent were recorded at conifer stands.
- Trees also provide ambient temperature mediation and help reduce heating and cooling costs. In winter, trees can reduce winter heating costs by 40 percent in some cases, as well as air-cooling savings during the summer. A single, isolated tree can, through transpiration, extract an amount of heat equivalent to that extracted by five-

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[33] National Park Service, *Economic Impacts of Protecting Rivers, Trails and Greenway Corridors*, 1995, pg. 8-9.

[34] National Park Service, *Economic Impacts of Protecting Rivers, Trails and Greenway Corridors*, 1995, pg. 8-9.

average room air conditioners running 20 hours a day.

Maintain Plant and Wildlife Habitats. One of the most important functions of floodplains is the maintenance of characteristic and diverse plant and animal communities. Hydrologic and vegetation diversity provides important resting, feeding and nesting areas for many species. Undisturbed floodplains have high natural biological diversity and productivity. River corridors are frequently used as flyways for migrating birds. Aquatic and wetland areas provide habitats for fish. Floodplains (especially wetlands) also typically contain habitats for species of special concern. According to the Environmental Law Institute, "Almost 35 percent of all rare and endangered animal species are either located in wetland areas or are dependent upon them, although wetlands only constitute about 5 percent of the nation's lands."[35] Inundated floodplains are important nursery and feeding areas of juvenile fish and other aquatic life, including some species of special concern.

During the last several years, there has been a proliferation of programs at the local, State and federal level (as well as within the non-public sector) designed to restore and/or enhance environmental resources. These programs vary in scope, geographic region, and objectives. Within California, a prominent program is the CALFED Bay-Delta Ecosystem Restoration Program that provides the foundation for a long-term ecosystem restoration effort that may take several decades to implement. [36] Some proposed actions include:

- Breeching levees for inter-tidal wetlands
- Constructing setback levees to increase floodplain and riparian corridors;
- Limiting further subsidence of Delta islands by implementing measures such as restoring wetlands to halt the oxidation of peat soils

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[35] Environmental Law Institute, *Our National Wetland Heritage: A Protection Guide*, 1996, pg. 6.

[36] CALFED is the group of federal and state agencies participating in the Bay-Delta Accord and working towards a long-term solution to Bay-Delta problems related to fish and wildlife, water supply reliability, natural disasters and water quality.

- Controlling introduced species and reducing the probability of additional introductions

- Acquiring land or water from willing sellers for ecosystem improvement

- Providing incentives to encourage environmentally friendly agricultural practices

Two other recent significant restoration examples include:

- The Headwaters agreement negotiated between the federal and State governments and Pacific Lumber to save about 10,000 acres containing old-growth redwood groves from commercial harvesting in Humboldt County along the north coast. Under this agreement, Pacific Lumber will be paid $480 million not to harvest these acres, plus accept tough logging restrictions on land along streams, especially those with salmon.[37]

- The City of Seattle and other neighboring local governments are preparing comprehensive plans to revive chinook run salmon on local streams and rivers. The cost of these plans is about $225 million, or about $475 per person for residents of Seattle. These plans include buying and restoring environmentally sensitive land, habitat protection, water conservation programs, improving construction regulations and public education efforts.[38]

Information from these types of programs can be very useful in indicating what society (or at least certain parties within society) may be willing to spend to either avoid damages to habitat, or in some cases, replace habitat, although the information is obviously site specific. A database of selected floodplain/habitat restoration projects is being developed for this study (Appendix B).

The maintenance or restoration of natural habitats can improve adjacent property values. For example, the CA Department of Water Resources commissioned a study to determine

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[37] Sacramento Bee, March 2, 1999.

[38] Contra Costa Times, February 28, 1999

the benefits of an Urban Stream Restoration Program. A hedonic price method was used to determine the impact of seven urban stream restoration projects in the greater San Francisco Bay Area. Residential property prices were found to increase by $4,500 to $19,000 due to the stabilization of stream banks and acquisition of land for educational trails, which represented about 3 to 13% of the mean property price in the study area.[39]

The maintenance or restoration of natural habitats can stimulate economic development if properly planned. In many communities, the economic base was established on the waterfront, and a restoration of the waterfront area can lead to significant improvements in commercial opportunities, especially with increased tourism. For example, the City of Napa's central business district is anticipating a major revitalization in combination with the river restoration being accomplished with the Napa flood control project (now under construction). Numerous other economic revitalization "success stories" can be found across the country. [40]

Finally, there are also numerous studies that have estimated habitat-related recreational values. A survey of these was conducted and the results are summarized in Table 3.

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[39] Streiner and Loomis, *Estimating the Benefits of Urban Stream Restoration Using the Hedonic Price Method*, 1996.

[40] For example, see Citizens for Napa River Flood Management, *Napa Flooding: Our Community Responds;* National Parks Service*, Economic Impacts of protecting Rivers, Trails and Greenway Corridors; and* ASCE *Using Multi-Objective Management to Reduce Flood Losses in Your Watershed.*

Table 3: Survey of Habitat Recreational Values ($ 1998)

Activity	Number of Studies	Methodologies	Range	Mean	Units
Camping	**24**	**Travel cost; Contingent valuation**	**9.10 - 32.5**	**23.50**	**$/Day**
Picnicking	**12**	**Travel cost; Contingent valuation**	**6.5 - 52**	**20.80**	**$/Day**
Biking	**2**	**Travel cost; Contingent valuation**	**60.20 - 61.38**	**60.81**	**$/Day**
Boating	**21**	**Travel cost; Contingent valuation**	**7.70 - 216.55**	**51.35**	**$/Day**
Recreational Fishing	**4**	**Travel cost; Contingent valuation**	**15 - 95.30**	**55.00**	**$/Day**
Waterfowl Hunting	**21**	**Travel cost; Contingent valuation**	**27.60 - 113.16**	**51.51**	**$/Day**
Flood Prevention	**3**	**Hedonic Pricing**	**5 - 10**	**7**	**% of property value**

FLOODPLAIN SERVICES VALUATION METHODS

Table 4 summarizes how the different valuation methods discussed in the report *Ecosystem Valuation Methods* can be applied for the floodplain functions and associated services. However, when using these methods, care must be taken to avoid double counting. Many of the human services shown in Table 2 reflect either the value of production resulting from a particular floodplain function or an avoided cost. Only one method should be selected for each type of benefit being evaluated, and the selection of that method will depend upon the circumstances being analyzed and the available data. For example, providing additional water supplies can be expected to increase income for agricultural or urban users. For agricultural users, it is possible to directly estimate the change in income (after deducting crop production expenses) through changes in cropping patterns. However, the analysis of urban water supplies is much more complex. In this situation, the change in values provided by the additional water supplies is often assumed to be equal to the avoided least cost of developing alternative water supplies.

Double counting can also occur if the values for each of the floodplain functions are estimated separately but then added to a value based upon replacement cost. Since the replacement cost value should incorporate the values of the individual functions, this value should not be added to the individual functional values.

Table 4: Methods for Valuing Floodplain Functions and Services

Natural Floodplain Functions and Services	Valuation Method						
	Revealed WTP *				Imputed WTP*	Expressed WTP*	Benefit Transfers
	Market Price Analysis	Value of Production	Hedonic Property Pricing	Travel Costs	Avoided/ Replacement Costs	Contingent Valuation	
Maintain Natural Channel Processes	X	X	X	X	X	X	X
Manage Flows		X	X	X	X	X	X
Maintain Water Supply	X	X		X	X	X	X
Maintain Water Quality	X	X		X	X	X	X
Maintain Soil Quality	X	X		X	X	X	X
Maintain Air Quality	X	X	X	X	X	X	X
Maintain Plant and Animal Habitats	X	X	X	X	X	X	X

* Willingness to pay. See *Ecosystem Valuation Methods* for a description of these methods.

CONCLUSIONS

Although floodplains are often viewed as hazardous areas, preserving (or restoring) them in their natural condition can provide many valuable services to humans, including floodwater retention, improved water supplies and quality, improved soil and air quality, and the maintenance of natural habitats. A key objective of floodplain management is to encourage communities to recognize the significant services and values associated with maintaining (or preserving) floodplains in their natural conditions. Although imperfect, methods are available for monetizing these services, which can assist in the evaluation of multi-objective programs that incorporate the protection of natural floodplains and their natural functions, and at the same time, remove people and property from harm's way.

An example of monetizing these services is presented in the paper *Middle Creek Ecosystem Restoration Project Case Study: Benefit/Cost Analysis*, which presents a benefit/cost analysis of a Corps/Lake County proposal to restore almost 1,600 acres of the Middle Creek floodplain at the northwest end of Clear Lake, CA. This land is currently in agricultural production. Benefits of the floodplain restoration include reduced on-site flood damage, the creation of on-site aquatic, wetland and riparian habitats, and the reduction of phosphorous laden sediment currently being deposited into Clear Lake. Reducing the sediment load flowing into the lake should gradually improve water quality within the lake and increase recreational use of the lake. The Corps' Sacramento District has recently completed a feasibility study recommending restoration of the entire floodplain. This feasibility study included a Combined NED/NER (national economic development/national ecosystem restoration) analysis.[41]

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[41] The Corps' economic analysis, including NED and NER, is discussed in the *Benefit and Cost Analysis Framework* report.

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