

# Watershed Management



## A Resource Management Strategy of the California Water Plan

California Department of Water Resources

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## Table of Contents

<b>Watershed Management .....</b>	<b>1</b>
Watershed Management in California .....	1
Potential Benefits .....	2
Potential Costs .....	2
Willingness to Pay .....	4
Major Implementation Issues.....	6
Altered Hydrologic Cycles.....	6
Altered Nutrient Cycles .....	7
Life Cycles and Migration Patterns of Wildlife.....	8
Fire and Water.....	8
Climate Change.....	8
Adaptation.....	8
Mitigation.....	9
Links to other Resource Management Strategy Reports.....	9
Recommendations.....	10
Policy-Level Recommendations .....	10
Strategic Practice Recommendations.....	10
References.....	11
References Cited.....	11
Additional References.....	11

## Tables

Table 1 Typical List of Watershed Products, Goods, and Services .....	3
Table 2 Estimates of Watershed Management Costs to Year 2030, from <i>California Water Plan Update 2005</i> and CALFED Program Estimates .....	5
Table 3 Cost Estimate to Fully Implement the Strategy — Willingness to Pay .....	7

## Boxes

Box 1 Watershed Defined.....	2
Box 2 Watershed Degradation and Water Treatment Costs .....	6

## **Acronyms and Abbreviations**

CEQA	California Environmental Quality Act
GHG	greenhouse gas
NEPA	National Environmental Policy Act

# Watershed Management

Watershed management is the process of creating and implementing plans, programs, projects, and activities to restore, sustain, and enhance watershed functions. These functions provide the goods, services, and values desired by the human community that are affected by conditions within a watershed. The practice of community-based watershed management, which is practiced in hundreds of watersheds throughout the state, has evolved as an effective approach to natural resource management. These community-based efforts are carried out with the active support, assistance, and participation of several State agencies and programs.

Managing at a watershed level has proven to be an appropriate organizing landscape unit for the coordination and integrated management of the numerous physical, chemical, and biological processes that make up a river basin ecosystem (Box 1). A watershed serves well as a common reference unit for the many different policies, actions, and processes that affect the system, and it also provides a basis for greater integration and collaboration among those policies and actions.

## Watershed Management in California

A primary objective of watershed management is to increase and sustain a watershed's ability to provide for the diverse needs of the communities that depend on it including local, regional, State, federal, and tribal stakeholders. Significant efforts to manage natural resources better using a watershed approach are occurring in several hundred structured efforts in all regions of California involving organizations, local governments, landowners/users, and stewardship groups along with State and federal agencies.

Many of these efforts are working to blend community goals and interests with the broader goals of the State as a whole in a manner consistent with improving environmental, social, institutional, and economic conditions within the watershed. The need to address environmental justice and social equity has been recognized and addressed, along with more traditional project management approaches.

In many communities, these organized efforts serve as forums to bring about collaborative management involving the public and private sector; the academic community; and people working at the local, regional, State, and national levels, all benefitting from the inherent capabilities of each group. The benefits of watershed-based management are being realized in such diverse locations as the upper Feather River, the Los Angeles River basin, and the Napa River.

In addition to these local efforts, a number of regional, statewide, and national initiatives have been carried out to help improve the overall ability to practice watershed management. A chronology of some notable initiatives in California can be found in *California Water Plan Update 2009*, Volume 2, Chapter 27, available online at <http://www.waterplan.water.ca.gov/cwpu2009/index.cfm> (California Department of Water Resources 2009).

Bond measures have brought significant funding for the maintenance and restoration work that is needed in many of California's watersheds. Proposition 50 (2002) and Proposition 84 (2006) stressed the need for integrated planning that includes objectives at the watershed and regional scales, and provide incentives to carry out work consistent with these plans.

## Box 1 Watershed Defined

### What is a Watershed?

In its historical definition, a watershed is the divide between two drainage streams or rivers separating rainfall runoff into one or the other of the basins. In recent years, the term has been applied to mean the entirety of each of the basins, instead of just the divide between them. The Continental Divide is a watershed according to the earlier definition, where rainfall runoff is directed toward the Gulf of Mexico or toward the Pacific Ocean. The Mississippi River basin and the Colorado River basin are watersheds under the new definition. Other parts of the world use the terms catchment, or river basin, to describe the drainage area between (historical) watersheds. The phrase “watershed event,” an occurrence that changes the pattern of all that follows, moving the flow of events toward a different outcome, is derived from the earlier definition of watershed.

A watershed includes all natural and artificial (human-made) features, including its surface and subsurface features, climate and weather patterns, geologic and topographic history, soils and vegetation characteristics, and land use. A watershed may be a small area or as large as the Sacramento, San Joaquin, or Klamath River basins.

Using watersheds as organizing units for planning and implementation of natural resource management means that:

- Large regions can be divided along topographic lines that describe a natural system more accurately than typical jurisdictional lines.
- Condition and trends analysis can be done on the basis of the entire natural system, in concert with economic and social conditions.
- Communities, including resource management and regulatory agencies, within, and outside a particular watershed can better track and understand the cumulative impacts of management activities on the watershed system.
- Managers within each watershed can adjust their measures and policies to meet management goals more effectively across scales, including regional and statewide goals.
- Multi-objective planning is facilitated by inclusion in, and reference to, a whole-system context.

Effective management recognizes the mutually dependent interaction of various basic elements of a watershed system including the hydrologic cycle, nutrient and carbon cycling, energy flows and transfer, soil and geologic characteristics, plant and animal ecology and the role of flood, fire, and other large scale disturbance.

Each must be considered in context with the others, because change in one spurs changes in the others, creating a different system outcome.

## Potential Benefits

Managing people’s interactions with and impacts on natural ecosystems using a watershed approach that emphasizes maintaining, restoring, or enhancing the many functions associated with these natural systems produces a number of significant benefits. Many of the benefits (e.g., reliable quantities of clean water, agricultural and forest products, biofuels) and avoided costs (e.g., reduced flood or fire damages) can be described using traditional economic terms, such as products, goods, or services, and are readily quantified and valued in the traditional marketplace. Other values associated with natural systems such as biological diversity, disease suppression, and climate moderation are more difficult to quantify monetarily because these values are not routinely traded in the marketplace. As a result, the term “ecosystem services” is often used to better describe and equate the monetary and non-monetary values or benefits provided to society by healthy watersheds. Some typical watershed products, goods, and services are listed in Table 1.

## Potential Costs

Costs associated with watershed management depend on many factors, such as the size of the watershed; the land and water use activities occurring in the watershed; the condition and trends of the watershed;

**Table 1 Typical List of Watershed Products, Goods, and Services**

<b>Typical Watershed Products, Goods, and Services (also described as ecosystem services)</b>	<b>Benefit of Service</b>
Provision of water supplies	Agriculture, municipal, industrial, and other beneficial uses.
Provision of food, fiber, fuel	Sustainable production of agricultural and forest products that are dependent on healthy productive soils, favorable climate and water conditions, and the availability of pollinators.
Water purification/waste treatment	Well managed watersheds produce clean, cool water generally useful for a broad range of beneficial uses. Virtually all fresh water used in California originates as precipitation that is intercepted, captured, routed, and released from watersheds in California and the Colorado River basin.
Flood mitigation	Healthy watersheds with adequate distributed wetlands and functional floodplains moderate the volume and timing of surface runoff reducing flood damage.
Drought mitigation/flow attenuation	A healthy watershed works like a sponge to store and release water to both streams and groundwater. Healthy watersheds in California increase the residence time of water, and tend to store and release water longer into the dry season.
Provision of aquatic and terrestrial habitat	Uplands, rivers, streams, floodplains, and wetlands provide necessary habitats for fish, birds, mammals, and countless other species, and generally sustain a strong level of biological diversity that provides wide benefits to society.
Soil fertility, health, productivity	Soil health and fertility is an essential component of primary ecosystem production, and is critical for maintenance of important terrestrial, floodplain, riparian, and wetland components and processes.
Nutrient, mineral cycling and delivery, carbon sequestration	Cycling of nutrients is necessary to maintain healthy, diverse biological systems, to sustain biological diversity that mediates disease, and to sustain populations of native species.
Biodiversity maintenance	Diverse assemblages of species work to provide the services (including all those listed in this table) upon which societies depend. Conserving genetic diversity preserves options for the future and increases the resilience of ecosystems in the face of the impacts of a changing climate.
Recreational opportunities	Swimming, fishing, hunting, boating, wildlife viewing, hiking, and skiing are all delivered or enhanced in healthy watersheds, often resulting in concurrent economic improvements in local communities reliant on recreation as a source of economic sustenance or growth.
Climate moderation/buffering	Generally, a diversified watershed ecological system is more robust and resilient to rapid climate changes or other types of disturbance. Maintaining a resilient watershed ecosystem will be of critical importance in the face of a changing climate. That adaptation will better ensure that watershed ecosystem functions will continue to provide the goods, services, and values of the systems experienced today.
Aesthetics	Quality of life is a major, but difficult to quantify, benefit of watershed conditions. Pleasant surroundings with clean air, clean water, and adequate recreational opportunities have been shown to be beneficial across a broad spectrum of social structures.
Managing salinity gradients	Freshwater flow regimes can determine salinity gradients in deltas, coastal estuaries, and near-shore marine environments, a key to biological richness and complexity.

Source: Table content adapted from *Rivers for Life: Managing Water for People and Nature* (2003) by Sandra Postel and Brian Richter.

and the values, goods, and services demanded from the watershed. Much of the cost of watershed management in California is associated with the specific land or water use activities occurring within the watershed on a recurring basis and is directly related to these uses. The additional or external costs of watershed management that are discussed in this resource management strategy report tend to be associated with interventions designed to influence management or improve the results of management, to offer specific protection for certain functions and values, or to restore the functional conditions and associated uses of a watershed. These interventions may come from various levels of government or interests either within or outside the watershed. A methodological approach is used for estimating costs associated with specific watershed-scale resource management efforts. Using this approach, the potential costs associated with these interventions are estimated by:

- Extrapolating costs based on available estimates of other program expenditures (see Table 2, used in *California Water Plan Update 2005* and *California Water Plan Update 2009*, in resource management strategy chapters on watershed management). Estimates are based on CALFED watershed management estimates scaled up for statewide coverage.
- Applying a “willingness to pay” approach based on existing examples (using CALFED Watershed Program analysis as part of program finance plan development).
- In addition to the more easily quantified benefits of well-functioning watersheds, effective watershed management can also result in significant avoided costs, such as lessened fire and flood damage, erosion and sediment loss reduction, water quality maintenance, reduced illnesses and treatment costs, and control of agricultural pests. An example is shown in Box 2, “Watershed Degradation and Water Treatment Costs.”

### Willingness to Pay

To estimate the approximate external costs to fully implement the watershed management strategy, an analysis developed by the CALFED Watershed Program was used, which examined areas where communities have chosen to provide quantifiable financial support for watershed management, thus demonstrating “a willingness to pay” for the services provided by a well-managed watershed. This analysis, developed using methods described by the U.S. Department of Energy (Ulibarri and Wellman 1997) and the U.S. Congressional Research Service (Breedlove 1999), is an attempt to assign a monetary value to effective watershed management.

Napa County was used as a basis for this comparison for several reasons. First, it has a demographic similarity to the demographic makeup of the state as a whole. Second, taxes are collected that are directly tied to implementation of community-generated watershed management plans; these tax levies also demonstrate strong local support among voters and elected officials for the values inherent in improved watershed management. Finally, these funds are generated and dispersed locally, by locally responsive government entities.

Valuations from three different Napa County tax measures were investigated:

- A half-cent sales tax passed by 68 percent of voters in the late 1990s that generates approximately \$10 million in revenue per year specifically for watershed management (the “Living River” program).
- A parcel tax of \$12.70 per parcel that is supported and levied within the City of Napa for watershed management.
- An additional parcel tax of \$12 per year specifically for stormwater runoff management inside the city’s watersheds.



**Table 2** Estimates of Watershed Management Costs to Year 2030, from *California Water Plan Update 2005* and CALFED Program Estimates

Period (years)	Assessment- Planning <sup>a</sup> (\$ millions)	Public Process <sup>b</sup> (\$ millions)	Projects <sup>c</sup> (\$ millions)	Total for Period (\$ millions)
2004-2009	\$10-\$37.5	\$8-\$16	\$14-\$80	\$160-\$667
2010-2015	\$10-\$30	\$8-\$16	\$14-\$88	\$160-\$804
2016-2030	\$10-\$25	\$8-\$16	\$14-\$100	\$160-\$2,115
Total				\$480-\$3,586

Source: *California Water Plan Update 2005*, Volume 2, *Resource Management Strategies*, Chapter 25, "Watershed Management."

Notes:

The CALFED service area is defined as the Sacramento and San Joaquin River basins, the Tulare Lake basin, the Delta and San Francisco Bay Area, and the portion of Central and Southern California serviced by the State Water Project.

<sup>a</sup> CALFED service area is estimated as 40 percent of statewide need. Therefore, statewide assessment and planning = 2.5 x CALFED values from draft CALFED Finance Plan (2004).

<sup>b</sup> The service area for public process is estimated as 25 percent of the statewide need. Therefore, statewide public process = 4x CALFED values.

<sup>c</sup> For projects, CALFED service area is estimated to be 25 percent of the statewide need. Therefore, statewide projects = 4x CALFED values.

These assessments generate funds (based on 2009 estimates) that range from nearly \$14,000 per square mile for the sales tax revenue, to just less than \$1,600 per square mile for the parcel tax. For the purposes of this value estimate, a lower amount of \$1,572 per square mile is used, which in turn, is adjusted to account for the slight difference in demographic statistics between Napa and California at large. These value estimates (Table 3) represent the annual external cost of fully implementing the watershed management strategy over approximately half the surface area of California, including all or part of the Sacramento River, San Joaquin River, Tulare Lake, San Francisco Bay, South Coast, and South Lahontan hydrologic regions.

Simple extrapolation of this value to the entire land area of the state would result in an estimated annual cost of \$221 million to fully implement the strategy. For this example, "fully implement" suggests extensive application within the regions of the policy-level and strategic practice recommendations in this resource management strategy report. It should be noted here that an as-yet-undetermined, but likely significant, portion of that cost is not an added cost, but existing expenditures applied differently. For instance, permits and stream alteration agreements issued by watershed boundary instead of jurisdictional boundary could result in considerable added benefit and positive effect without adding to the real cost of implementation. Also, land use planning done on the basis of watershed impact may yield higher beneficial results without increasing costs.

**Box 2 Watershed Degradation and Water Treatment Costs**

The development of watershed and aquifer recharge lands results in increased contamination of drinking water. With increased contamination comes increased treatment costs. The costs can be prevented with a greater emphasis on source protection. A study of 27 water suppliers conducted by the Trust for Public Land and the American Water Works Association in 2002 found that the more forest cover in a watershed, the lower the treatment costs. According to the study, “Approximately 50 to 55 percent of the variation in treatment costs can be explained by the percent of forest cover in the source area. For every 10 percent increase in forest cover in the source area, treatment and chemical costs decreased approximately 20 percent, up to about 60 percent forest cover.”

The study did not gather enough data on suppliers with more than 65 percent forest cover to draw conclusions. However, it is suspected that treatment costs level out when forest cover is between 70 and 100 percent. The 50 percent variation in treatment costs that cannot be explained by the percent forest cover in the watershed is likely explained by varying treatment practices, the size of the facility (larger facilities realize economies of scale), the location and intensity of development and row crops in the watershed, and agricultural, urban, and forestry management practices. The table shows the change in treatment costs predicted by this analysis, and the average daily and annual cost of treatment if a supplier treats 22 million gallons per day.

**Table A Change in Water Treatment Costs for Each 10 Percent of Forest Cover in Source Watershed**

Percent of Watershed Forested	Treatment and Chemical Costs per Million Gallons	Change in Costs	Average Treatment Costs Daily	Per Year
10%	\$115	19%	\$2,530	\$923,450
20%	\$93	20%	\$2,046	\$746,790
30%	\$73	21%	\$1,606	\$586,190
40%	\$58	21%	\$1,276	\$465,740
50%	\$46	21%	\$1,012	\$369,380
60%	\$37	19%	\$814	\$297,110

*Source: Extracted from Land Conservation and the Future of America’s Drinking Water - Protecting the Source (2004). Published by the Trust for Public Lands and the American Water Works Association.*

**Major Implementation Issues**

Managing land and water resources for selected products, services, and values has altered the conditions and functions of many watersheds in California. These management activities have produced some negative effects that need to be addressed to continue to effectively manage and utilize watershed services.

**Altered Hydrologic Cycles**

The hydrologic cycle includes precipitation, flow of water over the land and underground, and evaporation into the atmosphere. How land is managed can reduce rainwater infiltration and the timing and volume of runoff. Storms are increasingly characterized by high-intensity runoff over short periods, especially in urban areas but also in some rural areas, and that runoff creates a risk of flooding and reduces the ability of the water supply infrastructure to capture water for use during dry times. This compression of runoffs robs the streams and landscape of groundwater, leading to dry land, a shift in vegetation types, lower and warmer streams, and deterioration of stream channels, all of which lead to shifts in the plants and wildlife that can be supported. In some areas, diversion of water from streams in the watershed to other regions outside the watershed, or application of water imported from outside the

**Table 3 Cost Estimate to Fully Implement the Strategy — Willingness to Pay**

<b>Napa County</b>	<b>Less 10%</b>	<b>Bay-Delta Watershed Area (mi<sup>2</sup>)</b>	<b>Southern California (mi<sup>2</sup>)</b>	<b>Total Value Estimated</b>
\$1,572 per mi <sup>2</sup>	\$1,414 per mi <sup>2</sup>	48,050		\$67,942,700
			30,000	\$42,420,000
Total Valuation:	\$110,362,700			

Source: California Department of Water Resources, 2011

watershed, has dramatically changed ecological functions or altered the flow of water through the watershed.

In particular, high-elevation runoff is expected to result in higher flows over shorter durations, thereby causing earlier and greater spring flooding followed by longer, drier summers. Those conditions could have an impact on plants and wildlife, especially in sensitive environments. One innovative strategy involves placing snow fencing in small openings (in clear-cut tree harvest areas or high-elevation meadows) of 1.25 acres or less, which could reduce spring runoff and pollution from roadways, support local flood control, accelerate ecosystem restoration, and improve habitat. For more information on the application and benefits of snow fences, refer to resource management strategy report, *Other Resource Management Strategies*.

### **Altered Nutrient Cycles**

As watersheds are developed, the amount of dissolved nutrients in streams within the watershed is increased, often from inappropriate use or excessive application rates of fertilizers or biosolids, which can trigger dramatic changes in water bodies, vegetation, and wildlife communities.

Nutrients generated by human activity are frequently exported from the location where they are generated or applied by humans to a downstream or downslope water body, where they can support algae or other plant growth that impairs the usability and ecological quality of water bodies. In addition to direct effects on surface waters and groundwater, increased nutrients can lead to the establishment of non-native invasive plant species at the expense of native vegetation. Many native plants evolved under relatively low-nutrient conditions, whereas increased nutrient availability typically creates conditions that favor non-native invasive plant species. The invasive species often outcompete the native vegetation and form single-species stands with little or no biological diversity; little habitat value for wildlife; and altered soil conditions, such as reduced infiltration capacity.

By government regulation, biosolids must only be applied in an agricultural operation at a rate that just satisfies the agronomic need of the crop to be grown, and with location restrictions that avoid waterways as a means of eliminating or severely restricting nutrient runoff. Under appropriate application protocols, nutrient concentration increases are minimized and invasive species are less likely to become established.

## **Life Cycles and Migration Patterns of Wildlife**

Many projects built in the past, prior to modern environmental laws such as the California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA), have disrupted wildlife migration corridors or destroyed or degraded habitat that is critical for certain animal life stages. Some examples of the effects of watershed alteration on wildlife ecology are found in the changes in freshwater inflows to coastal wetlands caused by changed watershed conditions, which directly affect many estuarine and ocean species that breed and rear in these communities; blocked access to spawning and rearing habitats for anadromous fish by the dams that impound water on most significant California waterways; and reduction in extent of the riparian forests that support migration of Pacific Flyway bird species.

## **Fire and Water**

Active suppression of wildland fires since the 1920s has created an increased risk of larger, more intense wildfires that do much more damage to watersheds than fires of historical intensities. Modern watersheds have limited capabilities of rapidly recovering from these fires, and accelerated soil erosion, diminished productivity and diversity of plant communities, displaced wildlife, significant alterations of natural biological cycles, and limited subsequent human use of the lands are typical aftereffects. Catastrophic fires also have large effects on hydrology and water quality within a watershed, causing increased surface runoff and reduced infiltration, creating more frequent and severe downstream flood events, exacerbating water quality problems, increasing operation and maintenance costs for reservoirs and canal systems, and producing large economic losses to local communities.

## **Climate Change**

Watershed integrity is vulnerable to the changes in temperature, precipitation, and water flows that are likely under currently projected scenarios of climate change. As indicated in Box 1, each element of a watershed system must be considered in context with the others because changes in one element (e.g., the hydrologic cycle) spur changes in the others (e.g., the roles of flood and fire), creating a different system outcome. Watersheds within regions where precipitation decreases can become more susceptible to pests, fires, and pollutants. Projected increases in storm intensity could increase inland and coastal flooding, increasing the likelihood of downstream property damage and loss of life. Runoff from high-intensity storms would cause increased rates of soil erosion and soil loss, particularly in watersheds recovering from recent droughts or fires, because soils in those areas would lack vegetation cover that stabilizes soils.

## **Adaptation**

As indicated in Table 1, a diverse watershed ecosystem can be resilient to changes in climate, so maintaining healthy watershed ecosystems will be critically important in the face of a changing climate by ensuring that ecosystem functions within a watershed will continue to provide the goods, services, and values of the systems Californians rely on today. How land is managed affects the way watersheds can adapt to the effects of climate change, and an effective watershed management strategy provides multiple benefits to human society, such as producing water, food, fiber, and fuel; mitigating floods and droughts; providing aquatic and terrestrial habitats and recreational opportunities; moderating local climates; and maintaining biodiversity and healthy soils. Managing interactions with natural watershed systems to maintain, restore, and enhance the many functions within a watershed allows Californians to have reliable quantities of clean water, as well as agricultural and forest products. An effective watershed management

strategy also helps to reduce the cost of flood and fire damages, suppress disease, and increase biodiversity.

### **Mitigation**

California's forested watershed ecosystems have relatively high carbon sequestration potential, and appropriate vegetation management can significantly increase rates of carbon sequestration as well as reduce rates of natural greenhouse gas (GHG) emissions. Improved watershed management for water reuse, pollution control, and other ecosystem services could provide multiple opportunities to reduce the energy use and emissions of GHGs. Tracking and reporting changes in California's major watersheds could help to assess and evaluate water quality and watershed conditions for controlling pollution and saving related energy.

Supporting adaptive management programs could provide opportunities to control energy use and GHG emissions by avoiding negative impacts on ecological conditions, water quality, and watershed functions, as well as by adjusting the operations or redesigning existing projects to create benefits for climate change mitigation. Providing technical information and watershed education and outreach in the decision-making process could have long-term benefits for climate change mitigation related to the maintenance and improvement of watershed functions, water conservation, water reuse, and water pollution prevention.

Other opportunities within this strategy to mitigate for energy use and GHG emissions include management actions to maintain and improve watershed function, such as designing and selecting projects to avoid negative impacts on ecological conditions, water quality, and watershed functions, and controlling stormwater, reducing surface runoff, and retaining intact floodplains and wetlands to maintain and improve watershed function and control water pollution.

Water-use efficiency practices in watersheds could have benefits for reducing energy use and GHG emissions. Those practices include decreasing the amount of irrigated landscaping in the watershed and increasing the use of native vegetation in landscaping and agricultural buffer lands, as well as installing and maintaining stream flow gauges to measure water use. Improving watershed ecosystem functions by restoring and preserving stream channel morphology and creating habitats around stream and river corridors could provide carbon sequestration potential for GHG reduction. However, energy use efficiency and clean energy standards should be used to offset related GHG emissions during restoration.

### **Links to other Resource Management Strategy Reports**

Watershed management is linked to the following resource management strategy reports:

- *Flood Management.*
- *Drinking Water Treatment and Distribution.*
- *Pollution Prevention.*
- *Salt and Salinity Management.*
- *Urban Stormwater Runoff Management.*
- *Agricultural Land Stewardship.*
- *Ecosystem Restoration.*
- *Forest Management.*
- *Land Use Planning and Management.*

- *Recharge Area Protection.*
- *Outreach and Engagement.*

## Recommendations

### Policy-Level Recommendations

1. Establish a scientifically valid means of tracking and reporting changes in the state's major watersheds that provide reliable, current information to local communities, State and federal agencies, and others, regarding the net effects of management against the background of external change.
2. Support adaptive management programs that regularly assess the performance and condition of projects and programs to determine if they are satisfying ecological and community needs compatibly. Adjust the operations or redesign existing projects or programs as needed.
3. Clearly define expected products, goods, and services at the State level, to provide a large-scale basis from which to apply local variations and additions.
4. As appropriate and feasible, coordinate State funding and support within watersheds and between programs to generate more focused, measurable results.
5. Align agency goals and methods more effectively to reflect coordinated approaches to resource management using watersheds as the unit of implementation and effectiveness measurement.
6. Provide easy access to technical information such as geographic information system layers, monitoring data, planning models and templates, and assessment techniques from multiple sources, which are useful at multiple levels of decision-making.
7. Conduct management activities in a manner, and within a context, that is consistent with watershed dynamics and characteristics.
8. Provide local land-use decision-makers with watershed education and information access to promote maintenance and improvement of watershed functions in local decision-making.
9. Develop and implement a process to streamline and fast track projects which meet the goals of the following Strategic Practice Recommendations.
10. Establish basis and means of assigning monetary values to the benefits gained as a result of implementing projects that meet the goals of the following Strategic Practice Recommendations.

### Strategic Practice Recommendations

11. Use a watershed approach to coordinate forest management, land use, agricultural land stewardship, integrated resources planning, and other appropriate resource strategies and actions.
12. Design and select projects with ecological processes in mind and with a goal of making the projects as representative of the local ecology as possible.
13. Increase precipitation infiltration into the soil to reduce surface runoff to a level that is typical of natural runoff retention patterns. This goal is often achieved by reducing impervious surfaces within a watershed. Retain intact floodplain and other wetlands, to the extent possible, to maintain or increase residence time of water in the watershed.
14. Place snow fencing strategically in small openings (e.g., in clear-cut tree harvest areas or high-elevation meadows) of 1.25 acres or less, to strengthen forest and watershed management and to facilitate slower snow melt and thus extend runoff into the summer, among other benefits. Particularly when positioned atop ridgelines adjacent to cliffs and ravines, snow fencing could

enhance snow mass accumulation. (For more information on the application and benefits of snow fences, refer to resource management strategy report, *Other Resource Management Strategies*.)

15. Decrease the amount of irrigated landscaping in the watershed and increase the use of native vegetation in landscaping and agricultural buffer lands.
16. Design appropriate wildlife migration corridors and biological diversity support patches within watersheds when planning fire-safe vegetation alteration.
17. Promote the installation and maintenance of stream flow gauges in major drainages.
18. Maintain and create habitat around stream and river corridors that is compatible with stream and river functions. Provide as much upslope compatibility with these corridors as possible.
19. Where practical, design drainage and stormwater runoff controls and treatment to maximize infiltration into local aquifers, and minimize immediate downstream discharges during runoff.
20. Regional water quality control boards and stormwater agencies should set a high priority on protection and improvement of water quality in domestic water supply reservoirs, especially in watersheds where geology precludes infiltration of stormwater.
21. Provide regionally appropriate, regular, and dependable educational materials to encourage water conservation, water reuse, and water pollution prevention.
22. Restore and preserve stream channel morphology to provide floodwaters access to the floodplain and to encourage stable banks and channel form.
23. Restore the characteristics and functions of native grasslands, woodlands, forests, and other wildlands.
24. Remove or control invasive weeds as a part of overall resource management efforts.
25. Protect soil resources and restore the functions of drastically disturbed soils, to slow runoff and increase rainfall infiltration.
26. Proactively address the recovery of special-status species, at both watershed and population scales, and incorporate measures to avoid future listing of other at-risk species.

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*Publications staff: Acronyms and abbreviations will be presented for each chapter individually. References for citations will appear within each chapter, as well. Use the lists below to create acronym tables for each chapter, generate tables of contents, and crosscheck information within the text.*

*Right-click in the field and then select "Update Field" and "Update Entire Table."*

**Table of Contents**

This is set up to generate a list of all text styled as "Update 2013 heading 1" through "Update 2013 heading 5." It can be modified to collect any styles you want. You may change what it gathers by selecting the line of text below; right-clicking; and choosing Edit Field, Table of Contents, Options.

Table of Contents.....	i
Tables.....	i
Boxes .....	i
Acronyms and Abbreviations .....	ii
<b>Watershed Management .....</b>	<b>1</b>
Watershed Management in California .....	1
Potential Benefits.....	2
Potential Costs .....	2
Willingness to Pay .....	4
Major Implementation Issues.....	6
Altered Hydrologic Cycles .....	6
Altered Nutrient Cycles .....	7
Life Cycles and Migration Patterns of Wildlife.....	8
Fire and Water .....	8
Climate Change.....	8
Adaptation.....	8
Mitigation.....	9
Links to other Resource Management Strategy Reports.....	9
Recommendations.....	10
Policy-Level Recommendations .....	10
Strategic Practice Recommendations.....	10
References.....	11
References Cited.....	11
Additional References.....	11

**Table Mentions**

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This is set up to generate a list of all text styled as "Update 2013 table title," (which may be used in this template for placeholders).

<p><b>Table 1</b> Typical List of Watershed Products, Goods, and Services..... 3</p> <p><b>Table 2</b> Estimates of Watershed Management Costs to Year 2030, from <i>California Water Plan Update 2005</i> and CALFED Program Estimates..... 5</p> <p><b>Table 3</b> Cost Estimate to Fully Implement the Strategy — Willingness to Pay ..... 7</p>
<p><b>Figure Mentions</b> This is set up to generate a list of all text marked as a figure mention, using the letter F as the table identifier.</p>
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