Lahontan Surface Water Ambient Monitoring Program's 20-Year Water Quality Review and Program Recommendations

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List of Abbreviations and/or Acronyms

CRAM	California Rapid Assessment Method for streams and wetlands (www.cramwetlands.org)
CSCI	California Stream Condition Index; SWAMP PSA's macrobenthic stream condition index for wadeable streams (https://www.waterboards.ca.gov/water_issues/programs/swamp/bioassessment/sops.html)
Framework	the adaptive Monitoring and Assessment Framework outlined by WRAMP (https://www.mywaterquality.ca.gov/monitoring_council/wetland_workgroup/wramp/)
HU	Lahontan Regional Water Quality Control Board's Basin Plan Hydrologic Unit (https://www.waterboards.ca.gov/lahontan/water_issues/programs/basin_plan/references.html - see chapter 3)
PHAB	Physical Habitat Assessment Method developed by the PSA and other federal EPA and regional partners (https://www.waterboards.ca.gov/water_issues/programs/swamp/bioassessment/sops.html)
PSA	Statewide Bioassessment Program's Perennial Stream Assessment (a long-term statewide survey) (https://www.waterboards.ca.gov/water_issues/programs/swamp/bioassessment/statewide_program.html)
RCMP	Statewide Reference Condition Management Program (see PSA link, above)
Regional SWAMP	Lahontan Regional Water Quality Control Board's SWAMP (https://www.waterboards.ca.gov/lahontan/water_issues/programs/swamp/background.html)
SSO	Lahontan Regional Water Quality Control Board's Basin Plan Site Specific Objective/s (see Basin Plan link under HU above - chapter 3)
SWAMP	Surface Water Ambient Monitoring Program (https://www.waterboards.ca.gov/water_issues/programs/swamp/)
WQO	Lahontan Regional Water Quality Control Board's Basin Plan Water Quality Objective/s (see Basin Plan link under HU above - chapter 3)
WRAMP	Wetland and Riparian Area Monitoring Plan of the California Wetlands Monitoring Workgroup (https://www.mywaterquality.ca.gov/monitoring_council/wetland_workgroup/)

1. Executive Summary

The Lahontan Regional Water Quality Control Board's (Water Board) jurisdictional Region is located in the eastern Sierra Nevada mountain range in California. It extends nearly 600 miles from the northeastern border of the state to the southeastern Mojave Desert. It encompasses approximately 33,000 square miles. The Region has more than 700 lakes, and over 120,000 miles of streams. Over 90% of the streams are ephemeral streams located in the semi-arid desert regions of the Eastern Sierra and Mojave Desert, and less than 10% are perennial and intermittent streams.

This 20-year water quality monitoring status and trends report for the Lahontan Water Board's Surface Water Ambient Monitoring Program (Regional SWAMP) provides an overview of the environmental settings across the Region to give the reader a sense of the diverse ecological landscape, land uses, distribution and abundance of aquatic resources, and fire history. It includes a retrospective analysis of the Regional SWAMP's ongoing, targeted water quality monitoring results (2000 - 2021), and concludes by presenting an adaptive monitoring and assessment framework that was used to review the program and recommend future monitoring changes to improve efficiencies and address some of the recommendations listed in the 2019 Core Program Review.

Since its inception, the Regional SWAMP's water quality monitoring efforts have focused on compliance monitoring to address the overarching management question:

> "Are the streams within the Lahontan Region meeting the chemical and physical water quality objectives contained in the Basin Plan[1]?"

The Regional SWAMP employs a targeted survey design for its ongoing water quality monitoring program to address this question. This means that the program used best professional judgment to locate its monitoring stations in perennial streams on public lands, with private landowner permission, or public right-of-ways, near the bottom of watersheds in locations that are considered *'integrator'* sites. The program currently monitors 46 stations one to four times per year, in 22 streams across the Lahontan Region. Water samples are analyzed for up to 35 physical and chemical water quality parameters.

With nearly 30,000 water quality results reported between January 2000 and July 2021, this report summarizes the results by 5 subregions to begin to address the core question of whether the monitored streams are meeting the chemical and physical water quality objectives (WQOs) and site specific objectives (SSOs) contained in the Basin Plan. The subregions (listed from north to south) include Modoc, Truckee/Tahoe, Eastern Sierra (North and South), and Mojave. The report also explores the dataset for statistical trends over time at stations that

[1] Regional Water Board Meeting Notes Item 18 (Bishop, CA. July 10, 2019)

have been monitored for at least 9 years. Some of the specific questions addressed in the report include:

<u>What proportion of water quality results are exceeding the Basin Plan's SSOs and WQOs and where?</u>

The charts below show the percent of Basin Plan water quality exceedances for 16 physical and chemical parameters evaluated in this report, based on results from the Regional SWAMP's 46 monitoring stations sampled between January 2000 and July 2021. Figure E.1 summaries the percent exceedances for the Lahontan Region as a whole, and Figure E.2 presents the percent exceedances by subregion.

At the Lahontan Region level, Figure E.1 shows that most of the Basin Plan water quality exceedances in the Region were seen in Oxygen Saturation (T_OS, 40% of evaluated results exceeded the objective), Total Dissolved Solids (TDS, over 60% exceeded), and Total Phosphorus (T_P, nearly 60% exceeded the site specific objectives).

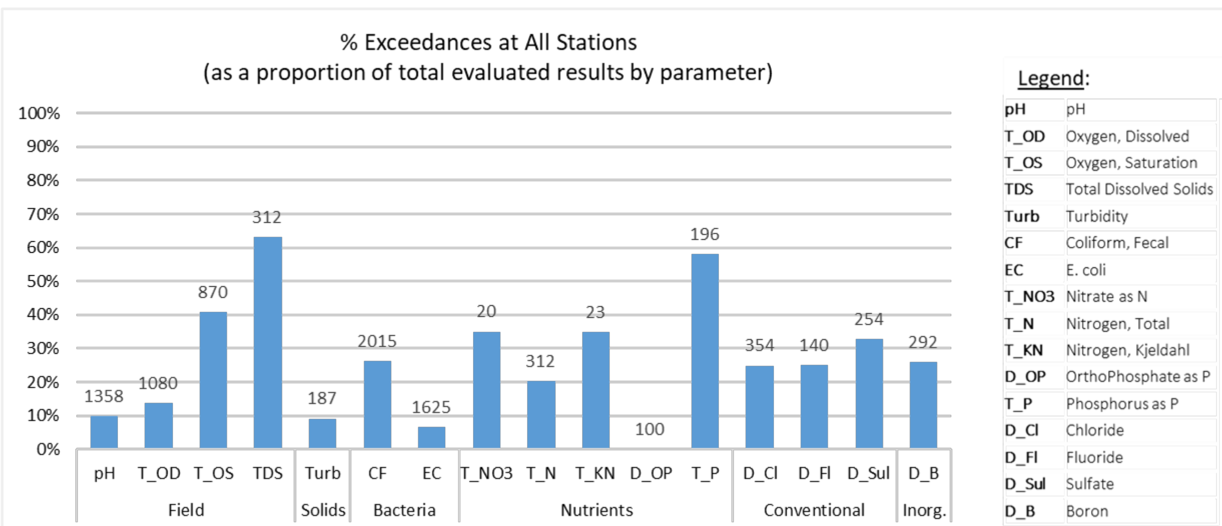

Figure E.1. Percent of Basin Plan water quality objective exceedances at all 46 Regional SWAMP monitoring stations as a proportion of the total evaluated results by parameter. The number above each bar indicates the total number of calculated or direct-measure results for all stations (2000-2021).

Drilling down to the subregion level, Figure E.2 shows the percent of water quality exceedances for all Regional SWAMP monitoring stations, sampled between January 2000 and July 2021 grouped into 5 subregions. Oxygen Saturation (T_OS) exceedances were most prevalent in the Eastern Sierra (South) and Mojave subregions where about 60% of the evaluated results exceeded the objectives in both subregions. Total Dissolved Solids (TDS) exceedances were significant in all subregions and ranged from 50-90% among subregions with the highest percentage in the Modoc (90%), Eastern Sierra (South, 60%), and Mojave (60%) subregions.

Truckee/Tahoe and Eastern Sierra (North) subregions exceeded the objectives in just over 40% of the calculated annual average TDS results. There are no Total Phosphorus (T_P) Basin Plan objectives for the Regional SWAMP stations located in the Eastern Sierra (South) or Mojave subregions, so T_P monitoring results from those southern subregions were not evaluated. However, nearly 60% of all the other evaluated results from stations in the northern portions Lahontan Region exceeded the Basin Plan water quality objectives: largely due to exceedances in the Eastern Sierra (North) subregion (80% of the results exceeded the site specific objectives). These summary charts provide a relatively straightforward way to identify which Basin Plan water quality parameters are exceeding objectives and in what subregions, with the caveat that it's important to keep in mind differences in the number of stations, sampling frequencies, and reported parameters represented in each subregion.

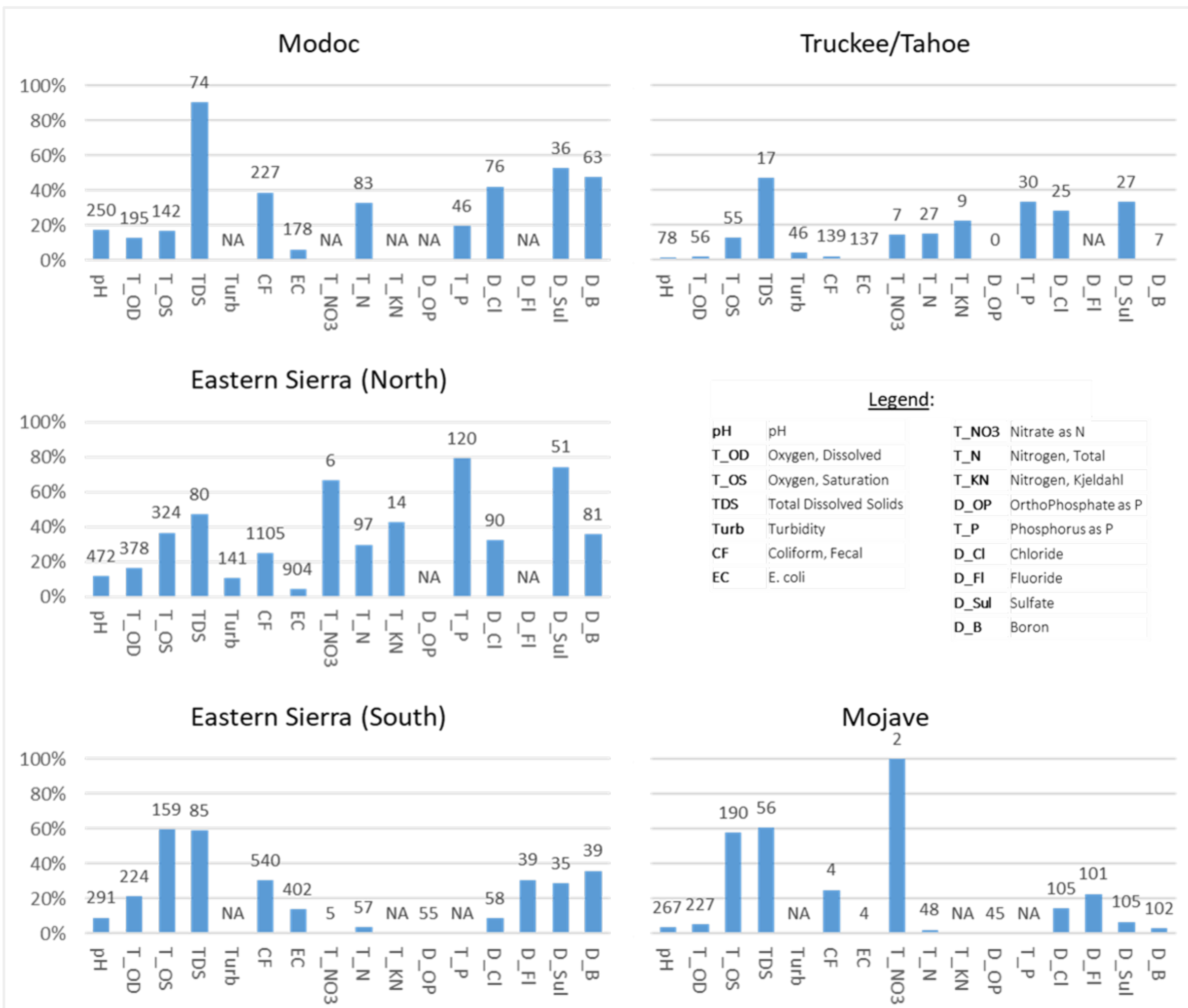

Figure E.2. Percent of Basin Plan water quality objective exceedances at all stations in each of the five subregions as a proportion of the total evaluated results (at all stations within each subregion) by parameter. The number above each bar indicates the total number of calculated or direct-measure results in the subregion (2000-2021). NA (not-available) indicates the parameter was not sampled in the subregion or that there are no SSOs or WQOs in that subregion for that specific parameter.

Are the proportions of water quality exceedances changing over time, and if so where?

To investigate change in the proportions of water quality exceedances over time, the Regional SWAMP monitoring dataset (2000-2021) was first divided into four multi-year increments of five years each[2]. Then the 46 monitoring stations were grouped by subregion and Basin Plan Hydrologic Unit (HU) to calculate the percent of water quality objective exceedances for each parameter and time interval. The results were tabulated and visually evaluated. If the percentage of exceedances changed more than five percent between the first and last 5-year interval an upward or downward change was assumed. Table E.1 summarizes the overall change in the proportions of Basin Plan exceedances observed in the Regional SWAMP monitoring data (2000-2021).

Table E.1. Summary of the change in the proportions of Basin Plan water quality objective exceedances 2000-2021, grouped by subregion and Basin Plan Hydrologic Unit (HU). An up or down arrow indicates an upward or downward change over time. A sideways arrow indicates no change. Blanks indicate no results and dot indicates not enough data to evaluate trends over time in the HU.

Subregion	Basin Plan HU	pH	Total Oxygen, Dissolved	Total Oxygen, Saturation	Dissolved Total Dissolved Solids	Total Turbidity	Coliform, Fecal	E. coli	Total Nitrogen, Total	Total Nitrogen, Total Kjeldahl	Dissolved Ortho-Phosphate as P	Total Phosphorus as P	Dissolved Chloride	Dissolved Fluoride	Dissolved Sulfate	Dissolved Boron
Modoc	Surprise Valley	→	↓	↓	↓		↓	→	↓				↓			↑
	Susanville	↓	↓	↓	↓		→	→	↑			↑	↑		↑	↑
Truckee/ Tahoe	Little Truckee River	.	.	.	.	.	→	→	.	.		.	.		.	
	Truckee River	→	→	↓	↓	↑	→	→	↑	↑		↑	↓		↓	→
	Lake Tahoe	.	.	.	.	.	→	→	.			.			.	
Eastern Sierra (North)	Carson River	→	→	↓	↓	→	→	→	↑	→		↓	→		↓	↓
	Walker River	↓	→	↑	↑		↑	↑	↓			↓	→			↑
Eastern Sierra (South)	Owens	→	↓	↓	↓		↓	→	↑		→		↑	↓	↑	↑
Mojave Desert	Mojave	→	↑	→	→		.	.	↑		→		↑	↓	→	↑

Are there any statistically significant upward or downward trends in water quality conditions over time, and if so where?

[2] The 5-year increments were grouped as follows: 2000-2004, 2005-2009, 2010-2014, and 2015-2021.

With 20 years of monitoring data at a number of monitoring stations the data were further analyzed to evaluate trends over time. A Mann Kendall and seasonal Mann Kendall test for trends were selected to evaluate trends, and the EnvStats package in R (a programming language) was used to complete the tests. The seasonal Mann Kendall test is a modification of the Mann Kendall test and is an appropriate method to evaluate monotonic trends (one directional trends over time) in seasonal water quality data because it is a nonparametric test that can accommodate seasonal cycles, skewed data, data gaps, and results below the detection limits.

The results of the statistical tests for trends for all stations and parameters indicated that less than 1% of the station/parameter pairs evaluated show significant monotonic upward or downward trends between 2000 and 2021. That is, only 14 stations and 12 parameters indicated potential trends at significance levels (p-values) of <0.05. This finding is not too surprising since there have not been significant ecological or anthropogenic changes at or near the specific targeted monitoring stations in the program, and given that some parameter concentrations have a wide range of variation over time, identifying overall monotonic upward or downward trends is difficult.

Of the significant trends identified, 14 monitoring stations showed potential trends in 1 to 5 parameters. Most of the stations are Temporary screening sites. Appendix D visually summarizes the water quality results over time, with graphical box and whisker plots (boxplots) for 29 of the regularly monitored water quality parameters at a subset of 26 stations (mostly stations that have been monitored for at least 9 years). The plots are a visual summary of the water quality results sampled between 2000 and 2021, and include (1) the minimum and maximum of the method detection limits (MDLs) reported since 2015 (when available) to show how the ambient range of field collected results compare to laboratory detection limits, and (2) a text 'flag' to identify when the seasonal Mann Kendal tests indicated a statistically significant trend over time.

A couple interesting outcomes of the statistical trend analyses that may warrant further review of the water quality conditions at the subregion and/or specific station scales include:

- Surprise Valley HU indicates that Total Nitrogen results may be declining at 3 stations in Bidwell Creek, Cedar Creek, and Mill Creek. However, the relative water quality concentrations observed at these sites were near or below the reported MDLs and further review of the data is warranted.
- Mojave station 628CRB001 (Crab Creek, at Crab Flats Rd.) a Temporary station in Deep Creek (sampled since 2008). At this station, several parameters indicate changes in concentrations over time. Dissolved Oxygen, Oxygen Saturation, and Dissolved Boron are going down, while Dissolved Calcium and Magnesium levels are going up. It appears that water quality conditions at this site might be changing and further review of the monitoring data is warranted.

Program Recommendations

Based on the 20-year retrospective water quality status and trends analyses presented in this report and discussions with the Regional SWAMP leads, a proposed adaptive monitoring and assessment framework (described in *Summary and Recommendations* section), was used to develop the following list of program recommendations. Some recommendations are specific and actionable, while others warrant additional consideration by a broader group such as a focused workgroup that can advise on the current program adjustment, or a formalized technical advisory committee that could be established to advise the program on an ongoing basis.

Recommendations for Regional SWAMP's ongoing water quality monitoring effort:

1. Clarify the geographic scope of the water quality monitoring effort.
2. Update the program's survey design and monitoring plan to include the target sample frame, sampling plan, station types and location information, parameter list and analytical methods, and additional monitoring and data analysis guidance.
3. In the updated sampling and analysis plan document the field sampling and analytical methods (and expected MDLs) for target parameters.
4. Review the current parameter list and determine if all are necessary.
5. Determine water quality and ecological health of intermittent and ephemeral streams.
6. Consider continuous monitors for multiple physical water quality parameters including streamflow.
7. Review the Long-term monitoring station locations and consider if changes are warranted.
8. Follow up from the recent 20-year status and trends assessment results by reviewing areas where there are a relatively high percentage of Basin Plan exceedances and decide on the next management steps.
    a. Evaluate if additional monitoring is still warranted at the current Temporary screening and Follow-up stations, or if some of the Temporary/Follow-up stations should become Long-term stations.
9. Data Management:
    a. Update archived data in CEDEN to address some of the water quality monitoring data clean-up that was completed for this report.
    b. Ensure that the CEDEN data templates are complete prior to data upload (especially for important quality assurance qualifiers and method detection limits).

Recommendations to support an adaptive management approach to watershed health assessment and address new and emerging challenges:

10. Convene an advisory group to advise on Regional SWAMP adjustments and a watershed approach to watershed health assessment for the Region. A workgroup or committee process would provide a forum for cross-program coordination and help identify collaborative monitoring opportunities that could be integrated into the Regional SWAMP.
11. Employ the adaptive monitoring and assessment Framework (described in report) to integrate new management initiatives or watershed health concerns into the Regional SWAMP.
12. Review the Regional SWAMP water quality efforts and consider if additional changes are warranted to support new management and monitoring questions and the broader concerns for watershed health and management. This could be a small or large review and adaptive program development effort depending on the current management and monitoring goals of the program.

2. Introduction

The Lahontan Regional Water Quality Control Board's (Water Board) jurisdictional Region is located along the eastern Sierra Nevada mountain range in California, extending nearly 600 miles from the northeastern border of the state to the southeastern Mojave Desert. It encompasses approximately 33,000 square miles, which is larger than the state of Maine, has over 700 lakes, and over 3,700 miles of perennial streams. It has two specially protected Outstanding National Resource Waters (ONRWs): Lake Tahoe and Mono Lake. The Region boasts the highest and lowest points in the contiguous United States (Death Valley at -282 ft. and Mt. Whitney at 14,494 ft.) and all of the waters flow to terminal basins, not the Pacific Ocean.

The Water Board's primary water quality standards applicable in the Region are found in the *Water Quality Control Plan for the Lahontan Region (*Basin *Plan)*[3]. The Basin Plan is unique in that it contains more than a thousand numeric water quality objectives (WQOs), most of which are site specific objectives (SSOs) that were adopted in the early 1970s. Prior to the creation of the Regional SWAMP, most water bodies in the Region had not been monitored for compliance with the Basin Plan's SSOs. The implementation of the Regional SWAMP, in July 2000, gave the Water Board the funding and opportunity to begin long-term monitoring.

Since its inception, the Regional Surface Water Monitoring Program (SWAMP) supports three core elements:

- Targeted, ongoing, quarterly water quality monitoring to evaluate chemical and physical parameter compliance with the WQOs and SSOs in the Basin Plan.
    - Those data are regularly included in the Water Board's Integrated Report process that analyzes the results against the various objectives and updates the Clean Water Act Section 303(d) list of impaired water bodies (currently updated every 6 years).
- Substantial funding to support SWAMP's statewide Bioassessment Monitoring Program through the SWAMP Perennial Streams Assessment program (PSA) and the Reference Condition Management Program (RCMP).
    - The PSA is an ongoing, long-term statewide survey of the ecological condition of wadeable perennial streams and rivers throughout California. The RCMP establishes and maintains a network of reference sites for wadeable streams and rivers throughout California. This network is vital to the establishment of reference conditions, which define the biological conditions expected in healthy streams when human activity in the environment is absent or minimal.

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[3] Basin Plan link: https://www.waterboards.ca.gov/lahontan/water_issues/programs/basin_plan/references.html

- Special Studies to further investigate specific water quality topics or concerns in the Region. A list of special studies and other reports can be found on the Lahontan Regional Water Board's "Available Reports" webpage[4].

The report has the following goals:

1. provide an overview of the water resources and ecological diversity in the Region,
2. summarize the status and trends of over 20 years of the Regional SWAMP's physical and chemical water quality monitoring data, and
3. recommend potential future monitoring changes, based on those analyses.

The Regional SWAMP currently monitors 46 targeted water quality stations in the Lahontan Region and reports on over 30 parameters that are sampled from one to four times per year at most stations. With nearly 30,000 water quality data points reported since its inception, this report cannot summarize the status and trends for all the stations and parameters. Rather, it condenses the water quality exceedance analyses and overall trend assessments into five subregions and Basin Plan hydrologic units (HUs).

[4] https://www.waterboards.ca.gov/lahontan/water_issues/programs/swamp/available_reports.html

3. Environmental Setting

The Lahontan Region is located in the easternmost portion of California and shares its eastern border with Nevada and is bounded in the west by the high Sierra Nevada mountain range (Figure 1). The Region is ecologically diverse and includes portions of 7 of California's 13 Level III Omernik ecoregions including ecoregions that resemble continental climate in the northern Modoc subregion, the high mountainous slopes of the eastern Sierra Nevada mountain range, and the arid Mojave Desert in the south.

Figure 1. Map of the Lahontan Region

Understanding differences in the landscape setting and land use conditions at the subregional and local scale across the Region, will help put the stream water quality status and trends assessment presented later in this report into a broader environmental context. Though the Region covers primarily arid landscapes, it spans a variety of ecoregions whose climates vary dramatically.

Many of the Region's streams flow eastward from the moist, mesic forested high mountain slopes of the eastern Sierra Nevada mountainous ecoregion to dry, xeric conditions of high-desert - crossing from the high mountains into the Northern, Central, and Mojave Basin ecoregions. The Region is generally in a rain shadow of the Sierra Nevada mountains to the west; however, precipitation amounts can be high (up to 70 inches) at higher elevations. Most precipitation in the mountainous areas falls as snow. Desert areas receive relatively little annual precipitation (less than 2 inches in some locations) but this can be concentrated and lead to flash flooding.

The Region includes the eastern slopes of the Warner, Sierra Nevada, San Bernardino, Tehachapi and San Gabriel Mountains, and all or part of other ranges including the White, Providence, and Granite Mountains. Topographic depressions include the Madeline Plains, Surprise, Honey Lake, Bridgeport, Owens, Antelope, and Victor Valleys.

The geology and soils of the Lahontan Region have been shaped by a variety of processes, and are correspondingly diverse. Parent materials in the northern mountains are granitic or volcanic; evidence of glacial action is widespread. Soils in the desert valleys of the Region are derived from alluvium. The varied topography, soils, and microclimates of the Lahontan Region support a corresponding diversity of plant and animal communities.

Vegetation ranges from sagebrush and creosote bush scrub in the desert areas to pinyon-juniper and mixed conifer forest at higher elevations. Subalpine and alpine cushion plant communities occur on the highest peaks. Wetland and riparian plant communities, including marshes, meadows, sphagnum bogs, riparian deciduous forest, and desert washes, are particularly important for wildlife, given the general scarcity of water in the Region.

The Region is sparsely populated and relatively pristine when compared to other Water Board Regions. Much of the Region is in public ownership, managed by agencies that include the U.S. Forest Service, National Park Service, Bureau of Land Management, military agencies, the California Department of Fish and Game, California Department of Parks and Recreation, and the City of Los Angeles Department of Water and Power. While some northern mountain communities are growing rapidly including Truckee and Mammoth Lakes in the north with estimated populations of about 17,000 and 7,000, the majority of the Region's residents live in high-density communities in the Mojave subregion in the south, of which the largest cities include Lancaster, Palmdale, Victorville, and Hesperia with populations of over 100,000. Table 1 lists the estimated populations of these and other communities based on the U.S. Census Bureau's estimates (https://www.california-demographics.com/cities_by_population; 5-year[5] and annual - 2020-2021[6] estimates).

Table 1. Community population estimates (2020-2021)

Subregion	City/Township	Population
Truckee/ Tahoe	Truckee	17,168
	South Lake Tahoe	21,414
Eastern Sierra (North)	Mammoth Lakes	7,271
Eastern Sierra (South)	Bishop	3,820
	Big Pine	1,373
	Independence	761
	Lone Pine	1,484

Subregion	City/Township	Population
Mojave	China Lake	2,450
	Mojave	3,780
	Boron	2,280
	Barstow	25,442
	Rosamond	20,255
	Lancaster	170,150
	Palmdale	165,761
	Victorville	135,950
	Hesperia	100,971
	Apple Valley	76,224
	Lake Arrowhead	9,741

[5] United States Census Bureau. B01001 SEX BY AGE, 2020 American Community Survey 5-Year Estimates. U.S. Census Bureau, American Community Survey Office. Web. 17 March 2022. http://www.census.gov/.

[6] United States Census Bureau. Annual Estimates of the Resident Population: April 1, 2020 to July 1, 2021. U.S. Census Bureau, Population Division. Web. May 2022. http://www.census.gov/.

There are several unique environmental factors that affect water quality in the Lahontan Region, including:

- Naturally high concentrations of certain “pollutants” (i.e., arsenic, boron, mercury, etc.) in some areas from natural volcanic and geothermal sources, and from evaporative concentration in desert environments;
- Water quality-quantity relationships (i.e., the Lahontan Region includes many natural ephemeral streams, as well as historical water bodies that have been significantly affected by water diversions (e.g. Mono Lake, Owens River) or groundwater drafting (e.g. Mojave River);
- Severe impacts to some watersheds in the 1990s and 2000s by wildfires or floods or both;
- Documented evidence of long-distance airborne transport of nutrients, pesticides and other compounds to the “pristine” streams in the Lahontan Region via atmospheric deposition.

Anthropogenic land uses that may contribute to point- and nonpoint-source water pollution and accelerated slope erosion in the Region include: roads, livestock grazing, land development (including large cannabis cultivation and industrial facilities), urban runoff, drainage from active or abandoned mines, historical and current stream flow diversions and channelization, groundwater removal, and various other land and forest management activities.

Cows in the Owens Valley, Inyo County, CA 2022. Courtesy of L. M. Freilich

3.1. Five Subregions

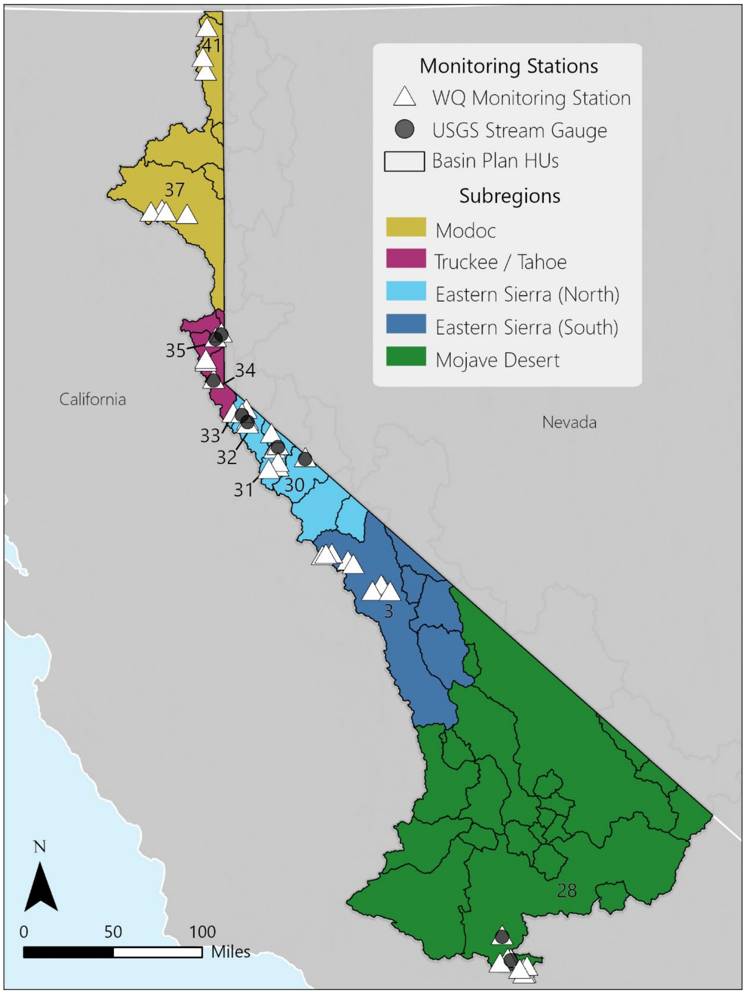
Because of the size and ecological diversity of the Lahontan Region, this report divides the Region into five subregions to support analyses and reporting. The subregions were identified by considering three factors: how the Regional SWAMP team generally thinks about the water quality monitoring stations as grouped by geography and landscape, Omernik Level III ecoregions, and Basin Plan HUs. The subregions (listed from north to south) include Modoc, Truckee/Tahoe, Eastern Sierra (North and South), and Mojave (Table 2). The consideration of the Omernik Level III ecoregions in identifying the subregions is consistent with SWAMP's statewide Bioassessment Monitoring PSA's 'assessment regions'[7] that also considered ecoregions, at the statewide level (with modifications)[8], when defining their regions.

The Basin Plan has many site specific objectives (SSOs) that are applied at the surface water hydrologic unit or groundwater basin level (HU). The Basin Plan identifies 42 HUs[9] and has SSOs for various surface waters (or stream reaches) in 17 of them. Regional SWAMP's water quality monitoring stations are located in 10 of the HUs that have SSOs (see Figure 2).

Table 2. Overview of the five subregions used in this report including their size (in square miles), relative % area, ecoregions, basing Plan HUs, and number of Regional SWAMP water quality monitoring stations in each subregion.

Subregion	Sq. Miles	% Total Area	Omernik Level-III Ecoregion	Basin Plan HU Name (Number) that contain monitoring locations	Number of Monitoring Stations
Modoc	3,945	12%	Eastern Cascades Slopes and Foothills, Northern Basin and Range, Cascades, Central Basin and Range, Sierra Nevada	Surprise Valley (41), Susanville (37)	7
Truckee/Tahoe	800	2%	Sierra Nevada	Truckee River (35), Lake Tahoe (34)	5
Eastern Sierra (North)	2,344	7%	Sierra Nevada, Central Basin and Range	West Fork Carson River (33), East Fork Carson River (32), West Walker River (31), East Walker River (30)	15
Eastern Sierra (South)	4,939	15%	Sierra Nevada, Central Basin and Range	Owens (3)	10
Mojave Desert	20,762	63%	Mojave Basin and Range, Southern and Baja California Pine-Oak Mountains	Mojave (28)	9
Totals	**32,791**		**7 Ecoregions**	**10 HUs**	**46**

[7] https://www.waterboards.ca.gov/water_issues/programs/swamp/bioassessment/docs/psa_memo_121015.pdf
[8] Personal communication with program lead scientist (April 2022)
[9] link to the Basin Plan webpage (Chapter 3 and Plates 1A & B and 2A & B)



Basin Plan HU Number and Name

41: Surprise Valley

37: Susanville

35: Truckee River

34: Lake Tahoe

33: West Fork Carson River

32: East Fork Carson River

31: West Walker River

30: East Walker River

3: Owens

28: Mojave

Figure 2. Map of the Lahontan Region's five subregions and the locations of Regional SWAMP's water quality monitoring and nearby USGS stream gauge stations. The 10 Basin Plan HUs where monitoring stations are located are indicated by their Basin Plan HU number in the map.

3.2. Distribution and Abundance of Aquatic Resources

The Lahontan Region has hundreds of lakes, and thousands of miles and acres of streams and wetlands. It has several of the largest lakes in California including Eagle Lake, Honey Lake and Lake Tahoe in the North Lahontan Region, and Mono Lake in the South Lahontan Region[10] (Figure 3). Lake Tahoe (122,000 acres) and Mono Lake (55,000 acres) and Honey Lake (47,000 acres) are the 2nd, 4th, and 5th largest lakes in California, and Lake Tahoe and Mono Lake are protected Outstanding National Resource Waters that have special protections against degradation under the Clean Water Act. Other smaller, yet significant reservoirs and lake beds in the South Lahontan Region include Crowley Lake (a reservoir), and Owens Lake - due to water diversions it is now a dry lakebed in the southern part of the Owens Valley, which is artificially flooded to control dust and provides important migratory bird habitat in the region.

[10] WorldAtlas: https://www.worldatlas.com/articles/which-are-the-largest-lakes-in-california.html

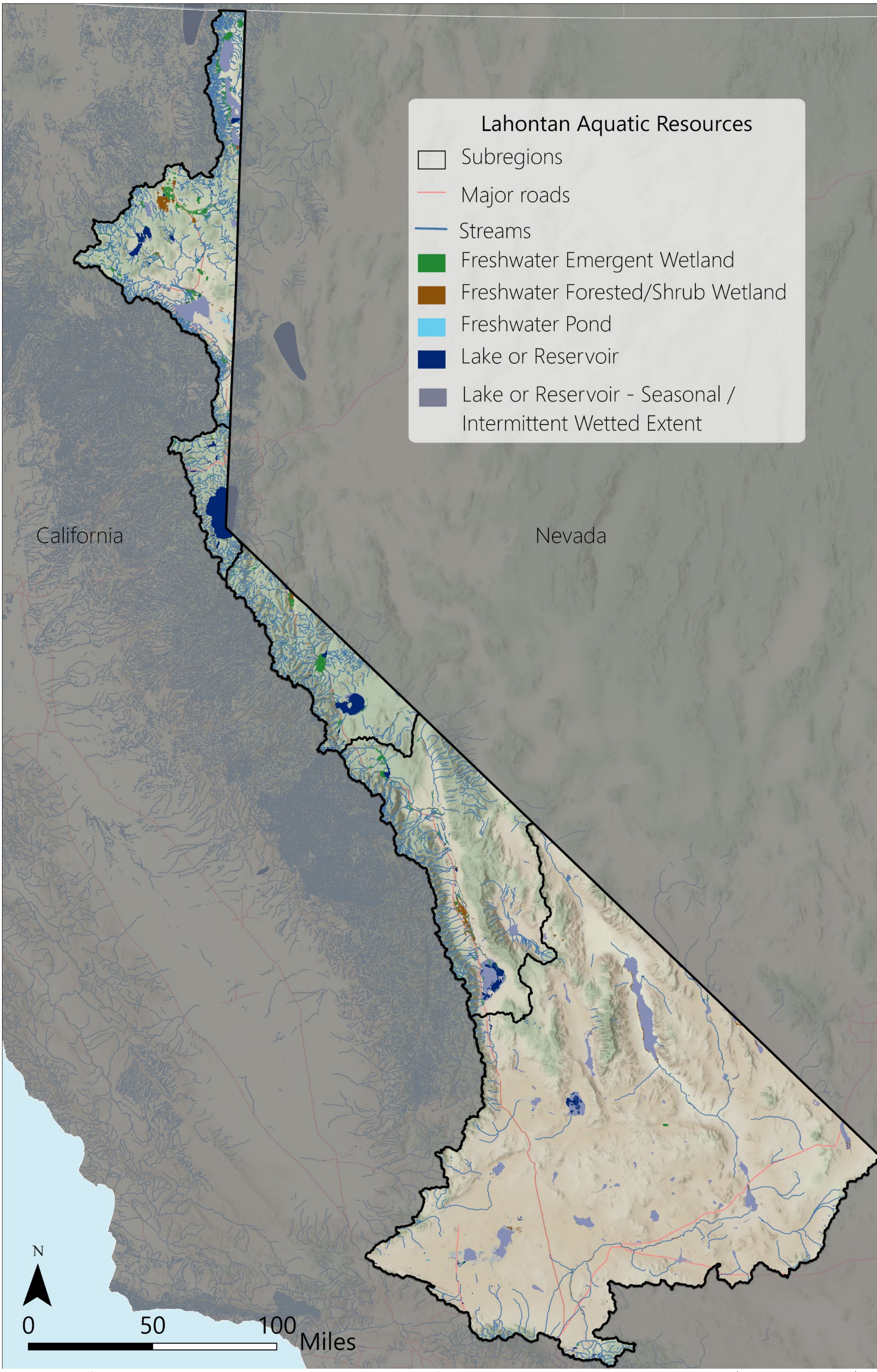


Figure 3. Map of perennial and intermittent streams, lakes, reservoirs, ponds, and forested and emergent wetlands in the Lahontan Region (NHD, 2019; NWI, 2022). Ephemeral streams are not shown for simplicity.

Table 3 lists the amount and distribution of perennial (has continuous flow of surface water year round), intermittent (only has surface water flow certain times of the year), and ephemeral (dry washes that flow only during and immediately following rain events) streams in the Region by subregion. Perennial and intermittent streams comprise just over 9,000 miles (or ~8%) of the nearly 122,000 miles of stream network. Ephemeral streams comprise the remaining 92% of the stream network.

Table 3. Miles of perennial, intermittent, and ephemeral streams in the Lahontan Region by subregion based on the National Hydrography Dataset (NHD, 2019). The table subtotals the miles of the perennial and intermittent streams in each subregion along with the percent contribution (light blue subtotal columns). The last three columns on the right (darker blue highlights), add the miles of ephemeral streams in each subregion, the total miles of streams for all three stream types, and percent of total contribution by subregion. Both the subtotals and totals are included to show the importance of ephemeral streams in the Mojave subregion.

Subregion (% of Total Area)	Perennial	Intermittent	Subtotal Perennial & Intermittent	Subtotal % of Stream Miles	Ephemeral	Total Miles of Streams	Total % of Stream Miles
Modoc (12%)	567	2,681	3,249	35%	5,761	9,009	7%
Truckee/Tahoe (2%)	569	41	611	7%	2,793	3,404	3%
Eastern Sierra (North, 7%)	1,236	291	1,527	17%	2,534	4,061	3%
Eastern Sierra (South, 15%)	1,198	960	2,159	24%	17,973	20,132	17%
Mojave (63%)	158	1,467	1,625	18%	83,480	85,105	70%
Total Miles (% of Total Stream Miles)	3,729 (3%)	5,442 (5%)	9,171 (8%)		112,540 (92%)	121,711	

In the Lahontan Region ephemeral streams comprise the majority of the stream network (about 113,000 miles) and 87% of them are located in the semi-arid and arid regions of the southern Eastern Sierra and Mojave Desert. Ephemeral streams provide the same ecological and hydrological functions as perennial and intermittent streams, namely providing hydrologic connectivity that move water, nutrients, and sediment throughout the watersheds[11]. When functioning properly, ephemeral and intermittent streams provide hydraulic connections across the landscape including functions such as stream energy dissipation during high-water flows that reduce erosion and improve water quality; surface and subsurface water storage and exchange; groundwater discharge; sediment transport, storage and deposition to aid in floodplain maintenance and development; nutrient storage and cycling; and wildlife habitat and migration corridors. Ephemeral streams should be considered as part of the overall watershed context when considering (and monitoring) anthropogenic impacts from

[11] Levick, L., J. Fonseca, D. Goodrich, M. Hernandez, D. Semmens, J. Stromberg, R. Leidy, M. Scianni, D. P. Guertin, M. Tluczek, and W. Kepner. 2008. The Ecological and Hydrological Significance of Ephemeral and Intermittent Streams in the Arid and Semi-arid American Southwest. U.S. Environmental Protection Agency and USDA/ARS Southwest Watershed Research Center, EPA/600/R-08/134, ARS/233046, 116 pp. https://www.epa.gov/sites/default/files/2015-03/documents/ephemeral_streams_report_final_508-kepner.pdf

development to water quality and overall stream ecosystem health. This is especially important in the fast growing urban areas in the south-eastern Mojave subregion where ephemeral streams comprise the majority of the stream network.

Table 4 shows the amount (in acres) of permanently or artificially flooded wetlands including emergent and forested wetlands (types of slope wetlands including wet meadows), ponds (depressional wetlands), and lakes and reservoirs in the Lahontan Region by subregion based on the National Wetlands Inventory (NWI, 2022).

Table 4. Surface acres of permanent or artificially flooded emergent and forested wetlands, ponds, and lakes and reservoirs in the Lahontan Region by subregion based on the National Wetlands Inventory (NWI, 2022).

Subregion (% of Total Area)	Freshwater Emergent Wetland	Freshwater Forested/ Shrub Wetland	Freshwater Pond	Lake & Reservoir	Total Wetland Acres	% of Total By Subregion
Modoc (12%)	10,878	354	1,212	30,652	43,096	17%
Truckee/Tahoe (2%)	304	81	673	93,537	94,595	38%
Eastern Sierra (North, 7%)	1,309	121	830	47,803	50,063	20%
Eastern Sierra (South, 15%)	3,733	908	994	34,742	40,377	16%
Mojave (63%)	597	0	2,995	19,100	22,692	9%
Total Acres	16,821	1,464	6,704	225,834	250,823	

The lakes and reservoirs shown in the aquatic resources map (Figure 3 above) show both the permanently flooded extents (in blue) as well as the potential maximum wetted extents (in gray) because there are many dry lake beds (or playas) in the southern portions of the Eastern Sierra (South) and Mojave subregions that are seasonally or intermittently wetted when there is runoff. Those temporary water bodies are important ecological habitats in those semi-arid and arid landscapes, and also support migratory birds.

3.3. Wildfire History

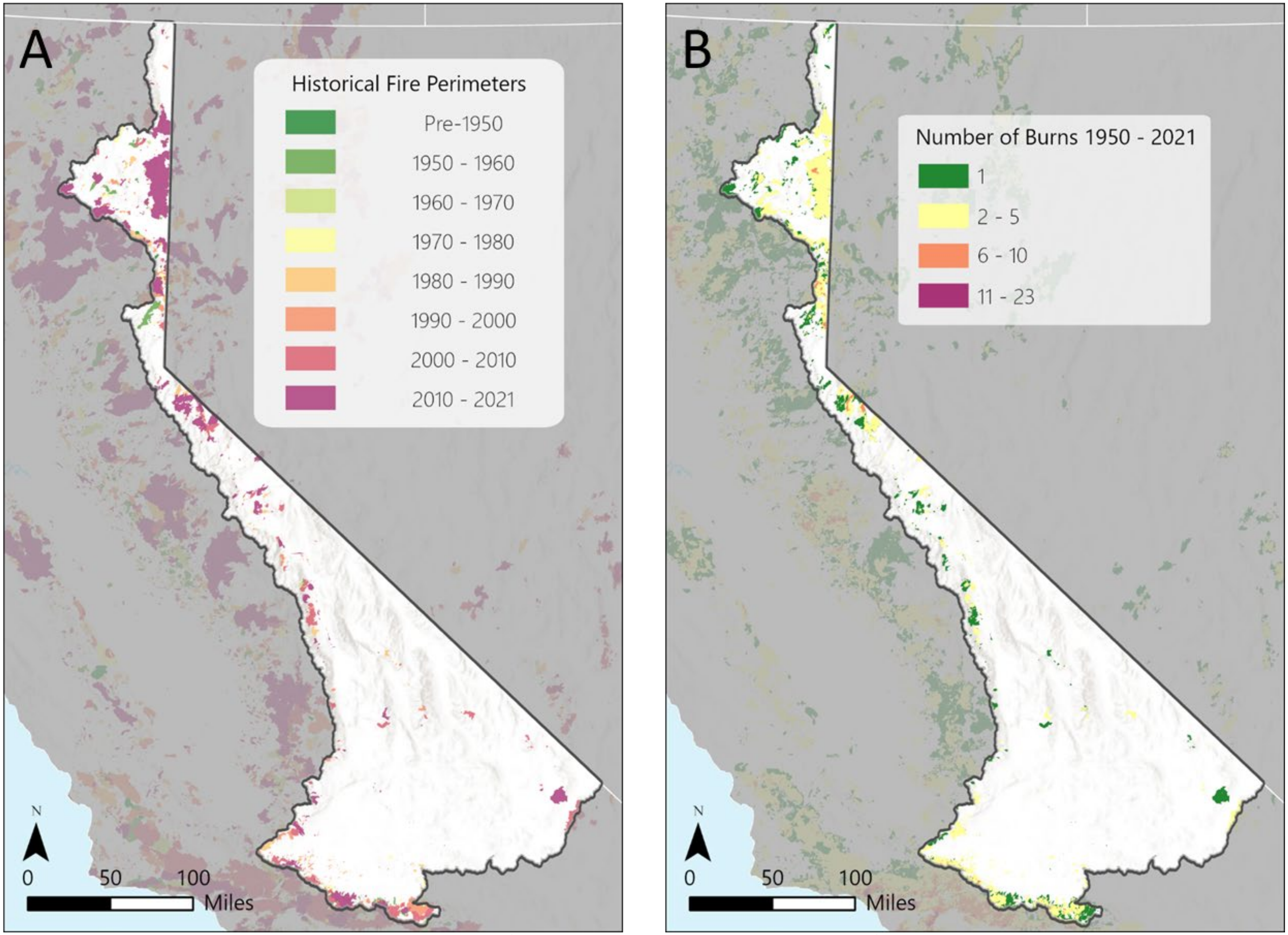
In recent years wildfires have devastated many areas across the west including California. Climate changes are leading to hotter, drier summers, and changing rainfall and snowpack patterns. With increased residential activities along the wildland-urban interface, wildfires pose threats to the wellbeing of people, wildlife, riparian habitats and water quality. Since 2014 some of the larger fires that have swept through the Region include the 2021 Caldor Fire (221,800 acres), the 2021 Tamarack Fire (68,000 acres), the 2020 Mountain View Fire (21,000), the 2020 Hog Fire (9500), the 2017 Farad Fire (747 acres), the 2016 Emerald Fire (176 acres), the 2014 Cascade Fire (20 acres), and the 2014 Boca Fire (84 acres). Several of these fires burned areas near or around some of the Regional SWAMP's long-term monitoring sites. The magnitude of impacts of the fires on local water quality is yet to be assessed.

Fire perimeter and history data are becoming more accessible and reliably updated and this report compiled historical fire perimeter data from the National Interagency Fire Center's - Wildland Fire Locations Full History database[12] (accessed July 2022). The database includes wildland fire incidents from the Integrated Reporting of Wildland Fire Information (IRWIN) and historical data converted to the IRWIN format. However, it should be noted that data prior to 2014 (when IRWIN was implemented) is incomplete and historical data may be incorporated into the database on an ongoing basis. As a result, the number and acres burned presented at the decadal scale in this report may be incomplete in the earlier decades and the increase in the number and acreage of fires over time should not be over interpreted: differences could be, in part, a result of reporting. Table 5 and Figures 4A and 4B summarize the number of fires and acres burned by decade since 1950, and illustrate the spatial location and size of those fires (Figure 4A). Figure 4B shows areas that have repeatedly burned over time. Note that the number of fires and acres burned in 2020-2021 (*just two years*) were roughly 80% of the number of fires and total acres burned in the previous decade (2010-2019), and higher than in the decade before that (2000-2009).

Table 5. Number of fires and acres burned by decade in the Lahontan Region (1950 - 2021; WFIGS, 2022). * represents only two years.

Decade/Year Range	Number of Fires	Acres Burned
1950 - 1959	84	145,063
1960 - 1969	92	96,883
1970 - 1979	136	60,925
1980 - 1989	242	179,528
1990 - 1999	225	200,747
2000 - 2009	370	400,519
2010 - 2019	694	558,177
*2020 - 2021	548	425,913
Totals	**2,391**	**2,067,755**

[12] Wildland Fire Interagency Geospatial Services (WFIGS, data accessed July 2022) https://data-nifc.opendata.arcgis.com/datasets/nifc::wfigs-wildland-fire-locations-full-history/about



Figures 4A and 4B. Maps of historical fire perimeters by decade (4A left, with the most recent fires visible on top) and the number of overlapping burned areas between 1950 and 2021 (4B right; WFIGS, accessed July 2022).

3.4. Hydrology

Streamflow within the Lahontan Region is largely driven by precipitation patterns (amount, timing, and type) resulting from the location within the state and the landform characteristics (elevation, topography, orogenic effects). Average annual precipitation amounts vary widely across the Region, from greater than 50 inches annually along the western side of Lake Tahoe, to less than 5 inches annually in the eastern basins within the Mojave Desert. Although California tends to receive the majority of its precipitation between October and April, there is variation in timing across the Region.

The Modoc subregion has variation in precipitation totals based upon elevation, with lower totals in low elevations, and higher totals in the adjacent higher elevations. The subregion is classified as a cold desert, and thus the majority of its precipitation falls as snow during the winter months. However, precipitation can also be rain during the warmer winters and the warmer spring months.

High elevation mountain areas along the Sierra Nevada crest, in the Truckee/Tahoe and Eastern Sierra (North and South) subregions, have the majority of precipitation falling as snow in a series of storm events throughout the winter. These areas also receive scattered, but sometimes very intense summer thunderstorms. Late spring snowmelt tends to drive peak streamflow for these areas, sometimes punctuated by a rain-on-snow event which can cause much larger peak discharges.

And in the Mojave subregion, the inland Mojave Desert areas (which are part of the Great Basin) include the hottest and driest locations within California. This area is dominated by the rain-shadow effect caused by the Sierra Nevada and the Transverse Range Mountains. This area receives the least amount of annual precipitation, falling both as light winter rains, and as rain during monsoonal thunderstorms. The monsoonal thunderstorms can be extreme, and cause episodic flash floods within the ephemeral channels. A single storm event can cause a large peak discharge, and it may be the only flow that occurs in an episodic channel in the Mojave for a number of years.

There are nine active streamflow gauges located in three of the five subregions: Truckee/Tahoe, Eastern Sierra (North), and Mojave. The stations are co-located with (or near) nine Regional SWAMP monitoring stations. Water quality is often correlated with streamflow. Flow can import pollutants or flush them away and is a vital component of overall ecological health of stream functions as it transports sediment and nutrients, shapes channels and floodplains, and supports vegetation.

Figure 5 illustrates the annual and seasonal patterns in flow for the Truckee/Tahoe, Eastern Sierra, and Mojave Desert subregions. For example, the General Creek near Meeks Bay CA gauge station is located on a smaller stream that flows into the west side of Lake Tahoe. The graph of daily flow (discharge) for 2000-2021 illustrates the regularity of annual snowmelt-driven peaks in discharge that occur during the late spring/early summer of each year. Year-to-year the daily discharge is relatively constant, with variability depending on the total amount of snowpack and the timing of warmer spring temperatures. Some years (e.g. 2006, 2017) have larger seasonal peaks due to large snowfall totals. In contrast, the Mojave River near Victorville CA gauge shows a much different pattern of daily discharge. This gauge shows a handful of elevated discharge periods, and two years (2005 and 2011) with much larger daily discharges. These discharges are due to large individual rain events in the watershed. These patterns, timing, and magnitude of flows described will have large effects upon the water quality measured at individual stations.

Lamarck Creek Sierra Nevada,
Inyo County, CA 2022. Courtesy of
L. M. Freilich

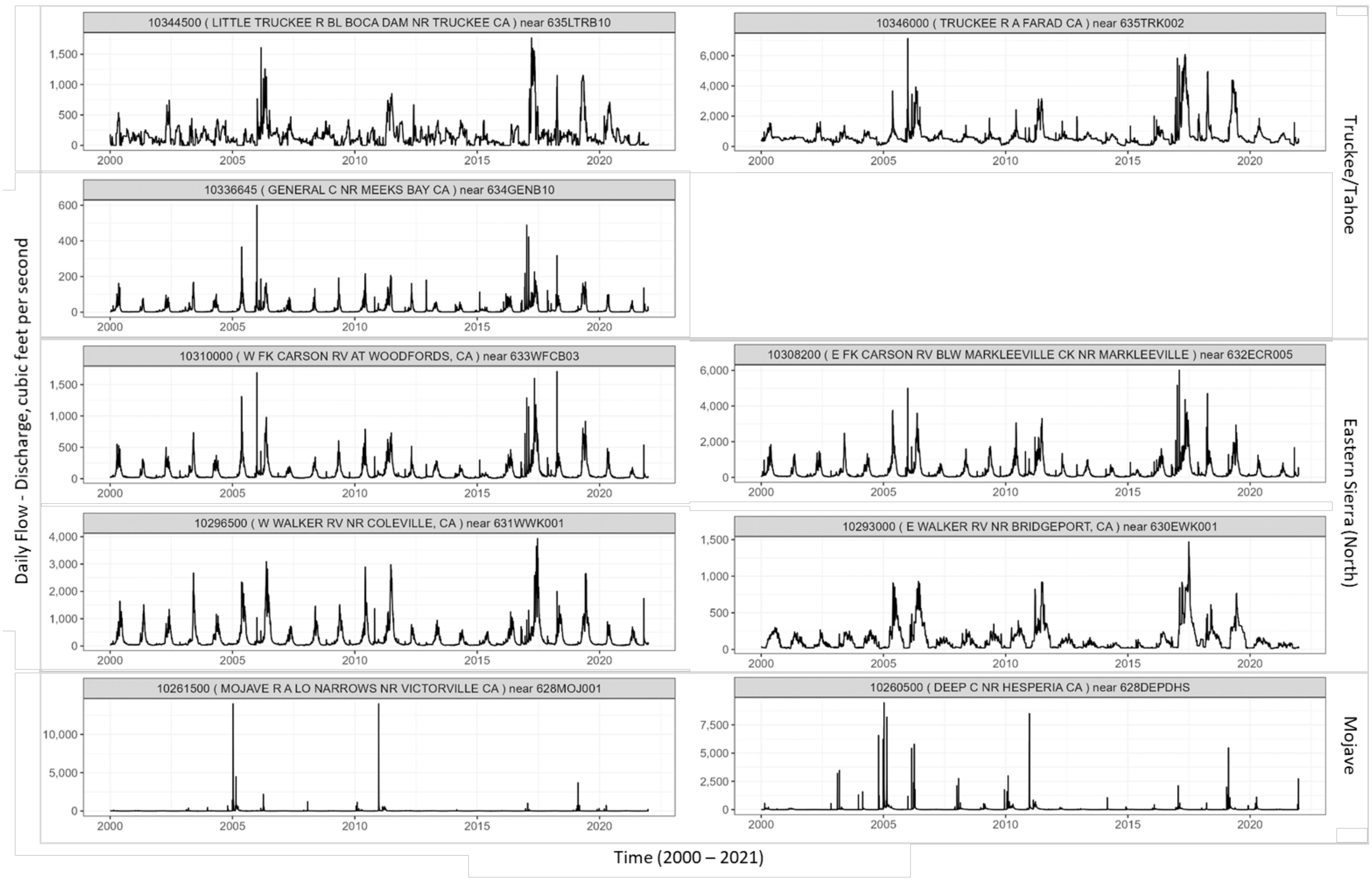


Figure 5. Daily flow for nine USGS stream gauge stations located near Regional SWAMP water quality monitoring stations (2000-2021). Notice that the different y-axis scales show significantly different maximum discharges among the different streams and the subregions (listed on the right). The Mojave subregion has the highest intermittent discharges on occasion especially at the Mojave RALO Narrows site near Victorville, CA (bottom left chart indicates flows well over 10,000 cfs/s twice in the last 20 years).

3.5. Environmental Context by Subregion

The environmental settings, dominant land uses, and potential nonpoint source concerns for water quality in each of the five subregions are summarized below. For additional information Appendix A includes Basin Plan HU specific land use descriptions for the streams that are monitored by the Regional SWAMP.

Modoc - This is the Lahontan Water Board's most northerly extent in the northeast corner of the state. It is a diverse subregion that includes small portions of several ecoregions including the southernmost extent of the *Eastern Cascades Slopes and Foothills* ecoregion, and portions of the *Cascades, Northern Basin and Range,* and *Sierra Nevada* ecoregions. The Modoc subregion is in the rain shadow of the Cascade Mountains that stretch from central Washington to northern California. It has a more continental climate, with greater temperature extremes, and less precipitation than areas to the west. Because of its dryness, the subregion has historically been more susceptible to fires. In the eastern lower elevations, xeric shrubs and grasslands are predominant with areas of cropland and pastureland occurring in the lake basins and larger river valleys. The lakes in the Modoc subregion provide habitat for migrating waterfowl, such as sandhill cranes, ducks, and geese.

Water quality concerns in the subregion are largely from livestock grazing, agriculture (alfalfa and row crops), construction-related impacts from land development, roads, timber harvest, herbicide use from silviculture and weed control, and septic systems. Salt and nutrients are of specific concern because of the terminal lakes basins, and heavy agriculture (Lahontan Basins SWRP[13]).

Truckee River/Lake Tahoe - This subregion is entirely within the *Sierra Nevada* ecoregion and includes high Sierra mountains and portions of the Lake Tahoe Basin within California. The Truckee River flows out of Lake Tahoe, crossing into Nevada and terminating in Pyramid Lake in Nevada. The SWAMP management team generally thinks of the Truckee River and Lake Tahoe Basin as a separate subregion from the Eastern Sierra (North) subregion because of the special protection status of Lake Tahoe, the higher population density, and high level of outdoor recreation-based tourism in the area. The larger towns in this subregion include Truckee and South Lake Tahoe, and land ownership includes a density of United States Forest Service lands, California State Parks and State Recreation Areas. The Lahontan Basin Plan includes special protections for waters in the Truckee[14] and Lake Tahoe[15] watersheds. Specifically, the prohibition of any waste attributable to human activity to land below the high

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[13] Lahontan Basins SWRP: Storm Water Resources Plan. Technical Memorandum Approach to Water Quality - Task 4.3 (Nov, 2017). https://drive.google.com/file/d/1fp0ft20-GUNsIEMM9jGrUaJFOQQgAaw6/view
[14] Truckee and Little Truckee Prohibition 2 (Ch.4): https://www.waterboards.ca.gov/lahontan/water_issues/programs/basin_plan/docs/2022/ch4to4-1-imp.pdf#page=24
[15] Tahoe Prohibition 2 (Ch. 5): https://www.waterboards.ca.gov/lahontan/water_issues/programs/basin_plan/docs/2022/ch5-laketahoe.pdf#page=35

water rim of Lake Tahoe or within the 100-year floodplain of any tributary to Lake Tahoe, the Truckee River, the Little Truckee River, or any tributaries to these waters. These are the only watersheds with such prohibitions. Additionally, Lake Tahoe warrants a dedicated chapter within the Basin Plan.

In the subregion, water quality concerns are largely from transportation corridors (railways and roads), urban runoff and construction-related impacts from rapid land development, ski areas and other recreation developments, livestock grazing, and timber harvests. Sediment resulting from hydromodification activities, such as reservoir management, is also a concern, as are impacts to wetlands and riparian areas from fill or channelization.

Eastern Sierra Nevada (North and South) - includes the eastern slopes of the *Sierra Nevada* ecoregion and relatively small portions of the westernmost extents of the *Central Basin and Range* ecoregion within high desert valleys and mountain ranges along the California/Nevada border. The Sierra Nevada is a high north-south trending mountain range in eastern California with a small extension into Nevada near Lake Tahoe. The Lahontan Water Board regional extent includes the majority of the eastern slopes of this ecoregion.

The Eastern Sierra Nevada has a mid-latitude climate that can range from mild to severe, with Mediterranean characteristics in the higher elevations, and a dry, mid-latitude desert climate marked by hot summers and mild winters in the eastern Sierra valleys. Because of the large elevation change of thousands of feet between the peaks and the valley floors, the subregion has a wide range of mild to hot dry summers and cool to cold wet winters. Much of the central and southern parts of these subregions is underlain by granitic rocks, as compared to the mostly sedimentary formations of the Klamath Mountains and volcanic rocks of the Cascades (to the north). There are areas of metamorphic and volcanic rocks in the eastern basins, and mostly xeric and udic soil moisture regimes.

These two subregions are known for high-gradient perennial streams and alpine lakes. The Owens River is a major river that runs north-to-south through the Eastern Sierra. At the higher eastern slope elevations there are forests of lodgepole pine, in addition to mixed conifer forests of ponderosa pine, sugar pine, Douglas-fir, and white fir. In the lower arid basins and valleys there are high desert conditions with sagebrush or saltbush-greasewood vegetation and willows. The mountains to the east have singleleaf pinyon, juniper, sagebrush, bitterbrush, serviceberry, snowberry, and bluebunch wheatgrass.

Land uses include outdoor recreation and tourism, forestry, rural residential, some ranching and woodland grazing, and some mining. The higher elevations are mostly public lands with national forests and national monuments. Mid elevations, especially in the Eastern Sierra Nevada South are mostly managed by the Bureau of Land Management. The Los Angeles

Department of Water and Power owns a large portion of land within the Owens River Basin. The larger towns in these subregions include Bridgeport, Mammoth Lakes, and Bishop.

In the Carson River watershed (Alpine County), potential water quality impacts largely come from numerous abandoned mines, livestock grazing, recreation, roads, use of herbicides for weed control, and timber harvests. Also of concern are impacts to wetlands and riparian areas from fill or channelization of the slope wetlands in the area.

In the Walker River watershed (Mono County), potential water quality impacts largely come from recreation, livestock grazing, roads, herbicide use for weed control, septic systems, abandoned mines, and timber harvests. Also of concern are impacts to wetlands and riparian areas from fill or channelization, as well as impacts from operation of the Bridgeport Reservoir.

In the Mono Basin, potential water quality impacts largely come from livestock grazing, roads, and hydromodification due to water exports. There are some concerns about the operation of Grant Lake as a reservoir, impacts from small hydroelectric plants, forest management, recreation (including the ski area at June Mountain), abandoned mines and urban runoff.

In the upper Owens River watershed, potential water quality impacts largely come from recreation, livestock grazing, roads, historic mining and mills, and hydromodification due to water exports and reservoir management. In the Town of Mammoth Lakes, additional concerns are from urban runoff, ski area operations, and construction-related impacts from rapid land development.

In the lower Owens River watershed, potential water quality impacts largely come from recreation, livestock grazing, roads, septic systems, and hydromodification due to water exports and reservoir management. In the City of Bishop, additional concerns are from urban runoff and construction-related impacts from land development.

Mojave - The Mojave Desert subregion includes the northern portion of the *Mojave Basin and Range* ecoregion in southeastern California. It is the largest ecoregional extent within the Lahontan Water Board region. The ecoregion has a dry, subtropical desert climate, marked by hot summers and warm winters. Death Valley in the central part of the subregion is one of the hottest places on the continent. The mean annual precipitation is about 6 inches, and ranges from 2 to over 35 inches on the wetter high peaks.

In the Mojave, creosote bush, white bursage, Joshua-tree and other yuccas, and black brush are typical. On alkali flats, saltbush, saltgrass, alkali sacaton, and iodine bush can be found. In the mountains, sagebrush, juniper, and single leaf pinyon occur. At high elevations, ponderosa pine, white fir, limber pine, and some bristlecone pine are common. Surface water is scarce, mostly intermittent and ephemeral streams. This ecoregion contains scattered north-south trending mountains which are generally lower than those of the Central Basin and Range.

Broad basins, valleys, and old lake beds occur between the ranges, with long alluvial fans. Elevations range from 85 m below sea level in Death Valley, to more than 3300 m on the highest mountain peaks. Deep Quaternary alluvial deposits comprise the valley floors and alluvial fans. The subregion has complex geology with intrusive granitic and other igneous rocks, recent volcanic, metamorphic, and sedimentary rocks including some carbonates. Aridisols and Entisols with a thermic and hyperthermic soil temperature regime and aridic soil moisture regime are common.

Most of this subregion is federally managed by the Bureau of Land Management and there is relatively little grazing activity because of the lack of water and forage for livestock. Other land uses include National parks, numerous military reservations, mining of silver, gold, talc, boron, and borate minerals, recreation and tourism. Heavy use of off-road vehicles and motorcycles in some areas has caused severe wind and water erosion problems. The larger cities include Lancaster, Palmdale, Mojave, Barstow, Baker, and Victorville.

Potential water quality impacts in the Mojave subregion largely come from over drafting of groundwater, including impacts to wetlands and springs, and impacts to groundwater quality. Impacts of confined animal facilities (i.e., dairies and chicken farms), other large agricultural activities, and groundwater cleanup at military reservations are an ongoing concern. In the last couple of decades the area is growing fast and is transitioning from predominantly agricultural to urban land uses. As a result more recent water quality issues may be coming from urban runoff and construction-related impacts from land development. Other development related water quality concerns include the use of chemical pesticides to control exotic plants and animals, as well as hydromodification caused by flood control projects.


Groundwater well in the Owens Valley, Inyo County, CA 2022. Courtesy of L. M. Freilich

4. Regional SWAMP's Monitoring Design and Sampling Effort

Since its inception, the Regional SWAMP's water quality monitoring efforts have focused on compliance monitoring to address the question:

> "Are the streams within the Lahontan Region meeting the chemical and physical water quality objectives contained in the Basin Plan[16]?"

With limited funding and a large Region, the placement of sampling stations targeted perennial streams located on public lands, or public right-of-ways, near the bottom of watersheds in locations that are considered *'integrator'* sites. The stations are located in areas that are easily accessible for sampling one to four times a year. In addition, a few stations were placed near the California and Nevada border in surface waters that cross state boundaries. With this *targeted monitoring design*, as opposed to a *random probabilistic design*, SWAMP results are best suited to evaluate local watershed conditions and should not be used to extrapolate inferences about conditions of streams across the whole Region.

The first five years of monitoring was led by the USGS who sampled 30 stations, one to four times per year, between 2000 and 2005. The data were evaluated and reported by Water Board staff in 2007 (RWQCB Lahontan Region 2007[17]).

The program started by monitoring 21 water quality parameters including:

- Field Measures: Temperature, Specific Conductivity, Dissolved Oxygen, pH, Alkalinity,
- Solid Parameters: Turbidity, Total Dissolved Solids,
- Indicator Bacteria: Fecal Coliform,
- Nutrients: Nitrogen, Phosphorus,
- Other Conventional Parameters: Chloride, Sulfate, Fluoride, Hardness,
- Inorganic Analytes: Calcium, Magnesium, Sodium, Potassium, Silica, Boron, Iron, and Manganese.

Data analyses of the first five years of monitoring indicated that the sampled sites were generally in compliance with numeric SSOs and WQOs of the Basin Plan and only 11% of all sample results exceeded objectives. Figures 6 and 7 are excerpts from the report and show the USGS sampling station locations and summarize the overall percentage of potential exceedances of Basin Plan objectives at the time.

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[16] Regional Water Board Meeting Notes Item 18 (Bishop, CA. July 10, 2019)

[17] California Regional Water Quality Control Board, Lahontan Region. 2007. Surface Water Ambient Monitoring Program (SWAMP) at the Lahontan Region: Summary of Results for Years 2000–2005. California Regional Water Quality Control Board, Lahontan Region, South Lake Tahoe, CA. July 2007. https://www.waterboards.ca.gov/lahontan/water_issues/programs/swamp/docs/report2000_05.pdf

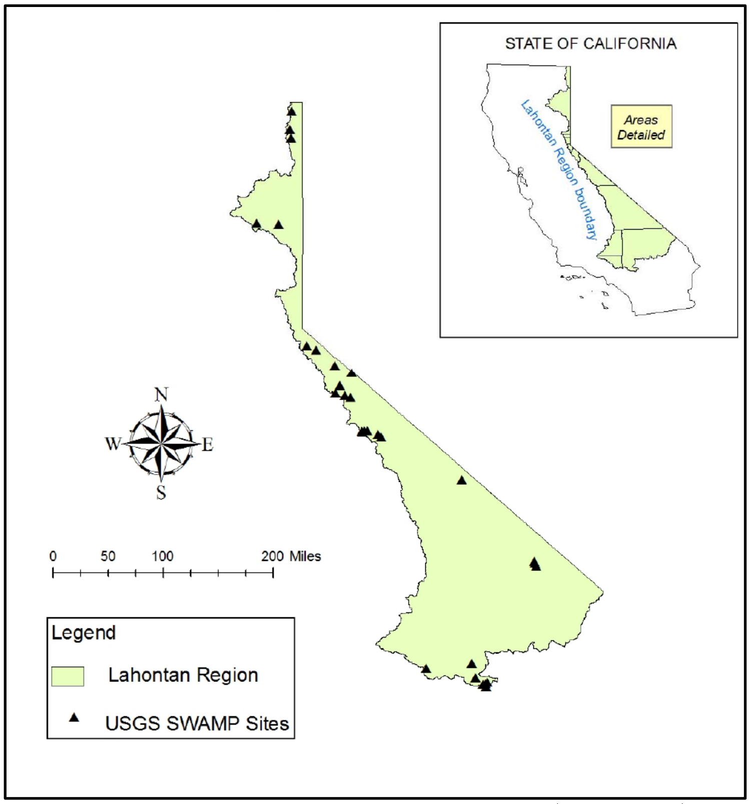
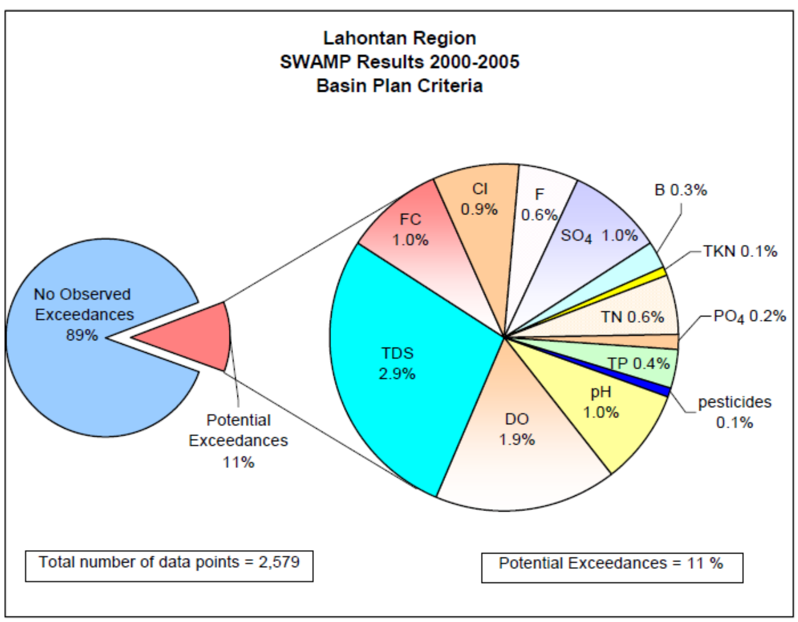


Figure 6. Regional SWAMP USGS Sampling Stations (2000 - 2005)



TDS = total dissolved solids; FC = fecal coliform bacteria; Cl = chloride; F = fluoride; SO_4 = sulfate; B = boron; TKN = total Kjeldahl nitrogen; TN = total nitrogen; PO_4 = phosphate; TP = total phosphorus; DO = dissolved oxygen

Figure 7. Summary chart of the Lahontan Region SWAMP potential exceedances of the Basin Plan water quality objectives (2000-2005).

After completing the 2007 report, the Regional SWAMP modified its ongoing water quality monitoring program in several ways to continue to adaptively address water quality conditions, compliance monitoring, and other concerns across the Region:

***First*,** the base program adjusted the location of some of its long-term monitoring stations and added temporary stations to screen streams to support ongoing compliance assessments for the Basin Plans' SSOs and WQOs.

- *Long-term "Permanent" stations.* Long-term monitoring efforts focus on large rivers/streams, generally as close to the bottom of the watershed as logistics and access allow. These sites are sampled approximately quarterly, on a long-term (permanent) basis, to evaluate trends over time and support compliance with the Basin Plans' SSOs and WQO's.

  There are 11 Long-term monitoring stations that are monitored for between 28 and 35 water quality parameters. Eight sites were established in the first few years of the program (2000 to 2003) and three new sites were added in 2013/2014.

- *Temporary "Screening" stations*. Temporary screening sites are generally monitored on a quarterly basis for a period of 2-5 years to evaluate compliance with Basin Plan SSOs, although several sites have been monitored for more than 15 years.

  At the time of this report, there are 23 Temporary stations that have been monitored for between 19 and 35 parameters, starting as early as 2000, but generally starting during or after 2010.

***Second*,** follow-up monitoring stations (or additional, more frequent sampling efforts at existing sites) were added to further investigate water quality in streams that indicated potential for concern.

- *Follow-up "Diagnostic" sampling.* Diagnostic sampling is conducted where data from permanent or screening stations indicate potential exceedances of SSOs or other potential issues. This follow-up sampling can occur at existing stations or new sites and is designed to characterize the magnitude and/or extent of exceedances of SSOs or investigate other potential water quality concerns. Sampling often is conducted more frequently than the routine sampling at permanent and screening sites (i.e., up to 10-12 times per year at follow-up stations, compared to 1-4 times per year at permanent and screening sites), or at new station locations. The greater sampling frequency allows calculation of more precise annual average analyte concentrations for compliance assessments, and better characterization of seasonal variations.

  At the time of this report, there are 12 distinct Follow-up stations that have been monitored for between 5 and 25 parameters, for a period of 1 to 9 years starting as early as 2001 (at three stations), but generally starting during or after 2007.

Third, Special Studies were implemented to address unique issues and to assist other statewide and regional programs with their monitoring needs in the Region. For example:

- The Regional SWAMP supported the Office of Environmental Health Hazard Assessment's (OEHHA) bioaccumulation studies in the Region by collecting fish tissue samples at recreational fishing locations.
- And, starting from the mid-nineties, the Lahontan Region has supported the statewide SWAMP Bioassessment Monitoring Program[18] in collecting data to develop methods and tools for assessing microbenthic communities in wadeable streams. Those datasets helped the Bioassessment Monitoring Program's Perennial Stream Assessment (PSA) develop the California Stream Condition Index (CSCI, an index of biotic integrity based on in-stream macrobenthic community measures). The data also supported the Reference Condition Management Program (RCMP), which established a network of reference sites for wadeable streams and rivers throughout California.

The PSA is led by the California Department of Fish and Wildlife who conducts ongoing macrobenthic community and physical habitat surveys, and applies the California Rapid Assessment Method for streams (CRAM) at many of their monitoring sites in the Lahontan Region. Until the development of these monitoring methods, there had been no bioassessment methods specific to the Region for evaluating the ecological condition of wadeable streams.

Working closely with the Regional SWAMP staff, the PSA team recently published a 10-year analysis of their monitoring results in "*An Ecological Assessment of Perennial Wadeable Streams and Rivers* (2008-2018)"[19]. The report, published in 2021, summarizes their statewide probabilistic survey results employing the CSCI methods. Overall, waters in the Lahontan Region are in very good ecological health (65% of streams were 'likely intact' based on the CSCI data for the Sierra Nevada region). Stream conditions showed no consistent directional change over the 11-year time frame. A comparison of sites that were known to have been impacted by human disturbance versus relatively undisturbed sites showed that undisturbed sites have higher CSCI scores; lower total nitrogen, ammonia, and alkalinity concentrations; and less riparian disturbance.

The PSA bioassessment report recommended follow up monitoring in areas that scored poorly or that had incomplete data and prioritizing protection of high quality areas in the Region. Other recommendations included that the Regional SWAMP, partner agencies, and permittees might coordinate to collect standardized analytes so that future assessments might share data that is consistently collected. Lastly, the Bioassessment Monitoring

[18] https://www.waterboards.ca.gov/water_issues/programs/swamp/bioassessment/statewide_program.html
[19] https://www.waterboards.ca.gov/water_issues/programs/swamp/bioassessment/docs/final_psa_report_2008-2018.pdf

Program should invest in developing tools to access non-perennial streams so that the Modoc and Mojave subregions can be better represented in future regional condition assessments.

The current Regional SWAMP's water quality monitoring effort samples 46 stations, one to four times per year, for up to 35 water quality parameters in 10 different Basin Plan Units across the Lahontan Region. Since 2005, the program added and dropped the following parameters:

- Added: Oxygen % Saturation, Electrical Conductivity, Total Salinity, Total Suspended Solids, Suspended Sediment Concentration, Nitrate & Nitrite as N[+], Nitrate as N[+], Nitrite as N[+], Total Kjeldahl Nitrogen, OrthoPhosphate as P
- Dropped: Hardness, Silica, and Manganese

[+] denotes parameters that are analyzed and reported in both the dissolved and total water fractions.

Table 6 lists the program's current water quality parameters with an asterisk indicating parameters that were added to the program since 2005. Figure 8 shows a map of the locations of the 46 current monitoring stations, and Table 7 lists general station and sampling information. Additional information including each station's listed beneficial uses, the number of parameters measured and the sampling period for each station that is included in this report, and the current 303(d) listings (by station) is provided in Appendix B.

Table 6. List of the Regional SWAMP water quality monitoring parameters (2000-2021). * indicates parameters that were added to the program after the initial program period (2000 - 2005).

Parameter Group	SWAMP Fraction and Parameter Name (Reporting Units)
Field Measures	Temperature (Deg C)
	pH
	Total Oxygen, Dissolved (mg/L)
	Total Oxygen, Saturation (%)*
	Total Alkalinity as CaCO3 (mg/L)
	Total Electrical Conductivity (uS/cm)*
	Total Salinity (ppt)*
	Total Specific Conductivity (uS/cm)
Solid Parameters	Particulate Suspended Sediment Concentration (mg/L)*
	Particulate Total Suspended Solids (mg/L)*
	Total Dissolved Solids (mg/L)
	Total Turbidity (NTU)
Indicator Bacteria	Coliform, Fecal (cfu/100mL)
	E. coli (cfu/100mL)*
Conventional Parameters	Dissolved Chloride (mg/L)
	Dissolved Fluoride (mg/L)
	Dissolved Sulfate (mg/L)

Parameter Group	SWAMP Fraction and Parameter Name (Reporting Units)
Inorganic Analytes	Dissolved Boron (mg/L)
	Dissolved Iron (ug/L)
	Dissolved Magnesium (mg/L)
	Dissolved Potassium (mg/L)
	Total Potassium (mg/L)*
	Dissolved Sodium (mg/L)
Nutrients	Dissolved Nitrate + Nitrite as N (mg/L)*
	Total Nitrate + Nitrite as N (mg/L)*
	Dissolved Nitrate as N (mg/L)*
	Total Nitrate as N (mg/L)*
	Dissolved Nitrite as N (mg/L)*
	Total Nitrite as N (mg/L)*
	Total Nitrogen, Total (mg/L)
	Total Nitrogen, Total Kjeldahl (mg/L)
	Dissolved OrthoPhosphate as P (mg/L)*
	Dissolved Phosphorus as P (mg/L)*
	Total Phosphorus as P (mg/L)

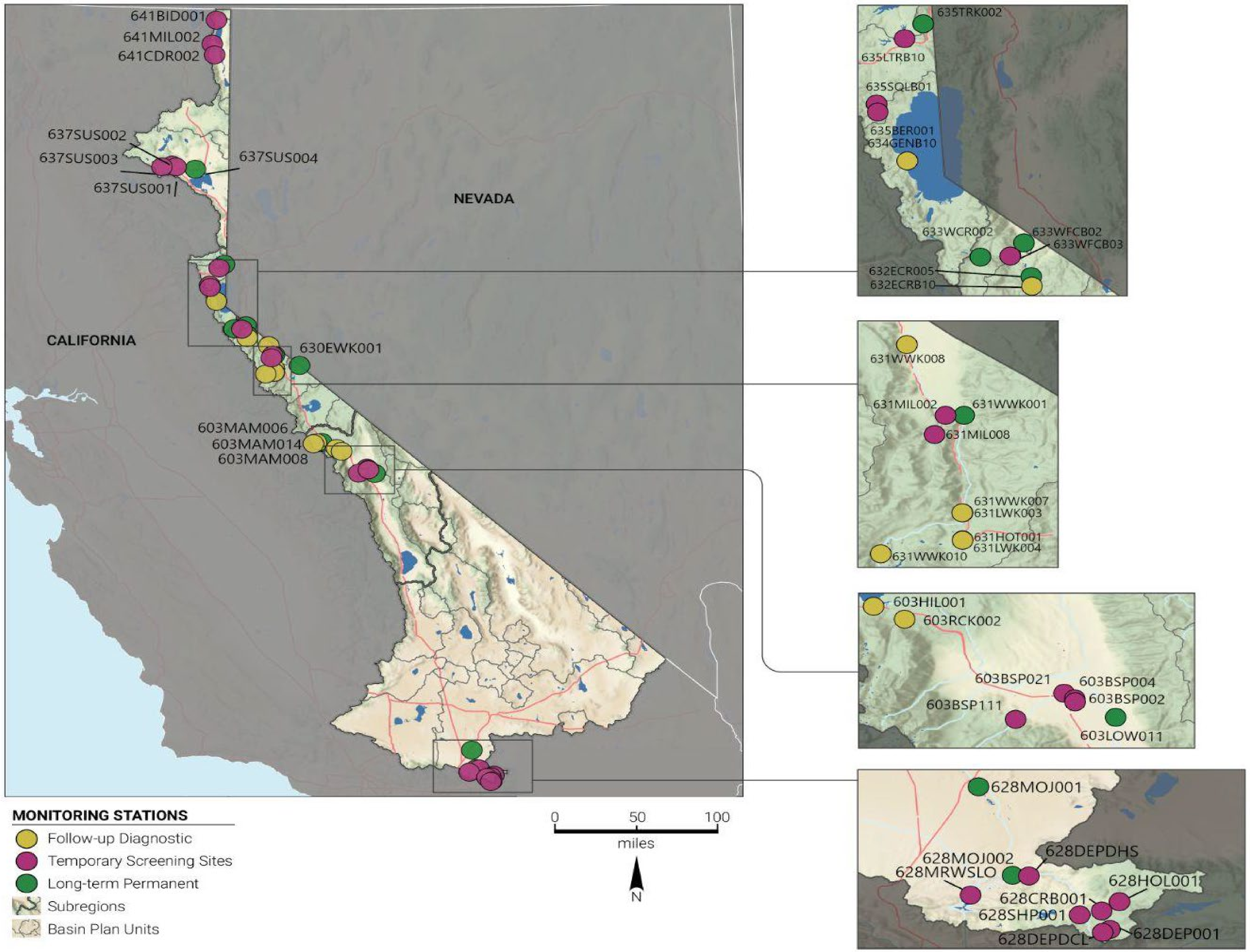


Figure 8. Map of the Lahontan Water Board's SWAMP 46 Long-term permanent, Temporary screening, and Follow-up diagnostic water quality monitoring stations (2000-2021).

Table 7. Station and sampling information for Regional SWAMP's 46 water quality monitoring stations.

Basin Plan HU Name (Number)	Station Code	Station Name	Station Type	Stream Name	Elevation (ft.)	Latitude	Longitude	N Param-eters	Sampling Period
Surprise Valley (41)	641BID001	Bidwell Creek, near former DWR gage site	Temporary	Bidwell Creek	4902	41.88246	-120.17444	35	2002 - 2017
Surprise Valley (41)	641CDR002	Cedar Creek, above Cedarville	Temporary	Cedar Creek	4751	41.52993	-120.18924	35	2003 - 2017
Surprise Valley (41)	641MIL002	Mill Creek, above Lake City	Temporary	Mill Creek	4675	41.64084	-120.21895	33	2002 - 2017
Susanville (37)	637SUS003	Susan River, above confluence w/ Willard Cr	Temporary	Susan River	4599	40.39603	-120.78140	35	2001 - 2019
Susanville (37)	637SUS002	Susan River at Lassen St	Temporary	Susan River	4208	40.41374	-120.66476	30	2008 - 2014
Susanville (37)	637SUS004	Susan River, at Commercial Road	Temporary	Susan River	4146	40.39705	-120.62122	32	2014 - 2019
Susanville (37)	637SUS001	Susan River, near Litchfield	Long-term	Susan River	4028	40.37771	-120.39514	35	2001 - 2020
Truckee River (35)	635BER001	Bear Creek, lower (moraine)	Temporary	Bear Creek	6170	39.18996	-120.19825	33	2000 - 2020
Lake Tahoe (34)	634GENB10	General Creek, above Hwy 89	Follow-up	General Creek	6257	39.05180	-120.11800	14	2013 - 2017
Truckee River (35)	635LTRB10	Little Truckee River, below Boca Reservoir	Temporary	Little Truckee River	5496	39.38551	-120.09517	31	2014 - 2020
Truckee River (35)	635SQLB01	Squaw Creek, above Truckee River	Temporary	Squaw Creek	6070	39.21145	-120.19955	30	2013 - 2020
Truckee River (35)	635TRK002	Truckee River, above Farad	Long-term	Truckee River	5179	39.42259	-120.03391	32	2013 - 2020

Table 7 continued. Station and sampling information for Regional SWAMP's 46 water quality monitoring stations.

Basin Plan HU Name (Number)	Station Code	Station Name	Station Type	Stream Name	Elevation (ft.)	Latitude	Longitude	N Param-eters	Sampling Period
East Fork Carson River (32)	632ECRB10	East Fork Carson River, above Hangman's bridge	Follow-up	East Fork Carson River	5474	38.68959	-119.76394	5	2013 – 2017
East Fork Carson River (32)	632ECR005	East Fork Carson River, below Markleeville	Long-term	East Fork Carson River	5394	38.71542	-119.76440	35	2001 - 2020
East Walker River (30)	630EWK001	East Walker River, at CA/NV state line	Long-term	East Walker River	5995	38.41399	-119.16574	35	2001 - 2020
West Fork Carson River (33)	633WCR002	West Fork Carson River, below Willow Creek	Long-term	West Fork Carson River	7062	38.77806	-119.91611	35	2003 - 2020
West Fork Carson River (33)	633WFCB03	West Fork Carson River, at Woodfords Bridge	Temporary	West Fork Carson River	5614	38.77504	-119.82301	32	2010 - 2020
West Fork Carson River (33)	633WFCB02	West Fork Carson River, at Paynesville Bridge	Long-term	West Fork Carson River	5085	38.80889	-119.77714	31	2010 - 2020
West Walker River (31)	631WWK010	West Walker River above Pack Station	Follow-up	West Walker River	7140	38.32316	-119.54865	5	2009 - 2012
West Walker River (31)	631HOT001	Hot Creek abv Little Walker River	Follow-up	West Walker River	6968	38.34206	-119.45074	5	2009 - 2014
West Walker River (31)	631LWK004	Little Walker River abv Hot Creek	Follow-up	West Walker River	6963	38.34170	-119.45089	5	2009 - 2014
West Walker River (31)	631LWK003	Little Walker River abv West Walker River	Follow-up	West Walker River	6596	38.37932	-119.45073	14	2007 - 2012
West Walker River (31)	631WWK007	West Walker River, above Little Walker River	Follow-up	West Walker River	6592	38.37927	-119.45112	14	2007 - 2012

Table 7 continued. Station and sampling information for Regional SWAMP's 46 water quality monitoring stations.

Basin Plan HU Name (Number)	Station Code	Station Name	Station Type	Stream Name	Elevation (ft.)	Latitude	Longitude	N Param-eters	Sampling Period
West Walker River (31)	631MIL008	Mill Creek at USFS boundary	Temporary	West Walker River	6196	38.48682	-119.48451	19	2014 – 2019
West Walker River (31)	631WWK001	West Walker River, near Coleville	Long-term	West Walker River	5583	38.51337	-119.44880	35	2002 - 2020
West Walker River (31)	631MIL002	Mill Creek above Hwy 39	Temporary	West Walker River	5424	38.51323	-119.47140	19	2014 - 2019
West Walker River (31)	631WWK008	West Walker River at Topaz	Follow-up	West Walker River	5038	38.61051	-119.51758	14	2008 - 2016
Owens (3)	603BSP111	Bishop Creek, at national forest boundary	Temporary	Bishop Creek	5015	37.33030	-118.49583	30	2013 - 2017
Owens (3)	603BSP021	North Fork Bishop Creek, above Bishop Cr Canal	Temporary	Bishop Creek	4164	37.38011	-118.40472	28	2013 - 2017
Owens (3)	603BSP004	South Fork Bishop Creek, above Bishop Cr Canal	Temporary	Bishop Creek	4134	37.36786	-118.38625	28	2012 - 2017
Owens (3)	603BSP002	Bishop Cr Canal at East Line St	Temporary	Drainage ditch	4134	37.36156	-118.38606	29	2010 - 2020
Owens (3)	603HIL001	Hilton Creek, at Lake Crowley	Follow-up	Hilton Creek	6784	37.57948	-118.74150	23	2001 - 2019
Owens (3)	603MAM008	Mammoth Creek, at Twin Lakes	Follow-up	Mammoth Creek	8599	37.62389	-119.00472	25	2001 - 2017
Owens (3)	603MAM014	Mammoth Creek, above Horsecamp	Follow-up	Mammoth Creek	7866	37.63480	-118.96759	5	2009 - 2017
Owens (3)	603MAM006	Mammoth Creek, at Hwy 395	Long-term	Mammoth Creek	7223	37.63799	-118.90771	35	2000 - 2020
Owens (3)	603LOW011	Lower Owens River, at Warm Springs Rd	Long-term	Owens River	4013	37.32534	-118.31365	28	2013 - 2017

Table 7 continued. Station and sampling information for Regional SWAMP's 46 water quality monitoring stations.

Basin Plan HU Name (Number)	Station Code	Station Name	Station Type	Stream Name	Elevation (ft.)	Latitude	Longitude	N Param-eters	Sampling Period
Owens (3)	603RCK002	Rock Creek, above diversion	Follow-up	Rock Creek	7405	37.54984	-118.68665	22	2001 - 2019
Mojave (28)	628DEP001	Deep Creek, above Deep Creek Lake	Temporary	Deep Creek	6211	34.21949	-117.07175	32	2001 - 2017
Mojave (28)	628DEPDCL	Deep Creek, upstream Deep Creek Lake	Temporary	Deep Creek	6039	34.21427	-117.08533	25	2018 - 2021
Mojave (28)	628CRB001	Crab Creek, at Crab Flats Rd	Temporary	Deep Creek	5902	34.25885	-117.08406	32	2001 - 2017
Mojave (28)	628HOL001	Holcomb Creek, at Crab Flats Rd	Temporary	Deep Creek	5467	34.27546	-117.05047	32	2001 - 2017
Mojave (28)	628DEPDHS	Deep Creek, downstream of Hot Springs	Temporary	Deep Creek	3206	34.34078	-117.20949	25	2018 - 2021
Mojave (28)	628MRWSLO	West Fork Mojave River, Silverwood Lake outfall	Temporary	Mojave River	3149	34.30944	-117.31678	25	2018 - 2021
Mojave (28)	628MOJ002	Mojave River, below Forks Reservoir	Long-term	Mojave River	2969	34.34462	-117.23852	33	2001 - 2021
Mojave (28)	628MOJ001	Mojave River, at Upper Narrows	Long-term	Mojave River	2713	34.53176	-117.28534	32	2001 - 2021
Mojave (28)	628SHP001	Sheep Creek, below Scout Camp	Temporary	Sheep Creek	5187	34.25364	-117.12391	32	2001 - 2017

5. Water Quality Status and Trends

The following water quality analyses begin to address the Regional SWAMP's overarching question of whether the streams within the Region are meeting the chemical and physical water quality objectives contained in the Basin Plan. More specific questions include:

- How do the overall proportions of Basin Plan objective exceedances compare to the initial 2000-2005 assessment in 2007 report?
- What proportion of water quality results are exceeding the Basin Plan's SSOs and WQOs and where?
- Are the proportions of water quality exceedances changing over time, and if so where?

With 20 years of monitoring data at a number of monitoring stations the data were further analyzed for trends to investigate the question:

- Are there any significant upward or downward trends in water quality conditions over time, and if so where?

This water quality analysis evaluated over 29,000 records for up to 35 parameters measured at 46 stations, in 22 streams across the five subregions between January 2000 and June 2021. The data formatting and standardization was completed by SFEI and reviewed by the Regional SWAMP coordinator to ensure completeness, removal of unusual outliers and duplicate records, and address other formatting anomalies.

90% of the data were clearly detected results, with values above the reporting limits (RL). The remaining 10% were qualified as "not-detected" (ND) or "detected but not quantifiable" (DNQ). DNQ results are often qualified as they are values above the method detection limit (MDL) and below the RL, below which the lab is less certain of the reported result. These qualified data are often included in environmental assessments and are standardized in different ways. For this report, the qualified data were handled as follows:

- ND values were replaced with ½ the MDL, and
- DNQ results (if not already reported by the lab as being a number between the MDL and RL) were replaced with ½ the RL.

Once standardized and reviewed, the data were ready to be analyzed. For more information about the data preparation and handling please refer to the Methods in Appendix C.

Before we present the summary results we would like to acknowledge that with a targeted monitoring design, in a subset of streams across the Region, one should not infer that the summary results presented here are characterizing the status and trends of water quality in streams across all the subregions or across the Lahontan Region as a whole. Rather they are characterizing conditions in the specific stream locations being monitored.

5.1. Water Quality Exceedance Summaries

5.1.1. HOW DO THE PROPORTIONS OF EXCEEDANCES COMPARE TO THE INITIAL 2000-2005 ASSESSMENT IN THE 2007 PROGRAM SUMMARY REPORT?

Figure 9 presents an overall, summary graphical chart of the percent of Basin Plan SSO and WQO water quality exceedances at all stations as a proportion of the total number of calculated or directly reported results for 16 parameters monitored between 2000 and 2021. Of the 9,138 calculated or directly measured (reported) water quality exceedance evaluations 1,962 comparisons exceeded the objectives, or 21% exceeded Basin Plan objectives.

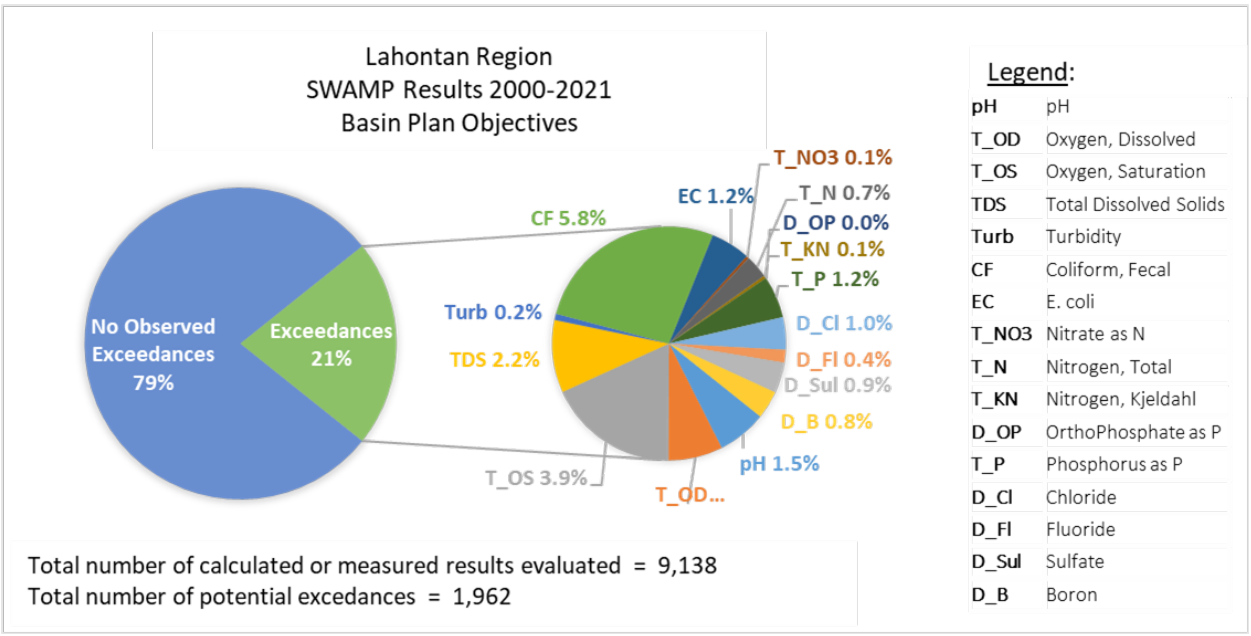


Figure 9. Summary chart of the percent of Basin Plan SSO and WQO water quality exceedances at all 46 Regional SWAMP monitoring stations as a proportion of the total number of calculated or measured results for 16 Basin Plan parameters combined.

This chart is similar to the summary chart presented in the 2007 program summary report that indicated that 11% of the total evaluated results exceeded Basin Plan objectives (see Figure 7 above). However, the charts are not be directly comparable because (1) the calculation methods were not provided in the report and could not be verified, (2) there are significant differences in the number and location of monitoring stations being assessed in the current Regional SWAMP, and (3) the list and number of parameters evaluated between the two reporting periods is different.

5.1.2. WHAT PROPORTION OF WATER QUALITY MEASURES ARE EXCEEDING THE BASIN PLAN'S SSOS AND WQOS AND WHERE?

The following charts characterize the percent of water quality exceedances for each individual parameter based on reported results from the Regional SWAMP's 46 monitoring stations sampled between January 2000 and July 2021. Figure 10 shows the percent of Basin Plan SSO or WQO water quality exceedances at all stations as a proportion of the total evaluated results by parameter. The numbers above each bar indicate the total number of calculated (e.g. annual means or rolling averages, etc.) or direct-measure results for all stations (2000-2021). Notice that total numbers of evaluated results vary a lot among the listed parameters. This is a result of several factors that are important to consider when reviewing these summaries:

- Some parameters are compared to the WQO as a direct measure of each reported result. For example, sampling a station 1-4 times a year will be counted as 1-4 direct comparisons to the WQO.
- Other parameters are compared to the SSO or WQO as a calculated value from several reported results (e.g. annual mean, rolling monthly mean, etc.). For example, sampling a station 1-4 times a year may be averaged into one annual average for comparison to an SSO or WQO.
- Different parameters have been assessed at different stations over different time periods and therefore the total number of assessments among parameters may be significantly different.

As a result of these differences, the temporal and spatial distribution of data represented by each bar (or parameter) in the charts below is variable. Nonetheless, these graphical summary charts of the proportion of exceedances by parameter can be informative and easily show which parameters have high or low exceedance rates over the reporting period.

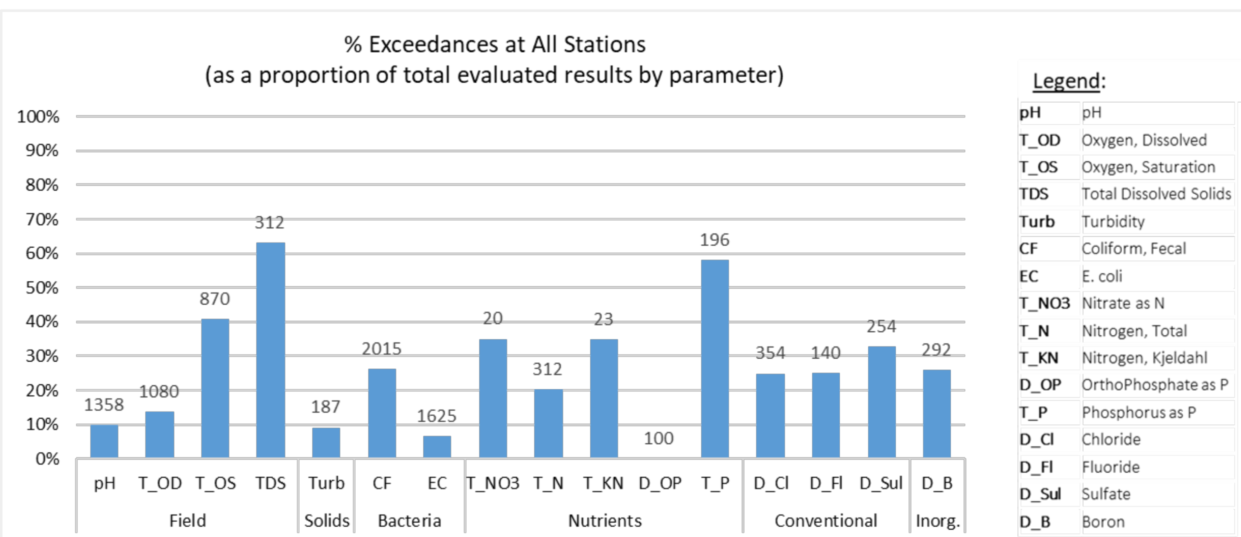


Figure 10. Percent of Basin Plan SSO or WQO water quality exceedances at all stations as a proportion of the total evaluated results by parameter. The number above each bar indicates the total number of calculated or direct-measure results for all stations (2000-2021).

Figure 11 shows the percent of Basin Plan SSO or WQO water quality exceedances for all the monitoring stations in each subregion as a proportion of the total evaluated results by parameter.

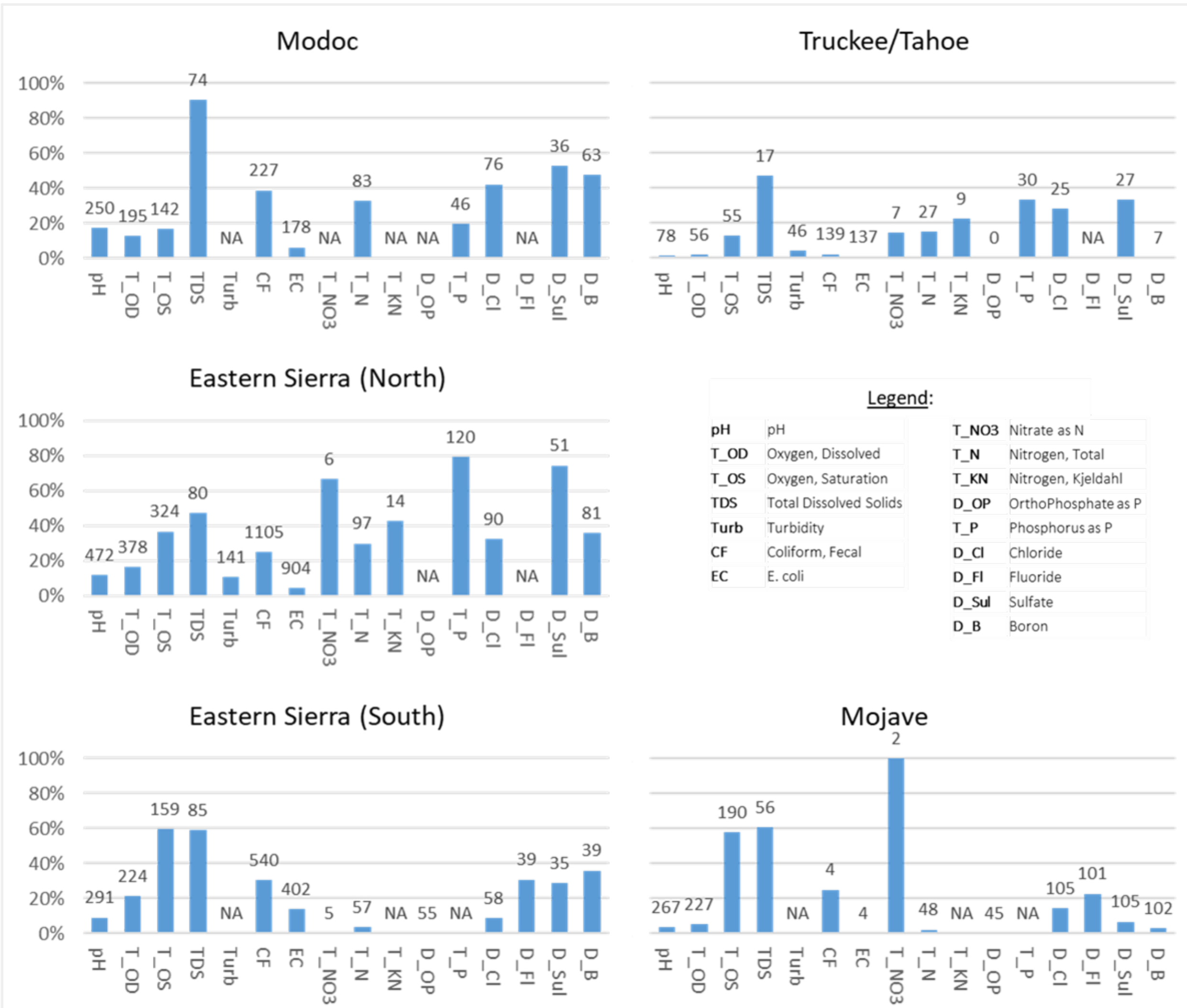


Figure 11. Percent of Basin Plan SSO or WQO water quality exceedances at all stations in each of the five subregions as a proportion of the total evaluated results (at all stations within each subregion) by parameter. The number above each bar indicates the total number of calculated or direct-measure results in the subregion (2000-2021). NA (not-available) indicates the parameter was not sampled in the subregion or that there are no SSOs or WQOs in that subregion for that specific parameter.

Reviewing the summary charts in Figures 10 and 11 for Total Dissolved Solids, as an example parameter, it exceeded the Basin Plan objective in over 60% of the total samples in the Region. Looking at the five subregional charts (Figure 11), the Modoc subregion exceeded the HU specific objective in over 80% of samples, Truckee/Tahoe and Eastern Sierra (North) subregions exceeded in just over 40% of samples, and the Eastern Sierra (South) and Mojave subregions exceeded in about 60% of the samples. Notice that Truckee/Tahoe only had 17 annual averaged results while the other subregions had 60 or more over the reporting period.

Another example, Total Phosphorus as P exceeded the SSO in almost 60% of the total samples in the Lahontan Region. Looking at the subregional charts, phosphorus exceedances were evaluated in Modoc, Truckee/Tahoe and Eastern Sierra (North) subregions, but not in the southern Eastern Sierra (South) and Mojave subregions. That was because, although the Regional SWAMP analyzed samples for total phosphorus in those subregions, there are no SSOs. Modoc exceeded the SSOs in less than 20% of the samples, Truckee/Tahoe exceeded in about 30% of the samples, and the Eastern Sierra (North) subregion had most of the exceedances with about 80% of the samples exceeding the SSOs.

In summary, Figure 10 (overall exceedance chart) indicates that the most exceedances in the Region are seen in Oxygen Saturation, Total Dissolved Solids, and Total Phosphorus. Drilling down to the subregion level (Figure 11), Oxygen Saturation exceedances are most prevalent in the Eastern Sierra (South) and Mojave subregions. Total Dissolved Solids exceedances are significant in all subregions with the highest percentage in the Modoc subregion and both Eastern Sierra (South) and Mojave subregions also have exceedances. Truckee/Tahoe and Eastern Sierra (North) subregions exceeded in just over 40% of the calculated results. Total Phosphorus exceeded SSOs in over 50% of the total assessments and this was largely due to exceedances in the Eastern Sierra (North) subregion. Phosphorus was measured in southern subregions but there are no objectives for phosphorus in those subregions. The column charts in Figures 10 and 11 provide a relatively straightforward way to identify which Basin Plan water quality parameters are exceeding objectives and in what subregions, with the caveat that it’s important to keep in mind the variable number of stations represented in each subregion and the sampling frequency differences.

At the station level, short descriptive summaries of the percent of Basin Plan objective exceedances (number of exceedances divided by the total number of results, times 100), by subregion, station, and parameter for the Regional SWAMP’s 11 long-term monitoring stations are presented in Tables 8 through 12. For a list of the parameters evaluated and their associated WQO or SSO evaluation thresholds please refer to the Methods section (Appendix C - Water Quality Objectives Exceedance Analyses).

Table 8. Summary of the percent of Basin Plan water quality objective exceedances in the Modoc subregion, by station and parameter, for the Regional SWAMP's long-term Susan River monitoring station (2000 - 2021).

Station Code	Sampling Period	Basin Plan Exceedance Summary
637SUS001_L (Susan River)	2001 - 2018	Of 16 Total Dissolved Solids results, 95% were above the SSO.
	2001 - 2019	Of 17 samples, 18% were above the Dissolved Chloride, 24% above the Total Nitrogen, and 6% were above the total Phosphorus SSOs.
	2001 - 2020	There were 80 and 66 samples of pH and Total Dissolved Oxygen (as mg/L) during the monitoring period and 36% and of the pH results were above the WQO of 8.5, and 20% of the DO results were below the COLD & SPAWN Beneficial Use objective of 8 mg/L.
	2003 - 2019	Of 72 Fecal Coliform measures, 65% were above the Maximum Rolling 30-day log mean of 20 cfu/100ml and 56% were above the rolling 30-day 90th percentile maximum value of 40 cfu/100ml.
	2008 - 2019	Of 12 Dissolved Boron and Sulfate results, 67% and 75% (respectively) were above the SSOs.

Table 9. Summary of the percent of Basin Plan water quality objective exceedances in the Truckee/Tahoe subregion, by station and parameter, for the Regional SWAMP's long-term Truckee River monitoring station (2000 - 2021).

Station Code	Sampling Period	Basin Plan Exceedance Summary
635TRK002_L (Truckee River)	2014 - 2018	Of the 5 Total Dissolved Solids results, 60% were above the SSO.
	2014 - 2020	Of the 36 Turbidity results, 6% exceeded the 2 NTU objective for the difference between the result and the mean of monthly mean calculated values. Of the 21 pH results, none exceeded the upper or lower WQOs of above 8.5 or below 6.5.
	2014 - 2020	Of the 7 Dissolved Boron results, none were above the SSO, and of 7 results for Dissolved Chloride and Sulfate, 29% and 0% were above the SSOs, respectively. Of the 7 Total Nitrogen and Total Phosphorus results, 0% and 29% were above the SSOs, respectively.
	2017 - 2018	Of the 2 total Total Kjeldahl Nitrogen and Total Nitrate results none were above their SSOs.
	2016 - 2020	Of the 13 and 14 results for Total Dissolved Oxygen (as mg/L) and Dissolved Oxygen (as % saturation), none exceeded any of the Beneficial Use WQOs or were below 80% saturation.
	2013 - 2019	Of the 26 and 33 E. coli calculated measures, none of the monthly 90th percentile values were above the maximum value of 320 cfu/100 ml or the rolling 6-week geometric mean maximum value of 100 cfu/100 ml. Of 37 Fecal Coliform calculated measures, none of the rolling 30-day log mean values were above the maximum value of 20 cfu/100ml or the rolling 30-day 90th percentile maximum value of 40 cfu/100ml.

Table 10. Summary of the percent of Basin Plan water quality objective exceedances in the Eastern Sierra (North) subregion, by station and parameter, for the Regional SWAMP's long-term Carson River and Walker River monitoring stations (2000 - 2021).

Station Code	Sampling Period	Basin Plan Exceedance Summary
632ECR005_L (East Fork Carson River)	2001 - 2017	Of the 17 Total Dissolved Solids results, 71% were above the SSO.
	2001 - 2020	Of the 20 results for Total Nitrogen and Total Phosphate, 20% and 90% of the results were above the SSOs, respectively.
	2002 - 2020	Of the 17 Dissolved Boron results, 41% were above the SSO, and of 19 results for Dissolved Chloride and Sulphate, 0% and 89% were above the SSOs, respectively. Of the 109 pH results only 4% were above the objective of 8.5 and none were below the minimum objective of 6.5. Of the 81 Total Dissolved Oxygen (as mg/L) results, 9% were below the Cold & Spawn beneficial use objective of 8 mg/L.
	2003 - 2019	Of the 90 Fecal Coliform calculated measures, 21% were above the maximum rolling 30-day log mean of 20 cfu/100ml and 19% were above the rolling 30-day 90th percentile maximum value of 40 cfu/100ml.
	2007 - 2020	Of the 65 Dissolved Oxygen (as % saturation) results, 23% were below the 80% saturation WQO.
	2008 - 2019	Of the 44 and 53 E. coli calculated measures, none of the monthly 90th percentile results were above the maximum value of 320 cfu/100 ml, and only 6% of the rolling 6-week geometric mean results were above the maximum value of 100 cfu/100 ml.
633WCR002_L (West Fork Carson River)	2003 - 2019	Of the 77 Fecal Coliform results, only 4% were above the Maximum Rolling 30-day log mean of 20 cfu/100ml and 1% were above the rolling 30-day 90th percentile maximum value of 40 cfu/100ml.
	2003 - 2020	Of the 397 Turbidity results, 7% exceeded the 2 NTU objective for the difference between the result and the mean of monthly mean calculated values. Of the 105 pH results, 6% exceeded the upper or lower WQOs of above 8.5 or below 6.5 (5% and 1%, respectively). Of the 79 Total Dissolved Oxygen (as mg/L) results, 8% were below the Cold & Spawn beneficial use objective of 8 mg/L, and 1% was below the Cold Beneficial Use Objective of 4 mg/L.
	2007 - 2020	Of the 67 Dissolved Oxygen (as % saturation) results, 55% were below the 80% saturation WQO.
	2008 - 2019	Of the 43 and 44 E. coli calculated measures, none of the monthly 90th percentile results were above the maximum value of 320 cfu/100 ml, and none were above the rolling 6-week geometric mean maximum value of 100 cfu/100 ml.
633WFCB02_L (West Fork Carson River)	2010 - 2019	Of the 60 and 179 E. coli calculated measures, 3% of the monthly 90th percentile results were above the maximum value of 320 cfu/100 ml, and 6% were above the rolling 6-week geometric mean maximum value of 100 cfu/100 ml. Of 182 Fecal Coliform calculated measures, 66% of the rolling 30-day log mean values were above the maximum value of 20 cfu/100ml and 70% were above the rolling 30-day 90th percentile maximum value of 40 cfu/100ml.

Table 10 continued. Summary of the percent of Basin Plan water quality objective exceedances in the Eastern Sierra (North) subregion, by station and parameter, for the Regional SWAMP's long-term Carson River and Walker River monitoring stations (2000 - 2021).

Station Code	Sampling Period	Basin Plan Exceedance Summary
	2014 - 2020	Of the 22 Turbidity results, 23% exceeded the 2 NTU objective for the difference between the result and the mean of monthly mean calculated values. Of the 22 pH results, 5% were below the lower WQO of 6.5 and none were above the upper WQO of 8.5.
	2016 - 2020	Of the 16 and 15 results for Total Dissolved Oxygen (as mg/L) and Dissolved Oxygen (as % saturation), none exceeded any of the Beneficial Use WQOs for Total Dissolved Oxygen (as mg/L) and 7% were below the 80% saturation WQO.
633WFCB03_T (West Fork Carson River)	2010 - 2019	Of the 58 and 179 E. coli calculated measures, none of the monthly 90th percentile results were above the maximum value of 320 cfu/100 ml or the rolling 6-week geometric mean maximum value of 100 cfu/100 ml (respectively). Of 181 Fecal Coliform calculated measures, none of the rolling 30-day log mean values were above the maximum value of 20 cfu/100ml and only 1% were above the rolling 30-day 90th percentile maximum value of 40 cfu/100ml.
	2014 - 2020	Of the 21 Turbidity results, 14% exceeded the 2 NTU objective for the difference between the result and the mean of monthly mean calculated values. Of the 21 pH results, none were below or above the lower and upper WQOs of 6.5 and 8.5.
	2016 - 2020	Of the 15 results for Total Dissolved Oxygen (as mg/L) and Dissolved Oxygen (as % saturation), 7% exceeded the Beneficial Use Cold & Spawn WQO for Total Dissolved Oxygen (as mg/L) and none were below the 80% saturation WQO.
630EWK001_L (East Walker River)	2001 - 2018	Of the 17 Total Dissolved Solids results, 29% were above the SSO.
	2001 - 2020	Of the 19 Dissolved Chloride, Total Nitrogen, and Total Phosphate results, 5%, 68% and 89% were above the SSOs, respectively. Of the 94 pH results only 32% were above the objective of 8.5 and none were below the minimum objective of 6.5. Of the 81 Total Dissolved Oxygen (as mg/L) results, 31% were below the Cold & Spawn beneficial use objective of 8 mg/L and 1% were below the Cold objective of 4 mg/L.
	2002 - 2020	Of the 17 Dissolved Boron results, 24% were above the SSO
	2003 - 2019	Of the 101 Fecal Coliform results, 6% were above the Maximum Rolling 30-day log mean of 20 cfu/100ml and 3% were above the rolling 30-day 90th percentile maximum value of 40 cfu/100ml.
	2004 - 2020	Of the 67 Dissolved Oxygen (as % saturation) results, 42% were below the 80% saturation WQO.
	2008 - 2019	Of the 63 and 65 E. coli calculated measures, none of the monthly 90th percentile results were above the maximum value of 320 cfu/100 ml, and only 2% of the rolling 6-week geometric mean results were above the maximum value of 100 cfu/100 ml.

Table 10 continued. Summary of the percent of Basin Plan water quality objective exceedances in the Eastern Sierra (North) subregion, by station and parameter, for the Regional SWAMP's long-term Carson River and Walker River monitoring stations (2000 - 2021).

Station Code	Sampling Period	Basin Plan Exceedance Summary
631WWK001_L (West Walker River)	2002 - 2018	Of the 16 Total Dissolved Solids results, 94% were above the SSO.
	2002 - 2020	Of the 17 Dissolved Boron results, 53% were above the SSO, and of 18 results for Dissolved Chloride, Total Nitrogen, and Total Phosphate results, 56%, 17% and 94% were above the SSOs, respectively. Of the 91 pH results only 12% were above the objective of 8.5 and none were below the minimum objective of 6.5. Of the 76 Total Dissolved Oxygen (as mg/L) results, 9% were below the Cold & Spawn beneficial use objective of 8 mg/L.
	2003 - 2019	Of the 95 Fecal Coliform results, 2% were above the Maximum Rolling 30-day log mean of 20 cfu/100ml and 1% were above the rolling 30-day 90th percentile maximum value of 40 cfu/100ml.
	2007 - 2020	Of the 66 Dissolved Oxygen (as % saturation) results, 32% were below the 80% saturation WQO.
	2008 - 2019	Of the 50 and 58 E. coli calculated measures, none of the monthly 90th percentile results were above the maximum value of 320 cfu/100 ml or the rolling 6-week geometric mean maximum value of 100 cfu/100 ml, respectively.

Table 11. Summary of the percent of Basin Plan water quality objective exceedances in the Eastern Sierra (South), by station and parameter, for the Regional SWAMP's Mammoth Creek and Owens River long-term monitoring stations (2000 - 2021).

Station Code	Sampling Period	Basin Plan Exceedance Summary
603MAM006_L (Mammoth Creek)	2000 - 2018	Of the 18 Total Dissolved Solids results, 83% were above the SSO.
	2000 - 2019	Of the 99 pH results, 10% exceeded the upper or lower WQOs of above 8.5 or below 6.5 (9% and 1%, respectively).
	2000 - 2020	Of the 19 Dissolved Boron results, 16% were above the SSO, and of 20 results for Dissolved Chloride, none were above the SSO. Of the 19 results for Dissolved Fluoride and Sulfate, 32% and 26% were above the SSOs, respectively. Of the 20 results for Total Ortho-Phosphate, none were above the SSO.
	2001 - 2019	Of the 77 Total Dissolved Oxygen (as mg/L) results, 17% were below the Cold & Spawn beneficial use objective of 8 mg/L.
	2001 - 2020	Of the 19 Total Nitrogen results, none were above the SSO.
	2004 - 2019	Of the 90 Fecal Coliform results, 26% were above the Maximum Rolling 30-day log mean of 20 cfu/100ml and 20% were above the rolling 30-day 90th percentile maximum value of 40 cfu/100ml.

Table 11 continued. Summary of the percent of Basin Plan water quality objective exceedances in the Eastern Sierra (South), by station and parameter, for the Regional SWAMP's Mammoth Creek and Owens River long-term monitoring stations (2000 - 2021).

Station Code	Sampling Period	Basin Plan Exceedance Summary
603MAM006_L (Mammoth Creek)	2007 - 2020	Of the 64 Dissolved Oxygen (as % saturation) results, 69% were below the 80% saturation WQO.
	2008 - 2019	Of the 50 and 52 E. coli calculated measures, none of the monthly 90th percentile results were above the maximum value of 320 cfu/100 ml, and 6% were above the rolling 6-week geometric mean maximum value of 100 cfu/100 ml.
	2018 - 2018	The one Total Nitrate as N result was also not above the SSO.
603LOW011_L (Owens River)	2013 - 2017	Of the 5 results for Dissolved Boron, Dissolved Chloride, Dissolved Fluoride, Dissolved Ortho-Phosphate, Dissolved Sulfate, all of the samples (100%) were above their respective SSOs. Of the 5 Total Nitrate results, none were above the SSO. Of the 5 Total Dissolved Solids results, 80% were above the SSO. Of the 19 pH results only 5% were above the objective of 8.5 and none were below the minimum objective of 6.5. Of the 8 Total Dissolved Oxygen (as mg/L) results, 50% were below the Cold & Spawn beneficial use objective of 8 mg/L. Of the 8 Dissolved Oxygen (as % saturation) results, 50% were below the 80% saturation WQO. Of the 20 and 21 E. coli calculated measures, 5% the monthly 90th percentile results were above the maximum value of 320 cfu/100 ml, and 5% were above the rolling 6-week geometric mean maximum value of 100 cfu/100 ml (respectively). Of 21 Fecal Coliform calculated measures, 29% of the rolling 30-day log mean values were above the maximum value of 20 cfu/100ml and 19% were above the rolling 30-day 90th percentile maximum value of 40 cfu/100ml.
	2017 - 2017	The one Total Nitrate as N result was also not above the SSO.

Table 12. Summary of the percent of Basin Plan water quality objective exceedances in the Mojave Desert subregion, by station and parameter, for the Regional SWAMP's long-term Mojave River monitoring stations (2000 - 2021).

Station Code	Sampling Period	Basin Plan Exceedance Summary
628MOJ001_L (Mojave River)	2001 - 2020	Of the 18 Dissolved Boron, Dissolved Chloride, Dissolved Fluoride, and Dissolved Sulfate results, none were above the SSOs.
	2001 - 2021	Of the 50 pH results, 2% were below the minimum WQO of 6.5 and none were above the maximum WQO of 8.5. Of the 49 Total Dissolved Oxygen (as mg/L) results, 12% were below the Cold beneficial use objective of 4 mg/L and 2% were below the Warm Beneficial Use WQO of 3 mg/L.
	2008 - 2021	Of the 35 Dissolved Oxygen (as % saturation) results, 86% were below the 80% saturation WQO.
628MOJ002_L (Mojave River)	2001 - 2020	Of the 18 Dissolved Boron, Dissolved Chloride results none were above their respective SSOs. Of the Dissolved Fluoride, and Dissolved Sulfate results, 22% and 6% were above their respective SSOs.
	2001 - 2021	Of the 50 pH results, 6% were above the maximum WQO of 8.5 and none were below the minimum WQO of 6.5. Of the 49 Total Dissolved Oxygen (as mg/L) results, 2% were below the Cold beneficial use objective of 4 mg/L.
	2008 - 2021	Of the 35 Dissolved Oxygen (as % saturation) results, 9% were below the 80% saturation WQO.

5.1.3. ARE THE PROPORTIONS OF WATER QUALITY EXCEEDANCES CHANGING OVER TIME, AND IF SO WHERE?

To investigate change in the proportions of water quality exceedances over time, the Regional SWAMP monitoring data (2000-2021) was first divided into four multi-year increments of five years each. Then the 46 monitoring stations were grouped by subregion and Basin Plan HU and the percent of water quality objective exceedances for each parameter and time interval was calculated. That is, for each Basin Plan HU, parameter, and time interval, we calculated the number of sample results that exceeded the SSO or WQO, divided by the total number of results reported, and multiplied by 100 to get the percent of exceedances.

The results were tabulated and visually evaluated. Tables 13 - 16 present the tabular results. If the percentage of exceedances changed more than five percentage points between the first and last 5-year interval an up or down arrow was added after each parameter. A sideways arrow indicates no change. Blank cells indicate there were no reported results for the time interval. Dot indicates that there was not enough time series data to evaluate if there was a five percentage point change (or more) in the proportions of exceedances over time.

Table 13. Percent of water quality exceedances for field measured parameters in 5-year intervals between 2000 and 2021. An up or down arrow indicates if the percentage of exceedances changed more than five points between the first and last periods shown in the table. A sideways arrow indicates no change. Blank cells indicate there were no reported results for the time interval. Dot indicates that there was not enough time series data to evaluate change in the proportions of exceedances over time.

Subregion	Basin Plan HU	pH					Total Oxygen, Dissolved (mg/L)					Total Oxygen, Saturation (%)					Total Dissolved Solids (mg/L)				
		2000-2004	2005-2009	2010-2014	2015-2021		2000-2004	2005-2009	2010-2014	2015-2021		2000-2004	2005-2009	2010-2014	2015-2021		2000-2004	2005-2009	2010-2014	2015-2021	
Modoc	Surprise Valley	0	0	5	0	→	20	0	8	0	↓		44	33	0	↓	100	100	83	78	↓
	Susanville	32	21	34	4	↓	27	14	17	8	↓		22	18	4	↓	100	100	88	92	↓
Truckee/ Tahoe	Little Truckee River				0	.				0	.				0	.				0	.
	Truckee River	0		0	0	→	0		0	0	→			100	10	↓			75	42	↓
	Lake Tahoe				0	.				12	.				25	.					.
Eastern Sierra (North)	Carson River	0	4	8	0	→	0	11	10	3	→		56	38	8	↓	67	20	54	28	↓
	Walker River	14	30	18	7	↓	21	24	22	24	→	0	54	37	15	↑	43	75	70	50	↑
Eastern Sierra (South)	Owens	4	1	25	4	→	26	23	18	20	↓		81	46	35	↓	88	92	72	67	↓
Mojave Desert	Mojave	3	3	0	2	→	25	50	17	88	↑		58	55	60	→	100	83	100	100	→

Table 14. Percent of water quality exceedances for turbidity and indicator bacteria in 5-year intervals between 2000 and 2021. An up or down arrow indicates if the percentage of exceedances changed more than five points between the first and last periods shown in the table. A sideways arrow indicates no change. Blank cells indicate there were no reported results for the time interval. Dot indicates that there was not enough time series data to evaluate change in the proportions of exceedances over time.

Subregion	Basin Plan HU	Total Turbidity (NTU)					Coliform, Fecal (cfu/100mL)					E. coli (cfu/100mL)				
		2000-2004	2005-2009	2010-2014	2015-2021		2000-2004	2005-2009	2010-2014	2015-2021		2000-2004	2005-2009	2010-2014	2015-2021	
Modoc	Surprise Valley						60	10	35	33	↓		0	5	0	→
	Susanville						30	36	56	34	→		0	5	8	→
Truckee/ Tahoe	Little Truckee River				0	.			0	0	→			0	0	→
	Truckee River			0	6	↑			5	2	→			2	0	→
	Lake Tahoe					.			0	0	→			0	0	→
Eastern Sierra (North)	Carson River	17	7	3	16	→	20	5	32	17	→		0	3	2	→
	Walker River						11	6	29	21	↑		0	10	1	↑
Eastern Sierra (South)	Owens						38	14	43	20	↓		4	19	9	→
Mojave Desert	Mojave								25		.			0		.

Table 15. Percent of water quality exceedances for nutrients in 5-year intervals between 2000 and 2021. An up or down arrow indicates if the percentage of exceedances changed more than five points between the first and last periods shown in the table. A sideways arrow indicates no change. Blank cells indicate there were no reported results for the time interval. Dot indicates that there was not enough time series data to evaluate change in the proportions of exceedances over time.

Subregion	Basin Plan HU	Total Nitrogen, Total (mg/L)					Total Nitrogen, Total Kjeldahl (mg/L)					Dissolved Ortho-Phosphate as P (mg/L)					Total Phosphorus as P (mg/L)				
		2000-2004	2005-2009	2010-2014	2015-2021		2000-2004	2005-2009	2010-2014	2015-2021		2000-2004	2005-2009	2010-2014	2015-2021		2000-2004	2005-2009	2010-2014	2015-2021	
Modoc	Surprise Valley	33	0	0	0	↓															
	Susanville	50	75	31	67	↑											12	38	7	27	↑
Truckee/ Tahoe	Little Truckee River				33	.				0	.									33	.
	Truckee River	0		0	17	↑	0		0	33	↑						0		0	44	↑
	Lake Tahoe				0	.														33	.
Eastern Sierra (North)	Carson River	17	20	0	33	↑	50	20	100	50	→						67	70	58	54	↓
	Walker River	71	50	19	43	↓											100	95	96	86	↓
Eastern Sierra (South)	Owens	0	0	0	10	↑						0	0	0	0	→					
Mojave Desert	Mojave	0	22	0	17	↑						0	0	20	0	→					

Table 16. Percent of water quality exceedances for conventional parameters and dissolved Boron (an inorganic analyte) in 5-year intervals between 2000 and 2021. An up or down arrow indicates if the percentage of exceedances changed more than five points between the first and last periods shown in the table. A sideways arrow indicates no change. Blank cells indicate there were no reported results for the time interval. Dot indicates that there was not enough time series data to evaluate change in the proportions of exceedances over time.

Subregion	Basin Plan HU	Dissolved Chloride (mg/L)					Dissolved Fluoride (mg/L)					Dissolved Sulfate (mg/L)					Dissolved Boron (mg/L)				
		2000-2004	2005-2009	2010-2014	2015-2021		2000-2004	2005-2009	2010-2014	2015-2021		2000-2004	2005-2009	2010-2014	2015-2021		2000-2004	2005-2009	2010-2014	2015-2021	
Modoc	Surprise Valley	100	43	33	33	↓												0	33	56	↑
	Susanville	38	38	33	60	↑							33	33	80	↑		17	53	80	↑
Truckee/ Tahoe	Little Truckee River				0	.									33	.					
	Truckee River			50	28	↓						50		25	33	↓			0	0	→
	Lake Tahoe															.					
Eastern Sierra (North)	Carson River	40	40	17	42	→						100	80	75	67	↓	40	0	50	33	↓
	Walker River	29	25	30	29	→											33	33	40	42	↑
Eastern Sierra (South)	Owens	6	0	15	14	↑	50	25	23	33	↓	25	25	27	31	↑	0	0	46	44	↑
Mojave Desert	Mojave	33	17	17	42	↑	85	28	47	76	↓	58	61	37	55	→	10	0	3	21	↑

The field measured parameters in Table 13 include trends for pH, dissolved oxygen, oxygen saturation and total dissolved solids. The majority of the trends for the various parameters and various subregions is either no change or a decrease in exceedances. For example, five of the seven HUs showed no change in pH through time, while the other two HUs (Susanville and Walker River) showed decreases. Oxygen saturation has five of the seven HUs registering decreases in exceedances through time, with just a single HU (Walker River) registering an increase (although the exceedances decrease from the 2005-2009 time period to the present). There are only three upward trends in exceedances in Table 13, however the trend for the Mojave HU for dissolved oxygen shows an increase in percentage from 25 to 88%.

Table 14 illustrates trends for turbidity and bacteria across the HUs. These measures largely show no trend because the magnitude of exceedances have not changed significantly through time (e.g. much of the E. coli data). However, this table also illustrates that some parameters have not been measured consistently through time, such as turbidity, reducing the total amount of data available. The greatest change is observed in fecal coliform in the Surprise Valley HU, with a reduction from 60 to 33 percent exceedance.

Table 15 illustrates trends for nutrients through time, and is also limited by the variable parameters collected through space and time. Four HUs show reductions in exceedances for various parameters, such as a reduction in Total Nitrogen for the Surprise Valley HU from 33 to 0 percent. However, five of the other six HUs show increased exceedance for Total Nitrogen.

In addition, the Truckee River HU registers increases in exceedances not just for Total Nitrogen, but also for Total Nitrogen Kjeldahl and Total Phosphorus.

And finally, Table 16 illustrates trends for Dissolved Chloride, Fluoride, Sulfate and Boron. These parameters have variable trends across the HUs, but two HUs (Susanville and Owens) both show increases in exceedances for Dissolved Chloride, Sulfate and Boron, with the Susanville HU having exceedances of 60, 80 and 80% for the three parameters during the most recent time period, respectively. In general, Dissolved Boron shows the most consistent results, with increases in exceedances observed in five of the seven reporting HUs.

5.2. Water Quality Trends Over Time

Evaluating trends in long-term water quality monitoring data is difficult because of a variety of largely uncontrollable factors both internal to the data and external in the environment. Some internal factors include: data gaps, outliers, values below detection limits, measurement error, and changes in analytical labs and methods that can lead to differences in detection limits, all of which are common in environmental monitoring datasets[20]. External environmental factors

[20] Fu and Wang. Statistical Tools for Analyzing Water Quality Data. Centre for Applications in Natural Resource Mathematics (CARM), School of Mathematics and Physics, The University of Queensland, Australia. https://eprints.qut.edu.au/95361/1/95361.pdf

that complicate analyses for water quality trends over time include: non-normal distributions (skewed or nonparametric data), seasonality, correlations with flow (stream discharge), and serial correlations[21].

These confounding factors are present in the Regional SWAMP's long-term dataset (2000-2021). As a result, a conservative approach was taken to evaluate trends over time for all station/parameter combinations. Three separate statistical tests were run and only when all three tests had a significance level where the p-values were less than 0.05 did we reject the null-hypothesis that there were no trends, and accept that the station/parameter pair as likely showing a significant trend over time.

5.2.1. ARE THERE ANY SIGNIFICANT UPWARD OR DOWNWARD TRENDS IN WATER QUALITY CONDITIONS OVER TIME, AND IF SO WHERE?

A Mann Kendall and seasonal Mann Kendall test for trends were selected to evaluate trends, and the EnvStats package[22] in R (a programming language) was used to complete the tests. The seasonal Mann Kendall test is a modification of the Mann Kendall test and is an appropriate method to evaluate monotonic trends (one directional trends over time) in seasonal water quality data because it is a nonparametric test that can accommodate seasonal cycles, skewed data, data gaps, and results below the detection limits[23,24].

To prepare the data for trend analyses, time intervals were standardized for all stations and parameters by taking the median water quality values for three different time intervals: quarterly, wet/dry season (with the wet season identified as October-April, and the dry season as May-September), and annual. All station/parameter combinations were evaluated regardless of the number of years and sampling frequency, letting the EnvStats package function determine which combinations had enough data to run the respective trend tests. Because the annual median dataset has no seasonal component to it the Mann Kendall test was run instead. Out of 1199 station/parameter combinations tested for all three time intervals, only 153 had at least 1 significant z-trend output where the p-value was <0.05. Of those only 23 combinations were significant for all three tests. Table 17 presents the significant test outputs which includes 14 different stations (many of them Temporary screening stations) and 12 different parameters.

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[21] Hirsch, R.M., J.R. Slack, and R.A. Smith. (1982). Techniques of Trend Analysis for Monthly Water Quality Data. Water Resources Research 18(1), 107-121.

[22] Millard SP (2013). EnvStats: An R Package for Environmental Statistics. Springer, New York.

[23] Hirsch, R.M., R.B. Alexander, and R.A. Smith. (1991). Selection of Methods for the Detection and Estimation of Trends in Water Quality. Water Resources Research 27(5), 803-813.

[24] Meals, D., J. Spooner, S. Dressing, and J. Harcum. 2011. Statistical analysis for monotonic trends, Tech Notes 6, November 2011. Developed for U.S. Environmental Protection Agency by Tetra Tech, Inc., Fairfax, VA https://www.epa.gov/sites/default/files/2016-05/documents/tech_notes_6_dec2013_trend.pdf

The results of the statistical tests for trends for all stations and parameters indicate few significant upwards or downwards trends were detected in the Regional SWAMP monitoring results between 2000 and 2021. This finding is not too surprising since there have not been significant ecological or anthropogenic changes at or near the specific targeted monitoring stations in the program, and given that some parameter concentrations have a wide range of variation.

Of the significant trends, 14 stations showed potential trends in 1 to 5 parameters (Table 17). Most of the stations are Temporary screening sites. A couple interesting outcomes that may warrant further review of the water quality conditions in the subregion and/or specific stations include:

- Surprise Valley HU indicates that Total Nitrogen results may be declining at 3 stations in Bidwell Creek, Cedar Creek, and Mill Creek. However, the relative water quality concentrations observed at these sites is near or below the reported MDLs and further review of the data is warranted.
- Mojave station 628CRB001 (Crab Creek, at Crab Flats Rd.) a Temporary station in Deep Creek (sampled since 2008). At this station, several parameters indicate changes in concentrations over time. Dissolved Oxygen, Oxygen Saturation, and Dissolved Boron are going down, while Dissolved Calcium and Magnesium levels are going up. It appears that water quality conditions at this site might be changing.

Table 17. Statistical test results for the 23 station/parameter combinations that were significant for all three tests. Tests included a Mann Kendall (MK) test on the calculated annual median values, and Seasonal Mann Kendall (SMK) test for trends based on calculated median values of wet and dry season results, and quarterly results. The number of calculated values (n Results) are listed for the wet/dry season test. The statistical test outputs include: tau, z-trend, and p-values are presented. The negative or positive values of tau and z-trend outputs indicate the direction of the monotonic trend (negative = downward; positive = upward) as indicated by the arrows.

Subregion	Basin Plan HU	Station Code and Site Type	Parameter	Sampling Period	n Results	Annual (MK)					Wet/Dry Season (SMK)					Quarterly (SMK)				
						MK_tau	zTrend	p_val	n years		SMK_tau	zTrend	p_val	n wet/dry		SMK_tau	zTrend	p_val	n Qtrs	
Modoc	Surprise Valley	641BID001_T	Total Nitrogen	2003-2017	24	-0.52	-2.26	0.02	12	↓	-0.51	-2.09	0.04	17	↓	-0.59	-2.72	0.01	23	↓
		641CDR002_T	Total Nitrogen	2003-2017	26	-0.67	-2.95	0.00	12	↓	-0.63	-3.19	0.00	18	↓	-0.68	-3.85	0.00	25	↓
		641CDR002_T	Dissolved Chloride	2003-2017	26	0.67	2.95	0.00	12	↑	0.51	2.77	0.01	18	↑	0.44	2.71	0.01	25	↑
		641MIL002_T	Total Nitrogen	2003-2017	24	-0.55	-2.40	0.02	12	↓	-0.58	-2.66	0.01	17	↓	-0.46	-2.19	0.03	23	↓
		641MIL002_T	Dissolved Magnesium	2008-2017	16	0.67	2.40	0.02	9	↑	0.64	2.20	0.03	11	↑	0.58	2.07	0.04	15	↑
Truckee/ Tahoe	Truckee/ Tahoe	635BER001_T	Temperature	2000-2020	23	-0.64	-2.50	0.01	10	↓	-0.49	-2.19	0.03	15	↓	-0.40	-2.33	0.02	23	↓
		635BER001_T	Oxygen, Dissolved	2000-2020	16	0.71	2.35	0.02	8	↑	0.64	2.47	0.01	11	↑	0.58	2.60	0.01	16	↑
		635BER001_T	Dissolved Magnesium	2000-2020	22	-0.61	-2.19	0.03	9	↓	-0.64	-2.69	0.01	14	↓	-0.61	-2.91	0.00	22	↓
Eastern Sierra (North)	Carson River	632ECR005_L	Electrical Conductivity	2007-2020	87	0.41	1.97	0.05	14	↑	0.30	1.99	0.05	26	↑	0.27	2.42	0.02	49	↑
		633WFCB02_L	Dissolved Boron	2014-2020	21	-0.71	-2.10	0.04	7	↓	-0.76	-2.68	0.01	11	↓	-0.64	-3.16	0.00	21	↓
	Walker River	630EWK001_L	pH	2001-2020	94	-0.42	-2.49	0.01	19	↓	-0.44	-3.49	0.00	34	↓	-0.41	-4.45	0.00	64	↓
		630EWK001_L	Turbidity	2001-2020	105	-0.44	-2.50	0.01	18	↓	-0.47	-3.55	0.00	32	↓	-0.40	-4.12	0.00	60	↓
Eastern Sierra (South)	Owens	603MAM008_F	Total Nitrogen	2001-2017	17	-0.87	-2.25	0.02	6	↓	-0.65	-2.30	0.02	10	↓	-0.52	-2.42	0.02	17	↓
		603MAM014_F	E. coli	2009-2017	49	-0.69	-2.52	0.01	9	↓	-0.56	-2.79	0.01	15	↓	-0.32	-2.03	0.04	25	↓
		603RCK002_F	Turbidity	2001-2019	43	-0.51	-1.97	0.05	10	↓	-0.57	-2.66	0.01	16	↓	-0.50	-2.67	0.01	25	↓
Mojave Desert	Mojave	628CRB001_T	Oxygen, Dissolved	2001-2017	34	-0.43	-2.18	0.03	15	↓	-0.49	-2.85	0.00	24	↓	-0.51	-3.30	0.00	27	↓
		628CRB001_T	Oxygen, Saturation	2008-2017	24	-0.64	-2.50	0.01	10	↓	-0.59	-2.91	0.00	16	↓	-0.56	-2.74	0.01	17	↓
		628CRB001_T	Dissolved Boron	2001-2017	31	-0.56	-2.74	0.01	14	↓	-0.52	-2.94	0.00	23	↓	-0.53	-2.16	0.03	25	↓
		628CRB001_T	Dissolved Calcium	2008-2017	22	0.51	1.97	0.05	10	↑	0.44	2.06	0.04	16	↑	0.47	2.23	0.03	17	↑
		628CRB001_T	Dissolved Magnesium	2008-2017	22	0.53	2.07	0.04	10	↑	0.46	2.23	0.03	16	↑	0.46	2.23	0.03	17	↑
		628DEP001_T	Dissolved Magnesium	2008-2017	21	0.60	2.33	0.02	10	↑	0.68	2.78	0.01	14	↑	0.64	2.59	0.01	15	↑
		628MOJ001_L	Dissolved Chloride	2001-2020	46	0.46	2.65	0.01	18	↑	0.38	2.60	0.01	28	↑	0.32	1.97	0.05	36	↑
		628SHP001_T	Oxygen, Saturation	2008-2017	20	-0.73	-2.86	0.00	10	↓	-0.71	-2.89	0.00	13	↓	-0.67	-2.69	0.01	14	↓

As mentioned above, identifying statistically significant trends in long-term water quality monitoring data is difficult and variations in hydrology and weather, and other environmental factors can confound the results. In addition non-detect values and detection limits that are highly variable over the monitoring periods evaluated can result in misleading, biased results. This may be the case for several of the conventional parameters and also for nutrients as mentioned in the Methods section in Appendix C. Visually reviewing plots of the data will help in interpreting the trend results.

5.2.2. SUMMARY PLOTS OF THE WATER QUALITY MONITORING DATA OVER TIME

Appendix D includes graphical plots for 29 of the regularly monitored water quality parameters at a subset of 26 stations. The parameters and stations were selected because they were monitored over a period of at least nine years with the exception of the Truckee/Tahoe subregion.

The water quality results are presented one parameter to a page and organized by subregion, stream name, and station code for the following station types:

- 11 core long-term stations,
- 10 temporary screening stations,
- 3 follow-up diagnostic stations, and
- 3 additional Truckee/Tahoe Temporary screening stations that have only been monitored since 2013. These stations were added to provide more representation of water quality conditions in the subregion.

The trends plots show seasonal results over time and highlight similarities (or differences) in water quality measures both seasonally and temporally by subregion, stream name, and station code. Each individual station plot consists of seasonal boxplots for 4 multi-year increments using the same 5-year time intervals as presented in the water quality exceedance summary section above (see Tables 13-16). As with the statistical trend analyses reported above, the wet season was defined as samples collected October through March, and the dry season included samples collected April through September. Stations and parameters that showed significant trends using the seasonal Mann Kendall tests are indicated with "** Sig. Trend*" in red. Please refer to Table 17 (above) for the specific test statistics. If available, the minimum and maximum MDLs, reported since 2015 by station and parameter, are shown on the individual plots to visually indicate if the reported ambient water quality results fall within the range of recently reported method detection limits or if they are well above those limits.

The graphically plotted data clearly show wide fluctuations in water quality concentrations for most parameters over the sampling period. Many parameters show seasonal differences. It is also clear from the minimum and maximum MDL lines overlaid on the plots that detection limits for some parameters may not be sensitive enough to detect ambient water quality concentrations at a number of stations. As a result, those results are reported and not detected, which makes it difficult to evaluate trends over time. In addition, if the Basin Plan SSO or WQOs are within the same range as the detection limits, it is not possible to assess exceedances.

Monitoring results that fall below the range of detection can bias and confound the interpretation of trend analyses because of the large number of non-detected results that get assigned ½ the MDL or RL. This is an important point and is especially important if the WQO or SSOs are also at (or near) the reporting limits of the analytical methods. For example, within the Regional SWAMP's dataset, Total Nitrogen results in the Modoc Surprise Valley area are examples where the ambient water quality concentrations appear to be within the range of the reported MDLs. A relatively large proportion of the results were reported as non-detect or below the reporting limits. The statistical trend analyses at the Surprise Valley stations indicated potentially significant downward trends over time, which might in-fact be influenced by non-detect results that may have reported lower detection limits over time.

6. Summary and Recommendations

For over two decades the Regional SWAMP has been monitoring streams across the Region, creating a large water quality chemistry and field measurements dataset that is publicly available through the California Data Exchange Network (CEDEN). The program also implements special studies to address areas of concern based on ongoing monitoring findings. The program continues to support statewide monitoring including SWAMP's Bioassessment Program's PSA that has developed a macrobenthic index of biotic integrity for perennial streams in California, and OEHHA by contributing bioaccumulation monitoring data for several fish consumption advisories. The Regional SWAMP's water quality dataset is the primary source to assess if surface waters in the Lahontan Region comply with Basin Plan water quality objectives. These assessments, performed in satisfaction of Clean Water Act sections 303(d) and 305(b) requirements, help resource managers prioritize where to investigate to further address water quality impacts, focus regulatory actions, and confirm the generally high quality of many of the Region's waters.

The program currently monitors 46 water quality stations one to four times per year, in 22 streams across the Lahontan Region. Water samples are analyzed for up to 35 physical and chemical water quality parameters. 16 of those parameters are evaluated against Basin Plan WQOs and SSOs for compliance assessments every 3-6 years.

With over 29,000 results reported over the past two decades (between January 2000 and June 2021) this water quality status and trends report identified only three parameters that exceeded objectives in more than 40% of the results among all stations evaluated: Oxygen Saturation, Total Dissolved Solids, and Total Phosphorus. At the subregional level Oxygen

Saturation exceedances were most prevalent in the Eastern Sierra (South) and Mojave subregions, Total Dissolved Solids exceedances were significant in all 5 subregions with the highest percentage in the Modoc subregion. Total Phosphorus exceedances were largely due to exceedances in the Eastern Sierra (North) subregion.

Screening for water quality trends over time using the seasonal Mann Kendall statistical tests indicated that less than 1% of the station/parameter pairs evaluated show significant monotonic upward or downward trends over time. That is, only 14 stations and 12 parameters indicated potential trends at significance levels (p-values) of <0.05. Evaluating trends in long-term water quality monitoring data is difficult because of confounding, uncontrollable factors both internal to the data and external in the environment. Our evaluation did not adjust the data for flow or any other confounding factors. It is not too surprising that more statistically significant trends were not observed in the Regional SWAMP dataset since there have not been large ecological or anthropogenic changes at or near the monitoring stations (with the exception of possible wildfires in some areas). And, given that some parameter concentrations exhibited a wide range of variation over time (see Appendix B), it was difficult to characterize monotonic trends.

The Region is ecologically diverse, and anthropogenic influences that impact water quality are variable among subregions. As population and development continues to increase there will be more potentially adverse anthropogenic impacts on streams and wetlands across the Region especially with increasing urban development in the south, and increasing recreation in the north. Impacts from agriculture and grazing remain a water quality concern across most of the Region, especially in the Modoc and Eastern Sierra subregions.

6.1. Program Recommendations

The Regional SWAMP is working to adjust core elements of its program. The goal is to develop an approach to adaptive management at the watershed or landscape level without compromising existing long-term compliance monitoring. The Regional SWAMP is reviewing and evaluating its long-standing monitoring practices to improve efficiencies and address new challenges.

Based on the 20-year retrospective water quality status and trends analyses presented in this report, discussions with the Regional SWAMP leads, a proposed adaptive monitoring and assessment framework (described below), was used to develop the following program recommendations. Some recommendations are specific and actionable, while others warrant additional consideration by a broader group such as a focused workgroup or a formalized technical advisory committee that could be established to advise the program on an ongoing basis.

<u>Recommendations for Regional SWAMP's ongoing water quality monitoring effort</u>

1. **Clarify the geographic scope of the water quality monitoring effort.** Conduct a level-1 landscape based geographic assessment using digital aquatic resource maps and other land use or land cover datasets to (1) characterize the stream resources across the Region and (2) formally identify and formalize the geographic scope (or sample frame) for the targeted stream monitoring effort. In other words, what is the geographic extent of the stream resources the Regional SWAMP is monitoring in order to assess Basin Plan water quality compliance?

2. **Update the program's survey design and monitoring plan to include the target sample frame, sampling plan, station types and location information, parameter list and analytical methods, and additional monitoring and data analysis guidance.** For example, describe how monitoring results (or data from other studies) will be used to guide the addition of Temporary stations, Follow-up monitoring, or other special studies.

3. **In the updated sampling and analysis plan document the field sampling and analytical methods (and expected MDLs) for target parameters.**

    a. Review the water quality monitoring ambient results to confirm that they are at least 3 times higher than the analytical laboratory's reported method detection limits (MDLs). At a minimum the expected laboratory MDLs should be at least 3 times lower than the Basin Plan objectives to ensure that ambient water sample results can be reliably compared to the regulatory objectives.

    b. To improve data reliability for Total Nitrogen results, the program should employ analytical methods that measure Total Nitrogen directly and ensure the reported MDLs are at least 3 times lower than the Basin Plan objectives.

4. **Review the current parameter list and determine if all are necessary.** Dropping unused parameters could provide a cost savings.

5. **Determine water quality and ecological health of intermittent and ephemeral streams.** 92% of Lahontan's stream network are ephemeral streams located largely in the southern part of the Region. Ephemeral and intermittent streams provide the same ecological and hydrological functions as perennial streams, yet there has been little monitoring to assess the ecological conditions of those stream resources.

6. **Consider continuous monitors for multiple physical water quality parameters including streamflow.** Rethink how the Regional SWAMP monitors Dissolved Oxygen, Temperature, Specific Conductance and other basic physical water quality parameters. This might include exploring opportunities to collaborate with other agencies already employing continuous monitors.

7. **Review the Long-term monitoring station locations and consider if changes are warranted**. This might be done through the adaptive management review process (recommendations below).
8. **Follow up from the recent 20-year status and trends assessment results by reviewing areas where there are a relatively high percentage of Basin Plan exceedances and decide on the next management steps.**
    a. **Evaluate if additional monitoring is still warranted at the current Temporary screening and Follow-up stations, or if some of the Temporary/Follow-up stations should become Long-term stations.**
9. **Data Management:**
    a. **Update archived data in CEDEN to address some of the water quality monitoring data clean-up that was completed for this report**. This would make future retrospective status and trends assessments easier. For example, remove duplicate entries, flag the handful of dropped results that were highly unusual, if possible add missing MDLs and RLs to the archived data.
    b. **Ensure that the CEDEN data templates are complete prior to data upload (especially for important quality assurance qualifiers and method detection limits).** Make sure the laboratories provide all the relevant QA information such as MDLs, RLs, analytical methods and indications if samples might be field or laboratory replicates. Ensure the QA review compliance codes are accurate and complete. Include field sampling methods.

<u>Recommendations to support an adaptive management approach to watershed health assessment and address new and emerging challenges</u>

10. **Convene an advisory group to advise on Regional SWAMP adjustments and a watershed approach to watershed health assessment for the Region. A workgroup or committee process would provide a forum for cross-program coordination and help identify collaborative monitoring opportunities that could be integrated into the Regional SWAMP.** A temporary workgroup, or more formal (ongoing) technical advisory committee, to advise on a watershed approach to watershed health assessment for the Region. The workgroup/committee would be a forum for cross-program coordination (internally within the Regional Water Board and also with other government agencies and local monitoring programs) and potentially help the program identify opportunities to share monitoring stations and data in support of a more robust and informed collaborative watershed health assessment program that addresses core resource management/monitoring questions.

11. **Employ the adaptive monitoring and assessment Framework (described in the following sections) to integrate new management initiatives or watershed health concerns into the Regional SWAMP.** This would mean developing new management/monitoring questions that articulate those concerns and stepping through the multi-step process of identifying health targets (or objectives), timelines for the assessment cycles, geographic extent, conceptual models, indicators, sampling plans, and data management and analytics for developing the final health assessments in a timely manner to address the monitoring questions and support resource management decisions.

12. **Review the Regional SWAMP water quality efforts and consider if additional changes are warranted to support new management and monitoring questions and the broader concerns for watershed health and management.** This could be a small or large review and adaptive program development effort depending on the current management and monitoring goals of the program.

    a. Smaller program adjustments might include adjusting the current water quality monitoring efforts to further coordinate with (and leverage data with) other existing monitoring programs such as the statewide SWAMP Bioassessment Program. This might include using the adaptive monitoring and assessment Framework to consider:

        i. Adding new Long-term stations at pristine reference sites to support regional reference site monitoring and climate change studies; or

        ii. Systematic review of existing monitoring stations and results to adjust the sampling plan. The program might decide that some stations could be sampled less frequently because no Basin Plan exceedances have been observed and there are no other water quality concerns, or a specific Temporary station, which has been monitored for a long time, should be reclassified as a Long-term station.

        iii. Determine new sites (and review existing stations) for where additional types of data collection, not just water quality, might help characterize watershed health.

            1. Coordinate further with the Bioassessment Program. It may be possible to pair RCMP reference sites with some of Regional SWAMP's long-term water quality monitoring stations.

            2. Coordinate further with USGS regarding real-time flow monitoring stations and other ongoing monitoring efforts as it

may be possible to collocate water quality monitoring at more flow monitoring stations.

b. Larger program adjustments might take more time and employ the adaptive monitoring and assessment Framework to support discussions that help develop additional management and monitoring questions to address new concerns. The advisory group process could work through each of the core program elements to plan and integrate additional monitoring indicators into the program. This process might result in further adjustments to the current water quality monitoring effort.

In the next section we provide additional context for the recommendations presented above by showing how we used a monitoring and assessment framework to organize core program elements, review them, and develop suggested program recommendations. In short, the framework helps resource managers systematically address the question: "Are each of the technical elements of the monitoring program helping to address the management and monitoring questions that, in turn, inform management decisions?" The framework can also be used to add new management/monitoring questions and incorporate new environmental indicators and sampling plans into an existing program.

6.1.1. ADAPTIVE MONITORING AND ASSESSMENT FRAMEWORK

With several decades of water quality and other environmental monitoring since the of the Clean Water Act of 1970, and recent advances in scientific understanding and information technology that enable programs to aggregate, analyze and visualize decades of experience across various scales of time and space, public environmental agencies at all levels of government are adapting their programs to better assess ecosystem services and overall watershed health[25]. The foundational concepts of watershed health and relevant literature have been described by Josh Collins (formally the Chief Scientist at SFEI and founding member of the CWMW) in a memo titled "*A Look Ahead: Toward Comprehensive Watershed Health Assessment and Reporting*"[26]. The memo presents a monitoring and assessment framework (Framework) depicted in Figure 12. The Framework was adapted from the State's Wetland and Riparian Area Monitoring Plan[27] (WRAMP), developed by the California Wetlands Monitoring Workgroup (CWMW) of the California Water Quality Monitoring Council. WRAMP provides overarching guidance on how to develop a standardized and coordinated statewide wetlands monitoring and assessment program. Dr. Collins's Framework incorporates technical elements

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[25] Introduction to the Clean Water Act (EPA link): https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=2569

[26] https://drive.google.com/file/d/12UQkOlMB2vTJaObYwHHCY787qw-q8fW2/view

[27] Link to State Water Board's WRAMP web page: https://www.mywaterquality.ca.gov/monitoring_council/wetland_workgroup/#:~:text=What%20is%20WRAMP%3F,a%20watershed%20or%20landscape%20context.

of the WRAMP and is intended as an organizational tool for both developing an environmental monitoring program and for evaluating how well the program is addressing its core management and/or monitoring questions that (in turn) inform management decisions.

The Framework formalizes a multi-step process for both developing a regional monitoring and assessment program and adaptively reviewing and adjusting the program. The program is organized around (and driven by) management and monitoring questions that are addressed through the development of monitoring goals (or objectives), a sampling plan, a data collection and storage system, and clearly defined data analyses to assess how well the monitoring indicators are performing relative to target health conditions (or target environmental goals or objectives). This iterative monitoring and assessment process informs ongoing management decisions, which (in turn) can help guide adjustments to core program elements as demonstrated below. A brief description of each step of the Framework follows Figure 12.

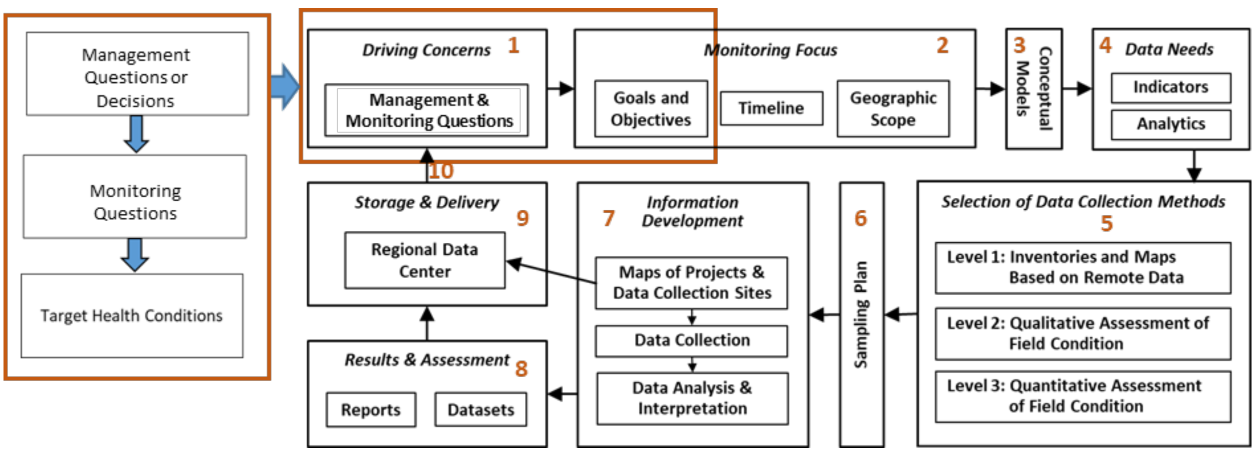

Figure 12. Technical program elements (or steps) of an adaptive monitoring and assessment Framework

Descriptions of the Frameworks Multi-step Process

1. The Management and Monitoring Questions and Decisions driving the program are about the status and trends of watershed health, and ways to improve health, relative to target ecological conditions, which serve as the goals and objectives of the program. Most of the targets will be provided by existing policies, programs, plans, or projects.
2. In addition to stating the health targets, the responsible agencies will also set the timeline and geographic scope for health assessments.
3. Conceptual models are tools used by the program and its advisors to identify factors and processes that must be monitored to assess health and thereby meet the program's information needs. The models should focus on cause-and-effect relationships that can strongly affect the certainty of the health assessment.

4. Needed data are identified based on the timeline (Step 2) and the conceptual modeling (Step 3). In essence, the needed data represent indicators (or measures) that the conceptual models suggest are most directly related to the targets (Step 1). An indicator might consist of one variable, such as stream flow or water temperature, or it might be an index that consists of multiple variables. Analytics refers to the graphic and statistical methods of data analysis that will be used to summarize the assessments and prepare them for interpretation.
5. Every kind of indicator and method of data collection can be classified into one of three categories or levels, based on the classification system developed by the USEPA[28]. This Step is necessary to optimize the cost/value ratio of the program. The program accomplishes this Step by answering the following questions: how can the Management Questions be addressed by using either Level-1 methods, Level-2 methods, and/or Level-3 methods? In general, monitoring costs increase with the level of monitoring data and methods.
6. The program must develop a survey design and sampling plan for data collection[29]. The survey design defines the target population or resource (e.g. streams or lakes) to be monitored based on the monitoring questions to address, and the sampling method. The sampling method can be either a probability-based random sample or non-probabilistic sample. Non-probabilistic sampling methods can include sites identified as they "happen to be handy" or by "expert choice" such as sampling sites defined by a set of inclusion criteria (e.g. stream water quality stations that integrate conditions upstream in a watershed). Statistically random, probabilistic sampling methods draw sample sites at random from a clearly defined sample frame (e.g. digital map of perennial and intermittent stream resources of interest). Probabilistic designs weight each random sample site for the proportion of all possible sites within the sample frame, allowing one to make inferences about the ecological conditions across the whole sample frame. The survey design and sampling plan may vary among indicators.
7. This step involves data collection, analysis, and interpretation. For many reasons, maps of sample sites annotated with information about their data should be uploaded into a public information system. Interpretation of assessment results can be aided by the advice and review of an independent third party, outside of the program. If the results do not meet the needs of the program, the sampling plan will need to be revised, entirely or in part, beginning with Step 1.
8. The monitoring results of one assessment period (or reporting cycle identified in Step 1) will consist of the finalized sample plan including the sample site maps, the finalized data, answers to the Management Questions, and a Health Report detailing the condition of the watershed relative to the target conditions.

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[28] https://www.epa.gov/wetlands/wetlands-monitoring-and-assessment
[29] https://archive.epa.gov/nheerl/arm/web/html/surdesignfaqs.html#whatframe

Many of the statewide and Regional SWAMP's existing core program elements are technical components of the Framework presented in the following sections. The Framework can be used to suggest ways the program leads can adjust their current water quality compliance monitoring efforts to improve efficiencies, and adapt other aspects of the program to address new challenges outlined in the June 2019 Regional SWAMP Core Program Review[30] recommendations. An excerpt of those recommendations, from the July 10, 2019 Board meeting agenda (item 8), is listed below:

2019 Core Program Review Recommendations:

1. "Re-evaluate monitoring to improve the program and address new challenges, including the following:
    a. Evaluate the health of the Region's waters and watersheds, including
    b. special studies;
    c. Adjust monitoring to adapt to climate change; and
    d. Analyze and report on the trends of water quality changes in the Region, including the prior 20 years of SWAMP data.
2. Identify opportunities to improve program efficiency, such as:
    a. Improved internal coordination and support between the Water Board's SWAMP and Regulatory and Enforcement Programs; and
    b. Increase stakeholder partnerships to improve monitoring efforts.
3. Maximize data access and uses of analytical tools through the use of new technology, and report on trends and other observations.
4. Integrate Water Board priorities in SWAMP more effectively.

6.1.2. APPLYING THE MONITORING AND ASSESSMENT FRAMEWORK TO THE REGIONAL SWAMP WATER QUALITY COMPLIANCE MONITORING PROGRAM (2000 - PRESENT)

The Regional SWAMP fits easily within the adaptive monitoring and assessment Framework. Employing the Framework to review and adjust the program provides a systematic way to identify what elements are working well and where there might be opportunities for improvement, change, or collaboration.

Below, the technical elements of the Framework are listed along with brief descriptions of the Regional SWAMP's core elements - demonstrating how the program fits into each element. In the following section, we used the Framework and program information to review the program and make adaptive management recommendations by circling back to the driving questions and decisions (see Figure 12 above). Essentially we evaluated if the sampling plan, monitoring

[30] https://www.waterboards.ca.gov/lahontan/board_info/agenda/2019/jul/item_8_swamp.pdf

efforts, data storage, and reporting to-date are actually addressing the intended management questions and informing management decisions. In addition, the resource management questions and sampling plans can be adjusted to address new questions and new goals such as those proposed in the 2019 Core Program Review.

1. Management and Monitoring Questions and Decisions (goals and objectives) driving the current Regional SWAMP program.

   Management/monitoring question:

   > "Are the streams within the Lahontan Region meeting the chemical and physical water quality objectives contained in the Basin Plan?"

   Management decisions:

   > Use the ongoing water quality monitoring results and exceedance assessments to make decisions about:
   >
   > - 303(d) listings,
   > - follow up studies to further investigate areas and pollutants of concern and identify potential sources of pollution, and
   > - regulatory actions to remediate potential sources of water pollution.

2. Health targets (goals and objectives), timeline for health assessments, and geographic scope

   The water quality health targets include the objectives listed in the Lahontan Region Basin Plan.

   The timeline of the health assessments has been every 3-6 years to support updates to the 303(d) list. In addition cumulative status and trends assessments have been completed.

   The geographic scope is focused on integrator sites in perennial or intermittent streams across the Region.

3. Conceptual Models

   Conceptual Models were not developed for the current program because the management/monitoring question focuses on regulatory water quality compliance monitoring.

4. Data Needs: Indicators and Analytics

   The target indicators include water chemistry and basic physical water quality parameters listed in the Basin Plan.

The data analysis methods (or analytics) used to evaluate the data against the health targets are prescribed in the Basin Plan for each water quality parameter. For example, many of the objectives are compared to annual average water quality concentrations, or the mean of monthly means, or rolling averages over 30-day periods. Others are simple straightforward comparisons between the reported ambient water quality result and the objective.

Updating the 303(d) list of impaired waters is a separate analytical process described in the Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List (Listing Policy). To develop an updated list, staff first reviews water quality data sets to affirm the high quality of the data. Then, staff assesses each data set against the applicable water quality objective. Assessment of each dataset results in a separate Line of Evidence. The Lines of Evidence are then assessed together to determine impairment status of the waterbody-pollutant combination. The number of water quality objective exceedances that would result in placement on the 303(d) list is set forth in binomial tables within the Listing Policy. Different exceedance rates are described and allowed depending on the type of pollutant. Similar rigor is taken when determining if a waterbody-pollutant combination can be removed from the 303(d) list.

5. Assign EPA Level

Water Quality monitoring is a quantitative, intensive site assessment method that involves the collection of field samples that are sent to an analytical laboratory for analyses. This intensive monitoring is characterized as an EPA Level 3 data collection method to meet regulatory requirements, or that might be used to follow up at sites of ecological concern after reviewing the results of a less expensive Level 2 rapid assessment survey.

6. Sampling Plan

The Regional SWAMP's survey design and sampling plan is described above in the *Regional SWAMP's Monitoring Design and Sampling Effort* section. Briefly, the program consists of a targeted survey design with stations located in perennial stream reaches within public lands, or public right-of-ways, near the bottom of watersheds in locations that are considered *'integrator'* sites. The stations are located in areas that are easily accessible for sampling one to four times a year.

The program currently monitors 46 stations in 22 streams, in 10 Basin Plan Units, across the Region. The stations are divided into 3 types: Long-term (n=11), Temporary screening (n=23), and Follow-up (n=12) station types. Each station is sampled one to four times per year on a quarterly basis for up to 35 chemical and basic physical water quality parameters. Follow-up sites may be monitored more frequently to further investigate specific water quality concerns.

7. Information Development

The Lahontan Water Board's 303(d) compliance assessment staff compile monitoring data for comparison to the Basin Plan objectives to update the 303(d) list every 3-6 years.

8. Results and Assessment

Besides updating the Region's 303(d) list, a cumulative status and trends summary report was published by the Water Board in 2007: the 5-year summary report[31] (described earlier in this report). This report includes the second water quality status and trends assessment (2000-2021). In addition, the Bioassessment Program recently published its statewide ecological assessment of wadeable streams and rivers report (CDFW 2021[32]).

9. Data Storage and Delivery

All of the Regional SWAMP's water quality monitoring results are compiled and formatted per SWAMP's standardized data management templates. The templates include information that archive important sampling and laboratory method information, reporting and method detection limits, and data compliance and quality assurance flags. Each dataset is reviewed by SWAMP's Quality Assurance Officer and questionable data are qualified as warranted. The monitoring results (including results since the program's inception in 2000) are uploaded and stored in the California Environmental Data Exchange Network[33] (CEDEN), an online data management system and public data access portal maintained by the State Water Quality Control Board.

10. Program Review and Adjustments

The Regional SWAMP made several adaptive adjustments to its program since its inception in 2000. For example:

- They added new monitoring stations and station types based on ongoing monitoring findings (e.g. adding Temporary screening sites to characterize water quality conditions in new areas, and adding Follow-up sites to investigate unusually high water quality monitoring results or other specific water quality topics of concern).

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[31] California Regional Water Quality Control Board, Lahontan Region. 2007. Surface Water Ambient Monitoring Program (SWAMP) at the Lahontan Region: Summary of Results for Years 2000–2005. California Regional Water Quality Control Board, Lahontan Region, South Lake Tahoe, CA. July 2007. https://www.waterboards.ca.gov/lahontan/water_issues/programs/swamp/docs/report2000_05.pdf

[32] CDFW 2021. Andrew C. Rehn. An Ecological Assessment of California's Perennial Wadeable Streams and Rivers (2008-2018). Aquatic Bioassessment Laboratory, California Department of Fish and Wildlife. March, 2021. https://www.waterboards.ca.gov/water_issues/programs/swamp/bioassessment/docs/final_psa_report_2008-2018.pdf

[33] http://www.ceden.org/about_us.shtml

- They supported the development of the macroinvertebrate index of biotic integrity for perennial streams by the SWAMP Bioassessment Program.
- They collected fish tissue samples to support bioaccumulation studies and the development of fish consumption advisories by OEHHA.

In June 2019, the Regional SWAMP completed an internal program review and developed recommendations that asked the program to review and address program efficiencies, incorporate collaboration opportunities within the Water Board and potentially with outside monitoring agencies, and generally adjust the monitoring effort to further support a watershed approach to water quality and watershed health assessments.

6.1.3. RECOMMENDATIONS FOR WATER QUALITY COMPLIANCE MONITORING ADJUSTMENTS USING THE FRAMEWORK

The following three program review questions helped to organize the review and recommendations for the Regional SWAMP's ongoing water quality monitoring efforts listed in the *Program Recommendations* section. The questions refer to the adaptive monitoring and assessment Framework - focusing on technical elements of the monitoring program and asking how well they are able to address the management/monitoring question that, in turn, informs management decisions.

Each question includes suggested evaluation tasks. Some tasks include specific review findings and/or recommendations based on the data analyses completed for the 20-year retrospective analyses and/or discussions with program leads, while others suggest additional work that might employ a focused workgroup or a formalized technical advisory committee to advise the program. The questions and evaluation tasks are not intended to be a comprehensive list but serve to demonstrate how one can use the Framework to organize a systematic review of core program elements. It is expected that the advisory group may adjust the questions or develop additional questions and recommendations.

1. How have the program's water quality monitoring findings been integrated back into the adaptive management framework to address the management/monitoring question and support management decisions?
    - Determine if the survey design, sampling plan, and geographic extent of the annual water quality monitoring efforts address the intended scope of the management/monitoring question.
    - Evaluate if, based on the Basin Plan water quality exceedance assessments, management decisions have been made. In other words - how well are the monitoring data being used to inform management decisions?
        - Are streams where there are ongoing and significant water quality exceedances being followed up on?

- Are pollution sources being identified and remediation action/s being implemented?

<u>Review/Recommendation</u>: The Regional SWAMP's water quality monitoring results are being used to inform management decisions. The program has added Follow-up monitoring stations to further investigate specific pollutants of concern based on observed water quality monitoring exceedances. The ongoing water quality monitoring and Follow-up studies have helped other Water Board programs make management decisions including: (1) updating the 303(d) list on a 3-6 year cycle, (2) additional TMDL studies, and (3) implementing remediation actions (e.g. Bishop Creek-Indicator Bacteria, West Fork Carson River- Multiple Pollutants).

2. Does the program's sampling plan and monitoring effort adequately address the original management question and decisions?

  - Determine if the survey design, sampling plan, and geographic extent of the quarterly water quality monitoring efforts address the intended scope of the management/monitoring question. In other words - decide if the current targeted monitoring design (which includes Long-term trends, Temporary screening, and Follow-up station types, located in streams in 10 Basin Plan Units across the Region) is comprehensive enough to address the current management/monitoring question.
    - Level-1 geographic extent assessment: Further review and characterize stream resources across the Region in relation to land use, land cover, stream type (e.g. perennial, intermittent, and ephemeral) in order to document and evaluate if the current survey design includes the desired target population of streams across the Region. For example, the program may want to:
      - Identify and characterize the full geographic extent and stream types the program is sampling across the Region. This is the water quality monitoring program's target resource extent or 'sample frame'. The program currently is targeting 'integrator' sites on perennial and intermittent streams that are largely located on public lands, and easily accessible for monitoring one to four times per year. It is not clear if there is a digital GIS map of those stream applicable stream resources, which can be used to assess if the targeted sampling effort is adequately sampling those resources.
      - Identify streams that may be vulnerable to anthropogenic impacts to water quality in order to monitor them on a

Temporary screening site basis to ensure they are not exceeding Basin Plan water quality objectives.
- Identify pristine, high water quality streams that might warrant further protections or serve as background reference sites.

- The level-1 sample frame review may lead to adjustments to the sampling plan and prompt discussions about how the water quality monitoring efforts might be adjusted to cover the full geographic extent of the target sample frame. This would then be an opportunity to review and update the ongoing water quality monitoring effort's sampling and analysis plan. For example, the 3 station types are monitoring tools that inform different aspect of the water quality monitoring effort:
  - Temporary screening sites are used to evaluate if there are any exceedances in new stream reaches across the Region. How should the program implement Temporary screening sites and how long should they generally be monitored?
  - Follow-up sites are used to further monitor specific water quality concerns observed in either the Long-term, Temporary site monitoring results (or concerns raised by other studies). What level of exceedances would trigger a Follow-up monitoring study and how should those studies be implemented?
  - Long-term status and trends sites are used to track long term trends over time and to screen for changes upstream that might warrant additional study. The program might review and document the rationale for placement of each Long-term status and trends site across the Region and document the kinds of analyses and timing for assessing trends over time. Additional questions regarding the Long-term status and trends stations include:
    - Should the program add some long-term monitoring stations in pristine stream reaches that serve as long-term reference sites to support climate change studies?
    - What kinds of other co-located monitoring indicators would be helpful to have at the Long-term monitoring stations (i.e. real-time continuous streamflow data, stream and adjacent riparian habitat assessment data, bioassessment indicators)?

<u>Review/Recommendation</u>: A survey design, sampling plan, and geographic scope review of the water quality monitoring effort should be included within a

broader context of program adjustments that include the emerging watershed health assessment approach and other concerns raised in the 2019 Core Program Review, with input from a workgroup process.

Specific recommendations for reviewing the survey design, sampling plan, and geographic scope of the Regional SWAMP's water quality monitoring effort include: (1) Clarify the geographic scope of the water quality monitoring effort by conducting a level-1 assessment to characterize the stream resources across the Region and formally identify and formalize the target sample frame (target stream reaches of concern that the Regional SWAMP is monitoring for Basin Plan water quality compliance); (2) Update the program's sampling and analysis plan to include the target sample frame, survey design, monitoring plan, station information, and general guidance such as how monitoring results (or data from other studies) may be used to guide the addition of follow-up monitoring studies. Document the program's field sampling and analytical methods (and target MDLs) for target parameters.

3. Are the program's monitoring efforts, laboratory analyses, and data management and access processes adequate for timely health assessments to support management decisions?
    - The Regional SWAMP's water quality monitoring results are publicly available on a regular and timely basis and used to inform the Region's compliance monitoring management decisions.
    - The following program efficiencies and specific data reliability observations were made during the data compilation and analyses for the above 20-year retrospective status and trends assessment:
        - Cost Savings: The program may be able to save on laboratory and reporting costs by dropping parameters that are not directly used for environmental assessments and decision making.
            - For example, only 16 of the 35 water quality parameters monitored were compared to Basin Plan WQOs and SSOs in this report. The program might confirm and document the rationale for the parameters it monitors and drop parameters that are unused.
        - Improve data reliability:
            - Review ambient results, Basin Plan objectives, and MDLs: To improve data quality, the program should review its water quality monitoring data to confirm that the ambient results and the target Basin Plan objectives are at least 3 times higher than the

analytical laboratory's reported method detection limits (MDLs). The 2000-2021 status and trends analyses indicate that some MDLs and/or reporting limits (RLs) are within the same range as either the ambient stream conditions and/or the Basin Plan water quality objectives and therefore the monitoring results are uncertain.

- Specific recommendation for Total Nitrogen: Total Nitrogen is one of several nutrient parameters listed in the Basin Plan. A review of the reported Total Nitrogen monitoring results indicates that several analytical and reporting methods have been used to report ambient concentrations. Sometimes the laboratory will submit calculated results from underlying component parameters, other times a separate Total Nitrogen analysis method has been used. The 20-year status and trends analysis included a small study of calculated vs. direct measured results and concluded that the two methods do not produce comparable results.
    - Confounding the issue is the fact that ambient water quality concentrations from many of the Regional SWAMP's monitoring sites report Total Nitrogen concentrations that are near or below the MDL. Basin Plan objectives are also generally within the range of ambient concentrations. As a result, Total Nitrogen and nutrient exceedance assessments in general, are less reliable.
    - To improve data reliability for Total Nitrogen results, we recommend that the program employ analytical methods that measure Total Nitrogen directly and that have detection limits at least 3 times lower than the Basin Plan objectives.

Review/Recommendation: Based on the 20-year retrospective analyses, the following program efficiencies and specific data reliability recommendations include:

- Cost savings: The program might confirm and document the rationale for the parameters it monitors and drop parameters that are unused.
- Review the water quality monitoring ambient results to confirm that the target Basin Plan objectives are at least 3 times higher than the analytical laboratory's reported method detection limits (MDLs).

- To improve data reliability for Total Nitrogen results, the program should employ analytical methods that measure Total Nitrogen directly and ensure the reported MDLs are at least 3 times lower than the Basin Plan objectives.

6.1.4. RECOMMENDATIONS FOR DEVELOPING A BROADER WATERSHED APPROACH USING THE FRAMEWORK

The Framework can also be used to integrate new management initiatives or watershed health concerns that resource managers want to integrate into the Regional SWAMP. This would mean developing new management/monitoring questions that articulate those concerns, and stepping through the multi-step process of identifying health targets (or objectives), timelines for the assessment cycles, geographic extent, monitoring indicators, sampling plans, data management and analytical process for completing the health assessments in a timely manner that would address the monitoring questions and support resource management decisions.

The Water Board and Regional SWAMP have participated and invested in an ongoing statewide effort to develop standardized monitoring and assessment methods for resource monitoring and management. For example, the Regional SWAMP invests in the Bioassessment Program's PSA that developed the statewide stream condition index (CSCI) and Physical Habitat assessments (PHAB), and implements the California Rapid Assessment Method (CRAM) for streams at many of their monitoring sites. They also support OEHHA's fish consumption advisory monitoring studies. The Regional Water Board's 401 dredge and fill certification permittees are required to upload their mitigation/restoration project information to the public Project Tracker website and employ the California Rapid Assessment Method (CRAM) to monitor project stream and wetland restoration performance. A number of Water Board staff are trained CRAM practitioners. And finally, in 2012, the Regional Water Board participated in a local demonstration of the WRAMP framework that applied some of these online tools and monitoring methods to conduct a baseline watershed health assessment in the Upper Truckee River and Third Creek watersheds in the Tahoe Basin employing CRAM (SFEI, 2012).

- It is recommended that the Regional SWAMP consider applying some of these established monitoring and assessment tools and the Framework to help the ongoing monitoring program adjust to include new watershed health concerns. The program should develop additional management questions that represent the Region's emerging environmental concerns and interest in a watershed approach to resource management. From those questions, more specific monitoring questions can be developed and an assessment timeline and geographic scope identified. Ecological health targets (or goals) can be decided in the process of identifying candidate indicators that could be monitored to address the management/monitoring questions and inform management decisions.

- The Regional SWAMP should consider engaging an advisory workgroup (or more formal technical advisory committee) to support collaboration with and coordination among other ongoing monitoring programs/efforts in the Region to discuss the idea of further sharing monitoring stations and data to support periodic watershed health assessments. For example USGS streamflow monitoring stations may be good sites to collocate water quality monitoring stations since streamflow is often correlated with water quality results - being able to normalize the water quality monitoring results to flow might help refine trends over time analyses. In addition, where possible employ the same sampling and/or laboratory analysis methods to ensure data comparability across the Region and programs.
- Consider using established stream bioassessment and overall ecological condition methods to complement the water quality monitoring program and support stream condition monitoring in the context of overall watershed health. Methods such as CSCI, PHAB, and CRAM are potential candidate indicators that the advisory group should review and consider. Each of these methods assess different aspects of stream water quality and overall ecological condition. A tiered monitoring and special study approach might be appropriate for a long term, ongoing watershed health assessment program. For example, CRAM is a well suited screening method to characterize the overall ecological condition of streams and adjacent riparian areas across the Region and to identify stream resources that are in good, fair, or poor condition. It has been verified and validated against level 3 data and the different stream modules have been calibrated to be able to compare condition scores across perennial, intermittent, and ephemeral streams across the Region, including the arid ephemeral streams in the south. CRAM evaluates four main aspects of overall stream condition including buffer and landscape context, hydrology, physical structure, and biotic structure. The CSCI assesses instream water quality in relation to its benthic macroinvertebrate community composition and their relative sensitivities and tolerances to pollutants. PHAB characterizes instream physical habitat indicators with a lot of specificity.

6.2. Conclusion

This large and comprehensive 20-year status and trends assessment resulted from a request stated in the 2019 Regional SWAMP core program review. The first recommendation of the program review was to re-evaluate monitoring to improve the program and address challenges, including to analyze and report on trends of the SWAMP dataset. The purpose was to summarize ~20-years of SWAMP water quality monitoring data, and other available data, to achieve the following objectives: 1) Assess status and trends; 2) Identify data or information gaps; 3) Identify potential changes to the current monitoring design; 4) Extract other information from the datasets as needed; 5) and Report findings and recommendations.

Finalizing this report has satisfied the program recommendation and provided the large dataset in a complete and accessible format. With this extensive dataset standardized and interpreted regional staff can utilize the recommendations above to move the program forward to develop new management questions and emerging concerns. Regional SWAMP staff have requested additional funding to form a work group between Regional Board staff and other monitoring experts to better articulate a SWAMP monitoring plan using the Framework described above and address recommendations suggested in this report.

Appendix A: Additional Environmental Setting Information by Basin Plan Hydrologic Unit

As described in the main body of the report, the Basin Plan's site specific objectives (SSOs) for some water quality parameters apply to surface waters at the HU level. Understanding the land use and setting at a watershed level can help put the water quality status and trends results into their respective landscape context. This appendix provides additional environmental setting and land use information for the 9 Basin Plan HUs that are actively monitored by the Regional SWAMP. It is organized by the 5 subregions, geographically from northern to southern California.

Modoc

Surprise Valley Hydrologic Unit

Surprise Valley is located within the high desert region known as the Great Basin, in the very northeastern corner of California in Modoc County. A series of alkaline lakes occupy low-lying areas, forested mountains line the west side of the valley, Hays Canyon Range lies east, and the Warner Mountains border the west. Communities in Surprise Valley include Eagleville, Cedarville, Lake City, and Fort Bidwell. Seventy percent of Modoc county remains publicly owned, primarily by the US Forest Service and Bureau of Land Management. Popular activities in the area include hiking, off-roading, birding, photography, fishing, mountain biking, and hunting. There are hot springs and abandoned mine shafts throughout the region.

Primary livelihoods in this region come from alfalfa farming and cattle ranches. Cattle drives still take place across open terrain and along valley byways. There are two sovereign Paiute tribal governments in the valley: The Cedarville Rancheria and Fort Bidwell Indian Community of the Fort Bidwell Reservation of California.

Susanville Hydrologic Unit

The Susanville Hydrologic Unit is located in Lassen County. The Susan River, the main waterway in the unit, is located along the northern boundary of the Sierra Nevada Mountains. It begins at over 6500 feet in volcanic highlands and runs approximately 67 miles along the Great Basin Divide into the intermittent Honey Lake. The Susan River watershed includes the U.S. Bureau of Land Management, U.S. Forest Service, and private property. This unit also includes Eagle Lake, an Outstanding National Resource Water. Land uses in the Susan River include agriculture, commercial, logging, ranching, and recreation. While farming, mining, and lumber were historically the main economic drivers in the area, the majority of employment now comes from one federal and two state prisons. Communities in the Susanville Hydrologic Unit include Susanville, Standish, and Janesville.

Truckee/Tahoe

Little Truckee River and Truckee River Hydrologic Units

The Little Truckee River HUC (listed separately in the Basin Plan is a subwatershed within the Truckee River HUC).

The Truckee River flows 120 miles from the outlet of Lake Tahoe in California, into Nevada, through the city of Reno, until it terminates at Pyramid Lake and is the only source of surface-water outflow from Lake Tahoe. The majority of the streamflow in the Truckee River comes from the Sierra Nevada snowpack. The Truckee River supplies water to a diverse group of water users: power generation, municipalities, industry, and agriculture as well as being the primary source of water for Pyramid Lake. Major cities in the Truckee River Basin are Truckee, California, and Reno and Sparks, Nevada. Recreational activities include white water rafting and fly fishing. Flow is highly regulated in the Truckee River watershed causing many long-standing conflicts among various economic, political, and ecological interests.

Lake Tahoe Hydrologic Unit

The Lake Tahoe Watershed consists of 63 tributaries that feed into the largest alpine lake in North America, Lake Tahoe. Lake Tahoe straddles the state line between California and Nevada and is designated an Outstanding National Resource Water and a "Waterbody of extraordinary ecological or aesthetic value" known for extraordinary clarity and purity, and deep blue color. Impacts to the watershed began in the mid 1800's with extensive logging when silver was discovered nearby. Population growth and tourism continued through the 1900's. Lake clarity levels fell with impacts to the watershed including: altered connectivity to the floodplain, heavy recreation use, poor erosion practices, water diversions, historical grazing and logging. These impacts increased nutrient and sediment loading which led to the development of the Lake Tahoe Total Maximum Daily Load (TMDL). The TMDL is designed to protect beneficial uses and decrease negative impacts to the watershed over time.

Eastern Sierra (North)

West Fork Carson Hydrologic Unit

The West Fork Carson River originates in the Toiyabe National Forest in the Sierra Nevada, flowing through Alpine County, California before crossing the state line into Nevada where it joins the East Fork Carson River to form the main stem of the Carson River. Historical practices in the watershed including logging, grazing and mining, combined with current uses such as roads, road maintenance, and recreation, have altered connectivity to the floodplain, increased channel incision, and elevated stream sedimentation.

East Fork Carson Hydrologic Unit

The East Fork Carson River originates in the Sierra Nevada mountain range at an elevation of over 10,000 feet, in Alpine County. It travels through lands managed by the U.S. Forest Service, U.S. Bureau of Land Management, as well as private lands. Before reaching Nevada, it joins the West Fork Carson River to become the Carson River. Possible factors impacting water quality include mining, grazing, geothermal hot springs, logging, channelization, rural communities, recreation, and water diversions. Non-native brown and rainbow trout have been stocked in the East Fork Carson River since the early 1900’s.

West Walker River Hydrologic Unit

The West Walker River HUC is a tributary to the Walker River which terminates at Walker Lake. It originates high in the Emigrant Wilderness, part of the Stanislaus National Forest. Several sections of the West Walker River are popular fishing destinations. Land uses include agriculture, grazing, dispersed recreation, and residential.

East Walker River Hydrologic Unit

The East Walker River begins on the eastern slope of the Sierra Nevada mountains, in the Sawtooth Range. It is a tributary of the Walker River which flows into Walker Lake, Nevada. The river runs through the U.S. of Land Management, U.S. Forest Service, and private property. Land Uses within the watershed include agricultural, cattle ranching, historical mining, and residential. Many recreationalist visit the region to fish, hike, camp, and visit the geothermal hot springs. Historically, the River is known to be one of the finest cutthroat fisheries in the Eastern Sierra, but often due to low snowpack, the higher water temperatures provide poor habitat.

Eastern Sierra (South)

Owens Hydrologic Unit

Mammoth Creek originates at the outflow of Twin Lakes above the town of Mammoth lakes in the southern portion of Mono County. The mountain stream drains from the Eastern Sierra into the Long Valley Caldera. It flows through the community of Mammoth Lakes before joining several geothermal springs and officially becomes Hot Creek downstream of Hot Creek Fish Hatchery. The area surrounding Mammoth Creek is geologically active. Land uses include commercial, Forest Service activities, grazing, residential, and recreation.

The Lower Owens River runs through the Owens Valley and terminates at Owens Lake. Since 1913 the Owens River has been diverted to Los Angeles causing Owens Lake and parts of the Owens River to dry up. A move to restore the Owens River Watershed in 2006 has led to re-watering 62 miles of river and floodplain and has resulted in the largest river restoration of its kind in the United States. Today the Lower Owens River is a year round destination for camping, fishing, kayaking, hiking, and hot spring enthusiasts. Land uses include agriculture, commercial, livestock management, municipal, residential, and recreation.

Mojave

Mojave Hydrologic Unit

The tributaries that form the Mojave River originate in the San Bernardino Mountains at an elevation of 7500 feet. The Mojave River is the largest river in the Mojave Desert and the mainstem begins at the Forks Reservoir, located at the confluence of the West Fork Mojave River and Deep Creek. The reservoir is used strictly for flood management therefore it remains dry most of the time. The Mojave River is unusual because for most of its length, water in the river flows underground and surface flow occurs at only a few locations that include the Narrows and Afton Canyon. Land uses within the watershed include commercial, urban, residential, and recreation.

Appendix B: Additional Regional SWAMP Water Quality Monitoring Station Information

There are 46 Regional SWAMP monitoring sites located in 10 different Basin Plan Hydrologic Units across the Lahontan Region. Please refer to Figure 8 in the main report for a map of the monitoring station locations. Tables B.1 – B.5 provide additional station information (beyond the information presented in Table 7 of the main report) by subregion such as surface water name, site type, sampling period, beneficial uses, indicators measured, 303(d) listing status, and links to the station's online Fact Sheets (if available). Please refer back to Table 7 for station locations (latitude and longitudes) and station elevations.

Table B.1. Modoc Region Station Information: Surprise Valley and Susanville Units (7 stations)

Station Code	Regional SWAMP Site Name	Basin Plan Surface Water Name	Station Type	Beneficial Uses	Sample Period*	Indicators Measured	303(d) Listings	2018 Integrated Report Fact Sheet Link
641BID001	Bidwell Creek, near former DWR gage site	Bidwell Creek	Temporary Screening Site	MUN, AGR, GWR, FRSH, REC1, REC2, COMM, COLD, WILD, SPWN	2002 - 2017	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Total Dissolved Solids	Fact Sheet
641CDR002	Cedar Creek, above Cedarville	Cedar Creek	Temporary Screening Site	MUN, AGR, GWR, FRSH, REC1, REC2, COMM, COLD, WILD, SPWN	2003 - 2017	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Chloride, Indicator Bacteria, Total Dissolved Solids	Fact Sheet
641MIL002	Mill Creek, above Lake City	Mill Creek	Temporary Screening Site	MUN, AGR, GWR, FRSH, REC1, REC2, COMM, COLD, WILD, SPWN	2002 - 2017	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Total Dissolved Solids	Fact Sheet

Station Code	Regional SWAMP Site Name	Basin Plan Surface Water Name	Station Type	Beneficial Uses	Sample Period*	Indicators Measured	303(d) Listings	2018 Integrated Report Fact Sheet Link
637SUS001	Susan River, near Litchfield	Susan River near Litchfield at Hwy. 395	Long-term Permanent Site	MUN, AGR, IND, GWR, FRSH, NAV, REC1, REC2, COMM, WARM, COLD, WILD, MIGR, SPWN	2001 - 2020	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Toxicity, Indicator Bacteria, Boron, Sodium, Sulfates, Total Dissolved Solids, Total Nitrogen, Turbidity	Fact Sheet
637SUS002	Susan River at Lassen St	Susan River at Lassen Street	Temporary Screening Site	MUN, AGR, IND, GWR, FRSH, NAV, REC1, REC2, COMM, WARM, COLD, WILD, MIGR, SPWN	2008 - 2014	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Indicator Bacteria, Unknown Toxicity, Nitrogen, Turbidity, Total Dissolved Solids	Fact Sheet
637SUS003	Susan River, above confluence w/ Willard Cr	Susan River above Willard Creek	Temporary Screening Site	MUN, AGR, IND, GWR, FRSH, NAV, REC1, REC2, COMM, WARM, COLD, WILD, MIGR, SPWN	2001 - 2019	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Chloride, Total Phosphorus, Total Dissolved Solids, Total Nitrogen	Fact Sheet
637SUS004	Susan River, at Commercial Road	Susan River at Lassen Street	Temporary Screening Site	MUN, AGR, IND, GWR, FRSH, NAV, REC1, REC2, COMM, WARM, COLD, WILD, MIGR, SPWN	2014 - 2019	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Indicator Bacteria, Unknown Toxicity, Nitrogen, Turbidity, Total Dissolved Solids	Fact Sheet

Table B.2. Truckee/Tahoe Region Station Information: Truckee River, Little Truckee River and Lake Tahoe Units (5 stations)

Station Code	Regional SWAMP Site Name	Basin Plan Surface Water Name	Site Type	Beneficial Uses	Sample Period	Indicators Measured	303(d) Listings	2018 Integrated Report Fact Sheet Link
635LTRB10	Little Truckee River, below Boca Reservoir	Little Truckee River below Boca Reservoir	Temporary Screening Site	MUN, AGR, GWR, FRSH, POW, REC1, REC2, COMM, COLD, WILD, RARE, MIGR, SPWN	2014 - 2020	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Indicator Bacteria	Fact Sheet
635BER001	Bear Creek, lower (moraine)	Bear Creek at Mouth	Temporary Screening Site	MUN, AGR, IND, GWR, REC1, REC2, COMM, COLD, WILD, RARE, MIGR, SPWN	2000 - 2020	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	No Listings	NA
635SQLB01	Squaw Creek, above Truckee River	Squaw Creek at Mouth	Temporary Screening Site	MUN, AGR, GWR, REC1, REC2, COMM, COLD, WILD, RARE, MIGR, SPWN	2013 - 2020	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Sediment/Siltation	Fact Sheet
635TRK002	Truckee River, above Farad	Truckee River at Stateline	Long-term Permanent Site	MUN, AGR, IND, GWR, FRSH, POW, REC1, REC2, COMM, COLD, WILD, RARE, MIGR, SPWN	2013 - 2020	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Sediment/Siltation, Nitrate	Fact Sheet
634GENB10	General Creek, above Hwy 89	General Creek	Follow-up Diagnostic Site	MUN, AGR, GWR, REC1, REC2, COMM, COLD, WILD, MIGR, SPWN	2013 - 2017	Field WQ, Indicator Bacteria, Solids, Nutrients, Inorganics	Iron, Dissolved Phosphorus	Fact Sheet

Table B.3. Eastern Sierra (North) Subregion Station Information: Carson River and Walker River Units (15 stations)

Station Code	Regional SWAMP Site Name	Basin Plan Surface Water Name	Site Type	Beneficial Uses	Sample Period	Indicators Measured	303(d) Listings	2018 Integrated Report Fact Sheet Link
632ECR005	East Fork Carson River, below Markleeville	East Fork Carson River	Long-term Permanent Site	MUN, AGR, GWR, FRSH, NAV, REC1, REC2, COMM, COLD, WILD, RARE, SPWN	2001 - 2020	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Dissolved Oxygen, Dissolved Boron, Turbidity, Indicator Bacteria, Sulfates, Total Phosphorus, Total Dissolved Solids	Fact Sheet
632ECRB10	East Fork Carson River, above Hangman's bridge	East Fork Carson River	Follow-up Diagnostic Site	MUN, AGR, GWR, FRSH, NAV, REC1, REC2, COMM, COLD, WILD, RARE, SPWN	2013 - 2017	Indicator Bacteria, Solids	Dissolved Oxygen, Dissolved Boron, Turbidity, Indicator Bacteria, Sulfates, Total Phosphorus, Total Dissolved Solids	Fact Sheet
633WCR002	West Fork Carson River, below Willow Creek	West Fork Carson River at Woodfords	Long-term Permanent Site	MUN, AGR, IND, GWR, FRSH, NAV, POW, REC1, REC2, COMM, COLD, WILD, RARE, SPWN	2003 - 2020	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Sulfates, Phosphorus (dissolved and total), Nitrate, Total Kjeldahl Nitrogen	Fact Sheet
633WFCB02	West Fork Carson River, at Paynesville Bridge	West Fork Carson River at Stateline	Long-term Permanent Site	MUN, AGR, IND, GWR, FRSH, NAV, POW, REC1, REC2, COMM, COLD, WILD, RARE, SPWN	2010 - 2020	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Indicator Bacteria, Iron, Nitrate, Total Nitrogen, Sulfates, Total Dissolved Solids, Total Kjeldahl Nitrogen, Turbidity	Fact Sheet
633WFCB03	West Fork Carson River, at Woodfords Bridge	West Fork Carson River at Woodfords	Temporary Screening Site	MUN, AGR, IND, GWR, FRSH, NAV, POW, REC1, REC2, COMM, COLD, WILD, RARE, SPWN	2010 - 2020	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Total Nitrogen, Total Dissolved Solids, Turbidity, Phosphorus (total and dissolved), Sulfates, Nitrate, Total	Fact Sheet

Station Code	Regional SWAMP Site Name	Basin Plan Surface Water Name	Site Type	Beneficial Uses	Sample Period	Indicators Measured	303(d) Listings	2018 Integrated Report Fact Sheet Link
							Kjeldahl Nitrogen, Chloride	
630EWK001	East Walker River, at CA/NV state line	East Walker River at Bridgeport	Long-term Permanent Site	MUN, AGR, IND, GWR, FRSH, NAV, REC1, REC2, COMM, COLD, WILD, RARE, SPWN	2001 - 2020	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Sedimentation/Siltation, Arsenic, Dissolved Oxygen, Phosphorus, Nitrogen, Turbidity, Manganese	Fact Sheet
631HOT001	Hot Creek abv Little Walker River	West Walker River at Coleville	Follow-up Diagnostic Site	AGR, GWR, REC1, REC2, COMM, WARM, COLD, WILD	2009 - 2014	Indicator Bacteria, Nutrients	Indicator Bacteria	Fact Sheet
631LWK003	Little Walker River abv West Walker River	West Walker River at Coleville	Follow-up Diagnostic Site	MUN, AGR, GWR, FRSH, NAV, REC1, REC2, COMM, COLD, WILD, MIGR, SPWN	2007 - 2012	Field WQ, Indicator Bacteria, Solids, Nutrients	Indicator Bacteria	Fact Sheet
631LWK004	Little Walker River abv Hot Creek	West Walker River at Coleville	Follow-up Diagnostic Site	MUN, AGR, GWR, FRSH, NAV, REC1, REC2, COMM, COLD, WILD, MIGR, SPWN	2009 - 2014	Field WQ, Indicator Bacteria, Solids, Nutrients	Indicator Bacteria	Fact Sheet
631MIL002	Mill Creek above Hwy 39	West Walker River at Coleville	Temporary Screening Site	MUN, GWR, REC1, REC2, COMM, COLD, WILD, RARE, SPWN	2014 - 2019	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional	Indicator Bacteria	Fact Sheet

Station Code	Regional SWAMP Site Name	Basin Plan Surface Water Name	Site Type	Beneficial Uses	Sample Period	Indicators Measured	303(d) Listings	2018 Integrated Report Fact Sheet Link
631MIL008	Mill Creek at USFS boundary	West Walker River at Coleville	Temporary Screening Site	MUN, GWR, REC1, REC2, COMM, COLD, WILD, RARE, SPWN	2014 - 2019	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional	Indicator Bacteria	Fact Sheet
631WWK001	West Walker River, near Coleville	West Walker River at Coleville	Long-term Permanent Site	MUN, AGR, GWR, FRSH, NAV, REC1, REC2, COMM, COLD, WILD, MIGR, SPWN	2002 - 2020	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Boron, Turbidity, Total Dissolved Solids, Chloride, Phosphorus	Fact Sheet
631WWK007	West Walker River, above Little Walker River	West Walker River at Coleville	Follow-up Diagnostic Site	MUN, AGR, GWR, FRSH, NAV, REC1, REC2, COMM, COLD, WILD, MIGR, SPWN	2007 - 2012	Field WQ, Indicator Bacteria, Solids, Nutrients	Boron, Turbidity, Total Dissolved Solids, Chloride, Phosphorus	Fact Sheet
631WWK008	West Walker River at Topaz	West Walker River at Coleville	Follow-up Diagnostic Site	MUN, AGR, GWR, FRSH, NAV, REC1, REC2, COMM, COLD, WILD, MIGR, SPWN	2008 - 2016	Field WQ, Indicator Bacteria, Solids, Nutrients	Boron, Turbidity, Total Dissolved Solids, Chloride, Phosphorus	Fact Sheet
631WWK010	West Walker River above Pack Station	West Walker River at Coleville	Follow-up Diagnostic Site	MUN, AGR, GWR, FRSH, NAV, REC1, REC2, COMM, COLD, WILD, MIGR, SPWN	2009 - 2012	Indicator Bacteria, Nutrients	Boron, Turbidity, Total Dissolved Solids, Chloride, Phosphorus	Fact Sheet

Table B.4. Eastern Sierra (South) Subregion Station Information: Owens Unit (10 stations)

Station Code	Regional SWAMP Site Name	Basin Plan Surface Water Name	Site Type	Beneficial Uses	Sample Period	Indicators Measured	303(d) Listings	2018 Integrated Report Fact Sheet Link
603MAM006	Mammoth Creek, at Hwy 395	Mammoth Creek (at Hwy. 395)	Long-term Permanent Site	MUN, AGR, GWR, FRSH, REC1, REC2, COMM, COLD, WILD, RARE, MIGR, SPWN	2000 - 2020	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Dissolved Oxygen, Total Dissolved Solids, Mercury, Phosphate (Orthophosphate, dissolved), Manganese, Indicator Bacteria	Fact Sheet
603MAM008	Mammoth Creek, at Twin Lakes	Mammoth Creek (at Twin Lakes Bridge)	Follow-up Diagnostic Site	MUN, AGR, GWR, FRSH, REC1, REC2, COMM, COLD, WILD, RARE, MIGR, SPWN	2001 - 2017	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Total Dissolved Solids, Mercury, Manganese	Fact Sheet
603MAM014	Mammoth Creek, above Horsecamp	Mammoth Creek (at Old Mammoth Road)	Follow-up Diagnostic Site	MUN, AGR, GWR, FRSH, REC1, REC2, COMM, COLD, WILD, RARE, MIGR, SPWN	2009 - 2017	Indicator Bacteria, Solids	Total Dissolved Solids, Mercury, Manganese	Fact Sheet
603RCK002	Rock Creek, above diversion	Rock Creek (above diversion)	Follow-up Diagnostic Site	MUN, AGR, IND, GWR, FRSH, POW, REC1, REC2, COMM, COLD, WILD, SPWN	2001 - 2019	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional	Total Dissolved Solids	Fact Sheet
603HIL001	Hilton Creek, at Lake Crowley	Hilton Creek	Follow-up Diagnostic Site	MUN, AGR, IND, GWR, FRSH, REC1, REC2, COMM, COLD, WILD, SPWN	2001 - 2019	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional	Total Dissolved Solids, Dissolved Oxygen	Fact Sheet

Station Code	Regional SWAMP Site Name	Basin Plan Surface Water Name	Site Type	Beneficial Uses	Sample Period	Indicators Measured	303(d) Listings	2018 Integrated Report Fact Sheet Link
603BSP002	Bishop Cr Canal at East Line St	Drainage ditch from ag. Lands near Bishop Creek	Temporary Screening Site	MUN, AGR, GWR, REC1, REC2, COMM, COLD, WILD	2010 - 2020	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Indicator Bacteria	Fact Sheet
603BSP004	South Fork Bishop Creek, above Bishop Cr Canal	Bishop Creek (at Hwy 395)	Temporary Screening Site	MUN, AGR, IND, GWR, REC1, REC2, COMM, COLD, WILD, SPWN	2012 - 2017	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Indicator Bacteria	Fact Sheet
603BSP021	North Fork Bishop Creek, above Bishop Cr Canal	Bishop Creek (at Hwy 395)	Temporary Screening Site	MUN, AGR, IND, GWR, REC1, REC2, COMM, COLD, WILD, SPWN	2013 - 2017	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Indicator Bacteria	Fact Sheet
603BSP111	Bishop Creek, at national forest boundary	Bishop Creek (Intake 2)	Temporary Screening Site	MUN, AGR, POW, REC1, REC2, COMM, COLD, WILD, SPWN	2013 - 2017	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	None	NA
603LOW011	Lower Owens River, at Warm Springs Rd	Owens River	Long-term Permanent Site	MUN, AGR, GWR, FRSH, NAV, REC1, REC2, COMM, COLD, WILD, RARE, SPWN	2013 - 2017	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Indicator Bacteria, Sodium	Fact Sheet

Table B.5. Mojave Desert Subregion Station Information: Mojave Unit (9 stations)

Station Code	Regional SWAMP Site Name	Basin Plan Surface Water Name	Site Type	Beneficial Uses	Sample Period	Indicators Measured	303(d) Listings	2018 Integrated Report Fact Sheet Link
628CRB001	Crab Creek, at Crab Flats Rd	Deep Creek (below Lake)	Temporary Screening Site	MUN, AGR, REC1, REC2, COMM, COLD, WILD, SPWN	2001 - 2017	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Dissolved Oxygen, Total Dissolved Solids	Fact Sheet
628DEP001	Deep Creek, above Deep Creek Lake	Deep Creek (below Lake)	Temporary Screening Site	MUN, AGR, GWR, REC1, REC2, COMM, COLD, WILD, BIOL, RARE	2001 - 2017	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Sulfates, Dissolved Oxygen, Chloride, Phosphate (Orthophosphate, dissolved), Total Dissolved Solids, Sodium	Fact Sheet
628DEPDCL	Deep Creek, upstream Deep Creek Lake	Deep Creek (below Lake)	Temporary Screening Site	MUN, AGR, GWR, REC1, REC2, COMM, COLD, WILD, BIOL, RARE	2018 - 2021	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Sulfates, Dissolved Oxygen, Chloride, Phosphate (Orthophosphate, dissolved), Total Dissolved Solids, Sodium	Fact Sheet
628DEPDHS	Deep Creek, downstream of Hot Springs	Deep Creek (at Forks Dam)	Temporary Screening Site	MUN, AGR, GWR, REC1, REC2, COMM, COLD, WILD, BIOL, RARE	2018 - 2021	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Sulfates, Dissolved Oxygen, Chloride, Phosphate (Orthophosphate, dissolved), Total Dissolved Solids, Sodium	Fact Sheet

Station Code	Regional SWAMP Site Name	Basin Plan Surface Water Name	Site Type	Beneficial Uses	Sample Period	Indicators Measured	303(d) Listings	2018 Integrated Report Fact Sheet Link
628HOL001	Holcomb Creek, at Crab Flats Rd	Deep Creek (below Lake)	Temporary Screening Site	MUN, AGR, REC1, REC2, COMM, COLD, WILD	2001 - 2017	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Sulfates, Fluoride, Total Dissolved Solids	Fact Sheet
628MOJ001	Mojave River, at Upper Narrows	Mojave River (at Victorville)	Long-term Permanent Site	MUN, AGR, GWR, REC1, REC2, COMM, WARM, COLD, WILD	2001 - 2021	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Dissolved Oxygen, Fluoride, Sulfates, Total Dissolved Solids, Manganese, Sodium	Fact Sheet
628MOJ002	Mojave River, below Forks Reservoir	Mojave River (at Forks)	Long-term Permanent Site	MUN, AGR, GWR, REC1, REC2, COMM, WARM, COLD, WILD	2001 - 2021	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Sulfates, Fluoride, Sodium	Fact Sheet
628MRWSLO	West Fork Mojave River, Silverwood Lake outfall	Mojave River (at Forks)	Temporary Screening Site	MUN, AGR, GWR, REC1, REC2, COMM, WARM, COLD, WILD, BIOL, RARE	2018 - 2021	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Chloride, Sodium, Sulfates, Total Dissolved Solids	Fact Sheet
628SHP001	Sheep Creek, below Scout Camp	Sheep Creek (at Allison Ranch)	Temporary Screening Site	MUN, AGR, GWR, REC1, REC2, COMM, WARM, COLD, WILD	2001 - 2017	Field WQ, Indicator Bacteria, Solids, Nutrients, Conventional, Inorganics	Dissolved Oxygen, Nitrate, Total Dissolved Solids	Fact Sheet

7. Appendix C: Methods

7.1. Geospatial Datasets

A number of geospatial datasets were used to characterize the environmental setting, review the distribution of water quality monitoring stations, and develop the subregions that helped to organize this report. The datasets were imported into a geographic information system (GIS) application (ArcGIS Pro from Esri) that allows one to explore, visualize and analyze data, and create maps. The application was used to develop cartographic maps and tabular summaries of the Basin Plan HUs and the amounts and distributions of aquatic resources presented in this report. The data sources, how they were used, and mapping methods are presented in Table C.1.

Table C.1. List of geospatial datasets used in this report including where they were used and basic analytical methods.

Geospatial Dataset Type	Where Used	Data Source	Method
Digital Elevation Model (DEM)	To estimate monitoring station elevations (Table 6)	Esri, USGS - default ArcPro DEM	Direct intersection with station location (latitude/longitude)
Topographic	Cartographic map figures	National Atlas of the United States. (2012). 100-Meter Resolution Elevation of the Conterminous United States. National Atlas of the United States. Available at: http://purl.stanford.edu/zz186ss2071.	Base layer in map figures.
Roads	Cartographic map figures	2019 TIGER/Line Shapefiles (machine readable data files) / prepared by the U.S. Census Bureau. 2019. Accessed in July 2022 from: https://catalog.data.gov/dataset/tiger-line-shapefile-2019-state-california-primary-and-secondary-roads-state-based-shapefile	Select roads used in base layer in map figures.
Water Board Boundary	Cartographic map figures and summary tables (Table 1)	CalWater221 geospatial data layer provided by Regional SWAMP Manager at RB6 (Kelly Huck) in July 2022.	Dissolving the polygons with attribute RB = 6 yields the Lahontan WB boundary.
Basin Plan Hydrologic Units/Areas	Cartographic map figures and summary tables	CalWater221 geospatial data layer provided by Regional SWAMP Manager at RB6 (Kelly Huck) in	Subset of columns RB = 6 resulted in 42 HUs consistent with those reported on the

Geospatial Dataset Type	Where Used	Data Source	Method
		July 2022.	Basin Plan website (Plates 1A&B and 2A & B) at: https://www.waterboards.ca.gov/lahontan/water_issues/programs/basin_plan/references.html
Fire Perimeters	Cartographic map figures and summary table	Wildland Fire Interagency Geospatial Services (WFIGS) Group: https://data-nifc.opendata.arcgis.com/datasets/nifc::wfigs-wildland-fire-locations-full-history/about GIS data accessed in August 2022.	Geometry and spatial extent were repaired. Fire year was derived from relevant columns, and then fires were dissolved by year to avoid double-counting fires that were digitized twice. Then the "Count Overlapping Features" tool was run to find the number of burns at each wildfire location. Geodesic area of each wildfire perimeter was calculated in acres using a North America Albers Equal Area Conic projection.
National Hydrography Dataset (NHD)	Cartographic map figures and summary table	U.S. Geological Survey, 2019, National Hydrography Dataset. Accessed in July 2022 at: https://www.usgs.gov/national-hydrography/access-national-hydrography-products	Fig. 3 mapped intermittent and perennial streams only (Feature Type = Stream/River and FCode = 46003 and 46006, respectively).
National Wetlands Inventory (NWI)	Cartographic map figures and summary table	National Wetlands Inventory, U.S. Fish & Wildlife Service (2022). National Wetlands Inventory. U.S. Fish & Wildlife Service. Accessed in July 2022 at: https://data.nal.usda.gov/dataset/national-wetlands-inventory	Fig. 3 mapped only System Name Palustrine and Lacustrine. Attributes in the Legend are listed by Wetland Types: Freshwater Emergent Wetland, Freshwater Forested/Shrub Wetland, Freshwater Pond, and Lake. Lake was further split to show intermittent wetted extent vs. perennial areas.

7.2. Water Quality 20-Year Retrospective Analysis Methods

Regional SWAMP water quality monitoring data were downloaded from the California Data Exchange Network (CEDEN) in July 2021. The initial dataset included nearly 30,000 records of the Regional SWAMP's water quality monitoring results sampled between January 2000 and June 2021.

7.2.1. DATA REVIEW AND CLEANUP

7.2.1.1. Completeness and Standardization

Working with Kelly Huck, the Regional SWAMP coordinator, to confirm all expected data were publically accessible in CEDEN, data were repeatedly downloaded to check for completeness. The final download was completed in July 2021 and included monitoring results through June 2021.

The initial data review dropped records where the Compliance Code = "Rej" (marked as rejected by the SWAMP QA process) or there were clearly no reported results. The remaining data included records with a variety of Batch Verification and Compliance Codes including:

- Batch Verification Codes included combinations of one or more of the following: Cursory verification (VAC), Minor Deviations flagged by QAO (VMD). Full verification (VAF), Incomplete QC flagged by QAO (VQI), and Not Recorded (NR)
- Compliance Codes: Compliant (Com) with associated QAPP, Historical (Hist) data that did not have supporting QA/QC data, Estimated (Est) data considered non-quantifiable, Pending (Pend) QA Review – mostly field collected measures, Not Recorded (NR), or Qualified (Qual or QualH) meaning that data were not compliant with the associated QAPP, the analytes were not listed in the QAPP, or the data were insufficiently documented.

Review of the qualified Qual and QualH results did not indicate unusual differences from other sample results so those data were kept. All other Batch Verification and Compliance Codes did not warrant immediate dropping of additional records.

Over 90% of the remaining dataset had reported results where the ResQualCode field indicated "=" (Result equal to) or "<" or ">" (Result less than or greater than) in the case of a number of Historical data records. These results and qualifiers were assumed to be valid data and were left unchanged (~26,000 results).

The remaining 10% of the records where the ResQualCode indicated ND (not-detected), DNQ (detected but not quantifiable) or NR (not recorded) were then reviewed and standardized (~2,800 results).

- NR: All but one record marked with NR lacked any reported results and those records were removed. One Total Alkalinity record had a reported result and no other indication to remove it so it was kept.

- DNQs: The Method Detection Limits (MDLs) and Reporting Limits (RLs) for records that were flagged as DNQ were reviewed and standardized.
    - All the DNQ results had reported RLs and often had a reported MDL. Missing MDLs for those records were updated to RL/3.
- NDs: MDLs and RLs for records that were flagged as ND were reviewed and standardized. All ND records had reported RL values and a mix of reported MDLs that included either negative RL values or a "NULL" placeholder of -88.
    - Negative MDL values that were exactly the opposite of the positive RL value were reported for a subset of Fecal Coliform and E. coli records. Those MDLs were updated to exactly the same as the positive RL value.
    - -88 placeholder MDL values were reported for about two dozen Total Nitrogen results. Those MDLs were updated to RL/3.

Handling of Results qualified as ND or DNQ:

- Results for ND records were set to 0.5 * MDL
- Results for DNQ records kept the reported result (if available), and missing results were set to 0.5 * RL[34].

7.2.1.2. Visual Data Review

The standardized data were plotted to look for unusual outliers and significant visual differences in results between laboratories.

- Various box and scatter plots were developed to visually review the initial downloaded dataset:
    - Outliers: Boxplots of all the results by station and analyte were developed to provide a general review of the dataset and look for highly unusual outliers. Only 5 highly unusual outliers were found and dropped (after discussing with the Regional SWAMP coordinator). The remaining data with less egregious outliers were kept because there were no specific reported qualifiers indicating any reasons to drop them.
    - Lab differences: Scatter plot points of all the results by station over time were color coded by laboratory to evaluate if data from specific labs seemed

[34] The rationale to use ½ the RL for DNQ qualified data is consistent with SWAMP data formatting guidance that indicates that DNQs should be between the MDL and RL. It should be noted that this may be inconsistent with data formatting practices for the Integrated Report where missing DNQ results are replaced with ½ MDL (personal communication with SWAMP coordinator).

unusually biased. The visual review indicated that, in general, the data above the detection limits were not compromised by changing labs.

- Differences in MDLs: Reported MDLs were overlaid on the boxplots to get a sense of the variability in reporting limits over time. The following parameters indicated the visible differences in reported MDLs that might confound the analytical assessments: Boron, Chloride, Fluoride, all of the nutrient parameters (nitrogen compounds and phosphates), Potassium, and Sulfate.

7.2.1.3. Calculated Total Nitrogen Results

Regional SWAMP historically reported a mix of lab-measured and lab-calculated Total Nitrogen results. In addition, about 40% of the samples were analyzed for one or more component analytes of Nitrate, Nitrite, and Total Kjeldahl Nitrogen (TKN) but not Total Nitrogen. At the request of the SWAMP coordinator, *missing* Total Nitrogen Results were calculated and added back into the working dataset with an identifying note that "SFEI calculated" the results added to the MethodName column. The final method for calculating Total Nitrogen from reported component analytes was as follows:

- The sum of available Nitrate, Nitrite, and TKN values, prioritizing Total fraction values if possible, but using Dissolved fraction values if necessary in the priority outlined below.
- Non-detect records were set to 0.5 * MDL, For DNQ records we used the reported value if available, otherwise 0.5 * RL
- Calculated results that only included sums from the "Dissolved" Fraction were not included in the dataset.

The sums were calculated by adding available 'Nitrogen, Total Kjeldahl' values for a sample with available Nitrate and Nitrite values with the following priority:

1. Reported 'Nitrate + Nitrite as N' with a FractionName of 'Total'
2. Reported 'Nitrate + Nitrite as N' with a FractionName of 'Dissolved'
3. The sum of reported 'Nitrite as N' and 'Nitrate as N', both with a FractionName of 'Total'
4. The sum of reported 'Nitrite as N' and 'Nitrate as N', both with a FractionName of 'Dissolved'

7.2.1.4. Mini-study to address how best to handle NDs and DNQs for summing Nitrogen Analytes

To evaluate the most appropriate way to handle NDs (non-detect, for values below the Method Detection Limit) or DNQs (detected, not quantified, for values between the MDL and Reporting Limit) among the summed nitrogen analytes, a mini-study was conducted to determine if setting qualified ND and DNQ results to ½ the detection limit or 0 significantly affected the SSO exceedance evaluations.

Two options were investigated:

- The 'High' option replaced ND result values with 0.5 * MDL and retained values reported in the Result field for DNQ result values or 0.5 * RL when no Result value was reported.
- The 'Low' option used 0 for all ND and DNQ result values.

The mini-study consisted of comparing SSO exceedances between calculated Total Nitrogen (T_N) results that employed the calculated 'High' and calculated 'Low' options:

- comparison of exceedances for T_N between calculated values (High vs. Low options), and
- between calculated values (High and Low options) vs. lab reported values (which ones are closer to the lab reported values? How different are they in comparison?

Outcome:

- In the comparison of SSO exceedances between calculated High and calculated Low only 4 calculated results indicated different exceedances. In consultation with the SWAMP coordinator, the team decided to add the 'High' calculated T_N values to the working dataset as described above.
- In the comparison between calculated values (High and Low options) vs. lab reported values of directly analyzed Total Nitrogen there was no clear pattern in the level of difference between the three options. Sometimes calculated values were higher than the direct reported Nitrogen values and sometimes they were below. This review suggests that SWAMP should have the labs measure Total Nitrogen directly and not submit calculated results based on component analytes.

7.2.2. THE FINAL ANALYSIS DATASET

The updated standardized analysis dataset included over 29,000 records from up to 35 parameters measured at 46 stations in 22 streams across the five subregions. Table C.2 summarizes the number of parameters measured (n Params), total results reported (n Results), and the sampling date range of sampling events (Min and Max Date) by Station and Site Type (StaCode_ST; L = Long-term, T = Temporary, F = Follow-up).

Table C.2. Regional SWAMP monitoring stations with the number of parameters measured (n Params), total results reported (n Results), and the sampling date range of sampling events (Min and Max Date)

Subregion	Stream Name	StaCode_ST	n Params	n Results	Min Date	Max Date
Modoc	Bidwell Creek	641BID001_T	35	453	7/2/2002	11/29/2017
Modoc	Cedar Creek	641CDR002_T	35	526	5/7/2003	11/30/2017
Modoc	Mill Creek	641MIL002_T	33	449	7/2/2002	11/30/2017
Modoc	Susan River	637SUS001_L	35	1,450	6/26/2001	8/19/2020

Table C.2 continued. Regional SWAMP monitoring stations with the number of parameters measured (n Params), total results reported (n Results), and the sampling date range of sampling events (Min and Max Date)

Subregion	Stream Name	StaCode_ST	n Params	n Results	Min Date	Max Date
Modoc	Susan River	637SUS002_T	30	545	2/18/2008	11/4/2014
Modoc	Susan River	637SUS003_T	35	1,323	6/26/2001	12/18/2019
Modoc	Susan River	637SUS004_T	32	611	11/18/2014	12/18/2019
Truckee/Tahoe	Bear Creek	635BER001_T	33	509	8/30/2000	2/25/2020
Truckee/Tahoe	General Creek	634GENB10_F	14	212	7/31/2013	12/20/2017
Truckee/Tahoe	Little Truckee River	635LTRB10_T	31	190	6/25/2014	2/25/2020
Truckee/Tahoe	Squaw Creek	635SQLB01_T	30	469	8/5/2013	2/25/2020
Truckee/Tahoe	Truckee River	635TRK002_L	32	629	7/29/2013	2/25/2020
Eastern Sierra (North)	East Fork Carson River	632ECR005_L	35	2,145	10/16/2001	1/29/2020
Eastern Sierra (North)	East Fork Carson River	632ECRB10_F	5	165	7/19/2013	10/30/2017
Eastern Sierra (North)	East Walker River	630EWK001_L	35	1,916	8/16/2001	3/11/2020
Eastern Sierra (North)	West Fork Carson River	633WCR002_L	35	2,189	4/7/2003	2/5/2020
Eastern Sierra (North)	West Fork Carson River	633WFCB02_L	31	824	5/24/2010	2/5/2020
Eastern Sierra (North)	West Fork Carson River	633WFCB03_T	32	811	5/24/2010	2/5/2020
Eastern Sierra (North)	West Walker River	631WWK001_L	35	1,924	8/21/2002	3/11/2020
Eastern Sierra (North)	West Walker River	631MIL002_T	19	73	8/13/2014	8/21/2019
Eastern Sierra (North)	West Walker River	631MIL008_T	19	31	10/2/2014	8/20/2019
Eastern Sierra (North)	West Walker River	631HOT001_F	5	148	1/7/2009	10/19/2014
Eastern Sierra (North)	West Walker River	631LWK003_F	14	129	11/8/2007	12/11/2012
Eastern Sierra (North)	West Walker River	631LWK004_F	5	148	1/7/2009	10/19/2014
Eastern Sierra (North)	West Walker River	631WWK007_F	14	127	11/8/2007	12/11/2012
Eastern Sierra (North)	West Walker River	631WWK008_F	14	441	2/5/2008	9/28/2016
Eastern Sierra (North)	West Walker River	631WWK010_F	5	80	1/7/2009	12/11/2012
Eastern Sierra (South)	Bishop Creek	603BSP004_T	28	523	6/5/2012	11/28/2017
Eastern Sierra (South)	Bishop Creek	603BSP021_T	28	463	3/21/2013	11/28/2017

Table C.2 continued. Regional SWAMP monitoring stations with the number of parameters measured (n Params), total results reported (n Results), and the sampling date range of sampling events (Min and Max Date)

Subregion	Stream Name	StaCode_ST	n Params	n Results	Min Date	Max Date
Eastern Sierra (South)	Bishop Creek	603BSP111_T	30	492	4/22/2013	11/28/2017
Eastern Sierra (South)	Drainage ditch	603BSP002_T	29	264	3/29/2010	8/17/2020
Eastern Sierra (South)	Hilton Creek	603HIL001_F	23	628	8/14/2001	8/27/2019
Eastern Sierra (South)	Mammoth Creek	603MAM006_L	35	1,926	1/21/2000	2/12/2020
Eastern Sierra (South)	Mammoth Creek	603MAM008_F	25	359	8/15/2001	10/4/2017
Eastern Sierra (South)	Mammoth Creek	603MAM014_F	5	148	6/23/2009	10/4/2017
Eastern Sierra (South)	Owens River	603LOW011_L	28	431	4/30/2013	11/28/2017
Eastern Sierra (South)	Rock Creek	603RCK002_F	22	668	8/14/2001	8/21/2019
Mojave Desert	Deep Creek	628CRB001_T	32	669	7/18/2001	9/27/2017
Mojave Desert	Deep Creek	628DEP001_T	32	662	7/18/2001	9/27/2017
Mojave Desert	Deep Creek	628DEPDCL_T	25	147	5/24/2018	6/21/2021
Mojave Desert	Deep Creek	628DEPDHS_T	25	162	5/24/2018	6/21/2021
Mojave Desert	Deep Creek	628HOL001_T	32	697	7/18/2001	9/27/2017
Mojave Desert	Mojave River	628MOJ001_L	32	903	7/17/2001	6/21/2021
Mojave Desert	Mojave River	628MOJ002_L	33	905	7/17/2001	6/21/2021
Mojave Desert	Mojave River	628MRWSLO_T	25	163	5/24/2018	6/21/2021
Mojave Desert	Sheep Creek	628SHP001_T	32	596	7/19/2001	9/26/2017
Summary	**22 Streams**	**46 Stations**	**Max n 35**	**Total 29,323**	**Start Date 1/21/2000**	**End Date 6/21/2021**

7.2.3. WATER QUALITY OBJECTIVES EXCEEDANCE ANALYSES

The standardized and formatted Regional SWAMP monitoring data was imported into R (a programing language for statistical computing and graphics). The data for 16 of the monitored parameters were compared to the Lahontan Basin Plan water quality objectives (WQO) or site specific objectives (SSO) for all 46 stations. Table C.3 lists the parameters evaluated and the general water quality objective evaluation method applied in the exceedance analyses. Please refer to Chapter 3 of the Basin Plan for more detailed information about the objectives.

Table C.3. List of Regional SWAMP water quality monitoring parameters evaluated in this report and their associated general Lahontan Basin Plan water quality objective (WQO) or site specific objective (SSO) evaluation guidance.

Parameter Group	Abbreviated Name	SWAMP Fraction and Parameter Name (Reporting Units)	WQO or SSO	WQO or SSO Evaluation (Exceeds if)
Field Measures	pH	pH	WQO	Direct measure - above or below objectives of 8.5 or 6.5
Field Measures	T_OD	Total Oxygen, Dissolved (mg/L)	WQO	Direct measure - below one or more beneficial use objectives or SSOs
Field Measures	T_OS	Total Oxygen, Saturation (%)	WQO	Direct measure - below objective of 80% saturation
Solids	TDS	Dissolved Total Dissolved Solids (mg/L)	SSO	Annual mean - above SSO
Solids	Turb	Total Turbidity (NTU)	WQO	Difference between result and mean of monthly mean greater than SSO
Indicator Bacteria	CF	Coliform, Fecal (cfu/100mL)	WQO	Rolling 30 day log mean above WQO of 20 cfu/100mL
Indicator Bacteria	EC	E. coli (cfu/100mL)	WQO	Rolling 6 wk. geometric mean above statewide* standard of 100 cfu/100mL
Nutrients	T_NO3	Total Nitrate as N (mg/L)	SSO	Annual mean - above SSO
Nutrients	T_N	Total Nitrogen, Total (mg/L)	SSO	Annual mean - above SSO
Nutrients	T_KN	Total Nitrogen, Total Kjeldahl (mg/L)	SSO	Mean of monthly mean - above SSO
Nutrients	D_OP	Dissolved OrthoPhosphate as P (mg/L)	SSO	Annual mean - above SSO
Nutrients	T_P	Total Phosphorus as P (mg/L)	SSO	Annual mean - above SSO
Conven-tional	D_Cl	Dissolved Chloride (mg/L)	SSO	Annual mean - above SSO
Conven-tional	D_Fl	Dissolved Fluoride (mg/L)	SSO	Annual mean - above SSO
Conven-tional	D_Sul	Dissolved Sulfate (mg/L)	SSO	Annual mean - above SSO
Inorganic Analyte	D_B	Dissolved Boron (mg/L)	SSO	Annual mean - above SSO

* New statewide standard not currently in Basin Plan. https://www.waterboards.ca.gov/bacterialobjectives/docs/bacteria.pdf

7.2.4. TESTING FOR TRENDS OVER TIME

After a literature review regarding candidate statistical methods for evaluating long-term water quality monitoring trends over time, and conferring with SFEI's Bay Regional Monitoring Program for Water Quality staff, a Seasonal Mann-Kendall statistical test for trends was selected as the statistical method to screen for significant overall up or down trends by station and parameter.

The *EnvStats* package[35] in R was employed to investigate for significant trends.

The Regional SWAMP dataset was large, with other 29,000 records for 46 stations and up to 35 parameters. Stations were sampled 1-4 times a year for a variable number parameters and variable number of years. Sometimes the SWAMP staff conducted intensive special studies and sampled a single parameter at a station for short periods of time (e.g. weekly for a several months).

The standardized dataset was prepared for statistical analyses by taking the median value reported for three different 'seasons': Quarterly, Wet/Dry Water Year, and Annual. A Seasonal Mann-Kendall test was run on the Quarterly and Wet/Dry Water Year datasets, and a regular Mann-Kendall test was run on the Annual dataset because it did not have a seasonal component. The EnvStats package's "kendallSeasonalTrendTest" outputs individual seasonal and overall test statistics (e.g. Kendall's tau statistic, p-value, and z-trend), as well as a modified Theil-Senn slope and y-intercept estimate (for both seasonal and overall trends).

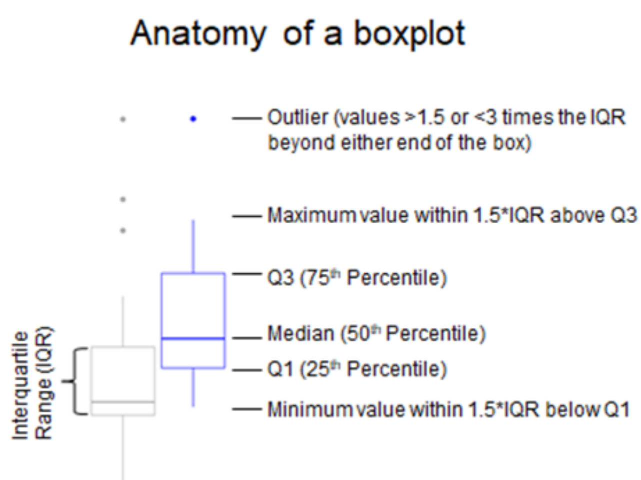
Because evaluating trends in long-term water quality monitoring data is difficult because of a variety of largely uncontrollable factors both internal to the data and external in the environment, a conservative approach was taken to evaluate trends over time in the Regional SWAMP's 20-year dataset. The three Quarterly, Wet/Dry Water Year, and Annual median value datasets were statistically evaluated and only when all three tests for any single station/parameter pair showed that all three p-values were < 0.05 did we reject the null-hypothesis that there were no trends, and accept that the station/parameter pair likely showed a significant trend over time.

[35] https://cran.r-project.org/web/packages/EnvStats/EnvStats.pdf

8. Appendix D: Graphical Boxplots of the Water Quality Monitoring Results

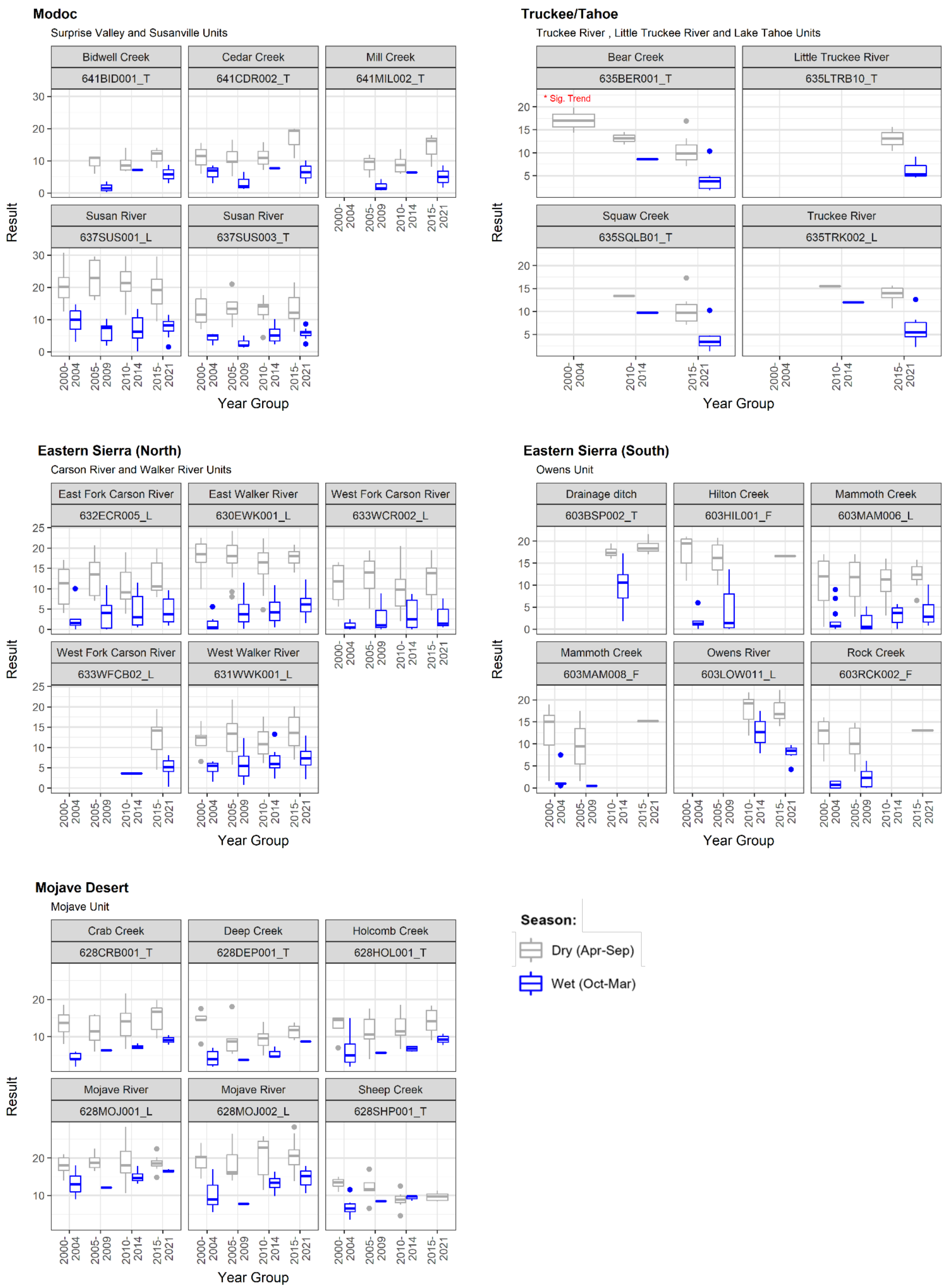
The following plots summarize the Lahontan SWAMP's monitoring results for a subset of parameters and stations. 29 of the 35 water quality parameters were regularly measured at 26 stations. The parameters and stations presented in the boxplots were selected because they were monitored over a period of at least nine years.

The boxplots show general statistical information about the seasonal results over time, and visually highlight similarities (or differences) in water quality measures both seasonally and temporally by subregion, stream name, and station code. The anatomy of a boxplot is outlined below:



Each individual station plot consists of seasonal boxplots for data that has been grouped in up to 4 multi-year increments using the same 5-year time intervals presented in the water quality exceedance summary section above (see Tables 12-15). As with the statistical trend analyses reported above, the wet season was defined as samples collected October through March, and the dry season included samples collected April through September. Stations and parameters that showed significant trends using the seasonal Mann Kendall tests are indicated with "* *Sig. Trend*" in red. Please refer to Table 16 (above) for the specific test statistics. If available, the minimum and maximum MDLs, reported since 2015 by station and parameter, are shown on the individual plots to visually indicate if the reported ambient water quality results fall within the range of recently reported MDLs or if they are well above those limits.

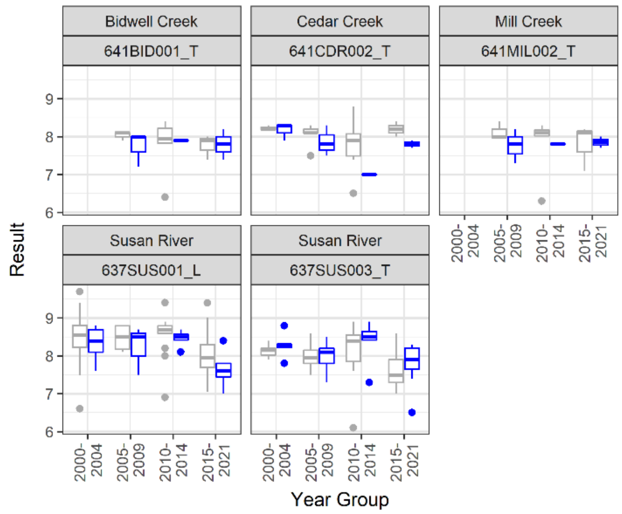
Temperature (Deg C)



pH

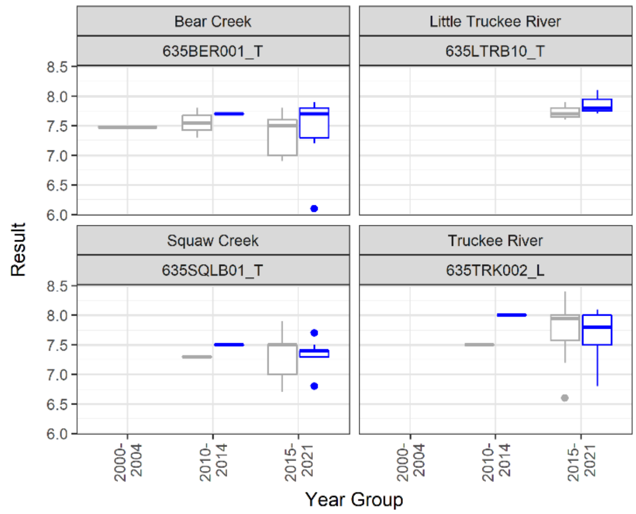
Modoc

Surprise Valley and Susanville Units



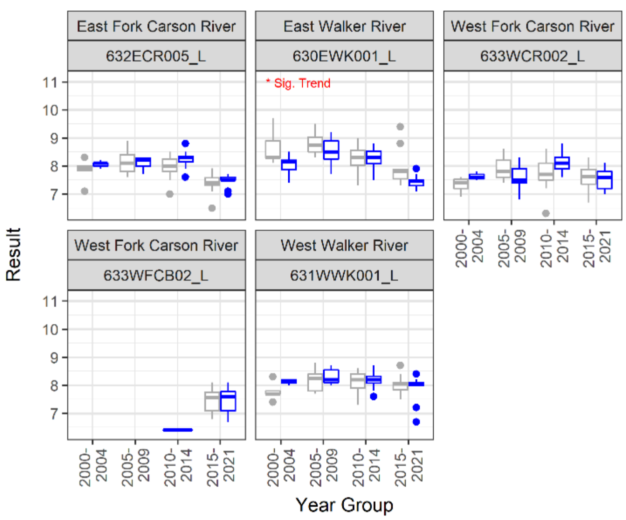
Truckee/Tahoe

Truckee River , Little Truckee River and Lake Tahoe Units



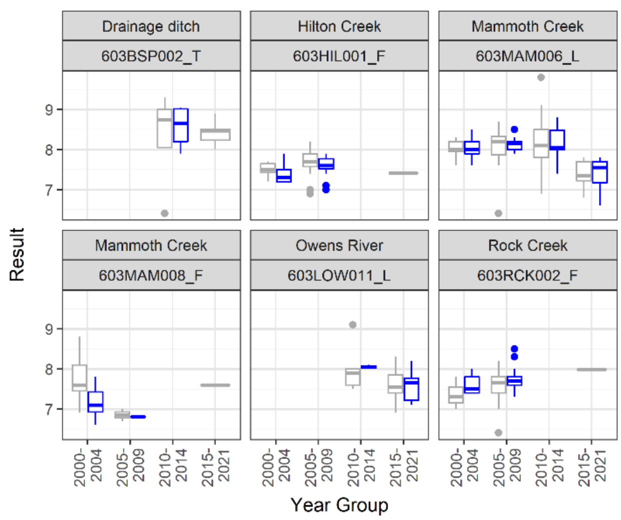
Eastern Sierra (North)

Carson River and Walker River Units



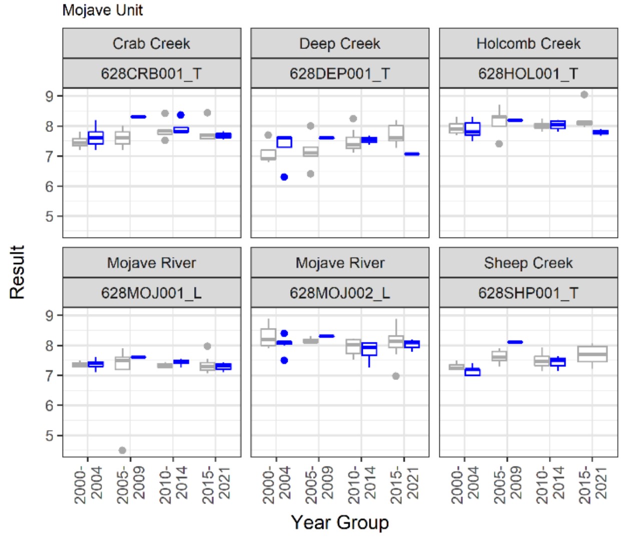
Eastern Sierra (South)

Owens Unit

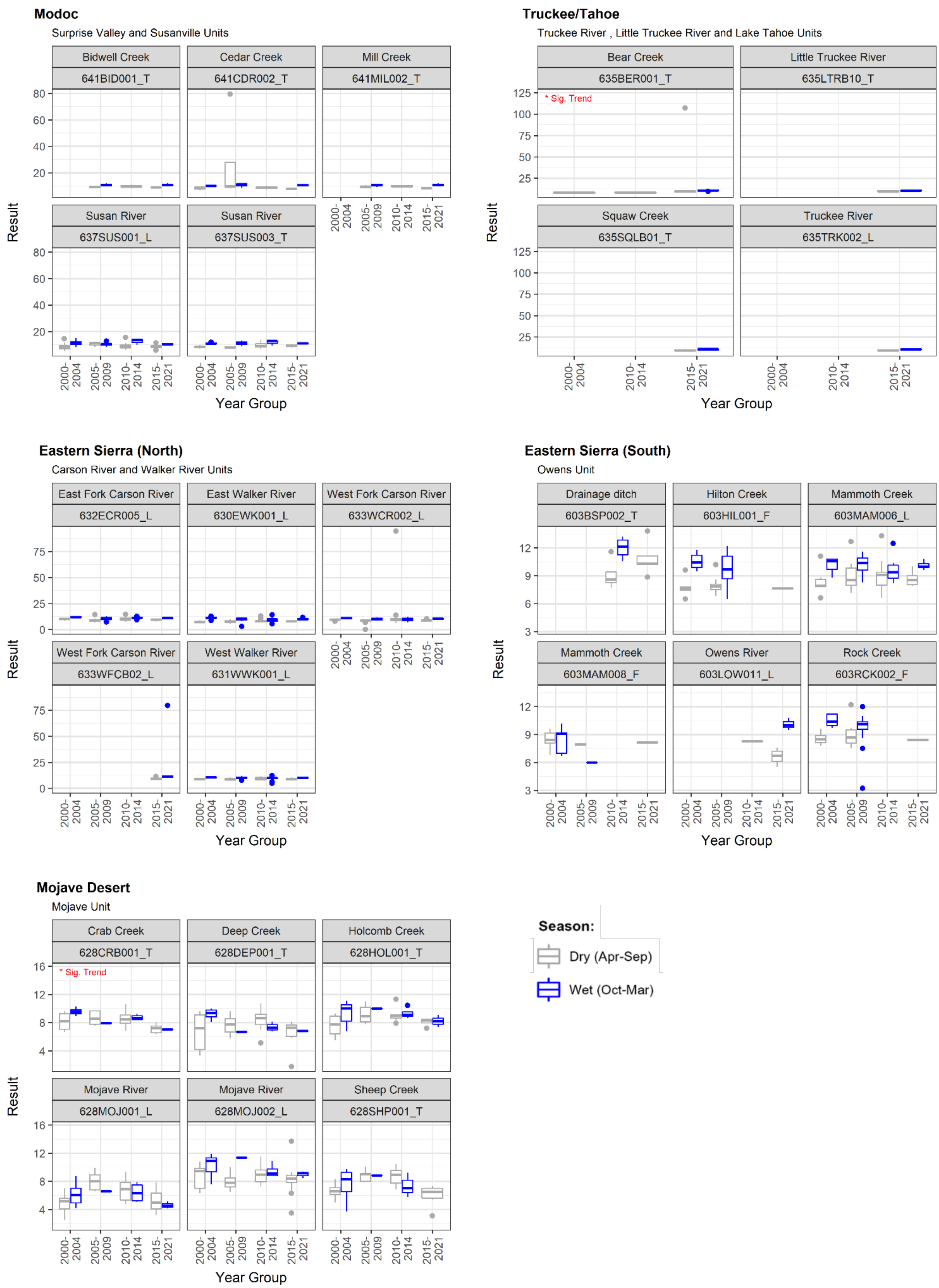


Mojave Desert

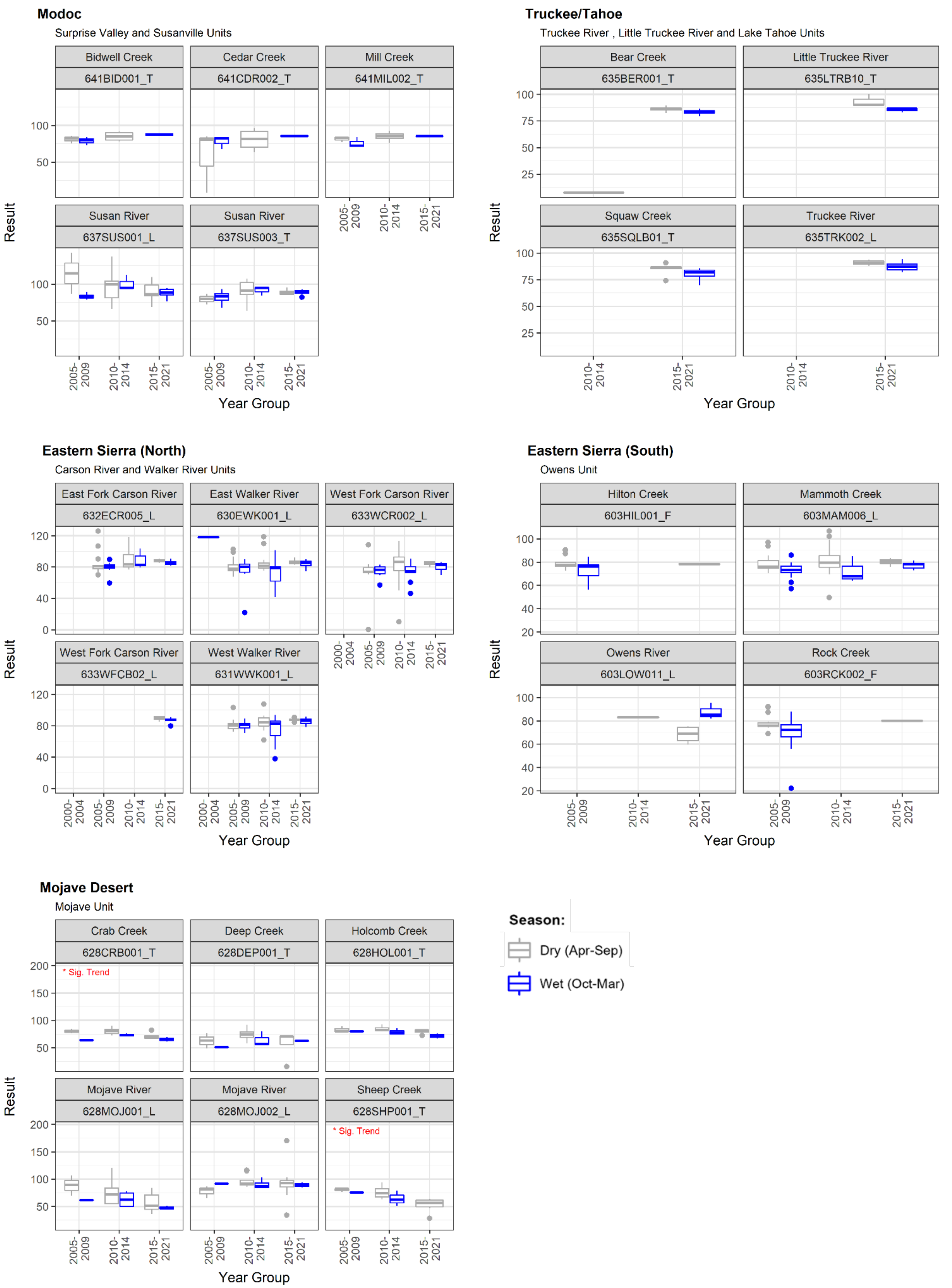
Mojave Unit



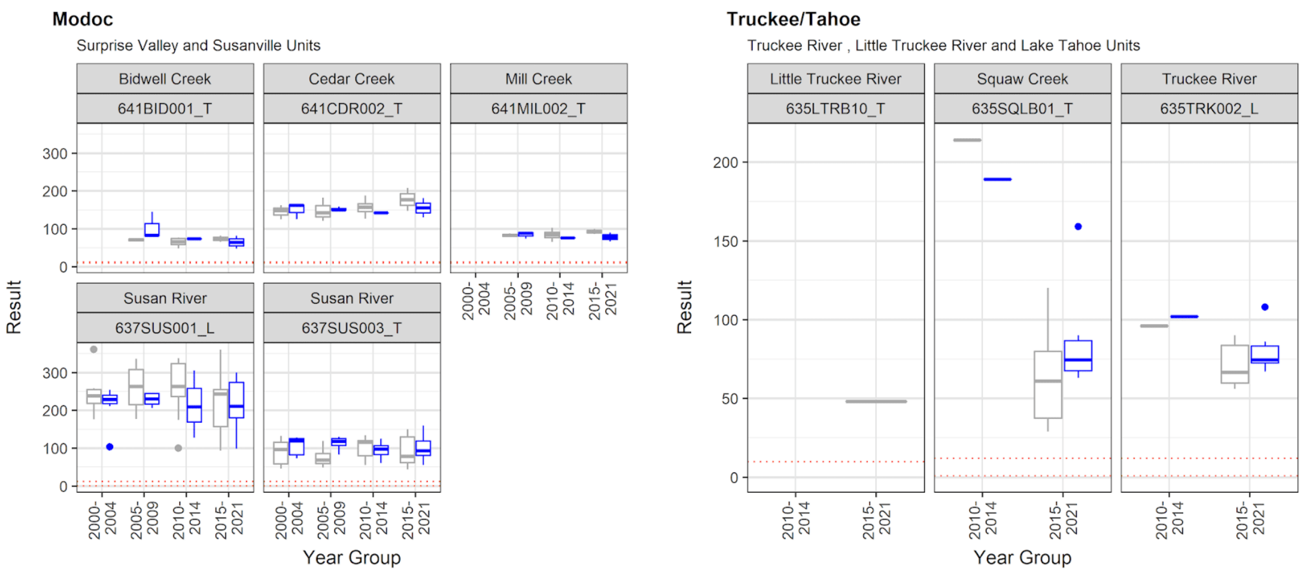
Total Oxygen, Dissolved (mg/L)

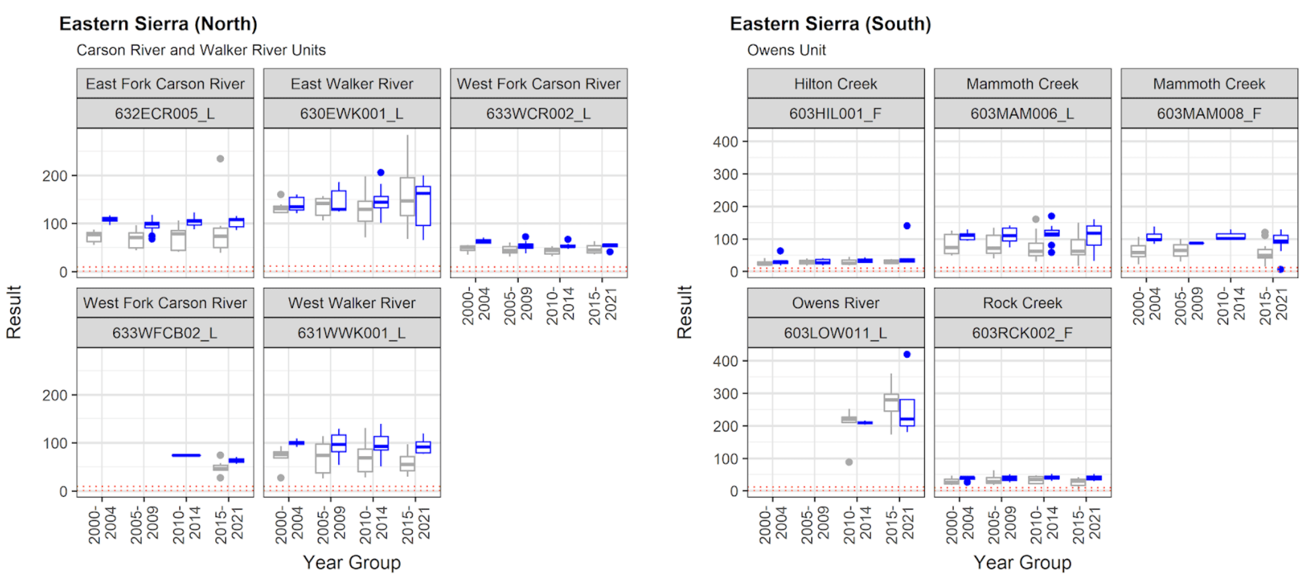


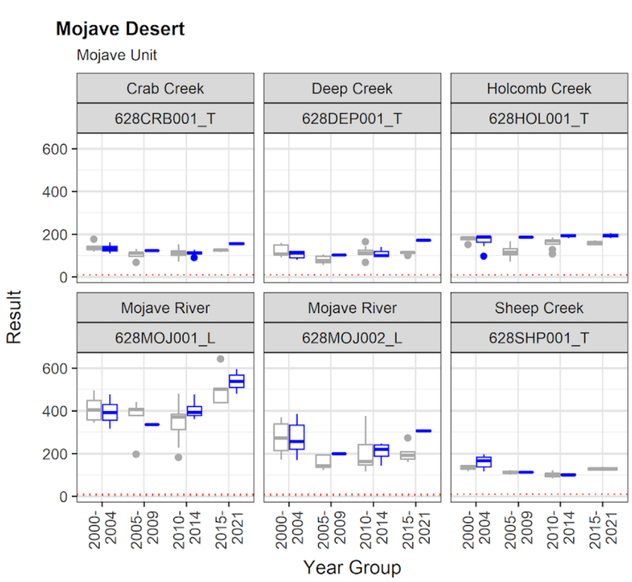
Total Oxygen, Saturation (%)



Dissolved Total Dissolved Solids (mg/L)

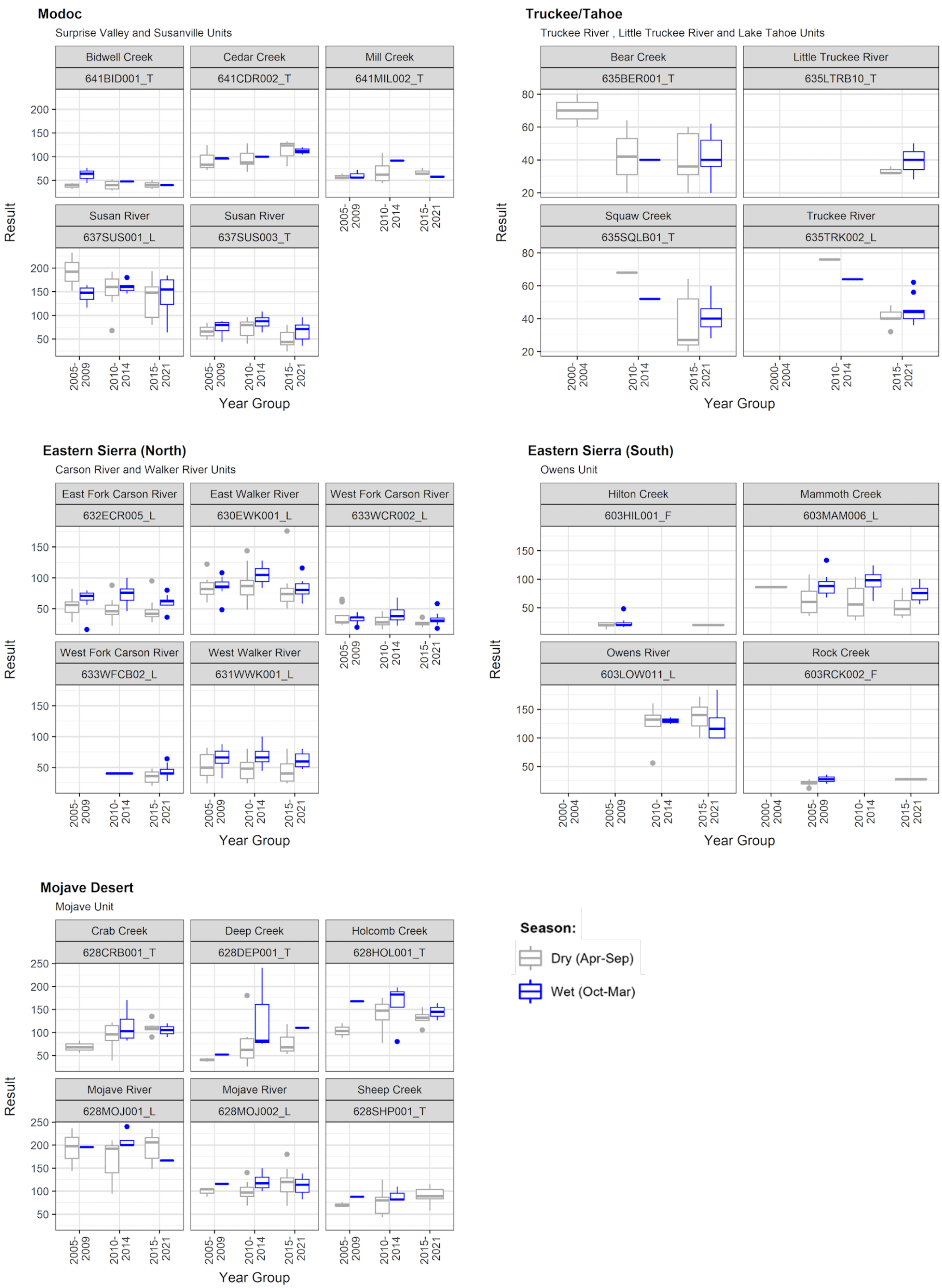




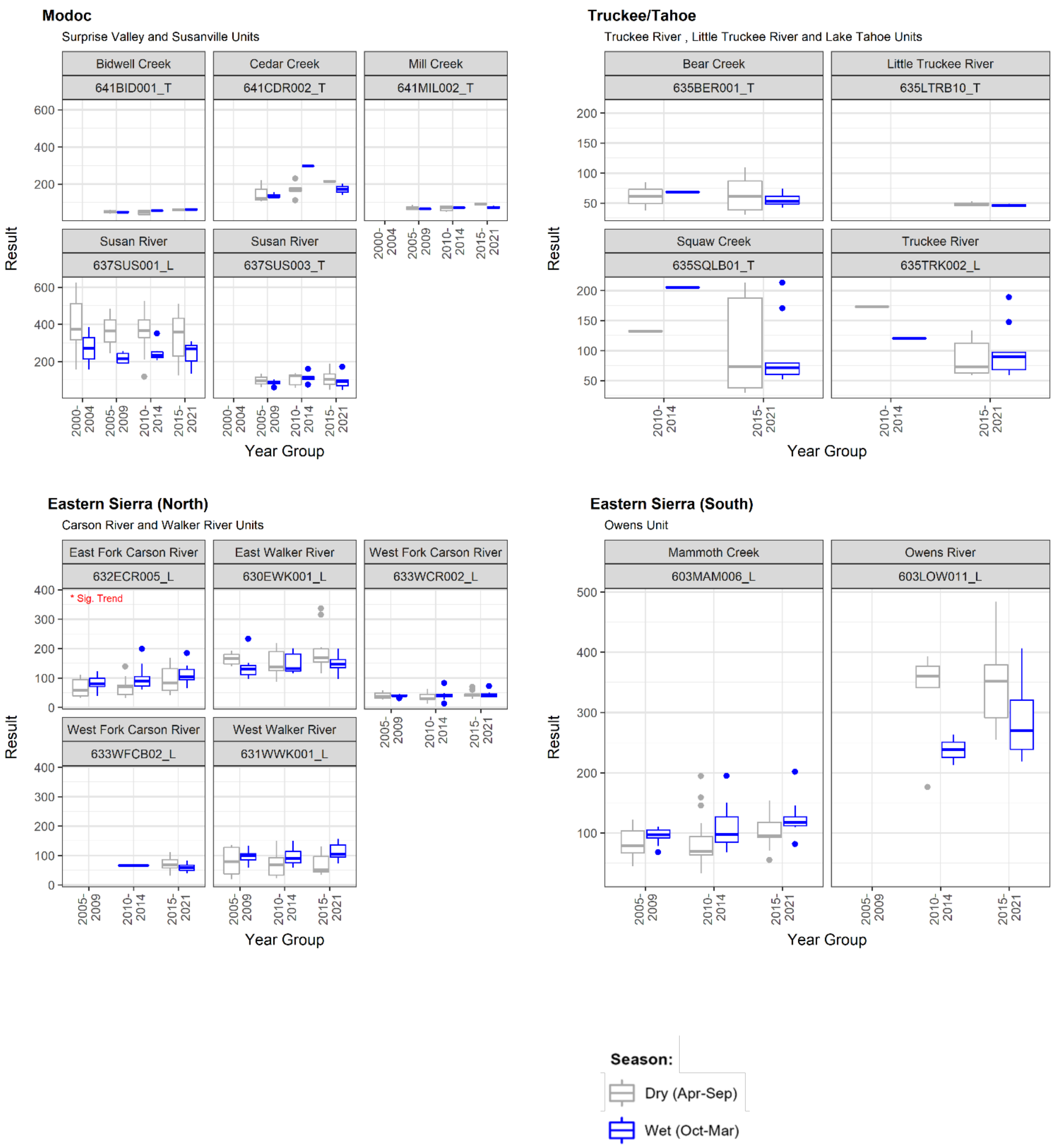


The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

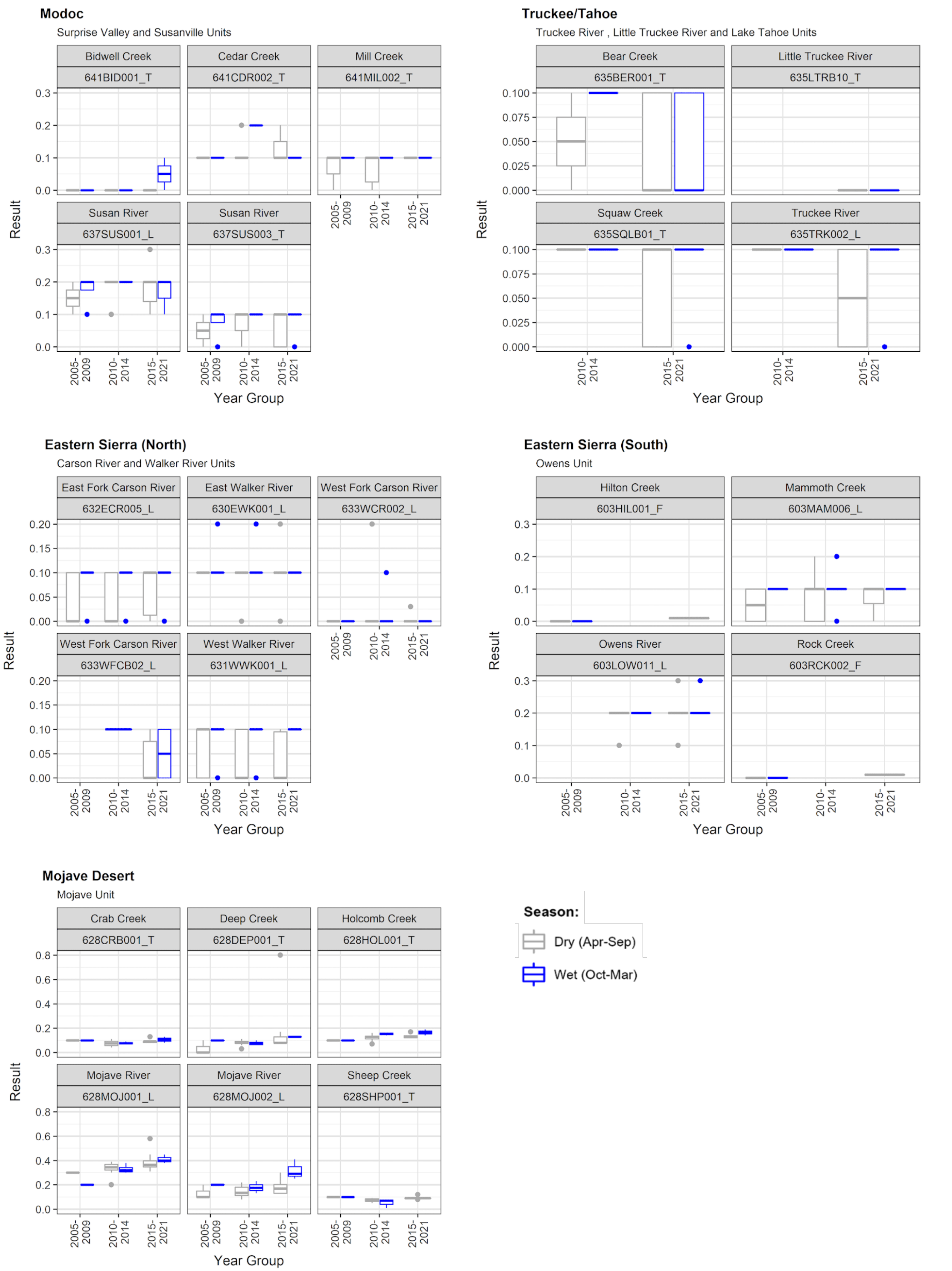
Total Alkalinity as $CaCO_3$ (mg/L)

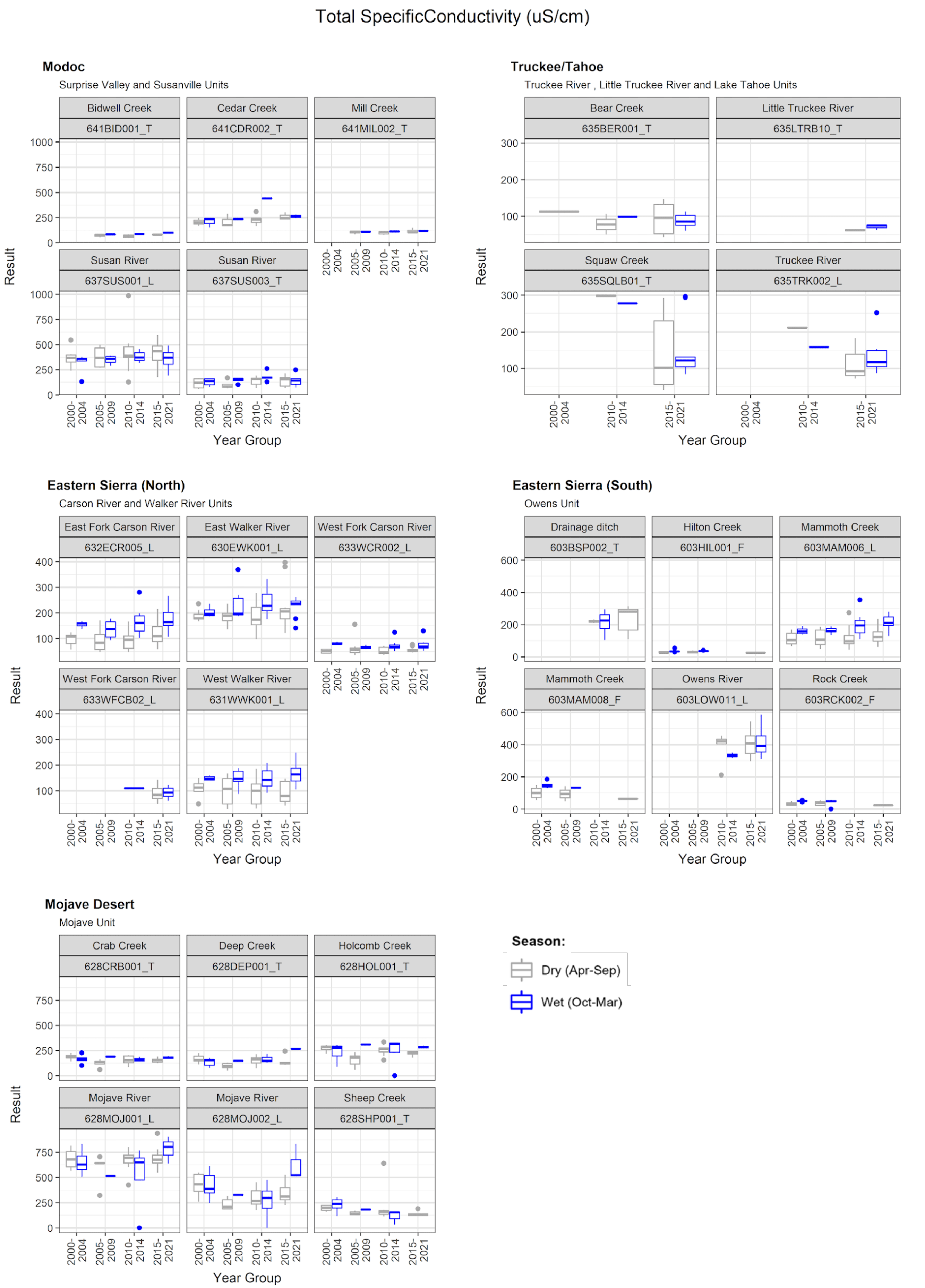


Total ElectricalConductivity (uS/cm)

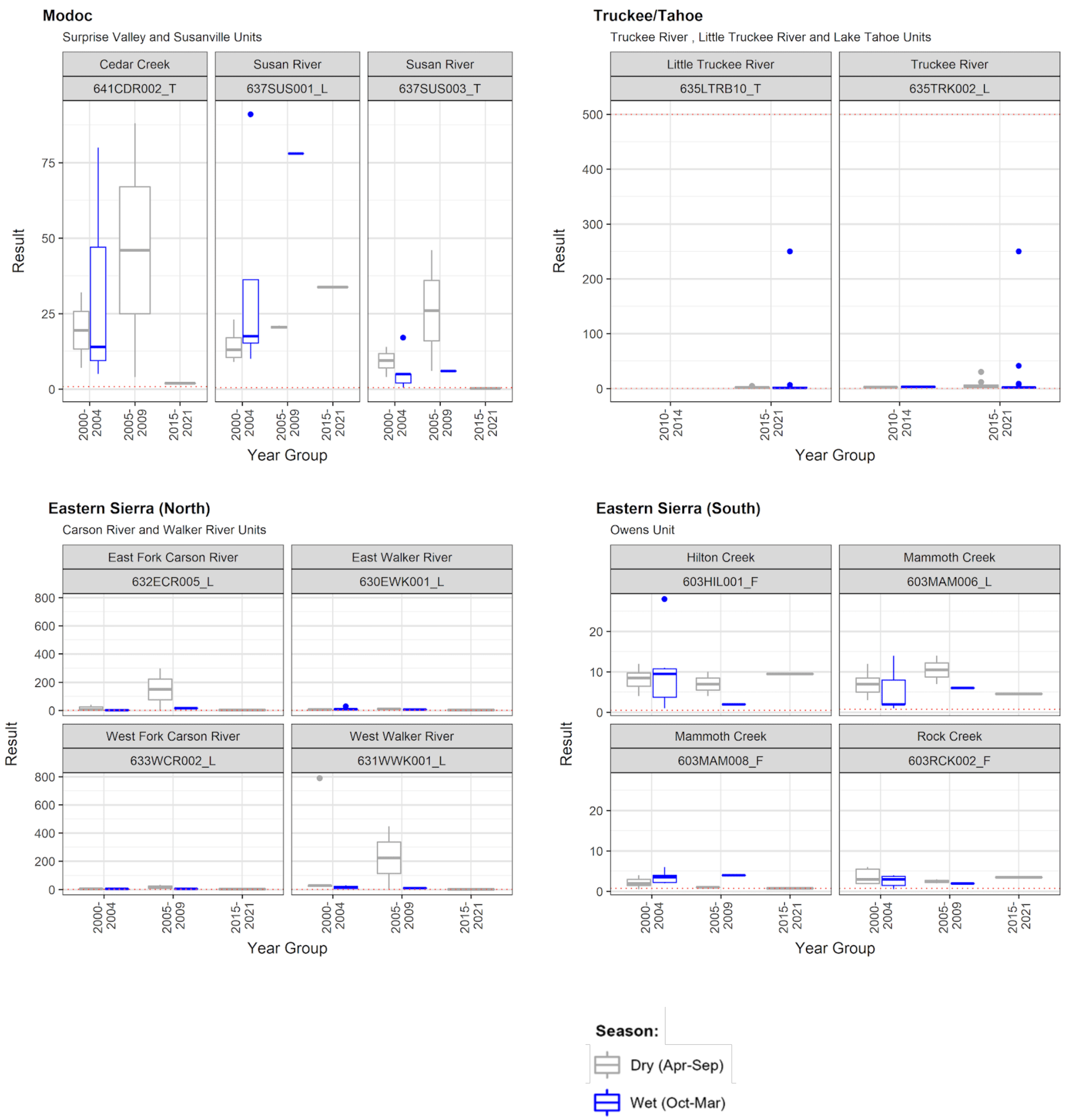


Total Salinity (ppt)




Total SpecificConductivity (uS/cm)
Modoc
Surprise Valley and Susanville Units
Bidwell Creek
641BID001_T
Cedar Creek
641CDR002_T
Mill Creek
641MIL002_T
Susan River
637SUS001_L
Susan River
637SUS003_T
Truckee/Tahoe
Truckee River , Little Truckee River and Lake Tahoe Units
Bear Creek
635BER001_T
Little Truckee River
635LTRB10_T
Squaw Creek
635SQLB01_T
Truckee River
635TRK002_L
Eastern Sierra (North)
Carson River and Walker River Units
East Fork Carson River
632ECR005_L
East Walker River
630EWK001_L
West Fork Carson River
633WCR002_L
West Fork Carson River
633WFCB02_L
West Walker River
631WWK001_L
Eastern Sierra (South)
Owens Unit
Drainage ditch
603BSP002_T
Hilton Creek
603HIL001_F
Mammoth Creek
603MAM006_L
Mammoth Creek
603MAM008_F
Owens River
603LOW011_L
Rock Creek
603RCK002_F
Mojave Desert
Mojave Unit
Crab Creek
628CRB001_T
Deep Creek
628DEP001_T
Holcomb Creek
628HOL001_T
Mojave River
628MOJ001_L
Mojave River
628MOJ002_L
Sheep Creek
628SHP001_T
Result
Year Group
2000-2004
2005-2009
2010-2014
2015-2021
Season:
Dry (Apr-Sep)
Wet (Oct-Mar)

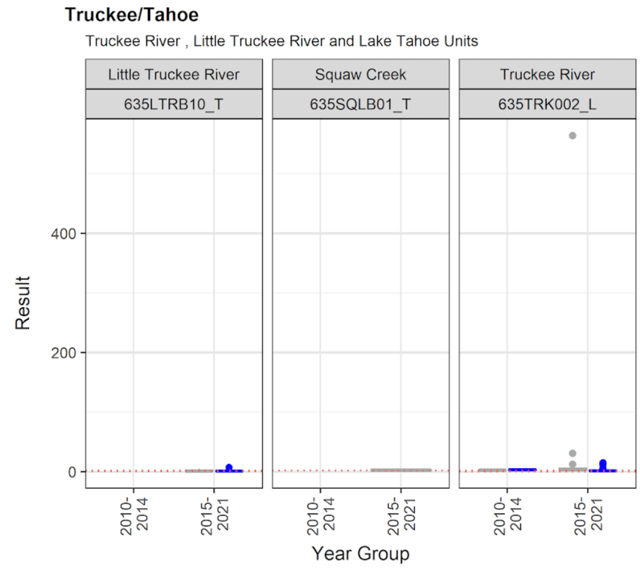
Particulate Suspended Sediment Concentration (mg/L)

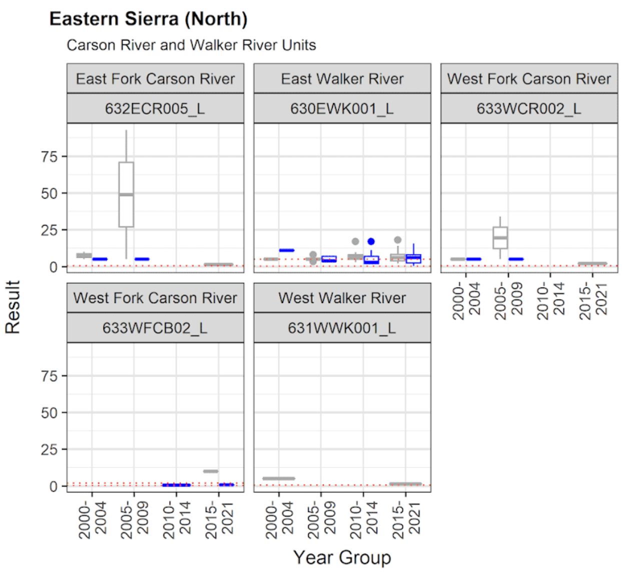


The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

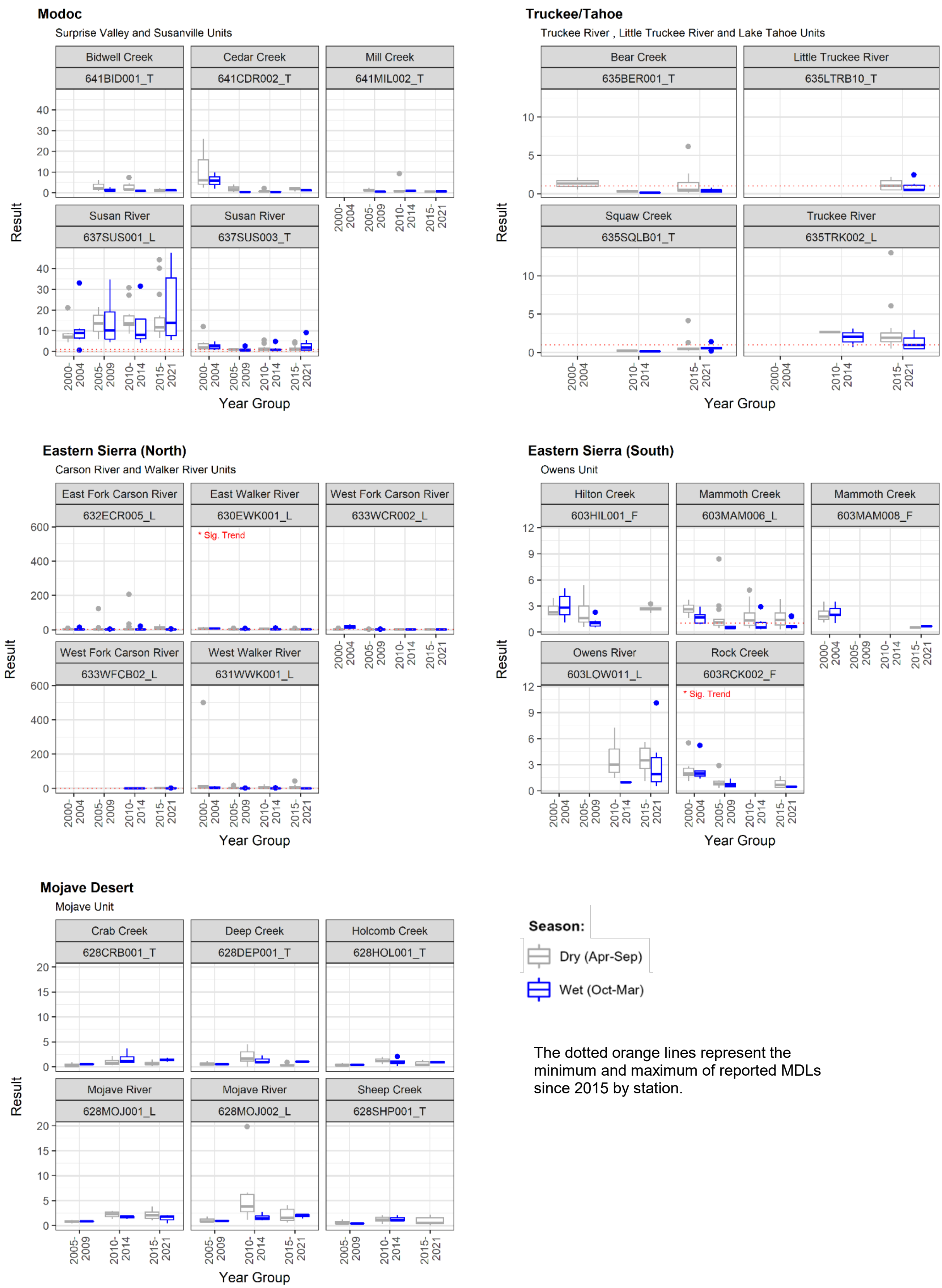
Particulate Total Suspended Solids (mg/L)

The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.



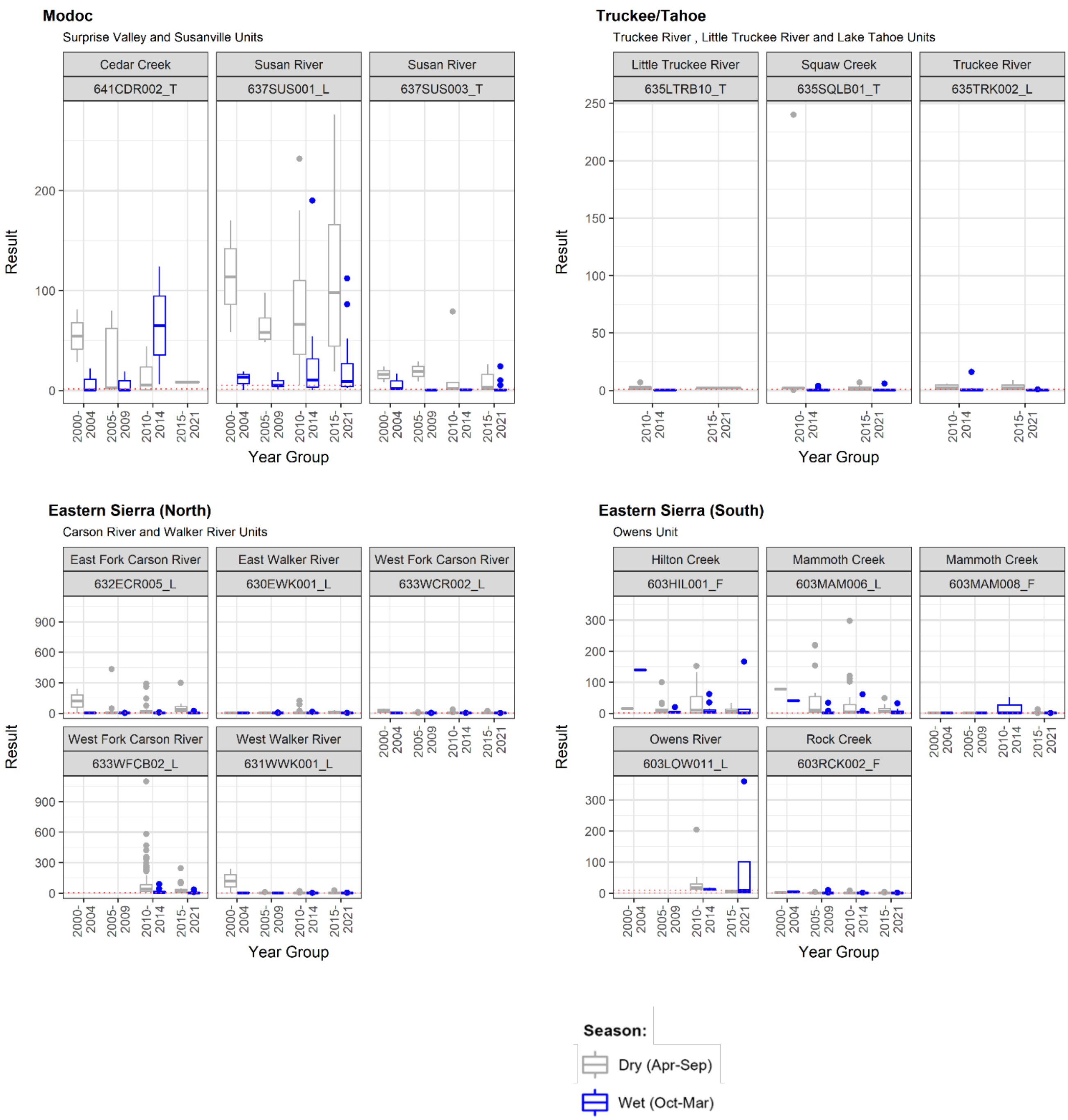


Total Turbidity (NTU)



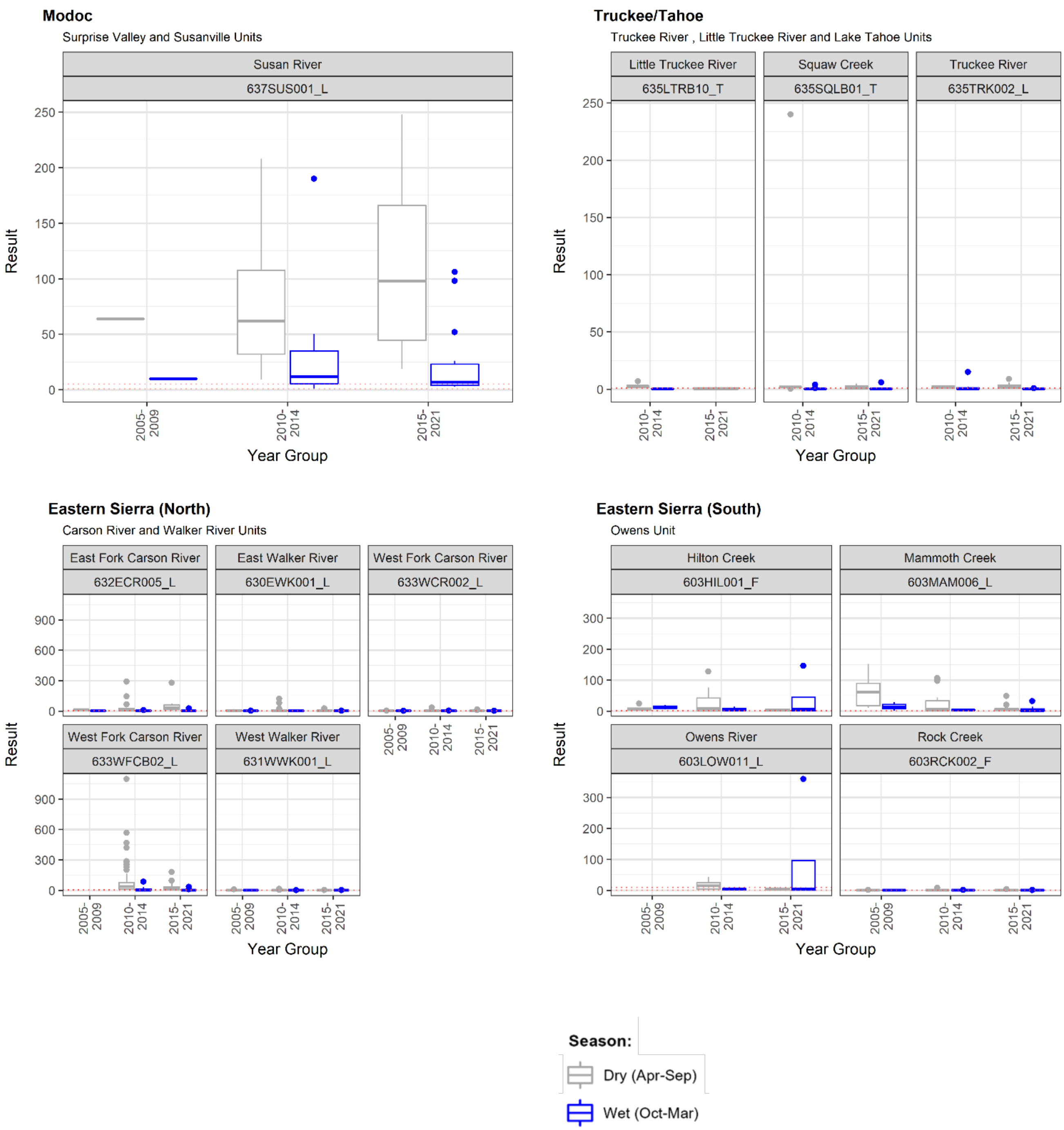
The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

Coliform, Fecal (cfu/100mL)



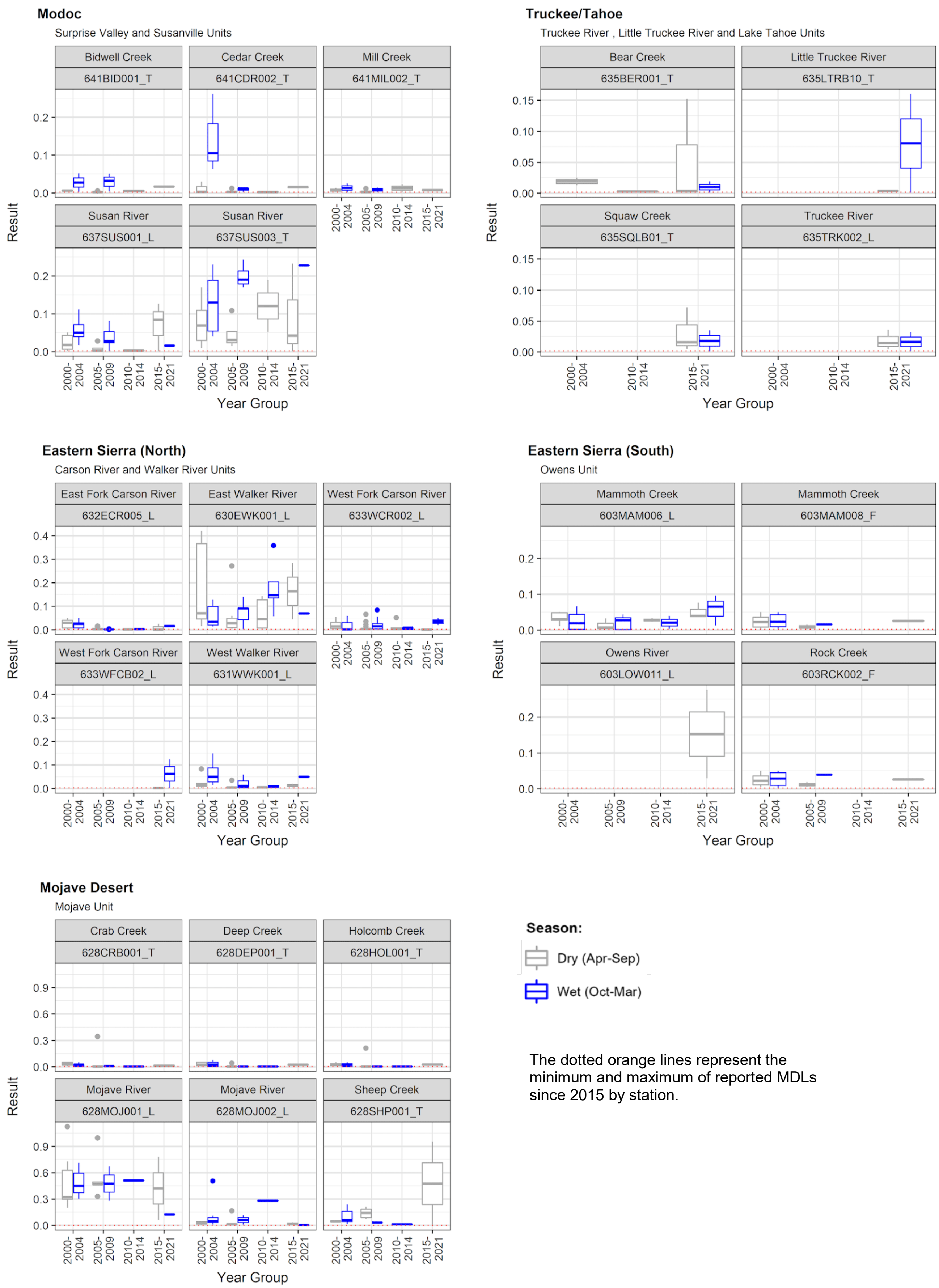
The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

E. coli (cfu/100mL)

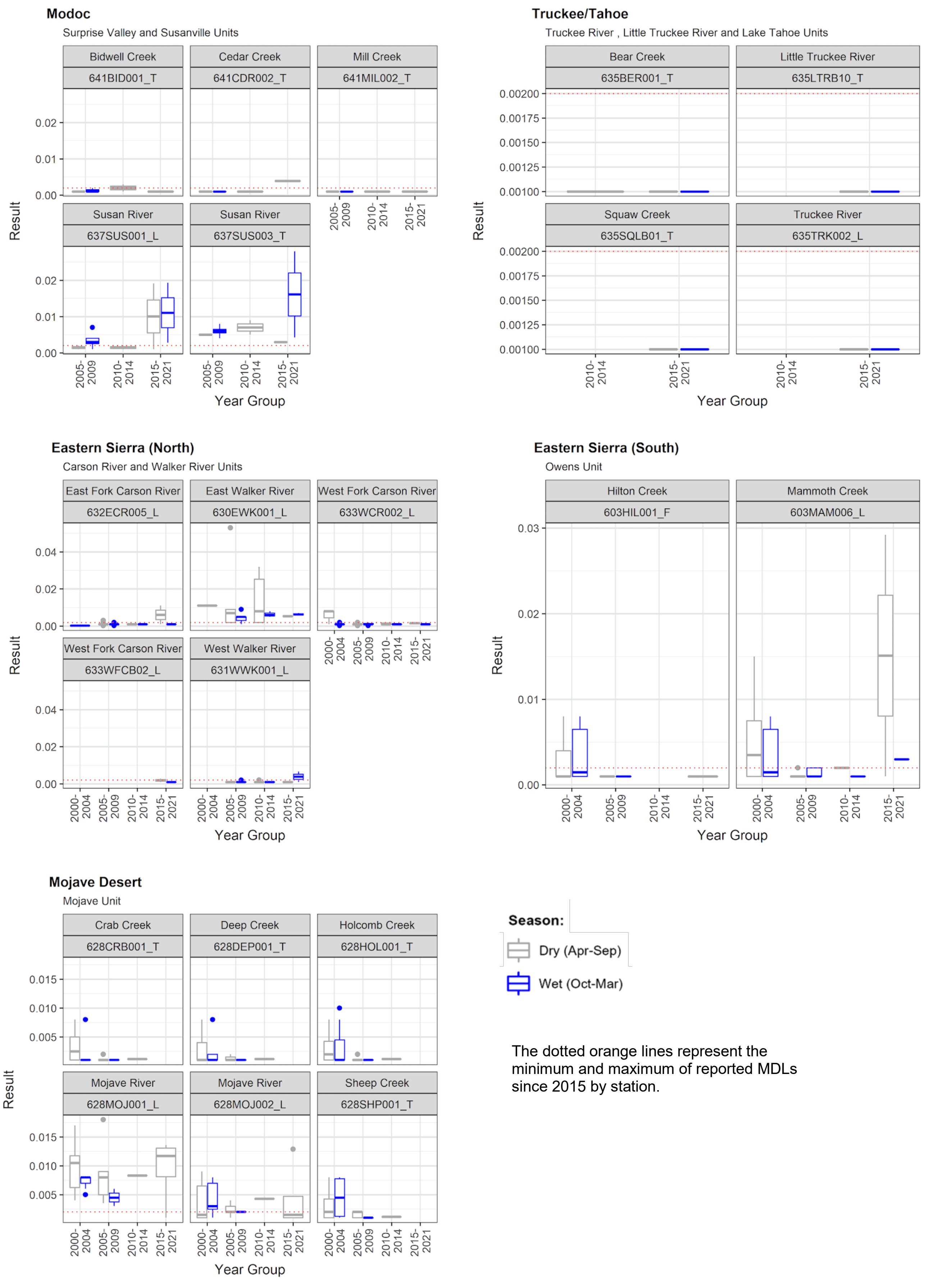


The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

Dissolved Nitrate + Nitrite as N (mg/L)

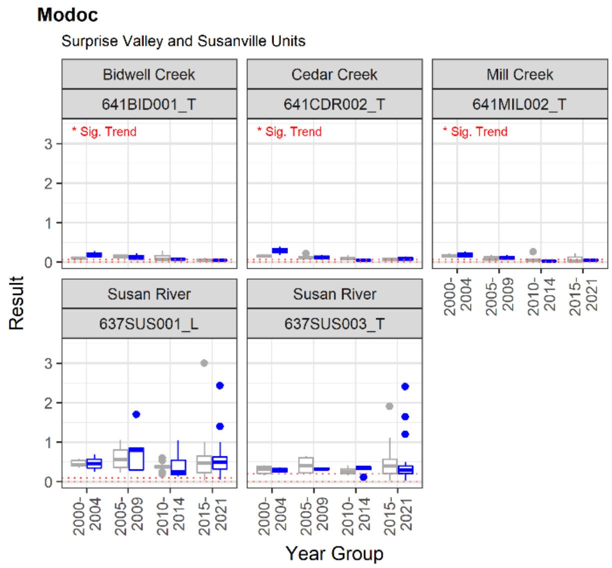


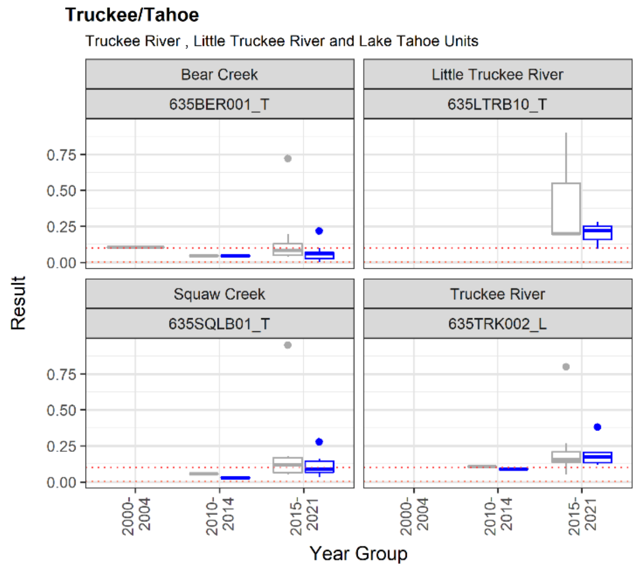
Dissolved Nitrite as N (mg/L)

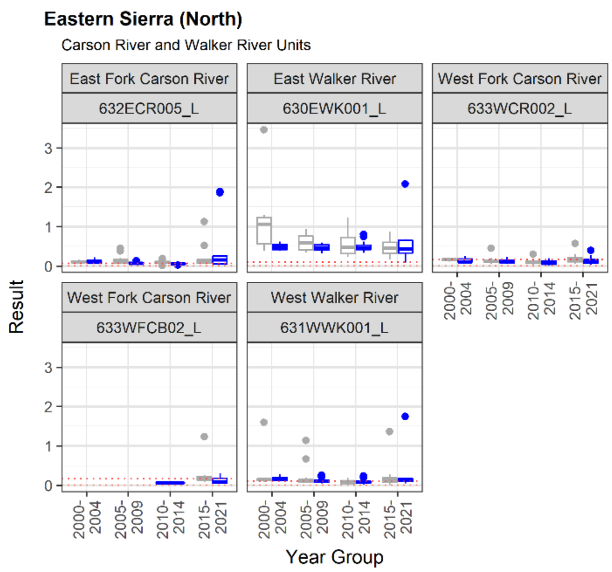


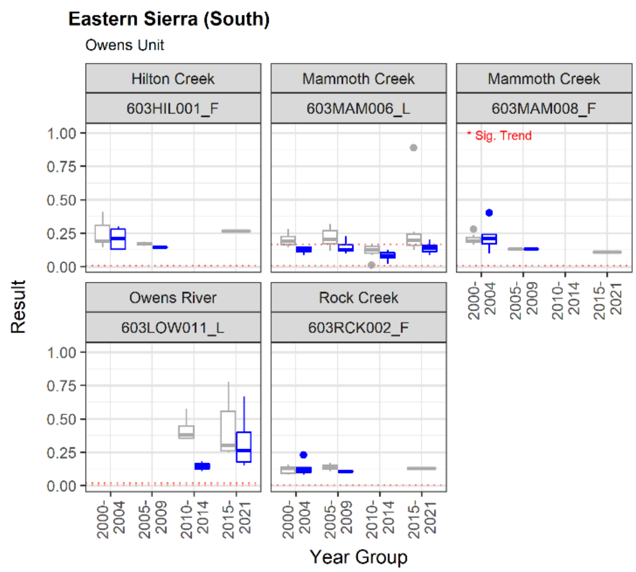
The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

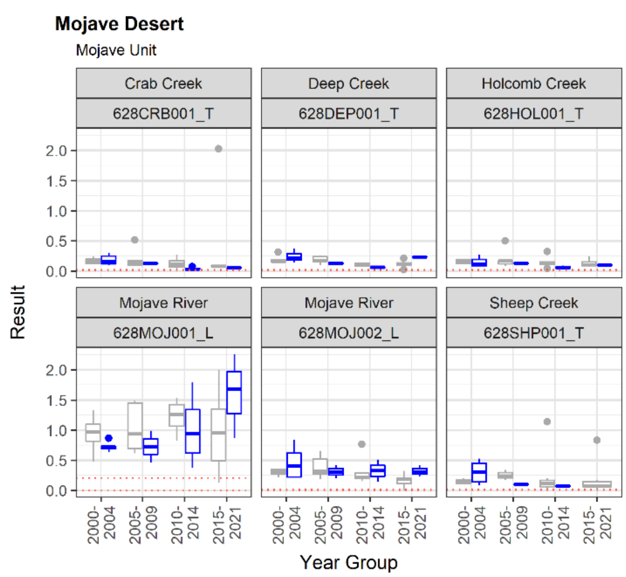
Total Nitrogen, Total (mg/L)





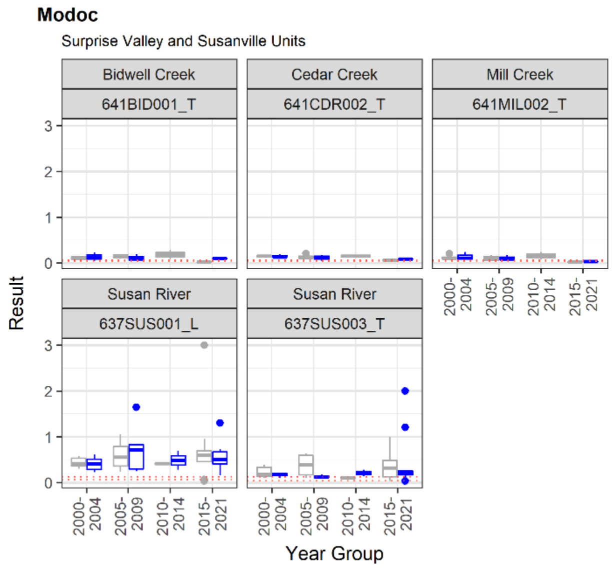


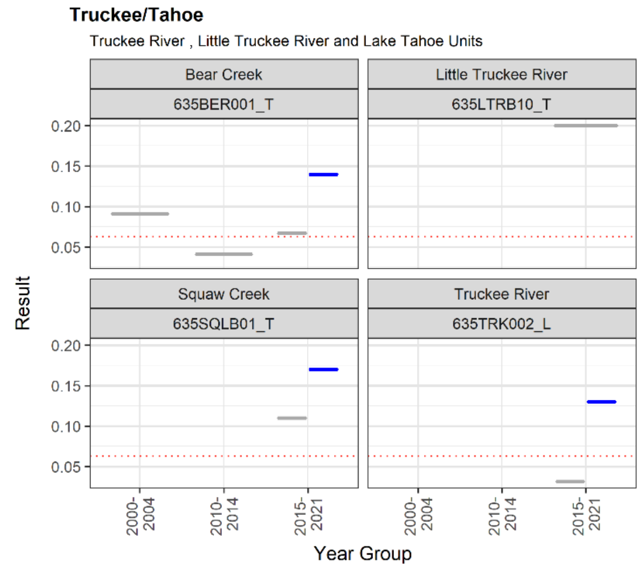


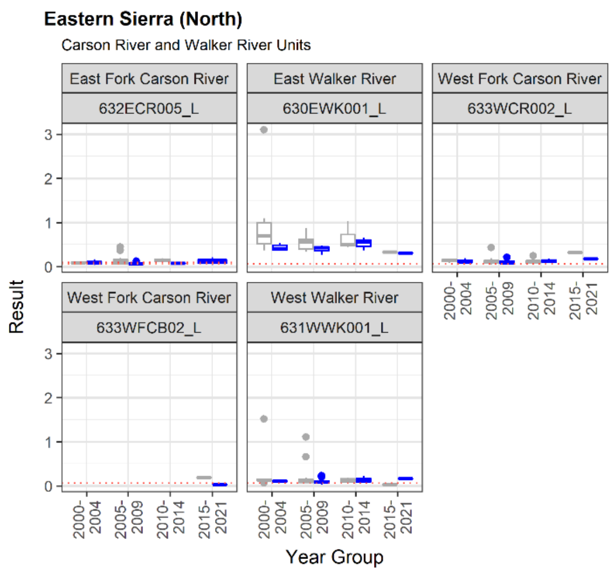


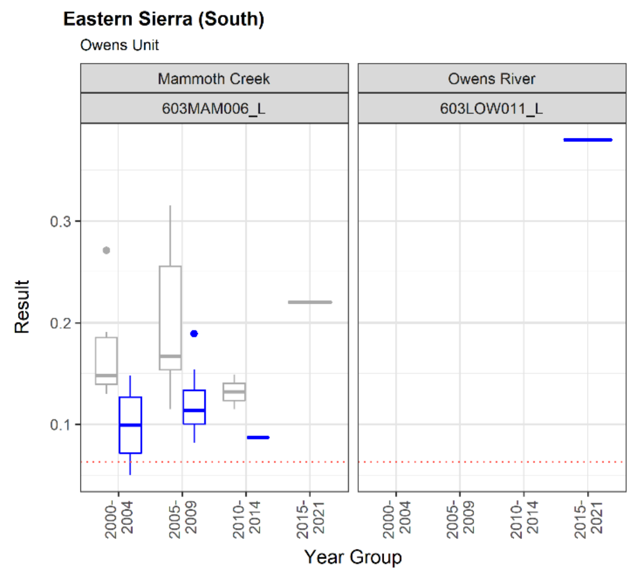
The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

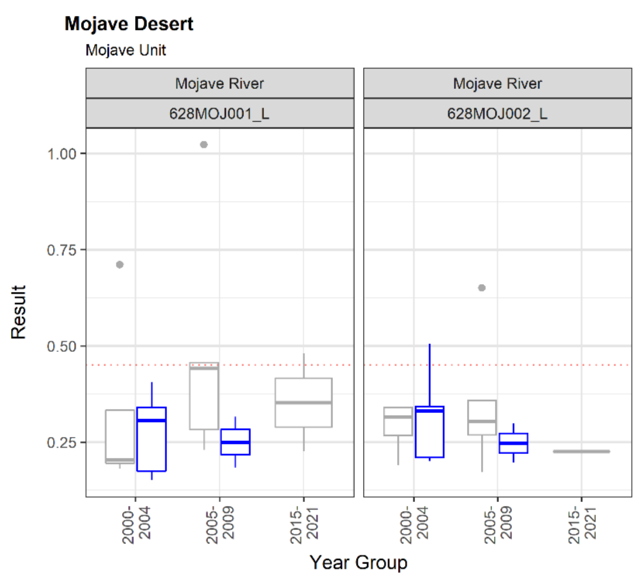
Total Nitrogen, Total Kjeldahl (mg/L)





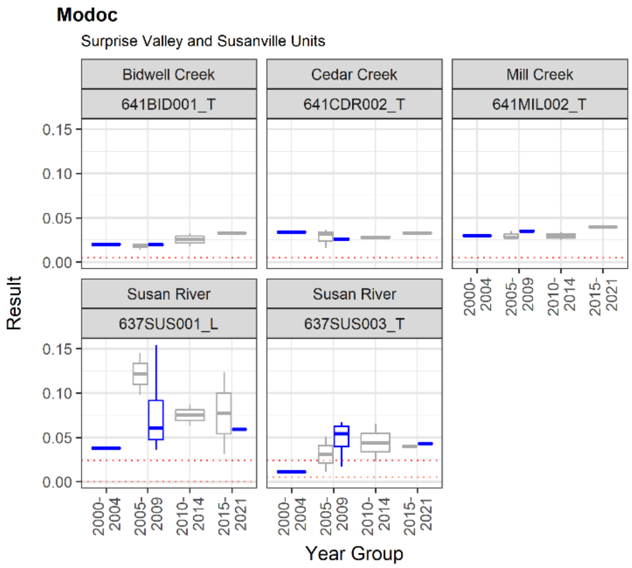


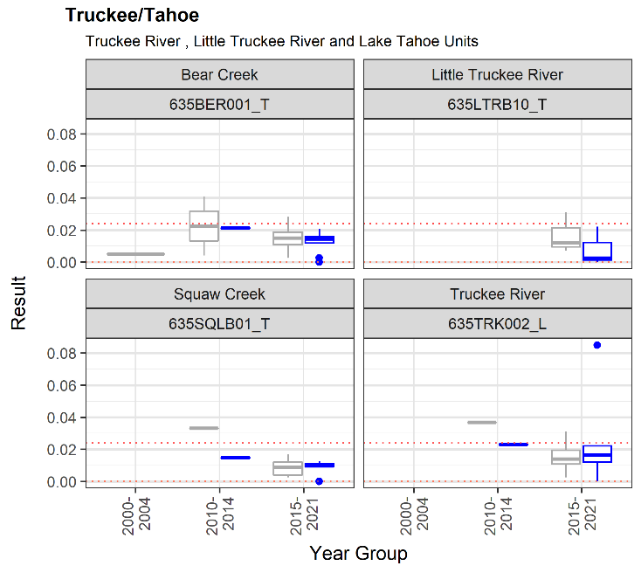


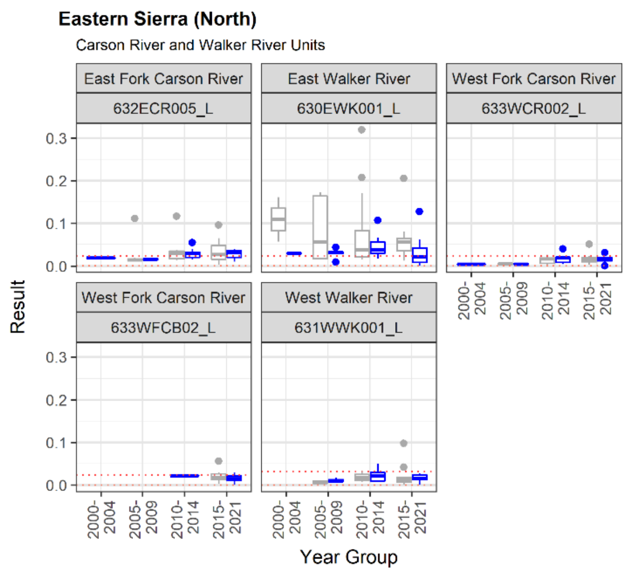


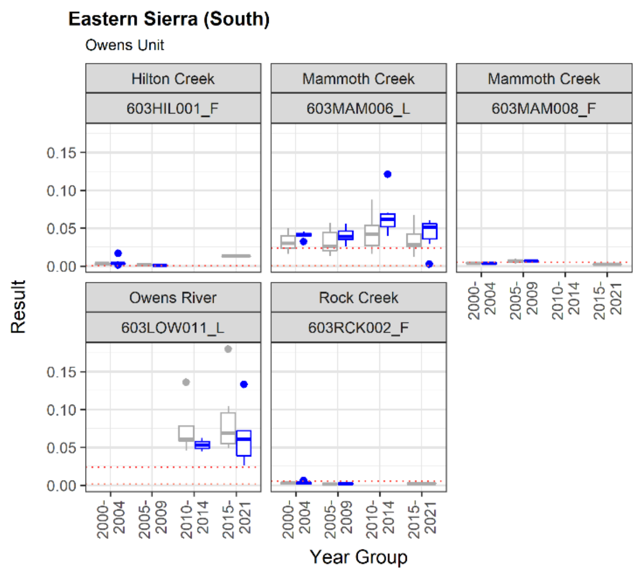
The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

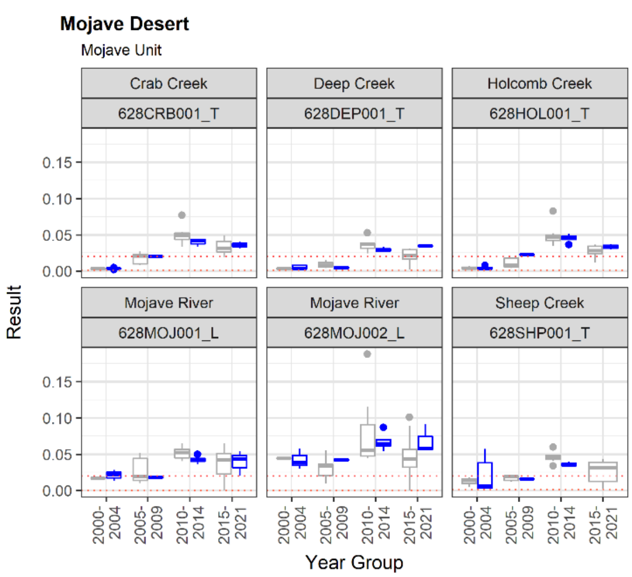
Dissolved OrthoPhosphate as P (mg/L)





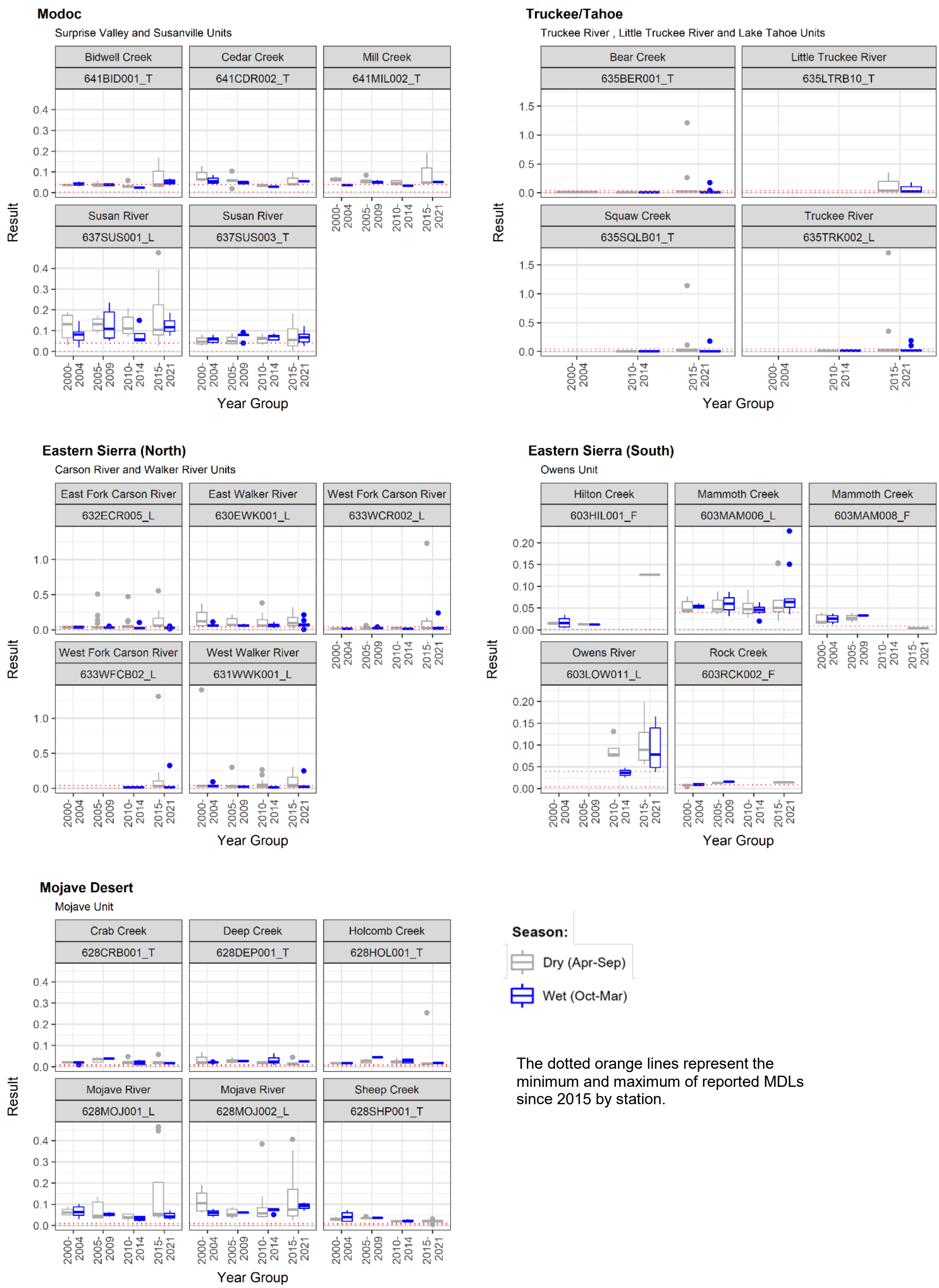






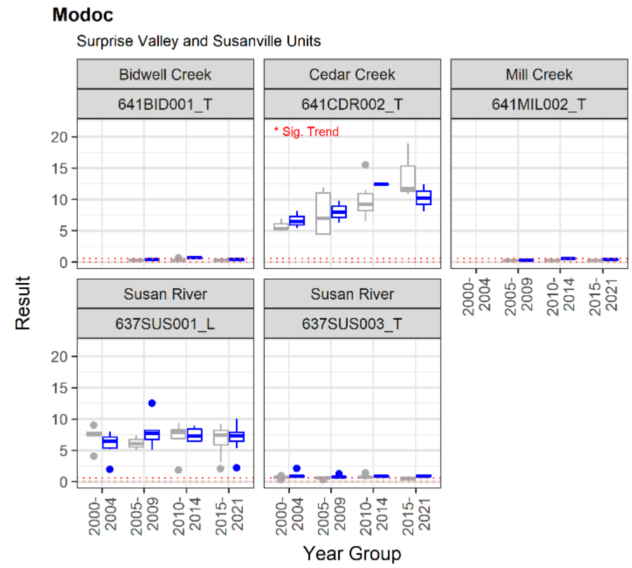
The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

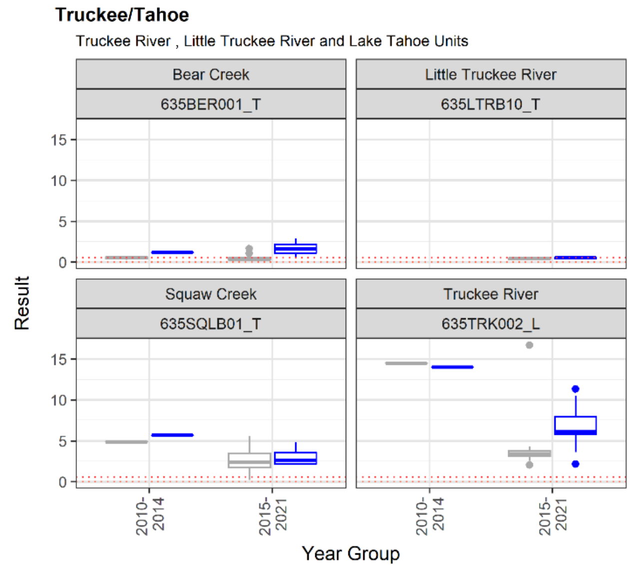
Total Phosphorus as P (mg/L)

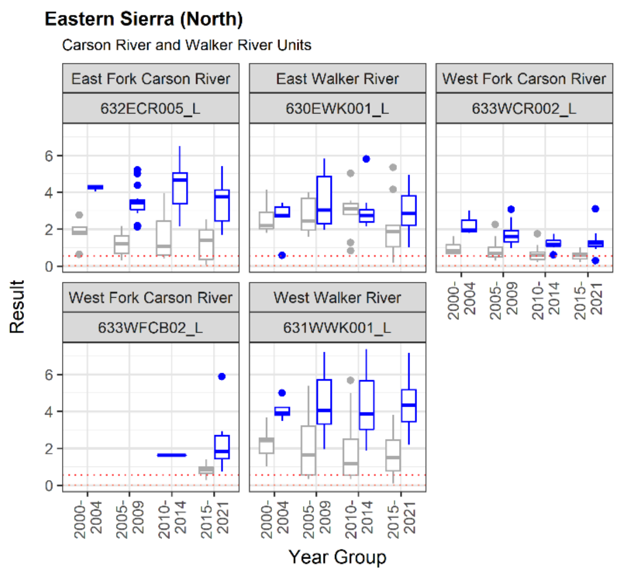


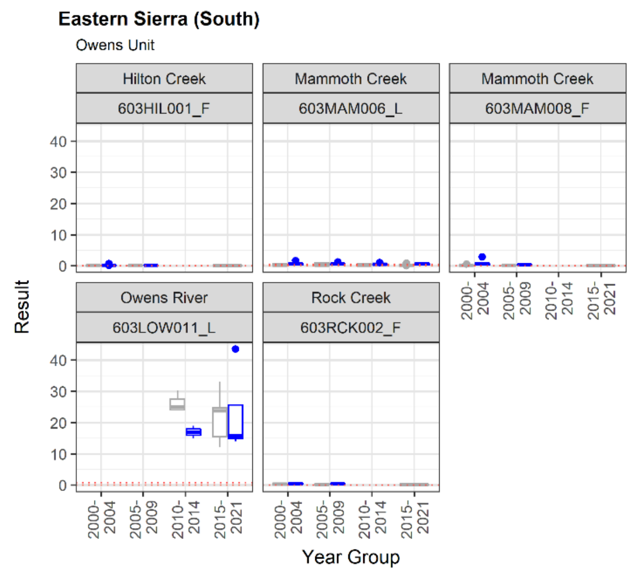
The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

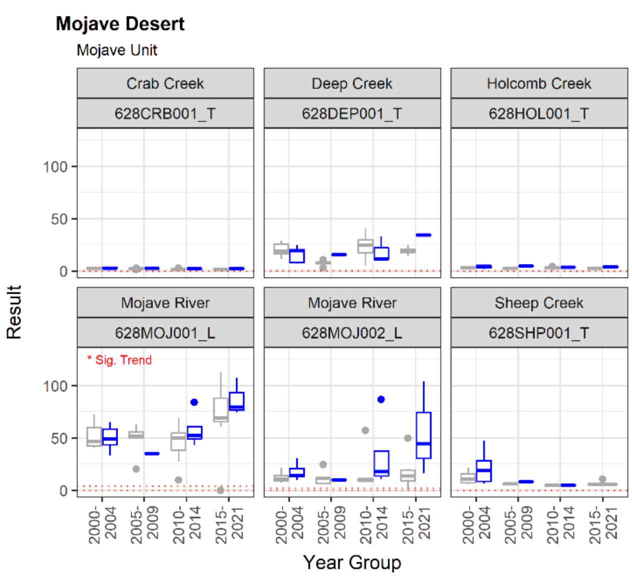
Dissolved Chloride (mg/L)





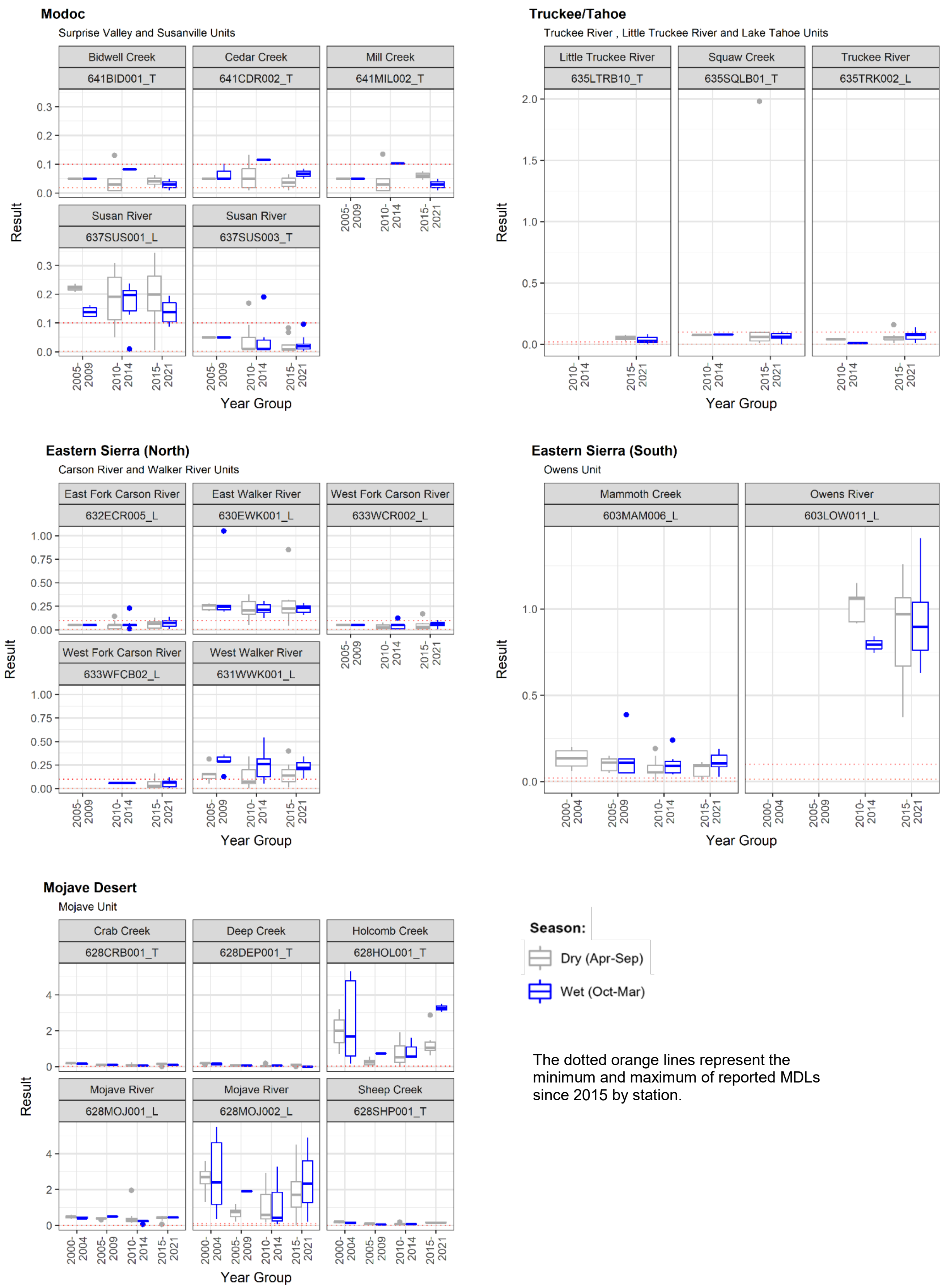






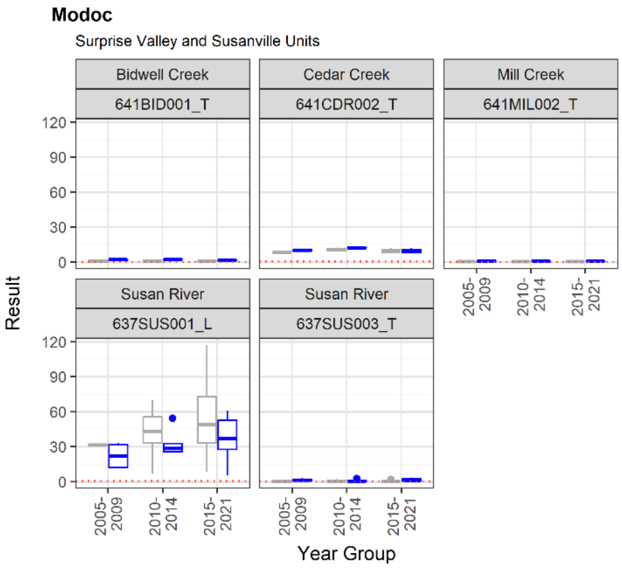
The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

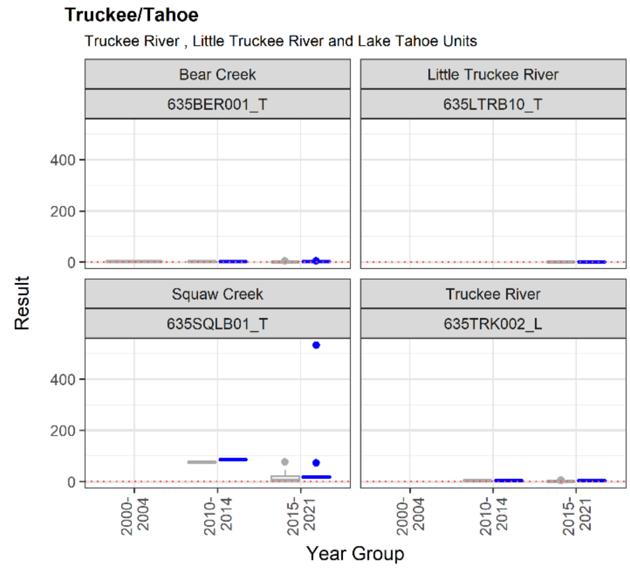
Dissolved Fluoride (mg/L)

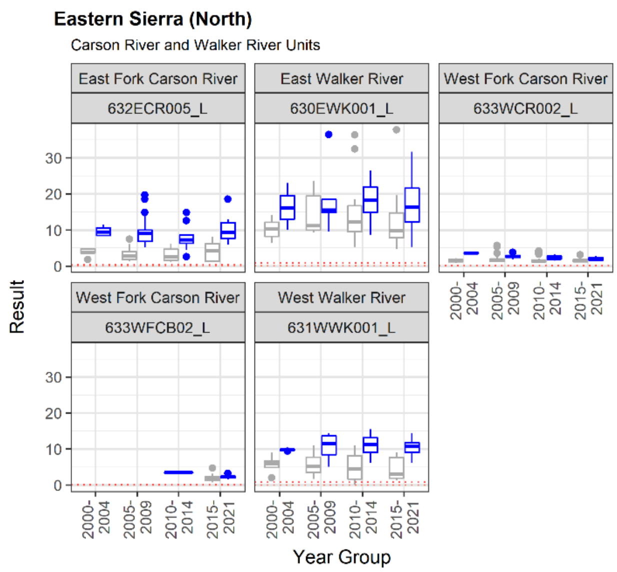


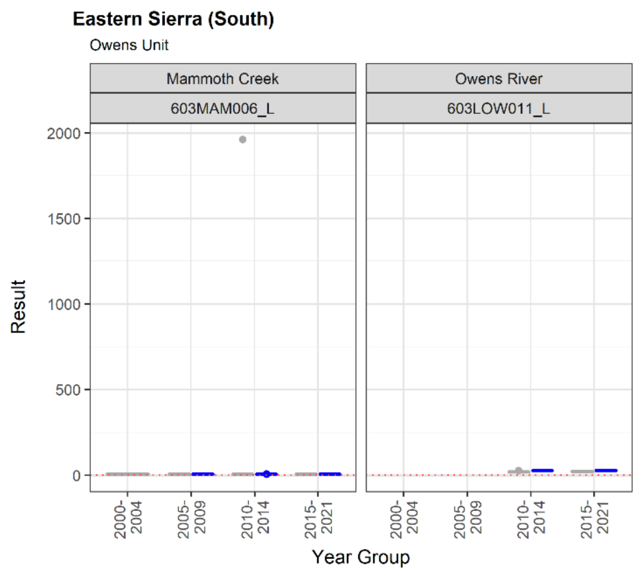
The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

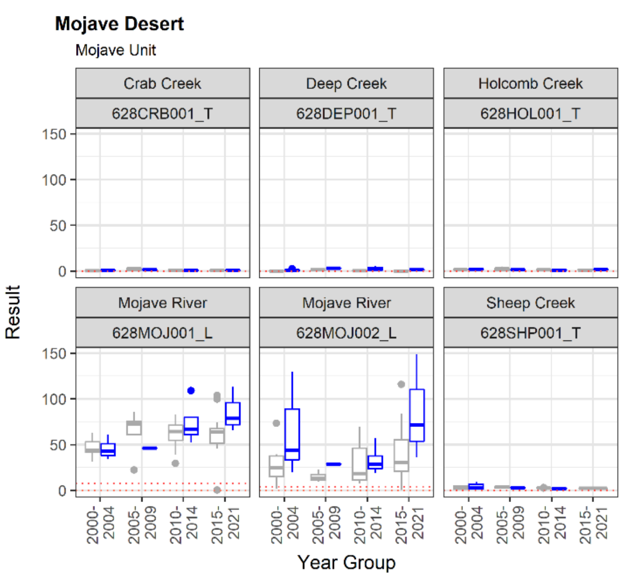
Dissolved Sulfate (mg/L)





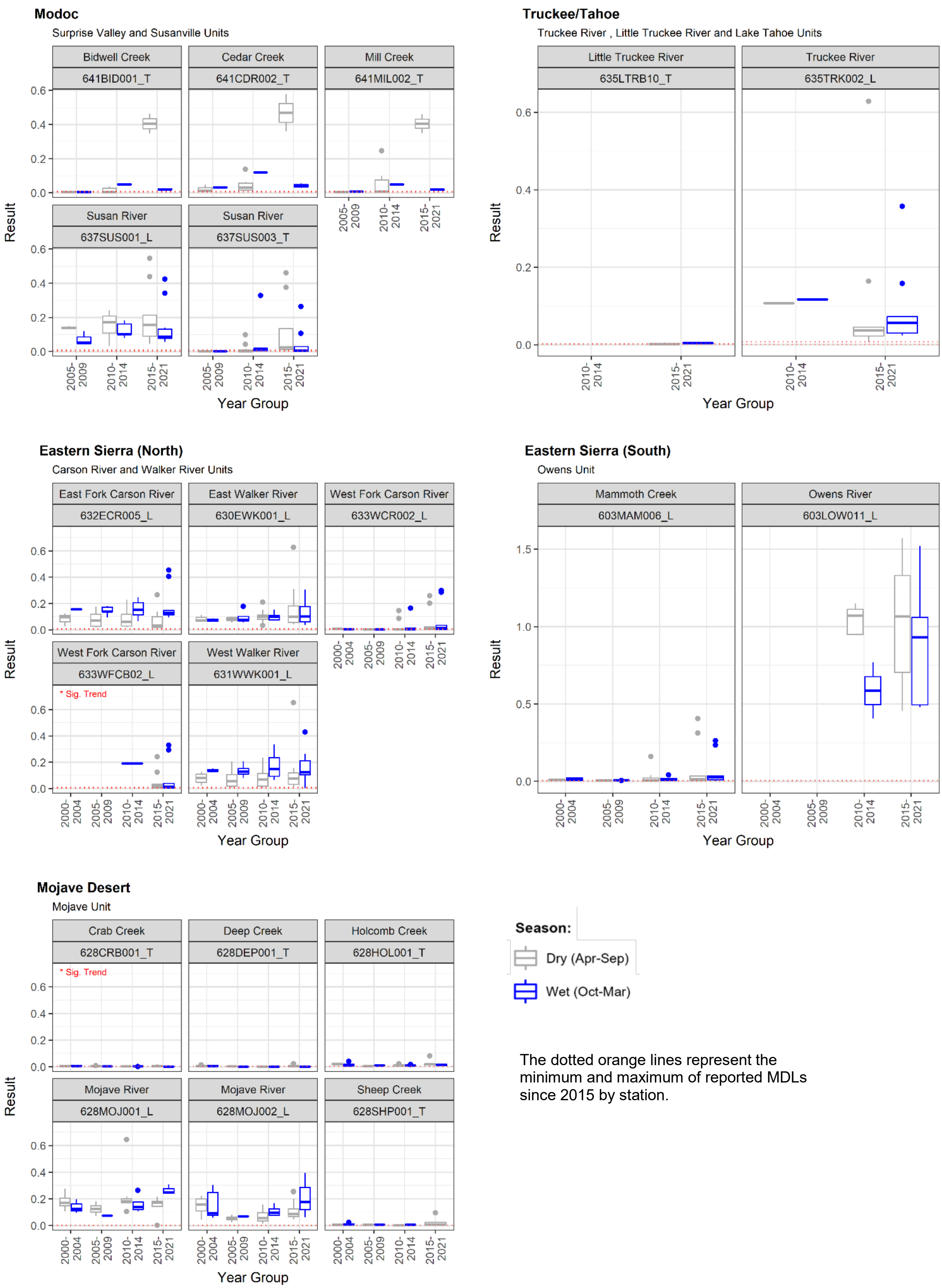




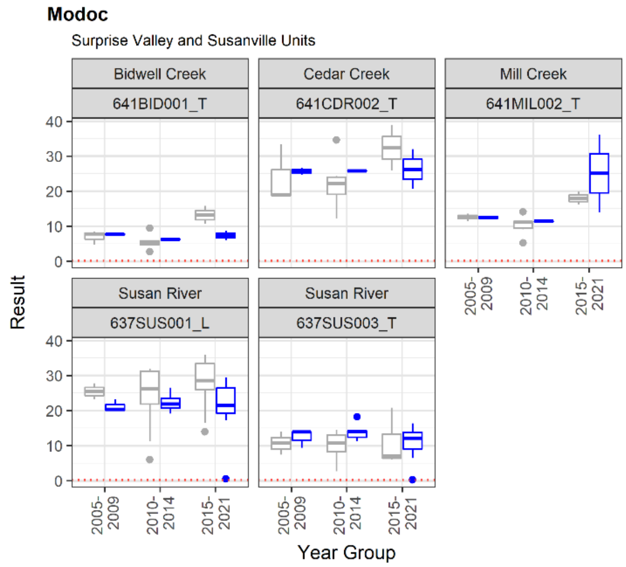


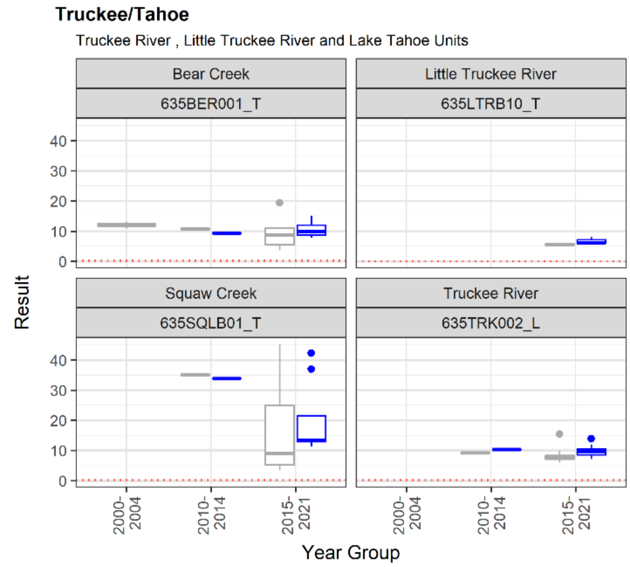
The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

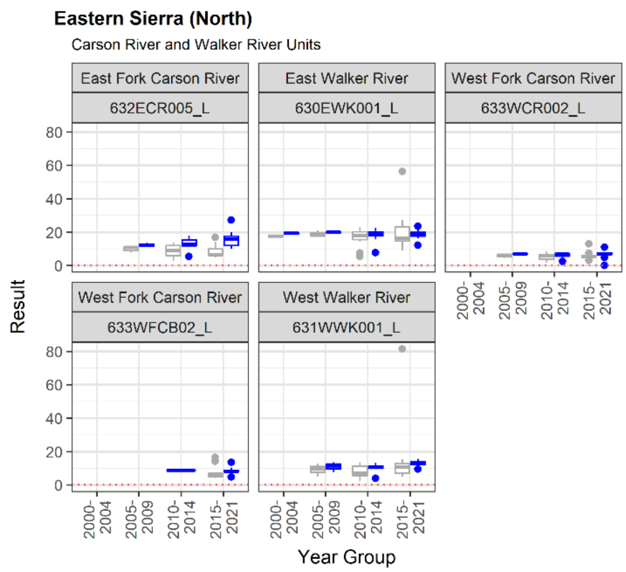
Dissolved Boron (mg/L)

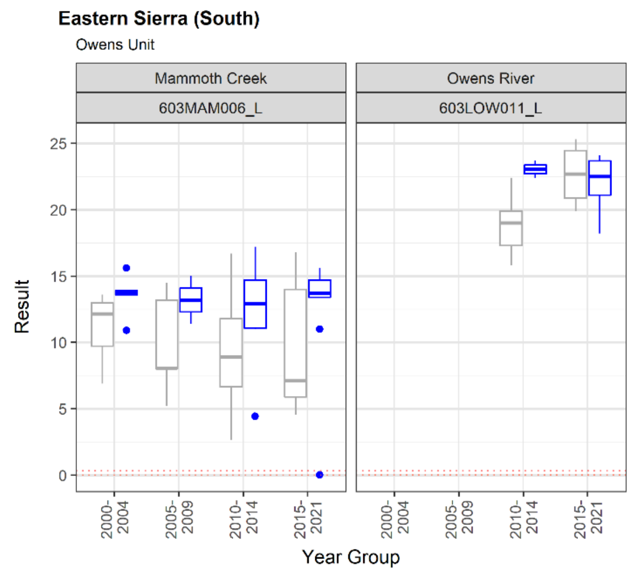


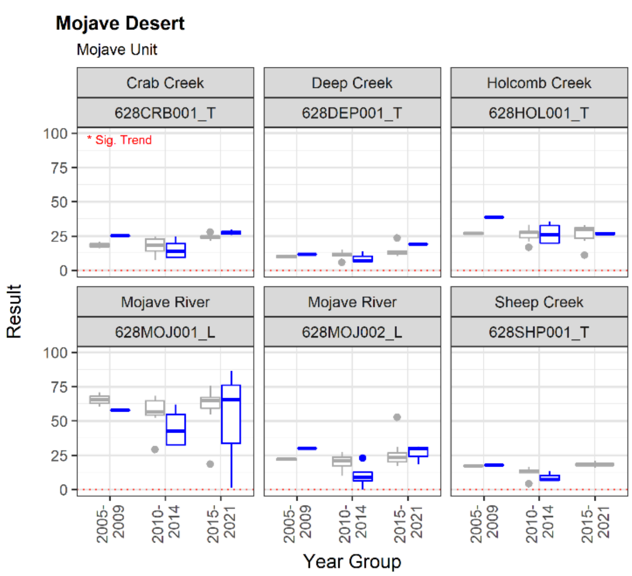
Dissolved Calcium (mg/L)





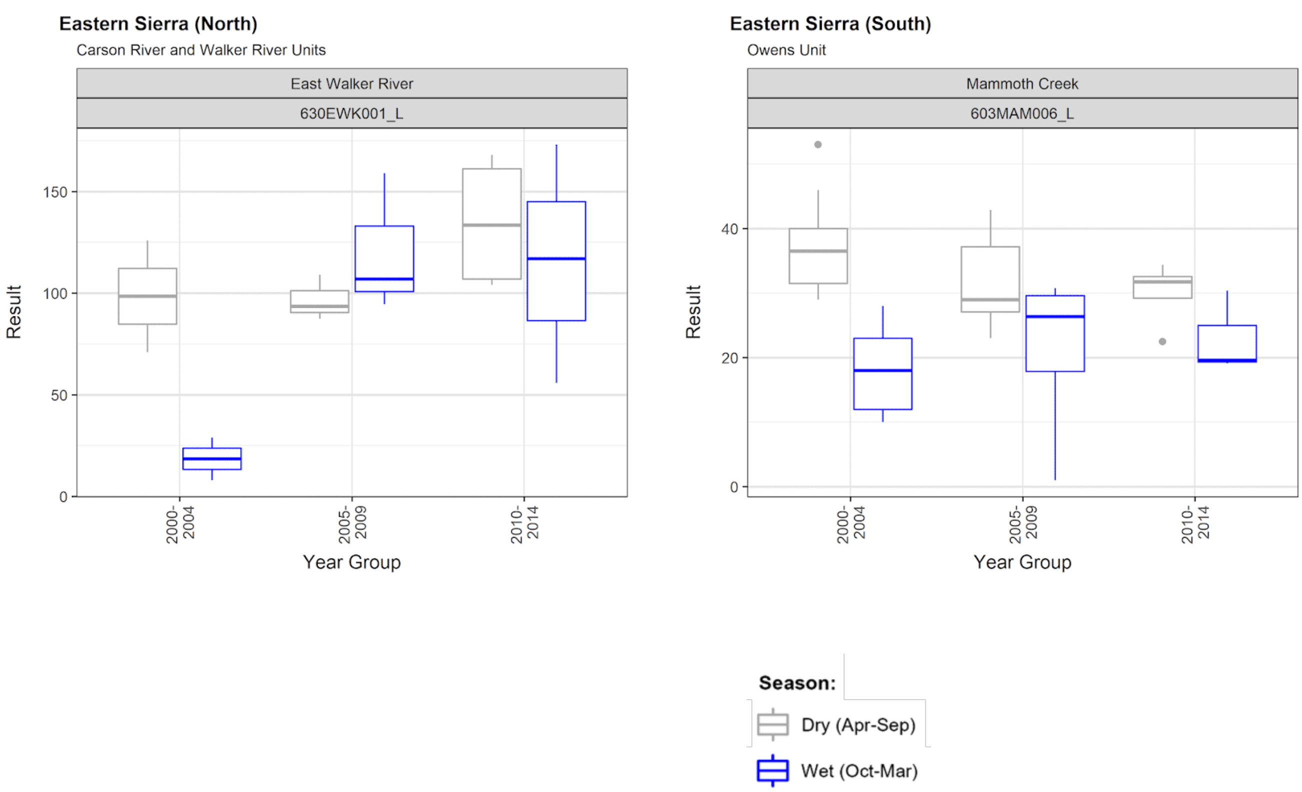




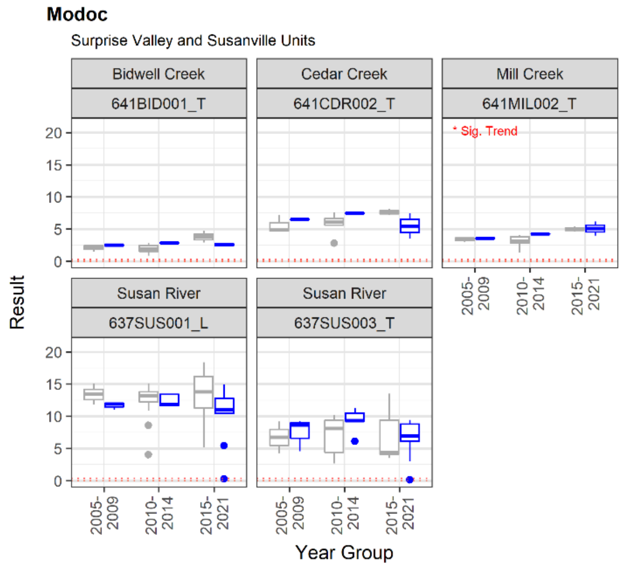


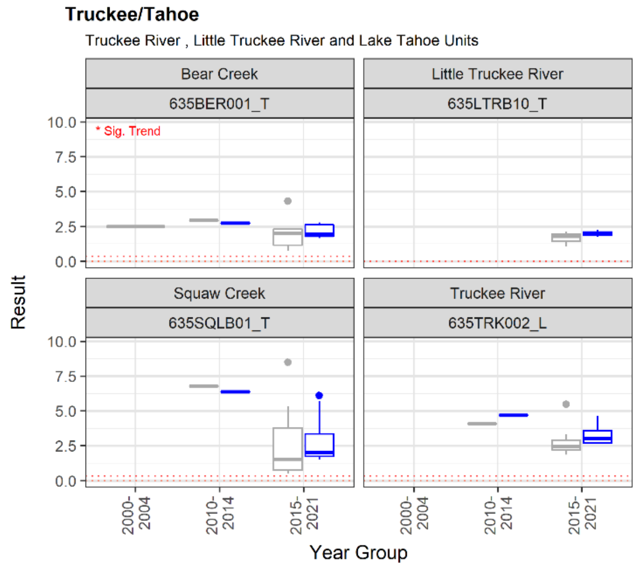
The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

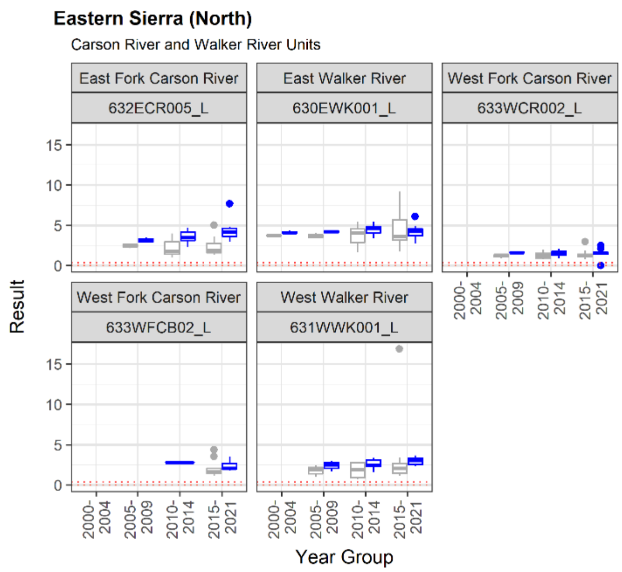
Dissolved Iron (ug/L)

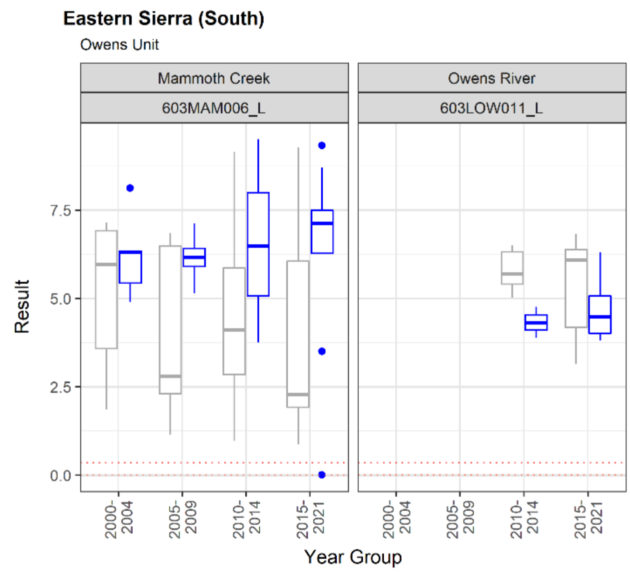


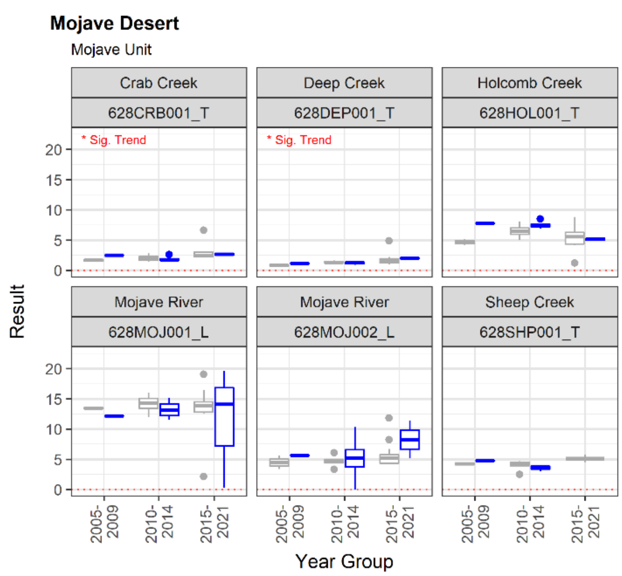
Dissolved Magnesium (mg/L)





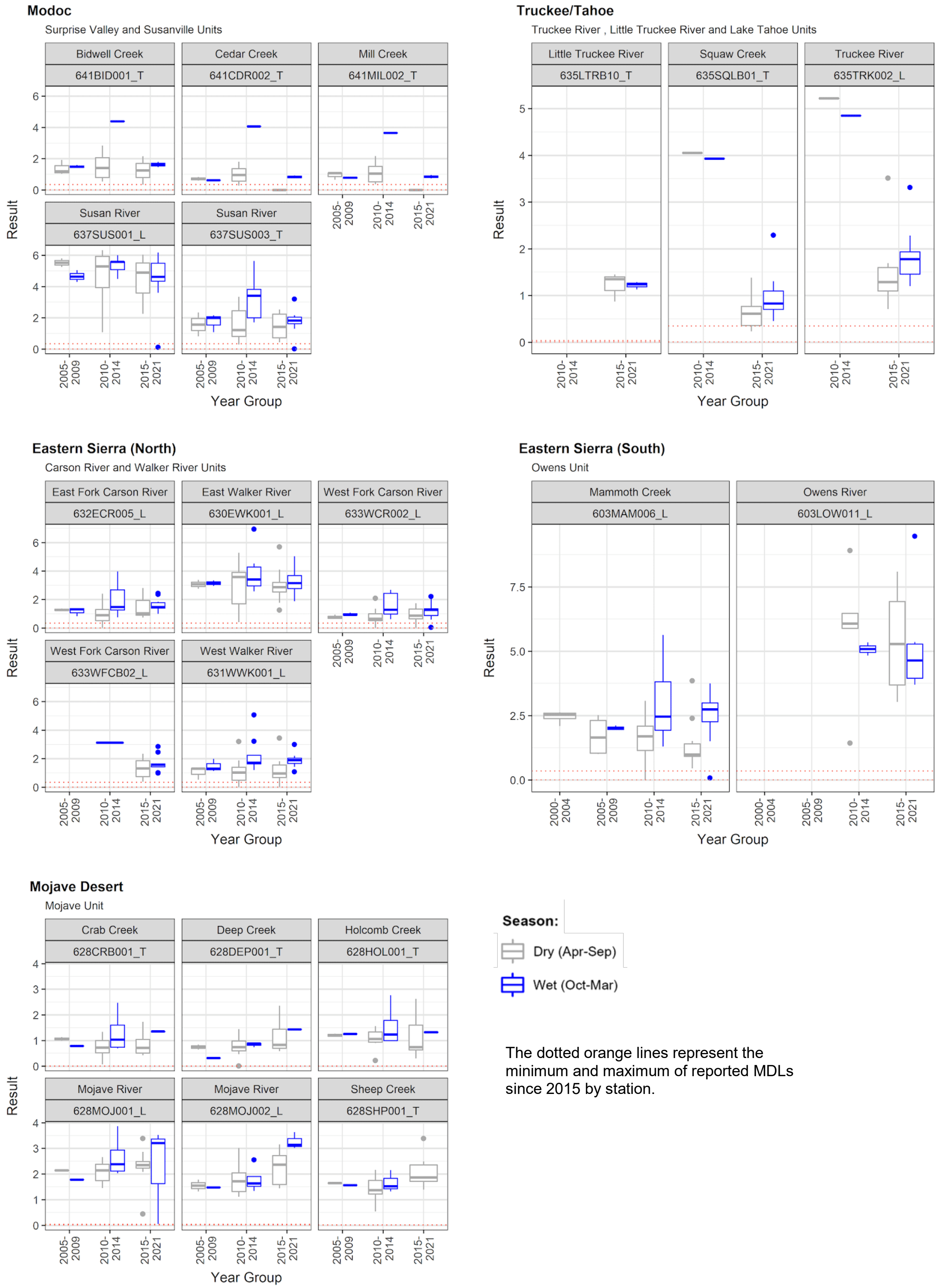






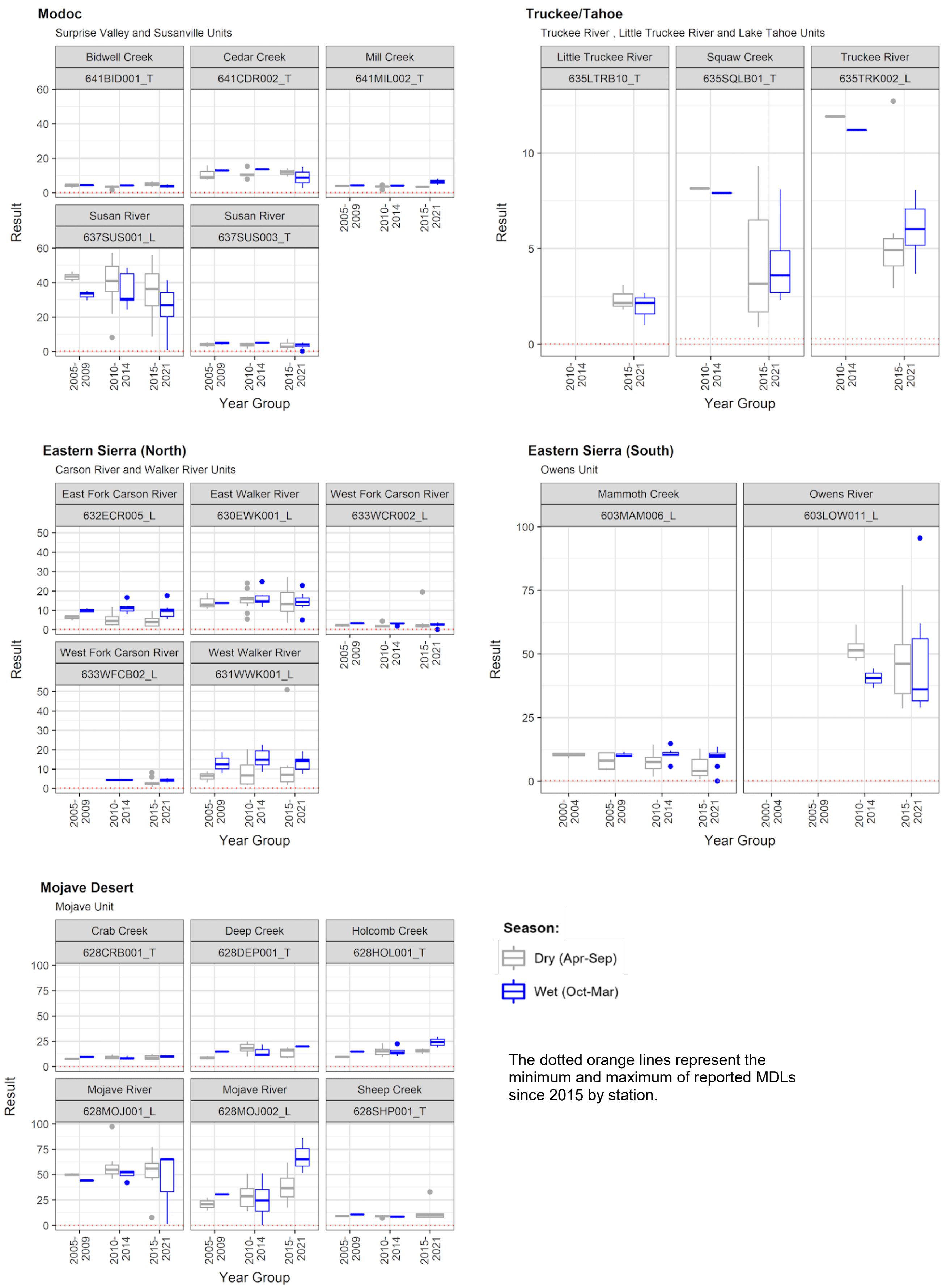
The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

Dissolved Potassium (mg/L)



The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.

Dissolved Sodium (mg/L)



The dotted orange lines represent the minimum and maximum of reported MDLs since 2015 by station.