Upper Sacramento, McCloud, and Lower Pit

# Integrated Regional Water Management Plan

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Upper Sacramento, McCloud, and Lower Pit
Regional Water Management Group

# Chapter 9:
# Climate Change

Upper Sacramento, McCloud, and Lower Pit
Integrated Regional Water Management Plan

# 9. Climate Change

Warming of the Earth's climate has become evident over the last several decades. The Department of Water Resources' (DWR) guidelines require that the Integrated Regional Water Management Plan (IRWMP) address "both adaptation to the effects of climate change and mitigation of greenhouse gas (GHG) emissions." In developing the general information in this chapter and our approach to modeling potential changes at a regional scale, we have relied extensively on work previously completed by those in other source water regions, in particular the Inyo-Mono IRWM region and, to a lesser extent, the Upper Pit IRWM region.

Though there is still debate over the anthropogenic (or man-made) contribution to climate change, the overwhelming consensus among climate scientists is that human-derived sources of greenhouse gases have sped up, if not caused, the observed warming in the last century. In the most recent report from the Intergovernmental Panel on Climate Change (IPCC), a body of international scientists and climate experts established by the United Nations, the authors state: "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" (IPCC 2007).

In the last decade several studies evaluating past changes as well as potential future changes and vulnerabilities within the USR have been undertaken. However, given the remote and rural nature of the USR, extensive information regarding climate change impacts, greenhouse gas mitigation, and adaptation strategies is not available in the same way that it is for a more populated area. The IRWM program is committed to improving the availability of climate change related information for water practitioners in the area through the availability and accessibility of the data management system (see Chapter 13, Data Management) and through the continued work of the regional water management group (RWMG) in implementing the Integrated Regional Water Management Plan (IRWMP). This will be done through partnerships with entities already doing work on climate projections, and through building on current understanding. Because the region is small and largely made up of disadvantaged communities, unless a grant opportunity specific to climate change research is made available, the Upper Sacramento, McCloud, and Lower Pit Region (USR) RWMG is not likely to be the primary investigator for future studies. However, because of the RWMG's collaborative and diverse nature, the organization represents and excellent opportunity for partnerships with research institutions, including private research, U.S. Forest Service (USFS) efforts, or state work on water supply and resources.

The discussion in this chapter will focus on anticipated climate change vulnerabilities in the USR. However, it should be noted that while climate change variability in California generally is predicted to be great in the coming century, that preliminary comparisons of variability in the State to variability in the USR show that the Mount Shasta region may potentially be buffered from climate change impacts as the variability may be slightly less. This indicates that the region may act as a potential refuge for both fish and wildlife species. In a Water Talks program put on by California Trout in early October, researchers discussed the importance of spring-fed systems as climate refugia; this potential warrants increased investment in this critical water source area to maintain the characteristics that make it potentially resilient to climate change and a resource for the rest of California.[20]

When assessing and evaluating climate change impacts and vulnerabilities, DWR's guidelines encourage IRWM regions to bear in mind four documents in particular. These documents, and how they are incorporated in this document, are briefly described below:

California Air Resources Board (CARB): *Climate Change Scoping Plan* (2008):
CARB's Scoping Plan discusses different business sectors, including water management, and recommends specific strategies that may help reduce GHG emissions. Because the USR is a source water area with minimal energy demands for water delivery (due to gravity-based delivery systems) and little energy intensive industry, much of this document is not applicable to the region. Nevertheless, in developing projects, proponents considered GHG emissions associated with project development and management, and where possible incorporated practices to reduce GHG emissions or provide alternative, renewable energy sources. Restoration and conservation projects that prevent forest loss and promote sustainable forests that act as a carbon sink are also consistent with CARB's recommendations.

DWRs' *Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water* (2008):
This white paper published by DWR urges a new approach to managing California's water and other natural resources in the face of climate change. The document emphasizes IRWM as the mechanism for fostering a collaborative regional approach to water management. At a regional level assessing and understanding vulnerability to the long-term increased risk and uncertainty associated with climate change is a key strategy. IRWM plans are expected to include projects that seek to improve understanding of springs and groundwater resources in the region, and to consider how they may be impacted by climate change. Because much of the region relies on these resources for water supply, understanding groundwater hydrology is essential for evaluating the region's vulnerability to climate change. Several statewide strategies identified in the DWR's white paper, particularly those addressing long-term funding for IRWM and management of water infrastructure, are critical to the region, and the USR RWMG had identified a potential strategy (in Chapter 15) to work together with other source water areas to advocate for the interests of these areas that are so critical to the water supply of the region as well as for the rest of the state.

California Natural Resource Agency's *California Climate Adaptation Strategy* (2009):
California Natural Resource Agency's (CNRA) Climate Adaptation Strategy (CAS) discusses statewide and sector-specific vulnerability assessments, looking, in particular, at which climate factors will be driving impacts within each sector and how impacts interact across sectors. By identifying these inter-relationships the document also highlights

[20] The Water Talks program is an ongoing series of information and educational events on water-related topics in the region and is a project of California Trout. Dr. James Thorne and PhD candidate Robert Lusardi spoke on October 2, 2013 on the topic of climate change in the USR, and specifically regarding spring-fed systems. While not specifically in the USR, one of the published studies on this topic is available at https://watershed.ucdavis.edu/pdf/Jeffres-et-al-SWRCB-2009.pdf.

opportunities to implement adaptation strategies across sectors. Strategies considered by the USR RWMG drew primarily from the following sectors addressed in the CAS:

- Biodiversity and Habitat: Potential impacts from climate change identified in the CAS include increased risk of wildfire, spread of invasive plants and animals, and loss of critical instream flows, among others.
- Water Management: Potential impacts from climate change identified in the CAS include reduced water supply due to loss of snowpack and changes in water quality.
- Forestry: Potential impacts from climate change identified in the CAS include changes in forest productivity, tree mortality, species migration barriers, increase in invasive species, changes in natural community structure, spread of diseases and insects, and reduction in ecosystem goods and services.
- Transportation and Energy Infrastructure: While the USR does not rely heavily on hydropower, hydropower energy facilities exist within the region. A decrease in water availability for hydropower generation is a potential impact from climate change identified in the CAS.

*Climate Change Handbook for Regional Water Planning* (2011):
This document was prepared jointly by DWR, United States Environmental Protection Agency (USEPA), United States Army Corps of Engineers (USACE), and the Resource Legacy Fund to assist IRWM regions in incorporating climate change analysis and methodologies into their planning efforts. This chapter closely follows the suggested guidelines laid out in that document. In particular, one of the core elements is a more detailed vulnerability assessment comprised of a series of questions related to various aspects of water management. The questions from this vulnerability assessment are addressed in Section 9.4 below.

## 9.1 Region Characterization

Chapter 3, Region Description, provides a thorough description of the USR, including climate, hydrology, geography, watersheds, and associated ecosystems, human uses, cultural resources, and water supplies and demands.

Some of the cost-share used to match the planning grant-funding award for the development of the USR IRWMP came from work completed in examining climate change in the USR. One of those projects is the long-term environmental data collection being done on Castle Lake as part of the Castle Lake Environmental Research and Education Program (CLEREP).[21] Castle Lake, located southwest of the City of Mount Shasta in the headwaters of the Upper Sacramento River watershed, has one of the longest continuous datasets (52 years) on biological, physical, and water quality parameters. One study in particular focused on ecosystem production through observing food web interactions in the lake, and how these might be affected and altered by climate change. The CLEREP study is not yet complete, but will be instrumental in understanding how species flexibility, persistence, and response may

[21] Work provided as match for this grant included researchers from Castle Lake Environmental Research and Education Program (CLEREP) continuing long-term physical and ecological monitoring from October 2008 through September 2010 and refining an empirical model based on CLEREP's dataset to investigate the effect of climate scenarios on water quality and ecosystem productivity.

occur to projected climate change effects throughout the Cascade, Sierra Nevada, and Great Basin portions of California.

One of the outcomes of the CLEREP effort at Castle Lake that has informed regional climate understanding on multiple levels is the research thesis produced in 2012 by Jacquelyn D. Brownstein. She investigated the connection between fish stocking, invertebrates, and the linkage between benthic (bottom) and pelagic (water column) feeding and energetics. Understanding how ecosystems throughout the USR function now will help landscape managers to be better prepared for the future and make decisions that add flexibility to the system in order to better accommodate adaptation as the climate changes.

Another important component of the region's vulnerability assessment is the STNF's National Climate Change Assessment of Watershed Vulnerability. The STNF, which manages large areas of land in the USR, represented U. S. Department of Agriculture's (USDA) Region 5 in this process and contributed key data and findings to the USR process. The pilot study assessed the inter-relationship of regional climate models and the projected exposure to key aquatic resources, recognizing that existing models and predictions project serious changes to worldwide hydrologic processes as a result of global climate change. Projections indicate that significant change may threaten National Forest System watersheds that are an important source of water used to support people, economies, and ecosystems.

A result of this study was the publication of *Assessing the Vulnerability of Watersheds to Climate Change: Results of National Forest Watershed Vulnerability Pilot Assessments*.

Eleven National Forests throughout the United States, representing each of the nine Forest Service regions, conducted assessments of potential hydrologic change due to ongoing and expected climate warming. A pilot assessment approach was developed and implemented. Each National Forest identified water resources important in that area, assessed climate change exposure and watershed sensitivity, and evaluated the relative vulnerabilities of watersheds to climate change. The assessments provided management recommendations to anticipate and respond to projected climate-hydrologic changes. Completed assessments differed in level of detail, but all assessments identified priority areas and management actions to maintain or improve watershed resilience in response to a changing climate. The pilot efforts also identified key principles important to conducting future vulnerability assessments. Initial priorities identified by the Forest Service in this report are to build knowledge, skills, and expertise, and to develop experience and partnerships. The report acknowledges that these initial steps will build toward planning and designing management actions to improve ecosystem resilience and improve forest response to climate change.

The study outcomes specific to the USR included an emphasis on using finer-scale assessment tools to get more detail on changes (the use of Hydrologic Unit Codes (HUCs) for sixth-order streams rather than fourth or fifth), and the importance of local historical data when assessing region-specific change. These lessons learned will be noted as the USR stakeholders proceed in their planning efforts.

## 9.2 Climate Change Impacts

Globally, air temperature has increased 1.3°F (0.7°C) over the last century (1906–2005) (IPCC 2007). This warming is not uniform, however. Polar regions are showing more warming than mid-latitude regions, at up to twice the global average rate in the last 100 years. High-elevation/mountainous regions are also experiencing increased warming. Trends in precipitation have also been observed, although not in consistent directions. Some areas, such as the Sahel, southern Africa, and parts of southern Asia have experienced decreased precipitation, while eastern North and South America and northern Europe have experienced increased precipitation. Other impacts related to these climatic changes include sea level rise, melting glaciers and polar ice caps, warming oceans, decreased snow cover, melting permafrost, droughts, and an increase in extreme weather events. All of these changes are expected to continue, if not accelerate, in the coming decades.

While it is important to understand current global climatic trends, regional and local climatic changes are more pertinent to natural resources management, planning, and policymaking. It is possible to understand past climatic trends through observed data, where they are available. Yet in order to predict future climate, scientists must use models, which are inherently imperfect. General circulation models (GCMs) are most commonly used to incorporate information about greenhouse gas emissions and other elements of the atmosphere-ocean system. These models produce large-scale output based on grid cells on the order of several kilometers, which, in mountainous areas, is not a useful scale for natural resources planning and management. Efforts to downscale GCMs and to develop regional climate models (RCMs) have improved over the last few years, although there is criticism as to the accuracy of these smaller-scale representations.

Perhaps the most criticized part of using models to project future climate is the uncertainty inherent in these models. Each model contains different assumptions about the atmosphere-ocean system and parameterizes elements of the climate differently. Thus, each model delivers slightly different projections of future temperature, precipitation, and other climatic variables. To use just one model as an indication of future climate is, therefore, problematic. Instead, the convention is to use an ensemble of several climate models to create a general picture of future climatic trends. In this way, the uncertainty of each model is accepted, but it does not prevent the use of climate models in climate change analyses.

A 2009 study commissioned by the California Climate Action Team (CAT), a group of state government officials working to implement greenhouse gas emissions reductions programs as well as the state's Climate Adaptation Strategy, used six GCMs to drive subsequent impact analyses (DWR 2010). These GCMs were selected based on their ability to model historical precipitation and temperature patterns and variability, as well as the El Niño Southern Oscillation, and are listed in Table 9.1, below.

**Table 9.1: General circulation models used by the California CAT and by those models used here.**

| Number | Model Name; group, country | Model ID | Primary Reference Year |
|---|---|---|---|
| 1 | Parallel Climate Model; National Center for Atmospheric Research (NCAR), USA | PCM | 2000 |
| 2 | Geophysical Dynamics Laboratory model version 2.1; U.S. Department of Commerce/National Oceanic and Atmospheric Administration (NOAA)/Geophysical Fluid Dynamics Laboratory, USA | GFDL-CM2.1 | 2006 |
| 3 | Community Climate System Model; NCAR, USA | CCSM3 | 2006 |
| 4 | Max Planck Institute for Meteorology, Germany | ECHAM5/MPI-OM | 2006 |
| 5 | Center for Climate System Research (University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change, Japan | MIROC3.2 (medres) | 2004 |
| 6 | Meteo-France/Centre National de Recharches Meteorologiques, France | CNRM-CM3 | 2005 |

One of the primary drivers of GCMs and RCMs are GHG emissions scenarios. The IPCC has developed a set of possible future GHG emissions based on different scenarios of global population growth, economic growth, and government regulations of GHGs, etc. (IPCC 2007). GCMs and RCMs incorporate these emissions scenarios to produce a suite of possible climatic changes.

A collaboration of research institutions and federal agencies has made the models, along with others, readily available through the World Climate Research Programme's (WRCP's) Coupled Model Intercomparison Project Phase 3 (CMIP3) model output archive[22]. Through the archive's website, the user can request biased-corrected spatial downscaled (BCSD) model output for any geographic region and for any time period within the 21st century. Both temperature and precipitation projections are available. This set of projections has been widely reviewed and used by scientists and practitioners in California. Models can be run with any combination of three IPCC Special Report on Emissions Scenarios (SRES) — A1B, A2, or B1. These emissions scenarios represent a set of "best guesses" of what future emissions might be based on population, economic conditions, energy sources, technological development, environmental policy, etc. A1B is a medium-emissions scenario, reaching approximately 700 parts per million (ppm) CO2 by 2100 (global CO2 is currently approximately 400 ppm). B1 represents a lower-emissions scenario, leveling-out at just over 500 ppm by 2100, while A2 is a higher-emissions scenario and reaches 850 ppm by 2100.

Several different runs of the six GCMs listed in Table 9.1 were used for an analysis of projected climatic changes for the USR for the 21st century, using the downscaling method described above. Data from the CMIP was used and the project team analyzed this data to get the results described in this chapter. Only the A2 and B1 emissions scenarios were used, in order to bound the high and low probabilities of changes in the atmosphere. Because the

[22] Available at: http://gdo- dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html#Welcome.

model output is only available on a grid scale, it was not possible to request projections for true watersheds. Instead a rectangle including the boundaries of the region was used as a best approximation.

Projections of temperature and precipitation were examined through the 21st century. For each year, average temperature was calculated for each of the two emissions scenarios. In addition, the highest temperature value and lowest temperature value were identified in an attempt to elucidate the range of possible temperature scenarios. Similarly, cumulative precipitation was calculated for each year based on the model output and two emissions scenarios. An average was calculated over the six models and then a highest precipitation value and lowest precipitation value were identified in order to acknowledge the uncertainty in the projections and the range of possibilities.

The graphs below show the outputs for these models for average daily temperature (Figure 9.1) and precipitation (Figure 9.2). For both emissions scenarios, temperature is expected to increase over the next century, increasing on average 0.019°C /year for the B1 scenario and 0.040°C /year under the A2 scenario. This means that under the more extreme A2 scenario, the models show that temperatures would be expected to increase on average by 4.2 °C (or 7.6 °F) between 2000 and 2100. There is less of a clear trend with the model outputs for precipitation. The A2 scenario shows a slightly larger decrease in annual precipitation across the region; however, the decrease is not substantial under either scenario. What is shown is increasing variability in the amount of precipitation from year to year. A finer analysis might also reveal changes in timing or concentration of precipitation. These would be interesting topics for future investigation by members of the RWMG.

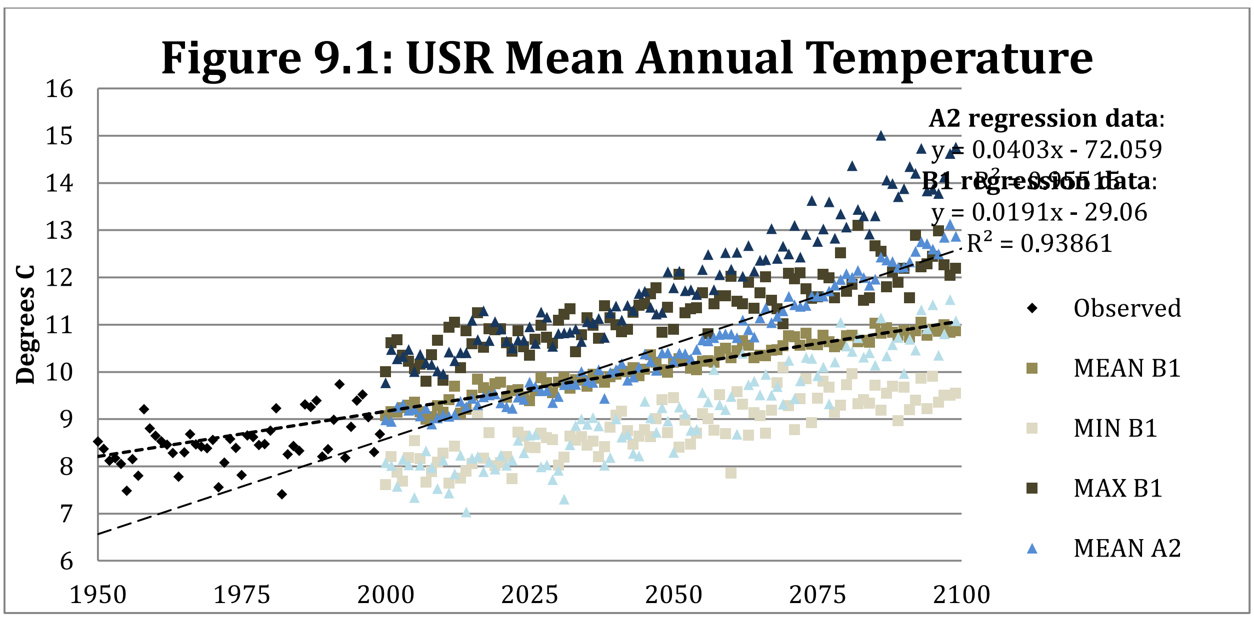
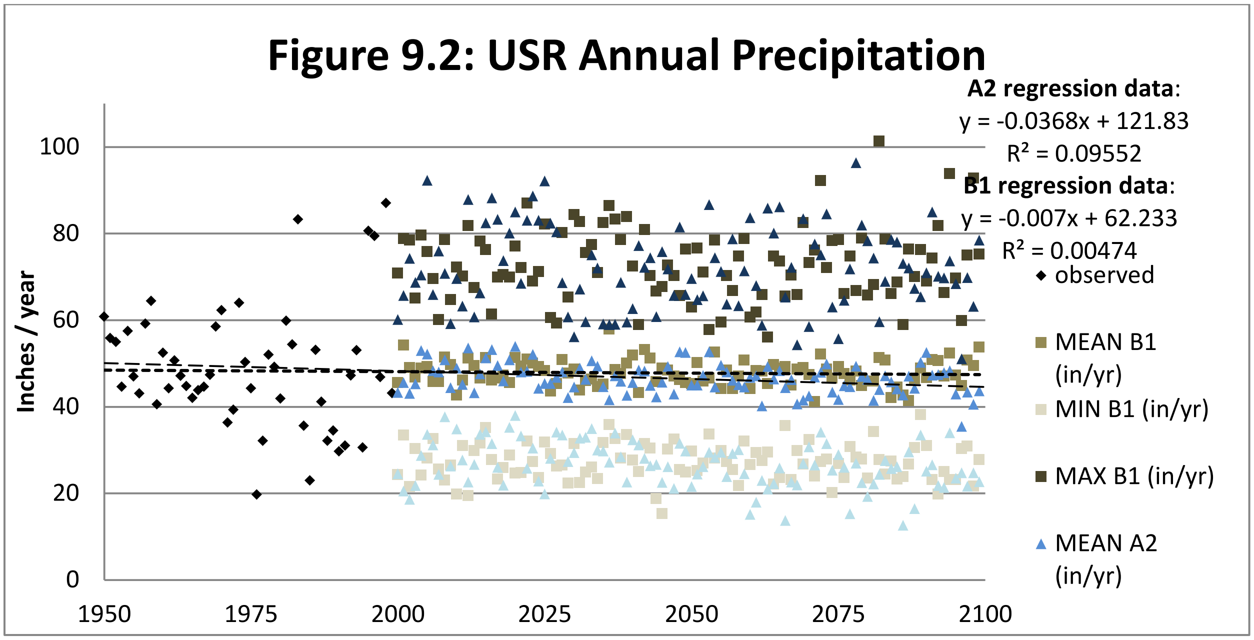


**Figure 9.1: USR Mean Annual Temperature**




### 9.2.1 Water Supply

When considering climate change impacts to water resources in the USR, the biggest concerns are with changes to the winter snowpack, glaciers, and long-term impacts on groundwater and spring resources. The connection between precipitation (snow and rain) that falls on Mount Shasta and the surrounding ranges that comprise the watersheds of the USR and the numerous springs that supply much of the water supply for the residents of the region is only beginning to be understood. California Trout's spring assessment (2009) and vulnerability assessment (2011), discussed in greater detail in Chapter 3, gave some insight into the complex interactions between climate, weather, and geology that affect the springs. Significant variation was found in the recharge elevation, residence time, and seasonal fluctuations in spring discharge. These findings suggest that some of the springs may be more vulnerable to impacts from climate change, especially springs with a lower recharge elevation and shorter residence time being most susceptible to changes in mountain snowpack.

Research done by the United States Geological Survey (USGS) on the Klamath Basin (immediately north of the USR, where geologic conditions may be similar), indicate that, while groundwater dependence and the occurrence of springs do buffer users somewhat from climate change, the "ground-water system in the upper Klamath Basin responds to external stresses such as climate cycles, pumping, lake stage variations, and canal operation. This response is manifest as fluctuations in hydraulic head (as represented by fluctuations in the water-table surface) and variations in groundwater discharge to springs. Basin-wide, decadal-scale climate cycles are the largest factor controlling head and discharge fluctuations. Climate-driven water-table fluctuations of more than 12 feet have been observed near the Cascade Range, and decadal-scale fluctuations of 5 feet are common throughout the basin. Ground-water discharge to springs and streams varies basin-wide in response to decadal-scale climate cycles" (USGS, 2010).

Further compounding this complex issue, previous research by Howat, et al. (2006) showed that the primary driver of the extent of the glaciers on Mount Shasta is precipitation, not temperature. Since there is much less agreement among models on precipitation, it follows that the future trends in the glaciers would also be uncertain, which is what Howat, et al. found. While some models showed the extent of Mount Shasta's glaciers continuing to expand downslope through 2100, under other models, the glaciers completely disappear by 2100.

Forest management adaptations to extreme precipitation, higher temperatures, and more extreme weather events are paramount to how the USR, surrounding regions, and much of northern California adapts to climate change with respect to water supply and ecological needs. Because the USR is the source water area for Shasta Lake Reservoir (California's largest surface water reservoir), which supplies water to much of California, understanding how specific management strategies affect the forests' response to climate change will continue to grow in importance. The USFS program Forests to Faucets is a good example of the growing understanding surrounding urban regions' and economies' dependence upon forested watersheds for water supplies.

### 9.2.2 Water Demand

The potential impacts of climate change on water demand in the USR have not been analyzed. Because of the sparse population, water demand is not high; however, during peak summer use, daily usage does, at times, exceed daily output from water sources, particularly in the City of Mount Shasta. The primary use for water during high demand times is maintenance of residential landscaping. Without changes in practices, it is likely that water usage will increase as temperatures increase. There are opportunities to reduce water demand, as demonstrated by the lower per capita usage in the City of Dunsmuir following the installation of water meters. In addition, regional jurisdictions may want to investigate the potential for temporary storage options, such as additional water tanks.

### 9.2.3 Water Quality

Water quality in the USR is very good and is considered to be some of the highest quality water in the United States. The protection of this resource is paramount to the USR and the State of California.[23] The primary threats to water quality in the USR are from transportation infrastructure, road and rail, the extensive network of dirt roads on both private and public forestlands, and, in the Lower Pit River, upstream agricultural practices. The increased risk of catastrophic wildfire associated with a changing climate, higher temperatures, and prolonged periods of drought, followed by significant storm events, can result in run-off and sedimentation that pose a significant threat to water in the USR. This combination of high intensity wildfire followed by intense rainfall was well illustrated during the late fall / early winter storms in 2012 following the 50,000-acre Bagley Fire. The result was massive volumes of debris flowed into Squaw Creek and several tributaries of the McCloud River. Stakeholders have suggested that a study of Squaw Creek may be helpful in understanding future climate effects in the USR; with a stand-replacing fire followed by two substantial floods, this may represent the region's future.

[23] Letton, Ben; personal communication 7/31/2013.

### 9.2.4 Flooding

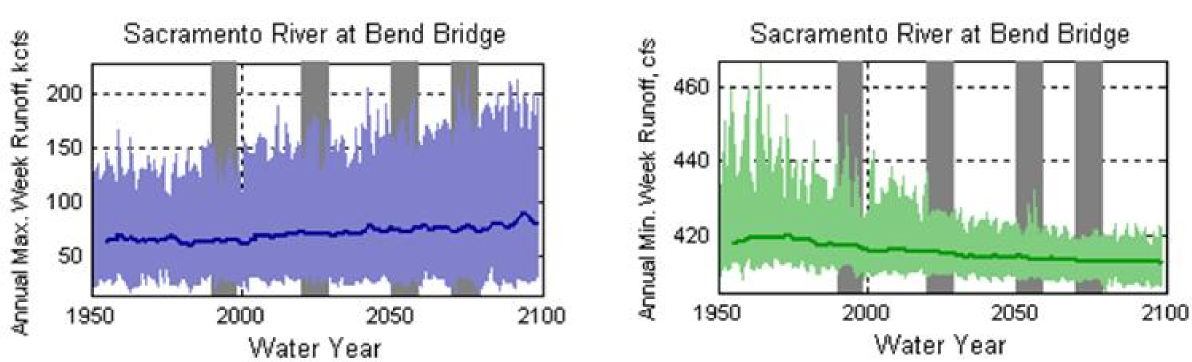
Although the USR does not experience flooding on the scale of the Sacramento-San Joaquin Delta or the Central Valley, localized flooding can be a major concern. The communities of McCloud and Dunsmuir, as well as several smaller communities along the Upper Sacramento River, have been impacted by flooding. In the USR, flooding is of greatest concern during rain-on-snow events. There have also been occasional significant impacts from debris flows associated with sections of Konwakiton Glacier (one of Mount Shasta's glaciers) breaking off, the most notable being in Mud Creek, a tributary to the McCloud River, which experienced substantial mud flows in years between 1924 and 1931. The impacts of warming temperatures and changing precipitation patterns on both of these types of events are not clear, but it seems likely that there could be an increased risk of flooding and debris flows, for which communities that fall in the USR's floodplains need to be prepared.

### 9.2.5 Ecosystem and Habitat Vulnerability

Impacts of a changing climate on terrestrial and aquatic ecosystems have been studied worldwide. One of the primary concerns related to climate change impacts on ecosystems is the movement of animal and plant species. In the USR, biologists from the STNF undertook vulnerability assessment as part of a pilot project implemented nationwide by the USFS. As part of this pilot study they identified that sensitive aquatic species were especially vulnerable to habitat loss due to potential increased risk of drying of small ponds and streams. In addition, threatened and endangered aquatic species were at risk due to warmer base flows.[24]

The Bureau of Reclamation, in its Draft Climate Change Modeling Appendix to the Shasta Lake Water Resources Investigation (U.S. Bureau of Reclamation 2013), shows the annual maximum runoff rising slightly over the next century (see graph below), while the annual minimum decreases slightly. Higher annual maximums indicate an increase in the number of extreme events (flooding), while lower annual minimums indicate decreased base flows through the dry season.

**Figure 9.3: Maximum and minimum annual flow projections of the Sacramento River to 2100. Source: Bureau of Reclamation Draft Climate Change Modeling Appendix to the Shasta Lake Water Resources Investigation**




[24] Mai, Christine; personal communication 2012.

## 9.3 Regional Climate Change Vulnerabilities, and Adaptation and Mitigation Strategies

This section examines major vulnerabilities related to water resources following the categorized impacts of the previous section. The questions posed follow the guidance provided in the *Climate Change Handbook for Regional Water Planning* (2011). Following each category are resource management strategies that could be employed to enhance regional adaptation to climate change impacts and/or mitigation of those impacts through decreased emissions. A useful companion piece to this review is the Western Shasta Resource Conservation District's (RCD's) Forest and Water Climate Adaptation: A Plan for Shasta County, California (Bryan, et al. 2012). While specific to the Shasta County portion of the USR, much of the information regarding vulnerabilities, as well as the strategies identified for adaptation, could be applied throughout the region. An important point for the USR is that any adaptive strategy must be practical and pragmatic because projected effects are usually vague and cannot be pinpointed. According to the RCD's plans, it is important to preserve the adaptive capacity of the region through increasing systemic flexibility and preserving resource managers' available options.

### 9.3.1 Water Supply

1) *Does a portion of the water supply in the region come from snowmelt?*
   Yes. Most communities in the region rely on spring water sources that are recharged primarily by snow that falls on the slopes of Mount Shasta. Recent studies of have found that both the recharge elevation of these springs and the residence time of the water underground vary widely among the springs, indicating that some supplies may be more vulnerable to impacts from climate change than others (California Trout 2009). A few small communities in the region rely on surface water diverted from streams that are fed by a combination of snowmelt and perennial springs. The region is largely forested, which presents an excellent opportunity for strategic management in order to preserve snowmelt and rainfall, and to enhance natural storage capacity.

2) *Would the region have difficulty in storing carryover supply surpluses from year to year?*
   Yes. There is almost no long-term storage capacity within the region associated with water supply above Shasta Lake Reservoir. That said, there is limited storage capacity associated with flood control and power supply infrastructure in the Upper Sacramento (Lake Siskiyou reservoir), McCloud (McCloud Reservoir), and Lower Pit (Iron Canyon and Pit 4, 5, and 6 Reservoirs) watersheds. The significant water storage in the region is in the groundwater systems, which are not well understood.

3) *Has the region faced a drought in the past during which it failed to meet local water demands?*
   Recent significant drought periods in California, from 1975–1977, 1987–1992, and in 2001, have had some impacts in Siskiyou and Shasta County; however, because community water systems in the region are dependent on perennial spring water sources, these communities are somewhat buffered from the impacts of drought. That said, in some dry years, the City of Mount Shasta has restricted water use by means of an odd/even day irrigating restriction, but never for domestic use. This has not been

implemented since the mid-1980s. Since that time, the City of Mount Shasta has added an additional well to the water supply system, and has better monitoring of storage tank levels.

4) *Does the region have invasive species management issues at its facilities, along conveyance structures, or in habitat areas?*
There are no invasive species issues that are currently impacting water infrastructure in the region. New Zealand mud snail has recently been found in Shasta Lake Reservoir and could easily be transported into USR rivers, streams, and reservoirs on boats or boots. While the mud snail may not have significant impact on water infrastructure as compared to other parts of California, its presence could have significant impacts on native aquatic populations and could affect regulatory activities throughout the region.

There are several invasive plants that are abundant along watercourses in the region including brooms, Marlahan mustard, and dyer's woad. With climate change altering the historic temperature and moisture regimes, these species are likely to grow quickly, creating a fire risk, using up water resources, and outcompeting native riparian species that are a food source for wildlife. Invasive species can represent a serious threat to the health of natural environments and habitats and agricultural and ranching operations, and can alter entire ecosystems by outcompeting natives. It is likely that climate change will only encourage this progression, so human action will be necessary to control the risk to resources and of catastrophic fire. (Bryan, et al. 2012)

<u>RMS for adapting to water supply vulnerabilities</u>:

- Regional/local Conveyance: add efficiency and control invasive species
- Recycled Municipal Water: to extend summer supplies for landscape use
- Conjunctive Use: high-flow/precipitation years could result in greater groundwater storage
- Regional/local Surface Storage: expand carryover capacity for rainwater throughout the region
- Ecosystem Restoration: functional ecosystems help to provide a more consistent water supply, and controlling invasive species will help the natural ecosystem to adapt without competition
- Groundwater Management: closely monitor seasonal flows to understand the groundwater/surface water dynamic
- Forest Management: see Ecosystem Restoration
- Watershed Management: see Ecosystem Restoration, also increase knowledge regarding groundwater interactions and use throughout the USR
- Land Use Planning and Management: identify recharge areas, and areas of low groundwater dependability, and avoid development in those areas
- Pollution Prevention: protect water supplies through maintaining beneficial uses
- Drinking Water Treatment and Distribution: ensure that distribution systems are efficient and effective

### 9.3.2 Water Demand

1) *Are there major industries that require cooling/process water in the planning region?*
There are several water bottling plants in the region. These facilities rely on spring water and groundwater for their operations. Apart from the bottling plants, there are no other industries in the region that currently demand significant quantities of water.

2) *Does water use vary by more than 50% seasonally in parts of the region?*
Yes. Summer use of water is several times the amount of winter use in the communities of Mount Shasta, Dunsmuir, and McCloud. Primary use of water during these periods of heavy use is for maintenance of residential landscaping. Particularly in Mount Shasta and McCloud, where there are no water meters, average household monthly water demand in the summer far exceeds averages statewide.

3) *Are crops grown in the region climate sensitive?*
There is no large-scale agriculture in the region.

4) *Do groundwater supplies in the region lack resiliency after drought events?*
Due to the volcanic geology of the region, groundwater resources are extremely complex and poorly understood. Recent studies by California Trout (2009) reflect some of this complexity, indicating that groundwater that emerges as springs around the region originates at varying elevations and resides underground for long periods of time, in some cases more than 50 years. While spring flows do vary seasonally and year to year, how these fluctuations are impacted by periods of extended drought is not currently known. Given the vast water resources found in this region, this is an area in need of additional study.

5) *Are water use curtailment measures effective in the region?*
Maybe. Given the relatively abundant water supply in the region, there have been few water use curtailment efforts. Water usage throughout the USR is far above state averages, particularly in summer months, so there is likely some cost effective “low-hanging fruit” to reduce water use in the region. Furthermore, average daily water usage in Dunsmuir, the only town in the USR to have installed water meters, is significantly less than in other communities, suggesting that curtailment measures could be effective if implemented.

6) *Are some instream flow requirements in the region either currently insufficient to support aquatic life, or occasionally unmet?*
No. With abundant perennial water supplies in all three watersheds and relatively little consumptive use of water from streams in the region, there is little problem with meeting instream flow requirements to support aquatic life. There is need to maintain adequate outflows from dams in the region, as regulated by licensing programs (e.g. Federal Energy Regulatory).

<u>RMS for adapting to water demand vulnerabilities</u>:

- Urban Water Use Efficiency: increase efficiency, especially for summer uses

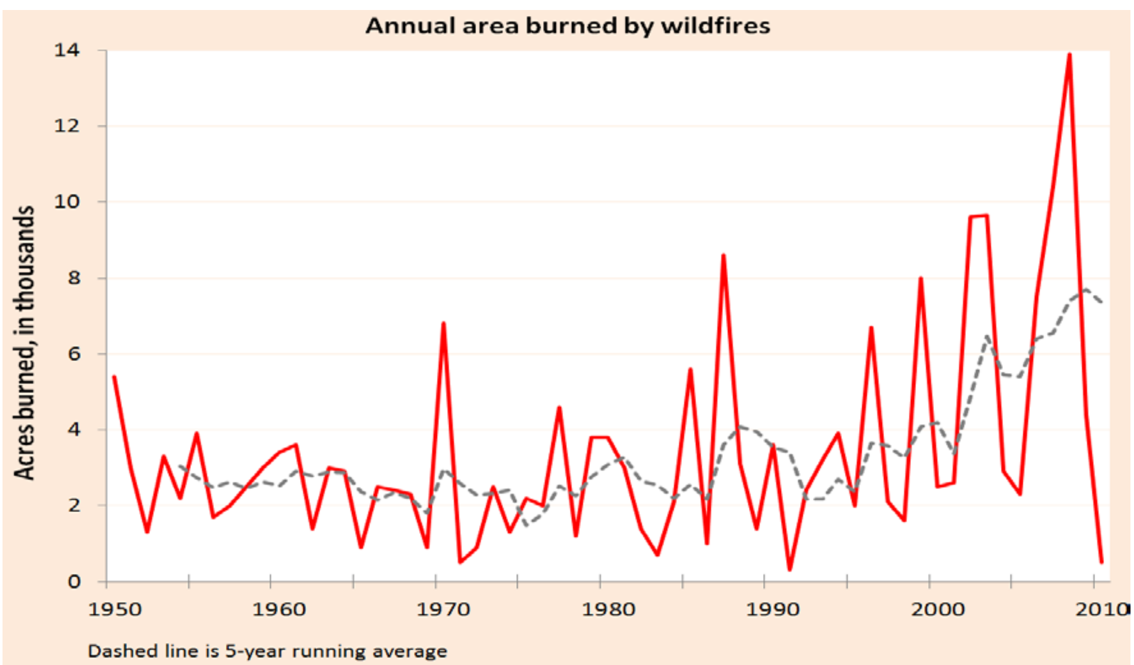
- Watershed Management: see Ecosystem Restoration, also increase knowledge regarding groundwater interactions and use throughout the USR
- Ecosystem Restoration: quantify ecosystem needs
- Land Use Planning and Management: use low-impact-development design wherever possible to minimize water use
- Education: ensure that water users understand the significance of potential change and how to adjust their water use habits
- Economic Incentives: could be used to encourage conservation

### 9.3.3 Water Quality

*1) Are increased wildfires a threat in the region? If so, does your region include reservoirs with fire-susceptible vegetation nearby which could pose a water quality concern from increased erosion?*

Yes. Wildfire is a pervasive threat to communities and water resources throughout the region. While local communities do not rely heavily on surface water resources in the USR, the watersheds are critical source water areas for the Central Valley Project, which provides water for municipal and agricultural uses throughout California. In 2012 the Bagley fire burned nearly 50,000 acres of rugged, difficult to access timberland in the McCloud and Squaw Creek watersheds. Extreme fire behavior in the summer followed by significant rainfall events that November and December resulted in significant erosion in these watersheds and substantial inputs of sediment and larger debris to Shasta Lake Reservoir.

**Figure 9.4: Annual area burned by wildfires in California between 1950 and 2010. Source: OEHHA 2013 update to Indicators of Climate Change in California.**




The potential for more frequent, extreme fire behavior is undoubtedly a risk associated with predicted temperature increases, longer dry periods, and, potentially, more storms. All the major reservoirs in the region are surrounded by mature, often over-stocked timber stands that are susceptible to natural or anthropogenic fire ignition. Potential impacts from wildfires on water quality are prevalent throughout the USR; areas of particular concern include the Upper Sacramento River canyon and Rainbow Ridge above Lake Siskiyou Reservoir due to the increased risk of ignition in the wildland-urban interface and along roads and railroads.

The California Office of Environmental Health Hazard Assessment (OEHHA) recently updated their 2009 report: Indicators of Climate Change in California. In this report, OEHHA states that "[t]he area burned by wildfires each year is highly variable, ranging from 31,000 acres in 1963 to 1.4 million acres in 2008, making it difficult to determine long-term trends. However, the data suggest a trend toward increasing acres burned statewide since 2000. The three largest fire years since 1950 have occurred in the past decade (2003, 2007 and 2008), and the annual average since 2000 (598,000 acres) is almost twice that for the 1950–2000 period (264,000 acres)."

2) *Does part of the region rely on surface water bodies with current or recurrent water quality issues? Are there water quality constituents potentially exacerbated by climate change?*
The Pit River is on the 303(d) list for nutrients, dissolved oxygen, and temperature. While surface water is not a large component of local water supplies, there are several small communities and Rancherias along the Pit River that rely on Pit River as a source of water. While flows in the Lower Pit River are heavily managed due to the series of dams and diversions for hydroelectric production on the river, increased temperatures and lower flows that could result from climate change have the potential to exacerbate the water quality issues already present in the Pit River.

In addition to the Pit River, West Squaw Creek and the portion of Shasta Lake Reservoir affected by the creek inflow are listed for cadmium, copper, lead, and zinc. While outside the USR planning area, the entirety of Shasta Lake Reservoir is listed for mercury.

As the region is largely forested, greater understanding of the role the forests play in preserving and improving water quality is an important consideration. Specific forest management strategies could aid in preserving summer base flow, supply water of adequate temperature and quantity for endangered species, and attenuating extreme precipitation events.

3) *Are seasonal low flows decreasing for some water bodies in the region? Are the reduced flows limiting the water bodies' assimilative capacity?*
To date, summer flows have not been observed to be decreasing in the USR's major rivers. As mentioned elsewhere, base flows remain relatively high on many streams in the region due to abundant perennial spring sources, which provide somewhat of a buffer as far as water supply and stream temperature throughout the region. That said, the current trends in flows are not well studied, and the potential long-term impacts and shifts in hydrology as a result of climate change are not well understood. The

impacts to assimilative capacity of local water bodies is of particular concern in the Upper Sacramento River where both Mount Shasta and Dunsmuir currently have permits to discharge treated effluent to the river from their wastewater treatment plants (WWTP). Seasonal low flows below Box Canyon dam, where the City of Mount Shasta's WWTP discharges, are already necessitating facility upgrades. Decreasing future flows could exacerbate this problem for the City of Mount Shasta.

The flow requirements on regional reservoirs for their downstream rivers have been met in the past, but the future for these flow requirements is unknown due to regulatory uncertainty. Box Canyon Dam, run by the Siskiyou Power Authority, has a mandate for temperature, dissolved oxygen, and flow into the river below the dam. While there has never been a problem with the dissolved oxygen and temperature (the water is pulled from deep in the reservoir, maintaining a cool temperature; it then runs through the power production mechanism, which substantially increases the dissolved oxygen content), the outflow required is more than the inflow during most summer months. The facility is outside Federal Energy Regulatory (FERC) oversight, so power production capacity projections have not been completed, and are currently unknown. It is possible that, because of projected climate effects on regional hydrology (longer periods of drought, with precipitation occurring less often, but with greater intensity), the flow mandate for Box Canyon Dam will become increasingly difficult with which to comply.

Future consumptive use of spring and groundwater by bottled water and beverage plants could reduce local river and stream flows due to the dependence of these waterways on springs and groundwater for the majority of their flow.

4) *Are there beneficial uses designated for some water bodies in the region that cannot always be met due to water quality issues?*
   Yes. In 2012, the City of Mount Shasta renewed its discharge permit for its WWTP. The permit included a compliance schedule for several contaminants because it is not currently able to meet discharge limits associated with one or more of the designated beneficial uses in the Upper Sacramento River, which include municipal and agricultural water supply, water-contact recreation, cold freshwater habitat, and wildlife habitat. The City of Mount Shasta is currently exploring options for upgrades to its plant, all of them likely costing several million dollars, to meet these standards.

5) *Does part of the region currently observe water quality shifts during rain events that impact treatment facility operations?*
   Yes. During significant precipitation events there is increased inflow and infiltration into wastewater collection pipes, as well as sedimentation, some of which makes its way into municipal treatment systems. The challenge, however, is not so much the constituents of this runoff, but the volume of the runoff that must be treated. WWTPs for water service utilities in all three of the region's communities (Mount Shasta, Dunsmuir, and McCloud) have limited capacities that are unable to handle high volumes during significant rain or rain-on-snow events.

RMS for adapting to water quality vulnerabilities:

- Matching Quality to Use: this may stretch USR water supplies
- Agricultural and Urban Water Use Efficiency: taking less water out of streams could allow for greater instream flow, and great dilution capacity
- Agricultural Lands Stewardship: agricultural lands could represent a carbon sequestration opportunity, and best management practices encourage on-farm runoff management
- Ecosystem Restoration: a functional ecosystem will help to filter polluted water, and will keep water at a temperature that is good for aquatic biota
- Forest Management: address catastrophic wildfire risk with fuels control efforts, address capacity of roads to withstand larger precipitation and post-fire runoff events, and maintain adequate forest cover to ensure clear cold-water streams
- Watershed Management: see Ecosystem Restoration, also, effective groundwater management will maintain the resource for use by all
- Water-dependent Recreation: ensure that recreation activities are designed and managed to protect water quality
- Pollution Prevention: take action to protect all waters from pollution
- Groundwater/aquifer Remediation: in the localized areas where historic industry may be a point source, work to control that pollution
- Drinking Water Treatment and Distribution: identify potential threats and work to remediate those; ensure that infrastructure is efficient and managed to a high standard
- Urban Runoff Management: prevent avoidable urban runoff
- Wastewater Treatment: make sure that wastewater treatment plants are designed and operated to standards that protect the waters to which they contribute
- Education: ensure that the public is aware of water quality issues and how to protect water quality

### 9.3.4 Flooding

1) *Does critical infrastructure in the region lie within the 200-year floodplain?*
200-year floodplain mapping is not available for the USR. Instead, 100-year data were used. Because of the generally high relief terrain, virtually no broad floodplains are present in the region. According to the Siskiyou County – Draft Hazard Mitigation Plan (2011), the majority of flood related hazards have to do with transportation. Roads are typically closed due to varying degrees of erosion-related washout; sections of Interstate 5 and Highway 89 pass through the 100-year floodplain and thus are exposed to flooding.

2) *Does aging critical flood protection infrastructure exist in your region?*
There is little flood protection infrastructure in the region. There are some older levees, but their exact extent is undetermined. Many of these older levees were built under earlier flood control and flood management goals, are exposed to scouring, and are at risk of failure. Some of the dams in the region were built with flood control as one of their intended purposes (e.g. Box Canyon Dam on the Upper Sac), though this is not their primary purpose.

3) *Have flood control facilities been insufficient in the past?*
There is no documented failure of flood control facilities (dams or levees) in the USR.

4) *Are wildfires a concern in parts of the region?*
Yes. Wildfires and potential flooding as a result of the loss of vegetation is a serious concern. See discussion regarding wildfires under Question 1 in Section 9.4.3, above.

RMS for adapting to flooding vulnerabilities:

- System Reoperation: manage water storage and conveyance facilities with climate projections in mind to better protect infrastructure from flooding
- Conjunctive Use: high-flow years could result in greater groundwater storage
- Regional/local Surface Storage: additional storage, or re-operated facilities, could contribute to flood security for local communities and infrastructure
- Agricultural Lands Stewardship: best management practices encourage water infiltration, which could attenuate peak flows
- Ecosystem Restoration: see Agricultural Lands Stewardship
- Forest Management: address catastrophic wildfire risk with fuels management projects
- Watershed Management: see Agricultural Lands Stewardship
- Land Use Planning and Management: avoid urban development in flood-prone areas
- Flood Risk Management: identify the flood risk throughout the USR
- Education: ensure that regional inhabitants and recreationalists understand regional flood dangers

### 9.3.5 Ecosystem and Habitat Vulnerability

1) *Does the region include aquatic habitats vulnerable to erosion and sedimentation issues?*
Yes. Because of the complex topography of the region and numerous waterways, erosion is an ongoing occurrence. As discussed earlier, the most significant threat to aquatic habitats is erosion exacerbated by extreme wildfire events.

2) *Do climate-sensitive fauna or flora populations live in the region?*
All plant and animal species are sensitive to shifts in climate in some way, although some species have broader tolerances than others. Generally wide-ranging or broadly distributed species like deer, bear, mountain lion, and ponderosa pine are better able to adapt to changing conditions. Species with narrow distributions or those whose presence in the USR is already at the edge of their habitat envelopes are at greater risk. For example, McCloud Redband trout, which only occur in a few small upper watershed streams, may be vulnerable to more frequent or extended dry periods. Overall, there has been little research on the potential impacts of climate change on species within the region.

3) *Do endangered or threatened species exist in the region? Are changes in species distribution already being observed in parts of your region?*

The only federally-listed species in the region is the Northern Spotted Owl, which is listed as threatened. The Pacific Fisher is currently a candidate species for listing under the Endangered Species Act. In addition, as discussed elsewhere in this document (Chapter 3, Region Description), the feasibility of restoring endangered winter-run Chinook salmon to portions of the McCloud or Upper Sacramento watersheds is being explored.

While not threatened or endangered, the local Redband Trout population inhabits some areas of intermittent and/or isolated stream segments (see Chapter 3, Region Description). This is located in the McCloud watershed, and these segments are largely spring-dependent. While the springs provide some buffer against low flows, extended drought could dry the streams, springs, and thereby strand or kill these trout populations. While some Redband would remain in other, more connected portions of regional waterways, losing this diversity would decrease regional biodiversity.

4) *Does the region rely on aquatic or water-dependent habitats for recreation or other economic activities?*
Yes. The area has a rich history of recreation and related tourism, much of it based around enjoyment of water resources. The beauty of the area, mineral springs, and other recreational opportunities have been a draw to the area since the late 19$^{th}$ century. The rivers, lakes, and streams provide opportunities for hiking, camping, fishing, and boating. All three watersheds are popular destinations for anglers; both the McCloud and Upper Sacramento are renowned for world-class cold-water trout fishing. The area around Mount Shasta is also a destination for tourism, an important component of which is the high quality spring waters that flow from the mountain.

5) *Does the region include one or more of the habitats described in the Endangered Species Coalition's Top 10 habitats vulnerable to climate change?*
No.

6) *Are there areas of fragmented aquatic or wetland wildlife habitat within the region? Are there movement corridors for species to naturally migrate? Are there infrastructure projects planned that might preclude species movement?*
Dams fragment aquatic habitat and prevent movement of fish and other aquatic species in all three watersheds in the region to varying degrees. Because of the rural nature of the region, terrestrial and wetland habitats are fairly intact, allowing for relatively unobstructed movement of most wildlife in a north-south pattern, allowing for access to a variety of elevations. The Interstate and railroad may be an obstacle to some wildlife movement between the Eddys and Mount Shasta (east-west movement). In recent years there has some been some development of wind power at the eastern edge of the region near around Hatchet Mountain. Impacts on avian and other species from these projects are not well understood.

RMS for adapting to ecosystem and habitat vulnerabilities:

- System Reoperation: address projected climate effects through system reoperation (low base flows, etcetera)
- Conjunctive Management and Groundwater Storage: make use of this strategy where possible to keep flows in the river when in a dry year
- Agricultural and Urban Water Use Efficiency: increased efficiency could maintain higher summer base flows
- Agricultural Lands Stewardship: implementing species management on grasslands could enhance the habitat value of agricultural lands
- Ecosystem Restoration: good habitat and ecosystem values adds flexibility into the system that should accommodate projected climate change impacts
- Forest Management: catastrophic fire is one of the most — if not the most — important and high-profile vulnerabilities for ecosystems, terrestrial and aquatic; fuels management is an important component of adaptation to climate change
- Watershed Management: address catastrophic wildfire risk with fuels control efforts
- Land Use Planning and Management: a careful identification of areas of high habitat value could result in avoided development in order to preserve these locations
- Education: this is an essential component of any adaptation strategy to reinforce the values provided by a functional ecosystem and rich biodiversity

### 9.3.6 Hydropower

1) *Is hydropower a source of electricity in the region?*
Pacific Power is the primary provider of electricity in the region. As of 2011, about 8.4% of their electricity was generated by hydropower. None of Pacific Power's hydroelectric facilities are located within the region; however, Pacific Gas & Electric generates substantial amounts of hydropower from its facilities in the McCloud and Pit River watersheds. Box Canyon Dam, located on the Upper Sacramento River, generates a small amount of hydropower. Box Canyon Dam is owned by the Siskiyou Power Authority, which is part of Siskiyou County government. This power operation is not large enough to come under FERC regulations, though it does have flow requirements. Please see Section 9.4.3, Water Quality: Question 3 (regarding flows) for more information regarding this power operation. The Redding Electric Utility, while outside the region, gets approximately 30% of its power from the power operations of the Central Valley Project, of which the power operations at Shasta Dam are a part. Climate change could substantially alter the power production of the Shasta Dam hydropower facilities due to higher temperatures reducing snowpack, a changed hydrologic regime, and higher rates of evaporation and transpiration in the feeder watersheds (e.g. the USR) (Bryan, et al. 2012).

2) *Are energy needs in the region expected to increase in the future? If so, are there future plans for hydropower generation facilities or conditions for hydropower generation in your region?*
While energy use throughout California has decreased as population has increased — due to efficiencies and public information campaigns — statewide energy needs are

expected to increase as the temperature warms due to increased use and dependence on cooling technologies. While there is likely little opportunity for development of additional major hydropower facilities in the region, the abundant spring water sources and high topographical relief do present opportunities to develop in-line hydropower associated with existing water delivery infrastructure. This opportunity is being explored by the McCloud Community Services District to meet local demand, as identified in Chapter 10, Project Development. The feasibility studies in McCloud could be applied to other communities in the region.

RMS for adapting to hydropower production vulnerabilities:

- System Reoperation: this could be examined in order to accommodate hydropower production under projected climate change effects
- Regional/local Surface Storage: additional storage could provide for additional resources for hydropower production

Table 9.2, below, shows a succinct summary of the climate change impacts, vulnerabilities, and adaptive strategies associated with each category of water use and resources, as described in the text above. More detail regarding how the strategies will be used is available in Chapter 8, Resource Management Strategies.

**Table 9.2: The impacts, vulnerabilities, adaptation strategies, and opportunities based on different categories of water use and resources in the USR.**

| Category | *Impacts* | *Vulnerabilities* | *Adaptive Strategies* |
|---|---|---|---|
| **Water Supply** | • Changes in amount of snowpack water equivalent<br>• Loss of storage with the retreat of glaciers<br>• Timing of snowmelt, runoff and streamflow<br>• Increased rain-on-snow events<br>• Extreme precipitation events<br>• More rain, less snow<br>• Groundwater recharge and storage<br>• Greater demands on storage infrastructure | • Storage capacity<br>• Springs recharge<br>• Knowledge of groundwater supply | • Regional/local Conveyance<br>• Recycled Municipal Water<br>• Conjunctive Use<br>• Regional/local Surface Storage<br>• Ecosystem Restoration<br>• Forest Management<br>• Watershed Management<br>• Land Use Planning and Management<br>• Pollution Prevention<br>• Drinking Water Treatment and Distribution<br>• Storm water management (natural and constructed) |
| **Water Demand** | • Longer, drier summers<br>• Increase in summer water demand<br>• Less water to share between a growing number of users<br>• Increased drought periods | • Competing groundwater uses<br>• Landscape irrigation<br>• Municipal water use | • Urban Water Use Efficiency<br>• Watershed Management<br>• Ecosystem Restoration<br>• Land Use Planning and Management<br>• Education<br>• Economic Incentives |
| **Water Quality** | • Intensified summer recreation<br>• Unknown impacts to groundwater quality | • Increasing wildfire<br>• Wildfire & sedimentation<br>• In-stream water | • Matching Quality to Use<br>• Agricultural and Urban Water Use Efficiency<br>• Agricultural Lands |

**Table 9.2: The impacts, vulnerabilities, adaptation strategies, and opportunities based on different categories of water use and resources in the USR.**

| Category | *Impacts* | *Vulnerabilities* | *Adaptive Strategies* |
|---|---|---|---|
| | • Greater pressure on standards for WWTP effluent<br>• Catastrophic fire<br>• Limited functionality of dirt roads | temperature<br>• Wastewater treatment<br>• Recreation<br>• Storm water | Stewardship<br>• Ecosystem Restoration<br>• Forest Management<br>• Watershed Management<br>• Water-dependent Recreation<br>• Pollution Prevention<br>• Groundwater/aquifer Remediation<br>• Drinking Water Treatment and Distribution<br>• Urban Runoff Management<br>• Wastewater Treatment<br>• Education |
| **Flooding** | • Increased rain-on-snow events<br>• Extreme precipitation events<br>• Increased wildfire incidence<br>• Unknown impacts of altered snowpack, snowmelt, and streamflow<br>• Potential increase of glacial pool melting resulting in debris flows | • Transportation infrastructure<br>• Aging flood control infrastructure<br>• Increased risk of wildfire<br>• Increased risk of debris flows | • System Reoperation<br>• Conjunctive Use<br>• Regional/local Surface Storage<br>• Agricultural Lands Stewardship<br>• Ecosystem Restoration<br>• Forest Management<br>• Watershed Management<br>• Land Use Planning and Management<br>• Flood Risk Management<br>• Education<br>• Retention |
| **Terrestrial and Aquatic Ecosystems** | • Changes to species distributions<br>• Novel and unpredictable species relationships and interactions<br>• Competitive advantage of invasive species<br>• Hydrological impacts – changes to water temperature, pH, DO, turbidity, and flow regimes | • Increasing Wildfire<br>• Wildfire & sedimentation<br>• Climate sensitive species<br>• Aquatic habitat-reliant recreation<br>• Fragmented aquatic habitat<br>• In-stream water temperature | • System Reoperation<br>• Conjunctive Management and Groundwater Storage<br>• Agricultural and Urban Water Use Efficiency<br>• Agricultural Lands Stewardship<br>• Ecosystem Restoration<br>• Forest Management<br>• Watershed Management<br>• Land Use Planning and Management<br>• Education |
| **Hydropower** | • Changes in amount of snowpack, SWE<br>• Timing of snowmelt, runoff and streamflow<br>• Increased rain-on-snow events<br>• Extreme precipitation events<br>• More rain, less snow | • Storage capacity<br>• Increased energy needs<br>• Decreased reliability of flows | • System Reoperation<br>• Regional/local Surface Storage |

**Table 9.2: The impacts, vulnerabilities, adaptation strategies, and opportunities based on different categories of water use and resources in the USR.**

| Category | *Impacts* | *Vulnerabilities* | *Adaptive Strategies* |
|---|---|---|---|
| | • Groundwater recharge and storage<br>• Greater demands on storage infrastructure<br>• Changes to species distributions | | |

## 9.4 Prioritizing Vulnerabilities

All of the vulnerabilities listed above represent important issues and considerations for the USR as a whole. Some vulnerabilities will be of high-priority to a certain suite of stakeholders because of their area of expertise, interests, or employment; these will likely differ from another stakeholder group for the same reasons. Thus, it is not possible to base an evaluation of priority on the relative importance of each from a qualitative perspective.

Identifying vulnerabilities for such a diverse group of stakeholders and issues should be an exercise in assessing how soon that vulnerability may occur, if it's not already (urgency), the degree of probability that the vulnerability will become a hazard, if it's not already (risk), and the relative level of effort and/or cost to address the vulnerability in addition to the efforts already occurring. While it's possible that a variety of scenarios may change the status of any of the vulnerabilities listed below (for example, the award of grant funds may make a wastewater treatment plant — otherwise a very high cost and effort activity — very low cost), these possible scenarios are not considered in this evaluation.

Table 9.3, below, displays the vulnerabilities on the left, and assesses their urgency, risk, and the cost/effort of addressing each, and assigns a level of priority based on those findings. A higher priority generally goes to something that has a higher urgency, higher risk, and lower cost/effort input — this is a way of identifying what some call "low hanging fruit". It is important to make the distinction that these priorities are relative to responding to climate change and not IRWM project prioritization.

**Table 9.3: Prioritizing USR vulnerabilities** via High, Medium, or Low (H, M, or L) Urgency, Risk, and Cost or Effort to address the vulnerability. The list is organized first by Urgency (High to Low), then Risk (High to Low), then Cost or Effort (Low to High, assuming that a lower cost is preferable for low-hanging fruit).

<table>
<tr><th>Vulnerability</th><th>Urgency</th><th>Risk</th><th>Cost or Effort</th><th>Priority</th></tr>
<tr><td>Loss of forest ecosystem function</td><td>H</td><td>H</td><td>L</td><td>1</td></tr>
<tr><td>Increasing wildfire</td><td>H</td><td>H</td><td>M</td><td rowspan="7">2</td></tr>
<tr><td>Wildfire & sedimentation</td><td>H</td><td>H</td><td>M</td></tr>
<tr><td>Water temperature</td><td>H</td><td>H</td><td>M</td></tr>
<tr><td>Knowledge of groundwater supply</td><td>H</td><td>H</td><td>M</td></tr>
<tr><td>Climate sensitive species</td><td>H</td><td>H</td><td>M</td></tr>
<tr><td>Natural system storage capacity</td><td>H</td><td>H</td><td>M</td></tr>
<tr><td>Springs recharge</td><td>H</td><td>H</td><td>M</td></tr>
<tr><td>Municipal water use</td><td>H</td><td>H</td><td>H</td><td rowspan="2">3</td></tr>
<tr><td>Competing uses for groundwater</td><td>H</td><td>H</td><td>H</td></tr>
</table>

**Table 9.3: Prioritizing USR vulnerabilities** via High, Medium, or Low (H, M, or L) Urgency, Risk, and Cost or Effort to address the vulnerability. The list is organized first by Urgency (High to Low), then Risk (High to Low), then Cost or Effort (Low to High, assuming that a lower cost is preferable for low-hanging fruit).

| ***Vulnerability*** | Urgency | Risk | Cost or Effort | Priority |
|---|---|---|---|---|
| Wastewater treatment | H | H | H | |
| Fragmented aquatic habitat | M | H | H | 4 |
| Decreased reliability of flows | M | H | H | |
| Reservoir storage capacity | M | M | H | 5 |
| Transportation infrastructure | M | M | H | |
| Aging flood control infrastructure | M | M | H | |
| Storm water | M | L | H | 6 |
| Recreation (general) | L | H | M | 7 |
| Recreation (aquatic) | L | H | M | |
| Landscape irrigation | L | M | M | 8 |
| Increased energy needs | L | L | H | 9 |

## 9.5 Greenhouse Gas Emissions and USR Project Development and Selection

Assessing each project's emissions was an important component of project sponsors' preparations and presentation of their submitted projects for RWMG consideration. In the process of project development, sponsors were encouraged to consider project alternatives that resulted in lower emissions projections, such as the inclusion of solar power in infrastructure upgrades, or the identification of a local labor force to decrease transportation emissions for workers coming from farther away (this latter strategy has the added benefit of keeping local resources within the region, thereby helping the local economy).

As stated in Chapter 10, Project Review Process and Implementation, the RWMG has identified the need for a technical advisory committee (TAC) for project development and review. They anticipate that points of greenhouse gas emissions and climate change adaptation will be some of the first considerations that the TAC examines as standards for project development. There are good examples throughout California and the west of adaptive strategies for infrastructure, as well as good cooperative strategies for natural resource management and integration. The TAC will look at best practices for all project types and will work with project sponsors to identify the best strategy to accommodate current needs, adaptive capacity for projected climate change impacts, and mitigate emissions to the extent possible.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