Conjunctive Use Plan for the San Lorenzo Watershed

Initial Study – Mitigated Negative Declaration

Appendices: A through H

prepared by

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Appendix A

Water Availability Assessment

Water Availability Assessment for San Lorenzo River Watershed Conjunctive Use Plan

Water Availability Assessment for San Lorenzo River Watershed Conjunctive Use Plan

Prepared for

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Acronyms and Abbreviations

% avg	percent of average
% dfa	percent departure from average
ac	acre
af	acre-feet
afm	acre-feet per month
afy	acre-feet per year
ASR	aquifer storage and recovery
avg	average
cfs	cubic feet per second
cfs/mi^2	cubic feet per second per square mile
ck	creek
CY	calendar year (January–December)
dfa	departure from average
ft	feet
ft bgs	feet below ground surface
ft msl	feet above mean sea level
gpm	gallons per minute
gpd	gallons per day
hp	horsepower
in	inches
in/yr	inches per year
max	maximum
MHA	Mount Hermon Association
mi	mile
mi^2	square miles
min	minimum
mgd	million gallons per day
mgy	million gallons per year
mth	month
Oly-#	Olympia well
Paso-#	Pasatiempo well
QH-#	Quail Hollow well
SCCWD	Santa Cruz City Water Department
SGMA	Sustainable Groundwater Management Act
SLR	San Lorenzo River
SLRBT	San Lorenzo River at Big Trees (USGS gauging station)
SLVWD	San Lorenzo Valley Water District
SMGB	Santa Margarita Groundwater Basin
sp	spring
SVWD	Scotts Valley Water District
USGS	U.S. Geological Survey
UWMP	Urban Water Management Plan
WAC	Water Systems Consulting

WTP	water treatment plant
WY	water year (e.g., WY 2018 was October 1, 2017, to September 30, 2018)

Conversion Factors

1 af	=	43,560	ft^3	=	325,851	gal	=	0.326	mg
1 afm	=	0.0166	cfs	=	7.434	gpm	=	0.0107	mgd
1 afy	=	0.00138	cfs	=	0.620	gpm	=	892.1	gd
1 cfs	=	448.8	gpm	=	0.646	mgd	=	724.5	afy
1 gpm	=	1,440	gpd	=	0.526	mgy	=	1.6141	afy
1 mgd	=	1.547	cfs	=	694.4	gpm	=	1,121	afy

Limitations

The results of this study are suitable for a planning-level evaluation of conjunctive use alternatives. The synthesized monthly records of water supply and use have limited precision and should not be used to evaluate compliance with specific regulatory, water-right, or habitat requirements. The alternatives are evaluated under optimal, hypothetical conditions without full regard for infrastructure and operational limitations, and as such likely overestimate potential yields. The actual yield of existing and future infrastructure will depend on numerous factors beyond the scope of this analysis.

The approach used to evaluate and compare conjunctive use alternatives does not consider the effects of stream diversions or groundwater pumping other than by San Lorenzo Valley Water District (SLVWD). Beyond the simplified approach used for this study, evaluating the effects of groundwater pumping on streamflow requires use of a calibrated numerical groundwater flow model, which was outside the scope of this study. The conjunctive use alternatives are evaluated and compared on the basis of the 1970-2017 climatic period without considering potential climate change.

The report provides additional details about the methods, results, and limitations of this study.

Executive Summary

The San Lorenzo Valley Water District (SLVWD) and the County of Santa Cruz received California state grant funds to develop a conjunctive use plan to improve aquatic habitat and water-supply reliability within the San Lorenzo River watershed. As part of the plan's development, this water availability assessment identifies options for increasing water-supply reliability and dry-period streamflows through the conjunctive use of available surface water and groundwater resources.

SLVWD operates three water systems: the North system supplied by both stream diversions and pumped groundwater; the South system supplied solely by groundwater; and the Felton system supplied solely by stream and spring diversions. The neighboring Scotts Valley Water District (SVWD) and Mount Hermon Association (MHA) rely solely on groundwater. Each system produces water in response to relatively immediate water demand and all groundwater is produced from within the Santa Margarita Groundwater Basin (SMGB).

Increasing the conjunctive use of groundwater and surface water supplies within the San Lorenzo River watershed has the potential to improve water rights compliance, instream flows, and groundwater storage. The potential for increased conjunctive use is supported by the occurrence of divertible streamflows exceeding local demand, the recent construction of system interties, and SLVWD's mostly unused annual allotment of Loch Lomond Reservoir storage.

This report presents alternatives for optimizing the conjunctive use of current and potential water sources using existing and potential infrastructure to improve aquatic habitat and water-supply reliability within the San Lorenzo River watershed. For each alternative, Exponent performed an analysis of monthly water supply, water production, and projected 2045 water demand over the 48-year climatic cycle spanning water years (WY) 1970-2017. The approach requires estimates of monthly streamflows and potential diversions based on estimated frequencies of mean daily flow adjusted for month and hydrologic year-type (e.g., wet, dry, etc.). Alternative conjunctive-use scenarios are compared to a base case calibrated to SLVWD's proportional use of surface-water and groundwater during WYs 2000-2017.

In addition to a simulated base case, a total of 22 conjunctive-use alternatives are evaluated, grouped as follows:

Scenario 1 – Optimizes the use of current sources assuming existing or modified infrastructure.

Scenario 2 – Adds use of SLVWD's allotment of Loch Lomond Reservoir storage, which substitutes for unpermitted diversions and groundwater pumping, contributing to groundwater storage recovery through in-lieu recharge.

Scenario 3 – Increases the yield of the Olympia wellfield in the North System through operating an aquifer storage and recovery (ASR) project supplied by available surface water in excess of monthly water demand.

Scenario 4 – Provides the remaining available surface water to the Scotts Valley area for use as in-lieu recharge (i.e., used as a substitute for groundwater pumping, contributes to groundwater storage recovery).

Each alternative consists of four parts: (1) a model of monthly water demand, (2) synthetic records of monthly unimpaired flows and potentially divertible flows, (3) estimates of sustainable groundwater yield, including estimated yield reductions during drought and heavy demand; and (4) a monthly accounting of demand and supply for an assumed set of production capacities and an assumed prioritized use of individual surface water and groundwater sources.

The evaluation of each alternative includes estimating (a) percent reductions in unimpaired flow downstream of simulated diversions and impaired flow downstream in Boulder Creek and the San Lorenzo River; and (b) percent reductions in drought minimum stream baseflow down gradient of simulated wells. The estimated reductions in flow are plotted and reported as percentages of streamflow remaining. These results reflect the influence of SLVWD stream diversions and SLVWD, SVWD, and MHA groundwater pumping only.

The results are suitable for a planning-level evaluation of conjunctive-use alternatives. The scenarios are simulated under optimal, hypothetical conditions without full regard for infrastructure and other operational limitations, and as such likely overestimate potential yields. The actual yield of modified infrastructure will depend on numerous factors beyond the scope of this analysis. The presented values of simulated monthly flow have limited precision and should not be used to evaluate compliance with specific regulatory, water-right, or habitat requirements. Evaluating the effects of groundwater pumping on streamflow, beyond the approach used for this study, will require use of a calibrated numerical groundwater flow model, which was not within the scope of this study.

The results support the following observations:

- Potential water transfers using system interties are insufficient to achieve Felton water rights compliance. The North system has no unused potential diversions during months when the Felton system is not in compliance. Increased production from the Pasatiempo wells for transfer to Felton would require locally unprecedented rates of production from an over-drafted aquifer. A supplemental source, such as imports from Loch Lomond, may be needed more than 20 percent of the time to comply with water rights.

- Complying with the Felton system water rights notably increases the minimum percentages of flows remaining downstream, particularly for Bull Creek.

- Estimated increases in water production resulting from assumed increases in stream diversion capacity indicate a potential to increase yields from SLVWD's diversion streams.

- South system imports of North and/or Felton system unused potential diversions allow 30 to greater than 50 percent reductions in South system groundwater production.

- Supplementing the North system with Felton system unused potential diversions provides a 20 percent reduction in North system groundwater pumping.

- Supplementing the North system with extractions from a hypothetical ASR project supplied by North and/or Felton unused potential diversions provides roughly 30 to 60 percent net reductions in North system groundwater pumping.

- Stream diversions for in-lieu recharge and ASR occur during high-flow periods and have relatively little effect on minimum flows remaining downstream of the diversions.

- Use of SLVWD's Loch Lomond allotment allows the Felton system to comply with its permitted water rights as well as reduce South system groundwater pumping by roughly 60 to 70 percent; as a result, unused North and Felton system potential diversions are available for ASR instead of South system in-lieu recharge.

- A 60 to 70 percent reduction in South system groundwater pumping as a result of imports from Loch Lomond and/or unused potential diversions represents a significant contribution to SMGB groundwater storage recovery. The degree to which SLVWD could recover this storage is uncertain.
- Using the system interties to supply the South system with unused potential diversions uses roughly 40 and 50 percent of North and Felton system unused diversions, respectively.
- With the addition of a Loch Lomond supply, optimal use of North and Felton unused potential diversions requires ASR. As simulated under optimal conditions, ASR uses roughly half of the remaining unused diversions and helps reduce North system groundwater pumping by roughly 30 to 60 percent.
- Reduced groundwater pumping as a result of imports from Loch Lomond and the transfer of unused diversions increase the percentage of drought minimum baseflows estimated to remain in lower Newell, Zayante, and Bean creeks to 60 to 80 percent, compared to 50 percent or less for the base case.
- The remaining North and Felton system potential unused diversions (i.e., exceeding the capacity of the hypothesized ASR project) are assumed to be available for export to SVWD, which would further contribute to the recovery of SMGB groundwater storage.

In summary, system interties combined with potential supplemental water supplies provide SLVWD with significant options and flexibility for increasing conjunctive use and improving stream baseflows. The results provide qualitative indications of the potential relative magnitude and effects of the various conjunctive use alternatives. Further application of this work and the development of conjunctive use alternatives are expected to occur in the context of in-stream flow objectives proposed by fishery biologists, in addition to cost, feasibility, and water rights considerations.

1 Introduction

The San Lorenzo Valley Water District (SLVWD) and the County of Santa Cruz (the County) received California state grant funds to develop a conjunctive use plan to improve aquatic habitat and water-supply reliability within the San Lorenzo River watershed. As part of this plan's development, this water availability assessment identifies options for increasing water-supply reliability and dry-period streamflows through the conjunctive use of available surface water and groundwater resources.

SLVWD provides water to three service areas by operating three separate water systems supplied by diversions from San Lorenzo River tributaries and groundwater pumped from the Santa Margarita Groundwater Basin (SMGB; Figures 1-1 and 1-2). The North system is supplied by both stream diversions and pumped groundwater, whereas the South system is supplied solely by groundwater and the Felton system is supplied solely by stream and spring diversions (Figure 1-3). The neighboring Scotts Valley Water District (SVWD) and Mount Hermon Association (MHA) rely solely on groundwater pumped from the SMGB and, in the case of SVWD, recycled water. Each system produces water in response to immediate water demand given that these systems lack substantial surface storage.

Increasing the conjunctive use of groundwater and surface water supplies within the San Lorenzo River watershed has the potential to address several water-resource issues and opportunities. Increased conjunctive use practices may address the following issues:

- Under existing water rights, Felton system stream diversions are not permitted during defined low-flow periods and are not permitted for use outside the Felton service area.
- State and federal fish and wildlife agencies may impose limitations on the North system's pre-1914 appropriative water rights to divert surface water.
- Groundwater overdraft in the Scotts Valley area, including in the vicinity of SLVWD's South system, must be addressed in compliance with the 2014

California Sustainable Groundwater Management Act (SGMA), which includes preventing impacts to groundwater dependent ecosystems.

Opportunities that may facilitate increased conjunctive use include:

- Since 2014, SLVWD has constructed bidirectional emergency interties between its three systems and between SLVWD and SVWD. Although currently permitted for emergency use, these interties provide a potential means for transferring water supplies among service areas.
- When exceeding local demand, divertible streamflows within the North and Felton systems have the potential to supply demand in other areas and to augment groundwater recharge.
- SLVWD has an agreement, unused since 1977, allowing it to purchase from the City of Santa Cruz a portion of the water stored in Loch Lomond Reservoir, which could be used to offset stream diversions and increase groundwater storage.

The reader is referred to previous reports for descriptions of the climate, hydrology, and hydrogeology of the San Lorenzo River watershed and SLVWD's water use and management (e.g., Johnson 2009, 2015).

1.1 Objectives

This assessment evaluates alternatives for optimizing the conjunctive use of current and potential water sources, with existing and potential infrastructure, to improve aquatic habitat and water-supply reliability within the San Lorenzo River watershed. Specific objectives include:

- Optimizing the conjunctive use of available water resources for water-supply reliability and long-term sustainability.
- Reducing Felton diversions to comply with low-flow and dry-period water-rights restrictions.
- Reducing the effect of North system stream diversions and groundwater pumping on dry-period streamflows.

- Reducing groundwater pumping (e.g., by in-lieu recharge) to promote the recovery of groundwater storage and production in the South system and other portions of Scotts Valley.

The considered means for achieving these objectives include:

- Using the inter-system emergency interties to provide:
  - The Felton service area with excess water produced by the other two service areas at times when Felton system diversions are not permitted.
  - The South system and SVWD with excess stream diversions from the Felton and North systems.
  - The North system with excess diversions from the Felton system.
- Using SLVWD's Loch Lomond Reservoir allotment to reduce Felton system diversions, South system groundwater pumping, and North system diversions and groundwater pumping.
- Using excess surface water to supply an aquifer storage and recovery (ASR) project in the Olympia wellfield.

1.2 Approach

To address these objectives, this assessment performs a monthly analysis of SLVWD water demand, available supply, and production over a varied climatic cycle. This approach is based on the following assumptions:

- The evaluated climatic cycle is a repeat of the 48-year period from October 1969 through September 2017, i.e., water years (WYs) 1970–2017. This period includes three critical drought periods, WYs 1976–1977, 1987–1992, and 2012–2016, and is reasonably well supported by historical precipitation, streamflow, and water production records (Section 1.3). The potential impacts of climate change on water supplies have not been considered.

- Average annual water demand for each service area for the design climatic cycle is based on 2045 demands projected by the 2015 SLVWD Urban Water Management Plan (UWMP) (WAC 2016) (Section 2). Water-year and monthly demand is varied in response to the climatic cycle in a manner similar to the historical record.
- The effective capacities of existing stream diversions, groundwater wells, pipelines, and treatment plants are approximated from near-maximum monthly rates achieved during the historical record (Section 3).
- Estimates of monthly total, divertible, bypassed, and downstream flows are simulated from estimated monthly frequencies of mean daily flow, adjusted for water-year percent-of-average streamflow (Section 4). Synthetic monthly flows of the San Lorenzo River and Boulder Creek are generated using the same method to trigger Felton system diversion restrictions and evaluate the effect of diversions on downstream flows. This method improves upon previous conjunctive use analyses that used monthly timesteps without accounting for daily flow variability (e.g., HEA 1983, 1984; Geomatrix 1999; Johnson 2009, 2015, 2016).
- The historical record of groundwater pumping, groundwater levels, and precipitation is used to estimate sustainable rates of seasonal groundwater production during average and wet years and reduced rates of production as a result of lowered groundwater levels during drought years (Section 5). The application of numerical models to obtain more dynamic estimates of groundwater-surface water interactions was outside the scope of this study.

On this basis, Section 6 presents analyses of monthly water supply and demand for the WY 1970–2017 climatic cycle that address the objectives presented in Section 1.1. Alternative conjunctive use scenarios are compared to a base case representative of the proportional use of surface water and groundwater supplies during WYs 2000–2017. Four alternative scenarios are analyzed:

- **Scenario 1** optimizes the use of current sources assuming existing or modified infrastructure.
- **Scenario 2** adds the use of SLVWD's allotment of Loch Lomond Reservoir storage.
- **Scenario 3** increases the yield of the Olympia wellfield through operating an ASR project supplied by surface water supplies in excess of monthly water demand.
- **Scenario 4** uses available surface water in excess of local demand to further increase groundwater storage in the Scotts Valley area through in-lieu recharge (i.e., in addition to in-lieu recharge for the Pasatiempo area in Scenarios 1 through 3).

The results of each case are summarized in tables and plots, including monthly plots of the estimated percent of streamflow remaining downstream of each diversion. Appendix A provides the tabulated monthly results for the simulated base case and each alternative conjunctive use scenario.

Section 7 provides conclusions and recommendations based on a summary of the results.

1.3 Available Data

Tables 1-1 and 1-2 summarize data records relevant to this study for precipitation, streamflow, diversions, and groundwater levels and pumping.

The climatic record is well represented by several stations with long-term precipitation records and the U.S. Geological Survey (USGS) gauging record for the San Lorenzo River at the Big Trees (SLRBT) station near Felton (Tables 1-1 and 1-2; Figure 1-4). However, the applicability of the SLRBT record to SLVWD's tributary diversion watersheds is limited because of significant differences in watershed area, physiography, hydrology, geology, and land use.

SLVWD has records of its North system monthly surface water diversions beginning January 1984 (Table 1-1). The available record for the Felton system surface water diversions extends back to January 1993. Because the diversion streams have not been fully gauged until recently, these records provide a lower bound for estimating total streamflow. Previous studies have extrapolated these records on a monthly basis to estimate potential diversions under existing infrastructure and water-rights conditions (Johnson 2009, 2015). However, these records are insufficient for estimating the remaining portion of streamflow available to support habitat or the potential for additional diversions.

Each SLVWD diversion stream has been gauged more or less continuously since 2013 or 2014 (Table 1-1). Except for the gauge immediately upstream of the Fall Creek diversion, the gauged records do not include the amount diverted. The first years of gauging coincided with the WY 2012–2015 drought, followed by nearly average precipitation in WY 2016, and a very wet WY 2017. Despite nearly average to well-above-average precipitation in WYs 2016 and 2017, stream baseflows during those years had not recovered fully from the preceding drought. Provisional gauging records of mean daily flow expressed in cubic feet per second (cfs) were provided for this study (Ruttenberg 2018, pers. comm.).

SLVWD has records of its North and South system monthly groundwater pumping since January 1984 and groundwater levels as early as 1976 (Table 1-1). SVWD and MHA groundwater pumping and water-level records extend back to 1976 and 1992, respectively.

Table 1-2 summarizes periods of record for selected stream gauges other than those summarized in Table 1-1. Boulder Creek, the receiving stream for two SLVWD North system diversion streams, was gauged continuously by the USGS during WYs 1969–1993. USGS-gauged streams potentially influenced by SLVWD groundwater pumping include Zayante Creek (gauged WYs 1958–1993) and Bean Creek (gauged WYs 1989–2007). Other USGS gauged streams with watershed conditions somewhat similar to SLVWD's diversion watersheds include Laguna and Majors creeks (gauged WYs 1969–1976) and San Vicente Creek (gauged WYs 1970–1985;

Figure 1-4). The County has gauged streams at stations throughout the San Lorenzo River watershed with varying frequency since 1975, mostly under low-flow conditions. Since 2014, gauging has been conducted for SLVWD at stations on Boulder, Zayante, Lompico, and Bean creeks, and the San Lorenzo River (Balance Hydrologics 2015, 2016, 2018). The City of Santa Cruz has gauged Newell Creek during portions of WYs 2009–2010 and 2014–2016 (Bassett 2018, pers. comm.).

	Water Years*																																															
Data Set	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
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Lockheed	🟨 ←1889	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
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Diversion watershed stream flows																																																
Peavine Creek at diversion**															▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*																🟩 x	🟩	🟩	🟩 x	🟩 x
Foreman Ck at and downstream of diversion**															▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*																	🟩 x	🟩	🟩 x	🟩 x
Clear Creek at diversion**															▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*																	🟩 x	🟩	🟩	
Sweetwater Creek at diversion**															▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*	▧ *e*																	🟩 x	🟩	🟩	
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Metered SLVWD surface-water treatment																																																
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Metered groundwater levels and pumping																																																
SLVWD North system wells																																																
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Quail Hollow water levels							▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
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SLVWD South system wells																																																
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SVWD wells																																																
Pumping							▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩	▩
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MHA wells																																																
Pumping																							🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧
Water levels																										🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧

Sources:

🟩 Balance Hydrologics (2016, 2018) for SLVWD
▤ California American Water records
▤ Citizen Utilities records
▧ Geomatrix Consultants (1999) for SLVWD
🟨 Lockheed records
🟪 Lompico County Water District records
🟧 Mount Hermon Association records
🟦 NOAA (https://www.ncdc.noaa.gov/cdo-web/datasets)
▨ SLVWD records
▩ SVWD records

wet year 1983
dry year 1976

Wet year ≥ 125% of average water-year rainfall
Dry year ≤ 80% average water-year rainfall

* e.g., water year 2017 extended from October 1, 2016 through September 30, 2017.
** Gauged records for "at diversion" exclude diverted flows.
x Partial water-year record.
(x) Point of diversions moved upstream to provide gravity flow to Lyon WTP.
e Estimated monthly flow record.

Table 1-1
Periods of Record for Precipitation, Stream Diversions, and Groundwater Water Levels and Pumping

Stream	Gauge No.	No. Measure-ments	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Boulder Creek																																																										
at Melissa Lane	2590	63																															i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i				
at Jamison Creek	2581	75																										i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i				
at Bracken Brae	2560	31																															i	i	i	i	i	i	i	i	i	i	i	i																
~1,100 ft upstream of San Lorenzo River		●																																																							🟩	🟩	🟩	🟩
about 400 feet upstream of Highway 9		●																																																							🟩	🟩	🟩	🟩
at Highway 9	251	152															i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i																					
at San Lorenzo River	250	130																										i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	
above San Lorenzo River	11160070	●																	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	x																						🟩	🟩	🟩	🟩
San Lorenzo River																																																										
at Waterman Gap	349	244															i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i														
near Boulder Creek	11160020	●									x	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	x																								
at Two Bar Creek	300	99																															i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
below Boulder Creek	2499	52																										i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i				
~1,100 ft downstream of Boulder Creek		●																																																							🟩	🟩	🟩	🟩
above Love Creek	180	122																										i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
~350 ft downstream downstream of Clear Creek		●																																																							🟩	🟩	🟩	🟩
at Mt. Cross Bridge	140	100																										i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i				
~400 ft upstream of Hwy 9 downstream of Fall Ck		●																																																							🟩	🟩	🟩	🟩
at Big Trees USGS	11160500	●	← 1937	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Newell Creek																																																										
below Dam	158	71																										i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i				
		69																																																	i	i	i			i	i	i	
at Rancho Rio	154	91																i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i				
at San Lorenzo River in Glen Arbor	150	131																										i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	
		69																																																	i	i	i			i	i	i	
at San Lorenzo River (estimated baseflows only)																									e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e	e																	
at Ben Lomond	11160200	●	← 1958													i	i	i																																										
Fall Creek at San Lorenzo River	110	25															i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i																
Lompico Creek																																																										
100 feet downstream of diversion at LCWD office		●																																																							🟩	🟩	🟩	🟩
at Carrol Ave	7528	125																										i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
at 2nd Carrol Ave Br	7542	26																i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i																							
Zayante Creek																																																										
at USGS gage	762	380															i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
at Zayante	11160300	●	← 1958	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	x																							
near former USGS gage site		●																																																							🟩	🟩	🟩	🟩
below Lompico Creek	749	56																															i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i				
McHenry Road Spring	73S	45																															i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i				
at Woodwardia Ave	73	93																			i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i				
at San Lorenzo River	70	170																								i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
Bean Creek																																																										
above Grazing Area	7142	72																															i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
Lockhart Gulch at Bean Creek	711	50																															i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i				
below Lockhart Gulch	7109	76																										i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i			
225 ft downstream of Lockhart Gulch Bridge	7117	27																											i	i																														
Dufour Creek above pond	71083P	88																												i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i				
at USGS gage	?	●																														🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦							🟩	🟩	🟩	🟩
at Mt Hermon Rd (USGS)	7106	145															i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i			
above Zayante Creek	71	108																															i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
Majors Creek near Santa Cruz	11161570	●										🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦																																									
Laguna Creek near Davenport	11161590	●										🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦																																									
San Vicente Creek near Davenport	11161800	●											🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦																																

Water Years*

Sources:

🟦 USGS (https://waterdata.usgs.gov/ca/nwis/sw)

🟨 Santa Cruz County records

🟩 Balance Hydrologics (2016, 2018) for SLVWD

🟪 City of Santa Cruz

🟦 Johnson (2003)

● Gauged continuously

* e.g., WY 2018 was October 1, 2017 to September 30, 2018.

x Partial water-year record.

i Intermittent low-flow measurements.

e Continuous baseflow record estimated from intermittent low-flow measurements.

wet year 1983

dry year 1976

wet year ≥ 125% of average water-year rainfall

dry year ≤ 80% average water-year rainfall

Table 1-2
Periods of Record for Selected Stream Gauging Stations

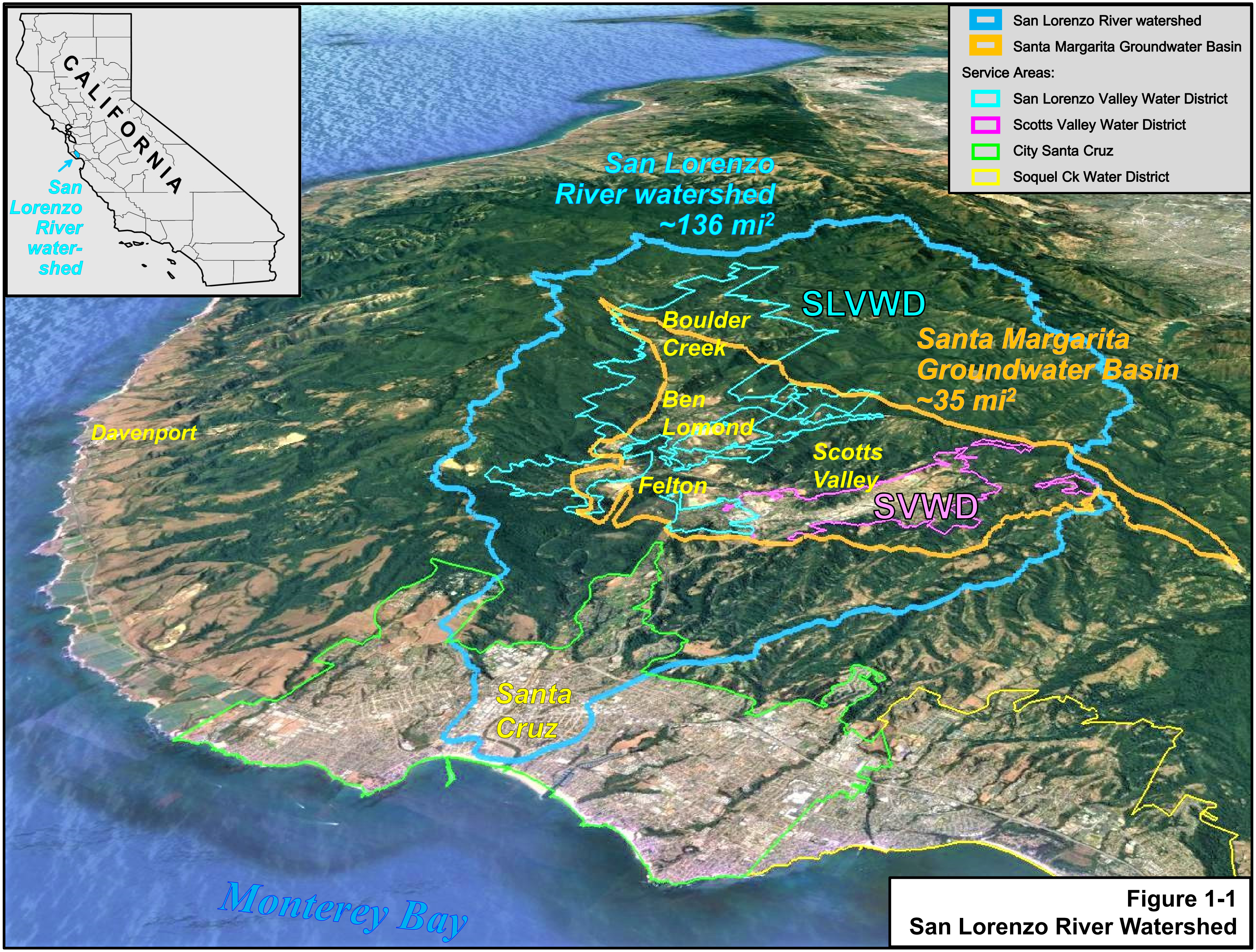


Figure 1-1
San Lorenzo River Watershed

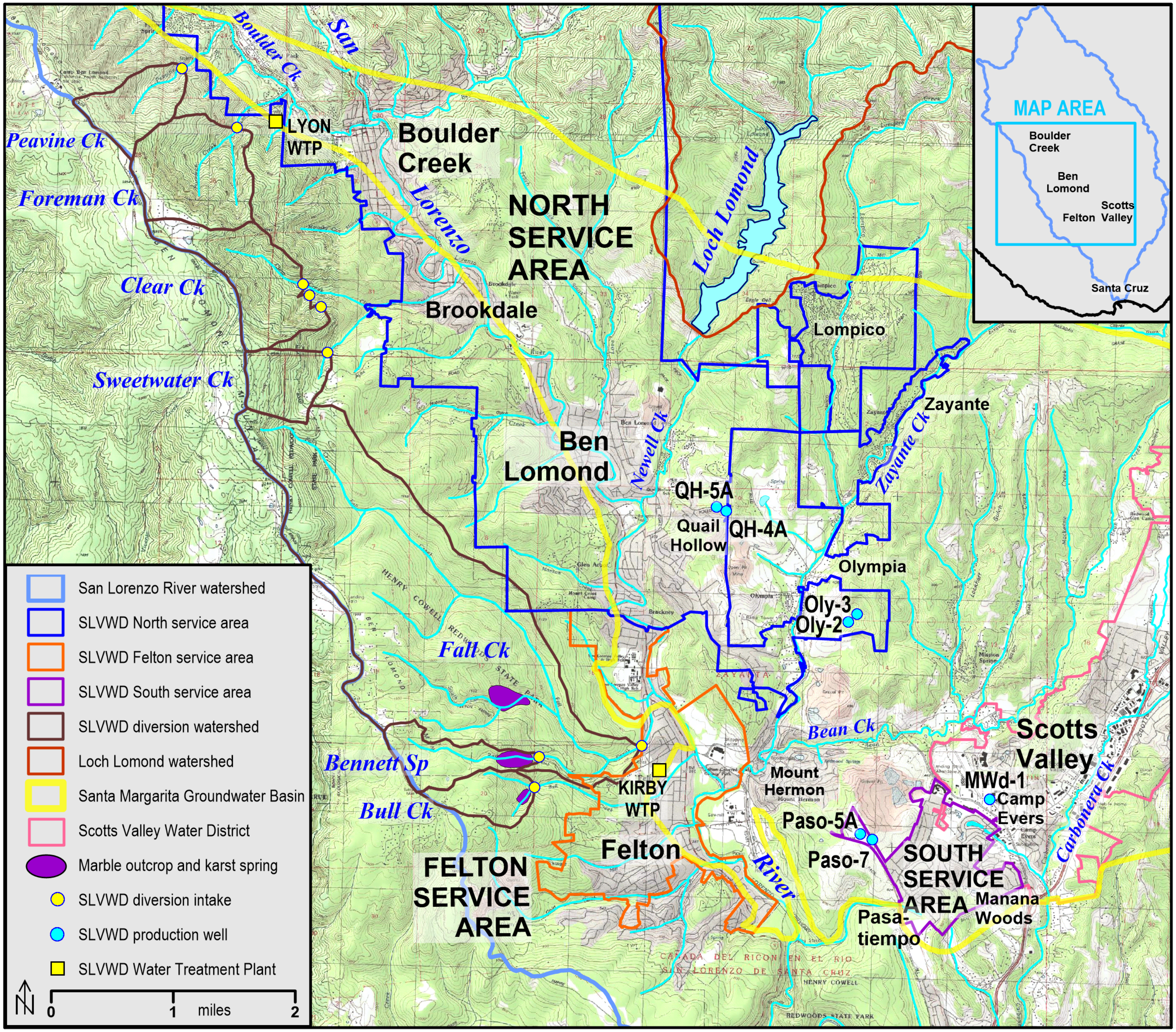
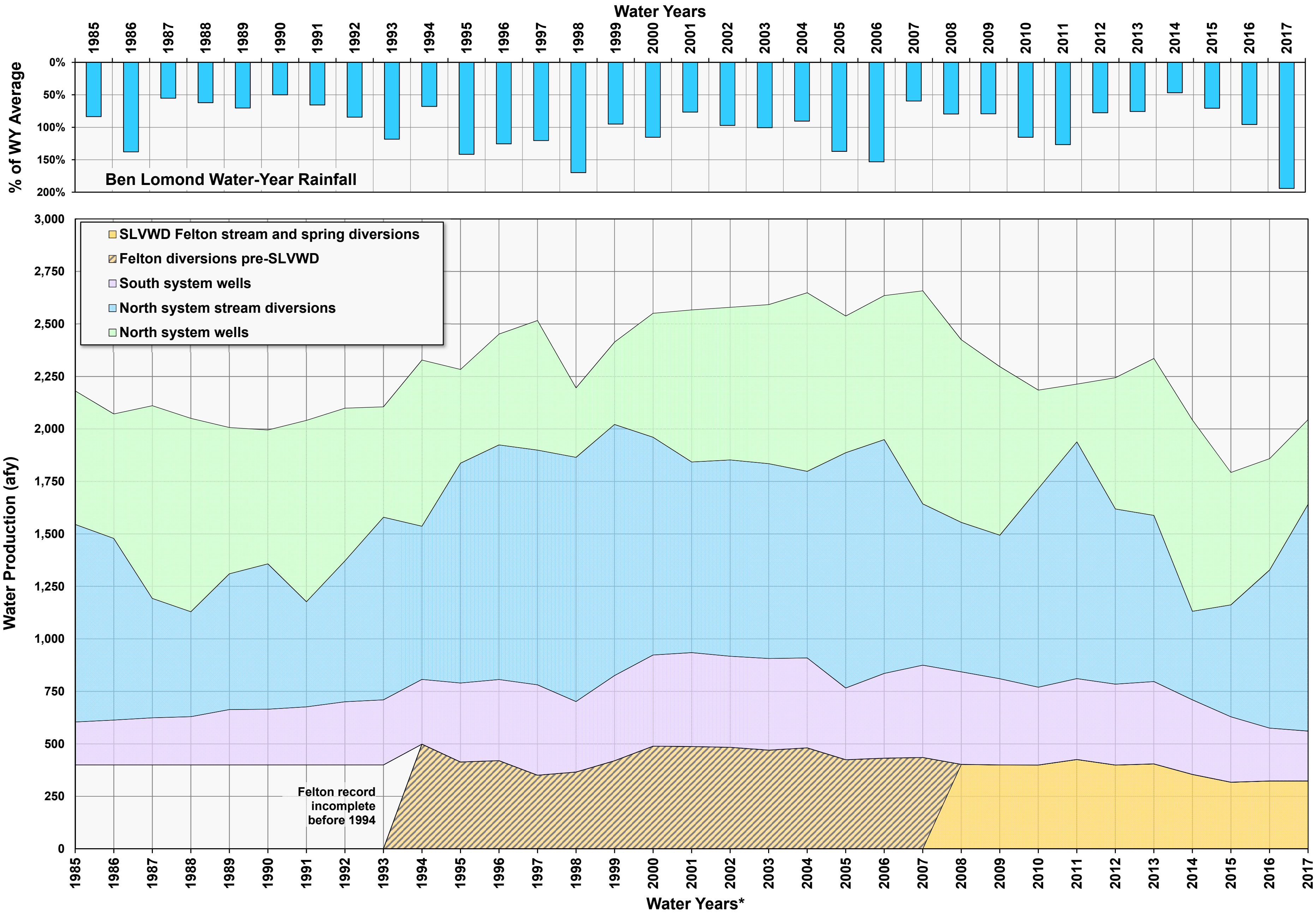


Figure 1-2
SLVWD Service Areas, Diversion Watersheds, Points of Diversion, Treatment Plants, and Production Wells



afy acre-feet per year

* e.g., WY 2018 was from October 1, 2017 to September 30, 2018.

Figure 1-3
SLVWD Annual Water Production by System, WYs 1985–2017

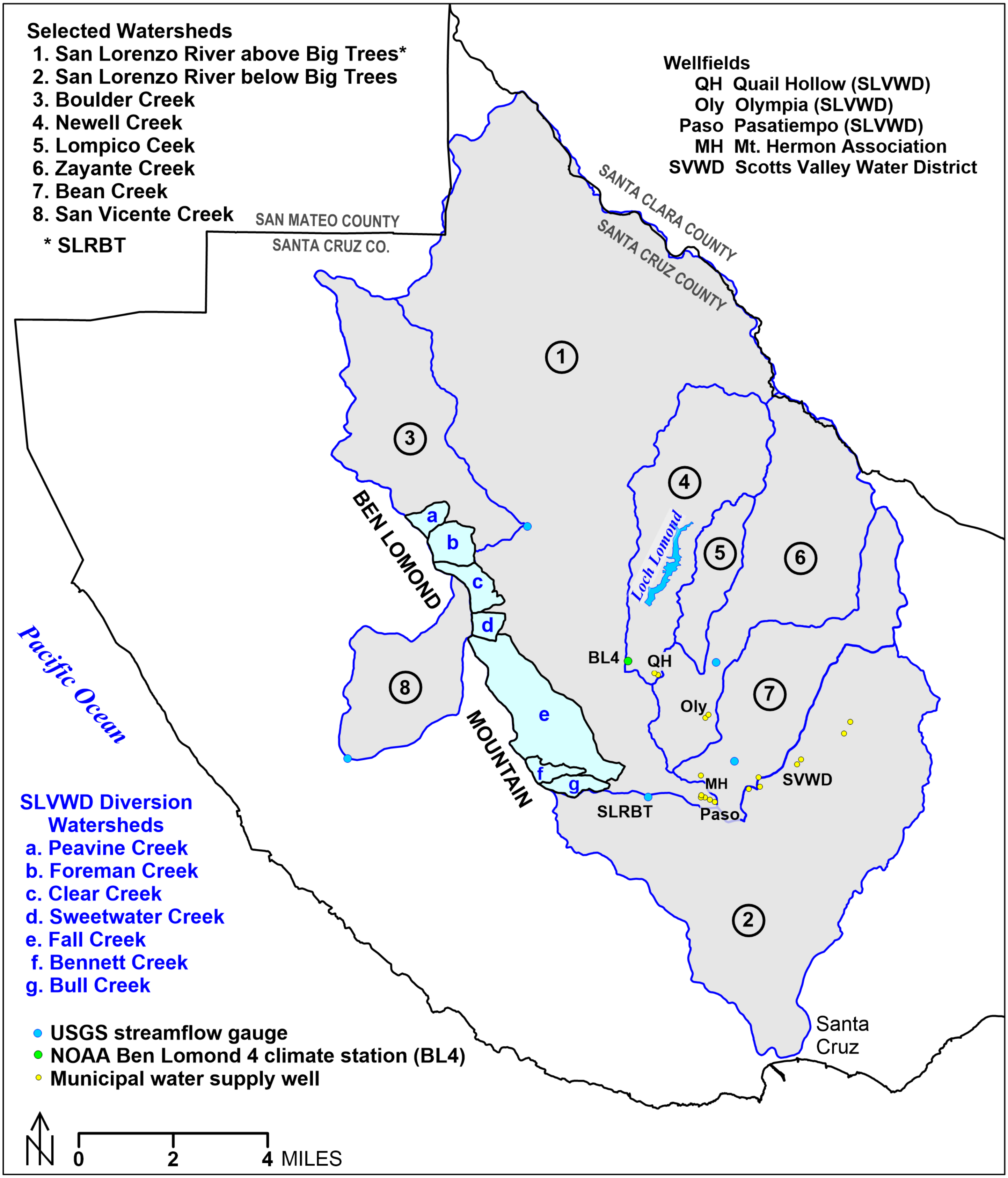


Figure 1-4
Selected Watershed Areas,
North-Central Santa Cruz County

2 Water Demand

SLVWD's record of monthly raw water production is nearly equivalent to its customer monthly water demand. This is because SLVWD's above-ground storage, imports, and exports of water are minor. Surface water is diverted and treated, and groundwater is pumped, only in response to fairly immediate water demand. SLVWD has sold relatively small amounts of water to MHA and SVWD under short-term, emergency situations and similarly has purchased relatively small amounts of water from SVWD, in each case less than 1 percent of SLVWD's annual water supply. This study defines water demand as total water use, including system losses and other unaccounted for produced water.

Table 2-1 provides the available record of annual water production from SLVWD's current sources since WY 1985 as well as a partial record for WY 1977. Annual water production for the North, South, and Felton service areas is plotted in Figures 2-1, 2-2, and 2-3, respectively.

Based on estimated 2045 total water demand for each SLVWD service area (WSC 2016), and including water demand for the recently annexed Lompico area (now part of the North service area), this study assumes the following average annual water demand:

- North service area: 1,545 acre-feet per year (afy)
- South service area: 365 afy
- Felton service area: 430 afy

SLVWD annual water demand fluctuates by as much as approximately ±20 percent in response to the climatic cycle, with the following characteristics (Johnson 2009, 2015):

- During multi-year droughts (e.g., 1976–1977, 1987–1992, and 2007–2009), water use may increase initially before declining in response to voluntary or mandatory water conservation.
- Reduced demand may persist for a year or more following a drought.

- Water demand tends to decrease during years with exceptionally high precipitation.
- Water demand tends to gradually increase to above-average levels between droughts.
- Water demand may vary as a result of additional factors, e.g., the significant reduction in water demand that occurred in apparent response to the economic recession that began in 2008.
- SLVWD's three service areas have not responded identically to these influences (Figures 2-1, 2-2, and 2-3).

Table 2-2 presents values of annual water demand assumed by this study for each SLVWD service area for the WY 1970–2017 design climatic cycle. In response to the climatic cycle, assumed annual demands vary above and below the projected 2045 average demand in a manner similar to the historical record of each service area. Figures 2-1, 2-2, and 2-3 compare the historical and assumed annual water demand for the North, South, and Felton service areas, respectively. Figure 2-4 is a plot of assumed annual demand for all three service areas.

The assumed annual demands are distributed monthly for each service area based on average monthly percentages for near-to-above average, dry, and very dry years (Figure 2-5). The monthly distribution of demand during the driest years reflects conservation rates of up to 40 percent during dry-season months of peak use.

Estimated SVWD water demand for 2040 is approximately 1,650 afy, of which 250 afy is assumed to be supplied by recycled water (Kennedy/Jenks 2016).

Water Year	Percent of Average Rainfall at Ben Lomond	North System						South System Wells	Felton Diversions[b]	Total	
		Stream Diversions		Wells		Loch Lomond	Total Production			by SLVWD	All Current Sources
		afy	%[a]	afy	%[a]	afy					
1977[c]	41%	400	53%	350	47%	350	1,100	160	-	1,260	-
1984	83%	-	-	-	-	-	-	-	-	-	-
1985	83%	941	60%	636	40%	0	1,576	204	-	1,781	-
1986	137%	865	59%	593	41%	0	1,457	214	-	1,671	-
1987	55%	569	38%	918	62%	0	1,486	224	-	1,710	-
1988	62%	500	35%	921	65%	0	1,421	229	-	1,650	-
1989	70%	647	48%	697	52%	0	1,344	263	-	1,607	-
1990	50%	693	52%	637	48%	0	1,330	265	-	1,595	-
1991	65%	501	37%	863	63%	0	1,364	276	-	1,640	-
1992	84%	671	48%	727	52%	0	1,398	301	-	1,698	-
1993	118%	870	62%	526	38%	0	1,395	310	-	1,705	1,705
1994	67%	729	48%	792	52%	0	1,521	308	498	1,829	2,328
1995	141%	1,047	70%	446	30%	0	1,493	376	414	1,869	2,283
1996	125%	1,117	68%	528	32%	0	1,645	386	420	2,031	2,451
1997	120%	1,118	64%	618	36%	0	1,735	430	351	2,165	2,516
1998	169%	1,163	78%	331	22%	0	1,494	336	366	1,829	2,195
1999	94%	1,196	75%	392	25%	0	1,588	406	419	1,994	2,413
2000	115%	1,037	64%	590	36%	0	1,628	434	489	2,062	2,551
2001	76%	908	56%	724	44%	0	1,632	447	487	2,079	2,567
2002	96%	935	56%	727	44%	0	1,662	433	484	2,095	2,579
2003	100%	928	55%	758	45%	0	1,685	436	470	2,122	2,592
2004	90%	889	51%	851	49%	0	1,739	428	481	2,167	2,648
2005	136%	1,121	63%	651	37%	0	1,772	341	424	2,113	2,538
2006	152%	1,114	62%	686	38%	0	1,800	403	432	2,203	2,635
2007	59%	768	43%	1,015	57%	0	1,783	440	435	2,223	2,658
2008	79%	712	45%	870	55%	0	1,581	441	402	2,079	2,425
2009	79%	684	46%	803	54%	0	1,486	410	400	2,297	2,297
2010	115%	947	67%	468	33%	0	1,415	371	399	2,185	2,185
2011	126%	1,128	80%	275	20%	0	1,403	385	426	2,213	2,213
2012	77%	834	57%	625	43%	0	1,460	386	399	2,244	2,244
2013	75%	791	51%	747	49%	0	1,538	392	405	2,335	2,335
2014	47%	421	32%	911	68%	0	1,332	355	354	2,042	2,042
2015	70%	534	46%	631	54%	0	1,164	311	317	1,793	1,793
2016	95%	753	59%	530	41%	0	1,283	252	323	1,858	1,858
2017	193%	1,080	73%	404	27%	0	1,484	237	324	2,044	2,044
2018											
1985-2017 avg	98%	855	56%	663	44%	0	1,518	346	413	1,968	2,324
min	47%	421	32%	275	20%	0	1,164	204	317	1,595	1,705
max	193%	1,196	80%	1,015	68%	0	1,800	447	498	2,335	2,658
2000-2017 avg	99%	866	56%	681	44%	0	1,547	384	414	2,120	2,345
min	47%	421	32%	275	20%	0	1,164	237	317	1,793	1,793
max	193%	1,128	80%	1,015	68%	0	1,800	447	489	2,335	2,658

🟦	Apparent partial record.
🟨	Not part of SLVWD.
-	No or partial record.
afy	acre-feet per year
avg	average
max	maximum
min	minimum

WY water year, e.g., WY 2018 was from October 1, 2017 to September 30, 2018.

[a] Percent of North system annual supply.

[b] Adjusted for WTP bypass flows.

[c] WY 1977 is for July 1976 through June 1977; WY 1984 partial record.

Table 2-1
SLVWD Annual Water Use by Service Area, WYs 1977 and 1985–2017

Water Year		Rainfall Percent of Average*	SLVWD Service Area						
			North		South		Felton		Total
			% dfa	afy	% dfa	afy	% dfa	afy	afy
1	1970	108%	0.0%	1,544	0.0%	360	0.0%	418	2,323
2	1971	90%	0.0%	1,544	0.0%	360	0.0%	418	2,323
3	1972	64%	7.5%	1,660	10.0%	395	15.0%	486	2,542
4	1973	138%	2.5%	1,583	0.0%	360	5.0%	441	2,384
5	1974	146%	0.0%	1,544	-2.5%	351	0.0%	418	2,314
6	1975	86%	5.0%	1,621	5.0%	378	10.0%	464	2,463
7	1976	44%	-5.0%	1,467	-5.0%	343	-5.0%	396	2,205
8	1977	41%	-17.5%	1,274	-17.5%	299	-20.0%	328	1,901
9	1978	144%	-5.0%	1,467	-5.0%	343	-2.5%	407	2,217
10	1979	87%	2.5%	1,583	2.5%	369	5.0%	441	2,393
11	1980	125%	0.0%	1,544	0.0%	360	0.0%	418	2,323
12	1981	67%	5.0%	1,621	17.5%	422	12.5%	475	2,518
13	1982	164%	0.0%	1,544	2.5%	369	2.5%	430	2,343
14	1983	195%	-2.5%	1,506	-5.0%	343	-2.5%	407	2,255
15	1984	82%	5.0%	1,621	5.0%	378	10.0%	464	2,463
16	1985	83%	7.5%	1,660	22.5%	439	17.5%	498	2,597
17	1986	137%	-2.5%	1,506	-2.5%	351	-2.5%	407	2,264
18	1987	55%	0.0%	1,544	5.0%	378	2.5%	430	2,352
19	1988	62%	-2.5%	1,506	-2.5%	351	-2.5%	407	2,264
20	1989	70%	-7.5%	1,428	-10.0%	325	-10.0%	373	2,127
21	1990	50%	-10.0%	1,390	-15.0%	307	-15.0%	351	2,048
22	1991	65%	-7.5%	1,428	-12.5%	316	-10.0%	373	2,118
23	1992	84%	-5.0%	1,467	-7.5%	334	-5.0%	396	2,197
24	1993	118%	-5.0%	1,467	-5.0%	343	2.5%	430	2,239
25	1994	67%	2.5%	1,583	5.0%	378	12.5%	475	2,435
26	1995	141%	0.0%	1,544	0.0%	360	7.5%	452	2,357
27	1996	125%	5.0%	1,621	2.5%	369	7.5%	452	2,443
28	1997	120%	10.0%	1,699	10.0%	395	0.0%	418	2,512
29	1998	169%	-2.5%	1,506	-5.0%	343	5.0%	441	2,289
30	1999	94%	0.0%	1,544	2.5%	369	10.0%	464	2,377
31	2000	115%	0.0%	1,544	12.5%	404	15.0%	486	2,435
32	2001	76%	2.5%	1,583	17.5%	422	17.5%	498	2,502
33	2002	96%	5.0%	1,621	12.5%	404	15.0%	486	2,512
34	2003	100%	7.5%	1,660	15.0%	413	12.5%	475	2,548
35	2004	90%	10.0%	1,699	10.0%	395	15.0%	486	2,580
36	2005	136%	12.5%	1,737	0.0%	360	7.5%	452	2,550
37	2006	152%	15.0%	1,776	12.5%	404	10.0%	464	2,644
38	2007	59%	12.5%	1,737	20.0%	430	10.0%	464	2,631
39	2008	79%	5.0%	1,621	20.0%	430	5.0%	441	2,493
40	2009	79%	2.5%	1,583	5.0%	378	2.5%	430	2,390
41	2010	115%	0.0%	1,544	0.0%	360	2.5%	430	2,334
42	2011	126%	0.0%	1,544	0.0%	360	5.0%	441	2,345
43	2012	77%	-2.5%	1,506	0.0%	360	2.5%	430	2,295
44	2013	75%	0.0%	1,544	2.5%	369	5.0%	441	2,354
45	2014	47%	-10.0%	1,390	-10.0%	325	-7.5%	385	2,099
46	2015	70%	-20.0%	1,235	-17.5%	299	-17.5%	339	1,873
47	2016	95%	-12.5%	1,351	-17.5%	299	-15.0%	351	2,000
48	2017	193%	-5.0%	1,467	-10.0%	325	-12.5%	362	2,154
Avg.**		100%	0.1%	**1,545**	1.4%	**365**	2.6%	**430**	**2,340**
Min.		41%	-20%	1,235	-17.5%	299	-20%	328	1,873
Max.		195%	15%	1,776	22.5%	439	17.5%	498	2,644

Percent of Average Rainfall

☐	>80% and <125%
🟦	≥125%
🟨	≤80%
🟧	≤60%

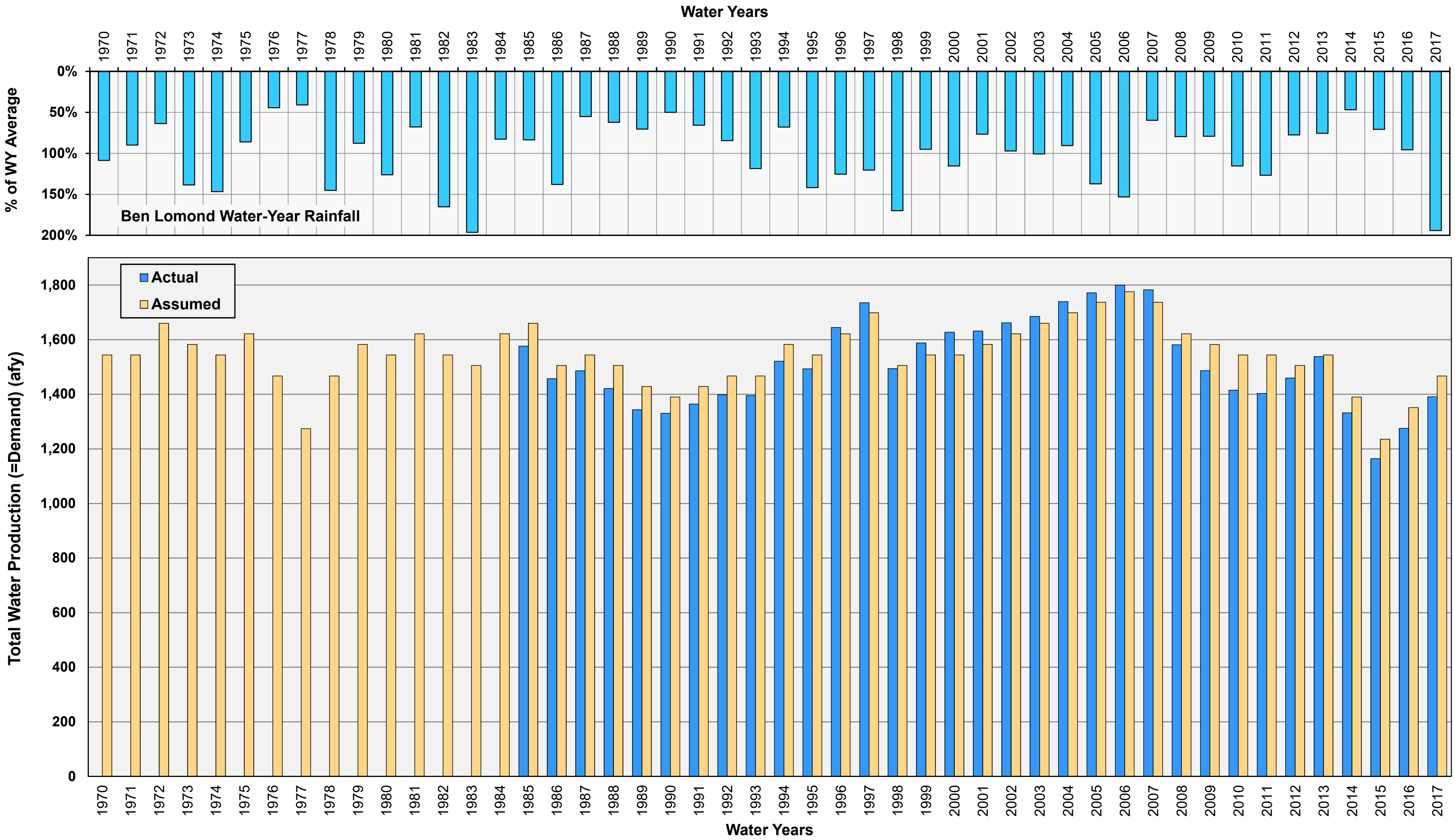
% dfa assumed percent departure from average

afy acre-feet per year

* NOAA Ben Lomond 4 station (estimated for WYs 1970-1974; Johnson, 2015)

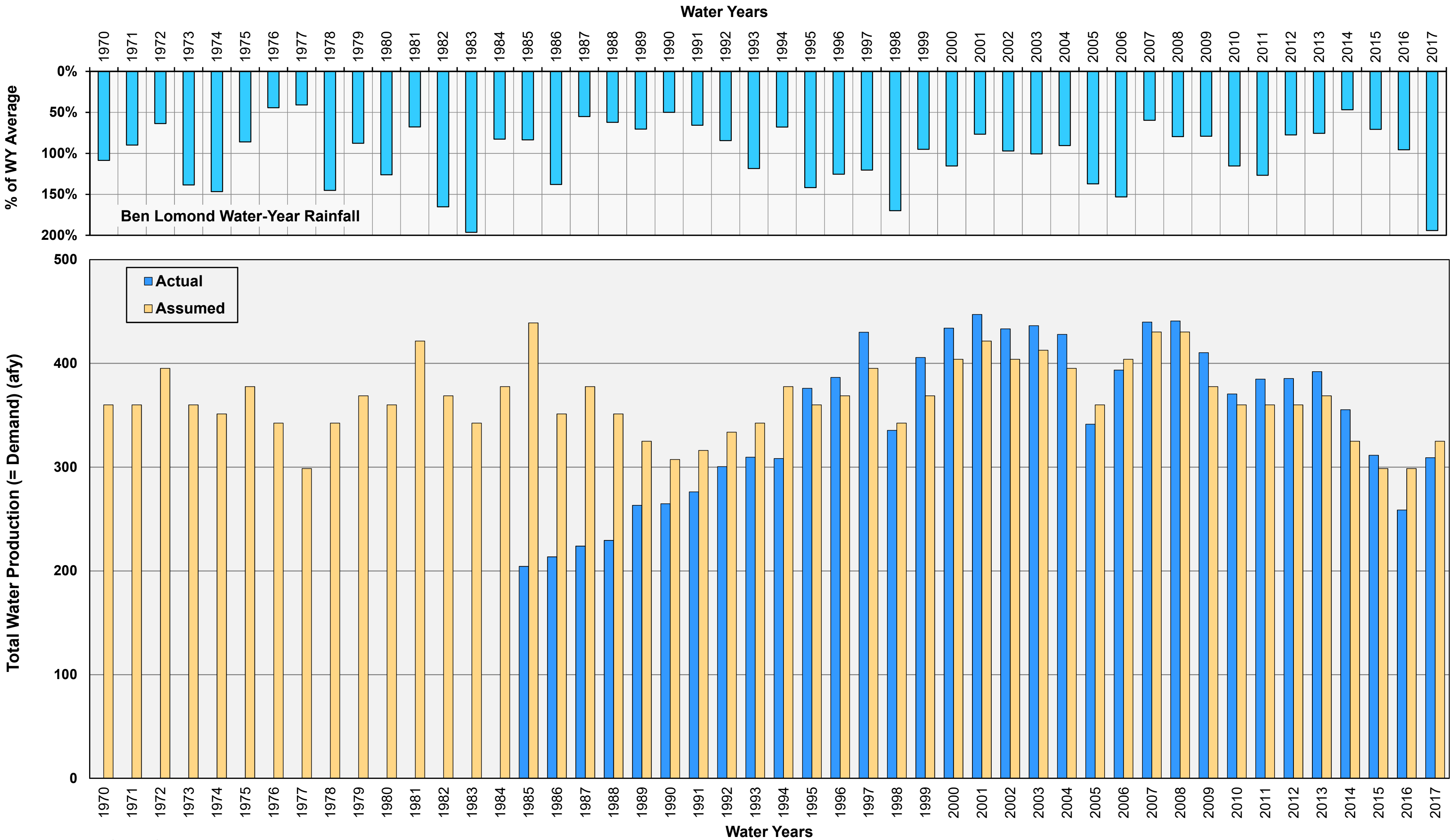
** Averages adopted from 2015 UWMP for WY 2045 (WAC, 2016); approximately 50 AFY are added to the North service area projected demand to account for the recent annexation of the Lompico service area.

Table 2-2
Assumed Water Demand for Design Climatic Period, WYs 1970–2017



afy acre-feet per year
WY water year, e.g., WY 2018 was October 1, 2017 to September 30, 2018.

Figure 2-1
Historical and Assumed 2045 North Service Area Water Demand, WYs 1970–2017 Climatic Period

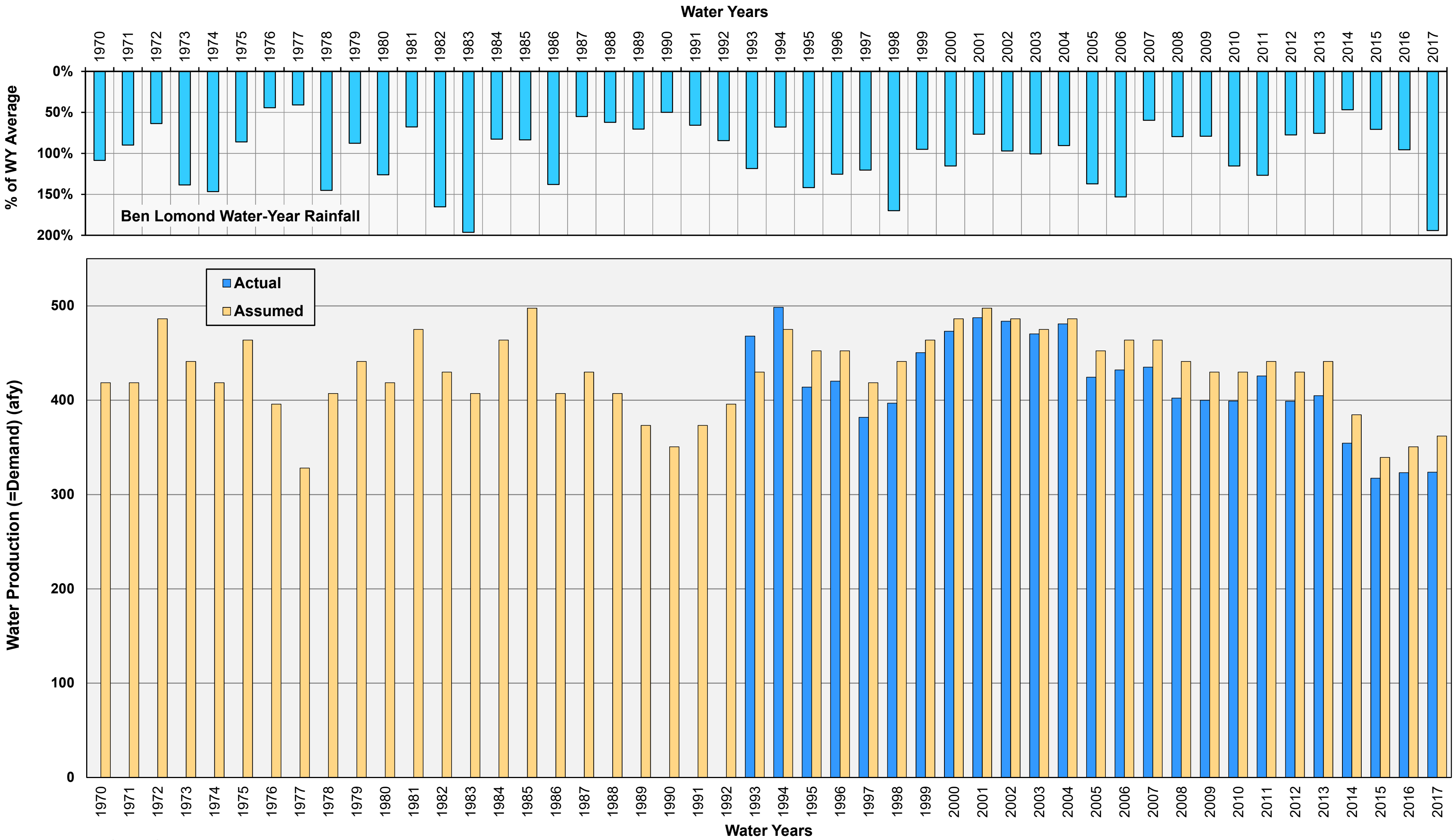


afy acre-feet per year

WY water year, e.g., WY 2018 was October 1, 2017 to September 30, 2018.

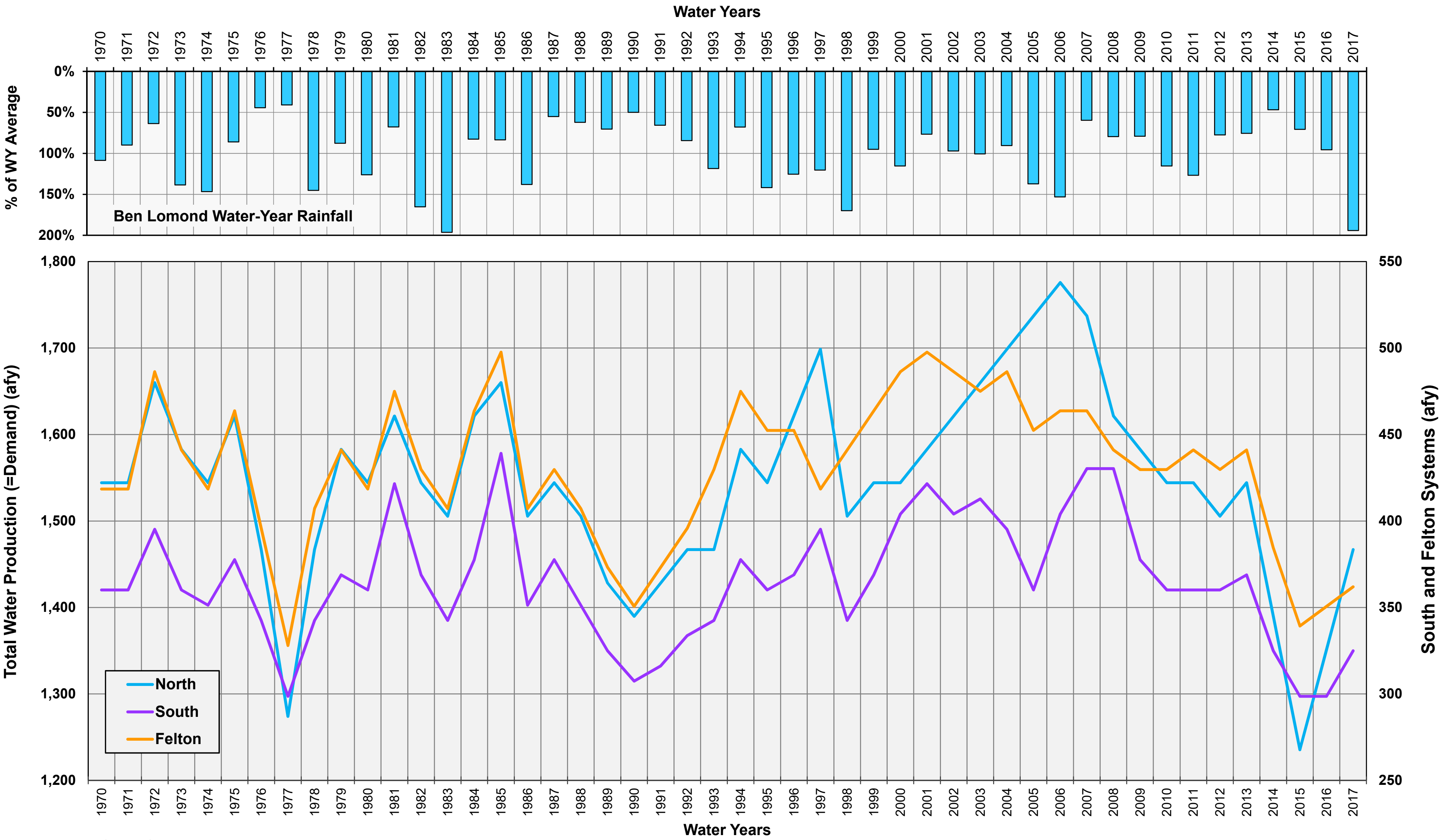
Figure 2-2

Historical and Assumed 2045 South Service Area Water Demand, WYs 1970–2017 Climatic Period



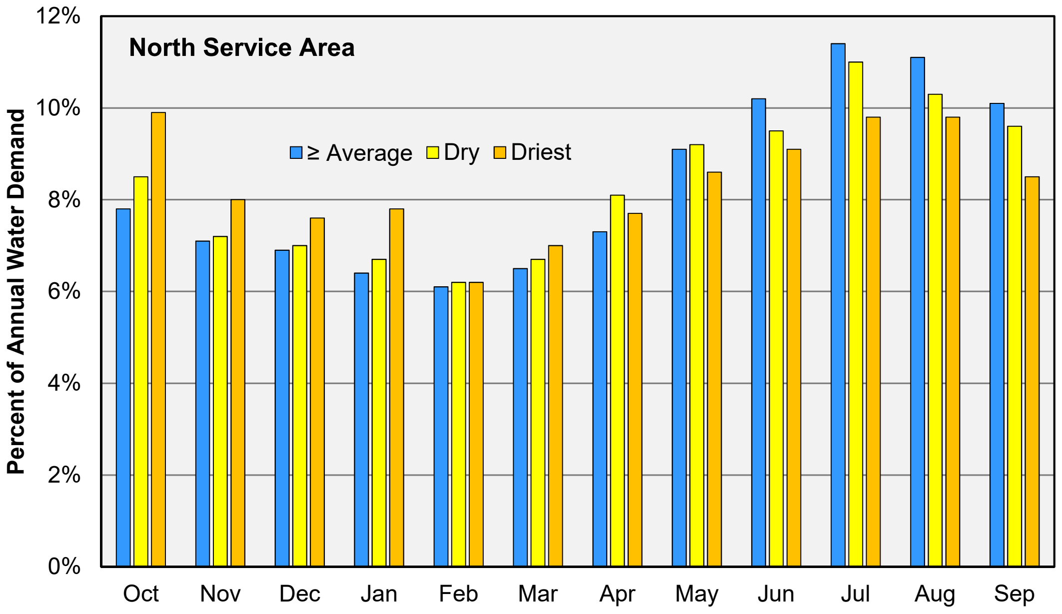
afy acre-feet per year
WY water year, e.g., WY 2018 was October 1, 2017 to September 30, 2018.

Figure 2-3
Historical and Assumed 2045 Felton Service Area Water Demand, WYs 1970–2017 Climatic Period



afy acre-feet per year
WY water year, e.g., WY 2018 was October 1, 2017 to September 30, 2018.

Figure 2-4
Assumed 2045 Water Demand by Service Area, WYs 1970–2017 Climatic Period



Percent of WY Demand			
North	≥ Average	Dry	Driest
Oct	7.8%	8.5%	9.9%
Nov	7.1%	7.2%	8.0%
Dec	6.9%	7.0%	7.6%
Jan	6.4%	6.7%	7.8%
Feb	6.1%	6.2%	6.2%
Mar	6.5%	6.7%	7.0%
Apr	7.3%	8.1%	7.7%
May	9.1%	9.2%	8.6%
Jun	10.2%	9.5%	9.1%
Jul	11.4%	11.0%	9.8%
Aug	11.1%	10.3%	9.8%
Sep	10.1%	9.6%	8.5%
WY	100%	100%	100%

Monthly Demand (af)			
North	Average	Dry	Driest
Oct	121	118	122
Nov	110	100	99
Dec	107	97	94
Jan	99	93	96
Feb	94	86	77
Mar	100	93	86
Apr	113	113	95
May	141	128	106
Jun	158	132	112
Jul	176	153	121
Aug	171	143	121
Sep	156	133	105
WY	1,545	1390*	1235**

Percent Conservation		
North	Dry	Driest
Oct	2%	-1%
Nov	9%	10%
Dec	9%	12%
Jan	6%	3%
Feb	9%	19%
Mar	7%	14%
Apr	0%	16%
May	9%	24%
Jun	16%	29%
Jul	13%	31%
Aug	17%	29%
Sep	14%	33%
WY	9%	18%

Assumption basis:

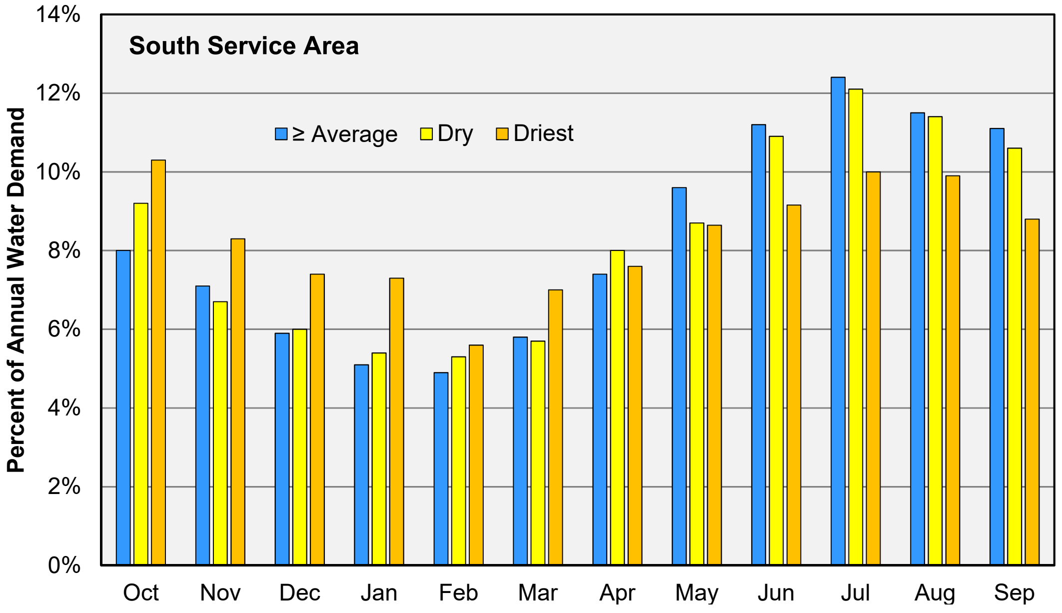
Recent near-average period:
approximate monthly averages for WYs 2008-2012.

Dry years:
approximate monthly averages for WYs 1988-1991, 2009, 2013.

Driest years:
approximate monthly averages for WYs 2014, 2015.

af acre-feet
* Average of average and driest.
** Minimum value from Table 2-2.
WY water year

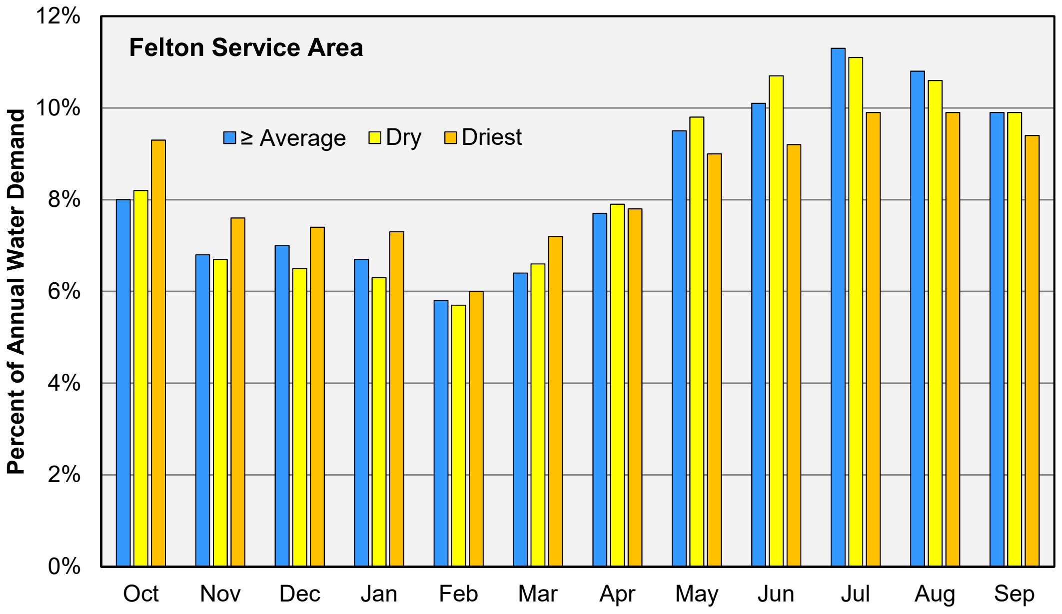
See Table 2-2 for WY rainfall record.
Percent conservation calculated from monthly acre-feet values as (average − dry or driest) ÷ average.



Percent of WY Demand			
South	≥ Average	Dry	Driest
Oct	8.0%	9.2%	10.3%
Nov	7.1%	6.7%	8.3%
Dec	5.9%	6.0%	7.4%
Jan	5.1%	5.4%	7.3%
Feb	4.9%	5.3%	5.6%
Mar	5.8%	5.7%	7.0%
Apr	7.4%	8.0%	7.6%
May	9.6%	8.7%	8.6%
Jun	11.2%	10.9%	9.2%
Jul	12.4%	12.1%	10.0%
Aug	11.5%	11.4%	9.9%
Sep	11.1%	10.6%	8.8%
WY	100%	100%	100%

Monthly Demand (af)			
South	Average	Dry	Driest
Oct	29	31	31
Nov	26	22	25
Dec	22	20	22
Jan	19	18	22
Feb	18	18	17
Mar	21	19	21
Apr	27	27	23
May	35	29	26
Jun	41	36	27
Jul	45	40	30
Aug	42	38	30
Sep	41	35	26
WY	365	332*	299**

Percent Conservation		
South	Dry	Driest
Oct	-5%	-5%
Nov	14%	4%
Dec	8%	-3%
Jan	4%	-17%
Feb	2%	7%
Mar	11%	1%
Apr	2%	16%
May	18%	26%
Jun	12%	33%
Jul	11%	34%
Aug	10%	30%
Sep	13%	35%
WY	8%	13%



Percent of WY Demand			
Felton	≥ Average	Dry	Driest
Oct	8.0%	8.2%	9.3%
Nov	6.8%	6.7%	7.6%
Dec	7.0%	6.5%	7.4%
Jan	6.7%	6.3%	7.3%
Feb	5.8%	5.7%	6.0%
Mar	6.4%	6.6%	7.2%
Apr	7.7%	7.9%	7.8%
May	9.5%	9.8%	9.0%
Jun	10.1%	10.7%	9.2%
Jul	11.3%	11.1%	9.9%
Aug	10.8%	10.6%	9.9%
Sep	9.9%	9.9%	9.4%
WY	100%	100%	100%

Monthly Demand (af)			
Felton	Average	Dry	Driest
Oct	34	31	31
Nov	29	25	25
Dec	30	25	24
Jan	29	24	24
Feb	25	22	20
Mar	28	25	24
Apr	33	30	26
May	41	37	30
Jun	43	41	30
Jul	49	42	32
Aug	46	40	32
Sep	43	38	31
WY	430	379*	328**

Percent Conservation		
Felton	Dry	Driest
Oct	10%	11%
Nov	13%	15%
Dec	18%	19%
Jan	17%	17%
Feb	13%	21%
Mar	9%	14%
Apr	10%	23%
May	9%	28%
Jun	7%	31%
Jul	13%	33%
Aug	13%	30%
Sep	12%	28%
WY	12%	22%

Figure 2-5
Assumed Monthly Water Demand as Percent of Annual Demand for Near-to-Above Average, Dry, and Driest Years

3 System Capacities

SLVWD's three water systems are currently supplied by the following surface water and groundwater sources:

North System	**South System**	**Felton System**
Active Stream Diversions (number of points of diversion)		
Peavine Creek (1) Foreman Creek (1) Clear Creek (3) Sweetwater Creek (1)	none	Fall Creek (1) Bennett Spring (2) Bull Creek (2)
Surface Water Treatment Plants (WTP)		
Lyon WTP	none	Kirby WTP
Active Groundwater Wells		
Quail Hollow (QH) wells: QH-4A and QH-5A Olympia (Oly) wells: Oly-2 and Oly-3	Pasatiempo (Paso) wells: Paso-5A and Paso-8* (*under construction as replacement for Paso-7)	none

Figure 3-1 schematically illustrates the configuration and interconnection of these water sources within and between the three systems. Table 3-1 provides a detailed record of the water produced by these sources since WY 1985.

Table 3-2 provides the twenty highest ranked monthly yields of each SLVWD source during the period of record, expressed as an equivalent continuous rate in gallons per minute (gpm). Table 3-3 summarizes the design, peak-month, and planned capacities of SLVWD diversions, wells, conveyance, and treatment facilities.

Based on maximum monthly rates of record (Tables 3-2 and 3-3), SLVWD's stream and spring diversions have the following estimated maximum capacities (expressed as equivalent continuous monthly rates):

North service area:	**gpm**	**cfs**
Foreman Creek	930	2.1
Peavine Creek	270	0.6
Clear Creek	300	0.7
Sweetwater Creek	260	0.6
Felton service area:	**gpm**	**cfs**
Fall Creek	280	0.6
Bennett Spring (to WTP)	200	0.45
Bennett Spring (2-in. line)	13	0.03
Bull Creek	225	0.5

These maximum rates generally cannot occur simultaneously because of limited raw water conveyance and treatment capacities. For example, the diversion capacities of Foreman, Peavine, Clear, and Sweetwater creeks exceeds the 1,100-gpm capacity of the trunk raw water line from the Foreman mixing vault to the Lyon water treatment plant (WTP) (Table 3-3).

North system diversions are processed by the Lyon WTP, which has a design capacity of 1,100 gpm, a maximum monthly output equivalent to approximately 980 gpm, and a potential capacity of 1,650 gpm if expanded. Felton system diversions are processed by the Kirby WTP, which has a design capacity of 700 gpm but typically operates at half capacity using only one of two units. The maximum continuous monthly production rate of the Kirby WTP is approximately 425 gpm (Table 3-3).

Based on maximum monthly rates of record (Table 3-2), SLVWD's groundwater production wells have the following estimated maximum capacities (expressed as equivalent continuous monthly rates):

North service area:	**gpm**	**cfs**
Quail Hollow wells	545	1.2
Olympia wells	780	1.7
Quail Hollow and Olympia wells	1,150	2.6
South service area:		
Pasatiempo wells	435	1.0

The design capacities of the inter-system emergency interties are as follows (Table 3-3):

System Intertie:	**gpm**	**cfs**
North-South	150/300/550 [a]	0.3/0.7/1.2 [a]
North-Felton	150	0.3
Felton-South (via North/direct)	150	0.3
South-SVWD	350	0.8

[a] current/expected/potential

Inspection of Table 3-2 suggests that maximum-monthly rates of water production, conveyance, and treatment may be considered outliers representative of peak performance during optimal circumstances atypical of normal conditions. Peak diversion rates reflect a combination of various operational constraints, including water rights; high-flow limitations; and limited intake, conveyance, and treatment capacities. The effective capacities assumed for simulating conjunctive use scenarios in Section 6 are generally somewhat less than the highest ranked monthly rates of record.

		North System																					South System									Felton System									Total	
		Stream Diversions								Wells								Interties					Pasatiempo Wells						Intertie			Streams		Bennett Spring				Intertie				
										Quail Hollow			Olympia																													
Water Year	WY Rainfall at Ben Lomond	Foreman Ck	Peavine Ck	Foreman & Peavine Cks	Clear Ck	Sweetwater Ck	Clear & Sweetwater Cks	Other Cks	Total	QH-4	QH-5	Total	Oly-2	Oly-3	Total	Loch Lomond	Total Production	To South System	From South System	To Felton System	From Felton System	Net Supply	Paso-5A	Paso-6	Paso-7	Total	Mañana Wds Well	Total Production	To North System	From North System	Net Supply	Fall Ck	Bull Ck	to Kirby WTP	as groundwater	Felton Acres Well	Total Production[b]	To North System	From North System	Net Supply	Produced by SLVWD	All SLVWD Current Sources
	% avg	afy																																								
1977[a]	41%	-	-	-	-	-		-	400	-	-	350	-	-	-	350	1,100	-	-	-	-	1,100	-	-	-	160	-	160	-	-	160	-	-	-	-	-	-	-	-	-	1,260	-
1985	83%	-	-	706	103	128	231	4	941	185	122	422	167	-	214	0	1,576	-	-	-	-	1,576	-	-	-	204	-	204	-	-	204	-	-	-	-	-	-	-	-	-	1,781	-
1986	137%	-	-	629	109	111	220	16	865	240	106	421	115	-	171	0	1,457	-	-	-	-	1,457	-	-	-	214	-	214	-	-	214	-	-	-	-	-	-	-	-	-	1,671	-
1987	55%	-	-	333	111	89	200	36	569	240	156	496	362	-	421	0	1,486	-	-	-	-	1,486	-	-	-	224	-	224	-	-	224	-	-	-	-	-	-	-	-	-	1,710	-
1988	62%	-	-	305	100	72	172	24	500	252	131	516	336	-	405	0	1,421	-	-	-	-	1,421	-	-	-	229	-	229	-	-	229	-	-	-	-	-	-	-	-	-	1,650	-
1989	70%	-	-	419	116	85	201	27	647	175	91	349	306	-	348	0	1,344	-	-	-	-	1,344	-	-	-	263	63	263	-	-	263	-	-	-	-	-	-	-	-	-	1,607	-
1990	50%	-	-	526	73	80	153	14	693	151	65	268	348	-	370	0	1,330	-	-	-	-	1,330	-	-	-	265	74	265	-	-	265	-	-	-	-	-	-	-	-	-	1,595	-
1991	65%	-	-	347	72	53	125	30	501	223	89	348	363	121	515	0	1,364	-	-	-	-	1,364	-	86	6	276	-	276	-	-	276	-	-	-	-	-	-	-	-	-	1,640	-
1992	84%	-	-	501	83	66	150	21	671	169	57	261	357	106	466	0	1,398	-	-	-	-	1,398	-	4	260	301	-	301	-	-	301	-	-	-	-	-	-	-	-	-	1,698	-
1993	118%	-	-	647	105	101	206	16	870	123	39	188	204	133	338	0	1,395	-	-	-	-	1,395	-	31	269	310	-	310	-	-	310	-	-	-	-	-	-	-	-	-	1,705	1,705
1994	67%	-	-	466	117	135	252	11	729	151	87	291	348	150	501	0	1,521	-	-	-	-	1,521	-	41	252	308	-	308	-	-	308	211	160	127	0	20	498	-	-	498	1,829	2,328
1995	141%	-	-	956	35	56	91	0	1,047	108	41	161	269	15	285	0	1,493	-	-	-	-	1,493	-	96	271	376	-	376	-	-	376	94	137	184	0	25	414	-	-	414	1,869	2,283
1996	125%	-	-	1,105	0	12	12	0	1,117	126	55	181	200	146	347	0	1,645	-	-	-	-	1,645	-	111	275	386	-	386	-	-	386	51	157	213	1	22	420	-	-	420	2,031	2,451
1997	120%	-	-	873	81	61	143	0	1,118	111	76	187	305	126	431	0	1,735	-	-	-	-	1,735	-	167	263	430	-	430	-	-	430	0	173	202	6	9	351	-	-	351	2,165	2,516
1998	169%	781	102	883	186	94	280	0	1,163	105	32	137	180	14	194	0	1,494	-	-	-	-	1,494	-	183	152	336	63	336	-	-	336	47	135	209	6	0	366	-	-	366	1,829	2,195
1999	94%	700	147	847	196	152	349	0	1,196	122	1	123	246	23	269	0	1,588	-	-	-	-	1,588	-	204	201	406	76	406	-	-	406	87	143	214	7	0	419	-	-	419	1,994	2,413
2000	115%	524	133	657	188	192	380	0	1,037	110	37	147	227	216	443	0	1,628	-	-	-	-	1,628	-	225	209	434	74	434	-	-	434	145	128	212	9	0	489	-	-	489	2,062	2,551
2001	76%	409	149	558	206	144	350	0	908	57	158	215	275	234	509	0	1,632	-	-	-	-	1,632	-	183	264	447	68	447	-	-	447	261	82	137	7	0	487	-	-	487	2,079	2,567
2002	96%	688	144	832	62	41	103	0	935	160	124	283	264	179	444	0	1,662	-	-	-	-	1,662	-	230	203	433	68	433	-	-	433	244	94	140	6	0	484	-	-	484	2,095	2,579
2003	100%	598	150	748	107	72	180	0	928	177	155	332	268	158	426	0	1,685	-	-	-	-	1,685	-	230	207	436	66	436	-	-	436	224	100	139	8	0	470	-	-	470	2,122	2,592
2004	90%	523	140	663	135	91	226	0	889	210	159	369	275	205	481	0	1,739	-	-	-	-	1,739	-	290	138	428	60	428	-	-	428	254	87	129	10	0	481	-	-	481	2,167	2,648
2005	136%	682	121	803	191	127	318	0	1,121	205	152	357	205	89	294	0	1,772	-	-	-	-	1,772	-	292	49	341	59	341	-	-	341	144	98	174	9	0	424	-	-	424	2,113	2,538
2006	152%	686	129	815	179	119	299	0	1,114	171	158	329	246	111	357	0	1,800	-	-	-	-	1,800	-	261	111	372	31	403	-	-	403	113	127	184	9	0	432	-	-	432	2,203	2,635
2007	59%	291	106	397	223	149	371	0	768	270	178	461	321	233	554	0	1,783	-	-	-	-	1,783	-	247	141	389	51	440	-	-	440	221	104	101	9	0	435	-	-	435	2,223	2,658
2008	79%	403	48	451	156	104	260	0	712	219	129	348	307	214	522	0	1,581	-	-	-	-	1,581	-	264	126	390	51	441	-	-	441	187	114	90	11	0	402	-	-	402	2,079	2,425
2009	79%	363	49	411	163	109	272	0	684	151	111	262	315	226	541	0	1,486	-	-	-	-	1,486	-	258	109	367	43	410	-	-	410	234	75	82	8	0	400	-	-	400	2,297	2,297
2010	115%	603	86	689	155	103	258	0	947	78	93	171	266	32	297	0	1,415	-	-	-	-	1,415	-	245	86	331	39	371	-	-	371	214	92	86	6	0	399	-	-	399	2,185	2,185
2011	126%	577	224	801	196	131	326	0	1,128	96	50	146	123	6	129	0	1,403	-	-	-	-	1,403	-	287	74	361	24	385	-	-	385	168	121	129	7	0	426	-	-	426	2,213	2,213
2012	77%	482	76	558	166	111	276	0	834	192	36	228	268	129	397	0	1,460	-	-	-	-	1,460	-	258	90	348	37	386	-	-	386	190	96	106	7	0	399	-	-	399	2,244	2,244
2013	75%	361	143	504	172	115	287	0	791	178	91	269	283	196	478	0	1,538	-	-	-	-	1,538	0	291	94	385	7	392	-	-	392	246	56	96	7	0	405	-	-	405	2,335	2,335
2014	47%	203	49	253	101	68	169	0	421	198	140	339	387	185	572	0	1,332	-	-	-	-	1,332	37	231	73	337	19	355	-	-	355	266	17	66	5	0	354	-	-	354	2,042	2,042
2015	70%	278	47	325	124	85	209	0	534	175	89	264	298	69	367	0	1,164	-	-	-	-	1,164	93	134	73	300	12	311	-	-	311	234	47	29	7	0	317	-	-	317	1,793	1,793
2016	95%	405	71	476	162	114	276	0	753	155	84	239	234	57	291	0	1,283	12	6	1	0	1,275	123	88	41	252	0	252	6	12	259	165	98	53	8	0	323	0	1	324	1,858	1,858
2017	193%	928	115	1,042	22	15	37	0	1,080	137	80	217	158	29	187	0	1,484	82	10	20	0	1,391	237	0	0	237	0	237	10	82	309	110	77	128	8	0	324	0	20	344	2,044	2,044
1985-2017 Avg	98%	524	111	622	127	97	224	6	855	164	96	283	267	126	381	-	1,518	47	8	11	0	1,515	98	183	150	337	45	346	8	47	349	171	105	135	7	3	413	0	11	414	1,968	2,324
Min	47%	203	47	253	0	12	12	0	421	57	1	123	115	6	129	-	1,164	12	6	1	0	1,164	0	0	0	204	0	204	6	12	204	0	17	29	0	0	317	0	1	317	1,595	1,705
Max	193%	928	224	1,105	223	192	380	36	1,196	270	178	516	387	234	572	-	1,800	82	10	20	0	1,800	237	292	275	447	76	447	10	82	447	266	173	214	11	25	498	0	20	498	2,335	2,658
2000-2017 Avg	99%	500	110	610	150	105	255	0	866	163	112	276	262	143	405	-	1,547	47	8	11	0	1,541	98	223	116	366	39	384	8	47	388	201	90	116	8	0	414	0	11	415	2,120	2,345
Min	47%	203	47	253	22	15	37	0	421	57	36	146	123	6	129	0	1,164	12	6	1	0	1,164	0	0	0	237	0	237	6	12	259	110	17	29	5	0	317	0	1	317	1,793	1,793
Max	193%	928	224	1,042	223	192	380	0	1,128	270	178	461	387	234	572	0	1,800	82	10	20	0	1,800	237	292	264	447	74	447	10	82	447	266	128	212	11	0	489	0	20	489	2,335	2,658

🟦 Apparent partial record.

🟨 Not part of SLVWD.

- No or partial record.

afy Acre-feet per year

% avg Percent of average, WYs 1970-2017 (WYs 1970-74 estimated).

WY Water year, e.g., WY 2017 was from October 1, 2016 to September 30, 2017.

[a] WY 1977 is for July 1976 through June 1977; WY 1984 only partial-year record.

[b] Adjusted for WTP bypass flows.

Table 3-1

SLVWD Historical Water Production, WYs 1977 and 1985–2017

Water Source			Month and Amount of Highest Ranked Rates of Monthly Water Production for Period of Record[a] (gpm)																			
		Rank:	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
North System	**Stream Diver-sions**	Foreman Creek	Mar-17 926	Apr-17 921	Apr-99 857	Apr-06 855	Jan-06 813	May-06 780	Mar-98 772	Mar-05 769	Apr-04 765	May-17 758	Feb-00 756	Jan-05 742	Mar-99 739	Apr-98 738	May-98 730	Feb-99 724	Feb-08 718	Mar-10 700	Mar-06 700	Feb-05 697
		Peavine Creek	Apr-97 270	May-97 249	Sep-17 230	Jun-97 214	Jul-11 208	Jan-13 202	Jun-99 197	Jun-11 185	Jul-99 172	May-11 171	Jan-11 169	Feb-13 167	Apr-01 158	Aug-11 158	Apr-11 157	Oct-17 155	Jul-97 154	Aug-99 152	Aug-98 147	Feb-06 144
		Foreman & Peavine Cks	Mar-17 926	Apr-17 921	May-17 881	May-06 867	Apr-99 866	Apr-06 861	Mar-05 829	Jan-06 823	Jun-96 821	Jan-05 815	Apr-04 815	Jul-95 810	Jul-96 805	Mar-97 805	May-95 796	Apr-96 795	Apr-95 784	Mar-96 783	Apr-02 783	Feb-97 778
		Clear Creek	Jul-98 302	Jun-99 277	Jul-06 268	May-00 258	Jun-10 249	Aug-11 241	Jul-11 237	Mar-07 235	Aug-98 231	Jun-06 230	Jun-00 228	Jul-10 223	Apr-08 221	Jun-05 221	Jun-98 213	Aug-06 213	May-01 211	Feb-88 206	Apr-09 204	Apr-16 202
		Sweetwater Creek	May-00 258	Jun-00 228	Jul-00 194	Jul-06 179	Aug-98 172	Aug-00 171	Jun-10 166	Aug-11 161	Jul-11 158	Mar-07 157	Jun-84 156	Sep-98 154	Jun-86 153	Jun-06 153	Jul-99 149	Jul-10 149	Apr-08 148	Jun-05 147	Aug-99 145	May-84 144
		5-Mile Pipeline[B]	May-00 515	Jun-00 457	Jul-06 447	Jun-99 416	Jun-10 416	Aug-98 403	Aug-11 402	Jul-11 395	Mar-07 392	Jul-00 388	Jun-06 383	Jul-98 381	Jul-10 372	Apr-08 369	Jun-05 368	Aug-06 354	May-01 352	Aug-00 343	Apr-09 340	Apr-16 337
		Lyon WTP	May-06 983	Jul-11 963	May-05 947	Mar-17 926	Apr-17 921	Jun-10 908	Jun-06 908	Jun-11 906	Jun-05 904	Mar-07 892	Feb-05 889	May-17 881	Mar-05 881	May-11 877	Apr-05 873	May-16 864	Apr-06 861	May-12 845	Jan-06 838	Apr-08 835
	Ground-water Wells	QH-4 & -4A	Jul-05 362	May-13 331	Jun-86 302	Jul-86 299	May-91 281	Nov-08 270	Aug-86 255	Sep-03 252	Jul-06 239	Sep-85 234	Sep-10 231	Sep-07 229	Jun-06 225	Jun-07 224	Jun-87 224	Aug-08 223	Jul-04 223	Jul-07 223	Aug-07 222	Jul-87 221
		QH-5 & -5A	Jul-05 183	Oct-84 182	Jul-06 182	Jan-87 181	Jul-03 181	Jul-04 177	Aug-03 175	Jun-01 173	Sep-03 172	Oct-02 168	Oct-03 167	May-01 166	Jul-08 164	Jun-07 164	Aug-04 162	Jun-06 161	Aug-08 160	Sep-04 159	Aug-02 158	Sep-02 157
		Quail Hollow (QH) wells total	Jul-05 545	Aug-84 523	Jul-86 511	Aug-87 511	Jul-87 504	Oct-84 496	Jun-87 493	Aug-85 472	Sep-85 468	Jun-86 468	Jun-85 460	Jul-84 460	Sep-87 451	Aug-86 450	Sep-84 441	Aug-88 430	Jul-88 430	Sep-03 424	Jun-84 422	Jul-85 422
		Oly-2	Aug-87 494	Jul-88 482	Aug-88 473	Jul-89 465	Sep-88 459	Aug-89 449	Jul-84 444	Jun-90 443	Sep-90 443	Oct-90 439	Sep-84 436	Sep-87 436	Jul-13 434	Aug-90 430	Sep-93 426	Aug-08 417	Jul-90 406	Jul-97 406	Feb-91 400	Aug-85 397
		Oly-3	Jul-93 429	Aug-96 423	Sep-96 403	Oct-96 390	Aug-94 386	Jun-91 360	Jun-07 357	Jul-07 353	Sep-01 352	Jun-01 350	Aug-03 349	Aug-08 346	Sep-03 345	Aug-02 345	Jul-01 343	Sep-12 341	Aug-01 337	Aug-07 336	Sep-94 323	Aug-12 320
		Olympia (Oly) wells total	Aug-94 779	Aug-08 763	Jul-13 734	Aug-02 713	Jun-07 712	Jul-07 711	Sep-01 708	Aug-03 704	Sep-03 702	Jun-01 702	Aug-07 696	Jul-01 689	Aug-01 680	Sep-94 659	Aug-04 654	Sep-12 649	Sep-04 646	Jul-02 645	Jul-94 644	Sep-07 642
South System	**Ground-water Wells**	Paso-5A	Jun-17 276	May-17 251	Oct-17 246	Aug-17 230	Sep-16 223	Jul-17 209	Dec-17 197	Feb-18 191	Oct-16 188	Nov-17 188	Nov-16 164	Sep-17 159	Jan-18 156	Jul-16 156	Aug-16 144	Mar-18 131	Dec-14 111	Jan-15 109	Feb-15 101	Sep-14 99
		Pasatiempo 6	Aug-05 286	Jul-04 281	Jul-05 280	Jun-04 260	Jul-06 249	Sep-04 248	Sep-05 246	Jul-09 245	Jun-05 244	Apr-04 244	Oct-05 244	Jul-13 242	Jun-13 241	May-04 240	Jul-10 240	Sep-13 240	Aug-08 239	Jul-03 238	Aug-09 235	Jul-11 235
		Pasatiempo 7	Aug-92 279	Sep-92 259	Apr-95 258	Jul-95 256	Jun-96 256	May-01 248	May-02 243	Jul-96 241	Aug-95 240	Sep-95 239	Jul-93 237	Mar-95 229	Jun-95 228	May-97 228	Apr-97 225	May-93 223	Jul-92 222	Aug-96 213	Aug-93 213	May-96 212
		Pasatiempo wells total	May-01 435	Jul-00 422	Jul-03 420	May-02 408	Jul-99 405	Aug-03 399	Jun-01 396	Jul-06 388	Aug-02 388	Jul-97 386	Jul-02 382	Jun-02 378	Jul-95 376	Aug-98 368	May-97 368	Aug-00 364	Aug-97 363	Jul-01 362	Jul-04 360	Jun-97 356
Felton System	**Stream and Spring Diver-sions**	Fall Creek	Sep-13 278	Aug-03 261	Jul-13 255	Jul-03 254	Jul-01 254	Jun-01 252	Sep-03 247	Jun-12 247	Jul-07 244	Jul-12 243	Aug-04 241	Jun-13 240	Aug-13 240	Jul-04 240	May-13 237	Aug-01 234	Aug-12 232	Sep-02 229	Jun-07 229	Jul-94 227
		Bennett Spring (to WTP)	Apr-17 199	Apr-00 176	Jul-98 175	Apr-99 173	May-99 172	Jun-98 170	Aug-07 165	Jun-99 164	Jan-17 163	Aug-98 163	Jun-06 162	Mar-99 162	May-06 159	May-00 159	Jun-95 159	Jul-95 158	Feb-99 157	Apr-96 157	Mar-98 156	Jun-96 154
		Bull Creek	Jan-94 226	Jan-93 168	Apr-97 166	Feb-95 158	Mar-93 155	May-97 154	Feb-93 150	Jun-96 146	Jun-93 144	Jun-97 141	Dec-93 141	Feb-16 138	Sep-93 137	Mar-97 136	Feb-08 136	Apr-11 135	Jan-06 133	May-99 133	Mar-11 132	Jul-96 131
		Kirby WTP	Jun-01 424	Jun-02 412	Jul-00 412	Jul-02 403	Jul-03 402	Aug-00 401	Jun-00 400	Aug-03 400	Jul-01 385	Jul-06 377	Jun-04 372	Sep-02 372	Jun-03 372	Aug-01 370	Aug-04 365	Jul-04 364	Sep-03 364	Jul-05 362	Aug-02 362	Aug-05 362
		Bennett Spring 2-inch line	Apr-08 13.4	Jun-17 10.8	Aug-08 10.1	Jul-08 10.0	Jun-00 9.7	Jun-08 9.7	Jul-07 9.2	Jun-07 9.1	Dec-08 8.7	Jun-12 8.6	Jun-04 8.3	Jul-17 8.2	Aug-04 8.2	Aug-11 8.2	Jul-04 8.1	Dec-15 8.1	May-00 8.1	Jun-09 8.0	Dec-03 8.0	Jul-03 8.0

[a] See Table 1-1 for periods of record.

[b] 5-mile pipeline is the conveyance for Clear and Sweetwater Creek diversions.

gpm gallons per minute; equivalent continuous monthly rate.

WTP water treatment plant

Table 3-2

SLVWD Highest Ranked Monthly Rates of Water Production

System	Water Source		Design, Maximum, and Planned Capacities			
			afm	gpm	cfs	note
North	**Diversions**	Foreman Ck	125	926	2.06	a
		Peavine Ck	36	270	0.60	a
		Foreman & Peavine Cks	161	1,196	2.66	b
			125	926	2.06	c
		Clear Ck	41	302	0.67	a,d
		Sweetwater Ck	35	258	0.57	a,d
		Clear & Sweetwater Cks	75	560	1.25	b,c
		Total diversions	236	1,755	3.91	b
	Wells	QH-4 or QH-4A	49	362	0.81	a
		QH-5 or QH-5A	25	183	0.41	a
		Quail Hollow total	73	545	1.21	b,c
		Oly-2	66	494	1.10	a
		Oly-3	58	429	0.96	a
		Olympia total	124	923	2.06	b
			105	779	1.74	c
Felton	**Diversions**	Fall Ck	37	278	0.62	a
		Bennett Sp (to WTP)	27	199	0.44	a
		Bennett Sp 2-inch line	1.8	13.4	0.03	a
		Bull Ck	31	226	0.50	a
		Total diversions	96	712	1.59	b
			61	459	1.02	c
South	**Wells**	Pasatiempo 5A	37	276	0.62	a
			47	350	0.78	g
		Pasatiempo 6	38	286	0.64	a,x
		Pasatiempo 7	38	279	0.62	a
		Pasatiempo 8	-	-		h
		Pasatiempo wells total	77	576	1.28	b
			60	435	0.97	c
		Manana Woods	11	80	0.18	a,x
Intertie Capacities		North-South	20	150	0.33	g,m
			40	300	0.67	g,n
			74	550	1.23	g,j
		North-Felton	20	150	0.33	g,m
		Felton-South (via North)	20	150	0.33	g,m
		South-SVWD	47	350	0.78	g,m
		Felton-South direct	-	-	-	j

Raw-Water Conveyance	Design, Maximum, and Planned Capacities			
	afm	gpm	cfs	note
Peavine line (to Foreman mixing vault)	36	270	0.60	g
5-mile pipeline (Clear & Sweetwater diversions to Foreman mixing vault)	74	550	1.23	e
	69	515	1.15	a,f
	54	400	0.89	i
Foreman line (all diversions to Lyon WTP)	148	1,100	2.45	e
	138	1,030	2.29	c
	222	1,650	3.68	j
Quail Hollow & Olympia wells	198	1,468	3.27	b
	155	1,150	2.56	c
WaterTreatment				
Lyon WTP	148	1,100	2.45	e
	135	983	2.19	a
	126-130	940-970	2.10	g
	222	1,650	3.68	j
WaterTreatment Kirby WTP	94	700	1.56	e
	57	424	0.95	a,l
	47	350	0.78	g,k
	141	1,050	2.34	j

Notes:

a Equivalent continuous rate for maximum month of record.*
b Equivalent continuous rate for sum of maximum months.*
c Equivalent continuous rate for maximum of monthly sums.*
d Approximate apportionment.
e Design capacity (as reported). * from Table 3-1
f Maximum month occurs in spring.
g R. Rogers/SLVWD, personal communication, April-May, 2018.
h Under construction.
i As tested February-March 2006.
j Planned or potential.
k Capacity as commonly used.
l 1993, first year of record.
m Current.
n Expected near term.
x Inactive.

Abbreviations:

afm	acre-feet per month
cfs	cubic feet per second
ck	creek
gpm	gallons per minute
sp	spring

Table 3-3
Design, Maximum-Monthly, and Planned Capacities of SLVWD Diversions, Wells, Conveyance, and Treatment Facilities

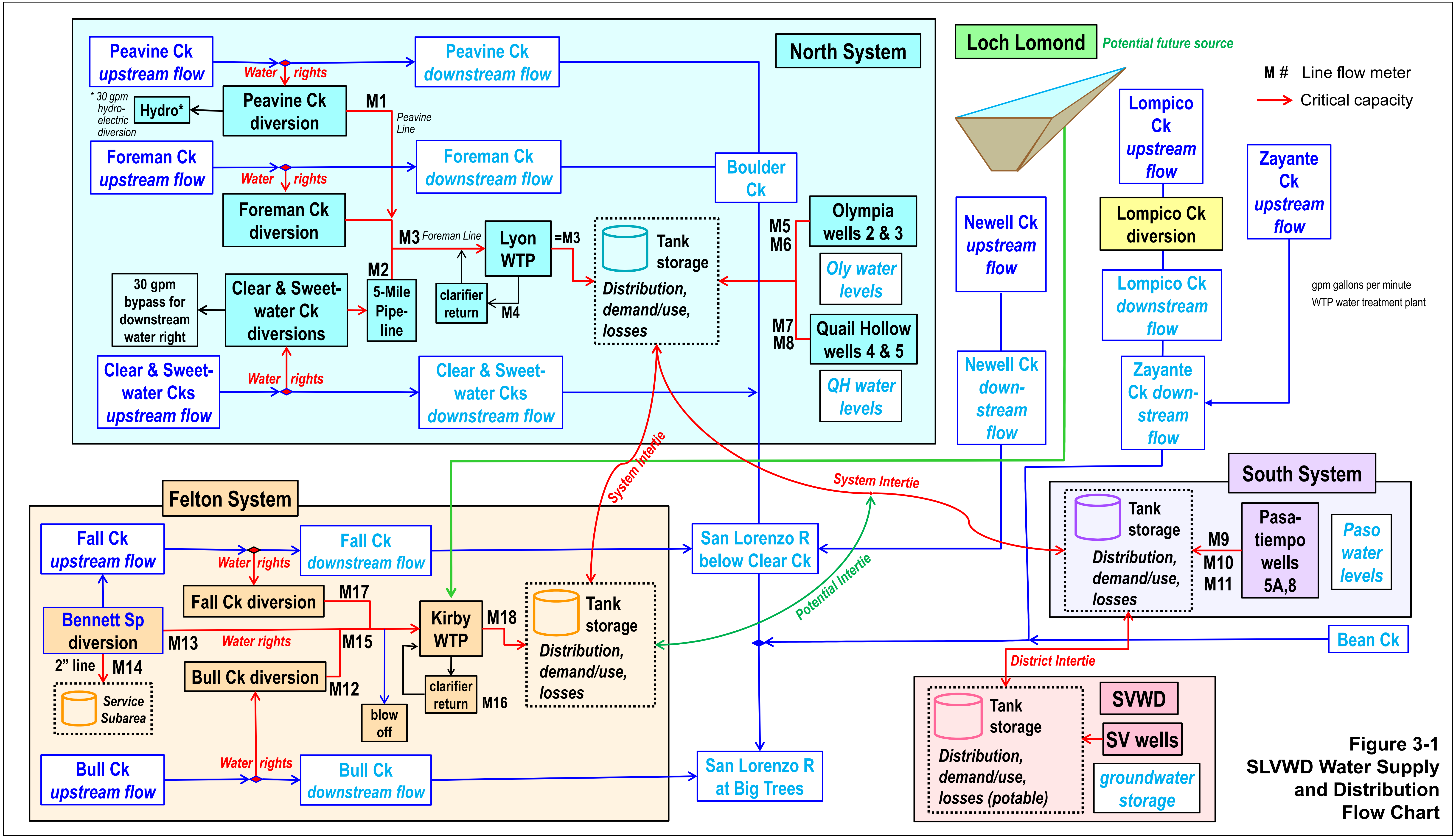


Figure 3-1
SLVWD Water Supply and Distribution Flow Chart

4 Surface Water Resources

Figure 1-2 shows the location of SLVWD's diversion watersheds and Table 4-1 provides diversion intake elevations, watershed drainage areas, and estimated watershed average precipitation. SLVWD's diversion watersheds have a combined area of approximately 4,310 acres, or 7.1 square miles (mi^2), equal to 6.3 percent of the San Lorenzo River watershed above the USGS SLRBT gauge. Additionally:

- Diversions on Peavine and Foreman creeks have a combined watershed area of 710 acres, equal to about 10 percent of the Boulder Creek watershed above its confluence with the San Lorenzo River.
- Diversions on Clear and Sweetwater creeks have a combined watershed area of 660 acres, about 2 percent of the San Lorenzo River watershed above its confluence with Clear Creek.
- The Fall Creek diversion has a watershed area of approximately 2,770 acres (4.3 mi^2), including the 225-acre watershed above the Bennett Spring diversion.
- The two Bull Creek diversions have a combined watershed area of 175 acres.
- The Fall, Bennett, and Bull Creek diversion watersheds compose 4.3 percent of the San Lorenzo River watershed above the Big Trees gauge.

The potential yields of SLVWD diversions are constrained by water rights and existing and potential bypass flow requirements (Section 4.1), and by the seasonal and year-to-year variability of divertible flows (Section 4.2) relative to existing and potential diversion capacities (Section 3).

4.1 Water Rights and Bypass Flow Requirements

This section describes SLVWD's stream and spring diversion water rights.

4.1.1 North System Diversion Streams

SLVWD has pre-1914 appropriative rights to divert water from Peavine, Foreman, Clear, and Sweetwater creeks, which has allowed it to supply water from these streams to its North system without restriction (Table 4-2). SLVWD has an agreement with a downstream water user to allow 30 gpm to bypass its Clear Creek diversion at all times. SLVWD's legal right to transfer potential available diversions outside the North system should be verified.

4.1.2 Felton System Diversion Streams

SLVWD has a permitted appropriative right to divert from Fall and Bull creeks and Bennett Spring to supply water to its Felton system (Table 4-3). The right is limited to a total diversion rate of 1.7 cfs and total annual diversions of 1,059 afy. Additionally, Fall Creek required bypass flows are defined separately for dry and non-dry years, and diversions are not permitted from any Felton source during defined low-flow conditions. Dry-year and low-flow conditions are defined in terms of the gauged flow of the San Lorenzo River at Big Trees.

The water rights permit defines Fall Creek bypass flows as follows:

Dry years: 0.75 cfs November 1–March 31
0.50 cfs April 1–October 31

Other years: 1.5 cfs November 1–Mar 31
1.0 cfs April 1–October 31

Dry years are triggered when SLRBT cumulative monthly flows are less than the following amounts:

October: < 500 af
October–November: < 1,500 af
October–December: < 5,000 af
October–January: < 12,500 af
October–February: < 26,500 af

Table 4-4 identifies dry and non-dry years for the SLRBT record since WY 1970. Dry years are triggered during 46 percent of all years.

Table 4-4 also identifies low-flow months since WY 1970 based on SLRBT monthly average flows below the permit thresholds. Diversions are not permitted from any of the Felton system sources during low-flow conditions when SLRBT flows are less than the following amounts:

October:	25 cfs
November–May:	20 cfs
September:	10 cfs

On an average monthly flow basis, low-flow conditions have occurred 11 percent of all months during WYs 1970–2017, nearly 50 percent of which occurred in October, with the remainder mostly in November (17 percent), September (13 percent), and May (10 percent). Because low-flow criteria are applicable on a daily basis, this is likely an under estimate of the number of months during which non-compliant diversions occur.

Finally, use of the water produced from Felton system diversions is permitted only within the Felton service area. Use of an existing or potential intertie between the Felton system and one or more other systems would require modification of the water right permit.

4.1.3 Loch Lomond Reservoir

In 1958, SLVWD sold 2,500 acres encompassing a portion of the Newell Creek watershed to the City of Santa Cruz with the agreement that SLVWD would be entitled to purchase 12.5 percent of the annual safe yield from a reservoir planned by the city. The city created Loch Lomond Reservoir with the completion of Newell Creek Dam in 1960. The reservoir has a drainage area of 8.3 mi^2 and a reservoir capacity of approximately 9,000 af. The city’s appropriative right allows a maximum direct diversion of 3,200 afy and a maximum use of 5,600 afy.

SLVWD began receiving a portion of the reservoir yield after the dam was completed, although records are only available for 1976–77, when it received 353 af. SLVWD has not received any water from Loch Lomond since 1977. Since implementation of the Federal 1989 Surface Water Treatment Rule, SLVWD has not had the means to treat diversions from Loch Lomond. In 1996 the City and SLVWD reached a draft agreement that allows SLVWD to purchase up to 313 afy of raw Loch Lomond water, or purchase the same amount of treated city water with the understanding that it would be interruptible during declared water-shortage emergencies (Kocher 1996). SLVWD has yet to exercise either allowance under this agreement. To exercise its allotment, SLVWD may need to connect to the City's raw water line and expand the Kirby WTP (SPH Associates 2010).

4.2 Method for Estimating Total and Divertible Flows

SLVWD has maintained a monthly record of the water it diverts from each stream since WY 1985 and began gauging the total or remaining flow of these streams in WY 2013 (Table 1-1). These data are insufficient for estimating potential diversions under a variety of conditions. This section presents the approach Exponent used to estimate total and potentially divertible flows under alternative infrastructure, operational, and water rights assumptions.

To estimate SLVWD's potentially available diversions and flows downstream of its diversions, Exponent synthesized monthly flow records representative of the WY 1970–2017 climatic cycle. The monthly flow estimates are derived from monthly probability curves of mean daily flow ("flow duration curves") for representative dry and wet years. Flow duration curves were also developed for SLRBT and Boulder Creek to synthesize equivalent records for use evaluating Felton water-rights restrictions and estimating the significance of diversions on downstream flows.

Figure 4-1 is a schematic illustration of a flow duration curve and its use to estimate the volume of divertible flows. A flow duration curve is a cumulative probability curve defined for some period (e.g., a water year or a month of the year) representing the percent of time mean daily flows are greater than flow rates indicated along the y-axis. The area under the curve represents the total volume of flow for the defined period. As illustrated in Figure 4-1, potentially divertible flows may be estimated as the portion of the area below the curve bounded at the low end by required minimum bypass flows and at the high end by diversion capacities and limitations associated with high flows (elevated turbidity and the potential for storm damage).

This approach allows for a more accurate evaluation of diversion capacities, water rights, and bypass flow requirements than previous studies that used monthly timesteps without accounting for the variability of daily flows (HEA 1983; Geomatrix 1999; Johnson 2009, 2015, 2016). The 1983 and 1999 studies estimated mean monthly flows based on correlations with the SLRBT and other gauged records, whereas the latter studies estimated potentially divertible monthly flows by extrapolating the diversion record while assuming no changes in infrastructure or water rights.

This study uses the SLRBT record to assign each year of the WY 1970–2017 climatic cycle to one of 14 increments between the driest and wettest years, labeled “A” through “N,” respectively (Table 4-5). Each increment represents an interval of 20 percent of average annual flow within an overall range of 10 to 320 percent of average. Estimated total and divertible monthly flows are calculated for each category using a weighted average monthly flow duration curve interpolated between the driest and wettest conditions.

Information used to develop flow duration curves for SLVWD’s diversion streams includes:

- Watershed area, estimated average precipitation, and average runoff estimated from average precipitation (e.g., Geomatrix 1999).
- Flow duration curves calculated for the USGS WY 1970–1985 gauged record of San Vicente Creek, which has watershed conditions similar to SLVWD’s diversion watersheds in terms of location, elevation, precipitation, geology, and streamflow hydrograph with sustained baseflows (Figure 1-4; Johnson 2009).
- SLVWD diversion records, which provide a lower bound for estimating total streamflow.

- Continuous gauging records for SLVWD diversion streams during portions of WYs 2013–2017 (Balance Hydrologics 2018). This period was characterized by extreme drought (WYs 2012–2015) followed by extreme precipitation (WY 2017) and thus may not be representative of more typical conditions. Except for the gauging station installed immediately upstream of the Fall Creek diversion, these records exclude flows diverted by SLVWD. Based on reported monthly average rates of water production, SLVWD's diversions must be added to the daily flow record before calculating the flow duration curves used to support this analysis.

Figures 4-2 and 4-3 present monthly flow duration curves derived from the driest and wettest years, respectively, of the USGS gauged record for San Vicente Creek near Davenport. Although slightly smoothed for plotting, the shapes of these curves are difficult to interpret in light of statistical noise associated with too short a gauging record (Table 4-5).

The units of the y-axis of these plots, and all flow duration curves presented in the remainder of this report, are in cubic feet per second per square mile (cfs/mi^2). Flow duration curves expressed in these units are easily compared between different watersheds and data sets.

Figures 4-4 and 4-5 present monthly flow duration curves for the driest and wettest years derived from SLVWD's combined record of Foreman and Peavine Creek diversions. This study used these and similar curves derived for each SLVWD diversion to interpret the lower limits of monthly flow.

The flow duration curves used in this study and presented in the remainder of this section were calibrated (adjusted) to reproduce SLVWD's historical record of diversions during WYs 2000–2017 (see Section 6-1). The calibration was most sensitive to seasonal and drought low-flow periods and poorly constrained by the available information for high flows. Thus, the results of this analysis are suitable for estimating divertible flows and flows remaining downstream of diversions during dry and average conditions but should not be used to support estimates of peak or total annual flow given a greater potential for errors.

4.3 Estimated Flow Duration Curves

Figures 4-6 and 4-7 present sets of monthly flow duration curves for SLRBT representative of the driest and wettest years, respectively, during WYs 1970–2017. These curves represent the impaired flow conditions of the historical record. In comparison to the historical record, Table 4-6 summarizes the monthly and annual SLRBT flows synthesized using weighted averages of these curves interpolated for each of the 14 intervals of annual flow defined in Table 4-5. To be consistent with dry-year designations defined by Felton water rights (Table 4-3), simulated monthly flows were exchanged among categories “A” through “N” (Section 4.2) some years as needed to represent later starts to the wet season. The bar charts presented in Figure 4-8 show a reasonably good fit between synthesized and gauged SLRBT annual flows and average monthly flows.

As shown in Figure 4-9, synthesized and gauged monthly flow hydrographs for WYs 1970–2017 match reasonably well for low to moderate flow conditions, consistent with the calibration approach discussed above. Although the synthesized hydrograph underestimates peak annual flows most years, potential errors associated with flows many times greater than diversion capacities are relatively inconsequential to the results of this study.

The wet- and dry-year monthly flow duration curves presented in Figures 4-10 and 4-11 were derived in a similar manner for Boulder Creek using the USGS WY 1977–1993 gauging record. Figure 4-12 shows a reasonably good fit between synthesized and gauged Boulder Creek annual flows and average monthly flows, and the bottom plot in Figure 4-9 shows a similarly good fit to the WY 1970–2017 hydrograph of monthly gauged flows. Similar to the synthesized record for SLRBT, these curves represent flows impaired by SLVWD and other upstream diversions.

Figures 4-13 and 4-14 are monthly flow duration curves for Foreman Creek representative of the driest and wettest years, respectively, developed using the approach and information discussed above. In the case of these and SLVWD’s other diversion streams, these curves represent unimpaired flows at the point of diversion. Figures 4-15 and 4-16 present similar sets of curves for Peavine Creek, and Figures 4-17 and 4-18 present the monthly flow duration curves for Clear and Sweetwater creeks combined. The Clear and Sweetwater Creek diversion watersheds are treated as one source given their diversion records are essentially combined; the diversions reported for each stream are typically estimated as a fixed percentage of the total diversion conveyed by the 5-mile pipeline.

Sets of monthly flow duration curves representative of the driest and wettest years are presented in Figures 4-19 and 4-20 for the combined monthly flows of Fall and Bennett creeks. Although each stream has separate diversions, Bennett Creek is a sub-watershed within the Fall Creek watershed such that its non-diverted flows contribute to total flow at the Fall Creek diversion. Thus, it was reasonable to develop sets of monthly flow duration curves only for the entire watershed above the Fall Creek diversion. Figures 4-21 and 4-22 present similarly derived sets of curves for the watershed above SLVWD's Bull Creek diversion.

Based on the SLRBT daily flow duration curves presented in Figures 4-6 and 4-7, Figure 4-23 provides plots of the estimated percent of time SLRBT flows are above the minimum thresholds required for permitted Felton diversions (Table 4-3). For example, these plots show that during the driest years, flows permitted for diversion occur less than 10 percent of the time during October and no more than 30 percent of the time during September to May. Exponent used these curves to help evaluate permitted Felton diversions on a statistically daily basis for the alternative conjunctive use scenarios presented in Section 6.

4.4 Low-Flow Records of Streams Potentially Effected by Groundwater Pumping

Tables 4-7 through 4-10 are a compilation of continuously gauged flows and intermittent low-flow measurements for streams potentially effected by SLVWD groundwater pumping, expressed in units of equivalent acre-feet per month (afm). Specifically, these tables provide flows for the following streams and periods of record:

Table 4-7. Selected San Lorenzo River Low-Flow Measurements at Stations between Brookdale and Felton, WYs 1986–2017

Table 4-8. Selected Newell Creek Low-Flow Measurements and Estimates, WYs 1974–2016

Table 4-9. Zayante Creek at Zayante Continuous Gauged Flow and Selected Low-Flow Measurements, WYs 1958–2016

Table 4-10. Selected Zayante Creek and Lompico Creek Low-Flow Measurements, WYs 1986–2017

The tables highlight selected minimum drought flows when the effects of groundwater pumping are potentially most significant. This information is used to support an evaluation of the potential effects of groundwater pumping under current conditions (Section 5.2) and alternative conjunctive use scenarios (Section 6).

Based on these records, impaired stream baseflows representative of worst drought conditions are approximated as follows for the purposes of this study:

	afm
San Lorenzo River between Brookdale and Felton	150
Newell Creek at San Lorenzo River	6
Lompico Creek	0
Zayante Creek at Zayante	1
Zayante Creek above Bean Creek	20
Bean Creek at Mount Hermon Bridge	80
Bean Creek at Zayante Creek	110
Zayante Creek at San Lorenzo River	130
San Lorenzo River at Big Trees (SLRBT)	400

Figure 4-24 is a map showing the distribution of these estimated minimum stream baseflows in relation to SLVWD, MHA, and SVWD production wells.

Watershed		Elevation		Approximate Areas								Estimated Average Precipitation
		At Intake or Gage	Watershed Max.	Above Intake or Gage		Above Confluence with Next-Named Stream[a]		Diversion Watershed as % of:				
		(ft msl)		(ac)	(mi^2)	(ac)	(mi^2)	Above Confluence[a]	Boulder Ck at SLR	SLR above Clear Ck	SLR at Big Trees	(in/yr)[h]
North System Diversions												
Peavine Creek		1,264	2,610	230	0.36	285	0.45	81%	3.2%	0.7%	0.3%	60
Foreman Creek[b]		927	2,610	480	0.75	580	0.91	83%	6.6%	1.4%	0.7%	
Boulder Ck watershed total		-	-	710	1.11	865	1.35	82%	10%	2.0%	1.0%	
Clear Creek	intake 1	1,378	2,610	360	0.56	1,050	1.64	34%	-	1.0%	0.5%	60
	intake 2	1,350		55	0.09			5.2%	-	0.2%	0.08%	
	intake 3	1,350		20	0.03			1.9%	-	0.06%	0.03%	
Sweetwater Creek		1,350		225	0.35			21%	-	0.6%	0.3%	
Clear Ck watershed total		-	-	660	1.03			63%	-	1.9%	1.0%	
North system total		-	-	1,370	2.14	1,915	2.99	72%	-	3.9%	2.0%	-
Felton System Diversions												
Fall Creek		352	2,300	2,770	4.33	3,155	4.93	88%	-	-	4.1%	56
Bull Creek 1 and 2[c]		800	1,680	175	0.27	455	0.71	38%	-	-	0.3%	51
Bennett Spring[c]	2-inch line[d]	875	1,600	225	0.35	285	0.45	79%	-	-	0.3%	53
	to Kirby WTP	810										
Felton system total[e]		-	-	2,940	4.95	3,895	6.09	81%	-	-	4.3%	-
SLVWD total		-	-	4,310	7.09	5,810	9.08	78%	-	-	6.3%	-
Boulder Creek and San Lorenzo River												
Boulder Ck at Boulder Creek[f]		430	2,650	7,300	11.4	-	-	-	100%	21%	11%	53
San Lorenzo R. above Clear Ck[g]		370	3,230	35,100	54.8	-	-	-	-	100%	51%	46
San Lorenzo R at Big Trees[f]		220	3,230	68,200	106.6	-	-	-	-	-	100%	46

Notes:

[a] Next-named streams: Boulder Ck for Peavine & Foreman Cks; SLR for Clear, Fall, & Bull Cks; Fall Ck for Bennett Sp.

[b] Included minor contribution from Silver Creek diversion (30 ac watershed) prior to 2007.

[c] Groundwater recharge areas contributing to springs may differ from watershed areas above intakes.

[d] Portion of Bennett Spring diversion supplied as groundwater.

[e] Bennett Spring is within the Fall Creek watershed.

[f] USGS gauged watershed.

[g] Portion of San Lorenzo River watershed upstream and including all current SLVWD North System diversions (not gaged).

[h] Geomatrix (1999).

Abbreviations:

ac	acres
ft msl	feet above mean sea level
in/yr	inches per year
mi^2	square miles
SLR	San Lorenzo River

Table 4-1
SLVWD Diversion Watersheds

Stream	Year of First Use[a]	State-ment of Diver-sion	Initial Filing Date	Stream Code	Point of Diversion	Tributary to:
Foreman Creek	1905	S008670	1/1/76	301109060	NW 1/4 of NE 1/4 Sec 25, T9S, R3W	Boulder Creek
Peavine Creek	1905	S008669	1/1/76	301109040	SW 1/4 of SW 1/4 Sec 24, T9S, R3W	
Clear Creek[b]	1905	S008416	1/1/74	301111000	NW 1/4 of SE 1/4 Sec 31, T9S, R3W	San Lorenzo R
Sweetwater Ck	1905	S008671	1/1/76	301111008	SW 1/4 of SE 1/4 Sec 31, T9S, R2W	Clear Creek

[a] Pre-1914 appropriative rights.

[b] 30 gpm bypass required for downstream user.

Source: http://www.waterrights.ca.gov/

Table 4-2
SLVWD North System Active Water Rights

Ck	creek
R	river
SLRBT	San Lorenzo River USGS gauge at Big Trees

Table 4-3
SLVWD Felton System Diversion Rights

Source: copy of cited permit.

Permit for Diversion and Use of Water, Division of Water Rights

Applicant: Citizen Utilities Company
Water Sources: Fall and Bull Creeks and Bennett Spring

Application No.: 24652 filed: 7/26/1974
Permit No.: 20123 issued: 8/3/1987

Section 5: Beneficial use not to exceed (all sources):

Total Diversion Rate			Total Annual Diversion		
cfs	*mgd*	*afm*	afy	*mgy*	*cfs*
1.7	*1.1*	*103*	**1,059**	*345*	*1.46*

Section 12: Required Fall Creek bypass flows (bypass all natural flow if less):

	Non-Dry Years		Dry Years*	
	cfs	*afm*	cfs	*afm*
April-October	**1**	*60*	**0.5**	*30*
November-March	**1.5**	*91*	**0.75**	*45*

* Dry year triggered when cumulative monthly SLRBT flows are

less than:	af
October	500
October-November	1,500
October-December	5,000
October-January	12,500
October-February	26,500

SLRBT gaging record corrected for City Santa Cruz diversions at Felton Weir.

Section 13: No diversions (all sources) if flow of San Lorenzo River at Felton Diversion Weir is less than:

	cfs
September	10
October	25
November-May	20

Section 20: Daily maximum total diversion rate:

cfs	*afm*
1.87	*113*

Bold indicates values from permit, *italics* indicate calculated, equivalent values.

af	acre-feet	cfs	cubic feet per second
afm	acre-feet per month	mgd	million gallons per day
afy	acre-feet per year	mgy	million gallons per year

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Percent of Average	
	afm												afy		
1970	1,998	1,845	11,301	49,534	14,701	23,273	6,218	4,015	2,565	1,549	1,451	1,154	119,605	130%	111%
1971	1,199	7,599	21,594	9,869	4,204	7,163	4,481	2,810	1,827	1,420	941	839	63,946	70%	
1972	922	1,505	6,462	3,363	4,044	1,826	1,964	1,224	803	639	561	649	23,963	26%	
1973	1,986	13,412	3,314	37,446	63,035	27,756	7,010	3,812	2,190	1,543	1,138	1,006	163,647	178%	
1974	1,691	11,002	15,587	23,611	7,014	36,481	27,306	6,143	3,291	2,767	1,894	1,386	138,173	151%	
1975	1,666	2,208	5,214	4,243	17,727	27,190	8,658	4,046	2,487	1,709	1,371	1,172	77,692	85%	**37%**
1976	1,918	1,440	1,420	1,260	1,277	1,734	1,470	990	702	551	658	591	14,012	15%	
1977	707	863	1,008	1,390	922	1,316	732	713	558	410	400	541	9,558	10%	
1978	508	1,327	4,304	52,633	29,773	28,069	16,298	6,481	3,070	2,048	1,304	1,244	147,059	160%	143%
1979	916	1,607	1,500	8,166	19,827	13,410	7,254	3,277	1,797	1,242	1,260	857	61,113	67%	
1980	1,623	1,517	8,639	35,128	53,333	15,753	7,908	4,212	2,761	2,189	1,482	1,291	135,837	148%	
1981	1,101	1,196	2,404	7,858	3,499	11,953	4,011	1,949	1,023	793	683	666	37,136	40%	
1982	978	6,069	10,355	71,756	28,996	35,632	54,791	8,166	3,671	2,644	2,054	1,547	226,659	247%	
1983	1,783	7,503	19,037	40,367	60,813	91,186	27,235	19,811	6,694	4,046	2,705	2,005	283,186	309%	
1984	1,998	12,186	29,668	11,332	7,253	5,946	3,701	2,669	1,987	1,525	1,205	904	80,376	88%	
1985	1,580	6,801	5,528	2,822	6,664	9,063	4,504	2,386	1,571	1,088	898	887	43,793	48%	
1986	904	2,059	3,197	7,360	85,083	50,414	8,949	4,439	2,523	1,777	1,340	1,363	169,409	185%	
1987	1,211	1,208	1,506	2,097	6,476	5,288	1,666	1,304	1,059	812	664	649	23,939	26%	**42%**
1988	769	1,107	4,913	5,067	1,611	1,377	1,654	1,230	785	646	583	495	20,236	22%	
1989	569	1,351	3,160	1,845	1,355	9,672	2,106	1,347	904	633	756	714	24,413	27%	
1990	1,838	2,452	1,765	2,564	2,738	1,752	1,279	1,802	1,077	836	701	586	19,390	21%	
1991	621	678	904	849	1,161	19,547	2,594	1,347	916	652	519	493	30,280	33%	
1992	935	857	2,441	2,232	25,810	8,885	2,547	1,672	1,071	805	615	519	48,389	53%	
1993	1,107	702	5,472	44,394	30,718	13,503	5,778	3,419	2,321	1,531	1,187	934	111,065	121%	
1994	1,021	1,380	3,314	2,312	10,502	2,736	2,178	1,857	1,041	775	664	678	28,459	31%	
1995	830	2,820	2,792	58,505	11,424	65,300	13,501	11,947	4,689	2,822	1,838	1,392	177,862	194%	154%
1996	1,211	1,166	5,620	19,215	48,392	24,712	8,676	7,747	3,850	2,380	1,623	1,363	125,955	137%	
1997	1,476	3,969	30,971	72,063	14,773	6,948	4,040	2,699	1,999	1,482	1,260	1,006	142,687	155%	
1998	1,064	3,844	5,196	26,409	102,910	21,551	16,155	11,006	7,813	4,027	2,496	1,833	204,305	223%	
1999	1,765	3,195	3,333	11,006	25,253	15,378	13,037	5,460	3,261	2,177	1,716	1,327	86,907	95%	
2000	1,285	2,053	1,605	16,934	46,746	22,037	7,908	4,489	2,701	2,023	1,470	1,345	110,595	120%	
2001	2,115	1,595	1,642	6,229	13,123	12,513	4,338	2,576	1,553	1,254	1,027	893	48,857	53%	**76%**
2002	941	3,493	22,658	15,526	5,881	7,280	4,022	2,755	1,738	1,365	1,125	988	67,772	74%	
2003	947	2,350	28,893	11,332	5,004	5,331	10,068	6,536	2,678	1,648	1,285	1,018	77,090	84%	
2004	935	1,577	16,952	17,020	25,091	11,603	4,005	2,380	1,624	1,242	996	857	84,280	92%	
2005	2,478	1,976	15,864	28,887	16,706	24,281	12,728	7,034	3,856	2,558	1,789	1,470	119,626	130%	173%
2006	1,359	1,565	28,684	26,163	9,902	45,913	62,360	10,188	5,034	3,210	2,220	1,720	198,318	216%	
2007	1,574	1,839	3,283	2,078	8,269	3,954	2,249	1,636	1,137	922	787	750	28,478	31%	**69%**
2008	990	869	1,802	23,734	13,546	4,950	2,315	1,629	1,077	879	762	684	53,238	58%	
2009	799	1,720	1,918	1,383	18,866	12,279	2,755	2,017	1,256	947	805	714	45,460	50%	
2010	6,087	1,172	2,410	22,640	21,054	15,839	14,477	4,888	2,380	1,642	1,230	976	94,796	103%	119%
2011	1,328	2,225	16,608	8,135	17,933	47,622	11,585	5,786	5,522	2,785	2,011	1,476	123,016	134%	
2012	1,789	1,839	1,488	4,120	2,134	16,817	9,842	3,271	1,952	1,488	1,088	922	46,750	51%	**48%**
2013	1,002	3,856	29,084	6,880	2,849	2,730	2,095	1,322	1,023	885	824	720	53,271	58%	
2014	701	851	978	812	2,721	3,074	1,803	867	607	519	430	468	13,831	15%	
2015	470	964	16,368	1,968	5,587	1,549	1,529	1,058	732	536	435	398	31,594	34%	
2016	430	702	2,570	14,517	3,181	43,533	4,677	2,582	1,505	1,125	892	738	76,453	83%	
2017	2,109	2,166	14,609	99,979	106,243	28,469	21,380	7,803	4,356	2,755	1,931	1,488	293,286	320%	320%
Avg	1,359	2,868	8,945	19,271	21,169	18,637	9,330	4,142	2,313	1,569	1,189	994	91,787	100%	117%
Min	430	678	904	812	922	1,316	732	713	558	410	400	398	9,558	10%	37%
Max	6,087	13,412	30,971	99,979	106,243	91,186	62,360	19,811	7,813	4,046	2,705	2,005	293,286	320%	320%

Source: https://waterdata.usgs.gov/ca/nwis/sw (gaged record extends back to WY 1937).

🟨 Dry-year designation triggered sometime from October through February as defined by water right (Table 4-3).

🟥 Felton diversions not permited based on monthly average SLRBT flow below permit threshold (Table 4-3).

afm, afy acre-feet per month, acre-feet per year

WY water year; e.g., WY 2017 extended from Oct. 1, 2016 through Sep. 30, 2017.

Table 4-4

San Lorenzo River at Big Trees Monthly Record of USGS Gauged Streamflow, WYs 1970–2017

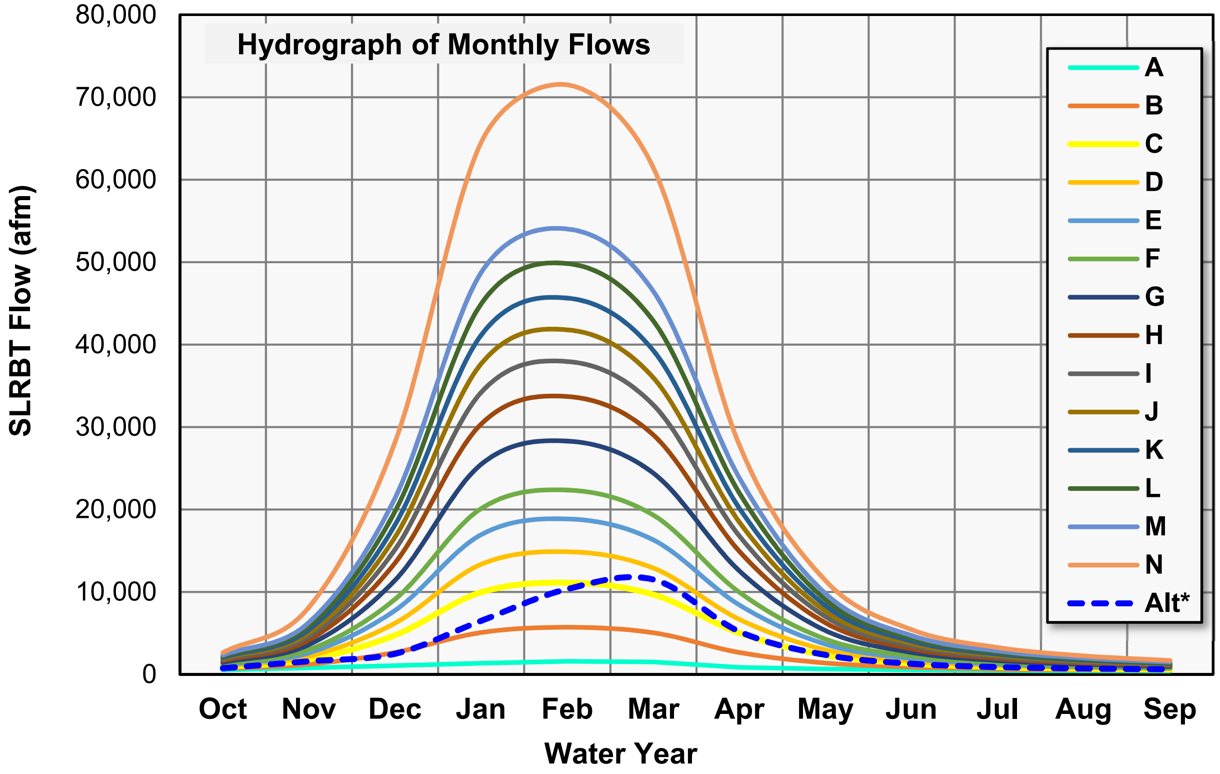
Ben Lomond 4 NOAA Precipitation Gauge					San Lorenzo River at Big Trees (SLRBT) USGS Gauge						SLVWD Diversion Streams Gauged by Balance Hydrologics	San Vicente Creek near Davenport USGS Gauge				
Rank	Water Year	Precip-itation (inches/year)*	Percent of Average Annual Precipitation for Period of Record (WYs 1975-2017)		Rank	Water Year	Annual Stream-flow (afy)	Percent of Average Annual Streamflow for Period of Record (WYs 1937-2017)	Group			Rank	Water Year	Annual Stream-flow (afy)	Percent of Average Annual Streamflow for Period of Record (WYs 1970-1985)	
1	1977	20.0	41%	40-60%	1	1977	9,569	10%	A	<20%		1	1977	602	9%	<15%
2	1976	21.6	44%		2	**2014**	13,824	15%			**2014**	2	1976	1,147	17%	
3	2014	22.8	47%		3	1976	14,010	15%								
4	1990	24.3	50%		4	1990	19,388	21%	B	20-40%						
5	1987	26.9	55%		5	1988	20,230	22%								
6	2007	29.0	59%		6	1987	23,929	26%								
7	1988	30.3	62%	60-80%	7	1972	23,968	26%				3	1972	1,474	22%	20-25%
8	1972	31.2	64%		8	1989	24,418	27%								
9	1991	32.0	65%		9	1994	28,456	31%								
10	1981	33.0	67%		10	2007	28,472	31%								
11	1994	33.1	67%		11	1991	30,286	33%								
12	1989	34.3	70%		12	**2015**	31,609	34%			**2015**					30-50%
13	2015	34.4	70%		13	1981	37,141	40%				4	1981	2,196	32%	
14	2013	36.8	75%		14	1985	43,789	48%	C	40-60%		5	1985	3,217	47%	
15	2001	37.2	76%		15	2009	45,622	50%								
16	2012	37.8	77%		16	2012	46,677	51%								
17	2009	38.6	79%		17	1992	48,391	53%								
18	2008	38.8	79%		18	2001	48,856	53%								
19	1984	40.3	82%	80-100%	19	2008	53,225	58%								
20	1985	40.7	83%		20	2013	55,449	60%								
21	1992	41.1	84%		21	1979	61,114	66%	D	60-80%		6	1979	3,594	53%	55-85%
22	1975	42.0	86%		22	1971	63,944	70%				7	1971	4,013	59%	
23	1979	42.7	87%		23	2002	67,758	74%								
24	2004	43.9	89%		24	**2016**	76,344	83%	E	80-100%	**2016**					
25	1971	43.9	90%		25	2003	77,081	84%								
26	1999	46.3	94%		26	1975	77,699	84%				8	1975	4,862	72%	
27	2016	46.6	95%		27	1984	80,375	87%				9	1984	5,766	85%	
28	2002	47.3	97%		28	2004	84,292	92%								
29	2003	49.0	100%		29	1999	86,920	95%								
30	1970	53.1	108%	100-120%	30	2010	95,008	103%	F	100-120%						
31	2010	56.2	115%		31	1993	111,059	121%	G	120-140%						
32	2000	56.2	115%		32	2000	112,261	122%								
33	1993	57.7	118%		33	1970	119,599	130%				10	1970	8,272	122%	100%-200%
34	1997	58.7	120%		34	2011	123,010	134%								
35	1996	61.1	125%	120-140%	35	2005	124,138	135%								
36	1980	61.4	125%		36	1996	125,958	137%								
37	2011	61.7	126%		37	1980	135,840	148%	H	140-160%		11	1980	9,988	147%	
38	2005	66.9	136%	140-160%	38	1974	138,170	150%				12	1974	13,643	201%	
39	1986	67.2	137%		39	1997	142,717	155%								
40	1973	67.8	138%		40	1978	147,068	160%				13	1978	6,636	98%	
41	1995	69.1	141%		41	1973	163,637	178%	I	160-180%		14	1973	9,652	142%	
42	1978	70.7	144%		42	1986	169,439	184%	J	180-200%						
43	1974	71.7	146%		43	1995	177,828	193%								
44	2006	74.6	152%		44	2006	198,330	216%	K	200-220%						
45	1982	80.5	164%	160-180%	45	1998	204,296	222%	L	220-240%						220%-300%
46	1998	82.8	169%		46	1982	226,686	246%	M	240-260%		15	1982	15,627	230%	
47	2017	94.6	193%	180-200%	47	1983	283,194	308%	N	300-320%		16	1983	17,849	263%	
48	1983	95.7	195%		48	**2017**	293,305	319%			**2017**					

afy acre-feet per year
WY water year

*Estimated for WYs 1970-1974 using regression with Santa Cruz and Lockheed gauges (Johnson 2015).

Table 4-5
Precipitation and Streamflow Annual Records Ranked from Driest to Wettest

Range of SLRBT Gauged Annual Flows			Target Flow for Category	Flow Duration Curve Weighting		Sum of Synthesized Monthly Flows	Percent Difference
WY Category		(afy)		Wettest	Driest	(afy)	
A	10-20%	9,500 - 14,000	10,000	0%	100%	10,170	1.7%
B	20-40%	20,000 - 37,000	27,000	6%	94%	26,982	-0.1%
C	40-60%	44,000 - 55,000	49,000	14%	86%	49,004	0.0%
D	60-80%	61,000 - 68,000	64,300	19%	81%	64,302	0.0%
E	80-100%	76,000 - 87,000	80,500	25%	75%	80,512	0.0%
F	100-120%	95,000	95,000	30%	70%	94,784	-0.2%
G	120-140%	111,000 - 126,000	119,000	38%	62%	118,999	0.0%
H	140-160%	136,000 - 147,000	141,000	46%	54%	141,020	0.0%
I	160-180%	164,000	164,000	52%	48%	158,312	-3.5%
J	180-200%	169,000 - 178,000	174,000	58%	43%	173,980	0.0%
K	200-220%	198,000	198,000	63%	37%	189,648	-4.2%
L	220-240%	204,000	204,000	69%	31%	206,741	1.3%
M	240-260%	227,000	227,000	75%	25%	223,833	-1.4%
N	300-320%	283,000 - 293,000	288,000	88%	12%	288,163	0.1%



* Monthly flows swapped among categories some years to simulate late start to wet season, relevant to Felton water rights; shown by dashed line as example.

afm, afy acre-feet per month, acre-feet per year
WY water year

Table 4-6
Summary of Synthesized Annual and Monthly Flows of the San Lorenzo River at Big Trees

WY	Oct	Nov	Dec	Jan	Feb	Apr	May	Jun	Jul	Aug	Sep
	afm										
Average of Balance Hydrologics low-flow measurements below Clear Ck*											
2014						608	304	167	105	**61**	**62**
2015	100							216	170	93	90
2016	**68**								409	195	168
2017	144								920	563	391
Average of Santa Cruz Co. low-flow measurements above Love Ck*											
1986	230	618								448	574
1987	457										
1990					792	679	619	424	369	248	233
1991	188	196	369	378	250		694	408	288	207	**166**
1992	**47**	239	333	748			864		299	261	396
1993	228	**190**							476		411
1994	377	366		574				756	223	210	201
1995	164								834		364
1996										596	
1997										341	
1998											678
1999	575									809	
2000	518									450	
2001	455							655		316	
2002	275							793	384		
2003	315										344
2004	326							738		319	
2005	659									504	
2006	681									889	
2007	808							405			
2008	333					745		324			226
2009	861							553		268	
2010								875			415
2013										288	
2015								255		**85**	
2017									841		
Avg	416	322	351	567	521	712	725	562	464	390	364
Min	47	190	333	378	250	679	619	255	223	85	166
Max	861	618	369	748	792	745	864	875	841	889	678

Data source: see Table 1-2

WY	Oct	Nov	Dec	Jan	Feb	Apr	May	Jun	Jul	Aug	Sep
	afm										
Average of Santa Cruz Co. low-flow measurements at Mt. Cross Bridge*											
1986	339	808								613	675
1987	496										
1990							497	455		291	
1991	**224**	**190**	406	410	291		813	430	344	**209**	243
1992	226	287		879				677	410	251	
1993	287	395							675	561	453
1994	399	456		744		834			342	298	**211**
1995	256										647
1997											
1999											
2000											
2001	644							768		393	
2002	349									560	
2003	499										
2004	420							877			
2005											
2006	875										
2007	868							498			
2008	386							380			
2009								646			
2010											498
2013										278	
Avg	448	427	406	678	291	834	655	591	443	384	455
Min	224	190	406	410	291	834	497	380	342	209	211
Max	875	808	406	879	291	834	813	877	675	613	675
Average of Balance Hydrologics low-flow measurements below Fall Ck*											
2014						869	595	403	293	246	**210**
2015	283							374	302	213	231
2016	**200**								749	501	
2017	430										

🟨	Selected drought minimums
afm	acre-feet per month
cfs	cubic feet per second
WY	water year

*Equivalent rate for average of 1-2 measurements per month; flows >15 cfs omitted.

Table 4-7

Selected San Lorenzo River Low-Flow Measurements at Stations Between Brookdale and Felton, WYs 1986–2017

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	afm											
Average of USGS low-flow measurements at Ben Lomond [a]												
1974											34	45
1975	61	54	80	60	72		89	80	60			
Average of Santa Cruz Co. low-flow measurements at San Lorenzo River [b]												
1986	115	107	108	122							158	
1987	157											
1990								64	88		40	
1991	57	27	51	58	66		101	93	61	68	59	54
1992	66	54	55	73		102	97	81	78	65	58	65
1993	56	59	77				54	114		87	74	76
1994	76	78		87		96	74	149	87	77	74	74
1995	103				172	174			187	207		199
1996							193				123	
1997							159		100		117	96
1998	125								215		179	137
1999	124								113			
2000	103								174		124	
2001	69											122
2002	62								136			
2003	132								16			
2004	85								89		78	
2005	75										99	
2006	89										176	
2007	118						98		72			
2008	73								90		58	
2009							115		96			
2010								119	64		76	
2011											98	
2012									101		86	52
2013		93					83		81			
2014	65						24		**17**		**14**	
2015							19		**6**		**7**	
2016							73		62		47	
Average of City Santa Cruz low-flow measurements at Glen Arbor Bridge [c]												
2009											73	58
2010	63	68	76					90	83	83	75	77
2011	77											
2014					38	45	26	20	16	15	15	15
2015	24	15	79	35	31	25	21	18	13	12	11	10
2016	10	15	30	121								
Avg	83	57	69	79	76	88	82	83	84	77	78	77
Min	10	15	30	35	31	25	19	18	6	12	7	10
Max	157	107	108	122	172	174	193	149	215	207	179	199

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Sum
	afm												
Estimated baseflow at San Lorenzo River [d]													
1984	97	119	146	163	160	167	149	136	112	98	87	84	1,517
1985	98	114	137	155	147	159	138	122	96	82	73	76	1,398
1986	96	117	149	178	182	216	212	207	178	155	124	95	1,908
1987	81	74	82	93	95	112	108	105	89	79	67	57	1,044
1988	60	65	79	92	96	109	103	99	84	74	62	53	975
1989	53	58	71	84	87	102	99	94	79	67	54	44	894
1990	45	50	62	75	79	95	94	90	74	60	44	**31**	799
1991	**27**	**32**	47	66	77	98	101	100	85	74	61	52	820
1992	56	63	78	91	95	106	100	93	76	66	56	52	932
1993	59	68	85	100	101	118	114	112	99	91	80	70	1,098
1994	71	73	83	92	88	99	89	81	66	60	60	70	931
1995	91	112	139	160	156	175	160	146	118	99	81	71	1,506
1996	81	97	125	151	162	184	176	166	138	117	94	78	1,569
1997	81	91	116	140	145	171	164	155	128	109	88	73	1,459
1998	77	95	134	178	196	240	237	232	199	173	138	104	2,004
1999	88	81	100	133	152	187	183	177	151	131	107	88	1,578
2000	86	91	110	130	140	165	168	171	154	143	123	102	1,583
2001	92	83	90	102	108	136	146	158	148	136	111	83	1,392
2002	67	59	71	93	108	143	156	166	153	141	121	97	1,374
2003	86	80	91	110	120	151	159	164	147	132	109	86	1,436
2004	78	77	95	118	133	157	153	148	125	108	88	73	1,353
2005	73	83	108										
Avg	75	81	100	119	125	147	143	139	119	105	87	73	1,313
Min	27	32	47	66	77	95	89	81	66	60	44	31	799
Max	98	119	149	178	196	240	237	232	199	173	138	104	2,004

[a] Equivalent monthly rate for 1 instantaneous measurement per month.

[b] Equivalent rate for average of 1-2 measurements/month.

[c] Equivalent rate for average of 2-5 measurements/month; flows >8 cfs omitted.

[d] Monthly baseflows estimated from available data for groundwater flow model calibration (Johnson, 2005).

🟨 Selected drought minimums

afm	acre-feet per month
cfs	cubic feet per second
WY	Water year; e.g., WY 2017 extended from Oct. 1, 2016 through Sep. 30, 2017.
	Data sources: see Table 1-2

Table 4-8
Selected Newell Creek Low-Flow Measurements and Estimates, WYs 1974–2016

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
	afm												afy
USGS continuous gauge at Zayante													
1958	62	57	207	614	5,762	3,911	5,962	547	290	174	105	58	17,751
1959	36	52	48	1,945	2,281	509	220	134	77	42	30	307	5,681
1960	51	50	62	262	1,871	183	122	94	42	24	18	19	2,798
1961	30	93	127	95	116	169	91	61	28	10	6	6	832
1962	13	48	115	84	3,169	1,431	165	116	67	42	27	32	5,307
1963	971	79	333	3,213	3,328	1,290	3,189	691	301	145	95	69	13,704
1964	92	530	149	774	209	175	111	87	69	32	10	24	2,262
1965	45	184	2,408	3,096	544	353	1,303	378	151	84	58	32	8,636
1966	39	185	324	469	668	268	144	88	49	27	19	17	2,296
1967	15	217	1,652	5,442	960	3,924	2,803	813	352	165	121	86	16,551
1968	73	85	190	1,318	801	734	296	145	89	45	33	23	3,832
1969	39	71	293	8,361	8,892	2,444	889	367	206	137	88	72	21,858
1970	86	67	898	6,035	908	2,073	367	224	134	79	69	60	11,000
1971	40	569	1,747	692	275	469	328	181	83	47	28	22	4,479
1972	21	55	315	184	182	71	87	50	34	14	9	14	1,034
1973	94	978	214	3,852	6,163	2,033	499	257	145	69	43	32	14,378
1974	66	797	941	2,079	604	3,638	1,906	422	186	135	62	47	10,883
1975	82	118	454	152	1,705	3,085	862	376	177	80	51	40	7,183
1976	115	70	62	61	67	105	84	40	28	9	18	19	679
1977	22	39	65	93	45	82	31	32	11	**4**	**1**	14	439
1978	13	83	388	7,385	3,188	3,217	1,277	544	222	125	64	58	16,566
1979	48	100	84	890	1,652	1,106	561	245	107	68	51	35	4,945
1980	77	85	619	2,915	5,250	1,350	651	321	177	121	74	56	11,696
1981	52	45	178	705	263	880	242	121	55	43	20	16	2,620
1982	34	554	907	6,230	2,600	1,975	5,256	531	259	202	99	77	18,725
1983	100	389	1,754	4,790	6,910	11,244	2,229	2,900	522	282	152	94	31,367
1984	141	852	3,020	834	442	385	242	177	126	87	61	49	6,414
1985	58	417	262	149	480	545	248	120	65	36	40	28	2,447
1986	36	113	207	640	11,857	6,865	611	278	138	101	65	62	20,973
1987	52	49	83	104	711	503	89	65	39	22	15	23	1,754
1988	24	49	387	398	91	63	96	65	35	18	15	11	1,252
1989	18	87	164	99	75	749	131	62	69	49	23	22	1,548
1990	139	226	141	144	193	148	86	121	71	42	33	27	1,370
1991	32	39	47	53	66	2,131	224	80	55	34	22	12	2,794
1992	19	36	98	124	2,715	615	223	105	55	28	10	**5**	4,034
1993	28	22	342	-	-	-	-	-	-	-	-	-	-
Avg	80	208	536	1,837	2,144	1,678	904	310	129	75	47	45	8,003
Min	13	22	47	53	45	63	31	32	11	4	1.3	5	439
Max	971	978	3,020	8,361	11,857	11,244	5,962	2,900	522	282	152	307	31,367

afm acre-feet per month

afy acre-feet per year

🟨 Selected drought minimums

cfs cubic feet per second

WY Water year; e.g., WY 2011 began Oct. 1, 2010 and extended through Sep. 30, 2011.

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	afm											
Average of Santa Cruz County low-flow measurements at Zayante*												
1976	-	30	12	98	51	86	-	-	-	**7**	-	**1**
1977	-	-	-	-	50	-	-	-	12	-	-	280
1978	9	-	-	-	-	-	-	-	-	105	-	12
1980	39	-	-	-	-	-	-	-	-	-	-	57
1981	-	-	-	-	-	-	-	129	-	-	-	15
1982	-	-	-	-	-	-	-	-	-	-	-	65
1984	-	-	-	-	-	-	214	-	-	-	-	-
1986	194	146	531	979	-	-	-	578	953	226	324	151
1987	206	216	323	365	657	882	390	571	337	147	31	115
1988	116	245	519	168	-	366	395	386	103	793	84	45
1989	135	333	181	322	126	1,063	600	278	157	57	56	14
1990	22	237	168	111	167	176	125	95	92	31	30	48
1991	14	44	18	45	41	-	-	157	61	40	51	10
1992	**7**	51	80	261	86	-	92	242	61	14	-	**4**
1993	46	12	160	-	-	-	178	-	227	32	34	39
1994	49	78	-	66	-	140	63	132	49	26	22	16
1995	26	17	169	-	187	-	-	-	287	167	-	65
1996	-	-	-	-	-	-	-	-	-	-	-	-
1997	-	83	-	-	-	-	288	-	93	-	-	51
1998	51	-	-	-	-	-	-	-	-	-	202	-
1999	120	-	-	-	-	-	-	-	149	-	112	-
2000	44	-	-	-	-	-	-	-	194	-	151	-
2001	-	-	-	-	-	-	-	-	-	56	-	81
2002	107	-	-	-	-	-	-	-	-	-	-	-
2003	44	-	-	-	-	-	-	-	-	-	-	243
2004	61	-	-	-	-	-	-	-	95	-	50	-
2005	28	-	-	-	-	-	-	-	-	-	130	-
2006	-	-	-	-	-	-	-	-	-	-	154	-
2007	86	-	-	-	-	-	118	-	59	-	26	-
2008	27	-	-	-	-	-	-	-	68	-	17	-
2009	-	-	-	-	-	-	215	-	74	-	-	-
2010	-	-	-	-	-	-	-	-	161	-	87	-
2011	-	-	-	-	-	-	-	-	-	-	128	-
2012	-	-	-	-	-	-	-	-	89	-	47	-
2013	-	-	-	-	-	-	116	-	-	-	-	-
2014	16	-	-	-	-	-	47	-	61	-	10	-
2015	-	-	-	-	-	-	77	-	41	-	10	-
2016	-	-	-	-	-	-	262	-	92	-	23	-
Avg	66	124	216	268	170	452	212	285	153	131	81	69
Min	7	12	12	45	41	86	47	95	12	7	10	1.2
Max	206	333	531	979	657	1,063	600	578	953	793	324	280

*Equivalent rate from averaging 1-6 measurements/month; flows >5 cfs omitted.

Data sources: http://waterdata.usgs.gov/ca/nwis/sw; Table 1-2.

Table 4-9

Zayante Creek at Zayante Continuous Gauged Flow and Selected Low-Flow Measurements, WYs 1958–2016

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	afm											
Zayante Creek: average of Santa Cruz Co. low-flow measurements at San Lorenzo River[a]												
1986	425	284		837	1,311		1,803	1,138	648		438	541
1987	432	378						372				
1988		280						291				
1989		228						920				
1990					474	453	312	299	300	350	193	224
1991	215	196	242		218			310	246	205	210	315
1992	**128**	184	221	374	274	1,522	619	374	246	204	204	187
1993	190	265	633			4,899	660	678	450	377	274	208
1994	264	243		311	2,032	638	463	460	363	220	242	183
1995	198	1,232	443		1,770	1,479			777	484		318
1996							1,722				346	
1997							833		415		333	304
1998	283						2,276		1,336		739	
1999	496						2,039		794		377	
2000	352						1,776		661		439	
2001	285										332	
2002	518						767		392			228
2003	309						1,351		935			571
2004	244						786		368		283	
2005	283						1,674				539	
2006	337						4,156		1,171			
2007	400						540		317			
2008	234								425		253	
2009							709		291			
2010								1,165	501		382	
2011										724	559	
2012									458		212	303
2013	416	345					551		348			
2014	301						400		256		206	
2015	189						413		160		**166**	
2016							808		430		310	
2017									1,028	633		
Avg	309	364	385	507	1,013	1,798	1,174	601	533	400	335	308
Min	128	184	221	311	218	453	312	291	160	204	166	183
Max	518	1,232	633	837	2,032	4,899	4,156	1,165	1,336	724	739	571

▨ Selected drought minimums

[a] Equivalent rate from averaging 1-3 measurements/month; flows >12 cfs omitted.

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	afm											
Lompico Creek: average of Santa Cruz Co. low-flow measurements at Carrol Avenue[b]												
1986	2.5	7.1	39					52	24		11	15
1987	26											
1991		0.6	3.1	3.1	2.8		47	6.8		5.5	1.8	3.0
1992	1.8	2.4	0.6	8.6	5.0	41	11	17	4	1.2	1.2	**0.0**
1993	**0.0**	1.8	18				45	27	19	6.8	5.5	1.2
1994	1.2	**0.0**		1.8		12	7.1	5.5	3.6	6.1	6.1	0.0
1995	0.0	6.5	22		16				51	21		8.3
1996							43					
1997		12					44		17			3.0
1998	3.1										20	
1999	37								23		32	
2000	16						55		18		20	
2001										15		
2002												
2003	17								41		19	
2004	1.8						34		10		6.0	
2005	13										14	
2006	10								44		16	
2007	12						27		9.2		3.5	
2008									10		6.0	
2009							34		14			
2010									19		12	
2011											15	
2012									23		16	
2013							12		11			
2014							10		10		3.9	
2015							16		5.2		2.2	
2016							37		18		5	
Avg	10	4.4	17	5	8	27	30	22	19	9.3	11	4.4
Min	0.0	0.0	0.6	1.8	2.8	12	7.1	5.5	3.6	1.2	1.2	0.0
Max	37	12	39	9	16	41	55	52	51	21	32	15

[b] Equivalent rate from averaging 1-2 measurements/month; flows >1 cfs omitted.

afm acre-feet per month
cfs cubic feet per second
WY water year

Table 4-10

Selected Zayante Creek and Lompico Creek Low-Flow Measurements, WYs 1986–2017

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
	afm												afy
USGS continuous gauge near Scotts Valley													
1989	-	-	-	-	175	1,045	251	143	131	115	113	118	-
1990	183	244	185	248	258	241	156	185	127	123	117	105	2,172
1991	121	119	133	130	134	1,967	272	143	117	**105**	115	109	3,465
1992	152	133	258	178	2,889	809	224	151	150	140	122	120	5,327
1993	131	117	745	4,925	2,896	1,387	470	239	179	143	140	134	11,506
1994	132	144	273	233	1,178	234	189	175	106	125	125	111	3,026
1995	193	299	299	6,129	726	4,413	668	732	258	176	134	125	14,153
1996	121	123	435	1,994	3,535	2,281	678	644	272	182	157	132	10,553
1997	142	310	4,459	5,917	873	394	284	219	165	124	124	128	13,139
1998	139	351	459	3,250	9,267	2,097	1,290	750	560	301	204	156	18,824
1999	179	298	295	1,432	2,620	1,121	1,017	256	184	147	133	124	7,808
2000	120	219	169	2,304	5,309	1,617	514	329	225	178	147	149	11,279
2001	233	163	166	679	1,725	1,424	275	172	129	124	114	103	5,307
2002	127	255	1,805	1,542	513	640	311	210	150	134	120	109	5,916
2003	125	221	2,911	1,158	348	454	642	451	212	151	123	116	6,912
2004	117	144	1,447	1,666	1,755	777	288	201	163	148	128	125	6,958
2005	340	242	1,711	2,497	1,439	2,216	879	360	253	196	158	140	10,430
2006	125	154	2,375	2,067	652	3,237	4,491	596	322	245	206	166	14,637
2007	164	200	279	200	553	292	194	140	128	119	109	**102**	2,479
Avg	158	207	1,022	2,030	1,939	1,402	689	321	202	157	136	125	8,549
Min	117	117	133	130	134	234	156	140	106	105	109	102	2,172
Max	340	351	4,459	6,129	9,267	4,413	4,491	750	560	301	206	166	18,824
Balance Hydrologics continuous gage above mouth at Mount Hermon													
2017	-	-	-	-	-	-	-	-	-	283	245	212	-

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	afm											
Average of Santa Cruz Co. low-flow measurements at Zayante Creek[a]												
1990								180			143	
1991	126							163				
1992	140								182			153
1993												127
1994				168					127			130
1996												190
1997											222	
1998												229
1999	216										197	
2000	195										218	
2001	213									154	144	
2002	173								143			116
2003	160										125	
2004	154								193		156	
2005	206										148	
2006	167											
2007	172						183		133		130	
2008	135								141			128
2009	139	147	162	134				197	145		135	
2010									212			182
2011	168									232	217	189
2013											139	
2014												**112**
2015	**108**						148			123		
2016								200				
2017	152	165										231
Avg	168	156	162	134			166	198	161	170	161	169
Min	108	147	162	134			148	197	133	123	125	112
Max	216	165	162	134			183	200	212	232	218	231

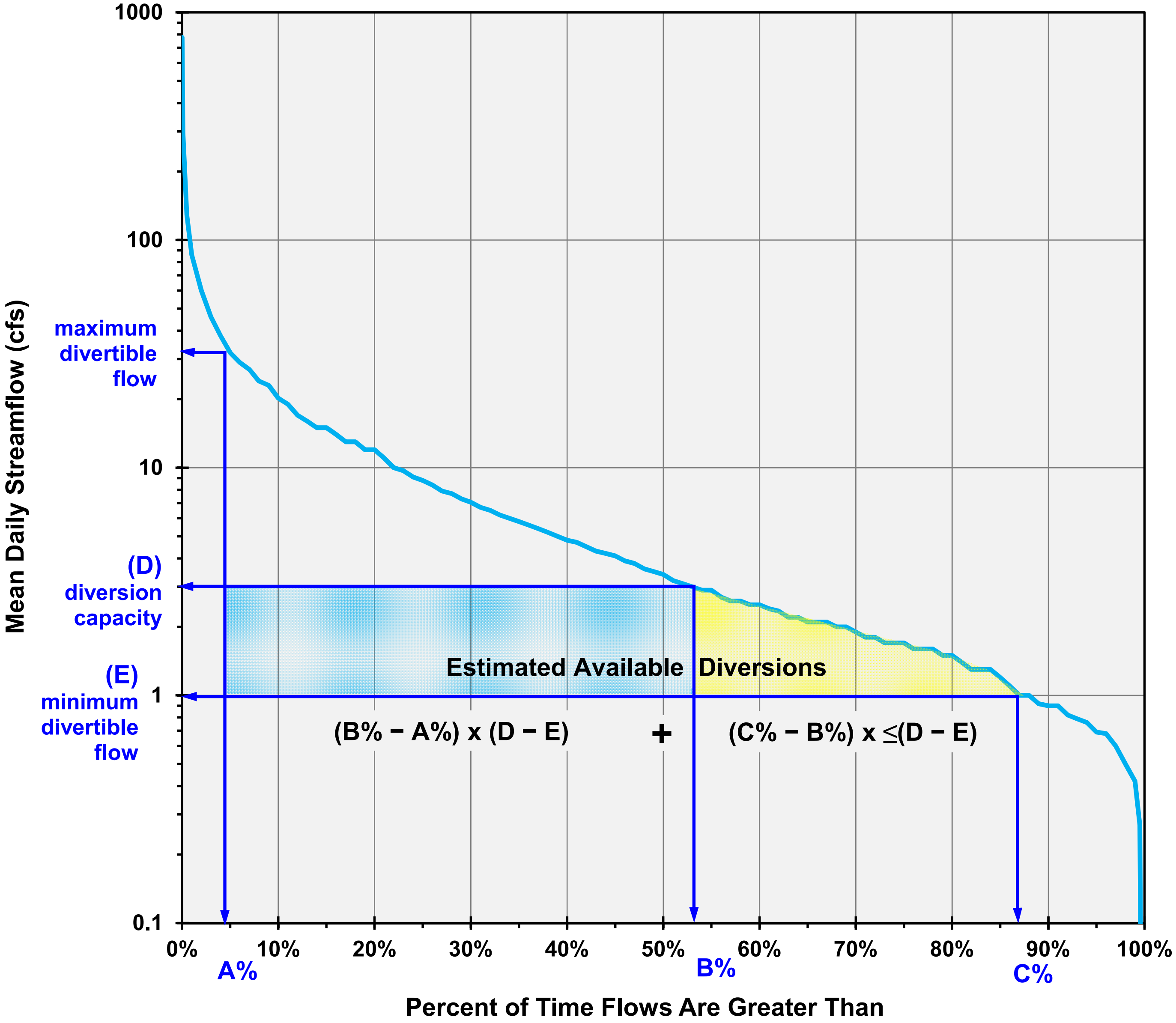
WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	afm											
Average of USGS low-flow measurements near Scotts Valley[b]												
1973	-	-	-	-	-	-	-	-	-	172	-	-
1974	-	262	-	-	-	-	-	-	-	264	-	-
Average of Santa Cruz Co. low-flow measurements at Mount Hermon Rd (USGS Gauge)[c]												
1976	-	155	172	-	-	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-	-	113	-	**80**	-
1978	-	-	-	-	-	-	-	-	-	-	-	161
1979	-	-	-	-	-	-	-	-	-	-	-	129
1980	-	-	-	-	-	-	-	-	-	-	-	129
1981	-	-	-	-	-	-	-	114	-	-	-	116
1982	-	-	-	-	-	-	-	-	-	-	-	119
1986	-	-	-	-	-	-	-	-	258	-	-	-
1987	205	-	-	-	-	-	-	167	-	-	-	-
1988	193	-	-	-	-	-	-	-	138	-	-	-
1989	-	124	-	-	-	-	-	-	-	-	-	-
1990	-	232	-	-	-	-	131	146	120	95	95	113
1991	124	120	-	135	112	-	-	158	122	117	117	105
1992	117	122	-	232	64	-	220	-	152	117	108	122
1993	129	132	-	-	-	-	-	243	174	168	136	132
1994	126	122	-	136	-	261	152	179	**89**	**85**	100	97
1995	168	138	-	-	-	52	-	-	82	146	157	-
1996	117	132	-	-	-	-	-	-	-	-	208	174
1997	-	113	-	-	-	-	267	-	163	-	146	-
1998	168	-	-	-	-	-	-	-	-	246	-	-
1999	191	-	-	187	-	-	-	-	202	-	154	-
2000	138	-	-	-	-	-	-	-	250	-	146	-
2001	141	-	-	-	-	-	274	-	113	-	123	-
2002	123	-	-	-	-	-	292	-	149	-	-	119
2003	154	-	-	-	-	-	-	-	-	-	129	-
2004	117	-	-	-	-	-	238	-	155	-	129	-
2005	172	-	-	-	-	-	-	-	232	-	129	-
2006	148	-	-	-	-	-	-	-	292	-	215	-
2007	160	-	-	-	-	-	155	-	119	-	117	-
2008	123	-	-	-	-	-	-	-	-	-	-	-
2015	89	-	-	-	-	-	-	-	-	-	-	-
Avg	145	150	172	172	88	156	216	168	162	157	135	126
Min	89	113	172	135	64	52	131	114	82	85	80	97
Max	205	262	172	232	112	261	292	243	292	264	215	174

[a] Equivalent rate for average of 1-2 measurements/month; flows >4 cfs omitted.
[b] Equivalent monthly rate for 1 instantaneous measurement per month; flows >5 cfs omitted.
[c] Equivalent rate for average of 1-2 measurements/month; flows >5 cfs omitted.

🟨 Selected drought minimums

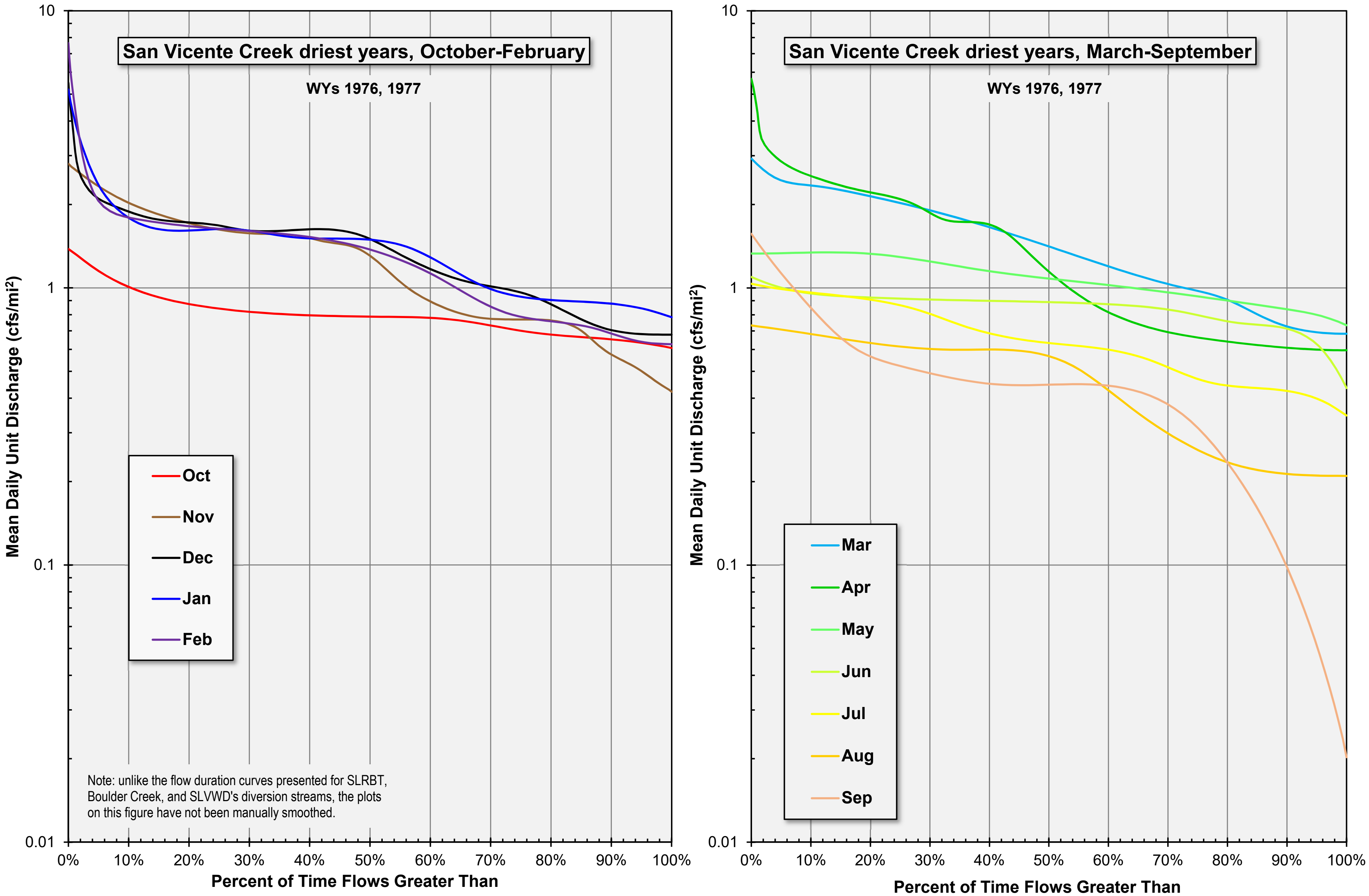
afm, afy	acre-feet per month, acre-feet per year
cfs	cubic feet per second
WY	Water year; e.g., WY 2017 extended from October 1, 2016 through September 30, 2017.
	Data source: see Table 1-2

Table 4-11
Bean Creek Continuous Gauged Flow and Selected Low-Flow Measurements, WYs 1973–2017



cfs cubic feet per second

Figure 4-1
Method of Estimating Divertible Flows from a Flow Duration Curve


San Vicente Creek driest years, October-February

WYs 1976, 1977

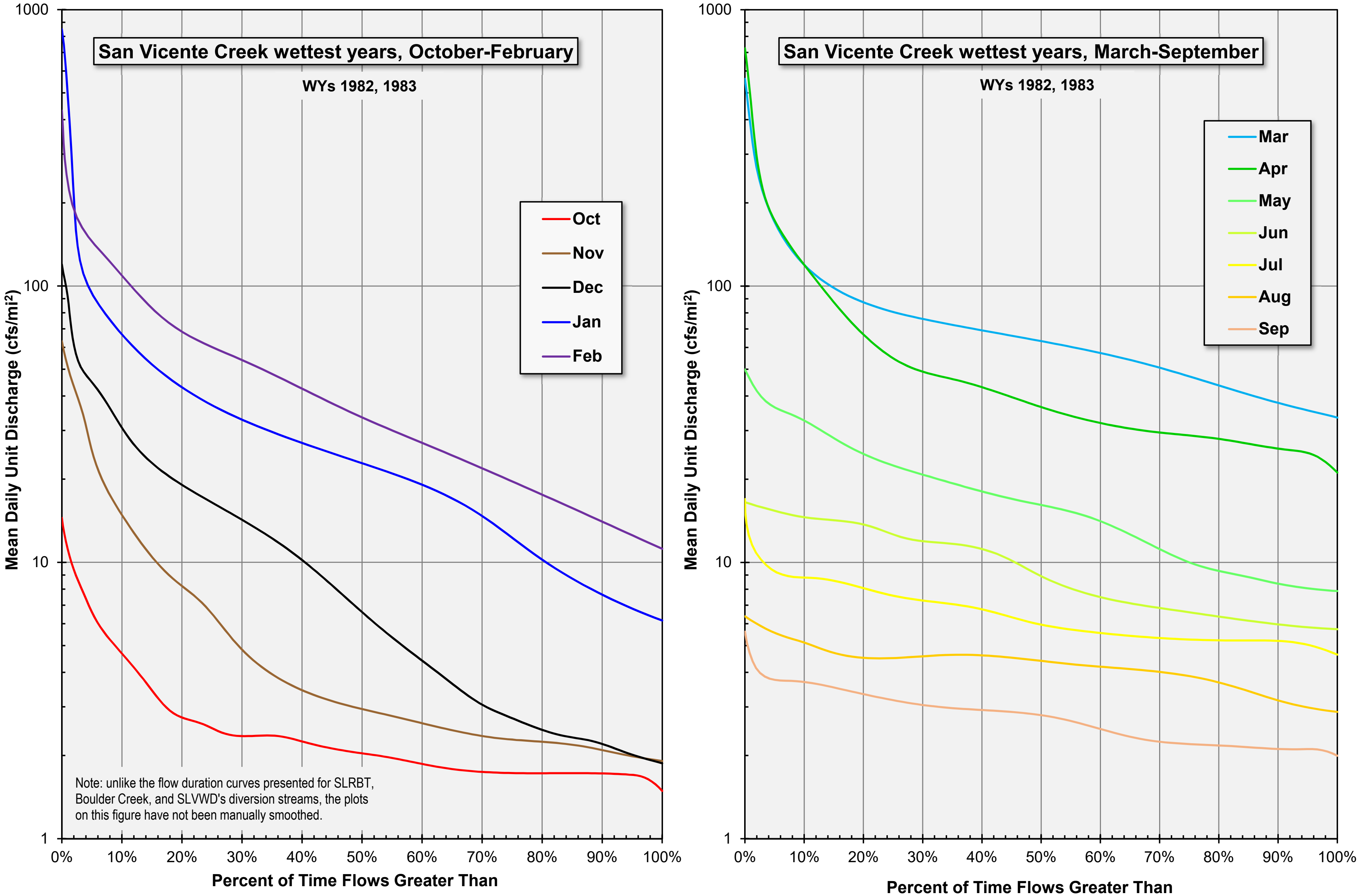
San Vicente Creek driest years, March-September

WYs 1976, 1977

Note: unlike the flow duration curves presented for SLRBT, Boulder Creek, and SLVWD's diversion streams, the plots on this figure have not been manually smoothed.

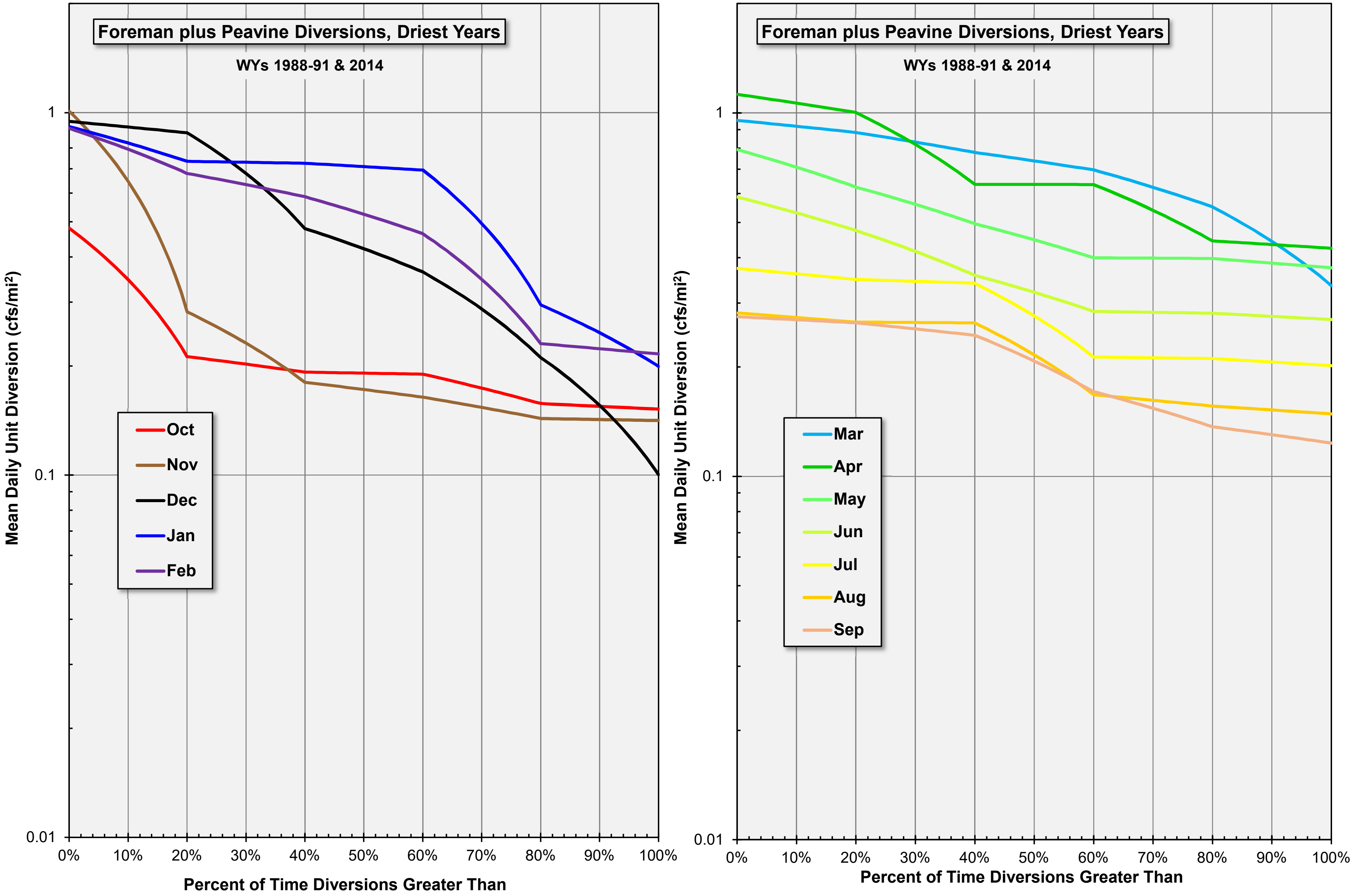
Period of record: WYs 1970-1985 (Table 1-2)
cfs/mi^2 cubic feet per second per square mile

Figure 4-2
San Vicente Creek near Davenport Monthly Flow Duration Curves, Driest Years



Period of record: WYs 1970-1985 (Table 1-2)
cfs/mi^2 cubic feet per second per square mile

Figure 4-3
San Vicente Creek near Davenport Monthly Flow Duration Curves, Wettest Years

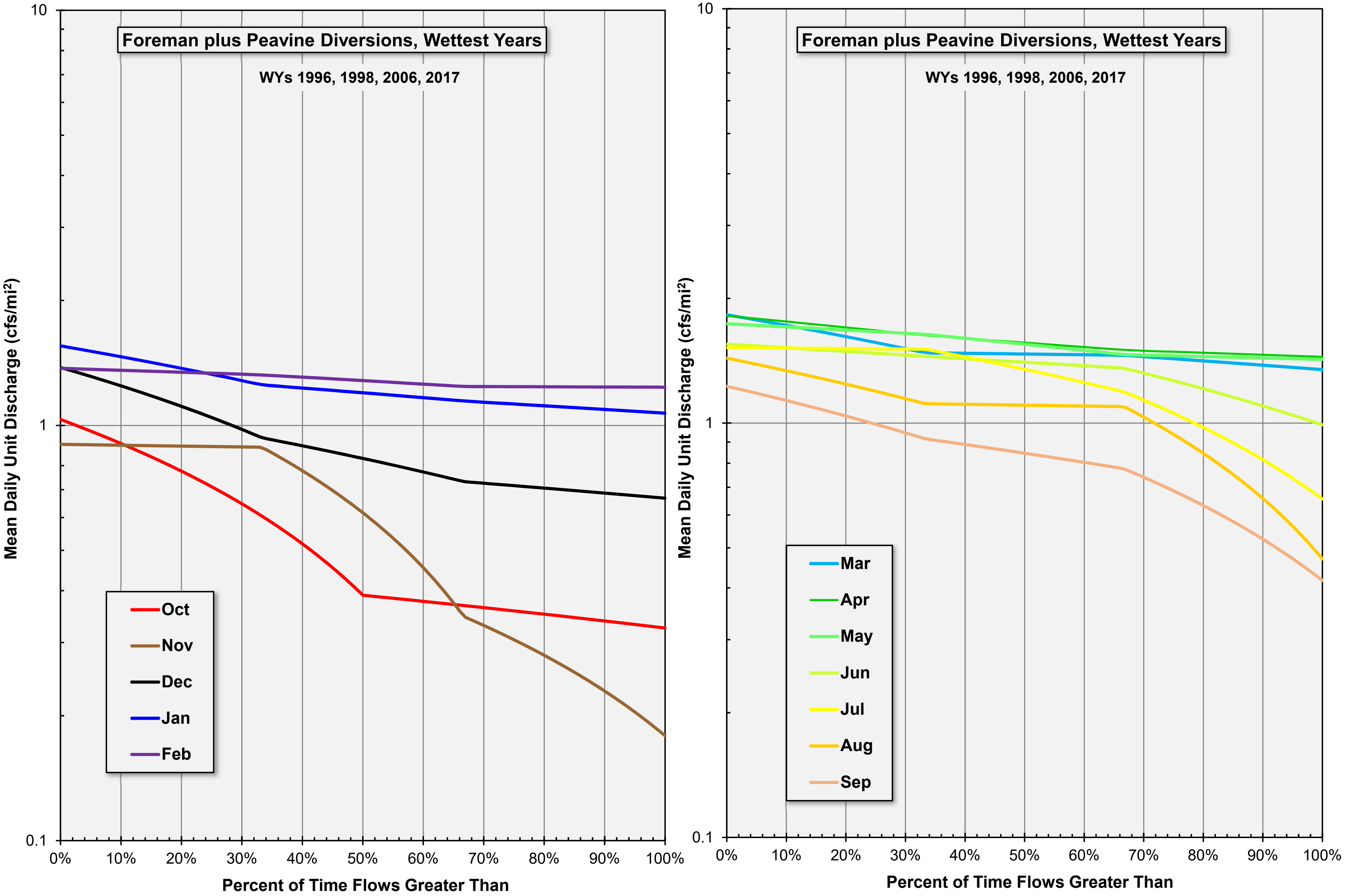


Period of record: WYs 1985-2017 (Table 1-1)

cfs/mi^2 cubic feet per second per square mile

Figure 4-4

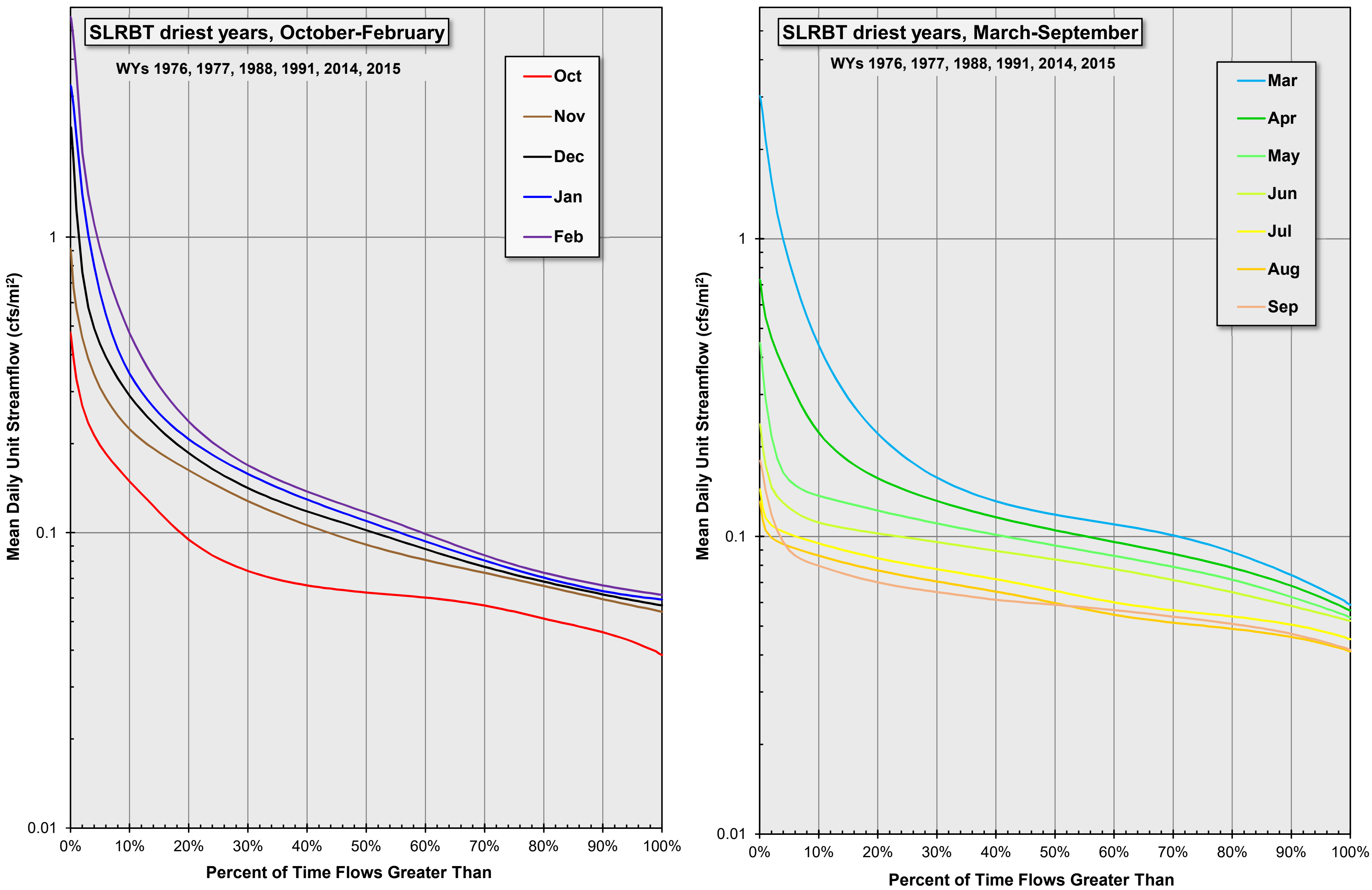
Monthly Flow Duration Curves for Foreman and Peavine Creeks Combined Diversions, Driest Years



Period of record: WYs 1985-2017 (Table 1-1)

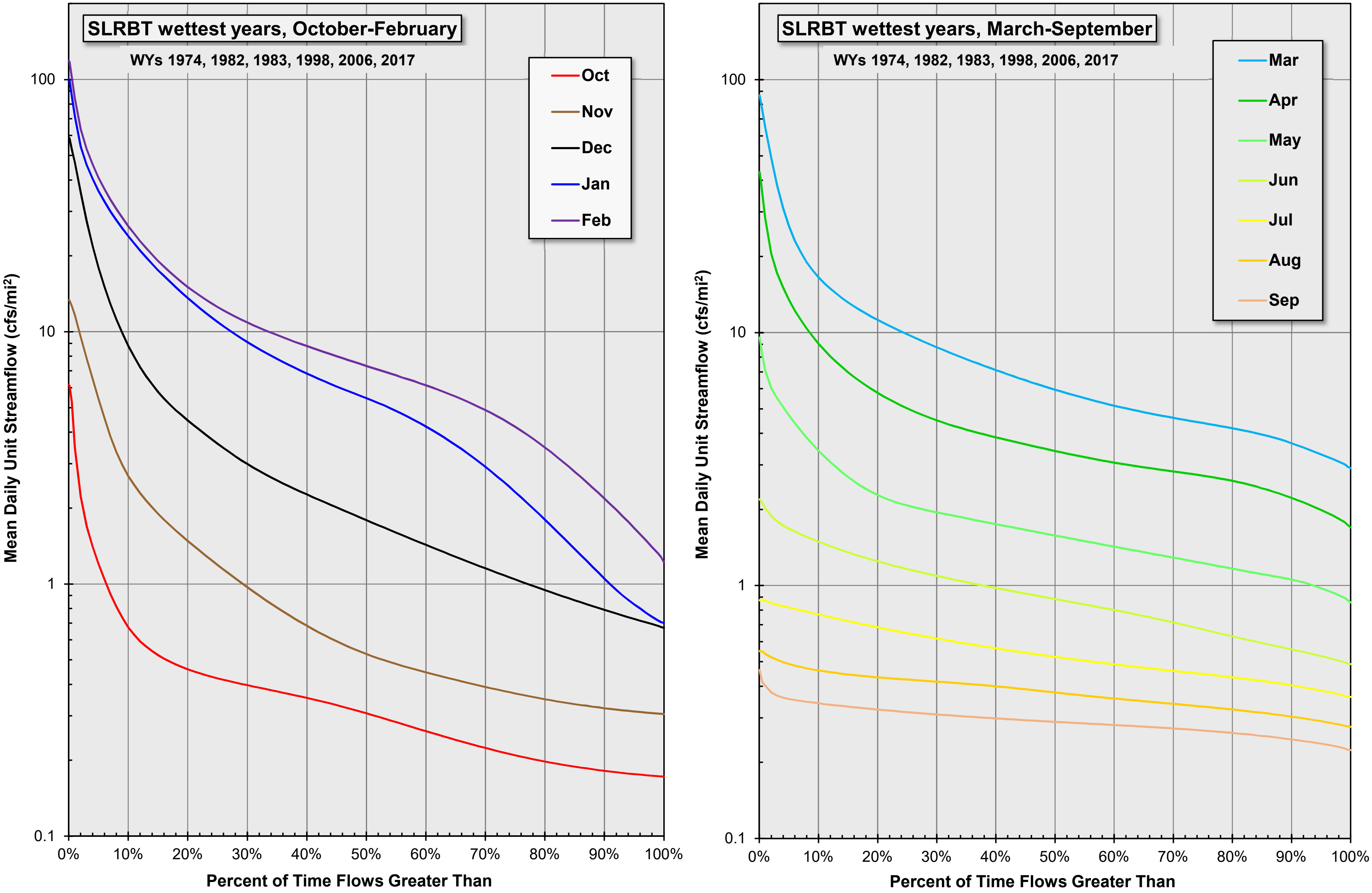
cfs/mi² cubic feet per second per square mile

Figure 4-5
Monthly Flow Duration Curves for Foreman and Peavine Creeks Combined Diversions, Wettest Years



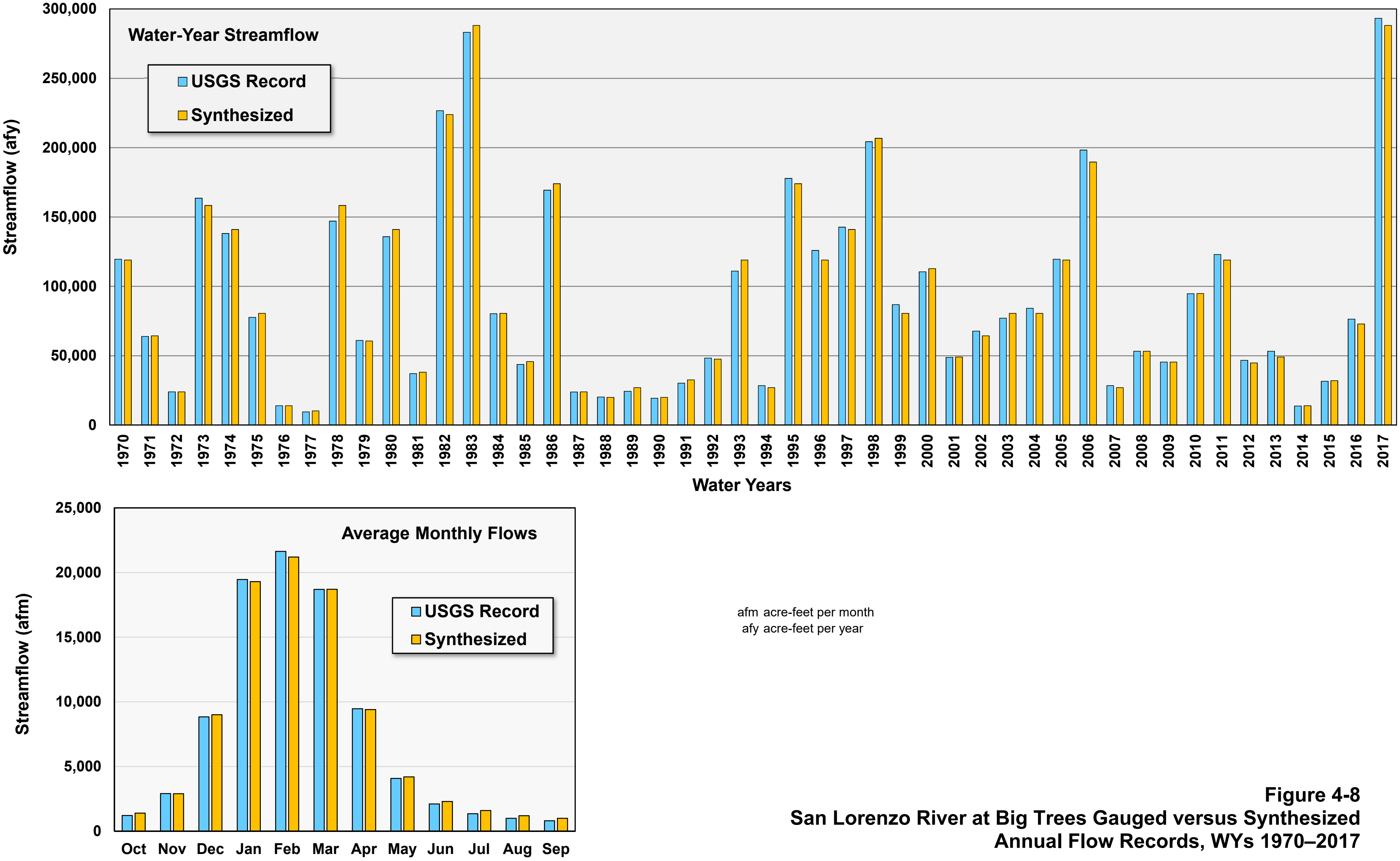
Period of record used: WYs 1970-2017 (Table 1-2)
cfs/mi^2 cubic feet per second per square mile

Figure 4-6
San Lorenzo River at Big Trees Monthly Flow Duration Curves, Driest Years



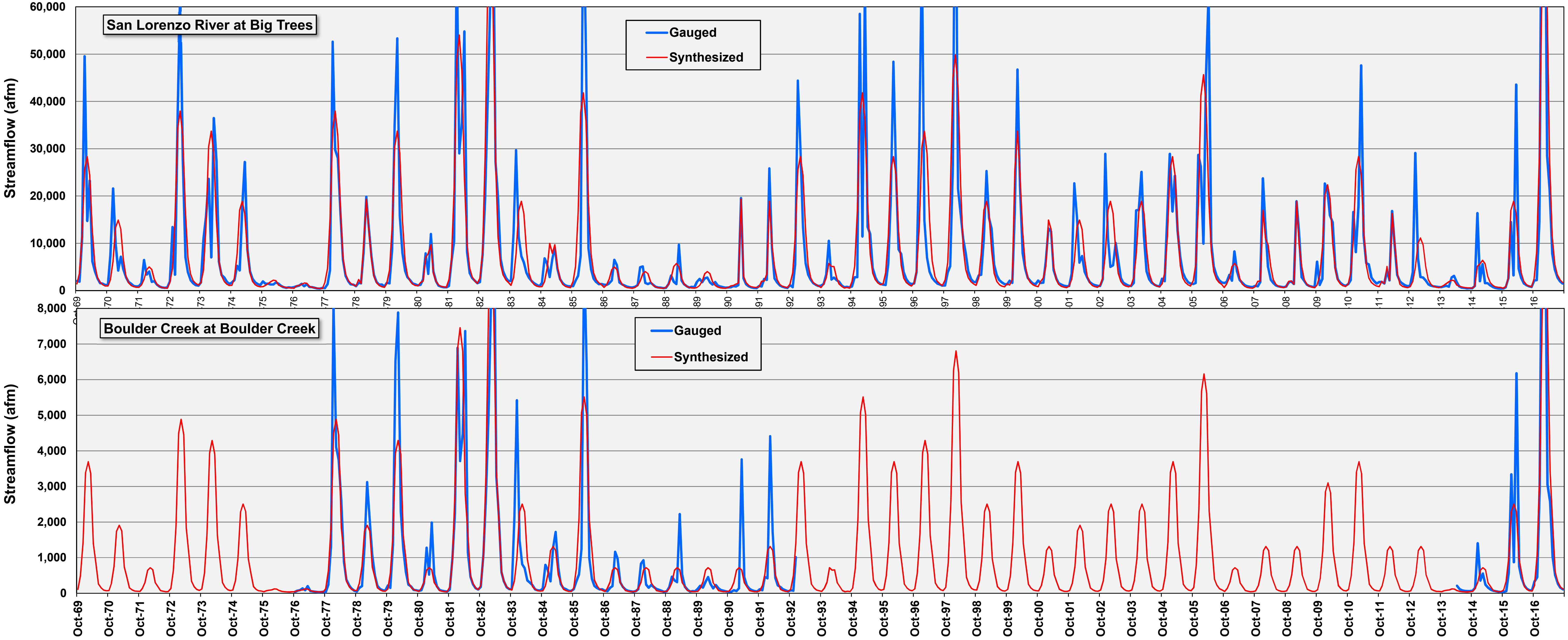
Period of record used: WYs 1970-2017 (Table 1-2)
cfs/mi^2 cubic feet per second per square mile

Figure 4-7
San Lorenzo River at Big Trees Monthly Flow Duration Curves, Wettest Years



afm acre-feet per month
afy acre-feet per year

Figure 4-8
San Lorenzo River at Big Trees Gauged versus Synthesized Annual Flow Records, WYs 1970–2017



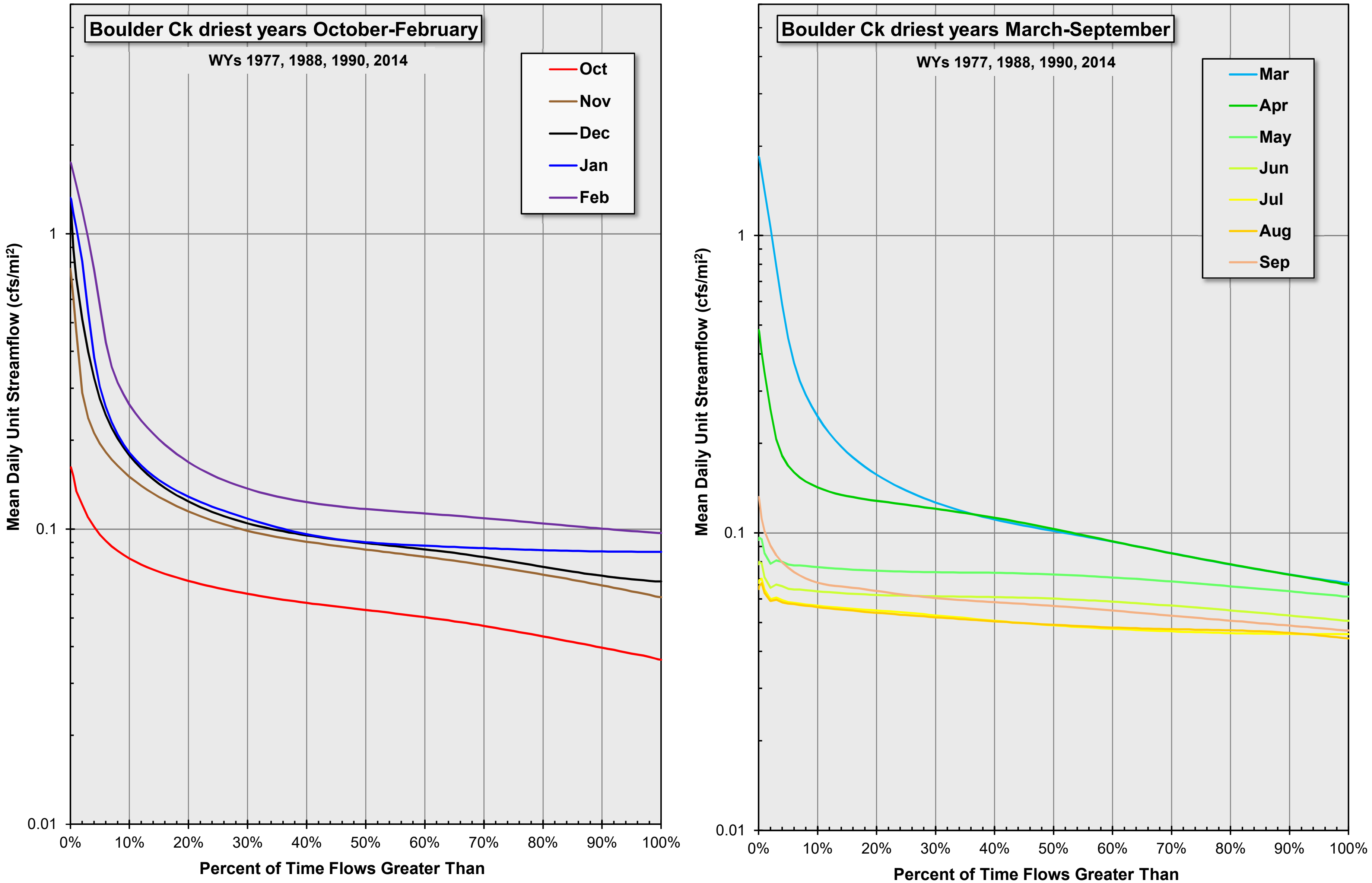
afm acre-feet per month

Note differences in vertical-axis scaling.

See Table 1-2 for source of gauged records.

Figure 4-9

San Lorenzo River at Big Trees and Boulder Creek Gauged versus Synthesized Monthly Streamflow, WYs 1970–2017

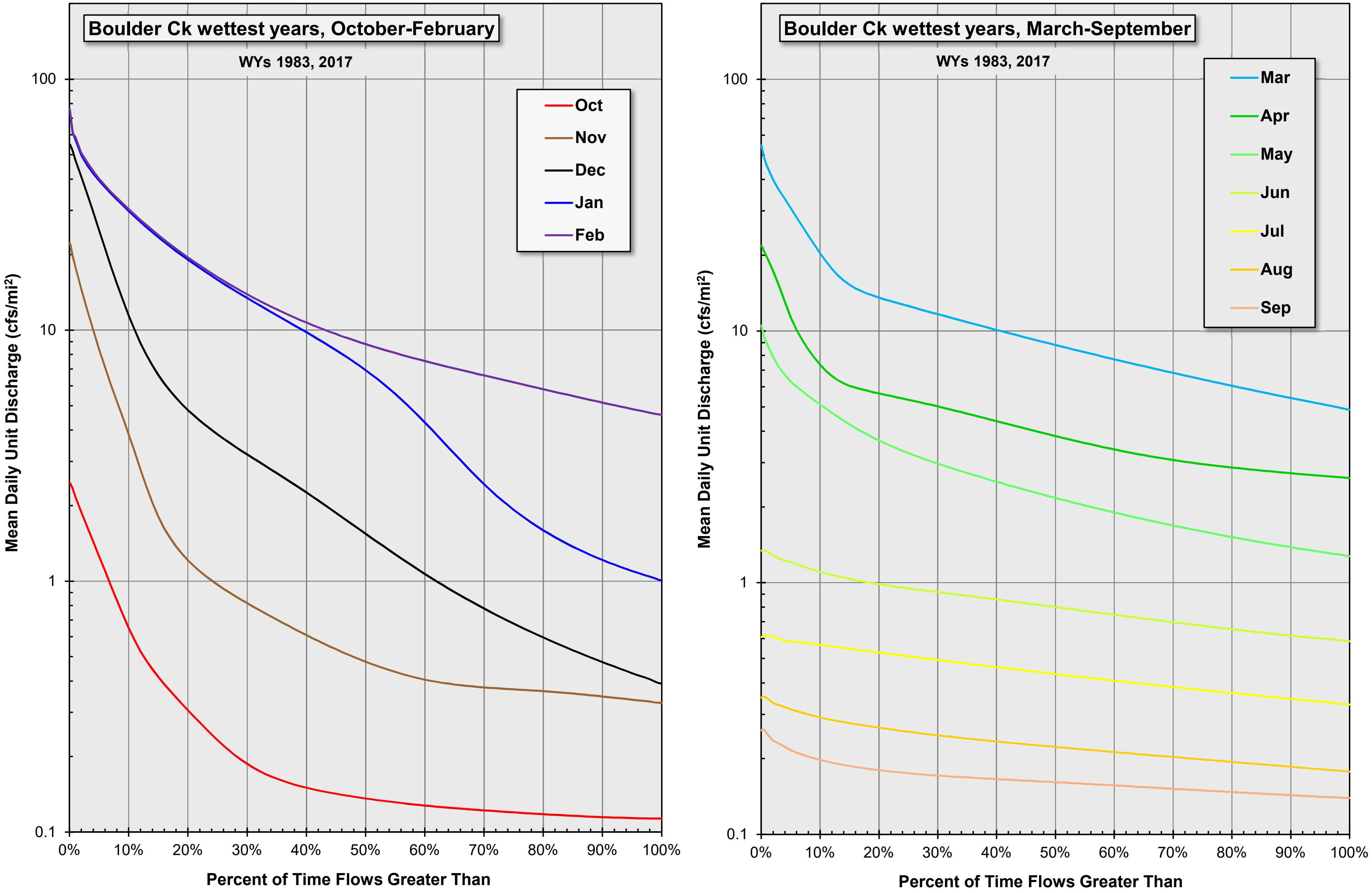


cfs/mi^2 cubic feet per second per square mile

Period of record: WYs 1977-1993, 2014-2017 (Table 1-2)

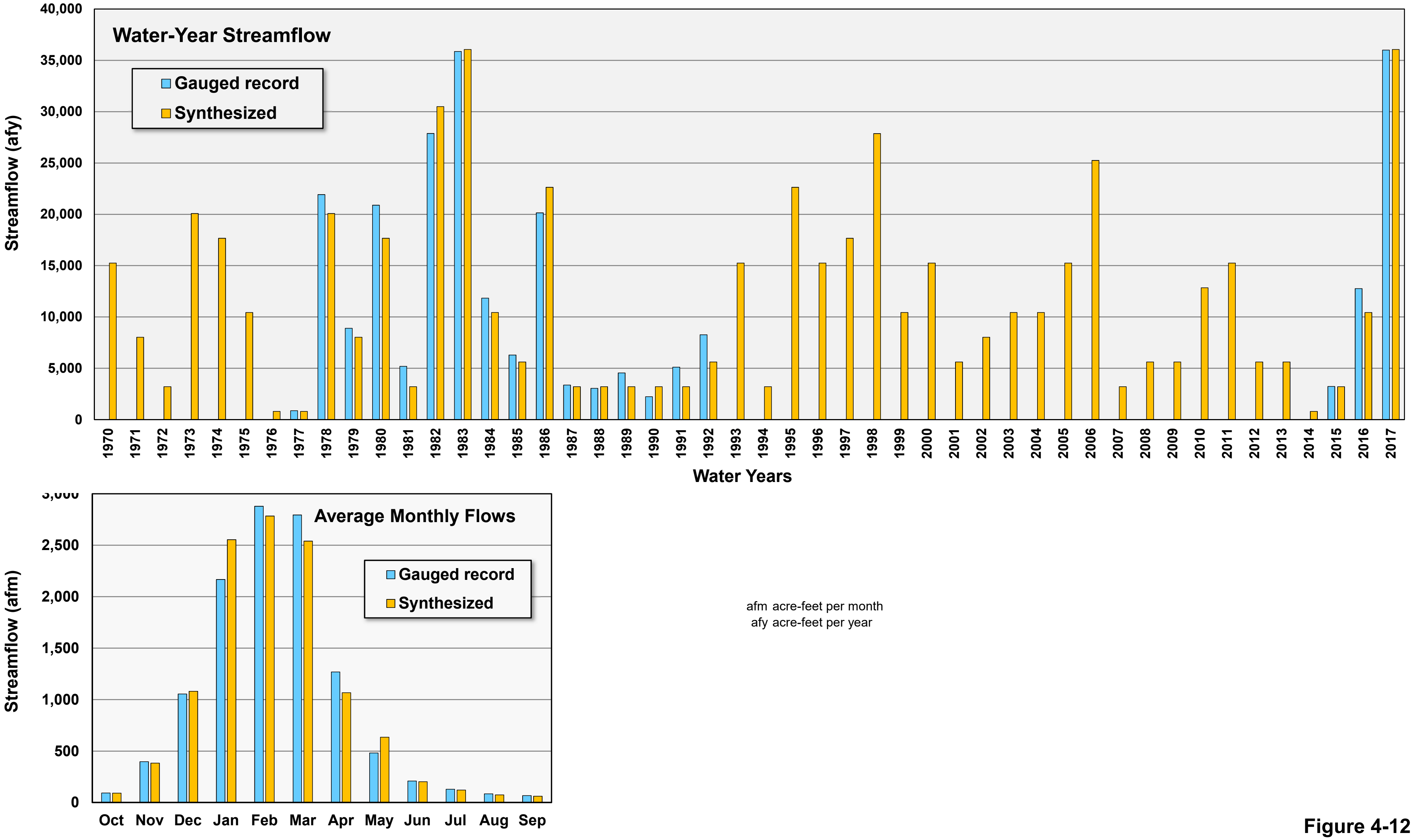
Figure 4-10

Boulder Creek at Boulder Creek Monthly Flow Duration Curves, Driest Years



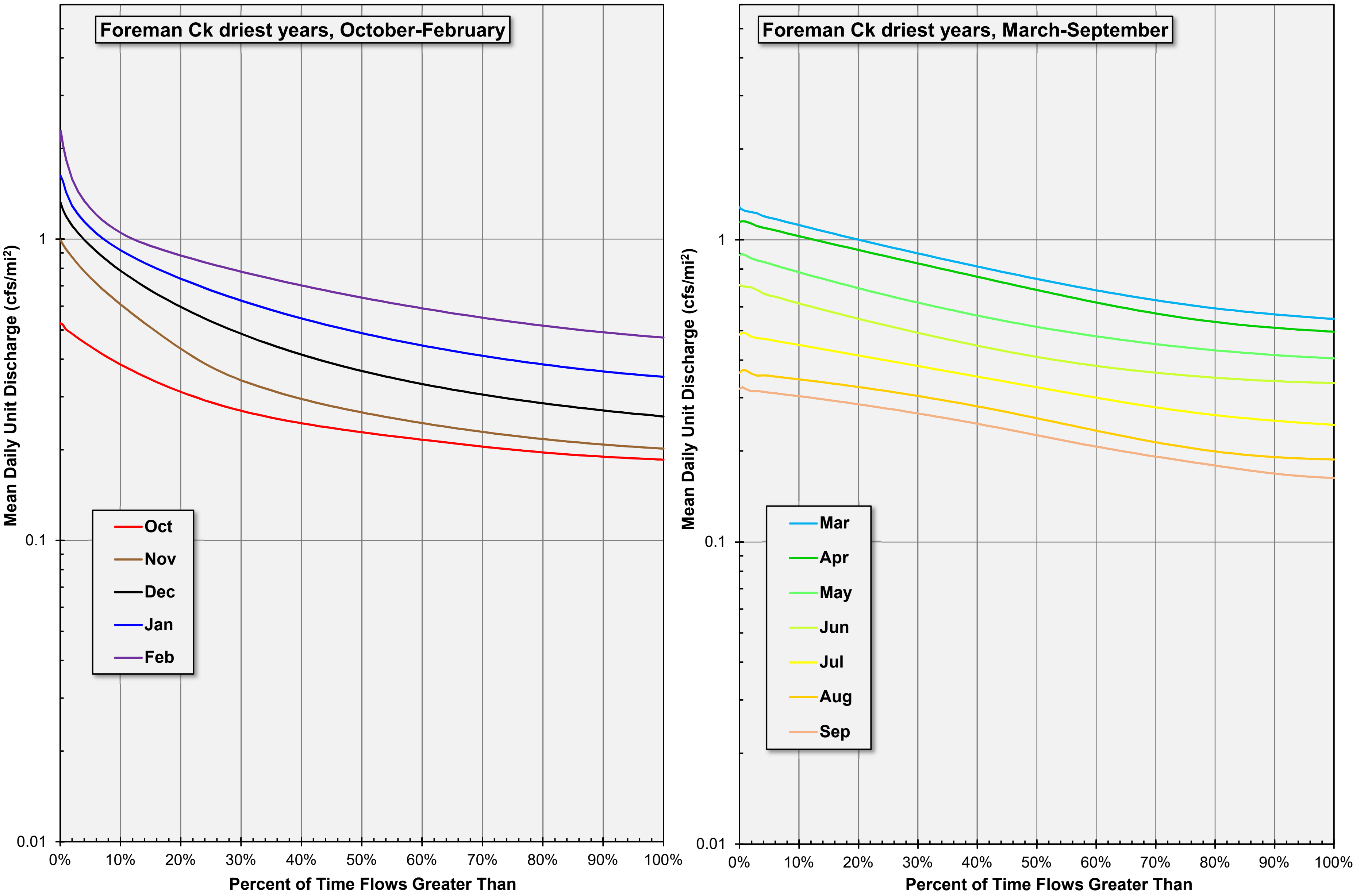
cfs/mi^2 cubic feet per second per square mile
Period of record: WYs 1977-1993, 2014-2017 (Table 1-2)

Figure 4-11
Boulder Creek at Boulder Creek Monthly Flow Duration Curves, Wettest Years



afm acre-feet per month
afy acre-feet per year

Figure 4-12
Boulder Creek Gauged versus Synthesized Annual Flows, WYs 1970–2017

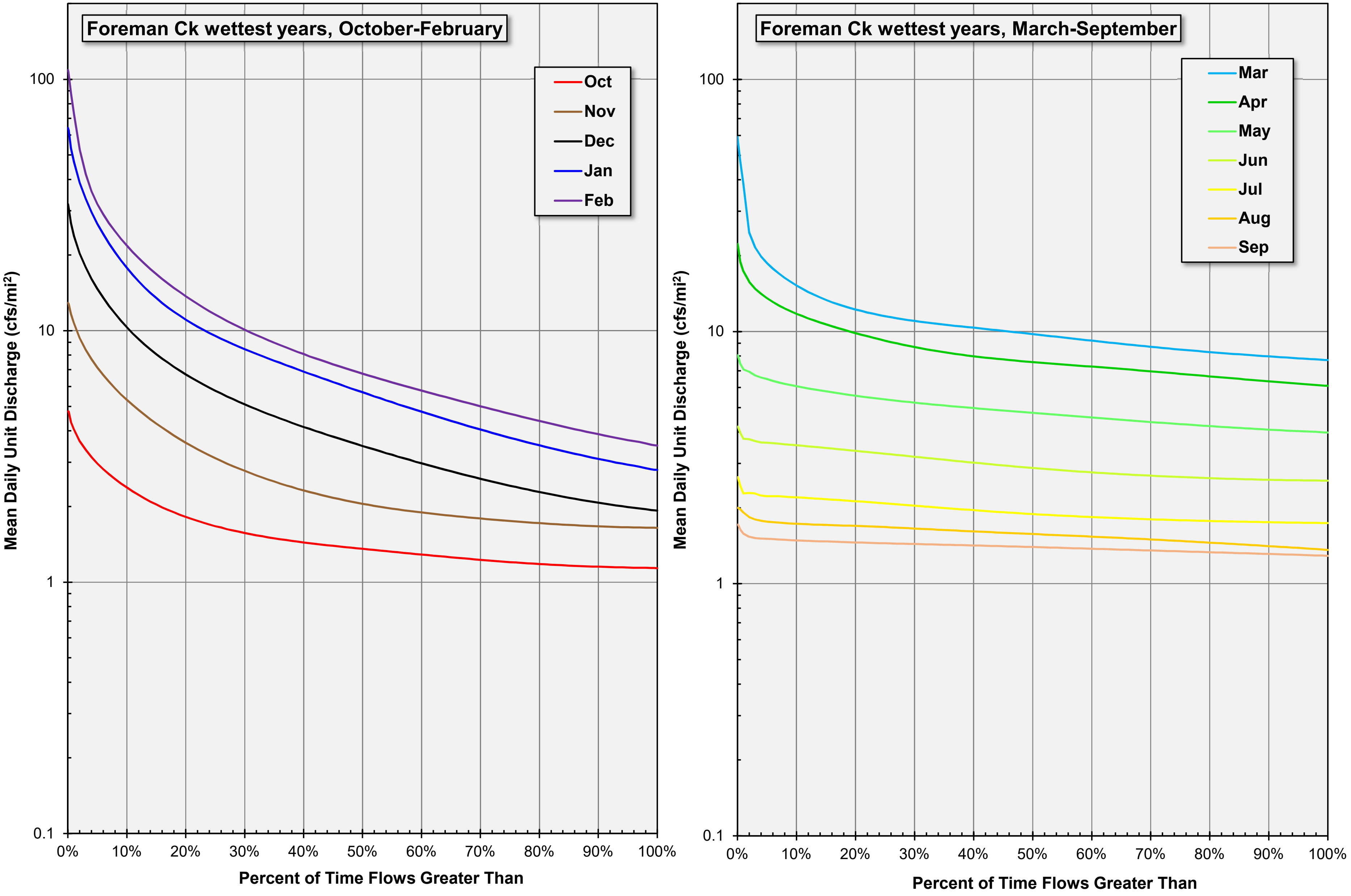


Foreman Ck driest years, October-February

Foreman Ck driest years, March-September

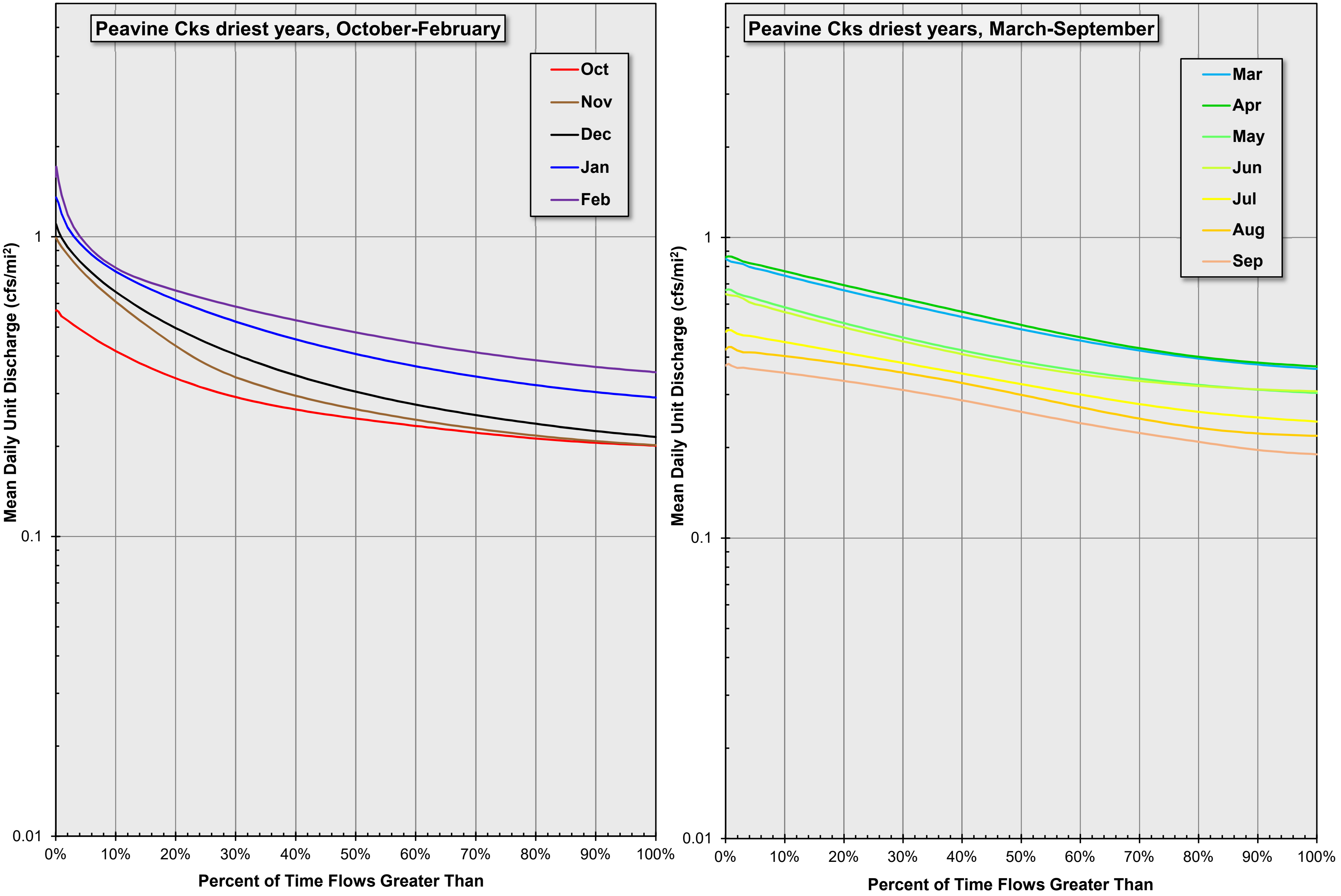
cfs/mi² cubic feet per second per square mile
Represents estimated total flow at point of diversion.

Figure 4-13
Foreman Creek Estimated Monthly Flow Duration Curves, Driest Years



cfs/mi^2 cubic feet per second per square mile
Represents estimated total flow at point of diversion.

Figure 4-14
Foreman Creek Estimated Monthly Flow Duration Curves, Wettest Years

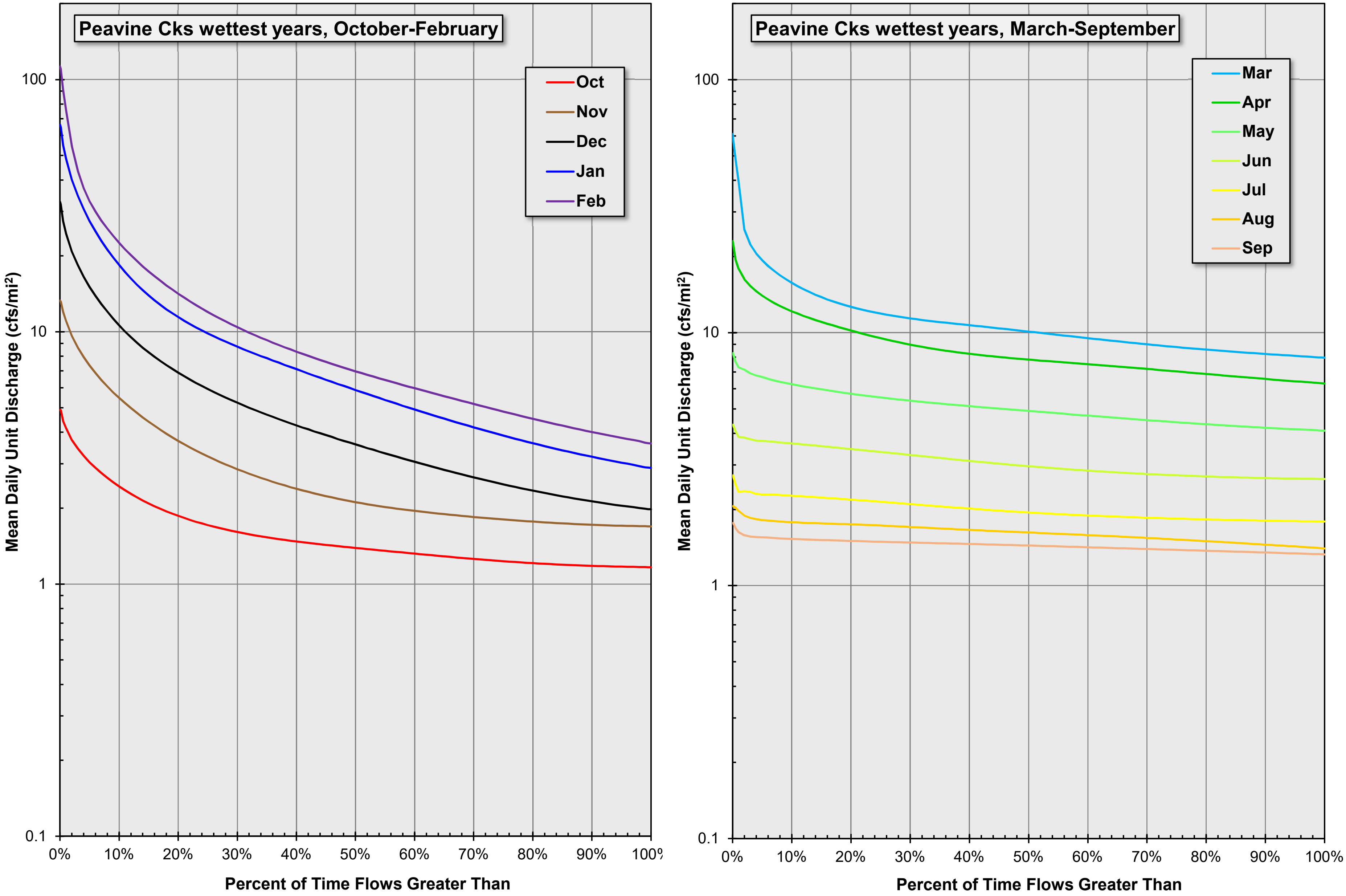


cfs/mi^2 cubic feet per second per square mile

Represents estimated total flow at point of diversion.

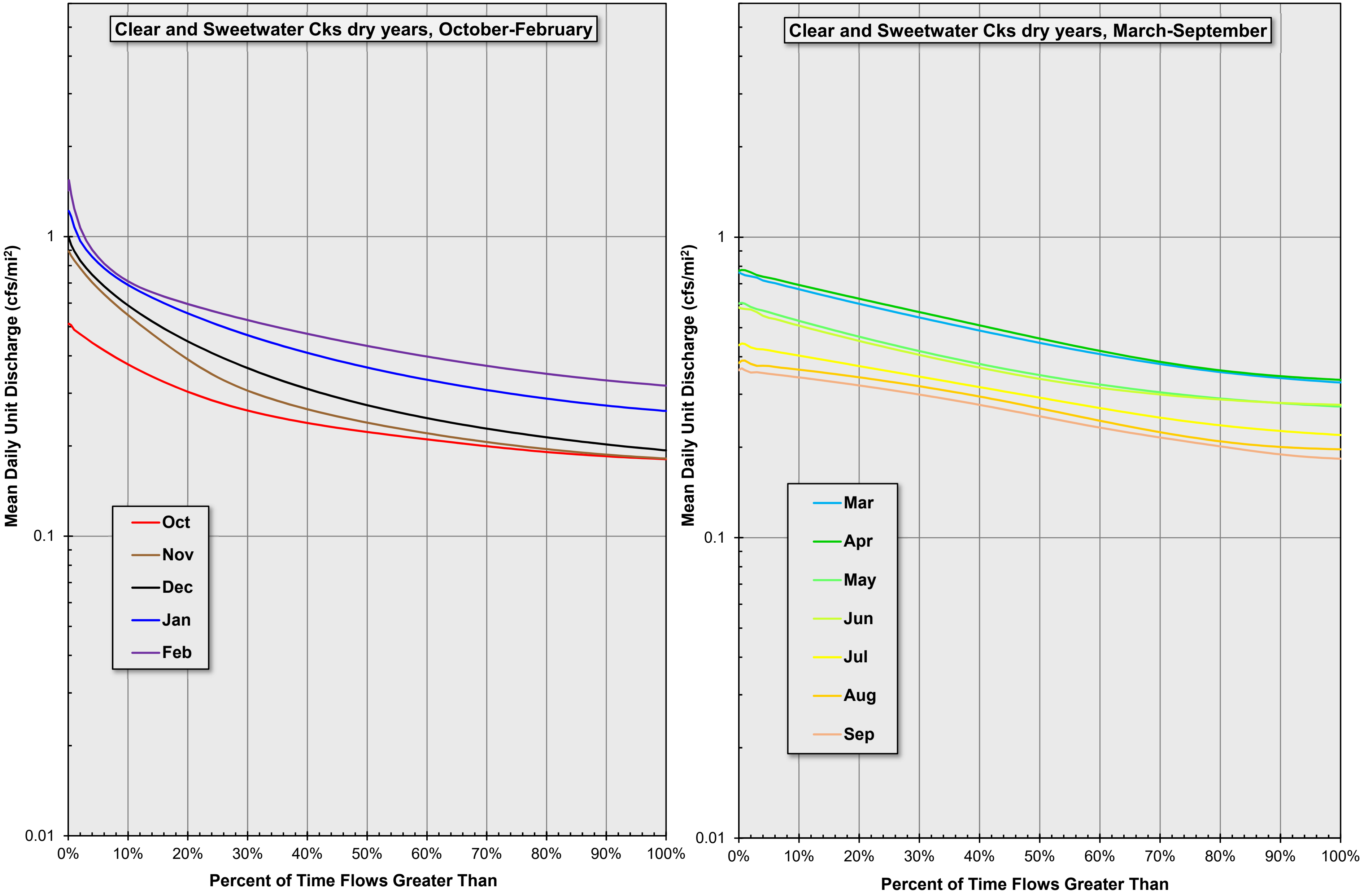
Figure 4-15

Peavine Creek Estimated Monthly Flow Duration Curves, Driest Years



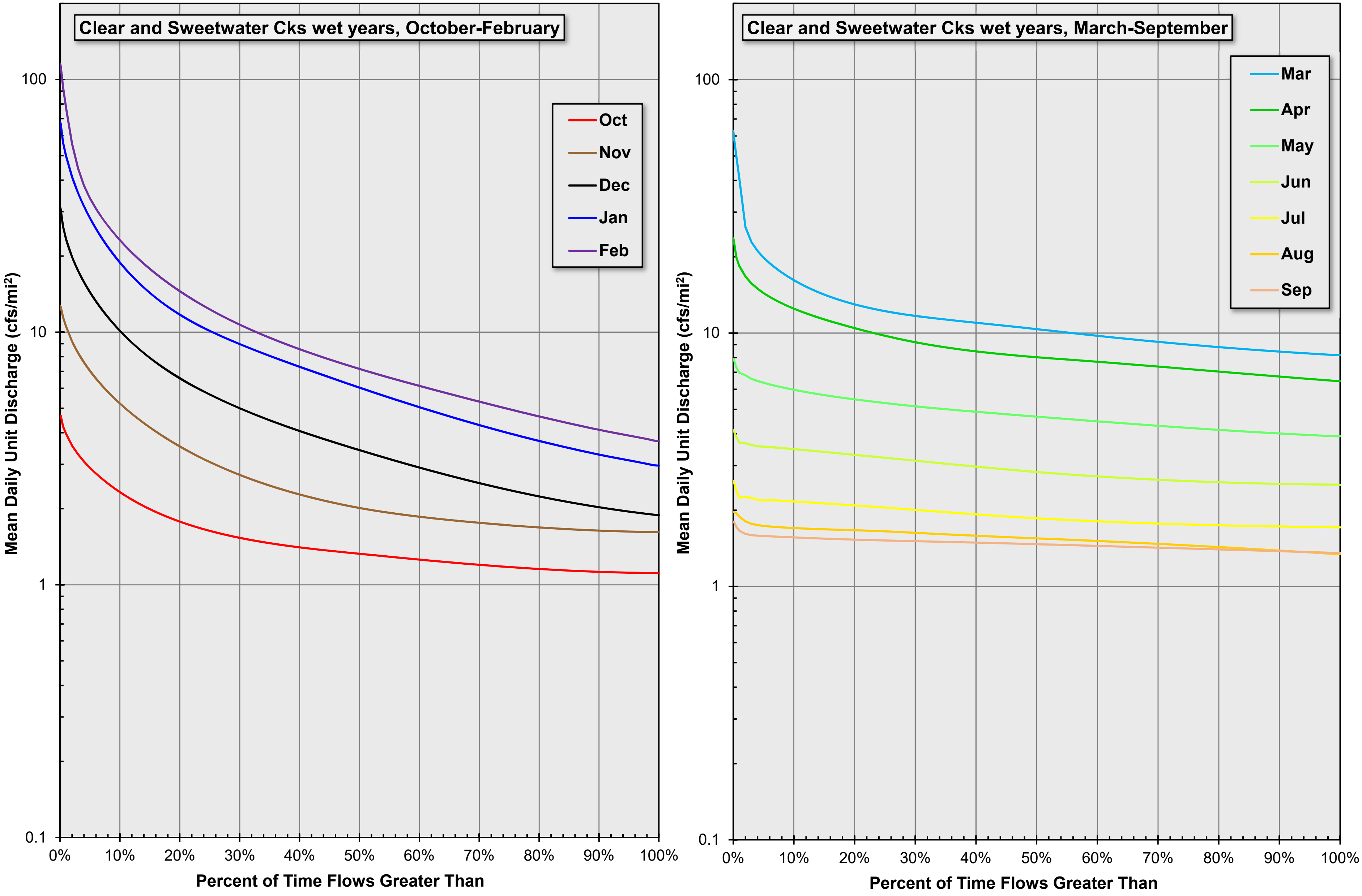
cfs/mi^2 cubic feet per second per square mile
Represents estimated total flow at point of diversion.

Figure 4-16
Peavine Creek Estimated Monthly Flow Duration Curves, Wettest Years



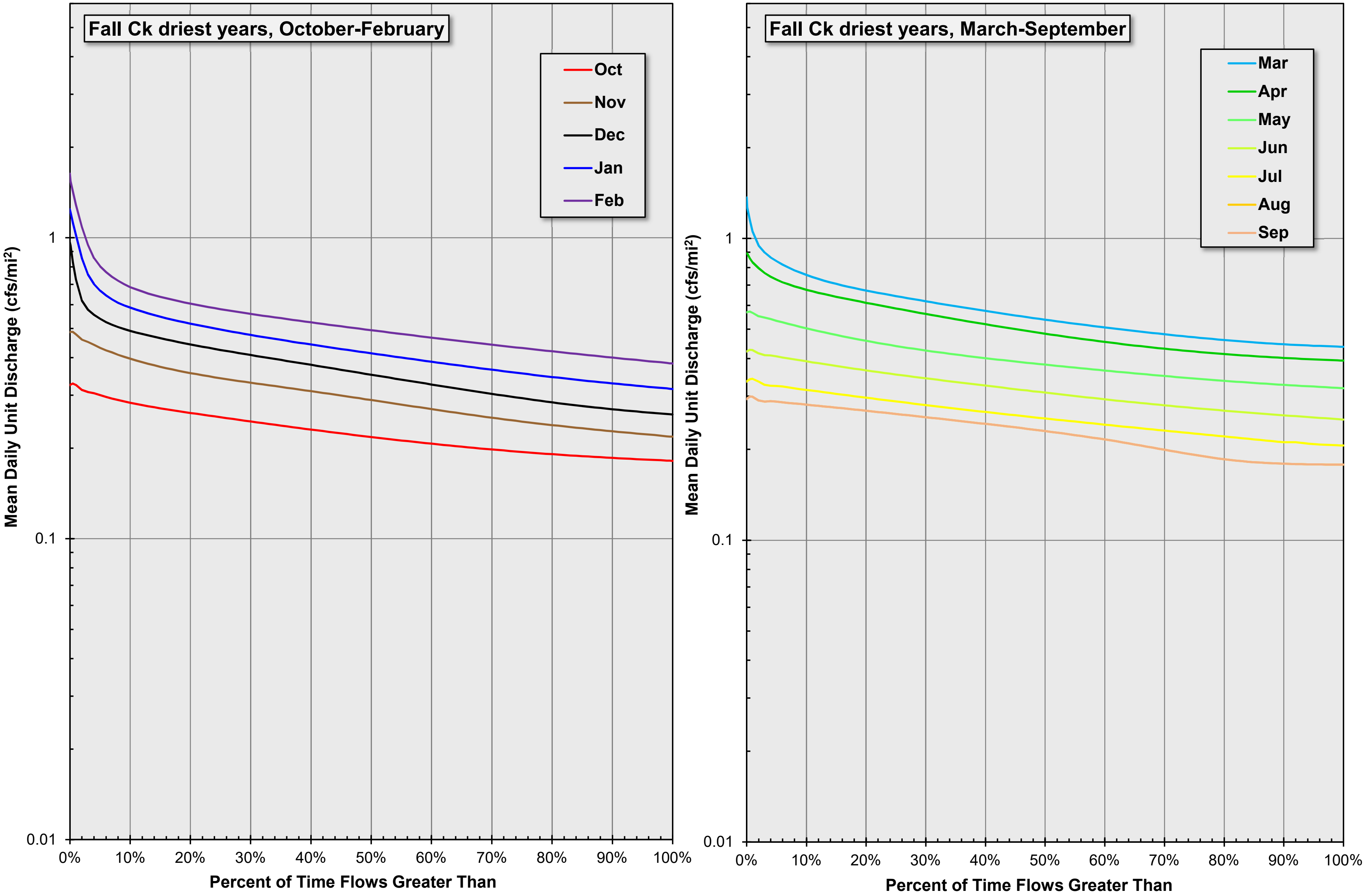
cfs/mi^2 cubic feet per second per square mile
Represents estimated total flow at point of diversion.

Figure 4-17
Clear and Sweetwater Creeks Combined Estimated Monthly Flow Duration Curves, Driest Years



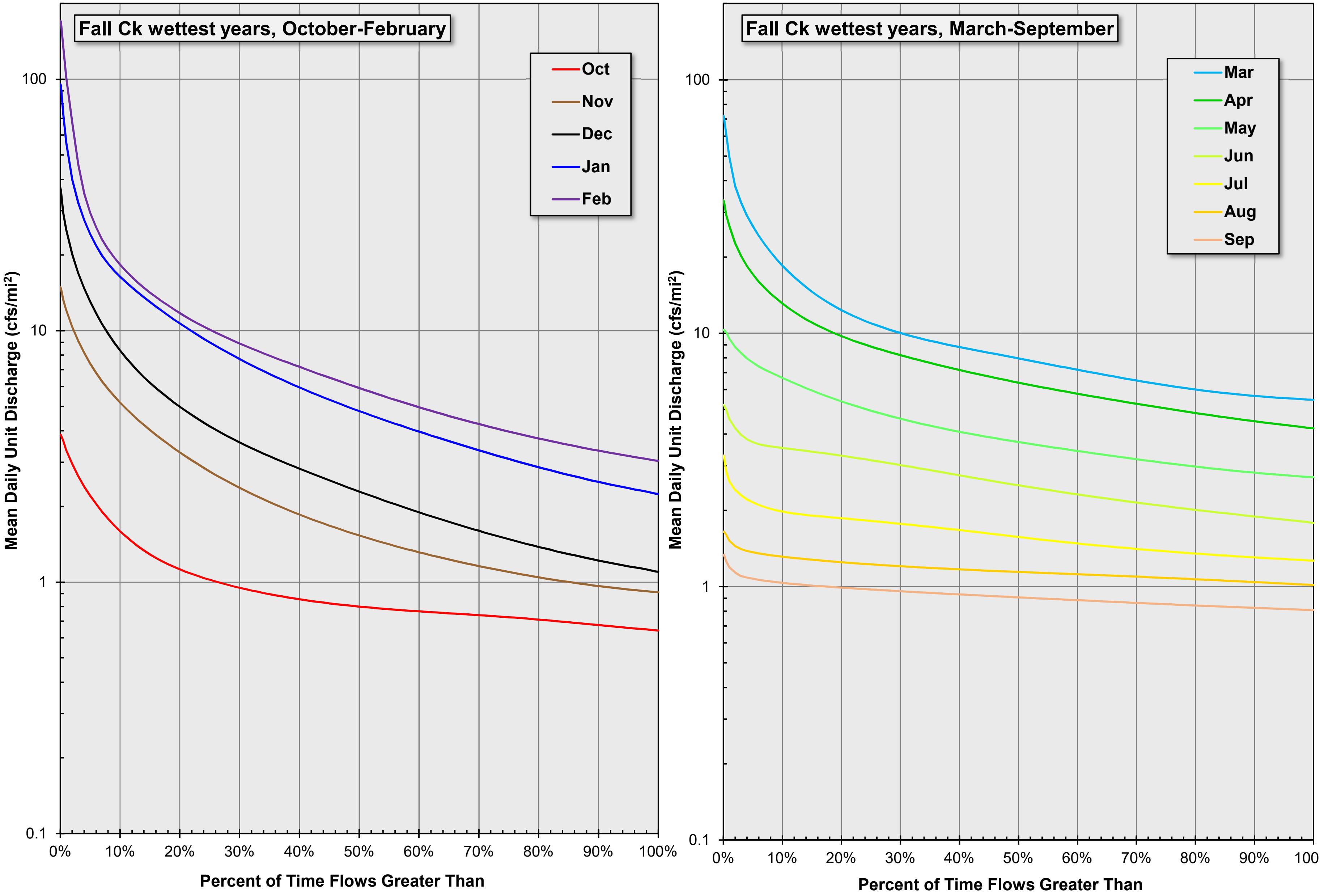
cfs/mi^2 cubic feet per second per square mile
Represents estimated total flow at point of diversion.

Figure 4-18
Clear and Sweetwater Creeks Combined Estimated Monthly Flow Duration Curves, Wettest Years



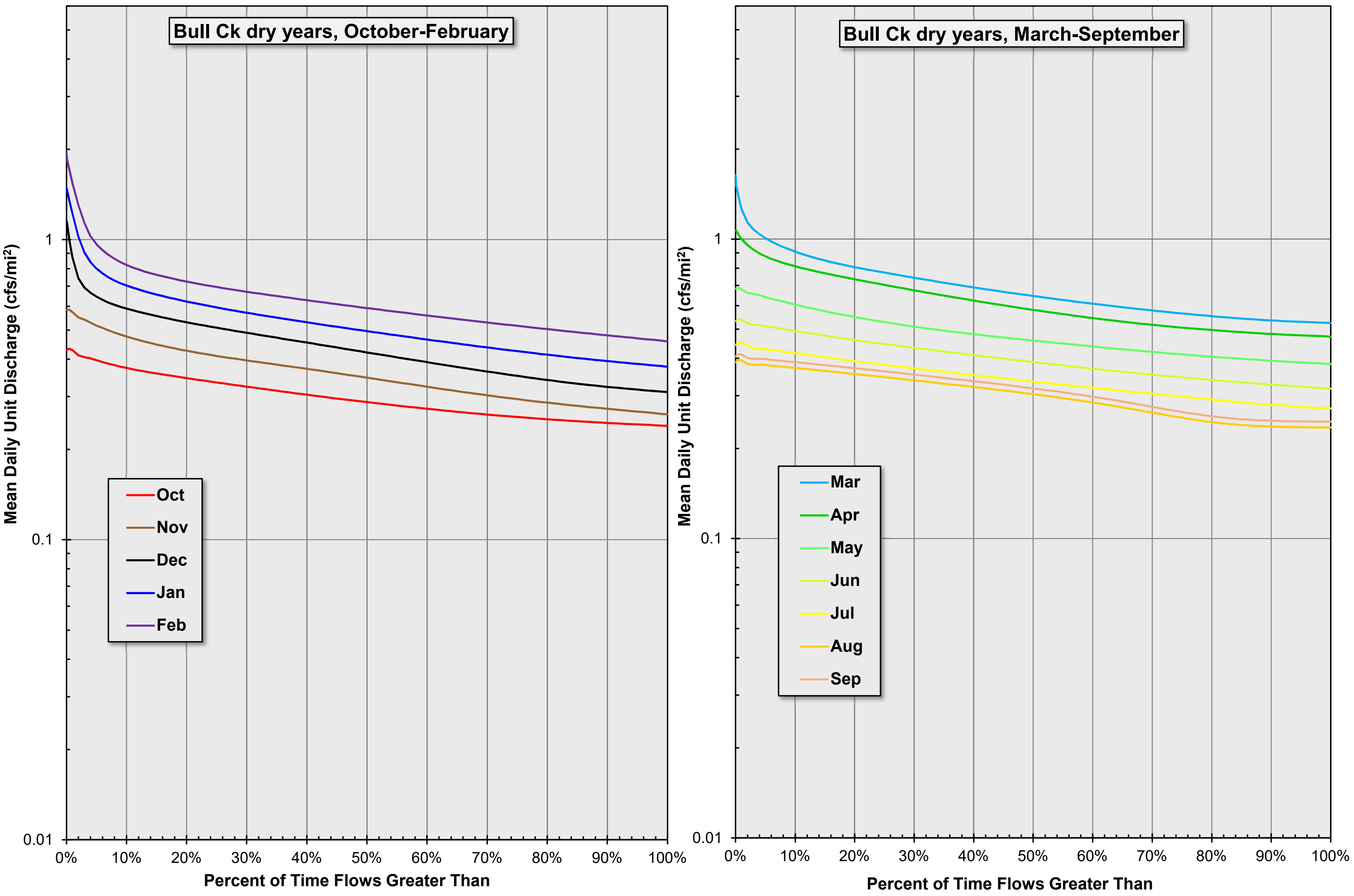
cfs/mi^2 cubic feet per second per square mile
Represents estimated total flow at point of diversion.

Figure 4-19
Fall Creek Estimated Monthly Flow Duration Curves, Driest Years



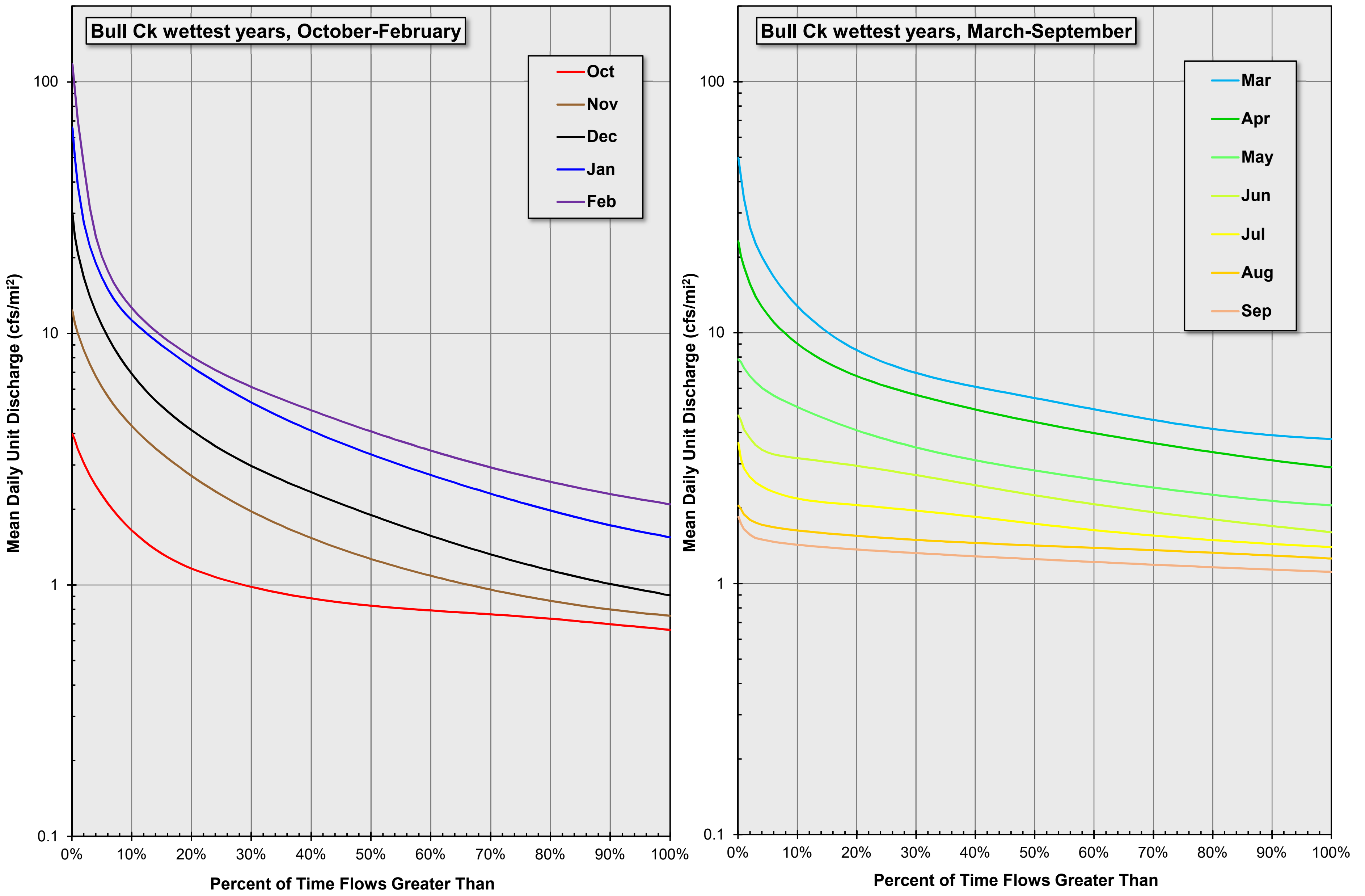
cfs/mi^2 cubic feet per second per square mile
Represents estimated total flow at point of diversion.

Figure 4-20
Fall Creek Estimated Monthly Flow Duration Curves, Wettest Years



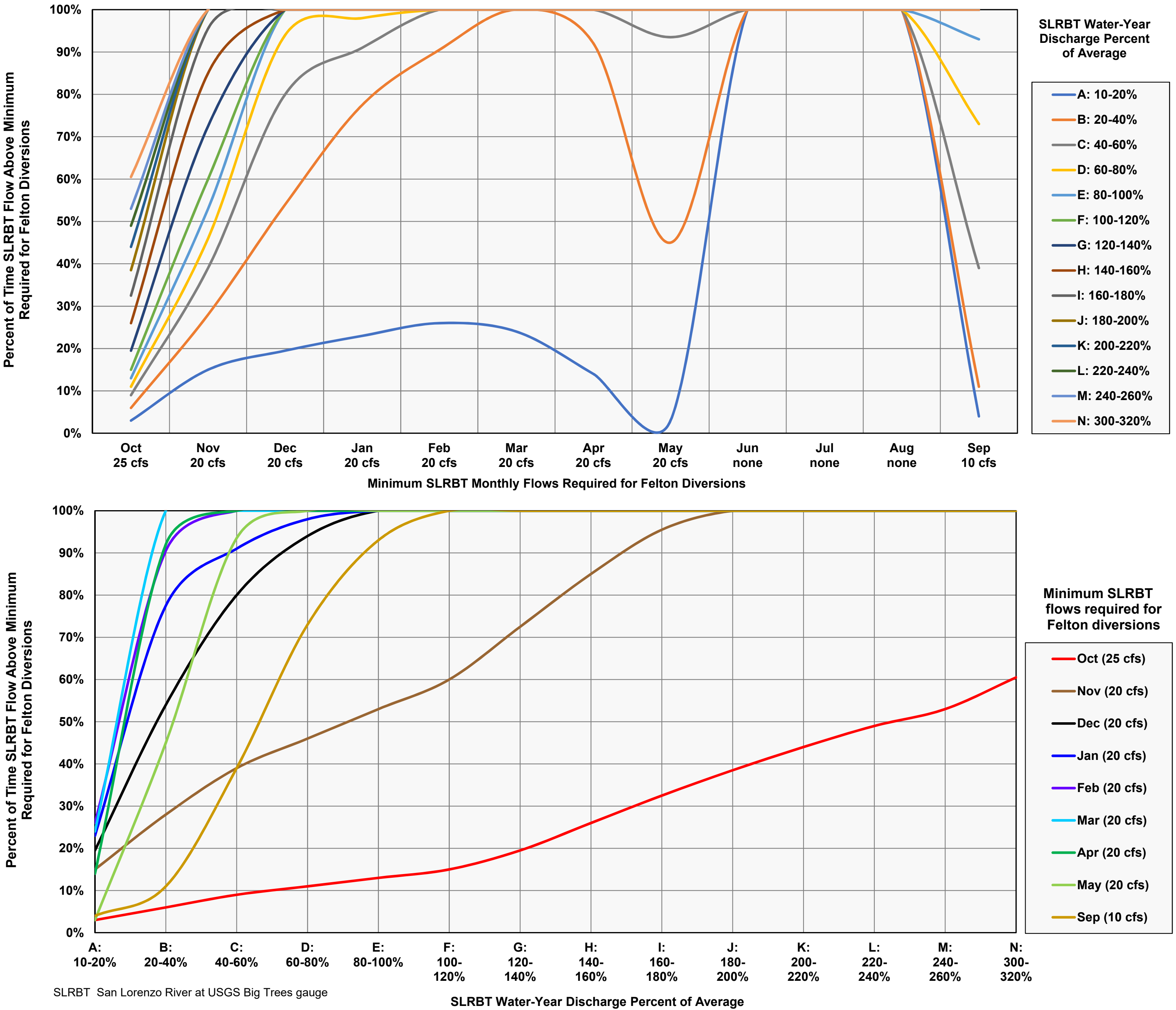
cfs/mi^2 cubic feet per second per square mile
Represents estimated total flow at point of diversion.

Figure 4-21
Bull Creek Estimated Monthly Flow Duration Curves, Driest Years



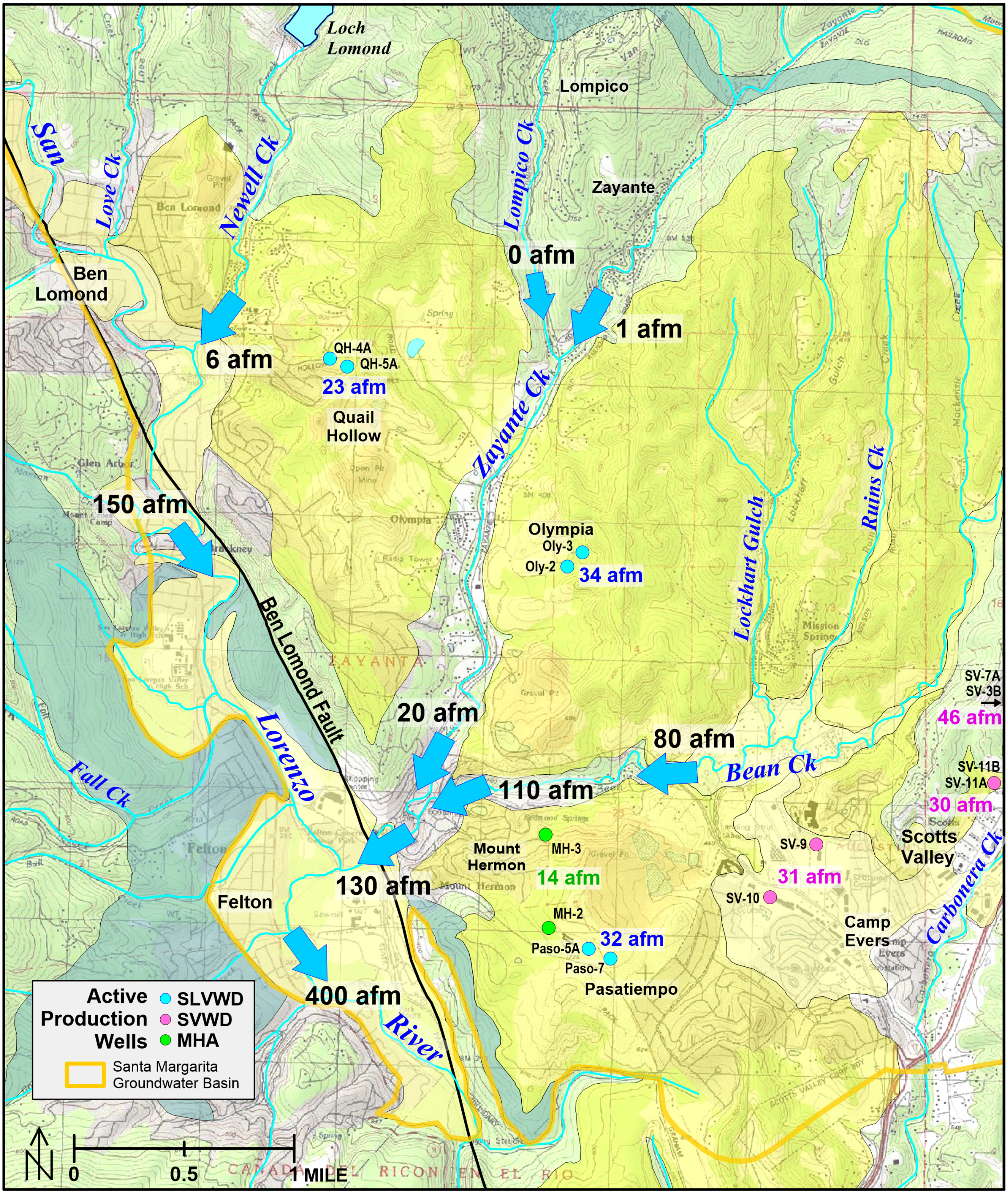
cfs/mi^2 cubic feet per second per square mile
Represents estimated total flow at point of diversion.

Figure 4-22
Bull Creek Estimated Monthly Flow Duration Curves, Wettest Years



SLRBT San Lorenzo River at USGS Big Trees gauge

Figure 4-23
Estimated Percent of Time SLRBT Flows are Above Minimum Required for Felton Diversions
(derived from SLRBT flow duration curves, Figures 4-6 and 4-7)



100 afm **Rough estimate of drought minimum baseflow**
(derived from Tables 4-6 through 4-11)

Average Monthly Groundwater Production (Table 5-3)
20 afm SLVWD (WYs 2000-2017)
20 afm SVWD (WYs 2010-2016)
20 afm MHA (CYs 2008-2017)
afm acre-feet per month

Areal Extent of Permeable Units
▭ **Alluvium**
▭ **Santa Margarita Sandstone** (partially covered)
▭ **Lompico Sandstone** (outcrop only)

Figure 4-24
Approximate Drought Minimum Baseflows of Streams Bounding SLVWD Wells

5 Groundwater Resources

The map presented in Figure 5-1 identifies three loosely defined groundwater subareas from which SLVWD draws approximately 45 percent of its average annual water supply: the Quail Hollow and Olympia areas, each encompassing about 3 mi^2, and the approximately 2-mi^2 Pasatiempo area. These subareas occur within the 35-mi^2 SMGB and are distinguished in places by sandhills of exposed Santa Margarita Sandstone and associated aggregate quarrying. Quail Hollow groundwater is relatively separate from the other groundwater subareas, whereas the Olympia and Pasatiempo subareas are contiguous with the loosely defined Mission Springs, Camp Evers, and Scotts Valley groundwater subareas to the east.

5.1 SLVWD Groundwater Production

SLVWD typically operates two wells in each of the Quail Hollow, Olympia, and Pasatiempo subareas. Table 5-1 provides a summary of SLVWD's current and/or recent operating wells. The Quail Hollow and Olympia wells draw solely from separate portions of the Santa Margarita Sandstone aquifer, whereas the Pasatiempo wells draw predominantly from the underlying Lompico Sandstone aquifer (Figure 5-1).

Wells operated by SLVWD do not draw directly from alluvial aquifers and do not directly induce streamflow infiltration, consistent with area groundwater levels that are generally higher than the elevation of the gaining streams that dissect or bound the groundwater subareas (Figure 5-1). The Monterey Formation aquitard partially separates the Santa Margarita and Lompico sandstone aquifers from streams bounding and/or overlying the groundwater subareas. SLVWD's pumping wells may intercept groundwater flowing toward springs and streams, but generally do not draw streamflow into the aquifer. This distinction is important with regard to conjunctive use because it helps distinguish groundwater and surface water as somewhat separate sources.

Since WY 2000, SLVWD annual groundwater production has averaged approximately 280 afy from the Quail Hollow wells, 400 afy from the Olympia wells, and 380 afy from the Pasatiempo wells (Table 3-1). The Quail Hollow and Olympia wells supply the North system and their use increases and decreases substantially in response to the availability of divertible streamflows (Figure 1-3). Since the 1970s, the Quail Hollow wells have experienced little if any long-term net decline in groundwater levels (Figure 5-2), whereas water levels in the Olympia wells have exhibited a slight long-term downward trend since the 1980s (Figure 5-3), suggesting that higher rates of extraction may be unsustainable without augmenting recharge.

As the sole water supply for the South system, production from SLVWD's Pasatiempo wells fluctuates with seasonal water demand. Pasatiempo groundwater levels have declined by as much as 200 ft since the early 1980s (Figure 5-4), consistent with long-term groundwater level declines throughout much of the general Scotts Valley area. Although well yields have been sufficiently reliable, replenishment of the aquifer through reduced pumping and possibly managed aquifer recharge is an expected outcome of future groundwater management under SGMA.

The simulation of alternative conjunctive use scenarios presented in Section 6 generally assumes that each well can produce continuously up to its capacity as needed when surface water supplies are insufficient. Based on information presented in Section 3, the combined wellfield capacities are assumed to be:

	gpm
Quail Hollow wells:	500
Olympia wells:	780
Pasatiempo wells:	450

Lower capacities are assumed for particular months of the climatic cycle based on detailed plots of monthly groundwater levels, pumping, and precipitation in relation to pump intake and well screen elevations. These plots are provided in Figures 5-5, 5-6, and 5-7 for the Quail Hollow, Olympia, and Pasatiempo wells, respectively. Reduced well capacities are indicated when water levels are drawn down to the elevation of the pump intake, typically during drought periods with heavy demand (such as during the early years of a drought before conservation reduces demand). Based on inspection of these plots and the groundwater level and production record summarized in Table 5-2, the capacities of the Quail Hollow and Olympia wells are assumed to decline in as many as three monthly steps to as low as 250 and 475 gpm, respectively, during the following months of the climactic cycle: July–September 1977; July–August 1989; July–September 1990; May–October 1991; May–September 1992; June–October 2008; June–October 2009; June–September 2014; May–November 2015; and May–October 2016.

5.2 Potential Effects of Groundwater Pumping on Stream Baseflow

As stated above in Section 5.1, SLVWD's wells may intercept groundwater flowing toward springs and streams, but generally do not draw water directly from streams. For this reason, and because of the slow rate of groundwater flow, it is reasonable to evaluate the potential effects of groundwater pumping by comparing rates of average annual pumping to minimum rates of stream baseflow. This implies there is effectively no difference between summer and winter groundwater pumping with regard to the potential effects on stream baseflow. A more refined evaluation of potential surface water-groundwater interactions would require the use of a numerical groundwater flow model, which was beyond the scope of this study.

Table 5-3 compares estimates of minimum monthly impaired baseflow from Section 4.4 with recent average monthly groundwater pumping rates. Because the effects of pumping are already reflected in the gauged and estimated streamflow records, the potential percent reduction in minimum monthly baseflow is calculated as the average groundwater pumping rate divided by the combined rates of baseflow and pumping. Subtracting this fraction from 1 and multiplying by 100 percent gives the estimated percent of baseflow remaining as a result of pumping. Based on this method, average rates of SLVWD, SVWD, and MHA groundwater pumping may reduce Newell, Zayante, and Bean Creek baseflows by as much as roughly 50 percent during worst case drought conditions (Table 5-3).

Well Name	Abbreviation	Year Drilled	Ground Surface or Ref. Pt. Elev.	Well Diameter		Depth:			Screened Intervals			Aquifer[a]	Pump	
				Boring	Casing	Completed Well	Sanitary Seal	Gravel Pack	Depth	Total Length	Total Interval		Size	Suction Intake
			(ft msl)	(in)		(ft bgs)				(ft)			(hp)	(ft bgs)
North System Wells														
Quail Hollow 4A	QH-4A	2001	597	22	12	260	120	266	180 - 250	70	70	Tsm	20	237
Quail Hollow 5A	QH-5A	2000	*516*	22	12	174	112	174	124 - 164	40	40	Tsm	20	155
Olympia 2	Oly-2	1981	525	24	12	310	160	325	230 - 250 280 - 300	20 20	70	Tsm	60	279
Olympia 3	Oly-3	1990	538	24	12	310	160	340	230 - 300	70	70	Tsm	60	279
South System Wells														
Pasatiempo 5A	Paso-5A	2012	750	24	12	710			400 - 700	300	300	Tlo		
Pasatiempo 6[b]	Paso-6	1990	775	24	12	790	381	805	560 - 580 600 - 620 710 - 770	20 20 60	210	Tlo	60	700
Pasatiempo 7[b]	Paso-7	1990	734	24	12	540	260	560	380 - 440 495 - 525	60 30	145	Tlo	60	535
Pasatiempo 8[c]	Paso-8	2018	-	-	-	-	-	-	- -	-	-	-	-	-
Manana Woods 1 *(inactive)*	MWd-1	1988	516	18	10	380	160	405	190 - 210 240 - 280 320 - 360	20 40 40	170	Tlo		

[a] Aquifers: Tsm = Santa Margarita Sandstone; Tlo = Lompico Sandstone.

[b] Wells to be replaced with Paso-8.

[c] Under construction as of October 2018.

ft bgs	feet below ground surface	hp	horsepower
ft msl	feet elevation above sea level	in	inchres

Table 5-1
SLVWD Groundwater Production Wells

				Diversions					Quail Hollow Wells				Olympia Wells			
	WY Rain-fall % of	Year of	Drought Cumu-lative %	Maximum		Minimum		Base-flow reces-sion	Maximum		Minimum During Dry, Heavy-Use Period		Maximum		Minimum During Dry, Heavy-Use Period	
CY	Avg.*	Drought	of Avg.	gpm	month	gpm	month	months	gpm	month	gpm	month	gpm	month	gpm	month
1985	83%	-	-	813	Dec	282	Sep	6	496	Oct	436	Jul	454	Aug	380	Sep
1986	138%	-	-	882	May	264	Dec	7	511	Jul	314	Dec	300	Aug	115	Nov
1987	55%	1	55%	606	Apr	123	Oct	6	511	Aug	399	Oct	540	Aug	373	Oct
1988	62%	2	59%	630	Feb	108	Sep	8	430	Aug	380	Oct	527	Jul	500	Sep
1989	71%	3	63%	766	Apr	229	Sep	4	352	Jul	264	Sep	527	Jul	422	Sep
1990	50%	4	60%	682	Nov	158	Dec	15	370	Dec	210	Oct	522	Oct	443	Jul
1991	66%	5	61%	733	Apr	163	Oct	8	365	May	258	Sep	544	Sep	508	Oct
1992	85%	6	65%	694	Apr	182	Nov	6	298	Aug	207	Jul	609	Aug	453	Oct
1993	119%	-	72%	871	Apr	182	Nov	7	243	Oct	192	Aug	473	Jul	310	Nov
1994	68%	7	72%	748	Mar	199	Sep	6	298	Jul	229	Sep	779	Aug	659	Sep
1995	142%	-	-	832	Jul	215	Oct	4	208	Oct	177	Sep	505	Oct	325	Sep
1996	125%	-	-	805	Jul	482	Nov	4	223	Jul	128	Sep	456	Jul	318	Oct
1997	120%	-	-	805	Mar	362	Aug	6	266	Jul	211	Sep	603	Sep	466	Jul
1998	170%	-	-	1,011	Jul	600	Nov	3	128	Jul	124	Oct	326	Sep	264	Oct
1999	95%	-	-	955	Jun	424	Oct	4	163	Jul	145	Oct	473	Sep	389	Jul
2000	116%	-	-	924	May	413	Oct	5	206	Aug	132	Oct	570	Sep	342	Oct
2001	77%	1	77%	810	Mar	253	Oct	5	306	Aug	231	Oct	708	Sep	575	Oct
2002	97%	2	87%	807	Apr	207	Sep	3	353	Oct	353	Oct	713	Aug	492	Oct
2003	101%	-	-	918	May	230	Nov	5	424	Sep	286	Nov	704	Aug	549	Oct
2004	91%	-	-	972	Apr	317	Oct	6	401	Jul	328	Oct	654	Aug	407	Oct
2005	137%	-	-	947	May	374	Nov	5	545	Jul	231	Oct	523	Aug	424	Oct
2006	153%	-	-	983	May	376	Oct	5	421	Jul	334	Oct	570	Sep	342	Oct
2007	60%	1	60%	892	Mar	248	Oct	8	388	Jun	342	Sep	712	Jun	506	Oct
2008	80%	2	70%	835	Apr	161	Oct	6	383	Aug	344	Sep	764	Aug	559	Oct
2009	79%	3	73%	770	Apr	216	Sep	4	341	Jul	304	Sep	590	Sep	563	Jul
2010	116%	-	-	908	Jun	326	Oct	4	353	Sep	214	Oct	328	Sep	275	Oct
2011	127%	-	-	963	Jul	407	Nov	6	219	Dec	122	Oct	314	Sep	183	Oct
2012	78%	1	78%	845	May	197	Nov	6	231	Oct	165	Sep	649	Sep	424	Oct
2013	76%	2	77%	748	Mar	170	Jan	9	376	May	284	Aug	734	Jul	454	Oct
2014	40%	3	64%	574	Mar	88	Dec	7	333	Nov	207	Sep	522	Jul	454	Oct
2015	71%	4	66%	610	Jan	108	Sep	10	288	Aug	224	Oct	501	Oct	408	Sep
2016	96%	5	72%	864	May	84	Oct	4	325	Sep	186	Oct	516	Oct	400	Aug
2017	194%	-	-	926	Mar	296	Oct	4	325	Jun	182	Oct	525	Sep	324	Aug
Avg	98%	-	-	822	-	256	-	-	336	-	247	-	553	-	412	-
Min	40%	-	-	574	-	84	-	-	128	-	122	-	300	-	115	-
Max	194%	-	-	1,011	-	600	-	-	545	-	436	-	779	-	659	-

▭	Drought period.
■	Yield potentially diminished during drought.

* Percent of average for WYs 1970-2017.

gpm gallons per minute

CY calendar year

WY water year

Table 5-2

Evaluation of North System Water Production During Drought

Wellfield	Average Monthly Groundwater Production[a]	Assumed Distribution of Pumping Effects									
		San Lorenzo River		Newell Creek		Zayante Creek		Bean Creek		All or Other Streams	
	afm	%	afm	%	afm	%	afm	%	afm	%	afm
SLVWD Quail Hollow wells	23	25%	6	25%	6	50%	12	-		-	
SLVWD Olympia wells	34	-		-		33%	11	67%	23	-	
SLVWD Pasatiempo wells	32	-		-		-		100%	32	-	
Mt. Hermon Association wells	14	-		-		-		100%	14	-	
SVWD wells 9,10A,11A,11B	61	-		-		-		100%	61	-	
SVWD wells 3B, 7A	46	-		-		-		?		100%	46

Stream	Minimum Drought Baseflows[b]	Percent of Drought Minimum Baseflow Remaining as a Result of Pumping[c]			
	afm	SLVWD	MHA	SVWD	Total
Newell Creek at San Lorenzo River	6	51%	-	-	-
Zayante Creek above Bean Creek	20	47%	-	-	-
Bean Creek at Zayante Creek	110	77%	94%	75%	46%
Zayante Creek at SLR	130	73%	95%	78%	46%
San Lorenzo River above Fall Creek	150	93%	-	-	-
San Lorenzo River at USGS gage	400	84%	98%	89%	71%

[a] Periods represented by average pumping:
SLVWD: WYs 2000-2017 (derived from data presented in Table 3-1)
SVWD: WYs 2010-2016 (derived from SVWD WY 2016 Annual Report Table 5)
MHA: CYs 2008-2017 (data provided by MHA)

afm acre-feet per month

[b] Estimated from Tables 4-4 and 4-7 through 4-11, as presented in Figure 5-14.

[c] Calculated as: 100 x {1 - [(pumping) ÷ (baseflow + pumping)]}

Estimated impacts from SLVWD, SVWD, and MHA groundwater pumping only.

Table 5-3

Percent of Drought Minimum Baseflow Remaining as a Result of Assumed Distribution of Groundwater Pumping Effects

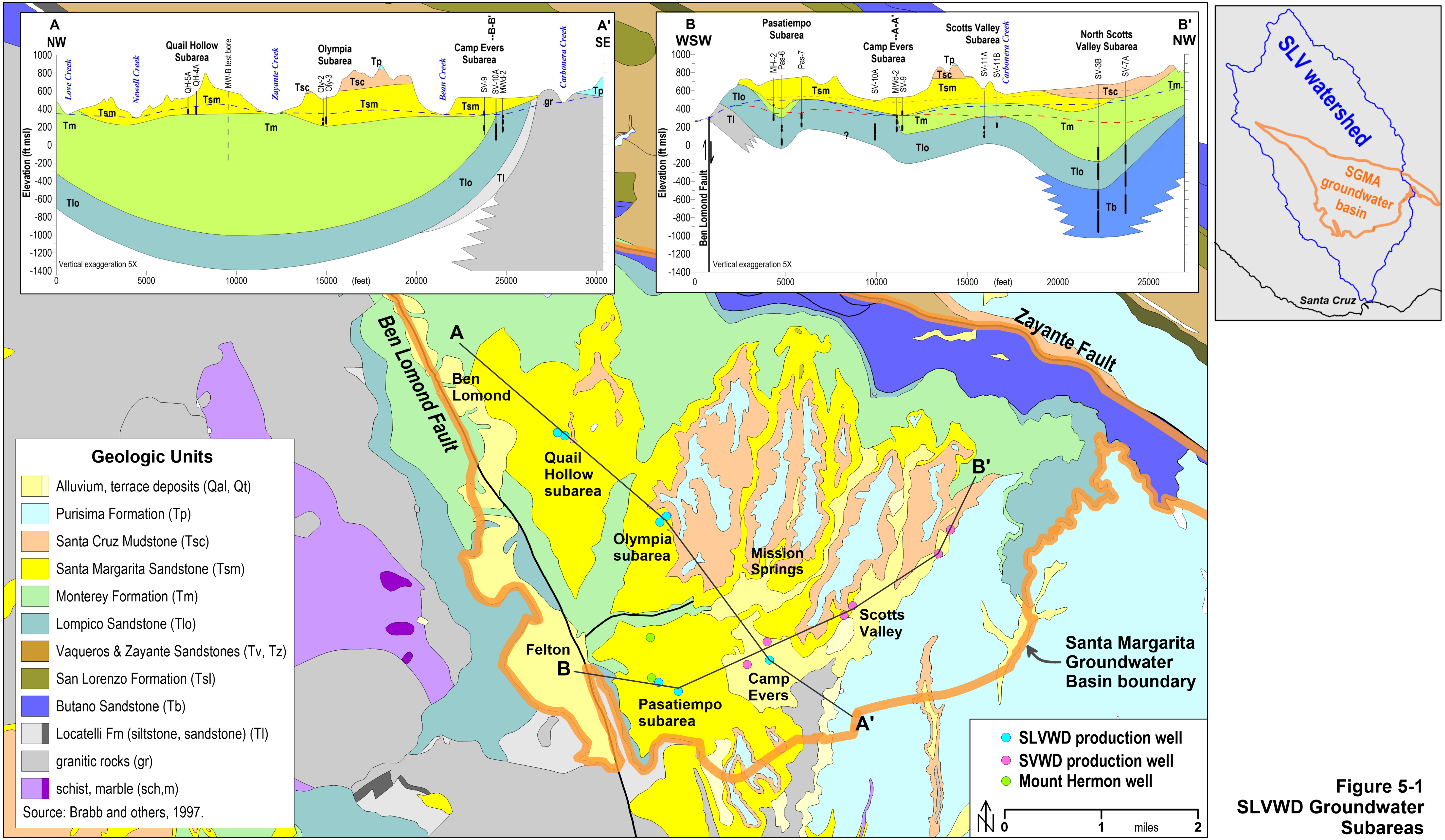
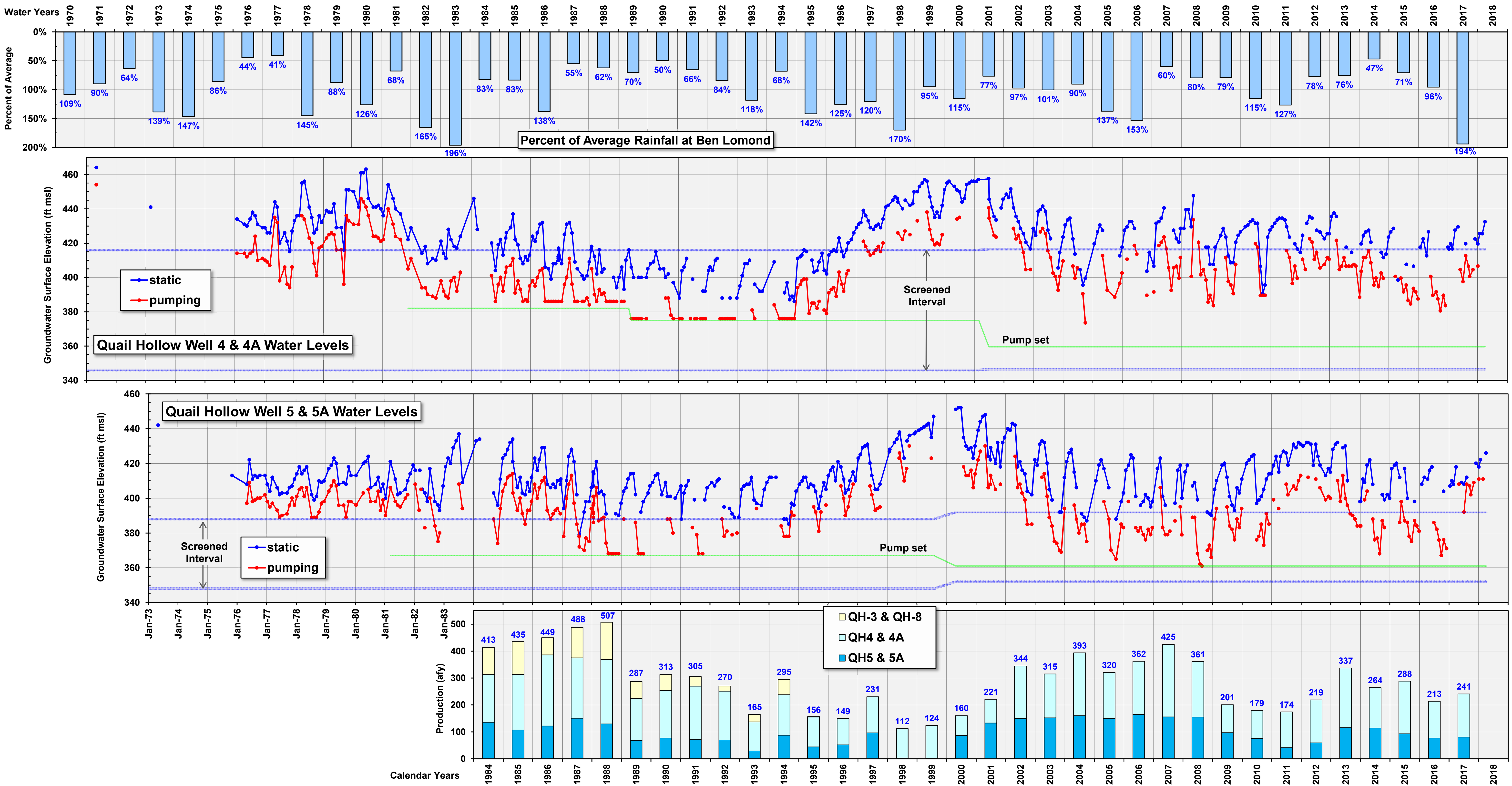


Figure 5-1
SLVWD Groundwater Subareas

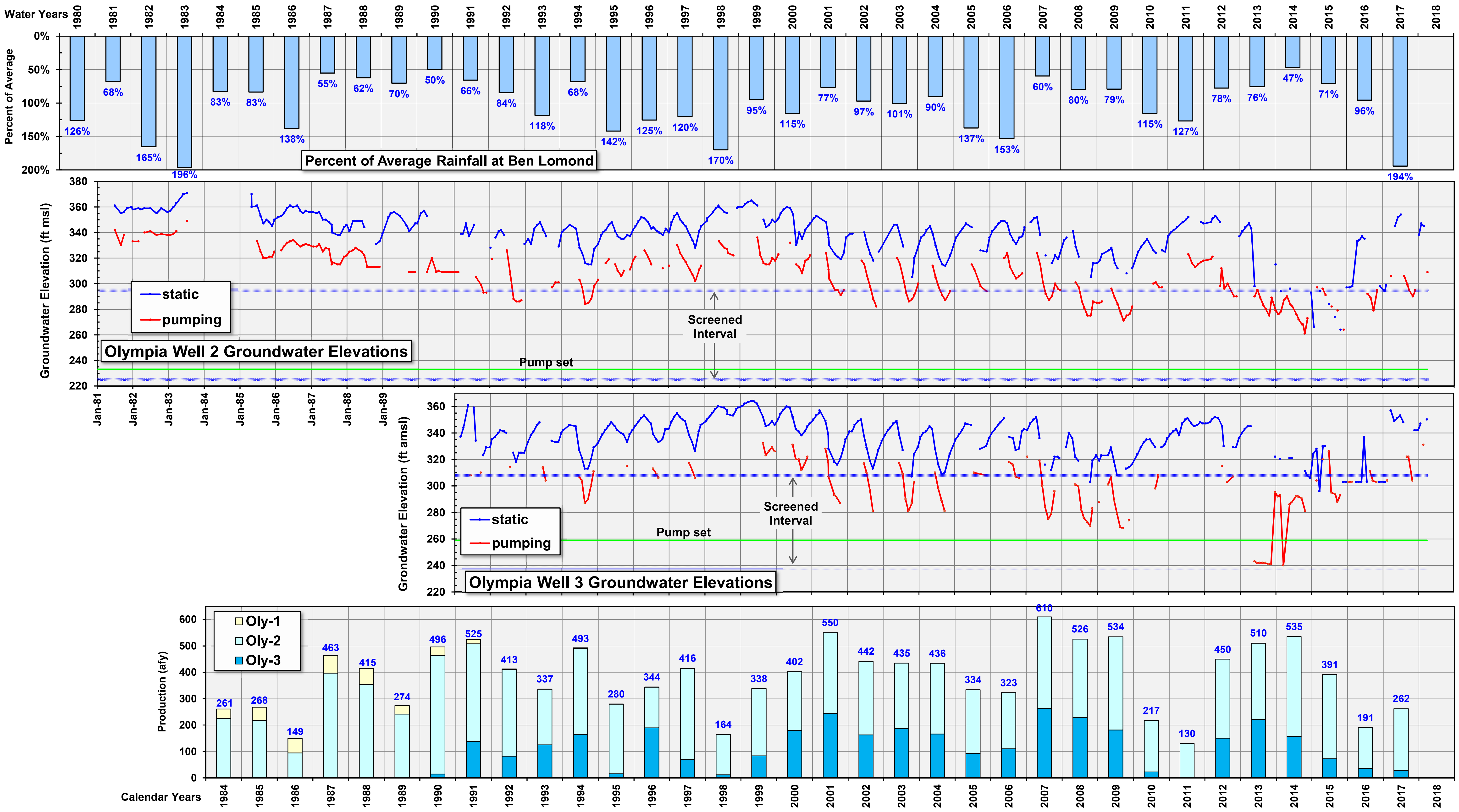


afy acre-feet per year

ft msl elevation in feet above mean sea level

Figure 5-2

SLVWD Quail Hollow Wells Groundwater Levels and Annual Pumping and Precipitation, 1970-2018

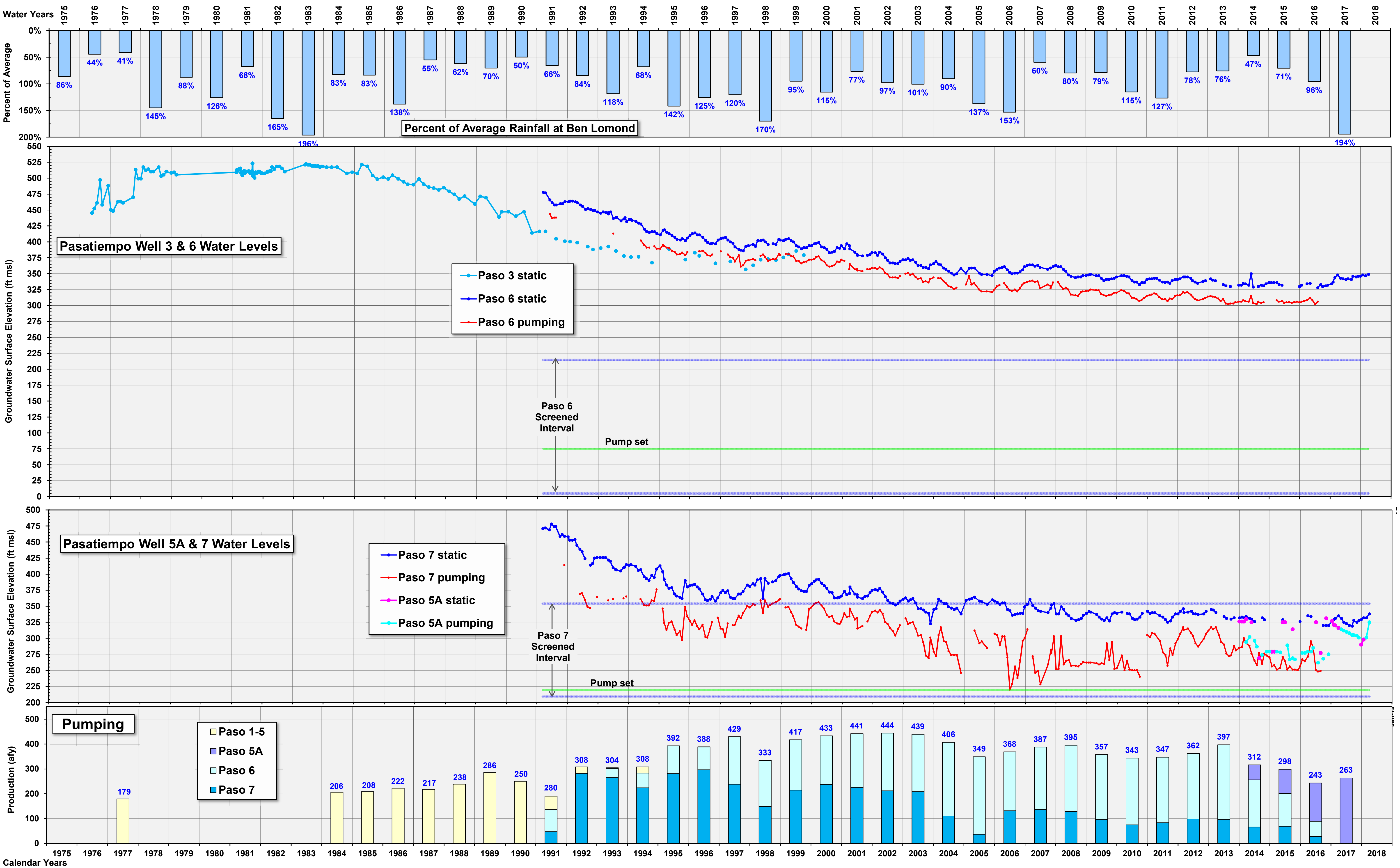


afy acre-feet per year

ft msl elevation in feet above mean sea level

Figure 5-3

SLVWD Olympia Wells Groundwater Levels and Annual Pumping and Precipitation, 1980-2018

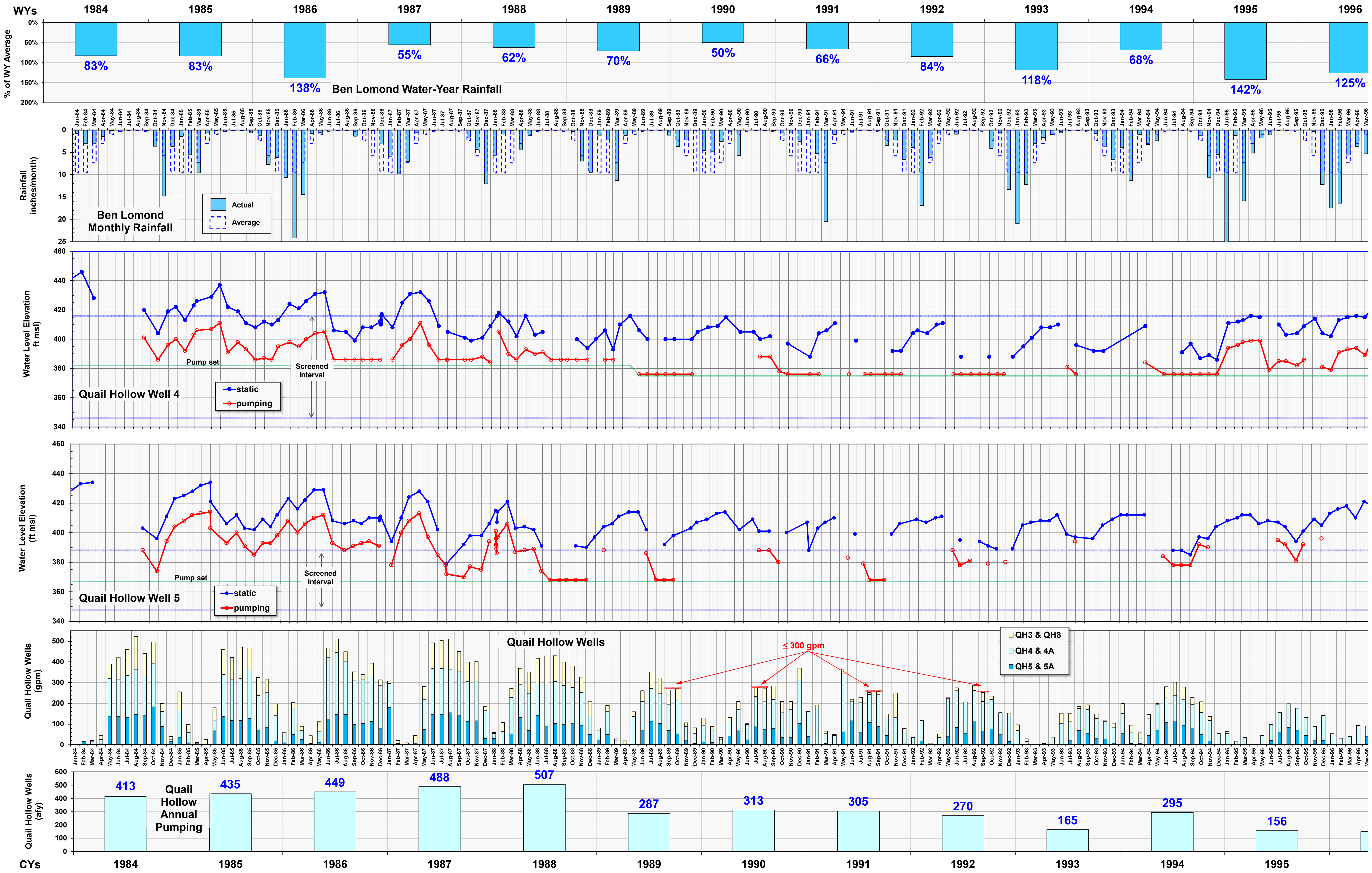


afy acre-feet per year

ft msl elevation in feet above mean sea level

Figure 5-4

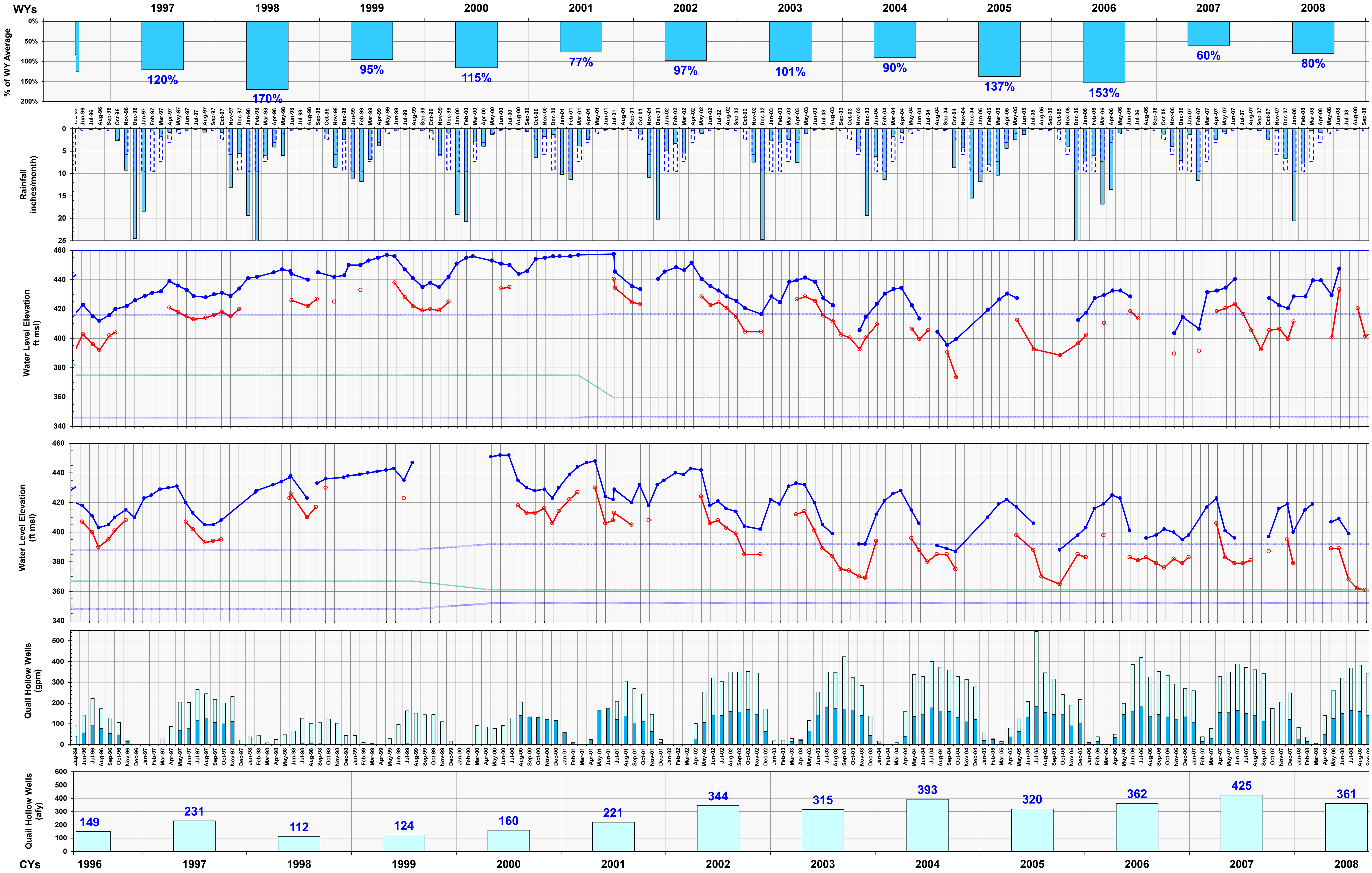
SLVWD Pasatiempo Wells Groundwater Levels and Annual Pumping and Precipitation, 1975-2018



afy acre-feet per year
ft msl elevation in feet above mean sea level
gpm gallons per minute

CY calendar year
WY water year (Oct-Sep)

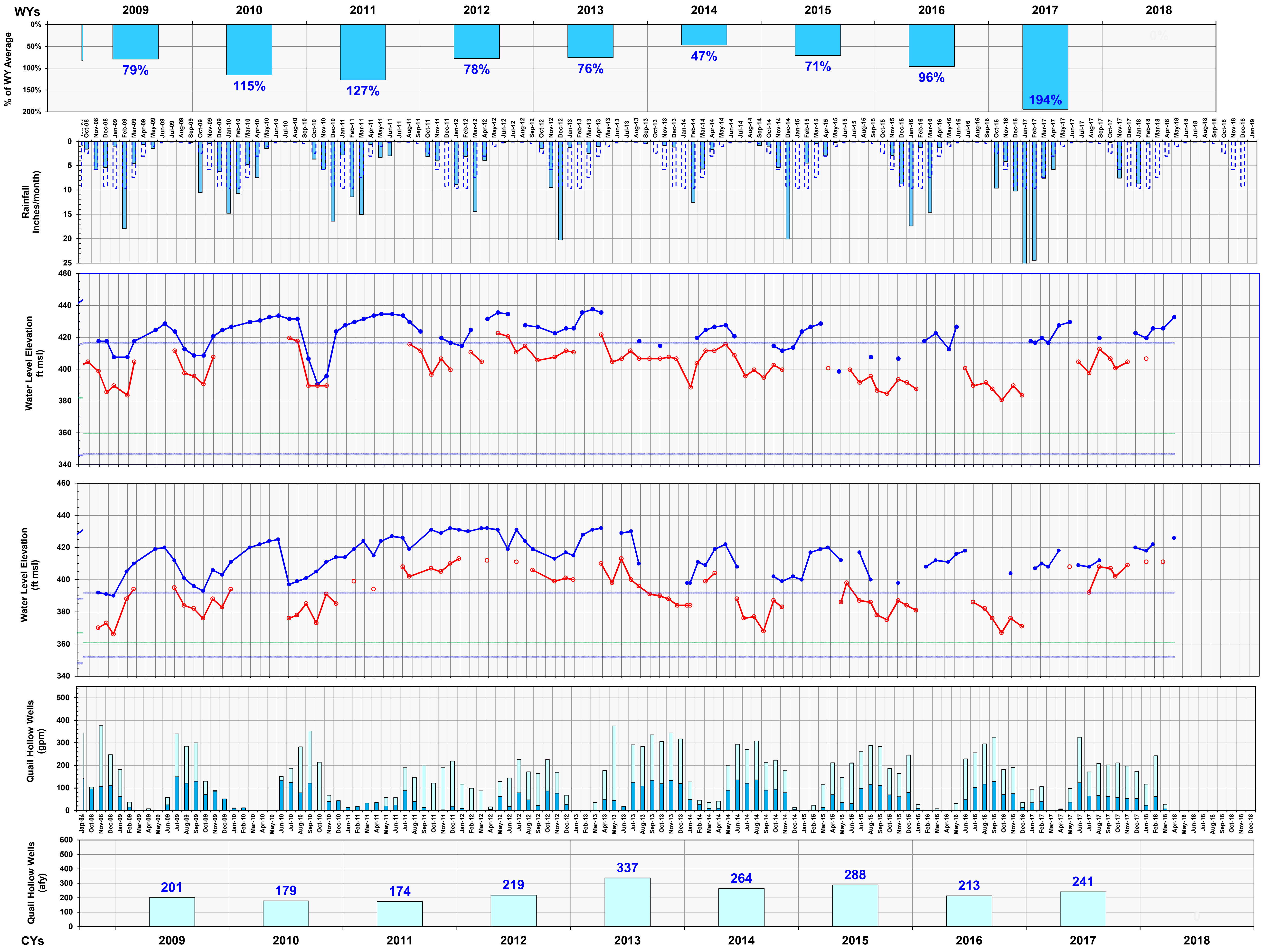
Figure 5-5
SLVWD Quail Hollow Wells Groundwater Levels and Monthly Pumping and Precipitation, CYs 1984-2018



AFY acre-feet per year
ft msl elevation in feet above mean sea level
gpm gallons per minute

CY calendar year
WY water year (Oct-Sep)

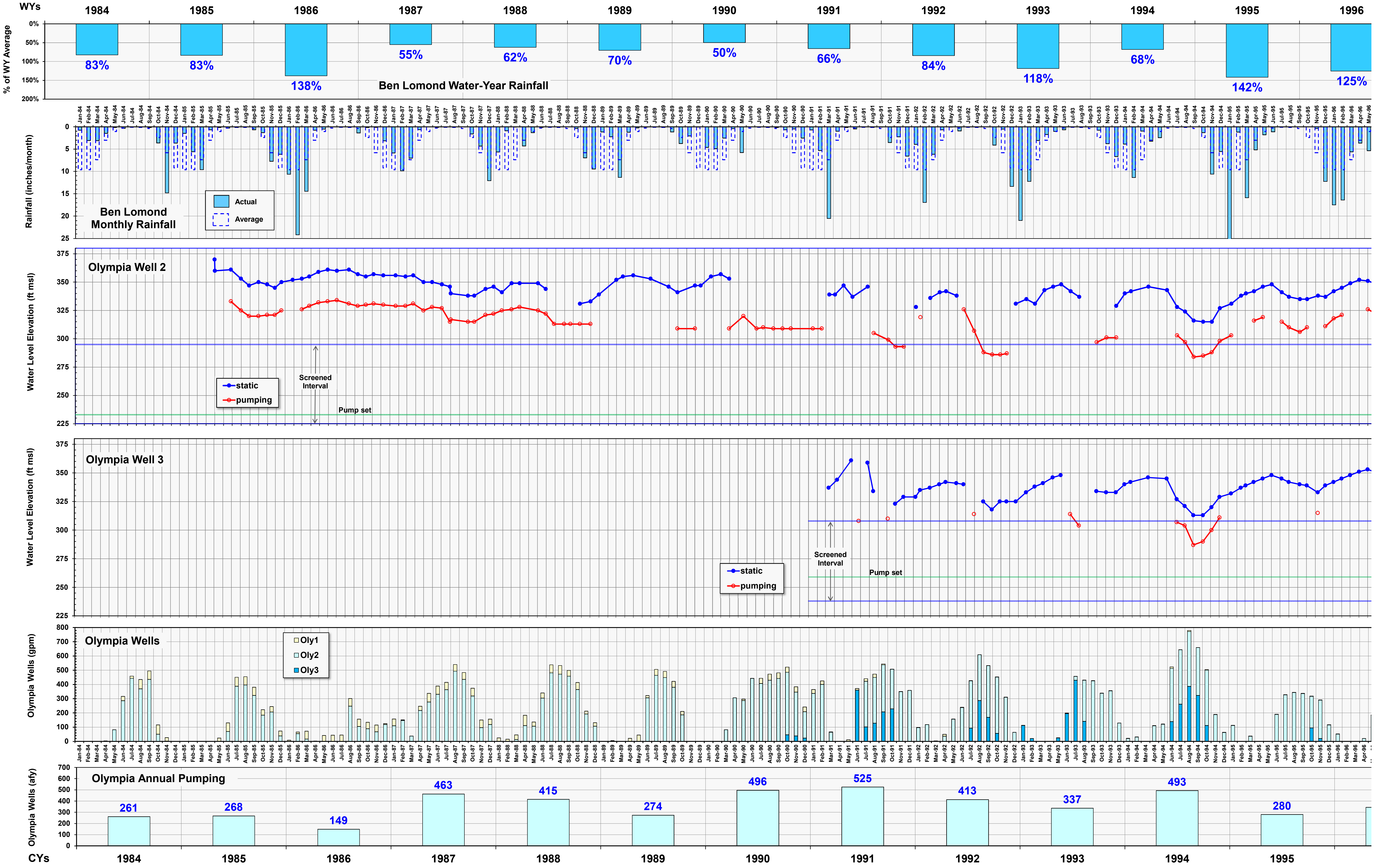
Figure 5-5
SLVWD Quail Hollow Wells Groundwater Levels and Monthly Pumping and Precipitation, CYs 1984-2018



AFY acre-feet per year
ft msl elevation in feet above mean sea level
gpm gallons per minute

CY calendar year
WY water year (Oct-Sep)

Figure 5-5
SLVWD Quail Hollow Wells Groundwater Levels and Monthly Pumping and Precipitation, CYs 1984-2018



afy acre-feet per year
ft msl elevation in feet above mean sea level
gpm gallons per minute

CY
WY

Figure 5-6
SLVWD Olympia Wells Groundwater Levels and Monthly Pumping and Precipitation, CYs 1984-2018

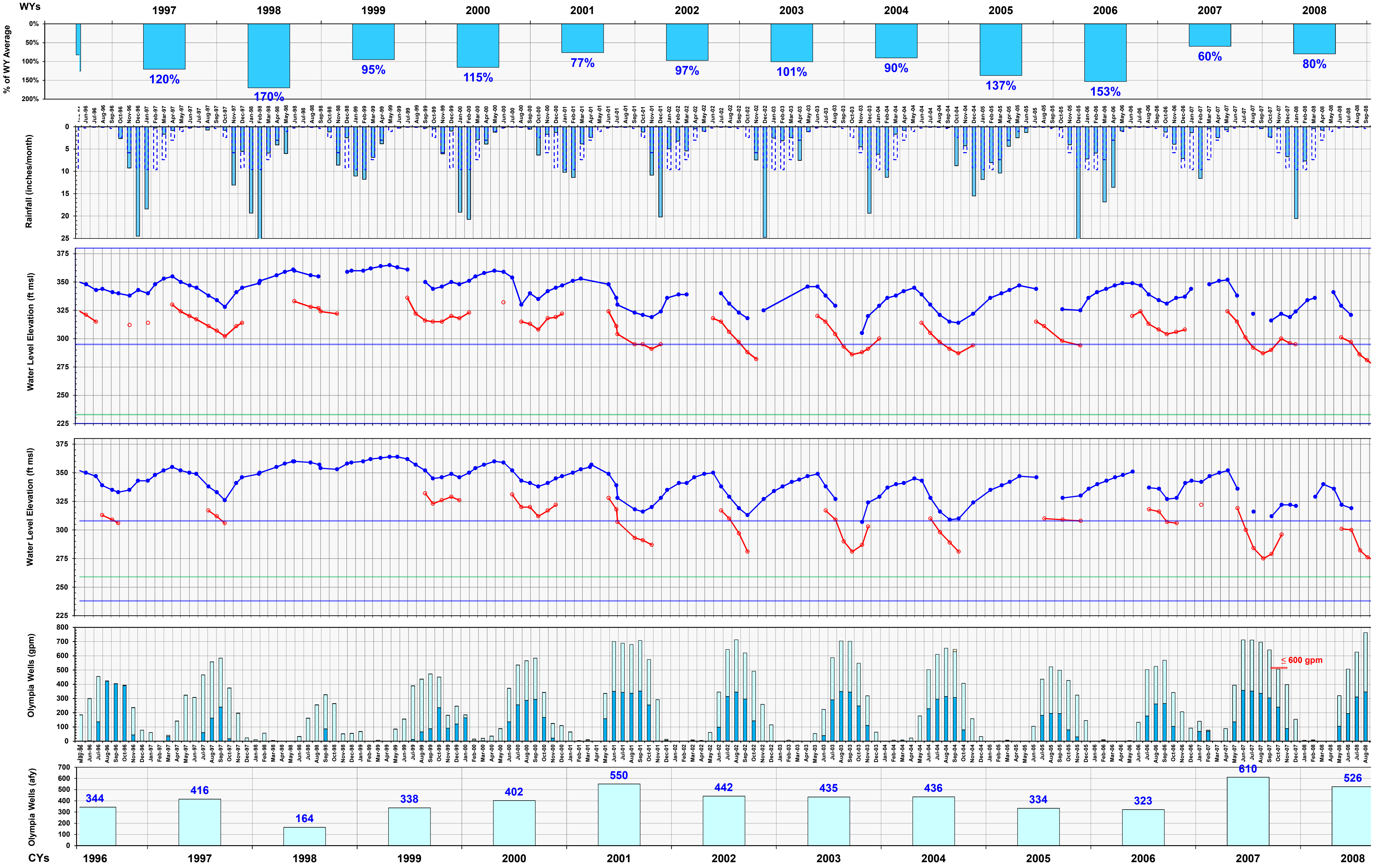


Figure 5-6
SLVWD Olympia Wells Groundwater Levels and Monthly Pumping and Precipitation, CYs 1984-2018

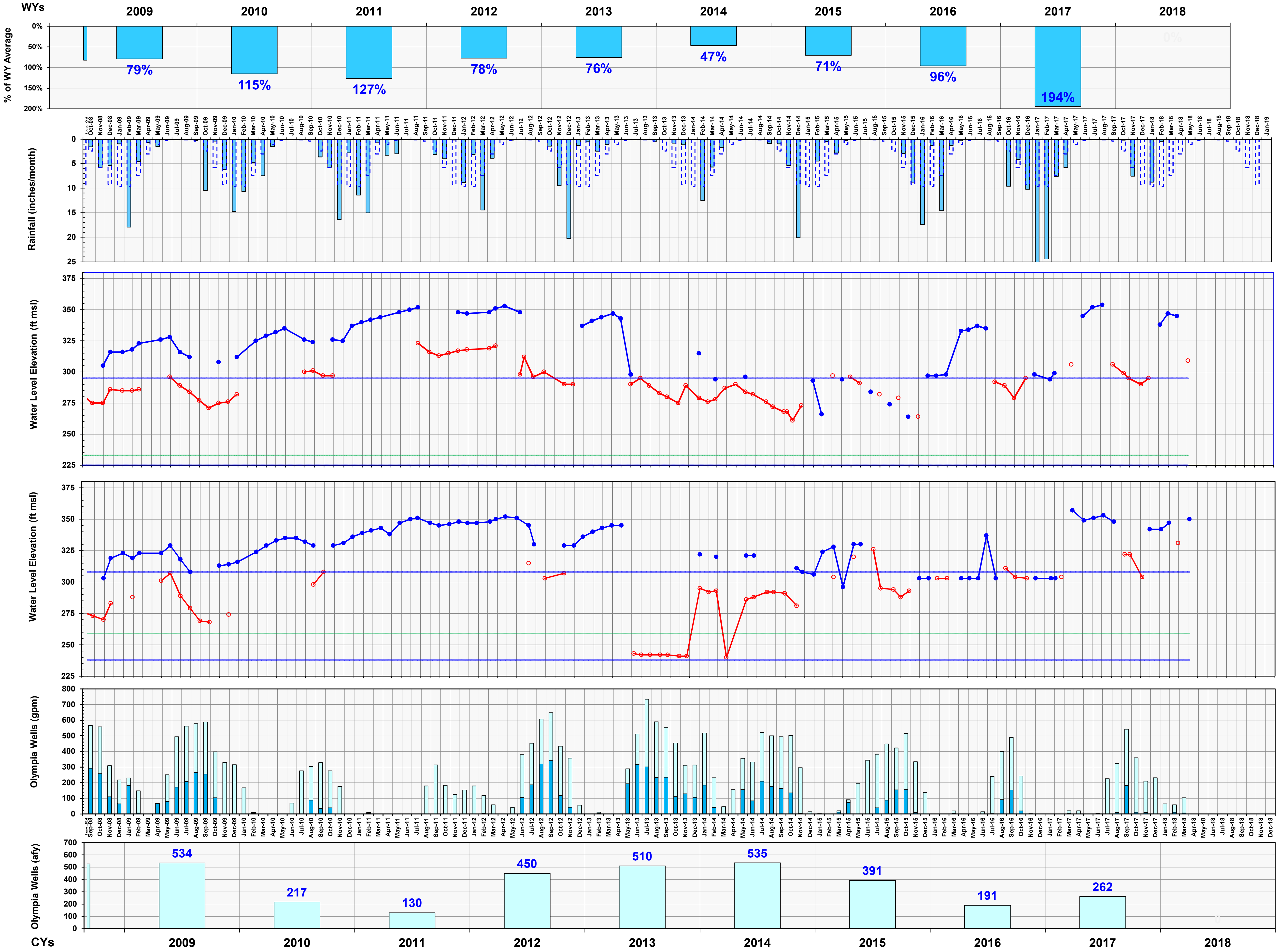
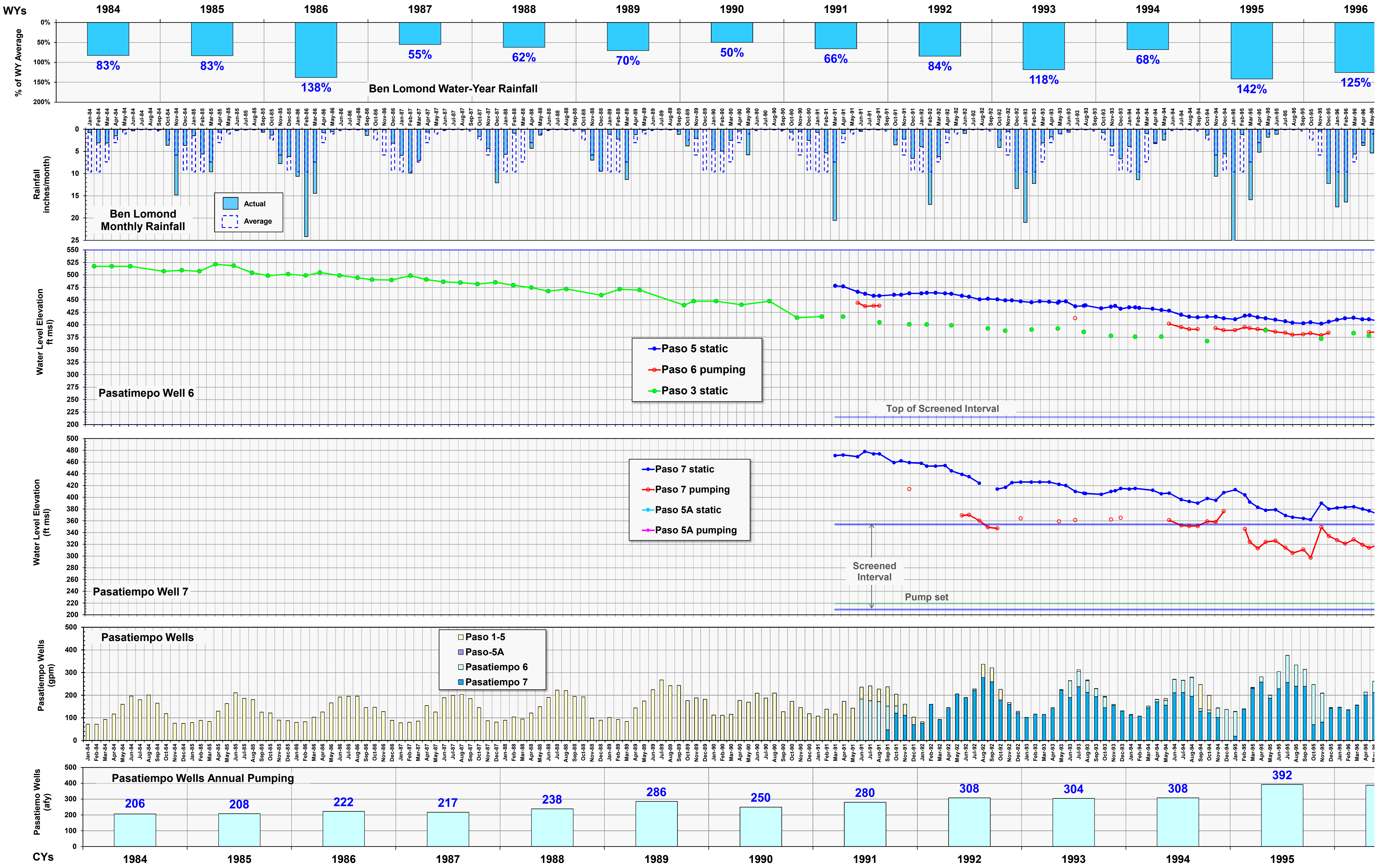


Figure 5-6
SLVWD Olympia Wells Groundwater Levels and Monthly Pumping and Precipitation, CYs 1984-2018



afy acre-feet per year
ft msl elevation in feet above mean sea level
gpm gallons per minute

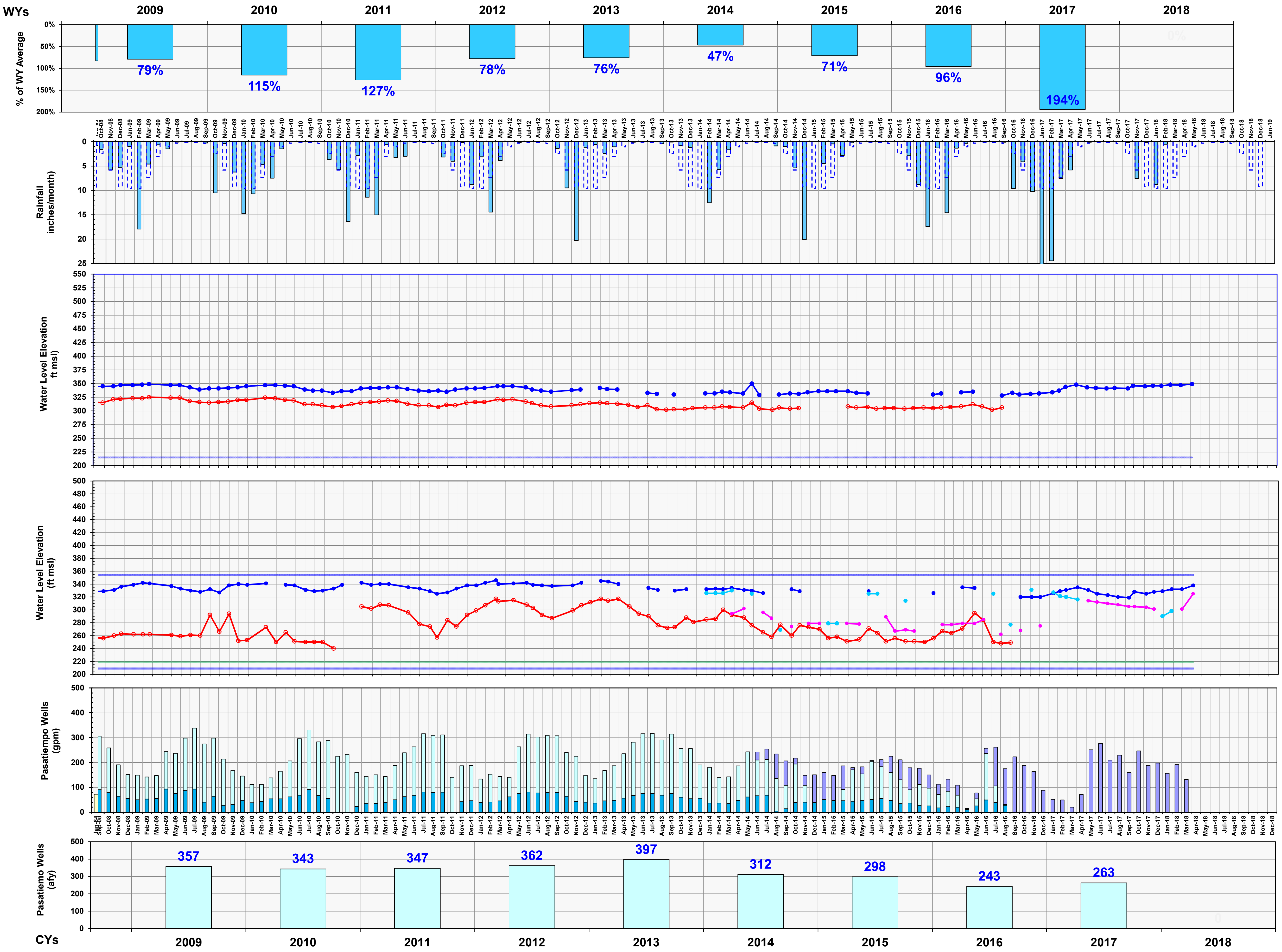
CY calendar year
WY water year

Figure 5-7
SLVWD Pasatiempo Wells Groundwater Levels and Monthly Pumping and Precipitation, CYs 1984-2018

AFY acre-feet per year
ft msl elevation in feet above mean sea level
gpm gallons per minute

CY calendar year
WY water year

Figure 5-7
SLVWD Pasatiempo Wells Groundwater Levels and Monthly Pumping and Precipitation, CYs 1984-2018



AFY acre-feet per year
ft msl elevation in feet above mean sea level
gpm gallons per minute

CY calendar year
WY water year

Figure 5-7
SLVWD Pasatiempo Wells Groundwater Levels and Monthly Pumping and Precipitation, CYs 1984-2018

6 Conjunctive Use Scenarios

On the basis of the analyses of water demand, production capacity, and available resources documented in Sections 2 through 5, this section presents simulations of SLVWD monthly water supply and water use for a base-case and alternative conjunctive use scenarios. Each simulation assumes a repeat of the WY 1970–2017 climactic cycle under assumed 2045 water demand.

The simulated base case and alternative conjunctive use scenarios are defined and grouped as follows:

- Base case – Calibrated to SLVWD's actual average, minimum, and maximum proportional use of surface water and groundwater sources during WYs 2000–2017; excludes the use of system interties.
- Scenario 1 – Optimizes the use of currently available sources using system interties and potential capacity enhancements assuming varying degrees of compliance with existing water rights; achieves Pasatiempo area in-lieu recharge by substituting excess North and Felton diversions for groundwater pumping.
- Scenario 2 – Scenario 1 plus use of SLVWD's allotment of water stored in Loch Lomond reservoir.
- Scenario 3 – Scenario 2 plus operation of an Olympia ASR project supplied by excess available stream diversions.
- Scenario 4 – Scenario 3 plus additional Scotts Valley in-lieu recharge by substituting excess available SLVWD surface water for SVWD groundwater pumping.

Scenarios 1, 2, and 3 include multiple alternatives. Table 6-1 summarizes the assumptions underlying 15 Scenario 1 alternatives, three alternatives each for Scenarios 2 and 3, and one alternative for Scenario 4.

6.1 Methods and Assumptions

Each conjunctive use alternative is simulated by calculating monthly water supply and use while assuming 2045 water demand and a repeat of the WY 1970–2017 climatic cycle. The evaluation of each alternative consists of the following steps:

1. A model of WY 1970–2017 monthly water demand is created from the annual and monthly distribution of system demands characterized in Table 2-2 and Figure 2-5. Each alternative is evaluated using this same demand model.
2. For each SLVWD diversion, a synthetic record of monthly unimpaired flows and potentially divertible flows is created from a set of the wet and dry monthly flow duration curves for a sequence of years classified by water-year types A through N (Table 4-6), given assumed diversion capacities, bypass rates, and water rights limitations.
3. Maximum groundwater pumping capacities are assumed for each of the three wellfields, with reduced capacities assumed for certain months during drought periods with heavy demand, as described in Section 5.1.
4. The monthly water supply and demand records created in the first three steps are used in a spreadsheet analysis that satisfies each system's monthly demand with available supplies according to assumed prioritization and limitations of use and then calculates the approximate percent of flow remaining downstream of each diversion.

Table 6-2 provides the water production and conveyance capacities assumed for each scenario. The assumed effective capacities were established through calibration of the base case and are generally somewhat lower than the highest monthly rates that occur during ideal but atypical circumstances (Table 3-2).

The left-hand columns of Table 6-3 list the water-year type assigned to each year of the 48-year WY 1970–2017 climatic cycle; letters A through N designate the driest to wettest years, respectively (Table 4-6).

For each system, the prioritization of use among available sources is from left to right across Table 6-2. To fulfill North service area monthly demand, each simulation uses available Foreman and Peavine diversions first, then draws on Clear and Sweetwater creeks, and finally groundwater pumping. Potential diversions from Fall Creek are used before diversions from Bull Creek. Potential stream diversions in excess of local monthly demand may be considered available for inter-system transfer or ASR.

Criteria for evaluating the results of the simulated alternatives include whether or not:

- The Felton system fulfills demand in compliance with water rights.
- The North system fulfills demand without potentially unsustainable groundwater pumping.
- In-lieu recharge is achieved in the South system and Scotts Valley areas.
- Stream baseflows increase with the potential to improve habitat.
- Potential surface water resources remain unused.

The percent of synthesized streamflow remaining downstream of SLVWD's simulated diversions is approximated as follows:

- The percent reduction in flow immediately downstream of each diversion is calculated as the simulated rate of diversion divided by the synthesized rate of unimpaired flow. Subtracting this fraction from 1 and multiplying by 100 gives the estimated percent of unimpaired flow remaining downstream of the diversion.
- Percent reductions in Boulder Creek and SLRBT flows are calculated as the simulated rate of upstream SLVWD diversions divided by the sum of the

synthesized impaired flow and the base-case rate of diversion. Subtracting this fraction from 1 and multiplying by 100 gives the estimated percent of flow remaining as a result of SLVWD diversions.

- As described in Section 5.2, the potential percent reduction in minimum monthly stream baseflow as a result of groundwater pumping is estimated separately as the average simulated pumping rate divided by the sum of the assumed rate of minimum impaired baseflow (Table 5-3) and the base-case pumping rate. Subtracting this fraction from 1 and multiplying by 100 percent gives the estimated percent of baseflow remaining as a result of SLVWD groundwater pumping.

Providing the simulation results in this manner is consistent with the highly approximate nature of the various flow estimates. These results reflect the effects of SLVWD stream diversions and groundwater pumping only, and are suitable for the intended planning-level evaluation of conjunctive use alternatives. Values of simulated monthly flow (e.g., expressed in units of afm, cfs, or gpm; tabulated in Appendix A) have limited precision and should not be used to evaluate compliance with specific regulatory, water-right, or habitat requirements.

In the following sections, water “imports” and “exports” refer to the transfer of water between SLVWD’s three systems and between SLVWD and SVWD. The phrase “unused potential diversions” refers to potential diversions within permitted water rights and diversion capacities that exceed demand within the service area within which they are diverted, but which potentially could be transferred to another system or used for ASR.

6.2 Base Case

Exponent selected and adjusted the assumptions underlying the base case simulation of the WY 1970–2017 climactic cycle under 2045 water demand to represent SLVWD’s recent and current production capacities and operational practices, with the exception of system interties. Because the use of system interties is only recent and relatively minor, their use is not included in the base case. Table 6-2 provides the assumed diversion, pumping, conveyance, and treatment capacities for the base case and other scenarios.

Table 6-3 presents an evaluation of how well the base case calibration reproduces SLVWD's actual average, minimum, and maximum proportional use of surface water and groundwater sources during WYs 2000–2017, a period representing "current and recent" conditions. On an average annual basis, the simulated base case matches the proportional contribution of each water source within 1 percent of total system production.

Figures 6-1, 6-2, and 6-3 illustrate a reasonably good fit between historical and simulated base-case hydrographs of monthly SLVWD water production, plotted both by system and by individual source. Figures 6-4 and 6-5 illustrate the results of the simulated base case on an annual and monthly basis, respectively.

Calibration of the base case requires assuming the Felton system diverts without fully complying with its permitted water rights, consistent with the system's reliance on its diversions as a sole water source (Table 4-4). Simulation of the base case results in non-compliant Felton diversions during all or portions of 23 percent of all 576 simulated months, of which 34 percent occur in October, 16 to 17 percent occur in September and November each, and 9 percent occur in May.

In the base case scenario, as well as in practice, groundwater pumping from the Olympia wells provides the final go-to source for the North system at times when the combined yields of other sources become insufficient. Pumping from the Quail Hollow wells is capped at an equivalent continuous rate of 500 gpm (~67 afm), which is assumed to decrease in up to three monthly steps to as little as 250 gpm during drought periods of heavy demand (Table 6-2; Section 5.1). Pumping from the Olympia wells is capped at an equivalent continuous rate of 780 gpm (~105 afm) based on historical maximum monthly production (Table 3-3) and is assumed to decrease in steps to as little as 475 gpm during drought periods of heavy demand. As a result of these imposed limits on pumping from groundwater storage, the base case simulates that North system total yield is insufficient to meet demand during 2.6 percent of all months, resulting in deficits of up to 30 afm during the months of July through October, and a water-year maximum deficit of 65 afy. The base case simulation assumes these deficits remain as unmet demand (Figure 6-5), whereas in practice additional groundwater would have been produced by exceeding the limits imposed by the simulation, consistent with the slight downward trend in Olympia groundwater levels (Figure 5-3).

Table 6-4 includes the average annual results for the simulated base case and Table 6-5 presents a more detailed summary including simulated minimum and maximum annual rates. On average, the North system produces approximately 900 afy from stream diversions and 640 afy from wells. Simulated diversions range to more than 1,200 afy and maximum simulated groundwater pumping is greater than 1,000 afy. Unused potential diversions (i.e., diversions that are permitted and within diversion capacities but exceed North system monthly demand) average nearly 300 afy and range from 0 to more than 800 afy. Four afy of average annual North system demand remains unmet due to the imposed groundwater pumping limitations, as discussed in the preceding paragraph.

Felton diversions average 430 afy in the simulated base case, the system's sole water source. Unused potential diversions average about 400 afy and range between 300 and 600 afy, assuming non-compliance with permitted water rights. Unused potential diversions for the North and Felton systems combined average more than 700 afy and range between 300 and more than 1,300 afy. South system demand is fully met by pumping an average of 365 afy from the Pasatiempo wells, which have an assumed continuous pumping capacity of 450 gpm (Tables 6-2, 6-4, and 6-5).

The simulated base-case hydrographs provided in Figures 6-6 and 6-7 compare simulated rates of diversion to synthesized unimpaired flows and potentially divertible flows (i.e., within diversion capacities and water rights). In the case of Fall and Bennett creeks (Figure 6-7), unpermitted diversions are apparent during months when simulated diversions plot above potentially divertible flows.

Figures 6-8 and 6-9 are hydrographs of the percent of simulated monthly flow remaining downstream of North and Felton system diversions for the base case scenario, as defined in Section 6.1. This evaluation only considers the effects of SLVWD stream diversions. On average, 26 and 63 percent of the unimpaired monthly flows of Foreman and Peavine creeks are simulated to remain downstream of their respective diversions (Table 6-6), with monthly minimums of 10 and 40 percent, respectively. These percentages are fairly constant for all of the evaluated conjunctive use alternatives because diversions in excess of North system demand mostly occur during high streamflow months when diversions compose only a small percentage of unimpaired flows. Base case simulated diversions represent an average of 14 percent of the flow of Boulder Creek, ranging monthly from 1 to 35 percent (i.e., an average of 86 percent of the flow remaining, ranging from 65 to 99 percent remaining).

On average, 83 and 64 percent of unimpaired flows remain downstream of the simulated Fall (including Bennett) and Bull creeks diversions, respectively, with a minimum of 32 percent remaining downstream of either diversion.

As defined in Section 6.1 and summarized in Table 6-6, the estimated percent of drought minimum baseflows remaining as a result of average base case groundwater pumping equals roughly 50 percent of potential Newell, Zayante, and Bean Creek baseflows. As calculated, average groundwater pumping by SLVWD, SVWD, and MHA accounts for 28 percent of SLRBT baseflow during drought minimum conditions. These values represent the effects of SLVWD groundwater pumping only, consistent with estimates derived from the historical record presented in Table 5-3.

Given the reasonably good match between the simulated base case and historical record (Table 6-3; Figures 6-1, 6-2, and 6-3), and the reasonable and well-documented underlying assumptions, the approach and method are suitable for evaluating qualitative differences between alternative conjunctive use scenarios.

6.3 Scenario 1: Optimize Use of Current Sources under Existing and Modified Conditions

As summarized in Table 6-1, the conjunctive use alternatives evaluated under Scenario 1 attempt to optimize currently available sources using system interties and potential capacity enhancements, assuming varying degrees of compliance with Felton water rights. Table 6-2 provides the assumed diversion, pumping, conveyance, and treatment capacities for each alternative.

The objectives of the Scenario 1 alternatives include: (a) reducing dry-season and drought Felton diversions in compliance with permitted water rights; (b) reduce the effect of groundwater pumping on stream baseflows during dry periods; (c) recover groundwater storage and sustainable groundwater production for the South system's Pasatiempo wells; and (d) produce groundwater sustainably from the Quail Hollow and Olympia wells.

The 15 conjunctive use alternatives evaluated under Scenario 1 are as follows (Table 6-1):

- Scenarios 1a and 1b evaluate full and partial compliance with the Felton system's permitted water rights.
- Scenarios 1c, 1d, and 1e evaluate the potential to increase stream diversions by increasing diversion capacities.
- Scenario 1f evaluates using the North-South system intertie to substitute North system unused potential stream diversions for South system groundwater pumping, thereby achieving "in-lieu recharge."
- Scenarios 1g1 through 1g4 evaluate transferring Felton system unused potential stream diversions to the South system as a substitute for groundwater pumping, thereby achieving in-lieu recharge.
- Scenarios 1h1 and 1h2 evaluate supplying the South system with unused potential stream diversions from both the North and Felton systems to reduce South system groundwater pumping.
- Scenario 1i evaluates reducing North system groundwater pumping by importing Felton system unused potential diversions.
- Scenarios 1j and 1k evaluate reducing North and South system groundwater pumping by importing unused potential diversions from the North and/or Felton systems.

6.3.1 Scenario 1a – Felton System Complies with Permitted Water Rights

Compared to the base case, Scenario 1a complies with Felton system permitted water rights by relying on water transfers using the existing system interties. As summarized in Tables 6-4 and 6-5, there are no unused North System potential diversions available during months when the Felton system requires a supplemental source to comply with water rights. Transfers of groundwater from the South system are not considered because of the nearly overdrawn conditions of the Pasatiempo area aquifer. In this case, Felton system diversions are simulated to average about 380 afy and demand remains unfulfilled by an average of 50 afy, ranging up to nearly 200 afy. Figure 6-5 illustrates the monthly distribution of unmet Felton demand for Scenario 1a during WYs 1970–2017. Additionally, average Felton unused potential diversions decrease by about 100 afy compared to the base case.

The simulated Scenario 1a hydrograph for the Felton system provided in Figure 6-10 shows that the simulated rates of diversion do not exceed the synthesized potentially divertible flows in compliance with water rights.

Figure 6-11 compares hydrographs of the percent of simulated monthly flow remaining downstream of the Felton system diversions (as defined in Section 6.1) for the base case and Scenario 1a. On average, 86 and 82 percent of simulated unimpaired monthly flows remain downstream of the Fall (including Bennett) and Bull creek diversions, respectively, with a minimum of about 40 to more than 50 percent of remaining downstream of either diversion (Table 6-6). As simulated, increases in minimum monthly flows are relatively minor for Fall Creek and more significant for Bull Creek compared to the base case.

6.3.2 Scenario 1b – Felton System Complies with Required Bypass Only

Scenario 1b assumes that the Felton system complies only with the flow bypass requirements of its permitted water rights, and not the SLRBT low-flow triggers that at times prevent all Felton diversions (Table 4-3). In this case, simulated Felton diversions average nearly 400 afy, about 5 percent higher than Scenario 1a, and are non-compliant during all or portions of 21 percent of all months (compared to 23 percent in the base case). Additionally, demand remains unfulfilled by an average of 35 afy, ranging up to 85 afy, due to the lack of a supplemental source of water during deficit months. On average, 86 and 64 percent of simulated unimpaired monthly flows are calculated to remain downstream of the Fall (including Bennett) and Bull creek diversions, respectively, with a minimum of about 30 to 50 percent remaining downstream of either diversion (Table 6-6).

6.3.3 Scenarios 1c, 1d, and 1e – All Diversion Capacities Doubled

For Scenarios 1c, 1d, and 1e, the capacities of the North and Felton systems to divert, convey, and treat surface water are effectively doubled (Table 6-2). These scenarios evaluate the upper bounds of potential surface water production.

Scenarios 1c, 1d, and 1e are otherwise equivalent to Scenario 1a, the base case, and Scenario 1b, respectively, in terms of Felton water-rights compliance (Table 6-1). Like the base case, Felton system diversions occur without regard to permitted water rights in Scenario 1d, whereas Scenario 1c fully complies, and Scenario 1e complies only with required bypass flows.

For these scenarios, North system unused potential diversions approximately double to 600 afy, on average, and range up to 1,900 afy. Average Felton system unused potential diversions more than double, increasing from nearly 800 afy to more than 1,000 afy for these scenarios, compared to 300 to 420 afy for the base case and Scenarios 1a and 1b (Tables 6-4 and 6-5).

Because demand remains unchanged and no in-lieu recharge is attempted in Scenarios 1c, 1d, and 1e, the calculated percent of monthly flow remaining downstream of the North and Felton system diversions does not substantially differ from Scenario 1a, the base case, and Scenario 1b, respectively. However, reduced North system groundwater pumping as a result of increased diversion capacities results in a roughly 5 percent increase in the drought minimum baseflows remaining in lower Newell and Zayante creeks (Table 6-6).

The potential magnitude of diversions estimated in Scenarios 1c, 1d, and 1e is highly approximate and should not be used in quantitative estimates of potentially available water supplies. Rather, the conceptual gains in potential water production indicated by these scenarios are intended to help guide decisions regarding potential infrastructure modifications. The actual yield of modified infrastructure will depend on numerous factors beyond the scope of this analysis. Given the uncertainty associated with the likely performance of modified infrastructure, the alternative conjunctive use scenarios presented and discussed in the remainder of this report assume the base case water production capacities for which the simulation procedure is calibrated. This allows other factors, such as system intertie use for in-lieu recharge, use of Loch Lomond, and ASR, to be evaluated on an apples-to-apples basis compared to the base case.

6.3.4 Scenario 1f – South System Imports North System Unused Potential Diversions

Scenario 1f is similar to Scenario 1a (i.e., base case but with Felton system complying with permitted water rights) with the exception that North system unused potential diversions are exported to the South system as a substitute for pumping the Pasatiempo wells (i.e., in-lieu recharge; Table 6-1). In this case, the South system imports an average and maximum of 115 afy and greater than 300 afy, respectively, as needed to fulfill demand during months when potential diversions exceed North system demand (Tables 6-4, 6-5, and 6-7). This results in an overall 32 percent reduction in South system groundwater pumping (Table 6-7). However, the conveyance capacity required for the maximum simulated monthly import, 337 gpm (on a continuous basis), slightly exceeds the North-South system intertie design capacity of 300 gpm (Tables 3-3, 6-2, and 6-7).

Figure 6-12 compares hydrographs of the percent of simulated monthly flow remaining downstream of the Felton system diversions (as defined in Section 6.1) for the base case and Scenario 1f. The percent of simulated monthly flow remaining downstream of North system diversions in Scenario 1f is only slightly less (≤1 percent) than the base case and Scenarios 1a and 1b. This is because diversions in excess of North system demand mostly occur during high streamflow months when diversions compose only a small percentage of unimpaired flows.

Reduced South system groundwater pumping as a result of importing North system unused potential diversions results in a slight increase (≤4 percent) in the drought minimum baseflows estimated to remain in lower Zayante and Bean creeks compared to the base case (Table 6-6).

The simulated export of unused potential stream diversions to the South system reduces North system average annual unused diversions to approximately 175 afy, compared to 290 afy for the base case (Table 6-4).

6.3.5 Scenarios 1g1 through 1g4 – South System Imports Felton System Unused Potential Diversions

Scenarios 1g1, 1g2, and 1g3 are equivalent to the base case and Scenarios 1a and 1b, respectively, except that Felton system unused potential diversions are exported to the South system as a substitute for pumping the Pasatiempo wells (i.e., in-lieu recharge; Table 6-1). In these cases, the South system imports an average of 200 to 280 afy, depending on water-rights compliance, and a maximum of nearly 320 afy, as needed to fulfill demand during months when potential diversions exceed Felton system demand (Tables 6-4, 6-5, and 6-7). This results in an overall reduction in South system groundwater pumping of 54 to 77 percent (Table 6-7). However, the conveyance capacity required for the maximum monthly simulated import, 290 gpm (continuous), exceeds the existing Felton-South (via North) system intertie capacity of 150 gpm (Tables 3-3, 6-2, and 6-7). A more direct intertie between the Felton and South systems would likely have greater capacity than the existing intertie via the North system.

Figure 6-13 compares hydrographs of the percent of simulated monthly flow remaining downstream of the Felton system diversions for Scenarios 1a and 1g2. In the case of Scenario 1g2, the percent of unimpaired monthly flows estimated to remain downstream of the Felton system diversions averages 82 and 64 percent for the Fall (including Bennett) and Bull creek diversions, respectively, with minimums of about 25 to 40 percent (Table 6-6). Figure 6-13 shows that increased diversions for in-lieu recharge occur during wet periods and do not lower minimum monthly flows downstream of the diversions. Reduced South system groundwater pumping as a result of importing Felton system unused potential diversions results in a 6 percent increase in the drought minimum baseflows estimated to remain in lower Zayante and Bean creeks compared to the base case (Table 6-6).

Scenario 1g4 is identical to Scenario 1g2 (i.e., Felton system complies with permitted water rights) except that the simulated Felton-South intertie capacity is limited to 150 gpm (Tables 6-1 and 6-2). In this case, the South system imports an average and maximum of 165 and 225 afy, respectively, as needed to fulfill demand during months when potential diversions exceed Felton demand (Tables 6-4, 6-5, and 6-7). This results in an overall 45 percent reduction in South system groundwater pumping (Table 6-7). The percent of unimpaired monthly flows remaining downstream of the diversions averages 82 and 68 percent for the Fall (including Bennett) and Bull creek diversions, respectively, with minimums of about 35 to 40 percent (Table 6-6). Reduced South system groundwater pumping results in an estimated 5 percent increase in drought minimum baseflows remaining in lower Zayante and Bean creeks compared to the base case (Table 6-6). The Felton system's remaining average annual unused potential diversions decrease to approximately 140 afy compared to about 300 afy for Scenario 1a (Table 6-4).

6.3.6 Scenario 1h1 and 1h2 – South System Imports North and Felton System Unused Potential Diversions

Scenario 1h1 and 1h2 assume that the South system imports both North and Felton system unused potential diversions (Table 6-1). Scenario 1h1 assumes that Felton diversions are unrestricted, whereas Scenario 1h2 assumes the Felton system complies with permitted water rights. Figure 6-5 includes a plot of the monthly results for Scenario 1h2.

In these cases, the South system imports an average of 115 afy from the North system, similar to Scenario 1f, and an average of 90 to 290 afy from the Felton system, depending on water-rights compliance, as needed to fulfill remaining demand (Tables 6-4, 6-5, and 6-7). This results in an overall reduction in South system groundwater pumping of 56 to 79 percent (Table 6-7), and as much as a 7 percent increase in lower Zayante and Bean Creek drought minimum baseflows (Table 6-6). However, the conveyance capacity required for the maximum monthly simulated import from the Felton system, about 290 gpm (on a continuous basis), exceeds the Felton-South (via North) system existing intertie capacity of 150 gpm (Tables 3-3, 6-2, and 6-7).

For Scenario 1h2, the percent of unimpaired monthly flows remaining downstream averages 72 and 63 percent for the Fall (including Bennett) and Bull creek diversions, respectively, with minimums of about 30 to 40 percent (Table 6-6). Reduced South system groundwater pumping results in an estimated 6 to 7 percent increase in drought minimum baseflows remaining in lower Zayante and Bean creeks compared to the base case (Table 6-6).

Similar to Scenario 1f, North system average annual remaining unused diversions decrease to approximately 175 afy, compared to 290 afy for the base case (Table 6-4). The Felton system's remaining average annual unused potential diversions decrease to approximately 100 to 135 afy, compared to about 300 afy for Scenario 1a. The average annual export of Felton diversions to the South system in Scenario 1h2 (90 afy) is less than half that of Scenario 1g2 (200 afy), which results from supplying the South system first with unused North system diversions. Among all of the evaluated Scenario 1 alternatives, Scenario 1h2 achieves the greatest use of North and Felton system potential diversions, resulting in 275 afy of potential diversions remaining unused, on average, compared to about 600 afy for Scenario 1a.

6.3.7 Scenario 1i – North System Imports Felton System Unused Potential Diversions

Scenario 1i assumes that the North system imports unused potential diversions from the Felton system, in compliance with water rights, to reduce North system groundwater pumping (Table 6-1). In this case, the North system imports an average and maximum of 130 afy and 265 afy, respectively, as needed to fulfill demand during months when North system diversions are insufficient and Felton potential diversions exceed Felton demand (Table 6-7). This results in an overall reduction in North system groundwater pumping of 20 percent. However, the conveyance capacity required for the maximum monthly simulated import from the Felton system, about 355 gpm, exceeds the Felton-North system intertie capacity of 150 gpm (Tables 3-3, 6-2, and 6-7). As such, total imports limited by the existing intertie capacity would be somewhat less, as is demonstrated by comparing the results for Scenarios 1j and 1k in Section 6.3.8. The Felton system's remaining average annual unused potential diversions decrease to approximately 180 afy, compared to about 300 afy for Scenario 1a.

6.3.8 Scenarios 1j and 1k – North System Imports Felton System Unused Potential Diversions and South System Imports Remaining Unused Potential Diversions

Scenarios 1j and 1k assume that the North system imports Felton system unused potential diversions to reduce North system groundwater pumping, while the South system imports any remaining unused potential diversions from the North and Felton systems to reduce South system groundwater pumping (Table 6-1). Scenario 1j assumes unlimited intertie capacities whereas Scenario 1k assumes the design intertie capacities (Tables 3-3 and 6-7). Figure 6-5 includes a plot of the monthly results for Scenario 1j.

North system exports to the South system average approximately 115 afy in both cases (similar to Scenarios 1f, 1h1, and 1h2), whereas Felton system exports to the North and South systems average 144 afy and 133 afy for Scenarios 1j and 1k, respectively. The remaining unused potential diversions average between 330 and 350 afy, compared to 600 afy for Scenario 1a (Table 6-4).

The average percentages of unimpaired monthly flows remaining downstream of the North and Felton system diversions are within the range of the other evaluated alternatives (Table 6-6). Simulated reductions in North and South system groundwater pumping are 20 percent and 36 percent, respectively, for Scenario 1j, and 17 and 39 percent for Scenario 1k (Table 6-7). Reduced North and South system groundwater pumping results in an estimated 6 to 10 percent increase in drought minimum baseflows remaining in lower Newell, Zayante, and Bean creeks compared to the base case (Table 6-6).

6.4 Scenario 2: Import from Loch Lomond

Scenario 2 evaluates SLVWD’s use of its Loch Lomond reservoir annual allotment of 313 afy. The three conjunctive use alternatives evaluated under Scenario 2 are (Table 6-1):

- Scenario 2a – North and Felton systems import from Loch Lomond to satisfy demand that remained unmet in Scenario 1a.

- Scenario 2b – Scenario 2a plus the South system imports water from Loch Lomond for in-lieu recharge.
- Scenario 2c – Scenario 2b plus the South system also imports unused potential diversions from the North system, and the North system imports unused potential diversions from the Felton system.

6.4.1 Scenario 2a – North and Felton Systems Use Loch Lomond to Fulfill Unmet Demand

As simulated for Scenario 2a, the North system imports an average and maximum of 4 and 65 afy (Tables 6-8 and 6-9), respectively, from Loch Lomond to fulfill demand unfulfilled in the base case because of limits imposed on groundwater pumping (Section 6.2). Additionally, the Felton system imports an average and maximum of 50 and 185 afy, respectively, from Loch Lomond to comply with its permitted water rights. Loch Lomond is the only supplemental source considered in this analysis that allows the Felton system to comply with its permitted water rights.

The maximum monthly rates of import would require conveyance capacities in excess of 200 and 300 gpm (continuous) for the North and South systems, respectively (Table 6-10). These imports only use about 16 percent of SLVWD's annual 313 afy Loch Lomond allotment, on average, but use up to 60 percent of the allotment some years (Table 6-10).

6.4.2 Scenario 2b – South System Imports from Loch Lomond for In-Lieu Recharge

In addition to the use of Loch Lomond as simulated in Scenario 2a, Scenario 2b assumes that the South system imports an average of 245 afy from Loch Lomond, ranging between 120 and 290 afy, as a substitute for pumping the Pasatiempo wells. In this case, SLVWD uses nearly 95 percent of its Loch Lomond annual allotment on average, ranging from 87 to 100 percent per year. The maximum monthly import requires a conveyance capacity of nearly 200 gpm (continuous) (Table 6-10).

The South system's use of Loch Lomond results in an overall 67 percent reduction in groundwater pumping (Table 6-10), which results in an estimated 7 to 8 percent increase in drought minimum baseflows remaining in lower Zayante and Bean creeks compared to the base case (Table 6-11).

6.4.3 Scenario 2c –South System Imports from Loch Lomond and North and South Systems Import Unused Potential Diversions

In addition to the use of Loch Lomond as simulated in Scenario 2b, Scenario 2c assumes that the North and South systems import unused potential diversions. Figure 6-14 includes a plot of the monthly results for Scenario 2c. In this case, the South system imports an average of 20 afy from the North system and the North system imports an average of 130 afy from the Felton system in response to seasonal differences in each system's supply and demand. Combined with South system imports from Loch Lomond, this results in an overall 21 percent reduction in North system groundwater pumping and 73 percent reduction in South system groundwater pumping (Table 6-10). Reduced North and South system groundwater pumping results in an estimated 5 to 11 percent increase in drought minimum baseflows remaining in lower Newell, Zayante, and Bean creeks compared to the base case (Table 6-11). The percentages of monthly flow remaining downstream of the North and Felton system diversions are within the respective ranges estimated for the other conjunctive use alternatives. The remaining unused North and Felton system potential diversions average nearly 450 afy, compared to 600 afy for Scenario 1a (Tables 6-4 and 6-8).

6.5 Scenario 3: Operate Olympia Area ASR Project

Scenario 3 evaluates the operation of a North system ASR project in addition to SLVWD's use of its Loch Lomond allotment. The three conjunctive use alternatives evaluated under Scenario 3 are (Table 6-1):

- Scenario 3a – ASR project uses North system unused potential diversions.
- Scenario 3b – ASR project uses Felton system unused potential diversions.

- Scenario 3c – ASR project uses North and Felton system unused potential diversions.

These alternatives assume an injection capacity of 400 gpm from December through May, extraction capacities ranging from 250 to 585 gpm from June through November (Table 6-2), and a 100 percent extraction efficiency. In each case, the percentages of monthly flow estimated to remain downstream of the North and Felton system diversions are within the ranges estimated for the other conjunctive use alternatives.

6.5.1 Scenario 3a – North System Operates ASR Project Using North System Unused Potential Diversions

In addition to the use of Loch Lomond as in Scenario 2b, Scenario 3a assumes storing unused North system potential diversions by operating an ASR project, and withdrawing this water to help meet North system demand during dry periods. In this case, an average of approximately 190 afy is injected and extracted, effectively reducing North system groundwater production by 30 percent, and increasing drought minimum baseflows in lower Newell, Zayante, and Bean creeks by 11 to 15 percent compared to the base case (Tables 6-10 and 6-11). The remaining unused North system potential diversions average 100 afy, compared to 290 afy for the base case (Tables 6-4 and 6-8).

6.5.2 Scenario 3b – North System Operates ASR Project Using Felton System Unused Potential Diversions

Scenario 3b assumes storing unused Felton system potential diversions by operating an ASR project and withdrawing this water to help meet North system demand during dry periods. In this case, an average of approximately 220 afy is injected and extracted, effectively reducing North system groundwater production by 34 percent, and increasing drought minimum baseflows in lower Newell, Zayante, and Bean creeks by 11 to 17 percent compared to the base case (Tables 6-10 and 6-11). The remaining unused Felton system potential diversions average 85 afy, compared to 300 afy for Scenario 1a (Tables 6-4 and 6-8).

6.5.3 Scenario 3c – North System Operates ASR Project Using North and Felton System Unused Potential Diversions

Scenario 3c assumes storing unused North and Felton system potential diversions by operating an ASR project and withdrawing this water to help meet North system demand during dry periods. Figure 6-14 includes a plot of the monthly results for Scenario 3c. In this case, an average of approximately 410 afy is injected and extracted, effectively reducing North system groundwater production by 64 percent and increasing drought minimum baseflows in lower Newell, Zayante, and Bean creeks by 14 to 33 percent compared to the base case (Tables 6-10 and 6-11). The remaining unused North and Felton system potential diversions average 185 afy, compared to 600 afy for Scenario 1a (Tables 6-4 and 6-8). Figures 6-15 and 6-16 provide hydrographs of the percentages of simulated monthly unimpaired flow remaining downstream of the North and Felton system diversions compared to the base case and Scenario 1a. Figures 6-15 and 6-16 show that increased diversions for in-lieu recharge occur during wet periods do not lower minimum monthly flows remaining downstream of the diversions.

6.6 Scenario 4: Further Contribute to Scotts Valley Area In-Lieu Recharge

Scenario 4 is the same as Scenario 3c except that North and Felton system unused potential diversions are provided to SVWD as a substitute for SVWD groundwater pumping in the Scotts Valley area (Table 6-1). Assuming the design 350 gpm (continuous) capacity of the SLVWD-SVWD intertie, an average of approximately 165 afy of unused potential diversions are provided to SVWD, ranging from 20 to 500 afy (Tables 6-8 and 6-9). Reduced SVWD pumping may help increase Bean Creek baseflows but is not estimated as part of this analysis. The remaining unused North and Felton system unused potential diversions average 17 afy, with a maximum of 200 afy.

No.	Base Case and Alternative Conjunctive Use Scenarios	Stream Diversion Capacities		Felton System Water Rights			Stream Diversion Exports Using System Interties						Import from Loch Lomond			Scotts Valley In-Lieu Recharge with Exported Diversions	
							North System to			Felton System to							
		Existing	Doubled	Comply	Not Comply	Comply with Bypass Only	Felton System	South System	Olympia ASR	South System	North System	Olympia ASR	to North System	to Felton System	to South System	from North System	from Felton System
	Historical Record, WYs 2000-2017 (from Table 3-3)	●			●		*	*									
	Synthesized Records, WYs 1970-2017:																
1	**Base case Simulated** historical record (calibrated to WYs 2000-2017)[a]	●			●												
	Scenario 1 Alternatives Using Existing and Modified Infrastructure and Water Rights Variations																
2	**1a.** Felton system complies with water rights.	●		○													
3	**1b.** Felton system complies with required bypass flows, but not SLRBT low-flow no-diversion requirements.	●				○											
4	**1c.** All diversion capacities doubled; Felton system complies with water rights.		●	○													
5	**1d.** All diversion capacities doubled; Felton system diverts without regard to water rights.		●		●												
6	**1e.** All diversion capacities doubled; Felton system complies with required bypass flows only.		●			○											
7	**1f.** South system imports North system unused potential diversions for in-lieu recharge; Felton system complies with water rights.	●		○			×	●									
8	**1g1.** South system imports Felton system unused potential diversions for in-lieu recharge; Felton system diverts without regard to water rights.	●			●		×			●							
9	**1g2.** Scenario 1g1 except Felton system complies with water rights.	●		○			×			●							
10	**1g3.** Scenario 1g1 except Felton system complies with required bypass flows only.	●				○	×			●							
11	**1g4.** Scenario 1g2 except intertie capacities limited.	●		○			×			▲							
12	**1h1.** South system imports unused potential diversion from North and Felton systems for in-lieu recharge; Felton system diverts without regard to water rights.	●			●		×	●		●							
13	**1h2.** Scenario 1h1 except Felton system comples with water rights.	●		○			×	●		●							
14	**1i.** North system imports Felton system unused potential diversions for in-lieu recharge; Felton system complies with water rights.	●		○			×				●						
15	**1j.** Scenario 1i plus South system imports unused potential diversion from North and Felton systems.	●		○			×	●		●	●						
16	**1k.** Scenario 1j except intertie capacities limited.	●		○			×	●		▲	▲						
	Scenario 2 – Import from Loch Lomond																
17	**2a.** North and Felton systems import from Loch Lomond to satisfy unmet demand in Scenario 1a.	●		●			×						●	●			
18	**2b.** Scenario 2a plus South system imports from Loch Lomond for in-lieu recharge.	●		●			×						●	●	●		
19	**2c.** Scenario 2b plus South system also imports North system unused diversions, and North system imports unused Felton system diversions.	●		●			×	●			●		●	●	●		
	Scenario 3 – Import from Loch Lomond and Operate Olympia Aquifer Storage and Recovery (ASR)																
20	**3a.** Scenario 2b plus North system operates Olympia area ASR using North system unused diversions.	●		●			×		⊙					●	●		
21	**3b.** Scenario 2b plus North system operates Olympia area ASR using Felton system unused diversions.	●		●			×					●		●	●		
22	**3c.** Scenarios 3a and 3b combined.	●		●			×		⊙			●		●	●		
	Scenario 4 – Contribute to Scotts Valley In-Lieu Recharge while Operating Olympia ASR and Importing from Loch Lomond																
23	**4.** Scenario 3c plus SVWD imports North and Felton system remaining unused potential diversions.	●		●			×		⊙			●		●	●	●	●

●	Base case condition or scenario assumption.	×	North system has no unused diversions when needed by Felton.
*	Minor use since 2016.	▲	Intertie capacities limited to rated values (Table 3-3).
○	Water rights compliance results in unmet demand some years.	⊙	Diversions exported to Olympia ASR imported back to North system.

All scenarios assume estimated 2045 demand and repeat of WY1970-2017 climatic cycle.

See Table 6-2 for assumed diversion, conveyance, and treatment capacities.

[a] Simulated base case does not reflect minor use of system interties in actual use since 2016.

Table 6-1
Summary of Conjunctive Use Scenario Alternative Assumptions

Base Case and Alternative Conjunctive Use Scenarios	North System[a]						Felton System[a]		South System	Interties					ASR of Unused Diversions[c]	
	Stream Diversions				Wells		Diversions								Source:	
	Foreman Creek	Peavine Creek	Clear & Sweetwater Cks	Conveyance to WTP	Quail Hollow[b]	Olympia[b]	Fall & Bennett Cks	Bull Creek	Pasatiempo Wells	North-South	Felton-South	Felton-North	SLVWD-SVWD	Loch Lomond	North System	Felton System
	gallons per minute (gpm; continuous)															
Historical Record, WYs 2000-2017 (from Table 3-3)	926		560	1,030	545	780	460		435	300	150	150	350	-	-	-
Base case Simulated historical record (calibrated to WYs 2000-2017)	800	200	515	800	500 *250*	780 *475*	440	166	450	-	-	-	-	-	-	-
Scenario 1 Alternatives Using Existing and Modified Infrastructure and Water Rights Variations																
1a. Felton system complies with water rights.	800	200	515	800	500 *250*	780 *475*	440	166	450	-	-	-	-	-	-	-
1b. Felton system complies with required bypass flows, but not SLRBT low-flow no-diversion requirements.										-	-	-	-	-	-	-
1c. All diversion capacities doubled; Felton system complies with water rights.	1,600	400	1,030	1,600			880	332	450	-	-	-	-	-	-	-
1d. All diversion capacities doubled; Felton system diverts without regard to water rights.										-	-	-	-	-	-	-
1e. All diversion capacities doubled; Felton system complies with required bypass flows only.										-	-	-	-	-	-	-
1f. South system imports North system unused potential diversions for in-lieu recharge; Felton system complies with water rights.	800	200	515	800			440	166	450	✱	-	-	-	-	-	-
1g1. South system imports Felton system unused potential diversions for in-lieu recharge; Felton system diverts without regard to water rights.										-	✱	-	-	-	-	-
1g2. Scenario 1g1 except Felton system complies with water rights.										-	✱	-	-	-	-	-
1g3. Scenario 1g1 except Felton system complies with required bypass flows only.										-	✱	-	-	-	-	-
1g4. Scenario 1g2 except intertie capacities limited.										-	150	-	-	-	-	-
1h1. South system imports unused potential diversion from North and Felton systems for in-lieu recharge; Felton system diverts without regard to water rights.										✱	✱	✱	-	-	-	-
1h2. Scenario 1h1 except Felton system comples with water rights.										✱	✱	✱	-	-	-	-
1i. North system imports Felton system unused potential diversions for in-lieu recharge; Felton system complies with water rights.										✱	✱	✱	-	-	-	-
1j. Scenario 1i plus South system imports unused potential diversion from North and Felton systems.										✱	✱	✱	-	-	-	-
1k. Scenario 1j except intertie capacities limited.										300	150	150	-	-	-	-
Scenario 2 – Import from Loch Lomond																
2a. North and Felton systems import from Loch Lomond to satisfy unmet demand in Scenario 1a.	800	200	515	800	500 *250*	780 *475*	440	166	450	-	-	-	-	✱	-	-
2b. Scenario 2a plus South system imports from Loch Lomond for in-lieu recharge.										-	-	-	-	✱	-	-
2c. Scenario 2b plus South system also imports North system unused diversions, and North system imports unused Felton system diversions.										✱	-	✱	-	✱	-	-
Scenario 3 – Import from Loch Lomond and Operate Olympia Aquifer Storage and Recovery																
3a. Scenario 2b plus North system operates Olympia area ASR using North system unused diversions.	800	200	515	800	500 *250*	780 *475*	440	166	450	-	-	-	-	✱	400 250	-
3b. Scenario 2b plus North system operates Olympia area ASR using Felton system unused diversions.										-	-	✱	-	✱	-	400 285
3c. Scenarios 3a and 3b combined.										-	-	✱	-	✱	400	400
															585	
Scenario 4 – Contribute to Scotts Valley In-Lieu Recharge while Operating Olympia ASR and Importing from Loch Lomond																
4. Scenario 3c plus SVWD imports North and Felton system remaining unused potential diversions.	800	200	515	800	500 *250*	780 *475*	440	166	450	-	-	✱	350	✱	400	400
															585	

[a] Assumed prioritization of use from left to right.

[b] Well pumping capacities decline in three steps to minimum rate (*bottom value*) during critical drought periods..

[c] December-May injection capacity (top value) and June-November extraction capacity (bottom values) adjusted to inject/extract equal amounts during synthesized record.

✱ Not limited during simulation.

Table 6-2
Assumed Water Production and Conveyance Capacities

Synthesized Climactic Cycle		
WY	SLRBT % avg	Type[a]
1970	130%	G
1971	70%	D
1972	26%	B
1973	178%	I
1974	150%	H
1975	84%	E
1976	15%	A
1977	10%	A
1978	160%	I
1979	66%	D (A,C,E)
1980	148%	H
1981	40%	B (C)
1982	246%	M
1983	308%	N
1984	87%	E
1985	48%	C (B)
1986	184%	J
1987	26%	B
1988	22%	B
1989	27%	B
1990	21%	B
1991	33%	B (A,F)
1992	53%	C (B)
1993	121%	G
1994	31%	B
1995	193%	J
1996	137%	G
1997	155%	H
1998	222%	L
1999	95%	E
2000	122%	G (B,H)
2001	53%	C (B,D)
2002	74%	D
2003	84%	E
2004	92%	E
2005	135%	G
2006	216%	K
2007	31%	B
2008	58%	C (B,E)
2009	50%	C (A,B,E)
2010	103%	F
2011	134%	G
2012	51%	C (A,B,E,F)
2013	60%	C
2014	15%	A
2015	34%	B (A,C)
2016	83%	E (A,B)
2017	319%	N

North System		Demand	Stream Diversions											Groundwater Wells			Import	Export Unused Diversions	Total System Use	Unmet Demand[c]	Total Diversions	Unused Potential Diversions
			Peavine Creek		Foreman Creek			Clear & Sweetwater Cks			Total											
			Potential[b]	Diverted	Potential[b]	Diverted	Unused Potential	Potential[b]	Diverted	Unused Potential	Potential[b]	Diverted	Unused Potential	Quail Hollow	Olympia	Total						
		acre-feet per year (afy)																				
Historical record, WYs 2000-2017	avg	1,541	-	110	-	500	-	-	255	-	-	866	-	276	405	681	1	6	1,541	-	-	-
	%	-	-	**7%**	-	**32%**	-	-	**17%**	-	-	**56%**	-	**18%**	**26%**	**44%**	-	-	**100%**	-	-	-
	min	1,164	-	47	-	203	-	-	37	-	-	421	-	146	129	275	0	0	1,164	-	-	-
	max	1,800	-	224	-	928	-	-	380	-	-	1,128	-	461	572	1,015	10	103	1,800	-	-	-
Base Case – Simulated Historical Record																						
Calibration period, WYs 2000-2017	avg	1,564	135	110	517	507	**35**	492	263	**229**	1,144	880	264	274	403	678	0	0	1,558	6	880	264
	%	-	-	**7%**	-	**32%**	-	-	**17%**	-	-	**56%**	-	**18%**	**26%**	**43%**	-	-	**100%**	0.4%	-	-
	min	1,235	35	35	197	197	0	197	197	0	429	429	0	160	230	390	0	0	1,235	0	429	0
	max	1,776	229	143	860	854	134	732	318	498	1,822	1,228	594	423	608	1,031	0	0	1,776	65	1,228	594
Simulation period, WYs 1970-2017	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	259	378	638	0	0	1,541	4	904	289
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	0	0	1,235	0	429	0
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	0	0	1,776	65	1,231	836

Felton System		Demand	Stream Diversions									Import	Total System Use	Total Diversions	Unused Potential Diversions
			Fall & Bennett Cks			Bull Creek			Total						
			Potential[b]	Diverted	Unused Potential	Potential[b]	Diverted	Unused Potential	Potential[b]	Diverted	Unused Potential				
		acre-feet per year (afy)													
Historical record, WYs 2000-2017	avg	419	-	325	-	-	90	-	-	414	-	1	414	-	-
	%	-	-	**78%**	-	-	**22%**	-	-	**100%**	-	-	**100%**	-	-
	min	317	-	225	-	-	17	-	-	317	-	0	317	-	-
	max	498	-	406	-	-	128	-	-	489	-	20	489	-	-
Base Case – Simulated Historical Record															
Calibration period, WYs 2000-2017	avg	436	706	346	361	145	90	55	852	436	416	0	436	436	416
	%	-	-	**79%**	-	-	**21%**	-	-	**100%**	-	-	**100%**	-	-
	min	346	695	266	302	68	53	15	762	346	337	0	346	346	337
	max	492	710	407	436	225	120	124	926	492	560	0	492	492	560
Simulation period, WYs 1970-2017	avg	430	705	340	366	147	90	57	852	430	422	0	430	430	422
	min	335	695	266	292	68	49	15	762	335	316	0	335	335	316
	max	492	710	409	436	225	120	124	926	492	560	0	492	492	560

South System		Demand	Pumped Groundwater	Import	Export	Total System Use	**SLVWD Total**	Unused North & Felton System Diversions	Total SLVWD Production
		acre-feet per year (afy)						acre-feet per year (afy)	
Historical record, WYs 2000-2017	avg	387	384	5	1	384		-	2,345
	min	259	237	0	0	237		-	1,793
	max	447	447	82	10	447		-	2,658
Base Case – Simulated Historical Record									
Calibration period, WYs 2000-2017	avg	375	374	0	0	374		680	2,368
	min	297	297	0	0	297		352	1,878
	max	432	432	0	0	432		1,145	2,642
Simulation period, WYs 1970-2017	avg	365	365	0	0	365		711	2,336
	min	297	297	0	0	297		333	1,878
	max	441	441	0	0	441		1,354	2,642

Simulated Base Case:
- Calculated on a monthly timestep using daily flow duration curves.
- Assumes 2045 demand and repeat of WY1970-2017 climatic cycle.
- Does not reflect minor use of system interties in actual use since 2016.
- See Table 6-2 for assumed diversion, conveyance, and treatment capacities.
- Felton system diversions non-compliant with water rights 23% of all 576 months.

afy	acre-feet per year
%	percent of historical and simulated system production (South system is 100% groundwater).
avg	average
min	minimum
max	maximum
SLRBT % avg	percent of average annual SLRBT flow

[a] Water year type as defined in Tables 4-5 and 4-6; alternate types assigned to selected months given parenthetically.

[b] Within diversion capacity and water rights.

[c] Unmet North system demand results from assumed limits on groundwater production.

Table 6-3
Results of Simulated Base Case In Comparison to Historical Record

Base Case and Scenario 1 Alternatives (existing and modified infrastructure and water rights variations)	North System											Felton System										South System					Unused North & Felton System Diversions	SLVWD Total
		Stream Diversions											Stream Diversions															
	Demand	Potential[a]	Diverted	Unused Potential	Groundwater Wells	Imports	Export Unused Potential Diversions	Total System Use	Unmet Demand [b]	Total Diversions Including for Export	Unused Potential Diversions	Demand	Potential[a]	Diverted	Unused Potential	Imports	Export Unused Potential Diversions	Total System Use	Unmet Demand [c]	Total Diversions Including for Export	Unused Potential Diversions	Demand	Pumped Groundwater	Imports	Exports	Total System Use		
	acre-feet per year (afy)																											
Base case Simulated historical record (calibrated to WYs 2000-2017)	1,545	1,192	904	289	638	0	0	1,541	4	904	289	430	852	430	422	0	0	430	0	430	422	365	365	0	0	365	711	2,336
1a. Felton system complies with water rights.	1,545	1,192	904	289	638	0	0	1,541	4	904	289	430	685	378	307	0	0	378	51	378	307	365	365	0	0	365	596	2,285
1b. Felton system complies with required bypass flows, but not SLRBT low-flow no-diversion requirements.	1,545	1,192	904	289	638	0	0	1,541	4	904	289	430	775	395	381	0	0	395	35	395	381	365	365	0	0	365	669	2,301
1c. All diversion capacities doubled; Felton system complies with water rights.	1,545	1,569	966	603	575	0	0	1,541	4	966	603	430	1,175	390	785	0	0	390	40	390	785	365	365	0	0	365	1,388	2,300
1d. All diversion capacities doubled; Felton system diverts without regard to water rights.	1,545	1,569	966	603	575	0	0	1,541	4	966	603	430	1,493	430	1,064	0	0	430	0	430	1,064	365	365	0	0	365	1,667	2,336
1e. All diversion capacities doubled; Felton system complies with required bypass flows only.	1,545	1,569	966	603	575	0	0	1,541	4	966	603	430	1,290	396	893	0	0	396	33	396	893	365	365	0	0	365	1,496	2,303
1f. South system imports North system unused potential diversions for in-lieu recharge; Felton system complies with water rights.	1,545	1,192	904	289	638	0	115	1,541	4	1,019	174	430	685	378	307	0	0	378	51	378	307	365	250	115	0	365	480	2,285
1g1. South system imports Felton system unused potential diversions for in-lieu recharge; Felton system diverts without regard to water rights.	1,545	1,192	904	289	638	0	0	1,541	4	904	289	430	852	430	422	0	281	430	0	710	142	365	84	281	0	365	431	2,336
1g2. Scenario 1g1 except Felton system complies with water rights.	1,545	1,192	904	289	638	0	0	1,541	4	904	289	430	685	378	307	0	198	378	51	577	109	365	167	198	0	365	398	2,285
1g3. Scenario 1g1 except Felton system complies with required bypass flows only.	1,545	1,192	904	289	638	0	0	1,541	4	904	289	430	775	360	381	0	252	360	35	611	129	365	113	252	0	365	418	2,266
1g4. Scenario 1g2 except intertie capacities limited.	1,545	1,192	904	289	638	0	0	1,541	4	904	289	430	685	378	307	0	165	378	51	543	142	365	200	165	0	365	431	2,285
1h1. South system imports unused potential diversion from North and Felton systems for in-lieu recharge; Felton system diverts without regard to water rights.	1,545	1,192	904	289	638	0	115	1,541	4	1,022	174	430	852	430	422	0	287	430	0	601	136	365	78	287	0	365	309	2,336
1h2. Scenario 1h1 except Felton system complies with water rights.	1,545	1,192	904	289	638	0	115	1,541	4	1,019	174	430	685	378	307	0	89	378	51	468	102	365	160	205	0	365	276	2,285
1i. North system imports Felton system unused potential diversions for in-lieu recharge; Felton system complies with water rights.	1,545	1,192	904	289	511	128	0	1,542	0	904	289	430	685	378	307	0	128	378	51	506	179	365	365	0	0	365	468	2,286
1j. Scenario 1i plus South system imports unused potential diversion from North and Felton systems.	1,545	1,192	904	289	511	128	115	1,542	0	1,019	174	430	685	378	307	0	144	378	51	522	163	365	234	131	0	365	337	2,286
1k. Scenario 1j except intertie capacities limited.	1,545	1,192	904	289	533	105	115	1,542	0	1,019	174	430	685	378	307	0	133	378	51	512	174	365	222	143	0	365	347	2,286

Color shading relative to compliance with Felton system water rights:

🟨 Not compliant.

🟩 Compliant with Fall Creek required bypass flows.

🟦 Fully compliant with SLRBT low-flow diversion thresholds.

All scenarios assume estimated 2045 demand and repeat of WY1970-2017 climatic cycle.

See Table 6-2 for overall summary of scenario alternative assumptions.

See Table 6-3 for assumed diversion, conveyance, and treatment capacities.

See Table 6-6 for more detailed results.

[a] Within diversion capacity and water rights

[b] Unmet North system demand results from assumed limits on groundwater production.

[c] Unmet Felton system demand results from water rights compliance.

Table 6-4

Summary of Simulated Base Case and Scenario 1 Conjunctive Use Alternatives, Annual Averages, WYs 1970–2017

Scenario		North System																					Felton System																South System					Unused North & Felton Divsersions	Scotts Valley In-Lieu Recharge	**SLVWD Total**
			Stream Diversions											Groundwater Wells										Stream Diversions																						
			Peavine Creek		Foreman Creek			Clear & Sweetwater			Total													Fall & Bennett Cks			Bull Creek			Total																
		Demand	Potential*	Diverted	Potential*	Diverted	Unused Potential	Potential*	Diverted	Unused Potential	Potential ^{a}	Diverted	Unused Potential	Quail Hollow	Olympia	Total	Import/ ASR Extract	Ex-port/ Inject Unused Pot. Div.	Total Sys-tem Use	Un-met Demand ^{b}	Total Diversions Including for Export	Unused Potential Diversions	Demand	Potential*	Diverted	Unused Potential	Potential*	Diverted	Unused Potential	Potential ^{a}	Diverted	Unused Potential	Import/ ASR Extract	Ex-port/ Inject Unused Pot. Div.	Total System Use	Un-met Demand ^{c}	Total Diversions Including for Export	Unused Potential Diversions	Demand	Pumped Groundwater	Import	Export	Total System Use			
		acre-feet per year (afy)																																												
Base Case Simulated historical record (calibrated to WYs 2000-2017)	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	259	378	638	0	0	1,541	4	904	289	430	705	340	366	147	90	57	852	430	422	0	0	430	0	430	422	365	365	0	0	365	711	0	2,336
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	0	0	1,235	0	429	0	335	695	266	292	68	49	15	762	335	316	0	0	335	0	335	316	297	297	0	0	297	333	0	1,878
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	0	0	1,776	65	1,231	836	492	710	409	436	225	120	124	926	492	560	0	0	492	0	492	560	441	441	0	0	441	1,354	0	2,642
Scenario 1 – Alternatives using existing and modified infrastructure and variations in water rights																																														
1a. Felton system complies with water rights.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	259	378	638	0	0	1,541	4	904	289	430	547	338	208	139	40	99	685	378	307	0	0	378	51	378	307	365	365	0	0	365	596	0	2,285
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	0	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	23	0	0	186	0	186	23	297	297	0	0	297	23	0	1,757
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	0	0	1,776	65	1,231	836	492	678	408	348	222	50	186	900	455	534	0	0	455	187	455	534	441	441	0	0	441	1,328	0	2,636
1b. Felton system complies with required bypass flows, but not SLRBT low-flow no-diversion requirements.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	259	378	638	0	0	1,541	4	904	289	430	628	304	324	147	90	57	775	395	381	0	0	395	35	395	381	365	365	0	0	365	669	0	2,301
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	0	0	1,235	0	429	0	335	505	219	207	68	49	15	572	268	231	0	0	268	0	268	231	297	297	0	0	297	247	0	1,826
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	0	0	1,776	65	1,231	836	492	706	350	436	225	120	124	926	457	560	0	0	457	85	457	560	441	441	0	0	441	1,354	0	2,635
1c. All diversion capacities doubled; Felton system complies with water rights.	avg	1,545	207	127	654	549	185	708	290	418	1,569	966	603	234	342	575	0	0	1,541	4	966	603	430	989	352	638	186	38	147	1,175	390	785	0	0	390	40	390	785	365	365	0	0	365	1,388	0	2,300
	min	1,235	36	36	198	198	0	200	200	0	433	433	0	23	32	55	0	0	1,235	0	433	0	335	279	200	51	34	21	11	313	221	62	0	0	221	0	221	62	297	297	0	0	297	62	0	1,792
	max	1,776	453	202	1,529	976	804	1,367	336	1,094	3,349	1,451	1,898	424	610	1,034	0	0	1,776	64	1,451	1,898	492	1,355	415	1,025	338	47	301	1,694	461	1,327	0	0	461	147	461	1,327	441	441	0	0	441	3,183	0	2,642
1d. All diversion capacities doubled; Felton system diverts without regard to water rights.	avg	1,545	207	127	654	549	185	708	290	418	1,569	966	603	234	342	575	0	0	1,541	4	966	603	430	1,300	339	961	194	91	103	1,493	430	1,064	0	0	430	0	430	1,064	365	365	0	0	365	1,667	0	2,336
	min	1,235	36	36	198	198	0	200	200	0	433	433	0	23	32	55	0	0	1,235	0	433	0	335	1,092	266	745	73	49	20	1,166	335	768	0	0	335	0	335	768	297	297	0	0	297	768	0	1,878
	max	1,776	453	202	1,529	976	804	1,367	336	1,094	3,349	1,451	1,898	424	610	1,034	0	0	1,776	64	1,451	1,898	492	1,412	408	1,138	340	120	239	1,744	492	1,377	0	0	492	0	492	1,377	441	441	0	0	441	3,233	0	2,642
1e. All diversion capacities doubled; Felton system complies with required bypass flows only.	avg	1,545	207	127	654	549	185	708	290	418	1,569	966	603	234	342	575	0	0	1,541	4	966	603	430	1,096	306	781	194	91	103	1,290	396	893	0	0	396	33	396	893	365	365	0	0	365	1,496	0	2,303
	min	1,235	36	36	198	198	0	200	200	0	433	433	0	23	32	55	0	0	1,235	0	433	0	335	741	221	90	73	49	20	814	270	497	0	0	270	0	270	497	297	297	0	0	297	497	0	1,826
	max	1,776	453	202	1,529	976	804	1,367	336	1,094	3,349	1,451	1,898	424	610	1,034	0	0	1,776	64	1,451	1,898	492	1,401	353	1,135	340	120	239	1,742	457	1,375	0	0	457	82	457	1,375	441	441	0	0	441	3,231	0	2,635
1f. South system imports North system unused potential diversions for in-lieu recharge; Felton system complies with water rights.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	259	378	638	0	115	1,541	4	1,019	174	430	547	338	208	139	40	99	685	378	307	0	0	378	51	378	307	365	250	115	0	365	480	0	2,285
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	0	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	23	0	0	186	0	186	23	297	13	0	0	297	23	0	1,757
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	0	329	1,776	65	1,559	507	492	678	408	348	222	50	186	900	455	534	0	0	455	187	455	534	441	417	329	0	441	999	0	2,636
1g1. South system imports Felton system unused potential diversions for in-lieu recharge; Felton system diverts without regard to water rights.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	259	378	638	0	0	1,541	4	904	289	430	705	340	366	147	90	57	852	430	422	0	281	430	0	710	142	365	84	281	0	365	431	0	2,336
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	0	0	1,235	0	429	0	335	695	266	292	68	49	15	762	335	316	0	230	335	0	616	77	297	1	230	0	297	96	0	1,878
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	0	0	1,776	65	1,231	836	492	710	409	436	225	120	124	926	492	560	0	323	492	0	778	237	441	182	323	0	441	1,033	0	2,642
1g2. Scenario 1g1 except Felton system complies with water rights.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	259	378	638	0	0	1,541	4	904	289	430	547	338	208	139	40	99	685	378	307	0	198	378	51	577	109	365	167	198	0	365	398	0	2,285
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	0	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	23	0	23	186	0	236	0	297	13	23	0	297	0	0	1,757
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	0	0	1,776	65	1,231	836	492	678	408	348	222	50	186	900	455	534	0	311	455	187	741	223	441	319	311	0	441	1,024	0	2,636
1g3. Scenario 1g1 except Felton system complies with required bypass flows only.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	259	378	638	0	0	1,541	4	904	289	430	628	304	324	147	90	57	775	360	381	0	252	360	35	611	129	365	113	252	0	365	418	0	2,266
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	0	0	1,235	0	429	0	335	505	219	207	68	49	15	572	201	231	0	167	201	0	398	60	297	1	167	0	297	75	0	1,772
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	0	0	1,776	65	1,231	836	492	706	350	436	225	120	124	926	447	560	0	328	447	85	770	237	441	247	328	0	441	1,033	0	2,627
1g4. Scenario 1g2 except intertie capacities limited.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	259	378	638	0	0	1,541	4	904	289	430	547	338	208	139	40	99	685	378	307	0	165	378	51	543	142	365	200	165	0	365	431	0	2,285
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	0	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	23	0	23	186	0	229	0	297	99	23	0	297	0	0	1,757
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	0	0	1,776	65	1,231	836	492	678	408	348	222	50	186	900	455	534	0	226	455	187	676	308	441	328	226	0	441	1,102	0	2,636
1h1. South system imports unused potential diversion from North and Felton systems for in-lieu recharge; Felton system diverts without regard to water rights.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	259	378	638	0	115	1,541	4	1,022	174	430	705	340	366	147	90	57	852	430	422	0	287	430	0	601	136	365	78	287	0	365	309	0	2,336
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	0	0	1,235	0	429	0	335	695	266	292	68	49	15	762	335	316	0	230	335	0	421	77	297	0	230	0	297	80	0	1,878
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	0	329	1,776	65	1,559	507	492	710	409	436	225	120	124	926	492	560	0	362	492	0	702	236	441	182	362	0	441	683	0	2,642
1h2. Scenario 1h1 except Felton system comples with water rights.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	259	378	638	0	115	1,541	4	1,019	174	283	547	338	208	139	40	99	685	378	307	0	89	378	51	468	102	365	160	205	0	365	276	0	2,285
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	0	0	1,235	0	429	0	0	209	158	23	29	28	0	237	186	23	0	13	186	0	236	0	297	0	23	0	297	0	0	1,757
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	0	329	1,776	65	1,559	507	815	678	408	348	222	50	186	900	455	534	0	155	455	187	533	222	441	319	344	0	441	657	0	2,636
1i. North system imports Felton system unused potential diversions for in-lieu recharge; Felton system complies with water rights.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	209	302	511	128	0	1,542	0	904	289	430	547	338	208	139	40	99	685	378	307	0	128	378	51	506	179	365	365	0	0	365	468	0	2,286
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	39	52	91	23	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	23	0	23	186	0	237	0	297	297	0	0	297	0	0	1,757
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	416	598	1,014	266	0	1,776	0	1,231	836	492	678	408	348	222	50	186	900	455	534	0	266	455	187	677	308	441	441	0	0	441	1,144	0	2,636
1j. Scenario 1i plus South system imports unused potential diversion from North and Felton systems.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	209	302	511	128	115	1,542	0	1,019	174	430	547	338	208	139	40	99	685	378	307	0	144	378	51	522	163	365	234	131	0	365	337	0	2,286
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	39	52	91	23	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	23	0	23	186	0	237	0	297	13	0	0	297	0	0	1,757
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	416	598	1,014	266	329	1,776	0	1,559	507	492	678	408	348	222	50	186	900	455	534	0	340	455	187	677	308	441	382	402	0	441	815	0	2,636
1k. Scenario 1j except intertie capacities limited.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	218	315	533	105	115	1,542	0	1,019	174	430	547	338	208	139	40	99	685	378	307	0	133	378	51	512	174	365	222	143	0	365	347	0	2,286
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	65	90	155	23	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	23	0	23	186	0	237	0	297	0	0	0	297	0	0	1,757
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	416	598	1,014	176	328	1,776	0	1,558	509	492	678	408	348	222	50	186	900	455	534	0	233	455	187	645	357	441	372	412	0	441	866	0	2,636

Color shading relative to compliance with Felton system water rights:
🟨 Not compliant.
🟩 Compliant with Fall Creek required bypass flows.
🟦 Fully compliant with SLRBT low-flow diversion thresholds.

All scenarios assume estimated 2045 demand and repeat of WY1970-2017 climatic cycle.
See Table 6-1 for overall summary of scenario alternative assumptions.
See Table 6-2 for assumed diversion, conveyance, and treatment capacities.

[a] Within Diversion Capacity and Water Rights
[b] Unmet North system demand results from assumed limits on groundwater production.
[c] Unmet Felton system demand results from water rights compliance.

avg average
min minimum
max maximum

Table 6-5

Results of Base Case and Scenario 1 Conjunctive Use Simulations, WYs 1970–2017

Scenario			Percent of Monthly Flow Remaining Downstream of Diversion							Percent of Drought Minimum Baseflow Remaining as a Result of Groundwater Pumping[c]						Percent of Months Felton Non-compliant
			Peavine Creek[a]	Fore-man Creek[a]	Boulder Creek[b]	Clear & Sweet-water Creeks[a]	Fall & Bennett Creeks[a]	Bull Creek[a]	San Lorenzo R at Big Trees[b]	Newell Creek at SLR	Zayante Ck above Bean Ck	Bean Ck at Zayante Ck	Zayante Ck at SLR	San Lorenzo R above Fall Ck	San Lorenzo R at Big Trees	
Base Case	Simulated historical record (calibrated to WYs 2000-2017)	avg	63	26	86	51	83	64	95	53	49	47	47	93	72	23
		min	40	10	65	19	32	32	86							
		max	96	81	99	100	99	94	100							
Scenario 1 Alternatives Using Existing and Modified Infrastructure and Water Rights Variations	**1a.** Felton system complies with water rights.	avg	63	26	86	51	86	82	96	53	49	47	47	93	72	0
		min	40	10	65	19	42	53	87							
		max	96	81	99	100	99	99	100							
	1b. Felton system complies with required bypass flows, but not SLRBT low-flow no-diversion requirements.	avg	63	26	86	51	86	64	95	53	49	47	47	93	72	21
		min	40	10	65	19	49	32	88							
		max	96	81	99	100	99	94	100							
	1c. All diversion capacities doubled; Felton system complies with water rights.	avg	59	24	85	47	85	83	95	57	54	47	48	94	73	0
		min	33	8	64	17	42	53	87							
		max	95	81	99	100	99	99	100							
	1d. All diversion capacities doubled; Felton system diverts without regard to water rights.	avg	59	24	85	47	83	64	95	57	54	47	48	94	73	16
		min	33	8	64	17	32	32	86							
		max	95	81	99	100	99	94	100							
	1e. All diversion capacities doubled; Felton system complies with required bypass flows only.	avg	59	24	85	47	86	64	95	57	54	47	48	94	73	14
		min	33	8	64	17	49	32	89							
		max	95	81	99	100	99	94	100							
	1f. South system imports North system unused potential diversions for in-lieu recharge; Felton system complies with water rights.	avg	62	25	86	43	86	82	95	53	49	51	50	93	73	0
		min	40	10	65	17	42	53	87							
		max	94	80	99	97	99	99	100							
	1g1. South system imports Felton system unused potential diversions for in-lieu recharge; Felton system diverts without regard to water rights.	avg	63	26	86	51	72	58	94	53	49	56	55	93	76	23
		min	40	10	65	19	16	27	83							
		max	96	81	99	100	99	90	100							
	1g2. Scenario 1g1 except Felton system complies with water rights.	avg	63	26	86	51	82	64	95	53	49	53	53	93	75	0
		min	40	10	65	19	40	27	85							
		max	96	81	99	100	99	99	100							
	1g3. Scenario 1g1 except Felton system complies with required bypass flows only.	avg	63	26	86	51	78	58	94	53	49	55	54	93	75	15
		min	40	10	65	19	39	27	86							
		max	96	81	99	100	99	90	100							
	1g4. Scenario 1g2 except intertie capacities limited.	avg	63	26	86	51	82	68	95	53	49	52	52	93	74	0
		min	40	10	65	19	40	34	86							
		max	96	81	99	100	99	99	100							
	1h1. South system imports unused potential diversion from North and Felton systems for in-lieu recharge; Felton system diverts without regard to water rights.	avg	62	25	86	43	73	63	94	53	49	57	55	93	76	23
		min	40	10	65	17	16	28	83							
		max	94	80	99	97	99	94	100							
	1h2. Scenario 1h1 except Felton system comples with water rights.	avg	62	25	86	43	83	73	95	53	49	54	53	93	75	0
		min	40	10	65	17	40	28	85							
		max	94	80	99	97	99	99	100							
	1i. North system imports Felton system unused potential diversions for in-lieu recharge; Felton system complies with water rights.	avg	63	26	86	51	83	69	95	62	59	48	50	95	74	0
		min	40	10	65	19	40	27	85							
		max	96	81	99	100	99	99	100							
	1j. Scenario 1i plus South system imports unused potential diversion from North and Felton systems.	avg	62	25	86	43	82	67	95	62	59	53	54	95	75	0
		min	40	10	65	17	40	27	85							
		max	94	80	99	97	99	99	100							
	1k. Scenario 1j except intertie capacities limited.	avg	63	25	86	43	82	68	95	60	57	53	54	94	75	0
		min	40	10	65	17	40	27	85							
		max	96	80	99	97	99	99	100							

Ck	creek
R	river
SLR	San Lorenzo River
SLRBT	San Lorenzo River at Big Trees

avg	average
min	minimum
max	maximum

[a] Calculated monthly as:
100 x {1 - [(diversions) ÷ (unimpaired flow)]}

[b] Calculated monthly as:
100 x [1 - [(diversions) ÷ (impaired flow + base case diversions)].

Only considers effects of SLVWD stream diversions.

[c] Calculated using method presented in Table 5-3.
Only considers effects of SLVWD, SVWD, and MHA groundwater pumping.

Color shading relative to compliance
with Felton system water rights:

🟨 Not compliant.

🟩 Compliant with Fall Creek required bypass flows.

🟦 Fully compliant with SLRBT low-flow diversion thresholds.

Table 6-6
Base Case and Scenario 1 Simulated Percent of Downstream Flow Remaining

Scenario		Simulated Intertie Use						Average Simulated Reduction in Pumping[b]			
		North System to South System		Felton System to South System		Felton System to North System		North System[c]		South System	
		Annual	Max. Rate[a]	Annual	Max. Rate[a]	Annual	Max. Rate[a]				
		afy	gpm	afy	gpm	afy	gpm	afm	%	afm	%
1f. South system imports North system unused potential diversions for in-lieu recharge; Felton system complies with water rights.	avg	115	337	0	0	0	0	0.0	0.0%	10	32%
	min	0									
	max	329									
1g1. South system imports Felton system unused potential diversions for in-lieu recharge; Felton system diverts without regard to water rights.	avg	0	0	281	292	0	0	0.3	0.6%	23	77%
	min			230							
	max			323							
1g2. Scenario 1g1 except Felton system complies with water rights.	avg	0	0	198	292	0	0	0.3	0.6%	17	54%
	min			23							
	max			311							
1g3. Scenario 1g1 except Felton system complies with required bypass flows only.	avg	0	0	252	292	0	0	0.3	0.6%	21	69%
	min			167							
	max			328							
1g4. Scenario 1g2 except intertie capacities limited.	avg	0	0	165	153	0	0	0.3	0.6%	14	45%
	min			23							
	max			226							
1h1. South system imports unused potential diversion from North and Felton systems for in-lieu recharge; Felton system diverts without regard to water rights.	avg	115	337	287	340	0	0	0.3	0.6%	24	79%
	min	0		230							
	max	329		362							
1h2. Scenario 1h1 except Felton system comples with water rights.	avg	115	337	89	241	0	0	0.3	0.6%	17	56%
	min	0		13							
	max	329		155							
1i. North system imports Felton system unused potential diversions for in-lieu recharge; Felton system complies with water rights.	avg	0	0	0	0	128	355	11	20%	0	0%
	min					23					
	max					266					
1j. Scenario 1i plus South system imports unused potential diversion from North and Felton systems.	avg	115	337	16	181	144	355	11	20%	11	36%
	min	0		0		23					
	max	329		73		340					
1k. Scenario 1j except intertie capacities limited.	avg	115	306	28	153	105	173	9	17%	12	39%
	min	0		0		23					
	max	328		84		176					

[a] Equivalent continuous rate for simulated maximum monthly rate.

[b] Compared to the base case; expressed in acre-feet per month for comparison to minimum monthly baseflows.

[c] Small reduction from imports needed to offset base-case unmet demand when well production insufficient.

Color shading relative to compliance with Felton system water rights:

🟨	Not compliant.
🟩	Compliant with Fall Creek required bypass flows.
🟦	Fully compliant with SLRBT low-flow diversion thresholds.

afm	acre-feet per month	avg	average
afy	acre-feet per year	min	minimum
gpm	gallons per minute	max	maximum

Table 6-7

Scenario 1 Simulated Use of System Interties and Resulting Reductions in Groundwater Pumping

Scenario	North System											Felton System										South System					Scotts Valley In-Lieu Recharge	Unused North & Felton System Diversions	SLVWD Total
		Stream Diversions											Stream Diversions																
	Demand	Potential[a]	Diverted	Unused Potential	Groundwater Wells[b]	Imports / ASR Extractions	Exports / Inject Unused Potential Diversions	Total System Use	Unmet Demand[c]	Total Diversions Including for Export	Unused Potential Diversions	Demand	Potential[a]	Diverted	Unused Potential	Imports	Exports / Inject Unused Potential Diversions	Total System Use	Unmet Demand[d]	Total Diversions Including for Export	Unused Potential Diversions	Demand	Pumped Groundwater	Imports	Exports	Total System Use			
	acre-feet per year (afy)																												
Base case--Synthesized historical record	1,545	1,192	904	289	638	0	0	1,541	4	904	289	430	852	430	422	0	0	430	0	430	422	365	365	0	0	365	0	711	2,336
Scenario 1 – Selected Results (from Table 6-4)																													
1a. Felton system complies with water rights.	1,545	1,192	904	289	638	0	0	1,541	4	904	289	430	685	378	307	0	0	378	51	378	307	365	365	0	0	365	0	596	2,285
1j. North system imports Felton system unused potential diversions for in-lieu recharge (Scenario 1i) plus South system imports unused potential diversion from North and Felton systems.	1,545	1,192	904	289	511	128	115	1,542	0	1,019	174	430	685	378	307	0	144	378	51	522	163	365	234	131	0	365	0	337	2,286
Scenario 2 – Import from Loch Lomond																													
2a. North and Felton systems import from Loch Lomond to satisfy unmet demand in Scenario 1a.	1,545	1,192	904	289	638	4	0	1,545	0	904	289	430	685	378	307	51	0	430	0	378	307	365	365	0	0	365	0	596	2,340
2b. Scenario 2a plus South system imports from Loch Lomond for in-lieu recharge.	1,545	1,192	904	289	638	4	0	1,545	0	904	289	430	685	378	307	51	0	430	0	378	307	365	119	246	0	365	0	596	2,340
2c. Scenario 2b plus South system also imports North system unused diversions, and North system imports unused Felton system diversions.	1,545	1,192	904	289	510	132	21	1,545	0	925	268	430	685	378	307	51	128	430	0	506	179	365	98	267	0	365	0	447	2,340
Scenario 3 – Import from Loch Lomond and Operate Olympia Aquifer Storage and Recovery																													
3a. Scenario 2b plus North system operates Olympia area ASR using North system unused diversions.	1,545	1,192	904	99	448	194	190	1,545	0	1,093	99	430	685	378	307	51	0	430	0	378	307	365	116	249	0	365	0	406	2,340
3b. Scenario 2b plus North system operates Olympia area ASR using Felton system unused diversions.	1,545	1,192	904	289	422	220	0	1,545	0	904	289	430	685	378	85	51	222	430	0	600	85	365	116	249	0	365	0	374	2,340
3c. Scenarios 3a and 3b combined.	1,545	1,192	904	99	229	412	190	1,545	0	1,093	99	430	685	378	85	51	222	430	0	600	85	365	116	249	0	365	0	185	2,340
Scenario 4 – Contribute to Scotts Valley In-Lieu Recharge while Operating Olympia ASR and Importing from Loch Lomond																													
4. Scenario 3c plus SVWD imports North and Felton system remaining unused potential diversions.	1,545	1,192	904	99	229	412	190	1,545	0	1,093	9	430	685	378	85	51	222	430	0	600	8	365	116	249	0	365	167	17	2,340

All scenarios assume estimated 2045 demand and repeat of WY1970-2017 climatic cycle
Felton system diversions as currently permitted, all scenarios.
See Table 6-2 for overall summary of scenario alternative assumptions.
See Table 6-3 for assumed diversion, conveyance, and treatment capacities.
See Table 6-7 for more detailed results.

[a] Within diversion capacity and water rights
[b] Does not include ASR extractions.
[c] Unmet North system demand results from assumed limits on groundwater production.
[d] Unmet Felton system demand results from water rights compliance.

Table 6-8
Summary of Simulated Scenario 2, 3, and 4 Conjunctive Use Alternatives, Annual Averages, WYs 1970–2017

Scenario[a]		North System																					Felton System																South System					Unused N Sys & Felton divs	**Scotts Valley In-Lieu Re-charge**	**SLVWD Total**
		Demand	Stream Diversions										Groundwater Wells			Import/ ASR Extract	Export/ Inject Unused Pot. Div.	Total System Use	Un-met Demand[c]	Total Diversions Including for Export	Unused Potential Diversions	Demand	Stream Diversions									Import/ ASR Extract	Export/ Inject Unused Pot. Div.	Total System Use	Un-met Demand[d]	Total Diversions Including for Export	Unused Potential Diversions	Demand	Pumped Groundwater	Import	Export	Total System Use			
			Peavine Creek		Foreman Creek		Unused Potential	Clear & Sweetwater			Total			Quail Hollow	Olympia	Total								Fall & Bennett Cks			Bull Creek			Total															
			Potential[b]	Diverted	Potential[b]	Diverted		Potential[b]	Diverted	Unused Potential	Potential[b]	Diverted	Unused Potential											Potential[b]	Diverted	Unused Potential	Potential[b]	Diverted	Unused Potential	Potential[b]	Diverted	Unused Potential														
		acre-feet per year (afy)																																												
Base Case Simulated historical record (calibrated to WYs 2000-2017)	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	259	378	638	0	0	1,541	4	904	289	430	705	340	366	147	90	57	852	430	422	0	**0**	430	0	430	422	365	365	0	0	365	711	0	2,336
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	0	0	1,235	0	429	0	335	695	266	292	68	49	15	762	335	316	0	0	335	0	335	316	297	297	0	0	297	333	0	1,878
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	0	0	1,776	65	1,231	836	492	710	409	436	225	120	124	926	492	560	0	0	492	0	492	560	441	441	0	0	441	1,354	0	2,642
Scenario 1 – Selected Results (from Table 6-6)																																														
1a. Felton system complies with water rights.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	259	378	638	0	0	1,541	4	904	289	430	547	338	208	139	40	99	685	378	307	0	0	378	51	378	307	365	365	0	0	365	596	0	2,285
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	0	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	23	0	0	186	0	186	23	297	297	0	0	297	23	0	1,757
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	0	0	1,776	65	1,231	836	492	678	408	348	222	50	186	900	455	534	0	0	455	187	455	534	441	441	0	0	441	1,328	0	2,636
1j. North system imports Felton system unused potential diversions for in-lieu recharge (Scenario 1i) plus South system imports unused potential diversion from North and Felton systems.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	209	302	**511**	**128**	**115**	1,542	0	1,019	174	430	547	338	208	139	40	99	685	378	307	0	144	378	51	522	163	365	234	131	0	365	337	0	2,286
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	39	52	91	23	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	23	0	23	186	0	237	0	297	13	0	0	297	0	0	1,757
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	416	598	1,014	266	329	1,776	0	1,559	507	492	678	408	348	222	50	186	900	455	534	0	340	455	187	677	308	441	382	402	0	441	815	0	2,636
Scenario 2 – Import from Loch Lomond																																														
2a. North and Felton systems import from Loch Lomond to satisfy unmet demand in Scenario 1a.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	259	378	638	4	0	1,545	0	904	289	430	547	338	208	139	40	99	685	378	307	51	0	430	0	378	307	365	365	0	0	365	596	0	2,340
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	0	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	23	0	0	335	0	186	23	297	297	0	0	297	23	0	1,878
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	65	0	1,776	0	1,231	836	492	678	408	348	222	50	186	900	455	534	187	0	492	0	455	534	441	441	0	0	441	1,328	0	2,642
2b. Scenario 2a plus South system imports from Loch Lomond for in-lieu recharge.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	259	378	638	4	0	1,545	0	904	289	430	547	338	208	139	40	99	685	378	307	51	0	430	0	378	307	365	119	246	0	365	596	0	2,340
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	0	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	23	0	0	335	0	186	23	297	50	121	0	297	23	0	1,878
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	65	0	1,776	0	1,231	836	492	678	408	348	222	50	186	900	455	534	187	0	492	0	455	534	441	225	292	0	441	1,328	0	2,642
2c. Scenario 2b plus South system also imports North system unused diversions, and North system imports unused Felton system diversions.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	208	302	510	132	21	1,545	0	925	268	430	547	338	208	139	40	99	685	378	307	51	128	430	0	506	179	365	98	267	0	365	447	0	2,340
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	113	162	275	23	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	23	0	23	335	0	237	0	297	0	121	0	297	0	0	1,878
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	425	612	1,038	331	73	1,776	0	1,303	775	492	678	408	348	222	50	186	900	455	534	187	266	492	0	677	308	441	217	365	0	441	1,082	0	2,642
Scenario 3 – Import from Loch Lomond and Operate Olympia Aquifer Storage and Recovery																																														
3a. Scenario 2b plus North system operates Olympia area ASR using North system unused diversions.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	99	183	264	448	194	190	1,545	0	1,093	99	430	547	338	208	139	40	99	685	378	307	51	**0**	430	0	378	307	365	116	249	0	365	406	0	2,340
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	51	74	125	150	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	23	0	0	335	0	186	23	297	50	126	0	297	23	0	1,878
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	515	343	493	836	202	322	1,776	0	1,552	515	492	678	408	348	222	50	186	900	455	534	187	0	492	0	455	534	441	225	292	0	441	1,006	0	2,642
3b. Scenario 2b plus North system operates Olympia area ASR using Felton system unused diversions.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	289	173	249	422	220	0	1,545	0	904	289	430	547	338	208	139	40	99	685	378	85	51	**222**	430	0	600	85	365	116	249	0	365	374	0	2,340
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	44	63	107	169	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	19	0	0	335	0	186	19	297	50	126	0	297	23	0	1,878
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	836	331	476	807	230	0	1,776	0	1,231	836	492	678	408	348	222	50	186	900	455	222	187	312	492	0	731	222	441	225	292	0	441	1,029	0	2,642
3c. Scenarios 3a and 3b combined.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	99	94	135	229	412	190	1,545	0	1,093	99	430	547	338	208	139	40	99	685	378	85	51	**222**	430	0	600	85	365	116	249	0	365	185	0	2,340
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	13	18	31	241	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	19	0	0	335	0	186	19	297	50	126	0	297	19	0	1,878
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	515	231	333	565	473	322	1,776	0	1,552	515	492	678	408	348	222	50	186	900	455	222	187	312	492	0	731	222	441	225	292	0	441	708	0	2,642
Scenario 4 – Contribute to Scotts Valley In-Lieu Recharge while Operating Olympia ASR and Importing from Loch Lomond																																														
4. Scenario 3c plus SVWD imports North and Felton system remaining unused potential diversions.	avg	1,545	141	112	543	528	44	509	264	245	1,192	904	99	94	135	229	412	190	1,545	0	1,093	9	430	547	338	208	139	40	99	685	378	85	51	222	430	0	600	8	365	116	249	0	365	17	167	2,340
	min	1,235	35	35	197	197	0	197	139	0	429	429	0	13	18	31	241	0	1,235	0	429	0	335	209	158	23	29	28	0	237	186	19	0	0	335	0	186	0	297	50	126	0	297	0	19	1,878
	max	1,776	257	154	1,008	937	174	802	325	663	2,067	1,231	515	231	333	565	473	322	1,776	0	1,552	145	492	678	408	348	222	50	186	900	455	222	187	312	492	0	731	62	441	225	292	0	441	207	500	2,642

All scenarios assume estimated 2045 demand and repeat of WY1970-2017 climatic cycle.
Felton system diversions as currently permitted, all scenarios.
See Table 6-1 for overall summary of scenario alternative assumptions.
See Table 6-2 for assumed diversion, conveyance, and treatment capacities.

[a] Scenarios 2abc, 3abc, and 4 Felton system complies with water rights.
[b] Within diversion capacity and water rights.
[c] Unmet North system demand results from assumed limits on groundwater production.
[d] Unmet Felton system demand results from water rights compliance.

afy acre-feet per year
avg average
min minimum
max maximum

Table 6-9

Results of Scenario 2, 3, and 4 Conjunctive Use Simulations, WYs 1970–2017

Scenario		Intertie Use (excluding for Loch Lomond)								Use of Loch Lomond Allotment										ASR of Unused Diversions				Average Reduction in Pumping[b]			
		North System to South System		Felton System to South System		Felton System to North System		SLVWD to SVWD		Export to:								SLVWD Allotment Remaining at End of WY (313 afy total)									
										North System		Felton System		South System						Injection		Extraction		North System[c]		South System	
		Annual	Max. Rate[a]	Annual	Max. Rate[a]	Annual	Max. Rate[a]	Annual	Max. Rate[a]	Annual	Max. Rate[a]	Annual	Max. Rate[a]	Annual	Max. Rate[a]	Total	Max. Rate[a]			Capa-city	Dec-May	Capa-city	Jun-Nov				
		afy	gpm	afy	gpm	afy	gpm	afy	gpm	afy	gpm	afy	gpm	afy	gpm	afy	gpm	af	%	gpm	afy	gpm	afy	afm	%	afm	%
Scenario 2 – Import from Loch Lomond																											
2a. North and Felton systems import from Loch Lomond to satisfy unmet demand in Scenario 1a.	avg	0	0	0	0	0	0	0	0	4	217	51	311	0	0	55	311	262	84%	-	-	-	-	0.3	0.6%	0	0%
	min									0		0		0	0	0		126	40%	-	-	-	-				
	max									65		187		0	0	192		313	100%	-	-	-	-				
2b. Scenario 2a plus South system imports from Loch Lomond for in-lieu recharge.	avg	0	0	0	0	0	0	0	0	4	217	51	311	246	194	301	311	12	4%	-	-	-	-	0.3	0.6%	20	67%
	min									0		0		121		274		0	0%	-	-	-	-				
	max									65		187		292		313		39	13%	-	-	-	-				
2c. Scenario 2b plus South system also imports North system unused diversions, and North system imports unused Felton system diversions.	avg	21	153	0	0	128	355	0	0	4	217	51	311	246	194	301	434	12	4%	-	-	-	-	11	21%	22	73%
	min	0		0		23				0		0		121		274		0	0%	-	-	-	-				
	max	73		0		266				65		187		292		313		39	13%	-	-	-	-				
Scenario 3 – Import from Loch Lomond and Operate Olympia Aquifer Storage and Recovery																											
3a. Scenario 2b plus North system operates Olympia area ASR using North system unused diversions.	avg	0	0	0	0	0	0	0	0	0	0	51	311	249	194	301	434	12	4%	400	190	250	194	16	30%	21	68%
	min									0		0		126		274		0	0%		0		150				
	max									0		187		292		313		39	13%		322		202				
3b. Scenario 2b plus North system operates Olympia area ASR using Felton system unused diversions.	avg	0	0	0	0	222	285	0	0	0	0	51	311	249	194	301	434	12	4%	400	222	285	220	18	34%	21	68%
	min					0						0		126		274		0	0%		0		169				
	max					312						187		292		313		39	13%		312		230				
3c. Scenarios 3a and 3b combined.	avg	0	0	0	0	222	285	0	0	0	0	51	311	249	194	301	434	12	4%	400	411	585	412	34	64%	21	68%
	min					0						0		126		274		0	0%		0		241				
	max					312						187		292		313		39	13%		634		473				
Scenario 4 – Contribute to Scotts Valley In-Lieu Recharge while Operating Olympia ASR and Importing from Loch Lomond																											
4. Scenario 3c plus SVWD imports North and Felton system remaining unused potential diversions.	avg	0	0	0	0	222	285	167	350	0	0	51	311	249	194	301	434	12	4%	400	411	585	412	34	64%	21	68%
	min					0		19				0		126		274		0	0%		0		241				
	max					312		500				187		292		313		39	13%		634		473				

[a] Equivalent continuous rate for simulated maximum monthly rate.

[b] Expressed in acre-feet per month for comparison to minimum monthly baseflows.

[c] Small reduction from imports needed to offset base-case unmet demand when well production insufficient.

afm	acre-feet per month
afy	acre-feet per year
gpm	gallons per minute

avg	average
min	minimum
max	maximum

Table 6-10

Scenarios 2, 3, and 4 Simulated Use of System Interties, Loch Lomond, and Olympia ASR and Resulting Reductions in Groundwater Pumping

Scenario			Percent of Monthly Flow Remaining Downstream of Diversion							Percent of Drought Minimum Baseflow Remaining as a Result of Groundwater Pumping[c]						Percent of Months Felton Non-compliant
			Peavine Creek[a]	Fore-man Creek[a]	Boulder Creek[b]	Clear & Sweet-water Creeks[a]	Fall & Bennett Creeks[a]	Bull Creek[a]	San Lorenzo R at Big Trees[b]	Newell Creek at SLR	Zayante Ck above Bean Ck	Bean Ck at Zayante Ck	Zayante Ck at SLR	San Lorenzo R above Fall Ck	San Lorenzo R at Big Trees	
Base Case	Simulated historical record (calibrated to WYs 2000-2017)	avg	63	26	88	51	83	64	96	53	49	47	47	93	72	23
		min	40	10	72	19	32	32	89							
		max	96	81	99	100	99	94	100							
		P_{10}	46	13	81	23	56	41	92							
Scenario 2 – Import from Loch Lomond	**2a.** North and Felton systems import from Loch Lomond to satisfy unmet demand in Scenario 1a.	avg	63	26	86	51	86	82	96	53	49	47	47	93	72	0
		min	40	10	65	19	42	53	87							
		max	96	81	99	100	99	99	100							
	2b. Scenario 2a plus South system imports from Loch Lomond for in-lieu recharge.	avg	63	26	86	51	86	82	96	53	49	55	54	93	75	0
		min	40	10	65	19	42	53	87							
		max	96	81	99	100	99	99	100							
	2c. Scenario 2b plus South system also imports North system unused diversions, and North system imports unused Felton system diversions.	avg	63	26	86	49	83	69	95	62	59	58	58	95	78	0
		min	40	10	65	18	40	27	85							
		max	96	81	99	100	99	99	100							
Scenario 3 – Import from Loch Lomond Plus Operate Olympia Aquifer Storage and Recovery	**3a.** Scenario 2b plus North system operates Olympia area ASR using North system unused diversions.	avg	61	25	86	42	86	82	95	66	64	58	59	95	78	0
		min	40	10	65	19	42	53	87							
		max	92	79	99	99	99	99	100							
	3b. Scenario 2b plus North system operates Olympia area ASR using Felton system unused diversions.	avg	63	26	86	51	84	67	95	68	66	58	59	96	79	0
		min	40	10	65	19	42	33	87							
		max	96	81	99	100	99	99	100							
	3c. Scenarios 3a and 3b combined.	avg	61	25	86	42	84	67	95	83	82	61	64	98	81	0
		min	40	10	65	19	42	33	87							
		max	92	79	99	99	99	99	100							
Scenario 4 – Valley In-Lieu Recharge	**4.** Scenario 3c plus SVWD imports North and Felton system remaining unused potential diversions.	avg	61	25	86	42	84	67	95	83	82	61	64	98	81	0
		min	40	10	65	19	42	33	87							
		max	92	79	99	99	99	99	100							

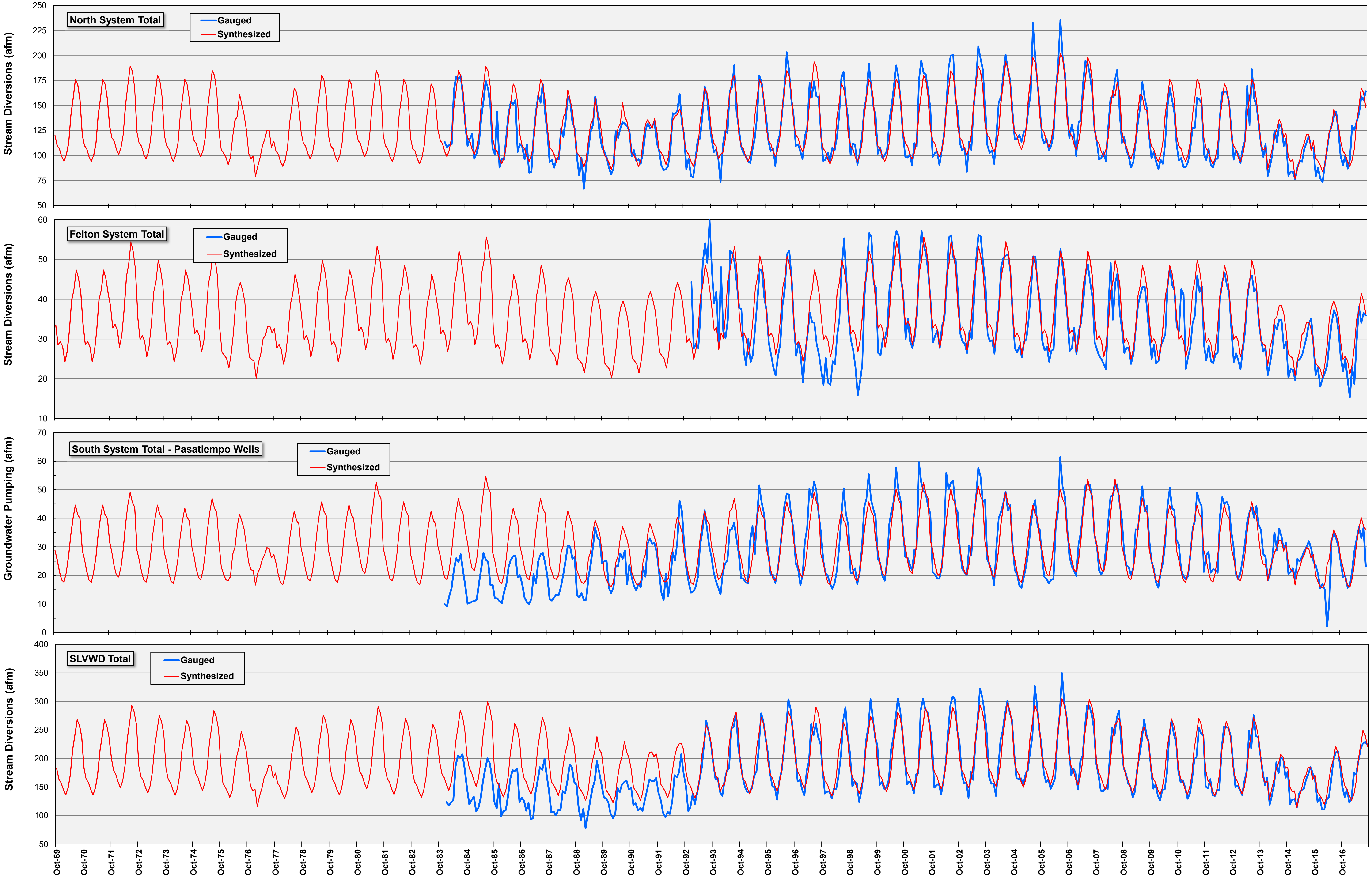
Ck	creek
R	river
SLR	San Lorenzo River
avg	average
min	minimum
max	maximum

[a] Calculated monthly as: 100 x {1 - [(diversions) ÷ (unimpaired flow)]}

[b] Calculated monthly as: 100 x [1 - [(diversions) ÷ (impaired flow + base case diversions)]. Only considers effects of SLVWD stream diversions.

[c] Calculated using method presented in Table 5-3. Only considers effects of SLVWD, SVWD, and MHA groundwater pumping.

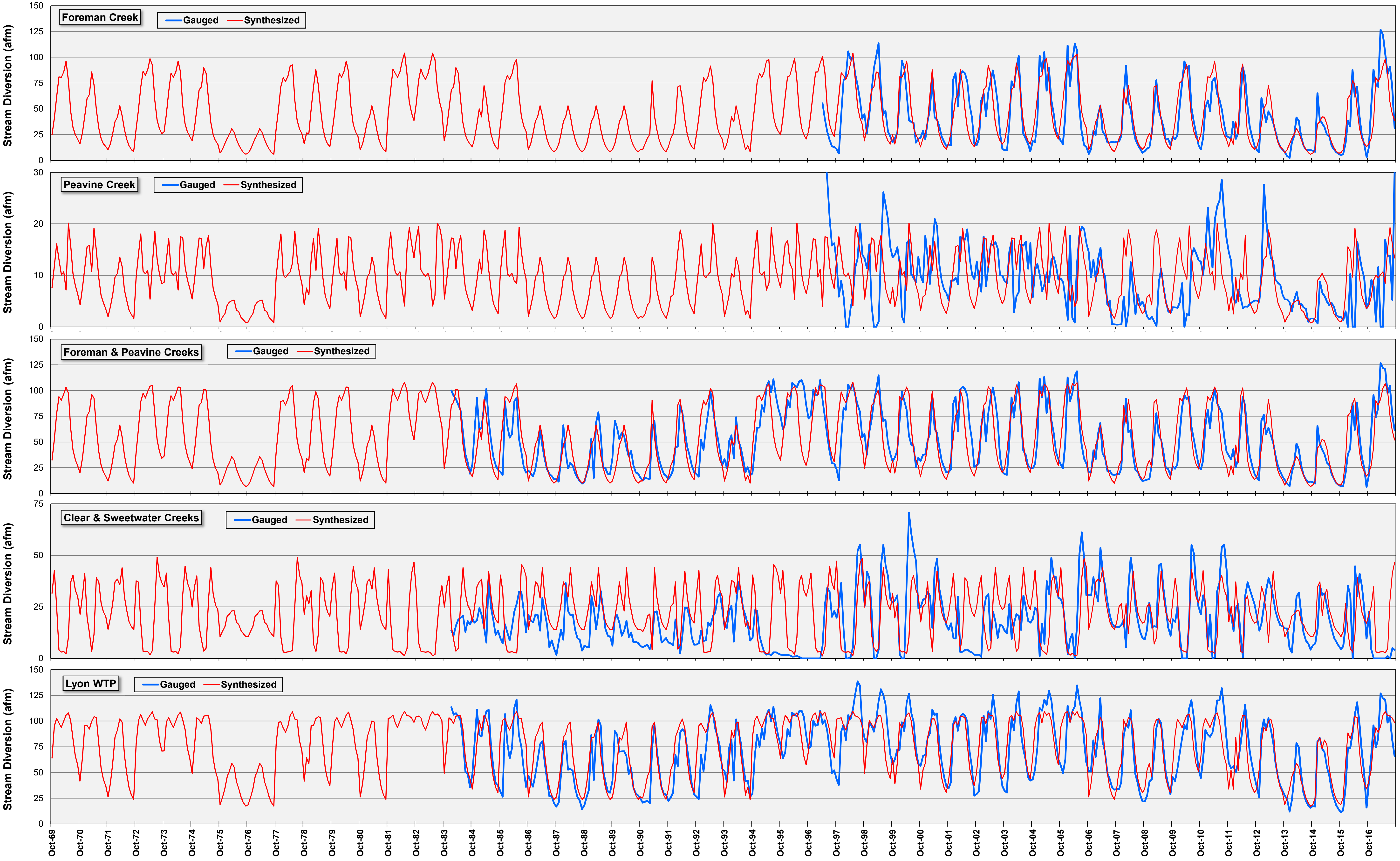
Table 6-11
Scenarios 2, 3, and 4 Simulated Percent of Downstream Flow Remaining



Note differences in vertical axis scaling.
See Table 1-1 for source of gauged records.

afm acre-feet per month

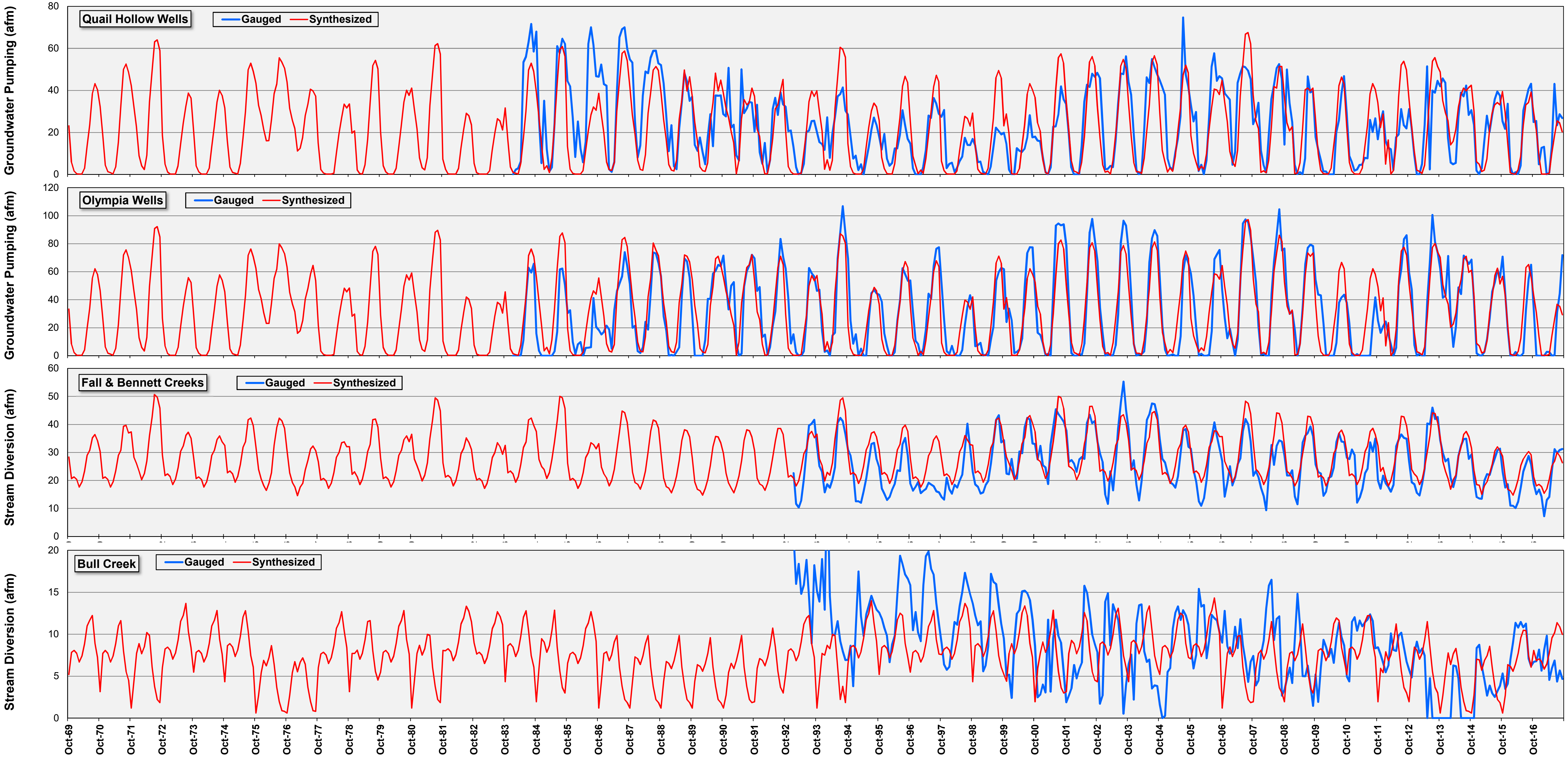
Figure 6-1
Base Case: Historical versus Simulated North, South, and Felton System Monthly Water Production Hydrographs
Assuming WY 1970–2017 Climatic Cycle, Currently Permitted Infrastructure, and Projected 2045 Demand



Note differences in vertical axis scaling.
See Table 1-1 for source of gauged records.

afm acre-feet per month

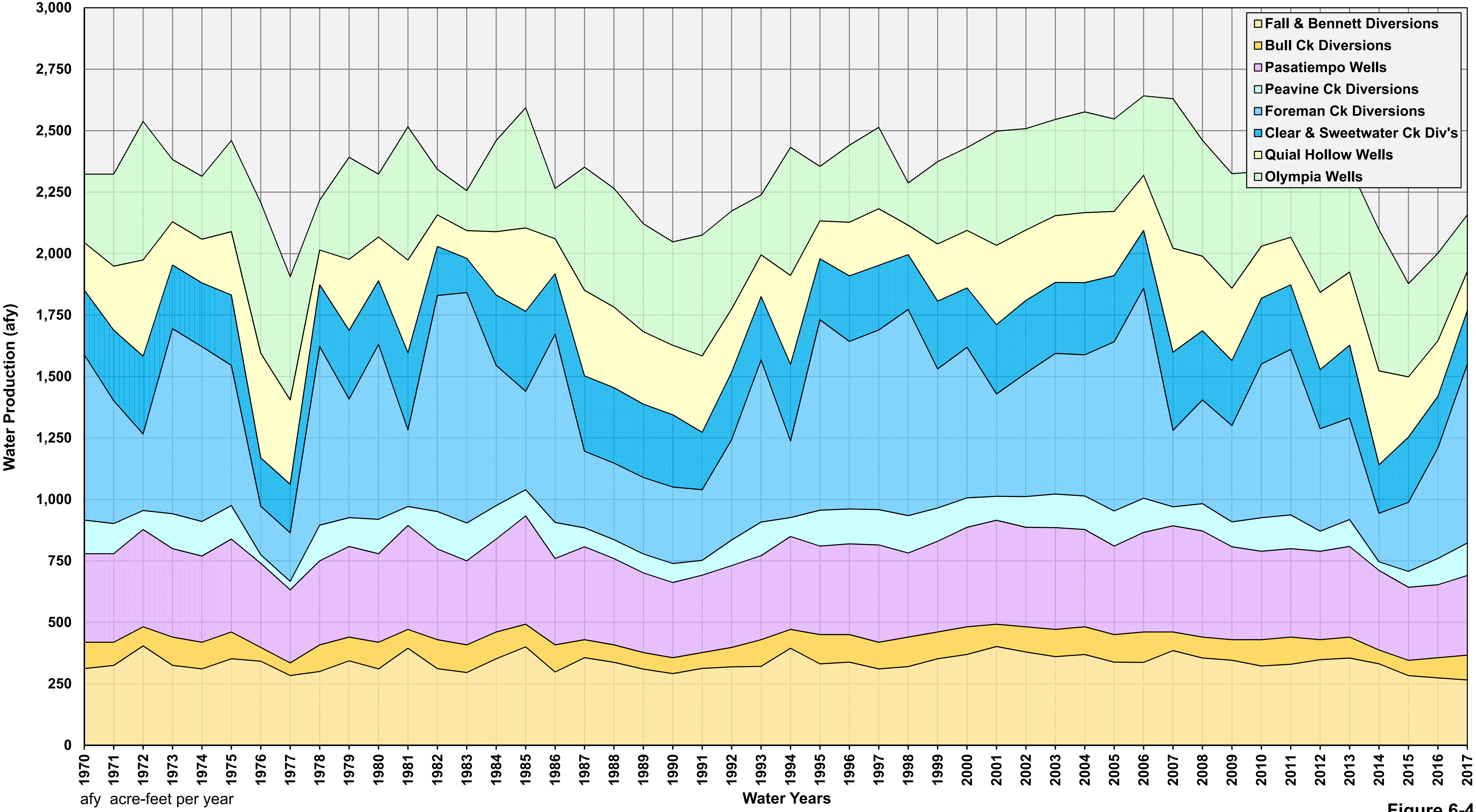
Figure 6-2
Base Case: Historical versus Simulated North System Monthly Surface Water Production Hydrographs
Assuming WY 1970–2017 Climatic Cycle, Currently Permitted Infrastructure, and Projected 2045 Demand



Note differences in vertical axis scaling.
See Table 1-1 for source of gauged records.

afm acre-feet per month

Figure 6-3
Base Case: Historical versus Simulated Monthly North System Groundwater and Felton System Surface Water Production Hydrographs
Assuming WY 1970–2017 Climatic Cycle, Currently Permitted Infrastructure, and Projected 2045 Demand

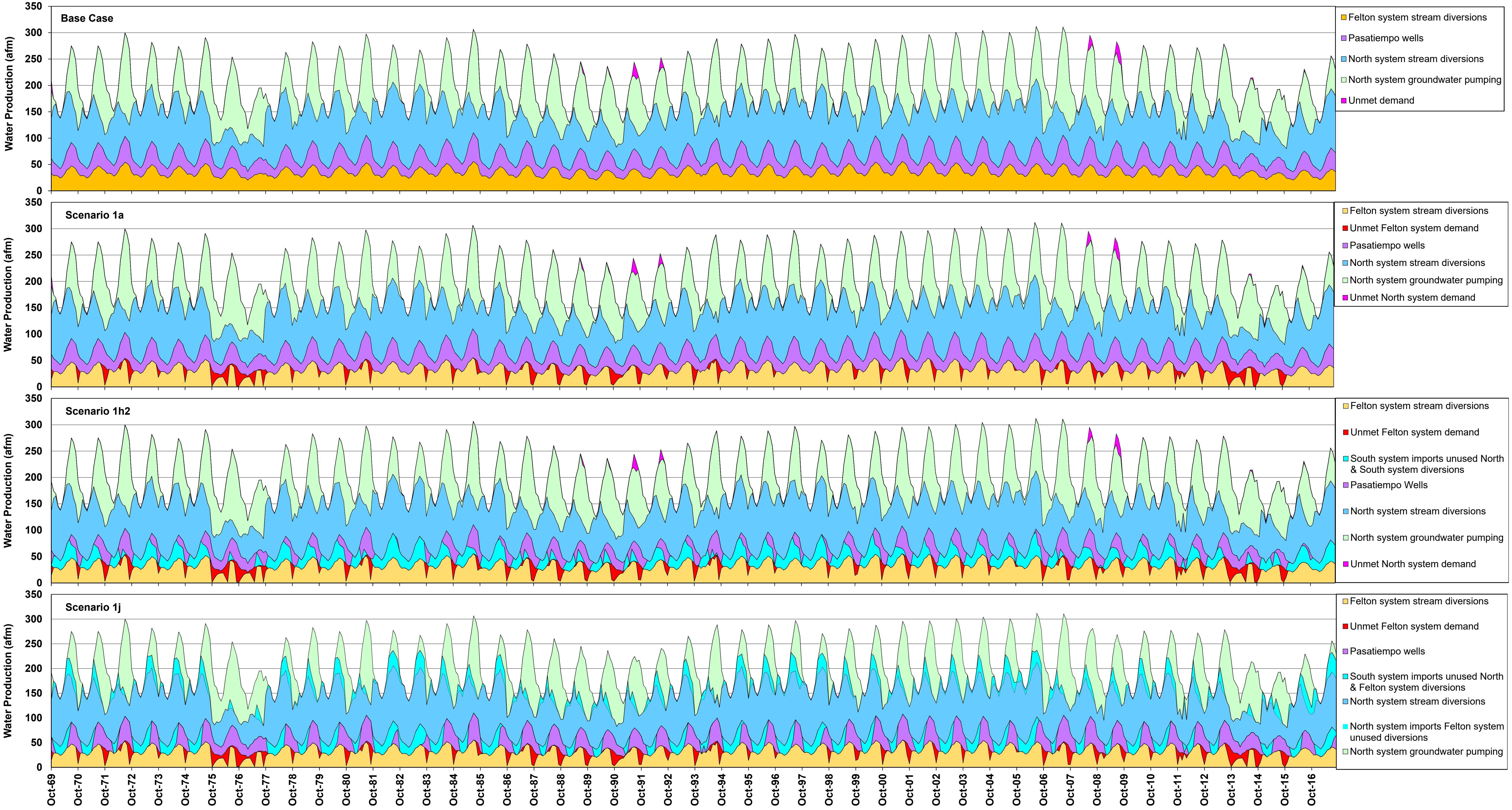


afy acre-feet per year

Source: Table 6-4; annual values derived from simulated monthly record.

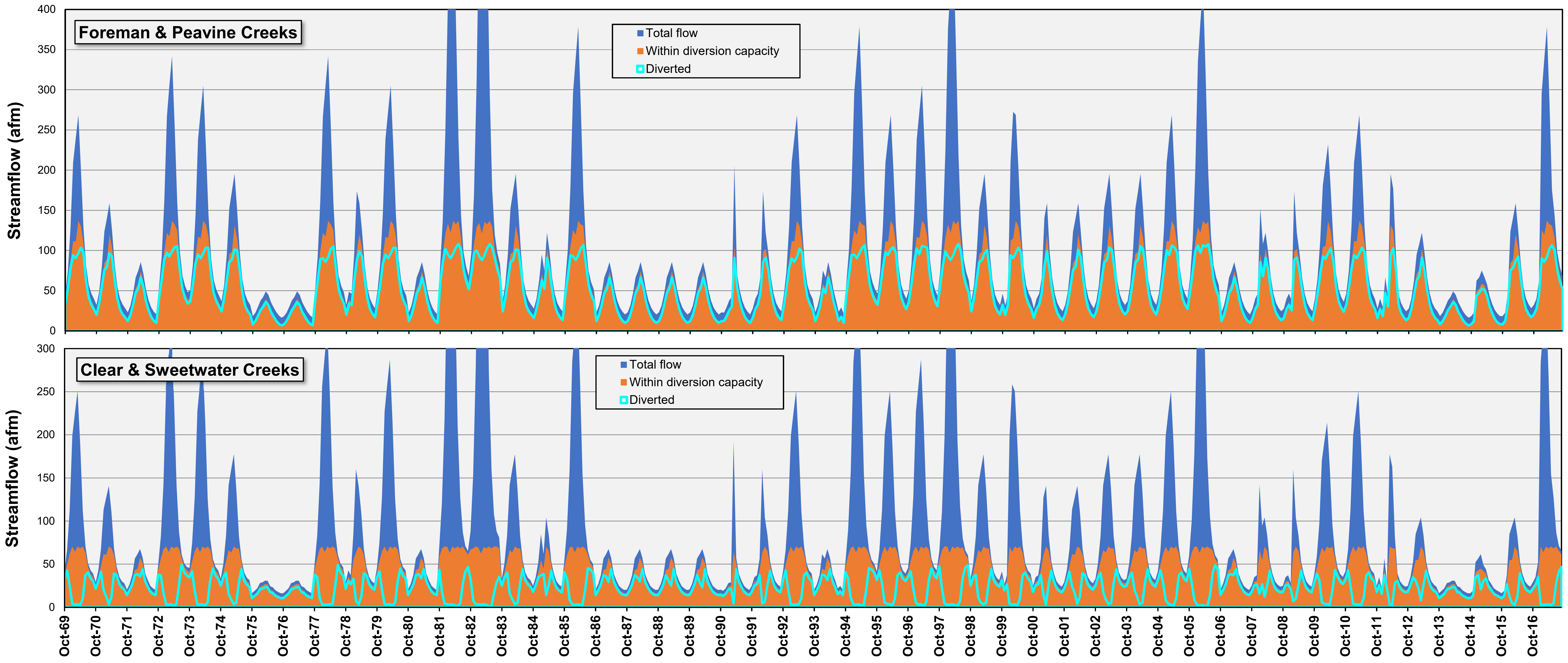
Figure 6-4

Base Case: Simulated SLVWD Annual Production Assuming WY 1970–2017 Climatic Cycle, Currently Permitted Infrastructure, and Projected 2045 Demand



afm acre-feet per month

Figure 6-5
Monthly Results for Base Case and Scenarios 1a, 1h2, and 1j, WYs 1970–2017

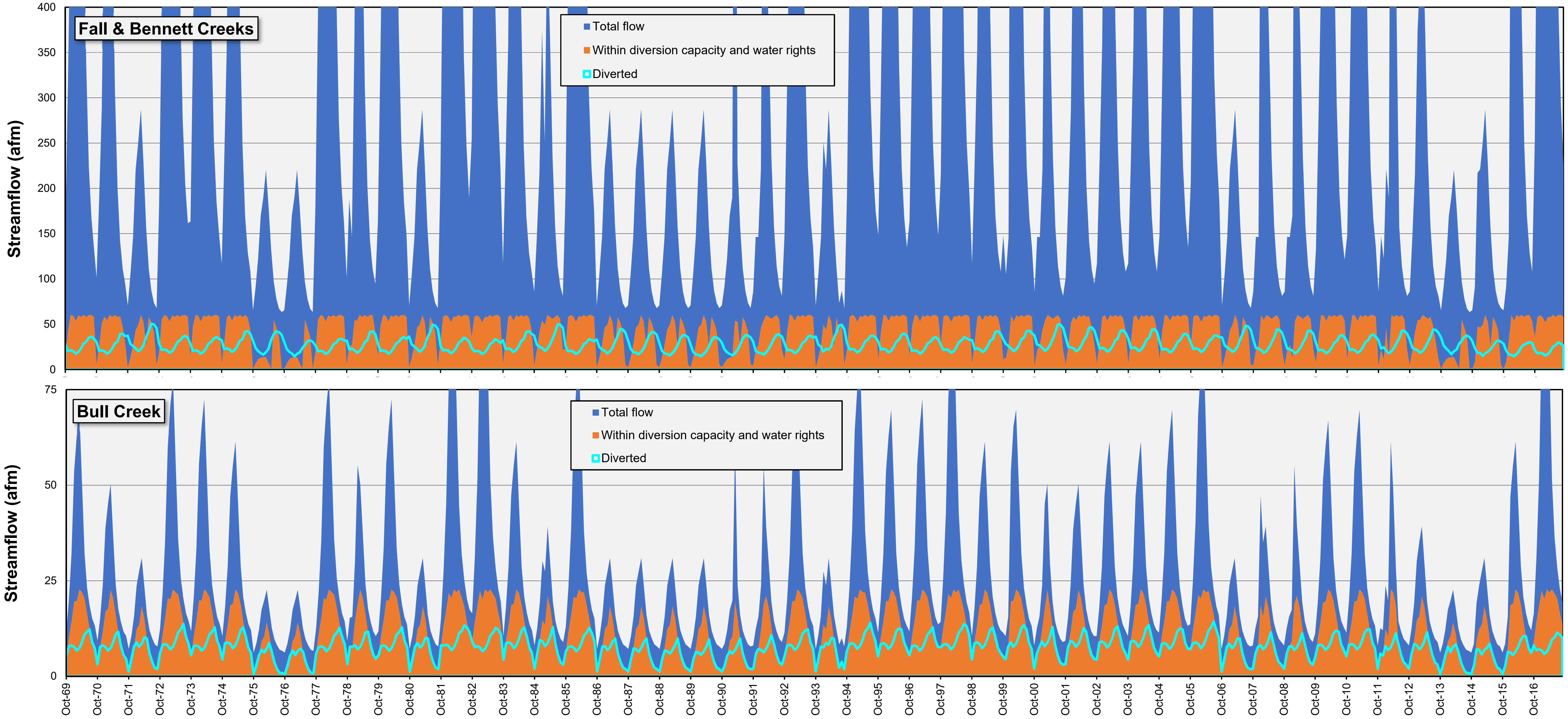


Note differences in vertical axis scaling.

afm acre-feet per month

Figure 6-6

Base Case: Hydrographs of North System Simulated Streamflow and Diversions Assuming WY 1970–2017 Climatic Cycle, Currently Permitted Infrastructure, and Projected 2045 Demand

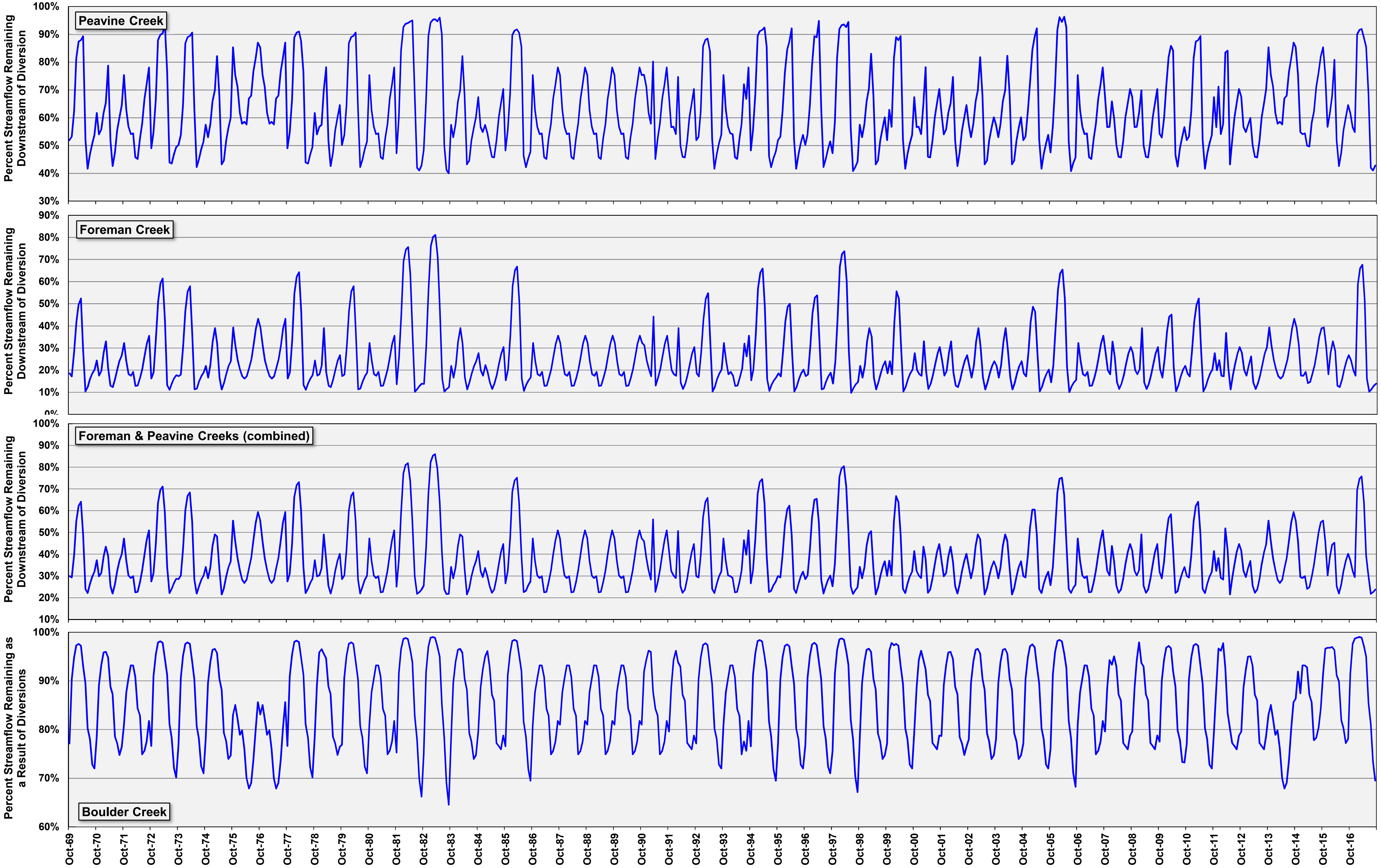


Note differences in vertical axis scaling.

afm acre-feet per month

Figure 6-7

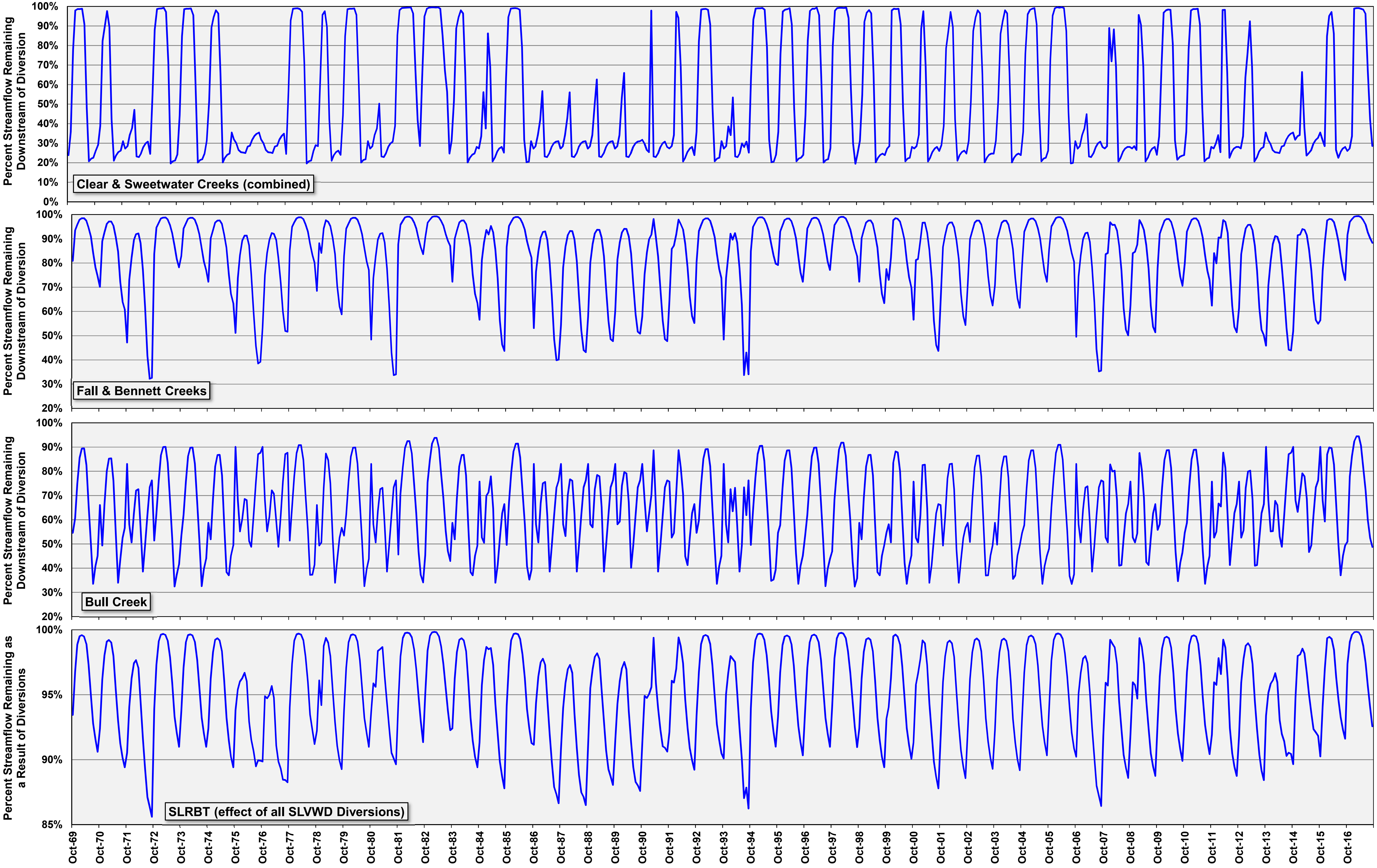
Base Case: Hydrographs of Felton System Simulated Streamflow and Diversions Assuming WY 1970–2017 Climatic Cycle, Current Infrastructure and Usage, and Projected 2045 Demand



Note differences in vertical axis scaling.

Figure 6-8

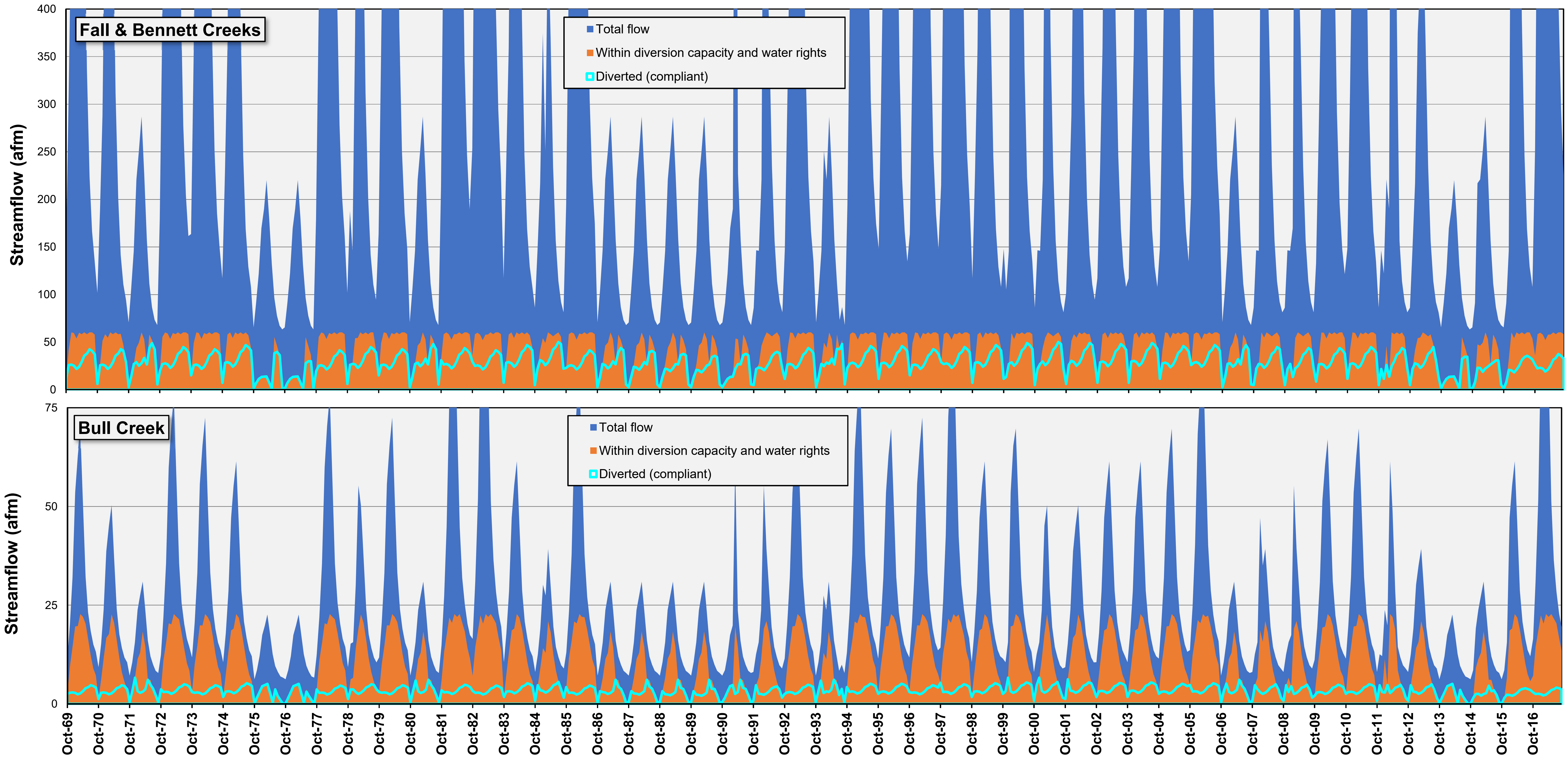
Base Case: Percent of Simulated Monthly Flow Remaining Downstream of North System Foreman and Peavine Creek Diversions Assuming WY 1970–2017 Climatic Cycle, Currently Permitted Infrastructure, and Projected 2045 Demand



Note differences in vertical axis scaling.

Figure 6-9

Base Case: Percent of Simulated Monthly Flow Remaining Downstream of North System Clear and Sweetwater Creek and Felton System Fall, Bennett, and Bull Creek Diversions Assuming WY 1970–2017 Climatic Cycle, Current Infrastructure and Usage, and Projected 2045 Demand

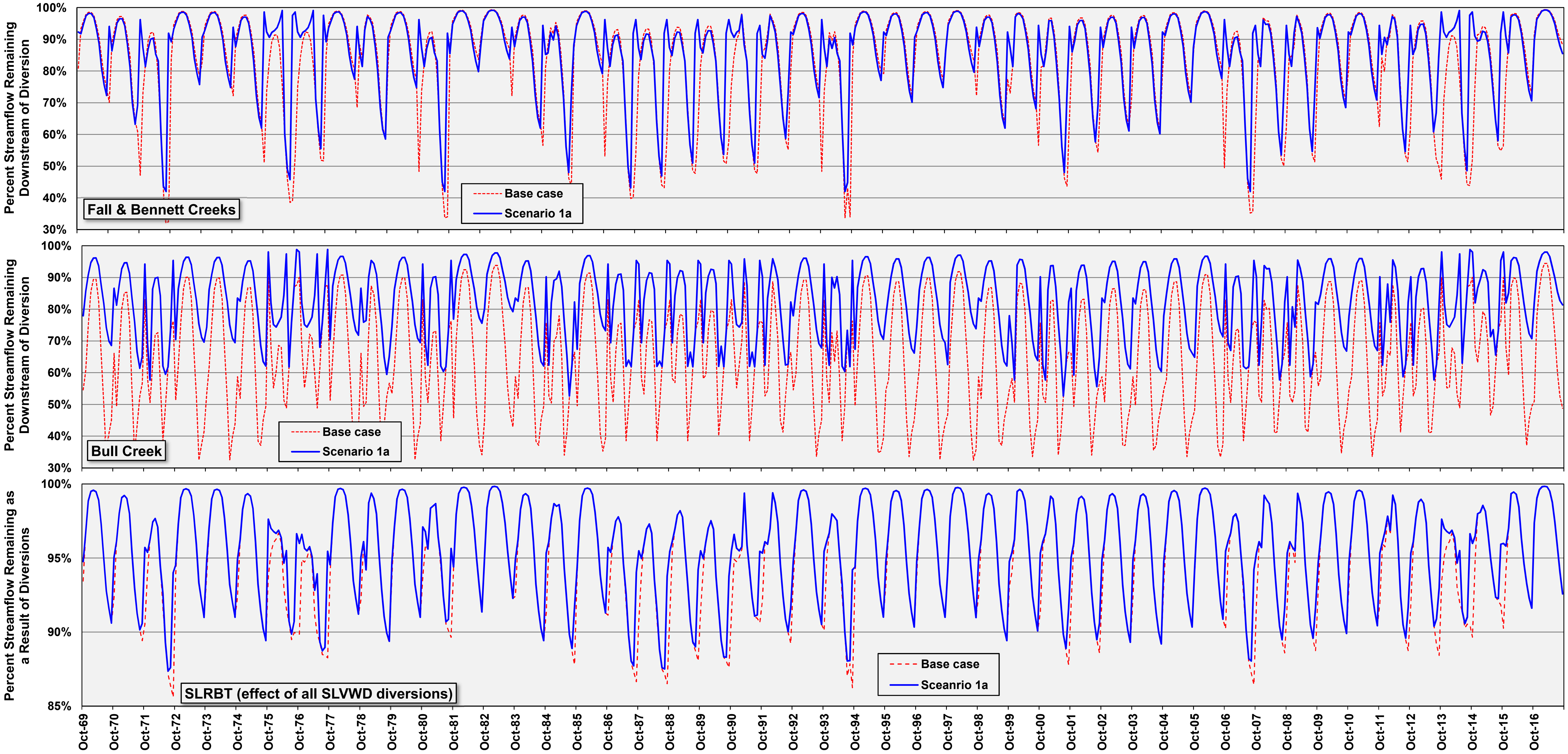


Note differences in vertical axis scaling.

afm acre-feet per month

Figure 6-10

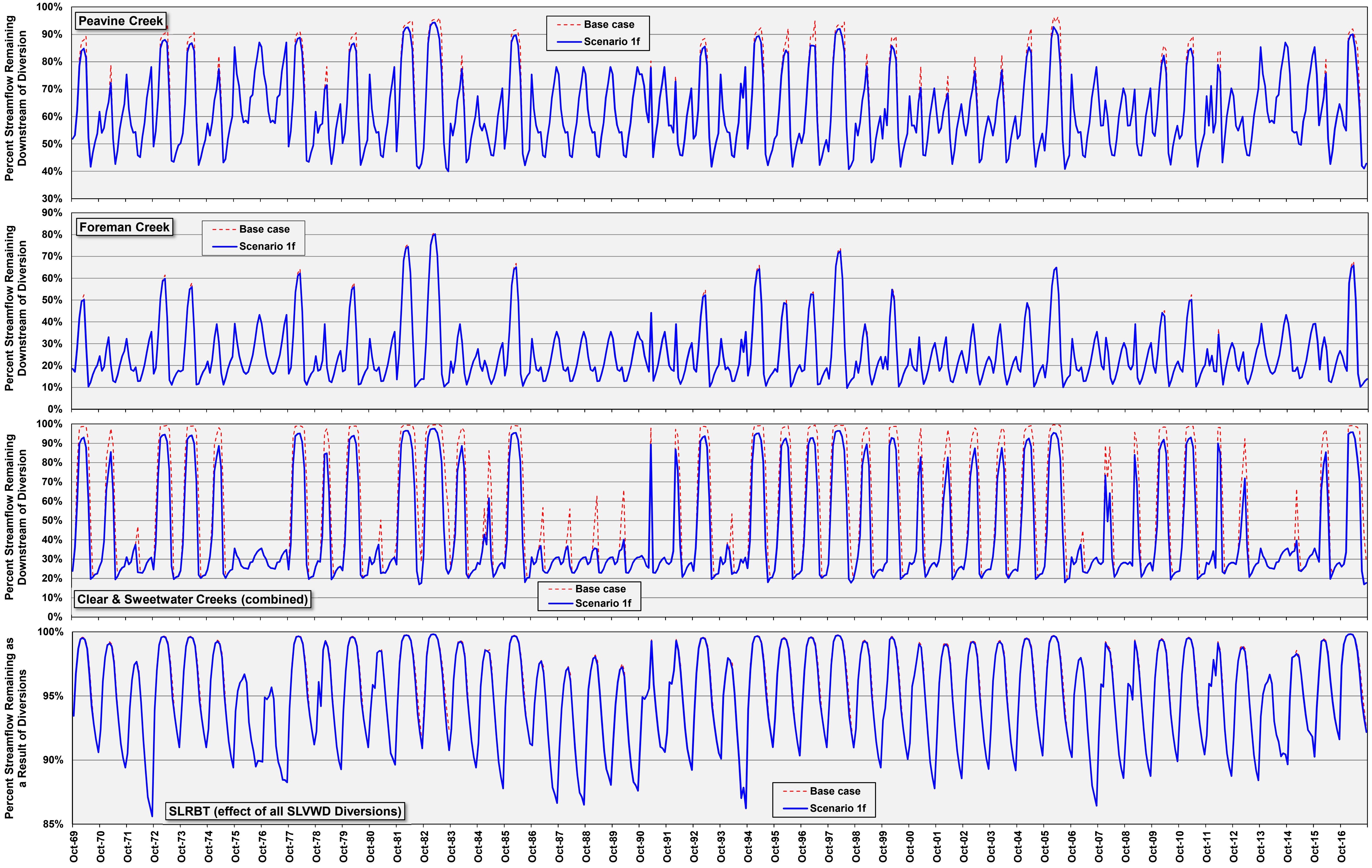
Scenario 1a: Hydrographs of Felton System Simulated Streamflow and Diversions Assuming WY 1970–2017 Climatic Cycle, Current Infrastructure, Permitted Use, and Projected 2045 Demand



Note differences in vertical axis scaling.

Figure 6-11

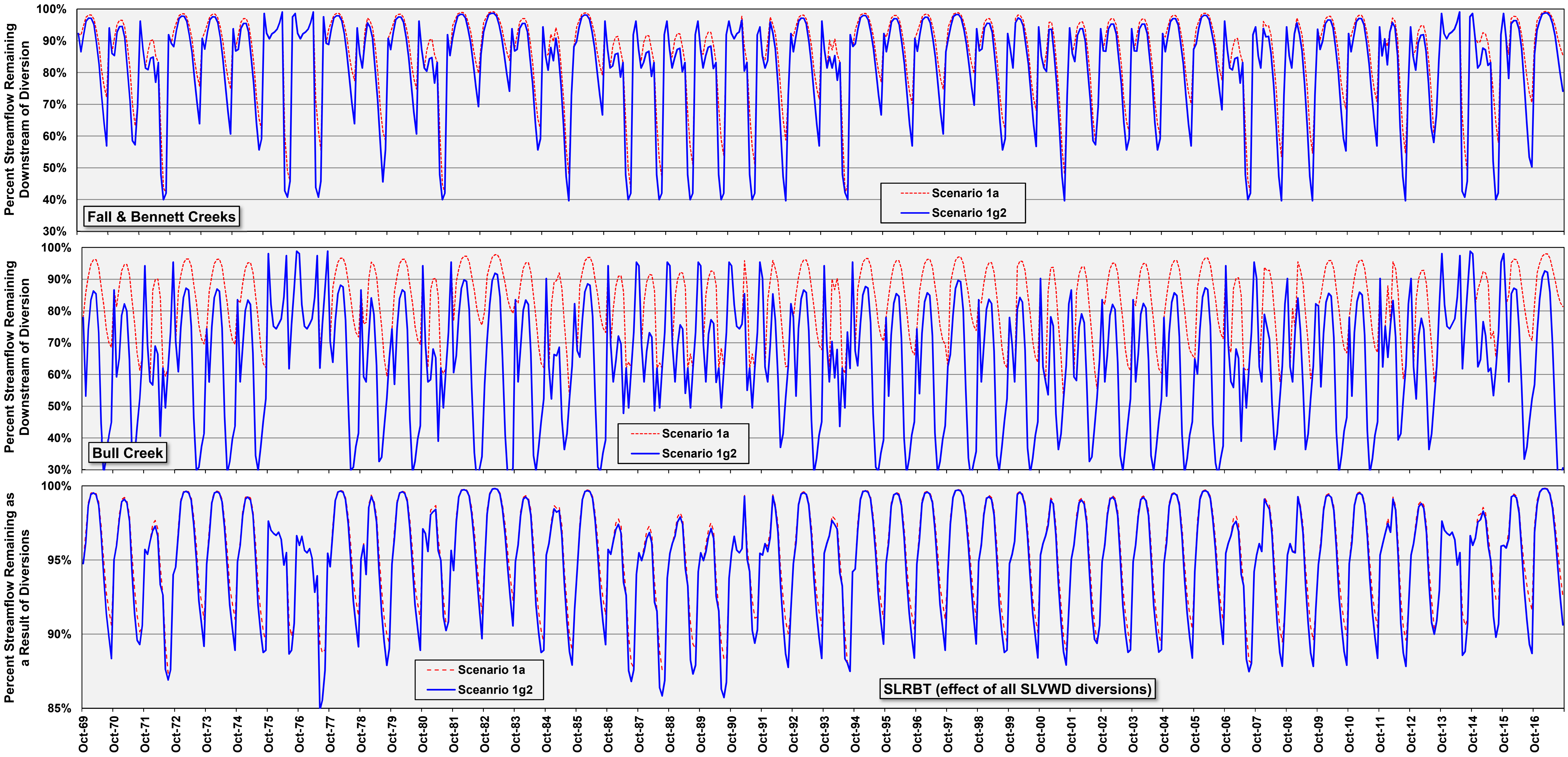
Scenario 1a: Percent of Simulated Monthly Flow Remaining Downstream of Felton System Fall, Bennett, and Bull Creek Diversions Assuming WY 1970–2017 Climatic Cycle, Current Infrastructure, Permitted Use, and Projected 2045 Demand



Note differences in vertical axis scaling.

Figure 6-12

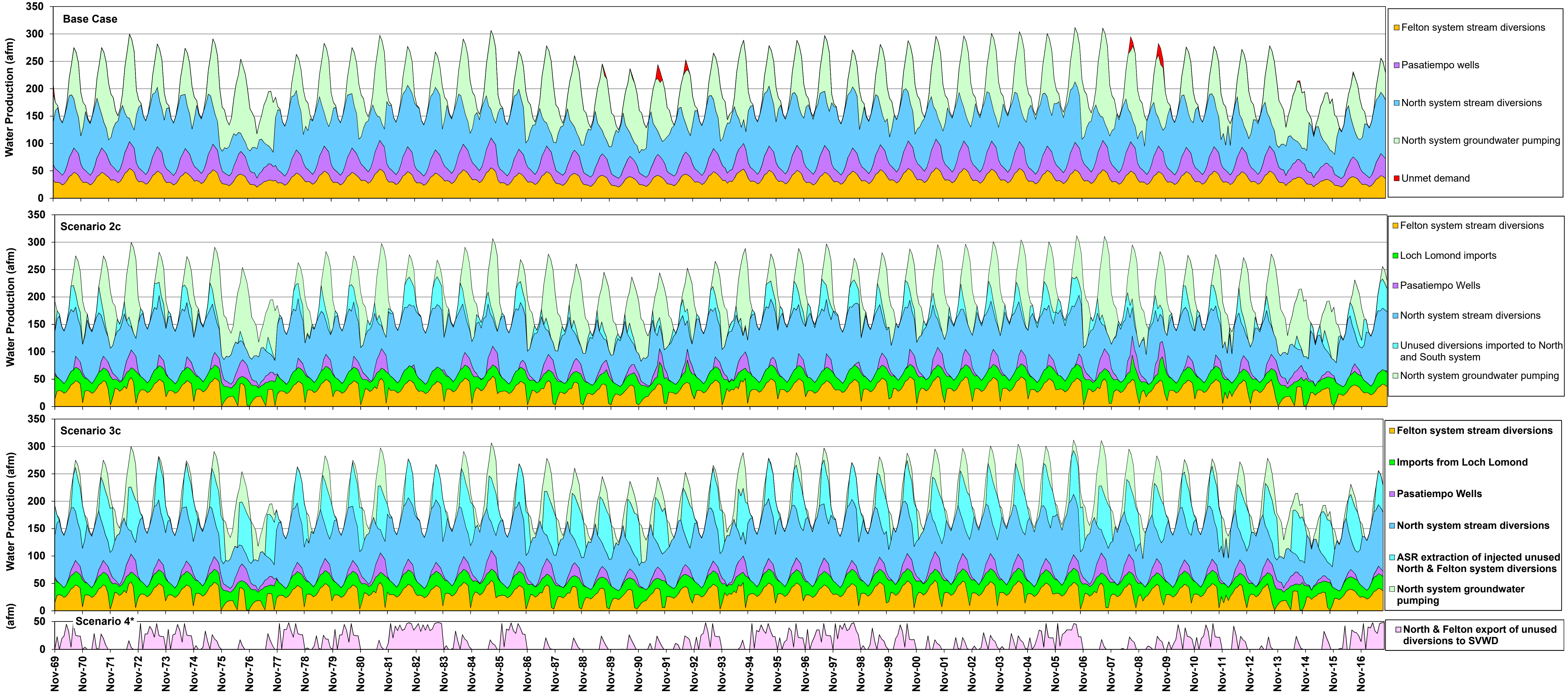
Scenario 1f: Percent of Simulated Monthly Flow Remaining Downstream of North System Diversions Assuming South System Import of Unused North System Potential Diversions and Felton Diversions as Permitted



Note differences in vertical axis scaling.

Figure 6-13

Scenario 1g2: Percent of Simulated Monthly Flow Remaining Downstream of Felton System Diversions Assuming South System Import of Unused Permitted Felton System Diversions

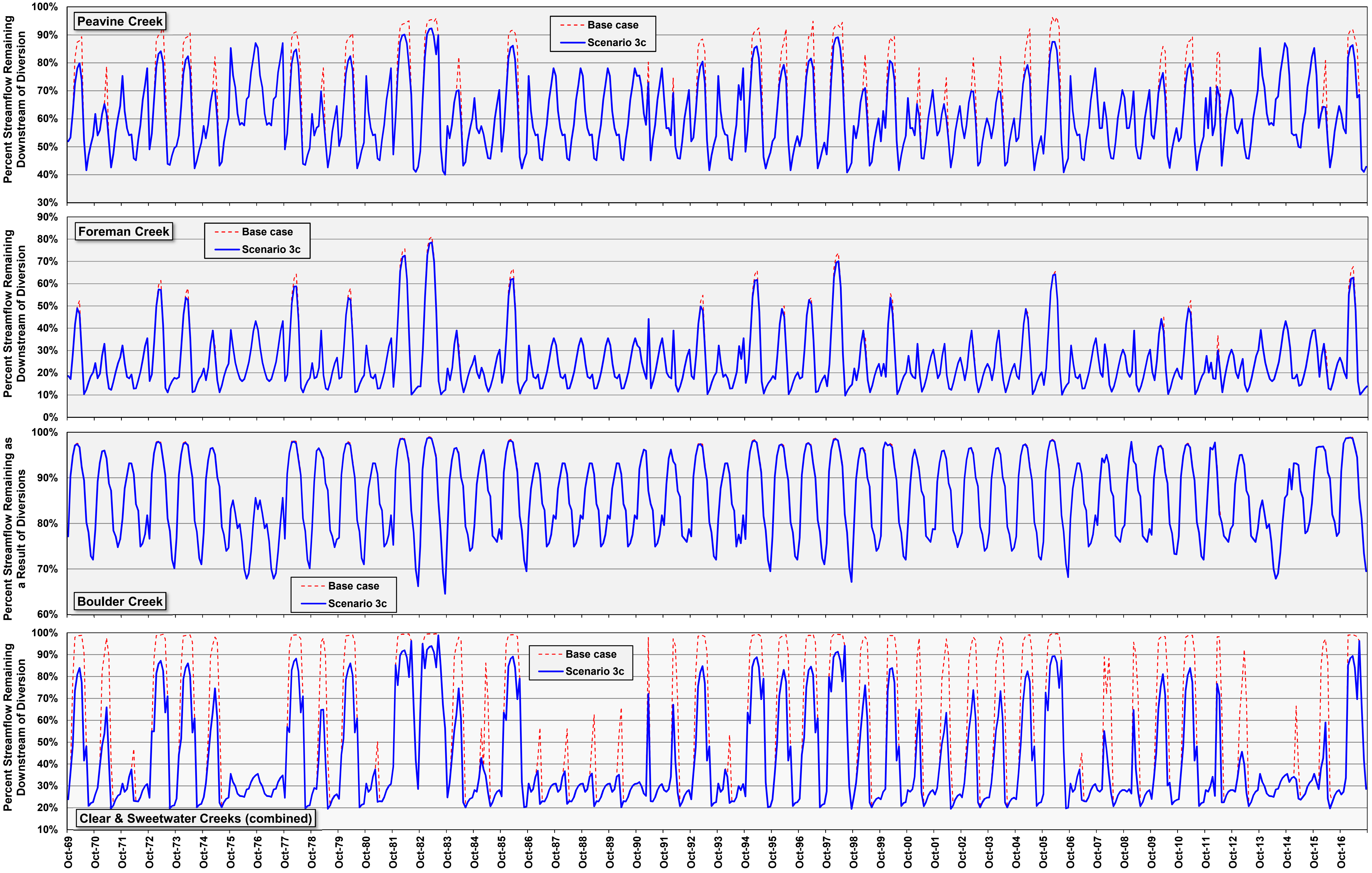


*Scenario 4 same as 3c except for export to SVWD.

afm acre-feet per month

Figure 6-14

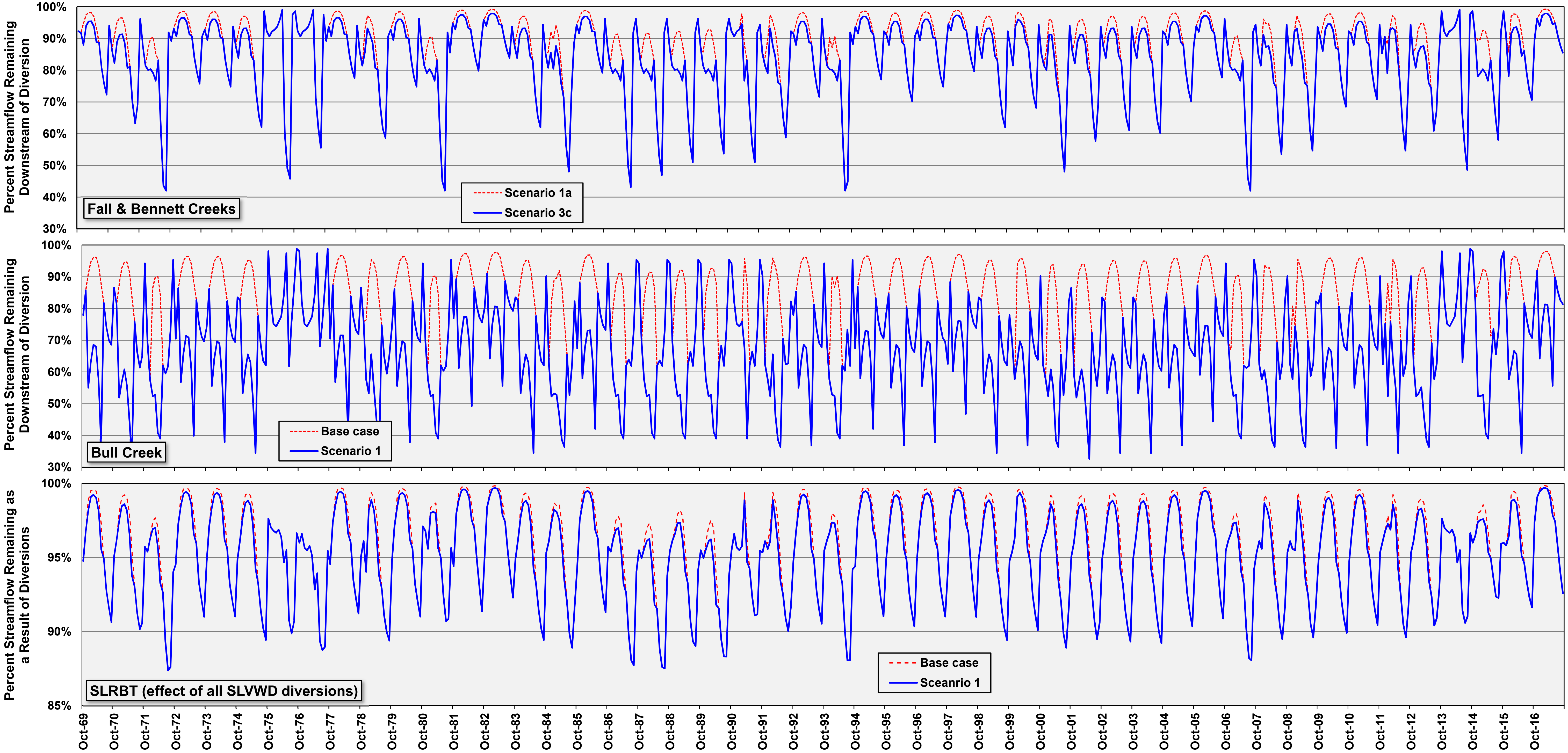
Monthly Results for Base Case and Scenarios 2c, 3c, and 4, WYs 1970–2017



Note differences in vertical axis scaling.

Figure 6-15

Scenario 3c: Percent of Simulated Monthly Flow Remaining Downstream of North System Diversions



Note differences in vertical axis scaling.

Figure 6-16

Scenario 3c: Percent of Simulated Monthly Flow Remaining Downstream of Felton System Diversions

7 Summary and Conclusions

On the basis of reasonably good calibration to the historical record (Section 6.2), the procedure described in Section 6.1 is used to simulate a base case and 22 conjunctive use alternatives documented in Section 6. As intended, the results are suitable for a planning-level evaluation of conjunctive use alternatives, i.e., to help qualify fundamental differences between alternatives. These scenarios are simulated under optimal, hypothetical conditions without full regard for infrastructure and other operational limitations, and as such likely overestimate potential yields. The actual yield of modified infrastructure will depend on numerous factors beyond the scope of this analysis. The presented values of simulated monthly flow have limited precision and should not be used to evaluate compliance with specific regulatory, water-right, or habitat requirements. Evaluating the effects of groundwater pumping on streamflow, beyond the simple approach used for this study, requires use of a calibrated numerical groundwater flow model, which was not within the scope of this study.

Figure 7-1 provides a summary of the base case and alternative conjunctive use scenarios evaluated in Section 6. The upper three stacked-bar charts represent simulated average annual North, Felton, and South system water production, indicated by source, for WYs 1970–2017. These plots also indicate percent reductions in groundwater pumping and compliance with Felton system water rights. The bottom bar chart indicates average annual amounts of unused stream diversions and Loch Lomond allotment for each scenario.

The bar charts presented in Figure 7-2 compare the minimum percentage of monthly streamflow simulated to remain downstream of SLVWD's diversions for each scenario during the simulation period. The bar charts in Figure 7-3 compare the minimum percentage of estimated drought stream baseflow remaining as a result of the groundwater pumping assumed by each scenario.

The simulation results summarized in Figure 7-1 support the following observations:

- Potential water transfers using the system interties are insufficient to achieve Felton water rights compliance (Scenario 1a). The North system has no unused potential diversions during months when the Felton system is not in compliance. Increased production from the Pasatiempo wells for transfer to Felton would require locally unprecedented rates of production from an over-drafted aquifer. A supplemental source, such as imports from Loch Lomond (Scenario 2), may be needed as much as 23 percent of the time to comply with Felton system water rights.

- Estimated increases in water production with assumed increases in diversion capacity (Scenarios 1c, 1d, 1e) are highly approximate but indicate the potential for increased yields with increased diversion, conveyance, and treatment capacities.

- South system imports of North and/or Felton system unused potential diversions allows 30 to greater than 50 percent reductions in South system groundwater pumping (e.g., Scenario 1h2).

- Supplementing the North system's water supply with Felton system unused potential diversions provides a 20 percent overall reduction in North system groundwater pumping (e.g., Scenario 1i).

- Supplementing the North system with extractions from an ASR project supplied by North and/or Felton unused potential diversions hypothetically allows roughly 30 to 60 percent net reductions in overall North system groundwater pumping (Scenario 3).

- Use of SLVWD's Loch Lomond allotment allows the Felton system to comply with its permitted water rights as well as reduce South system groundwater pumping by roughly 60 to 70 percent; as a result, unused potential diversions from the North and Felton systems are available for ASR instead of being used for South system in-lieu recharge (e.g., Scenario 3c).

- A 60 to 70 percent reduction in South system groundwater pumping as a result of imports from Loch Lomond and/or unused potential diversions represents a significant contribution to SMGB groundwater storage recovery. The degree to which SLVWD could recover this storage is uncertain.

- Using the system interties to supply the South system with unused potential diversions uses roughly 40 and 50 percent of North and Felton system unused diversions, respectively.
- With the addition of a Loch Lomond supply, use of North and Felton unused potential diversions requires ASR. As simulated under optimal conditions, ASR uses roughly half of the remaining unused diversions and helps reduce North system groundwater pumping by roughly 30 to 60 percent (Scenario 3).
- The remaining North and Felton system potential unused diversions (i.e., exceeding the capacity of the hypothesized ASR project) are assumed available for export to SVWD (Scenario 4), averaging more than 150 afy and ranging up to 500 afy assuming a conveyance capacity of 350 gpm, which further contributes to the recovery of SMGB groundwater storage. The degree to which this increased storage benefits production from the SLVWD Pasatiempo wells is uncertain but likely limited.

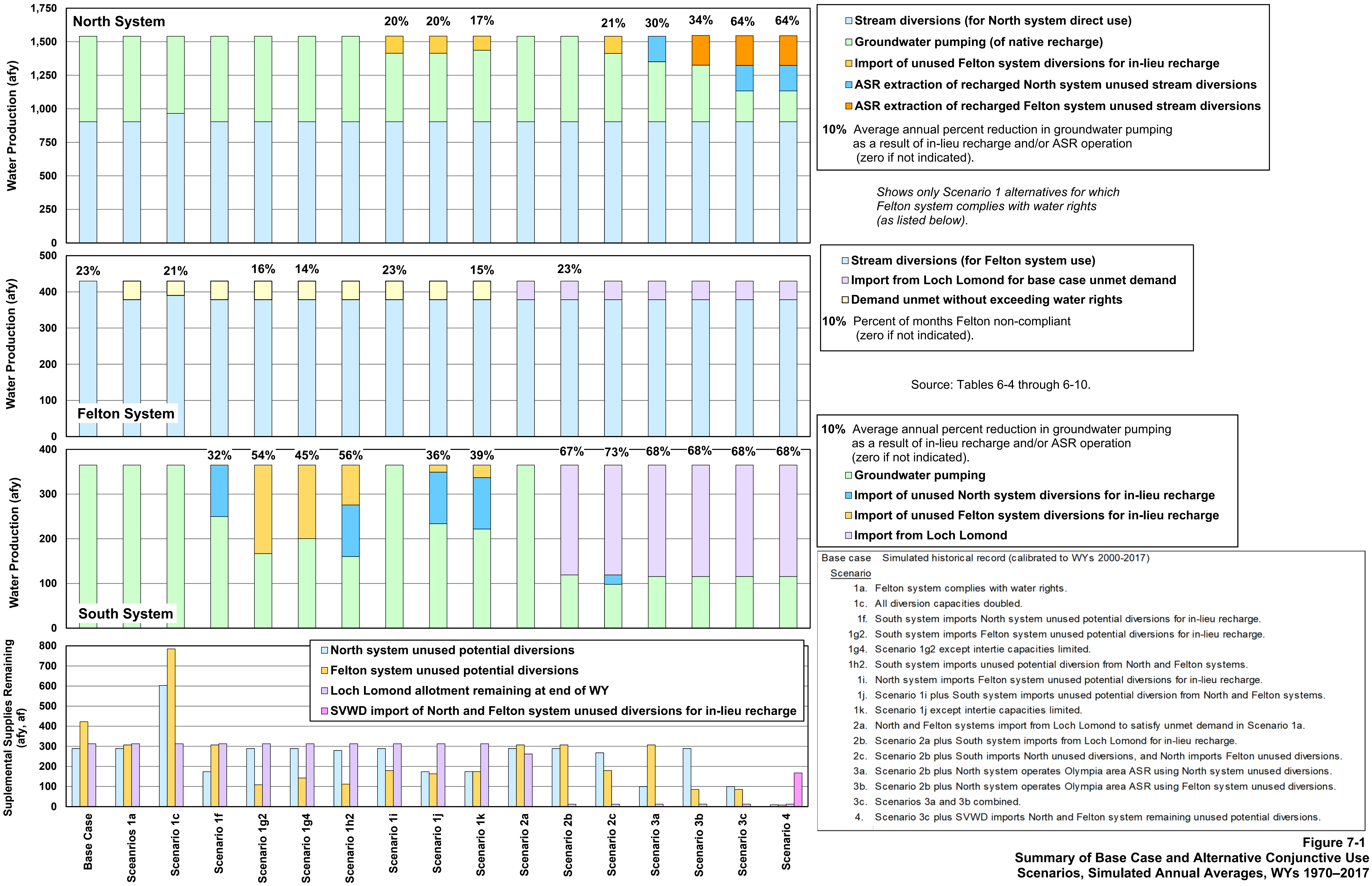
The simulation results summarized in Figures 7-2 and 7-3 support the following observations:

- Complying with the Felton system water rights (Scenario 1a) notably increases the minimum percentages of flows remaining downstream of diversions, particularly for Bull Creek (see also Figure 6-11).
- Stream diversions for in-lieu recharge and ASR occur during high-flow periods and have relatively little effect on minimum flows remaining downstream of the diversions (e.g., see also Figures 6-12 and 6-13).
- Reduced groundwater pumping as a result of imports from Loch Lomond and the transfer of unused diversions increases the percentage of drought minimum baseflows estimated to remain in lower Newell, Zayante, and Bean

creeks to 60 to 80 percent, compared to roughly 50 percent or less for the base case (Tables 5-3, 6-6, and 6-11).

In summary, system interties combined with supplemental water supplies from Loch Lomond and/or an ASR project provide SLVWD with significant options and flexibility for increasing conjunctive use and improving stream baseflows. The results provide qualitative indications of the potential relative magnitude and effects of the various alternatives considered. Further application of this work is expected to occur in the context of in-stream flow objectives recommended by fishery biologists.

Given an apparent range of potentially successful options for increasing conjunctive use, alternatives selection may be expected to depend largely on cost, feasibility, and the recommendations of fishery biologists. For example, importing from Loch Lomond may be significantly easier, less costly, and more predictable to operate than an ASR project. Operational experience from implementing a relatively feasible alternative will guide the potential adoption of additional conjunctive use measures. Logistical, water rights, and environmental considerations, combined with the highly approximate nature of the alternative conjunctive use simulations presented in this assessment, limit the basis for formulating recommendations based on the simulation results alone.



Shows only Scenario 1 alternatives for which Felton system complies with water rights (as listed below).

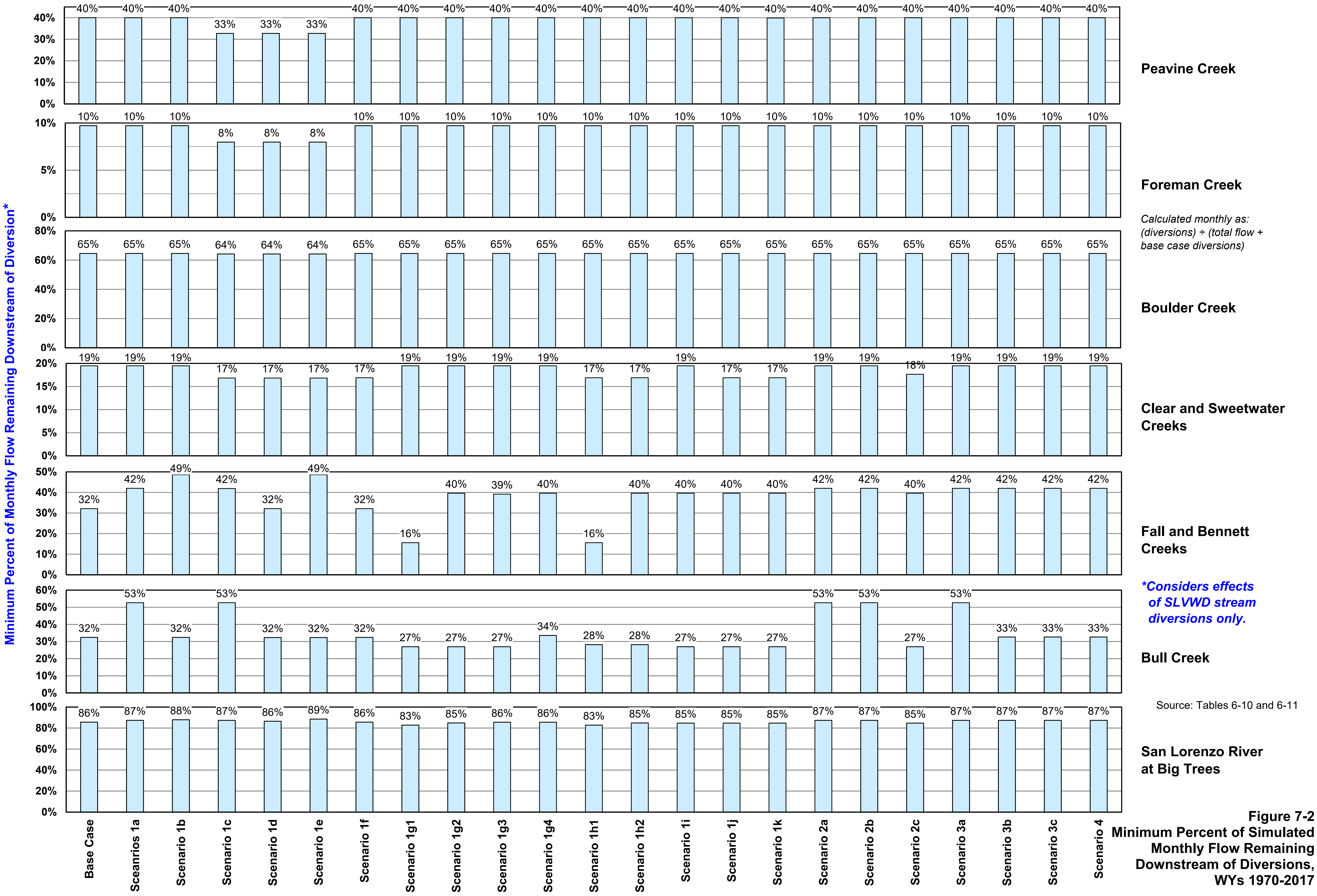
Source: Tables 6-4 through 6-10.

Base case Simulated historical record (calibrated to WYs 2000-2017)

Scenario

1a. Felton system complies with water rights.
1c. All diversion capacities doubled.
1f. South system imports North system unused potential diversions for in-lieu recharge.
1g2. South system imports Felton system unused potential diversions for in-lieu recharge.
1g4. Scenario 1g2 except intertie capacities limited.
1h2. South system imports unused potential diversion from North and Felton systems.
1i. North system imports Felton system unused potential diversions for in-lieu recharge.
1j. Scenario 1i plus South system imports unused potential diversion from North and Felton systems.
1k. Scenario 1j except intertie capacities limited.
2a. North and Felton systems import from Loch Lomond to satisfy unmet demand in Scenario 1a.
2b. Scenario 2a plus South system imports from Loch Lomond for in-lieu recharge.
2c. Scenario 2b plus South imports North unused diversions, and North imports Felton unused diversions.
3a. Scenario 2b plus North system operates Olympia area ASR using North system unused diversions.
3b. Scenario 2b plus North system operates Olympia area ASR using Felton system unused diversions.
3c. Scenarios 3a and 3b combined.
4. Scenario 3c plus SVWD imports North and Felton system remaining unused potential diversions.

Figure 7-1
Summary of Base Case and Alternative Conjunctive Use Scenarios, Simulated Annual Averages, WYs 1970–2017

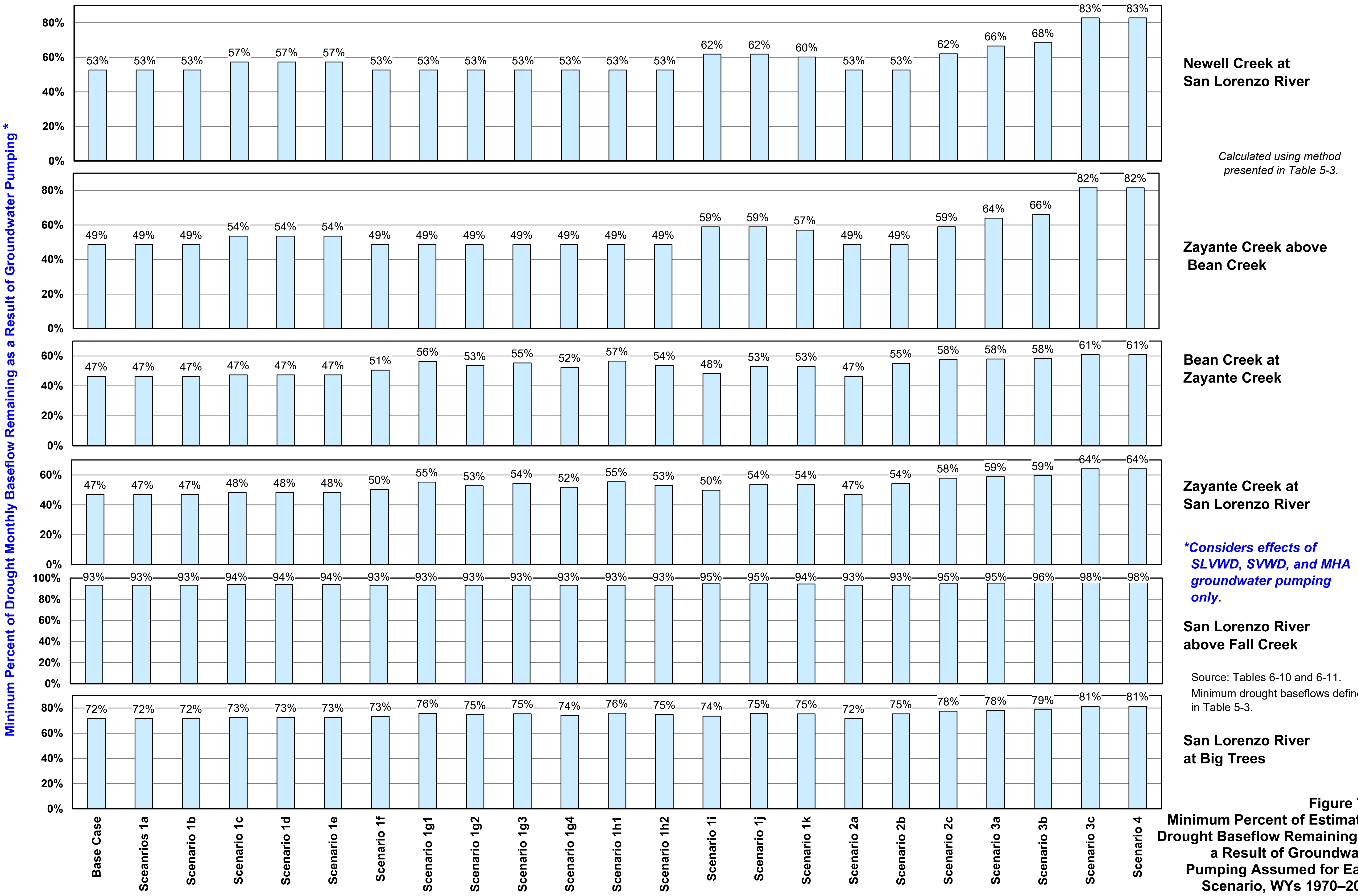


Calculated monthly as: (diversions) ÷ (total flow + base case diversions)

****Considers effects of SLVWD stream diversions only.***

Source: Tables 6-10 and 6-11

Figure 7-2
Minimum Percent of Simulated Monthly Flow Remaining Downstream of Diversions, WYs 1970-2017



Calculated using method presented in Table 5-3.

****Considers effects of SLVWD, SVWD, and MHA groundwater pumping only.***

Source: Tables 6-10 and 6-11.
Minimum drought baseflows defined in Table 5-3.

Figure 7-3
Minimum Percent of Estimated Drought Baseflow Remaining as a Result of Groundwater Pumping Assumed for Each Scenario, WYs 1970–2017

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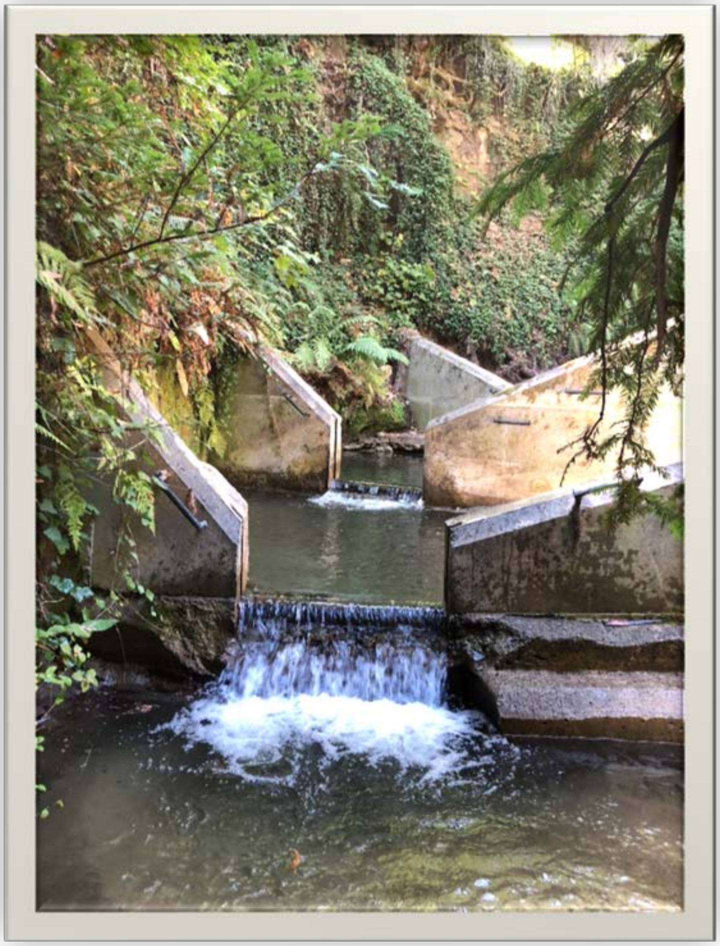
Appendix B

Fisheries Resource Considerations

Fisheries Resource Considerations for the San Lorenzo River Watershed Conjunctive Use Plan

(Revised Final)



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November 21, 2019

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Acronyms and Abbreviations

°C	degrees Celsius
af	acre-feet
afy	acre-feet per year
ASR	aquifer storage and recovery
Balance	Balance Hydrologics, Inc.
CDFG	California Department of Fish and Game (now CDFW)
CDFW	California Department of Fish and Wildlife (formerly CDFG)
cfs	cubic feet per second
DWA	D.W. Alley & Associates
ft	feet
ft msl	feet above mean sea level
gpm	gallons per minute
in-lieu recharge	practice of providing surplus surface water to historical groundwater users, thereby leaving groundwater in storage for later use
mm	millimeters
MHA	Mount Hermon Association
NMFS	National Marine Fisheries Service
PHABSIM	Physical Habitat Simulation
sq. mi.	square miles
SLRBT	San Lorenzo River at Big Trees (USGS gauging station)
SLVWD	San Lorenzo Valley Water District
SMGB	Santa Margarita Groundwater Basin
sq. mi.	square miles
SVWD	Scotts Valley Water District
USGS	U.S. Geological Survey
WAA	Water Availability Analysis (Exponent 2019)
WY	water year (i.e., October 1 through September 30)

CHAPTER 1
Introduction

1.1 Background

The San Lorenzo Valley Water District (SLVWD or District) and County of Santa Cruz (County) are jointly developing the *San Lorenzo River Watershed Conjunctive Use Plan* to identify opportunities for improving the reliability of surface and ground water supplies for the District through conjunctively managing its water supplies while also increasing stream baseflows for fish in the San Lorenzo River watershed. The District serves 22,000 customers with water sourced from eight currently active stream diversions on tributaries to the San Lorenzo River, one groundwater spring, and eight active groundwater wells within the Santa Margarita Groundwater Basin (SMGB). The District's operations are comprised of three largely independent water systems: (1) the North System located in the San Lorenzo Valley, (2) the South System located in the Scotts Valley area, and (3) the Felton System located in Felton (formerly the Citizens Utilities Company of California Service Area) (Figure 1-1). Theoretically, interconnection of these independent systems has the potential to provide the District with greater flexibility to move water supplies between the systems by utilizing surplus surface water to augment ground water supplies during winter and spring, and conversely, increasing reliance on groundwater sources during the low surface seasons of summer and fall, thereby enhancing habitat quality and quantity for the steelhead (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*) populations of the San Lorenzo River watershed during times when low baseflows limit fish growth and survival.

Through recent grant funding, the District has already developed some of the needed infrastructure, such as pipeline interties, to implement conjunctive use. In support of the conjunctive use plan development, the District analyzed existing water sources and demands to identify the timing and amount of surface water and groundwater that could be made available for transfer under various conjunctive use scenarios, and what the resulting effects of such transfers would be on downstream flows and groundwater storage. The *Water Availability Assessment for San Lorenzo River Watershed Conjunctive Use Plan* (WAA) prepared by Exponent (2019) analyzes a total of 22 conjunctive use scenarios that fall into four broad categories: (1) Optimizing the use of current sources of water under existing and modified conditions; (2) importing water from Loch Lomond; (3) development and operation of an Aquifer Storage and Recovery (ASR) project in the Olympia subarea of the SMGB; and (4) contributing to Scotts Valley area in-lieu recharge.

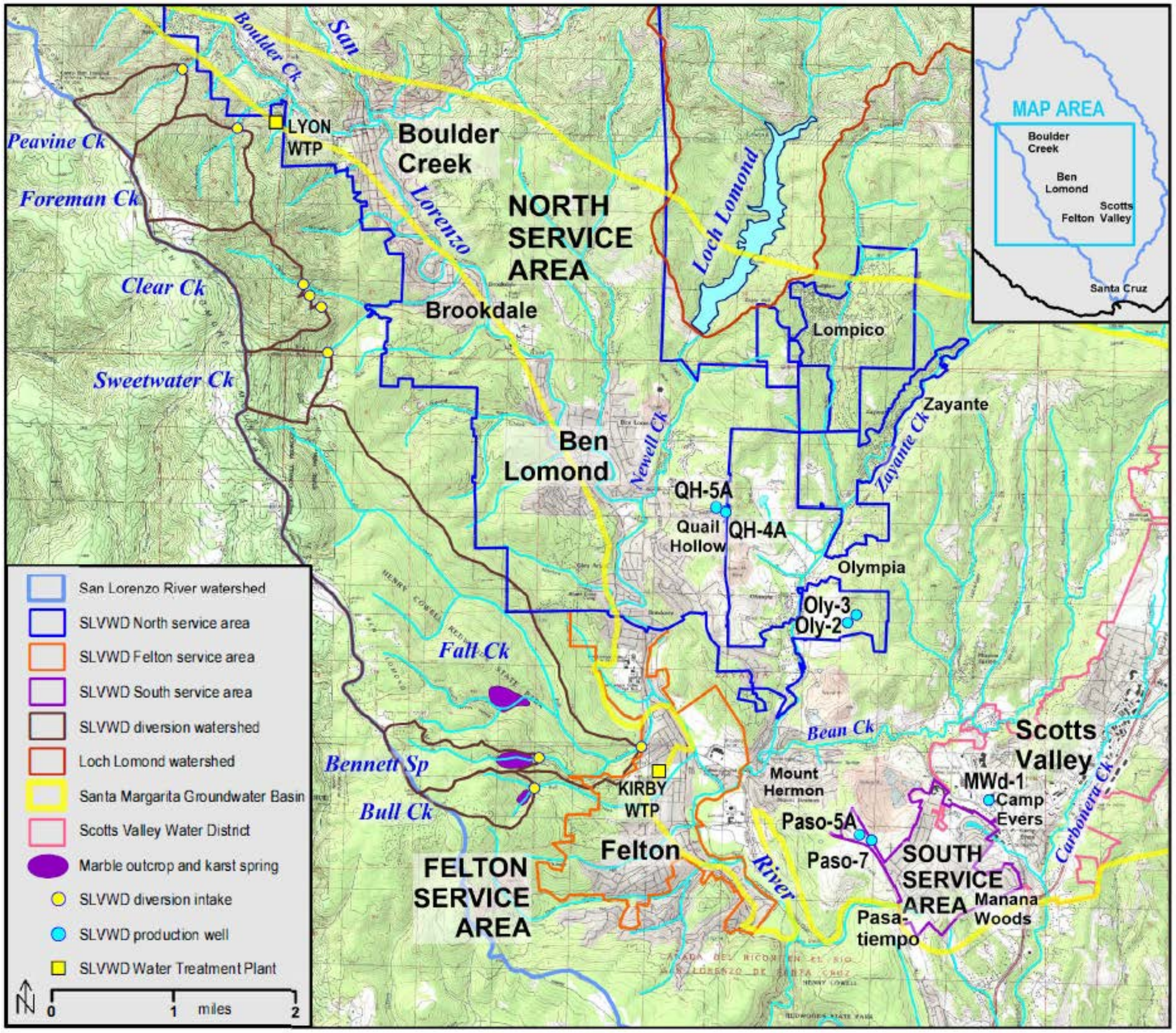

Figure 1-1
SLVWD Service Areas, Diversion Watersheds, Points of Diversion, Treatment Plants, and Production Wells

SOURCE: Exponent (2019)

The WAA defines the following four objectives for the Conjunctive Use Plan:

- Optimizing the conjunctive use of available water resources for water-supply reliability and long-term sustainability;
- Reducing Felton diversions to comply with low-flow and dry-period water rights restrictions;
- Reducing the effect of North system stream diversions and groundwater pumping on dry-period streamflows;
- Reducing groundwater pumping (e.g., by in-lieu recharge) to promote the recovery of groundwater storage and production in the South system and other portions of Scotts Valley.

In accordance with these objectives, the conjunctive use scenarios identified and analyzed in the WAA are focused primarily on water supply reliability and sustainability, with particular emphasis on groundwater sustainability. Based on the results of the WAA, SLVWD has selected three conjunctive use scenarios for moving forward toward implementation.

While potential indirect benefits to the fisheries resources of the San Lorenzo River watershed (e.g., increased drought baseflow levels in streams currently affected by groundwater pumping) are presented in the WAA, the conjunctive use scenarios were not developed or analyzed with a specific goal of maximizing benefits to fisheries. Exponent (2019) summarize the findings of the WAA as follows:

> “In summary, system interties combined with potential supplemental water supplies provide SLVWD with significant options and flexibility for increasing conjunctive use and improving stream baseflows. The results provide qualitative indications of the potential relative magnitude and effects of the various conjunctive use alternatives. Further application of this work and the development of conjunctive use alternatives are expected to occur in the context of in-stream flow objectives proposed by fishery biologists, in addition to cost, feasibility, and water rights considerations.”

The purpose of this conjunctive use fisheries resources considerations assessment is to (1) evaluate and summarize the expected effects to fisheries resources of the three conjunctive use projects identified by SLVWD for advancing; (2) evaluate and summarize conjunctive use scenarios presented in the WAA that would be expected to maximize fisheries benefits; and (3) recommend a combination of scenarios that, if implemented together over time, would promote watershed-wide improvements to instream flows.

1.2 Approach to Analysis

For the past two decades, SLVWD, the County, and other stakeholders have funded an extensive steelhead monitoring program in the San Lorenzo River watershed conducted by D.W. Alley &

Associates (DWA). The annual reports prepared for this monitoring program, as well as the *San Lorenzo River Enhancement Plan* (Alley et al. 2009), provide a wealth of information regarding salmonid habitat quality, population trends, and observations of potential limiting factors such as low flows, passage barriers, and sources of disturbance. For some streams in the watershed, available fisheries population and utilization data are limited. In these cases, the current version of the National Marine Fisheries Service (NMFS) Intrinsic Potential (IP) model for salmonid species (NMFS 2016) was reviewed to determine potential availability of steelhead and coho salmon habitat. The IP model describes the potential for a stream reach to exhibit habitat characteristics suitable for an anadromous salmonid species as a function of the geomorphologic and hydrologic characteristics of the landscape and provides an index (0.01 to 1.00) of the relative likelihood of suitable habitat occurring under pristine conditions. It should be noted, however, that IP data are sometimes misinterpreted as representing a rating of habitat *quality*, suggesting that a rating of “low”, for example, indicates that steelhead habitat of low quality is present within the reach. That is not the case. As described in the underlying documentation for the IP model (Agrawal et al. 2005), NMFS “used the IP modeling framework to estimate the likelihood—strictly speaking, the relative likelihood—that a stream reach will exhibit suitable habitat for juveniles of a particular species” and warns that the “IP models estimate neither the actual, fine-scale distribution of habitat within a basin nor the quality of habitat in a given reach under current or historical conditions.”

In addition to annual fish monitoring reports, DWA have prepared a number of stand-alone assessments such as focused water temperature evaluations and fish passage flow assessments. Moreover, the District’s watershed management plan (SLVWD 2009) provides a valuable overview of current water operations, infrastructure, and natural resources, while hydrologic assessment and monitoring work conducted by Balance Hydrologics (Balance) and others provide important baseline streamflow information for the District’s water supply system. A thorough review of the available sources of existing data provided the foundation for a synthesis of existing fisheries resource conditions in drainages affected by SLVWD surface water diversions and groundwater extractions (Chapter 2).

The existing effects of SLVWD’s diversions on fish and aquatic habitat were analyzed based on data provided by Balance and DWA, as well as preliminary instream flow needs estimates developed for comparative purposes. The methods used for the analysis, as well as its results, are presented in Chapter 3.

The results of the WAA of 22 conjunctive use scenarios (Exponent 2019) were reviewed and evaluated for potential effects on fisheries resources in the context of existing diversion effects (Chapter 4). In particular, three scenarios selected by SLVWD for further consideration were evaluated for their expected relative benefits to fisheries habitat. Furthermore, an additional scenario aimed at maximizing fisheries benefits of conjunctive use, based largely on a modified version of one of the WAA-analyzed scenarios, is presented and analyzed for consideration.

Chapter 5 provides a summary of the conclusions of this analysis and outlines a recommendation for a conjunctive use approach.

Similar to the approach used in the WAA, the results of this analysis of fisheries resource considerations for the *San Lorenzo River Watershed Conjunctive Use Plan* are suitable for a planning-level evaluation of conjunctive use alternatives. Due to the limited precision of the synthesized monthly records of water supply (Exponent 2019), the results should not be used to evaluate compliance with specific regulatory, water-right, or habitat requirements. Instead, this comparative analysis is intended to identify the relative fisheries benefits of individual conjunctive use scenarios and to narrow down the selection of potential projects to move forward in the planning process.

CHAPTER 2
Existing Conditions

2.1 Watershed Overview

The following overview of the San Lorenzo River watershed is based, in large part, on the thorough descriptions presented in the *San Lorenzo River Salmonid Enhancement Plan* (Alley et al. 2004) and the District's Watershed Management Plan (SLVWD 2009).

The San Lorenzo River drains a 138 square mile (sq. mi.) watershed located in northern Santa Cruz County (Figure 2-1). It consists of a 25-mile long mainstem and 9 principle tributaries that include Branciforte, Carbonera, Zayante, Bean, Fall, Newell, Bear, Boulder, and Kings creeks. Much of the watershed is forested with pockets of urban areas (e.g., Santa Cruz, Scotts Valley, Felton, Ben Lomond, and Boulder Creek) and an increasing proportion of rural residential developments. Paved and unpaved roads occur in stream corridors, providing access to the small mountain communities and towns that occur throughout the San Lorenzo Valley (e.g., Felton, Ben Lomond, Brookdale, Boulder Creek, Lompico, Zayante, and Mt. Hermon).

Elevations in the watershed range from the 3,214 feet at the summit of Castle Rock Peak, down to sea level at the mouth of the river in the City of Santa Cruz. With its headwaters at an elevation of approximately 2,900 feet, the San Lorenzo River drops 2,000 feet in the first 3 miles. Small, steep tributaries feed the river from the west at Ben Lomond Mountain, while wider, more gently sloping tributaries feed the river from the east and northeast.

Annual rainfall varies between 15 inches to more than 100 inches throughout the watershed, depending upon location and year (SLVWD 2009). Ben Lomond Mountain, source of the SLVWD's surface water, averages near the high end of the range. Rainfall averages approximately 46 inches per year in the watershed upstream of Felton, but less than that in the remainder of the watershed. Coastal fog is an important part of the summer climate, creeping into inland valleys at night and in mornings. Average daily temperatures vary throughout the watershed and by season, generally ranging from 30°F and 90°F.

2.2 Fisheries Resources

The San Lorenzo River and its estuary are inhabited by at least 25 different species of native fish (DWA 2009). These include salmonids such as central California coast (CCC) steelhead and historically CCC coho salmon. These species are anadromous fish that occupy freshwater streams and rivers as juveniles, migrate to the ocean to grow and mature, and then return to spawn in their natal freshwater streams. Both of these species are afforded protections under the federal

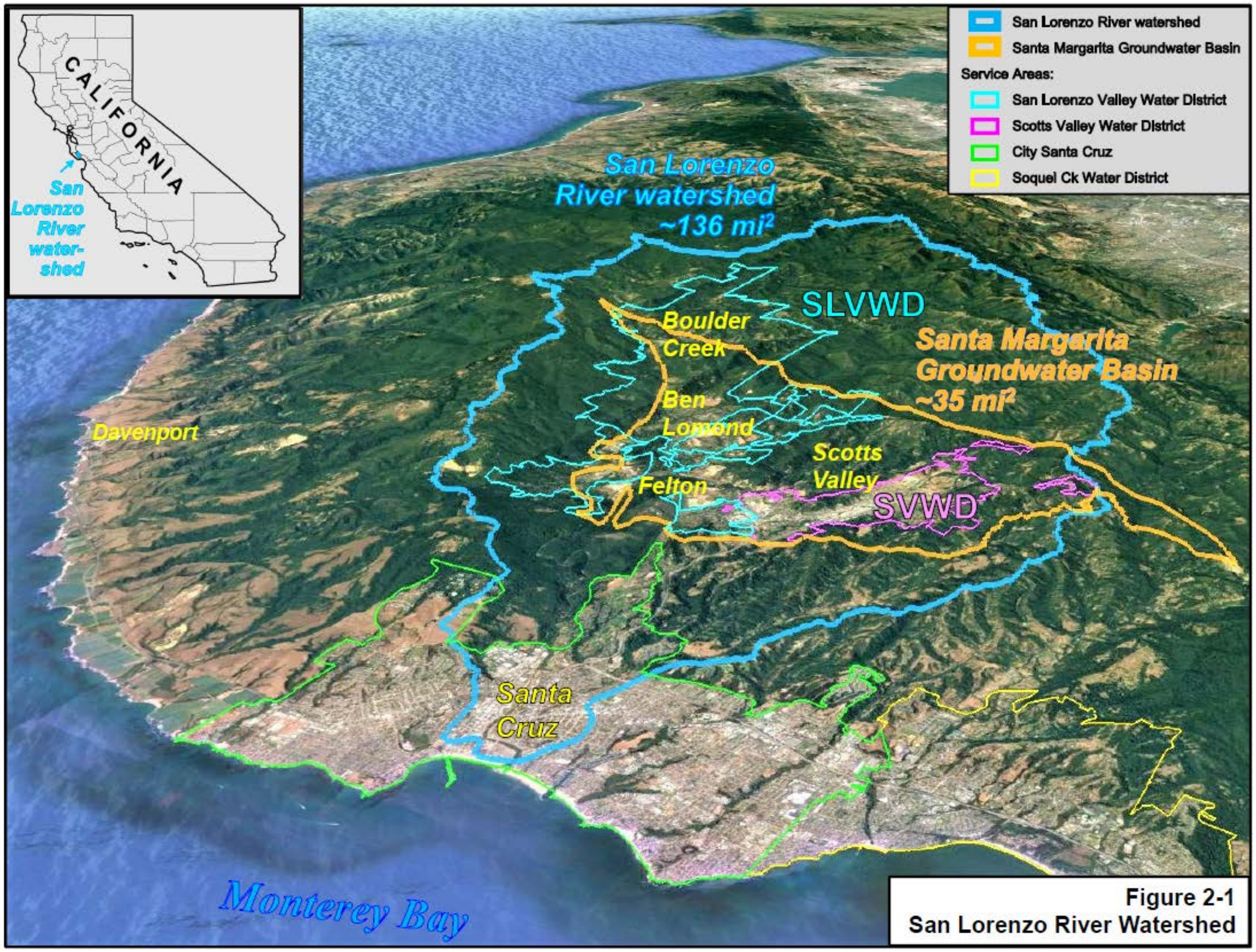

Figure 2-1
San Lorenzo River Watershed

SOURCE: Exponent (2019)

Endangered Species Act and are the primary focus of this conjunctive use plan assessment. While other native species are also important for a diverse and balanced aquatic ecosystem, steelhead and coho salmon are generally considered keystone species, and ecological management practices aimed at benefitting these salmonids are generally accepted to provide suitable conditions for other native fish species that have coevolved with steelhead and coho salmon. This assessment has been prepared to provide relevant fisheries considerations for the development of the San Lorenzo River Watershed Conjunctive Use Plan. A general understanding of the life history cycle and habitat requirements of steelhead and coho salmon has been assumed for purposes of this report, with the focus of this assessment placed on information relevant to enhancing instream flow conditions. For a thorough discussion of the life history cycle and habitat requirements of salmonids and other native fish in the San Lorenzo River, the reader is referred to DWA (2009).

SLVWD does not operate water diversion facilities directly on the mainstem San Lorenzo River, but all of its existing surface and groundwater supply facilities are located within drainages tributary to the mainstem. Past and current salmonid population trends in the San Lorenzo River are the subject of an extensive long-term monitoring program and have been summarized in numerous reports (e.g., Alley et al. 2004; DWA 2009; DWA 2017a) and an online database (County of Santa Cruz 2019). While salmonid population densities fluctuate from year to year and overall trends are difficult to define conclusively in the absence of unbiased estimates of spatial structure based on stratified-random sampling and annual estimates of adult recruitment and spawning success, general estimates of population and habitat utilization trends are available. The following overview of existing salmonid habitat conditions and utilization in the mainstem San Lorenzo River is based largely on the thorough discussion provided by DWA (2009) in SLVWD's Watershed Management Plan (SLVWD 2009).

The upper San Lorenzo River mainstem (i.e., upstream of the Boulder Creek confluence) has relatively low but cool spring and summer baseflow. Juvenile steelhead growth is generally slow in this well-shaded reach, but relatively high densities of yearlings are thought to contribute a significant portion of adult steelhead returns to the watershed. Immediately upstream of Boulder Creek, the mainstem river channel has a low gradient, steep canyon walls with tall redwoods, and is dominated by long, sediment-laden pools separated by short, shallow riffles. As stream gradient increases further upstream, pools become shorter and habitat variety increases. Limiting factors to salmonids in the upper mainstem include low spring and summer streamflow and sedimentation from erosion.

The middle mainstem extends from the Boulder Creek confluence downstream to the Zayante Creek confluence. This reach has higher annual streamflow than the upper mainstem and a wider, more open canyon. Water temperatures are warmer in the middle mainstem than in the upper mainstem, and juvenile steelhead tend to occupy fastwater habitat at riffles, runs and heads of pools where food (aquatic insect) production is higher. The majority of the middle mainstem is dominated by long, deep pools containing lower food supplies. Spawning habitat availability is considered limited and juvenile steelhead densities are generally low (DWA 2017a).

The lower mainstem San Lorenzo River below the confluence of Zayante Creek has much greater spring and summer baseflow than upstream reaches, providing higher food availability even during summer baseflow conditions. Based on limited scale analyses, steelhead growth rates in this reach appear to be high enough to allow many juveniles to reach smolt size after one growing season. The lower mainstem was estimated to be a major contributor to adult returns. Spawning habitat is poor due to high sand content in spawning glides, and most juveniles rearing in this reach likely originate in the upstream tributaries.

San Lorenzo River estuary is located in the center of the City of Santa Cruz, discharging to the Monterey Bay at Main Beach and the Santa Cruz Beach Boardwalk. The historic San Lorenzo River lagoon surface area has been reduced by over 80% as a result of road and railroad crossings, extensive floodplain development, and flood control levee construction and maintenance, thereby dramatically simplifying the morphologic complexity of the lagoon (2NDNATURE 2006). The necessity of flood control has eliminated the adjacent low-lying marsh habitat that would typically be inundated during winter runoff and summer lagoon conditions. The lagoon area downstream of Riverside Drive is extremely exposed, devoid of any vegetation and its substrate is homogenous beach sand. Annual vegetation management in the active channel is conducted each fall to maintain flood capacity. Nevertheless, the San Lorenzo River lagoon supports seasonal juvenile steelhead rearing as well as a population of tidewater gobies (*Eucyclogobius newberryi*), a federal endangered species. Sandbar-formed lagoons such as the San Lorenzo River lagoon may provide highly productive rearing habitat in which juvenile steelhead grow fast enough during their first year of lagoon rearing to migrate to the ocean, and most enter the ocean at a larger size than the same year class fish rearing in freshwater habitats of the stream system (Bond et al. 2008). Larger size greatly improves survival in the ocean, and the lagoon-reared fish represented a large majority of the returning adult spawning population (Bond et al. 2008). Juvenile steelhead population estimates for the San Lorenzo River lagoon vary seasonally and annually, but high growth rates are regularly documented (e.g., HES 2017).

2.3 Existing Conditions

2.3.1 Surface Water Resources

North System

The surface water components of SLVWD’s North System consist of diversions located on the eastern slope of Ben Lomond Mountain from Boulder Creek to Brookdale, with multiple diversion boxes that feed into a gravity pipeline (Five-Mile Pipeline) and ultimately to the Lyon Treatment Plant in Boulder Creek. SLVWD’s North System includes surface water diversions on Peavine Creek and Foreman Creek (tributaries to Boulder Creek), Clear Creek (tributary to the mainstem San Lorenzo River), and Sweetwater Creek (tributary to Clear Creek). Historically, SLVWD also diverted approximately 10 acre-feet per year (afy) from Silver Creek, a small drainage tributary to Boulder Creek. However, this diversion has been inactive for the past 10 years, and SLVWD has no plans to reactivate it in the near future (Balance 2019).

SLVWD has pre-1914 appropriative rights to divert water from Peavine, Foreman, Clear, and Sweetwater creeks, which generally enable it to supply water from these streams to its North System without restriction. SLVWD has an agreement with a downstream water user to allow 30 gallons per minute (gpm) to bypass its Clear Creek diversion at all times.

Peavine Creek

Peavine Creek is a tributary to Boulder Creek northwest of the community of Boulder Creek and has a total drainage area of 285 acres (0.45 square mile). SLVWD diverts from an intake at elevation 1,264 feet above mean sea level (msl). The mapped length of Peavine Creek upstream of the diversion is approximately 3,100 feet, and the drainage area above the diversion is approximately 230 acres (0.36 square mile). No information regarding the fisheries resources of Peavine Creek appear to be available. NMFS (2016) rates the lowermost 0.4 miles of Peavine Creek as having a low intrinsic potential for exhibiting habitat characteristics suitable for juvenile steelhead, as a function of the geomorphologic and hydrologic characteristics of the landscape. However, the majority of this stream, including the reach containing SLVWD’s diversion site, is located in the steep terrain typical of the eastern slopes of Ben Lomond Mountain and does not have an intrinsic potential to support steelhead. NMFS (2016) rates the entire Peavine Creek drainage as not intrinsically suitable for juvenile coho salmon. Balance (2018a) note that the Brook Lane crossing of Peavine Creek near its confluence with Boulder Creek presents a 12-ft vertical drop. This feature presents a significant impediment to fish movement into this tributary. Based on the available information, Peavine Creek is not considered to have anadromous salmonid value for the purpose of this assessment.

Foreman Creek

Foreman Creek consists of about 1.3 stream miles and is tributary to Boulder Creek. It drains a watershed area of approximately 580 acres (0.9 sq. mi.). SLVWD diverts from an intake at elevation of 927 feet msl. The mainstem Foreman Creek channel above the intake is approximately 3,800 ft. long and an additional eastern branch located upstream of the diversion consists of approximately 3,000 ft of channel. In total, the drainage area above the diversion is approximately 480 acres (0.75 square miles). Baseflows in Foreman Creek may be augmented by groundwater recharged within a roughly 120-acre area immediately west of the watershed divide along the crest of Ben Lomond Mountain (SLVWD 2009).

Resident rainbow trout (the non-anadromous form of *O. mykiss*) or steelhead were noted in Foreman Creek during a 1959 survey of stream condition by the California Department of Fish and Game (CDFG, now the California Department of Fish and Wildlife [CDFW]) staff. In a 1996 memo concerning habitat limitations in central coast streams, CDFG staff noted that water diversions reduce flows sufficiently to impact Foreman Creek, particularly during summer when low flow occurs naturally (Becker and Reining 2008). However, a steelhead and coho salmon distribution map produced by the County based on information from CDFW and local fishery biologists indicates that Foreman Creek is not utilized by salmonids “due to channel steepness and/or lack of suitable habitat” (County of Santa Cruz 2004). NMFS (2016) rate the lowermost 0.3 miles of Foreman Creek as having a moderate intrinsic potential to exhibit habitat characteristics suitable for juvenile steelhead. Similar to Peavine Creek, the remainder of Foreman Creek, including the reach containing SLVWD’s diversion site, has excessively steep gradients and is not rated as having an intrinsic potential to support steelhead. NMFS (2016) rates the entire Foreman Creek drainage as intrinsically unsuitable for juvenile coho salmon. Based on the available information, Foreman Creek is not considered to have anadromous salmonid value for the purpose of this assessment.

Boulder Creek

SLWVD does not have any water diversion facilities on Boulder Creek, but as described above, Peavine and Foreman Creeks are tributaries to Boulder Creek, and therefore SLVWD's diversions from these two subbasins have the potential to affect Boulder Creek streamflows and fish habitat. Boulder Creek is the uppermost tributary to the middle mainstem San Lorenzo River, as defined in the *San Lorenzo River Salmonid Enhancement Plan* (Alley et al. 2004).

DWA (2009) describe Boulder Creek downstream of the Hare Creek confluence as flowing through a heavily shaded canyon with steep, near-vertical walls and a streambed dominated by large granitic cobbles and boulders in turbulent riffles and runs. Relatively deep pools are present but contain virtually no instream fish refuge except from depth and large, unembedded boulders. High winter water velocities within the confined channel tend to wash out large wood and likely also flush out overwintering juvenile steelhead more easily than in other tributaries. Spawning-sized gravels and small cobbles are limited, and steep boulder riffles may impede adult passage at lower flows. Summer water temperatures in Boulder Creek are among the coolest in the San Lorenzo River watershed. Juvenile steelhead growth is relatively slow in Boulder Creek and low spring and summer baseflows may limit steelhead populations. (DWA 2009)

DWA have sampled fish populations at two sites on Boulder Creek annually since 1997; one site (17a) is located near Boulder Creek's confluence with the mainstem San Lorenzo River and downstream of both the Peavine and Foreman creeks confluences; the other site (17b) is located downstream of the Bracken Brae Creek confluence and upstream of the Peavine and Foreman creeks confluences. Based on data from 1997 through 2018 (County of Santa Cruz 2019), the average total density of juvenile steelhead at the two sampling sites have been fairly similar. At the downstream site (17a), population densities have ranged from a low of 8.1 fish/100 feet of channel to a high of 142.9 fish/100 ft, with an average of 47.8 (± 37.4) fish/100 ft. At the upstream site (17b), the range of total juvenile densities has been narrower at 26.0 to 108.7 fish/100 ft for an average of 60.3 (± 25.1) fish/100 ft. During most years, total juvenile steelhead densities are somewhat higher at the upstream site (i.e., outside the influence of SLVWD's diversions) than the downstream site (i.e., within the influence of the diversions), but considering the temporal variability in site-specific habitat conditions (County of Santa Cruz 2019) and the large standard deviations in the population estimates, it is difficult to correlate variations in population densities to the effects of water diversions. Nevertheless, the hydrologic effects of SLVWD diversions on Boulder Creek are not insignificant (see below) and it is reasonable to assume juvenile steelhead rearing habitat in Boulder Creek would benefit from increased summer flows.

Clear Creek (including Sweetwater Creek)

Clear Creek is a tributary to the middle mainstem San Lorenzo River near Brookdale and drains a watershed area of approximately 1,050 acres (1.64 sq. mi.). SLVWD operates three separate water intakes on Clear Creek; one on the mainstem and two on unnamed tributaries. Water intakes range in elevation from 1,330 to 1,358 feet msl. Clear Creek diversions were moved upstream in 1995 to allow gravity conveyance to the District's new treatment plant. The mapped length of Clear Creek upstream of the main-stem diversion is approximately 3,800 feet, and the drainage area above the diversions is approximately 435 acres (0.68 sq. mi.). Baseflows may be augmented by groundwater recharge within a roughly 300-acre area immediately west of the watershed divide along the crest of Ben Lomond Mountain (SLVWD 2009).

SLVWD also operates a diversion on Sweetwater Creek, a tributary to Clear Creek accounting for approximately 30 percent (335 acres) of the total Clear Creek watershed upstream of its San Lorenzo River confluence. The Sweetwater Creek diversion was also moved upstream in 1995 and is now located at elevation 1,330 feet msl. The drainage area upstream of the Sweetwater Creek diversion is approximately 660 acres (1.03 sq. mi.) and the mapped length of upstream channel is approximately 1,300 feet.

When surveyed by the CDFG in January 1957, Clear Creek was described as unimportant for steelhead because a permanent bedrock barrier at the mouth precluded upstream migration of adult spawners (Titus et al. 2010). No fish were observed in the creek, despite plantings of hatchery reared resident rainbow trout in 1945 and 1947, nor were any fish seen in the lower stream in October 1959 (Titus et al. 2010). During a fish passage barrier survey in mid-May 1980, three resident rainbow trout were observed in lower Clear Creek, but the creek mouth still contained a complete migration barrier, and other barriers were identified upstream (Titus et al. 2010). However, DWA (2002) note that Clear Creek is “known to contain steelhead from past sampling and observation”, but no recent information on steelhead presence or abundance appears to be available. A 1996 CDFG memorandum notes that water diversions reduce flows sufficiently to impact Clear Creek, particularly during summer when low flow occurs naturally (Becker and Reining 2008). A county-wide stream crossing inventory and fish passage evaluation concluded that the Clear Creek Road crossing of Clear Creek is fully passable to fish, but that another crossing immediately downstream of Clear Creek Rd “appears very undersized and is probably a barrier” (Ross Taylor & Associates 2004). The report furthermore ranks Clear Creek a low priority stream for fish passage enhancement, in part due to its “limited length of poor-quality habitat” (Ross Taylor & Associates 2004). NMFS (2016) rate approximately 1.4 miles of Clear Creek and approximately 0.1 mile of Sweetwater Creek as having a moderate intrinsic potential to support habitat characteristics suitable for juvenile steelhead rearing, but no intrinsic potential to support coho salmon. Based on the available information, Clear Creek is considered to have limited anadromous salmonid value for the purpose of this assessment.

Felton System

SLVWD’s Felton System relies entirely on surface water diversions from Fall and Bull creeks, tributaries to the middle San Lorenzo River, and Bennett Spring and Creek, tributary to Fall Creek. SLVWD diverts from Fall Creek via a diversion gallery installed in the stream bed which is backwatered by a v-notch weir fitted with a fish ladder. Water is pumped by pipeline to the nearby Kirby treatment plant in Felton. The Bull and Bennett Creek intakes are primarily spring-fed diversions that are combined into a single diversion line to Kirby treatment plant. The Felton System diversions are operated under a permitted appropriative right limited to a combined total diversion rate of 1.7 cubic feet per second (cfs) and a total annual diversion volume of 1,059 afy. The permitted right includes bypass flow requirements on Fall Creek, defined separately for dry and non-dry years, and diversions are not permitted from any Felton source during defined low-flow conditions in the San Lorenzo River. Dry-year and low-flow conditions are defined in terms of the gauged flow of the San Lorenzo River at Big Trees (SLRBT) USGS gage.

The water rights permit defines Fall Creek bypass flows as follow:

Dry years:	0.75 cfs during November 1–March 31
	0.50 cfs during April 1–October 31
Other years:	1.5 cfs during November 1–Mar 31
	1.0 cfs during April 1–October 31

Dry years are defined as water years in which cumulative flows at SLRBT are less than the following amounts:

October:	< 500 af
October–November:	< 1,500 af
October–December:	< 5,000 af
October–January:	< 12,500 af
October–February:	< 26,500 af

Diversions are not permitted from any of the Felton system sources during low-flow conditions when SLRBT flows are less than the following rates:

September:	10 cfs
October:	25 cfs
November–May:	20 cfs

Fall Creek (including Bennett Spring)

Fall Creek is a tributary to the middle mainstem San Lorenzo River in Felton and drains a watershed area of approximately 3,155 acres (4.93 sq. mi.). SLVWD’s water intake is located at an elevation of 350 msl, approximately 0.5 miles upstream of the San Lorenzo River confluence. The watershed area upstream of the intake is 2,770 acres (4.33 sq. mi.) and includes the 285-acre (0.45 sq. mi.) Bennett Spring subbasin. Approximately 5.5 miles of mapped steam channel are located upstream of the diversion. The Bennet Springs intakes are located at elevations of 800-900 ft msl, and the watershed area above the intakes is approximately 225 acres (0.35 sq. mi.).

Fall Creek is known to support steelhead. Juvenile coho salmon were observed in Fall Creek in 1981 (DWA 2009) but have not been detected there since (DWA 2017a). Based on a summary description by DWA (2009), Fall Creek is one of the most shaded and coolest tributaries in the San Lorenzo River watershed. For example, from June 10 through September 30, 2016, the maximum weekly average water temperatures (MWAT) in Fall Creek remained below 15.5°C near its confluence with the San Lorenzo River, and below 16.0°C immediately above SLVWD’s diversion weir (DWA 2017b). Even though much of the creek is within Henry Cowell Park, it is subject to large sediment inputs from steep hillslopes prone to landslides. The landscape is apparently still recovering from past clear-cut logging and limekiln operations. Stream gradient is moderate to steep and the channel is dominated by shallow, fast riffles with relatively few pools.

DWA (2015) conducted habitat typing on Fall Creek upstream and downstream of the SLVWD intake. The 0.5-mile reach immediately downstream of the diversion (Reach 15a) consists of a moderate-gradient (3 percent), entrenched, narrow and heavily shaded channel reach dominated by shallow riffle habitat with limited pool habitat for rearing yearling steelhead or coho salmon. Riffles account for 50 percent of habitat units, while pools account for only 25 percent of available habitat within the reach. Pools are generally shallow with mean and maximum depths of less than one foot (DWA 2015). Upstream of the diversion, DWA (2015) found similar habitat conditions. While the upper survey reach (Reach 15b) is less confined, riffles account for an even higher percentage (61 percent) of habitat, with pools accounting for 24 percent. Juvenile steelhead growth is very slow in Fall Creek despite relatively high summer baseflows, and steelhead are limited by poor pool development, a highly sedimented streambed, and heavy shading (DWA 2009). SLVWD is currently in the process of upgrading the fish ladder to ensure it provides fully passable conditions for both adult and juvenile salmonids.

DWA have sampled juvenile salmonid populations in Fall Creek annually in the fall. Index reach 15b, located upstream of SLVWD’s Fall Creek intake was sampled annually between 1997 and 2001, and from 2008 through the present. Index reach 15a, located downstream of the intake, has only been sampled since 2014. During the five years (2014-2018) that both sites were surveyed, the average total juvenile steelhead density was 37.1 fish/100 ft (± 20.2) at the upstream site (15b) and 34.9 fish/100 ft (± 7.7) at the downstream site (15a). Average densities of fish less than 75 millimeters (mm) standard length during that period were 29.1 fish/100 ft (± 19.7) at the upstream site and 28.5 fish/100 ft (± 7.3) at the downstream site. As such, in addition to presenting similar habitat conditions, baseflow juvenile steelhead densities are also comparable upstream and downstream of SLVWD’s Fall Creek diversion.

Bennett Creek joins Fall Creek approximately 0.3 miles upstream of SLVWD’s Fall Creek diversion intake. In 1980, CDFG staff stated, “Bennett Creek is impassable to upstream migrating fish”, but in terms of streamflow contributions, the drainage has been characterized as a “significant perennial tributary” to Fall Creek (Becker and Reining 2008).

Bull Creek

Bull Creek is a tributary to the middle mainstem San Lorenzo River in Felton and drains a watershed area of approximately 455 acres (0.71 sq. mi.). SLVWD operates two water intakes on Bull Creek at an elevation of approximately 800 ft msl. The combined drainage area upstream of the two diversion points is approximately 175 acres (0.27 sq. mi.).

A 1975 CDFG protest to the water right application on Bull Creek attributes steelhead “spawning and nursery areas” to the creek but does not provide evidence of steelhead observations (Becker and Reining 2008). CDFG staff interviewed a local landowner in the Bull Creek watershed who noted that he had never seen salmonids in the stream (Becker and Reining 2008). A 2014 fishery assessment of Bull Creek concluded that the drainage provides very limited, poor quality habitat for a small, presumably resident rainbow trout population (DWA 2014). Spawning conditions were noted to be very poor in this highly sedimented stream. A 900-foot culvert system near its confluence with the San Lorenzo River was deemed to effectively prohibit or severely limit passage for adult steelhead into Bull Creek (Kittleson 2017). DWA (2014) concluded that habitat conditions in Bull Creek “would not likely improve with higher baseflow due to very poor pool development” and that “no measures are warranted to improve steelhead or coho access to this small tributary or to consider instream flows for steelhead or coho salmon in Bull Creek.” Based on the available information, Bull Creek is not considered to have anadromous salmonid value for the purpose of this assessment, but Kittleson (2017) notes that Bull Creek should be managed to protect or enhance habitat for the existing resident rainbow trout population.

Loch Lomond Reservoir

In 1958, SLVWD sold 2,500 acres of land encompassing a portion of the San Lorenzo River tributary watershed of Newell Creek to the City of Santa Cruz (City) with the agreement that SLVWD would be entitled to purchase 12.5 percent of the annual safe yield from a reservoir planned by the city. The City created Loch Lomond Reservoir with the completion of Newell Creek Dam in 1960. The reservoir has a drainage area of 8.3 sq. mi. and a reservoir capacity of approximately 9,000 af. The City’s Newell Creek appropriative water right license authorizes a maximum of 5,600 afy of water to be diverted to storage between September 1 and July 1. The maximum amount of withdrawal of water from storage in the Loch Lomond Reservoir under this license is limited to 3,200 afy. The City is also authorized to divert water from the San Lorenzo River at the Felton Diversion Facility under two separate water right permits that allow for a combined maximum diversion of 3,000 afy to storage at Loch Lomond Reservoir between September 1 and June 1 under one permit and October 1 and June 1 under the other permit (City of Santa Cruz 2018). Water diverted at Felton is transported by a large diameter pipeline and a series of pump stations to Loch Lomond Reservoir for storage. Water from both the Felton Diversion and Newell Creek are stored in Loch Lomond Reservoir, and the total maximum amount of water that is authorized to be held in the reservoir is 8,624 afy (City of Santa Cruz 2018).

SLVWD began receiving a portion of the reservoir yield after the dam was completed, although records are only available for 1976–77, when it received 353 af. SLVWD has not received any water from Loch Lomond since 1977. Since implementation of the Federal 1989 Surface Water Treatment Rule, SLVWD has not had the means to treat diversions from Loch Lomond. In 1996, the City and SLVWD reached a draft agreement that allows SLVWD to purchase up to 313 afy of raw Loch Lomond water or purchase the same amount of treated city water with the understanding that it would be interruptible during declared water-shortage emergencies (Kocher 1996). SLVWD has yet to exercise either allowance under this agreement. To exercise its allotment, SLVWD may need to connect to the City’s raw water line and expand the Kirby water treatment plant (SPH Associates 2010, cited in Exponent 2019).

Since 2001, the City has been developing a Habitat Conservation Plan (HCP) with NMFS and CDFW for federal and California Endangered Species Act compliance for water supply operations that may affect steelhead and coho salmon (City of Santa Cruz 2018). As part of the HCP process, the City, NMFS, and CDFW negotiated minimum flow requirements for streams affected by the City’s diversions, including Newell Creek and the San Lorenzo River at Felton, the two sources of Loch Lomond water. Moreover, the City has committed to implementing these minimum flows as part of its water rights modification process regardless of the final outcome of the HCP process (City of Santa Cruz 2018). Although SLVWD has the right to a 313 afy allotment of stored Loch Lomond water, this water is diverted by the City pursuant to applicable bypass requirements at Newell Dam and the Felton Diversion for the protection of steelhead and coho salmon. SLVWD therefore does not have any bypass flow requirements associated with its Loch Lomond allotment.

2.3.2 Groundwater Resources

SLVWD draws approximately 45 percent of its average annual water supply from three loosely defined groundwater subareas of the SMGB (Exponent 2019). In addition to SLVWD, the Scotts Valley Water District (SVWD) and Mt. Hermon Association (MHA) also operate groundwater wells within the SMBG. Wells in the Quail Hollow and Olympia areas are part of SLVWD's North System, and the Pasatiempo area wells are part of SLVWD's South System, which is supplied solely by groundwater. As described in the WAA (Exponent 2019), wells operated by SLVWD do not draw directly from alluvial aquifers and do not directly induce streamflow infiltration because area groundwater levels are generally higher than the elevation of the gaining streams that dissect or bound the groundwater subareas. As such, SLVWD's wells may intercept groundwater flowing *toward* springs and streams, but generally do not draw water directly *from* streams (Exponent 2019). The streams assumed to be indirectly affected by SLVWD's groundwater production are primarily Bean and Zayante creeks, and to a lesser extent Newell Creek and the mainstem San Lorenzo River (Exponent 2019). The fishery resources of these streams are briefly described below.

Zayante Creek

Zayante Creek is a major eastern tributary to the San Lorenzo River in Felton and the confluence marks the dividing line between the middle and lower San Lorenzo River, as defined in Alley et al. (2004). Based on a DWA (2009) synopsis of salmonid habitat conditions, Zayante Creek and its tributary Bean Creek (discussed below) are significant contributors to the juvenile steelhead population and adult index of the San Lorenzo River watershed. Lower Zayante Creek, downstream of the Bean Creek confluence, receives heavy sediment inputs from Bean Creek, but supports relatively high growth rates for juvenile steelhead in wetter years with higher spring and summer baseflow. Juvenile densities are typically low. Between the Bean Creek confluence and the Lompico Creek[1] confluence, long pools dominate the stream. Stream shading is moderate and instream wood and overhanging vegetation provide good cover. Upstream of Lompico Creek, the stream gradient increases and step-run habitat units become more abundant. Large yearling steelhead are abundant in pools. Despite higher annual streamflows than other San Lorenzo River tributaries, low summer streamflow and sedimentation are considered the primary factors limiting fish habitat in Zayante Creek (Alley et al. 2004).

Bean Creek

Based on the summary description of DWA (2009), the lower reaches of Bean Creek near Mount Hermon are prone to heavy fine sediment loading from landslides and recreational use has

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[1] In 2015, SLVWD assimilated the Lompico County Water District, including its diversion on Lompico Creek. However, SLVWD does not currently operate this diversion, and this water source is not considered in the conjunctive use plan evaluation.

degraded summer habitat for salmonids. A short reach between Mt. Hermon Road and Ruins Creek has historically supported an intact riparian corridor and good pool cover provided by instream wood in a meandering stream channel. This short reach is periodically a very productive steelhead segment. Upstream of the Ruins Creek confluence, summer baseflows are low, with variable segments frequently drying out. Upstream of the Mackenzie Creek confluence summer streamflows remain low and steelhead are restricted to available pool habitats. Juvenile coho salmon were observed in this low gradient, cool water reach in 2005 (DWA 2009). Surface flow in upper Bean Creek is thought to be vulnerable to groundwater pumping (DWA 2009).

Newell Creek

Newell Creek is a tributary to the San Lorenzo River in Ben Lomond. The Loch Lomond Reservoir is located approximately 1.7 miles upstream of the San Lorenzo River confluence. The Newell Creek watershed area is approximately 9.9 sq. mi, with the reservoir capturing runoff from approximately 8.3 sq. mi. Below the reservoir, Newell Creek has approximately one mile of easily accessible steelhead habitat below a bedrock chute that presents a significant impediment to fish passage (HES 2014). Winter spawning flows are likely much reduced in Newell Creek until the reservoir fills and spills in winter (DWA 2009). The water right license for Loch Lomond requires year-round minimum releases of 1 cfs to Newell Creek. Hydrologic modeling indicates that the operation of the reservoir results in a slight reduction in median flows through the anadromous reach (compared to reservoir inflows) during the early part of the juvenile salmonid rearing period in wet, normal and dry years, and in an augmentation of median flows during the latter part of the rearing period due to the 1 cfs minimum release (ENTRIX, Inc. 2004, cited in HES 2012). Total juvenile steelhead densities in Newell Creek near its confluence with the San Lorenzo River have fluctuated greatly between 2009 and 2018, ranging from less than 10 fish/100 ft during the drought years of 2014 through 2016, to over 35 fish/100 ft in 2012 and 2013 (County of Santa Cruz 2019). The 10-year average total juvenile density for the Newell Creek sampling site is 19.0 (± 13.6) fish/100 ft (County of Santa Cruz 2019).

CHAPTER 3
Existing Effects Analysis

3.1.1 Methods

The WAA for the San Lorenzo River Watershed Conjunctive Use Plan (Exponent 2019) presents alternative scenarios for optimizing the conjunctive use of existing and potential water sources to improve SLVWD's water-supply reliability within the San Lorenzo River watershed. To support the comparative analysis of conjunctive use alternatives, Exponent (2019) simulated monthly streamflow estimates and potential diversions based on estimated frequencies of mean daily flow adjusted for month and hydrologic year-type (e.g., wet, dry, etc.) over a 48-year climatic cycle spanning water years (WY) 1970-2017. As noted by Exponent (2019), the results of the WAA provide qualitative indications of the potential relative magnitude and effects of the various conjunctive use alternatives and are suitable for planning-level evaluations, but the synthesized monthly records of water supply and use "have limited precision and should not be used to evaluate compliance with specific regulatory, water-right, or habitat requirements." As such, the synthetic streamflow estimates developed for the WAA were not used to evaluate potential existing effects of SLVWD's surface water diversions on salmonid habitat conditions, but rather as a comparative tool for differentiating the relative potential benefits of the different conjunctive use scenarios presented in Chapter 4.

Since 2014, SLVWD has contracted with Balance Hydrologics, Inc. (Balance) to gage and analyze streamflows in channels serving as surface water sources to better understand how its diversions may affect flow and aquatic habitat in the San Lorenzo River and its tributaries. Although the hydrologic record developed through this intensive monitoring program extends over only four water years (2014-2017), it includes the severe drought conditions of WYs 2014 and 2015, near-average conditions of WY 2016, and the record-setting wet conditions of WY 2017 (i.e., 300 percent of mean 1937-2017 annual flow at SLRBT), and therefore provides a valuable range of actual streamflow and habitat conditions that steelhead, coho salmon, and other native fishes may reasonably be expected to experience in the San Lorenzo River watershed. Balance has prepared four separate annual monitoring reports (Balance 2015, 2018a, 2018b, and 2019)[2]. The data summaries provided in these reports informed the evaluation of existing effects of SLVWD's diversions on fisheries habitat.

In support of Balance's streamflow monitoring effort, DWA (2018a) evaluated potential water temperature effects of SLVWD's surface water diversions during the same four WY (2014-2017)

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[2] References to Balance streamflow data presented in this effects analysis frequently span all four monitoring years and associated annual reports. As such, these data are simply cited as "Balance", without reference to specific report publication years.

period. Summer baseflow water temperatures were recorded with continuous data loggers deployed in tributary streams affected by SLVWD diversions as well as in the mainstem San Lorenzo River upstream and downstream of the confluences of those tributaries. Applying widely-cited salmonid temperature studies, DWA (2018a) used maximum weekly average temperature (MWAT) threshold criteria of 20 degrees celsius (°C) and 16.7°C to evaluate rearing habitat suitability for juvenile steelhead and coho salmon, respectively. The results of this study were applied to the analysis of existing effects of SLVWD diversions on fisheries habitat suitability.

DWA (2018b) also conducted an assessment of salmonid fish passage flow requirements in Fall Creek downstream of SLVWD's Fall Creek diversion using a critical riffle analysis methodology based on CDFW's standard operating procedure for such analyses (CDFG 2012). Critical riffle analyses consist of empirical evaluations of the relationship between stream discharges and water depths across the most critical (i.e., shallowest) riffles. The CDFW standard protocol specifies conservative minimum depth requirements for various life stages of salmonids (i.e., adults, smolts, and juveniles), but DWA (2018b) developed alternative minimum depth criteria based on available regional data of fish sizes. Based on the results of the analysis, DWA (2018b) estimate a 17-27 cfs instream flow requirement for adult steelhead and coho salmon passage and spawning, approximately 7 cfs for yearling and older juvenile salmonids, and 1-2 cfs for young-of-the-year juvenile movement (Table 3-1).

Instream flow criteria, such as those derived from critical riffle analyses or Physical Habitat Simulation (PHABSIM) studies, are used by fisheries managers and regulatory agencies to determine site-specific bypass flow requirements at surface water diversions. For the purposes of this conjunctive use plan evaluation, however, such criteria are arguably of lesser value because, from a fisheries perspective, the overall goal of the plan is to *increase* summer baseflow levels to the greatest extent possible in stream reaches where baseflows are most limiting to juvenile salmonid growth and survival. As such, a conjunctive use scenario that is estimated to increase summer baseflows in a priority salmonid stream by 0.25 cfs would be considered more beneficial for fisheries resources than one that would not increase baseflows in that stream, regardless of specific summer juvenile salmonid rearing flow requirement estimates that may have been developed for this stream. Furthermore, any increases in winter high flow diversions considered in the WAA for some conjunctive use scenarios would be relatively minor and consist only of diverting water that exceeds winter demand at existing diversion rates and capacities[3] for transfers to another system (e.g., for in-lieu recharge). As documented by Balance and described below, SLVWD's existing surface water diversions in the North and Felton system are relatively small and therefore have negligible effects on the high winter flows necessary for adult salmonid passage and spawning. As natural stream flows gradually recede in the spring, the relative effects of SLVWD diversions on flows increase. Based on available data, however, SLVWD's diversion

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[3] The WAA analyzes three conjunctive use scenarios (1c, 1d, and 1e) under which SLVWD would double the diversion, conveyance, and treatment capacities of the North and Felton system diversions. However, SLVWD did not select either of these scenarios for implementation in the foreseeable future. Should such an expansion of diversion capacities be considered in the future, more detailed instream flow requirement analyses should be conducted to assess the potential effects of increased diversion rates on downstream fisheries habitat.

rates do not appear to significantly affect spring flows necessary for juvenile salmonid (smolt) migration to the ocean either. Balance (unpublished) compared the frequencies with which the DWA (2018b) minimum smolt passage flow requirement of 7.1 cfs was met or exceeded upstream and downstream of SLVWD's Fall Creek diversion during the spring (March 15 – June 30) period of WY 2014-2017. On average, the passage threshold was exceeded on 38 days upstream of the diversion and on 37 days downstream of the diversion, suggesting that diversions rarely affect attainment of the smolt instream flow recommendation on Fall Creek.

In-lieu of extensive instream flow needs assessments with limited relevance to this conjunctive use evaluation, a standard setting hydrology-based "desktop" procedure applied by CDFW (2017) to develop interim instream flow determinations was used for this analysis to provide rough theoretical estimates of relative flow targets for the two primary fisheries streams affected by SLVWD surface water diversions, Boulder Creek and Fall Creek. Insufficient hydrologic data were available to conduct a similar analysis on the significant fisheries tributaries affected by groundwater extractions (Bean and Zayante creeks)[4]. The CDFW (2017) methodology consists of the application of the following three standard setting methods to identify flow needs for priority stream functions:

- R2 Consultants (2008) regression formula using watershed area, mean annual discharge, and minimum passage depth requirement to estimate an appropriate passage flow (Qfp). The equation was developed using data from cross sections collected in 13 streams in Mendocino, Sonoma, Napa, and Marin counties, is considered to be descriptive of streams over a broader region (R2 Consultants 2008).
- Hatfield & Bruce (2000) regression equations for adult spawning and juvenile rearing. These equations were developed using the "peak of the curve" results (i.e., optimum flow) from 127 PHABSIM studies conducted across western North America, with most of the data representing California, Washington, Idaho, and Oregon.
- Tessmann (1980) adaption of the Tennant (1975) method for basin wide hydrology.

The results of the standard setting hydrology-based analysis for Fall Creek compared favorably to the empirical estimates provide by DWA (2018b) (Table 3-1), suggesting that the Boulder Creek estimates are sufficiently applicable for planning-level purposes.

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[4] Exponent (2019) provide mean monthly unimpaired flow estimates for streams containing SLVWD surface water diversions, but not for stream affected by groundwater extractions.

TABLE 3-1

LIFESTAGE-SPECIFIC INSTREAM FLOW RECOMMENDATIONS (CFS) FOR FALL CREEK AND BOUDLER CREEK BASED ON EMPIRICAL AND STANDRAD-SETTING METHODOLOGIES

	Fall Creek (DWA 2018b)	Fall Creek (CDFW 2017)	Boulder Creek (CDFW 2017)
Adult migration/spawning	17-27	16.6	19.6
Smolt migration	7.1	7.1	8.4
Juvenile movement/rearing	1-2	1.9	2.0

3.1.2 Surface Water Resources

North System

Boulder Creek

SLVWD's diversions on Peavine and Foreman creeks affect streamflow in Boulder Creek. The combined maximum capacity of these two diversions is 2.7 cfs, but maximum diversion rates in the North System generally cannot occur simultaneously because of limited raw water conveyance and treatment capacities (Exponent 2019). Based on SLVWD production records and diversion gaging conducted by Balance during May 2014 through September 2017, the highest average monthly combined diversion rate at the Peavine and Foreman facilities was approximately 2.0 cfs in March and April of 2017, in the midst of a water year with approximately 300 percent of the historic (1937-2017) mean annual discharge for the San Lorenzo River watershed (Balance 2019). During the drought years of 2014 and 2015, the combined mean monthly diversion rates from the Boulder Creek tributaries only exceed 1.0 cfs on one occasion (December 2015) and were less than 0.25 cfs during July through September baseflow conditions.

Balance compared gaged daily mean flows in Boulder Creek to the combined monthly mean SLVWD diversion rates in Peavine and Foreman creeks to calculate the relative percentages of decreased Boulder Creek flow downstream of the tributary confluences resulting from the diversions. Based on this analysis, SLVWD diverts between 0.1 to 38.3 percent of Boulder Creek flows at the Peavine and Foreman diversions annually. As would be expected based on limited diversion capacities and variable seasonal streamflows, SLVWD's diversions generally account for less than 5 percent of Boulder Creek flows during the winter and early spring. Beginning in May, SLVWD's diversions account for gradually increasing percentages of the unimpaired flow and typically decrease Boulder Creek summer baseflows by over 25 percent in July through September. It should be noted that the highest relative diversion-related reductions in Boulder Creek flows documented by Balance occurred in July through September of very wet WY 2017. In below-normal (2014 and 2015) and normal (2016) water years, the Peavine and Foreman diversions are largely limited to a combined total of less than 0.25 cfs by low summer baseflows in these two tributaries, but higher WY 2017 baseflows enabled SLVWD to maintain combined average monthly diversion rates exceeding 1.0 cfs, thereby accounting for a greater portion of Boulder Creek flows. Nevertheless, even with SLVWD's higher average diversion rates, WY 2017 impaired flows in Boulder Creek remainder above the instream flow recommendation level

(2.0 cfs) derived from application of the CDFW (2017) methodology for much of the July through September baseflow period. During the relatively normal water year of 2016, however, impaired Boulder Creek flows measured during July through September were slightly below the CDFW (2017) flow recommendations. During WYs 2014 and 2015 drought conditions, July through September, even unimpaired Boulder Creek streamflows were well-below the CDFW (2017) recommendations. Although adding SLVWD diversions back into the impaired monthly mean flows would not have attained recommended instream flow levels, even the limited summer diversions that occurred during these two years likely exacerbated already critically low and presumably stressful streamflow conditions for juvenile salmonids and other native fish in Boulder Creek.

Summer water temperature monitoring conducted by DWA (2018a) in WYs 2014-2017 indicates that temperatures remained below the juvenile steelhead target MWAT threshold of 20°C at three Boulder Creek monitoring sites (upstream of the Peavine Creek confluence, downstream of the Foreman Creek confluence, and immediately upstream of the mainstem San Lorenzo River) during all four years. Based on these data, DWA (2018a) concluded that SLVWD water diversions appeared unlikely to result in adverse temperature impacts to steelhead in Boulder Creek.

Maximum weekly average temperatures at the three Boulder Creek sites exceeded the conservative target MWAT threshold of 16.7°C for juvenile coho salmon in 2014 and 2015 (DWA 2018a). In 2016, the coho salmon criterion was met upstream of Peavine Creek, but was exceeded below Foreman Creek and above the San Lorenzo River for one week (DWA 2018a). Notably, the coho salmon criterion was exceeded for one week upstream of Peavine Creek and for over two weeks downstream of Foreman Creek during the above-average WY 2017. As noted by Balance (2019), review of the data from four years of monitoring suggests that more flow does not necessarily mean lower water temperatures, either universally within the valley or (seemingly) in specific cases where known special geologic or other natural factors apply.

Balance (2018b) also monitored and analyzed streamflow and water temperature data when all diversions from the North System, including Peavine and Foreman, were shut down for maintenance of the Lyon Water Treatment Plant from September 1 to 7, 2016. Based on the analysis, shutting down the Peavine and Foreman diversions did not have a discernible effect on stream temperature during the shutdown period (Balance 2018). It is important to note, however, that the shutdown occurred during a time of regionally cool temperatures, which may have masked the effects of the additional cool water inflows from the streams usually used for diversions into the SLVWD system (Balance 2018).

Clear Creek

As described above, available fisheries resource information for Clear Creek and its tributary, Sweetwater Creek, is limited. Due to its steep topography, noted limited habitat, and lack of definitive evidence of utilization by anadromous salmonids, SLVWD's diversions in the Clear Creek drainage were evaluated in the context of their potential effects on downstream fisheries resources in the mainstem San Lorenzo River. This focus on the mainstem should not be interpreted as implying that Clear Creek does not support valuable ecological functions, but rather that this tributary is considered a lower priority for conjunctive use-related enhancements to salmonid habitat than streams with consistently documented salmonid utilization.

The combined maximum diversion capacity of Clear Creek diversion boxes 1, 2 and 3 is 0.7 cfs, and the capacity of the Sweetwater Creek diversion is 0.6 cfs (Exponent 2019). As discussed above, existing limitations in the North System’s delivery and treatment capacity mean that these maximum capacities are rarely, if ever, fully utilized. Based on Balance monitoring, the monthly mean diversion rate from Clear Creek was typically less than 0.25 cfs during WYs 2014-2017, and the highest diversion rate was 0.45 cfs (April 2016). July through September diversion rates were typically less than 0.1 cfs. For the Sweetwater Creek diversion, monthly mean diversion rates were typically less than 0.2 cfs, and the highest rate was 0.34 cfs (January 2016). Water is rarely diverted at the Sweetwater diversion during the July-September baseflow season. SLVWD typically operates the Clear Creek system to bypass at least 35 gpm (0.08 cfs) to provide for a 30 gpm downstream water right.

Based on synoptic streamflow measurements conducted by Balance, the combined Clear Creek and Sweetwater Creek diversions typically account for a reduction of less than approximately 9 percent of mainstem San Lorenzo River flows, with the greatest relative reductions occurring during the summer baseflow period. For example, measurements collected in August 2016 show a combined diversion rate of 0.31 cfs and a mainstem San Lorenzo River streamflow of 3.17 cfs below the Clear Creek confluence.

Water temperatures in Clear Creek tend to remain cool throughout the summer, consistently satisfying the juvenile steelhead MWAT threshold of 20°C and exceeding the 16.7°C coho salmon threshold only occasionally for short periods of time (DWA 2018a). In comparison to temperatures in Clear Creek, water temperatures in the San Lorenzo River below Clear Creek are typically about 1-4°C warmer. The San Lorenzo River upstream and downstream of the Clear Creek confluence exceeded the steelhead temperature criterion during 2014 and 2015 drought conditions, but generally remained below that threshold in 2016 and 2017 (DWA 2018a). The coho salmon criterion was not satisfied above or below the Clear Creek confluence in either of the four monitoring years. During the summer months, Clear Creek serves to cool the San Lorenzo River to a small degree, but not sufficiently to affect attainment of temperature criteria. It should be noted, however, that deep pools in the San Lorenzo River below Clear Creek are, at times, stratified and provide cooler refuge conditions for salmonids (DWA 2018a). Cool water inflows from Clear Creek likely help maintain the cooler pool temperatures at depth.

Fall Creek

Fall Creek is a well-documented steelhead stream and is known to have supported coho salmon in the past. As such, SLVWD’s diversion on Fall Creek has the potential to affect salmonids in Fall Creek as well as in the San Lorenzo River downstream of Fall Creek. SLVWD’s Bennet Spring diversions are located upstream of the limit of anadromy, but diversions may also affect Fall Creek and San Lorenzo River fisheries resources. The maximum capacity of the Fall Creek diversion is 0.6 cfs and approximately 0.5 cfs for the Bennett Spring diversions (Exponent 2019). However, as is the case in the North system, the Felton system is limited by treatment capacities. Felton system diversions (including from Bull Creek) are processed by the Kirby water treatment plant, which has a design capacity of 700 gpm (1.6 cfs) but typically operates at half capacity using only one of two units (Exponent 2019). The maximum continuous monthly production rate of the Kirby WTP is approximately 425 gpm (1.0 cfs). During WYs 2014-2017, mean monthly diversions at Fall Creek never exceeded 0.5 cfs. Unlike North system diversions, however, Fall Creek diversions do not vary greatly from season to season. Based on SLVWD production records, diversions from Bennett Spring rarely reach 0.4 cfs.

Balance measures Fall Creek streamflow at two gaging sites. Since August 2013, Balance has maintained a stream gage about 150 feet upstream of the Fall Creek diversion. This open-channel flow gage is in a straight and confined reach of the creek located within the Fall Creek Unit of Henry Cowell Redwoods State Park. This gage is located downstream of the Bennett Creek confluence. A stage recorder is also operated by SLVWD just upstream and next to the Fall Creek diversion weir, recording data at 2-minute intervals, facilitating calculation of bypass flow through SLVWD’s V-notch weir for the full year. Prior to peaks in very high-flow events, SLVWD removes the V-notch weir to protect it from damage. Balance staff have developed a rating curve for the V-notch weir, to a maximum calibrated flow of 5.8 cfs. The stage data and operations logs from SLVWD are used by Balance to complement and validate the upstream gaging record. However, Balance (2019) notes that the calibration of flow past the v-notch weir in relation to the upstream gage is challenging due to the coarse resolution of the staff plate at the v-notch and a high degree of turbulence and water-level fluctuations at the sensor location. The temporary dewatering of the Fall Creek fish ladder immediately downstream of the v-notch weir in 2018 also revealed a substantial amount of leakage through and around the weir (Podlech pers. obs.), therefore resulting in underestimation of bypass flows measured by the v-notch stage recorder. To better estimate flow at the v-notch weir, or flow bypassed past the diversion, Balance began using SLVWD’s analog spiral graphs of instantaneous diversion records to quantify bypass flows, where flow downstream was calculated by subtracting diversion from the upstream flow record.

Based on WY 2014-2017 flow data, summer baseflows in Fall Creek upstream of the diversion were approximately 1 cfs during the drought years of 2014 and 2015, 2 cfs in the near-normal year 2016, and 3 cfs in the above-average year 2017. Mean monthly Fall Creek diversion rates during July through September 2014-2017 ranged between 0.3-0.5 cfs, thus reducing flows below the diversion by that amount. During drought years (e.g., 2014 and 2015), these diversion rates may reduce Fall Creek flows by up to 50 percent (e.g., Balance 2018a), but DWA (2018b) note that even during those conditions, juvenile steelhead reared successfully downstream of the diversion under the cool water conditions typical for Fall Creek. DWA (2018b) estimate that a baseflow of approximately 1-2 cfs in Fall Creek is sufficient to provide hydrologic connectivity (defined as minimum depth of 0.1 ft across the shallowest riffles) during the spring and early summer juvenile redistribution period, but also note that juvenile steelhead reared successfully below the diversion during lower drought (WYs 2014 and 2015) baseflows conditions.

As described in Section 2.3.1 above, surveys conducted by DWA have documented similar baseflow habitat conditions and juvenile steelhead densities upstream and downstream of SLVWD’s Fall Creek diversion. Moreover, the juvenile steelhead MWAT threshold of 20°C was satisfied both upstream and downstream of the Fall Creek diversion in all four monitoring years

(DWA 2018a). The significantly lower coho MWAT criterion of 16.7°C was also satisfied at both locations most of the time, with a period of 1.5 weeks in 2015 and 2 days in 2017 at the downstream location being the only exceptions (DWA 2018a). However, even during those short periods, the MWAT at the lower site did not exceed 17°C.

Based on available streamflow, physical habitat, water temperature, and fish density data, SLVWD's Fall Creek diversions do not appear to have discernable effects on the fisheries resources of this tributary stream, although diversions during severe drought conditions likely exacerbate already stressful conditions.

Based on synoptic streamflow measurements conducted by Balance, diverted flow versus total flow in the San Lorenzo River downstream of Fall Creek during water years 2014-2017 ranged from about 1 percent to slightly over 10 percent. As would be expected, the greatest relative percentages are higher (up to 10 percent) under the drought conditions prevalent during WYs 2014 and 2015, and lower (5 percent or less) during years of normal or wet conditions such as 2016 and 2017, respectively. At the time of the greatest measured effect (10.8 percent) of Fall Creek diversions on San Lorenzo River flows, measurements collected in September 2015 show a mainstem flow of 3.89 cfs below the Fall Creek confluence. Adding SLVWD diversions back in would have resulted in an estimated mainstem flow of 4.36 cfs, assuming no streamflow gains or losses between the diversion facility and the mainstem.

Based on water temperature monitoring conducted on the San Lorenzo River immediately upstream and downstream of the Fall Creek confluence, inflows to the mainstem river helped reduce the period of juvenile steelhead temperature threshold exceedances during 2014 and 2015 drought conditions from 4.5-5.5 weeks upstream of Fall Creek to only one week (during which it was nearly met) downstream of Fall Creek (DWA 2018a) in each of the two years. DWA (2018a) note that water diversion from Fall Creek may have prevented the temperature criterion from being fully met in the mainstem river below Fall Creek downstream to the Bull Creek confluence during the drought years of 2014 and 2015. The coho salmon temperature criterion was never satisfied during four years of monitoring, either upstream or downstream of the Fall Creek confluence (DWA 2018a). Unlike some of the tributary streams, summer water temperatures in the mainstem San Lorenzo River are generally considered too warm for juvenile coho salmon rearing.

During normal and above-normal water years, SLVWD's Fall Creek diversions are unlikely to have discernable effects on San Lorenzo River mainstem fisheries resources due to the relatively minor relative contributions of Fall Creek flows to the mainstem San Lorenzo River. However, the relative contributions from Fall Creek to the mainstem are much higher during prolonged drought conditions due to the tributary's karst geology providing more persistent (multi-year) groundwater outflows (Balance 2018b). During these extreme low flow conditions, Fall Creek diversions account for up to 10 percent of potential loss to mainstem flows. While even impaired Fall Creek inflows help to improve mainstem salmonid habitat quality (e.g., reduced water temperatures) during severe drought conditions, this relative loss of inflow may exacerbate already stressful conditions in the mainstem San Lorenzo River.

Bull Creek

As described above, Bull Creek is a small tributary to the San Lorenzo River characterized by poor salmonid habitat quality and a significant migration barrier in its lowermost reach precluding anadromous salmonid access. A resident rainbow trout population is present in Bull Creek. SLVWD's diversions from Bull Creek were evaluated primarily in the context of potential effects on downstream fisheries resources in the mainstem San Lorenzo River.

The maximum capacity of SLVWD's Bull Creek diversion is 0.5 cfs (Exponent 2019). Based on Balance monitoring, the monthly mean diversion rate from Bull Creek during WYs 2015-2017, was typically less than 0.25 cfs, and the highest documented monthly diversion rate was 0.32 cfs (February 2016). July through September diversions were typically around 0.1 cfs.

Balance's synoptic flow investigations on the mainstem San Lorenzo River did not include measurements immediately downstream of Bull Creek, and the potential relative reduction in streamflow resulting from the Bull Creek diversions is not known. However, given that Bull Creek diversion rates are similar to those on Clear Creek, particularly during the July-September low flow period, and San Lorenzo River flows are higher below Bull Creek than below Clear Creek, it is reasonable to assume that Bull Creek diversions reduce San Lorenzo River flows by less than 5 percent during the low flow season.

Water temperature in Bull Creek tends to remain cool throughout the summer, consistently satisfying the juvenile steelhead MWAT threshold of 20°C and satisfying the 16.7°C coho salmon threshold during the normal and wet water years of 2016 and 2017, respectively (DWA 2018a). However, due to the limited relative contribution of Bull Creek flows to the mainstem, accretions from this tributary do not appear to affect San Lorenzo River water temperatures, with the steelhead criterion generally being met both upstream and downstream of the Bull Creek confluence while the coho salmon criterion was never met upstream or downstream during the monitoring period.

3.1.3 Groundwater Resources

The potential effects of groundwater extractions on surface water streamflows, and thereby on fisheries resources, is more difficult to quantify. Groundwater pumping reduces the amount of groundwater that flows to streams and, in some cases, can draw streamflow into the underlying groundwater system. As described by Exponent (2019), SLVWD's wells may intercept groundwater flowing toward springs and streams, but generally do not draw water directly from streams because area groundwater levels are generally higher than the elevation of the gaining streams that dissect or bound the groundwater subareas. As such, Exponent (2019) evaluated the potential effects of groundwater pumping by comparing rates of average annual pumping to minimum (drought) rates of stream baseflow. This approach assumes that monthly average pumping rates are similar throughout the year and that the relative effects of pumping on streamflow increase as streamflows decrease, with the greatest effects occurring during minimum baseflow conditions. To develop estimates of the potential effects of current pumping on streamflow, Exponent (2019) compared estimates of minimum monthly impaired baseflow with recent average monthly groundwater pumping rates. Because the effects of pumping are already reflected in the gauged and estimated streamflow records (i.e., impaired flows), Exponent (2019) estimated the potential percent reduction in minimum monthly baseflow as the average groundwater pumping rate divided by the combined rates of baseflow and pumping to calculate the percent of baseflow remaining as a result of pumping. It should be noted that this approach assumes a 1:1 relationship between pumping and streamflow reductions. In other words, the analysis assumes that every acre-foot of groundwater pumped represents an acre-foot of surface water flow reduction, and is therefore a conservative (i.e., worst-case) estimate of pumping effects on streamflow. A more refined evaluation of potential surface water-groundwater interactions would require the use of a numerical groundwater flow model, which was beyond the scope of the WAA study.

Based on this method, Exponent (2019) estimated that the average rates of SLVWD, SVWD, and MHA groundwater pumping may reduce Newell, Zayante, and Bean creek baseflows by roughly 50 percent during worst-case drought conditions (see WAA Table 5-3). Drought baseflow reductions in the San Lorenzo River at the SLRBT gage are estimated at almost 30 percent. For example, the combined effects of SLVWD, SVWD, and MHA groundwater pumping is estimated to reduce drought baseflows in Bean Creek at the Zayante Creek confluence from approximately 0.5 cfs to 0.25 cfs. Such reductions in streamflow during critically stressful conditions likely have detrimental effects on juvenile salmonids growth and survival.

3.1.4 Summary

SLVWD’s typical surface water diversion rates constitute a minor portion of the winter high flow season. Beginning in May, the diversions account for gradually increasing percentages of the unimpaired flow. During summer (July through September) baseflow conditions, SLVWD’s have variable effects on fisheries resources depending on water year type, diversion rates, and downstream resource sensitivity. During drought baseflow conditions, surface water diversions likely reduce streamflows sufficiently to exacerbate already stressful juvenile salmonid rearing conditions, particularly in Boulder Creek. Water temperatures are generally not affected by surface water diversions such that rearing habitat suitability downstream of the diversions is altered.

The effects of groundwater extractions on eastern watershed tributaries (e.g., Zayante and Bean creeks) are also largely inconsequential during most of the year, but can result in reductions of up to 50 percent of drought minimum baseflows in these streams at critically stressful times.

Table 3-2 summarizes typical effects of SLVWD’s diversions and pumping on San Lorenzo River watershed streams.

TABLE 3-2

SUMMARY OF ESTIMATED EFFECTS OF SLVWD SURFACE WATER DIVERSIONS AND GROUNDWATER EXTRACTIONS ON SAN LORENZO RIVER WATERSHED STREAMS

Surface Water Sources	Typical maximum diversion rate (cfs)	Typical Jul-Sep diversion rate (cfs)	Jul-Sep diversion % of receiving stream* flow	Steelhead MWAT met below diversion	Coho salmon MWAT met below diversion
Peavine/Foreman Creeks	2.0	<0.25	>20	✓	X ✓
Clear/Sweetwater Creeks	0.7	<0.1	<9	✓	✓
Fall/Bennett Creeks	0.9	0.5	<10	✓	✓
Bull Creek	0.3	0.1	<5	✓	X ✓

Groundwater Sources	Estimated Mean Monthly Loss (cfs) from SLVWD Groundwater Production	% Loss of Drought Minimum Baseflow from SLVWD Groundwater Production
Newell Creek at San Lorenzo River	0.1	49
Zayante Creek above Bean Creek	0.4	53
Zayante Creek at San Lorenzo River		27
Bean Creek at Zayante Creek	0.9	23
San Lorenzo River above Fall Creek	0.1	7
San Lorenzo River at USGS gage		16

* = next downstream named waterbody (e.g., San Lorenzo River in the case of Fall Creek)

✓= typically meets criterion

X ✓= typically meets criterion during wet and normal water years, but not in dry years

CHAPTER 4

Conjunctive Use Effects Analysis

Of the 22 individual conjunctive use scenarios simulated by Exponent (2019) in the WAA, SLVWD selected three scenarios for further consideration. SLVWD based its selection primarily on operational and infrastructure opportunities and constraints. The three selected scenarios represent conjunctive use projects that could be implemented in the near future. The first part of this section discusses the anticipated effects of SLVWD-selected scenarios on salmonid resources. While these scenarios may not represent the greatest fisheries benefits possible from the various conjunctive use scenarios presented in the WAA, the ability to implement these options fairly quickly may be considered a fisheries benefit in and of itself.

The second part of this section discusses the expected effects of a modified WAA scenario identified through this analysis as potentially representing the most beneficial options for fisheries resources. Its implementation, however, would require more extensive operational and funding considerations, and it is therefore identified here for consideration in longer-term conjunctive use planning efforts.

4.1 SLVWD-Selected Scenarios

4.1.1 Scenario 1b – Felton System Complies with Required Bypass Only

SLVWD's Felton water right permit contains two separate bypass flow terms (Section 2.3.1). One requirement establishes minimum bypass flows (i.e., 1.5 cfs winter/spring and 1.0 cfs summer/fall during normal water years; 0.75 cfs winter/spring and 0.5 cfs summer/fall during dry water years) to be maintained in Fall Creek below the diversion, and the other requirement is intended to protect minimum low flows in the San Lorenzo River at the SLRBT gage (i.e., 10 cfs in September; 25 cfs in October; and 20 cfs November through May). Under WAA Scenario 1b, SLVWD would comply with its Fall Creek bypass flow requirement but would seek a water right permit modification to relieve it of the SLRBT low-flow requirements that at times prevent all diversions for the Felton system.

Exponent (2019) analyzed the frequency of low-flow conditions at SLRBT, as defined by the water right permit terms, during a 48-year period of SLRBT records (WYs 1970-2017). On an average monthly flow basis, SLVWD diversions from the Felton System would not have been allowed during the month of October in 31 out of 48 years (65 percent) and in the month of November in 11 out of 48 years (23 percent) (Table 4-1). Because the SLRBT low-flow criteria are applicable on a daily basis, this is likely an under-estimate of the number of months during which non-compliant diversions would occur (Exponent 2019).

TABLE 4-1

FREQUENCY OF LOW-FLOW CONDITIONS PROHIBITING FELTON SYSTEM DIVERSIONS DURING A 48-YEAR PERIOD OF SLRBT RECORDS (WYS 1970-2017) ON AN AVERAGE MONTHLY FLOW BASIS

October	65%	April	2%
November	23%	May	13%
December	6%	June	0%
January	4%	July	0%
February	2%	August	0%
March	0%	September	17%
		All months	**11%**

Source: Exponent (2019)

One of the stated goals of the Conjunctive Use Plan is to enable SLVWD to fully comply with its existing permitted water right for the Felton system. While SLVWD's ability to fully comply with the current terms of its permits is clearly an important legal and regulatory consideration, the primary purpose of this fisheries assessment is to identify best approaches for conjunctively using existing water supplies for the benefit of fisheries resources in the San Lorenzo River watershed. The underlying purposes of water right permit restrictions on diversions broadly fall into one of two categories: (1) protecting the water rights of senior permit holders, and (2) protecting other beneficial uses, including environmental resources such as fisheries. Based on a review of State Water Resources Control Board (SWRCB) Decision 1611 (SWRCB 1986) granting Citizens Utility Company of California (prior owner and operator of the Felton system) water right application 24652, the existing water right contains both categories of permit terms. The bypass flow requirements for Fall Creek are based on protest dismissal terms recommended by the CDFG and the County of Santa Cruz for the protection of fisheries resources in Fall Creek below the diversion. The bypass requirement at the SLRBT gage, on the other hand, appears to have been included primarily to protect the City of Santa Cruz's senior water rights at the Felton Diversion, which include the same bypass terms. In Decision 1611, SWRCB (1986) noted that "to the extent that flows in the San Lorenzo River below the Felton Diversion Weir exceed these required bypass flows, the appropriation of water from Fall Creek will not interfere with the City's diversion at the Felton Diversion Weir."

Although the City's permitted bypass terms at SLRBT were originally "proposed by the Department" (i.e., CDFW) "to protect fisheries within the river" (SWRCB 1986), Decision 1611 notes that the City's stated concern regarding the potential adverse effects of Citizens United's application on fish in the San Lorenzo River "is unsubstantiated since the proposed diversion is small compared to the total flow in the mainstem San Lorenzo River especially during the fish migration months of November through June" (SWRCB 1986).

The original CDFW justification for proposing the inclusion of the SLRBT bypass terms in the City's permits, and by extension in SLVWD's permit, is not provided in Decision 1611 and was not available for this assessment. From a fisheries perspective, potential justifications for the SLRBT requirements are difficult to conceive of, primarily due to the unusual monthly steps in bypass requirement levels that do not appear to be founded in the life history periodicity of anadromous salmonids in the San Lorenzo River. The permitted bypass requirement schedule increases from 10 cfs in September to 25 cfs in October, prior to the onset of the typical adult steelhead (December) and coho salmon (November) migration periods. Chinook salmon (*O. tshawytscha*) are the only central California anadromous salmonid migrating as early as October, and this species does not occur in the San Lorenzo River. Furthermore, unless a major storm event has occurred by the time the October bypass threshold goes into effect, the sandbar at the San Lorenzo River Lagoon would most likely still be closed, thereby preventing all adult salmonid entry into the watershed. More confounding than the September-to-October increase in the bypass requirement, however, is the subsequent *decrease* to 20 cfs in November, the early onset of potential adult salmonid migration. Per the permit terms, this requirement remains in effect through May and thus the entire salmonid migration and spawning season.

The permitted increase in bypass flow requirements in early fall and subsequent decrease for late fall through spring is highly unusual and possibly unique in flow management and regulations for the benefit of steelhead and coho salmon in California and does not appear to be ecologically justified. Regardless of this scheduling anomaly, however, the permitted bypass flow requirements themselves may also be insufficient for the assumed purpose of protecting adult salmonid passage in the San Lorenzo River below the SLRBT gage. Salmonid passage flow needs in the San Lorenzo River below the City’s Felton Diversion have previously been estimated by a number of researchers, as summarized by Berry (2016). Based on its interpretation of the findings of these studies, the City has recently proposed a commitment to bypassing up to 40 cfs at the Felton Diversion during the period of December through May to protect adult salmonid migration and spawning flow needs (City of Santa Cruz 2018). SLVWD’s combined diversions from the Felton system (1.6 cfs system maximum capacity; 1.0 cfs maximum historic production) represent less than 4 percent of the City’s proposed instream flow commitment and are therefore highly unlikely to affect attainment of the 40 cfs adult salmonid migration and spawning flow needs, especially since such flows would occur during the wet season when water demands on the Felton system decrease.

During the period of September-November, the City proposes to continue complying with its existing water right permit terms. However, the City rarely, if ever, exercises its rights during that period. The City operates the Felton Diversion to allow for a flushing flow each fall to scour any debris accumulated during low flow periods and only begins diverting after there have been two flow events, each exceeding 100 cfs (ENTRIX, Inc. 2004, as cited in HES 2012). Since the City does not typically exercise its water right at the Felton Diversion during the September-November period unless flows at SLRBT are significantly higher than the existing permit terms, relieving SLVWD of those permit terms would be unlikely to affect the City’s senior rights.

While it may be argued that the biological justification for the pre-adult migration season minimum flow requirements in September and October were intended to protect juvenile salmonids rearing in the river, this does not appear to be the case since neither the City’s nor SLVWD’s water right permits stipulate minimum flow thresholds for the June through August summer rearing period. The City’s water right permit does not allow for diversions during that period, thereby negating the need for instream flow requirements. However, SLVWD’s water right allows for year-round diversions, and the fact that the permit terms do not stipulate minimum flow requirements for the warm, low flow period of June-August, but do stipulate instream flow requirements starting in September, is further evidence that the goal of the SLRBT requirements in SLVWD's permit was to protect the City's senior rights.

The existing September-November bypass flow requirements and the City's proposed commitment to higher bypasses during the December-May period are appropriate fisheries protection measures for the City's Felton Diversion, which relies on periodically diverting large amounts of water (up to 20 cfs permitted) to storage during high flow events. However, imposing these restrictions on SLVWD's Felton system diversions, which rely on direct diversions at a maximum effective rate of less than 1.0 cfs (or maximum permitted rate of 1.6 cfs) on a year-round basis, significantly constrains SLVWD's water supply without providing discernable fisheries protection or enhancement in the San Lorenzo River. Moreover, SLVWD's bypass flow requirements on Fall Creek ensure that proportionally appropriate contributions of Fall Creek flows to the mainstem are protected during summer and fall baseflow conditions. Under conjunctive use Scenario 1b, SLWVD would continue to comply with the Fall Creek bypass flow requirements.

Based on WAA simulated water supply effects, Scenario 1b would reduce, but not eliminate, the Felton system's unfulfilled demand to an average of 35 afy and a maximum of 85 afy due to the lack of a supplemental source of water during deficit months (Exponent 2019). Under Scenario 1b, the percentage of minimum flow remaining below the Fall Creek diversion is simulated to increase from 32 percent to 49 percent under Scenario 1b (see WAA Table 6-6). However, those results are based in part on the assumption that SLVWD would have been out of compliance with its Fall Creek bypass flow requirements during simulated years that preceded the District's purchase of the Felton system. In practice, SLVWD has rarely been out of compliance with the Fall Creek bypass permit term. From a fisheries perspective, Scenario 1b could potentially allow SLVWD to rely more heavily on diversions from the lower priority Bull Creek drainage and thereby reduce reliance on Fall Creek diversions during summer baseflow conditions.

Scenario 1b does not represent a true "conjunctive use" project as it simply assumes that SLVWD would no longer have to comply with its existing SLRBT bypass requirements. However, Scenario 1b would provide SLVWD with more flexibility in its operation of the Felton system in a manner that does not appear to adversely affect fisheries resources in the San Lorenzo River while potentially improving fish habitat conditions in Fall Creek.

4.1.2 Scenario 1f – South System Imports North System Unused Potential Diversions

Under Scenario 1f, SLVWD would export unused potential diversions from the North system to the South system as a substitute for pumping groundwater from the Pasatiempo wells, thereby providing in-lieu recharge of the SMGB. The WAA defines the term "unused potential diversions" as potential diversions within permitted water rights and diversion capacities that exceed demand within the service area within which they are diverted, but which potentially could be transferred to another system or used for aquifer storage and recovery (ASR). In other words, existing diversion capacities or rates in the North system would not increase under

Scenario 1f. Rather, some water that is currently left in the stream un-diverted because simulated monthly demands in the North system are fully met would be diverted under Scenario 1f and transferred to the South system via the existing North-South intertie.

Based on the results of the WAA, an average of 115 afy and a maximum of 300 afy would be transferred to the South system, as needed, to fulfill demand during months when potential diversions exceed North system demand (Exponent 2019). Implementation of this conjunctive use project is estimated to result in an overall 32 percent reduction in South system groundwater pumping. The percent of simulated monthly flow remaining downstream of North system diversions under Scenario 1f is only slightly less (≤1 percent) than under the existing base case scenario. This is because diversions in excess of North system demand would mostly occur during high streamflow months when diversions comprise only a small percentage of unimpaired flows.

The majority of the transferred water would originate from the combined Clear Creek and Sweetwater Creek diversions (see WAA Figure 6-12) because these account for approximately 85 percent of the North system’s average unused potential of 289 afy (Exponent 2019). Peavine and Foreman creeks account for a combined North system unused potential of only 44 afy (15%), and high flows in Boulder Creek are therefore not expected to be adversely affected by the additional diversion of unused potential from Peavine and Foreman creeks under Scenario 1f when compared to existing baseline conditions (see WAA Figure 6-12). Since the capacities of the existing diversions would remain unchanged and the diversion of unused potential would only occur during high flow months, the effect of additional diversions on flows in the San Lorenzo River would be negligible under Scenario 1f.

The 32 percent reduction in South system groundwater pumping simulated for Scenario 1f is estimated to increase the percentage of drought baseflow remaining as a result of assumed groundwater pumping effects by 4 percent in Bean Creek at the Zayante Creek confluence, 3 percent in Zayante Creek at the San Lorenzo River confluence, and 1 percent in the San Lorenzo River at SLRBT compared to existing baseline conditions. These estimated increases in drought baseflows are modest (approximately 0.1 cfs) but biologically relevant during the most critically low flow years in these tributaries where low summer streamflows are considered a primary factor limiting fish habitat even in non-drought years (Alley et al. 2004).

Overall, the simulated effects of Scenario 1f would result in no discernable impact to high surface flows, a meaningful reduction in groundwater pumping promoting in-lieu recharge, and a modest but potentially important increase in minimum drought baseflows in eastern tributary streams. Implementation of this conjunctive use project only requires SLVWD to receive permission to use an existing intertie constructed on an emergency basis for normal (i.e., non-emergency) operations, and therefore represents a “low-hanging fruit” project with long-term water supply benefits and modest but timely fisheries benefits.

4.1.3 Scenario 2b – South System Imports from Loch Lomond for In-Lieu Recharge

SLVWD staff selected Scenario 2b, the import of its Loch Lomond water allotment to the South system as a substitute for pumping the Pasatiempo wells. However, as conceived and simulated in the WAA, Scenario 2b incorporates Scenario 2a, the import of an average of 4 afy of Loch Lomond water to the North system and an average of 50 afy to the Felton system to help meet unmet demand in those systems. SLVWD staff have indicated that the District currently does not plan to import Loch Lomond water to the North and Felton systems. While the imports to the South system account for the majority (78 percent on average) of SLVWD's 313 afy Loch Lomond allotment, and therefore comprise the bulk of the simulated effects to water supply, streamflow, and groundwater levels estimated in the WAA for Scenario 2b, it is important to keep in mind that Exponent (2019) did not simulate a stand-alone scenario comprised of Loch Lomond imports to only the South system, as selected by SLVWD for the Conjunctive Use Plan. As such, results for the Scenario 2b simulation presented in the WAA must be considered in this context.

Scenario 2b assumes that the South system imports an average of 245 afy from Loch Lomond, ranging between 120 and 290 afy. The South system's use of Loch Lomond water would result in a simulated 67 percent reduction in groundwater pumping from the Pasatiempo wells. This in turn would results in an estimated 8 percent increase in drought minimum baseflows remaining in Bean Creek at the Zayante Creek confluence, and a 7 percent increase in drought minimum baseflows in Zayante Creek at the San Lorenzo River confluence (see WAA Table 6-11), equivalent to a drought baseflow increase of approximately 0.15 cfs in both streams. The mainstem San Lorenzo River at SLRBT would receive a 3 percent (0.2 cfs) increase in drought baseflow levels.

Water is diverted and stored in Loch Lomond Reservoir under the City of Santa Cruz's water right permits pursuant to applicable permit terms related to diversion season, maximum diversion rate, and minimum flow requirements for Newell Creek and the San Lorenzo River. Furthermore, the City is in the process of finalizing and implementing a Habitat Conservation Plan (HCP) aimed at avoiding and minimizing effects of its diversions on steelhead and coho salmon, including the agreed-upon increase in bypass flows during the adult salmonid migration and spawning season (see Section 4.1.1). SLVWD's allotment of water stored in Loch Lomond therefore represents environmentally "free" water, or water for which the potentially adverse effects of diversion will have already been avoided or minimized. In other words, no additional adverse effects to streamflows and fisheries habitat would occur if SLVWD were to exercise its Loch Lomond allotment under Scenario 2b. From a fisheries perspective, therefore, Scenario 2b represents an entirely beneficial conjunctive use project.

Moreover, it should be noted that while the estimated increase of approximately 0.15 cfs in minimum drought baseflow levels in Bean and Zayante creeks may be considered modest, the combined implementation of scenarios 1f and 2b may result in a cumulative increase of approximate 0.25 cfs in both creeks during drought conditions, representing a not-insignificant benefit to fisheries resources in these tributaries during the most stressful juvenile rearing periods.

4.2 Fisheries Benefits-Based Scenario

SLVWD lacks significant water storage infrastructure, such as reservoirs, and therefore currently lacks the ability to increase surface water diversions during the high flow winter and spring seasons for storage and later use during the low-flow summer and fall periods. Groundwater levels at the South system's Pasatiempo wells have declined substantially since the early 1980s, and the North system's Olympia wells have exhibited a slight long-term downward trend as well, suggesting that higher rates of extraction may be unsustainable without augmenting recharge (Exponent 2019). SLVWD's 313 afy Loch Lomond allotment provides a potential source of stored water, and conjunctively using this allotment to supply South system demand and promote in-lieu groundwater recharge, as envisioned under Scenario 2b discussed above, is expected to enhance groundwater sustainability and drought baseflow levels in important fisheries tributaries. However, SLVWD's ability to reduce surface water diversion rates in the North and/or Felton systems to enhance fisheries habitat during the low flow period is significantly constrained by a lack of substitute water supply storage infrastructure.

The WAA analyzed three scenarios (3a through 3c) that would increase the yield of the Olympia wellfield in the North System through operation of a hypothetical aquifer storage and recovery (ASR) project supplied by available surface water in excess of monthly water demand (December through May). In the case of Scenario 3a, the ASR would be supplied by an average of 194 afy of unused potential diversions from the North system, and under Scenario 3b, an average of 222 afy of unused potential diversion from the Felton system would be injected into the ASR. Scenario 3c combines the unused potential diversions from the North and Felton systems for an average ASR injection of 412 afy (Exponent 2019). As analyzed in the WAA, all three scenarios assume that the yield from such an ASR project would be used to offset groundwater pumping from the North system (Olympia and Quail Hollow wells). It is important to note that scenarios 3a through 3c all incorporate Scenario 2b (South System Imports from Loch Lomond for In-Lieu Recharge) selected by SLVWD and discussed above in Section 4.1.3.

Under Scenario 3c, the injection and subsequent extraction of an average of 412 afy would reduce North system groundwater pumping by an estimated 64 percent. Combined with the 68 percent reduction in South system pumping due to Loch Lomond imports, Scenario 3c would increase drought minimum baseflows in lower Newell, Zayante, and Bean creeks by 14 to 33 percent compared to existing conditions (see WAA Tables 6-10 and 6-11). These estimated drought baseflow increases are equivalent to approximately 0.26 cfs in Bean Creek at the Zayante Creek confluence, 0.37 cfs in Zayante Creek at the San Lorenzo River confluence, and 0.6 cfs in the San Lorenzo River at SLRBT, and therefore represent potentially significant enhancements of instream flows during the most critical periods. As is the case with all conjunctive use scenarios simulated to rely on currently unused potential diversions, the increased diversions for ASR would occur during wet periods and are not expected to lower minimum monthly flows remaining downstream of the diversions (see WAA Figures 6-15 and 6-16).

While the WAA assumed that all ASR extractions under Scenarios 3a through 3c would be applied to offsetting North system groundwater pumping, the following section discusses a potential modified version of Scenario 3c that utilizes a portion of the simulated ASR storage recovery supply to offset surface water diversions for fisheries enhancement. This modified scenario was identified conceptually during preparation of this fisheries resources assessment and was therefore not considered or analyzed in the WAA. However, Johnson (2019) subsequently analyzed the water supply and conjunctive use implications of this additional scenario, herein identified as Scenario 3d, and the results of the additional analysis informed the following discussion.[5]

4.2.1 Scenario 3d – North System Operates ASR Project Using North and Felton System Unused Potential Diversions, and Reduces Baseflow Diversions from North System

The underlying WAA assumption for Scenario 3c (discussed above) is that the injection and recovery of currently unused potential North and Felton systems diversions in an ASR project would be used to offset the amount of groundwater otherwise withdrawn at the Olympia wells to meet North system summer demand. Under Scenario 3d, SLVWD would implement Scenario 3c, but utilize a portion of the estimated ASR injection/extraction volumes to reduce or temporarily forego summer surface water diversions from the North system, specifically Peavine and Foreman creeks, for fisheries benefits in Boulder Creek and the middle San Lorenzo River reach.

Based on SLVWD production data for WY 2014-2017, average summer baseflow diversions (i.e., combined monthly diversion rates for the Peavine and Foreman diversions) ranged from 0.68 cfs in July to 0.33 cfs in September. The total average combined diversion volume for the July-September period was 91 afy. As such, the total average 2014-2017 summer baseflow diversions from Peavine and Foreman creeks represent less than 25 percent of the estimated average 417 afy of currently unused North and Felton systems high flow diversions to be stored in ASR under Scenario 3d. During drought years 2014 and 2015, SLVWD diverted a combined total of only 36 af and 27 af, respectively, during the July-September low flow period, yet these diversions represented over 20 percent of the unimpaired Boulder Creek flow during that period.

As documented by Balance (2018b), Boulder Creek summer baseflows rose by just under 1 cfs when SLVWD shut-off all its North System diversions for six days in September 2016 for treatment plant maintenance. After the diversions were reinstated, Boulder Creek flows receded gradually to pre-shutdown levels over a period of about two weeks, suggesting substantial shallow groundwater recharge had occurred during the shutdown. Using a portion of injected ASR water to reduce Peavine and Foreman Creek diversion when Boulder Creek flow drops below approximately 2.5 cfs, and foregoing those diversions entirely when Boulder Creek flows drops to approximately 1.5 cfs, would be expected to significantly enhance baseflow rearing conditions for juvenile steelhead and other native fish in Boulder Creek. Moreover, the fisheries benefits of reducing or foregoing baseflow diversions in the Boulder Creek subbasin would be expected to extend downstream into the middle reach of the San Lorenzo River, where Alley et

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[5] Nicholas Johnson, formerly of Exponent, was the primary analyst and author of the WAA (Exponent 2019), and his subsequent analysis of Scenario 3d (Johnson 2019) was conducted consistent with methods applied to the previous WAA analyses.

al. (2004) noted the largest impacts of streamflow reductions on juvenile steelhead growth and densities in the mainstem during dry water years.

Johnson (2019) analyzed the water supply implications of Scenario 3d assuming SLVWD would entirely forego from Peavine and Foreman creeks during the period of July through September. Although the reduction in summer diversions from these two sources may be managed in a more nuanced manner based on ambient Boulder Creek streamflow levels, especially during above-average water years, the Johnson (2019) analysis provides a valuable bookend evaluation of the maximum potential fisheries benefit (i.e., complete elimination of summer diversions). Under Scenario 3d, the injection and subsequent extraction of an average of 417 afy would reduce North system groundwater pumping by an estimated 53 percent. Combined with the 68 percent reduction in South system pumping due to Loch Lomond imports, Scenario 3d would increase drought minimum baseflows in lower Newell, Zayante, and Bean creeks by 12 to 30 percent compared to existing conditions (Johnson 2019). These estimated drought baseflow increases are equivalent to approximately 0.22 cfs in Bean Creek at the Zayante Creek confluence, 0.32 cfs in Zayante Creek at the San Lorenzo River confluence, and 0.53 cfs in the San Lorenzo River at SLRBT, and therefore represent potentially significant enhancements of instream flows during the most critical periods. Consistent with Scenario 3c described above, the increased diversions for ASR would occur during wet periods and would not lower minimum monthly flows remaining downstream of the diversions (see WAA Figures 6-15 and 6-16).

While using a portion of the simulated ASR water supply as substitute for baseflow surface diversions (Scenario 3d) rather than applying all of it to reducing groundwater water pumping rates (Scenario 3c) would slightly reduce the WAA-estimated drought baseflow levels benefits to Newell, Zayante, and Bean creeks, the direct benefits to Boulder Creek, estimated at over 1 cfs in some years, as well as to the middle San Lorenzo River, outweigh the slight reduction in benefits to Newell, Zayante, and Bean creeks. In other words, Scenario 3d would distribute the potential benefits of ASR to fisheries habitat throughout a larger portion of the watershed than WAA-envisioned Scenario 3c.

As analyzed by Johnson (2019), SLVWD would utilize Lock Lomond water to meet Felton system unmet summer demand under Scenario 3d. However, SLVWD could potentially also draw from ASR storage to meet Felton system demand during times when diversions at Fall Creek diversions are restricted or prohibited due to Fall Creek bypass requirements, as occurred periodically during WYs 2014 and 2015 (Balance 2015 and 2018a). As described above, SLVWD’s simulated unmet demand in the Felton system under Scenario 1b (Felton System Complies with Required Bypass Only) is 35 afy on average and up to maximum of 85 afy. The use of an average 35 afy use of ASR water for meeting Felton unmet demand would account for approximately 8.4 percent of the simulated average of 417 afy of ASR storage under Scenario 3d.

Furthermore, SLVWD may consider voluntarily complying with the existing non-dry year bypass requirement of 1 cfs in Fall Creek even during dry years, when the currently permitted requirement for a bypass drops to 0.5 cfs. This would help maintain Fall Creek drought streamflows closer to the instream flow recommendations developed through application of the CDFW (2017) methodology as well as the levels identified by DWA (2018b) for unimpeded juvenile salmonid movement. Estimates of the amount of ASR water that would be needed to offset a voluntary increase in Fall Creek bypass flows during dry years are not provided by Johnson (2019), but should be analyzed if SLVWD elects to incorporate this additional fisheries enhancement component into the implementation and operation of Scenario 3d.

If SLVWD chooses to implement Scenario 3d, or any other conjunctive use project that includes temporary reductions in permitted surface water diversions, SLVWD should consider filing petitions for instream flow dedication pursuant to Water Code section 1707 with the State Water Resources Control Board. A section 1707 dedication serves to formally recognize the transaction, preserves the right holder’s rights to the water dedicated to instream flows, and protects the flow dedications from downstream diversion by other right holders.

CHAPTER 5
Summary and Recommendations

5.1 Summary

Based on a review of available fisheries, hydrology, and water supply information, the existing effects of SLVWD's water supply systems on fisheries resources of the San Lorenzo River watershed were analyzed. SLVWD's surface water diversion facilities are located in western tributaries to the mainstem San Lorenzo River that exhibit relatively stable and cool summer baseflows due to their limestone and granitic geology. Most of the diversion are located in steep terrain upstream of the extent of suitable salmonid habitat. Existing capacities and effective rates of SLVWD's surface water diversion are relatively small, accounting for less than 5 percent of flows in downstream streams supporting steelhead and coho salmon during most of the year. During summer baseflow conditions, the relative effects of some SLVWD's diversions increase to as much as 25 percent (e.g., in Boulder Creek). The diversions of cool tributary waters generally do not appear to adversely affect temperatures in downstream receiving channels in most years but may have some limited effect during drought years (e.g., below Fall Creek). Groundwater pumping from the SMGB by SLVWD and others affect baseflows in the sandstone-dominated eastern tributaries of the San Lorenzo River, particularly during below-average and drought years.

The results of the water availability analysis of 22 conjunctive use scenarios (Exponent 2019) were reviewed and evaluated for potential effects on fisheries resources in the context of existing diversion effects. In particular, three scenarios selected by SLVWD for further consideration were evaluated for their expected relative benefits to fisheries habitat. Scenario 1b would relieve SLVWD of existing minimum flow requirements at SLRBT and provide it greater flexibility in its operation of the Felton system in a manner that is not expected to adversely affect fisheries resources of the San Lorenzo River while potentially improving fish habitat conditions in Fall Creek. The other two SLVWD-selected scenarios would promote in-lieu recharge of the SMGB by supplying the South system with imports of North system unused potential diversions (Scenario 1f) or Loch Lomond allotment water (Scenario 2b). Both these scenarios are estimated to result in modest increases in drought minimum baseflow in Bean and Zayante creeks, as well as minor increases in the San Lorenzo River due to reduced pumping of the Pasatiempo wells.

Neither of the three conjunctive use scenarios selected by SLVWD, or of the 22 scenarios analyzed in the WAA, would enable SLVWD to reduce direct surface water diversions from salmonid-supporting streams during low summer baseflow conditions. Scenario 3d, a fisheries benefits-based scenario identified in this evaluation and based on WAA Scenario 3c, would utilize a portion of currently unused potential diversions from the North and Felton systems stored and recovered from an hypothetical ASR project to reduce or temporarily suspend surface water diversions from tributaries to Boulder Creek, as well as potentially Fall Creek, during low baseflow conditions. The majority of ASR-injected water would remain available for in-lieu recharge through reduced groundwater pumping from the Olympia wells, as envisioned by the WAA-analyzed version of Scenario 3c.

Table 5-1 provides a qualitative matrix summarizing and comparing expected effects of the four conjunctive use scenarios.

TABLE 5-1

QUALITATIVE SCORE MATRIX OF ASSUMED INSTREAM FLOW EFFECTS EXPECTED TO RESULT FROM IMPLEMENTATION OF FOUR CONJUNCTIVE USE SCENARIOS

Surface Water Sources	**Scenario 1b**	**Scenario 1f**	**Scenario 2b**	**Scenario 3d**
Boulder Creek wet season flow	0	0	0	0
Boulder Creek dry season flow	0	0	0	+2
Clear Creek wet season flow	0	-1	0	-1
Clear Creek dry season flow	0	0	0	0
Fall Creek wet season flow	0	0	0	-1
Fall Creek dry season flow	+1	0	0	+1
Bull Creek wet season flow	0	0	0	-1
Bull Creek dry season flow	0	0	0	0
Newell Creek drought minimum flow	0	0	+1	+2
Bean Creek drought minimum flow	0	+1	+1	+2
Zayante Creek drought minimum flow	0	+1	+1	+2
San Lorenzo River drought minimum flow	0	+1	+1	+2
Score:	**1**	**2**	**4**	**7**

Notes:

0 = minimal or no effect
+1 = moderate improvement
+2 = significant improvement
-1 = moderate reduction

5.2 Recommendations

The WAA analyzed 22 conjunctive use scenarios separately and largely on a stand-alone basis. Now that SLVWD has selected three potential scenarios for further consideration, and a fourth is presented here for potential additional benefits to salmonids and other native species in the San Lorenzo River watershed, the implementation, over time, of a feasible combination of scenarios should be analyzed. Based on the above analysis, near-term implementation of Scenarios 1b and 2b, combined with future implementation of Scenario 3d would provide basin-wide improvements to fisheries resources and water supply reliability, including increased summer baseflows in Boulder, Fall, Bean, and Zayante creeks and, by extension the mainstem San Lorenzo River, as well as reduced pumping and increased sustainability of groundwater sources of the SMGB. If fully implemented, this combination of conjunctive use projects would also enable SLVWD to fully comply with modified Felton system water right terms. It should be noted that Scenario 3d, as simulated by Johnson (2019), incorporates implementation of Scenario 2b.

SLVWD-selected Scenario 1f is recommended for short-term implementation as it represents the conjunctive use project that could be implemented with existing infrastructure. If and when Scenario 3d is implemented, however, Scenario 1f would need to be abandoned as both scenarios rely on unused potential diversion from the North system. Given the limited implementation needs and costs of Scenario 1f, it is assumed that SLVWD would be able to switch from Scenario 1f operations to Scenario 3d operations without additional effort or lost investment. Furthermore, implementation of Scenario 1f would provide SLVWD with additional operational flexibility if and when Scenario 3d is implemented.

CHAPTER 6
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Appendix C

SLVWD Facilities Damaged by the CZU Complex Fires

SLVWD Facilities Damaged by The CZU Complex

Facility Name	Damage Status	Repair or Replacement Status	Fire Resilient Materials (Existing/ Proposed/ Recommended)	Valve/Hydrant for Connection (Existing/ Proposed/ Recommended)
Alder Tank	Damaged	Replaced (permanent)	No Access, Walk-in site only Existing 700-gallon poly tank off 2-inch main	None
Alta Via Distribution Piping	Damaged	Awaiting repairs	Planned buried ductile iron pipe to fire harden	Multiple fire hydrants to be installed with project
Bennett Springs Intake Line	Damaged	Awaiting repairs	--	--
Big Steel Booster Piping	Damaged	Repaired	Buried ductile iron pipe fire hardened	--
Big Steel Lyon Piping	Damaged	Repaired	Buried ductile iron pipe fire hardened	--
Big Steel Tank	Damaged	Repaired	Existing steel tank	*Recommendation:* Recommend installing fire connection on tank or fire hydrant on roadway
Blackstone tank and piping	Damaged	Tanks repaired; Piping awaiting repairs	Poly tanks installed, in process of possibly removing this site	No fire truck access, very tight narrow road with no turn around for trucks fire hydrant at bottom of road
Clear Creek Intakes	Damaged	Awaiting repairs	--	--
Eckley Tank, Booster, and Piping	Damaged	Awaiting repairs; Tank replaced; Power set replaced	*Recommendation:* Replace poly tank with steel tank; no existing pump building Planned CZU project to build fire resistant pump station	Existing hydrant within 200 feet of this locations

Facility Name	Damage Status	Repair or Replacement Status	Fire Resilient Materials (Existing/ Proposed/ Recommended)	Valve/Hydrant for Connection (Existing/ Proposed/ Recommended)
Felton-Empire Grade	Damaged trees	No repairs proposed; legacy roads could be opened potentially	--	--
Foreman Creek	Damaged	In repairs	--	--
Harmon Street 2" Piping	Damaged	Temporarily repaired	--	--
Little Lyon Tank	Damaged	Awaiting repairs	Existing steel tank	Existing hydrant at this location
Malosky Creek	Damaged	No repairs proposed	--	--
Peavine Intake and Piping	Damaged	Awaiting repairs	--	--
Riverside Grove booster pump station	Damaged	Out to bid for repairs	In process of changing out roof to fire resistant materials	Existing hydrant at this location
South Reservoir Distribution Piping	Damaged	Awaiting repairs	Planned buried ductile iron pipe to fire harden	Multiple fire hydrants to be installed with project
Sweetwater Creek	Damaged	Awaiting repairs	--	--

Appendix D

Air Quality and Greenhouse Gas Modeling Results

Road Construction Emissions Model, Version 9.0.0

Daily Emission Estimates for -> Conjunctive Use Plan for the San Lorenzo Watershed **Project Phases (Pounds)**	**ROG (lbs/day)**	**CO (lbs/day)**	**NOx (lbs/day)**	**Total PM10 (lbs/day)**	**Exhaust PM10 (lbs/day)**	**Fugitive Dust PM10 (lbs/day)**	**Total PM2.5 (lbs/day)**	**Exhaust PM2.5 (lbs/day)**	**Fugitive Dust PM2.5 (lbs/day)**	**SOx (lbs/day)**	**CO2 (lbs/day)**	**CH4 (lbs/day)**	**N2O (lbs/day)**	**CO2e (lbs/day)**
Grubbing/Land Clearing	1.85	20.45	14.83	0.64	0.64	0.00	0.61	0.61	0.00	0.04	3,891.00	0.89	0.03	3,923.05
Grading/Excavation	0.08	1.11	8.77	0.30	0.30	0.00	0.13	0.13	0.00	0.04	4,574.50	0.00	0.72	4,788.87
Drainage/Utilities/Sub-Grade	1.14	12.61	10.05	0.40	0.40	0.00	0.37	0.37	0.00	0.03	2,625.65	0.68	0.02	2,649.36
Paving	1.67	15.74	15.98	0.63	0.63	0.00	0.58	0.58	0.00	0.04	3,817.38	1.23	0.03	3,858.55
Maximum (pounds/day)	1.85	20.45	15.98	0.64	0.64	0.00	0.61	0.61	0.00	0.04	4,574.50	1.23	0.72	4,788.87
Total (tons/construction project)	0.19	2.04	2.40	0.09	0.09	0.00	0.07	0.07	0.00	0.01	816.31	0.11	0.07	839.06

Notes:
Project Start Year -> 2024
Project Length (months) -> 20
Total Project Area (acres) -> 0
Maximum Area Disturbed/Day (acres) -> 0
Water Truck Used? -> No

	Total Material Imported/Exported Volume (yd^3/day)		Daily VMT (miles/day)			
Phase	Soil	Asphalt	Soil Hauling	Asphalt Hauling	Worker Commute	Water Truck
Grubbing/Land Clearing	0	0	0	0	0	0
Grading/Excavation	583	0	1,227	0	0	0
Drainage/Utilities/Sub-Grade	0	0	0	0	0	0
Paving	0	0	0	0	0	0

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

Total Emission Estimates by Phase for -> Conjunctive Use Plan for the San Lorenzo Watershed **Project Phases** **(Tons for all except CO2e. Metric tonnes for CO2e)**	**ROG (tons/phase)**	**CO (tons/phase)**	**NOx (tons/phase)**	**Total PM10 (tons/phase)**	**Exhaust PM10 (tons/phase)**	**Fugitive Dust PM10 (tons/phase)**	**Total PM2.5 (tons/phase)**	**Exhaust PM2.5 (tons/phase)**	**Fugitive Dust PM2.5 (tons/phase)**	**SOx (tons/phase)**	**CO2 (tons/phase)**	**CH4 (tons/phase)**	**N2O (tons/phase)**	**CO2e (MT/phase)**
Grubbing/Land Clearing	0.04	0.45	0.33	0.01	0.01	0.00	0.01	0.01	0.00	0.00	85.60	0.02	0.00	78.30
Grading/Excavation	0.01	0.10	0.77	0.03	0.03	0.00	0.01	0.01	0.00	0.00	402.56	0.00	0.06	382.31
Drainage/Utilities/Sub-Grade	0.09	0.97	0.77	0.03	0.03	0.00	0.03	0.03	0.00	0.00	202.18	0.05	0.00	185.07
Paving	0.06	0.52	0.53	0.02	0.02	0.00	0.02	0.02	0.00	0.00	125.97	0.04	0.00	115.51
Maximum (tons/phase)	0.09	0.97	0.77	0.03	0.03	0.00	0.03	0.03	0.00	0.00	402.56	0.05	0.06	382.31
Total (tons/construction project)	0.19	2.04	2.40	0.09	0.09	0.00	0.07	0.07	0.00	0.01	816.31	0.11	0.07	761.19

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

The CO2e emissions are reported as metric tons per phase.

Conjunctive Use Plan

Last Updated: 5/21/21

Compression-Ignition Engine Brake-Specific Fuel Consumption (BSFC) Factors **[1]**:

HP: 0 to 100	0.0588	HP: Greater than 100	0.0529

Values above are expressed in gallons per horsepower-hour/BSFC.

CONSTRUCTION EQUIPMENT

Construction Equipment	#	Hours per Day	Horsepower	Load Factor	Construction Phase	Fuel Used (gallons)
Concrete/Industrial Saws	1	8	81	0.73	Demolition Phase	1,195.31
Air Compressors	1	8	78	0.48	Demolition Phase	756.85
Rubber Tired Loaders	1	8	203	0.36	Demolition Phase	1,328.85
Excavators	1	8	158	0.38	Demolition Phase	1,091.74
Tractors/Loaders/Backhoes	1	8	97	0.37	Site Preparation Phase	708.64
Plate Compactors	1	8	8	0.43	Site Preparation Phase	67.92
Air Compressors	1	8	78	0.48	Site Preparation Phase	739.24
Rubber Tired Loaders	1	8	203	0.36	Site Preparation Phase	1,297.95
Excavators	1	8	158	0.38	Site Preparation Phase	1,066.35
Concrete/Industrial Saws	1	8	81	0.73	Building Construction Phase	2,335.02
Plate Compactors	1	8	8	0.43	Building Construction Phase	135.84
Cranes	1	8	231	0.29	Building Construction Phase	2,379.57
Excavators	1	8	158	0.38	Building Construction Phase	2,132.70
Rough Terrain Forklifts	1	8	100	0.4	Building Construction Phase	1,579.58
Rubber Tired Loaders	1	8	203	0.36	Building Construction Phase	2,595.89
Rollers	1	8	80	0.38	Paving Phase	314.41
Graders	1	8	187	0.41	Paving Phase	713.28
Rubber Tired Loaders	1	8	203	0.36	Paving Phase	679.88
Pavers	1	8	130	0.42	Paving Phase	507.95
Scrapers	1	8	367	0.48	Paving Phase	1,638.85
Paving Equipment	1	8	132	0.36	Paving Phase	442.09
					Total Fuel Used	**23,707.89**
						(Gallons)

Construction Phase	Days of Operation
Demolition Phase	43
Site Preparation Phase	42
Building Construction Phase	84
Paving Phase	22
Total Days	191

WORKER TRIPS

Constuction Phase	MPG [2]	Trips	Trip Length (miles)	Fuel Used (gallons)
Demolition Phase	24.4	0	21.0	0.00
Site Preparation Phase	24.4	59	21.0	2132.70
Grading Phase	24.4	0	21.0	0.00
Building Construction Phase	24.4	0	21.0	0.00
Paving Phase	24.4	0	21.0	0.00
Architectural Coating Phase	24.4	0	21.0	0.00
			Fuel	**2,132.70**

HAULING AND VENDOR TRIPS

Trip Class	MPG [2]	Trips	Trip Length (miles)	Fuel Used (gallons)
HAULING TRIPS				
Demolition Phase	7.5	0	21.0	0.00
Site Preparation Phase	7.5	59	21.0	165.20

Grading Phase	7.5	0	21.0	0.00
Building Construction Phase	7.5	0	21.0	0.00
Paving Phase	7.5	0	21.0	0.00
Architectural Coating Phase	7.5	0	21.0	0.00
			Fuel	**165.20**

Total Gasoline Consumption (gallons)	**2,132.70**
Total Diesel Consumption (gallons)	**23,873.09**

Sources:

[1] United States Environmental Protection Agency. 2018. *Exhaust and Crankcase Emission Factors for Nonroad Compression-Ignition Engines in MOVES2014b* . July 2018. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100UXEN.pdf.

[2] United States Department of Transportation, Bureau of Transportation Statistics. 2019. *National Transportation Statistics 2019* . Available at: https://www.bts.gov/topics/national-transportation-statistics.

Appendix E

Biological Technical Memorandum

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May 6, 2021
Project No: 20-10506

Carly Blanchard, Environmental Planner
San Lorenzo Valley Water District
13060 Highway 9
Boulder Creek, California 95006

Subject: Biological Technical Memorandum for the San Lorenzo Valley Water District Conjunctive Use Plan for the San Lorenzo River Watershed, Santa Cruz County, California

Dear Ms. Blanchard:

This letter report has been prepared by Rincon Consultants, Inc. (Rincon) to assist the San Lorenzo Valley Water District (SLVWD or District) with the San Lorenzo River Watershed Conjunctive Use Plan (plan) for California Environmental Quality Act (CEQA) review in support of an Initial Study-Mitigated Negative Declaration (IS-MND). The analysis was based on a desktop review of existing technical information and a site reconnaissance survey for biological resources.

Project Description

The District and the County of Santa Cruz have jointly developed the San Lorenzo River Watershed Conjunctive Use Plan (plan) to identify surface and groundwater supply reliability projects within the San Lorenzo River watershed. The main purpose of the plan is to optimize the conjunctive use of surface and groundwater sources to improve aquatic habitat and water supply reliability within the San Lorenzo River watershed.

The District's operations are comprised of three largely independent water systems (see Attachment 1, Figure 1):

1. North System located in the San Lorenzo Valley;
2. South System located in the Scotts Valley area; and
3. Felton System located in Felton.

Each system produces water independently in response to immediate water demand, as the systems lack substantial surface storage infrastructure or interconnection. The plan includes three selected conjunctive use scenarios (see Attachment 1, Figure 2a, Figure 2b and Figure 3), which are described in detail in the draft Initial Study-Mitigated Negative.

Water infrastructure associated with the various water use scenarios identified in the plan are located throughout the San Lorenzo Valley Water District's service area in Santa Cruz County. Specifically, the physical improvements proposed under the Loch Lomond Scenario would be located in the community of Felton, California. The northern terminus of infrastructure improvements would occur under the San Lorenzo Way Bridge, located near 6660 Highway 9, Felton, California 95018. A pipeline would be suspended under the bridge within the bridge development footprint, running east to west. From the western side of the San Lorenzo Way bridge, pipeline installation would run underground under Highway 9, along Clearview Place, and south along Cooper Street within the public right-of-way. The new waterline would then run south within the Cooper Street right-of-way to tie-in to the existing water line at Farmer Street, near 6560 Highway 9 in Felton. Additional infrastructure upgrades would occur at Kirby Water Treatment Plant, located at 195 Kirby Street in Felton (Assessor's Parcel Number [APN] 06528103).

Methods

On February 18, 2021, Rincon senior biologist Samantha Kehr and principal planner Megan Jones met with SLVWD staff to discuss the proposed plan and view a pump station, the location of the new raw pipeline, and the Kirby Water Treatment plant. During this visit representative photographs of the plan area were taken. The study area for this analysis included the District's three water systems where the plan will be implemented, and any locations where infrastructure improvements are proposed (e.g., the Loch Lomond Scenario).

Rincon then conducted a desktop review of available resources and databases, including a record search of the California Department of Fish and Wildlife (CDFW) California Natural Diversity Database (CNDDB; 9-quad search area), the California Native Plant Society (CNPS), Inventory of Rare and Endangered Plants was also accessed for this review, the United States Fish and Wildlife Service (USFWS) Information for Planning and Consultation (IPaC) and the National Oceanic and Atmospheric Administration fisheries to identify federally-listed and proposed species known to occur in the region (see Attachment 3). Following the survey, Rincon confirmed habitat types, wildlife, and fish species in the region based on background and database information in the context of observed habitats.

Results

Existing Conditions

Land uses within the plan area and the surrounding area consist of forestland, residential, and paved roads. The areas where infrastructure improvements are proposed consist of the San Lorenzo River (above the ordinary high water mark [OHWM]), developed roads, and the existing Kirby Water Treatment Plant, with developed redwood forest occurring in the surrounding area. The topography of the plan area is generally characterized by steep hills that slope towards the San Lorenzo River. Elevation within the plan area generally ranges between 1,200 feet (ft) and 300 ft above mean sea level.

The San Lorenzo Way Bridge, where infrastructure improvements are proposed under the Loch Lomond Scenario, crosses a narrow, deeply incised channel that runs northwest to southeast. The river channel is generally straight in the vicinity of the bridge, exposing rock on both banks. The topography above both banks generally consists of rising terrain leading to hills on both sides of the valley. Heavy vegetation, including mature redwood trees, exist along both banks.

Vegetation Communities and Land Covers

Vegetation within the plan area consists of natural vegetation communities and developed areas, including but not limited to: upland and riparian redwood forest, developed redwood forest, landscaped areas, ruderal communities, and paved roadways.

Plant communities are considered sensitive biological resources if they have limited distributions, high wildlife value, include sensitive species, or are particularly susceptible to disturbance. CDFW ranks sensitive communities as "threatened" or "very threatened" and keeps records of their occurrences in CNDDB. CNDDB vegetation alliances are ranked 1 through 5 based on NatureServe's (2010) methodology, with those alliances ranked globally (G) or statewide (S) as 1 through 3 considered sensitive. Some alliances with the rank of 4 and 5 have also been included in the 2018 sensitive natural communities list under CDFW's revised ranking methodology (2018c).

Redwood forest is considered a sensitive natural community by CDFW with a rank of G3 S3. Additionally, redwood alliances with California bay laurel, Douglas fir, and tan oak are also considered sensitive and are likely to be common in the plan area. Construction of the new raw water connection between the City of Santa Cruz's Newell Creek pipeline and the Felton raw water system would cross the San Lorenzo River; however, the new pipeline would be constructed within the footprint of the new San Lorenzo Way Bridge, which has already been analyzed and permitted. Therefore, installation of the new pipeline under the Loch Lomond Scenario would be subject to the resource agency permits obtained for the bridge replacement project and no additional disturbance or permitting is anticipated. There would be no impacts to sensitive natural communities as a result of plan implementation.

Special Status Species

Special-Status Plants

Fifty-nine (59) special status plant species known to occur in the region may occur in the plan area (see Attachment 3). Because the plan will not require infrastructure improvements in natural habitats other than what was already permitted for the San Lorenzo Way Bridge Replacement project (under the Loch Lomond Scenario), no special-status plant species are expected to be affected by the proposed plan.

Special-Status Wildlife

Thirty-four (34) special status animal species known to occur in the region may occur in the plan area (see Attachment 3). Because the plan will not require infrastructure improvements in natural habitats other than what was already permitted for the San Lorenzo Way Bridge Replacement (under the Loch Lomond Scenario), no terrestrial or semi-aquatic special-status wildlife species are expected to be affected by the proposed plan. Alteration to the flow rate is expected to have a beneficial impact on salmonids (i.e., coho salmon and steelhead) known to occur in the San Lorenzo River watershed, as discussed below and summarized in Table 1.

Several special status amphibian, reptile, and mammal species (i.e., California red-legged frog, western pond turtle, American badger, horay bat, white-tailed kite, osprey) may be present in the San Lorenzo River watershed. However, due to the limitation of improvements to the permitted bridge replacement footprint, impacts to these species are not expected, can be fully avoided, and would not require additional permitting.

Table 1 Special Status Wildlife Potential Impacts

		Potential for Impacts		
Scientific Name **Common Name**	**Status** **Fed/State ESA** **CDFW**	**SLRBT Low-Flow Requirements ModificationSLRBT Low-Flow Requirements Modification Scenario**	**North Systems Diversions Scenario**	**Loch Lomond Scenario**
Oncorhynchus kisutch pop. 4 coho salmon Central California Coast Ecologically Significant Unit	FE/SE G4/S2	Not Expected	Beneficial Impact	Beneficial Impact
Oncorhynchus mykiss irideus pop. 8 steelhead Central California Coast Distinct Population Segment	FT/None G5T2T3Q/S2S3	Not Expected	Beneficial Impact	Beneficial Impact

FE = Federally Endangered
FT = Federally Threatened
FC = Federal Candidate Species
FS=Federally Sensitive
SE = State Endangered
ST = State Threatened
SC = State Candidate
SSC =CDFW Species of Special Concern

G1 or S1	Critically Imperiled Globally or Subnationally (state)
G2 or S2	Imperiled Globally or Subnationally (state)
G3 or S3	Vulnerable to extirpation or extinction Globally or Subnationally (state)
G4/5 or S4/5	Apparently secure, common and abundant
GH or SH	Possibly Extirpated – missing; known from only historical occurrences but still some hope of rediscovery

T – Intraspecific Taxon (subspecies, varieties, and other designations below the level of species)
Q – Questionable taxonomy that may reduce conservation priority
? – Inexact numeric rank

SLRBT Low-Flow Requirements Modification SLRBT Low-Flow Requirements Modification Scenario[1] Fisheries Evaluation

The SLRBT Low-Flow Requirements Modification Scenario by itself would have no effect on listed salmonids in the affected tributaries and may result in beneficial effects overall. Under this scenario, SLWVD would continue to comply with Fall Creek bypass flow requirements and there would be no changes to Fall Creek diversion volumes or schedules. As noted by Podlech (2019), this scenario would not require changes to current operations, infrastructure changes or upgrades, or construction activities and therefore would not result in any new environmental impacts relative to existing conditions. Fall Creek is known to support steelhead but not coho salmon (though coho salmon were historically present and Fall Creek is a candidate for coho salmon recovery), and its tributary Bennett Creek is impassible to anadromous salmonids but provides a substantial perennial flow contribution to Fall Creek (Podlech 2019). It is assumed that any changes to the operation of diversions on Bennett Spring/Bennett Creek and Bull Creek under this scenario would be negligible and would have no discernable effect on salmonid habitat in these tributaries or downstream reaches of the San Lorenzo River.

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[1] The SLRBT Low-Flow Requirements ModificationSLRBT Low-Flow Requirements Modification Scenario is named “Scenario 1b” in the WAA, Fisheries Resource Considerations, and Conjunctive Use Plan documents. It has been renamed in this IS-MND document for clarification and ease of reading.

Under this scenario, the District would petition the State Water Board to amend water right Permit 20123 to relieve the District of the SLRBT low flow requirement and this would require CEQA analysis. Elimination of the bypass requirement at the SLRBT gage would likely have no effect on listed salmonids in the San Lorenzo River. As described in detail by Podlech (2019), the SLRBT bypass requirement provides no apparent protection or enhancement for steelhead or coho salmon, as neither its magnitude nor its timing corresponds to the presence or ecological needs of these species in the San Lorenzo River.

Implementation of the SLRBT Low-Flow Requirements Modification Scenario as part of the Conjunctive Use Plan would likely provide cumulative benefits to steelhead because it would allow the District to maximize the fisheries enhancement benefits of other conjunctive use projects (i.e., long-term plans under Phase 2), potentially by facilitating greater in-lieu groundwater recharge and associated surface flow improvements. These actions would provide a cumulative benefit to salmonids by enhancing instream flows and improving habitat conditions in the San Lorenzo River and affected tributaries.

North System Diversions Scenario[2] Fisheries Evaluation

Under this scenario, unused potential diversions from North System surface water sources would be transferred to the South System during the wet season (December–April) when streamflows are highest, thus minimizing the proportional reduction in flows downstream of the diversion locations and the potential for impacts to anadromous salmonids. Most of the transferred water would originate from the combined Clear Creek, Foreman Creek, and Sweetwater Creek diversions, which account for approximately 85% of the combined unused surface diversion potential of the North System. Simulations indicate the transfers would result in monthly flow reductions of 1% or less downstream of the diversions. Potential flow reductions in Peavine and Foreman creeks, tributaries to Boulder Creek that represent about 15% of the combined unused surface diversion potential of the North System, are expected to be negligible. There would be no increase in existing diversion capacities or rates in the North System under this scenario and no construction or new infrastructure.

Podlech (2019) concluded that this scenario would result in a moderate reduction in Clear Creek wet season flow, noting that Clear Creek is considered to have limited anadromous salmonid value for the purposes of evaluating effects of the Conjunctive Use Plan scenarios. This determination was based on the lack of positive evidence of steelhead or coho salmon in Clear Creek or its tributary Sweetwater Creek, likely barriers to salmonid passage near Clear Creek's downstream end, and previous assessments by other investigators that rated Clear Creek's habitat quality as poor (Ross Taylor & Associates 2004) and its intrinsic potential to support steelhead as moderate (NMFS 2017). NMFS (2017) determined that Clear Creek had no intrinsic potential to support coho salmon. Podlech (2019) evaluated equivalent data for Peavine and Foreman creeks and determined these tributaries to have no anadromous salmonid value for purposes of his assessment. He concluded that the negligible wet season flow reductions in these tributaries are not anticipated to cause adverse impacts to flows in Boulder Creek or the San Lorenzo River downstream of the Boulder Creek confluence.

Implementation of the North System Diversion Scenario would likely provide benefits to listed salmonids by reducing South System groundwater pumping and increasing dry season baseflow in Bean Creek,

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[2] The North System Diversion Scenario is named "Scenario 1f" in the WAA, Fisheries Resource Considerations, and Conjunctive Use Plan documents. It has been renamed in this IS-MND document for clarification and ease of reading.

Zayante Creek, and the lower San Lorenzo River. Although the increase in dry season baseflow would be minor, it would help alleviate the limiting effects of low summer flows on steelhead and coho salmon in these eastern tributaries (Podlech 2019, Alley et al. 2004). In the upper San Lorenzo River and North System tributaries, the effect of additional wet season diversions under this scenario would be negligible and adverse impacts are not expected.

Loch Lomond Scenario[3] Fisheries Evaluation

Under this scenario, the import of Loch Lomond water to the South System would allow a reduction in groundwater pumping that would increase baseflows in Bean Creek, Zayante Creek, and the lower San Lorenzo River. Any necessary infrastructure improvements would have no effect on fish, fish habitat, or fish movement. Simulated increases in drought minimum baseflow would be approximately 0.15 cfs in Bean and Zayante creeks and 0.2 cfs in the lower San Lorenzo River at Big Trees. The effects of increased baseflows are expected to be entirely beneficial to anadromous salmonids. If the Loch Lomond Scenario is implemented in combination with the North System Diversion Scenario, the combined 0.25 cfs increase in drought minimum flows in Bean and Zayante creeks may provide additional cumulative benefits to anadromous salmonids rearing under drought-stressed conditions.

Nesting Birds

The plan area contains suitable nesting habitat for numerous migratory bird species, which could nest in the trees and shrubs during the nesting season (generally February 1 through August 31). Migratory bird species are protected pursuant to the California Fish and Game Code and federal Migratory Bird Treaty Act. In areas where physical improvements are proposed under the Loch Lomond Scenario, impacts may occur if active nests are present in undeveloped and landscaped areas adjacent to active construction or staging through disturbance and nest abandonment. With the implementation of a preconstruction survey impacts to nesting birds would be reduced to less than significant.

Jurisdictional Waters

The plan area is located within the Santa Cruz Mountains, part of the Pacific Coast Range, with the San Lorenzo River watershed (Hydrologic Unit Code #18060001502), the Zayante Creek-San Lorenzo sub-watershed, and parts of the Carbonera Creek-San Lorenzo River sub-watershed. Potentially jurisdictional features in the plan area include the San Lorenzo River and numerous creeks, streams, and drainages, containing adjacent wetlands and riparian corridors. The San Lorenzo River is perennial to intermittent, exhibiting annual variations in water level, and is a Traditional Navigable Waterway that outlets directly into the Pacific Ocean. The areas below the OHWM of the San Lorenzo River and associated tributaries are considered ‘non-wetland waters’ or ‘other waters of the U.S.,’ and are subject to U.S. Army Corps of Engineers (USACE) jurisdiction. These features (and associated riparian corridors) also fall under the jurisdiction of CDFW, as these have a clearly defined bed and bank, and provide habitat for a variety of aquatic, semi-aquatic, and terrestrial wildlife species; and Regional Water Quality Control Board (RWQCB) under the new revised regulations. Because the plan will not require infrastructure improvements in jurisdictional areas other than what was already permitted for the San Lorenzo Way

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[3] The Loch Lomond Scenario is named “Scenario 2b” in the WAA, Fisheries Resource Considerations, and Conjunctive Use Plan documents. It has been renamed in this IS-MND document for clarification and ease of reading.

Bridge Replacement project under the Loch Lomond Scenario, no impacts or jurisdictional permitting is expected. Impacts would be less than significant.

Wildlife Movement

Wildlife movement corridors, or habitat linkages, are generally defined as connections between habitat patches that allow for physical and genetic exchange between otherwise isolated animal populations. Such linkages may serve a local purpose, such as providing a linkage between foraging and denning areas, or they may be regional in nature. Some habitat linkages may serve as migration corridors, wherein animals periodically move away from an area and then subsequently return. Other corridors may be important as dispersal corridors for young animals. A group of habitat linkages in an area can form a wildlife corridor network. Regional and local corridors for terrestrial wildlife movement are likely to occur in undeveloped areas, and corridors for salmonids are known to occur in the San Lorenzo River, however no development is proposed in natural habitats and redirection of flows after diversion is expected to have a beneficial impact for salmonid movement. Impacts would be less than significant.

Local Policies and Ordinances

The plan area occurs within unincorporated Santa Cruz County, and the Cities of Felton, Ben Lomond, Brookdale, Santa Cruz, and Boulder Creek. No tree removal or development within any sensitive habitats that might be protected by local policies and ordinances is proposed, beyond what the City of Santa Cruz has already proposed for the San Lorenzo Way Bridge Replacement project under the Loch Lomond Scenario. Therefore, impacts would be less than significant.

Habitat Conservation Plans

The City of Santa Cruz is currently developing a Habitat Conservation Plan (HCP), which would include parts of the plan area. However, this HCP has not yet been adopted. The plan area is not within any adopted Habitat Conservation Plan (HCP) or Natural Community Conservation Plan (NCCP) areas. Although the HCP was not reviewed for this evaluation, it is understood that its objectives include avoiding and minimizing effects of the City's diversions on steelhead and coho salmon. The District will continue to coordinate with the City of Santa Cruz to make sure development of Conjunctive Use Plan is consistent with the HCP. No impacts to potentially covered species are expected, and the plan would have an overall beneficial impact for salmonids, therefore implementation of the plan would not conflict with state, regional, or local habitat conservation plans.

Mitigation Measures

BIO 1 Nesting Bird Survey

For proposed infrastructure improvements associated with the Loch Lomond Scenario, a qualified biologist will conduct a general pre-construction nesting bird survey for all migratory birds and raptors not more than 14 days prior to construction activities involving ground clearing, vegetation trimming or tree removal if these activities commence during the nesting season (February 1 and September 1) and occur adjacent to undeveloped or landscaped areas that provides suitable nesting habitat. The survey will consist of a qualified biologist conducting a visual inspection of the disturbance area plus a 200-foot buffer and vicinity, as is feasible depending on possible access and/or line-of-site constraints, to detect any suitable nesting locations and determine if any nests occur. If active nests are found the qualified biologist shall establish an appropriate buffer, taking into account the species sensitivity and physical location of the nest (line of site to the work area), to be in compliance with CFGC 3503 and 3503.5. In no cases shall the buffer be smaller than 50 feet for non-raptor bird species and 200 feet for raptor species. To prevent encroachment, the established buffer(s) shall be clearly marked by high visibility material. The established buffer(s) shall remain in effect until the young have fledged or the nest has been abandoned as confirmed by the qualified biologist.

Conclusions and Recommendations

Implementation of the proposed plan would allow more flexibility to divert surface flows during the winter and spring (peak flow season) and/or provide in-lieu groundwater recharge to improve surface flows during the summer (low flow season). Increasing the conjunctive management of groundwater and surface water supplies within the San Lorenzo River watershed has the potential to address several water-resource issues and opportunities. The proposed plan would result in no discernable effect on salmonid habitat or would provide increased flow for anadromous fish during low flow periods while improving water supply reliability for the District.

Because the plan would result in no discernable effect on salmonid habitat or increase flows during the low flow season, and infrastructure improvements associated with San Lorenzo Way Bridge Replacement project under the Loch Lomond Scenario would be limited to what has already been analyzed and approved for the San Lorenzo Way bridge replacement, implementation of the plan would avoid impacts to State and federally-regulated jurisdictional features and special-status plant and wildlife species and no additional regulatory agency permitting is anticipated at this time.

Under each plan scenario, the District would utilize existing allotments of water transferred from one system to another and would not exceed those existing allotments at any time. Once in the receiving system, the plan would allow the District to direct appropriate quantities of water to the appropriate end use or downstream location based on needs. This flexibility would not alter the magnitude or timing of water transfers between systems, but rather would allow the District to meet specific needs at each end use location within each system.

In conclusion, the proposed plan would have an overall beneficial impact for salmonids and would not have a significant impact on other special status wildlife or sensitive biological resources. Implementation of mitigation measure BIO 1, impacts to nesting birds would be reduced to less than significant.

Sincerely,
Rincon Consultants, Inc.

Samantha Kehr
Senior Biologist

Craig Lawrence
Senior Regulatory Specialist

Megan Jones
Principal/Project Manager

Attachments

Attachment 1	Figures
Attachment 2	Representative Site Photographs
Attachment 3	Agency Database Queries

References

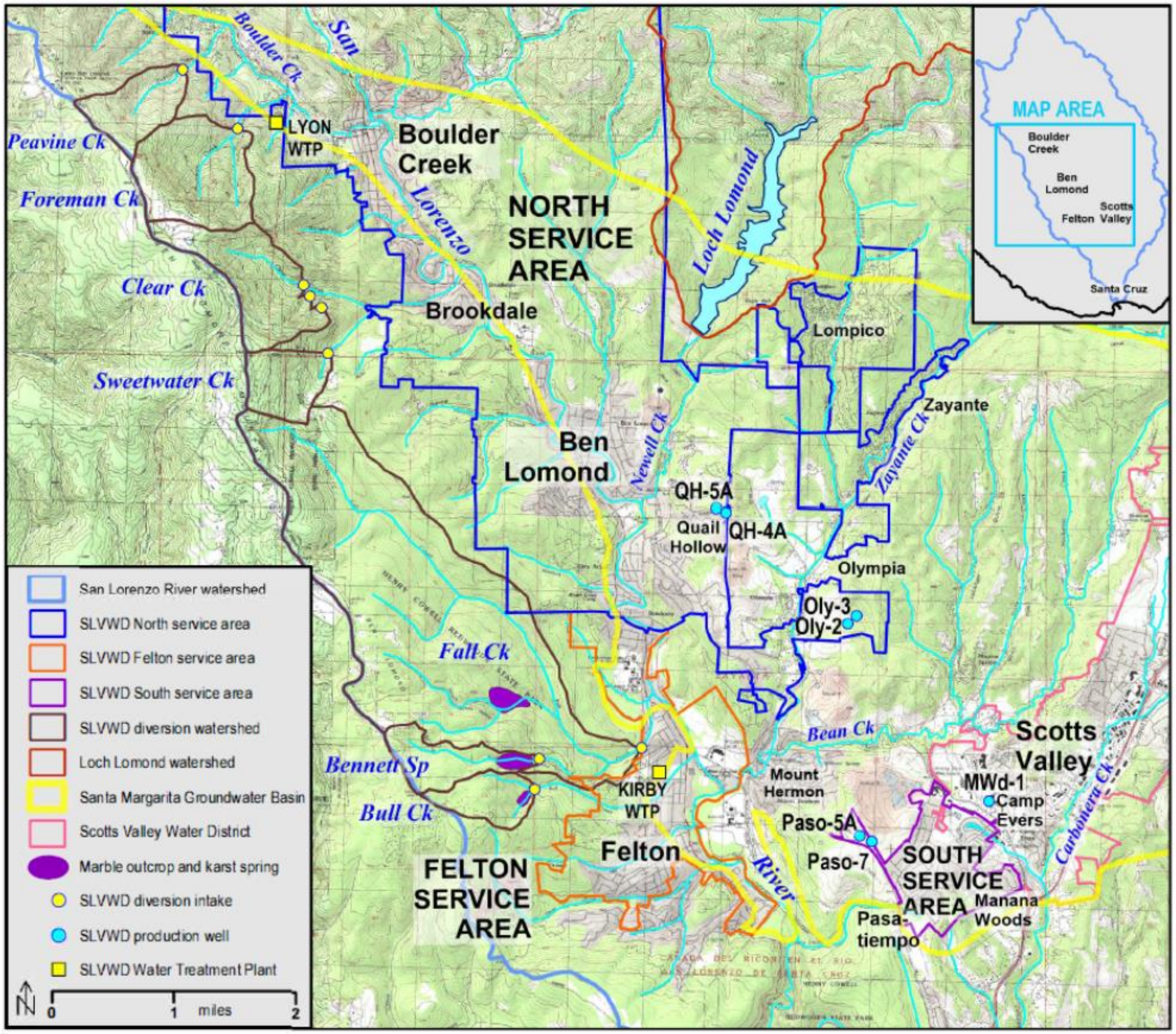
Exponent. 2019. Water Availability Assessment for San Lorenzo River Watershed Conjunctive Use Plan. Prepared for the San Lorenzo Valley Water District.

Podlech, M. 2019. Fisheries Resource Considerations for the San Lorenzo River Watershed Conjunctive Use Plan (Revised Final). Prepared for the San Lorenzo Valley Water District

Attachment 1

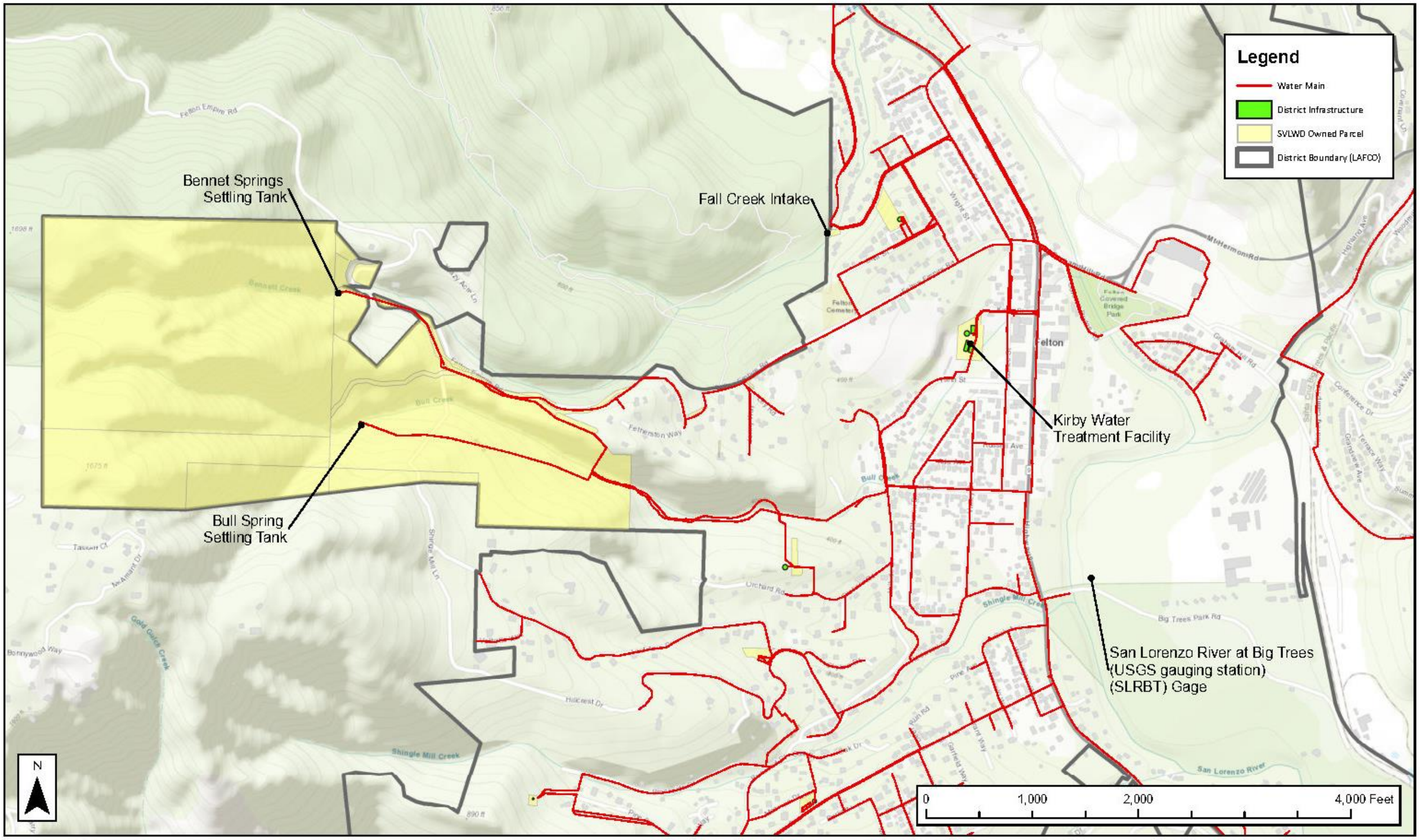
Figures

Figure 1 Regional Location, SLVWD Service Areas, Diversion Watersheds, Points of Diversion, Treatment Plants, and Production Wells



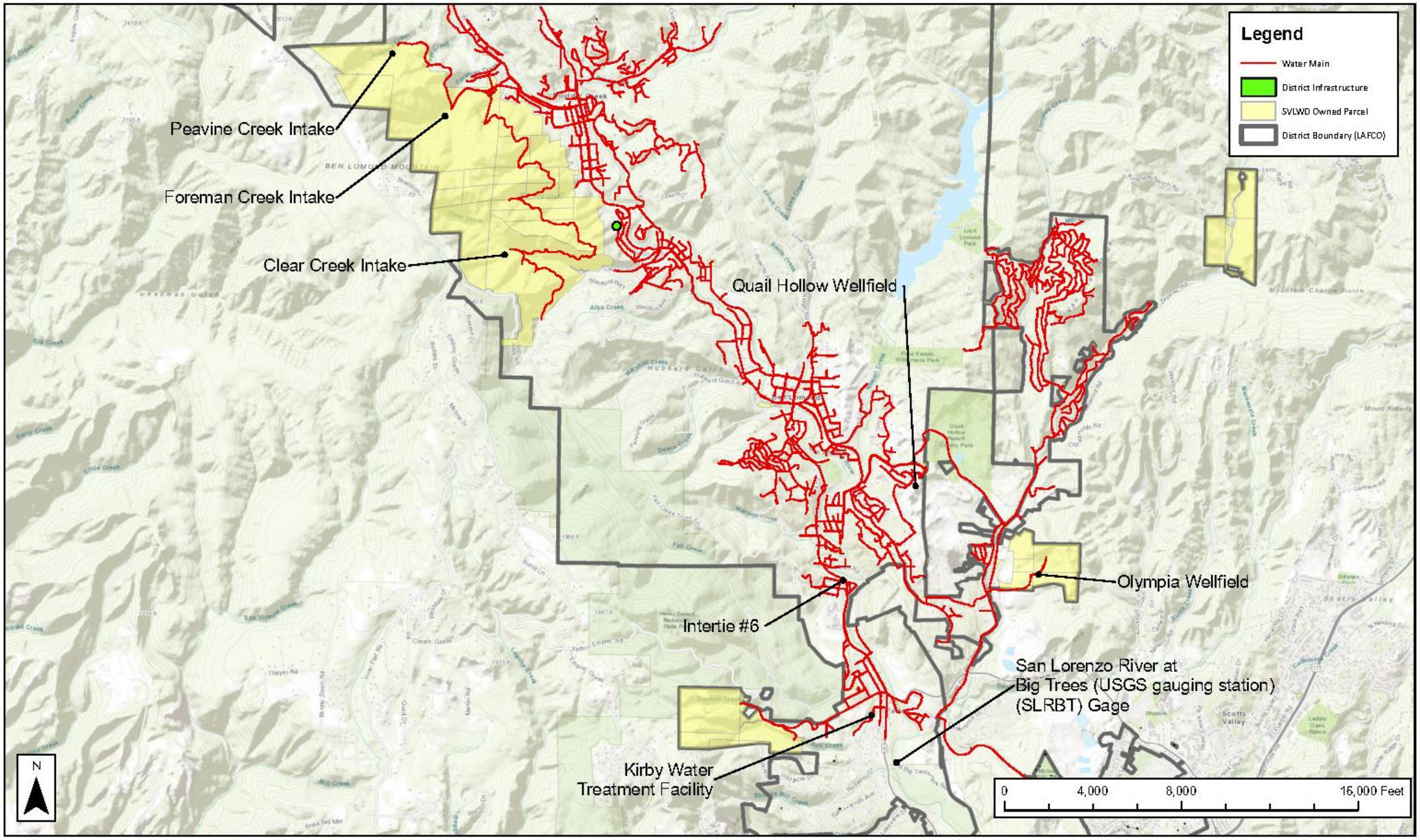
Source: (SLVWD 2021)

Figure 2a **SLRBT Low-Flow Requirements ModificationSLRBT Low-Flow Requirements Modification Scenario Diversion Locations**



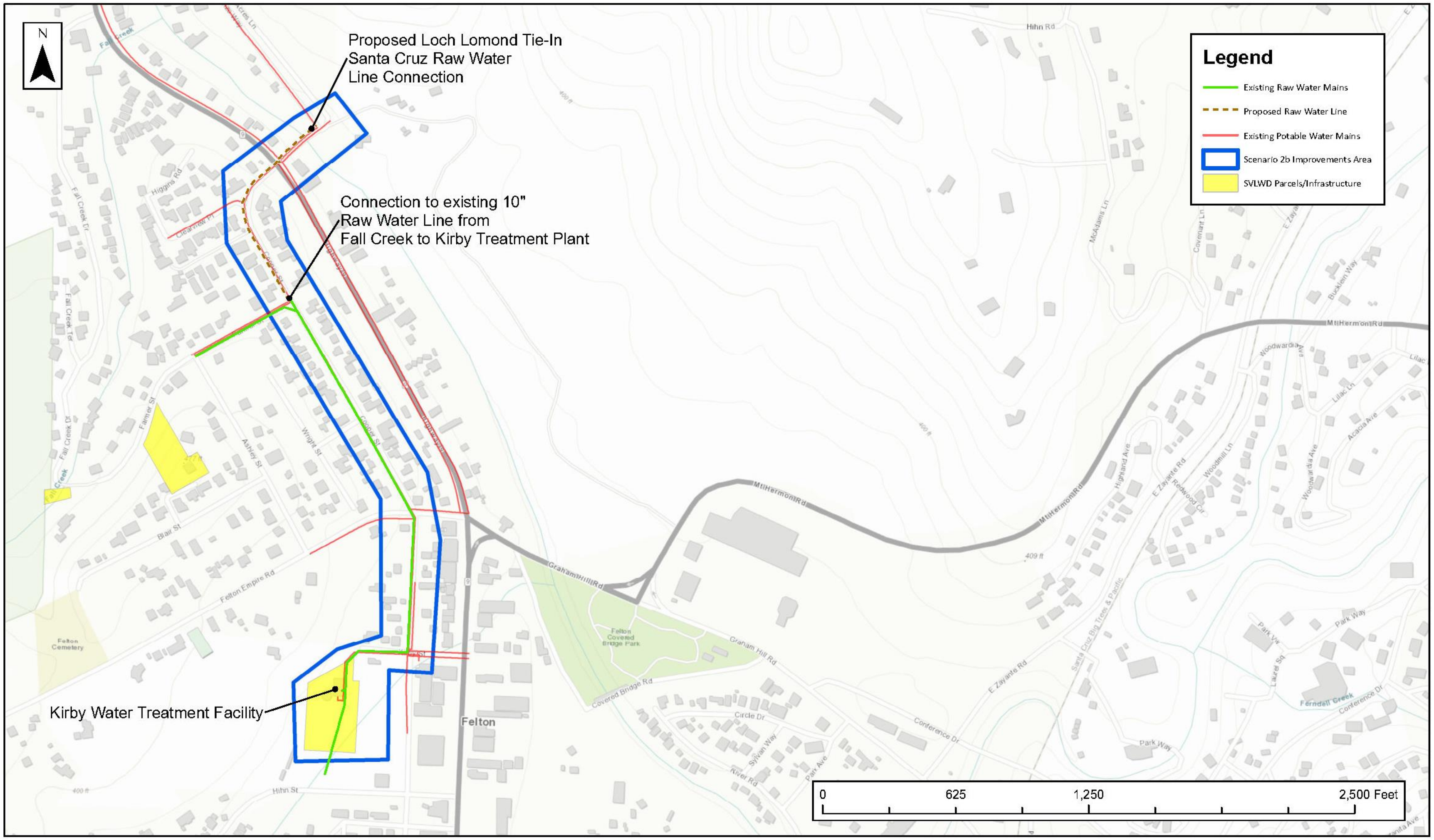
San Lorenzo Valley WATER DISTRICT	Scale:	Conjunctive Use Exhibit: Scenario 1b	Location:	Drawn By:	Approved By:	Date:	Page:
	1:10,000		Felton, CA	JWS	JLW	3/5/2021	1 of 2

Figure 2b North System Diversions Scenario Diversion Locations



San Lorenzo Valley WATER DISTRICT	Scale:	Conjunctive Use Exhibit: Scenario 1f	Location:	Drawn By:	Approved By:	Date:	Page:
	1:48,000		Felton, CA	JWS	JLW	3/5/2021	2 of 2

Figure 3 Lock Lomond Scenario New Infrastructure

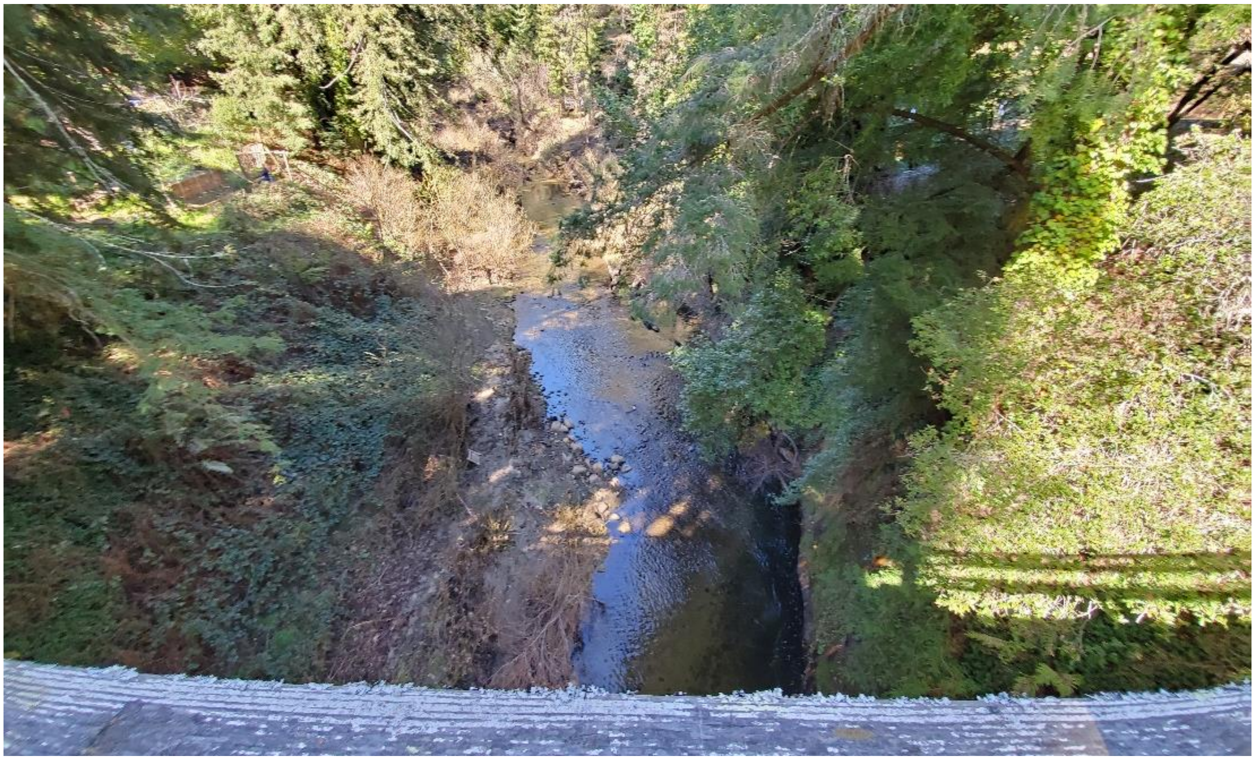


San Lorenzo Valley WATER DISTRICT	Scale:	Conjunctive Use Exhibit	Location:	Drawn By:	Approved By:	Date:	Page:
	1:5,000		Felton, CA	JWS	JLW	2/10/2021	1 of 1

Attachment 2

Representative Site Photographs

Photograph 1. The existing San Lorenzo Way Bridge, facing southwest.



Photograph 2. The San Lorenzo River upstream of the existing San Lorenzo Way Bridge, facing north.

Photograph 3. The alignment of the new raw water line west of the San Lorenzo River, facing east.

Photograph 4. The alignment of the new raw water line in a developed road west of the San Lorenzo River, facing south.

Photograph 5. The Kirby Water Treatment Plant, facing northwest.

Photograph 6. Inside the Kirby Water Treatment Plant, facing northwest.

Attachment 3

Agency Queries

Appendix F

Cultural Records Search Results

Report List

20-2211 :: 20-10506 SLVWD Conjunctive Use Plan

Report No.	Other IDs	Year	Author(s)	Title	Affiliation	Resources
S-003752	Caltrans - 04217 - 380971; Voided - E-6 SCR; Voided - S-4889	1979		Historic Properties Survey Report, 04-SCr-9 P.M. 7.0, Bridge Replacement, Bridge Number 36-45, Town of Felton, Santa Cruz County, 04217 - 380971	Caltrans, District 4	
S-003752a		1977	Mara Melandry	Archaeological Survey Report on Bridge Replacement, SCr-9 PM 7.0, near the town of Felton, Santa Cruz County, 04216 - 400691, Fall Creek Bridge 36-45	Caltrans, District 4	
S-003752b		1978	John W. Snyder	Bridge Evaluations, 04-SCr-9 P.M. 7.01; 9.33, 04216 - 400691	Caltrans	
S-003752c		1979	John W. Snyder	Historic Architectural Survey Report, 04-SCr-9 7.0, Bridge No. 36-45, 04217 - 380971	Caltrans	
S-003787	Voided - E-41 SCR	1972	Rob Edwards	Archaeological Aspect of Environmental Impact Report on PG&E Power Line Alignment from Davenport to Mt. Hermon: Preferred and Secondary Alignments	Cabrillo College	44-000011, 44-000012, 44-000026, 44-000027, 44-000028, 44-000048, 44-000059, 44-000068, 44-000069, 44-000072, 44-000073, 44-000074, 44-000075, 44-000076, 44-000077, 44-000082
S-004066	Caltrans - 04226-397401; Voided - E-320 SCR	1979	Diane C. Watts	Archaeological Survey Report, 04-SCR-9, P.M. 6.46/8.11, proposed shoulder widening near Felton, Santa Cruz County, 04226 - 397401	Caltrans	44-000401
S-004075	Voided - E-329 SCR; Voided - E-333 SCR; Voided - S-4079	1980	Trudy Haversat and Gary S. Breschini	Minor Subsurface Auger Sampling at 150 Oak Avenue, Near CA-SCR-228, Felton,Santa Cruz County, California	Archaeological Consulting	44-000230
S-010226	Caltrans - 4354-120980	1988	Terry Jones	Negative Archaeological Survey Report, Proposed Road Widening for a Left Turn Channelization Between the Entrance to San Lorenzo Valley High School and the Entrance to San Lorenzo Valley Elementary School, 04-SCR-9 P.M.7.2/7.4 4354-120980	California Department of Transportation	
S-012694	Caltrans - 04274-116190	1986	Glenn J. Gmoser	Historic Properties Survey Report, 04-SCR-9 P.M. 8.4/8.7, Proposed Widening of SCR-9 and Felton Bridge at Graham Hill Road, Santa Cruz County, 04274-116190	Caltrans	44-000401, 44-001117, 44-001118, 44-001119, 44-001120, 44-001121, 44-001122, 44-001123, 44-001124
S-012694a		1985	Glenn J. Gmoser	Negative Archaeological Survey Report, 4-SCR-9 P.M. 6.5	Caltrans District 4	

Report List

20-2211 :: 20-10506 SLVWD Conjunctive Use Plan

Report No.	Other IDs	Year	Author(s)	Title	Affiliation	Resources
S-012694b		1986	Gregory King	Historic Architectural Survey Report for a Proposed Widening of SCR-9 and Felton Bridge in Santa Cruz County; 04-SCR-9, P.M. 6.4/6.7	Caltrans District 4	
S-012694c		1985	Stephen D. Mikesell	An Evaluation of the Felton Bridge (36C-101_	Caltrans District 4	
S-016692	Voided - S-17863	1994	Robert Cartier	Cultural Resource Evaluation of Redtree Properties, APN 71-201-43 and APN 71-331-05, -06, in the City of Felton, County of Santa Cruz	Archaeological Resource Management	
S-016692a		1995	Robert Cartier, Lynne Eckert, Jeanne Goetz, Marion Pokriots, and Jon Reddington	Historic Research and Archaeological Testing Program Evaluation for the Redtree Properties, APN 71-201-43 and APN 71-331-05, -06, in the City of Felton, County of Santa Cruz	Archaeological Resource Management	
S-017180		1994	Mark V. Thornton	A Survey and Historic Significance Evaluation of the CDF Building Inventory, CDF Archaeological Reports, Number 17, Volume 1 of 2	California Department of Forestry and Fire Protection	12-000929, 12-000930, 17-001375, 23-003605, 27-001736, 27-001738, 28-000769, 28-000770, 35-000199, 43-000674, 43-000675, 43-000676, 43-000677, 43-000680, 43-002456, 44-000297, 44-000298, 49-001729, 57-000133, 57-000134
S-017180a		1994	Mark V. Thornton	A Survey and Historic Significance Evaluation of the CDF Building Inventory,CDF Archaeological Reports, Number 17, Volume 2 of 2	California State University, Fresno	
S-021591		1998		Seismic Retrofit Programmatic Agreement Short Form HPSR, 05-SCR-Co. Rd., Bridge Number 36C-0038, Seismic Retrofit Work of the Conference Drive Bridge	Basin Research Associates, Inc.	
S-021591a		1998	Colin I. Busby	Negative Archaeological Survey Report, 05-SCR-Co. Rd., Bridge Number 36C-0038, Seismic Retrofit Work of the Conference Drive Bridge	Basin Research Associates, Inc.	
S-021971	Submitter - Project 2700	1999	Mary Doane and Trudy Haversat	Preliminary Archaeological Reconnaissance of Portion of Assessor's Parcel Number 066-211-07, Felton, Santa Cruz County, California	Archaeological Consulting	
S-022415	Submitter - Project 2754; Voided - S-24760	1999	Mary Doane and Trudy Haversat	Preliminary Archaeological Reconnaissance of the Mount Hermon Christian Conference Center, Mount Hermon, Santa Cruz County, California	Archaeological Consulting	44-000971

Report List

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Report No.	Other IDs	Year	Author(s)	Title	Affiliation	Resources
S-022415a		2002	Carrie D. Wills and Brett Rushing	Archaeological Assessment of the Sawmill Area and Southern Pacific Railroad Depot at Redwood Camp, Mount Hermon, California	ENTRIX, Inc.	
S-022539	Caltrans - EA 05-0E0601	2000	Kelda Wilson	Archaeological Survey Report, 05-SCR-9, PM 5.9-168 EA 05-0E0601, Construction of a Drainage System in the Shoulder of State Route 9 in Felton, Santa Cruz County	Caltrans District 5	44-000401
S-022825	Caltrans - EA 05-0E7001	2000	Kelda Wilson	Negative Archaeological Survey Report, 05-SCR-9, 236, PM 9:6.2/6.5 CU 05-168, EA 05-0E7001, Proposed Asphalt-Concrete Overlay on Portions of State Route 9	California Department of Transportation	44-000401
S-026659	Submitter - Project 3385	2003	Mary Doane and Trudy Haversat	Preliminary Archaeological Reconnaissance of the City of Santa Cruz Water Department Felton Booster Pump Station Site, Felton, Santa Cruz County, California	Archaeological Consulting	
S-028809	Submitter - H&A 04-XY	2004	Matthew R. Clark	An Archaeological Reconnaissance of the Proposed San Lorenzo Valley Trail Alignment Alternatives, Boulder Creek-Santa Cruz, Santa Cruz County, California	Holman & Associates	44-000116, 44-000230, 44-000401, 44-000431
S-030907	Caltrans - EA 43-984433	2004	Christopher McMorris	Caltrans Historic Bridge Inventory Update: Metal Truss, Moveable, and Steel Arch Bridges, Contract: 43A0086, Task Order: 01, EA: 43-984433, Volume I: Report and Figures	JRP Historical Consulting	01-003158, 01-003190, 01-010835, 01-011433, 23-004262, 27-001805, 28-001020, 35-000383, 38-001339, 38-002455, 38-004878, 49-002862, 49-002864, 49-002865, 49-002866, 49-002867, 49-002870, 49-004522
S-034931	Other - AT&T Wireless Project #1466 "Felton"	2008	Carolyn Losee	Cultural Resources Investigation for AT&T Wireless Project #1466 "Felton" 131 Kirby Street, Felton, Santa Cruz County, California 95017, EBI Project #61082126 (letter report)	Archaeological Resources Technology	
S-037033	Submitter - AACC 10-03-20	2010	Robert L. Edwards and Charr Simpson Smith	Final Report: Archaeological Reconnaissance Report, 5865 Graham Hill Road, Felton, Santa Cruz County, California.	Archaeological Associates of Central California	
S-038258		2011	Allika Ruby	PG&E Camp Evers 2105 Blitz Project (letter report)	Far Western Anthropological Research Group, Inc	
S-039178	Submitter - AACC 12-05-46	2012	Robert L. Edwards and Charr Simpson Smith	Archaeological Reconnaissance Report for a Proposed New Library on Gushee Street, Felton, Santa Cruz County, California, APN 065-073-03	Archaeological Associates of Central California	

Report List

20-2211 :: 20-10506 SLVWD Conjunctive Use Plan

Report No.	Other IDs	Year	Author(s)	Title	Affiliation	Resources
S-040523	OTIS Report Number - FCC_2013_0306_011	2013	Lorna Billat	Collocation Submission Packet; Felton Fire; CNU3500; 131 Kirby Street, Felton	Earth Touch, Inc.	44-000769
S-040523a		2013	Dana Supernowicz	Architectural Evaluation Study of the Felton Fire Project, AT&T Mobility Site No. CNU3500, 131 Kirby Street, Felton, Santa Cruz County, California 95018	Historic Resource Associates	
S-040523b		2013	Carol Roland-Nawi	[FCC_2013_0306_011]; Re: Felton Fire / CNU3500, 131 Kirby Street, Felton, Collocation	Office of Historic Preservation	
S-041946	OHP PRN - FHWA 20130930001	2013	Brad Brewster and Heidi Koenig	Historic Property Survey Report: Felton Covered Bridge Restoration Project, Felton, Santa Cruz County, California, California Department of Transportation District 5 - San Luis Obispo, Federal ID# NHCBPPL-5936 (101)	Environmental Science Associates, Inc.	44-000209
S-041946a		2013	Nancy Sipel	FHWA20130930001: Finding of Effect Notification for the Felton Covered Bridge Restoration Project, Santa Cruz County, California	California Department of Transportation	
S-047860		1995	Susan Lehmann	County of Santa Cruz, Survey of Historic Resources, Additions - 1995		44-000471, 44-000980, 44-000996, 44-000997, 44-000998, 44-000999, 44-001000, 44-001001, 44-001002, 44-001003, 44-001004, 44-001005, 44-001006, 44-001007, 44-001008, 44-001009, 44-001011, 44-001012, 44-001013, 44-001014, 44-001015, 44-001016, 44-001017, 44-001018
S-051509	Other - AR-843-35	1975	Paul E. Nesbitt	Statewide Survey Project of Cultural Resources in Relation to Departmental Development Projects, Historical and Recreational Facilities, Volume I: Reports 1-9 (inclusive)	California Department of Parks and Recreation	27-000199, 27-000200, 27-000209, 27-000210, 27-000302, 27-000575, 27-000576, 27-000729, 27-000730, 27-000731, 27-001721, 27-003682, 28-000062, 28-000231, 28-000237, 28-000238, 28-000239, 41-000118, 49-000488
S-051509a		1975	Henry S. Keesling and G.R. Stammerjohan	Statewide Survey Project of Cultural Resources in Relation to Departmental Development Projects, Report #1 - Andrew Molera State Park	California Department of Parks and Recreation	

Report List

20-2211 :: 20-10506 SLVWD Conjunctive Use Plan

Report No.	Other IDs	Year	Author(s)	Title	Affiliation	Resources
S-051509b		1975	Henry S. Keesling and G.R. Stammerjohan	Statewide Survey Project of Cultural Resources in Relation to Departmental Development Projects, Report #2 - Palm Beach State Beach	California Department of Parks and Recreation	
S-051509c		1975	Henry S. Keesling and G.R. Stammerjohan	Statewide Survey Project of Cultural Resources in Relation to Departmental Development Projects, Report #3 - New Brighton State Beach	California Department of Parks and Recreation	
S-051509d		1975	Henry S. Keesling and G.R. Stammerjohan	Statewide Survey Project of Cultural Resources in Relation to Departmental Development Projects, Report #4 - Henry Cowell Redwoods State Park	California Department of Parks and Recreation	
S-051509e		1975	Henry S. Keesling and G.R. Stammerjohan	Statewide Survey Project of Cultural Resources in Relation to Departmental Development Projects, Report #5 - San Gregorio State Beach	California Department of Parks and Recreation	
S-051509f		1975	Henry S. Keesling and G.R. Stammerjohan	Statewide Survey Project of Cultural Resources in Relation to Departmental Development Projects, Report #6 - Half Moon Bay State Beach	California Department of Parks and Recreation	
S-051509g		1975	Henry S. Keesling and G.R. Stammerjohan	Statewide Survey Project of Cultural Resources in Relation to Departmental Development Projects, Report #7 - Mount Diablo State Park	California Department of Parks and Recreation	
S-051509h		1975	Henry S. Keesling and G.R. Stammerjohan	Statewide Survey Project of Cultural Resources in Relation to Departmental Development Projects, Project #8 - Sugarloaf Ridge State Park	California Department of Parks and Recreation	
S-051509i		1975	Henry S. Keesling and G.R. Stammerjohan	Statewide Survey Project of Cultural Resources in Relation to Departmental Development Projects, Report #9 - Bothe-Napa Valley State Park	California Department of Parks and Recreation	

Resource List

20-2211 :: 20-10506 SLVWD Conjunctive Use Plan

Primary No.	Trinomial	Other IDs	Type	Age	Attribute codes	Recorded by	Reports
P-44-000209	CA-SCR-000207H	Resource Name - Felton Covered Bridge; National Register - NPS 73000451-0000; CHL - SHL-0583-0000; OHP Property Number - 013208; OHP PRN - 619.0-84-HP-44-001	Structure	Historic	HP19	1970 (Linda Ishihara, Jerry Hughes, County Department of Parks and Recreation); 1979 (Jim Arbuckle, San Lorenzo Valley Historical Society); 1979 (J. Cooper, [none])	S-003983, S-041946
P-44-000210	CA-SCR-000208H	Resource Name - Felton Presbyterian Church; Voided - S-3984 (E-328); OHP Property Number - 013209; OHP PRN - NPS-78000774-0000; OHP PRN - 5018-0002-0000	Building	Historic	HP16	1977 (Mrs. Edith E Fikes, Faye G. Belardi Board of Trustees); 1979 (J. Cooper, Cabrillo College); 1984 ([none], Basin Research Associates)	S-003984
P-44-000230	CA-SCR-000228	Resource Name - SCAS 79-408 #1	Site	Prehistoric	AP02; AP15	1980 (Peter Johnson, Chuck Smith, [none])	S-004075, S-004079, S-028809
P-44-000297		Resource Name - Felton Ranger Unit Headquarters; OHP Property Number - 105919; OHP Property Number - 105921; OHP PRN - St.Ag. -3540-0211, 0212; Other - Ranger's Residence Felton Ranger Unit Headquarters; Other - State Residence/Forestry Office Felton Ranger Unit Headquarters; Other - 8-Bay Equipment GarageFelton or Santa Cruz-San Mateo Ranger Unit Headquarters; Other - 8-Bay Equipment Shed Felton Ranger Unit Headquarters	Building	Historic	HP02; HP09; HP35	1994 (Mark V. Thornton, CDF)	S-017180, S-024598
P-44-000401	CA-SCR-000329H	Resource Name - OC-9, MC-9; Other - Highway 9 (Santa Cruz County)	Structure, Site, Other	Historic	HP37	1999 (J. Berg, S. Mikesell, FWARG, JRP)	S-004066, S-012694, S-022539, S-022825, S-027556, S-028236, S-028809, S-028812, S-029528, S-030187, S-037509, S-038430, S-051507, S-052719
P-44-000769		Resource Name - Felton Fire District Station	Building	Historic	HP09	2013 (Dana Supernowicz, Historic Resource Associates)	S-040523

Resource List

20-2211 :: 20-10506 SLVWD Conjunctive Use Plan

Primary No.	Trinomial	Other IDs	Type	Age	Attribute codes	Recorded by	Reports
P-44-000855		Resource Name - Cowell Home Ranch District	District	Historic	AH09; HP02; HP04; HP08	2006 (David G. Eselius, Historic Opportunities of Santa Cruz)	S-015955, S-048231, S-053071, S-053760, S-053762
P-44-001014		Resource Name - Rose Acres Ranch; OHP Property Number - 013241; OHP PRN - 1518-0001-0000	Building	Historic	HP04	1995 (Susan Lehmann, SCR County)	S-047860
P-44-001117		Resource Name - 6338 Highway 9; Other - Map Reference #1	Building	Historic	HP06	1986 (Gregory King, Caltrans District 4)	S-012694
P-44-001118		Resource Name - Lazy Daze Motel; Other - Ana-Don Motel; Other - Map Reference #2	Building	Historic	HP06	1986 (Gregory King, Caltrans District 4)	S-012694
P-44-001119		Resource Name - Beach Street; Other - Map Reference #3	Building	Historic	HP06	1986 (Gregory King, Caltrans District 4)	S-012694
P-44-001120		Resource Name - Bea's Beauty Salon; OTIS Resource Number - Map Reference #4	Building	Historic	HP06	1986 (Gregory King, Caltrans District 4)	S-012694
P-44-001121		Resource Name - 9420-24 Highway 9; Other - Map Reference #5	Building	Historic	HP06	1986 (Gregory King, Caltrans District 4)	S-012694
P-44-001122		Resource Name - 6407 Highway 9; Other - Map Reference #6	Building	Historic	HP02	1986 (Gregory King, Caltrans District 4)	S-012694
P-44-001123		Resource Name - 6385 Highway 9; Other - Map Reference #7	Building	Historic	HP02	1986 (Gregory King, Caltrans District 4)	S-012694
P-44-001124		Resource Name - Giblin's Chevron Service; Other - Map Reference #8	Building	Historic	HP05	1986 (Gregory King, Caltrans District 4)	S-012694

Appendix G

Energy Calculations

Conjunctive Use Plan

Last Updated: 5/21/21

Compression-Ignition Engine Brake-Specific Fuel Consumption (BSFC) Factors **[1]**:

HP: 0 to 100	0.0588	HP: Greater than 100	0.0529

Values above are expressed in gallons per horsepower-hour/BSFC.

CONSTRUCTION EQUIPMENT

Construction Equipment	#	Hours per Day	Horsepower	Load Factor	Construction Phase	Fuel Used (gallons)
Concrete/Industrial Saws	1	8	81	0.73	Demolition Phase	1,195.31
Air Compressors	1	8	78	0.48	Demolition Phase	756.85
Rubber Tired Loaders	1	8	203	0.36	Demolition Phase	1,328.85
Excavators	1	8	158	0.38	Demolition Phase	1,091.74
Tractors/Loaders/Backhoes	1	8	97	0.37	Site Preparation Phase	708.64
Plate Compactors	1	8	8	0.43	Site Preparation Phase	67.92
Air Compressors	1	8	78	0.48	Site Preparation Phase	739.24
Rubber Tired Loaders	1	8	203	0.36	Site Preparation Phase	1,297.95
Excavators	1	8	158	0.38	Site Preparation Phase	1,066.35
Concrete/Industrial Saws	1	8	81	0.73	Building Construction Phase	2,335.02
Plate Compactors	1	8	8	0.43	Building Construction Phase	135.84
Cranes	1	8	231	0.29	Building Construction Phase	2,379.57
Excavators	1	8	158	0.38	Building Construction Phase	2,132.70
Rough Terrain Forklifts	1	8	100	0.4	Building Construction Phase	1,579.58
Rubber Tired Loaders	1	8	203	0.36	Building Construction Phase	2,595.89
Rollers	1	8	80	0.38	Paving Phase	314.41
Graders	1	8	187	0.41	Paving Phase	713.28
Rubber Tired Loaders	1	8	203	0.36	Paving Phase	679.88
Pavers	1	8	130	0.42	Paving Phase	507.95
Scrapers	1	8	367	0.48	Paving Phase	1,638.85
Paving Equipment	1	8	132	0.36	Paving Phase	442.09
					Total Fuel Used	**23,707.89**
						(Gallons)

Construction Phase	Days of Operation
Demolition Phase	43
Site Preparation Phase	42
Building Construction Phase	84
Paving Phase	22
Total Days	191

WORKER TRIPS

Constuction Phase	MPG [2]	Trips	Trip Length (miles)	Fuel Used (gallons)
Demolition Phase	24.4	0	21.0	0.00
Site Preparation Phase	24.4	59	21.0	2132.70
Grading Phase	24.4	0	21.0	0.00
Building Construction Phase	24.4	0	21.0	0.00
Paving Phase	24.4	0	21.0	0.00
Architectural Coating Phase	24.4	0	21.0	0.00
			Fuel	**2,132.70**

HAULING AND VENDOR TRIPS

Trip Class	MPG [2]	Trips	Trip Length (miles)	Fuel Used (gallons)
		HAULING TRIPS		
Demolition Phase	7.5	0	21.0	0.00
Site Preparation Phase	7.5	59	21.0	165.20

Grading Phase	7.5	0	21.0	0.00
Building Construction Phase	7.5	0	21.0	0.00
Paving Phase	7.5	0	21.0	0.00
Architectural Coating Phase	7.5	0	21.0	0.00
			Fuel	**165.20**

Total Gasoline Consumption (gallons)	**2,132.70**
Total Diesel Consumption (gallons)	**23,873.09**

Sources:

[1] United States Environmental Protection Agency. 2018. *Exhaust and Crankcase Emission Factors for Nonroad Compression-Ignition Engines in MOVES2014b* . July 2018. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100UXEN.pdf.

[2] United States Department of Transportation, Bureau of Transportation Statistics. 2019. *National Transportation Statistics 2019* . Available at: https://www.bts.gov/topics/national-transportation-statistics.

Appendix H

Noise Data and Manufacturer Equipment Specifications

```
                        Roadway Construction Noise Model (RCNM),Version 1.1

Report date:             04/30/2021
Case Description:        Conjunction Use Plan - Demolition

                                **** Receptor #1 ****

                                           Baselines (dBA)
Description                 Land Use        Daytime    Evening    Night
-----------                 --------        -------    -------    -----
Residents along pipeline    Residential        60.0       55.0     50.0
                                     Equipment
                                     ---------
                                     Spec    Actual    Receptor    Estimated
                    Impact  Usage    Lmax    Lmax      Distance    Shielding
Description         Device   (%)     (dBA)   (dBA)      (feet)       (dBA)
-----------         ------  -----    -----   -----     --------    ---------
Concrete Saw            No     20             89.6         15.0          0.0
Compressor (air)        No     40             77.7         15.0          0.0
Excavator               No     40             80.7         15.0          0.0
Front End Loader        No     40             79.1         15.0          0.0

                                     Results
                                     -------
                                                            Noise Limits (dBA)                          Noise Limit Exceedance (dBA)
                                           ----------------------------------------------    ----------------------------------------------
                        Calculated (dBA)         Day           Evening          Night              Day           Evening          Night
                        ----------------   --------------   -------------  --------------    --------------  --------------  --------------
Equipment                  Lmax    Leq        Lmax    Leq      Lmax    Leq      Lmax    Leq       Lmax    Leq     Lmax    Leq     Lmax    Leq
----------------------  ------  ------     ------  ------  ------  ------  ------  ------    ------  ------  ------  ------  ------  ------
Concrete Saw             100.0    93.0        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Compressor (air)          88.1    84.1        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Excavator                 91.2    87.2        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Front End Loader          89.6    85.6        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
               Total     100.0    95.0        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
```

```
                               **** Receptor #2 ****

                                           Baselines (dBA)
Description                  Land Use        Daytime    Evening    Night
-----------                  --------        -------    -------    -----
Residents near Kirby Pant    Residential        60.0       55.0     50.0

                                     Equipment
                                     ---------
                                     Spec    Actual     Receptor    Estimated
                    Impact  Usage    Lmax    Lmax       Distance    Shielding
Description         Device   (%)     (dBA)   (dBA)       (feet)       (dBA)
-----------         ------  -----    -----   -----      --------    ---------
Concrete Saw            No     20             89.6         150.0          0.0
Compressor (air)        No     40             77.7         150.0          0.0
Excavator               No     40             80.7         150.0          0.0
Front End Loader        No     40             79.1         150.0          0.0

                                     Results
                                     -------
                                                            Noise Limits (dBA)                          Noise Limit Exceedance (dBA)
                                           ----------------------------------------------    ----------------------------------------------
                        Calculated (dBA)         Day           Evening          Night                 Day           Evening          Night
                        ----------------   --------------   -------------  --------------    --------------  --------------  --------------
Equipment                  Lmax    Leq        Lmax    Leq     Lmax    Leq     Lmax    Leq       Lmax    Leq     Lmax    Leq     Lmax    Leq
----------------------  ------  ------     ------  ------  ------  ------  ------  ------    ------  ------  ------  ------  ------  ------
Concrete Saw              80.0    73.0        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Compressor (air)          68.1    64.1        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Excavator                 71.2    67.2        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Front End Loader          69.6    65.6        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
               Total      80.0    75.0        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
```

```
                        Roadway Construction Noise Model (RCNM),Version 1.1

Report date:             04/30/2021
Case Description:        Conjunction Use Plan -Paving
                                **** Receptor #1 ****
                                           Baselines (dBA)
Description                 Land Use        Daytime    Evening    Night
-----------                 --------        -------    -------    -----
Residents along pipeline    Residential        60.0       55.0     50.0
                                     Equipment
                                     ---------
                                     Spec    Actual    Receptor    Estimated
                    Impact  Usage    Lmax    Lmax      Distance    Shielding
Description         Device   (%)     (dBA)   (dBA)      (feet)       (dBA)
-----------         ------  -----    -----   -----     --------    ---------
Grader                  No     40     85.0               15.0          0.0
Front End Loader        No     40             79.1       15.0          0.0
Paver                   No     50             77.2       15.0          0.0
Roller                  No     20             80.0       15.0          0.0
Scraper                 No     40             83.6       15.0          0.0

                                     Results
                                     -------
                                                            Noise Limits (dBA)                          Noise Limit Exceedance (dBA)
                                           ----------------------------------------------    ----------------------------------------------
                        Calculated (dBA)         Day           Evening          Night              Day           Evening          Night
                        ----------------   --------------   -------------  --------------    --------------  --------------  --------------
Equipment                  Lmax    Leq        Lmax    Leq     Lmax    Leq     Lmax    Leq       Lmax    Leq     Lmax    Leq     Lmax    Leq
----------------------  ------  ------     ------  ------  ------  ------  ------  ------    ------  ------  ------  ------  ------  ------
Grader                   100.0    93.0        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Front End Loader          93.7    86.7        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Paver                     88.1    84.1        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Roller                    91.0    83.0        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Scraper                   91.2    87.2        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
               Total     100.0    95.4        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
```

```
                                **** Receptor #2 ****

                                           Baselines (dBA)
Description                  Land Use        Daytime    Evening    Night
-----------                  --------        -------    -------    -----
Residents near Kirby Pant    Residential        60.0       55.0     50.0

                                     Equipment
                                     ---------
                                     Spec    Actual     Receptor    Estimated
                    Impact  Usage    Lmax    Lmax       Distance    Shielding
Description         Device   (%)     (dBA)   (dBA)      (feet)        (dBA)
-----------         ------  -----    -----   -----      --------    ---------
Grader                  No     40     85.0                 150.0          0.0
Front End Loader        No     40             79.1         150.0          0.0
Paver                   No     50             77.2         150.0          0.0
Roller                  No     20             80.0         150.0          0.0
Scraper                 No     40             83.6         150.0          0.0

                                     Results
                                     -------
                                                            Noise Limits (dBA)                            Noise Limit Exceedance (dBA)
                                           ----------------------------------------------     ----------------------------------------------
                        Calculated (dBA)         Day           Evening          Night                 Day           Evening          Night
                        ----------------   --------------   -------------   --------------    --------------  --------------  --------------
Equipment                  Lmax    Leq        Lmax    Leq     Lmax    Leq     Lmax    Leq        Lmax    Leq     Lmax    Leq     Lmax    Leq
----------------------  ------  ------     ------  ------  ------  ------   ------  ------    ------  ------  ------  ------  ------  ------
Grader                    75.5    71.5        N/A     N/A     N/A     N/A     N/A     N/A        N/A     N/A     N/A     N/A     N/A     N/A
Front End Loader          69.6    65.6        N/A     N/A     N/A     N/A     N/A     N/A        N/A     N/A     N/A     N/A     N/A     N/A
Paver                     67.7    64.7        N/A     N/A     N/A     N/A     N/A     N/A        N/A     N/A     N/A     N/A     N/A     N/A
Roller                    70.5    63.5        N/A     N/A     N/A     N/A     N/A     N/A        N/A     N/A     N/A     N/A     N/A     N/A
Scraper                   74.0    70.1        N/A     N/A     N/A     N/A     N/A     N/A        N/A     N/A     N/A     N/A     N/A     N/A
               Total      75.5    75.2        N/A     N/A     N/A     N/A     N/A     N/A        N/A     N/A     N/A     N/A     N/A     N/A
```

```
                        Roadway Construction Noise Model (RCNM),Version 1.1
Report date:             04/30/2021
Case Description:        Conjunction Use Plan -Pipeline Installation and Construction
                                **** Receptor #1 ****

                                           Baselines (dBA)
Description                 Land Use        Daytime    Evening    Night
-----------                 --------        -------    -------    -----
Residents along pipeline    Residential        60.0       55.0     50.0
                                     Equipment
                                     ---------
                                       Spec    Actual    Receptor    Estimated
                      Impact  Usage    Lmax    Lmax      Distance    Shielding
Description           Device   (%)     (dBA)   (dBA)     (feet)        (dBA)
-----------           ------  -----    -----   -----     --------    ---------
Concrete Saw              No     20             89.6         15.0          0.0
Compactor (ground)        No     20             83.2         15.0          0.0
Compressor (air)          No     40             77.7         15.0          0.0
Crane                     No     16             80.6         15.0          0.0
Excavator                 No     40             80.7         15.0          0.0

                                     Results
                                     -------
                                                            Noise Limits (dBA)                          Noise Limit Exceedance (dBA)
                                           ----------------------------------------------    ----------------------------------------------

                        Calculated (dBA)         Day           Evening          Night              Day           Evening          Night
                        ----------------   --------------   -------------  --------------    --------------  --------------  --------------

Equipment                  Lmax    Leq        Lmax    Leq     Lmax    Leq     Lmax    Leq       Lmax    Leq     Lmax    Leq     Lmax    Leq
----------------------  ------  ------     ------  ------  ------  ------  ------  ------    ------  ------  ------  ------  ------  ------
Concrete Saw             100.0    93.0        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Compactor (ground)        93.7    86.7        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Compressor (air)          88.1    84.1        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Crane                     91.0    83.0        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Excavator                 91.2    87.2        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
               Total     100.0    95.4        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
```

```
                                **** Receptor #2 ****

                                           Baselines (dBA)
Description                  Land Use        Daytime    Evening    Night
-----------                  --------        -------    -------    -----
Residents near Kirby Pant    Residential        60.0       55.0     50.0

                                     Equipment
                                     ---------
                                       Spec    Actual    Receptor    Estimated
                      Impact  Usage    Lmax    Lmax      Distance    Shielding
Description           Device   (%)     (dBA)   (dBA)      (feet)       (dBA)
-----------           ------  -----    -----   -----     --------    ---------
Concrete Saw              No     20              89.6       150.0          0.0
Compactor (ground)        No     20              83.2       150.0          0.0
Compressor (air)          No     40              77.7       150.0          0.0
Crane                     No     16              80.6       150.0          0.0
Excavator                 No     40              80.7       150.0          0.0

                                     Results
                                     -------
                                                            Noise Limits (dBA)                          Noise Limit Exceedance (dBA)
                                           ----------------------------------------------    ----------------------------------------------
                        Calculated (dBA)         Day           Evening          Night              Day           Evening          Night
                        ----------------   --------------   -------------  --------------    --------------  --------------  --------------
Equipment                  Lmax    Leq        Lmax    Leq     Lmax    Leq     Lmax    Leq       Lmax    Leq     Lmax    Leq     Lmax    Leq
---------------------   ------  ------     ------  ------  ------  ------  ------  ------    ------  ------  ------  ------  ------  ------
Concrete Saw              80.0    73.0        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Compactor (ground)        73.7    66.7        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Compressor (air)          68.1    64.1        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Crane                     71.0    63.0        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Excavator                 71.2    67.2        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
               Total      80.0    75.4        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
```

```
                        Roadway Construction Noise Model (RCNM),Version 1.1

Report date:             04/30/2021
Case Description:        Conjunction Use Plan -Site Preparation

                                **** Receptor #1 ****

                                           Baselines (dBA)
Description                 Land Use        Daytime    Evening    Night
-----------                 --------        -------    -------    -----
Residents along pipeline    Residential        60.0       55.0     50.0
                                     Equipment
                                     ---------
                                       Spec    Actual    Receptor    Estimated
                      Impact  Usage    Lmax    Lmax      Distance    Shielding
Description           Device   (%)     (dBA)   (dBA)      (feet)       (dBA)
-----------           ------  -----    -----   -----     --------    ---------
Backhoe                   No     40             77.6         15.0          0.0
Compactor (ground)        No     20             83.2         15.0          0.0
Compressor (air)          No     40             77.7         15.0          0.0
Excavator                 No     40             80.7         15.0          0.0

                                     Results
                                     -------
                                                            Noise Limits (dBA)                          Noise Limit Exceedance (dBA)
                                           ----------------------------------------------    ----------------------------------------------
                        Calculated (dBA)         Day           Evening          Night              Day           Evening          Night
                        ----------------   --------------   -------------  --------------    --------------  --------------  --------------
Equipment                  Lmax    Leq         Lmax    Leq     Lmax    Leq     Lmax    Leq       Lmax    Leq     Lmax    Leq     Lmax    Leq
----------------------  ------  ------     ------  ------  ------  ------  ------  ------    ------  ------  ------  ------  ------  ------
Backhoe                   88.0    84.0        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Compactor (ground)        93.7    86.7        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Compressor (air)          88.1    84.1        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Excavator                 91.2    87.2        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
               Total      93.7    91.8        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
```

```
                                **** Receptor #2 ****

                                           Baselines (dBA)
Description                  Land Use        Daytime    Evening    Night
-----------                  --------        -------    -------    -----
Residents near Kirby Pant    Residential        60.0       55.0     50.0

                                     Equipment
                                     ---------
                                       Spec    Actual      Receptor    Estimated
                      Impact  Usage    Lmax    Lmax        Distance    Shielding
Description           Device   (%)     (dBA)   (dBA)       (feet)        (dBA)
-----------           ------  -----    -----   -----       --------    ---------
Backhoe                   No     40               77.6        150.0          0.0
Compactor (ground)        No     20               83.2        150.0          0.0
Compressor (air)          No     40               77.7        150.0          0.0
Excavator                 No     40               80.7        150.0          0.0

                                     Results
                                     -------
                                                            Noise Limits (dBA)                          Noise Limit Exceedance (dBA)
                                           ----------------------------------------------    ----------------------------------------------
                        Calculated (dBA)         Day           Evening          Night              Day           Evening          Night
                        ----------------   --------------  --------------  --------------    --------------  --------------  --------------
Equipment                  Lmax    Leq        Lmax    Leq     Lmax    Leq     Lmax    Leq       Lmax    Leq     Lmax    Leq     Lmax    Leq
----------------------  ------  ------     ------  ------  ------  ------  ------  ------    ------  ------  ------  ------  ------  ------
Backhoe                   68.0    64.0        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Compactor (ground)        73.7    66.7        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Compressor (air)          68.1    64.1        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
Excavator                 71.2    67.2        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
               Total      73.7    71.8        N/A     N/A     N/A     N/A     N/A     N/A       N/A     N/A     N/A     N/A     N/A     N/A
```

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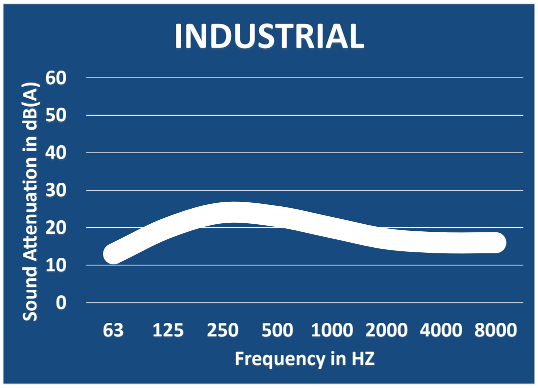
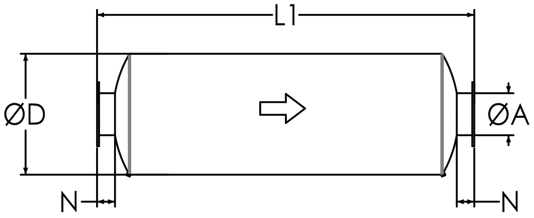
Industrial Grade Silencers

Model NTIN-C (Cylindrical), 15-20 dBA

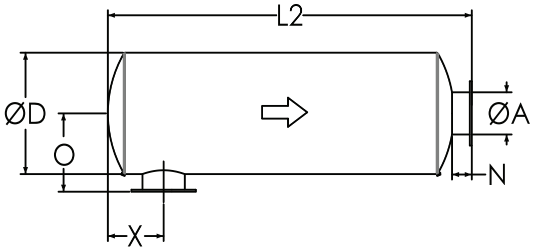
TYPICAL ATTENUATION CURVE



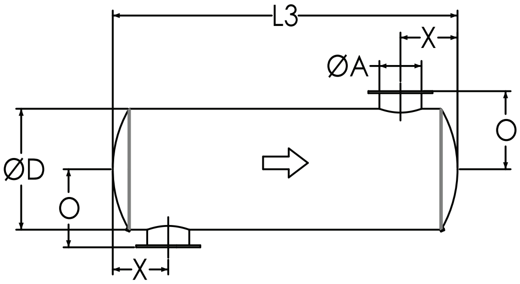
TYPICAL CONFIGURATIONS



END IN END OUT (EI-EO)



SIDE IN END OUT (SI-EO)



SIDE IN SIDE OUT (SI-SO)

Nett Technologies' Industrial Grade Silencers are designed to achieve maximum performance with the least amount of backpressure.
The silencers are Reactive Silencers and are typically used for reciprocating or positive displacement engines where noise level regulations are low.

FEATURES & BENEFITS

- Over 25 years of excellence in manufacturing noise and emission control solutions
- Compact modular designs providing ease of installations, less weight and less foot-print
- Responsive lead time for both standard and custom designs to meet your needs
- Customized engineered systems solutions to meet challenging integration and engine requirements

Contact Nett Technologies with your projects design requirements and specifications for optimized noise control solutions.

OPTIONS

- Versatile connections including ANSI pattern flanges, NPT, slip-on, engine flange, schedule 40 and others
- Aluminized Steel, Stainless Steel 304 or 316 construction
- Horizontal or vertical mounting brackets and lifting lugs

ACCESSORIES

- Hardware Kits
- Flexible connectors and expansion joints
- Elbows
- Thimbles
- Raincaps
- Thermal insulation: integrated or with thermal insulation blankets
- Please see our accessories catalog for a complete listing

PRODUCT DIMENSIONS (in)

Model*	A	D	L1	L2	L3	X**	X	N	O
	Outlet	Dia	EI-EO	SI-EO	SI-SO	Min	Max	Nipple	O
NTIN-C1	1	4	20	18	16	3	7	2	4
NTIN-C1.5	1.5	6	22	20	18	3	8	2	5
NTIN-C2	2	6	22	19	16	3	8	3	6
NTIN-C2.5	2.5	6	24	21	18	4	9	3	6
NTIN-C3	3	8	26	23	20	5	10	3	7
NTIN-C3.5	3.5	9	28	25	22	5	11	3	8
NTIN-C4	4	10	32	29	26	5	12	3	8
NTIN-C5	5	12	36	33	30	6	14	3	9
NTIN-C6	6	14	40	36	32	7	16	4	11
NTIN-C8	8	16	50	46	42	8	21	4	12
NTIN-C10	10	20	52	48	44	11	21	4	14
NTIN-C12	12	24	62	58	54	12	26	4	16
NTIN-C14	14	30	74	69	64	15	31	5	20
NTIN-C16	16	36	82	77	72	18	35	5	23
NTIN-C18	18	40	94	89	84	18	42	5	25
NTIN-C20	20	40	110	105	100	19	52	5	25
NTIN-C22	22	48	118	113	108	22	56	5	29
NTIN-C24	24	48	130	125	120	24	62	5	29

* Other models and custom designs are available upon request. Dimensions subject to change without notice. All silencers are equipped with drain ports on inlet side. The silencer is all welded construction and coated with high heat black paint for maximum durability.

** Standard inlet/outlet position.

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- Unique roll-up design for compact storage and transportation
- Double or triple up for noise 'hot spots'
- Ability to add branding or messages
- Range of accessories available
- Weatherproof – absorbs sound but not water
- Fire retardant
- 1 person can do the job of 2 or 3 people

Why is it all too often we see construction sites with fencing but no regard for sound issues created from the construction that is taking place? This is due to the fact that there has not been an efficient means of treating this type of noise that was cost effective ***until now.***

Echo Barrier temporary fencing is a reusable, outdoor noise barrier. Designed to fit on all types of temporary fencing. Echo Barrier absorbs sound while remaining quick to install, light to carry and tough to last.

BENEFITS: Echo Barrier can help reduce noise complaints, enhance your company reputation, extend site operating hours, reduce project timescales & costs, and improve working conditions.

APPLICATIONS: Echo Barrier works great for construction & demolition sites; rail maintenance & replacement; music, sports and other public events; road construction; utility/maintenance sites; loading and unloading areas; outdoor gun ranges.

DIMENSIONS: 6.56' × 4.49'.

WEIGHT: 13 lbs.

ACOUSTIC PERFORMANCE: 10-20dB noise reduction (greater if barrier is doubled up).

INSTALLATION: The Echo Barrier is easily installed using our quick hook system and specially designed elastic ties.

Echo Barrier Transmission Loss Field Data

	125Hz	250Hz	500Hz	1KHz	2KHz	4KHz	8KHz
Single Layer	6	12	16	23	28	30	30
Double Layer	7	19	24	28	32	31	32

• Soundproofing Products • Sonex™ Ceiling & Wall Panels • Sound Control Curtains • Equipment Enclosures • Acoustical Baffles & Banners • Solid Wood & Veneer Acoustical Ceiling & Wall Systems
• Professional Audio Acoustics • Vibration & Damping Control • Fire Retardant Acoustics • Hearing Protection • Moisture & Impact Resistant Products • Floor Impact Noise Reduction
• Sound Absorbers • Noise Barriers • Fabric Wrapped Wall Panels • Acoustical Foam (Egg Crate) • Acoustical Sealants & Adhesives • Outdoor Noise Control • Assistive Listening Devices
• OSHA, FDA, ADA Compliance • On-Site Acoustical Analysis • Acoustical Design & Consulting • Large Inventory • Fast Shipment • No Project too Large or Small • Major Credit Cards Accepted