# Chapter 3 Current Conditions of Major Components and Processes

This chapter expands on the descriptions of the watershed history in Chapter 2 by examining the current human, physical, and biological conditions of the watershed. Human components include demographics; land uses, including mining and timber harvest; water use; and fire management. Physical components and processes include geology, hydrology, and climate. Biological components and processes include biological communities, unique biological resources, and game animals.

## 3.1 Human Components and Processes

For the purposes of this assessment, human components and processes are discussed in terms of the physical modifications that humans have made to the natural environment. Modifications to the landscape include construction of the transportation network; residential development, including urban and rural communities; mining; agriculture and ranching; forest management; and water resource management. These land uses shape and are shaped by the natural world in which they occur. Land ownership guided historic land use patterns and continues to guide development today.

Resource assessment and land management in the watershed are currently based on several local, state, and federal management plans. As discussed in the Section 2.3, *Evolution of Laws and Regulations Affecting the Watershed*, resource assessment and planning on federally owned lands in the watershed are a matter of jurisdiction. The STNF LRMP directs land management for USFS land; the BLM Redding Land Management Plan directs land management for BLM land; and the U.S. Army Corps of Engineers Flood Control Manual dictates how the Bureau of Reclamation manages Shasta Dam. California State Park legislation and regulations provide guidance for land management of most state lands in the watershed, and other state land is managed in accordance with CDFG’s Lands Program. County and city general plans direct development and land use on private lands in the watershed. These local plans are prepared in accordance with state regulations.

### 3.1.1 Human Communities, Demographics, and Transportation

Chapter 2 provided the context for the ways land use, topography, and biological resources affected the rise and fall of communities in the watershed. Several of these communities are still thriving and have grown together to form larger communities, particularly around Mount Shasta. In contrast, many of the historic mining communities and settlements in the river canyon have disappeared as changes occurred in land use and transportation networks, leaving behind only remnants of past inhabitance. Pieces of old mining equipment, building foundation remnants, and fruit trees provide visible evidence of past communities in the watershed.

## Communities

Communities in the watershed tend to be clustered at the base of Mount Shasta and along the major transportation corridors. Communities in the watershed include the City of Mt. Shasta and outlying residential development, the city of Dunsmuir and outlying residential development, Castella, Lakehead, and Lakeshore. In addition to these communities, several privately owned residential parcels are located in isolated parts of the watershed. These residences are typically located in secluded mountain settings and along the Sacramento River.

## Demographics

The population of the watershed has increased over the years, but remains relatively low and sparse compared to populations in the rest of the state. The total population for the watershed is approximately 11,000, with the majority of the people living within a 25-square-mile radius at the base of Mount Shasta (Shasta County 1998, U.S. Census 2000, PMC 2007).

Approximately 7,300 people live in the community of Mt. Shasta, 3,621 within the city limit and 3,670 in the adjacent unincorporated area (PMC 2007). The community of Mt. Shasta is perched above the Sacramento River canyon between the base of Mount Shasta and the Eddy Mountains. Dunsmuir, the next largest community in the watershed with approximately 2,000 people, is the northernmost community in the river canyon (U.S. Census 2000).

The Shasta-Siskiyou county line is located immediately south of Dunsmuir. The population estimate for the Shasta County portion of the Sacramento River canyon is a little over 1,700 (Shasta County 1998). Castella and Sweetbriar are two small mountain communities 6 and 9 miles south of Dunsmuir and adjacent to Castle Crags State Park. The communities of Lakehead and Lakeshore are located at the north end of the Sacramento River Arm of Shasta Lake, 20 miles south of the other river canyon communities. The population of these neighboring reservoir communities is approximately 550 (U.S. Census 2000).

Populations fluctuate seasonally in all of these communities. This is evidenced by the number of second homes and the amount of outdoor recreational use in the watershed, including hiking, boating, fishing, and skiing.

## Land Use

Land ownership has guided historic and current land use patterns in the watershed. A large portion of land in the watershed is federally owned forest land managed by the STNF (Figure 3.1-1). The STNF manages land for multiple uses, including timber harvest, recreation, and wildlife values. Five broad categories of land use apply to the STNF lands in the watershed: Congressionally Reserved Areas, Late Successional Reserves (LSR), Administratively Withdrawn Areas, Riparian Reserves, and Matrix (Figure 3.1-2) (U.S. Forest Service 1995). Standards and guidelines are imposed for each of these land uses. Lands designated as Riparian Reserve, for example, have specific management standards and guidelines for air quality, biological diversity, fire and fuels, etc.

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Figure  3.1-1.  Land Ownership

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Figure 3.1-2.  Land Use Planning Jurisdictions

Table 3.1-1 describes each STNF land use in the watershed. Most of these lands (approximately 225,500 acres) are designated as Matrix. These lands are managed primarily for timber harvest, wildlife, and recreation values. Portions of STNF managed as Wilderness and National Recreation Area include the Castle Crags Wilderness (approximately 14,700 acres) and the Whiskeytown-Shasta-Trinity National Recreation Area (NRA) (approximately 32,300 acres). Specific planning guidance for the NRA is provided in the *Shasta and Trinity Units, Whiskeytown-Shasta-Trinity National Recreation Area Management Guide*.

**Table 3.1-1. STNF Land Use Designations in the Watershed**

| LAND USE DESIGNATION | DESCRIPTION OF LAND USE |
|---|---|
| ***National Forest Lands*** | |
| Matrix | Mixed use. Most timber harvest would occur on these lands. Standards and guidelines are in place to ensure appropriate conservation of ecosystems as well as provide habitat for rare and lesser-known species. |
| Late-Successional Reserves | Established to protect and enhance conditions of late-successional and old-growth forest ecosystems and to ensure the support of related species, including the northern spotted owl. |
| Administratively Withdrawn Areas | Recreation and visual areas, backcountry, and other areas where management emphasis precludes scheduled timber harvesting. |
| Riparian Reserves | Provide an area along streams, wetlands, ponds, lakes, and unstable and potentially unstable areas where riparian-dependent resources receive primary emphasis. |
| Congressionally Withdrawn | Wilderness areas where management emphasis is on enhancing the natural conditions for wildlife habitat and non-motorized recreation. Timber harvest is precluded. |
| ***Bureau of Land Management Lands*** | |
| Interlakes Special Recreation Management Area | Multiple land uses permitted that are compatible with motorized and non-motorized outdoor recreation. |
| ***Private Lands in Siskiyou County and Shasta County*** | |
| Residential | Low-density to high-density residential areas generally encompass lands with access to community water, sewer, and utility services. Rural Residential areas encompass lands that receive minimal community services, and are usually within or near a rural community center. |
| Agricultural | Land identified as suitable for cropland and ranchland. |
| Commercial | Land identified for development with commercial business operations. |
| Resource | Land identified as containing valuable natural resources, including timber, minerals, and conservation values (e.g., wildlife habitat, water resources, or scenic value). |

**Table 3.1-1. STNF Land Use Designations in the Watershed**

| LAND USE DESIGNATION | DESCRIPTION OF LAND USE |
|---|---|
| Public Facilities | Land publicly owned by county or city, including parks, nature preserves, community centers, educational facilities, and infrastructure maintenance facilities. |
| Industrial | Land identified for light to heavy industrial uses, such as manufacturing operations. |

BLM manages a small portion of the watershed near Shasta Lake west of Backbone Ridge. These lands consist of several sections (i.e., 620-acre tracts) located in a patchwork of private, STNF, and BLM ownership. This area is managed in accordance with the *Interlakes Special Recreation Management Area* (Bureau of Land Management 1993). Land in this area is managed for multiple uses, including motorized recreation, timber harvest, wildlife habitat, scenic viewshed, and mineral development.

The California State Parks agency manages Castle Crags State Park, which covers about 4,000 acres of the watershed. This land is protected from development and is managed for resource preservation and non-motorized outdoor recreation.

Private land uses in the watershed include timber harvest, residential, agricultural, industrial, and commercial development. Land uses on private lands are guided by the city and county general plans. Each county and city in the watershed is required by state law to adopt a General Plan to guide the physical development of private lands in the area. Each General Plan has a Land Use Element section that defines the types of land uses allowed in the area.

## Transportation

Development and maintenance of transportation infrastructure continues to affect the watershed from both an ecological and a land-use perspective. I-5 and the Union Pacific Railway remain the major north-south transportation corridors. These transportation corridors generally run parallel to one another, with the railroad tracks immediately adjacent to the Sacramento River through much of the canyon.

As Chapter 2 describes, as the mode of mass transportation changed along with the nature of the road that became I-5 and the vehicles travelling along it, community development patterns followed. The raised construction of the interstate highway visually disconnects drivers and passengers from the river below and connects them to the surrounding mountains instead. At the same time, increased fuel efficiency and decreased travel time decreased the need for the private guesthouses that had developed throughout the river canyon to accommodate travelers.

## 3.1.2 Mining

### Mineral Resources

As described in Section 2.2.3, *Mining*, mineral resources played a significant role in the history of the watershed, and mining activity continues to occur in several locations. The Siskiyou County and Shasta County general plans describe the region as rich in mineral resources. However, the quality of minerals, the total area being mined, and the number of operations are greatly reduced from historic levels both regionally and within the watershed.

The STNF Minerals Specialist describes current mineral resources in the watershed as "spotty" (Van Susteren 2010), and depletion of the easily accessible mineral resources in the watershed is well documented (e.g., copper, silver, and gold) (Chapter 2).

The California Geological Survey (CGS) has not identified the presence and significance of mineral deposits in Shasta or Siskiyou counties (Kohler 2002). The CGS designates Mineral Resource Zones (MRZ) throughout the state in accordance with the California Surface Mining and Reclamation Act of 1975 (SMARA) (see Section 2.3, *Evolution of Laws and Regulations Affecting the Watershed*). The lack of MRZ designations in the region is likely attributable to the rural demographic rather than a complete lack of important minerals.

### Mining Activity in the Watershed

Several factors have contributed to the decline of mining in the watershed, including the accessibility of minerals, the cost of developing the mineral resources, and court orders. Existing mining activity in the watershed is limited to two permitted commercial operations and small-scale recreational gold mining. The Spring Hill Mine, owned by Sousa Ready Mix, is located in the City of Mt. Shasta. This aggregate operation is located on private land in the Spring Hill area adjacent to I-5 (PMC 2007). Stone and cinder are excavated and used for aggregate and concrete production. An underground gold mine is permitted to operate in the STNF at Pollard Flat, adjacent to the Sacramento River (Van Susteren 2008). This tunnel claim is worked intermittently (Van Susteren 2010). STNF is currently reviewing a proposal to operate a placer gold mine at Pollard Flat. The proposed operation would disturb approximately 1 acre of surface lands. Another gold mine may open in 2010 on the STNF across the river from the existing underground gold mine. A permit application is currently under review by the STNF (Van Susteren 2010).

Despite the spotty nature of the mineral resources remaining in the watershed, mining claims cover the majority of the Sacramento River and its tributaries, including several claims above Siskiyou Lake. In recent years, speculators claimed much of the river and sold the claims to hobby miners via the internet. These claims were intermittently worked by suction dredges in the summer months until a court order required CDFG to suspended all suction dredge mining permits in 2009 (California Department of Fish and Game 2010, Van Susteren 2010). The moratorium on instream dredge mining is in effect until CDFG completes environmental review of the permitting program and updates applicable regulations accordingly (estimated to occur in late summer 2011).

No permitted mines operate in the NRA (Office of Mine Reclamation 2000, Van Susteren 2008). Federal lands in the NRA, except those with valid existing rights, were withdrawn from mineral entry by the legislation that created the NRA. BLM and the USFS conducted validity determinations on most of the existing claims and contested the majority of them based on the absence of a valid discovery. There are five claims in the NRA that predate the withdrawal. The lands covered by these claims remain open to mineral leasing, but there are no approved operating plans for these claims. Hard rock minerals in the NRA are available for prospecting, exploration, and development under solid mineral leasing regulations (36 CFR Subpart 3583). Authorization for this land use requires permits and leases subject to USFS terms and conditions to protect the values of the NRA.

The historic Balakala, Keystone, and Mammoth Complex mines of the West Shasta Copper-Zinc Mining District and the Bully Hill Mine of the East Shasta Copper-Zinc Mining District are undergoing active remediation (Office of Mine Reclamation 2000).

It is possible that other small mining activities occur in the watershed. The State of California does not regulate mining operations that produce less than 1,000 cubic yards of material. Additionally, gold panning for recreation is also not regulated by the state or federal governments.

### 3.1.3 Agriculture and Ranching

Agriculture and ranching occupy much of the valley and foothill areas of Siskiyou and Shasta counties; however, these activities are limited in the watershed because of the steep mountainous terrain, federal land designations, and historic development patterns. Currently, there are no grazing allotments on federal lands in the watershed. The last grazing allotment in the watershed, the Bear Creek allotment, was recently eliminated. A portion of the allotment remains, but is located within the Shasta watershed. There are no grazing permits authorized for the Shasta Unit of the NRA, primarily because of a lack of suitable range. No grazing occurs on state lands in the watershed.

Several small- and medium-sized farms and cattle ranches operate on the outskirts of the City of Mt. Shasta and the NRA. Farms and ranches in the watershed are primarily family owned and operated (Shasta County 1998). In Shasta County, the number of farms has been slowly increasing since 1969, while the average farm size decreases (Shasta County 1998). A similar trend is reported in Siskiyou County, where historic ranches have been subdivided into smaller “ranchettes.” Cattle from private lands occasionally wander into the NRA around Shasta Lake, where much of the private land is designated as Open Range (Van Susteren 2010).

### 3.1.4 Timber Resources Use

#### Timber Management

Timber management, otherwise known as forestry, is a specialized form of agriculture in which the crops take decades to mature for harvest. Over the last 40 years, public policy has had a direct bearing on forest management at both the national level and local level. As described in Chapter 2, a number of federal and state forest management policies have been enacted over the last century, the goal of which was to encourage forest management practices that would yield sustainable, healthy forest ecosystems. Two recent federal statutes in particular have arguably had the greatest impact on the management of federal forests: the Northwest Forest Plan (NWFP) (1994) and the Healthy Forests Restoration Act (HFRA) (2003). These policies are described in detail in Section 2.3, *Evolution of Laws and Regulations Affecting the Watershed*.

## Forest Vegetation

Throughout the western United States, a century of fire suppression and logging has left forestlands fire prone and has put forest health at jeopardy. Such is the case in much of the upper Sacramento River watershed as well.

The watershed forests exhibit a variable response to disturbance from fire or logging. Some stands regenerate quickly through natural processes, while others are prevented from naturally regenerating to original densities due to competition from pioneer early seral species. Many decadent shrublands that formed following historic wildland fires have not naturally regenerated to conifer tree types (USDA Forest Service 2001b). Some of these shrublands are now mature and over mature and are vulnerable to stand-replacing fire (USDA Forest Service 2001b). Additionally, within the upper Sacramento River headwaters watershed, there has been a general species composition shift in many mixed-conifer stands to more shade-tolerant white fir (USDA Forest Service 2001b). There has been a significant reduction in the old-growth forest age class, and the amount of moderate and dense canopy closure stands have been reduced (USDA Forest Service 2001b). The density of some of the white fir stands near the watershed’s headwaters has now reached levels that exceed the capability of the site to support, and mortality has begun a natural thinning process (USDA Forest Service 2001b). As vegetation growth and mortality in these dense stands continues to increase, the risk of a stand-replacing wildfire also increases. However, management practices derived from policies such as those set forth by the NWFP and HFRA are being used to improve forest sustainability.

Insects and disease pathogens are common in the watershed. Overcrowded, decadent stands, particularly those experiencing drought stress, are at greatest risk of attack. Most of the organisms are host-specific, causing mortality, top-kill, dieback, defoliation, or structural weakening. These processes can create snags, downed logs, defects, and small openings within a stand. In general, the native insects and pathogens present in the watershed cause small-scale disturbances, not catastrophic effects (USDA Forest Service 2001b).

One non-native pathogen, *Cronartium ribicola*, has spread throughout the entire United States; this pathogen is widespread throughout the watershed area. This introduced pathogen targets white pine (*Pinus monticola*) and sugar pine, among others. Sugar pine has exhibited some resistance to infection in areas outside the watershed, but, currently, no resistant trees have been identified in the watershed itself or in the range in which white pine blister rust is capable of breeding in the watershed (USDA Forest Service 2001b).

The watershed contains several populations of Port-Orford-cedar (Figure 3.1-3), a species known for its versatile wood. Active restrictions to prevent the spread of the root disease *Phytophthora lateralis* (USDA Forest Service 2001b) have been applied to areas in the watershed where Port-Orford-cedar stands are located. The disease is easily spread by waterborne spores and the movement of moist soils that contain the spores (USDA Forest Service 2001b). Active restrictions are designed to limit the movement and activities of vectors, principally humans, and include closing roads to travel, requiring dry season harvesting, and cleaning of all vehicles before they leave infested areas or enter clean areas. In addition, specific measures to contain infestations have occurred on land managed by the USFS.

Port-Orford-cedar root disease was discovered within the Shasta-Trinity National Forest at Scott Camp Creek in 2001. This is the only known Port-Orford-cedar root disease infestation on the Shasta-Trinity National Forest. Girdling of the infected Port-Orford-cedar took place in 2003. USFS personnel came back twice in 2005 and re-girdled with much deeper cuts to make sure the job was completely effective. Since 2006, monitoring has continued and no new infections have been found. Additionally, baiting with Port-Orford-cedar seedlings has tracked the decline of *P. lateralis* on the site (1 PL positive in 24 baits in 2008; 0 PL positive in 25 baits in 2009).

In the mainstem of the Sacramento River, outside the boundary of the Shasta-Trinity National Forest, the Port-Orford-cedar root disease was first discovered by Greg DeNitto and Dave Schultz near the I-5 Conant Road exit in 1995. In a survey of Port-Orford-cedar and root disease on the Sacramento River from 2000-2002, researchers found that the furthest downstream Port-Orford-cedar was a single tree north of Pollard Flat on a gravel bar on the east shore of the Sacramento River. Groups of Port-Orford-cedar became more common upstream (north) from there. The survey identified 10 separate infestations of Port-Orford-cedar root disease along the main stem of the Sacramento River. The furthest south infestation was near the mouth of Shotgun Creek, and the furthest north was at Shasta Retreat, north of Dunsmuir. The number of Port-Orford-cedar affected at each site varies.

For more information on Port-Orford-cedar, see Section 3.3.3 *Biotic Communities in the Watershed*.

Table 3.1-2 summarizes the most common current vegetative conditions occurring on the watershed's federal forestlands, including the causal mechanism and anticipated future trends.

**Table 3.1-2. Forest Health Conditions**

| EXISTING CONDITION | CAUSAL MECHANISM | FUTURE TRENDS |
|---|---|---|
| Less than 5 percent old-growth within the watershed. | Historic logging and stand-replacing fire removed much of the old-growth component. | Allocation of Late Successional and Riparian reserves should create old-growth stands on approximately 20 percent of the watershed within the next century. |
| Overstocked stands that are susceptible to stand-replacing fire and insect and disease attack. | Exclusion of wildland fire since aggressive suppression actions started in early to mid 1900's. | Continued aggressive suppression actions and development of overstocked conditions. Increasing potential for stand-replacing fires. |
| Plantations dominated by ponderosa pine and not representative of adjoining mixed conifer type. | Reforestation following logging and shrubland conversions that used ponderosa pine as the preferred species. | Continued use of ponderosa pine as the dominant species in reforestation of shrublands. |
| Shrublands that have not advanced to early seral stage conifer forests. | Historic logging and stand-replacing fires during both historic and prehistoric times. | Older shrublands continue to occupy sites that could support forested communities. Some development of conifer tree cover, mostly shade-tolerant white fir. Increasing potential for stand-replacing fires. |
| Build-up of natural fuel, both live and dead, that exceeds desired future conditions. | Exclusion of wildland fire since aggressive suppression actions started in early to mid 1900s. | Continued aggressive suppression actions and build-up of live and dead fuels. Increasing potential for stand-replacing fires. |

Source: USDA Forest Service (2001b)

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Figure 3.1-3 Port-Orford-Cedar Locations

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## Timber Harvest

The upper Sacramento River watershed contains approximately 261,100 acres of forested lands (USDA Forest Service 2008a). Timber is commercially harvested at varying scales, often in conjunction with fuels management activities, throughout the watershed. Commercial timber species in the watershed include ponderosa pine, Jeffrey pine (*Pinus jeffreyi*), Douglas-fir, white fir, sugar pine, western white pine, red fir (*Abies magnifica*), lodgepole pine (*Pinus contorta*), and incense cedar (*Libocedrus decurrens*). Port-Orford-cedar is also found at the fringes of some perennial streams and wet meadow areas (USDA Forest Service 2001b). The mix of species varies with elevation, aspect, and soil type (USDA Forest Service 2001b). Noncommercial forestlands in the watershed typically support stands of chaparral, knobcone pine, gray pine (*Pinus sabineana*), and hardwoods, including black oak (*Quercus kelloggii*) and live oak (*Quercus* spp.). Such lands are almost entirely non-federal, falling under state, county, or private ownership (USDA Forest Service 2001b).

### *Private Lands*

On private lands in the watershed, parcels that have been zoned to restrict their use to the growing and harvesting of timber and compatible uses are designated as Timber Production Zones (TPZ) (Shasta County 2004). Such lands may be used for growing of forest products and compatible uses only, and property taxes for these lands are based on these limited uses (Shasta County 2004). Siskiyou County also designates private lands used for timber production as TPZs. In both counties, the purpose of the TP zoning district is to preserve lands devoted to and used for growing and harvesting timber and to provide for uses compatible with the growing and harvesting of timber. In both counties the TP district is equivalent to the timberland production zone (TPZ) referred to in the California Timberland Productivity Act of 1982; land within a TP district is subject to all conditions and restrictions applicable to a TPZ under the act.

Large-scale private landholders in the watershed, such as Roseburg Resources Company and Sierra Pacific Industries, manage their holdings as commercial forestland. Management objectives for such lands are based on sustainable forestry and landscape practices. Private commercial timberland management decisions are tied to regional trends in population growth, diversifying economies, and to some degree by public expectations of how these lands ought to be managed.

Active forest management practices, such as thinning and understory brush removal, are routinely employed by these companies as a means of reducing potential loss of merchantable timber to wildfire. Other pre-emptive actions taken by these companies might include:

- The creation of shaded fuel breaks, or defensible space, through thinning, typically along ridges, near towns/communities, and along major roads.
- Routine removal of ladder fuels.
- Actively cooperating with nearby communities and agencies to make fire awareness a community issue.

### *Public Lands*

Most timber management activities on public lands in the watershed occur within the STNF's Matrix land allocation, Late Successional Reserves (LSR), and Managed Late Successional Areas (MLSA) (USDA Forest Service 2001b). As a result of passage of the NWFP, the Record of Decision on Management of Habitat for Late-Successional and Old-Growth Forest Related Species within the Range of the Northern Spotted Owl (USDA Forest Service and USDI Bureau of Land Management 1994) established a network of LSRs and MLSAs in order to (1) provide old-growth forest habitat, (2) provide for populations of species that are associated with late-successional forests, and (3) help ensure that late-successional species diversity will be conserved on federal lands (USDA Forest Service 1999a). All, or part, of three designated LSRs (Eddy, Deer, and Wagon) and one MLSA (Castle Lake) are located in the portion of the STNF within the watershed. The management objective within the LSRs is to protect and enhance conditions of late-successional forest ecosystems, which serve as habitat for late-successional and old-growth related species, including the northern spotted owl (USDA Forest Service 1995, 1999). Similarly, MLSAs are intended to maintain and enhance late-successional forest ecosystems that are not only areas of potential habitat, but are areas that have been identified as owl activity centers (USDA Forest Service 1995). Figure 3.1-4 shows the locations of LSRs and MLSAs in the watershed. These areas account for approximately 38,780 acres of the timbered watershed.

Matrix lands consists of lands on which most timber harvest will occur and where standards and guidelines are in place to ensure appropriate conservation of ecosystems as well as provide habitat for rare and lesser known species. Vegetation is managed on Matrix lands to maintain forest health and provide a sustained supply of forest products, whereas the objective of management actions taken on LSR and MLSA lands is to protect and enhance the conditions of late successional and old-growth forests.

In mixed conifer stands, the stand composition objective is to increase the percentage of pine and Douglas-fir to be more representative of historic conditions (USDA Forest Service 2001b). The age stand class diversity objective is to increase the percentage of late successional and old-growth forests to represent more historic levels (USDA Forest Service 2001b). This objective is mandated by the allocation of LSRs, Riparian Reserves (e.g., the Sacramento River), and Congressionally Withdrawn Areas (i.e., the Castle Crags Wilderness) in the watershed (USDA Forest Service 2001b).

Priority silvicultural objectives and treatments for forested Matrix lands are:

- Ensure that existing plantations become established at required stocking levels and have a mix of species that represent natural stand composition. Treatments will include release, thinning, and interplanting.

- Ensure that stocking levels maintain forest health. In overstocked stands, the treatment would be thinning and uneven-age management. In understocked stands, the treatment would be site clearing and interplanting.

- Restore previously forested lands that have converted to shrublands as a result of wildland fire or other natural disturbance. Treatment would be site clearing and planting.

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Figure 3.1-4 Locatio**ns of Late Successional Reserves and Ma**naged Late Successional Areas

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- Obtain a representative mix of conifer tree species in the mixed conifer zone. Treatments will be group selection and regeneration harvest and site clearing for natural and artificial reforestation.

Silvicultural treatments in LSRs and the MLSA include thinning and prescribed fire, but any such actions are subject to comprehensive environmental review and will be guided by the objective of maintaining adequate amounts of suitable old-growth habitat. The age and structure of timber stands protected under an LSR or MLSA designation reduces the amount of suitable harvestable timberland in the watershed.

Following the guidance of the NWFP and HFRA, among other federal and state statutes related to timber management, the USFS developed and has begun implementing an annual program of fuels reduction projects, giving priority to at-risk communities that have developed wildfire protection plans. The fuels management actions that have recently been completed or are currently proposed in the watershed, as of the date of this document (USDA Forest Service 2007c, 2007b, 2007a, 2008c), include:

- **Deer Creek Timber Stand Improvement—**a pre-commercial thinning, pruning, and brush mastication project proposed on approximately 700 acres of conifer tree plantations located approximately 5 miles west of the City of Mt. Shasta. The objective is to create an approximately 1.0-mile-long shaded fuel break along Rainbow Ridge.

- **Elmore Mountain Hazardous Fuels Project**—a hazardous fuels reduction and wildlife habitat improvement project proposed for the Elmore Mountain area in the Whiskeytown–Shasta-Trinity NRA, approximately 2 miles south of the community of Lakeshore.

- **Mt. Shasta Plantation Maintenance Project**— a pre-commercial thinning, pruning, and brush mastication project conducted on approximately 5,000 acres of conifer tree plantations. Completed 2007.

- **Lakehead Fuel Hazard—**a fuels treatment project in the Wildland-Urban Interface (WUI) adjacent to the community of Lakehead. Completed 2007.

- **North Shore/Rainbow Ridge Shaded Fuel Break—**creation of a shaded fuelbreak approximately 150 feet on either side of the North Shore Road and Rainbow Ridge. Included removal of brush and some trees less than 10 inches in diameter, and the burning of piles of brush and cut trees. Area is approximately 60 acres total. Completed 2007.

### *Reforestation*

Natural and human-caused disturbances in California's forests make reforestation an essential element of forestry management. The dry summer climate and abundance of volatile vegetation—conditions that are common to the watershed—ensure that wildfire will occur at some time in the forest. Other natural events that can significantly change the forest structure and that have been known to occur in the watershed include windstorms, insect and disease attacks, floods, and mudflows in the headwaters region around Mt. Shasta. In the wake of such events, reforestation is commonly used to restore the forested values desired by the public. Planting new trees that are suited to the environmental conditions found in the watershed (e.g., soils, precipitation amounts), and that are able to survive exposure to full sunlight, may be necessary to ensure reestablishment of the forest. As many as 500 trees per acre may be planted in a disturbed area in a manner similar to agricultural row crops. It is important to note that not all plantations have been created following disturbance; instead, some plantations, such as some of those adjacent to the Everitt Memorial Highway, were established in an effort to convert brush fields to forests (Bachman personal communication). Over time, these “plantation” stands require thinning to allow adequate growing space for trees, reduce crowding, and minimize the chance of loss to wildfire. Larger trees can eventually be thinned to produce commercial products. No publicly available data that accurately characterizes the extent of private plantations in the watershed could be located for incorporation into this assessment.

#### ***Economic Implications***

Since the early 1990s, the contribution of National Forests to regional timber supplies across the state of California has declined sharply (U.S. Department of Agriculture 1994). Passage of the NWFP was intended to restart the commercial logging industry, which was slowed in the 1980s and early 1990s by federal court injunctions. These injunctions held that the USFS and the BLM had failed to consider adequately the effects of timber sales on species associated with old-growth forests in the Pacific Northwest, of which the upper Sacramento River watershed is a part. In the watershed, commercial timber harvest on public lands has been minimal, primarily limited to fuels management actions. Timber sales that have occurred in the watershed since 1990 are shown on Figure 3.1-5. The Shasta Lake West Watershed Assessment (USDA Forest Service 2000), which covers lands primarily within the upper Sacramento River watershed, states that no commercial logging had occurred on public lands in the 10 years prior to its issuance. Timber harvesting and its associated byproducts continue to maintain an important role in the region. However, changes in utilization levels (i.e., harvested volumes) and the type of wood products now available (often smaller diameter logs suitable for biomass or small saw logs) have led to a shift in the economic base of some communities in the watershed and a refocusing of goods and services marketed to both residents and visitors to the area. In the watershed, recreational opportunities (described in Section 3.1.6, *Recreation and Tourism*) have surpassed timber production to become a primary driver of the local economy.

#### Conclusions

The establishment of LSRs, the MLSA, and the focus on fuels management and forest health means that a higher percentage of merchantable timber harvested from the watershed will be as biomass and small-diameter saw logs. The USFS and others manage their lands for multiple uses and for the protection of communities against catastrophic wildfire. Local economies, once heavily associated with timber production, will continue to find new markets based on the many uses of lands in the watershed, such as recreation. Future trends in forest management within the watershed are discussed in Chapter 5

### 3.1.5 Water Resources Utilization and Infrastructure

As discussed in Section 2.2.6, *Water Resources and Infrastructure*, Shasta Dam and Box Canyon Dam and the reservoirs created by them are the most prominent water supply/flood control

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Figure  3.1-5	Timber Sales Since 1990

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infrastructure features present in the watershed and have directly and indirectly induced significant changes in the landscape.

## Shasta Lake and Shasta Dam

The Sacramento River is the largest river system in California and accounts for an average annual discharge of 21.6 million acre-feet (af) into the Sacramento/San Joaquin River Delta. The Sacramento River watershed upstream from Shasta Lake has an area of about 6,420 square miles. Water from the river provides water supplies for agricultural, municipal, and environmental needs as well as flood control throughout the Central Valley of California. The Bureau of Reclamation's Central Valley Project (CVP) controls the hydrology of the Sacramento River in the Shasta County area. Shasta Dam is the CVP's dominant feature, with a current storage capacity in Shasta Lake of 4.5 million af. In addition to altering flood flows in the Sacramento River, Shasta Dam has changed the seasonal hydrology of the river by storing water during the wet season and releasing water later in the year. Flow releases are scheduled on an annual basis to meet flood control requirements and scheduled agricultural deliveries as well as to help meet the needs of aquatic species listed under the federal and state endangered species acts.

Although its primary function is water storage, Shasta Lake has evolved into a significant recreation destination and is managed as such by the USFS and other landowners having property adjacent to the lake. The USFS's Shasta Unit of the Whiskeytown-Shasta-Trinity NRA oversees management of most federal lands around the lake, including the reach of the Sacramento River Arm that extends upstream to the community of Lakehead. Shasta Lake is a significant economic base for many businesses in the watershed.

Currently, a proposal to enlarge the storage capacity of Shasta Lake is being considered. The primary objectives for the proposed increased storage capacity are to: (1) enhance the restoration of anadromous fish populations in the Sacramento River, primarily upstream from the Red Bluff Diversion Dam and (2) increase water supplies and water supply reliability for agricultural, municipal and industrial, and environmental purposes to help meet future water demands. Secondary objectives associated with the proposed dam raising are to: (1) preserve and restore ecosystem resources in the Shasta Lake area and along the upper Sacramento River, (2) reduce flood damage along the Sacramento River; (3) develop additional hydropower capabilities at Shasta Dam, and (4) preserve outdoor recreation opportunities at Shasta Lake (Bureau of Reclamation 2006).

## Lake Siskiyou and Box Canyon Dam

Before it reaches Shasta Lake, flow in the upper Sacramento River is supplied by numerous streams and rivers. Eight significant drainages—the south, middle, and north forks of the Sacramento River; Scott Camp Creek; Castle Lake Creek; Wagon Creek; Big Springs Creek/Cold Creek; and Cascade Gulch—convey runoff from Mount Shasta into Lake Siskiyou, a 430-acre reservoir created in 1968 with the building of Box Canyon Dam (SHN Consulting Engineers & Geologists 2004). Upstream of the dam, flows are unregulated and are affected only by direct precipitation and runoff from rainfall and snowmelt (SHN Consulting Engineers & Geologists 2004). The reservoir is fed by the high-elevation snowpack that often persists into the early summer months and by subsurface flows of water from Mount Shasta, which maintain perennial flows in the watershed's significant drainages. The outfall from numerous high-elevation lakes in the mountains surrounding Lake Siskiyou also contributes to the reservoir's level and ability to produce continuous flow in the upper Sacramento River. The largest of these lakes are Toad, Castle, Gumboot, Cedar, Cliff, Gray Rock, and Timber lakes.

Use of water in the upper Sacramento River for the production of hydroelectric power was first explored in 1952 by the California-Oregon Power Company, which subsequently determined that such a project would not meet its requirements (SHN Consulting Engineers & Geologists 2004). In 1957, the California Department of Water Resources identified the Sacramento River headwaters area west of Mount Shasta as a possible reservoir site. Further feasibility studies and site investigations ultimately led to the construction of Box Canyon Dam and the creation of Lake Siskiyou. At a height of 209 feet, Box Canyon Dam provided an excellent opportunity for Siskiyou County to generate limited hydroelectric power under a Federal Energy Regulatory Commission (FERC) exemption, through Pacific Power and Light (SHN Consulting Engineers & Geologists 2004). The power generation facility is operated by Synergistics Corporation and is licensed to supply a maximum of 5 megawatts of power (SHN Consulting Engineers & Geologists 2004). Siskiyou County receives an annual revenue of $500,000 from Synergistics, regardless of the amount of power generated (SHN Consulting Engineers & Geologists 2004).

Because recreation is a primary use of Lake Siskiyou and outflows are critical to the maintenance of lake levels and continuous flow in the upper Sacramento River below the dam, lake levels are maintained at or near full pool year-around. Both the lake and the dam are located on county-owned lands. The Siskiyou County Flood Control and Water Conservation District (part of the county's Public Works Department) administers lands around the lake to provide opportunities for public and private development (through leases) for recreational purposes.

## Community Water Systems

In addition to the many domestic water systems that are scattered throughout the watershed, a number of local community and city water systems are also either partially or fully dependent on water derived from the watershed. These include the following:

- Lakeshore Heights Mutual Water Utility
- City of Redding
- City of Shasta Lake
- Bella Vista Water District
- Centerville Community Services District
- Mountain Gate Community Services District
- Dunsmuir City Water Department
- Lake Siskiyou Mutual Water Company
- Crag View Community Service District
- City of Mt. Shasta
- Bridge Bay Resort
- Shasta Dam Public Utilities District

There is no formal agreement with these users regarding watershed management; however, water quality for these domestic uses must meet state objectives (USDA Forest Service 1995).

## Commercial Water Development

Long recognized for its purity and quality, bottled drinking water from the Mount Shasta area has become a profitable and somewhat controversial use of the water resource. The short- and long-term effects of bottling plant intake on the groundwater supply are unknown. Currently two commercial plants, Mt. Shasta Spring Water and Aquapenn Spring Water, operate in the upper Sacramento River watershed.

## Economic Implications

Recreation and tourism are two of the primary drivers of the watershed’s local economy. Many businesses and communities have shifted their economic base away from that of logging and forest products to take advantage of the economic opportunities afforded by the region’s abundant recreational and scenic qualities. The creation of Shasta Lake and Lake Siskiyou, for example, attracts large numbers of visitors annually who contribute significantly to local economies. As described previously, the maintenance and potential growth of a number of local community and city water systems are dependent on water available in the watershed.

Shasta Dam is the cornerstone of the CVP. Agricultural production in the Central Valley relies in large part on water supplied by the Sacramento River watershed system. Similarly, numerous communities throughout the Central Valley also draw their municipal water supplies from water stored in Shasta Lake. The system of water storage that has been created in the watershed (i.e., Lake Siskiyou/Box Canyon Dam, Shasta Lake/Shasta Dam) is also critical to fish and wildlife. Although the construction of Shasta Dam significantly altered the historic range of anadromous fish in the upper Sacramento River, outflows are used to maintain anadromous fisheries and wildlife habitat downstream, subsequently contributing to local economies throughout the Sacramento River system. In addition, flood control associated with the dams and lakes within the watershed serve to protect downstream communities and properties from catastrophic flooding.

The proposed raising of Shasta Dam would have both long- and short-term economic implications. It is anticipated these implications would be fully assessed during the planning phase of the project.

The commercial development of groundwater resources in the watershed is a use of water that has created jobs and contributes to the local economies of the City of Mt. Shasta and Dunsmuir. However, the long-term effects of such use on the aquifer(s) are unknown.

## Conclusions

The water resource infrastructure that has been created in the watershed is not only locally significant, but is also critical to the state’s economy. Shasta Dam is the cornerstone of the CVP. Its interrelationship with Box Canyon Dam, which provides flood control in the upstream portion of the watershed, and Shasta Lake, which allows for the storage of a large portion of the water needed to meet the demands of the Central Valley’s agricultural producers and communities, is critical to the state and local economies. The importance of the water infrastructure in the watershed itself is reflected in the region’s increased commercial and residential development over recent years, which is tied to community and city water developments and the abundant recreational and tourism opportunities that it affords. Factors that influence the biological integrity of the watershed are discussed in Chapter 4.

## 3.1.6 Recreation and Tourism

The Shasta Cascade area is described and promoted as an "outdoor recreation wonderland" (California Travel and Tourism Commission; and California Business Transportation and Housing Agency, Division of Tourism 2006). In the upper Sacramento River watershed, there are abundant opportunities for tourists and local residents to enjoy such activities as fishing, hunting, camping, boating, cycling, skiing, and mountaineering. These recreational activities promote a healthy lifestyle and are important industries that feed the local economies.

### Recreational Activities

Across California, the tourism industry is an important economic driver for many local economies, and recreational activities in the watershed play an important role in the economies of both Shasta and Siskiyou counties. In 2005, California was the destination for more than 335 million leisure and business travelers and almost 14 million international travelers (California Travel and Tourism Commission and California Business Transportation and Housing Agency Division of Tourism 2006), and in 2007, travel spending generated $2.2 billion dollars in local tax dollars (Dean Runyon Associates 2008).

One of the audiences often targeted for their recreation and tourism dollars is the "baby boomer" population. This generation is coming of age and seeking what is described as "softer vacations" (Urness 2007), with RV camping being one of the most popular passive recreation activities for people between the ages of 55 and 64 (KOA 2007). In the upper Sacramento River region, facilities began accommodating motor homes as early as the 1960s. Today, facilities such as the Lake Siskiyou Camp Resort continue to thrive and offer full RV hookups and hundreds of campsites (SHN Consulting Engineers & Geologists 2004, California State Parks 2005).

Another outdoor recreation activity that is rising in popularity is off-highway vehicle (OHV) parks and trails. Between 1995 and 2003, annual sales of OHVs tripled, and more than 1.1 million vehicles were sold in 2003 (Cordell et al. 2005). California accounts for about 11 percent of the U.S. total (Cordell et al. 2005). California State Parks estimates that OHV recreation contributes $9 billion annually to California's economy (California State Parks 2007). Most of this recreation occurs on publicly owned land, and it is the responsibility of the federal or state agency to implement policies and regulate OHV recreation.

In 2009, the California State Parks Off-Highway Motor Vehicle Recreation Division released its strategic plan, which responds to the increasing pressures on existing OHV areas and promotes development of additional areas while maintaining the highest standards of sustainability and environmental protection. In June 2009, the STNF issued a Draft Environmental Impact Statement disclosing the impacts of prohibiting OHV cross-country travel off designated roads/trails and adding additional roads/trails for OHV use based on vehicle class and season (USDA Forest Service 2008b). The proposed action would add approximately 44.2 miles of existing unauthorized routes to the National Forest Transportation Systems (NFTS) for public motor use. Approximately 36.51 miles of unauthorized routes would be added as roads classified open to all vehicle classes and approximately

7.69 miles would be added as motorized trails. Designating specific routes for OHV use would help lessen the impacts that unauthorized routes have on the forest system and would bring the Forest Plan into conformity with the Travel Management Rule (CFR Part 212, Subpart B).

While the national trends for recreational vehicle camping and OHV use are expected to rise, there is debate about the popularity of nature-based recreation in the United States. After reviewing national and state park visitation numbers, hunting and fishing licenses sales, and camping reservations, a 2008 report by University of Illinois scholars determined that since the 1980s, there has been a decline in nature-based recreation in the United States (Pergams and Zaradic 2008). That same year, H. Ken Cordell of the USFS argued that a rise in nature-based recreation and an increased demand for recreational activities existed between 1994 and 2008 (Cordell 2008), with the exception of hunting. This was attributed to a decline in popularity of game hunting, a more urban population, and an increase in private residences encroaching on natural lands (Cordell et al. 2008, Rogers 2008). In the watershed, however, hunting is still a popular activity, and many businesses (e.g., restaurants, supply stores, guides, motels) benefit economically from hunters' continued use of the region.

Fishing also remains a popular recreational activity that contributes notably to the local economy, particularly in the upper Sacramento River watershed region. The local chambers of commerce and visitors bureaus actively promote the excellent fishing in the watershed region, and several fishing events and tournaments occur year-round in the region (Siskiyou County Economic Development 2006, City of Dunsmuir 2008). Between November 2004 and April 2005, CDFG observed 191 anglers who fished for a total estimated 7,316 hours during the winter fishing season. During the same period, CDFG issued 304 non-resident sport fishing licenses in Shasta County and another 209 in Siskiyou County. The CDFG's study determined that 60 percent of the anglers interviewed traveled more than 75 miles from home, with most coming from Sacramento and the San Francisco Bay Area. Those traveling long distances for short fishing trips spent on average one night in a local hotel (Dean 2005). The anglers were also likely to eat in local restaurants, purchase their supplies from local businesses, and employ local fishing guides. According to the Mt. Shasta Chamber of Commerce, recreation, lodging and food services, entertainment, and art comprise 8 percent of the city's employment industries (City of Mt. Shasta 2008).

The watershed is fortunate to have recreational opportunities for every season. Mountain climbing is one sport enjoyed year round at Mount Shasta. Professional guides from such companies as Alpine Skills, Shasta Mountain Guides, and Sierra Wilderness, are highly trained professionals employed to guide climbers up the mountain safely. Winter sports, particularly downhill and cross-country skiing, are other popular draws and attract hundreds of visitors to the region each year. Downhill skiers frequent the Mt. Shasta Board & Ski Park, which opened in 1985. The Ski Park contributes to the local economy and employs people in such areas as food service, maintenance, and sales as well as professional guides and instructors (Mt. Shasta Ski Park 2008). The Nordic Center is another venue for cross-country skiing at Mount Shasta. It opened during the winter of 1991-1992 and offers beginner and intermediate lessons. This is a community-based facility and contributes to the local economy by employing local residents in a variety of positions and attracting outside visitors who spend money at other local businesses.

## Recreation Facilities

As previously stated, camping (including RV/trailer camping) and boating are popular activities in the watershed. Within the area, there are both publicly and privately operated campgrounds. Along the river, there are campsites around three primary destination spots: Castle Crags State Park, Lake Siskiyou, and Shasta Lake.

### Castle Crags State Park

At Castle Crags State Park, there are 76 developed campsites and six environmental campsites. The developed campsites can accommodate family camping and RV/trailers. Amenities include fire rings, picnic tables, restrooms, and showers. The environmental campsites at Castle Crags State Park offer campers a more natural setting (i.e., table, clearing for tents, and a primitive toilet nearby) (California State Parks 2008). Privately operated facilities for buying gas and supplies are conveniently located adjacent to the park (California State Parks 2002).

### Lake Siskiyou

Lake Siskiyou was developed in 1969 for recreational use under the Davis-Grunsky Act and is situated on lands owned by Siskiyou County. As part of the development of the reservoir, Siskiyou County is obligated to promote commercial recreational development around the lake, which has led to the development of commercial improvements around the lake, such as Lake Siskiyou Camp-Resort and the Mt. Shasta Resort. Lake Siskiyou Camp-Resort has more than 300 campsites, with amenities including toilets, showers, picnic tables, fire rings, recreation halls, arcade, grocery store, outdoor movie theatre, laundry facilities, bait and tackle shop, fishing dock, boat launching, marina, and mooring. The Mount Shasta Resort includes a golf course, tennis courts, restaurant, and chalets for lodging. Non-commercial opportunities for use of the lake exist in the form of beaches and boat launch areas, and a hiking trail has been constructed around a major portion of the lake.

### Shasta Lake

Within the upper Sacramento River watershed region of Shasta Lake, there are several campgrounds that together offer more than 100 campsites. Antlers Resort is the furthest north on the lake and has 41 single and 18 double sites. It operates year round and offers potable water, toilets, picnic tables, bear boxes, fire rings, and paved parking. Antlers Resort can also accommodate RVs/trailers up to 30 feet in length. Southeast of Antlers is Gregory Creek campground. It is open between late spring and late summer. The 18 single sites have picnic tables and fire rings. Gregory Creek can accommodate smaller RVs/trailers (16 feet maximum). Lakeshore East is located southwest of Gregory Creek. It offers amenities similar to those offered by Antlers, but has fewer sites, with only 17 single sites, six double sites, and three yurts. Lakeshore East also operates year round. Nelson Point is on Salt Creek Inlet and is one of the smaller campground facilities, with only eight single sites available. It is open during the summer and offers campers picnic tables, fire rings, stoves/grills, and an unpaved parking spot. Like Gregory Creek, it can only accommodate RVs/trailers up to 16 feet long. Just west of Nelson Point on the Sacramento River is Beehive Cove, which is open year round for shoreline camping. The facilities are limited, with only portable restrooms and trash receptacles. Gooseneck Cove is southwest of Beehive and is on the Sacramento River Arm of Shasta Lake. It is a small campground with eight sites and is accessible only by boat.

Many campers who frequent Shasta Lake come with their boats and take advantage of the public boat ramps. Each ramp is paved and features a lighted parking area, public restrooms, and garbage and recycling containers. Antlers and Sugarloaf (Sacramento River Arm, furthest north from the dam) each have eight launching lanes, Centimudi (located on Shasta Lake, northeast of the dam) has 19 launching lanes, and Packers Bay has 10 launching lanes.

In addition to the public facilities, Shasta Lake has privately owned facilities in the region that cater to boaters. Sugarloaf Resort, located on the Sacramento River Arm of Shasta Lake, features 16 cabins and offers moorage. Houseboats, patio, ski, and fishing boats are all available for rental at the Sugarloaf Resort. Packers Bay Marina, south of Sugarloaf and northwest of the Pit River Bridge, caters to visitors interested in vacationing on houseboats. The company has a fleet of boats available for rental and is in close proximity to Packers Bay. Bridge Bay Marina is a full-service marina located at the southern end of Shasta Lake in the watershed region. The marina has mooring facilities, fueling docks, slips, houseboat accommodations, and a lodge. There is also a restaurant, small grocery store, and bait shop. Houseboats, patio, ski, and fishing boats are available for rental. Digger Bay Marina is located the farthest south in the region and closest to Shasta Dam. Amenities include a floating grocery store and tackle shop, boat rentals, boat repair shop, and a gas dock.

## 3.1.7 Historical and Cultural Resources

The following discussion is a brief overview of the general characteristics and locations of known archaeological sites in the watershed. This information was synthesized from a general overview of archaeological site records housed at the Northeast Information Center of the California Historic Resources Information System. Specific locations of sites and archaeological materials are protected information and are therefore omitted from the discussion.

### Native Americans

Prehistoric and historical archaeological resources of Native Americans occur throughout the watershed, and may include temporary campsites with lithic scatters or food-processing artifacts; bedrock mortar locales; villages and areas of long-term occupation; petroglyph or rock art sites; historic homesteads or occupations; and prehistoric, historic, and modern-day Traditional Cultural Properties. In the watershed, temporary campsites are most often found in high-elevation areas where occupation during winter would be difficult; however, they are also found in lower elevations throughout the region. These sites usually consist of scatters of lithic debitage or the waste materials from the creation of stone tools and other food processing artifacts, such as milling stones or mortars. Although temporary campsites may seem to be less important than a large village site, they supply important information regarding the use of resources and movement of people in the watershed, and sometimes the small sites with less visible material may actually be an older occupation. Large villages and long-term occupation areas are usually located near perennial water sources such as springs and major streams.

Many of the largest and most recently occupied village sites in the watershed were built over during the historic era by Euro-American communities, destroyed by mining activities, or inundated by the creation of Shasta Lake; however, many smaller or older village sites still exist. Several known historic-era homesteads or occupations by Native Americans in the watershed are on flat areas along main waterways, oftentimes alongside Euro-America sites (Basgall and Hildebrandt 1989). An example of this co-occupation occurred at Upper Soda Springs where Ross and Mary McCloud lived alongside and employed Trinity Wintu, including Grant Towendolly (Masson 1966).

As discussed in Section 2.1.2, *Ethnography*, Native American peoples were, like all people, intimately involved with the environment, and this involvement manifested itself in their cosmological and mythological beliefs concerning the landscape and world around them. Prehistoric, historic, and modern Traditional Cultural Properties, sacred locations, and important use areas are located throughout the watershed and include but are not restricted to mountains, unique landforms, caves, distinctive rock outcrops, waterfalls, pools, springs, and resource gathering areas. These locations may be considered negative, positive, or neutral in their energies or influence. Many locations have been recorded by ethnographers and writers (Masson 1966, Basgall and Hildebrandt 1989) and many are known but are not in the public record (Native American Heritage Commission personal communication).

## Euro-Americans

Historically, resource use in the watershed has included exploitation of animal and fish resources, particularly the fur trade of the early 19th century and recreational hunting of the late 19th and the 20th centuries; the timber and mining industries; roads, trails, railroads, and other routes of travel; homesteading, agriculture and ranching; and recreation, including resorts and campsites. Although much of the known occupation is concentrated in the small valleys and flats along the Sacramento River and its major tributaries, other uses cover the entirety of the watershed. As described in Section 2.2.1, *The Fur Trade and Early Exploration,* the fur traders of the early 19th century trapped along the streams and rivers in the region, and, although no known archaeological resources from this era exist, it is conceivable that some evidence may yet remain.

Roads, trails, and railroads create an interconnected web of routes of travel throughout the region. Many of the trails and roads remain only as blazed trees, barely identifiable wagon ruts, or abandoned segments of asphalt; however, many travel routes persist today on or near the original routes. Along these routes lay many small historic and modern communities as well as numerous campgrounds and resorts.

Historic communities were usually centered on stage stops and railroad stations, particularly along the Sacramento River itself, and served as community and mercantile centers for larger populations spread throughout the surrounding region. Some of the communities have faded from the landscape, leaving behind an interstate exit name like Lamoine, while others are robust and growing towns like Dunsmuir. Similar to the communities, most of the resorts and camping areas in the watershed were located near mineral and other springs easily accessible from the railroad and later from asphalted roads. Some, like Shasta Springs, have been repurposed but survive to the present day, and some, such as the CCC camp at Sims, have been reclaimed by nature and only traces survive. Recreational campsites, resorts, and communities create a robust archaeological record, including landscaping, foundations, and trash deposits, which may still be found and interpreted by researchers.

After the construction of the railroad through the Sacramento River canyon, railroad logging became a major industry in the watershed. Extensive networks of railroad grades and evidence of logging from this era can be found throughout the watershed, in particular west of the Sacramento River extending out from the present day communities of Mt. Shasta, Dunsmuir, Castella, and Lamoine towards the Shasta and Trinity counties border. Archaeological evidence of the logging activities include sawmill locations, work camps, railroad grades, donkey platforms, skid trails and log chutes, high-cut tree stumps, and trash scatters.

The upper Sacramento River watershed contains many valuable mineral resources that have been mined in the historic era, including gold, copper, lime, and asbestos. The largest and most productive mining occurred in the southwestern portion of the watershed and involved the extraction and refinement of copper ore. The creation of Shasta Lake inundated the town of Kennett, the center of a large mining and copper smelter industry; however, archaeological traces of the mines remain above the water line to the west of the lake. Archaeological evidence of gold mining may be found along creeks, particularly in the area of Delta, where an early gold mining town existed in the 1850s. Other minerals, such as lime and asbestos, would exhibit an archaeological footprint similar to other mining concerns. Trash scatters, machinery, foundations, landscape alterations, water ditches and dams, mining tailings or adits, and work camps may be found in the archaeological record of mining ventures.

## 3.1.8 Fire and Fuels

The following discussion of fire and fuels describes the regions' fire regime (i.e., return intervals, severity, fire rotation1); the influence that humans have had on the fire regime and vegetation structure of the watershed; and the effects and spatial extent of documented fires that have occurred in the watershed. A detailed discussion of the methodology used to ascertain the region's fire regime is presented in Appendix A.

### History of Fire and Fire Management

The record of fire in the Klamath Mountains, including the watershed, extends back to about 13,000 to 15,000 years before present (Skinner et al. 2006). Forest structure, species composition, soil properties, wildlife habitat, landscape patterns, watershed hydrology, nutrient cycling, and other ecosystem processes have evolved in large part in response to fire (Frost and Sweeney 2000). Most native species and communities in the region have co-evolved with fire, adapting to its periodic occurrence. Some researchers have suggested that the region's globally outstanding biodiversity is due at least in part to the natural disturbance regime in general and fire in particular (Frost and Sweeney 2000). Present-day vegetation assemblages found in the watershed coalesced approximately 3,000 to 4,000 years ago when the climate cooled and became moister than the preceding millennia (Skinner et al. 2006).

Fossilized charcoal deposits preserved in lake sediments indicate that the frequency of fire extending back over the previous 15,000 years is a function of variation in precipitation and temperature, while trends in the spatiality and severity of burns reflect the amount of available biomass at the time of the burn rather than fire frequency (Skinner et al. 2006). Paleoecological evidence suggests there is only a loose coupling between fire regimes and any particular vegetation assemblage (Whitlock et al. 2003, Skinner et al. 2006).

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[1] *The length of time necessary to burn an area of specific size (e.g., the watershed).*

Prior to the introduction of fire suppression, fires in the mid-elevation Douglas-fir–dominated forests of the Klamath Mountains region were fairly frequent, generally less severe, and had shorter fire rotations than in similar forests in other regions. The development and dynamics of stand conditions were strongly influenced by this fire regime (Taylor and Skinner 1998). Few forested regions have experienced fires as frequently and with such high variability in fire severity as those in the Klamath Mountains (Taylor and Skinner 1998). These mixed-severity fires perpetuated multi-aged stands.

As discussed in Section 2.1.3, *Native Americans and Fire*, the Native American populations that inhabited the region prior to the arrival of Euro-Americans likely had well-developed traditions of intentional burning that undoubtedly had a significant influence on vegetation patterns (Frost and Sweeney 2000). Although fires ignited by Native Americans were more commonly applied in the lower elevation oak woodlands, such as those that occur in the southern portion of the watershed, oral history suggests that anthropogenic fires regularly burned up to 6,000 feet in elevation (Lininger 2003). Historical accounts of Native American subsistence patterns suggest that fire was ignited in oak woodlands at intervals typically less than 5 years, with the more heavily used sites burning almost every year (Frost and Sweeney 2000). Low-intensity, frequent fires sustained the character of many oak woodlands by retarding conifer encroachment, while making acorn gathering easier. However, it is difficult to confirm the historical frequency of fire in oak woodlands since oaks are capable of regenerating from both seedlings and basal sprouts, and their thick, corky bark protects them from low-intensity fire. Though Native American ignitions appear to have been widespread, the broad scale extent of their influence on the fire regime and vegetation is unknown (Skinner et al. 2006).

Prior to the mid-nineteenth century (which coincides with the influx of Euro-American settlers), it is believed that fires in mid-elevation forests—such as those in the watershed dominated by Douglas-fir, ponderosa pine, and hardwoods—were relatively common as anthropogenic fires spread out of the lowlands (Lininger 2003). Although historically, as now, mid-elevation forests in the region experienced a high number of lightning ignitions, it is probable that Native Americans also ignited fires in these forests to clear travel corridors and/or maintain populations of plants used for food and basketry (Frost and Sweeney 2000). Regardless of the ignition source, studies in mid-elevation forest types similar to those occupying a majority of the watershed determined that fires would have burned at low to moderate intensity, with frequencies ranging from about 3 to 90 years and median return intervals of about 10 to 13 years (Wills and Stuart 1994, Frost and Sweeney 2000).

Euro-American settlers in the early to mid 1800s are reported to have set fires to make travel easier, to clear ground for prospecting, to drive game, and to encourage forage production for sheep and cattle (Whittaker 1960, Skinner et al. 2006). Though settlement is thought to have increased fire frequency and perhaps fire intensity, no increases in fire occurrence during the settlement period are evident in fire scar studies conducted in the region (Agee 1991; Wills and Stuart 1994; Taylor and Skinner 1998, 2003; Skinner et al. 2006).

Following the end of World War I, the demand for national forest resources increased considerably, especially for water and timber. However, this demand was not only for tangible forest products. Increased outdoor recreation and the expansion of homesites into forested lands increased the potential for fire ignitions in the watershed. The fire suppression policy, which was aggressively applied throughout most of the 20th century, was intended to protect public and private lands and properties. The policy of excluding fire, or at the very least, significantly limiting its extent, has resulted in an unnatural build-up of fuels and the encroachment of a less fire-tolerant understory in most western United States forests. Ironically, studies indicate that the effects of fire suppression have been far less in the Klamath/Siskiyou region, which includes the watershed, than in many other forested regions of the west (Frost and Sweeney 2000). The primary reasons for this difference are that: (1) fire suppression was effective over a considerably longer period in other regions—sometime between 1850–1900 rather than during the mid-twentieth century (Skinner and Chang 1996); and (2) fire return intervals are on average longer and more variable in the Klamath Mountains (Frost and Sweeney 2000). Further, difficult terrain has caused most fire suppression efforts in the Klamath/Siskiyou region to be most successful in areas closer to human settlements—because protecting private property has always been given priority—and less so at higher elevations and in remote areas with steep terrain (Frost and Sweeney 2000).

As described in Section 2.3, *Evolution of Laws and Regulations Affecting the Watershed*, the 1994 NWFP significantly altered timber management practices across the Pacific Northwest. Fewer and smaller timber sales have contributed to increased fuel loads as many forests are managed to perpetuate old-growth or late-successional characteristics. Concurrently, in recent years, societal concerns for managing natural resources have shifted to include the role of fire as a dynamic and predictable part of wildland ecosystems (Stephens and Sugihara 2006). Fire is now recognized for its role in the functioning of the healthy, natural ecosystem. The focus of fire policy and management has shifted away from the overall goal of removing fire toward the much more complex goal of managing fire (Stephens and Sugihara 2006). The *Collaborative Approach for Reducing Wildfire Risks to Communities and the Environment: Ten-Year Comprehensive Strategy* (U.S. Department of Agriculture and U.S. Department of the Interior 2006) established by the National Fire Plan recognizes the importance of fuel management and that key decisions in setting priorities for restoration, fire, and fuel management should be made collaboratively at local levels (Stephens and Sugihara 2006).

The STNF has a comprehensive fire program with engine companies, hand crews, helitack, lookout, fire managers, dispatchers, and an air tanker base, any of which may be deployed in the event of fire in the watershed. In addition, CalFire is a significant presence in the wildfire suppression community of the region. A cooperative fire protection agreement has been adopted by federal and state fire protection agencies, providing for wildfire protection for lands that are “intermingled” or adjacent to public lands regardless of ownership (USDI Bureau of Land Management et al. 2001). The federal agencies and the state have agreed upon and have prepared maps of Direct Protection Areas (DPAs), filed in the offices of each fire agency, in which each assumes the responsibility of maintaining a wildland fire protection system. These maps show the established DPAs and are kept current on an annual basis.

Although limited in their extent, some fire history studies that have been conducted on the STNF and in the larger Klamath Mountains region have included portions of the watershed (USDA Forest Service 2000, Skinner 2001, Fry and Stephens 2006). Prior to about 1922, when fires in the watershed began being recorded and mapped, studies have shown that fires were a common ecosystem process (Fry and Stephens 2006); however, their extent and year of occurrence are unavailable. Table 3.1-3 summarizes the year and approximate size and location of fires documented in the watershed since the 1920s. This table corresponds to Figure 3.1-6.

**Table 3.1-3. Documented Fires in the Watershed (1922–2008)**

| FIRE ID # | FIRE NAME | FIRE YEAR | ACRES BURNED |
|---|---|---|---|
| 0 | — | 1922 | 159 |
| 1 | — | 1922 | 339 |
| 2 | — | 1922 | 607 |
| 3 | — | 1923 | 148 |
| 4 | — | 1924 | 186 |
| 5 | — | 1924 | 634 |
| 6 | — | 1924 | 3,332 |
| 7 | — | 1924 | 398 |
| 8 | — | 1924 | 114 |
| 9 | — | 1924 | 1,000 |
| 10 | — | 1924 | 152 |
| 11 | — | 1930 | 293 |
| 12 | — | 1930 | 273 |
| 13 | — | 1931 | 155 |
| 14 | — | 1931 | 424 |
| 15 | — | 1931 | 847 |
| 16 | — | 1931 | 125 |
| 17 | — | 1931 | 1218 |
| 18 | — | 1931 | 142 |
| 19 | — | 1931 | 101 |
| 20 | — | 1931 | 240 |
| 21 | — | 1931 | 247 |
| 22 | — | 1931 | 102 |
| 23 | — | 1932 | 110 |
| 24 | — | 1933 | 401 |
| 25 | — | 1934 | 775 |
| 26 | — | 1934 | 674 |
| 27 | — | 1934 | 183 |
| 28 | — | 1934 | 156 |
| 29 | — | 1934 | 157 |
| 30 | — | 1936 | 1,375 |
| 31 | — | 1939 | 313 |
| 32 | — | 1939 | 203 |
| 33 | — | 1939 | 7,936 |
| 34 | — | 1944 | 223 |
| 35 | — | 1944 | 120 |
| 36 | — | 1945 | 97 |
| 37 | — | 1946 | 82 |
| 38 | — | 1949 | 125 |
| 39 | — | 1950 | 154 |
| 40 | Tunnel 16 | 1950 | 154 |
| 41 | Lester Flat | 1950 | 111 |
| 42 | — | 1951 | 189 |
| 43 | — | 1952 | 830 |
| 44 | — | 1952 | 8 |
| 45 | Leach Ranch | 1954 | 213 |
| 46 | East Fork | 1962 | 217 |
| 47 | — | 1985 | 1,782 |
| 48 | Bow | 1990 | 550 |
| 49 | Pocket | 1996 | 47 |
| 50 | Sugar | 1999 | 3,154 |

**Table 3.1-3. Documented Fires in the Watershed (1922–2008)**

| FIRE ID # | FIRE NAME | FIRE YEAR | ACRES BURNED |
|---|---|---|---|
| 51 | Sugar | 1999 | 3 |
| 52 | Sugar | 1999 | 1 |
| 53 | Sugar | 1999 | 3 |
| 54 | Sheep | 1999 | 2,047 |
| 55 | Sheep | 1999 | 19 |
| 56 | Sheep | 1999 | 80 |
| 57 | Reptile | 1999 | 6 |
| 58 | Reptile | 1999 | 1,617 |
| 59 | Jackass | 1999 | 3,498 |
| 60 | Jackass | 1999 | 75 |
| 61 | Jackass | 1999 | 25 |
| 62 | Lunch | 1999 | 1,426 |
| 63 | Lunch | 1999 | 2 |
| 64 | Lunch | 1999 | 5 |
| 65 | Lunch | 1999 | 4 |
| 66 | Bohemotash | 1999 | 4,158 |
| 67 | High | 1999 | 3,064 |
| 68 | Pollard | 2003 | 41 |
| 69 | Green | 2003 | 13 |
| 70 | Tollhouse | 2005 | 13 |
| 71 | Bass | 2006 | 9 |
| 72 | Motion | 2008 | 7,813 |
| 73 | Elmore | 2008 | 243 |

Source: USDA Forest Service 2008e

## Regional Fire Environment

California is composed of a diverse landscape that is mirrored in its wide range of climates, geomorphology, and vegetation. In fact, the biological diversity (both plant and animal) of the state has been driven over space and time by the occurrence of fire and the ecological processes it perpetuates. Climatic variations, geomorphology, and vegetation throughout the state are often described using an ecosystem classification system of bioregions (Miles and Goudey 1997) based on consistent patterns in vegetation and fire regimes over a specific landform (e.g., mountain ranges, coastal steppes, deserts, the Central Valley) (Sugihara and Barbour 2006). In this context, the watershed falls primarily within the Klamath Mountains bioregion, with some incursion into the Southern Cascades bioregion on the western and southern slopes of Mount Shasta.

## Climate and Weather

California's unique Mediterranean climate, which is typified by long, dry summers and cool, wet winters, is conducive to the occurrence of fire (Sugihara and Barbour 2006). In California, the eastern Klamath Mountains are the first major mountain range encountered by southwesterly flowing winds moving northeast across the Sacramento Valley (Skinner et al. 2006). Orographic uplift (the upward lift of an air mass over mountainous terrain) of moist air masses over the eastern Klamath Mountains produces high levels of precipitation, falling mostly as snow in the higher elevations. Steep elevation gradients have a further effect on temperature and the spatial pattern of precipitation, with most precipitation falling between October and April.

In the watershed, there are no readily discernible differences in the precipitation pattern and climate of the Southern Cascades bioregion from that occurring in the Klamath bioregion. A west-to-east precipitation and temperature gradient creates wetter and warmer conditions on the west side of the southern Cascades Range south of Mount Shasta. Conifer forests, intermixed with woodlands and shrublands, dominate the mid-montane zone.

Lightning is common in the Klamath Mountains and the southern Cascades, increasing in occurrence with distance inland from the Pacific Ocean and with increasing elevation. Although it seems counterintuitive, the number of lightning strikes does not necessarily correspond to the number of lightning-caused fires (Skinner et al. 2006). Lightning-caused fires result from storms that produce drier air and more unstable weather patterns than storms that produce a greater number of lightning strikes. Conditions in the Klamath Mountains and the southern Cascades favor lightning-caused ignitions, which when coupled with the steep topography, extensive strong canyon inversions, and the difficult access for fire-suppression forces, can create situations where fires burn for weeks to months and cover very large areas (Skinner and Taylor 2006, Skinner et al. 2006).

## Ecological Zones

In California, vegetation is the meeting place of fire and ecosystems. The plants are the fuel and fire is the driver of vegetation change. Fire and vegetation are often so interactive that they can scarcely be considered separately from each other (Barbour et al. 1993).

The Klamath Mountains bioregion is an area of exceptional floristic diversity and complexity in vegetative patterns (Whittaker 1960, Stebbins and Major 1965, Skinner et al. 2006). The Klamath Mountains are recognized as a transition zone where the floras from the Cascade/Sierra Nevada axis and the Oregon/California coastal mountains intersect. The rugged terrain, diverse lithology (rock-forming processes), and diverse fire regimes combine to create the heterogeneity of plant life that has evolved over time in the Klamath Mountains bioregion. Conifer forests and woodlands are found in all elevational zones throughout the bioregion (Skinner et al. 2006). Despite the complex intermixing of vegetation, which is further complicated by rugged topography, three general ecological zones based on elevation are used to characterize the Klamath Mountains heterogenic vegetative assemblage: lower montane, mid to upper montane, and subalpine (see Section 3. 3, *Biological Components and Processes,* for additional details on the vegetation communities present in the watershed).

In the watershed, shrublands are the dominant vegetative form in the lower montane zone. Warm, dry, rocky sites typify the areas of the watershed where shrublands occur, as do areas in which site quality has been permanently reduced by past disturbance such as mining, or that are in the early successional stages of recovery from a disturbance such as fire or clearing. However, the lower montane zone is not purely shrublands. Douglas-fir–dominated and mixed evergreen forests also occur with relative frequency in this zone. Although not so common in the watershed, small areas of grasslands also occur.

The mid- to upper-montane zone of the watershed is differentiated from the lower montane zone by the increased importance of the conifer component and a decrease in hardwoods. The extreme northern end of the watershed is the only area in the watershed where the subalpine zone occurs. There is no upper elevation limit of the subalpine zone, which occurs on the higher elevation slopes

Insert 11x17 Figure

Figure 3.1-6 Fire History

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of Mount Shasta on the east side of the watershed, and Mount Eddy and the Trinity Mountain Range (a part of the Klamath Mountains) on the west side. Vegetation types found in this zone of the Klamath Mountains (and the southern Cascades for the Mount Shasta portion of the watershed) are a function of the soil depth or parent material rather than low temperatures (Sawyer and Thornburgh 1977, Skinner et al. 2006). Forests in the subalpine zone are generally open patchy woodlands of widely spaced trees, with a discontinuous understory of shrubs and herbs and large areas of bare ground (Skinner et al. 2006).

## Fire Regimes

Fire regimes[2] in the Klamath Mountains have varied over millennia, primarily due to variations in climate. In terms of fire regimes, historical conditions and processes are most often described by ignition source, frequency, severity, seasonality, and spatial extent over a landscape (Frost and Sweeney 2000). The steep and complex topography of the Klamath Mountains provides for conditions that make it difficult to separate fire regimes by ecological zones (Skinner et al. 2006). The most common fire regime in the Klamath Mountains typically extends from the lower montane through the mid-montane into the upper montane ecological zones, from canyon bottoms to over 6,000 feet in elevation. Because the Klamath Mountains are generally very rugged, several ecological zones can occur over the elevational gradient of a single slope. These steep, continuous slopes that run from low to high elevation, coupled with varying slope aspects and summer drought conditions, create conditions for frequent, mostly low- and moderate-intensity fires in most ecological zones of the Klamath Mountains (Skinner et al. 2006).

Vegetative species composition within the watershed and tree age and stand structure demonstrate the influence that topography has had on the region’s fire regimes. A discussion of the fire history of the watershed is presented in the following section.

## Fuel Loads and Distributions

Following a disturbance such as fire or logging, vegetation typically returns in a series of successional stages (e.g., grasses give way to shrubs, which eventually give way to trees), each of which will influence fire behavior in unique ways. Vegetative properties, including type, density, size, and structure of vegetation in a given area, are considered when assessing fuel loads. A quantitative basis for rating fire danger and predicting fire behavior became possible with the development of mathematical fire behavior models (Anderson 1982). Mathematical modeling of potential fire behavior and/or fire danger indices requires inputs that describe fuel properties, specifically fuel loads and distribution of fuels among fuel size classes. The collections of fuel properties are referred to as “fuel models” and are organized into four groups: grass, shrub, timber, and slash. These four groups are indicative of the stratum of available surface fuels most likely to carry the spreading fire. Within these groups, further distinctions are made based on the fuel load and depth and its orientation (vertical or horizontal). Fire behavior predictive fuel models (Albini 1976) representing the fuel load

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[2] *Description of the patterns of fire occurrences, frequency, size, severity, and sometimes vegetation and fire effects as well, in a given area or ecosystem. A fire regime is a generalization based on fire histories at individual sites. Fire regimes can often be described as cycles because some parts of the histories usually are repeated, and the repetitions can be counted and measured, such as fire return interval (National Wildfire Coordinating Group Incident Operations Standards Working Team 2007).*

and the ratio of surface area to volume for each fuel size class, the depth of the fuel bed involved in the flaming fire front, and fuel moisture, including that at which fire will not spread—referred to as the "moisture of extinction"—are used to model potential fire behavior during the severe period of the fire season when wildfires pose greater control problems and impacts on land resources. Accordingly, standard fire behavior fuel models (Scott and Burgan 2005) were input into the FlamMap fire modeling computer program to determine potential fire intensity (predicted flame length) should a fire ignite.

In the watershed, forest vegetation management actions and past wildfires account for much of the current vegetation condition, including the amount of late-successional habitat in the watershed (USDA Forest Service 1999a). Although the LSR Assessment (USDA Forest Service 1999b) is specific to late-successional forest habitat and thus does not directly address the potential fire risk associated with the various seral[3] and other climax[4] habitats occurring throughout the watershed, vegetative conditions in the LSRs are the result of the dynamic, diverse biological and physical conditions that occur throughout the watershed. The structure and compositions of the nearly continuous coniferous forests of the middle and upper watershed (see Section 3.3, *Biological Components and Processes*) vary by forest type, site quality, and fire regime. Changes brought about by fire suppression efforts have not only changed the forest structure, stand density, and species composition of the watershed, but have also had a direct effect on forest health.

Fuel models in the watershed were identified by the USFS using aerial photograph imagery, forest stand assessment information, and field verification. Eight standard fuel models (1, 2, 4–6, and 8–10) and three "custom" fuel models were used to identify urban areas (Fuel Model 28), open water (Fuel Model 98), and bare ground (Fuel Model 99) in the watershed (Figure 3.1-7).

In those parts of the LSRs/MLSA that are roaded and where recreational use occurs, the incidence of human-caused fire starts is generally analogous to an increased level of risk. While lightning has and continues to be a significant source of fire starts, the influence of humans, not only as a source of ignition, but whose management actions (e.g., suppression) have dramatically altered the type and structure of vegetation in the watershed, is often a determinant of risk.

## Fire Behavior

Fire behavior is a function of weather, topography, and fuels, with weather being the most variable factor. These characteristics determine not only how a fire will burn at its leading edge but also the immediate and long-term effects of a fire on the vegetative community, post-fire erosion potential, and effects on biological resources and the human environment.

### Methodology

For the purpose of predicting potential fire behavior in the watershed, environmental variables, including weather conditions common to the region, fuel loads (provided by the USFS), and watershed topography, were input into the FlamMap computer model (Fire Sciences Lab and Systems

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[3] *"Seral" refers to a plant species or community that will be replaced by another species or community in the absence of disturbance.*

[4] *"Climax" refers to species or communities representing the final (or indefinitely prolonged) stage of succession.*

Figure 3.1-7 Modeled Fire Intensity

for Environmental Management 2006). It was used by the USFS to generate the predictions presented in the following discussion.

### *FlamMap*

FlamMap was designed to help plan fuel treatments (Finney 2006, Husari et al. 2006). It calculates fire behavior independently for each pixel across the landscape and holds the key fire weather variables (i.e., wind speed, wind direction, fuel moisture) constant (Vaillant 2008). Outputs capture the spatial variability in fire behavior due to differences in fuel conditions (Finney 2006).

In order to model potential fire behavior, eight data layers are used, consisting of topographic information (elevation, slope, and aspect), canopy characteristics (canopy cover, canopy base height, canopy bulk density, and canopy height), and surface fuels information (fuel model). In addition, simulation of fire behavior requires the input of non-temporal and non-spatial weather and fuel moisture information. Six fuel models were used in FlamMap: #1 (grass), #2 (grass/shrub), #3 (shrub), #4 (timber and understory), #5 (timber and litter), and #6 (slash).

### *Influence of Weather Systems on Fire Behavior*

Critical fire weather in the Klamath Mountains bioregion is generated by conditions of both the California and Pacific Northwest weather types (Hull et al. 1966, Skinner et al. 2006). Sustained periods of high-velocity winds and low humidity will have a direct effect on fire behavior. In the Klamath Mountains, critical fire weather conditions are created by three different weather patterns: (1) Pacific High–Post-Frontal (Post Frontal), (2) Pacific High–Pre-Frontal (Pre-Frontal), and (3) Subtropical High Aloft (Subtropical High) (Hull et al. 1966, Skinner et al. 2006). Post-Frontal conditions occur when high pressure following the passage of a cold front causes strong winds from the north and northeast. Relative humidity levels drop and temperatures increase with these winds. Pre-Frontal conditions occur when strong southwesterly or westerly winds are generated by the dry, southern tail of a rapidly moving cold front. Although relative humidity levels increase and temperatures decrease, the strong winds that characterize this weather condition are often associated with the rapid spread of fire through heavy fuels. Subtropical High conditions result when descending air from high pressure causes temperatures to rise and humidity levels to drop. An inversion layer is often created by such conditions, which traps smoke in canyons and valleys, and reduces fire intensity. Under Subtropical High conditions, fires create mainly low- to moderate-severity effects. However, fires burning above the inversion layer often burn at much higher intensity; thus, the steep topography of the Klamath Mountains will often determine the severity and intensity of fires occurring in the region.

### *Fire Intensity and Severity*

The magnitude of fire effects is described in terms of fire intensity and fire severity, two distinctly different terms. Fire intensity is defined as the amount of energy released from a fire and may or may not be used to describe the effects of fire on the biota (Frost and Sweeney 2000). Rate of spread, the amount of fuel consumed, and the position of the fire’s active front within the forest profile (i.e., surface, subcanopy, and overstory) are descriptors of fire intensity.

Fire severity refers to the qualitative degree to which vegetation and site conditions have been altered by a fire (Frost and Sweeney 2000). Temporal and spatial factors such as forest structure, fuel availability and moisture, topography, weather, and fire behavior in adjacent areas combine to dictate the severity of a fire. Post-fire, the mortality rate of a dominant tree species present in a given area can be an indicator of fire severity. Three levels of fire severity are commonly used to further characterize fire effects:

- **High severity**—Most trees, including overstory trees, are killed
- **Moderate severity**—Partial stand-replacing fires that include areas of both low and high severity; some overstory trees are killed or heavily damaged in patches
- **Low severity**—Light surface fires that have minimal impacts on forest overstories, but may kill small trees and shrubs

Historic fire severity usually cannot be directly measured. Inferences are generally drawn based on patterns of fire return intervals, stand age class structures, and species composition (Frost and Sweeney 2000).

Fire frequency and severity are, in general, inversely related. Longer intervals between fires allow for a greater accumulation of fuels that lead to hotter, more severe fires when ignited (Agee 1993, Frost and Sweeney 2000). The continuity of surface fuels in the watershed is fragmented by rivers, ridges, rock outcrops, and serpentine barrens, all of which influence the extent and pattern of most fires. Shallow, rocky, and dry soils on lower elevation steep canyon slopes prevent establishment of most shrubs and trees. Thus, fuels accumulate rather slowly and are often discontinuous. Local-scale variations in topography can affect the moisture content of fuel by influencing microclimate and can further affect fire regimes by influencing fuel continuity (Frost and Sweeney 2000). In the watershed, the upper Sacramento River acts as an effective barrier to the spread of many low-intensity and some moderate-intensity fires.

In the steep, narrow canyons of the watershed, differentials in temperature, humidity, and fuel moisture between the canyon bottoms and the ridgetops are amplified by the common occurrence of strong thermal inversions (Schroeder and Buck 1970, Skinner et al. 2006). Diurnal patterns of local sun exposure and wind flow combine with slope steepness to affect fire behavior (Schroeder and Buck 1970, Rothermel 1983, Skinner et al. 2006). The exposure to wind and solar insulation combines with position on steep slopes to create conditions where upper slopes experience higher intensity fires more often than do lower slopes (Skinner et al. 2006). The greater drying and heating of fuels on steep slopes, especially those with westerly or southern aspects, contribute to greater fire and burn intensity (as depicted in Figure 3.1-7). As shown on Figure 3.1-7, fire severity generally occurs in a somewhat predictable pattern, where the upper third of slopes and ridgetops, particularly on south- and west-facing aspects, experience the highest proportion of high-severity burns, while the lower third of slopes and north- and east-facing aspects experience mainly low-severity fires. Middle slope positions typically act as an intermediary of severity between the upper and lower slopes.

When wildfire occurs in the watershed, the severity of the fire combined with the slope conditions (e.g., steepness, aspect) will determine the susceptibility of the burn area to soil erosion. In the upper part of the watershed, steep and convergent landforms may pose less of an erosion hazard due to gradual spring snowmelt runoff, although post-fire gullying may be significant in these areas. In the mid and southern parts of the watershed, where most precipitation falls as rain, the erosion potential following wildfire can be significant. In all parts of the watershed, burned-over convergent areas will concentrate overland flow, making these areas particularly susceptible to gully development. The volume and types of sediment eroded from the watershed's hillslopes strongly influence the types of aquatic habitats that form in the Sacramento River and its tributaries.

The severity with which wildfire has and will burn in the watershed has a significant effect on the types of vegetative communities that occupy a previously burned area. Few forested regions have experienced fires as frequently and with such high variability in fire severity as those in the Klamath Mountains (Taylor and Skinner 1998). In some areas of the watershed that have been subject to particularly severe fire, forests have been replaced by a persistent shrub-dominated community that inhibits the reestablishment of tree species. Mature or over-mature shrub-dominated vegetative communities are vulnerable to atypical fire behavior (i.e., increased fire severity). The effects of fire severity on vegetative communities, and, consequently, its effect on wildlife species is discussed in Section 3.3.4, *Plants, Wildlife, and Fish of Ecological/Cultural Concern*.

### *Fire Behavior in Dominant Vegetation Types in the Watershed*

The following is a discussion of the dominant types of vegetative communities occurring in the watershed and their relationship to fire behavior and fire effects.

#### Oak Woodlands

Many low-elevation sites, river canyons, and areas of droughty, shallow, rocky soils below about 3,000 feet elevation are occupied by oak-dominated woodlands. Although these woodland types may differ in terms of species composition and structure, they all occur in areas that are physiologically marginal for tree growth because of water limitations caused by low rainfall and/or thin, droughty soils (Frost and Sweeney 2000).

Canyon live oak is a common, dominant species in the lower montane zone of the watershed, particularly near Shasta Lake and in the southern portion of the watershed. This species, like most oaks, is sensitive to fire and is easily top-killed by fire. Dense canopies and thin bark make canyon live oak susceptible to crown scorch and cambium damage, but like most oaks, if the top is killed, it will sprout vigorously from the root crown.

The accumulation of fuel in oak woodlands, such as canyon live oak stands, growing on unproductive sites found in the lower to middle portions of the watershed occurs rather slowly and is often discontinuous. The hardwood and brush species in these areas have evolved under a fire regime of low- to moderate-intensity surface fires; however, exclusion of natural wildfires over the past century has increased the intensity with which fires now burn (USDA Forest Service 2000).

#### Douglas-Fir

Moderate to dense Douglas-fir communities occur in the lower to mid elevations of the watershed. Typically, Douglas-fir prefers the cooler northern or eastern exposures at lower elevations, but at higher elevations becomes much more variable. Species composition in Douglas-fir dominated communities consists of other conifer species such as ponderosa pine, sugar pine, and incense cedar; hardwoods, including canyon live oak, California black oak, and big-leaf maple; and a shrub understory.

Douglas-fir forests tend to occur in relatively dry areas where fire return intervals are fairly frequent. Known for its superior ability to adapt to fire, mature Douglas-fir stands are resistant to low- and moderate-severity fires and are likely to maintain dominance (Agee 1993). However, when low- to moderate-severity fire occurs in immature Douglas-fir stands, the species is not as fire tolerant and may be out-competed by shrubs and hardwoods for decades before regaining dominance.

### Ponderosa Pine

Ponderosa pine is a fire-adapted species that evolved under frequent low-severity fires. The frequency of these historic, pre-suppression era fires (often occurring at a mean fire interval of 10 years or less) have reduced potential competition from shrubs and grasses that would compete with young ponderosa pine trees for limited resources, such as sun and moisture, and would also periodically thin the stand. Pine needles, small twigs, and branches accumulated on the forest floor would be quickly consumed, allowing for the establishment of the shade-intolerant pine seedlings. Fire suppression activities in the watershed have significantly altered the composition of ponderosa pine stands by interrupting the natural fire return interval and creating unnatural accumulations of understory vegetation or dense, even-aged stands of plantation-grown ponderosa pine capable of carrying an active crown fire.

### Mixed Conifer

Fire intensities appear to have been mostly low to moderate in the mixed conifer forest of the eastern Klamath Mountains (which includes the watershed), generally thinning the forest according to species' susceptibility to fire, tree size, and density (Frost and Sweeney 2000). Pre-historic and historic land use patterns had a particular influence on the fire histories of mixed conifer forests (Agee 1993). In the western United States, this forest type experienced a significant component of Native American burning. In the watershed, it may be speculated that periodic burning by Native Americans was done not only to make the collection of acorns easier, but to kill diseases and pests, create openings for hazel and beargrass—both of which were used for basketry—and maintain travel corridors along ridgetops. Fire return intervals were relatively frequent in mixed conifer forests of the region, averaging a mean fire-return interval of 37 years between 1650 and 1930 in the nearby Siskiyou Mountains (Agee 1993).

Douglas-fir is a major component of mixed conifer forests in the watershed, although ponderosa pine is a common co-dominant. Its ability to adapt to relatively frequent fire enables mature Douglas-fir to maintain dominance so long as fires are not too intense. Low- to moderate-intensity fires typically top-kill the understory hardwoods, leaving them to resprout from the ground. However, if mixed conifer forests burn at higher frequencies (i.e., every one or two decades), young Douglas-fir trees will not be fire-tolerant and will be killed, leaving the hardwoods to resprout again and become dominant for many decades as Douglas-fir trees must compete not only with hardwoods but shrub species as well. Eventually, a mixed conifer forest will re-emerge with multiple-age species. The patterns of stand development in mixed conifer forests represent variable fire severities and the ability of the different species to take advantage of post-fire conditions (Agee 1993).

### Shasta Red Fir

Shasta red fir is a high-elevation species found in parts of the watershed where substantial winter snows tend to accumulate. Natural fire frequencies in Shasta red fir forests are relatively long (often 65 to 125+ years); thus, when fire occurs, it burns at a moderate level of severity (Agee 1993). Red fir communities are composed of moderate to dense conifer stands dominated by red fir. Associated species include white fir and, occasionally, mountain hemlock (*Tsuga mertensiana*) and western white pine. Shrubs that may be present include huckleberry oak (*Quercus vacciniifolia*) and mountain spirea (*Spiraea densiflora*).

Red fir-dominated forests represent a classic mosaic of patches associated with historical variation in disturbance intensity, primarily from fire (Agee 1993). However, fire suppression has resulted in minor landscape-level shifts in the forest mosaic of red fir forests, although the variable fire intensities and regimes under which these forests have evolved suggest that under most weather conditions, fires in this forest type will remain within controllable intensities (Agee 1993).

### Riparian Areas

Riparian areas are found in all vegetative habitat types. In the Klamath Mountains, these areas are often dominated by species such as deciduous hardwoods that are relatively uncommon in upland settings. Lower ambient temperatures, moister air and soils, and less flammable vegetation combine to reduce fire intensities in riparian areas (Frost and Sweeney 2000). While stand-replacing fires can occur in riparian areas, particularly in steep canyons, which can act as a wind tunnel, it is much more common for fire to burn as a low-intensity ground fire. In less steep montane riparian areas, disturbance from high winds may be lower than in surrounding uplands and along ridgelines, and, consequently, the quantity of downed large wood fuels could potentially decrease (Dwire and Kauffman 2003). During fire events, if wind speeds are lower in riparian areas than surrounding uplands, fire behavior may be less severe, with decreased rates of spread, decreased flame lengths, and lower fireline intensities (Dwire and Kauffman 2003). Shrubs and some deciduous trees may be subject to topkill, but most of these species readily resprout and soil stability is not impaired (Frost and Sweeney 2000). Most conifers survive such fires, and fire-sensitive species like Pacific yew (*Taxus brevifolia*) often do so because they grow in wetter microsites (Frost and Sweeney 2000).

However, the higher fuel loads that result from the higher vegetation densities and low fire return intervals generally associated with riparian areas can increase the vulnerability of these areas in drought conditions to increased fire severity, intensity, and return intervals. Under drought conditions, with the simultaneous occurrence of high temperatures, high wind speeds, and low relative humidity, fire weather could likely override local physical variables as the primary determinant of fire behavior (Dwire and Kauffman 2003). Such conditions may cause fire to behave similarly in riparian areas and in uplands.

The landscape position and size of the riparian areas appear to be an important determinant of the fire regime for a particular location. Small, narrow riparian areas, particularly those associated with intermittent and ephemeral streams, are likely to experience more frequent and higher intensity fires than large, broad riparian areas, and those in drier areas will probably burn more frequently than those in wetter areas (Frost and Sweeney 2000, Skinner et al. 2006). Riparian areas along perennial watercourses, such as the upper Sacramento River, serve as an effective barrier to the spread of low-intensity and some moderate intensity fires and have a strong influence on the patterns of fire occurrence beyond their immediate vicinity (Skinner et al. 2006). Consequently, by affecting fire spread, riparian areas are a key topographic feature that also contribute to the structure and dynamics of upland forest landscapes (Taylor and Skinner 2003, Skinner et al. 2006).

## Wildfire Relationships with Urban and Wildland Settings

It has been said that the wildland–urban interface (WUI) is a defining fire management issue of the 21st century (Husari et al. 2006). However, interface issues have been a part of the fire dynamic for as long as fires have burned from wildlands into communities. Expanding communities are at risk, not so much because of fuel accumulations within the community itself, but because of the vegetation types in which homes and towns are being built. In California, vegetation types that naturally burn with high intensity and rapid spread are increasingly punctuated by new homes and communities, greatly increasing the number of people and amount of property at risk.

Continued development in the interface area is causing fire resources and funding for fuel management programs to be reoriented, with the emphasis now on home and community protection rather than fire suppression. Increasing loss of homes in the interface has spurred Congress to allocate more fuel management funds to treat more acres at risk (Husari et al. 2006). The use of prescribed fire as a fuel management tool can be an efficient means by which the federal policy of emphasizing the restoration of fire to the ecosystem can be achieved, but it is not without some risk. The potential for escape, particularly into the WUI, and the health impacts associated with smoke generated by prescribed fire are a liability. Although the Klamath Mountains generally have a far lower human population compared to California as a whole, the Klamath and the Southern Cascades (in the vicinity of the upper Sacramento River watershed) bioregions are classified by CalFire as mixed interface because of the dispersed nature of dwellings in small, scattered communities in flammable wildland vegetation (Skinner and Taylor 2006, Skinner et al. 2006).

Within the Mt. Shasta community WUI, there is a high risk of human-caused fires due to the presence of residences, railroad tracks, and Interstate 5. Human-caused fires are often the result of negligence, but there have been some cases of arson reported in the Mt. Shasta community. Lightning-caused fires (as a percentage of all fires) are not as common in the WUI, but episodes of multiple lightening strikes can stretch suppression resources beyond their ability to deal with the numerous fires that could be ignited by a single storm. In these situations, fires located in or near the most valuable resource at risk, such as the City of Mt. Shasta, receive the highest priority.

Other communities in the watershed, including Dunsmuir and Lakehead, provide additional examples of the inexorable WUI development radiating outward from the Interstate 5 corridor into the forested areas of the watershed. Fire hazard severity zones have been delineated by CalFire for both Siskiyou and Shasta counties and for some specific communities (California Department of Forestry and Fire Protection 2008). In addition, some communities in the watershed (Lakehead, City of Mt. Shasta, and Dunsmuir) have or are currently preparing Community Wildfire Protection Plans (CWPP), which are prepared by a consortium of community volunteers organized into a Fire Safe Council. The intent of these community-based fire protection plans is to identify measures that will reduce the risk of wildfire spread into or out of the community; identify key properties, infrastructure, and other valuable assets at risk, including streams, timber, and wildlife; prioritize areas of hazardous fuels and identify fuel treatment needs (e.g., fuel breaks, defensible space); and assess community fire emergency preparedness. The advent of the CWPP program stems from the HFRA. This landmark legislation included the first meaningful statutory incentives for the USFS and BLM to give consideration to the priorities of local communities as they develop and implement forest management and hazardous fuel reduction projects (Society of American Foresters 2004).

The State of California has adopted a number of building code regulations and requirements specific to homes and other buildings located in the WUI (California Department of Forestry and Fire Protection 2007). Primary among these is Public Resources Code 4291 (effective January 1, 2009), which requires landowners having property in or adjacent to mountainous, forested, brush-covered, or grass-covered areas to maintain a defensible space no greater than 100 feet from each side of structures. A greater distance may be required by state law, local ordinance, or regulation. The intent of such codes is to provide minimum standards to increase the ability of a building to resist vegetation fires.

## 3.2 Physical Components and Processes

### 3.2.1 Climate and Air Quality

Within the watershed, topography and elevation are highly variable, with elevations ranging from 1,075 feet near Delta to 14,162 feet at the summit of Mount Shasta. Approximately 50 percent of the watershed is located above 3,000 feet, and approximately 16 percent is above 6,000 feet. As a result of this vast vertical range, air temperature, rainfall, and snowfall amounts can vary greatly across the watershed, and regional weather patterns, local storm patterns, topography, and elevation ultimately determine the climate of any specific location.

The global position of the watershed (approximately $41^{o}$ north latitude and $122^{o}$ west longitude) and its proximity to the ocean greatly influence its climate, which can be characterized as Mediterranean, having a distinctive hot and dry summer season and a cool and wet winter season. The main controlling factor of a Mediterranean-type climate in California is the relationship between the subtropical high and the westerlies, which are the prevailing winds in the mid-latitudes ($35–65^{o}$) of the globe. During the summer, the center of a subtropical high resides in the southwestern portion of the United States and expands pole ward, exerting its influence on the west coast between approximately $30^{o}$ and $40^{o}$ north latitude. Subsiding air from the high creates stable atmospheric conditions when coupled with cold ocean currents along the coast. The stable subtropical high-pressure air mass diverts the westerlies away from California. During the winter, the subtropical high shifts to the south, which allows the westerlies to transport moisture-laden storms that formed in the Pacific Ocean into California and the interior United States. Although this is an overgeneralization of the regional weather patterns, the movement of the sub-tropical high largely influences the general weather pattern of the watershed.

There is little meteorological data regarding storm movement in the watershed. Observational and anecdotal evidence suggests that most storms generally track from west to east with some slight variation to the north or south. However, the topographic disposition of the watershed can often greatly influence precipitation amounts and types regardless of the storm track. Often, easterly moving low-pressure systems track to the north of the watershed, but precipitation amounts can be the greatest to the south along the Sacramento River canyon and on the southern flanks of Mount Shasta.

It appears that higher pressure air from the Sacramento Valley to the south flows north up the Sacramento River canyon towards the low-pressure center of the storm. The topographic confines of the canyon combined with adiabatic5 cooling of the air mass causes large amounts of precipitation to fall. This phenomenon is observed in the climate record of weather stations in the subbasin[6] and will be discussed in conjunction with regional weather patterns and topography to characterize the climate of the upper Sacramento River watershed. The spatial and temporal distribution of precipitation is used to classify landforms and runoff/erosion potential.

## Data Sources

In the watershed, 24 weather-monitoring stations are actively collecting weather observations or have collected weather observations in the past (Table 3.2-1; note that some stations are listed twice due to an interruption in data collection or change of the data steward). The historical weather records of all of the stations contain enough data to characterize the rainfall, snowfall, and air temperature of the watershed. Rainfall data are the most abundant type of data in the historic record and air temperature the rarest. The weather station at the town of Mt. Shasta (#45983) has the most complete and extensive record (1948–2009) of air temperature, rainfall, and snowfall observations of the stations in the watershed.

In order to characterize the climate of the watershed across a range of elevations, three zones were chosen based on site elevation and the length and quality of climate records from nearby weather stations (Figure 3.2-1). The weather station near the City of Mt. Shasta is considered representative of the upper elevations of the subbasin. The weather stations near Dunsmuir (#42574 and 42572) are considered representative of the middle elevations, and the weather stations near Shasta Lake (i.e., Lakehead, Lakeshore, Vollmers, and Gibson) are considered representative of the lower elevations of the subbasin. Annual snowpack trends were characterized using snow course data from the highest elevation stations.

## Precipitation

### *General Trends*

In the subbasin, precipitation occurs as both rainfall and snowfall. All of the three precipitation zones summarized herein receive abundant precipitation during the winter and limited amounts of precipitation from thunderstorms during the summer months (Figure 3.2-2). The lower elevation Lakehead/Lakeshore area receives the most precipitation of the three areas analyzed, followed by Dunsmuir and the City of Mt. Shasta, respectively. Generally, the amount of precipitation in an area increases with elevation, but this is not true along the Sacramento River canyon. Located at an elevation of 1,100 feet, the Lakehead/Lakeshore area receives approximately 69 inches of combined precipitation. The data suggest that this area receives 10 more inches of precipitation than the Dunsmuir area at 2,400 feet in elevation receives in the form of rain and 17 more inches of precipitation than the City of Mt. Shasta at 3,500 feet in elevation.

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[5] *Changes in temperature caused by the expansion (cooling) or compression (warming) of a body of air as it rises or descends in the atmosphere.*

[6] *See Section 3.2.7,* Hydrology, *for a definition of subbasin as used herein.*

**Table 3.2-1. Current and Historic Weather Monitoring Stations in the Upper Sacramento River Watershed**

| STATION ID | STATION NAME | OPERATOR[A] | DATA STEWARD | LATITUDE (OW) | LONGI-TUDE (ON) | ELEVA-TION (FT) | AIR TEMP | RAINFALL DATA | SNOW DATA | WIND DATA | OTHER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DLT | Sacramento River at Delta | USGS/BOR | CDEC | 40.94 | 122.416 | 1,075 | X | | | | |
| LKS | Lakeshore | BOR | CDEC | 40.867 | 122.383 | 1,100 | X | X | | X | |
| 44709 | Lakeshore 1&2 | NWS | WRCC | 40.52 | 122.23 | 1,080 | X | X | | | |
| 44683 | Lakehead | NWS | WRCC | | | | | X | X | | |
| 49386 | Vollmers | NWS | WRCC | 40.57 | 122.26 | 1,340 | | X | X | | |
| SUG | Sugarloaf | USFS | CDEC | 40.917 | 122.438 | 4,200 | X | X | | X | X |
| GIB | Gibson | DWR | CDEC | 41.0225 | 122.3992 | 1,633 | X | X | | | |
| GBS | Gibson Maintenance Station | NWS | CDEC | 41.025 | 122.41 | 1,650 | | X | | | |
| 43405 | Gibson Maintenance Station | NWS | WRCC | 41.01 | 122.24 | 1,650 | | X | X | | |
| SLT | Slate Creek | BOR | CDEC | 41.045 | 122.478 | 5,700 | X | X | X | | |
| GRD | Girrard | BOR | CDEC | 41.133 | 122.283 | 4,800 | X | X | | | |
| DNM | Dunsmuir Treatment Plant | NWS | CDEC | | | | | X | | | |

## Table 3.2-1.  Current and Historic Weather Monitoring Stations in the Upper Sacramento River Watershed

| STATION ID | STATION NAME | OPERATOR[A] | DATA STEWARD | LATITUDE (OW) | LONGI-TUDE (ON) | ELEVA-TION (FT) | AIR TEMP | RAINFALL DATA | SNOW DATA | WIND DATA | OTHER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 42574 | Dunsmuir Treatment Plant | NWS | WRCC | 41.12 | 122.16 | 2,170 | X | X | X | | |
| 42572 | Dunsmuir RS | NWS | WRCC | 41.13 | 122.16 | 2,420 | | X | X | | |
| GYR | Grey Rocks Lake | USFS-MTS | CDEC | 41.217 | 122.417 | 6,200 | | | X | | |
| NFS | North Fork Sacramento River | USFS-MTS | CDEC | 41.305 | 122.493 | 6,900 | | | X | | |
| MSH | Mount Shasta | USFS-MTS | CDEC | 41.372 | 122.23 | 7,900 | | | X | | |
| SDF | Sand Flat | BOR | CDEC | 41.3504 | 122.2464 | 6,750 | X | X | X | | |
| SFT | Sand Flat Snow Course | USFS-MTS | CDEC | 41.353 | 122.247 | 6,800 | | | X | | |
| MTS | Mount Shasta | DWR | CDEC | 41.313 | 122.316 | 3,545 | X | X | | | |
| MTA | Mount Shasta | USFS | CDEC | 41.315 | 122.317 | 3,550 | X | X | X | X | X |
| MSC | Mount Shasta | NWS | CDEC | | | | | X | | | |
| 45983 | Mount Shasta | NWS | WRCC | 41.19 | 122.19 | 3,590 | X | X | X | | |
| MSH | Mount Shasta | USFS-MTS | CDEC | 41.372 | 122.23 | 7,900 | | | X | | |

[a] Operator Codes:

| | |
|---|---|
| BOR- U.S. Bureau of Reclamation | USFS- U.S. Forest Service |
| CDEC - California Data Exchange Center | USFS-MTS- USFS Mt. Shasta Ranger District |
| DWR- California Department of Water Resources | USGS- U.S. Geologic Survey |
| NWS- National Weather Service | WRCC- Western Regional Climate Center |

A majority of the subbasin's annual precipitation falls between December and March (Figure 3.2-2). January is the wettest month of the year, with all three areas receiving an average of at least 10 inches of precipitation and the Dunsmuir area averaging nearly 15 inches of combined precipitation. However, the Lakehead/Lakeshore area has the greatest average monthly precipitation amounts in 10 out of 12 months of the year. This discrepancy is most obvious in April, November, and December. These months occur on the fringes of the region's wet season, and it is possible that storms generated during these months lack sufficient energy to distribute precipitation evenly upslope along the Sacramento River canyon.

The aforementioned relationships between monthly and annual precipitation trends suggest that the topography of the Sacramento River canyon and the abrupt topographic rise of nearly 14,000 vertical feet between the Sacramento Valley and the summit of Mount Shasta greatly influence local precipitation patterns in the subbasin.

## Rainfall

### *Annual Trends*

The annual rainfall records of the City of Mt. Shasta, Dunsmuir, and Vollmers were analyzed to determine the mean annual rainfall for each area. In order to track temporal changes in precipitation trends, the total rainfall for each calendar year was compared to mean (normal) annual rainfall at eachsite to determine if the rainfall in a particular year was above or below the mean rainfall of the area (Figure 3.2-3). Long-term precipitation trends were analyzed by plotting the cumulative departure from the annual mean against an annual timeline for each site.

Figure 3.2-3 shows the wetting and drying trends over the last 60 years. Abrupt changes in cumulative departure from the mean between 1973 and the present are the most notable. These changes can be explained by the high amount of annual rainfall variability during the period. At Dunsmuir, the five largest and lowest rainfall years on record occurred between 1973 and the present (37 years), and four of the five largest and lowest rainfall years on record occurred between 1983 and 2010 (27 years). These trends suggest that there has been increased annual rainfall variability since 1973, but statistical analysis of these data shows that any increases in annual precipitation variability are not statistically significant. Another trend worth noting is that between 1994 and 2009, rainfall amounts were above normal 10 years during the period. These data suggest that the area may be currently experiencing above-average precipitation amounts despite the three below-average years between 2007 and 2009.

### *24-Hour Rainfall Trends*

The watershed receives large amounts of rainfall due, in part, to its close proximity to the Pacific Ocean. Fast-moving or very low pressure systems can distribute large amounts of rainfall in a short time. High-intensity rainfall can initiate hillslope erosion, flash flooding, and slope failure. Figure 3.2-4 illustrates the occurrence and intensity of 24-hour rainfall events. On average, Gibson and the lower elevations of the watershed can expect to receive one annual event that produces 3.3 inches of rain in 24 hours, which is equivalent to constantly receiving 0.13 inch of rain every hour for an entire day. The City of Mt. Shasta can expect to receive one annual event that produces 2.2 inches of rain in 24 hours. This difference suggests that the topography between the two sites—the Sacramento River

Insert 11x17 Figure 3.2-1

Figure 3.2-1 Location of Weather Stations

Blank back of 11x17 Figure  3.2-1

Figure 3.2-2. Average Monthly and Annual Precipitation for City of Mt. Shasta, Dunsmuir, and Lakehead/Lakeshore

Figure  3.2-3.  Annual Trends in Rainfall

Figure  3.2-4.   24-Hour Rainfall Frequency Curves canyon—plays a role in precipitation distribution within the subbasin. The narrow north-south oriented canyon forces extremely intense rainfall events mid-slope, as shown in Figure 3.2-4. For example, a 10-year, 24-hour rainstorm at Gibson is between 7 and 8 inches compared between 4 and 5 inches in the City of Mt. Shasta. This volume of rainfall in such a short period will frequently cause upslope convergent hillslopes to fail, especially those cleared of vegetation and/or compacted.

## Snowfall and Snowpack

Snowfall occurs at all elevations of the subbasin, but areas above 5,000 feet can receive a majority of their annual precipitation in the form of snow. Approximately 50 percent of the watershed is located above 3,000 feet and, as a result, snowfall and snowpack are major influences on the hydrologic cycle of the area.

The annual snow depth records for the Mount Shasta snow course (7,900 feet), Sand Flat snow course (6,800 feet), and Slate Creek snow course (5,700 feet) were analyzed to characterize the mean annual (January–April) snow depths at varying elevations. In order to track temporal changes in the snowpack in the subbasin, the mean snow depth of each calendar year was compared to the mean snow depth for the period of record at each site (Figure 3.2-5). This comparison helps to determine if the mean snow depth in a particular year was above or below the mean annual snow depth for each snow course. Long-term trends were also analyzed by plotting the cumulative departure from the annual mean against an annual timeline for each site.

Several climate trends are apparent in Figure 3.2-5. All three sites follow the same general snow depth pattern, as demonstrated by the cumulative departure from the mean at all three sites. The general trend is an above-average snowpack between 1950 and 1973, followed by a series of years with a highly variable snowpack between 1974 and 1994, and above-average snowpack between 1995 and 2006. The snowpack variability between 1975 and 1994 can be explained by the occurrence of historic events. For example, four of the five lowest snowpack years occurred at the Mt. Shasta and Sand Flat snow courses during this period as well as three of the five greatest snow depth years on record. In addition, the greatest measured snow depth occurred at all sites in 1983 and the lowest occurred in 1977. Between 1997 and 2009, the trend has been one of above-average snow depths for all sites, with a below-normal trend between 2006 and 2009.

Rainfall and snowpack are closely related within the subbasin. Between 1974 and the present, the trend in annual precipitation closely follows the trend in snow depth at all snow courses. In short, if there is an above-normal precipitation year, there is an above-normal snowpack the same year. However, this relationship is not consistent through the record. Between 1955 and 1977, a majority of the years had an above-average snowpack but below average rainfall. During this period, it is likely that this trend resulted from cooler winter air temperatures causing increased snowfall amounts from the available precipitation. The air temperature data for this period provide further support to this hypothesis.

## Air Temperature

Air temperature trends in the watershed are consistent with a Mediterranean-type climate of hot summers and mild winters (Figure 3.2-6). The highest average maximum temperatures occur in July and the coldest average minimum temperatures occur in January.

Figure 3.2-5. Annual Seasonal Snow Depth Trends

Figure 3.2-6. Monthly and Seasonal Air Temperature

The warmest area in the watershed, the Lakehead/Lakeshore area, is also located at the lowest elevation (1,100 feet). In July, maximum temperatures in this area occasionally exceed 95 °F or drop below 60 °F (Figure 3.2-6). In January, temperatures rarely reach 52 °F or drop below 32 °F (freezing). The temperature data for the Lakeshore/Lakehead area suggest that the portions of the watershed around 1,000 feet in elevation generally have a mild climate. These low-elevation areas remain frost-free for a majority of the year, average maximum temperatures are above 50 °F all year, and summer temperatures are less than 95 °F a majority of the time.

The coldest area analyzed in the watershed is the City of Mt. Shasta. The City of Mt. Shasta weather station is located at an elevation of approximately 3,550 feet. In July, temperatures in the area occasionally exceed 85 °F or drop below 50 °F (Figure 3.2-6). In January, maximum temperatures can reach 43 °F or drop below 26 °F. These temperature data suggest that the portions of the upper watershed around 3,500 feet in elevation generally have a cool climate. Average minimum temperatures are greater than 40 °F for only four months of the year, and average maximum temperatures exceed 80 °F for only two months of the year.

In order to track temporal changes and temperature trends in the watershed, the average air temperature for each calendar year was compared to mean annual temperature at each of three sites, City of Mt. Shasta, Dunsmuir, and Gibson, to determine if the air temperature of a particular year was above or below the mean at the site (Figure 3.2-7). The City of Mt. Shasta has a complete record, but Dunsmuir and Gibson have limited historic data available. Long-term air temperature trends were analyzed by plotting the cumulative departure from the annual mean against an annual timeline for each site.

The most noteworthy trend visible on Figure 3.2-7 is the negatively sloping trend of the cumulative departure lines of the Mt. Shasta weather station between 1963 and 1985. The incomplete temperature records of the Dunsmuir and Gibson stations also suggest the period had a cooling trend. It appears that the air temperature of the City of Mt. Shasta was generally below normal in this 32-year span. There also appears to be a slight warming trend that has been occurring between 2000 and the present. During this period, the average annual air temperature of the City of Mt. Shasta was nearly 5 percent above normal for the entire period.

The cooling trend between 1963 and 1985 also corresponds with an increased snowpack trend that occurs between 1955 and 1977 at all of the snow courses (Figure 3.2-5). Cooler temperatures generally produced an above-normal snowpack during this period, which means that as the annual temperature decreased, the annual snowpack increased. However, between 1985 and the present, cooler temperatures generally had less influence on snow depth and the snow depth more closely correlated with precipitation. To determine the significance of this discrepancy, the relationship between annual air temperature and snowpack was compared between two periods: 1963 to 1985 and 1985 to present. Analysis indicates that variability between the two periods is not statistically significant, which suggests that all fluctuations within the record are within the natural variation. This suggests that annual average air temperature has little effect on snowpack depth at higher elevations.

Figure 3.2-7. Annual Air Temperature Trends

## Air Quality

The watershed spans two air basins. The northern portion of the watershed is located in the Northeast Plateau Air Basin, which is characterized by the Klamath Basin and Modoc Plateau and is bounded by the Cascade Range in the east and the Klamath Range in the west. The southern portion of the watershed is located in the Northern Sacramento Valley Air Basin, which is characterized by the expansive Sacramento Valley and is bounded by the Klamath and Coast ranges to the west and the southern limits of the Cascade Range and northern limits of the Sierra Nevada to the east.

The watershed falls under two local air quality management jurisdictions, the Siskiyou County Air Pollution Control District and the Shasta County Air Quality Management District. Both local districts are tasked with implementing federal and state emissions standards and other air quality regulations within their respective jurisdictions. The districts are responsible for regulating stationary source emissions by issuing air quality permits that require implementation of Best Available Control Technology (BACT) if specified trigger levels are exceeded.

Air quality in this remote part of the state is generally good. Tables 3.2-2 through 3.2-4 summarize the air quality in the watershed. Pursuant to the 1990 federal Clean Air Act (CAA) Amendments, the EPA has classified air basins (or portions thereof) as either “attainment” or “non-attainment” for each criteria air pollutant, based on whether or not the National Ambient Air Quality Standards (NAAQS) have been achieved. The California Air Resources Board (CARB) also classifies air basins and air quality districts as being in attainment or non-attainment for state air quality standards. Under the federal CAA Amendments, Shasta and Siskiyou counties are designated attainment or unclassified for all federal ambient standards (California Air Resources Board 2010). Shasta County is in attainment for most California air quality standards, but is not in attainment for the California particulate matter and ozone standards (California Air Resources Board 2010). With the exception of ozone, Siskiyou County is designated as in attainment for state air quality standards. Siskiyou County’s attainment status for ozone is “non-attainment-transitional,” which means that the air district came into non-attainment as an operation of law when the ozone standards were changed (California Air Resources Board 2010). As required by the California Clean Air Act (CCAA), the Shasta County air quality district has prepared an air quality attainment plan, the Northern Sacramento Valley Planning Area 2006 Air Quality Attainment Plan (Shasta County et al. 2006). The plans address the CCAA requirement to bring the district into compliance with state ambient air quality standards, specifically requirements for ozone. The plan contains control programs for stationary sources and mobile sources. Because of the relative intractability of the PM10 and PM2.5 problem, the CCAA excludes this pollutant from the planning requirements to which other pollutants, such as ozone, are subject. Because Siskiyou County’s “non-attainment” status is transitional and accounts for minor air quality exceedances that are associated with wildfire events, the County does not have an ozone attainment plan (Olson 2010). The County continues to work with CARB staff to ensure compliance with state air quality requirements (Olson 2010).

California has adopted ambient standards that are more stringent than the federal standards for the criteria air pollutants. These standards are referred to as the California Ambient Air Quality Standards (CAAQS). Under the CCAA, patterned after the federal CAA, areas have been designated as attainment or non-attainment with respect to the state ambient air quality standards.

**Table 3.2-2. Air Pollutant Trends by Air Basin (2000 to 2010)**

| | POLLUTANT (TONS/DAY, ANNUAL AVERAGE) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ROG (INCLUDING O3 PRECURSORS) | | | CO | | | PM10 | | | PM2.5 | | | NOX | | | SOX | | |
| **AIR BASIN** | **2000** | **2005** | **2010** | **2000** | **2005** | **2010** | **2000** | **2005** | **2010** | **2000** | **2005** | **2010** | **2000** | **2005** | **2010** | **2000** | **2005** | **2010** |
| Sacramento Valley | 243 | 207 | 183 | 1520 | 1223 | 1032 | 222 | 227 | 232 | 74 | 73 | 74 | 318 | 290 | 250 | 6 | 5 | 4 |
| Northeast Plateau | 33 | 31 | 30 | 341 | 319 | 307 | 74 | 73 | 72 | 26 | 25 | 25 | 32 | 30 | 25 | — | — | — |

Source: California Resources Board (2009)

**Table 3.2-3. Ambient Air Quality Monitoring Data in the Multi-Region Habitat Conservation Plan Area, 2005**

| | POLLUTANT | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **$O_3$ (PPM)** | | | | | **CO (PPM)** | | | | | **PM10 (PPM)** | | | |
| | Max. 1 hr *0.09 ppm* | Max. 8 hr *0.07 ppm/ 0.008 ppm* | Days > State 1 hr max. conc. | Days > State 8 hr max. conc. | Days > Fed 8 hr max. conc. | Max. 1 hr | Max. 8 hr *9.0 ppm* | Days > State 1 hr max. conc | Days > State 8 hr max. conc. | Days > Fed 8 hr max. conc. | Max. 24 hr. State *50 $\mu g/m^3$* | Max. 24 hr. Fed *20 $\mu g/m^3$* | Days > State 24 hr conc. | Days > Nat. 24 hr std |
| Sacramento Valley Air Basin | 0.134 | 0.128 | 33 | 62 | 25 | 8.0 | 4.2 | — | 0 | 0 | 109 | 110 | 42 | 0 |
| Northeast Plateau Air Basin | 0.070 | 0.062 | 0 | 0 | 0 | — | — | — | — | — | 28 | 29 | 0 | 0 |

| | POLLUTANT | | | | | | |
|---|---|---|---|---|---|---|---|
| | **$PM_{2.5}$** | | **$NO_2$** | | **$SO_2$** | | |
| | Max. 24 hr. State | Max. 24 hr Fed *35 µg/m* | Max. 1 hr *0.18 ppm* | Max. An. Avg. | Max. 24 hr. *0.04 ppm* | Exp. > 1 hr. ppm-hrs/pers | Max. Ann. Avg |
| Sacramento Valley Air Basin | 82.7 | 80.0 | 0.079 | 0.016 | 0 | 0.99 | 0.00 |
| Northeast Plateau Air Basin | 26.0 | 26.0 | — | — | — | — | 0.00 |

Source: California Air Resources Board (2009)

**Table 3.2-4. Summary of the Federal and State Ambient Air Quality Standards for Criteria Air Pollutants**

| POLLUTANT | AVERAGING TIME | FEDERAL STANDARD | STATE STANDARD |
|---|---|---|---|
| Ozone ($O_3$) | 1-Hour<br>8-Hour | 0.12 ppm<br>0.08 ppm | 0.09 ppm<br>-- |
| Carbon monoxide (CO) | 1-Hour<br>8-Hour | 35 ppm<br>9 ppm | 20 ppm<br>9 ppm |
| Nitrogen dioxide ($NO_2$) | 1-Hour | -- | 0.25 ppm |
| | Annual | 0.053 ppm | -- |
| Sulfur dioxide ($SO_2$) | 1-Hour | -- | 0.25 ppm |
| | 24-Hour | 0.14 ppm | 0.04 ppm |
| | Annual | 0.03 ppm | -- |
| Fine particulate matter ($PM_{2.5}$) | 24-Hour | 65 $\mu g/m^3$ | -- |
| | Annual Arithmetic Mean | 15 $\mu g/m^3$ | -- |
| Respirable particulate matter ($PM_{10}$) | 24-Hour | 150 $\mu g/m^3$ | 50 $\mu g/m^3$ |
| | Annual Arithmetic Mean | 50 $\mu g/m^3$ | -- |
| | Annual Geometric Mean | -- | 30 $\mu g/m^3$ |
| Lead (Pb) | 30-day Average | -- | 1.5 $\mu g/m^3$ |
| | Calendar Quarter | 1.5 $\mu g/m^3$ | -- |

Notes:
ppm = parts per million
$\mu g/m^3$ = micrograms per cubic meter
Source: California Air Resources Board (2009)

### *Federal and State Air Quality Requirements*

The 1977 federal CAA required the EPA to identify National Ambient Air Quality Standards (NAAQS) to protect public health and welfare. NAAQS have been established for the following "criteria"[7] air pollutants: ozone ($O_3$), carbon monoxide (CO), nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$), suspended particulate matter ($PM_{10}$ and $PM_{2.5}$), and lead (Pb).

CARB, California's state air quality management agency, regulates mobile source emissions and oversees the activities of county Air Pollution Control Districts (APCDs) and regional Air Quality Management Districts (AQMDs). CARB regulates local air quality indirectly by establishing state ambient air quality standards and vehicle emission standards, by conducting research activities, and through its planning and coordinating activities.

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[7] *Termed "criteria" pollutants because EPA publishes criteria documents to justify the choice of standards.*

### 3.2.2 Climate Change

It is generally agreed by the scientific community that the ambient temperatures of the earth's air and oceans are increasing and will continue to increase into the foreseeable future. In the Pacific Northwest, a warming trend was documented during the 20th century and a continued rise in temperatures is predicted (National Assessment Synthesis Team 2000; Mote et al. 2003; Furniss et al. 2009). Although it is still uncertain how increased air and water temperatures will affect the climates in different parts of the world, especially at a local level, wetter winters are expected in the Pacific Northwest (Mote et al. 2003).

It has been suggested that overall warming will bring large changes in the snowline (Mote et al. 2003), with substantial reductions in the snowpack at lower elevations, causing the timing of the snowmelt to shift earlier into spring (Furniss et al. 2009). It has also been suggested that in higher elevation watersheds, mainly in the Sierra Nevada, the air temperature increases are resulting in rising snow lines, opening up larger areas of a given catchment to rainfall versus snowfall. Long term, this change could shift the flood regime and increase the frequency of flooding (California Climate Change Center 2009).

The upper Sacramento River watershed sits on the boundary between the climate of the Pacific Northwest and the Mediterranean climate of central California and is equally influenced by both climate zones. As a result, the effects of climate change may not fit regional predictions. Existing climate data at Mt. Shasta do not show any significant changes for at least the last 50 years. For this period, the average annual air temperature has not measurably increased.

### 3.2.3 Geology and Soils

The upper Sacramento River watershed is located principally within the Klamath Mountains and Cascade Geomorphic Provinces. The streams draining the assessment area cover a broad expanse of land with a widely diverse and complicated geology. A large portion of the area is underlain by rock units of the Klamath Mountains Province (Figure 3.2-8). This province has been divided into four belts separated by northwest trending faults caused by subduction along the margin between the Pacific and North American Plates. The assessment area covers portions of the eastern, central, and western belts (USDA Forest Service 1995).

Klamath Mountains rocks range in age from the Ordovician Period through the Jurassic Period, or 500 million years to 135 million years before present. The diverse assemblage of rock types in this province were formed as part of an island arc system and include a mix of marine sedimentary and volcanic rock types. Figure 3.2-8 illustrates this diversity in rock types upstream of Shasta Lake.

Metasedimentary rock units dominate the assessment area, including limestone units generally known as McCloud Limestone. The weathering characteristics of limestone have resulted in large areas in the southern portion of the assessment area where the rock has become exposed. Locally, small intrusions of igneous rocks can be found throughout the area, typically iron-rich ultramafics and silica-rich granitics (USDA Forest Service 1995). Within the metamorphic terrain, Castle Crags is a large granitic pluton that was intruded during the Jurassic Period around 65 million years ago. The higher elevations of all of these terrains were glaciated approximately 13,000 years ago, contributing

Figure 3.2-8 Distribution of Different Rock Types to the formation of many cirque lakes such as Castle Lake, Gray Rock Lake, Timber Lake, and Little Castle Lake.

The northeastern portion of the assessment area is underlain by volcanic rocks of the Cascade Range and the Modoc Plateau. These volcanic rocks are generally younger than 4 million years old. The exposed rock units of the Cascades were deposited over millions of years by volcanic activity. Within this area, the rock units were produced by extrusive igneous activity of Mount Shasta and features associated with the underlying magma chamber. Volcanic debris was extruded above the surface of the earth and deposited on top of the rocks of the Klamath Mountains Geomorphic Province to the north and east. The volcanic deposits that blanket the northeastern portion of the watershed contribute to the rich topographic diversity of the area.

Within the watershed, the units of the Klamath Mountains Geomorphic Province and Cascade Range have been reworked by fluvial and glacial action over the past 1 million years. Alluvial, glacial, and mass wasting deposits are all exposed in the area. Glacial deposits are localized and concentrated in the areas surrounding Mount Shasta and the higher elevation areas along the western portion of the basin.

Large earthquakes are rare in the upper Sacramento River watershed because of the distance to the major fault zones associated with the San Andreas Fault and the Cascadia Subduction Zone of northern California. Only four earthquakes with a magnitude of five or greater have had an epicenter within 100 miles of the assessment area in the last 100 years (Northern California Earthquake Data Center 2008). However, the region has regularly experienced smaller earthquakes (between magnitude three and five). Additionally, there are many pre-Quaternary (inactive) faults located throughout the Klamath Mountains and within the watershed.

Mount Shasta (14,179 feet), the largest stratovolcano of the Cascade chain (217.5 cubic miles), is the dominant mountain landform located in the upper portion of the watershed. It consists of four overlapping volcanic cones that have built a complex shape, including the main summit and the prominent satellite cones of Shastina (12,330 feet). If Shastina were a separate mountain, it would rank as the third-highest peak of the Cascade Range. There are seven named glaciers on Mount Shasta; however, none of them drains into the upper Sacramento River.

About 600,000 years ago, andesitic lavas erupted on what is now Mount Shasta’s western flank near McBride Spring in the watershed. Over time, an ancestral Shasta stratovolcano was built to a large but unknown height, and sometime between 300,000 to 360,000 years ago the entire north side of the volcano collapsed, creating an enormous landslide of 6.5 cubic miles in volume outside of the watershed.

Mount Shasta has erupted, on average, at least once per 800 years during the last 10,000 years and about once per 600 years during the last 4,500 years. The last known eruption occurred about 200 years ago. Eruptions during the last 10,000 years produced lava flows and domes on and around the flanks of Mount Shasta, and pyroclastic flows from summit and flank vents extended far from the summit. Most of these eruptions also produced large mudflows, many of which reached more than tens of kilometers (dozens of miles) from Mount Shasta. Future eruptions like those of the past could endanger the communities of Weed, Mt. Shasta, McCloud, and Dunsmuir, located at or near the base of Mount Shasta. Such eruptions will most likely produce deposits of lithic ash, lava flows, and pyroclastic flows. Lava flows and pyroclastic flows may affect low- and flat-lying ground almost anywhere within approximately 12.4 miles of the summit of Mount Shasta, and mudflows may cover valley floors and other low areas as much as several tens of kilometers from the volcano. Based on its past behavior, Mount Shasta is not likely to erupt large volumes of pumiceous ash in the future. Areas subject to the greatest risk from air-fall tephra are located mainly east and within about 30 miles of the summit of the volcano. The degree of risk from air-fall tephra decreases progressively as the distance from the volcano increases.

Two of the main eruptive centers at Mount Shasta, the Shastina and Hotlum cones, were constructed during the Holocene (approximately the last 10,000 years). Holocene eruptions also occurred at Black Butte, a group of overlapping dacite domes about 8 miles west of Mount Shasta. Evidence of geologically recent eruptions at these two main vents and at flank vents forms the chief basis for assessing the most likely kinds of future eruptive activity and associated potential hazards.

In the last 8,000 years, the Hotlum Cone has erupted at least eight or nine times. About 200 years ago, the last significant Shasta eruption came from this cone and created a pyroclastic flow, a hot lahar (mudflow), and three cold lahars, which streamed 7.5 miles down Shasta's east flank via Ash Creek. A separate hot lahar went 12 miles down Mud Creek. This eruption was observed by the explorer La Perouse from his ship off the California coast in 1786.

The U.S. Geological Survey (USGS) has analyzed the risk of future eruptions on the local population centers around the mountain, including the City of Mt. Shasta as well as Weed, Dunsmuir, and McCloud (Miller 1980). The main hazards are pyroclastic flows and mud flows (Figure 3.2-9). The majority of the City of Mt. Shasta is located within the predicted zone of pyroclastic flows.

### 3.2.4 Mineral Resources

Within the assessment area, mineralized rock formations have been mined for several valuable minerals, including copper, gold, silver, and tungsten. Mining is permitted on all public lands not withdrawn from mineral entry, and the United States Mining Laws (30 U.S.C. 21-54) confer statutory right to enter upon public lands in search of minerals. Regulations found in 36 CFR 228, Subpart A, set forth rules and procedures to minimize adverse environmental impacts on National Forest resources. Access for mineral exploration and development is generally unrestricted, subject to the mitigation of adverse impacts to surface resources.

Access for mineral exploration on public lands is restricted in wildernesses, the “wild” portions of Wild and Scenic Rivers, botanical areas, Research Natural Areas (RNAs), National Recreation Areas (NRAs), and areas that have been withdrawn from mineral entry. Minerals in the NRA are not locatable (minerals that may be acquired under the Mining Law of 1872, as amended) but they are leasable (USDA Forest Service 1995).

Mineralized rock formations are relatively sparse in the upper watershed, whereas downstream areas are highly mineralized and are where major mining operations historically occurred. In the lower portion of the subbasin near Shasta Lake, the mining activities were focused on development of massive sulfide deposits. Similar to other areas in the Klamath Mountains Geomorphic Province, copper was the most commonly found metal. Zinc, sulfur, iron, limestone, gold, and silver were produced as by-products of copper production. Once disturbed by mining activities, these types of

Figure 3.2-9 Mud and Pyroclastic Flow Hazard Areas, Mount Shasta Area mineral deposits are a known source of toxic mine waste and acidic fluids to the Sacramento River (United States Department of Agriculture 2000). Other sources found within the upper Sacramento River consist of alluvial sand and gravel, crushed stone, volcanic cinders, limestone, and diatomite.

Most mining within the assessment area ceased prior to 1945. The Golinsky Mine is located in the assessment area about 7 miles west of Shasta Dam in the headwaters of Little Backbone Creek. This abandoned mine complex is very large and has been extensively remediated. The Mammoth and Sutro Mines are of notable size and are located within the assessment area.

### 3.2.5 Soils

Climate, geology, topography, and other factors determine soil characteristics. Soil productivity is defined as the capacity of the soil to produce a plant community or sequence of plant communities under a specified system of management. The factors that influence the productivity of soil are soil depth, percent of rock fragments, texture, available water-holding capacity, nutrient status, maintenance of the duff layer, mineral toxicity, and pH. Other environmental factors that influence soil productivity are precipitation, aspect, slope gradient, and elevation. The productivity of the soil types in the STNF ranges from very low to high (USDA Forest Service 1995 (Figure 3.2-10). Within the assessment area, the most productive soils occur in flat valley bottoms.

Soils in most of the assessment area have been mapped; however, approximately 21 square miles of the area, mainly near the City of Mt. Shasta, has not been mapped. Soils of low productivity comprise about half of the assessment area, soils of moderate productivity comprise about 30 percent of the area, and soils of high productivity comprise about 20 percent of the area.

Approximately 25 percent of the soils in the assessment area are classified as highly to very highly erodible. The greatest threats to the maintenance of soil productivity are sheet and gully erosion. Nearly all bare soil is subject to erosion if a sufficient amount of surface water flow is present. Some soils have a higher propensity to erode than others do. Examples of highly erodible soils in the study area are Estel Family, Neuns Family, Goulding Family, and Deadwood Family (Table 3.2-5).

The Soil Survey of the Shasta-Trinity National Forest, California (U.S. Department of Agriculture 1983) identifies 62 soil map units in the assessment area (Figure 3.2-10). The most common soil families are Marpa, Nuens, Goulding, and Estel. These four families are well drained and are of fine loamy-loamy/skeletal mixed composition. The taxonomy characterizing these soils is Ultic Haploxeralfs. Except for Nuens, they also have medium to high erosion severity as defined by the erosion hazard rating (EHR).

#### Geomorphology

The geomorphic expression of the upper Sacramento River subbasin is controlled by the bedrock geology as expressed in topographic features, including the type, rate, and magnitude of erosional processes. The soils developed from the underlying parent material have distinct and characteristic properties that can affect vegetation patterns and disturbance mechanisms at multiple spatial and temporal scales.

11x17

Figure 3.2-10 Soil Type and Erodeability Map

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**Table 3.2-5. Soil Types by Erosion Severity in the Upper Sacramento River Subbasin Ranked in Descending Order by Percent of Total Assessment Area**

| SOIL NAME | LOW EHR | MED EHR | HIGH EHR | VERY HIGH EHR | NOT MAPPED |
|---|---|---|---|---|---|
| Etsel Family | 0% | 0% | 30% | 0% | 0% |
| Neuns Family | 2% | 10% | 11% | 0% | 0% |
| Rock Outcrop | 2% | 1% | 11% | 0% | 0% |
| Goulding Family | 0% | 8% | 10% | 0% | 0% |
| Deadwood Family | 0% | 6% | 9% | 0% | 0% |
| Marpa Family | 5% | 29% | 5% | 0% | 0% |
| Gozem Family | 0% | 1% | 4% | 0% | 0% |
| Toadlake Family | 0% | 7% | 3% | 0% | 0% |
| Ishi Pishi Family, deep | 5% | 0% | 3% | 0% | 0% |
| Endlich Family | 0% | 2% | 2% | 0% | 0% |
| Sadie Family, deep | 3% | 0% | 2% | 0% | 0% |
| Weitchpec Family | 1% | 0% | 2% | 0% | 0% |
| Olete Family | 2% | 4% | 2% | 0% | 0% |
| Asta Family | 0% | 0% | 1% | 0% | 0% |
| Skymor Family | 4% | 0% | 1% | 0% | 0% |
| Parks Family | 0% | 0% | 1% | 0% | 0% |
| Washougal Family | 8% | 0% | 1% | 0% | 0% |
| Rock Outcrop, metamorphic | 0% | 0% | 1% | 0% | 0% |
| Rock Outcrop, ultramafic | 0% | 0% | 1% | 0% | 0% |
| Hugo Family | 1% | 3% | 0% | 0% | 0% |
| Lithic Haploxeralfs | 0% | 0% | 0% | 0% | 0% |
| Dubakella | 0% | 0% | 0% | 0% | 0% |
| Jayar Family | 1% | 3% | 0% | 0% | 0% |
| Deadfall Family | 0% | 0% | 0% | 0% | 0% |
| Rock Outcrop, limestone | 0% | 0% | 0% | 0% | 0% |
| Andic Cryumbrepts | 0% | 2% | 0% | 0% | 0% |
| Atter Family | 3% | 0% | 0% | 0% | 0% |
| Beaughton Family | 0% | 0% | 0% | 0% | 0% |
| Chaix Family | 0% | 0% | 0% | 18% | 0% |
| Chawanakee Family | 0% | 0% | 0% | 32% | 0% |
| Dubakella Family | 0% | 0% | 0% | 0% | 0% |
| Dunsmuir Family | 11% | 0% | 0% | 0% | 0% |
| Germany Family | 3% | 0% | 0% | 0% | 0% |
| Holland Family | 2% | 4% | 0% | 0% | 0% |
| Holland Family, ashy | 3% | 0% | 0% | 0% | 0% |
| Holland Family, deep | 10% | 3% | 0% | 0% | 0% |
| Hugo Family, moderately deep | 0% | 0% | 0% | 0% | 0% |
| Huntmount Family | 3% | 0% | 0% | 0% | 0% |
| Inville Family | 5% | 0% | 0% | 0% | 0% |
| Ishi Pishi Family | 3% | 3% | 0% | 0% | 0% |
| Jayar Family, deep | 0% | 1% | 0% | 0% | 0% |
| Konocti Family | 0% | 2% | 0% | 0% | 0% |
| Lithic Xerumbrepts | 0% | 1% | 0% | 0% | 0% |
| Merkel Family | 2% | 0% | 0% | 0% | 0% |
| Millsholm Family | 0% | 0% | 0% | 0% | 0% |
| Nanny Family | 0% | 0% | 0% | 0% | 0% |
| Neuns Family, deep | 0% | 2% | 0% | 0% | 0% |
| Ovall Family | 0% | 0% | 0% | 2% | 0% |
| Revit Family | 2% | 0% | 0% | 0% | 0% |

**Table 3.2-5. Soil Types by Erosion Severity in the Upper Sacramento River Subbasin Ranked in Descending Order by Percent of Total Assessment Area**

| SOIL NAME | LOW EHR | MED EHR | HIGH EHR | VERY HIGH EHR | NOT MAPPED |
|---|---|---|---|---|---|
| Rock Outcrop, granitic | 0% | 0% | 0% | 47% | 0% |
| Rock Outcrop, sedimentary | 3% | 0% | 0% | 0% | 0% |
| Rock Outcrop, volcanic | 8% | 0% | 0% | 0% | 0% |
| Rubble Land | 1% | 0% | 0% | 0% | 0% |
| Shadeleaf Family | 0% | 0% | 0% | 0% | 0% |
| Shasta Family | 0% | 0% | 0% | 0% | 0% |
| Sheld Family | 3% | 1% | 0% | 0% | 0% |
| Tamflat Family | 0% | 0% | 0% | 0% | 0% |
| Toadlake Family, till substratum | 0% | 2% | 0% | 0% | 0% |
| Typic Cryaquolls | 1% | 0% | 0% | 0% | 0% |
| Washougal Family, deep | 1% | 0% | 0% | 0% | 0% |
| Wintoner Family | 0% | 0% | 0% | 0% | 0% |
| Xerofluvents | 1% | 0% | 0% | 0% | 0% |

HER = Erosion hazard rating

The geomorphic expression of the area was characterized using NetMap, an automated watershed analysis tool. The NetMap system used for the upper Sacramento River subbasin provides a unique capability for this assessment. The analytical tool kit that is part of NetMap allows detailed investigations into the physical attributes of the watershed that can inform pre- and post-wildfire management (see Chapter 4), forestry, road maintenance, habitat restoration, and monitoring. Such watershed analysis assessments pertinent to natural resource management can continue to be conducted by interested stakeholders following the original assessment described herein.

To characterize the geomorphic types (i.e., landforms) within the assessment area, the subbasin was divided into three watersheds for NetMap analyses (Figure 3.2-11). Each of the three watersheds is further divided into Hydrologic Unit Code (HUC) 6th field subwatersheds (5,000–10,000 acres); these three watersheds are used as part of the analysis to classify various watershed attributes. The subwatersheds are included to show the distribution of attributes with each of the three watersheds..

## Hillslope Conditions and Processes

Hillslope conditions and processes, or the hillslope geomorphology of the watershed, strongly influence the environmental conditions that occur there, including the susceptibility of the land to erosion, including following wildfires; the supply of sediment to streams and rivers; and the types of aquatic habitats that form in tributaries and in the Sacramento River.

The focus of this section is on the topographic conditions important for surface and fluvial erosion, landslides, and instream sediment supply and storage attributes. Within this framework, the effects of the Box Canyon Dam and Lake Siskiyou on the downstream sediment supply of the Sacramento River will also be assessed.

Figure  3.2-11  Upper Sacramento River Watersheds

### *Hillslope Gradient and Form: Generic Erosion Potential*

Hillslope gradient fundamentally controls erosion type and magnitude (Dunne and Leopold 1978). For instance, in mountain environments, the highest density of shallow failures due to heavy precipitation occurs on slopes in excess of approximately 35 degrees (> 72 percent) (Dragovich et al. 1993). Hillslope gradient is also a factor in controlling the location of surface and gully erosion that often occurs following fire in semi-arid landscapes; erosion is generally more intense on steeper slopes that are convergent (Istanbulluoglu et al. 2003). Surface erosion can also occur on more gentle terrain, although its magnitude is directly proportional to slope gradient (Elliot et al. 2000).

The morphological form of hillslopes that is related to erosion is often classified into several types, including convergent, divergent, and planar. Divergent and planar slopes typically do not concentrate overland flow. Convergent areas, also referred to as swales, focus the transport of sediment and water. Over time (centuries), soil creep causes soils to thicken in convergent areas, making them more susceptible to landsliding (Dietrich and Dunne 1978). During storms, convergent areas focus shallow subsurface flow, thereby increasing saturation and making them more susceptible to failures. Convergent areas also concentrate overland flow, making them focal areas for gully development, particularly on bare or denuded hillslopes. Steep convergent areas are commonly an initiation point for debris flows in headwater streams (Dietrich and Dunne 1978).

To estimate the intrinsic hillslope erosion potential in the watershed, NetMap generates maps of hillslope gradient combined with curvature, expressed as:

$$(A_L * S)/b$$

*where:*

***b*** is a measure of local topographic convergence (the length of an elevation contour crossed by flow out of the pixel, values less than one pixel length indicate convergent topography)

$\boldsymbol{A_L}$ is a measure of local contributing area (within one pixel length)

***S*** is slope gradient (Miller and Burnett 2007a).

This gradient-slope convergent parameter is defined as generic erosion potential (GEP) in NetMap.

The GEP equation can be applied to any landscape with steep and convergent topography since such landscapes are preferential locations for erosion. In the assessment area, steep and convergent landforms above 5,500 feet have less erosion potential due to gradual spring snowmelt runoff rather than intense rainfall. The GEP equation does not address other important erosion processes, such as deep-seated rotational failures and earthflows.

The scale of this assessment dictates that the GEP be used as a coarse-level screening for erosion potential. The modeled potential for concentrated surface or gully erosion, as indicated by the GEP, is highly variable across the watershed (Figure 3.2-12). Very high values of GEP, indicating a high potential for bare surface erosion or gullies (in convergent areas), are relatively uncommon.

Figure 3.2-12 Generic Erosion Potential

The three watersheds of the upper Sacramento River watershed show marked differences in the spatial distribution of GEP (Figure 3.2-13). The lowest modeled GEP values (per HUC 6th field subbasin) occur in the northern portion of the watershed and the highest values occur south of Castle Crags. The spatial pattern of hillslope gradient and convergence, represented by GEP, appears to be driven largely by rock type. The mechanically strong igneous and plutonic rocks located in the mid to northern portion of the watershed (exclusive of the Mount Shasta, Shastina, and Black Butte volcanic area) are composed of peridotite, greenstone, and granite/granodiorite. Hard rocks of this lithology are more erosion resistant and could promote less headwater channel incision, and, thus, overall lower gradient hillslopes (Figure 3.2-14). Lower gradient hillslopes cause less mass wasting and gullying and, thus, less topographic convergence (in unchanneled, hillslope areas). The reverse is true in the landscape south of Castle Crags, where hillslope gradients become steeper and where greater channel dissection has led to greater topographic convergence and higher modeled GEP ratings (Figure 3.2-14). Additionally, the occurrence of alpine glaciation in the upper elevation areas along the western portion of the study watershed would also presumably lead to smoother, less convergent topography (and lower GEP ratings).

### *Hillslope Gradient and Form: Shallow Landslide Potential*

GEP provides a universal index for predicting the likelihood of surface erosion, gullying, and shallow landsliding. A more focused prediction for shallow landsliding (specifically) is applied to the watershed.

There are a variety of models available to predict shallow landslides (Sidle 1987, Montgomery and Dietrich 1994, Pack et al. 1998). Most models require information on hillslope topography, including gradients and some measure of topographic convergence. In NetMap, the GEP described in the previous section was calibrated using digitized landslide inventories from the Oregon Coast Range (Robison et al. 1999), from which landslide density (e.g., number of landslides per unit area, or area of landslides per unit area) was determined as a function of topographic and vegetation attributes (Miller and Burnett 2007a). Shallow landslide susceptibility in the watershed is predicted in the context of mature forest cover (e.g., not in devegetated conditions following fire). Calculations are made at the resolution of the 10-meter DEM, which for available USGS-provided data, reflects 40-foot contours mapped at 1:24,000 scale. In areas outside of the calibration landscape, the shallow landslide potential parameter is best used as a relative index (high–low).

Topographic information provided by 1:24,000 scale mapping does not resolve all topographic features pertinent to landslide locations (Benda and Dunne 1997). For instance, the landslide model does not account for small streamside failures (often referred to as inner gorge landslides) because of the inability of 10-meter DEMs to resolve low-relief landforms. Mapped landslide potential may not resolve all small convergent areas, which is important to site-specific assessments. However, mapped landslide potential resolves topographic controls over larger areas, such as the relative risk between different first-order basins or between larger watersheds.

The modeled shallow landslide potential for the subbasin reveals that there is large spatial variability across the three watersheds (Figure 3.2-15 and Figure 3.2-16). The areas predicted to have frequent shallow landslides tend to be in steep and convergent topography with frequent rainfall runoff rather than snowfall (Figure 3.2-15). This type of landform is relatively common in the lower and middle watersheds and along the I-5 corridor (Figure 3.2-16. The shallow landslide predictions were not

Figure 3.2-13 Modeled Generic Erosion Potential — Upper Sacramento River Watersheds

Figure  3.2-14      Modeled Generic Erosion Potential  Compared to Bedrock Geology

Figure 3.2-15 Modeled Shallow Landslide Potential in Steep and Convergent Areas

Figure 3.2-16 Shallow Landslide Potential — Upper Sacramento River Watersheds verified in the field. However, a small amount of aerial photograph verification occurred as part of the assessment. Figure 3.2-15 compares the modeled shallow landslide potential and an active shallow landslide (from 2009 Google Earth image) for the same area. The location of this shallow failure corresponds to the area predicted to have high failure potential. The maps of predicted landslide susceptibility reveal an overall low density of unstable zones (particularly in the northern portion of the subbasin (Figure 3.2-16). The lowest potential for shallow landslides occurs in the northernmost section of the assessment area, and landslide potential increases down valley (Figure 3.2-16). This pattern appears to be driven, in part, by the precipitation patterns and harder rock types (igneous) in the northern areas and mechanically weaker (sedimentary) rocks in the mid to lower watersheds. A contributing factor in smoothing the landscape (lowering hillslope gradients and reducing hillslope roughness [swales or convergent areas]) is likely alpine glaciation during the Pleistocene (e.g., Figure 3.2-14, left panel).

In addition to topographic drivers, climate is a major driving factor in shallow landslide initiation. For example, extended periods of antecedent rainfall (weeks) followed by short periods (hours to days) of high precipitation intensity (often in the absence of snowfall) favors shallow landsliding in more humid, temperate climate zones along coastal regions (Sidle et al. 1985). This type of climate is not found in the upper portion of the subbasin, where snow is common in the uplands and long periods of low to moderate rainfall are rare (see Section 3.2.2, *Climate Change*). However, the middle and lower portions of the subbasin experience frequent and very intense rainfall, where the 2-year, 24-hour rainfall is over 4 inches, making these areas more landslide prone.

Landslide predictions at the scale of the entire watershed can be used as a coarse level screen to focus subsequent field investigations in the contexts of pre-fire and post-fire management planning and forestry activities (see Chapter 5).

### *Hillslope-Channel Connectivity: Sediment Delivery Potential*

Hillslope-channel connectivity refers to the hydrologic (surface flow) connection between hillsides and stream channels. Hillslopes that are steeper and hence more erosion prone and that are in close proximity to stream channels, such as in headwater environments, should have a high “connectivity” (Figure 3.2-17). In contrast, rivers surrounded by large floodplains, channels in wide valleys, or streams coupled to hillsides of low erosion potential should have a lower connectivity.

NetMap contains a tool for calculating hillslope-channel connectivity or the potential for sediment delivery. An index of hillslope-channel connectivity is calculated by dividing the cumulative hillslope GEP (along the hillslope that drains directly into discreet channel segments [channel segment scale in NetMap is between 109 and 219 yards) by a channel confinement parameter (defined by valley width divided by channel width, Figure 3.2-17).

The coupling of channels to hillslopes, or the potential for sediment delivery (given an erosion event, particularly one that occurs independently of a stream channel [e.g., bank erosion or debris flows]), is predicted to be highly variable across the watershed. In general, modeled hillslope-channel connectivity is lower in the northern portion of the watershed and increases in the eastern and southern areas in conjunction with the steeper and more highly dissected landscapes found in those locations (Figure 3.2-18).

Figure 3.2-17 Modeling of Hillslope-Channel Connectivity

Figure 3.2-18 Modeled Hillslope-Channel Connectivity — Upper Sacramento River Watersheds

### *Debris Flow Potential*

A debris flow is defined as a highly mobile slurry of soil, rock, vegetation, and water that can travel many hundreds of yards from its point of initiation through steep and confined mountain channels. Debris flows are initiated by liquefaction of landslide material concurrently with failure or immediately thereafter as the soil mass and reinforcing roots break up. Debris flows contain 70 to 80 percent solids and only 20 to 30 percent water by volume. Entrainment of additional sediment and organic debris in first- and second-order channels can increase the volume of the original landslide by 1,000 percent or more, enabling debris flows to become more destructive as their volume increases with distance traveled. Debris flows often deposit in low-gradient valley floors.

There are a variety of models developed to predict debris flows and their movement and deposition in headwater streams, primarily in mountain landscapes (Benda and Cundy 1990, Fannin and Rollerson 1993, Lancaster et al. 2001). Most of these models require information on network characteristics of headwater systems such as channel gradients and tributary junction angles. NetMap uses a model that utilizes digital elevation data to predict the susceptibility of headwater streams to debris flows (Miller and Burnett 2007b).

Predictions of debris flows in NetMap are based on four topographic attributes: (1) channel gradient, (2) valley width or channel confinement, (3) angles of tributary junctions, and (4) cumulative length of scour and deposition (i.e., rate of volume increase or decrease) (Miller and Burnett 2007b). In the model, debris flow runout is separated into zones of scour, transitional flow, and deposition. The functional relationships between debris flow scour and deposition and the four topographic factors are based on field research that has illustrated the physical constraints on debris flow travel. For example, debris flow movement declines with decreasing channel slope (Swanson and Lienkaemper 1978, Benda and Cundy 1990, Fannin and Rollerson 1993), declines at sharp-angled tributary junctions (Benda and Cundy 1990), is less in large forests and longer in clearcuts (Ketcheson and Froelich 1978), and increases with larger volumes (Benda and Cundy 1990).

Debris flow susceptibility values indicate the relative potential for debris flow movement through a reach. The susceptibility value is based, in part, on the shallow landslide potential (e.g., Figure 3.2-15) and the probability for delivery from each hillslope pixel. The implications of a given debris flow susceptibility value vary with position within a channel network and with the gradient, size, and valley morphology of the receiving channel. For steep headwater channels, a high debris flow susceptibility value implies a potential for debris flow scour. For lower gradient headwater channels and at tributary junctions, a high susceptibility value implies a potential for debris flow deposition. For mainstem channels, the consequences of debris flow delivery vary with the potential for fluvial transport of the deposited material. The deposits may be long-lived in small, low-gradient channels, resulting in formation of debris fans. As channel size and/or gradient increase, the potential for erosion of debris flow deposits increases. Boulder lags, truncated fans, and downstream fluvial deposition of debris flow–supplied material may be the only evidence of past debris flows. NetMap includes a function for predicting the fate (i.e., erosion) of debris flow deposits and a classification of potential debris flow effects in channels (see below), but it was not applied in this watershed assessment. Debris flows can be viewed as both a hazard to aquatic environments or as a source of habitat heterogeneity (Benda et al. 2003).

The debris flow susceptibility model applied to the watershed indicates that most of the assessment area has a relatively low likelihood of debris flows. However, as shown in Figure 3.2-19, an example of a shallow failure that transformed downstream due to a debris flow is shown in an area just south of the Castle Crags (Figure 3.2-19). These features are also present in the South Fork of Castle Creek, where natural hillslope failure has triggered large inner gorge debris flows. Also shown in Figure 3.2-19 is the corresponding debris flow predicted based on the landform type. Although this Figure shows an example of a debris flow in a steep headwater stream in the upper watershed, most headwater streams in this area are predicted to have a low susceptibility to debris flows due to the lack of frequent rainfall runoff–driven flood events.

The predicted debris flow potential is higher in the middle to lower watersheds of the assessment area due to the steeper hillsides and higher drainage density (see below) in those locations (Figure 3.2-20). The higher debris flow potential in steep headwater streams appears (again) to be driven mainly by landform type. The mechanically weaker sedimentary rocks and the absence of alpine glaciation (during the Pleistocene) (e.g., Figure 3.2-9) have led to a more highly dissected and steeper landscape that can be conducive to debris flows. However, similar to predictions of generic erosion and shallow landslide potential (Figure s 3.2-12 and 3.2-15), the intense rainfall patterns in this portion of the subbasin likely increase the probability of debris flows. Regardless, the predicted probability is low when compared to more humid coastal watersheds in northern California, Oregon, and Washington.

As with all screening tools for slope instability and downstream propagation of impacts (e.g., debris flows), field validation of watershed attributes is critical in the context of pre- and post-wildfire planning and timber harvest and road construction.

### *Local Sediment Supply and Sediment Storage*

To understand how erosion potential in a watershed relates to the supply of sediment to stream channels, a sediment budget is often constructed (e.g., Reid and Dunne 1996). In the watershed, an approximate and partial sediment budget was developed using the generic erosion parameter (Figure 3.2-12). In general, areas that are steeper and more convergent are predicted to have a higher erosion potential (surface erosion, gullying, and shallow landsliding) and thus a higher sediment supply to channels.

The average annual sediment supply in the watershed is estimated using an average basin-wide sediment yield of 100 $t/km^2/yr$ (this value is used as an illustration, since the actual average sediment yield [in the absence of land use] is unknown). The estimated basin sediment yield is distributed across all hillslopes in the watershed using GEP values (GEP per pixel cell) as the index of relative sediment supply. Sediment yield is considered to be linearly proportional to GEP. For instance, higher GEP values will yield higher sediment yield values in the area of 200–300 $t/km^2/yr$ compared to lower GEP values that may have sediment yield values considerably less than the 100 $t/km^2/yr$ on average. Despite hillslope variations in sediment yield (tied linearly proportional to GEP values), the basin average sediment yield must remain at the estimated average of 100 $t/km^2/yr$.

The spatial variation in sediment supply (from hillslopes to channels) is predicted across the watershed. Overall, predicted sediment supply to stream channels is lower in the northernmost watershed and increases in the mid and southern portions of the watershed (Figure 3.2-21).

Figure 3.2-19 Debris Flow Potential

Figure 3.2-20 Modeled Debris Flow Potential — Upper Sacramento River Watersheds

Figure 3.2-21 Modeled Sediment Supply — Hillslopes to Stream Channels

This pattern is due to less steep and dissected hillslopes (e.g., less basin dissection), presumably related to the harder rocks and history of alpine glaciation that characterize the northern portion of the watershed. Average sediment yields in the northern and mid portions of the watershed range are often less than the average of 100 t/km$^2$/yr (and as low as 10–20 t/km$^2$/yr in the more gentle areas along the foot slopes of Mount Shasta). Much higher values (100–300 t/km$^2$/yr) are predicted to occur in the mid to southern portions of the watershed due to the steeper hillslopes and higher landscape dissection (more frequent and pronounced convergent areas [unchanneled swales]) (Figure 3.2-21).

Classification of the three break out watersheds according to their average sediment yield shows a non-uniform distribution of predicted sediment yields across the assessment area (Figure 3.2-22). The differences in average sediment yields across the three watersheds are significant. For example, 80 percent of all channel segments in the northern, mid, and southern watersheds have sediment yields less than 100 t/km$^2$/yr, 125 t/km$^2$/yr and 180 t/km$^2$/yr, respectively (Figure 3.2-23).

The approximate sediment budget (Figure 3.2-21) does not account for other erosion processes such as bank erosion (along colluvial toeslopes) and earthflows. It also does not account for erosion related to land use activities, including in urban areas (City of Mt. Shasta, Dunsmuir, etc.), timber harvest areas, and unpaved roads (see Chapter 4 for an analysis of fire-related erosion and road surface erosion potential). Nevertheless, the approximate sediment budget does provide an index of relative sediment supply that can be used to help interpret variation in sediment supply and storage in channels as well as the effects of Box Canyon Dam on sediment routing throughout the lower portions of the Sacramento River (below). The analysis also clearly predicts that the mid and southern watershed areas dominate the sediment supply to stream channels, and it is in those locations where wildfires and land use activities (e.g., timber harvest areas and roads) can have the greatest potential impacts related to erosion and sediment supply to streams.

The predicted sediment supply is related to in-channel sediment storage potential in NetMap by dividing the average annual sediment supply by stream power. Stream power reflects the ability of a channel to transport, and thus store, sediment and is generally calculated as the product of channel gradient and drainage area (per channel segment, as a surrogate for discharge) (Richards 1982). Streams with higher stream power have less opportunity to create large in-channel storage reservoirs in contrast with streams of lower power that can create larger reservoirs of sediment.

Using the relationship described above, sediment storage potential is predicted to vary considerably across the watershed. Certain portions of the mainstem Sacramento River are predicted to have a higher sediment storage compared to other segments. The higher sediment storage found in some of these areas is connected to the high sediment supply and sediment storage in tributaries that originate from the eastern side of the mid basin and across the southern watershed (Figure 3.2-24). Insights into the spatial patterns of sediment supply (Figure 3.2-21) and sediment storage (Figure 3.2-24) are used in the analyses of potential wildfire and land use impacts in Chapter 4.

The average sediment supply represents the central tendency of a given catchment with quasi-static topographic attributes. Erosion and sediment supply vary greatly in time and space in most landforms and are highly stochastic processes driven by interactions among storms, sediment flux potential, and

Figure 3.2-22 Modeled Average Annual Sediment Supply — Upper Sacramento River Watersheds

Figure 3.2-23 Average Annual Sediment Yield — Upper Sacramento River Watersheds

Figure 3.2-24 Sediment Storage Potential vegetation (Benda and Dunne 1997a). An analysis of the stochastic aspects[8] of the upper Sacramento River basin is outside the scope of this watershed assessment. Nevertheless, a cursory examination of historical photos (in Google Earth) illustrates the temporally variable sediment supply driven by large storms and floods. In the example shown in Figure 3.2-25, the mainstem Sacramento River (near Soda Creek in the mid watershed) has an absence of in-channel sediment storage in photo year 1993. In 1998 (following a major flood in the basin that occurred in December 1997), new extensive gravel bars formed both upstream and downstream of the confluence with Soda Creek (Figure 3.2-25). Presumably, this increase in sediment storage in the form of bars was related to the 1997 storm and associated flood (and heightened hillslope and in-channel erosion). By 2005 (9 years after the large flood), the gravel bars had either reduced in area due to fluvial erosion or they had become vegetated, or both. There are other examples visible on Google Earth not shown here that reflect the stochastic behavior of sediment supply and storage in both the mainstem Sacramento River and its tributaries.

### *Box Canyon Dam in the Upper Sacramento River: Effects on Sediment Supply and Storage*

Box Canyon Dam, a concrete gravity structure impounding 430 acres of water (Lake Siskiyou), was completed in 1969. It is located on the Sacramento River between the communities of Mt. Shasta and Dunsmuir in the upper watershed. The dam effectively traps all of the sediment (bedload and suspended load, perhaps with the exception of silt and clay) that enters Lake Siskiyou from upstream and from several tributaries along the northern and southern boundaries, thereby reducing the sediment supply to the Sacramento River below the lake. The sediment reduction effect of the Box Canyon Dam can be evaluated using the predictions of average sediment supply presented earlier (e.g., Figure 3.2-20).

NetMap was used to model transport (route) of the predicted average sediment supply (or yield) along the Sacramento River and all of its tributaries. This was accomplished by summing the local sediment supply (Figure 3.2-20) downstream and by dividing the steadily increasing amount of sediment by the steadily increasing drainage area along stream and river channels. In this simple approximation of downstream varying average sediment yields, sediment storage and particle breakdown (attrition) are not accounted for directly.

The modeling of sediment supply downstream in pre-dam conditions reveals that upstream of the (future) Box Canyon Dam, sediment yield is between 80 and 90 t/km2/yr (recall that the basin average sediment yield is 100 t/km2/yr) (Figure 3.2-26). Immediately below that location, the average sediment yield drops to 70–75 t/km2/yr because of the area of low erosion potential located along the foot slopes of Mount Shasta on the north side of the river (also see Figure 3.2-13). The sediment yield increases along the mid portion of the Sacramento River below Castle Crags due to the abundance of medium size tributaries of relatively high sediment supply, most originating from the eastern side of the watershed in the mechanically weaker sedimentary rocks that are predicted to have a higher erosion rate (Figure 3.2-26).

A similar analysis was performed but with the Box Canyon Dam and Lake Siskiyou capturing 100 percent of the sediment that originates from the streams that enter the lake (inclusive of the Sacramento River). The predicted sediment yield is reduced to less than 10 t/km2/yr and increases to

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[8] *Stochastic aspects are those involving or containing a random variable or variables.*

Figure  3.2-25	Sediment Supply to Streams — Sacramento River, Central Watershed

Figure 3.2-26 Average Annual Sediment Yield — Pre-Box Canyon Dam between 20 and 50 t/km2/yr about 12 to 25 miles below Lake Siskiyou (Figure 3.2-27). The sediment yield steadily increases downstream towards Shasta Lake (reservoir) to around 70 to 75 t/km2/yr.

The NetMap model predicts a 95 percent reduction in coarse sediment yield below the dam. Sediment yield continues to be reduced by 50 percent 18.6 miles downstream of the dam (Figure 3.2-28). The predicted sediment yield 37 miles downstream (near Shasta Lake) is approximately 80 percent of the pre-dam environment. Such dramatic reductions in sediment supply have likely altered the dynamic equilibrium of the upper Sacramento River downstream of the dam. However, as mentioned above, particle breakdown (or attrition) is not accounted for in the calculation described. Bedload size particles (mainly cobbles, gravels, and pebbles in the Sacramento River) break down with distance traveled from the erosion source. Based on tumbling mill studies of particle attrition (Benda and Dunne 1997) and an applied approximate breakdown rate of 10 percent per 0.62 miles (e.g., 10 percent of the rock volume is converted from bedload to suspended load sizes), the reduction in in-channel gravel storage should be significantly less than the values shown in Figure 3.2-28. Considerations of gravel attrition suggest that the reduction in in-stream gravel may approach less than 10 percent 18.6 miles downstream and approach zero 25 to 37 miles below the lake. Even with attrition, however, reduction of in-stream gravels should be significant (>50%) 6.2 miles or more below the dam and Lake Siskiyou.

## Landscape Stratification

Landscape stratification can provide information about how the various physical and biological properties of an ecosystem are spatially organized at large scales (Cleland et al. 1997). The watershed is stratified into several zones using the foregoing analysis of geology (lithology), hillslope topography, erosion potential, and sediment supply, routing, and storage.

The various landforms within the subbasin are classified into Lithotopo Units and are used to analyze natural and human-altered hydrologic and geomorphic processes within the subbasin following Shilling et al.'s (2005) guidance and McCammon et al. (1998). These units are presumed to be spatially and temporally a function of climate, bedrock geology, tectonic setting, soil type, ground cover, slope stability, slope steepness and convergence, and stream network geometry. For this assessment, Lithotopo Units are classified by mapping individual polygons with similar climate, topography, and bedrock geology. Data sources used to stratify the subbasin into lithotopo units include (1) bedrock geology, (2) dormant and active landslides, and (3) topography generated from NetMap. A GIS project was used to generate the lithotopo unit polygons, and data gathered as part of this assessment were used to refine each lithotopo unit.

Geology, specifically rock type, is destiny in the context of many of the physical attributes of the watershed. As described above, topography (hillslope gradient and form [convergent-divergent shapes]), erosion potential, hillslope-channel connectivity, and sediment supply appear to be related spatially to differences in lithology, specifically rock mechanical strength and to some extent the occurrence of alpine glaciation. The highest erosion potential, hillslope-channel connectivity, and sediment supply are associated with mechanically weaker sedimentary rocks that occur in the mid and southern portions of the study basin. Conversely, the relatively low relief area within the diverse volcanic deposits associated with Mount Shasta has a predicted low erosion potential.

Figure 3.2-27 Impact on Downstream Sediment Supply — Post-Box Canyon Dam

Figure 3.2-28 Predicted Reduction of Sediment Supply Decreases — Downstream Lake Siskiyou

An additional watershed attribute that is influenced by rock strength or erodibility is channel density (number of channels of all sizes per unit area). NetMap's channel density tool is used to classify channel density (km/km$^2$) across all HUC 6th field subbasins in the assessment area. The lowest channel densities (primarily driven by headwater streams) range from a low of 2 to 3 km/km$^2$ in the northernmost watershed. The channel densities increase from 3 to 5 km/km$^2$ in the mid to southern portion of the watershed (Figure 3.2-29). The higher drainage density associated with the sedimentary rocks of the mid to southern watersheds is presumably related to the weaker rocks that promote a greater drainage network dissection (increased channel development and incision).

The drainage density attribute is added to the other discriminating factors (topography, erosion potential, hillside/channel connectivity, sediment supply, channel sediment storage) to stratify the watershed into 4 to 5 prominent zones. The zones include (1) volcanics of the Mount Shasta area, (2) igneous rocks of the northern and northern mid sections of the watershed, (3) plutonic rocks of the Castle Crags areas are subsumed within zone 2 but differentiated based on rock exposure, steepness and lack of vegetation), and (4) sedimentary rocks (Figure 3.2-30). Implications of the landscape stratification on aquatic habitats and on impacts associated with wildfire and land use activities are described later in the report.

## Fluvial Conditions and Processes

### *Channel Network Dynamics*

The stream network in the assessment area is defined within NetMap by using a flow routing algorithm that includes parameters of (1) drainage area, (2) drainage area per unit contour length (specific drainage area), and (3) gradient (Miller 2003). NetMap searches for the optimization of specific drainage area to drainage density (km/km$^2$) by identifying the inflection point in that relationship (Figure 3.2-31). Values of specific drainage area below the inflection can cause drainage density to be under predicted. Values above the inflection can cause drainage density to be over predicted, leading to drainage feathering (too many channels on any given hillslope). The predicted drainage densities (per watershed) are between 3 and 5 (Figure 3.2-29) and are typical of many mountain drainage basins (Benda et al. 2004b). The stream network is divided into individual reaches of between approximately 66 feet and 657 feet (average 327 feet) using an algorithm that searches for similarities in gradient, channel width, valley width, and drainage area (e.g., segments are created where geomorphic conditions change, often at tributary confluences).

The fish-bearing portion of the network is also specified in NetMap. This requires knowledge of the existing fish distribution. If this is not available, then channel gradient and flow thresholds are used to truncate that portion of the total stream network that is likely to contain fish (either resident or anadromous). For resident fish (appropriate for the present day upper Sacramento River watershed [above the Shasta Lake Dam]), a gradient threshold of 20 percent is used to identify fish streams, including even above gradient barriers. In a later analysis of the historical range of anadromous fish in the watershed, a migration-blocking gradient barrier of 10 percent is used. In the analyses of fluvial geomorphology that follow, results will be shown for the predicted resident fish streams only.

Figure 3.2-29 Drainage Density — Upper Sacramento River Watersheds

Figure 3.2-30  Landscape Stratification — Upper Sacramento River Project Area

Figure 3.2-31 Stream Network

### *Stream Gradient*

In the upper Sacramento River, the stream gradients range from over 50 percent in the steepest headwater streams (for example, most of the assessment area) to less than 1 or 2 percent in the low-relief areas located south of Mount Shasta and in the lower river. Channel gradients are shown for all streams and only for the fish-bearing network in the uppermost subbasin (Figure 3.2-32). The subbasin has high topographic roughness formed by ridges that intersect the streams where bedrock outcrops emerge and create falls and rapids. The abundance of bedrock control points is evident in the fact that the average stream gradient of the subbasin is about 25 percent, with over 69 percent of the stream channels steeper than 10 percent. Less than 5 percent of the stream reaches are classified as low gradient, with about 3 percent with a gradient of less than 1.5 percent. As shown in Figure 3.2-32, most of the lower gradient reaches are along the inner gorge of the mainstem and near the headwaters along the contact between Cascade volcanic and Klamath metamorphic rock formations.

Stream gradient is an important parameter for predicting the quality and abundance of fish habitats of different species, channel morphology, and the sensitivity of channels to changes induced by floods, large wood, and sediment transport and storage. Such channel attributes are examined below.

### *Stream Order*

Stream order provides a means to evaluate the relative size and position of channels within a river network. In the Strahler (1952) stream ordering method, the upper tips of a river network are classified as “order 1.” The channel becomes a stream of “order 2” where two first order streams converge. Similarly, a 3rd order stream forms where two “order 2” streams intersect. An illustration of Strahler stream ordering is shown in Figure 3.2-32.

The upper Sacramento River is a 7th order river (e.g., the channel of the largest drainage area located immediately above Lake Shasta) (Figure s 3.2-32 and 3.2-33). Channels of orders 1 and 2 are generally considered “headwater” streams. Because of the hierarchical branched pattern of river networks, there are significantly greater numbers of headwater streams compared to 3rd-, 4th-, and higher order channels. Typically, 1st- and 2nd-order streams can comprise about 70 percent of the cumulative length of channels within a drainage network.

Headwater streams typically have many non-fluvial characteristics. In hilly to mountainous terrain, such as in the watershed, headwater streams reflect a mix of hillslope and channel processes because of their close proximity to sediment source areas. Their morphology is an assemblage of residual soils, landslide deposits, wood, boulders, thin patches of poorly sorted alluvium, and stretches of bedrock. Longitudinal profiles of these channels are strongly influenced by steps created by sediment deposits, large wood, and boulders. Due to the combination of small drainage area; stepped, shallow gradient; large roughness elements; and cohesive sediments, headwater streams typically transport little sediment or coarse wood debris by fluvial processes (Benda et al. 2005). Consequently, headwaters act as sediment reservoirs for periods spanning decades to centuries. The accumulated sediment and wood may be episodically evacuated by debris flows, debris floods, or gully erosion and transported to larger channels, particularly following large and severe wildland fires. Such processes may be locally important in the watershed. In mountain environments, these processes deliver significant amounts of materials that form riverine habitats in larger channels. In managed steepland forests, accelerated rates of landslides and debris flows have the potential to seriously affect the morphology of headwater streams and downstream resources.

Figure  3.2-32      Channel Gradients

Figure  3.2-33  Stream Order

### *Stream Width and Flow Depth*

Stream width in NetMap is calculated using a regression function because channel banks are not readily resolvable from a 10-meter DEM (10-meter length scale in the X, Y, and Z coordinates). The widths of channels (bank full) were measured in the field over a range of drainage areas (247–98,842 acres) during the parameter validation stage of this assessment. The regression function is: channel width = 1.949*drainage area^0.4409 (Figure 3.2-34). Predicted channel widths range from approximately 3 feet to 144 feet just above Shasta Lake. Only channel widths for the uppermost basin are shown (Figure 3.2-35).

Predicted channel widths for first-order streams are less than 4.9 feet. Widths of fish-bearing streams (for resident fish with a gradient threshold of 20 percent) are a minimum of about 9.8 feet and increase downstream.

The bankfull flow depth commonly scales with stream size or drainage area. Because an empirical relationship between depth and drainage area is not available for the assessment area, a published relationship for the Oregon Coast Range (Burnett et al. 2003) was used (Figure 3.2-36).

### *Stream Power and Substrate Size*

The size of sediment in channels (cobbles, gravels, pebbles, etc.) is an important determinant of fish habitat quality and availability (Bisson et al. 1987, Everest et al. 1987). Substrate size, particularly the median diameter ($D_{50}$), can be used to help characterize intrinsic habitat potential for various fish species.

The particle size composition of the streambed can be characterized (and predicted) if the relationship between bed shear stress and particle size is known for a given channel type. This relationship is typically sensitive to specific watershed conditions involving local lithology, stream network geometry, and the nature and timing of disturbances in a landscape. Bed shear stress is calculated in NetMap as the product of channel gradient, flow depth (bankfull or when bedload is in transit), and water density. Then, based on field-measured substrate sizes (within specific watersheds or landscapes), a power law regression between substrate $D_{50}$ and shear stress is created. Particle size values are given for the various substrate name categories (e.g., sand, pebbles, gravel, etc.); in NetMap, the Wentworth (1922) scale is used to define those categories.

The relationship between bed shear stress and particle size in the assessment area is not known. A relationship between shear stress and substrate $D_{50}$ based on a regional regression appropriate for the Pacific Northwest (Buffington et al. 2004) is used for illustrative purposes. However, there may be many departures from this average relationship having to do with specific lithology as well as finer grained substrate due to large-scale mass wasting disturbances (Miller and Benda 2003).

Based on predicted stream power (channel gradient multiplied by drainage area) in the watershed (Figure 3.2-37) and applying the default relationship between stream power and substrate $D_{50}$, the substrate size is predicted for the watershed (upper subbasin only, Figure 3.2-38). The majority of substrate (defined by the median grain size or $D_{50}$**)** is in the gravel to cobble size categories.

Figure 3.2-34 Stream Order for the Defined Fish-Bearing Portion of the Assessment Area (Resident Fish <20%)

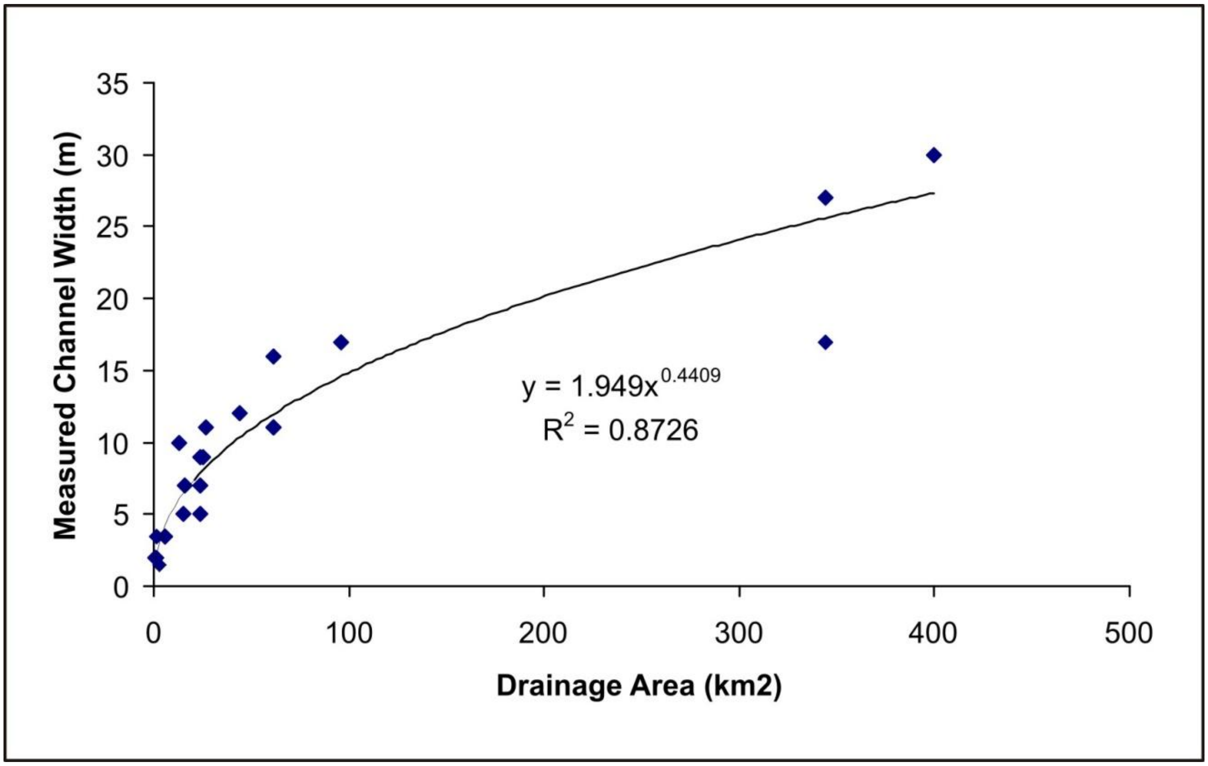

**Figure 3.2-35. Relationship of Channel Width to Drainage Area.** Channel width (bankfull width) measured in the field plotted against drainage area reveals the typical nonlinear relationship. The regression equation was used within NetMap to assign widths to channel segments based on drainage area. In general, channels cannot be resolved digitally using 10-meter DEMs.

Figure 3.2-36 Modeled Channel Widths

Figure 3.2-37 Modeled Flow Depth (Bankfull)

Figure 3.2-38 Modeled Stream Power

### *In-Stream Wood Accumulation Types*

Large wood in streams that originates from riparian forests through mortality, bank erosion, and landsliding play an important role in the geomorphology and ecology of streams and rivers (Bisson et al. 1987). Protecting riparian sources of wood to streams is becoming a major component of forestry policy (Bilby and Bisson 2004). Examples include establishing riparian protection zones for wood recruitment (Young 2000), mandating in-stream wood abundance standards or targets (National Marine Fisheries Service 1996), monitoring abundance of wood in streams (Schuett-Hames et al. 1999), and implementing in-stream wood restoration programs (Cedarholm et al. 1997). The processes of forest mortality, bank erosion, streamside landsliding, debris flows, and wildfires govern the supply of wood to streams. An analysis of wood accumulation types in the watershed was not conducted due to a lack of detailed information on riparian forest conditions.

In streams and rivers, large wood in streams can create different types of deposits or accumulations, including (1) individual spanning logs, (2) spanning and partial stream-spanning jams, (3) scattered accumulations on lateral bars, and (4) no wood accumulation (too high energy streams) (Figure 3.2-39). NetMap contains a tool for predicting types of in-stream wood accumulations that can form given the range of drainage areas (surrogate for stream size and stream power) and tree size scaled by channel width. For illustrative purposes, an average tree height of 98 feet is used to predict spatial variation in wood accumulation types in the upper subbasin of the assessment area. For example, the probability of spanning jams in the watershed varies from almost 100 percent to less than zero. The probabilities are used to estimate the most likely type of wood accumulation that would occur across the watershed (Figure 3.2-40).

### *Floodplains*

Floodplain landforms are important for both aquatic and terrestrial wildlife, and thus wider floodplains areas often serve as critical habitats. Wide floodplains also are associated with unconfined channels, and the degree of channel confinement is a parameter in fish habitat potential (see below).

In this analysis, a height above the channel (as detected in a 10-meter DEM) of one channel depth was used to map floodplains (e.g., their approximate locations and dimensions) in the watershed. The results are displayed as both a stream reach attribute (line segments in a GIS) and a polygon showing the variation between left and right sides of the channel (Figure 3.2-41). For example, in the uppermost subbasin, floodplain widths range from less than 17 feet to over 600 feet. In addition, floodplains are non-uniformly distributed across the basin (Figure 3.2-42).

Maps of approximate floodplain locations and dimensions can be used for a variety of purposes in land use management and restoration. For instance, variation in floodplain widths may indicate important geomorphic and ecologic transitions (Figure 3.2-41). The predicted floodplain polygon can be used to identify where roads may intersect floodplains and thus where road surface erosion (and its delivery to streams via floodplains) may be of concern (see Chapter 5).

Figure 3.2-39 Modeled Substrate Size

Figure 3.2-40 Woody Debris Accumulation Types

Figure 3.2-41 Modeled Large Woody Accumulation Types

Figure 3.2-42 Modeled Floodplains

### *Tributary Confluence Effects*

The influence of tributaries on mainstem streams and rivers is well recognized, although not often quantified. Tributaries can deliver higher inputs of nutrients and invertebrates that have been shown to increase primary and secondary productivity in receiving streams at confluences (Kiffney and Richardson 2001). Fish may use tributary mouths as thermal refugia (Scaarnecchia and Roper 2000) or as dispersal corridors that support higher species diversity (Osborne and Wiley 1992). Tributaries also alter the hydraulic geometry of receiving streams, including width, depth, and bar size and occurrence (Best 1988), and they can alter the particle size distribution, either coarsening or fining the channel bed (Rice et al. 2001). Variations in hyporheic exchange also commonly occur at confluences (Baxter and Hauer 2000).

On a somewhat larger morphological scale, topographic knick points in rivers associated with tributary fans and sediment mixing at tributary intersections result in a large variety of morphologic effects at and near confluences, including terraces and wide floodplains, channel meanders and braids, changes in bed substrate including boulder deposits and rapids, deeper and wider channels, mid-channel bars, ponds, and log jams (Church 1983, Grant and Swanson 1995) (Figure 3.2-43).

All nutrient, thermal, and morphological effects can contribute to habitat heterogeneity; hence, tributary confluences can be biological hot spots (Benda et al. 2004a). Consequently, the pattern of the channel network in terms of spacing and size of tributaries in a watershed should influence the non-uniform distribution of certain types of habitats and habitat heterogeneity linked to confluences. For example, geological or topographic constraints on the formation of tributary basins can lead to clumped distributions of intersecting tributaries and associated confluence-derived heterogeneity.

Overall, morphological effects of confluences may tend to be most pronounced in lower-gradient portions of rivers and may decline in steep, narrow valleys where high stream energy quickly erodes fans, or in wide valley floors where fans are isolated from mainstem rivers. In addition, the erosion regime of a watershed, particularly if it is punctuated in time, may influence how tributary confluences affect mainstem channel morphology. NetMap contains a tool for predicting the potential morphological consequences of tributary confluences on channel morphology and aquatic and riparian habitats. In general, the probability of a tributary affecting the morphology of a mainstem river depends on the size of the tributary relative to the size of the mainstem. The empirically based model in NetMap employs logistic regression (based on data from 14 studies in the western United States and Canada) (Benda et al. 2004b). The model was applied to the upper subbasin of the watershed, and it illustrates how channel network geometry leads to spatial variation in confluence effects (Figure 3.2-44).

The extent of confluence-related sedimentary effects in mainstem channels should decrease downstream due to the amount of sediment (and organic) material introduced into the mainstem channel from the tributary. In addition, diffusive sediment transport (e.g., Lisle et al. 2001) should also cause a decay of sediment-related changes downstream of confluences. Tributaries can be viewed in terms of sedimentary links (Rice et al. 2001), with a downstream exponential decay in confluence effects. This concept has been used to describe the decreasing grain size observed downstream of sediment sources (e.g., tributary junctions). To apply this concept in the watershed, the probability of tributary effects (e.g., Figure 3.2-44) is applied to mainstem channel pixels downstream of each tributary junction, with a magnitude that decays exponentially with distance, or

Figure 3.2-43 Modeled Floodplain Variation

Figure 3.2-44 Tributary Confluence Effects

$P_x = P_{x0}e^{-\alpha x.}$ $P_x$ is the probability of confluence effect at a distance x downstream from the tributary, $P_{x0}$ is the probability at the tributary (Figure 3.2-44), and $\alpha$ is a decay coefficient. Values reported in the literature span two orders of magnitude, ranging from ~0.05 to 5.0 $\text{km}^{-1}$, and a decay coefficient of 0.5 per square kilometer is used in the illustrative calculation (Figure 3.2-45**)**. The downstream decay of confluence effects is used for predicting channel sensitivity later in this section.

### *Channel/Habitat Sensitivity*

Floods and increased erosion and sediment supply to streams can alter habitats, in some cases degrading them. Channels have different degrees of sensitivity to changes in flow and sediment supply. In general, channels of lower gradient have a greater sensitivity to fluctuations in discharge and sediment supply (Sullivan et al. 1987). Lower gradient channels are more responsive to high flows and higher sediment supply, and they may aggrade and become laterally unstable, resulting in increased bank erosion. Such processes can negatively affect aquatic habitats by filling pools with sediment, by reducing summer low-flow levels (through increased inter-gravel flow), and by increasing fine sediment levels in substrates (Bisson et al. 1987).

An index of channel sensitivity was developed and applied in the uppermost basin of the watershed. The parameters of channel gradient, channel confinement (floodplain width/channel width), and tributary confluence effects (their decay downstream from confluences, e.g., Figure 3.2-45) were used. A commonly applied approach to modeling channel habitat characteristics (Morrison et al. 1998) was used in this exercise. The method involves multiplying the index scores together and then taking the geometric mean of that product. The method assumes that the channel attributes are of approximately equal importance and only minimally compensatory. The index scores, in this case representing channel sensitivity, range from one to zero, with larger values indicating a higher sensitivity. For additional information on the modeling approach, see also Burnett et al. 2007.

The variable weighting applied to each parameter is shown in Figure 3.2-46. For example, the lower channel gradients (0.001–0.02) are weighted the highest (1.0–0.8) while the steepest (and most resistant to change) channel gradients (>0.08) are weighted the least (<0.2). Similarly, unconstrained channels and channels in close proximity to large tributaries are weighted the most. In addition, the parameter of channel gradient was given twice the weight as the other two.

The model reveals significant spatial variability in channel sensitivity across the watershed (Figure 3.2-47). The steeper and more confined streams, particularly those segments located away from large tributary confluences, are predicted to have a low sensitivity. In contrast, lower gradient and unconfined reaches, particularly those located immediately downstream of large tributary confluences, have a higher sensitivity. For instance, the inset box in Figure 3.2-47 illustrates how channel sensitivity abruptly increases in the lower gradient and wider floodplain areas located immediately downstream of a large (high sediment supply) tributary (this area is also characterized by a large floodplain, see Figure 3.2-42).

An index of channel sensitivity could be used to identify which channels (and associated habitats) would be most vulnerable to increases in erosion and sediment supply, conditions that might follow wildfires.

Figure 3.2-45 Modeled Tributary Confluence Effects Probability

Figure 3.2-46 Modeled Thermal Load

Figure 3.2-47 Channel Sensitivity Index

## 3.2.6 Hydrology

### Surface Water

### *Hydrologic Setting*

The upper Sacramento River watershed drains an area of about 600 square miles and is classified as the Sacramento Headwaters HUC-4 Subbasin 18020005 (Figure 3.2-48). Herein, we refer to the watershed assessment area as the "subbasin" and its component "subwatersheds." The upper Sacramento River has several perennial tributaries, and the mainstem reach of the river is mostly unregulated. Box Canyon Dam is located 29 miles upstream of the upper Sacramento River at Delta stream gauge and is designed to store water for power generation (Figure 3.2-48). The entire subbasin drains to Shasta Lake and is within the upper Sacramento River basin. For this assessment, the subbasin is divided into three watersheds and the available data are summarized accordingly (Figure 3.2-48). Available upland hydrology data are summarized by watershed in Table 3.2-6.

**Table 3.2-6. Subbasin Hydrology Subwatershed Attributes**

| Water-Shed | Subwatershed Name | ID | Drainage Area (Acres) | Drainage Area (Mi$^2$) | Stream Length (Mi) | Drainage Density (Mi/Mi$^2$) | Average Elevation (Ft) | Average Stream Gradient (Dec %) |
|---|---|---|---|---|---|---|---|---|
| Upper | Cascade Gulch | 1001 | 10946 | 17 | 56 | 0.8 | 6243 | 0.16 |
| Upper | Avalanche Gulch | 1002 | 6717 | 10 | 34 | 1 | 6308 | 0.13 |
| Upper | Big Canyon Creek | 1003 | 6573 | 10 | 62 | 1.6 | 4356 | 0.25 |
| Upper | Lower Wagon Creek | 1004 | 9994 | 16 | 32 | 0.5 | 4545 | 0.09 |
| Upper | Spring Hill | 1005 | 6987 | 11 | 48 | 0.9 | 3786 | 0.09 |
| Upper | Upper Wagon Creek | 1006 | 2427 | 4 | 30 | 0.1 | 3978 | 0.04 |
| Upper | Tom Dow Creek | 1007 | 5773 | 9 | 12 | 0.7 | 5947 | 0.14 |
| Upper | North Fork Sacramento River | 1008 | 5676 | 9 | 32 | 1.1 | 3995 | 0.14 |
| Upper | Mott | 1009 | 6207 | 10 | 57 | 1.9 | 2856 | 0.22 |
| Upper | Scott Camp Creek | 1010 | 7755 | 12 | 17 | 0.4 | 5556 | 0.14 |
| Upper | Middle Fork Sacramento River | 1011 | 9006 | 14 | 25 | 0.3 | 3822 | 0.08 |
| Upper | Upper Soda Creek | 1012 | 5711 | 9 | 30 | 4.3 | 3256 | 0.34 |
| Upper | Lower South Fork Sacramento | 1013 | 4718 | 7 | 36 | 1 | 4043 | 0.11 |
| Upper | Ney Springs Creek | 1014 | 5599 | 9 | 44 | 1.8 | 2614 | 0.26 |
| Upper | Hedge Creek | 1015 | 4777 | 7 | 43 | 1.5 | 2852 | 0.22 |
| Upper | Upper South Fork Sacramento | 1016 | 10079 | 16 | 27 | 0.5 | 5464 | 0.15 |
| Upper | Middle Soda Creek | 1017 | 9702 | 15 | 24 | 0.8 | 3535 | 0.19 |
| Upper | Little Castle Creek | 1018 | 6592 | 10 | 59 | 1.6 | 2635 | 0.24 |
| Upper | Upper Soda Springs | 1019 | 4513 | 7 | 37 | 0.7 | 3214 | 0.18 |
| Upper | North Fork Castle Creek | 1020 | 7626 | 12 | 30 | 0.7 | 4874 | 0.13 |
| Upper | Upper Castle Creek | 1021 | 11577 | 18 | 89 | 2.4 | 2334 | 0.2 |
| Upper | Lower Soda Creek | 1022 | 9580 | 15 | 45 | 2.3 | 2622 | 0.26 |
| Upper | Lower Castle Creek | 1023 | 3721 | 6 | 22 | 1.1 | 3444 | 0.24 |
| Middle | Sweetbrier Creek | 1024 | 6102 | 10 | 27 | 1.2 | 3608 | 0.13 |

**Table 3.2-6. Subbasin Hydrology Subwatershed Attributes**

| Water-Shed | Subwatershed Name | ID | Drainage Area (Acres) | Drainage Area ($Mi^2$) | Stream Length (Mi) | Drainage Density ($Mi/Mi^2$) | Average Elevation (Ft) | Average Stream Gradient (Dec %) |
|---|---|---|---|---|---|---|---|---|
| Middle | Flume Creek | 1025 | 6899 | 11 | 19 | 1 | 4888 | 0.2 |
| Middle | Mears Creek | 1026 | 5297 | 8 | 25 | 0.9 | 3840 | 0.16 |
| Middle | Lower South Fork Sacramento R | 1027 | 8484 | 13 | 45 | 2.6 | 2428 | 0.25 |
| Middle | North Fork Shotgun Creek | 1028 | 8952 | 14 | 23 | 0.8 | 2986 | 0.17 |
| Middle | Upper Slate Creek | 1029 | 6558 | 10 | 28 | 0.8 | 5626 | 0.11 |
| Middle | Boulder Creek | 1030 | 12018 | 19 | 44 | 1 | 3197 | 0.14 |
| Middle | Upper South Fork Sacramento R | 1031 | 5526 | 9 | 136 | 2.6 | 2481 | 0.27 |
| Middle | Middle Slate Creek | 1032 | 4591 | 7 | 38 | 2.8 | 3906 | 0.3 |
| Middle | Lower Slate Creek | 1033 | 5568 | 9 | 23 | 0.8 | 2825 | 0.16 |
| Middle | North Salt Creek | 1034 | 15489 | 24 | 19 | 1.1 | 3148 | 0.23 |
| Middle | South Fork Slate Creek | 1035 | 3568 | 6 | 51 | 3.6 | 4116 | 0.37 |
| Middle | Campbell Creek | 1036 | 2561 | 4 | 32 | 4.7 | 1934 | 0.32 |
| Middle | Mosquito Creek | 1039 | 4061 | 6 | 55 | 2.2 | 2162 | 0.27 |
| Middle | Upper Dog Creek | 1040 | 7107 | 11 | 39 | 5.1 | 1870 | 0.29 |
| Middle | Lower Dog Creek | 1042 | 5644 | 9 | 46 | 4.8 | 2052 | 0.3 |
| Lower | Upper Middle Salt Creek | 1037 | 6581 | 10 | 54 | 3.5 | 2372 | 0.3 |
| Lower | Campbell Creek | 1038 | 2797 | 4 | 37 | 3.3 | 1723 | 0.23 |
| Lower | Lower Middle Salt Creek | 1041 | 4392 | 7 | 80 | 5.5 | 1963 | 0.35 |
| Lower | Doney Creek | 1043 | 11033 | 17 | 118 | 4.5 | 1539 | 0.25 |
| Lower | Upper Salt Creek | 1044 | 6201 | 10 | 54 | 2.4 | 2115 | 0.25 |
| Lower | Charlie Creek | 1046 | 3222 | 5 | 38 | 4.9 | 2047 | 0.39 |
| Lower | North Fork Backbone Creek | 1047 | 6764 | 11 | 38 | 1.7 | 2323 | 0.29 |
| Lower | Sugarloaf Creek | 1048 | 6575 | 10 | 67 | 3.9 | 1821 | 0.31 |
| Lower | Middle Salt Creek | 1049 | 4121 | 6 | 35 | 2.4 | 1469 | 0.17 |
| Lower | Lower Salt Creek | 1050 | 3206 | 5 | 23 | 2.9 | 1315 | 0.17 |
| Lower | Haycock Peak | 1051 | 716 | 1 | 6 | 3.9 | 1271 | 0.18 |
| Lower | South Fork Backbone Creek | 1052 | 5990 | 9 | 27 | 1.1 | 2211 | 0.25 |
| Lower | Little Sugarloaf Creek | 1053 | 2303 | 4 | 17 | 2.9 | 1416 | 0.32 |
| Lower | Obrien Creek Inlet | 1054 | 5030 | 8 | 37 | 3.1 | 1269 | 0.17 |
| Lower | Lower Backbone Creek | 1055 | 11160 | 17 | 108 | 3.7 | 1959 | 0.3 |
| Lower | Adler Creek | 1056 | 1257 | 2 | 11 | 5.4 | 1214 | 0.28 |
| Lower | Upper Squaw Creek | 1058 | 8438 | 13 | 66 | 2.4 | 2697 | 0.28 |
| Lower | Lower Squaw Creek | 1059 | 6169 | 10 | 65 | 4.9 | 1516 | 0.29 |

This table is based on modeled results that have not been field verified.

Generally, there is an overall lack of stream flow data for this subbasin. The surface flow of the upper Sacramento River has been consistently monitored (by the USGS) at only one location (since 1945). The lack of stream flow data at other sites within the subbasin greatly limits our understanding of the water balance. The sole gauge is located just upstream of Shasta Lake at Delta

(DLT) (latitude 40°56′23″ and longitude 122°24′58″) (Figure 3.2-48). Stream flow data from this gauge are used to characterize the annual low flow, high flow, and average flow hydrology of the subbasin.[9] Most of the subbasin, about 425 square miles, is above this gauge, which is located at an elevation of 1,075 feet.

This reach of the upper Sacramento River remained unregulated until 1968, when Box Canyon Dam was put into operation. The mean annual runoff of the upper Sacramento River near Delta for the period of 1945–2009 is 1,191 cubic feet per second (cfs). There is a wide range of annual runoff, with 1977 being the driest year and 1958 the wettest (Figure 3.2-49). There appears to be a statistically significant relationship between years with a deep snowpack and high runoff volume, where 92 percent of time the measured runoff is higher as a function of average snow depth. This relationship is strong for individual years as well as running 7-year running averages. Large flood years do not always correlate as well with wet periods where very large floods have occurred during dryer cycles (e.g., flood of 1996). The highest runoff periods occurred in the late 1950s, mid 1970s, early 1980s, and mid 2000s, coincident with the highest precipitation periods, as described above. There have been several dry spells during the period of record, and overall there are more years below the average annual runoff than above (Figure 3.2-49). The mid 1990s was a particularly dry period, with the lowest consecutive dry years recorded to date. This period's streamflow record correlates well with the precipitation record (Figure 3.2-49).

Compared to other unregulated subbasins in northern California, the watershed has high average annual runoff. For example, Cottonwood Creek near Andersen, California, has a unit runoff of 1.0 cfs per square mile of drainage area, whereas the upper Sacramento River at Delta has a unit runoff of 2.8 cfs per square mile. This is similar to the water yield measured on Mad River near Arcata, California, also with a unit runoff of 2.8 cfs per square mile.

The low flow (i.e., baseflow) of the upper Sacramento River, described herein using the 7-day minimum flow, ranged from 117 cfs in 1977 to 290 cfs in 1958, with an average of 187 cfs for the period of record. Baseflow tends to occur in September and October. The average unit baseflow runoff is 0.4 cfs per square mile of drainage area, with most of this runoff attributable to groundwater discharge. Analysis of the daily stream flow record shows that the operation of Box Canyon Dam has not measurably changed the baseflow discharge of the upper Sacramento River. Since 1968, there has been more annual variability in the 7-day minimum flow.

Flooding in the watershed is most often caused by snowmelt and rainfall runoff. The largest measured flood events have typically occurred in January and February of El Nino weather years. These floods are often caused by rain-on-snow climatic events, where a large cold snow storm is followed by a large warm rain storm and significant snowmelt and runoff occur. The largest measured flood events in the watershed occurred in 1974, 1997, and 2006, with river flows peaking at over 50,000 cfs (Figure 3.2-50). The largest flood occurred in 1974 and peaked at 69,800 cfs. Unlike other subbasins in northern California, the upper Sacramento River watershed did not flood during one of the largest floods in the region, the flood of 1964. The largest flood in the last 15 years,

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[9] *The longest record of usable turbidity data is a series of manual turbidity probe measurements taken at DLT about once a month from 1998 to 2010. There are also 20 years of continuous turbidity data available for DLT; however, the continuous data are not presently usable due to technical problems encountered with the probe (Greg Gotham, U.S. Bureau of Reclamation, personal communication).*

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Figure 3.2-48 Subwatersheds and ERA

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**Figure 3.2-49** Mean annual runoff and cumulative departure of the upper Sacramento River near Delta

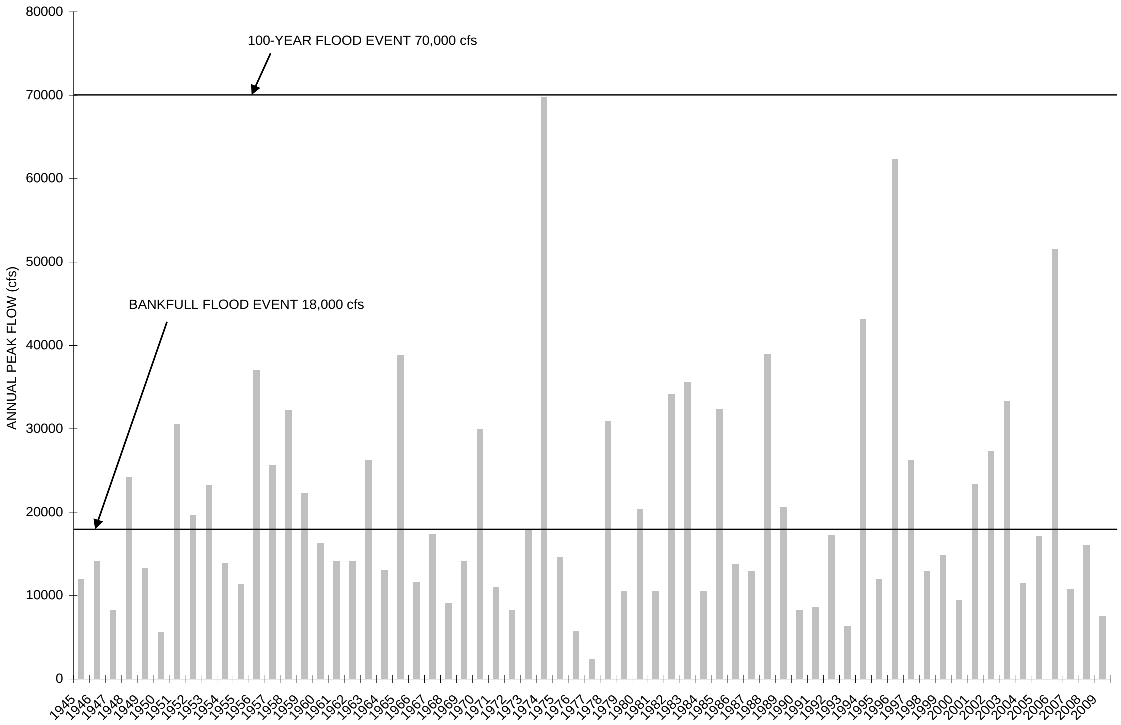

**Figure 3.2-50.** Peak flood events of the Upper Sacramento River near Delta

known as the flood of 1996, occurred in early 1997, when the entire region flooded. The river peaked at 62,300, cfs which, based on the existing data, equates to a 60-year flood event. The peak bankfull flood event that occurs 50 percent of the time is about 18,000 cfs, and the 100-year flood event that occurs about 1 percent of the time is about 70,000 cfs.

Given the long-term variability in climate and runoff, the significance of the measured flood events of the upper Sacramento River can be evaluated through historical streamflow records. The extensive period of streamflow records for northern California provides an estimate of significant floods prior to 1945. There have been a number of large floods recorded, with the largest occurring in January 1862, which is known to have been a very large—basically a regional—flood similar to the floods of 1964 and 1996. Other significantly large flood events in the region occurred in 1862, 1881, 1890, and 1909. Presumably, most of these floods occurred in this subbasin as well. The available flow data suggest that the flood events measured in water year 1974 and 1997 were the largest floods of record for the upper Sacramento River (DLT gauge period of record). These data suggest that historically, this subbasin has experienced similar floods for at least the last 150 years.

### *Subbasin Hydrology*

For the upper Sacramento River subbasin, there are three watersheds that were used to stratify the assessment area (Figure 3.2-48). Further, watershed attributes were summarized by subwatershed to show the distribution of these attributes within the three watersheds. The subwatersheds are listed in Table 3.2-6. Landform and land use data are summarized for each of the watersheds in Chapter 4.

The shape, texture, drainage pattern, and drainage efficiency of the watersheds are used to qualify and quantify the frequency and magnitude of upland rainfall-runoff relationships. The results of this analysis are used in Chapter 4 to help assess upslope erosion, sediment delivery, and instream sediment transport and storage. Watershed morphometric features are measured using NetMap and 10-meter DEM, including drainage area, maximum and minimum elevation, basin length, stream network length, and channel type. The NetMap model was used to measure the longitudinal profile, distribution of hillslope parameters such as gradient, and drainage efficiency of each watershed and the entire subbasin.

The average subbasin elevation is 3,000 feet, and the average watershed elevation ranges from over 6,000 feet in the upper watershed to about 1,500 feet in the lower watershed (Table 3.2-6). Using the NetMap-generated stream layer, this subbasin has about 2,440 miles of active stream channels. As described above, most of these stream channels are steep, with an average stream gradient of 22 percent. The drainage density is higher in the lower watershed than the upper; near Mount Shasta the average drainage density is less than 1 mile of stream per square mile of drainage area (Table 3.2-6). In the lower watershed, the drainage density is about 5 miles per square mile. Within this subbasin, baseflow does not increase with drainage density and is highest in the northern portion of the drainage where there are fewer stream channels.

The balance between rainfall-runoff and stream channel response are controlled by the types of landforms within the subbasin. Land use activities that create less-permeable ground surfaces, like urban development and road construction, alter the rainfall-runoff balance. Cumulatively, land management activities are known to alter the water balance and can measurably change the magnitude, frequency, duration, and timing of storm runoff (Schumm et al. 1984 and Ziemmer et al. 1991). This assessment created a land use footprint map that combined available land use data into one GIS layer (Figure 3.2-48) to estimate the hydrologic alteration caused by land use activities within the subbasin. This method follows the Equivalent Roaded Area (ERA) method for the Shasta-Trinity National Forest (Shilling et al. 2005). This map includes the following features and is described in more detail in Appendix B:

- major highways
- urban areas and roads
- forest roads
- railroads

Typically, the ERA analysis would include timber harvest. However, within the upper Sacramento River subbasin, the quality of the available harvest data on private lands is too poor to include in this analysis (see data gaps discussion in Chapter 4). The combined land use data for roads and other developed areas were used to create the footprint layer in GIS, and the available data were integrated into NetMap and intersected with the Lithotopo Unit layer (described above) to characterize the relative level of ERA values for the subbasin and three watersheds. Using readily available public data, each type of use feature was classified according to how impervious it makes the ground (see Appendix B). For roads, the impervious area is assumed to be the road prism, and it is also assumed that there is no infiltration within this area (i.e., 100 percent impervious). The same assumption applies to urban areas and the railroad corridor.

The footprint layer was summarized for the subbasin and by watershed. The subbasin average ERA is 4 percent and ranges from 0 to 17 percent. The ERA resulting from roads and urban areas is lower in the upper watershed (Figure 3.2-48) as a result of both the actual land use footprint being smaller and the landforms the uses occur on (the upper watershed has less runoff potential given the climate and drainage patterns). The highest ERA in the watershed occurs in urban areas southwest of Mount Shasta and roaded areas in the middle watershed (Figure 3.2-48). Urban areas, a source of storm runoff, cover about one percent of the subbasin with a maximum of eight percent in the upper watershed. For road related ERA, the Interstate 5 corridor is a large impervious area that measurably increases runoff during rainstorms and accounts for about 10 percent of the ERA from roads. The railroad footprint accounts for about 10 percent as well. Roads on Forest Service and private lands account for 60 percent of the total road ERA, and roads used to access urban areas account for 20 percent of the road ERA.

## 3.2.7 Water Quality

This section discusses the existing water quality conditions of the upper Sacramento River watershed. The aspects of water quality discussed include the legal basis and authority for water quality monitoring activities, the status of water quality monitoring activities, surface water quality, groundwater quality, and ongoing discharges in the watershed, including point-source and non-point source discharge activity.

### Water Quality Monitoring Activities in the Subbasin

#### *Legal Basis and Authority*

Most water quality monitoring activities in the watershed are mandated by federal and California law. The primary laws governing water quality in the watershed are the federal Clean Water Act (CWA) and the Porter-Cologne Water Quality Control Act (Porter-Cologne Act) (see Section 2.3, *Evolution of Laws and Regulations Affecting the Watershed*).

#### *Basin Plan*

The upper Sacramento River watershed is subject to compliance with the Basin Plan prepared by the Central Valley Regional Water Quality Control Board (Regional Water Board) in 2009. Even though the Basin Plan does not include actual monitoring activity, it is the document that sets the water quality objectives and drives on-going water quality monitoring efforts pertinent to the assessment area. Therefore, the Basin Plan and relevant components are described.

The format for Basin Plans as described in the Porter-Cologne Act follows a logical progression towards water quality protection by

- describing the resources and beneficial uses to be protected;
- stating water quality objectives for the protection of those uses;
- providing implementation plans (which include specific prohibitions, action plans and policies) to achieve the water quality objectives;

- describing the statewide plans and policies which apply to the waters of the region; and
- describing the region’s surveillance and monitoring activities (Central Valley Regional Water Quality Control Board 2009).

The 2009 Basin Plan applies to the entire Sacramento and San Joaquin watersheds, covers 27,210 square miles, and includes the entire area drained by the Sacramento River. The Basin Plan divides the upper Sacramento River into three segments: (1) source to Box Canyon Reservoir, (2) Lake Siskiyou, and (3) from Box Canyon Dam to Shasta Lake (Figure 3.2-51). Designated beneficial uses of the upper Sacramento River are listed in Table 3.2-7 and in the Basin Plan (Central Valley Regional Water Quality Control Board 2009). Table 3.2-7 also illustrates whether these beneficial uses currently exist or whether they have the potential to exist.

**Table 3.2-7. Upper Sacramento River Beneficial Uses**

| | | AGRICULTURE | | RECREATION | | | FRESHWATER HABITAT | | SPAWNING | | WILD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AGR | | REC 1 | | REC 2 | | | | | |
| | HYDRO UNIT NO. | IRRIGATION | STOCK WATERING | CONTACT | CANOEING AND RAFTING | OTHER NON-CONTACT | WARM | COLD | WARM | COLD | WILDLIFE HABITAT |
| Source to Box Canyon Reservoir | 525.22 | E | E | E | X | E | X | E | X | X | E |
| Lake Siskiyou | 525.22 | X | X | E | X | E | E | E | X | P | E |
| Box Canyon Dam to Shasta Lake | 525.2 | E | E | E | E | E | X | E | X | E | E |

E = Existing beneficial Use
P = Potential beneficial Use
X = Not suitable for use
Source: Adapted from Central Valley Regional Water Quality Control Board (2009)

The beneficial uses of these segments include:

- **Agricultural Supply (AGR).** Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing. This use, specifically irrigation and stock watering, is designated as existing for the following two segments: source to the Box Canyon Reservoir and Box Canyon Dam to Shasta Lake.
- **Water Contact Recreation (REC-1).** Uses of water for recreational activities involving body contract with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, and use of natural hot springs. Canoeing and rafting is a separate subcategory. This use is designated as existing for all three segments.

- **Non-Contact Water Recreation (REC-2).** Uses of water for recreational activities involving proximity to water, but where there is generally no body contact with water, nor any likelihood of ingestion of water. These uses include, but are not limited to, picnicking, sunbathing, sightseeing, or aesthetic enjoyment in conjunction with the above activities. This use is designated as existing for all three segments.

- **Warm Freshwater Habitat (WARM).** Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates. This use is designated as existing for Lake Siskiyou.

- **Cold Freshwater Habitat (COLD).** Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates. This use is designated as existing for all three segments.

- **Spawning, Reproduction, and/or Early Development (SPWN).** Uses of water that support high-quality aquatic habitats suitable for reproduction and early development of fish. Two subcategories, warm and cold, are included to further describe spawning habitat type, but only cold habitat exists within the upper Sacramento River. This use is designated as existing for the Box Canyon Dam to Lake Shasta and is considered a potential use for Lake Siskiyou.

- **Wildlife Habitat (WILD).** Uses of water that support terrestrial or wetland ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats or wetlands, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources. This use is designated as existing for all three segments.

The Basin Plan identifies both numeric and narrative water quality objectives applicable to the water draining out of the watershed. Table 3.2-8 summarizes the water quality objectives by the categories that have been established by the Regional Water Board to protect the designated beneficial uses. The water quality objectives by specific beneficial uses or individual segments of the upper Sacramento River are individually shown below.

The upper Sacramento River above Shasta Lake is not listed as water quality limited under Section 303(d) of the CWA (Central Valley Regional Water Quality Control Board 2006). For the 36.4-mile reach listed in the Basin Plan, all the beneficial uses are listed as threatened, but supporting (U.C. Davis 2010). The threatened status is related to the suspicion that metals from urban runoff and storm sewers are degrading water quality and threatening beneficial uses. Additionally, significant impacts to water quality have occurred within this reach, namely the Cantara spill of herbicides in 1991 and metals contamination from mine drainage near Shasta Lake.

The Basin Plan identifies water quality objectives for cadmium, copper, zinc, and water temperature that apply to the 36.4-mile reach of the watershed. The Regional Water Board determined that cadmium, copper, and zinc do impair the 25-mile segment of the upper Sacramento River between Keswick Dam and Cottonwood Creek (Regional Water Quality Board 2002). Although this segment of river is not within the watershed, the “impaired” water quality designation is likely a result of metals discharged by acid-mine drainage (AMD) input derived from remnant upstream mining activities (Regional Water Quality Control Board 2002). Water quality objective thresholds for

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Figure 3.2-51 Basin Plan Segments of the Upper Sacramento River

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cadmium, copper, and zinc are designated for the segment of the Sacramento River above the Highway 32 Bridge at Hamilton City, which is inclusive of the Sacramento River above Shasta Dam.

**Table 3.2-8. Water Quality Objectives for the Upper Sacramento River**

| CATEGORY | OBJECTIVE THRESHOLD | APPLICABLE PORTION OF WATER BODY |
|---|---|---|
| Bacteria | In waters designated for contact recreation (REC-1), the fecal coliform concentration based on a minimum of not less than five samples for any 30-day period shall not exceed a geometric mean of 200/100 ml, nor shall more than 10 percent of the total number of samples taken during any 30-day period exceed 400/100 ml. | Upper Sacramento River |
| Biostimulatory substances | Water shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses. | Upper Sacramento River |
| Color | Water shall be free of coloration that causes nuisance or adversely affects beneficial uses. | Upper Sacramento River |
| Chemical constituents | Waters designated for use as domestic or municipal supply shall not contain concentrations of chemical constituents in excess of the limits specified in Title 22 of California Code of Regulations (CCR). | Upper Sacramento River |
| ▪ Cadmium | Waters not to exceed 0.00022 mg/l dissolved concentration. | Sacramento River and tributaries above State Hwy 32 bridge at Hamilton City |
| ▪ Copper | Waters not to exceed 0.0056 mg/l dissolved concentration. | Sacramento River and tributaries above State Hwy 32 bridge at Hamilton City |
| ▪ Zinc | Waters not to exceed 0.016 mg/l dissolved concentration. | |
| Dissolved oxygen | The monthly median of the mean daily dissolved oxygen (DO) concentration shall not fall below 85 percent of saturation in the main water mass, and the 95th percentile concentration shall not fall below 75 percent of saturation. | Upper Sacramento River |
| | The dissolved oxygen concentrations shall not be reduced below the following minimum levels at any time: | |
| | ▪ Waters designated WARM 5.0 mg/l | Lake Siskiyou |
| | ▪ Water designated COLD 7.0 mg/l | Upper Sacramento River |
| | ▪ Waters designated SPWN 7.0 mg/l | Box Canyon Dam to Shasta Lake |
| Floating material | Water shall not contain floating material in any amounts that cause nuisance or adversely affect beneficial uses. | Upper Sacramento River |

**Table 3.2-8. Water Quality Objectives for the Upper Sacramento River**

| CATEGORY | OBJECTIVE THRESHOLD | APPLICABLE PORTION OF WATER BODY |
|---|---|---|
| Oil and grease | Waters shall not contain oils, greases, waxes, or other materials in concentrations that result in a visible film or coating on the surface of the water or on objects in the water, or otherwise adversely affect beneficial uses. | Upper Sacramento River |
| pH | Shall not be depressed below 6.5 nor raised above 8.5. Changes in normal ambient pH levels shall not exceed 0.5 in fresh waters with designated COLD or WARM beneficial uses. | Upper Sacramento River |
| Pesticides | No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses.<br>Discharges shall not result in pesticide concentrations in bottom sediments or aquatic life that adversely affects beneficial uses.<br>Total identifiable persistent chlorinated hydrocarbon pesticides shall not be present in the water column at concentrations detectable within the accuracy of analytical methods approved by the EPA or Executive Officer.<br>Waters designated for use as domestic or municipal supply shall not contain concentrations of pesticides in excess of the limiting concentrations set forth in CCR.<br>Pesticide concentrations shall not exceed those allowable by applicable antidegradation policies (State Water Resources Control Board Resolution No. 68-16 and 40 C.F.R. Section 131.12) | Upper Sacramento River |
| Sediment | The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses. | Upper Sacramento River |
| Settleable material | Water shall not contain substances in concentrations that result in the disposition of material that causes nuisance or adversely affects beneficial uses. | Upper Sacramento River |
| Suspended material | Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses. | Upper Sacramento River |
| Tastes and odors | Water shall not contain taste- or odor-producing substances in concentrations that impart undesirable tastes or odors to fish flesh or other edible products of aquatic origin, or that cause nuisance, or otherwise adversely affect beneficial uses. | Upper Sacramento River |

**Table 3.2-8. Water Quality Objectives for the Upper Sacramento River**

| CATEGORY | OBJECTIVE THRESHOLD | APPLICABLE PORTION OF WATER BODY |
|---|---|---|
| Temperature | At no time or place shall the temperature of any WARM or COLD water be increased by more than 5 ˚F above the natural receiving water temperature. | Upper Sacramento River |
| | From 1 December to 15 March, the maximum temperature shall be 55 ˚F. | Source to Box Canyon Reservoir, Box Canyon Dam to Shasta Lake |
| | From 16 March to 15 April, the maximum temperature shall be 60 ˚F. | |
| | From 16 April to 15 May, the maximum temperature shall be 65 ˚F. | |
| | From 16 May to 15 October, the maximum temperature shall be 70 ˚F. | |
| | From 16 October to 15 November, the maximum temperature shall be 65 ˚F. | |
| | From 16 November to 30 November, the maximum temperature shall be 65 ˚F. | |
| | The temperature in the epilimnion shall be less than or equal to 75 ˚F or mean daily ambient air temperature, whichever is greater. | Lake Siskiyou |
| Toxicity | All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal, or aquatic life. | Upper Sacramento River |
| Turbidity | Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses. | Upper Sacramento River |
| | Increases in turbidity attributable to controllable water quality factors shall not exceed the following limits: | |
| | Where natural turbidity is less than 1 Nephelometric Turbidity Unit (NTU), controllable factors shall not cause downstream turbidity to exceed 2 NTU. | |
| | Where natural turbidity range is 1–5 NTU's, increases shall not exceed 1 NTU. | |
| | Where natural turbidity range is 5–50 NTU's, increases shall not exceed 20 percent. | |
| | Where natural turbidity range is 50–100 NTU's, increases shall not exceed 10 NTU's. | |
| | Where natural turbidity range is greater than 100 NTU's, increases shall not exceed 10 percent. | |

Source: Water Quality Control Plan for the Central Valley Region (2009)

Six water temperature objectives are identified (Table 3.2-8) for the entire upper Sacramento River and for the following three segments that comprise the Sacramento River above Shasta Lake: (1) Source to Box Canyon Reservoir, (2) Lake Siskiyou, and (3) Box Canyon Dam to Shasta Lake. The water temperature objectives are numeric and account for temporal fluctuations in ambient water temperature.

The CWA includes provisions for reducing soil erosion relevant to water quality. It makes it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions. This pertains to construction sites where soil erosion and storm runoff and other pollutant discharges could affect downstream water quality. The water quality objectives related to sediment are described in Table 3.2-8. For free flowing streams, the turbidity levels are often a function of the suspended sediment, and the water quality objective for turbidity is numeric. Relevant to the assessment area is the relationship between fine sediment and metals. Metals commonly adsorb to clay size particles that are charged, and the fine sediment becomes the transport mechanism delivering metals to the hydrologic system.

### *Sacramento Watershed Coordinated Monitoring Program*

The Sacramento Watershed Coordinated Monitoring Program (SWCMP) is a monitoring effort by the California Department of Water Resources (DWR), Northern District, and the Regional Water Board. The SWCMP is designed to meet the monitoring needs of the Regional Water Board's Surface Water Ambient Monitoring Program (SWAMP) and the DWR Northern District. The purpose of the SWAMP is to implement comprehensive statewide water quality monitoring (Department of Water Resources 2009). The SWCMP program monitors and assesses ambient water quality of the Sacramento River and its larger tributaries at locations from upstream of Lake Shasta downstream to the lower ends of all of the larger tributary streams to the Sacramento River (Department of Water Resources 2009).

SWCMP requires that a minimum of 19 water constituents be measured at each water quality monitoring site either continuously or per sampling event (Table 3.2-9). At a minimum, DWR measures the basic parameters in the field and collects grab samples to be analyzed by DWR's Bryte Laboratory during each sampling event. Additional monitoring of metal and mineral constituents is performed by DWR Northern District but is independent of SWCMP (Department of Water Resources 2009).

**Table 3.2-9. SWCMP Water Quality Sampling Parameters**

| MANDATORY CONSTITUENTS TO BE MONITORED | |
|---|---|
| **Constituent** | **Collection** |
| Water temperature | Continuous measurement every 15 minutes |
| pH | Measured with pH meter during each sample collection event |
| Electrical conductivity (EC) | Measured with EC meter during each sample collection event |
| Dissolved oxygen (DOP | Measured with DO meter during each sample collection event |
| Turbidity | Measured with turbidity meter during each sample collection event |
| Total suspended solids | Grab sample; laboratory analysis |
| Total and dissolved arsenic | Grab sample; laboratory analysis |
| Total and dissolved copper | Grab sample; laboratory analysis |

**Table 3.2-9. SWCMP Water Quality Sampling Parameters**

| MANDATORY CONSTITUENTS TO BE MONITORED | |
|---|---|
| Alkalinity | Grab sample; laboratory analysis |
| Total hardness | Grab sample; laboratory analysis |
| Total ammonia as nitrogen | Grab sample; laboratory analysis |
| Total Kjeldahl nitrogen | Grab sample; laboratory analysis |
| Total organic nitrogen | Grab sample; laboratory analysis |
| Dissolved ammonia | Grab sample; laboratory analysis |
| Dissolved nitrate + nitrite | Grab sample; laboratory analysis |
| Dissolved ortho-phosphate | Grab sample; laboratory analysis |
| Total ohosphorus | Grab sample; laboratory analysis |
| Total organic carbon | Grab sample; laboratory analysis |
| **OPTIONAL CONSTITUENTS TO BE MONITORED** | |
| **Constituent** | **Collection** |
| Water column toxicity | Grab sample; laboratory analysis |
| Pathogens | Grab sample; laboratory analysis |
| **ADDITIONAL MONITORING BY DWR (NORTHERN DISTRICT) INDEPENDENT OF SWCMP** | |
| **Minerals** | **Metals** |
| Total calcium | Total and Dissolved Aluminum |
| Dissolved calcium | Total and Dissolved Cadmium |
| Total magnesium | Total and Dissolved Chromium |
| Dissolved magnesium | Total and Dissolved Iron |
| Dissolved sodium | Total and Dissolved Lead |
| Dissolved potassium | Total and Dissolved Manganese |
| Dissolved sulfate | Total Mercury |
| Dissolved chloride | Total and Dissolved Nickel |
| Dissolved boron | Total and Dissolved Selenium |
| Dissolved hardness | Total and Dissolved Silver |
| | Total and Dissolved Zinc |

Source: California Department of Water Resources (2009)

### *Upper Sacramento River Water Quality Management Operational Plan (Cantara Trustee Council)*

SWCMP has occupied one sampling location, Sacramento River at Delta (DWR station # A2130000), in the watershed above Shasta Lake (Department of Water Resources 2009). Grab samples have been collected at this station on a quarterly basis between 2001 and the present. In addition, DWR station #A2130000 geographically coincides with an existing monitoring station (DLT) that is monitored and maintained by the USGS and the U.S. Bureau of Reclamation. As a result, a continuous record (1-hour sampling interval) exists for dissolved oxygen concentration, water temperature, and turbidity[10]

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[10] *The longest record of usable turbidity data is a series of manual turbidity probe measurements taken at DLT about once a month from 1998 to 2010. There are also 20 years of continuous turbidity data available for DLT; however, the continuous data are not presently usable due to technical problems encountered with the probe (Greg Gotham, U.S. Bureau of Reclamation, personal communication).*

of the Sacramento River at Delta. In this discussion, both monitoring sites will be referred to collectively by the acronym DLT.

On July 14, 1991, near the city of Dunsmuir, a Southern Pacific train derailed along a section of track known as the Cantara Loop. A chemical tank car containing the herbicide metam sodium fell into the Sacramento River and released 19,000 gallons of the chemical into the river. As the metam sodium mixed with the water, highly toxic compounds were created. Virtually all aquatic life in the Sacramento River between the Cantara Loop and Shasta Lake was destroyed (2007).

As a result of a lawsuit filed against Southern Pacific, the Cantara Trustee Council (CTC) was established to address the effects of the spill on the upper Sacramento River. In 1996, the CTC granted funding to the Regional Water Board to conduct water quality monitoring and develop an enhanced regulatory program on the upper Sacramento River (Cantara Trustee Council 2007). The CTC's upper Sacramento River Water Quality Management Operational Plan was released in March 1997, and water quality monitoring activities were implemented in 1997 (Cantara Trustee Council 1997). At a minimum, the priority pollutants listed in Table 3.2-10 were monitored.

**Table 3.2-10. Minimum Water Quality Monitoring Components of Upper Sacramento River**

| CONSTITUENT | INITIAL FREQUENCY |
|---|---|
| Sediment and turbidity | Minimum two per month at selected sites with emphasis during storm events. |
| Temperature | Continuous recording June through October at 11 sites. |
| Nutrients and bacteria | Quarterly at 10 locations. |
| Petroleum products and hazardous materials | Sample urban runoff during the first runoff producing storm event of the season at two locations. |
| Ambient chronic toxicity | Two screenings will be done in one year. |

Under the upper Sacramento River Water Quality Management Operational Plan, water quality monitoring activities continued for five years.

### *National Water-Quality Assessment Program*

The National Water-Quality Assessment Program (NAWQA) is administered by the USGS and is a primary source for long-term, nationwide information on the quality of streams, groundwater, and aquatic ecosystems (U.S. Geological Survey 2001). The NAWQA seeks to improve scientific and public understanding of water quality in the nation's major river basins and groundwater systems.

An assessment of the Sacramento River basin is one of 51 water-quality assessments that have been initiated since 1991 (Domagalski et al. 2000). The results and findings from water quality data collected from 1994 through 1998 were reported in a 2000 USGS report (Domagalski et al. 2000). A second cycle of studies on the Sacramento River basin was scheduled to begin in 2004, but continued water quality monitoring on the upper Sacramento River was not included in the study design.

Although the Sacramento River is studied in detail by NAWQA, there are no NAWQA monitoring sites in the watershed. However, NAWQA is included in this section because the analysis of downstream water quality data has raised some questions about the AMD inputs in the watershed, which will be discussed later.

## Surface Water Quality

The water quality of the Sacramento River and its major tributaries supports nearly all beneficial uses most of the time (Domagalski et al. 2000). In general, water quality is exceptional in the watershed. Most of the water in the upper Sacramento River and its tributaries is derived from snowmelt; as a result, the water in the system is relatively pure and low in dissolved minerals (Domagalski et al. 2000). However, storm runoff and AMD from historic mining activities near Little Backbone Creek is a source of cadmium, copper, and zinc to the mainstem river and Shasta Lake (Alpers et al 2000).

Like surface flow data, surface water quality monitoring stations and associated data are severely lacking in the watershed. However, the water quality of the upper Sacramento River can be broadly characterized using existing water quality data from the DLT monitoring site, which has the most complete set of water quality data for the upper Sacramento River. As stated above, the DLT monitoring site is located upstream of the mouth of the upper Sacramento River at Shasta Lake. The site location allows a characterization to be made for the comprehensive water quality of the watershed above Shasta Lake, excluding Little Backbone Creek.

At the DLT site, DWR Northern Division collected grab samples of surface waters on a quarterly basis between 2001 and the present. The surface water samples were tested for 204 different analytes; of these, only 49 analytes were detected (Table 3.2-11). In addition, the USGS collects continuous data (one-hour interval) for dissolved oxygen concentration, water temperature, and turbidity of the Sacramento River at the DLT site. An extensive data set exists for dissolved oxygen concentration and water temperature between 1990 and the present. As stated above, however, the longest record of usable turbidity data is a series of manual turbidity probe measurements taken at DLT about once a month from 1998 to 2010. There are also 20 years of continuous turbidity data available for DLT; however, the continuous data are not presently usable due to technical problems encountered with the probe (Greg Gotham, U.S. Bureau of Reclamation, personal communication). Summaries were created from this data set for dissolved oxygen concentration (Table 3.2-12) and water temperature (Table 3.2-13).

### *Chemical Constituents*

Based on the water data collected by DWR Northern Division (Table 3.2-11), surface water at the DLT monitoring site does not contain any chemical constituents that exceed the objective thresholds set forth in Title 22 of the California Code of Regulations (CCR) during the period of record.

### Table 3.2-11.  Water Quality Summary of DWR Grab Samples Results from the DLT

| CONSTITUENT | UNITS | DATA | TOTAL | CONSTITUENT | UNITS | DATA | TOTAL |
|---|---|---|---|---|---|---|---|
| Ammonia | mg/L or mg/L as N | Number of samples | 10.0 | Dissolved zinc | µg/L | Number of samples | 21.0 |
| | | Average result | 0.1 | | | Average result | 0.4 |
| | | Maximum result | 0.1 | | | Maximum result | 1.0 |
| Conductance (EC) | µS/cm | Number of samples | 18.0 | Hardness | mg/L as CaCO3 | Number of samples | 35.0 |
| | | Average result | 115.9 | | | Average result | 46.7 |
| | | Maximum result | 159.0 | | | Maximum result | 62.0 |
| | | Minimum result | 66.0 | | | Minimum result | 26.0 |
| Dissolved aluminum | µg/L | Number of samples | 21.0 | pH | pH Units | Number of samples | 28.0 |
| | | Average result | 22.3 | | | Average result | 7.4 |
| | | Maximum result | 191.0 | | | Maximum result | 8.6 |
| | | Minimum result | 1.1 | | | Minimum result | 6.0 |
| Dissolved ammonia | mg/L as N | Number of samples | 31.0 | Total alkalinity | mg/L as CaCO3 | Number of samples | 28.0 |
| | | Average result | 0.0 | | | Average result | 51.9 |
| | | Maximum result | 0.0 | | | Maximum result | 71.0 |
| | | Minimum result | 0.0 | | | Minimum result | 31.0 |
| Dissolved arsenic | µg/L | Number of samples | 21.0 | Total aluminum | µg/L | Number of samples | 25.0 |
| | | Average result | 3.1 | | | Average result | 80.1 |
| | | Maximum result | 7.3 | | | Maximum result | 598.0 |
| | | Minimum result | 0.1 | | | Minimum result | 4.6 |
| Dissolved boron | mg/L | Number of samples | 35.0 | Total arsenic | µg/L | Number of samples | 25.0 |
| | | Average result | 0.1 | | | Average result | 3.4 |
| | | Maximum result | 0.2 | | | Maximum result | 7.3 |
| | | Minimum result | 0.0 | | | Minimum result | 0.7 |

### Table 3.2-11. Water Quality Summary of DWR Grab Samples Results from the DLT

| CONSTITUENT | UNITS | DATA | TOTAL | CONSTITUENT | UNITS | DATA | TOTAL |
|---|---|---|---|---|---|---|---|
| Dissolved cadmium | µg/L | Number of samples | 21.0 | Total cadmium | µg/L | Number of samples | 25.0 |
| | | Average result | 0.0 | | | Average result | 0.0 |
| | | Maximum result | 0.0 | | | Maximum result | 0.0 |
| | | Minimum result | 0.0 | | | Minimum result | 0.0 |
| Dissolved calcium | mg/L | Number of samples | 35.0 | Total calcium | mg/L | Number of samples | 29.0 |
| | | Average result | 6.3 | | | Average result | 6.5 |
| | | Maximum result | 9.0 | | | Maximum result | 10.0 |
| | | Minimum result | 4.0 | | | Minimum result | 4.0 |
| Dissolved chloride | mg/L | Number of samples | 35.0 | Total chromium | µg/L | Number of samples | 25.0 |
| | | Average result | 4.0 | | | Average result | 1.6 |
| | | Maximum result | 9.0 | | | Maximum result | 6.0 |
| | | Minimum result | 1.0 | | | Minimum result | 0.6 |
| Dissolved chromium | µg/L | Number of samples | 21.0 | Total copper | µg/L | Number of samples | 25.0 |
| | | Average result | 1.1 | | | Average result | 0.6 |
| | | Maximum result | 2.6 | | | Maximum result | 2.4 |
| | | Minimum result | 0.6 | | | Minimum result | 0.3 |
| Dissolved copper | µg/L | Number of samples | 21.0 | Total dissolved solids | mg/L | Number of samples | 34.0 |
| | | Average result | 0.4 | | | Average result | 72.7 |
| | | Maximum result | 0.9 | | | Maximum result | 103.0 |
| | | Minimum result | 0.2 | | | Minimum result | 42.0 |

### Table 3.2-11. Water Quality Summary of DWR Grab Samples Results from the DLT

| CONSTITUENT | UNITS | DATA | TOTAL | CONSTITUENT | UNITS | DATA | TOTAL |
|---|---|---|---|---|---|---|---|
| Dissolved hardness | mg/L as CaCO3 | Number of samples | 25.0 | Total hardness | mg/L as CaCO3 | Number of samples | 4.0 |
| | | Average result | 45.9 | | | Average result | 45.0 |
| | | Maximum result | 55.0 | | | Maximum result | 53.0 |
| | | Minimum result | 31.0 | | | Minimum result | 39.0 |
| Dissolved iron | µg/L | Number of samples | 21.0 | Total iron | µg/L | Number of samples | 25.0 |
| | | Average result | 25.9 | | | Average result | 100.1 |
| | | Maximum result | 153.0 | | | Maximum result | 716.0 |
| | | Minimum result | 6.0 | | | Minimum result | 9.2 |
| Dissolved lead | µg/L | Number of samples | 21.0 | Total Kjeldahl nitrogen | mg/L | Number of samples | 2.0 |
| | | Average result | 0.0 | | | Average result | 0.4 |
| | | Maximum result | 0.0 | | | Maximum result | 0.4 |
| | | Minimum result | 0.0 | | | Minimum result | 0.4 |
| Dissolved magnesium | mg/L | Number of samples | 35.0 | Total lead | µg/L | Number of samples | 25.0 |
| | | Average result | 7.2 | | | Average result | 0.1 |
| | | Maximum result | 8.0 | | | Maximum result | 0.6 |
| | | Minimum result | 4.0 | | | Minimum result | 0.0 |
| Dissolved manganese | µg/L | Number of samples | 21.0 | Total magnesium | mg/L | Number of samples | 29.0 |
| | | Average result | 0.9 | | | Average result | 7.6 |
| | | Maximum result | 2.4 | | | Maximum result | 9.0 |
| | | Minimum result | 0.2 | | | Minimum result | 6.0 |

### Table 3.2-11. Water Quality Summary of DWR Grab Samples Results from the DLT

| CONSTITUENT | UNITS | DATA | TOTAL | CONSTITUENT | UNITS | DATA | TOTAL |
|---|---|---|---|---|---|---|---|
| Dissolved nickel | µg/L | Number of samples | 21.0 | Total manganese | µg/L | Number of samples | 25.0 |
| | | Average result | 6.8 | | | Average result | 5.6 |
| | | Maximum result | 12.5 | | | Maximum result | 47.7 |
| | | Minimum result | 3.3 | | | Minimum result | 1.3 |
| Dissolved nitrate | mg/L | Number of samples | 1.0 | Total mercury | ng/L | Number of samples | 5.0 |
| | | Average result | 0.3 | | | Average result | 0.6 |
| | | Maximum result | 0.3 | | | Maximum result | 1.0 |
| | | Minimum result | 0.3 | | | Minimum result | 0.4 |
| Dissolved nitrate + nitrite | mg/L as N | Number of samples | 35.0 | Total nickel | µg/L | Number of samples | 25.0 |
| | | Average result | 0.0 | | | Average result | 8.7 |
| | | Maximum result | 0.1 | | | Maximum result | 26.5 |
| | | Minimum result | 0.0 | | | Minimum result | 3.9 |
| Dissolved organic carbon | mg/L as C | Number of samples | 3.0 | Total organic carbon | mg/L as C | Number of samples | 3.0 |
| | | Average result | 2.0 | | | Average result | 3.1 |
| | | Maximum result | 3.7 | | | Maximum result | 6.9 |
| | | Minimum result | 1.1 | | | Minimum result | 1.2 |
| Dissolved ortho-phosphate | mg/L as P | Number of samples | 34.0 | Total phosphorus | mg/L | Number of samples | 35.0 |
| | | Average result | 0.0 | | | Average result | 0.1 |
| | | Maximum result | 0.0 | | | Maximum result | 1.5 |
| | | Minimum result | 0.0 | | | Minimum result | 0.0 |

### Table 3.2-11. Water Quality Summary of DWR Grab Samples Results from the DLT

| CONSTITUENT | UNITS | DATA | TOTAL | CONSTITUENT | UNITS | DATA | TOTAL |
|---|---|---|---|---|---|---|---|
| Dissolved potassium | mg/L | Number of samples | 35.0 | Total selenium | µg/L | Number of samples | 25.0 |
| | | Average result | 0.8 | | | Average result | 0.2 |
| | | Maximum result | 1.9 | | | Maximum result | 0.3 |
| | | Minimum result | 0.0 | | | Minimum result | 0.1 |
| Dissolved selenium | µg/L | Number of samples | 21.0 | Total suspended solids | mg/L | Number of samples | 36.0 |
| | | Average result | 0.2 | | | Average result | 6.8 |
| | | Maximum result | 0.3 | | | Maximum result | 33.0 |
| | | Minimum result | 0.2 | | | Minimum result | 1.0 |
| Dissolved sodium | mg/L | Number of samples | 35.0 | Total zinc | µg/L | Number of samples | 25.0 |
| | | Average result | 5.7 | | | Average result | 1.4 |
| | | Maximum result | 10.0 | | | Maximum result | 6.5 |
| | | Minimum result | 2.0 | | | Minimum result | 0.1 |
| Dissolved sulfate | mg/L | Number of samples | 35.0 | | | | |
| | | Average result | 2.1 | | | | |
| | | Maximum result | 3.0 | | | | |
| | | Minimum result | 1.0 | | | | |

### Table 3.2-12. Recorded Maximum Concentrations of Cadmium, Copper, and Zinc at the DLT

| CONSTITUENT | MAXIMUM CONCENTRATION THRESHOLD A (MG/L) | MAXIMUM CONCENTRATION AT DLT |
|---|---|---|
| Cadmium | 0.00022 | 0 |
| Copper | 0.0056 | 0.0009 |
| Zinc | 0.016 | 0.0065 |

**Table 3.2-13. Recorded Annual Water Temperature Summary at the DLT**

| YEAR | ANNUAL MEDIAN WATER TEMPERATURE (˚F) | ANNUAL MAXIMUM WATER TEMPERATURE (˚F) | ANNUAL MINIMUM WATER TEMPERATURE (˚F) |
|---|---|---|---|
| 1990 | 56 | 77 | 35 |
| 1991 | 50 | 80 | 36 |
| 1992 | 53 | 76 | 38 |
| 1993 | 48 | 72 | 35 |
| 1994 | 52 | 78 | 36 |
| 1995 | 52 | 72 | 39 |
| 1996 | 50 | 74 | 38 |
| 1997 | 54 | 78 | 40 |
| 1998 | 49 | 71 | 34 |
| 1999 | 51 | 78 | 39 |
| 2000 | 50 | 75 | 39 |
| 2001 | 51 | 78 | 34 |
| 2002 | 52 | 77 | 37 |
| 2003 | 51 | 76 | 34 |
| 2004 | 52 | 75 | 34 |
| 2005 | 50 | 74 | 37 |
| 2006 | 48 | 72 | 39 |
| 2007 | 51 | 76 | 35 |
| 2008 | 50 | 75 | 35 |
| 2009 | 51 | 76 | 36 |
| Median | 50.7 | 75.5 | 36.1 |
| Maximum | 56.1 | 80.0 | 40.1 |
| Minimum | 48.1 | 71.2 | 33.6 |

### *Copper, Cadmium, and Zinc*

Surface water at the DLT did not exceed any of the Basin Plan objective thresholds (Table 3.2-11) for dissolved cadmium, copper, or zinc. The Basin Plan specifically identifies objective thresholds for several water quality constituents in the watershed. Cadmium, copper, and zinc are of particular interest because it has been reported that there may be cadmium inputs to the Sacramento River above Shasta Dam and copper and zinc concentrations appear to follow a similar trend (Alpers et al. 2000). In addition, the mainstem reach of the river is listed as threatened by metals input from storm runoff and sewage discharge.

### *Temperature*

The median annual water temperature recorded at the DLT is 50.7 ˚F with a range of between 48.1 ˚F and 56.1˚F. Water temperatures as high as 80 ˚F and as low as 33.6 ˚F have been recorded at the site. In every year of record (Table 3.2-13), the annual maximum recorded water temperature has exceeded all six of the time-specific water temperature thresholds set by the Basin Plan (Table 3.2-9). This fact does not indicate that all of the Basin Plan’s maximum time-specific water temperature objectives were exceeded. Rather, it is unknown which time-specific threshold was exceeded each year and how frequently. However, the maximum water temperature threshold for all objectives is 70 ˚F and the maximum annual water temperature at DLT exceeded 70 ˚F every year during the period of record. As a result, the only conclusion that can be made is that during the period of record the maximum annual temperature of the Sacramento River exceeded one of the Basin Plan's six water quality thresholds.

### *Dissolved Oxygen*

The median annual dissolved oxygen water concentration recorded at the DLT is approximately 10.0 mg/L with a range of between 4.4 mg/L and 11.3 mg/L (Table 3.2-14). Dissolved oxygen concentrations as low as 2 mg/L and as high as 18 mg/L were measured at the site. Using this data, the water of the upper Sacramento River can be characterized as being approximately 95 percent saturated, which suggests it has the capacity to support abundant aquatic life.

**Table 3.2-14. Recorded Annual Dissolved Oxygen at the DLT**

| YEAR | MEDIAN ANNUAL DISSOLVED OXYGEN CONCENTRATION (MG/L) | MAXIMUM ANNUAL DISSOLVED OXYGEN CONCENTRATION (MG/L) | MINIMUM ANNUAL DISSOLVED OXYGEN CONCENTRATION (MG/L) |
|---|---|---|---|
| 1990 | 4.9 | 15.6 | 2.0 |
| 1991 | 4.6 | 10.7 | 2.0 |
| 1992 | 4.4 | 15.0 | 2.2 |
| 1993 | 8.6 | 12.0 | 2.0 |
| 1994 | 8.1 | 18.0 | 2.0 |
| 1995 | 7.4 | 12.2 | 2.1 |
| 1996 | 10.0 | 15.8 | 2.3 |
| 1997 | 5.3 | 10.7 | 2.0 |
| 1998 | 10.5 | 17.6 | 2.0 |
| 1999 | 11.2 | 16.2 | 2.0 |
| 2000 | 11.3 | 14.7 | 2.0 |
| 2001 | 9.9 | 15.0 | 3.0 |
| 2002 | 11.1 | 17.3 | 2.0 |
| 2003 | 10.1 | 15.9 | 2.1 |
| 2004 | 9.6 | 15.6 | 2.0 |
| 2005 | 10.1 | 13.3 | 2.6 |
| 2006 | 10.3 | 14.9 | 7.1 |
| 2007 | 10.2 | 15.9 | 2.7 |
| 2008 | 10.4 | 15.1 | 2.0 |
| 2009 | 11.0 | 16.5 | 2.9 |
| Median | 10.0 | 15.4 | 2.0 |
| Maximum | 11.3 | 18.0 | 7.1 |
| Minimum | 4.4 | 10.7 | 2.0 |

For 16 of the 20 years of record (Table 3.2-14), the annual median dissolved oxygen concentration of the Sacramento River at the DLT monitoring station did not fall below Basin Plan thresholds (Table 3.2-9) set for dissolved oxygen. In the years the thresholds were exceeded (1990-1992, 1997), however, there were large irregularities in the data set, and suspect data points (<2mg/L or > 18 mg/L) were removed from the analysis. Although this did increase the quality of the dataset, the annual median dissolved oxygen concentrations for the aforementioned years were still approximately half of the other 16 annual median values that met Basin Plan criteria. A few explanation for this large variance include: (1) equipment malfunction; (2) equipment placed in area with limited mixing from surface water such as a backwater area; (3) equipment buried by fluvial sediments ; or (4) site was inundated by Shasta Lake due to increased water storage, thus changing the flow regime at the station from flowing water to quiescent water. Even though a definitive explanation for the irregular data is not provided here, all irregularities are likely a result of technical monitoring complications and any characterization of water quality using this data should be done with caution.

### *Sediment and Turbidity*

Sediment and the associated impacts on water quality are a concern in the subbasin and are defined by the State of California as soil, sand, and minerals washed from land into water, usually after rain, that accumulate in reservoirs and streams. Excess sediment commonly degrades fish and wildlife habitat and can cloud water. There are no suspended sediment or bedload data available within the subbasin. There are, however, some turbidity data commonly used as a surrogate for suspended sediment. The turbidity data available for the upper Sacramento River at Delta and Hazel Creek in the middle watershed suggest that since 1998 during low-flow conditions the water clarity is meeting water quality objectives for turbidity, hence sediment (see Appendix B). No other turbidity data are available for other tributaries within subbasin. There are not enough turbidity data available for high-flow conditions to help assess the present sediment load of the subbasin or compare it to water quality objectives. The Basin Plan targets reducing storm water runoff in an attempt to reduce the amount of cadmium, copper, and zinc delivered to the river and lake systems. Trace metals and fine sediment are linked and reducing erosion typically reduces the amount of metals as well. Metals like cadmium commonly adsorb to sediment particles. The Basin Plan sets the stage to identify the occurrence of controllable sediment discharge sources within the subbasin to improve and prevent degrading water quality. Controllable sediment discharge sources are locations or sites that deliver sediment to a stream, are caused by human activity, and may feasibly mitigated.

It was difficult to obtain reliable sediment and turbidity data for the subbasin to help verify the predicted sediment loads and trends. Like for stream flow, there are very limited data available for a subbasin this size (i.e., about 500 square miles). None of the data from the Cantara monitoring listed in Table 3.2-10 were available, and the location of these data is unknown as of the date of this assessment. Turbidity data have been collected over the last 20 years by the BOR at the DLT gauge. However, the turbidity readings taken using a probe are not considered accurate, especially during high-flow conditions. As part of data discovery and analysis review, it was learned that the turbidity data reported on CDEC are not reliable between January and June. SPI provided turbidity records from 2003 to present for Hazel Creek, one of the main tributaries in the middle watershed. These turbidity data are shown in Appendix B.

## Groundwater Quality

According to the DWR (Department of Water Resources 2003), groundwater quality in the Sacramento River Hydrologic Region is generally excellent. However, most of the groundwater quality data are collected from areas downstream of the upper Sacramento River watershed and there are no state-identified groundwater aquifers that fall within the assessment area (Department of Water Resources 2003). There is therefore a lack of groundwater quality data.

In the rural mountains areas of the watershed, domestic supplies come almost entirely from groundwater (Department of Water Resources 2003). A few communities are supplied by surface water, but most communities rely on groundwater supplies for public use (Department of Water Resources 2003). In these regions, groundwater supplies are extracted from highly fractured rocks within the subsurface, but these supplies are highly variable in both quantity and quality (Department of Water Resources 2003).

A majority of the subbasin is underlain by the discontinuous sequences of metamorphic rocks within the Klamath Mountains, and a small area of the northern portion of the watershed is underlain by volcanic deposits of the Cascade Range. The Klamath Mountains, mainly made up of meta-sediment and peridotite rock types, are generally impermeable. Most void spaces capable of storing groundwater are created by fractures and remnant stratigraphic sedimentary features. Overall, the Klamath Mountains bedrock lacks the storage capacity needed to sustain a reliable groundwater aquifer. However, within the northern portion of the subbasin, the volcanic deposits of the Cascade Range are a reliable source of very clean groundwater, as evidenced by the water bottling plants on the flanks of Mount Shasta.

The groundwater quality data that does exist comes from the City of Mt. Shasta Annual Consumer Confidence Report (CCR). A CCR is required when any public water system with more than 10,000 service connections detects contaminants levels above public health goals set by local standards or the State of California (http://www.oehha.ca.gov/water/phg/allphgs.html). The City of Mt. Shasta's public water supply is extracted from one large groundwater spring (Cold Spring) and two groundwater wells within the town limits. Because all the water sources emanate from the subsurface, it is assumed that they can provide some insight into the groundwater quality of the northern portion of the watershed. Brief summaries (Tables 3.2-15, 3.2-16, 3.2-17, and 3.2-18) were created from six years (2003–2008) of CCRs from the City of Mt. Shasta.

**Table 3.2-15. Contaminants Detected with a Primary Drinking Water Standard**

| ANALYTES | SAMPLE YEARS | LEVEL DETECTED RANGE | RANGE OF DETECTIONS | MAXIMUM CONTAMIN-ANT LEVEL (MCL) | PUBLIC HEALTH GOAL (PHG) | TYPICAL SOURCE |
|---|---|---|---|---|---|---|
| Fluoride (ppm) | 2002, 2007 | 0.1–0.12 | 0–0.12 | 2 | 1 | Erosion of natural deposits |
| Chromium (ppb) | 2002 | 1 ppb | 1 ppb | 50 ppb | N/A | Discharge from steel and pulp mills and chrome plating plants. Also naturally occurring. |

**Table 3.2-16. Contaminants Detected with a Secondary Drinking Water Standard**

| ANALYTES | SAMPLE YEARS | LEVEL DETECTED RANGE | RANGE OF DETECTIONS | MAXIMUM CONTAMIN-ANT LEVEL (MCL) | TYPICAL SOURCE |
|---|---|---|---|---|---|
| Specific conductance (Umho/cm) | 2000, 2004, 2007 | 62 – 75.8 | 45–101 | 1600 | Substances that form ions when in water; seawater influence. |
| Total dissolved solids (ppm) | 1993, 2004, 2007 | 89 – 99 | 60–101 | 1000 | Erosion of natural deposits. |
| Chloride (ppm) | 2007 | 0.64 | 0.19–1.2 | 500 | Erosion of natural deposits. |
| Zinc (ppb) | 2007 | 71.2 | 71.2 | 5000 | Runoff or leaching from natural deposits; industrial waste. |

**Table 3.2-17. Detectable Amounts of Lead and Copper**

| ANALYTE | SAMPLE YEARS | # OF SAMPLES COLLECTED | REGULA-TORY ACTION LEVEL (AL) | MAXIMUM CONTAMIN-ANT LEVEL (MCL) | 90TH PERCENTILE LEVEL DETECTED | # SITES EXCEEDING AL |
|---|---|---|---|---|---|---|
| Lead (ppb) | 2006 – 2009 | 20 | 15 | 2 | ND | 0 |
| Copper (ppm) | 2006 – 2009 | 20 | 1.3 | 0.17 | 0.519 | 0 |

**Table 3.2-18. Detectable Amounts of Sodium and Hardness**

| ANALYTE | SAMPLE YEARS | LEVEL DETECTED RANGE (PPM) | RANGE OF DETECTIONS (PPM) | TYPICAL SOURCE |
|---|---|---|---|---|
| Sodium | 2002, 2007 | 4.28–5.5 | 2.85–6.0 | Generally found in ground and surface water |
| Hardness | 2002, 2006, 2007 | 23.3–31.0 | 12.0–31.0 | Generally found in ground and surface water |

## Ongoing Discharges in the Upper Sacramento River Watershed

### *Regulated Under the National Pollutant Discharge Elimination System*

The National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. NPDES is authorized by the CWA and is administered by the State of California through EPA authorization. Point sources are discrete conveyances such as pipes or ditches. Industrial, municipal, and other facilities must obtain NPDES permits if their discharges go directly to surface waters. Facilities may also need to obtain a NPDES permit if they discharge pollutants into a storm sewer system.

Within the watershed, four NPDES permits have been issued for discharge directly into surface waters. Permit information is listed in Table 3.2-19.

**Table 3.2-19. NPDES Regulated Point-Source Discharges**

| NPDES ID | FACILITY NAME | CITY | COUNTY | DESCRIPTION |
|---|---|---|---|---|
| CA0078441 | City of Dunsmuir WWTP | Dunsmuir | Siskiyou | Sewage system |
| CA0004596 | Mt. Shasta Fish Hatchery | Mt. Shasta | Siskiyou | Fish hatcheries and preserves |
| CA0078051 | Mt. Shasta STP | Mt. Shasta | Siskiyou | Sewage system |
| CAU000133 | Southern Pacific Transportation Company | Dunsmuir | Siskiyou | Railroads, line haul operations |

Hazardous waste information is contained in the Resource Conservation and Recovery Act Information (RCRAInfo), a national program management and inventory system regarding hazardous waste handlers. Hazardous waste activities are also regulated under the NPDES guidelines. In general, all generators, transporters, treaters, storers, and disposers of hazardous waste are required to provide information about their activities to state environmental agencies. If hazardous waste is not discharged directly into a watercourse, it has the potential to be discharged into groundwater or surface water by seepage or a spill on land.

Within the watershed, 12 hazardous waste handlers have been identified. Hazardous waste handler and facility information is listed in Table 3.2-20.

**Table 3.2-20. NPDES Hazardous Waste Handlers**

| FACILITY NAME | CITY | COUNTY |
|---|---|---|
| Caltrans Mt. Shasta | Mt. Shasta | Siskiyou |
| Caltrans District 2 Bibson Maintenance Station | Dunsmuir | Siskiyou |
| Caltrans Mt. Shasta Maintenance Station | Mt. Shasta | Siskiyou |
| CCDA Waters LLC | Mt. Shasta | Siskiyou |
| Hazmat Cleanup Center | Dunsmuir | Siskiyou |
| Mt. Shasta Cleaners | Mt. Shasta | Siskiyou |
| Pacific Bell | Mt. Shasta | Siskiyou |
| Pacific Bell | Mt. Shasta | Siskiyou |
| Pacific Bell | Mt. Shasta | Siskiyou |
| Pacific Bell | Mt. Shasta | Siskiyou |
| Pacific Bell | Mt. Shasta | Siskiyou |
| Union Pacific Railroad | Dunsmuir | Siskiyou |

***Nonpoint Source Discharges***

In the watershed, acidic drainage from several copper-zinc mines of the West Shasta mining district flows into Shasta Lake by way of two tributaries, Little Backbone Creek and West Squaw Creek (Alpers et al. 2000). Of the 14 mines identified as potential metal dischargers in the watershed (Regional Water Quality Control Board and California Environmental Protection Agency 2002), 10 mines are upstream of Shasta Dam and five have hydrologic connectivity with Shasta Lake. Data from several studies and from monitoring data from the Regional Water Board suggest that these mines are a significant source of cadmium, copper, and zinc (Alpers et al 2000).

In this document, only the mines on Little Backbone Creek will be discussed. The Mammoth, Golinski, and Sutro mines are estimated to contribute copper loads of 70.55, 1.1, and 0.11 pounds per day, respectively, on an annual basis to Shasta Lake (Alpers et al. 2000). Additionally, it has been reported that a significant portion of the cadmium loads that are present downstream of Shasta Dam may come from Shasta Lake and its tributaries, depending on the flow regime (Alpers et al. 2000).

Nonpoint source regulations cover other types of ground-disturbing activities. Most relevant to the assessment area are construction; timber harvest; and mining regulations and Best Management Practices.

# 3.3 Biological Components and Processes

## 3.3.1 Introduction

The upper Sacramento River watershed encompasses a wide diversity of biotic communities (groups of plant, wildlife, and fish populations that interact with one another in the same environment). This diversity results from the large size of the watershed in combination with the variety of landforms, soil types, topography, and microclimates, which have been influenced by natural variation as well as human use and management. The plant species present in a community are generally a response to abiotic (non-living) factors such as climate, topography, and soils, whereas the wildlife species present are largely determined by the plant assemblages. Thus, biological communities are commonly defined in terms of their dominant plant species (e.g., oak woodland, mixed chaparral, annual grassland), and this convention is used in this analysis.

This section describes the biotic communities in the watershed, as well as its sensitive botanical, wildlife, and fisheries resources; invasive and introduced species; and ecologically and culturally important biological resources.

## 3.3.2 Sources of Data

A variety of literature provided general information on biological resources of interest in the watershed, and the published results of local and regional research applicable to resource issues are discussed. In addition, GIS data layers and spatial analysis of vegetation layers were employed to clarify local patterns.

Vegetation data layers produced by the USFS, Region 5, Remote Sensing Lab (RSL) (USDA Forest Service 2008a) were chosen as the basis for describing communities in the watershed because they provide comprehensive coverage of the watershed at a consistent scale. In addition, the scale of the imagery is larger (i.e., provides more detail) than that available from other comprehensive sources (e.g., California GAP Analysis). The RSL vegetation mapping team is responsible for producing a comprehensive vegetation database that meets regional and national vegetation mapping standards. A mapping methodology has been developed to capture forest vegetation characteristics using automated, systematic procedures that efficiently and cost-effectively map large areas with minimal bias. However, inaccuracies may occur as vegetation types are assigned based on the use of models and are not 100 percent ground-truthed.[11] The California Wildlife Habitat Relationship (CWHR) and Classification and Assessment with Landsat of Visible Ecological Groupings (CALVEG) classification systems were used to categorize the vegetation data.

To describe the diversity of wildlife species in the watershed, the CWHR database system (California Department of Fish and Game 2008b) was used in combination with information provided by local experts. The CWHR is a predictive system based on scientific information concerning wildlife species and their habitat relationships. Fish and invertebrates are not included in the CWHR system. In addition, the California Natural Diversity Database (CNDDB) was used to identify known occurrences of rare, threatened, and endangered plants and wildlife. Information on known occurrences of invasive plants on portions of the watershed managed by the STNF was provided by the USFS. Information on locally occurring plants, fish, and wildlife was also provided by various experts and persons with local knowledge.

### 3.3.3 Biotic Communities in the Watershed

As explained in Section 3.1.8, *Fire and Fuels*, vegetation patterns are shaped by the ecological forces at work in a region. Climate, topography, soil, the frequency of natural disturbance, and human management are all driving factors that affect how vegetation is distributed on the landscape.

The watershed straddles two ecological provinces, the Klamath Mountains and the Cascade Range (see Section 3.2.3, *Geology and Soils*, for details on the geology of the watershed) (USDA Forest Service 1997). In the Klamath Province, the complexity of the geology and terrain has a strong influence on the structure, composition, and productivity of vegetation (Whittaker 1960), producing exceptional floristic diversity and complexity in vegetative patterns (Whittaker 1960, Stebbins and Major 1965). The diverse patterns of climate, topography, and parent materials in the Klamath Mountains create a mosaic of vegetation patterns more complex than that found in the Sierra Nevada or Cascade Range (Sawyer and Thornburgh 1977). Indeed, the Klamath-Siskiyou ecoregion, which encompasses a large portion of the watershed, has been designated as “globally outstanding” in terms of biological distinctiveness (Ricketts et al. 1999).

The watershed is characterized by biotic communities typical of the Klamath and California Cascades provinces. The Klamath Province is dominated by Douglas-fir, Douglas-fir/mixed hardwood, mixed conifer, mixed conifer/hardwoods, and ponderosa/Jeffrey pine forests (USDA Forest Service 1999a). The California Cascades Province is dominated by mixed conifer and/or ponderosa pine associations on relatively dry sites (USDA Forest Service 1999a).

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[11] *For a complete description of the methods used by RSL, visit http://www.fs.fed.us/r5/rsl/projects/mapping/details.shtml#mud.*

The biotic communities present in the watershed are summarized in Table 3.3-1 and depicted in Figure 3.3-1. Dominant plant species and species composition in these communities vary, with dramatic changes often occurring in relation to aspect, slope, geologic substrate, or juxtaposition with other communities. By far, the dominant community in the watershed is Sierran mixed conifer, covering approximately 46 percent of the total area of the watershed. Mixed hardwood is the next most abundant community, covering approximately 12 percent of the watershed, followed by mixed chaparral, mixed hardwood-conifer, white fir, and lacustrine. The remaining communities each cover less than 3 percent of the watershed.

**Table 3.3-1. Biotic Communities Occurring in the Upper Sacramento River Watershed**

| CWHR HABITAT | ACRES | PERCENT OF TOTAL |
|---|---|---|
| Alpine dwarf-shrub (ADS) | 182 | 0.05 |
| Annual grassland (AGS) | 3,172 | 0.83 |
| Barren (BAR) | 9,004 | 2.35 |
| Bitterbrush (BBR) | 31 | <0.01 |
| Blue oak gray pine (BOP) | 2,496 | 0.65 |
| Closed-cone pine-cypress (CPC) | 1,420 | 0.37 |
| Cropland (CRP) | 13 | <0.01 |
| Deciduous orchard (DOR) | 4 | <0.01 |
| Douglas-fir (DFR) | 6,666 | 1.74 |
| Eastside pine (EPN) | 3,800 | 0.99 |
| Fresh emergent wetland (FEW) | 3 | <0.01 |
| Jeffrey pine (JPN) | 386 | 0.10 |
| Klamath mixed conifer (KMC) | 10,464 | 2.73 |
| Lacustrine (LAC) (Shasta Lake) | 15,181 | 3.96 |
| Low sage (LSG)* | 1 | <0.01 |
| Mixed chaparral (MCH) | 9,316 | 2.43 |
| Mixed hardwood-conifer (MHC) | 27,229 | 7.11 |
| Montane chaparral (MCP) | 28,785 | 7.51 |
| Montane hardwood (MHW) | 47,612 | 12.43 |
| Montane riparian (MRI) | 89 | 0.02 |
| Pasture (PAS) | 52 | 0.01 |
| Perennial grassland (PGS)* | 290 | 0.08 |
| Ponderosa pine (PPN) | 8,517 | 2.22 |
| Red fir (RFR) | 9,114 | 2.38 |
| Sagebrush (SGB) | 2 | <0.01 |
| Sierran mixed conifer (SMC) | 176,389 | 46.04 |
| Subalpine conifer (SCN) | 2,873 | 0.75 |
| Urban (URB) | 2,777 | 0.72 |
| Valley foothill riparian (VRI)* | 360 | 0.09 |
| Wet meadow (WTM) | 1,117 | 0.29 |
| White fir (WFR) | 15,694 | 4.10 |
| Total | 383,039 | |

*Although included in the GIS data layer obtained from RSL (USDA Forest Service 2008a), low sage and valley foothill riparian communities are not known to occur in the watershed. The low sage community identified in Figure 3.3-1 is likely mixed chaparral, while the valley foothill riparian community is likely montane riparian. In addition, the perennial grassland community is most likely to be composed of irrigated pastures.

For the purposes of this document, the biotic communities in the watershed have been divided into three general categories: aquatic, riparian, and terrestrial. The function and composition of each type of community is described below. A comprehensive list of wildlife species (not including fish) potentially occurring in the watershed is included as Appendix C. Both common and scientific names of these species are provided in Appendix C. To increase readability, the scientific names of wildlife species other than fish are not included below.

## Aquatic Communities

### *Introduction*

Aquatic ecosystems perform many important environmental functions. For example, they recycle nutrients, purify water, attenuate floods, recharge ground water, and provide habitats for flora and fauna. The aquatic landscape and associated habitat in the upper Sacramento River watershed are diverse and include two reservoirs, 25+ sub-alpine lakes, the south, middle, and north fork of the Sacramento River headwaters (above Box Canyon Dam), the Sacramento River mainstem (below Box Canyon Dam), many perennial tributaries to both the headwaters and river mainstem, and a complex of springs, intermittent steams, seasonal floodplains, wetlands, springs, seeps, fens, and wet meadows. These landforms serve as habitat for many aquatic species and communities. In some cases (e.g., lakes and reservoirs) aquatic communities remain fairly constant throughout the year, though sub-habitat use may vary between seasons (Dr. Sudeep Chandra, personal communication). In other aquatic habitats (e.g., wet meadows, fens, and, wetlands), aquatic communities may be strongly seasonal as well as interannually variable.

### *Geographic Context*

For the purposes of discussing aquatic communities and resources, the watershed can be divided into three geographic subregions: (1) the headwaters (encompassing all portions of the watershed that drain into Lake Siskiyou), (2) the central watershed (generally the drainage areas below Box Canyon Dam and above the Sacramento Arm of Shasta Lake), and (3) Sacramento Arm (the portion of the watershed including and draining into the Sacramento Arm of Shasta Lake). These three regions of the watershed have a number of differences in their physical and biotic characteristics that support distinguishing between them for the purposes of discussion. The utility of this distinction is further reinforced by the existence of a number of differences in land and resource use, management, and research histories.

#### Headwaters

The headwaters aquatic landscape includes the snowmelt-driven west-side streams and rivers as well as east-side tributaries fed by spring waters from Mount Shasta, all of which drain into Lake Siskiyou. In addition, this portion of the watershed includes 17 sub-alpine lakes. Lake Siskiyou has a surface area of 430 acres and sits at an elevation of 3,200 feet. The alpine lakes range from 50 acres to under an acre in size and from 5,600 to 6,480 feet in elevation. Also contributing to the diversity of the headwaters aquatic landscape are numerous wet meadows, seeps, fens, and other wetlands. In addition to these features, there are a number of constructed ponds (including some for trout propagation), pools, and diversions/ditches. Of the available aquatic habitat in the headwaters, one reservoir, 15 alpine lakes, and approximately 66 miles of streams contain fish (USDA Forest Service

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Figure 3.3-1 Vegetation Communities

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2001b). This habitat as well as the other available aquatic habitat is also home to a variety of other aquatic fauna of interest, including planktonic organisms, invertebrates (native and introduced), and amphibians.

### Central Watershed

The central watershed drains into the mainstem Sacramento River between Box Canyon Dam and the Sacramento River Arm of Shasta Lake. It includes many precipitation- and spring-fed tributaries, both perennial and intermittent, joining the Sacramento mainstem from both the west and the east. Also contributing to this portion of the watershed are eight lakes as well as several constructed ponds, ditches, and diversions. Wetland habitats, including seeps, wet meadows, and seasonal floodplains are also present in this portion of the watershed.

### Sacramento Arm (Shasta Lake)

At the southern end of the watershed, the Sacramento Arm encompasses a portion of Shasta Lake, the largest human-made reservoir in California. Shasta Lake has a surface area of approximately 30,000 acres, a storage capacity of 4,550,000 af, and a maximum depth of 517 feet (USDA Forest Service 2006).

## *Aquatic Communities*

The discussion of aquatic communities and their key species has been sequenced hierarchically, beginning at the base of the foodweb and progressing up to higher level consumers (i.e., microbes and planktonic organisms, invertebrates, amphibians and aquatic reptiles, and fish and fisheries). Of the special-status species present in the watershed (Table 3.3-3), seven are aquatic. Of these seven, three are fish species (rough sculpin (*Cottus asperrimus*), hardhead (*Mylopharodon conocephalus*), and rainbow trout (*Oncorhynchus mykiss*)), three are amphibians (Cascades frog, foothill yellow-legged frog, and tailed frog), and one is an aquatic reptile (northwestern pond turtle). In addition to these, several other species are considered species of interest for the purposes of this analysis. This inclusion is generally based on the species' unique history in the watershed, importance as game species, or relationship to a specific habitat type of interest. Additional information on special-status species occurring or potentially occurring in aquatic habitats in the watershed is provided in Section 3.3.4, *Plants, Wildlife, and Fish of Ecological/Cultural Concern*.

### Invertebrates

Aquatic macroinvertebrate species and communities, which include insects, snails, clams, crayfish, worms, and other invertebrates living in the aquatic environment, are a critical component of aquatic ecosystems and resources. These organisms maintain critical roles in aquatic foodwebs by both breaking down and repackaging carbon from aquatic and terrestrial primary producers, making it available to higher trophic levels. In addition to their roles in the transfer of energy and availability of prey, aquatic macroinvertebrates, and the composition of their communities, are often used as bio-indicators of ecosystem condition. Their environmental sensitivity, sub-habitat scale ecosystem requirements, rapid reproductive rates, and short life spans make them effective benchmarks against which to measure disturbance.

An assortment of different aquatic invertebrates characterizes the three segments of the watershed. The following summary focuses on those species and/or communities with key historic, current, or potential future implications for the ecological condition of the watershed.

**Aquatic Insects.** Aquatic insects generally feed on algae, terrestrial and aquatic organic debris, and other macroinvertebrates. They provide a critical food source for fish and amphibian species, and certain aquatic insects with a terrestrial life phase have been shown to provide an important food source for riparian and upland reptile, bird, and bat species.

Aquatic insects are often used as indicators of disturbance or degradation within a system, or quality of stream habitat. This is the case as certain taxa and community assemblages (e.g., Tricoptera (caddisflies), Ephemeroptera (mayflies), and Plecoptera (stoneflies)) are often associated with less disturbed conditions and others (e.g., Chironomidae (non-biting midges)) with more. Among the range of disturbance agents that can affect aquatic invertebrate communities are sedimentation, alteration of in-stream vegetation, altered surface and groundwater hydrology, the introduction of predatory species, and climate.

In the headwaters subregion of the watershed, information on the composition and distribution of aquatic insect communities is sparse. CDFG stream surveys, primarily from the late 1970s and early 1980s, identify Odonata (dragonflies and damselflies), caddisflies, mayflies, and Diptera (true flies) as the dominant taxa in most of the streams in this portion of the watershed, but provide little information on relative abundance or diversity of genera represented within each of these larger groupings. Some additional information on upper watershed aquatic insect presence has also been captured as a component of different isolated research projects that have occurred as components of the University of California, Davis, Castle Lake Long-Term Research program. Most recently, the dominant aquatic insect taxa at Castle Lake were determined to include all of those commonly reported in the upper watershed stream surveys (mentioned above). In 2008, the Castle Lake Long Term Research Program began a 3-year in depth study of invertebrate production and flux in Castle Lake basin. The study was designed specifically to characterize the benthic macroinvertebrate communities, as well as spatial and temporal trends in their distribution and abundance. The study is being carried out in collaboration with the USFS and results are expected to be available sometime in mid-2010. Little or no current information is available on the aquatic insect communities of other lakes in the upper watershed, though their communities are likely to resemble those at Castle Lake.

In the central watershed, the bulk of the existing information on aquatic insects was gathered in response to the Cantara spill. All members of the aquatic insect communities were essentially eliminated by the spill (Cantara Trustee Council 2007). Data from 1991 through 1993 and 1996 showed that, at that the end of that period, the composition of the aquatic insect community in the upper Sacramento River mainstem was still unstable, with significant changes continuing to occur (Department of Water Resources 1997). Specifically, opportunistic species initially dominated many of the monitored locations, especially those downstream from the spill site (Department of Water Resources 1997). However, these initial data also indicated development of comparable, though quite variable, numbers of organisms and species, and biomasses between monitoring stations upstream and downstream from the spill (Department of Water Resources 1997). By the second year of the study, the number of species in each order at monitoring stations affected by the spill appeared to be similar (Department of Water Resources 1997). Communities remained unstable, however, with rapid succession continuing (Department of Water Resources 1997). Researchers hypothesized that the continued succession observed in the communities may have resulted from their continued adjustments to the affects of the spill or reaction to other factors that influenced the composition of the aquatic macroinvertebrate communities (Department of Water Resources 1997). However, that the community composition of riffles affected by the chemical spill differed from that of the upstream control station lead researchers to believe that recolonization was not yet complete (Department of Water Resources 1997).

Subsequent surveys conducted by California Department of Water Resources in 2001 revealed higher densities of a mayfly, stonefly, caddisfly assemblage compared to midges and other flies in two out of six sample stations (Boullion 2006, Cantara Trustee Council 2007). In its final report, the Cantara Trustee Council pointed out that midges and other flies represent species groups that are more successful under conditions of poor water quality or stress while the mayfly, stonefly, caddisfly assemblage represents species groups that indicate high-quality aquatic conditions (Cantara Trustee Council 2007). Despite the Council's including this observation, seemingly as an indication of recovery, the conclusion of the 2001 DWR study could only hypothesize that recovery of these insect assemblages was complete, as continued population fluctuations could not be attributed to any specific driver (Boullion 2006).

**Mollusks.** Mollusks in the upper Sacramento River serve as primary herbivores and detrivores in benthic stream communities and are major food items for fish and other stream-dwelling or stream-related animals (Frest and Johannes 1997). The freshwater mollusk fauna of the Sacramento River and its tributaries has long been considered exceptionally diverse, but it remains only partially known. In fact, very little information on the fresh water mollusks of the watershed was available prior to the Cantara spill and the research performed to assess its impact and the system's recovery. Additionally, many of the genera present had not been well described or researched anywhere within their broad range, despite being locally abundant and easily collected in springs, streams, and rivers (Hershler et al. 2007).

In the headwaters portion of the watershed, mollusk populations remain largely undescribed. In the central portion of the watershed, initial CDFG surveys following the Cantara spill showed that mollusk densities were low at all upper Sacramento River sample locations affected by the spill compared to the control sites (Cantara Trustee Council 2007). Nevertheless, a diverse mollusk population was found to exist, including generalists snails such as *Physella* as well as cold water–specific genera such as *Fluminicola* (pebble snails) and *Vorticifex* (Frest and Johannes 1993, 1994, 1995, and 1997). Frest and Johannes (1997) provide a detailed summary of both bivalve and gastropod species' presence, distribution, and habitat affinity in the mid segment of the watershed. Of particular note in their report are accounts of 22 new taxa first described as part of the post-Cantara monitoring effort (though a few proved to be previously present in museum collections) (Frest and Johannes 1997). Many of the previously undescribed *Fluminicola* species recorded during the post-spill monitoring, and general diversity and diversification in *Fluminicola* were also more recently described by Hershler and others (2007). Their study reveals that the highly endemic pebble snails of the upper Sacramento River are a polyphyletic assemblage with four separate clades. The upper Sacramento River clade was believed to originate as a result of late Neogene separation of this basin from the neighboring northwestern Great Basin and Klamath River basin, consistent with biogeographical hypotheses based on the distributions of fishes (Hershler et al. 2007). The upper

Sacramento River pebble snails evolved in association with the complex of regional landscape and drainage diversification as well as adaptation to dynamic and often insular spring habitats (Hershler et al. 2007).

While adequate baseline data did not (and do not) exist to thoroughly compare pre- and post-spill communities, the more rapid recolonization of generalists such as *Physella* after the spill (Cantara Trustee Council 2007) suggests the possibility of altered community composition as the result of the event. A reintroduction of several species was proposed following the Cantara spill, based on monitoring of population recovery (Frest and Johannes 1994). This proposed action, however, was never performed.

**Crayfish.** Non-native signal crayfish are present throughout the upper Sacramento River watershed, although the specific distribution, status, and impact of their populations have been researched only in Castle Lake (Kats and Ferrer 2003) and in tributaries and the mainstem Sacramento River below Box Canyon Dam following the Cantara spill (Clark et al. 1991, Goldman 1992, Brett and Goldman 1993, 1994)

In the headwaters segment of the watershed, what little information is available on crayfish distribution and population status suggests that there has been both expansion and contraction of population size and range in different areas. In Castle Lake, crayfish were first recorded in 1988 (Elser et al. 1994) and were believed to have been introduced shortly before. In 1994, Elser and others estimated the population to be 10,100 individuals. By 2001, however, it appeared from sampling results that the crayfish population of the lake had been wiped out (Dr. Sudeep Chandra, personal communication). Reasons for the disappearance of crayfish from Castle Lake are unclear. However, predation by river otters, possibly in combination with decreased winter temperatures and productivity in their primary habitat, are the leading hypotheses. Ultimately, the disappearance of this non-native species from Castle Lake may have reduced disturbance in the system, as the study by Elser and others (1994) indicated the potential for crayfish to produce sizeable impacts in the lake, particularly on macrophyte populations and littoral habitat productivity and structure.

Conversely, in the south fork of the Sacramento River, crayfish are currently present and appear anecdotally to be expanding because they are widely distributed in locations where they were not in the late 1970s when the streams were last surveyed.

### Amphibians and Aquatic Reptiles

The upper Sacramento River has a high diversity of herpetofauna, which include 12 aquatic amphibian species and one aquatic reptile species. Luke and Sterner (1994) attribute this diversity to the overlapping distributions of generalist species that range broadly over the western United States. Amphibians and aquatic reptiles are integral and often abundant members of aquatic ecosystems (Burton and Likens 1975, Bury et al. 1980, Luke and Sterner 1994). Amphibians alone often constitute the highest fraction of vertebrate biomass in an ecosystem (Blaustein and Wake 1990). Additionally, both amphibians and aquatic reptiles provide important links within and across aquatic and terrestrial food webs, consuming large amounts of invertebrate prey from both habitats (Wake 1991) and sustaining numerous predators at multiple trophic levels. Declines in their populations can have widespread, negative consequences for community structure and ecosystem health. Many of these consequences, however, are just beginning to be identified and understood.

Amphibian species and communities can be effective bio-indicators of aquatic ecosystem condition (Luke and Sterner 1995), often reflecting impacts from a broad range of factors such as toxins (as from herbicides) uv-b, species introductions (Halliday and Heyer 1997), timber harvest, (Bury et al. 1991) and grazing (Burton and Likens 1975, Bury et al. 1980, Luke and Sterner 1994). This wide-ranging sensitivity to disturbance agents has also, in the context of California's highly disturbed river systems, factored into the decline of many amphibian populations across the state. Their broad susceptibility has meant almost continual pressure on many of their populations despite changing land use practices over time. In addition, a historic lack of understanding of their role in ecosystem structure and function has contributed to changes in their populations receiving little attention until recently.

While information on amphibian populations in the watershed is limited, what is available suggests a pattern of continual pressure over time, decline in several native populations, and potentially the extirpation of one species. In its *Assessment of the Sacramento River Headwaters*, the USFS concluded that historic grazing in the watershed and fish introductions both likely resulted in a decline in amphibian populations (USDA Forest Service 2001b). The assessment also suggested the possibility that the drastic reduction in grazing within the watershed may have resulted in those populations having stabilized somewhat (USDA Forest Service 2001b). Additional pressure from stocking, accumulation of pollutants in the environment, and predation by other introduced species, however, are likely working against whatever gains have been made since the conclusion of the grazing era. Kats and Ferrer (2003) indicate that species whose introductions are of particular concern for amphibian populations include predatory fish, bullfrogs, and crayfish. All of these species are present in the watershed. In addition, predatory pressure from stocked fish and crayfish may be increasing as crayfish populations expand and increased fishing drives increased stocking. Although a comprehensive study on the impacts of species introductions has not been performed in the upper Sacramento River watershed, research in the neighboring Marble Mountains, Russian, and Trinity Alps wildernesses suggests that the presence and distribution of the Pacific chorus frog and the Cascades frog (species also present in the upper Sacramento River watershed) was negatively affected by the presence of introduced trout in those regions (Welsh et al. 2006).

The most comprehensive research on amphibians in the watershed was conducted following the 1991 Cantara toxic spill. Surveys in the central portion of the watershed were conducted between 1991 and 1994 on the Sacramento River mainstem and 28 of its tributaries. Findings from the study suggest that amphibian populations were significantly affected by the spill. This was the case not only in the mainstem, but also in the tributaries, and was a function of increased predation from river otters and other predators (Luke and Sterner 1995). Additionally, it was hypothesized that impacts on tributaries would slow repopulation of the mainstem (Luke and Sterner 1995). Estimated recovery times for species of interest ranged from 10–14 years for foothill yellow-legged frogs to 27–35 years for Pacific giant salamanders (Luke and Sterner 1995). Neither the ongoing status of these and other amphibian populations nor the degree of their recovery is known.

In 2002, surveys for terrestrial amphibians were conducted at 40 locations in the region north of Shasta Lake (Nauman and Olson 2004). Three species of reptiles and nine species of amphibians were detected, including the federally listed Shasta salamander (see *Special-Status Fish and Wildlife* for a detailed discussion of this species in the watershed).

## Fish

Historically, the fish population of what is now considered the upper Sacramento River included a range of native resident fishes, several large seasonal runs of anadromous salmonids (i.e., salmon and steelhead (*Oncorhynchus* spp.)), and migratory populations of sturgeon (*Acipenser* spp.). However, anadromous fishes have not been found in the upper Sacramento River since the 1943 completion of Shasta Dam, and sturgeon are limited to a white sturgeon (*Acipenser transmontanus*) population in Shasta Lake. The current fish assemblage in the watershed is composed primarily of native, introduced, and regularly stocked resident coldwater and warmwater fishes (Appendix D).

The fish assemblage in the watershed varies by subregion. The species in the headwaters portion of the watershed consist primarily of introduced char and possibly a few remnant minnows and suckers in isolated locations. The one exception to this is Lake Siskiyou, which supports a diverse assemblage of primarily introduced warm- and coldwater fishes. The fish assemblage in the central watershed subregion is dominated by rainbow trout. A variety of native species are also present in the mainstem Sacramento River, but are largely absent from the tributaries, with the exception of the riffle sculpin. Several non-native warmwater species are present in the Sacramento River mainstem, with increasing presence in the southern end, close to Lake Shasta. However, these species are also largely absent from the tributaries.

The current composition and distribution of fish species inhabiting Lake Siskiyou and its tributaries reflect the historic fishery, the operational impacts of Shasta Dam as well as dams on several of the upstream tributaries, and the introduction of non-native fish species. The Shasta Lake fish assemblage includes native and non-native species, dominated by mostly introduced warmwater and coldwater species (Weidlein 1971 and CDFG unpublished data). The Shasta Lake tributaries have been managed to favor naturally produced (“wild”) and stocked (hatchery-cultured) native and non-native trout species (Rode 1988, Moyle 2002, Rode and Dean 2004).

The distribution and productivity of organisms and aquatic habitats of Shasta Lake are greatly affected by the reservoir’s dynamic seasonal fluctuations in surface elevation and thermal stratification. The reservoir’s flood control, water storage, and water delivery operations typically result in declining water elevations during the summer through the fall months, rising or stable elevations during the winter months, and rising elevations during the spring months and, sometimes, into the early-summer months, while storing precipitation and snow melt runoff. During summer months, the epilimnion (relatively warm surface layer) is 30 to 50 feet deep and warms up to 80 °F. Water temperatures above 68 °F favor warmwater fishes such as bass (*Micropterus* spp.) and catfish. Deeper water layers are cooler and suitable for coldwater species. Shasta Lake is classified as a cool-water, mesotrophic, monomictic reservoir because it is moderately productive (mesotrophic) and has one period of mixing each year (monomictic), although it never completely turns over (i.e., the warm and cold layers do not mix completely (Bartholow et al. 2001).

**Coldwater Species.** Shasta Lake and its tributaries provide very productive habitats for coldwater fish species, which typically prefer or require temperatures cooler than 70 °F. During the cooler months, coldwater species such as rainbow trout, brown trout (*Salmo trutta*), and landlocked Chinook (*Oncorhynchus tshawytscha*) may be found rearing throughout the lake; however, these species do not spawn in the lake, preferring to spawn in tributary streams.

Native species such as white sturgeon, hardhead (*Mylopharodon conocephalus*), riffle sculpin, Sacramento sucker (*Catostomus occidentalis*), and Sacramento pikeminnow (*Ptychocheilus grandis*) tend to reside in cooler water strata in the reservoir and in and near tributary inflows (Moyle 2002). Trout may also congregate near the mouths of the reservoir's tributaries, including the upper Sacramento River, at various times of the year for various purposes, including thermal refuge, foraging, and spawning, when conditions are favorable for these species.

Climate conditions and reservoir storage volume are the two most influential factors affecting cold-water habitat and primary productivity in Shasta Lake (Bartholow et al. 2001). Coldwater habitat provided by Shasta Lake is a function of the total storage and associated surface area. This relationship is influenced by variation in the water-surface elevation throughout the year. Variation in water-surface elevation is a function of water demand, water quality requirements, and inflow. Water-surface elevations can change based on the water-year type. Typically, primary production in reservoirs is associated with storage volumes when all other factors are held constant (Stables et al. 1990). Increased storage and the corresponding increase in surface area results in a greater total biomass and a greater abundance of plankton and fish because the available habitat area is increased.

**Warmwater Species.** The warmwater fish habitats of Shasta Lake occupy two ecological zones: the littoral (shoreline/rocky/vegetated) and the pelagic (open water). The littoral zone lies along the reservoir shoreline down to the maximum depth of light penetration on the reservoir bottom, and supports populations of spotted bass (*Micropterus punctulatus*), smallmouth bass (*Micropterus dolomieui*), largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), channel catfish (*Ictalurus punctatus*), and other warmwater species.

Warmwater species, such as largemouth bass, smallmouth bass, spotted bass, and other sunfishes, were introduced into Shasta Lake and have become well established with naturally sustaining populations. These warmwater fishes feed primarily on invertebrates while young and become predaceous on other fishes, including engaging in some cannibalism, as they grow. Spawning activity usually begins during late March or April when temperatures rise to around 60 °F.

The primary factors affecting warmwater fish abundance and production in Shasta Lake include seasonal reservoir fluctuations, availability of high-quality littoral habitat, and annual climate variations (Ratcliff 2006). Reservoir level fluctuations, the associated shoreline erosion, and suppression of shoreline and emergent vegetation are generally thought to be the most significant factors affecting warmwater fish production in reservoirs, including Shasta Lake (Moyle 2002, Radcliff 2006). Water-level variations influence physical, chemical, and biological processes, which in turn affect fish populations. Reservoir drawdowns reduce water depths and influence thermal stratification and the resulting temperature, dissolved oxygen, and water chemistry profiles.

## Riparian Communities

The term "riparian" pertains to the terrestrial moist soil zone immediately landward of aquatic wetlands, other freshwater bodies, both perennial and intermittent watercourses, and many estuaries. They are the interfaces between terrestrial and aquatic communities. The importance of riparian areas far exceeds their minor proportion of the total acreage in the watershed because of their prominent location within the landscape and the intricate linkages between terrestrial and aquatic communities (Gregory et al. 1991).

Riparian vegetation is important in determining the structure and function of stream ecosystems. Headwater streams are characteristically shaded and kept cool by overhanging riparian vegetation. Shade from this vegetation moderates stream temperatures, often preventing excessive summer temperatures that may be lethal to invertebrates and fish. Shading also affects the rate of chemical reactions and concentrations, metabolic rates of stream invertebrates, cues for life cycle events of aquatic organisms, and the activities of primary producers such as algae and aquatic plants (Knight and Bottorff 1984). Riparian vegetation also often supplies large amounts of organic detritus to the stream, forming a dependable food base for stream invertebrates and fish year after year (Knight and Bottorff 1984).

Fish are not usually considered part of riparian communities, but they interact directly with these communities in many ways, such as feeding on terrestrial insects, using overhanging vegetation as cover, or using flooded vegetation for spawning (Baltz and Moyle 1984). Also important are indirect interactions between riparian systems and fish through nutrient cycling and through the effects of riparian vegetation on flows and temperatures (Baltz and Moyle 1984).

Riparian woodlands form an important link between aquatic and terrestrial wildlife communities. Most aquatic insects are either directly or indirectly dependent on riparian vegetation at some stage in their life cycles (Erman 1984). In California, it is estimated that riparian systems provide habitat for 83 percent of the amphibians and 40 percent of the reptiles known to occur in the state (Brode and Bury 1984). Many species are permanent residents of the riparian zone, while others are transients or temporal visitors.

In addition, riparian woodlands represent some of the most important habitats for terrestrial birds and mammals due to their high floristic and structural diversity, high biomass (and therefore high food abundance), and high water availability. In addition to providing breeding, foraging, and roosting habitat for a diverse array of wildlife, the ribbon-like network of riparian habitats provide movement corridors for some species, connecting a variety of habitats throughout region. Further, trees that fall into aquatic features (e.g., streams, lakes) from riparian forests become habitat for aquatic organisms and are potentially an important link between terrestrial and aquatic ecosystems.

Riparian communities in the watershed are described in more detail below.

### *Montane Riparian*

Montane riparian communities include overstory plant species such as black cottonwood (*Populus trichocarpa*), white alder (*Alnus rhombifolia*), mountain alder (*Alnus incana*), willow (*Salix* spp.), big-leaf maple (*Acer macrophyllum*), Oregon ash (*Fraxinus latifolia*), vine maple (*Acer circinatum*), mock orange (*Philadelphus coronarius*), black-fruited dogwood (*Cornus sessilus*), and mountain dogwood (*Cornus nuttallii*). Understory species include spicebush (*Lindera benzoin*), Douglas' spirea (*Spiraea douglasii*), western azalea (*Rhododendron occidentale*), Indian rhubarb (*Darmera peltata*), sedges (*Carex* spp.), horsetail (*Equisetum* spp.), gooseberry (*Ribes* spp.), California blackberry (*Rubus ursinus*), and Himalayan blackberry (*Rubus discolor*).

Common species nesting and foraging primarily in the riparian tree canopy include the chestnut-backed chickadee, bushtit, and downy woodpeckers. Other resident species, such as the spotted towhee and song sparrow, nest and forage on or very close to the ground, usually in dense vegetation.

A variety of mammals also occur in riparian communities, including the deer mouse, raccoon, ringtail, and Virginia opossum.

Coarse woody debris (snags, fallen logs, windblown trees, and large branches) is an important component of montane riparian communities, as well as many other terrestrial communities. It is an essential habitat component for many birds and mammals, supplying cover, feeding habitat, and/or reproduction habitat. Perhaps the best-recognized use of snags (dead trees that are still standing) is for shelter by cavity-dwelling species. Primary cavity species, such as the northern flicker, acorn woodpecker, and hairy woodpecker, create cavities in snags. Secondary cavity species, such as spotted owls, red breasted nuthatches, oak titmice, tree swallows, and ringtails, use and/or enlarge preexisting cavities. In addition to cavities, protected sites associated with loose bark are important for bat roosting.

Coarse woody debris is also an important substrate for a number of vascular and non-vascular plants, including a variety of algae, mosses, ferns, gymnosperms, and angiosperms (Harmon et al. 1986). Some species are superficially attached to the surface of the woody debris (epiphytes), and some vascular plants may send their roots into rotting wood and bark to extract water and nutrients. Still other vascular plants root in the mat of decaying fine litter that often accumulates on the surface of woody debris.

The leaf litter, fallen tree branches, and logs associated with the riparian communities in the watershed provide cover for amphibians such as the western toad, Pacific chorus frog, Pacific giant salamander, and rough skin newt. A variety of reptiles are also expected to occur here, including the western fence lizard, western skink, and northern alligator lizard.

## Terrestrial Communities

Many processes in terrestrial communities, such as erosion, nutrient cycling, input of organic material, evaporative water loss, and movement of wildlife, result in direct interactions with neighboring aquatic and riparian communities. In addition, the conditions of the upslope vegetation and soil can critically affect the capability of a watershed to retain moisture and modulate surface and subsurface runoff into streams (Shilling et al. 2005).

The vegetation and wildlife species typical of the terrestrial communities in the watershed are described in more detail below. Detailed information about the special-status species potentially occurring in these communities is provided in Section 3.3.4, *Plants, Wildlife, and Fish of Ecological/Cultural Concern*.

### Sierran Mixed Conifer

Sierran mixed conifer is the most common community in the watershed, occupying 46 percent of the watershed’s 383,039 acres. The overstory is composed of moderate to dense stands dominated by a mix of Douglas-fir, ponderosa pine, sugar pine, incense cedar, and white fir, and occasionally knobcone pine. Hardwood trees are also present and may include canyon live oak (*Quercus chrysolepis*), California black oak, mountain dogwood, and big-leaf maple. The understory includes shrubs such as bush tanoak (*Lithocarpus densiflorus*), huckleberry oak, deer brush (*Ceanothus* *integerrimus*), snowdrop bush (*Styrax officinalis*), poison oak (*Toxicodendron diversilobum*), gooseberry, greenleaf manzanita, whiteleaf manzanita, and mock orange.

The multi-layered vegetation in the Sierran mixed conifer community supports a variety of wildlife, including several federally and/or state-listed species.  A significant feature of the community is the presence of cavity-bearing trees.  Mature fire-damaged and wind-damaged forests typically contain snags, which are a valuable resource for birds and mammals such as the flammulated owl, northern pygmy owl, northern spotted owl (federally listed as threatened), and Pacific fisher (federal candidate for listing) that prefer cavities for nest and den sites.  Snags also support wood-boring insects that provide food for bark-gleaning insectivorous birds such as the brown creeper.  Other birds foraging and/or breeding in this habitat include the American peregrine falcon, bald eagle (state listed as endangered), sharp-shinned hawk, mountain quail, western wood-pewee, and western tanager.  Mammals found in this habitat include the long-eared myotis, western red bat, northern flying squirrel, long-tailed weasel, brush rabbit, western red-backed vole, and bobcat.  Reptiles and amphibians found in this community include the Pacific chorus frog, Pacific giant salamander, rubber boa, and western skink.

### Montane Hardwood

The montane hardwood community is the second-most common community in the watershed, accounting for approximately 12 percent of the total land cover.  This community is dominated by hardwoods and typically occurs on hotter, steep, rocky exposures; although black oak may occur on cooler slopes.  The montane hardwood community is dominated by canyon live oak and California black oak, with some stands composed almost entirely of only one of these species.  Shrubs that may occur include Brewer’s oak (*Quercus garryana* var. *breweri*), snowdrop bush, poison oak, whiteleaf manzanita, common manzanita (*Arctostaphylos manzanita*), western redbud (*Cercis occidentalis*), skunkbush (*Rhus trilobata*), deer brush, buckbrush (*Ceanothus cuneatus*), mock orange, and California buckeye (*Aesculus california*).

Mast crops (i.e., nuts) provided by montane hardwood forests are an important resource for many species, including the acorn woodpecker, Steller’s jay, mountain quail, western gray squirrel, and mule deer.  In addition, cavities in mature trees provide nesting and denning habitat for species such as the northern flicker, western screech owl, American kestrel, and Virginia opossum.  In mesic areas, many amphibians are found in the detrital layer, including ensatina and western skinks.

### Alpine Dwarf-Shrub

The alpine dwarf-shrub community occurs above the tree line in the extreme northeastern portion of the watershed.  Thus, this community is subject to intense solar radiation and freezing nights year-round.  As a result, the perennial herbs and shrubs composing this community are usually less than 18 inches tall.  In the watershed, this community is composed of open to moderate stands of shrubs and other species such as buckwheat (*Erigonum* spp.), knotweed (*Polygonum* sp.), arnica (*Arnica* spp.), and lupine (*Lupinus* spp.).

Wildlife that may occur in this habitat include the mountain bluebird, white-crowned sparrow, American pika, bushy-tailed woodrat, montane vole, and common porcupine.

### Annual Grassland

Annual grasslands are scattered throughout the watershed, but occur mostly in the area northwest of Mt. Shasta. These communities are composed of various annual grasses and forbs and are productive wildlife habitat. Grassland bird species such as the mourning dove, savannah sparrow, and house finch as well as rodents such as the California ground squirrel, Botta's pocket gopher, and deer mouse may forage on the seed crop this community provides. These species in turn attract predators such as the American kestrel, red-tailed hawk, and coyote. Reptile species expected to occur here include the western fence lizard, western skink, western rattlesnake, gopher snake, and racer.

### Barren

Barren land consists primarily of rock and bare soil. Vegetation is usually not present, although sparse opportunistic grasses/forbs or weedy species may occur. This habitat provides few resources for wildlife species; however, some species associated with adjacent habitats likely forage on the bare soil to some extent.

### Bitterbrush

Bitterbrush communities occur along the northern boundary of the watershed and are composed of moderate to dense chaparral stands dominated by antelope bitterbrush (*Purshia tridentata*). Associated species include rabbitbrush (*Chrysothamnus* spp.), greenleaf manzanita, big sagebrush (*Artemisia tridentata*), and bitter cherry (*Prunus emarginata*).

Bitterbrush is highly digestible and is an especially important winter food source for black-tailed deer (California Department of Fish and Game 2008c). The seeds are also eaten by many species of birds, rodents, and insects. Wildlife species typically found in this habitat include the western fence lizard, Brewer's blackbird, black-tailed jackrabbit, and American badger.

### Blue Oak Gray Pine

Although classified as blue oak foothill pine in Figure 3.2-1, within the watershed, this community does not include any blue oak (*Quercus douglasii*); rather, it is composed of gray pine and canyon live oak. Shrubs that may be present include buckbrush, poison oak, whiteleaf manzanita, and snowdrop bush. Various grasses and forbs are also present.

The blue oak–gray pine plant community provides breeding habitat for a large variety of wildlife species, although no species is completely dependent on it for breeding, feeding, or cover. Acorns and gray pine seeds are an important resource for many of the species using this habitat, such as the acorn woodpecker, western scrub-jay, western gray squirrel, and deer. Snags and trees containing cavities provide nesting habitat for birds such as the western bluebird, tree swallow, and northern flicker as well as potential roost sites for bats. Raptors, including the red-tailed hawk, American kestrel, and great horned owl, may also nest in these woodlands. The newly emerged leaves of oaks in the spring support an abundance of insects that attract migrating and nesting warblers, vireos, flycatchers, and other insectivorous birds. In addition, the shrubs provide habitat for birds such as spotted towhees, California towhees, wrentits, and blue-gray gnatcatchers. Characteristic reptiles and amphibians include western toads, a wide variety of snakes (common garter snakes, California whipsnakes, gopher snakes, and western rattlesnakes among others), western skinks, northern alligator lizards, and western fence lizards. Coyotes and gray foxes may forage here.

Closed-Cone Pine-Cypress

Closed-cone pine-cypress communities are dominated by dense stands of knobcone pine. Associated overstory species may include ponderosa pine, gray pine, and canyon live oak. Shrub species commonly found in this community include whiteleaf manzanita, poison oak, Brewer’s oak, buckbrush, deer brush, western redbud, and snowdrop bush.

Numerous game species and nongame species make use of this type of habitat for feeding and cover. Steller’s and western scrub jays and downy woodpeckers as well as western gray squirrels extract seeds from partially opened cones. The great horned owl and red-tailed hawk are among the few species known to use this habitat for breeding.

Cropland

Cropland is extremely rare in the watershed, comprising only 13 acres. It occurs at one location in the northeastern portion of the watershed. Cropland provides wildlife habitat similar in many respects to that found in annual and perennial grasslands.

Deciduous Orchard

Orchards, which are very rare in the watershed, provide limited habitat for wildlife species. The absence of an herbaceous understory deprives many species of food and cover, and on-going maintenance operations may discourage many species. Some species that are tolerant of human encroachment, however, can be quite abundant in such habitats, including northern flickers, western scrub-jays, American crows, and American robins.

Douglas-Fir

Douglas-fir communities typically occur in moderate to dense stands on northern or eastern exposures at lower elevations, but are more variable at higher elevations. The overstory is dominated by Douglas-fir but may also include ponderosa pine, sugar pine, incense cedar, and knobcone pine as well as hardwoods such as canyon live oak, California black oak, mountain dogwood, and big-leaf maple. Shrub species occurring in this community include deer brush, snowdrop bush, poison oak, gooseberry, whiteleaf manzanita, and mock orange.

Mature and old-growth Douglas-fir communities support a high abundance of wildlife species. Wildlife living in the dense canopy are sheltered from enemies and high wind, abundant snags provide ample habitat for cavity nesters, and the lush understory of herbs, shrubs, and small trees that occur where sunlight breaks through the canopy provides protection as well as a food sources for a variety of birds and mammals (Benyus 1989). Wildlife typical of this habitat include the spotted owl, Pacific-slope flycatcher, chestnut-backed chickadee, golden crowned kinglet, Pacific giant salamander, black salamander, western tailed frog, Pacific fisher, western pocket gopher, Douglas’ squirrel, and shrew-mole.

### Eastside Pine

In California, eastside pine communities occur from about 4,000–6,500 feet in elevation, approximately east of a line drawn from Lake Tahoe to Hilt, a small town on Interstate 5 where it crosses the California-Oregon border (California Department of Fish and Game 2008c). The watershed is situated along the approximate western limits of this community's range. Within the watershed, the eastside pine community occurs only on the lower west slopes of Mt. Shasta, and is composed of ponderosa and Jeffrey pine–dominated stands that may include occasional incense cedar and Douglas-fir trees. The understory includes big sagebrush and rabbitbrush shrubs.

Eastside pine stands often form important migratory and winter range for deer, while higher elevation stands with grassy understories near water may be important fawning areas. Large pine branches also form good nesting substrates for large raptors, such as the red-tailed hawk, northern goshawk, and golden eagle, which prey on the small mammals found in this habitat, including the deer mouse, pinyon mouse, and Douglas' squirrel. Other species likely to occur include the sooty grouse, northern flicker, long-eared owl, northern saw-whet owl, and common porcupine, whose winter diet includes the twigs, bark, and cambium of conifers.

### Jeffrey Pine

The Jeffrey pine community is dominated by stands of Jeffrey pine, but may also include ponderosa pine and, occasionally, incense cedar and Douglas-fir trees. This community type is scattered throughout the north-central portion of the watershed. The value of the Jeffrey pine forest as habitat for wildlife is due in large part to the food value of Jeffrey pine seeds, which are included in the diet of numerous wildlife species. The bark and foliage also serve as important food sources for deer, squirrels, and rodents, while the insects that infest the pines provide a food source for woodpeckers and other insect eaters. Other species using this habitat include nuthatches, brown creepers, Sooty grouse, great horned owls, and northern flying squirrels.

### Klamath Mixed Conifer

Klamath mixed conifer communities have an overstory dominated by a mix of moderate to dense stands of Douglas-fir, ponderosa pine, sugar pine, incense cedar, white fir, and occasional knobcone pine as well as hardwoods such as canyon live oak, California black oak, and big-leaf maple. The shrub layer may include bush tanoak, huckleberry oak, deer brush, snowdrop bush, poison oak, gooseberry, whiteleaf manzanita, and mock orange.

The Klamath mixed conifer community provides a wide array of nesting and feeding opportunities and thermal cover for wildlife because of its diverse vegetation and soils. Species commonly found in this habitat include the mountain quail, hairy woodpecker, sharp-shinned hawk, western gray squirrel, and gray fox. The leaf litter also provides habitat for reptiles and amphibians, such as the California mountain kingsnake and ensatina.

### Mixed Chaparral

Mixed chaparral is found on a variety of slopes and aspects. Many of the plants found in this community are highly adapted to periodic natural fires. Adaptations include the ability to produce seeds at an early age; the production of seeds that require scarification, or the heat of a fire, in order to germinate; and the ability to sprout from underground woody plant structures after a fire. The mixed chaparral community is composed of open to dense mixed stands of chaparral species such as Brewer's oak, snowdrop bush, poison oak, whiteleaf manzanita, common manzanita, western redbud, silktassel (*Garrya* spp.), skunkbush, deer brush, buckbrush, interior live oak (*Quercus wislizenii*), bush poppy (*Dendromecon rigida*), California buckeye, California ash (*Fraxinus dipetala*), and yerba santa (*Eriodictyon glutinosum*). Lianas (woody vines) that may occur in this community include greenbriar (*Smilax rotundifolia*), chaparral honeysuckle (*Lonicera interrupta*), and virgin's bower (*Clematis virginiana*).

Mixed chaparral provides habitat for a wide variety of wildlife species. It provides seeds, fruit, and protection from predators and harsh weather. In addition, it provides singing, roosting, and nesting sites for many species of birds, including the California quail, wrentit, and Bewick's wren. Other animals common in this habitat include the black-tailed jackrabbit, gray fox, coyote, deer mouse, western fence lizard, and northern alligator lizard.

### Montane Chaparral

Montane chaparral communities are composed of open to dense stands of chaparral, and are found on variable slopes and aspects, depending on location. This community is found at a higher elevation and watershed position than the mixed chaparral community. Like mixed chaparral, most plant species occurring in montane chaparral communities are adapted to periodic natural fires. Species found in this community include whiteleaf manzanita, greenleaf manzanita, western redbud, silktassel, deer brush, bush tanoak, huckleberry oak, bitter cherry, western choke-cherry (*Prunus virginiana* var. *demissa*), mountain whitethorn (*Ceanothus cordulatus*), tobacco brush (*Ceanothus velutinus*), bush chinquapin (*Chrysolepis sempervirens*), rabbitbrush, antelope bitterbrush, gooseberry, and big sagebrush.

The wildlife values of montane chaparral are similar to those described above for mixed chaparral.

### Mixed Hardwood-Conifer

Mixed hardwood-conifer communities often form transitional areas between dense coniferous forests and montane hardwood, mixed chaparral, or open woodlands. They are composed of open to dense stands dominated by a mix of conifers and hardwoods. Conifers that may be present include Douglas-fir, ponderosa pine, sugar pine, incense cedar, gray pine, and knobcone pine, and hardwoods include canyon live oak, California black oak, and big-leaf maple. Shrubs that may occur include deer brush, buckbrush, brewer oak, snowdrop bush, poison oak, gooseberry, whiteleaf manzanita, mock orange, western redbud, and bush tanoak.

The variability of the canopy cover and understory vegetation make mixed hardwood-conifer communities suitable for numerous species of wildlife. Hollow trees and logs provide denning sites for mammals such as the coyote, black bear, and striped skunk, while cavities in mature trees are used by cavity-dwelling species such as the acorn woodpecker, violet-green swallow, northern flicker, great horned owl, raccoon, and pallid bat. In addition, raptors, such as the red-tailed hawk, construct nests in the upper canopy of mature trees. Moreover, mast crops are an important food source for many birds as well as mammals, including the western scrub and Steller's jay, acorn woodpecker, California quail, black-tailed deer, and western gray squirrel. In moist areas, many reptiles are found in the detrital layer, including ensatina and western fence lizards. Snakes, including the western rattlesnake and sharp-tail snake, also occur in this community.

### Pasture

Pasture is rare in the watershed (52 acres) and consists of lands used for grazing livestock or horses. Many of the same species found in annual grassland habitat are also found in this community.

### Ponderosa Pine

The ponderosa pine community is composed of open to dense stands of ponderosa pine. Associates include knobcone pine, Douglas-fir, gray pine, canyon live oak, and California black oak. Shrubs include whiteleaf manzanita, poison oak, Brewer's oak, buckbrush, deer brush, western redbud, and snowdrop bush.

Ponderosa pine needles, cones, buds, pollen, twigs, seeds, and associated fungi and insects provide food for many species of birds and mammals, including the pygmy nuthatch, white-headed woodpecker, western gray squirrel, black-tailed deer, and black bear. Mature trees provide nesting habitat for raptors such as the bald eagle, osprey, sharp-shinned hawk, and red-tailed hawk, while snags and hollow logs provide shelter for species such as the flammulated owl, Virginia opossum, and western spotted skunk.

### Red Fir

Red fir communities are composed of moderate to dense conifer stands dominated by red fir. Associated species include white fir and, occasionally, mountain hemlock and western white pine. Shrubs that may be present include huckleberry oak and mountain spirea.

Mature red fir forests provide important habitat for many animals. American martens use large snags, stumps, and logs for den sites, and red fir cones are cut and cached by a variety of squirrels. Other species typically found here include the pileated woodpecker, mountain quail, northern goshawk, black bear, and black-tailed deer.

### Sagebrush

Sagebrush communities include moderate to dense chaparral stands dominated by big sagebrush. Other associated species include rabbitbrush, greenleaf manzanita, and antelope bitterbrush. This community is very rare in the watershed, occupying only 2 acres.

### Subalpine Conifer

Subalpine conifer communities occur at high elevations and are the last community before the tree line. Conifers present include western white pine, mountain hemlock, foxtail pine (*Pinus balfouriana*), and whitebark pine (*Pinus albicaulis*).

Coniferous forests at high elevations in California typically support fewer species of wildlife than other major forest types in the state (California Department of Fish and Game 2008c). However, these aged forests often have a profusion of snags and downed logs that provide shelter for cavity dwellers such as the pileated woodpecker, mountain chickadee, and northern flying squirrel. Other wildlife species occurring in subalpine communities include the mountain quail, Clark's nutcracker, golden-mantled ground squirrel, western red-backed vole, American marten, black-tailed deer, and black-tailed jackrabbit.

### Urban

Urban habitat includes roadways, residential areas, and commercial areas. Urban areas are largely denuded of native vegetation and what vegetation does exist is predominantly non-native or ornamental. The wildlife species most often associated with urban areas are those that are most tolerant of periodic human disturbances, including several introduced species such as European starlings, rock doves, and house mice. Native species that are able to use these habitats include western fence lizards, American robins, Brewer's blackbirds, northern mockingbirds, mourning doves, house finches, black-tailed jackrabbits, and striped skunks. In addition, bats that forage in nearby habitats may make use of small cavities around the eaves of structures.

### White Fir

White fir communities are composed of moderate to dense conifer stands dominated by white fir. Associated species include Douglas-fir, ponderosa pine, Jeffrey pine, incense cedar, sugar pine, and, occasionally, red fir. Shrubs that may be present include huckleberry oak, bush tanoak, deer brush, mountain whitethorn, and gooseberry.

White fir is probably the coolest, moistest non-riparian habitat in the lower to mid-elevation forests in the watershed (California Department of Fish and Game 2008c). White fir trees are used as foraging habitat by a number of insect-gleaning birds, such as yellow-rumped warblers, western tanagers, mountain chickadees, chestnut-backed chickadees, golden-crowned kinglets, and black-headed grosbeaks (Airola and Barrett 1985). In addition, white fir seeds are eaten by squirrels, the bark is eaten by porcupines, and, during the winter, black-tailed deer feed on the buds and leaves.

### Wet Meadow

Wet meadow communities occur in scattered locations along the western and northwestern portions of the watershed. Species commonly found in this community include hair grass (*Deschampsia cespitosa*), sedges (*Carex* spp.), sneezeweed (*Helenium autumnale*), western azalea, cluster rose (*Rosa pisocarpa*), and mountain spirea.

Wet meadows are generally too wet to provide suitable habitat for small mammals; however, deer may feed in this community. Waterfowl, such as the mallard, frequent streams flowing through these communities, and yellow-headed blackbirds and red-winged blackbirds nest in wet meadows with tall vegetation. Amphibians and reptiles are common in wet meadows, including the Pacific chorus frog, bullfrog, Cascades frog, striped racer, and western terrestrial garter snake.

## Unique Ecological Communities

### *Serpentine*

Serpentine soils can occur in a number of the biotic communities discussed above. They have a high proportion of endemic plants (i.e., plants that are restricted to serpentine). This is because of the harsh nature of serpentine soils, which stems from its strange chemical and physical characteristics. Serpentine soils have high concentrations of heavy metals and magnesium, low calcium concentrations, and low concentrations of essential plant nutrients. In addition, because serpentine soils are dark in color, they absorb tremendous amounts of solar energy, which results in parched soils. Thus, most communities occurring on serpentine soil consist of only a few small populations of dwarfs and xerophytes (plants designed to conserve water). In addition, some species have adapted so well to these harsh conditions that they grow exclusively on serpentine soil (endemic). Over 200 species and varieties of plants are endemic to serpentine soils in California (Schoenherr 1991). Serpentine endemism is not restricted to plants, but no one knows how many insect species are restricted to these areas.

A number of plants that are known to occur, or potentially occur, in the watershed are generally found on serpentine soils, including special-status species (see below for a discussion of special-status species), such as serpentine Beegum onion (*Allium hoffmanii*), goldenbush (*Ericameria ophitidis*), Trinity buckwheat (*Eriogonum alpinum*), peanut sandwort (*Minuartia rosei*), and Red Mountain catchfly (*Silene campanulata* ssp. *campanulata*).

### *Port-Orford-Cedar*

Port-Orford-cedar is the largest member of the cypress family (Cupressaceae), and the fine wood of this tree has long been recognized for its characteristic beauty. Port-Orford-cedar has been an extremely valuable commercial species, both for its use in landscaping and as a finished wood product. Individual mature Port-Orford-cedar trees can bring up to $50,000 on the open market (USDA Forest Service 2008d). The Japanese highly prize the wood for use in their homes, and it is important for traditional uses, such as ceremonial houses and sweat lodges, to Native Americans who inhabit its range.

This valuable tree, however, has a very limited range, occurring naturally (the species has been widely cultivated as an ornamental) only in northwestern California and southwestern Oregon. The species range is primarily along the coast. However, a major inland disjunction includes small populations along the upper Trinity and Sacramento River drainages southwest of Mount Shasta (Zobel 1990) and includes populations in the watershed (Figure 3.1-3). It is often described as a serpentine endemic, but it is also found on other soil types (Schoenherr 1991). With the exception of the northern part of its range, Port-Orford-cedar usually grows primarily along streams and in areas with year-round seepage (Hansen et al. 2000).

As discussed in Section 3.1.4, *Timber Resources Use*, management of Port-Orford-cedar has become difficult in much of its range because of the introduction of *Phytophthora lateralis*, a fatal root rot.

## Protected Areas in the Watershed

The federal and state governments have established protections for biological resources within various portions of the watershed. The Cantara/Ney Springs Wildlife Area (operated by the CDFG) was established primarily to provide habitat for wildlife species. This wildlife area is located in Siskiyou County 3 miles south of the City of Mt. Shasta on the Sacramento River. It is composed of 93 acres of mixed conifer, hardwoods, and riparian vegetation occupying two areas along the upper Sacramento River.

The STNF occupies approximately 52 percent of the lands in the watershed, and as discussed in Section 2.3.3, *Timber Management*, the USFS must provide for a diversity of plant and animal communities as part of their multiple use mandate. The USFS must maintain "viable populations of existing native and desired non-native species in the planning area" (36 CFR 219.19). In addition, the STNF LRMP contains goals, standards, and guidelines designed to guide the management of the STNF. Goals pertinent to biological resources include (1) integrate multiple resource management on a landscape level to provide and maintain diversity and quality of habitats that support viable populations of plants, fish, and wildlife; (2) monitor and protect habitat for federally listed threatened and endangered and candidate species; (3) assist in recovery efforts for threatened and endangered species; (4) cooperate with the state to meet objectives for state-listed species; (5) manage habitat for sensitive plants and animals in a manner that will prevent any species from becoming a candidate for threatened or endangered status; (6) meet habitat or population objectives established for management indicators; (7) cooperate with federal, state, and local agencies to maintain or improve wildlife habitat; and (8) maintain natural wildlife species diversity by continuing to provide special habitat elements within forest ecosystems (USDA Forest Service 1995).

As discussed in Section 3.1.4, *Timber Resources Use*, all, or part, of three LSRs (Eddy, Deer, and Wagon) and one MLSA (Castle Lake) are located in the watershed. The management objective within the LSRs is to protect and enhance conditions of late-successional forest ecosystems, which serve as habitat for late-successional and old-growth related species, including the northern spotted owl (USDA Forest Service 1995, 1999). Similarly, MLSAs are intended to maintain and enhance late-successional forest ecosystems; but MLSAs are not only areas of potential habitat, they have also been identified as owl activity centers (USDA Forest Service 1995). The STNF also has a system of Riparian Reserves to protect and enhance riparian dependent resources. The Riparian Reserve System is designed much like the Late Successional Reserve System.

Castle Crags State Park is located 6 miles south of Dunsmuir on I-5. The 4,350-acre park is managed by the California Department of Parks and Recreation. A primary purpose of this department is to preserve the state's extraordinary biological diversity by restoring, maintaining, and protecting native species and natural communities.

The U.S. Fish and Wildlife Service (USFWS) has designated critical habitat for the northern spotted owl (federally listed as threatened) within the watershed boundary (Figure 3.2-2). Critical habitat is a term used in the federal Endangered Species Act (FESA) to refer to specific geographic areas that are essential for the conservation of a threatened or endangered species and that may require special management considerations. The purpose of designating critical habitat is to require federal agencies to consider the effects of actions they carry out, fund, or authorize on habitat that is essential to the conservation of a listed species. The designation of critical habitat on private land has no impact on private landowner activities that do not require federal funding or permits. The designation of critical habitat is only applicable to federal activities.

## 3.3.4 Plants, Wildlife, and Fish of Ecological/Cultural Concern

### Special-Status Plants

Rare plants are either limited in geographic distribution or they occur in small isolated populations. The reasons for rarity can be natural or anthropogenic; however, only infrequently does a single “cause” by itself truly explain why a species is rare (California Native Plant Society 2001).

California’s unique and varied climatic conditions, diverse geological formations, and striking topography contribute to a wealth of variation in present-day local growing conditions. Add to this the state’s long geological past, and what has resulted is a high degree of endemism (species that grow only in California and nowhere else) (Nakamura and Nelson 2001). However, many rare and endangered species in California that began as natural rarities have, through one form or another of human-induced detrimental changes in their populations and/or habitat, become anthropogenic rarities (California Native Plant Society 2001).

For the purpose of this analysis, special-status plants are those that are

- listed or proposed for listing as threatened or endangered under FESA;
- listed or proposed for listing by the State of California as threatened or endangered under the California Endangered Species Act (CESA), or listed as rare under the California Native Plant Protection Act; or
- considered by the California Native Plant Society (CNPS) to be “rare, threatened, or endangered in California” (Lists 1B and 2).

The distribution and abundance of rare plants in the watershed is governed by a combination of availability of suitable habitat; connectivity of habitat for dispersal and colonization; and losses of local populations from human impacts, climatic fluctuations, and other environmental events such as floods, fires, and diseases.

Because of the size of the watershed, the following assessment of potentially occurring special-status plants is limited to a search of the CNDDB (California Department of Fish and Game 2008b) within the watershed boundary and information provided by local experts. The CNDDB is a database consisting of historical observations of special-status plant species, wildlife species, and natural communities. It is limited to reported sightings and is not a comprehensive list of special-status species that may occur in a particular area. Therefore, additional special-status plants may occur in the watershed. A list of USFS Sensitive and endemic plants potentially occurring on the STNF is provided as Appendix E.

The CNDDB search yielded 42 special-status plants known to occur in the watershed (Figure 3.2-3). These plants are listed in Table 3.3-2. Information on the habitat requirements of these species was obtained from the CNPS online Inventory of Rare and Endangered Plants (California Native Plant

Society 2008), which features information on the habitats and statewide distribution of special-status plants in California.

**Table 3.3-2. Special-Status Plants Known to Occur in the Upper Sacramento River Watershed**

| SCIENTIFIC NAME COMMON NAME | STATUS* | HABITAT | COMMENTS |
|---|---|---|---|
| *Arctostaphylos klamathensis*<br>Klamath manzanita | 1B.2 | Chaparral, lower montane coniferous forest, subalpine coniferous forest, and upper montane coniferous forest/rocky serpentinite or gabbro. | Recorded at several locations in the west-central portion of the watershed |
| *Asarum marmoratum*<br>Marbled wild-ginger | 2.3 | Lower montane coniferous forest. | Recorded at two locations (one historical (1894) and one recent (1993)) along the I-5 corridor in the watershed. |
| *Balsamorhiza lanata*<br>Woolly balsamroot | 1B.2 | Cismontane woodland/rocky, volcanic. | Recorded at one location in the northern-western portion of the watershed. |
| *Botrychium virginianum*<br>Rattlesnake fern | 2.2 | Bogs and fens; lower montane coniferous forest; meadows and seeps; and riparian forest/streams. | Recorded at one location in the north-central portion of the watershed. |
| *Calochortus greenei*<br>Greene's mariposa-lily | 1B.2 | Cismontane woodland; meadows and seeps; pinyon and juniper woodland; and upper montane coniferous forest/volcanic. | Recorded at one location in the north-central portion of the watershed. |
| *Campanula shelteri*<br>Castle Crags harebell | 1B.3 | Lower montane coniferous forest. | Recorded in several locations in the watershed in the vicinity of Castle Crags State Park. |
| *Campanula wilkinsiana*<br>Wilkin's harebell | 1B.2 | Meadows and seeps; subalpine coniferous forest; and upper montane coniferous forest. | Recorded in the northeastern most portion of the watershed near the base of Mt. Shasta. |
| *Carex limosa*<br>Mud sedge | 2.2 | Bogs and fens; lower montane coniferous forest; meadows and seeps; and upper montane coniferous forest. | Recorded at one location along the west-central watershed boundary. |
| *Castilleja miniata* spp. *elata*<br>Siskiyou paintbrush | 2.2 | Bogs and fens and lower montane coniferous forest/often serpentinite. | Recorded at one location in the watershed near the base of Mt. Shasta. |
| *Chaenactis douglasii* var. *alpine*<br>Alpine dusty maidens | 2.3 | Alpine boulder and rock field. | Recorded at one location in the watershed near the base of Mt. Shasta. |

### Table 3.3-2. Special-Status Plants Known to Occur in the Upper Sacramento River Watershed

| SCIENTIFIC NAME COMMON NAME | STATUS* | HABITAT | COMMENTS |
|---|---|---|---|
| *Chaenactis suffrutescens*<br>Shasta chaenactis | 1B.3 | Lower montane coniferous forest and upper montane coniferous forest/sandy, serpentinite. | Recorded at three locations in the north-central portion of the watershed. However, all three records are from the early 1900s. |
| *Clarkia borealis* ssp. *borealis*<br>Northern clarkia | 1B.3 | Chaparral; cismontane woodland; and lower montane coniferous forest. | Recorded at several locations in the southern portion of the watershed, around Shasta Lake and along the I-5 corridor. |
| *Cordylanthus tenuis* ssp. *pallescens*<br>Pallid bird's-beak | 1B.2 | Lower montane coniferous forest (gravelly, volcanic alluvium). | Recorded at several locations in the north-central portion of the watershed. |
| Draba *aureola*<br>Golden alpine draba | 1B.3 | Alpine boulder and rock field; subalpine. | Recorded at one location along the northwestern watershed boundary. |
| *Draba carnosula*<br>Mt. Eddy draba | 1B.3 | Subalpine coniferous forest and upper montane coniferous forest/serpentinite, rocky. | Recorded at two locations along the northwestern watershed boundary. |
| *Epilobium oreganum*<br>Oregon fireweed | 1B.2 | Bogs and fens/lower montane coniferous forest and upper montane coniferous forest/mesic. | Recorded at two locations along the northern watershed boundary. |
| *Epilobium siskiyouense*<br>Siskiyou fireweed | 1B.3 | Alpine boulder and rock field; subalpine coniferous forest; and upper montane coniferous forest/rocky serpentinite. | Recorded at several locations along the northwestern watershed boundary. |
| *Eriogonum alpinum*<br>Trinity buckwheat | 1B.2 | Alpine boulder and rock field; subalpine coniferous forest; and upper montane coniferous forest/serpentinite, rocky. | Recorded at several locations along the western watershed boundary. |
| *Eriogonum pyrolifolium* var*. pyrolifolium*<br>Pyrola-leaved buckwheat | 2.3 | Alpine boulder and rock field (sandy or gravelly, pumice). | Recorded at three locations in the northeastern-most portion of the watershed. |
| *Erythronium klamathense*<br>Klamath fawn lily | 2.2 | Meadows and seeps; upper montane coniferous forest. | Recorded at one location in the central portion of the watershed. |
| *Eurybia merita*<br>Subalpine aster | 2.3 | Upper montane coniferous forest. | One historical record (1882) along the northern watershed boundary. |

## Table 3.3-2. Special-Status Plants Known to Occur in the Upper Sacramento River Watershed

| SCIENTIFIC NAME COMMON NAME | STATUS* | HABITAT | COMMENTS |
|---|---|---|---|
| *Galium serpenticum* ssp*. scotticum*<br>Scott Mountain bedstraw | 1B.2 | Lower montane coniferous forest (serpentinite). | Recorded at two locations along the northwestern watershed boundary. |
| *Aleppo avens*<br>Geum aleppicum | 2.2 | Great Basin scrub; lower montane coniferous forest; and meadows and seeps. | Recorded at two locations in the northern portion of the watershed. |
| *Hierochloe odorata*<br>Nodding vanilla-grass | 2.3 | Meadows and seeps. | Recorded at one location in the north-central portion of the watershed. |
| *Hulsea nana*<br>Little hulsea | 2.3 | Alpine boulder and rock field; subalpine coniferous forest/rocky or gravelly volcanic. | Recorded (1959) in one location along the northwestern watershed boundary. |
| *Ivesia longibracteata*<br>Castle Crags ivesia | 1B.3 | Lower montane coniferous forest (granitic, rocky). | One record in Castle Crags State Park. |
| *Lewisia cantelovii*<br>Cantelow's lewisia | 1B.2 | Broadleafed upland forest; chaparral; cismontane woodland; and lowland montane coniferous forest/mesic, granitic, sometimes serpentinite seeps. | Recorded at five locations in the central watershed. |
| *Meesia uliginosa*<br>Broad-leaved hump moss | 2.2 | Bogs and fens; meadows and seeps; subalpine coniferous forest; and upper montane coniferous forest/damp soil. | One record near the City of Mt. Shasta. |
| *Neviusia cliftonii*<br>Shasta snow-wreath | 1B.2 | Cismontane woodland; lower montane coniferous forest; and riparian woodland/often streamsides; sometimes carbonate, volcanic, or metavolcanic. | One record in the watershed in the Sacramento River Arm of Shasta Lake (Waters Gulch). |
| *Ophioglossum pusillum*<br>Northern adder's-tongue | 2.2 | Marshes and swamps; valley and foothill grassland. | One historical record (1894) near the City of Mt. Shasta. |
| *Parnassia cirrata* var. *intermedia*<br>Cascade grass-of-parnassus | 2.2 | Bogs and fens; meadows and seeps/rocky serpentine soil. | Two records in the central watershed. |
| *Penstemon filiformis*<br>Thread-leaved beardtongue | 1B.3 | Cismontane woodland; lower montane coniferous forest/rocky. | Numerous records in the east-central portion of the watershed. |
| *Phacelia leonis*<br>Siskiyou phacelia | 1B.3 | Meadows and seeps; upper montane coniferous forest (openings)/often serpentinite. | Four records along the western watershed boundary. |

**Table 3.3-2. Special-Status Plants Known to Occur in the Upper Sacramento River Watershed**

| SCIENTIFIC NAME<br>COMMON NAME | STATUS* | HABITAT | COMMENTS |
|---|---|---|---|
| *Polemonium chartaceum*<br>Mason's sky pilot | 1B.3 | Alpine boulder and rock field; subalpine coniferous forest/rocky, serpentinite, granitic, or volcanic. | Two records along the northwestern watershed boundary. |
| *Potentilla cristae*<br>Crested potentilla | 1B.3 | Alpine boulder and rock field; subalpine coniferous forest/seasonally mesic, often serpentinite seeps, gravelly or rocky. | Two records in the northern portion of the watershed. |
| *Raillardella pringlei*<br>Showy raillardella | 1B.2 | Bogs and fens; meadows and seeps; and upper montane coniferous forest/mesic, serpentinite. | Five records along the western watershed boundary. |
| *Schoenoplectus subterminalis*<br>Water bulrush | 2.3 | Bogs and fens; marshes and swamps (montane lake margins). | One record in the west-central portion of the watershed. |
| *Scutellaria galericulata*<br>Marsh skullcap | 2.2 | Lower montane coniferous forest; meadows and seeps; and marshes and swamps. | One recorded historical occurrence (1894) near the City of Mt. Shasta. |
| *Silene suksdorfii*<br>Cascade alpine campion | 2.3 | Alpine boulder and rock field; subalpine coniferous forest; and upper montane coniferous forest/volcanic, rocky. | One record near the base of Mt. Shasta. |
| *Vaccinium scoparium*<br>Little-leaved huckleberry | 2.2 | Subalpine coniferous forest (rocky). | Two records in the central portion of the watershed. |

*CNPS Listing Status

| | |
|---|---|
| List 1B | 'Plants rare, threatened, or endangered in California and elsewhere.' |
| List 2 | 'Plants rare, threatened, or endangered in California but more common elsewhere.' |

Extensions

| | |
|---|---|
| .3 | Not very endangered in California |
| .2 | Fairly endangered in California |
| .1 | Seriously endangered in California |

In addition, several populations of an unusual and undescribed huckleberry (*Vaccinium* sp.) have been found in the last decade at several locations around Shasta Lake, including sites within the watershed boundary. The huckleberry most closely fits the description of red huckleberry (*Vaccinium parvifolium*) except that the berries are purple. This undescribed huckleberry is disjunct from the nearest known extant red huckleberry populations by approximately 40 miles, with the Trinity Alps and other Klamath Ranges lying between them. The undescribed inland plants grow in a distinct, much less moist habitat than does the coastal red huckleberry. Most of the known sites for this odd huckleberry are associated with abandoned or active mines in the watershed (Lindstrand personal communication); in some places, the plants grow on acid mine drainage.

## Invasive Plants and Other Noxious Weeds

When plants that evolved in one region of the globe are moved to another region, a few flourish, crowding out native vegetation and the wildlife that feeds on the native species. These invasive plants have a competitive advantage because they are no longer controlled by their natural predators and can quickly spread out of control. The scientific community has come to view invasive species as posing serious threats to biological diversity, second only to the threats resulting from habitat loss and fragmentation (Bossard et al. 2000). Invasive species present complex management issues; even when the species are no longer being actively introduced, they continue to spread and invade new areas. Invasive species affect native species and habitats in several ways, including by altering nutrient cycles, fire frequency and/or intensity, and hydrologic cycles; by creating changes in sediment deposition and erosion; by dominating habitats and displacing native species; by hybridizing with native species; and by promoting non-native animal species (Bossard et al. 2000). In California, approximately 3 percent of the plant species growing in the wild are considered invasive, but they inhabit a much greater proportion of the landscape (California Invasive Plant Council 2007).

Plant pests are defined by law, regulation, and technical organizations, and are regulated by many different sources, including the California Department of Food and Agriculture (CDFA) and the United States Department of Agriculture (USDA). The CDFA uses an action-oriented pest-rating system. The rating assigned to a pest by the CDFA does not necessarily mean that one with a low rating is not a problem; rather the rating system is meant to prioritize response by the CDFA and county agricultural commissioner’s. The California Invasive Plant Council (Cal-IPC) has developed a list of plant pests specific to California wildlands. The Cal-IPC list is based on information submitted by land managers, botanists, and researchers throughout the state and on published sources. To determine plant pests potentially occurring in the watershed (Appendix F), this list was reviewed and local experts were contacted to gather knowledge of known weed locations.

A “weed management area” (WMA) is a local organization that brings together all interested landowners, land managers, special districts, and the public in a county or other geographical area for the purpose of coordinating and combining their actions and expertise to deal with their common weed control problems.

Two weed management areas operate in the watershed. The Shasta County WMA functions under the authority of a mutually developed memorandum of understanding and is subject to statutory and regulatory requirements. The Siskiyou County WMA is a cooperative task force focused on the control and eradication of noxious weeds. The Siskiyou County Department of Agriculture (SCDA) has a long history of weed management work and has been the main contact for the WMA.

## Special-Status Fish and Wildlife

For the purpose of this analysis, special-status fish and wildlife include:

- Species listed or proposed for listing as threatened or endangered under FESA,
- Species listed or proposed for listing by the State of California as threatened or endangered under CESA,

- Species designated as “species of special concern” by CDFG,
- Species designated as “fully protected” by CDFG,
- Species considered sensitive or endemic by the USFS, or
- Birds designated as “birds of conservation concern” by the USFWS.

Table 3.3-3 (Figure 3.2-4) identifies 36 special-status wildlife species that are known to occur or may occur in the watershed. Their distribution, legal status, general habitat requirements, and known occurrences in the watershed (based on CNDDB (California Department of Fish and Game 2008b) and CWRH (California Department of Fish and Game 2008c)) are also provided. Detailed information concerning threatened and endangered species is provided below in “Species Accounts,” and information on other special-status species can be found in Appendix G.

**Table 3.3-3. Special-Status Wildlife Species Known to Occur in the Upper Sacramento River Watershed**

| SCIENTIFIC NAME COMMON NAME | STATUS* | HABITAT | COMMENTS |
|---|---|---|---|
| ***Federally or State-Listed Species*** | | | |
| *Cottus asperrimus*<br>Rough sculpin | CT<br>FSS | Prefers sand or gravel substrate in cool streams or reservoirs. Spawns in streams. | Occurs in Shasta Lake. |
| *Hydromantes shastae*<br>Shasta salamander | CT<br>FSS | Moist limestone fissures and caves in volcanic and other rock outcroppings, and under woody debris in mixed pine-hardwood stands. | Known only from the southeastern Klamath Mountains region. Twenty-five known occurrences in the watershed near Shasta Lake. |
| *Falco peregrinus anatum*<br>American peregrine falcon | BCC<br>CP<br>FD | Forages in many habitats; requires cliffs for nesting. | Species has been recorded nesting in the watershed. |
| *Haliaeetus leucocephalus*<br>Bald eagle | CE<br>CP<br>FD | Uncommon to common in riverine and open wetland habitats. Perches high in large, stoutly limbed trees, on snags or broken-topped trees or on rocks near water. Roosts communally in winter in dense, sheltered, remote conifer stands. | Common at Shasta Lake, which has the highest density of breeding bald eagles in the continental United States. Nine nesting territories have been recorded in the watershed. |
| *Strix occidentalis caurina*<br>Northern spotted owl | FT | In northern California, resides in large stands of old growth, multi-layered mixed conifer, redwood, and Douglas-fir habitats. | Numerous northern spotted owl territories have been recorded in the watershed.†<br>Critical habitat is present in the watershed. |

## Table 3.3-3. Special-Status Wildlife Species Known to Occur in the Upper Sacramento River Watershed

| SCIENTIFIC NAME<br>COMMON NAME | STATUS* | HABITAT | COMMENTS |
|---|---|---|---|
| *Coccyzus americanus occidentalis*<br>Western yellow-billed cuckoo | BCC<br>CE<br>FC | Nesting habitat is cottonwood/willow riparian forest. Occurs only along the upper Sacramento Valley portion of the Sacramento River, the Feather River in Sutter Co., the south fork of the Kern River in Kern Co., and along the Santa Ana, Amargosa and lower Colorado rivers. | The species was recorded in the watershed in 1951. However, the western yellow-billed cuckoo has been extirpated from this location (California Department of Fish and Game 2008b). |
| *Empidonax traillii*<br>Willow flycatcher | CE<br>FSS | Rare summer resident in wet meadow and montane riparian habitats at elevations of 2,000 to 8,000 feet. No longer known to nest in Sacramento Valley but migrates through the north state region in spring and fall. | Willow flycatchers occur as a migrant in riparian habitat; and may nest in suitable habitat in the upper portion of the watershed. |
| *Gulo gulo luteus*<br>California wolverine | CT<br>FP | A variety of habitats within the elevations of 1,600 and 14,200 feet. Most commonly inhabits open terrain above timberline. | Species has been recorded within the watershed; however, it is believed extirpated from this region. |
| *Martes pennanti* pacifica<br>Pacific fisher | CSC<br>FC<br>FSS | Intermediate to large dense stages of coniferous forests and deciduous riparian habitats with greater than 50 percent canopy closure. | The Pacific fisher has been recorded in numerous locations throughout the entire watershed. |
| *Vulpes vulpes nector*<br>Sierra Nevada red fox | CT | Red fir and lodgepole pine forests in the sub-alpine zone and alpine fell-fields of the Sierra Nevada. | The Sierra Nevada red fox has been recorded historically in the vicinity of Mt. Shasta, but is not expected to occur in the watershed. |
| ***Other Special-Status Species*** | | | |
| *Mylopharodon conocephalus*<br>Hardhead | CSC<br>FSS | Prefers deep, rock- and sand-bottomed pools of small to large rivers and impoundments. | Occurs in Shasta Lake. |
| *California floater*<br>Anodonta californiensis | FSS | Aquatic mollusk potentially occurring in shallow areas of clean, clear ponds, lakes, and rivers with a silty substrate. | Suitable habitat is present in the watershed. |
| *Hydromantes shastae*<br>Shasta hesperian | FSS | Mixed conifer and conifer/woodland habitats (riparian and/or riverine habitats). | Endemic to Klamath Province. The species has been recorded along the Sacramento River in the watershed. |

### Table 3.3-3. Special-Status Wildlife Species Known to Occur in the Upper Sacramento River Watershed

| SCIENTIFIC NAME<br>COMMON NAME | STATUS* | HABITAT | COMMENTS |
|---|---|---|---|
| *Monadenia troglodytes troglodytes*<br>Shasta sideband | FSS | Mixed conifer and woodland habitats, especially near limestone. | Endemic to Shasta County. Known occurrences in the McCloud Arm of Shasta Lake, but no records within the watershed. |
| *Monadenia troglodytes wintu*<br>Wintu sideband | FSS | Mixed conifer and woodland habitats, especially near limestone. | Endemic to Shasta County. Not known to occur in the watershed. |
| *Trilobopsis roperi*<br>Shasta chaparral | FSS | Mixed conifer and conifer/woodland habitats. | Endemic to Shasta County. Known to occur near Shasta Lake within the watershed. |
| *Rana cascadae*<br>Cascades frog | CSC | Open coniferous forests along the sunny, rocky banks of ponds, lakes, streams, and meadow potholes. From 2,600 to 9,000 feet in elevation in Cascades and Trinity Mountains. | Species has been recorded in the northwestern portion of the watershed. |
| *Rana boylii*<br>Foothill yellow-legged frog | CSC<br>FSS | Rocky streams in a variety of habitats. Found in Coast Ranges. | Species has been recorded in numerous locations throughout the watershed. |
| *Ascaphus truei*<br>Tailed frog | CSC | Clear, rocky, swift, cool perennial streams in densely forested habitats. | Species has been recorded in numerous locations in the central portion of the watershed. |
| *Actinemys marmorata*<br>Western pond turtle | CSC<br>FSS | Slow water aquatic habitat with available basking sites. Hatchlings require shallow water with dense submergent or short emergent vegetation. Require an upland oviposition site near the aquatic site. | Species has been recorded in the central and southern portions of the watershed. |
| *Asio otus*<br>Long-eared owl | CSC | Dense riparian and live oak thickets near meadow edges, and nearby woodland and forest habitats; also found in dense conifer stands at higher elevations. | Suitable habitat is present in the watershed. |
| *Otus flammeolus*<br>Flammulated owl | BCC | A variety of coniferous habitats from ponderosa pine to red fir forests. Prefers low to intermediate canopy closure. | Occurs as a summer resident in the watershed. |
| *Aquila chrysaetos*<br>Golden eagle | BCC<br>CP<br>CSC | Breeds on cliffs or in large trees or electrical towers and forages in open areas. | Suitable habitat is present in the watershed. |

### Table 3.3-3. Special-Status Wildlife Species Known to Occur in the Upper Sacramento River Watershed

| SCIENTIFIC NAME<br>COMMON NAME | STATUS* | HABITAT | COMMENTS |
|---|---|---|---|
| *Accipiter gentiles*<br>Northern goshawk | BCC<br>CSC<br>FSS | Breeds in dense, mature conifer and deciduous forests, interspersed with meadows, other openings and riparian areas; nesting habitat includes north-facing slopes near water. | Northern goshawks have been recorded in the watershed. |
| *Buteo regalis*<br>Ferruginous hawk | BCC | Requires large, open tracts of grasslands, sparse shrub, or desert habitats with elevated structures for nesting. | May occur as winter resident or migrant in the watershed. |
| *Falco mexicanus*<br>Prairie falcon | BCC | Uses open terrain for foraging; nests in open terrain with canyons, cliffs, escarpments, and rock outcrops. | May occur as permanent resident in the watershed. |
| *Melanerpes lewis*<br>Lewis's woodpecker | BCC | Open, deciduous, and conifer habitats with brushy understory, and scattered snags and live trees for nesting and perching. | May occur as summer resident in the watershed. |
| *Picoides albolarvatus*<br>White-headed woodpecker | BCC | Montane coniferous forests up to lodgepole pine and red fir habitats. | Suitable habitat is present in the watershed. |
| *Cypseloides niger*<br>Black swift | BCC<br>CSC | Nests in moist crevice or cave or sea cliffs above the surf or on cliffs behind, or adjacent to, waterfalls in deep canyons; forages widely over many habitats. | Species has been recorded near Mossbrae Falls. |
| *Chaetura vauxi*<br>Vaux's swift | CSC | Prefers redwood and Douglas-fir habitats. Nests in hollow trees and snags or, occasionally, in chimneys and forages aerially. | Suitable habitat is present in the watershed. |
| *Contopus cooperi*<br>Olive-sided flycatcher | CSC, BCC | Wide variety of forest and woodland habitats below 9,000 feet. Preferred nesting habitat includes mixed conifer, montane hardwood-conifer, Douglas-fir, redwood, red fir, and lodgepole pine. | Suitable habitat is present and the species is known to occur in the watershed. |

### Table 3.3-3. Special-Status Wildlife Species Known to Occur in the Upper Sacramento River Watershed

| SCIENTIFIC NAME<br>COMMON NAME | STATUS* | HABITAT | COMMENTS |
|---|---|---|---|
| *Progne subis*<br>Purple martin | CSC | Breeding habitat includes old-growth, multi-layered, open forest and woodland with snags; forages over riparian areas, forest, and woodlands. | Shasta Lake is one of the few known breeding sites in interior California. However, the species has not been recorded breeding within the portion of Shasta Lake within the watershed. |
| *Dendroica petechia brewsteri*<br>California yellow warbler | CSC | Breeds in riparian woodlands, particularly those dominated by willows and cottonwoods. | Suitable habitat is present and the species is known to occur in the watershed. |
| *Icteria virens*<br>Yellow-breasted chat | CSC | Breeds in riparian habitats having dense understory vegetation, such as willow and blackberry. | Suitable habitat is present and the species is known to occur in the watershed. |
| *Lanius ludovicianus*<br>Loggerhead shrike | BCC<br>CSC | Forages in open grassland habitats in the lowlands and foothills of California. Nests in shrubs and trees. | Suitable habitat is present in the northern portion of the watershed. |
| *Martes americana*<br>American marten | FSS | Mixed evergreen forests with abundant cavities for denning and nesting and open areas for foraging. | Species has been recorded in the northern portion of the watershed. |
| *Lepus americanus* klamathensis<br>Oregon snowshoe hare | CSC | Montane riparian habitats with thickets of alders and willows and in stands of young conifers interspersed with chaparral. | Species has been recorded just east of the northern watershed boundary. |
| *Corynorhinus townsendii*<br>Townsend's western big-eared bat | CSC<br>FSS | Roosts in colonies in caves, mines, bridges, buildings, and hollow trees in a variety of habitats. Forages along habitat edges. Habitat must include appropriate roosting, maternity, and hibernacula sites free from disturbance by humans. | Species has been recorded in a limestone cave on the Big Backbone Creek Arm of Shasta Lake within the watershed. |
| *Antrozous pallidus*<br>Pallid bat | CSC<br>FSS | Forages over many habitats; roosts in buildings, large oaks or redwoods, rocky outcrops and rocky crevices in mines and caves. | Suitable habitat is present in the watershed. |
| *Lasiurus blossevillii*<br>Western red bat | FSS | Riparian forests | Suitable habitat is present in the watershed. |

**Table 3.3-3. Special-Status Wildlife Species Known to Occur in the Upper Sacramento River Watershed**

| SCIENTIFIC NAME<br>COMMON NAME | STATUS* | HABITAT | COMMENTS |
|---|---|---|---|
| *Euderma maculatum*<br>*Spotted bat* | CSC | Ponderosa pine region of the western highlands. Prefers cracks/crevices of high cliffs and canyons for roosting. | Species has been recorded in the northern half of the watershed. |
| *Eumops perotis*<br>Western mastiff bat | CSC | Many open habitats, including conifer and deciduous woodlands, grassland, and chaparral. Roosts in crevices in cliff faces and high buildings. | Species has been recorded in the northern portion of the watershed. |
| *Taxidea taxus*<br>American badger | CSC | Herbaceous, shrub, and open stages of most habitats with dry, friable soils. | Suitable habitat is present in the watershed. |
| *Bassariscus astutus*<br>Ring-tailed cat | CP | Riparian habitats and brush stands of most forest and shrub habitats. Nests in rock recesses, hollow trees, logs, snags, abandoned burrows, and woodrat nests. | Suitable habitat is present and he species is known to occur in the watershed. |

†Northern spotted owl occurrences are considered sensitive. Thus, they are not depicted in Figure 3.2-4.

*Status Codes:

BCC = Bird of Conservation Concern
CE = State listed as endangered
CP = California fully protected
CSC = California species of special concern
CT = California Threatened
FC = Federal candidate for listing
FD = Federally delisted
FPD = Proposed for federal delisting
FSS = Forest Service Sensitive
FT = Federally listed as threatened

## Neotropical Migratory Birds

Of the nearly 800 bird species known to occur in the United States, approximately 500 migrate across our borders, with the large majority wintering in Central and South American (U.S. Fish and Wildlife Service 2001). Hemisphere-wide habitat loss due to deforestation and development threaten the future survival of these neotropical migrants. The USFS is actively integrating neotropical migratory bird management into forest management planning and implementation. It conducts a variety of surveys to identify downward population trends; implements actions to reverse these trends; restores and protects key habitats; conducts inventories and long-term population trend monitoring; addresses fragmentation issues; and implements management practices targeted at habitat features limiting bird populations. The USFS is also involved in national programs such as Monitoring Avian Productivity and Survivorship (MAPS) and Breeding Bird Surveys (BBS). Bird monitoring is one aspect of overall monitoring and inventory of habitat conditions, biodiversity, and forest plan implementation used by the USFS. The USFS is also actively engaged in a broad array of research efforts regarding neotropical migrant birds. Some of these efforts include examining the impacts of cowbird parasitism, logging, grazing, fragmentation, and burning on neotropical migrants. Additional efforts are aimed at investigating ecosystem processes and functions within a complete watershed perspective. A list of neotropical migrants known to occur on the STNF is included as Appendix H.

### *Species Accounts*

#### Rough Sculpin

Rough sculpins are primarily found in clear, cool, fast water. They live in spring-fed streams where water temperatures rarely exceed 59 °F and occupy areas with aquatic vegetation and a sand or gravel substrate (U.C. Cooperative Extension 2003). However, they are capable of surviving in lakes or reservoirs where surface water temperatures reach 86 °F (U.C. Cooperative Extension 2003). Rough sculpins are known to occur in Shasta Lake.

#### Shasta Salamander

The Shasta salamander is endemic to a small region of the southeastern Klamath Mountains, generally located north and northeast of Redding, California. Five occurrences of this species have been recorded in the watershed near Shasta Lake (California Department of Fish and Game 2008b). The Shasta salamander has long been known to occur in habitats associated with limestone formations (Stebbins 2003) and was recently found to occur in various non-limestone habitats (Lindstrand 2000, Nauman and Olson 2004). Shasta salamanders have been found at elevations ranging from approximately 800 feet to 3,800 feet (Lindstrand 2008).

Shasta salamander limestone habitat includes large or small limestone outcrops and the immediately adjacent areas. This habitat consists of mainly steep and rocky limestone bluffs, cliffs, and outcrops, and is characterized by abundant limestone rock with fissures, cracks, and occasional small caves. Vegetative cover varies, and includes barren rock with sparse herbaceous growth, open to dense shrub habitat, and open to dense woodland habitat.

Shasta salamander non-limestone habitat has yet to be fully understood and defined. Non-limestone habitat is known to occur in the Shasta Lake area and elsewhere in the southeastern Klamath Mountains region, and includes a variety of montane hardwood-conifer, montane hardwood, and ponderosa pine habitat (Lindstrand 2000, Nauman and Olson 2004). Typically, these habitats are characterized by sparse to dense conifer and/or hardwood canopy closure, open to moderate shrub growth, and a sparse to dense herbaceous layer, and include some type of a ground cover component such as downed woody debris, scattered rock, or leaf/litter layer.

#### Bald Eagle

The bald eagle first gained federal protection in 1940 when Congress passed the Bald Eagle Protection Act. It was later amended to include golden eagles and renamed the Bald and Golden Eagle Protection Act. The bald eagle was first listed under the federal ESA on February 14, 1978, when it was designated as endangered throughout the lower 48 states, except in Michigan, Minnesota, Wisconsin, and Oregon, where it was designated as threatened (43 FR 6233). The bald eagle was reclassified as threatened in all of the lower 48 states on July 12, 1995 (60 FR 36000). The USFWS proposed to remove the species from the list of endangered and threatened wildlife (delist) on July 6 1999 (64 FR 36454) due to the population’s successful rebound. It was delisted on August 8, 2007 (72 FR 37346). The bald eagle continues to be protected under the federal Bald and Golden Eagle Protection Act.

Most of a bald eagle's annual food requirements are derived from or obtained around aquatic habitats. The type of food consumed most often consists of fish, water birds, and small to medium-sized mammals. Because of the dietary association, nesting territories are usually found near water. Perches are used primarily during the day for resting, preening, and hunting, and may include human-made structures such as power poles, although natural perches are used most often. Roosting areas will contain a night communal roosting tree that is tall enough to provide safety from threats from the ground. The number and quality of these roost trees determine the size and importance of the roost. Bald eagle wintering areas and roosts are usually found where human activity is infrequent and/or muted. In California, breeding pairs are found mostly in Butte, Lake, Lassen, Modoc, Plumas, Shasta, Siskiyou, and Trinity counties (California Department of Fish and Game 2008c).

Bald eagles are common at Shasta Lake, occurring at the highest recorded density in the continental United States. Approximately 20 nest sites are currently believed to be active in the watershed. Management of bald eagles on Shasta Lake is directed by knowledge of territory protection needs (Forest Order – December 2004 and updated annually). Each known territory has a strategy that determines management zones and directs which activities are permitted during different times of the year (Forest Order 2004). Activities within these zones may be restricted to ensure that activities permitted within a unit will not have a negative effect on bald eagles.

### Northern Spotted Owl

Northern spotted owls are associated with late-successional forest conditions consisting of relatively dense canopies, large-diameter live and dead standing trees, multi-storied crowns, and large diameter downed woody debris (55 FR 26114). In California, the range of the northern spotted owl extends from the Coast Ranges to San Francisco Bay. Spotted owls subsist on a diet of small mammals, birds, amphibians, reptiles and insects.

Locally suitable nesting and roosting habitat is defined as mixed-conifer, Douglas-fir, and true fir stands below 6,000 feet in elevation with an overstory of Douglas-fir, ponderosa pine, sugar pine, incense cedar, white fir, and/or red fir, averaging or above 18 inches dbh; a mid-story composed of the same species with or without hardwoods; a total canopy cover of 50–100 percent; minimum of 1.5 snags per acre greater than 40 inches dbh, and 6–8 down logs per acre greater than 10 inches in diameter (USDA Forest Service 1999a). Foraging habitat includes any stand having a canopy closure of greater than 40 percent (USDA Forest Service 1999a). Nest stand and home range size are dependent on suitability, distribution, and amount of available habitat.

Critical habitat was originally designated on January 15, 1992 (57 FR 1796) and was revised on August 13, 2008 (73 FR 47325). The critical habitat designation includes units within the watershed boundaries.

### Western Yellow-Billed Cuckoo

The western yellow-billed cuckoo is generally considered a neotropical migrant that arrives in California to begin breeding in June. It prefers open woodland with clearings and low, dense, scrubby vegetation; often associated with watercourses (Hughes 1999). The yellow-billed cuckoo is an interspecific brood parasite, laying eggs in the nests of at least 11 other bird species (Hughes 1999). Major declines among western populations of yellow-billed cuckoos in the twentieth century have occurred due to habitat loss and fragmentation, local extinctions, and low colonization rates. The species is now extremely rare in most areas (Laymon and Halterman 1989).

In California, breeding populations of greater than five pairs that persist every year are currently limited to the Sacramento River from Red Bluff to Colusa and the South Fork Kern River from Isabella Reservoir to Canebrake Ecological Reserve (Laymon 1998). Although the species was historically recorded in the watershed (1951), western yellow-billed cuckoos have been extirpated from this location (California Department of Fish and Game 2008b), and the species is not known to occur elsewhere in the watershed.

### Willow Flycatcher

Willow flycatchers nest in dense riparian thickets and forage on insects, berries, and seeds. The species has been eliminated as a breeding bird from most of its former range in California, primarily due to the loss and degradation of riparian habitat. In the watershed, willow flycatchers are a rare to locally uncommon spring and fall migrant, occurring in open woodland, chaparral, wet meadow, and riparian habitats.

### Pacific Fisher

In California, the Pacific fisher historically occurred in the conifer-dominated forests in the north Coast Ranges, Klamath Mountains, and Cascade Range, and south through the Sierra Nevada to Kern County (Grinnell et al. 1937). Fishers in California have experienced a reduction in geographic range and currently occur as two disjunct populations separated by roughly 248.5 miles (Zielinski et al. 2004). The two remnant populations are located in the southern Sierra Nevada and in the northwest’s north Coast Ranges and Klamath Mountains (Zielinski et al. 2004). Fishers occur at elevations between 1,090 to 5,000 feet in the northwest and between 4,000 to 8,000 feet in the southern Sierra Nevada (Freel 1991, U.S. Department of the Interior 2006).

The fisher West Coast Distinct Population Segment (DPS) occurs in Washington, Oregon, and California. The area of the DPS includes the Cascade Range and all areas west to the coast in Oregon and Washington; and in California, the North Coast from Mendocino County north to Oregon, east across the Klamath Mountains and the southern Cascade Mountains, and south through the Sierra Nevada. All historical and current fisher populations in California occur within the DPS. The Pacific fisher has been recorded in numerous locations throughout the watershed (California Department of Fish and Game 2008b).

### Sierra Nevada Red Fox

The Sierra Nevada red fox inhabits various habitats in alpine and subalpine zones (California Department of Fish and Game 1991b). They were historically found in the high elevations of the Sierra Nevada and from Mount Shasta and Lassen Peak westward to the Trinity Mountains (Aubry 1997). The Sierra Nevada red fox occurs at elevations from 4,500 to 11,500 feet, but is most commonly found above 7,000 feet (Aubry 1997). The only population known to exist in recent times is found in Lassen National Park and the surrounding Lassen National Forest (Perrine et al. 2007). The Sierra Nevada red fox has been recorded near Mount Shasta (California Department of Fish and Game 2008b).

### *Extirpated Species*

Several wildlife species appear to have been extirpated from the watershed, which means they are no longer known to occur in the area but still occur in other parts of their historic range. Large mammals that have been extirpated include the grizzly bear (*Ursus arctos horribilis*), wolverine, pronghorn antelope (*Antilocapra americana*), and white-tailed deer (*Odocoileus virginianus ochrourus*) (Cronise 1868; Williams 1986, California Department of Forestry and Fire Protection 2003, Laliberte and Ripple 2004).

The grizzly bear once occurred widely throughout California, roaming the Cascades until the 1850s or 1870s (Jameson and Peeters 1988). Because its centers of density coincided with ranching activities, it was persecuted whenever encountered. The last grizzly bear in California was killed in the early 1920s (Jameson and Peeters 1988).

The wolverine, currently state listed as threatened, was likely never numerous in California relative to densities found in other parts of the species' range (California Department of Forestry and Fire Protection 2003). Broadly, they are restricted to boreal forests, tundra, and western mountains.

In 2007, Aubry et al. compiled 820 verifiable and documented records of wolverine occurrences (specimens, DNA detections, photos, and accounts of wolverines being killed or captured) in the continuous United States from 1801 to 2005 (Aubry et al. 2007). Anecdotal accounts (i.e., visual observations made at a distance or reports of tracks or other sign) were not included. (Note that anecdotal sightings have been reported on the Lassen National Forest (1990s) and on the Plumas National Forest. No current records (1995 to 2005) were found for Oregon or California, despite concerted efforts to obtain verifiable evidence of wolverine occurrence using remote cameras, bait stations, and helicopter surveys in many areas of the Pacific states (Zielinski 2004, Aubry et al. 2007). However, in 2008, a photograph of a wolverine was taken on the Tahoe National Forest and verified by a species expert (Zielinski personal communication). To determine the origin of this individual, a genetic analysis was performed on hair and scat samples (Zielinski 2008). This analysis ruled out that this animal persisted from the historical California population. It also eliminated the possibility that the animal came from the current Cascade population. The source location of this animal remains in question.

The pronghorn antelope once inhabited most of the grassland, oak woodland, and sagebrush-steppe plant communities in California (California Department of Forestry and Fire Protection 2003). However, by the early 1870s their numbers were significantly reduced due to market hunting, livestock competition, and changing land use practices. In 1923, it was estimated that less than 1,100 pronghorn were present in seven areas of California (California Department of Forestry and Fire Protection 2003). By 1943, pronghorn were found only in northeastern California (California Department of Forestry and Fire Protection 2003).

Historically, white-tailed deer were reported from localities in Lassen, Modoc, Mono, Shasta, and Siskiyou counties (Grinnell 1933, Hall and Kelson 1959 as cited in Williams 1986) Hall and Kelson, 1959. Little is known of their habitat in California. They were probably extirpated from California sometime between the 1930s and 1950s, mainly because of loss of habitat (Williams 1986).

Although the disappearance of these species is a concern, a greater concern exists for the species that still occur in low numbers in the watershed (see Table 3.3-3).

## Locally Important Wildlife and Fish Populations

Hunting is an important cultural value to local residents of the watershed, and many native wildlife species are locally important because of their recreational value. Game species also attract people from outside of the watershed. Information is provided below for a few of these species, including their historic and current distribution, habitat requirements, and population trends.

### *Game Fish*

The sport fishery in the watershed is based primarily around salmonids, and specifically rainbow trout. The fishery of the headwaters portion of the watershed can largely be characterized as created, managed, and maintained through the introductions and continued stocking of regionally native (though often not historically naturally occurring at stocking locations) and non-native fish species. Though warmwater fish populations are self-sustaining, the trout populations in the lakes and many of the streams must be sustained artificially through annual stocking programs provided by CDFG (USDA Forest Service 2001b).

In the central portion of the watershed, a fishery exists in the mainstem for both wild and stocked rainbow trout, brown trout, and spotted bass. Tributary fishing in this portion of the watershed is primarily for rainbow trout.

No stocking of Shasta Dam occurred during the initial impoundment period as it was hoped that the native rainbow trout population would provide enough fish to support the sport fishery (California Department of Fish and Game 1991a). However, by 1946, the excellent rainbow trout fishery that had developed was beginning to decline. Thus, in 1948 and 1949, CDFG conducted large plantings of fingerling rainbow trout. This was followed by the introduction of Kamloops strain rainbow trout and kokanee salmon in the late 1950s, but the desired trophy trout fishery did not develop (California Department of Fish and Game 1991a). In 1949 and 1950, largemouth bass were stocked to increase angler opportunities. This was followed by the introduction of smallmouth bass, threadfin shad (*Dorosoma petense*), black crappie, and channel catfish in the early 1960s (California Department of Fish and Game 1991a). In the period from 1971 through 1974, three species of salmon, three strains of brown trout, and several strains of rainbow trout were stocked experimentally in the lake (California Department of Fish and Game 1991a). Florida strain largemouth bass (*Micropterus salmoides floridanus*) and Alabama spotted bass were introduced in 1981 and 1982 (California Department of Fish and Game 1991a). Subsequently, the spotted bass population exploded and Shasta Lake has become a premier black bass tournament water in California.

Currently, hatchery- and pen-reared trout and salmon are planted at various locations in Shasta Lake several times each year to support the sport fishery (Baumgartner personal communication). About 60,000 pounds of juvenile rainbow trout are planted annually (Baumgartner personal communication).

### Salmonids

Throughout the watershed, salmonids, and specifically several species of trout, dominate fish assemblages. While rainbow trout are native to the watershed, non-native trout species including brook trout (*Salvelinus fontinalis*), brown trout, lake trout, and cutthroat trout were also introduced across the watershed and stocked at different times to varying degrees of intensity. In recent years, stocking of non-native trout (all except rainbow trout) has been reduced or eliminated from much of the watershed. Nevertheless, self-sustaining populations of several species (most notably brook and brown trout) continue to persist in a number of locations.

Rainbow trout continue to be heavily stocked throughout the watershed. Stocking spans locations including the mainstem Sacramento River and its larger tributaries where rainbow trout were present historically as well as headwater streams and sub-alpine lakes, many of which were not known to support fish populations prior to introduction and stocking. In many of the larger, more accessible streams, as well as in the Sacramento mainstem, stocking occurs largely as a buffer where natural reproduction cannot meet pressure from anglers (USDA Forest Service 2001b). In some of the smaller streams in the watershed, stocking occurred for several years, but tapered off as natural production was sufficient to meet existing angler demands (USDA Forest Service 2001b). In the lakes, rainbow trout population size and the perceived need for stocking appear to be controlled by a combination of angler pressure, lake productivity, and the presence and availability of an inflow or outflow with spawning habitat. In the Sacramento mainstem, stocking continues. However, genetic research conducted as part of the fish recovery monitoring after the Cantara spill suggests that there is little introgression between the naturally reproducing (i.e., “wild”) and hatchery reared rainbow trout populations (Nielsen et al. 2000). Additionally, wild populations appear to constitute the majority of the trout present in the river (Nielsen et al. 2000), suggesting that stocked fish constitute essentially a “put and take” fisheries for anglers.

### Other Native Species

In addition to rainbow trout, several other native fish species are still found in the watershed, including white sturgeon, Sacramento blackfish (*Orthodon microlepidotus*), hardhead, rough sculpin, riffle sculpin, Sacramento sucker, and Sacrament pikeminnow. All of these fish species are currently found in the Shasta Lake segment of the watershed. In the Upper Sacramento segment, fewer of the species are present in the mainstem (principally Sacramento sucker, riffle sculpin, speckled dace, and Sacramento pikeminnow), and even fewer in the tributaries. In the headwaters portion, native fish presence appears to be continually decreasing, with persisting populations of riffle sculpin, Sacramento sucker, and Sacramento pikeminnow. It has also been suggested that speckled dace continue to persist in the upper watershed (USDA Forest Service 2001b), but this has not been confirmed. Distribution of these relic populations appears to have been limited primarily to the forks of the Sacramento River and Lake Siskiyou (USDA Forest Service 2001b). However, there has not been a recent assessment of the status of these populations or their distribution. Additionally, there is some anecdotal evidence of a decline in Sacramento sucker presence from the South Fork of the Sacramento, where they were known to occur historically but have not been observed in recent years.

### Non-Native Species

In addition to the various non-native salmonid species introduced and in some cases stocked in the watershed over time, a suite of other non-native species have also found their way into the watershed through both planned introductions and illegal or accidental ones. The list of other, primarily warmwater, non-native species present in the watershed is composed of many of the alien species now common to other regions of California, including several species of sunfish and catfish as well as mosquitofish (*Gambusia affinis*), minnows, and carp.

The most diverse assemblages of introduced species in the watershed are found in the two reservoirs, Lake Siskiyou and Shasta Lake. Upon its completion in 1968, Lake Siskiyou was initially stocked with trout species, and in the early 1970s, warmwater fish were introduced by CDFG. Since 1970, Siskiyou Lake has, at different times, been stocked with largemouth bass, smallmouth bass, spotted bass, green sunfish, brown bullhead, carp, and golden shiners (USDA Forest Service 2001b). Brown trout, brook trout, and catchable rainbow trout continue to be planted. Grass carp were also illegally introduced into a local pond, but have not been recorded elsewhere (USDA Forest Service 2001b).

Warmwater non-native species in Shasta Lake include spotted bass, smallmouth bass, black crappie, channel catfish, and bluegill. Any of the non-native fish found in Shasta Lake may also be found in the lower stream reaches of its tributaries as well as in some of the intermittent streams around the lake arms that host fish when lake levels are high (e.g., Dry Fork, Charlie, Doney, Little Sugarloaf, Elmore, Alder, Adler, Shoemaker, and Bull creeks) (USDA Forest Service 2000). Even so, the dominant species in these tributary streams is rainbow trout, and the lower reaches of these streams likely serve as spawning sites for lake-run rainbow trout during the spring (USDA Forest Service 2000).

In general, populations of warmwater non-native species in the watershed have not been closely tracked. In part, this may be a function of their populations being largely self sustaining (USDA Forest Service 2000, 2001a).

## ***Mammals***

### Deer

Deer are a significant wildlife species in California and an integral component in the food chain. In 2002, CDFG estimated the total population of deer in California as more than 544,000 animals (California Department of Fish and Game 2002). The six subspecies of mule deer found in the state occupy approximately 56 percent of the states lands, although only one subspecies, Columbian black-tailed deer, are found in the watershed (California Department of Fish and Game 2002).

Deer serve as grazers of wildland plants and as prey for carnivores. In addition, deer are the most popular, and accessible, big game animal in the state (California Department of Fish and Game 2002). Deer are among the most studied wildlife species in California, and from this long history of study, researchers have learned that deer often respond predictably to California’s changing wildland environment, particularly to changes in forestland habitats that are dominated by a mix of herbaceous and shrub vegetation (California Department of Fish and Game et al. 1998). Thus, deer are often used by CDFG, USFS, and BLM as an indicator species for a variety of other birds and mammals that use similar habitats (California Department of Fish and Game et al. 1998).

The California deer population peaked during the late 1950s and early 1960s (California Department of Forestry and Fire Protection 2003). In 1976, *A Plan for California Deer* was developed by CDFG to respond to the decline in deer numbers resulting from the loss and degradation of high-quality deer habitat. With the growing human population in California and continuing loss of high-quality deer habitats, biologists have realized that the goal to restore deer herd numbers to those in the 1960s is unlikely and unrealistic. Biologists are currently developing a more realistic approach through a Strategic Plan for California Deer in order to manage deer herds more effectively, given the existing and anticipated changes to California’s environment.

In addition, important deer habitats are identified through statewide surveys and investigations conducted throughout the year. The data are used for analysis of local and statewide land-use planning efforts, as well as providing recommendations to the Lands Committee for possible land acquisition through the Wildlife Conservation Board.

CDFG manages deer in California using established deer herds, which are based on approximate natural boundaries of reproductively isolated populations. The state is also divided into 11 Deer Assessment Units (DAU), and the watershed includes portions of two of these units, the North Coast DAU and the Cascade–North Sierra Nevada DAU. The following information concerning these two DAUs is from *An Assessment of Mule and Black-Tailed Deer Habitats and Populations in California* (California Department of Fish and Game et al. 1998).

The North Coast unit comprises about 16,500 square miles south of the Oregon border and west of Interstate 5. Columbian black-tailed deer populations occur at comparatively higher densities in this unit than elsewhere in the state. Deer are migratory in some areas where topographic variation is high, such as the Trinity Alps and Marble Mountains area. Elsewhere they seasonally move within a year-round home range and are considered resident deer. The deer population in the North Coast DAU has been considered fairly stable in recent years, varying from about 170,000–250,000. This DAU is the most productive (based on a per unit area evaluation) in terms of deer/square mile.

The Cascade–North Sierra Nevada unit comprises about 7,000 square miles from the Oregon border south to the Lake Almanor area and Feather River drainage. Deer populations consist of black-tailed and Rocky Mountain mule deer (*Odocoileus hemionus hemionus*); however, as stated above, only Columbian black-tailed deer occur in the watershed. The deer population has changed from 60,000–70,000 animals down to 35,000–45,000 in the past several years. Deer productivity in the winter ranges of Shasta-Tehama counties has been linked to fall rains and the germination of annual vegetation. Recent deer declines may be partially attributable to a hard freeze several years ago that killed desirable browse species in some parts of the summer range.

### Bear

Black bears are recognized as an important component of California’s ecosystems and as a valuable resource for the people of California. They can be found mostly in mountainous areas above 3,000 feet in elevation (California Department of Fish and Game 1998). As omnivores, black bears will eat whatever seems edible. They commonly consume ants and other insects in summer, but prefer nut crops, especially acorns, and manzanita berries in the fall. Mostly they are plant eaters, but they have been reported catching and consuming young deer fawns.

Black bears occupy a variety of habitat; however, bear populations are most dense in forested areas with a wide variety of seral stages (California Department of Fish and Game 1998). Mixed conifer forests, montane hardwood conifer, chaparral, and hardwood are important habitat types and support the greatest bear densities in the watershed (California Department of Forestry and Fire Protection 2003). Habitats with both vegetative and structural diversity provide alternate food resources when other foods are in short supply. Vegetation and structure diversity not only allow for greater survival of existing bears, they also provide for increased reproduction (California Department of Fish and Game 1998).

The black bear has been classified as a game mammal since 1948. Since that time, hunting regulations have become more restrictive, prohibiting trapping, killing of cubs or sows with cubs, and reducing the bag limit from two to one bear per license year. Before the early 1980s, regulation changes were infrequent. However, in 1982, CDFG began recommending regulatory and legislative changes to reduce poaching and increase its ability to monitor bear populations.

Black bear numbers in California are now increasing. Important demographic measures such as sex ratio of harvested bears, median age, and number of bears harvested indicate increasing population levels. In addition, the illegal take of bears has been greatly reduced from levels seen prior to 1985. Current population levels are estimated between 17,000 and 23,000. This is up from an estimated population of 10,000 to 15,000 in the early 1980s (California Department of Forestry and Fire Protection 2003).

#### Mammals Harvested for Furs

CDFG has been gathering information on the number of mammals harvested for furs, their value, and the number of licenses sold in California since 1919. Data for the 2006–2007 trapping season indicate that bobcats were the most economically important animals, providing 80 percent of the total value of California’s furs (Garcia 2007). Muskrats were second in value, coyotes ranked third, and gray foxes were fourth for the year. Shasta County reported the harvest of 1 beaver, 17 bobcats, 18 gray foxes, 9 mink, 2 mink, 1,340 muskrats, 5 opossums, 6 raccoons, and 9 striped skunks during the 2006–2007 season (Garcia 2007). For the same period, Siskiyou County reported the harvest of 2 badgers, 7 beavers, 163 bobcats, 66 coyotes, 139 gray foxes, 1 mink, 2,373 muskrats, 11 raccoons, and 6 striped skunks (Garcia 2007).

### *Upland Game Birds*

#### Wild Turkeys

The wild turkey is a member of the bird order Galliformes, which also includes grouse, pheasants, partridge, and quail. It is the largest game bird in North America. In California, wild turkeys can be found primarily from sea level to about 3,000 feet in elevation, but occasionally as high as 5,000–6,000 feet (California Department of Fish and Game 2005). In the watershed, they are known to occur on the west side of Shasta Lake. Oak habitats with a permanent water source have been described as the major requirement for turkeys in California; however, they also use ponderosa pine habitats and pinyon juniper in association with ponderosa and Jeffrey pines (California Department of Fish and Game 2005). The average wild turkey harvest in Shasta and Siskiyou counties between 1991 and 2003 was 1,131 and 200–400, respectively (California Department of Fish and Game 2005).

#### Mountain Quail and California Quail

Two species of quail occur in the watershed, the mountain quail and the California quail. To measure hunter effort and game harvest each year, CDFG conducts an annual “Game Take Hunter Survey.” According to the 2000 survey, quail are the third most popular game species in terms of time spent in pursuit, behind only ducks and deer (Mastrup 2002). The California quail comprises most of the annual quail harvest. In 2000, Siskiyou County was ranked first for percent total of mountain quail harvest in the state and tenth for California quail harvest, while Shasta County ranked ninth for mountain quail harvest (Mastrup 2002).

The California quail is associated with a combination of brushy vegetation and more open weedy or grassy habitat with some water supply. They avoid dense forests and dense chaparral (Mastrup 2002). A good distribution and quality of cover is important for efficient and safe access to food and water.

The mountain quail is an animal of mixed evergreen forests and chaparral. This quail is found in habitats associated with pinyon-juniper, oak woodland, chaparral, coastal forest, and mountain forests (Mastrup 2002). Mountain quail like thick brush that covers about half of the area.

### Introduced/Invasive Wildlife Species

For over two centuries, people have imported animals into California that are not native to the state. Whether brought here intentionally for food, sport, ornament, as pets, or by accident, many of these species have now been introduced into the wild (California Department of Fish and Game 2003). Although Californians have benefited from the introduction of plant and animal species necessary for food or other human pursuits, many other introduced species can wreak havoc on the state’s environment and economy. Those species that cause harm and, once established, spread quickly from their point of introduction are often called “invasive” or “nuisance” species.

Invasive species threaten the diversity and/or abundance of native species through competition for resources, predation, interbreeding with native populations, parasitism, transmitting diseases, or causing physical or chemical changes to the invaded habitat. Through their impacts on natural ecosystems, agricultural and other developed lands, and water delivery and flood protection systems, invasive species may also negatively affect human health and/or the economy. Examples of direct impacts to human activities include the clogging of navigable waterways and water delivery systems, weakening flood control structures, damaging crops, introducing diseases to animals that are raised or harvested commercially, and diminishing sport fish populations (California Department of Fish and Game 2008a). A few of the more common introduced/invasive wildlife and fish species present in the watershed are discussed in additional detail below (see also *Game Fish* above for a discussion of nonnative game fish).

### *Mosquitofish*

Mosquitofish have been introduced throughout the world to control mosquito populations, and these introductions have had negative effects on amphibians. In experimental studies, mosquitofish decreased the survival of larval Pacific treefrogs (Goodsell and Kats 1999) and California newts (Gamradt and Kats 1996) and inflicted tail injury, reduced metamorph size, and altered activity patterns of larval California red-legged frogs (Lawler et al. 1999).

### *New Zealand Mud Snail*

The New Zealand mud snail was recently (December 2007) confirmed to live in Shasta Lake (California Department of Fish and Game 2008d). New Zealand mud snails, which reproduce rapidly and can crowd out native insects that aquatic wildlife depend upon for survival, were first discovered in California in 2000 in the Owens River in Mono County (California Department of Fish and Game 2008d). New Zealand mud snail colonies disrupt the base of the food chain by consuming algae and competing with native bottom-dwelling invertebrates. A population decline of invertebrates can follow the introduction of New Zealand mud snails, which reduces fish forage. With a decrease in food availability, fish populations can decline as well.

New Zealand mud snails can grow as large as one-quarter inch but are often much smaller and are parthenogenic (i.e., able to start a new population with only one snail). They have the potential for extraordinary population densities —up to nearly 1 million snails per square meter and comprising up to 95 percent of the invertebrate biomass of a river. It is believed that populations in New Zealand are kept in check naturally by a native parasite. In North America, however, native stream communities can be altered because the snail has no natural predators or parasites, and its populations have flourished where they have been introduced. It is not believed they can be eradicated once established (California Department of Fish and Game 2008d).

### *American Bullfrog*

The American bullfrog is native to the eastern and midwestern United States and southeast Canada. It has been accidentally and intentionally introduced (e.g., for food in the 1920s by commercial frog farmers due to its large, meaty legs) throughout the world. The American bullfrog is now established throughout most of the western United States and southwestern Canada (California Herps 2008). Their large size, high mobility, generalized eating habits, and huge reproductive capabilities have made bullfrogs extremely successful invaders and a threat to biodiversity (AmphibiaWeb 2008). Bullfrogs prey on native amphibians as well as young western pond turtles, ducklings, and other aquatic and riparian vertebrates (Graber 1996).

### *Birds*

Wild turkeys in California are the result of introductions, which started before the turn of the century, and are managed as resident game birds. For more information on turkeys, see *Locally Important Wildlife and Fish Populations* above.

Barred owls have been expanding their range in the western United States since the 1970s, and were first documented in California in 1981 (Evens and LeValley 1982). They have successfully colonized a variety of forested and riparian habitats, and have been documented in the watershed near Slate Creek (Lindstrand personal communication). The range expansion of the barred owl may have a negative effect on spotted owls. Barred owls have successfully colonized habitats that are also used by spotted owls and are slightly larger and more aggressive in interactions with the spotted owl (Dark et al. 1998).

***Mammals***

Domestic cats first arrived in North America with European colonists several hundred years ago. Since that time, cats have thrived as pets, strays, and semi-wild (feral) predators. Free-ranging cats can have a large impact on native wild animals. Nationwide, rural cats probably kill over a billion small mammals and hundreds of millions of birds each year. Some of these kills are house mice, rats, and other species considered pests, but many are native songbirds and mammals whose populations may already be stressed by other factors, such as habitat destruction (Coleman et al. 1997).

Domestic pigs were introduced to California in the 1700s by explorers and settlers who allowed them to forage freely, especially in the fall to take advantage of fallen acorns (Waithman 2001). This resulted in some pigs becoming feral. Since that time, domestic pigs have occasionally escaped and been added to the wild population. In addition, in the 1920s, the European wild boar was introduced into California, which resulted in a wild boar/feral domestic pig hybrid (Waithman 2001). Wild pigs can cause a variety of damage. A common complaint is rooting resulting in the destruction of crops and pastures. Damage to farm ponds and watering holes for livestock is another common problem.

Virginia opossums were first introduced to California in 1910 (Jameson and Peeters 1988). They now occur widely in moist woodlands and brushy habitats at lower elevations.

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### 3.4.2 Personal Communications

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