CHAPTER 6

STAKEHOLDER ISSUES

Stakeholders have identified sixteen issues that pose challenges to achieving watershed goals. These issues stem from past practices or anticipated consequences of new land use practices and relate to water quality, hydrologic function, site stability, conservation biology, and economic conditions. Effective responses to these issues can improve watershed conditions and help guide future projects to safeguard natural resources and provide sustained economic productivity. Information on projects to address issues presented here are part of the accompanying document *Bear Creek Stewardship Priorities, 2010 – 2014*.

Some watershed issues are long-standing and have concerned residents and county advisors since at least the late 1930s (Agricultural Extension Service of Colusa County 1941). These include: creek erosion, fire control, water supply, overgrazing, weed control, and road repair. Other stakeholder issues are more recent, such as: the growing recreation demand, contaminants in the environment, a proposed wind energy development, and impacts from climate change.

This assessment does not attempt to prioritize watershed issues in a single ranking of importance as stakeholders have different outlooks about priorities. Concerned stakeholders are already actively addressing issues based on common interests, collaborative partnerships, and availability of funding.

The following sections outline stakeholder issues, their consequences in the watershed, their interactions, and strategies for resolving issues in the future.

6.1 Toxic Chemicals

Chemical contaminants to soil, water, and air are a priority for many stakeholders. The principal toxic chemical of concern is mercury. Other chemical elements occur at naturally high background levels but are not known at present to contribute to environmental problems.

Mercury and Human Health

Mercury found in Bear Creek watershed comes from natural sources and from sources generated by people. Naturally occurring “background” sources of mercury in Bear Creek waterways come from spring waters, the atmosphere when vaporized mercury settles on the ground or on vegetation, and normal soil erosion in the course of winter storms (Stanish and

Cooke 2007). Some atmospheric mercury settling over the watershed may come from human sources outside the watershed as well, such as from coal-burning power plants. Abandoned mercury mines inside the watershed are the major component of human-generated mercury. Both natural and human sources contribute significantly to the total mercury load in the Sacramento-San Joaquin Delta downstream, a critical source of water for millions of Californians.

The Central Valley Regional Water Quality Control Board (CVRWQCB) oversees control of mercury from human-generated sources that increase mercury levels in streams above natural background levels. The CVRWQCB has identified Bear Creek and its tributary Sulphur Creek as impaired water bodies because of their unnaturally high amounts of total mercury (Sulphur Creek only) and methylmercury.

Mine waste at abandoned mine sites in Sulphur Creek subwatershed and potentially at the Rathburn-Petray mine complex in the foothills above Bear Valley is generating mercury-rich sediment that erodes into waterways. Soil disturbances from roads and from livestock grazing are secondary sources for increased mercury in Bear Creek and its tributaries (Cooke and Morris 2005). Together, these land uses increase the transport of mercury found in mine waste and soil into streams in Bear Creek watershed.

Mercury concentrations in fish from Bear Creek watershed also exceed State of California standards for safe human consumption of fish. The concern for people is that consuming water and fish from Bear Creek watershed would increase mercury in their bodies and damage their health. Mercury enters the body principally in the form of methylmercury. Certain naturally occurring bacteria, living in streambeds where oxygen is largely absent, convert mercury into an organic form (that is, containing carbon), methylmercury. Methylmercury can enter the food chain, passing from bacteria to algae and small invertebrates, up the food chain to large invertebrates, to fish, and then to fish-eating people and wildlife.

Boron and Agricultural Crops

Bear Creek water has high concentrations of dissolved boron derived naturally from soils and spring waters. The Yolo County Flood Control and Water Conservation District continues to monitor boron in Bear Creek to track concentrations because boron in irrigation water can be toxic to crop plants. No evidence is available at present to suggest that land uses in Bear Creek watershed are increasing boron concentrations in water above background levels.

Other Contaminant Elements

The California Office of Public Health sets standards for maximum contaminant levels (MCLs) for other potentially toxic elements and compounds in California drinking water based on human health and economic concerns. Water flowing from abandoned mercury mine sites in Sulphur Creek subwatershed has higher levels than established MCLs for aluminum, antimony, arsenic, barium, fluoride, and manganese. The few data available on these elements from the California Department of Water Resources (2001 – 2006) show that levels of these potential contaminants fall to levels below MCLs permitted for drinking water standards by the time water reaches the mouth of Bear Creek.

Industrial Pesticides and Fertilizers

In 2001, the last time that the Department of Water Resources monitored for industrial organic solvents, fertilizers, and pesticides in lower Bear Creek, data collected did not detect any compounds above threshold amounts that would indicate contamination.

Recent illegal cultivation of marijuana on public lands in Bear Creek watershed is creating an undetermined impact to water and soil. Since 2007, law enforcement officers have found containers of two highly toxic industrial pesticides and contaminant fertilizers at illegal marijuana growing sites in the watershed: carbofuran, used to kill native species of rodents, and methamidophos, an insecticide. On other BLM lands managed by the Ukiah Field Office, officers have found pools diverted alongside streams to mix fertilizers.

The BLM is instituting a rapid response procedure based on early alerts from the BLM and Colusa County law enforcement officers to send BLM restoration specialists to growing sites to halt environmental damage from marijuana cultivation (G. Mangan, pers. comm.). Currently, no dedicated funds are available to public land managers and private landowners to cover costs of site restoration once sites are cleared of plants and hazardous materials. Also, no program is in place to specifically test for the residues of industrial pesticides and fertilizers at sites impacted by illegal marijuana cultivation.

6.2 Sediment Delivery to Watercourses

Large quantities of sediment move down Bear Creek watershed drainages annually during storm events, discharging pollutants to the waterways. Approximately 276,000 tons (or 205,000 cubic yards) of sediment was generated from large-scale erosion events (observable at a 1:20,000 map resolution) in Bear Creek watershed above Highway 20 between 1937 and 2005 (Hoorn et al. 2008). Sulphur Creek subwatershed and the canyons on lower Bear Creek leading downslope from Cortina Ridge are parts of the watershed most susceptible to sediment erosion (Figure 4.5).

Sediment from Abandoned Mines

In Sulphur Creek subwatershed, mercury-rich sediment is particularly an issue where sediment from abandoned mines routinely enters waterways during storm events. Annually, up to 72,000 tons of sediment from all sources erode from the subwatershed (Churchill and Clinkenbeard 2003), depending on winter storm frequency and intensity. Churchill and Clinkenbeard (2003) also estimated that 51,400 tons of mine waste sediments cover the ground surface in Sulphur Creek subwatershed. These sediments are highly susceptible to erosion. On average, mine sediments put 9.2 kg (20.3 lbs) of mercury into Sulphur Creek annually. Information on the mercury contribution from mine waste from the Rathburn-Petray mine complex on the southwest side of Bear Valley is less clear (Churchill and Clinkenbeard 2003). Sediment from the mine complex appears to mix with naturally mercury-rich stream sediments around cold springs found in the alluvial fan downslope from the mine complex (Slowey and Rytuba 2008).

Sediment from Roads and Trails

Poorly designed roads, trails, and culverts are another source of erosion. In Leesville and Lower Bear Creek subwatersheds in particular, culverts empty water onto eroding soils, accelerating soil erosion and sedimentation into creeks. CALTRANS estimates that the two state highways in the watershed generate twelve tons of sediment that enter lower Bear Creek annually (Table 5.14).

Sediment from Illegal Dumping

The extent of illegal dumping of soil and rock into Bear Creek and its tributaries is unknown. In August 2008, however, the CVRWQCB cited CALTRANS for dumping sediment next to Bear Creek along Highway 16. Dumping had been occurring at the Highway 16 site for many years.

Sediment Stemming from Domestic and Wild Animals

Animals, both wild and domestic, are drawn to riparian areas for water and high-quality forage. Larger animals such as livestock and elk often concentrate at these sites, and over time they reduce vegetative cover, disturb soil, and cause banks to erode, both releasing sediment and reducing the sediment-catching function of riparian zones.

Sediment Stemming from Loss of Vegetation

The interaction between fires and conversion of oak woodlands to grasslands promotes vegetation loss and soil erosion on upland sites. Conversion generates income from oak fuelwood and provides greater livestock forage on the cleared land. After deforestation and fires, rainfall strikes soils more powerfully in the absence of shrub and tree canopies and results in larger and more erosive overland water flows. These flows ultimately transfer increased sediment loads into Bear Creek tributaries. Loss of oak woodlands on steep slopes has led to landslides on some hillsides in the BLM Bear Creek Ranch.

Unstable channel conditions also contribute sediment. Abnormally high stream flows in winter storms accumulate from overland water flow across devegetated areas and build force along lower Bear Creek next to Highway 16. At several stretches in lower Bear Creek, narrow canyons further concentrate powerful high flows. Banks along lower Bear Creek are showing signs of extensive high bank erosion that sloughs even more soil into the Creek. At the same time, periodic high stream flows are undermining the anchoring function of long-established riparian shrub and oak tree root systems, leading to further vegetation loss and soil erosion.

6.3 Creek Channel Alterations

Creeks and their associated riparian zones have many important ecological functions. When properly functioning, riparian zones do the following:

- provide habitat for fish and wildlife
- stabilize creek channels and protect banks from erosion
- retain rainwater and attenuate flooding
- filter nutrients
- maintain water quality
- provide livestock with forage and water during drought periods

People have altered waterways in Bear Creek watershed for agriculture, tourism, mining, and land reclamation. During the late 1880's, miners moved the lower main stem of Sulphur Creek from the west side of Sulphur Creek valley to its current location on the east**,** adjacent to Manzanita Mine. In the late 1890's, rechanneling at the north end of Bear Valley altered the course of Bear Creek (J. Keegan, pers. comm.), and dynamiting rock formations along Bear Creek in lower Bear Valley is said to have resulted in downcutting Bear Creek and its tributaries as the level of the streambed lowered (Reed 2006).

These modifications have altered the hydrologic function of creeks and their associated floodplains. While such alterations can benefit agriculture and other land uses, they can also lead to a loss of critical ecosystem services.

Figure 3.2 displays the human alterations to Bear Creek and its tributaries. Bear Valley, where agriculture has supported people's livelihoods for 150 years, is the most transformed part of Bear Creek watershed. Ranchers have constructed water impoundments for stock water supplies. Many stock ponds are also found on the BLM Bear Creek Ranch and on rangeland on the east side of the watershed north of Highway 20. One challenge – especially for public land managers – is how to use these water sources to also benefit wildlife and water conservation. Further development of off-stream watering for livestock may be necessary to sustain livestock operations, particularly if drought conditions continue.

Alterations to creek channels come from sources other than people. Tamarisk, a non-native invasive plant, has invaded along Bear Creek and lower Sulphur Creek. At places, it traps sediments and develops stable hummocks that can redirect creek flow and flooding patterns (Birkeland 1996). Uplift of the earth in areas characterized by shifting plates and earthquakes such as the western side of the Sacramento Valley may also reshape channels (J. Alderson, pers. comm.).

6.4 Creek and Tributary Headcuts

A headcut is a sudden change in elevation or knickpoint at the leading edge of a gully. Headcuts intensify runoff, accelerate soil erosion, destabilize stream banks, and alter stream flow over time. Without remedial action to curb them, headcuts deepen over time and create a wider channel. This downcutting in the streambed can lead to a loss of floodplain function and a lower water table. Downstream from a headcut, the deepened channel disrupts natural water flow by concentrating water over a smaller area of ground surface, and the stream is less likely to flood the surrounding land at times of high rainfall (Wilder and Roberts 2002). During the summer drought, the level of shallow groundwater associated with main-stem creeks and their tributaries drops further, resulting in reduced base flow, less soil moisture, and lower annual vegetation production (Rosgen 1996).

Headcuts on Bear Creek, Sulphur Creek, upstream from Leesville, and in other small tributaries throughout the watershed are creating extensive corridors of topsoil loss. The causes of headcuts differ by site. In Leesville subwatershed, poor culvert design and placement appears to be the principal cause. In other areas, causes are less obvious and yet to be determined. Thirty-seven headcuts have been mapped thus far in Bear Valley tributaries (J. Alderson, pers. comm.). In Sulphur Creek subwatershed, headcutting has recently accelerated, resulting in extensive movement upstream in just a few years (J. Alderson, C. Thomsen, pers. obs.). The entire wetland complex in the Sulphur Creek valley is now subject to degradation from active headcuts (Hoorn et al. 2008; C. Thomsen, pers. comm.).

Another adverse impact is sediment delivery and accompanying reduction in water quality. More sediment, formerly constituting the streambed, banks and floodplain, erodes as the headcut moves upstream. The adverse impact of sediment on water quality intensifies if the increased sediment comes from mercury-rich soils or mercury-laden mine waste. Streams in ultramafic areas, mostly from the west side of the watershed, deliver naturally high background concentrations of heavy metals to watershed streams and may release even higher metal loads to waterways as headcuts become more extensive.

Ranchers are noticing a decline in forage production related to the lowered water table as streambeds deepen on account of widespread head cuts and channel incision in Bear Valley. The sunken water table is drying out rangeland and reducing the length of the growing season for forage. Options to counteract arid soil conditions are needed to restore the capacity of rangelands to support livestock.

6.5 Roads, Trails, and Firelines

Roads, trails, and firelines leave an enduring imprint on Bear Creek watershed by affecting hydrologic function, water quality, site stability, vegetation cover, and wildlife habitat. Cartographers at the BLM and the US Forest Service have mapped 215 miles of existing roads and trails on public highways and on public lands in Bear Creek watershed. An unknown amount of roads and trails are on private lands. In Sulphur Creek subwatershed, Hoorn et al. (2008) mapped an additional 23 miles of trails on private lands in addition to the 100 miles on public lands.

Maintenance for Road and Trail Infrastructure

Road repairs have long been an issue in the watershed. The Colusa County Agricultural Extension Service in 1941 cited the need for road improvements to Leesville and Bear Valley roads. The Colusa County General Plan (Sedway Cooke Associates 1989) notes that sufficient funding to address deferred maintenance of county roads remains an ongoing challenge. CALTRANS and the Colusa County Department of Public Works are likely to remain underfunded in the foreseeable future, so prioritization is needed for effective remedial actions that improve roads for safety and environmental benefits. Without improvements in design and maintenance, roads and trails will continue to function poorly and contribute to chronic water quality problems.

New incentives and funding could enable Colusa County to repair county roads in Bear Creek watershed known to transport sediment into Bear Creek and its tributaries (Cooke and Morris 2005). Funding is especially needed in Sulphur Creek subwatershed where more than a third of the private road mileage, most of it furnishing access to abandoned mines, is carrying mercury-rich sediments to Sulphur Creek.

Roadways in Eroding Landscapes

Roads constitute the second largest source of sediment after abandoned mine waste in Sulphur Creek. In Sulphur Creek subwatershed, 67 percent of surface (non-mine) sediment (estimated at 16,158 cubic yards or 21,815 tons) comes from cutbank surfaces next to roads

(Hoorn et al. 2008). Road maintenance is particularly needed where soils and rock on the cutbank side of roads are vulnerable to erosion, under conditions of steep slopes, high rainfall, and sparse vegetation. Both sedimentary soils (Maymen, Skyhigh, and Sleeper) and ultramafic soils (Henneke, Montara, and Okiota) along roads in the watershed are eroding locally. Severe erosion on Skyhigh and Sleeper soils where they abut Highway 16 next to lower Bear Creek creates frequent slides onto the highway that require ongoing attention. Road crews routinely place sloughed roadcut material onto fill slopes along Bear and Sulphur creeks to clear roadways following major winter storms. To avoid an eventual large-scale landslide of Henneke soil from steeps slopes on the south side of Highway 20 west of Bear Creek, CALTRANS received a right-of-way permit from the BLM to remove topsoil from a ten-acre patch of public land. The remaining exposed ultramafic rock and soils is now in need of further stabilization and revegetation to halt sediment delivery to Bear Creek (O'Dell and Claassen 2006a,b). Revegetating the site may cost up to $20,000 per acre (V. Claassen, pers. comm.).

Off-Highway Vehicle Route Designation

Federal land management agencies are currently designating the off-highway vehicle (OHV) routes for public recreation and travel throughout California. Reducing erosion by closing and restoring vegetation to unneeded or poorly designed trails is one aim of route designation. The Mendocino National Forest has completed its OHV route designations, and the BLM Ukiah Field Office is beginning its second phase of designating OHV routes in Bear Creek watershed. The OHV trails on the BLM public lands in Sulphur Creek subwatershed, Bear Valley foothills, and Walker Ridge will be designated next as either open or closed to motorized use. Most of these trails are on ultramafic soils, often predisposed to landslides and soil erosion. OHV travel planning by federal agencies is also taking into account impacts to air quality from route designation on traffic volume from OHV-recreation visitors driving on unpaved county roads to reach motorized trails on federal lands.

Roads to Support Wind Energy Development

Plans to develop wind energy resources on Walker Ridge in Bear Creek watershed are underway. The BLM has not issued permits for any projects, however. Eventual development would entail new road construction and widening of existing roadways and trails to support energy production and conveyance to power stations. AltaGas Income Trust, the project proponent will publish a plan of development, detailing the locations of new or modified utility roads. The BLM has in place best management practices (refer to Chapter 8) that address road design and maintenance so that wind energy production is compatible with other resource uses and protections.

The Interaction of Roads and Trails with Non-native Invasive Plants

Roads and trails alter the distribution of plant nutrients, the flow of surface and subsurface water, and soil depth along verges, often in ways that increase habitat suitability and growth for non-native invasive species (Gelbard and Belnap 2003). Vehicle corridors are also point sources for wildfires that promote multiple species of non-native fire-adapted annual grasses. Research in Bear Valley (Gelbard and Harrison 2003, 2005) indicates that roads have a negative impact on native vegetation. Native perennial bunchgrasses such as purple needlegrass (*Nassella pulchra*) thrive best away from roads. On the other hand, non-native invasive weed species, particularly yellow starthistle, have a lower survival rate with increasing distances from roads and their associated disturbances.

Restoration for OHV Trails and Firelines

CALFIRE created more than 21 miles of new firelines across ultramafic soils on steep slopes during the 2008 Walker Fire for the purposes of containing the fire and protecting private property and public resources. Emergency stabilization for the fireline did not take place. A funding source to revegetate the fireline is not available from federal or State of California sources for public lands. Private landowners must bear the cost to curb erosion of ultramafic soils on their property from the fireline.

6.6 Fire

The frequency of large wildfires has not increased in Bear Creek watershed since 1950 (California Department of Fire and Forestry Protection data), in contrast to other, more populated parts of California where conditions of fire weather (for example, Santa Ana winds) are different (Keeley et al. 2004). Until 2008, wildfires inside Bear Creek watershed were comparatively small-scale, less than 2,500 acres in extent. The 2008 Walker Fire in Bear Creek watershed burned an area nearly three times the acreage of the previous largest fire recorded since 1950.

The large extent of this fire is not attributable to a trend to larger fires. Regional circumstances at the time of the fire were extraordinary. The human-caused Walker Fire came at the same time as an unusually large number of lightning strikes ignited wildfires across northern California. Operations for suppressing wildfires were stretched beyond the normal response capacity of fire management agencies, and sufficient resources to contain the Walker Fire could not be marshaled as quickly. As a result, the fire burned more extensively.

One major concern for some stakeholders is making fire suppression more cost-effective and less expensive overall. Watershed stakeholders are rethinking strategies for fire suppression and considering the use of fuel treatments to reduce costs. Implementing strategic landscape fuel treatments in advance of fires may help landowners and land managers avoid adverse impacts to property, air quality, post-fire soil erosion, and biological diversity resulting from wildfires. The effectiveness of fuel treatments needs review, particularly on sites that have ultramafic soils or otherwise naturally low productivity. A one-size-fits-all approach may not be warranted.

Fire managers are now focusing on the time that a fire spends over a piece of ground ("residence time") during a fire as a factor in designing prescribed burns and containing wildfires (B. Bahro, US Forest Service fire modeler, pers. comm.) that better meet land management goals. These considerations may be important in determining, for example, the amount of mercury vaporized into the atmosphere during fires or passing into streams during the rainy season. Scientists are just beginning to study the effects of wildfire on the release of mercury from soils and vegetation. Studies in other states indicate that mercury levels in soils drop steeply (Biswas et al. 2007, 2008) and mercury levels in streams rise significantly (Caldwell et al. 2000) after wildfire.

Another factor is the role of people as ignition sources. With more people on remote roads across public lands, the likelihood of human ignitions grows. Policies and programs to address human behavior and actions that create fire hazard and wildfire ignitions are difficult to implement and make effective.

Using Fire to Enhance Biological Diversity and Restore Native Species

Many rare chaparral plant species do not germinate without periodic fire in their habitats, and their current rarity may be the result of unnaturally long intervals between fires (Safford and Harrison 2004). Harrison et al. (2003) found that a single managed fire on ultramafic soils, where most rare plant species occur in Bear Creek watershed, had a positive effect on native plant diversity. Techniques of burning under managed conditions can increase germination, growth, spread, and seedbank replenishment for rare species. But the habitat requirements for the sixteen federal sensitive plant species on public lands and the two additional CNPS Class 1B taxa on private lands in Bear Creek watershed are poorly understood. Research for long-term conservation of rare plants and other native species is needed.

Fire suppression in the past five or more decades may be shifting the composition and structure of oak woodlands and chaparral. Foothill pines are less able to survive wildfires than oaks or chaparral shrubs and are becoming more common in the absence of fires (Ledig 1999). Increasingly, pines are competing with blue oaks for water and nutrients. Greater competition among trees in denser stands may be reducing oak tree vigor as pines emerge above the oak canopy and beginning shading oaks. With a greater number of more flammable pines among less robust oaks, the stage is set for more intense wildfires and greater oak mortality (C. Thomsen, pers. obs., D. McCreary, pers. comm.).

Without periodic wildfire, chamise can form single-species chaparral stands on both ultramafic and non-ultramafic soils. As chamise gets older and larger, nutrients for plant growth become scarcer, and dead biomass (fire fuels) accumulates on and under chamise shrubs (Rundel 1982, Stohlgren et al. 1984). The surrounding area becomes more susceptible to intense fires. At the same time, the plant and animal species diversity declines. Introduction of fire on an average 20-year interval for non-ultramafic soils may reduce fuel buildups, rejuvenate chamise growth, and create a more complex and species-rich wildlife habitat.

6.7 Oak Woodlands

Oak Species at Risk

Areas occupied by oak woodlands have been shrinking in many parts of California, including Colusa County. In western Colusa County, woodcutting and efforts to improve land for livestock grazing have resulted in major losses of native oak woodlands (Light and Pedroni 2002). Of particular concern in the watershed are two oak species found only in California, blue oak (*Quercus douglasii*) and valley oak *(Q. lobata*). These species may be at risk of long-term decline because of failure of the two species to regenerate sufficient seedlings and surviving saplings at many sites over the last 50 years to replace trees lost from natural mortality and land clearing (Zavaleta et al. 2007). Evidence of regeneration problems exist in the watershed, especially for valley oak.

Factors limiting regeneration of blue and valley oaks depend on biotic conditions and the land use history at a site. While many blue oaks stands investigated over the last 50 years had little or even no regeneration, the natural mortality of large blue oaks was also very low. In many places, oak seedlings rarely attain the height of saplings and small trees because ungulate animals (deer, elk, livestock) browse the young oaks unimpeded. Tule elk also use woody plants for antler rubbing and can girdle trunks of sapling trees.

Mature valley oaks remain part of the riparian community in three locations: at the south end of Bear Valley, on the BLM Bear Creek Ranch, and locally in the Leesville area. Much less common than blue oaks, valley oaks are more vulnerable to population decline and regeneration failure. Studies on valley oak elsewhere in California indicate that it has the lowest number of germinating seedlings and surviving saplings of the major oak species in California, and that germination of valley oaks may fail entirely over many years. Best regeneration, mostly under or near the canopies of full-grown trees, occurs where cattle or other large browsing animals are absent (Tyler et al. 2006).

Public Policy and Remedies for California Oaks

Losses of oaks come in part from public policies and incentives. For example, from the 1940s through the 1960s, the federal government and the State of California subsidized cutting oak woodlands as a means for increasing production of livestock forage and livestock production (Campos Palacín et al. 2002). As landowners and the public at-large have understood the multiple values from oak woodlands, the range of benefits from oak woodlands has expanded. Oak woodlands furnish both agricultural and forestry products (beef, sheep, wool, game animals, fuelwood, forage, acorns) and ecosystem services (watershed protection, soil conservation, wildlife habitat, shade for livestock, carbon storage, and landscape aesthetics) that in turn support other economic sectors (water delivery, tourism, carbon credits, recreational settings). The challenge to stakeholders is how to maintain the greatest value from oak woodlands on both private and public lands for an uncertain future.

Environmental Factors Affecting Oak Woodlands

The following subsections describe and evaluate briefly the biological, hydrological, and climatic stresses to oak woodlands. Some of stress factors have their origins in human causes such as the unintentional introduction of non-native plants and fungi.

Tree Loss from Soil Erosion

Medium-sized blue oaks are being lost along the Highway 16 corridor from soil erosion. At least two sources of erosion are at work: bank sloughing after stream undercutting of highly erodible soils during high winter flows in Bear Creek; and soil slides at road cuts. In each instance, oak root systems become exposed to the air and their ability to anchor the tree bole and stabilize soil is undermined.

Interactions with Non-native Plants

Invasive non-native plants such as annual grasses and yellow starthistle typically grow from late fall to summer coinciding with rainfall patterns. Their abundance results in competition with oaks for available soil water. Invasive annuals have been shown to dry soils out excessively, leading to less available water for young oaks (Gerlach 2004, Gordon and Rice 1993).

Fungal Diseases

The non-native fungus *Phytophthera ramorum* responsible for sudden oak death, has not affected oaks in Bear Creek watershed. Other native fungi such as mildews, root rots, and wood decomposers are common on oaks but do not cause large-scale epidemics of oak disease and death in the watershed.

Plant Parasites

A native plant, the Pacific mistletoe (*Phoradendron villosum*), germinates on live branches in the oak canopy and establishes a root system inside oak branches to draw water and nutrients. Mistletoe can greatly reduce oak growth when infestations are dense. Tending trees to remove mistletoe especially from young trees can help recover tree growth (Huntsinger et al. 1997).

Animal Predation

Native insects defoliate, feed on tree sap, and burrow into acorns (Swiecki and Bernhardt 2006), and these species may depress oak tree growth and seedling germination. The long-term impact from acorn damage by insects to the capacity for species regeneration is not clear (Tyler et al. 2006). Additional predation on acorns comes from insects, rodents, deer, cattle, and people.

Rodents such as ground squirrels and voles can kill oak seedlings. Once seedlings reach sapling size, browsing by large animal browse and antler rubbing by elk has been reducing the growth and health of young valley oaks in the riparian zone of the BLM Bear Creek Ranch (C. Thomsen pers. obs.).

Drought

Blue oak woodlands are the most drought-resilient of the major forest types in California (Waddell and Barrett 2005). Drought usually induces early defoliation in oaks, especially on shallow soils, to avoid prolonged water loss. Robust oak seedlings resprout from the base to produce new shoots if the previous shoot has died back from drought.

Fire and Oaks

Larger oak trees are more resistant to fire – largely on account of low tree density where these trees occur. Crown fires are rare in the North Coast Range blue oak woodlands (Christensen et al. 2008). Blue oaks resprout vigorously after fire as long as burning is not frequent. A review of demography and recruitment studies of blue oaks has found that fires do not promote tree growth or increase the rate of oak seedling germination (Tyler et al. 2006).

Climate Change

Climate modeling at a fine resolution for California predicts that the ranges of blue oak and valley oak will contract to 59 percent and 54 percent of their current ranges respectively and that ranges will shift northward. According to modeling, both oak species would disappear from the watershed by 2100 (Kueppers et al. 2005). The model calls into question the practicality of maintaining oak woodlands in Bear Creek watershed, if the assumptions in the climate change model are correct.

6.8 Disturbances to Ultramafic Soils

Both natural landslides and land uses disturb ultramafic soils significantly, increasing erosion and sedimentation, altering habitat value, and affecting species composition.

Potential Energy Developoment

Ultramafic soils cover 41 percent of the geothermal lease area (Colusa County Soil Survey 2006, BLM lease boundaries). Care is needed in site planning to avoid eroding these ultramafic soils as they often have naturally high content of heavy metals and thus degrade water quality in streams coming from subwatersheds with ultramafic geology and soils (Morrison et al. 2008). Constructing access roads and turbine pads on ultramafic soils for wind energy may also degrade unusual vegetation communities and rare plant habitat plus destabilize ultramafic rocks and soils.

Grazing Disturbances on Ultramafic Soils

Grazing has been occurring on ultramafic soils in Bear Valley, on Love Lady Ridge (now discontinued), and on the BLM Bear Creek Ranch for more than a century. Different soil series, topographic settings, and grazing practices create varied responses in vegetation on ultramafic soils. Grazing practices can do greater damage on naturally unproductive soils. For example, uplands, meadow complexes, and drainages on ultramafic (and as yet unnamed) haploxerert soils west of Cowboy Camp on the Bear Creek Ranch are characterized by steep, exposed slopes, lower than recommended levels of residual dry matter, landslips, headcuts, gullies, and degraded channel networks from grazing (field evaluations by C. Thomsen, J. Alderson, J. Weigand, 2008).

Non-native Invasive Species at Disturbed Ultramafic Sites

Generally, ultramafic soils and their vegetation types are resistant to non-native invasive plants (Harrison et al. 2006). But, some non-native invasive species are now adapting to ultramafic soils where disturbances to ultramafic soils have been intense. Barb goatgrass (*Aegilops triuncialis*), for example, is able to grow on many ultramafic soils (Thomson 2007). Its presence may also be causing unexpected changes in soils. Batten et al. (2006, 2007), for example, found that barb goatgrass increases soil sulfate in invaded sites. The long-term significance of these changes to site productivity and species composition is not understood at present.

Under the unique soil conditions of Bear Creek watershed, intense ground disturbances resulting from bulldozer traffic at the Rathburn-Petray Mine complex now host a well-established population of yellow starthistle, barb goatgrass, and bromes. Unmanaged mine roads and OHV trails in Sulphur Creek subwatershed are fragmenting rare plant habitat on ultramafic soils and facilitating movement of non-native plants throughout Sulphur Creek (Hoorn et al. 2008).

One source of invasive plants has been the choice of non-native species used to stabilize and reclaim highly-disturbed abandoned mine sites occurring on ultramafic soils. Williamson and Harrison (2002) found that orchardgrass (*Dactylis glomerata*) and tall wheatgrass (*Thinopyrum ponticum*) readily invaded adjacent undisturbed ultramafic soils from remediated abandoned mine sites. This finding underscores the need to use local native plant materials rather than non-native grasses in remediation projects to revegetate and stabilize abandoned mine sites.

Rare Plants

Ultramafic soils have a high ratio of magnesium to calcium and contain high concentrations of nickel and manganese. The unusual soil chemistry prevents most native plant species on adjacent non-ultramafic soils from growing on them. However, some species tolerate ultramafic soils and occur only on those soils. Because ultramafic soils are rare and often appear in discontinuous habitat patches within a landscape dominated by other soils, many plant species adapted to these soils have limited ranges and are rare within those ranges.

One unique feature of the watershed is the high number of rare plant species found on Walker Ridge. One ultramafic-endemic plant, Indian Valley brodiaea (*Brodiaea coronaria* ssp. *rosea*), is listed as a State of California endangered species and has less than twenty separate populations, two of which are known for Bear Creek watershed. Disturbances to soils in the limited habitats of rare plant species such as the brodiaea pose threats to their populations and to native species diversity.

6.9 Non-native Invasive Species

Non-native invasive species have been intentionally introduced by watershed residents, while others arrived by wind, water, wildlife, domestic animals, vehicles, or as hay contaminants. Invasive plants displace native species, alter wildlife habitat, and impair agricultural production. They alter fire and flood regimes, change erosion and sedimentation patterns and nutrient cycling, and reduce water and light availability (di Tommaso and Johnson 2006). Plants such as yellow starthistle and many grasses from the Mediterranean Basin plague hikers and animals with spines and seeds that detach and cling to clothing and fur. Yellow starthistle depletes soil moisture, sometimes equivalent to as much as nine inches of rainfall in infested soils (Gerlach 2004). On the BLM Bear Creek Ranch, invasive plant control is a major land stewardship activity, taking a substantial share of staff time and financial resources.

At least 47 invasive species occur in the watershed, 12 of which are designated as “noxious” by the California Department of Food and Agriculture (CDFA), and 35 that are listed by the California Invasive Plant Council (Cal-IPC) as “invasive plants of greatest ecological concern" (Table 2.13). Several species, including tall wheatgrass, Ravenna grass, matrimony vine (*Lycium barbarum*), bird's foot trefoil, and sweet clover are not listed by either Cal-IPC or CDFA but are invasive in the watershed.

Yellow starthistle, medusahead, and barb goatgrass are the most widespread noxious weeds in grassland communities. These and other Mediterranean Basin annual grasses and forbs comprise the dominant vegetation. Many of these same non-native grassland species dominate the understory of blue oak woodlands and compete with oak seedlings for moisture, nutrients, and light. Field collections in 1999 (C. Thomsen, pers. obs.) found smilograss (*Piptatherum mileaceum*) growing profusely on burned over chamise stands on the BLM Bear Creek Ranch. Smilograss is also well adapted to riparian zones and is occurring with greater frequency along Sulphur Creek.

Along Bear Creek, weeds such tamarisk, perennial pepperweed, and tall wheatgrass are now the dominant vegetation in many areas, displacing native riparian plants and preventing native plant establishment (C. Thomsen, pers. obs.). Although they provide some habitat benefits to wildlife, the dense thickets of these three species are altering riparian plant species composition and hydrologic function.

Ranchers and grazing operators in the watershed are concerned that increasingly arid soils are favoring the most widespread and unpalatable invasive plant species. These species are effectively outcompeting desired livestock forage species. The spread of perennial pepperweed, in particular, is damaging forage productivity in Bear Valley floodplains (J. Alderson, pers. comm.).

6.10 Impacts from Certain Grazing Practices and Browsing and Gnawing Animals

Animals can have beneficial as well as adverse impacts on vegetation conditions desired by land managers and landowners. Research in Bear Valley has shown that livestock grazing helps to maintain the high diversity of native wildflower species there (Gelbard and Harrison 2003). Many areas in the watershed, however, are characterized by low levels of residual dry matter, soil compaction, upland terracettes, streambank and channel degradation, and active headcutting, some of which may be in response to overgrazing in the past. Similarly for wildlife, Johnson and Cushman (2007) studied the impacts of reintroduced tule elk in Marin County and found that elk have both positive and negative effects on native vegetation.

A study conducted just north of Bear Creek watershed found that livestock compacted soil around blue oak saplings. This fact may contribute to blue oak saplings in grazed plots having smaller stem diameters and heights than saplings in ungrazed plots (Jansen et al.

1997). Tyler et al. (2006) have noted that livestock grazing may have a positive impact for oak seedling and sapling growth if oak seedlings and saplings are protected from grazing with tubes around their stems. Livestock grazing on non-native grasses surrounding the protected oaks promotes oak growth over grass growth by reducing the competitiveness of grasses for water.

With few exceptions, unprotected young valley oaks along Bear Creek are not regenerating to replace old trees. Seedlings are abundant in some locations, but saplings are rare and appear to only be surviving in one location where tule elk are less frequent (C. Thomsen, pers. comm.). Elk browsing tends to reduce native woody plant cover and may shift vegetation composition to grass-dominated vegetation (Johnson and Cushman 2007). Beaver also play a role in suppressing regeneration of willows and cottonwoods along Bear Creek (G. Mangan and C. Thomsen, pers. obs.).

Ranchers in the watershed and elsewhere in the region are finding that the harm attributed to livestock grazing is exaggerated or misplaced. Modern techniques and multiple-use considerations, often identified as "holistic grazing" (Butterfield et al. 2006), interweave livestock grazing into detailed planning for forage cropping, protection for wildlife habitat, and water and soil conservation. Widespread attitudes about the unsuitability of livestock grazing on public lands appear to drive a trend to more grazing closures and reduced numbers of animals on allotments that ranchers have traditionally relied on.

6.11 Low Recruitment of Native Woody Riparian Plants

Riparian zones are among the most productive terrestrial environments and are critical to the hydrologic function of the watershed. Multiple ecosystem services come from riparian zones, for example: wildlife habitat, water sources for animals, flood protection, and drought alleviation. When native riparian woody plants are lacking or in poor condition, these services become degraded, affecting recreation, agriculture, and water delivery. Low recruitment of native woody plants in riparian zones usually results from one or more of the previously cited issues that interact in the riparian zone: sediment delivery to watercourses; creek channel alterations; creek and tributary headcuts; non-native invasive species; and impacts from grazing, browsing, and gnawing animals (beaver, cattle, tule elk). Together, these five factors are preventing successful regeneration and sustained habitat for native shrubs and trees along streams.

Over the last century, loss of riparian habitat quality in Bear Creek watershed has resulted from disturbances to riparian areas. Soil loss on streambanks from excessive animal or vehicle use has meant smaller areas for riparian species to germinate and grow. Downcutting in stream beds means that stream levels drop, stream banks are left higher and drier, and the land is less capable of supporting wetland and woody riparian plants.

Without adequate cover of trees and shrubs in riparian zones, the strike force of rain on soil and soil erosion from stream flow is intensified. The result can be a spiral downward in the productivity of riparian sites that undermines land managers' and landowners' objectives to draw maximum sustainable benefits from riparian lands. After native species disappear, non-native plants such as tamarisk, perennial pepperweed, and tall wheatgrass invade riparian sites and outcompete native species for water and nutrients.

Animal Browse on Native Riparian Woody Plants

Browsing animals prefer riparian species such as willows for their high nutrient value, especially nitrogen (Shoenecker et al. 2004). In northern California, elk and deer have been found to thwart regeneration in riparian zones significantly if browsing is not controlled, but exclosures to prevent entry of deer into restoration sites have been effective in promoting rapid growth of willows (Opperman and Merenlender 2001). Baker et al. (2005) showed that beaver cutting and elk browsing occurring jointly can stunt riparian vegetation even more intensively than if only one browsing species is present.

Where livestock have had uncontrolled access to riparian vegetation in Bear Creek watershed, woody plants are mostly absent. The browsing intensity over many decades appears too intense to allow regrowth and sustain vigor of woody species. Annual surveys by the BLM and CDFG between 1970 and 2000 describe severely degraded conditions along lower Bear Creek resulting from excessive livestock grazing on the Bear Creek Ranch prior to acquisition by the BLM. Some ranchers, however, in the watershed prefer not to encourage woody species to establish along their streams (J. Alderson, pers. comm.).

6.12 Growing Demand for Recreation and Tourism

Open space on public lands and the network of public roads and trails in Bear Creek watershed afford opportunities for many kinds of recreation but also create challenges for recreation management. Some areas are accumulating refuse from shot-gun shells, excessive soil compaction and erosion from equestrian riding and foot traffic, and inappropriate OHV use on Walker Ridge.

Increasing Regional Population

Populations of the three counties surrounding Bear Creek watershed (Colusa, Lake, and Yolo) are projected to grow by an additional 60 percent between 2010 and 2050 (California Department of Finance 2007). The value of the watershed for recreation will rise as urbanization expands and open space contracts with the increased population. Understanding the carrying capacity for recreation for Bear Creek watershed will be critical to providing sustainable recreation opportunities on public lands. Conflicts associated with increased use will likely arise. Tasks for recreation planning include accommodating more people but with a lower impact per person, alleviating the potential for user conflicts, and enhancing recreation experiences through environmental education.

New Jobs in the Recreation and Tourism Industry

Nearby cities such as Williams and Clear Lake have been suggested as “gateways” for recreation and tourism for the proposed Berryessa Snow Mountain National Conservation Area, which includes the public lands within the Bear Creek watershed. One focus is how to have recreation contribute more significantly to the local economies of gateway cities in Colusa and Lake counties and in the Capay Valley of Yolo County.

Personal Safety

Criminal marijuana cultivation on public lands by heavily armed growers is a concern. Contact between growers and recreational users who unwittingly enter illegal marijuana gardens could have unfortunate results. A program to close down illegal operations on public lands is essential to healthy and safe recreation.

6.13 Potential Environmental Impacts of Energy Developments

As the newest land use to arrive in Bear Creek watershed, commercial energy production must fit in with other pre-existing land uses, particularly on public lands committed to multiple uses. The constraints to energy development are greater today that in the past for several reasons discussed below. Proponents of energy developments must consider environmental impacts, including cumulative impacts, in their designs for alternative energy projects.

Energy Development and Protection of Biological Diversity

CDFG species of special concern (equivalent to BLM and USFS sensitive species) with ranges inside the present energy lease areas include foothill yellow-legged frog, western pond turtle, pallid bat, and Townsend’s big-eared bat and at least eight BLM and US Forest Service sensitive plant species (GIS data from the Department of Fish and Game’s California Natural Diversity Database 2009). Concern for the fate of bats and raptor birds in the vicinity of wind turbine projects may require special operations and mitigations. No information is currently available on bat and raptor populations and their habitat use patterns on Walker Ridge that can serve as a baseline for detecting eventual impacts from geothermal and wind energy development projects in the watershed.

Energy Development and Ground Disturbance on Sensitive Soils

Installation of energy projects would incur an as yet unspecified amount of disturbance on the ultramafic soils which predominate in the energy lease areas. Large amounts of earth moving for project development would have the potential to further impair water quality and undermine hydrologic function. The portion of the Geysers KGRA in Bear Creek watershed encompasses 36 percent of the remaining 188 acres of rare hydric soils, critical for hydrologic function in Sulphur Creek subwatershed (Reed 2006). Extra measures will be necessary to prevent sediment delivery from energy sites to streams in Bear Creek watershed. Ground disturbance and increased vehicle traffic may promote the spread of noxious weeds such as barbed goatgrass and yellow starthistle.

At the same time that the BLM will be closing undesignated OHV trails in energy lease areas, the leaseholder for the wind project may be constructing new access roads to support construction and infrastructure maintenance at energy production sites. Energy projects may require a widened Walker Ridge Road. Increasing the surface area taken up by roads might also increase sediment erosion from ultramafic soils. Vehicle travel will likely generate larger amounts of dust, which naturally contains asbestos and heavy metals. The health impacts to exposed workers and recreation visitors in the area are not presently known.

Interactions between Energy Production and Recreation

Energy developments may affect scenic values that draw visitors to Wilbur Hot Springs, Walker Ridge, and Bear Valley. Design and installation of energy projects need to protect the visual quality of the surrounding landscape upon which recreation and tourism depend. With the growing demand for both energy and recreation opportunities, the two uses may come into conflict. Increasing traffic and noise may lower the recreation value of public lands in the vicinity of energy installations. In some areas, public lands will be closed to public access to secure energy facilities.

Energy Development and Climate Change

At a global scale, projects to capture energy from sustainable sources such as wind and sunlight have a positive impact for the environment. Shifting energy production and use away from fossil fuels (petroleum, natural gas, coal) to wind, solar, and geothermal energy can reduce emissions of carbon dioxide and other greenhouse gases into the atmosphere and hopefully moderate climate change. Energy development potentially at the expense of the local environment to improve the global environment may make some stakeholders uncomfortable.

6.14 Fiscal and Policy Obstacles for Landowners to Meet Regulatory Targets

Regulatory agencies establish targets and timelines to accomplish restoration of water quality, air quality, and wildlife habitat. Projects to restore ecosystem services and economic productivity for land uses can be costly, as evidenced from the cost estimates to clean up abandoned mines in the Bear Creek watershed and restore impaired water quality (TetraTech 2003, Ecology and Environment 2008). Finding funds to meet targets and timelines is challenging in difficult economic times. Regulatory agencies are not always clear about where the money is to come from to reach restoration goals.

Abandoned Mine Cleanups

Pragmatic regulatory policies can accelerate people's involvement in mercury mine cleanups. A major issue for watershed stakeholders is the slow pace of progress being made toward fairly assigning costs to parties responsible for abandoned mines and their mine waste. Despite scientific documentation of the mercury problems, recommended prescriptions for technical solutions, clear regulatory targets to reduce mercury and methylmercury in Bear Creek watershed, and the public desire to cleanup abandoned mines since at least 2003, cleanups are proceeding slowly. The CVRWQCB is now addressing mercury at abandoned mine sites on private lands in the watershed by involving the public at every step to develop cleanup and abatement orders for the Central, Cherry Hill, Empire, Manzanita, West End, and Wide Awake mines. All of these mines are on private property. The CVRWQCB Clean Up and Abatement Orders are already in place for the mines entirely or partially on federal public lands.

Costs for compliance with cleanup regulations are daunting to landowners. These landowners have inherited impaired conditions from previous landowners or mining companies who caused the damage decades ago. Many landowners are reluctant to clean up abandoned mercury mines because of ambiguity about who should pay. Ambiguity comes from the fact that the so-called "potentially responsible parties" for mine abandonment and subsequent mercury contamination are not always known immediately and require time to identify and locate. The landowner is responsible for underwriting the search for the parties (whether persons or corporations) responsible for the mercury contamination. If no other potentially responsible party can be located during the search, the current landowner is by default the party liable for the cost of the abandoned mine cleanup.

In cleanups of the abandoned Abbot and Turkey Run mercury mines in the adjacent North Fork Cache Creek watershed, none of the private landowners paid for the costs of mine remediation and site restoration. In the case of these mines, the corporate responsible parties were identified, located, and required to pay for the needed mine cleanups.

Restrictions on Ranching Operations

Increasingly, ranchers feel an economic burden on their operations from restrictions designed to protect air quality and water quality. Measures in place are obstacles to basic management needs for forage production and water for livestock. Using fire as a tool to improve forage and control the spread of invasive plants is greatly limited because other lands uses and vehicle emissions outside the watershed have put air quality at risk for the Sacramento Valley region.

Maintaining water flows for water quality in Bear Creek is a major priority for water agencies. In recent drought years, permitting for construction of stock ponds and other off-stream watering systems has become more difficult. Water has been scarce for all beneficial uses of Bear Creek. Many ranchers, however, see an imbalance in water agency decisions in allocating water for ranchers, who have only water from the watershed to draw upon, and for consumers outside the watershed, who have multiple options for obtaining water.

6.15 Climate Change

The State of California is taking a leading role nationally to address the impacts to society and the environment from climate change. Six working groups are jointly developing from different perspectives the Climate Adaptation Strategy (CAS) for California. The Strategy consists of a synthesis of current information about expected impacts from climate change, explicit strategies to promote societal and environmental resiliency in response to climate change, and steps in the short term and long term to offset adverse impacts from climate change. The discussion draft is available for public review (California Energy Commission 2009) online.

The CAS is being formulated at a political and geographic scope larger than individual watersheds. Proposed actions in Bear Creek watershed in support of the CAS are beyond the scope of this watershed assessment until the Strategy is completed. This watershed assessment, however, is useful as a source of information for implementing the forthcoming CAS at the watershed scale. Climate change is likely to modify land uses and management practices designed to maintain or increase land use productivity. Many land uses of key importance to the State of California's response to climate change are present or could be present in Bear Creek watershed in the future, namely: agriculture, energy, recreation, water delivery, and ecosystem services (for example, carbon sequestration and conservation of biological diversity). In addition, many stakeholder issues identified in Bear Creek watershed assessment are also key issues for the CAS. Those common issues include: fire, oak woodlands, increasing demand for recreation, and toxic chemicals. Efforts to enhance the productivity of these land uses and to resolve related stakeholders' issues in the watershed can fulfill watershed goals while providing support for statewide actions for societal and environmental adaptation to climate change.

Many land management practices possible today for good watershed stewardship are also practices that can facilitate the watershed and California as a whole to adapt and respond effectively to climate change. Stakeholders' issues concerning sustainability in Bear Creek watershed link directly to wider issues of climate change in an uncertain future. Table 6.1 provides a summary of the crossover issues between the Bear Creek watershed assessment and the California Climate Adaptation Strategy.

Table 6.1 – Crosswalk of issues covered in both the California Climate Adaptation Strategy and the Bear Creek watershed assessment

Land Use or Ecosystem Service	Climate Adaptation Strategy Issues	Bear Creek Watershed Stakeholder Issues
	Oak Woodlands	
Carbon Sequestration	Avoid cutting woodlands for fuelwood to maintain carbon **storage in soils and trees** and reduce carbon dioxide (a "greenhouse" gas)	Reduce loss and increase area of oak woodlands to maintain woodlands for erosion control, **carbon storage in soils and trees,** soil fertility, and wildlife habitat
	Creek and Tributary Headcuts	
Agriculture	**Drought** from climate change is more intense and reduces agricultural productivity	Soil loss from stream downcutting lowers the water table, and creates longer periods of soil **drought** on agricultural lands and wildlands in the summer. Loss of forage production and available water for livestock during long drought cycles puts the economic viability of ranches at risk.
	Potential Environmental Impacts of Energy Developments	
Energy Development	**Alternative energy projects** may cause losses to sensitive, rare, and state and federally listed species and may fragment habitats in the process of reducing use of carbon fuels and mitigating climate change	Without careful planning and mitigation measures, **alternative energy projects** may causes losses to sensitive, rare, and state listed species, and will fragment habitats
	Growing Demand for Recreation and Tourism	
Recreation	Climate change may reduce **aesthetic, educational, health, and economic benefits** from outdoor recreation	Population growth within driving distance of Bear Creek is creating growing demand for **aesthetic, educational, health, and economic benefits** from outdoor recreation
	Toxic Chemicals and **Sediment Delivery to Watercourses**	
Water Delivery	Fewer but more **powerful winter storms and floods** may increase the amount of soil erosion, pollutants and contaminants in water designated for municipal and domestic uses	**Powerful winter storms and floods** generate the largest inputs of mercury-laden sediments from mine waste into the main stem of Bear Creek which has a beneficial use as a municipal and domestic water supply

Land Use or Ecosystem Service	Climate Adaptation Strategy Issues	Bear Creek Watershed Stakeholder Issues
	Fire and Non-native Invasive Species	
Biological Diversity and Water Delivery	Catastrophic fire sometimes leads to … **increased … sedimentation**, and increased opportunities for **invasions of non-native species** that could compromise management efforts to protect native species in the face of climate change … Maximizing **prescribed burning** … needs to be done with … climate change scenarios in mind.	More intensive management of **prescribed burning** can help prevent catastrophic fires that alter vegetation cover, **increase sedimentation** in waterways, and shift soil nutrient balances to favor **invasions of non-native species**, particularly annual grasses.

6.16 Information Gaps

This section does not discuss specific information gaps about resources already taken up in previous chapters. Instead, this section steps back to consider gaps in information about how stakeholders can work best to resolve stakeholder issues and achieve real improvements for Bear Creek watershed and for their own lives.

One significant information gap in Bear Creek watershed concerns the gap in communicating information among stakeholders in Bear Creek watershed – about stakeholder desires, needs, or expectations – and connecting stakeholders in productive ways to jointly make progress on stakeholder issues, especially issues that a single stakeholder cannot resolve alone. Lack of communication can be a major source of information gaps.

Stakeholders interested in watershed issues may want to make progress on issues but may not know how to go about resolving these issues. How can stakeholders acquire the technical information and the interpersonal skills to collaborate on resolving issues collectively? People can shape their roles in watershed stewardship to include active learning and purposeful sharing of information. Nevertheless, the commitment to acquiring and sharing information can be time consuming, and time may be in short supply for stakeholders with many other commitments.

Another gap in information concerns information about methods that stakeholders can collaboratively apply to overcome impasses with one another in the process of forging solutions to watershed issues of common concern. Impasses may consist of personality differences, seemingly intractable political or economic barriers to progress, or overwhelming uncertainty about the correct action to take. Information about techniques to improve interpersonal skills, negotiate solutions, and handle complexity and uncertainty comfortably are tools from which some stakeholders, and certainly the authors of this assessment, could benefit.

Finally, agency efforts to overcome information gaps occur irregularly and are often short-lived, especially as agencies have many priorities and limited funding. New technical information and advances in knowledge comes in spurts. Seldom do the best intentions of land management agencies to establish adaptive management anticipate, much less fund, watershed monitoring. Without monitoring, however, learning from the outcomes of stewardship actions is less likely and the risk increases of making the same mistake repeatedly.