System Indicators

Water & Air Quality, Temperature, Precipitation, and Snowpack

SIERRA NEVADA CONSERVANCY

Final Report

September 2012

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Introduction

This report is the third in a series of five reports that present analyses of nineteen Sierra Nevada System Indicators developed in 2008 through public outreach and approved by the Sierra Nevada Conservancy (SNC) Board. This report encompasses the Indicators that deal specifically with air and water. They are Water Quality, Air Quality, (Air) Temperature, Precipitation, and Snowpack. There are many inter-relationships between these Indicators, especially between temperature and snowpack.

The characteristics of water and air quality in the Sierra Nevada are quite different than other parts of the state. The Region has unique water quality issues and air quality that is largely out of the region's control. Because the Sierra is the predominant supplier of surface water for the state, and that water supply is vulnerable to annual variation and long-term changes in temperature, precipitation, and snowpack, understanding the climate of the Sierra Nevada, and possible adverse trends, is crucial to the water supply and economic health of the state, as well as critical to protecting the environmental and economic health of the Region.

State data resources (State Water Resources Control Board, Air Resources Board, and Department of Water Resources) were combined and contrasted with other data resources and analytical techniques to develop an assessment that is unique and useful to the SNC Region.

The water quality section used the Clean Water Act 303(d) List of impaired water bodies; GIS capabilities enabled editing the data to SNC boundary for the first time. The air quality analysis was limited to a more straightforward assessment of data from the Air Resources Board at the air basin and county level. In the climate section, historical temperature and precipitation data were acquired from the PRISM Climate Group, which uses sophisticated modeling techniques to develop a comprehensive spatial picture of measurement data, and then analyzed through GIS in ways specifically useful to the Sierra Nevada and validated with direct temperature readings. DWR Cooperative Snow Surveys data (along with data from the Central Sierra Snow Lab) was used to assess historical snowpack trends, with some novel analysis employed.

The data and analysis in this report provide a unique overview of air and water conditions and trends that are specific to the SNC Region.

Highlights

- Overall, the water quality of rivers, lakes, and streams in the Sierra is better than much of the state in terms of human health. But there are some specific water quality issues. Mining legacy mercury in rivers and streams – 535 miles, and reservoirs – 104,000 acres, is extensive and difficult to deal with. As indentified by the State Water Resources Control Board (SWRCB), river and lake health suffers from increased water temperature and nutrient loading often associated with agriculture and grazing. Over 300 miles of streams do not meet health standards for pathogens due to agriculture and grazing, inadequate sewage treatment, and other factors according to SWRCB.

- Ozone in the Sierra Nevada is almost entirely due to pollution coming from or through the Central Valley. Ozone levels are often higher than portions of the Valley, as winds push the pollution into the foothills and mountains. However, annual ozone levels have been in sharp decline since the early 2000's as statewide ozone levels have generally declined. The South Subregion along the San Joaquin Valley has the worst pollution – both highest ozone levels and highest particulate levels.
- Temperatures have increased throughout the Sierra Nevada Region over the past 40 years, but more so at higher elevations. Also, nighttime low temperatures have increased more than have daytime highs. Average nighttime low temperatures above 6,000' have increased in the range of 3 degrees F over the past 40 years.
- Year-to-year precipitation is so erratic that it is not possible to clearly discern any long-term increase or decrease, though it appears that there has been no significant long-term change over the past 40 years.
- As with precipitation, the large annual variation in total snowpack tends to obscure any real trend over the past 40 years. However, a long-term comparison of April 1st to March 1st measurements for each year substantiates that average April 1st snowpack has significantly declined ***relative*** to March 1st snowpack in the past 20 years, implying earlier snow melt and/or less snowfall during March. The analysis also indicates some amount of decline in actual April 1st snowpack depths. This analytical framework can continue to provide a measure of important snowpack changes at regional levels as well as overall for the Sierra Nevada in the future.

Indicators

Water Quality in the Sierra Nevada

The State Water Resources Control Board (SWRCB) 2010 303(d) List (List), developed under the Clean Water Act, was used for this System Indicator. The List indicates water bodies that exceed defined water quality standards, but does not provide data on the actual level of pollutants. [See description of List methodology at the end of this section.]

A new List is developed every few years, with the last previous years being 2006 and 2002. The 2010 List is the first one with data available in GIS (Geographic Information System) format, which allowed us to quantify water bodies (miles of stream/acres of lakes and reservoirs) specific to the Sierra Nevada Conservancy (SNC) boundary. Unfortunately, this precludes us from being able to compare the 2010 data to that of previous years in a comprehensive way.

Even more problematic in comparing to previous years is that the number of impairment listings has increased dramatically between reports. Statewide, the 2002 List included 1,883 listings. This grew to 2,238 in 2006, and 3,507 in 2010. As the 2010 SWRCB Staff Report states, rather than necessarily indicating a worsening in pollution, "The large number of new listings is most likely a result of the large volume of new water quality data that has become available since the 2006 List. In addition, more protective water quality standards are now applicable to some water bodies." There were also some de-listings in 2010 (see pg. 16 at the end of this section).

Now that the List provides GIS compatibility, it will be possible to clearly track new listings and de-listings in the Sierra Nevada in future years.

The List certainly doesn't provide a complete story of water quality in the Sierra Nevada. It only includes surface water bodies; it does not assess groundwater quality. The List also does not quantify the actual level of the pollution. It does, however, provide a continuous, legally authoritative review of pollutants in surface waters to the extent that the health and beneficial use of water resources is compromised.

Overview of water impairments

The List identifies Rivers & Streams (referenced in this report as Streams, and measured in miles) and four kinds of area water bodies: Lakes & Reservoirs, Saline Lakes, Wetlands, and Estuaries (all referenced in this report as Lakes, and measured in acres). Many streams and lakes have multiple pollutants or other impairment issues.

The List identifies impaired water bodies as to both a pollutant category and specific pollutants. For instance, Pesticides is a category which includes specific pesticides such as Diazinon, Diuron, Group A pesticides, etc. (see table on next page). In some cases, it makes more sense for this report to assess pollutant categories and in other cases, specific pollutants.

The List also includes the sources of the pollutants, when known. Unfortunately, a large proportion of the impairment sources are identified as 'unknown'.

Overall, water quality in the Sierra Nevada is certainly better than many areas of the State, such as the Central Valley and Southern California. However, there are certain pollutants that are extensive and specific to the history or current land use of the Sierra Nevada, which warrant focus. These top issues include mercury, temperature, nutrients, pathogens, and toxicity.

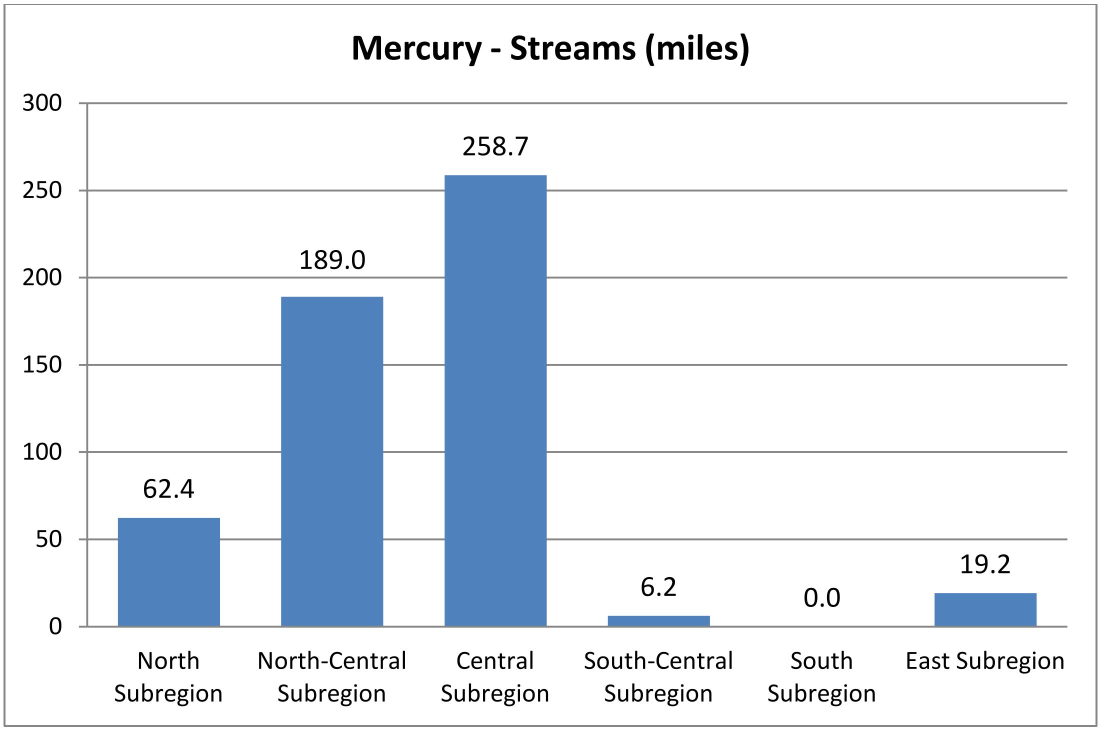
303(d) List Impairments within the SNC Region	
Pollutant Category	**Pollutant**
Metals and Metaloids	Mercury, Arsenic, Aluminum, Cadmium, Copper, Iron, Manganese, Silver, Zinc, unspecified metals
Miscellaneous	Invasive species, pH, Temperature
Nutrients	Nitrogen (including as Nitrates), Phosphorus, organic enrichment/low-dissolved oxygen, ammonia
Other inorganics	Sulfates
Other organics	PCB's
Pathogens	Bacteria, E. Coli, Fecal coliform, unspecified pathogens
Pesticides	Chlorpyrifos, Diazinon, Diuron, Group A, Pyrethroids
Salinity	Salinity, Total dissolved solids
Sediment	Sediment/Silt, Turbidity
Toxicity	Sediment toxicity, Unknown toxicity

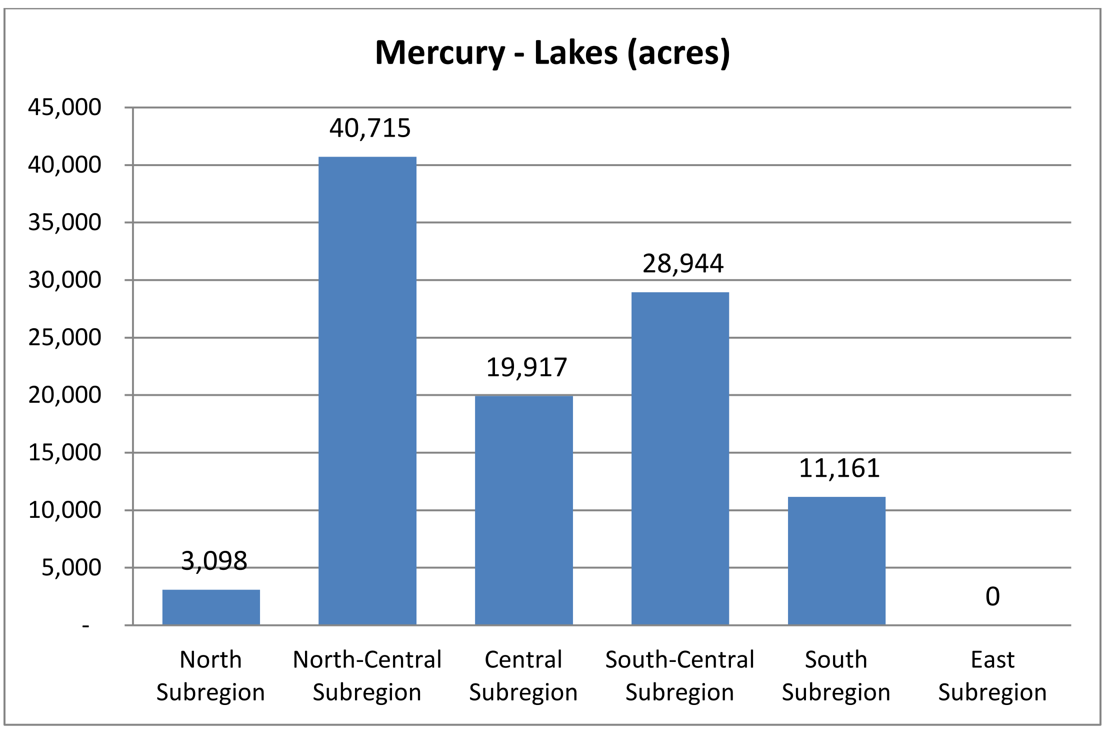
Mercury

Within the SNC Region, 535.5 miles of rivers and creeks, and 103,835 acres of lakes and reservoirs are listed for mercury impairment. Mercury is in almost all cases a gold mining legacy. As expected, the majority of rivers and creeks listed for mercury are in the 'gold country' within the Central and North-Central Subregions, and are identified as a consequence of 'resource extraction'. Major listed river segments include the North and South forks of the American (a total of 121 miles), the Feather River (59 miles), the Bear River (27 miles in Placer, Nevada, and Yuba Counties), Butte Creek in Butte County (48 miles), and the Yuba River (133 miles). However, over 60 miles of the Susan River in Lassen County is also listed for mercury, with the source identified primarily as 'natural'. Additionally, the source of mercury in creeks in the East Subregion (Mono County) is listed as natural or unknown.

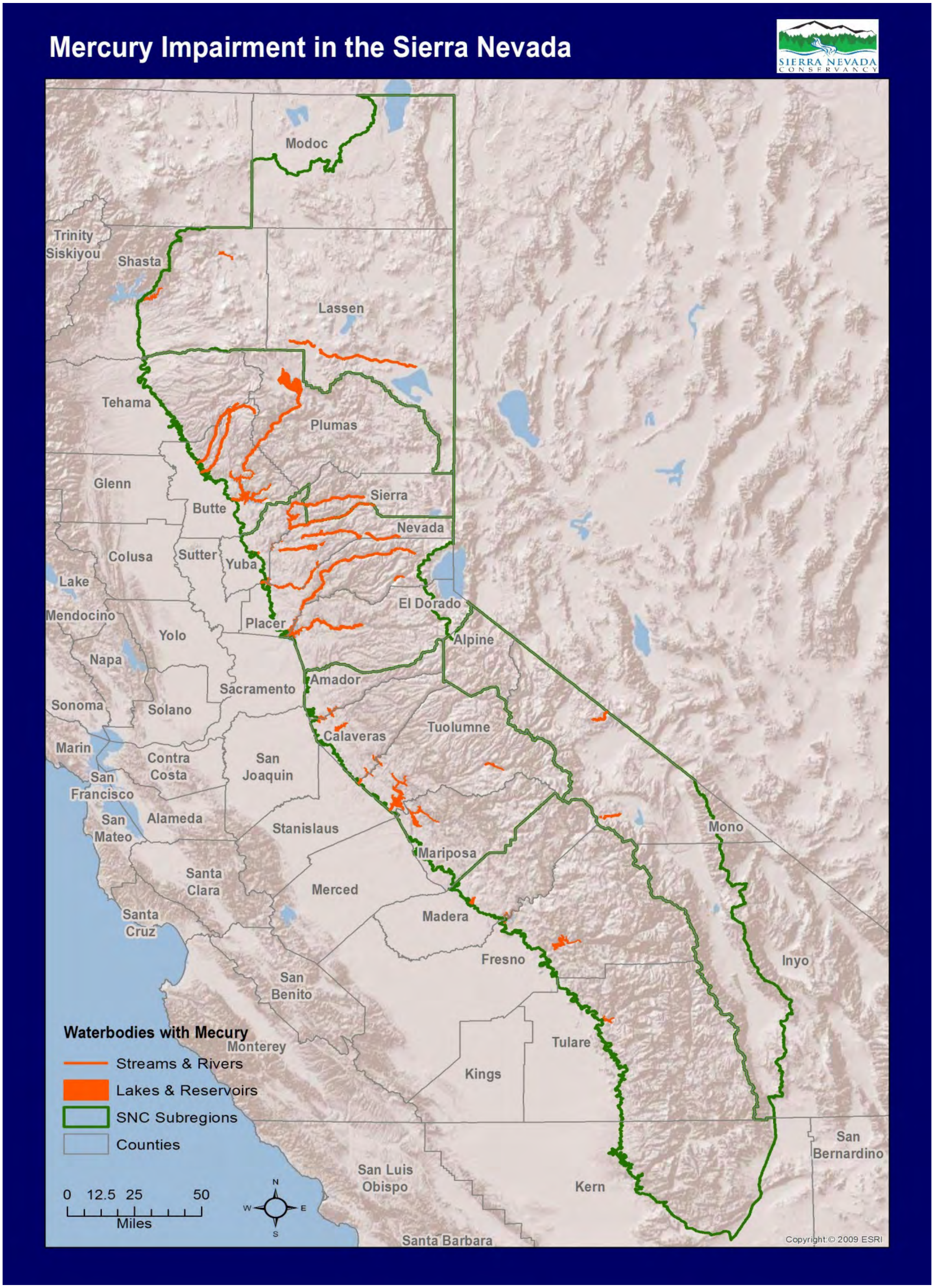
The geographic distribution of lakes and reservoirs listed for mercury is a bit different even though historic gold mining is still primarily the cause. While the North-Central and Central Subregions account for a large share of the mercury impairment in streams, the South-Central Subregion encompasses nearly 30,000 acres of impaired lakes. Major lakes and reservoirs in these three Subregions identified for mercury (approximately 90,000 acres total) include Lake Almanor, Lake Oroville, Folsom Reservoir, Don Pedro Lake, Hetch Hetchy, and McClure Reservoir. One small lake in the heart of the Central Subregion with known severe mercury contamination, Lake Combie, was the focus of a previous SNC grant to assess the potential for mercury extraction from lake sediment.

The South Subregion includes four lakes on the List for mercury, totaling over 11,000 acres (including Pine Flat Reservoir, and Millerton, Hensley, and Kaweah Lakes), while Lake Britton and a small portion of an arm of Lake Shasta extending into the Region account for 3,100 acres in the North Subregion. In total, 27 lakes and reservoirs are listed for mercury.





The map on the next page provides a visual depiction of mercury pollution in the Sierra Nevada.



Mercury Impairment in the Sierra Nevada
SIERRA NEVADA CONSERVANCY
Modoc
Trinity
Siskiyou
Shasta
Lassen
Tehama
Plumas
Glenn
Butte
Sierra
Nevada
Colusa
Sutter
Yuba
Lake
Mendocino
Yolo
Placer
El Dorado
Alpine
Napa
Sacramento
Amador
Sonoma
Solano
Tuolumne
Calaveras
Marin
Contra Costa
San Joaquin
San Francisco
San Mateo
Alameda
Stanislaus
Mono
Mariposa
Santa Clara
Merced
Santa Cruz
Madera
Fresno
Inyo
San Benito
Monterey
Tulare
Kings
San Luis Obispo
Kern
San Bernardino
Santa Barbara
Waterbodies with Mecury
Streams & Rivers
Lakes & Reservoirs
SNC Subregions
Counties
0 12.5 25 50
Miles
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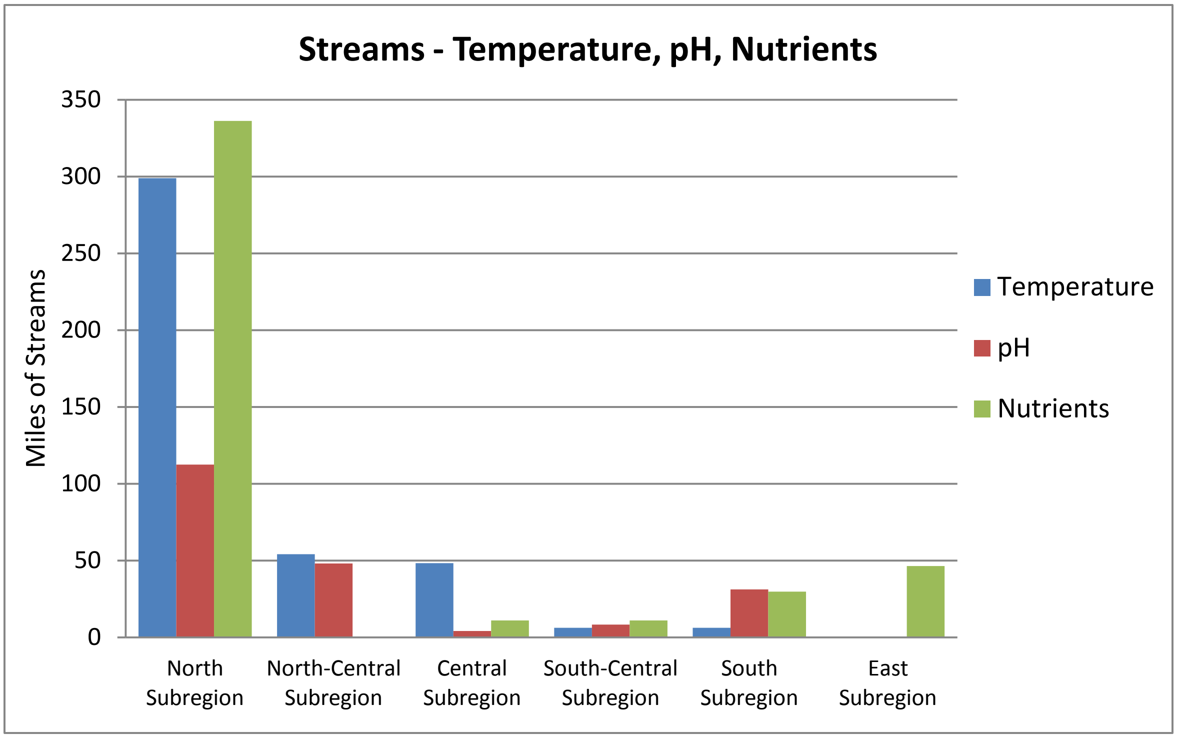
Three impairments – Temperature, pH, and Nutrients

As the following chart clearly shows, issues with stream temperature, pH, and nutrients are all dominated by the North Subregion.



Lakes are a different story. There are no lakes identified for temperature issues, but 37,910 acres of lakes are identified for nutrients and 9,785 acres of lakes are identified for pH. While more than half of the acres of lakes with nutrient impairment are in the North Subregion (all in Lassen County), there is also substantial lake nutrient impairment in the South and East Subregions. Almost all of the lake pH impairment is in the South Subregion.

Lakes – pH and Nutrients (acres)		
	pH	Nutrients
North Subregion	19	20,705
North-Central	0	0
Central Subregion	0	0
South-Central	299	0
South Subregion	9,467	9,466
East Subregion	0	7,739
Total	9,785	37,910

Temperature

There are 414 miles of rivers and creeks listed for temperature (water too warm) in the SNC Region. Of these, 299 miles (72 %) are accounted for by the Pit River running through Modoc, Lassen, and Shasta Counties. The source for the increased temperature is identified on the List as 'grazing'. Precisely how the cattle grazing is causing increased water temperature is not described on the List, but a presumed major cause is a reduction of cooling vegetation along the river and tributary creeks.

The majority of the rest is in the North-Central Subregion (North Fork Feather River) and Central Subregion (South Fork Yuba River). The cause for the Feather River, below Lake Almanor, is listed as 'hydromodification'[1]; for the Yuba River, between Spaulding and Englebright Reservoirs is listed as 'unknown'.

Increased water temperature can impact aquatic wildlife by changing the habitat characteristics, both directly by moving ambient temperature out of the accustomed range for specific aquatic species, and also by facilitating nutrient loading and changes to pH to the detriment of aquatic life.

Nutrients

In general terms, 'nutrients' are chemicals or compounds that 'feed' organic life; in the context of water quality, to the detriment of the aquatic ecosystem. In terms of the List, 'nutrients' are identified not only as specific chemical 'foods' (often fertilizer runoff), but also as the impacts of nutrients – undesirable enrichment of organic materials in the water and resulting reduced oxygen in the water.

'Nutrients' is a pollutant category which comprises a number of 'pollutants' – nitrogen (or nitrates), phosphorus, organic enrichment, and low-dissolved oxygen. These specific pollutants are very much interrelated. These nutrients feed microorganisms which consume oxygen in the water. Higher water temperatures both aid this organic growth and reduce the ability of water to hold oxygen, reducing the water's ability to supply oxygen to aquatic wildlife.

As shown in the chart above, the North Subregion accounts for over 336 miles of the total 435 miles (77 %) listed for nutrient impaired rivers and creeks in the SNC Region. This includes the same 299 miles of the Pit River as well as 37 miles of the Susan River headwaters. Eagle Lake (20,705 acres) is the only lake in the North Subregion listed for nutrients (nitrogen and phosphorus).

In the East Subregion, the upper West Fork of the Carson River in Alpine County, along with a couple of creeks in Mono County, are listed for nutrients. Listed large lakes in the East Subregion include Bridgeport Reservoir and Crowley Lake. Thirty miles of the Fresno River above Hensley Reservoir is listed in the South Subregion, as are Hensley Lake and Lake Isabella.

The List identifies agriculture and grazing as either the primary or contributing source for 77 percent of the 435 miles of streams cited for nutrient pollution, including the 299 miles of the

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[1] Hydromodification is defined as: alteration of the hydrologic characteristics of coastal and noncoastal waters, which in turn could cause degradation of water resources. In the case of a stream channel, this is the process whereby a stream bank is eroded by flowing water.

Pit River for which agriculture and grazing is the indicated source of excess nutrients that result in low-dissolved oxygen. The sources of excess nutrients in the East Subregion listed rivers include silviculture, waste disposal, hydromodification, and recreation along with agriculture and grazing. The source for other streams is listed as 'unknown'.

The List identifies many nutrient sources for 20,705 acre Eagle Lake, including agriculture, grazing, recreation, municipal runoff, atmospheric deposition, and natural sources. Sources of nutrients for most of the other lakes are listed as unknown.

pH

pH is a measure of the acidity of water. Most aquatic life is acclimated to a fairly small pH range. If the pH of the water gets out of that range in either direction, the health of the organism will suffer, or perhaps the fish, plant, or organism will no longer be able to survive there.

A total of 205 miles of streams and 9,785 acres of lakes in the SNC Region are listed for pH impairment. As shown in the chart above, 112.5 miles (55%) of impaired streams are in the North Subregion while the majority of impaired acres of lakes (97%) are in the South Subregion. Butte Creek is the only stream listed in the North-Central Subregion, while Deer Creek in Tulare County accounts for most of the pH stream impairment in the South Subregion. The source for the pH impairment for all streams is listed as 'unknown' except for 4.3 miles in Nevada County which is noted as 'natural'.

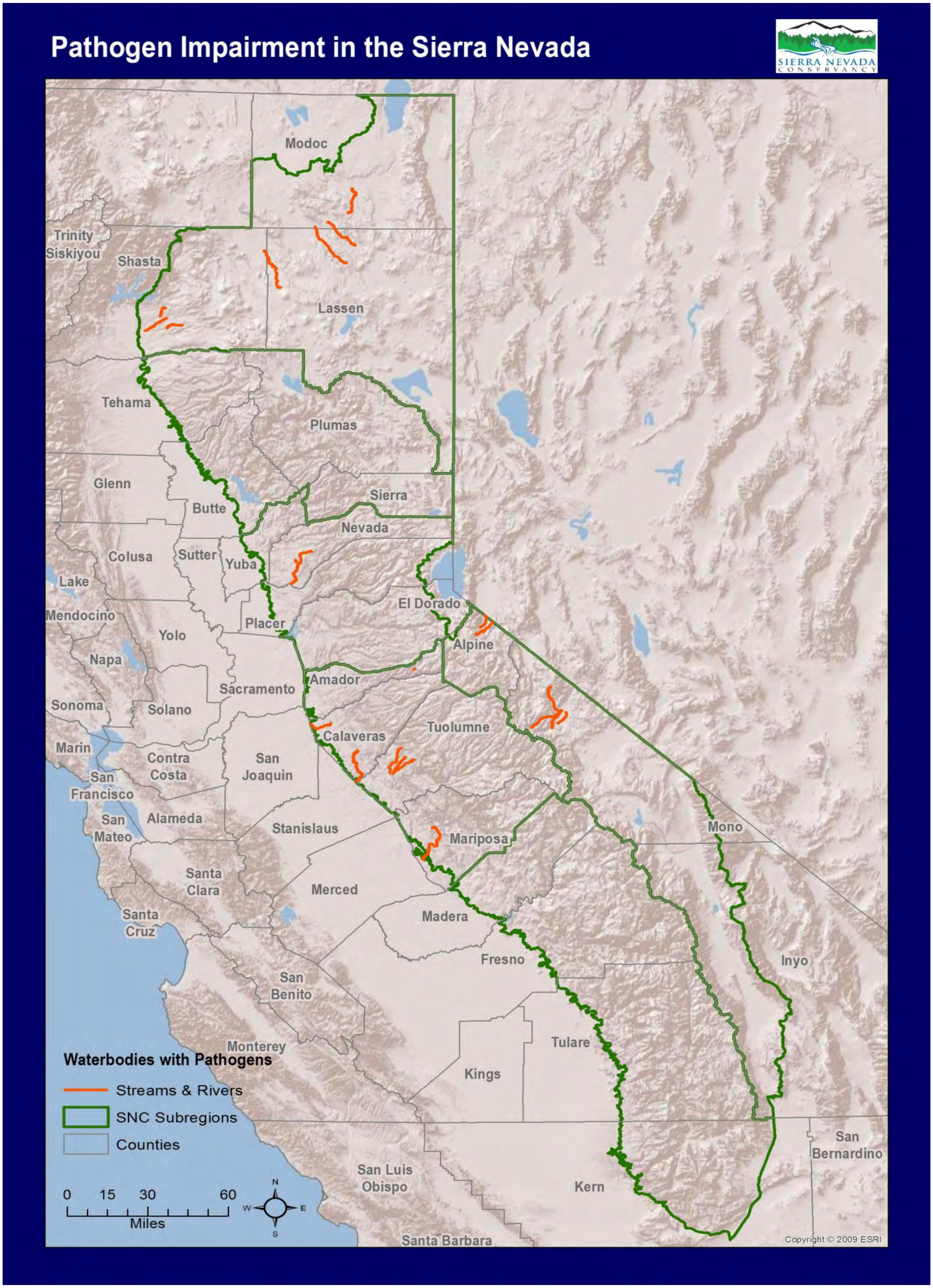
Deer Creek in Tulare County (29 miles) is listed for **high** pH. The Bear River in Amador County (8 miles) is listed for **low** pH. For the other 168 miles of pH- impaired streams, the List does not indicate if the pH is low or high.

There are two large reservoirs listed for pH – Lakes Isabella (7,710 acres) and Hensley (1,669 acres) – both in the South Subregion. Amador Lake (299 acres) is listed for high pH; the other four listed lakes are not specified as to high or low pH. The source of pH impairment for all lakes is listed as unknown.

Pathogens

'Pathogens' is a pollutant category which includes specific pathogenic descriptions: bacteria, E.Coli and fecal coliform, as well as unspecified pathogens. These are all really different ways of describing different aspects of the same thing – harmful bacteria from animal or human feces. Pathogens are a specific concern for human health.

302 miles of streams are listed for pathogens within the Region, with the bulk located in North, South-Central, and East Subregions (see map and table on next pages). As opposed to many of the other 303(d) impairments, the pathogens listings are nearly all limited to creeks rather than major rivers (the Carson and East Walker Rivers in the East Subregion are the two exceptions).


Pathogen Impairment in the Sierra Nevada
SIERRA NEVADA CONSERVANCY
Modoc
Trinity
Siskiyou
Shasta
Lassen
Tehama
Plumas
Glenn
Butte
Sierra
Nevada
Colusa
Sutter
Yuba
Lake
El Dorado
Mendocino
Placer
Yolo
Alpine
Napa
Amador
Sacramento
Sonoma
Solano
Tuolumne
Calaveras
Marin
Contra Costa
San Joaquin
San Francisco
Alameda
Stanislaus
San Mateo
Mariposa
Mono
Santa Clara
Merced
Santa Cruz
Madera
Fresno
Inyo
San Benito
Monterey
Tulare
Kings
Kern
San Bernardino
San Luis Obispo
Santa Barbara
Waterbodies with Pathogens
Streams & Rivers
SNC Subregions
Counties
0 15 30 60
Miles
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W E
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Many of the creeks are listed for multiple sources, which are a combination of agriculture and human sources including sewage/waste and recreation. A number of creeks are listed for 'unknown' sources, while a few are listed strictly as agriculture. Three creeks in Tuolumne County all around the Sonora/Jamestown area are listed for E.Coli. Wolf Creek in Nevada County (23 miles, listed for fecal coliform, source 'unknown') runs through highly populated wildland-urban interface, though it does support some grazing.

The East Walker River in Mono County is identified for a combination of agriculture, recreation, and urban sources; the Carson River in Alpine County is identified as primarily agriculture caused. The only lake listed for pathogens is 28 acre Ramona Lake in Fresno County, listed for E. Coli, and the source listed as unknown.

Miles of Impaired Rivers and Streams		
	Pathogens	Toxicity
North Subregion	108.2	62.4
North-Central	0	258.0
Central Subregion	24.4	1.7
South-Central	101.5	58.2
South Subregion	0	45.9
East Subregion	67.7	0
Total	301.8	426.2

Toxicity

Toxicity refers to substances in water that produce detrimental physiological responses in human, plant, animal, or aquatic life. It applies whether toxicity is due to a single substance or to the interactive effect of multiple substances. Toxicity is assessed through analysis of indicators such as species diversity and population density, growth anomalies, indicator organisms and biotoxicity tests.

Over 426 miles of streams are listed for toxicity in the SNC Region (see table above). The largest extent, 258 miles, is in the North-Central Subregion. Unfortunately, the List provides no direct indication of what is actually causing the toxicity in the various water bodies. Virtually all of the streams are simply classified as 'unknown toxicity'. For all the listings, the cause is listed as 'unknown'. Many of the streams listed for toxicity are also listed for other impairments that might produce toxicity (including mercury, pesticides, pathogens, salinity, and pH), but some are not listed on the List for anything but toxicity.

In the North-Central Subregion, 221 miles of the Feather River (all branches, plus Concow Creek, a tributary) are listed for toxicity. The Susan River accounts for all the toxicity listing in the North Subregion. Most of the listing in the South-Central Subregion is accounted for by Bear Creek in Mariposa County and Littlejohns Creek in Calaveras County, though lower portions of Stanislaus and Tuolumne are listed. Deer Creek in Tulare County and Lower Kings River in Fresno County account for most of the South Subregion listing. Only one lake in the

Sierra Nevada is listed for toxicity, the 28 acre Ramona Lake that is listed for several other impairments.

Arsenic

Arsenic is listed for only two streams in the Sierra Nevada: 9.7 miles of Kanaka Creek in Sierra County (North-Central Subregion) and 1.7 miles of an unnamed tributary to Mammoth Creek in Mono County. The source for Kanaka Creek is identified as resource extraction; the source for Mammoth Creek tributary is listed as unknown.

There is only one lake listed for arsenic – 57,757 acre Honey Lake in the North Subregion. The multiple sources indicated include natural sources, unspecified nonpoint sources, construction/land development, and hydromodification.

Arsenic is a naturally occurring element in the Sierra, but mining has caused exposure and concentration in tailings and stream courses. Arsenic is highly toxic.

Pesticides

'Pesticides' is a pollutant category that encompasses any number of specific pesticides, five of which are identified in the SNC Region (see table at beginning of Water Quality section). Most are insecticides. Class A pesticides are those that are known human carcinogens.

There are 41.5 miles of streams listed for pesticides in four of the six Subregions, not including the North and East Subregions. They include 11 miles of Bear Creek in Calaveras County.

Most of the listings for the Region include the lower reaches of rivers that flow out of the Sierra into the Central Valley:

- Bear River below Camp Far West Reservoir
- Feather River below Lake Oroville
- Kings River below Pine Flat Reservoir
- Lower Stanislaus River below Tulloch Reservoir
- Tuolumne River below San Pedro Reservoir

These river segments are listed for multiple agricultural insecticides. It should be noted that there may be little or no pesticides for the portions of these listed segments that are actually within the SNC boundary, but because the listing is for the entire segment and the segments fall both within and outside the SNC boundary, there is no way of knowing whether the pollutant is actually in the Region or not. For instance, the List includes a 20 mile stretch of the Tuolumne River from Don Pedro Reservoir to the San Joaquin River as impaired for three pesticides. Only 3.5 miles of this stretch (just below Don Pedro Reservoir) is inside the SNC Region and included in our figures. However, it is highly likely that these agricultural pesticides are found primarily or entirely downstream in the farmland of the Valley rather up in the foothills within the SNC Region immediately below the dams.

There are no lakes listed for pesticides.

Other Impairment issues

Metals other than Mercury

There are various metals, largely mining legacy (except for Honey Lake), identified in the streams and lakes of the Sierra Nevada – primarily copper, manganese, zinc, and iron. A total of 70.5 miles of streams are listed for one or more metals (other than mercury and arsenic). They include 9.4 miles of Little Grizzly Creek in the North-Central Subregion, 8 miles of Deer Creek (El Dorado County) in the Central Subregion, 11 miles of Bear Creek (Calaveras County) in the South-Central Subregion, and the East Walker River and Mammoth Creek in the East Subregion.

The Honey Lake Area Wetlands and Wildlife Management Ponds (a total of 63,257 acres) are listed for 'metals'; individual metals are not identified. Multiple sources are described, including natural sources, agriculture, and geothermal development. Comanche Reservoir in the South-Central Subregion is listed for copper and zinc; Haiwee Reservoir Inyo County is listed for copper.

Metals other than Mercury		
	Streams (miles)	Lakes (acres)
North Subregion	1.1	63,257
North-Central	10.9	0
Central Subregion	14.8	0
South-Central	16.5	2,433
South Subregion	0	0
East Subregion	27.2	1,703
Total	70.5	67,393

Sediment

'Sediment' is a pollution category which contains sediment/siltation and turbidity as specific pollutants. Sediment/siltation of streams can damage fish spawning habitat and negatively affect downstream water quality. Turbidity is a measure of the cloudiness of water.

A total of 93 miles of streams are listed for sediment/siltation. The Central Subregion accounts for 46.2 miles (the Truckee River and various creeks). The East Subregion contains 32.5 miles of listed rivers and creeks, and the Fall River is in the North Subregion accounts for 11.8 miles.

There are a wide variety of identified sources for the sediment/siltation. They include silvaculture, resource extraction, and urban sources in the Central Subregion. For the 35-mile stretch of the Truckee River, the List includes those causes along with grazing, land development, hydromodification, and recreation. In the East Subregion, grazing and silviculture are major sources of sedimentation. On the Fall River in Shasta County, silviculture is the identified source.

Two rivers are also listed for turbidity. The Susan River below Susanville (16.5 miles) is due to agriculture. Eight miles of the East Walker River below Bridgeport is listed for both sediment and turbidity.

Salinity

There are just over 200 miles of rivers and creeks in the SNC Region listed for salinity, all in the North and East Subregions. In the North Subregion, 54 miles of the Susan River and 37 miles of the Pit River, as well as 12 miles of Bidwell Creek in the far north-east of Modoc County have excess salinity, with the source indicated as unknown. In the East Subregion, the East Fork Carson River accounts for 46 miles and Rock Creek (a tributary to the Owens River) for 35 miles. Salinity in Rock Creek, and 4 miles of Monitor Creek in Alpine County, is a result of mining.

There are two main saline water bodies, listed for salinity/total dissolved solids/chlorides. The history of Mono Lake (39,744 acres) is well understood. Causes of the salinity are natural sources and hydromodification. The other is Honey Lake and the associated waterfowl management ponds (total 58,422 acres). The salinity arises from the constant cycle of dry season evaporation of the lake. Identified sources on the List include natural and nonpoint sources, agricultural diversions and return flows, and geothermal development. Ramona Lake is Fresno County (28 acres) is the only other lake listed for salinity (source unknown).

PCB's

All the listed PCB impairments are in the North-Central Subregion associated with the Feather River (North and South Forks plus Lower Feather River totaling 93.7 miles) and Lake Oroville (15,400 acres). The sources are 303(d) listed as 'unknown', though PCB's are man-made industrial related chemicals. PCB's are carcinogenic and highly toxic.

Sulfates

Four miles of Monitor Creek in Alpine County is listed for Sulfates from mining legacy.

Conclusions related to water quality

Pollutants differ as to the duration of their impact, and whether current practices are adding to the flow or they are a legacy of past practices. Some will require extensive cleanup or mitigation while others can be reduced or eliminated as a natural outcome of changing land management practices.

Mercury contamination in and around stream courses is a particularly extensive and intractable problem. Its evidence and consequences will linger for decades and centuries without specific cleanup efforts to clean up historic mine tailings and stream bottoms, or in some way keeping them out of the active ecosystem. Other metals, arsenic, and PCBs are also of this nature, though not as extensive in scope.

Other pollution problems may be more solvable. Pathogens, excess nutrients, and pH could be reduced through implementation of various agricultural and grazing practices, and by addressing sewage issues where they occur. The SNC has funded and aided numerous projects, working with landowners to improve their ability to graze cattle with reduced adverse impacts on water quality.

The List provides a sign post of where much of the work to improve water quality needs to be targeted. Detailed information and strategies need to be coordinated with the Regional Water Quality Control Boards to bring resources to these efforts.

Regional Board 5 – Central Valley Region – contains all the west drainage of the Sierra Nevada and northeastern California within the SNC Region. Region Board 6 – Lahontan Region – contains all the east drainage of the Sierra Nevada.

De-Listings

There were only two de-listings to the 2010 List within the SNC portion of SWRCB Region 5. They were the Feather River, below lake Oroville, which was delisted for the pesticide Diazinon (but this stretch of river is still listed for other pesticides); and Lower Bear River Reservoir in Amador County, which was delisted for copper.

There were more de-listings in Region 6. These included: Upper Truckee River for pathogens; Mammoth Creek, headwaters to Twin Lakes (Inyo County) for mercury and metals; East Walker River, below Bridgeport, for nitrogen and phosphorus; and Twins Lakes (Mono County) for nitrogen and phosphorus.

These de-listings were generally a result of re-evaluation of the weight-of-evidence on which the original listing was based (such as additional sampling and data), rather than a known reduction or elimination of the pollution source.

The 2010 303(d) List - Methodology

The State Water Resource Control Board (SWRCB) develops the 303(d) List under the mandate of the federal Clean Water Act. This mandate requires the states to identify waters that do not meet applicable water quality standards, with technology-based controls alone, and to develop Total Maximum Daily Loads (TMDLs). The SWRCB collects data on water quality and potential failure to meet standards from both internal programs and outside agencies. For the 2010 List, the agency received over 22,000 fact sheets detailing potential surface water quality impairments in California. Each fact sheet includes one or more Lines of Evidence (LOEs), a description of data and information used as a basis for recommending a decision – why the impairment should be placed on the List, or taken off.

There is not a simple measure of acceptable pollution levels for water bodies in general, though there are detailed determination procedures for each pollutant. An acceptable threshold for a particular pollutant depends on the water body and takes into account the effects as well as the concentration of the pollutant. The SWRCB uses a 'weight-of-evidence' approach (detailed in the Water Quality Control Policy) to make a final determination on whether to include an impairment on the list (or delete one). It also establishes a date for which a TMDL criteria for each impaired lake or stream segment must be established. For most of the Region 5 or Region 6 water segments, the TMDL date is around 2019 to 2021.

Air Quality

A great deal of air pollution in the Sierra Nevada is beyond any possible local control. Most of the ozone, and some of the particulates, are blown into the Region from the west. Much of the particulates come from dusty roads associated with the rural nature of the Region or from wildfires. There are not easy technological fixes. Still, it is important to understand and characterize the extent and distribution of air pollution so the Region can tackle what is possible in its role to meet state and federal air quality standards.

Three pollutants are assessed for the air quality Indicators:

- Ozone
- PM10 (suspended particulate matter smaller than 10 micrometers in size)
- PM2.5 (suspended particulate matter smaller than 2.5 micrometers in size)

Ozone pollution is generally discussed in terms of the number of days per year that it exceeds a health-based standard, rather than the actual level of the pollutant. The standard used here is the California state 8-hour standard (where a monitoring site indicates an exceedence for any day in which the ozone level averages over .070 ppm for any 8-hour period during that day. Particulate Matter can also be portrayed through daily exceedences of a standard, but data is also available for average annual levels (micrograms per cubic meter of air) which better addresses actual year-to-year trends.

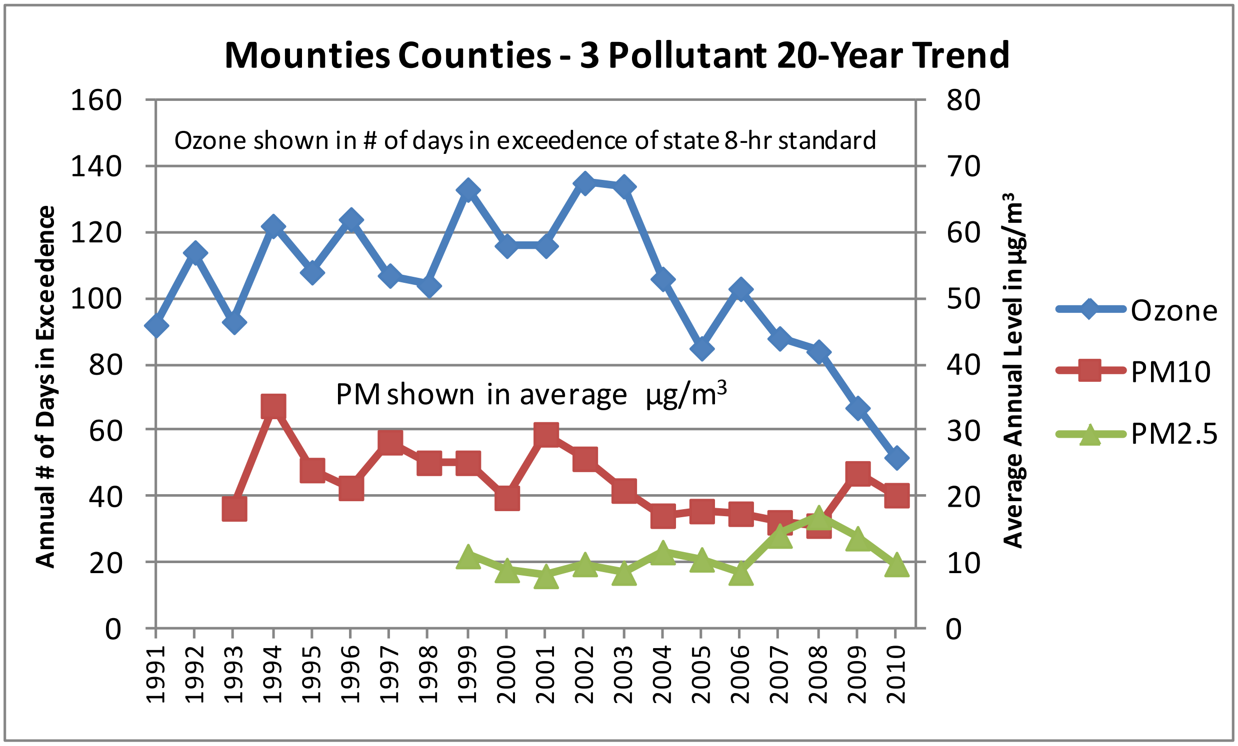
Although data is available at the county level, the low number of monitoring sites in some counties and other data issues limit analysis of PM10 and PM2.5. Some of these data problems can be mitigated by looking at Air Basins rather than counties. These basins include many more monitoring sites, so that clearly bad data points can be excluded without serious consequence and other anomalous data tends to be suppressed. The Air Basin data sets also include data for every year since 1990 (except 2008 for PM2.5). It should be noted that for ozone, the Air Basin (especially the Mountain Counties) will indicate more days of exceedences than any of the individual counties, since an exceedence in any of its counties' monitoring sites will be included in the Basin totals.

The five Air Basins included in this analysis are:

- Mountain Counties - includes all four counties of the South-Central Subregion, El Dorado and Placer Counties (but excluding the Tahoe Basin and Valley portions of those two counties), plus Nevada, Sierra and Plumas Counties
- San Joaquin Valley – includes all of the counties of the South Subregion
- Sacramento Valley Basin - Yuba, Butte, Tehama, and Shasta Counties
- Northeast Plateau - Lassen and Modoc, along with Siskiyou County
- Great Basin Valleys – corresponds to the SNC East Subregion

The Mountain Counties Air Basin is a good starting point to look at air pollution in the SNC Region. It is entirely within the Region and includes a substantial portion of the Sierra Nevada range. The Sacramento and San Joaquin Basins include substantial parts of the Sierra, but their data are dominated by the Central Valley.

The Mountain Counties graph compares the 20-year trend from 1991-2010 for the three pollutants. Strong trends over time are difficult to substantiate because of large yearly fluctuations. For ozone, after a general trend to worsening pollution up to 2002 there appears to have been significant improvement between 2003 and 2010; but without looking at a longer trend and potential confounding weather impacts, care should be exercised in interpretation. However, since 2007-2009 were drought and heavy fire years, the trend looks encouraging. No clear trends in PM pollution is evident since consistent data has been available (Mountain Counties data only extends back to 1993 for PM10 and 1999 for PM2.5)



Ozone

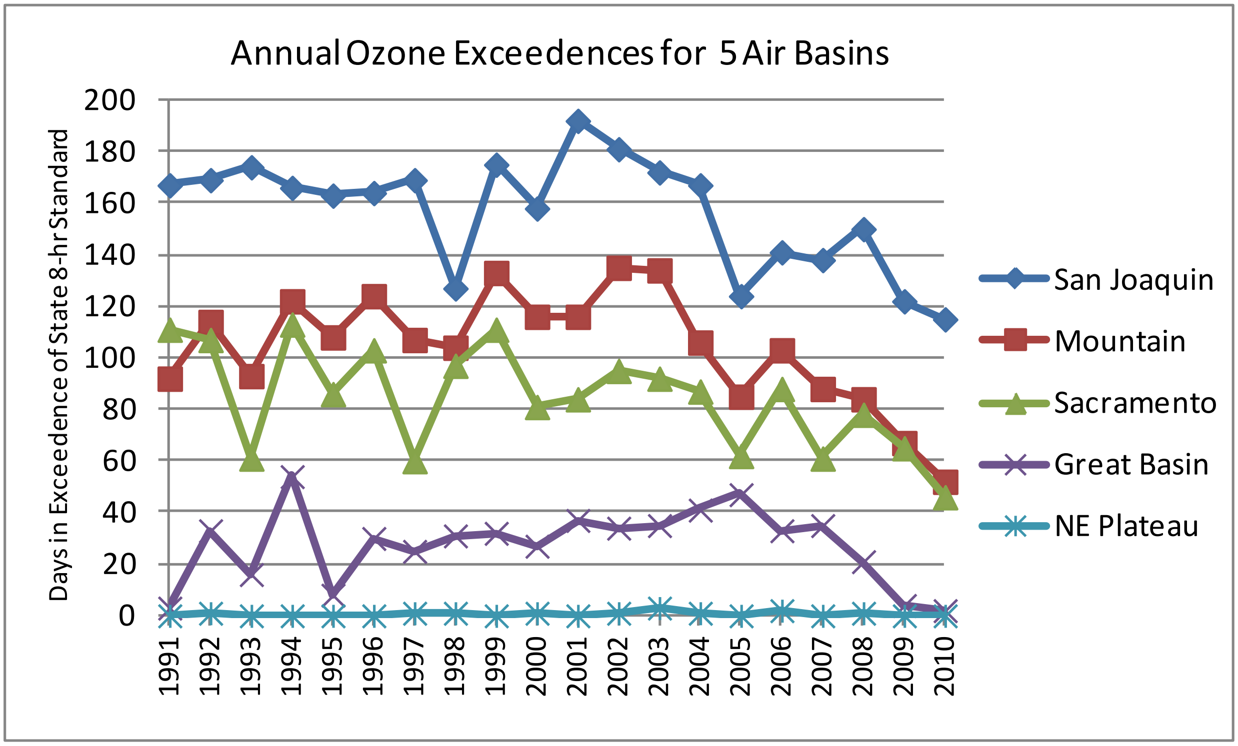
Ozone (O_3) is not a directly emitted pollutant, but rather is formed from precursor pollutants (nitrogen oxide and various hydrocarbons) in the presence of strong sunlight, which is why ozone pollution is largely a summer phenomenon. The source of the precursors, and where those precursors are converted to ozone, is the key issue to understanding ozone pollution in the SNC Region. It is well documented that little ozone is formed in the mountains – the vast majority of ozone is formed in the Central Valley or beyond and transported into the foothills and mountains.

Key points regarding ozone pollution in the five Air Basins that relate to the SNC Region:

- The San Joaquin Valley, encompassing the South Subregion, has the most unhealthful air.
- The Mountain Counties often has worse air quality than the Sacramento Valley, despite the fact that most of the ozone enters the mountains from the Central Valley, indicating

that significant pollution is actually 'blown' out of the Valley into higher ground. (This has been dubbed the 'bathtub ring' effect—see later discussion on Ozone Transport.) The more remote and sparsely populated Northeast Plateau counties almost never exceed the ozone standard.

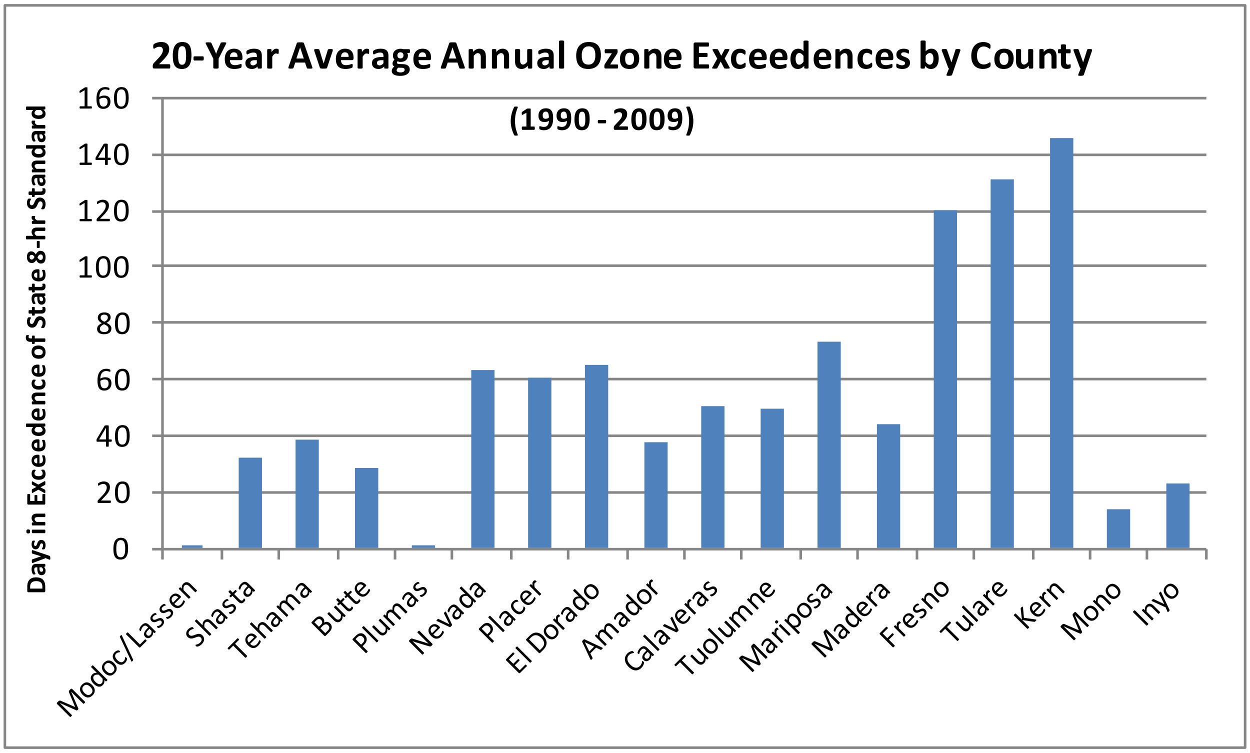
- The Air Basin trends do indicate improvement in ozone levels since the early to mid 2000's, but it should be noted that the California Air Resources Board indicates that 2009 was an anomalously good air-quality year, though 2010 showed continued improvement. More time is required to know how consistent this trend may be.



In addition to this air basin level analysis, the chart below depicts a 20-year average of annual ozone exceedences based on county level data. This county breakdown provides a better representation of the actual number of days of high ozone levels at a finer resolution than provided by air basin data, but does not indicate change over time for the counties. While it is generally consistent with the Basin-scale analysis, there are a couple of additional key points regarding differences in ozone pollution in different counties of the SNC Region (Note: Data is for the entire county, not just for the portion inside the SNC Region; also suitable data was not available for Sierra County):

- Plumas County has very few bad-air days, no doubt because of its topographic isolation from transport from the Sacramento Valley. Plumas is much more in line with the Northeast Plateau counties. [There was one anomalous year - 2002 - that was excluded from the data.]

- Counties of the southern San Joaquin Valley have particularly high ozone levels.



Ozone Transport

According to the CARB report *Ozone Transport: 2001 Review*, "The Mountain Counties Air Basin violates the State ozone standard due to transport from the Sacramento Valley, the San Joaquin Valley and the San Francisco Bay Area." The 2001 report (the most recent update on ozone transport in California) further states that "all ozone violations" in the Mountain Counties are attributable to transport from these outside regions, whose pollutants "have a dominant effect on ozone concentrations in the Mountain Counties". This includes the Sierra foothills towns of Grass Valley and Colfax, where violations are considered entirely due to transport from the Broader Sacramento Area. (The western portions of Placer and El Dorado Counties within the SNC Region, including the town of Auburn, are considered part of the Broader Sacramento Area.)

For the northern and central portion of the Mountain Counties, ozone primarily flows east and north from the Broader Sacramento Area, the Bay Area, and/or the San Joaquin Valley, largely driven by a circulation pattern pushed by the 'delta breeze' during the summer. Ozone transport from and through the Sacramento region "dominates the air quality of the Upper Sacramento Valley, as far north as Butte and Tehama Counties." This ozone can then be pushed up into the Sierra foothills. Transportation is the largest cause of ozone that is *generated* in the Sierra Nevada, particularly along the 80 and 50 corridors, and contributes to ozone pollution in portions of the Central Subregion; but is not significant enough on a county or air basin scale to lead to violations on its own.

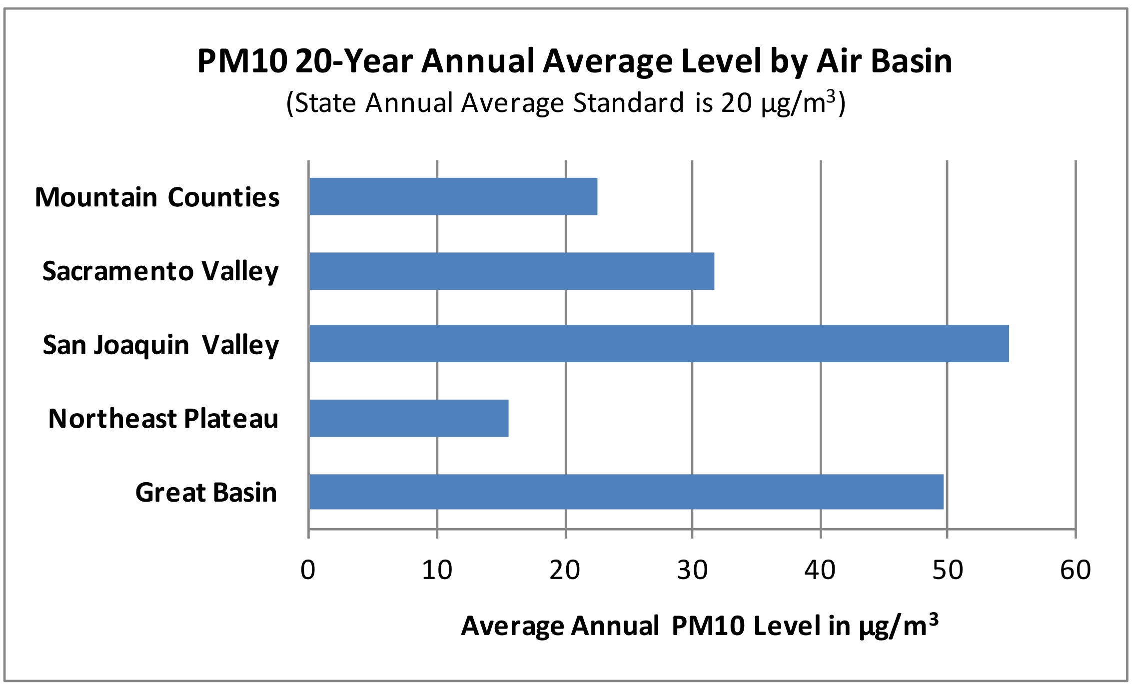
For the southern portion of the Mountain Counties, afternoon breezes push ozone into the Sierra Nevada foothills from the San Joaquin Valley, where it can cause ozone violations in areas such as Sonora and Yosemite, and even cross over the Sierra and cause violations in Mammoth Lakes. Eddy currents within the San Joaquin Valley also carry ozone into the Sierra foothills of Fresno, Tulare, and Kern Counties.

Note that "Under the California Clean Air Act, when emissions from one region contribute to ozone violations in a downwind area, the upwind area shares responsibility for controlling those emissions sources. The State and federal government also share in this responsibility…"[2]

Particulate Matter

PM10

PM10 are very small particles that can stay suspended in air for significant periods (hours to days) but are nonetheless large enough to irritate the lungs when inhaled and are associated with respiratory ailments. These particles tend to be composed of the fine components of dust and soot. The state standard for PM10 is an annual average level below 20 micrograms per cubic meter of air. PM10 would best be analyzed at the county level, but data are not available by county, so are analyzed at the Air Basin level.



As shown in the chart above, there are a few key points regarding PM10 pollution in the five Air Basins that relate to the SNC Region:

- Most of the Air Basins do not come close to meeting the state standard; only the Northeast Plateau has consistently met the state standard. However, it is impossible to know from this data set how the portions of the Sacramento and San Joaquin Basins

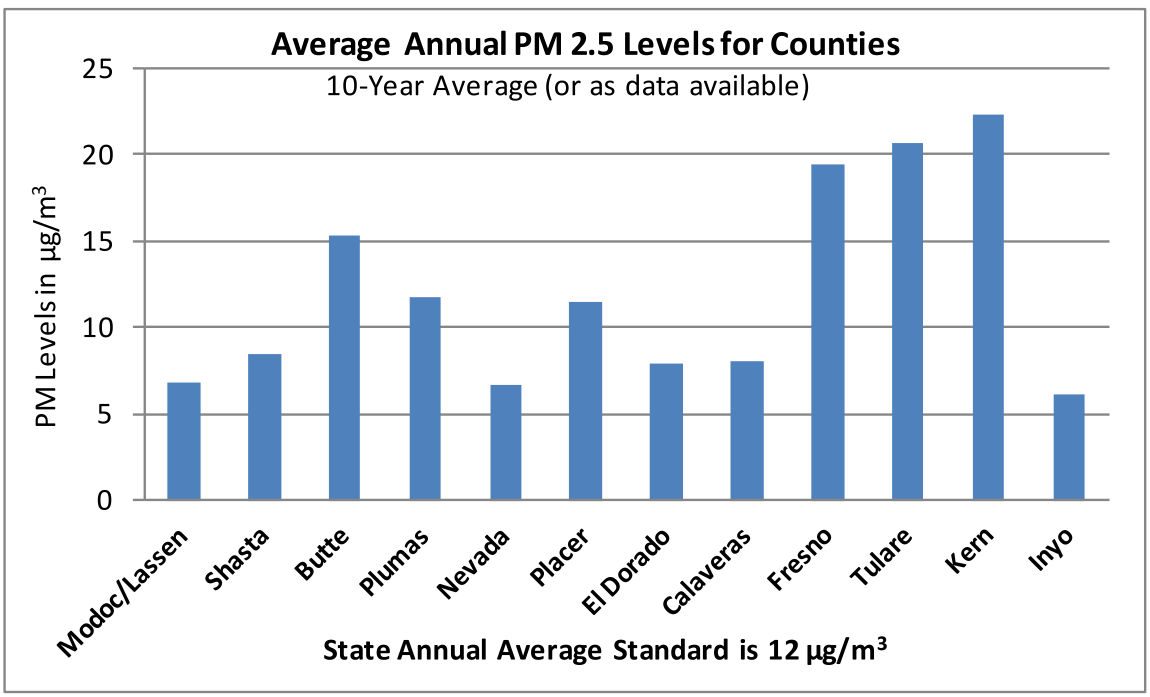
[2] From Page 3 of the CARB "Ozone Transport: 2001 Review" report

within the SNC Region compare to the Sacramento and San Joaquin Basins on the whole. The up-slope parts of the basins might have much lower pollution levels.

- The Mountain Counties Basin has not met the state standard many of the past 20 years (with annual exceedence days between 6 and 95), but did meet the state standard from 2004-2008 with virtually no days in exceedence of the standard.
- The high PM10 levels in the Great Basin are due largely to arid and windy conditions.

PM2.5

PM2.5 are smaller particles than PM10, and are of particular health concern. They penetrate deeper into the lungs, are less physically irritating, but can lead to a greater variety of health risks beyond respiratory irritation. The state standard for PM2.5 is an annual average level below 12 micrograms per cubic meter of air. PM2.5 data is available for some counties of the SNC Region, but the data don't extend back very far (it is a newer standard) and there are substantial data gaps. Data is sporadic at the air basin level too, so that level of analysis provides no advantage. With these caveats in mind, the chart below shows average annual PM 2.5 levels for the thirteen counties in the SNC Region where sufficient data are available.



In viewing the chart above, several key points emerge:

- Fresno, Tulare, and Kern Counties, in the San Joaquin Valley, are consistently well above state standard for PM2.5. In Inyo County (in the Great Basin) PM2.5 levels are much lower than PM10 corroborating that larger dust particles are the predominant issue there.

- Placer and Butte Counties tend to have levels at or above the state standard, but how much of it is associated the valley outside the SNC Region is not discernable from the data.
- Plumas County seems surprisingly high for its geographic location, but data is only available since 2005, though it is fairly consistent for the five years in which PM2.5 is reported (2004, 2005, 2007, 2009, and 2010).

Generation and transport of particulate matter

Airborne particulate matter may be directly emitted or formed as a secondary pollutant in the atmosphere. The larger PM10 pollutants are generally directly formed emissions, such as dust or soot. PM2.5, a subset of PM10, may be direct emissions (such as fine soot) or secondarily formed in the atmosphere – mostly small particulate nitrates and sulfates.

As compared to ozone, long distance transport is not particularly relevant to PM10 pollution; the particles are generally too heavy to be suspended long enough to travel great distances. PM2.5 is another matter; small particles carried by wind from China form a component of particulate pollution in the Sierra Nevada.

The nature of PM10 varies considerably by location, as well as the season. In more urban areas along the western foothills of the Sierra, a high percentage of particulates are generated by transportation and industry, though a large portion of PM10 in the rural portions of the Valley consists of dust from dirt roads and soot from residential and agricultural combustion. In the more rural areas, the majority of PM2.5 is combustion related, with a smaller component consisting of ammonium nitrates and sulfates from transportation and industrial processes. PM10 tends to be heaviest in summer and fall, while PM2.5 is highest in late fall and winter.

In the Mountain Counties, most of PM10 in late spring to early fall (wildfires excluded) is due to dust from unpaved roads, and in the colder months results from residential and controlled combustion. PM2.5 accounts for a majority of total PM10. The vast majority of PM2.5 is related to combustion, with very little from secondary nitrate and sulfate creation. Certainly, summer wildfires can produce huge localized spikes in PM10 and PM2.5.

In contrast, PM2.5 accounts for a much smaller portion of PM10 in the Northeast Plateau and Great Basin Valley. PM10 derives primarily from dust, particularly in the Great Basin, where winds can cause huge spikes in PM10 measurements. Particulate pollution is less seasonal in these remote areas than in the mountains or Central Valley.

This description of PM generation and transport comes primarily from the California EPA Air Resources Board report *Characterization of Ambient PM10 and PM2.5 in California: Technical Report June 2005*.

Temperature, Precipitation and Snow Pack

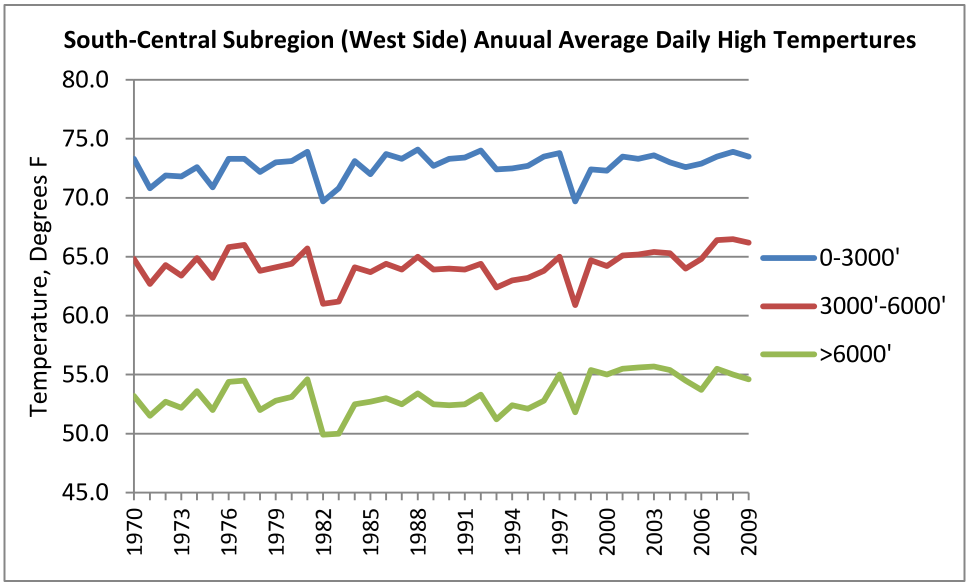
Data for the temperature and precipitation analyses were developed from the PRISM Climate Group data sets (PRISM data set methodology is described at the end of the Temperature section), which are the highest quality spatial climate data sets currently available. Because potential warming and weather pattern shifts could occur differently in different parts of the Region and at different elevations, these data were analyzed not only for the Region as a whole, but were also separated out for each Subregion, and further differentiated for three elevation bands and the western and eastern slopes of the Sierra Nevada.

Temperature

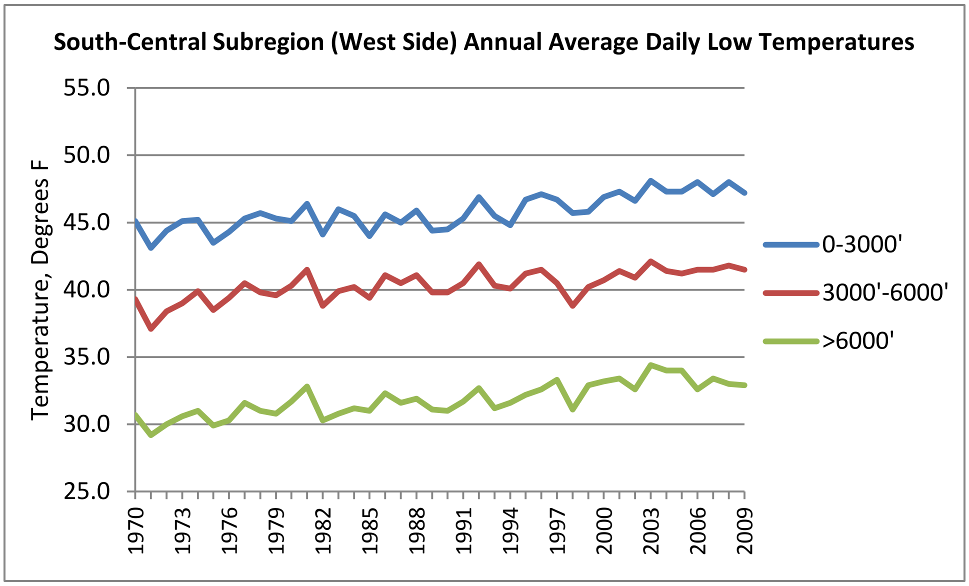
Data were developed for both annual average daily high temperatures (daytime highs) and average daily low temperature (nighttime lows from 1970-2009.

Two trends are evident from the data:

- while there is a overall noticeable increase in average annual temperatures over the past 40 years, temperatures have risen more at higher elevations
- nighttime lows have risen more than daytime high temperatures.



For example, the two charts to the right display the annual average daily highs and daily lows for the South-Central Subregion on the west side of the Sierra. This Subregion is fairly typical of the pattern for all of the Subregions.

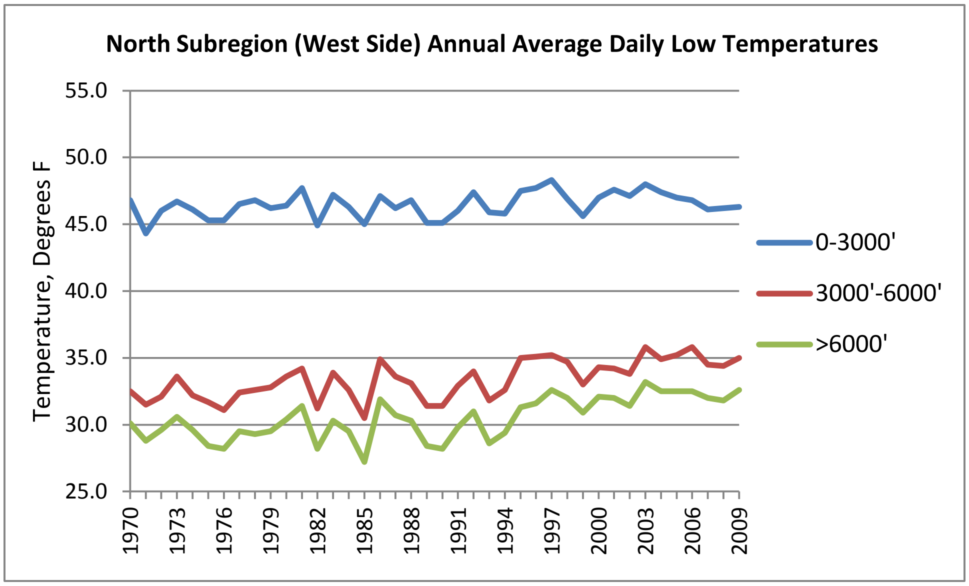


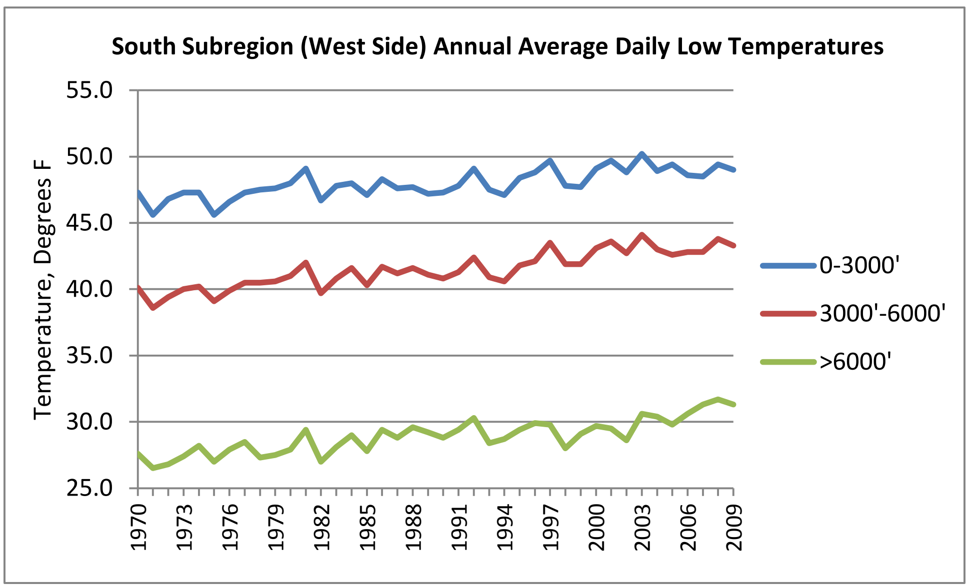
There has been only a slight increase in daytime high temperatures at lower elevations over the past 40 years, but there is a more noticeable increase above 6,000'.

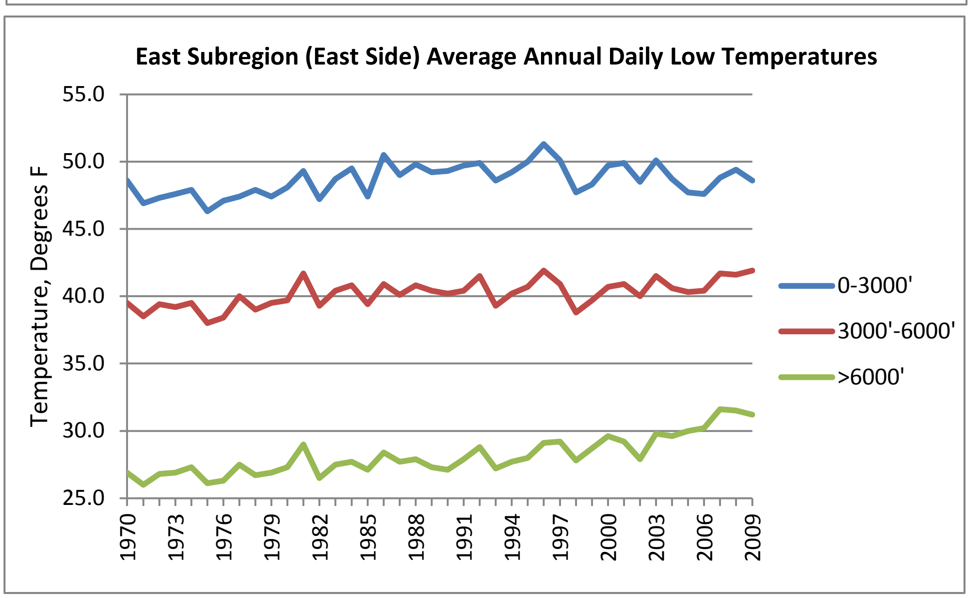
On the other hand, nighttime low temperatures have increased noticeably at all elevations, and are even more pronounced at the highest elevations.

The three charts to the right show the average annual low temperatures for three of the other Subregions. They demonstrate the consistency of the trend across the Sierra, from North to South, and West to East. (However, nighttime lows below 3,000' appear to have increased more in the South-Central Subregion than for most of the other Subregions.)

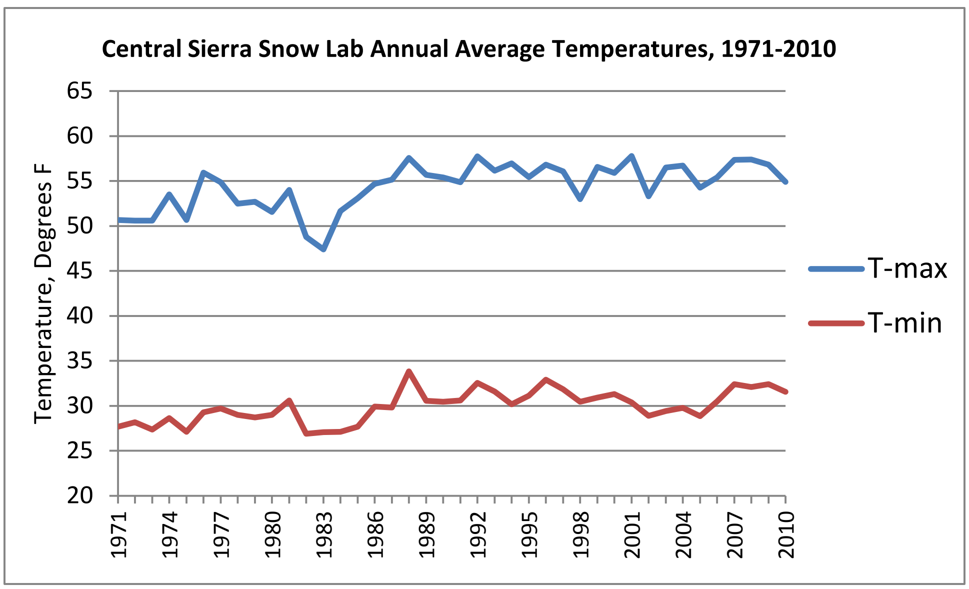
In all cases, average nighttime low temperatures at higher elevations have risen faster than at lower elevations.







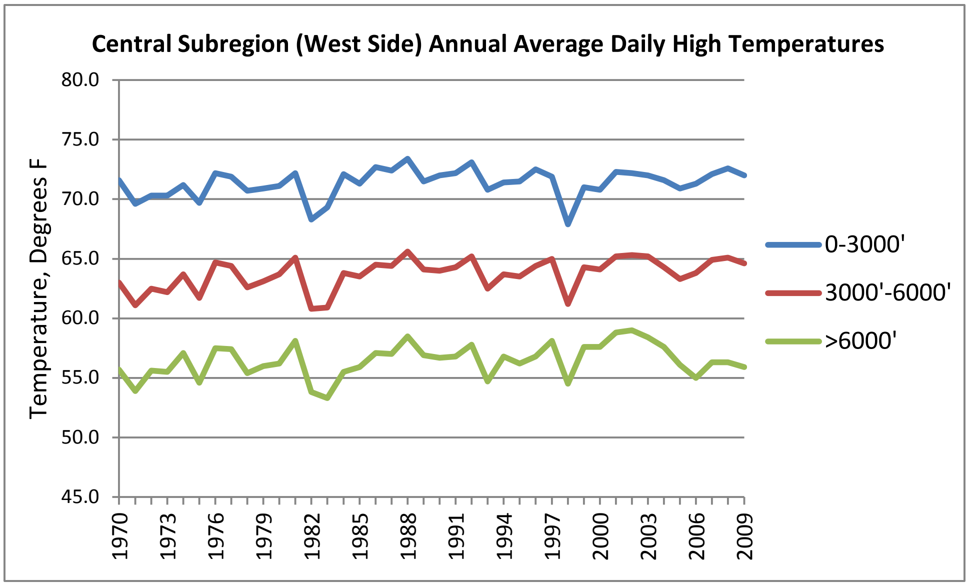
While the PRISM data is the best comprehensive measure of temperature in the Sierra Nevada available, it is a modeled data set, meaning that it takes actual temperature measurements and applies sophisticated techniques to estimate temperatures between the known points to create a temperature grid of the Region. In rural and high elevation areas, there are fewer physical readings from which to develop the database than in more populated areas, so there is less confidence in the accuracy of the modeled data. Therefore, a detailed temperature measurement history from the Central Sierra Snow Lab, operated by UC Berkeley, was used as a means of corroborating the trends identified using the PRISM data analysis. Annual averages of daily high and low temperatures were developed from daily data over the past four decades supplied by the Snow Lab. A graph of annual average daily high and low temperatures is shown below. The Snow Lab is located at approximately 7,000' elevation at Donner Summit, and so compares to the elevation band on the other graphs of >6,000' where increasing temperature trends are the strongest.

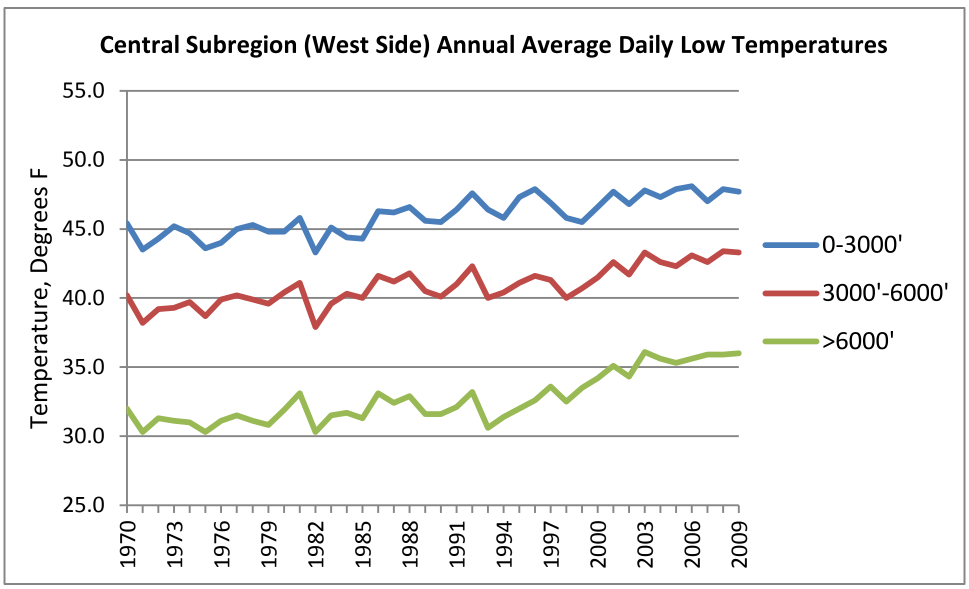


At the Snow Lab, annual average daytime ***high*** (T-max) temperatures are substantially higher now than 40 years ago, though the trend has been somewhat erratic, and daytime highs show no sign of increase since the mid-1980's. Average annual ***low*** (T-min) temperatures have also risen over the past 40 years, in a similar pattern. The vertical scaling on the graph make the trend appear flatter than the other charts, but the actual nighttime temperature increase has been similar to the Subregional PRISM data. A conservative analysis of the Snow Lab daily low temperature data indicates a temperature rise of approximately 3^{o} F from 1971 to 2010[3]. The South-Central Subregion nighttime lows indicate a 3 to 3.5 degrees F rise from 1970-2009.

[3] A centered 5-year moving average was applied to the T-min data, smoothing out annual variations. A linear trend line was then run on the moving average. The temperature increase over the shorter time span of the moving average (1973-2008) was 3.0 degrees F.

It should be noted the Central Sierra Snow Lab is located in the Central Subregion. The graphs of Central Subregion for both daily high and low temperatures are shown below. The trend for average annual daily high temperatures above 6,000' is fairly similar to the Snow Lab nighttime low temperature trend. However, the annual average daily low temperatures above 6,000' indicate a particularly rapid increase in temperatures over the past 15 years which is not indicated at the Snow Lab location. Further assessment is warranted to determine if this is because the Snow Lab location is not indicative of average high elevation temperatures in the Central Subregion, or if there is a problem with the PRISM modeling in this area.



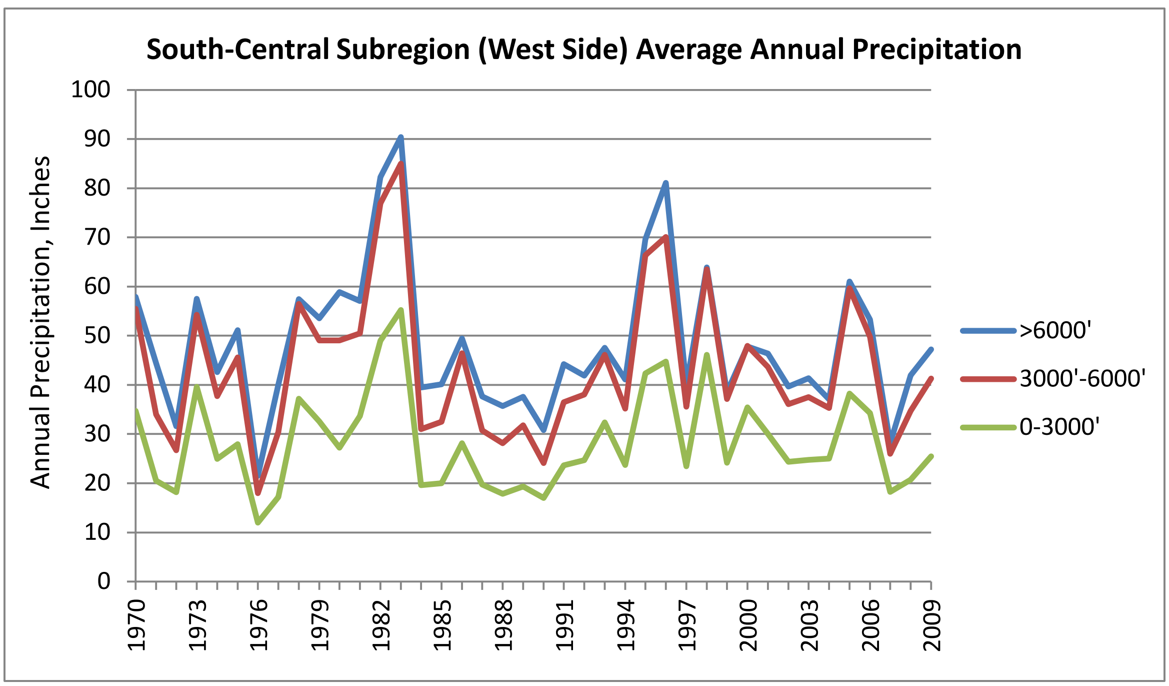


The PRISM (Parameter-elevation Regressions on Independent Slopes Model) data sets are developed by the PRISM Climate Group at Oregon State University. PRISM is a knowledge-based system which uses point measurements of temperature, precipitation, and other climate factors to create continuous, digital elevation-based mapping coverage through GIS (Geographic Information system). SNC utilized an 800 meters elevation-based raster set to provide continuous temperature and precipitation layers specific to the SNC Region. PRISM is utilized by USDA Forest Service, NCRS, and NOAA (National Oceanic and Atmospheric Administration).

Precipitation

Unlike temperature, there is no meaningful trend in the amount of rain or snowfall. Linear trend lines (not shown) applied to the Subregion graphs indicate a slight decrease in precipitation generally over the past 40 years. However, because the trend is slight and highly influenced by the first and last years in the data sets, this trend really cannot be viewed as significant. If there is a gradual change in the average precipitation in the Sierra Nevada occurring now or in the future, it will take a much longer timeframe to bring it to light. The data sets that have been created as a result of the Sierra Nevada System Indicators Project provide a framework for identifying potential future long-term changes in precipitation between Subregions, different elevations, or for the Region as a whole.

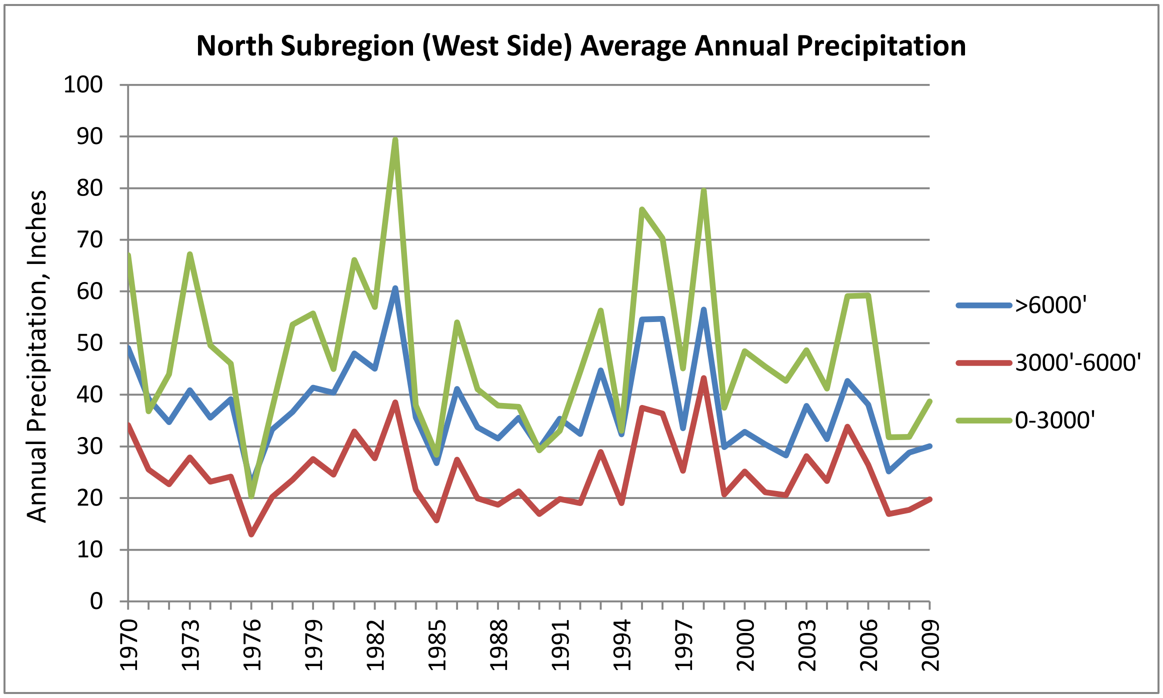
The data do allow us to compare the differences in precipitation levels at different elevations and among Subregions. These comparisons tell us that precipitation patterns in the South-Central (shown below), Central, and North-Central Subregions are fairly similar. They also tell us that precipitation is greater above 3,000' than at foothill elevations for most of the Sierra Nevada. The exception is the North Subregion (see chart on next page). With lower mountains but extensive high plateau, it has a quite different elevation rainfall pattern. Here, the heaviest rain falls below 3,000', while the plateau elevation within the 3,000'- 6,000' elevation band

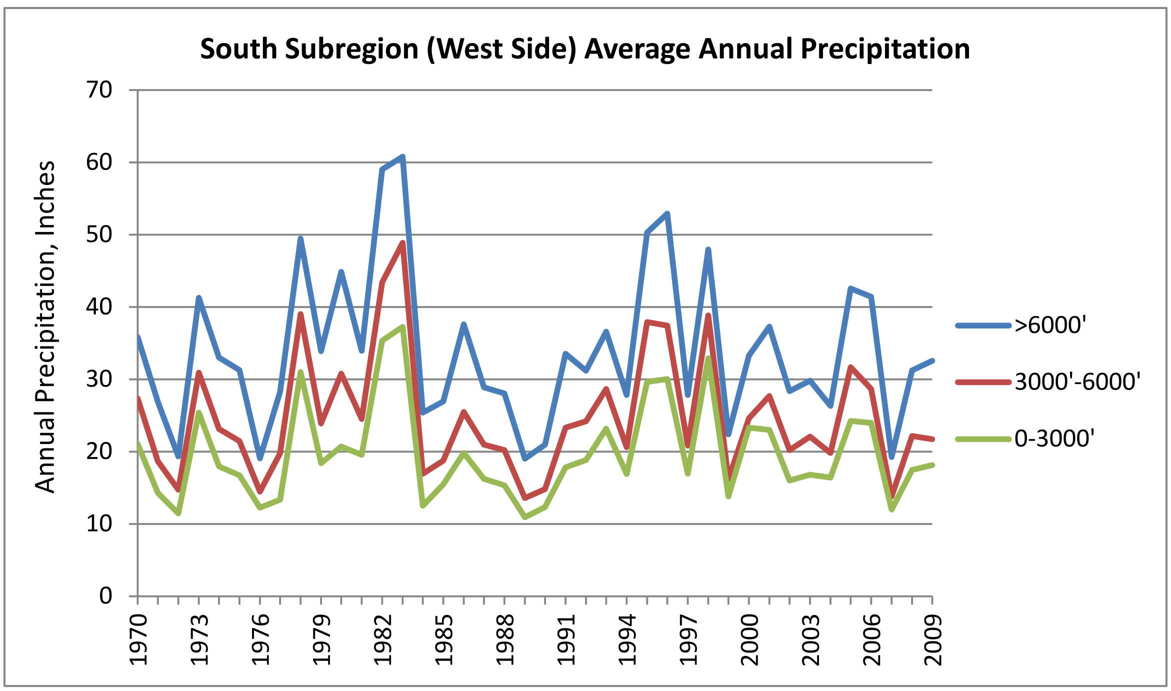


receives the least precipitation.

The South Subregion (see chart on next page), with its high peaks, receives proportionally heavier snow above 6,000' than other west facing Subregions. The East Subregion (chart not shown), in the rain shadow of the mountains, receives the least amount of rain and snow. This Subregion receives only 5 to 10 inches of precipitation per year averaged over the elevations between 3,000' and 6,000'. While elevations above 6,000' receive considerably more precipitation, it is still significantly less than what is received at those elevations on the west slope of the Sierra.

Below are two Subregions with very different precipitation patterns.





Snow Pack

In California, most of the precipitation falls during the winter while much of the need for water, particularly for agriculture, is in the summer. The Sierra Nevada provides an invaluable service by capturing a tremendous amount of precipitation as snow and storing it as snowpack for gradual release through the spring into scores of supporting reservoirs for distribution to the rest of the state.

Because California is so dependent on the supply of water that flows from the snowpack each year, the Department of Water Resources (DWR) measures the snow and estimates the water that will be available for the coming year. DWR reports to the public the year's snowpack depth as a percent of average annual snowpack, rather than the number of inches of snow that has fallen. Also, the snowpack depth is converted to inches of 'snow water equivalent' (Snow WEQ). There are good reasons for this; it is vital to know how much water the winter's snow will provide. Measuring snowfall is problematic. Snow may fall relatively 'dry' and fluffy (full of trapped air on the ground) or wet and heavy. Simply, cores of snow are taken down to the ground surface with a metal tube, the depth is measured, the snow is weighed, and converted to the number of inches it would be in the tube if it were melted.

The DWR Cooperative Snow Surveys ('cooperative' because DWR relies on cooperating partners such as the Forest Service, irrigation districts, and PG&E to take measurements in their geographic domains) measures more than two hundred snow courses scattered throughout the mountains multiple times throughout the snow season (on or as close as possible to the first day of each month).[4]

Although there is large variability from year to year in the total amount of snowfall in the Sierra, where it falls across the Region, and how quickly the snowpack melts, it is possible to use different data sources to uncover a consistent picture of the trends in annual snowpack across the Region. The following analysis shows that the year-to-year ***pattern*** of snowpack creation and melt is quite consistent across the Sierra wherever it is rigorously measured. While there is no significant trend indicating that average annual snowfall/snowpack is increasing or decreasing in the Sierra overall, there is a clear trend that snowpack is melting earlier (or more late-season snow is falling as rain instead). As shown in the various following charts comparing March and April snowpacks, the equivalent of several inches of water has been lost between April 1st snowpack as compared to the March 1st snowpack over the past 20 years or so.

The importance of April 1st snowpack

April 1st is the most important snow measurement of the year, and is the primary benchmark for estimating water availability and comparing years. Generally, most of the year's snow has fallen by then and little snow has yet melted with the onset of spring. In most years, the snowpack is deepest then. Because of its importance, more snow courses are measured for April than in other months, as many as 250, in order to provide the most accurate estimate of total snow-water volume for the year.

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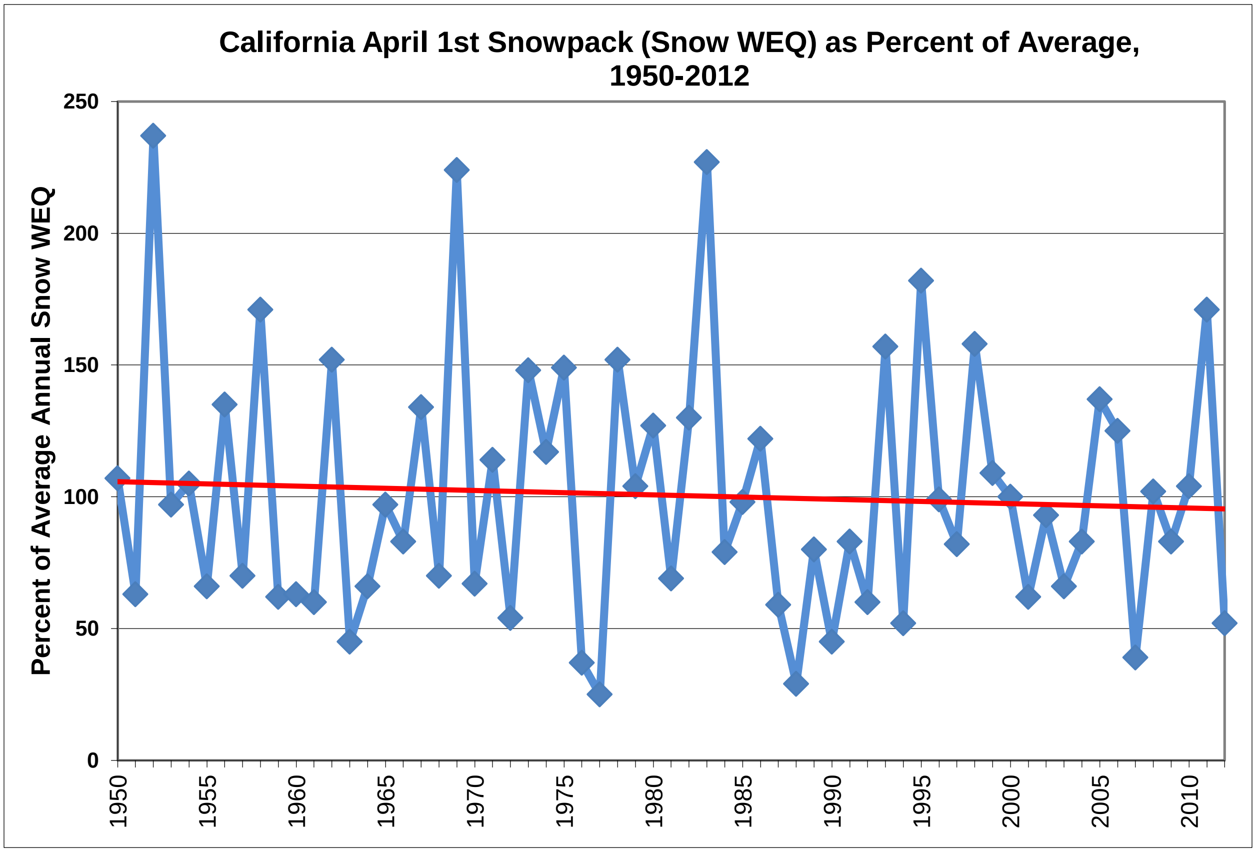
[4] Data for snowpack was acquired from the Department of Water Resources CDEC (California Data Exchange Center) site, as well as directly from the DWR cooperative Snow Surveys Chief.

The chart below graphs the April 1st Snow WEQ from 1950 through 2012 as a percentage of average April 1st Snow WEQ. Snow WEQ varies greatly from year to year, from nearly 240% of average in 1952 to only 25% of average in 1977, a ten-fold spread. This makes it challenging to discern any real trend. The red line on the chart is the linear trend line – but it is shown for illustrative purposes only. While it indicates an 8 - 10% decline in April 1st snowpack statewide over the past 63 years, the trend line cannot be taken to be meaningful. With such wide swings from year to year, the trend line is very sensitive to even one year of extreme data, even over six decades. For example, if the graph did not include the first three years, which include the huge 1952 snowfall, the resulting 60 year trend would not show any noticeable decline. If the graph ended with the heavy snow year of 2011 rather than including the low snow year of 2012, the trend line would also be much flatter. A more sophisticated approach is needed to



assess any real decline (or increase) in snowpack.

Another problem with analyzing snowpack in this way over a long period is that 'average' changes over time. For quite a long time, the 'average' that is being used for comparison has been the mean of the 50 year period from 1950 to 2000. That is expected to change soon, with the new average being 1960 to 2010. Of course, the raw data can be adjusted for the new average, but it would be cumbersome over the long haul. A better way is to analyze real Snow WEQ data measured in inches rather than looking at it as a percent of average.

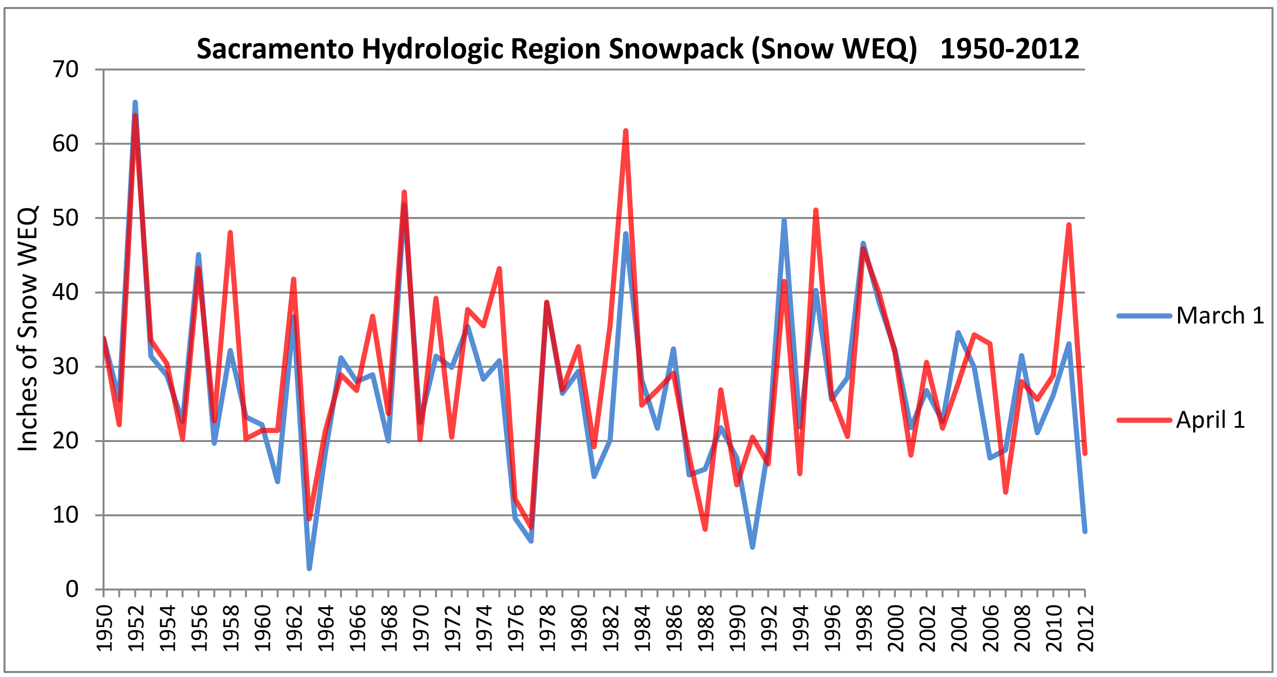
Using actual Snow WEQ measurements

Measuring snowpack in inches of Snow WEQ affords an unchanging, objective standard for comparing years. In addition, we would like to be able to analyze changes in snowpack regionally rather than just at the state level. Figures are available in inches of Snow WEQ, averaged for each of the state's hydrologic regions.

There are six hydrologic regions that contain all the mountain areas that are covered by the Cooperative Snow Survey. Only the North Coast is irrelevant to the SNC Region. The five hydrologic regions that encompass the Sierra Nevada are the Sacramento, San Joaquin, Tulare, North Lahontan, and South Lahontan.

Comparing April 1st and March 1st

The chart below is for the Sacramento Hydrologic Region (which includes the Pit, Feather, Yuba, and American River watersheds) and shows snowpack in inches of Snow WEQ rather than percent of average snowpack. The April 1st snow course measurement averages are the red line. As expected, the year to year pattern of snowpack for this large region is quite similar to that of the overall state, whether reported in actual depth of snow or as a percent of average snowpack. Close to 80 snow courses are measured on or about each April 1st in this hydrologic

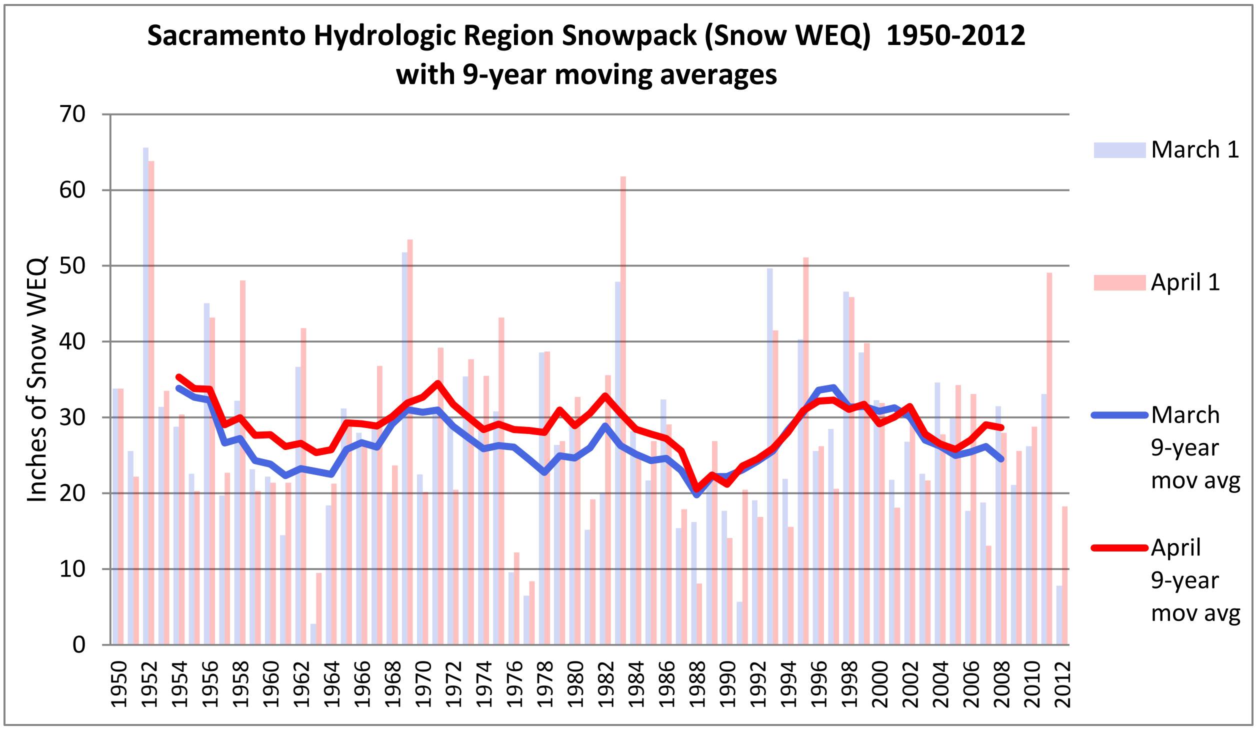


region to produce an average snowpack measurement for each year. As it was for the state in general, 1952 was the biggest snow year, with 63.8 inches WEQ in April. 1977 had only 8.4 inches, though 1988 had even less at 8.1 inches WEQ.

The chart also includes the March 1st snow course measurements for the Sacramento Region. A visual inspection of the chart reveals that in most years, but certainly not every year, the April 1st snowpack (in WEQ) is deeper than March 1st. In discussions with Frank Gehrke, the DWR Snow Surveys Chief, it was thought that comparing snowpack depth between March and April over time would highlight any changing relationship between the two measurement periods.

Because April 1st is taken to be the time of year that the snowpack is deepest, if the average April 1st depth decreases relative to the March 1st depth, it would indicate that either less snow was falling in late winter or snow was beginning to melt earlier.

The chart below is the same as the one above (converted to a bar chart), except that a 9-year moving average for each of the two months is added. The 9-year moving average is much more informative than a simple linear trend. It indicates changes throughout the time period rather



than taking the time period as a whole; and is not subject to the distortions of the beginning and end points of the time series. It aids analysis by evening out the large year-to-year variations into 9 year groupings.[5]

As indicated in the charts above, in some years the April 1st snowpack (in Snow WEQ) was a foot-or-more deeper than March 1st while in other, albeit fewer, years the March 1st snowpack was deeper than April. What's most interesting, however, are the more general patterns revealed by looking at the 9-year moving average. From the mid-50's through the mid-80's, the 9-year moving average for the Sacramento Region shows April 1st snowpack to *average* typically 3 to 5 inches deeper than March 1st during this time period. However, that gap closed up in the late 1980's and since that time, on average, April and March snowpack depths have been about the same. This more recent trend has been interrupted by the last two winters; for while 2011 had far above average snowfall and 2012 was far below average, both years had substantial March snows, which are reflected in a re-emerging gap in the 9-year moving averages. This serves to highlight that this analysis is not predictive. However, if over the coming years and

[5] The trend lines start as the average of the first 9 years as the data point for the middle year of that group, and then shifts the average each subsequent year (e.g. the average of 1950-1958 becomes the data point for 1954, the average of 1951-1959 becomes the data point for 1955, and so on).

decades, the moving average of the April 1st snowpack should continually fall at or below that of March 1st, it would document earlier snowmelt in the Sierra than the recent historical pattern.

The analysis above was just for one hydrologic region. Each of the five hydrologic regions encompassing the SNC Region has its own history, but the overall patterns for all five are similar. However, unlike the Sacramento hydrologic region, most of the regions still average a slightly deeper snowpack on April 1st than on March 1st. The charts of the other four hydrologic regions are included in the appendix.[6]

Beyond the March-April comparison, the data for the hydrologic regions do illustrate differences in regional amounts of late season snowpack. The Eastside regions – North and South Lahontan – receive less snow than the Westside (which is certainly not news), while the Sacramento hydrologic region averages a bit less March and April snowpack than the more southerly San Joaquin and Tulare regions. Tulare is the only hydrologic region where overall annual snowpack appears to have increased somewhat over the past half century.

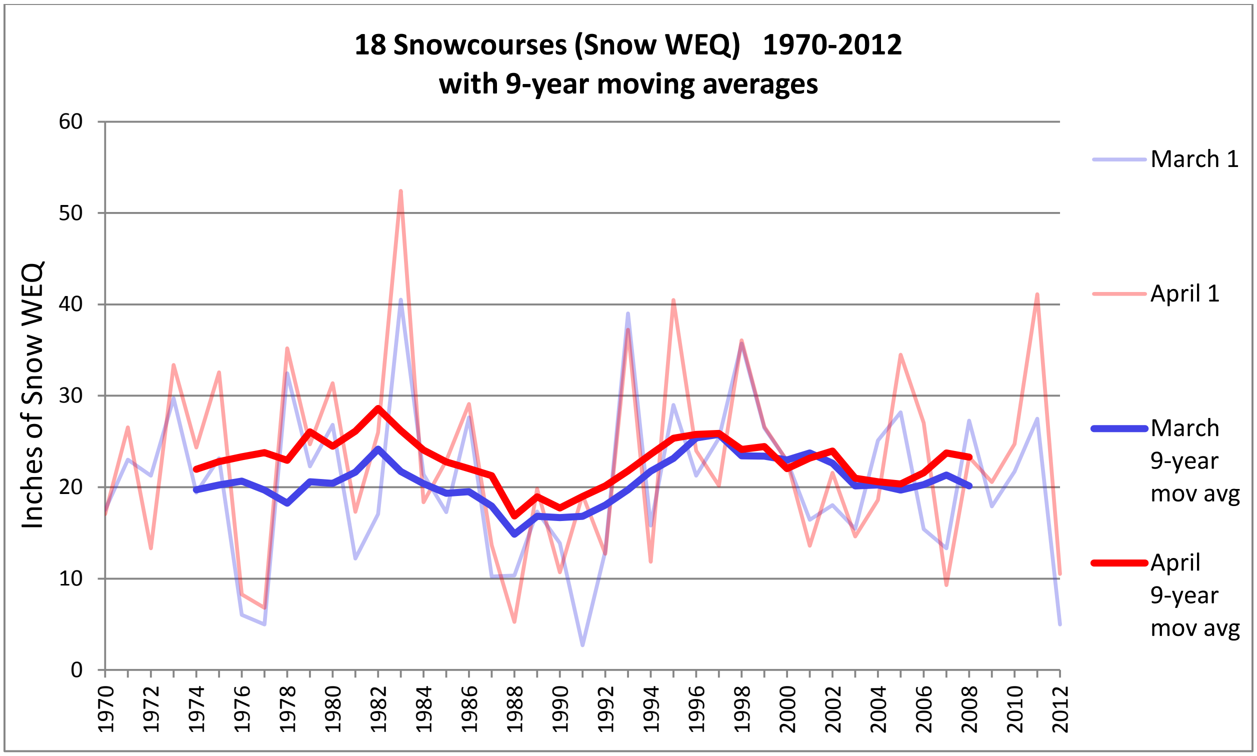
Verifying with single location measurements

To the extent possible, the DWR Snow Surveys collects data for the same snow courses year after year. Measuring the same courses provides year-to-year data consistency and measuring a large number of courses provides the best estimate possible of the average regional snowpack depth and resulting total volume of water.

In a typical year, the April 1st Snow Survey includes almost 80 snow course measurements in the Sacramento Hydrologic Region, about 70 in the San Joaquin Region, about 45 in the Tulare, 17-18 in the North Lahontan, and about 20 in the South Lahontan. The March 1st Survey generally includes five to ten fewer snow courses than April. However, through the measurement history, data gaps emerge in many of the snow courses for either April or March.

As a supplement to the hydrologic region averages, an analysis was made to identify individual snow course locations where there is a complete record for both March and April for a long time frame with no missing years. An SNC review of data provided by DWR, covering 1970 to 2012 (43 years), yielded 18 snow courses that had Snow WEQ measurements for both months for all 43 years. (Almost 100 more were missing only one year or just a few years for either March or April.) These 18 courses are spread across the Sierra, from the Pit River watershed in the north to the Kern watershed in the south. Taken together, these 18 snow courses provide an excellent cross section of Sierra snowpack from year to year. The snowpack Snow WEQ was averaged for the 18 courses, and are displayed along with 9-moving averages on the chart below.

[6] Note: DWR does not have March data for the South Lahontan region before 1958, and there were only 2 snow courses measured in 1958, and so was not included.

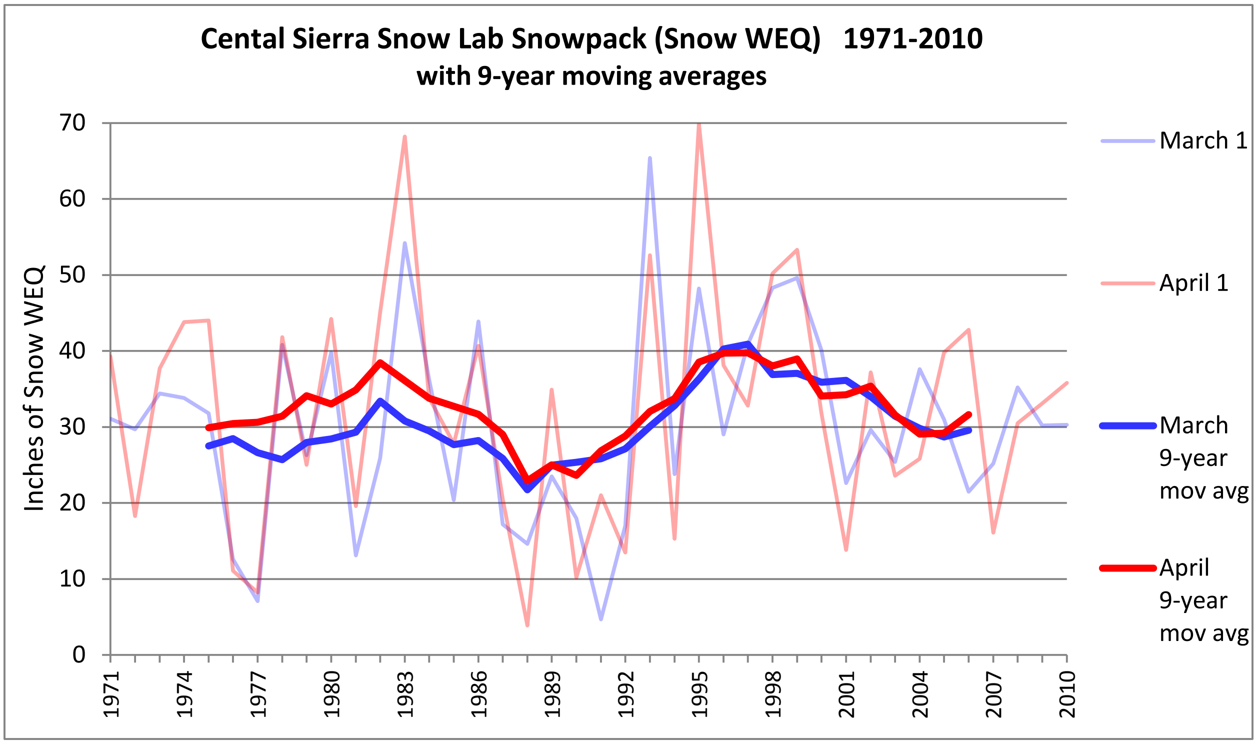


Over the same time period (1970-2012), this graph is barely distinguishable from the Sacramento Hydrologic Region graph, especially in the moving-average relationship between March and April snowpack. The amount of average snowpack for these combined 18 snow courses is less than for the Sacramento Region, but the year-to-year patterns are the same. In other words, using a targeted set of snow courses with complete data is entirely consistent with the hydrologic region-scale analysis.

Data from the Central Sierra Snow Lab

The UC Berkeley Snow Lab, located at 6,900' elevation at Donner Summit, provides the most detailed single location snow analysis in the Sierra Nevada. Although they take much more frequent snow measurements than just monthly, the March 1st and April 1st Snow WEQ was graphed to provide yet another single location comparison under the same parameters. The chart, including 9-year moving averages, is shown below. The time series is slightly different; it starts into 1971 and does not include 2011 and 2012.

Once again, the relationship between April and March is entirely consistent with all the other data sets. Because it does not include 2011 and 2012, both years of which had heavy March snows throughout the region, a growing gap between the March and April snowpacks after 2010 would be expected, as with all the other data sets from the influence of these years on the moving average.



Conclusion related to snowpack

This analysis clearly demonstrates a decline in April 1st snowpack relative to March 1st, and also indicates some degree of actual decline in average April snowpack depth, though it does not quantify the change. It does appear that the relative decrease in April snowpack compared to March is in the range of perhaps several inches of Snow Water Equivalent, which is quite substantial, given an average April 1st snowpack depth in the range of 20 to 35 inches of Snow WEQ. A Department of Water Resources report claims a 10 percent decline in April snowpack over the past century, with presumably much of this decline since 1950.[7] That report employed a very different analysis in its finding – assessing runoff water flow changes rather than snow depth changes to indicate reduced snowpack. This SNC report provides a different strategy to look at snowpack change that is potentially complimentary, and certainly points in the same direction.

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[7] 2008 DWR report "Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water." This report states that early spring snowpack in the Sierra Nevada has decreased by 10% in the past century. The methodology used a "full natural flows" approach that looked at percent changes to April through July water flows.

Precipitation, Temperature, and Snowpack Relationships

There are three important questions to ask when considering potential future changes in snowpack (and hence the timing of California's water supply): 1) is there a long run change in precipitation? 2) Is more (or less) precipitation falling as rain rather than snow? And 3) is snowpack melting earlier (or later)?

As to the first question, at this point there is no clear evidence of significant change in total precipitation in the past four decades. The year to year variation is so great that it would take many years or decades to tease out any real change in the rainfall pattern.

For any particular elevation, the second and third questions are primarily dependent on any specific changes in temperature – the season and the actual temperatures. Depending on elevation and ambient temperature, warming weather may cause more rain (rather than snow) and faster snow melt. There is substantial evidence of generally warming temperatures, dependent on elevation and time of day. What has not been investigated yet is if indicated warming is occurring in any particular season. That is another level of analytical complexity yet to be tackled.

Question number 2 is the most difficult to address. There is not really a system in place (that we have been able to find) to measure whether precipitation is falling as rain or as snow on a geographic scale. The Central Sierra Snow Lab does consistently note observations proportioning precipitation as to rain or snow. With considerable effort, over time, a relationship could be determined on how much snowpack loss is due to melting and snow not falling in the first place. However, a single location provides a weak basis for a regional assessment.

Regarding question 3, if April 1st snowpack in any one year is less than March 1st snowpack, we know that more snowpack melted than new snow fell, and that April 1st is not the best date to characterize the annual snowfall. If April 1st snowpack is greater than March 1st, we know that some snow has fallen, but it challenging to determine if there was also increased rain and/or snow melt that reduced the potential snowpack for that month.

At this point, the data for rising temperatures does correlate with a relative decrease in the amount of April 1st snowpack compared to a month earlier.

Contact Information

For more detailed information on the individual Indicators or explanation of their development, please contact:

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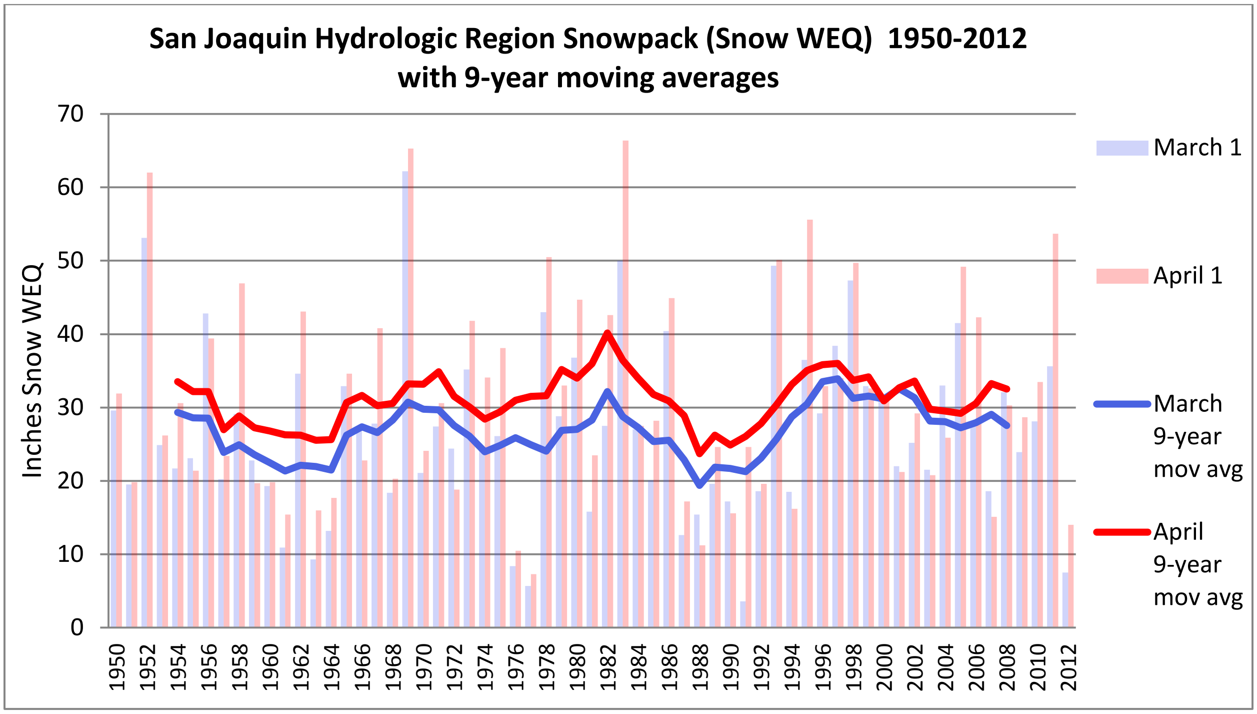
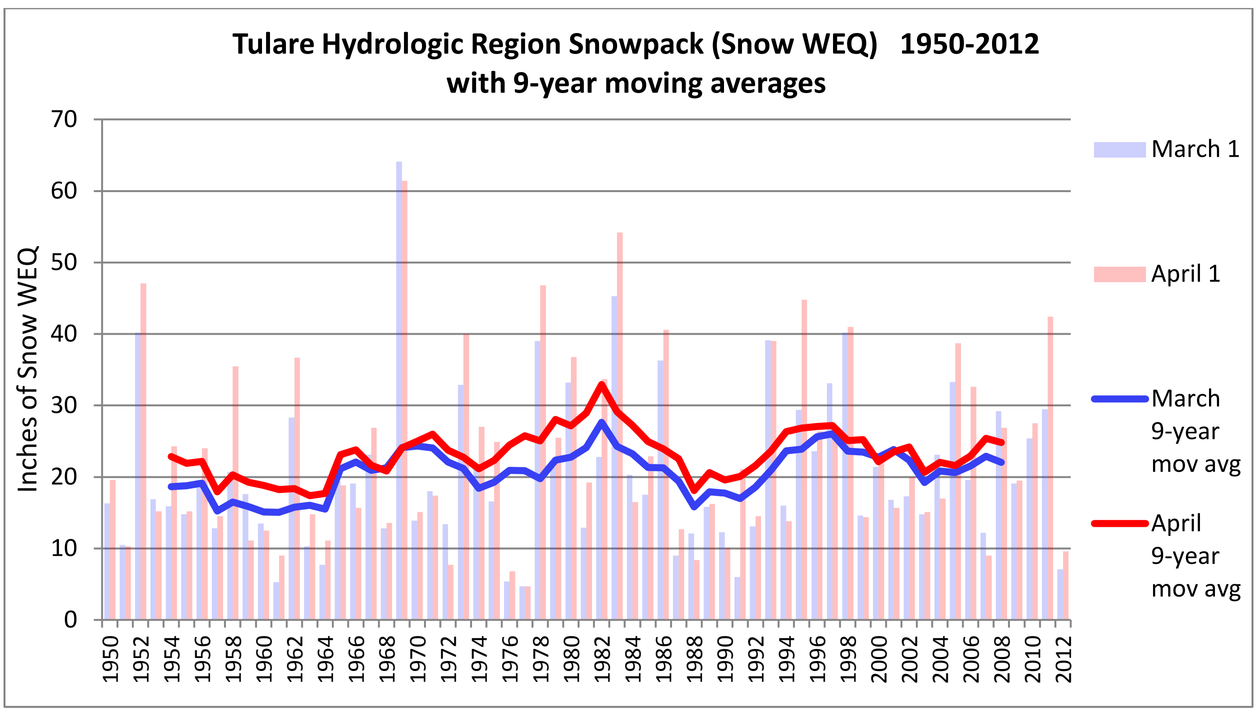
Appendices

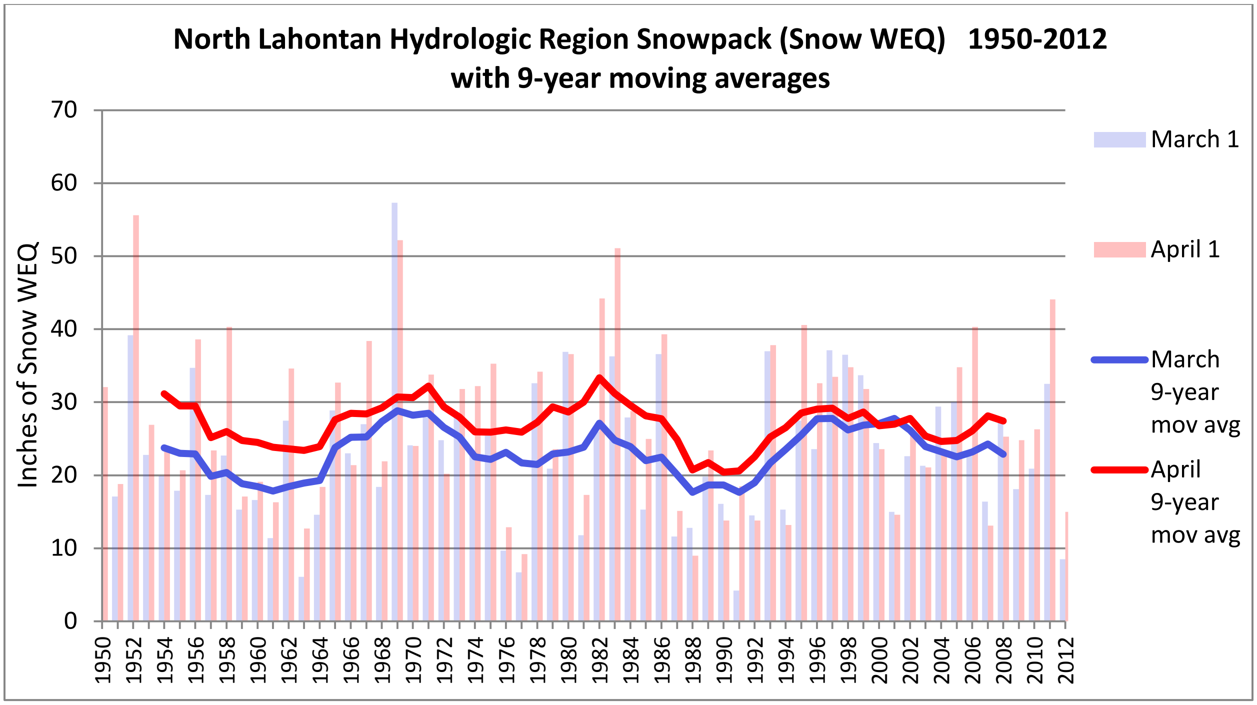
- Snowpack Charts for Four Hydrologic Regions
- Tables of Specific 303(d) Listed Impaired Water Bodies

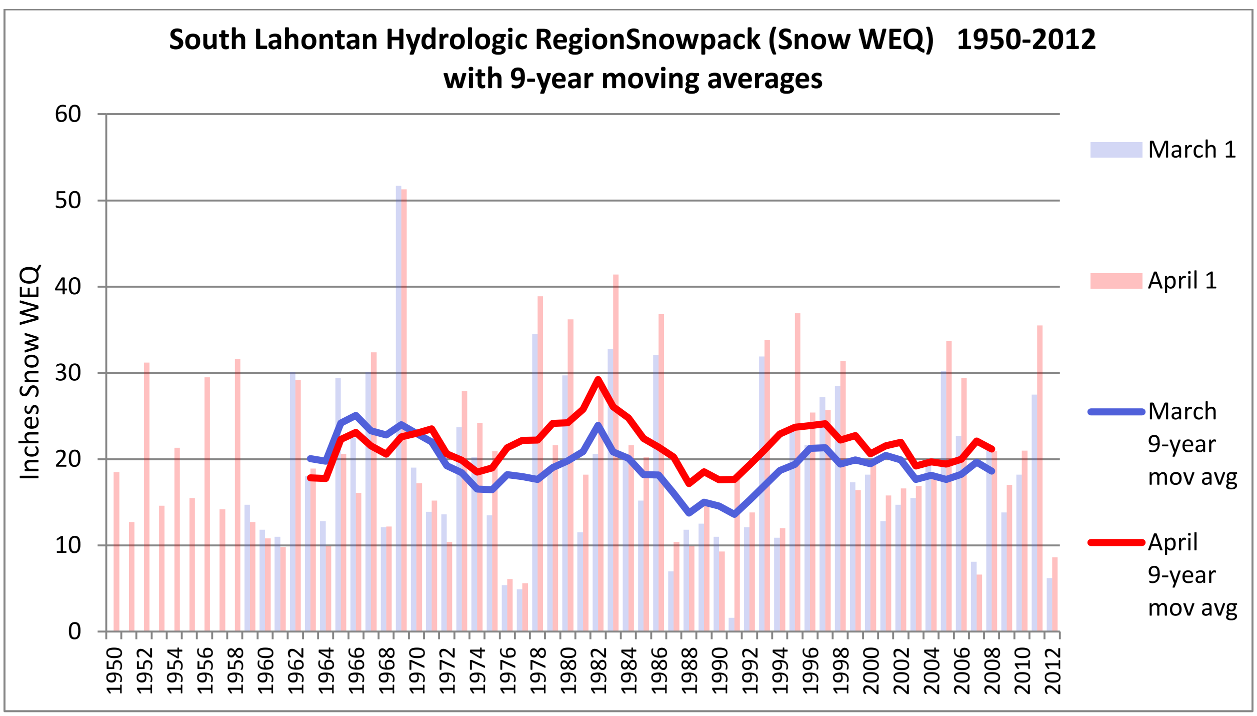
Snowpack Charts for Four Hydrologic Regions

(Sacramento included in the text body)






North Lahontan Hydrologic Region Snowpack (Snow WEQ) 1950-2012
with 9-year moving averages
Inches of Snow WEQ
March 1
April 1
March 9-year mov avg
April 9-year mov avg


South Lahontan Hydrologic RegionSnowpack (Snow WEQ) 1950-2012
with 9-year moving averages
Inches Snow WEQ
March 1
April 1
March 9-year mov avg
April 9-year mov avg

Tables of Specific 303(d) Listed Impaired Water Bodies

Mercury - Streams (in miles)

	Butte	Calaveras	El Dorado	Lassen	Mono	Nevada	Placer	Plumas	Sierra	Tehama	Tuolumne	Yuba	Total
American River, North Fork			1.9				74.6						76.5
American River, South Fork			44.6										44.6
Bear River, Lower (below Camp Far West Reservoir)							1.4					1.2	2.7
Bear River, Upper (from Combie Lake to Camp Far West Reservoir)						11.1	13.5						24.6
Big Chico Creek	24.0									11.3			35.3
Bodie Creek					9.7								9.7
Butte Creek	48.2												48.2
Deer Creek (from Deer Creek Reservoir to Lake Wildwood)						16.1							16.1
Feather River, Lower (below Lake Oroville Dam)	4.7												4.7
Feather River, North Fork (below Lake Almanor)	13.1							41.1					54.2
Gold Run						1.9							1.9
Humbug Creek						2.2							2.2
Little Deer Creek						4.1							4.1
Mammoth Creek (Old Mammoth Road to Highway 395)					6.0								6.0
Mammoth Creek (Twin Lakes outlet to Old Mammoth Road)					1.9								1.9
Mammoth Creek, unamed tributary					1.7								1.7
Stanislaus River, Lower		1.5									1.2		2.7
Susan River (Headwaters to Susanville)				37.3									37.3
Susan River (Litchfield to Honey Lake)				8.5									8.5
Susan River (Susanville to Litchfield)				16.5									16.5
Tuolumne River, Lower (below Don Pedro Reservoir)											3.5		3.5
Yuba River, Lower												1.0	1.0
Yuba River, Middle Fork						16.7			20.7			7.7	45.2
Yuba River, North Fork									28.1			10.1	38.2
Yuba River, South Fork						41.9	6.5						48.3
Grand Total	**90.0**	**1.5**	**46.5**	**62.4**	**19.2**	**93.9**	**96.0**	**41.1**	**48.9**	**11.3**	**4.7**	**20.1**	**535.5**

Mercury - Lakes (Acres)

	Amador	Butte	Calaveras	El Dorado	Fresno	Madera	Mariposa	Nevada	Placer	Plumas	Shasta	Tulare	Tuolumne	Yuba	Total
Almanor Lake										25,315					25,315
Britton Lake											1,100				1,100
Camanche Reservoir	1,367		1,066												2,433
Camp Far West Reservoir								100	730					899	1,730
Combie, Lake								170	192						362
Don Pedro Lake													11,056		11,056
Englebright Lake								413						341	754
Folsom Lake				6,040					3,759						9,799
Hell Hole Reservoir									1,370						1,370
Hensley Lake						1,669									1,669
Hetch Hetchy Reservoir													1,840		1,840
Kaweah Lake												1,702			1,702
McClure Reservoir							5,605								5,605
Millerton Lake					1,091	928									2,019
New Bullards Bar Reservoir														3,864	3,864
New Hogan Lake			3,180												3,180
New Melones Reservoir			748										907		1,654
Oroville, Lake		15,400													15,400
Oxbow Reservoir (Ralston Afterbay)				32					33						65
Pardee Reservoir	1,184		1,001												2,185
Pine Flat Reservoir					5,771										5,771
Rollins Reservoir								547	227						774
Scotts Flat Reservoir								660							660
Shasta Lake											1,998				1,998
Slab Creek Reservoir				242											242
Tulloch Reservoir			525										467		992
Wildwood, Lake								289							289
Grand Total	**2,551**	**15,400**	**6,520**	**6,315**	**6,862**	**2,597**	**5,605**	**2,179**	**6,311**	**25,315**	**3,098**	**1,702**	**14,269**	**5,105**	**103,827**

Metals other than Mercury - Streams (net miles)

	Alpine	Amador	Calaveras	El Dorado	Mono	Nevada	Placer	Plumas	Shasta	Sierra	Yuba	Total	Metals
Aspen Creek	0.9											0.9	metals
Bear Creek			11.1									11.1	coper
Bear River (Lower Bear River Res. to Mokelumne River, N Fork)		5.4										5.4	copper
Bear River, Lower (below Camp Far West Reservoir)							1.4				1.2	2.7	copper
Bryant Creek	3.2											3.2	metals
Carson Creek (from WWTP to Deer Creek)				2.1								2.1	aluminum, manganese
Deer Creek (Sacramento County)				7.9								7.9	iron
Dolly Creek								1.5				1.5	copper, zinc
East Walker River, below Bridgeport Reservoir					8.0							8.0	manganeze
Humbug Creek						2.2						2.2	copper, zinc
Kanaka Creek										9.7		9.7	arsenic
Leviathan Creek	3.2											3.2	metals
Little Cow Creek (downstream from Afterthought Mine)									1.1			1.1	cadmium, copper, zinc
Little Grizzly Creek								9.4				9.4	copper, zinc
Mammoth Creek (Old Mammoth Road to Highway 395)					6.0							6.0	manganese
Mammoth Creek (Twin Lakes outlet to Old Mammoth Road)					1.9							1.9	manganese
Mammoth Creek, unamed tributary near Old Mammoth Rd					1.7							1.7	arsenic
Monitor Creek	4.0											4.0	alum, iron, mang, silver
Grand Total	**11.4**	**5.4**	**11.1**	**10.0**	**17.5**	**2.2**	**1.4**	**10.9**	**1.1**	**9.7**	**1.2**	**82.0**	

Metals other than Mercury – Lakes (net acres)

	Amador	Calaveras	Inyo	Lassen	Total	Metal
Camanche Reservoir	1,367	1,066			2,433	copper, zinc
Haiwee Reservoir			1,703		1,703	copper
Honey Lake				57,757	57,757	arsenic
Honey Lake Area Wetlands				62,592	62,592	metals
Honey Lake Wildfowl Management Ponds				665	665	metals
Grand Total	**1,367**	**1,066**	**1,703**	**121,014**	**125,150**	

Temperature - Streams (in miles)

	Butte	Calaveras	Lassen	Madera	Modoc	Nevada	Placer	Plumas	Shasta	Tuolumne	Total
Feather River, North Fork (below Lake Almanor)	13.1							41.1			54.2
Pit River (from confluence of N and S forks to Shasta Lake)			83.3		105.8				109.9		299.0
Stanislaus River, Lower		1.5								1.2	2.7
Tuolumne River, Lower (Don Pedro Res. to San Joaquin River)										3.5	3.5
Willow Creek (Madera County)				6.2							6.2
Yuba River, South Fork (Spaulding Res. to Englebright Res.)						41.9	6.5				48.3
Grand Total	**13.1**	**1.5**	**83.3**	**6.2**	**105.8**	**41.9**	**6.5**	**41.1**	**109.9**	**4.7**	**413.9**

pH - Streams (in miles)									
	Amador	Butte	Lassen	Modoc	Nevada	Tulare	Yuba	Total	
Ash Creek, Upper			13.5	5.8				19.3	
Bear River (from Allen to Upper Bear River Res.)	8.4							8.4	(low)
Butte Creek		48.2						48.2	
Deer Creek						28.9		28.9	(high)
Deer Creek					4.2		0.1	4.3	
Kaweah River (below Terminus Dam)						2.4		2.4	
Pit River, North Fork				22.8				22.8	
Pit River, South Fork			0.7	37.2				37.9	
Rush Creek				9.6				9.6	
Willow Creek			21.9	1.0				22.9	
Grand Total	**8.4**	**48.2**	**36.2**	**76.3**	**4.2**	**31.3**	**0.1**	**204.7**	

pH - Lakes (acres)						
	Amador	Kern	Madera	Shasta	Tulare	Total
Amador Lake	299					299
Eastman Lake				19		19
Hensley Lake			1,669			1,669
Isabella Lake		7,710				7,710
Success Lake					88	88
Grand Total	**299**	**7,710**	**1,669**	**19**	**88**	**9,785**

Nutrients - Streams (net miles)

	Alpine	Calaveras	Lassen	Madera	Modoc	Mono	Placer	Shasta	Total	nutrient
Bear Creek		11.1							11.1	low oxygen
Carson River, West Fork (Headwaters to Woodfords)	18.0								18.0	nitrogen, phosphorus
Carson River, West Fork (Woodfords to Paynesville)	3.6								3.6	nitrogen
Fresno River (Above Hensley Reservoir)				29.9					29.9	low oxygen
Hilton Creek						11.3			11.3	low oxygen
Miners Ravine							9.4		9.4	low oxygen
Pit River (from confluence of N and S forks to Shasta Lake)			83.3		105.8			109.9	299.0	nutrients, low oxygen
Pleasant Grove Creek							1.7		1.7	low oxygen
Susan River (Headwaters to Susanville)			37.3						37.3	nitrogen
Swauger Creek						13.6			13.6	phosphorus
Grand Total	**21.6**	**11.1**	**120.6**	**29.9**	**105.8**	**24.9**	**11.1**	**109.9**	**434.9**	

Nutrients - Lakes (net acres)

	Alpine	Fresno	Inyo	Kern	Lassen	Madera	Mono	Total	nutrient
Bridgeport Reservoir							2,615	2,615	nitrogen, phosphorus
Crowley Lake							4,861	4,861	oxygen, amonia
Eagle Lake (Lassen County)					20,705			20,705	nitrogen, phosphorus
Hensley Lake						1,669		1,669	oxygen
Hume Lake		87						87	oxygen
Indian Creek Reservoir	164							164	phosphorus
Isabella Lake				7,710				7,710	oxygen
Pleasant Valley Reservoir			99					99	low oxygen
Grand Total	**164**	**87**	**99**	**7,710**	**20,705**	**1,669**	**7,476**	**37,910**	

Pathogens - Streams (in miles)											
	Alpine	Amador	Calaveras	Lassen	Mariposa	Modoc	Mono	Nevada	Shasta	Tuolumne	Total
Ash Creek, Upper				13.5		5.8					19.3
Bear Creek (from Bear Valley to San Joaquin River)					27.3						27.3
Bear Creek			11.1								11.1
Beaver Creek				19.9					2.9		22.7
Buckeye Creek							17.2				17.2
Canyon Creek						18.7					18.7
Carson River, West Fork (Paynesville to State Line)	3.3										3.3
Carson River, West Fork (Woodfords to Paynesville)	3.6										3.6
Clover Creek									11.2		11.2
Curtis Creek										11.6	11.6
East Walker River, above Bridgeport Reservoir							7.4				7.4
French Ravine								1.7			1.7
Indian Creek	11.7										11.7
Littlejohns Creek			24.6								24.6
Oak Run Creek									5.6		5.6
Rattlesnake Creek (at W Mokelumne River, N Fork)		0.9									0.9
Robinson Creek (Hwy 395 to Bridgeport Res)							1.8				1.8
Robinson Creek (Twin Lakes to Hwy 395)							9.1				9.1
South Cow Creek									7.9		7.9
Sullivan Creek (from Phoenix Res. to Don Pedro Lake)										10.8	10.8
Swauger Creek							13.6				13.6
Willow Creek				21.9		1.0					22.9
Wolf Creek (Nevada County)								22.8			22.8
Woods Creek										15.2	15.2
Grand Total	**18.6**	**0.9**	**35.7**	**55.3**	**27.3**	**25.4**	**49.1**	**24.4**	**27.5**	**37.6**	**301.8**

Toxicity - Streams (in miles)										
	Butte	**Calaveras**	**Fresno**	**Lassen**	**Mariposa**	**Placer**	**Plumas**	**Tulare**	**Tuolumne**	**Total**
Bear Creek					27.3					27.3
Concow Creek (tributary to West Branch Feather River)	9.7									9.7
Deer Creek								28.9		28.9
Fall River, tributary to Feather River, Middle Fork	12.8						9.5			22.3
Feather River, Lower (below Lake Oroville Dam)	4.7									4.7
Feather River, Middle Fork (Sierra Valley to Lake Oroville)	10.7						68.4			79.1
Feather River, North Fork (below Lake Almanor)	13.1						41.1			54.2
Feather River, South Fork (Little Grass Valley Res to Lake Oroville)	17.0						18.0			34.9
Feather River, West Branch (from Griffin Gulch to Lake Oroville)	38.1									38.1
Kaweah River (below Terminus Dam)								2.4		2.4
Kings River, Lower (Pine Flat Reservoir to Island Weir)			14.6							14.6
Littlejohns Creek		24.6								24.6
Mud Creek	4.6									4.6
Pleasant Grove Creek						1.7				1.7
Stanislaus River, Lower		1.5							1.2	2.7
Sucker Run	10.6									10.6
Susan River (Headwaters to Susanville)				37.3						37.3
Susan River (Litchfield to Honey Lake)				8.5						8.5
Susan River (Susanville to Litchfield)				16.5						16.5
Tuolumne River, Lower (below Don Pedro Reservoir)									3.5	3.5
Grand Total	**121.2**	**26.2**	**14.6**	**62.4**	**27.3**	**1.7**	**136.8**	**31.3**	**4.7**	**426.2**

Pleasant Grove Creek - sediment toxicity; all the rest unknown toxicity
all sources unknown

Pesticides - Streams (net miles)

	Butte	Calaveras	Fresno	Placer	Tuolumne	Yuba	Total	pesticide
Bear Creek		11.1					11.1	diazinon
Bear River, Lower (below Camp Far West Reservoir)				1.4		1.3	2.7	chlorpyrifos, diazinon
Comanche Creek (from Little Chico Creek to Angel Slough)	0.5						0.5	diuron
Feather River, Lower (below Lake Oroville Dam)	4.7						4.7	chlorpyrifos, Group A
Kings River, Lower (Pine Flat Reservoir to Island Weir)			14.6				14.6	chlorpyrifos
Pleasant Grove Creek				1.7			1.7	pyrethroids
Stanislaus River, Lower		1.5			1.2		2.7	chlorpyrifos, diazinon, Group A
Tuolumne River, Lower (below Don Pedro Reservoir)					3.5		3.5	chlorpyrifos, diazinon, Group A
Grand Total	**5.2**	**12.6**	**14.6**	**3.1**	**4.7**	**1.3**	**41.5**	

Salinity/Total Dissolved Solids - Streams (in miles)

	Alpine	Inyo	Lassen	Modoc	Mono	Total
Bidwell Creek				12.3		12.3
Carson River, East Fork	46.4					46.4
Mammoth Creek (Headwaters to Twin Lakes outlet)					2.6	2.6
Mammoth Creek (Old Mammoth Road to Highway 395)					6.0	6.0
Mill Creek (Modoc County)				4.2		4.2
Monitor Creek	4.0					4.0
Pit River, South Fork			0.7	37.2		37.9
Rock Creek (tributary to Owens River)		15.4			20.0	35.4
Susan River (Headwaters to Susanville)			37.3			37.3
Susan River (Susanville to Litchfield)			16.5			16.5
Grand Total	**50.4**	**15.4**	**54.5**	**53.7**	**28.6**	**202.6**

Pit River - salinity; all the rest 'total dissolved solids'

Sediment/Siltation - Streams (in miles)

	Alpine	Mono	Nevada	Placer	Shasta	Sierra	Total
Bronco Creek			1.2				1.2
Clearwater Creek		12.6					12.6
East Walker River, below Bridgeport Reservoir		8.0					8.0
Fall River (Pit)					11.8		11.8
Gray Creek (Nevada County)			2.6				2.6
Humbug Creek			2.2				2.2
Squaw Creek				7.9			7.9
Truckee River			22.4	10.1		2.4	35.0
Wolf Creek (Alpine County)	11.8						11.8
Grand Total	**11.8**	**20.7**	**28.4**	**18.0**	**11.8**	**2.4**	**93.2**

Turbidity - Streams (in miles)

	Lassen	Mono	Total
East Walker River, below Bridgeport Reservoir		8.0	8.0
Susan River (Susanville to Litchfield)	16.5		16.5
Grand Total	**16.5**	**8.0**	**24.5**