Big Valley Groundwater Sustainability Agency

GROUNDWATER SUSTAINABILITY PLAN
for Big Valley Basin (5-015)

January 2022

COUNTY OF LAKE WATER RESOURCES

BIG VALLEY
GROUNDWATER SUSTAINABILITY PLAN

ACKNOWLEDGMENTS

The Big Valley Groundwater Sustainability Agency gratefully acknowledges the funding contribution from the California Department of Water Resources. Funding for this project has been provided in part from the California Drought, Water, Parks, Climate, Coastal Protection, and Outdoor Access For All Act of 2018 (Proposition 68) and through an agreement with the State Department of Water Resources.

BIG VALLEY GROUNDWATER SUSTAINABILITY AGENCYBOARD OF DIRECTORS

Eddie "EJ" Crandell
Jessica Pyska
Bruno Sabatier
Tina Scott
Moke Simon

GROUNDWATER SUSTAINABILITY PLAN ADVISORY COMMITTEE MEMBERS

The Big Valley Groundwater Sustainability Plan Advisory Committee (GSPAC) was established in April 2021 to act as advisors for the Big Valley Basin Groundwater Sustainability Plan (GSP) and is made up of those persons representing various beneficial users and uses of groundwater in the Big Valley Basin. The GSPAC provided general input, reviewed draft GSP content, defined sustainable management criteria, and offered input on next steps for GSP implementation. The Big Valley Groundwater Sustainability Agency appreciates the contributions of the members listed below.

Marina Deligiannis, Lake County Water Resources
Sky Hoyt, Domestic Well Owner
Kyle Reams, Kelseyville Unified School District
Pat Scully, Scully Packing Company
David Weiss, Bella Vista Farming Company
Scott Hornung, Lake County Special Districts
Val Nixon, Lake County Land Trust
Sarah Ryan, Big Valley Band of Pomo Indians
Brenna Sullivan, Lake County Farm Bureau
Peter Windrem, Chi Council for Clear Lake Hitch

MEMBER AGENCY STAFF

Scott De Leon,
Lake County Water Resources Director

Marina Deligiannis,
Lake County Deputy Water Resources Director

William Fox,
Lake County Water Resources Program Coordinator

LAND ACKNOWLEDGEMENT

Big Valley Basin is located in the traditional land of the Big Valley Band of Pomo Indians.

PLANNING, TECHNICAL, AND FACILITATION SUPPORT

Luhdorff & Scalmanini Consulting Engineers and Stantec Consulting Inc. performed modeling, planning, facilitation, and other technical support for the Big Valley Groundwater Sustainability Agency in addition to composing the Big Valley Basin Groundwater Sustainability Plan.

PROFESSIONAL GEOLOGIST
EDDY W. TEASDALE
No. 7791
STATE OF CALIFORNIA

CERTIFIED HYDROGEOLOGIST
EDDY W. TEASDALE
No. 926
STATE OF CALIFORNIA

REGISTERED PROFESSIONAL ENGINEER
IBRAHIM M. KHADAM
C 72496
EXP. 6/22
CIVIL
STATE OF CALIFORNIA

Eddy Teasdale, Supervising Hydrogeologist, PG CHG
January 20, 2022

Ibrahim Khadam, Senior Principal-Water PE
January 20, 2022

Luhdorff & Scalmanini Consulting Engineers

Eddy Teasdale, Supervising Hydrogeologist
John McHugh, Senior Hydrogeologist
Nicholas Newcomb, Project Hydrogeologist
Jeevan Jayakody PG, Project Hydrogeologist
Cab Esposito, Project Hydrogeologist
Matthew Sturdivant, Staff Hydrogeologist
Vicki Kretsinger Grabert, Senior Principal Hydrologist
Evan Davis, Staff Geologist

Stantec

Ibrahim Khadam, Senior Principal-Water
Christy Clark, Senior Public Relations Specialist
Megan Murray, Water Resources Planner
Maliheh Karamigolbaghi, Water Resources EIT
Tori Klug, Civil Engineer
Maritza Flores, Water Resources Engineer
Sam Price, GIS Analyst
Tom Butler, Associate Hydrogeologist
Tom Regan, Hydrogeologist
Chaoying Jiao, Associate Hydrogeologist
Khandriale Clark, Technical Editor

On behalf of the Big Valley Groundwater Sustainability Agency, thank you to all of the community members who participated in public meetings, information sessions, and outreach events while developing this Groundwater Sustainability Plan. Your input was vital to shaping this plan, and we look forward to implementation activities to achieve groundwater sustainability in the Big Valley Basin.

EXECUTIVE SUMMARY

Introduction

The purpose of this Groundwater Sustainability Plan (GSP) is to verify and maintain sustainable groundwater management in the Big Valley Groundwater Basin (referred to herein as Big Valley Basin or Basin) (**Figure ES-1**; Basin Number 5-015) by meeting the regulatory requirements set forth in the three-bill legislative package: Assembly Bill (AB) 1739 (Dickinson), Senate Bill (SB) 1168 (Pavley), and SB 1319 (Pavley) collectively known as the Sustainable Groundwater Management Act of 2014 (SGMA). This is codified as Section (§) 10720 - 10737.8 of the California Water Code (CWC). Under SGMA, high- and medium-priority basins not identified as critically overdrafted must develop and submit a GSP to the California Department of Water Resources (DWR) by January 31, 2022. GSPs are prepared and implemented by Groundwater Sustainability Agencies (GSA) that are formed from local agencies or combinations of local agencies as outlined in CWC § 10723, with the goal to reach sustainability within 20 years of implementing the sustainability plans.

SGMA defines sustainable groundwater management as “management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results.”

Big Valley Basin was identified as a medium-priority basin by DWR based on components such as population and groundwater use; therefore, it is subject to SGMA. The Big Valley Basin GSP is being developed by the Lake County Watershed Protection District (District), which serves as the sole GSA in the Big Valley Basin. The Big Valley GSA has jurisdiction over most of the region, excluding the portion containing the Big Valley Rancheria which is governed by the Big Valley Band of Pomo Indians of the Big Valley Rancheria, a federally recognized tribe.

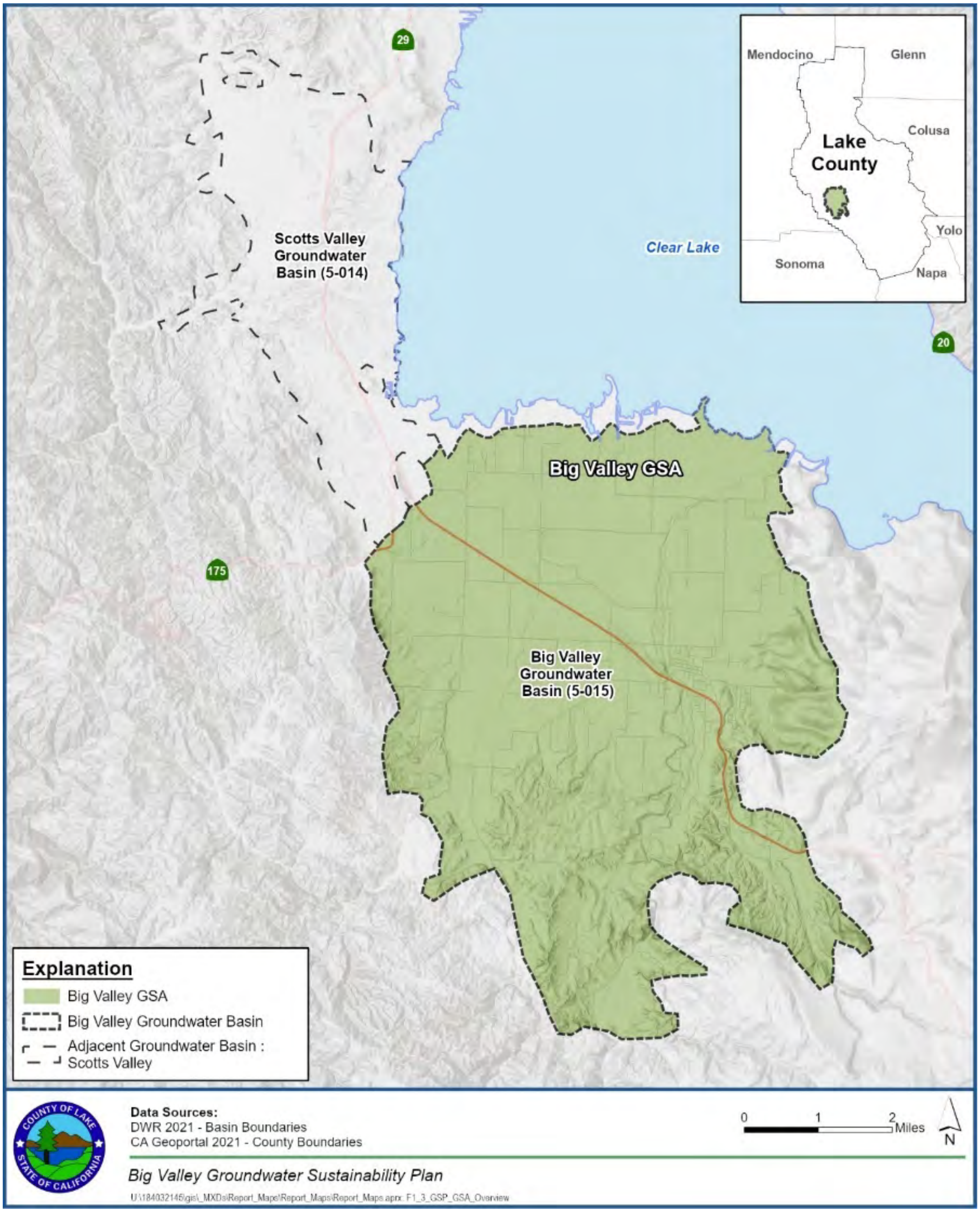

Figure ES-1. Boundaries of Big Valley Basin

Outreach Efforts

This GSP is being developed through a multifaceted outreach and engagement process with identified beneficial users in the Big Valley Basin, including agriculture, domestic well owners, special districts, Tribes, land use organizations, and environmental organizations. The GSP is also supported through a formally chartered advisory committee, the Groundwater Sustainability Plan Advisory Committee (also referred to as GSPAC), that provides guidance to the Big Valley GSA's Board of Directors, made up of the Lake County Board of Supervisors. All of GSPAC meetings, subcommittee meetings, public meetings, and Board of Directors updates held during GSP development have been open to the public and recorded for on-demand viewing. The GSP communication efforts done to date include the development of a Communications and Engagement Plan that provides a foundation for ongoing outreach activities that will be carried out during GSP implementation in the years ahead.

Plan Area

Big Valley Basin (DWR Bulletin 118: 5-015) is a 37.8 square mile (24,227 acres) area south and adjacent to Clear Lake, the largest natural freshwater lake entirely within California. Big Valley Basin is shown on the map in **Figure ES-2**. Big Valley Basin is bordered by Clear Lake to the north and the Scotts Valley Groundwater Basin (referred to herein as the Scotts Valley Basin) to the northwest. Adobe and Kelsey Creeks are the primary streams that flow through Big Valley and drain north into Clear Lake.

Big Valley Basin is at most six miles wide and approximately eight miles long. The ground surface in the northern portion of the Basin gently slopes to the north towards Clear Lake. There are uplands on the west side of the valley, and separate uplands occur in the south-central portion of the valley. DWR estimates the storage capacity of Big Valley Basin to be 105,000 acre-feet (AF), with usable groundwater storage of approximately 60,000 AF (DWR 2003). Big Valley Basin is the source of water supply for Kelseyville and supports the agricultural area in Lake County.

Groundwater is extracted from the Basin through wells. Production wells are more frequently found in the central and northern portion of the Basin and range from 42 to 421 feet. However, most production wells are about 150-160 feet deep on average. Domestic wells are not as deep and range from 42 to 292 feet. Domestic wells are located throughout the Basin but are heavily concentrated around Kelsey Creek.

Total water use is an estimated 12,944 acre-feet per year (AFY). Most of the water is used for agricultural purposes (11,928 AFY in 2013), with the remainder used by municipal and domestic water uses (622 AFY and 340 AFY, respectively in 2020).

There are three primary water users in Big Valley Basin: agriculture, municipal, and rural domestic. Agricultural irrigation is supplied mostly from groundwater sources, with limited amounts from surface water. Municipal water from KCWWD #3 and rural domestic water are exclusively supplied from groundwater.

There are no incorporated cities within the Big Valley Basin. There is one large community, Kelseyville, and one small community, Finley. The communities of Kelseyville, Finley, Lands

End, and part of the Big Valley Rancheria receive water from groundwater wells owned and operated by the Kelseyville County Water Works District No.3 (KCWWD #3). Other portions of the Big Valley Rancheria are supplied by the Big Valley Rancheria Water District's two public water systems. Both of these systems are supplied by groundwater.

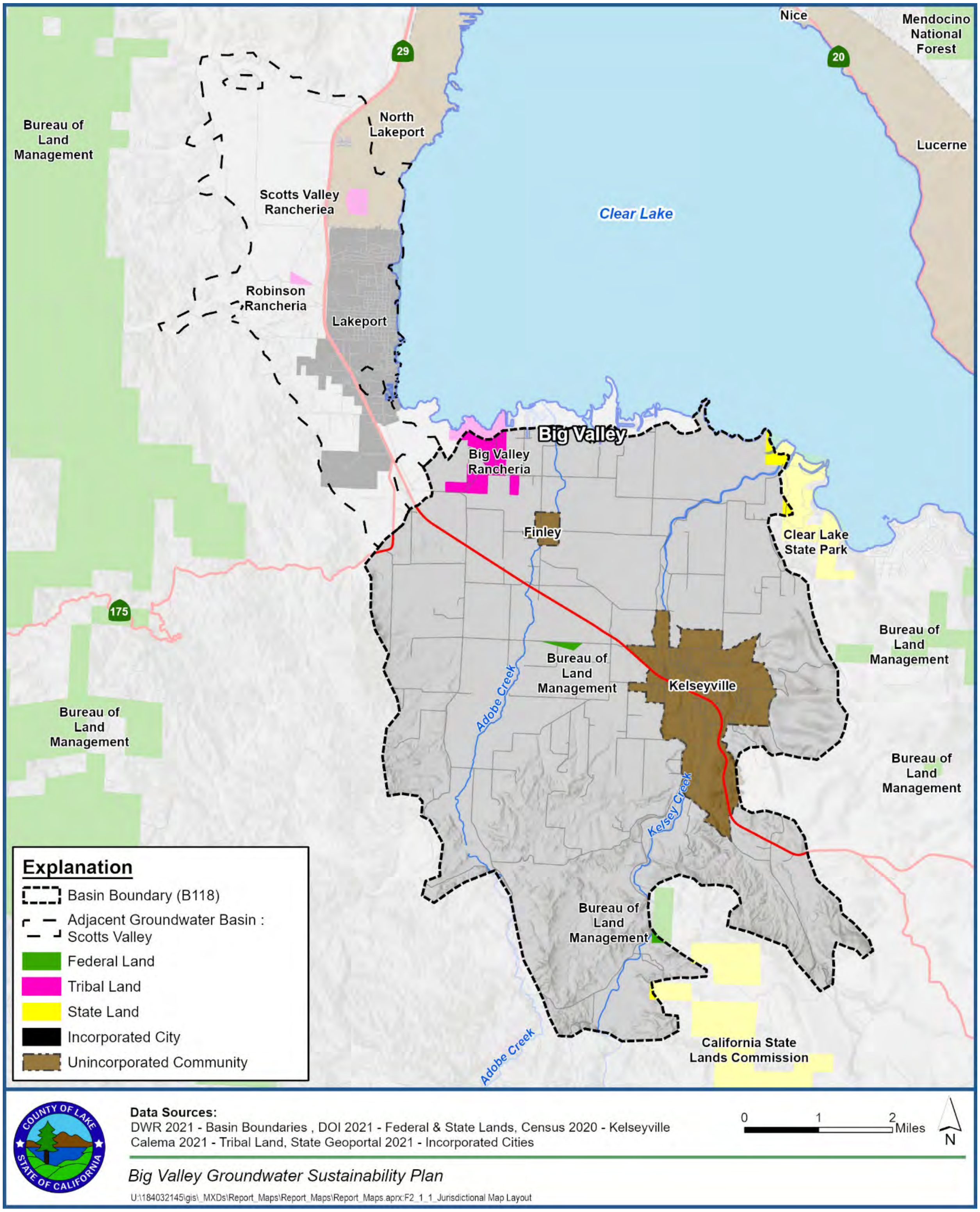

Figure ES-2. Big Valley Basin Communities, and Public Lands

Hydrogeologic Conceptual Model

The Big Valley Basin is a roughly triangular-shaped basin bounded by the Mayacamas Mountains on the west and south, Mt. Konocti on the east and Clear Lake on the north (SMFE, 1967). The surface of the groundwater basin area in the north of the valley is, for the most part, a broad plain that gently slopes toward the Lake (CAI, 2003). A central upland in the southern part of the Basin is divided into two smaller valleys which have been incised by Kelsey and Adobe Creeks on the east and west, respectively. Both streams discharge north into Clear Lake.

Three groundwater producing aquifer deposits were identified in Big Valley Basin, in addition to the underlying fractured bedrock water-bearing formation (**Figure ES-3**):

- Quaternary Alluvium and Lake Deposits – covers the northern portion of the Basin and includes recent stream channel, overbank and alluvial fan deposits, and lake deposits.
- Kelseyville Formation - occupies the southern portion of the Basin.
- "Volcanic Ash" Aquifer - occurs throughout the central part of the Basin as a thin layer (one to eight feet in thickness).
- Fractured Bedrock – are limited to the upland areas. Limited in extent but may store and transmit water locally.

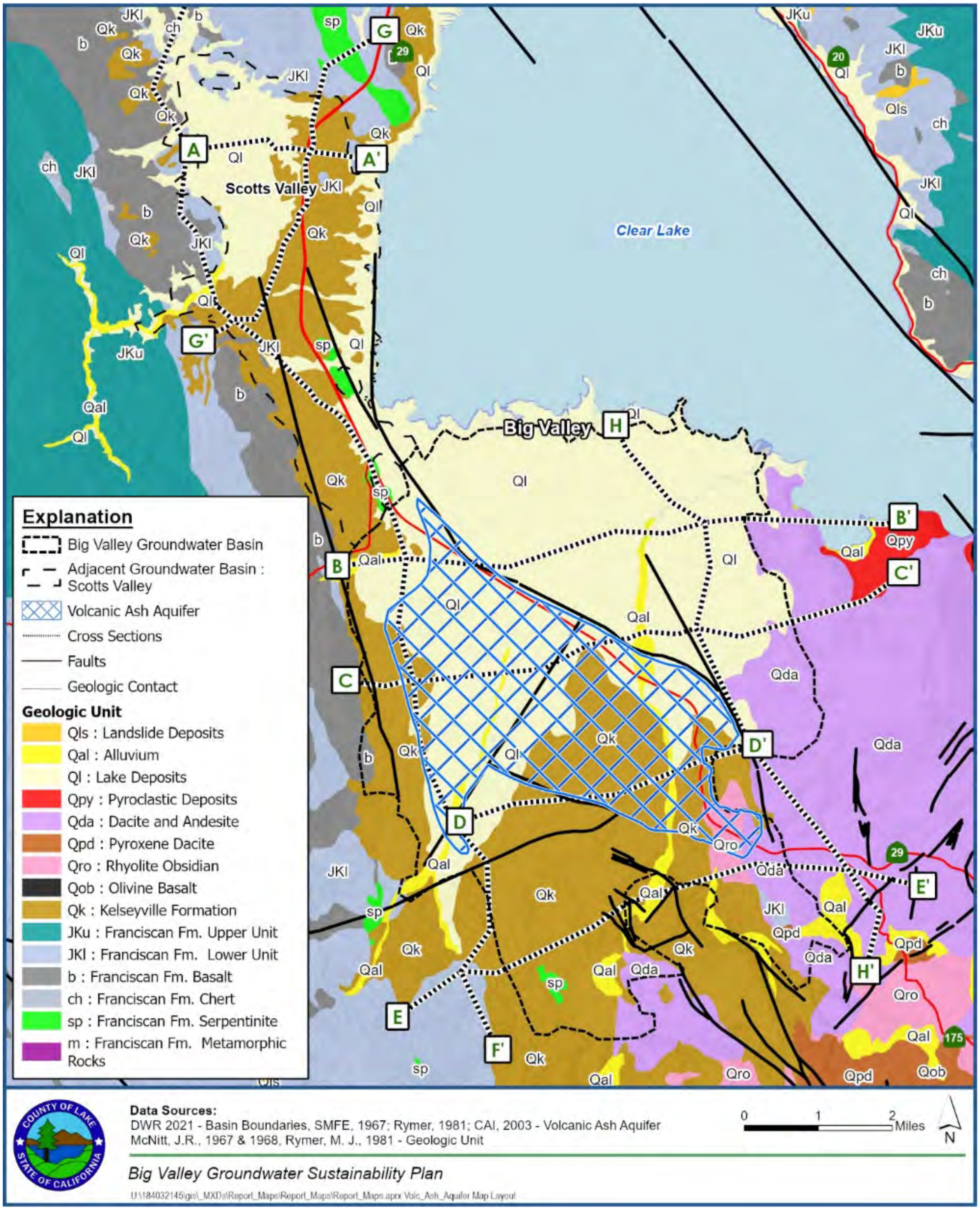

Figure E-3. Geologic Map of the Big Valley Basin

Existing Groundwater Conditions

Despite seasonal and climate-influenced short-term fluctuations, groundwater levels in the Basin remained stable during the last three decades. Groundwater has a general northward flow from the uplands towards Clear Lake. Groundwater flow directions in the Basin are primarily determined by the topography and influenced by local groundwater withdrawal and recharge. Depth to water in the northern portion of the Basin is significantly shallower than in the southcentral (area around the headwaters of Hill Creek) and southern portions.

Seasonal high-water levels (in winter/spring seasons) in the northern portion generally range between five and 20 ft bgs. Occasionally, water levels of several wells rose above the ground surface (flowing artesian conditions) after periods of intense precipitation. Seasonal low water levels (in summer/fall seasons) in this area can be five to 25 feet deeper than seasonal high-water levels depending on well location, construction, and local water use.

Seasonal high-water levels in the south central and southern portions of the Basin range between about 70 and 130 ft bgs, while seasonal low water levels can be 20 to 50 feet deeper.

In general, the magnitude of water level fluctuations between dry and wet climatic periods are smaller than the seasonal fluctuations.

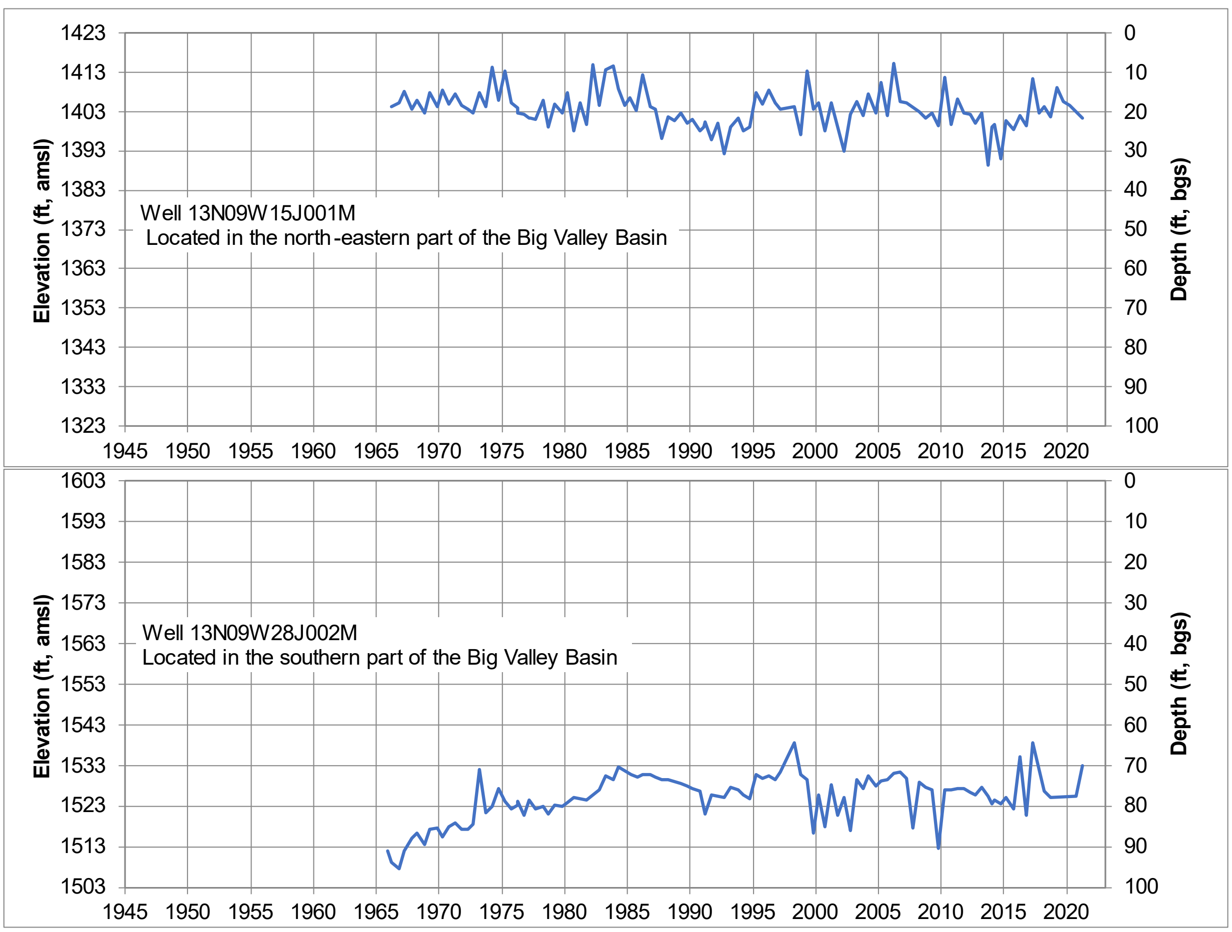

Figure ES-4. Example Groundwater Elevation Hydrographs in Big Valley Basin

Widespread presence of contaminants at undesirable levels (concentrations that exceed applicable regulatory limits) has not been reported in groundwater samples in the Basin. Within the GSP there TDS, nitrate, arsenic, and boron in groundwater are discussed and summarized.

Maximum vertical displacement measured using the InSAR approach from June 2015 to October 2020 was -0.25 feet in the Big Valley Basin. On average, the maximum subsidence in the Basin was -0.05 feet per year. This measured subsidence is likely elastic subsidence, meaning the land surface can recover (rise) if groundwater is recharged and again fills the pore spaces. This elastic subsidence is not a cause of concern based on historic groundwater use and the composition of the subsurface geology.

In Big Valley Basin, there are two primary, gauged streams—Kelsey Creek and Adobe Creek. The potential exists for these streams to be interconnected to groundwater. During the wet winter months streams are predominantly sourced from precipitation, and in the dryer summer months the streams there is little to no flow. During wet conditions the creeks may be gaining water from groundwater or losing water from groundwater. During dry conditions the creeks are losing water to groundwater. However, confirmation of the impacts to surface water, as well as characterization of hydraulic connectivity, would require additional intermediate surface water gauges and monitoring with new shallow monitoring wells to better understand the nature and timing of hydraulic connectivity in the creeks.

Both terrestrial and aquatic habitat ecosystems are identified from the Natural Communities Commonly Associated with Groundwater dataset and exist along Kelsey Creek and above Adobe Creek Reservoir. The Clear Lake hitch (*Lavinia exilicauda chi*) (hitch) are a large minnow endemic to Clear Lake and its tributaries. The hitch migrates each spring from the lake into the tributaries to spawn. These habitats are potential Groundwater Dependent Ecosystems (GDE) if and when the surface water bodies are interconnected and dependent on groundwater. Further monitoring is needed to establish groundwater dependence through frequent monitoring of groundwater from future shallow wells located close to existing surface water monitoring stations.

Water Budgets

A water budget summarizes the inflows to and outflows from a basin (GSP Regulation § 354.18[b]). These inflows and outflows result in a change in the account balance, or storage. Inflows and outflows in the hydrologic system are largely controlled by processes occurring on the land surface, such as climate and weather patterns, variable land use, and irrigation. All water budgets were developed using outputs from the Big Valley Integrated Hydrologic Model (BVIHM), which simulates hydrogeologic and hydrologic conditions across the Basin. The BVIHM uses MODFLOW code to simulate groundwater flow, as well as other integrated packages to simulate streamflow, evapotranspiration, drains, farms, and other associated processes. Together, these components create an integrated surface water and groundwater model to estimate water budgets for the Basin. Development of the BVIHM involved the study and analyses of hydrogeologic conditions, as well as the assembly of all direct measurements or estimates of water demands and supplies for each water use sector, which includes agriculture, public water systems, native vegetation, and self-supplied users.

Water budgets were created using water years (October the prior year through September) and for the two time periods 1989 – 2019 and 2020-2070. The former is the historic budget based on past records, and the later are projected budgets that relay on numerical model and projected conditions including the effects of climate change. Climate change was accounted for with two scenarios, wet-moderate warming scenario and dry-extreme warming scenario. The historic and all predicted future water budgets on an average annual basis over those periods of time show close to zero storage change (i.e., no change in storage when long-term changes are considered).

Analysis of the budgets demonstrates the basin water budget is essentially balanced but varies year to year based on different hydraulic conditions. Precipitation in the form of rain is the dominant source of water to the basin and strongly influences the basin budget and its variability. The average annual change in groundwater storage over the historical water budget period is about 200 AFY (an increase in storage) with a cumulative storage increase of 6,000 AFY over the 32-year period. By comparison, DWR estimates the storage capacity of Big Valley Basin to be 105,000 AF, with usable groundwater storage of approximately 60,000 AF (DWR 2003). The cumulative storage increase is equivalent to an increase of about 0.25 AF per acre across the entire Basin (about 24,200 acres).

Annual change in groundwater storage ranges from a net decrease of up to 7,400 AFY to a net increase of up to 10,700 AFY during the historic period. In general, groundwater storage increases in wet years and decreases in drier years. The decrease of groundwater storage during relatively dry years is not an indication of overdraft, but it is likely due to removal of temporary surplus of groundwater. Temporary surplus removal is the extraction of a volume of aquifer storage to enable the capture of recharge and reduction in subsurface outflow from the Basin without impacting beneficial users of groundwater to an unreasonable degree.

Assuming potential uncertainty of 25 percent associated with the water budget estimates, an associated range of values for the estimated sustainable yield is 22,000 to 36,000 AFY. The water budget is based on estimates, imperfect and incomplete data and assumptions. Uncertainties associated with water budget components have been computed or estimated and are documented in the GSP.

Sustainable Management Criteria

The sustainable management criteria (SMC) characterize the conditions that constitute sustainable groundwater management for the Big Valley Basin. The SMCs defines the sustainability goal and establish undesirable results, minimum thresholds (MT), and measurable objectives (MO) for each applicable sustainability indicator (**Table ES-1**).

- **Sustainability goal:** The sustainability goal qualitatively describes the objectives and desired conditions for the Basin and how existing management is expected to continue meeting that goal. The goal of this GSP is:

  "Sustainable management of the groundwater resources of the Big Valley Basin for the long-term community, environmental, and economical benefits of existing and future residents and businesses in the Basin."

- **Undesirable results:** Undesirable results define the conditions at which each applicable sustainability indicator would become significant and unreasonable in the Basin.
- **Minimum thresholds:** MTs are quantitative guidance levels for each sustainability indicator that are set just above conditions that, could generate undesirable results, based on the best available information. MTs violations could result in undesirable results, probationary status, and the State Water Resource Control Board intervention.
- **Measurable objectives:** MOs are the desired condition, set above MTs, that allow for active management of the Basin during dry periods. The MOs are set to provide a reasonable margin of operational flexibility that will accommodate droughts, climate change, conjunctive use operations, or other groundwater management activities.
- **Interim milestones:** Interim milestones are set to guide conditions during implementation of the GSP to assist in achieving MOs within 20 years. In the Big Valley Basin, the interim milestones are set at the same levels as the MOs, as implementation activities are not required to achieve the MOs.

A sustainability indicator is defined by SGMA as one of six effects caused by groundwater conditions that, when significant and unreasonable, cause undesirable results:

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply
- Significant and unreasonable reduction of groundwater storage
- Significant and unreasonable seawater intrusion
- Significant and unreasonable degraded water quality
- Significant and unreasonable land subsidence
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water

1 **Table ES-1. Summary of Minimum Thresholds, Measurable Objectives, and Undesirable Results**

Sustainability Indicator	Minimum Threshold	Measurable Objective	Undesirable Result
Chronic Lowering of Groundwater Elevations	Lowest historical spring groundwater elevation, plus an operational flexibility margin, at each RMS for groundwater elevation.	Average of historical spring groundwater elevations at each RMS for groundwater elevation.	Occurs when spring groundwater elevation at 33 percent (2 out of 6) of RMS for groundwater elevation fall below their MTs for two consecutive years at the same sites.
Reduction of Groundwater Storage	Same as chronic lowering of groundwater levels	Same as chronic lowering of groundwater levels	Same as chronic lowering of groundwater levels
Degraded Water Quality	TDS of 750 mg/L	TDS of 500 mg/L	Occurs when 29 percent (2 out of 7) of RMS for water quality exceed the MTs for two consecutive years at the same sites, and where it can be established that GSP implementation is the cause of the exceedance.
Land Subsidence	No more than 0.5 feet of inelastic subsidence over a five-year period at each RMS for land subsidence, solely due to lowering of groundwater elevations.	No more than 0.20 feet of inelastic subsidence over a five-year period at each RMS for land subsidence, solely due to lowering of groundwater elevations.	Occurs when 33 percent (2 out of 6) of RMS for land subsidence exceed the MTs over a five-year period, and where it can be established that the subsidence is irreversible and is caused by lowering of groundwater elevations.
Seawater Intrusion	Not Applicable	Not Applicable	Not Applicable
Depletion of Interconnected Surface Water (ISW)	Lowest historical spring groundwater elevation, plus an operational flexibility margin and adjusted for maximum GDEs root depth, at each RMS for depletion of ISW.	Average of historical spring groundwater elevations a at each RMS for depletion of ISW.	Occurs when spring groundwater elevation at 33 percent (2 out of 6) of RMS for depletion of ISW fall below their MTs for two consecutive years at the same sites.

Key:
GDE = Groundwater Dependent Ecosystems
GSP = Groundwater Sustainability Plan
ISW = Interconnected Surface water
mg/L = milligrams per liter
MT = minimum threshold
RMS = representative monitoring network site
TDS = total dissolved solid

2

Monitoring Networks

Monitoring networks are established for each relevant sustainability indicator in Big Valley Basin, groundwater levels, groundwater quality, subsidence, and surface water depletions. Additionally, the groundwater level monitoring network supports estimation of groundwater storage.

The monitoring networks are intended to support and improve an understanding of conditions in the Big Valley Basin, supporting ongoing management and future updates to this GSP. The SGMA regulations regarding GSP development require that monitoring networks be developed to promote the collection of sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions, and yield representative information about groundwater conditions necessary to evaluate the effectiveness of GSP implementation.

The current groundwater monitoring network in Big Valley Basin consists of 49 wells that are monitored either semi-annually or monthly by Lake County Watershed Protection District. These active monitoring wells are proposed to be the groundwater level monitoring network. A subset of the groundwater monitoring network is selected as the representative monitoring network sites (RMS), chosen to monitor sustainability in Basin (**Table ES-2** and **Figure ES-4**). RMS are identified for each indicator. Measurable objectives and minimum thresholds are defined at each RMS.

Table ES-2. Representative Monitoring Sites Network

Well Number	Gird Section/ Location	Levels/ Storage	Water Quality	Land Subsidence [1]	Interconnected Surface Water
14N09W32G002M	North	X	X	X	
13N09W08M003M	Northwest	X	X	X	
13N09W03R001M	Northeast/ Kelsey Creek	X	X	X	X
13N09W18J001M	West-Central	X	X	X	
13N09W15J001M	East-Central	X	X	X	
13N09W28J002M	Southwest	X	X	X	
1710007-007 (Well 8)	East-Central		X		
13N09W02C002M	Kelsey Creek – DWR Gage				X
13N09W15B002M	Kelsey Creek – HWY 29				X
13N09W19J001M	Adobe Creek - Bell Hill Well				X
13N09W09D005M	Adobe Creek - Argonaut Well				X
14N09W33K001M	Adobe Creek - Soda Bay Well				X

Note:

[1] The InSAR data for the 100x100-meter pixel nearest to the RMS well is used to monitor subsidence.

Key:

DWR = California Department of Water Resources

HWY = Highway

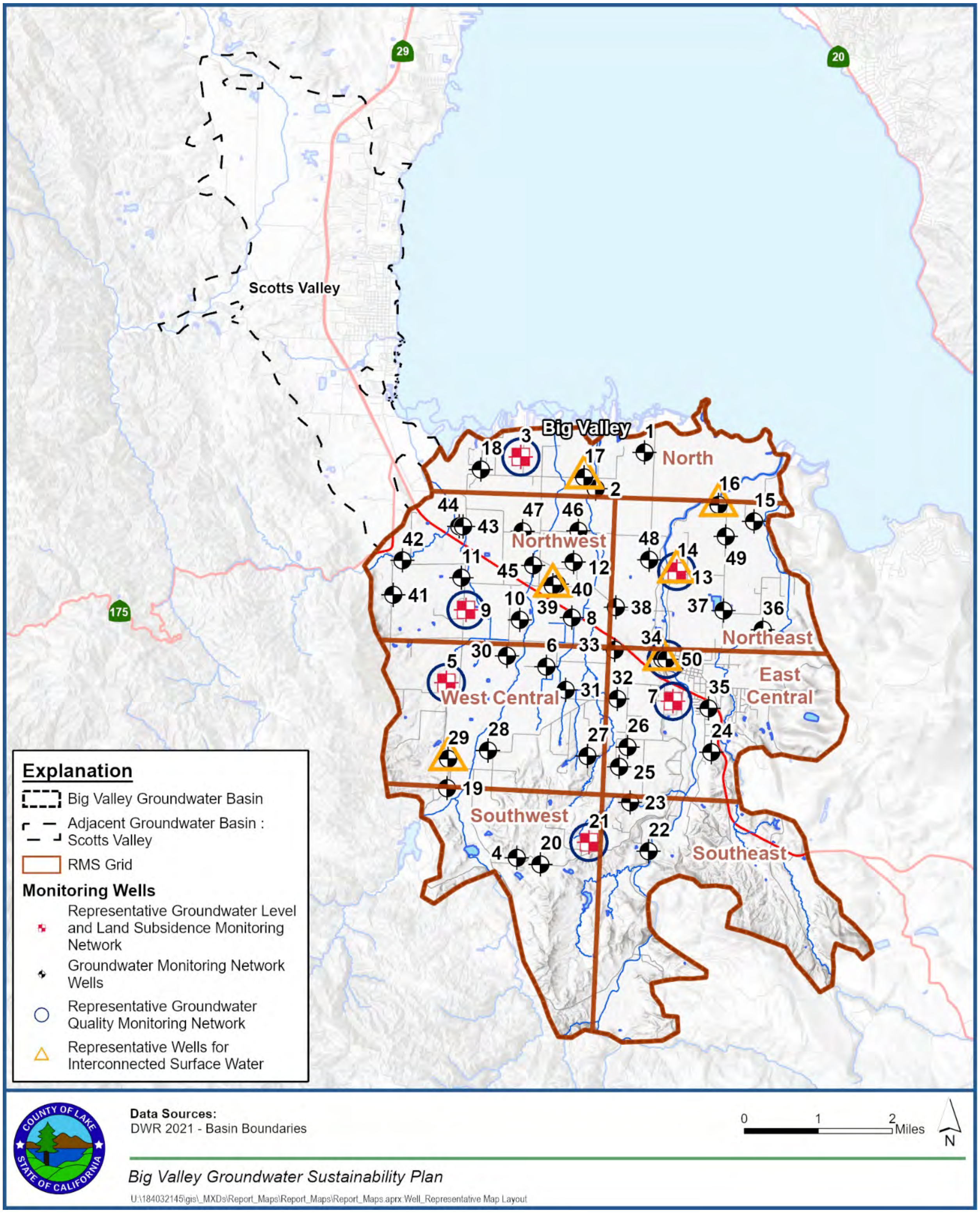

Figure ES-4. Big Valley Groundwater Monitoring Network and Representative Monitoring Sites

Projects and Management Actions and Implementation

GSP implementation activities include GSA-required activities, and consideration of projects and management actions (PMA).

GSA required activities includes:

- GSA administrative activities – including operation and maintenance, project management and coordination, administrative and finance staff, engineering and consulting, and legal services.
- Groundwater monitoring program activities – including data collection, data review and analysis, installation and maintenance of monitoring wells and equipment, and data management.
- GSP updates – including the required Annual Reports and the GSP Five-Year Update.
- Outreach and engagement activities – including facilitation and management of the GSP Advisory Committee, outreach consistent with the C&E Plan, and development and maintenance of a GSA website.

Due to the sustainable condition of the Big Valley Basin, implementation of PMAs will occur on an as-needed basis:

- Tier 1A PMAs are to help reach sustainability. None have been identified due to the sustainable conditions of the Basin.
- Tier 1B PMAs are to comply with other SGMA requirements, fill data gaps, and support GSA operations. Seven (7) PMAs were identified that will be implemented by the GSA, depending on resource availability.
- Tier 2 PMAs are to improve management and contribute to achieving measurable objectives. Six (6) PMAs were identified that may be implemented by the GSA or stakeholders if resources available.
- Tier 3 PMAs are to support wider water management in the basin, including activities outside the purview of the GSA. Five (5) PMAs were identified that may be implemented by interested stakeholders, with GSA coordination.

During GSP implementation, the GSA will use adaptive management to take actions in response to events that may affect long term Big Valley Basin sustainability or cause a short-term undesirable condition. Two types of trigger events are defined:

- Long-term basin sustainability triggers – occur when (1) a negative trend causes a sustainability indicator to approach a minimum threshold (MT), or (2) an MT is exceeded.
- Short-term acute drought triggers – occur (1) during extended drought period, or (2) when a drought emergency is declared.

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Abbreviations and Acronyms

§	Section
µg/L	micrograms per liter
ACCU	Adobe Creek Conjunctive Use
AEM	airborne electromagnetic
AF	acre-feet
AFY	acre-feet per year
Big Valley Basin	Big Valley Groundwater Basin
BMP	best management practice
BVGSA	Big Valley Groundwater Sustainability Agency
BVIHM	Big Valley Integrated Hydrological Model
C&E Plan	Communication and Engagement Plan
CASGEM	California Statewide Groundwater Elevation Monitoring Program
CCR	California Code of Regulations
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
County	County of Lake
CWC	California Water Code
District	Lake County Watershed Protection District
DMS	data management system
DWR	California Department of Water Resources
EAR	Electronic Annual Report
EC	electrical conductivity
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration
eWRIMS	Water Rights Information Management System
ft bgs	feet below the ground surface
GAMA	Groundwater Ambient Monitoring and Assessment
GDE	groundwater dependent ecosystem
General Plan	Lake County General Plan
GMP	Groundwater Management Plan
gpm/ft	gallons per minute per foot

GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
GSPAC	Groundwater Sustainability Plan Advisory Committee
GWS	Groundwater system
HCM	hydrogeologic conceptual model
HWSSRS	Household Water Supply Shortage Reporting System
JKl	lower Jurassic-Cretaceous unit
JKu	upper Jurassic-Cretaceous unit
KCWWD #3	Kelseyville County Water Works District No.3
Lake County	County of Lake
LUST	leaking underground storage tank
MCL	Maximum Contaminant Level
mg/L	milligrams per liter
MO	measurable objective
msl	mean sea level
MT	Minimum Threshold
NCCAG	Natural Communities Commonly Associated with Groundwater
NDMI	Normalized Derived Moisture Index
NDVI	Normalized Derived Vegetation Index
NPDES	National Pollution Discharge Elimination System
OES	County Division of Environmental Health and County Office of Emergency Services
PET	potential evapotranspiration
PLSS	Public Land Survey System
PMA	projects and management action
PWS	public water system
RMS	representative monitoring network site
RWQCB	Regional Water Quality Control Boards
SB	Senate Bill
Scotts Valley Basin	Scotts Valley Groundwater Basin
SGMA	Sustainable Groundwater Management Act
SMC	sustainable management criterion
SMCL	Secondary Maximum Contaminant Level
SMFE	Soil Mechanics and Foundation Engineers
SVWQC	Sacramento Valley Water Quality Coalition
SWRCB	State Water Resources Control Board
SWS	Surface Water System
TDS	total dissolved solids
TNC	The Nature Conservancy
TSS	Technical Support Services
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WY	water year

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1. INTRODUCTION

1.1 Purpose of the Groundwater Sustainability Plan

The purpose of this Groundwater Sustainability Plan (GSP), that was adopted by Resolution 2022-07 (see **Appendix 1A**), is to verify and maintain sustainable groundwater management in the Big Valley Groundwater Basin (referred to herein as Big Valley Basin or Basin) (**Figure 1-1**; Basin Number 5-015) by meeting the regulatory requirements set forth in the three-bill legislative package: Assembly Bill (AB) 1739 (Dickinson), Senate Bill (SB) 1168 (Pavley), and SB 1319 (Pavley) collectively known as the Sustainable Groundwater Management Act (SGMA). This is codified as Section (§) 10720 - 10737.8 of the California Water Code (CWC). Under SGMA, high- and medium-priority basins not identified as critically overdrafted must develop and submit a GSP to the California Department of Water Resources (DWR) by January 31, 2022. GSPs are prepared and implemented by Groundwater Sustainability Agencies (GSA) that are formed from local agencies or combinations of local agencies as outlined in CWC §10723. SGMA defines sustainable groundwater management as "management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results," which are any of the following effects caused by groundwater conditions occurring throughout the Big Valley Basin:

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply
- Significant and unreasonable reduction of groundwater storage
- Significant and unreasonable seawater intrusion
- Significant and unreasonable degraded water quality
- Significant and unreasonable land subsidence
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water

A GSP's planning and implementation horizon is defined by SGMA as a "50-year time period over which a groundwater sustainability agency determines that plans and measures will be implemented in a basin to ensure that the basin is operated within its sustainable yield."

1.2 Sustainability Goal

The sustainability goal provides a qualitative description of the objectives and desired conditions of the Big Valley Basin. It is supported by the locally defined undesirable results, minimum thresholds, measurable objectives, and interim milestones presented later in **Section 4**.

The sustainability goal for the Big Valley Basin is: *the sustainable management of the groundwater resources of the Big Valley Basin for the long-term community, environmental, and economical benefits of existing and future residents and businesses in the Basin.*

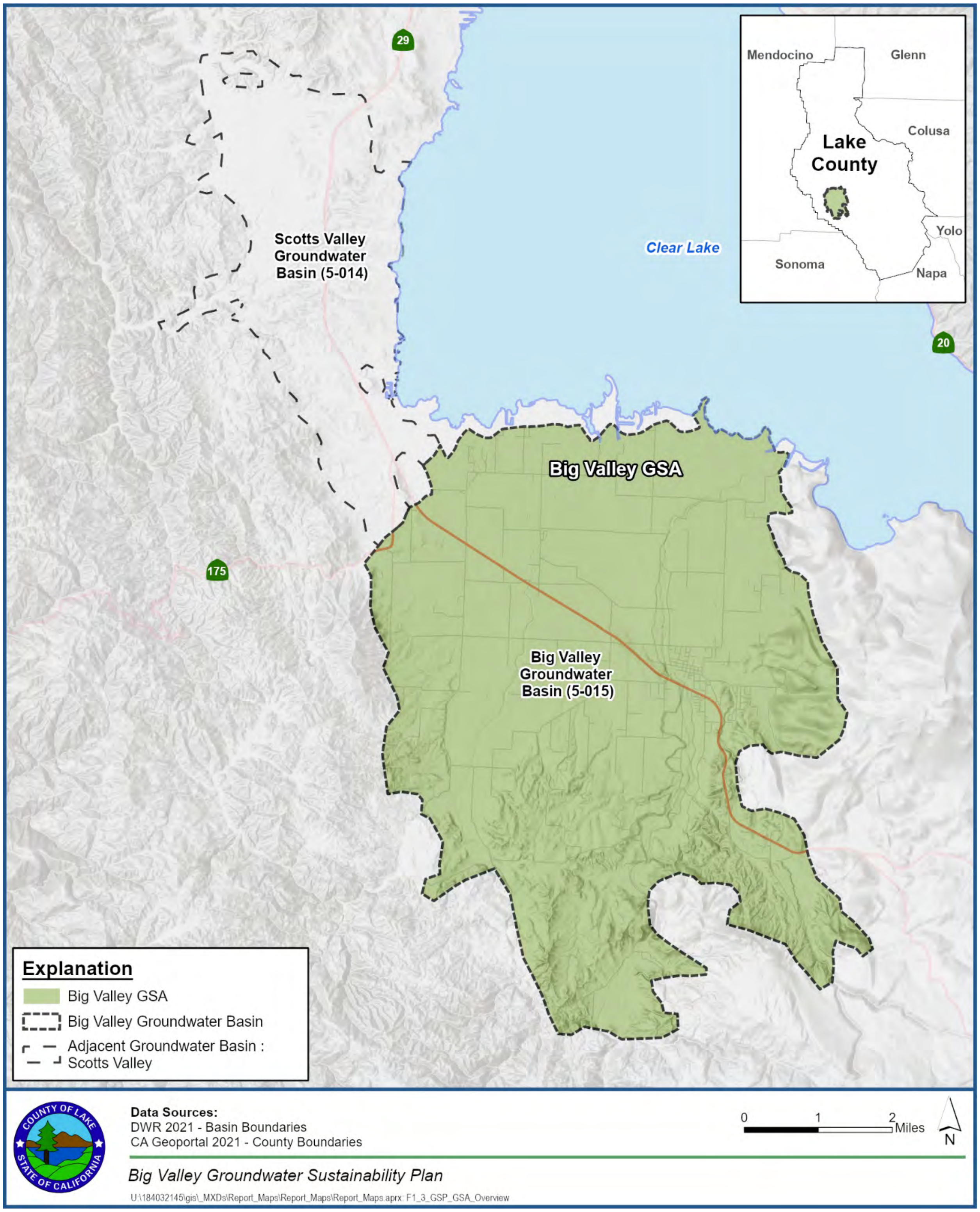

Figure 1-1. Boundaries of Big Valley Basin

1.3 Agency Information

The information below details the organization structure and legal authority of the agency responsible for implementing the GSP. See **Appendix 1B** for the GSA charter.

1.3.1 Organization and Management Structure

The Lake County Watershed Protection District (District) will uphold SGMA and oversee Big Valley GSP implementation, serving as the sole GSA in the Big Valley Basin. The Big Valley GSA has jurisdiction over most of Big Valley Basin, excluding the portion containing the Big Valley Rancheria which is governed by the Big Valley Band of Pomo Indians of the Big Valley Rancheria, a federally recognized tribe. Note the Lake County Watershed Protection District is the legal name of the governing entity, but the common-use name is the Lake County Water Resources Department. This GSP will use the legal name throughout the remainder of this document.

The District is guided by three main purposes:

- Control and impound the flood and storm waters of the County of Lake (referred to herein as "Lake County" or "County"),
- Conserve and protect waters of the County, including surface water and groundwater, and
- Protect, develop, and improve the quality of all waters within the County for all beneficial uses.

To carry out these purposes, the District is responsible for a variety of functions, including:

- Water Resources Planning: plan for groundwater and watershed management.
- Flood Control: administer the National Flood Insurance Program for Lake County, plan and implement flood control projects, and maintain levees and creeks.
- Operations and Maintenance: operate and maintain the Kelsey Creek Detention Structure, Adobe Creek Reservoir, Highland Springs Reservoir, Highland Springs Park; and the Middle Creek Flood Control Project.
- Prevention of other environmental damage.

The key contacts and mailing address for the District are provided below:

Scott De Leon, Water Resources Director
Marina Deligiannis, Deputy Water Resources Director, GSP Contact
Marina.Deligiannis@lakecountyca.gov
Lake County Water Resources Department
255 North Forbes Street, Room 309
Lakeport, California 95453

1.3.2 Legal Authority of the GSA

The Lake County Flood Control and Water Conservation District was authorized by CWC, Chapter 65, to protect and maintain water resources within Lake County. The Lake County Flood Control and Water Conservation District became the Lake County Watershed Protection District with the enacting of SB 1136, Chapter 108 of the CWC. The District is part of the County Department of Public Works and reports to the Lake County Watershed Protection District Board of Directors who are also the County Board of Supervisors. Because of the District's responsibilities regarding water resources, it is an authorized groundwater management agency as defined by the CWC §10753 (a) and (b).

1.3.3 Estimated Cost of Implementing the GSP and the GSA's Approach to Meet Costs

Implementation of the GSP is estimated to cost between $180,000 and $800,000 per year. Costs for projects and management actions are variable depending on the tier in addition to funding and resources availability. Some of these costs are already being incurred through existing groundwater management. Development of this GSP was mostly funded through a Proposition 68 Groundwater Sustainability Grant – Phase 3 from DWR, along with contributions from the County. Implementation of the GSP, including projects and management actions, will be funded through available future grant funding as well as existing revenue streams provided by the County. More detailed information about costs and funding can be found in **Section 6**.

1.4 GSP Organization

This GSP is organized according to DWR's "GSP Annotated Outline" for standardized reporting. The Preparation Checklist for GSP Submittal can be found in **Table 1-1**. The GSP Elements Guide can be found in **Appendix 1C**.

The GSP is presented in seven sections:

- This section, Section 1, Introduction, introduces the GSP and provides information on the GSA.

- Section 2, Plan Area and Basin Setting, summarizes the plan area as it relates to jurisdictions, land and water use, relevant existing water monitoring programs, and existing water management programs. Furthermore, the section provides the hydrogeologic conceptual model (HCM), details on current and historical groundwater conditions, the water budget, and an estimate of sustainable yield.

- Section 3, Monitoring Network, outlines the overall and representative monitoring networks for groundwater levels, groundwater quality, land subsidence, and interconnected surface water.

- Section 4, Sustainable Management Criteria, provides information on defining undesirable results and establishing measurable objectives, interim milestones, minimum thresholds, and additional non-regulatory criteria for the relevant sustainability indicators.

- Section 5, Projects and Management Actions to Achieve Sustainability Goal, summarizes the projects and management actions that are intended to support continued sustainable groundwater management in Big Valley Basin.

- Section 6, Plan Implementation, includes details on the as-needed approach to implementation of much of the GSP and identifies the estimated cost and potential funding sources for the identified projects and management actions.

- Section 7, Notices and Communication, describes the efforts undertaken to obtain public comment and feedback such as an advisory group, workshops, and surveys. The section highlights how this information was used to support the decision-making process.

- Section 8 provides the references cited.

Table 1-1. Preparation Checklist for Groundwater Sustainability Plan Submittal

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 3. Technical and Reporting Standards				
352.2		Monitoring Protocols	• Monitoring protocols adopted by the GSA for data collection and management • Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin	Section 3.2.5, 3.3.6, 3.4.5, 3.5.3, Appendix 3A
Article 5. Plan Contents, Subarticle 1. Administrative Information				
354.4		General Information	• Executive Summary • List of references and technical studies	Executive Summary and Section 8
354.6		Agency Information	• GSA mailing address • Organization and management structure • Contact information of Plan Manager • Legal authority of GSA • Estimate of implementation costs	Section 1.3
354.8(a)	10727.2(a)(4)	Map(s)	• Area covered by GSP • Adjudicated areas, other agencies within the basin, and areas covered by an Alternative • Jurisdictional boundaries of federal or State land • Existing land use designations • Density of wells per square mile	Sections 2.1.1, through 2.1.3

Table 1-1. Preparation Checklist for Groundwater Sustainability Plan Submittal (contd.)

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 5. Plan Contents, Subarticle 1. Administrative Information (cont.)				
354.8(b)		Description of the Plan Area	• Summary of jurisdictional areas and other features	Section 2.1.1
354.8(c) 354.8(d) 354.8(e)	10727.2(g)	Water Resource Monitoring and Management Programs	• Description of water resources monitoring and management programs • Description of how the monitoring networks of those plans will be incorporated into the GSP • Description of how those plans may limit operational flexibility in the basin • Description of conjunctive use programs	Section 2.1.5
354.8(f)	10727.2(g)	Land Use Elements or Topic Categories of Applicable General Plans	• Summary of general plans and other land use plans • Description of how implementation of the GSP may change water demands or affect achievement of sustainability and how the GSP addresses those effects • Description of how implementation of the GSP may affect the water supply assumptions of relevant land use plans • Summary of the process for permitting new or replacement wells in the basin • Information regarding the implementation of land use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management	Section 2.1.2.4

Table 1-1. Preparation Checklist for Groundwater Sustainability Plan Submittal (contd.)

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 5. Plan Contents, Subarticle 1. Administrative Information (contd.)				
354.8(g)	10727.4	Additional GSP Contents	**Description of Actions related to:** • Control of saline water intrusion • Wellhead protection • Migration of contaminated groundwater • Well abandonment and well destruction program • Replenishment of groundwater extractions • Conjunctive use and underground storage • Well construction policies • Addressing groundwater contamination cleanup, recharge, diversions to storage, conservation, water recycling, conveyance, and extraction projects • Efficient water management practices • Relationships with state and federal regulatory agencies • Review of land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity • Impacts on groundwater dependent ecosystems	Section 2.1.7
354.10		Notice and Communication	• Description of beneficial uses and users • List of public meetings • GSP comments and responses • Decision-making process • Public engagement • Encouraging active involvement • Informing the public on GSP implementation progress	Section 7, Appendix 7C, and7A

Table 1-1. Preparation Checklist for Groundwater Sustainability Plan Submittal (contd.)

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 5. Plan Contents, Subarticle 2. Basin Setting				
354.14		Hydrogeologic Conceptual Model	• Description of the Hydrogeologic Conceptual Model • Two scaled cross-sections • Map(s) of physical characteristics: topographic information, surficial geology, soil characteristics, surface water bodies, source and point of delivery for imported water supplies	Section 2.2.1
354.14(c)(4)	10727.2(a)(5)	Map of Recharge Areas	• Map delineating existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas	Section 2.2.1.9
	10727.2(d)(4)	Recharge Areas	• Description of how recharge areas identified in the plan substantially contribute to the replenishment of the basin	Sections 2.1.6.2, 2.2.1.6, 2.2.1.9, and 2.2.2.5
354.16	10727.2(a)(1) 10727.2(a)(2)	Current and Historical Groundwater Conditions	• Groundwater elevation data • Estimate of groundwater storage • Seawater intrusion conditions • Groundwater quality issues • Land subsidence conditions • Identification of interconnected surface water systems • Identification of groundwater-dependent ecosystems	Section 2.2.2 through 2.2.3
354.18	10727.2(a)(3)	Water Budget Information	• Description of inflows, outflows, and change in storage • Quantification of overdraft • Estimate of sustainable yield • Quantification of current, historical, and projected water budgets	Section 2.2.4 and 2.2.5
	10727.2(d)(5)	Surface Water Supply	• Description of surface water supply used or available for use for groundwater recharge or in-lieu use	Sections 2.1.6.2, 2.2.1.6, and 5.4

Table 1-1. Preparation Checklist for Groundwater Sustainability Plan Submittal (contd.)

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 5. Plan Contents, Subarticle 2. Basin Setting (contd.)				
354.20		Management Areas	• Reason for creation of each management area • Minimum thresholds and measurable objectives for each management area • Level of monitoring and analysis • Explanation of how management of management areas will not cause undesirable results outside the management area • Description of management areas	Not applicable
Article 5. Plan Contents, Subarticle 3. Sustainable Management Criteria				
354.24		Sustainability Goal	• Description of the sustainability goal	Section 4.3
354.26		Undesirable Results	• Description of undesirable results • Cause of groundwater conditions that would lead to undesirable results • Criteria used to define undesirable results for each sustainability indicator • Potential effects of undesirable results on beneficial uses and users of groundwater	Sections 4.4.1, 4.5.1, 4.7.1, 4.8.1, 4.9.1
354.28	10727.2(d)(1) 10727.2(d)(2)	Minimum Thresholds	• Description of each minimum threshold and how they were established for each sustainability indicator • Relationship for each sustainability indicator • Description of how selection of the minimum threshold may affect beneficial uses and users of groundwater • Standards related to sustainability indicators • How each minimum threshold will be quantitatively measured	Sections 4.4.2, 4.5.2, 4.7.2, 4.8.2, 4.9.2

Table 1-1. Preparation Checklist for Groundwater Sustainability Plan Submittal (contd.)

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 5. Plan Contents, Subarticle 3. Sustainable Management Criteria (contd.)				
354.30	10727.2(b)(1) 10727.2(b)(2) 10727.2(d)(1) 10727.2(d)(2)	Measurable Objectives	• Description of establishment of the measurable objectives for each sustainability indicator • Description of how a reasonable margin of safety was established for each measurable objective • Description of a reasonable path to achieve and maintain the sustainability goal, including a description of interim milestones	Sections 4.4.3, 4.5.3, 4.7.3, 4.8.3, 4.9.3
Article 5. Plan Contents, Subarticle 4. Monitoring Networks				
354.34	10727.2(d)(1) 10727.2(d)(2) 10727.2(e) 10727.2(f)	Monitoring Networks	• Description of monitoring network • Description of monitoring network objectives • Description of how the monitoring network is designed to: demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features; estimate the change in annual groundwater in storage; monitor seawater intrusion; determine groundwater quality trends; identify the rate and extent of land subsidence; and calculate depletions of surface water caused by groundwater extractions • Description of how the monitoring network provides adequate coverage of Sustainability Indicators • Density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends • Scientific rational (or reason) for site selection • Consistency with data and reporting standards • Corresponding sustainability indicator, minimum threshold, measurable objective, and interim milestone	Section 3

Table 1-1. Preparation Checklist for Groundwater Sustainability Plan Submittal (contd.)

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 5. Plan Contents, Subarticle 4. Monitoring Networks (contd.)				
354.34	10727.2(d)(1) 10727.2(d)(2) 10727.2(e) 10727.2(f)	Monitoring Networks	• Location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used • Description of technical standards, data collection methods, and other procedures or protocols to ensure comparable data and methodologies	Section 3, Appendix 3A
354.36		Representative Monitoring	• Description of representative sites • Demonstration of adequacy of using groundwater elevations as proxy for other sustainability indicators • Adequate evidence demonstrating site reflects general conditions in the area	Section 3.2.2, 3.3.3, 3.4.2, 3.5.2, 4.5, 4.9.1.4
354.38		Assessment and Improvement of Monitoring Network	• Review and evaluation of the monitoring network • Identification and description of data gaps • Description of steps to fill data gaps • Description of monitoring frequency and density of sites	Section 3.2 through 3.5

Table 1-1. Preparation Checklist for Groundwater Sustainability Plan Submittal (contd.)

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 5. Plan Contents, Subarticle 5. Projects and Management Actions				
354.44		Projects and Management Actions	• Description of projects and management actions that will help achieve the basin's sustainability goal • Measurable objective that is expected to benefit from each project and management action • Circumstances for implementation • Public noticing • Permitting and regulatory process • Timetable for initiation and completion, and the accrual of expected benefits • Expected benefits and how they will be evaluated • How the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included • Legal authority required • Estimated costs and plans to meet those costs • Management of groundwater extractions and recharge	Section 5
354.44(b)(2)	10727.2(d)(3)		• Overdraft mitigation projects and management actions	Section 5

Table 1-1. Preparation Checklist for Groundwater Sustainability Plan Submittal (contd.)

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 8. Interagency Agreements				
357.4	10727.6	Coordination Agreements - Shall be submitted to the Department together with the GSPs for the basin and, if approved, shall become part of the GSP for each participating Agency.	• Coordination Agreements shall describe the following: • A point of contact • Responsibilities of each Agency • Procedures for the timely exchange of information between Agencies • Procedures for resolving conflicts between Agencies • How the Agencies have used the same data and methodologies to coordinate GSPs • How the GSPs implemented together satisfy the requirements of SGMA • Process for submitting all Plans, Plan amendments, supporting information, all monitoring data and other pertinent information, along with annual reports and periodic evaluations • A coordinated data management system for the basin • Coordination agreements shall identify adjudicated areas within the basin, and any local agencies that have adopted an Alternative that has been accepted by the Department	The Big Valley Basin is managed under a single GSP by a single GSA; a coordination agreement is not necessary

Key:
GSA = Groundwater Sustainability Agency
GSP = Groundwater Sustainability Plan
SGMA = Sustainable Groundwater Management Act

2. PLAN AREA AND BASIN SETTING

2.1 Description of the Plan Area

Big Valley Basin (DWR Bulletin 118 basin ID 5-015) is a 37.8 square mile (24,227 acres) area south of and adjacent to Clear Lake, the largest natural freshwater lake entirely within California. The Big Valley Basin is shown on the map, **Figure 2-1**. The Big Valley Basin is bordered by Clear Lake to the north and the Scotts Valley Groundwater Basin (referred to herein as the Scotts Valley Basin) to the northwest. Adobe and Kelsey Creeks are the primary streams that flow through Big Valley and drain to the north into Clear Lake. There are other intermittent creeks that are described in **Section 2.1.3.1**.

Big Valley Basin is at most six miles wide and approximately eight miles long. The ground surface in the northern portion of the basin gently slopes to the north towards Clear Lake. There are uplands on the west side of the valley, and separate uplands occur in the south-central portion of the valley that have been uplifted approximately 400 feet by faulting (Lake County 2003). DWR estimates the storage capacity of Big Valley Basin to be 105,000 acre-feet (AF), with usable groundwater storage of approximately 60,000 AF (DWR 2003). The Big Valley Basin is the source of water supply for the community of Kelseyville and supports the largest agricultural area in Lake County.

2.1.1 Summary of Jurisdictional Areas and Other Features

Jurisdictional areas and other features beyond the District include communities, tribal lands, and public lands. Refer to **Figure 2-1** for the boundaries of the jurisdictional areas within Big Valley Basin. There are no adjudicated areas or areas covered by an alternative plan in the Big Valley Basin.

2.1.1.1 Adjacent Basin

The Scotts Valley Basin (DWR Bulletin 118 basin ID 5-014) covers 7,320 acres and supplies water to the City of Lakeport and adjacent areas, west of Clear Lake. The Basin includes Scotts Valley Basin, the foothills between Scotts Valley and Clear Lake, and the foothills immediately to the south of Lakeport. DWR estimates the storage capacity of Scotts Valley Basin to be 5,900 AF, with usable groundwater storage of approximately 4,500 AF (DWR 2003).

Scotts Valley Basin is located adjacent to Big Valley Basin and the two may be hydrologically contiguous (DWR 2003). As such, Scotts Valley Basin will be incorporated into the hydrogeologic conceptual model.

2.1.1.2 Communities

There are no incorporated cities within the Big Valley Basin. There is one large community, Kelseyville, and one small community, Finley.

Finley is an unincorporated community with a population of approximately 657 residents. Kelseyville has a population of 3,560 as of 2019. The community is predominately white-non-Hispanic (65.4 percent), followed by other-Hispanic (28.5 percent), and white-Hispanic (4.4 percent) (Data USA 2021).

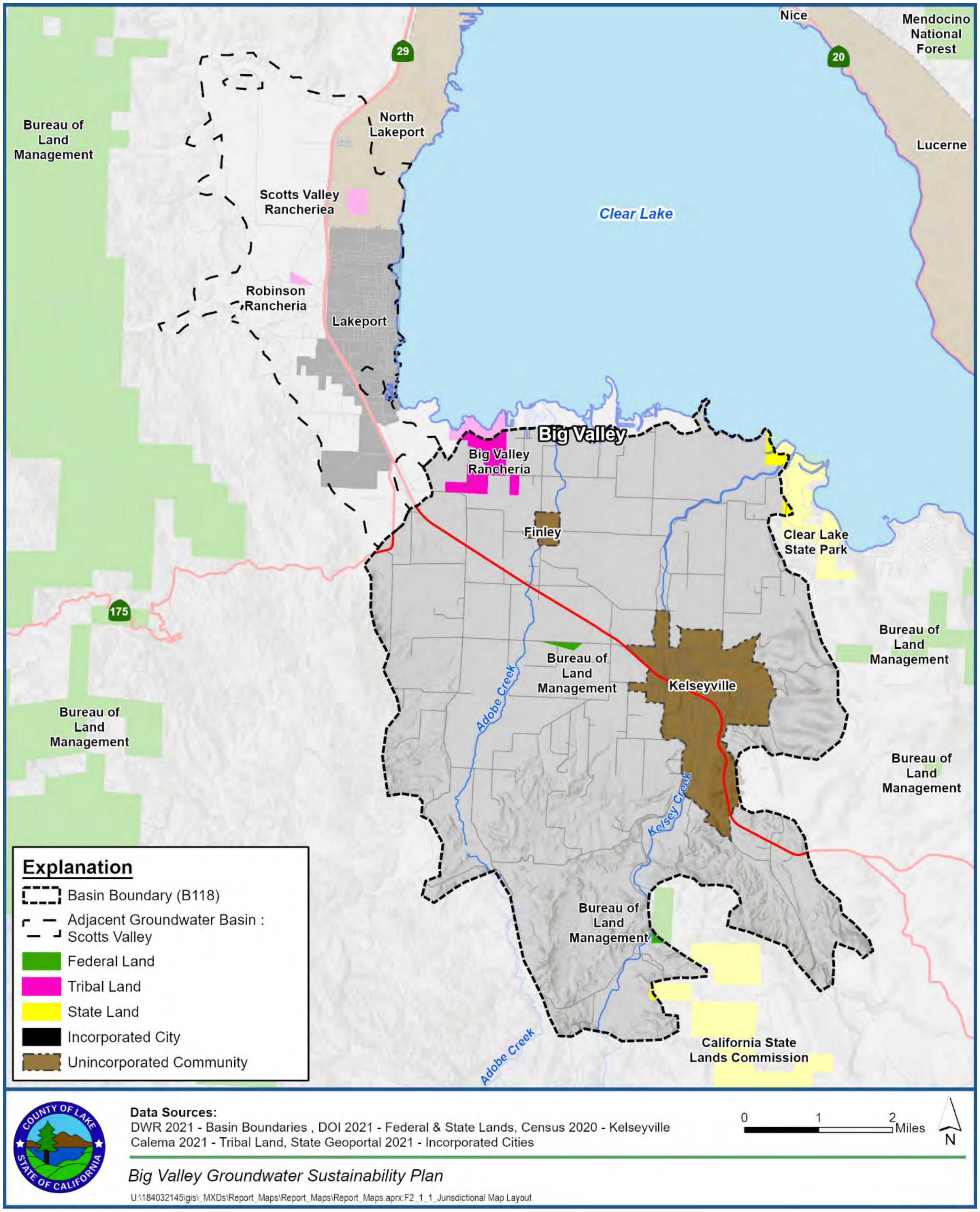

Figure 2-1. Big Valley Basin Boundaries, Communities, and Public Lands

Kelseyville is considered a severely disadvantaged community[1] in the State of California, with a median-household income of $41,680 (DWR 2018). Note that the remainder of Big Valley Basin, at the census tract level, is considered a disadvantaged community (DWR 2018). Information about community outreach and engagement efforts in the Basin are detailed in **Section 7**.

The communities of Kelseyville, Finley, Lands End, and part the Big Valley Rancheria receive water from groundwater wells owned and operated by the Kelseyville County Water Works District No.3 (KCWWD #3). The Kelseyville water system was constructed in the late 1960s and was significantly updated in 2006. The 2006 improvements involved a 14,000-foot intertie with Finley, previously serviced by Community Service Area #6, and a new storage tank.

The KCWWD #3 water treatment and distribution system includes:

- 1,280 service connections serving a population of 4,200 residents as of July 2021
- Four wells and one backup well
- Over 146,000 feet of distribution pipeline
- One 1,000,000-gallon storage tank, and two 250,000-gallon storage tanks

KCWWD #3 future capital improvement projects will focus on the distribution system (piping and looping). These projects are needed in the near term for the existing customer base and reasonable future growth. Note these communities are one hundred percent reliant on groundwater. By sustainably managing the basin, the GSA is ensuring access to a more affordable water supply when compared to alternatives (i.e., imported water, bottled water, or treated surface water).

In addition to KCWWD #3, the Big Valley Rancheria has two public water system (PWS # 0605164 and # 0605152). Developed in 2003, the Big Valley Water Treatment Plant serves Konocti Vista Casino, an 80-room hotel and 90-slip marina, 74 space recreational vehicle park, several buildings, and 38 Tribal homes. Facilities include one active well, a treatment plant, a pumping facility, a 270,000-gallon storage tank, and a distribution system. The system obtains water from a groundwater well located adjacent to Soda Bay Road about one fourth mile southwest of the Big Valley Rancheria. The other public water system serves a community center (approximately 30 people) at the gymnasium and is also supplied by groundwater.

Approximately 1,876 residents live outside the Kelseyville and Finley communities (see **Section 2.1.4.2** for population estimation calculation). Some of these residents obtain their water from state small systems that have five to fourteen connections. There are three state small water systems in Big Valley, Park Lands Mutual Water Corp., Torri Mobile Homes LLC, and Stark Duplexes. These systems are overseen by the Lake County Environmental Health Department.

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[1] A disadvantaged community is one with an average median household income of less than 80 percent of California’s overall MHI ($56,982). A severely disadvantaged community is one with an average median household income of less than 60 percent of California’s overall MHI ($42,737) (DWR 2018).

Residents not served by a state small system obtain their water supply from domestic wells and use septic tanks for their wastewater needs.

2.1.1.3 Public Lands

Small portions of state and federal land lie within Big Valley Basin (less than 100 acres). As shown in **Figure 2-1**, some of Clear Lake State Park, California State Lands Commission forests, and Bureau of Land Management forests are within Big Valley Basin boundary. Overall, there are no substantial public lands within the Basin.

2.1.1.4 Tribal Lands

The Big Valley Rancheria Band of Pomo Indians is largely within the Big Valley Basin (84.4 acres within Big Valley Basin of 117.3 total acres). The Big Valley Tribe of Pomo Indians are descendants of the Xa-Ben-Na-Po Band of Pomo Indians that historically inhabited the Clear Lake watershed for over 11,800 years. The tribal members, currently 350 who live on the Rancheria and another 1,200 outside of the Rancheria, have played a large role in the protection, study, and understanding of the hydrology of the Big Valley Basin.

While the Big Valley Rancheria Band of Pomo Indians is the only tribe with jurisdiction in Big Valley Basin, there are several other tribes that have a cultural tie to the land. A request to the California Native Heritage Commission identified several tribes including the Elem Indian Colony Pomo Tribe, Guidiville Indian Rancheria, Koi Nation of Northern California, Middletown Rancheria of Pomo Indians, Mishewal-Wappo Tribe of Alexander Valley, Pinoleville Pomo Nation, Scotts Valley Band of Pomo, Robinson Rancheria, and the Habematolel of Upper Lake who have historical and cultural ties to the land within the Big Valley Basin. For more information about tribal outreach and engagement efforts, refer to Section 6.

2.1.2 Land Use Elements or Topic Categories of Applicable General Plans

The subsequent sections discuss population and land use within Big Valley Basin, with a focus on agriculture.

2.1.2.1 Population Trends

Big Valley Basin had a population of approximately 6,076, including the 350 tribal members on the Big Valley Rancheria (US Census Bureau 2019). The largest community is Kelseyville which has fluctuated in population over the past decade (see **Table 2-1**).

Table 2-1. Population Trends in Big Valley Basin: 2010-2019

Area	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Kelseyville	3,126	2,923	3,282	3,568	3,516	3,783	3,822	3,647	3,330	3,560
Lake County	65,056	64,921	64,976	64,900	65,073	64,690	64,343	64,627	64,590	64,080

Source: Data USA and California Department of Finance 2020

Kelseyville is adding additional housing with the Kelseyville Apartments development. The development is planned for 157 units, the first 53 of which were constructed in 2020 (Lake County 2019). This development, in addition to others, may increase the Kelseyville population.

Although not currently included in the Lake County General Plan (General Plan), there are several developments slated for construction in the upcoming decades. By 2042, the population of Lake County is estimated to slightly increase to 65,595, up from the 2019 population of 64,080 (California Dept. of Finance 2020). While these developments would not be within Big Valley Basin, they could impact water demand and groundwater conditions.

2.1.2.2 Current and Historical Land Use Conditions

Big Valley Basin is one of the most intensely farmed areas in Lake County. Of the 24,227 acres, roughly a third of the land is used for agriculture and about 60 percent is rural or open space. Only three percent is urban, which accounts for the communities of Kelseyville and Finley. See **Figure 2-2** for land use by parcel in Big Valley Basin.

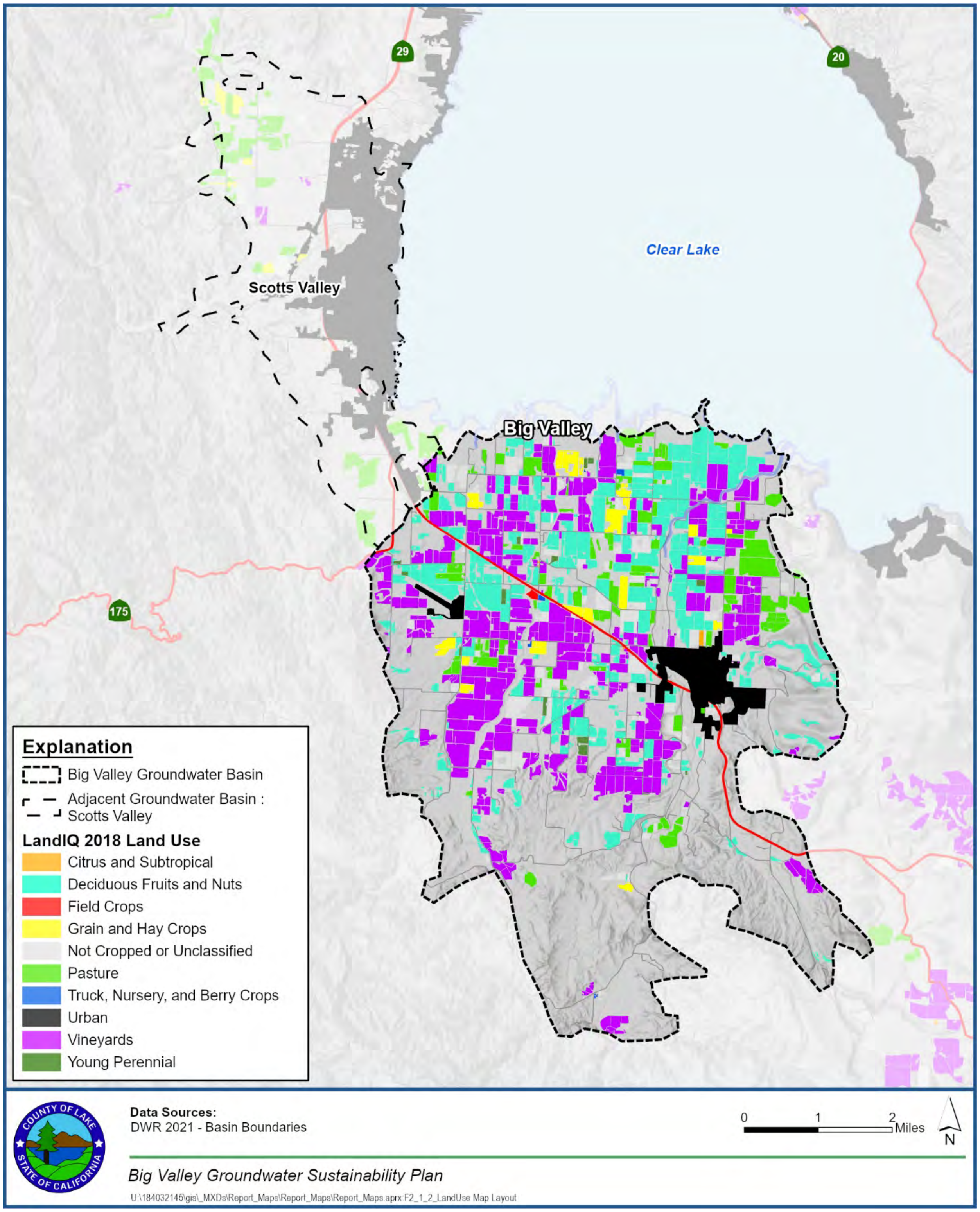

Figure 2-2. Land Use in Big Valley Basin (2018)

2.1.2.3 Current and Historical Irrigation Practice

As of 2018, there were 8,222 acres under irrigation (Land IQ, LLC 2018). Wine grapes, pears, and walnuts are the most cultivated crops in Big Valley Basin. **Table 2-2** presents the current and historical crop acreages collected from DWR land use data.[2]

Table 2-2. Current and Historical Crops by Acreages: 2001-2018

Crop Category	1995	2001	2013	2016	2018
Citrus and Subtropical	1	0	19	3	9
Deciduous Fruits and Nuts	6,421	4,389	3,586	2,990	3,010
Other	28	34	12	30	47
Pears	3,647	2,149	1,530	1,310	1,303
Walnuts[1]	2,746	2,206	2,044	1,649	1,660
Field Crops	237	8	0	0	9
Grain and Hay Crops	241	162	1,237	610	324
Pasture	802	620	1,552	956	1,028
Truck, Nursey, and Berry Crops	12	24	44	14	12
Vineyards	2,450	3,480	3,491	3,343	3,761
Total	**10,164**	**8,663**	**9,929**	**7,916**	**8,222**

Source: DWR

Note:

[1] Roughly half of the walnuts are dry farmed.

As shown in the table, irrigated acreage has remained relatively stable in Big Valley Basin over the past 20 years. While the total acreage has not significantly changed, the crop types have. Pears were historically the most popular crop in Big Valley Basin, with peak production of about 8,000 acres in 1980 (Lake County 2010). Since then, pear acreage has dropped to 1,303 acres in 2018. Farmers have replaced pears with wine grapes, a high value crop. From a water demand perspective, this crop replacement has reduced groundwater demand as pears require significantly more applied water than wine grapes on an area basis (2.2 AF/acre compared to 0.5 AF/acre) (Lake County 2006a). This can be attributed to both crop demands and irrigation methods; wine grapes are irrigated with highly efficient drip irrigation whereas pears are irrigated with the less efficient sprinklers.

[2] The 2018 Land IQ dataset was developed using remote sensing, statistical, and temporal analysis methods. The data was then reviewed and revised by DWR. The 2018 data set has greater than 95 percent accuracy. The 1995, 2001, 2013, and 2016 data sets used similar technology, but DWR did not release an accuracy percentage. Rather, the data disclaimer states, "While the Department believes the information to be reliable and has made efforts to assure its reliability at the time the information was compiled, the information is provided 'as is.'"

While not captured in **Table 2-2**, cannabis, both legal and illegal, is another crop that has increased in acreage over the past decade. The Lake County Community Development Department, Planning Division has existing permitting data on past, current, and proposed commercial cannabis throughout the County. As of November 2021, there are around twenty pending or approved cannabis operations in Big Valley Basin. The Community Development Department is in the process of creating a databased that will georeference all legal cannabis projects throughout Lake County and will include well locations included in the permit application as well as the proposed water use estimates. Additionally, there are several large-scale studies out of the University of California that examine groundwater use by cannabis cultivators which can help the County in future planning.

While growth in cannabis cultivation has the potential to alter water demand, the County has taken steps to regulate where cannabis can be grown. Nearly all of Big Valley Basin lies within a Farmland Protection Zone (98 percent of agricultural zoned land), which requires that cannabis be grown in a greenhouse. Greenhouse cultivated cannabis has more reliable irrigation and water-use data than cannabis grown in native soil and can also serve to limit legal cannabis production.

2.1.2.4 General Plan Considerations

Implementation of the GSP will be influenced by existing policies and regulations outlined in existing General Plan. Specific plans are required by state law to be consistent with general plan policies, and general plans and specific plans are required by state law to be consistent with airport land use compatibility plans. Implementation of this GSP will support all goals and polices established in the General Plan, consistent with SGMA and GSP Regulations.

The General Plan was first adopted in 1993 and most recently updated in 2008. The General Plan contains the goals and policies that will guide future development and resource utilization and protection within the County. There are several General Plan elements that are relevant to GSP implementation including water resources element, agricultural resources element, land use element, and the housing element.

The relevant General Plan goals are listed below:

- WR-1. To provide for the current and long-range water needs of the County and for the protection of the quality and quantity of groundwater resources.
- WR-2. To protect the quality of surface water and groundwater resources to meet the needs of all beneficial users.
- WR-3. To provide a sustainable, affordable, long-term supply of water resources to meet existing and future domestic, agricultural, industrial, environmental, and recreational needs within the County, so as to maintain sustainability between new development and available water supplies.
- WR-4. To manage the water resources in Lake County's diverse watersheds and develop new sources of surface water and enhance groundwater recharge.
- WR-5. Encourage efficient use of water for new and existing land uses.

Water is also an integral part of the General Plan Housing Element. The administrative draft, which covers the planning period from 2019-2027, discusses how housing is tied to water and sewer capacity constraints. The report states that Kelseyville wastewater system, in addition to the other wastewater systems in the County, has the capacity to support housing developments with their current infrastructure.

The General Plan Housing Element also has a policy related to housing sites and groundwater:

- HE-54. Immediately following revisions to County Flood Maps based on new Light Detection and Ranging data, the Community Development Department shall review the updated mapping of groundwater recharge and stormwater areas. Multifamily zoning will be reviewed for their continued suitability for the provision of affordable housing. Sites deemed to be no longer suitable for affordable housing shall be removed from the affordable housing site inventory.

In addition to the Lake County General Plan, there is a plan specific to Kelseyville, the Kelseyville Area Plan. As Kelseyville is the largest community in Big Valley Basin, it is important for this GSP to be in parody with the Kelseyville Area Plan. The Kelseyville Area Plan has several objectives and policies that connect to the GSP such as protecting and preserving water resources quality and quantity and monitor groundwater use the prevent long-term degradation and depletion. This GSP is in accordance with and supports the Kelseyville Area Plan.

2.1.3 Water Resources

Big Valley Basin has several surface water and groundwater resources, as described in the sections below.

2.1.3.1 Surface Water

Big Valley Basin is adjacent to Clear Lake, the largest lake entirely within California. With inflow from Scotts, Middle, and Kelsey Creeks (see **Figure 2-3**), the lake supports several beneficial uses including agriculture, recreation, freshwater habitat, wildlife habitat, commercial/sport fishing, Tribal traditional cultural uses, and municipal and domestic water supply. There are 19 water utilities that source water from Clear Lake, supporting two-thirds of Lake County residents. Of the 19 purveyors, 17 purchase water from the Yolo County Flood Control and Water Conservation District, which manages water stored in the lake. As of 2000, the Clear Lake consumptive use was 14,000 AF (Lake County 2010a).

Clear Lake is listed as an impaired water body on the U.S. Environmental Protection Agency (EPA) 303(d) list for nutrients. This is in part due to the shallow, warm nature of the lake, but also anthropogenic sources around the lake such as septic tanks, stormwater drainage, and agricultural runoff. A Total Maximum Daily Load was established in 2006 for nutrients. Nutrient water quality issues, particularly toxic cyanobacteria, continue to be a problem. Several water purveyors have experienced water treatment issues and rising costs. One purveyor has even had to update their system by increasing the length of their intakes to avoid nutrient dense water along the shore.

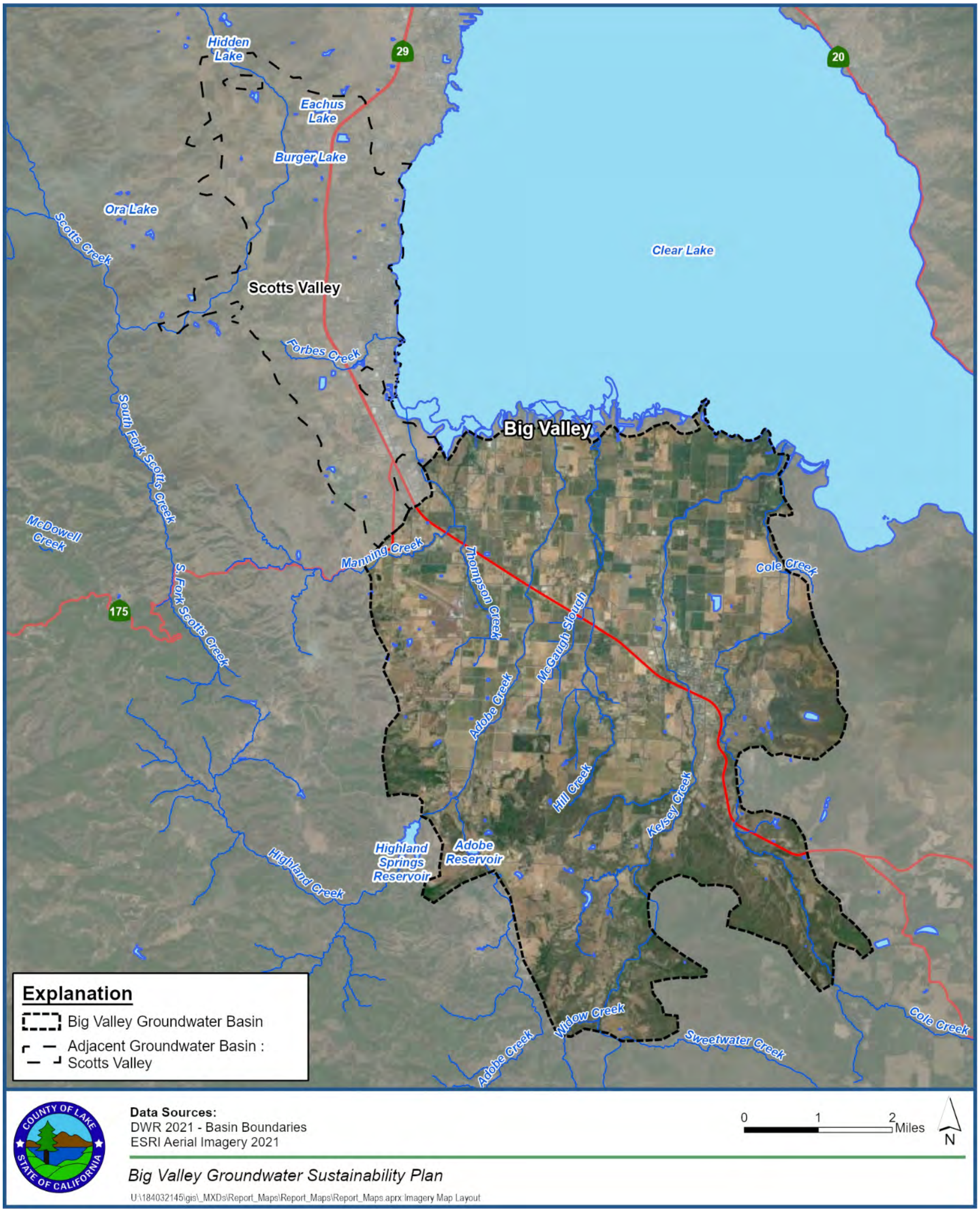

Figure 2-3. Surface Water Bodies in the Big Valley

Clear Lake is also listed as impaired for mercury. The mercury impairment can be directly attributed to the Sulphur Bank Mercury Mine, which operated from 1865 until 1957. The site is now an EPA Superfund site. The EPA has taken several steps to reduce mercury in the lake, including a 1992 project to control direct erosion of mine tailings into the lake and a 2007-2008 project to remove contaminated mine wastes (Lake County 2010a). Additionally, a Total Maximum Daily Load was established for mercury in 2002.

The mercury and nutrient impairments have had a serious impact on fish and wildlife, including the Clear Lake Hitch. The Clear Lake hitch is a large, lake-adapted minnow endemic to Clear Lake watershed. Adult hitch migrate each February through May upstream in Clear Lake's intermittent tributaries to spawn and then return to the lake. The hitch were a food stable and cultural component for the Pomo tribes of the region, but their population has steeply declined. Studies have found that the hitch's decline can be attributed to water quality degradation, instream barriers, drought, and climate change. As a result, the Clear Lake hitch have been listed as a threatened species under the California Endangered Species Act since 2014, but do not have a federal status as of 2021 (Center for Biological Diversity 2021).

Kelsey Creek, the third largest tributary to Clear Lake, is one of the primary spawning habitats for the Clear Lake hitch. The 22.5-mile creek flows year-round in the upper reaches, but usually goes dry in mid-summer in the lower reaches (Lake County 2010b). The water quality varies by reach with colder temperatures and higher dissolved oxygen found in the upper reaches and warmer temperatures and lower dissolved oxygen found in the lower reaches. Kelsey Creek has two gauges, monitored by the U.S. Geological Survey (USGS) and DWR. Flow varies by water year; in dry years the average annual flow at the USGS gage can be as low as 4.8 cubic feet per second (cfs), but up to 206 cfs in wet years (Lake County 2010b). From 1947-2020, the average annual flow is around 71 cfs (USGS 2021). The creek supports irrigation, recreation, and fishing and has one major structure, the Kelsey Creek Detention Structure.

The other major surface water feature in the Basin is Adobe Creek. Adobe Creek is an 11-mile stream with flows controlled by Adobe Creek Reservoir and Highland Spring Reservoir. The Adobe Creek Reservoir was built in 1964 for flood control purposes. The reservoir is impounded by an earthen dam and has a storage capacity of 785 AF. The reservoir supports recreation and the irrigation of walnuts and grapes (Lake County 2017). The Adobe Creek Reservoir spillway limits outflow to 940 cfs, but no water is released in the summer months. While the reservoir has successfully reduced flooding along the Adobe Creek watershed, it has contributed to channel downcutting and bank erosion. This has lowered the maximum water table level, reducing aquifer storage (Lake County 2010a).

Highland Springs Reservoir is also in the Adobe Creek watershed and located west of Adobe Creek Reservoir. The Highland Springs Reservoir impounds Highland Creek, a tributary of Adobe Creek, with an earthen dam. The reservoir consists of two spillways and has a total storage capacity of 4,590 AF. The normal operation of the reservoir is "hands off" except for a small amount of water (less than 0.5 cfs) released downstream in the summer months to recharge nearby wells (Lake County 2017). It is important to note that neither Highland Springs Reservoir nor Adobe Creek Reservoir have flow monitoring gages on the spillways so actual flow rates are unknown.

Highland Springs Reservoir has an associated park run by the District. The Highland Springs Park supports numerous recreation opportunities and fishing access, but motorized boats are prohibited on the lake.

There are other streams in Big Valley Basin including Manning Creek, Thompson Creek, McGaugh Slough, Hill Creek, and Cole Creek. There is limited information available about these creeks as they are ephemeral and thus, are not monitored for flow. However, the Big Valley Rancheria has a few water quality sampling sites at Thompson Creek, Cole Creek, and Manning Creek that have data dating back to 2011. McGaugh Slough is also tested for water quality as part of the Irrigated Lands Regulatory Program.

2.1.3.2 Groundwater

A thorough description of groundwater conditions can be found in **Section 2.2.2 Current and Historic Groundwater Conditions**.

Groundwater is accessed from wells throughout the Basin. Maps of Big Valley Basin well density, based off well completion reports, can be found in **Figure 2-4** and **Figure 2-5**. This information was collected from the DWR well completion report map application compiled from County data. This dataset does not include well coordinates, but rather centroids to estimate a well's location. Additionally, well completion reports do not guarantee that a well was ever used or is still in use. That level of detail is only available for registered wells with both an ID and coordinates, which is significantly fewer than the wells with only a well completion report. The Lake County database, maintained by the District, keeps information on the registered wells.

Production wells are more frequently found in the central and northern portion of the Basin and range from 42 to 421 feet deep on average. However, most production wells are about 150-160 feet deep. Domestic wells are not as deep and range from 42 to 292 feet. Domestic wells are located throughout the Basin but are heavily concentrated around Kelsey Creek.

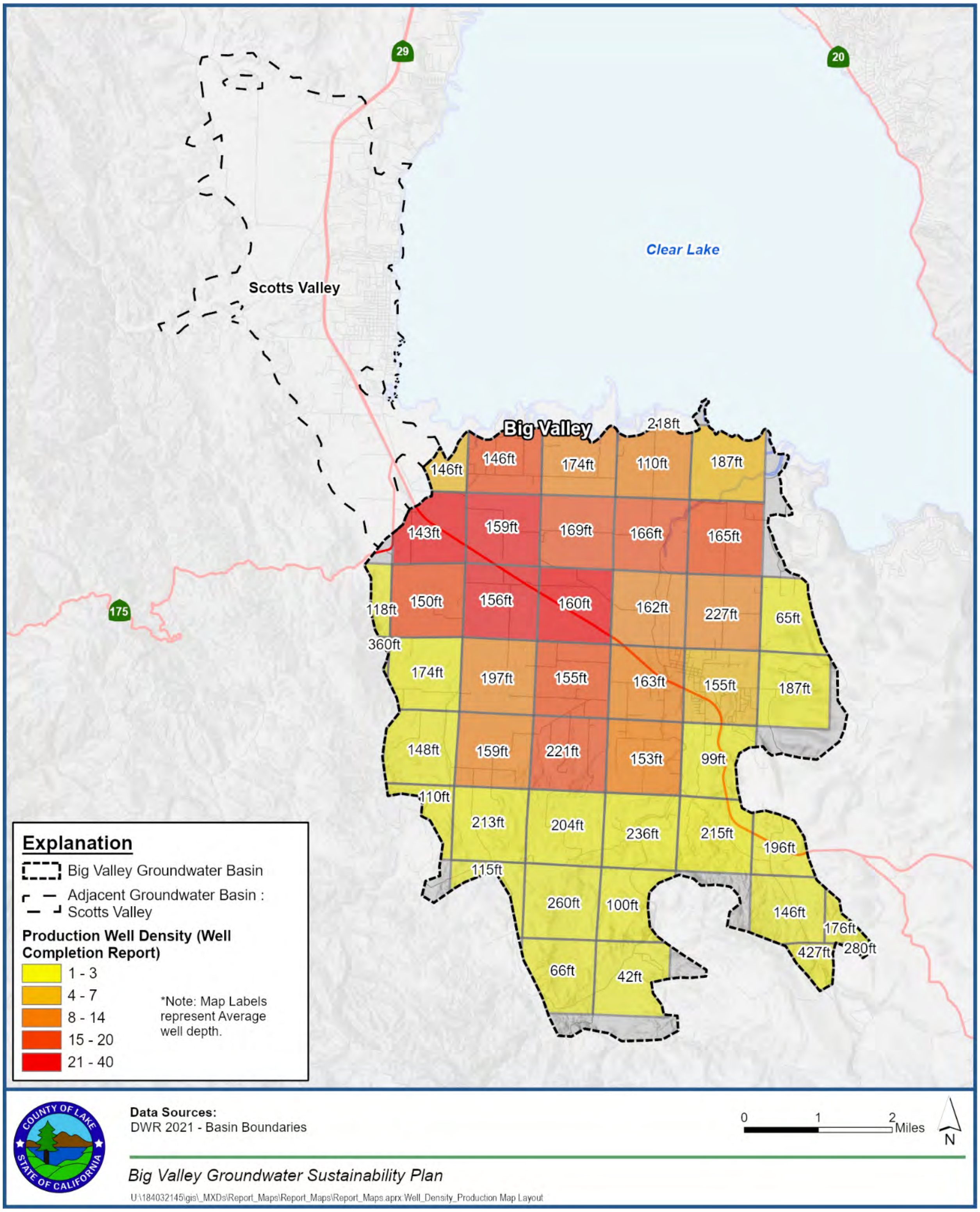

Figure 2-4. Production Well Density in Big Valley Basin

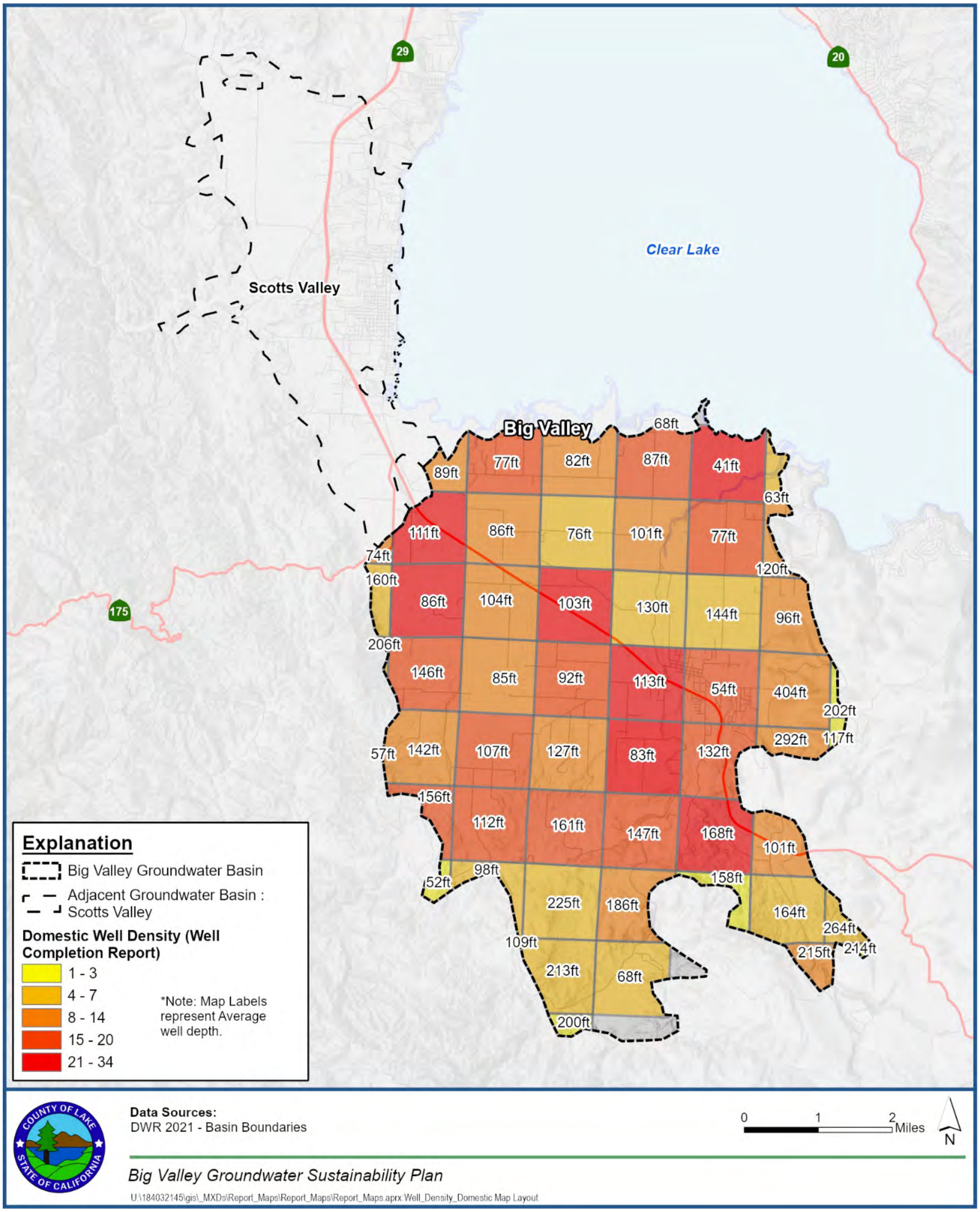

Figure 2-5. Domestic Well Density in Big Valley Basin

2.1.4 Water Use

There are three primary water users in Big Valley Basin: agriculture, municipal, and rural domestic. Agricultural irrigation is supplied mostly from groundwater sources, with limited amounts from surface water. Municipal water from KCWWD #3 and rural domestic water are exclusively supplied from groundwater.

Total water use is an estimated 12,944 acre-feet per year (AFY). Most of the water is used for agricultural purposes (11,928 AFY in 2013), with the remainder used by municipal and domestic water uses (622 AFY and 340 AFY, respectively in 2020). These water use volumes come from the 2018 Big Valley Groundwater Annual Report and other sources.

2.1.4.1 Agricultural Water Use

Agricultural water use, by and large, is not monitored. However, it can be estimated using the number of irrigated acres, the crop type, and the irrigation rate. The historical agricultural water use in Big Valley Basin was estimated using DWR land use datasets and irrigation rate (also known as the evapotranspiration of applied water measured in AF per acre). The DWR datasets also include the source of water for each crop type, but do not specify the source. Clear Lake is the main surface water source, but Kelsey and Adobe Creeks may be a source as well (personal comm. Scott Webb 2021).

Agricultural demand has declined since 1995 and has since fluctuated between 9,427 and 11,928 AF. In any given year, regardless of hydrologic conditions, groundwater accounts for 98 to 99 percent of agricultural water supply. The irrigation demand from 1995 to 2013 is presented in **Table 2-3** below.

Table 2-3. Irrigation Demand from All Water Sources for 1995 to 2013

	1995	2001	2006	2013
Total Irrigation Demand, AF	**17,126**	**10,554**	**9,427**	**11,928**
Surface Water Irrigation, AF	0	0	4	47
Groundwater Irrigation, AF	16,929	10,385	9,247	11,881
Other Irrigation, AF	198	167	176	0

Key:
AF = acre-feet

2.1.4.2 Municipal and Rural Domestic Water Use

KCWWD #3 supplies water to a population of 4,200 from four wells. Water use varies from year to year but is relatively stable (**Table 2-4**). In 2020, the municipal water use was 622 AF or 132 gallons per day per person (personal comm. Scott Hornung 2021).

Table 2-4. Municipal Water Use, 2013-2020

Supplier [1]	Unit	2013	2014	2015	2016	2017	2018	2019	2020
Kelseyville County Water Works District #3	AFY	657	445	411	452	499	513	621	622
	per capita water use in gallon per day[2]	140	95	87	96	106	109	132	132

Source: Lake County 2019 and personal comm. Scott Hornung

Notes:
[1] The Big Valley Rancheria Band of Pomo Indians Public Water System is not included in this table nor are the state small systems.
[2] Assuming a population of 4,200 served
Key:
AFY = acre-feet per year

Residents outside the KCWWD #3 and Big Valley Rancheria service areas receive water supply from domestic wells. These wells are primarily used for human consumption but may be used for some non-potable purposes such as landscape irrigation. In Big Valley, there are 21 registered domestic wells in the Lake County geospatial information system database. However, the online SGMA viewer reveals that there are 647 domestic wells with well completion records. These wells are identified by their township and range, not specific coordinates nor well identification numbers; it is possible that many of these wells may no longer be in use.

Rural domestic use (private domestic wells) is not monitored; however, it can be conservatively estimated. This can be done by multiplying population data by per capita water use. The population on domestic wells can be estimated by subtracting the population served by KCWWD #3 and the Big Valley Rancheria Public Water System from the total Basin population. This calculation yields 1,876 people on domestic wells in 2020. A 2006 water demand study prepared by CDM in cooperation with DWR estimated rural per capita water use at 162 gallons per day, which equates to approximately 340 AF of groundwater demand for rural domestic use in 2020 (Lake County 2006a).

2.1.4.3 Recycled Water Use

Lake County uses treated effluent for geothermal power production. Effluent is piped to the Geyser steam field where it is exposed to molten rock to generate steam. The Geyser steam fields can produce 100 megawatts and lie within the Kelsey Creek sub-watershed.

Piped effluent is insufficient to keep the pipeline at capacity so water from Clear Lake is used to augment the supply. There are plans to expand the effluent pipeline to connect the community of Kelseyville, which would reduce the amount of water drawn from Clear Lake (Lake County 2010a). This project is currently on hold due to funding constraints, but there is a renewed interest in the project as of 2021 (personal comm. Scott Hornung 2021).

2.1.5 Water Resources Monitoring Programs

There are several ongoing efforts to monitor water resources in Big Valley Basin and throughout the County. These monitoring programs have various agency leads and are dictated by regulation. Data collected from the programs will improve basin characterization and guide management but will require additional coordination and integration which may limit operational flexibility. The water resources monitoring programs are summarized in the sections below.

2.1.5.1 Surface Water Flow and Stage Monitoring

Surface water flow and stage monitoring activities are conducted by several government agencies. Clear Lake levels are monitored by the USGS with a gauge at Lakeport, and outflow is measured by a USGS gauge on Cache Creek below the Cache Creek Dam. There are also four USGS gauges on Clear Lake tributaries including one Kelsey Creek, one on Adobe Creek, one on Highland Creek, and one on Forbes Creek. DWR has stream gauges within the watershed as well, on Scotts, Middle, and Kelsey Creeks.

In addition to these gauges, the Big Valley Rancheria placed three transducers along Adobe Creek in late 2018. The transducers measure pressure, temperature, and water depth, unlike the other gauges which measure stream flow. A map of the transducer and gauge locations can be found on **Figure 2-6**. More information on streamflow monitoring and interconnected surface water can be found in **Section 2.2.2.5**.

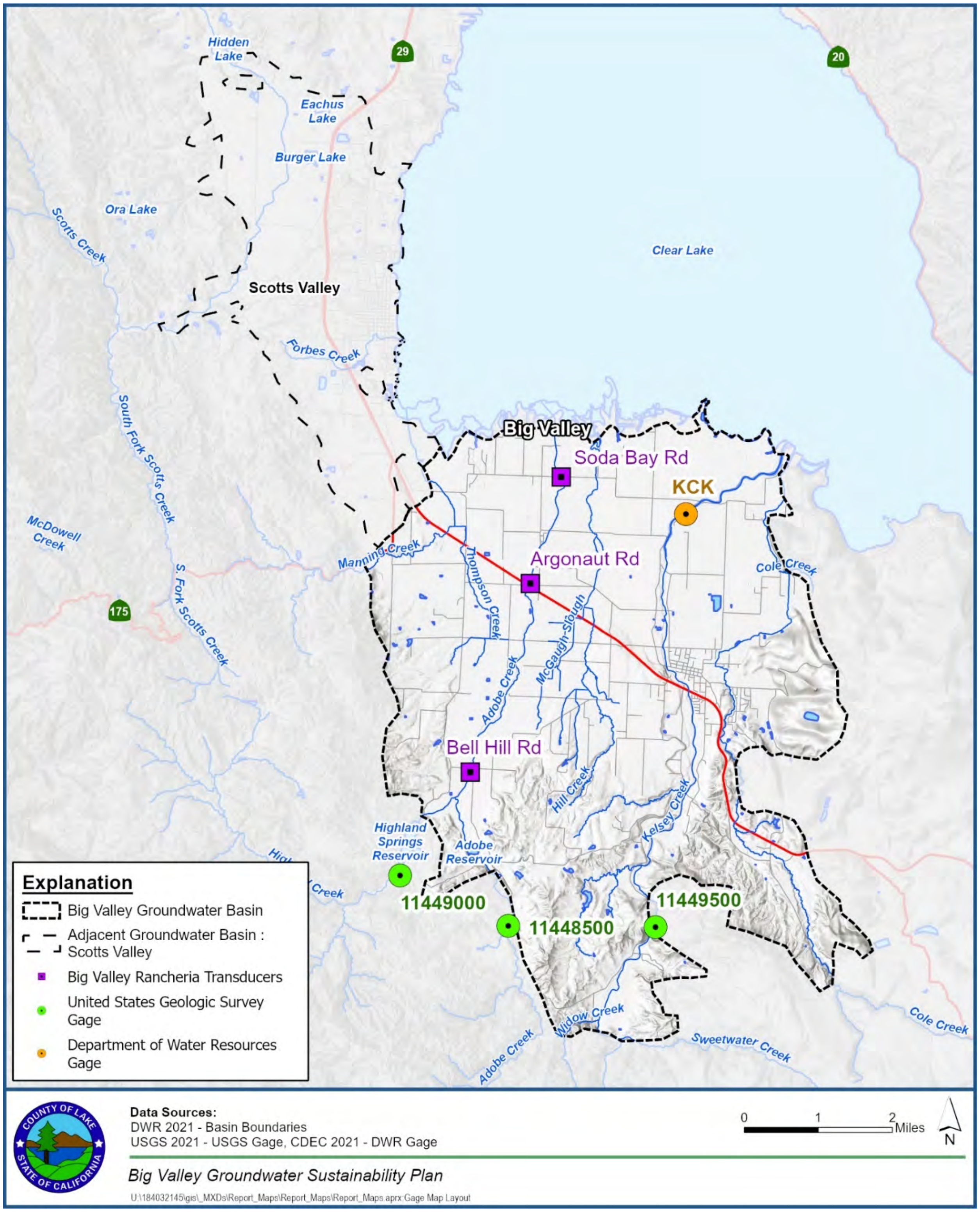

Figure 2-6. Surface Water Flow and Stage Measurement Locations in Big Valley and Surrounding Area

2.1.5.2 California Statewide Groundwater Elevation Monitoring Program

The California Statewide Groundwater Elevation Monitoring Program (CASGEM) is a statewide program implemented by DWR to collect groundwater levels, facilitate collaboration with local monitoring entities, and to report information to the public. Lake County has been importing monitoring data into CASGEM since 2011. In compliance with CASGEM, the District notified DWR of its intent to be the designated Monitoring Entity for all Lake County basins, including Big Valley Basin. The District then defined and submitted a Groundwater Monitoring Plan to DWR to monitor for seasonal and long-term groundwater level trends in the monitoring area. As of 2021, there are 24 wells that are monitored by Lake County or DWR under the CASGEM Program and voluntary program (see **Figure 2-7**).

2.1.5.3 Groundwater Quality Monitoring

Groundwater quality is routinely monitored at the four municipal wells operated by KCWWD #3 in Kelseyville and two wells operated by the Big Valley Rancheria Public Water System. These wells are tested for drinking water quality as required by both state and federal regulations.

Outside of these municipal drinking water wells, groundwater quality is initially tested when a well is constructed. However, private well owners are not required to report this information so that data many not be publicly available. Some wells have not been tested since they were constructed while others have been sampled multiple times, though mostly at irregular intervals. There are 26 wells that have been sampled at least one time since 2019. In a one-time collection effort, DWR sampled six wells in August 2021 for a variety of parameters (see **Section 2.2.2.3** for details). Groundwater water quality data collected by DWR, in addition to the County, USGS, State Water Resources Control Board (SWRCB) Division of Drinking Water, and Department of Pesticide Regulation, are stored by the Groundwater Ambient Monitoring and Assessment (GAMA) Program.

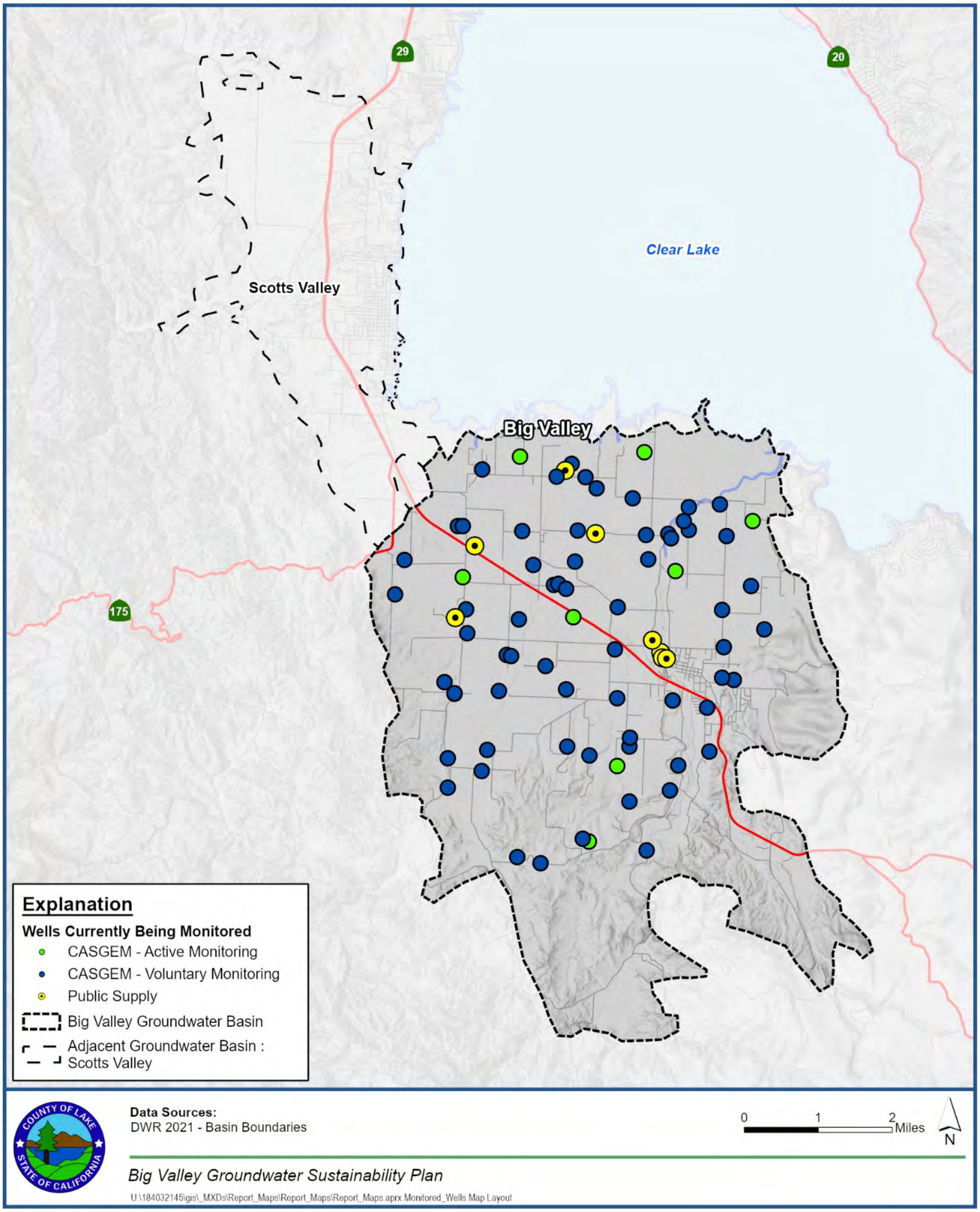

Figure 2-7. California Statewide Groundwater Elevation Monitoring Program Wells in Big Valley

2.1.5.4 Other Related Water Quality Monitoring

There are several other related water quality monitoring programs that occur within Big Valley Basin and Lake County.

Central Valley Regional Water Quality Control Board – Irrigated Lands Regulatory Program

The Irrigated Lands Regulatory Program, founded in 2003, establishes waste discharge requirements for irrigated agricultural lands throughout the Central Valley to prevent surface water impairment. As part of the Irrigated Lands Regulatory Program, irrigated land producers must submit a "Conditional Waiver for Irrigation Return Flows and Storm Water Runoff from Irrigated Lands." This conditional waiver requires dischargers to apply for individual Waste Discharge Requirement Permits or to participate in a watershed group that assists in monitoring and achieving water quality objectives. Due to the permit and monitoring expense for individual permits, almost all irrigated agricultural landowners in Lake County have joined the Sacramento Valley Water Quality Coalition (SVWQC) to comply with the conditional waiver requirements.

As part of the SVWQC water quality monitoring plan, monitoring is carried out in Lake County six times a year. These monitoring events sample representative surface water sites during a range of hydrologic conditions, including first storm flush, winter and spring flows, and the dry season. Representative monitoring sites are chosen based on proximity to concentrated agriculture and lack of influence from urban sources.

Monitoring occurs on a two-year cycle. During assessment years, a suite of parameters is monitored including water and sediment toxicity tests, temperature, dissolved oxygen, pH, conductivity, turbidity, and levels of pesticides, metals, and nutrients. If pesticides are detected above allowable limits, the Agricultural Commissioner evaluates pesticide use in the area. If two exceedances occur within a monitoring site, a Management Plan is triggered, which requires source determination, grower outreach, and additional levels of Regional Board oversight. Management Plans are lifted after two years with no exceedances for that particular parameter.

In 2005 and 2006, McGaugh Slough in Big Valley Basin was monitored (**Figure 2-3**). The only exceedance found in McGaugh Slough was for the bacteria species E. coli; however, there has been no determination as to whether the source of the E. coli was from livestock, birds, humans, or another source.

The SVWQC has also developed a Groundwater Quality Trend Monitoring Program with the purpose of determining current water quality conditions of groundwater relevant to irrigated agriculture. Wells are sampled in accordance with the annual and five-year sampling schedule. They are tested for nitrate, total dissolved solids (TDS), pH, dissolved oxygen, oxidation-reduction potential, turbidity, and other parameters. There is one well in Big Valley Basin that is a part of this program (SVWQC00007). It was most recently sampled in the summer of 2020.

State and Federal Entities – Groundwater Ambient Monitoring and Assessment Program

Established in 2000, the GAMA Program is a statewide groundwater quality monitoring program based on interagency collaboration among SWRCB and the Regional Water Quality Control Boards, DWR, Department of Pesticide Regulation, USGS, and Lawrence Livermore National Laboratory, and cooperation with local water agencies and well owners. The main goals of GAMA are to:

- Improve statewide comprehensive groundwater monitoring
- Increase the availability of groundwater quality information to the public
- Conduct special projects and data assessments to support programs involving groundwater quality in California

The Priority Basin Project provides a comprehensive statewide assessment of groundwater quality to help identify and understand the risks to groundwater. The Big Valley Basin was included in the North Coast Ranges Assessment and conducted in 2009.

Department of Pesticide Regulation – Surface Water Protection Program

The Department of Pesticide Regulations' Surface Water Protection Program monitors agricultural and non-agricultural sources of pesticide residues in surface water. The program includes both a preventative and response component toward reducing the presence of pesticides in surface water. The preventative component includes local outreach to promote management practices that reduce pesticide runoff, while the response component includes mitigation options to meet water quality goals and identify self-regulating efforts to reduce pesticide exposure. This program compiles pesticide-related data from other agencies including the Big Valley Rancheria. More information on the data can be found at https://www.cdpr.ca.gov/docs/emon/surfwtr/surfdata.htm.

Big Valley Rancheria Surface Water Monitoring Programs

The Big Valley Rancheria has a robust set of surface water monitoring programs. Their water quality monitoring program on Clear Lake and its associated tributaries combines data collected from the Tribe (1999-2014) with data from other public agencies to create a master dataset dating back to 1956 and covering a wide range of water quality parameters (Big Valley Rancheria n.d.).

Additionally, the Rancheria, in support with the Elem Indian Colony, has a cyanobacteria and cyanotoxin monitoring program on Clear Lake and its associated tributaries. The program began in 2014 and regularly collect samples two times during the summer. The Rancheria also collects stormwater monitoring data (including fecal speciation). For more information, see their website at https://www.bvrancheria.com/epa.

Department of Toxic Substances Control - Envirostor

Envirostor is the Department of Toxic Substances Control's data management system for tracking information regarding hazardous waste facilities and sites with known contamination. Envirostor contains data on the three cleanup efforts within Big Valley Basin.

National Pollution Discharge Elimination System

The National Pollution Discharge Elimination System (NPDES) is a permitting program run by the EPA. The purpose of the program is to regulate point sources that discharge pollutants to waters of the United States.

The NPDES program has been delegated to the State of California for implementation through the SWRCB and the nine Regional Water Quality Control Boards (RWQCB), collectively referred to as Water Boards. In California, NPDES permits are also referred to as waste discharge requirements that regulate discharges to waters of the United States. The Central Valley RWQCB oversees the permitting in Lake County. There are three government agencies with NPDES permits for pesticide applications in the Clear Lake watershed—Vector Control for mosquito abatement, Watershed Protection District/Water Resources Department for aquatic weed control, and California Department of Food and Agriculture for hydrilla (*Hydrilla verticillata*) management.

2.1.5.5 Land Subsidence Monitoring

Land subsidence is a gradual settling or sudden sinking of the Earth's surface due to subsurface movement of earth materials. The causes of subsidence include groundwater pumping, peat loss, and oil extraction. In California, groundwater extraction is the major factor of land subsidence. The effects of subsidence include damage to buildings and infrastructure, increased flood risk in low-lying areas, and lasting damage to groundwater aquifers and aquatic ecosystems. Neither DWR nor the USGS have land subsidence monitoring devices (extensometers) in Big Valley Basin. However, data on recent trends of land subsidence for most of California, including the Big Valley Basin, are available from remote sensing measurements of changes in land surface altitudes using Interferometric Synthetic Aperture Radar (InSAR). InSAR uses radar signals from Earth-orbiting satellites to measure changes in land-surface altitude at high degrees of resolution and spatial detail (Galloway et al., 2000). These measurements are repeated at pre-set time intervals to develop maps of ground-surface displacement (subsidence) overtime. For more information on subsidence in Big Valley Basin, see **Section 2.2.4.4 Land Subsidence**.

2.1.6 Water Resources Management Programs

The District has several ongoing efforts to manage water resources in Big Valley Basin and throughout the County. Several of these programs are highlighted in the sections below.

2.1.6.1 Groundwater Management Plan

The District has a long history of sustainable groundwater management. In 1998 the District, with the assistance of the Big Valley Groundwater Management Zone Commission, produced the Big Valley Groundwater Management Plan. This document was adopted by the District on May 18, 1999.

In 2000, funding from the Local Groundwater Assistance Act (AB 303) allowed the District to inventory existing groundwater conditions and uses and to develop a groundwater management plan for all of the County's thirteen basins. These efforts resulted in the Lake County Groundwater Management Plan (GMP),[3] which describes the management of thirteen groundwater basins. The Lake County GMP was adopted by the District in 2006 (Lake County 2006b). The Lake County GMP documents the status of water use and supply, identifies areas of need, and provides recommendations to ensure a supply of high-quality water into the future. The Lake County GMP satisfies the requirements under AB 3030 and SB 1983, which required

[3] Lake County GMP is available at: http://www.lakecountyca.gov/Government/Directory/WaterResources/Programs___Projects/Groundwater_Management.htm

agencies to have a groundwater management plan in order to receive state grant funding for groundwater resources projects.

In addition to the Lake County GMP, the District obtained funding in 2003 to update the Big Valley Groundwater Recharge Investigation that had defined the Basin's hydrogeology since 1967 (Lake County 2003). The updated document supports groundwater planning and management.

2.1.6.2 Conjunctive Use

The County operates a conjunctive use program in Big Valley Basin, the Kelsey Creek Detention Structure. Located on Kelsey Creek one and a half miles north of the Main Street Bridge in Kelseyville, the Kelsey Creek Detention Structure was constructed in 1987 to enhance the natural recharge from Kelsey Creek and raise the streambed level upstream of the structure. The detention structure supplements recharge in the spring to replace water pumped for frost protection and early irrigation.

The detention structure consists of three large control gates that alter the water levels. When the gates are open, they form a dam across the creek approximately two feet high. When the gates are closed, they form a dam approximately 10 feet high. There are two permanent rock and concrete fish ladders on either side of the detention structure that allow for fish passage over the dam. As stated in the Clear Lake Integrated Water Management Plan, "The operating criteria requires maintenance of spring flows and opening the structure when hitch runs are detected. However, due to its height and design, the Detention Structure remains a partial barrier to hitch passage" (Lake County 2010a).

The detention structure has been in operation since 1992. Depending on operations, the detention structure has a maximum enhanced recharge rate of about 240 AF per year (DWR 1980). Well elevation data from nearby wells demonstrate that the detention structure is recharging the aquifer. The District received reports that previously dry wells, within the detention structure's influence area, began flowing once the structure was in operation (Lake County 2006). See Section **2.2.2.5** for a detailed explanation of the relationship between Kelsey Creek and groundwater.

The County has also considered another conjunctive use project in Big Valley Basin, the Adobe Creek Conjunctive Use Project. Feasibility reports estimate the project would result in groundwater recharge of about 700 AF per year. To date, the project has been unsuccessful in securing grant funding and has not been constructed. However, it is the County's goal to have this project constructed within the near future. Additional information on Adobe Creek Conjunctive Use Project can be found in **Section 5**.

2.1.6.3 Drought Management Plan and Conservation Efforts

Lake County Special Districts, which includes KCWD #3, have developed a Drought Management Plan, most recently updated in April 2021 (Lake County Special Districts 2021). The Drought Management Plan details the triggers, actions, and tools available for each of the four drought stages. The four drought stages are listed below.

- Stage 1. Voluntary Conservation and compliance with State conservation regulations and requirements. Emphasis on community awareness and outreach.

- Stage 2. Initiate mandatory conservation measures (implement surcharge for violations through a “Water Waste” Urgency Ordinance)

- Stage 3. Through additional Urgency Ordinances, implement additional mandatory conservation measures and revised water rates (Base, Tier 1, Tier 2 rate structure adjustments) to financially discourage non-essential water use. Include surcharges for usage over the maximum allowed.

- Stage 4. Implement Urgency Ordinance with stringent consumption limits and penalties.

In conjunction with the Drought Management Plan, Lake County has several ongoing water conservation measures. For example, Water Conservation Ordinance (2291) requires low-flush toilets and low flow shower heads in all new construction and retrofit of all toilets and showers prior to the close of escrow. The County also provides water conservation tips on their website to encourage voluntary demand reduction.

2.1.6.4 Well Construction, Well Destruction, and Abandonment Policies

Well construction, repair, or destruction is subject to permitting by the Lake County Environmental Health Department. The program permits and reviews all wells for proper construction, operation, and maintenance The process for permitting new or replacement wells in the Big Valley Basin is managed by the Lake County Environmental Health Department under Chapter 9 Article VIII of the Lake County Code, which incorporates by reference the standards set forth by the State of California in DWR Bulletin 74-81, entitled “Water Wells Standards: State of California.” These standards include locations with minimum setbacks for septic systems, seals, surface construction, disinfection, casing specifications, well development, water quality sampling, and others.

2.1.7 Additional GSP Elements

SGMA requires that the following topics are addressed in the GSP. See below for references to where each topic is addressed.

- Control of saline water intrusion: Saline water intrusion does not apply to Big Valley Basin as the Basin does not border any saline water bodies.

- Wellhead protection areas and recharge areas: Wellhead protection is discussed in **Section 2.1.6.4** and recharge areas are discussed in **Section 2.2.1.6**.

- Migration of contaminated groundwater: There are no known migration plumes in Big Valley Basin.

- A well abandonment and well destruction program: Details on well abandonment and well destruction are discussed in **Section 2.1.6.4**.

- Replenishment of groundwater extractions: Details on recharge programs are discussed in **Section 2.1.6.2**.

- Activities implementing, opportunities for, and removing impediments to, conjunctive use or underground storage: Details on existing conjunctive use program are discussed in in **Section 2.1.6.2**. Proposed projects to enhance conjunctive use are described in **Section 5**.

- Well construction policies: Details on well construction policies are contained in **Section 2.1.6.4**.

- Measures addressing groundwater contamination cleanup, groundwater recharge, in-lieu use, diversions to storage, conservation, water recycling, conveyance, and extraction projects: Recycled water is discussed in **Section 2.1.4.3**, water conservation is discussed in **Section 2.1.6.3** and in-lieu groundwater use is discussed in **Section 5.4**.

- Efficient water management practices, as defined in CWC §10902, for the delivery of water and water conservation methods to improve the efficiency of water use: Details on efficient water management practices are discussed in **Section 2.1.6.3**.

- Efforts to develop relationships with state and federal regulatory agencies: Coordination between other agencies is discussed in regard to the monitoring programs (**Section 2.1.5)** and in regards outreach efforts (**Section 7**).

- Processes to review land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity: The GSA will coordinate with other County departments involved in land use planning on policies and actions that may impact groundwater supply and/or quality.

- Impacts on groundwater dependent ecosystems: an overview is presented in **Section 2.2.3**.

2.2 Basin Setting

The Basin Setting describes the Big Valley Basin's HCM, current and historical groundwater conditions, groundwater dependent ecosystems, water budget, and sustainable yield.

2.2.1 Hydrogeologic Conceptual Model

The sections below present the HCM for the Basin.

2.2.1.1 Regional Geologic Setting

The Basin is located in the northern Coast Ranges Geomorphic Province of California (CGS 2002). The northern Coast Ranges extend from the San Francisco Bay to the Oregon border and are comprised of a series of folded and faulted northwest-southeast trending mountain ranges and valleys. The northern Coast Ranges are predominantly underlain by a complex assemblage of Jurassic-Cretaceous age metasedimentary and metaigneous rocks of the Franciscan Formation, which is locally intruded and overlain by Miocene to Pleistocene-age volcanic rocks, the Sonoma Volcanics and Clear Lake Volcanics, respectively, and flanked on the east (along the western border of the Sacramento Valley), by the Late Jurassic and Cretaceous age marine sedimentary rocks of the Great Valley Sequence (CGS 2018). The intermontane valleys are underlain by Quaternary alluvium and lacustrine deposits.

The Basin is a roughly triangular-shaped basin bounded by Mayacamas Mountains on the west and south, Mt. Konocti on the east and Clear Lake on the north (SMFE 1967). The Mayacamas Mountains are underlain by the Franciscan Formation, which is locally comprised of marine metasedimentary rocks (e.g., graywacke sandstone, chert, shale), metavolcanic rocks (e.g., greenschist, basalt) and metaigneous rocks (e.g., serpentinite, blueschist). Mt. Konocti and Camelback Ridge on the eastern and southeastern margins of the Basin, respectively, are underlain by the Pleistocene age Clear Lake Volcanics (Rymer, 1981; Hearn et al.,1995), a large volcanic center comprised of a variety of volcanic flows and intrusive pyroclastic rocks (e.g., tuff), rhyolitic obsidian, dacite, andesite and olivine basalt (McNitt, 1967; 1968). The valley floor is largely underlain by unconsolidated Quaternary alluvial deposits interbedded with fine grained lacustrine deposits of an ancient Clear Lake. **Figure 2-8** shows the surficial geology in the Basin (modified after McNitt 1967; 1968, and Rymer 1981).

2.2.1.2 Structure

The Basin is part of the Clear Lake basin and is considered a volcano-tectonic depression bounded and traversed by a number of faults (McLaughlin et al. 1981) related to tensional shear and extension caused by right lateral movement along the San Andreas fault zone and related faults located west of the Basin. This shearing and extensional tectonic process is overprinted on the complexly folded and faulted Franciscan Formation which was formed by the accretion of subducted deep marine oceanic crust and sedimentary deposits (accretionary wedge) onto the continental margin of western North America.

Hearn et al. (1988) divided the geologic and structural evolution of the Clear Lake basin into three processes:

1. Regional and subregional fault systems have controlled the margins and broad subsidence in the basin,

2. Volcanic eruptions have caused subsidence and volcanic rocks have filled part of the basin, and

3. Erosional and depositional processes have influenced the distribution, character, and amount of basin fill.

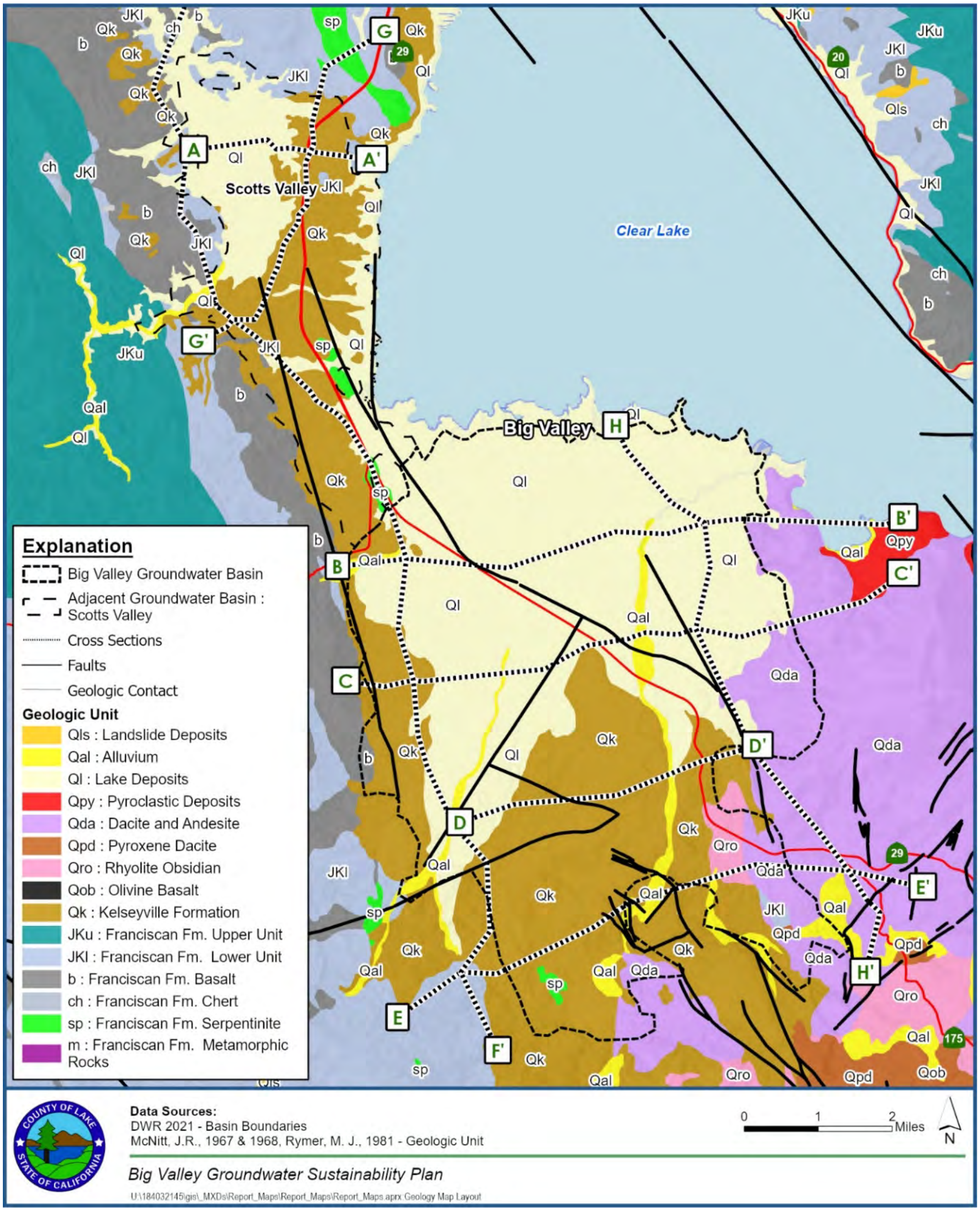

Figure 2-8. Geologic Map of the Big Valley Basin

2.2.1.3 Faults

A number of faults bound and traverse portions of the Basin. This section describes the faults located within and adjacent to the Basin.

Collayomi Fault Zone

The Collayomi fault zone extends northwest from the Geysers Geothermal Field to the southern margin of the Basin. The fault zone is well defined along portions of its length and has a N50°W trend. Northward, the Collayomi fault zone becomes more diffuse and splays into a fan-shaped array of short, northwest-trending faults, which may connect to a major northwest trending fault that bounds the west side of the Clear Lake basin (Hearn et al. 1988). Hearn et al. (1988) and Bryant (2000) report right lateral offset of Pleistocene Clear Lake volcanic rocks at an average rate of movement of about 0.7 to 0.9 millimeters/year. According to Bryant (2000), there is no geomorphic evidence of Holocene movement along the fault.

Big Valley Fault

The Big Valley fault is a splay of the Collayomi fault zone according to Hearn et al. (1988). The Big Valley fault can be divided into three segments:

- The N10°W segment (southeast of Kelseyville) exhibits right-lateral offset,
- The concealed Big Valley fault segment trending N65°W was identified based on water-well data, an eroded topographic scarp, and tilted beds of the Kelseyville Formation (SMFE 1967; Hearn et al., 1988). More than 210 feet of vertical displacement along this concealed segment was reported (Rymer 1981; Hearn et al.1988).
- The third segment extends further north and bends to N30°W to N35°W. In addition, a north-south branch was inferred to explain the straight shoreline at Lakeport (Hearn et al. 1988). The concealed segments of the Big Valley fault traversing Kelseyville northward are considered to be Late Quaternary active; however, the southern section of the fault south of Kelseyville is considered to be historically active (CGS 2010).

Adobe Creek/Wight Way Fault

The Adobe Creek fault (also locally known as the Wight Way fault) is a northeast trending fault (N65°E) extending from the western side of the Mayacamas Mountains to within a few miles southwest of Kelseyville (CG, 2010). The Adobe Creek/Wight Way fault truncates the northwestern extent of the Collayomi fault zone and the southeastern extent of the informally named “West Margin fault” (SMFE 1967). The “Wight Way fault” forms a partial barrier to groundwater flow, offsets Pleistocene terrace deposits in the southern portion of the Basin and is reported to have a vertical displacement of over 180 feet (SMFE 1967; Hearn et al. 1988). Rymer (1981) reported that the “Adobe Creek fault” is offset, as the Kelsey Tuff is exposed at ground surface to the east of the Adobe Creek fault, while to the west, the Kelsey Tuff occurs at depths ranging between 50 to 150 feet below the ground surface (ft bgs). The faults are considered to display Late Quaternary activity (CGS 2010).

West Margin Fault

The West Margin fault is inferred to exist as a N15°W to N25°W trending fault (Hearn et al., 1988) along the western edge of the Basin and eastern base of the Mayacamas Mountains but is reportedly concealed (CGS 2010). The fault is considered to be Quaternary active (CGS

2010) and post-dates deposition of the Kelseyville Formation (Hearn et al. 1988). Movement along the fault appears to be vertical and likely extensional in origin with older Franciscan Formation deposits uplifted on the west side relative to younger Pleo-Pleistocene sedimentary deposits underlying the Basin on the east side.

Konocti Bay Fault Zone

In the Mt. Konocti area, there are many relatively short north-northwest trending faults that comprise the Konocti Bay fault zone. These faults largely occur along the southeastern and southwestern flanks of Mt. Konocti and are considered to be Holocene active (Bryant, 2000; CGS 2010).

2.2.1.4 Geomorphology

Previously referred to as the Kelseyville Basin in DWR Bulletin 118 (DWR 1975), the Basin is located in the west-central portion of Lake County and occupies an area of about 24,210 acres (38 square miles; DWR 2004). The Basin shares a boundary with the Scotts Valley Basin (DWR Basin 5-14) to the northwest. To the north, the Basin is bordered by Clear Lake. Rugged northwest trending mountainous terrain of the Mayacamas Mountains borders the Basin to the west and south. Rugged mountainous volcanic terrain of Mt. Konocti borders the Basin to the east and southeast.

The surface of the groundwater basin on the valley floor is, for the most part, a broad plain that gently slopes toward Clear Lake (Lake County 2003). A central upland in the southern part of the Basin is divided into two smaller valleys which have been incised by Kelsey and Adobe Creeks on the east and west, respectively. Both streams discharge into Clear Lake on the north.

Surface elevations on the valley floor range from about 1,325 feet above mean sea level (msl) at the shoreline of Clear Lake to 1,400 feet msl at the head of the valley (Lake County 2003). Upland areas to the east rise to about 2,000 feet msl while the central upland rises to about 1,600 feet msl. The Mayacamas Mountains bordering the Big Valley Basin attains elevations of approximately 3,000 feet msl on the west and 3,200 feet msl on the southwest. The Mt. Konocti highlands attain elevations of more than 4,200 feet msl on the east and 4,000 feet msl on the southeast.

2.2.1.5 Stratigraphy

Geologic mapping by McNitt (1967; 1968) in the Kelseyville and Lakeport 15-minute quadrangles identified the major geologic units and structures in the Basin. Rymer (1981) revised the stratigraphy of the Plio-Pleistocene sedimentary deposits in the Basin, dividing the Cache Formation into three geographically separate formations with the Kelseyville Formation occurring within the Basin (**Figure 2-8**). The stratigraphic units are summarized in **Table 2-5**. Compared to the Jurassic-Cretaceous rocks and Clear Lake volcanic rocks, the younger alluvial and basin deposits and Kelseyville Formation are of more hydrogeologic interest in the Basin because they are more transmissive and have a much larger storage capacity than the bedrock units surrounding and underlying the Quaternary sedimentary deposits.

Unnamed Jurassic-Cretaceous Rocks (JKl, JKu)

McNitt (1967; 1968) subdivided the previously assigned Franciscan Formation into two distinctive units: the lower Jurassic-Cretaceous unit (JKl) and the upper Jurassic-Cretaceous unit (JKu). Consisting of interbedded sandstone and shale, the upper unit directly overlies the lower unit. The lower unit is comprised of a dense graywacke interbedded with chert and basalt and intruded or interbedded with mafic igneous rocks. These rocks constitute the “basement rocks” in the Basin.

Lower Unit, Jurassic-Cretaceous (JKl)
The predominant and only persistent rock type within the lower unit (**JKl**) is graywacke sandstone. Chert, and various igneous (basalt) and metamorphic rocks (e.g., serpentinite, greenshist) occur as conformable, discontinuous lenses and sheets scattered at irregular intervals vertically and horizontally within the graywacke (McNitt, 1968).

Table 2-5. Summary of Subsurface Stratigraphy of the Big Valley Basin

<table>
<tr><th>Geologic Time</th><th>Symbol</th><th>Formation</th><th>Description</th><th>Note</th></tr>
<tr><td rowspan="2">Recent</td><td>Qls</td><td rowspan="9"></td><td>Landslides</td><td></td></tr>
<tr><td>Qal</td><td>Alluvium</td><td></td></tr>
<tr><td>Late Quaternary</td><td>Ql</td><td>Lake deposits</td><td></td></tr>
<tr><td rowspan="5">Pleistocene</td><td>Qpy</td><td>Pyroclastic deposits</td><td rowspan="5">Volcanic Rocks of Clear Lake</td></tr>
<tr><td>Qda</td><td>Dacite and andesite</td></tr>
<tr><td>Qpd</td><td>Pyroxene dacite</td></tr>
<tr><td>Qro</td><td>Obsidian, flows, tuffs, and breccia</td></tr>
<tr><td>Qob</td><td>Olivine basalt</td></tr>
<tr><td>Pliocene-Pleistocene</td><td>Qk</td><td>Kelseyville Formation</td><td>Lacustrine clay, silt, and gravel</td><td>Cache Formation</td></tr>
<tr><td>Jurassic-Cretaceous</td><td>JKu</td><td>Upper Unit</td><td>Muscovite-bearing sandstone; shale</td><td rowspan="6">Franciscan Formation</td></tr>
<tr><td rowspan="5">Jurassic-Cretaceous</td><td>JKl</td><td rowspan="5">Lower Unit</td><td>graywacke with minor interbedded shale and conglomerate</td></tr>
<tr><td>B</td><td>basalt</td></tr>
<tr><td>Ch</td><td>chert</td></tr>
<tr><td>Sp</td><td>serpentinite</td></tr>
<tr><td>M</td><td>metamorphic rocks</td></tr>
</table>

Upper Unit, Jurassic-Cretaceous (JKu)
Comprising of light to medium gray sandstone interbedded with gray to buff shale, the upper unit (**JKu**) directly overlies the lower unit (**JKl**). Bedding is poorly developed in the upper unit. Sandstones in the upper unit are composed of clastic grains such as quartz, feldspar, rock fragments, and muscovite. The detrital flakes of muscovite in the upper unit reach a maximum diameter of 2 millimeters. This characteristic is used in the field to distinguish the upper unit from similar appearing lower unit.

Cache Formation

Soil Mechanics and Foundation Engineers Inc. (SMFE 1967) noted the subsurface presence of the Cache Formation. McNitt (1968) assigned isolated siltstone, sandstone, and local conglomerate as the Cache Formation. Rymer (1981) subdivided the nonmarine Cache Formation of former usage into three units and termed them as: Cache, Lower Lake, and Kelseyville Formations. Similar to Christensen Associates, Inc. (Lake County, 2003), the present study follows Rymer's (1981) subdivision for the Cache Formation. As shown on the geologic map (**Figure 2-8**), the Kelseyville Formation (Qk) mapped by Rymer (1981), and Lake County (2003) includes both the Cache Formation (TQc) and Terrace deposits (Qt) mapped by McNitt (1968).

Kelseyville Formation (Qk)

Rymer (1981) defined the lacustrine and less abundant fluvial deposits exposed near Kelseyville as the Kelseyville Formation. The Kelseyville Formation crops out in the southern half of Big Valley in the upland area. The type section of the Kelseyville Formation mapped by Rymer (1981) consists of approximately 96 percent sandstone interbedded with about 3 percent conglomerate and 1 percent tuff. Poor consolidation and poor to moderate sorting are common in the sandstone. The sandstone is typically poorly to moderately stratified in beds that are commonly continuous through limited exposures. At the type section, Rymer (1981) estimated that the minimum thickness of the Kelseyville Formation is more than 1,600 feet (500 meters). Conglomerate occurs in lenses or thin interbeds in sandstone and is generally composed of granules and pebbles derived from the Franciscan Formation.

Because of its distinctive character and its presence throughout much of Big Valley, the Kelsey Tuff Member of the Kelseyville Formation is useful as a marker bed (Rymer 1981). At a thickness of four to five feet, the Kelsey Tuff Member is best exposed to the south and southeast of Kelseyville. In a small canyon in the central upland area, the Kelsey Tuff Member is exposed in a six- to seven-foot-thick section. According to Rymer (1981), the Kelsey Tuff Member consists of two units. The lower unit is less than one-foot thick and is composed of thin beds that range in color from light gray to yellowish gray. The upper unit is an unsorted bed of pumiceous basaltic andesite lapilli tuff that is gray to yellowish gray. The tuff consists of angular fragments and grains of porous volcanic rocks.

The Kelseyville Formation in Big Valley is of Pleistocene age. The Franciscan Formation underlies most of the Kelseyville Formation. Serpentinite also underlies the Kelseyville Formation locally.

Volcanic Rocks of Clear Lake (Qpy, Qda, Qpd, Qro, Qob)

The volcanic rocks of Clear Lake include pyroclastic deposits (Qpy), dacite and andesite (Qda), pyroxene dacite (Qpd), obsidian in flows, tuffs, and breccia (Qro) and olivine basalt (Qob). Note that the order of the above list does not imply relative age.

Lake Deposits (Ql)

Underlying the topsoil of the lower Big Valley is a thick unconsolidated layer of silt deposits. Based on the uniformly fine particle size of the silt and extremely flat upper surface, McNitt (1967; 1968) identified this unit as lacustrine in origin. To the south, this deposit overlies the Kelseyville Formation.

Alluvium (Qal)

The surface distribution of younger alluvium is restricted to the streams flowing into Big Valley. The younger alluvium generally extends to depths of 40- to 90-feet and consists of alternating layers of gravel, sand, silt, and clay (DWR 2003). In the mountains to the south, scattered older alluvial deposits occur as remnants of older channel deposits and are typically disrupted by faulting.

2.2.1.6 Groundwater Producing Formations

Characterization of the aquifers in the Basin were conducted by Soil Mechanics and Foundation Engineers Inc. (SMFE 1967), DWR (2003), and Lake County (2003). Based on driller's logs, SMFE (1967) and Lake County (2003) developed five and seven geologic cross sections, respectively, to depict subsurface geologic conditions in the Basin.

SMFE (1967) designated four hydrogeologic units: young alluvium and lakebed (i.e., lacustrine) deposits in the lowland area; older, high level alluvial deposits in the upland area; "volcanic ash" and fracture zones in the Clear Lake Volcanics and the Franciscan Formation. Lake County (2003) identified four aquifers. The Quaternary floodplain and basin deposit system (Ql, Qal) contains an upper aquifer (A1) and a lower aquifer (A2). The Kelseyville Formation (Qk) also contains two aquifers: the upper aquifer (A3) and underlying "volcanic ash" aquifer, where the upper aquifer (A3) is similar in characteristics to the A2 aquifer.

Based on these prior studies, there appears to be three groundwater producing aquifer deposits and the underlying fractured bedrock water-bearing formation in the Basin:

- **Quaternary Alluvium (Qal) and Lake Deposits (Ql)** – includes recent stream channel, overbank and alluvial fan deposits, and lake deposits.

- **Kelseyville Formation (Qk)** – excludes the Kelsey Tuff Member, the Kelseyville Formation was mapped as Quaternary terrace deposits in SMFE (1967) and DWR (2003).

- **"Volcanic Ash" Aquifer (Qk)** – Rymer (1981) and Hearn et al. (1988) termed as Kelsey Tuff Member and included in the Kelseyville Formation.

- **Fractured Bedrock** – fracture zones in both the lower (JKl) and upper (JKu) Franciscan Formation and Clear Lake volcanic rocks (Qpy, Qda, Qpd, Qro and Qob), though generally limited, may store and transmit water locally.

Quaternary Alluvium (Qal) and Lake Deposits (Ql)

This section summarizes the hydrogeologic characteristic of the Quaternary alluvium (Qal) and lake deposits (Ql). Sediments contained in this hydrogeologic unit range in character from lacustrine silt and clay to alluvial and fluvial sand and gravel. A near surface fine grained layer is present over most of the lowland area north of the Big Valley fault. At a depth of about 70 feet bgs, one or a series of "blue clay" layers are present (SMFE 1967). To the east of Kelsey Creek, a similar clay layer is present at a depth of about 130 feet bgs. SMFE (1967) postulated that this is the same layer offset by displacement along a branch of the Big Valley fault.

Coarse grained materials were deposited along river channels of ancestral Kelsey and Adobe Creeks, over floodplain and in river delta areas at depths of 20 to 70 feet bgs. In general, these coarse-grained deposits give way to finer grained sediments to the north, toward Clear Lake. Less continuous zones of coarse-grained deposits are present between depths of 50 and 200 ft bgs, which is the depth interval that most of the water wells in the Basin were perforated. Lake County (2003) defined the A1 aquifer as ranging in thickness from 10 to 126 feet and occupies much of the northern portion of the Basin. The A2 aquifer underlies the A1 aquifer and is composed of fluvial deposits of gravel, sand, and silty clay. The thickness of the A2 aquifer ranges from 14 to 140 feet (Lake County 2003).

The general flow direction of groundwater in the Quaternary alluvium and lake deposits is northward toward Clear Lake. SMFE (1967) reported that this groundwater movement occurs principally in the upper 70 feet above the persistent “blue clay” layer and suggests groundwater circulation in the deep aquifers is probably limited.

Kelseyville Formation (Qk)
While the Quaternary alluvium and lake deposits are distributed in the northern portion of the Basin; the Kelseyville Formation occupies the southern portion of the Basin (**Figure 2-8**). These two hydrogeologic units are separated by the Big Valley Fault, which uplifted the Kelseyville Formation in the south (Lake County 2006a).

Excluding the Kelsey Tuff Member, Lake County (2003) designated the water bearing portion of the Kelseyville Formation as the A3 aquifer. The A3 aquifer contains similar deposits as the A1 and A2 aquifers and is comprised of fluvial gravel, sand, and silt deposits. The thickness of the A3 aquifer ranges from five to 160 feet.

Volcanic Ash Aquifer (Qk)
Logged by drillers as “volcanic cinders,” “volcanic ash,” or “volcanic gravel” and referred by SMFE (1967) as “volcanic-ash aquifer” and “aquifer ash,” the Kelsey Tuff member of the Kelseyville Formation (Rymer, 1981) was identified by Lake County (2003) as the “volcanic ash” aquifer. The aquifer, where present, ranges from one to eight feet in thickness. A few wells completed in this aquifer reported a yield over 1,000 gallons per minute. Given the relatively small aquifer thickness, Well Completion Reports for wells completed in the volcanic ash aquifer do not indicate how long pumping at this elevated pumping rate can be sustained.

The horizontal extent of the “volcanic ash” was delineated by SMFE (1967), Rymer (1981) and Lake County (2003) and a compilation is depicted in **Figure 2-9**. Bounded by the Big Valley Fault to the north and northeast, the “volcanic ash” aquifer defines a band approximately 3 miles wide that extends diagonally across the valley. SMFE (1967) reported that the “volcanic ash” aquifer is offset by the Adobe Creek fault system and the “volcanic ash” aquifer is tilted down to the northeast in the area west of the Adobe Creek fault. Lake County (2003) estimated the lateral distribution of the “volcanic ash” aquifer included in the Kelseyville Formation amounts to about 15 square miles.

Figure 2-9 indicates that the “volcanic ash” aquifer occurs throughout most of the Basin. To the south, the “volcanic ash” aquifer is exposed in Kelsey Creek and along Highway 29. The “volcanic ash” aquifer is overlain by 50 to 150 feet of Quaternary alluvium west of Adobe Creek Fault. North of the Big Valley fault, Rymer (1981) reported that in one well the “Volcanic ash” aquifer is overlain by over 500 feet of Quaternary alluvium. However, in most instances, driller's logs that reported encountering volcanic ash, volcanic cinders, or volcanic gravel, indicated depths of less than 200 ft bgs.

The presence of the "volcanic ash" aquifer to the north of the Big Valley Fault is certain, even to the north at depth below the sediments of Clear Lake (Hearn et al.,1988). However, its lateral and vertical extent in this area is unknown. The greater depth of the "volcanic ash" aquifer north of the Big Valley fault and the generally much shallower depth of wells drilled in the Big Valley Basin minimizes the development of groundwater supplies from this aquifer in this area. Except in areas where the "volcanic ash" crops out, groundwater contained in the "volcanic ash" aquifer is encountered under artesian conditions. Based on measured water levels in wells which were perforated in the "volcanic ash" aquifer only, SMFE (1967) estimated pressure heads of up to 100 to 150 feet. In areas where water level measurements from wells completed in both the "volcanic ash" aquifer and the overlying alluvial aquifer, only slight water level differences were observed (SMFE 1967), which suggests that the "volcanic ash" aquifer may be in hydraulic communication with the alluvial aquifer.

Under natural conditions, the "volcanic ash" aquifer is recharged by infiltration of precipitation in hilly areas to the south where it outcrops. Surface water also recharges the "volcanic ash" aquifer along upstream river channels where it is in hydraulic communication with streambed alluvial deposits. The "volcanic ash" aquifer may also be recharged from the fractured bedrock aquifer to the south. Recharge from slightly permeable, fine-grained sediments in the central and northern areas of the Big Valley Basin to the 'volcanic ash" aquifer occurs to a much lesser extent.

Regionally, groundwater in the "volcanic ash" aquifer flows from the south (highland area) to the north (SMFE 1967; Lake County 2003). This regional flow regime is interrupted by intra aquifer flow or modified by thinning, warping, or faulting of the aquifer. SMFE (1967) reported that the Adobe Creek fault down dropped the "volcanic ash" aquifer approximately 180 feet on the northwest side of the fault. Due to the minimal thickness of the "volcanic ash" aquifer, even relatively minor fault displacement would completely offset the aquifer and break hydraulic continuity across the fault (SMFE 1967). However, groundwater level contours presented by SMFE (1967) and Lake County (2003) in the Adobe Creek fault area are continuous on either side of the Adobe Creek fault and suggest that the "volcanic ash" aquifer is not displaced by the Adobe Creek fault. It is estimated that approximately 31,500 AF of water is stored in the "volcanic ash" aquifer (SMFE 1967). The "volcanic ash" aquifer is the only source of groundwater in the upland areas.

Fractured Bedrock

Compared to the Quaternary alluvial and lake deposits and Kelseyville Formation, fractured areas in the Franciscan Formation and Clear Lake volcanic rocks are of less hydrogeologic significance. Precipitation infiltrates into the subsurface in outcrop areas via fractures or after a brief surface flow. This water either discharges to temporary springs or seeps out to lower reaches of creeks or as underflow that recharges the other hydrogeologic units in the Basin.

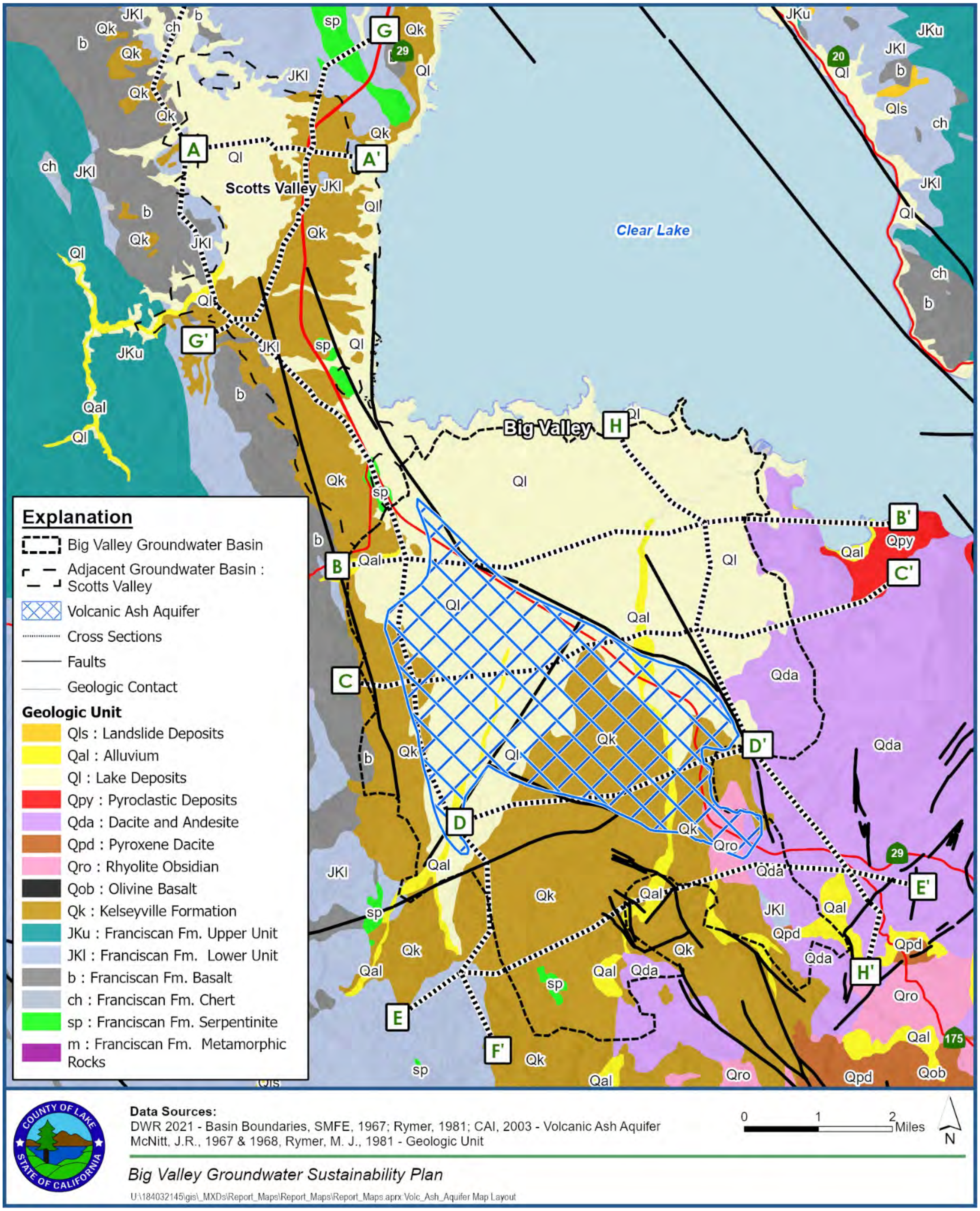

Figure 2-9. Spatial Distribution of the "Volcanic Ash" Aquifer

2.2.1.7 Geologic Cross Sections

More than 1,000 lithologic well logs were reviewed and analyzed and 107 well logs were selected to create eight geologic cross sections, A-A' through H-H', in the Basin and adjacent Scotts Valley Basin. **Figure 2-9** shows the locations of the geologic cross sections. Each geologic cross section represents a different portion of the Basin (six cross sections), including two complete cross sections (A-A' and G-G') and the northern portion of cross section F-F', which illustrates geologic conditions in the adjacent Scotts Valley Basin. Presented below are summaries of geologic conditions depicted in each cross section.

Cross Section A – A'

Cross section A – A' (**Figure 2-10**) trends west (A) to east (A') in the Scotts Valley Basin (**Figure 2-9**). Fine-grained lacustrine deposits (CL) underly the area to depths of about 300 ft bgs with some interbedded coarser-grained lenses and layers of interbedded lacustrine and alluvial deposits (SC/GC) and alluvial deposits (SP/SW-GP/GW). In the eastern portion of the cross-section near Clear Lake the Franciscan Formation (JKl) was encountered in two boreholes and is interpreted to occur at a relatively shallow depth of about 13 ft bgs in easternmost Well X84.

Cross Section B – B'

Trending west-east, cross section B – B' (**Figure 2-11**) transects the northernmost portion of the Basin (**Figure 2-9**). The geologic cross section extends beyond the western and eastern margins of the Basin where Franciscan Formation (JKl) and Clear Lake Volcanic rocks (Qda and Qpy) are exposed, respectively. Within the Basin, well depths range between 121 and 225 ft bgs. The Basin is largely underlain by interbedded sequences of lacustrine deposits (CL), interbedded alluvial and lacustrine deposits (SC/GC) and alluvial deposits (SW/SP-GP/GW). The lowermost logged portion of the Basin in this area is comprised of a minimum of 50 to 100 feet of silty clay/clayey silt (CL/ML), which constitute lacustrine deposits. Wells in this area are largely completed across multiple lithologies overlying the silty clay/clayey silt deposits. Along the Basin margins, a thin veneer of alluvial sand deposits (SP/SW) locally overlies the Franciscan Formation on the west while alluvial clayey gravel/gravelly clay locally overlies the Clear Lake Volcanic rocks on the east.

Cross Section C – C'

Cross section C – C' (**Figure 2-12**) trends in a general west-east direction, is roughly parallel to cross section B – B' (**Figure 2-9**) and traverses the north-central portion of the Basin. The western end of the cross section is underlain by ocean floor basaltic rocks (b) of the Franciscan Formation. The eastern end is underlain by dacite and andesite (Qda) of the Clear Lake Volcanics.

Four wells were drilled to a depth of more than 300 feet: one at the western margin in Franciscan Formation basalt to a depth of 300 feet, one in the middle in interbedded alluvium and lacustrine deposits to a depth of 580 feet, one in the eastern portion of the Basin in interlayered alluvial and lacustrine deposits, and the fourth one near the east end of the cross section in Clear Lake volcanic rocks to a depth of 600 feet. All the other wells along this cross section were drilled to a depth of between 100 and 242 ft bgs. Of note, is that Well X278 was drilled to a depth of 580 ft bgs but completed to a depth of 210 ft bgs. It is unknown from the driller's log if the reason for not completing this well to the maximum depth drilled was due to encountering greywacke sandstones of the Franciscan Formation versus an alluvial sand deposit or budgetary issues.

Similar to cross section B – B', except at Well X287, the bottom layer is a thick continuous clay layer. Overlying the basal lacustrine clay deposits are interbedded and laterally discontinuous alluvial sands and gravels (SW/SP-GW/GP) and mixed lacustrine and alluvial (SC/GC) deposits. In the westernmost portion of the Basin, thin layers of volcanic ash or cinders were reported in three driller's logs. These wells were completed almost entirely in these volcanic sediments. Owing to the relative proximity of these wells to each other and the variable depths of the volcanic deposits encountered, at least two faults have been depicted as offsetting these thin layers by presumably extensional (i.e., normal) faulting with east (basin) side down relative movement. The faults depicted may be assigned to the West Margin fault described in 2.2.1.3. In the east-central portion of the cross section it appears the alluvial and lacustrine deposits have been offset vertically along the presumed Big Valley fault.

Cross Section D – D'

Cross section D – D' (**Figure 2-13**) roughly trends west to east (**Figure 2-9**) across the south-central portion of the Basin. The western two-thirds of the cross section is predominantly underlain by lacustrine clay deposits and locally overlying interbedded alluvial and lacustrine deposits. Farther east toward the Basin margin interbedded alluvial and lacustrine deposits overlie a 4-foot-thick pumice/sand layer, assumed correlative to the "volcanic ash" aquifer. This layer appears to be stratigraphically related to an approximate 6-inch volcanic ash layer reported in the driller's log for Well X311. This well is completed in the volcanic ash aquifer. Well X286, which encountered the pumice/sand layer, was completed in the Clear Lake volcanic rocks (Qro). The intervening sediments between the Clear Lake Volcanics and the pumice/sand layer is comprised of a mixture of clay, rocks, pumice, and sand designated as a gravelly clay/clayey gravel (GC).

Cross Section E – E'

Cross section E – E' (**Figure 2-14**) trends roughly west to east along the southern portion of the Basin (**Figure 2-9**). The cross section is dominated by rugged hilly terrain with exposures of bedrock on the margins and within the Basin. On the west, Franciscan Formation rocks of the Mayacamas Mountains crop out. These rocks also occur at relatively shallow depths of less than 150 ft bgs at Wells X322 and X324 in the western half of the cross section. In the eastern half of the cross section, exposures of Clear Lake volcanic rocks predominate. Overlying these bedrock materials is a up to 300 feet or more of interbedded alluvial and lacustrine deposits (SC/GC) and lacustrine deposits (CL). A relatively thick layer of gravelly sand (GP/GW) occurs in the western portion of the cross section beneath the Adobe Creek drainage. Near the central portion of the cross section, two apparent fault-bound uplifts of Franciscan Formation and Clear Lake Volcanics occur and may be related to movement along fault strands of the Collayomi fault zone.

Cross Section F – F'

Cross section F – F' (**Figure 2-15**) trends in an approximate north-south, direction along the western margin of the Basin and Scotts Valley Basin (**Figure 2-9**). Franciscan Formation rocks crop out in the northern third and southern margin of the cross section and is penetrated by most wells in the Basin bottom. Basin sediments consist of interbedded and laterally discontinuous layers of alluvial (SP/SW-GP/GW), interbedded alluvial and lacustrine deposits

(SC/GC) and lacustrine deposits (CL-ML/CL). These sediments have an approximate accumulated thickness of less than 400 feet near the Big Valley Basin- Scotts Valley Basin boundary. Along the Big Valley Basin and Scotts Valley Basin boundary is an apparent uplifted serpentinite body associated with the Franciscan Formation. The Franciscan Formation also appears to be uplifted on the northwest along a presumed northerly extension of the West Margin fault in the Scotts Valley Basin. In the Basin bottom most wells are completed in the various deposits encountered in the borehole regardless of water bearing capability. In the northwestern Scotts Valley Basin and within the uplifted Franciscan Formation block northwest of the presumed West Margin fault, all the wells are completed in the Franciscan Formation at depths of less than 355 ft bgs.

Cross Section G – G'
Cross section G-G' (**Figure 2-16**) trends in an approximate northeast to southwest direction across the northeastern and central portions of the Scotts Valley Basin (**Figure 2-9**). Franciscan Formation rocks crop out in the northeastern and southwestern margins of the cross section and is penetrated by most wells in these portions of the basin. Basin sediments consist of interbedded and laterally discontinuous layers of alluvial (SP/SW-GP/GW), interbedded alluvial and lacustrine deposits (SC/GC) and lacustrine deposits (CL-ML/CL). These sediments have an approximate accumulated thickness of less than 400 feet. Near the northeastern margin of the cross section is an apparent uplifted serpentinite body associated with the Franciscan Formation. The Franciscan Formation also appears to be uplifted on the southwest along a presumed northerly extension of the West Margin fault. In the basin bottom most wells are completed in the more permeable water-bearing deposits; however, where the Franciscan Formation occurs at shallow depths the wells are completed in these rocks.

Cross Section H – H'
Cross section H – H' (**Figure 2-17**) trends northwest to southeast along the eastern margin of the Basin (**Figure 2-9**). The southeastern half of the cross section is underlain by outcrops of dacite and andesite (Qda) of the Clear Lake Volcanics. Rhyolite obsidian (Qro) underlies basin sediments in the east-central portion of the Basin. Basin sediments consist of interbedded and laterally discontinuous layers of alluvial (SP/SW-GP/GW), interbedded alluvial and lacustrine (SC/GC) and lacustrine (CL-ML/CL) deposits. Well depths in the Basin sediments range between 190 and 325 ft bgs and are completed across most of the geologic materials encountered in the well bores regardless of the water bearing capability. A number of wells were also drilled and completed in the rugged borderland terrain underlain by dacite and andesite.

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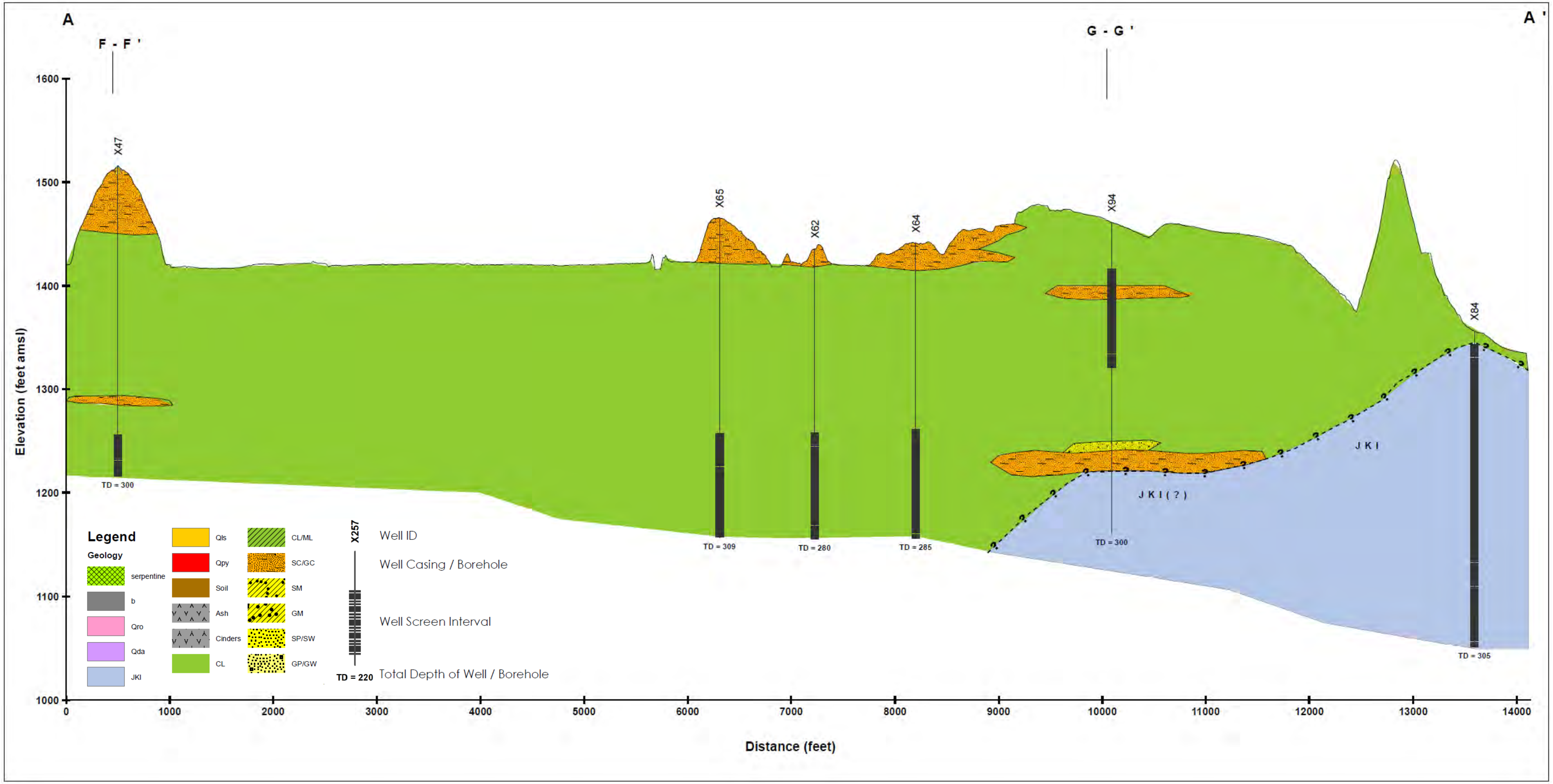

Figure 2-10. Cross Section A – A'

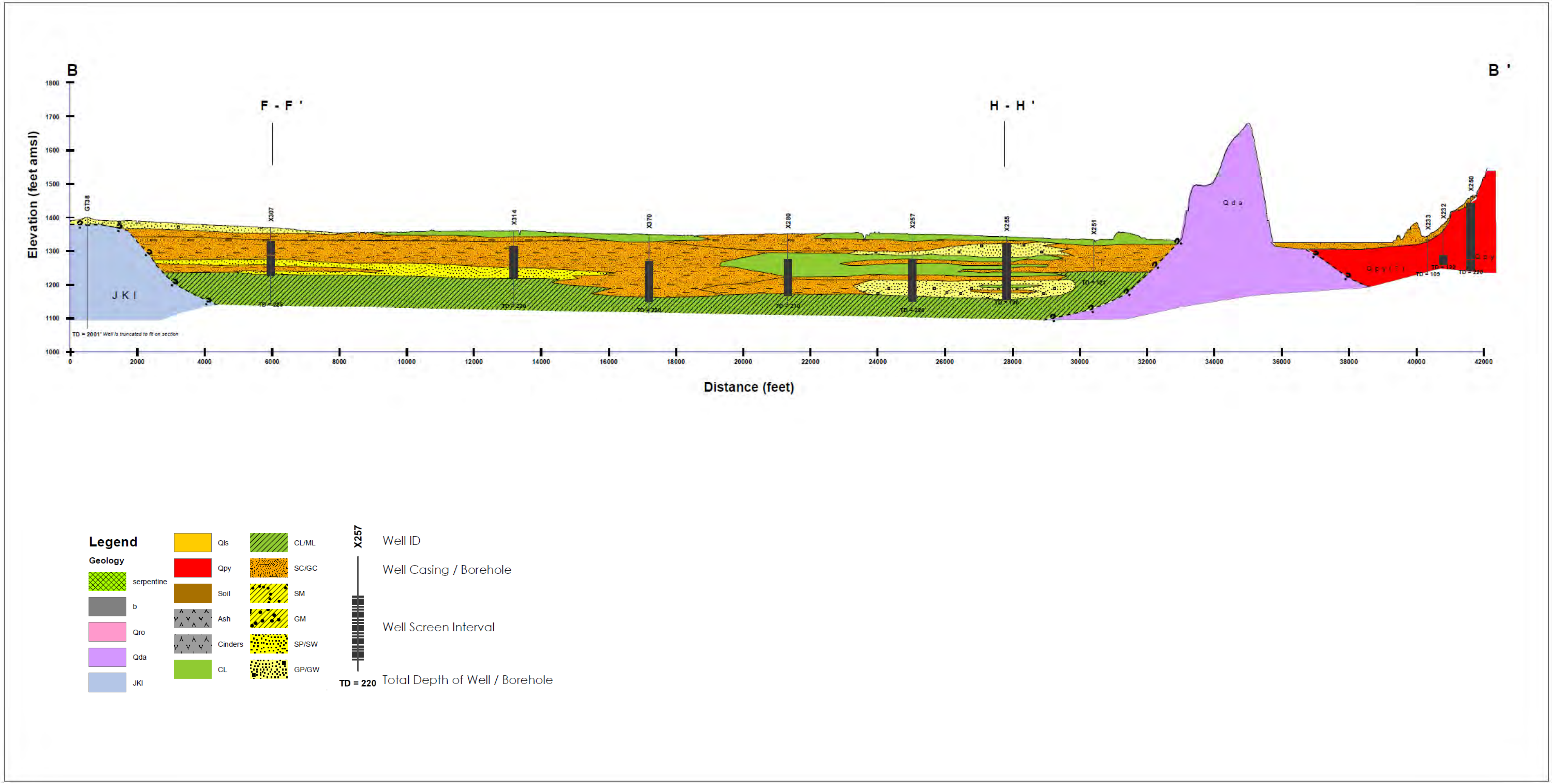

Figure 2-11. Cross Section B – B'

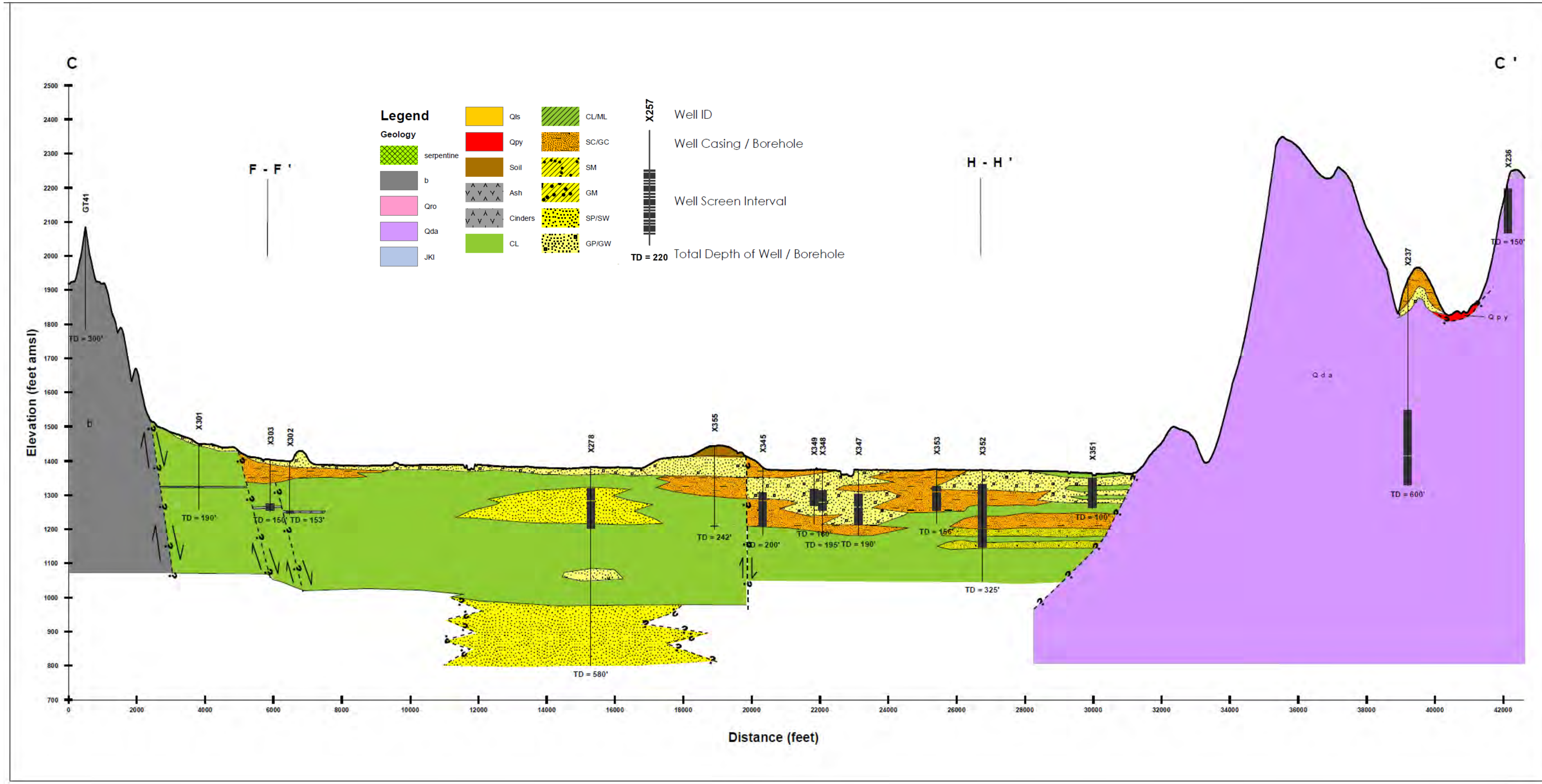

Figure 2-12. Cross Section C – C'

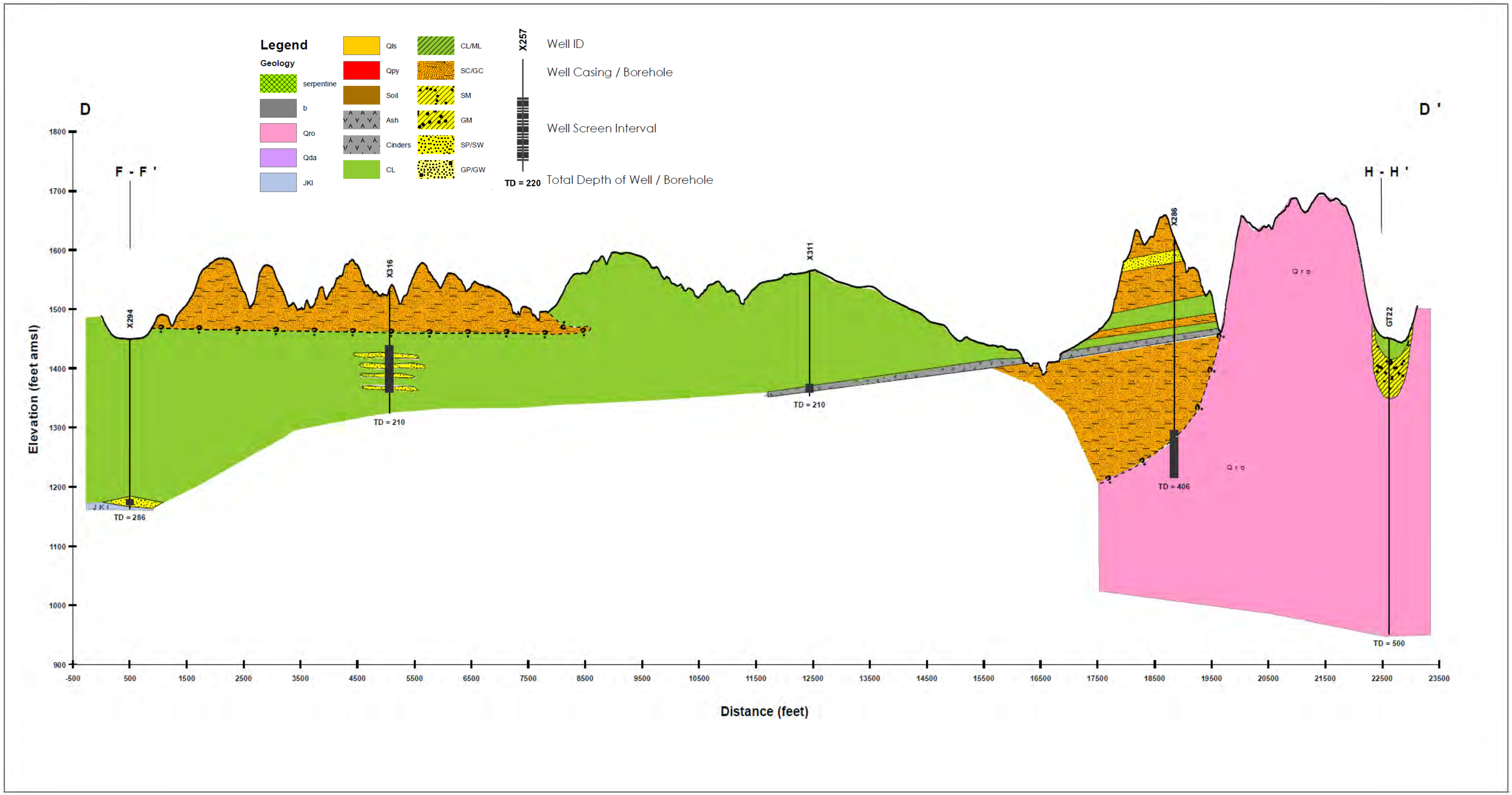

Figure 2-13. Cross Section D – D'

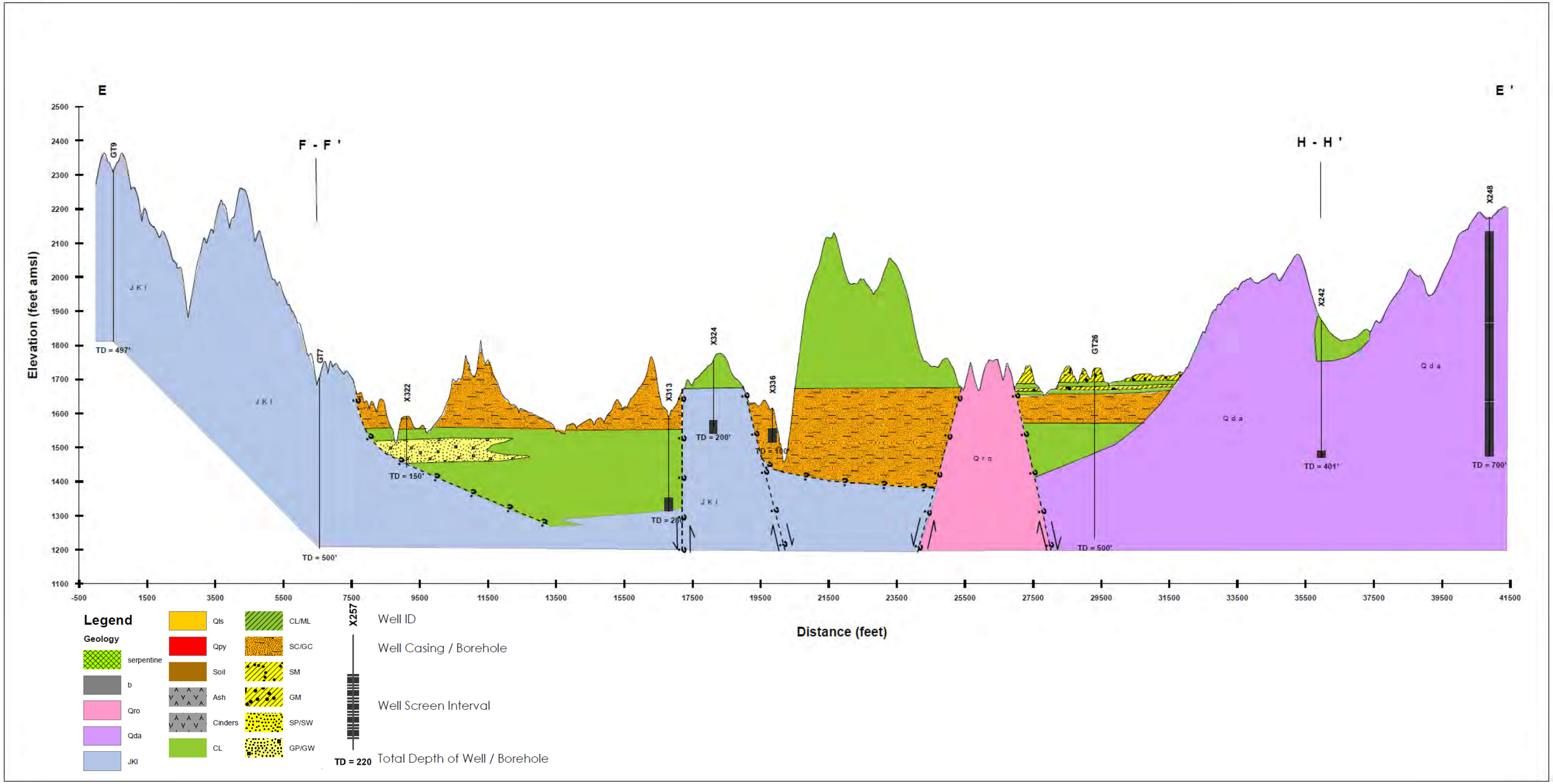

Figure 2-14. Cross Section E – E'

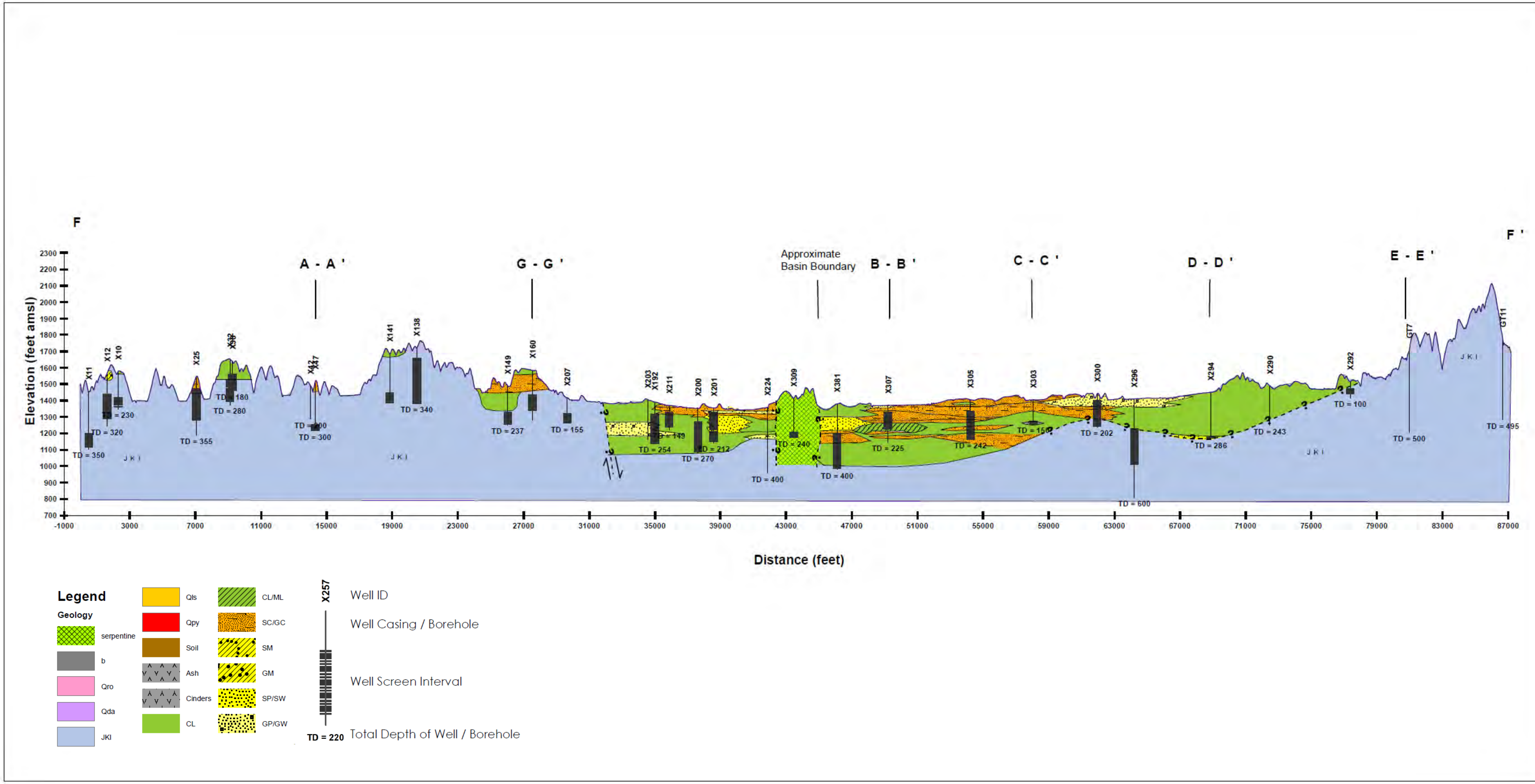

Figure 2-15. Cross Section F – F

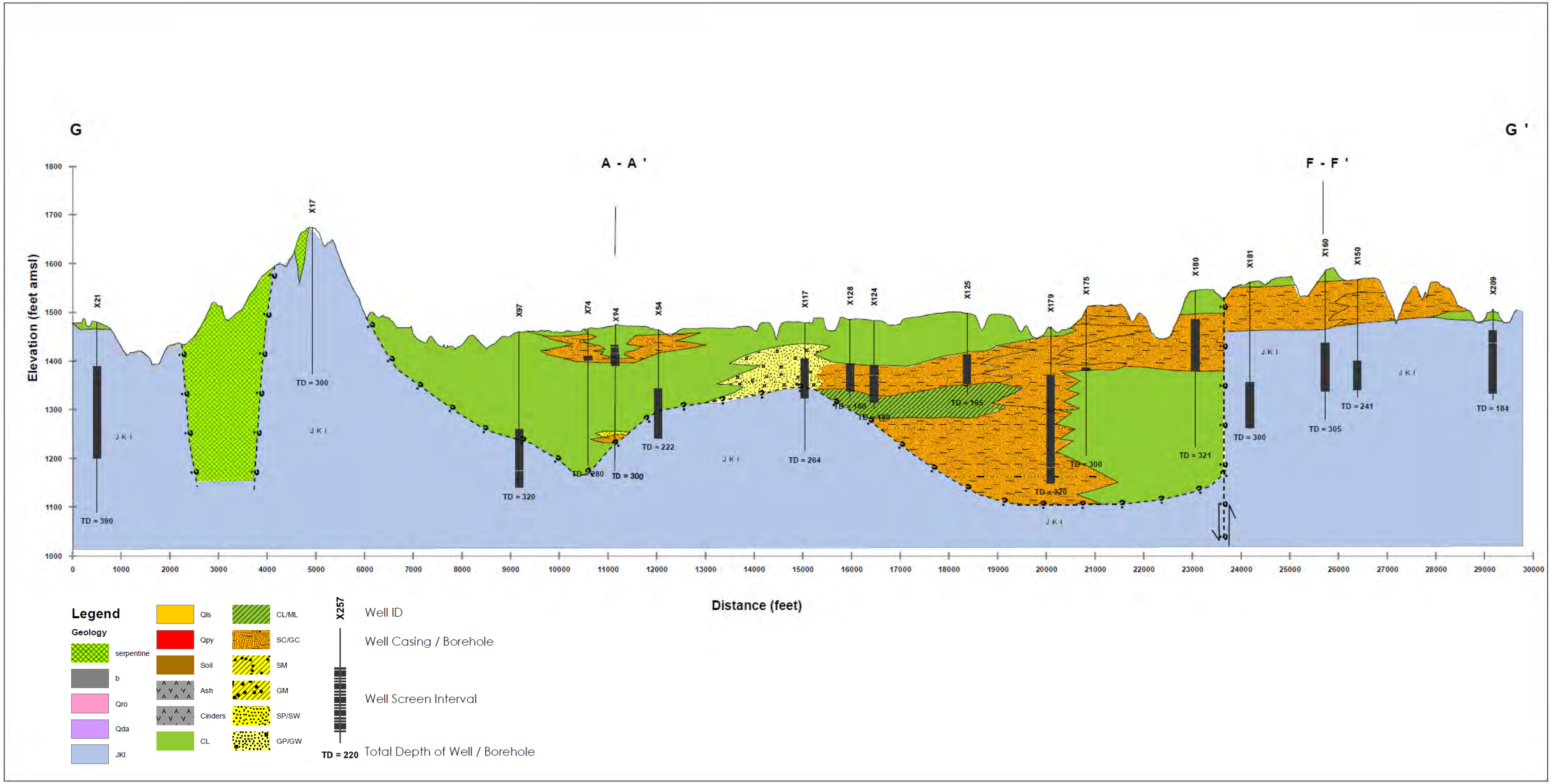

Figure 2-16. Cross Section G – G'

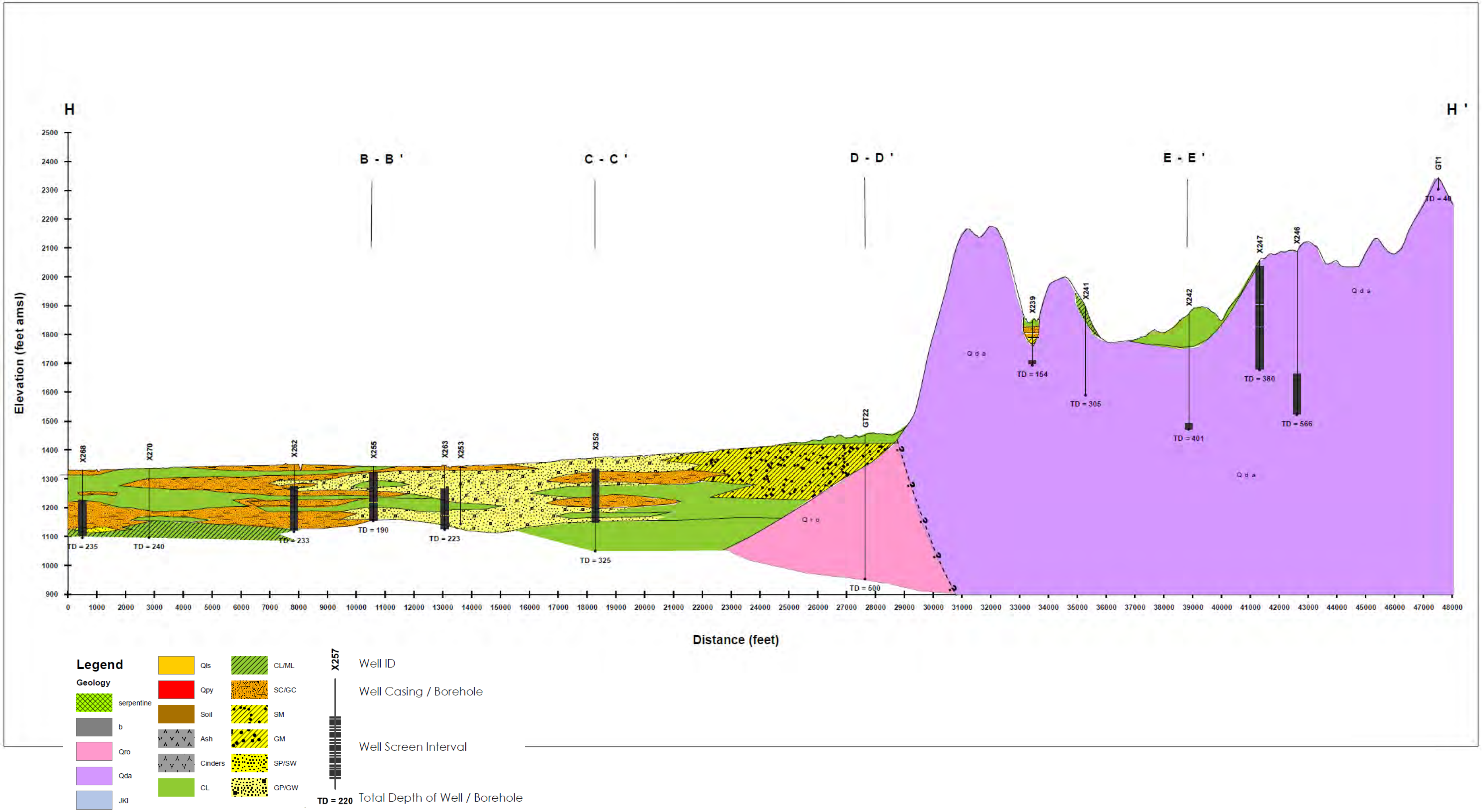

Figure 2-17. Cross Section H – H'

2.2.1.8 Basin Boundaries

This section describes the boundaries of the Basin.

Lateral Boundaries

The north side of the Basin is open to Clear Lake. Lateral boundaries present in the Basin consist of impermeable bedrock to the east, southeast, south, southwest, and west. To the northwest, however, an artificial boundary was established by DWR to separate the Scotts Valley Basin from the Big Valley Basin. DWR (2003) suggests this shared boundary may be hydrologically contiguous (**Figure 2-1**). Based on geologic conditions, groundwater boundaries, and topography, the Basin has been divided into five subbasins: Western Upland, the Adobe Creek-Manning Creek Subbasin, the Kelseyville Subbasin, the Central Upland and Upper Big Valley Subbasin, and the Cole Creek Upland (SMFE 1967; Lake County 2003).

Bottom of the Big Valley Basin

As discussed above, the alluvial aquifer and “volcanic ash” aquifer are of hydrogeologic significance in the Basin. To the west and southwest, the Basin is bordered by the Franciscan Formation, to the east and southeast by Clear Lake volcanic rocks. Except for some wells drilled close to the Basin boundaries (see cross sections E-E’, F-F’ in the Basin and F-F’ and G-G’ in the Scotts Valley Basin), none of the wells on the valley floor of the Basin encountered bedrock. Thus, the bottom of the Basin is defined herein as top of the Franciscan Formation and Clear Lake Volcanics bedrock at or near the Basin boundaries and drilled well depth on the basin floor.

Figure 2-18 presents the results of depth to “base” of the Basin. The “base” of the Basin extends from land surface in areas close to the Basin boundaries to the west, south and east to slightly over 300 feet on the Basin floor. The configuration of the base of the Basin is an uneven surface. It is a complex erosional surface overprinted by faulting along the West Margin, Adobe Creek and Big Valley faults and the Collayomi fault zone. In general, the base of the Basin reflects the underlying structure and tilts north toward Clear Lake.

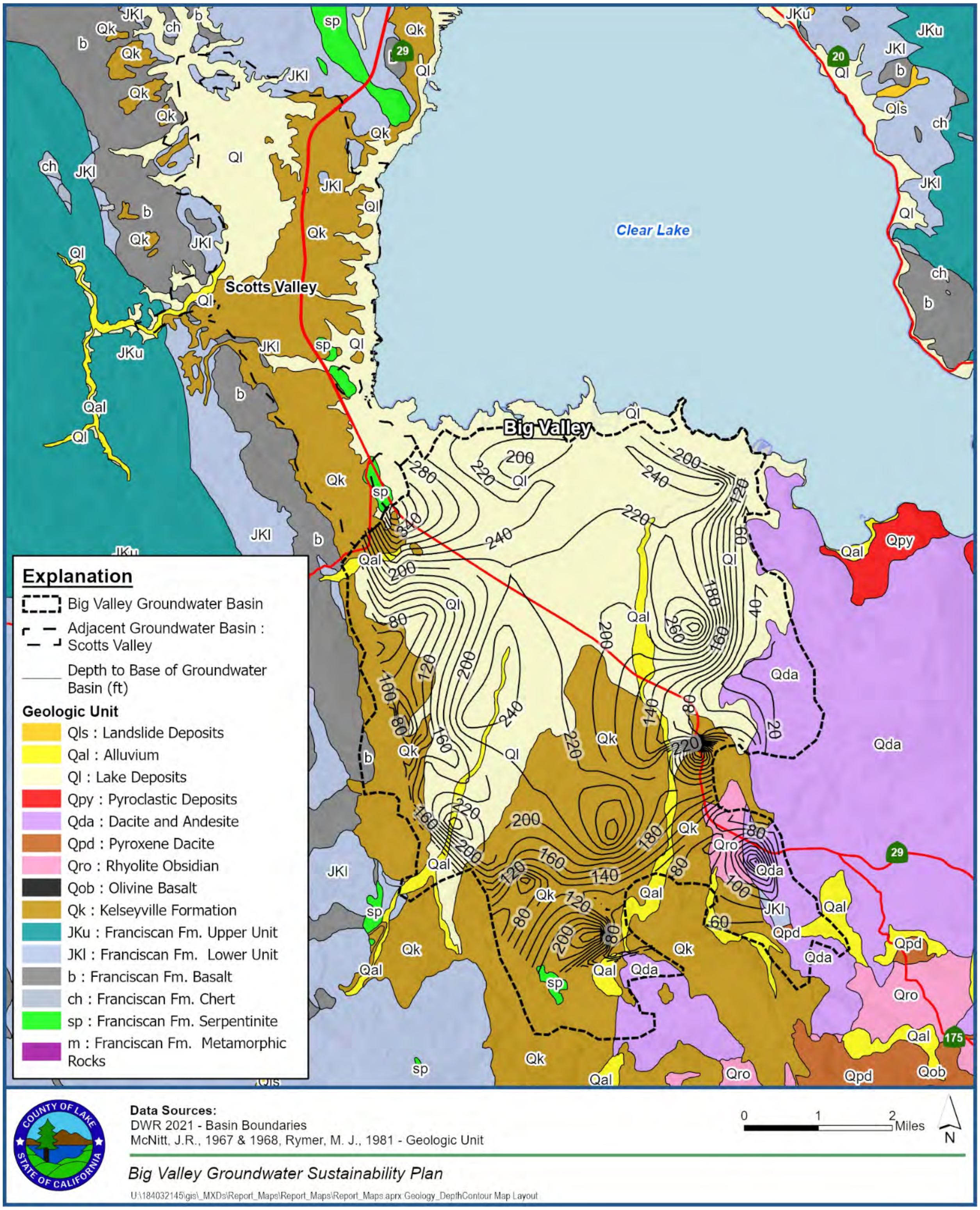

Figure 2-18. Contour Map of Depth to Base of Big Valley Basin

2.2.1.9 Hydrogeologic Characteristics

There are two principal hydrogeologic units in the Basin that provide water to meet irrigation, domestic and municipal water use. They are the volcanic ash aquifer and the Quaternary Alluvium. Storage capacity and transmissivity of these two units are discussed in this section.

Specific Yield and Storage Capacity

Specific yield is defined as the volume of water released from storage by an unconfined aquifer per unit surface area per unit decline of the water table (Bear 1979). The specific yield of the alluvial aquifer in the 'Kelseyville Basin' portion of the Basin was estimated from well logs to average 22 percent (SMFE 1967). Lake County (2003) calculated the change in the amount of groundwater in storage in the Basin for the period December 1, 1949, and March 31,1950 at approximately 19,723 AF using the water balance method and 12,460 AF using the change in groundwater level method and assigning a specific yield value of 7 percent to the dewatered aquifer volume based on DWR (1957) for the upper 20 feet of soils in the Basin. DWR (1957) estimated the specific yield of the 20 to 40-foot soil depth interval to be 10 percent.

DWR (1960) estimated the storage capacity of the Basin to be 105,000 AF for a saturated depth interval of 10 to 100 ft bgs. DWR (2004) estimated the usable storage of the Basin to be 60,000 AF.

Transmissivity

Transmissivity is defined as the rate of flow of water through a unit width of aquifer extending the full saturated height [thickness] of the aquifer under a unit hydraulic gradient (Ferris et al., 1962). It is calculated as the product of hydraulic conductivity and saturated thickness of an aquifer. SMFE (1967) reported that wells drilled into the "volcanic ash" aquifer and the specific capacity ranges from 11 to 140 gallons per minute per foot (gpm/ft). Assuming a confined water condition and a thickness of five feet, these specific capacity values correspond to hydraulic conductivities of over 500 to over 7,000 feet per day. A porosity of 0.47 and hydraulic conductivity of 2,800 feet per day were reported by SMFE (1967) from tests of a sample of the "volcanic ash" aquifer. Laboratory tests by Lake County (2003), however, indicated a hydraulic conductivity value of 11 feet per day, which is more representative on a regional scale.

The distribution of well yields in gallons per minute in the Basin is shown in **Figure 2-19**. There is a greater density of production wells on the Basin floor relative to the surrounding areas and relatively high-capacity production wells are concentrated in the Kelseyville subbasin and the Adobe Creek-Manning Creek subbasin.

Based on an analysis of development and/or pumping test data in DWR Well Completion Reports specific capacity was calculated by dividing the pumping rate by the drawdown or gpm/ft. Specific capacity is not a constant but decreases with an increase in pumping rate and duration of pumping.

Applying the empirical relationship between specific capacity and transmissivity (T) developed by Driscoll (2007), the calculated specific capacity value was used to estimate the transmissivity of the aquifer, where:

Transmissivity (T in gallons per day per foot, gpd/ft) = 1,500 x Specific Capacity (in gpm/ft) for an unconfined aquifer and T = 2,000 x Specific Capacity for a confined aquifer.

A contour map of the estimated transmissivity in feet^2/day is shown in **Figure 2-20**. Note that the transmissivity values shown are labeled using a logarithmic scale. It can be seen from **Figure 2-20** that high transmissivity values are concentrated in areas where the "volcanic ash' aquifer occurs in the Kelseyville subbasin.

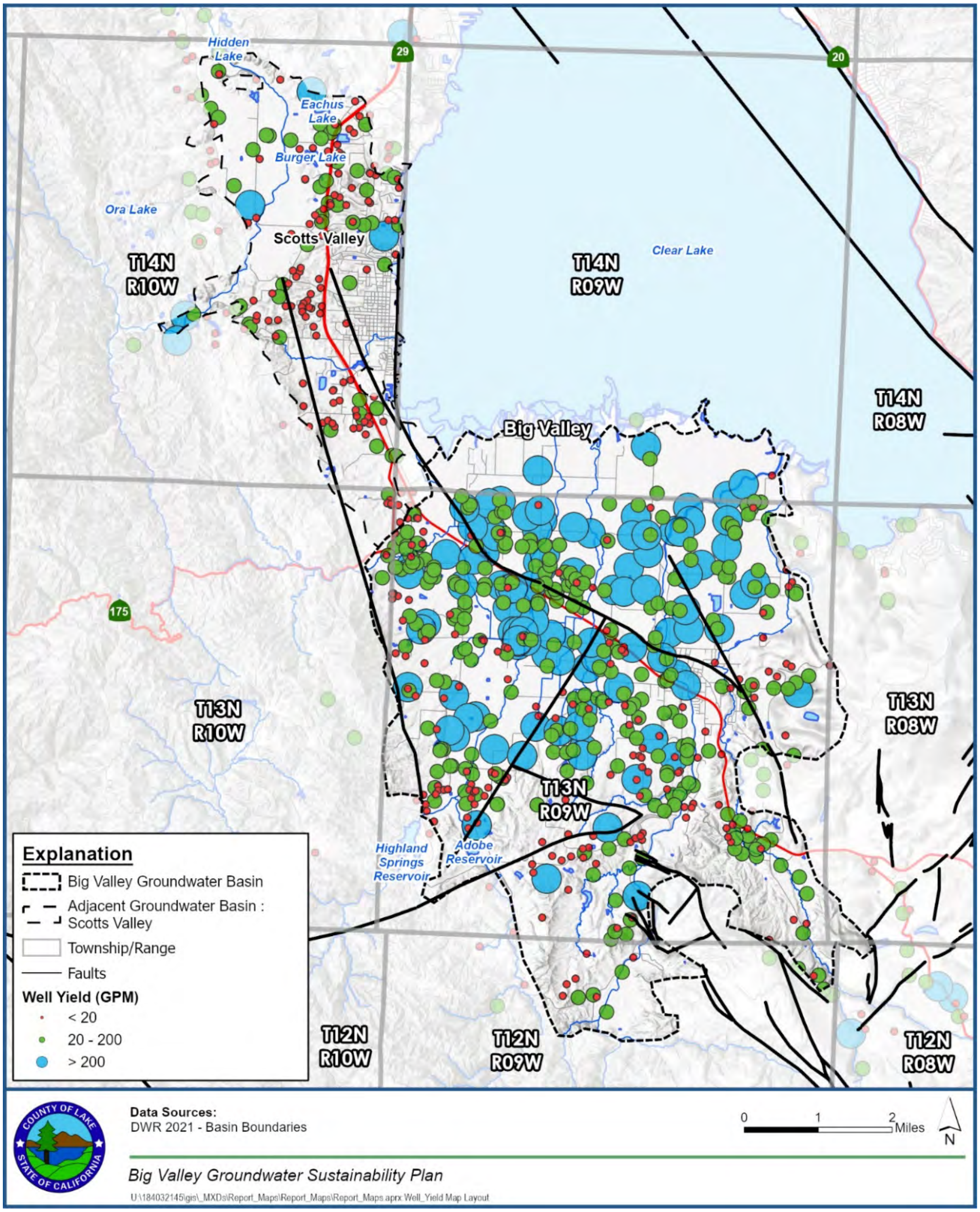

Figure 2-19. Well Yield in Gallons per Minute in the Big Valley Basin

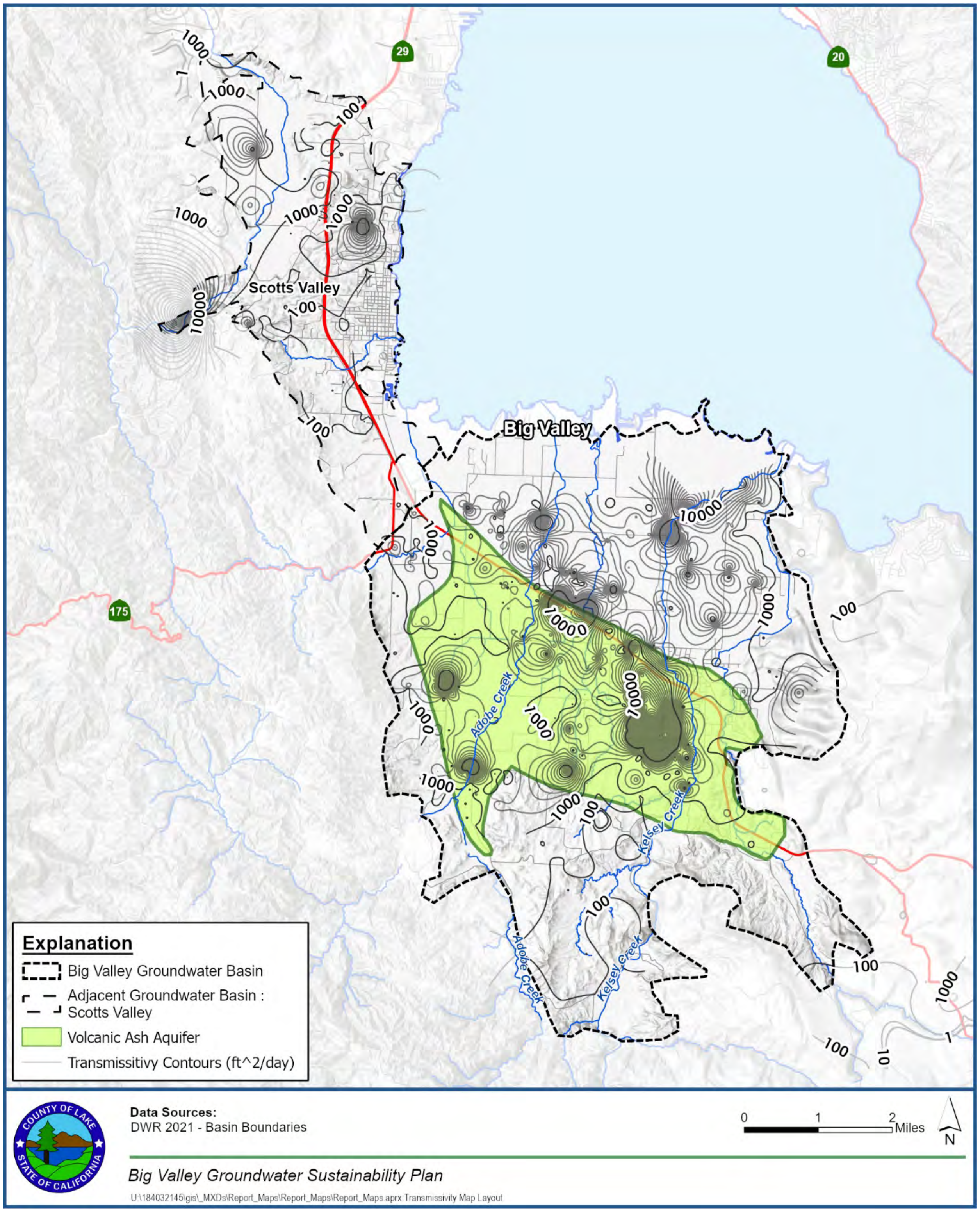

Figure 2-20. Transmissivity in Feet^2/day in the Big Valley Basin

Groundwater Recharge Areas

Existing recharge in the Basin outside of stream recharge and subsurface groundwater flow, occurs primarily from deep percolation of rainfall and irrigation water. Recharge occurring from the land can be impacted by land use practices, as changes to the land surface (such as paving or building) can reduce the amount of recharge, as can changes in irrigation practices.

The primary factors that influence recharge in the Basin are the presence of water and subsurface conditions that are conducive to recharge. Thus, areas that are extensively irrigated tend to have more recharge and areas that are underlain by coarser-grained soils tend to have more recharge. Conversely, unirrigated areas and areas underlain by finer-grained soils tend to have less recharge. A quantitative assessment of sources of recharge can be found in the groundwater budget discussion in **Section 2.2.4**.

The Soil Agricultural Groundwater Banking Index is a suitability index for groundwater recharge on agricultural land based on five major factors: deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition. Land within the Basin generally received a moderately poor rating (**Figure 2-21)** largely owing to the presence of finer-grained surficial soils derived from erosion of lacustrine deposits in the lowland areas of the Basin. However, as shown in **Figure 2-21**, there are localized areas of coarser-grained soils along the major and some of the minor streams as noted in the elongated green strips along Adobe Creek and Thompson Creek where the potential for recharge is much greater. In addition, in localized areas throughout the Basin there are coarser-grained surficial soils that are conducive to recharge. Potential higher priority areas of artificial recharge may be along stream channels in the southern upland areas of the Basin including Cole Creek, Kelsey Creek, Adobe Creek, and Highland Creek, and Manning Creek on the western edge of the Basin where underlying soils have a moderately good to excellent groundwater recharge rating.

Areas of discharge occur along the major and minor stream channels where they traverse areas that are underlain by finer-grained soils as shown in the lowland area of the Basin in **Figure 2-21**. In this area recharge is limited and surface water runoff discharges into Clear Lake. Likewise, the potential for runoff during high intensity precipitation events in this area is higher and leads to runoff into nearby drainages which discharge into Clear Lake.

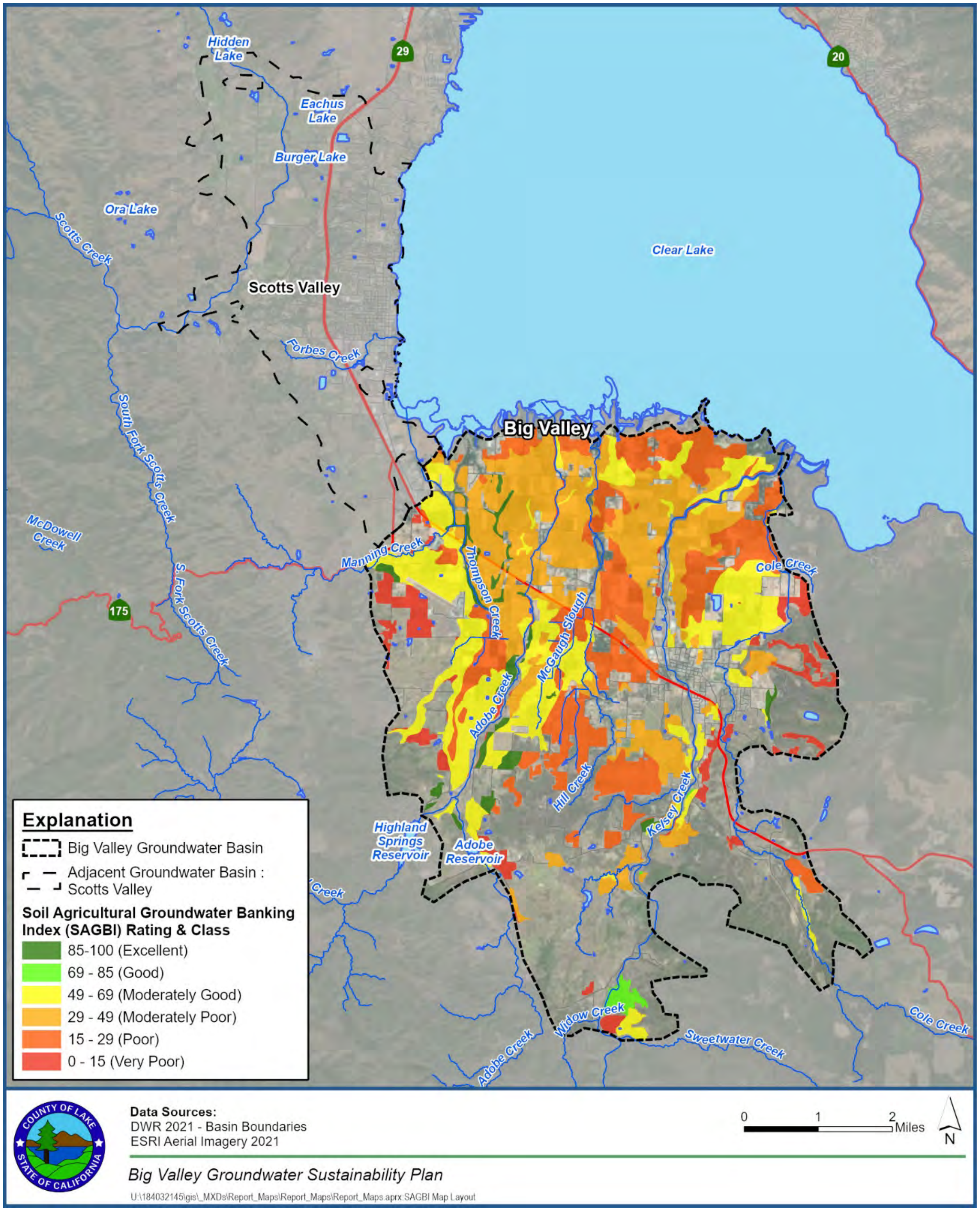

Figure 2-21. Soil Agricultural Groundwater Banking Index Groundwater Recharge Sustainability Index

2.2.1.10 Hydrogeologic Conceptual Model Data Gaps and Uncertainties

The HCM was developed with best available science and information. However, data gaps and uncertainties do exist such as the hydrologic connectivity between the Big Valley Basin and Scotts Valley Basin, the lateral and vertical extent of the Volcanic Ash aquifer, and the interaction between surface water bodies and the aquifers. Efforts to fill data gaps are underway including DWR's airborne electromagnetic (AEM) survey (November 2021) and installation of multiple monitoring wells through DWR's Technical Support Services (TSS) Program (application in process as of January 2022). Information from these efforts, and from other reputable sources will be incorporated into the HCM as it becomes available.

2.2.2 Current and Historical Groundwater Conditions

An understanding of groundwater levels and the direction of flow is essential to sustainable groundwater management. This includes both the spatial and temporal variation of groundwater levels which are a function of geology, groundwater management practices, land use, and climatic conditions. Historical and current groundwater levels of the Basin were evaluated using data obtained from public databases (DWR Water Data Library and CASGEM), the District, and information available from publications by the US Geological Survey and DWR. The BVGSA performed a quality assurance/quality control process on compiled data, which included evaluation of data for completeness and duplication, as well as identification of questionable data. In the following discussion on groundwater conditions, the Basin is considered as a single-aquifer system equivalent to the combination of the Volcanic Ash aquifer and the Quaternary Alluvium. Characteristics of the aquifer system are discussed in detail in **Section 2.2.2.1**.

2.2.2.1 Groundwater Levels and Flow Direction

Groundwater level hydrographs were generated for wells with time series data of sufficient periods of record. Representative hydrographs and the locations of corresponding wells are shown in **Figure 2-22**, while the hydrographs used for the groundwater level evaluation are included in **Appendix 2A**. The hydrographs throughout the Basin show seasonal variations, and changes that correspond to wet and dry periods. Spring groundwater levels of most wells in the lowland area have a moderate or strong positive correlation with the annual precipitation in the Basin (Pearson correlation coefficient 0.40 to 0.81). However, water levels of most wells in the upland areas have a poor correlation with the annual precipitation (correlation coefficient < 0.40). During the last four decades, multi-year wet periods occurred in 1982-1984, 1995-1998, and 2003-2006, while multi-year dry periods occurred in 1987-1992, 2007-2009, and 2012-2015.

Wet and dry periods were identified by comparing the total annual rainfall of a water year (WY) and the long-term (WY 1950-2020) mean rainfall estimated for Kelseyville using the Basin Characterization Model presented by Flint et al. (2021). A water year is the 12-month period that begins on October 1 of the previous calendar year and ends on September 30. The annual precipitation and cumulative departure curve of precipitation at Kelseyville is indicative of the Basin hydrology (**Figure 2-23**). Some hydrographs show a decline in groundwater levels during the 1960-1980 period, and this is attributed to local impacts of gravel mining within the Kelsey Creek and Adobe Creek channels (e.g., Lake County, 1999) as well as periods of below-normal precipitation.

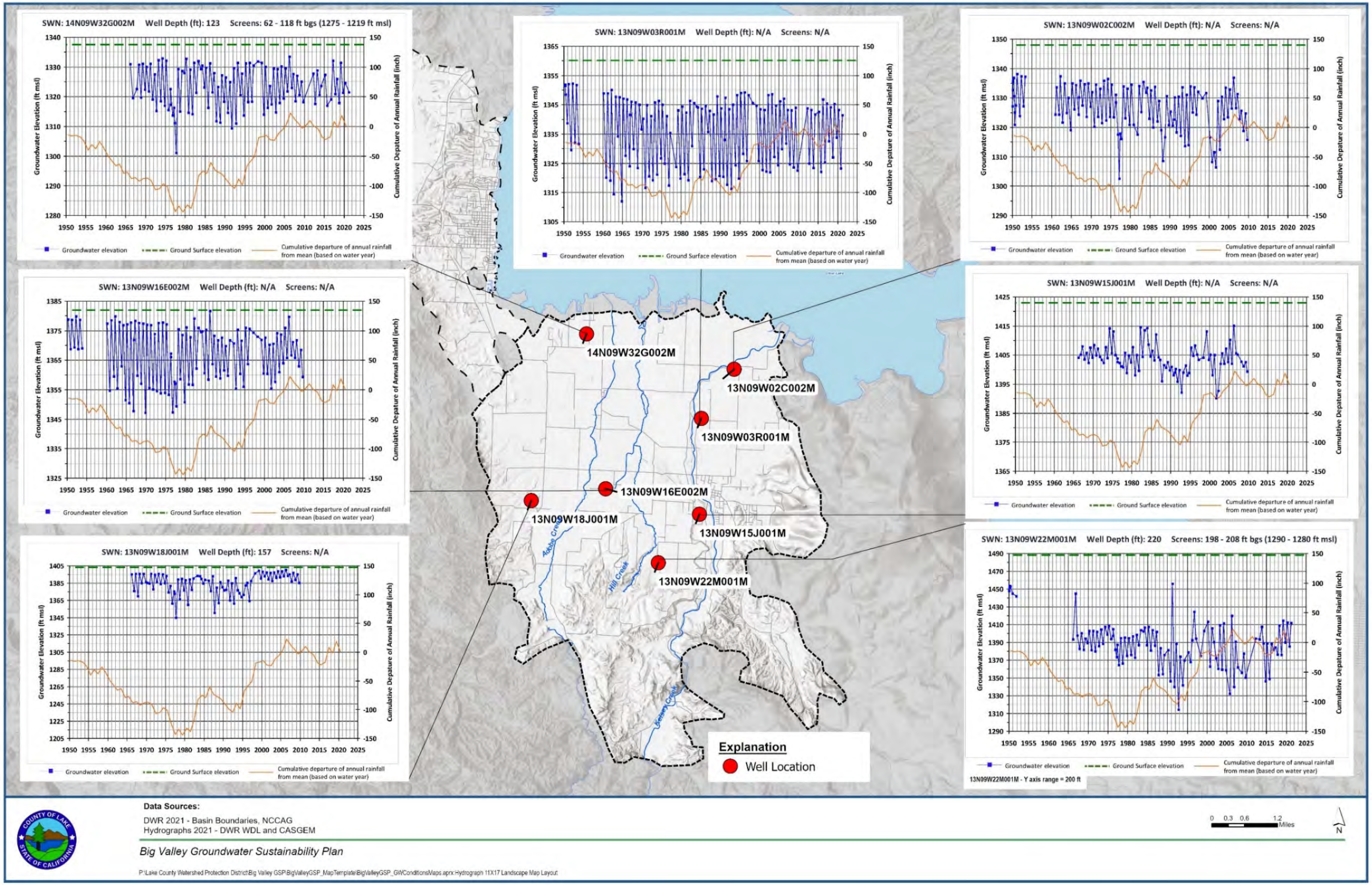

Figure 2-22. Panel Map of Selected Groundwater Elevation Hydrographs in Big Valley Basin

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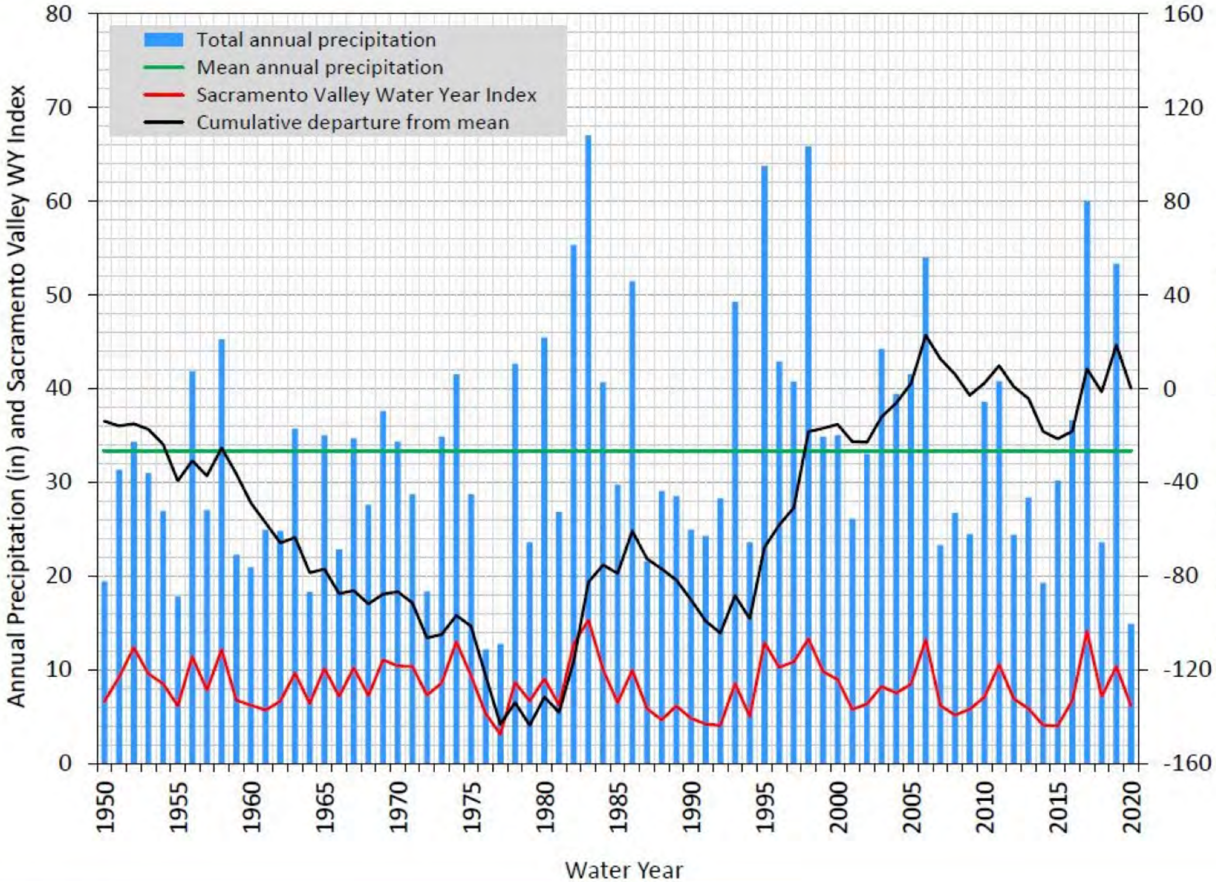


Data Sources:
DWR 2021 -Basin Boundaries
Flint et al., 2021. The Basin Characterization Model - A regional water balance software package (BCMv8) data release and model archive for hydrologic California, water years 1896-2020, U.S. Geological Survey data release.

Big Valley Groundwater Sustainability Plan

P:\Lake County Watershed Protection District\Big Valley GSP\BigValleyGSP_MapTemplate\BigValleyGSP_GWConditionsMaps.aprx:Big Valley Map layers Map Layout

Figure 2-23. Annual Precipitation and Cumulative Departure - Kelseyville, CA

Groundwater Levels

Depth to water in the northern portion of the Basin is significantly shallower than in the southcentral- (area around the headwaters of Hill Creek) and southern- portions. Seasonal high-water levels (in winter/spring seasons) in the northern portion generally range between 5 and 20 ft bgs. Occasionally, water levels of several wells rose above the ground surface (flowing artesian conditions) after periods of intense precipitation. Seasonal low water levels (in summer/fall seasons) in this area can be 5 to 25 feet deeper than seasonal high-water levels depending on well location, construction, and local water use. In general, the magnitude of water level fluctuations between dry and wet climatic periods ranges from a few feet to less than 10 feet; therefore, they are significantly smaller than the seasonal fluctuations. Seasonal high-water levels in the south central and southern portions of the Basin range between about 70 and 130 ft bgs, while seasonal low water levels can be 20 to 50 feet deeper. Water level fluctuations between dry and wet periods are smaller than the seasonal fluctuations. Sufficient data are not available to evaluate groundwater levels in the southern uplands of the Basin (areas south and southeast of Wight Way).

Despite seasonal and climate-influenced short-term fluctuations, groundwater levels in the Basin remained stable during the last three decades. A statistical analysis was conducted using seasonal high water level data from 26 wells that have a minimum of 30 annual winter/spring measurements from 1990 to 2020. No statistically significant trend exists in water levels of 20 wells (at 5 percent significance level). Four wells have statistically significant, but very small declining water levels (about 0.1 feet per year), while two wells have statistically significant increasing water levels (about 0.1 to 0.3 feet per year). The declining trend of water levels at four wells is not an indication of groundwater overdraft in the Basin. Water level statistical analyses, for trend, both parametric (Ordinary least squares regression) and nonparametric (Mann-Kendall and Theil–Sen) methods, and an assessment of outlier water levels (Rosner's outlier test) are included in **Appendix 2A**.

Groundwater Elevation Contours and Flow Directions

Contours of equal groundwater elevation ("Contours") were created to evaluate general groundwater flow directions in the Basin using seasonal high and seasonal low water elevations. Contours were initially created using the spatial analyst tools in ArcGIS software, and then modified based on professional judgement. Contours were not developed for areas of the Basin where groundwater elevation data were lacking.

Contour maps were created to evaluate seasonal high and seasonal low groundwater conditions for 2019 and 2015. Winter/spring and summer/fall groundwater elevations for 2019 represent current conditions and are presented on **Figure 2-24** and **Figure 2-25**, respectively. Precipitation data indicate wet climatic conditions in WY 2019 (total precipitation in WY 2019 is significantly higher than the long-term mean annual precipitation). Groundwater elevations of 2015 represent conditions that occur during dry climatic conditions (**Figure 2-26** and **Figure 2-27**).

All groundwater contour maps indicate a general northward flow from the uplands towards Clear Lake. General groundwater flow directions in the Basin are primarily determined by the topography and influenced by local groundwater withdrawal and recharge. In 2015 and 2019 time periods groundwater elevations are highest in the southern areas of the Basin and lowest in the northern areas on the Basin floor. During wet conditions, seasonal high groundwater elevations range from about 1330 feet msl in the northern portion of the Basin to 1430 feet msl in the south central and southern portions of the Basin (Figure 2 17). Seasonal low groundwater elevations are about 10 feet lower than the seasonal high elevations throughout the Basin, but general contour pattern remains nearly similar (Figure 2 18). During dry conditions, both seasonal high and low groundwater elevations in the south central and southern portions of the Basin are about 10 feet lower compared to groundwater elevations in a wet year (**Figure 2-27** and **Figure 2-28**).

General horizontal hydraulic gradients estimated using groundwater contour maps are about 15 feet per mile in the northwestern portion of the Basin, and about 25 to 30 feet per mile in northeastern and south/south central portions of the Basin. Horizontal hydraulic gradients do not significantly change between seasons or dry and wet periods. Water level data indicate a consistent, vertically downward hydraulic gradient in the aquifer; however, accurate quantification of vertical gradient is difficult because of lack of data from nested or clustered monitoring wells. Vertical hydraulic gradient was evaluated using closely located individual wells (distance less than 2,000 feet), but the gradient could not be quantified in a meaningful way because of the long well screens.

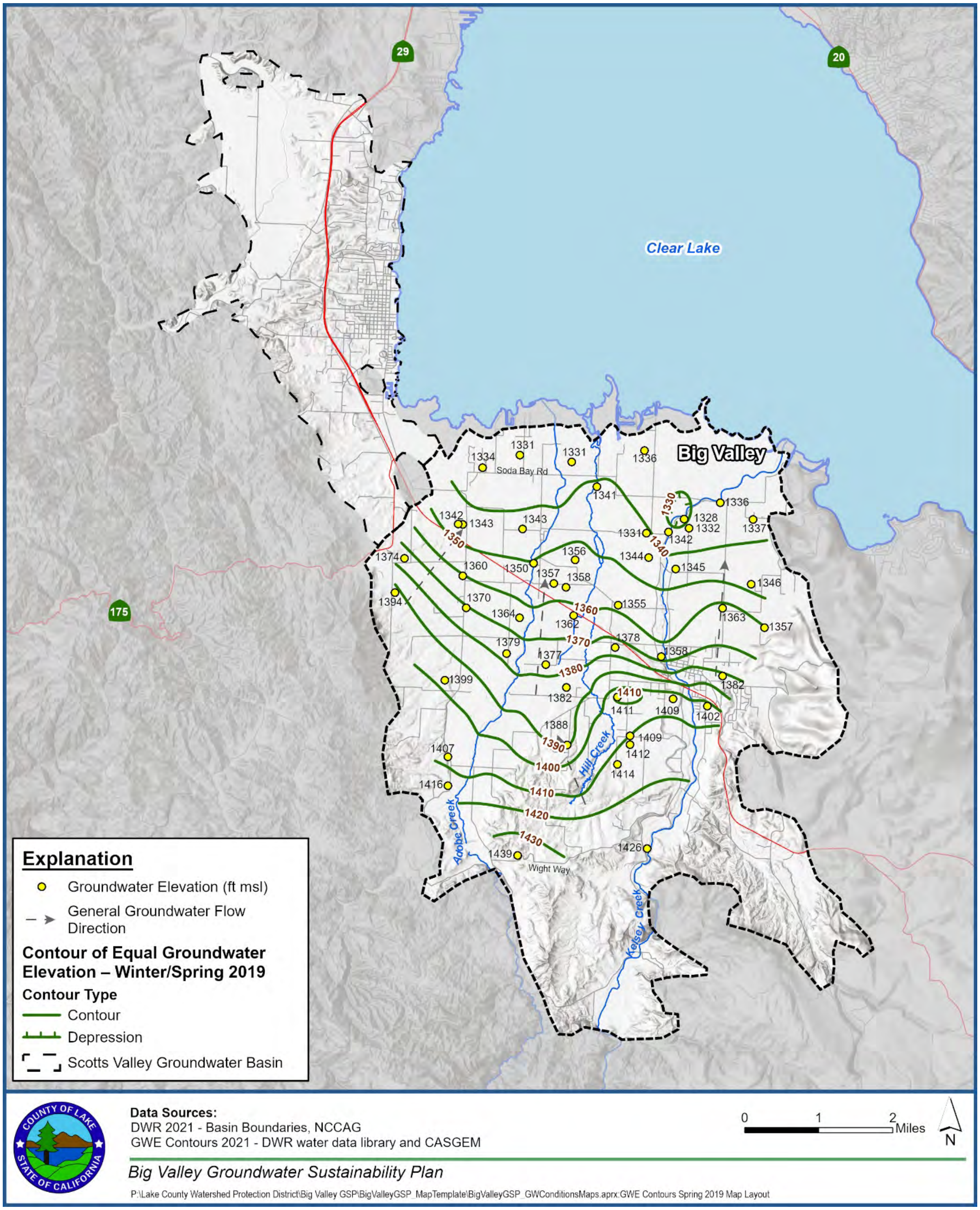


Figure 2-24. Contours of Equal Groundwater Elevation in Big Valley Basin – Seasonal High of 2019

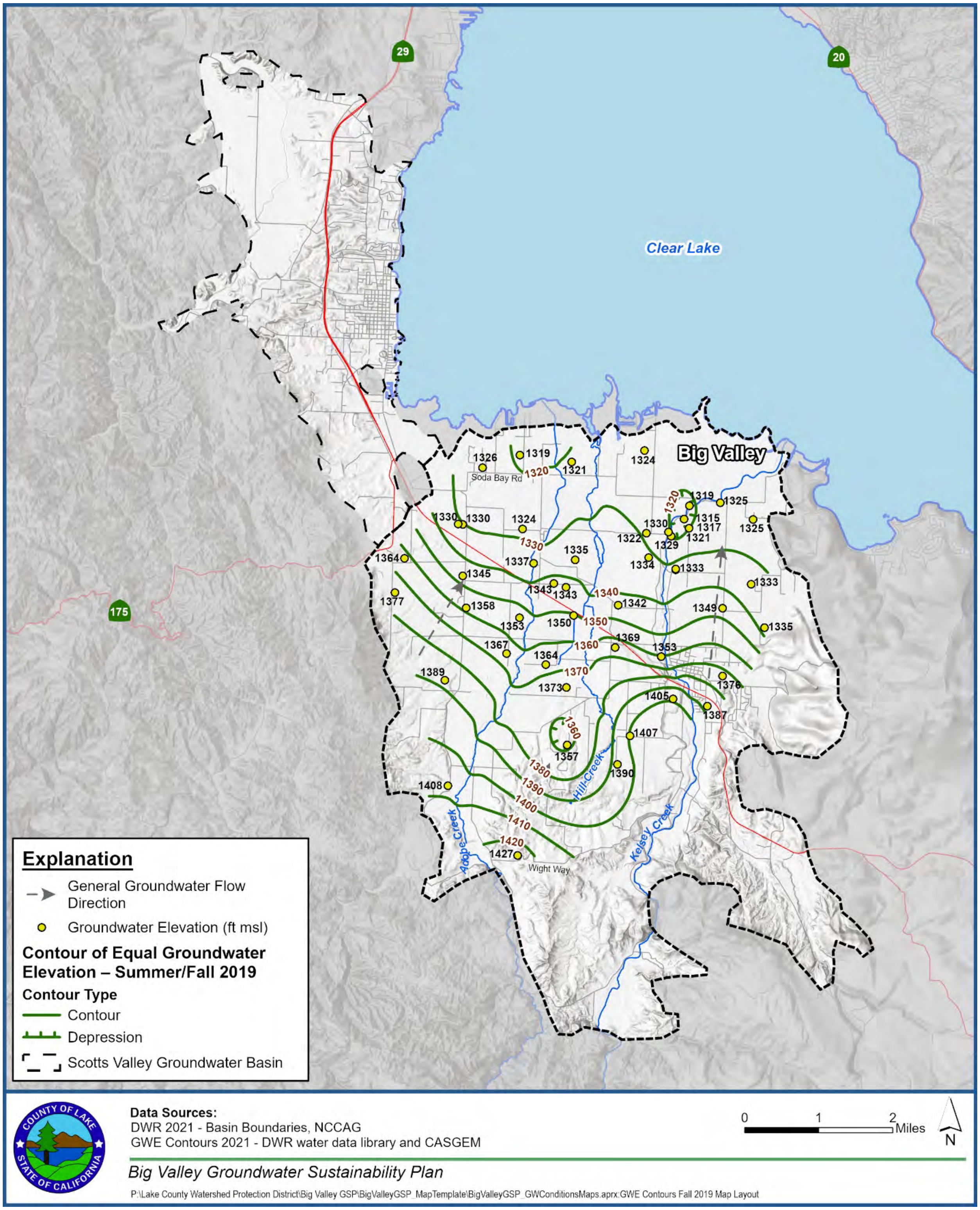


Figure 2-25. Contours of Equal Groundwater Elevation in Big Valley Basin – Seasonal Low of 2019

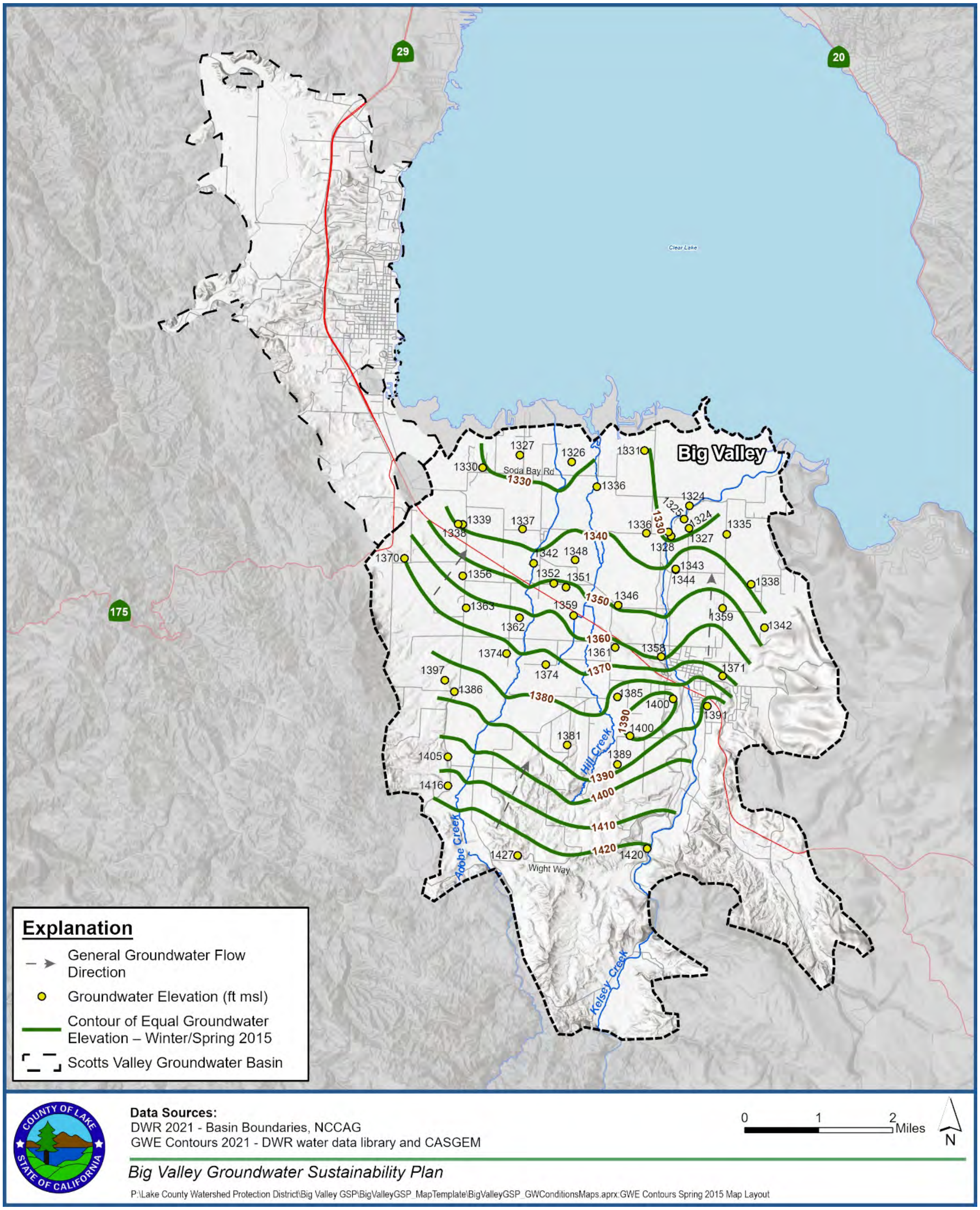


Figure 2-26. Contours of Equal Groundwater Elevation in Big Valley Basin – Seasonal High of 2015

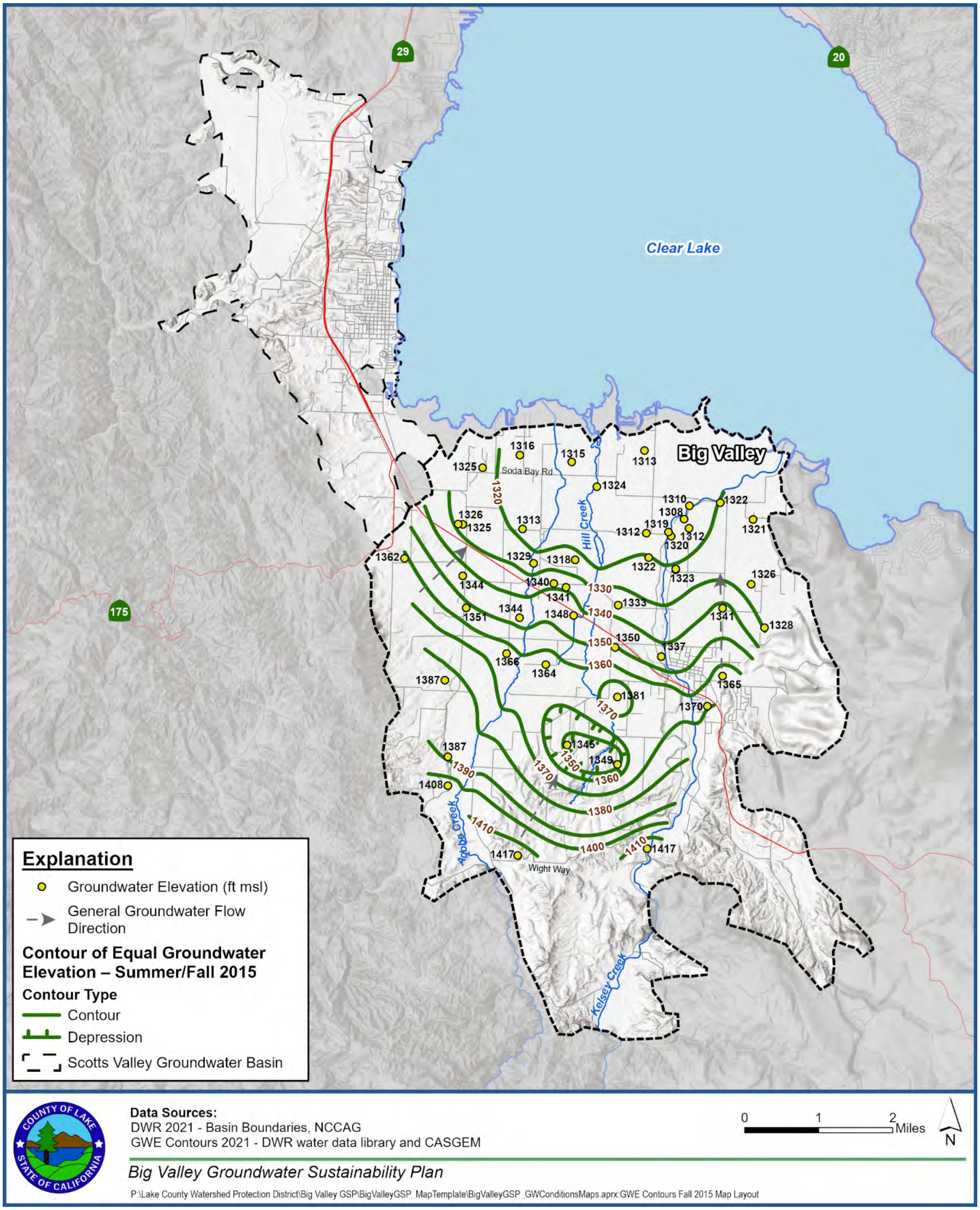


Figure 2-27. Contours of Equal Groundwater Elevation in Big Valley Basin – Seasonal Low of 2015

2.2.2.2 Change in Groundwater Storage

Change in seasonal high groundwater elevations (winter/spring to winter/spring) from 1965 to 2019 was estimated to evaluate change in groundwater storage during this period. Seasonal high groundwater elevations of 1965 are shown in **Figure 2-28**. Groundwater elevation surfaces for 1965 and 2019 were separately created by interpolating available water levels in each year; the difference between these two surfaces (**Figure 2-29**), which encompasses a volume of both water and porous media, was calculated. Sufficient water level data were available to evaluate groundwater level changes only in lowland areas of the Basin (the colored area in **Figure 2-29**). This area is approximately 13,050 acres, which is about 55 percent of the Basin area. This area includes about 70 percent of all domestic, agricultural, and municipal water supply wells in the Basin (estimated based on well completion reports available from DWR).

Between 1965 and 2019, groundwater elevation decreased by less than a foot to over 10 ft in some areas in the Basin: primarily in areas along Kelsey Creek and Adobe Creek north of Highway 29, and in area between Adobe Creek and Hill Creek in south central portion of the Basin. In the remaining areas, groundwater levels increased by up to five feet. However, the increase in groundwater levels was over 10 feet in some areas south of Highway 29 and east of Hill Creek.

The estimated changes in groundwater elevations between 1965 and 2019 corresponds to an increase of approximately 2,600 AF of groundwater storage. This storage amount is calculated using the volume difference between the two groundwater surfaces (1965 and 2019) and a specific yield of 0.08 (Lake County WPD 2006). This volume is approximately 4 percent of the estimated usable groundwater storage of the Basin per California's Groundwater Bulletin 118 (DWR 2004).

This estimated storage change does not imply an increasing trend between 1965 and 2019. It may indicate a relatively stable groundwater storage over time. However, lack of good data coverage in the uplands area of the Basin makes it harder to make a definite conclusion. It should also be noted that this estimate of storage change may reflect specific conditions observed in these two years. A detailed year-to-year historical groundwater storage changes are also estimated using a surface water-groundwater flow model discussed in **Section 2.2.4**.

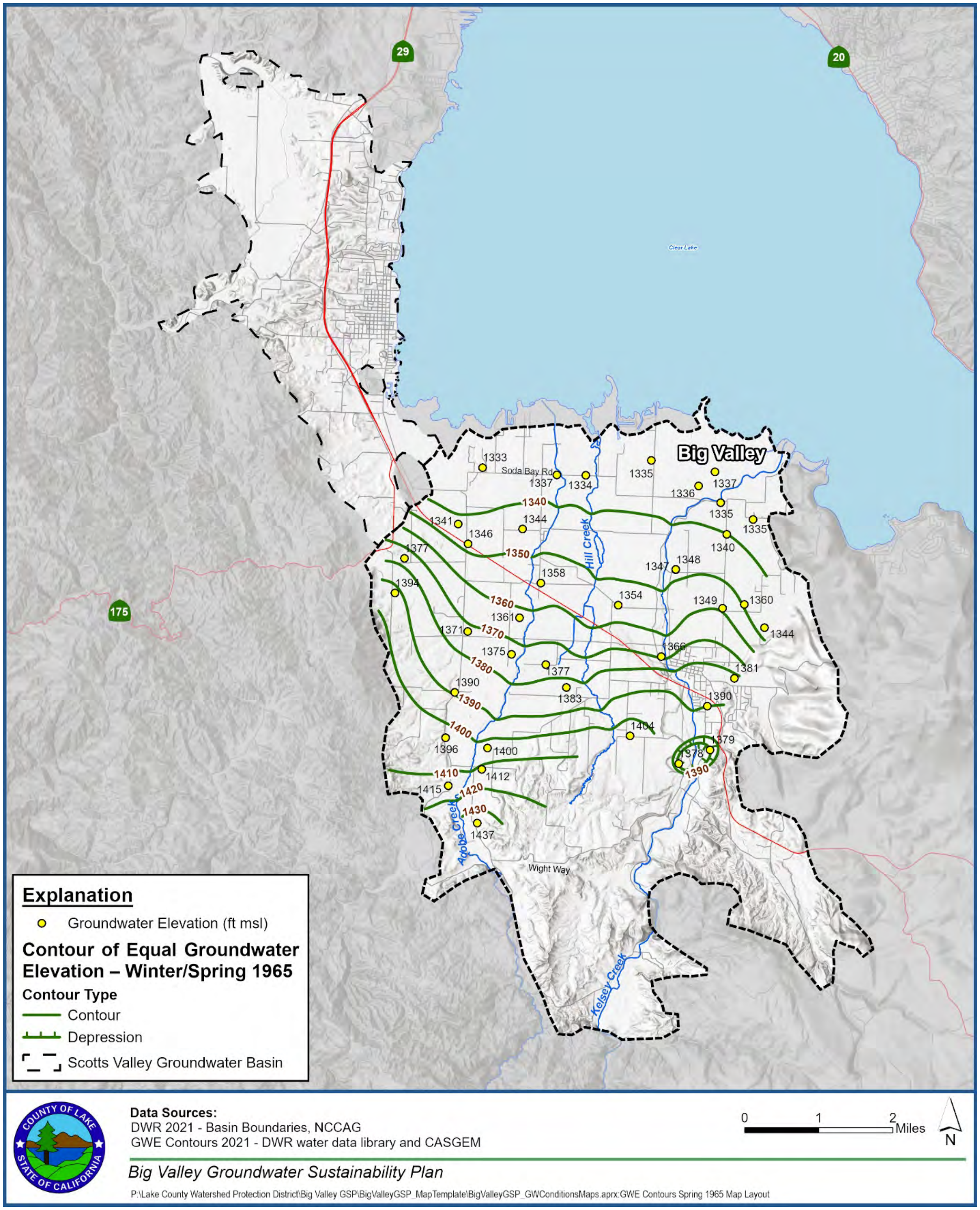


Figure 2-28. Contours of Equal Groundwater Elevation in Big Valley Basin – Seasonal High of 1965

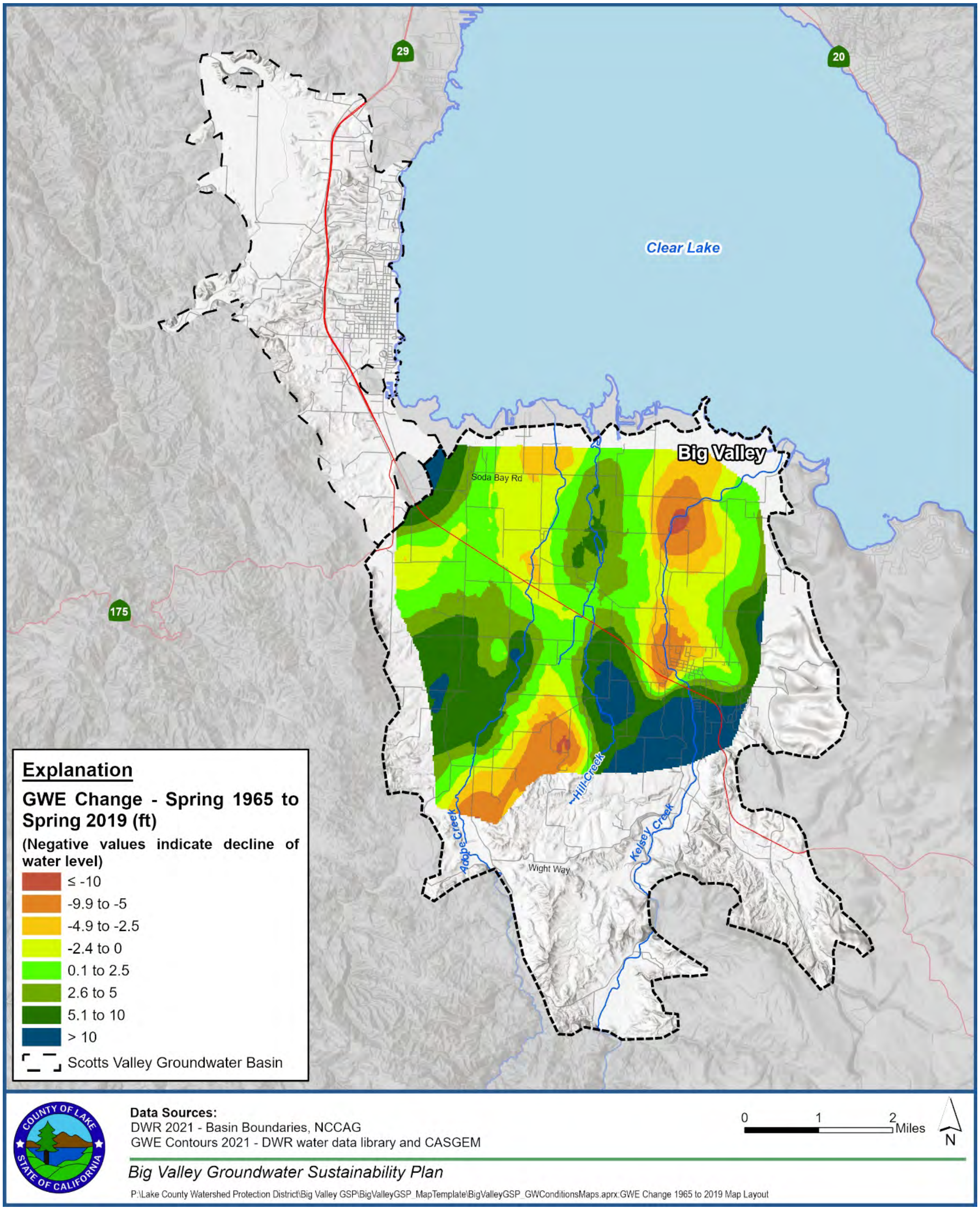


Figure 2-29. Change of Groundwater Elevation in Big Valley from Spring 1965 to Spring 2019

2.2.2.3 Groundwater Quality

The evaluation of groundwater quality in the Basin included a literature review (e.g., Lake County 1999, 2003, and 2006b) and evaluation of groundwater quality data collected from the SWRCB GAMA and Geotracker databases. Previous studies did not identify any widespread groundwater quality concerns. However, Lake County (1999 and 2003) stated that local concerns exist associated with increasing nitrate concentrations in groundwater, occurrence of boron at concentrations undesirable for some crops, and potential groundwater quality degradation due to intrusion of geothermal water. Widespread presence of contaminants at undesirable levels (concentrations that exceed applicable regulatory limits) has not been reported in groundwater samples in the Basin. The following discussion focuses on TDS, nitrate, arsenic, and boron in groundwater. The range of historical concentrations of these constituents are presented in **Table 2-6** and timeseries graphs of concentrations for wells with sufficient period of record are presented in **Appendix 2B-1**. Groundwater quality test results of six CASGEM wells sampled in July 2021 under the DWR's Sustainable Groundwater Management Program Technical Support Services are presented in **Appendix 2B-2**. This section concludes with a brief discussion of open regulatory cleanup sites in the Big Valley Basin.

Table 2-6. Range of Concentrations of General Groundwater Quality Constituents

Constituent	Water Quality Concentration Limit (mg/L)	Range of Concentration from 1944 to 2021*
Arsenic	0.010 [1]	0.00007 – 0.050
Boron	1 [2], 5 [3]	0.03 - 4.4
Nitrate (as nitrate)	10 [1]	0.02 – 65.5
Total Dissolved Solids	500 [4], 1,000 [5]	113 – 1,535

Notes:
* The number of wells collecting groundwater quality data varied over time. Concentrations below detection limits are not accounted for minimum values.
[1] Federal (U.S. EPA) and California primary drinking water maximum contaminant level.
[2] California State Notification Level for groundwater wells used for public drinking water.
[3] USDA recommended limit for livestock and poultry.
[4] California secondary maximum contaminant level for drinking water – recommended limit.
[5] California secondary maximum contaminant level for drinking water – upper limit.
Key:
mg/L = milligrams per liter

Total Dissolved Solid

The occurrence of TDS in groundwater at undesirable concentrations is not a concern at present. Historically, only one sample has exceeded the upper Secondary Maximum Contaminant Level (SMCL) of 1,000 milligrams per liter (mg/L). The TDS concentration of any other sample in the Basin has not exceeded 802 mg/L. A sample tested in 2021 had a TDS concentration of 1,535 mg/L. Excluding that sample, a total of 227 groundwater samples from 52 wells were tested for TDS since 1954. Test results of 42 samples from 16 wells exceeded the recommended SMCL of 500 mg/L but results of only four samples were higher than 700 mg/L. Analytical data do not show spatial or temporal trends in TDS. Wells with TDS that exceeded 500 mg/L at least once exist throughout the Basin (**Figure 2-30**).

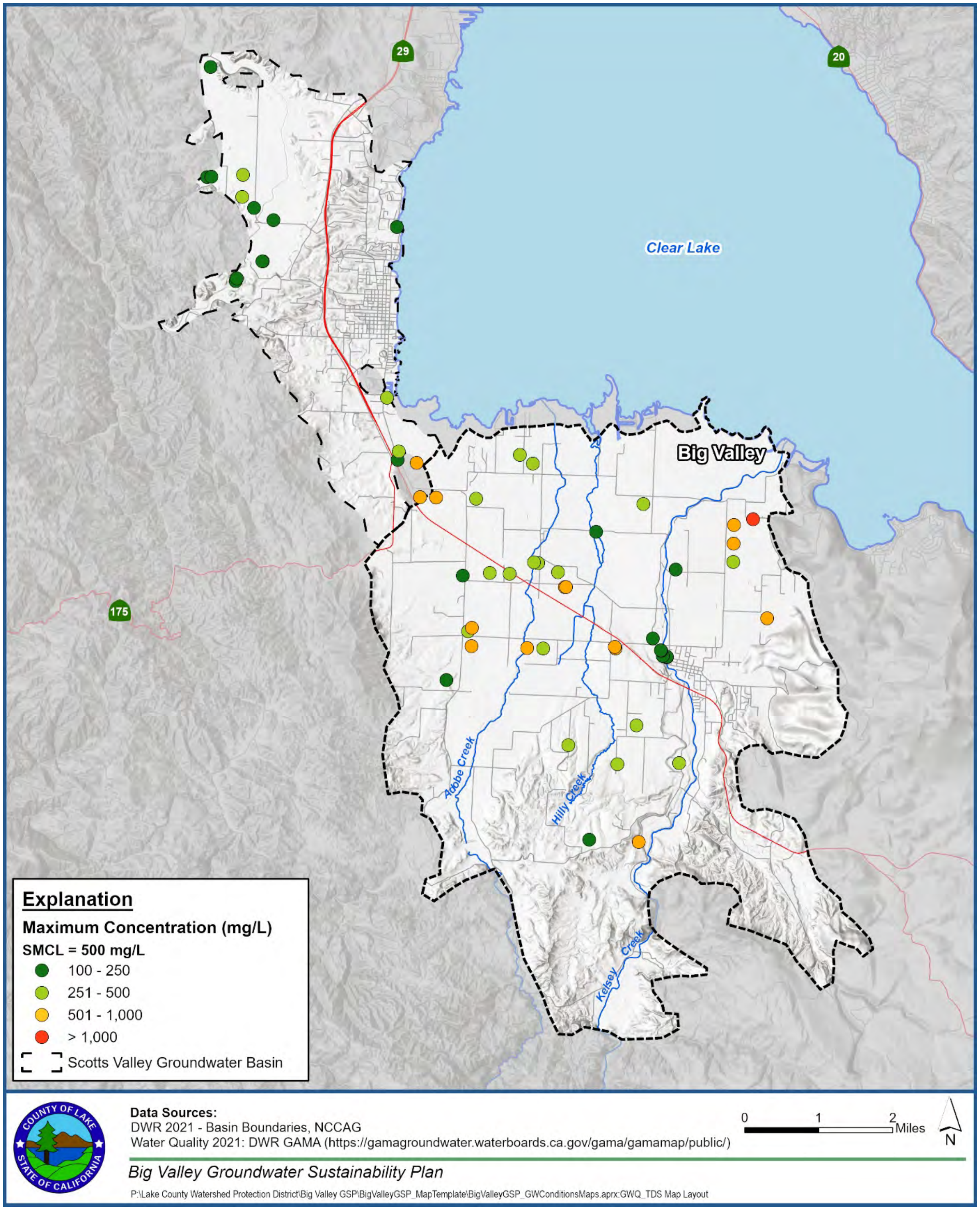


Figure 2-30. Maximum Historical Total Dissolved Solids Concentration by Well in Big Valley Basin

Nitrate

The occurrence of nitrate at undesirable concentrations is not a concern in the Big Valley Basin at present. A total of 381 groundwater samples from 96 wells were tested for nitrate since 1952 and results of seven samples from six wells exceeded the Maximum Contaminant Level (MCL) of 10 mg/L (measured as N). The highest historical concentrations, 65.5 and 63.3 mg/L, were from samples collected from two wells in the central portion of the Basin in 1970 (**Figure 2-31**). None of the other analytical results exceeded 14 mg/L, and only one sample had a concentration that exceeded the MCL after 1970. Wells with analytical results that exceeded 5 mg/L at least once are in the central and northeastern portions of the Basin. Recent (post-1980) nitrate analytical results do not have an increasing trend. Potential sources of nitrate include agricultural fertilizers, and human wastes from onsite waste disposal systems (e.g., septic tanks and leach fields). Elevated concentrations of nitrate in drinking water pose a serious health risk for infants which can cause methemoglobinemia (blue baby syndrome).

Boron

The occurrence of boron at undesirable concentrations is not a basin-wide concern at present, but boron concentrations over 1.0 mg/L have been reported in groundwater samples collected from the central and eastern portions of the Basin (**Figure 2-32**). A total of 283 groundwater samples from 80 wells were analyzed for boron since 1944 and concentrations of 13 samples from four wells were greater than 1 mg/L, with a highest historical concentration of 4.4 mg/L reported in 1975. A total of 56 samples collected from 13 wells located in the northeastern, central, and eastern portions of the Basin had concentrations higher than 0.50 mg/L. However, a concentration above 0.50 mg/L has not been reported after 2007 and available data do not show an increasing trend in boron concentrations at any well in the Basin. Boron is an unregulated chemical for drinking water, but it has a California State Notification Level of 1.0 mg/L which applies to groundwater wells used for public drinking water. Certain crops are sensitive to boron over 0.50 mg/L. The primary source of boron in groundwater is hydrothermal influx from the Clear Lake volcanic field (Lake County 1999).

Arsenic

Available water quality data suggest that arsenic is currently not a groundwater quality concern in the Basin. Since 1960, 88 samples collected from 36 wells were analyzed and only two samples exceeded the MCL of 10 micrograms per liter (µg/L). These two results (collected in 1987 from two wells) are both 50 µg/L (**Figure 2-33**). The majority of test results (79 of 88) were less than 4.0 µg/L, and an increasing trend of arsenic concentrations was not observed in the Basin. Chronic exposure to arsenic can adversely affect skin, the cardiovascular system, the nervous system, and cause cancer.

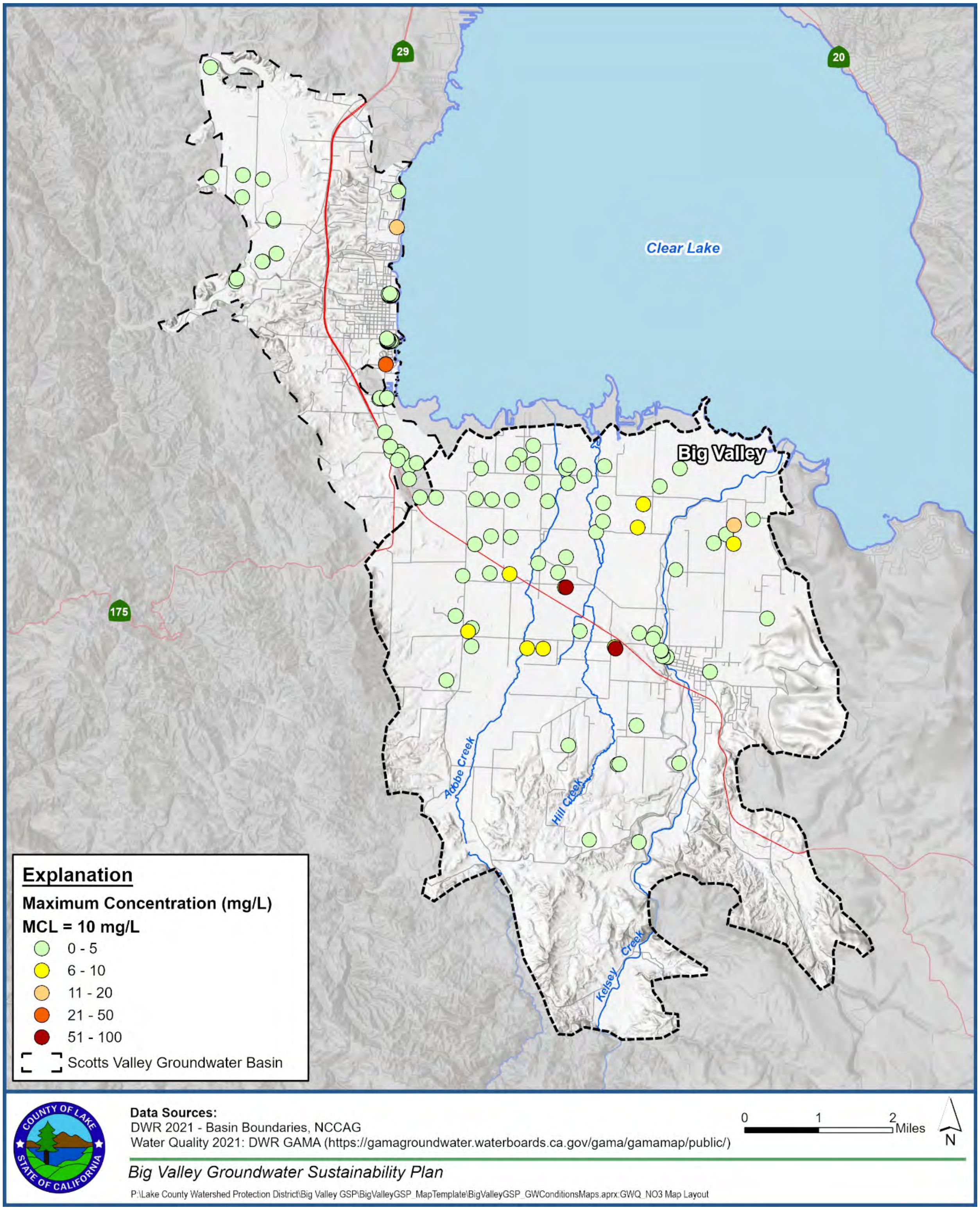


Figure 2-31. Maximum Historical Nitrate Concentration by Well in Big Valley Basin

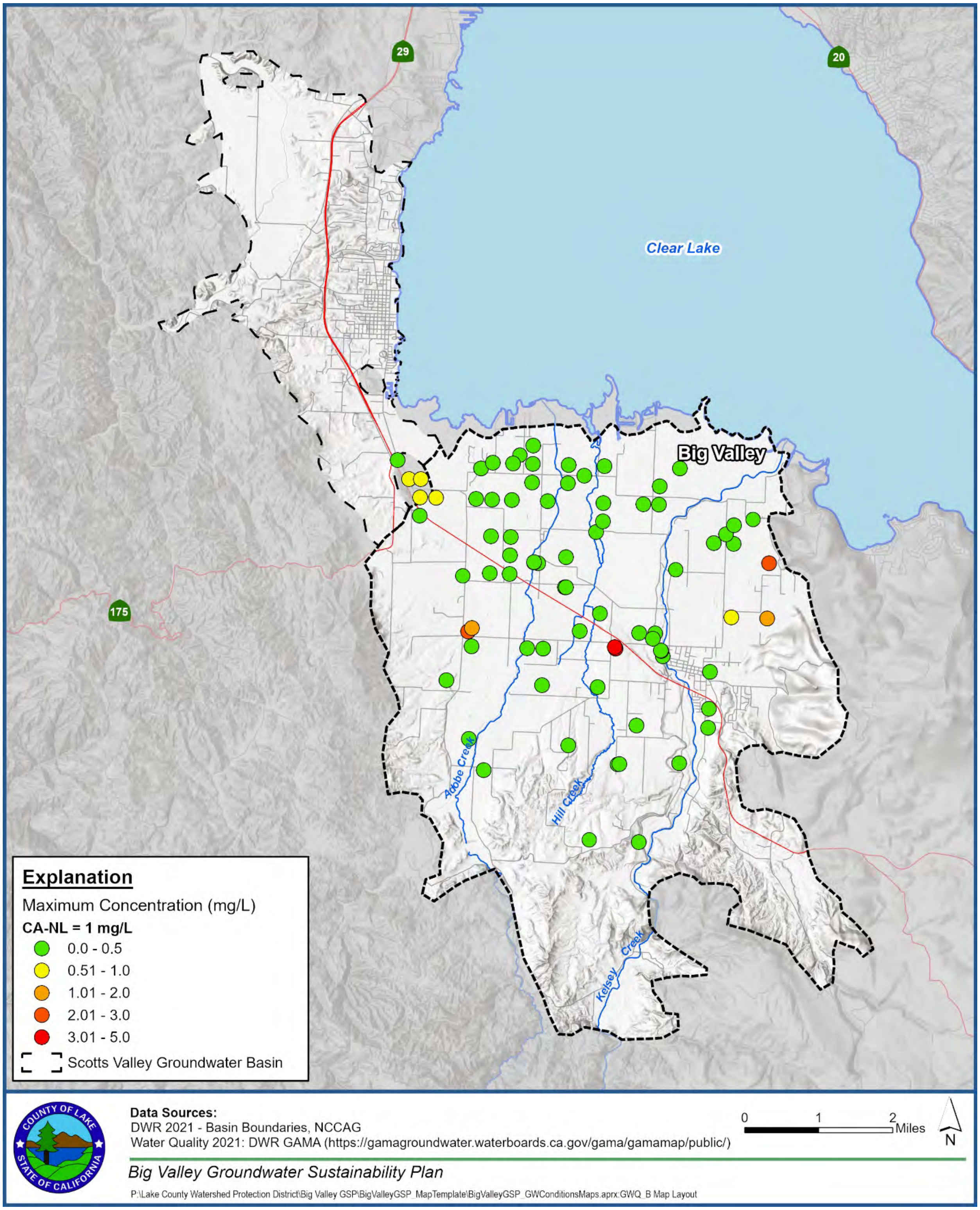


Figure 2-32. Maximum Historical Boron Concentration by Well in Big Valley Basin

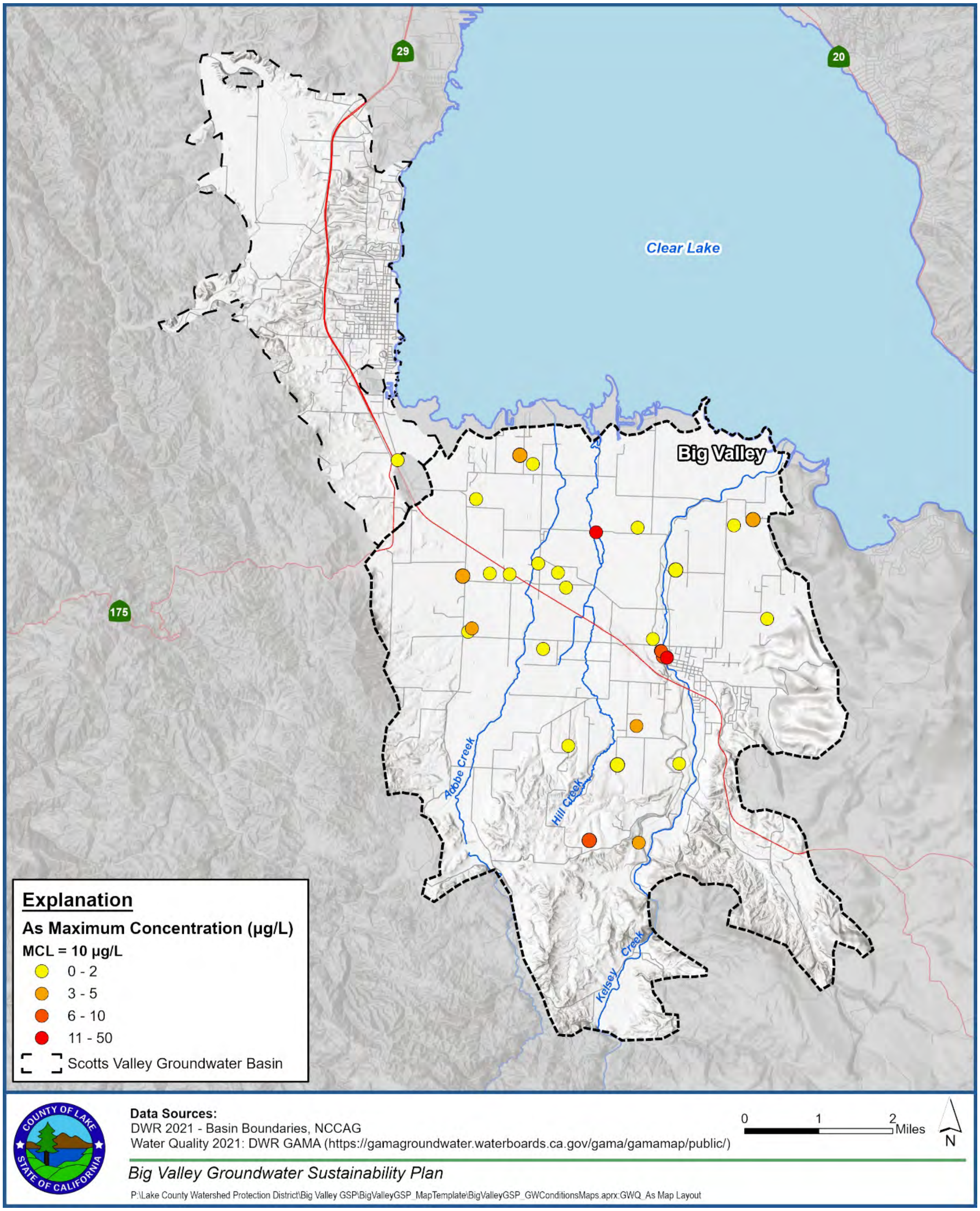


Figure 2-33. Maximum Historical Arsenic Concentration by Well in Big Valley Basin

Other Contaminants

Iron and manganese at concentrations exceeding their Secondary Maximum Contaminant Levels (300 µg/L and 50 µg/L, respectively) occur at domestic and municipal wells at various locations in the Basin. These metals can cause aesthetically undesirable water characteristics, like color, taste, and odor.

Regulatory Cleanup Sites

Groundwater sampling analytical data obtained from groundwater monitoring wells associated with regulatory cleanup sites contained anthropogenic organic compounds associated with industrial products and pesticides at concentrations greater than their regulatory limits (California or federal MCLs for drinking water). These compounds were occasionally detected in samples collected from municipal and domestic wells at concentrations lower than regulatory limits, and do not indicate widespread groundwater quality concerns.

The SWRCB Geotracker database identifies three cleanup program sites and one leaking underground storage tank (LUST) cleanup site that are currently open in the Basin (**Figure 2-34**). Cleanup program sites are regulated under the SWRCB Site Cleanup Program and/or similar programs conducted by Regional Water Quality Control Boards. LUST sites are fuel-contaminated sites regulated pursuant to Title 23 of the California Code of Regulations, Chapter 16.

Airpower Inc. cleanup program site is currently in verification monitoring phase after remediation. Potential contaminants of this site are petroleum fuels, oils, and volatile organic compounds. Closure evaluation report for this site (GEOCON 2021) states that it is unlikely that the contaminant plume would have a measurable impact on groundwater quality of nearby water supply wells.

Kelseyville Hot Plant cleanup program site is in the assessment stage. This site includes an asphalt hot batch plant, a concrete batch plant, a gravel crushing facility, and above ground storage tanks for asphalt products, diesel fuel and motor oil. Potential contaminants at this site include chromium, diesel, and waste oils. Groundwater contamination was detected onsite; however, the extent of the contamination is not adequately characterized to evaluate the impact on groundwater in the vicinity of the site.

Two Jacks Kelseyville above ground storage tank cleanup program sites are contaminated with kerosene. The two Jacks Kelseyville underground storage tank is a LUST site. Potential contaminants at this site include benzene, diesel, gasoline, methyl-tert-butyl ether, tert-butyl alcohol, other fuel oxygenates, naphthalene, toluene, and xylene. Both sites are in assessment stage and have not been adequately characterized to evaluate impacts on groundwater.

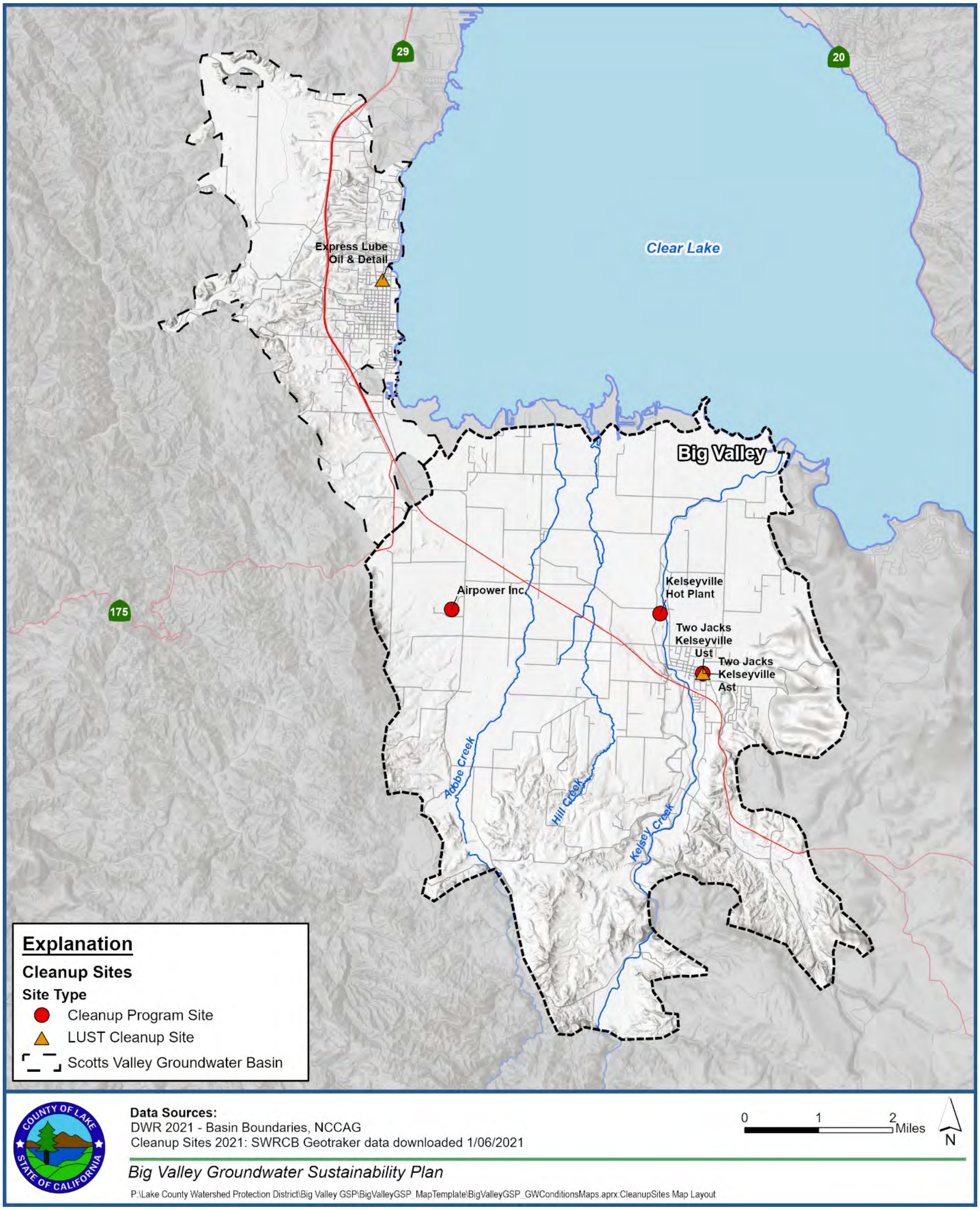


Figure 2-34. Open Cleanup Sites in Big Valley Basin

2.2.2.4 Land Subsidence

Subsidence occurs when groundwater is extracted from the pore spaces in the geologic material, leading to compaction. The compaction causes the ground surface elevation to drop. In addition to groundwater extraction, oil and gas extraction can lead to subsidence. There are no active oil or gas wells in the Big Valley Basin (CalGEM 2021). The Geysers Geothermal Field is located approximately five miles south of the Basin. Although a number of exploratory and geothermal gradient wells have been drilled in and around the Basin, there are no active geothermal fluid extraction wells in the Basin (CalGEM 2021). As a result, land subsidence related to the extraction of geothermal fluids is not currently a concern in the Basin.

In 2015 DWR began reporting InSAR surveys to assist with subsidence studies related to SGMA. Vertical measurements are collected by the European Space Agency Sentinal-1A satellite and compared to previous measurements to establish a change in surface elevation. The vertical measurements are collected as point data sets that represent 100-meter by 100-meter areas and are used to interpolate grid maps.

Maximum vertical displacement measured using the InSAR approach from June 2015 to October 2020 was -0.25 feet in the Big Valley Basin (**Figure 2-35**). On average, the maximum subsidence in the Basin was -0.05 feet per year. This measured subsidence is likely elastic subsidence, meaning the land surface can recover (rise) if groundwater is recharged and again fills the pore spaces. This elastic subsidence is not a cause of concern. Based on the available evidence, inelastic land subsidence that results in permanent land compaction and loss of groundwater storage is not occurring in the Big Valley Basin.

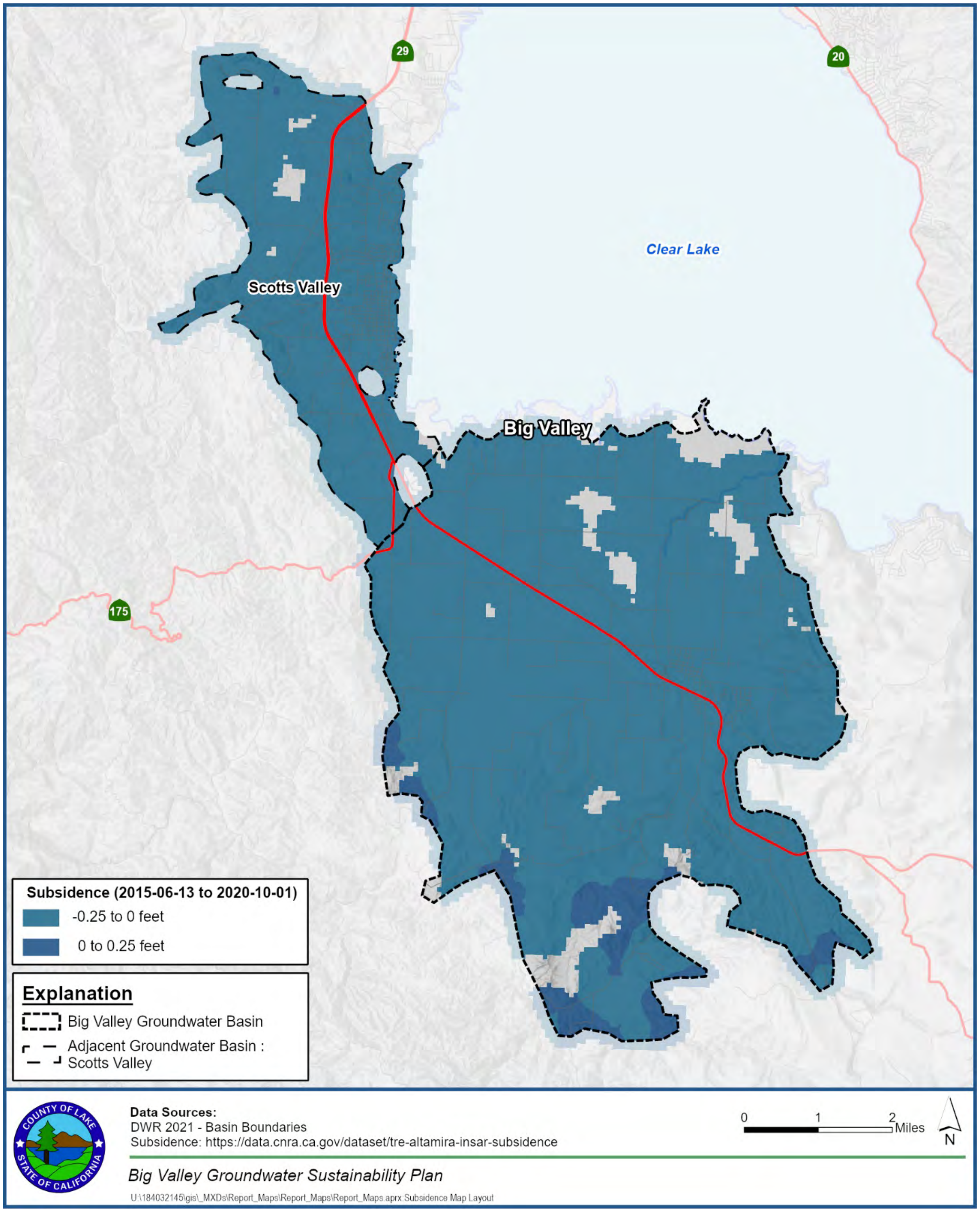


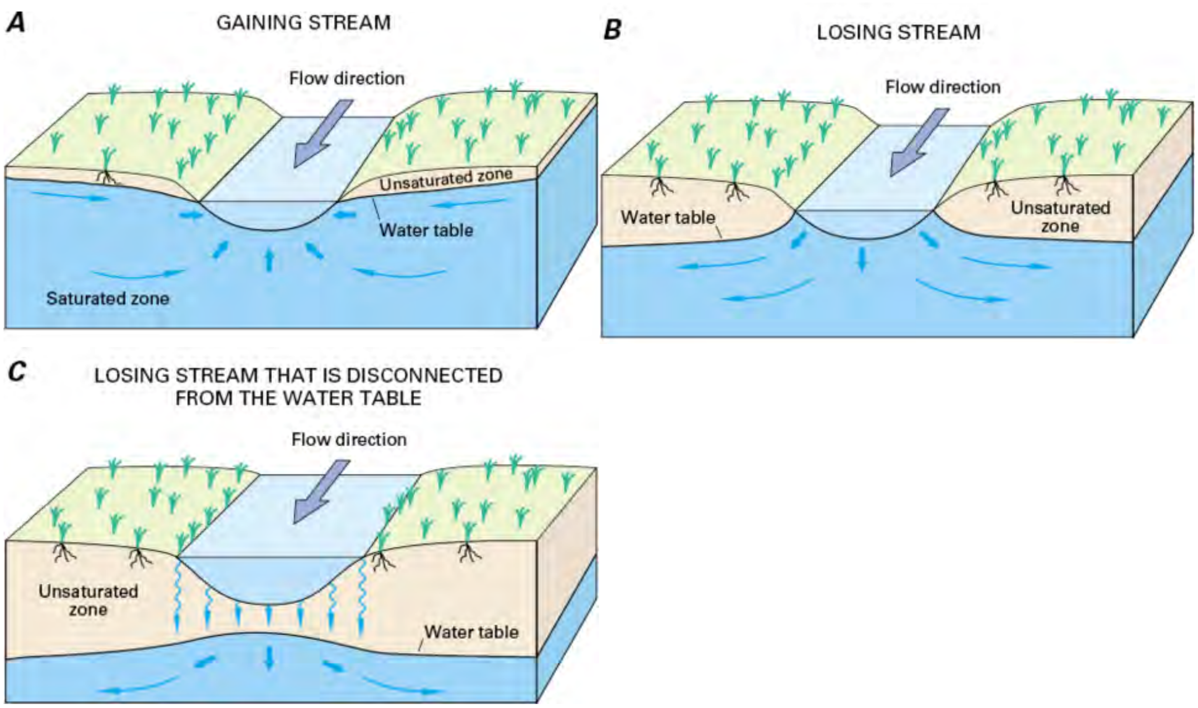
Figure 2-35. Observed Land Subsidence in Big Valley (2015 to 2020)

2.2.2.5 Interconnected Surface Water Systems

Interconnected Surface Water Systems

Surface water and groundwater systems are often connected, resulting in: (1) streams gaining water from inflow of groundwater through the streambed, (2) streams losing water by outflow through the streambed, and (3) streams losing and gaining depending upon the location along the stream. Groundwater inflow to streams is critical for sustaining their flow during dry periods. While streams discharge to groundwater systems is also critical for groundwater recharge and maintenance of healthy aquifer systems, the movement of water between groundwater and surface-water systems can affect the water quality of both systems.

For a stream to gain water, the elevation of the water table adjacent to the stream must be higher than the stream-water surface (**Figure 2-36**). For a stream to lose water to groundwater, the water table must be below the elevation of the adjacent stream-water surface. A losing stream can be hydraulically connected or disconnected from the underlying groundwater aquifer. If the water table has large variations during the year, a stream segment could receive water from groundwater for a portion of the year and lose water at other times.



Source: USGS Circular 1186

Figure 2-36. Illustrations of Surface Water-Groundwater Interaction: (A) a Gaining Stream, (B) a Losing Stream, and (C) Losing Stream Hydraulically Disconnected

In Big Valley Basin, there are two primary, gauged streams—Kelsey Creek and Adobe Creek (**Figure 2-37**). There are two active streamflow gauge stations on Kelsey Creek, one monitored by the USGS on the upstream segment and another by DWR on the downstream segment 500 feet upstream Soda Bay Road Bridge. The DWR station (CDEC KCK, Station number A85005) has data from 1980 to present, with a gap in 1991, 2005, and 2006. The USGS gauge (USGS 11449500) has a record of streamflow data since 1947.

Adobe Creek had one USGS gauge (USGS 11448500) above the Adobe Creek reservoir with a streamflow record from 1954 to 1978. Just outside the Basin, there was a USGS gauge (11449000) on Highland Creek (USGS 11449000) upstream of Highland Springs Reservoir that collected streamflow data from 1954 to 1962.

There are no streamflow gauges at the reservoir outlets nor downstream Adobe and Highland Springs Reservoirs. However, the Big Valley Rancheria has two efforts that will help address these data gaps. In 2018, the Big Valley Rancheria placed three transducers along Adobe Creek. There are plans to convert the collected stage data into flow data in the future. From the transducer data, the Rancheria, in collaboration with FlowWest, developed a synthetic hydrograph for Adobe Creek (FlowWest 2020). Additionally, in 2021, the Big Valley Rancheria was awarded a Bureau of Indian Affairs Triable Climate Resilience Grant to install a gauge at Highland Springs and Adobe Creek Reservoirs.

The other streams in Big Valley Basin—Manning Creek, Thompson Creek, McGaugh Slough, Hill Creek, and Cole Creek—are not monitored for streamflow.

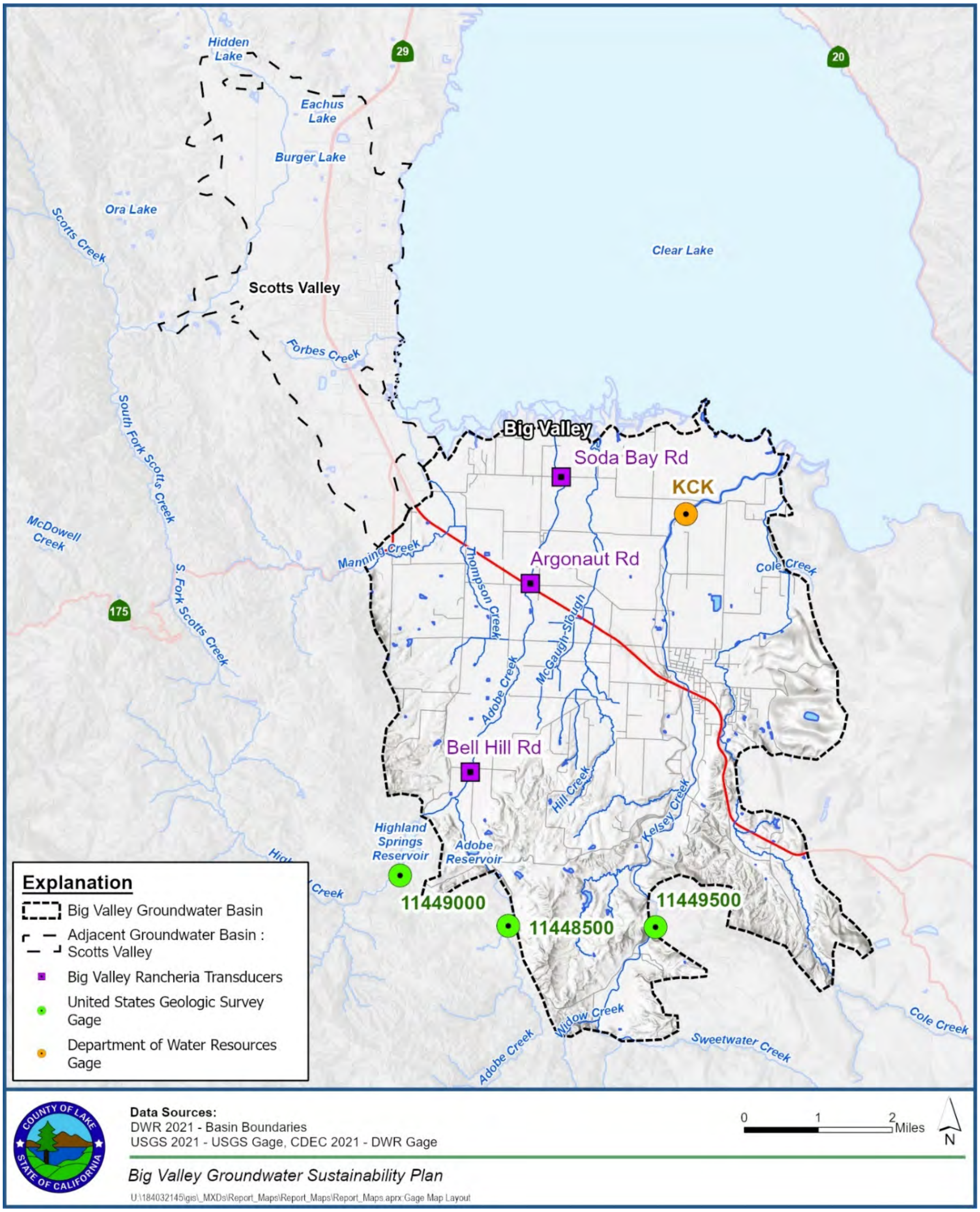


Figure 2-37. Surface Water Gauges in Big Valley Basin

Kelsey Creek Streamflow

The flow in Kelsey Creek is precipitation dependent. As such, it varies seasonally, with higher flows in the wet, winter months and lower flows in the dry, summer months (**Figure 2-38**). Over the past decade, the monthly average flow ranged from about 100 to 700 cfs in the winter months and less than 1 to 20 cfs in the summer months. Note that summer flows in 2014 and 2015 are the lowest daily and monthly mean over the historical record, coinciding with the statewide drought.

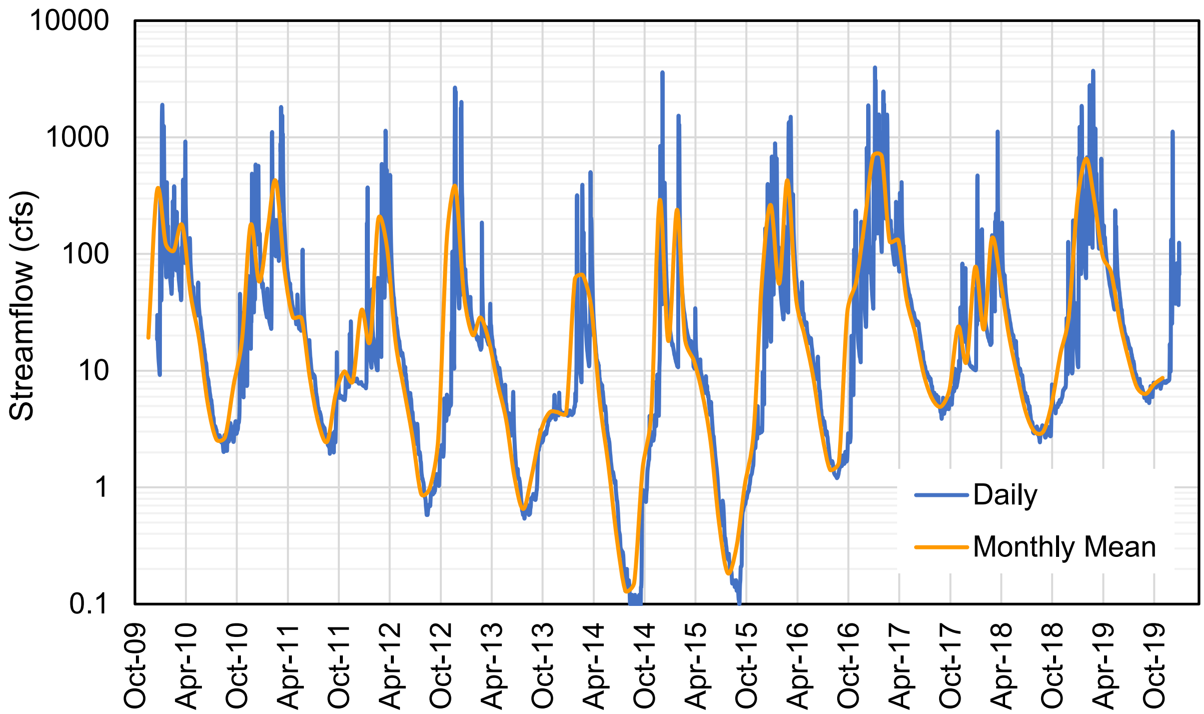


Figure 2-38. Kelsey Creek Streamflow 2010-2020 at USGS Station 11449500 (logarithmic scale)

Figure 2-39 compares the streamflow at the upstream USGS gauge and the downstream DWR gauge for the period of 2015 to 2021. Winter daily flows in Kelsey Creek can exceed 1,000 cfs, while summer flows fluctuate between 1 and 10 cfs. As further exemplified in **Figure 2-40**, during winter months, flows at the downstream gauge are slightly higher than those at the upstream gauge, reflecting runoff to the streams. However, the largest contribution to Kelsey Creek flow is from areas outside the Big Valley Basin. During summer months, there is little to no flow in Kelsey Creek south of the Main Street Bridge in Kelseyville.

The long-term average annual Kelsey Creek streamflow is 71 cfs, with streamflow varying between wet and dry years (**Figure 2-41**). In years with lower-than-average precipitation (e.g., 1977 and 2014), the annual average streamflow ranges from 5 to 75 cfs. However, in years with higher-than-average precipitation (e.g., 2017 and 2019), the annual average streamflow ranges from 75 to 205 cfs.

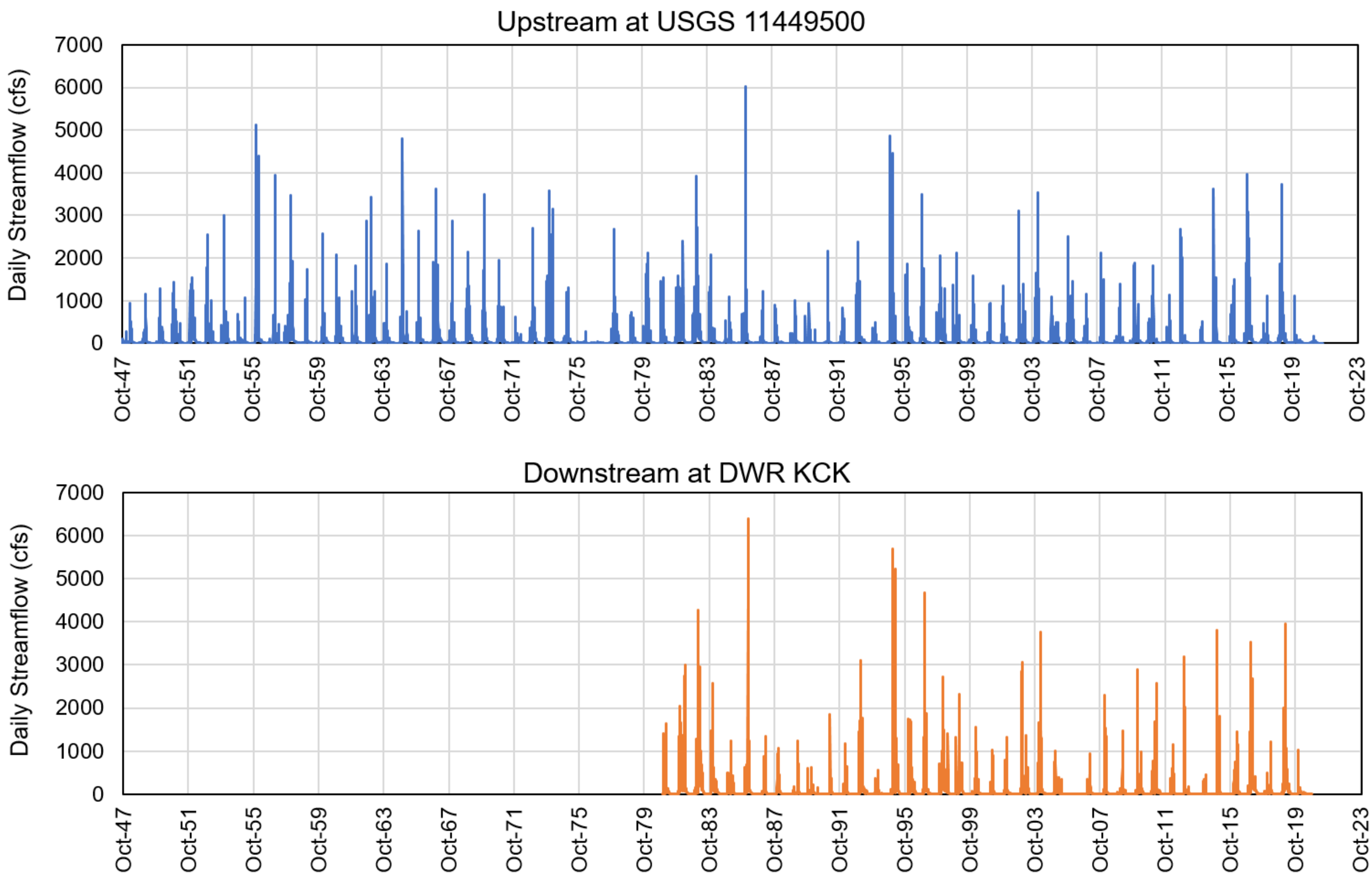
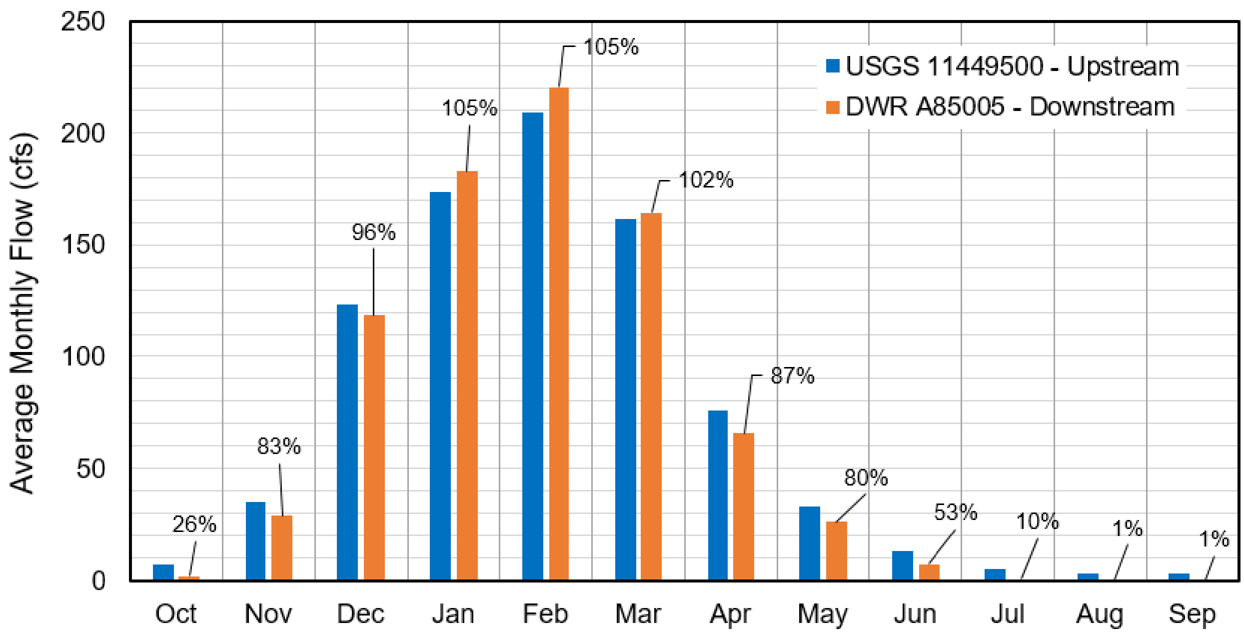


Figure 2-39. Kelsey Creek Daily Streamflow at Upstream and Downstream Gauge Stations (1954-2021)



Notes: the percentages are the ratio of downstream flow to upstream flows

Figure 2-40. Kelsey Creek Annual Monthly Streamflow at USGS Station 11449500 compared to DWR KCK (1980-2020)

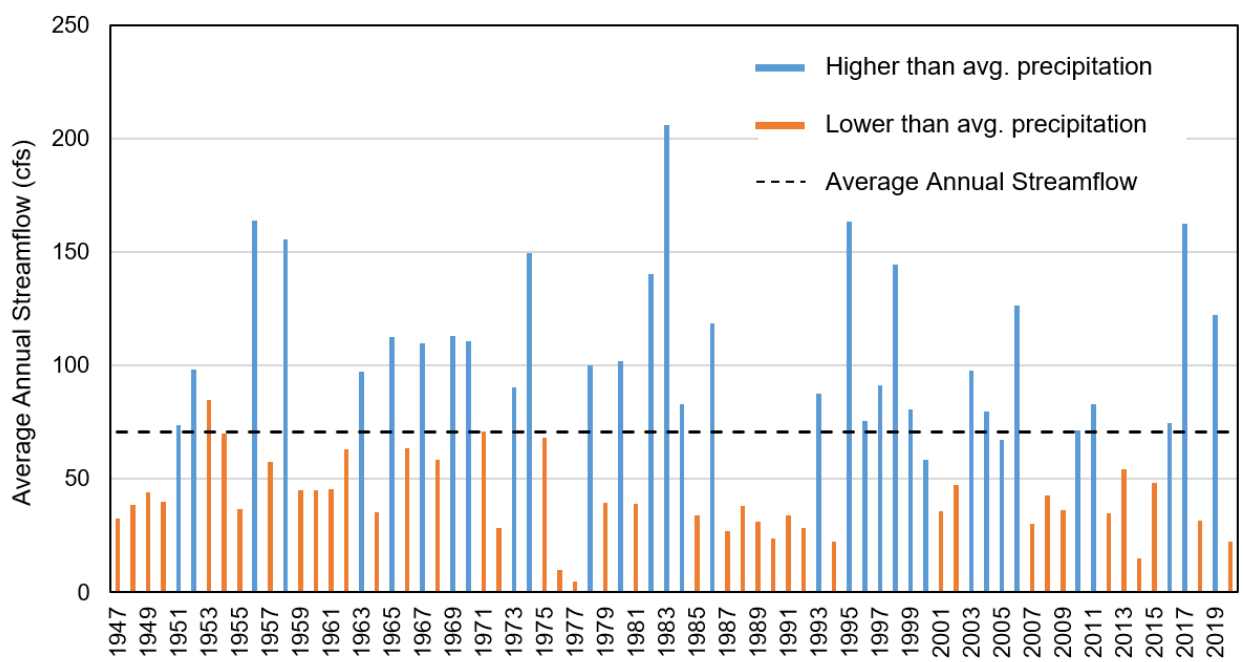


Figure 2-41. Kelsey Creek Annual Average Streamflow at USGS Station 11449500 (1947-2020)

Kelsey Creek Connection to Groundwater

To understand the relationship between Kelsey Creek and the groundwater aquifer, **Figure 2-42** compares the profile of Kelsey Creek channel with the groundwater elevations along the creek channel for representative wet and dry conditions. **Figure 2-42** shows that Kelsey Creek immediately downstream of State Highway 29 is potentially hydraulically connected to the groundwater basin for up to 2 miles during wet conditions (winter and spring).

As demonstrated in the HCM (refer to cross-section D-D'), and by Christensen Associates, Inc. (Lake County 2003), the channel of Kelsey Creek changes composition which impacts the ability for recharge. From the Main Street Bridge, "Kelsey Creek is directly floored by strata of the Kelseyville Formation which provides little opportunity for recharge" (Lake County 2003). Downstream of the Main Street Bridge, the Creek channel is highly permeable with coarse sandy and gravel bed (**Figure 2-43**). "This channel reach of Kelsey Creek provides the principal recharge to the aquifers of the northern Big Valley area" (Lake County 2003).

During dry conditions (summer and fall), the portion of the creek that is hydraulically connected shrinks to less than 1 mile. In this area of seasonal hydraulic connectivity, the creek may be gaining and losing depending on surface water elevation in the creek, relative to groundwater elevations. Downstream of the area with seasonal hydraulic connectivity, the creek is losing and also may be hydraulically disconnected from the groundwater aquifer. The summer and fall low flows coincide with the bulk of groundwater extraction to accommodate agricultural demands (FlowWest 2020). In the wet months of February and March, groundwater is extracted for frost protection. There is a concern by some stakeholders in the Basin that groundwater pumping for frost protection may reduce streamflow during hitch spawning causing entrapment. However, when comparing the downstream flow to the upstream flow, there is no apparent differences that would indicate sudden surface water reduction indicative of the frost protection impacts.

However, confirmation of the impacts to surface water, as well as characterization of hydraulic connectivity, would require additional intermediate surface water gauges and monitoring with new shallow monitoring wells to better understand the nature and timing of hydraulic connectivity in this section of the creek.

Figure 2-44 compares Kelsey Creek streamflow at DWR KCK gauge to groundwater elevations at nearby well (ID 13N09W02C002M). It shows that streamflow increases during the winter months, peaking around February-March and decreases to a minimum around July-August. The groundwater elevations also follow a similar pattern, reflecting recharge cycles and summer groundwater extraction in the Basin. However, **Figure 2-44** reveals there is about a one- to two-month lag between the surface water and groundwater response to the dry and wet cycles. Groundwater elevations peak around April, while streamflow peaks around February-March. The lowest groundwater elevation is typically around October and shows increases shortly thereafter, indicating recharge. Conversely, when daily streamflow decreases, so does the groundwater surface.

It is important to note that the well data is gathered bi-annually whereas the streamflow data is gathered daily. While there is a pattern between streamflow and groundwater elevations, there is a lack of sufficient spatial and temporal data to determine the groundwater pumping impacts to surface water flow.

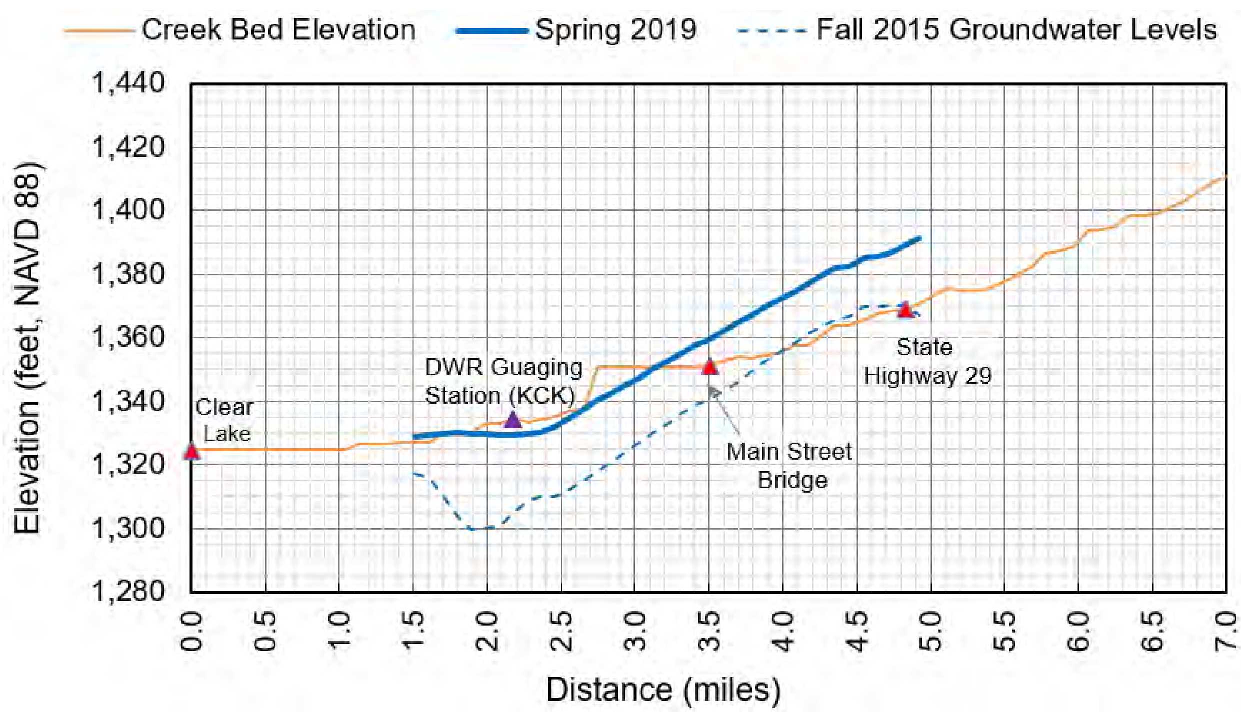


Figure 2-42. Profile of Kelsey Creek Channel Relative to Groundwater Elevations During Representative Wet and Dry Conditions

Figure 2-43. Kelsey Creek Channel Downstream (left) and Upstream (right) from the Main Street Bridge

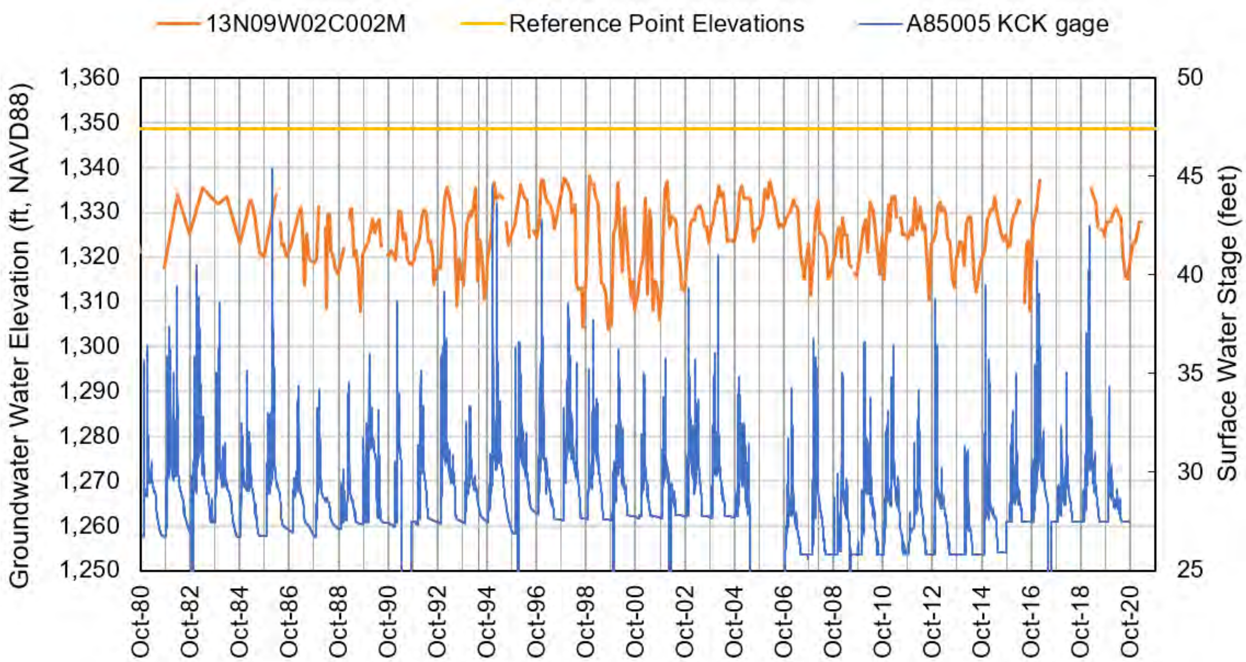


Figure 2-44. Kelsey Creek Daily Stage Relative to Nearby Well Groundwater Elevation (1980 to 2021)

Kelsey Creek Streamflow Depletions

Figure 2-45 to Figure **2-47** show the interim results of the potential stream depletion rate due to groundwater pumping simulated by the Big Valley Basin's integrated hydrologic model. The model was run for KCK stream gage station, above HW29, and Adobe Creek. In these figures, the spring groundwater elevations at three monitoring wells were compared to the average annual depletion of Kelsey Creek (at KCK and above HW29) to assess how the historical rates of stream depletion changes in different water years.

No significant correlation was identified between the surface water depletions and groundwater elevations at the six monitoring wells. The lack of correlation fits with the fact that the groundwater elevation measurements were made at deep wells reflecting deeper aquifers. It is expected to see a correlation between depletion and shallow groundwater elevations.

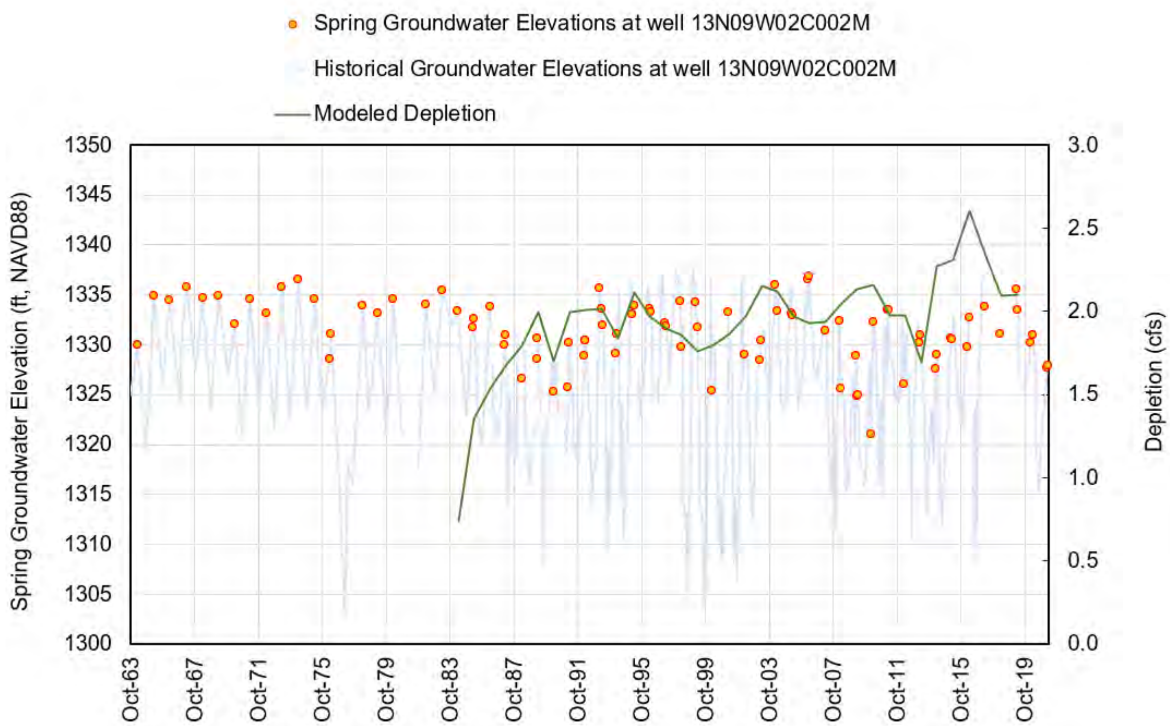


Figure 2-45. Spring Groundwater Elevation Measurements at Well 13N09W02C002M and Modeled Average Annual Depletion at KCK Stream Gage Stations

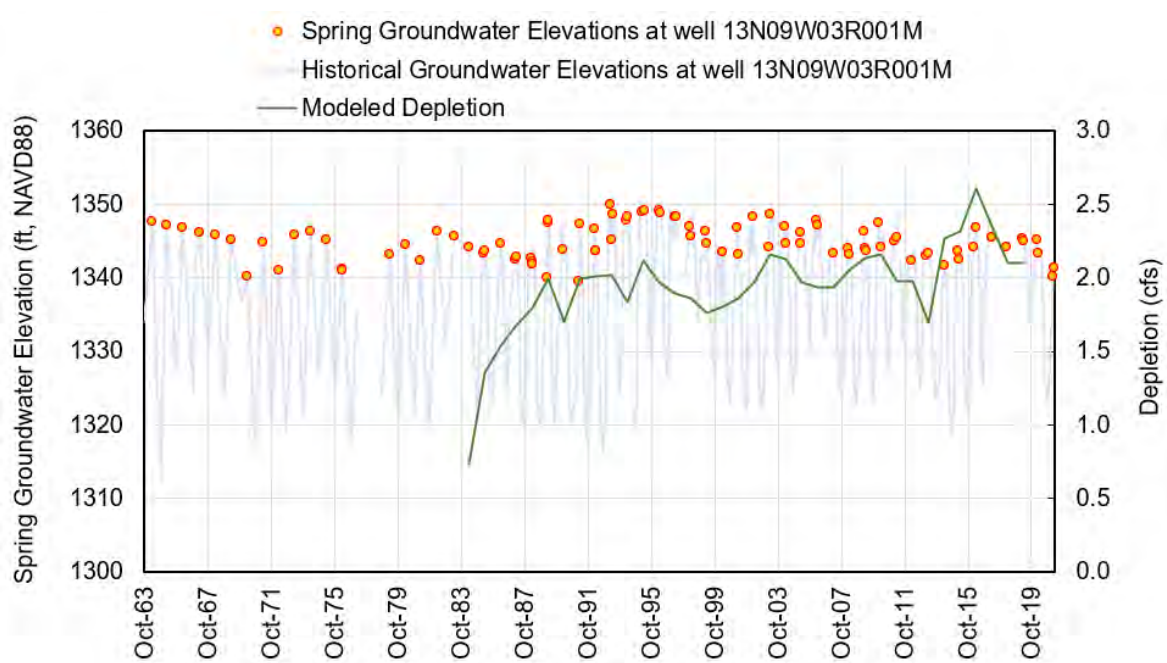


Figure 2-46. Spring Groundwater Elevation Measurements at Well 13N09W03R001M and Modeled Average Annual Depletion at KCK

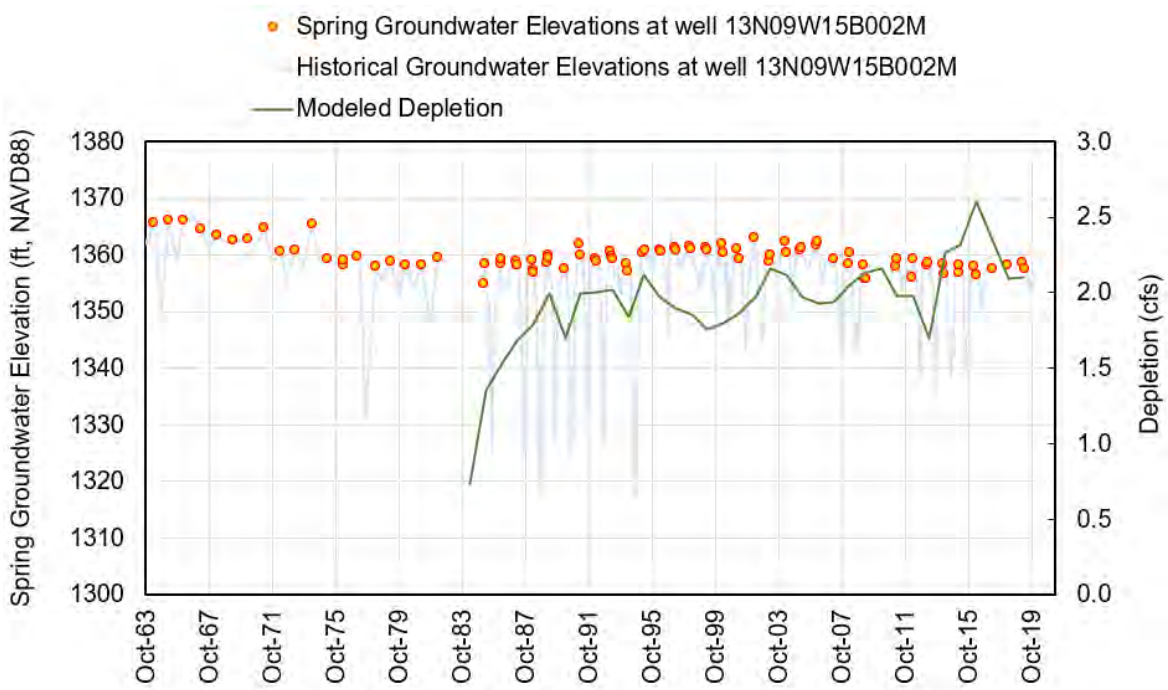


Figure 2-47. Spring Groundwater Elevation Measurements at Well 13N09W15B002M and Modeled Average Annual Depletion at KCK

Adobe Creek Streamflow

Figure 2-48 shows daily Adobe Creek streamflow record upstream of Adobe Creek Reservoir and Highland Springs Reservoirs, in addition to the synthetic data for Adobe Creek below the reservoirs.[1] It shows that Adobe Creek is also a precipitation dominant stream. In the dry, summer months, there is little to no flow; however, in the wet, winter months streamflow can reach over 1,200 cfs a day. This pattern can also be observed on a monthly basis (**Figure 2-49**).

Figure 2-50 shows the annual variability in flow due to dry and wet conditions. In years with lower-than-average precipitation (e.g.,1994 and 2013), the annual average streamflow can be less than 15 cfs, based off the synthetic data. However, in years with higher-than-average precipitation (e.g.,1983 and 2019), the annual average streamflow can range between 40 to 129

[1] FlowWest (2020): "T*o estimate streamflow for Adobe Creek, FlowWest implemented a statistical model that used nearby Kelsey Creek flows to estimate Adobe Creek flows. The streamflow data for 1971-1977 for both creeks was used to parameterize the model. The model performed very well with a reported adjusted R-squared value of 0.92, a value that ranges from 0 to 1 to indicate the total variance explained by the model. The 1970 data was then used to quantify how well the model predicted streamflow for Adobe Creek. Using the 1970 flow data as a validation dataset, the model predictions were less than 1 cfs away from actual observed data. This model was then used to estimate daily streamflow for the years 1978-2019."*

cfs. For real-time data on Adobe Creek, **Figure 2-51** shows the stage data gathered from the transducers. The transducers also show the wet and dry cycle.

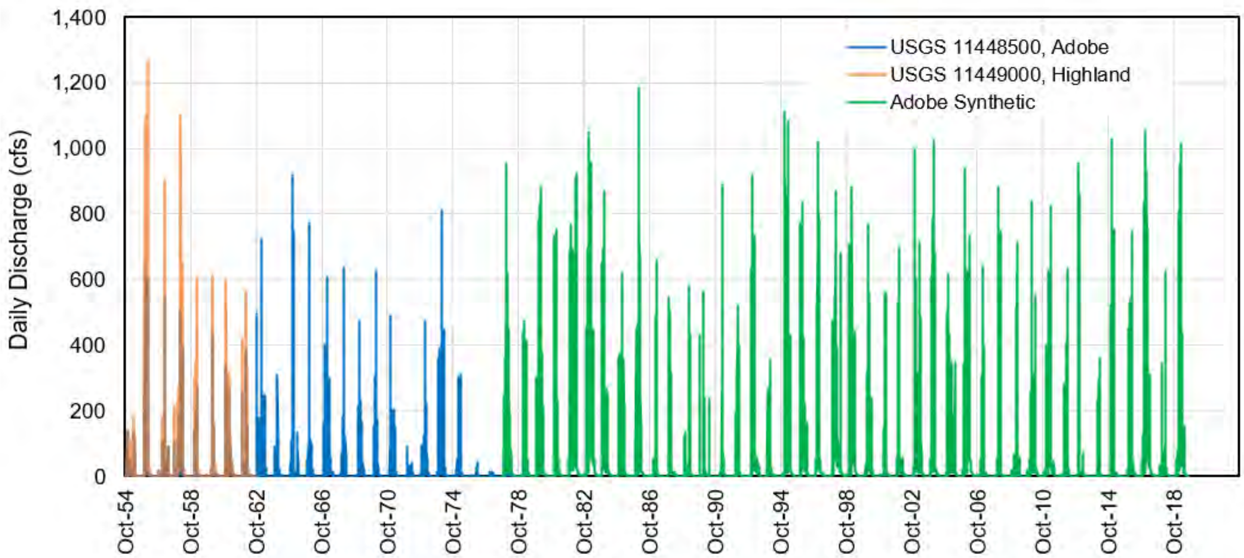


Figure 2-48. Adobe Creek Streamflow at USGS Station 11448500, USGS Station 11449000, and Synthetic Data from FlowWest (1954-2019)

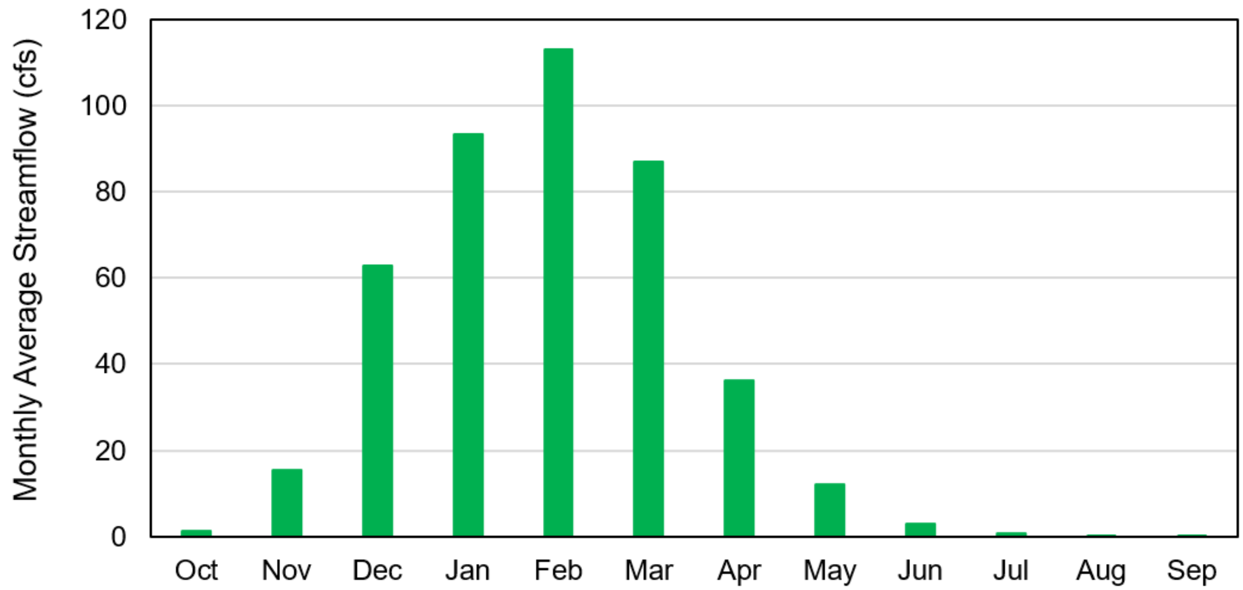


Figure 2-49. Adobe Creek Monthly Average Streamflow Using FlowWest Synthetic Data (1977-2019)

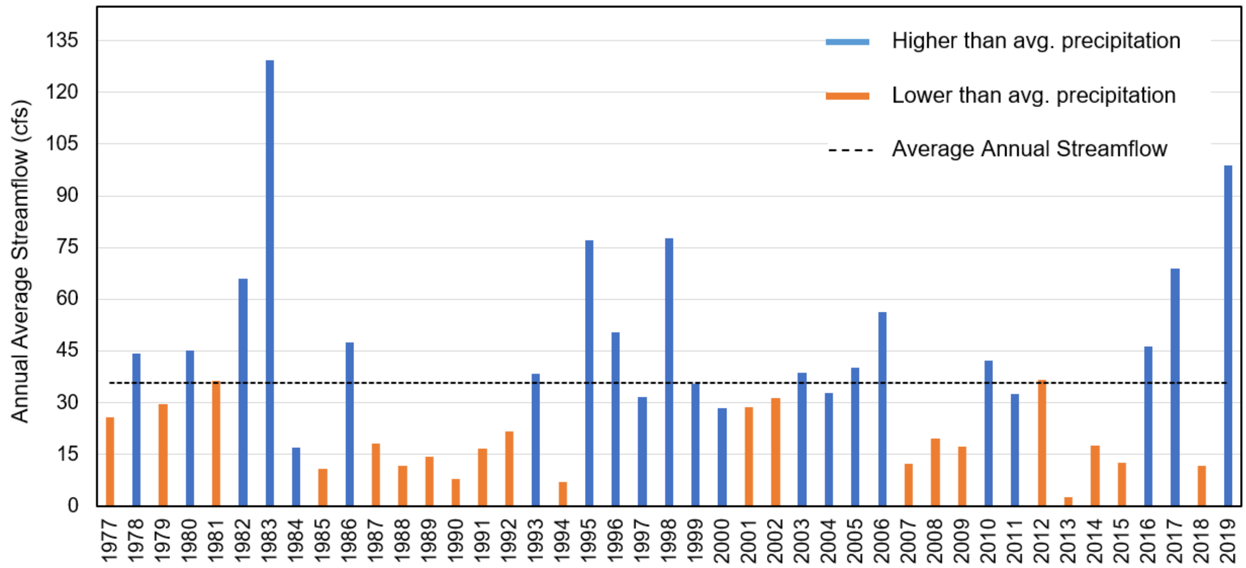
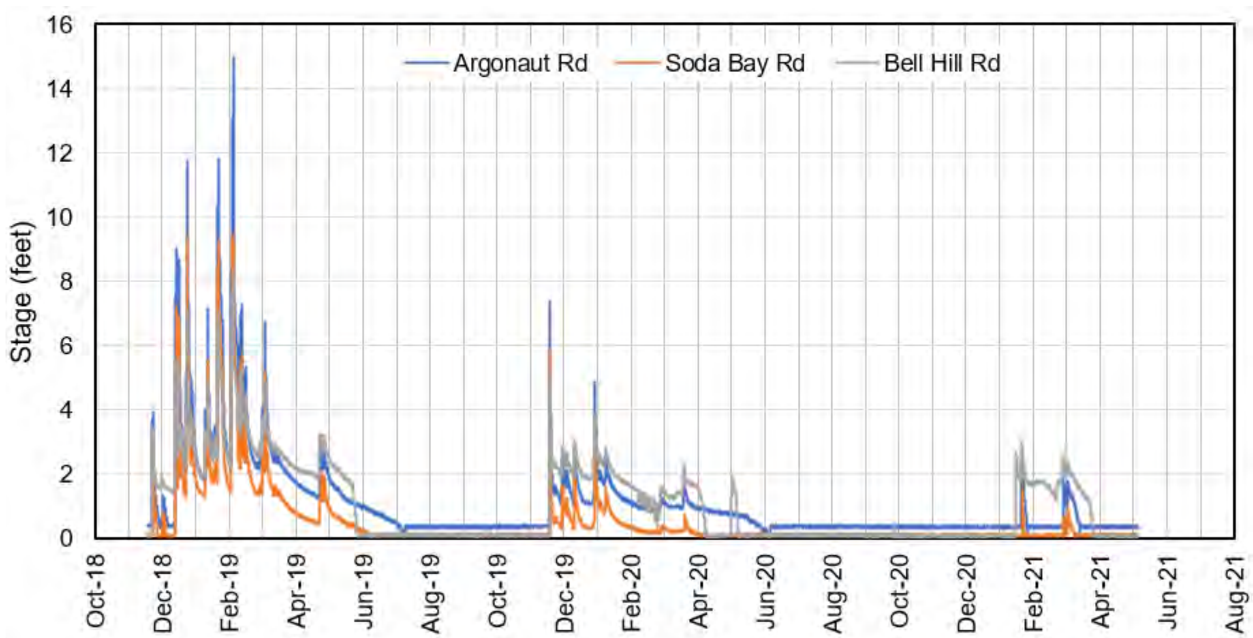


Figure 2-50. Adobe Creek Annual Average Streamflow Using FlowWest Synthetic Data (1977-2019)



Source: Flow West (2021)

Figure 2-51. Adobe Creek Surface Water Stage at Argonaut Road and Soda Bay Road (2019-2021)

Adobe Creek Connection to Groundwater

Figure 2-52 compares the profile of the Adobe Creek channel with the groundwater elevations along the creek channel for representative wet and dry conditions. It shows that Adobe Creek is hydraulically connected to the groundwater aquifer for approximately 1.3 miles upstream from State Highway 29 during wet conditions (winter and spring). However, during dry conditions (summer and fall), Adobe Creek is losing water and also may be hydraulically disconnected from the groundwater aquifer due to low flows in the creek and increased groundwater extraction. Confirmation of the disconnected condition would require monitoring with new shallow monitoring wells to better characterize the nature and timing of hydraulic connectivity in this section of the creek.

During wet conditions, the creek may be gaining and losing depending on the flow in the creek as regulated by releases from Adobe Creek and Highland Springs Reservoirs. During dry conditions, Adobe Creek is losing (i.e., contributing recharge) to the groundwater aquifer.

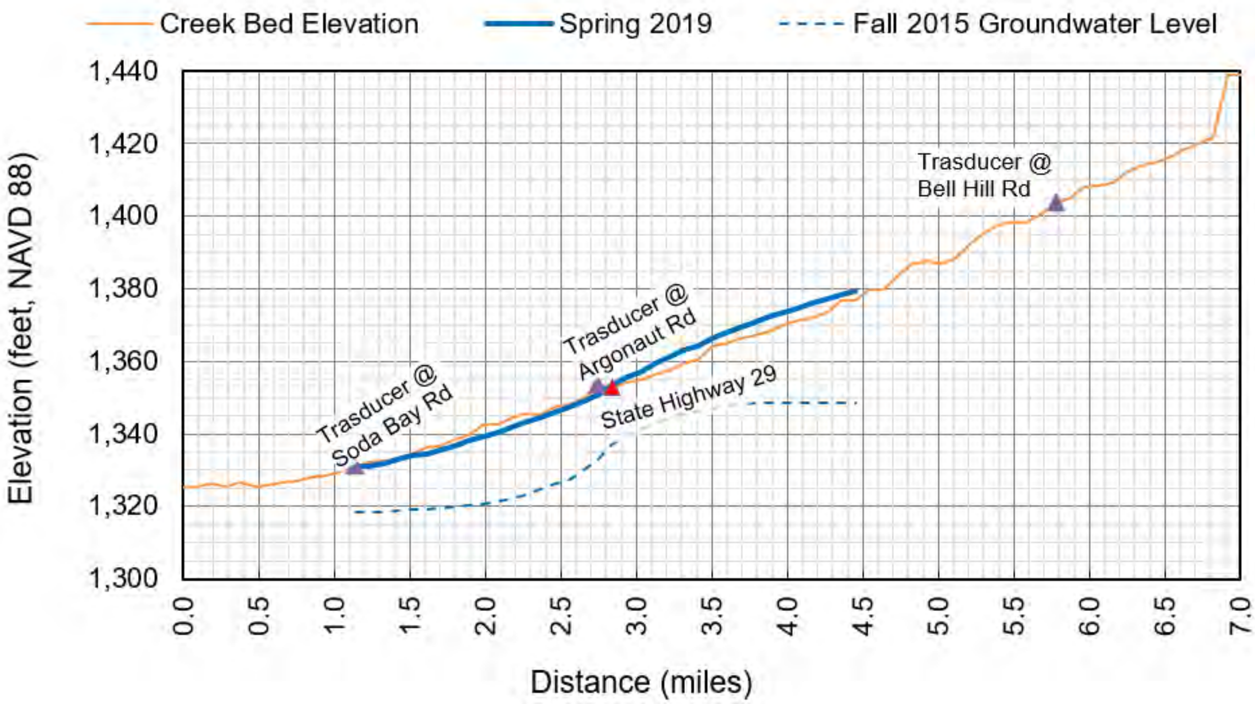


Figure 2-52. Profile of Adobe Creek Channel Relative to Groundwater Elevations During Representative Wet and Dry Conditions

Adobe Creek Streamflow Depletions

Figure 2-53 through **Figure 2-55** show the interim results of the potential stream depletion rate (or volume) due to groundwater pumping simulated by Big Valley Basin's integrated hydrologic model at Adobe Creek. Similar to Kelsey Creek, the spring groundwater elevations at three monitoring wells were compared to the average annual depletion to assess the historical rates of stream depletion correlation to groundwater elevation or water year type. Again, no significant correlation was identified between the surface water depletions and groundwater elevations in neither of wells. As discussed before, these groundwater elevation measurements were made at deep wells which may not be representative of shallow aquifers.

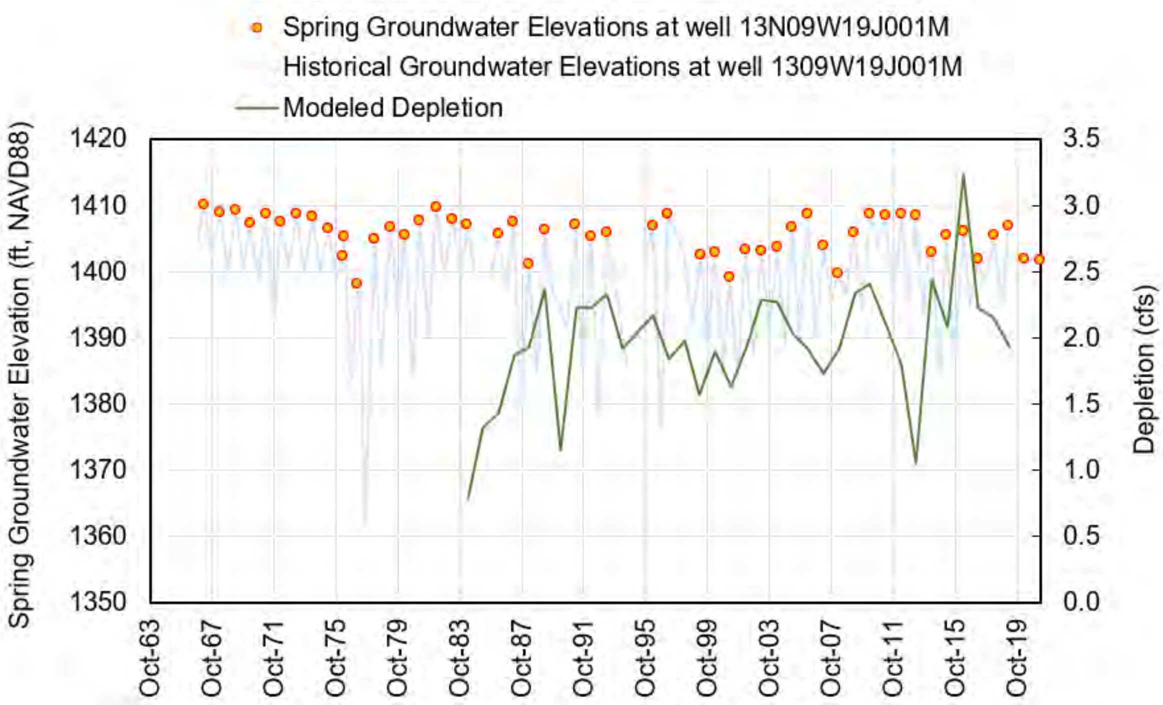


Figure 2-53. Spring Groundwater Elevation Measurements at Well 13N09W19J001M and Modeled Average Annual Depletion at Adobe Creek

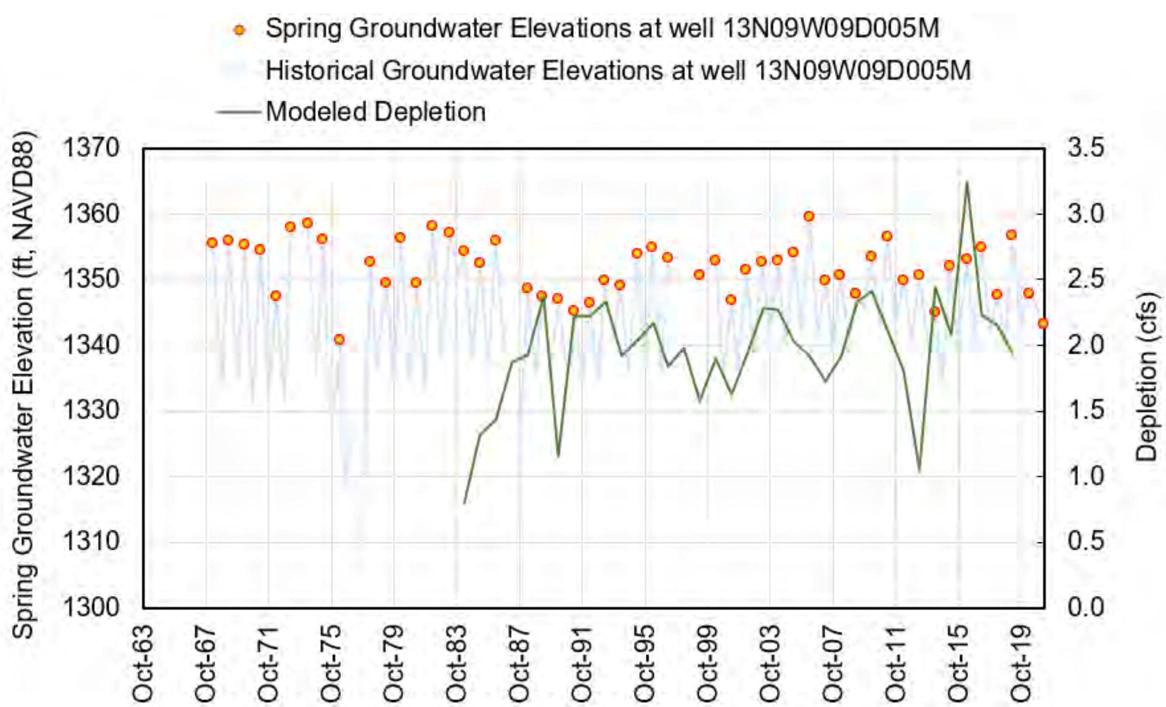


Figure 2-54. Spring Groundwater Elevation Measurements at Well 13N09W09D005M and Modeled Average Annual Depletion at Adobe Creek

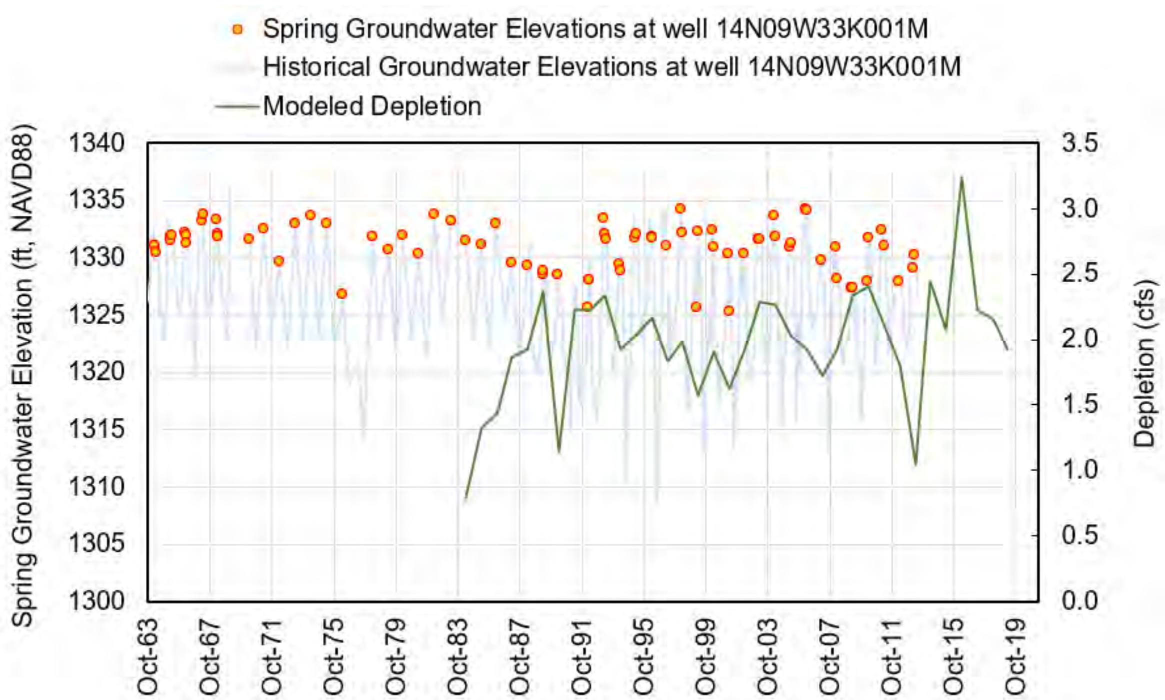


Figure 2-55. Spring Groundwater Elevation Measurements at Well 14N09W33K001M and Modeled Average Annual Depletion at Adobe Creek

Other Big Valley Creeks Connection to Groundwater

There are several other streams in Big Valley, including Manning Creek, Thompson Creek, McGaugh Slough, Hill Creek, and Cole Creek (see **Figure 2-3**). These streams are not currently monitored for flow or stage even though there is water quality data. Pattern of connection to groundwater for these creeks is likely to follow the same pattern for Kelsey and Adobe Creeks. These creeks are likely to be losing during low groundwater elevation conditions (summer and fall) and gaining in certain locations if groundwater elevations are high enough during winter and spring.

Simulated Surface Water-Groundwater Interconnection

The calibrated Big Valley Integrated Hydrological Model (BVIHM) was used to simulate the interconnection between surface water and groundwater in Big Valley Basin. **Figure 2-56** shows the average monthly relationship between surface water and groundwater for 2015, a dry year. Figure **2-57** shows the same relationship for 2018, a wet year. The relationship between surface bodies and groundwater aquifer are reflected in the following three conditions:

- “Red” color indicates the surface water body losing to groundwater aquifer because groundwater elevations are lower than creek bed.
- “Blue” color indicates the surface water body gaining from groundwater aquifer because groundwater elevations are higher than the creek bed.
- “Black” color indicates no surface water flows in the creek.

Figure 2-56. Simulated Average Monthly Interconnection of Surface Water Bodies in Big Valley Basin for 2015.

Figure 2-56 and Figure 2-57 show that during summer and fall (June to October) there are no flows in most of creeks except on Kelsey Creek and in the upper portions of Basin. During winter and spring (November to May), flows in these rainfed creeks vary based on amount of precipitation during wet and dry years.

Groundwater elevations are low during summer and fall. As winter rain starts and creeks start to flow, these creeks turn from black-colored (i.e., dry) to red-colored (i.e., contributing recharge to the groundwater aquifer). This typically starts in October-November.

As rainfall continue from December to April, portions of the creeks turn from red-colored to blue-colored (i.e., gaining flow from the groundwater aquifer). This occurs because the groundwater elevations rise and reach creek bed elevations at various locations in the Basin. This pattern applies to most creeks in the basin, include Adobe Creek.

As discussed earlier, Kelsey Creek above Main Street Bridge remains connected to groundwater aquifer because of the high groundwater elevations in that area. That section of the creek is blue-colored, indicating gaining conditions. However, the magnitude of these gains is likely small because of the observed low hydraulic conductivity of the creek bed material in that section.

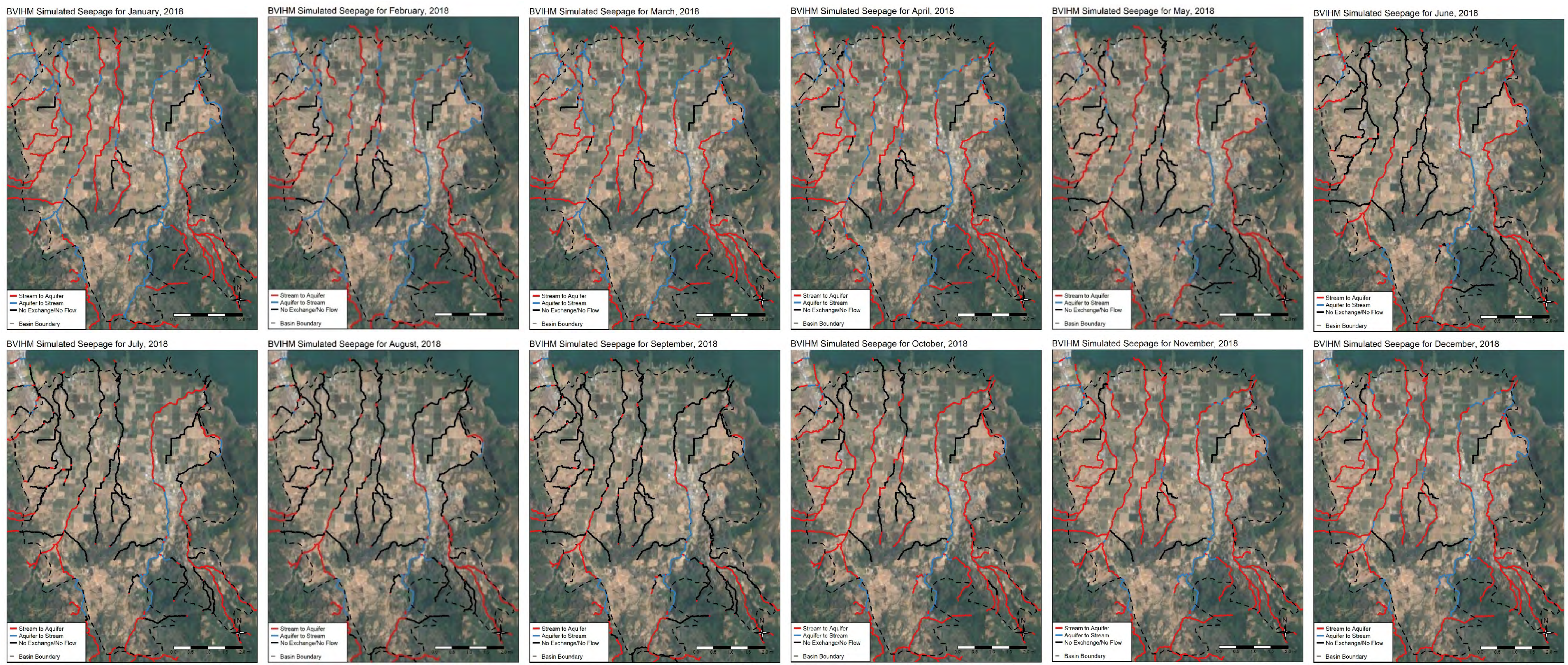


Figure 2-57. Simulated Average Monthly Interaction of Surface Water Bodies in Big Valley Basin for 2018

2.2.3 Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDE) are defined as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" (Cal. Code of Regs, title 23, § 351[m]). Sustainable groundwater management under SGMA singles out six "undesirable results" to be avoided, one of which is the adverse impacts on GDEs. Identifying and assessing GDEs can be relevant for assessing whether certain groundwater management activities may have an undesirable impact on the beneficial uses of surface water that may be associated with GDEs.

2.2.3.1 Identification of GDEs

GDEs are a subset of the existing habitat in the Basin that rely on groundwater as their primary source of water that is crucial to their survival. Most of the undeveloped land in Big Valley Basin is covered with dense California chaparral type brush. Areas of open grassland with scattered brush and trees also exist in the upper portions of the valley. Riparian habitat within the Big Valley Basin exists along the creeks. There are no federal or state wildlife refuge areas within the Basin. However, the Lake County Land Trust owns two properties close to the Basin, Melo Wetland Preserve and Wright Property. Both of these areas are wetland preserves and a part of the California Department of Fish and Wildlife (CDFW)-approved Big Valley Wetlands Conceptual Area Protection Plan.

The identification of GDEs can be performed by assessing whether a habitat would exist if groundwater levels were deeper than the root zone. If the answer is "no," then it is a GDE. If the answer is "yes, the ecosystem would exist if groundwater levels were deeper," then it is not a GDE.

The identification of GDEs for the Big Valley Basin relied on the Natural Communities Commonly Associated with Groundwater (NCCAG) database. The NCCAG database was developed by a working group composed of DWR, CDFW, and The Nature Conservancy (TNC). The database was developed from publicly available state and federal agency datasets that mapped California vegetation, wetlands, springs, and seeps, and these were screened to retain types and locations commonly associated with groundwater. TNC advises that if sufficient data are not available in time for the 2020/2022 plan, questionable polygons from the NCCAG dataset be included in the GSP until data gaps are reconciled in the monitoring network. The NCCAG database defined two habitat classes:

- Wetland features commonly associated with the surface expression of groundwater under natural, unmodified conditions.
- Vegetation types commonly associated with the subsurface presence of groundwater (i.e., phreatophytes).

Figure 2-58 shows the habitat locations identified by the NCCAG database within the Big Valley Basin. Wetlands are identified along most of the tributaries to Clear Lake including Adobe Creek, Kelsey Creek, Manning Creek, Thompson Creek, Hill Creek, and Cole Creek. Riparian mixed hardwood habitat (40.2 acres) is identified along the downstream section of Kelsey Creek (**Figure 2-58**, inset 1). Fremont cottonwood habitat (6.9 acres) is identified upstream of Adobe Creek Reservoir (see **Figure 2-58**, inset 2).

All the NCCAG identified habitats in the Big Valley Basin are along the creeks, which are likely connected to the underlying aquifer. These creeks undoubtedly contribute water to recharge the aquifer. However, the degree of the aquifer's contribution to the creeks and their adjacent habitats is unclear. During different hydrologic conditions (i.e., wet and dry periods), the degree and importance of the aquifer's contribution to the creeks may vary.

The distinction between GDEs and NCCAGs that are not GDEs is important from a management perspective. As noted above, GDE is an important beneficial use designation under SGMA. Management of GDEs has a strong linkage to groundwater use, while management of NCCAGs may require focus on land use or irrigation activities, more so than groundwater management. Criteria for identifying GDEs within the NCCAGs requires verification that these habitats rely on groundwater rather than another readily available abundant source of water that these habitats have access to.

These criteria include the following:

- **Habitats able to access shallow groundwater** – According to the GDE rooting depth database[2] and University of California Cooperative Extension Master Gardener Program of Lake County, oak trees are considered amongst the most common plants and also the deepest-rooted species in the region, with a maximum root zone of roughly 30 feet. Therefore, NCCAGs where groundwater is within 30 feet of the ground surface were considered capable of accessing shallow groundwater and are designated as potential GDEs, pending the verification of other criteria steps in the process.

- **Habitats supplied with supplemental water** – NCCAGs that are managed habitat receiving supplemental irrigation supplies, such as irrigated refuges and managed wetlands, are not considered GDEs.

- **Habitats adjacent to surface water seepage sources** – NCCAGs that are adjacent to—that is, within 50 feet of—irrigated fields, surface water reservoirs, and drainage canals are considered able to access seepage from these features as their primary supply source. This is because horizontal hydraulic conductivity is typically much higher than vertical conductivity. Habitats in proximity of surface water seepage tend to access them more readily than deeper groundwater. As such, they are not considered GDEs.

- **Population of certain animal classes** – If there is a decline in the population of certain animal classes (e.g., fish, amphibians, reptiles, mammals, birds, anthropoids) compared to baseline conditions or there has been loss of an endemic species or species listed as a sensitive, threatened, or endangered species associated with the groundwater conditions, the species are considered as GDEs.

Terrestrial Habitat

The two NCCAGs identified as GDEs in the Big Valley Basin are Fremont cottonwood and riparian mixed hardwood (**Figure 2-59**). Both of these are riparian trees that grow near streams,

[2] https://groundwaterresourcehub.org/sgma-tools/gde-rooting-depths-database-for-gdes/ (accessed June 2021)

rivers, springs, seeps, wetlands, and well-watered bottomlands at elevations below 6,600 ft. Note that what TNC has identified as wetlands seem to rely on surface waters, and it was noticed during a recent field investigation that there wasn't any evidence of those wetlands. Rather mixed riparian habitat was observed along the creeks. Therefore, to be consistent with the observations, the wetlands designation is changed to "riparian habitats" that are stream-fed for most of the year. However, because there are uncertainties regarding the level of dependency of these habitats on groundwater sources, these habitats are also considered as potential GDEs.

It should be noted that the identified GDEs along Kelsey Creek may also benefit from access to surface water (**Figure 2-59**). Similarly, the GDEs above Adobe Creek Reservoir may also benefit from access to seepage from the reservoir (**Figure 2-60**). The native oak woodland also seems to be a riparian corridor which is stream-fed. The field investigation confirmed that these GDEs most definitely benefit from proximity to surface water resources. However, lacking detailed investigation, it is difficult to quantify the relative contribution of groundwater and surface water on the health of these GDEs.

Per TNC guidance, GDEs identified by NCCAG dataset are only the starting point to create a full list of potential GDEs for a basin. It is worth noting that the largest native oak woodland (68.1 acres) remaining in Big Valley is along McGaugh Slough between Big Valley Road and Finley East Road. This area floods frequently during storm events. The soil in this area is heavy, black clay that is impenetrable when it is wet. This area was not included in the NCCAG database as a potential GDE within the Big Valley Basin, and it was added to the list of potential GDEs after the field investigation and stakeholders' recommendation. **Figure 2-61** shows the updated map of potential GDEs identified in this study for the Big Valley Basin.

Aquatic Habitat

The NCCAGs for the Big Valley Basin only cover the wetland and vegetation types. Fish and wildlife species that rely on groundwater are also classified among the beneficial uses and users of groundwater. Clear Lake hitch (*Lavinia exilicauda chi*) (hitch) are a large minnow endemic to Clear Lake and its tributaries. The hitch migrates each spring from the lake into the tributaries to spawn. According to Center for Biological Diversity, Adobe Creek and Kelsey Creeks among other creeks in the area are tributaries that provide spawning habitat for hitch (Center for Biological Diversity 2012).

Higher groundwater levels resulting in higher flows in the creeks during hitch spawning periods (February through May) can be beneficial to the survival of these threatened species. Therefore, Clear Lake hitch are also considered potential GDEs. Note that there are uncertainties on location and magnitude of hydraulic connectivity between surface and groundwater aquifer, as discussed in **Section 2.2.2.5**.

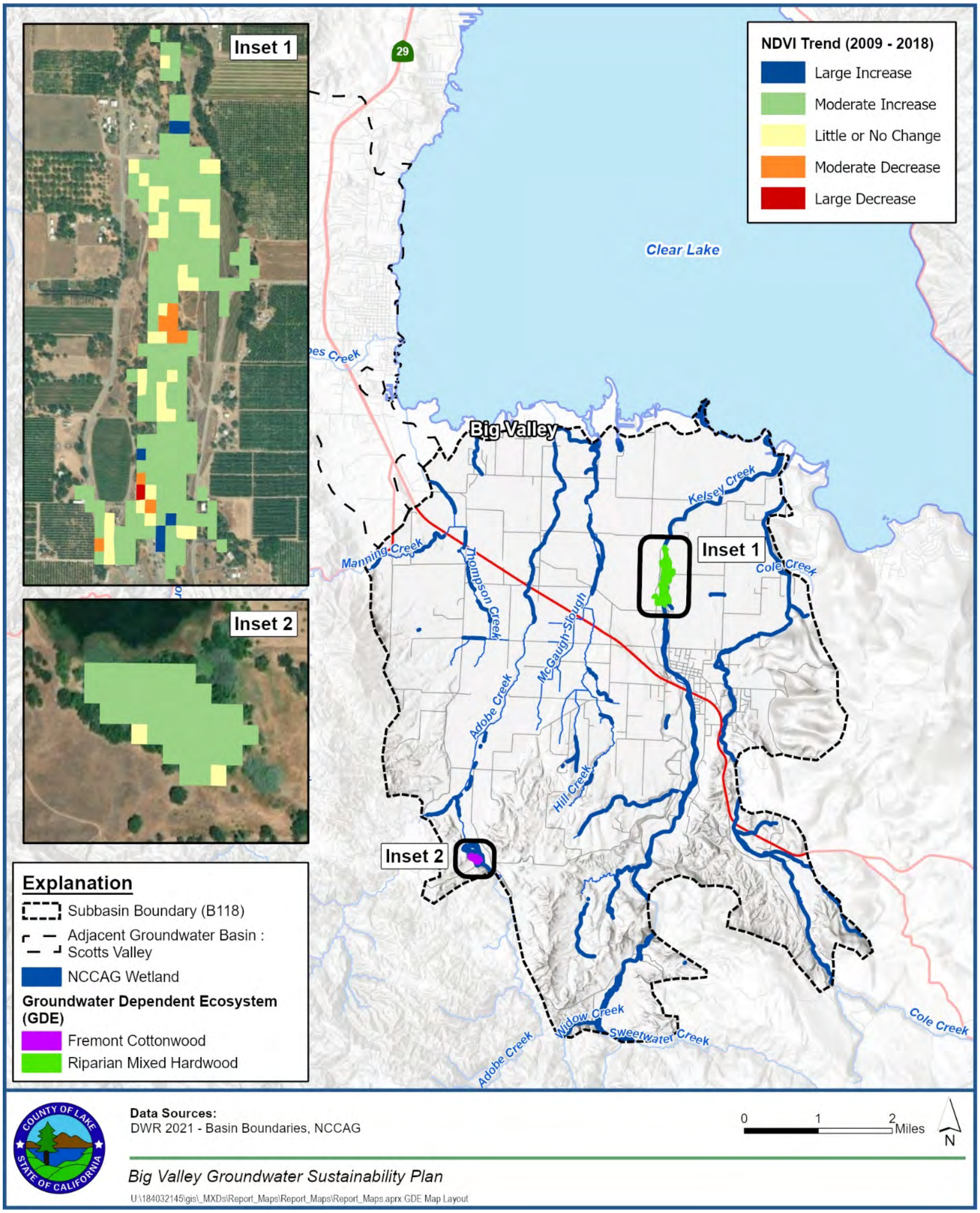


Figure 2-58. Big Valley Identified Groundwater Dependent Ecosystems Based on the NCCAG Dataset (Comparison of 2009-2018 Health Conditions)

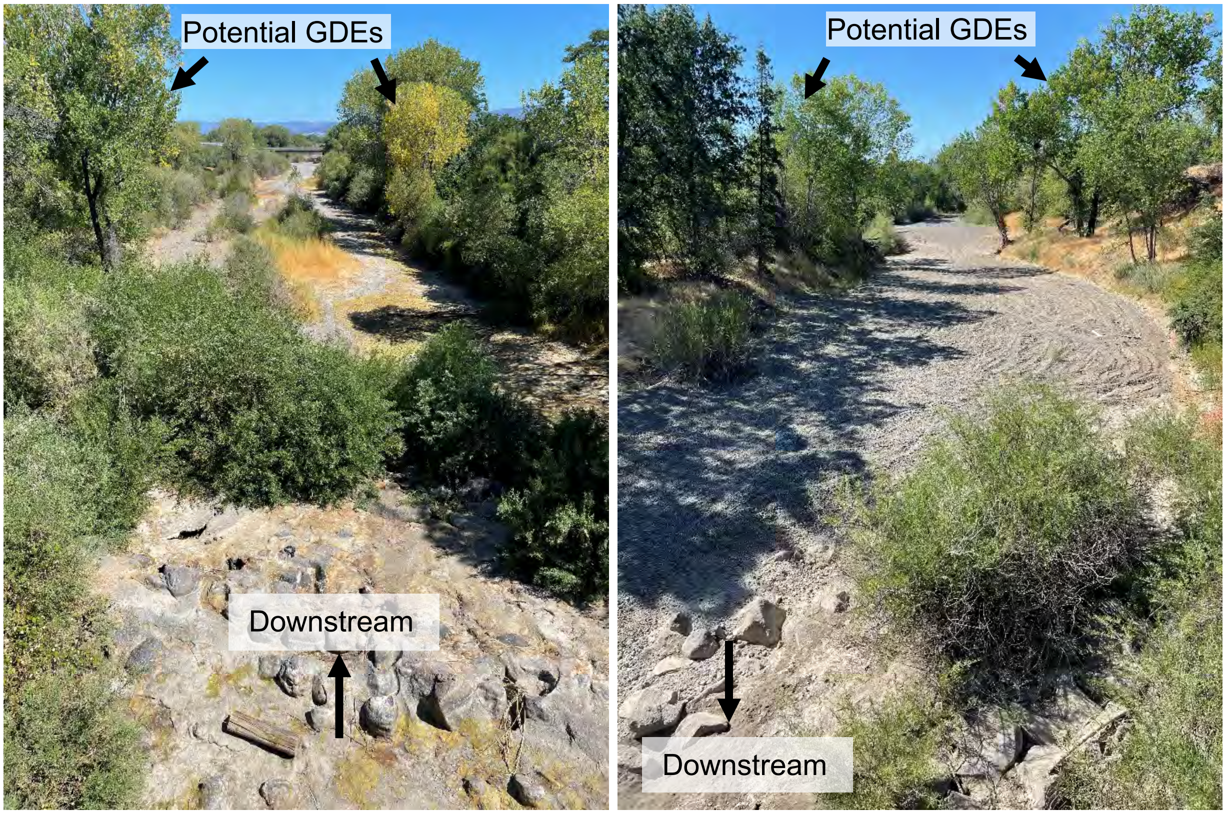


Figure 2-59. The GDEs Along Kelsey Creek: Upstream Section in the Proximity of Main Street Bridge (left), and Downstream Section in the Proximity of the Groundwater Recharge Structure

Figure 2-60. The Potential GDEs Above Adobe Creek Reservoir

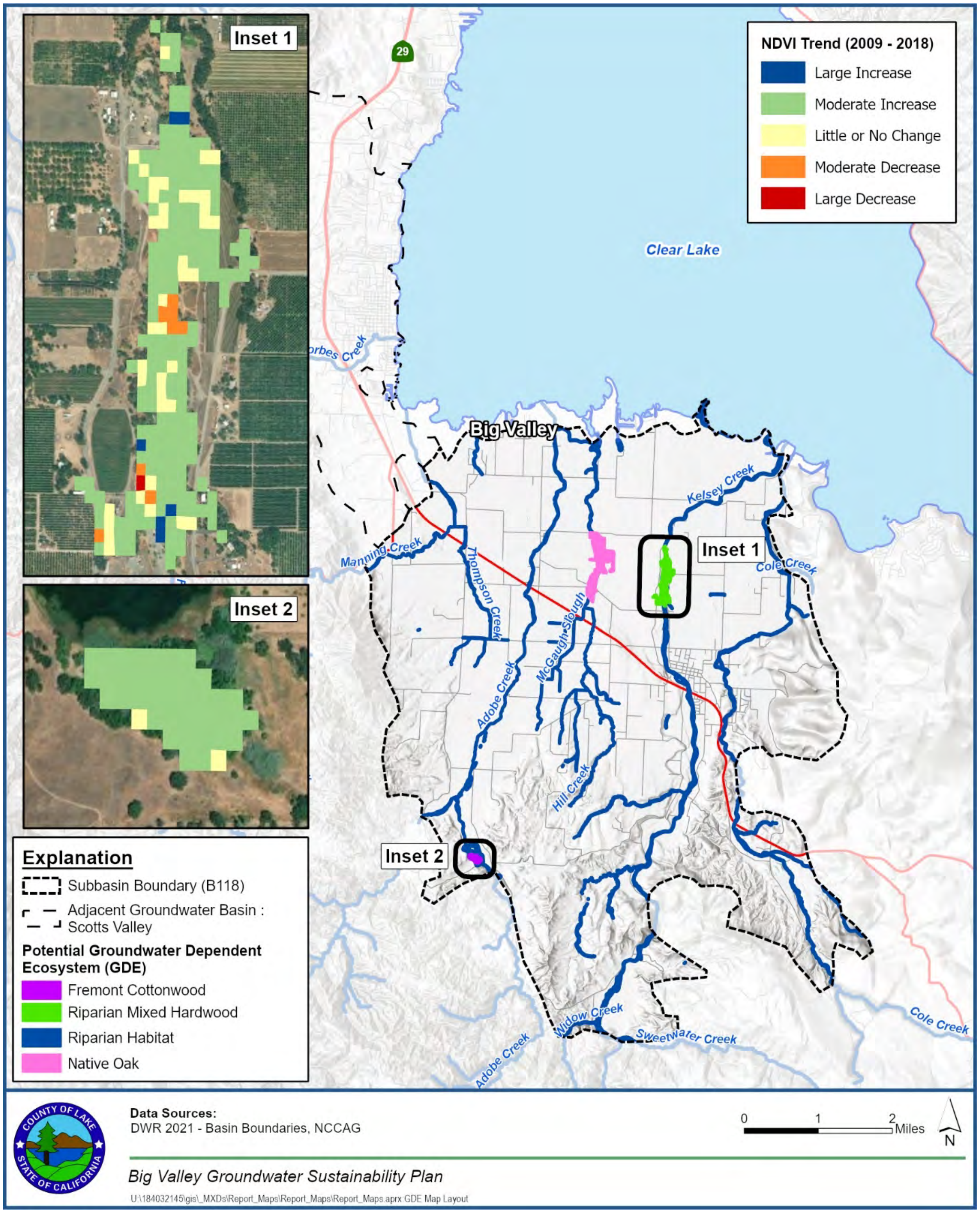


Figure 2-61. Big Valley Groundwater Dependent Ecosystems (Comparison of 2009-2018 Health Conditions)

2.2.3.2 Groundwater Conditions in Vicinity of the GDEs

Figure 2-62 shows the observed depth to groundwater in wells in the proximity of the two identified GDEs along Kelsey Creek and above Adobe Creek Reservoir. Spring depth to groundwater around the GDEs along Kelsey Creek are typically about 10 to 20 ft bgs which is consistent with groundwater level shown in **Figure 2-24**. Summer depth to groundwater can vary across the observed wells, ranging from 25 to 50 feet bgs. This larger variability in the summer may be due to the effects of groundwater extraction during dry periods. However, there are no apparent long-term trends of either declining or increasing groundwater levels, suggesting stable groundwater conditions exist in the vicinity of the Kelsey Creek GDEs between 1985 and 2018. **Figure 2-62**, which shows a different trend between 1965 and 2019, suggests groundwater declining in the area prior to 1985.

The nearest well to the GDEs above Adobe Creek Reservoir is about one-half mile to the east. Spring depth to groundwater in this well is 70 to 90 ft bgs, while summer groundwater depths are typically 100 to 150 ft bgs. Note that because of the long distance to this nearest well, the observed groundwater depths may not be indicative of the conditions around the GDEs location.

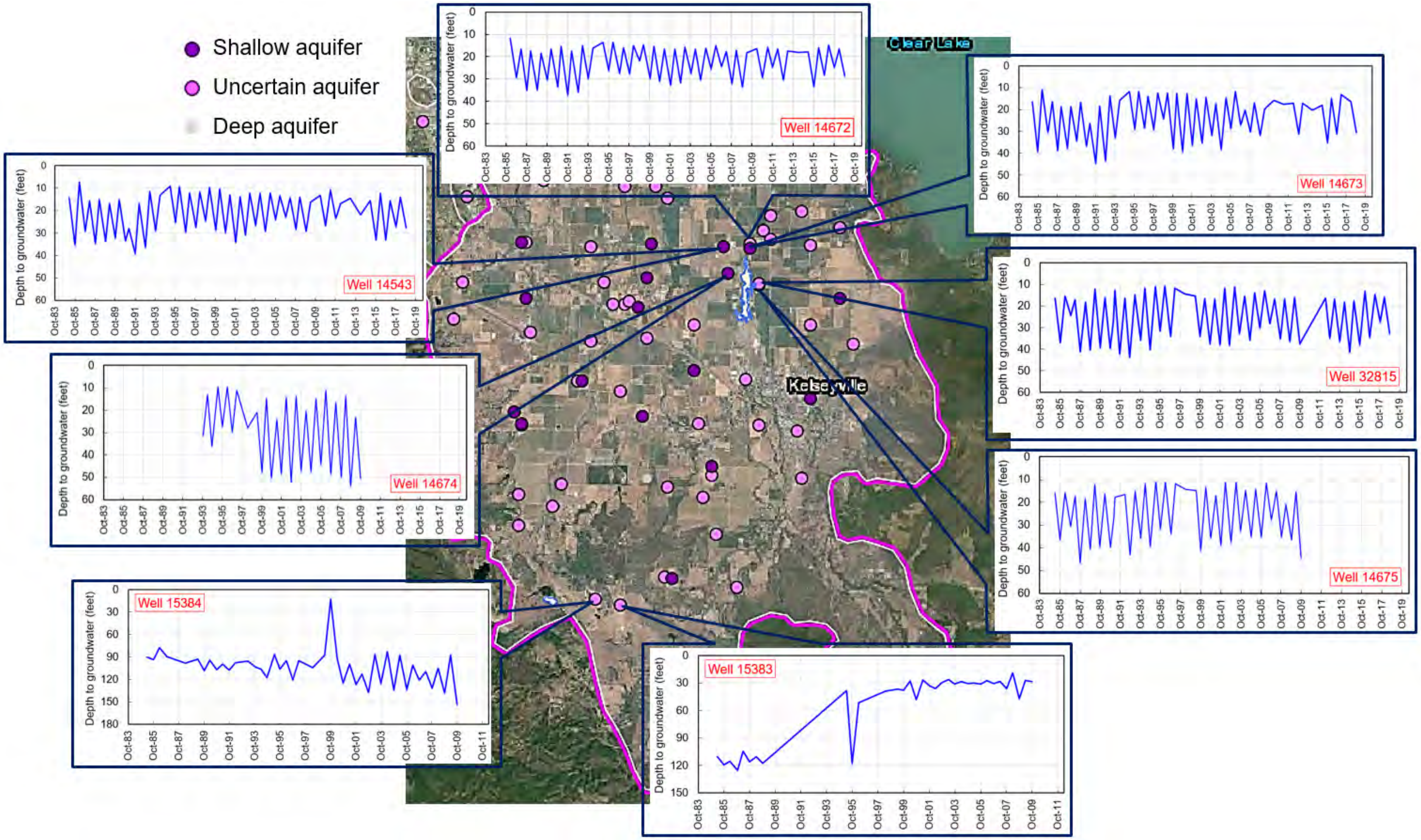


Figure 2-62. Depth to Groundwater at Wells in the Proximity of Big Valley GDEs

2.2.3.3 Long-Term Health of the Potential GDEs

This section uses available information to describe the relative long-term health of the identified potential GDEs.

Terrestrial Habitat

Assessment of GDEs long-term health includes the examination of (1) the extent and spread of GDEs, and (2) the relative vegetation health of the GDEs over time. This assessment can be conducted using the Normalized Derived Vegetation Index (NDVI), which is a remote sensing derived index that measures the strengths of Chlorophyll absorption of visible light. Healthy green vegetation tends to have higher NDVI, while dead leaves have lower NDVI. A decline in NDVI values over time could be associated with declines in the health of plants, including reduced tree canopy, reduced understory, shifts in vegetation type, tree mortality, and habitat fragmentation. The NDVI can also be used to assess the extent and spread of GDEs. Normalized Derived Moisture Index (NDMI) is another vegetation metric which can provide a proxy for water stress analysis, which is another helpful variable for inferring ecosystem health. Vegetation with adequate access to water tend to have higher NDMI.

Figure 2-61, Inset 1 and Inset 2, compares the NVDI for the identified GDEs between 2009 and 2018. This range incorporates both dry year (2009) and wet year (2018) conditions. It shows an overall moderate increase in the NDVI between dry and wet conditions. This is consistent with the observed changes in groundwater elevations between wet and dry periods (**Figure 2-62**).

Figure 2-63, Inset 1 and Inset 2, compares the NVDI for the identified GDEs along the Kelsey Creek and above the Adobe Creek Reservoir between 1985 and 2018. Note that data for native oak woodland along McGaugh Slough is not available, as this area was not identified as GDE indicators by NCCAG. The figure shows little to no change in the extent or conditions of the GDEs above Adobe Creek Reservoir. It shows no change in the extent of the Kelsey Creek GDEs, with moderate increase in NDVI, indicating improvement in GDEs health over time. Comparing **Figure 2-61** and **Figure 2-63**, it is evident that there has been little to no change in the extent and spread of the GDEs over the past 20 years. This indicates that groundwater management activities have not impacted the health and presence of GDEs in the Big Valley Basin.

Figure 2-64 shows the average summer NDVI calculated for the driest part of the year (July 7 – September 9). This summer NDVI period represents vegetation health when the plants are most likely dependent on groundwater. **Figure 2-64** (top) shows that the vegetation health of the GDEs along Kelsey Creek (riparian mixed hardwood) has improved since 1985. In 2018, the summer NDVI (0.44) is 24 percent above the long-term average (0.36). Note that the NDVI declines during drought periods (e.g., 2009), but the trend has generally been upward. **Figure 2-64** (bottom) shows the average summer NDMI calculated for the same time period as it was for the NDVI. The two vegetation metrics of the GDEs along the Kelsey Creek have a strong positive correlation with each other (Pearson correlation coefficient of 0.88). However, neither metric in this area has a strong correlation with the annual precipitation (correlation coefficient of 0.37 for NDVI and 0.54 for NDMI). There is also no significant correlation between the NDVI (correlation coefficient < 0.33) and NDMI (correlation coefficient < 0.11) with depth to groundwater at wells across these GDEs.

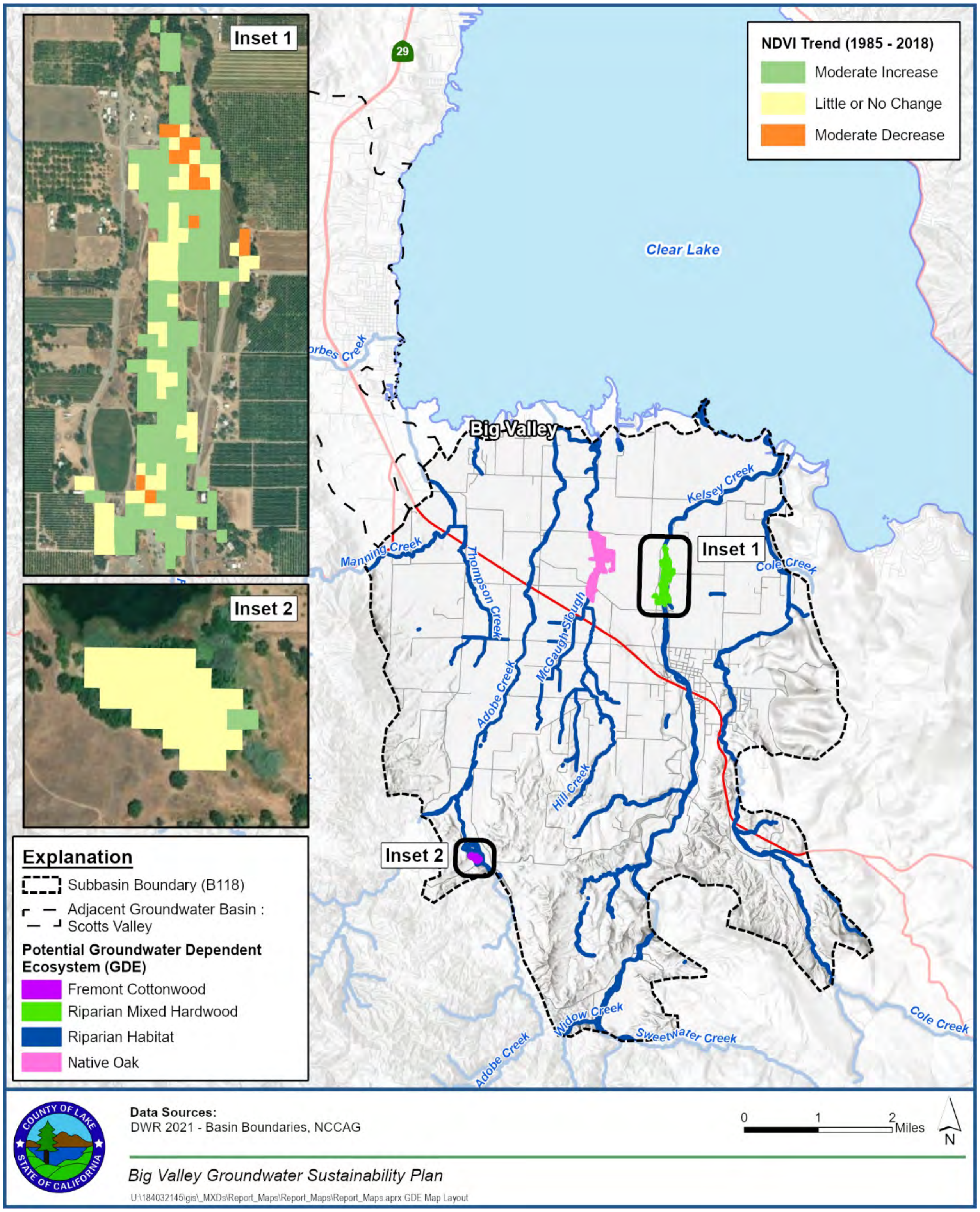


Figure 2-63. Big Valley Groundwater Dependent Ecosystems (Comparison of 1985 to 2018 Health Conditions)

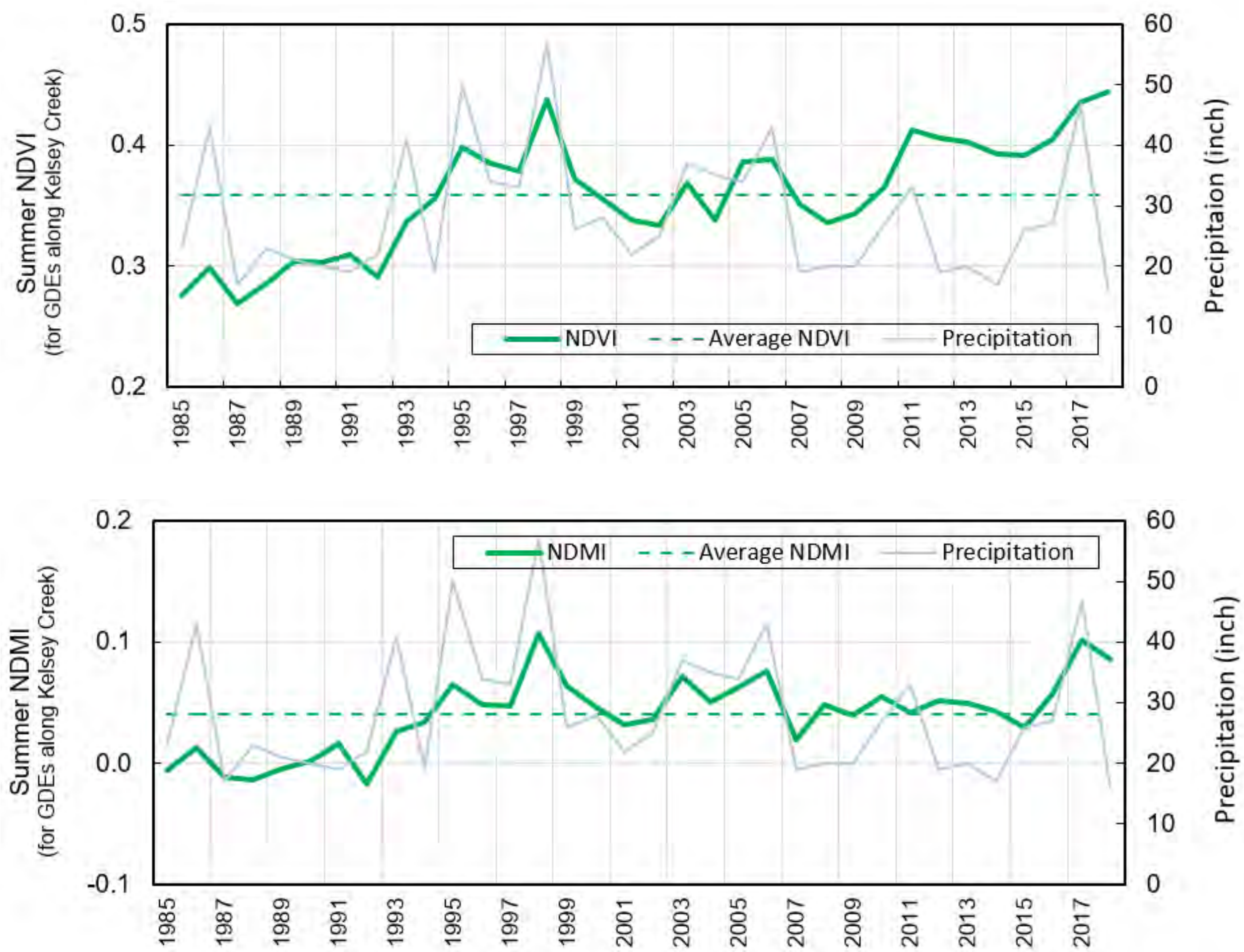


Figure 2-64. Average Summer Normalized Derived Vegetation Index (top) and Average Summer Normalized Derived Moisture Index (bottom) for the GDEs Along Kelsey Creek

GDEs are the primary beneficial uses of surface waters in this basin. Stream diversions are considered as primary uses, but they are very minimal in the Big Valley Basin. **Figure 2-65** shows the NDVI and NDMI compared to the modeled depletion at KCK. As discussed above, there has been minimal to no change in the extent and health of the GDEs since 1985 to date. Although the interim modeled depletion results show a slightly increasing trend (**Figure 2-65**), on account of the health analysis it is concluded that these levels of depletions which were identified from the interim results of the model are unlikely to affect the overall health of the terrestrial GDEs.

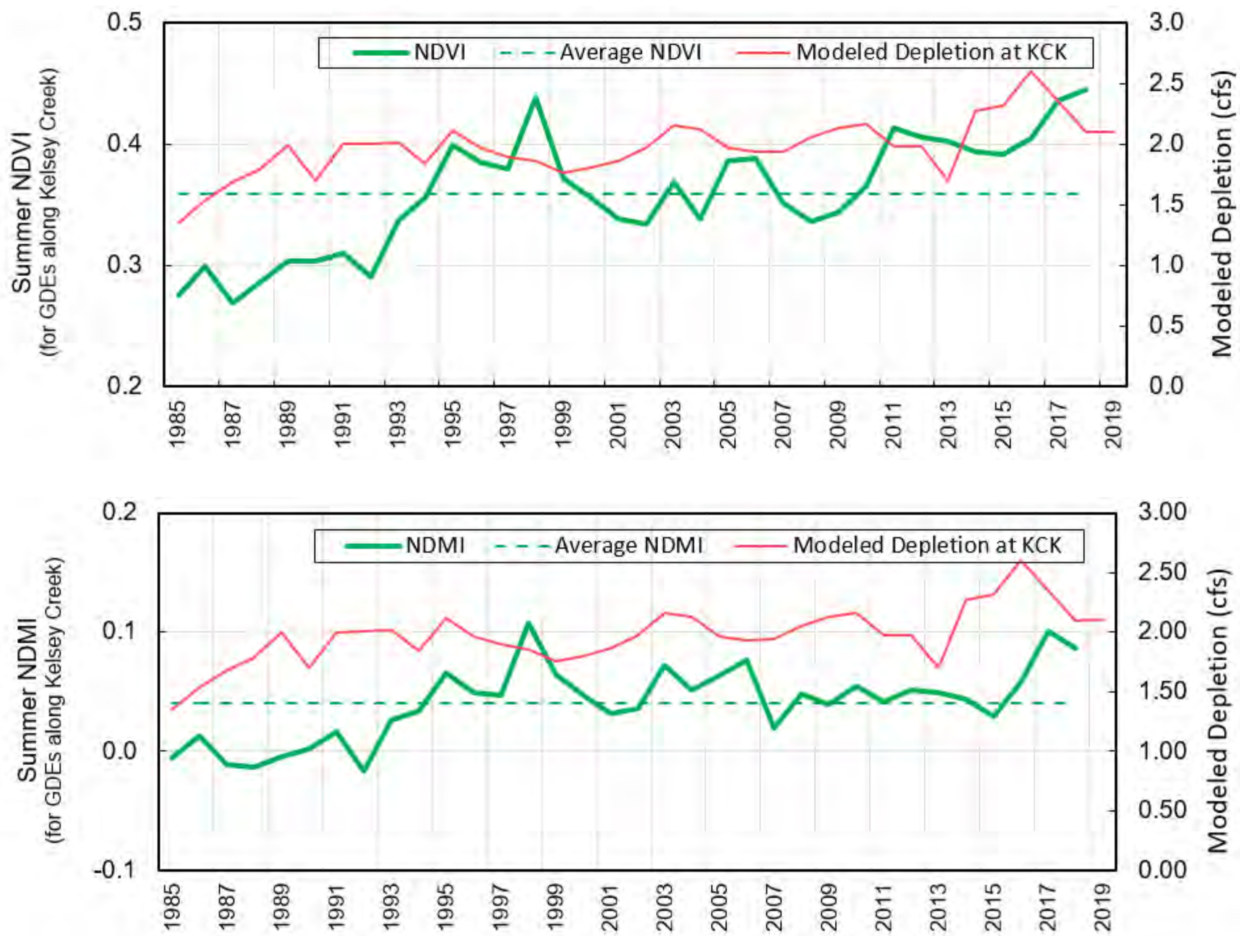


Figure 2-65. Average Summer Normalized Derived Vegetation Index (top) and Average Summer Normalized Derived Moisture Index (bottom) vs. Modeled Depletion for the GDEs Along Kelsey Creek

Figure 2-66 (top) shows that the vegetation health of the GDEs above the Adobe Creek Reservoir (Fremont cottonwood) has also improved since 1985. In 2018, the summer NDVI (0.83) is 11 percent above the long-term average (0.75). **Figure 2-66** (bottom) shows the vegetations moisture content of these GDEs. Similar to the GDEs along the Kelsey Creek, both vegetation metrics have a strong positive correlation with each other (Pearson correlation coefficient of 0.79) following a minimum correlation with the annual precipitation (correlation coefficient of 0.06 for NDVI and 0.13 for NDMI). There is also no significant correlation between the NDVI (correlation coefficient < 0.33) and NDMI (correlation coefficient < 0.11) with depth to groundwater in Well 15384.

Groundwater depth in Well 15384, which is the nearest well, is relatively deep, more than 150 feet (see **Figure 2-62**). Thus, groundwater levels in Well 15384 may not be representative of groundwater levels in the reservoir area. Well 15383, east of this well, is shallower with a depth to groundwater of 30 feet. The analysis shows that there is a negative meaningful correlation between Well 15384 and the two vegetation metrics (correlation coefficient of 0.66 for NDVI and 0.54 for NDMI). However, owing to the greater distance from the reservoir, this well may also not be representative of groundwater levels in the reservoir area. It is also likely that the Fremont cottonwood GDEs are relying on another water source, in this case the Adobe Creek Reservoir, to maintain its health. Proximity to the reservoir most likely explains why the GDE health index is increasing despite a decreasing trend in groundwater levels.

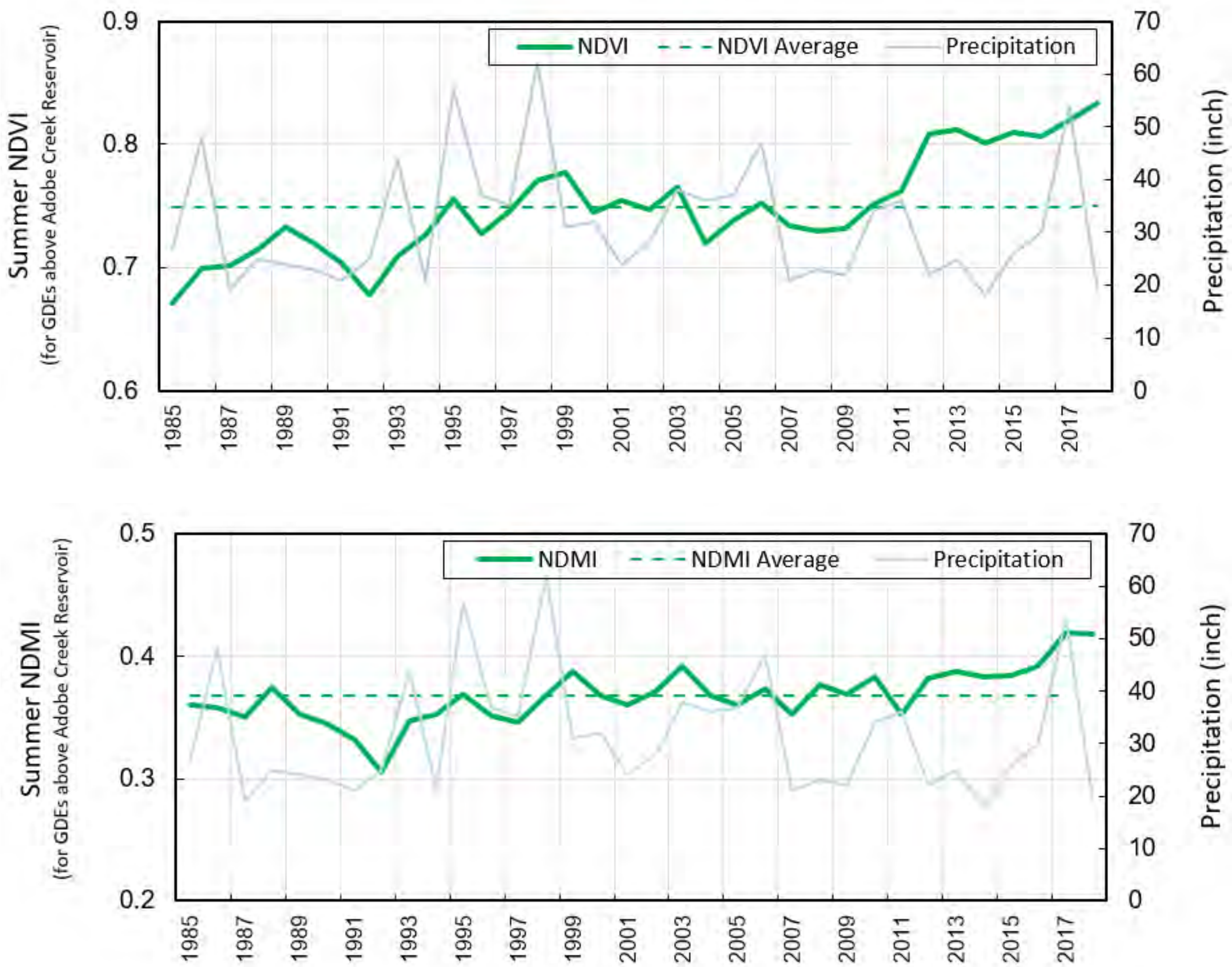


Figure 2-66. Average Summer Normalized Derived Index (top) and Average Summer Normalized Derived Moisture Index (bottom) for the GDEs Above Adobe Creek Reservoir

Figure 2-67 shows the NDVI and NDMI compared to the modeled depletion at Adobe Creek. Following the same line of reasoning discussed above, it is concluded that if depletion remains within the range displayed on **Figure 2-67**, the overall health of the terrestrial GDEs above Adobe Creek will not affected.

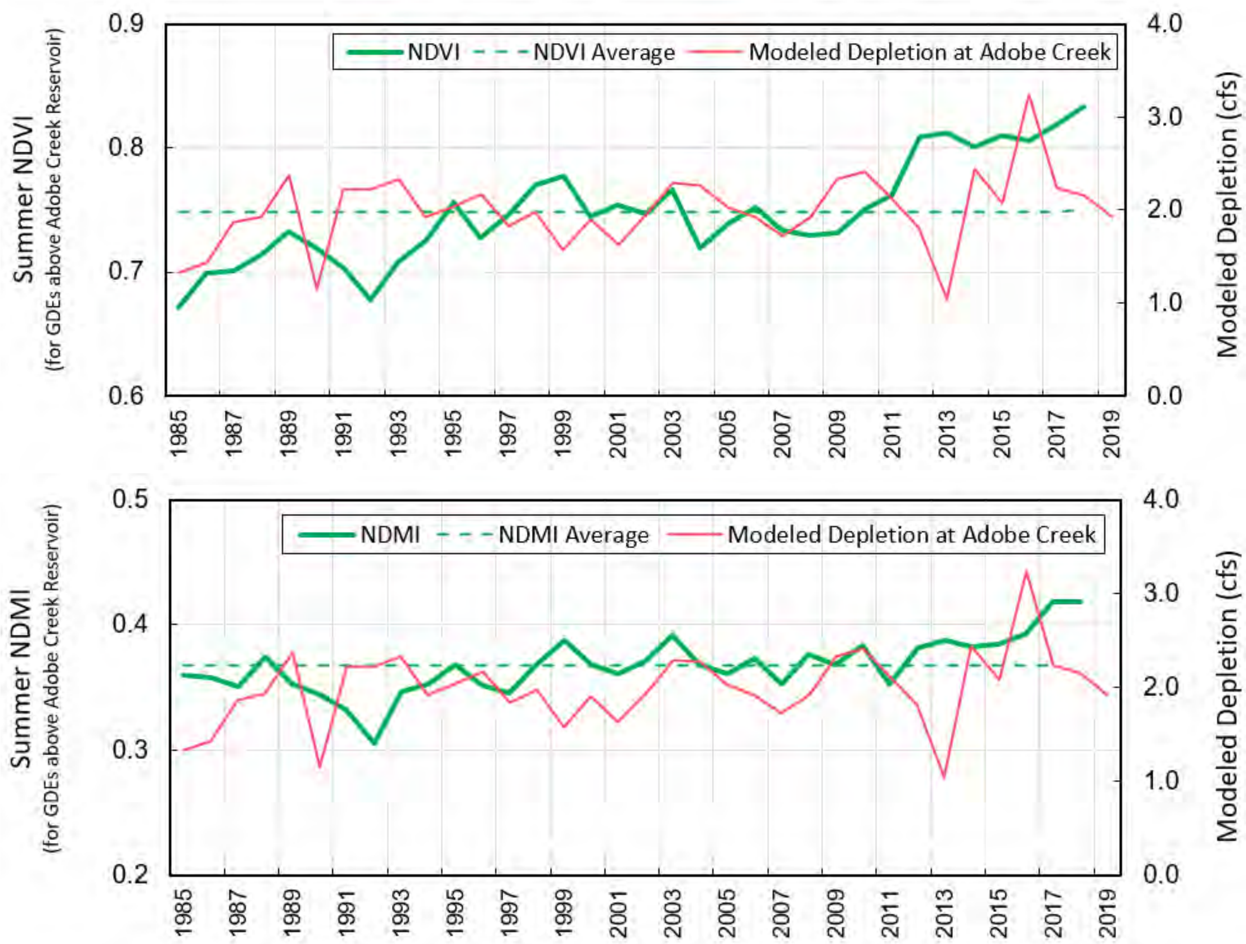


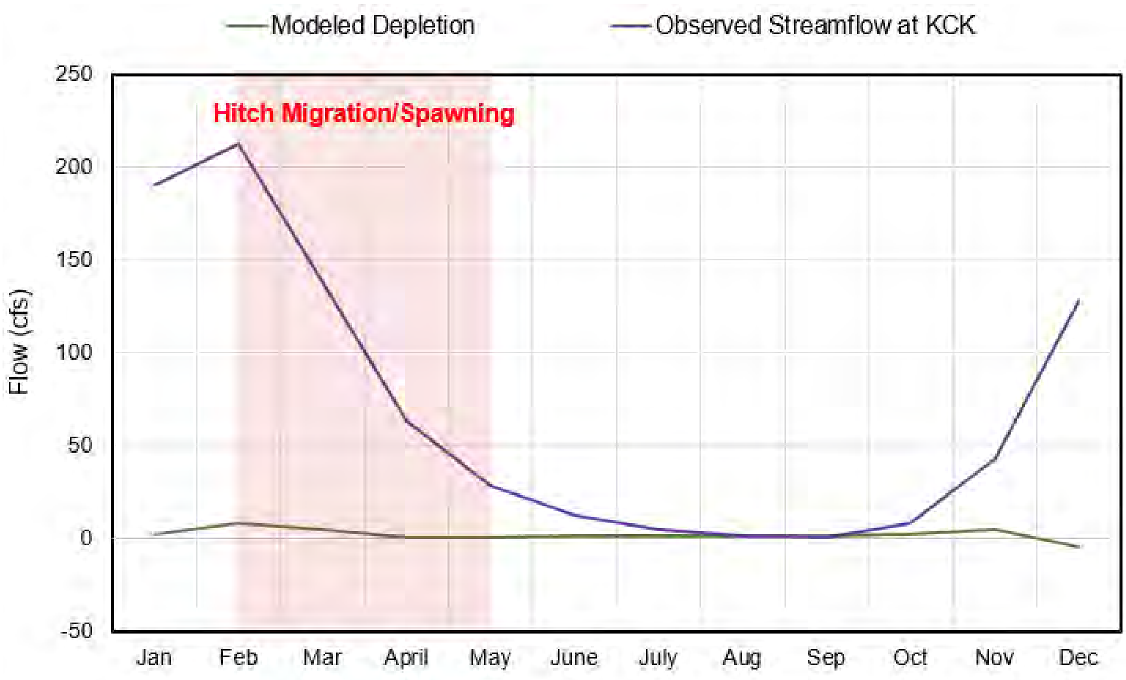
Figure 2-67. Average Summer Normalized Derived Index (top) and Average Summer Normalized Derived Moisture Index (bottom) vs. Modeled Depletion for the GDEs Above Adobe Creek Reservoir

Aquatic Habitat

In August 2014, the California Fish and Game Commission voted to list the hitch as threatened under California Endangered Species Act. From 2014-2017, CDFW conducted surveys in Adobe and Kelsey Creeks to estimate the abundance and distribution of hitch. CDFW is currently gathering information on the hitch to allow for informed decisions on future fisheries management at Clear Lake. The estimate of population size based on the measurements, so far, has confirmed the decline in the population. Multiple factors are believed to be contributing to decline of hitch populations, including loss of spawning habitat and nursery areas, migration barriers that block passage to spawning grounds, alteration of creek habitat, in-channel mining, temporary road-building through channels, water pumping, predation by and competition from introduced invasive fish, and the impacts of pollutants.

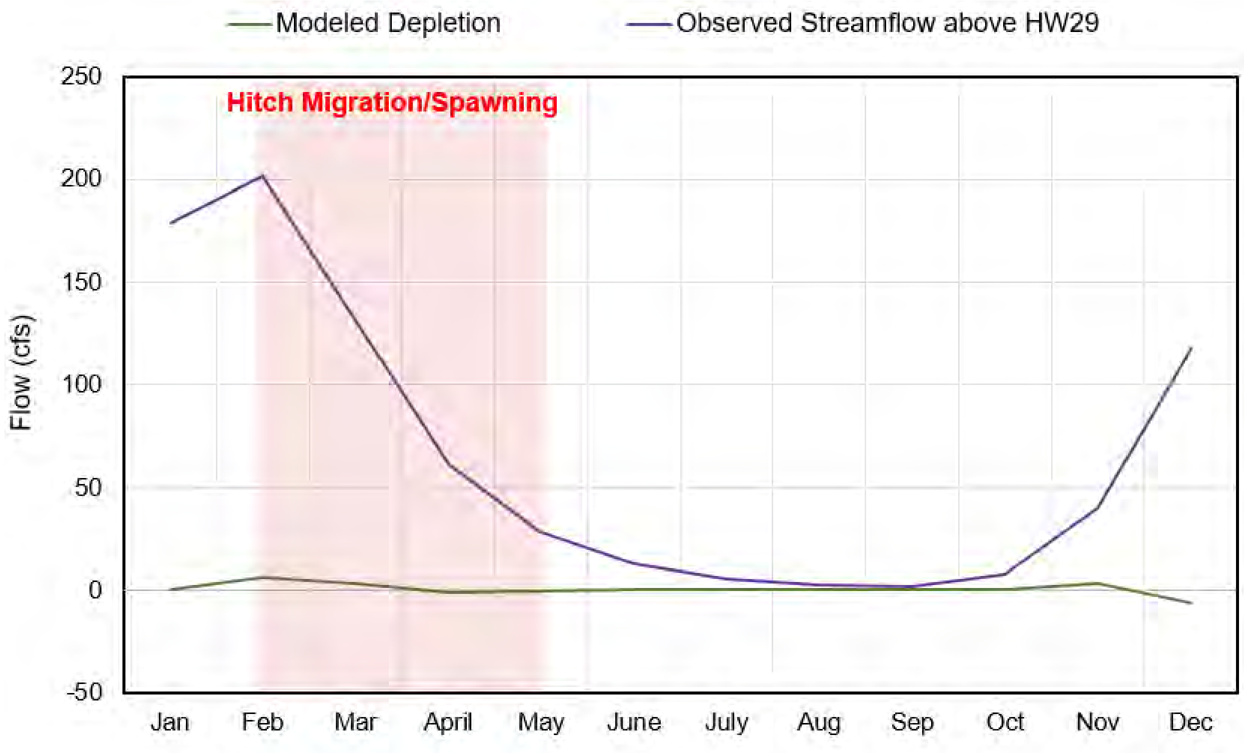
Aquatic habitats health, in particular hitch, is tied to Spring conditions (see Section 2.2.3.4). **Figure 2-68** to **Figure 2-70** show the historical monthly average depletions identified by the model respectively at KCK, above HW29, and Adobe Creek. The figures show that modeled depletions are higher in spring which coincides with the duration of hitch migration period (mid-

February to mid-May). However, the magnitude of depletion relative to the measured stream flow is negligible. Based on the currently available data, the effects of depletions seem to be small relative to available flow in the stream. As it will be discussed later in Section 2.2.3.4, there are concerns about the adverse impacts of other activities including frost protection pumping affecting localized area in the stream in which case the extent of these affects cannot be determined due to lack of high spatial and temporal resolution data. This issue needs to be reassessed in future when there is additional data available.



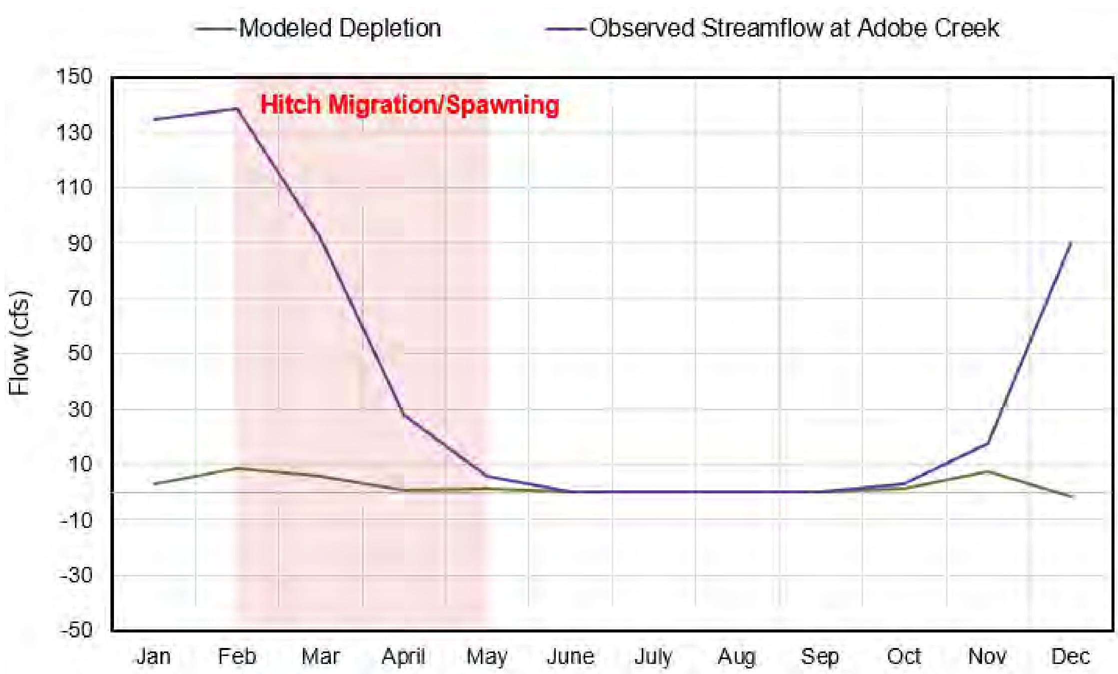
Note that the red transparent box shows the hitch migration window.

Figure 2-68. Historical Monthly Average Modeled Water Depletion at KCK



Note that the red transparent box shows the hitch migration window.

Figure 2-69. Historical Monthly Average Modeled Water Depletion above HW29



Note that the red transparent box shows the hitch migration window.

Figure 2-70. Historical Monthly Average Modeled Water Depletion at Adobe Creek

2.2.3.4 Impact of the Groundwater Management

This section uses available information to describe the potential impacts of groundwater management activities on the identified potential GDEs.

Terrestrial Habitat

As discussed in **Section 2.2.3.3**, despite fluctuations in groundwater elevations since 1985, the long-term health indicis of the potential GDEs along the Kelsey Creek and above Adobe Creek Reservoir remained above historical average. It is, however, seen that both NDVI and NDMI responded to the occurrence of wet and drought conditions. If there is an extensive and persistent dewatering of groundwater beyond what has been historically observed, it is possible to see impacts on these health indicis of the GDEs. Note that these potential GDEs may also rely on surface water for some or most of their needs. Therefore, long-term decline in groundwater levels may not necessarily be observed in health indicis of the GDEs.

Aquatic Habitat

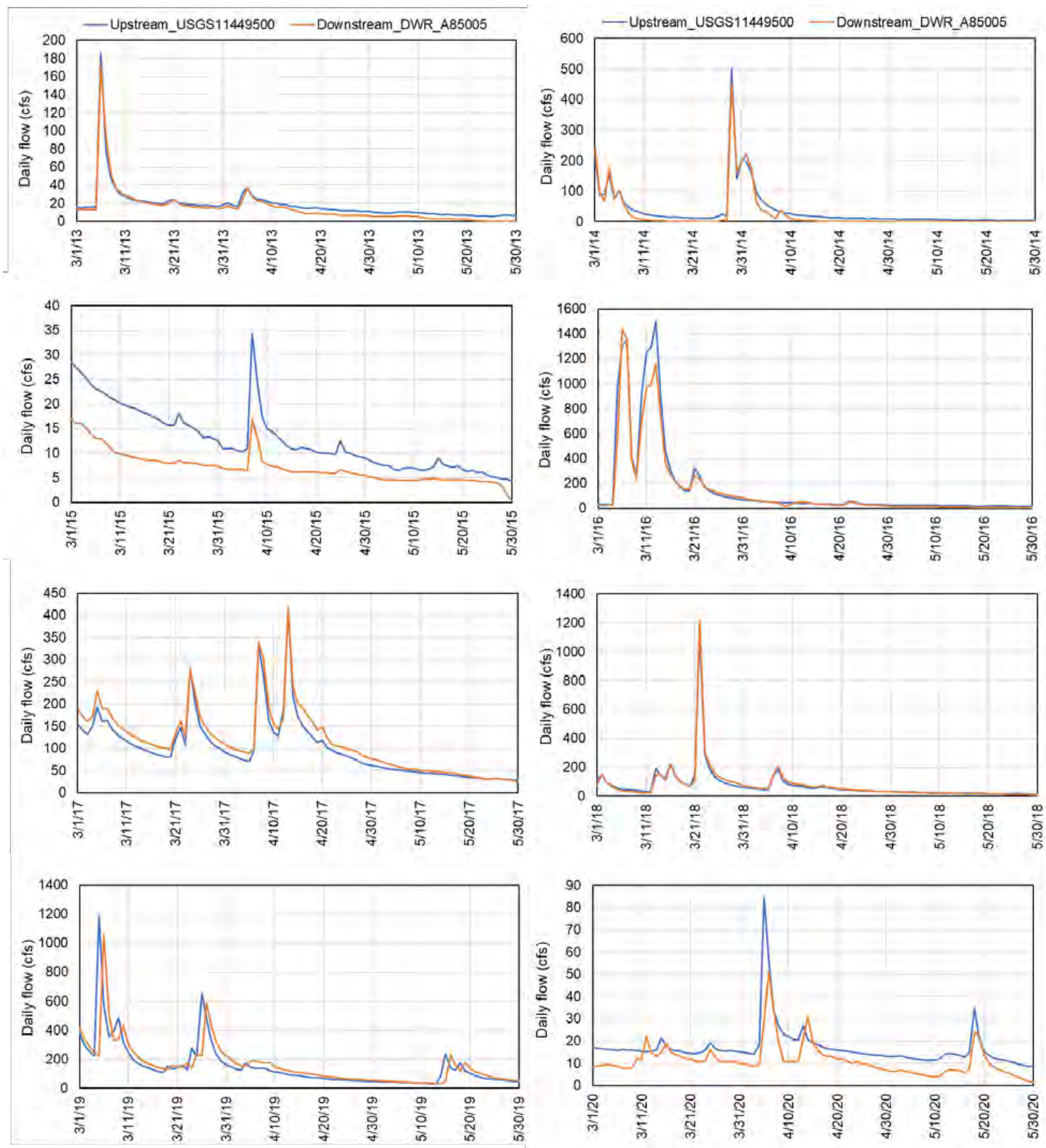
In the Clear Lake Basin, hitch spawning occurs in tributary streams, and the spawning migrations, which resemble salmon runs on a miniature scale, usually take place from mid-March through May and occasionally into June, depending on stream flow (Center for Biological Diversity, 2012). Hitch migrate into tributary streams to spawn. Adults return to Clear Lake post-spawning and larval fish move quickly downstream to the lake within a couple weeks of hatching. Hitch embryos hatch out of their eggs after approximately seven days, and the larvae become free-swimming after another seven days. Larval fish must move downstream to Clear Lake quickly before streams dry up. In the lake, larvae remain inshore and are thought to depend on stands of tulles for cover until they reach approximately 2 inches and assume a pelagic lifestyle. Males reach breeding age in their first or second year, while female hitch become mature by their second or third year. Later, adult hitch migrates up to tributary streams to spawn in the spring to begin the life cycle again.

The timing of the hitch migration (mid-February through May) typically coincides with high-flow events during spring when groundwater pumping is at a very low level for irrigation at this time. Limited and intermittent groundwater occurs during the spring for frost/freeze protection between February and May. Frost/freeze protection depends on the principle of heat fusion to maintain plant temperature at or near 32 degrees Fahrenheit (0 degrees Celsius). Essentially, as the air temperature surrounding the plants drops below freezing levels, the water begins to freeze and crystalize. The objective of any crop frost/freeze protection is to keep plant tissues above their critical temperatures, which is the temperature at which tissues will be killed. Using water is one of the frost management techniques.

In the Big Valley Basin, groundwater is pumped and applied to crops over night when freezing conditions are forecasted to prevent crop damage. The concern is that the groundwater extraction for this purpose might cause sudden drop in the groundwater elevation, especially in areas close to the creeks, thereby affecting the creeks flow conditions. All three of hitch life cycle phases, explained above, can be impacted by low surface water levels: (1) adults could be affected migrating to the creeks and back to the lake, (2) eggs could dry off and die, which could then cause a long-term population decline, and (3) juveniles could get trapped when trying to migrate back.

The effects of intermittent groundwater pumping for frost/freeze protection on surface water depletions are hard to discern in the available monitoring datasets for both surface water and the groundwater. However, when comparing the downstream flow to the upstream flow, there is no apparent differences that would indicate sudden surface water reduction indicative of the frost protection impacts (see **Figure 2-71**). Therefore, the magnitude, frequency, and extent of this effect cannot be clearly identified based on available data. Also note that if these conditions occur, they are likely to be localized in small areas and will happen over a short period of time. However, the special and temporal resolution of monitoring data do not support detailed assessments.

The timing of the hitch life cycle and how it is possibly affected by interconnected surface water depletion requires both surface water and groundwater data that have sufficient temporal (daily or more frequent) and spatial resolution (multiple locations along each water body). Additional intermediate surface water gauges and monitoring with new shallow monitoring wells is required to better understand the nature and timing of hydraulic connectivity along the creeks important to hitch spawning. Further field studies and data collection is needed to provide confidence to correlations and impacts from non-sustainable groundwater management.



Note: 2021 data is not available for DWR gauge

Figure 2-71 Comparisons of Kelsey Creek Daily Spring (March-May) Flows at USGS Station 11449500 Compared to DWR KCK/A85005 (2013-2020)

2.2.4 Water Budget Information

This section presents the historical, current, and projected (future) water budgets for the Big Valley Basin (Basin) and contains information required by SGMA regulations with other important information required in an effective GSP. Water budgets provide a quantitative accounting of the water that flows into and out of a specified area and detail various processes and components of the hydrologic cycle within the system (GSP Regulation § 354.18[b]). Additionally, the water budgets can be used to inform the development of sustainable management criteria and management actions, as well as to identify data uncertainties, monitoring needs, overdraft conditions, and beneficial uses of groundwater. The water budget analyses presented in this section provide the foundation for characterizing potential groundwater conditions based on future projections of water supplies and demands.

DWR has published guidance and best management practice (BMP) documents related to the development of GSPs (DWR 2016), including Water Budget BMPs. Consistent with these BMPs, this section presents the water budget development methodology, evaluation of estimated water budgets to describe the hydrologic systems in the Basin, and an analysis of uncertainty for various water budget components.

2.2.4.1 Objectives

The purpose of a water budget is to quantity the hydrologic components that make up the water supplies, water uses, and the resulting change in groundwater storage within the Basin. In accordance with GSP Regulations §354.18(b), the water budget presented for the Basin quantifies the following:

1. Total surface water entering and leaving the Basin by water source type (i.e., surface water, groundwater, and imported water)

2. Inflow to the Groundwater System by water source type, including subsurface groundwater inflow and infiltration of precipitation, applied water, and surface water systems, such as lakes, streams, rivers, canals, springs and conveyance systems.

3. Outflows from the Groundwater System by water use sector, including evapotranspiration, groundwater extraction, groundwater discharge to surface water sources, and subsurface groundwater outflow.

4. The change in the annual volume of groundwater in storage between seasonal high conditions.

5. If overdraft conditions occur, a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions.

6. The water year type associated with the annual supply, demand, and change in groundwater stored.

7. An estimate of sustainable yield for the basin.

2.2.4.2 Water Budget Information

A water budget summarizes the inflows to and outflows from a basin (GSP Regulation § 354.18[b]). These inflows and outflows result in a change in the account balance, or storage. Inflows and outflows in the hydrologic system are largely controlled by processes occurring on the land surface, such as climate and weather patterns, variable land use, and irrigation. The water budgets presented in this section are divided into Land Surface System water budget, Stream System water budget, and a Groundwater System water budget. The Land Surface System and Stream System collectively make the Surface Water System. The complete water budget of the Basin is a product of the interconnected water budgets of the Surface Water System (SWS) and Groundwater System (GWS).

Inflows to the SWS include precipitation, surface water inflows via streams, imported water for irrigation (e.g., diversions from streams and the Clear Lake), applied groundwater (for irrigating crops) and groundwater discharge to surface water sources (from areas of high groundwater levels). Outflows from the SWS include evapotranspiration (ET), surface water outflows via streams, evaporation from surface water bodies, deep percolation of applied water, deep percolation of precipitation, and infiltration of surface water (seepage). Water used for irrigation leaves the SWS due to plant transpiration and evaporation from the ground surface (collectively known as evapotranspiration; ET). The excess portion of applied irrigation (i.e., portion that is not subjected to ET) can then exit the SWS and enter the GWS through deep percolation. Similarly, precipitation is either consumed by crops and native vegetation or evaporates from bare soil. The portion of precipitation not subjected to evapotranspiration percolates through the soil and recharges the GWS as deep percolation.

The Stream System accounts the stream flow and water exchange between streams and GWS within the Basin. The inflows to the Stream System are stream flow that enter the Basin across the southern and western boundaries, land surface runoff of precipitation and applied irrigation water, and groundwater discharge to streams in areas where gaining conditions occur. Outflows from the Stream System are stream flow that leaves the basin (i.e., discharge into the Clear Lake), water diversions and seepage (stream leakage). The magnitudes of groundwater discharge to a stream (gain to the stream) and seepage from stream flow (loss from the stream) determine the net stream leakage depending on the characteristics and seasonality of the hydraulic boundary conditions along that stream.

Stresses on the GWS are driven by the Land Surface System and Stream System. Inflows to the GWS include areal recharge to the aquifer from deep percolation of precipitation and applied water, subsurface inflow along the Basin boundaries, and seepage from streams. The major outflows from the GWS are groundwater pumping, uptake by plants, discharge to surface water, and lateral flow to areas outside the Basin.

2.2.4.3 Water Budget Methods and Data Sources

All water budgets described in this section were developed using outputs from the BVIHM, which simulates hydrogeologic and hydrologic conditions across the Basin. The BVIHM utilizes MODFLOW code to simulate groundwater flow, as well as other integrated packages to simulate streamflow, evapotranspiration, drains, farms, and other associated processes. Together, these components create an integrated surface water and groundwater model to estimate water budgets for the Basin. Development of the BVIHM involved the study and analyses of hydrogeologic conditions, as well as the assembly of all direct measurements or estimates of water demands and supplies for each water use sector, which includes agriculture, public water systems, native vegetation, and self-supplied users. Hydrogeological characteristics and historical groundwater conditions used to develop the BVIHM are presented in detail in **Sections 2.2.2** and **2.2.3**, respectively.

Water Budget Analysis Periods
Per the California Code of Regulations (CCR) Title 23 §354.18, each GSP must include a water budget for the basin that provides an accounting and assessment of the total annual volume of groundwater and surface water entering and leaving the basin, including historical, current and projected water budget conditions, and the change in the volume of water stored. Water budget information shall be reported in tabular and graphical forms. The historical, current, and projected water budget periods for the Big Valley were selected based on the Big Valley Basin water year type, historical wet and dry periods, antecedent dry conditions, and availability of adequate data, as well as current hydrologic, cultural, and water management conditions in the Basin.

WYs, as opposed to calendar years, are used as the time unit for analyses, following the DWR standard water year period (October 1 through September 30). Unless otherwise noted, all years referenced in this section are water years. The type of a particular water year for the Basin (wet, above normal, below normal, dry, and critical) was determined using weighted annual precipitations of that water year and the previous water year as described in the DWR Water Year Type Dataset Development Report (DWR 2021). The annual precipitation estimated for Keysville using the Basin Characterization Model presented by Flint et al., 2021 was used for this exercise.

Historical Water Budget Period
The historical water budget for the Basin must quantify all required water budget components starting with the most recently available information and extending back a minimum of 10 years, or as is sufficient to calibrate and reduce the uncertainty of the water budget (CCR Title 23 § 354.18[c][2][B]). The historical water budget period effectively represents long-term average historical hydrologic conditions. Therefore, the historical water budget enables evaluation of the effects of historical hydrologic conditions and water demands on the water budget and groundwater conditions within the Basin over a period representative of long-term hydrologic conditions. For the Big Valley GSP, a 32-year historical water budget period that span from 1988 to 2019 was selected following evaluation of precipitation records and Big Valley water year type classification (**Table 2-7** and **Figure 2-72**). A detailed discussion on the Basin's historical groundwater conditions is presented in **Section 2.2.2**.

Table 2-7. Big Valley Basin Water Year Type Classification for Historical Water Budget Period (1988 – 2019)

Big Valley Water Year Type	Abbreviation	Number of Years from 1989 to 2019	Percent Total Years from 1989 to 2019
Wet	W	9	28%
Above Normal	AN	8	25%
Below Normal	BN	4	13%
Dry	D	8	25%
Critical	C	3	9%
Total		**32**	**100%**

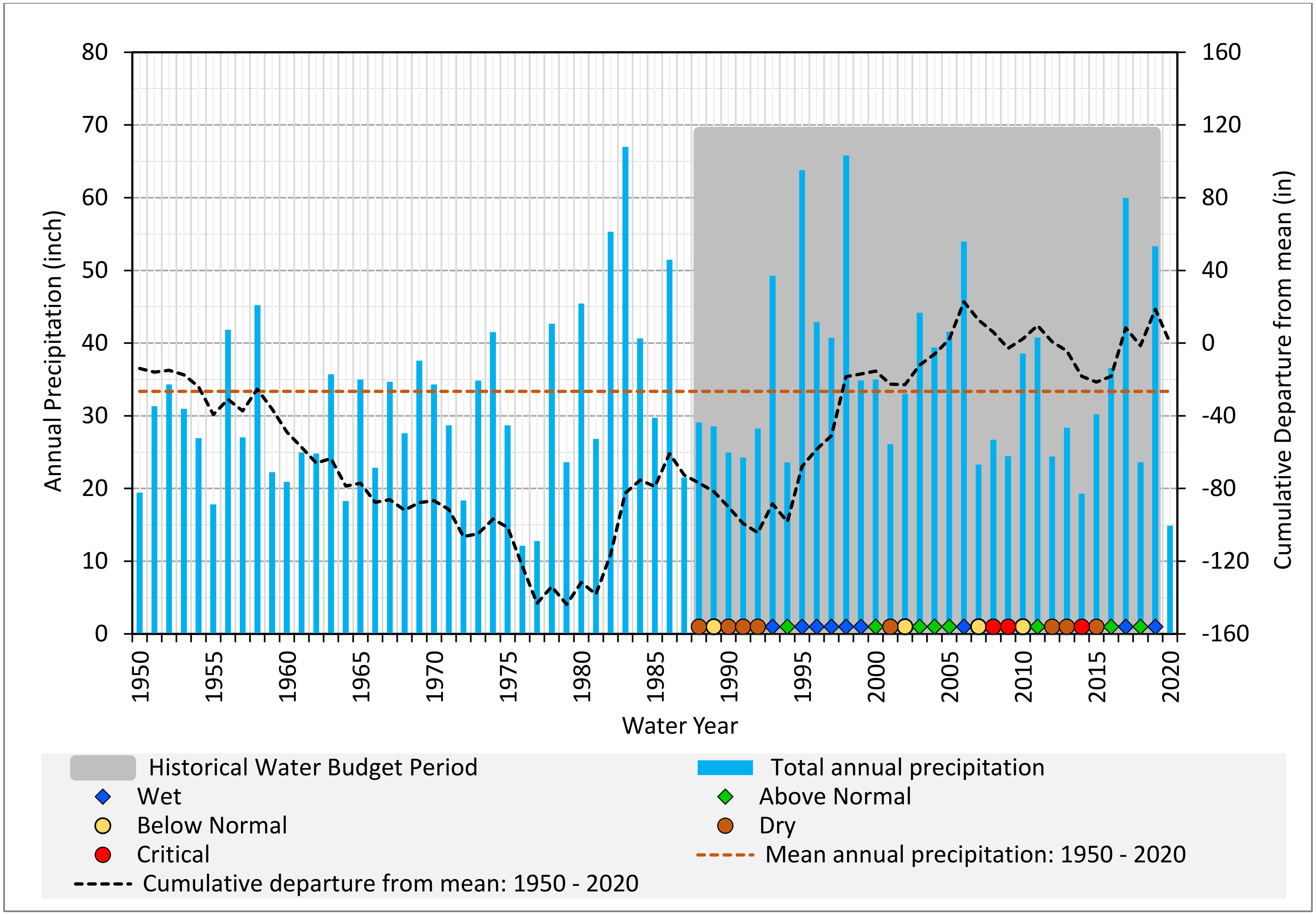


Figure 2-72. Annual Precipitation and Cumulative Departure – Kelseyville, CA

Current Water Budget Period

The current water budget must include the most recent hydrology, water supply, water demand, and land use information (CCR Title 23 § 354.18[c][1]). The current water budget presents information on the effects of recent hydrologic and water demand conditions on the Groundwater System. The characteristics of the current water budget can be highly influenced by the water year type(s) of selected year(s). Therefore, for consideration in estimating the current water budget, the results for several recent periods were selected as listed below:

- Recent 1 year (2019)
- Recent 1 year (2018)
- Recent 4 years (2016-2019)
- Recent 6 years (2014-2019)
- Recent 10 years (2010-2019)

These various periods result in widely varied inflows and outflows, much of which is attributed to varied precipitation and water demands in individual years (see results in **Section 2.2.4.7**). Because of the year-to-year variability in water budget results, the current water budget summarizes results from the various recent periods considered to provide an appropriate and reasonable representation of the current water budget based on recent conditions.

Projected Water Budget Period

GSP regulations (CCR Title 23 § 354.18[c][3]) require the development of projected water budgets based on at least 50 years of historical data to estimate future conditions of supply, demand, and aquifer response to GSP implementation, and to identify the uncertainties of these projected water budget components. The projected water budget of this GSP covers a 51-year period from 2020 through 2070.

Future hydrology inputs to the BVIHM were developed assuming that climatic conditions of 2020-2070 period will be consistent with the historical climatic conditions of 1969-2019 period. Historical climatic data for the projected baseline scenario (Projected Scenario A) were obtained from the USGS Basin Characterization Model (Flint et al., 2021). Future water budgets under two different climate change scenarios; wet-moderate warming (Projected Scenario B) and dry-extreme warming (Projected Scenario C), were developed to evaluate potential impacts of climate change on hydrology of the Basin. Development of projected water budgets are described in detail in **Appendix 2C**.

Water Budget Time Step

GSP Regulations require water budget analyses be conducted on at least an annual time step. However, water budget calculations were performed on a monthly time step to support the evaluation of sustainability indicators and potential projects and management actions. These sustainability evaluations may require data and analyses at a time step sufficient to assess seasonal conditions and trends within an annual interval in addition to long-term trends spanning years. For reporting purposes, water budget results are summarized by water year.

2.2.4.4 Water Budget Conceptual Model

A water budget is defined as a complete accounting of all water flowing into and out of a defined system over a specified period of time. The system, in this case, is defined as the groundwater-producing aquifers (alluvium and lake deposits, volcanic ash aquifer and underlying fractured bedrock), and the associated surface water and Land Surface System (hydrogeologic units in the Basin are described in detail in **Section 2.2.1**). The conceptual model for the Basin's water budgets utilizes the physical setting, characteristics, and hydrologic processes detailed in **Sections 2.2.1** and **2.2.2**, along with historical, current, and projected water inflows and outflows.

Study Area

The water budget study area is defined as the Big Valley Groundwater Basin. The lateral and vertical extents of the plan area are described in **Sections 2.1** and **2.2.1**. The vertical extent of the water budget study area is divided into the SWS and GWS. The SWS represents the land surface to a depth of the bottom of the plant root zone.[1] The GWS extends from the bottom of the plant root zone to the definable bottom of the Basin. During the BVIHM development, the study area (Big Valley Basin and adjacent areas included in the model) was divided into 18 subregions, referred to as water balance subregions, based on the type of land use, and the Basin boundary (**Figure 2-73**). Water balance subregions can facilitate to develop local-scale water budgets to support planning and management actions as needed.

[1] The root zone is defined as "the upper portion of the soil where water extraction by plant roots occurs." The depth to the bottom of the root zone varies by crop, but typically ranges from 2-7 feet (ASCE, 2016).

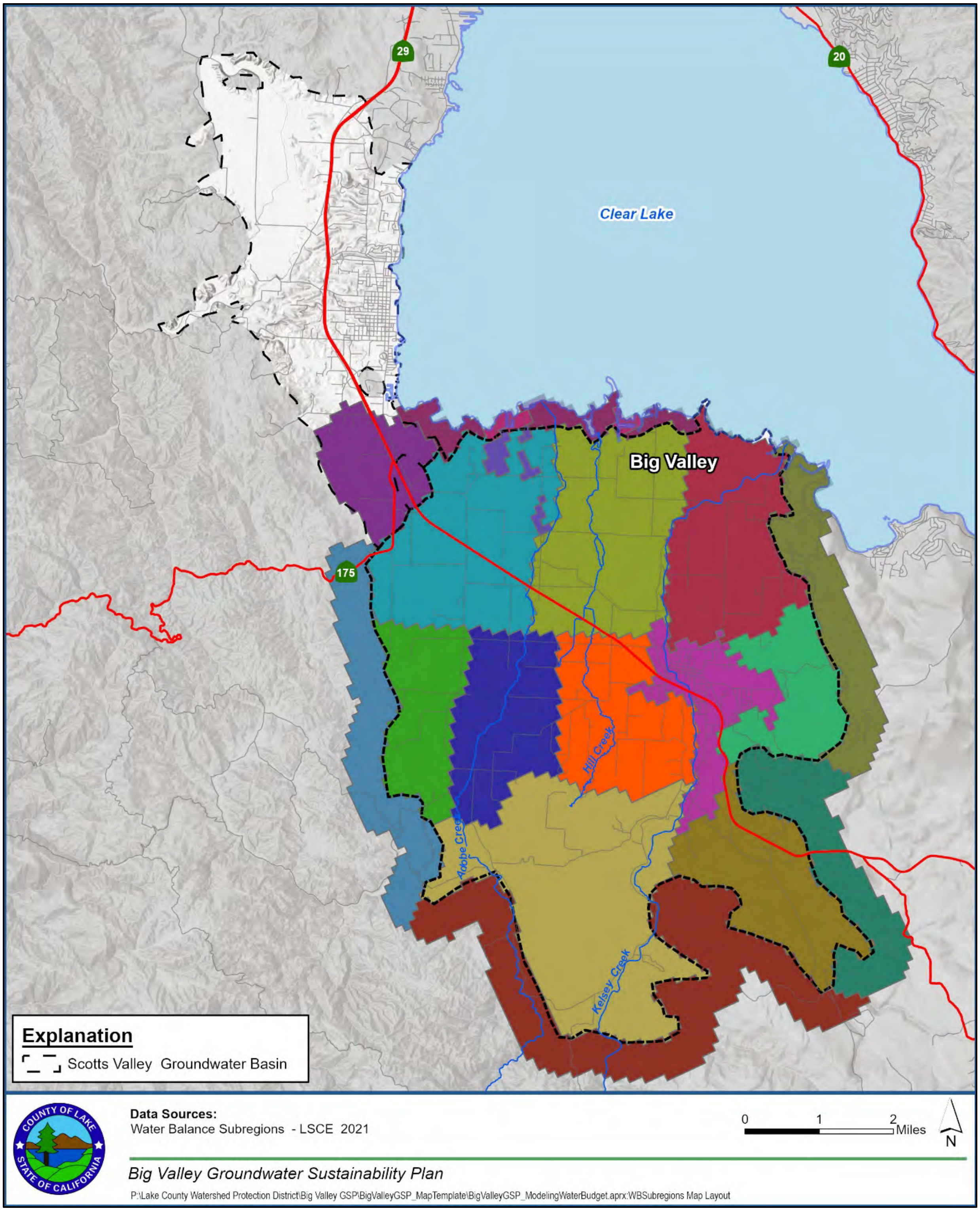


Figure 2-73. Big Valley Integrated Hydrologic Model Study Area and Water Balance Subregions

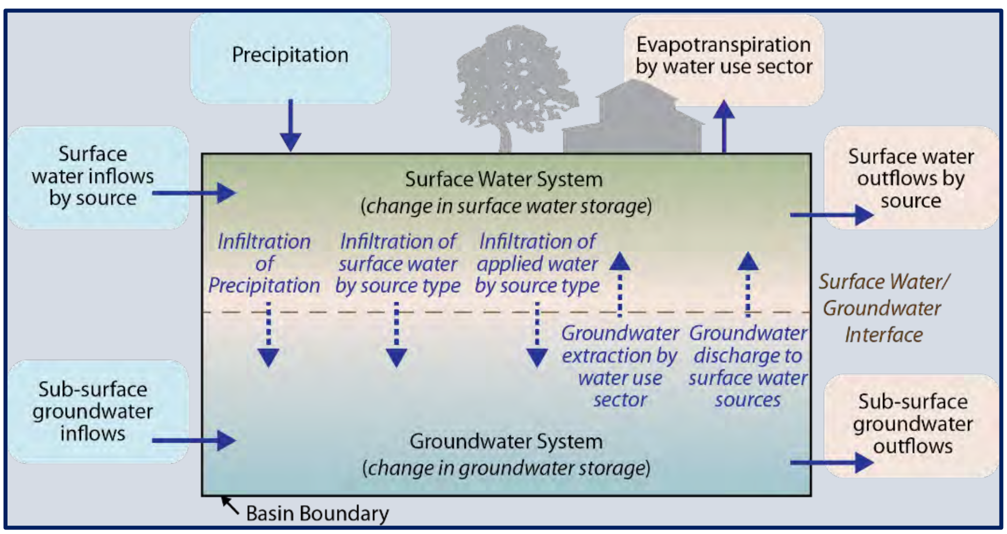
General Water Budget Accounting Structure and Components

For accounting purposes, the Basin's water budget is divided into the SWS and GWS as described above. These systems are referred to as accounting centers. Flows between accounting centers and storage within each accounting center represent water budget components. Separate but related water budgets were prepared for each accounting center that together represent the overall water budget of the Basin. A schematic of the general water budget accounting structure is presented in **Figure 2-74**, which is consistent with the conceptual framework of the BVIHM. Required components for each accounting center are listed in **Table 2-8**, along with the corresponding section of the GSP Regulations (CCR Title 23 § 354). Note that precipitation is not explicitly listed as a required water budget component, though it is needed to provide complete accounting of inflows and outflows of the Basin.

Some water budget components may be estimated independent of the water budget, while others may be calculated based on the fundamental principle that the difference between basin inflows and outflows is balanced by a change in the volume of water in storage. Water budgets developed for the Basin use a structure consistent with recommendations from DWR's Water Budget Best Management Practices (DWR 2016) and utilizes the basic water budget equation (**Equation 1**).

Inflow – Outflow = Change in Storage

Equation 1 Water Budget Equation



Source: DWR, 2016a

Table 2-8. Water Budget Components by Accounting Center and Associated Groundwater Sustainability Plan Regulations

Accounting Center	Water Budget Component (Flow Direction)	Groundwater Sustainability Plan Regulation Section[1]
Basin	Surface Water Inflow[2] (+)	§354.18(b)(1)
	Precipitation (+)	Implied
	Subsurface Groundwater Inflow (+)	§354.18(b)(2)
	Evapotranspiration[3] (-)	§354.18(b)(3)
	Surface Water Outflow[2] (-)	§354.18(b)(1)
	Subsurface Groundwater Outflow (-)	§354.18(b)(3)
	Change in Storage	§354.18(b)(4)
Surface Water System (SWS)	Surface Water Inflow[2] (+)	§354.18(b)(1)
	Precipitation (+)	Implied
	Groundwater Extraction (+)	§354.18(b)(3)
	Groundwater Discharge (+)	§354.18(b)(3)
	Evapotranspiration[3] (-)	§354.18(b)(3)
	Surface Water Outflow[2] (-)	§354.18(b)(1)
	Infiltration of Applied Water[4,5] (-)	§354.18(b)(2)
	Infiltration of Precipitation[4] (-)	§354.18(b)(2)
	Infiltration of Surface Water[6] (-)	§354.18(b)(2)
	Change in SWS Storage[7]	§354.18(a)
Groundwater System (GWS)	Subsurface Groundwater Inflow (+)	§354.18(b)(2)
	Infiltration of Applied Water[4,5] (+)	§354.18(b)(2)
	Infiltration of Precipitation[4] (+)	§354.18(b)(2)
	Infiltration of Surface Water[6] (+)	§354.18(b)(2)
	Subsurface Groundwater Outflow (-)	§354.18(b)(3)
	Groundwater Extraction (-)	§354.18(b)(3)
	Groundwater Discharge (-)	§354.18(b)(3)
	Change in GWS Storage	§354.18(b)(4)

Notes:

[1] California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2 Groundwater Sustainability Plans, Article 5 Plan Contents

[2] By water source type.

[3] Evapotranspiration includes total evapotranspiration and evaporation, by water use sector. Total evapotranspiration includes the combined evaporation from the soil and transpiration from plants, resulting from both applied water and precipitation. In this context, evaporation is the direct evaporation from open water surfaces.

[4] Synonymous with deep percolation.

[5] Includes infiltration of applied surface water and groundwater

[6] Synonymous with seepage. Includes infiltration of lakes, streams, canals, drains, and springs.

[7] Change in storage of root zone soil moisture, not groundwater.

Detailed Water Budget Accounting Structure and Components

To estimate the water budget components required by the GSP Regulations, the SWS water budget accounting center is subdivided into two detailed accounting centers representing the Land Surface System, which includes irrigated and non-irrigated lands, and the Stream System, which include natural waterways. The Land Surface System is further subdivided into accounting centers representing water use sectors identified in the GSP regulations as "categories of water demand based on the general land uses to which the water is applied, including urban, industrial, agricultural, managed wetlands, managed recharge, and native vegetation" (CCR Title 23 § 351[al]). The water use sector accounting centers of the Basin's water budget include the Agriculture sector (includes semi-agricultural), Public Water Systems sector (urban and urban industrial), Native Vegetation sector (includes open space, riparian vegetation, wetlands), and Self-Supplied sector (includes urban/rural residential, commercial, and industrial).

Detailed water budget components are defined for each detailed accounting center. Within the Land Surface System accounting center, detailed water budget components are also defined for each water use sector accounting center. The addition of these detailed water budget accounting centers and components allows the development of water budgets based on the best available data and science by facilitating the incorporation of information from urban water management plans and other sources. Water budget components for each detailed accounting center within the Basin's SWS and GWS are described in **Table 2-9** through **Table 2-11**.

Table 2-9. Land Surface System Water Budget Components

Detailed Accounting Center	Detailed Component	Category	Description
Land Surface System Water Use Sectors: Agriculture, Public Water Systems, Native Vegetation, Self-Supplied	Precipitation	Inflow	Direct precipitation on the land surface.
Land Surface System Water Use Sectors: Agriculture, Public Water Systems, Native Vegetation, Self-Supplied	Non-Routed Deliveries	Inflow	Applied water to the land surface. This water is sourced from imported water, recycled water, direct stream diversions and specified pumping from municipalities and small public water supply systems.
	Groundwater Pumping	Inflow	Groundwater applied to the land surface to meet residual crop water demands.
	Groundwater Uptake	Inflow	The uptake of shallow groundwater through vegetation root systems.
	Septic Recharge	Inflow	Seepage from septic systems to the unsaturated zone.
	Drain Flows	Inflow	Groundwater seepage to drainage systems emptying on to the land surface.
	Deep Percolation	Outflow	Deep infiltration of precipitation and applied water below the root zone.
	Runoff	Outflow	Direct runoff of precipitation and applied water.
	Evapotranspiration	Outflow	Combined evaporation from the soil and transpiration from plants, resulting from both applied water and precipitation.

Table 2-10. Stream System Water Budget Components

Detailed Accounting Center	Detailed Component	Category	Description
Stream System	Surface Water Inflows	Inflow	Surface water inflows at upper boundary of water budget area.
	Land Surface Runoff	Inflow	Runoff from the land surface into stream channels.
	Stream Leakage	Inflow	Seepage into streams from the Groundwater System during times of natural flow.
	Stream Leakage	Outflow	Seepage from streams into the Groundwater System during times of natural flow.
	Surface Water Diversions	Outflow	Surface water removed from stream for irrigation uses on the land surface.
	Surface Water Outflows	Outflow	Surface water outflows at lower boundary of water budget area.

Table 2-11. Groundwater System Water Budget Components

Detailed Accounting Center	Detailed Component	Category	Description
Groundwater System	Net Recharge	Inflow	Recharge to the Groundwater System as a result of deep percolation of precipitation and applied water, excluding any evaporation of groundwater.
	Subsurface Inflow	Inflow	Subsurface groundwater entering the Basin from the surrounding watershed.
	Stream Leakage	Inflow	Seepage from streams to the Groundwater System during times of natural flow.
	Evapotranspiration from Groundwater	Outflow	Consumptive use of groundwater through vegetation root water uptake.
	Subsurface Outflow	Outflow	Subsurface groundwater exiting the Basin.
	Stream Leakage	Outflow	Seepage into streams from the Groundwater System during times of natural flow.
	Groundwater Pumping	Outflow	Groundwater pumping for use on the land surface.
	Drain Flows	Outflow	Groundwater seepage into drainage catchments installed in certain agricultural land uses.

2.2.4.5 Water Budget Components

The water budget components that comprise inflows and outflows are listed in **Table 2-12**. The complete water budget consists of two accounting centers, a SWS water budget (composed of Land Surface System and Stream System) and a GWS water budget.

Table 2-12. Land Surface System, Stream System, and Groundwater System Water Budget Components

Land Surface System Water Budget Components	
Inflows	***Outflows***
Precipitation	Deep Percolation
Groundwater Uptake	Runoff
Non-Routed Deliveries	Evapotranspiration
Groundwater Pumping	
Septic Recharge	
Drain Flow	
Stream System Water Budget Components	
Inflows	***Outflows***
Surface Water Inflow	Surface Water Outflow
Land Surface Runoff	Surface Water Diversions
Stream Leakage (Gain)	Stream Leakage (Loss)
Groundwater System Water Budget Components	
Inflows	***Outflows***
Deep Percolation	Subsurface Outflow
Subsurface Inflow	Stream Leakage (Gain)
Stream Leakage (Loss)	Groundwater Extraction
	Evapotranspiration
	Groundwater Uptake
	Drain Flow

Land Surface System

The Land Surface System water budget represents the total amount of water that enters and leave the Basin on the land surface. The following sections describe each Land Surface System water budget component.

Precipitation (Inflow)

Precipitation values used in the model were obtained from the USGS Basin Characterization Model (Flint et al., 2021), which utilized precipitation data modeled by the PRISM Climate Group at Oregon State University. This data set provided monthly precipitation data for the Basin area for the historical, current, and projected water budgets.

Groundwater Uptake (Inflow)
Groundwater uptake is absorption of shallow groundwater through vegetation root systems. Groundwater is drawn into the plant tissue where it is eventually released as vapor by leaves, known as transpiration.

Non-Routed Deliveries (Inflow)
Non-routed deliveries are used to represent water supplied to Kelseyville and two other small public water systems (PWS) in the Basin (Westgate Petroleum and Skypark Properties), which report to the state. PWS were identified within the Electronic Annual Report (EAR) database maintained by the SWRCB. These reports include monthly reports of water supply and use from 2013 through 2019. Prior to 2013, monthly records were estimated using average monthly amounts and subdivided into wet and dry years. Based on information included in the EAR, all reported water supplied to PWS in the Basin is sourced from groundwater reported as "Municipal Pumping" in the groundwater budget.

Semi-Routed Deliveries/ In-stream Diversion (Inflow)
Semi-routed deliveries represent direct in-stream diversions from streams in the Basin to supply agricultural water users. In-stream diversions occur from numerous points along Kelsey Creek, Adobe Creek and Cole Creek and smaller tributaries which are reported to the SWRCB through the Water Rights Information Management System (eWRIMS). Monthly diversion volumes from 2010 to 2019 were obtained from eWRIMS reports available through the SWRCB. Prior to 2010, monthly diversion data from eWRIMS is unavailable and estimated from monthly average amounts based on the available record. The amount of surface water used for irrigation is very small compared to the amount of groundwater (described below). Recycled water is not used for irrigation or groundwater recharge within the Basin.

Groundwater Pumping (Inflow)
Groundwater is applied to the land surface for agricultural and irrigation purposes. The amount of water required to irrigate a crop is based on the water demand of that crop type and the climatic conditions (evapotranspiration and precipitation). The amount of groundwater needed to meet irrigation demand not met by precipitation and surface water diversions is estimated based on land use data, climatic data, and known surface water diversions. According to the 1995 DWR land use survey, 99 percent of irrigated agricultural lands in the Basin (a total of about 8,800 acres) were supplied solely by groundwater. The 2013 DWR land use survey data indicated a decrease in irrigated lands to about 6,000 acres with 98 percent of these lands irrigated solely with groundwater. More recent land use surveys do not include information on irrigation. In the projected baseline water budget, the amount of applied groundwater was calculated based on land use data from 2018 (the most recent available data).

Frost Protection (Inflow)
Irrigation for frost protection occurs on pear orchards and vineyards in the Basin generally from March through May. Irrigation for frost protection was estimated using minimum temperature data obtained from local weather stations maintained by the Western Weather Group and the PRISM Climate Group. The volume of irrigation for frost protection was estimated based on crop acreage assuming an irrigation rate of 0.11 acre-inches per hour for four hours in each day where minimum temperatures drop below 32 degrees Fahrenheit. This is represented by specifying and external added demand which is met largely through additional inflow via groundwater pumping.

Drain Flow (Inflow)
Tile drainage systems are used in some irrigated lands for the purpose of removing excess water from soil below the ground surface. In areas where groundwater elevation is within several feet from the ground surface and poorly drained soils create perched groundwater conditions, tile drains may be necessary to avoid oversaturating the soil and damaging crops. Use of tile drainage systems is not a common practice in the Basin; therefore, it was not included in the water budget.

Septic Recharge (Inflow)
Most water used for domestic purposes returns to the unsaturated zone through septic leach fields, which is considered an inflow to the Land Surface System. Septic recharge is applied to lands that self-supply groundwater through domestic wells. Approximately 80 percent of all indoor water use is assumed to return to the Land Surface System as septic return flow.

Deep Percolation (Outflow)
Deep percolation accounts for all the water that infiltrates to groundwater from precipitation and applied water. A majority of precipitation and applied water to the land surface leave the system through evaporation and runoff, with the remaining water available to percolate into the soil column where it is subject to evapotranspiration and soil absorption. After these processes the remaining water continues to percolate downward through the soil column past the plant root zone and enters the Groundwater System. Deep percolation depends on several factors, including irrigation efficiency, climate conditions, land surface slope, land use, soil texture and soil type, antecedent soil moisture, vegetation cover, and seasonal plant activity.

Runoff (Outflow)
Land surface runoff within the Basin accounts for excess precipitation and applied water that are not effectively used by crops and not subject to deep percolation. The remaining water after these processes flows downgradient as land surface runoff that is subject to enter the Stream System. Runoff as an inflow to the Stream System reflects seasonal patterns in precipitation, resulting in increased stream flows during the winter and spring months and decreased stream flows during the summer and fall months.

Evapotranspiration (Outflow)
ET is the amount of water evaporated from soil or other surfaces and consumed by vegetation through transpiration. The amount of transpiration, thus ET, is dependent on the vegetation or crop type and climatic conditions. Evapotranspiration data was obtained from the USGS Basin Characterization Model (Flint et al., 2021) as potential evapotranspiration (PET) and calibrated to measured PET from California Irrigation Management and Information System stations across California. The derived output from calibrated PET results in reference evapotranspiration at a monthly time step for the Basin. Evapotranspiration is both an inflow and outflow to the Land Surface System given that crops and other vegetation uptake shallow groundwater and applied water through their root systems, which in turn exits the Land Surface System through plant transpiration. For reporting purposes, ET outflow from the Land Surface System also accounts for evaporation.

Stream System

The Stream System water budget represents the total amount of water entering and leaving the Basin on the ground surface. The following sections describe each Stream System water budget component.

Surface Water Flow (Inflow/Outflow)

Surface water inflows and outflows represent the total amount of surface water entering and leaving the Basin in streams or canals. Flows of Kelsey Creek, Adobe Creek, Cole Creek, McGaugh Slough, Hill Creek, Thompson Creek, Manning Creek, Rumsey Slough, Highland Creek, McIntire Creek, Sweetwater Creek, and numerous tributary streams are included in the Stream System (main surface water features in the Basin are shown in **Figure P**).

Stream Leakage (Inflow/Outflow)

Stream leakage accounts for the loss or gain of surface water in streams. Stream leakage occurs as an inflow to the Stream System when groundwater discharges into the Stream System through the stream interface (gaining stream conditions), whereas stream leakage occurs as an outflow from the Stream System when water within the stream infiltrates through the stream interface to recharge the Groundwater System (losing stream conditions).

Groundwater System

The Groundwater System water budget represents the total amount of subsurface water entering and leaving the Basin. Below is a brief description of each water budget component.

Deep Percolation (Inflow)

Deep percolation accounts for all the water that infiltrates to groundwater from precipitation and applied irrigation water and is considered direct recharge to the groundwater budget. Groundwater recharge primarily occurs through deep percolation of precipitation and applied irrigation water in the Basin.

Subsurface Flow (Inflow/Outflow)

Subsurface inflows and outflows include lateral groundwater flow to or from the upper portions of the watershed surrounding the Basin as well as between the Scotts Valley Basin and were estimated using the numerical model. Flow between the Basin and the upper portions of the watershed are largely influenced by mountain block recharge assigned at the upland portion of the numerical model boundary. Mountain block recharge was estimated using the Basin Characterization Model. Lateral subsurface flow between the Basin and the Scotts Valley Basin was estimated using the numerical model and is a function of the simulated volume and distribution of groundwater recharge and pumping.

Stream Leakage (Inflow/Outflow)

Similar to stream leakage described in the Stream System, stream leakage within the Groundwater System accounts for the same processes that occur under gaining and losing stream conditions. Flow between the stream and Groundwater System is computed using Darcy's law and assumes uniform flow between a stream and aquifer over a given section of the stream and corresponding volume of aquifer. Stream leakage across the streambed is dependent on both the stream head and the groundwater head, where the volume of water that seeps from the stream is determined by the infiltration rate and wetted area of the stream.

Groundwater Uptake (Outflow)
As described in the Land Surface System, groundwater uptake is an outflow to the Groundwater System due to crop and vegetation root water uptake of shallow groundwater. Additionally, groundwater uptake by GDEs is an important aspect due to the ecological significance of riparian and wetland habitats that rely on shallow groundwater during the dry season and account for a significant amount of groundwater consumption within the Basin. The rate of groundwater withdrawal by all crop and vegetation types is estimated as the difference in simulated evapotranspiration when all vegetation types are assumed to be non-irrigated, compared to irrigated vegetation. Crop and vegetation evapotranspiration is dependent on the availability of shallow groundwater and the rooting depth of each crop and vegetation type.

Groundwater Extraction (Outflow)
The total amount of extracted groundwater is composed of the groundwater used for crop irrigation and frost protection, groundwater pumped by public water systems, and groundwater pumped by self-supplied users. Groundwater extraction for agriculture and crop irrigation is estimated based on crop water demand (evapotranspiration and frost protection) that is not met by precipitation and surface water diversions. Groundwater extractions by public water systems was obtained from the EAR database maintained by the SWRCB from 2013 through 2020. Prior to 2013, groundwater pumping was estimated based on average monthly pumping for wet and dry years. Groundwater extraction for self-supplied users is estimated based on land use data and the 1990 and 2010 census for populations outside of public water system service areas.

Change in Groundwater Storage
Changes in groundwater storage reflect the sum of the inflow (positive values) and outflow (negative values) water budget components. A positive change in groundwater storage is an increase in storage typified by a rise in groundwater levels, whereas a negative change is a decrease in storage typified by a decline in groundwater levels. The water budgets presented in this section account for the inflows, outflows, and changes in groundwater storage for the Basin.

2.2.4.6 Historical Water Budget
This section summarizes the results and analyses relating to the historical water budgets for the Basin. Detailed descriptions and presentation of results for each of the individual water budget components, and the processes and data sources used in their development are included in **Appendix 2C**.

Land Use Sectors
Characterizing historical land use is foundational for accurately quantifying how and where water is beneficially used. Land use areas are also used to distinguish the water use sector in which water is consumed, as required by the GSP Regulations. **Table 2-13** presents the annual land use acreages over the historical period (1989-201) in the Basin by water use sector as defined by the GSP Regulations (CCR Title 23 § 351[al]). In the Basin, water use sectors include native vegetation, agricultural, and urban land uses. The urban water use sector covers all urban, residential, industrial, and semi-agricultural land uses.

On average, native vegetation, agricultural and urban lands covered approximately 13,000 acres, 9,100 acres, and 2,100 acres, respectively, between 1989 and 2019. The total acreage of each water use sector has remained relatively steady over time. Detailed land use details are presented in **Section 2.1** and **Appendix 2C**.

Table 2-13. Big Valley Basin Historical Land Use Areas Used for Water Budget Calculations (acres)

Water Year and Type	Native Vegetation	Agricultural	Urban[1]	Total
1988 (D)	12,900	9,500	1,800	24,200
1989 (BN)	12,900	9,500	1,800	24,200
1990 (D)	12,900	9,500	1,800	24,200
1991 (D)	12,900	9,500	1,800	24,200
1992 (D)	12,900	9,500	1,800	24,200
1993 (W)	12,900	9,500	1,800	24,200
1994 (AN)	12,900	9,500	1,800	24,200
1995 (W)	12,900	9,500	1,800	24,200
1996 (W)	12,900	9,500	1,800	24,200
1997 (W)	12,900	9,500	1,800	24,200
1998 (W)	12,900	9,500	1,800	24,200
1999 (W)	12,900	9,500	1,800	24,200
2000 (AN)	12,900	9,500	1,800	24,200
2001 (D)	12,900	9,500	1,800	24,200
2002 (BN)	12,900	9,500	1,800	24,200
2003 (AN)	12,900	9,500	1,800	24,200
2004 (AN)	12,900	9,500	1,800	24,200
2005 (AN)	12,900	9,500	1,800	24,200
2006 (W)	12,900	9,500	1,800	24,200
2007 (BN)	12,900	9,500	1,800	24,200
2008 (C)	12,900	9,500	1,800	24,200
2009 (C)	12,900	9,500	1,800	24,200
2010 (BN)	13,000	8,400	2,800	24,200
2011 (AN)	13,000	8,400	2,800	24,200
2012 (D)	13,000	8,400	2,800	24,200
2013 (D)	13,000	8,400	2,800	24,200
2014 (C)	13,000	8,400	2,800	24,200
2015 (D)	13,000	8,400	2,800	24,200
2016 (AN)	13,000	8,400	2,800	24,200
2017 (W)	13,600	7,900	2,700	24,200
2018 (AN)	13,600	7,900	2,700	24,200
2019 (W)	13,600	7,900	2,700	24,200
Average	**13,000**	**9,100**	**2,100**	**24,200**

Notes:
[1] Area includes land classified as urban, residential, industrial, and semi-agricultural.
All acreages are rounded to the nearest 100.
Some land use acreages in this table may be slightly different than the acreages presented in Section 2.1 of this GSP because of the differences in grouping of land use classes and rounding.

Land Surface System Budget

Annual inflows to and outflows from the Land Surface System of the Basin are summarized in **Table 2-14** and **Figure 2-76**. Inflows to the Land Surface System include precipitation, groundwater uptake (evapotranspiration of groundwater), applied water for irrigation (non-routed deliveries, stream diversions and groundwater), and septic recharge. The outflows from the

Land Surface System include land surface runoff that enters the Stream System, evapotranspiration, and deep percolation. Deep percolation is the inflow to the Groundwater System minus groundwater uptake from plants and evaporation at the land surface. The total of inflows is in balance with the total outflows in a water year. The total volume of water in the Land Surface System budget averages about 101,000 AFY for the 1988-2019 period, with the highest volumes in wet years (average about 133,000 AFY) and the lowest volumes in critical years (average about 76,000 AFY).

Precipitation makes up the largest fraction of the total inflows. Over the historical water budget period, the average basin-wide precipitation is about 73,800 AFY with the minimum and maximum of 39,200 acre-feet in 2014 and 133,500 acre-feet in 1998, respectively. The average, minimum and maximum volumes are equivalent to basin-wide precipitation of 36.6, 19.4 and 66.2 inches per year, respectively. Groundwater uptake and groundwater pumping during this period also represent large inflows averaging about 13,4500 and 13,000 AFY, respectively. Variability of groundwater uptake between water years of different types is relatively low. In general, groundwater uptake is higher in wet years and lower in dry years, reflecting the difference of shallow groundwater availability for plants during wet and dry years. In contrast, variability of groundwater pumping between different water year types is relatively high. Over the 1988 – 2019 period, annual groundwater pumping averages about 11,100 AFY for wet years and 17,300 AFY for critical years. Contribution of non-routed deliveries, in-stream diversions and septic recharge to the Land Surface System budget are very small and each at averages about 300 AFY.

Land surface runoff and ET are the major outflows from the Land Surface System. Runoff and ET average about 51,400 and 33,700 AFY, respectively over the historical water budget period. Annual runoff is highly variable (on average 75,800 AFY in wet years and 31,900 AFY in critical years). In contrast, annual ET varies within a relatively narrow range with increased ET in wet years (on average 36,00 AFY) compared to dry and critical years (31,000 AFY in critical years). Deep percolation is about 16,000 AFY on average for the 1988 – 2019 period. Annual deep percolation is higher in wet years compared to drier years (on average 21,700 AFY in wet years and 13,600 AFY in critical years). The major components of the Basin's Land Surface System budget appear to be strongly influenced by variability of annual precipitation.

Table 2-14. Big Valley Basin Historical Land Surface System Water Budget (1988 – 2019)

Water Year and Type	Inflow (Acre-Feet)						Outflow (Acre-Feet)		
	Precipitation	Groundwater Uptake	Non-Routed Delivery	In-Stream Diversion	Groundwater Pumping[1]	Septic Recharge	Runoff	Evapo-transpiration	Deep Percolation
1988 (D)	59,300	11,800	300	400	13,600	300	-40,300	-32,700	-12,700
1989 (BN)	58,200	10,900	300	400	12,800	300	-37,600	-33,400	-11,800
1990 (D)	50,700	11,400	300	200	12,000	300	-30,200	-35,100	-9,600
1991 (D)	49,400	10,300	300	400	15,400	300	-33,100	-30,700	-12,300
1992 (D)	57,600	11,000	300	400	14,800	300	-37,600	-33,500	-13,200
1993 (W)	100,200	14,500	300	300	9,700	300	-68,900	-37,400	-18,900
1994 (AN)	48,000	11,600	300	400	14,200	300	-31,500	-32,300	-10,900
1995 (W)	129,900	17,100	300	400	12,500	300	-95,000	-37,200	-28,300
1996 (W)	87,500	16,400	300	300	12,300	300	-61,500	-37,100	-18,500
1997 (W)	83,100	15,600	300	300	12,700	300	-57,900	-35,700	-18,800
1998 (W)	133,500	18,900	300	300	9,900	300	-96,900	-38,800	-27,500
1999 (W)	71,100	16,500	300	400	13,700	300	-50,800	-33,700	-17,700
2000 (AN)	71,200	15,000	300	400	11,200	300	-47,700	-36,400	-14,300
2001 (D)	52,900	12,800	300	300	15,000	300	-35,800	-32,700	-13,200
2002 (BN)	67,400	12,500	300	400	14,900	300	-47,800	-32,300	-15,600
2003 (AN)	90,000	14,300	300	300	13,000	300	-64,800	-34,600	-18,700
2004 (AN)	80,100	14,100	300	300	13,600	300	-59,800	-32,100	-16,900
2005 (AN)	84,700	15,300	200	300	10,400	300	-56,000	-38,500	-16,800
2006 (W)	110,100	17,600	300	300	10,200	300	-81,300	-35,800	-21,700
2007 (BN)	47,500	13,000	300	400	14,600	300	-32,700	-31,900	-11,400
2008 (C)	54,500	12,300	300	400	20,000	300	-40,300	-29,000	-18,500
2009 (C)	49,700	11,000	300	400	16,500	300	-31,600	-33,100	-13,400

Table 2-14. Big Valley Basin Historical Land Surface System Water Budget (1988 – 2019) (contd.)

Water Year and Type	Inflow (Acre-Feet)						Outflow (Acre-Feet)		
	Precipitation	Groundwater Uptake	Non-Routed Delivery	In-Stream Diversion	Groundwater Pumping[1]	Septic Recharge	Runoff	Evapo-transpiration	Deep Percolation
2010 (BN)	78,600	13,000	300	1,100	11,500	300	-53,500	-33,800	-17,300
2011 (AN)	83,000	14,800	300	600	9,700	300	-57,500	-34,200	-16,900
2012 (D)	49,700	12,500	300	300	13,000	300	-33,000	-31,500	-11,500
2013 (D)	57,900	11,000	400	200	13,200	300	-39,100	-31,600	-12,300
2014 (C)	39,200	8,200	300	100	15,500	300	-23,800	-30,900	-8,900
2015 (D)	61,500	9,600	300	100	14,700	300	-42,300	-30,700	-13,500
2016 (AN)	74,900	11,400	300	100	13,500	300	-54,000	-31,100	-15,300
2017 (W)	122,200	15,900	300	100	10,000	300	-91,800	-33,300	-23,600
2018 (AN)	48,200	12,100	300	100	12,900	300	-31,800	-31,400	-10,700
2019 (W)	108,400	15,500	300	100	8,900	300	-78,500	-34,900	-19,900
Average 1989 - 2019	**73,800**	**13,400**	**300**	**300**	**13,000**	**300**	**-51,400**	**-33,700**	**-16,000**
W	105,100	16,400	300	300	11,100	300	-75,800	-36,000	-21,700
AN	72,500	13,600	300	300	12,300	300	-50,400	-33,800	-15,100
BN	62,900	12,400	300	600	13,500	300	-42,900	-32,900	-14,000
D	54,900	11,300	300	300	14,000	300	-36,400	-32,300	-12,300
C	47,800	10,500	300	300	17,300	300	-31,900	-31,000	-13,600

Notes:
[1] Calculated pumping needed to meet residual irrigation and frost protection demand for agriculture and urban and residential landscaping.
All volumes are rounded to the nearest 100 acre-feet.

Key:
AN = above normal
BN = below normal
C = critical
D = dry
W = wet

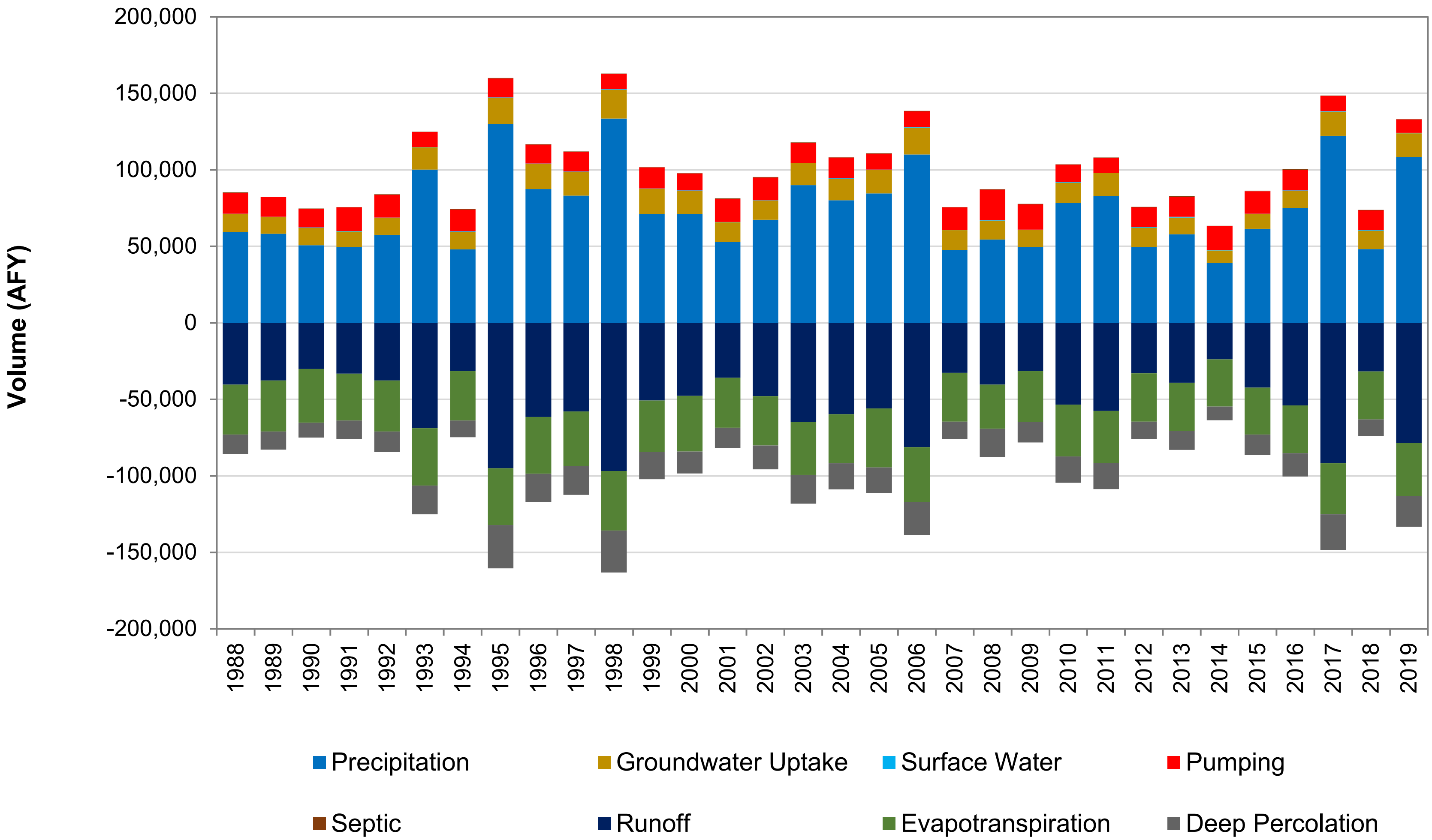


Figure 2-75. Big Valley Basin Historical Land Surface System Water Budget (1988 – 2019)

Stream System Budget

Annual inflows and outflows of the Stream System budget are summarized in **Table 2-15** and **Figure 2-76**. Inflows to the Stream System include stream inflow, stream gain from groundwater, and surface runoff. Outflows from the Stream System include stream outflow, stream loss (leakage to groundwater), and diversions from streams. The total inflow is in balance with the total outflow. The total volume of water in the Stream System budget averages about 144,000 AFY for the 1988-2019 period, with the highest volumes in wet years (average about 234,000 AFY) and the lowest volumes in critical years (average about 74,300 AFY).

Stream flow that enters the Basin makes up the largest fraction of the total inflows. Over the historical water budget period, the average stream inflow was about 85,400 AFY with the highest inflows during wet years (147,000 AFY on average) and the lowest inflows during critical years (37,800 AFY). Surface water runoff to streams averages about 56,000 AFY for the historical period with the highest runoff occurring in wet years (82,600 AFY on average) and the lowest runoff occurring in critical years (34,800 AFY). In comparison to these two inflows, stream gain from groundwater discharge is relatively small with an average of about 3,000 AFY over the historical period.

Stream outflow that exits the Basin is the major outflow from the Stream System, and it is larger than the stream inflow on annual basis primarily due to the contribution of runoff. Over the historical period, stream outflow averages about 137,000 AFY. Similar to stream inflow, stream outflow is also highest in wet years (227,000 AFY on average) and lowest in critical years (66,400 AFY on average). Stream loss to groundwater averages about 7,500 AFY over the historical period, and its variability is relatively small. On annual basis, stream loss is consistently greater than stream gain indicating a net flow from the Stream System to the Groundwater System. The only exception occurs for 1998, when the stream gain exceeds the stream loss due to very high annual precipitation. Direct diversion from streams is a small fraction of the Stream System budget and averages about 300 AFY.

Table 2-15. Big Valley Basin Historical Stream System Water Budget (1988 – 2019)

Water Year	Stream Inflow (AF)	Stream Outflow (AF)	Stream Gain (AF)	Stream Loss (AF)	Runoff (AF)	Diversions (AF)	Total Inflow (AF)	Total Outflow (AF)
1988 (D)	56,300	-95,000	2,500	-7,400	44,000	-400	102,800	-102,900
1989 (BN)	45,500	-78,000	1,700	-10,100	41,300	-400	88,400	-88,400
1990 (D)	33,500	-60,600	1,700	-7,500	33,000	-200	68,200	-68,200
1991 (D)	43,600	-72,400	1,300	-8,500	36,300	-400	81,200	-81,200
1992 (D)	49,300	-82,500	1,500	-9,100	41,200	-400	91,900	-91,900
1993 (W)	120,700	-189,700	3,000	-8,600	74,900	-300	198,600	-198,700
1994 (AN)	35,400	-64,200	1,800	-7,000	34,300	-400	71,500	-71,500
1995 (W)	197,200	-296,900	4,900	-8,200	103,300	-400	305,400	-305,400
1996 (W)	108,700	-173,800	4,300	-5,800	66,900	-300	179,900	-179,900
1997 (W)	111,800	-172,800	4,700	-6,500	63,100	-300	179,700	-179,700
1998 (W)	188,900	-295,200	7,900	-6,700	105,400	-300	302,200	-302,200
1999 (W)	90,400	-145,000	5,200	-5,700	55,500	-400	151,100	-151,100
2000 (AN)	80,300	-128,600	3,700	-7,000	51,900	-400	135,900	-136,000
2001 (D)	45,600	-79,800	2,600	-7,100	39,000	-300	87,200	-87,200
2002 (BN)	82,000	-129,000	2,600	-7,400	52,200	-400	136,800	-136,800
2003 (AN)	116,300	-181,700	3,000	-7,900	70,500	-300	189,800	-189,900
2004 (AN)	102,200	-164,200	3,600	-6,300	65,000	-300	170,800	-170,800
2005 (AN)	95,000	-150,700	3,300	-8,300	60,900	-300	159,300	-159,300
2006 (W)	167,200	-254,200	5,500	-6,800	88,500	-300	261,300	-261,300
2007 (BN)	38,100	-70,400	2,800	-5,700	35,600	-400	76,500	-76,600
2008 (C)	60,200	-98,900	2,500	-7,400	44,000	-400	106,700	-106,700
2009 (C)	35,500	-62,500	1,600	-8,800	34,500	-400	71,600	-71,600
2010 (BN)	93,400	-143,200	2,100	-9,700	58,400	-1,100	153,900	-153,900

Table 2-15. Big Valley Basin Historical Stream System Water Budget (1988 – 2019) (contd.)

Water Year	Stream Inflow (AF)	Stream Outflow (AF)	Stream Gain (AF)	Stream Loss (AF)	Runoff (AF)	Diversions (AF)	Total Inflow (AF)	Total Outflow (AF)
2011 (AN)	97,300	-155,000	3,200	-7,300	62,500	-600	163,000	-163,000
2012 (D)	36,800	-68,100	2,100	-6,600	36,000	-300	75,000	-75,000
2013 (D)	58,800	-96,700	2,000	-6,700	42,600	-200	103,500	-103,500
2014 (C)	17,700	-37,700	900	-6,700	26,000	-100	44,500	-44,500
2015 (D)	63,300	-102,200	1,300	-8,300	46,000	-100	110,600	-110,600
2016 (AN)	91,000	-142,800	1,600	-8,500	58,900	-100	151,400	-151,400
2017 (W)	194,100	-291,400	5,100	-7,900	100,100	-100	299,300	-299,300
2018 (AN)	34,300	-64,900	2,100	-6,100	34,700	-100	71,100	-71,100
2019 (W)	143,300	-224,800	4,200	-7,900	85,300	-100	232,800	-232,800
Average 1988 - 2019	**85,400**	**-136,700**	**3,000**	**-7,500**	**56,000**	**-300**	**144,400**	**-144,500**
W	146,900	-227,100	5,000	-7,100	82,600	-300	234,500	-234,500
AN	81,500	-131,500	2,800	-7,300	54,800	-300	139,100	-139,100
BN	64,800	-105,200	2,300	-8,200	46,900	-500	113,900	-113,900
D	48,400	-82,200	1,900	-7,600	39,800	-300	90,100	-90,100
C	37,800	-66,400	1,700	-7,600	34,800	-300	74,300	-74,300

Note:
All volumes are rounded to the nearest 100 acre-feet.
Key:
AF = acre-feet
AN = Above Normal
BN = Below Normal
C = Critical
D = Dry
W = Wet

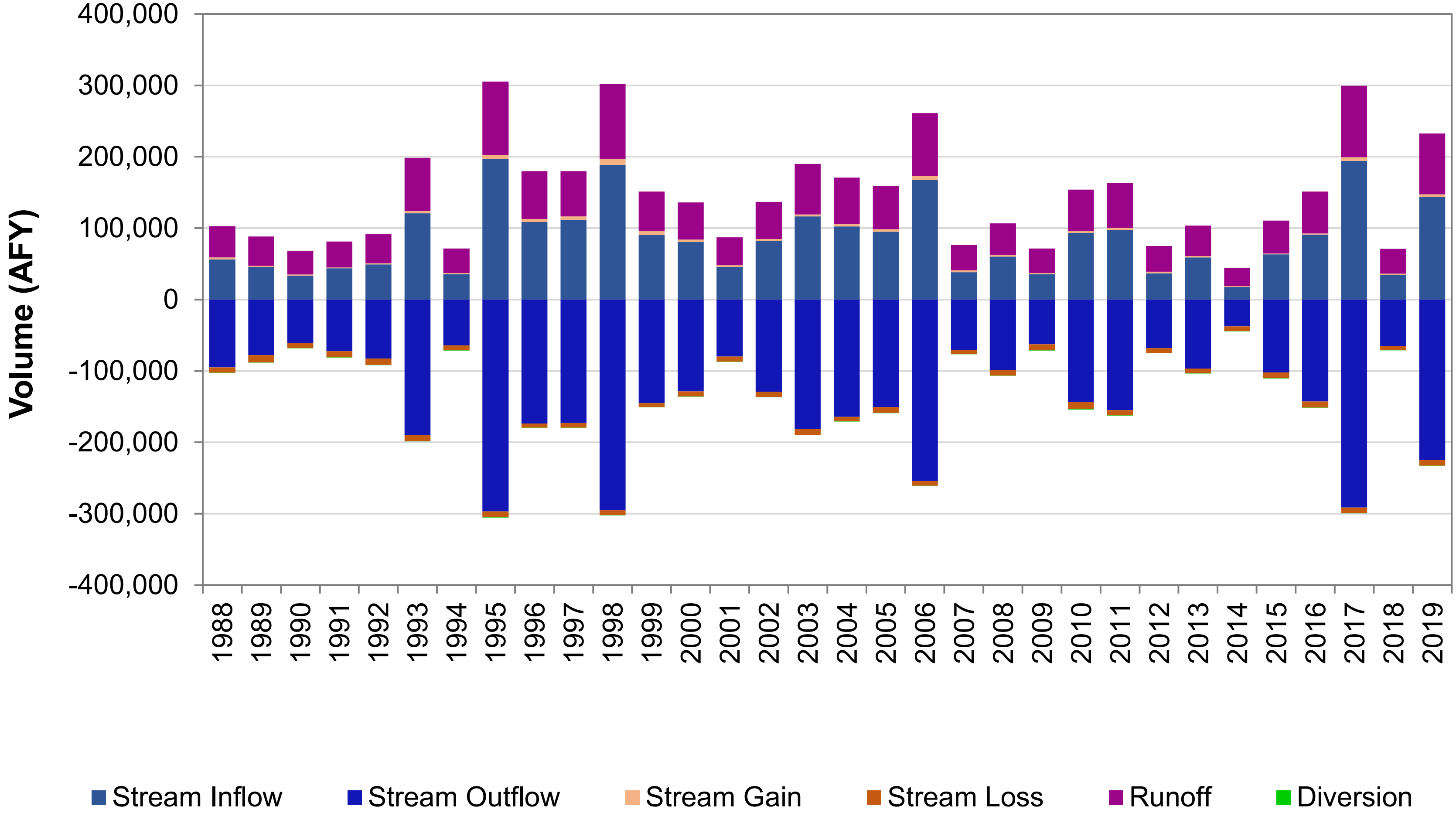


Figure 2-76. Big Valley Basin Historical Stream System Water Budget (1988 – 2019)

Groundwater System Budget

Annual inflows and outflows of the Stream System are summarized in **Table 2-16** and **Figure 2-77**. Inflows to the Groundwater System include deep percolation of precipitation and applied water, subsurface inflow from surrounding areas, and leakage of streamflow to the aquifer system. Outflows from the Groundwater System include groundwater pumping for agricultural, domestic, and municipal uses, groundwater uptake, and discharge of groundwater to streams. Annual stream leakage values presented in this section are the net inflows to the Groundwater System (i.e., stream leakage to aquifer minus groundwater discharge to streams). The difference between the total inflows and total outflows accounts for the storage change in the Groundwater System.

Deep percolation makes up the largest fraction of the total GWS inflows. Average deep percolation over the historical water budget period is about 16,000 AFY with the highest percolation occurring during wet years (about 21,700 AFY on average) and lower volumes occurring in drier years. Subsurface inflow from hillsides (surrounding areas of the Basin, except Scotts Valley and the Clear Lake) also represents a large inflow component to the Groundwater System averaging about 6,200 AFY. Similar to deep percolation, subsurface inflow from hillsides is higher during wet years (about 8,000 AFY) and lower during drier years (about 4,900 AFY in dry and critical years). Subsurface inflows from the Scotts Valley Basin and Clear Lake are relatively small averaging about 600 AFY and 100 AFY, respectively. Stream leakage to the GWS averages about 4,500 AFY over the historical period. As described in the Stream System budget, net stream leakage consistently occurs from the Stream System to GWS on annual basis (except in 1998), with higher volumes in dry years (about 6,000 AFY on average) and lower volumes in wet years (about 2,100 AFY).

Groundwater uptake is the main outflow from the GWS. During the historical period, it averages about 13,400 AFY. Groundwater uptake is higher during wet years (about 16,400 AFY on average) due to the abundance of shallow groundwater and lower during drier years due to limited availability of groundwater (about 10,500 AFY on average in critical years). Total groundwater pumping by all sectors (agricultural, domestic, and municipal) also averages about 13,700 AFY. Agricultural pumping accounts for a majority of total groundwater extractions over the historical period, ranging from 7,300 AFY to 16,400 AFY annually and averaging about 10,700 AFY (77 percent of total pumping). Domestic pumping averages about 2,600 AFY (19 percent of total pumping) with a relatively small variation between water years. By comparison, municipal pumping is relatively smaller and averages about 400 AFY (4 percent of total pumping). Both agricultural and domestic pumping are lowest in wet years and highest in critical years corresponding to annual changes in precipitation.

The average annual change in groundwater storage over the historical water budget period is about 200 AFY (an increase in storage) with a cumulative storage increase of 6,000 AFY over the 32-year period (**Figure 2-77**). By comparison, DWR estimates the storage capacity of Big Valley Basin to be 105,000 AF, with usable groundwater storage of approximately 60,000 AF (DWR 2004). The cumulative storage increase is equivalent to an increase of about 0.25 acre-feet per acre across the entire Basin (about 24,200 acres). Year to year change in groundwater storage ranges from a net decrease of up to 7,400 AFY to a net increase of up to 10,700 AFY during this period. Annual groundwater storage changes are presented in **Table 2-16** and storage decreases are denoted by the negative sign. In general, groundwater storage increases in wet years and decreases in drier years. The decrease of groundwater storage during relatively dry years is not an indication of overdraft, but likely due to removal of temporary surplus of groundwater. Temporary surplus removal is the extraction of a volume of aquifer storage to enable the capture of recharge and reduction in subsurface outflow from the Basin without impacting beneficial users of groundwater to an unreasonable degree.

Table 2-16. Big Valley Basin Historical Groundwater System Water Budget (1988 – 2019)

Water Year and Type	Stream Leakage (AF)	Inflow from Hillsides (AF)	Inflow from Scotts Valley Basin (AF)	Inflow from Clear Lake (AF)	Deep Percolation (AF)	Groundwater Uptake (AF)	Agricultural Pumping (AF)	Domestic Pumping (AF)	Municipal Pumping (AF)	Groundwater Storage Change (AF)	Cumulative Groundwater Storage Change (AF)
1988 (D)	4,900	5,600	500	100	12,700	-11,800	-11,100	-2,800	-400	-2,300	-2,300
1989 (BN)	8,400	5,100	600	100	11,800	-10,900	-10,600	-2,600	-400	1,600	-700
1990 (D)	5,700	4,300	500	100	9,600	-11,400	-9,800	-2,600	-400	-4,100	-4,800
1991 (D)	7,200	4,500	600	100	12,300	-10,300	-12,700	-3,000	-400	-1,900	-6,700
1992 (D)	7,700	4,700	600	100	13,200	-11,000	-12,200	-2,900	-400	-300	-7,000
1993 (W)	5,600	6,500	600	100	18,900	-14,500	-7,900	-2,100	-400	6,800	-200
1994 (AN)	5,200	4,700	600	100	10,900	-11,600	-11,700	-2,800	-400	-5,100	-5,300
1995 (W)	3,300	8,800	700	100	28,300	-17,100	-10,400	-2,400	-400	10,700	5,400
1996 (W)	1,500	7,600	600	100	18,500	-16,400	-10,200	-2,400	-400	-1,100	4,300
1997 (W)	1,800	7,400	600	100	18,800	-15,600	-10,500	-2,600	-400	-400	3,900
1998 (W)	-1,200	9,300	600	0	27,500	-18,900	-8,200	-2,000	-400	6,500	10,400
1999 (W)	600	7,500	600	100	17,700	-16,500	-11,400	-2,700	-400	-4,500	5,900
2000 (AN)	3,300	6,400	600	100	14,300	-15,000	-9,300	-2,200	-400	-2,300	3,600
2001 (D)	4,500	5,400	600	100	13,200	-12,800	-12,300	-3,000	-400	-4,800	-1,200
2002 (BN)	4,800	6,300	600	100	15,600	-12,500	-12,300	-2,900	-400	-600	-1,800
2003 (AN)	4,900	7,300	700	100	18,700	-14,300	-10,700	-2,500	-400	3,700	1,900
2004 (AN)	2,800	7,100	600	100	16,900	-14,100	-11,200	-2,700	-400	-1,000	900
2005 (AN)	5,000	6,400	600	100	16,800	-15,300	-8,700	-2,100	-400	2,400	3,300
2006 (W)	1,200	8,700	600	0	21,700	-17,600	-8,300	-2,200	-400	3,800	7,100

Table 2-16. Big Valley Basin Historical Groundwater System Water Budget (1988 – 2019) (contd.)

Water Year and Type	Stream Leakage (AF)	Inflow from Hillsides (AF)	Inflow from Scotts Valley Basin (AF)	Inflow from Clear Lake (AF)	Deep Percolation (AF)	Groundwater Uptake (AF)	Agricultural Pumping (AF)	Domestic Pumping (AF)	Municipal Pumping (AF)	Groundwater Storage Change (AF)	Cumulative Groundwater Storage Change (AF)
2007 (BN)	2,900	5,800	500	100	11,400	-13,000	-12,100	-2,800	-400	-7,400	-300
2008 (C)	4,900	6,000	700	100	18,500	-12,300	-16,400	-3,900	-400	-2,800	-3,100
2009 (C)	7,200	4,700	600	100	13,400	-11,000	-13,600	-3,200	-400	-2,200	-5,300
2010 (BN)	7,600	5,800	600	100	17,300	-13,000	-9,400	-2,400	-400	6,200	900
2011 (AN)	4,100	6,100	600	100	16,900	-14,800	-7,800	-2,100	-400	2,600	3,500
2012 (D)	4,500	4,700	500	100	11,500	-12,500	-10,600	-2,700	-400	-5,000	-1,500
2013 (D)	4,700	5,200	500	100	12,300	-11,000	-10,800	-2,700	-500	-2,200	-3,700
2014 (C)	5,800	3,900	600	100	8,900	-8,200	-12,700	-3,100	-400	-5,100	-8,800
2015 (D)	7,000	4,900	600	100	13,500	-9,600	-12,000	-3,000	-300	1,200	-7,600
2016 (AN)	7,000	5,900	700	100	15,300	-11,400	-11,000	-2,800	-400	3,500	-4,100
2017 (W)	2,800	8,700	600	0	23,600	-15,900	-8,300	-2,100	-400	9,100	5,000
2018 (AN)	4,000	5,200	500	100	10,700	-12,100	-10,800	-2,500	-400	-5,300	-300
2019 (W)	3,700	7,200	600	0	19,900	-15,500	-7,300	-1,800	-400	6,300	6,000

Table 2-16. Big Valley Basin Historical Groundwater System Water Budget (1988 – 2019) (contd.)

Water Year and Type	Stream Leakage (AF)	Inflow from Hillsides (AF)	Inflow from Scotts Valley Basin (AF)	Inflow from Clear Lake (AF)	Deep Percolation (AF)	Groundwater Uptake (AF)	Agricultural Pumping (AF)	Domestic Pumping (AF)	Municipal Pumping (AF)	Groundwater Storage Change (AF)	Cumulative Groundwater Storage Change (AF)
Average 1988 - 2019	**4,500**	**6,200**	**600**	**100**	**16,000**	**-13,400**	**-10,700**	**-2,600**	**-400**	**200**	
W	2,100	8,000	600	100	21,700	-16,400	-9,200	-2,300	-400	4,100	
AN	4,500	6,100	600	100	15,100	-13,600	-10,200	-2,500	-400	-200	
BN	5,900	5,800	600	100	14,000	-12,400	-11,100	-2,700	-400	-100	
D	5,800	4,900	600	100	12,300	-11,300	-11,400	-2,800	-400	-2,400	
C	6,000	4,900	600	100	13,600	-10,500	-14,200	-3,400	-400	-3,400	

Note:
All volumes are rounded to the nearest 100 acre-feet.
Key:
AF = acre-feet
AN = above normal
BN = below normal
C = critical
D = dry
W = wet

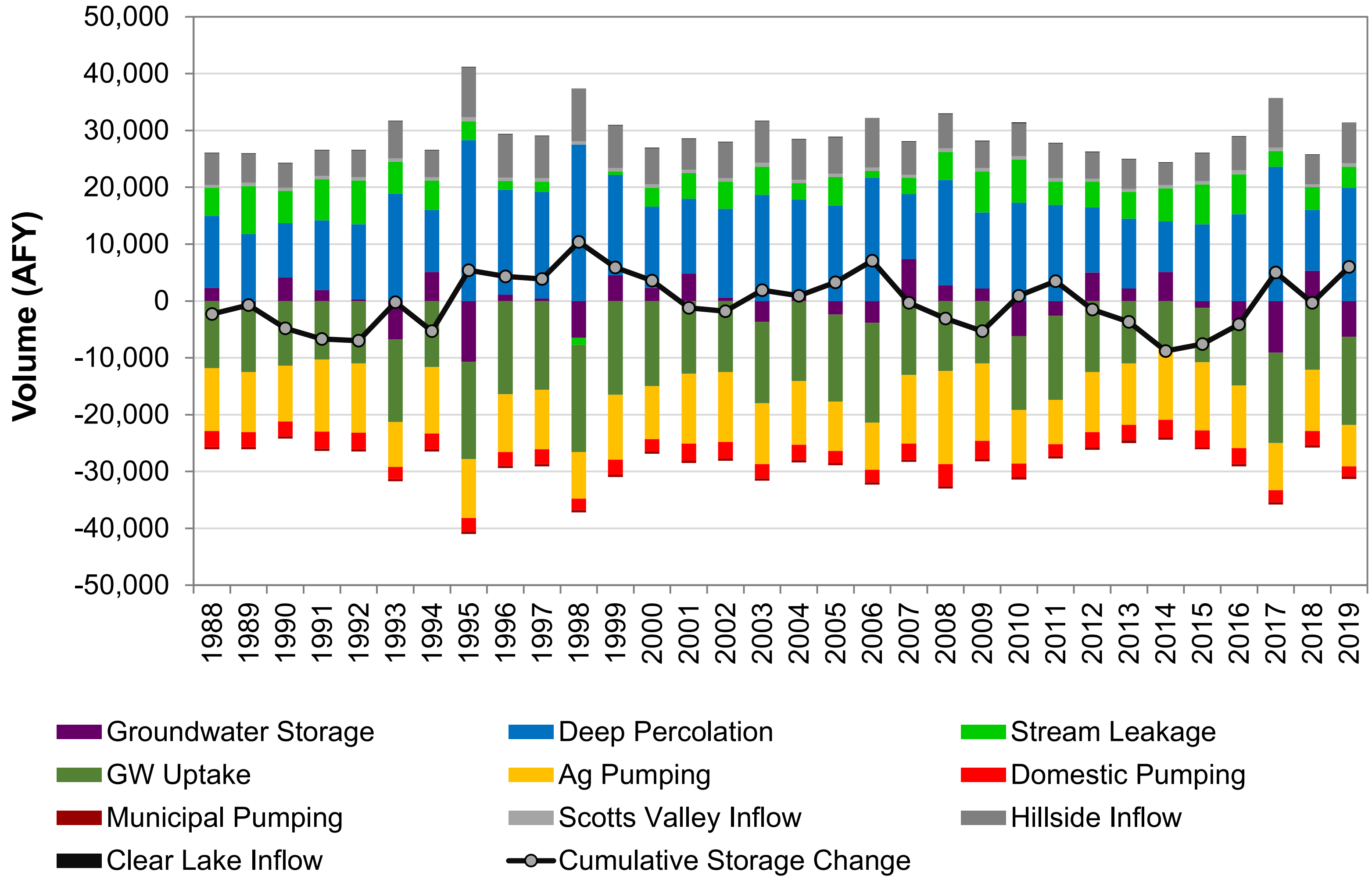


Figure 2-77. Big Valley Basin Historical Groundwater System Water Budget (1988 – 2019)

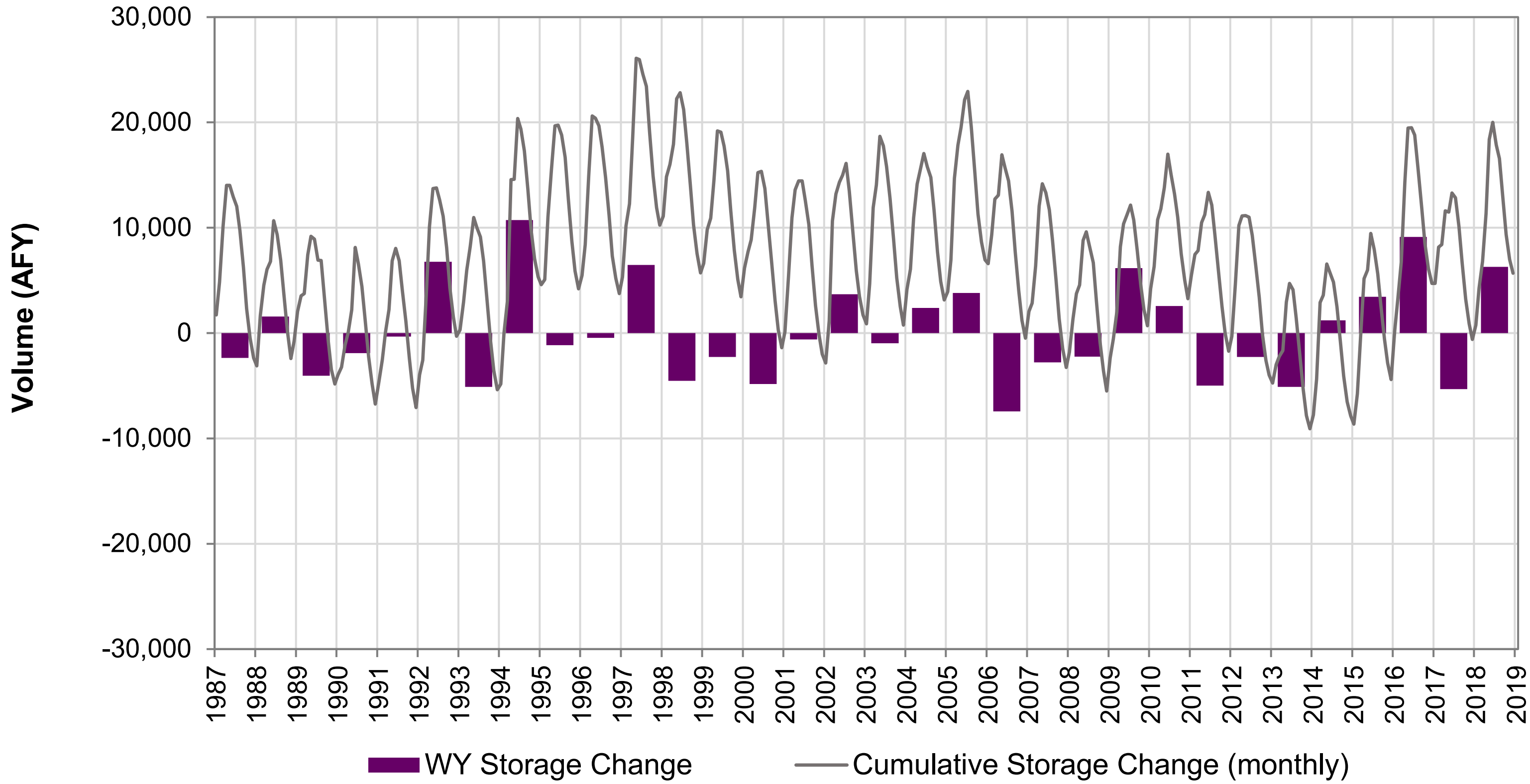


Figure 2-78. Big Valley Basin Historical Groundwater Storage Change (1988 -2019)

2.2.4.7 Current Water Budget

As described in **Section 2.2.4.3**, several recent water budget periods are considered to represent the current water budget. Because the hydrology and land use conditions can vary year to year, estimating the current water budget can be challenging. To evaluate the current water budget, results from the historical model run were summarized for five different recent time periods to evaluate variability and trends. The five different recent water budget periods evaluated include the following:

- Recent 1 year (2019)
- Recent 1 year (2018)
- Recent 4 years (2016-2019)
- Recent 6 years (2014-2019)
- Recent 10 years (2010-2019)

Annual precipitation appears to be the most significant factor that influences the Basin's water budget. Comparison of these recent water budget periods provides a representation of how water use varies with precipitation and water supply conditions from year to year. Based on these comparisons and consideration of the hydrologic conditions over these recent periods, the recent six-year period from 2014 through 2019 is believed to provide a reasonable representation of the current water budget. This period incorporates recent land use conditions and spans six years that collectively have precipitation comparable with the long-term average. The six-year period includes two wet years, two above-normal years, a dry year, and a critical year. During this period, annual precipitation at Kelseyville ranges from 19.3 inches to 60.0 inches, with an average of 37.2 inches, which is slightly higher than the long-term (1950-2020) average annual precipitation of 33.7 inches. Although the 2014 through 2019 period provides a summary of the water budget for recent years that appear to be reasonably representative of recent conditions, it is not necessarily representative of any longer-term average conditions. The current water budget evaluation follows.

Land Surface System Budget

Different recent Land Surface System water budget periods were compared to better understand how water budget components vary depending on precipitation, water demands, and water supply conditions. The Land Surface System water budget results for these different recent time periods are presented in **Table 2-17**. Results are highly variable between two years, 2018 and 2019. The total volume of water budget inflows and outflows vary by about 59,000 acre-feet between these two years. Precipitation, runoff, and deep percolation have the largest variability corresponding to the difference of annual rainfall in each year (23.6 inches in 2018 and 53.3 inches in 2019 at Kelseyville). When comparing the average annual water budget results for recent multi-year periods, the variability is considerably reduced. The maximum difference in total water budget volumes between the three different recent multi-year periods is about 16,000 AFY.

The selected current water budget period of 2014-2019 (highlighted blue in **Table 2-17**) has a total flow volume of about 101,000 AFY on average in the Land Surface System. The largest inflow is precipitation (75,700 AFY) and the other major inflows are groundwater pumping (12,600 AFY) and groundwater uptake (12,100 AFY). Non-routed delivery (300 AFY), septic recharge (300 AFY) and stream diversion (100 AFY) inflows are relatively very small. The largest outflow is runoff (53,700 AFY), and the other outflows are evapotranspiration (32,300 AFY) and deep percolation (15,300 AFY).

Table 2-17. Comparison of Recent Land Surface System Water Budget Periods

Land Surface System Water Budget Component		Recent Water Budget Periods and Average Volume of Flow (AFY)				
		Recent 10 Years (2010-2019)	**Recent 6 Years (2014-2019)**	**Recent 4 Years (2016-2019)**	**Recent 1 Year 2018**	**Recent 1 Year 2019**
Inflows	Precipitation	72,400	75,700	88,400	48,200	108,400
	Groundwater Uptake	12,400	12,100	13,700	12,100	15,500
	Non-Routed Delivery	300	300	300	300	300
	In-stream Diversion	300	100	100	100	100
	Groundwater Pumping	12,300	12,600	11,300	12,900	8,900
	Septic Recharge	300	300	300	300	300
	Total Inflows	***97,900***	***101,100***	***114,200***	***73,900***	***133,500***
Outflows	Runoff	-50,500	-53,700	-64,000	-31,800	-78,500
	Evapotranspiration	-32,300	-32,100	-32,700	-31,400	-34,900
	Deep Percolation	-15,000	-15,300	-17,400	-10,700	-19,900
	Total Outflows	***-97,900***	***-101,100***	***-114,100***	***-73,900***	***-133,300***

Note:
All volumes are rounded to the nearest 100 acre-feet.
Key:
AFY = acre-feet per year

Stream System Budget

Different recent water budget periods were compared to better understand how individual Stream System water budget components vary depending on precipitation, water demands, and water supply conditions. The Stream System water budget results for these different recent time periods are presented in **Table 2-18**. Results are highly variable between two years, 2018 and 2019. The stark difference in hydrology, principally from precipitation, for 2018 and 2019 is evident in the water budget components. At Kelseyville annual rainfall was 23.6 inches in 2018, and it is less than half of the 2019 rainfall, 53.3 inches. When comparing the average annual water budget results for recent multi-year periods, the variability is considerably reduced. The maximum difference in total water budget volumes between the three different recent multi-year periods is about 48,000 AFY.

The selected current water budget period of 2014-2019 (highlighted blue in **Table 2-18**) has a total flow volume of about 152,000 AFY on average in the Stream System. The average annual stream inflow, runoff and stream gain are about 90,600 AFY, 58,500 AFY and 2,500 AFY, respectively. The average annual stream outflow, stream loss and diversions are about 144,600 AFY, 7,600 AFY and 100 AFY, respectively.

Table 2-18. Comparison of Recent Stream System Water Budget Periods

Stream System Water Budget Component		Recent Water Budget Periods and Average Volume of Flow (AFY)				
		Recent 10 Years (2010-2019)	Recent 6 Years (2014-2019)	Recent 4 Years (2016-2019)	Recent 1 Year 2018	Recent 1 Year 2019
Inflow	Stream Inflow	83,000	90,600	115,700	34,300	143,300
	Stream gain	2,500	2,500	3,300	2,100	4,200
	Runoff	55,100	58,500	69,800	34,700	85,300
	Total Inflows	***140,500***	***151,600***	***188,700***	***71,100***	***232,800***
Outflow	Stream Outflow	-132,700	-144,000	-181,000	-64,900	-224,800
	Stream Loss	-7,600	-7,600	-7,600	-6,100	-7,900
	Diversions	-300	-100	-100	-100	-100
	Total Outflows	***-140,500***	***-151,600***	***-188,700***	***-71,100***	***-232,800***

Note:
All volumes are rounded to the nearest 100 acre-feet.
Key:
AFY = acre-feet per year

Groundwater System Budget

Different recent water budget periods were compared to better understand how Groundwater System budget components vary depending on variations in the Land Surface System, Stream System, subsurface flows, and groundwater demand. The Groundwater System water budget results for these different recent time periods are presented in **Table 2-19**. As with the results for the current Land Surface System and Stream System budget summaries, results are highly variable between two years, 2018 and 2019. The total change in groundwater storage differs by more than 11,000 acre-feet ranging from a decrease in storage of about 5,300 acre-feet in 2018 (a negative storage change) to an increase in storage of about 6,300 acre-feet in 2019. Variability of deep percolation, groundwater pumping for agriculture, groundwater uptake, stream leakage and subsurface inflow from hillsides account for most of the difference in groundwater storage between the two years. The other components in the Groundwater System budget are relatively stable between the two years.

There is considerably less variability in most of the different water budget components when comparing between the three different recent multi-year periods, although the deep percolation and groundwater uptake show relatively higher differences between the three recent periods. Average annual change in storage is 3,400 AFY, 1,600 AFY and 1,100 AFY for the recent four-year, six-year and 10-year periods, respectively. This difference is likely attributable to the 2012-2015 drought period consisting of dry and critical years, which are included only in the recent six- and 10-year periods. All four water years in the most recent four-year period of 2016-2019 includes only wet and above-normal water years.

The selected current water budget period of 2014-2019 (highlighted blue **Table 2-19**) has deep percolation of 15,300 AFY on average. Net subsurface inflows total about 6,600 AFY on average over this period, while stream leakage averages about 5,100 AFY. The total groundwater pumping averages about 13,300 AFY. This volume includes agricultural, domestic, and municipal pumping of 10,400 AFY, 2,600 AFY and 400 AFY, respectively. Groundwater uptake averages about 12,100 AFY over this period. The average annual groundwater storage increase of 1,600 AFY during the 2014-2019 period is equivalent to an increase of approximately 0.07 acre-feet per acre across the entire Basin.

Table 2-19. Comparison of Recent Groundwater System Water Budget Periods

Groundwater System Water Budget Component	Recent Water Budget Periods and Average Volume of Flow (AFY)				
	Recent 10 Years (2010-2019)	**Recent 6 Years (2014-2019)**	**Recent 4 Years (2016-2019)**	**Recent 1 Year (2018)**	**Recent 1 Year (2019)**
Stream Leakage	5,100	5,100	4,400	4,000	3,700
Total Subsurface Inflows	6,400	6,600	7,400	5,800	7,800
Subsurface Inflow from Hillsides	5,800	6,000	6,800	5,200	7,200
Subsurface Inflow from Scotts Valley Basin	600	600	600	500	600
Subsurface Inflow from Clear Lake	100	100	100	100	0
Deep Percolation	15,000	15,300	17,400	10,700	19,900
Groundwater Uptake	-12,400	-12,100	-13,700	-12,100	-15,500
Groundwater Pumping	-13,000	-13,300	-12,100	-13,700	-9,500
Agricultural Pumping	-10,100	-10,400	-9,400	-10,800	-7,300
Domestic Pumping	-2,500	-2,600	-2,300	-2,500	-1,800
Municipal Pumping	-400	-400	-400	-400	-400
Annual Groundwater Storage Change	**1,100**	**1,600**	**3,400**	**-5,300**	**6,300**

Note:
All volumes are rounded to the nearest 100 acre-feet.

Key:
AFY = acre-feet per year

2.2.4.8 Projected Water Budget Development

GSP regulations (CCR Title 23 § 354.18[c][3]) require the development of a projected water budget based on at least 50 years of historical data to estimate future changes in water supply, demand, and aquifer condition. The projected water budget of the Big Valley Basin GSP covers a 51-year period from 2020 through 2070 to estimate future demands under three different climate scenarios: baseline scenario (Scenario A), wet-moderate warming climate scenario (Scenario B), and dry-extreme warming climate scenario (Scenario C). **Table 2-20** summarizes the conditions evaluated within the future scenarios, extending through 2070. Based on information collected from local plans and stakeholders, all three scenarios assumed that present population and land use practices would not significantly change during the projected period.

Scenario A is considered the projected baseline scenario because it uses historical hydrologic conditions from 1969 to 2019 to develop future hydrologic conditions from 2020 to 2070. Uncertainty due to climate change was evaluated in accordance with Section 354.18(c)(3) of the GSP regulations and rely on downscaled outputs from global circulation models (GCM) recognized by the California Fourth Climate Change Assessment (Pierce et al., 2018). Selection of climate models used to develop model inputs was informed by discussion and coordination with the DWR and USGS. Based on discussion, it was determined that locally downscaled results from two GCMs are the most suitable for evaluating the anticipated range in future climate in the Big Valley Basin. These include:

- **CNRM-CM5–RCP45 (CNRM)**. This model was developed by the Centre National de Reserches Meteorologiques and Centre Europeen de Reserches et de Formation Avancee en Calcul Scientifique (CERFACS) which simulates cool and wet future conditions.

- **HadGEM2-ES-RCP85 (HadGEM)**. This model was developed by the Met Office Hadley Center and simulates warm and dry future conditions.

These models align with the “Wet and Moderate Warming” and “Dry with Extreme Warming” model scenarios provided in the climate change guideline document prepared by DWR for developing climate change related inputs for GSP development (DWR, 2018). They are also included in a suite of models developed by the USGS using the BCM, which were readily available for GSP preparation. These models were used to develop future projections of climate (precipitation and potential evapotranspiration) and tributary inflow, and surface water supply.

Table 2-20. Summary of Big Valley Integrated Hydrologic Model Projected Water Budget Scenarios

Model Scenario	Projected Climate	Projected Water Supply	Projected Land Use and Population Change
Projected Scenario A	Baseline (Historical) Hydrology	Historical Surface Water Deliveries	Land use and population change consistent with local plans
Projected Scenario B	CNRM-RCP4.5 (Warming and Wetter)	Projected Surface Water Deliveries affected by Climate Change	Land use and population change consistent with local plans
Projected Scenario C	HADGEM2-RCP8.5 (Warming with Multi-decade Drought)	Projected Surface Water Deliveries affected by Climate Change	Land use and population change consistent with local plans

2.2.4.9 Projected Water Budget Scenario A (Baseline Scenario)

Results of the projected Scenario A water budgets for the 2020-2070 period are summarized in this section. This scenario was developed assuming that climatic conditions of 2020-2070 period will be consistent with the historical climatic conditions of 1969-2019 period.

Land Surface System Budget

The volumes of the projected baseline Land Surface System water budget components are nearly similar to volumes estimated for the historical water budget period. Projected annual inflows and outflows of the Land Surface System budget are summarized in **Table 2-21** and **Figure 2-79**. The total annual volume of water in the projected Land Surface System budget ranges from 54,000 AFY to 167,000 AFY with an average of 102,000 AFY. Over the projected period, the average basin-wide precipitation is about 73,900 AFY. Groundwater pumping and groundwater uptake average about 14,500 and 13,200 AFY, respectively. Non-routed deliveries, in-stream diversions and septic recharge are relatively very small, and each component remains between 200 AFY and 400 AFY on annual basis. The major outflows from the Land Surface System: runoff and evapotranspiration, average about 52,400 AFY and 34,300 AFY, respectively. Annual deep percolation is about 15,700 AFY on average. Projected groundwater pumping is on average 12 percent greater than the historical water budget period (an increase of 1,500 AFY on average). Changes (increases or decreases) in all other projected Land Surface System water budget components are less than 2 percent, except in-stream diversion, which has a volumetric increase of 100 AFY on average yielding a 33 percent increase.

Table 2-21. Big Valley Basin Projected Land Surface System Water Budget (2020 – 2070) - Scenario A

Water Year	Inflow (AF)						Outflow (AF)		
	Precipitation	Groundwater Uptake	Non-Routed Delivery	In-Stream Diversion	Groundwater Pumping[1]	Septic Recharge	Runoff	Evapo-transpiration	Deep Percolation
2020	85,700	16,400	300	400	13,600	300	-63,900	-34,800	-17,900
2021	79,100	15,300	300	400	14,400	300	-59,500	-33,200	-17,000
2022	67,000	14,000	400	400	14,300	300	-48,200	-33,500	-14,500
2023	42,000	11,100	300	400	15,800	300	-26,300	-33,600	-9,900
2024	79,700	13,700	300	400	14,900	300	-59,600	-32,500	-17,100
2025	94,200	16,000	300	400	12,900	300	-69,700	-35,200	-19,000
2026	65,600	14,700	300	400	13,700	300	-46,700	-34,200	-14,100
2027	29,100	10,500	300	400	15,400	300	-15,100	-33,500	-7,200
2028	28,700	7,500	300	400	17,300	300	-14,400	-32,600	-7,500
2029	95,200	13,300	300	400	13,600	300	-68,100	-35,900	-18,900
2030	52,000	12,100	300	400	15,900	300	-35,300	-33,600	-12,000
2031	93,100	14,800	300	400	13,200	300	-68,100	-34,900	-19,100
2032	55,000	12,200	400	400	15,500	300	-37,300	-33,800	-12,500
2033	113,000	16,200	200	400	11,700	300	-83,000	-36,500	-22,200
2034	136,700	19,700	200	400	9,900	300	-102,000	-38,800	-26,300
2035	82,500	16,300	300	400	13,600	300	-60,700	-35,100	-17,600
2036	60,800	13,000	300	400	14,700	300	-43,200	-32,700	-13,600
2037	104,600	16,400	300	400	11,900	300	-76,900	-35,900	-20,900
2038	43,900	12,400	400	400	16,700	300	-31,700	-30,800	-11,400
2039	59,300	11,100	300	400	15,700	300	-41,000	-32,700	-13,400
2040	58,300	10,300	300	400	14,900	300	-38,300	-33,600	-12,600

Table 2-21. Big Valley Basin Projected Land Surface System Water Budget (2020 – 2070) - Scenario A (contd.)

Water Year	Inflow (AF)						Outflow (AF)		
	Precipitation	Groundwater Uptake	Non-Routed Delivery	In-Stream Diversion	Groundwater Pumping[1]	Septic Recharge	Runoff	Evapo-transpiration	Deep Percolation
2041	50,700	10,800	300	300	14,600	300	-30,300	-35,800	-10,800
2042	49,400	9,600	400	400	16,300	300	-33,900	-30,600	-11,800
2043	56,800	10,100	300	400	16,000	300	-38,000	-33,200	-12,700
2044	100,900	13,800	200	400	12,000	300	-70,200	-37,900	-19,500
2045	48,000	10,800	300	400	16,000	300	-32,000	-32,300	-11,400
2046	129,900	16,500	300	400	11,800	300	-95,900	-37,800	-25,400
2047	86,700	15,600	300	400	13,500	300	-61,300	-37,700	-17,800
2048	83,200	14,500	300	400	13,000	300	-58,800	-35,900	-17,000
2049	133,500	18,400	200	300	10,500	300	-97,500	-40,000	-25,700
2050	71,100	15,500	300	400	13,400	300	-51,700	-33,800	-15,400
2051	70,300	14,200	300	400	13,300	300	-47,700	-36,500	-14,600
2052	53,600	11,900	300	400	15,800	300	-37,200	-32,500	-12,500
2053	67,400	11,600	300	400	16,000	300	-48,700	-32,100	-15,100
2054	90,000	13,700	300	400	14,900	300	-65,600	-34,900	-19,000
2055	79,200	13,500	300	400	16,200	300	-60,000	-32,000	-17,800
2056	85,000	14,700	200	300	11,800	300	-56,500	-39,300	-16,400
2057	110,100	17,300	300	400	12,700	300	-82,300	-36,300	-22,400
2058	47,500	12,200	300	400	16,200	300	-33,300	-31,900	-11,700
2059	54,200	10,600	400	400	17,300	300	-40,800	-28,800	-13,500
2060	50,400	9,900	300	400	16,100	300	-32,700	-33,000	-11,500
2061	78,600	12,400	200	400	13,400	300	-53,900	-35,500	-15,900

Table 2-21. Big Valley Basin Projected Land Surface System Water Budget (2020 – 2070) - Scenario A (contd.)

Water Year	Inflow (AF)							Outflow (AF)	
	Precipitation	Groundwater Uptake	Non-Routed Delivery	In-Stream Diversion	Groundwater Pumping[1]	Septic Recharge	Runoff	Evapo-transpiration	Deep Percolation
2062	83,000	14,300	300	400	12,000	300	-57,700	-35,900	-16,600
2063	49,600	11,600	300	400	15,500	300	-33,300	-32,800	-11,600
2064	57,900	10,200	400	400	16,200	300	-39,500	-32,800	-13,100
2065	39,200	7,400	400	400	18,700	300	-24,100	-32,100	-10,100
2066	61,500	8,700	300	400	17,300	300	-42,500	-32,000	-14,000
2067	74,800	10,800	300	400	17,000	300	-54,500	-32,300	-16,700
2068	123,200	16,100	200	400	13,500	300	-92,900	-35,900	-24,800
2069	48,200	11,600	400	400	16,500	300	-32,000	-33,700	-11,600
2070	108,400	15,600	300	300	13,000	300	-78,600	-37,600	-21,600
Average	**73,900**	**13,200**	**300**	**400**	**14,500**	**300**	**-52,400**	**-34,300**	**-15,700**

Notes:
[1] Calculated pumping needed to meet residual irrigation and frost protection demand for agriculture and urban and residential landscaping.
All volumes are rounded to the nearest 100 acre-feet.
Key:
AF = acre-feet

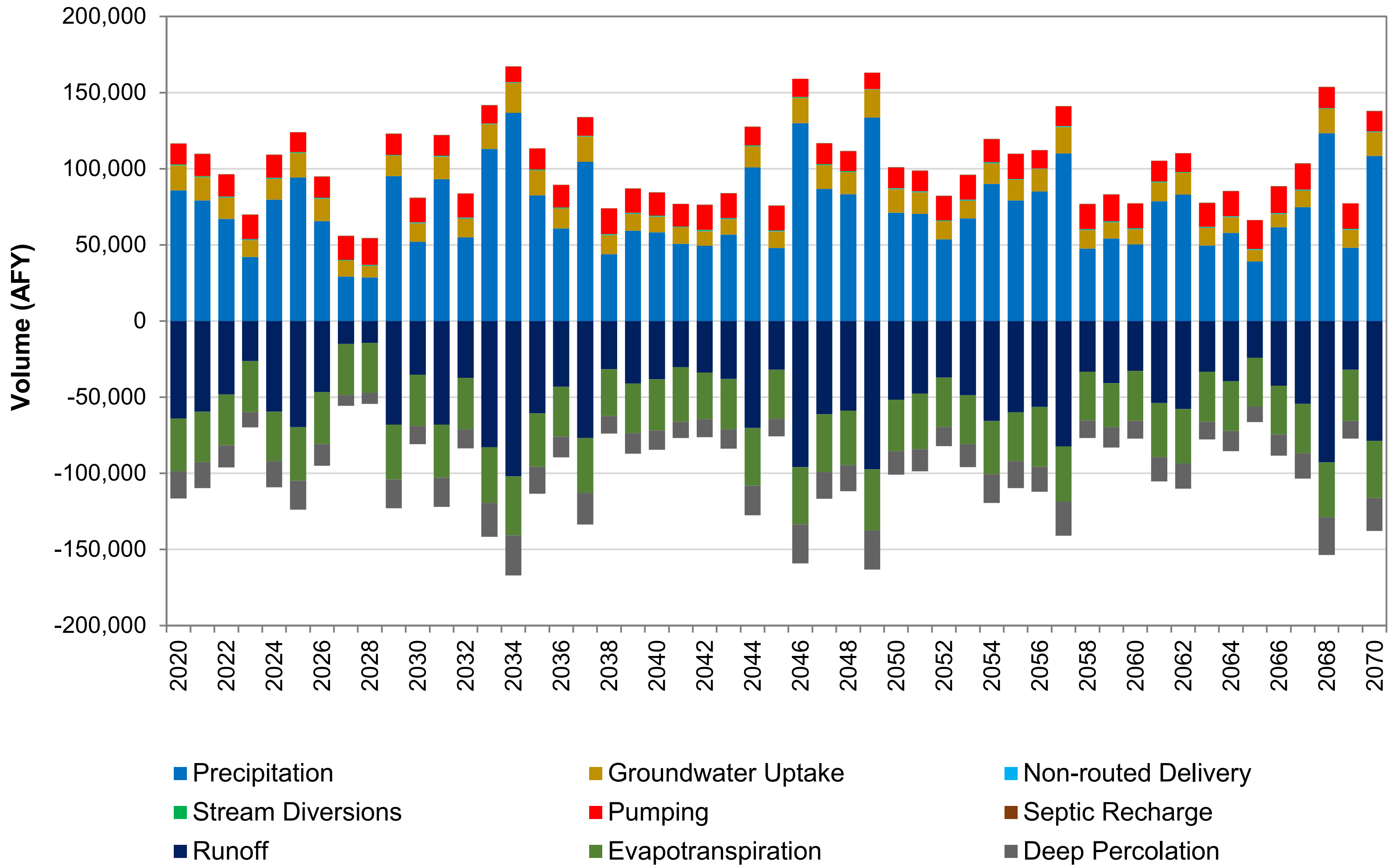


Figure 2-79. Big Valley Basin Projected Land Surface System Water Budget (2020 – 2070) - Scenario A

Stream System Budget

The total volume of water in the projected baseline Stream System water budget is on average 12 percent greater in comparison to the historical Stream System water budget, mainly due to the increased stream inflow and outflow for the projected period. Annual inflows and outflows from the projected baseline Stream System budget are summarized in **Table 2-22** and **Figure 2-80**. The total volume of water in the projected Stream System budget ranges from 31,500 AFY to 341,000 AFY with an average of about 162,000 AFY. Over the projected period, the average stream inflow is about 101,000 AFY. Surface water runoff to streams averages about 57,400 AFY during this period, while stream gain from groundwater discharge averages about 3,100 AFY. Stream outflow averages about 154,000 AFY over the projected period. Stream loss to groundwater and in-stream diversion averages about 7,900 AFY and 400 AFY, respectively during this period. In comparison to the historical water budget, projected stream inflow is on average 19 percent greater (an increase of 16,000 AFY). Percent increases of stream gain and runoff are relatively smaller, and each is about 3 percent. Corresponding to relatively large increase of stream inflow, stream outflow increases by 12 percent on average (an increase of 17,000 AFY). Stream loss is 5 percent greater on average. In-stream diversion increases by 100 AFY on average and that corresponds to an increase of 33 percent compared to the historical budget.

Table 2-22. Big Valley Basin Projected Stream System Water Budget (2020 – 2070) - Scenario A

WY	Stream Inflow (AF)	Stream Outflow (AF)	Stream Gain (AF)	Stream Loss (AF)	Runoff (AF)	Diversion (AF)	Total Inflow (AF)	Total Outflow (AF)
2020	184,600	-254,000	5,200	-6,700	71,300	-400	261,100	-261,100
2021	181,500	-245,000	4,800	-7,300	66,500	-400	252,800	-252,700
2022	133,700	-183,400	3,800	-7,600	53,800	-400	191,300	-191,400
2023	64,100	-87,100	2,200	-8,400	29,600	-400	95,900	-95,900
2024	182,000	-242,500	3,400	-8,900	66,500	-400	251,900	-251,800
2025	225,500	-299,900	4,900	-8,100	78,000	-400	308,400	-308,400
2026	127,200	-174,800	3,700	-8,100	52,300	-400	183,200	-183,300
2027	39,300	-50,700	2,100	-8,000	17,600	-400	59,000	-59,100
2028	14,300	-22,700	1,200	-8,800	16,400	-400	31,900	-31,900
2029	209,800	-277,200	2,500	-10,700	75,900	-400	288,200	-288,300
2030	90,300	-124,000	2,200	-7,400	39,400	-400	131,900	-131,800
2031	168,500	-238,100	4,000	-8,400	74,400	-400	246,900	-246,900
2032	60,500	-96,300	2,500	-7,100	40,800	-400	103,800	-103,800
2033	178,700	-264,800	4,600	-8,900	90,700	-400	274,000	-274,100
2034	221,300	-334,300	8,600	-6,500	111,200	-400	341,100	-341,200
2035	105,200	-172,900	7,000	-5,000	65,900	-400	178,100	-178,300
2036	64,100	-106,700	3,400	-7,800	47,300	-400	114,800	-114,900
2037	148,900	-228,700	4,800	-8,600	83,900	-400	237,600	-237,700
2038	37,000	-67,900	2,600	-5,900	34,600	-400	74,200	-74,200
2039	56,100	-95,000	2,200	-7,600	44,700	-400	103,000	-103,000
2040	45,600	-78,100	1,400	-10,500	42,000	-400	89,000	-89,000
2041	33,300	-59,900	1,500	-7,700	33,100	-300	67,900	-67,900
2042	43,700	-72,600	1,100	-8,900	37,100	-400	81,900	-81,900

Table 2-22. Big Valley Basin Projected Stream System Water Budget (2020 – 2070) - Scenario A (contd.)

WY	Stream Inflow (AF)	Stream Outflow (AF)	Stream Gain (AF)	Stream Loss (AF)	Runoff (AF)	Diversion (AF)	Total Inflow (AF)	Total Outflow (AF)
2043	48,500	-81,500	1,200	-9,400	41,500	-400	91,200	-91,300
2044	121,800	-191,300	2,700	-9,100	76,300	-400	200,800	-200,800
2045	35,400	-64,300	1,600	-7,200	34,900	-400	71,900	-71,900
2046	197,100	-296,400	4,200	-8,800	104,200	-400	305,500	-305,600
2047	107,300	-171,200	3,800	-6,100	66,600	-400	177,700	-177,700
2048	112,400	-173,600	4,300	-6,800	64,000	-400	180,700	-180,800
2049	188,600	-293,800	7,100	-7,500	105,900	-300	301,600	-301,600
2050	90,500	-145,000	4,600	-6,100	56,300	-400	151,400	-151,500
2051	79,100	-126,500	3,300	-7,400	52,000	-400	134,400	-134,300
2052	46,400	-81,500	2,400	-7,500	40,500	-400	89,300	-89,400
2053	82,100	-129,500	2,400	-7,700	53,200	-400	137,700	-137,600
2054	116,400	-181,800	2,700	-8,300	71,400	-400	190,500	-190,500
2055	101,100	-162,400	3,200	-6,700	65,200	-400	169,500	-169,500
2056	95,400	-150,700	3,000	-8,800	61,500	-300	159,900	-159,800
2057	167,200	-254,000	5,000	-7,400	89,600	-400	261,800	-261,800
2058	38,100	-70,600	2,600	-5,900	36,200	-400	76,900	-76,900
2059	59,700	-98,300	2,000	-7,600	44,500	-400	106,200	-106,300
2060	36,300	-64,000	1,400	-9,100	35,700	-400	73,400	-73,500
2061	93,500	-143,600	1,900	-10,100	58,700	-400	154,100	-154,100
2062	97,300	-154,100	2,700	-8,400	62,800	-400	162,800	-162,900
2063	36,700	-66,800	1,800	-7,600	36,300	-400	74,800	-74,800
2064	59,100	-96,200	1,700	-7,400	43,100	-400	103,900	-104,000
2065	17,800	-37,400	800	-7,200	26,300	-400	44,900	-45,000

Table 2-22. Big Valley Basin Projected Stream System Water Budget (2020 – 2070) - Scenario A (contd.)

WY	Stream Inflow (AF)	Stream Outflow (AF)	Stream Gain (AF)	Stream Loss (AF)	Runoff (AF)	Diversion (AF)	Total Inflow (AF)	Total Outflow (AF)
2066	63,300	-101,400	1,100	-9,000	46,400	-400	110,800	-110,800
2067	90,700	-141,600	1,300	-9,500	59,400	-400	151,400	-151,500
2068	196,100	-292,800	4,500	-8,900	101,400	-400	302,000	-302,100
2069	34,300	-63,600	1,800	-7,000	34,800	-400	70,900	-71,000
2070	143,100	-222,600	3,500	-9,100	85,400	-300	232,000	-232,000
Average	**101,400**	**-153,600**	**3,100**	**-7,900**	**57,400**	**-400**	**161,900**	**-161,900**

Note:
All volumes are rounded to the nearest 100 acre-feet.
Key:
AF – acre-feet

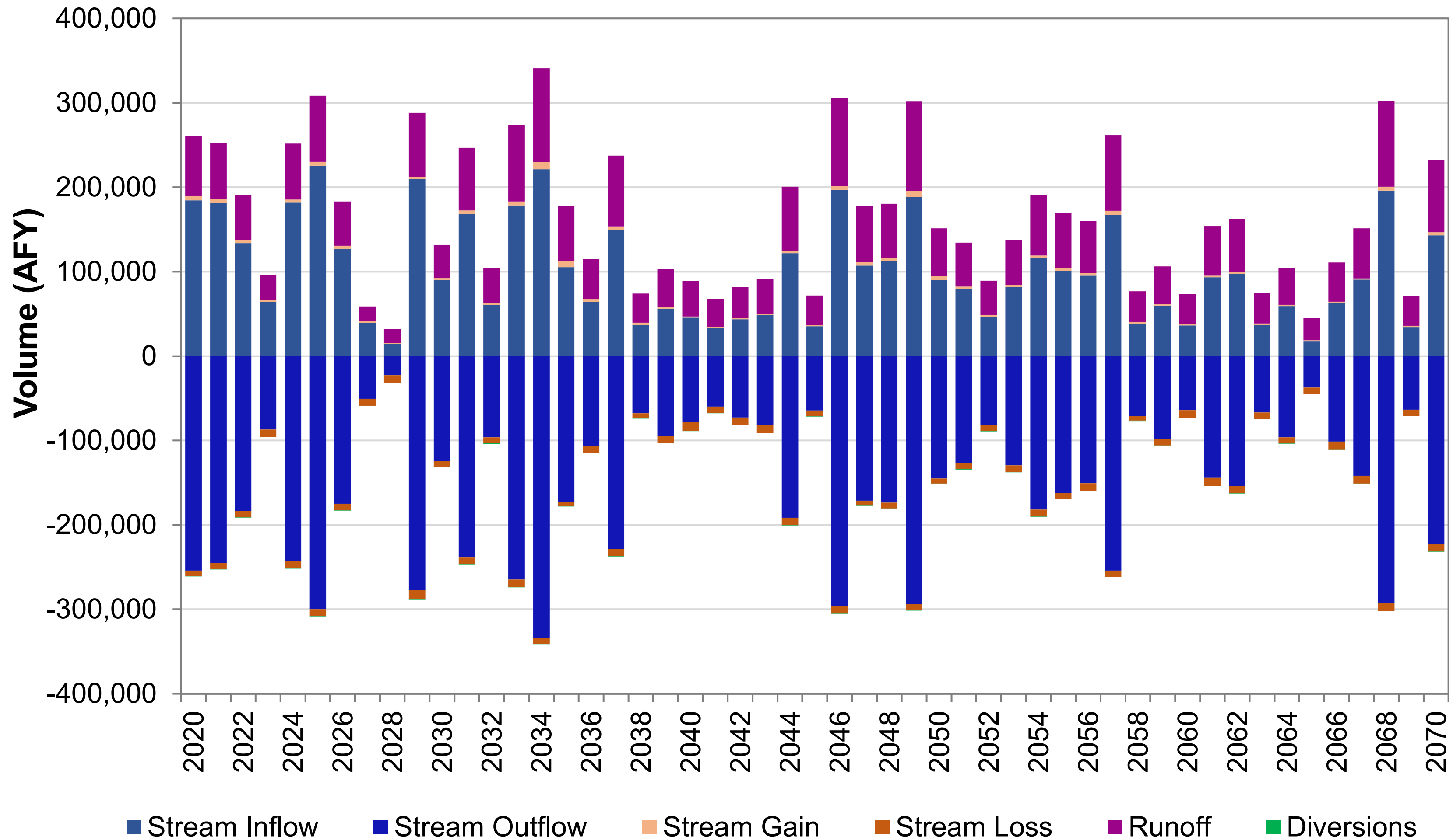


Figure 2-80. Big Valley Basin Projected Stream System Water Budget (2020 – 2070) - Scenario A

Groundwater System Budget

Changes in most components of the projected baseline Groundwater System budget are less than 10 percent in comparison to the historical budget. For the projected period, the average annual groundwater storage change is zero, indicating no significant change in groundwater storage will occur. Annual inflows and outflows of the projected baseline Groundwater System budget are summarized in **Table 2-23** and **Figure 2-81**. Over the projected water budget period, the average deep percolation is about 15,700 AFY. Subsurface inflow from hillsides averages about 7,000 AFY for this period, while subsurface inflows from the Scotts Valley Basin and Clear Lake average about 600 AFY and 100 AFY, respectively. Stream leakage to the GWS averages about 4,800 AFY. During the projected period, groundwater uptake averages about 13,200 AFY. Agricultural, domestic and municipal groundwater pumping average about 12,100 AFY, 2,800 AFY, and 400 AFY, respectively making the total annual groundwater pumping about 15,300 AFY on average.

In comparison to the historical water budget period, projected subsurface inflow from hillsides is on average 13 percent greater (an increase of 800 AFY). Percent increase of stream leakage is about 7 percent (300 AFY). When outflows are considered, projected agricultural pumping is on average 13 percent greater compared to the historical budget (an increase of 1,400 AFY). Percent increase of domestic pumping is about 8 percent (200 AFY). Changes (increases or decreases) in all other Groundwater System water budget components are less than 2 percent.

The average annual groundwater storage change over the projected water budget period under Scenario A is close to zero (i.e., no change in storage when long-term changes are considered). However, year to year change in groundwater storage ranges from a net decrease of up to 8,400 AFY to a net increase of up to 10,600 AFY during this period. The cumulative storage over the 51-year projected period is a decrease of 2,200 acre-feet that and is equivalent to a decrease of approximately 0.09 acre-feet per acre across the entire Basin.

Table 2-23. Big Valley Basin Projected Groundwater System Water Budget (2020 – 2070) - Scenario A

Water Year	Stream Leakage (AF)	Inflow from Hillsides (AF)	Inflow from Scotts Valley Basin (AF)	Inflow from Clear Lake (AF)	Deep Percolation (AF)	Groundwater Uptake (AF)	Agricultural Pumping (AF)	Domestic Pumping (AF)	Municipal Pumping (AF)	Groundwater Storage Change (AF)	Cumulative Groundwater Storage Change (AF)
2020	1,600	9,500	700	100	17,900	-16,400	-11,200	-2,800	-400	-1,000	-1,000
2021	2,500	9,800	700	100	17,000	-15,300	-11,800	-2,900	-400	-200	-1,200
2022	3,800	8,900	700	100	14,500	-14,000	-11,800	-2,800	-400	-1,000	-2,200
2023	6,200	6,600	700	100	9,900	-11,100	-13,100	-3,000	-400	-4,100	-6,300
2024	5,600	9,000	700	100	17,100	-13,700	-12,300	-2,900	-400	3,300	-3,000
2025	3,200	10,800	700	100	19,000	-16,000	-10,600	-2,500	-400	4,200	1,200
2026	4,300	8,600	700	100	14,100	-14,700	-11,400	-2,700	-400	-1,400	-200
2027	5,800	5,900	600	100	7,200	-10,500	-12,800	-2,900	-400	-6,900	-7,100
2028	7,600	4,400	500	100	7,500	-7,500	-14,400	-3,200	-400	-5,300	-12,400
2029	8,100	9,100	800	100	18,900	-13,300	-11,200	-2,600	-400	9,500	-2,900
2030	5,300	7,100	700	100	12,000	-12,100	-13,300	-3,000	-400	-3,600	-6,500
2031	4,400	8,800	700	100	19,100	-14,800	-10,900	-2,600	-400	4,300	-2,200
2032	4,600	6,400	600	100	12,500	-12,200	-12,800	-2,900	-400	-4,200	-6,400
2033	4,300	9,000	700	100	22,200	-16,200	-9,600	-2,400	-400	7,600	1,200
2034	-2,100	10,800	600	0	26,300	-19,700	-8,200	-2,000	-400	5,300	6,500
2035	-2,100	8,600	600	100	17,600	-16,300	-11,300	-2,600	-400	-5,900	600
2036	4,400	6,600	600	100	13,600	-13,000	-12,200	-2,900	-400	-3,200	-2,600
2037	3,800	8,100	600	100	17,900	-16,400	-9,800	-2,400	-400	4,500	1,900

Table 2-23. Big Valley Basin Projected Groundwater System Water Budget (2020 – 2070) - Scenario A (contd.)

Water Year	Stream Leakage (AF)	Inflow from Hillsides (AF)	Inflow from Scotts Valley Basin (AF)	Inflow from Clear Lake (AF)	Deep Percolation (AF)	Groundwater Uptake (AF)	Agricultural Pumping (AF)	Domestic Pumping (AF)	Municipal Pumping (AF)	Groundwater Storage Change (AF)	Cumulative Groundwater Storage Change (AF)
2038	3,400	5,900	600	100	17,000	-12,400	-13,800	-3,100	-400	-8,400	-6,500
2039	5,400	5,700	600	100	14,500	-11,100	-13,100	-2,900	-400	-2,400	-8,900
2040	9,100	5,200	600	100	9,900	-10,300	-12,400	-2,800	-400	1,700	-7,200
2041	6,200	4,400	600	100	17,100	-10,800	-12,100	-2,800	-400	-4,000	-11,200
2042	7,800	4,500	600	100	19,000	-9,600	-13,600	-3,000	-400	-1,800	-13,000
2043	8,200	4,700	600	100	14,100	-10,100	-13,300	-2,900	-400	-500	-13,500
2044	6,500	6,700	700	100	7,200	-13,800	-10,000	-2,300	-400	6,900	-6,600
2045	5,600	4,900	600	100	7,500	-10,800	-13,400	-3,000	-400	-5,000	-11,600
2046	4,600	8,800	700	100	18,900	-16,500	-9,800	-2,300	-400	10,600	-1,000
2047	2,400	7,700	700	100	12,000	-15,600	-11,300	-2,500	-400	-1,200	-2,200
2048	2,500	7,500	600	100	19,100	-14,500	-10,800	-2,500	-400	-500	-2,700
2049	400	9,400	600	0	12,500	-18,400	-8,700	-2,100	-400	6,500	3,800
2050	1,500	7,500	600	100	22,200	-15,500	-11,200	-2,600	-400	-4,500	-700
2051	4,200	6,600	600	100	26,300	-14,200	-11,100	-2,500	-400	-2,200	-2,900
2052	5,100	5,500	600	100	17,600	-11,900	-13,200	-2,900	-400	-4,700	-7,600
2053	5,400	6,400	700	100	13,600	-11,600	-13,300	-3,000	-400	-600	-8,200
2054	5,600	7,500	700	100	20,900	-13,700	-12,500	-2,800	-400	3,700	-4,500
2055	3,500	7,300	700	100	11,400	-13,500	-13,500	-3,000	-400	-1,000	-5,500
2056	5,900	6,600	600	100	13,400	-14,700	-9,800	-2,300	-400	2,400	-3,100

Table 2-23. Big Valley Basin Projected Groundwater System Water Budget (2020 – 2070) - Scenario A (contd.)

Water Year	Stream Leakage (AF)	Inflow from Hillsides (AF)	Inflow from Scotts Valley Basin (AF)	Inflow from Clear Lake (AF)	Deep Percolation (AF)	Groundwater Uptake (AF)	Agricultural Pumping (AF)	Domestic Pumping (AF)	Municipal Pumping (AF)	Groundwater Storage Change (AF)	Cumulative Groundwater Storage Change (AF)
2057	2,400	9,000	700	100	12,600	-17,300	-10,600	-2,400	-400	3,800	700
2058	3,400	6,000	600	100	10,800	-12,200	-13,500	-3,000	-400	-7,400	-6,700
2059	5,600	5,800	600	100	11,800	-10,600	-14,400	-3,200	-400	-3,000	-9,700
2060	7,700	4,700	600	100	12,700	-9,900	-13,400	-3,000	-400	-2,000	-11,700
2061	8,200	6,100	700	100	19,500	-12,400	-11,100	-2,600	-400	4,500	-7,200
2062	5,700	6,500	600	100	11,400	-14,300	-10,000	-2,300	-400	2,500	-4,700
2063	5,800	5,100	600	100	25,400	-11,600	-12,900	-2,900	-400	-4,700	-9,400
2064	5,600	5,500	600	100	17,800	-10,200	-13,600	-2,900	-400	-2,100	-11,500
2065	6,400	4,300	600	200	17,000	-7,400	-15,600	-3,400	-400	-5,200	-16,700
2066	7,900	5,300	700	100	25,700	-8,700	-14,400	-3,200	-400	1,300	-15,400
2067	8,100	6,300	800	200	15,400	-10,800	-14,100	-3,100	-400	3,600	-11,800
2068	4,300	9,200	800	100	14,600	-16,100	-11,100	-2,700	-400	8,900	-2,900
2069	5,100	5,600	600	100	12,500	-11,600	-13,800	-3,100	-400	-5,700	-8,600
2070	5,600	7,600	700	100	15,100	-15,600	-10,800	-2,500	-400	6,400	-2,200
Average (2020-2070)	**4,800**	**7,000**	**600**	**100**	**15,700**	**-13,200**	**-12,100**	**-2,800**	**-400**	**0**	

Note: All volumes are rounded to the nearest 100 acre-feet.

Key:
AF = acre-feet

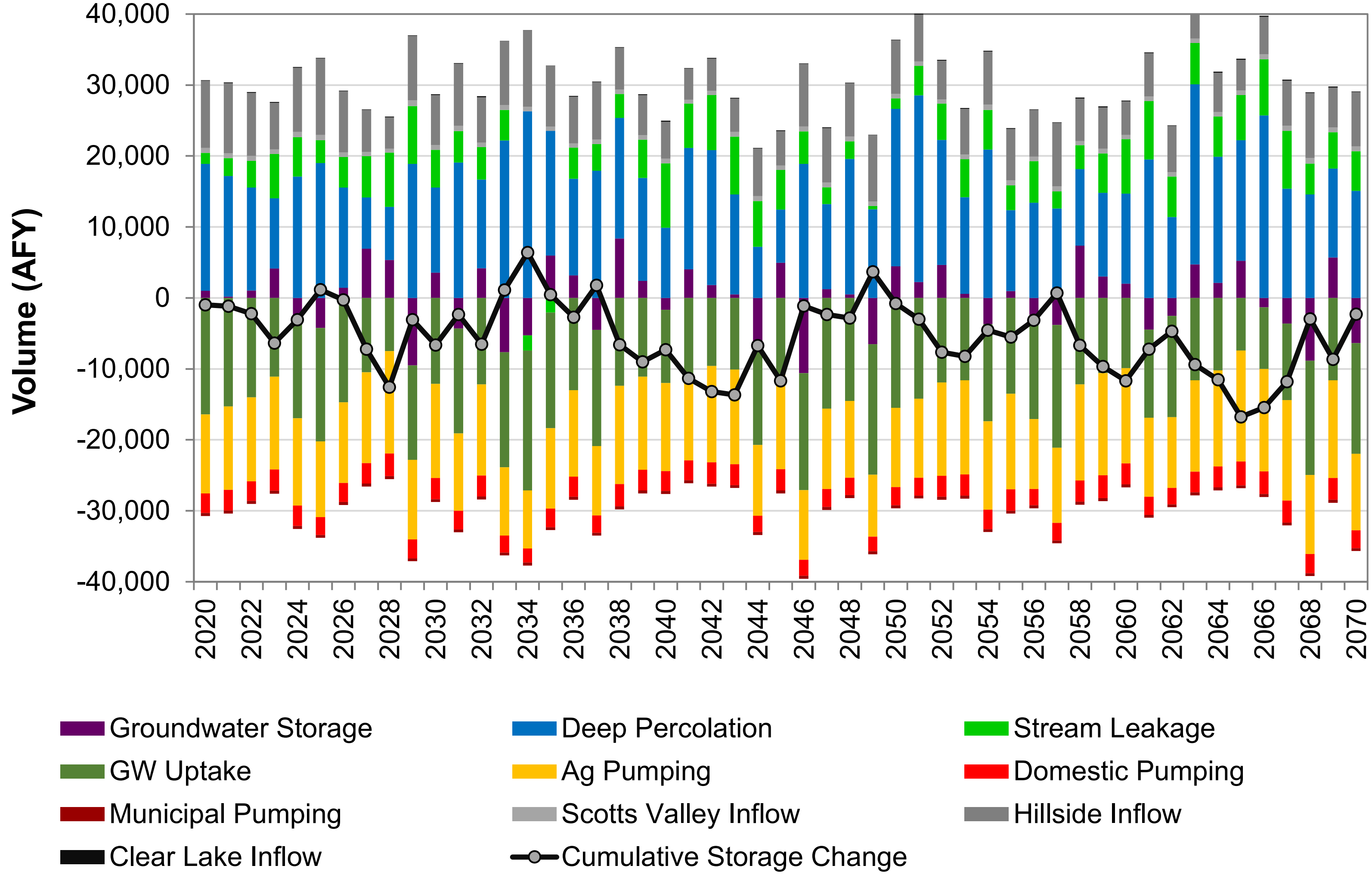


Figure 2-81. Big Valley Basin Projected Groundwater System Water Budget (2020 – 2070) - Scenario A

2.2.4.10 Projected Water Budget Scenario B (Wet - Moderate Warming Climate Change)

Results of the projected Scenario B water budgets for the 2020-2070 period are summarized in this section. This scenario assumes wetter and moderately warmer hydrologic conditions compared to baseline conditions assumed in Scenario A. Simulation results show increased precipitation in the Land Surface System under assumed conditions, and its influences on the Stream System and Groundwater System water budgets.

Land Surface System Budget

Several components of the projected Scenario B Land Surface System budget show relatively large percent changes (greater than 10 percent) compared to the projected baseline (Scenario A) budget. Projected annual inflows and outflows of the Scenario B Land Surface System budget are summarized in **Table 2-24** and **Figure 2-82**. The total annual volume of water in the projected Scenario B Land Surface System budget ranges from 71,000 AFY to 231,000 AFY with an average of 125,000 AFY. Over the projected period, the average basin-wide precipitation is about 94,400 AFY. Groundwater uptake and groundwater pumping average about 16,000 and 13,300 AFY, respectively. Non-routed deliveries, in-stream diversions and septic recharge are relatively very small, and each component remains between 300 AFY and 400 AFY throughout the projected period. The major outflows from the Land Surface System: runoff and evapotranspiration, average about 69,000 AFY and 36,200 AFY, respectively. Annual deep percolation is about 19,400 AFY on average.

Projected precipitation in Scenario B is on average 28 percent greater in comparison to Scenario A (an increase of 20,500 AFY on average). Also, year to year variability of annual precipitation is greater in Scenario B (standard deviations of annual precipitation for Scenario A and Scenario B are 26,700 AFY and 33,100 AFY, respectively). Groundwater uptake in Scenario B is 21 percent greater than that in Scenario A (an increase of 2,800 AFY). In contrast, groundwater pumping is 8 percent less (a decrease of 1,200 AFY). Non-routed delivery, stream diversions, groundwater pumping, and septic recharge over the projected period are consistent between Scenario A and Scenario B. When outflows are considered, runoff, deep percolation and evapotranspiration under Scenario B are on average 32 percent, 24 percent, and 6 percent greater compared Scenario A (increases of 16,600 AFY, 3,700 AFY and 1,900 AFY, respectively). Comparison of Land Surface System water budget results of Scenario A and Scenario B reflects the influence of increased precipitation under wet – moderate warm climatic conditions assumed for Scenario B.

Table 2-24. Big Valley Basin Projected Land Surface System Water Budget (2020 – 2070) - Scenario B

Water Year	Inflow (AF)						Outflow (AF)		
	Precipitation	Groundwater Uptake	Non-Routed Delivery	In-Stream Diversion	Groundwater Pumping[1]	Septic Recharge	Runoff	Evapo-transpiration	Deep Percolation
2020	94,200	16,400	300	300	11,000	300	-62,800	-41,800	-17,900
2021	92,000	16,900	300	400	12,600	300	-68,600	-34,700	-19,200
2022	47,000	12,300	300	400	12,600	300	-24,200	-39,400	-9,200
2023	72,800	13,200	300	400	15,600	300	-53,700	-32,600	-16,300
2024	136,200	18,000	300	400	13,400	300	-105,200	-35,600	-27,700
2025	77,700	15,700	300	400	14,300	300	-57,500	-34,200	-16,900
2026	108,200	17,100	200	400	10,600	300	-77,900	-37,900	-21,000
2027	107,900	17,700	300	400	13,600	300	-82,600	-35,100	-22,500
2028	76,700	15,600	200	300	12,700	300	-52,900	-37,300	-15,700
2029	43,400	11,300	300	400	15,500	300	-27,100	-33,900	-10,200
2030	119,400	16,400	300	400	12,900	300	-88,500	-37,300	-23,800
2031	71,000	14,500	300	400	14,100	300	-51,200	-33,900	-15,400
2032	99,200	15,600	300	400	14,400	300	-74,600	-34,600	-20,900
2033	78,600	15,000	300	400	14,200	300	-54,900	-37,300	-16,400
2034	76,600	13,700	300	400	13,100	300	-51,500	-37,400	-15,500
2035	121,600	17,400	300	400	12,600	300	-91,200	-36,900	-24,400
2036	162,900	21,200	200	400	11,400	300	-125,700	-38,700	-32,000
2037	172,300	22,500	300	400	10,100	300	-131,700	-40,900	-33,200
2038	104,600	19,800	300	400	10,900	300	-76,900	-38,500	-20,800
2039	125,300	20,100	300	400	11,800	300	-95,400	-37,600	-25,100
2040	46,900	13,300	300	400	15,100	300	-30,900	-34,400	-10,900

Table 2-24. Big Valley Basin Projected Land Surface System Water Budget (2020 – 2070) - Scenario B (contd.)

Water Year	Inflow (AF)						Outflow (AF)		
	Precipitation	Groundwater Uptake	Non-Routed Delivery	In-Stream Diversion	Groundwater Pumping[1]	Septic Recharge	Runoff	Evapo-transpiration	Deep Percolation
2041	60,500	12,300	300	400	14,500	300	-39,600	-35,700	-13,000
2042	47,300	11,500	300	400	15,800	300	-30,500	-34,100	-11,000
2043	116,700	15,700	300	400	14,100	300	-88,800	-34,700	-24,000
2044	94,300	15,900	300	400	12,500	300	-67,300	-37,400	-18,900
2045	125,700	17,700	200	400	10,800	300	-92,800	-37,900	-24,300
2046	102,900	18,300	200	400	11,200	300	-74,800	-38,100	-20,400
2047	154,500	21,100	300	400	11,400	300	-120,000	-37,200	-30,700
2048	95,400	18,200	300	400	14,000	300	-72,800	-35,300	-20,400
2049	96,900	17,500	300	400	12,100	300	-70,400	-37,500	-19,500
2050	101,300	17,500	300	400	14,500	300	-78,900	-33,500	-21,800
2051	97,700	16,700	200	400	12,000	300	-69,700	-38,200	-19,200
2052	56,000	13,700	400	400	15,300	300	-40,900	-31,700	-13,300
2053	58,900	12,100	300	400	15,400	300	-38,800	-35,600	-13,000
2054	97,000	14,500	300	400	14,500	300	-72,200	-34,500	-20,300
2055	86,700	14,900	300	400	13,300	300	-61,500	-36,600	-17,700
2056	122,900	18,000	300	400	13,300	300	-94,800	-35,100	-25,300
2057	69,000	14,300	300	400	14,700	300	-49,500	-34,300	-15,200
2058	62,300	12,900	300	400	15,600	300	-43,400	-34,300	-14,000
2059	123,100	16,800	300	400	12,100	300	-92,600	-35,900	-24,400
2060	197,800	23,200	300	400	8,700	300	-149,300	-44,200	-37,100
2061	75,300	17,200	300	400	13,400	300	-53,800	-37,000	-16,000

Table 2-24. Big Valley Basin Projected Land Surface System Water Budget (2020 – 2070) - Scenario B (contd.)

Water Year	Inflow (AF)						Outflow (AF)		
	Precipitation	Groundwater Uptake	Non-Routed Delivery	In-Stream Diversion	Groundwater Pumping[1]	Septic Recharge	Runoff	Evapo-transpiration	Deep Percolation
2062	51,600	13,100	300	400	15,700	300	-35,500	-33,800	-12,100
2063	103,300	16,100	300	400	12,700	300	-74,100	-38,400	-20,500
2064	90,200	15,900	300	400	13,400	300	-65,100	-36,900	-18,500
2065	90,600	15,700	300	400	14,300	300	-66,400	-36,000	-19,100
2066	65,800	13,000	300	300	13,900	300	-44,700	-35,000	-13,700
2067	60,800	13,500	300	400	14,900	300	-42,800	-33,800	-13,600
2068	65,000	12,400	300	400	15,600	300	-46,200	-33,200	-14,500
2069	90,100	14,100	300	400	14,900	300	-66,200	-34,800	-19,100
2070	119,800	16,800	300	400	13,500	300	-89,800	-37,100	-24,100
Average	**94,400**	**16,000**	**300**	**400**	**13,300**	**300**	**-69,000**	**-36,200**	**-19,400**

Note:
[1] Calculated pumping needed to meet residual irrigation and frost protection demand for agriculture and urban and residential landscaping.
All volumes are rounded to the nearest 100 acre-feet.
Key:
AF = acre-feet

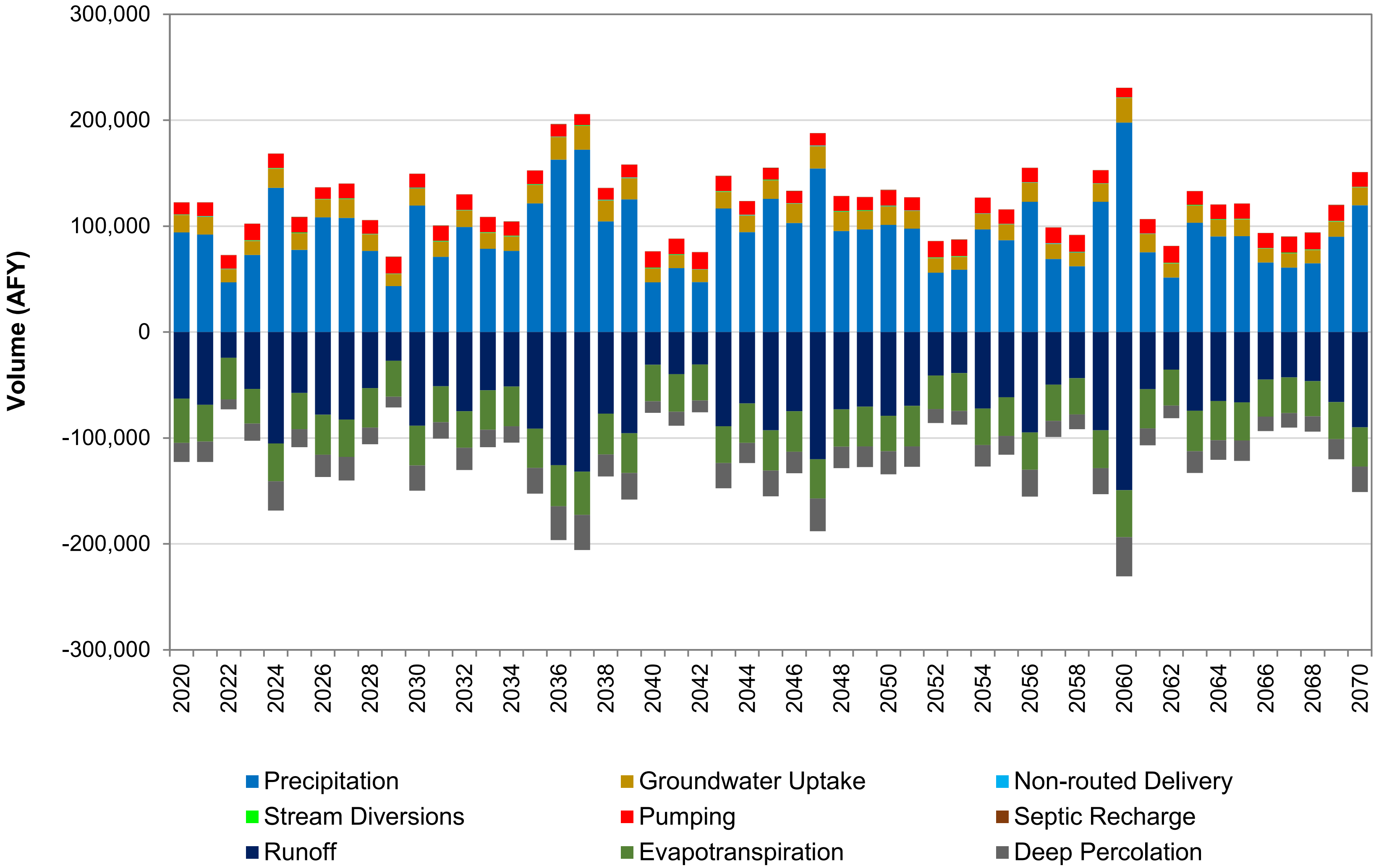


Figure 2-82. Big Valley Basin Projected Land Surface System Water Budget (2020 – 2070) - Scenario B

Stream System Budget

The total volume of water in the projected Scenario B Stream System water budget is on average 35 percent greater in comparison to Scenario A budget, mainly due to the increased stream inflow and outflow for the projected period. Annual inflows and outflows of the projected Scenario B Stream System budget are summarized in **Table 2-25** and **Figure 2-83.** The total volume of water in the projected Stream System budget ranges from 53,500 AFY to 528,000 AFY with an average of about 217,500 AFY. The average stream inflow is about 137,000 AFY. Surface water runoff to streams averages about 74,800 AFY over this period, while stream gain from groundwater discharge averages about 5,600 AFY. Average stream outflow is about 210,000 AFY. Stream loss to groundwater and diversion from streams averages about 7,000 AFY and 400 AFY, respectively during this period. In comparison to Scenario A, stream inflow under Scenario B is on average 35 percent greater (an increase of 35,700 AFY). Percent increases of stream gain and runoff are 81 percent and 30 percent, respectively and correspond to volumetric increases of 2,500 AFY and 17,400 AFY, respectively. Corresponding to relatively large increase of stream inflow and runoff, stream outflow increases by 37 percent on average (an increase of 56,500 AFY). In-stream diversion remains unchanged, but stream loss decreases by 11 percent on average compared to Scenario A (a decrease of 900 AFY) as elevated groundwater levels lead to increased groundwater discharge to streams resulting in a net decrease of stream leakage.

Table 2-25. Big Valley Basin Projected Stream System Water Budget (2020 – 2070) - Scenario B

Water Year	Stream Inflow (AF)	Stream Outflow (AF)	Stream Gain (AF)	Stream Loss (AF)	Runoff (AF)	Diversion (AF)	Total Inflow (AF)	Total Outflow (AF)
2020	120,800	-186,300	4,200	-6,400	68,000	-300	193,000	-193,000
2021	138,500	-210,800	5,100	-6,800	74,400	-400	218,000	-218,000
2022	25,100	-45,100	2,200	-8,000	26,200	-400	53,500	-53,500
2023	99,100	-152,600	2,800	-7,200	58,200	-400	160,100	-160,200
2024	223,700	-336,400	6,500	-7,500	114,100	-400	344,300	-344,300
2025	99,100	-158,800	4,300	-6,500	62,300	-400	165,700	-165,700
2026	154,600	-236,600	5,700	-8,000	84,600	-400	244,900	-245,000
2027	176,600	-267,300	7,300	-5,700	89,500	-400	273,400	-273,400
2028	96,200	-150,200	4,400	-7,300	57,300	-300	157,900	-157,800
2029	32,100	-56,200	2,200	-7,200	29,400	-400	63,700	-63,800
2030	191,100	-284,500	5,300	-7,600	96,000	-400	292,400	-292,500
2031	89,200	-141,200	3,900	-6,900	55,400	-400	148,500	-148,500
2032	157,300	-235,600	4,700	-7,100	81,000	-400	243,000	-243,100
2033	102,500	-157,400	3,300	-7,400	59,500	-400	165,300	-165,200
2034	87,300	-138,800	3,300	-7,200	55,800	-400	146,400	-146,400
2035	191,200	-289,200	6,400	-6,800	98,800	-400	296,400	-296,400
2036	294,700	-436,500	12,200	-6,400	136,400	-400	443,300	-443,300
2037	295,200	-446,900	15,100	-5,800	142,800	-400	453,100	-453,100
2038	171,500	-259,200	10,000	-5,200	83,300	-400	264,800	-264,800
2039	204,100	-312,200	10,800	-5,800	103,400	-400	318,300	-318,400
2040	37,500	-69,200	4,400	-5,900	33,600	-400	75,500	-75,500
2041	53,900	-90,600	2,600	-8,600	43,100	-400	99,600	-99,600
2042	42,800	-69,100	2,000	-8,400	33,100	-400	77,900	-77,900

Table 2-25. Big Valley Basin Projected Stream System Water Budget (2020 – 2070) - Scenario B (contd.)

Water Year	Stream Inflow (AF)	Stream Outflow (AF)	Stream Gain (AF)	Stream Loss (AF)	Runoff (AF)	Diversion (AF)	Total Inflow (AF)	Total Outflow (AF)
2043	188,100	-281,300	5,200	-8,000	96,400	-400	289,700	-289,700
2044	131,300	-200,500	4,600	-7,900	72,900	-400	208,800	-208,800
2045	204,800	-305,400	7,800	-7,700	100,900	-400	313,500	-313,500
2046	166,300	-248,700	7,400	-5,800	81,100	-400	254,800	-254,900
2047	266,300	-403,300	13,000	-5,900	130,300	-400	409,600	-409,600
2048	144,500	-224,900	7,600	-5,700	78,900	-400	231,000	-231,000
2049	134,100	-209,800	6,600	-6,800	76,200	-400	216,900	-217,000
2050	165,500	-251,800	7,200	-6,400	85,800	-400	258,500	-258,600
2051	129,700	-202,500	5,800	-8,400	75,700	-400	211,200	-211,300
2052	66,300	-109,000	4,000	-5,100	44,300	-400	114,600	-114,500
2053	55,300	-91,400	2,200	-7,600	41,900	-400	99,400	-99,400
2054	151,400	-224,600	3,600	-8,600	78,500	-400	233,500	-233,600
2055	112,300	-174,600	3,800	-8,000	66,800	-400	182,900	-183,000
2056	206,700	-311,300	8,000	-5,900	102,800	-400	317,500	-317,600
2057	81,700	-132,900	4,300	-6,300	53,600	-400	139,600	-139,600
2058	60,200	-101,800	2,600	-7,500	46,900	-400	109,700	-109,700
2059	202,000	-300,200	6,100	-8,300	100,800	-400	308,900	-308,900
2060	349,900	-521,400	16,200	-6,100	161,800	-400	527,900	-527,900
2061	95,100	-154,800	7,100	-5,100	58,100	-400	160,300	-160,300
2062	57,200	-92,100	3,400	-6,800	38,700	-400	99,300	-99,300
2063	144,600	-221,300	4,900	-8,100	80,200	-400	229,700	-229,800
2064	123,100	-191,000	4,800	-6,900	70,400	-400	198,300	-198,300
2065	129,700	-198,600	4,500	-7,200	72,000	-400	206,200	-206,200

Table 2-25. Big Valley Basin Projected Stream System Water Budget (2020 – 2070) - Scenario B (contd.)

Water Year	Stream Inflow (AF)	Stream Outflow (AF)	Stream Gain (AF)	Stream Loss (AF)	Runoff (AF)	Diversion (AF)	Total Inflow (AF)	Total Outflow (AF)
2066	63,600	-105,700	2,800	-9,200	48,800	-300	115,200	-115,200
2067	80,900	-123,000	2,900	-6,800	46,300	-400	130,100	-130,200
2068	78,300	-122,500	2,600	-8,200	50,300	-400	131,200	-131,100
2069	125,400	-192,700	3,400	-7,500	71,700	-400	200,500	-200,600
2070	193,600	-288,300	5,500	-8,000	97,500	-400	296,600	-296,700
Average	**137,100**	**-210,100**	**5,600**	**-7,000**	**74,800**	**-400**	**217,500**	**-217,500**

Note:
All volumes are rounded to the nearest 100 acre-feet.
Key:
AF = acre-feet

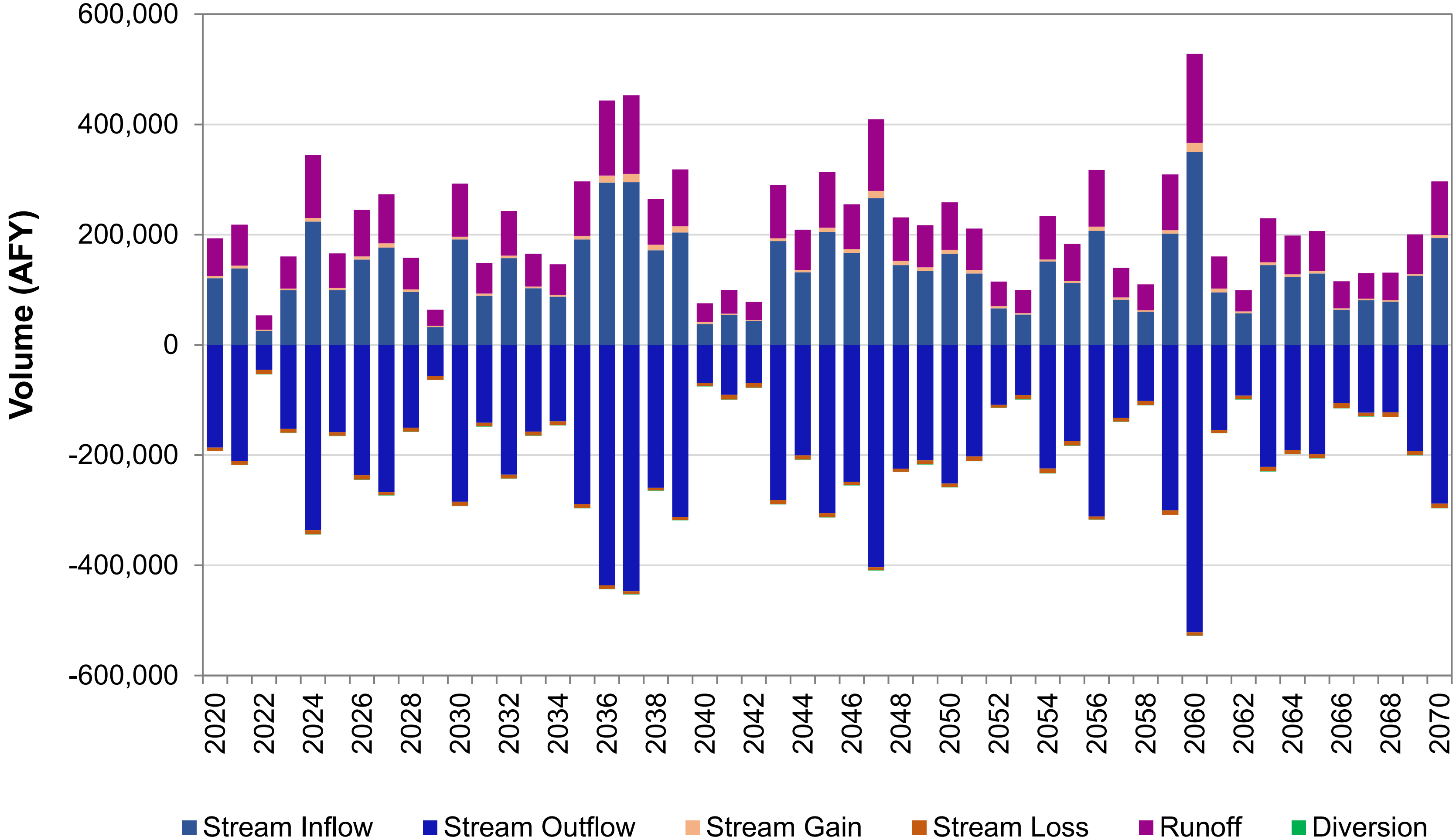


Figure 2-83. Big Valley Basin Projected Stream System Water Budget (2020 – 2070) - Scenario B

Groundwater System Budget

Percent changes of stream leakage, subsurface flow from hillsides, deep percolation, and groundwater uptake of the Scenario B Groundwater System budget are relatively large (greater than 20 percent) in comparison to Scenario A. The average annual groundwater storage change for the projected period under Scenario B is zero, indicating that no significant change in groundwater storage will occur. Annual inflows and outflows of the projected Scenario B Groundwater System budget are summarized in **Table 2-26** and **Figure 2-84**. Over the projected water budget period, the average deep percolation is about 19,400 AFY. Subsurface inflow from hillsides is about 8,500 AFY on average while subsurface inflows from the Scotts Valley Basin and Clear Lake are about 600 AFY and 100 AFY, respectively. Stream leakage to the GWS averages about 1,400 AFY. Over the projected period, groundwater uptake is about 16,000 AFY on average. Agricultural, domestic, and municipal groundwater pumping average about 11,100 AFY, 2,600 AFY, and 400 AFY, respectively making the total annual average groundwater pumping about 14,100 AFY.

In comparison to Scenario A, Scenario B deep percolation is on average 24 percent greater (an increase of 3,700 AFY), while subsurface inflow from hillsides is on average 21 percent greater (an increase of 2,300 AFY). In contrast, projected stream leakage is on average 71 percent less compared to Scenario A (a decrease of 3,100 AFY). When outflows are considered, groundwater uptake is on average 21 percent greater (an increase of 1,500 AFY) in Scenario B. However, Scenario B agricultural pumping and domestic pumping decrease by 8 percent and 7 percent, respectively compared to Scenario A (decreases of 1,000 AFY and 200 AFY, respectively). Volumes of the other Groundwater System budget components are consistent with Scenario A.

The average annual change in groundwater storage over the projected period under Scenario B is close to zero (i.e., no change in storage when long-term changes are considered). However, year to year change in groundwater storage ranges from a net decrease of up to 9,200 AFY to a net increase of up to 9,200 AFY during this period. The cumulative storage increase of 1,500 acre-feet over the 51-year projected period is equivalent to an increase of approximately 0.06 acre-feet per acre across the entire Basin.

Table 2-26. Big Valley Basin Projected Groundwater System Water Budget (2020 – 2070) - Scenario B

Water Year	Stream Leakage (AF)	Inflow from Hillsides (AF)	Inflow from Scotts Valley Basin (AF)	Inflow from Clear Lake (AF)	Deep Percolation (AF)	Groundwater Uptake (AF)	Agricultural Pumping (AF)	Domestic Pumping (AF)	Municipal Pumping (AF)	Groundwater Storage Change (AF)	Cumulative Groundwater Storage Change (AF)
2020	2,200	7,500	600	100	17,900	-16,400	-9,100	-2,200	-400	0	0
2021	1,800	8,200	600	100	19,200	-16,900	-10,300	-2,600	-400	-400	-400
2022	5,900	5,300	500	100	9,200	-12,300	-10,400	-2,500	-400	-4,600	-5,000
2023	4,400	6,700	700	100	16,300	-13,200	-12,900	-3,000	-400	-1,500	-6,500
2024	1,100	10,500	700	100	27,700	-18,000	-11,100	-2,600	-400	7,900	1,400
2025	2,200	7,800	600	100	16,900	-15,700	-11,900	-2,700	-400	-3,000	-1,600
2026	2,300	8,800	600	0	21,000	-17,100	-8,700	-2,200	-400	4,300	2,700
2027	-1,600	9,600	700	0	22,500	-17,700	-11,300	-2,700	-400	-1,000	1,700
2028	2,900	7,400	600	0	15,700	-15,600	-10,600	-2,500	-400	-2,400	-700
2029	5,000	5,600	600	100	10,200	-11,300	-12,900	-3,000	-400	-5,900	-6,600
2030	2,300	9,300	700	100	23,800	-16,400	-10,700	-2,500	-400	6,100	-500
2031	3,000	7,200	600	100	15,400	-14,500	-11,700	-2,700	-400	-2,900	-3,400
2032	2,300	8,800	700	100	20,900	-15,600	-11,900	-2,800	-400	2,100	-1,300
2033	4,200	7,300	700	100	16,400	-15,000	-11,800	-2,700	-400	-1,300	-2,600
2034	3,900	7,000	600	100	15,500	-13,700	-11,000	-2,400	-400	-500	-3,100
2035	400	9,400	700	100	24,400	-17,400	-10,500	-2,400	-400	4,200	1,100
2036	-5,800	12,500	600	0	32,000	-21,200	-9,500	-2,200	-400	6,000	7,100
2037	-9,300	14,000	600	0	33,200	-22,500	-8,500	-2,000	-400	5,100	12,200

Table 2-26. Big Valley Basin Projected Groundwater System Water Budget (2020 – 2070) - Scenario B (contd.)

Water Year	Stream Leakage (AF)	Inflow from Hillsides (AF)	Inflow from Scotts Valley Basin (AF)	Inflow from Clear Lake (AF)	Deep Percolation (AF)	Groundwater Uptake (AF)	Agricultural Pumping (AF)	Domestic Pumping (AF)	Municipal Pumping (AF)	Groundwater Storage Change (AF)	Cumulative Groundwater Storage Change (AF)
2038	-4,800	10,700	500	0	20,800	-19,800	-9,100	-2,100	-400	-4,200	8,000
2039	-5,000	11,300	600	0	25,100	-20,100	-9,900	-2,300	-400	-700	7,300
2040	1,600	6,800	500	100	10,900	-13,300	-12,600	-2,900	-400	-9,200	-1,900
2041	6,000	5,900	600	100	13,000	-12,300	-12,000	-2,800	-400	-1,900	-3,800
2042	6,300	5,400	600	100	11,000	-11,500	-13,100	-3,100	-400	-4,600	-8,400
2043	2,800	9,300	700	0	24,000	-15,700	-11,600	-2,800	-400	6,300	-2,100
2044	3,300	8,200	700	100	18,900	-15,900	-10,300	-2,400	-400	2,100	0
2045	-100	10,000	600	0	24,300	-17,700	-8,900	-2,200	-400	5,500	5,500
2046	-1,700	9,400	600	0	20,400	-18,300	-9,300	-2,200	-400	-1,400	4,100
2047	-7,100	12,700	600	0	30,700	-21,100	-9,500	-2,200	-400	3,600	7,700
2048	-1,900	10,000	600	100	20,400	-18,200	-11,700	-2,600	-400	-3,600	4,100
2049	100	9,100	600	100	19,500	-17,500	-10,000	-2,400	-400	-900	3,200
2050	-800	9,900	700	100	21,800	-17,500	-12,000	-2,800	-400	-1,100	2,100
2051	2,500	8,700	600	100	19,200	-16,700	-9,900	-2,400	-400	1,900	4,000
2052	1,100	7,000	600	100	13,300	-13,700	-12,700	-2,900	-400	-7,500	-3,500
2053	5,400	6,200	600	100	13,000	-12,100	-12,800	-2,900	-400	-2,900	-6,400
2054	5,000	8,500	700	100	20,300	-14,500	-12,000	-2,800	-400	4,900	-1,500
2055	4,200	7,700	700	100	17,700	-14,900	-10,900	-2,600	-400	1,400	-100
2056	-2,100	10,300	700	0	25,300	-18,000	-11,100	-2,600	-400	2,100	2,000

Table 2-26. Big Valley Basin Projected Groundwater System Water Budget (2020 – 2070) - Scenario B (contd.)

Water Year	Stream Leakage (AF)	Inflow from Hillsides (AF)	Inflow from Scotts Valley Basin (AF)	Inflow from Clear Lake (AF)	Deep Percolation (AF)	Groundwater Uptake (AF)	Agricultural Pumping (AF)	Domestic Pumping (AF)	Municipal Pumping (AF)	Groundwater Storage Change (AF)	Cumulative Groundwater Storage Change (AF)
2057	2,000	7,600	600	100	15,200	-14,300	-12,200	-2,800	-400	-4,100	-2,100
2058	4,900	6,300	700	100	14,000	-12,900	-13,000	-3,000	-400	-3,200	-5,300
2059	2,200	9,500	700	0	24,400	-16,800	-10,000	-2,400	-400	7,200	1,900
2060	-10,100	14,500	600	-100	37,100	-23,200	-7,300	-1,700	-500	9,200	11,100
2061	-2,000	8,800	600	100	16,000	-17,200	-11,100	-2,500	-400	-7,800	3,300
2062	3,400	6,700	600	100	12,100	-13,100	-13,000	-3,000	-400	-6,600	-3,300
2063	3,200	8,500	700	100	20,500	-16,100	-10,500	-2,500	-400	3,400	100
2064	2,100	8,100	600	100	18,500	-15,900	-11,100	-2,600	-400	-500	-400
2065	2,700	8,300	700	0	19,100	-15,700	-11,800	-2,700	-400	100	-300
2066	6,300	6,400	600	100	13,700	-13,000	-11,400	-2,800	-400	-500	-800
2067	3,900	6,500	600	100	13,600	-13,500	-12,300	-2,900	-400	-4,400	-5,200
2068	5,700	6,600	700	100	14,500	-12,400	-12,900	-3,000	-400	-1,100	-6,300
2069	4,000	7,600	700	100	19,100	-14,100	-12,400	-2,800	-400	1,700	-4,600
2070	2,400	9,700	700	100	24,100	-16,800	-11,200	-2,600	-400	6,100	1,500
Average 2020-2070	**1,400**	**8,500**	**600**	**100**	**19,400**	**-16,000**	**-11,100**	**-2,600**	**-400**	**0**	

Note: All volumes are rounded to the nearest 100 acre-feet.

Key:
AF = acre-feet

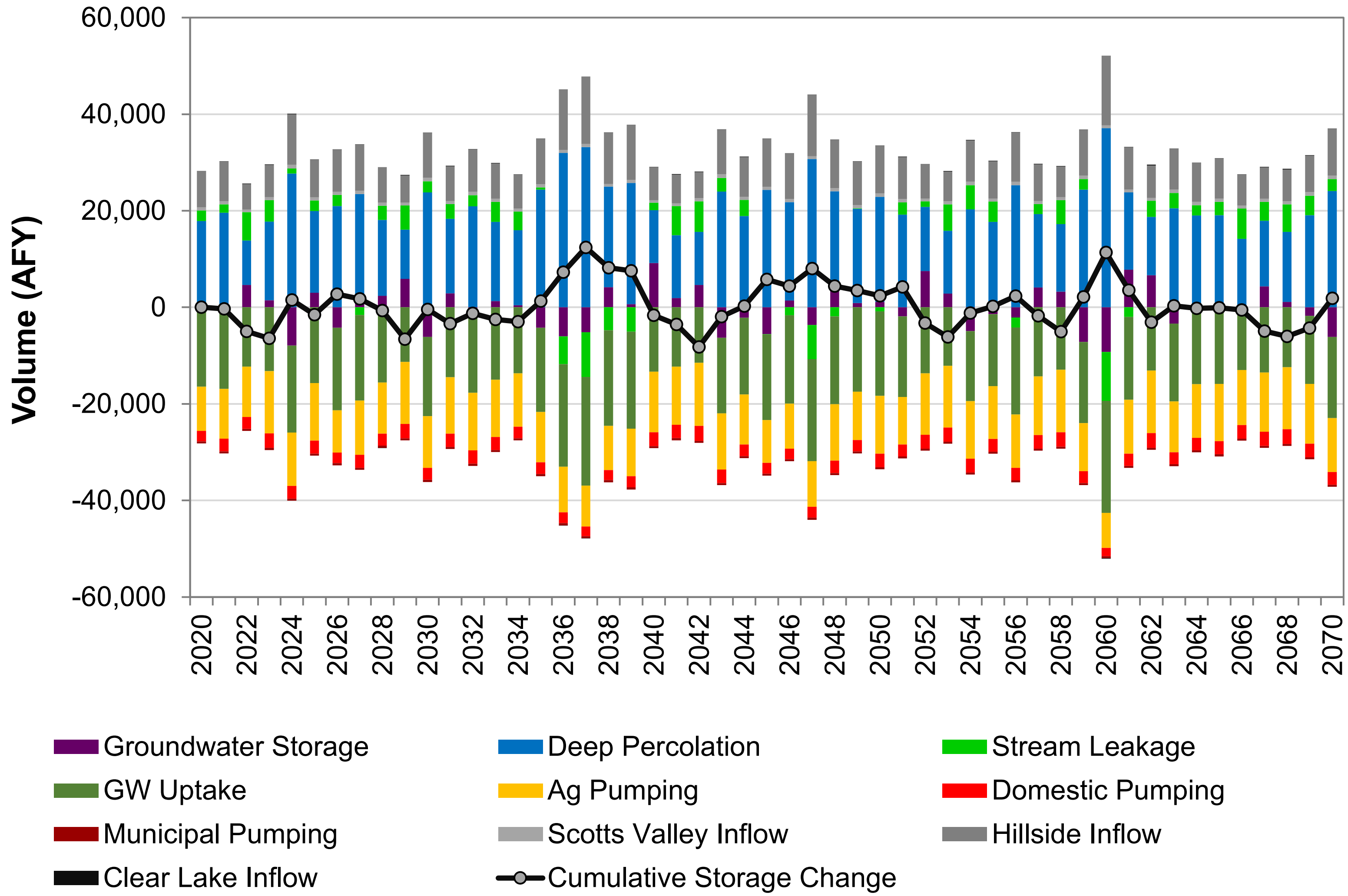


Figure 2-84. Big Valley Basin Projected Groundwater System Water Budget (2020 – 2070) - Scenario B

2.2.4.11 Projected Water Budget Scenario C (Dry-Extreme Warming Climate Change)

Results of the projected Scenario C water budgets are summarized in this section. This scenario assumes dry and extremely warm hydrologic conditions compared to Scenario A.

Land Surface System Budget

All components in the projected Scenario C Land Surface System budget, except groundwater pumping, show relatively small changes (less than 4 percent) compared to Scenario A. Projected annual inflows and outflows of the Scenario C Land Surface System budget are summarized in **Table 2-27** and **Figure 2-85**. The total annual volume of water in the Scenario C Land Surface System budget ranges from 56,600 AFY to 189,000 AFY with an average of 105,000 AFY. Over the projected period, the basin-wide precipitation is about 75,100 AFY on average. Groundwater pumping and groundwater uptake average about 15,400 and 13,200 AFY, respectively. Non-routed deliveries, diversion from streams and septic recharge are relatively very small and each component remains between 300 AFY and 400 AFY throughout the projected period. The major outflows from the Land Surface System: runoff and evapotranspiration, average about 53,000 AFY and 35,500 AFY, respectively. Annual deep percolation is about 16,100 AFY on average. Projected groundwater pumping is on average 16 percent greater compared to Scenario A (an increase of 900 AFY). Anticipated changes in all other components in Scenario C Land Surface System budget are smaller than 4 percent compared to Scenario A.

Table 2-27. Big Valley Basin Projected Land Surface System Water Budget (2020 – 2070) - Scenario C

Water Year	Inflow (AF)						Outflow (AF)		
	Precipitation	Groundwater Uptake	Non-Routed Delivery	In-Stream Diversion	Groundwater Pumping[1]	Septic Recharge	Runoff	Evapo-transpiration	Deep Percolation
2020	46,200	13,000	300	400	14,900	300	-29,400	-35,000	-10,600
2021	51,200	10,800	300	400	15,600	300	-34,600	-32,100	-11,900
2022	44,800	9,700	300	400	17,100	300	-29,700	-32,000	-11,000
2023	93,300	12,900	300	400	15,700	300	-67,500	-35,800	-19,500
2024	108,300	15,900	300	400	13,100	300	-78,900	-37,600	-21,700
2025	95,400	16,200	300	400	13,000	300	-69,300	-36,700	-19,500
2026	51,100	12,200	300	400	15,900	300	-34,100	-34,100	-11,900
2027	98,200	15,000	200	400	13,100	300	-69,900	-37,600	-19,700
2028	44,500	11,300	300	400	16,400	300	-28,900	-33,600	-10,700
2029	96,400	14,100	300	400	13,600	300	-69,500	-35,800	-19,600
2030	111,500	16,600	300	400	13,400	300	-82,700	-37,100	-22,600
2031	61,900	13,700	300	400	14,700	300	-43,300	-34,200	-13,800
2032	62,700	12,200	400	400	16,600	300	-44,900	-33,200	-14,500
2033	73,000	12,600	300	400	15,500	300	-51,600	-34,600	-15,900
2034	82,400	14,200	300	400	14,800	300	-58,400	-36,700	-17,200
2035	122,100	17,200	300	400	13,100	300	-90,600	-38,300	-24,400
2036	156,200	20,300	200	400	11,500	300	-117,500	-40,900	-30,400
2037	71,800	16,300	300	400	13,800	300	-51,900	-35,400	-15,600
2038	101,700	17,200	300	400	12,700	300	-73,100	-39,000	-20,400
2039	77,200	15,600	300	400	15,300	300	-55,700	-36,600	-16,800
2040	85,300	15,000	300	400	13,600	300	-60,500	-36,800	-17,500

Table 2-27. Big Valley Basin Projected Land Surface System Water Budget (2020 – 2070) - Scenario C (contd.)

Water Year	Inflow (AF)						Outflow (AF)		
	Precipitation	Groundwater Uptake	Non-Routed Delivery	In-Stream Diversion	Groundwater Pumping[1]	Septic Recharge	Runoff	Evapo-transpiration	Deep Percolation
2041	97,100	16,200	300	400	14,400	300	-72,100	-36,100	-20,400
2042	74,100	14,900	200	300	12,100	300	-48,500	-38,800	-14,700
2043	28,600	9,500	300	400	17,500	300	-14,300	-34,700	-7,700
2044	95,400	13,800	300	400	14,300	300	-69,300	-35,500	-19,600
2045	128,800	17,700	300	400	13,400	300	-97,700	-37,100	-26,100
2046	73,900	15,000	200	400	13,300	300	-51,300	-36,400	-15,400
2047	46,300	11,200	300	400	17,100	300	-31,200	-33,000	-11,400
2048	107,200	15,500	300	400	15,400	300	-81,700	-34,800	-22,700
2049	92,100	15,700	300	400	14,200	300	-67,200	-36,600	-19,200
2050	88,100	15,700	300	400	12,300	300	-60,500	-39,200	-17,300
2051	78,600	14,800	300	400	14,900	300	-56,600	-35,800	-16,900
2052	70,900	13,400	300	400	15,500	300	-50,000	-35,300	-15,400
2053	51,500	12,100	300	400	15,600	300	-32,400	-36,200	-11,400
2054	46,800	10,500	300	400	16,600	300	-30,500	-33,300	-11,100
2055	54,400	10,400	300	400	16,900	300	-35,200	-35,200	-12,200
2056	69,100	11,500	300	400	16,700	300	-49,000	-33,800	-15,300
2057	59,200	10,800	300	400	16,800	300	-38,800	-35,900	-13,100
2058	73,200	11,300	300	400	18,000	300	-53,100	-33,700	-16,500
2059	103,000	14,900	300	400	15,000	300	-75,700	-36,800	-21,300
2060	39,100	10,400	300	400	18,100	300	-25,000	-33,300	-10,200
2061	68,100	10,900	300	400	17,200	300	-47,500	-34,500	-15,200

Table 2-27. Big Valley Basin Projected Land Surface System Water Budget (2020 – 2070) - Scenario C (contd.)

Water Year	Inflow (AF)						Outflow (AF)		
	Precipitation	Groundwater Uptake	Non-Routed Delivery	In-Stream Diversion	Groundwater Pumping[1]	Septic Recharge	Runoff	Evapo-transpiration	Deep Percolation
2062	66,400	11,600	300	400	17,300	300	-45,200	-36,300	-14,700
2063	52,600	10,100	400	400	18,200	300	-36,700	-32,300	-12,800
2064	50,900	9,000	400	400	17,500	300	-32,600	-34,100	-11,800
2065	87,300	12,200	300	400	14,800	300	-59,000	-38,800	-17,500
2066	64,800	12,000	300	400	15,500	300	-42,800	-36,700	-13,800
2067	43,800	8,900	300	400	17,400	300	-27,300	-33,100	-10,500
2068	79,400	12,300	300	400	16,600	300	-57,000	-35,200	-17,200
2069	46,000	10,000	300	400	17,300	300	-28,500	-34,900	-10,700
2070	58,900	9,200	300	400	19,800	300	-43,300	-30,900	-14,600
Average	**75,100**	**13,200**	**300**	**400**	**15,400**	**300**	**-53,000**	**-35,500**	**-16,100**

Notes:
[1] Calculated pumping needed to meet residual irrigation and crop protection demand for agriculture and urban and residential landscaping.
All volumes are rounded to the nearest 100 acre-feet.

Key:
AF = acre-feet

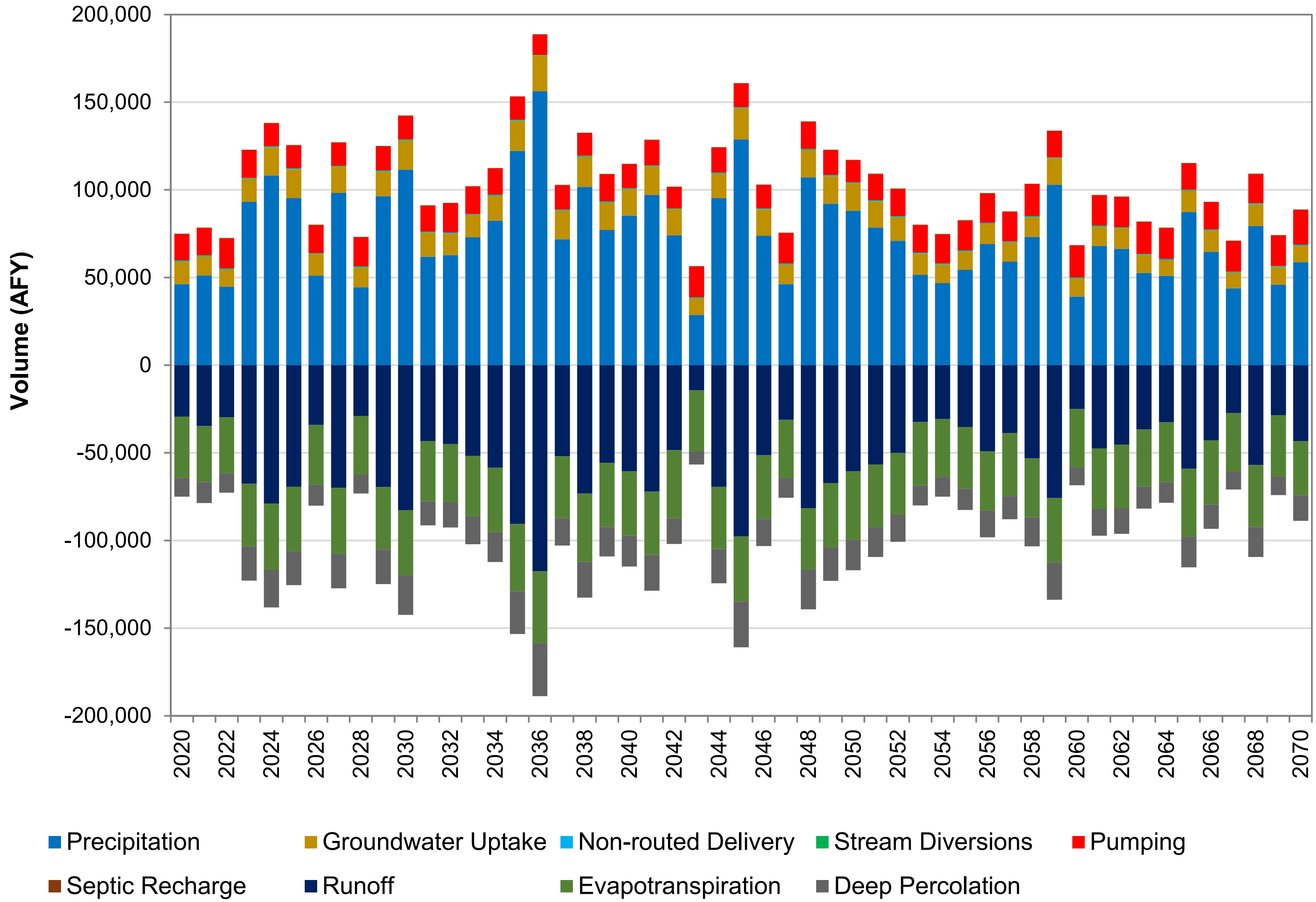


Figure 2-85. Big Valley Basin Projected Land Surface System Water Budget (2020 – 2070) - Scenario C

Stream System Budget

The total volume of water in the projected Scenario C Stream System water budget is on average 5 percent less in comparison to Scenario A, mainly due to the decreased stream inflow and outflow. Annual inflows and outflows from Scenario C Stream System budget are summarized in **Table 2-28** and **Figure 2-86**. The total volume of water in the projected Stream System budget ranges from about 27,000 AFY to 401,000 AFY with an average of about 154,000 AFY. Over the projected period, the average stream inflow is about 94,000 AFY. Surface water runoff to streams is about 57,400 AFY on average over this period, while stream gain from groundwater discharge is about 3,100 AFY on average. Stream outflow averages about 154,000 AFY over the projected period. Stream loss to groundwater and in-stream diversions average about 7,900 AFY and 400 AFY, respectively during this period. In comparison to Scenario A, projected stream inflow under Scenario C is on average 7 percent less (a decrease of 7,400 AFY). Projected stream gain is 10 percent less and it equates to a decrease of 300 AFY on average. Corresponding to the reduced stream inflow, stream outflow also decreases by 5 percent on average (a decrease of 7,800 AFY) compared to Scenario A. All other inflow and outflow components of the Stream System budget are consistent with Scenario A. Reduced stream flow and stream gain in comparison to Scenario A reflect the influence of dry-extreme warm climatic conditions assumed for Scenario C.

Table 2-28. Big Valley Basin Projected Stream System Water Budget (2020 – 2070) - Scenario C

WY	Stream Inflow (AF)	Stream Outflow (AF)	Stream Gain (AF)	Stream Loss (AF)	Runoff (AF)	Diversion (AF)	Total Inflow (AF)	Total Outflow (AF)
2020	29,900	-57,600	2,400	-6,100	31,700	-400	64,000	-64,100
2021	45,200	-75,600	1,700	-8,700	37,700	-400	84,600	-84,700
2022	37,200	-61,700	1,200	-8,600	32,100	-400	70,500	-70,700
2023	121,200	-186,300	1,900	-9,600	73,100	-400	196,200	-196,300
2024	160,300	-241,200	3,800	-8,200	85,600	-400	249,700	-249,800
2025	127,400	-199,800	4,500	-6,800	75,000	-400	206,900	-207,000
2026	36,700	-68,900	2,200	-6,500	36,800	-400	75,700	-75,800
2027	128,000	-198,200	3,500	-8,500	75,600	-400	207,100	-207,100
2028	35,300	-60,500	1,800	-7,600	31,300	-400	68,400	-68,500
2029	129,800	-199,800	3,400	-8,300	75,200	-400	208,400	-208,500
2030	183,800	-270,100	4,600	-7,700	89,800	-400	278,200	-278,200
2031	64,700	-107,100	3,000	-7,100	46,800	-400	114,500	-114,600
2032	71,100	-115,300	2,600	-6,500	48,500	-400	122,200	-122,200
2033	88,500	-137,600	2,200	-8,800	56,100	-400	146,800	-146,800
2034	110,200	-167,200	2,800	-8,800	63,400	-400	176,400	-176,400
2035	197,700	-293,900	5,500	-7,000	98,100	-400	301,300	-301,300
2036	262,700	-394,200	10,600	-6,000	127,200	-400	400,500	-400,600
2037	99,000	-154,100	5,200	-6,000	56,300	-400	160,500	-160,500
2038	151,700	-228,100	5,000	-7,300	79,200	-400	235,900	-235,800
2039	102,000	-159,200	4,100	-6,900	60,400	-400	166,500	-166,500
2040	114,300	-176,800	4,500	-7,200	65,500	-400	184,300	-184,400
2041	146,500	-221,000	4,200	-7,500	78,200	-400	228,900	-228,900
2042	77,800	-125,700	3,600	-7,800	52,400	-300	133,800	-133,800

Table 2-28. Big Valley Basin Projected Stream System Water Budget (2020 – 2070) - Scenario C (contd.)

WY	Stream Inflow (AF)	Stream Outflow (AF)	Stream Gain (AF)	Stream Loss (AF)	Runoff (AF)	Diversion (AF)	Total Inflow (AF)	Total Outflow (AF)
2043	9,700	-19,700	1,400	-6,700	15,500	-400	26,600	-26,800
2044	124,500	-193,000	2,900	-9,000	74,900	-400	202,300	-202,400
2045	207,600	-311,500	6,000	-7,500	105,800	-400	319,400	-319,400
2046	83,000	-135,600	4,100	-6,600	55,400	-400	142,500	-142,600
2047	38,800	-67,100	2,000	-7,100	33,700	-400	74,500	-74,600
2048	166,400	-249,300	3,400	-8,800	88,600	-400	258,400	-258,500
2049	132,200	-201,600	4,000	-7,100	72,800	-400	209,000	-209,100
2050	115,900	-176,400	3,600	-8,500	65,700	-400	185,200	-185,300
2051	109,100	-167,700	3,900	-6,200	61,200	-400	174,200	-174,300
2052	85,500	-134,100	2,800	-8,000	54,200	-400	142,500	-142,500
2053	43,300	-71,500	1,900	-8,500	35,100	-400	80,300	-80,400
2054	37,100	-62,600	1,500	-8,700	33,000	-400	71,600	-71,700
2055	53,800	-83,000	1,300	-10,000	38,300	-400	93,400	-93,400
2056	81,500	-126,400	1,600	-9,400	53,000	-400	136,100	-136,200
2057	58,200	-91,700	1,300	-9,500	42,000	-400	101,500	-101,600
2058	98,400	-148,900	1,400	-8,300	57,700	-400	157,500	-157,600
2059	146,600	-222,000	2,700	-9,100	82,100	-400	231,400	-231,500
2060	23,800	-44,400	1,400	-7,500	27,100	-400	52,300	-52,300
2061	76,900	-120,300	1,500	-9,100	51,400	-400	129,800	-129,800
2062	73,500	-114,100	1,400	-9,500	49,000	-400	123,900	-124,000
2063	46,300	-78,600	1,300	-8,300	39,700	-400	87,300	-87,300
2064	37,800	-64,600	900	-9,200	35,400	-400	74,100	-74,200
2065	109,100	-164,200	1,600	-10,100	63,900	-400	174,600	-174,700

Table 2-28. Big Valley Basin Projected Stream System Water Budget (2020 – 2070) - Scenario C (contd.)

WY	Stream Inflow (AF)	Stream Outflow (AF)	Stream Gain (AF)	Stream Loss (AF)	Runoff (AF)	Diversion (AF)	Total Inflow (AF)	Total Outflow (AF)
2066	77,200	-116,300	1,700	-8,700	46,500	-400	125,400	-125,400
2067	26,000	-47,100	1,000	-9,400	29,800	-400	56,800	-56,900
2068	115,400	-169,800	1,800	-8,800	61,800	-400	179,000	-179,000
2069	32,800	-55,700	1,100	-8,900	31,000	-400	64,900	-65,000
2070	60,500	-99,800	1,200	-8,400	46,900	-400	108,600	-108,600
Average	**94,000**	**-145,800**	**2,800**	**-8,000**	**57,400**	**-400**	**154,200**	**-154,200**

Note:
All volumes are rounded to the nearest 100 acre-feet.
Key:
AF = acre-feet

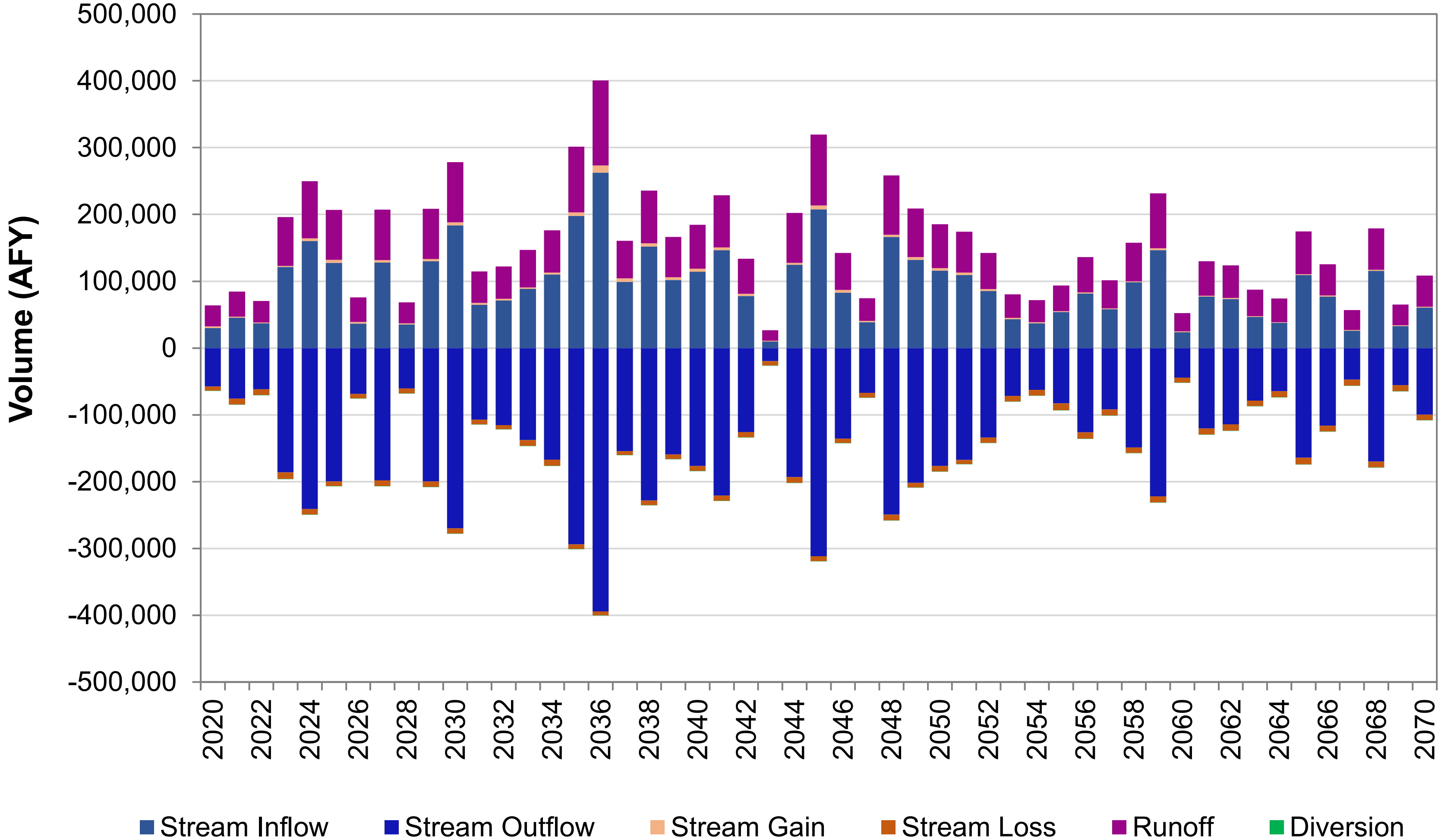


Figure 2-86. Big Valley Basin Projected Stream System Water Budget (2020 – 2070) - Scenario C

Groundwater System Budget

For the projected period, the groundwater storage decreases by about 300 AFY on average under Scenario C. This decrease is primarily attributable to increased agricultural and domestic pumping. Annual inflows and outflows of the projected Scenario C Groundwater System budget are summarized in **Table 2-29** and **Figure 2-87**. The average deep percolation is about 16,100 AFY. Subsurface inflow from hillsides averages about 6,900 AFY during this period, while subsurface inflows from the Scotts Valley Basin and Clear Lake average about 700 AFY and 100 AFY, respectively. Stream leakage to the GWS is about 5,200 AFY on average. During the projected period under Scenario C, groundwater uptake averages about 13,200 AFY. Agricultural, domestic, and municipal groundwater pumping averaged about 12,800 AFY, 2,900 AFY, and 400 AFY, respectively making the total annual groundwater pumping about 16,100 AFY on average. In comparison to Scenario A, Scenario C stream leakage is on average 8 percent greater (an increase of 400 AFY), while deep percolation is on average 3 percent greater (an increase of 400 AFY). Agricultural pumping increases by 6 percent compared to scenario A (an increase of 700 AFY). Volumetric change of any other component of the Groundwater System budget does not exceed 100 AFY.

Groundwater storage decreases by 300 AFY on average over the projected period under Scenario C. Year to year groundwater storage change ranges from a net decrease of 9,400 AFY to a net increase of 6,600 AFY during this period. The cumulative storage decrease of 15,200 acre-feet over the 51-year projected period is equivalent to a decrease of approximately 0.62 acre-feet per acre across the entire Basin.

Table 2-29. Big Valley Basin Projected Groundwater System Water Budget (2020 – 2070) - Scenario C

Water Year	Stream Leakage (AF)	Inflow from Hillsides (AF)	Inflow from Scotts Valley Basin (AF)	Inflow from Clear Lake (AF)	Deep Percolation (AF)	Groundwater Uptake (AF)	Agricultural Pumping (AF)	Domestic Pumping (AF)	Municipal Pumping (AF)	Groundwater Storage Change (AF)	Cumulative Groundwater Storage Change (AF)
2020	3,700	5,300	500	100	10,600	-13,000	-12,200	-3,000	-400	-8,300	-8,300
2021	7,000	5,100	600	200	11,900	-10,800	-12,900	-3,100	-400	-2,400	-10,700
2022	7,300	4,900	600	200	11,000	-9,700	-14,100	-3,300	-400	-3,600	-14,300
2023	7,700	6,900	800	100	19,500	-12,900	-12,900	-3,000	-400	5,700	-8,600
2024	4,400	8,400	700	100	21,700	-15,900	-10,800	-2,600	-400	5,700	-2,900
2025	2,300	8,200	700	100	19,500	-16,200	-10,800	-2,500	-400	900	-2,000
2026	4,300	5,800	600	100	11,900	-12,200	-13,200	-3,000	-400	-6,000	-8,000
2027	5,000	7,400	700	0	19,700	-15,000	-10,800	-2,600	-400	4,000	-4,000
2028	5,800	5,200	600	100	10,700	-11,300	-13,600	-3,100	-400	-6,000	-10,000
2029	4,900	7,600	700	100	19,600	-14,100	-11,200	-2,600	-400	4,600	-5,400
2030	3,100	9,100	700	100	22,600	-16,600	-11,100	-2,600	-400	4,800	-600
2031	4,100	6,600	600	100	13,800	-13,700	-12,200	-2,800	-400	-3,800	-4,400
2032	3,900	6,600	700	100	14,500	-12,200	-13,800	-3,100	-400	-3,800	-8,200
2033	6,600	6,600	700	100	15,900	-12,600	-12,800	-3,000	-400	1,100	-7,100
2034	6,000	7,100	700	100	17,200	-14,200	-12,200	-2,900	-400	1,500	-5,600
2035	1,500	9,800	700	100	24,400	-17,200	-10,900	-2,500	-400	5,500	-100
2036	-4,600	12,200	700	0	30,400	-20,300	-9,600	-2,200	-400	6,200	6,100
2037	900	8,100	600	100	15,600	-16,300	-11,500	-2,600	-400	-5,600	500
2038	2,400	8,700	700	0	20,400	-17,200	-10,600	-2,400	-400	1,600	2,100

Table 2-29. Big Valley Basin Projected Groundwater System Water Budget (2020 – 2070) - Scenario C (contd.)

Water Year	Stream Leakage (AF)	Inflow from Hillsides (AF)	Inflow from Scotts Valley Basin (AF)	Inflow from Clear Lake (AF)	Deep Percolation (AF)	Groundwater Uptake (AF)	Agricultural Pumping (AF)	Domestic Pumping (AF)	Municipal Pumping (AF)	Groundwater Storage Change (AF)	Cumulative Groundwater Storage Change (AF)
2039	2,800	7,700	700	100	16,800	-15,600	-12,700	-2,900	-400	-3,600	-1,500
2040	2,700	8,000	700	100	17,500	-15,000	-11,300	-2,600	-400	-300	-1,800
2041	3,300	8,600	700	100	20,400	-16,200	-12,000	-2,800	-400	1,800	0
2042	4,200	6,700	600	0	14,700	-14,900	-10,100	-2,300	-400	-1,500	-1,500
2043	5,200	4,700	600	100	7,700	-9,500	-14,600	-3,200	-400	-9,400	-10,900
2044	6,100	7,300	700	100	19,600	-13,800	-11,800	-2,800	-400	5,000	-5,900
2045	1,500	10,000	700	0	26,100	-17,700	-11,100	-2,600	-400	6,600	700
2046	2,500	7,200	600	100	15,400	-15,000	-11,100	-2,600	-400	-3,300	-2,600
2047	5,100	5,800	600	200	11,400	-11,200	-14,200	-3,200	-400	-5,900	-8,500
2048	5,400	8,700	800	100	22,700	-15,500	-12,800	-2,900	-400	6,000	-2,500
2049	3,100	8,400	700	100	19,200	-15,700	-11,900	-2,700	-400	900	-1,600
2050	4,900	7,600	700	100	17,300	-15,700	-10,200	-2,400	-400	1,800	200
2051	2,300	7,700	700	100	16,900	-14,800	-12,400	-2,800	-400	-2,900	-2,700
2052	5,200	6,900	700	100	15,400	-13,400	-12,900	-3,000	-400	-1,300	-4,000
2053	6,600	5,600	600	100	11,400	-12,100	-12,900	-2,900	-400	-4,000	-8,000
2054	7,200	5,200	700	200	11,100	-10,500	-13,800	-3,100	-400	-3,600	-11,600
2055	8,800	5,200	700	200	12,200	-10,400	-14,000	-3,200	-400	-1,100	-12,700
2056	7,800	6,100	700	200	15,300	-11,500	-13,900	-3,100	-400	1,300	-11,400

Table 2-29. Big Valley Basin Projected Groundwater System Water Budget (2020 – 2070) - Scenario C (contd.)

Water Year	Stream Leakage (AF)	Inflow from Hillsides (AF)	Inflow from Scotts Valley Basin (AF)	Inflow from Clear Lake (AF)	Deep Percolation (AF)	Groundwater Uptake (AF)	Agricultural Pumping (AF)	Domestic Pumping (AF)	Municipal Pumping (AF)	Groundwater Storage Change (AF)	Cumulative Groundwater Storage Change (AF)
2057	8,200	5,600	700	200	13,100	-10,800	-14,000	-3,100	-400	-500	-11,900
2058	6,900	6,500	800	200	16,500	-11,300	-14,900	-3,300	-400	1,000	-10,900
2059	6,300	8,000	800	100	21,300	-14,900	-12,500	-2,800	-400	5,900	-5,000
2060	6,100	5,300	700	100	10,200	-10,400	-15,100	-3,300	-400	-6,900	-11,900
2061	7,600	6,300	700	200	15,200	-10,900	-14,300	-3,100	-400	1,200	-10,700
2062	8,100	6,100	700	200	14,700	-11,600	-14,400	-3,100	-400	200	-10,500
2063	6,900	5,400	700	200	12,800	-10,100	-15,200	-3,300	-400	-2,900	-13,400
2064	8,300	5,000	700	200	11,800	-9,000	-14,700	-3,200	-400	-1,400	-14,800
2065	8,500	6,200	700	100	17,500	-12,200	-12,400	-2,700	-400	5,300	-9,500
2066	7,100	5,900	700	100	13,800	-12,000	-13,000	-2,900	-400	-700	-10,200
2067	8,400	4,800	700	200	10,500	-8,900	-14,500	-3,200	-400	-2,400	-12,600
2068	7,000	6,800	700	200	17,200	-12,300	-13,800	-3,100	-400	2,300	-10,300
2069	7,700	4,900	600	100	10,700	-10,000	-14,400	-3,200	-400	-3,800	-14,100
2070	7,200	5,800	800	200	14,600	-9,200	-16,500	-3,600	-400	-1,100	-15,200
Average 2020-2070	**5,200**	**6,900**	**700**	**100**	**16,100**	**-13,200**	**-12,800**	**-2,900**	**-400**	**-300**	

Note:
All volumes are rounded to the nearest 100 acre-feet.

Key:
AF = acre-feet

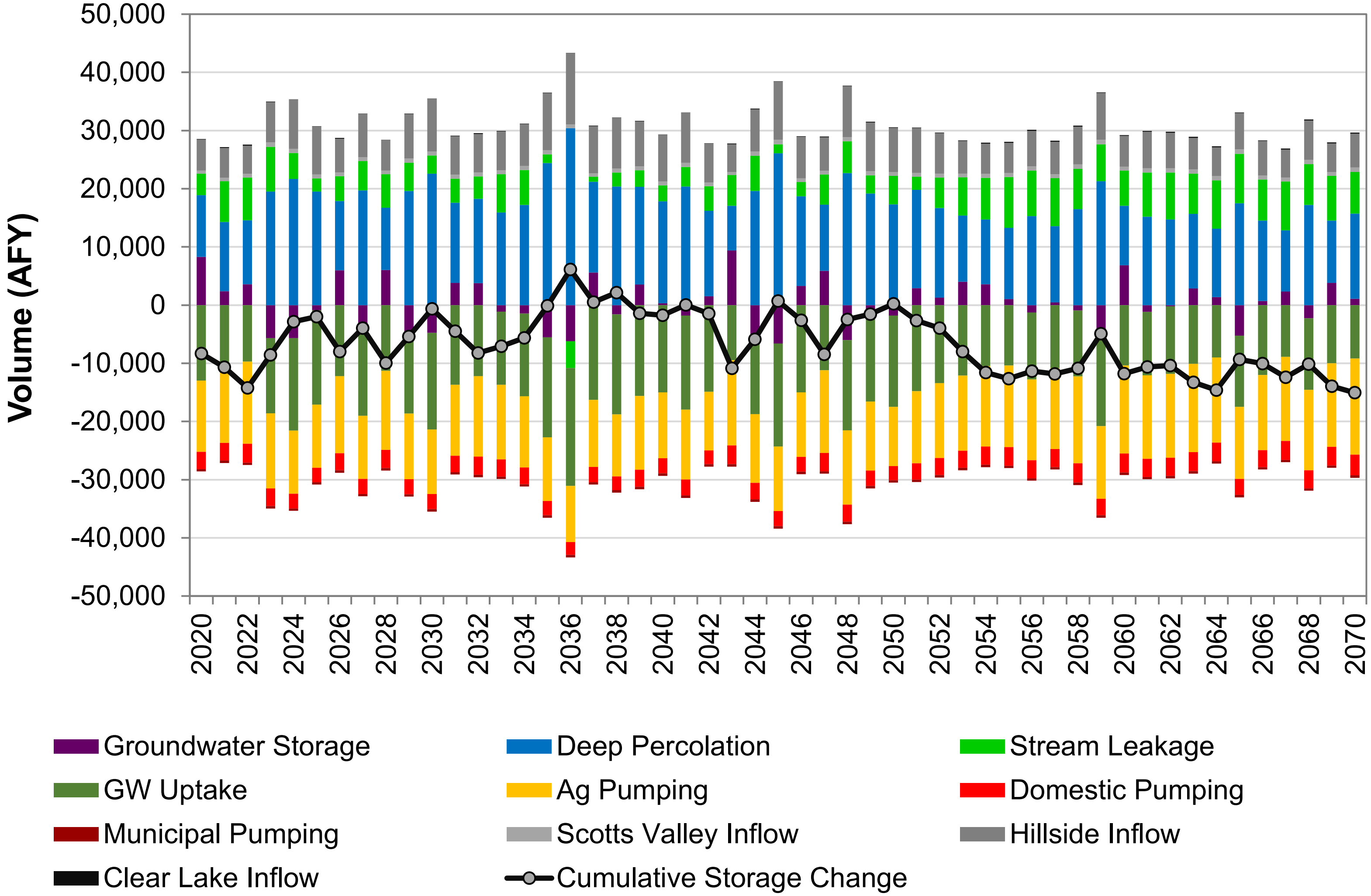


Figure 2-87. Big Valley Basin Projected Groundwater System Water Budget (2020 – 2070) - Scenario C

2.2.4.12 Uncertainty in Water Budget Estimates

Uncertainties associated with water budget components have been computed or estimated following the process described by Clemmens and Burt (1997). In summary:

1. The uncertainty of each independently estimated water budget component (excluding the closure term) is calculated or estimated as a percentage that approximately represents a 95 percent confidence interval for the average annual component volume of the component. Uncertainty percentages are based on the accuracy of measurement devices, the uncertainty of supporting calculations and estimation procedures, and professional judgement.

2. Assuming random, normally distributed error, the standard deviation is calculated for each independently estimated component as the average uncertainty on a volumetric basis (uncertainty percentage multiplied by the average annual component volume) divided by two.

3. The variance is calculated for each independently estimated component as the square of the standard deviation.

4. The variance of the closure term is estimated as the sum of variances of all independently estimated components.

5. The standard deviation of the closure term is estimated as the square root of the sum of variances.

6. The 95 percent confidence interval of the closure term is estimated as twice the estimated standard deviation.

Estimated uncertainties were calculated following the above procedure for the Basin's water budgets.

Table 2-30 provides a summary of typical uncertainty values associated with water budget components, along with the sources of these uncertainty values. These uncertainties provide a basis for evaluating confidence in water budget results and help to identify data needs that may be addressed during GSP implementation.

Uncertainty associated with the Groundwater System budget depends in part on the model inputs relating to the Land Surface System and Stream System budgets with additional sources of uncertainty associated with model inputs relating to the Groundwater System, including aquifer and streambed properties, specification of boundary conditions, and simplification required in modeling of the subsurface heterogeneity. Furthermore, the uncertainty in the Groundwater System budget results derived from a numerical model such as the BVIHM depends to a considerable degree on the calibration of the model and can vary by location and depth within the Basin. The BVIHM simulates the integrated groundwater and surface water system and metrics relating to the calibration of the model indicate the model is well calibrated in accordance with generally accepted professional guidelines and is sufficient for GSP-related applications. The calibration and sensitivity of the model and different model parameters are presented in **Appendix 2C**.

Table 2-30. Estimated Uncertainty of Major Water Budget Components

Water Budget Component	Data Source	Estimated Uncertainty (%)	Source
Surface Water Flow	Measurement	5%[1]	Accuracy of US Geologic Survey and California Department of Water Resources streamflow gages
Water Rights Diversions	Measurement / Estimate	10%	Required diversion measurement accuracy, per California Senate Bill 88.
Precipitation	Calculation	20%[2]	Clemmens, A.J. and C.M. Burt, 1997.
Groundwater Pumping	Calculation	20%	Typical uncertainty for calculated groundwater pumping. The uncertainty is a product of the combined uncertainty of all components used for the calculation (crop water demands, precipitation, other water supplies and irrigation efficiency).
Evaporation	Calculation	20%	Clemmens and Burt, 1997; typical accuracy of calculation based on California Irrigation Management and Information System reference ET and free water surface evaporation coefficient
Evapo-transpiration	Calculation	10%	Clemmens and Burt, 1997; typical accuracy of total irrigation water consumption on irrigated land
Deep Percolation	Calculation	20%[2]	Estimated accuracy of deep percolation calculated based on annual land use and NRCS soils characteristics
Infiltration of Surface Water	Calculation	15%	Typical accuracy of seepage calculation using NRCS soils characteristics, approximated stream bed properties and measured streamflow data compared to field measurements.
Subsurface Flows	Calculation	15% - 30%[3]	Typical accuracy of subsurface flows calculated using flow model
Groundwater Storage	Calculation	15% - 30%[3]	Typical accuracy groundwater storage calculated using flow model

Notes:

1 Higher uncertainty of 10%-20% is typical for estimated surface water inflows, including un-gaged inflows from small watersheds into creeks that enter the Basin.

2 The uncertainty of these water budget components is based on typical accuracies given in technical literature and the cumulative estimated accuracy of all inputs used to calculate the components.

3 Higher uncertainty of 15%-30% is typical for estimated subsurface flows and groundwater as a result of limitations in available input data and simplification required in modeling of the subsurface heterogeneity

2.2.5 Estimate of Sustainable Yield

GSP Regulations require the GSP quantify the sustainable yield for the Basin. Sustainable yield is defined as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result" (CWC § 10721[w]). Historical and projected model results show that the conditions in the Basin under the historical and anticipated future conditions, including potential climate change conditions, will not cause the occurrence of undesirable results in the Basin over the 50-year GSP planning period based on sustainability indicator Minimum Thresholds (MT) developed for the Basin.

A summary comparison of the results from the historical and different projected water budget scenarios is included in **Table 2-31**. Over the historical water budget period, the average annual volume of groundwater pumping in the Basin is estimated to be about 13,700 AFY. An additional volume of 13,400 AFY of groundwater was estimated to be taken up and consumed directly by plants reflecting a total historical groundwater extraction volume of about 27,100 AFY on average. Observed groundwater level conditions and simulated water budget results suggest there has been little or no historical long-term change in groundwater storage in the Basin.

Under the projected baseline scenario without climate change (Scenario A), total groundwater extraction (combination of groundwater pumping and uptake) within the Basin increases to 28,500 AFY (an increase of 1,400 AFY compared to historical budget), mainly due to increased groundwater pumping. Under the projected wet-moderate warming climate change scenario (Scenario B) total groundwater extraction increases to 30,100 AFY (an increase of 3,000 AFY compared to historical budget), as a result of increased groundwater uptake. Under the projected dry-extreme warming climate change scenario (Scenario C) total groundwater extraction increases to 29,300 AFY (an increase of 800 AFY compared to historical budget), mainly due to increased groundwater pumping. Under all of the simulated scenarios (historical and projected), the change in storage is very small or practically zero, recognizing typical uncertainty associated with water budget estimates and the magnitude of other water budget components.

Accordingly, for the purpose of the GSP, the sustainable yield is estimated to be 29,000 AFY, which is equal to the volume of groundwater extracted annually in the Basin (combination of groundwater pumping and uptake) minus the simulated annual decrease in storage under the projected dry-extreme warming climate change scenario (Scenario C) and considering the level of uncertainty associated with water budget estimates. This volume is comparable with the annual volume of inflows to the Groundwater System (stream leakage, subsurface inflows, and deep percolation) occurring within the Basin.

Assuming potential uncertainty of 25 percent associated with the water budget estimates, an associated range of values for the estimated sustainable yield would be 22,000 to 36,000 AFY. It is possible that the true sustainable yield is higher as no model scenarios were developed to test the maximum possible volume of groundwater extraction. The sustainable yield estimate provided here is consistent with the sustainability goal for the Basin and will be reviewed as the Basin implements the GSP, including through periodic review and updates to the BVIHM and water budget results and ongoing monitoring of Basin conditions as required by GSP Regulations.

Potential for significant and unreasonable stream depletion resulting in adverse impacts on surface water beneficial users through decreased groundwater discharge to surface water or increased induced stream leakage in the Basin was also considered in estimating the sustainable yield of the Basin. Differences in hydrology between historical and projected water budget periods, as well as climate change scenarios can greatly affect the stream flow and net stream leakage. Understanding the influences of projected conditions on interconnected surface water is confounded by the different factors involved. While net leakage quantifies the overall exchange of groundwater and surface water, it does not distinguish changes that are a result of groundwater conditions from changes that result from streamflow conditions. Both groundwater conditions and streamflow conditions can and do change based on the hydrology and climate (e.g., precipitation, surface water inflows). For example, increases in streamflow entering the Basin can increase the net stream leakage; conversely decreased streamflow entering the Basin can lower the net stream leakage volume. Similarly, lowered groundwater levels can lead to decreased groundwater discharge to streams resulting in increased net stream leakage volumes.

The simulated stream leakage volumes for historical, projected baseline (Scenario A) and projected dry-extreme warm climate (Scenario C) water budgets vary within a relatively narrow range (4,500 AFY to 5,200 AFY). However, stream leakage for projected wet-moderate warm climate (Scenario B) is relatively lower (1,400 AFY) due to increased gain from groundwater and decreased loss under anticipated wet climatic conditions. Year to year variability of stream leakage within each scenario indicates the strong influence of precipitation on stream flow and stream leakage. Groundwater pumping seems to have a less control on stream flow and leakage. Therefore, widespread significant and unreasonable stream depletion conditions are not expected to occur at the estimated sustainable yield of 29,000 AFY.

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3. MONITORING NETWORK

This section discusses the proposed monitoring networks identified to characterize groundwater and related surface water conditions in Big Valley Basin, as well as to evaluate changing conditions that occur through the implementation of the GSP. Monitoring networks are established for each sustainability indicator relevant to monitoring in Big Valley Basin including groundwater levels, groundwater quality, subsidence, and surface water depletions. Additionally, the groundwater level monitoring network supports estimation of groundwater storage. Of the six sustainability indicators listed under SGMA, only seawater intrusion is not covered by a monitoring network in this plan; Big Valley Basin is geologically isolated from the Pacific Ocean and, thus, undesirable results related to seawater intrusion are not likely to occur.

The following subsections include the monitoring network objectives, details, and data reporting methods. Existing monitoring programs were described in **Section 2.1.5** and used, where practical, in the development of this GSP's monitoring networks. Data gaps and a plan to fill them are provided for each monitoring network.

3.1 Monitoring Networks Objectives

The monitoring networks are intended to support and improve an understanding of conditions in the Big Valley Basin, supporting ongoing management and future updates to this GSP. The GSP Regulations require that monitoring networks be developed to promote the collection of sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions, and yield representative information about groundwater conditions necessary to evaluate the effectiveness of the GSP implementation. In accordance with CCR Title 23 § 354.34 the monitoring networks objectives shall:

- Demonstrate progress toward achieving measurable objectives as described in the GSP.
- Monitor impacts to the beneficial uses and/or users of groundwater.
- Monitor changes in groundwater conditions relative to the measurable objectives, minimum thresholds, and the non-regulatory criteria defined specifically for groundwater levels.
- Support estimation of annual changes in water budget components.

The monitoring locations need to be spatially distributed to provide comprehensive analysis of current and ongoing conditions in Big Valley Basin. This includes selection of the appropriate temporal frequency and spatial density to evaluate groundwater conditions related to the effectiveness of the GSP.

3.2 Groundwater Level Monitoring Network

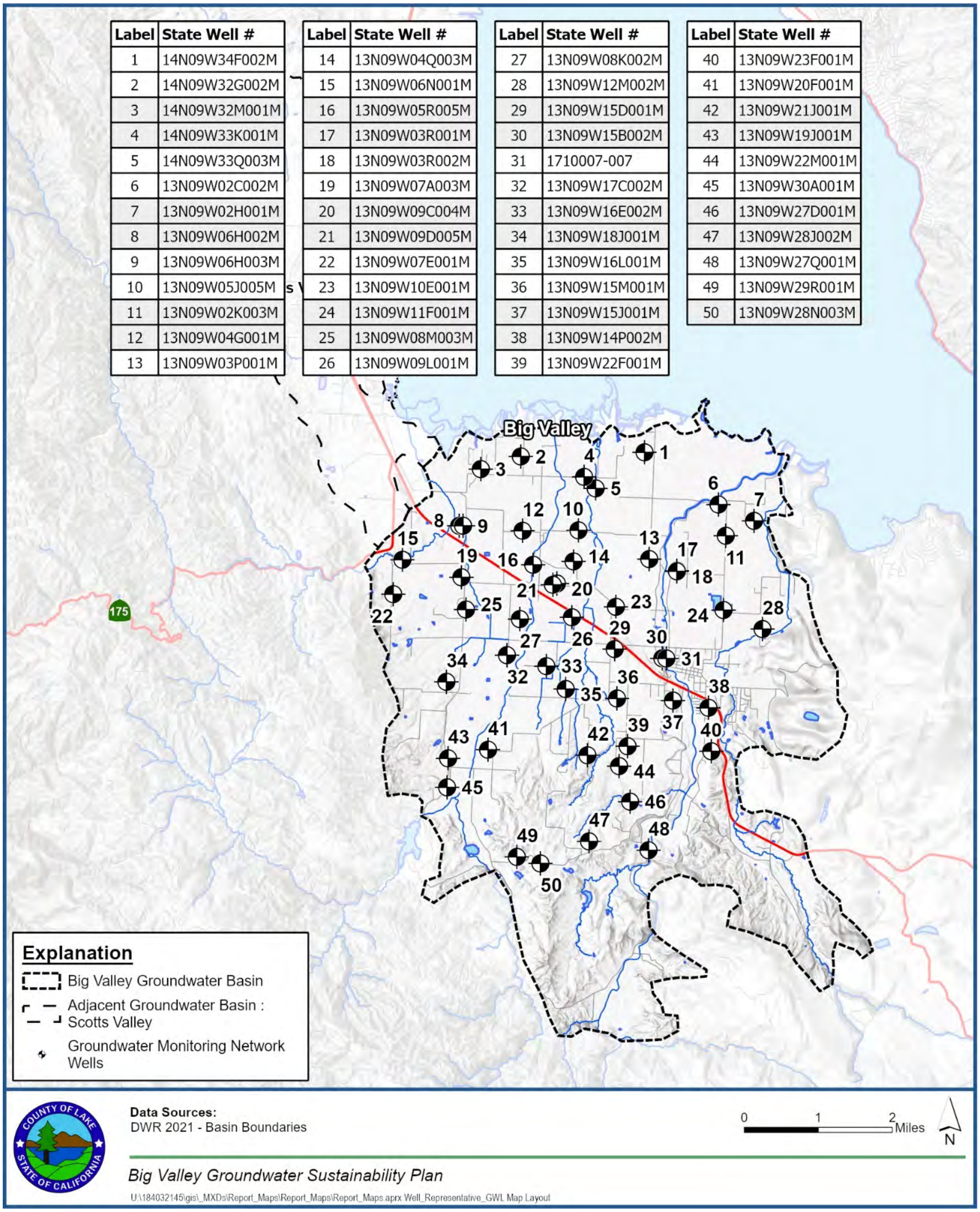
In accordance with CCR Title 23 § 354.34(c) the groundwater level monitoring shall be designed to demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features by the following methods:

- A sufficient density of monitoring wells to collect representative measurements through depth discrete perforated intervals to characterize the groundwater table or potentiometric surface for each principal aquifer.
- Static groundwater elevation measurements shall be collected at least two times per year to represent seasonal low and seasonal higher groundwater conditions.

The groundwater level monitoring network was chosen based on review of available water level data and the hydrogeologic conceptual model. Review of groundwater contour maps suggest that water bearing strata (Volcanic Ash aquifer and the Quaternary Alluvium) are likely interconnected on the Basin scale and thus can be considered as a single aquifer system. The groundwater level monitoring network uses existing wells and, where possible, wells with known construction attributes were preferred.

3.2.1 Monitoring Wells Selected for the Monitoring Network

There are 85 wells historically monitored for water levels in Big Valley Basin, principally by DWR and the District. Among these historically monitored wells, at least 11 of the 85 have been destroyed and are no longer accessible for monitoring. The current monitoring network consists of 49 wells that are monitored either semi-annually or monthly by District. These active monitoring wells are proposed to be the groundwater level monitoring network. Note that there currently are no dedicated multi-completion wells being monitored. A summary of the proposed groundwater level monitoring network wells is illustrated in **Figure 3-1** and listed in **Table 3-1**.



Label	State Well #
1	14N09W34F002M
2	14N09W32G002M
3	14N09W32M001M
4	14N09W33K001M
5	14N09W33Q003M
6	13N09W02C002M
7	13N09W02H001M
8	13N09W06H002M
9	13N09W06H003M
10	13N09W05J005M
11	13N09W02K003M
12	13N09W04G001M
13	13N09W03P001M
14	13N09W04Q003M
15	13N09W06N001M
16	13N09W05R005M
17	13N09W03R001M
18	13N09W03R002M
19	13N09W07A003M
20	13N09W09C004M
21	13N09W09D005M
22	13N09W07E001M
23	13N09W10E001M
24	13N09W11F001M
25	13N09W08M003M
26	13N09W09L001M
27	13N09W08K002M
28	13N09W12M002M
29	13N09W15D001M
30	13N09W15B002M
31	1710007-007
32	13N09W17C002M
33	13N09W16E002M
34	13N09W18J001M
35	13N09W16L001M
36	13N09W15M001M
37	13N09W15J001M
38	13N09W14P002M
39	13N09W22F001M
40	13N09W23F001M
41	13N09W20F001M
42	13N09W21J001M
43	13N09W19J001M
44	13N09W22M001M
45	13N09W30A001M
46	13N09W27D001M
47	13N09W28J002M
48	13N09W27Q001M
49	13N09W29R001M
50	13N09W28N003M

Figure 3-1. Big Valley Proposed Groundwater Level Monitoring Network Wells

Table 3-1. Groundwater Level Monitoring Network Wells

FIGURE 3-1 Label	STATE WELL NO.	LATITUDE (NAD83)	LONGITUDE (NAD83)	RPE (feet, NAVD88)	WELL DEPTH (feet, bgs)	PERFORATIONS (feet, bgs)	MONITORING FREQUENCY
6	13N09W02C002M	39.0104	-122.831	1348.53			Monthly
7	13N09W02H001M	39.00738	-122.822	1338.5			Monthly
17	13N09W03R001M	38.99718	-122.841	1361.3		Not Reported	Monthly
18	13N09W03R002M	38.9971	-122.841	1361.24			Monthly
14	13N09W04Q003M	38.9984	-122.867	1360.33	120		Monthly
19	13N09W07A003M	38.99465	-122.895	1363.4	35	15-35	Monthly
27	13N09W08K002M	38.9868	-122.88	1375.64			Monthly
26	13N09W09L001M	38.98751	-122.867	1363.4			Monthly
33	13N09W16E002M	38.9778	-122.873	1382.26			Monthly
2	14N09W32G002M	39.01859	-122.881	1338.2	123	62-68; 90-118	Monthly
5	14N09W33Q003M	39.01281	-122.862	1342.8	185		Monthly
1	14N09W34F002M	39.02018	-122.85	1338.6	220	112-220	Monthly
25	13N09W08M003M	38.9884	-122.8936	1371.8	246	40-80; 160-170; 190-200; 223-245.	Monthly
37	13N09W15J001M	38.9718	-122.841	1422.88			Monthly
34	13N09W18J001M	38.9741	-122.898	1403.37	157		Monthly
49	13N09W29R001M	38.9403	-122.879	1553.43			Monthly
11	13N09W02K003M	39.0043	-122.829	1346.34	51		Semi-Annual
13	13N09W03P001M	38.9993	-122.848	1356.43			Semi-Annual
12	13N09W04G001M	39.0041	-122.88	1348.12			Semi-Annual
16	13N09W05R005M	38.997506	-122.87707	1359.30	165	72-165	Semi-Annual
10	13N09W05J005M	39.0045	-122.866	1355.32			Semi-Annual
8	13N09W06H002M	39.0047	-122.896	1352.82			Semi-Annual
9	13N09W06H003M	39.0047	-122.895	1352.62			Semi-Annual
15	13N09W06N001M	38.9977	-122.91	1378.14			Semi-Annual
22	13N09W07E001M	38.9909	-122.912	1397.15	20		Semi-Annual
20	13N09W09C004M	38.994	-122.871	1361.63			Semi-Annual
21	13N09W09D005M	38.9937	-122.872	1361.53			Semi-Annual
23	13N09W10E001M	38.9898	-122.856	1358.64			Semi-Annual
24	13N09W11F001M	38.9898	-122.829	1362.86			Semi-Annual
28	13N09W12M002M	38.9863	-122.819	1360.78			Semi-Annual

Table 3-1. Groundwater Level Monitoring Network Wells (contd.)

FIGURE 3-1 Label	STATE WELL NO.	LATITUDE (NAD83)	LONGITUDE (NAD83)	RPE (feet, NAVD88)	WELL DEPTH (feet, bgs)	PERFORATIONS (feet, bgs)	MONITORING FREQUENCY
38	13N09W14P002M	38.9706	-122.832	1402.7			Semi-Annual
30	13N09W15B002M	38.98	-122.844	1379.56	68		Semi-Annual
29	13N09W15D001M	38.9815	-122.856	1448.85			Semi-Annual
36	13N09W15M001M	38.9719	-122.855	1412.07			Semi-Annual
35	13N09W16L001M	38.9734	-122.868	1383.07	72		Semi-Annual
32	13N09W17C002M	38.9797	-122.883	1383.86			Semi-Annual
43	13N09W19J001M	38.9592	-122.897	1413.39			Semi-Annual
41	13N09W20F001M	38.9611	-122.887	1408.19	35		Semi-Annual
42	13N09W21J001M	38.9606	-122.862	1499.19			Semi-Annual
39	13N09W22F001M	38.9626	-122.852	1447.69	90		Semi-Annual
44	13N09W22M001M	38.95868	-122.854	1488.39	220	198-208	Semi-Annual
40	13N09W23F001M	38.9621	-122.831	1430.31			Semi-Annual
46	13N09W27D001M	38.9518	-122.851	1509.91	38		Semi-Annual
48	13N09W27Q001M	38.9424	-122.846	1438.73			Semi-Annual
47	13N09W28J002M	38.94378	-122.861	1603.22	100		Semi-Annual
50	13N09W28N003M	38.9392	-122.873	1593.73	200		Semi-Annual
45	13N09W30A001M	38.9535	-122.897	1422.7			Semi-Annual
3	14N09W32M001M	39.0159	-122.891	1338.7	70		Semi-Annual
4	14N09W33K001M	39.015	-122.865	1339.01	93		Semi-Annual

3.2.2 Representative Monitoring

A subset of the groundwater level monitoring network was selected as the representative monitoring network sites (RMS), chosen to monitor groundwater levels that are reflective of deeper regional groundwater conditions in Big Valley Basin. To consider the RMS spatial distribution and representative area, Big Valley Basin was subdivided into seven grids (size and geometry varies based on proximity to the basin boundary), each containing approximately six Public Land Survey System (PLSS) Sections, and with an overall area of approximately four to six square miles (**Figure 3-2**). Preferred RMS wells were identified based on having a long monitoring history and with well depths (if known) greater than the average domestic well depth in the immediate area. The average domestic well for each PLSS section and four to six square mile grid was estimated by reviewing DWR's well completion reports through the SGMA Data Viewer, the results of which are summarized in **Table 3-2**. Other factors that were considered in the selection of the RMS wells include locations that were near areas of higher domestic well counts and those wells with screen intervals and/or water levels that indicate they are not directly influenced by surface water.

One well in each of the north, northwest, northeast, west-central, east-central, and southwest grids were identified as the representative monitoring sites. Some deep wells, with construction details, were excluded from the representative monitoring network since their water elevations were significantly different than other wells in the basin. These wells were generally located in the southern half (east-central, southwest, and southeast sections) of Big Valley Basin. They are generally deeper, installed in bedrock, and/or located near or within upland areas. In these areas, several wells from the CASGEM voluntary network were selected preliminarily on the long history of water level measurements and consistency of water levels with other wells in the Subbasin; however, well construction details for these wells were unknown. The District subsequently determined the construction depth of these potential well sites in east-central and southwest grids.

No RMS well was selected for the southeast grid, as this grid lies primarily in upland areas with available wells generally shallow and located near surface water sources. **Table 3-2** provides a summary of the wells selected for the RMS network. **Figure 3-2** illustrates the location of the representative groundwater level RMS network.

Note that all of the wells used for monitoring water levels are production wells for domestic and agricultural uses. Ideally the representative monitoring network would consist solely of dedicated monitoring wells that are not actively used for water production purposes and are installed sufficiently distant from pumped wells to avoid interference that might affect water levels. Therefore, when monitoring water levels at these RMS wells, care should be taken to collect measurements of the static water level when water levels are not influenced by recent pumping.

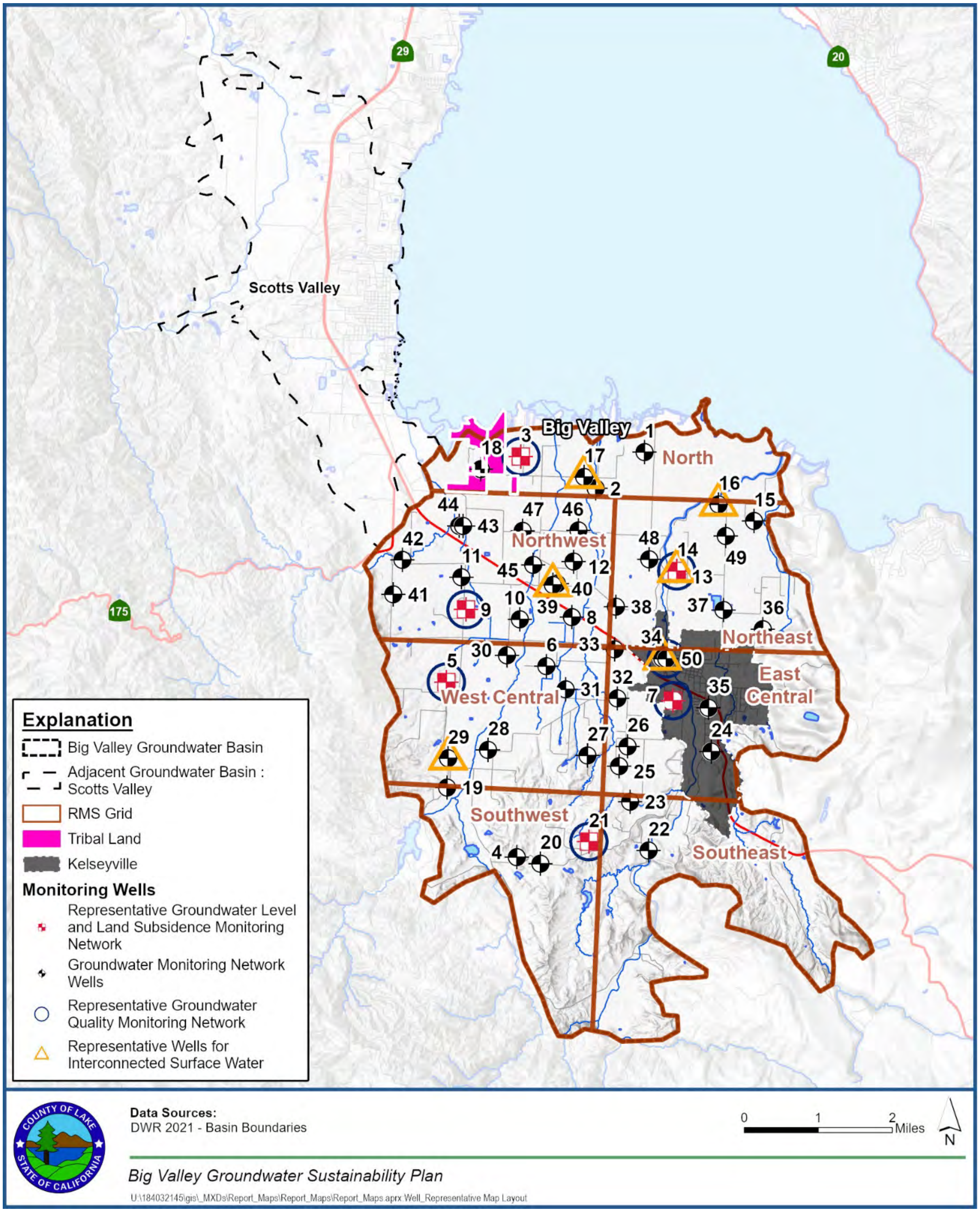


Figure 3-2. Representative Monitoring Networks

Table 3-2. Representative Groundwater Level Monitoring Network

State Well Number	Average Domestic Well Depth[1,2]	Monitoring Program	Well Depth (feet, bgs)	Screen Interval (feet, bgs)	Grid
14N09W32G002M	<89/ 77	CASGEM	123	62 – 118	North
13N09W08M003M	<111/ 104	Voluntary	246	40-80; 160-170; 190-200; 223-245	Northwest
13N09W03R001M	<144/ 101	CASGEM	167	--	Northeast
13N09W18J001M	<146/ 146	Voluntary	157	--	West-Central
13N09W15J001M	<404/ 113	Voluntary	51.5	--	East-Central
13N09W28J002M	<225/ 112	Voluntary	100	--	Southwest
Grid primarily in upland area, wells are shallow and/or near surface water[3]					Southeast

Notes:

[1] First value is the maximum domestic well depth reported for a PLSS Section within the Grid, second number reflects average domestic well depth for the PLSS Section containing the RMS well.

[2] Excludes average depth from PLSS Sections located in topographically upland areas.

[3] Water levels suggest wells in this grid may be disconnected from alluvial basin aquifer or heavily influence by surface water recharge.

Key:
bgs = below ground surface
CASGEM = California State Groundwater Elevation Monitoring
PLSS = Public Land Survey System

3.2.3 Spatial Density

The DWR's *Monitoring Networks and Identification of Data Gaps BMP* provides a summary of recommended well densities from various sources that are dependent on a number of specific conditions (**Table 3-3**), and they serve as guidelines for establishing monitoring well networks. However, the actual monitoring well density depends on local conditions such as the basin's geology, groundwater use, and how the GSP define undesirable results. Big Valley Basin is relatively small at only 38 square miles with an annual groundwater extraction that has been estimated to be 24,410 acre-feet for agriculture, municipal, and industrial uses (DWR 2003).

Hopkins (1984) provides recommendations for well density that are dependent on annual pumping. To use the Hopkins density guidelines the annual groundwater production needs to be normalized to 100 square miles, equating to a normalized annual yield of 64,200 acre-feet per 100 square miles. Based on this metric, there should be a minimum of four wells per 100 square miles. The actual spatial density for the RMS wells within the Big Valley Basin far exceeds this recommendation with 1.3 wells per square mile (or a normalized density of 130 wells per 100 square miles). The six RMS wells have a normalized spatial density of 16 wells per 100 square miles.

Table 3-3. Monitoring Well Density Considerations

Reference	Monitoring Well Density (wells per 100 miles^2)
Heath (1976)	0.2 - 10
Sophocleous (1983)	6.3
Hopkins (1984) Basins pumping more than 10,000 acre-feet/year per 100 miles^2	4.0
Basins pumping between 1,000 and 10,000 acre-feet/year per 100 miles^2	2.0
Basins pumping between 250 and 1,000 acre-feet/year per 100 miles^2	1.0
Basins pumping between 100 and 250 acre-feet/year per 100 miles^2	0.7

Source: DWR (2016)

3.2.4 Monitoring Frequency

Wells within Big Valley Basin are monitored either monthly or semi-annually using electronic water level sounding tape. Semi-annual monitoring allows for the capture of seasonal high and low groundwater conditions with monitoring generally occurring in April and October of each year. Based on review of wells that are monitored on a monthly basis, continued monitoring during April and October is appropriate to capture seasonal high and low water levels. Additionally, it is recommended that all of the RMS wells be included in District's monthly monitoring program.

This monitoring frequency is consistent with the objectives outlined in the *DWR's Monitoring Networks and Identification of Data Gaps BMP*. The DWR guidance for monitoring frequency is based on the *National Framework for Ground-water Monitoring in the United Stated (ACWI 2013),* and uses groundwater aquifer withdrawal and aquifer characteristics for recommended frequency (**Table 3-4**). Note that if new monitoring wells are constructed in the future, they should be monitored more frequently to establish the dynamic range of conditions and external stresses affecting the groundwater levels. The guidance recommends that an understanding of the full range of monitoring well conditions should be reached prior to establishing long-term monitoring frequency.

Big Valley Basin would be considered both unconfined and confined with moderate withdrawals and a high recharge rate of about 11 inches per year. Based on **Table 3-4**, the Big Valley Basin groundwater monitoring frequency should be monthly. This recommendation is consistent with the mix of monthly and semi-annual monitoring performed by the District, given the long history of management and monitoring conducted in the Basin.

Table 3-4. Monitoring Frequency Based on Aquifer Properties and Withdrawals

Aquifer Type	Nearby Long-Term Aquifer Withdrawals		
	Small Withdrawals	Moderate Withdrawals	Large Withdrawals
Unconfined			
"low" recharge (<5 in/yr)	Once per quarter	Once per quarter	Once per month
"high" recharge (>5 in/yr)	Once per quarter	Once per month	Once per day
Confined			
"low" hydraulic conductivity (<200 ft/d)	Once per quarter	Once per quarter	Once per month
"high" hydraulic conductivity (>200 ft/d)	Once per quarter	Once per month	Once per day

Source: ACWI (2013)

3.2.5 Groundwater Level Monitoring Protocols

Groundwater monitoring protocols will be performed following the District's Groundwater Monitoring Procedures, provided as **Appendix 3A**.

3.2.6 Data Gaps

Big Valley Basin has a monitoring network that is sufficient for monitoring groundwater levels to meet the need of implementing the GSP. However, to improve the understanding of the hydraulic conditions within the Basin, additional monitoring wells could be designed and installed for the following purposes:

- Assess vertical hydraulic gradient;
- Understand deeper conditions in the East-Central grid; and,
- Assess stream-aquifer interaction near surface water bodies.

The use of multiple completion wells could meet these objectives and limit the number of locations required compared to installation of traditional wells. Additional details on these monitoring opportunities are discussed in **Section 5 - Project and Management Actions**.

3.2.7 Plan to Fill Data Gaps

Data gaps will be filled based on available funding and level of need and may be filled over the full implementation period of the GSP. Available grants and technical assistance will be sought to fill data gaps to limit the local financial burden to the District. These grants may include Technical Support Services and grant opportunities administered by DWR.

3.3 Groundwater Quality Monitoring Network

Groundwater quality monitoring will be conducted through a groundwater well monitoring network. The groundwater quality monitoring network is designed to demonstrate that water quality sustainability indicators are being observed for the purpose of meeting the sustainability goal and at locations spatially distributed throughout the Basin. The groundwater quality network was established to monitor salinity (through the monitoring of electrical conductivity (EC)). Monitoring is also established to track the overall quality for other constituents that are not managed under this GSP, namely arsenic, nitrate, boron, and TDS.

3.3.1 Monitoring Wells Selected for the Monitoring Network

Limited recent groundwater quality data exists in the Basin. Seven wells are proposed to spatially characterize and monitor on-going water quality trends throughout the Basin. These wells include the six well proposed as the RMS wells for water levels and one additional well (Well 8) from KCWWD #3, who are already required to monitor municipal water quality. The well details and locations are shown in **Table 3-5** and **Figure 3-2**.

Table 3-5. Representative Groundwater Quality Monitoring Network

Well Number	Monitoring Entity	Well Depth (feet, bgs)	Screen Interval (feet, bgs)	Monitoring Frequency*
14N09W32G002M	District	123	62 – 118	Quarterly/Annual
13N09W08M003M	District	246	40-80; 160-170; 190-200; 223-245	Quarterly/Annual
13N09W03R001M	District	167	--	Quarterly/Annual
13N09W18J001M	District	157	--	Quarterly/Annual
13N09W15J001M	District	51.5	--	Quarterly/Annual
13N09W28J002M	District	220	--	Quarterly/Annual
1710007-007 (Well 8)	KCWWD #3	110	70 – 110	Quarterly/Annual

Notes:
*Baseline water quality sampling to occur quarterly for 2-years followed by annual monitoring.
Key:
bgs = below ground surface
District = Lake County Watershed Protection District
KCWWD #3 = Kelseyville County Water Works District #3

3.3.2 Water Quality Parameters

EC, arsenic, nitrate, boron, and TDS will be sampled or measured through the water quality monitoring program. While only TDS is a sustainable management criteria indicator, a broader suite of water quality parameters is incorporated into the monitoring program to allow for regular assessment of water quality. Arsenic and nitrate are important water quality indicators for human health, while TDS is generally regarded as an aesthetic concern for drinking water. Boron and TDS are important water quality indicators for agricultural beneficial uses.

3.3.3 Representative Monitoring Network

The representative monitoring network for water quality uses the same network as the groundwater level monitoring network, with one addition, Well 8 from KCWWD #3 (**Table 3-5**). The RMS network uses salinity (measured as EC) for setting thresholds and does not include the other monitored constituents.

3.3.4 Spatial Density

The selected groundwater quality representative monitoring wells provides adequate coverage for the Big Valley Basin aquifer. The groundwater quality monitoring network consists of seven wells with a normalized well density of over 18 wells per 100 square miles.

DWR's Monitoring Networks and Identification of Data Gaps BMP (DWR 2016b) states, "The spatial distribution must be adequate to map or supplement mapping of known contaminants." Using this guidance, professional judgment was used to verify that the proposed water quality monitoring wells provide sufficient spatial density.

3.3.5 Monitoring Frequency

Sampling for water quality parameters will be measured quarterly for all RMS wells identified in **Table 3-5** for a period of two years to establish current baseline conditions in the Big Valley Basin. The data will be used evaluate potential seasonal and long-term trends in water quality. Once baseline monitoring has been completed, annual monitoring will occur during the October water level monitoring event.

3.3.6 Groundwater Quality Monitoring Protocols

Groundwater monitoring protocols will be performed following the District's Groundwater Monitoring Procedures, provided as **Appendix 3A**.

3.3.7 Data Gaps

The groundwater quality monitoring network was designed to closely align with the groundwater level RMS monitoring network, with the exception of one additional well, KCWWD's #3 Well 8. Current data gaps to the groundwater quality monitoring program are the lack of recent water quality data and the fact that most of the wells are private domestic or irrigation wells. More frequent and recent baseline monitoring of the groundwater quality will provide information on seasonal and long-term trends.

The groundwater quality monitoring network uses wells with known depths, however the screen interval(s) for several of the wells are not known, making depth discrete comparison of water quality data difficult. A video survey of wells lacking well construction information should be conducted to confirm construction attributes. This process could be challenging for private wells as the well pump would need to be temporarily removed to allow the survey to be completed. Additionally, the installation of dedicated multi-completion monitoring wells would aid in the collection of depth discrete water quality data.

3.3.8 Plan to Fill Data Gaps

Data gaps will be filled based on available funding and level of need and may be filled over the full implementation period of the GSP. Available grants and technical assistance will be sought to fill data gaps to limit the local financial burden to the District. These grants may include Technical Support Services and grant opportunities administered by DWR.

3.4 Land Subsidence Monitoring Network

Land subsidence monitoring is conducted through surveying a network of dedicated monuments and through remote sensing. A dedicated network of surveyed monuments currently does not exist in the Big Valley Basin. Accordingly, land subsidence estimates were derived from InSAR data. According to the California Natural Resources Agency (2021), InSAR data that are collected by the European Space Agency Sentinel-1A satellite and processed by TRE ALTAMIRA Inc., under contract with the DWR.

This dataset represents measurements of vertical ground surface displacement in more than 200 of the high-use and populated groundwater basins across the State of California between January of 2015 and October of 2020. Included in this dataset are point data that represent average vertical displacement values for 100x100-meter areas, as well as geospatial information system rasters that were interpolated from the point data; rasters represent total vertical displacement relative to June 13, 2015. The reported accuracy in vertical displacement of California's ground surface over time, as measured InSAR satellites, as statistically compared to available ground-based continuous global positioning systems data was 18 mm (0.71 inches) at the 95% confidence level (Towill, Inc. 2021).

3.4.1 Monitoring Sites Selected for the Monitoring Network

The land subsidence monitoring will consist of documenting the total vertical change in elevation using the InSAR data for the 100x100-meter pixel at dedicated locations throughout the Basin. The 100x100-meter InSAR pixel nearest to the RMS water level monitoring wells will be used as the land subsidence monitoring network, as identified in **Table 3-6**. These locations were chosen based on spatial distribution and density in the Basin and to align closely with the groundwater level RMS monitoring network.

Table 3-6. Representative Groundwater Subsidence Monitoring Network

InSAR Pixel ID	InSAR Pixel Latitude (NAD83)	InSAR Pixel Longitude (NAD 83)	Monitoring Well near 100x100 meter InSAR Grid	Monitoring Entity*	Monitoring Frequency
D8W3SQK	39.018937	-122.877828	14N09W32G002M	DISTRICT	Annual
D8BV25P	38.988343	-122.894832	13N09W08M003M	DISTRICT	Annual
D8H7YN0	38.996442	-122.841554	13N09W03R001M	DISTRICT	Annual
D82C4H5	38.973946	-122.899367	13N09W18J001M	DISTRICT	Annual
D8159A4	38.972146	-122.877828	13N09W15J001M	DISTRICT	Annual
D7I3DXN	38.939753	-122.873294	13N09W28J002M	DISTRICT	Annual

Note:
* InSAR data is provided by DWR.

3.4.2 Representative Monitoring Network

The RMS network for land subsidence is located in close proximity to the groundwater level monitoring network (**Table 3-6**). The representative monitoring network uses InSAR data from the 100x100 meter pixel nearest to the monitoring wells identified in **Table 3-6**. The center of the 100x100 meter InSAR pixel used as the RMS network for land subsidence is also identified in **Table 3-6**.

3.4.3 Spatial Density

The selected land subsidence RMS network has adequate coverage for the Big Valley Basin and has the same spatial density as the groundwater level RMS monitoring network. DWR's Monitoring Networks and Identification of Data Gaps BMP (DWR 2016b) states, "the network should be designed to provide consistent, accurate, and reproducible results. Where subsidence conditions are occurring or believed to occur, a specific monitoring network should be established to observe the sustainability indicator such that the sustainability goal can be met." Using this guidance, professional judgment was used to verify that the proposed land subsidence monitoring network provides sufficient spatial density.

3.4.4 Monitoring Frequency

The InSAR vertical displacement raster data will be used to evaluate land subsidence in the Big Valley Basin. The interpolated vertical displacement in feet will be monitored annually and reported based on the change estimated during the most recently reported calendar year.

3.4.5 Monitoring Protocols

Annual acquisition of InSAR data from DWR's website will be used to analyze and report apparent land subsidence.

3.4.6 Data Gaps

The Big Valley Basin remote sensing-based monitoring network is sufficient for estimating land subsidence to meet the objectives of the GSP.

3.4.7 Plan to Fill Data Gaps

There are currently no identified data gaps, however if they become apparent then they will be filled based on available funding and level of need and may be filled over the full implementation period of the GSP. Available grants and technical assistance will be sought to fill data gaps to limit the local financial burden to the District. These grants may include Technical Support Services and grant opportunities administered by DWR.

3.5 Depletions of Interconnected Surface Water Monitoring Network

Monitoring of depletions of interconnected surface water is accomplished by monitoring of shallow groundwater and surface water, where interconnected surface water conditions exist. The purpose of monitoring is to characterize the spatial and temporal exchanges between surface water and groundwater to calibrate relevant models and apply the tools and methods necessary to calculate depletions of surface water caused by groundwater extractions. Typical monitoring networks designed to monitor the depletions of interconnected surface water use a combination of stream gage stations and shallow monitoring wells.

Kelsey and Adobe Creeks are the two principal creeks in the Basin and six stream gage stations currently exist between them. Three gages are operated by the Big Valley Rancheria and are located on Adobe Creek. These include Bell Hill Rd., Argonaut Rd., and Soda Bay Rd. Stations. The DWR operates a gage located along Kelsey Creek (KCK is the CDEC station, DWR refers to it as A85005). The USGS operated gage 11448500 on Adobe Creek from 1954 to 1978 and currently operates gage 11449500 on Kelsey Creek. Both of these gages are located at the upstream southern boundary of the Basin. Given the distance and upland location of the USGS stream stations they are not ideal to monitor the interconnection of surface water and groundwater in the Subbasin. To complement the stream gauging stations, wells located near the gages were selected to monitor water levels. Well depth, if known, was used to screen potential locations, with the preference for using shallow wells for the monitoring network.

3.5.1 Monitoring Sites Selected for Monitoring Network

The monitoring sites for depletion of interconnected surface water include a DWR stream gage on Kelsey Creek and three gage stations operated by the Big Valley Rancheria along Adobe Creek. Wells located near these gage stations were also selected to monitor groundwater levels. Two additional wells on Kelsey Creek and upstream of the KCK gage are also included to monitor the potential interaction of surface water and groundwater at various locations within the Basin. Wells were selected based on proximity to the stream gage stations and depth, if known, with closer, shallower wells being preferred. The monitoring sites are also relevant to monitoring conditions for GDEs. A summary of the interconnected surface water monitoring sites is provided in **Table 3-7** and illustrated in **Figure 3-3**.

Table 3-7. Interconnected Surface Water Monitoring Network

Site Name	Type	Latitude (NAD 83)	Longitude (NAD 83)	Well Depth (feet, bgs)	Screen Interval (feet, bgs)	Monitoring Entity	Monitoring Frequency*	Distance to Creek/Gage (mi)
13N09W02C002M	KCK Well	39.0104	-122.831	--	--	DISTRICT	Monthly	0.20/0.45
13N09W03R001M	Kelsey Creek – Midstream	38.997183	-122.84134	167	--	DISTRICT	Monthly	0.15/0.78
13N09W15B002M	Kelsey Creek – Upstream	38.98	-122.8443	68	--	DISTRICT	Monthly	0.04/1.98
13N09W19J001M	Bell Hill Well	38.9592	-122.897	--	--	DISTRICT	Monthly	0.34/0.35
13N09W09D005M	Argonaut Well	38.9937	-122.872	--	--	DISTRICT	Monthly	0.30/0.30
14N09W33K001M	Soda Bay Well	39.015	-122.865	93	--	DISTRICT	Monthly	0.16/0.31
KCK	Stream Gauge	39.008400	-122.839218	N/A	N/A	DWR	Continuous	0.00/ N/A
Bell Hill Road	Stream Gauge	38.956636	-122.891291	N/A	N/A	BVR	Continuous	0.00/ N/A
Argonaut Road	Stream Gauge	38.993863	-122.877657	N/A	N/A	BVR	Continuous	0.00/ N/A
Soda Bay Road	Stream Gauge	39.014849	-122.870715	N/A	N/A	BVR	Continuous	0.00/ N/A

*Some of these wells are monitored bi-annually. The Lake County Watershed Protection District plans to monitor them monthly, and as funding becomes available, data loggers may be installed to allow for continuous monitoring.

Key:

-- = no data

bgs = below ground surface

BVR = Big Valley Rancheria

District = Lake County Watershed Protection District

N/A = Not applicable

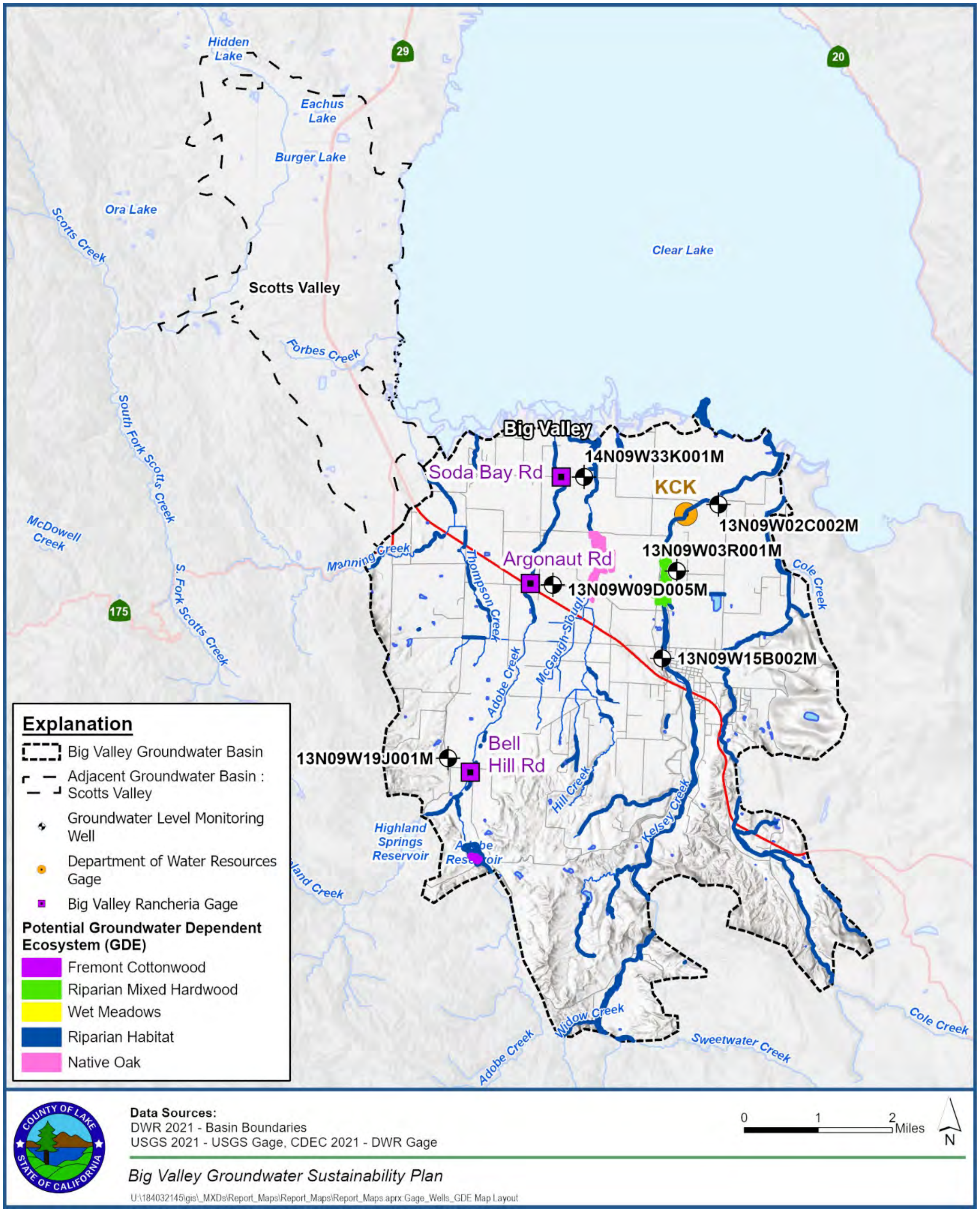


Figure 3-3. Interconnected Surface Water Monitoring Network

3.5.2 Representative Monitoring Network

Depletions of interconnected surface water are monitored by proxy using the groundwater level monitoring network and stream gages. The RMS network for interconnected surface water is provided in **Table 3-7** and graphically illustrated on **Figure 3-3**.

3.5.3 Monitoring Protocols

Groundwater monitoring protocols will be performed following the groundwater and surface water monitoring procedures, provided as **Appendix 3A**.

3.5.4 Spatial Density

The characterization of depletion of interconnected surface water requires additional data collection to ascertain the degree of hydraulic connectivity and magnitude of impact of groundwater extraction influence on surface water. The monitoring network described in **Table 3-7** would need to be revisited in the future, using DWR's Best Management Practices for Monitoring Networks and Identification of Data Gaps, to determine its spatial coverage adequacy.

3.5.5 Monitoring Frequency

Streamflow/stream stage are monitored continuously with a sample interval of 15 minutes. Groundwater monitoring should also be continuous using pressure transducers, with a 1-hour sample interval for depletion analysis. The monitoring wells are currently monitored bi-annually, however, the Lake County Watershed Protection District plans to monitor them monthly, and as funding becomes available, data loggers may be installed to allow for continuous monitoring.

3.5.6 Data Gaps

The interconnected surface water monitoring network could be improved through the installation of multi-completion wells closer to the Kelsey and Adobe Creek stream gage stations. Also surface water monitoring (stage and flow) on Kelsey Creek near the Main Street bridge should be conducted in the future. Opportunities to fill data gaps for depletions will also benefit the understanding of GDEs located downstream of the KCK stream gage. In addition, stream flow monitoring of McGaugh Slough could also be considered. The District will coordinate with Big Valley Rancheria regarding stream gage monitoring protocols so that data collection efforts and quality are consistent with the GSP.

3.5.7 Plan to Fill Data Gaps

Data gaps will be filled based on available funding and level of need. Data gaps may be filled over the full implementation period of the GSP. The District will seek available grants and technical assistance to limit the local financial burden. The District is working with DWR through the Technical Support Services to install additional shallow monitoring wells along Adobe and Kelsey Creek.

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4. SUSTAINABLE MANAGEMENT CRITERIA

This section of the GSP describe the sustainable management criteria (SMC), which characterize the conditions that constitute sustainable groundwater management for the Big Valley Basin. The SMCs defines the sustainability goal and establish undesirable results, MTs, and measurable objectives (MO) for each applicable sustainability indicator.

- **Sustainability goal:** The sustainability goal qualitatively describes the objectives and desired conditions for the Big Valley Basin and how existing management is expected to continue meeting that goal.

- **Undesirable results:** Undesirable results define the conditions at which each applicable sustainability indicator would become significant and unreasonable in the Big Valley Basin.

- **Minimum thresholds:** MTs are quantitative guidance levels for the sustainability indicator being monitored that are set just above conditions that, could generate undesirable results, based on the best available information. MTs violations could result in undesirable results, probationary status, and SWRCB intervention.

- **Measurable objectives:** MOs are the desired condition, set above MTs, that allow for active management of the Big Valley Basin during dry periods. The MOs are set to provide a reasonable margin of operational flexibility between the MOs and the MTs that will accommodate droughts, climate change, conjunctive use operations, or other groundwater management activities.

- **Interim milestones:** Interim milestones are set to guide conditions during implementation of the GSP to assist in achieving MOs within 20 years. In the Big Valley Basin, the interim milestones are set at the same levels as the MOs, as implementation activities are not required to achieve the MOs.

4.1 Sustainability Indicators

A sustainability indicator is defined by SGMA as one of six effects caused by groundwater conditions that, when significant and unreasonable, cause undesirable results. The six sustainability indicators are as follows:

1. **Chronic lowering of groundwater levels** indicates a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Note that <u>overdraft during a period of drought is not sufficient to establish a chronic lowering</u> of groundwater levels if extractions and groundwater recharge are managed, as necessary, to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.

2. Significant and unreasonable **reduction of groundwater storage**

3. Significant and unreasonable **seawater intrusion**

4. Significant and unreasonable **degraded water quality**, including the migration of contaminant plumes that impair water supplies

5. Significant and unreasonable **land subsidence** that substantially interferes with surface land uses

6. **Depletions of interconnected surface water** result in significant and unreasonable adverse impacts on beneficial uses of the surface water.

SGMA allows for flexibility in the development of SMCs, including the use of other sustainability indicators as a proxy, and identification of indicators that are not applicable to the basin. The six sustainability indicators are incorporated into this GSP as follows:

- Indicators incorporated into the GSP using specific sustainable management criteria:
  - Chronic lowering of groundwater levels
  - Degraded water quality
  - Land subsidence
- Indicators incorporated into the GSP using other sustainability indicators as a proxy:
  - Reduction of groundwater storage, through use of chronic lowering of groundwater levels indicator as a proxy
  - Depletions of interconnected surface water, through use of groundwater levels as a proxy
- Indicators not applicable to the Big Valley Basin
  - Seawater intrusion

The GSA will periodically evaluate this GSP, assess changing conditions in the plan area that may warrant modifications of the GSP or management objectives, and may adjust components accordingly. Continued data collection and an improved understanding of basin conditions in the future may lead to changes in the sustainable management criteria discussed herein.

4.2 Summary of Sustainability Criteria

A summary of the developed MOs, MTs, and undesirable results is provided in **Table 4-1**. A discussion on each sustainability indicator is provided in the subsequent sections and include:

- Potential causes and effects of undesirable results, and how they will be identified;
- Description of MTs, metrics used for their measurements, and applicable existing local, state, or federal standards; and
- Description of MOs and Path to achieving and maintaining the sustainability goal.

Table 4-1 Summary of Minimum Thresholds, Measurable Objectives, and Undesirable Results

Sustainability Indicator	Minimum Threshold	Measurable Objective	Undesirable Result
Chronic Lowering of Groundwater Elevations	Lowest historical spring groundwater elevation, plus an operational flexibility margin, at each RMS for groundwater elevation.	Average of historical spring groundwater elevations at each RMS for groundwater elevation.	Occurs when spring groundwater elevation at 33% (2 out of 6) of RMS for groundwater elevation fall below their MTs for two consecutive years at the same sites.
Reduction of Groundwater Storage	Same as chronic lowering of groundwater levels	Same as chronic lowering of groundwater levels	Same as chronic lowering of groundwater levels
Degraded Water Quality	TDS of 750 mg/L	TDS of 500 mg/L	Occurs when 29% (2 out of 7) of RMS for water quality exceed the MTs for two consecutive years at the same sites, and where it can be established that GSP implementation is the cause of the exceedance.
Land Subsidence	No more than 0.5 feet of inelastic subsidence over a five-year period at each RMS for land subsidence, solely due to lowering of groundwater elevations.	No more than 0.20 feet of inelastic subsidence over a five year period at each RMS for land subsidence, solely due to lowering of groundwater elevations.	Occurs when 33% (2 out of 6) of RMS for land subsidence exceed the MTs over a 5-year period, and where it can be established that the subsidence is irreversible and is caused by lowering of groundwater elevations.
Seawater Intrusion	Not Applicable	Not Applicable	Not Applicable
Depletion of Interconnected Surface Water (ISW)	Lowest historical spring groundwater elevation, plus an operational flexibility margin and adjusted for maximum GDEs root depth, at each RMS for depletion of ISW.	Average of historical spring groundwater elevations a at each RMS for depletion of ISW.	Occurs when spring groundwater elevation at 33% (2 out of 6) of RMS for depletion of ISW fall below their MTs for two consecutive years at the same sites.

Key: GDE = Groundwater Dependent Ecosystems; GSP = Groundwater Sustainability Plan; mg/L = milligrams per liter; MT = minimum threshold; RMS = representative monitoring network site; TDS = total dissolved solid

4.3 Sustainability Goal

The sustainability goal qualitatively describes the objectives and desired conditions for the Big Valley Basin and how existing management is expected to continue meeting that goal.

4.3.1 Description of the Goal

The goal of this GSP is "*sustainable management of the groundwater resources of the Big Valley Basin for the long-term community, environmental, and economical benefits of existing and future residents and businesses in the Basin*."

This goal is considered achieved with all the following conditions are met:

- Long-term aggregate groundwater use is equal to the Basin's estimated sustainable yield.
- The average annual rate of groundwater storage change within the Basin, averaged across indicator wells is generally stable when groundwater storage is equivalent to 2015 baseline conditions.
- Groundwater levels are maintained at elevations necessary to avoid undesirable results, including the loss of water availability for well users.
- Groundwater quality exhibit concentrations that do not significantly and unreasonably impact beneficial users of groundwater.
- Subsidence is maintained at current levels or below current levels to avoid undesirable results such as impacts to critical infrastructure and inelastic subsidence.
- Interconnected surface waters are maintained at levels needed to avoid undesirable results to beneficial users including GDEs.

4.3.2 Measures to Achieve Goal and Operate Within Sustainable Yield

Additional measures are not necessary to operate the Big Valley Basin within sustainable yield. Measures to be taken are based on activities to monitor and improve the understanding of the Basin. Adaptive management will allow for development of new measures in the future, if deemed necessary. Additional information is provided in **Section 5**

4.3.3 Goal Achievement Within 20 Years

There are no identified unreasonable results in Big Valley Basin under the historical, current, projected, and projected with climate change conditions (see **Table 4-2**). As the conditions outlined in **Section 4.3.1** are largely being met, the sustainability goal is currently reached through existing local management of the groundwater resource. The sustainability goal will be maintained through proactive monitoring and management by the GSA as described in this GSP.