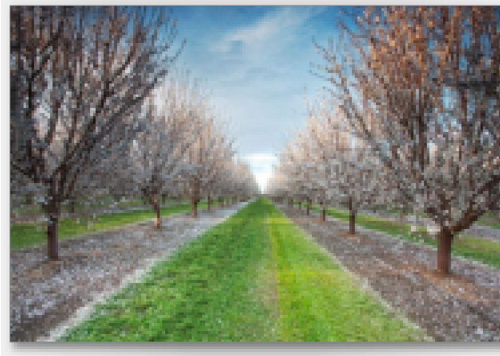
BUTTE SUBBASIN



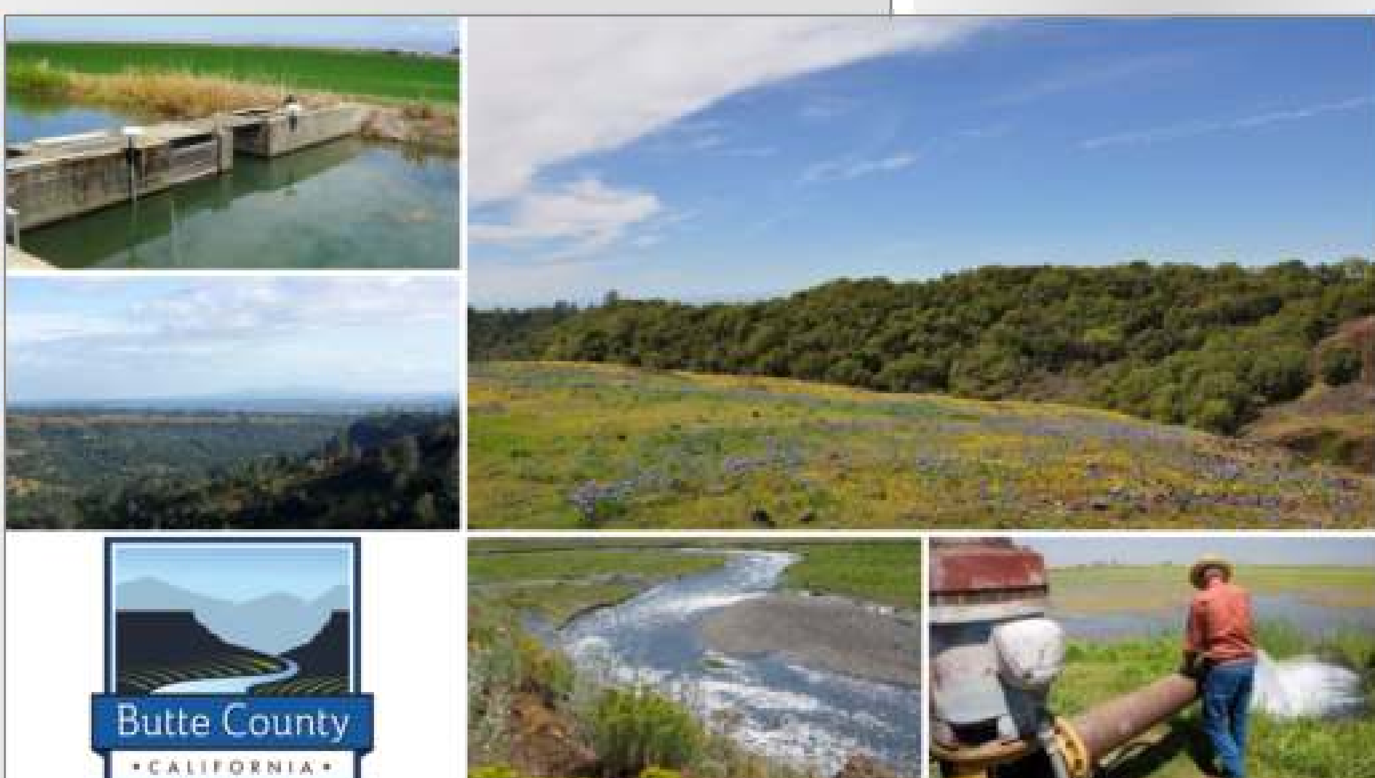
Sustainable Groundwater Management Act (SGMA)

Public Review Draft

January 2022

Prepared by

Davids Engineering, Inc
Woodard & Curran, Inc.
GEI Consultants, Inc.



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List of Abbreviations

2070CT	2070 central tendency
AEM	Airborne Electromagnetic Method
ADVM	Acoustic doppler velocity meter
AF/yr	acre-feet per year
AFY	acre-feet per year
AN	above normal
AWMPs	Agricultural Water Management Plans
b	aquifer thickness
BBGM	Butte Basin Groundwater Model
BCDWRC	Butte County Department of Water and Resource Conservation’s
bgs	below ground surface
BMP	Best Management Practice
BMPs	Sustainable Management Criteria Best Management Practices
BN	below normal
BWGWD	Biggs-West Gridley Water District
C	critical
Cal Poly	California Polytechnic State University, San Luis Obispo
CASGEM	California Statewide Groundwater Elevation Monitoring
CECs	chemicals of Emerging Concern
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
Chico State	California State University, Chico
CODSS	canal operations decision support system
CVRWQCB	Central Valley Regional Water Quality Control Board
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
CWC	California Water Code
D	dry
DE	Davids Engineering
DACs	disadvantaged communities
DMS	Data Management System
DTSC	Department of Toxic Substances Control
DWR	Department of Water Resources
EA/FONSI	Environmental Assessment/Finding of No Significant Impact
EC	electrical conductivity
EDF	Environmental Defense Fund
ESA	Endangered Species Act

ET	crop evapotranspiration
FRRAWMP	Feather River Regional Agricultural Water Management Plan
GAMA	Groundwater Ambient Monitoring and Assessment
GAR	Groundwater Quality Assessment Report
GDEs	groundwater dependent ecosystems
GEI	GEI Consultants
gpm	gallons per minute
GQTMWP	Groundwater Quality Trend Monitoring Work Plan
GSAs	Groundwater Sustainability Agencies
HCM	Hydrogeologic Conceptual Model
HMI	Human Machine Interface
HVAs	High Vulnerability Areas
ILRP	Irrigated Lands Regulatory Program
IMs	Interim Milestones
InSAR	Interferometric Synthetic Aperture Radar
ITRC	Irrigation Training and Research Center
JPL	Jet Propulsion Laboratory
K	hydraulic conductivity
MAF	million acre-feet
MCL	maximum contaminant level
MSL	mean sea level
mm	millimeters
MOs	Measurable Objectives
MTs	Minimum Thresholds
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NRCS	Natural Resources Conservation Service
O&M	operation and maintenance
PFAS	polyfluoroalkyl substances
PFOS	Perfluorooctanesulfonic acid
RD1004	Reclamation District No. 1004
RD2106	Reclamation District No. 2016
RID	Richvale Irrigation District
RMN	representative monitoring network
RMS	representative monitoring site
RT	RemoteTracker
RTU	remote terminal unit
SCADA	Supervisory Control and Data Acquisition
SDWIS	State Drinking Water Information System
SEWD	Sutter Extension Water District

SGMA	Sustainable Groundwater Management Act
SHPO	State Historic Preservation Office
SVWQC	Sacramento Valley Water Quality Coalition
SWP	State Water Project
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resource Control Board's
T	Transmissivity
TAF	thousands of acre-feet
TAF/yr	Thousands of acre-feet per year
TDS	Total Dissolved Solids
TNC	The Nature Conservancy
UC Davis	University of California, Davis
UCCE	University of California Cooperative Extension
USBR	U.S. Bureau of Reclamation
UWMP	Urban Water management Plan
W	wet
W&C	Woodard & Curran
WCWD	Western Canal Water District
WDL	California Water Data Library
µs/cm	microsiemens/centimeter

Executive Summary (Reg. § 354.4)

In September 2014, the California legislature passed the Sustainable Groundwater Management Act (SGMA), establishing new measures for groundwater management and regulation statewide. SGMA provides for local control of groundwater resources while requiring sustainable management of the state's groundwater basins. Under the provisions of SGMA, local agencies must establish governance of their subbasins by forming Groundwater Sustainability Agencies (GSAs) with the authority to develop, adopt, and implement a Groundwater Sustainability Plan (GSP, or Plan) for the subbasin. Under the GSP, GSAs must adequately define and monitor groundwater conditions in the subbasin and establish criteria to achieve and maintain sustainable groundwater management within 20 years of GSP adoption.

The Butte Subbasin is identified by California Department of Water Resources (DWR) as a medium priority basin. Therefore, the Butte Subbasin GSAs must develop, adopt, and submit a GSP (or GSPs) to DWR for the entire Butte Subbasin by January 31, 2022. The Butte Subbasin is managed by eleven GSAs, which are working together under a Subbasin Cooperation Agreement[1] to develop one GSP for the entire Subbasin. This Butte Subbasin GSP satisfies the requirements established by SGMA and DWR, and outlines the strategy by which the Butte Subbasin GSAs will maintain sustainable groundwater management through the implementation period until 2042.

A pragmatic approach to sustainable groundwater management requires firm understanding of: (1) historical trends and current groundwater conditions in the subbasin (including, but not limited to, groundwater levels, groundwater extraction, and groundwater quality), and (2) what must change in the future to ensure sustainability without causing undesirable results[2] or negatively affecting beneficial uses and users of groundwater, including groundwater dependent ecosystems.

In developing this GSP, a Hydrogeologic Conceptual Model (HCM) and water budgets were created to first characterize historical and current groundwater conditions in the subbasin. The historical water budget identified historical trends in surface water availability and groundwater extraction and recharge, while the current water budget evaluated current land use and cropping in the context of the Subbasin's hydrology and water supply. The projected water budget evaluated projected future land use effects on water demand in the context of potential effects

[1] The cooperation agreement is available on Butte Subbasin website (www.buttebasingroundwater.org) and attached as Appendix 1.B.

[2] California Water Code (CWC) Section 10721(x) defines undesirable results as one of more of the following effects (summarized): chronic lowering of groundwater levels, significant and unreasonable reduction of groundwater storage, significant and unreasonable seawater intrusion, significant and unreasonable degraded water quality, significant and unreasonable land subsidence, and depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

of climate change on the Subbasin's future hydrologic and climatic conditions. Although within the uncertainty of the modeling, each water budget showed a slight reduction in groundwater storage over time.

Projects and management actions were then developed with the goal of bringing the projected change in groundwater storage to zero. Three ongoing projects are being implemented and are estimated to provide a sufficient volume of average annual benefit to bring the projected reduction in groundwater storage to zero. There are also four projects and management actions described in greater detail estimated to be the next best projects for implementation to maintain sustainability. An additional 18 projects and management actions are included in the GSP that may potentially be implemented by the GSAs to support ongoing sustainability, adapt to changing conditions in the subbasin, provide operational flexibility, or maintain other water management objectives.

This GSP has been developed by the Butte Subbasin GSAs through outreach and engagement and considers feedback received from local agencies, agricultural water users, municipal water users, Disadvantaged Community (DAC) members, and other stakeholders in the subbasin. Public meetings and workshops have been hosted throughout GSP development. The Butte Subbasin GSAs have met together regularly and have also met multiple times with GSAs in adjacent subbasins, sharing data and information on groundwater conditions and GSP projects to ensure that this Plan will not interfere with the ability of adjacent subbasins to also maintain sustainable groundwater management.

The following sections in this Executive Summary provide a concise overview of the complete Butte Subbasin GSP.

ES-1 Introduction

Groundwater serves as an important source of supply for agricultural, municipal, domestic, and environmental beneficial uses throughout the Butte Subbasin[3]. Agriculture in the Butte Subbasin relies on about 130,000 acre-feet of groundwater annually to produce an array of commodities that contribute to the roughly $690 million dollar agricultural economy within the Butte Subbasin.[4] Managed wetlands in the Subbasin also rely on approximately 30,000 acre-feet of groundwater annually to provide a variety of environmental benefits, and groundwater supports a large portion of the Subbasin's population of roughly 15,000 people.[5] Surface water is available to support agriculture throughout much of the Subbasin (and managed wetlands in some locations), although it is subject to curtailment during times of drought. During these periods,

[3] Groundwater basin number 5-021.70, which is part of the Sacramento Valley Groundwater Basin.
[4]Butte County 2019 Crop & Livestock Report: Butte County Crop Report.
[5] U.S. Census Bureau, 2010 Estimate

groundwater pumping temporarily increases and groundwater levels decrease, although they increase again following times of drought once surface water is available again. The Butte Subbasin underlies approximately 265,000 acres, and the sustainable management of groundwater in the Subbasin is important for long-term prosperity within the region.

The Sustainable Groundwater Management Act of 2014 (SGMA) provides for local control of groundwater resources while requiring sustainable management of these resources. SGMA requires groundwater basins or subbasins to establish governance by forming local Groundwater Sustainability Agencies (GSAs) with the authority to develop, adopt, and implement a Groundwater Sustainability Plan (GSP or Plan). Under this Plan, GSAs must adequately define and monitor groundwater conditions in the subbasin and establish criteria to maintain or achieve sustainable groundwater management within 20 years of GSP adoption.

Sustainable management of groundwater is defined under SGMA as the “management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results” (California Water Code (CWC) Section 10721(v)). These undesirable results include significant and unreasonable lowering of groundwater levels, loss of groundwater storage and supply, degradation of water quality, land subsidence, and depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water. Sea water intrusion, while a SGMA-defined undesirable result, is not applicable to the Butte Subbasin.

The Butte Subbasin has been identified by the California Department of Water Resources (DWR) as a medium-priority subbasin. Under SGMA, GSAs in medium- or high-priority subbasins are required to prepare and adopt a GSP (or GSPs) by January 31, 2022 (CWC Section 10720.7(a)(2)).

This is the GSP for the eleven GSAs that represent the entirety of the subbasin area: Biggs-West Gridley Water District GSA, Butte Water District GSA, City of Biggs GSA, City of Gridley GSA, Colusa Groundwater Authority GSA, County of Butte GSA, County of Glenn GSA, Reclamation District No. 1004 GSA, Reclamation District No. 2106 GSA, Richvale Irrigation District GSA, and Western Canal Water District GSA (**Figure ES-1**). A cooperation agreement between all eleven GSAs in the Butte Subbasin detailing required GSA and GSP cooperation and coordination is in place. The purpose of this GSP is to characterize groundwater conditions in the Butte Subbasin, establish sustainability goals, and to describe programs and management actions the GSAs intend to implement to maintain sustainable groundwater management through 2042.

This GSP also serves to comply with DWR’s requirements that the Butte Subbasin GSAs prepare, adopt and implement a plan “consistent with the objective that a basin be sustainably managed within 20 years of Plan implementation without adversely affecting the ability of an adjacent basin to implement its Plan or achieve and maintain its sustainability goal over the planning and implementation horizon" as defined in the California Code of Regulations Title 23 (CCR), Section 350.4 (f) that detail the requirements and components of the GSP.

As mandated under 23 CCR Section 354.24, GSAs within the Butte Subbasin have established a "sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline." Specifically, this sustainability goal establishes that the Butte Subbasin will be operated within its sustainable yield by 2042, or 20 years following the initiation of GSP implementation in January 2022. 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 Section 10721(w)).

ES-2 Plan Area and Basin Setting

The Plan Area is defined as the Butte Subbasin (5-21.70), which is part of the Sacramento Valley Groundwater Basin. The Butte Subbasin was formed through basin boundary updates approved by DWR in early 2021 and was formed from portions of the West Butte and East Butte Subbasins, each of which was previously described in Bulletin 118 (DWR, 2016). The subbasin is bounded in the south by the Sutter Subbasin, in the west by the Sacramento River and the Colusa Subbasin, in the north by the Corning and Vina Subbasins, and in the east by the Feather River and the Wyandotte Creek Subbasin (**Figure ES-1**). The vertical boundaries of the subbasin are the land surface (upper boundary) and the definable bottom of the basin (lower boundary). The vertical extent of the subbasin is subdivided into a surface water system (SWS) and groundwater system (GWS). The SWS represents the land surface down to the bottom of plant root zone[6], within the lateral boundaries of the subbasin. The GWS extends from the bottom of the root zone to the base of freshwater for the subbasin, within the lateral boundaries of the subbasin.

ES-2.1. Hydrogeologic Conceptual Model

The Butte Subbasin is generally comprised of relatively flat topography that slopes gently downward from the northeast to the southwest. Topographic elevations vary from about 140 feet above mean sea level (MSL) in the northeast to about 50 feet above MSL in the southwest. A notable feature within the Butte Subbasin is the "Butte Basin", which lies to the south of Chico and west of the Feather River. Characterized by an expansive, flat topography, the Butte Basin was, prior to flood control on the Feather and Sacramento rivers, an area of extensive seasonal flooding. This slow-moving floodwater deposited the fine clay that now provides the rich agricultural soil conducive to rice production (DWR 2005).

[6] **The depth to the bottom of the root zone varies by crop, but typically ranges from 2-7 feet (ASCE, 2016).**

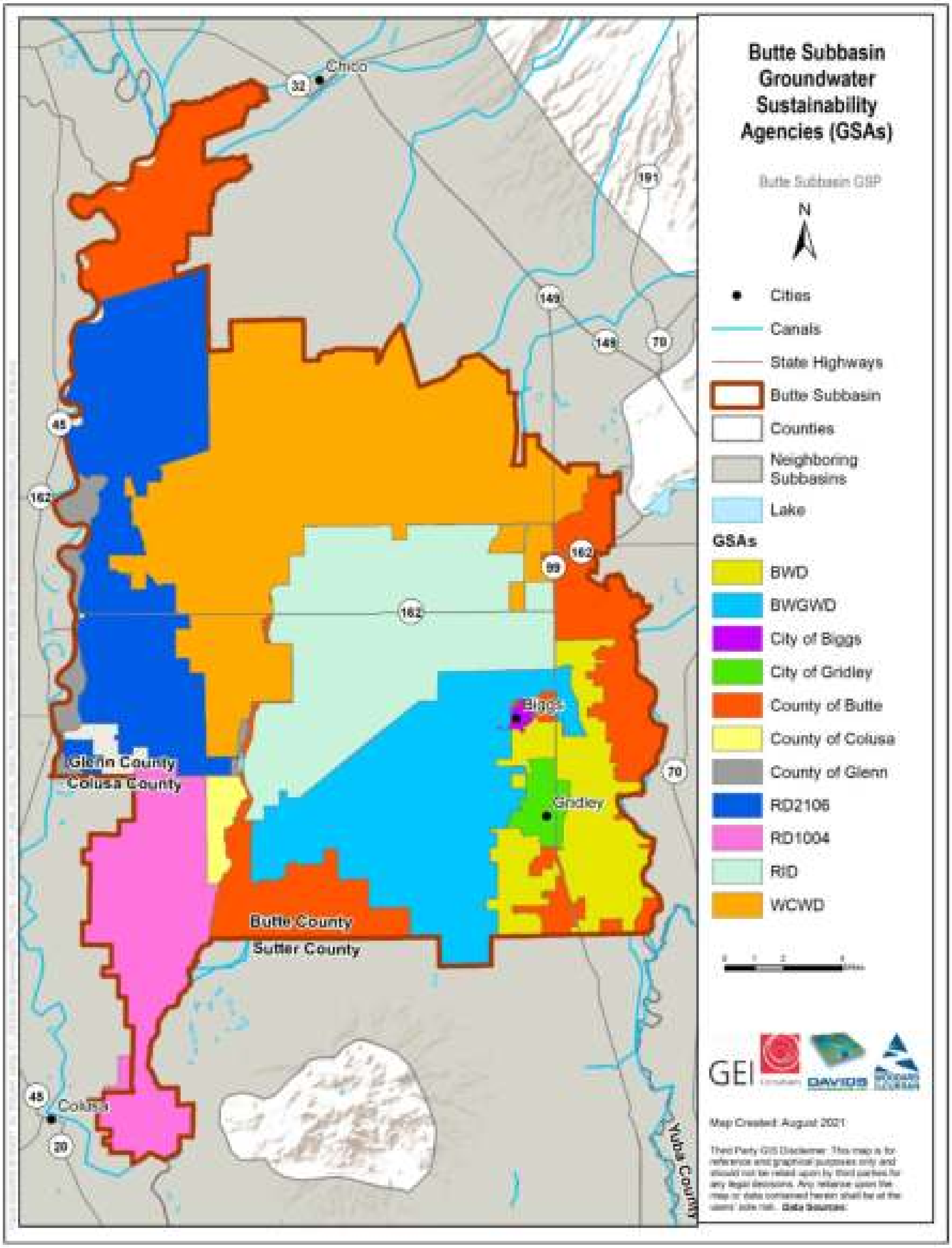


Figure ES-1. Butte Subbasin Boundary and Groundwater Sustainability Agencies

The Sutter Buttes, which lie outside the Subbasin to the south, provide the only significant topographic relief on the Sacramento Valley floor. In the Butte Basin, groundwater mounds up on the north side of the Sutter Buttes before it flows westward around the Buttes and between the buried Colusa dome and southward (DWR 2014).

The region is composed of a diverse mix of geologic units. The main hydrogeologic units and source of groundwater in the Subbasin is the Tuscan Formation. Other units that supply lesser amounts of groundwater to the Subbasin are the Laguna, Riverbank, and Modesto formations (DWR 2005). Groundwater occurs under both unconfined and confined conditions. Unconfined conditions are generally present in the surficial Quaternary deposits and in the Pliocene deposits that are exposed at the surface. Confined conditions usually exist at a depth of 200 feet or more, where one or more confining layers rests above the underlying aquifer deposits. Although the Tuscan Formation is unconfined where it is exposed near the valley margin in the east, at depth the Tuscan Formation is semi-confined or confined and forms the major aquifer system throughout the eastern side of the northern Sacramento Valley.

DWR defines "principal aquifers" under SGMA as the "aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems" (Cal. Code of Regs., title 23, § 351(aa)). Through an examination of hydrographs and lithology logs from multi-completion monitoring wells, two principal aquifers are defined in the Butte Subbasin: 1) Primary Aquifer and 2) Very Deep Aquifer. The Very Deep Aquifer is at depths greater than 700 feet below ground surface. The Primary Aquifer is divided into the following zones, based on depth below ground surface: Very Shallow is 0-100 feet, Shallow is 100-200 feet, Intermediate is 200-600 feet, and Deep is 600-700 feet. Available data show a hydraulic connection between the shallow and deepest zones of the aquifer system.

Groundwater recharge is the downward movement of water from the surface to the groundwater system. This can include percolation of water from rainfall, irrigation, or water bodies (i.e., rivers, lakes and canals). Several water sources and mechanisms recharge the groundwater system in the Butte Subbasin. Stable isotope data suggests downward vertical migration of water percolating directly into the Tuscan Formation at the outcrop outside the Subbasin to the east or through recharge into the local alluvial fans are predominant recharge mechanisms for the deeper aquifer zones of the Butte Subbasin. This recharged water enters the Subbasin in part as subsurface groundwater flow from the Vina Subbasin and the foothill areas to the east. There is evidence that the Thermalito Afterbay and applied irrigation water also provide recharge to the groundwater system in the Butte Subbasin, and it is likely that the Sacramento River and Feather River also contribute recharge to the Subbasin at times along certain reaches.

Groundwater extraction, or water produced, from the Primary Aquifer is used to meet irrigation, domestic, and municipal water demand. Domestic supply is largely used to meet rural residential demands; domestic wells are shallow with the vast majority being less than 100 feet deep. Municipal supply is largely used to meet demand from towns such as Biggs and Gridley. The Very Deep Aquifer is only accessed by a limited number of wells.

ES-2.2. Water Budget

A water budget is defined as a complete accounting of all water flowing into and out of a defined volume[7] over a specified period of time. When the water budget volume is an entire subbasin, the water budget facilitates assessment of the total volume of groundwater and surface water entering and leaving the subbasin over time, along with the change in the volume of water stored within the subbasin. The Butte Basin Groundwater Model (BBGM) was utilized to support development of water budgets with separate, but interrelated, water budgets being developed for the surface water system and groundwater system. Water budgets were developed for the Subbasin to characterize historical, current, and projected water budget conditions. The GSP Emergency Regulations require evaluation of water budgets over a minimum of 10 years for the historical water budget, using the most recent hydrology for the current water budget, and 50 years of hydrology for the projected water budget. Hydrologic periods were selected for each water budget category based on consideration of the best available information and science to support water budget development and based on consideration of the ability of the selected periods to provide a representative range of wet and dry conditions.

The objective of the historical water budget is to evaluate availability or reliability of past surface water supplies and aquifer response to water supply and demand trends relative to water year type. The historical water budget was calculated for water years[8] 2000 to 2018, which was selected based on the level of confidence in historical input data and information to support water budget development considering land use, surface water availability, hydrology, and other factors.

The objective of the current water budget is to understand the impact of current land use on water demand in the context of the Subbasin's hydrology and water supply. This requires a water budget that considers current land use conditions and average historical hydrologic and climatic conditions. The current water budget was calculated using the most recently available land use (2015 and 2016) and urban demands (average of 2016 to 2018) over 50 years of historical hydrology. The period selected was 1971 to 2018 (48 years) with 2004 – 2005 (two relatively normal years) repeated at the end of the scenario to complete the 50-year timeframe. Reasons for selecting this period include the BBGM having a simulation period from 1971 to 2018, the

[7] Where 'volume' refers to a space with length, width and depth properties, which for purposes of the GSP means the defined aquifer and associated surface water system.

[8] A water year is defined as the period from October 1 of the prior year to September 30 of the current year. For example, water year 2000 refers to the period from October 1, 1999 to September 30, 2000.

Sacramento Valley Water Year Index for this period being nearly equivalent to the value to Index value for the full period of record beginning in 1906, and the inclusion of a combination of wet and dry cycles. One advantage of evaluating the current conditions water budget over a representative 50-year period is that the results provide a baseline for evaluation of the projected water budgets.

The objective of the projected water budget is to understand the impact of projected land use on water demand in the context of potential effects of climate change on the Subbasin's future hydrologic and climatic conditions. The projected water budget was calculated using the most recently available land use information adjusted for future conditions based on the Butte County 2030 General Plan over 50 years of historical hydrology, using the same time period as the current water budget. Three projected water budget scenarios were developed across a range of future conditions that may occur: these scenarios include one in which no climate change occurs, one with adjustments to precipitation, evapotranspiration, and surface water supplies based on the 2030 Central Tendency climate change datasets provided by DWR to support GSP development, and one with adjustments to precipitation, evapotranspiration, and surface water supplies based on the 2070 Central Tendency climate change datasets provided by DWR to support GSP development.

Average annual water budget estimates for the projected water budget scenario with 2070 Central Tendency climate change are summarized for the land and surface water system in **Figure ES-2** and the groundwater system in **Figure ES-3**.

The water budget results can be used to evaluate the availability and reliability of historical surface water supplies and provide insight into the ability to operate the basin within the sustainable yield (defined below). Historical water budget estimates indicate an average annual decrease in storage of ten thousand acre-feet per year for the period from water year 2000 to 2018, although it is worth noting that the historical analysis period experienced somewhat less precipitation than the long-term average and included historic drought conditions from approximately 2007 to 2015. The current and projected water budgets also show an average annual decrease ranging from over one thousand acre-feet per year in the current water budget to two thousand acre-feet per year in the projected water budget under 2070 Central Tendency climate change conditions. Even though this is within the uncertainty of the model, due to this estimated decrease, projects and management actions were developed with the goal of bringing the projected change in groundwater storage to zero.

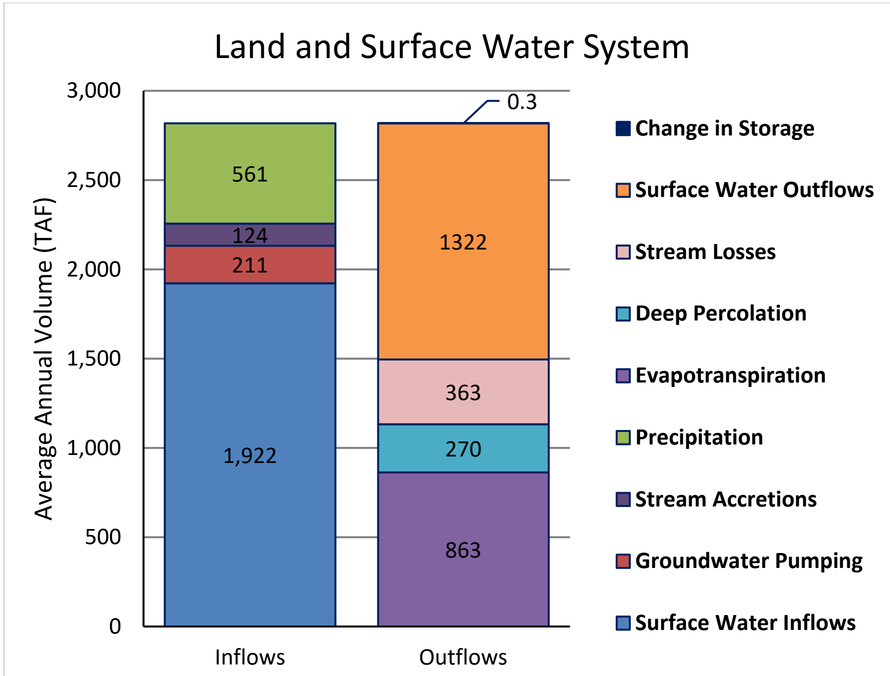


Figure ES-2. Average Annual Future Conditions with 2070 Climate Change Land and Surface Water System Water Budget

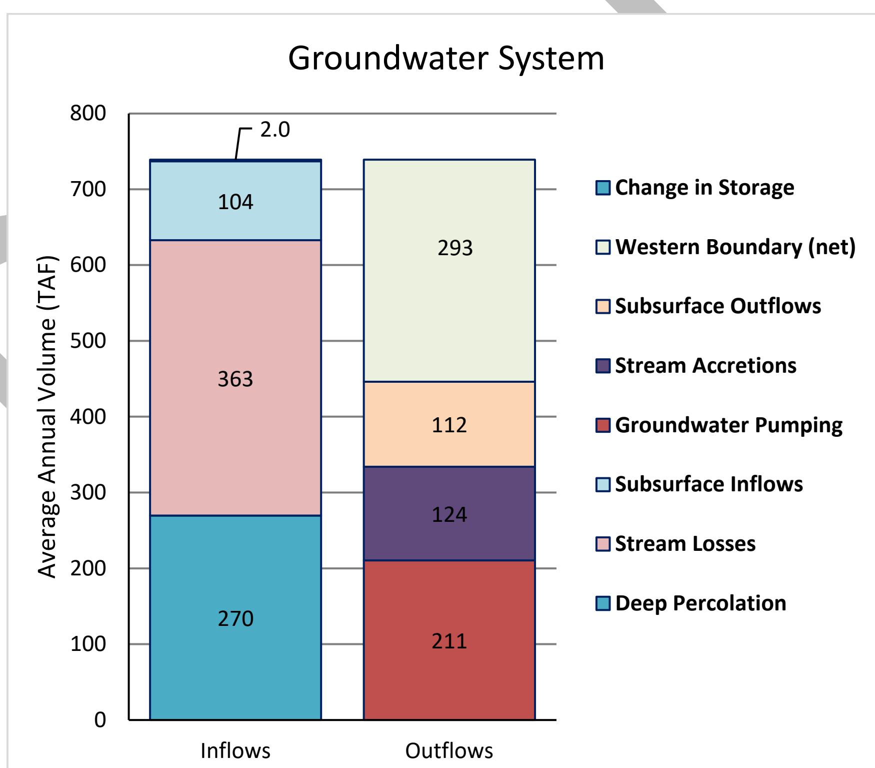


Figure ES-3. Average Annual Future Conditions with 2070 Climate Change Groundwater System Water Budget

GSP Regulations require the water budget to quantify the sustainable yield for the subbasin. Sustainable yield refers to the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin, that can be withdrawn annually from a groundwater supply without causing an undesirable result. Estimates have been developed for the basin as the long-term annual groundwater pumping, minus the average annual decrease in groundwater storage, as summarized in **Table ES-1** for the projected future scenario under 2070 Central Tendency climate change conditions. The sustainable yield is estimated as the long-term average annual groundwater extraction during the 50-year modeled period and will vary, often substantially, from year to year. As described in a following section, projects and management actions are estimated to reduce groundwater pumping enough to bring the average annual change to Basin storage to zero when fully implemented.

Table ES-1. Estimated Groundwater Pumping, Decrease in Storage, and Change in Sustainable Yield.

Baseline Scenario	Groundwater Pumping (AFY)	Decrease in Groundwater Storage (AFY)	Difference (AFY)
Future, 2070 Climate Change	210,500	2,000	208,500

ES-3 Sustainable Management Criteria

ES-3.1. Sustainability Indicators

A sustainability indicator is defined by the Sustainable Groundwater Management Act (SGMA) as one of six effects caused by groundwater conditions that, when significant and unreasonable, cause undesirable results. The six sustainability indicators are described in the document *Sustainable Management Criteria, Best Management Practices for the Sustainable Management of Groundwater* (DWR, 2017) as follows:

"Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering 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.

Significant and unreasonable reduction of groundwater storage.

Significant and unreasonable seawater intrusion.

Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.

Significant and unreasonable land subsidence that substantially interferes with surface land uses.

Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water."

SGMA allows several pathways to meet the distinct local needs of each basin, including:

- Development of sustainable management criteria for each sustainability criterion
- Use of other sustainability indicators as a proxy
- Identification of specific indicators that are not applicable to the basin.

Sustainable management criteria have been established for the chronic lowering of groundwater levels, the degradation of groundwater quality, inelastic land subsidence, and depletions of interconnected surface water. Chronic reductions of groundwater storage utilize groundwater levels as a monitoring proxy, and because of the Butte Subbasin's distance from the Pacific Ocean, bays, deltas, or inlets, seawater intrusion is not an applicable sustainability indicator.

Significant and unreasonable effects occur when minimum thresholds (MTs) are exceeded for one or more sustainability indicators. A summary of the sustainable management MTs, measurable objectives (MO) and undesirable results is provided in **Table ES-2**. Locally defined undesirable results were based on discussion with GSA staff and technical representatives, input received from interested stakeholders and the public through public meetings, and through individual stakeholder input to various GSA representatives. The sustainable management criteria will be maintained through proactive monitoring and management by the GSAs.

Table ES-2. Summary of Minimum Thresholds, Measurable Objectives, and Undesirable Results.

Sustainability Indicator	Minimum Threshold	Measurable Objective	Undesirable Result
Chronic Lowering of Groundwater Levels (Primary Aquifer & Very Deep Aquifer)	Determined through two-step process[1] designed to be protective of domestic wells while allowing for conjunctive use by agriculture.	Average of last five years of measured groundwater level data	25 percent of wells fall below minimum threshold for 24 consecutive months
Reduction of Groundwater Storage[2]	No long-term reduction in groundwater storage based on measured groundwater levels	No long-term reduction in groundwater storage based on measured groundwater levels	25 percent of wells fall below minimum threshold for 24 consecutive months
Seawater Intrusion	Not Applicable	Not Applicable	Not Applicable

Sustainability Indicator	Minimum Threshold	Measurable Objective	Undesirable Result
Degraded Water Quality	Salinity is the primary constituent of concern: the greater of 900 µS/cm or the measured historical high.	Salinity is the primary constituent of concern: 700 µS/cm.	25 percent of wells fall below minimum threshold for 24 consecutive months
Inelastic Land Subsidence	0.5 feet over a 5-year period	0.25 feet over a 5-year period	25 percent of monitoring locations fall below minimum threshold
Depletion of Interconnected Surface Water[2]	10 feet below the measured historical low	Average of last five years of measured groundwater level data	25 percent of monitoring locations fall below minimum threshold

1. This two-step process is described in **Section 4.3.1.**
2. Monitoring of groundwater levels are used as a proxy for change in groundwater storage and depletion of interconnected surface water, as described in **Section 4**.

Groundwater sustainability in this Subbasin is also dependent on surface water supplies and thus will always be vulnerable to any future conditions affecting the availability of surface water supplies. A variety of factors have the potential to influence future surface water availability such as hydrologic changes (due to climate change or other factors) or regulatory changes that may impact the contractual quantities of water the California Department of Water Resources (DWR) is obligated to provide per the Feather River Diversion Agreements. Future conditions that impact the future availability of surface water supplies (including hydrologic and/or regulatory changes) may require revisions to the sustainability indicators. Overall, long-term sustainability will be maintained through implementation of the projects and management actions and adaptive management as described in this GSP.

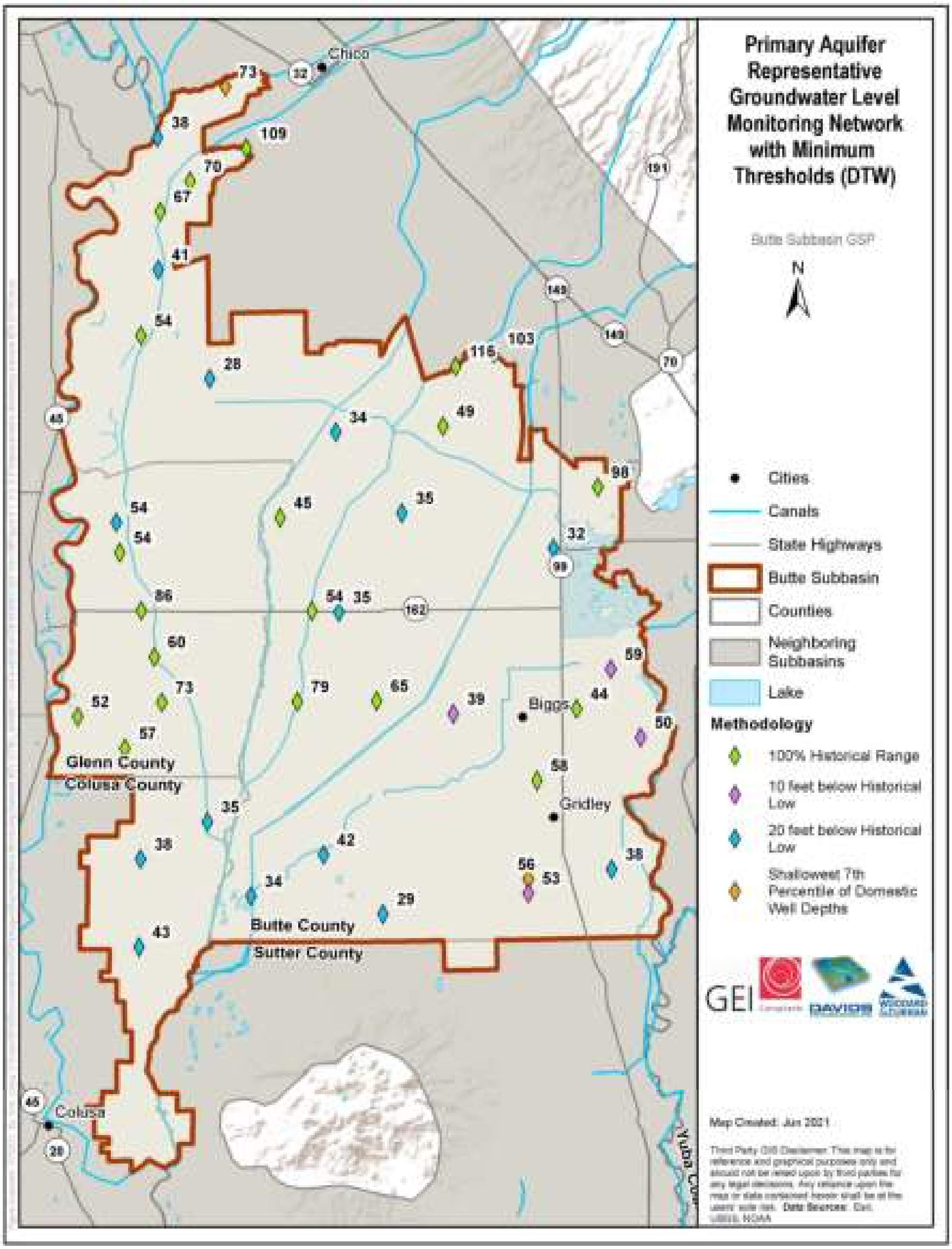
ES-3.1.1. Chronic Lowering of Groundwater Levels

The GSP regulations provide that the "minimum thresholds for chronic lowering of groundwater levels shall be the groundwater level indicating a depletion of supply at a given location that may lead to undesirable results." If they are sufficient in magnitude, chronic lowering of groundwater levels in the Subbasin has the potential to cause significant and unreasonable declines such as:

- Dewatering of a subset of the existing groundwater infrastructure, starting with the shallowest wells

- Increased costs to pump groundwater
- Adverse effects on groundwater dependent ecosystems (GDEs) to the extent connected with the primary aquifer, including difficulty for plants and animals to access groundwater
- Changes in irrigation practices and crops grown
- Adverse effects to property values and the regional economy

Implementation of the GSP is intended to avoid these effects by monitoring and implementing projects and management actions, as necessary, to maintain groundwater levels above the minimum thresholds. Minimum thresholds are designed to be protective of domestic wells while allowing flexibility to support conjunctive use. During times of surface water curtailment and drought (such as in 2015), the Subbasin depends on groundwater resources and drawn down groundwater levels. Historically, the aquifer and groundwater levels have always recovered in the first year following a drought. **Figure ES-4** shows the minimum thresholds for the wells included into the primary aquifer representative monitoring network.



824
825 *Figure ES-4. Primary Aquifer Representative Groundwater Level Monitoring Network with*
826 *MTs (DTW)*

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ES-3.1.2. Reduction of Groundwater Storage

The groundwater storage reduction metric will be evaluated using groundwater levels as a proxy in conjunction with annual evaluations of long-term groundwater storage changes. If reductions of groundwater in storage were to reach undesirable results levels, the effects could potentially cause the dewatering of existing groundwater infrastructure and changes in irrigation practices and crops grown and could adversely affect groundwater dependent ecosystems and property values. Additionally, reaching undesirable results for reduction of groundwater in storage could adversely affect the many beneficial uses of groundwater in the Subbasin, including domestic and irrigation uses. Based on considerations applied in developing the groundwater level MTs, reduction in groundwater storage minimum thresholds do not exceed any identified significant and unreasonable level of depleted groundwater storage volume.

ES-3.1.3. Seawater Intrusion

The seawater intrusion sustainability criterion is not applicable to the Butte Subbasin.

ES-3.1.4. Degraded Water Quality

The undesirable result for the degradation of water quality is a result stemming from a causal nexus between groundwater quantity related activities, such as groundwater extraction or groundwater recharge, and groundwater quality that causes significant and unreasonable effects. The causal nexus reflects that the undesirable results are water quality issues associated with groundwater pumping and other groundwater-related activities rather than water quality issues resulting from land use practices, naturally occurring water quality issues, or other issues not associated with groundwater pumping and other groundwater-related activities.

The primary constituent of concern in the Butte Subbasin is salinity. If groundwater quality were degraded such that undesirable levels are reached, the effects could potentially cause a shortage in supply to groundwater users without additional treatment, with domestic wells being most vulnerable, although high levels of salinity can impact both drinking water uses and agricultural uses. The GSAs will monitor salinity and other constituents during GSP implementation, and plan to review and revise the preliminary minimum thresholds and approach during the first 5-year GSP update. However, existing water quality monitoring in the Butte Subbasin indicates that groundwater quality in the Subbasin is of good quality and is unlikely to be significantly and unreasonably undesirable at this time.

ES-3.1.5. Land Subsidence

The undesirable result for land subsidence is a result due to groundwater extraction that causes significant and unreasonable reduction in the viability of the use of critical infrastructure (likely primarily water conveyance infrastructure) and potentially decreased groundwater storage resulting from the irreversible compression of portions of the underlying aquifers. Historically, land subsidence has not been an issue in the Butte Subbasin (the current subsidence rate has been measured to be less than 0.0325 feet per 5 years), even during the 2015 drought when groundwater levels were lower. Minimum thresholds were selected to represent conditions that are just above conditions that could collectively generate undesirable results in the Butte Subbasin.

ES-3.1.6. Depletion of Interconnected Surface Water

The undesirable result for depletion of interconnected surface water is a result that causes significant and unreasonable adverse effects on beneficial uses and users of interconnected surface waters. If undesirable results were to occur, the effects could potentially reduce groundwater contribution to surface water courses (e.g. rivers and creeks), result in a reduction of the number of days per year a stream in the Subbasin flows, lower stream flows, and/or result in increased temperatures that could potentially impact riverine and riparian habitats through the reduction in the contribution of cooler groundwater flows to the surface water course.

Groundwater levels in the vicinity of a stream or river are considered to be a reasonable proxy for monitoring depletions of surface water (EDF, 2018). Minimum thresholds for depletion of interconnected surface waters were set at 10 feet below the measured historical low for each of the representative monitoring wells. The minimum threshold was selected such that levels would be protective of the beneficial use of interconnected surface water and of shallower groundwater near streams and rivers, including those of shallower domestic users and potential groundwater dependent ecosystems. An additional 10 shallow monitoring wells will be installed to improve monitoring of depletion of interconnected surface water (see **Table ES-3**).

ES-4 Monitoring Networks

The objective of the representative monitoring networks is to observe and record data on groundwater levels, quality and related conditions, such as the interconnection of surface water and groundwater and land subsidence. Wells included in the existing representative monitoring networks were selected with sufficient temporal frequency and spatial density to provide baseline information about current conditions in the Subbasin to assist with establishing Sustainable Management Criteria, as described above, and to evaluate conditions related to the effectiveness of the GSP, specifically to detect short-term, seasonal, and long-term trends. The representative monitoring networks are described in **Section 3** and will be periodically reviewed and modified as needed.

ES-5 Subbasin Projects and Management Actions

In accordance with SGMA regulations, projects and management actions were developed to maintain the Butte Subbasin sustainability goal through 2042 and avoid undesirable results over the GSP planning and implementation horizon. Projects generally refer to structural features whereas management actions are typically non-structural programs or policies designed to improve water management, reduce groundwater pumping, or address other undesirable results that may occur in the Subbasin.

These projects and management actions were devised and prioritized to directly address projected future changes in subbasin conditions that may otherwise cause undesirable results. Without projects and management actions, the key imbalance in future groundwater conditions is a projected decrease in groundwater storage, with an average annual expected decrease of 2,000 acre-feet per year (AF/yr) in the future conditions under the 2070 central tendency (2070CT) climate change scenario. Projects and management actions were devised and planned to address this imbalance by providing an average annual benefit to groundwater storage of at least this volume. This is considered to be a conservative approach to achieving groundwater sustainability, considering the assumptions and limitations of the future projected subbasin water budget and projected 2070CT hydrology. While the future scenario with 2070CT climate change adjustment assumes that the effects of 2070CT climate change are occurring every year, in actuality these effects will gradually occur with significant uncertainty in their magnitude and interannual variability. Throughout GSP implementation, the GSAs plan to continue monitoring sustainability indicators and will continue implementation of projects and management actions to ensure that undesirable results are avoided.

Projects and management actions included in the GSP are divided into three categories: (1) Ongoing, (2) Planned and (3) As Needed. Ongoing are all currently underway and planned for completion prior to 2023; Planned and As Needed are proposed as potential projects that may be implemented to support ongoing sustainability, adapt to changing conditions in the subbasin, or maintain other water management objectives. The list of Ongoing and Planned projects and management actions included in the GSP is shown in **Table ES-3**. The total estimated average annual benefit of the Ongoing projects and management actions at full implementation is almost 9,000 acre-feet per year, and the Planned projects and management actions have the estimated potential for over 9,000 additional acre-feet per year. There are an additional 18 As Needed projects and management actions included and described in **Section 5** of the GSP.

As GSP implementation proceeds, the GSAs will continue to accept additional projects and management actions proposed by agencies and stakeholders. The GSAs will continue to maintain a list of all proposed projects and management actions on the GSP website and, as needed, will periodically review projects and management actions for implementation.

Table ES-3. Ongoing and Planned Projects and Management Actions.

Project/Management Action Name	Project/ Management Action Type	Proponent	Project Status (GSP Description)	Gross Average Annual Benefit at Full Implementation (AF/yr)
Ongoing Projects and Management Actions: Projects and Management Actions in this category are planned to be completed prior to 2042. The expected yield of these projects and management actions are expected to support GSAs in achieving the GSP sustainability goal and responding to changing conditions in the Subbasin.				
System Modernization	Improved Water Management	Biggs-West Gridley Water District	Ongoing (Detailed)	3,320
System Modernization	Improved Water Management	Richvale Irrigation District	Ongoing (Detailed)	3,790
Boundary Flow and Primary Spill Measurement	Improved Water Management	Western Canal Water District	Ongoing (Detailed)	1,829
Planned Projects and Management Actions: Projects and Management Actions in this category are available if continued monitoring indicates that they are needed to meet the sustainability goal by 2042, or to maintain other water management objectives. The expected yield of these projects and management actions are expected to support GSAs in achieving the GSP sustainability goal and responding to changing conditions in the Subbasin.				
Installation of Additional Shallow Monitoring Wells[1]	Improved Data and Monitoring	All GSAs	Planned (Detailed)	N/A
Dual Source Irrigation Systems	In-Lieu Recharge	Butte Water District	Planned (Detailed)	9,772
Multi-Benefit Recharge	Direct Recharge	Multi-Agency / Jurisdictions	Planned (Detailed)	175
Grower Education	Improved Water Management	Multi-Agency / Jurisdictions	Planned (Detailed)	N/A

1. In contrast to the other Planned Projects and Management Actions, the Installation of Additional Shallow Monitoring Wells is scheduled for implementation and expected to be complete at the latest by the time of the first 5-Year Update to the GSP in 2027. Other Planned Projects and Management Actions will be implemented dependent on future monitoring and planning efforts, and funding sources.

ES-6 Plan Implementation

Administering and implementing the GSP, and monitoring and reporting progress, is projected to cost roughly $440,000 dollars per year in total for all eleven GSAs in the Butte Subbasin, with a total cost of $2.2 million over the first five years of implementation. This does not include the capital and annual operating cost of projects and management actions, which were described in the prior section. Costs are expected to be higher during years in which five-year periodic evaluations are required, and slightly lower during years in which annual reports are required.

Development of this GSP was funded through a Proposition 1 Grant, and contributions from individual GSAs (e.g. through in-kind staff time, or separately contracted consulting services).

Individual GSAs are also funding additional, ancillary studies and implementation efforts. To fund GSA operations and GSP implementation, GSAs are developing a financing plan that will include one or more of the following financing approaches:

- **Grants and low-interest loans**: GSAs will continue to pursue grants and low interest loans to help fund planning studies and other GSA activities. However, grants and low-interest loans are not expected to cover most GSA operating costs for GSP implementation.
- **Groundwater extraction charge**: A charge per acre-foot pumped would be used to fund GSP implementation activities.
- **Other Fees and charges**: Other fees may include permitting fees for new wells or development, transaction fees associated with contemplated groundwater markets, or commodity-based fees, all directed at aiding with sustainability objectives. Depending on the justification and basis for a fee, it may be considered a property-related fee subject to voting requirements of Article XIII D of the California Constitution (passed by voters in 1996 as Proposition 218) or a regulatory fee exempt from such requirements.
- **Assessments:** Special benefit assessments under Proposition 218 could include a per-acre (or per-parcel) charge to cover GSA costs.
- **Taxes:** This could include general property related taxes that are not directly related to the benefits or costs of a service (ad valorem and parcel taxes), or special taxes imposed for specific purposes related to GSA activities.

GSAs are pursuing a combined approach, targeting available grants and low interest loans, and considering a combination of fees and assessments to cover operating and program-specific costs as necessary. As required by statute and the State of California Constitution, GSAs would complete an engineer’s report, rate study, and other analysis to document and justify any rate, fee, or assessment.

While some sustainability projects began shortly after SGMA became law (e.g. Ongoing), the GSP implementation schedule allows time for GSAs to develop and implement projects and management actions to meet all sustainability objectives by 2042. **Figure ES-5** illustrates the GSP implementation schedule for projects and management actions implemented by each GSA. The GSP implementation schedule also shows mandatory reporting and updating for all GSAs, including annual reports and five-year periodic updates (evaluations) prepared and submitted to DWR.

RID	System Modernization									
BWGWD	System Modernization									
WCWD	Boundary Flow and Primary Spill Measurment									
BWD				Dual Source Irrigation Systems*						
Multiple GSAs				Multi-Benefit Recharge and Grower Education*						
All GSAs	Installation of Additional Shallow Monitoring Wells				Implement additional projects and management actions as necessary or dependent on funding					
	Annual Reporting				Annual Reporting		Annual Reporting		Annual Reporting	
				Periodic Evaluation		Periodic Evaluation		Periodic Evaluation		Periodic Evaluation
Time Period	2022	2023	2024-2026	2027	2028-2031	2032	2033-2036	2037	2038-2041	2042

*Note: Implementation and scale of these projects is dependent on funding availability.

Figure ES-5. Butte Subbasin GSP Implementation Schedule, 2022 – 2042

Figure ES-6 illustrates a tentative schedule for completion of GSP Studies to increase understanding of the Butte Subbasin, improve characterization of Subbasin conditions and data management, and, ultimately, to improve implementation of the GSP and sustainable groundwater management.

The GSP Implementation Plan uses the best available information and the best available science to provide a road map for the Butte Subbasin to meet its sustainability goal by 2042 and comply with the SGMA regulations. During each five-year update, progress will be assessed, and the implementation plan revised as necessary, to maintain or achieve the sustainability goal by 2042 and comply with the SGMA regulations.

Butte Creek Stream-Aquifer Interaction Study	Planned each year					
Sutter Buttes Water Quality Interbasin Working Group*	Planned each year					
Butte Basin Groundwater Model (BBGM) Updates and Enhancement*			Planned for 2024 through 2026			
Well Inventory Program*	Planned for 2022 through 2026					
Review and Updates of Data Management System (DMS)*	Planned for 2022 through 2024					
Reporting	Annual Report	Annual Report	Annual Report	Annual Report	Annual Report	Periodic Evaluation
Time Period	2022	2023	2024	2025	2026	2027

*Note: Implementation and scale of these studies is dependent on funding availability.

Figure ES-6. Butte Subbasin GSP Studies Implementation Schedule, 2022 – 2027

1. Introduction

1.1 Purpose of the Groundwater Sustainability Plan (GSP or Plan)

The purpose of this GSP is to characterize groundwater conditions in the Butte Subbasin, establish sustainability goals, and to describe programs and management actions the Groundwater Sustainability Agencies (GSAs) will implement to maintain sustainable groundwater management through 2042. This plan encompasses the entirety of the Butte Subbasin and has been collaboratively developed by the eleven GSAs within the Butte Subbasin, which include Biggs-West Gridley Water District (BWGWD) GSA, Butte Water District (BWD) GSA, City of Biggs GSA, City of Gridley GSA, Colusa Groundwater Authority (CGA) GSA, County of Butte GSA, County of Glenn GSA, Reclamation District No. 1004 (RD1004) GSA, Reclamation District No. 2106 (RD2106) GSA, Richvale Irrigation District (RID) GSA, and Western Canal Water District (WCWD) GSA.

This GSP also serves to comply with DWR's requirements that the Butte Subbasin GSAs prepare, adopt and implement a plan "consistent with the objective that a basin be sustainably managed within 20 years of Plan implementation without adversely affecting the ability of an adjacent basin to implement its Plan or achieve and maintain its sustainability goal over the planning and implementation horizon" as defined in the California Code of Regulations Title 23 (CCR), Section 350.4 (f) that detail the requirements and components of the GSP.

1.2 Sustainability Goal

As mandated under 23 CCR Section 354.24, the eleven GSAs within the Butte Subbasin have established a "sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline." Specifically, this sustainability goal establishes that the Butte Subbasin will be operated within its sustainable yield by 2027. Following this, adaptive management and the implementation of additional projects and management actions will be done to address changing conditions ensure that the Butte Subbasin continues to be operated within its sustainable yield for the 20 years following the initiation of GSP implementation in January 2022.

SGMA regulations define sustainable yield 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 Section 10721(w)). Subbasin sustainable yield must therefore be determined in the context of the complete basin setting, which includes historical, current, and projected conditions regarding groundwater, surface water, and land use. Groundwater sustainability in this Subbasin is dependent on surface water supplies and thus will always be vulnerable to any future conditions (hydrologic or regulatory) affecting the availability of surface water supplies. Potential future changes in surface water availability would first be addressed through adaptive management strategies that include implementation of additional projects and management actions necessary to remain sustainable, but future conditions that impact the future availability of surface water supplies may require revisions to sustainability indicators. Overall, long-term sustainability will be achieved through implementation of the projects and management actions and adaptive management as described in this GSP.

To maintain the sustainability goal, this GSP details accounting of the Butte Subbasin used to identify sustainable yield, and establishes the criteria for GSAs to operate sustainably. Finally, planned monitoring networks, projects, and management actions are proposed to maintain and verify sustainable groundwater use. To facilitate review, **Table 1-1** aligns the regulations with this GSP's corresponding section.

Table 1-1. Sustainable Goal Development and Associated GSP Sections.

Sustainability Goal Development	23 CCR Section	Requirement	GSP Section
Context, basis for goal	§ 354.12	Basin Setting	2.2
	§ 354.14	Hydrogeologic Conceptual Model	2.2.1
	§ 354.16	Groundwater Conditions	2.2.2
	§ 354.18	Water Budget	2.2.3
	§ 354.20	Management Areas	2.2.4
Establishment of goal	§ 354.24	Sustainability Goal	4.1.2
	§ 354.26	Undesirable Results	4.2
	§ 354.28	Minimum Thresholds	4.3
	§ 354.30	Measurable Objectives	4.3
Measures of ensuring goal achievement	§ 354.32	Introduction to Monitoring Networks	3.1
	§ 354.34	Monitoring Network	3.2 through 3.6
	§ 354.36	Representative Monitoring	3.2 through 3.6
	§ 354.38	Assessment and Improvement of Monitoring Network	3.2 through 3.6. 4.4, 5.9
	§ 354.44	Projects and Management Actions	5

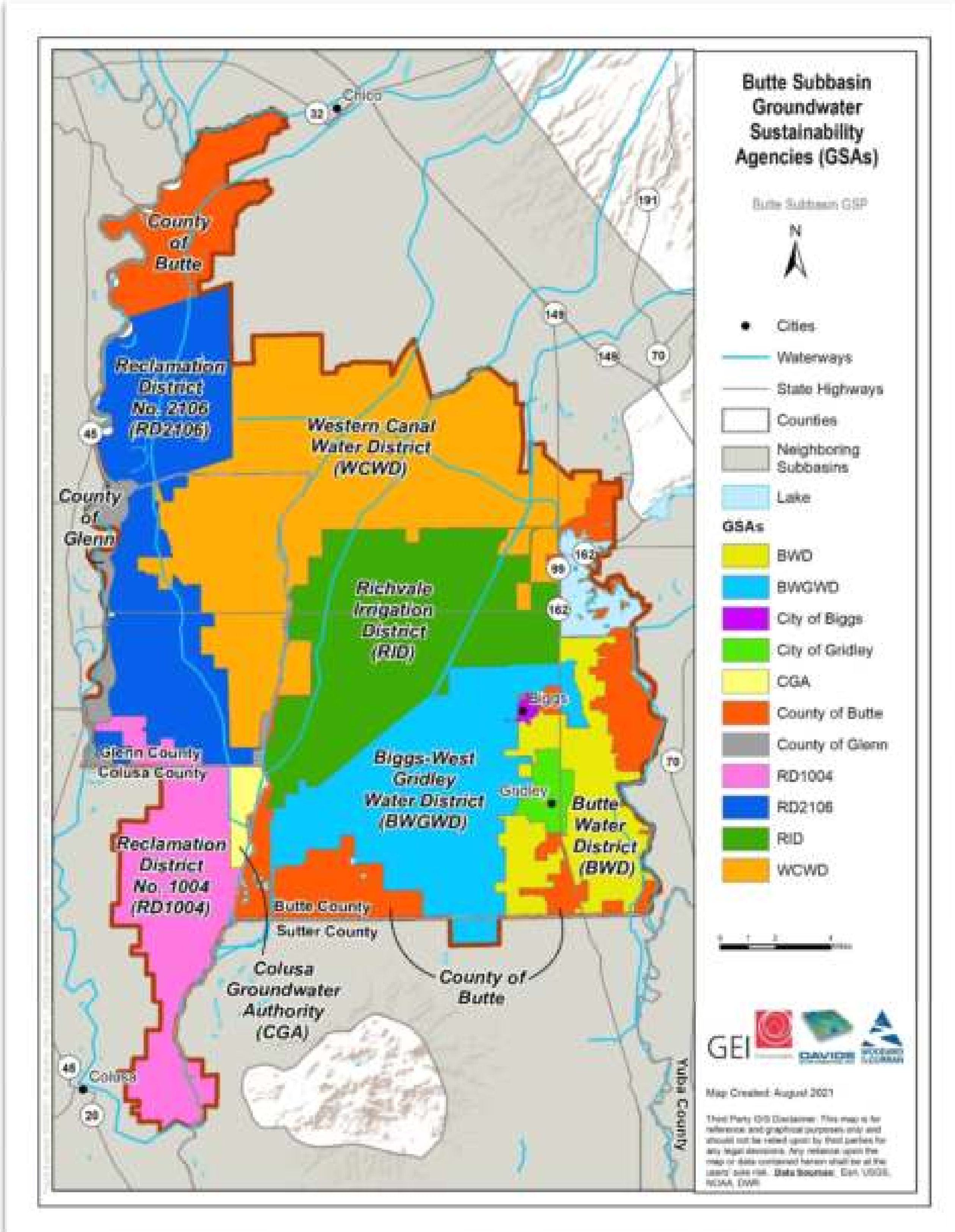
1.[illegible] Agency Information *(Reg. § 354.6)*

Eleven GSAs have formed within the Butte Subbasin; they include:

1. Biggs-West Gridley Water District (BWGWD) GSA
2. Butte Water District (BWD) GSA
3. City of Biggs GSA
4. City of Gridley GSA
5. Colusa Groundwater Authority (CGA) GSA
6. County of Butte GSA
7. County of Glenn GSA
8. Reclamation District No. 1004 (RD1004) GSA

9. Reclamation District No. 2106 (RD2106) GSA
10. Richvale Irrigation District (RID) GSA
11. Western Canal Water District (WCWD) GSA

Figure 1-1 delineates the areas within the Butte Subbasin managed by each of the GSAs; in total, the eleven GSAs cover the entirety of the Butte Subbasin. Information on each GSA (including their mailing address, plan manager and contact information, organization and management structure, and legal authority) is described below. Information provided by each GSA to DWR pursuant to CWC Section 10723.8 is included in **Appendix 1.A**.



1081

1082 *Figure 1-1. Butte Subbasin Groundwater Sustainability Agencies (GSAs).*

All the GSAs in the Butte subbasin entered into a Cooperation Agreement ("Cooperation Agreement Among the Groundwater Sustainability Agencies in the Butte Subbasin" – available in **Appendix 1.B**) for the primary purposes of:

1. Developing, adopting, and implementing a single, legally sufficient GSP for the Butte Subbasin in order to implement SGMA requirements and achieve the sustainability goals outlined in SGMA
2. Cooperatively carry out the purposes of SGMA

Additional purposes include:

1. Coordinating subbasin-wide public involvement and stakeholder outreach and engagement in developing and implementing the Butte Subbasin GSP
2. Maintaining mutual respect for the autonomy of individual GSAs and preservation of each Member's separate legal authorities, powers, duties and rights as separate public agencies and GSAs. All decision-making authority resides with the GSAs' governing bodies.

The Cooperation Agreement created the Butte Subbasin Advisory Board (Butte Advisory Board, or BAB). The Butte Advisory Board is composed of one member from the governing board of each GSA and includes an alternate member from each of the GSAs. The creation of the BAB accomplished the following:

1. Established a GSA cooperation forum
2. Established a publicly noticed venue pursuant the Ralph M. Brown Act for public involvement in GSP development and implementation in the Basin
3. Created a mechanism whereby GSAs raise and attempt in good faith to resolve disputes that may occur between and among GSAs
4. Allowed the BAB make advisory recommendations to the GSAs concerning development and implementation of the GSP.

Topics where the GSAs desire coordinated decision making will be considered by the Butte Advisory Board, and the GSA managers will strive for unanimous recommendations that will be presented to each GSA's governing bodies for consideration. The GSAs desire to informally resolve all disputes and controversies, whenever possible, at the least possible level of formality and cost. If a dispute occurs, the disputing GSAs shall meet and confer to discuss in an attempt to resolve the matter. If informal resolution cannot be achieved, the matter will be referred to the BAB for resolution. The Butte Advisory Board may engage the services of a trained mediator or resort to all available legal and equitable remedies to resolve disputes.

Each GSA as a GSA has the sole right to: 1) approve the sections or chapters of the GSP related to Sustainable Criteria and Projects and Actions as applicable within the GSA's boundaries or Management Area; 2) consider the interests of beneficial uses and users as required by Water code §10723.4 and GSP regulation §354.10; and 3) exercise the powers, without limitation, conferred upon a GSA by SGMA.

The Cooperation Agreement is initially funded through a GSP grant awarded by the DWR to Butte County and through in-kind contributions of GSAs. In subsequent years and as needed, continuing cooperation may be funded by additional GSA contributions. If the GSAs decide that cost-sharing is required for any contract or expenditure made pursuant to this Agreement, any cost-sharing allocations shall be agreed to in writing by the GSAs in advance of executing any contracts with consultants, vendors, or other contractors or incurring any expense. Such written approval for cost-sharing shall be subject to any necessary approvals required by each GSA's governing body or designee pursuant to that GSA's contract approval procedures. Any such contracts shall be drafted in a manner that reflects that consultants, vendors, or contractors hired to perform work under this Agreement are working on behalf of the GSAs and will be expected to work with the GSAs on a collective basis and with each GSA on an individual basis, as needed. Such contracts shall be made enforceable by the GSAs.

Information about individual GSAs is included below. The estimated cost of implementing the GSP and plans for meeting those costs are described in **Section 1.4**.

1.3.1 Biggs-West Gridley Water District (BWGWD) GSA

1.3.1.1 *Plan Manager and Mailing Address*

Plan Manager: Eugene Massa, General Manager
emassa@bwgwater.com
530-846-3317

Mailing Address: 1713 West Biggs-Gridley Road, Gridley, CA 95948

1.3.1.2 *Organization and Management Structure*

Biggs-West Gridley Water District was formed on September 24, 1942 by a vote of landowners within the proposed district. It operates under a Board of Directors.

1.3.1.3 *Legal Authority*

Biggs-West Gridley Water District was formed in 1942 and is a California Water District established and operated under the provisions of the California Water District Law and is responsible for providing irrigation water to agricultural and environmental water users within its service area boundary. BWGWD is committed to an open and inclusive process of implementing SGMA in the Butte Subbasin in coordination with other GSAs.

1.3.2 Butte Water District (BWD) GSA

1.3.2.1 *Plan Manager and Mailing Address*

Plan Manager: Mark Orme
morme@buttewater.net
530-846-3100

Mailing Address: 735 Virginia Road, Gridley, CA 95948

1.3.2.2 *Organization and Management Structure*

Butte Water District was proposed, organized, and formed 1952. It operates under a Board of Directors.

1.3.2.3 *Legal Authority*

Butte Water District was formed 1952 and is a California Water District responsible for providing irrigation water to agricultural water users within its service area boundary. BWD is committed to an open and inclusive process of implementing SGMA in the Butte Subbasin in coordination with other GSAs.

1.3.3 City of Biggs GSA

1.3.3.1 *Plan Manager and Mailing Address*

Plan Manager: Mark Sorensen, City Manager
mark@marksorensen.net
530-868-0100

Mailing Address: 465 C Street, Box 307, Biggs, CA 95917-0307

1.3.3.2 *Organization and Management Structure*

Biggs is a general law city operating under the California Government Code. Five Council Members are presently elected citywide (at-large) and serve four-year terms; each Council Member must reside within the city limits. The City Council is the legislative body of Biggs with a broad range of municipal powers. It holds monthly meetings which members of the public are invited to attend to observe and comment.

1.3.3.3 *Legal Authority*

The City of Biggs is the local agency with exclusive drinking water supply, water quality and water production management responsibilities within and for the City of Biggs. The City of Biggs committed to an open and inclusive process of implementing SGMA in the Butte Subbasin in coordination with other GSAs.

1.3.4 City of Gridley GSA

1.3.4.1 *Plan Manager and Mailing Address*

Plan Manager: Paul Eckert, City Administrator
eckert@gridley.ca.us
530-846-4675

Mailing Address: 685 Kentucky Street, Gridley, CA 95948

1.3.4.2 *Organization and Management Structure*

The City of Gridley utilizes the Council/Administrator Form of Government. The City Council is the governing body of the City. The five Councilmembers are elected at large by the voters of Gridley for four-year terms, and the Mayor is elected by a majority vote of the City Council. The City Council is the legislative body of Gridley; it holds bimonthly meetings which members of the public are invited to attend to observe and comment.

1.3.4.3 *Legal Authority*

The City of Gridley is the local agency with water, water management, and land use responsibilities within its incorporated boundary and adopted Sphere of Influence boundary. The City of Gridley committed to an open and inclusive process of implementing SGMA in the Butte Subbasin in coordination with other GSAs.

1.3.5 Colusa Groundwater Authority (CGA) GSA

1.3.5.1 *Plan Manager and Mailing Address*

Plan Manager: Mary Fahey, Water Resources Manager
mfahey@countyofcolusa.com
530-458-0719

Mailing Address: 100 Sunrise Blvd., Suite A, Colusa, CA 95932

1.3.5.2 *Organization and Management Structure*

The Colusa Groundwater Authority is a twelve-member Joint Powers Authority established on June 29, 2017 by execution of the Joint Exercise of Powers Agreement Establishing the Colusa Groundwater Authority. The business of the Authority is conducted by a Board of Directors that is composed of and appointed as follows:

- One member of the County Board of Supervisors, appointed by the County Board of Supervisors;
- One member of the Colusa City Council, appointed by the City of Colusa City Council;
- One member of the Williams City Council, appointed by the City of Williams City Council;
- One member of the Board of the Glenn Colusa Irrigation District, appointed by the Glenn Colusa Irrigation District;
- One member of the Board of the Maxwell Irrigation District or the Westside Water District, said appointment to alternate every two years beginning with an appointment by the Maxwell Irrigation District of one of its Board members;
- One member of the Board of the Princeton-Codora-Glenn Irrigation District or the Provident Irrigation District, said appointment to alternate every two years beginning with an appointment by the Princeton-Codora-Glenn Irrigation District of one of its Board members;
- One member of the Board of the Colusa County Water District, appointed by the Colusa County Water District;
- One member of the Board of Reclamation District 108, appointed by Reclamation District 108;
- One member of the Board of Reclamation District 479, appointed by Reclamation District 479;
- One member of the Board of the Colusa Drain Mutual Water Company, proposed by the Colusa Drain Mutual Water Company, which will be appointed by the Authority;
- Two representatives of private groundwater pumpers, recommended by the Colusa County Groundwater Commission and appointed by the County Board of Supervisors, who are members of the Colusa County Groundwater Commission.

Decision-making Process

The Board of Directors of the Colusa Groundwater Authority will conduct all business by vote of a majority of the Directors present, if a quorum shall be established, and each Director shall have one (1) vote. Prior to voting, Board members shall endeavor in good faith to reach consensus on the matters to be determined such that any subsequent vote shall be to confirm the consensus of the Board. If any Board member or Member strongly objects to a consensus-based decision prior to a vote being cast, the Board shall work in good faith to reasonably resolve such strong objection, and, if the same is not resolved collaboratively, then the matter will proceed to a vote for final resolution. Supermajority vote is required for certain actions.

1.3.5.3 *Legal Authority*

RECITALS (Joint Exercise of Powers Agreement Establishing the Colusa Groundwater Authority)

- A. On August 29, 2014, the California Legislature passed comprehensive groundwater legislation contained in SB 1168, SB 1319 and AB 1739. Collectively, those bills, as subsequently amended, enacted the “Sustainable Groundwater Management Act,” or

"SGMA." Governor Brown signed the legislation on September 16, 2014, and it became effective on January 1, 2015.

- B. Each of the Members overlies the Colusa and Yolo County portions of the Colusa Subbasin of the Sacramento Valley Groundwater Basin, California Department of Water Resources Basin No. 5-021.52, and/or the Colusa County portion of the Butte Subbasin of the Sacramento Valley Groundwater Basin, Department of Water Resources Basin No. 5-021.70, as such subbasin boundaries may be modified from time to time in accordance with Cal. Water Code Section 10722.2 ("Basin").
- C. Each of the Members is authorized to become, or participate in, a Groundwater Sustainability Agency ("GSA") under SGMA.
- D. The Members desire, through this Agreement, to form the Colusa Groundwater Authority ("Authority"), a separate legal entity, for the purpose of acting as the GSA for the Basin.
- E. The mission of the Authority is to provide a dynamic, cost-effective, flexible and collegial organization to ensure SGMA compliance within the Basin.
- F. The Authority will serve a coordinating, administrative and implementing role in order to provide for sustainable groundwater management of the Basin. Each of the Members (or groups of Members) will have responsibilities to carry out the Groundwater Sustainability Plan and to coordinate with the Authority to implement SGMA within the Members' jurisdictional areas.
- G. This Agreement shall form the Authority, which shall be the GSA for purposes of carrying out SGMA in the Basin.

1.3.6 County of Butte GSA

1.3.6.1 *Plan Manager and Mailing Address*

Plan Manager: Christina Buck
cbuck@buttecounty.net
530-552-3595

Mailing Address: 308 Nelson Avenue, Oroville, CA 95965

1.3.6.2 *Organization and Management Structure*

The County of Butte GSA is governed by the Butte County Board of Supervisors. The Butte County Water Commission provides advice to the Board of Supervisors on water related matters. The Water Commission is a nine member, Brown Act compliant committee that meets once a month. The Butte County Department of Water and Resource Conservation staffs the Water Commission and executes water resource programs for the County of Butte. The Department of Water and Resource Conservation has been designated to lead the SGMA implementation efforts for the County.

1.3.6.3 *Legal Authority*

Butte County has land use authority except for areas within the jurisdictional boundaries of local municipalities (e.g., Cities of Chico, Biggs, Gridley, Oroville and Paradise). Butte County has flood management authority and water supply responsibility through its State Water Project Contract. Butte County has an adopted Groundwater Management Plan for the portions of the county.

1.3.7 County of Glenn GSA

1.3.7.1 *Plan Manager and Mailing Address*

Plan Manager: Lisa Hunter, Water Resources Coordinator
lhunter@countyofglenn.net
530-934-6501

Mailing Address: 720 North Colusa Street, Willows, CA 95988

1.3.7.2 *Organization and Management Structure*

The County of Glenn GSA is governed by the Glenn County Board of Supervisors. The Glenn County Water Advisory Committee provides advice to the Board of Supervisors on water related matters, and the Glenn County Water Resources Program is responsible for disseminating information, facilitating outreach, and encouraging involvement in groundwater and water resource activities in Glenn County.

1.3.7.3 *Legal Authority*

The County of Glenn has land use and flood control responsibilities in the Butte Subbasin. Glenn County also has a Groundwater Management Plan for all portions of the County, including the areas within the Butte Subbasin.

1.3.8 Reclamation District No. 1004 (RD1004) GSA

1.3.8.1 *Plan Manager and Mailing Address*

Plan Manager: Terry Bressler, District Manager
rd1004@comcast.net
530-458-7459

Mailing Address: 317 Fourth Street, Colusa, CA 95932

1.3.8.2 Organization and Management Structure

Reclamation District No. 1004 is a California reclamation district formed under Water Code section 50000 et seq. with authority and responsibility under those statutes. It operates under the Direction of a Board of Directors.

1.3.8.3 Legal Authority

Reclamation District No. 1004 is a California reclamation district formed under Water Code section 50000 et seq. with authority and responsibility under those statutes for acquiring property, acquiring and operating water rights and irrigation systems, and constructing, maintaining, and operating drains, canals, sluices, water gates, levees, and pumping plants (among others) for the reclamation of land and control of flooding within its boundaries. The District is committed to an open and inclusive process of implementing SGMA in the Butte Subbasin in coordination with other GSAs.

1.3.9 Reclamation District No. 2106 (RD2106) GSA

1.3.9.1 Plan Manager and Mailing Address

Plan Manager: Danny Robinson
drobinson@llanoseco.com
530-624-6150

Mailing Address: 8369 Hugh Baber Lane, Chico, CA 95928

1.3.9.2 Organization and Management Structure

Reclamation District No. 2106 is a California reclamation district formed under Water Code section 50000 et seq. with authority and responsibility under those statutes. It operates under the Direction of a Board of Directors.

1.3.9.3 Legal Authority

Reclamation District No. 2106 is a California reclamation district formed under Water Code section 50000 et seq. with authority and responsibility under those statutes for acquiring property, acquiring and operating water rights and irrigation systems, and constructing, maintaining, and operating drains, canals, sluices, water gates, levees, and pumping plants (among others) for the reclamation of land and control of flooding within its boundaries. The District is committed to an open and inclusive process of implementing SGMA in the Butte Subbasin in coordination with other GSAs.

1.3.10 Richvale Irrigation District (RID) GSA

1.3.10.1 *Plan Manager and Mailing Address*

Plan Manager: Sean Early
searly@richvaleid.com
530-701-8181
www.richvaleid.com

Mailing Address: 1148 Richvale Highway, Richvale, CA 95974

1.3.10.2 *Organization and Management Structure*

Richvale Irrigation District is a Special District. It operates under the Direction of a Board of Directors (3 Voting + 1 Treasurer = 4). The Richvale Irrigation District Board are elected by the landowners within the District boundary. Serving at the will of the Board is the Board Secretary/Manager and one Attorney as General Counsel. The Richvale Irrigation District Board meets monthly on the 3rd Thursday. The Decision-Making Process for RID is as follows: The Board of Directors sets policy through regular and special board meetings and the Secretary/Manager enacts those policies.

1.3.10.3 *Legal Authority*

Richvale Irrigation District ("RID") is an Irrigation District in Butte County formed and existing under Division 11 of the California Water Code (hereinafter "Wat. Code"), § 20500 et. seq. As an Irrigation District that maintains and manages a water supply, RID is a local agency as defined by the Sustainable Groundwater Management Act ("SGMA"), Wat. Code § 10721(n) (" 'Local agency' means a local public agency that has water supply, water management, or land use responsibilities within a groundwater basin."). Consistent with Chapter 4 of SGMA, RID formed the Richvale Irrigation District GSA ("RID GSA"), one of eleven independent Groundwater Sustainability Agencies overlying the Butte Subbasin. The RID GSA is an exclusive GSA within RID GSA's boundary, pursuant to Wat. Code §§ 10723 and 10723.8. The RID GSA is granted the statutory powers of a GSA and may implement the Groundwater Sustainability Plan ("GSP") for the Butte Subbasin, consistent with SGMA. Wat. Code § 10720 et. seq. The GSP for the Butte Subbasin is a single Plan developed and implemented in cooperation with all eleven Butte Subbasin GSAs, including the RID GSA. Wat. Code § 10727(b)(2). Upon adoption and submission of the GSP, the RID GSA may exercise the powers found in SGMA, Chapter 5 in addition to, and not as a limitation on, powers under other existing authority. Wat. Code § 10725(b).

1.3.11 Western Canal Water District (WCWD) GSA

1.3.11.1 *Plan Manager and Mailing Address*

Plan Managers: Ted Trimble
Ted@westerncanal.com
530-342-5083

Anjanette Shadley
anjanette@westerncanal.com
530-342-5083

Mailing Address: 2003 Nelson Ave, Richvale, CA 95958

1.3.11.2 *Organization and Management Structure*

Western Canal Water District (WCWD) was formed by a vote of landowners on December 18, 1984. It operates under a Board of Directors.

1.3.11.3 *Legal Authority*

Western Canal Water District (WCWD) was formed by a vote of landowners on December 18, 1984 and is a California Water District responsible for providing irrigation water to agricultural and environmental water users within its service area boundary. WCWD has a history of actively participating in local and statewide surface water and groundwater management and is engaged in a collaborative, open, and inclusive process in implementing SGMA.

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

The costs of GSP implementation have been estimated on a Subbasin-wide level and have been aggregated into six (6) categories including GSA administration, GSP studies, GSP implementation and updates, project planning, monitoring and data management, and contingency to cover any unanticipated costs. The Subbasin-wide costs will be distributed amongst the eleven GSAs in the Butte Subbasin. However, GSAs manage costs and expenses in different ways and as such may record costs in different categories than the six categories shown here.

These estimated costs are documented in Plan Implementation Section (**Section 6**), along with a description of GSP financing alternatives and approaches (**Section 6.3**) that GSAs will use to meet costs of GSP implementation.

1.5 GSP Organization

This GSP has been developed by the consulting team on behalf of the Butte Subbasin GSAs. The consulting team is comprised of Davids Engineering (DE), Woodard & Curran (W&C), and GEI Consultants (GEI).

The GSP is organized as follows:

- **Section 1** of this Plan provides an introduction to the Butte Subbasin GSAs and the development of this GSP.
- **Section 2** provides a detailed summary of the Plan area and development of the basin setting, including the hydrogeologic conceptual model, current and historical groundwater conditions, water budgets, and management areas.
- **Section 3** describes the monitoring network objectives, followed by a description of the proposed monitoring networks to track and verify progress toward the subbasin sustainability goals (which are described subsequently).
- **Section 4** establishes the subbasin sustainability goal to be maintained through coordination among all GSAs in the subbasin. This section also establishes undesirable results and sustainability thresholds for each sustainability indicator.
- **Section 5** describes projects and management actions for achieving the subbasin sustainability goal.
- **Section 6** presents the Plan implementation strategy, costs, and schedule.

This organization generally aligns with the Plan Contents outlined in 23 CCR Section 354. To facilitate DWR review and assure compliance with all applicable GSP regulations, **Table 1-2** was prepared to cross-reference between sections of this GSP to applicable sections and the GSP regulations. Terminology in this GSP has also been used in alignment with the SGMA definitions provided in CWC Section 10721 and in 23 CCR Section 351. These definitions are provided as **Appendix 1.D** of this GSP.

Table 1-2. Cross Reference of GSP Regulations[9] and Associated GSP Sections.

Subarticle	Section	Paragraph	Requirement	GSP Section
1. Administrative Information	4. General Information	(a)	Executive summary	Executive Summary
		(b)	List of references and technical studies	7
	6. Agency Information	-	Agency information pursuant to CWC § 10723.8, along with:	App. 1.A
		(a)	Agency name and mailing address	1.3
		(b)	Agency organization and management structure, persons with management authority for Plan implementation	1.3
		(c)	Plan manager name and contact information	1.3
		(d)	Legal authority of agency	1.3
		(e)	Estimate of Plan implementation costs and description of how Agency plans to meet costs	1.4, 6.1, 6.2, 6.3
	8. Description of Plan Area	(a)	Maps of Plan area	2.1.1
		(b)	Written description of Plan area	2.1.1
		(c)-(d)	Identification of existing water resource monitoring and management programs, and description of any such planned programs	2.1.2
		(e)	Description of conjunctive use programs	2.1.2
		(f)	Description of the land use elements or topic categories	2.1.3
		(g)	Description of additional Plan elements (CWC § 10727.4)	2.1.4
	10. Notice and Communication	(a)	Description of the beneficial uses and users of groundwater in the subbasin	2.1.5, 2.1.5.2
		(b)	List of public meetings	2.1.5, App. 2.A
		(c)	Comments and responses regarding the Plan	2.1.5, App. 2.A
		(d)	Description of communication procedures	2.1.5, App. 2.A
2. Basin Setting	12. Introduction to Basin Setting	-	Information about the basin setting (physical setting, characteristics, current conditions, data gaps, uncertainty)	2.2
	14. Hydrogeologic Conceptual Model	(a)	Description of the subbasin hydrogeologic conceptual model	2.2.1
		(b)	Summary of regional geologic and structural setting, subbasin boundaries, geologic features, principal aquifers and aquitards	2.2.1
		(c)	Cross-sections depicting major stratigraphic and structural features	2.2.1
		(d)	Maps of subbasin physical characteristics	2.2.1

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

Subarticle	Section	Paragraph	Requirement	GSP Section
	16. Groundwater Conditions	(a)-(g)	Description of current and historical groundwater conditions including: 1. Groundwater elevation 2. Change in storage 3. Seawater intrusion 4. Groundwater quality issues 5. Land subsidence 6. Interconnected surface water systems 7. Groundwater dependent ecosystems	2.2.2
	17. Water Budget	(a)	Water budget providing total annual volume of groundwater and surface water entering and leaving the subbasin, including historical, current and projected water budget conditions, and change in storage.	2.2.3
		(b)-(f)	Development of a numerical groundwater and surface water model to quantify current, historical, and projected: 1. Total surface water entering and leaving by water source type 2. Inflow to the groundwater system by water source type 3. Outflows from the groundwater system by water use sector 4. Change in groundwater storage 5. Overdraft over base period 6. Annual supply, demand, and change in storage by water year type. 7. Estimated sustainable yield	2.2.3
	20. Management Areas	(a)	Description of management areas	2.2.4
		(b)	Describe purpose, minimum thresholds, measurable objectives, monitoring, analysis	N/A
		(c)	Maps and supplemental information	N/A
3. Sustainable Management Criteria	22. Introduction to Sustainable Management Criteria	-	Criteria by which an Agency defines conditions that constitute sustainable groundwater management for the subbasin	4
	24. Sustainability Goal	-	Description of subbasin sustainability goal, including basin setting information used to establish the goal, sustainability indicators, discussion of measures to ensure the subbasin will be operated within its sustainable yield, and an explanation of how the sustainability goal is likely to be achieved and maintained.	4.1.2
	26. Undesirable Results	(a)	Processes and criteria used to define undesirable results applicable to the subbasin.	4.2
		(b)-(c)	Description of undesirable results, including cause of groundwater conditions and potential effects on beneficial uses and users of groundwater.	4.2
	28. Minimum Thresholds	(a)	Establish minimum thresholds to quantify groundwater conditions for each applicable sustainability indicator.	4.3

Subarticle	Section	Paragraph	Requirement	GSP Section
		(b)-(d)	Describe information and criteria to select, establish, justify, and quantitatively measure minimum thresholds.	4.3
	30. Measurable Objectives	(a)-(g)	Establish measurable objectives, including interim milestones in increments of five years, to achieve and maintain the subbasin sustainability goal.	4.3
4. Monitoring Networks	32. Introduction to Monitoring Networks	-	Description of monitoring network, monitoring objectives, monitoring protocols, and data reporting.	3
	34. Monitoring Network	(a), (e)-(g)	Development of monitoring network to yield representative information about groundwater conditions.	3
		(b)-(d)	Monitoring network objectives.	3.1
		(h)	Maps and tables of monitoring sites.	3.2 through 3.6
		(i)	Monitoring protocols.	3.2 through 3.6
	36. Representative Monitoring	(a)-(c)	Designation of representative monitoring sites.	3.2 through 3.6
	38. Assessment and Improvement of Monitoring Network	(a)-(d)	Evaluation of monitoring network, including uncertainty, data gaps, and efforts to fill data gaps	3.2 through 3.6, 4.4, 5.9
		(e)	Adjustment of monitoring frequency and density to assess management action effectiveness	3.2 through 3.6
	40. Reporting Monitoring Data to the Department	-	Copy of monitoring data from data management system	3.1
5. Projects and Management Actions	44. Projects and Management Actions	(a)-(c)	Description of projects and management actions to achieve and maintain the subbasin sustainability goal.	5

2 Plan Area and Basin Setting

2.1 Description of the Plan Area (Reg. § 354.8)

The Plan Area is defined as the Butte Subbasin (5-21.70), part of the Sacramento Valley Groundwater Basin, as described in DWR Bulletin 118 (DWR, 2016) with boundary updates approved most recently in Spring 2021.

The lateral extent of the subbasin is defined by the subbasin boundaries, which were finalized throughs basin boundary modification requests submitted to and reviewed and approved by DWR in Spring 2021. The Butte Subbasin is comprised of portions of the former East Butte and West Butte Subbasins, which are described in Bulletin 118 (DWR, 2016). It is bounded by the following subbasins: Vina to the north, Corning to the northwest, Colusa to the west, Sutter to the south, and Wyandotte Creek to the east (**Figure 2-1**). The Sacramento River and Feather River flow along the western boundary and eastern boundary of portions of the Subbasin, respectively, as well.

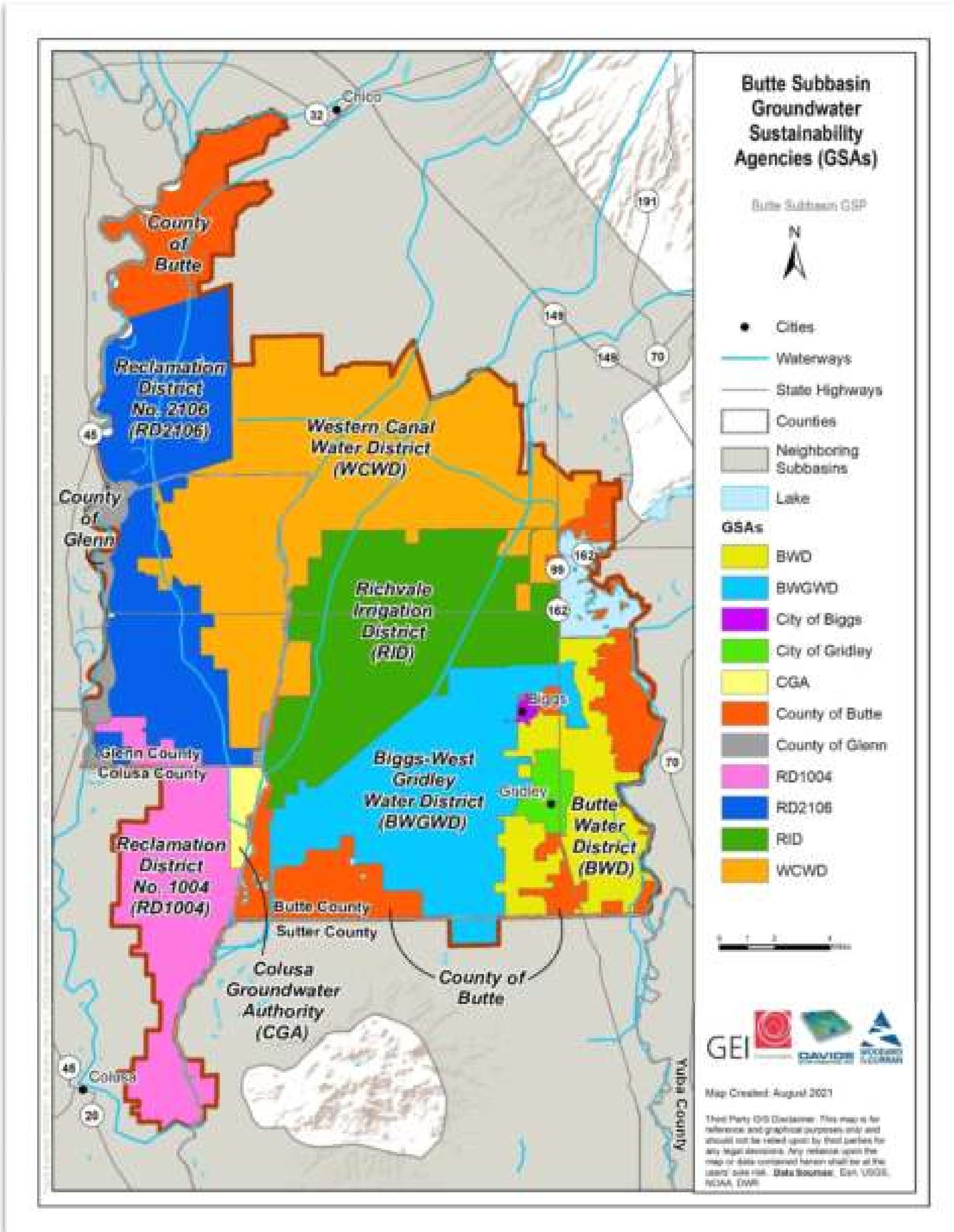


Figure 2-1. Butte Subbasin GSAs and Neighboring Subbasins.

The vertical boundaries of the subbasin are the land surface (upper boundary) and the definable bottom of the basin (lower boundary). The definable bottom was established as part of development of the preliminary hydrogeologic conceptual model (HCM) during previous data collection and analysis efforts conducted by DE and GEI (**Section 2.2.1**). The vertical extent of the subbasin is subdivided into a surface water system (SWS) and groundwater system (GWS). The SWS represents the land surface down to the bottom of plant root zone[10], within the lateral boundaries of the subbasin. The GWS extends from the bottom of the root zone to the definable bottom of the subbasin, within the lateral boundaries of the subbasin.

2.1.1 Summary of Jurisdictional Areas and Other Features (Reg. § 354.8 b)

As identified in **Section 1.3**, the Butte Subbasin is divided among eleven GSAs for GSP development. **Figure 2-1** depicts the areas managed exclusively by each GSA in this GSP; no area in the subbasin is covered by an alternative. The subbasin lies within the jurisdictional boundaries of Butte, Colusa, and Glenn Counties. Land use areas in the Butte Subbasin can be broadly classified as agricultural, urban, wetlands, and native vegetation. Agricultural land use (and water use) encompasses all agricultural crops in the Butte Subbasin, including idle agricultural land. Managed wetlands are state and federally managed lands managed to provide wildlife habitat and environmental benefits. Urban land use includes urban, industrial, and semi-agricultural land.

2.1.2 Water Resources Monitoring and Management Programs (Reg. § 354.8 c, d, e)

Existing surface water and groundwater monitoring and management programs within the Butte Subbasin are identified below following a summary of water planning documents applicable to the Subbasin GSAs.

Continued monitoring is required to track the progress of GSP implementation by providing data on groundwater and surface water availability in the subbasin. The monitoring network is described in **Section 3**.

2.1.2.1 Water Management and Planning Documents

As stewards of the water resources within their jurisdictions, the local agencies that have formed each of Butte Subbasin's GSAs have participated in, prepared and adopted several water planning documents in the past. These include:

[10] The depth to the bottom of the root zone varies by crop, but typically ranges from 2-7 feet (ASCE, 2016).

- Regional Water Plans
  - Northern Sacramento Valley Integrated Regional Water Management Plan
    - The six counties of the Northern Sacramento Valley have been working together for over 10 years to lay the foundation for an integrated regional plan to address water-related issues such as economic health and vitality; water supply reliability; flood, stormwater and flood management; water quality improvements; and ecosystem protection and enhancement. The counties have completed the development of a valley-wide Integrated Regional Water Management Plan, and have committed to continuing the efforts of regional water management through this plan. The Integrated Regional Water Management (IRWM) is a collaborative effort to enhance coordination of the water resources in a region. IRWM involves multiple agencies, stakeholders, tribes, individuals and groups to address water-related issues and offer solutions which can provide multiple benefits to the region. Representatives of the six counties are working in partnership with community stakeholders, tribes and the public to identify the water-related needs of the region. This information was used to develop goals and objectives of the IRWM Plan, and the identification of projects and programs to be included in the Plan. The Plan was adopted in April, 2014, and will better position the region and local partners to receive funding for high-priority projects.
  - Feather River Regional Agricultural Water Management Plan (FRRAWMP)
    - A regional agricultural water management plan has been developed for the irrigation water suppliers along the Feather River, many of which are within the Butte Subbasin. The plan is comprised of regional components and supplier-specific components. The regional components include an inventory of surface water and groundwater supplies and uses and through water balance analyses characterizes the interaction between irrigated lands, underlying groundwater systems, and the surrounding environment; an evaluation of opportunities to enhance water management and monitoring in the region to meet local, regional, and statewide water management objectives; and identification and characterization of interdependencies between agricultural water suppliers and other water uses, including other agriculture in the region and important wetlands and aquatic ecosystems; among other components. The FRRAWMP was originally developed in 2014 and most recently updated in 2021.
- Agricultural Water Management Plans (AWMPs)

  - Butte Water District, Biggs-West Gridley Water District, Richvale Irrigation District, and Western Canal Water District have all developed Agricultural Water Management Plans as part of the regional FRRAWMP. These AWMPs were most recently updated in 2021.
  - Reclamation District No. 1004 has developed Water Management Plans as part of the Sacramento Valley Regional Water Management Plan, (SVRWMP) prepared by the Sacramento River Settlement Contractors in cooperation with the U.S. Bureau of Reclamation. The SVRWMP was most recently updated in 2016, and the RD1004 AWMP was most recently updated in 2021.
- Groundwater Management Plans
  - The County of Butte has a Groundwater Management Plan that covers the entire County except for areas covered by Urban Water Management Plans. The Butte County Groundwater Management Plan can be found at: http://www.buttecounty.net/waterresourceconservation/groundwatermanagementplan
  - The County of Colusa has a Groundwater Management Plan that covers the entire County; it is available online at: https://www.countyofcolusa.org/658/Groundwater-Management-Plan
  - The County of Glenn has a Groundwater Management Plan that covers the entire County; more information can be found at: https://www.countyofglenn.net/committee/water-advisory-committee/management-plan
- Other Plans
  - Portions of the Butte subbasin is subject to the Butte County General Plan 2030, the Glenn County General Plan, Colusa County General Plan, the City of Biggs General Plan and the City of Gridley General Plan. In 2018, the Camp Fire destroyed 18,000 structures in Butte County displacing over 27,000 residents. In 2020, the North Complex Fire destroyed homes in Berry Creek, Feather Falls and other areas. While the Town of Paradise, Concow, Berry Creek and other impacted areas rebuild, many residents have relocated to other parts of Butte County. The existing General Plans may not fully account for the relocation of Camp Fire survivors. A focused accounting of changes to residential land use as a result of the Camp Fire and other wildfire events should be conducted.

Information developed for these plans regarding GSA surface water and groundwater supplies, distribution infrastructure, and monitoring programs have contributed to the development of this GSP.

Development and implementation of this GSP has and will continue to consider the interests of all beneficial uses and users of groundwater, including agricultural water users, municipal water

users, disadvantaged communities (DACs), interconnected surface water (ISW) habitats, groundwater dependent ecosystems (GDEs), and other stakeholders.
Implementation of this GSP will support all goals for the protection of natural resources and DACs, including those established in the plans above, consistent with SGMA and GSP regulations.

2.1.2.2 *Surface Water Monitoring and Management Programs*

Surface water flows into and within the Butte Subbasin are extensively monitored through existing federal, state, regional, and local programs. Data and spatial information from these monitoring programs have been incorporated directly into this GSP to support water budget development, per 23 CCR Section 354.18.

These sources and the data they provide are summarized below.

Federal, State, and Regional Programs

In support of GSP development, surface water data were collected from the following agencies and programs:

- California Data Exchange Center (CDEC)
- California State Water Resources Control Board (SWRCB)
  - SWRCB GeoTracker
- Department of Water Resources Water Data Library (WDL)
- United States Geological Survey (USGS)
  - National Water Information System (NWIS)

Local Programs

Water data were also collected from the following local monitoring programs:

- WCWD and Joint Districts (RID, BWGWD, and BWD) records of monthly diversions
- WCWD, RID, and BWGWD records of water deliveries and other operational data
- The Joint Districts' SCADA system

Program Limitations on Operation Flexibility in Basin

Continued operation of these water monitoring programs will support tracking the progress of the GSP implementation plan by providing data on water availability and inflows and outflows from the subbasin. Limitations on surface water deliveries will limit operational flexibility by reducing surface water supplies available for conjunctive use programs.

2.1.2.3 Groundwater Monitoring and Management Programs

There are a variety of local, state, and federal monitoring programs currently and historically conducted in Butte Subbasin related to groundwater levels, groundwater quality, and land subsidence. Each monitoring category is described in more detail in the sections below.

Groundwater Level Monitoring

Groundwater level monitoring has been conducted historically by a variety of entities in the Subbasin including Butte County, Western Canal Water District, DWR, United States Bureau of Reclamation (USBR), and Geotracker GAMA.

Groundwater Quality Monitoring

Groundwater quality monitoring has historically been conducted by a variety of entities in the Subbasin including the Cities of Biggs and Gridley, Butte County, USGS for the Groundwater Ambient Monitoring and Assessment Program (GAMA), and by other entities and for other programs. All public drinking water supply systems must conduct groundwater quality monitoring as part of requirements for the Division of Drinking Water (DDW). The required frequency and constituents for DDW monitoring vary by water system and monitoring point. Some historical groundwater quality monitoring has also been conducted by well owners in the subbasin for other purposes.

Land Subsidence Monitoring

Land subsidence monitoring has been conducted by DWR and others. Additionally, through remote sensing and similar data acquisition methods such as InSAR, maps of periodic snapshots of spatial distribution of land subsidence have been historically generated including by DWR, USGS, and the NASA Jet Propulsion Laboratory (JPL). The frequency of such land subsidence mapping efforts has been variable but has increased in frequency and regularity since 2010 and is anticipated to continue in the future.

2.1.2.4 Conjunctive Use Programs

To support overall water management objectives, water distributors in the Butte Subbasin strategically manage their conjunctive use of surface and groundwater supplies. Western Canal Water District, Richvale Irrigation District, Biggs-West Gridley Water District and Butte Water District receive surface water from the Feather River through the Thermalito Afterbay. Reclamation District No. 1004 receives surface water from the Sacramento River. These districts practice conjunctive use of these surface water supplies through policies to encourage grower use of surface water when available. These combined practices reduce groundwater pumping and increase groundwater recharge, providing increased groundwater supplies available for use in dry years. Irrigation by surface water supplies provides the advantage of in-lieu recharge of groundwater, and brings an important additional resource into the Basin to help meet crop water demands.

2.1.3 Land Use Elements or Topic Categories of Applicable General Plans *(Reg. § 354.8 f)*

The Butte Subbasin lies primarily within Butte County, although portions of it also lie within Colusa and Glenn Counties. The County General Plan is applicable for all areas within the subbasins in these counties. Additionally, the Cities of Biggs and Gridley each have a General Plan that is applicable to lands within their GSA boundaries.

2.1.3.1 *Butte County General Plan*

The Butte County General Plan 2030 was adopted by the Butte County Board of Supervisors in October 2010. The General Plan 2030 identifies the goals, policies and actions governing land use in the unincorporated portions of Butte County. The General Plan 2030 reflects the community desire to conserve and enhance the legacy of their forebears, namely, sustainable development. To this end, the General Plan 2030 envisions and supports a Butte County in 2030 where:

- Urban development will be primarily centralized within and adjacent to the existing municipal limits and larger unincorporated communities. Urban development will have efficient, reliable public facilities and infrastructure. Employment centers and a range of services will be located near residential areas so that people spend less time in their cars. Residential communities will be walkable, bicycle facilities will be provided, and there will be access to public transit.
- Small unincorporated areas will be well-planned through community-driven planning processes so that community character is preserved and adequate public services and facilities are provided. Rural residential development will be limited and will strive to be compatible with agricultural and environmental uses, and will address wildfire risks and public services needs.
- Agriculture and open space will continue to dominate Butte County's landscape and be an important part of the County's culture and economy. Existing agricultural areas will be maintained and an array of agricultural services will support agriculture while providing new jobs to Butte County residents.

The General Plan 2030 includes an optional Water Resources Element in addition to the mandatory elements of Land Use, Housing, Economic Development, Agriculture, Circulation, Conservation and Open-space, Health and Safety and Public Facilities and Services. In adopting the Water Resources Element, the General Plan 2030 recognized the importance and interrelationship between land use and water resources management. The General Plan 2030 Water Resources Element has six goals:

1. Maintain and enhance water quality;
2. Ensure an abundant and sustainable water supply to support all uses in Butte County;

3. Effectively manage groundwater resources to ensure a long-term water supply for Butte County;
4. Promote water conservation as an important part of a long-term and sustainable water supply;
5. Protect water quality through effective storm water management, and;
6. Improve stream bank stability and protect riparian resources.

Key Water Resources Element policies include:

- W-P1.4 Where appropriate, new development shall be Low Impact Development (LID) that minimizes impervious area, minimizes runoff and pollution and incorporates best management practices.
- W-P2.1 The County supports solutions to ensure the sustainability of community water supplies.
- W-P2.3 Water resources shall be planned and managed in a way that relies on sound science and public participation.
- W-P2.5 The expansion of public water systems to areas identified for future development on the General Plan land use map is encouraged.
- W-P2.6 The County supports water development projects that are needed to supply local demands.
- W-P2.8 The County supports Area of Origin water rights, the existing water right priority system and the authority to make water management decisions locally to meet the county's current and future needs, thereby protecting Butte County's communities, economy and environment.
- W-P2.9 Applicants for new major development projects, as determined by the Department of Development Services, shall demonstrate adequate water supply to meet the needs of the project, including an evaluation of potential cumulative impacts to surrounding groundwater users and the environment.
- W-P3.1 The County shall continue to ensure the sustainability of groundwater resources, including groundwater levels, groundwater quality and avoidance of land subsidence, through a basin management objective program that relies on management at the local level, utilizes sound scientific data and assures compliance.
- W-P3.2 Groundwater transfers and substitution programs shall be regulated to protect the sustainability of the County's economy, communities and ecosystem, pursuant to Chapter 33 of the Butte County Code.
- W-P3.3 The County shall protect groundwater recharge and groundwater quality when considering new development projects.
- W-P4.1 Agricultural and urban water use efficiency shall be promoted.
- W-P4.2 Water conservation efforts of local Resource Conservation Districts, the Natural Resource Conservation Service and irrigation districts should be coordinated.
- W-P4.3 The County shall work with municipal and industrial water purveyors to implement water conservation policies and measures.
- W-P4.4 Opportunities to recover and utilize wastewater for beneficial purposes shall be promoted and encouraged.

- W-P4.5 The use of reclaimed wastewater for non-potable uses shall be encouraged, as well as dual plumbing that allows graywater from showers, sinks and washers to be reused for landscape irrigation in new developments.
- W-P4.6 New development projects shall adopt best management practices for water use efficiency and demonstrate specific water conservation measures.
- W-P5.2 New development projects shall identify and adequately mitigate their water quality impacts from stormwater runoff.
- W-P5.3 Pervious pavements shall be allowed and encouraged where their use will not hinder mobility.

Implementation of the Butte subbasin GSP will provide for sustainable groundwater management and is not anticipated to affect water supply assumptions in the General Plans.

Information on the Butte County General Plan 2030 and related documents can be found at www.buttegeneralplan.net.

2.1.3.2 *Permitting Process for Wells in Butte Subbasin*

Butte County Permitting Process for Wells

The construction, repair or destruction of wells is subject to permitting by the Butte County Division of Environmental Health pursuant to Chapter 23B of the Butte County Code, Water Wells. The chapter provides minimum procedures for the proper construction of water wells and for the proper destruction of abandoned wells in order to ensure that water obtained from wells within the County of Butte will be suitable for the purposes for which used and that wells constructed or abandoned pursuant to this chapter will not cause pollution or impairment of the quality of the groundwater within the county. An additional purpose is to reduce potential well interference problems to existing wells and potential adverse impacts to the environment which could be caused by the construction of new wells or the repair or deepening of existing wells where a permit is required. Important provisions of the Section include:

- The construction, repair, reconstruction, deepening, abandonment and destruction of wells in Butte County must follow the standards in Bulletin 74-81 and its supplement bulletin 74-90, Water Well Standards, State of California.
- After July 25, 1996, the pumping capacity of a new well cannot be greater than fifty (50) gallons per minute per acre to reasonably serve the overlying land, including contiguous parcels of land under the same ownership as the land upon which the well is located.
- Wells can only be drilled by a person licensed to drill water wells pursuant to the provisions of Business and Professions Code section 7000 et seq. possessing a C-57 water well contractors license required by section 13750.5 of the California Water Code.
- Domestic well owners are required to insure that a new well will operate properly assuming a repeat of the groundwater conditions experienced during the period 1987 through 1994 in the area in which the new well is located.

- Well drillers reports must be filed with Butte County as well as with the Department of Water Resources.
- Notification of well permit applications are required in specific instances to adjoining landowners and/or local agencies with an adopted groundwater management plan pursuant to part 2.75 of division 6 of the California Water Code (commencing at section 10750). Landowners and/or local agencies are provided thirty (30) days to provide comments prior to permit issuance.
- Wells with a casing diameter greater than eight (8) inches are required to be drilled at specific distances away from existing wells.
- In addition to well sealing requirements specified within state well standards bulletin 74-81 and bulletin 74-90, the seal shall be extended five (5) feet into the first consolidated formation encountered below fifteen (15) feet to a maximum required sealing depth of fifty (50) feet.

2.1.3.3 . *Effects of Land Use Plans Outside Subbasin*

The Sutter County General Plan and zoning ordinance is the only land use plan adjacent to, but not included in, the Butte subbasin. The Sutter County General Plan will not have any impact on the Butte GSP to maintain or achieve sustainable groundwater management. The GSAs in the Butte subbasin will continue to monitor amendments to the Sutter County General Plan.

2.1.4 Additional GSP Elements *(Reg. § 354.8 g)*

There are various GSP elements to be addressed in this subsection of the GSP as described below. In some cases, the related information is provided elsewhere in the GSP and the section where the information is provided is noted. In other cases, additional information is provided below.

These elements include, but are not limited to, wellhead protection, well abandonment and well destruction, well construction policies, migration of contaminated groundwater, replenishment of groundwater extraction, conjunctive use, efficient water management practices, and relationships with state and federal agencies. These elements will be described in more detail in the final GSP.

2.1.5 Notice and Communication *(Reg. § 354.10)*

2.1.5.1 *Overview*

California's Sustainable Groundwater Management Act (SGMA) of 2014 requires broad and diverse stakeholder involvement in GSA activities and the development and implementation of Groundwater Sustainability Plans (GSPs) for groundwater basins around the state, including the Butte Subbasin. The intent of SGMA is to ensure successful, sustainable management of groundwater resources at the local level. Success will require cooperation by all beneficial users (defined below), and cooperation is far more likely if beneficial users have consistent messaging of valid information and are provided with opportunities to help shape the path forward.

To facilitate stakeholder involvement in the GSA process, a Communication and Engagement Plan (**Appendix 2.A.a**) was created for the GSAs in the Butte Subbasin for the following purposes:

> *The Butte Subbasin Groundwater Sustainability Agencies' (GSAs) Boards and the Butte Subbasin Advisory Board are committed to keeping the **public informed**, providing the public with **balanced and objective information** to assist the public in understanding the Sustainable Groundwater Management Act (SGMA), available options and recommendations, and **creating an open process** for public input on development and implementation of the Groundwater Sustainability Plan (GSP). The primary objective of this Communication and Engagement Plan is to identify and carry forward intentional, effective engagement to ensure widespread support and understanding for the GSP and its implementation.*

2.1.5.2 *Description of Beneficial Uses and Users in the Basin*

Under the requirements of SGMA, all beneficial uses and users of groundwater must be considered in the development of GSPs, and GSAs must encourage the active involvement of diverse social, cultural, and economic elements of the population. Beneficial users, therefore, are any stakeholders who have an interest in groundwater use and management in the Butte Subbasin community. Their interest may be related to GSA activities, GSP development and implementation, and/or water access and management in general. Notice was given to appropriate cities and counties per Water Code §10728.4 requiring requires GSAs provide at least a 90-day notice to cities and counties prior to adoption of a Plan.

To assist in identifying categories of beneficial uses and users in the Butte Subbasin, the Communications and Engagement Plan included a Stakeholder Engagement table (**Table 2-1** below and Table 1 in **Appendix 2.A.a**).

Table 2-1. Stakeholder Engagement Categories, Groups, and Engagement Purpose.

Category of Interest	Stakeholder Groups	Engagement Purpose
General Public • Citizens groups • Community leaders • Interested individual • Universities/Academia	• Each GSA maintains interested parties lists. • Groundwater Pumpers Advisory Group (GPAC)	Inform to improve public awareness of sustainable groundwater management
Land Use • Municipalities • Local land use agencies • Regional land use agencies • Community Service Districts	• Butte City Community Service District	Consult and involve to ensure land use policies are supporting GSPs and there are no conflicting policies between the GSAs / GSP and local government agencies
Private Users • Private pumpers (domestic and agricultural) • Schools and colleges • Hospitals	• Colusa Properties • Manzanita School • Richvale Elementary School	Inform and involve in assessing impacts to groundwater users
Urban/ Agricultural Users • Water agencies • Irrigation districts • Municipal water companies • Mutual water companies • Resource conservation districts • Farmers/Farm Bureaus • Water Districts • Water users associations • Irrigated Lands Regulatory Program Coalition	• Reclamation District No. 2054 • Reclamation District No. 2106 • Reclamation District No. 1004 • Reclamation District No. 777 • Reclamation District No. 2056 • Dayton Mutual Water Company • Sartain Mutual Water Company • Northern California Water Association • Butte County Farm Bureau • Colusa County Farm Bureau • Glenn County Farm Bureau • Butte County Resource Conservation District • Colusa County Resource Conservation District • Glenn County Resource Conservation District • Agricultural Groundwater Users of Butte County • Sacramento Valley Irrigated Lands Program • California Rice Commission • Butte County Rice Growers Associations	Collaborate to ensure sustainable management of groundwater

Category of Interest	Stakeholder Groups	Engagement Purpose
Environmental and Ecosystem Uses • Federal and state agencies • Wetland managers • Environmental groups	• Sierra Club • Butte Creek Watershed Conservancy • Friends of Butte Creek • Trout Unlimited • Audubon • California Waterfowl/Ducks Unlimited • Butte Environmental Council • Sacramento River Preservation Trust • The Nature Conservancy • Gray Lodge State Wildlife Refuge	Inform and involve to consider and incorporate potential ecosystem impacts to GSP process
Surface Water Users • Irrigation Districts • Water Districts • Water user associations • Agricultural users	• Biggs West Gridley Water District • Butte Water District • Richvale Irrigation District • Western Canal Water District	Inform and involve to collaborate to ensure sustainable water supplies
Economic Development • Chambers of commerce • Business groups/associations • Elected officials • State Assembly members • State Senators • Economic Development Team	• Butte County Water Commission	Inform and involve to support a stable economy
Human Right to Water • Disadvantaged communities • Small water systems • Environmental justice groups/community-based organizations • De minimis well owners	• City of Biggs • City of Gridley	Inform and involve to provide safe and secure groundwater supplies to all communities reliant on groundwater
Tribes • Federally Recognized Tribes • Non-Federally Recognized Tribes	• Tribal engagement is not anticipated in this subbasin as area Tribes' interests reside outside of the Butte Subbasin in adjacent basins.	Inform, involve and consult with tribal government
Federal Lands • U.S. Fish and Wildlife Service	• U.S. Fish and Wildlife Service North Central Valley Wildlife Management Area • U.S. Fish and Wildlife Service	Inform, involve and collaborate to ensure basin sustainability

Category of Interest	Stakeholder Groups	Engagement Purpose
• U.S. Bureau of Reclamation • U.S. Army Corps of Engineers	Sacramento River National Wildlife Refuge	
Integrated Water Management • Regional water management groups (IRWM regions) • Flood agencies	• North Sacramento Valley (NSV) Integrated Regional Water Management Group • Upper Feather River Integrated Regional Water Management Group • Central Valley Flood Protection Board	Inform, involve and collaborate to improve regional sustainability
General Public • **Citizens groups** • **Community leaders** • **Interested individual** • **Universities/Academia**	• Each GSA maintains interested parties lists. • Groundwater Pumpers Advisory Group (GPAC)	Inform to improve public awareness of sustainable groundwater management
Land Use • **Municipalities** • **Local land use agencies** • **Regional land use agencies** • **Community Service Districts**	• Butte City Community Service District	Consult and involve to ensure land use policies are supporting GSPs and there are no conflicting policies between the GSAs / GSP and local government agencies
Private Users • **Private pumpers (domestic and agricultural)** • **Schools and colleges** • **Hospitals**	• Colusa Properties • Manzanita School • Richvale Elementary School	Inform and involve in assessing impacts to groundwater users
Urban/ Agricultural Users • **Water agencies** • **Irrigation districts** • **Municipal water companies** • **Mutual water companies** • **Resource conservation districts** • **Farmers/Farm Bureaus** • **Water Districts** • **Water users associations** • **Irrigated Lands Regulatory Program Coalition**	• Reclamation District No. 2054 • Reclamation District No. 2106 • Reclamation District No. 1004 • Reclamation District No. 777 • Reclamation District No. 2056 • Dayton Mutual Water Company • Sartain Mutual Water Company • Northern California Water Association • Butte County Farm Bureau • Colusa County Farm Bureau • Glenn County Farm Bureau • Butte County Resource Conservation District	Collaborate to ensure sustainable management of groundwater

Category of Interest	Stakeholder Groups	Engagement Purpose
	• Colusa County Resource Conservation District • Glenn County Resource Conservation District • Agricultural Groundwater Users of Butte County • Sacramento Valley Irrigated Lands Program • California Rice Commission • Butte County Rice Growers Associations	
Environmental and Ecosystem Uses • **Federal and state agencies** • **Wetland managers** • **Environmental groups**	• Sierra Club • Butte Creek Watershed Conservancy • Friends of Butte Creek • Trout Unlimited • Audubon • California Waterfowl/Ducks Unlimited • Butte Environmental Council • Sacramento River Preservation Trust • The Nature Conservancy • Gray Lodge State Wildlife Refuge	Inform and involve to consider and incorporate potential ecosystem impacts to GSP process
Surface Water Users • **Irrigation Districts** • **Water Districts** • **Water user associations** • **Agricultural users**	• Biggs West Gridley Water District • Butte Water District • Richvale Irrigation District • Western Canal Water District	Inform and involve to collaborate to ensure sustainable water supplies
Economic Development • **Chambers of commerce** • **Business groups/associations** • **Elected officials** • **State Assembly members** • **State Senators** • **Economic Development Team**	• Butte County Water Commission	Inform and involve to support a stable economy
Human Right to Water • **Disadvantaged communities** • **Small water systems** • **Environmental justice groups/community-**	• City of Biggs • City of Gridley	Inform and involve to provide safe and secure groundwater supplies to all communities reliant on groundwater

Category of Interest	Stakeholder Groups	Engagement Purpose
based organizations • **De minimis well owners**		
Tribes • **Federally Recognized Tribes** • **Non-Federally Recognized Tribes**	• Tribal engagement is not anticipated in this subbasin as area Tribes' interests reside outside of the Butte Subbasin in adjacent basins.	Inform, involve and consult with tribal government
Federal Lands • **U.S. Fish and Wildlife Service** • **U.S. Bureau of Reclamation** • **U.S. Army Corps of Engineers**	• U.S. Fish and Wildlife Service North Central Valley Wildlife Management Area • U.S. Fish and Wildlife Service Sacramento River National Wildlife Refuge	Inform, involve and collaborate to ensure basin sustainability
Integrated Water Management • **Regional water management groups (IRWM regions)** • **Flood agencies**	• North Sacramento Valley (NSV) Integrated Regional Water Management Group • Upper Feather River Integrated Regional Water Management Group • Central Valley Flood Protection Board	Inform, involve and collaborate to improve regional sustainability

2.1.5.3 Communications

Decision-making Processes

As noted above, the Butte Subbasin includes 11 GSAs for the development, adoption and implementation of a single GSP.

GSA Boards are the final decision-makers for the Butte Subbasin. To assist in GSP development, the GSAs convened a Butte Advisory Board (BAB) in 2019 to bring together local agencies and related parties vested with the authority and/or ability to support implementation of SGMA in the Butte Subbasin. The BAB has been meeting approximately bi-monthly since its formation.

Generally, the representatives attending the GSA Managers meetings are technical experts associated with the various Subbasin GSAs. In addition to coordinating between the GSAs, the GSA Managers and BAB developed recommendations for GSP development, which were presented to the GSA boards in public meetings as well as at subbasin-wide public meetings during regularly scheduled BAB meetings on Zoom.

Public Engagement Opportunities

There were a number of different meetings at which the public had the opportunity to engage during the GSP development process:

- **GSA meetings**: Each of the GSAs in the Butte Subbasin held regular public meetings on Zoom, generally on a bi-monthly or monthly schedule.
- **Butte County Technical Advisory Committee**: County staff made presentation on draft chapter and received comment and recommendations for revisions.
- **Butte County Water Commission:** County staff made presentation on draft chapters and received final recommendations.
- **Groundwater Pumper Advisory Committee:** County and technical staff made presentation on draft chapter, facilitated discussion, and received comments and recommendations.
- **Cities of Biggs and Gridley:** Held periodic public meetings regarding GSP development, adoption, and implementation.

Figure 2-2 describes the GSP process steps, including topic development, technical review, and public meetings both at the Subbasin and individual level.

Encouraging Active Involvement

The Butte Subbasin lacks organized DAC organizations and therefore made it difficult to identify and engage these communities. The BAB sought out potential DAC representatives through discussions with area leaders and encouraged participation. However, during the plan development time period of January 2020 through 2021 opportunities to be publicly engaged were severely limited due to on-going COVID-19 restrictions.

Soliciting Written Comments

In addition to soliciting feedback at GSA meetings, an opportunity was provided to offer written comments on the plan via an online comment form or letter. Each GSA notified their respective stakeholders via email at each opportunity to provide comments. Basin Setting Sections were released for a 30-day comment period of August 10, 2020 to September 8, 2020. Comments were solicited from July 2, 2021 through July 31, 2021 on the Draft Sustainable Management Criteria, Monitoring Networks, Groundwater Dependent Ecosystems and Project and Management Action Sections.

Written comments and responses can be found in **Appendix 2.A.b**.

PLACEHOLDER – INSERT CBI TIMELINE

Figure 2-2. Plan Development Sequence (public meetings in yellow).

2.1.5.4 *Informing the Public about GSP Development Progress*

Interested Parties List

An email distribution list of Subbasin-wide stakeholders and beneficial users was developed for outreach throughout the GSP planning process. The list was maintained and updated by individual GSAs and through Butte, Colusa and Glenn Counties. In many cases, information was distributed in both English and Spanish. Any interested member of the public can be added to the list by signing up via the website at: https://www.buttebasingroundwater.org/.

A list of stakeholder groups and interested parties in the Butte Subbasin is also included in Table 1 of the Communications and Engagement Plan (**Appendix 2.A.a).**

Distribution of Public Meeting Notices

Typically, before a public meeting in the Subbasin, an email template was created with key information provided then emailed out to the respective Interested Party lists. Public Meeting Notices and information about public meetings (including agenda and meeting materials) were also posted on the Subbasin website[11], described below, in advance of each meeting. **Figure 2-3** shows a photo from one of the public meetings.

Press Outreach

Press releases were issued at key junctures and decision-making points for the Subbasin.

Development and Maintenance of Butte Subbasin Website

Throughout the planning process, Western Canal Water District GSA staff have maintained a Subbasin website with information about Subbasin-wide planning efforts related to SGMA. Additionally, Butte, Colusa, and Glenn Counties each maintain a web page for local implementation of SGMA.

The Butte Subbasin website contains:

- Meeting Information (Agenda and meeting materials)
- GSP Development (Sections, Public Notice, Technical documentation)
- Projects and Management Actions (Public Notice and Description)
- SGMA Resources Page and Advisory Board Page
- And other SGMA- and GSP-related materials.

Summary of Engagement Opportunities and Public Comments

Table 3 of the Communications and Engagement Plan, in **Appendix 2.A.a**, provides details about engagement opportunities throughout the GSP development and adoption processes. The

[11] **https://www.buttebasingroundwater.org**

timeframe, milestone or stage, required community engagement under SGMA, and communication strategies are all included. The timeframe extends from shortly after GSA formation through GSP adoption. These engagement opportunities provide various avenues for stakeholders to provide input on GSP development. **Appendix 2.A.b** summarizes the public comments received, organized by type of water user, and outlines how this input influenced decision-making in GSP development.

Figure 2-3. GSA Public Event on 8/14/19.

2.2 Basin Setting

2.2.1 Hydrogeologic Conceptual Model *(Reg. § 354.14)*

A Hydrogeologic Conceptual Model (HCM) identifies the major factors contributing to groundwater flow and movement and how different features and characteristics affect conditions within a subbasin. This section describes the HCM for the Butte Subbasin (Subbasin). The HCM serves as an important component of the basin setting, providing the framework for understanding groundwater conditions and water budgets.

Much of the information in this section is compiled from existing reports detailing the hydrogeology of the Sacramento Valley and the formations making up the aquifer systems in the groundwater basin. These reports by the Department of Water Resources (DWR) include the Geology of the Northern Sacramento Valley, 2014 (DWR 2014), and the Butte County Groundwater Inventory Analysis, 2005 (DWR 2005). In addition, the Butte County Lower Tuscan Aquifer Monitoring, Recharge, and Data Management Project Final Report (Brown and Caldwell

2013) and the Glenn and Colusa County Hydrogeologic Conceptual Model Report, 2018 (West Yost Associates and Davids Engineering 2018) provide a valuable foundation to support GSP development. Better understanding the hydrogeology, aquifer dynamics, and recharge paths of the aquifer systems in the Northern Sacramento Valley region is an area of active research.

2.2.1.1 *Basin Boundaries*

2.2.1.1.1 Lateral Boundaries

The Butte Subbasin is situated in the central portion of the Sacramento Valley Groundwater Basin. It is bounded by the following subbasins: Vina to the north, Corning to the northwest, Colusa to the west, Sutter to the south, and Wyandotte Creek to the east. The lateral boundaries of the Subbasin are jurisdictional in nature and it is recognized that groundwater flows across each of the defined boundary lines to some degree. The western boundary is a combination of the Butte-Glenn County line along the Sacramento River, the Sacramento River through portions of Glenn and Colusa Counties and the jurisdictional boundary of Reclamation District No. 1004 (RD1004). The southern boundary is a combination of RD1004 service area boundary, the Butte-Sutter County line, and a small section that follows the service area boundary of Biggs West Gridley Water District. The Feather River and the Thermalito Afterbay forms the boundary of the Subbasin along its eastern side. From the Afterbay, the Subbasin's eastern boundary continues along Wilber Road, Nelson Avenue and along the service area boundary of Thermalito Water and Sewer District until it jogs over to the Western Canal Water District service area boundary along the property boundary of parcel 030-010-007. The northern boundary follows the Western Canal Water District Boundary, RD2106 boundary and property boundaries of lands owned by the M&T Ranch.

2.2.1.1.2 Bottom of Basin

Continental sediments of the Tehama, Tuscan and Laguna Formation compose the major fresh groundwater-bearing formations in the valley. The base of these continentally derived formations is generally accepted as the base of fresh water in the northern Sacramento Valley (Berkstresser 1973, Olmsted and Davis 1961, as cited in DWR 2014). DWR has corroborated this assertion through analysis of geophysical logs and water quality sampling results obtained from groundwater level observation wells that were drilled, installed, and tested since the year 2000 in the northern Sacramento Valley (DWR 2014). The base of these continental sediments defines the bottom of the Subbasin.

Locally, the base of fresh groundwater fluctuates depending on local changes in the subsurface geology and geologic formational structure (DWR 2005). Of note in the Butte Subbasin is the occurrence west of the Sutter Buttes in the vicinity of the Colusa domes and Willows Fault where freshwater is mapped to a depth of only 400 feet in contrast to 1600 to 1800 feet nearby to the south. **Figure 2-4** shows the base of fresh groundwater in the Subbasin (DWR 1973).

2.2.1.2 *Topography, Surface Water and Recharge*

2.2.1.2.1 Terrain and Topography

Elevations within the Butte Subbasin decrease gently from the northeast to the southwest, with elevations ranging from less than 140 feet above mean sea level (msl) in the northeast to approximately 50 feet above msl in the southwest to the west of the Sutter Buttes.

A notable feature within the Butte Subbasin is the “Butte Basin” This area lies south of Chico and west of the Feather River. Characterized by an expansive, flat topography, the Butte Basin was, prior to flood control on the Feather and Sacramento rivers, an area of extensive seasonal flooding. This slow-moving floodwater deposited the fine clay that now provides the rich agricultural soil conducive to rice production (DWR 2005). In this area, groundwater mounds up on the north side of the Sutter Buttes before it flows westward around the Buttes and between the buried Colusa dome and southward (DWR 2014).

The Sutter Buttes, which lie outside the Subbasin, provide the only significant topographic relief on the Sacramento Valley floor. This small-scale volcanic mountain range intruded the valley sediments during the early Pleistocene epoch (1.2 million years before present). The intrusion buckled the valley sediments upward, forming a barrier to groundwater flow. The Sutter Buttes block the general north-to-south trend of groundwater migration, forcing groundwater to the surface. The upward movement results in a shallow groundwater table and the formation of wetlands along the west side of the Sutter Buttes (DWR 2005). **Figure 2-5** shows the topography of the Butte Subbasin.

2.2.1.2.2 Soils

The area along portions of the Sacramento River and the Feather River is underlain by lighter textured soils consisting of loamy sands and sandy loams with higher infiltration rates. These areas correspond to irrigated lands dominated by orchards. In contrast, soils with a restrictive layer and low water holding capacity are well suited for growing rice. This land use dominates the central portion of the Subbasin. **Figure 2-6** shows the distribution of Hydrologic Soil Groups for the Butte Subbasin. Note that soils designated as C/D are lands having soils with that would have been classified as having very low infiltration rates (Group D) but have characteristics such as natural slope or land management such as artificial drainage that improved their drainage relative to that of similar soils. Soils designated as C/B are also lands that would be classified as Group D on the basis of their soil characteristics alone but that behave as Group B because of their natural setting or management improvements.

Based on the Digital General Soil Map of the United States, or STATSGO2, soil data for the Butte Subbasin, the dominant soil mapping unit within the area is Stockton-Clear Lake-Capay, which is poorly drained and represents approximately 64.1% of the Subbasin. Other prominent soils include Vina-Brentwood (9.5% of area), and Vina-Riverwash-Reiff-Columbia (8.7% of area).

Characteristics of these soils are summarized in **Table 2-2**. The distribution of dominant soils (e.g. “map units”) in the Butte Subbasin is shown in **Figure 2-7**.

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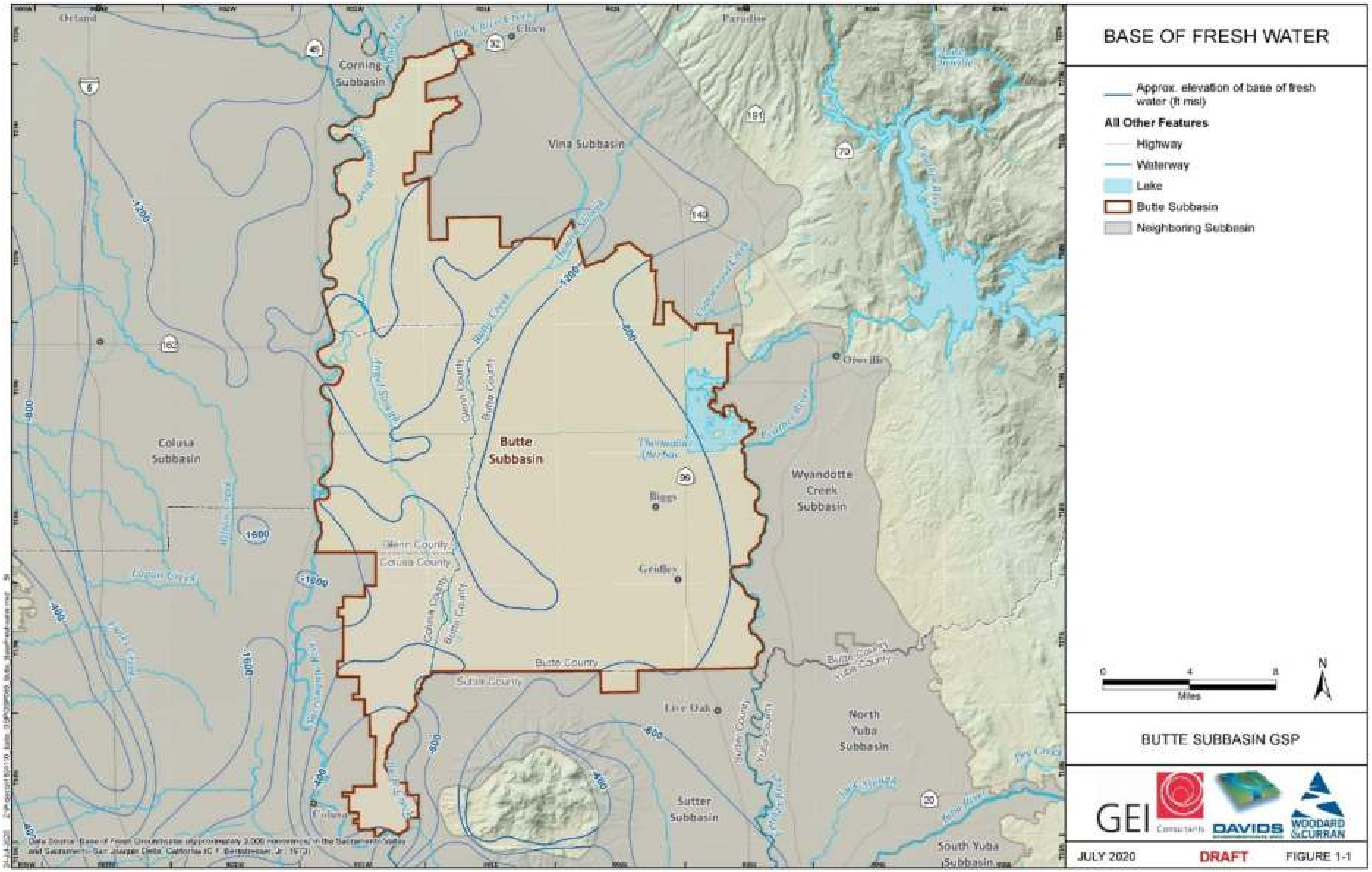

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Figure 2-4. Base of Fresh Groundwater

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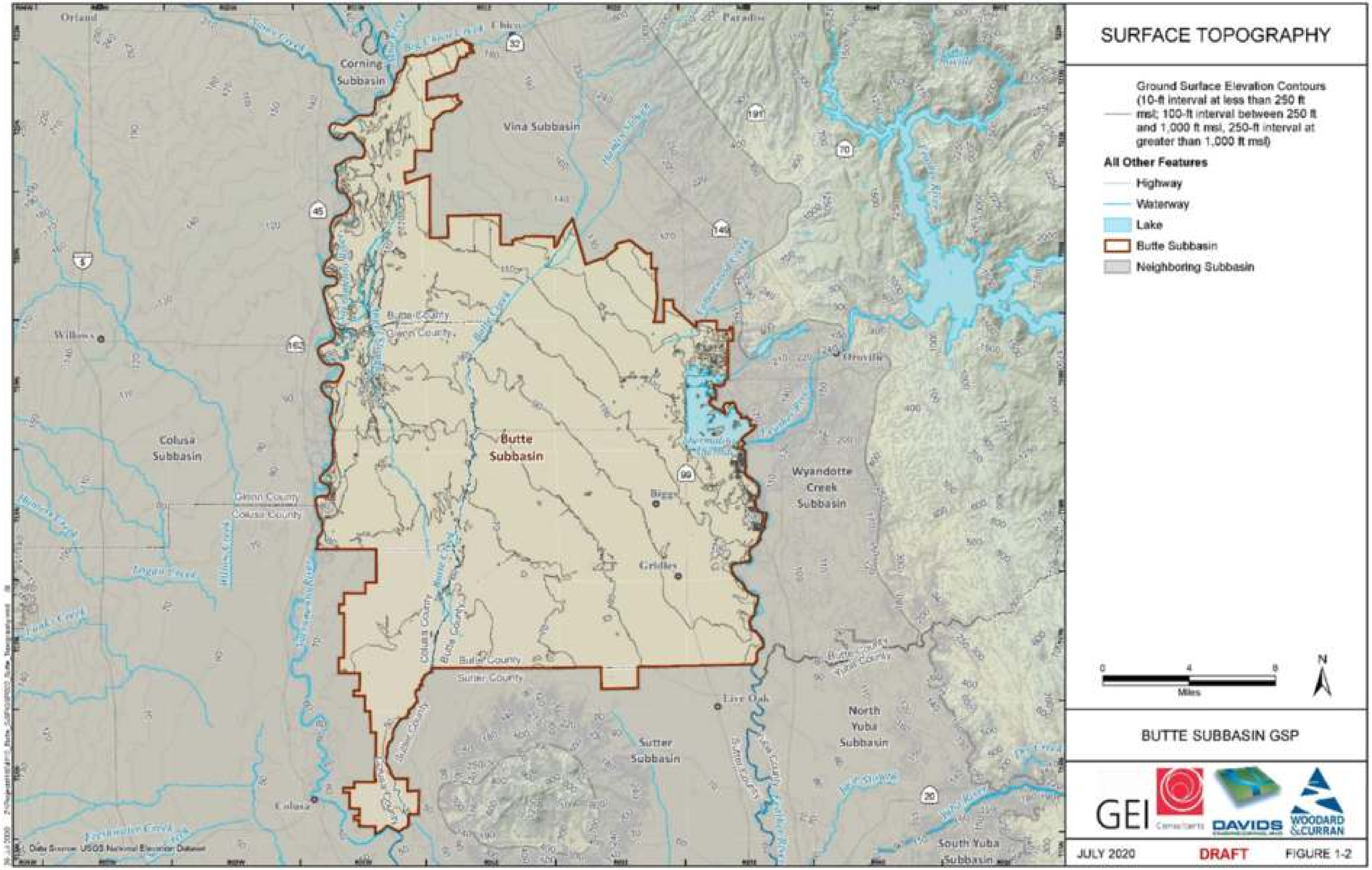

145 *Figure 2-5. Topography of the Butte Subbasin.*

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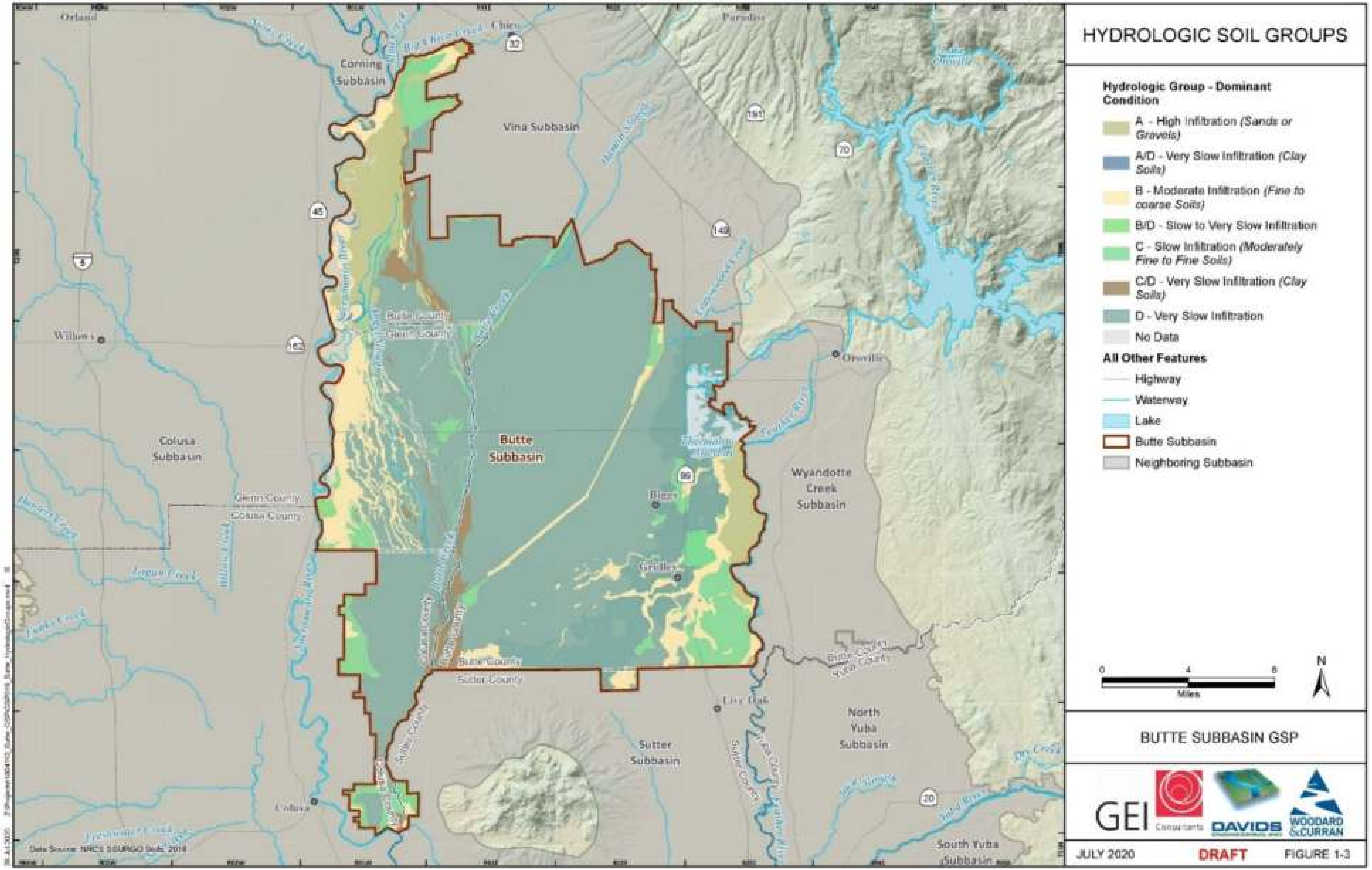

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148 *Figure 2-6. Hydrologic Soil Groups.*
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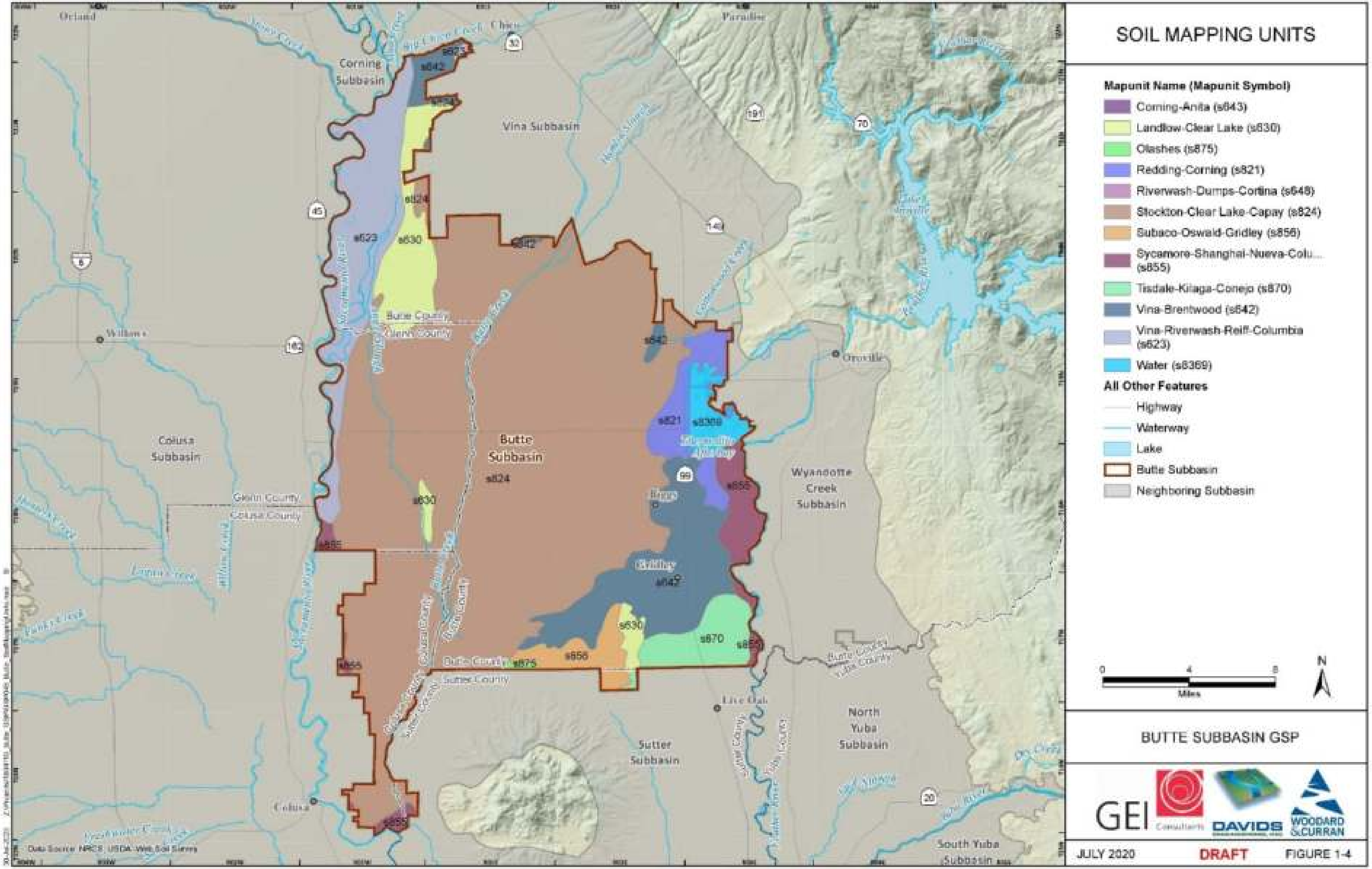

151 *Figure 2-7. STATSGO2 Soil Mapping Units (see Table 2-1 for soil characteristics).*

Table 2-2. STATSGO Soil Table for Butte Subbasin.

Soil Map Unit	Percent of Area	Sum of Acres	Slope Range	Drainage
Butte Subbasin	**100%**	**265,500**		
Corning-Anita (s643)	0.0%	2.94	4.3	Somewhat poorly drained
Landlow-Clear Lake (s630)	4.9%	12,889.19	1	Moderately well drained
Olashes (s875)	0.1%	371.15	2	Well drained
Redding-Corning (s821)	3.1%	8,131.38	5.3	Moderately well drained
Riverwash-Dumps-Cortina (s648)	0.0%	32.67	2.6	Poorly drained
Stockton-Clear Lake-Capay (s824)	64.1%	17,0224.46	1	Poorly drained
Subaco-Oswald-Gridley (s856)	2.0%	5,289.91	1	Somewhat poorly drained
Sycamore-Shanghai-Nueva-Columbia (s855)	3.1%	8,359.22	1	Somewhat poorly drained
Tisdale-Kilaga-Conejo (s870)	2.9%	7,758.71	1	Well drained
Vina-Brentwood (s642)	9.5%	25,353.21	1.1	Well drained
Vina-Riverwash-Reiff-Columbia (s623)	8.7%	23,013.58	2.6	Well drained

2.2.1.2.3 Surface Water

2.2.1.2.3.1 Surface Water Sources and Channels

The Sacramento River and Feather River border portions of the Subbasin on its western and eastern sides, respectively. Other larger surface water bodies within or traversing the Subbasin include the Thermalito Afterbay and Butte Creek. Big Chico Creek flows along a portion of the Subbasin's northern border. Smaller local streams entering and traversing the subbasin include Little Chico Creek, Little Dry Creek, and Angel Slough. **Figure 2-8** illustrates the location of rivers, streams, and major water supply and drainage features. Primary canals include the Western Main Canal, Western Lateral 374, Richvale Main Canal, Sutter Butte Canal, Biggs Extension Canal, Minderman Canal, and Biggs-West Gridley Main Canal.

Water is distributed from the Feather River through the Thermalito Afterbay to canals serving multiple users including Western Canal Water District (WCWD) and the Joint Districts. The Joint Districts include Richvale Irrigation District, Biggs-West Gridley Water District, Butte Water District[12], and Sutter Extension Water District[13]. Butte Creek and the Sacramento River are also significant sources for diversion of irrigation water supply. Diverters from Butte Creek include M&T Ranch, Parrott Investment Company, Gorrill Ranch, RD1004, the California Department of

[12] A portion of Butte Water District's service area falls within the Sutter Subbasin.
[13] All of Sutter Extension Water District's service area falls within the Sutter Subbasin.

Fish and Wildlife, and others. Diverters from the Sacramento River include M&T Ranch, Parrott Investment Company, RD1004, and others. The Cherokee Canal is a significant flood control feature crossing the subbasin.

2.2.1.2.3.2 Groundwater Recharge Areas

Groundwater recharge is the downward movement of water from the surface to the groundwater system. This can include percolation of water from rainfall, irrigation, or water bodies (i.e., rivers, lakes and canals). Several water sources and mechanisms recharge the groundwater system in the Butte Subbasin with **Figure 2-9** showing generalized precipitation source areas characterized by their elevation.

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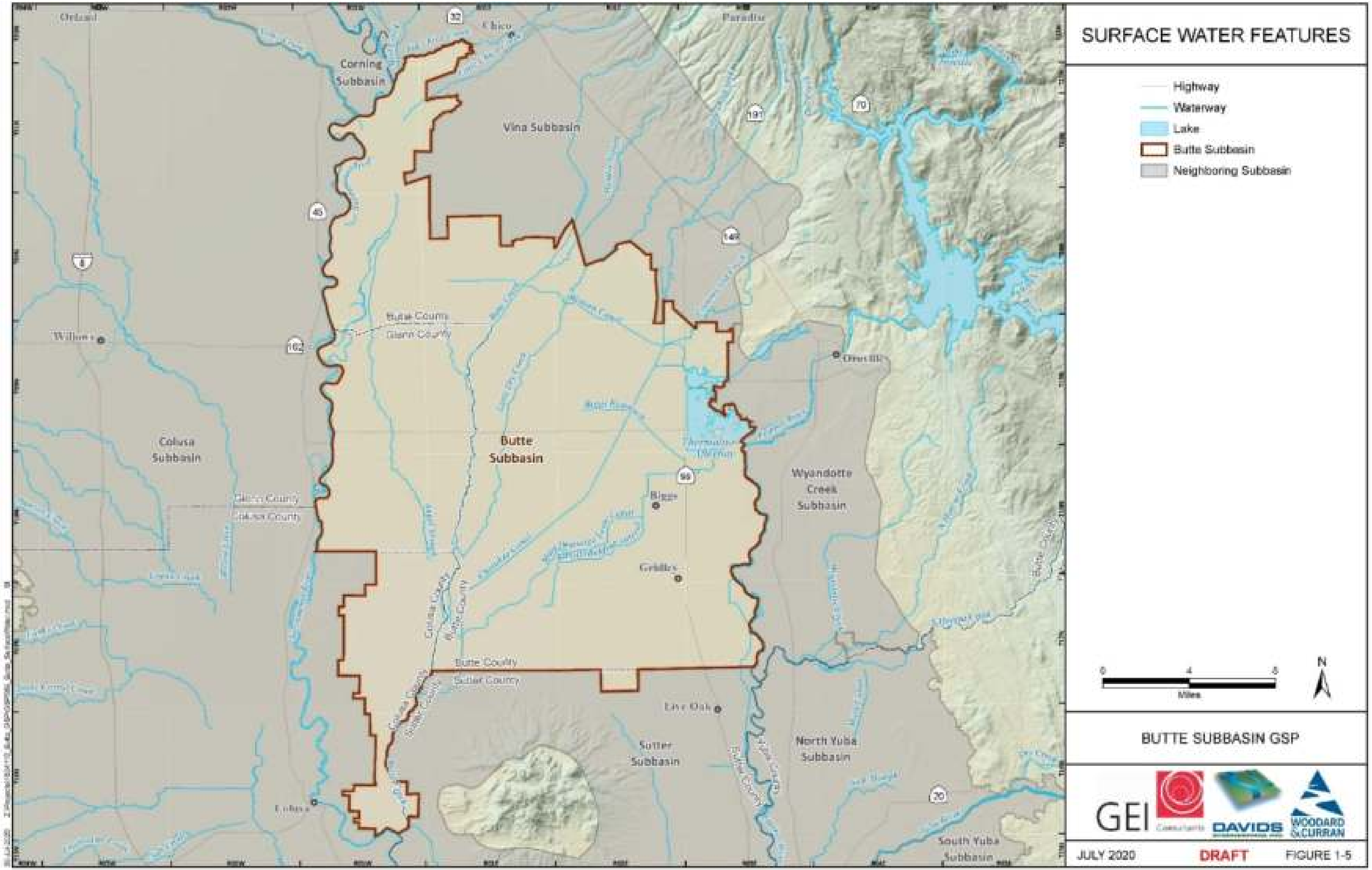

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185 ***Figure 2-8. Surface Water Features of the Butte Subbasin.***
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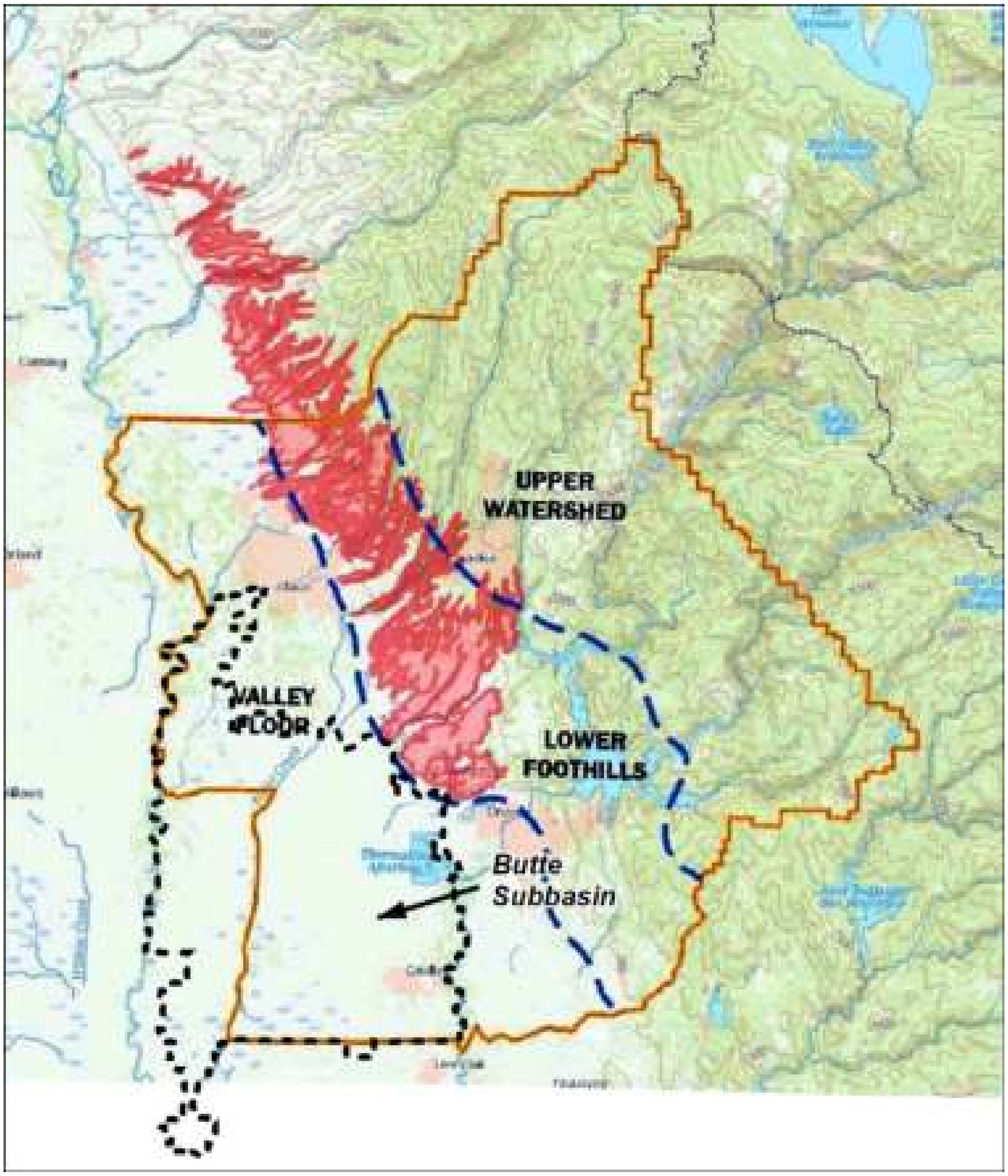

Figure 2-9. Precipitation Source Areas (Brown and Caldwell 2017, modified to add Butte Subbasin).

There is evidence that applied irrigation water provides recharge to the groundwater system in the Butte Subbasin. Although flooded rice fields predominantly exist on soils with low infiltration rates and a shallow restrictive layer, cumulatively over large acreage (and due to variable infiltration rates across rice fields), small infiltration rates still lead to notable recharge of applied water. For example, Feather River water diverted from the Thermalito Afterbay and applied to fields for irrigation provide some recharge to shallow zones of the aquifer system from infiltration in canals or flooded fields. Water from a domestic well (<100 feet deep) sampled for the Butte County Stable Isotope Recharge Study (Brown and Caldwell 2017) showed characteristics of irrigation water from the Feather River. These results aligned with extensive shallow groundwater data from rice fields from a USGS study drawing similar results (USGS Dawson, 2001). This well is likely screened in the alluvium overlying aquifer materials of the Tuscan Formation (Brown and Caldwell 2017). Additional information describing recharge from irrigation using surface water in the basin is available for WCWD and the Joint Districts in the Feather River Regional Agricultural Water Management Plan (NCWA 2014). Recharge is further characterized in the Water Budget (**Section 2.2.3**).

Stable isotope data analyzed from multi-completion wells in the northeastern and central area of the Butte Subbasin suggested intermediate and deeper zones of the aquifer are recharged from elevations consistent with the valley floor and the lowest elevation areas of the Lower Foothills region to the east of the subbasin (Brown and Caldwell 2017). This suggests downward vertical migration of water percolating directly into the Tuscan Formation at the outcrop outside the Subbasin to the east or through recharge into the local alluvial fans is a predominant recharge mechanism for the deeper aquifer zones of the Butte Subbasin. This recharged water enters the Subbasin in part as subsurface groundwater flow from the Vina Subbasin and the foothill areas to the east.

Groundwater level conditions and contours in the vicinity of the Thermalito Afterbay suggest this water body contributes recharge to the Butte Subbasin. When the facility was built by DWR, groundwater levels downgradient rose and caused damage to crops. DWR has a series of pumps along the eastern perimeter of the Afterbay to maintain a relatively constant head in the area. Nonetheless, it is estimated that approximately 26 TAF/year recharge occurs from the Afterbay primarily into the Butte Subbasin and to a lesser extent to the Wyandotte Creek Subbasin (see Water Budget in **Section 2.2.3**). The Sacramento River and Feather Rivers also likely contribute recharge to the Subbasin at times along certain reaches (**Section 2.2.3**).

Additional recharge through management activities of flood flows or irrigation practices has potential in the Butte Subbasin. The Soil Agricultural Groundwater Banking Index (SAGBI) 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. As shown on **Figure 2-10**, land within the area generally received a moderately poor rating except for along the Sacramento River in the Angel Slough area and in the southeastern area of the Subbasin. It should be noted that the need for direct artificial recharge is low given the generally shallow groundwater conditions in the majority of the Subbasin.

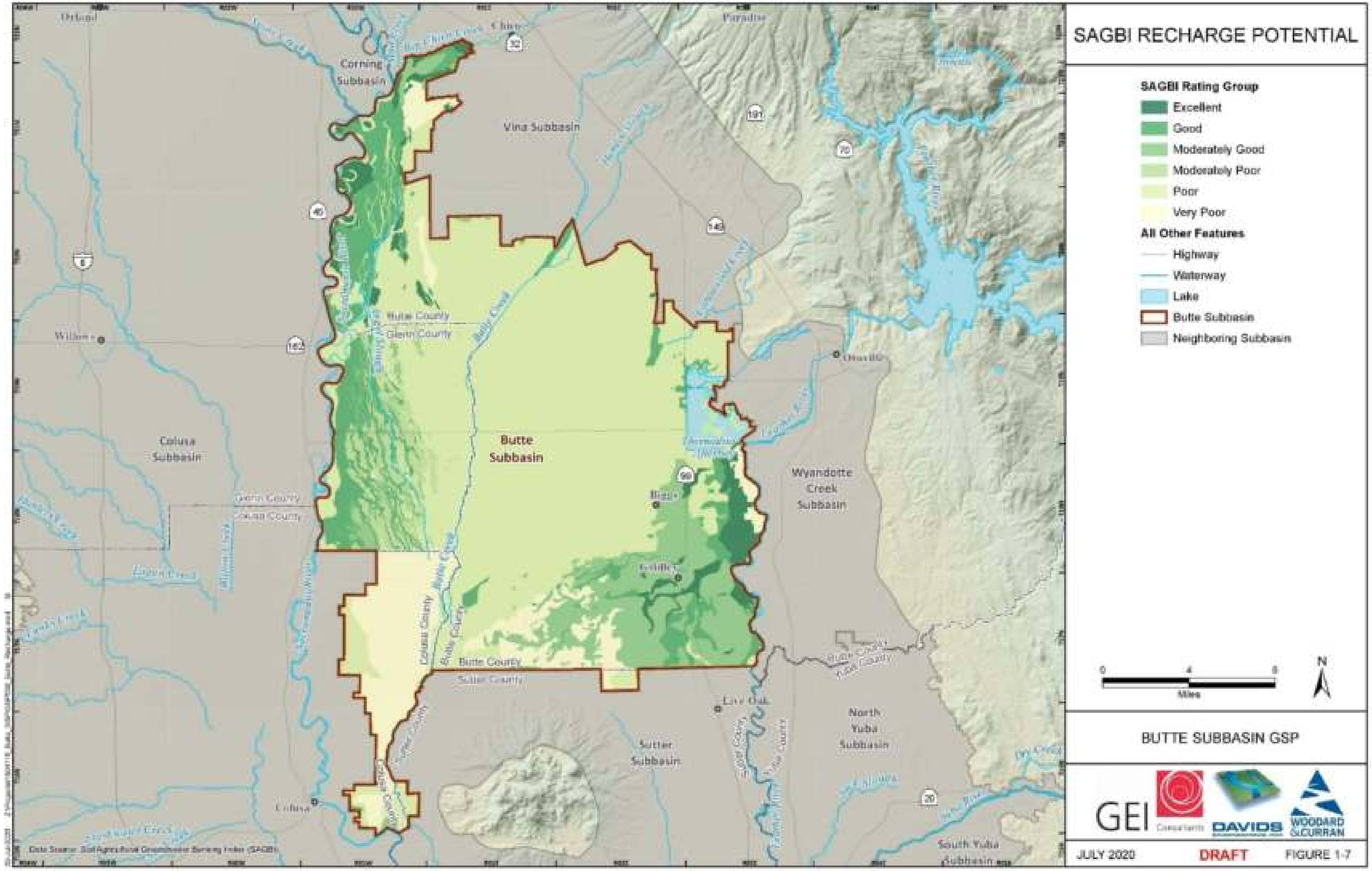

Figure 2-10. SAGBI Rating Group Recharge Potential.

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2.2.1.3 Regional Geologic and Structural Setting

The regional structure of the Sacramento Valley groundwater basin consists of an asymmetrical trough tilting to the southwest with a steeply dipping western limb and a gently dipping eastern limb (Page 1986). Older granitic and metamorphic rocks underlie the valley forming the basement bedrock on which younger marine and continentally derived sediments and volcanic rock have been deposited. Along the valley axis and west of the present-day Sacramento River, basement rock is at considerable depth, ranging from 12,000 to 19,000 feet below ground surface (bgs). Overlying marine and continentally derived sediments have been deposited almost continuously from the Late Jurassic period to the present. Of these deposits, older sediments in the basin were emplaced in a marine environment and usually contain saline or brackish groundwater. Younger sediments were deposited under continental conditions and generally contain fresh groundwater. Sediments thin near the margins of the basin, exposing older metamorphic and granitic rocks underlying and bounding the Sacramento Valley sediments (DWR 2005).

2.2.1.4 Geologic Formations

The region is composed of a diverse mix of geologic units. The main hydrogeologic units and source of groundwater in the Subbasin are the Tuscan Formation. Other units that supply lesser amounts of groundwater to the Subbasin are the Laguna, Riverbank, and Modesto formations (DWR 2005).

Groundwater occurs under both unconfined and confined conditions. Unconfined conditions are generally present in the surficial Quaternary deposits and in the Pliocene deposits that are exposed at the surface. Confined conditions usually exist at a depth of 200 feet or more, where one or more confining layers rests above the underlying aquifer deposits. Although the Tuscan Formation is unconfined where it is exposed near the valley margin in the east, at depth the Tuscan Formation is semi-confined or confined and forms the major aquifer system throughout the eastern side of the northern Sacramento Valley.

Table 2-3 provides brief descriptions of the significant geologic units that are present in the Subbasin. The geologic units are in depositional order, with the oldest (first deposited or intruded) units at the bottom of the column and the youngest units at the top.

Figure 2-11 is the Surficial Geologic Map for the Butte Subbasin, which shows the surface distribution of geologic units. The surface geology is composed mostly of Basin Deposits and the Modesto Formation.

Table 2-3. Geologic Units of the Butte Subbasin.

System	Series	Geologic Unit	Lithologic Character	Maximum Thickness[a], ft	Water-bearing Character
Quaternary	Holocene	Alluvium, Qa	Unconsolidated unweathered gravel, sand, silt, and clay[a].	80	Deposits are moderately to highly permeable with high permeability gravelly zones yielding large quantities to shallow wells[b]. Although deposits along Chico Creek are important recharge areas[b], extensive water-bearing capacity is restricted by thickness and areal extent[a].
Quaternary	Holocene	Basin Deposits, Qb	Unconsolidated[e] fine-grained silts and clays, locally interbedded with stream and channel deposits along the Sacramento River[a].	150	Deposits are typically saturated nearly to the ground surface[b]. The low to moderate permeability results in yields of small quantity and poor groundwater quality to domestic wells[a,b].
Quaternary	Pleistocene	Modesto Formation, Qm	Poorly sorted unconsolidated weathered and unweathered gravel, sand, silt, and clay[c].	200	Moderately to highly permeable[a].
Quaternary	Pleistocene	Riverbank Deposits, Qr	Poorly sorted unconsolidated to semi-consolidated[c] pebble and small cobble gravels interlensed with reddish clay, sand, and silt[a].	200	Water-bearing capability is limited by thickness. These poorly to highly permeable deposits supply moderate groundwater amounts to domestic and shallow irrigation wells. Deeper irrigation wells may be supplied if the wells contain multiple perforation zones[a].
Neogene & Quaternary	Pliocene & Pleistocene	Laguna Formation, Tla	Fluviatile moderately consolidated and poorly to well cemented; heterogeneous mixture of interbedded alluvial gravel, fine sand, silt, and clay of granitic and metamorphic origin[e].	500	Generally has low to moderate permeability, except in scattered gravels in the upper portion. Yields moderate quantities of water to wells along the eastern margin of the valley[e].
Neogene & Quaternary	Pliocene & Pleistocene	Tehama Formation, Tte	Fluviatile moderately consolidated pale green, gray, and tan sandstone and siltstone enclosing lenses of sand and gravel; silt and gravel; and cemented conglomerate derived from the Coast Ranges[a,c].	2,000	Local high permeability zones within this characteristically low to moderate permeability unit, widespread distribution, and deep thickness cause this formation to be the principal water bearing unit in the area. Deep well yields are typically moderate but are highly variable[b].

System and Series		Geologic Unit	Lithologic Character	Maximum Thickness[(a),] ft	Water-bearing Character
Neogene	Pliocene	Tuscan Formation, Tt	This series of volcanic flows, consolidated tuff breccia, tuffaceous sandstone, and volcanic ash derived from the Cascade Range interfingers with the Tehama Formation as it westerly grades into volcanic sands, gravels, and clays[(a,b)]. The formation is divided by layers of thin tuff or ash units into four lithologically similar units A-D[(a)].	1,500	Within this formation, moderately to highly permeable volcanic sediments are hydraulically confined by layers of tuff breccias and clays[(b)]. Units A and B are the primary water-bearing zones and are composed of volcanic conglomerate, sandstone, and siltstone layers interbedded with lahars. Stratigraphically higher, the massive lahar deposits of unit C confine groundwater in the permeable beds of units A and B1.

Notes:
(a) Department of Water Resources web page (www.wq.water.ca.gov).
(b) Department of Water Resources, Bulletin 118-6, 1978.
(c) Department of Water Resources, Bulletin 118-7 (Draft, not published).
(d) Department of Water Resources, Sacramento River Basin-Wide Water Management Plan-Draft, 2000.
(e) Department of Water Resources, Geology of the Northern Sacramento Valley, 2014.

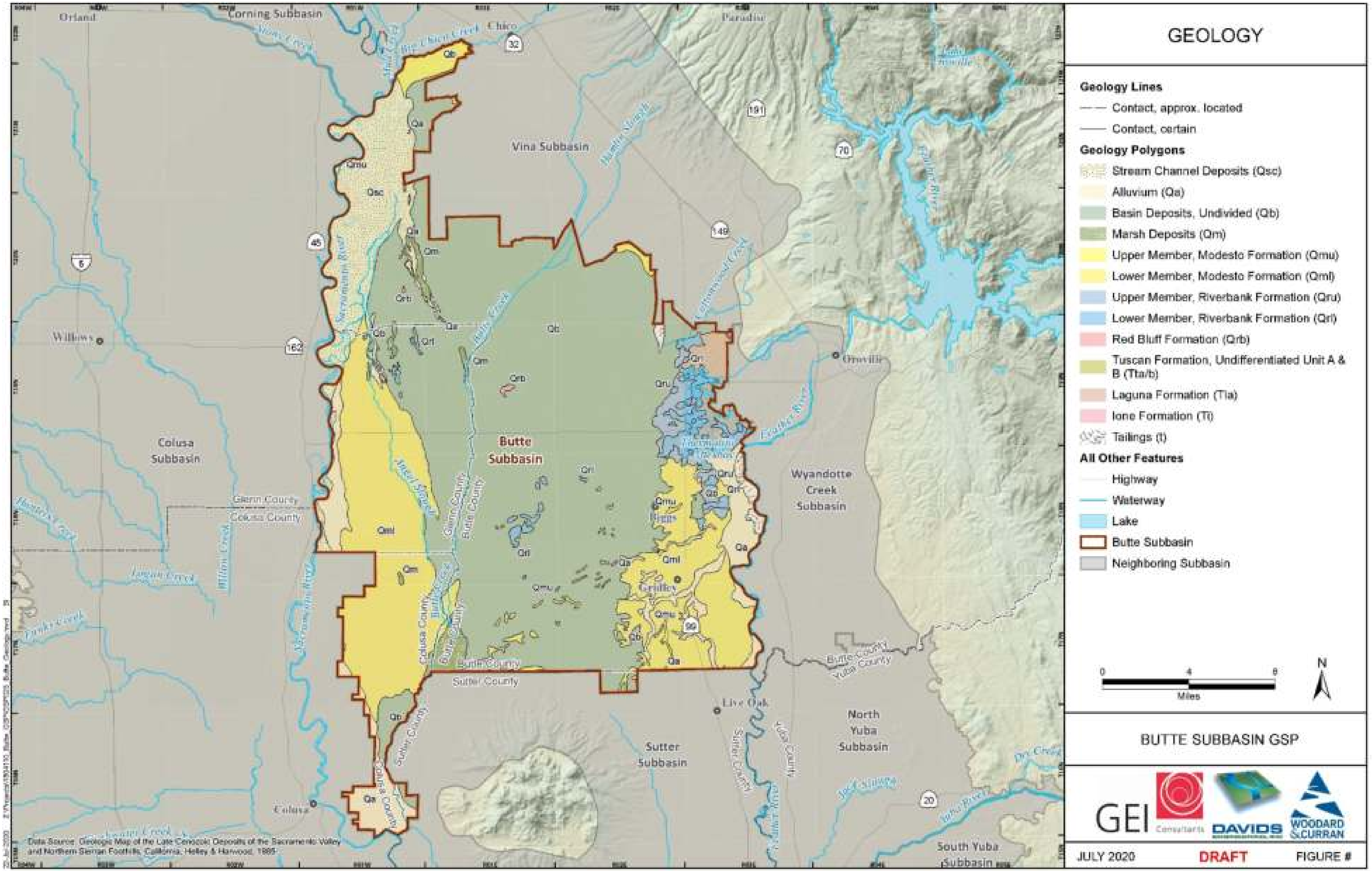

Figure 2-111. Surficial Geology of the Butte Subbasin (units defined in Table 2-2).

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2.2.1.5 *Groundwater Producing Formations*

Groundwater resources exist in the alluvial groundwater basin where spaces between gravel, sand, and clay particles of various formations store and transmit water in the aquifer systems. Principal hydrogeologic units of the Sacramento Valley groundwater basin consist of Pliocene sedimentary deposits, such as the Tuscan, Laguna, and Tehama formations, comprising primarily a semi-confined to confined aquifer system. Younger, overlying Quaternary terrace deposits, collectively referred to as Quaternary Alluvium, include, the Riverbank Formation and Modesto Formation and Basin Deposits. These comprise generally an unconfined aquifer system (DWR 2005, as cited in David Engineering 2016). These formations are discussed below.

2.2.1.5.1 Tuscan Formation

Tuscan Formation deposits are characterized by their Cascade Range origin and volcanic signature. The formation extends from Redding south to near Oroville, where surface exposures of the Tuscan formation are seen on the east side of the Sacramento Valley. In the subsurface, the volcanic sediments of the Tuscan Formation intermix with the metamorphic sediments of the Tehama Formation (Garrison 1962; Lydon 1968). The westward extent of the intermixed sediments generally occurs in the subsurface west of the Sacramento River (DWR 2014).

Overall, the Tuscan Formation is composed of a series of volcanic lahars (mudflows) that includes volcanic conglomerate, sandstone, and siltstone, and pumiceous tuff layers that were deposited over a period of about 1 million years (Lydon 1968; Helley and Harwood 1985). The source areas of the lahars were the eroded ancestral volcanoes, Mount Yana and Mount Maidu, that were historically located northwest and south of Lassen Peak in the Cascade Range (Lydon 1968). As the lahars flowed westward off of the ancestral volcanoes and onto the valley floor, they fanned out, causing deposition to vary in thickness and in topographic elevation. Over time, ancient streams and rivers flowed downslope over the lahars, forming channels which were then infilled with reworked volcanic sand and gravel sediments whose pore spaces contain fresh groundwater. Subsequent lahars flowed over and covered the reworked sediments, creating a confining layer over the sand and gravel aquifers (DWR 2014).

The Tuscan Formation has been divided into four units, A, B, C and D by Helley and Harwood (1985). The oldest and deepest unit, A is composed of interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone that contain minor amounts of metamorphic rocks. Overlying Unit A in places is Unit B, which is more widespread throughout the eastern part of the northern Sacramento Valley. It is composed of interbedded lahars, volcanic conglomerate, volcanic sand, volcanic sandstone, and siltstone, but no metamorphic rocks, and shows a more regularly layered sequence (Helley and Harwood 1985). Unit C overlies Unit B and is composed of a series of lahars with some interbedded volcanic conglomerate and sandstone. Tuscan Unit D is not present in the Butte Subbasin (DWR 2014).

The Tuscan Formation is unconformably and intermittently overlain by the youngest deposits of the Tehama Formation toward the center of the valley; or by the Red Bluff, Modesto, or Riverbank formations; or by stream channel and Basin Deposits in varying locations. In the southern part of the valley, the tuff breccia of the Sutter Buttes overlies and possibly interfingers with the Tuscan Formation north of the Sutter Buttes (DWR 2014).

2.2.1.5.2 Tehama Formation

Exposures of the Tehama Formation are seen on the west side of the valley from Redding south to Vacaville. In the subsurface, the metamorphic and sedimentary deposits of the Tehama Formation intermix with the volcanic sediments of the Tuscan Formation (Helley and Harwood 1985). Previous studies inferred that the eastward extent of the intermixed sediments generally occurs in the subsurface west of the Sacramento River. Recent DWR efforts confirm the intermixing of Tehama and Tuscan formation sediments from analysis of lithologic cuttings and geophysical logs (DWR 2014).

The Tehama Formation is composed of noncontiguous layers of metamorphic pale green, gray, and tan sandstone and siltstone, with lenses of pebble and cobble conglomerate (Helley and Harwood 1985). The source area of the Tehama Formation sediments is the Coast Ranges to the west and, to a lesser extent, the Klamath Mountains to the north. Sediments were deposited by streams flowing from the west under floodplain conditions. These fluvial deposits are characterized by a series of poorly sorted sediments, by channels of coarser sediments in the finer-textured strata, and by the lenticular character of the coarser beds (Russell 1931; DWR 2014).

The Tehama Formation is unconformably overlain intermittently by the Tuscan Formation toward the center of the valley; or by the Red Bluff, Modesto, or Riverbank formations; or by the Stony Creek fan alluvium further north in varying locations (DWR 2014).

2.2.1.5.3 Laguna Formation

The Laguna Formation extends discontinuously from Oroville south into the San Joaquin Valley. The Laguna Formation is a heterogeneous mixture of interbedded alluvial gravel, fine sand, silt, and clay of granitic and metamorphic origin (Olmsted and Davis 1961). Near Oroville, the gravel deposits are of granitic or metamorphic composition and are contained within a silty to sandy matrix; clay is more predominant in the fine-grained sediments south of Oroville. The Laguna Formation was deposited by the ancestral Feather, and by the Yuba, Bear, and American rivers to the south (Helley and Harwood 1985). During the Pliocene and Pleistocene epochs, uplift of the Sierra Nevada increased the erosion of the plutonic and metamorphic rocks on the eastern side of the valley. Rivers and streams carried the eroded material westward to the valley floor, and as the water overtopped the banks, it spread out across the broad floodplains of the valley, depositing the sediments into broad alluvial fans (DWR 2014).

2.2.1.5.4 Quaternary Alluvium

Younger sediments which may include the Riverbank or Modesto Formations, basin deposits, or surficial alluvium are collectively referred to as the Quaternary Alluvium. They are described in more detail below.

2.2.1.5.4.1 Riverbank and Modesto Formations

The Riverbank Formation consists of poorly to highly permeable pebble and small cobble gravels interbedded with reddish clay, sand, and silt. The formation is exposed throughout the Sacramento Valley and the San Joaquin Valley, extending discontinuously from Redding south to Merced (Marchand and Allwardt 1981). Terrace deposits of the Riverbank Formation appear in stream cuts that are topographically above the younger Modesto Formation terrace deposits. The terraces were formed by streams carrying eroded material from the surrounding mountain ranges to the base of the foothills, where they were deposited in wide alluvial fans and terrace deposits. Groundwater generally occurs under unconfined conditions. The Riverbank Formation is overlain by the Modesto Formation, basin deposits, or surficial alluvium.

The Riverbank Formation was formed by streams carrying eroded material from the Cascade Range, Sierra Nevada, and foothill areas to the base of the foothills where it was deposited in wide alluvial fans. It is present in discontinuous surface exposures, primarily from west of Oroville southward. In many places, the Riverbank Formation has been covered by more recent alluvial fan development. The thickness of the formation varies from less than 1 foot to over 200 feet, depending on location (Helley and Harwood 1985). The Riverbank Formation primarily overlies the Laguna Formation in the southeastern area and the Tuscan Formation in other portions of the Subbasin (DWR 2005).

The Modesto Formation consists of moderately to highly permeable gravels, sands, and silt and is widespread throughout the Sacramento Valley, occurring from Redding south into the San Joaquin Valley. The most notable occurrences are found along the Sacramento and Feather rivers and their tributaries. The Modesto sediments were deposited by streams that still exist today, and they are seen in the terrace and alluvial fan sediments that border present-day streams (Helley and Harwood 1985). The source area for the formation sediments are the surrounding Coast Ranges, Klamath Mountains, Cascade Range, and Sierra Nevada. Fresh groundwater occurs generally under unconfined conditions. (DWR 2014)

Wells penetrating the sand and gravel units of the Riverbank and Modesto Formations produce up to about 1,000 gallons per minute (gpm); however, the production varies depending on local formation thickness. Wells screened in the Riverbank and Modesto Formations are generally domestic and shallow irrigation wells (DWR 2004a; DWR 2004b).

2.2.1.5.4.2 Basin Deposits

The Holocene-age basin deposits overlie the alluvial fans and terrace deposits of the Riverbank and Modesto formations. Large exposures of basin deposits are seen in Butte, Glenn, Colusa, and Sutter counties, where they form the highly productive agricultural soils characteristic of these areas. Thickness of the basin deposits varies throughout the Sacramento Valley from less than 10 feet along the valley margins to more than 200 feet in the center of the valley (Helley and Harwood 1985). The basin deposits are composed of fine silts and clays, which were deposited by sediment-laden floodwaters that rose above the natural levees of streams and rivers, overflowing and spreading out across vast low-lying areas. These deposits provide limited quantities of groundwater to shallow wells because of the fine-grained nature of the sediments (Olmsted and Davis 1961; DWR 2014).

Overlying the alluvial fans of the Riverbank and Modesto formations are the fine silts and clays of the Holocene basin deposits. Basin deposits are the result of sediment- laden floodwater that rose above the natural levees of streams and rivers and spread out across vast low-lying areas. Basin deposits are seen in the Butte Subbasin, forming the highly productive agricultural soils characteristic of these areas (California 1985).

Thickness of the basin deposits varies generally from less than 10 feet along the margins of the exposure to more than 100 feet in the center of the valley. Basin deposits provide limited quantities of groundwater to shallow wells due to the fine-grained nature of the sediments. The location and thickness of basin deposits in the region can be seen on the geologic map as well as on the four cross-sections. Alluvium overlies the basin deposits along presently active stream and river channels (DWR 2005).

2.2.1.6 *Cross Sections*

Figure 2-12A is a cross-section key which shows where Butte Subbasin cross-sections exist in relation to those in the adjacent subbasins. **Figures 2-12B** to **2-12E** are cross-sections for the Butte Subbasin. The Tehama, Tuscan, and Laguna formations are unconformably overlain by younger sediments, which may include the Riverbank Formation, or the Modesto Formation; basin deposits; or surficial alluvium. These younger geologic units have been mapped collectively as Quaternary Alluvium on the cross section due to their relatively small thickness compared with the underlying geologic formations (DWR 2014).

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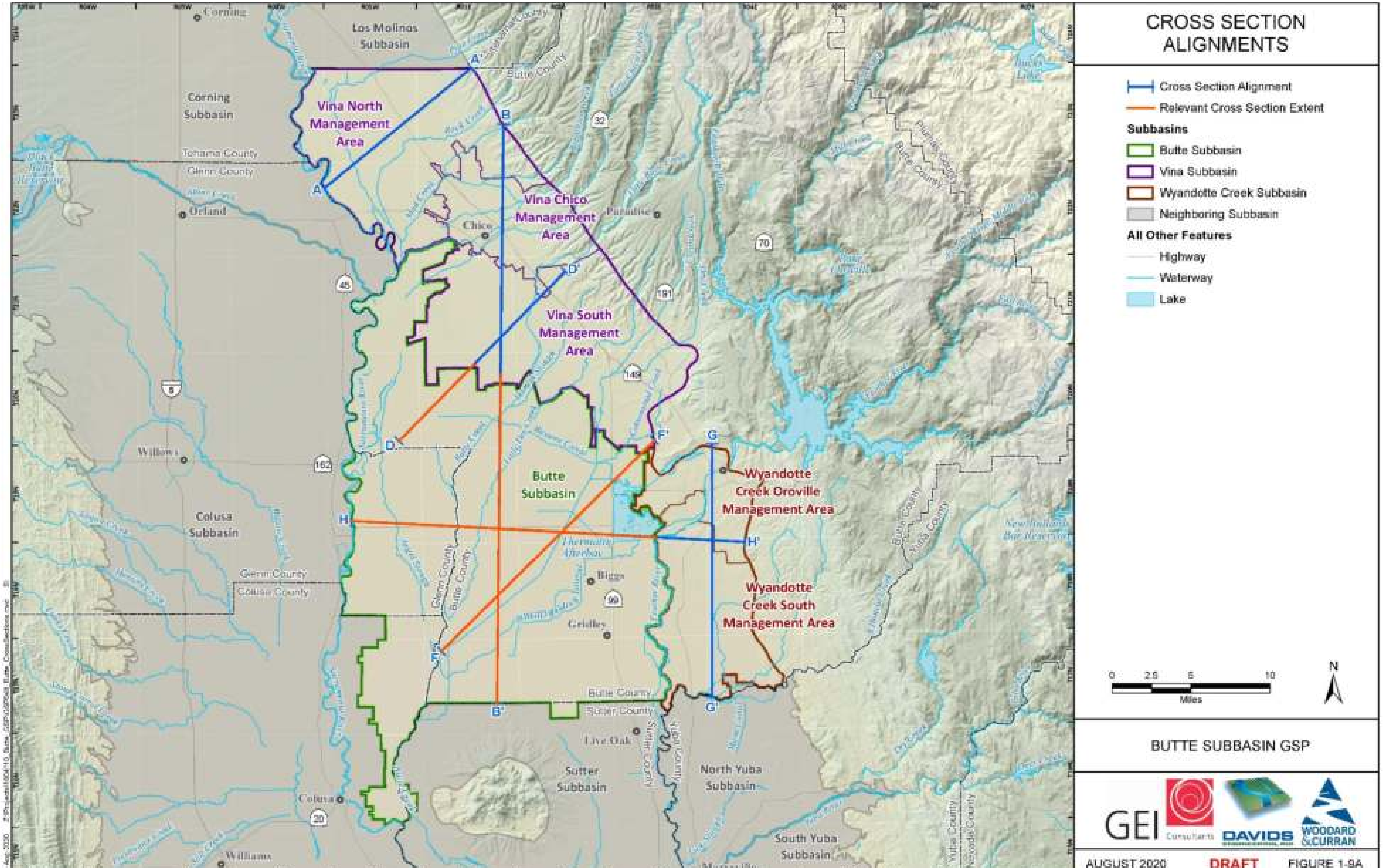

536 *Figure 2-12A. Alignment and Extent of Geologic Cross-Sections.*

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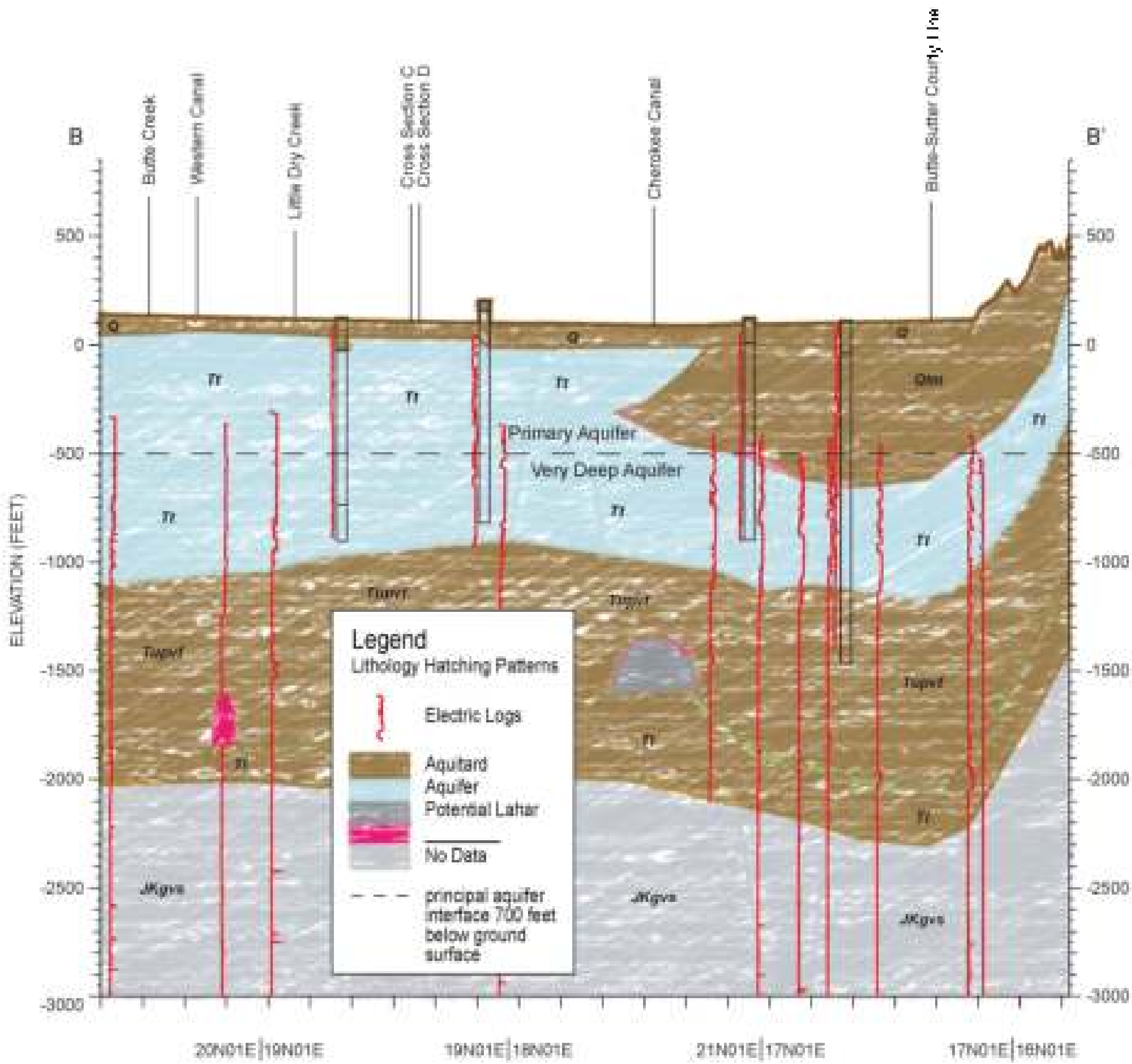

Figure 2-12B. North-South Geologic Cross Section B-B'

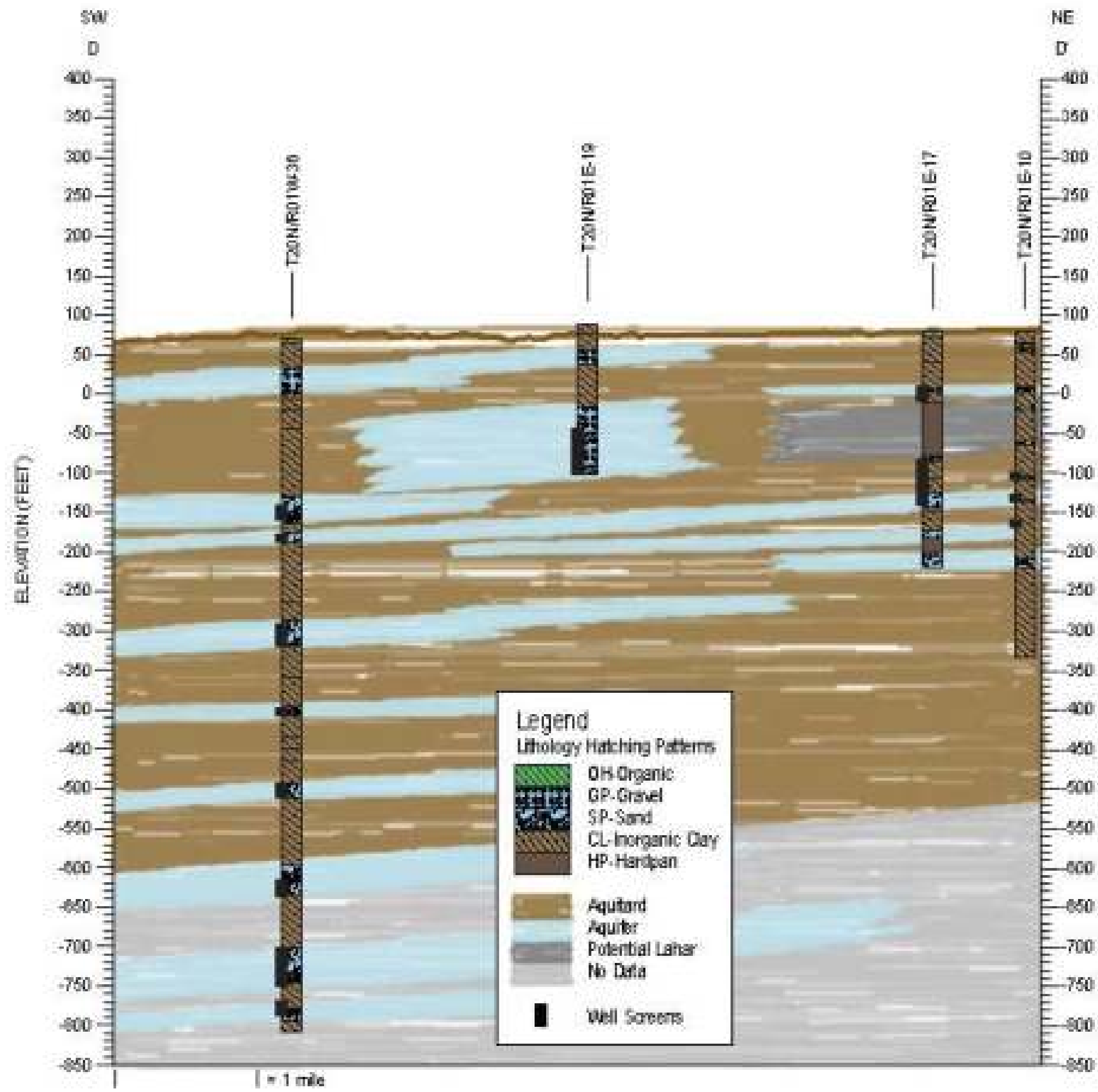

Figure 2-12C. Northeast-Southwest Diagonal Geologic Cross Section D-D'

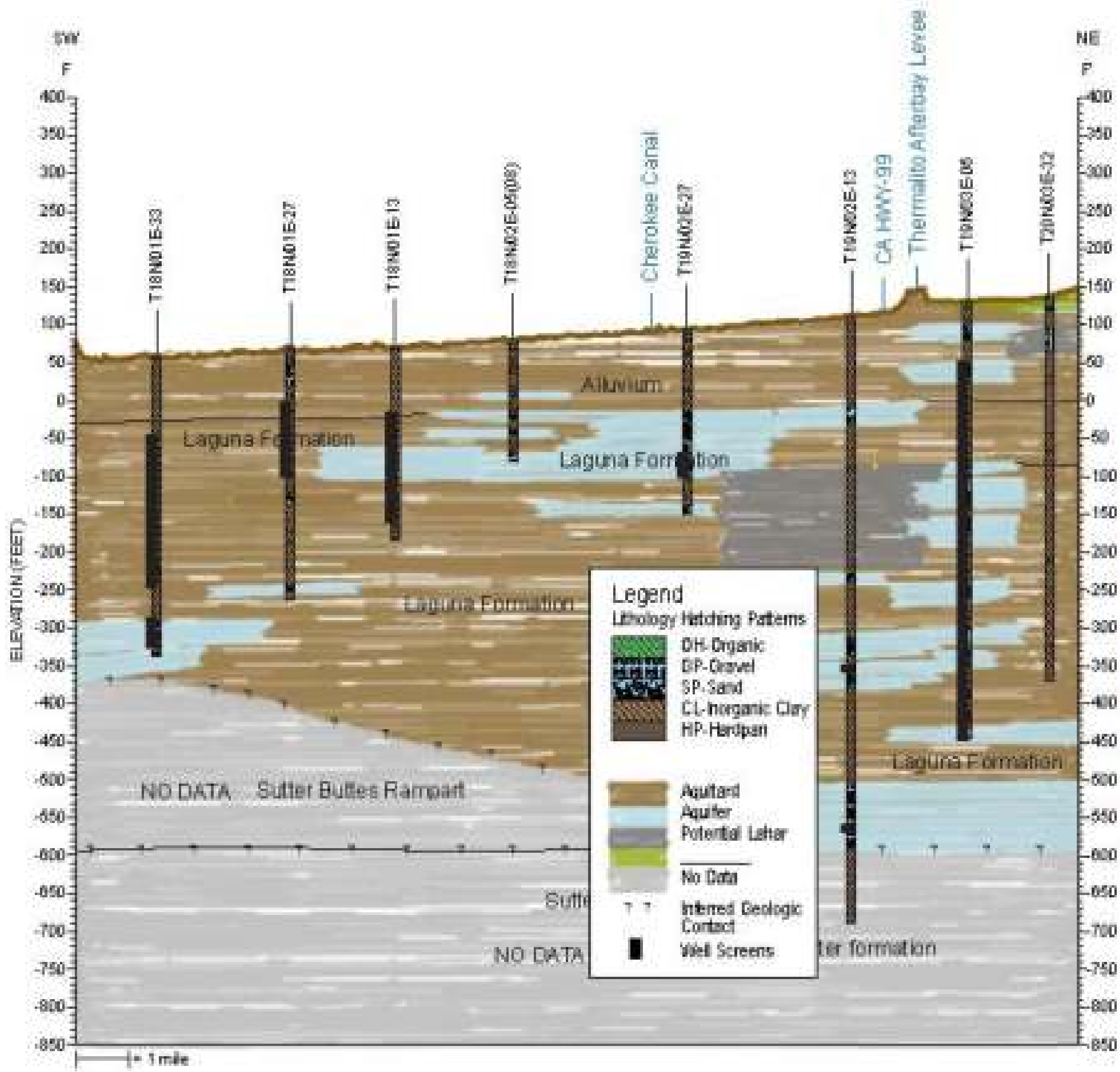

Figure 2-12D. Northeast-Southwest Geologic Cross Section F-F'

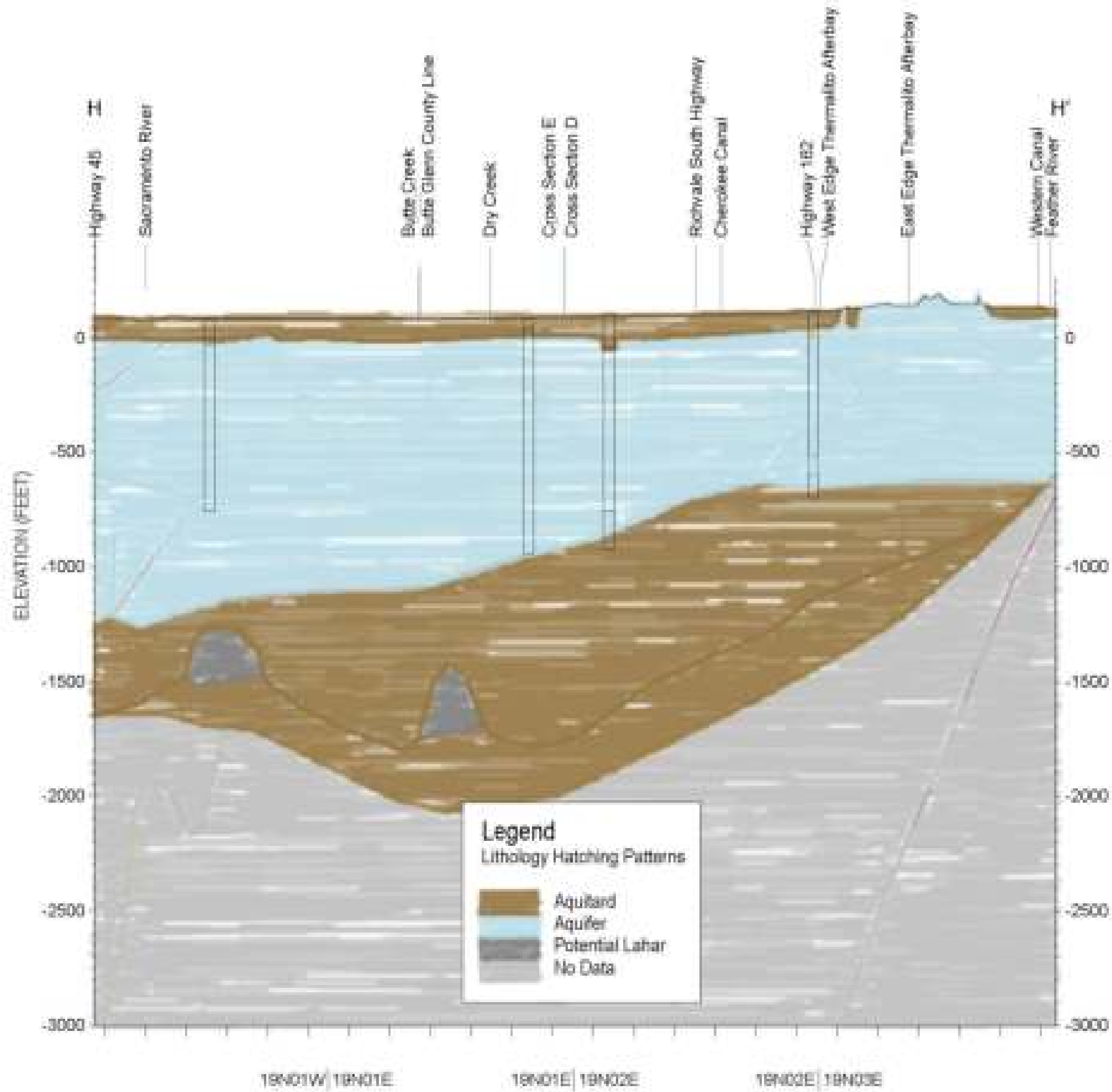

Figure 2-12E. East-West Geologic Cross-Section H-H'

2.2.1.7 Key Geologic Features

Barriers to groundwater flow in the Northern Sacramento Valley region include geologic structures such as the Red Bluff Arch, the Corning domes, the Sutter Buttes, and the buried Colusa dome. In the northern part of the valley, the Red Bluff Arch acts as a groundwater divide separating the Sacramento Valley groundwater basin from the Redding groundwater basin. South of Corning, the surface expression of the Corning domes influences the flow patterns of Stony Creek and Thomes Creek. Stony Creek flows southeast of the domes, with regional flow to the confluence of the Sacramento River, whereas Thomes Creek flows northeast of the domes, against regional flow to the Sacramento River (Blake et al. 1999). In the southern part of the valley in the Butte Subbasin, groundwater mounds up on the north side of the Sutter Buttes before it flows westward around the Buttes and between the buried Colusa Dome and southward (DWR 2014).

2.2.1.7.1 Willows Fault

The Willows fault is a steeply dipping, high-angle (greater than 74 degrees), reverse fault with east-side-up movement (Redwine 1972). The Willows fault progresses roughly north-northwest through the Sacramento Valley, trending from the south end of the valley at the Stockton fault near Stockton and terminating at the north end of the valley west of the Red Bluff fault. Traversing northwestward from the Stockton fault, the Willows fault progresses through the city of Sacramento and bends west-northwest around the Sutter Buttes where it displaces the Colusa dome. It then trends in a north-northwesterly direction through the Willows area where it again bends west-northwest. The Willows fault terminates at the north end of the Sacramento Valley in the Red Bank area west of Red Bluff. Notable splays off of the Willows fault include the Corning fault, the Paskenta fault zone, Black Butte Fault segment, the Elder Creek fault, and the Cold Fork fault (Jennings and Strand 1960; Harwood and Helley 1987).

The base of freshwater in vicinity of the Colusa Dome and Sutter Buttes (described below) rises to close to 400 feet below ground surface (DWR unpublished data). Prior work in this area suggests that connate marine water can move upward along fault zones (Curtin 1971).

2.2.1.7.2 Colusa Dome

The Colusa Dome is a subsurface feature that has been identified on geophysical logs of wells that were drilled for the natural gas industry. The dome is found at depth about 4 miles west of the Sutter Buttes and is a large, oval-shaped uplift measuring about 12 miles north to south and about 3 to 4 miles east to west. The vertical axis or arch of the dome is more than 1,500 feet (Williams and Curtis 1977). Williams and Curtis (1977) state that uplift of the Cretaceous sedimentary beds was caused by viscous bodies of magma rising and was similar to the cause of uplift of the Sutter Buttes.

However, Harwood and Helley (1987a) analyzed electric logs from oil and gas wells drilled in the area and concluded that the buried Colusa Dome was formed partly by east-side-up drag on a high angle reverse fault, most likely caused by the Willows fault, or a splay off of the Willows fault, and partly by magmatic intrusion that was localized by movement on that fault. In addition, they concluded that the orientation and movement patterns of geologic structures near the Sutter Buttes and the buried Colusa Dome suggest that deformation occurred in a regional east-west compressive stress field. The age of the Colusa Dome is contemporaneous with the age of the Sutter Buttes, about 1.36 to 1.56 Ma. (Hausback and Nilsen 1999; DWR 2014)

2.2.1.7.3 Sutter Buttes

The Sutter Buttes are the eroded remnants of a single volcano that erupted during the early Pleistocene, less than 2 million years ago (Hausback and Nilsen 1999) and provide the only significant topographic relief on the Sacramento Valley floor. This small-scale volcanic mountain range intruded the valley sediments during the early Pleistocene (1.2 million years before present) epoch. The intrusion buckled the valley sediments upward, forming a barrier to groundwater flow. The Sutter Buttes block the general north-to-south trend of groundwater migration, forcing groundwater to the surface. The upward movement results in a shallow groundwater table and the formation of wetlands along the west side of the Sutter Buttes.

2.2.1.7.4 Effects on Groundwater Flow

These structures cause a deviation in the typical regional direction of groundwater flow which is generally toward the Sacramento River from the northeast to the southwest and from the northwest to the southeast. However, in the area of the Gray Lodge Wildlife Refuge north of the Sutter Buttes, groundwater flow converges toward the Butte Sink. Groundwater from the central portion of the Butte Subbasin flows southwestward, while groundwater from the Sacramento River flows southeastward and eastward. The converging groundwater flow in this area is structurally controlled due to the intrusion of the Sutter Buttes to the east and the buried Colusa Dome to the west (DWR 2005).

2.2.1.8 *Principal Aquifers and Aquitards*

DWR defines "principal aquifers" under SGMA as the "aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems" (Cal. Code of Regs., title 23, § 351(aa)). Through an examination of hydrographs and lithology logs from multi-completion monitoring wells, two principal aquifers are defined in the Butte Subbasin: 1) Primary Aquifer and 2) Very Deep Aquifer.

The following observations from monitoring wells with continuous data in the Butte Subbasin support the definition of two principal aquifers:

- For the purposes of these observations the zones are defined as follows below ground surface: Very Shallow is 0-100 feet. Shallow is 100-200 feet. Intermediate is 200-600 feet. Deep is 600-700 feet. Very Deep is greater than 700 feet.
- Generally, the shallow, intermediate and deep zones of the aquifer systems in the Butte Subbasin show similar patterns of variability in groundwater levels (within and between years).
- However, the shallow and intermediate zones appear to be more heavily affected by groundwater pumping than other zones (evidenced by greater variability in water levels during the irrigation season).

- A vertical gradient exists in most multi-completion wells in the Butte Subbasin as shown by hydrographs depicting different groundwater levels in different zones of the aquifer system. In some cases, the direction of the vertical gradient (upward or downward) changes seasonally or over time from year to year.
- Monitoring wells across the Subbasin with screened intervals 700 feet below ground surface or deeper have shared characteristics and patterns in their observed water levels. This led to identification of the "Very Deep" zone.
- Although the Very Deep zone shows similar patterns in the timing of groundwater level variability from year to year compared to shallower zones, groundwater levels also show some distinct characteristics. Groundwater levels change more gradually over time (hydrographs appear "smoother" with less extremes) and water levels are higher than in shallower zones. The latter indicates an upward vertical gradient from a pressurized aquifer system in the Very Deep Zone.
- Vertical gradients suggest these different zones of the aquifer system are semi-confined and aquifer materials at various depths likely have different hydrogeologic properties. In addition, pumping activity concentrated in different zones likely also contributes to the differences in groundwater levels and gradients between zones.
- Lithology descriptions from a number of the monitoring wells show thick intervals of clay or fine-grained material (50-200 feet thick) separating screened intervals in multi-completion wells.
- Despite these thick fine-grained layers, trends and patterns in water levels within and between years show a hydraulic connection between the shallow and deepest zones of the aquifer system.

Groundwater levels shown in the hydrograph of multi-completion monitoring well 18N01W02E001-003 located near Butte City are presented in **Figure 2-13** below and reflect many of the observations outlined above.

Additional analysis of well logs is needed to identify the primary geologic formations making up the aquifer materials of these two principal aquifers.

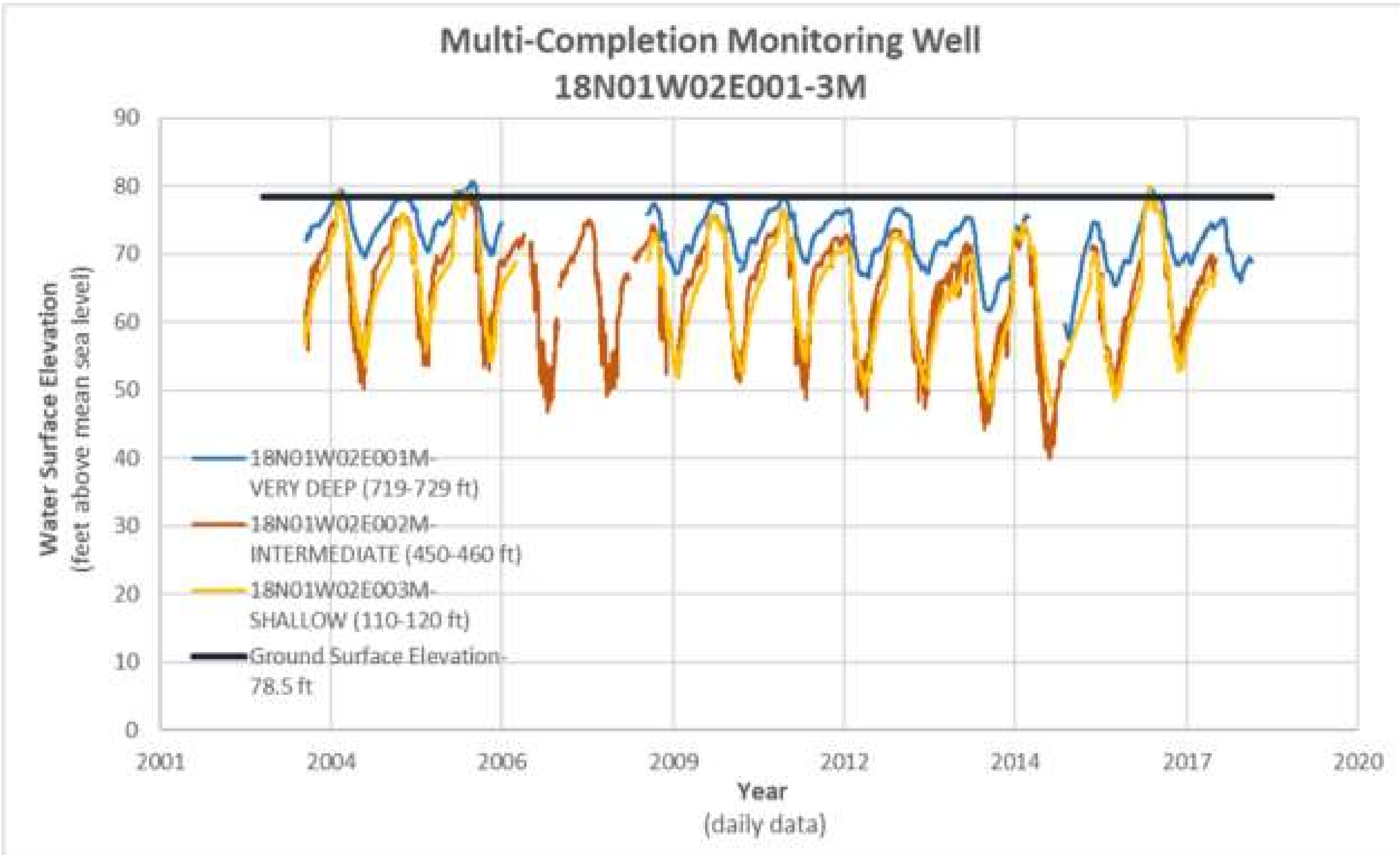

Figure 2-13. Groundwater Levels in Multi-completion Well near Butte City.

2.2.1.8.1 Primary Uses

Water produced from the Primary Aquifer is used to meet irrigation, domestic, and municipal water demand. Domestic supply is largely used to meet rural residential demands. Domestic wells are shallow with the vast majority being less than 100 feet deep. Municipal supply is largely used to meet demand from towns such as Biggs and Gridley.

The Very Deep Aquifer is only accessed by a limited number of wells.

2.2.1.8.2 Storage Coefficient

Specific Yield, or storativity, quantifies the ability of the aquifer to hold or store water. Estimates of specific yield for areas in the Butte Subbasin range from 5.9 to 7.7 percent (DWR 2005; DWR 2004a; DWR 2004b).

2.2.1.8.3 Transmissivity

Transmissivity (T) quantifies the ability of water to move through aquifer materials. The aquifer hydraulic conductivity (K) quantifies the rate of groundwater flow and is related to the transmissivity and aquifer thickness (b) by the following formula: $T = K \times b$. Limited hydraulic conductivity data is available for the subbasin.

2.2.1.8.4 Water Quality

Calcium-magnesium bicarbonate and magnesium-calcium bicarbonate waters are the predominant groundwater water types in the Subbasin. Magnesium bicarbonate waters occur locally near Biggs-Gridley, south and east to the Feather River. Total dissolved solids range from 122 to 570 mg/L, averaging 235 mg/L (DWR 2004a). Sodium bicarbonate type waters occur at the southern tip of the subbasin west of the Sutter Buttes. Water quality impairments include localized high concentrations of manganese, iron, magnesium, total dissolved solids, conductivity, ASAR, and calcium occurring within the Subbasin (DWR 2004a; DWR 2004b).

In the vicinity of the Colusa Dome and Willows Fault, the base of fresh water rises to close to 400 feet below ground surface (DWR unpublished data). This mound of saline water is explored and documented by Curtin 1971, suggesting that connate marine water moves upward along fault zones. Areas of high chloride water are thought to be from Cretaceous marine sedimentary rocks brought closer to the surface by faulting associated with the formation of the Sutter Buttes (Hull 1984). A study of groundwater quality in the Sacramento Valley also sampled a well in this area and observed elevated levels of salinity and other constituents such as total dissolved solids, chloride, and boron (USGS 2008).

The Butte Basin is defined as the flood basin between the Sacramento and Feather Rivers from Chico in the north to Yuba City in the South. Groundwater in the Butte Basin has a somewhat higher average dissolved-solids concentration compared to the eastern margins of the valley, possibly reflecting longer subsurface residence times or a change in sediment lithology. High silica concentrations may be a result of recharge from the Tuscan volcanic rocks facies in the east and from volcanic material around the Sutter Buttes. Even at 1,333 feet however the dissolved solids concentration of water is only moderate, at 526 mg/L (Hull 1984).

2.2.1.9 *Opportunities for HCM Improvements*

Additional monitoring and data collection provides opportunities to improve the HCM and understanding of the Butte Subbasin. A description of additional monitoring and data collection activities with this potential are described below. The installation of shallow monitoring wells under the "Field testing and monitoring equipment installation to understand the recharge rates and stream losses in the recharge zone" opportunity will be implemented to a fill a data gap in the monitoring network for depletions of interconnected surface water, as described in **Sections 4.4 and 5.9**. Of the remaining opportunities, some or all may be pursued during GSP implementation, depending on available funding and GSA priorities.

2.2.1.9.1 Field testing and monitoring equipment installation to understand the recharge rates and stream losses in the recharge zone

It might be useful to expand stream gauging locations to document changes in stream-aquifer interactions. In addition to the stream gauging, a series of shallow dedicated monitoring wells with temperature sensors installed along stream courses in the recharge corridor and downstream to the Sacramento River may help identify what sections of streams are losing or gaining. Shallow dedicated monitoring wells in the vicinity of potential GDEs may also provide valuable information. A total of 10 shallow monitoring wells are planned for installation, as described in **Sections 4.4 and 5.9**.

2.2.1.9.2 Identify areas where additional monitoring would help increase understanding of the aquifer

It would be useful to determine areas within the subbasin where additional monitoring would help increase understanding of the aquifer and the best approaches to increase monitoring in these areas, which could include installation of new wells or increased monitoring at existing wells.

2.2.1.9.3 Assess Interaction between Sacramento and Other River Stage Response to Changes in Groundwater Levels

It is recommended that additional studies be conducted to better assess the interaction between the river stage on the Sacramento River, Feather River, and other major tributaries with changes in groundwater levels in the Primary and Very Deep aquifers in the subbasin.

2.2.1.9.4 Expand Isotopic Analysis to Further Assess Groundwater Recharge

Future recharge and aquifer studies should include the collection and interpretation of stable isotope data. Methodology considerations include:

1. Seasonal sampling should be performed as part of future surface water and groundwater isotope studies for purposes of assessing groundwater recharge.
2. Monitoring wells with multiple screened intervals (multi-completion monitoring wells) are recommended to assess stable isotope data at different depths. Sampling locations in this study with a single well-screen interval do not provide nearly as much insight as sampling locations with wells screened at multiple depths.
3. Monitoring wells with relatively short-screened zones (20 feet or less) are preferred to minimize mixing between aquifer zones or between aquifer zones and residual water retained within the aquitard zones between aquifers. The previously referenced final report of the Lower Tuscan Aquifer Monitoring, Recharge, and Data Management Project (Brown and Caldwell 2013) determined that the aquitards can release large volumes of water to the aquifer in areas where large volumes of groundwater are extracted.

2.2.1.9.5 Characterize recharge source with general water quality

It would be useful to conduct general mineral analysis on groundwater samples to evaluate whether elevated electrical conductivity (EC) values observed are due to irrigation influences (e.g. elevated nitrate, calcium, sulfate) or due to geologic formation characteristics (e.g. elevated sodium, chloride, and boron) or other influences.

2.2.1.9.6 Contribution of recharge from rainfall directly on the Lower Tuscan outcrop

Stable isotope abundances indicate that a substantial proportion of recharge is derived from elevations consistent with the outcrop of the Lower Tuscan Formation (i.e., within the Lower Foothills). Thus, it would be useful to collect local precipitation during an entire precipitation season at varying elevations across the outcrop and analyzed for stable isotopes to better correlate or calibrate the groundwater isotope values with local precipitation sources.

2.2.1.9.7 Recharge rate

Most well locations and depths could be sampled and analyzed for presence of tritium to help distinguish whether recharge to individual aquifer zones is occurring over periods shorter than about 60 years, or whether recharge is occurring over longer timeframes. This can help better understand the nature of hydraulic connection between different zones in the aquifer system.

2.2.1.9.8 Additional Airborne Electromagnetic Method (AEM) data collection

AEM data collection could help address uncertainty in the structure of the subbasin and confining layers. AEM data may also help identify and better characterize areas of shallow saline water.

2.2.1.9.9 Limited data for aquifer properties of the Primary and Very Deep principal aquifers.

Limited sources of data exist providing estimates of transmissivity and storativity for the defined Primary and Very Deep aquifers, as defined for the GSP.

2.2.2 Current and Historical Groundwater Conditions *(Reg. § 354.16)*

2.2.2.1 *Description of Current and Historical Conditions*

Groundwater conditions in the Butte Subbasin are continually monitored and are comprehensively described in the 2001 and 2016 Water Resource Inventory and Analysis Reports produced by Butte County; these reports are included as Appendix 2.B.a and 2.B.b, respectively. These documents and other reports portray a subbasin that has adequate groundwater resources to meet demands under most hydrologic conditions. However, comparison of the reports illustrates how in the period between their issuance, groundwater conditions have become more constrained, and, as forces ranging from population growth to climate change play out, the value of well-informed water management policies and practices is likely to increase. In short, as shown below**,** while groundwater conditions in the Subbasin remain stable, maintaining this condition in the future may become less the result of a state of nature and more the reward for thoughtful management. Groundwater sustainability in this Subbasin is also dependent on surface water supplies and thus will always be vulnerable to any future conditions affecting the availability of surface water supplies. A variety of factors have the potential to influence future surface water availability such as hydrologic changes (due to climate change or other factors) or regulatory changes (such as any that may impact the contractual quantities of water DWR is obligated to provide per the Feather River Diversion Agreements). During times of surface water curtailment and drought (such as in 2015), the Subbasin depends on groundwater resources and draws down groundwater levels. Historically, the aquifer and groundwater levels have always recovered in the first year following a drought. The water budget analysis presented in this section provides a quantitative assessment of how conditions have changed in the Butte Subbasin and an indication of how conditions may change in the future.

2.2.2.2 *Groundwater Trends*

2.2.2.2.1 Elevation and flow directions

Figures 2-14 and **2-15** show groundwater elevations in the Primary Aquifer of the Butte Subbasin for the spring and fall of 2015 and **Figures 2-16** and **2-17** show the same information for the spring and fall of 2019. **Figures 2-16** and **2-19** show groundwater elevations in the Very Deep Aquifer of the Butte Subbasin for the spring and fall of 2015, and **Figures 2-20** and **2-21** show elevation contours for the spring and fall of 2019.

Contours plotted on **Figures 2-14** through **2-21** show first encountered groundwater as reported by the California Statewide Groundwater Elevation Monitoring (CASGEM) Program. The data were processed as follows:

- Data from CASGEM were used to identify wells in the Butte Subbasin plus supplemental sites used to extend the contours to the west.

- Water level readings for 2015 and 2019 were then filtered for measurements taken between September 20th and October 30th for the fall contours and between March 20th and April 30th for the spring contours.

Wells showing depths to first encountered groundwater deeper than 500 feet were eliminated from the data set. The remaining readings were sorted by well depth. Wells having identical state well number site codes were then filtered to select the shallowest well from each nested well cluster.

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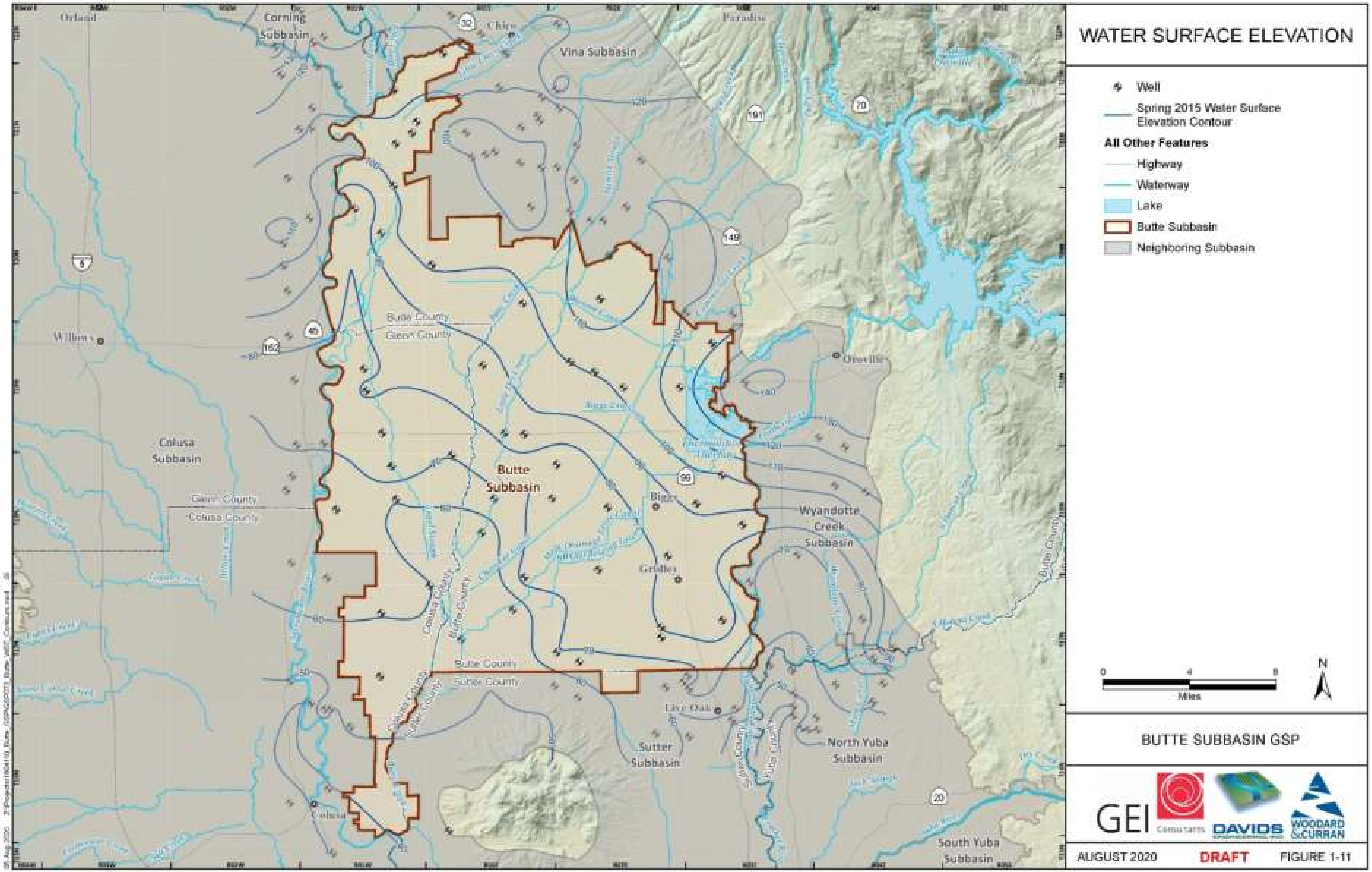
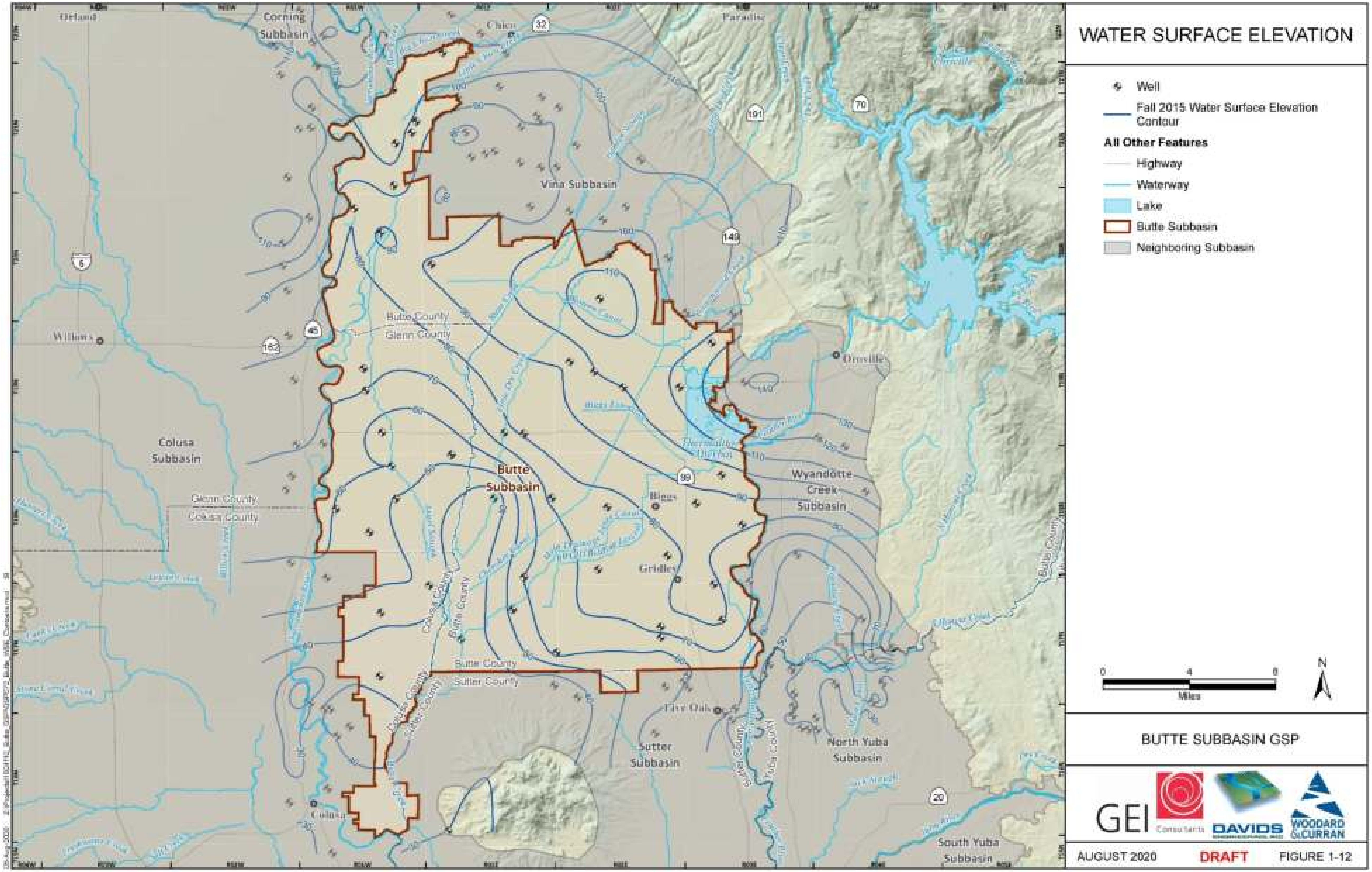


Figure 2-14. Water Surface Elevation Contours – Primary Aquifer (Spring 2015)



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879 *Figure 2-15. Water Surface Elevation Contours – Primary Aquifer (Fall 2015)*

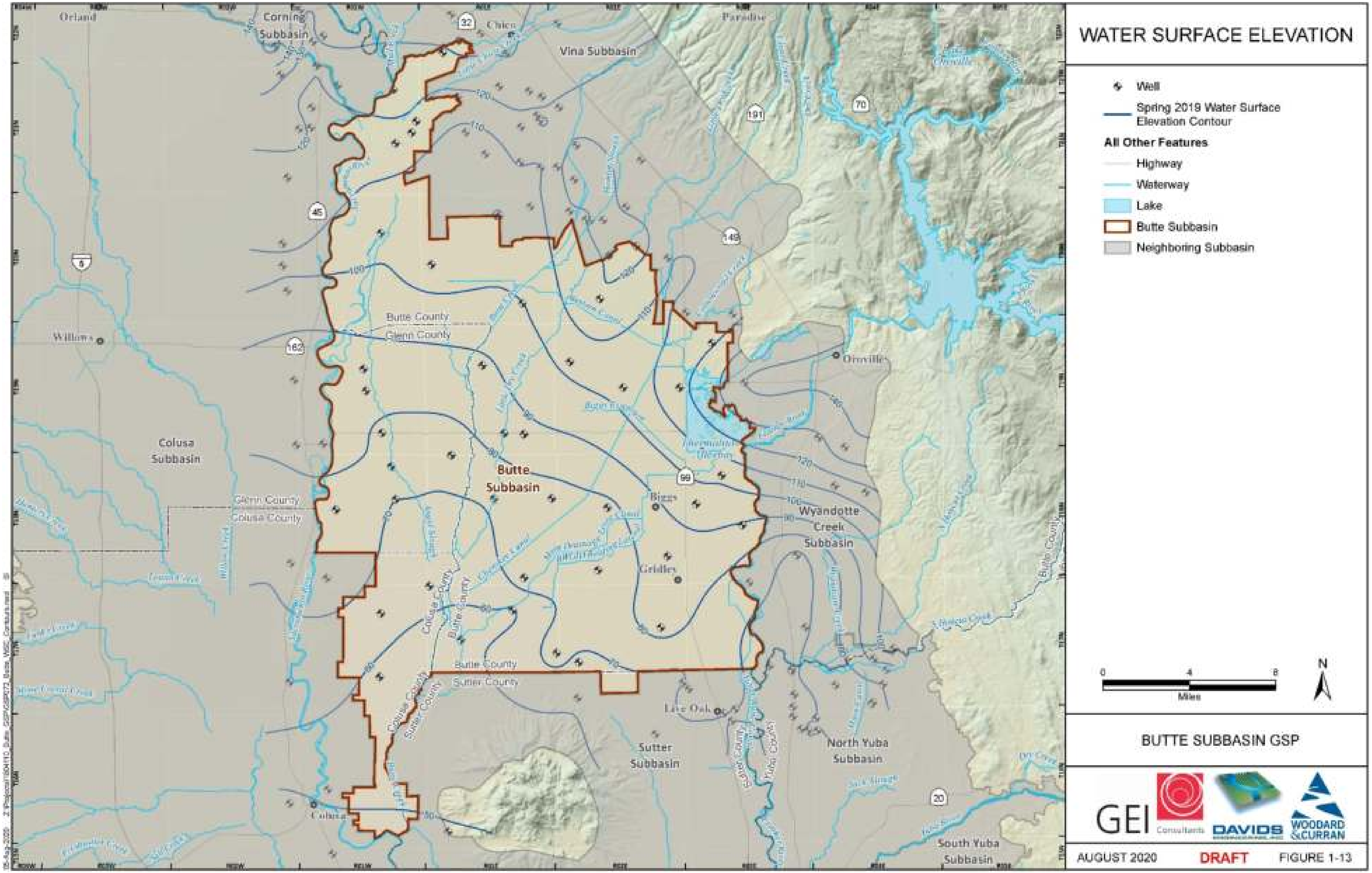

Figure 2-16. Water Surface Elevation Contours – Primary Aquifer (Spring 2019)

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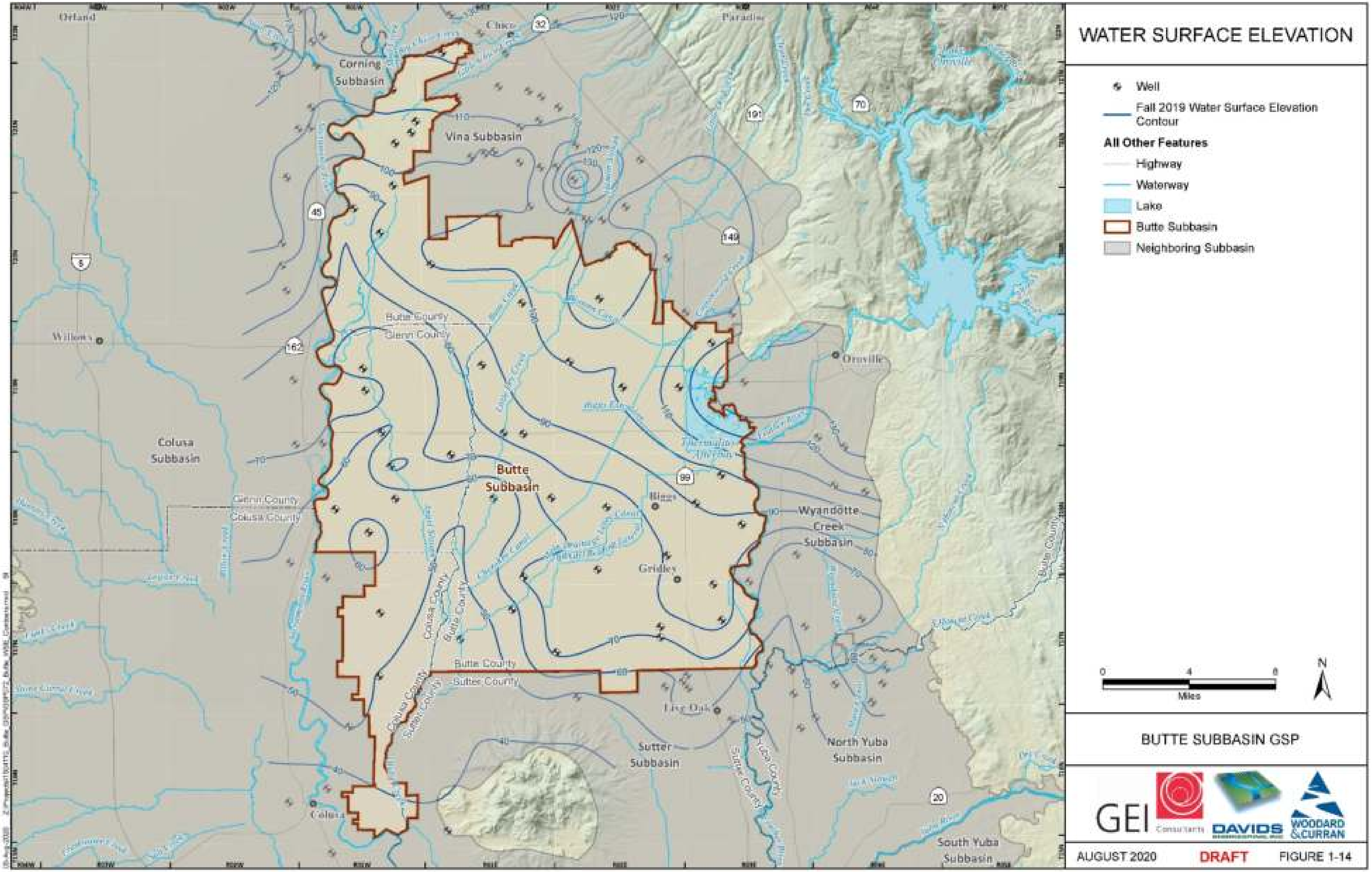


883 *Figure 2-17. Water Surface Elevation Contours – Primary Aquifer (Fall 2019)*

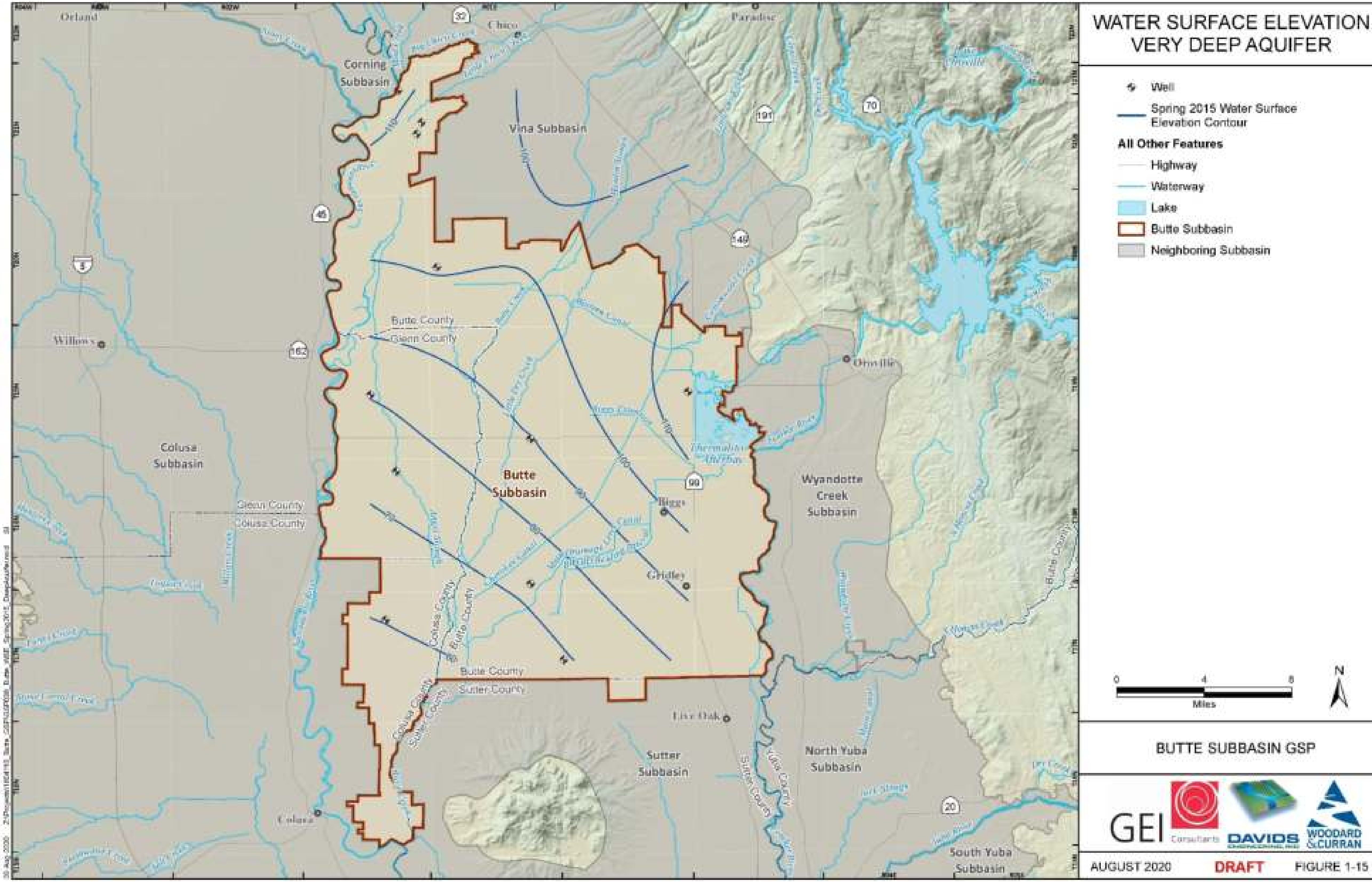
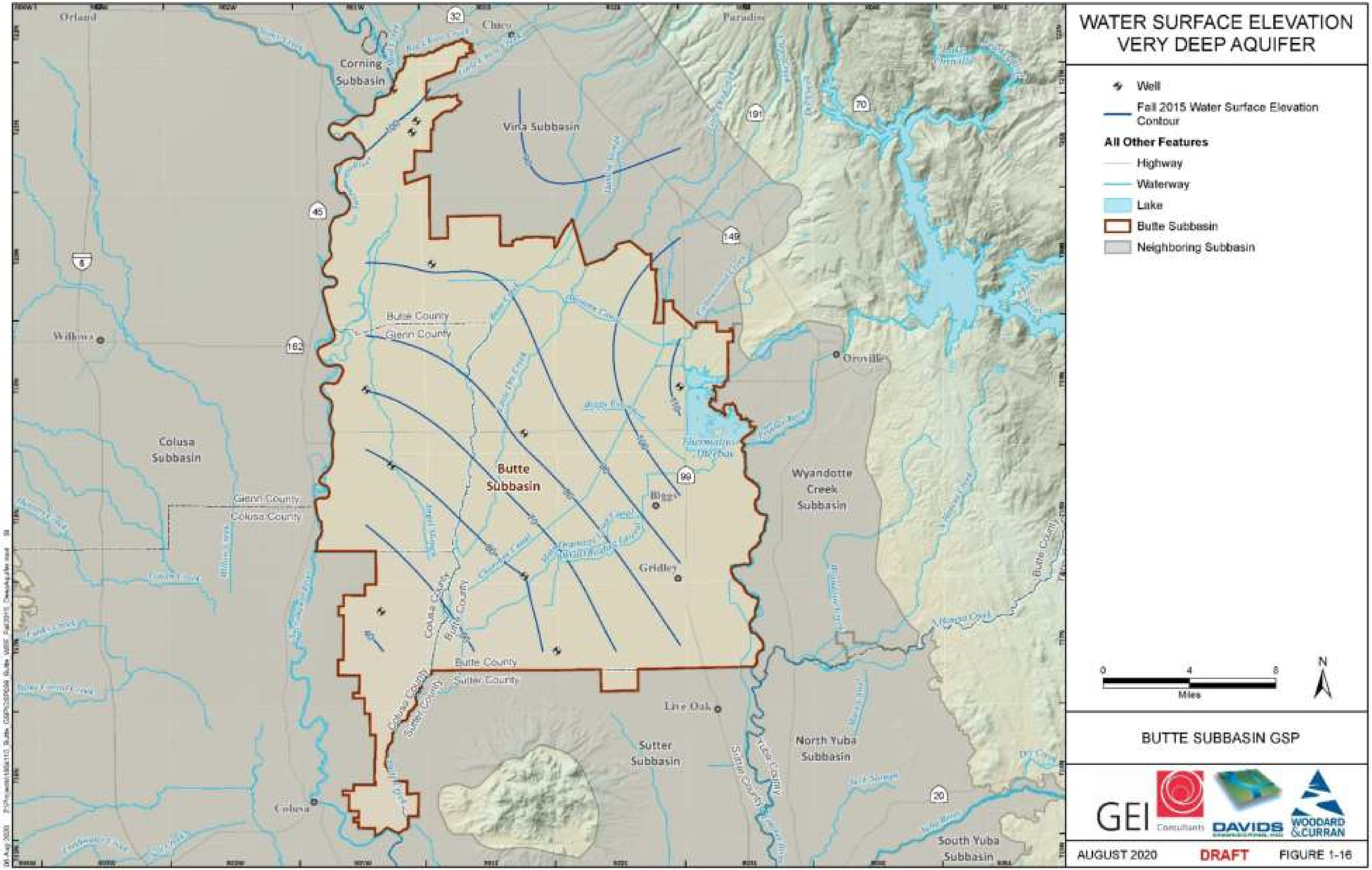


Figure 2-18. Water Surface Elevation Contours – Very Deep Aquifer (Spring 2015)



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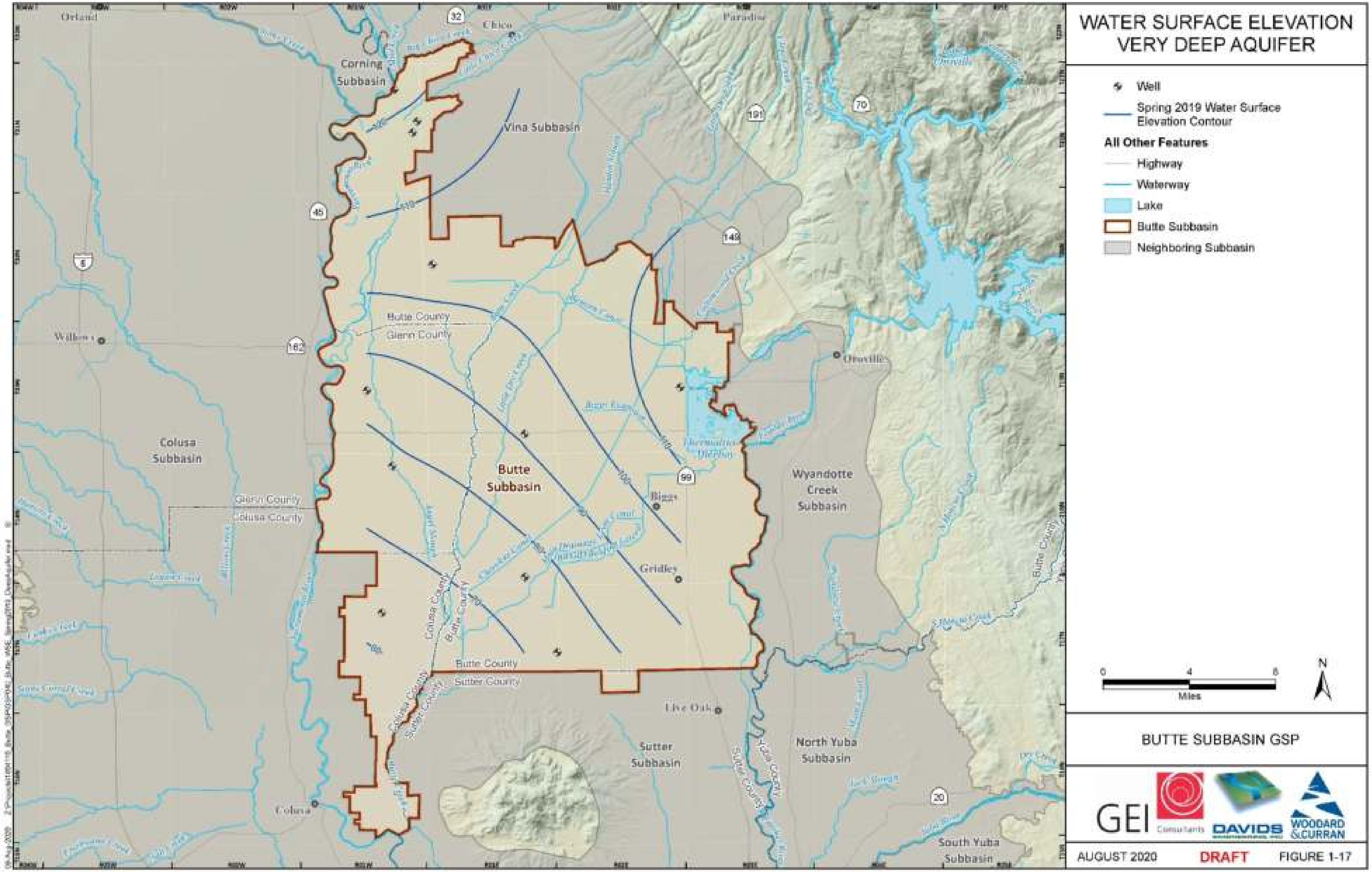
887 *Figure 2-19. Water Surface Elevation Contours – Very Deep Aquifer (Fall 2015)*



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889 *Figure 2-20. Water Surface Elevation Contours – Very Deep Aquifer (Spring 2019)*

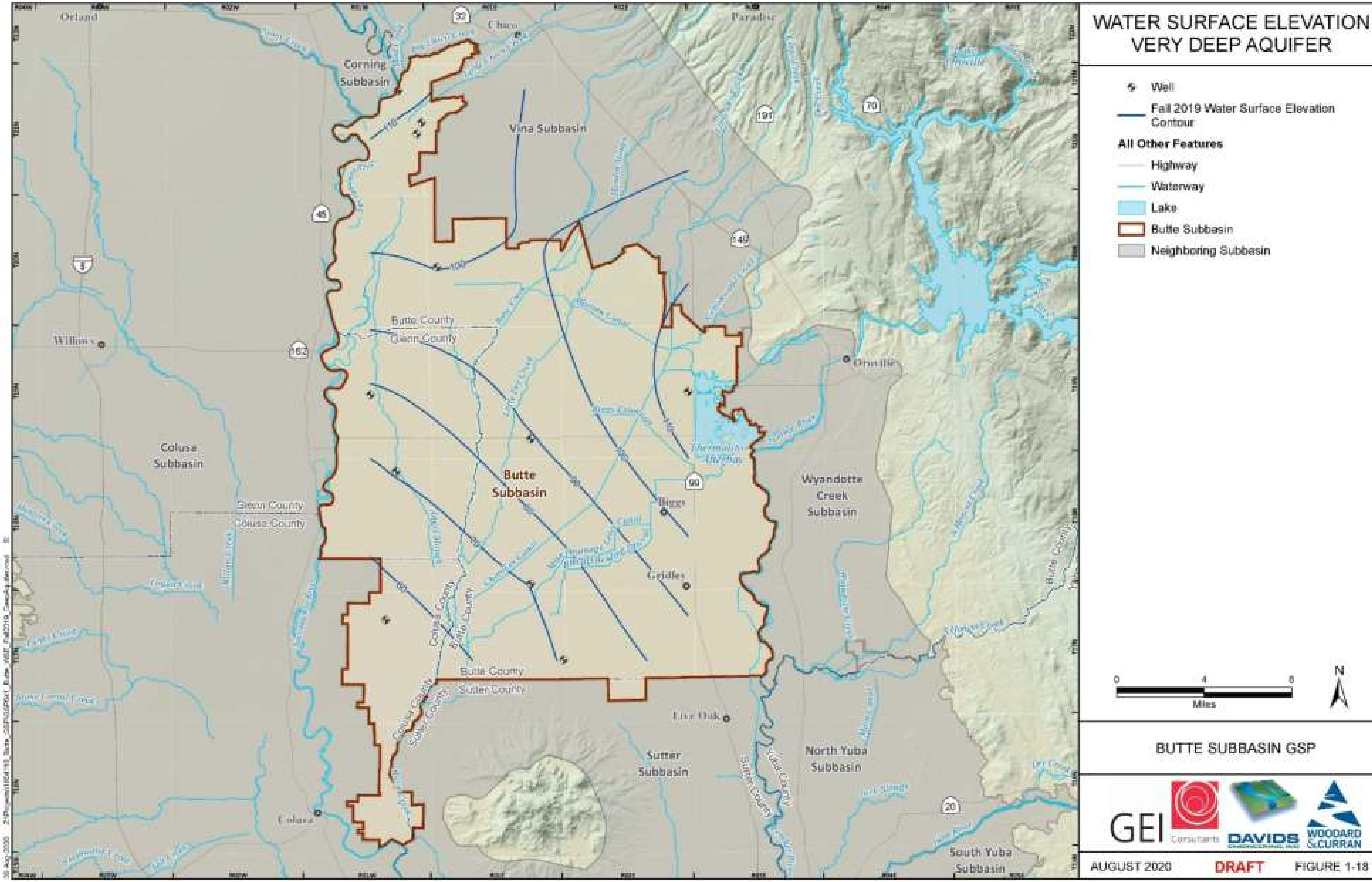


Figure 2-21. Water Surface Elevation Contours – Very Deep Aquifer (Fall 2019)

The four contour maps of the Primary Aquifer (**Figure 2-14** through **Figure 2-17**) each display groundwater elevations that are higher in the north of the Subbasin than in the south indicating a general gradient that causes water to flow from north and from foothill recharge areas and Thermalito Afterbay in the east toward the south. Elevations in fall 2015 tend to be lower than in the spring, a pattern typical of valley floor locations and reflective of increased pumping during the 2015 irrigation season (described in more detail below). However, fall 2019 elevations are similar to spring 2019 elevations.

The Butte Subbasin practices conjunctive use to manage surface water and groundwater supplies. During normal or wet hydrologic conditions, the Butte Subbasin has surface water available to support irrigation demands and provide recharge over a large portion of the Subbasin. However, during dry periods and drought, if surface water supplies are curtailed, groundwater pumping is increased to support irrigation demands. This increased pumping typically results in a decrease in groundwater levels; however, groundwater levels tend to recover following dry periods once surface water availability again increases, showing no long-term or chronic decrease in groundwater levels. This pattern is demonstrated through a comparison of groundwater elevations in 2015 and 2019, as described below.

When comparing elevations observed in the spring of 2015 with those reported in 2019, 2015 observations across the Subbasin are marginally higher, but similar, to those reported in 2019. This demonstrates consistency in groundwater elevations over this period. However, fall elevations observed in 2019, while similar to the 2015 elevations in the vicinity of the Thermalito Afterbay along the eastern boundary of the Subbasin, are higher than those observed in 2015 at locations in the interior of the Subbasin. This is likely the result of the higher level of groundwater pumping that occurred during the 2015 irrigation season, relative to other years, in response to the curtailed supply of surface water available to Feather River Settlement Contractors. However, groundwater levels recovered following the 2015 irrigation season, resulting in similar spring 2019 measurements relative to spring 2015 and higher fall 2019 measurements relative to fall 2015.

The corresponding contour maps of groundwater elevations in the Very Deep Aquifer (**Figure 2-18** through **Figure 2-21**) present steady elevations in the vicinity of Thermalito Afterbay that decrease toward the southwest indicating a clear gradient of flow with water recharged from the foothills to the east of the Vina Subbasin and radiating from the Afterbay moving toward the southwest. The decline in groundwater elevations between spring and fall results in a steepening of the gradient between the two periods.

Elevations observed in the Very Deep Aquifer in the spring of 2019 compare closely with those reported in 2015. However, elevations in the fall of 2019 in the southwest of the Subbasin are approximately 20 feet higher than those reported in 2015, an outcome that may be another manifestation of the high volume of groundwater pumped during 2015.

2.2.2.2.2 Lateral/vertical gradients

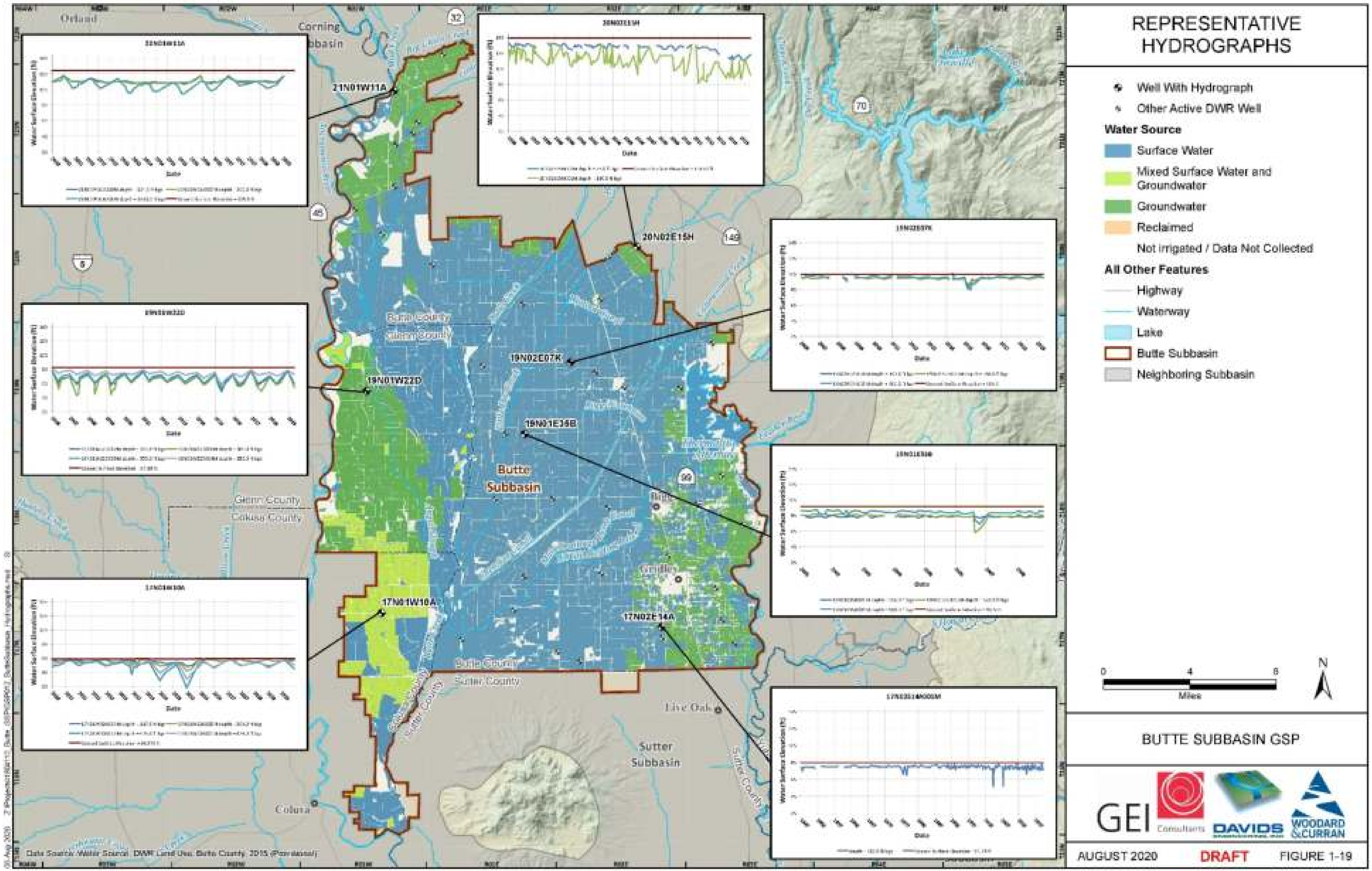
Lateral groundwater gradients generally reflect the ground surface topography. In the foothills east of the Sacramento Valley the gradient is steep, as high as 60 feet per mile. However, the gradient in the Butte Subbasin is gentle reflecting the area's flat topography and the presence of the Sacramento River. In places the gradient is as little as 3 feet per mile and the overall gradient in the Subbasin is approximately 5 feet per mile.

In the southeast of the Subbasin, groundwater flow converges in the Butte Sink where it may support wetlands in this area. The Sutter Buttes and Colusa Dome, a subsurface feature west of the Sutter Buttes, impede groundwater movement to the south. This impediment may cause groundwater to move upward, resulting in a shallow groundwater table and the formation of wetlands (DWR 2000).

Figure 2-22 is a map of the Butte Subbasin that displays hydrographs of key monitoring wells. Just as comparison of the spring and fall contours indicated the shift in groundwater elevations that typically occurs between the seasons, the hydrographs display annual oscillations in elevations as well as trends over the monitoring period, snapshots of which are captured in comparison between the 2015 and 2019 contours. Each of the hydrographs display water surface elevations in feet above mean sea level and also gives the depth of the bottom of the well which indicates the location of the zone being measured.

Most of the hydrographs are taken from single completion wells where only one aquifer depth is screened, however a number of the hydrographs are from clusters of nested monitoring wells which measure groundwater elevations at three or four depths at a single location.

Hydrographs for the selected wells in the Butte Subbasin echo the seasonal fluctuations illustrated in the contour maps with groundwater elevations at all locations being shallower in the winter and spring than in the summer and fall. Most of the hydrographs show annual changes in groundwater levels oscillating around a central axis. As observed in the comparison between 2015 and 2019 groundwater contours, hydrographs at three locations (19N02E207K002M-004M, 19N01E35B001M-003M, and 17N01W10A001M-0004M) show pronounced dips in 2015 which may result from increases in groundwater extraction in response to curtailed deliveries of surface water. Well 20N02E15H001M-002M located near the boundary with the Vina Subbasin shows the greatest declines in water levels during the period that corresponds with the recent drought with the shallow well also indicating a recovery in water levels. By contrast, water levels observed at three depths in the well located between the Sacramento River and Harbean Slough (21N01W11A001M-003M) show little impact from the drought.



970
971 *Figure 2-22. Representative Hydrographs.*

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Vertical groundwater gradients are typically measured by comparing groundwater elevations using multi-completion or nested wells that are designed to measure elevations from different aquifer zones. If groundwater levels in the shallower zones are higher than in the deeper ones, the gradient allows downward movement of groundwater. In locations where groundwater levels in the shallower zones are lower than in the deeper zones, the gradient encourages upward movement of groundwater. In locations where groundwater levels are similar in elevation and track each other in fluctuations, as is most often the case with nested wells in the Butte Subbasin, there is no apparent vertical gradient or no vertical movement of groundwater.

The hydrographs of the nested well located between Angel Slough and the Sacramento River (19N01W22D004M-007M) show water levels in the very shallow well that display relatively little annual fluctuation, suggesting a correspondence between groundwater elevations and river levels. The deeper wells display greater fluctuation in seasonal water levels that tend to track each other indicating some connection between the shallow, intermediate and deep zones.

2.2.2.2.3 Regional patterns

The series of contour maps and hydrographs presented above complement each other in showing how groundwater levels respond to seasonal variations in demand and recharge and are affected by long-term events such as the recent drought (e.g. 2015). The patterns in groundwater conditions observed in the Butte Subbasin resemble those found throughout the region and are driven by similar forces. However, in contrast to some neighboring subbasins, the Butte Subbasin is dominated by surface water supplies, which tends to reduce reliance on groundwater pumping and moderate fluctuations in groundwater elevations in much of the Subbasin. However, during times of surface water curtailment and drought (such as in 2015), the Subbasin depends on groundwater resources and draws down groundwater levels. Historically, the aquifer and groundwater levels have always recovered in the first year following a drought.

In addition to the impacts of local water use and regional hydrology, groundwater conditions in the Butte Subbasin are also affected by the Subbasin’s setting. As the groundwater contour maps show, there is a pattern of groundwater recharge that originates in the foothills east of the Vina Subbasin flowing into the Butte Subbasin along with recharge from Thermalito Afterbay. South of the Afterbay, groundwater contours in both the Butte and the Wyandotte Creek subbasins indicate accretion to the Feather River. Groundwater flow originating outside of the Butte Subbasin is augmented by recharge generated within the Subbasin through precipitation and deep percolation of applied surface water. These sources of recharge contribute water to low lying areas within the Subbasin, such as the Butte Sink, and to groundwater moving to neighboring subbasins to the southwest.

2.2.2.2.4 Change in storage

Changes in groundwater storage in the Butte Subbasin follows a pattern typically seen in the majority of the Sacramento Valley, where during normal to wet years, water stored in the aquifer system is withdrawn over the summer when demand is high. During this time the main pathways for groundwater recharge are deep percolation from irrigation applications and canal seepage. Net reductions in storage during the summer are replenished over the winter from precipitation and surface water inputs, allowing storage to potentially rebound by the following spring. This pattern is often disrupted during dry and critical years when demands for groundwater may equal or exceed those of normal and wet years, but reduced precipitation, lower stream levels and the possibility of curtailed surface water deliveries reduces opportunities to replenish depleted storage.

Review of the hydrographs from monitoring wells in the subbasin indicate that groundwater elevations, and hence groundwater storage, are relatively stable. As the water budget (*see* **Section 2.2.3**) indicates, the subbasin benefits from substantial recharge resulting from diversions of surface water for irrigated agriculture in the area. In addition, the Sacramento River, Feather River, and other streams both serve to stabilize groundwater elevations and storage volumes by providing recharge in certain reaches and at certain times.

The dynamics of the interaction between inflows, outflows, changes in groundwater elevations and changes in storage are captured in the water budget for the Butte Subbasin and are estimated by the Butte Basin Groundwater Model (BBGM)(BCDWRC 2021).

A graph depicting estimates the annual and cumulative change in the volume of groundwater in storage between seasonal high groundwater conditions, including the annual groundwater use and water year type based on the Sacramento Valley Water Year Index[14] is provided in **Figure 2-23**. Water year types are identified as wet (W, shaded blue), above normal (AN, shaded green), below normal (BN, shaded yellow), dry (D, shaded orange), or critical (C, shaded red). Annual change in storage was estimated using the BBGM based on March groundwater storage amounts. Groundwater pumping was estimated using the BBGM and is shown on a water year basis[15]. Values are reported in thousands of acre-feet (TAF).

As indicated in the figure, groundwater storage has generally decreased in dry and critical years and increased in wet years. In above normal and below normal years, changes in storage are less predictable, with increases in some years and decreases in others. For the recent historical period, which was marked by relatively dry conditions from 2007 to 2016, with the exception of the wet year of 2011, there has generally been a decline in groundwater storage within the

[14] Additional details describing the Sacramento Valley Water Year Index are available from the California Data Exchange Center (https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST).
[15] A water year is defined as the period from October 1 of the prior year to September 30 of the current year. For example, water year 2000 refers to the period from October 1, 1999 to September 30, 2000.

subbasin. Historical and projected changes in storage are discussed in greater detail in the Water Budget (**Section 2.2.3**).

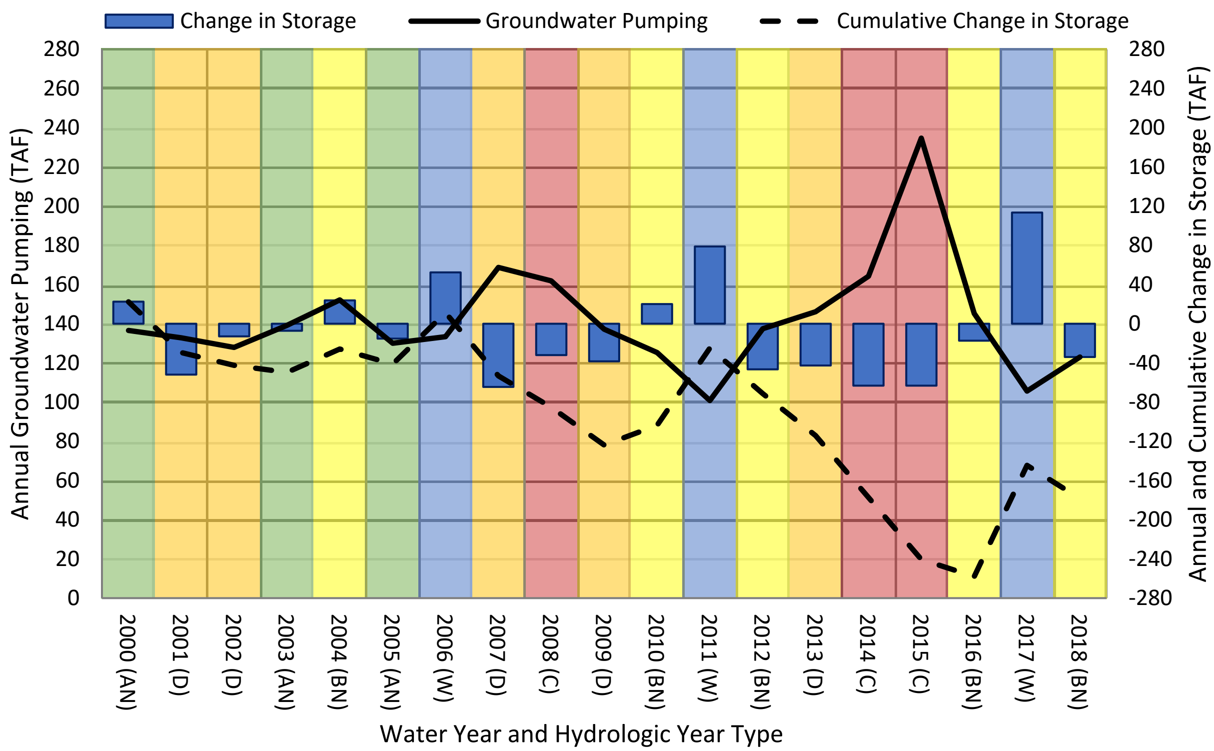


Figure 2-23. Change in Storage and Groundwater Pumping by Water Year Type.

2.2.2.3 Seawater Intrusion

Seawater intrusion is not applicable to the Butte Subbasin because of the distance from the Subbasin to the Pacific Ocean, bays, deltas, or inlets (the Butte Subbasin is inland). Seawater intrusion is not present and is not likely to occur.

2.2.2.4 Groundwater Quality

2.2.2.4.1 General Water Quality of Principal Aquifers

The goal of groundwater quality management under SGMA is to supplement information available from other sources with data targeted to assist GSAs in the Butte Subbasin to comply with the requirements of SGMA. Development of groundwater quality-related Sustainable Management Criteria for the Butte Subbasin is not intended to duplicate or supplant the goals and objectives of ongoing programs including those by the counties, compliance with the State Water Resource Control Board's (SWRCB) Irrigated Lands Regulatory Program (ILRP) by the Sacramento Valley Water Quality Coalition (SVWQC) and the California Rice Commission, and the Division of Drinking Water's State Drinking Water Information System (SDWIS).

The cornerstones for water quality monitoring of the Primary Aquifer are programs managed by the counties. Each of the wells included in these networks is monitored either by DWR or the associated (CASGEM) collaborators in each county. Details of these programs as well as information on monitoring conducted by the SVWQC and the California Rice Commission are included in section of the GSP which describes the Groundwater Monitoring Network.

Because irrigated agriculture is the predominant land use in the Subbasin, monitoring of the groundwater quality data developed through the Groundwater Quality Trend Monitoring Work Plan (GQTMWP) being implemented by the SVWQC for compliance with the Central Valley Regional Board's Irrigated Lands Regulatory Program (ILRP) will be an important source of information to GSAs in the Butte Subbasin. These programs indicate that water quality in the Butte Subbasin in generally good. One broad indicator is the absence of any high-ranking High Vulnerability Areas (HVAs) in the Subbasin and the presence of medium ranking HVAs only in the extreme north where the Subbasin approaches Chico. The majority of agricultural lands are observed to show very low levels of nitrates in groundwater (SVWQC 2016).

Among the contaminants that may affect groundwater conditions in the future are chemicals of Emerging Concern (CECs). These are contaminants having toxicities not previously recognized, which may have the potential to cause adverse effects to public health or the environment and are found to be building up in the environment or to be accumulating in humans or wildlife. CECs such as Perfluorooctanesulfonic acid (PFOS) and Per- and polyfluoroalkyl substances (PFAS) will not be monitored under the groundwater quality monitoring program established for SGMA. However, GSAs will have access to data on CECs collected by other agencies and will be attentive to the effect the presence of CECs may have on groundwater management in specific locations.

Concerns have also been raised over connate water and arsenic concentrations found in the vicinity of the Sutter Buttes (Sutter County 2012). A study of groundwater quality in the Sacramento Valley also sampled a well in this area and observed elevated levels of salinity and other constituents such as total dissolved solids, chloride, arsenic, and boron (USGS 2008). Related to this, the CGA, GGA and the GSAs in the Butte, Sutter, Yolo, North Yuba and South Yuba Subbasins plan to form and participate in an interbasin working group to address groundwater quality issues in the vicinity of and associated with the unique geology of the Sutter Buttes (see **Section 6.1.2.2**).

2.2.2.4.2 Description and Map of Known Sites and Plumes

The SGMA regulations require that Groundwater Sustainability Plans describe locations, identified by regulatory agencies, where groundwater quality has been degraded due to industrial and commercial activity. Locations of impacted groundwater were searched for by reviewing information available on the SWRCB Geotracker/GAMA website, the California Department of Toxic Substances Control (DTSC) EnviroStor website, and the Environmental

Protection Agency's National Priorities List. Cases that have been closed by the supervisory agency are not considered.

The EnviroStor and Geotracker/GAMA databases were searched to identify the locations and details of known impacted groundwater or potentially impacted groundwater in the Butte Subbasin. The sites were divided into the following categories based on regulatory designation:

- Other Sites with Corrective Action (Current);
- Sites Needing Evaluation (Active or Inactive);
- Federal Superfund-Listed Sites, and
- Leaking Underground Storage Tank Cleanup Sites

This search resulted in no active DTSC Cleanup Program Sites being identified in the Butte Subbasin; therefore, no map of known groundwater contamination sites and plumes has been included in the description of groundwater conditions.

2.2.2.5 *Land subsidence*

2.2.2.5.1 Rates and locations

The SGMA regulations define the minimum threshold for significant and unreasonable land subsidence to be quantified by the "rate and the extent of land subsidence". The harmful effects of subsidence result from the damage it may cause to critical infrastructure and the costs of repairing or mitigating those damages. In the instance of the Butte Subbasin, critical infrastructure that could be affected by subsidence includes Union Pacific Railroad facilities, irrigation district facilities including conveyance infrastructure, bridges, state and county roads and highways, and U.S. Highway 99.

Land subsidence is a gradual settling or sudden sinking of the Earth's surface owing to subsurface movement of earth materials often caused by groundwater or oil extraction. The potential effects of land subsidence include differential changes in elevation and gradients of stream channels, drain and water transport structures, failure of water well casings due to compressive stresses generated by compaction of aquifer system, and compressional strain in engineering structures and houses. Inelastic land subsidence in areas of active groundwater extraction is a major concern due to infrastructure damage, permanent reduction in the groundwater storage capacity of the aquifer, well casing collapse, and increased flood risk in low lying areas. To date, no inelastic land subsidence has been recorded in the Butte Subbasin.

Processes that can contribute to land subsidence include aquifer compaction by overdraft, hydrocompaction (shallow or near-surface subsidence) of moisture deficient deposits above the water table that are wetted for the first time since deposition, and subsidence caused by tectonic forces (Ireland et al., 1984). Land subsidence in the Butte Subbasin would most likely occur as a result of aquitard consolidation. An aquitard is a saturated geologic unit that is incapable of transmitting significant quantities of water. As the pressure created by the height of water (i.e., head) declines in response to groundwater withdrawals, aquitards between production zones are exposed to increased vertical loads. These loads can cause materials in aquitards to rearrange and consolidate, leading to land subsidence. Factors that influence the rate and magnitude of consolidation in aquitards include mineral composition, the amount of prior consolidation, cementation, the degree of aquifer confinement and aquitard thickness.

Subsidence has elastic and inelastic deformation components. As the head lowers in the aquifer, the load that was supported by the hydrostatic pressure is transferred to the granular skeletal framework of the formation. As long as the increased load on the formation does not exceed the pre-consolidation pressure, the formation will remain elastic. Under elastic conditions, the formation will rebound to its original volume as hydrostatic pressure is restored. However, when the head of the formation is lowered to a point where the load exceeds pre-consolidation pressure, inelastic deformation may occur. Under inelastic consolidation, the formation will undergo a permanent volumetric reduction as water is expelled from aquitards (USGS 2000).

To determine whether subsidence is occurring, a subsidence monitoring network has been established throughout the Sacramento Valley, the Sacramento Valley GPS Subsidence Monitoring Network. This system consists of observation stations and extensometers managed jointly by U.S. Bureau of Reclamation (Reclamation) and DWR. The observation stations are a result of DWR's efforts to establish a subsidence monitoring network to capture changes in subsidence across the Sacramento Valley. The observation stations are established monuments with precisely surveyed land surface elevations, which are distributed throughout the Sacramento Valley such that the entire Subbasin is well represented. In 2008, DWR along with numerous partners performed the initial GPS survey of the observation stations to establish a baseline measurement for future comparisons. The network was resurveyed again in 2017 using similar methods and equipment as those used in the 2008 survey and results were analyzed to depict the change in elevation at each station between those two years (DWR 2018).

Extensometers are installed in wells or boreholes and are a more site-specific method of measuring land subsidence as they can detect changes in the thickness of the sediment surrounding the well due to compaction or expansion. These instruments can detect very slight changes in land surface elevation on a continuous basis with an accuracy of +/- 0.01 feet or approximately 3 millimeters (mm). Three extensometers located in the Butte Subbasin have a period of record beginning in 2005 and were located by DWR based on a high likelihood of seeing subsidence in these areas if it were to occur, due to the presence of known clay and other fine grained deposits in these areas. Data are available on an ongoing basis and can be found in the

DWR Water Data Library[16]. While seasonal displacements of – 9.13 mm (+/- 0.3 mm) have been recorded at one of these extensometers during 2006 a *wet* water year and 2015 a *critical* water year, changes in ground surface elevations are slight and remain at or above baseline levels in 2019.

Recent subsidence studies in the Central Valley have utilized satellite- and aircraft-based Interferometric Synthetic Aperture Radar (InSAR). Much of the InSAR work has been led by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL). However, because JPL InSAR data is limited to a period from 2015 through 2017, TRE ALTIMIRA InSAR available through DWR was used for this analysis as data from this source is available for a period extending from June 2015 through September 2019.

2.2.2.5.2 Historical and Recent Cumulative Subsidence and Rates of Subsidence

The data shown in **Table 2-4** includes the range of cumulative subsidence observed within the Butte Subbasin over the period between 2008 and 2017 as reported by Sacramento Valley GPS Subsidence Monitoring stations included in the Butte Subbasin Monitoring Network and a range of annual subsidence rates calculated from the cumulative totals. The range of recent cumulative subsidence and rates of subsidence over the period from June 2015 through September 2019 is also presented in the table and are based on InSAR data. As both the Sacramento Valley GPS monuments and InSAR monitor changes in land surface elevations, the data do not distinguish between elastic and inelastic subsidence, however the cumulative subsidence values observed by both sources indicate that inelastic subsidence is not significant in the Butte Subbasin.

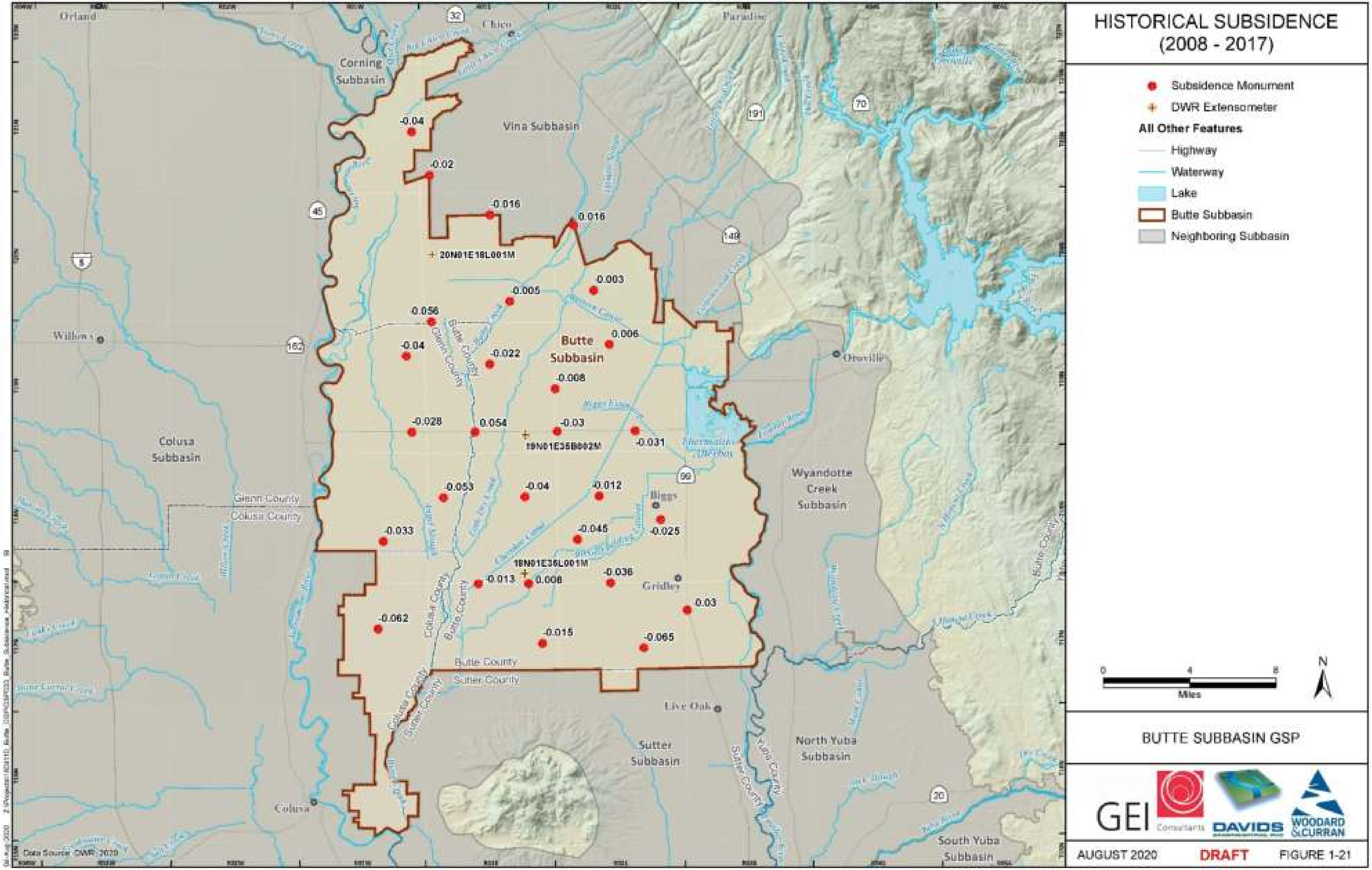
Table 2-4. Cumulative Subsidence and Approximate Annual Rate of Subsidence

Subbasin Area (square miles)	Date Range	Cumulative Subsidence (feet)	Calculated Annual Rate of Subsidence (feet/year)	Source
289	2008-2017	0.054 to -0.083	0.006 to -0.009	Sac Valley
289	2015-2019	0.25 to -0.50	0.063 to -0.125	InSAR

Figures 2-24 and **2-25** show historical and recent levels of subsidence within the Butte Subbasin. Historical levels for the period from 2008 to 2017 are shown on **Figure 2-24** – Historical Subsidence as are the locations of subsidence monitoring network monuments and extensometers used to measure subsidence. Recent levels for the period from 2015 through 2019 are presented on **Figure 2-25** – Recent Subsidence. The values presented in **Table 2-4** and on **Figures 2-24** and **2-25** support the observation that inelastic land subsidence due to groundwater withdrawal is unlikely to result in an Undesirable Result in the Butte Subbasin. It

[16] Available at https://wdl.water.ca.gov/

should also be noted that **Figure 2-25** shows the greatest changes in land surface elevation to be confined to pockets and not to broad areas.



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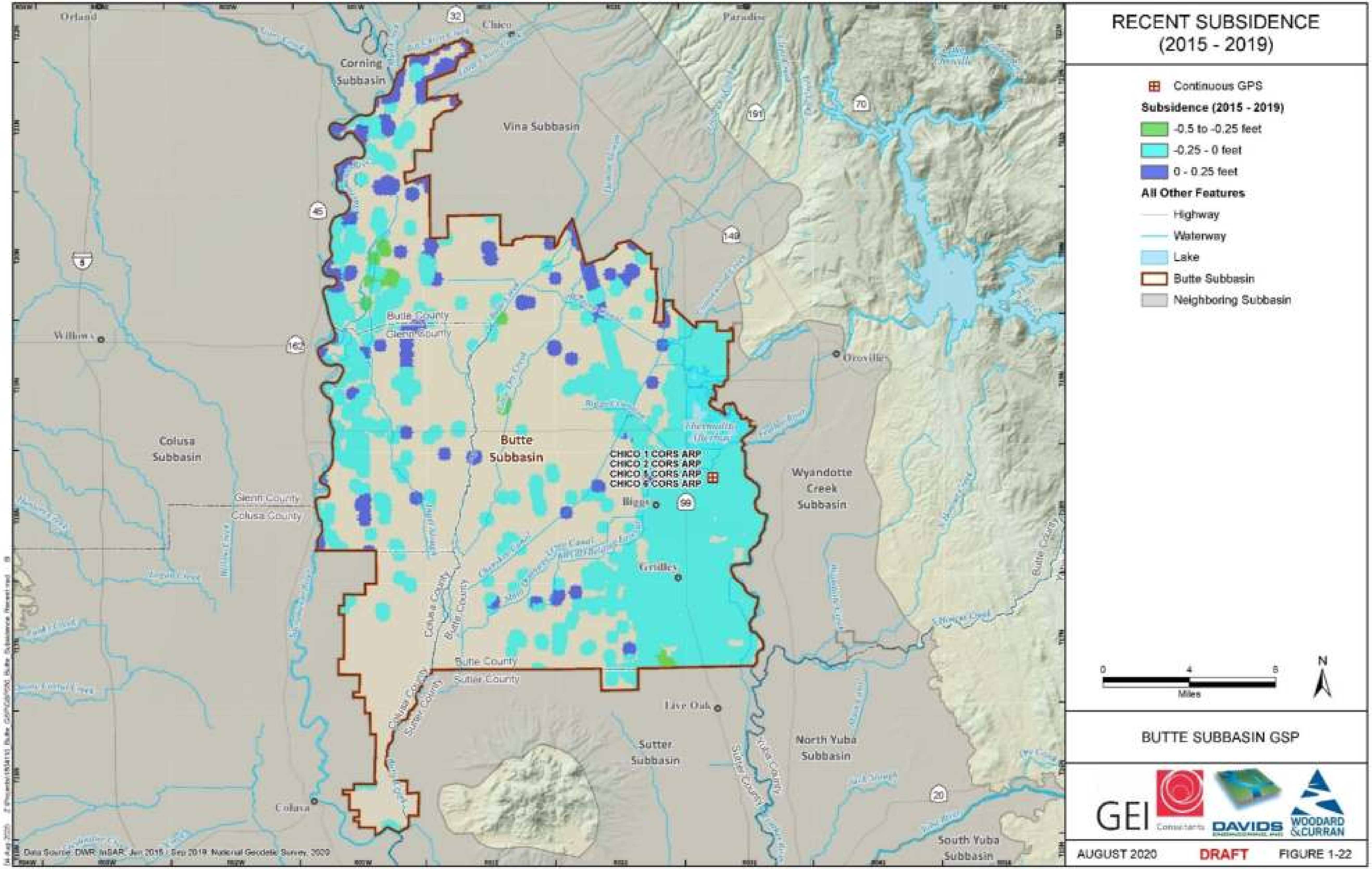
1239 *Figure 2-24. Historical Subsidence in the Butte Subbasin (2008 – 2017)*



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1241 *Figure 2-25. Recent Subsidence in the Butte Subbasin (2015-2019)*

2.2.2.6 *Interconnected Surface Water Systems*

2.2.2.6.1 Streamflow Depletion and Accretion

The term interconnected surface water systems describes surface water features that are hydraulically connected by a continuous saturated zone to an underlying aquifer such that changes in elevations of either the aquifer or the surface water features propagate throughout the interconnected system.

Interconnected surface waters are classified as either gaining or losing with respect to the condition of the surface water feature with gaining reaches gaining thorough accretion of groundwater and losing reaches losing through depletion to groundwater. It is important to recognize that these interconnections are dynamic and are affected by factors including variations in local geology, hydrology and water use. Thus, at a single point in time, a stream may have both gaining and losing reaches, and reaches that are gaining under certain seasonal, or long-term hydrologic and water use conditions may become losing under others. Moreover, changes in water use or hydrology may cause interconnected surface water features to decouple from the groundwater system.

The difference between gaining and losing reaches is illustrated in **Figure 2-26**. For gaining reaches, the water table adjacent to the stream is above the elevation of water in the stream, resulting in flow of water from the groundwater system to the stream (gains or accretions). For losing reaches, the water table adjacent to the stream is below the elevation of water in the stream, resulting flow of water from the stream to the groundwater systems (losses or seepage). In both cases, flows in the stream are directly connected to the groundwater system, with no unsaturated zone present beneath the streambed.

Direct measurement of interactions between groundwater systems and surface water features is difficult because of the need for a monitoring system that tracks both stream stage and groundwater elevations at nearby locations (see Monitoring Network Section for the Butte Subbasin). Therefore, the interaction between the groundwater system and surface water features within the Butte Subbasin is analyzed through use of the BBGM (BCDWRC 2021) which, absent the presence of a monitoring system dedicated to assessing interactions at selected locations, integrates information from groundwater monitoring wells and stream stages to model gradients that control flow between surface water and groundwater.

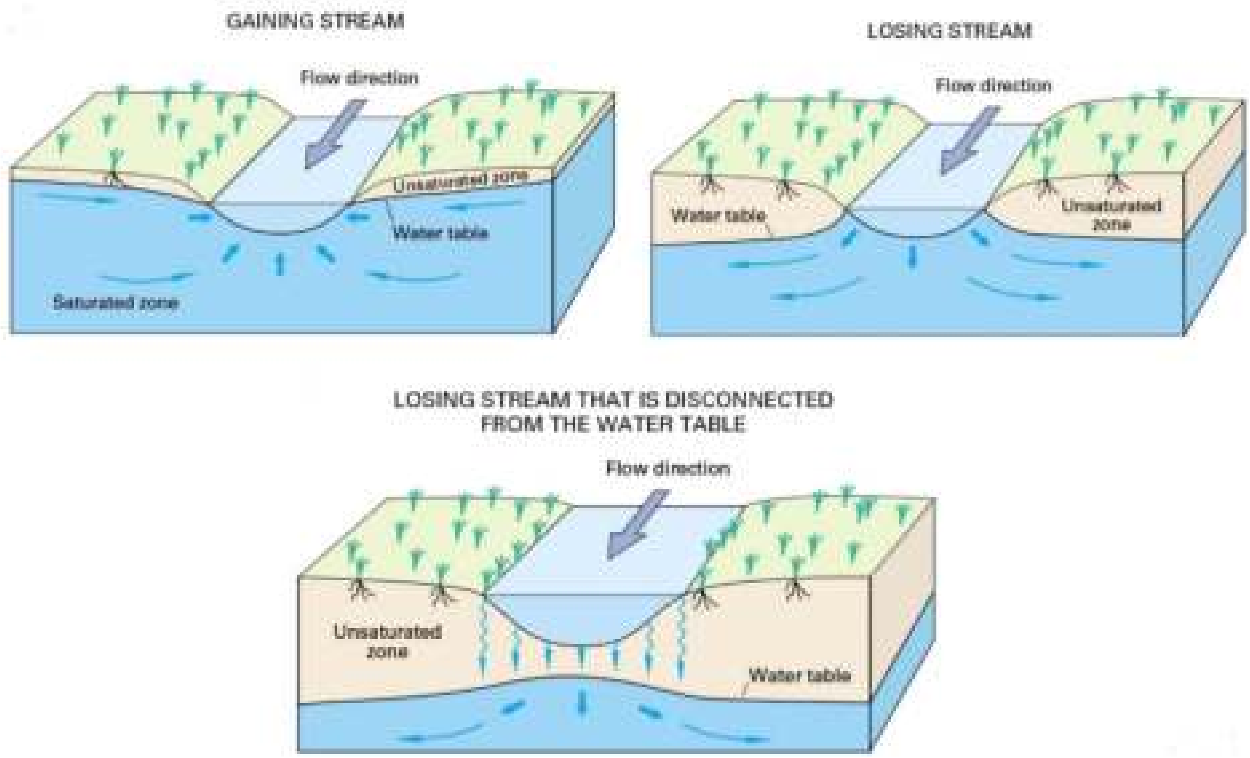


Figure 2-26. Illustration of Gaining and Losing Interconnected and Disconnected Stream Reaches (Source: USGS)

The BBGM was utilized to evaluate stream segments within the subbasin and to classify them as being primarily gaining or losing over the historical period from water year 2000 to 2018. A total of 32 stream segments traversing or bounding the subbasin with a total length of approximately 140 miles were defined. The segments range in length from 1.5 to 7.7 miles with an average length of 4.4 miles and are shown in **Figure 2-27**. The results of this analysis are shown in **Figure 2-28**. The figure shows the percent of months for the period from water year 2000 to 2018 with gaining conditions and classifies streams as primarily gaining (gaining conditions more than 80 percent of the time), primarily losing (losing conditions more than 80 percent of the time), or mixed. As indicated in **Figure 2-28**, stream segments in the subbasin tend to be gaining more than 80 percent of the time, with the exception of segments of smaller streams near or along the northern boundary of the subbasin and segments of the Sacramento River from around five miles north of Glenn and to the south. One segment north of Glenn had estimated gains only seven percent of the time between 2000 and 2018.

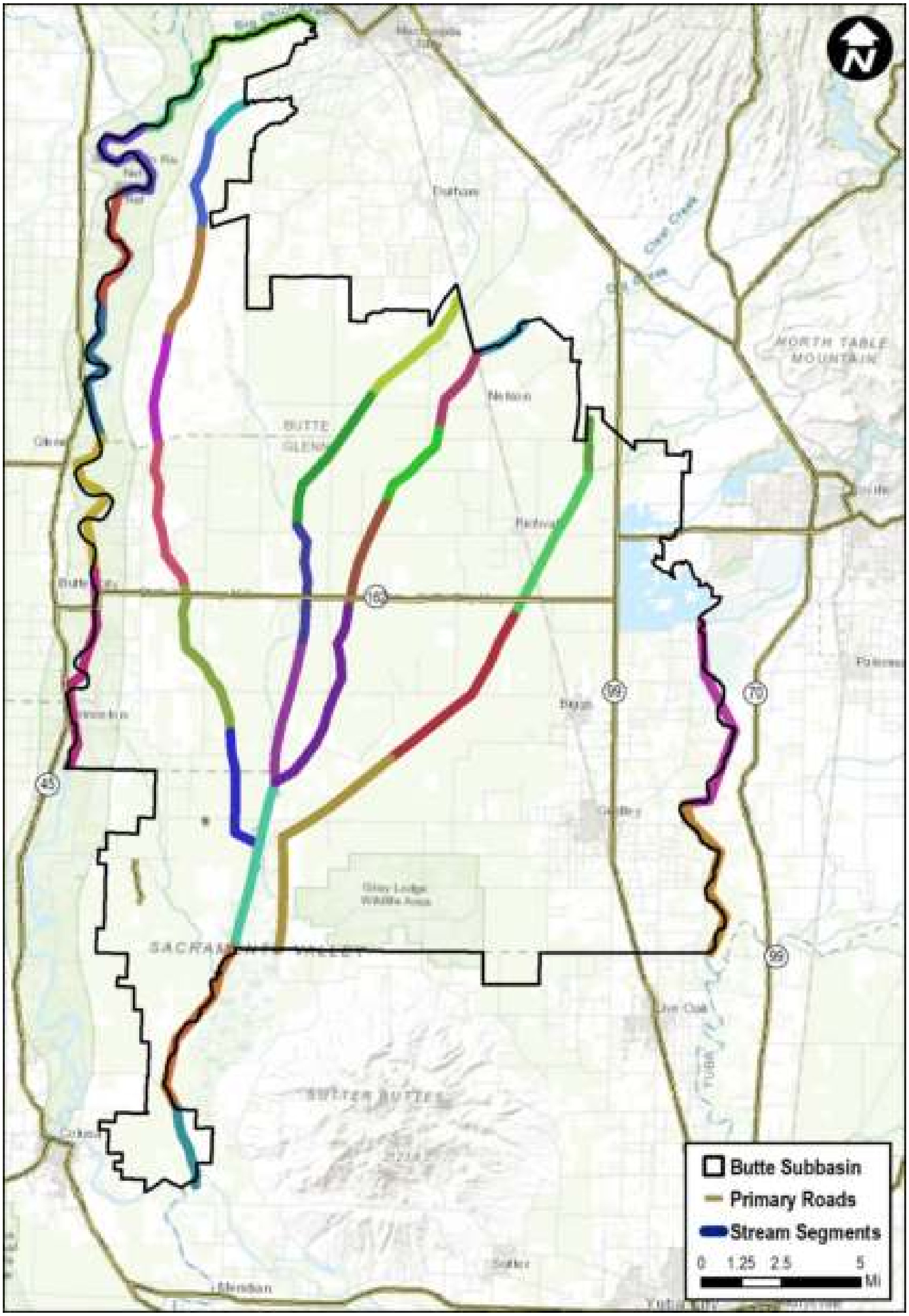


Figure 2-27. Butte Subbasin Stream Segments

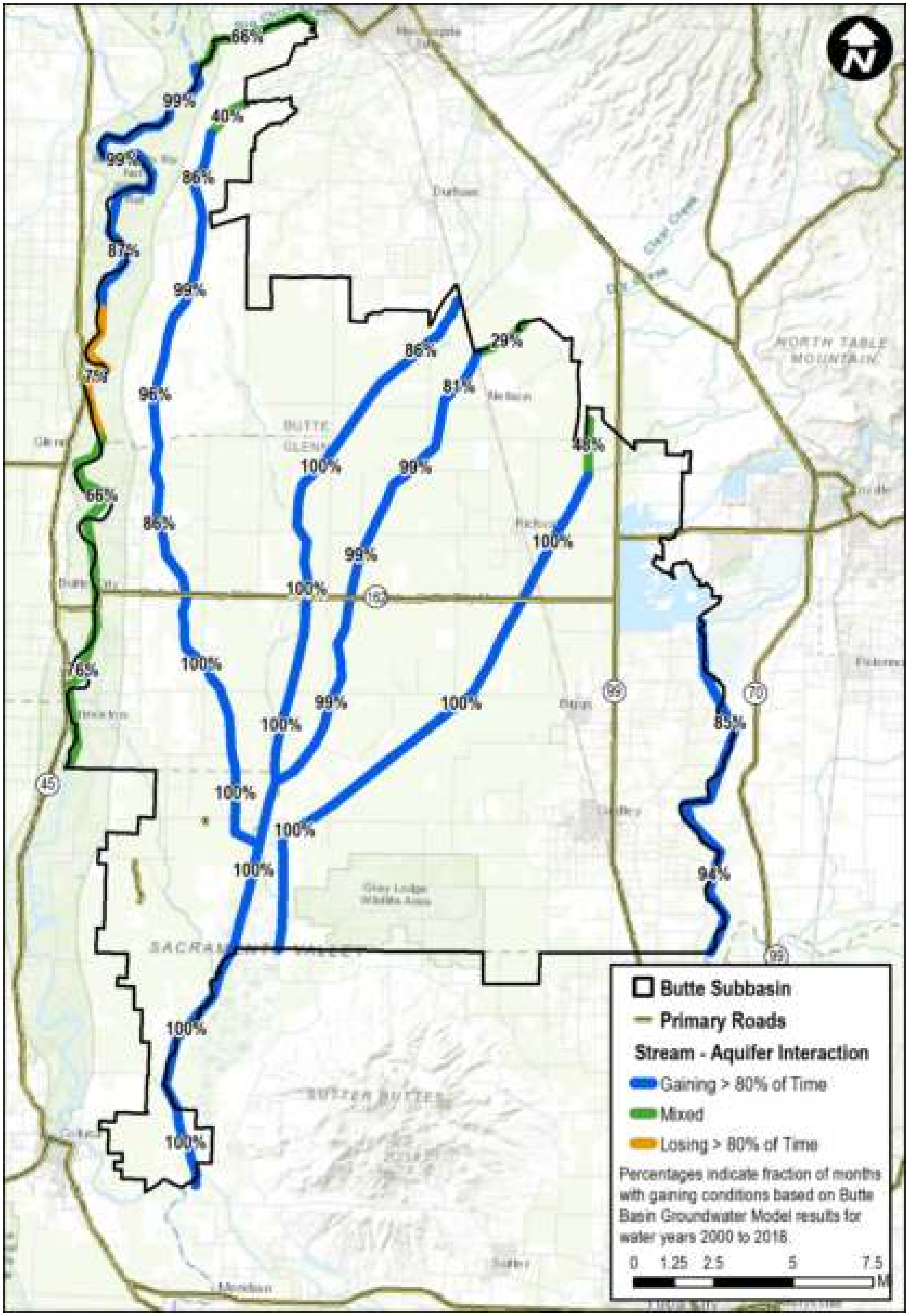


Figure 2-28. Butte Subbasin Gaining and Losing Stream Reaches Based on BBGM, Water Year 2000 to 2018

To further evaluate the interconnectedness of streams with the groundwater system in the basin, streambed elevations at individual stream nodes from the BBGM were compared to groundwater elevations from spring groundwater level measurements provided by DWR as part of the SGMA Data Viewer[17]. Spring groundwater levels were available for 2014 to 2018. As indicated in **Figure 2-29**, the vast majority of stream nodes within the Subbasin had spring groundwater levels at or above the estimated streambed elevation. Some stream nodes with groundwater elevations below the estimated streambed elevation occurred in the northernmost portions of the Subbasin.

Based on consideration of the frequency with which stream segments are gaining based on BBGM results and on consideration of the spring depth to groundwater below the estimated streambed depth along each primary stream, it is likely that all streams traversing or bounding the subbasin are connected to the groundwater system.

The presence of mixed or mostly losing reaches along the Sacramento River from north of Glenn south to approximately Princeton based on the BBGM results from 2000 to 2018 (refer to **Figure 2-28)** is somewhat incongruous with the comparison of 2014 to 2018 spring groundwater elevations reported by DWR to stream node elevations estimated in the BBGM. This may result from differences in the time frames evaluated; differences in simulated groundwater elevations by the BBGM, which influence whether a stream segment is identified as gaining or losing, and groundwater elevations reported by DWR based on monitoring data; or uncertainty in streambed elevations estimated in the BBGM. Despite the incongruity, the available information suggests that streams are connected to the groundwater system and likely experienced gains in streamflow historically.

[17] Accessed at https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels.

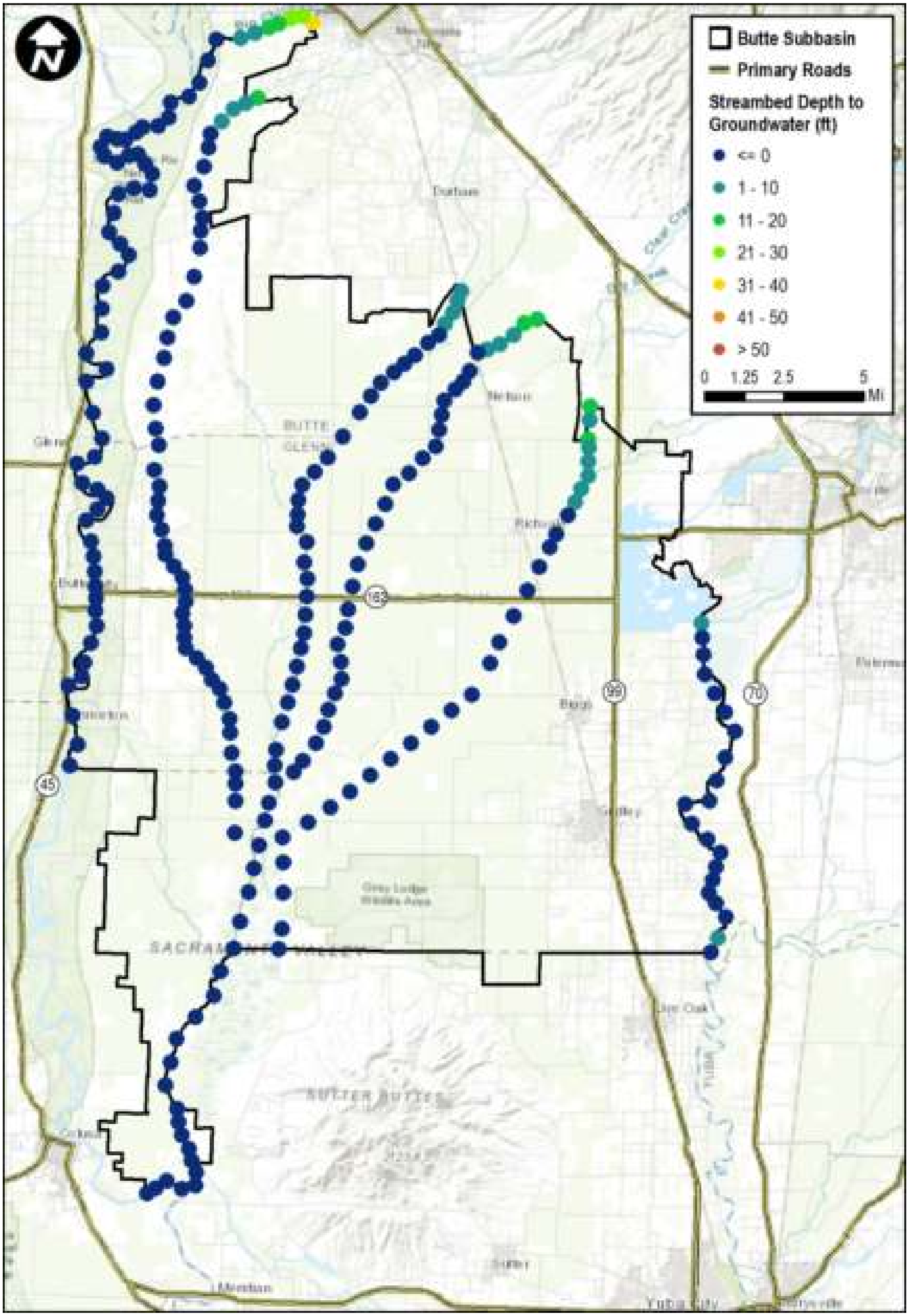


Figure 2-29. Butte Subbasin Average Spring Depth to Groundwater, 2014 to 2018.

2.2.2.6.2 Timing and Amount of Surface Water – Groundwater Interaction

The timing and amount of surface water – groundwater interaction was estimated using the BBGM for the primary streams in the subbasin. Monthly net gains to streamflow from groundwater were estimated on a monthly basis -for the historical period from water year 2000 to 2018 and are summarized in **Table 2-5**. Average monthly gains to streamflow are expressed in cubic feet per second. Negative values denote average losses from streamflow to groundwater (i.e., seepage or leakage).

Table 2-5. Average Monthly Gains to Streamflow from Groundwater, Water Years 2000 to 2018 (cfs)

Stream	Monthly Gains from Groundwater (cfs)												Average (cfs)
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
Angel Slough	42	44	43	55	60	69	71	65	54	44	42	45	53
Big Chico Creek	0	0	0	1	1	1	2	2	1	1	1	1	1
Butte Creek	113	109	108	120	121	127	132	129	126	117	122	120	120
Cherokee Canal	73	64	66	77	80	84	85	77	78	72	77	78	76
Dry Creek	0	0	0	0	0	0	0	0	0	0	0	0	0
Feather River	19	24	31	42	34	42	36	29	12	4	7	11	24
Little Chico Creek	0	0	0	0	0	1	1	1	0	0	0	0	0
Little Dry Creek	18	17	13	17	17	18	20	20	20	20	20	19	18
Sacramento River	415	465	366	183	300	237	420	478	457	447	487	428	390
Total	681	722	627	495	612	580	767	801	748	706	756	703	683

Average monthly gains from groundwater are greatest for the Sacramento River, at approximately 390 cfs. Gains are least between January and March, potentially due to relatively high river stage, reducing the gradient between the adjacent groundwater table. Gains tend to be greatest during late spring and summer (approximately May to August), potentially due to relatively low river stage, reducing the gradient between the adjacent groundwater table. It should be noted that interaction with the Sacramento River is subject substantially greater uncertainty than other streams, due to the river representing the western boundary of the BBGM model domain. It is recommended that this uncertainty be addressed through future refinements to the BBGM (**Section 6.1.2.3**).

On average, streams traversing or bounding the subbasin are currently estimated to gain approximately 683 cfs on average, or approximately 495,000 acre-feet annually. Excluding the Sacramento River, streams traversing or bounding the subbasin are currently estimated to gain approximately 293 cfs on average, or approximately 212,000 acre-feet annually.

2.2.3 Water Budget Information *(Reg. § 354.18)*

This section describes historical, current, and projected water budgets in accordance with §354.18 of the GSP Emergency Regulations, including quantitative estimates of inflows to and outflows from the basin over time and annual changes in water storage within the basin. Components of the water budgets are depicted in **Figure 2-30**.

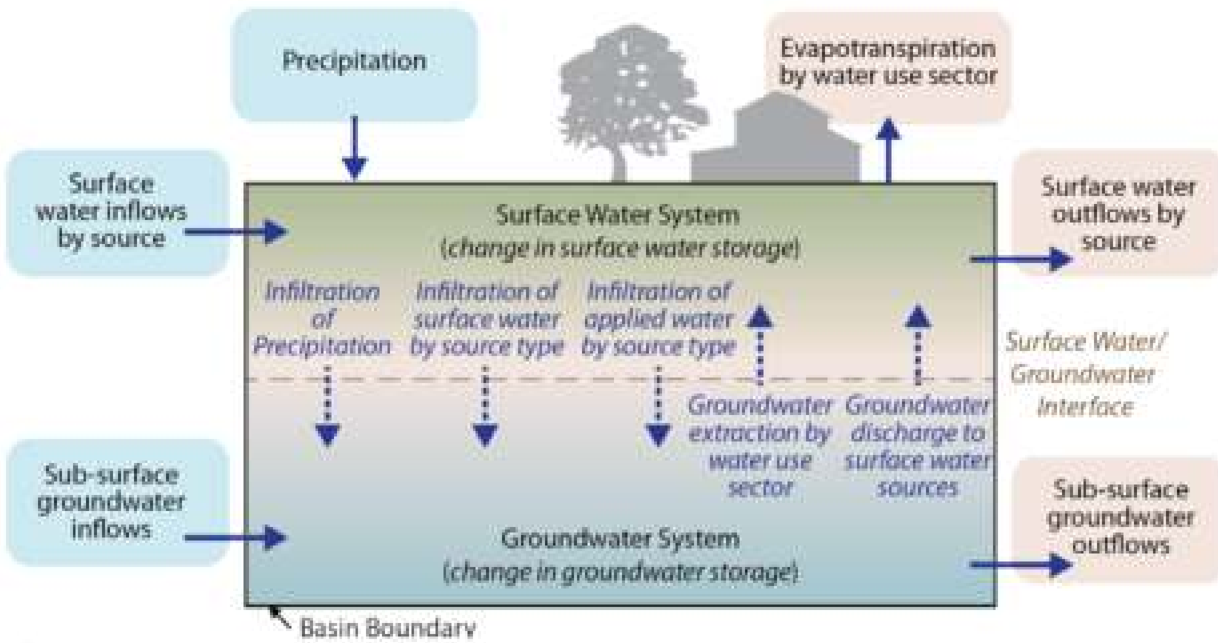


Figure 2-30. Water Budget Components (DWR 2016).

Water budgets were developed considering hydrology, water demand, water supply, land use, population, climate change, surface water – groundwater interaction, and subsurface groundwater inflows and outflows to and from neighboring basins. Water budget results are reported on a water year basis spanning from October 1 of the prior year to September 30 of the current year.

2.2.3.1 *Selection of Hydrologic Periods*

The GSP Emergency Regulations require evaluation of water budgets over a minimum of 10 years for the historical water budget, using the most recent hydrology for the current water budget, and 50 years of hydrology for the projected water budget. Hydrologic periods were selected for each water budget category based on consideration of the best available information and science to support water budget development and based on consideration of the ability of the selected periods to provide a representative range of wet and dry conditions.

- Historical – The 19-year period from water years[18] 2000 to 2018 was selected based on the level of confidence in historical input data and information to support water budget development considering land use, surface water availability, hydrology, and other factors. Water budget results for the historical period are available in **Appendix 2.C**.
- Current Conditions – Historical water budget information for 2018 represents the most recent hydrology developed for GSP analysis (i.e precipitation, evapotranspiration, stream inflows). To provide a broader basis for understanding current water budget conditions, a water budget scenario combining most recently available land use (2015 and 2016) and urban demands (average of 2016 to 2018) over the 50 years of historical hydrology was developed. The period selected was 1971 to 2018 (48 years) with 2004 – 2005 (two relatively normal years) repeated at the end of the scenario to complete the 50-year timeframe. An advantage of evaluating the current conditions water budget over a representative 50-year period is that the results provide a baseline for evaluation of the projected water budgets. Water budget results for 2018, the most current available year, are available in **Appendix 2.A**.
- Future Conditions – Consistent with the current conditions water budget, the period selected for the projected water budgets was 1971 to 2018 (48 years) with 2004 – 2005 repeated at the end of the scenarios.

Selection of the 50-year hydrologic period for the current and projected water budget scenarios was based primarily on three considerations:

- The BBGM (BCDWRC 2021), the primary tool used to develop the water budgets, has a simulation period from water years 1971 to 2018.
- The Sacramento Valley Water Year Index[19] over the period from 1971 to 2018 has an average of 8.0, as compared to 8.1 for the 103-year period from 1906 to 2018 (1906 is the first year for which the index is available) indicating the selected 50 years is relatively representative of longer term patterns and amounts of runoff in the Sacramento Valley watershed. (**Figure 2-31**)
- The selected period includes a combination of wet and dry cycles, including relatively wet periods in the early 1970's, mid 1980's, and late 1990's and dry periods in the late 1970's, early 1990's, and from approximately 2007 to 2015.

18 A water year is defined as the period from October 1 of the prior year to September 30 of the current year. For example, water year 2000 refers to the period from October 1, 1999 to September 30, 2000.

19 The Sacramento Valley Water Year Index classifies water years as wet, above normal, below normal, dry, or critical based on Sacramento River unimpaired flows. Additional details describing the Sacramento Valley Water Year Index are available from the California Data Exchange Center (https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST).

Additionally, annual precipitation for the 1971 to 2018 period averaged approximately 26.3 inches per year, as compared to 24.8 inches for the 1906 to 2018 period. This is only a difference of 1.5 inches (6%), indicating comparable conditions for 1971 to 2018 to the full period of record for the Sacramento Valley Index.

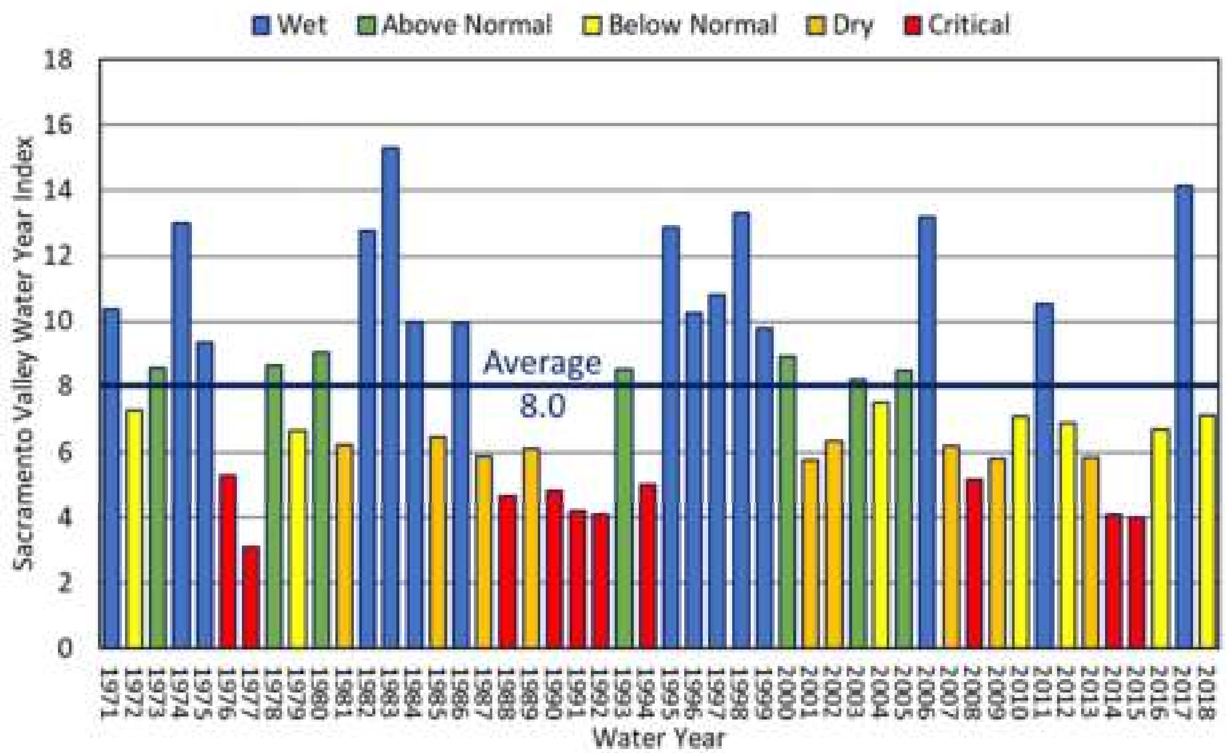


Figure 2-31. 1971 – 2018 Sacramento Valley Water Year Index and Water Year Types.

2.2.3.2 Usage of the Butte Basin Groundwater Model

Development of the original BBGM (BCDWRC 2021) began in 1992 under the direction and funding of the Butte Basin Water Users Association. The model has been updated over time to simulate historical conditions through water year 2018. The model performs calculations on a daily time step with some daily input (i.e., precipitation, stream inflow), some monthly input data (i.e., surface water diversions) and some annual input data (i.e., land use). Refinements to the model over time include additional crop types to better represent ponded crops (i.e., rice and wetlands), recalibrated soil parameters, and elemental land use. The development of the BBGM is described in more detail in Butte County Department of Water and Resource Conservation's (BCDWRC) groundwater modeling report (BCDWRC 2021).

To prepare water budgets for this GSP, historical BBGM results for water years 2000 to 2018 have been relied upon, and four additional baseline scenarios have been developed to represent current and projected conditions utilizing 50 years of hydrology (described previously). Specific assumptions associated with these scenarios are described in the following section.

2.2.3.3 Water Budget Assumptions

Assumptions utilized to develop the historical, current, and projected water budgets are described below and summarized in **Table 2-6**.

Table 2-6. Summary of Water Budget Assumptions

Water Budget	Analysis Period[1]	Hydrology	Land Use	Water Supplies
Historical Simulation	2000 – 2018	Historical	Historical	Historical
Current Conditions Baseline	1971 – 2018	Historical	Current (2015 and 2016)	Current (2015 and 2016 surface water diversions, 2016-2018 average urban demands)
Future Conditions, No Climate Change Baseline	1971 – 2018	Historical	Current, adjusted based on Butte County 2030 General Plan	Current (2015 and 2016 Surface water diversions and 2050 projected urban demands)
Future Conditions, 2030 Climate Change Baseline	1971 – 2018	Historical, adjusted based on 2030 climate change	Current, adjusted based on General Plan	Current, adjusted based on climate change
Future Conditions, 2070 Climate Change Baseline	1971 – 2018	Historical, adjusted based on 2070 climate change	Current, adjusted based on General Plan	Current, adjusted based on climate change

2.2.3.3.1 Historical

A historical water budget was developed to support understanding of past aquifer conditions, considering surface water and groundwater supplies utilized to meet demands. The historical water budget was developed using the BBGM and incorporates the best available science and information. Historical water supplies and aquifer response have been characterized by water year type based on DWR's Sacramento Valley Water Year Index.

As described previously, water years 2000 to 2018 were selected to provide a minimum of ten years across a range of hydrologic conditions. This period includes relatively wet years in 2006, 2011, and 2017 as well as dry conditions between 2007 and 2009 and between 2013 and 2015.

Information utilized to develop the historical water budget includes:

- Analysis Period – Water years 2000 to 2018
- Stream Inflows – Inflows of surface water into the basin were estimated based on stream gage data from USGS and DWR where available (e.g. Butte Creek and Big Chico Creek). For ungauged streams, inflows were estimated using the NRCS rainfall runoff method applied at the watershed scale, considering precipitation timing and amount, soil

characteristics, and other factors. Additional detail describing stream inflows is described in the BBGM model report (BCDWRC 2021).

- Land Use – Land use characteristics for agricultural, native, and urban (including rural residential) lands were estimated annually based on a combination of DWR land use surveys and county agricultural commissioner cropping reports. DWR land use data were available for 1994, 1999, 2004, 2011, 2014, 2015, and 2016. Additional detail describing the development of land use estimates can be found in the BBGM model report (BCDWRC 2021).
- Agricultural Water Demand – Agricultural irrigation demands were estimated using the BBGM, which simulates crop growth and water use on a daily basis, considering crop type, evapotranspiration, root depth, soil characteristics, and irrigation practices. For ponded land uses (rice and managed wetlands), pond depths and pond drainage are also considered to simulate demands.
- Urban and Industrial Water Demand[20] – Urban and industrial demands were estimated based on a combination of pumping data provided directly by water suppliers and estimates of population and per capita water use over time. Additional detail describing the development of urban demand estimates can be found in the BBGM model report (BCDWRC 2021).
- Surface Water Diversions – Surface water diversions were estimated based on a combination of reported diversions by water suppliers and, in some cases, agricultural water demand estimates for areas known to receive surface water but for which reported diversion data were not available.
- Groundwater Pumping – For urban water suppliers, historical pumping was estimated from reported pumping volumes over time. Pumping to meet agricultural and managed wetlands demands was estimated within the BBGM by first estimating the total demand and then subtracting surface water deliveries to calculate estimated groundwater pumping required to meet the remaining demand.

2.2.3.3.2 Current Conditions

The current conditions water budget was developed as a baseline to evaluate projected water budgets considering future conditions and is based on 50 years of hydrology along with the most recent information describing land use, urban demands, and surface water supplies. The 50-year hydrologic period was selected rather than the most recent year for which historical water budget information is available to allow for direct comparison of potential future conditions to

[20] Current estimates of industrial water use not supplied by urban water suppliers have not been explicitly included at this time and are identified as a data gap that could be filled as part of future GSP updates. These water uses are small relative to other water uses (i.e., agricultural and urban) and tend to be non-consumptive in nature. Additionally, future refinements of the BBGM to incorporate rural residential demands may also be made; these demands were estimated as part of the 2016 Water Inventory & Analysis and are also small relative to other uses.

current conditions. The use of a representative hydrologic period containing wet and dry cycles supports the understanding of uncertainty in groundwater conditions over time, establishment of sustainable management criteria, and development of projects and management actions to avoid undesirable results.

The current water budget estimates current inflows, outflows, and change in storage for the basin using 50 years of representative hydrology and the most recent water supply, water demand, and land use information.

Information utilized to develop the current conditions baseline water budget include:

- Analysis Period – 50-years of hydrology were utilized representing the period from 1971 to 2018, with 2004 and 2005 repeated following 2018.
- Stream Inflows – Inflows of surface water into the basin were estimated utilizing the same information as for the historical water budget.
- Land Use – Land use for agricultural, native, and urban (including rural residential) lands was estimated annually using the most recent land use information. Specifically, 2015 and 2016 land use were mapped to the 50-year analysis period, with 2015 land use applied to extreme dry years corresponding to rice idling due to curtailment of Feather River surface water supplies and 2016 land use applied to all other years. Extreme dry years were identified based on April to July inflows of the Feather River to Lake Oroville, based on agreements between Feather River water users and the State Water Project. April to July runoff to the Feather River is believed to be a reasonable indicator of surface water supplies and associated changes in cropping patterns within the basin, which are primarily associated with Butte Creek.
- Agricultural Water Demand – Agricultural irrigation demands were estimated using the BBGM, in the same manner as the historical water budget.
- Urban and Industrial Water Demand – Urban and industrial demands were estimated based on recent demands. Specifically, average demands for the period 2016 to 2018 were assumed.
- Surface Water Diversions – Similar to land use, surface water diversions were estimated based on 2015 and 2016 conditions, with 2015 diversion assumed for extreme dry years corresponding to curtailments of Feather River surface water supplies and 2016 diversions assumed for other years. For the current conditions scenario, reduced surface water was estimated for four years within the 50-year simulation period.
- Groundwater Pumping – Pumping to meet urban demands was estimated based on average 2016 to 2018 demands, as described above. Pumping to meet agricultural and managed wetlands demands was estimated using the BBGM as described previously for the historical water budget.

2.2.3.3.3 Future Conditions Scenarios

Three projected baseline water budget scenarios were developed considering a range of future conditions that may occur. The scenarios consider future planned land use changes (i.e., development), along with changes in climate, including precipitation, surface water inflows, and evapotranspiration. These baselines provide information regarding changes in basin conditions (e.g. groundwater storage) that may occur in the future over a series of wet and dry cycles.

The projected water budget estimates potential future inflows, outflows, and change in storage for the basin using 50-years of representative hydrology (including modifications based on climate change projections), the most recent water supply and water demand, and planned future land use information.

Information utilized to develop the future conditions baseline water budgets include:

- Analysis Period – 50-years of hydrology were utilized representing the period from 1971 to 2018, with 2004 and 2005 repeated following 2018.
- Stream Inflows
    - Future Conditions, No Climate Change – Inflows of surface water into the basin were estimated utilizing the same information as for the historical water budget.
    - Future Conditions, 2030 Climate Change – Precipitation, evapotranspiration, and surface water supplies were adjusted to reflect climate change based on the 2030 Central Tendency climate change datasets provided by DWR to support GSP development.
        - For precipitation and evapotranspiration, monthly change factors were applied to historical values to estimate potential future conditions.
        - For streamflows, DWR estimates of stream inflows were utilized where available; for streams without direct estimates of inflows, inflows were estimated using streamflow change factors applied at the watershed scale.
    - Future Conditions, 2070 Climate Change – Precipitation, evapotranspiration, and surface water supplies were adjusted to reflect climate change based on the 2070 Central Tendency climate change datasets provided by DWR to support GSP development.
        - For precipitation and evapotranspiration, monthly change factors were applied to historical values to estimate potential future conditions.
        - For streamflows, DWR estimates of stream inflows were utilized where available; for streams without direct estimates of inflows, inflows were estimated using streamflow change factors applied at the watershed scale.
- Land Use – Land use for agricultural, native, and urban (including rural residential) lands was estimated annually using the most recent land use information and modified based on planned development according to the Butte County 2030 General Plan. Specifically, 2015 and 2016 land use were mapped to the 50-year analysis period, with 2015 land use

applied to extreme dry years and 2016 land use applied to all other years. 2015 and 2016 land use data were modified to reflect planned development, generally resulting in an increase in urban land through development of previously undeveloped (i.e., native) lands.

  - Future Conditions, No Climate Change – Land use was assumed to be similar to the current conditions water budget scenario.
  - Future Conditions, 2030 Climate Change – 2015 and 2016 land use data were mapped to the 50-year analysis period considering 2030 central tendency climate change projections, with 2015 land use used for extreme dry years and 2016 land use used for all other years.
  - Future Conditions, 2070 Climate Change – 2015 and 2016 land use data were mapped to the 50-year analysis period considering 2070 central tendency climate change projections, with 2015 land use used for extreme dry years and 2016 land use used for all other years.

- Agricultural Water Demand – Agricultural irrigation demands were estimated using the BBGM, in the same manner as the historical water budget.
- Urban and Industrial Water Demand – Urban and industrial demands were estimated based projected urban demands. Specifically, future urban demands were estimated based on preliminary draft demand estimates provided by urban water suppliers (e.g. CalWater) as part of 2020 Urban Water management Plan (UWMP) development.
- Surface Water Diversions – Similar to land use, surface water diversions were estimated based on 2015 and 2016 conditions, with 2015 diversions assumed for extreme dry years and 2016 diversions assumed for other years. Extreme dry years are identified based on terms of settlement agreements between the Feather River settlement contractors in the basin and the State of California, which are based primarily on April to July unimpaired Feather River inflows into Lake Oroville.
  - For the 2030 central tendency scenario, reduced surface water was estimated for eleven years within the 50-year simulation period.
  - For the 2070 central tendency scenario, reduced surface water was estimated for thirteen years within the 50-year simulation period.
- Groundwater Pumping – Pumping to meet urban demands was estimated based on draft projections from UWMPs currently under development, as described above. Pumping to meet agricultural and managed wetlands demands was estimated using the BBGM as described previously for the historical water budget.

2.2.3.4 *Water Budget Estimates*

As described previously, water budget estimates were developed using the BBGM. Primary components of the land and surface water system water budget include the following:

- Inflows
    - Surface Water Inflows – Inflows at the land surface through streams, canals, or other waterways. These inflows may also include overland flow from upslope areas outside of the basin. Note that although interactions with streams along the boundary of the basin (i.e., diversions and stream-aquifer interaction) are accounted for, the flow in the stream is not considered an inflow to the basin. Inflows from streams that traverse the basin are accounted for explicitly.
    - Precipitation – Rainfall intercepting the ground surface within the basin boundary.
    - Groundwater pumping – Extraction of groundwater to meet agricultural, urban, managed wetlands, or other beneficial uses.
    - Stream Accretions – Gains in streamflow from shallow groundwater occurring when the water level in the aquifer adjacent to the stream is greater than the water level in the stream.
- Outflows
    - Surface Water Outflows – Outflows at the land surface through streams, canals, or other waterways. These outflows may also include overland flow to downslope areas outside of the basin.
    - Evapotranspiration – Consumptive use of water including both evaporation and transpiration components.
    - Deep Percolation – Recharge of the groundwater system through the vertical movement of precipitation and applied irrigation water below the root zone.
    - Seepage (also referred to as losses or leakage) – Recharge of the groundwater system from streams, canals, or other water bodies.
    - Change in Storage – Changes in soil moisture storage within the upper several feet of soil in the root zone, as well as changes in storage in surface water bodies within the basin. These changes are general negligible on an annual basis but vary over the course of a year based on precipitation patterns and other factors.

Primary components of the groundwater system water budget include the following:

- Inflows
    - Deep Percolation – Described above.
    - Subsurface Inflows – Groundwater inflows from adjacent basins or from the foothill area.
    - Seepage – Described above.
- Outflows
    - Groundwater Pumping – Described above.
    - Subsurface Outflows – Groundwater outflows to adjacent basins.
    - Accretions – Described above.

- Western Boundary Net Outflows – Sacramento River gains from groundwater and subsurface outflows to the Colusa and Corning Subbasins along the shared boundary along the river. The split between these outflows is uncertain at this time and will be addressed through future refinements to the BBGM and through coordination and collaboration with neighboring subbasins as part of GSP implementation.

- Change in Storage – Changes in water storage in the aquifer system. These changes tend to be large compared to changes in root zone soil moisture storage and can vary substantially from year to year.

Many components of the water budget can be estimated based on measured data (e.g. precipitation, diversions, evapotranspiration, etc.) and are used to develop inputs to the BBGM to support water budget development. Other components are more difficult to measure or do not have measured values readily available (e.g. deep percolation, subsurface flows, groundwater pumping, surface water-groundwater interaction, etc.) and are estimated using the BBGM. Additional detail describing the BBGM is available in [REFERENCE MODEL DOCUMENT].

Average annual water budget estimates for the historical water budgets and for the current and projected water budget scenarios are summarized in **Table 2-7** for the land and surface water system and in **Table 2-8** for the groundwater system. Additional information and discussion regarding the water budgets is provided in the following subsections. It is anticipated that the water budgets will be refined and updated over time as part of GSP implementation in the basin. Detailed historical water budget results are provided in **Appendix 2.C**, including water year 2018, the most current available water budget.

Table 2-7. Water Budget Summary: Land and Surface Water System.

Component	Historical (AFY)	Current (AFY)	Future, No Climate Change (AFY)	Future, 2030 Climate Change (AFY)	Future, 2070 Climate Change (AFY)
Inflows					
Surface Water Inflows	1,926,800	1,926,500	1,931,200	1,913,900	1,922,200
Outside Diversions	*823,300*	*740,000*	*740,000*	*711,300*	*703,400*
Sacramento River Diversions	*113,500*	*97,500*	*97,500*	*96,600*	*96,300*
Little Chico Creek	*25,600*	*29,500*	*29,600*	*31,200*	*32,500*
Butte Creek	*247,900*	*269,800*	*269,800*	*289,400*	*301,300*
Little Dry Creek	*8,100*	*10,700*	*10,700*	*11,500*	*12,300*
Dry Creek	*24,700*	*25,800*	*25,800*	*27,500*	*29,300*
Precipitation Runoff from Upslope Lands	*60,500*	*61,700*	*64,100*	*69,000*	*75,200*
Applied Water Return Flows from Upslope Lands	*21,600*	*17,400*	*18,300*	*17,600*	*17,400*
Other Inflows from Boundary Streams	*574,100*	*646,300*	*647,600*	*634,200*	*629,700*
Precipitation	501,000	525,900	525,900	546,900	561,300
Groundwater Pumping	142,200	162,800	162,600	189,400	210,500
Agricultural	*114,800*	*130,300*	*129,900*	*152,200*	*170,700*
Managed Wetlands	*25,100*	*30,700*	*30,700*	*35,200*	*37,800*
Stream Gains from Groundwater	218,500	154,800	152,700	137,200	123,500
Total Inflow	***2,788,600***	***2,770,000***	***2,772,400***	***2,787,400***	***2,817,500***
Outflows					
Evapotranspiration	816,100	822,700	822,100	836,500	862,800
Agricultural	*606,200*	*627,000*	*626,200*	*640,300*	*665,800*
Urban and Industrial	*8,300*	*7,400*	*7,800*	*8,000*	*8,200*
Managed Wetlands	*87,600*	*78,000*	*78,000*	*80,700*	*82,100*
Native Vegetation	*34,000*	*35,400*	*35,300*	*36,300*	*36,600*
Canal Evaporation	*79,900*	*74,800*	*74,800*	*71,200*	*70,200*
Deep Percolation	265,800	268,000	268,000	269,700	269,600
Precipitation	*83,900*	*89,500*	*89,300*	*89,200*	*89,000*
Applied Surface Water	*146,400*	*139,500*	*139,400*	*132,100*	*132,100*
Applied Groundwater	*35,500*	*39,100*	*39,300*	*48,400*	*48,400*
Seepage	277,200	355,400	356,300	361,000	363,200
Streams	*177,900*	*260,500*	*261,400*	*268,900*	*272,000*
Lakes	*26,400*	*26,400*	*26,400*	*26,400*	*26,400*
Canals and Drains	*72,900*	*68,500*	*68,500*	*65,700*	*64,800*
Surface Water Outflows	1,429,400	1,324,100	1,326,200	1,320,400	1,322,300
Precipitation Runoff	*33,300*	*37,000*	*37,100*	*39,700*	*42,000*
Applied Surface Water Return Flows	*47,900*	*65,800*	*65,700*	*56,200*	*51,400*
Applied Groundwater Return Flows	*8,200*	*12,700*	*12,700*	*12,500*	*13,200*
Streams	*1,309,600*	*1,178,400*	*1,180,500*	*1,181,800*	*1,185,600*
Butte Creek Diversions to Sutter Subbasin	*30,500*	*30,100*	*30,100*	*30,100*	*30,100*
Total Outflow	***2,788,500***	***2,770,200***	***2,772,600***	***2,787,600***	***2,817,800***
Change in Storage (Inflow - Outflow)	***100***	***-200***	***-200***	***-200***	***-300***

Table 2-8. Water Budget Summary: Groundwater System.

Component	Historical (AFY)	Current (AFY)	Future, No Climate Change (AFY)	Future, 2030 Climate Change (AFY)	Future, 2070 Climate Change (AFY)
Inflows					
Subsurface Inflows	103,100	110,700	105,400	105,700	104,200
Colusa Subbasin	*17,100*	*15,500*	*15,500*	*16,400*	*17,300*
Sutter Subbasin	*6,600*	*5,300*	*5,300*	*5,400*	*5,500*
Vina Subbasin	*65,400*	*75,100*	*70,800*	*69,500*	*66,600*
Wyandotte Creek Subbasin	*14,000*	*14,800*	*13,700*	*14,400*	*14,900*
Deep Percolation	265,800	268,000	268,000	269,700	269,600
Precipitation	*83,900*	*89,500*	*89,300*	*89,200*	*89,000*
Applied Surface Water	*146,400*	*139,500*	*139,400*	*132,100*	*132,100*
Applied Groundwater	*35,500*	*39,100*	*39,300*	*48,400*	*48,400*
Seepage	277,200	355,400	356,300	361,000	363,200
Streams	*177,900*	*260,500*	*261,400*	*268,900*	*272,000*
Lakes	*26,400*	*26,400*	*26,400*	*26,400*	*26,400*
Canals and Drains	*72,900*	*68,500*	*68,500*	*65,700*	*64,800*
Total Inflow	***646,100***	***734,100***	***729,700***	***736,400***	***737,000***
Outflows					
Subsurface Outflows	112,800	113,300	113,000	111,200	112,200
Colusa Subbasin	*34,800*	*31,900*	*31,900*	*31,300*	*30,800*
Sutter Subbasin	*34,200*	*42,200*	*42,200*	*41,300*	*41,800*
Vina Subbasin	*28,600*	*25,900*	*25,500*	*25,800*	*26,600*
Wyandotte Creek Subbasin	*15,200*	*13,300*	*13,300*	*12,900*	*13,000*
Groundwater Pumping	142,200	162,800	162,600	189,400	210,500
Agricultural	*114,800*	*130,300*	*129,900*	*152,200*	*170,700*
Urban and Industrial	*2,300*	*1,800*	*2,000*	*2,000*	*2,000*
Managed Wetlands	*25,100*	*30,700*	*30,700*	*35,200*	*37,800*
Stream Gains from Groundwater	218,500	154,800	152,700	137,200	123,500
Western Boundary Net Outflows	182,400	304,400	302,700	300,100	292,800
Total Outflow	***655,900***	***735,300***	***731,000***	***737,900***	***739,000***
Change in Storage (Inflow - Outflow)	***-9,800***	***-1,200***	***-1,300***	***-1,500***	***-2,000***

2.2.3.4.1 Historical

The historical water budget provides a foundation for how the basin has behaved historically, including insight into historical groundwater conditions (e.g. observed water levels). Also, in accordance with the GSP Regulations, the historical water budget covers a period of at least ten years (19-year period from 2000 to 2018), is used to evaluate the availability and reliability of historical surface water supplies and provides insight into the ability to operate the basin within the sustainable yield. Note that the historical analysis period experienced somewhat less precipitation than the long-term average and included historic drought conditions from approximately 2007 to 2015.

Average annual inflows to and outflows from the basin for the historical land and surface water system water budget were estimated to be 2.79 million acre-feet (MAF) per year. Average annual values were presented previously in **Table 2-7** and are shown graphically in **Figure 2-32**.

Primary inflows to the land and surface water system include surface water inflows (1,927 TAF/yr[21]), precipitation (501 TAF/yr), stream gains from groundwater (i.e., accretions) (219 TAF/yr), and groundwater pumping (142 TAF/yr). Surface water inflows include Butte Creek, Little Chico Creek, Dry Creek, and several other streams, as well as overland runoff of precipitation and applied water from upslope lands. Additionally, a primary source of surface water inflows includes diversions from the Feather River, Sacramento River, and Butte Creek.

Primary outflows from the land and surface water system include surface water outflows (1,429 TAF/yr), evapotranspiration (816 TAF/yr), deep percolation (267 TAF/yr), and stream losses (also referred to as seepage) (277 TAF/yr). Surface water outflows include outflows through Butte Creek, the Cherokee Canal, and other streams, as well as overland runoff of precipitation and applied water to downslope lands. Additionally, water is diverted from Butte Creek for use in the Sutter Subbasin. Evapotranspiration is primarily from agricultural lands but also from managed wetlands, canal evaporation, native vegetation, and urban and industrial lands. Deep percolation is primarily from precipitation, but also from applied water. Stream losses include a combination of seepage from canals and drains, stream seepage, and seepage from Thermalito Afterbay.

The average annual change in storage in the land and surface water system is negligible due to similar soil moisture content in the root zone, on average, across water years, and limited storage capacity exists in surface water bodies within the basin.

Annual results for the historical land and surface water system water budget are provided in **Appendix 2.C.**

[21] TAF/yr – Thousands of acre-feet per year.

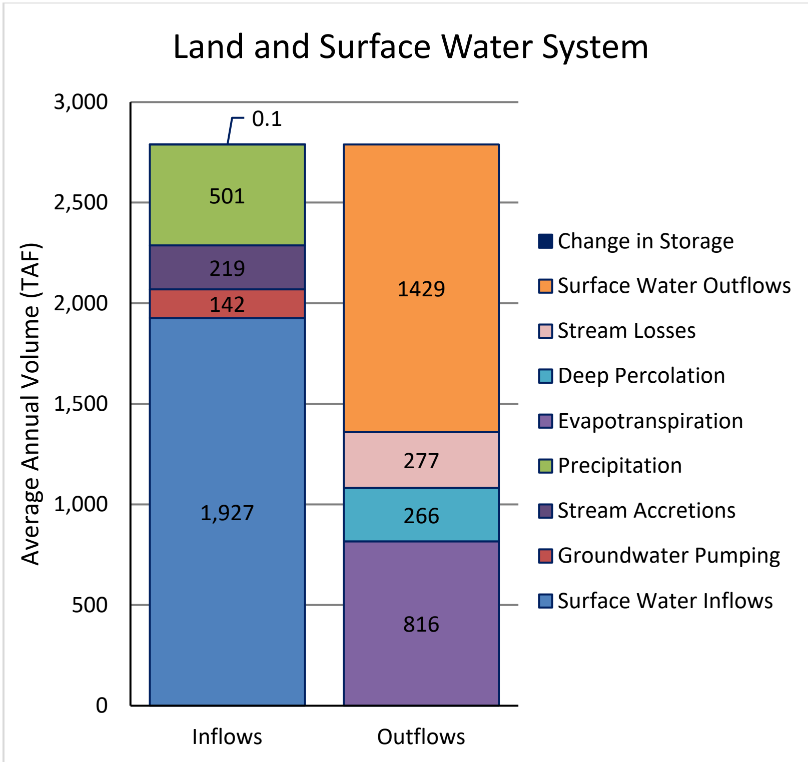


Figure 2-32. Average Annual Historical Land and Surface Water System Water Budget

Average annual inflows to and outflows from the groundwater system were estimated to be 646 TAF and 656 TAF, respectively, with an average decrease in groundwater storage of 10 TAF per year during the historical simulation period. Average annual values were presented previously in **Table 2-8** and are shown graphically in **Figure 2-33**.

Inflows to the groundwater system include deep percolation (267 TAF/yr[22]); subsurface inflows from the Colusa, Sutter, Vina, and Wyandotte Creek subbasins (103 TAF/yr); and stream losses (277 TAF/yr). Outflows from the groundwater system include groundwater pumping (142 TAF/yr); subsurface outflows to the Colusa, Sutter, Vina, and Wyandotte Creek subbasins (113 TAF/yr); western boundary net outflows (182 TAF/yr); and stream gains from groundwater (219 TAF/yr).

Western boundary net outflows represent Sacramento River gains from groundwater and subsurface outflows to the Colusa and Corning subbasins along the shared boundary along the Sacramento River. The split between these outflows is uncertain at this time and will be addressed through future refinements to the BBGM and through coordination and collaboration with neighboring subbasins as part of GSP implementation.

[22] TAF/yr – Thousands of acre-feet per year.

Annual results for the historical groundwater system water budget are provided in **Appendix 2.C.**

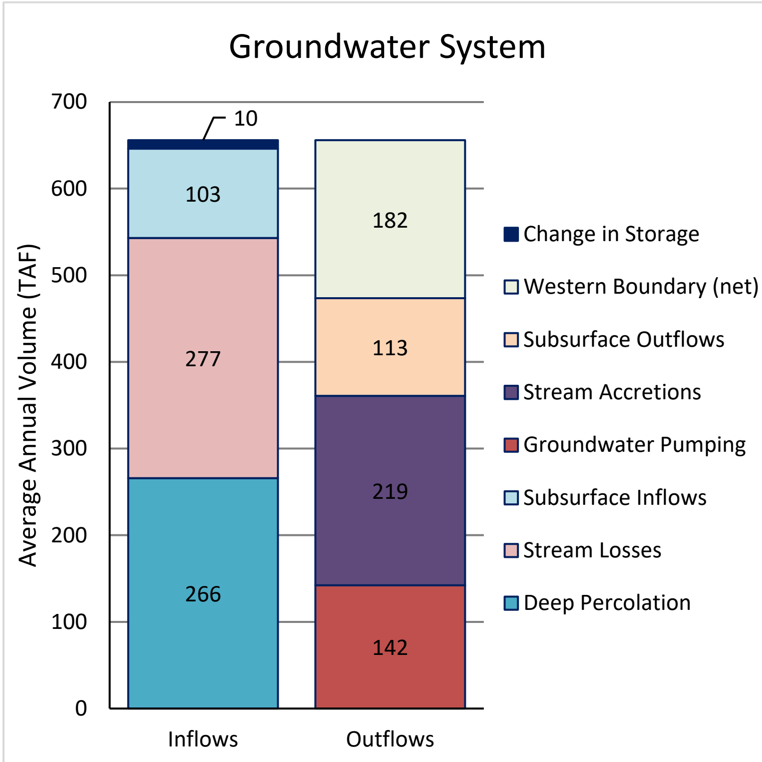


Figure 2-33. Average Annual Historical Groundwater System Water Budget.

Historical water supplies and change in groundwater storage are summarized by water year type in **Table 2-9** based on the Sacramento Valley Water Year Index. Between 2000 and 2018, there were 3 wet years, 3 above normal years, 5 below normal years, 5 dry years, and 3 critical years. Historical surface water deliveries were greatest in wet years and least in above normal years. Groundwater pumping was greatest in dry years and least in above normal years. Historically, groundwater storage in the basin has tended to increase in wet years and to decrease in above normal, below normal, dry, and critical years, with reductions in storage in above normal and below normal years less than reductions in dry and critical years. The relationship between surface water deliveries and hydrologic year type in the Butte Subbasin is somewhat complex in that in some years crop idling based water transfers occur, and surface water deliveries decrease to some extent.

Table 2-9. Historical Water Supplies and Change in Groundwater Storage by Hydrologic Water Year Type.

Water Year Type	Surface Water Deliveries (AFY)	Groundwater Pumping (AFY)	Total Supply (AFY)	Change in Groundwater Storage (AFY)
Wet	1,003,400	148,600	1,152,000	73,500
Above Normal	777,300	123,500	900,700	-2,400
Below Normal	969,800	147,100	1,116,900	-4,300
Dry	831,400	173,800	1,005,300	-36,900
Critical	912,900	140,900	1,053,800	-64,400

2.2.3.4.1.1 Availability or Reliability of Historical Surface Water Supplies

As indicated in **Table 2-9**, historical surface water supplies for delivery to agricultural land vary based on water year type. The primary sources of surface water in the basin are the Feather River, Sacramento River, and Butte Creek. Surface water supplies are relatively reliable in the basin and represent approximately 86 percent of total water supplies. Under climate change there may be a reduction in the availability of surface water for irrigation in the basin due to a reduction in April to July inflows to Lake Oroville. Potential effects of this reduced reliability are evaluated as part of the projected water budgets in the following sections.

Under diversion agreements between Western Canal Water District and the Joint Districts with the state, Feather River diversions can be reduced under the following conditions:

DWR forecasted April to July unimpaired runoff into Lake Oroville is less than 600,000 ac-ft[23], or Total current year predicted and prior year actual deficiencies in unimpaired runoff (as compared to 2,500,000 ac-ft) exceed 400,000 ac-ft for one or more successive prior water years with less than 2,500,000 ac-ft of runoff.

When a reduction is allowed, WCWD and the Joint Districts supplies subject to reduction can be reduced by up to 50 percent in any one year, but not more than 100 percent in any seven years, cumulatively. Additionally, reductions in any given year cannot exceed the percent reduction experienced for agricultural use by SWP contractors. Historically, reductions have occurred in 1977, 1991, 1992, and 2015. In each year, supplies subject to reduction were reduced by 50%.

In addition to April to October Feather River supplies, WCWD and Joint Districts are entitled to divert water between November and March for beneficial use. Diversions during the winter period primarily support rice straw and habitat for migratory waterfowl and shorebirds but may provide other beneficial uses.

[23] The final, official forecast must be made by April 10 of each year.

2.2.3.4.1.2 Suitability of Tools and Methods for Planning

The water budgets presented herein have been developed using the best available information and best available science and structured in a manner consistent with the hydrogeologic conceptual model of the basin. The BBGM, which is used to organize information for the water budgets, develop water budget scenarios, and perform water budget calculations, is currently the best available tool and is suitable for GSP development for the subbasin. The BBGM has been developed over the past several decades and updated over time to use updated model code, updated datasets, and updated input parameters through a series of efforts. Refinements to the BBGM have been made through extensive engagement with local stakeholders as part of several past efforts.

The water budgets developed using the BBGM support the development of sustainable management criteria, evaluation of the monitoring network, and development of projects and management actions as part of GSP development. It is anticipated that the BBGM will be updated and refined in the future as part of GSP implementation. Additional information describing the BBGM is available in BCDWRC's groundwater modeling report (BCDWRC 2021).

2.2.3.4.1.3 Ability to Operate the Basin within the Sustainable Yield

Sustainable yield refers to 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. As a result, determination of sustainable yield requires consideration of SGMA's six sustainability indicators. Historical water budget estimates indicate an average annual decrease in storage of 10 thousand acre-feet per year for the period from water year 2000 to 2018. Operation of the basin within the sustainable yield will likely require incorporation of projects and management actions into the GSP and implementation over the 50-year SGMA planning and implementation horizon. The estimated sustainable yield of the basin is described in greater detail in **Section 2.2.3.7**.

2.2.3.4.2 Current Conditions

The current conditions baseline water budget provides a foundation to understand the behavior of the basin considering current land use and urban demands over a broad range of hydrologic conditions as well as a basis for evaluating how groundwater conditions may change in the future based on comparison of water budget results to projected water budgets presented in the following section. A 50-year hydrologic period was selected, rather than a single, recent year to improve the basis for estimation of sustainable yield under current conditions.

Average annual inflows to and outflows from the basin for the current conditions land and surface water system baseline water budget were estimated to be 2.77 million acre-feet (MAF) per year. Average annual values were presented previously in **Table 2-7** and are shown graphically in **Figure 2-34**.

Primary inflows to the land and surface water system include surface water inflows (1,927 TAF/yr), precipitation (526 TAF/yr), stream gains from groundwater (i.e., accretions) (155 TAF/yr), and groundwater pumping (163 TAF/yr). Surface water inflows include Butte Creek, Little Chico Creek, Dry Creek, and several other streams, as well as overland runoff of precipitation and applied water from upslope lands. Additionally, a primary source of surface water inflows includes diversions from the Feather River, Sacramento River, and Butte Creek.

Primary outflows from the land and surface water system include surface water outflows (1,324 TAF/yr), evapotranspiration (823 TAF/yr), deep percolation (268 TAF/yr), and stream losses (also referred to as seepage) (365 TAF/yr). Surface water outflows include outflows through Butte Creek, the Cherokee Canal, and other streams, as well as overland runoff of precipitation and applied water to downslope lands. Additionally, water is diverted from Butte Creek for use in the Sutter Subbasin. Evapotranspiration is primarily from agricultural lands but also from managed wetlands, canal evaporation, native vegetation, and urban and industrial lands. Deep percolation is primarily from precipitation, but also from applied water. Stream losses include a combination of seepage from canals and drains, stream seepage, and seepage from Thermalito Afterbay.

The average annual change in storage in the land and surface water system is negligible due to similar soil moisture content in the root zone, on average, across water years, and limited storage capacity exists in surface water bodies within the basin.

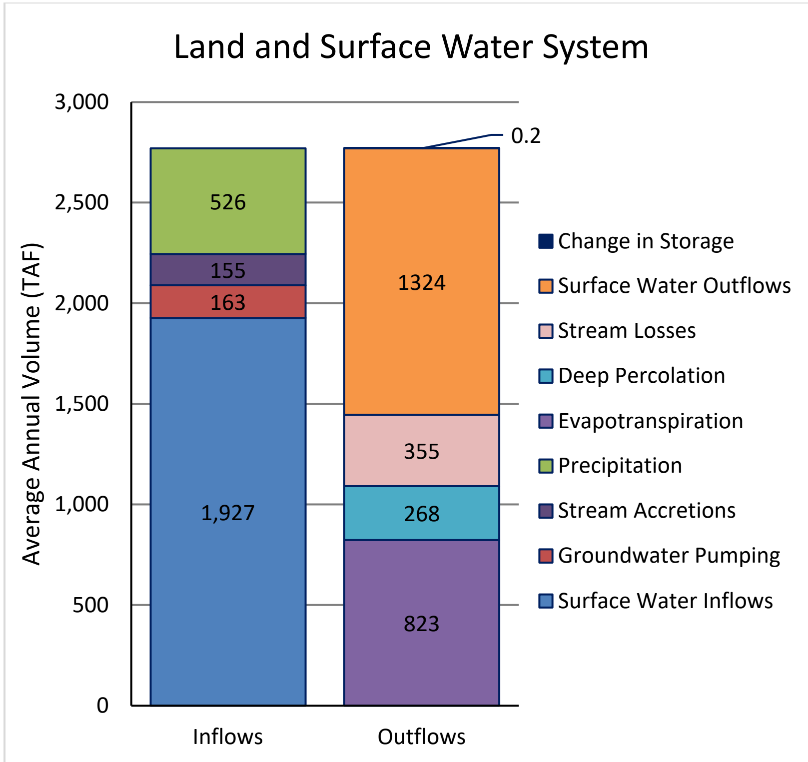


Figure 2-34. Average Annual Current Conditions Land and Surface Water System Water *Budget*

Average annual inflows to and outflows from the groundwater system were estimated to be 734 TAF and 735 TAF, respectively, with an average decrease in groundwater storage of 1 TAF per year during the current conditions baseline simulation period. Average annual values were presented previously in **Table 2-8** and are shown graphically in **Figure 2-35**.

Inflows to the groundwater system include deep percolation (268 TAF/yr[24]); subsurface inflows from the Colusa, Sutter, Vina, and Wyandotte Creek subbasins (111 TAF/yr); and stream losses (355 TAF/yr). Outflows from the groundwater system include groundwater pumping (163 TAF/yr); subsurface outflows to the Colusa, Sutter, Vina, and Wyandotte Creek subbasins (113 TAF/yr); western boundary net outflows (304 TAF/yr); and stream gains from groundwater (155 TAF/yr).

Western boundary net outflows represent Sacramento River gains from groundwater and subsurface outflows to the Colusa and Corning Subbasins along the shared boundary along the Sacramento River. The split between these outflows is uncertain at this time and will be addressed through future refinements to the BBGM and through coordination and collaboration with neighboring subbasins as part of GSP implementation.

[24] TAF/yr – Thousands of acre-feet per year.

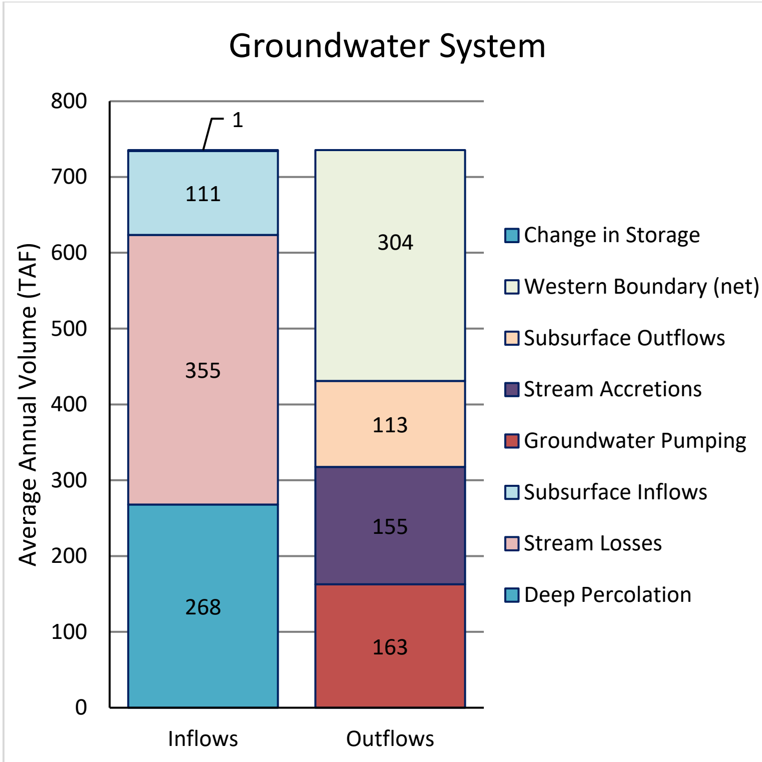


Figure 2-35. Average Annual Current Conditions Groundwater System Water Budget

2.2.3.4.3 Future Conditions Scenarios

Three projected water budgets were developed for the basin to provide baseline scenarios representing potential future conditions considering planned development under the Butte County 2030 General Plan and climate change centered around 2030 and 2070 based on central tendency climate change datasets provided by DWR. The projected water budget scenarios provide a foundation to understand the behavior of the basin considering potential land use and urban demands over a broad range of hydrologic conditions, modified based on climate change projections). Use of a 50-year hydrologic period provides a basis for estimation of sustainable yield under potential future conditions.

2.2.3.4.3.1 Future Conditions, no Climate Change

Average annual inflows to and outflows from the basin for the future conditions without climate change projected land and surface water system baseline water budget were estimated to be 2.77 million acre-feet (MAF) per year. Average annual values were presented previously in **Table 2-7** and are shown graphically in **Figure 2-36**.

Primary inflows to the land and surface water system include surface water inflows (1,931 TAF/yr), precipitation (526 TAF/yr), stream gains from groundwater (i.e., accretions) (153 TAF/yr), and groundwater pumping (163 TAF/yr). Surface water inflows include Butte Creek, Little Chico Creek, Dry Creek, and several other streams, as well as overland runoff of precipitation and applied water from upslope lands. Additionally, a primary source of surface water inflows includes diversions from the Feather River, Sacramento River, and Butte Creek.

Primary outflows from the land and surface water system include surface water outflows (1,326 TAF/yr), evapotranspiration (822 TAF/yr), deep percolation (268 TAF/yr), and stream losses (also referred to as seepage) (356 TAF/yr). Surface water outflows include outflows through Butte Creek, the Cherokee Canal, and other streams, as well as overland runoff of precipitation and applied water to downslope lands. Additionally, water is diverted from Butte Creek for use in the Sutter Subbasin. Evapotranspiration is primarily from agricultural lands but also from managed wetlands, canal evaporation, native vegetation, and urban and industrial lands. Deep percolation is primarily from precipitation, but also from applied water. Stream losses include a combination of seepage from canals and drains, stream seepage, and seepage from Thermalito Afterbay.

The average annual change in storage in the land and surface water system is negligible due to similar soil moisture content in the root zone, on average, across water years, and limited storage capacity exists in surface water bodies within the basin.

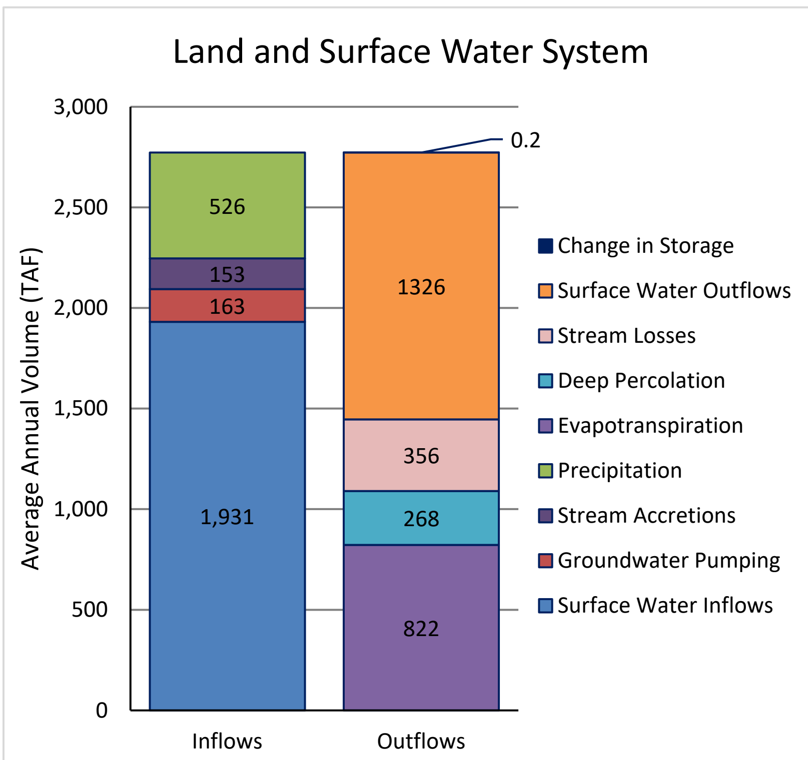


Figure 2-36. Average Annual Future Conditions without Climate Change Land and Surface Water System Water Budget

Average annual inflows to and outflows from the groundwater system were estimated to be 730 TAF and 731 TAF, respectively, with an average decrease in groundwater storage of 1 TAF per year during the current conditions baseline simulation period. Average annual values were presented previously in **Table 2-8** and are shown graphically in **Figure 2-37**.

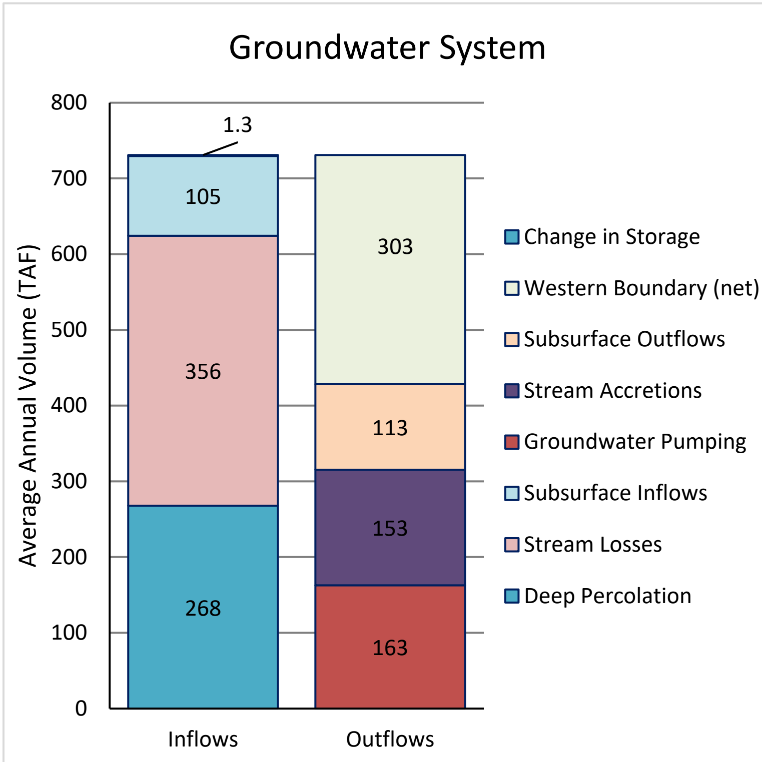


Figure 2-37. Average Annual Future Conditions without Climate Change Groundwater System Water Budget

Inflows to the groundwater system include deep percolation (268 TAF/yr[25]); subsurface inflows from the Colusa, Sutter, Vina, and Wyandotte Creek subbasins (105 TAF/yr); and stream losses (356 TAF/yr). Outflows from the groundwater system include groundwater pumping (163 TAF/yr); subsurface outflows to the Colusa, Sutter, Vina, and Wyandotte Creek subbasins (113 TAF/yr); western boundary net outflows (303 TAF/yr); and stream gains from groundwater (153 TAF/yr).

Western boundary net outflows represent Sacramento River gains from groundwater and subsurface outflows to the Colusa and Corning subbasins along the shared boundary along the Sacramento River. The split between these outflows is uncertain at this time and will be addressed through future refinements to the BBGM and through coordination and collaboration with neighboring subbasins as part of GSP implementation.

[25] TAF/yr – Thousands of acre-feet per year.

2.2.3.4.3.2 Future Conditions, 2030 Climate Change

Average annual inflows to and outflows from the basin for the future conditions with 2030 climate change projected land and surface water system baseline water budget were estimated to be 2.79 million acre-feet (MAF) per year. Average annual values were presented previously in **Table 2-7** and are shown graphically in **Figure 2-38**.

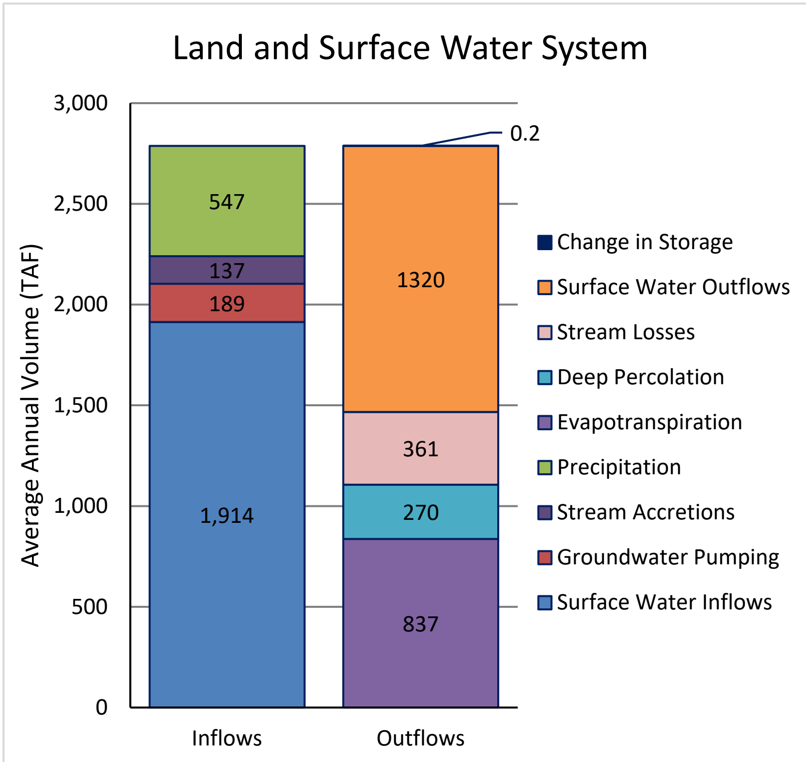


Figure 2-38. Average Annual Future Conditions with 2030 Climate Change Land and Surface Water System Water Budget

Primary inflows to the land and surface water system include surface water inflows (1,914 TAF/yr), precipitation (547 TAF/yr), stream gains from groundwater (i.e., accretions) (137 TAF/yr), and groundwater pumping (189 TAF/yr). Surface water inflows include Butte Creek, Little Chico Creek, Dry Creek, and several other streams, as well as overland runoff of precipitation and applied water from upslope lands. Additionally, a primary source of surface water inflows includes diversions from the Feather River, Sacramento River, and Butte Creek.

Primary outflows from the land and surface water system include surface water outflows (1,320 TAF/yr), evapotranspiration (837 TAF/yr), deep percolation (270 TAF/yr), and stream losses (also referred to as seepage) (361 TAF/yr). Surface water outflows include outflows through Butte Creek, the Cherokee Canal, and other streams, as well as overland runoff of precipitation and applied water to downslope lands. Additionally, water is diverted from Butte Creek for use in the Sutter Subbasin. Evapotranspiration is primarily from agricultural lands but also from managed wetlands, canal evaporation, native vegetation, and urban and industrial lands. Deep percolation is primarily from precipitation, but also from applied water. Stream losses include a combination of seepage from canals and drains, stream seepage, and seepage from Thermalito Afterbay.

The average annual change in storage in the land and surface water system is negligible due to similar soil moisture content in the root zone, on average, across water years, and limited storage capacity exists in surface water bodies within the basin.

Average annual inflows to and outflows from the groundwater system were estimated to be 736 TAF and 738 TAF, respectively, with an average decrease in groundwater storage of 2 TAF per year during the 50-year simulation period. Average annual values were presented previously in **Table 2-8** and are shown graphically in **Figure 2-39**.

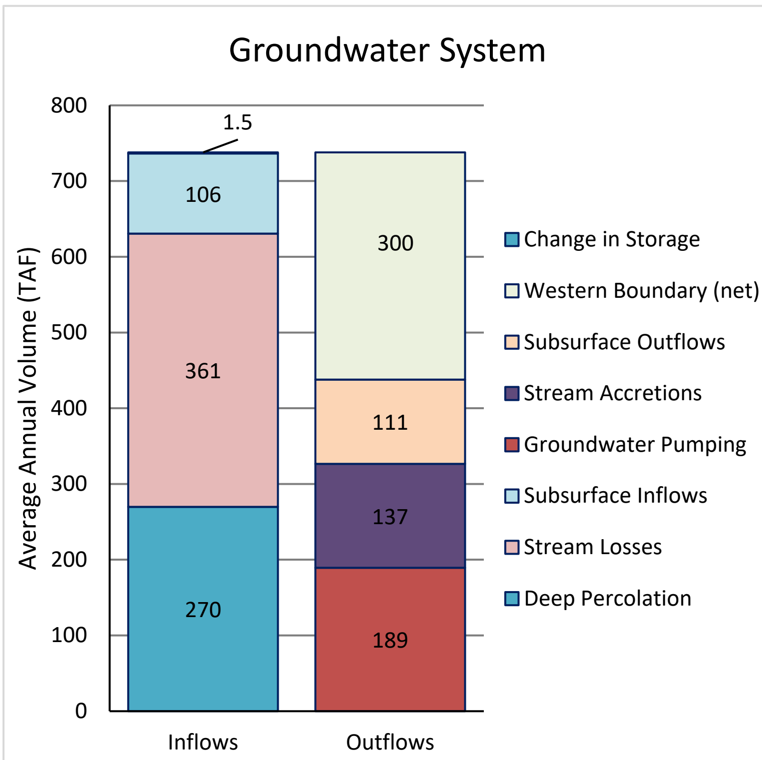


Figure 2-39. Average Annual Future Conditions with 2030 Climate Change Groundwater System Water Budget

Inflows to the groundwater system include deep percolation (270 TAF/yr[26]); subsurface inflows from the Colusa, Sutter, Vina, and Wyandotte Creek subbasins (106 TAF/yr); and stream losses (361 TAF/yr). Outflows from the groundwater system include groundwater pumping (189 TAF/yr); subsurface outflows to the Colusa, Sutter, Vina, and Wyandotte Creek subbasins

[26] TAF/yr – Thousands of acre-feet per year.

(111 TAF/yr); western boundary net outflows (300 TAF/yr); and stream gains from groundwater (137 TAF/yr).

Western boundary net outflows represent Sacramento River gains from groundwater and subsurface outflows to the Colusa and Corning subbasins along the shared boundary along the Sacramento River. The split between these outflows is uncertain at this time and will be addressed through future refinements to the BBGM and through coordination and collaboration with neighboring subbasins as part of GSP implementation.

2.2.3.4.3.3 Future Conditions, 2070 Climate Change

Average annual inflows to and outflows from the basin for the future conditions with 2070 climate change projected land and surface water system baseline water budget were estimated to be 2.82 million acre-feet (MAF) per year. Average annual values were presented previously in **Table 2-7** and are shown graphically in **Figure 2-40**.

Primary inflows to the land and surface water system include surface water inflows (1,922 TAF/yr), precipitation (561 TAF/yr), stream gains from groundwater (i.e., accretions) (124 TAF/yr), and groundwater pumping (211 TAF/yr). Surface water inflows include Butte Creek, Little Chico Creek, Dry Creek, and several other streams, as well as overland runoff of precipitation and applied water from upslope lands. Additionally, a primary source of surface water inflows includes diversions from the Feather River, Sacramento River, and Butte Creek.

Primary outflows from the land and surface water system include surface water outflows (1,322 TAF/yr), evapotranspiration (863 TAF/yr), deep percolation (270 TAF/yr), and stream losses (also referred to as seepage) (363 TAF/yr). Surface water outflows include outflows through Butte Creek, the Cherokee Canal, and other streams, as well as overland runoff of precipitation and applied water to downslope lands. Additionally, water is diverted from Butte Creek for use in the Sutter Subbasin. Evapotranspiration is primarily from agricultural lands but also from managed wetlands, canal evaporation, native vegetation, and urban and industrial lands. Deep percolation is primarily from precipitation, but also from applied water. Stream losses include a combination of seepage from canals and drains, stream seepage, and seepage from Thermalito Afterbay.

The average annual change in storage in the land and surface water system is negligible due to similar soil moisture content in the root zone, on average, across water years, and limited storage capacity exists in surface water bodies within the basin.

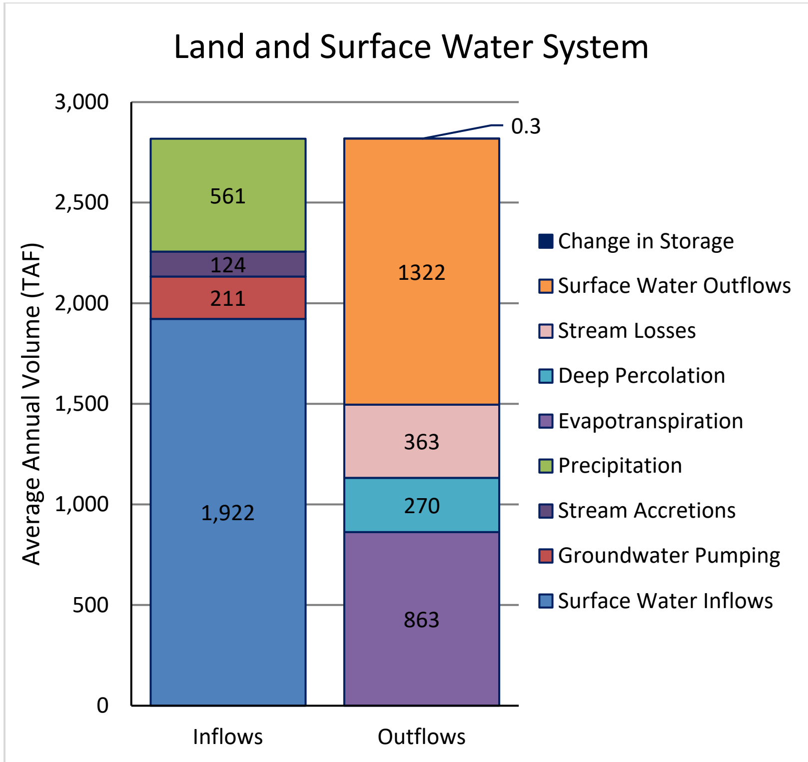


Figure 2-40. Average Annual Future Conditions with 2070 Climate Change Land and Surface Water System Water Budget

Average annual inflows to and outflows from the groundwater system were estimated to be 737 TAF and 739 TAF, respectively, with an average decrease in groundwater storage of 2 TAF per year during the 50-year simulation period. Average annual values were presented previously in **Table 2-8** and are shown graphically in **Figure 2-41**.

Inflows to the groundwater system include deep percolation (270 TAF/yr[27]); subsurface inflows from the Colusa, Sutter, Vina, and Wyandotte Creek subbasins (104 TAF/yr); and stream losses (363 TAF/yr). Outflows from the groundwater system include groundwater pumping (211 TAF/yr); subsurface outflows to the Colusa, Sutter, Vina, and Wyandotte Creek subbasins (112 TAF/yr); western boundary net outflows (293 TAF/yr); and stream gains from groundwater (124 TAF/yr).

Western boundary net outflows represent Sacramento River gains from groundwater and subsurface outflows to the Colusa and Corning subbasins along the shared boundary along the Sacramento River. The split between these outflows is uncertain at this time and will be addressed through future refinements to the BBGM and through coordination and collaboration with neighboring subbasins as part of GSP implementation.

[27] TAF/yr – Thousands of acre-feet per year.

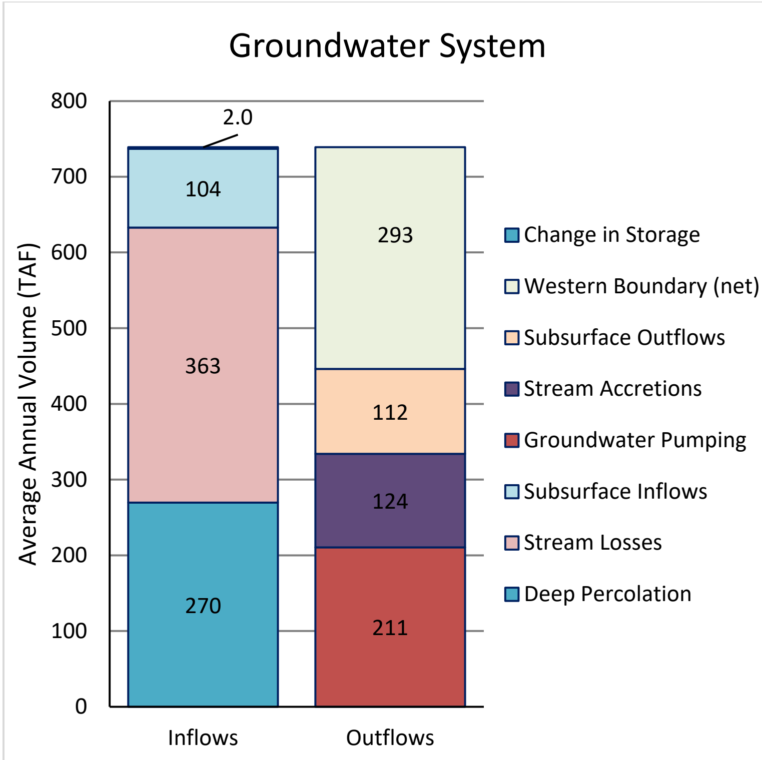


Figure 2-41. Average Annual Future Conditions with 2070 Climate Change Groundwater System Water Budget

2.2.3.4.3.4 Comparison of Water Budget Scenarios

A figure depicting cumulative change in storage for the current conditions and three future conditions baseline scenarios is provided on the following page (**Figure 2-42**). In the figure, the cumulative change in groundwater storage is shown for the 50-year hydrologic period. The x-axis (horizontal axis) is labeled with the historical reference year along with the corresponding water year type based on the Sacramento Valley Water Year Index. Years are identified as wet (W), above normal (AN), below normal (BN), dry (D), or critical (C).

Estimated changes in storage are similar for the current conditions and future conditions without climate change scenarios due to limited anticipated urban growth in the subbasin. For the climate change scenarios, there is a greater overall decrease in storage over the 50-year period, representing the potential for reduced surface water supplies resulting from decreased April to July inflows to Lake Oroville. For all scenarios, the amount of water stored in the subbasin varies substantially between wet and dry cycles, which is an important consideration in the development of sustainable management criteria.

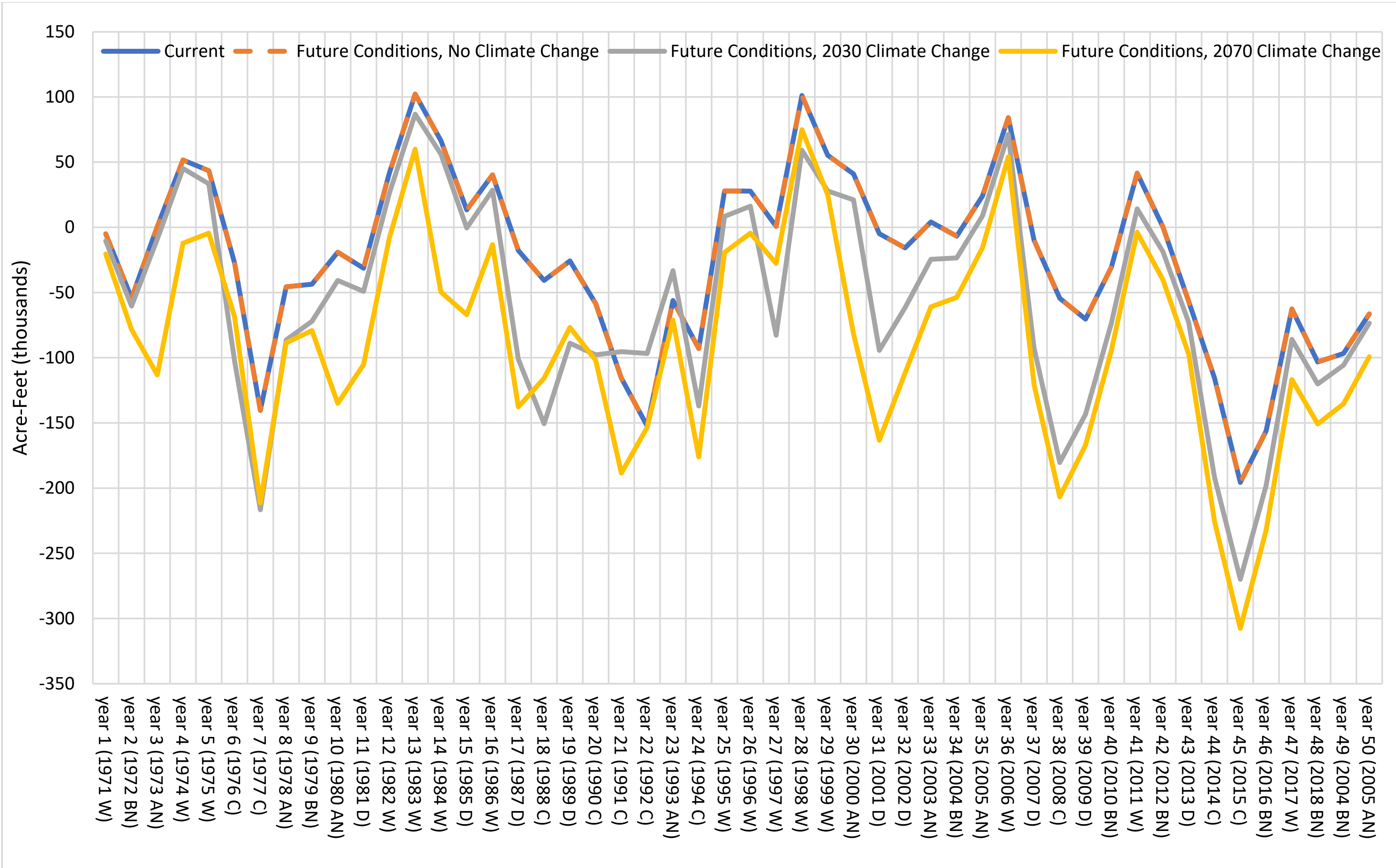


Figure 2-42. Cumulative Change in Groundwater Storage for Current and Future Conditions Baseline Scenarios.

2.2.3.5 *Water Budget Uncertainty*

Uncertainty refers to a lack of understanding of the basin setting that significantly affects an Agency's ability to develop sustainable management criteria and appropriate projects and management actions in a GSP, or to evaluate the efficacy of plan implementation, and therefore may limit the ability to assess whether a basin is being sustainably managed. Uncertainty exists in all components of each water budget and in the assumptions used to project potential future conditions related to planned development and associated urban demands as well as projections of climate change. These uncertainties are not expected to substantially limit the ability to develop and implement a GSP for the basin including the ability develop sustainable management criteria and appropriate projects and management actions, nor the ability to assess whether the basin is being sustainably managed over time. It is anticipated that these uncertainties will be reduced over time through monitoring and additional data collection, refinements to the BBGM and other tools, and coordination with neighboring basins.

2.2.3.6 *Overdraft Conditions*

Based on the current conditions and future conditions baseline scenarios, which approximate long-term average conditions in the subbasin considering climate change and other factors, there is the potential for overdraft conditions to occur. Overdraft estimates range from approximately 1,200 to 2,000 acre-feet per year based on average annual estimated decrease in storage presented previously in **Table 2-8** and in **Table 2-10** in the following section.

2.2.3.7 *Sustainable Yield Estimate*

As described previously, sustainable yield refers to 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. Estimates have been developed for the basin for each scenario as the long-term annual groundwater pumping, minus the average annual decrease in groundwater storage, as summarized in **Table 2-10**. Ultimately, it is anticipated that other factors will be considered in refining these estimates as part of development of sustainable management criteria for the basin.

Table 2-10. Estimated Groundwater Pumping, Decrease in Storage, and Change in Sustainable Yield.

Baseline Scenario	Groundwater Pumping (AFY)	Decrease in Groundwater Storage (AFY)	Difference (AFY)
Current	162,800	1,200	161,600
Future, No Climate Change	162,600	1,300	161,300
Future, 2030 Climate Change	189,400	1,500	187,900
Future, 2070 Climate Change	210,500	2,000	208,500

2.2.3.8 *Opportunities for Improvements to Water Budget*

As described in **Section 2.2.3.5**, while there is inherent uncertainty in every water budget component and the resulting water budget, this uncertainty is not expected to substantially limit the ability to develop and implement a GSP for the basin including the ability develop sustainable management criteria and appropriate projects and management actions, nor the ability to assess whether the basin is being sustainably managed over time. However, there are opportunities to improve the measurement or estimation of specific water budget components that will improve water accounting and the water budget for the Butte Subbasin, which are described below. Some or all of these opportunities may be pursued during GSP implementation, depending on available funding and GSA priorities.

2.2.3.8.1 Refine Surface Water Diversion Estimates

While many of the large diversions are continuously monitored and recorded, limited information is available for others. It is recommended that GSAs in the basin work with local stakeholders and responsible state and federal agencies to better document surface water diversions, including investigation of riparian diversions in some area and additional information describing water supplies for managed wetlands. Diversion estimates developed as part of the water budgets provide a good basis to support discussion with diverters.

2.2.3.8.2 Refine Groundwater Pumping Estimates

Groundwater pumping for irrigation has generally been estimated based on estimates of crop irrigation requirements in areas known to rely on groundwater. It is recommended that GSAs look for opportunities to verify and refine groundwater pumping estimates to support water budget updates by obtaining pumping data from cooperative landowners.

2.2.3.8.3 Refine Deep Percolation Estimates

Deep percolation in some areas may return to the surface layer through accretion in drains and natural waterways or may be consumed by phreatophytic vegetation. It is recommended that GSAs look for opportunities to further understand and investigate the ultimate fate of deep percolation from agricultural lands. Through modeling of specific waterways and shallow groundwater, the BBGM can help support these investigations.

2.2.3.8.4 Refine Urban Lands Water Budgets

The relative proportion of non-consumed water returning as deep percolation or surface runoff does not explicitly account for percolation from stormwater retention ponds or releases from wastewater treatment plants to local waterways. There is an opportunity to refine water budgets for developed lands to verify and refine estimates of non-consumed water. Additionally, there is an opportunity to evaluate and develop refined water use estimates for industrial uses.

2.2.3.8.5 Refine Characterization of Interbasin Flows and Net Outflows along Western Boundary

Interbasin flows are dependent on conditions in adjacent basins. It is recommended that GSAs refine estimates of subsurface groundwater flows from and to neighboring basins through coordination with GSAs in neighboring basins during or following GSP development and through review of modeling tools that cover the Sacramento Valley region, including the C2VSim and SVSim integrated hydrologic model applications developed by DWR.

2.2.4 Management Areas

Management areas have not been delineated in the Butte Subbasin at this time. The creation of management areas will be considered by GSAs in the Subbasin during GSP implementation.

3 Monitoring Networks

3.1 Monitoring Network Objectives

The objective of the monitoring networks is to observe and record data on groundwater levels, quality and related conditions, such as the interconnection of surface water and groundwater and land subsidence. Wells included in the existing monitoring networks were selected based on the availability of datasets with sufficient temporal frequency and spatial variability to evaluate conditions related to the effectiveness of the GSP, specifically to detect short-term, seasonal, and long-term trends, and to provide for required spatial density and trend analyses. Parameters monitored at these existing networks provide historical baseline information for establishing the current status of basin conditions and trends to inform the development of relevant Sustainability Indicators (SIs) that will be useful in tracking these SIs and progress towards achieving the sustainability goal as the GSP is implemented. The complete list of SIs is presented below (DWR 2014):

1. Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued;
2. Significant and unreasonable reduction of groundwater storage;
3. Significant and unreasonable seawater intrusion;
4. Significant and unreasonable degradation of groundwater quality, including the migration of contaminant plumes that impair water supplies;
5. Significant and unreasonable land subsidence that substantially interferes with surface land uses; and
6. Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

The existing monitoring networks form a pool of monitoring locations that will serve as the backbone of the representative monitoring network used to assess SGMA compliance. The existing network will support improved understanding of conditions in the Butte Subbasin, inform ongoing management of the Subbasin and contribute to future updates to the GSP. These objectives will be implemented in a manner that will:

- Demonstrate progress toward achieving or maintaining Measurable Objectives (MOs), Minimum Thresholds (MTs), and Interim Milestones (IMs);
- Monitor changes in groundwater conditions, and
- Quantify annual changes in water budget components.

At locations where MOs reflect current conditions, monitoring data will be used to substantiate that sustainable groundwater conditions are being maintained. At other locations, data collected from the monitoring network will be used to track progress toward achieving locally established

MOs set for groundwater elevations, water quality constituent concentrations, groundwater-surface water interactions and rates of subsidence at monitoring locations throughout the Butte Subbasin. At locations where MOs reflect current conditions, monitoring data will be used to substantiate the sustainable groundwater conditions are being maintained. Observations from the monitoring network will also be used to confirm that groundwater elevations, water quality constituent concentrations, subsidence rates and streamflow depletion do not breach locally established MTs.

Most SIs will be monitored directly through measurement of groundwater levels, concentrations of key water quality constituents and observation of ground surface elevations and stream stages. However, the SI for reduction in groundwater storage will use change in groundwater elevations as a proxy for reductions in storage with the volume of change in storage being estimated based on observed changes in elevations.

Groundwater elevations are also used as proxies for stream flow depletion as recommended by the Environmental Defense Fund (EDF) (2021). In each of these instances, “significant and unreasonable” reductions are the guideposts used to warn of unsustainable groundwater conditions.

In addition to being central to SGMA compliance by enabling tracking of SIs, data collected through the monitoring network will be used to update inputs to the water budget and to guide interpretation of water budget results. Monitoring data will also be used to assess impacts of groundwater management on various categories of beneficial uses and users and to monitor overall groundwater conditions from local and Subbasin-wide perspectives.

The monitoring networks for groundwater levels, degraded water quality, land subsidence, and depletions of interconnected surface water are described below. The Butte Basin Groundwater Model (BBGM) (BCDWRC 2021) and/or groundwater level data will be used to estimate changes in groundwater storage based on observed changes in groundwater levels.

Seawater intrusion is not considered to be a SI relevant to the Butte Subbasin because seawater intrusion is not present and is not likely to occur in the Subbasin due to the distance from the Pacific Ocean, bays, deltas, or inlets. However, there is some evidence that connate groundwater of a quality characteristic of its ancient marine origins is present in the Butte Subbasin in the vicinity of the Sutter Buttes below the base of freshwater and that this water has the potential to affect beneficial uses due to its brackish nature and concentrations of inorganic arsenic (USGS 2008; Sutter County 2012). An interbasin working group will be formed to address groundwater quality issues associated with the Sutter Buttes; this is described in more detail in **Section 6.1.2.2.**

The location of existing monitoring sites and the frequency of monitoring at each site are presented below, as is the spatial density of locations in each of the monitoring networks. Data gaps and plans to fill these gaps are also discussed as part of the program for defining the representative monitoring network to be used in monitoring SIs to ensure SGMA compliance. Explanations of how gaps identified in the monitoring network will be filled to develop the representative networks are provided in **Section 4.4**. The schedule and costs associated with maintaining and improving monitoring networks is discussed in **Sections 5 and 6.**

The goal of defining the monitoring networks, identifying gaps in the networks and developing and implementing a program to fill those gaps is to develop a set of representative monitoring networks capable of collecting information needed to address:

- Short-term trends in groundwater and related surface conditions;
- Seasonal trends in groundwater and related surface conditions;
- Long-term trends in groundwater and related surface conditions, and
- Provide adequate coverage by establishing sufficient density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends listed above.

Data from the monitoring networks will be stored in the Butte Subbasin Data Management System (DMS), which is described in **Section 6.7**, and a copy of all monitoring data will be included in Annual Reports and submitted electronically on forms proved by DWR.

3.2 Groundwater Level Monitoring

3.2.1 Background

Groundwater level monitoring is conducted through a network of monitoring wells used for observation of groundwater levels and computation of flow directions and hydraulic gradients in the principal aquifers of the Butte Subbasin. The network also allows for characterization of the groundwater table or potentiometric surface of the principal aquifers.

In total, 89 wells from the following monitoring networks were evaluated for inclusion in the Butte subbasin monitoring network: CASGEM, SGMA Data Viewer, WDL, GAMA, and Geotracker. Wells were reviewed with respect to the degree to which data from these wells is representative of conditions in the area, use in existing monitoring programs, permission of the well owner to access the well, and the length and continuity of the monitoring record. The water level data, construction details, and other relevant information for this monitoring network were gathered using publicly available datasets and tools developed by DWR and other agencies and compiled for this report. **Table 3-1** lists the 51 wells of the 89 total selected to monitor groundwater levels in the Subbasin and **Figures 3-1 and 3-2** shows the locations of these wells. The multi-completion wells noted in the table are at sites where more than one monitoring well has been installed at a single location. The wells are drilled, screened, and sealed at different depths with each well designed to measure groundwater heads in a selected aquifer zone. In the Butte Subbasin, these multi-completion wells provide valuable information on vertical gradients within the underlying aquifer.

Each of these 51 wells has been selected based upon its location within the Subbasin, screened interval depths and effective aquifer zones, quality of groundwater level data history, construction details, and well use type. These data were compiled using Department of Water Resources websites and other sources including the following: CASGEM, SGMA Data Viewer, WDL, GAMA Water Quality, Geotracker, and the BBGM Calibration Model. The well completion reports for each well were reviewed to refine the monitoring network list to showcase the most effective completion/well in the area for both principal aquifers. The wells were also assigned to four separate networks based on relevant criteria: 1) primary aquifer, 2) very deep aquifer, 3)groundwater quality (see **Section 3.4**), and 4) interconnected surface water (see **Section 3.6**).

Table 3-1. Butte Subbasin Groundwater Level Monitoring Well Locations

State Well Number	Monitoring Frequency	DWR Subbasin Bulletin 2018	Total Well Depth	Depth to Top Screen (ft bgs)	Depth to Bottom Screen (ft bgs)	Ground Surface Elevation (ft msl)	Model Layer	Minimum Threshold Elevation (ft msl)	Measureable Objective Elevation (ft msl)	Water Level Measurement Date Range	Well Type
Primary Well Monitoring Network; Wells less than 700 feet deep											
17N01E06D001M	Quarterly	Butte	500	110, 200, 240, 280, 440	140, 220, 260, 300, 500	63.37	2	35	6	2003-2021	Irrigation
17N01E10A001M	Quarterly	Butte	110	66	110	65.34	2	42	17	1953-2021	Residential
17N01E17F001M	Quarterly	Butte	160	130	150	58.97	2	34	7	1992-2021	Observation
17N01E24A006M	Hourly	Butte	75	45	55	72.8	2	29	6	2007-2021	Observation
17N01W10A004M	Quarterly	Butte	117	88	98	64.28	2	38	5	2010-2021	Observation
17N01W27A003M	Quarterly	Butte	203	160	170	66.61	3	43	14	2011-2021	Observation
17N02E14A001M	Quarterly	Butte	102	70	102	84.79	2	56	15	1947-2021	Irrigation
17N02E14H001M	Quarterly	Butte	102	60	102	86.29	2	53	23	2000-2021	Other
17N03E08K002M	Quarterly	Butte	100			91.27	2	38	13	2000-2021	Residential
18N01E13A002M	Quarterly	Butte	317	80	317	79.34	3	65	12	2001-2021	Irrigation
18N01E15D002M	Quarterly	Butte	112	56	112	72.35	2	79	7	1976-2021	Residential
18N01W02E003M	Quarterly	Butte	200	110	120	78.5	2	60	19	2003-2020	Observation
18N01W14B001M	Quarterly	Butte	204	59, 145	83, 173	72.38	2	73	26	2000-2021	Irrigation
18N01W17G001M	Quarterly	Butte	108	48	108	81.39	2	52	21	1964-2021	Irrigation
18N01W22L001M	Quarterly	Butte	147	76, 108	92, 124	72.39	2	57	17	1953-2021	Irrigation
18N02E16F001M	Quarterly	Butte	80	20	60	82.32	1	39	13	1947-2021	Irrigation
18N02E25M001M	Quarterly	Butte	220	61	220	89.3	3	58	18	1959-2021	Irrigation
18N03E08B003M	Quarterly	Butte	463	156	463	112.3	6	59	29	2001-2021	Irrigation
18N03E18F001M	Quarterly	Butte	462	100, 190	150, 220	99.8	8	44	14	1947-2021	Irrigation
18N03E21G001M	Quarterly	Butte	125			106.28	8	50	31	1953-2021	Irrigation
19N01E09Q001M	Quarterly	Butte	200	140	200	92.36	5	45	11	1991-2021	Irrigation
19N01E27Q001M	Quarterly	Butte	548	260	280	87.35	5	54	9	1978-2021	Observation
19N01E35B001M	Hourly	Butte	156.7	85, 125	95, 135	86.5	1	35	4	2001-2021	Observation
19N01W15D002M	Quarterly	Butte	300	250, 275	260, 295	91	5	54	25	2012-2021	Residential
19N01W22D007M	Quarterly	Butte	120	80	90	87.38	2	54	20	2006-2021	Observation
19N01W27R001M	Quarterly	Butte	465	68	108	83.38	2	86	33	1974-2021	Irrigation
19N02E07K004M	Hourly	Butte	192	140	150	102.7	5	35	5	2006-2021	Observation
19N02E13Q001M	Hourly	Butte	221	130, 200	140, 210	119.88	6	32	5	2001-2021	Observation
19N03E05N002M	Quarterly	Butte	180	24	48	142.31	6	98	37	1976-2021	Residential
20N01E18L003M	Hourly	Butte	173	100	110	107.35	2	28	5	2001-2021	Observation
20N01E35C001M	Quarterly	Butte	92	49.5	92	102.35	1	34	6	1947-2021	Residential
20N01W11N002M	Quarterly	Butte	170	84	170	107.17	4	54	22	2008-2021	Stockwatering
20N02E15H001M	Hourly	Butte	180	170	180	144.01	6	103	44	1995-2020	Observation
20N02E16P001M	Hourly	Butte	466			131.83	6	116	30	1990-2020	Irrigation
20N02E28N001M	Quarterly	Butte	277	160	277	123.43	6	49	12	1947-2021	Other
21N01E08K002M	Quarterly	Butte	181.2	19.2	181.2	146.04	5	109	49	1992-2021	Irrigation
21N01W11A002M	Hourly	Butte	200	125, 175	135, 185	129.3	2	38	15	2010-2021	Observation
21N01W13J003M	Quarterly	Butte	400	355	385	127.68	5	70	25	2012-2021	Observation
21N01W23J001M	Quarterly	Butte	54			121.36	7	67	23	1941-2021	Irrigation
21N01W35K002M	Hourly	Butte	270	75	135	114.36	4	41	18	1994-2021	Irrigation
22N01E32E004M	Hourly	Butte	160	85	160	150.94	5	73	39	1992-2021	Residential

State Well Number	Monitoring Frequency	DWR Subbasin Bulletin 2018	Total Well Depth	Depth to Top Screen (ft bgs)	Depth to Bottom Screen (ft bgs)	Ground Surface Elevation (ft msl)	Model Layer	Minimum Threshold Elevation (ft msl)	Measureable Objective Elevation (ft msl)	Water Level Measurement Date Range	Well Type
Very Deep Aquifer Well Monitoring Network; Wells greater than 700 feet deep											
17N01E24A003M	Hourly	Butte	833	770	790	72.8	5	30	3	2007-2021	Observation
17N01W10A001M	Quarterly	Butte	828	770, 790	780, 800	64.28	4	60	10	2010-2021	Observation
18N01E35L001M	Hourly	Butte	840	816	836	70	5	36	1	2005-2021	Observation
18N01W02E001M	Quarterly	Butte	739	719	729	78.5	4	59	11	2003-2020	Observation
19N01E35B002M	Hourly	Butte	980	930	950	86.5	6	30	-1	2005-2021	Observation
19N01W22D004M	Quarterly	Butte	820	780	790	87.38	5	47	12	2006-2021	Observation
19N02E13Q003M	Hourly	Butte	690	670	680	119.88	8	27	5	2006-2021	Observation
20N01E18L001M	Hourly	Butte	1000	767, 873	810, 894	107.35	6	62	11	1999-2021	Observation
21N01W11A001M	Hourly	Butte	1311	810, 960, 1050, 1270	820, 970, 1060, 1280	129.3	6	55	22	2010-2021	Observation
21N01W13J001M	Quarterly	Butte	830	780	820	127.68	6	62	26	2012-2021	Observation

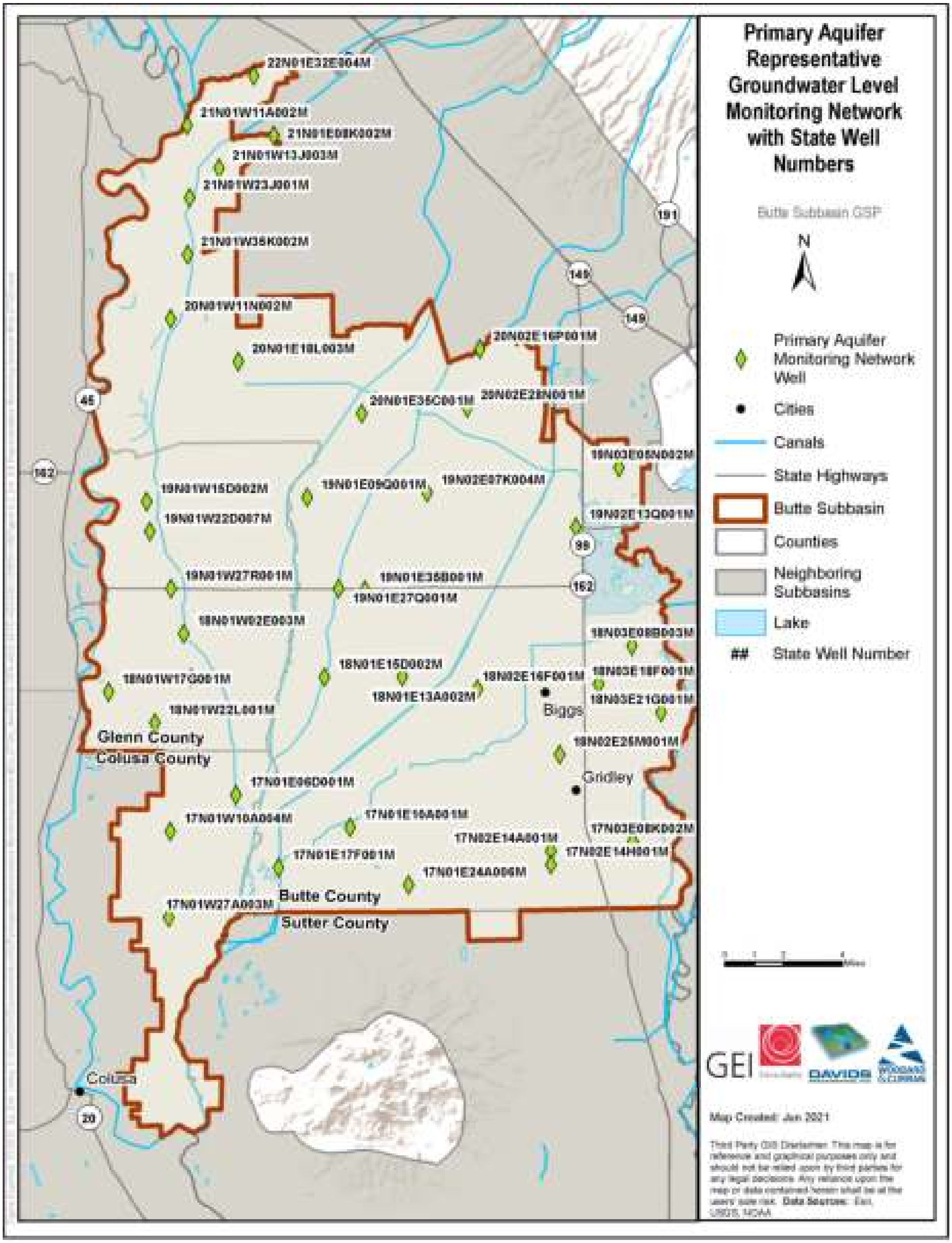


Figure 3-1. Primary Aquifer Representative Groundwater Level Monitoring Network

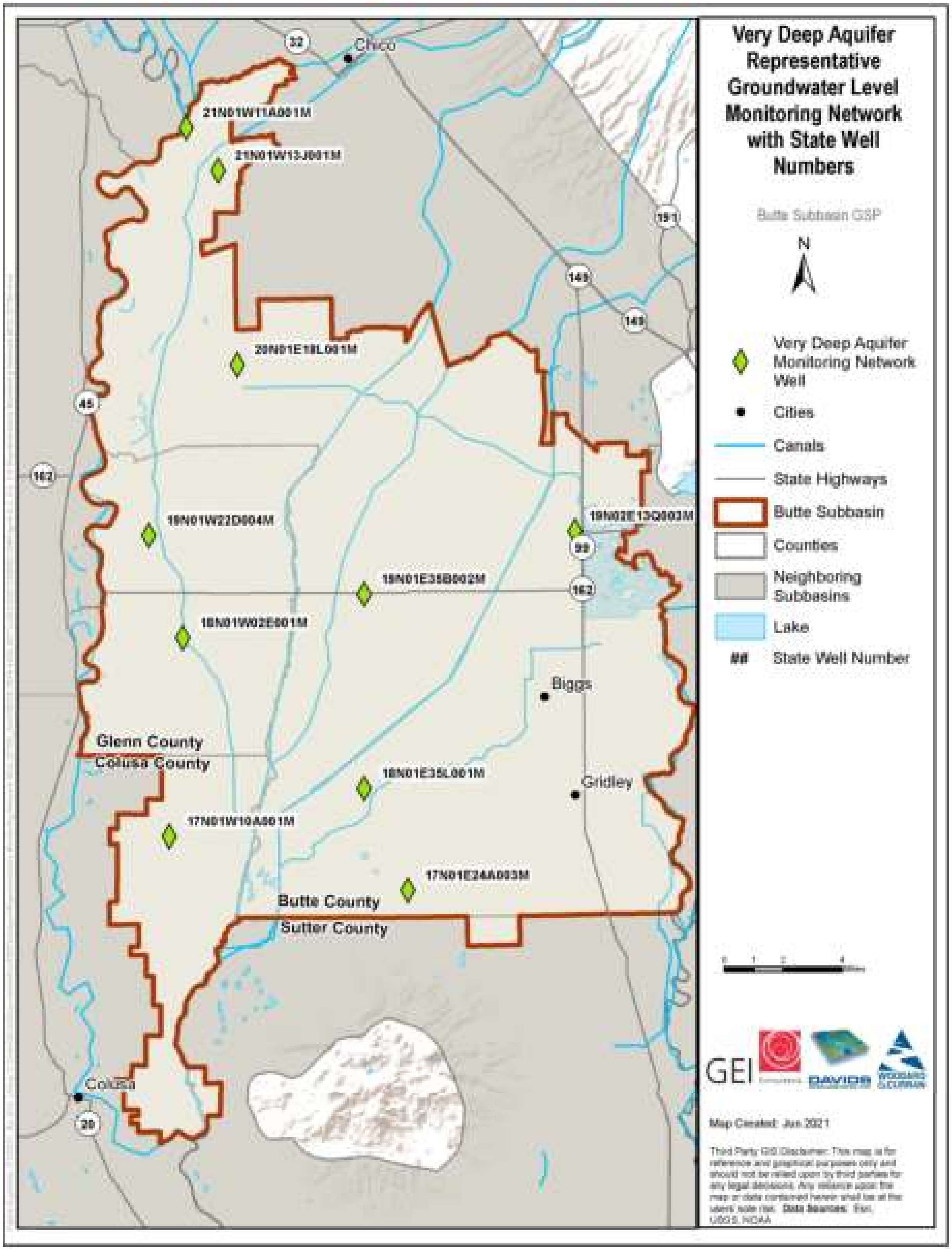


Figure 3-2. Very Deep Aquifer Representative Groundwater Level Monitoring Network

3.2.2 Location and density of monitoring sites and frequency of measurement

Each of the wells in the existing representative network is monitored either by DWR or the associated California Statewide Groundwater Elevation Monitoring (CASGEM) collaborators in each county. Of the wells in the existing monitoring network, 35 are measured manually on a quarterly basis, and 16 are measured continuously (hourly intervals) using data loggers, 12 of which are multi-completion wells. The network includes 23 multi-completion wells. The locations of monitoring wells in both the primary and very deep aquifers are shown on the Monitoring Well Location maps (**Figures 3-1 and 3-2**).

For the purpose of SGMA compliance, water levels in all monitoring wells in the Butte Subbasin will be monitored on at least a semi-annual basis – Spring (prior to the major irrigation season) and Fall (after completion of the major irrigation season). All wells will be measured within one week of one another following a schedule that will be developed for the Subbasin in coordination with entities also monitoring those wells, including DWR, the counties, other collaborators as identified, and neighboring subbasins.

Groundwater pumping typically peaks during the summer growing season and slows in the fall and winter. Therefore, generally, spring levels represent an annual high prior to summer pumping to meet irrigation demands while fall levels represent an annual low. In addition to the coordinated spring and fall elevation measurements made at all wells in the representative monitoring network, data will continue to be taken at wells now monitored more frequently than required under SGMA and in accordance with their existing monitoring schedules. For wells that cannot be monitored on the regular monitoring schedule, a notation will be made in the standard data sheet that the well was unable to be measured.

Groundwater elevation data will be used to observe annual changes and for analysis of long-term trends. Analysis of trends in groundwater levels, together with data on surface water deliveries and groundwater extraction, will be important tools for tracking the Subbasin's progress in meeting and/or maintaining its MOs and in determining the appropriate measures to support sustainable groundwater management.

The 41 primary aquifer monitoring sites, and 10 very deep monitoring sites (51 wells) comprising the representative monitoring network for groundwater levels include 38 wells in Butte County (31 primary, 7 very deep), 4 wells in Colusa County (3 primary, 1 very deep) and 9 wells in Glenn County (7 primary, 2 very deep). These wells are distributed over the 415 square-mile area of the Butte Subbasin with a spatial density of over 3 wells per 100 square miles (sq.mi.) for the deep network, and 10 wells per 100 sq.mi. in the primary network. The primary network density significantly exceeds the density presented in the DWR Best Management Practice (BMP) documentation entitled *Monitoring Networks and Identification of Data Gaps* (DWR, 2016), while the very deep network is better than the Hopkins well density rating for basins pumping between

1,000 and 10,000 acre-feet/year. In the Butte Subbasin, most pumping is from the primary aquifer, hence the availability of more monitoring wells. **Table 3-2** is from the BMP and shows a range of recommended monitoring network densities.

Table 3-2. Monitoring Well Density Considerations (Source: DWR, 2016)

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

Annual groundwater pumping presented in the water budget section of the GSP shows a historical rate of pumping in the Subbasin of 142,000 acre-feet per year (AFY) (34,217 AFY per 100 square miles) and a current condition pumping rate of 162,800 AFY (39,229 AFY per 100 square miles).

3.3 Groundwater Storage Monitoring

3.3.1 Background

The BMP for Monitoring Networks and Identification of Data Gaps (DWR 2016) notes:

> *While change in groundwater storage is not directly measurable, change in storage can be estimated based on measured changes in groundwater levels… and a clear understanding of the Hydrogeologic Conceptual Model…. The HCM [Hydrogeologic Conceptual Model] describes discrete aquifer units and the specific yield values associated with these units. This data, together with information on aquifer thickness and connectivity, can be used to calculate changes in the volume of groundwater storage associated with observed changes in groundwater elevation.*

As suggested in the preceding passage, measured changes in groundwater levels can serve as a proxy for changes in storage. For this reason, the representative monitoring network for monitoring changes in groundwater storage is the same as that used for monitoring changes in groundwater levels. Monitoring sites and wells included in this network are presented above in **Table 3-1** with well locations shown in **Figures 3-1 and 3-2**.

3.3.2 Frequency of measurement

The semi-annual frequency of monitoring described above for monitoring groundwater levels will enable observed change in levels to serve as a proxy to indicate changes in groundwater storage. Data presented in the HCM on parameters such aquifer layer composition and thickness and the specific yield and hydraulic conductivity of these layers are integrated in the Butte Basin Groundwater Model (BBGM), as described in the modeling report (BCDWRC 2021), and allow the model to be used to estimate changes in groundwater storage that result from observed changes in groundwater elevations. As data on aquifer characteristics and modeling capabilities improve, the methodologies used to relate changes in groundwater elevations with corresponding changes in storage will be updated.

3.4 Groundwater Quality

3.4.1 Background

Assessment of groundwater quality in the Butte Subbasin focuses on annual observation of salinity (which will be observed through monitoring of electrical conductivity or EC), temperature, and pH in the principal aquifers. Each of these parameters is influenced by ambient conditions and the parent material of the principal aquifers. Total Dissolved Solids (TDS) and pH are also influenced by human activity. While only salinity will be used to monitor attainment of MOs and avoidance of breaches in MTs, changes in pH and temperature may indicate shifting groundwater conditions and trigger additional investigation.

The groundwater quality monitoring network implemented for representative monitoring under SGMA will build upon existing programs in place. Additional monitoring will continue to be conducted by DWR and other agencies to track constituents not managed under this GSP, including a variety of minerals, metals, pesticides and herbicides. Data from ongoing monitoring by various state and federal agencies will be available to the GSAs to augment local datasets and understanding of water quality in the Butte Subbasin and can be found on the State Board's Groundwater Ambient Monitoring and Assessment (GAMA) program at https://www.waterboards.ca.gov/gama/.

Nine sites are included in the groundwater quality monitoring network based on use in existing monitoring programs, the existing period of record, the quality of data reported and subject to permission of the well owner to monitor the well. Water quality monitoring in the Butte Subbasin has historically been conducted by Butte and Glenn Counties during the summer.

Sites which discharge agricultural runoff are regulated by the Irrigated Lands Regulatory Program (ILRP) by the State Water Resources Control Board or one of the nine Regional Water Quality Control Boards. Many ILRP sites in the Central Valley operate under general orders (broad-based

Waste Discharge Requirements or WDRs) or commodity-specific orders designed to prevent discharges of agricultural runoff from causing or contributing to exceedances of water quality objectives. The Butte Subbasin falls within the Butte-Yuba-Sutter Watershed of the Sacramento Valley Water Quality Coalition (SVWQC), the body that implements the ILRP in the Sacramento Valley. The Butte-Yuba-Sutter subwatershed encompasses all of Butte and Yuba Counties and the majority of Sutter County. A large portion of the subwatershed is located on the Sacramento Valley floor, where the majority of agricultural production occurs; however, the subwatershed extends into the upper watershed as far as Lake Oroville. Groundwater quality monitoring within this subwatershed is largely conducted by DWR and local agencies and reported through the GAMA program.

The first groundwater technical report for the SVWQC was the Groundwater Quality Assessment Report (GAR), conditionally approved by Central Valley Regional Water Quality Control Board (CVRWQCB) in September 2016 (SVWQC 2016). This document identified High Vulnerability Areas (HVAs) susceptible to nitrate contamination and assigned priority rankings to these areas. No HVAs were identified in the Butte Subbasin. However, further reviews of HVAs may be conducted through the Trend Monitoring Program and will be documented in the GAR 5-year update (SVWQC 2019).

The California Rice Commission operates a second coalition in the Sacramento Valley that reports groundwater quality data for compliance with the ILRP (CRC 2016). Wells monitored by this coalition are shallow “rice” wells that are typically 35 feet deep with screened intervals extending from 25 to 30 feet below ground surface. While the California Rice Commission’s 2018 Annual Monitoring Report listed three monitoring wells within Butte County, none within the Butte Subbasin. The 2019 report listed no monitoring wells in Butte County (CRC 2019).

To study regional groundwater quality, DWR’s Northern Region Office collects groundwater samples from DWR-dedicated monitoring wells that are used exclusively for groundwater level and groundwater quality monitoring.

Additionally, to address groundwater quality issues in the vicinity of and associated with the unique geology of the Sutter Buttes, the CGA, GGA and the GSAs in the Butte, Sutter, Yolo, North Yuba and South Yuba Subbasins will form and participate in the Sutter Buttes Water Quality Interbasin Working Group. The interbasin working group is described in greater detail in **Section 6.1.2.2** and has objectives of proposing studies and providing a forum for local entities to propose and develop projects to protect or improve groundwater quality.

Table 3-3 presents information on each of the wells monitored in the Butte Subbasin groundwater quality monitoring network. **Figure 3-3** shows the location of wells listed in the table.

Table 3-3. Groundwater Quality Monitoring Locations

Well Number	Monitoring Frequency	DWR Subbasin Bulletin 2018	Total Well Depth	Depth to Top Screen (ft bgs)	Depth to Bottom Screen (ft bgs)	Ground Surface Elevation (ft msl)	Model Layer	Well Type
19N02E13Q003M	Hourly	Butte	690	670	680	119.88	8	Observation
18N01W02E001M	Quarterly	Butte	739	719	729	78.5	4	Observation
19N01W22D004M	Quarterly	Butte	820	780	790	87.38	5	Observation
17N01W10A001M	Quarterly	Butte	828	770, 790	780, 800	64.28	4	Observation
21N01W13J001M	Quarterly	Butte	830	780	820	127.68	6	Observation
17N01E24A003M	Hourly	Butte	833	770	790	72.8	5	Observation
18N01E35L001M	Hourly	Butte	840	816	836	70	5	Observation
19N01E35B002M	Hourly	Butte	980	930	950	86.5	6	Observation
20N01E18L001M	Hourly	Butte	1000	767, 873	810, 894	107.35	6	Observation

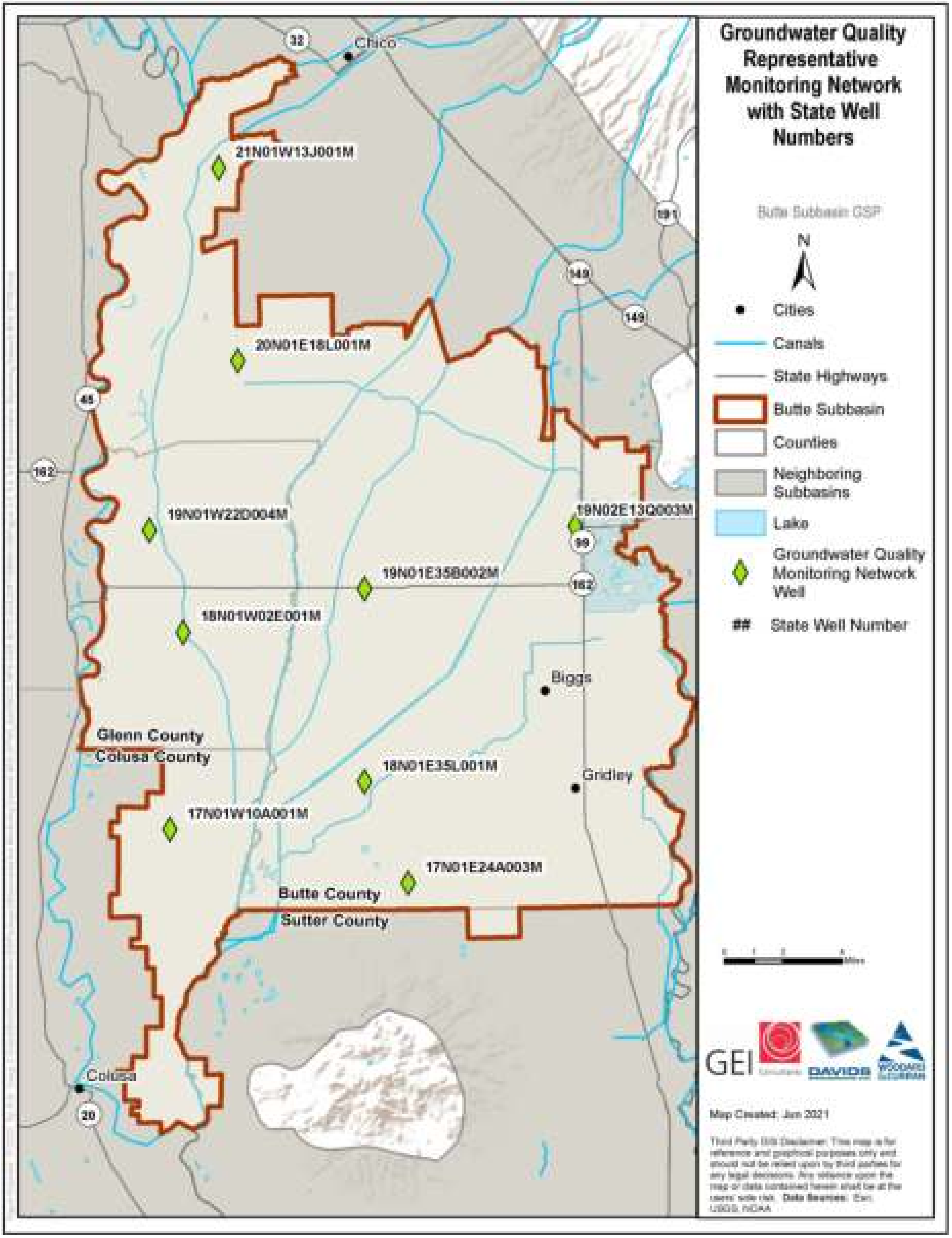


Figure 3-3. Groundwater Quality Representative Monitoring Network.

3.4.2 Frequency of measurement

Following Butte and Glenn Counties' ongoing water quality monitoring program, data will be collected for monitoring the groundwater quality sustainability indicator on an annual basis.

The sites in the representative monitoring network are distributed over the 415 square-mile area of the Butte Subbasin resulting in a monitoring network with a spatial density of 1.45 sites per 100 square miles.

3.5 Land subsidence

3.5.1 Background

Inelastic land subsidence in areas of active groundwater extraction has the potential to be of major concern due to infrastructure damage, permanent reduction in the storage capacity of an aquifer, well casing collapse, and increased flood risk in low lying areas. Inelastic subsidence typically occurs as the result of the compression of soil structure in clay layers within aquifers and aquitards due to the withdrawal of water from storage within these layers. This water supports the structure of the clay layers, and dewatering permanently rearranges or collapses this structure, a process that cannot be reversed as groundwater cannot re-enter the clay structure after collapse.

Available data indicate that inelastic land subsidence due to groundwater withdrawal has not been observed in the Butte Subbasin. This is likely due to subsurface materials that are not conducive to compaction and stable groundwater levels.

The primary mechanism for subsidence monitoring in the Butte Subbasin is a group of continuous GPS monitoring sites or monuments, established to create the Sacramento Valley GPS Subsidence Monitoring Network. This program has been developed jointly by DWR and U.S Bureau of Reclamation with cooperation and assistance from local entities, including counties and irrigation and water districts. The locations of these monuments are shown on **Figure 3-4.** Monuments used to monitor subsidence in the Butte Subbasin network include 29 monuments located either in the interior of the Subbasin or on the boundaries between the Butte Subbasin and the Vina and Wyandotte Creek Subbasins. In addition to the GSP monuments, three extensometers operated by DWR lie within the Butte Subbasin. Data from this monitoring network are collected, analyzed and reported by DWR.

Data from monuments in the Butte Subbasin portion of the Sacramento Valley GPS Subsidence Monitoring Network have been used to monitor cumulative subsidence in the vicinity of the Butte Subbasin. Data were recorded in 2008 and again in 2017 and satisfy the SGMA requirement to evaluate historic subsidence (DWR 2018).

Observations from the GPS Subsidence Monitoring Network will be supplemented by InSAR data released by DWR. This information reports vertical ground surface displacement using data collected by the European Space Agency's Sentinel-1A satellite and processed by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL) [28]. Data released to date from DWR's InSAR program provide cumulative vertical ground surface displacements from June 2015 through September 2019 and are used in the GSP to fulfill the requirement to estimate the rate and extent of recent subsidence. InSAR data collection and mapping is regional and is not based on a defined network of monitoring locations. Therefore, no InSAR sites are shown on **Figure 3-4**.

3.5.2 Location and density of monitoring sites and frequency of measurement

Both the Sacramento Valley GPS Monitoring Network and InSAR program monitor subsidence on a continual basis, and data from both sources requires post processing and analysis. Therefore, while the monitoring is continual, the frequency of reporting is dependent on the work performed by DWR and by NASA's JPL.

3.6 Groundwater/Surface Water Interaction

3.6.1 Background

Monitoring depletions of interconnected surface water is conducted by monitoring water levels (stage) in streams and groundwater levels to characterize spatial and temporal exchanges between surface water and groundwater and to calibrate and apply the tools and methods necessary to estimate depletions. The existing monitoring network incorporates data from active stream gages reported to the California Data Exchange Center (CDEC), the California Water Data Library (WDL) and the USGS National Water Information System and groundwater level monitoring, utilizing a subset of the locations described under the Butte Subbasin's groundwater level monitoring network.

The monitoring sites for the Butte Subbasin include the stream gages shown in **Table 3-4** and **Figure 3-5** and groundwater monitoring sites shown in **Table 3-1** and **Figure 3-1 and 3-2.** The groundwater monitoring sites selected for monitoring groundwater-surface water interactions follow guidance provided by the Environmental Defense Fund (EDF, 2021) and include wells between 2,000 and 7,280 feet from major rivers and streams in the Subbasin with screens at levels appropriate for monitoring shallow groundwater levels selected from the entire array of existing wells in the primary aquifer groundwater level representative monitoring network, as described in **Section 3.1.2** above.

[28] https://data.ca.gov/dataset/tre-altamira-insar-subsidence-data

Table 3-4. Butte Subbasin Surface Water Interaction Monitoring Sites

Stream Monitored	Gage ID	Gage Network	Measurement Frequency
Cherokee Canal Near Richvale	CHC	CDEC	hourly
Feather River Near Gridley	GRL	CDEC	hourly
Sacramento River at Butte City	BTC	CDEC	hourly
Sacramento River at Ord Ferry	ORD	CDEC	hourly

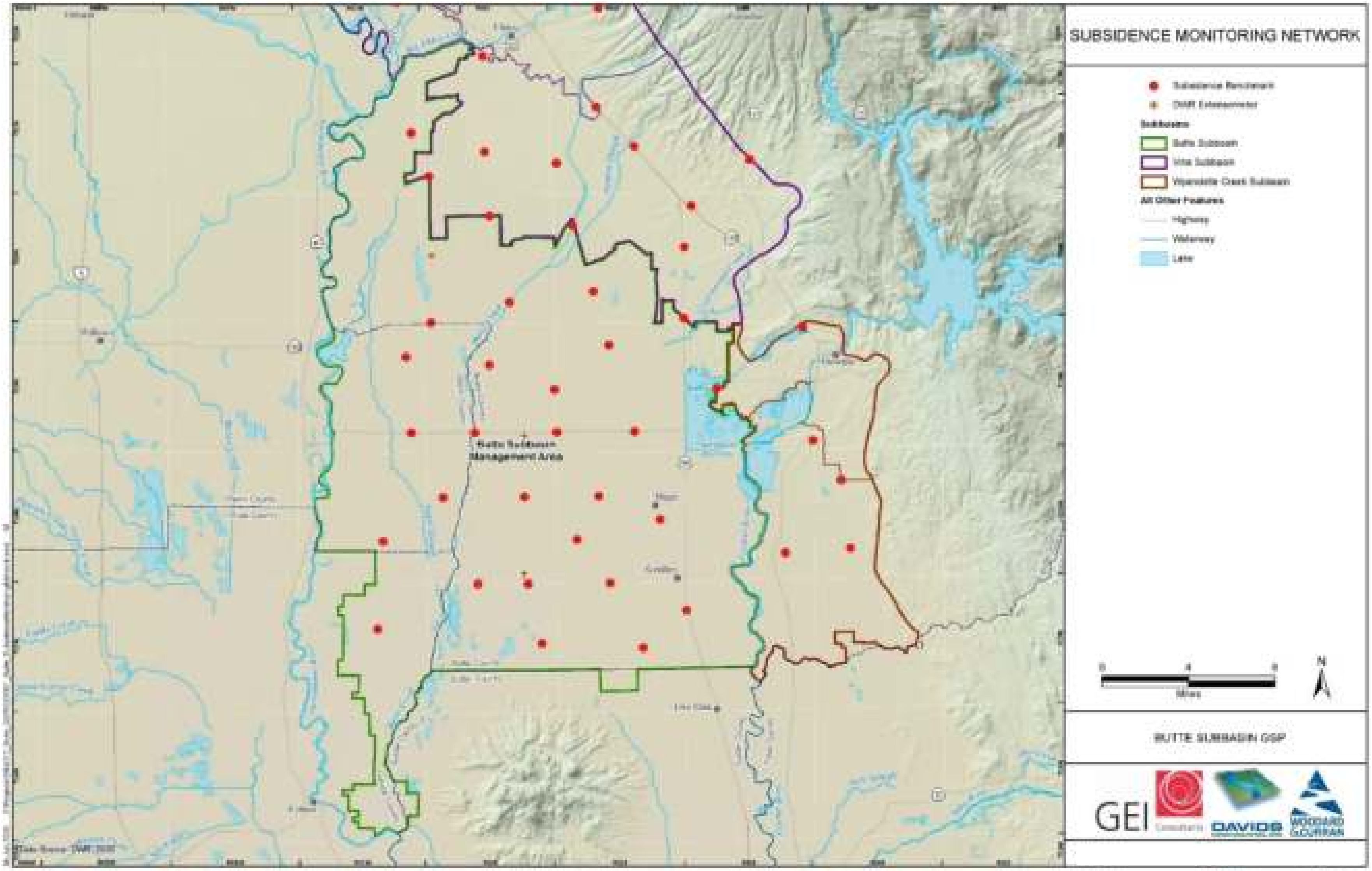


Figure 3-4. Subsidence Monument and Extensometer Locations in the Butte Subbasin.

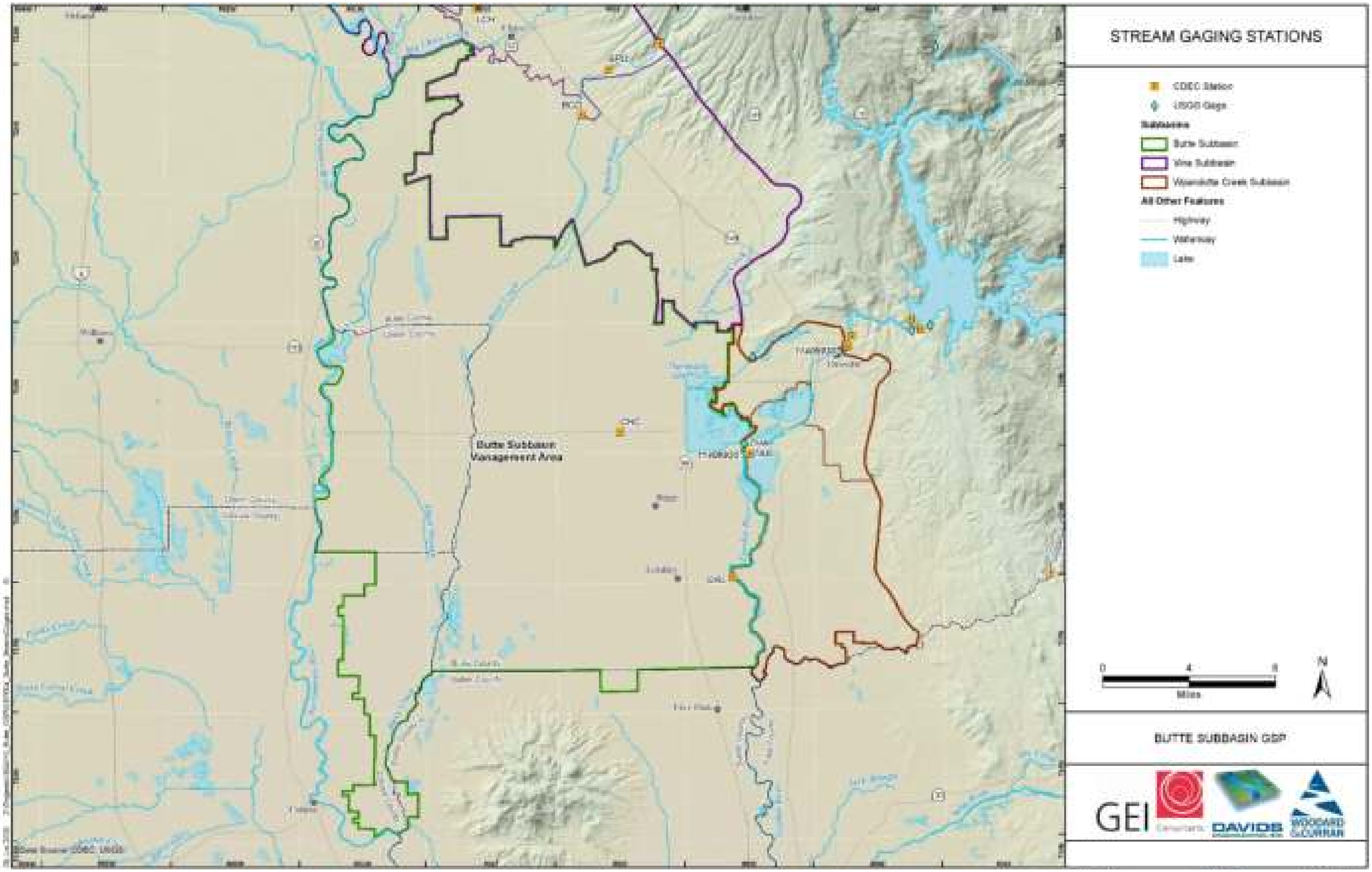


Figure 3-5. Stream Gage Locations in the Butte Subbasin.

As with locations used for monitoring of other SIs, the network of stream gages and wells used to monitor interactions between groundwater and streamflow includes sites selected for their period of record, the quality of data reported and subject to permission of the landowner to monitor the well.

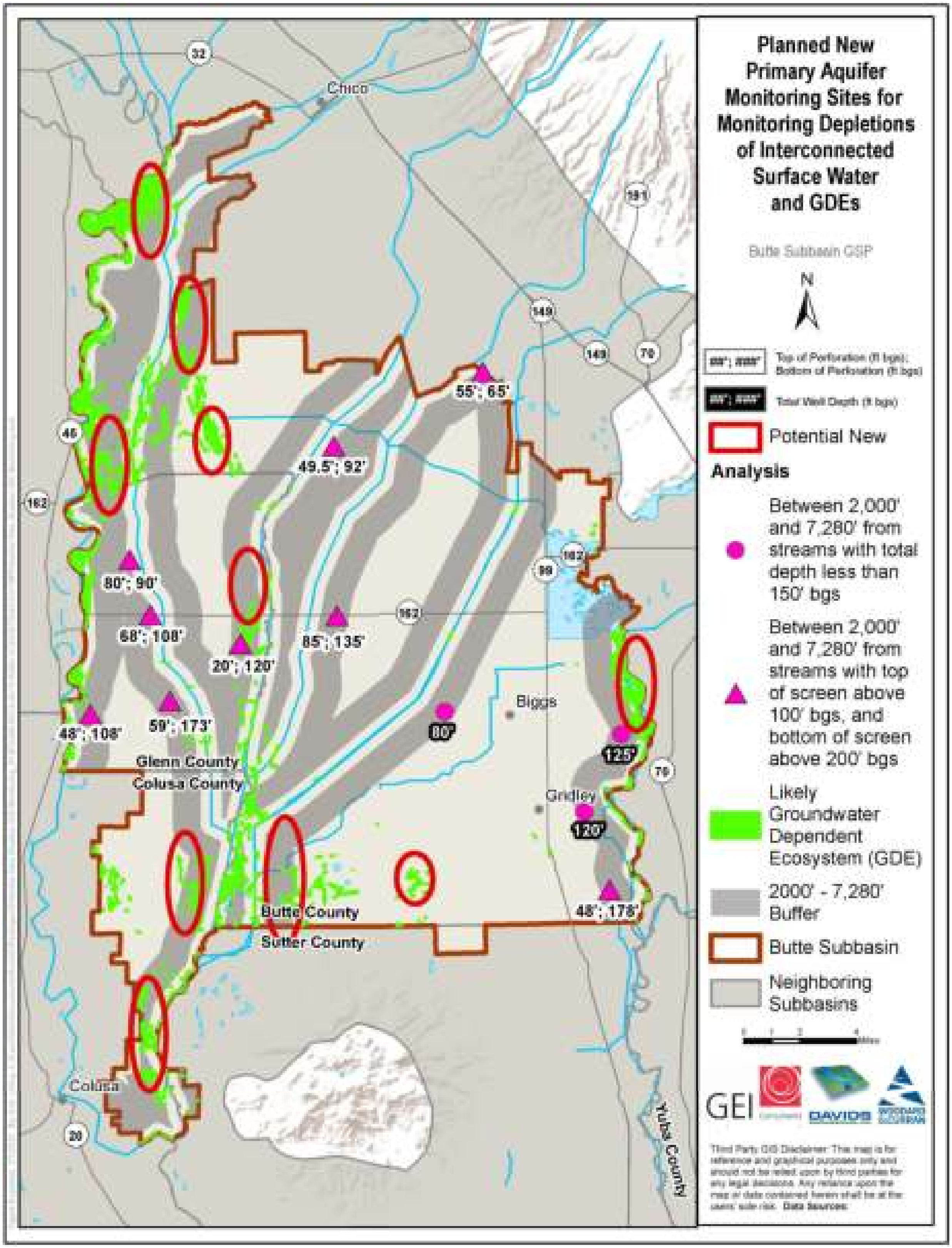
In addition to being used to identify interactions between groundwater levels and streamflow, data from the network of stream gages and monitoring wells will be used to update and refine the calibration of the BBGM. This model may be used to combine data on groundwater levels and stream flows with data on aquifer parameters and water use to estimate the relation between groundwater conditions and stream flow and to identify instances where groundwater use depletes surface water.

A total of 12 monitoring wells and 4 stream gages are included in the Butte Subbasin's representative monitoring network for monitoring groundwater-streamflow interactions. As described below, an additional 10 shallow wells will also be installed to improve monitoring of surface water depletion and GDEs. Following these installations and further analysis of the well data, the density of monitoring locations and frequency of their measurements will be addressed.

3.6.2 Location and density of monitoring sites and frequency of measurement

The current network of 12 wells includes one near the Sacramento River, three near Butte Creek, two near Little Dry Creek, two near Dry Creek, one near Angel Slough and three near Feather River.

The GSAs are planning to install 10 additional shallow wells to improve monitoring of surface water depletion and GDEs. All 10 of the new shallow wells will provide monitoring for GDEs and seven of the wells will be sited at locations to allow them to be added to the interconnected surface water representative monitoring network (RMN). This is described in greater detail in **Sections 4.4 and 5.9**. The seven new shallow wells include two near the Sacramento River, two near Butte Creek, one near Little Dry Creek, one near Angel Slough and one near Feather River (**Figure 3-6**). These locations and densities of monitoring sites follow the guidelines suggested by EDF (2021).



2546 *Figure 3-6. Planned New Primary Aquifer Monitoring Sites for Monitoring Depletions of*
2547 *Interconnected Surface Water and GDEs.*

4 Sustainable Management Criteria

This Section describes the sustainable management criteria that will be used to achieve and maintain the sustainable management of the Butte Subbasin.

4.1 Sustainability Terminology

This section describes the sustainability goal and undesirable results for the Butte Groundwater Subbasin (Subbasin) for each applicable sustainability indicator.

- **Sustainability goal:** The sustainability goal qualitatively describes the overall objectives and desirable conditions for the Subbasin.
- **Undesirable results:** Undesirable results statements describe the conditions at which each applicable sustainability indicator would become significant and result in unreasonably negative impacts to beneficial uses and users in the Subbasin.

4.1.1 Sustainability Indicators

A sustainability indicator is defined by the Sustainable Groundwater Management Act (SGMA) as one of six effects caused by groundwater conditions that, when significant and unreasonable, cause undesirable results. The six sustainability indicators are described in the document *Sustainable Management Criteria, Best Management Practices for the Sustainable Management of Groundwater* (DWR, 2017) as follows:

"Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering 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[29].

Significant and unreasonable reduction of groundwater storage.

Significant and unreasonable seawater intrusion.

Significant and unreasonable degraded water quality, including the migration of

[29] As a recent example within the Butte Subbasin, surface water supplies were curtailed in 2015 during the recent drought, resulting in increased groundwater extractions and reductions in groundwater levels. However, if groundwater levels increase in subsequent years with increased surface water availability, the groundwater level reductions in 2015 are not representative of chronic lowering of groundwater levels but rather conjunctive use and greater reliance on groundwater resources during times of drought.

contaminant plumes that impair water supplies.

Significant and unreasonable land subsidence that substantially interferes with surface land uses.

Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water."

SGMA allows several pathways to meet the distinct local needs of each basin, including:

- Development of sustainable management criteria for each sustainability criterion
- Use of other sustainability indicators as a proxy
- Identification of specific indicators that are not applicable to the basin.

Sustainable management criteria have been established for the chronic lowering of groundwater levels, the degradation of groundwater quality, inelastic land subsidence, and depletions of interconnected surface water. Chronic reductions of groundwater storage utilizes groundwater levels as a monitoring proxy, and because of the Butte Subbasin's distance from the Pacific Ocean, bays, deltas, or inlets, seawater intrusion is not an applicable sustainability indicator.

Continued data collection and an improved understanding of Subbasin conditions in the future may lead to changes in the sustainable management criteria discussed herein. **Section 6** of this GSP describes the 5-year GSP update process.

4.1.2 Sustainability Goal

The sustainability goal provides a qualitative description of the objectives and desired conditions of the Butte Subbasin. It is supported by locally-defined undesirable results and quantitative minimum thresholds, measurable objectives, and interim milestones. Demonstration of the absence of undesirable results supports a determination that a basin is operating within its sustainable yield and, thus, that the sustainability portion of the goal has been achieved and needs to be maintained during the implementation period.

The sustainability goal for the Butte Subbasin is:

> *…to maintain, through a cooperative and partnered approach, locally managed sustainable groundwater resources to preserve and enhance the economic viability, social well-being and culture of all Beneficial Uses and Users without experiencing undesirable results.*

4.1.3 Measures to Operate within Sustainable Yield

Based on the current conditions and future conditions baseline scenarios, which approximate long-term average conditions in the subbasin considering climate change and other factors, model results indicate a slight decrease in groundwater storage over time (see **Section 2.2.3**). Even though this is within the uncertainty of the model, projects and management actions are being and will be implemented to offset this decrease in groundwater storage and maintain the long-term sustainability of the Butte Subbasin, as described in **Section 5**. Additionally, some recommended measures and management actions focus on activities to monitor and improve understanding of the Subbasin, and adaptive management will allow for development of new measures or actions in the future if deemed necessary. Additional information about projects and management actions and plan implementation is provided in **Sections 5 and 6** of this GSP.

4.1.4 Sustainability Achievement within 20 Years

As the historical, current, projected, and projected with climate change model results indicate (see **Section 2**), there is a slight decrease in groundwater storage over time (see **Section 2.2.3**). Even though this is within the uncertainty of the model, projects and management actions are being and will be implemented to offset this decrease in groundwater storage and maintain the long-term sustainability of the Butte Subbasin, as described in **Section 5**. However, groundwater sustainability in this Subbasin is also dependent on surface water supplies and thus will always be vulnerable to any future conditions affecting the availability of surface water supplies. A variety of factors have the potential to influence future surface water availability such as hydrologic changes (due to climate change or other factors) or regulatory changes that may impact the contractual quantities of water the California Department of Water Resources (DWR) is obligated to provide per the Feather River Diversion Agreements. Potential future changes in surface water availability would first be addressed through adaptive management strategies that include implementation of additional projects and management actions necessary to remain sustainable. Future conditions that impact the future availability of surface water supplies (including hydrologic and/or regulatory changes) may require revisions to the sustainability indicators. Overall, long-term sustainability will be achieved through implementation of the projects and management actions and adaptive management as described in this GSP.

4.2 Undesirable Results

Undesirable results are defined in SGMA as one or more significant and unreasonable effect caused by groundwater conditions occuring throughout the Subbasin, as assessed using the six sustainability indicators described earlier: chronic lowering of groundwater levels, reduction in groundwater storage, seawater intrusion, degraded water quality, inelastic land subsidence, and/or depletions of interconnected surface water. DWR has released *Sustainable Management Criteria Best Management Practices* (BMPs) were developed to help Groundwater Sustainability

Agencies (GSA)s establish their sustainability criteria by first identifying the specific and unreasonable effects caused by groundwater conditions in the Subbasin that constitute undesirable results, and then identifying quantitative criteria to define when and where the effects of groundwater conditions cause undesirable results for each applicable sustainability indicator. These criteria typically define a quantitative number and location of monitoring points that may be below a specific minimum threshold over a predetermined period of time prior to a GSA identifying conditions as an undesirable result. The *Sustainable Management Criteria* BMP states that "undesirable results will be defined by minimum threshold exceedances" (DWR, 2017).

This section presents the undesirable results statements for the Subbasin which were developed through a process to (1) characterize specific groundwater conditions that lead to undesirable results and (2) identify minimum thresholds that, when exceeded, indicate that undesirable results may occur. Input from Butte Subbasin stakeholders, including GSA members and the public, and evaluation of current Subbasin conditions related to each sustainability indicator were used to guide creation of the undesirable results statements. These statements are based on quantitative thresholds which are used here to indicate where undesirable results might be occurring in the monitoring network. **Section 3** describes the related monitoring networks. While undesirable results are identified at the Subbasin scale, this scale may be modified by the Butte Subbasin GSA if appropriate or necessary in the future.

Five sustainability indicators are identified that could have significant and unreasonable impacts on beneficial uses in the Subbasin: chronic lowering of groundwater levels, reduction in groundwater storage, degraded water quality, inelastic land subsidence, and depletions of interconnected surface water. Undesirable results information for each of the five applicable sustainability indicators was developed based on current Subbasin conditions, the California Water Code, SGMA regulations, BMPs, and stakeholder input. For each sustainability indicator, the following has been developed:

- Description of undesirable results – describes the specific significant and unreasonable effects that constitute undesirable results
- Definition and identification of undesirable results – the criteria used to define when and where groundwater conditions cause undesirable results, defined and detected by minimum threshold exceedances
- Potential causes of undesirable results – describes what could cause groundwater conditions that lead to undesirable results
- Potential effects of undesirable results – describes what could happen to beneficial uses and users of groundwater if undesirable results occur
- Evaluation of undesirable results – describes if undesirable conditions are present in the Subbasin/detected through monitoring

Undesirable results related to seawater intrusion are not present in the Subbasin and are not likely to occur. Thus, criteria for undesirable results related to those sustainability indicators are not established in this GSP.

4.2.1 Chronic Lowering of Groundwater Levels

4.2.1.1 *Description of Undesirable Results*

Chronic lowering of groundwater levels is considered to be significant and unreasonable when it reduces the long-term viability of Beneficial Uses and Users over the planning and implementation horizon of this GSP. Long-term viability is expected to be reduced when a significant number of wells and environmental users are no longer able to extract sufficient groundwater to supply beneficial uses.

It is anticipated that groundwater levels will fluctuate over time, including periodic decreases in groundwater levels during times of drought (such as in 2015 when surface water supplies in the Subbasin were curtailed and groundwater extractions increased) and recovery during normal or wet years (such as other periods where surface water is available in the Subbasin for agricultural production and provides recharge). These periodic fluctuations in groundwater level should not impact the long-term viability of Beneficial Uses and Users, unless recovery periods do not occur and there is a consistent decrease in groundwater levels over a longer period of time, which will be observed through the Monitoring Networks.

4.2.1.2 *Identification of Undesirable Results*

Groundwater levels in the Subbasin are monitored through a primary aquifer representative monitoring network (monitoring depths less than 700 feet below ground surface or bgs) and a very deep aquifer representative monitoring network (monitoring depths greater than 700 feet bgs). Groundwater conditions are expected to cause undesirable results from the chronic lowering of groundwater levels during GSP implementation under the following conditions:

- Primary aquifer monitoring network: when 25% of representative monitoring wells (i.e., 11 of 41 representative monitoring wells) fall below their minimum groundwater elevation thresholds for 24 consecutive months.
- Very deep monitoring network: when 25% of representative monitoring wells (i.e., three (3) of 10 representative monitoring wells) fall below their minimum groundwater elevation thresholds for 24 consecutive months.

Minimum threshold levels for each well were selected by the process described in **Section 4.3.1**. These criteria are based on review of current groundwater conditions and consultation with Subbasin stakeholders from which it was determined that minimum threshold exceedances at 25% of representative monitoring wells represented a “significant” number of affected wells, and that exceedance of these levels for 24 consecutive months or longer (e.g. no recovery of groundwater levels through two consecutive seasonal high periods[30]) will potentially harm the "long-term viability" of affected beneficial uses and users. The 25 percent of the RMS wells below minimum thresholds for 24 consecutive months criterion was estimated to be an indicator of a significant, widespread problem, and thus represented undesirable results.

4.2.1.3 *Potential Causes of Undesirable Results*

Potential causes of undesirable results for the chronic lowering of groundwater levels are groundwater pumping that exceeds the average sustainable yield in the Subbasin, and future changes in precipitation in the contributing watersheds (Butte Creek, Honcut Headwaters-Lower Feather River, Sacramento River - Stone Corral, Big Chico Creek-Sacramento River). Potential local impacts to groundwater levels could be caused by one or more of the following:

- Changed conditions with regards to the reliability of surface water supplies for multiple beneficial uses including irrigation
- Reductions in the amount of precipitation and/or changes in stream flows that recharge the Butte Subbasin due to changes in conditions upstream from the Subbasin
- Increases in the consumptive use of groundwater due to increases in agricultural development on lands without surface water supplies

4.2.1.4 *Potential Effects of Undesirable Results*

If groundwater levels were to reach levels indicating undesirable results, effects could potentially cause:

- Dewatering of a subset of the existing groundwater infrastructure, starting with the shallowest wells
- Increased costs to pump groundwater
- Adverse effects on groundwater dependent ecosystems (GDEs), to the extent they are connected with the primary aquifer, including difficulty for plants and animals to access groundwater
- Changes in irrigation practices and crops grown
- Adverse effects to property values and the regional economy

Implementation of the GSP is intended to avoid these effects by monitoring and implementing projects and management actions, as necessary, to maintain groundwater levels above the minimum thresholds.

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[30] If groundwater levels were drawn down below MTs through an extended period of drought during which groundwater extractions were substantially higher than during non-drought periods, the "24 consecutive months or longer" period in the MT definition allows for recovery of water levels over the course of two consecutive winter/springs (seasonal high periods).

4.2.1.5 *Evaluation of the Presence of Undesirable Results*

Section 4.3.1 discusses how minimum thresholds were selected. **Appendix 4.A** presents the hydrographs of groundwater levels for each representative monitoring site with historical observations through 2017 or 2019, projected future levels through 2068 and the established depth of the minimum threshold. Of the 41 monitoring sites in the primary aquifer monitoring network and 10 monitoring sites in the very deep aquifer monitoring network, groundwater elevations in all wells were well above the minimum threshold during their latest measurements collected in 2021, indicating that the Subbasin currently does not have an undesirable condition for the chronic lowering of groundwater levels. The GSAs in cooperation with the DWR Northern Region Office will continue to monitor groundwater levels to identify potential undesirable results in the future and adapt GSP implementation, as needed, to avoid these conditions.

4.2.2 Reduction of Groundwater Storage

4.2.2.1 *Description of Undesirable Results*

The undesirable result for the reduction of groundwater in storage is a result that would cause significant and unreasonable reduction in the long-term viability of Beneficial Uses and Users over the planning and implementation horizon of this GSP.

4.2.2.2 *Justification of Groundwater Levels as a Proxy*

The change in groundwater storage is directly correlated to changes in groundwater elevation in unconfined aquifers. By setting minimum thresholds for groundwater levels, storage is also effectively managed. Therefore, the use of groundwater levels as a proxy metric for the groundwater storage sustainability indicator is appropriate.

4.2.2.3 *Potential Causes of Undesirable Results*

Potential causes of undesirable results for the reduction in groundwater storage are groundwater pumping that exceeds the average sustainable yield in the Subbasin and/or decreases in precipitation in the contributing watersheds in the future. This could be caused by increases in consumptive use of water due to increased agricultural productivity, shifts from agricultural to urban land uses resulting in concomitant changes in primary water supply from surface water to groundwater, changes to availability or reliability of surface water supplies for multiple beneficial uses including irrigation, or other local changes in the hydrogeologic system such as increases to impervious surfaces.

4.2.2.4 *Potential Effects of Undesirable Results*

If reductions of groundwater in storage were to reach undesirable results levels, the effects could potentially cause the dewatering of existing groundwater infrastructure and changes in irrigation practices and crops grown and could adversely affect groundwater dependent ecosystems and property values. Additionally, reaching undesirable results for reduction of groundwater in storage could adversely affect the many beneficial uses of groundwater in the Subbasin, including domestic and irrigation uses.

4.2.2.5 *Identification of Undesirable Results*

The undesirable result for the reduction of groundwater storage is monitored by proxy using the groundwater levels and is considered to occur during GSP implementation if either 25% of primary aquifer representative monitoring wells (i.e., 11 of 41 representative monitoring wells) or very deep aquifer representative monitoring wells (i.e., 3 of 10 representative monitoring wells) fall below their minimum groundwater elevation thresholds for 24 consecutive months. The 25 percent of the RMS wells below MTs for 24 consecutive months criterion was estimated to be an indicator of a significant, widespread problem indicating undesirable results.

4.2.2.6 *Evaluation of the Presence of Undesirable Results*

Groundwater level data show that none of the 41 primary aquifer representative monitoring wells or 10 very deep aquifer representative monitoring wells exceed their minimum thresholds and therefore the reduction of groundwater storage is not identified to be in an undesirable condition.

4.2.3 Seawater Intrusion

Seawater intrusion is not an applicable sustainability indicator in the Subbasin because of the proximity of the Subbasin to the ocean (the Butte Subbasin is inland). Seawater intrusion is not present and is not likely to occur in the Butte Subbasin due to the distance from the Pacific Ocean, bays, deltas, or inlets. Therefore, there is no possibility of an undesirable result due to seawater intrusion.

4.2.4 Degraded Water Quality

4.2.4.1 *Description of Undesirable Results*

The undesirable result for the degradation of water quality is a result stemming from a causal nexus between groundwater quantity related activities, such as groundwater extraction or groundwater recharge, and groundwater quality that causes significant and unreasonable effects to Beneficial Uses and Users including reduction in the long-term viability of these uses over the planning and implementation horizon of this GSP.

The causal nexus reflects that the undesirable results are water quality issues associated with groundwater pumping and other groundwater-related activities rather than water quality issues resulting from land use practices, naturally occurring water quality issues, or other issues not associated with groundwater pumping and other groundwater-related activities.

4.2.4.2 *Potential Causes of Undesirable Results*

Potential causes of undesirable results for the degraded water quality are conditions where groundwater management activities result in the degradation of groundwater quality, such as increased evapotranspiration causing increased salinity and/or the introduction of other constituents of concern into the Butte Subbasin or upwelling or introduction of connate groundwater from below the base of freshwater. Degraded groundwater quality may also be potentially caused by changes in the quality of interconnected groundwater, which is dependent on the quality of stream water, or imported water flowing to the Subbasin.

In regards to upwelling or introduction of connate water, the CGA, GGA and the GSAs in the Butte, Sutter, Yolo, North Yuba and South Yuba Subbasins plan to form and participate in the Sutter Buttes Water Quality Interbasin Working Group to address groundwater quality issues in the vicinity of and associated with the unique geology of the Sutter Buttes. The interbasin working group is described in greater detail in **Section 6.1.2.2** and has objectives of proposing studies and providing a forum for local entities to propose and develop projects to protect or improve groundwater quality.

4.2.4.3 *Potential Effects of Undesirable Results*

If groundwater quality were degraded such that undesirable levels are reached, the effects could potentially cause a shortage in supply to groundwater users without additional treatment, with domestic wells being most vulnerable as treatment costs or access to alternate supplies can be high for small users. High levels of salinity can impact both drinking water uses and agricultural uses, as there are maximum values associated with aesthetics (taste, color, and odor) for drinking water and crop health and yield for agriculture.

4.2.4.4 *Identification of Undesirable Results*

Undesirable results for degraded groundwater quality are assessed through monitoring by collecting samples from representative monitoring site (RMS) wells and measuring electrical conductivity (EC) to analyze salinity, the key concern for groundwater quality in the Butte Subbasin that is considered to stem from a causal nexus with groundwater quantity-related activities (ex. groundwater pumping). The GSAs have established a groundwater quality monitoring network for the collection of water quality data required to identify undesirable results. Undesirable results are considered to occur during GSP implementation if 25% of RMS wells (i.e., 3 of 9 RMS wells) exceed the established threshold value for EC for 24 consecutive months[31]. Exceedance of MTs by 25% of RMS wells for 24 consecutive months was estimated to

[31] In the case of groundwater levels, exceedance of a minimum threshold is caused by groundwater levels dropping below the threshold. However, for groundwater quality, exceedance of a minimum threshold is counterintuitively caused by measuring levels higher than the threshold. The minimum threshold for groundwater quality is a highest allowable value, rather than lowest.

be an indicator of a significant, widespread problem causing undesirable results.

No existing groundwater quality monitoring in the Butte Subbasin is deep enough or has sufficient information to adequately monitor groundwater quality in the very deep aquifer. As part of this GSP, the GSAs will establish a new groundwater quality monitoring network for the very deep aquifer using the very deep aquifer RMS wells used for monitoring groundwater levels. Salinity data will be collected from these RMS wells through non-purging methodologies, and will be used to monitor the occurrence of undesirable results. Like the primary aquifer, undesirable results are considered to occur during GSP implementation if 25% of very deep aquifer RMS wells fall above their minimum threshold values for 24 consecutive months. Similar to the primary aquifer, exceedance of MTs by 25% of RMS wells for 24 consecutive months is considered to be an indicator of a significant, widespread problem resulting in undesirable results.

4.2.4.5 *Evaluation of the Presence of Undesirable Results*

Section 4.3 discusses how minimum thresholds were selected. As shown in Section 2, Basin Setting, that discusses *Groundwater Conditions*, existing water quality monitoring in the Butte Subbasin indicates that groundwater quality in the Subbasin is of good quality and is unlikely to be significantly and unreasonably undesirable at this time. Specifically, historical electrical conductivity values, calculated from total dissolved solids (TDS) measurements at the nine RMS wells, are all below the minimum threshold levels, and only one measurement of the 49 in the historic record between 1958 and 2018 exceeded 900 microsiemens/centimeter (µs/cm), with averages ranging from approximately 250 to 580 µs/cm. These results indicate that the Subbasin does not currently exceed the requirements for an undesirable condition for degraded water quality. Additionally, results from 2016-2019 published in the *Northern Sacramento Valley Groundwater Quality Report* (CNRA, 2020), indicate that only three of 30 wells sampled in the Butte Subbasin exceeded 900 µs/cm, and that none exceeded the California drinking water primary maximum contaminant level (MCL). However, because of the limited duration of groundwater quality data, the GSAs will carefully monitor levels of salinity and other constituents and will review and revise the preliminary minimum thresholds and approach during the 5-year GSP update.

4.2.5 Inelastic Land Subsidence

4.2.5.1 *Description of Undesirable Results*

The undesirable result for land subsidence is a result due to groundwater extraction that causes significant and unreasonable reduction in the viability of the use of critical infrastructure over the planning and implementation horizon of this GSP.

4.2.5.2 *Potential Causes of Undesirable Results*

Potential causes of undesirable results for inelastic land subsidence are likely tied to groundwater pumping/production resulting in dewatering of compressible clays in the subsurface. As discussed in the *Hydrogeologic Conceptual Model* section in **Section 2**, the Butte Subbasin is comprised of a diverse mix of geologic units, including the Tuscan, Tehama, and Laguna Formations and a collection of younger formations and deposits referred to as the Quaternary Alluvium. These formations are comprised of volcanic sediments and layers of tuff breccias and clays (Tuscan); overlain by moderately consolidated sandstone, siltstone, sand, gravel, silt, and clay (Tehama and Laguna); overlain by unconsolidated gravel, sand, silt, and clay (Quaternary Alluvium). Clay layers are generally susceptible to subsidence, including inelastic (or permanent) subsidence, when exposed to significant and prolonged dewatered conditions as a result of groundwater pumping and production.

4.2.5.3 *Potential Effects of Undesirable Results*

If inelastic land subsidence conditions were to reach undesirable results levels, the effects could potentially cause damage to local infrastructure such as canals, roadways, and bridges. Excessive subsidence may also lead to decreased groundwater storage resulting from the irreversible compression of portions of the underlying aquifers.

4.2.5.4 *Identification of Undesirable Results*

The undesirable result for inelastic land subsidence is monitored by DWR's Sacramento Valley monument network and is considered to occur during GSP implementation when 25% of representative monitoring locations (i.e., 8 of 31 benchmarks) measure a subsidence rate greater than 0.5 feet per 5 years. Twenty-five percent of the monument network measuring a subsidence rate greater than the MT was estimated to be an indicator of a significant, widespread problem potentially resulting in undesirable results.

4.2.5.5 *Evaluation of the Presence of Undesirable Results*

Section 4.3 discusses how minimum thresholds were selected. **Appendix 4.A** presents the graphs of historical subsidence rates and shows thresholds for each monitoring site. Of the 31 monitoring sites, none were below the minimum threshold in the latest measurement from 2017, indicating that the Subbasin does not currently exceed the requirements for an undesirable condition for inelastic land subsidence.

4.2.6 Depletions of Interconnected Surface Water

4.2.6.1 *Description of Undesirable Results*

The undesirable result for depletion of interconnected surface water is a result that causes significant and unreasonable adverse effects on Beneficial Uses and Users of interconnected surface waters within the Butte Subbasin over the planning and implementation horizon of this GSP.

4.2.6.2 *Potential Causes of Undesirable Results*

Potential causes of undesirable results for depletions of interconnected surface water are tied to groundwater production that could result in lowering of groundwater elevations in the primary aquifer near surface water bodies. This could change the hydraulic gradient between the water surface elevation in the surface water course and the groundwater elevation, resulting in increased depletions of surface water to groundwater.

4.2.6.3 *Potential Effects of Undesirable Results*

If depletions of interconnected surface waters were to reach undesirable results levels, the effects could potentially reduce groundwater contribution to surface water courses (e.g. rivers and creeks), result in a reduction of the number of days per year a stream in the Subbasin flows, lower stream flows, and/or result in increased temperatures that could potentially impact riverine and riparian habitats through the reduction in the contribution of cooler groundwater flows to the surface water course.

4.2.6.4 *Identification of Undesirable Results*

The undesirable result for depletion of interconnected surface water is considered to occur during GSP implementation when 25% of interconnected surface water representative monitoring wells (i.e., 3 of 12 representative monitoring wells) fall below their minimum thresholds for 24 consecutive months. Minimum threshold exceedances at 25% of representative monitoring wells represents a “significant” number of affected wells in the RMS network, and exceedance of these levels (MTs) for 24 consecutive months or longer (as indicated by a lack of groundwater level recovery over two consecutive seasonal high periods) will potentially harm the “long-term viability” of affected beneficial uses and users. The 25 percent of RMS wells below MTs for 24 consecutive months criterion was estimated to be an indicator of a significant, widespread problem, potentially leading to undesirable results.

4.2.6.5 *Evaluation of the Presence of Undesirable Results*

Section 4.3 discusses how minimum thresholds were selected. **Appendix 4.A** presents the hydrographs of groundwater levels through 2020 and the established depth of the minimum threshold for each monitoring site. Of the 12 interconnected surface water representative monitoring sites, none were below the minimum threshold in the latest measurement indicating that the Subbasin does not currently exceed the requirements for an undesirable condition for depletion of interconnected surface water.

4.3 Sustainability Thresholds

Sustainability thresholds include minimum thresholds, measurable objectives, and interim milestones:

- Minimum thresholds (MT) are a numeric value for each sustainability indicator which are used to define when undesirable results occur. Minimum thresholds are set at each representative monitoring location in the monitoring network for each sustainability indicator using a consistent methodology – actual MT values will vary by location to match local conditions (i.e. distance from surface water bodies, groundwater dependent ecosystems, nearby well infrastructure).
- Measurable objectives (MO) are specific, quantifiable goals for maintaining or improving specified groundwater conditions that are included in the adopted GSP to maintain the Subbasin's sustainability goal. Similar to MTs, MOs are established using a consistent methodology with actual MOs varying by location to match local conditions as they relate to the sustainability goal.
- Interim milestones (IM) are a target value representing measurable conditions, set in increments of five years, in the event a Basin needs help reaching sustainability for any sustainability indicator by 2042.

Sustainability thresholds are described below by sustainability indicator.

4.3.1 Chronic Lowering of Groundwater Levels

As described in **Section 4.2.1**, chronic lowering of groundwater levels is considered to be significant and unreasonable when:

> *…it reduces the long-term viability of Beneficial Uses and Users over the planning and implementation horizon of this GSP.*

Chronic lowering of groundwater levels is expected to cause undesirable results when groundwater levels at a significant number of wells fall below the MT levels, described below. MTs are defined for individual wells as the groundwater level beyond which supply is depleted and may lead to undesirable results for Beneficial Uses and Users near that location. Thus, the MT at each well is defined through evaluation of local well conditions and responsiveness to local monitoring. By avoiding these MTs, groundwater levels are protective of nearby well infrastructure.

As described in **Section 2** *Basin Setting*, the Butte Subbasin has two principal aquifers – the primary aquifer and the very deep aquifer – and therefore two groundwater level monitoring networks. Groundwater levels in the Subbasin are monitored by a primary aquifer representative monitoring network (with screened depths less than 700 feet below bgs) and a very deep aquifer representative monitoring network (with screened depths greater than 700 feet bgs). **Figure 3-1** and **Figure 3-2** in **Section 3** *Monitoring Networks* show the location of the wells in the primary aquifer and very deep aquifer groundwater representative monitoring networks, respectively. The following subsections describe the sustainability thresholds used for the chronic lowering of groundwater levels within each of the monitoring networks.

4.3.1.1 *Primary Aquifer Minimum Thresholds*

Minimum thresholds (MTs) for primary aquifer groundwater level representative monitoring wells were calculated using a process designed to be protective of domestic wells while also allowing for conjunctive use and groundwater extraction by agriculture.
The MT for each well in the primary aquifer was calculated based on the following process and criteria:

1. Determine the shallower of:
    a. The shallowest 7th percentile of nearby domestic wells[32]
    b. The range of measured groundwater levels or 20 feet (whichever is greater) below the observed historic low
2. If the resulting value is shallower than the observed historic low, set the MT as 10 feet deeper than the observed historic low.

Setting minimum thresholds using this process is protective of Beneficial Uses and Users of the primary aquifer, including agricultural, municipal, and domestic uses, because the minimum threshold is calculated to be at a level that allows for adequate flexibility for increased groundwater extractions during drought periods (e.g. 2015) while protecting at least 93% of nearby domestic wells that are less than 700 feet deep (the maximum depth of the primary aquifer representative monitoring network), therefore avoiding undesirable results. In addition, this methodology includes consideration of the spatial location of each monitoring well and changing conditions across the Subbasin. GDEs will be monitored by a dedicated interconnected surface water depletion representative network since the existing groundwater level network is not suitable for GDE monitoring; this is described in **Section 4.4**. **Figure 4-1** shows the minimum threshold for each well in the primary aquifer groundwater level representative monitoring network.

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[32] **This protects at least 93% of domestic wells in DWR's well completion report database, which was a threshold determined through coordination and discussion with local stakeholders.**

4.3.1.2 *Primary Aquifer Measurable Objectives*

Measurable objectives were calculated for each well as the average of the last five years of measured groundwater level data. The measurable objective was calculated for each well using the average of the last five years of measured groundwater level data. This method is generally representative of both drought and recovery conditions within the Subbasin as most wells utilize data collected between 2012 and 2017. **Figure 4-2** shows the measurable objective for each well in the primary aquifer groundwater level representative monitoring network.

4.3.1.3 *Primary Aquifer Margin of Operational Flexibility*

The Subbasin's primary aquifer margin of operational flexibility is the difference between the measurable objective and the minimum threshold for each well. The margin of operational flexibility is intended to provide adequate flexibility to allow for increased groundwater production during drought years (e.g. 2015) with recovery during normal or wet years. This ensures undesirable results are not triggered due to drought conditions that the GSA cannot control, while allowing for adequate local recovery of groundwater levels after those drought periods, thereby maintaining sustainability over the long term.

4.3.1.4 *Primary Aquifer Interim Milestones*

Interim milestones are intended to provide a glidepath towards sustainability over the implementation horizon by providing progressive targets for groundwater levels every five years after GSP submittal. After sustainability is reached, interim milestones are not required and basins are managed according to the MO (defined in the GSP Emergency Regulations as "…specific, quantifiable goals for **the maintenance** or improvement **of specified groundwater conditions**…to achieve the sustainability goal for the basin"). For the Butte Subbasin, since groundwater levels are already at or near MOs, it is reasonable to set the interim milestones equal to the MOs to provide numerical metrics for GSAs to track maintenance of the Subbasin's sustainability goal relative to the overall sustainability goal, ensuring that the basin remains sustainable.

Water levels in the Butte Subbasin are planned to be managed according to the MOs and maintained within the Subbasin's margin of operational flexibility as established by the minimum thresholds and measurable objectives. Some fluctuation is expected between years, depending on hydrologic conditions, fluctuations in water supply availability, groundwater production, and groundwater recharge. These fluctuations are expected to show decreasing groundwater levels during dry periods and increasing groundwater levels following dry period during normal or wet years, with groundwater levels remaining within the margin of operational flexibility.

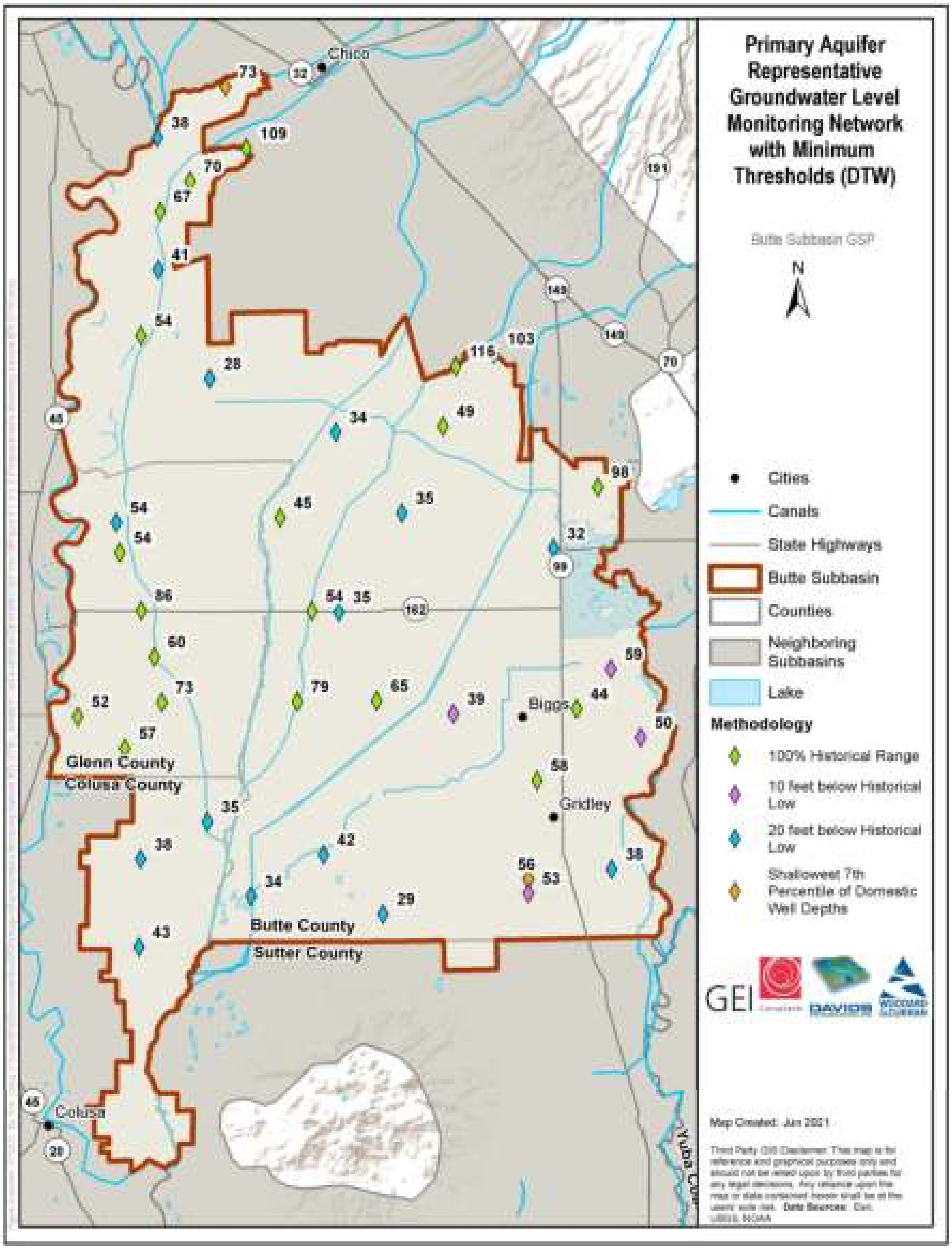
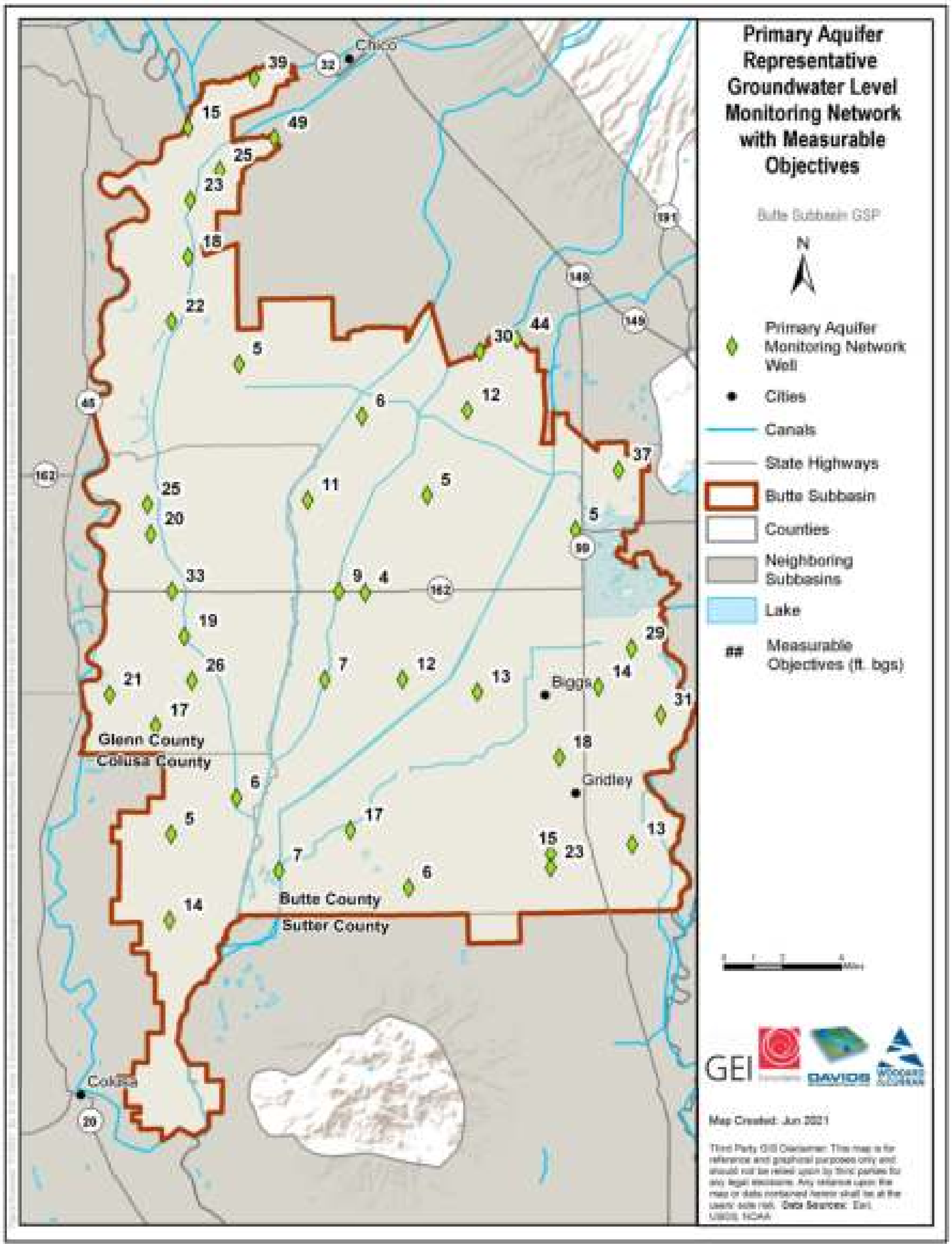


Figure 4-1: Primary Aquifer Representative Groundwater Level Monitoring Network with MTs (DTW)



3099 ***Figure 4-2: Primary Aquifer Representative Groundwater Level Monitoring Network with MOs***
3100 ***(DTW)***

4.3.1.5 *Primary Aquifer Thresholds for Groundwater Levels*

Appendix 4.A includes hydrographs for all 41 primary aquifer groundwater level representative wells in the Subbasin with their accompanying minimum thresholds and measurable objectives. **Table 4-1** lists wells in the representative monitoring network and the numerical values for the minimum threshold (MT) and measurable objective (MO) as values in feet below ground surface (bgs) and above mean sea level (amsl).

Table 4-1: Primary Aquifer Groundwater Level Representative Monitoring Network and Sustainability Criteria

State Well Number	Total Depth (ft bgs)	Depth to Top Screen (ft bgs)	Depth to Bottom Screen (ft bgs)	Ground Surface Elevation (ft amsl)	MT (ft amsl)	MO (ft amsl)	MT (dtw fbgs)	MO (dtw fbgs)
17N01E06D001M	500	110, 200, 240, 280, 440	140, 220, 260, 300, 500	63	28	57	35	6
17N01E10A001M	110	66	110	65	24	48	42	17
17N01E17F001M	160	130	150	59	25	52	34	7
17N01E24A006M	75	45	55	73	44	67	29	6
17N01W10A004M	117	88	98	64	26	59	38	5
17N01W27A003M	203	160	170	67	23	53	43	14
17N02E14A001M	102	70	102	85	29	70	56	15
17N02E14H001M	102	60	102	86	33	63	53	23
17N03E08K002M	100	0	0	91	54	78	38	13
18N01E13A002M	317	80	317	79	26	67	65	12
18N01E15D002M	112	56	112	72	14	65	79	7
18N01W02E003M	200	110	120	79	28	60	60	19
18N01W14B001M	204	59, 145	83, 173	72	15	46	73	26
18N01W17G001M	108	48	108	81	34	60	52	21
18N01W22L001M	147	76, 108	92, 124	72	23	55	57	17
18N02E16F001M	80	20	60	82	43	69	39	13
18N02E25M001M	220	61	220	89	32	71	58	18
18N03E08B003M	463	156	463	11	54	83	59	29
18N03E18F001M	462	100, 190	150, 220	100	56	86	44	14
18N03E21G001M	125	0	0	106	57	75	50	31
19N01E09Q001M	200	140	200	92	50	81	45	11
19N01E27Q001M	548	260	280	87	40	78	54	9
19N01E35B001M	157	85, 125	95, 135	87	52	83	35	4
19N01W15D002M	300	250, 275	260, 295	91	38	66	54	25
19N01W22D007M	120	80	90	87	38	67	54	20
19N01W27R001M	465	68	108	83	19	50	86	33
19N02E07K004M	192	140	150	103	68	98	35	5
19N02E13Q001M	221	130, 200	140, 210	120	88	115	32	5
19N03E05N002M	180	24	48	142	65	105	98	37

State Well Number	Total Depth (ft bgs)	Depth to Top Screen (ft bgs)	Depth to Bottom Screen (ft bgs)	Ground Surface Elevation (ft amsl)	MT (ft amsl)	MO (ft amsl)	MT (dtw fbgs)	MO (dtw fbgs)
20N01E18L003M	173	100	110	107	79	102	28	5
20N01E35C001M	92	49.5	92	102	69	96	34	6
20N01W11N002M	170	84	170	107	57	85	54	22
20N02E15H001M	180	170	180	144	66	100	103	44
20N02E16P001M	466	0	0	132	52	102	116	30
20N02E28N001M	277	160	277	123	75	111	49	12
21N01E08K002M	181	19.2	181.2	146	67	97	109	49
21N01W11A002M	200	125, 175	135, 185	129	92	114	38	15
21N01W13J003M	400	355	385	128	68	103	70	25
21N01W23J001M	54	0	0	121	68	98	67	23
21N01W35K002M	270	75	135	114	74	96	41	18
22N01E32E004M	160	85	160	151	78	112	73	39

4.3.1.6 *Very Deep Aquifer Minimum Threshold*

The minimum threshold for very deep aquifer groundwater level representative monitoring wells was also calculated using the same two-step process as the primary aquifer and described in **Section 4.3.1.1.**

Setting minimum thresholds using this methodology is protective of the Beneficial Uses of the very deep groundwater aquifer, including agricultural, municipal, and domestic uses, because the minimum threshold is calculated to be at a level that allows for adequate flexibility to compensate for drought periods (e.g. 2015) while protecting up to 93% of supply wells greater than 700 feet deep (the minimum depth of the very deep aquifer representative monitoring network), thereby avoiding undesirable results. In addition, this methodology includes consideration of the spatial location of each monitoring well and changing conditions across the Subbasin. **Figure 4-3** shows the minimum threshold for each well in the very deep aquifer groundwater level representative monitoring network.

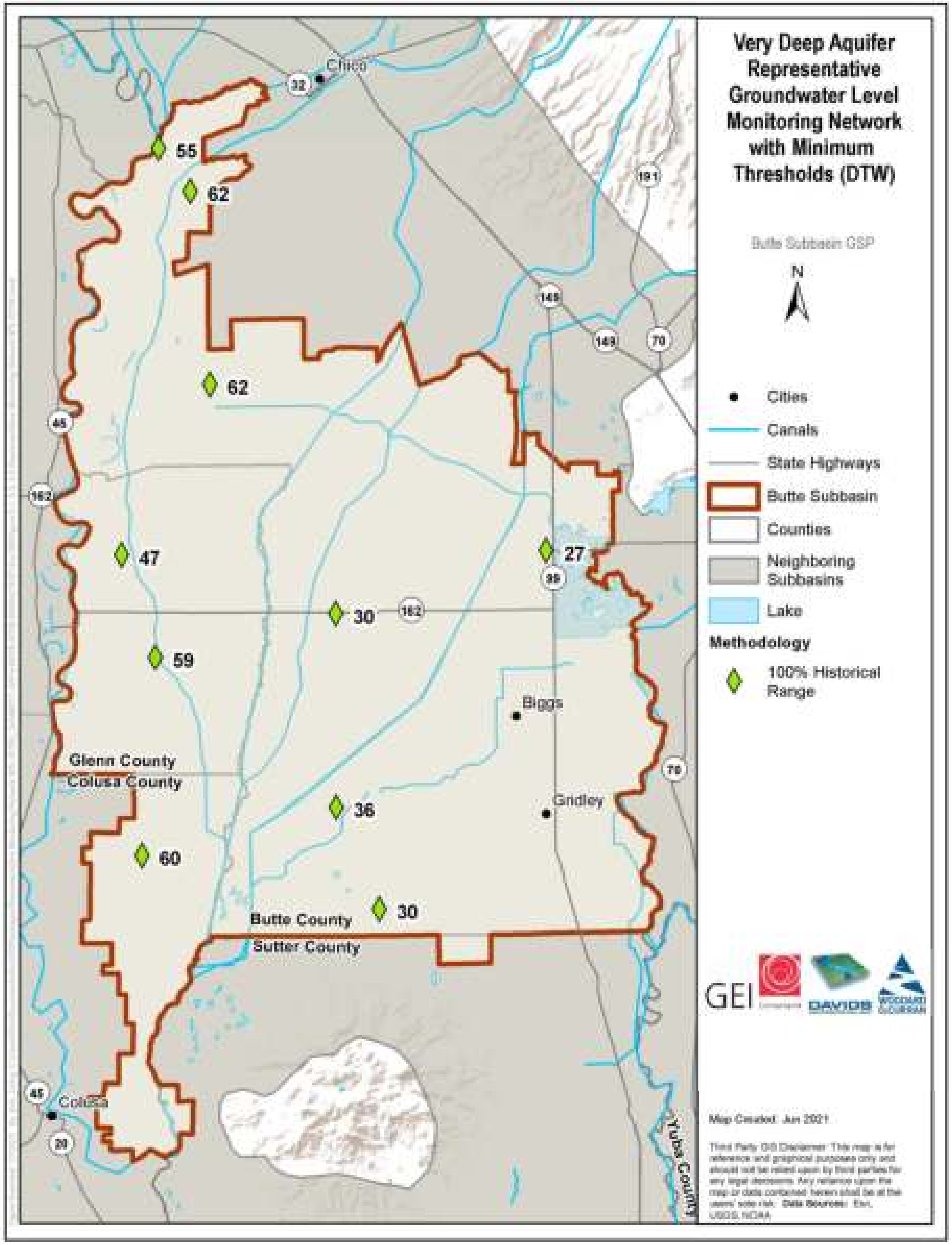


Figure 4-3: Very Deep Aquifer Representative Groundwater Levels Monitoring Network with MTs (DTW)

4.3.1.7 *Very Deep Aquifer Measurable Objective*

The measurable objective was calculated for each well using the average of the last five years of measured groundwater level data. This method is generally representative of drought and recovery conditions within the Subbasin as most wells utilize data collected between 2012 and 2017. **Figure 4-4** shows the measurable objective for each well in the very deep aquifer groundwater level representative monitoring network.

4.3.1.8 *Very Deep Aquifer Margin of Operational Flexibility*

The Subbasin's very deep aquifer margin of operational flexibility is the difference between the measurable objective and the minimum threshold for each well. The margin of operational flexibility is intended to provide adequate flexibility to allow for increased groundwater production during drought years (e.g. 2015) with recovery during normal or wet years. This ensures undesirable results are not triggered due to drought conditions that the GSA cannot control, while allowing for adequate local recovery of groundwater levels after those drought periods, thereby maintaining sustainability over the long term.

4.3.1.9 *Very Deep Aquifer Interim Milestones*

Interim milestones are intended to provide a glidepath towards sustainability over the implementation horizon by providing progressive targets for groundwater levels every five years after GSP submittal. After sustainability is reached, interim milestones are not required and basins are managed according to the MO (defined in the GSP Emergency Regulations as "…specific, quantifiable goals for **the maintenance** or improvement **of specified groundwater conditions**…to achieve the sustainability goal for the basin"). For the Butte Subbasin, since groundwater levels are already at or near MOs, it is reasonable to set the interim milestones equal to the MOs to provide numerical metrics for GSAs to track maintenance of the basin's sustainability relative to the overall sustainability goal, ensuring that the basin remains sustainable.

Water levels in the very deep aquifer are planned to be managed according to the MOs and maintained within the Subbasin's margin of operational flexibility as established by the minimum thresholds and measurable objectives for wells screened in this aquifer. Some fluctuations are likely to occur between years depending on hydrologic conditions, fluctuations in surface water supply availability, groundwater production, and groundwater recharge. These fluctuations are expected to show decreasing groundwater levels during dry periods and increasing groundwater levels following dry period during normal or wet years, with groundwater levels remaining within the margin of operational flexibility.

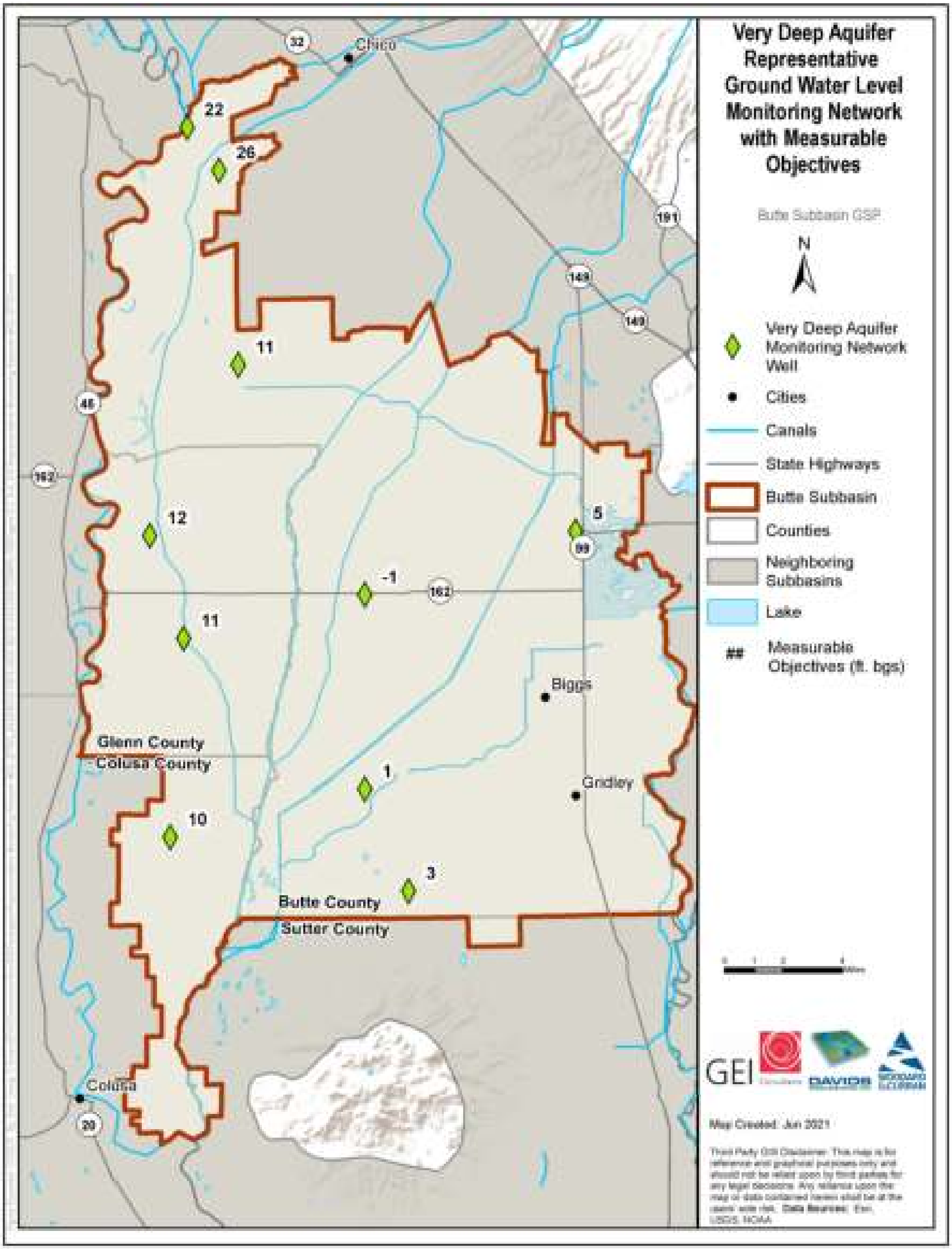


Figure 4-4: Very Deep Aquifer Representative Groundwater Level Monitoring Network with MOs (DTW)

4.3.1.10 Very Deep Aquifer Sample Hydrographs and Thresholds for Groundwater Levels

Appendix 4.A includes hydrographs for all 10 very deep aquifer groundwater level representative wells in the Subbasin with their accompanying minimum thresholds and measurable objectives. **Table 4-2** lists wells in the representative monitoring network and the numerical values for the minimum threshold (MT) and measurable objective (MO) as values in feet below ground surface (bgs) and above mean sea level (amsl).

Table 4-2: Very Deep Aquifer Groundwater Level Representative Monitoring Network and Sustainability Criteria

State Well Number	Total Depth (ft bgs)	Depth to Top Screen (ft bgs)	Depth to Bottom Screen (ft bgs)	Ground Surface Elevation (ft amsl)	MT (ft amsl)	MO (ft amsl)	MT (dtw fbgs)	MO (dtw fbgs)
17N01E24A003M	833	770	790	73	43	70	30	3
17N01W10A001M	828	770, 790	780, 800	64	4	54	60	10
18N01E35L001M	840	816	836	70	34	69	36	1
18N01W02E001M	739	719	729	79	20	68	59	11
19N01E35B002M	980	930	950	87	56	87	30	-1
19N01W22D004M	820	780	790	87	40	76	47	12
19N02E13Q003M	690	670	680	120	93	114	27	5
20N01E18L001M	1000	767, 873	810, 894	107	45	96	62	11
21N01W11A001M	1311	810, 960, 1050, 1270	820, 970, 1060, 1280	129	75	107	55	22
21N01W13J001M	830	780	820	128	66	102	62	26
21N01W24B001M	1018	800	820	127	51	101	76	26
22N01E29R001M	685	210	685	167	62	123	105	44

4.3.2 Reduction of Groundwater Storage

The undesirable result for the reduction of groundwater storage is

> *…a result that would cause significant and unreasonable reduction in the long-term viability of Beneficial Uses and Users over the planning and implementation horizon of this GSP.*

The undesirable result for the reduction of groundwater storage is monitored by proxy using groundwater levels and is protective of groundwater already in storage. The following subsection describes proxy monitoring in greater detail.

4.3.2.1 *Proxy Monitoring*

Monitoring for a reduction of groundwater storage in the Subbasin uses groundwater levels as a proxy for determining sustainability, as permitted by Title 23 CCR Section 354.28 (d), Section 1.5.2.5. As described above, any benefits to groundwater storage are expected to coincide with groundwater level management.

Because of the Butte Subbasin's interconnection with nearby surface water bodies, measurable changes in storage are a small portion of the overall available storage in the Subbasin. The limiting factor to storage use is existing well infrastructure (depth of wells) and near surface conditions, not the amount of volume in storage. Therefore, the established primary aquifer and very deep aquifer groundwater level minimum thresholds are protective against significant and unreasonable changes in storage.

4.3.3 Seawater Intrusion

Seawater intrusion is not an applicable sustainability indicator because seawater intrusion is not present and is not likely to occur in the Butte Subbasin due to the distance between the Subbasin and the Pacific Ocean, bays, deltas, or inlets. Therefore, there is no possibility of an undesirable result due to seawater intrusion and establishing criteria for undesirable results because of seawater intrusion is not required per Title 23 CCR Section 354.28(d), Section 1.5.2.5.

4.3.4 Degraded Water Quality

The undesirable result for degraded water quality is:

> *…a result stemming from a causal nexus between groundwater quantity related activities, such as groundwater extraction or groundwater recharge, and groundwater quality that causes significant and unreasonable effects to Beneficial Uses and Users including reduction in the long-term viability of these uses over the planning and implementation horizon of this GSP.*

Figure 3-3 in **Section 3** *Monitoring Networks* shows the location of the wells in the groundwater quality representative monitoring network. The following subsections describe the sustainability thresholds used for the groundwater quality monitoring network.

4.3.4.1 *Minimum Threshold*

As described in **Section 2** *Basin Setting*, salinity is the primary constituent of concern in the Butte Subbasin due to concerns around the migration of connate water upwelling from the very deep aquifer near the Sutter Buttes. A preliminary minimum threshold for salinity (measured as electrical conductivity or EC) was proposed for the Subbasin. The minimum threshold for electrical conductivity in water quality representative monitoring wells was set as the higher of 900 µs/cm or the measured historical high, whichever is greater[33]. This minimum threshold was set based on best available data, the Butte County Basin Management Objective program, and maximum contamination levels (MCLs). However, because of the short record of available groundwater quality data, the GSAs will review and revise the preliminary minimum thresholds and approach during the 5-year GSP update. As part of GSP implementation, the GSAs will continue to monitor and may expand its groundwater quality representative monitoring network.

Figure 3-3 in **Section 3** *Monitoring Networks* show the location of the wells in the groundwater quality representative monitoring network.

The GSAs will also consider setting minimum thresholds for other constituents as part of the 5-year update. The established minimum thresholds will take into consideration:

- Maximum Contamination Levels (MCL)
- Local conditions (historical measurements)
- Agricultural requirements (Irrigated Lands Regulatory Program [ILRP], Central Valley Salinity Alternatives for Long-Term Sustainability [CV-SALTS])

Additionally, to address groundwater quality issues in the vicinity of and associated with the unique geology of the Sutter Buttes, the CGA, GGA and the GSAs in the Butte, Sutter, Yolo, North Yuba and South Yuba Subbasins will form and participate in the Sutter Buttes Water Quality Interbasin Working Group. The interbasin working group is described in greater detail in **Section 6.1.2.2** and has objectives of proposing studies and providing a forum for local entities to propose and develop projects to protect or improve groundwater quality.

Figure 3-3 in **Section 3** *Monitoring Networks* show the location of the wells in the groundwater quality representative monitoring network.

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[33] In the case of groundwater levels, exceedance of a minimum threshold is caused by groundwater levels dropping below the threshold. However, for groundwater quality, exceedance of a minimum threshold is counterintuitively caused by measuring levels higher than the threshold. The minimum threshold for groundwater quality is a highest allowable value, rather than lowest.

4.3.4.2 *Measurable Objective*

The preliminary measurable objective for salinity is set at 700 µs/cm for agricultural use, consistent with the Butte County Basin Management Objectives. Measurable objectives for other constituents will be considered as part of the 5-year update to this GSP.

4.3.4.3 *Margin of Operational Flexibility*

The Subbasin's groundwater quality margin of operational flexibility is the difference between the measurable objective and the minimum threshold for each constituent of concern at each representative monitoring well location. The margin of operational flexibility is intended to provide adequate flexibility to allow for changes in groundwater quality constituent concentrations under various basin conditions, such as drought years. This ensures undesirable results are not triggered due to temporary fluctuations in groundwater conditions that are anticipated to occur during the implementation horizon.

4.3.4.4 *Groundwater Quality Interim Milestones*

Interim milestones are intended to provide a glidepath towards sustainability over the implementation horizon by providing progressive targets for groundwater quality every five years after GSP submittal. After sustainability is reached, interim milestones are not required and basins are managed according to the MO (defined in the GSP Emergency Regulations as "…specific, quantifiable goals for **the maintenance** or improvement **of specified groundwater conditions**…to achieve the sustainability goal for the basin"). For the Butte Subbasin, since groundwater quality is already at or near MOs, it is reasonable to set the interim milestones equal to the MOs to provide numerical metrics for GSAs to track maintenance of the basin's sustainability goal relative to the overall sustainability goal, ensuring that the basin remains sustainable. Existing water quality constituent levels are planned to be maintained within the Subbasin's margin of operational flexibility as established by the minimum thresholds and measurable objectives.

4.3.5 Inelastic Land Subsidence

The undesirable result for inelastic land subsidence is:

> *…a result due to groundwater extraction that causes a significant and unreasonable reduction in the viability of the use of critical infrastructure over the planning and implementation horizon of this GSP.*

As discussed in **Section 2** *Basin Setting*, land subsidence has not been an issue in the Butte Subbasin (the current subsidence rate has been measured to be less than 0.0325 feet per 5 years), even during the 2015 drought when groundwater levels were lower due to surface water curtailments and increased groundwater extractions. Despite this lack of historical subsidence, measurable objectives and minimum thresholds have been established to assist in the management of land subsidence should conditions change. **Figure 3-4** in **Section 3** *Monitoring Networks* shows the location of the benchmarks in the inelastic land subsidence representative monitoring network. The following subsections describe the sustainability thresholds used for the inelastic land subsidence monitoring network.

4.3.5.1 *Minimum Thresholds*

Minimum thresholds were selected to represent conditions that are just above conditions that could collectively generate undesirable results in the Butte Subbasin. While the sensitivity of local infrastructure to land subsidence is not well understood, water conveyance infrastructure is likely the most sensitive to land subsidence. Should additional information be developed on the vulnerability of Subbasin infrastructure to subsidence, these minimum thresholds may be refined.

The minimum threshold for inelastic land subsidence has been set at 0.5 feet over a 5-year period at each of the monitoring locations in the Butte Subbasin, consistent with the nearby Yuba Subbasins GSP. This level of subsidence is considered unlikely to cause a significant and unreasonable reduction in the viability of the use of water conveyance infrastructure over the planning and implementation horizon of this GSP, based on input from water managers.

4.3.5.2 *Measurable Objective*

The measurable objective for land subsidence has been set at 0.25 feet of subsidence per 5-year period at each site (0.05 feet over 1 years; 1 foot over 20 years). This rate is small but recognizes the limitations of the subsidence monitoring network, which measures subsidence with an accuracy of 0.17 feet (DWR 2018).

4.3.5.3 *Margin of Operational Flexibility*

The inelastic land subsidence margin of operational flexibility is 0.25 feet per 5-year period, the difference between the measurable objective and the minimum threshold for each benchmark. This value is approximately twice the potential error (0.17 feet) in the benchmark measurements, allowing for a range between the minimum thresholds and a measurable objective that is set within the measurable range to allow for management if the measurable objective were to be exceeded.

4.3.5.4 *Interim Milestones*

Since the Subbasin does not currently have any monuments with statistically significant inelastic land subsidence, interim milestones are not needed.

4.3.5.5 *Thresholds for Land Subsidence*

This GSP will continue use of the DWR Sacramento Valley Subsidence Network for monitoring and will review the Subbasin's inelastic land subsidence minimum threshold and measurable objective during the 5-year update.

4.3.6 Depletions of Interconnected Surface Water

The undesirable result for depletions of interconnected surface water is:

> *…a result that causes significant and unreasonable adverse effects on Beneficial Uses and Users of interconnected surface water within the Butte Subbasin over the planning and implementation horizon of this GSP***.**

Figure 3-6 in **Section 3** *Monitoring Networks* shows the location of representative monitoring wells in the interconnected surface water representative monitoring network. Groundwater levels in the vicinity of a stream or river are considered to be a reasonable proxy for monitoring depletions of surface water (EDF, 2018). The following subsections describe the sustainability thresholds used for the interconnected surface water monitoring network.

4.3.6.1 *Minimum Thresholds*

Minimum thresholds for depletion of interconnected surface waters were set at 10 feet below the measured historical low for each of the representative monitoring wells. The minimum threshold was established to prevent undesirable results while taking into consideration key water bodies (including the Sacramento River, Feather River, Butte Creek, Little Dry Creek, Dry Creek, and Angel Slough) and groundwater dependent ecosystems (GDEs).

The minimum threshold was selected such that levels would be protective of the beneficial use of interconnected surface water and of shallower groundwater near streams and rivers, including those of shallower domestic users and potential groundwater dependent ecosystems. The additional 10 feet in depth below the measured historical low (during which no undesirable results were observed) is intended to provide an appropriate margin of operational flexibility during GSP implementation. While information and understanding of interconnected surface waters is limited, groundwater levels that exceed the minimum threshold in the future for an extended period of time could impact beneficial uses of interconnected surface waters by reducing the volume and changing the timing of surface water availability, and potentially impacting the beneficial uses of groundwater by dewatering domestic wells and limiting groundwater supplies to groundwater dependent ecosystems. As additional data are collected during GSP implementation, minimum thresholds may change and the threshold calculations revised to reflect a better understanding of this complex interaction and the Subbasin's unique conditions.

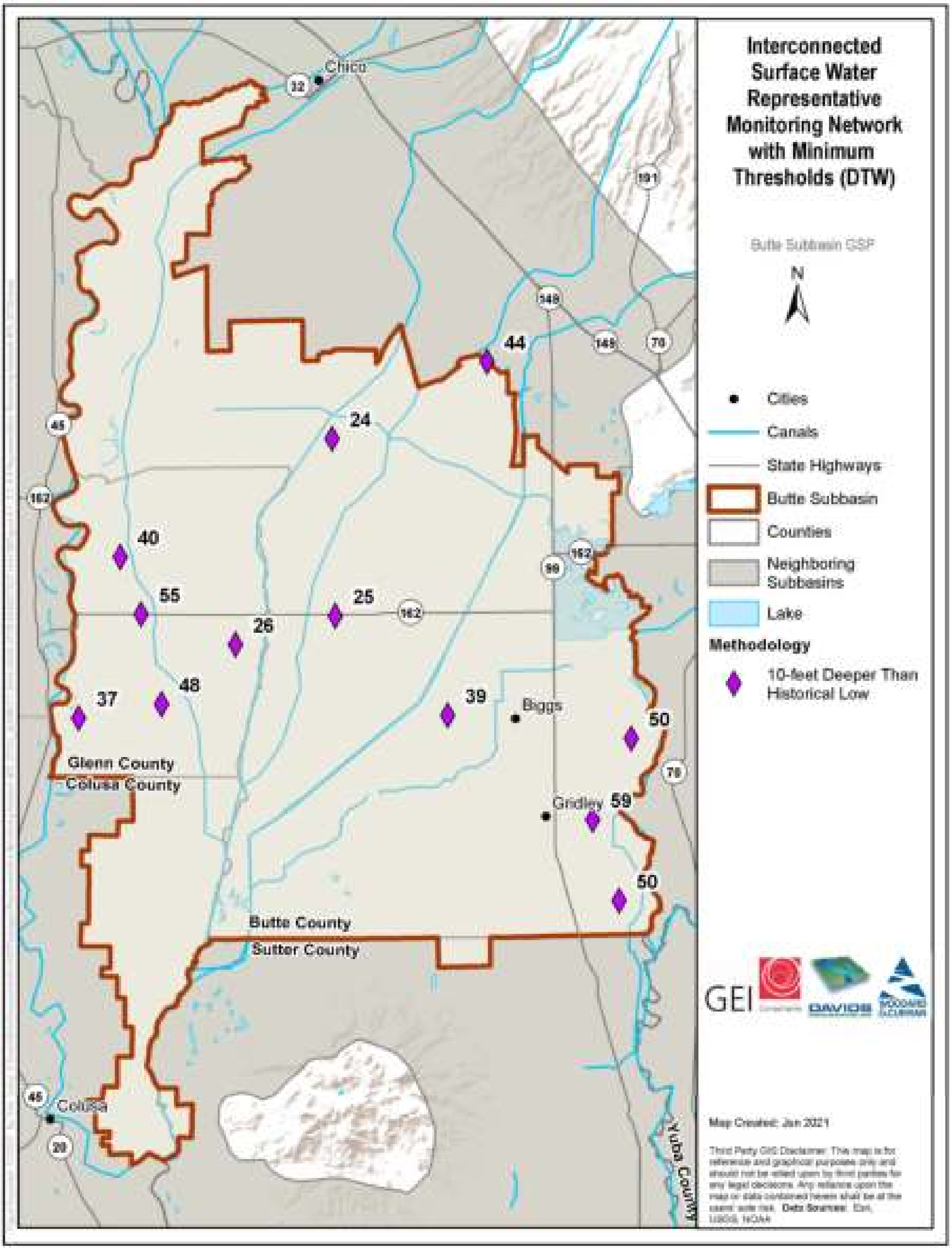
Figure 4-5 shows the MTs for each well in the interconnected surface water representative monitoring network. RMS wells were selected within a one-mile band surrounding rivers and streams, at distances of between 2,000 feet and 7,280 feet from those waterways. Selected RMS wells had either a total depth of less than 150 feet bgs, or a top screen above 100 feet bgs and and a bottom screen above 200 feet bgs.

4.3.6.2 *Measurable Objective*

The measurable objective was calculated for each representative monitoring well using the average of the last five years of groundwater levels measured data. This method is generally representative of drought and recovery conditions within the Subbasin as most wells utilize data recorded between 2012 and 2017. It is also consistent with the measurable objective calculation method for groundwater levels sustainability indicator. **Figure 4-6** shows the measurable objective for each well in the interconnected surface water representative monitoring network.

4.3.6.3 *Margin of Operational Flexibility*

The Subbasin's interconnected surface water margin of operational flexibility is the difference between the measurable objective and the minimum threshold for each well. The margin of operational flexibility is intended to provide adequate flexibility to allow for increased groundwater production during drought years with recovery during normal or wet years. This ensures undesirable results are not triggered due to drought conditions that the Butte Subbasin GSAs cannot control while allowing for adequate local recovery of groundwater levels after those drought periods, therefore maintaining sustainability in the long term.



3392

3393 ***Figure 4-5: Interconnected Surface Water Representative Monitoring Network with MTs***
3394 ***(DTW)***

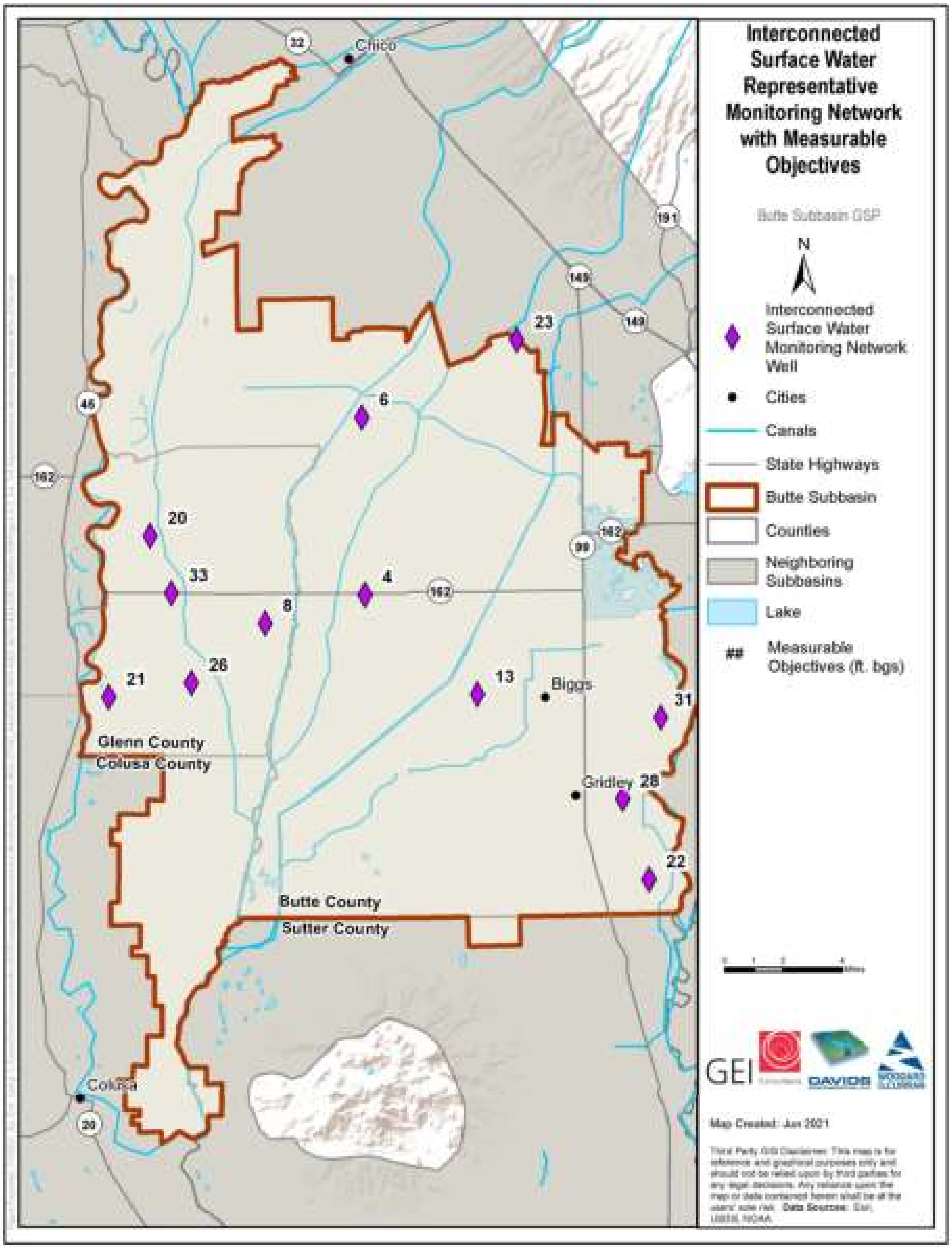


Figure 4-6: Interconnected Surface Water Representative Monitoring Network with MOs (DTW)

4.3.6.4 *Interim Milestones*

Interim milestones are intended to provide a glidepath towards sustainability over the implementation horizon by providing progressive targets for groundwater levels every five years after GSP submittal. After sustainability is reached, interim milestones are not required and basins are managed according to the MO (defined in the GSP Emergency Regulations as "…specific, quantifiable goals for **the maintenance** or improvement **of specified groundwater conditions**…to achieve the sustainability goal for the basin"). Interim milestones are intended to provide numerical metrics for GSAs to track the progress or maintenance of the basin sustainability relative to the overall sustainability goal, thereby ensuring long-term sustainability. Because the minimum thresholds and measurable objectives for the depletions of interconnected surface waters were established to support Subbasin sustainability, the interim milestones have been set at the measurable objectives.

Water levels are planned to be maintained within the Subbasin's margin of operational flexibility as established by the minimum thresholds and measurable objectives for interconnected surface waters, with some fluctuations anticipated between years depending on hydrologic conditions, fluctuations in surface water supply availability, groundwater production, and groundwater recharge.

4.3.6.5 *Sample Hydrographs and Thresholds for Groundwater Levels*

Appendix 4.A includes hydrographs for the 12 interconnected surface water representative wells in the Subbasin with their accompanying minimum thresholds and measurable objectives.

Table 4-3 lists wells in the representative monitoring network and the numerical values for the minimum threshold and measurable objective.

4.4 Data Gaps

The GSAs recommend that 10 locations be added to the interconnected surface water depletion representative monitoring network to provide a more robust interconnected surface water monitoring network in the Subbasin. These wells would be installed shallower than 30 feet and would be installed near existing groundwater dependent ecosystems and surface water gages. Preliminary minimum thresholds would be established after two years of monitoring. A project to install 10 additional wells is described in **Section 5.9** of this GSP; the description includes a discussion of estimated costs and anticipated benefits.

Table 4-3: Interconnected Surface Water Representative Monitoring Network and Sustainability Criteria

SWN	CASGEM ID	Total Depth	Top Screen	Bottom Screen	Ground Surface Elevation	MT (f amsl)	MO (f amsl)	MT (dtw fbgs)	MO (dtw fbgs)
17N03E05C003M					97	38	69	59	28
17N03E16N001M					87	38	65	50	22
18N01E05D002M					79	53	71	26	8
18N01W14B001M		204			72	25	46	48	26
18N01W17G001M		108			81	44	60	37	21
18N02E16F001M		80			82	43	69	39	13
18N03E21G001M		125			106	57	75	50	31
19N01E35B001M		156.7			87	62	83	25	4
19N01W22D007M		120			87	48	67	40	20
19N01W27R001M		465			83	29	50	55	33
20N01E35C001M		92			102	79	96	24	6
20N02E15H002M					144	100	121	44	23

5 Projects and Management Actions to Achieve Sustainability Goal *(Reg. § 354.44)*

5.1 Introduction

This section describes the projects and management actions that are ongoing, planned or proposed as needed for implementation by agencies in the Butte Subbasin. In accordance with SGMA regulations, projects and management actions were developed to maintain the Butte Subbasin sustainability goal and avoid undesirable results over the GSP planning and implementation horizon. Projects generally refer to structural features whereas management actions are typically non-structural programs or policies designed to improve water management, reduce groundwater pumping, or address other undesirable results that may occur in the Subbasin.

5.2 Development Approach

Projects and management actions developed for the Butte Subbasin are described in the sections below in accordance with 23 CCR §354.44. These projects and management actions were devised and prioritized to directly address projected future changes in subbasin conditions that may otherwise cause undesirable results. The projected future changes in subbasin conditions without projects and management actions were assessed through comparison of the current subbasin water budget conditions and future subbasin water budget conditions adjusted by 2070 central tendency (2070CT) climate change factors (see **Section 2** for additional information).

A comparison of key water budget parameters is shown in **Table 5-1.** Without projects and management actions, the key imbalance in future groundwater conditions is a projected decrease in groundwater storage, with an average annual expected decrease of 2,000 acre-feet per year (AF/yr) in the future conditions scenario. Even though this is within the uncertainty of the model, projects and management actions were thus devised and planned to address this imbalance by providing an average annual benefit to groundwater storage of at least this volume. Per 23 CCR § 354.44(b)(9), projects and management actions described in this GSP are expected to manage the balance of groundwater extractions and recharge to ensure that chronic lowering of groundwater levels or depletion of supply during periods of drought is offset by increases in groundwater levels or storage during other periods. In particular, projects that provide direct and in-lieu recharge benefits to the subbasin are planned to increase the use and recharge of available surface water supplies during wetter and full-supply years, offsetting any potential increases in groundwater pumping during dry and curtailment years. Additionally, projects that improve water management and enhance water use efficiency will allow for increased operational efficiency and utilization of reduced surface water supplies during curtailment years, potentially offsetting or reducing groundwater pumping required to meet irrigation demands in those years.

This is considered to be a conservative approach to achieving groundwater sustainability, considering the assumptions, uncertainties, and limitations of the future projected subbasin water budget and projected 2070 climate change hydrology. While the future scenario with 2070CT climate change adjustment assumes that the effects of 2070CT climate change are occurring every year, in actuality these effects will gradually occur with significant uncertainty in their magnitude and interannual variability. Throughout GSP implementation, the GSAs plan to continue monitoring sustainability indicators and will expand implementation of projects and management actions to ensure that the measurable objectives are met.

The magnitude of change in other water budget parameters in **Table 5-1** is considered to be within the uncertainty of the model (described in **Section 2**). Changes in surface water outflows are expected to decrease slightly, but this change is 0.1 percent of the current total surface water outflows. Overall seepage to the groundwater system is expected to increase in the future, while stream gains from groundwater (accretion) are expected to decrease somewhat. However, these changes are 0.6 percent and -3.2 percent of the current total outflows, respectively. The GSAs will continue to monitor these changes and will adjust projects and management actions as needed.

Table 5-1. Selected Subbasin Water Budget Parameters (Average AF/yr, 2019-2068)

Water Budget Parameter	Current Conditions	Future Conditions with 2070 Climate Change	Difference (Future - Current)	Difference as Percent of Current Surface Water Outflows
Change in Groundwater Storage	-1,200	-2,000		
Total Seepage to Groundwater (Streams, Lakes, Canals, Drains)	355,400	363,200	7,800	0.6%
Net Stream Gains from Groundwater (Accretion)	-105,700	-148,500	-42,800	-3.2%
Surface Water Inflows	1,926,500	1,922,200	-4,300	-0.3%
Surface Water Outflows	1,324,100	1,322,300	-1,800	-0.1%

5.3 Summary of Projects and Management Actions

All projects and management actions identified in the Butte Subbasin are listed in **Table 5-2**, with a description of the project or management action type, the proponent, and the project status. Projects and management actions with an Ongoing status are selected to “achieve the sustainability goal for the basin… [and] respond to changing conditions in the basin” (23 CCR §354.44(a)), supporting GSAs to meet the interim milestones and measurable objectives set in this plan and avoid minimum thresholds even under future climate change conditions; projects and management actions with a Planned status are described in detail and may be implemented to support ongoing sustainability, adapt to changing conditions in the subbasin, or maintain other water management objectives. Therefore, only those projects and management actions identified as “ongoing” or “planned” are described in the complete level of detail required under 23 CCR §354.44(b). However, other projects and management actions may also be implemented in the future “as needed”[34] to complement and support groundwater sustainability planning efforts, whether by supporting District water management goals, facilitating regional coordination, or improving data and monitoring. These “as needed” projects and management actions are described in less detail in this plan. Additional project development and description will occur as those projects are needed, prioritized, evaluated for feasibility, and selected for implementation[35]. Additional information and projects will be provided in annual reports and periodic GSP updates when known.

The measurable objectives expected to directly benefit from each type of project or management action are summarized in **Table 5-3**. All proposed projects and management actions are expected to benefit groundwater levels and groundwater storage, whether through direct or in-lieu groundwater recharge, or improved data collection, monitoring, and management of water supplies. Projects that enhance groundwater monitoring and strategic use of available surface water in lieu of groundwater are also expected to reduce surface water depletion by enhancing understanding and management of surface water. Grower education is also expected to benefit water quality by encouraging on-farm management of nutrient application, tailwater, and pumping to reduce potential degradation of water quality.

Table 5-4 and **Table 5-5** summarize the estimated groundwater recharge benefit and capital, operating, and maintenance costs of ongoing and planned projects and management actions, respectively. Project cost information is limited for many other proposed projects because a detailed feasibility assessment has not been completed. GSAs will further develop projects during the GSP implementation period and refine estimated costs as projects are identified for implementation. Additional information about all projects and management actions is provided in a matrix format in **Appendix 5.A**.

[34] These projects and management actions also have a project status classification of “as needed” as shown in Table 5-2.

[35] Depending on GSA priorities and available funding, even if they are not “needed” some of these projects and management actions may be implemented to support ongoing sustainability, to adapt to changing conditions in the Subbasin, or to achieve other water management objectives.

Table 5-2. Description of Projects and Management Actions Proposed in the Butte Subbasin.

Project/Management Action Name	Project/ Management Action Type	Proponent	Brief Description	Project Status (GSP Description)
Ongoing Projects and Management Actions: Projects and Management Actions in this category are planned to be completed prior to 2042. The expected yield of these projects and management actions are expected to support GSAs in achieving the GSP sustainability goal and responding to changing conditions in the Subbasin.				
System Modernization	Improved Water Management	Biggs-West Gridley Water District	Upgrade and modernize system infrastructure to improve system operability and efficiency, reduce operational spillage, and enhance the timing of farm deliveries. Modernization improvements will include: 1. Improvements at canal headings to improve water level control, flow control, flow measurement, SCADA, and automation/measurement 2. Improvements at customer delivery turnouts to improve delivery flexibility and steadiness 3. Implementation of a canal operations decision support system (CODSS)	Ongoing (Detailed)
System Modernization	Improved Water Management	Richvale Irrigation District	Upgrade and modernize system infrastructure to improve system operability and efficiency, reduce operational spillage, and enhance the timing of farm deliveries. Modernization improvements will include: 1. Improvements at canal headings to improve water level control, flow control, flow measurement, SCADA, and automation/measurement 2. Improvements at control structures to improve water level control, flow control, flow measurement, SCADA, and automation/measurement	Ongoing (Detailed)
Boundary Flow and Primary Spill Measurement	Improved Water Management	Western Canal Water District	Install measurement and monitoring equipment at boundary outflow and spillage sites to allow real-time monitoring and adjustment to upstream operations. Real-time monitoring will be implemented through the establishment of a District Supervisory Control and Data Acquisition (SCADA) system.	Ongoing (Detailed)
Planned Projects and Management Actions: Projects and Management Actions in this category are available if continued monitoring indicates that they are needed to meet the sustainability goal by 2042, or to maintain other water management objectives. The expected yield of these projects and management actions are expected to support GSAs in achieving the GSP sustainability goal and responding to changing conditions in the Subbasin.				
Dual Source Irrigation Systems	In-Lieu Recharge	Butte Water District	Incentivize the use of irrigation systems capable of using both surface water and groundwater. These systems will increase use of surface water and on-farm recharge of surface water, and offset groundwater pumping.	Planned (Detailed)
Multi-Benefit Recharge	Direct Recharge	Multi-Agency / Jurisdictions	A multi-benefit recharge program will provide groundwater recharge through normal farming operations while also providing critical wetland habitat for waterbirds migrating along the Pacific Flyway. Fields with soil and cropping conditions conducive to groundwater recharge will be flooded and maintained with shallow depths. Water will be sourced from existing water rights contracts, depending on availability. GSAs may also consider financial compensation for participation to offset field preparation, irrigation, and water costs.	Planned (Detailed)

Project/Management Action Name	Project/ Management Action Type	Proponent	Brief Description	Project Status (GSP Description)
Grower Education	Improved Water Management	Multi-Agency / Jurisdictions	A grower education and outreach program is proposed as a management action for the Butte Subbasin. The program will provide growers with educational resources that help them to plan and implement on-farm practices that simultaneously support groundwater sustainability and maintain or improve agricultural productivity.	Planned (Detailed)
Installation of Additional Shallow Monitoring Wells[1]	Improved Data and Monitoring	All GSAs	Install 10 shallow monitoring wells in key areas of the Subbasin to support monitoring of interconnected surface water and groundwater dependent ecosystems	Planned (Detailed)
As Needed Projects and Management Actions: Projects and Management Actions in this category are proposed as potential projects that GSAs may wish to implement, as needed, to support ongoing sustainability, to adapt to changing conditions in the Subbasin, and to maintain other water management objectives.				
Alternate Delivery to RID Secondary via Kelleher Dam	Improved Water Management	Richvale Irrigation District	Increased water supply, and supply reliability, delivery flexibility, and/or instream flow; improved water quality, increase water management and reduce groundwater depletion in curtailment years	As Needed (Simple)
Boundary Flow and Primary Spill Measurement	Improved Water Management	Butte Water District	Increased water supply, and supply reliability, delivery flexibility, and/or instream flow; improved water quality, increase water management and reduce groundwater depletion in curtailment years	As Needed (Simple)
Boundary Flow and Primary Spill Measurement	Improved Water Management	Richvale Irrigation District	Increased water supply, and supply reliability, delivery flexibility, and/or instream flow; improved water quality, increase water management and reduce groundwater depletion in curtailment years	As Needed (Simple)
Develop Partnerships to Implement Project Addressing Regional Water Management	Improved Water Management	Multi-Agency / Jurisdictions	Partnerships could be directly between individual agricultural suppliers, environmental water managers, or others and could involve several parties working in coordination to achieve multiple benefits (including potential benefits to GDEs)	As Needed (Simple)
Facilitate financing of capital improvements for on-farm irrigation systems	Improved Water Management, Ag Conservation	Multi-Agency / Jurisdictions / Landowner	Facilitate financing of capital improvements for on-farm irrigation systems	As Needed (Simple)
Facilitate use of available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not harm crops or soils	Improved Water Management	Multi-Agency / Jurisdiction / Landowner	Facilitate use of available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not harm crops or soils	As Needed (Simple)
Improve Monitoring of Surface Water Outflows and Refine Water Balances to Improve Understanding of SW-GW Interactions / Net Recharge	Improved Water Management, Improved Data and Monitoring	Multi-Agency / Jurisdictions	Improved understanding of these interactions would enhance the evaluation of conjunctive management opportunities to increase local water supplies to meet local and regional water management objectives.	As Needed (Simple)

Project/Management Action Name	Project/ Management Action Type	Proponent	Brief Description	Project Status (GSP Description)
Improved Delivery Service to Pressurized Irrigation Systems	In-Lieu Recharge	Butte Water District	Increased ability to meet irrigation water needs using available surface water.	As Needed (Simple)
Increase planned conjunctive use of surface water and groundwater within the supplier service area	Conjunctive Use	Western Canal Water District	Continue usage of surface water when available and conjunctive use of surface water and groundwater during periods of shortage to meet demand. Shortage allocation policies are designed to facilitate the conjunctive use of groundwater in surface water shortage years. WCWD works in coordination with Butte County, Glenn County, and DWR.	As Needed (Simple)
Little Butte Creek Reservoir Main Canal Bypass Project	Reduce Groundwater Reliance / Depletion in Case of Failure	Western Canal Water District	Increased water supply, and supply reliability, delivery flexibility, and/or instream flow; improved water quality, increase water management and reduce groundwater depletion in curtailment years	As Needed (Simple)
M & T - Llano Seco Fish Screen Project	Reduce Groundwater Reliance / Depletion in Case of Failure	M & T Ranch, Chico / Rancho Llano Seco	Long-term dredging, retain existing rock-toe revetment and modify existing intake structure to cone screens.	As Needed (Simple)
Monitoring Well[2]	Improved Data and Monitoring	Multi-Agency / Jurisdiction / Landowner	Installing a monitoring well between 2 deep wells	As Needed (Simple)
Parrott Phelan Diversion Restoration Project	Reduce Groundwater Reliance / Depletion in Case of Failure	M & T Ranch / Rancho LLano Seco / Butte Co Water Resource Conservation	The diversion and fish screening project that had been completed in 1995 were in jeopardy. A cooperative project between a variety of agencies resulted in the reestablishment of the original channel and a flood bypass to handle excess flood flows to protect the diversion from channel realignment in the future. The flood bypass channel contains rock slope protection along Butte Creek just past the entrance to the overflow. Shotcrete and rock slope protection was utilized to stabilize the entrance to the overflow channel to prevent additional erosion.	As Needed (Simple)
Re-Establish Historical Monitoring Locations and Identify New Sites	Improved Data and Monitoring	Multi-Agency / Jurisdictions	There is limited information describing surface flows between water use areas within the region. Current hydrologic condition and system responses to water management activities are not adequately monitored.	As Needed (Simple)
Removal of Bottlenecks on the Sutter-Butte Main Canal	In-Lieu Recharge	Butte Water District	Increased ability to meet irrigation and environmental water needs using available surface water.	As Needed (Simple)
Shu Fly / Cherokee Project	Improved Water Management	Richvale Irrigation District	Increased water supply, and supply reliability, delivery flexibility, and/or instream flow; improved water quality, increase water management and reduce groundwater depletion in curtailment years	As Needed (Simple)
System Modernization	Improved Water Management	Butte Water District	Increased water supply, and supply reliability, delivery flexibility, and/or instream flow; improved water quality, increase water management and reduce groundwater depletion in curtailment years	As Needed (Simple)

Project/Management Action Name	Project/ Management Action Type	Proponent	Brief Description	Project Status (GSP Description)
System Modernization	Improved Water Management	Western Canal Water District	Increased water supply, and supply reliability, delivery flexibility, and/or instream flow; improved water quality, increase water management and reduce groundwater depletion in curtailment years	As Needed (Simple)

[1] In contrast to the other Planned Projects and Management Actions, the Installation of Additional Shallow Monitoring Wells is scheduled for implementation and expected to be complete at the latest by the time of the first 5-Year Update to the GSP in 2027. Other Planned Projects and Management Actions will be implemented dependent on future monitoring and planning efforts, and funding sources.

*[2] Project proponent not listed in project and management actions matrix (**Appendix 5.A.1**).*

Table 5-3. Measurable Objectives Expected to Benefit from Projects and Management Action Types Proposed in the Butte Subbasin.

Project/ Management Action Type	Sample Project/Management Action Names	Measurable Objectives Expected to Directly Benefit			
		Groundwater Levels	Groundwater Storage	Water Quality	Surface Water Depletion
Improved Water Management	System Modernization; Boundary Flow and Primary Spill Measurement; Alternate Delivery to RID Secondary via Kelleher Dam; Develop Partnerships for Regional Water Management; Facilitate financing of capital improvements for on-farm irrigation systems; Facilitate use of available recycled water; Shu Fly / Cherokee Project	X	X		X
	Grower Education	X	X	X	X
	Facilitate use of available recycled water	X	X		
In-Lieu Recharge	Dual Source Irrigation Systems; Improved Delivery Service to Pressurized Irrigation Systems; Removal of Bottlenecks on the Sutter-Butte Main Canal	X	X		X
Direct Recharge	Multi-Benefit Recharge	X	X		
Improved Data and Monitoring	Improve Monitoring of Surface Water Outflows and Refine Water Balances to Improve Understanding of SW-GW Interactions / Net Recharge; Re-Establish Historical Monitoring Locations and Identify New Sites	X	X		X
	Monitoring Well	X	X		
Conjunctive Use	Increase planned conjunctive use of surface water and groundwater in supplier service areas	X	X		X
Reduce Groundwater Reliance/Depletion	Little Butte Creek Reservoir Main Canal Bypass Project, M & T - Llano Seco Fish Screen Project; Parrott Phelan Diversion Restoration Project	X	X		

Table 5-4. Benefits and Costs of Ongoing Projects and Management Actions in Butte Subbasin that are Planned to Maintain the GSP Sustainability Goal.

Project/Management Action Name	Proponent	Project Status	First Year of Implementation	Gross Average Annual Benefit at Full Implementation (AF/yr)	Estimated Capital Cost ($)	Estimated Annual Cost at Full Implementation ($/yr)
System Modernization	Biggs-West Gridley Water District	Ongoing	2017	3,320	$1,494,622[1]	$16,530[1]
System Modernization	Richvale Irrigation District	Ongoing	2016	3,790	$1,496,638[1]	$20,430[1]
Boundary Flow and Primary Spill Measurement	Western Canal Water District	Ongoing	2021	1,829	$152,831[2]	$1,979[2]
			Total	8,939	$3,144,091	$38,939

[1] Estimated project cost developed March 2016 for full project implementation.
[2] Estimated project cost developed September 2020 for full project implementation.

Table 5-5. Benefits and Costs of Planned Projects and Management Actions in Butte Subbasin that are Planned to Respond to Changing Conditions.

Project/Management Action Name	Proponent	Project Status	First Year of Implementation	Gross Average Annual Benefit at Full Implementation (AF/yr)	Estimated Capital Cost ($)	Estimated Annual Cost at Full Implementation ($/yr)
Dual Source Irrigation Systems	Butte Water District	Planned	To Be Determined[1]	9,772[2]	(reported as part of annualized cost)	$223,625[2]
Multi-Benefit Recharge	Multi-Agency / Jurisdictions	Planned	To Be Determined[1]	175	(reported as part of annualized cost)	$7,000
Grower Education	Multi-Agency / Jurisdictions	Planned	To Be Determined[1]	N/A[3]	N/A	$10,000
Installation of Additional Shallow Monitoring Wells	All GSAs	Planned	To Be Determined[4]	N/A[5]	$100,000	$20,000

[1] Planned initiation of the project or management action will be determined as GSP implementation and annual reporting proceeds. The timing of implementation will be informed by improved understanding of basin groundwater conditions over time, and will be planned to manage changing hydrologic or groundwater conditions to maintain the GSP sustainability goal.

[2] Estimated project benefit and cost developed January 2018 for full project implementation, originally conceptualized to entirely support groundwater sustainability in the Butte Subbasin (See **Appendix 5.E**). This project is scalable and may be implemented in a lesser or greater number of fields than originally conceptualized, depending on need and grower interest.

[3] Grower education does not have a specific annual volumetric benefit, but is expected to generally improve use of existing surface water supplies and reduce net consumption of groundwater supplies, supporting groundwater sustainability efforts.

[4] Although the first year of implementation is unknown at this time, the installation of additional shallow monitoring wells is scheduled to be complete before the first 5-Year Update to this GSP.

[5] Installation of additional shallow monitoring wells does not have a specific annual volumetric benefit, but is expected to address data gaps and improve sustainable groundwater management, particularly with regard to monitoring potential depletions of interconnected surface water.

As GSP implementation proceeds, the GSAs will continue to accept additional projects and management actions proposed by agencies and stakeholders. The GSAs will continue to maintain a list of all proposed projects and management actions on the GSP website[36]. Projects and management actions can be added to the matrix (**Appendix 5.A**) at any time, and will be reviewed for inclusion in the GSP at the discretion of the GSAs. Review of new projects and management actions will occur during the periodic, five-year GSP updates, and at other times at the discretion of the GSAs.

5.4 System Modernization Projects

5.4.1 Overview

Biggs-West Gridley Water District (BWGWD) and Richvale Irrigation District (RID) have planned and are in the process of implementing modernization projects for their irrigation distribution systems. The system modernization projects are part of each district's comprehensive plan for system modernization and boundary flow monitoring developed as part of the Feather River Regional Agricultural Water Management Plan (FRRAWMP). Detailed information about each project is included in the FRRAWMP and in project documentation included in **Appendices 5.B and 5.C.**

Improvements made through each project will help system operators to strategically manage surface water diversions from the Feather River, supporting their ability to increase system efficiency, reduce operational spillage, and/or reduce excess farm deliveries. As part of these projects, the districts will replace and improve existing infrastructure, evaluate existing operations, and develop and implement management strategies and tools to meet local water management objectives, including water conservation at the district scale and improved delivery service to customers, or to meet regional or statewide objectives. Specific elements of each District's system modernization project are summarized below, and described in **Appendices 5.B and 5.C.**

The basic technical objective of each system modernization project is to provide system operators with improved information and tools that help them to better match flows at the headings of individual canals to downstream demands, thereby reducing operational spillage while also improving levels of service to district customers. System modernization is generally implemented to maintain one or more of the following goals:

1. Increase the efficiency of the distribution system to conserve water at the district scale,
2. Increase the efficiency of the distribution system to irrigate additional land in times of

[36] https://www.buttebasingroundwater.org/

shortage,

3. Increase the level of service provided to growers (increased delivery flexibility; steadier delivery flows) and respond to changes in cropping or irrigation method,
4. Reduce risks to the safety of operations staff, and
5. Improve the overall operability and management of the District.

System modernization improvements will increase the flexibility, consistency, and adequacy of supply to sublaterals; increase delivery steadiness and consistency; and concentrate the routing of flow fluctuations to a designated measurement location providing operators with feedback to help determine the status of deliveries or the need for a change at the lateral heading to improve operations.

The system modernization projects generally include improvements to four site categories: heading structures, upstream water level control structures, spill structures, and customer delivery points (i.e. farm turnouts). **Table 5-6** identifies the modernization objectives of improvements to each site category, and the measurable objectives that are expected to benefit from these improvements. Each project is expected to promote the ongoing maintenance of sustainable conditions in the Butte Subbasin.

Table 5-6. Modernization Objectives and Measurable Objective Benefits of System Modernization Site Improvements.

Site Category	General Modernization Objective	Measurable Objective Benefitted
Heading Structures	• Replace old, aging and/or deteriorated structures and equipment, as needed. • Provide increased accuracy, repeatability, and consistency in downstream deliveries to district customers prevent farm runoff and tail end spills. • Improve ability for flow adjustments to prevent spill and enhance delivery service. • Increase safety of site for operators.	• Groundwater levels (in-lieu recharge benefit) • Groundwater storage (in-lieu recharge benefit)
Upstream Water Level Control Structures	• Replace old, aging and/or deteriorated structures and equipment, as needed. • Maintain constant upstream deliveries by reducing fluctuation in desired upstream water level over a range of canal flow rates. • Simplify operations by reducing the need to add or remove flashboards to maintain water levels across a range of flows. • Facilitate the ability to make frequent flow changes through the system, as needed. • Consolidate safety spills by eliminating intermediate safety spills, where practical. • Increase safety site for operators.	• Groundwater levels (in-lieu recharge benefit) • Groundwater storage (in-lieu recharge benefit)

Site Category	General Modernization Objective	Measurable Objective Benefitted
Spill Structures	• Provide accurate and accessible measurement of spillage flow rate from the lateral as feedback on heading operation, general lateral operation, and district water accounting. • Increase safety of operating site.	• Groundwater levels (in-lieu recharge benefit) • Groundwater storage (in-lieu recharge benefit) • Water quality
Customer Delivery Points	• Replace old, aging and/or deteriorated structures and equipment, as needed. • Provide increased accuracy, repeatability, and consistency in deliveries to district customers prevent farm runoff and tail end spills.	• Groundwater levels (in-lieu recharge benefit) • Groundwater storage (in-lieu recharge benefit)

5.4.2 Implementation

The system modernization projects will generally be implemented in multiple phases. The anticipated timeline for ongoing system modernization work in BWGWD and RID is summarized in **Table 5-7** and **Table 5-8**, respectively.

The first phase of system modernization generally concentrates on modernizing primary inflow and operational outflow locations. These are generally the primary diversion locations or headings and main or primary canal end outflow points. The type and sophistication of improvement required to meet objectives varies by site, but the general objective is to provide improved control over the water that enters the district, as informed by improved information describing the timing and amount of water leaving the district. Readily accessible measurement of inflows and outflows has several benefits, including information for operational adjustments, data for water accounting and billing, and information to support prioritization of additional improvements by quantifying potential benefits.

The second phase of modernization would improve key control points along main supply canal(s) between the headings and outflows to increase conveyance efficiency. This would include main canal water level control structures and lateral headings. Existing control sites may be abandoned (in some cases), re-configured, retrofitted, downsized, or retained. The addition of these modernization improvements would generally provide steadier delivery of water from the main canal to laterals and turnouts, simplify operations by adding automation and increased the ability to make flow changes, and concentrate primary routing of flow fluctuations along the main canal.

Later phases would improve primary lateral control structures and primary end spills to improve control, and build on lateral heading flow control completed under earlier phases to improve secondary control points along laterals and sublateral control points.

Specific system modernization improvements that are currently being implemented in BWGWD and RID are summarized in the following section.

5.4.2.1 Specific Improvements by District

Specific improvements planned for implementation in each district are summarized below.

5.4.2.1.1 Specific Improvements in BWGWD

The BWGWD system modernization project will conserve water by reducing operational spillage through a combination of infrastructure modernization improvements and implementation of a canal operations decision support system (CODSS).

Modernization improvements to District infrastructure will include improvements at 130 customer delivery turnouts to provide accurate delivery measurement, improvements at 9 canal headings to provide improved flow measurement, and flow measurement and real time monitoring at 6 primary operational spills. Real-time monitoring will be implemented through the establishment of a District SCADA system.

The CODSS will be implemented using the canal management capability of the District's existing RemoteTracker (RT) delivery measurement and water order tracking system to provide operators with tools needed to improve canal operations and reduce spillage. The RT is an integrated turnout flow measurement, data management and volumetric accounting system that has been certified to be capable of measuring farm delivery volumes within +/-5%. The RT system is comprised of:

1. A wireless water velocity sensor to measure turnout flows across the range of conditions that exist at BWGWD gravity deliveries,
2. A ruggedized tablet PC carried in the operator's vehicle and used to record delivery flows and customer water orders, and
3. A database residing on a file server connected to the tablet PC via a cellular Internet connection

By establishing accurate delivery measurement throughout the District and enabling operators to accurately and frequently measure and adjust flow rates at canal headings, operators will be able to aggregate total deliveries at the heads of individual canals, calculate required increases and decreases to match customer orders, and reduce excess flows in the system. Real time spill monitoring at primary spills will provide critical feedback to operators to further optimize canal operations.

Additional information about specific project elements is provided in **Appendix 5.B.2**.

5.4.2.1.2 Specific Improvements in RID

Modernization improvements to RID infrastructure will include improvements at 14 check structures and lateral canal headings along the Main Canal and Main West Canal to provide improved water level control, flow control, flow measurement, Supervisory Control and Data Acquisition (SCADA), and automation. The project will improve delivery flexibility and steadiness for 22 delivery turnouts along the Main Canal and Main West Canal and 110 delivery turnouts along lateral canals served by the Main Canal and Main West Canal. These turnouts serve approximately 40 percent of the District's irrigated area.

Additional information about specific site improvements is provided in **Table 2** of **Appendix 5.C.2.**

5.4.2.2 *Implementation Schedule*

The project schedule shown in **Table 5-7** and **Table 5-8** summarizes the general activities and duration of ongoing system modernization improvements in BWGWD and RID, respectively. Additional phases of project implementation will be developed and reported as needed. Construction of the proposed improvements is expected to follow completion of final designs, bidding, and work related to environmental and cultural resources compliance and permitting. Improvements are planned to be strategically sequenced so that project benefits will begin following the first construction season, allowing verification of project benefits to begin as well. Where applicable, improvements on a given lateral will be sequenced so that entire laterals are completed before moving on to other laterals. Improvements to primary spill sites will also be sequenced to coincide with any delivery measurement improvements on upstream laterals. Procurement, installation, commissioning and testing of SCADA equipment and software will be completed as the civil improvements are completed. Post-project monitoring will be conducted following construction. Public outreach is planned throughout project implementation.

Table 5-7. Implementation Schedule for Biggs-West Gridley Water District System Modernization Project.

Timeline Activity	Year Start[1]	Year End[1]
Prepare Final Designs and Bidding Documents	2018	2021
Environmental and Cultural Resources Compliance and Permitting	2018	2021
Construction of Civil and SCADA Improvements	2022	2023
Training and Implementation Support	2020	2023
Monitoring and Verification	2017	2023 (Ongoing as needed[2])
Public Outreach	2017	2023 (Ongoing as needed[2])

[1] Actual and anticipated timeline activity start and end dates have changed since the schedule identified in the project proposal (Appendix 4.B.2, Figure 5).
[2] End dates are given for the project implementation period. However, monitoring, verification, and public outreach related to system modernization may continue in the future to the extent that they are needed for ongoing operation of the system modernization improvements.

Table 5-8. Implementation Schedule for Richvale Irrigation District System Modernization Project.

Timeline Activity	Year Start[1]	Year End[1]
Prepare Final Designs and Bidding Documents	2018	2021
Environmental and Cultural Resources Compliance and Permitting	2021	2021
Construction of Civil and SCADA Improvements	2021	2022
Training and Implementation Support	2021	2023
Monitoring and Verification	2016	2023 (Ongoing as needed[2])
Public Outreach	2017	2023 (Ongoing as needed[2])

[1] Actual and anticipated timeline activity start and end dates have changed since the schedule identified in the project proposal (Appendix 4.C.2, Figure 3).
[2] End dates are given for the project implementation period. However, monitoring, verification, and public outreach related to system modernization may continue in the future to the extent that they are needed for ongoing operation of the system modernization improvements.

5.4.2.3 *Notice to Public and Other Agencies*

The public and other agencies will be notified of system modernization activities through outreach and communication channels identified in the GSP. Public outreach is planned to occur throughout project implementation and post-implementation monitoring and verification, as needed.

5.4.2.4 *Construction Activities and Requirements*

Specific construction activities are summarized in **Appendices 4.B.2 and 4.C.2** for the BWGWD and RID system modernization projects, respectively, along with an appraisal-level estimate of probable project cost for each item. Infrastructure improvements in the system modernization projects generally include construction or installation of the following components:

- Upstream water level control improvements, including:
  - Automated upstream water level controls on new gates
  - Automated upstream water level control “drop structures”
- Operational spill improvements
- Acoustic doppler velocity meter (ADVM) equipment
- Lined canal sections for ADVM installations
- Flumes
- SCADA base station
- SCADA remote terminal unit (RTU) installations
- On-farm delivery measurement equipment

As needed, other construction and project activities may include:

- Conversion of water level control structures to flow control structures

- Development of orifice gate ratings

5.4.2.5 *Water Source*

The system modernization projects described in this section are not expected to rely on additional water supplies from outside the jurisdiction of each District. Rather, system modernization is expected to enhance the use of existing surface water sources available to growers through increased reliability and flexibility of surface water deliveries and increased operational efficiency of conveyance systems.

5.4.2.6 *Circumstances and Criteria for Implementation*

The system modernization projects described in this section are currently in progress. Ongoing implementation of these projects does not depend on the implementation or performance of other projects or activities. While operation of these system modernization projects is not expected to terminate, any future changes to these projects will be made to align with each District's goals and the overall Subbasin sustainability goal.

5.4.2.7 *Legal Authority, Permitting Processes, and Regulatory Control*

Districts have the authority to plan and implement modernization improvements to their water distribution systems. Permitting and regulatory processes that are expected to affect the system modernization improvement projects include:

- U.S. Army Corps of Engineers Section 404 Permits (plan to file exemption under Section 404(f)(1)(C) of Clean Water Act)
- Regional Water Quality Control Board Section 401 Water Quality Certification (not required if exempt from USACE Section 404)
- State Water Resources Control Board Construction General Permit and Storm Water Pollution Prevention Plan (SWPPP)
- State Historic Preservation Office (SHPO) and National Historic Preservation Act (NHPA) Section 106 Coordination
- California Endangered Species Act (CESA) Consultation
- Endangered Species Act (ESA) Compliance
- National Environmental Policy Act (NEPA) Compliance
- California Environmental Quality Act (CEQA)

A summary of the compliance plans for each permitting and regulatory process is identified in **Appendix 5.B.2** (**Table 5-4**) and **Appendix 5.C.2** (**Table 5-5**) for the BWGWD and RID projects, respectively.

5.4.3 Operation and Monitoring

The system modernization project will be accomplished by each district following the implementation schedule identified above. Planning, permitting, construction, training, monitoring, and public outreach will be coordinated with outside consultants and professionals, as needed and as identified in the project proposals (**Appendices 5.B.2 and 5.C.2)**.

Performance measures and project monitoring will be used to demonstrate, verify, and report project performance and benefits. Without-project and with-project monitoring will be conducted to quantify the spillage reduction benefits of the project by comparing changes in:

- Spillage
- Diversions
- Farm deliveries.

With-project data verification will also be conducted. A project monitoring plan has been developed for each project based on performance measures suggested by the U.S. Bureau of Reclamation (USBR) for water use efficiency projects. These plans for the BWGWD and RID projects are described in Section I.G.6 of **Appendices 5.B.2 and 5.C.2**, respectively.

In addition to comparing without- and with-project spillage, diversions, and farm deliveries, District operators and customers will be consulted to better understand:

- The means by which spillage and farm deliveries are reduced,
- Challenges to achieving additional benefits, and
- Expected increases in conservation over time as greater experience with utilizing the improvements implemented through the project is gained.

The districts will also monitor and document the use of water conserved by system modernization.

5.4.4 Project Benefits and Costs

5.4.4.1 *Benefits*

The estimated average annual volumes of water conservation expected from the system modernization projects are summarized in **Table 5-9** by district. These benefits are expected to occur primarily through spillage reduction. Actual project benefits will be monitored and verified as described in the previous section. Project benefits are expected to occur every year following construction and implementation of modernization improvements. The actual total benefits will vary from year to year, depending on water supply and operational conditions. The districts plan to continue supporting project operations, maintenance, and capital replacement costs into the future.

Each project is also expected to support the districts in better management of their full Feather River water supply, totaling nearly 215,000 AF annually in BWGWD and 190,000 AF annually in RID (**Table 5-9**).

To the extent that water conserved by this project is retained in Lake Oroville, conserved water could be released strategically at desired times and in desired amounts to meet a variety of ecosystem restoration, water quality, or other water supply needs. This water may be used to meet instream flow or other demands; be diverted to provide habitat benefits for migratory waterfowl, shorebirds, and other species; be diverted to provide direct or in-lieu recharge; or be used to improve water supply reliability under drought conditions. The proposed project provides multiple statewide benefits while preserving local flexibility and building on the districts' existing water use efficiency efforts. Targeted project benefits to water flow, water quality, and water quantity are summarized in **Table 5-10**.

The proposed project represents a significant step forward in implementing comprehensive water management improvements as part of each districts' delivery measurement improvement plans and comprehensive system modernization and boundary outflow and primary spill measurement projects developed as part of the FRRAWMP.

Table 5-9. Estimated Water Conservation Benefit of System Modernization Projects.

District	Estimated Average Annual Water Conservation Benefit at Full Project Implementation (AF/yr)	Average Total Feather River Water Supply (AF/yr; 2000-2014)
Biggs-West Gridley Water District	3,320	214,920
Richvale Irrigation District	3,790	189,400

Table 5-10. Targeted System Modernization Project Benefits to Water Flow, Quality, and Quantity.

Targeted Project Benefit	Benefit Category	Beneficiary	Location	Timing
Provide flow to improve aquatic ecosystem conditions.	Flow	Ecosystem	Feather River	Year-round
Reduce salinity to enhance and maintain beneficial uses of water.	Quality	Ag, M&I	Downstream waterways	Year-round
Reduce temperatures to enhance and maintain aquatic species.	Quality	Ecosystem	Feather River	Year-round
Provide long-term diversion flexibility to increase water supply for beneficial uses.	Quantity	Ecosystem, Groundwater, Ag, or M&I	All suitable lands	Year-round
Provide long-term diversion flexibility to increase water supply.	Quantity	Ecosystem, Groundwater	Wetlands and other suitable lands	Variable

5.4.4.2 Costs

The planning-level costs of the system modernization projects are summarized in **Table 5-11.** Additional information on costs for specific modernization improvements in BWGWD and RID are summarized in **Appendices 5.B.2** and **5.C.2**, respectively.

Total implementation costs for the RID system modernization project are estimated to be $1,496,638 (dollar values estimated in 2016). Based on an estimated project life of 30 years and amortization rate of 6%, the annualized project cost is $108,729 per year. Thus, the estimated project cost per unit of water conserved is approximately $28.69 per AF. Based on the cost of water for water transfers in the region recent years on the order of $500 per AF or more, the benefit to cost ratio for the proposed project as a whole is approximately 17.4 (17.4 = 500/28.69) or more. Thus, the project is cost effective from an overall perspective.

Total implementation costs for the BWGWD system modernization project are estimated to be $1,494,622. Based on an estimated project life of 35 years and amortization rate of 6%, the annualized project cost is $103,090 per year. Thus, the estimated project cost per unit of water conserved is approximately $31.05 per AF. Based on the cost of water for water transfers in the region recent years on the order of $500 per AF or more, the benefit to cost ratio for the proposed project as a whole is approximately 16.1 (16.1 = 500/31.05) or more. Thus, the project is cost effective from an overall perspective.

Table 5-11. Planning-Level Costs of System Modernization Projects.

District	Capital Cost ($)	Annual O&M Cost ($/yr)	Annualized Cost ($/yr; Annualized Capital Cost plus O&M)	Annualized Cost Per AF Benefit
BWGWD	$1,494,622 (Mar 2016)	$16,530 (Mar 2016; Tasks 6a and 6b)	$103,090 (Mar 2016, assuming project life of 35 years and amortization rate of 6%)	$31.05 (Mar 2016, based on 3,320 AF/yr benefit)
RID	$1,496,638 (Mar 2016)	$20,430 (Mar 2016; Tasks 6a and 6b)	$108,729 (Mar 2016, assuming project life of 30 years and amortization rate of 6%)	$28.69 (Mar 2016, based on 3,790 AF/yr benefit)

5.5 Boundary Flow and Primary Spill Measurement Projects

5.5.1 Overview

Western Canal Water District (WCWD) has planned and is in the early stages of implementing a boundary flow and primary spill measurement project at three key outflow sites in its distribution system. The boundary flow and primary spill measurement project is part of the district's comprehensive plan for system modernization and boundary flow monitoring developed as part of the Feather River Regional Agricultural Water Management Plan (FRRAWMP). Detailed information about the plan is included in the FRRAWMP and in project documentation included in **Appendix 5.D.**

In this project, WCWD will:

1. Install flow monitoring and telemetry at three key boundary outflow sites,
2. Establish a Supervisory Control and Data Acquisition (SCADA) base station, and
3. Integrate the boundary outflow measurement sites into the SCADA system.

The three boundary outflow sites identified for this project represent approximately 70 percent of total district outflow. Without these improvements, WCWD water operators are unable to remotely monitor key boundary outflows, making it difficult to identify when system inflows do not meet irrigation demands or conversely, when system inflows exceed irrigation demands. As a result, significant operational spillage has historically occurred at the end of laterals. The time required for operators to manually measure outflows at the boundary outflow sites further diminishes the operators' ability to make changes and adjustments to customer deliveries and upstream water control structures in the canal system, further increasing operational spillage.

Following project completion, water operators will be able to remotely monitor system outflows and quickly respond to any excess or shortages by moving water within the system and by changing diversions at Thermalito Afterbay. Enhanced monitoring afforded by this project will help operators to reduce operational spillage and leave water in the Feather River system to meet the needs of threatened and endangered aquatic species, including Chinook Salmon and Steelhead Trout, as well benefiting measurable objectives in the GSP.

Measurable objectives expected to benefit from this project are:

- **Groundwater levels and groundwater storage**: This project will increase water supply reliability, helping to meet customer water crop water needs using surface water supply. This is expected to offset groundwater pumping needs, particularly in curtailment years, and supply on-farm recharge of surface water to the groundwater system.
- **Water quality**: To the extent there are times when the quality of return flows to Butte Creek is not optimal for species of interest in Butte Creek, there is a potential to implement water conservation measures to reduce these return flows and enhance water quality in Butte Creek.

Other benefits of this project are also anticipated. Conserved water could be utilized to increase flow in the Feather River at strategic times, benefitting endangered species such as Chinook Salmon and Steelhead Trout. Water conserved by this project could also be used by others who rely on water from the Feather River, including State Water Project contractors and downstream disadvantaged communities (DACs) that may benefit from recharge and water supply from the Feather River.

5.5.2 Implementation

To implement this project, WCWD will work with engineering consultants to prepare final designs and ultimately construct and install the planned system improvements. Environmental and cultural resources compliance and permitting work will be coordinated with final design efforts to streamline construction and installation efforts.

The planned system improvements implemented in this project will establish a SCADA system for the District, consisting of:

1. A SCADA base station at the district office,
2. SonTek acoustic doppler velocity meters (ADVM) that will be installed in two existing pipes at the Butte Creek Spill,
3. Pressure transducers that will be installed upstream of the existing weir structures at both the 501 Drain Spill and the Little Dry Creek Spill, and
4. Cellular telemetry equipment installed at all three sites, for integration with the District's SCADA system.

The SCADA base station will include a dedicated computer and monitor, data server, back-up battery power supply and related accessories. The software used for the Human Machine Interface (HMI) will be an open architecture type such as ClearSCADA and allow the development of individual operating and data retrieval screens for each site and a separate screen for generating user-defined reports and alarms. The SCADA HMI will be configured for remote access to provide the operators with real-time monitoring and alarms via their portable field laptops or mobile phones.

The measurement devices and methods at each remote monitoring site will be calibrated through field measurements using stream gaging techniques to ensure accurate flow measurement across a range of flows.

Real time monitoring of these sites will help district water operators to optimize surface water use, allowing them to quickly detect excesses and shortages in the system and to reduce operational spillage while improving response to customer demands. Monitoring and verification work will occur throughout project implementation to identify the pre-implementation and post-implementation benefits and effects of the project on the WCWD system.

Additional information about specific project elements is provided in **Appendix 5.D.2.**

5.5.2.1 *Implementation Schedule*

The project schedule is shown in **Table 5-12**. Early stages of project implementation have begun as of summer 2021, beginning with the final project design and completion of environmental permitting. Construction of the proposed improvements is expected to follow completion of final designs and work related to environmental and cultural resources compliance and permitting. Monitoring will be conducted as improvements are completed and following completion to verify project benefits.

Table 5-12. Implementation Schedule for Western Canal Water District Boundary Spill and Primary Outflow Measurement Project.

Timeline Activity	Year Start[1]	Year End[1]
Prepare Final Designs for System Improvements	2021	2021
Environmental and Cultural Resources Compliance and Permitting	2021	2022
Construction of System Improvements	2022	2022
Training and Implementation Support	2022	2022
Monitoring and Verification	2021	2022 (Ongoing, as needed[2])

[1] Anticipated timeline activity start and end dates are reported in the schedule identified in the project proposal (Appendix 4.D.2, Figure 2).

[2] End dates are given for the project implementation period. However, monitoring and verification related to boundary outflow and primary spill measurement may continue in the future to the extent that they are needed for ongoing operation of these improvements.

5.5.2.2 *Notice to Public and Other Agencies*

The public and other agencies will be notified of ongoing project implementation efforts through the outreach and communication channels identified in the GSP. Public outreach is planned to occur throughout project implementation and post-implementation monitoring and verification, as needed.

5.5.2.3 *Construction Activities and Requirements*

Specific construction activities are listed in **Appendix 5.D.2**, along with a scope-level estimate of probable project cost for each item. Infrastructure improvements required for the WCWD boundary outflow and primary spill measurement project are expected to include construction or installation of the following general components:

- SCADA base station
- Remote monitoring equipment at three sites:
  - Pressure transducer installations (upstream of weirs at Little Dry Creek and 501 Drain outflows)
  - ADVM installation (in pipeline at Butte Creek outflow)
- Associated hardware, including field radio equipment to support SCADA integration

Each of the monitoring sites will powered by solar systems with a minimum of two days of reserve battery power, and will be installed with weatherproof enclosures to house and protect the measurement, power, and telemetry equipment. Measurement devices and methods were selected for each site based on existing system infrastructure so that no additional site improvements are required to implement this project.

5.5.2.4 *Water Source*

The boundary outflow and primary spill measurement project is not expected to rely on additional water supplies from outside the jurisdiction of WCWD. Rather, the project is expected to enhance the use of existing surface water sources available to growers by improving system monitoring and control and by reducing surface water outflows and increasing the operational efficiency of the conveyance system.

5.5.2.5 *Circumstances and Criteria for Implementation*

The boundary outflow and primary spill measurement project described in this section is currently in progress. Ongoing implementation of this project does not depend on the implementation or performance of other projects or activities. While operation of the project is not expected to terminate, any future changes will be made to align with each District's goals and the overall Subbasin sustainability goal.

5.5.2.6 *Legal Authority, Permitting Processes, and Regulatory Control*

Districts have the authority to plan and implement projects that improve measurement of distribution system flows. Potential permitting or regulatory processes that could affect the boundary system outflow and primary spill measurement project include:

- State Historic Preservation Office (SHPO) and National Historic Preservation Act (NHPA) Section 106 Coordination
- Endangered Species Act (ESA) Compliance
- National Environmental Policy Act (NEPA) Compliance

Despite minimal or no ground-disturbing activities, it is anticipated the project will require NEPA compliance, including environmental and cultural resources review. Due to the limited ground disturbance to complete the project work, it is anticipated that the project will qualify for a Categorical Exclusion according to the qualification factors found in Reclamation's NEPA Handbook. Otherwise, the project will likely require an Environmental Assessment/Finding of No Significant Impact (EA/FONSI). A summary of the compliance plan for each permitting and regulatory process is identified in **Appendix 5.D.2** (**Table 5-6**).

WCWD has initiated environmental and cultural resources permitting activities as of summer 2021.

5.5.3 Operation and Monitoring

The boundary flow and primary spill measurement project will be accomplished by WCWD following the implementation schedule identified above. Planning, permitting, construction, training, and monitoring efforts will be coordinated with outside consultants and professionals, as needed and as identified in the project proposal (**Appendices 5.D.2**).

Project benefits from spillage reduction will be calculated as the difference between without-project and with-project estimated spillage normalized for differences in total annual diversions to account for differences in season length or other factors. Monitoring of operational spills will continue throughout and following project implementation. With-project spillage will be monitored specifically during the 2021 and 2022 irrigation seasons as improvements are made to develop estimates of with-project spillage.

Without-project spillage was originally estimated as part of the FRRAWMP via a multi-year water balance representing the period 1999 to 2014. To refine FRRAWMP estimates and quantify actual without-project boundary outflow volumes, WCWD has monitored seasonal April to October flows at primary drain outflow points since 2016. Primary drain outflow monitoring utilizes pressure transducers with local dataloggers and field calibration measurements to create continuous outflow records at the monitored sites, including the proposed project sites. Spill volumes are also recorded daily using the District's H2oTech RemoteTracker system, which is used to periodically record deliveries at customer turnouts and at operational spill sites. In addition to monitoring spillage, diversions are monitored and recorded to further define without-project conditions.

The use of water conserved will also be documented by WCWD, to the extent that usage information is available. WCWD water operators will additionally be consulted to document number of system adjustments performed to minimize spillage and other changes in system operations.

5.5.4 Project Benefits and Costs

5.5.4.1 *Benefits*

Table 5-13 summarizes the expected water savings associated with the proposed improvements. It is estimated that the SCADA and flow measurement improvements will reduce outflow by 10 percent, resulting in a total reduction in spillage of 1,829 AF per year, occurring between May and October.

This water is expected to be retained in Thermalito Afterbay, and would be available for other beneficial uses elsewhere in the District and the Feather River region. For example, this water may potentially be:

- Used to meet instream flow or other demands;
- Diverted to provide habitat benefits for migratory waterfowl, shorebirds, and other species;
- Diverted to provide direct or in-lieu recharge; or
- Used to improve water supply reliability under drought conditions.

According to Agricultural Water Management Council guidelines, prepared for the CALFED Bay Delta Water Use Efficiency program, incorporating flow measurement and telemetry typically reduces spillage by 10 to 30 percent.[37] The 10 percent reduction assumed for this project is on the lower end of the typical range, providing a conservative estimate of project benefits. Savings may be lower or higher for a specific year depending on whether the District is curtailed or participating in a water transfer or if they have full supply and a full plant year.

These system improvements are also expected to help the District's water operators to more effectively and efficiently adjust system inflows and maneuver water to supply deliveries. These improvements will enhance management of the District's overall surface water supply, totaling approximately 223,000 AF per year (**Table 5-13**). While there is limited opportunity to increase overall water supplies by reducing operational losses since these losses become available for downstream use, there are opportunities to increase local, regional, and statewide water supply and water supply reliability by better managing when and where available water supplies are used and when and where water returns to the system. This project could also be used to support strategic spillage of water into Butte Creek to maintain certain in-stream flow requirements to meet the needs of threatened and endangered aquatic species, including Chinook Salmon and Steelhead Trout. Butte Creek is an important passageway for the endangered spring-run Chinook Salmon and Steelhead.

Table 5-13. Estimated Water Conservation Benefit of Boundary Outflow and Primary Spill Measurement Project.

District	Estimated Water Conservation Benefit at Full Project Implementation (AF/yr; May-Oct)	Average Total Surface Water Supply (AF/yr; April-October 1999-2014)
Western Canal WD	1,829	223,000

5.5.4.2 *Costs*

The planning-level costs of the boundary outflow and primary spill measurement project are summarized in **Table 5-14**. Additional information on costs for specific system improvements are summarized in **Appendix 5.D.2.**

[37] **Monitoring and Verification: Spillage Reduction. Agricultural Water Management Council**

In total, the project is expected to cost approximately $152,800. This total includes estimated costs for preparing final designs, completing compliance and permitting work, implementing and constructing system improvements, conducting training and support, completing monitoring and verification, and managing all efforts throughout the duration of the project.

The portion of the total cost resulting from construction and installation of system improvements at boundary spills and primary outflow sites is estimated to be $95,519 (**Table 5-15**). Annual operations and maintenance costs over the project life are expected to be approximately $1,979 per year. Based on component-based useful life (generally 1-15 years) and an amortization rate of 6%, the annualized project cost is $13,409 per year, including operations and maintenance. Thus, the estimated implementation cost per unit of water conserved is approximately $7.33 per AF of anticipated benefit.

Table 5-14. Planning-Level Costs of Western Canal Water District Boundary Outflow and Primary Spill Measurement Project.

Project Component	Total Cost ($) (Sept 2020)	Percent of Total Project Cost
Project Management and Administration	$9,552	6%
Prepare Final Designs	$4,776	3%
Environmental and Cultural Resources Compliance & Permitting	$28,656	19%
Implementation of System Improvements	$95,519	62%
Training and Implementation Support	$4,776	3%
Monitoring and Verification	$9,552	6%
	$152,831	**100%**

Table 5-15. Detailed Planning-Level Costs of Western Canal Water District Boundary Outflow and Primary Spill Measurement Project for Implementation of System Improvements.

Project Component	Capital Cost ($)	Annual O&M Cost ($/yr)	Annualized Cost ($/yr; Annualized Capital Cost plus O&M)	Annualized Cost Per AF Benefit
Implementation of System Improvements	$95,519 (Sept 2020)	$1,979 (Sept 2020)	$13,409 (Sept 2020, based on component-based useful life values and amortization rate of 6%)	$7.33 (Sept 2020, based on 1,829 AF/yr benefit)

5.6 Dual Source Irrigation Systems

5.6.1 Overview

Dual source irrigation systems have been proposed and investigated as a potential opportunity for supporting groundwater sustainability in the Butte Subbasin. This section describes a program proposed in Butte Water District (BWD) that would support growers in implementing dual source irrigation systems, though a similar program could be implemented by other GSAs.

The overall goal of promoting dual source irrigation systems is to increase the use of existing, available surface water supplies for irrigation in areas where irrigators have begun to use more groundwater. One of the main challenges to enhancing recharge in BWD is the expansion of orchard crops and the shift in irrigation of these crops, from surface irrigation using surface water to low-volume, pressurized irrigation using groundwater. By incentivizing or promoting the use of dual source systems, BWD will encourage growers that currently use groundwater to also use surface water, with in-lieu recharge benefits to the Subbasin. These systems will promote conjunctive use by allowing growers to use either groundwater or surface water for irrigation through the same system depending on availability.

Implementation of dual source irrigation systems in Butte County is proposed in a 2018 study, “Evaluation of Restoration and Recharge within the Butte County Groundwater Basins.” Excerpts of this study that focus on dual source irrigation systems are provided in **Appendix 5.E**.

In the 2018 study, dual source irrigation systems were evaluated as a promising opportunity for enhancing in-lieu groundwater recharge by incentivizing the use of surface water in lieu of groundwater whenever available. The study characterized the typical components of dual source irrigation systems and the relative upfront (capital) and ongoing (operations and maintenance) costs of these systems compared to systems that use only groundwater. The study also evaluated the agronomic factors that affect whether growers choose to utilize groundwater, surface water, or both sources when available. Finally, a preliminary economic analysis of local and regional benefits and costs of utilizing dual source systems to address potential groundwater overdraft conditions in Butte County was presented. General findings and conclusions of this study are summarized as a basis for this GSP project.

A program that promotes dual source irrigation systems is expected to benefit measurable objectives related to groundwater levels and groundwater storage. By encouraging growers to use surface water when it is available, dual source irrigation systems provide:

- **In-lieu groundwater recharge**: In fields formerly irrigated exclusively using groundwater, surface water applied through a dual source irrigation system will offset a similar volume of groundwater pumping, leaving that groundwater in the underlying aquifer for future beneficial use.
- **Direct groundwater recharge**: Irrigation provides a significant volume of recharge through deep percolation of applied water. As irrigators have shifted from surface irrigation toward pressurized irrigation using groundwater, the proportion of deep percolation supplied by surface water has decreased. Even though the low-volume irrigation techniques used to apply groundwater minimize the total volume of water needed to satisfy crop demands, this shift in water source results in a net depletion of groundwater (i.e., more extraction than recharge) rather than a net recharge observed from application of surface water. Irrigating with surface water thus supports groundwater sustainability by supplying more surface water to the groundwater system through in-field recharge.

Expanded use of dual source irrigation systems represents a significant opportunity to preserve the agronomic advantages of groundwater use while mitigating increased reliance on groundwater and supporting groundwater sustainability.

5.6.2 Implementation

At the district-level, BWD is considering implementing a program to encourage or incentivize grower adoption of dual source irrigation systems.

This program can be supported through several mechanisms:

1. **Grower education**: Educating growers on the benefits and advantages of dual source irrigation systems, both at the field level and in the larger context of the Butte Subbasin, may encourage growers to voluntarily adopt dual source irrigation systems. A sample framework for implementing a grower education program is outlined in **Section 5.8** of this GSP.
2. **Incentives**: BWD may consider creating an incentive program to encourage adoption of dual source systems by offsetting the cost of the additional components needed for these systems. Incentives may be funded through the District or through external programs

such as those offered by the Natural Resources Conservation Service (NRCS), which has provided past funding to growers to convert from older and less efficient irrigation systems (such as flood systems) to newer systems that are more efficient (such as sprinkler systems). Recent policy in Butte County has been to fund these projects only when the grower retains the use of surface water, promoting the use of dual source irrigation systems.

3. **Surface water delivery improvements**: Enhancing the availability and reliability of surface water supplies to support low-flow, long-duration irrigation events will support growers as they adopt dual source irrigation systems. The advantage of groundwater as an on-demand water supply diminishes if surface water is available with similar consistency and reliability.

Implementation of this program must address the agronomic and economic considerations that led growers to shift from use of surface water delivered through district-owned facilities to pumping of groundwater from grower-owned wells.

A primary consideration of growers is cost: the use of a dual source system may or may not result in a net cost savings over time depending on several factors. Dual source irrigation systems require additional components and operating costs beyond a groundwater-only irrigation system, as growers must convey and filter surface water, in addition to pressurization. Specific components and annual operating costs are summarized below in **Section 5.6.2.3** and in **Appendix 5.E.** Incentives may help to encourage growers who are hesitant about implementing dual source irrigation systems because of economic reasons.

Another primary reason growers prefer groundwater is the reliability of an on-demand water source. If surface water is available on-demand or with greater flexibility during the growing season, this may help to encourage the adoption of dual source irrigation systems and reduce dependence on groundwater. Reliability of water supply is important not just seasonally or annually, but also within a given year when water might be needed on specific days (e.g. for frost protection), or to supply water during particularly dry winter and early spring months.

Another primary factor for fruit and nut trees is disease risk. Root and crown rot (Phytophthora) is transmitted through surface water in Butte County and can result in permanent crop damage and yield reduction. Thus, a benefit of using groundwater for orchard irrigation as compared to surface water is reduced risk of root and crown rot; however, there are several management options to prevent contact between wood and water, reducing this risk. Other factors that may result in advantages or disadvantages of using surface water include chemical constituents, such as mineral content and nitrates in groundwater and total dissolved solids and related considerations such as infiltration and salinity. Grower education programs can be useful in addressing these concerns of using dual source irrigation systems.

At the field-level, dual source irrigation systems are implemented by installing or integrating four primary components into a groundwater-only or "single source" system: a surface water irrigation "turnout" or point of delivery to the field, a pipeline or ditch to convey water from the turnout to a pump station, a pump or pumps for pressurization, and filtration equipment. The precise layout and specific components for dual source systems will vary from field to field, as described in **Section 5.6.2.3.** However, these four components generally account for the additional equipment needed for dual source systems as compared to groundwater only or "single source" systems. Implementation of a district-level program to encourage adoption of dual source systems can be designed to support growers in identifying and sizing the specific components needed for their individual fields.

5.6.2.1 *Implementation Schedule*

At this time, the dual source irrigation systems program has been developed and evaluated only at an investigative, planning level. This project will ultimately be selected for implementation according to the criteria identified in **Section 5.6.2.5.** At that time, BWD will develop the program following the general implementation schedule presented in **Table 5-16**.

Initial program planning and refinement of dual source irrigation system recommendations is expected to begin in the first two years of project implementation. BWD will proceed to plan a program incentive strategy and investigate funding opportunities for grower incentives. BWD will also likely develop partnerships for grower education and program implementation, coordinating these efforts with implementation of other grower education programs described in **Section 5.8**, as applicable. Potential agencies and groups that GSAs may consider partnering with are:

- University of California Cooperative Extension (UCCE)
- California State University, Chico (Chico State)
- University of California, Davis (UC Davis)
- Irrigation Training and Research Center (ITRC) at California Polytechnic State University, San Luis Obispo (Cal Poly)

As the structure of the program and partnerships are developed, implementation of dual source irrigation systems are expected to occur throughout GSP implementation.

5.6.2.2 *Notice to Public and Other Agencies*

The public and other agencies will be notified of project implementation activities through outreach and communication channels identified in the GSP.

Table 5-16. Dual Source Irrigation System Program Implementation Schedule.

Phase/Timeline Activity	Description	Year Start	Year End
Program Structure Development and Planning	Identifying program goals, a program structure, and a plan for assisting growers in installing dual source irrigation systems.	Years 1-2 of Project Implementation	Ongoing, as needed
Refinement of dual source irrigation system recommendations	Reviewing dual source irrigation system technology and developing framework for identifying and recommending components and implementation requirements for growers	Years 1-2 of Project Implementation	Ongoing, as needed
Create Incentive Strategy	Planning potential incentive strategies and investigating funding sources.	Years 2-3 of Project Implementation, As Applicable	Ongoing, as needed
Partnership Development	Identifying and teaming with partner agencies to plan and implement program	Years 2-3 of Project Implementation, As Applicable	Ongoing, as needed
Program Implementation	Facilitating conversion to dual source irrigation systems and coordinating education and outreach activities with partners, as applicable	Year 4 of Project Implementation	Ongoing

5.6.2.3 *Construction Activities and Requirements*

Construction activities that would be required for this project center on field-level implementation of dual source irrigation systems. The district will refine the specific recommendations for implementing dual source irrigation systems as part of this project. Eventually, this program will help growers to identify the specific components that will need to be constructed or installed on a field-by-field basis.

Typical system components required for a dual source system are:

1. **Surface water irrigation "turnout" or point of delivery to the field:** An irrigation turnout provides a method to deliver surface water from a canal to a field or on-farm conveyance system and, when equipped with a screen or trash rack, a method to prevent large debris from entering the on-farm system. Turnouts typically consist of a submerged circular canal gate and a screen or trash rack. In some cases, the inlet piping of the pressure pump is equipped with a rotating, self-cleaning screen or other filter to enable pumping directly from the canal, thereby eliminating the need for a turnout gate.
2. **Pipeline or ditch to convey water from the turnout to a pump station:** The conveyance component includes any additional ditches or pipelines that may be needed to convey surface water to the irrigation system. Surface water supplies in the area are all non-pressurized, so a pump or pumps may be needed to lift the surface water to the field, overcome any pipe friction losses, and/or provide pressurization for the irrigation system. Where water can be delivered via gravity, an open ditch or low head pipeline may be used to convey water to the point of pressurization.
3. **Pump or pumps for pressurization**: Typically, a centrifugal pressure pump or vertical turbine sump pump is used to overcome friction, provide lift, and pressurize surface

water.

4. **Filtration**: Surface water typically contains solids, which may include inorganic materials (sand, silt, and clay), aquatic organisms (algae, weeds, and fish), and trash (sticks, litter, etc.). Filtration of surface water may be accomplished in several stages, including construction of a small reservoir to settle solids prior to pumping, pre-screening at the turnout or pump intake using screens or trash racks, primary filtration downstream of the pump, and sometimes backup or secondary filtration downstream of the primary filter. The need for these different filtration components depends on the conditions of a given field.

Although the layout and specific components for dual source systems will vary from field to field, these four components generally account for the additional equipment needed for dual source systems as compared to groundwater-only or "single source" systems.

The 2018 evaluation of dual source irrigation systems in Butte County (**Appendix 5.E**) provides additional information about required construction activities and requirements, including all the components of a sample dual source system located in a 250-acre walnut orchard in BWD.

5.6.2.4 *Water Source*

The dual source irrigation systems described in this section are not expected to rely on additional water supplies from outside the jurisdiction of the District. Rather, dual source irrigation systems are expected to enhance conjunctive use of groundwater and existing surface water sources available to growers.

5.6.2.5 *Circumstances and Criteria for Implementation*

The dual source irrigation systems described in this section were originally evaluated as part of a 2018 study in Butte County (**Appendix 5.E**), and are planned for future implementation pending funding and changes in future groundwater conditions in the Butte Subbasin. BWD and other GSAs will monitor groundwater levels in the Subbasin through the monitoring plan in this GSP. If groundwater levels decline near or below minimum thresholds, this project will be prioritized to support in-lieu recharge in those areas where undesirable results may occur. BWD and other GSAs may also decide to implement this project at an earlier time to enhance surface water use.

Ongoing implementation of dual source irrigation systems does not depend on the implementation or performance of other projects or activities, though they will benefit from the system modernization improvements described in **Section 5.4**. While operation of these projects is not expected to terminate, any future changes will be made to align with the BWD's (or another GSA's) goals and the overall Subbasin sustainability goal.

5.6.2.6 *Legal Authority, Permitting Processes, and Regulatory Control*

Districts have the authority to plan, incentivize, and support the use of dual source irrigation systems in their irrigation service areas. Depending on the scale and nature of specific construction activities that will need to be implemented to install dual source irrigation system infrastructure, potential permitting or regulatory processes that could affect the project include:

- State Historic Preservation Office (SHPO) and National Historic Preservation Act (NHPA) Section 106 Coordination
- Endangered Species Act (ESA) Compliance
- National Environmental Policy Act (NEPA) Compliance
- California Environmental Quality Act (CEQA)
- State Water Resources Control Board Construction General Permit and Storm Water Pollution Prevention Plan (SWPPP; to the extent that any soil disruption occurs from construction related to surface water conveyance)

5.6.3 Operation and Monitoring

At the field-level, the layout and operation of dual source irrigation systems will vary between locations based on four main factors:

- **Field Size and Crop Water Requirements**: Peak capacity is a function of field size, peak crop evapotranspiration (ET), and the uniformity with which water is applied. For the Sacramento Valley, peak ET is around 0.3 to 0.4 inches per day for most crops, translating to approximately 7 to 9 gallons per minute (gpm) per acre based on a system distribution uniformity of 80%. In many cases, systems may be designed with greater capacity (e.g. 12 gpm per acre) to be able to meet peak crop water requirements while avoiding pumping during peak energy demand periods to reduce electrical costs.
- **Distance**: The distance from the surface water source to the point of application affects the required length of ditch or pipeline required to convey the water. Distances to consider include the distance from the turnout to the pressure pump and the distance from the pressure pump to the point at which the pump discharge ties into the system mainlines. This may be at the groundwater well or other location. In addition to conveyance, the distance from the pressure pump to existing electrical distribution lines is a factor affecting cost for electric pumps.
- **Water Quality**: The type and amount of solids to be removed through filtration affects the number and types of filtration required. Generally, some form of pre-screening to remove large solids will be needed, followed by primary filtration downstream of the pressure pump. Selection of filtration also depends upon the orifice size of the sprinkler nozzles or emitters for pressurized systems.
- **Pressure Requirements**: The amount of pressurization required includes any lift required to convey water from the turnout to the point of application, friction losses in the conveyance and irrigation system itself, pressure loss through the filters, and discharge

pressure required by the emitters.

The District may monitor grower adoption and amenability to dual source irrigation systems through periodic grower surveys before and during project implementation. Information gathered from these surveys would be used to refine and guide project implementation.

The benefit of dual source irrigation systems on measurable objectives in the Subbasin (groundwater levels and groundwater storage) will be monitored using the monitoring network sites and monitoring practices described in the GSP.

5.6.4 Project Benefits and Costs

Implementation of dual source irrigation systems in BWD is expected to provide several on-farm and basin-wide benefits. Potential benefits and costs of dual source irrigation systems at the field-level and program-level are summarized below.

5.6.4.1 *Field-Level Benefits and Costs*

At the field-level, the primary categories of expected benefits are:

- **In-lieu groundwater recharge benefits**: the volume of groundwater pumping offset by implementation of dual source irrigation systems and use of surface water
- **Economic benefits**: the variable cost of groundwater pumping that is offset by implementation of dual source irrigation systems and use of surface water

In-lieu groundwater recharge and economic benefits are expected throughout project implementation, beginning as groundwater-only single-source irrigation systems are converted to dual source systems. The exact volume and cost of groundwater pumping that is offset each year depends on surface water supply availability and the precise crops, irrigation needs, and total agricultural area that is ultimately served by dual source systems. However, in the 2018 evaluation dual source irrigation systems were estimated to offset approximately 50 percent of crop water demand in fields served, providing average per-acre benefits of 1.28 AF/ac, or approximately 15 in/ac. Actual benefits would be monitored during project implementation as described in the operation and monitoring section, above.

Implementation of dual source systems have associated costs that are likely to differ from the costs associated with a single source groundwater system for the same orchard. These cost differences or “marginal” costs include capital, maintenance, and operations costs.

The greatest additional capital costs for a typical dual system are the additional infrastructure needed to convey and pressurize surface water. Some participating fields may need a pressure pump at each dual source pump station and electrical line extensions to bring power to the existing turnout locations. Other participating fields may require gravity pipelines to convey surface water from turnouts to existing well locations. Other additional capital costs include the cost of sump and turnout connections, the cost of extending the mainline to the turnout locations, and the cost of installing filtration equipment. Filtration needs depend on both the quality of the water and the type of irrigation method, with greater filtration needed for drip and microspray systems than for sprinklers.

Operations costs for dual source systems include the cost of surface water and groundwater. Surface water costs include purchasing surface water from the supplier and the cost of pumping and pressurizing the water. Groundwater costs include the cost of lifting the water and pressurizing it.

The additional capital and maintenance costs associated with these components represent an additional upfront investment required to utilize dual source systems, as compared to systems relying solely on groundwater for irrigation; the use of surface water results in a reduction in lift requirements and associated energy requirements compared to the use of groundwater. In some cases, the reduced energy requirements and cost savings may be greater than the capital and maintenance costs of the dual system components, resulting in a net cost savings over time to growers using dual source systems.

Table 5-17 summarizes the estimated annual costs and cost differences for installing and operating all components of a single source and dual source irrigation system for a sample 250-acre walnut orchard in BWD. Additional information about specific component costs of dual source systems are summarized in **Appendix 5.E** (**Table 6-4**).

5.6.4.2 *Program-Level Benefits and Costs*

A program to encourage implementation of dual source irrigation systems is expected to maintain significant economic and groundwater recharge benefits in the Subbasin. Appendix 4.E contains a 2018 economic assessment of a selected dual source irrigation systems to evaluate associated costs, benefits to the grower, and benefits accruing to others in the Subbasin.

Economic benefits quantified in the analysis include:

- The value of stable groundwater levels reflected in the avoided cost of groundwater pumping by all groundwater users within the County;
- The benefit of increased future water supply reliability, reflected in reduced water supply risk to growers; and
- Avoided costs of fallowing (or other programs) to manage groundwater overdraft.

The basin-wide economic benefits of increased recharge can be disaggregated into avoided energy and capital costs, reduced financial risk, and avoided third-party costs. The district-level economic benefits of dual source irrigation systems also include increased revenue, as growers purchase and use more surface water supply.

Table 5-17. Estimated Annual Costs and Cost Differences for Components of Single Source and Dual Source Systems: Example 250-Acre Walnut Orchard in Butte Water District (Appendix 5.E, Table 6-3).

Cost Item	Estimated Annual Cost		
	Single Source	Dual Source	Difference
Capital			
Pressure Pumps	$1,350	$3,900	$2,550
Electrical Line Extension	$0	$3,050	$3,050
Gravity Pipeline	$0	$200	$200
Sump & Turnout Connection	$0	$850	$850
SUBTOTAL	$1,350	$8,000	$6,650
Operations and Maintenance			
Energy	$48,350	$40,800	-$7,550
Equipment Maintenance	$850	$3,250	$2,400
SUBTOTAL	$49,200	$44,050	-$5,150
GRAND TOTAL	**$50,550**	**$52,050**	**$1,500**

Costs quantified in the 2018 analysis include:

- The capital cost of the equipment required for the dual system at the farm
- The variable cost of operating the surface system, net of any cost savings over the existing groundwater system
- The capital and operating cost of conveying surface water to the fields included in the dual system
- The cost of purchasing surface water from a willing seller
- The opportunity cost of any capital in the existing groundwater well that is not used (or underutilized) once the dual system is implemented

The marginal costs of implementing dual source irrigation systems is summarized in **Figure 5-1**, illustrating the change in the cost of project implementation per acre-foot of water savings as the in-lieu program is expanded up to 20,000 AF in the eastern and western portions of the Butte Subbasin. These marginal costs were quantified by assessing the total cost of a dual source system in each field in Butte County that is currently irrigating with groundwater (as of the 2018 analysis), and then ranking fields from lowest to highest net cost and identifying the expected volume of groundwater that would be offset by a dual source system. In this reconnaissance-level analysis, it is assumed that approximately 50% of the overall annual crop water requirements in fields served by a dual source irrigation system would be met by surface water. The cost per acre-foot generally differs between regions and increases as the total quantity of in-lieu water supply increases.

Two important assumptions underlie the marginal cost calculations. First, sufficient surface water can be secured by project proponents to serve the fields that participate in the in-lieu program, and the additional surface water has the same cost as existing surface water supplies. Second, the in-lieu program conveyance and operating costs assume that contiguous 2,000-acre blocks are added to the program. If surface water supplies are more expensive, or smaller parcels are connected, the marginal cost of the program will increase. The actual scale of the project during implementation could be determined based on various criteria, including minimizing costs, maximizing existing surface water use, or maximizing benefits based on other sustainability criteria. The District (or other GSAs) will refine the project scale and costs as implementation occurs.

Based on the 2018 analysis, a program to implement dual source irrigation systems in the Butte Subbasin is proposed and scaled to offset approximately 9,772 AF of net groundwater pumping per year, at an annual marginal cost of approximately $223,625 (**Table 5-18**). As described in **Appendix 5.E**, these total costs and benefits were conceptualized to entirely support groundwater sustainability in the Butte Subbasin. In practice, this project is scalable and may be implemented in a lesser or greater number of fields than originally conceptualized, depending on need and grower interest. The preliminary evaluation of local and regional benefits and costs associated with dual source systems, although reliant on several key assumptions at the initial stage of investigation, suggest that benefits may significantly exceed the costs and additional investigation could be warranted.

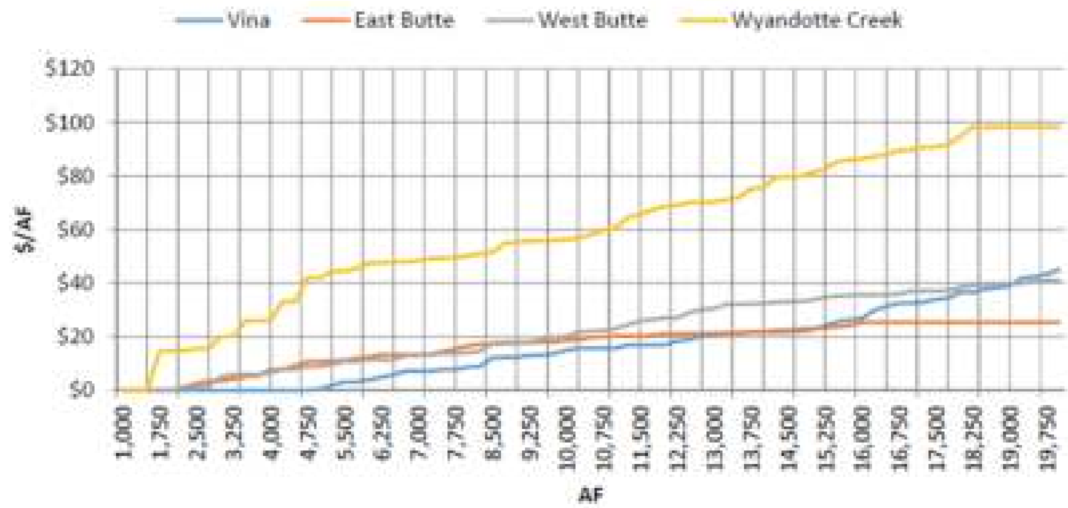


Figure 5-1. Marginal Cost of Implementing Dual Source Irrigation Systems by Subbasin in Butte County (Appendix 5.E, Figure 6-16).

Table 5-18. Planning-Level Benefits and Costs of Dual Source Irrigation System Program in Butte Subbasin.

Project	Expected Annual Benefit at Full Implementation (AF/yr)	Annualized Marginal Cost ($/yr)	Annualized Marginal Cost Per AF Benefit
Dual Source Irrigation System Program	9,772[1]	$223,625 (Jan 2018, **Appendix 5.E, Table 6-10;** sum of East Butte and West Butte in-lieu marginal cost)	$22.88 (Jan 2018)

[1]**Appendix 5.E, Table 6-10**. Expected annual benefit at full implementation is the sum of East Butte and West Butte average overdraft. However, this project is scalable depending on need and interest, and will be implemented across specific fields that will be identified during project implementation.

[2]**Appendix 5.E, Table 6-10**. Annualized marginal cost is the sum of East Butte and West Butte in-lieu marginal cost. Actual cost will vary depending on the scaled implementation of this project.

5.7 Multi-Benefit Recharge Projects

5.7.1 Overview

The Nature Conservancy (TNC) has provided GSAs with guidelines and support to implement an on-farm, multi-benefit groundwater recharge program in the Butte Subbasin. The program would build on the successful TNC BirdReturns program by strategically flooding agricultural fields with the goals of (1) recharging groundwater supplies while (2) simultaneously creating critical winter habitat for shorebirds migrating along the Pacific Flyway. GSAs may consider offering financial incentives to growers to compensate them for recharging groundwater through field flooding in the course of normal farming operations, with multiple benefits to the underlying aquifer, waterbirds migrating along the Pacific Flyway, and all beneficial users of groundwater in the subbasin.

With an incentive structure, the program would provide financial compensation for recharging groundwater through normal farming operations while also providing critical wetland habitat for waterbirds migrating along the Pacific Flyway. Fields with soil and cropping conditions conducive to groundwater recharge will be flooded and maintained with shallow depths. The program could be structured to pay for field preparation, irrigation, and water costs to encourage grower participation.

This section summarizes implementation activities, operation and monitoring efforts, and related costs and benefits of a multi-benefit groundwater recharge program in the Butte Subbasin.

5.7.2 Implementation

Implementation of a multi-benefit groundwater recharge program in the Subbasin would occur in multiple phases, with expansion of the program over time as voluntary grower participation increases. Multi-benefit recharge would be implemented at selected sites in the Butte Subbasin, with multi-benefits to groundwater recharge and temporary wetland habitat formation. Recharge and wetland habitat benefits in the early phases of the project would be analyzed, reported, and used to inform development and later implementation of the program.

Implementation of this project will commence with selection of sites suitable for multi-benefit recharge, and initiation of any necessary permitting and environmental documentation. GSAs will use resources provided by TNC to identify fields with soil and cropping conditions conducive to groundwater recharge and temporary wetland habitat formation. In later phases of project implementation, suitable fields will continue to be identified following similar criteria, with refinement according to lessons learned from early project implementation.

Suitable project sites would be selected by the following characteristics:

- Soil characteristics that are conducive to recharge, as indicated by:
    - Soil types
    - SAGBI rating relationship
- Crop types that are conducive to high-quality, open wetland habitat suitable for bird stopovers when flooded (i.e., not orchards)
- Crop types that are suitable for recharge (i.e., suitable for flooding in mid-July through mid-October, and conducive to deep percolation)
- Water supply and infrastructure characteristics that are suitable for flooding (i.e., existing flood irrigation infrastructure, existing surface water supply)

The process for identifying and enrolling suitable fields in the program is documented extensively on the TNC BirdReturns project website (https://birdreturns.org/).

GSAs will conduct outreach to local growers to identify willing participants that irrigate fields where multi-benefit groundwater recharge can be implemented. Outreach will be conducted through existing communication pathways described in the GSP. Participant responses will be gathered and organized through surveys that request information regarding:

- Field characteristics (location, size, cropping, field preparation methods)
- Existing water supply characteristics (water supply source(s), timing of water source(s))
- Existing measurement and monitoring infrastructure (flow meters, groundwater well)
- Other relevant information

GSAs, with potential support from TNC, would then coordinate with participating growers to implement on-farm, multi-benefit groundwater recharge. Following initial site selection and completion of any necessary permitting and environmental documentation, fields will be prepared for flooding and monitoring. At that time, necessary monitoring equipment will be installed, as needed. The program could be designed to pay for field preparation, irrigation, and water costs through an GSA-planned incentive structure.

During the "flooding window" (mid-July through mid-October), enrolled fields would then be flooded and maintained at a shallow depth to supply groundwater recharge and temporary open wetland habitat for migrating shorebirds. Finally, after completion of the program requirements, contract fees (if applicable) would be paid to participants.

5.7.2.1 *Implementation Schedule*

A typical annual timeline of project implementation is provided in **Table 5-19**. At this time, the multi-benefit groundwater recharge program has been developed and evaluated only at an investigative, planning level. This project will ultimately be selected for implementation according to the criteria identified in **Section 5.7.2.5.** At that time, GSAs would develop and implement the program annually following the general implementation schedule presented in **Table 5-19**.

Table 5-19. Expected Annual Implementation Timeline for the Butte Subbasin Multi-Benefit Groundwater Recharge Project.

Timeline Activity	Start	End
Participant Applications	April 1	August 15
Site Selection	June	September
Construction, Site Preparation	July	September
Operation	mid-July	Mid-October
Financial Incentive Payment	October	December

5.7.2.2 *Notice to Public and Other Agencies*

The public and other agencies will be notified of project implementation activities through outreach and communication channels identified in the GSP.

5.7.2.3 *Construction Activities and Requirements*

Multi-benefit groundwater recharge will be conducted on existing agricultural fields with flood irrigation system infrastructure.

Prior to field flooding, GSAs could facilitate a survey of the fields and install pressure transducers or flow meters at inlets and outlets and in adjacent wells to facilitate measurement of applied water depths and volumes and changes in groundwater depth to estimate groundwater recharge.

5.7.2.4 *Water Source*

Surface water used in this project is expected to be available from existing surface water rights contracts. Existing diversions and conveyance infrastructure will be used to supply surface water for multi-benefit groundwater recharge. Surface water will be delivered during a "flooding window" from mid-July through mid-October.

5.7.2.5 *Circumstances and Criteria for Implementation*

The primary constraints on the operation of this project are (1) the availability of sufficient surface water supply, and (2) the participation of growers with fields conducive to groundwater recharge.

Surface water supply conditions needed for this project include:

- Availability of surface water supplies that are sufficient to flood participating fields according to the specified flooding depth and duration
- Appropriate timing of surface water supply availability during the project "flooding window" (mid-July through mid-October), when wetland habitat for waterbirds migrating along the Pacific Flyway is most critically needed

- Reliability of surface water supplies, based on historical reliability and expected future reliability

Grower participation needed for this project includes:

- Willingness of growers to participate in this program, informed by program applications
- Availability of participating fields suitable for groundwater recharge, based on soil texture, crop type, and availability of suitable surface water flood irrigation infrastructure

A multi-benefit groundwater recharge program is planned for future implementation pending funding and changes in future groundwater conditions in the Butte Subbasin. GSAs will monitor groundwater levels in the Subbasin through the monitoring plan in this GSP. If groundwater levels decline near or below minimum thresholds, this project will be prioritized to support in-lieu recharge in those areas where undesirable results may occur. GSAs may also decide to implement this project at an earlier time to maintain these multiple benefits for the subbasin.

Ongoing implementation of a multi-benefit groundwater recharge program does not depend on the implementation or performance of other projects or activities. While operation of this program is not expected to terminate, any future changes will be made to align with the District's goals and the overall Subbasin sustainability goal.

5.7.2.6 *Legal Authority, Permitting Processes, and Regulatory Control*

The following agencies have potential permitting roles for the multi-benefit groundwater recharge project: County, the State Water Resources Control Board (SWRCB), and USBR (if using CVP contract supply). If necessary, the GSA will obtain land grading permits from the County. If necessary, the GSA will apply or facilitate applications for permits required from the SWRCB for diversion of surface water to the extent that diversion is not already permitted under existing water rights and contracts. Recharge projects may also require an environmental review process under CEQA. If required, this project would need either an Environmental Impact Report and Negative Declaration or Mitigated Negative Declaration.

5.7.3 Operation and Monitoring

Following site selection, operation of the multi-benefit recharge project begins with site preparation. Prior to the "flooding window," field preparation is completed to enhance wetland habitat and recharge potential. Existing vegetation may be removed or incorporated, depending on recommendations or requirements associated with initial field conditions. Flow rate and groundwater level monitoring equipment will also be installed in the fields to facilitate project monitoring. Soil and water samples could be collected to ascertain water quality prior to wetting, as desired. Wooden stakes will also be installed to support monitoring of water depths and bird presence.

After site preparation, multi-benefit groundwater recharge will be implemented through field flooding. During the implementation period (mid-July through mid-October), participants will spread water on their fields and maintain a shallow depth (4 inches maximum) for four to six weeks. Participants will record any changes in water flow in an irrigation log. Meanwhile, the GSA would coordinate monitoring of field depth, bird presence, water delivery, and changes in groundwater depth.

5.7.4 Project Benefits and Costs

The expected benefits and costs of the multi-benefit recharge program are summarized in **Table 5-20**.

Actual participation in the program will vary from year to year, depending on grower interest, water availability, changes in cropping, and other factors. It is estimated that an average of approximately 100 acres will participate in the multi-benefit recharge program each year, assuming that approximately 10 percent of all eligible field areas will participate in the program in an average year. The total eligible area suitable for the multi-benefit recharge project was evaluated based on recharge potential and cropping, as described in **Appendix 5.F.** Recharge potential was quantified based on the area-weighted soil agricultural groundwater banking index (SAGBI) rating of fields in the Subbasin, considering only fields with a SAGBI recharge rating “moderately good” or higher (UC Davis, 2021). Crop areas suitable for multi-benefit recharge were evaluated based on 2018 Land IQ spatial land use data (Land IQ, 2021), filtering land areas by crop type to exclude permanent crops, rice, crops with growing seasons unsuited to the flooding window, and non-agricultural areas. In total, approximately 1,000 acres in the Butte Subbasin are eligible for multi-benefit recharge according to these criteria. Additional information is described in **Appendix 5.F.**

Based on observed infiltration rates in a pilot multi-benefit recharge pilot project in Colusa County, infiltration rates are expected to range between 0.2 and 1.2 inches per day for participating fields in Butte County. Assuming an average of 30 days of flooding per year, the average expected recharge benefit of the multi-benefit recharge program is approximately 175 AF per year (ranging from 50 to 300 AF per year, depending on actual field recharge rates). While changes in water availability may impact the extent of program participation from year to year, the program is anticipated to continue every year, providing both groundwater recharge and migratory bird habitat along the Pacific Flyway.

Typical program cost components are summarized in **Table 5-21**, on a per site basis. Slightly higher costs are typically incurred in the first year a site participates in the program, as more coordination and site preparation is typically required. As a site continues to participate in the program, lower costs are anticipated from year to year. Costs per site may vary depending on future changes in program requirements and incentives. The total costs of the program will vary over time, depending on the number of sites enrolled and the extent to which new sites are enrolled or returning sites continue to participate in the multi-benefit recharge program.

Table 5-20. Estimated Average Recharge Volume and Temporary Wetland Habitat Formation for the Multi-Benefit Groundwater Recharge Project.

Project	Estimated Area Eligible for Project (Acres)	Estimated Area of Participating (Acres)	Estimated Average Annual Recharge[1] (AF/year)	Estimated Average Annual Cost[2]	Annualized Cost Per AF Benefit
Multi-Benefit Groundwater Recharge	1,015	100	175	$7,000	$40

[1] Average estimated benefit, assuming 100 acres flooded for 30 days each year, with an estimated recharge rate ranging from 0.2-1.2 inches/day (50-300 AF/year).
[2] Assumes that on average 50% of sites are new and 50% of sites are established in a given year, and that average participating field sizes are 50 acres. See Table 5-21 for unit costs per site.

Table 5-21. Estimated Capital Cost and Average Annual Operating Cost per Site for the Multi-Benefit Groundwater Recharge Project.

Cost Component Per Site	Estimated Average Annual Cost at New Sites ($)[1]	Estimated Average Annual Cost at Established Sites ($)[1]
Equipment and Direct Cost	$2,000	$1,000
Other Cost (Labor, Coordination, Administration, Analysis and Development)	$2,000	$2,000
Total	$4,000	$3,000

[1] Costs estimated based on implementation costs for a multi-benefit recharge pilot project in Colusa County. Typical costs will vary between individual programs, depending on how the GSA and/or participating agencies plan to implement and monitor the program.

5.8 Grower Education Relating to On-Farm Practices for Sustainable Groundwater Management

5.8.1 Overview

A grower education and outreach program is proposed as a management action for the Butte Subbasin. The program will provide growers with educational resources that help them to plan and implement on-farm practices that simultaneously support groundwater sustainability and maintain or improve agricultural productivity. Implementation of these on-farm practices will be recorded, along with estimated or measured benefits to groundwater sustainability resulting from these practices.

Four categories of on-farm practices, or on-farm management actions, that may be covered in this program are:

1. Maximizing the use of surface water (e.g. "in-lieu" recharge),
2. Managing soils to improve infiltration and root zone soil moisture storage,
3. Reducing (and minimizing) non-beneficial ET, and
4. Precision nutrient management.

In aggregate, these on-farm practices will promote both agricultural productivity and economic benefits along with sustainable groundwater management[38]. **Table 5-22** identifies the measurable objectives that will be supported by each category of on-farm management actions.

General topics identified for the grower education program are summarized below. Additional information and topics are summarized in **Appendix 5.G**.

Table 5-22. Measurable Objectives Benefitted by On-Farm Management Actions.

On-Farm Management Action	Measurable Objectives Benefitted
Maximizing surface water use	groundwater levels, groundwater storage
Managing soils to improve infiltration and root zone soil moisture storage	groundwater levels, groundwater storage
Reducing non-beneficial ET	groundwater levels, groundwater storage
Precision nutrient management	water quality

5.8.1.1 *Maximizing use of surface water ("in-lieu" recharge)*

The use of surface water for irrigation whenever it is available is a crucial practice to support sustainable groundwater management. The use of surface water both offsets local groundwater demand through reduced groundwater pumping ("in-lieu" recharge) and increases groundwater recharge through the non-consumptive recoverable flow of deep percolation of applied surface water from the land surface to the underlying aquifer. The on-farm practices to maximize the use of surface water include implementing a dual-source irrigation system, reducing tailwater resulting from irrigation, and other actions to promote the conjunctive management of surface water and groundwater.

A dual-source irrigation system is capable of diverting and utilizing surface water for irrigation when available and utilizing groundwater if surface water is unavailable. The benefits of this practice are that every acre-foot of surface water that is utilized is an acre-foot of groundwater that remains in the aquifer ("in-lieu recharge"), supporting sustainable groundwater levels and

[38] In most cases, not all on-farm practices will be able to implemented. Also, some practices will not work in tandem with one another. For example, maximizing the use of available surface water and precision irrigation scheduling are not possible on the same field at the same time.

maintaining groundwater storage. Additionally, the applied surface water will inevitably result in some direct groundwater recharge through deep percolation. These positive impacts will initially occur in the aquifer directly beneath the grower's lands, while also influencing surrounding lands. The potential drawbacks to this system are the initial construction costs and higher maintenance costs associated with a more complex irrigation system that can draw from two water sources, as well as the potential for sediments and debris in surface water to obstruct irrigation systems. If the dual-source irrigation system is designed to accommodate this, surface water and groundwater could be intermixed during irrigation to mitigate these effects.

The on-farm management practice of reducing tailwater from irrigation and holding that water within the irrigated area will either increase the ET, increase the deep percolation, or some combination of the two. The practical steps taken to maintain these will vary from field to field. If there are irrigation application uniformity issues with over- and under-irrigation occurring in certain parts of the field, addressing these issues will promote tailwater reduction. Also, if there are low-lying portions of a field or border strips that are not in agricultural production, excess applied water can be directed to these areas where it can be contained by topography or the construction of low berms and allowed to infiltrate the ground and recharge the underlying groundwater system, rather than flowing off the field.

The two practices above are examples of conjunctive management, which recognizes that surface water and groundwater are interdependent and seeks to combine and balance the beneficial use of both water sources to promote sustainable water use while minimizing any negative economical or environmental impacts that have the potential to occur (Dudley and Fulton, 2006). Conjunctive management is often practiced on a larger scale, but it can be applied by individual growers through the practices above (and others) to maximize surface water usage when available and promote groundwater sustainability.

5.8.1.2 *Managing soil to improve infiltration and root zone soil moisture storage*

Another on-farm practice that will promote groundwater sustainability is management of soil at the ground surface and within the root zone to improve infiltration of applied water and reduce runoff or ponding on the ground surface. This can be implemented through a variety of on-farm practices including planting cover crops or utilizing crop rotations to increase organic matter content in the root zone, application of manure or other organic material, limiting soil compaction by minimizing use of heavy equipment, and if there is a restrictive layer near the surface of the ground, potentially using deep ripping or tillage to improve infiltration past the restrictive layer (Sanden et al, 2016; USDA-NRCS, 2014). Improving infiltration will result in increases in direct recharge, and improving soil moisture storage may increase effective precipitation and slightly reduce the required volume and frequency of irrigation.

5.8.1.3 Reducing non-beneficial evapotranspiration

This section describes two potential methods for reducing non-beneficial ET through altering and carefully controlling the timing and volume of applied water.

5.8.1.3.1 Precision irrigation scheduling

Precision irrigation scheduling has the potential to benefit both grower profits and sustainable groundwater management. Precision irrigation scheduling enables growers to accurately identify the timing and volume of irrigation water to apply to maximize crop productivity while minimizing water application. It typically requires real-time or near real-time information on soil moisture and weather conditions and is crop dependent. When effectively implemented, precision irrigation scheduling promotes sustainable groundwater management through increased water use efficiency; water that otherwise would have been applied to the field remains in the groundwater system or is available for use elsewhere.

5.8.1.3.2 Regulated deficit irrigation

Regulated deficit irrigation applies irrigation water during important drought-sensitive growth stages for a crop and reduces applied irrigation water (i.e. deficit irrigation) during other growth stages where there will be little to no effect on crop yields. This on-farm management practice needs to be prudently applied, but it has the potential to reduce applied water and associated irrigation costs while having little to no impact on crop yields. It promotes sustainable groundwater management through reduced consumptive use; water that otherwise would have been applied to the field is not consumed and remains in the groundwater system or is available for use elsewhere.

5.8.1.4 Precision nutrient management

Another negative impact to the groundwater system that can result from irrigated agriculture is the degradation of groundwater quality occurring from excess application of nutrients (i.e. nitrogen, phosphorus, etc.) and pesticides or herbicides. As applied water infiltrates the ground and percolates to the aquifer, it can transport excess nutrients, pesticides, or herbicides applied on the land surface during crop production. At high concentrations, these materials are a health concern if this groundwater is pumped and used for human consumption. Improving on-farm nutrient management and efficiency of nutrient application will save on-farm costs and reduce the nutrient influx to the groundwater system.

5.8.2 Implementation

GSAs will implement the grower education program by planning, preparing, and conducting outreach efforts related to the topics above. Outreach efforts may include seminars, trainings, workshops, and publications on topics related to on-farm water management and groundwater sustainability.

As GSAs begin to conceptualize and implement specific grower education programs and tools, they may consider partnering with local grower groups, educational and agricultural extension professionals, and others who are experienced in grower outreach and are knowledgeable about local agricultural practices. Potential agencies and groups that GSAs may consider partnering with are:

- University of California Cooperative Extension (UCCE)
- California State University, Chico (Chico State)
- University of California, Davis (UC Davis)

Staff and researchers at UCCE, Chico State, and UC Davis regularly partner with counties and other local agencies to conduct applied research and education programs throughout California.

5.8.2.1 *Implementation Schedule*

A general implementation schedule for the grower education program is presented in **Table 5-23.** Planning and partnership development are expected to begin in the first two years of GSP implementation, recurring as needed over the GSP implementation period. As topics are planned and partnerships are developed, education programs are expected to occur throughout GSP implementation.

It is anticipated that the public and other agencies will be notified of planned grower education activities through outreach and communication channels identified in the GSP.

Table 5-23. Grower Education Program Implementation Schedule.

Phase/Timeline Activity	Description	Year Start	Year End
Education Topic Planning	Identifying specific education topics relevant to local agricultural practices and groundwater conditions	Year 1 of Project Implementation	Ongoing
Partnership Development	Identifying and teaming with partner agencies to plan and implement grower outreach	Year 2 of Project Implementation	Ongoing
Education Program Implementation	Conducting grower education and outreach activities	Year 3 of Project Implementation	Ongoing

5.8.2.2 *Notice to Public and Other Agencies*

The public and other agencies will be notified of planned grower education activities through outreach and communication channels identified in the GSP.

5.8.2.3 *Construction Activities and Requirements*

There are no anticipated construction activities that would affect the grower education program. The grower education program will primarily require development and distribution of technical and educational resources, which GSAs will prepare through the partnerships described above.

5.8.2.4 *Water Source*

While there is no water source directly used in this program, the grower education program will promote conjunctive use of groundwater and all surface water sources available to growers, and will promote reduction in non-beneficial ET of all water sources.

5.8.2.5 *Circumstances and Criteria for Implementation*

Grower education programs will add value to other groundwater sustainability efforts at any time during GSP implementation. Because on-farm water management decisions are so impactful to achieving and maintaining groundwater sustainability, implementation of grower education programs is anticipated throughout GSP implementation, with planning efforts beginning the first year of GSP implementation. Over time, programs will be tailored to reflect current technologies and best practices in on-farm water management, especially as the GSAs' understanding of groundwater conditions in the Butte Subbasin grows.

5.8.2.6 *Legal Authority, Permitting Processes, and Regulatory Control*

GSAs have the authority to plan and partner with other groups to implement grower education activities. There are no anticipated permitting or regulatory processes that would affect the grower education program.

5.8.3 Operation and Monitoring

The grower education program will be accomplished by GSAs through partnerships with agencies, as described under the implementation section, above. GSAs and partner agencies will develop and distribute educational materials on topics relevant to local agricultural practices and groundwater conditions.

Grower responses to specific educational topics will be assessed and monitored through pre- and post-workshop surveys. These surveys will be designed to identify the extent to which growers adopt recommended practices.

All benefits to measurable objectives in the Butte Subbasin will be evaluated through groundwater monitoring and water quality monitoring at nearby monitoring sites, as identified in **Section 3** of the GSP.

5.8.4 Benefits and Costs

Implementation of grower education activities is ultimately expected to benefit groundwater levels, groundwater storage, and water quality. Encouraging growers to implement on-farm water management practices that maximize surface water use and reduce non-beneficial ET is expected to provide in-lieu recharge benefits to the groundwater system. Encouraging soil management to enhance infiltration is expected to enhance direct groundwater recharge. Both in-lieu and direct recharge are anticipated to benefit groundwater levels and groundwater storage. Encouraging growers to implement precision nutrient management is also expected to help manage nutrient loading in the subbasin, with benefits to water quality.

The benefits of grower education are expected throughout program implementation, beginning the first or second year of education program implementation (**Table 5-23**). These benefits will be monitored as described in the operation and monitoring section, above.

The total cost of the grower education program will vary depending on the types and extent of educational outreach. Grower outreach and education through social media communication may be inexpensive or virtually free, while seminars, trainings, workshops, and publications will likely incur planning and development costs. Total costs are expected to be proportional to the expansion of the education program over time. Conceptual-level estimated costs for grower education are approximately $10,000, assuming approximately two workshops per year, and that $5,000 is required for workshop preparation, implementation, and related distributed materials. Refined costs will be developed and actual costs will be described in the GSP annual reports as specific education activities are planned and implemented.

5.9 Installation of Additional Shallow Monitoring Wells

5.9.1 Overview

This project will install shallow monitoring wells in areas of the subbasin where the GSAs are interested in monitoring potential hydrologic impacts to interconnected surface water and groundwater dependent ecosystems. This project is designed to address data gaps identified in the GSP in **Section 4.4**, and will support ongoing monitoring of interconnected surface water and groundwater dependent ecosystems.

5.9.2 Implementation

The GSAs are planning to install 10 additional shallow wells to improve monitoring of surface water depletion and GDEs. All 10 of the new shallow wells will provide monitoring for GDEs and seven of the wells will be sited at locations to allow them to be added to the interconnected surface water representative monitoring network (RMN). The new shallow wells include two near the Sacramento River, two near Butte Creek, one near Little Dry Creek, one near Angel Slough and one near Feather River (**Figure 5-2**). These locations and densities of monitoring sites follow the guidelines suggested by EDF (2021).

5.9.2.1 Implementation Schedule

Implementation is planned to occur as soon as possible, pending permitting and funding.

5.9.2.2 *Notice to Public and Other Agencies*

The public and other agencies will be notified of project implementation activities through outreach and communication channels identified in the GSP.

5.9.2.3 *Construction Activities and Requirements*

This project will construct ten (10) shallow wells, each:

- 35-50 feet deep
- 2” diameter
- PVC casing with a 10-foot screened interval

5.9.2.4 *Water Source*

This project is not expected to rely on additional water supplies from outside the jurisdiction of the District.

5.9.2.5 *Circumstances and Criteria for Implementation*

Implementation is planned to occur as soon as possible, pending permitting and funding.

5.9.2.6 *Legal Authority, Permitting Processes, and Regulatory Control*

It is expected that county permits will be required for this project.

5.9.3 Operation and Monitoring

5.9.4 Benefits and Costs

The estimated cost for this project is approximately $80,000 to $100,000, assuming the average cost to drill a new shallow well in this area is between $7,000 and $9,000, excluding design and contingencies. Potential funding may come from infrastructure grants, district funding, or other sources. The primary benefit of this project will be to improve monitoring of interconnected surface water and groundwater dependent ecosystems, supporting ongoing GSP implementation and efforts to maintain groundwater sustainability. However, this project is generally expected to benefit measurable objectives related to groundwater levels and depletions of interconnected surface water, particularly. The project is also expected to support monitoring and protection of groundwater dependent ecosystems. Specific benefits and costs will be determined as the project is developed further.

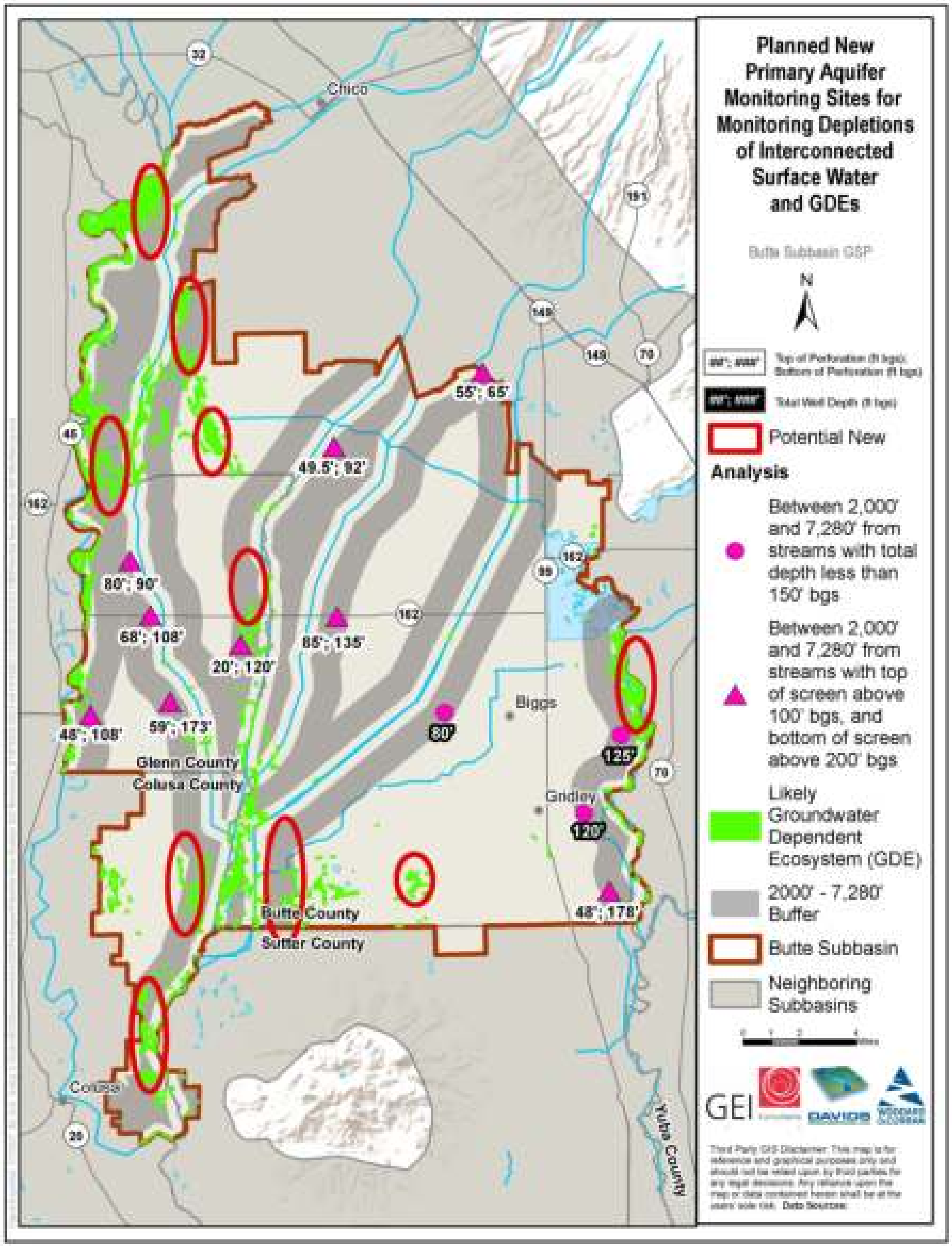


Figure 5-2. Planned New Primary Aquifer Monitoring Sites for Monitoring Depletions of Interconnected Surface Water and GDEs.

5.10 Other Identified Projects

To the extent that future monitoring indicates the occurrence of undesirable results in the Subbasin, additional projects and management actions will be implemented to address these changing conditions. Other proposed projects and management actions that will be implemented "as needed" are described in simplified detail below. Additional project development and description will occur as these projects are needed, or as GSAs pursue their implementation to support ongoing sustainability or maintain other water management objectives.

5.10.1 Multi-Agency / Jurisdiction / Landowner Projects

Proposed projects that would be implemented through coordination between multiple agencies, jurisdictions (e.g. city or county government), landowners, and/or other agencies in the Subbasin are summarized below.

5.10.1.1 *Facilitate use of available recycled water*

5.10.1.1.1 Overview

This project would facilitate use of available recycled water of suitable quality for various agricultural purposes, directly utilizing recycled water that otherwise would not be used beneficially within the Subbasin. This project will support improved water management and water use efficiency by identifying additional water supply sources to meet agricultural demand in the Subbasin and to supply groundwater recharge to the underlying aquifer. This project directly aligns with the efficient water management practice identified in California Water Code §10608.48 (c)(2). Agricultural water suppliers that are required to submit agricultural water management plans must implement this practice if locally cost-effective and technically-feasible; therefore, this project also supports agricultural water management planning requirements.

5.10.1.1.2 Implementation

This project will help agricultural water suppliers to identify available recycled water sources of suitable quality that are otherwise unused in the Subbasin. Recycled water may be used for irrigation or other agronomic purposes, replacing and offsetting a like quantity of groundwater or surface water. Eligible recycled water supply must meet all health and safety criteria, and must not harm crops or soils. This project can be designed to supply groundwater recharge and surface water supply benefits to disadvantaged communities, provided that the quality of this water is determined to be of suitable high quality for use. Required permitting activities will be determined as the project is developed further.

5.10.1.1.3 Benefits and Costs

This project is currently in the early conceptual stage. As such, the expected yield and anticipated costs of this project have yet to be determined. However, this project is generally expected to benefit measurable objectives related to groundwater levels, change in groundwater storage, and surface water depletion. Specific benefits and costs will be determined as the project is developed further. Potential funding sources may include grant funding from the USDA-NRCS or other sources.

5.10.1.2 *Facilitate financing of capital improvements for on-farm irrigation systems*

5.10.1.2.1 Overview

This project would facilitate financing of capital improvements for on-farm irrigation systems. This project will support improved agricultural water conservation and on-farm water management by helping growers to upgrade their irrigation system to potentially improve water use efficiency and improve precision in nutrient application. This project directly aligns with the efficient water management practice identified in California Water Code §10608.48 (c)(3). Agricultural water suppliers that are required to submit agricultural water management plans must implement this practice if locally cost-effective and technically-feasible; therefore, this project also supports agricultural water management planning requirements.

5.10.1.2.2 Implementation

This project will help growers to upgrade on-farm infrastructure and improve their irrigation equipment by providing direct financial assistance or by providing technical assistance to help growers apply for financial assistance programs implemented by other entities. Typical on-farm capital improvements may include upgrading from low-efficiency to high-efficiency irrigation systems, or upgrading to dual source irrigation systems (see **Section 5.6**).

While on-farm irrigation efficiency improvements have the potential to reduce on-farm groundwater recharge (see **Section 5.8**), facilitating capital improvements for on-farm irrigation systems has several benefits. Improved irrigation systems can help growers to reduce non-beneficial evaporative losses from fields and can improve nutrient management to preserve downstream water quality. If dual source irrigation systems are installed, they may allow growers to utilize surface water instead of groundwater, providing in-lieu groundwater recharge benefits to the Subbasin. This project can be designed to benefit disadvantaged communities, especially to the extent that financing of capital improvements for on-farm irrigation systems is made available to disadvantaged communities. Required permitting activities will be determined as the project is developed further.

5.10.1.2.3 Benefits and Costs

This project is currently in the early conceptual stage. As such, the expected yield and anticipated costs of this project have yet to be determined. However, this project is generally expected to benefit measurable objectives related to groundwater levels, change in groundwater storage, surface water depletion, and water quality. Specific benefits and costs will be determined as the project is developed further. Potential funding sources may include grant funding from the USDA-NRCS or other sources.

5.10.1.3 Improve Monitoring of Surface Water Outflows and Refine Water Balances

5.10.1.3.1 Overview

This project would improve monitoring of surface water outflows and refine water balances in the Subbasin, with the goal of improving understanding of interactions between surface water and groundwater, and of the precise balance of net recharge from the surface water system in the Subbasin. Greater knowledge of surface water and groundwater interactions would enhance ongoing refinement of the basin setting and the evaluation of conjunctive management opportunities to increase local water supplies to meet local and regional water management objectives. This project was proposed in the Feather River Regional Agricultural Water Management Plan (FRRAWMP 2014).

5.10.1.3.2 Implementation

This project will organize a multi-agency effort to

- Increase monitoring and share knowledge of surface water outflows from the Subbasin, and
- Enhance and coordinate the refinement and reporting of water balances for districts and areas in the subbasin.

Improved, basin-wide data and monitoring afforded by this project will benefit future understanding and refinement of the basin setting as GSP implementation proceeds. These data may also benefit GSAs as they explore conjunctive management opportunities to increase local water supplies to meet local and regional water management objectives. These data will also support various other water management planning activities in the Subbasin, from District-level agricultural water management planning to regional-scale integrated water management planning. This project is anticipated to have basin-wide benefits, thereby benefitting all disadvantaged communities, environmental users, and other beneficial users in the Butte Subbasin. There are no anticipated permitting activities that would be required for this project, though this would be determined as the project is developed further.

5.10.1.3.3 Benefits and Costs

This project has been proposed as a potential project for the Butte Subbasin. As such, the expected yield and anticipated costs of this project have yet to be determined. However, this project is generally expected to benefit measurable objectives related to groundwater levels, change in groundwater storage, and surface water depletion. Specific benefits and costs will be determined as the project is developed further. Potential funding sources may include grant funding or other sources.

5.10.1.4 Develop Partnerships to Support Regional Water Management

5.10.1.4.1 Overview

This project will develop and foster partnerships between agencies in the Butte Subbasin to support regional water management. Such partnerships may support regional water management planning or project development. This project was proposed in the 2014 FRRAWMP, and is aimed at improving water management and operational enhancement among the various entities in the Subbasin.

5.10.1.4.2 Implementation

Partnerships in this project could be directly between individual agricultural suppliers, environmental water managers, or others, and could involve several parties working in coordination to maintain multiple benefits. Inter-agency projects may be planned to support basin-wide and common interests, such as supporting groundwater dependent ecosystems. This project is anticipated to have basin-wide benefits, thereby benefitting all disadvantaged communities, environmental users, and other beneficial users in the Butte Subbasin. Voluntary agreements may be required for implementation.

5.10.1.4.3 Benefits and Costs

This project has been proposed as a potential project among agencies in the Butte Subbasin. The expected yield and anticipated costs of this project have yet to be determined. However, this project is generally expected to benefit measurable objectives related to groundwater levels, change in groundwater storage, and surface water depletion. Specific benefits and costs will be determined as the project is developed further. Potential funding sources may include grant funding or other sources.

5.10.1.5 Re-Establish Historical Monitoring Locations and Identify New Sites

5.10.1.5.1 Overview

This project would re-establish historical monitoring locations and identify net monitoring sites, with the goal of improving data and monitoring in the Subbasin. Greater knowledge of surface water flows, hydrologic conditions, and groundwater system responses to water management activities would support GSAs as they implement the GSP and work to maintain groundwater sustainability. This project was proposed in the 2014 FRRAWMP.

5.10.1.5.2 Implementation

This project will organize a multi-agency effort to re-establish monitoring sites and identify new sites (including surface water and groundwater monitoring sites) in areas where data gaps, significant uncertainty, or specific concerns for hydrologic conditions exist. This project may be supported by DWR, among other local interests. At present, there is limited information describing surface flows between water use areas within the region. Also, current hydrologic conditions and system responses to water management activities are not adequately monitored. This project would directly address these needs, and support a variety of water management planning activities in the Subbasin, from District-level agricultural water management planning to regional-scale integrated water management planning. This project is anticipated to have basin-wide benefits, thereby benefitting all disadvantaged communities, environmental users, and other beneficial users in the Butte Subbasin. Required permitting activities will be determined as the project is developed further.

5.10.1.5.3 Benefits and Costs

This project has been proposed as a potential project among agencies in the Butte Subbasin. The expected yield and anticipated costs of this project have yet to be determined. However, this project is generally expected to benefit measurable objectives related to groundwater levels, change in groundwater storage, and surface water depletion. Specific benefits and costs will be determined as the project is developed further.

5.10.1.6 Monitoring Well in Southwestern Butte Subbasin

5.10.1.6.1 Overview

This project will install an additional monitoring well in the southwestern portion of the Butte Subbasin, providing GSAs with additional data related to groundwater levels.

5.10.1.6.2 Implementation

The proposed monitoring well would be installed in the southwestern portion of the Butte Subbasin. Implementation is planned to occur as soon as possible, pending permitting and funding. It is expected that a Glenn County permit will be required for this project.

5.10.1.6.3 Benefits and Costs

The estimated cost for this project is approximately $140,000. Potential funding may come from RD 1004 or other sources. Expected benefits that have yet to be determined. However, this project is generally expected to benefit measurable objectives related to groundwater levels and change in groundwater storage. Specific benefits and costs will be determined as the project is developed further.

5.10.2 Butte Water District GSA Projects

Proposed projects that would be implemented by Butte Water District GSA are summarized below.

5.10.2.1 *Boundary Flow and Primary Spill Measurement*

5.10.2.1.1 Overview

BWD has proposed a boundary flow and primary spill measurement project for its irrigation distribution system as part of its comprehensive plan for system modernization and boundary flow monitoring developed and reported in the Feather River Regional Agricultural Water Management Plan (FRRAWMP). The project is similar to the boundary flow and primary spill measurement project currently being implemented by WCWD, described in **Section 5.5**. The project will support water operators in remote monitoring of system outflows and help them to quickly respond to any excess or shortages by moving water within the system and by changing diversions at Thermalito Afterbay. Enhanced monitoring afforded by this project will help operators to reduce operational spillage and leave water in the Feather River system to meet the needs of threatened and endangered aquatic species, including Chinook Salmon and Steelhead Trout.

5.10.2.1.2 Implementation

Potential improvements that will be implemented as part this project will generally consist of:

- Remote monitoring equipment at all sites (e.g. SonTek acoustic doppler velocity meters (ADVM) or pressure transducers), and
- Associated hardware, including field radio equipment to support SCADA integration

The measurement devices and methods at each remote monitoring site will be calibrated through field measurements using stream gaging techniques to ensure accurate flow measurement across a range of flows. Real time monitoring of these sites will help district water operators to optimize surface water use, allowing them to quickly detect excesses and shortages in the system and to reduce operational spillage while improving response to customer demands. Monitoring and verification work will occur throughout project implementation to identify the pre-implementation and post-implementation benefits and effects of the project on the BWD system. Anticipated permitting requirements are expected to be the same as those described in **Section 5.5**. The timeline for implementation is subject to available funding.

5.10.2.1.3 Benefits and Costs

The total combined cost of all boundary outflow and primary spill measurement improvements is estimated to be approximately $530,000 (as of July 2014). Potential funding sources may include grant funding or other sources. Through implementation of the complete project, it is estimated that between approximately 3,500 and 10,500 af per year will be conserved by this project. These system improvements are also expected to help the District’s water operators to more effectively and efficiently adjust system inflows and maneuver water to supply deliveries. While there is limited opportunity to increase overall water supplies by reducing operational losses since these losses become available for downstream use, there are opportunities to increase local, regional, and statewide water supply and water supply reliability by better managing when and where available water supplies are used and when and where water returns to the system.

5.10.2.2 System Modernization

5.10.2.2.1 Overview

BWD has proposed a modernization project for its irrigation distribution system as part of its comprehensive plan for system modernization and boundary flow monitoring developed and reported in the FRRAWMP. The project is similar to the system modernization projects currently being implemented by BWGWD and RID, described in **Section 5.6.** System modernization improvements will help system operators to strategically manage surface water diversions from the Feather River, supporting their ability to increase system efficiency, reduce operational spillage, and/or reduce excess farm deliveries. The system modernization projects generally include improvements to three site categories: heading structures, upstream water level control structures, and spill structures. **Table 5-6** in **Section 0** identifies the modernization objectives of improvements to each site category, and the measurable objectives that are expected to benefit from these improvements. Each project is expected to promote the ongoing maintenance of sustainable conditions in the Butte Subbasin.

5.10.2.2.2 Implementation

The system modernization project will likely be implemented in multiple phases, with multiple potential levels of improvement. The complete proposed system modernization plan will include comprehensive improvements to the district's distribution system, adding several automated control structures, improved measurement, and other modernization improvements. The timeline for implementation is subject to available funding. Anticipated permitting requirements are expected to be the same as those described in **Section 5.6.** The timeline for implementation is subject to available funding.

5.10.2.2.3 Benefits and Costs

The total combined cost of all phases and levels of system modernization improvements is estimated to be approximately $14,000,000 (as of July 2014). Potential funding sources may include grant funding or other sources. Through implementation of the complete system modernization program, it is estimated that between approximately 2,000 and 5,000 af per year will be conserved by this project. Improvements would allow reduced operational spillage and reduced deliveries due to increased delivery efficiency, which would reduce on-farm tailwater and, in some cases, deep percolation. Reduced deliveries result in reduced diversions, which results in corresponding reductions in spillage and drainage outflows. Available water not diverted remains in storage and could potentially be available to meet unmet local demands or to meet regional or statewide objectives. Additionally, water quality benefits may occur through reduced tailwater outflow.

5.10.2.3 Improved Delivery Service to Pressurized Irrigation Systems

5.10.2.3.1 Overview

BWD has proposed a project to improve delivery service to pressurized irrigation systems as part of its comprehensive plan for system modernization and boundary flow monitoring developed and reported in the Feather River Regional Agricultural Water Management Plan (FRRAWMP). The project is directly related to and supportive of the District's dual source irrigation system project described in **Section 5.6.** The project will also be supported by the District's planned system modernization project described above. This project will help supply surface water to irrigators that use pressurized irrigation systems, offsetting groundwater use with in-lieu groundwater recharge benefits to the Subbasin.

5.10.2.3.2 Implementation

This project will increase BWD's ability to meet irrigation water needs using available surface water. System modernization improvements that will benefit improved delivery service flexibility and consistency include:

- Heading control structures
- Upstream water level control structures
- Spill control structures
- Remote monitoring and control equipment

Enhancing the availability and reliability of surface water supplies to support low-flow, long-duration irrigation events will support growers as they adopt dual source irrigation systems. The advantage of groundwater as an on-demand water supply diminishes if surface water is available with similar consistency and reliability. Anticipated construction and permitting requirements are expected to be similar to those described in **Section 5.6.** The timeline for implementation is subject to available funding.

5.10.2.3.3 Benefits and Costs

The total project cost is estimated to be approximately $3,900,000 (as of July 2014). Potential funding sources may include infrastructure grant funding, district funding, or other sources. The expected yield of this project has not been estimated at this time. In the future it is anticipated that the estimated benefits of this project will be evaluated as more information becomes available.

5.10.2.4 Removal of Bottlenecks on the Sutter-Butte Main Canal

5.10.2.4.1 Overview

BWD has proposed a project to remove bottlenecks on the Sutter-Butte Main Canal, improving delivery service to irrigation customers. This project is proposed as part of the district's comprehensive plan for system modernization and boundary flow monitoring developed and reported in the Feather River Regional Agricultural Water Management Plan (FRRAWMP). The project will be supported by the District's planned system modernization project and improved delivery service to pressurized irrigation systems project, described above.

5.10.2.4.2 Implementation

This project will increase BWD's ability to meet irrigation water needs using available surface water by reducing capacity constraints that prevent conveyance and full utilization of supplies.

Enhancing the availability and reliability of surface water supplies offsets demand for groundwater, providing in-lieu recharge benefits to the Subbasin. Anticipated construction and permitting requirements are expected to be similar to those described in **Section 5.6**, including CEQA and NEPA permitting. The timeline for implementation is subject to available funding.

5.10.2.4.3 Benefits and Costs

The total project cost is estimated to be approximately $870,000 (as of July 2014). Potential funding sources may include infrastructure grant funding, district funding, or other sources. The expected yield of this project has not been estimated at this time. In general, measurable objectives expected to benefit from the project include groundwater levels, change in groundwater storage, and surface water depletion. In the future it is anticipated that the estimated benefits of this project will be evaluated as more information becomes available.

5.10.3 M & T Ranch, Chico / Rancho Llano Seco

Proposed projects that would be implemented by M&T Ranch and Chico / Rancho Llano Seco are summarized below.

5.10.3.1 M & T - Llano Seco Fish Screen Project

5.10.3.1.1 Overview

The M&T – Llano Seco Fish Screen Project will modify the M & T Chico Ranch Pump Station intake structures at the Sacramento River to clear inflows and incorporate fish screens. This project will reduce groundwater reliance and potential depletion, in case of failure of the diversion.

5.10.3.1.2 Implementation

Implementation of the project will modify existing intake structure to cone screens. The project will require long-term dredging at the intake, and will retain existing rock-toe revetment. Implementation is planned to occur as soon as possible, pending final designs, permitting, and funding. Permits anticipated to apply to this project include USACE 404, RWQCB Section 401, and CADFW Section 1602 permits. The project is expected to benefit beneficial users in Butte County within disadvantaged communities.

5.10.3.1.3 Benefits and Costs

The anticipated benefit of this project is approximately 20,000 to 40,000 acre-feet per year, depending on water supplies at the intake. In general, this project is expected to enhance water supply and supply reliability and improve delivery flexibility to water users, also reducing groundwater use in curtailment years. Anticipated costs are not available at this time, as they will depend on the final project design. In the future it is anticipated that the costs and estimated benefits of this project will be evaluated as more information becomes available. Potential funding sources may include grant funding, cost share, or other sources.

5.10.3.2 Parrott Phelan Diversion Restoration Project

5.10.3.2.1 Overview

The Parrott Phelan diversion restoration project is planned to restore the diversion and fish screening project, originally completed in 1995 and currently in jeopardy of failure. This project will reduce groundwater reliance and potential depletion, in case of failure of the diversion.

5.10.3.2.2 Implementation

This cooperative project has been planned by a variety of agencies, and will be implemented jointly with the Butte County Department of Water and Resource Conservation. As planned, the project will result in reestablishment of the original channel and provide a flood bypass to handle excess flood flows to protect the diversion from channel realignment in the future. The flood bypass channel will contain rock slope protection along Butte Creek just past the entrance to the overflow. Shotcrete and rock slope protection will be utilized to stabilize the entrance to the overflow channel to prevent additional erosion. Implementation depends on securing necessary permits and funding. Permits anticipated to apply to this project include USACE 404, RWQCB Section 401, and CADFW Section 1600 permits. The project is expected to benefit beneficial users in Butte County within disadvantaged communities.

5.10.3.2.3 Benefits and Costs

The anticipated benefit of this project is approximately 10,000 to 30,000 acre-feet per year, depending on water supplies. In general, this project is expected to enhance water supply and supply reliability and improve delivery flexibility to water users, also reducing groundwater use in curtailment years. Anticipated costs have not been developed at this time, as they will depend on the extent of permit perimeters. In the future it is anticipated that the costs and estimated benefits of this project will be evaluated as more information becomes available. Potential funding sources may include grant funding, cost share, or other sources.

5.10.4 Richvale Irrigation District GSA

Proposed projects that would be implemented by Richvale Irrigation District GSA are summarized below.

5.10.4.1 *Alternate Delivery to RID Secondary Service Area via Kelleher Dam*

5.10.4.1.1 Overview

This project would provide an alternate delivery route to RID's secondary service area using Kelleher Dam, a privately owned dam located on the east side of the Cherokee Canal. The objective of this project is to convey water to the secondary service area, enhancing RID's water management efforts by avoiding several key constraints of current service. First, delivering water to secondary users currently requires that the entire distribution system be charged, resulting in operational spillage. Second, the secondary users often require water during periods when rice fields are being drained, increasing the accretion to fields and preventing complete drainage. Use of Kelleher Dam would alleviate these challenges and reduce water loss through spillage. This project is proposed as part of the "Potential Projects to Enhance RID Water Management Capabilities" in the FRRAWMP. Additional information is provided in **Appendix 5.C.1**.

5.10.4.1.2 Implementation

An alternate delivery to RID's secondary service area from Kelleher Dam has been identified by RID in the FRRAWMP at a conceptual planning level. Water would be siphoned under the Cherokee Canal to allow delivery to the secondary service area using the Kelleher supply ditches and diversion dam. The conceptual system would consist of:

- A siphon of approximately 500 linear feet and 36 inch diameter, with a capacity of 25 cubic feet per second (cfs)
- A flow measurement point constructed at the diversion, with remote monitoring equipment to verify the delivery rate to the secondary service area and support water accounting

No modifications to the existing diversion dam are assumed to be required. This project is anticipated to benefit water users in RID and RID's secondary service area, with indirect benefits to environmental water users that may benefit by improved, strategic timing of instream flows from water conserved by this project. Required permitting activities will be determined as the project is developed further.

5.10.4.1.3 Benefits and Costs

The reconnaissance-level total cost estimate for this project is approximately $1,114,000, with estimated annualized costs of $61,000 (as of July 2014). These costs include engineering and design, legal, environmental, and contingencies. A net benefit analysis has not been performed for this project at this time. In the future it is anticipated that the costs and estimated benefits of this project will be evaluated as more information becomes available. In general, this project is expected to enhance water supply and supply reliability and improve delivery flexibility to secondary users, also reducing groundwater use in curtailment years. To the extent that water conserved by the project is retained in storage upstream, this project may also improve the timing of instream flow. This project may also improve water quality and water management by helping the District to manage drainage from fields and the Distribution system.

5.10.4.2 *Boundary Flow and Primary Spill Measurement*

5.10.4.2.1 Overview

RID has proposed a boundary flow and primary spill measurement project for its irrigation distribution system as part of its comprehensive plan for system modernization and boundary flow monitoring developed and reported in the Feather River Regional Agricultural Water Management Plan (FRRAWMP). The project is similar to the boundary flow and primary spill measurement project currently being implemented by WCWD, described in **Section 5.5**. Additional information about the RID project is described in **Appendix 5.C.1.** The project will support water operators in remote monitoring of system outflows and help them to quickly respond to any excess or shortages by moving water within the system and by changing diversions at Thermalito Afterbay. Enhanced monitoring afforded by this project will help operators to reduce operational spillage and leave water in the Feather River system to meet the needs of threatened and endangered aquatic species, including Chinook Salmon and Steelhead Trout.

5.10.4.2.2 Implementation

Potential improvements that will be implemented as part this project and described in **Appendix 5.C.1**, and will generally consist of:

- A SCADA base station
- Remote monitoring equipment at all sites (e.g. SonTek acoustic doppler velocity meters (ADVM), Remote Tracker flow measurement devices, or pressure transducers), and
- Associated hardware, including field radio equipment to support SCADA integration

The measurement devices and methods at each remote monitoring site will be calibrated through field measurements using stream gaging techniques to ensure accurate flow measurement across a range of flows. Real time monitoring of these sites will help district water operators to optimize surface water use, allowing them to quickly detect excesses and shortages in the system and to reduce operational spillage while improving response to customer demands. Monitoring and verification work will occur throughout project implementation to identify the pre-implementation and post-implementation benefits and effects of the project on the RID system. Anticipated permitting requirements are expected to be the same as those described in **Section 5.5.** The timeline for implementation is subject to available funding.

5.10.4.2.3 Benefits and Costs

The total combined reconnaissance-level cost of all boundary outflow and primary spill measurement improvements is estimated to be approximately $381,000, with estimated annualized costs of $36,000 (as of July 2014). Potential funding sources may include grant funding or other sources. It is estimated that between approximately 4,500 and 13,500 af per year will be conserved by this project. These system improvements are also expected to help the District's water operators to more effectively and efficiently adjust system inflows and maneuver water to supply deliveries. While there is limited opportunity to increase overall water supplies by reducing operational losses since these losses become available for downstream use, there are opportunities to increase local, regional, and statewide water supply and water supply reliability by better managing when and where available water supplies are used and when and where water returns to the system.

5.10.4.3 *Shu Fly/Cherokee Project*

5.10.4.3.1 Overview

The Shu Fly / Cherokee Project is planned to improve water management in the RID service area.

5.10.4.3.2 Implementation

Implementation is expected to occur in 3-5 years, depending on funding and implementation of other ongoing or planned district projects. This project is anticipated to benefit water users in RID, with indirect benefits to environmental water users that may benefit by improved, strategic timing of instream flows from water conserved by this project. Required permitting activities will be determined as the project is developed further.

5.10.4.3.3 Benefits and Costs

This project has been proposed as a potential project among agencies in the Butte Subbasin. The conceptual-level estimated total cost for this project is approximately $4,000,000. Potential funding sources may include grant funding or other sources. The expected yield has yet to be determined. Implementation of the Shu Fly/Cherokee project is expected to increase water supply and supply reliability, flexibility, and/or instream flow; improve water quality; increase water management, and reduce groundwater depletion in curtailment years. This project is generally expected to benefit measurable objectives related to groundwater levels, change in groundwater storage, and surface water depletion. Specific benefits and costs will be determined as the project is developed further.

5.10.5 Western Canal Water District GSA

Proposed projects that would be implemented by Western Canal Water District GSA are summarized below.

5.10.5.1 System Modernization

5.10.5.1.1 Overview

WCWD has proposed a modernization project for its irrigation distribution system as part of its comprehensive plan for system modernization and boundary flow monitoring developed and reported in the Feather River Regional Agricultural Water Management Plan (FRRAWMP). Detailed information about the project is included in the FRRAWMP and in project documentation included in **Appendix 5.D.1.** The project is similar to the system modernization projects currently being implemented by BWGWD and RID, described in **Section 5-4.** System modernization improvements will help system operators to strategically manage surface water diversions from the Feather River, supporting their ability to increase system efficiency, reduce operational spillage, and/or reduce excess farm deliveries. The system modernization projects generally include improvements to three site categories: heading structures, upstream water level control structures, and spill structures. **Table 5-6** in **Section 5-4** identifies the modernization objectives of improvements to each site category, and the measurable objectives that are expected to benefit from these improvements. Each project is expected to promote the ongoing maintenance of sustainable conditions in the Butte Subbasin.

5.10.5.1.2 Implementation

The system modernization project will be implemented in multiple phases, with multiple potential levels of improvement. The complete proposed system modernization plan described in **Appendix 5.D.1** represents comprehensive improvements to the district's distribution system, adding several automated control structures, improved measurement, new heading structures, re-regulation points, and SCADA:

- SCADA office base station
- Modernization of primary inflow locations and primary operational outflow locations
- Improvement of Main Canal (Western Canal) primary control points
- Improvement of lateral primary control points and spill routing
- Improvement of lateral secondary points, sublateral control points, and secondary spill points

Specific planned improvements and construction requirements are described in **Appendix 5.D.1.** Anticipated permitting requirements are expected to be the same as those described in **Section 5-4.**

5.10.5.1.3 Benefits and Costs

The total combined cost of all phases and levels of system modernization improvements is estimated to be approximately $11,180,000, with estimated annualized costs of $743,000 (as of July 2014). Costs for individual phases and levels of modernization improvements are further summarized in **Appendix 5.D.1 Table 6.** Additionally, the costs of a SCADA base station and mobile operator terminals that would form the backbone of the District SCADA system have been estimated (approximately $138,000 total, as of July 2014), along with the cost of spare equipment to be kept on hand to repair or replace individual site components (approximately $24,000 total, as of July 2014).

Through implementation of the complete system modernization program, it is estimated that approximately 20 to 50 percent of existing operational spillage could be conserved annually, or between approximately 5,000 and 12,000 af per year. Improvements would allow reduced operational spillage and reduced deliveries due to increased delivery efficiency, which would reduce on-farm tailwater and, in some cases, deep percolation. Reduced deliveries result in reduced diversions, which results in corresponding reductions in spillage and drainage outflows. Available water not diverted remains in storage and could potentially be available to meet unmet local demands, provide direct or in-lieu groundwater recharge, or to meet regional or statewide objectives. Additionally, water quality benefits may occur through reduced tailwater outflow, depending on the quality of tailwater.

5.10.5.2 *Little Butte Creek Reservoir Main Canal Bypass Project*

5.10.5.2.1 Overview

WCWD has proposed a project that would construct a bypass canal from a reservoir on Little Butte Creek and provide unrestricted supply via siphons to the Main and Ward Canals. The reservoir is formed in an intentionally impounded section of Little Butte Creek that accepts inflows from the east via the Western Canal and allows for delivery on the west side to the Main and Ward Laterals. This project will increase conveyance from the reservoir, reduce fluctuations in supply, and add measurement to deliveries made to the Main and Ward Canals. These improvements are expected to increase operational efficiency and surface water utilization in WCWD, helping to reduce groundwater reliance and depletion in case of failure. The project will also provide additional data to support water use monitoring. The Little Butte Creek Reservoir Main Canal bypass project is part of the district's comprehensive plan for system modernization and boundary flow monitoring developed as part of the Feather River Regional Agricultural Water Management Plan (FRRAWMP). Detailed information about the plan is included in the FRRAWMP and in project documentation included in **Appendix 5.D**.

5.10.5.2.2 Implementation

In this project, a bypass canal would be constructed from the impounded section of Little Butte Creek along the eastern edge of the Creek until approximately the location of the Front and Back Slide Gates, where three individual siphons would carry the flow under the Creek to provide unrestricted flow to supply the Main and Ward Canals. A conceptual project design of the project elements was developed in the FRRAWMP, assuming:

- Total length of newly constructed canal would be approximately 6,300 feet, with an additional 1,200 feet of inverted siphons (ranging from 200 feet to 700 feet each).
- Design capacity estimated at 500 cfs.
- Limited ground slope (approximately 0.00013 ft/ft) is estimated to exist along the proposed alignment.
- A trapezoidal canal with a top width of approximately 60 ft was assumed, and two parallel 60" diameter pipes were assumed for each siphon.
- Siphons would be installed using bore and jack methods to minimize impacts to the Creek.
- The canal would be unlined and embankments constructed of compacted earth fill sourced from excavation. It was assumed cut and fill quantities would approximately balance requiring no import.

Permits that may be required for this project include USACE 404, RWQCB Section 401, CADFW Section 1600 permits. CEQA and NEPA activities are also likely needed. An environmental impact/benefit analysis should be completed to evaluate the environmental impact that removal might pose, as opposed to simply removing the gate panels and abandoning the structure. This project is currently in the initial planning phase, as recent failure has been noticed and is an immediate issue of concern to the district. The project is expected to be initiated and completed in the next 1-10 years.

5.10.5.2.3 Benefits and Costs

The reconnaissance level total cost estimates for total implementation of this project is approximately $12,815,000 with estimated annualized costs of $758,000 (as of July 2014). Estimated costs do not account for the removal of the Front and Back Slide Gates, which would add additional cost. Potential funding sources may include infrastructure grant funding, district funding, or other sources.

In general, measurable objectives expected to benefit from the project include groundwater levels, change in groundwater storage, and surface water depletion. The construction of a reservoir bypass canal and related components has no water conservation benefits that could be reasonably quantified at this stage of design. In the future it is anticipated that the estimated volumetric benefits of this project will be evaluated as more information becomes available. Several qualitative benefits to WCWD include:

- Reduction of labor requirements associated with operations of the reservoir.
- Increased capacity to meet downstream irrigation demand
- Reduced potential for environmental impacts associated with impounding water
- Feather River water and Little Butte Creek flows no longer required to be comingled.
- Potential for reduced spillage due to additional control over inflows.
- Increased safety due to elimination of the Front and Back Slide Gates.

5.10.5.3 *Increase planned conjunctive use of surface water and groundwater within the supplier service area*

5.10.5.3.1 Overview

WCWD is planning to increase conjunctive use of surface water and groundwater within the district's service area. In this water management strategy, WCWD will continue to use surface water when it is available, providing in-lieu and direct groundwater recharge benefits of surface water use to the Subbasin. During periods of shortage, WCWD will use both surface water and groundwater to meet demand. This project directly aligns with the efficient water management practice identified in California Water Code §10608.48 (c)(8). As an agricultural water supplier subject to agricultural water management planning regulations, WCWD must implement this practice if locally cost-effective and technically-feasible; therefore, this project also supports WCWD's agricultural water management planning efforts.

5.10.5.3.2 Implementation

Conjunctive use generally consists of increased use of surface water for irrigation and groundwater recharge in years when sufficient surface water supply is available, balanced by increased groundwater pumping in years when surface water supply is curtailed. To be effective and sustainable, groundwater conditions must be routinely monitored and conjunctive use must be managed to ensure that sufficient recharge is done in wetter years to offset increased groundwater demand in drier, curtailed years. WCWD's shortage allocation policies are designed to facilitate the conjunctive use of groundwater in surface water shortage years. WCWD plans to work in coordination with Butte County, Glenn County, and DWR to implement and monitor conjunctive use.

5.10.5.3.3 Benefits and Costs

While conjunctive use is generally ongoing in WCWD, this project is currently in the planning phase for expansion and further development. The expected yield and anticipated costs of this project have yet to be determined. However, this project is generally expected to benefit measurable objectives related to groundwater levels, change in groundwater storage, and surface water depletion. Conjunctive use also benefits districts and growers by sustaining the total irrigation supply to meet water demand regardless of surface water supply conditions from year to year. Specific benefits and costs will be determined as the project is developed further. Potential funding sources may include grant funding, district funding, or other sources.

5.11 Project Financing

The GSAs intend to finance the capital costs of projects through available state and federal grants and/or assessments through the District corporate structures. Operation and maintenance costs will be paid using revenues raised through water rates and/or fees and assessments. The Districts will explore and conduct any necessary studies and decision processes (including Proposition 218 elections) to approve rates, fees, or assessments to provide the required funding.

Specific grant funding sources for ongoing projects in the Butte Subbasin include:

- CALFED Water Use Efficiency Grant
  - Biggs-West Gridley Water District system modernization project: "Infrastructure Modernization and Canal Operations Decision Support"
  - Richvale Irrigation District system modernization project: "Phase I Distribution System Modernization"
- WaterSMART Grants: Water and Energy Efficiency Grant
  - Western Canal Water District boundary outflow and primary spill measurement project: "SCADA System Implementation and Boundary Outflow Monitoring"

5.12 Coordination Between GSAs

As part of the Butte Subbasin GSP, all GSAs in the Butte Subbasin have agreed to coordinate with each other, and with neighboring GSAs in the surrounding subbasins. Coordination will continue among these and other agencies as needed to implement projects successfully. Coordination will include potential pursuit of grant funding, design and construction efforts that affect multiple GSAs, and joint education and outreach efforts.

All the GSAs in the Butte subbasin entered into a Cooperation Agreement ("Cooperation Agreement Among the Groundwater Sustainability Agencies in the Butte Subbasin" – available in **Appendix 1.B**) that details coordination within the Subbasin. There is also an Interbasin Coordination Plan (**Appendix 7.A**) that describes coordination with neighboring GSAs in adjacent subbasins.

5.13 Subbasin Water Available for Projects

Ongoing and planned projects in the Butte Subbasin are generally aimed at maximizing use of existing surface water supplies and reducing boundary outflows. Consequently, existing water rights contracts are the primary source of surface water available for and managed by projects. Available surface water is generally diverted from the Feather River based on a combination of pre-1914, riparian, and appropriative water rights and based on diversion agreements between Feather River Contractors and the State of California (State). The precise availability of total surface supplies varies from year to year, depending on hydrologic conditions and stipulations in the districts' diversion agreements.

Ongoing and planned projects and management actions, described in detail in **Sections 5.2 through 5.7** above, are expected to "achieve the sustainability goal for the basin… [and] respond to changing conditions in the basin" (23 CCR §354.44(a)). Districts implementing projects currently in progress hold pre-1914 water rights on the Feather River and, as a result, have a relatively reliable surface water supply. **Table 5-24** summarizes the average total diversions, average other inflows, average drainage, and average deliveries that pass through the distribution systems of districts currently implementing projects and management actions. Averages are summarized from the 2021 Feather River Regional Agricultural Water Management Plan (FRRAWMP), based on the flow paths indicated in **Table 5-25**. Average total diversions range from approximately 107,000 to 307,000 AF per year per district. Much of this surface water is delivered to support agricultural and environmental beneficial uses in or around each district, with total deliveries ranging from approximately 76,000 to 271,000 AF per year per district. Some water also leaves the distribution systems through outflow locations, and is available for other beneficial uses downstream, whether inside or outside the Subbasin. A portion of each District's surface water diversions may be beneficially used to support recharge projects, to the extent that they are not already used beneficially for other purposes in other locations in the District or the Subbasin. The total surface water used or available for use in 1999-2019 ranged from 112,000 to 282,000 AF per year per district.

Specific details about the water supplies available to each district are summarized below and in the 2021 Feather River Regional Agricultural Water Management Plan (FRRAWMP).

Table 5-24. Average Annual Diversions, Other Inflows, and Drainage from Districts with Ongoing or Planned Projects and Management Actions, Water Years 1999-2019 (Source: FRRAWMP, 2021)

District	Joint Districts	Average Total Diversion[1] (AF/water year)	Average Total Other Inflow[1] (AF/water year)	Average Total Drainage[1] (AF/water year)	Average Total Deliveries (AF/water year)[1]
Biggs-West Gridley Water District	X	210,400	153,100	163,900	180,900
Butte Water District	X	106,600	86,100	81,000	75,800
Richvale Irrigation District	X	190,700	114,300	174,300	146,700
Western Canal WD		306,800	157,300	182,300	270,500

[1] Data sources listed in **Table 5-24**. Volumes rounded to 100 AF.

Table 5-25. Summary of Data Sources and Water Budget Flow Paths Included in Annual Diversions, Other Inflows, and Drainage from District Distribution Systems (Source: FRRAWMP, 2021).

District	Data Source (FRRAWMP, 2021)	FRRAWMP Water Budget Flow Paths Included			
		Diversions	Other Inflows	Drainage	Deliveries
Biggs-West Gridley Water District	Volume II, Chapter 3, Table 3.4	Main Canal Diversion, Branch A Diversion, Sutter-Butte Canal Diversions, Lateral 8 Diversion	RD833 Drains, Drains from BWD, Precipitation, Shallow GW Interception, Runoff of Precipitation, Tailwater	Snake Creek, Other Drains, Hamilton and RD833 Drains	Deliveries (to Private Ditches and Farmed Lands), Deliveries via Schwind, Cassady, and Rising River Laterals
Butte Water District	Volume II, Chapter 4, Table 4.4	Deliveries to Butte Water District	SEWD Conveyance Losses, Other Inflows, Snake Creek, Precipitation, Shallow Groundwater Interception, Runoff of Precipitation, Tailwater	Drains to BWGWD, Other Drains	Deliveries (to Farmed Lands)
Richvale Irrigation District	Volume II, Chapter 5, Table 5.4	Richvale Main Canal Diversion, Minderman Canal Diversion, Cherokee and Suez Canal Diversions (less Minderman Canal Deliveries)	Little Dry Creek, Precipitation, Shallow GW Interception, Runoff of Precipitation, Tailwater	RID Main Drain, Drainage Districts 100 and 200, RD833, Cherokee Canal	Deliveries (to Farmed Lands)
Western Canal WD	Volume II, Chapter 7, Table 7.4	Western Main Canal Diversion, 374 Lateral Diversion, Gorrill Ranch Diversion	Minor Sloughs and Drains, Precipitation, Shallow GW Interception, Runoff of Precipitation, Tailwater	Butte Creek Spill, 501 Main Drain, DD100 Drains, DD100 - Main Drain, Little Dry Creek, Cottonwood Creek, Subsurface Outflow to Butte Creek	Deliveries (to Private Ditches and Farmed Lands)

5.13.1 Joint Districts

BWGWD, BWD, RID, and Sutter Extension Water District (SEWD) formed the Joint Water Districts Board (Joint Districts) in 1957. The Joint Districts hold pre-1914 appropriative water rights to divert water from the Feather River, a tributary to the Sacramento River, and are parties to the May 27, 1969 Agreement on Diversion of Water from the Feather River, an agreement with the State regarding their diversions from the Feather River. The diversion agreement, included in **Appendix 5.H**, specifies the Joint Districts' water right for diverting up to 555,000 AF from the Feather River at the Thermalito Afterbay, established following its construction and the construction of Lake Oroville as part of the State Water Project (SWP) (Joint Board, 1969). The

555,000 AF diversion amount is available to the Joint Districts during the period from April 1 through October 31. The volume of water available for recharge is affected by the unavailability of supplies specified in the 1969 agreement during the non-allotted water season (November 1 through March 31), subject to reasonable and beneficial use.

The diversion agreement provides a consistent, reliable surface water supply to the Joint Districts. As stipulated in the 1969 agreement, water supply available to the Joint Districts depends on Lake Oroville inflow. Surface water supply can be reduced under the following conditions:

- DWR forecasted April to July unimpaired runoff into Lake Oroville is less than 600,000 AF[39], or
- Total current year predicted and prior year actual deficiencies in unimpaired runoff (as compared to 2,500,000 AF) exceed 400,000 AF for one or more successive prior water years with less than 2,500,000 AF of runoff.

When either of the above conditions are met, the Joint Board diversion amount of 555,000 AF can be reduced by up to 50 percent in any one year, but not by more than 100 percent in any seven consecutive years. Additionally, reductions in any given year cannot exceed the percent reduction experienced for agricultural use by SWP contractors.

Historically during years of reduced diversions, DWR has curtailed Joint Board water supplies by the full allowed amount, 50 percent, in each instance. In consideration of abandoning the Middle Fork Power Project on the Middle Fork of the Feather River, the State of California agreed to supply the Joint Water Districts an additional 35,000 acre-feet of water from the Feather River during drought reduction years under the terms of the 1969 agreement (**Appendix 5.H**). This 35,000 AF is divided equally among the Joint Districts, providing an additional 8,750 AF to each.

5.13.2 Western Canal

WCWD holds pre-1914 surface water rights for the diversion of:

- up to 150,000 AF of natural flow from the Feather River from April 1 through October 31, subject to reduction during drought under terms of its diversion agreement with the State, and
- up to 145,000 AF of upstream stored water on the North Fork of the Feather River, not subject to reduction.

[39] The final, official forecast must be made by April 10 of each year.

The district's diversion agreement is included in **Appendix 5.H**. The volume of water available for recharge is affected by the unavailability of supplies specified in the diversion agreement during the non-quantified period subject to reasonable and beneficial use, from November to February.

In addition to Feather River supplies, WCWD also has an adjudicated water right on Butte Creek subject to surplus availability and dependent on hydrologic conditions.

6 Plan Implementation

To maintain the Subbasin sustainability goal through 2042 and avoid undesirable results through 2092 as required by SGMA and the GSP regulations, various projects and management actions have been developed and will be implemented by the GSAs. **Section 5**: Projects and Management Actions describes each GSAs' projects and management actions, gross benefit, and operations. In addition, **Section 5** provides an estimate of the project-specific capital and operating costs, if available, for the projects and management actions. This section describes:

- Costs for GSAs to administer GSP activities (not including the project-specific costs described in **Section 5**), as required by GSP Regulation § 354.6(e)
- Financing approaches.
- Timeline and roadmap for implementing all GSA projects and management actions between 2022 and 2042.
- Monitoring and reporting, including the contents of annual reports and five-year periodic evaluations that must be provided to the California Department of Water Resources (DWR) (GSP Regulation § 356.2 and §356.4).
- And data management.

6.1 Description of GSA Implementation Costs

Total GSP implementation costs include both project-specific costs and costs for GSAs to administer and operate all other aspects of the GSP. The eleven GSAs implementing the Butte Subbasin GSP will incur costs for managing the GSP, planning and studies, monitoring implementation, and providing general administration. Projected capital and operating costs of projects and management actions are summarized in **Section 5** and are not repeated in this section. For the purposes of this section, each GSAs' implementation costs are aggregated into six (6) categories including GSA administration, GSP studies, GSP implementation and updates, project planning, monitoring and data management, and contingency to cover any unanticipated costs. The following subsections describe the general types of costs that could fall under each category. In practice, each GSA will allocate GSP implementation costs to cost categories that are consistent with its internal bookkeeping and accounting practices.

6.1.1 GSA Administration

Administration of the GSP will be conducted by the eleven GSAs working together under the Subbasin cooperation agreement[40]. Administrative costs generally include coordination meetings (including meetings of GSA managers, Butte Subbasin Advisory Board meetings, and interbasin

[40] A copy of the cooperation agreement is available on the Butte Subbasin Groundwater Advisory Board website: www.buttebasingroundwater.org

coordination), reporting, record keeping, bookkeeping, grant administration and preparation, legal advice, continued outreach to stakeholders, and government relations. GSAs will also need to continue to monitor projects and management actions to assess their benefit, economic feasibility, and coordinate with stakeholders and other GSAs if modification of projects and management actions is necessary to ensure the Subbasin meets sustainability objectives.

The eleven GSAs implementing the Butte Subbasin GSP anticipate that significant coordination of administrative tasks will be required. Many GSP projects and management actions require coordination between one or more GSAs, and overall Subbasin sustainability depends on continued coordination, planning, and evaluation of groundwater conditions. In general, it is anticipated that most administrative tasks will have a lead GSA. The lead GSA for each administrative task will keep the other GSAs informed through periodic updates to stakeholders and other GSAs.

Each GSA will conduct public outreach/engagement to provide timely information to stakeholders regarding GSP implementation progress and Subbasin conditions. Most GSAs will develop and maintain a website that will be used to post data, reports, and meeting information. In addition, each GSA will conduct general business administration including record keeping, bookkeeping, and general management.

6.1.2 GSP Studies

GSP implementation may require various planning, technical, and economic/fiscal studies. These are additional costs that are not covered by the cost of specific projects and management actions (see **Section 5**), including for example, more detailed evaluation of proposed projects and assessment of overall cost-effectiveness of GSP implementation strategies.

Planning Studies. GSAs will continue to develop planning studies to integrate the GSP with other regional water management efforts, monitor Subbasin conditions, and update the GSP to ensure that the Subbasin meets all sustainability objectives. GSAs will continue to evaluate Subbasin conditions and adjust short- and long-term Subbasin planning efforts accordingly. Other planning studies may include evaluating projects and developing other programs to support sustainable management.

Technical Evaluations. Subbasin GSAs are required to prepare annual updates and five-year periodic evaluations for DWR (§356.2 and §356.4). These reports will require additional technical analysis. GSAs will continue to monitor groundwater levels in the Subbasin to document progress toward sustainability objectives. Additional monitoring wells may be installed, and GSAs will evaluate and report groundwater conditions, water use, and change in groundwater storage as required by DWR. GSAs will continue to evaluate data gaps and implement programs to improve data availability.

Economic/Fiscal Analyses. GSAs will develop economic and fiscal studies to support implementation of projects and management actions and the overall GSP. This may include cost-effectiveness assessments and preliminary investigations of proposed projects. Fiscal analyses are expected to include rate studies and other analysis required to implement fees or assessments, willingness to pay, and ability to pay studies. GSAs will engage legal and technical experts to help develop the required studies. Economic impact studies will be developed to evaluate GSP implementation, understand distribution of costs to different stakeholder groups, and identify methods for reducing those costs during the implementation period.

Some anticipated GSP Studies, an Interbasin Working Group, and the estimated costs of each are shown in **Table 6-1** below. These studies will provide valuable information to support GSP implementation; they will be implemented as necessary, or as a funding source for each is identified. A tentative schedule for completion of these studies is included in **Section 6.4** (**Figure 6-2**). The total known estimated cost for these studies over the first five years of GSP implementation is $525,000. Each is described in greater detail following the table.

6.1.2.1 *Butte Creek Stream-Aquifer Interaction Study*

This study was initiated in 2021 and is planned to continue in subsequent years; it is being led by CSU Chico with support and funding from the Butte County Department of Water and Resource Conservation, Western Canal Water District, Llano Seco Ranch, and M&T Ranch.

The study seeks to better understand Butte Creek stream-aquifer interactions (i.e. gains and losses) through high frequency flow measurements (in both space and time) between points of diversion in specified stream reaches along Butte Creek. It is anticipated that this study will provide valuable data regarding accretions and depletions to and from Butte Creek over space and time that can be used to refine the characterization of Butte Creek within the Butte Basin Groundwater Model (BBGM).

Table 6-1. Study Name, Description and Estimated Cost for GSP Studies

Study Name or Working Group	Description	Estimated Cost
Butte Creek Stream-Aquifer Interaction Study	Initiated in 2021, this study evaluates stream-aquifer interactions through flow measurement and other field data collection along Butte Creek.	$20,000 per year
Sutter Buttes Water Quality Interbasin Working Group	This interbasin working group will seek to address groundwater quality problems associated with the unique geology of the Sutter Buttes area. It will propose studies and provide a forum for project development.	Estimated cost not available[1,2]
Butte Basin Groundwater Model (BBGM) Updates and Enhancement	This study will update and enhance the BBGM to improve its representation of the Butte Subbasin.	$225,000[1]
Well Inventory Program	This program will facilitate additional data collection to build an inventory and improve accuracy and information available about wells in the Butte Subbasin.	$40,000 for the first year and $20,000 for the second through fourth years[1]
Review and Updates of Data Management System (DMS)	This study will review and revise the Butte Subbasin DMS in order to improve the organization and efficiency of data management.	$80,000[1,2]

Notes:

1. Completion of this study is dependent on funding sources identified and obtained; grant funding opportunities will be investigated.
2. The cost of this study will be shared with neighboring subbasins who will also benefit from completion of the study.

6.1.2.2 Sutter Buttes Water Quality Interbasin Working Group

The CGA, GGA and the GSAs in the Butte, Sutter, Yolo, North Yuba and South Yuba Subbasins will participate in an interbasin working group focused on collaborative discussions, consensus-building and planning to address groundwater quality matters associated with the unique geology of the Sutter Buttes area. The goals of the working group will be to:

- Identify and prioritize groundwater quality conditions
- Coordinate with local, state and federal agencies
- Develop data and information needs
- Conduct high-level planning for groundwater studies and projects to protect or improve groundwater quality as needed
- Identify and pursue grant funding opportunities for groundwater studies and projects
- Provide a forum supporting cooperation, collaboration and information sharing during implementation of studies and projects

It is expected that groundwater studies identified by the interbasin working group would be grant funded and implemented by research entities, such as USGS or DWR. If projects are identified to protect or improve groundwater quality, they would be led and implemented by local entities such as the counties, agricultural water districts and agencies, municipalities, and other public water suppliers using a variety of funding sources, including grants and loans.

Although the surface expression of the Sutter Buttes is limited to the Sutter Subbasin, the subsurface extent of volcanic deposits and associated geologic structures is greater and may influence groundwater quality in the adjacent Butte, Colusa, Yolo, North Yuba and South Yuba Subbasins. Groundwater in the volcanic sediments of the Sutter Buttes Rampart has arsenic concentrations that frequently and significantly exceed the drinking water standard. The formation of the Sutter Buttes has resulted in the uplift of basement rocks, and corresponding reductions in the depth to the base of fresh groundwater. Faults may provide conduits or otherwise influence the movement of poor quality groundwater.

Objectives of the working group and the to-be-identified studies are to:

- Propose studies to:
    - Improve knowledge of the subsurface extent of the Sutter Buttes Rampart
    - Improve the understanding of local hydrogeology and faulting in the Sutter Buttes area
    - More fully characterize arsenic geochemistry within the subsurface extent of the Sutter Buttes Rampart
    - Improve knowledge of the depth to the base of freshwater and the structural features (folds and faults) that control the depth to the base of freshwater and groundwater movement in the area
    - Assess the risk of upwelling, or movement along faults, of saline or brackish connate groundwater
    - Assess the potential for mobilization of arsenic and/or connate waters beyond the subsurface extent of the Sutter Buttes Rampart
- Provide a forum for local entities to propose and develop projects to protect or improve groundwater quality

6.1.2.3 *Butte Basin Groundwater Model (BBGM) Updates and Enhancement*

The BBGM is a valuable tool for water management in the Butte, Vina, and Wyandotte Creek Subbasins that was originally developed in 1992 and has been periodically updated over time since. The BBGM has been significant in development of the Butte Subbasin GSP, specifically in defining Subbasin conditions and creating the water budgets. The model is currently developed for a simulation period from 1971 through 2018. The BBGM model, and its development, are described in greater detail in Butte County Department of Water and Resource Conservation's (BCDWRC) groundwater modeling report (BCDWRC 2021).

This study would seek to update the model for the period from 2018 to the present, as well as the incorporating the following potential refinements to the model:

- Refinement of interbasin flows and net outflows along the Sacramento River and the western boundary of the subbasin.
  - This would be accomplished in coordination with neighboring basins and include review of other modeling tools that cover the Sacramento Valley region, including the C2VSim and SVSim integrated hydrologic model applications developed by DWR.
- Refinement of stream-aquifer interactions and surface water diversion, groundwater pumping, and deep percolation estimates based on available information and newly obtained information.
- Incorporation of rural residential water demand (which is small relative to other uses).
- Refinement of urban lands water budgets to explicitly account for percolation from stormwater retention ponds and/or releases from wastewater treatment plants to local waterways, and refine estimates of non-consumed urban water use.

Improvements to the BBGM would result in a corresponding improvement to the water budgets and understanding of Subbasin conditions, assisting with GSP implementation.

6.1.2.4 *Well Inventory Program*

The Butte Subbasin GSAs have an existing initial inventory of many of the water supply wells within the Subbasin; these were developed and organized to provide data for earlier water management efforts, initial SGMA planning, and GSP development. However, this inventory is not complete and would greatly benefit from additional data collection under a Well Inventory Program. This program would both increase the quantity of wells in the inventory and improve the quality of the data on existing wells in the inventory. Activities that could be completed as part of the program include:

- Further analysis of well logs, county well permits, and visits to well locations to verify the accuracy of information in the well inventory
- Incorporation of well completion reports into the well database to improve understanding of the hydrogeology of the Subbasin
- Establishing protocols for updating the well inventory as new wells are installed and old wells are decommissioned
- Conducting outreach to landowners to encourage participation and submittal of well information, or verification of accuracy of existing well information

The well inventory program has the potential to support GSP implementation through increased understanding of groundwater development, identification of potential new monitoring sites, and increased understanding of hydrogeologic and current groundwater conditions.

6.1.2.5 *Review and Updates of Data Management System (DMS)*

The Butte Subbasin Data Management System (DMS) has been developed as an integrated network of digital file folders, databases and linked programs and tools; it is described in greater detail in **Section 6.7**. It was necessary for development of the GSP and was developed on a schedule to keep pace with and support GSP development, but there are opportunities to improve organization and more efficiently store, manage, and retrieve data.

This study will review existing data management structures and protocols, identify opportunities for improvements, and establish an improved DMS. The data will be managed so that appropriate tables, graphs, and maps supporting the GSP annual reports and periodic evaluations can be queried and provided to DWR. It is anticipated that the DMS would be developed for the full Butte Basin Groundwater Model (BBGM) domain and costs for developed would be shared between the Butte, Vina, and Wyandotte Creek Subbasins, as the BBGM is used to support GSP development and implementation in all three subbasins.

6.1.3 GSP Implementation and Updates

GSP implementation costs include internal GSA coordination, meetings, and document preparation. This cost category includes costs not covered by GSA Administration and GSP Studies, in addition to costs incurred to comply with annual updates and five-year periodic evaluations.

Annual reports. GSP Regulation §356.2 requires GSAs to prepare and submit annual reports to DWR. GSAs will prepare any required technical analysis, data, summary material, and provide a report on sustainable management objectives. GSAs expect that annual reports will also require inter- and intra-GSA coordination as well as stakeholder outreach.

Periodic evaluations. GSP Regulation §356.4 requires GSAs to prepare and submit five-year evaluation reports. In contrast to the annual report, this report requires additional evaluation of sustainability conditions, objectives, monitoring, and documentation of new information that is available since the last update to the GSP. GSAs expect that periodic evaluations will also require significant inter- and intra-GSA coordination and stakeholder outreach.

6.1.4 Project Planning

GSAs will incur additional costs for project planning. Project capital and operating and maintenance costs for projects that are included in the GSP are already summarized in **Section 5**. However, GSAs expect to evaluate other project ideas proposed by stakeholders, assess cost-effectiveness of proposed projects, and evaluate the joint implementation of multiple projects to ensure the GSP continues to meet sustainability objectives. Technical studies may include feasibility assessments, environmental studies, water rights evaluations, coordination with permitting agencies, and other project planning efforts. GSAs may evaluate land acquisition and easements, pursue grant applications, administer grants, and engage other legal and technical services.

As needed, the GSAs will coordinate on the specific studies and analyses necessary to improve understanding of Subbasin conditions. The GSAs will use new information on Subbasin conditions to improve projects and management actions to maintain sustainability. Evaluations and updates will occur annually (annual report) and every five-years (periodic evaluation) as required by GSP Regulations, but GSAs anticipate that planning, coordination, and studies will be continuous and ongoing during the 2022 to 2042 implementation period.

6.1.5 Monitoring and Data Management

GSAs may implement programs to monitor groundwater extractions, measure groundwater elevations, and track total water use. Potential monitoring activities include installing and measuring monitoring wells, maintaining existing wells, data management and maintenance of the data management system, and deploying other technology.

GSAs will oversee the monitoring programs outlined in **Section 3**; they will also monitor 10 new shallow monitoring wells distributed throughout the subbasin (which will be installed as described in **Section 5.9**)[41]. These activities will include tracking Subbasin conditions and sustainability indicators. Data from the monitoring programs will be organized into the data management system and routinely evaluated to ensure progress is being made toward sustainability and to identify whether undesirable results are occurring.

6.1.6 Contingency

An additional contingency cost is included for planning purposes. This may include actions needed to respond to critically dry years, if Subbasin conditions start trending towards minimum threshold levels in any area, or to cover unanticipated activities such as litigation. The contingency has been estimated as 10% of all other estimated costs.

6.2 Estimate of GSA Implementation Costs

This section summarizes estimated costs for the entire Butte Subbasin to implement non-project-specific costs of the GSP; costs are presented for each of the six cost categories identified above. The Subbasin-wide costs will be distributed amongst the eleven GSAs in the Butte Subbasin.

[41] Per the explanation at the beginning of this section, the costs for ongoing monitoring of these 10 shallow monitoring wells may be included in this section. However, the estimated cost for the project of installing the wells was previously described in the Section 5 on Projects and Management Actions.

However, GSAs manage costs and expenses in different ways and as such may record costs in different categories than the six categories shown here. Additionally, some GSAs are still developing operating budgets and may issue requests for proposals to engage additional consultant technical services, but these costs are not known at this time.

The GSAs covered by the GSP include Biggs-West Gridley Water District GSA, Butte Water District GSA, City of Biggs GSA, City of Gridley GSA, Colusa Groundwater Authority GSA, County of Butte GSA, County of Glenn GSA, Reclamation District No. 1004 GSA, Reclamation District No. 2106 GSA, Richvale Irrigation District GSA, and Western Canal Water District GSA.

As shown in **Table 6-2**, estimated annual GSA Implementation costs for the Butte Subbasin (excluding the costs of specific projects) are anticipated to be approximately $360,000 and $600,000 per year over the next five years with a total estimated cost of approximately $2.2 million. GSA administration may include, but are not limited to, administration of the GSP, Subbasin coordination, communications, and government relations. Studies may include, but are not limited to, rate studies, Proposition 218 processes, planning or research studies (such as those described in **Section 6.1.2**), and other legal and technical support. Implementation and updates may include, but are not limited to, preparing and implementing the initial GSP, internal GSA coordination, meetings, guidance document preparation, costs for periodic updates to the GSP, and coordination and agreements for future updates. Project planning, as needed, may include, but is not limited to, evaluation of additional projects and management actions, and costs to plan any new programs or projects not included in **Section 5**. Monitoring and data management costs may include, but are not limited to, equipment costs, well monitoring and other data collection activities, and data management. Contingency costs would cover cost overruns and unanticipated activities such as litigation.

The eleven GSAs will recover GSP implementation costs through grants and local revenues that are yet to be determined; the GSAs are currently evaluating options. **Section 6.3** provides a general description of how the GSAs may recover GSP implementation costs.

6.2 GSP Financing

Administering the GSP and monitoring and reporting progress is projected to cost between approximately $360,000 and $600,000 per year across the eleven Subbasin GSAs that are jointly preparing this GSP. Costs are expected to be higher during years in which five-year periodic evaluations are required, and slightly lower during years in which annual reports are required. This does not include the capital and annual operating cost of projects and management actions (see **Section 5**).

Table 6-2. Butte Subbasin GSA Implementation Costs

Cost Category	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026
GSA Administration	$128,000	$134,000	$143,000	$149,000	$157,000
GSP Studies	$127,000	$107,000	$182,000	$157,000	$157,000
GSP Implementation and Updates	$55,000	$45,000	$45,000	$35,000	$200,000
Project Planning	$10,000	$20,000	$10,000	$10,000	$15,000
Monitoring	$20,000	$20,000	$20,000	$20,000	$20,000
Contingency	$34,000	$33,000	$40,000	$38,000	$55,000
Total	**$374,000**	**$359,000**	**$440,000**	**$409,000**	**$604,000**

Development of this GSP was funded through a Proposition 1 Grant, and contributions from individual GSAs (e.g. through in-kind staff time, or separately contracted consulting services). Individual GSAs are also funding additional, ancillary studies and implementation efforts. To fund GSA operations and GSP implementation, GSAs are developing a financing plan that will include one or more of the following financing approaches:

- **Grants and low-interest loans**: GSAs will continue to pursue grants and low interest loans to help fund planning studies and other GSA activities. However, grants and low-interest loans are not expected to cover most GSA operating costs for GSP implementation.
- **Groundwater extraction charge**: A charge per acre-foot pumped would be used to fund GSP implementation activities.
- **Other Fees and charges**: Other fees may include permitting fees for new wells or development, transaction fees associated with potential groundwater markets, or commodity-based fees, all directed at aiding with sustainability objectives. Depending on the justification and basis for a fee, it may be considered a property-related fee subject to voting requirements of Article XIII D of the California Constitution (passed by voters in 1996 as Proposition 218) or a regulatory fee exempt from such requirements.
- **Assessments:** Special benefit assessments under Proposition 218 could include a per-acre (or per-parcel) charge to cover GSA costs.
- **Taxes:** This could include general property related taxes that are not directly related to the benefits or costs of a service (ad valorem and parcel taxes), or special taxes imposed for specific purposes related to GSA activities.

GSAs are pursuing a combined approach, targeting available grants and low interest loans, and considering a combination of fees and assessments to cover operating and program-specific costs. As required by statute and the Constitution, GSAs would complete an engineer's report, rate study, and other analysis to document and justify any rate, fee, or assessment.

6.4 Schedule for Implementation

The GSP implementation schedule allows time for GSAs to develop and implement projects and management actions and meets all sustainability objectives by 2042. Although projects and activities to sustainably manage groundwater resources in the Butte Subbasin precede the time that SGMA became law and are already contributing to Subbasin goals, another other projects have been initiated since SGMA became law, the GSAs will begin implementing other GSP activities in 2022, with full implementation of projects and management actions to maintain sustainability through 2042. **Figure 6-1** illustrates the GSP implementation schedule for projects and management actions that will be implemented by each GSA. The GSP implementation schedule also shows mandatory reporting and updating for all GSAs, including annual reports and five-year periodic updates (evaluations) prepared and submitted to DWR. Additionally, **Figure 6-2** illustrates a tentative GSP Study schedule for the GSP Studies outlined in **Section 6.1.2**.

Groundwater sustainability in this Subbasin is also dependent on surface water supplies and thus will always be vulnerable to any future conditions affecting the availability of surface water supplies. A variety of factors have the potential to influence future surface water availability such as hydrologic changes (due to climate change or other factors) or regulatory changes that may impact the contractual quantities of water the California Department of Water Resources (DWR) is obligated to provide per the Feather River Diversion Agreements. Future conditions that impact the future availability of surface water supplies (including hydrologic and/or regulatory changes) may require revisions to the sustainability indicators. Potential changes may impact the cost and schedule of certain GSP implementation activities, such as project and management actions, but should not impact overall GSP implementation. Overall, long-term sustainability will be achieved through implementation of the projects and management actions and adaptive management as described in this GSP.

The Butte Subbasin GSP implementation plan for projects and management actions recognizes that some projects may take several years to plan and develop, and that implementation of specific projects and management actions will have to be flexible and adaptable to changing conditions within the Butte Subbasin. The GSP implementation schedule presented here will be periodically reevaluated and modified, as needed, during the implementation period in order to maintain planned targets and maintain sustainability.

Time Period	2022	2023	2024-2026	2027	2028-2031	2032	2033-2036	2037	2038-2041	2042
RID	System Modernization									
BWGWD	System Modernization									
WCWD	Boundary Flow and Primary Spill Measurment									
BWD			Dual Source Irrigation Systems*							
Multiple GSAs			Multi-Benefit Recharge and Grower Education*							
All GSAs	Installation of Additional Shallow Monitoring Wells				Implement additional projects and management actions as necessary or dependent on funding					
All GSAs	Annual Reporting				Annual Reporting		Annual Reporting		Annual Reporting	
All GSAs				Periodic Evaluation		Periodic Evaluation		Periodic Evaluation		Periodic Evaluation

*Note: Implementation and scale of these projects is dependent on funding availability.

Figure 6-1. Butte Subbasin GSP Implementation Schedule, 2022 – 2042

Time Period	2022	2023	2024	2025	2026	2027
Butte Creek Stream-Aquifer Interaction Study	Planned each year					
Sutter Buttes Water Quality Interbasin Working Group*	Planned each year					
Butte Basin Groundwater Model (BBGM) Updates and Enhancement*			Planned for 2024 through 2026			
Well Inventory Program*	Planned for 2022 through 2026					
Review and Updates of Data Management System (DMS)*	Planned for 2022 through 2024					
Reporting	Annual Report	Annual Report	Annual Report	Annual Report	Annual Report	Periodic Evaluation

*Note: Implementation and scale of these studies is dependent on funding availability.

Figure 6-2. Butte Subbasin GSP Studies Implementation Schedule, 2022 - 2027

6.5 Annual Reports

GSP Regulation §356.2 requires annual reports to be submitted to DWR by April 1 of each year following the adoption of the GSP. GSAs will prepare annual reports that comply with the requirements of §356.2. It is anticipated that GSAs will need to develop independent analyses and data (e.g. for surface water use by a particular GSA) as well as joint analyses (e.g. estimating the Subbasin-wide change in groundwater storage) in order to develop annual reports. GSAs will work together under the Subbasin cooperation agreement to complete annual reports. Annual reports must provide basic information about the Subbasin in addition to technical information including:

- Groundwater elevation data from monitoring wells
- Hydrographs of groundwater elevations
- Total groundwater extractions for the prior year
- Surface water supply used in the prior year, including for groundwater recharge or other in-lieu uses
- Change in groundwater storage
- Progress towards implementing the GSP

The following subsections provide a general outline of what information will be provided in the annual report. The annual report provided to DWR will fully comply with the requirements of §356.2.

6.5.1 General Information (§356.2(a))

General information will include an executive summary that highlights the key content of the annual report. This will include a description of the sustainability goals and provide a description of GSP projects, an updated implementation schedule, and a map of the Subbasin. Any important changes or updates since the last annual report will be noted and described.

6.5.2 Subbasin Conditions (§356.2(b))

The subbasin conditions section of the annual report will provide an update on groundwater and surface water conditions in the Subbasin.

Current groundwater conditions with respect to the sustainability goals in the Subbasin will be described. GSAs will summarize the groundwater monitoring network data and report current and change in groundwater elevation. This will include groundwater elevation contour maps for each aquifer in the Subbasin tailored to specific hydrogeologic conditions across the region. This will show seasonal high and low conditions within the current season and show historical data from at least January 1, 2015.

Total groundwater extractions will be summarized (in tabular and map form) by water use sector and the method of measurement will be identified (e.g. metering, satellite analysis, crop-based ET estimates, etc.). All data and methods used to characterize extractions and levels will follow best practices and be described in the annual report.

Total ET_{aw} in the Subbasin will be summarized and parsed into ET_{aw} of surface water and ET_{aw} of groundwater using the available information on applied surface water. Surface water data will show whether it was used for direct or in-lieu recharge and identify all sources for each GSA.

The groundwater system balance will be used to estimate the change in groundwater storage. Change in storage will be summarized in tabular form and as a map for each aquifer in the Subbasin. A graph will show the water year type, groundwater use, change in storage, and cumulative change in storage for the Subbasin using historical data from no later than January 1, 2015.

6.5.3 Plan Implementation Progress (§356.2(b))

The annual report will summarize GSP implementation of projects and management actions and other GSA-related activities and describe progress toward established interim milestones and planned sustainability objectives. It will summarize sustainability conditions in the Subbasin.

6.6 Periodic Evaluation (Five-Year Updates)

DWR will review the GSP's progress toward meeting its sustainability goals at least every five years. GSAs will prepare the periodic evaluation to summarize GSP implementation, whether the GSP is meeting sustainability goals, and summarize implementation of projects and management actions. An evaluation will also be made whenever the GSP is amended. A summary of the general information that will be included in the five-year periodic evaluation required by §356.4 is provided in the following subsections.

6.6.1 Sustainability Evaluation (§356.4(a) - §356.4(d))

The evaluation will summarize current groundwater conditions for each sustainability indicator and describe overall progress towards sustainability. A summary of interim milestones and measurable objectives will be included, along with an evaluation of groundwater elevations in relation to minimum thresholds. If any minimum thresholds are found to be exceeded, the GSAs will investigate probable causes and implement actions to correct conditions, as necessary.

Implementation of projects and management actions will be documented and used to adaptively manage the Subbasin. This will include a summary of actual implementation timelines compared to the proposed timeline (**Figure 6-1**) and implementation schedule described in **Section 5**, and evaluation of the project contribution to improving conditions. If conditions are improving faster or slower than projected, the reason for the difference from the projection will be evaluated. If conditions are improving slower than projected because any projects or management actions are not implemented according to the specified timeline, the deviation from the original plan will be documented and to the extent possible, corrective actions to speed implementation will be taken. Similarly, if conditions are improving faster than projected, the scale or timeline of some projects or management actions may be re-evaluated and revised.

The evaluation will analyze and describe the effect of projects and management actions on Subbasin sustainability indicators and compare that to the estimated gross benefits of the projects and management actions presented in **Section 5**. If differences are identified, these will be described in the periodic evaluation. If projects or management actions are not performing as expected, the update will describe steps the GSAs will take to implement additional projects or reduce groundwater extractions, if warranted. Any changes to the implementation schedule of projects and management actions will be described in the periodic evaluation.

As GSP projects and management actions are implemented, monitoring data may indicate unanticipated effects. Also, land uses and economic conditions may change in ways that cannot be anticipated at this time; it may be necessary to revise the GSP to account for these changes. The elements of the GSP including the basin setting, management areas, undesirable results, minimum thresholds, and measurable objectives will be reconsidered by the GSAs during the periodic evaluations. Any proposed revisions will be documented in the periodic evaluation.

6.6.2 Monitoring Network Description (§356.4(e))

Section 3 details the planned monitoring network and protocols. The effectiveness of the monitoring network and overall GSP implementation depends on timely, accurate, and comprehensive data. The GSP includes Data Management System (DMS) protocols, as well as expanded monitoring wells and data collection. If data gaps are identified, a plan will be developed to improve the monitoring network, consistent with §354.38 of the GSP regulations.

GSAs expect that additional data gaps may be identified in future GSP updates. The periodic evaluations of the GSP will assess changes to the monitoring program needed to acquire additional data sources, and how the new information will be used and incorporated into any future GSP updates. The installation of new data collection facilities and analysis of new data will be prioritized in the GSP.

6.6.3 New Information (§356.4(f))

GSAs are continuing to monitor Subbasin conditions and 10 additional monitoring wells are being installed to improve monitoring of surface water depletion and GDEs. In addition, the DMS will allow GSAs to identify additional data gaps and implement procedures to secure additional data. Land use and economic incentives for farming and other water uses in the Subbasin may change as the GSP is implemented. GSAs expect that new information about groundwater conditions, projects and management actions, and sustainability objectives will continue to be available. An adaptive management approach will be applied to identify, review, and incorporate all new information into the GSP. Periodic evaluations will indicate whether new information warrants changes to any aspect of the GSP, including the basin setting, measurable objectives, minimum thresholds, or undesirable results.

6.6.4 GSA Actions ((§356.4(g) - §356.4(h))

GSAs are continuing to monitor, manage, and collaborate to meet the sustainability goals specified in the GSP. Within their allowed authorities, if necessary, GSAs will evaluate new regulations or ordinances that could be implemented to help maintain sustainability objectives. Any changes in regulations or ordinances will be summarized in the periodic update. The effect on any aspect of the GSP, including the basin setting, measurable objectives, minimum thresholds, or undesirable results will be described.

The five-year periodic evaluation will include a summary of state laws and regulations or local ordinances related to the GSP that have been implemented since the previous periodic evaluation and address how these may require updates to the GSP. Enforcement or legal actions taken by the GSAs in relation to the GSP will be summarized in this section along with how such actions support sustainability in the Subbasin.

6.6.5 Plan Amendments, Coordination, and Other Information (§356.4(i) - §356.4(k))

Any proposed or completed amendments to the GSP will be described in the periodic evaluation. This will also include a summary of amendments that are being considered or developed at that time. This may include changes to the basin setting, measurable objectives, minimum thresholds, or undesirable results.

Any changes to the GSA cooperation agreement, or other Subbasin coordination agreements will be documented and summarized. GSAs will summarize any other information deemed appropriate to support the GSP and provide required information to DWR for review of the GSP.

6.7 Data Management System (§352.6)

The Butte Subbasin Data Management System (DMS) has been developed as an integrated network of digital file folders, databases and linked programs and tools. It is described in greater detail in the DMS Summary Report (**Appendix 6.A**). Each element is directly or indirectly linked to a centralized water budget database and the Butte Basin Groundwater Model, which are used to organize and calculate the Subbasin water budget (**Figure 6-3**). Inputs to the water budget database are organized into inputs that are managed and implemented at the subbasin-level and inputs that are managed at the GSA-level. Subbasin-level inputs include:

- **Time series**: time series data managed in a database structure and used to quantify surface water inflows/outflows and groundwater levels
    - USGS station data
    - DWR-compiled data (WDL and CDEC)
- **Weather:** weather data managed in a database structure and used to quantify reference evapotranspiration and precipitation, and to support root zone water budget calculations (crop evapotranspiration, infiltration, runoff)
    - CIMIS station data
    - NCEI (NOAA) station data
    - PRISM data
- **eWRIMS**: water rights diversions records managed publicly in a database structure and used to help quantify surface water supply utilized for irrigation
- **GIS:** spatially-defined geographic data managed in GIS and used to support land use analyses and spatial water use by sector
    - DWR spatial data (subbasin boundaries, GSA boundaries, land use survey spatial coverages, Land IQ land cover classification and analysis)
    - DWR interpolation tool results (spatial and temporal interpolation of spatial coverages, using Ag Commission reports)
    - Local land use data comparison and validation

Inputs to the subbasin water budget that are managed at the GSA-level include:

- **Time series:** time series data relating to GSA-specific inflows that are managed in a database structure and used to quantify surface water inflows/outflows
- **Local Data:** local data managed in spreadsheets and used to quantify GSA-specific inflows/outflows (diversions and deliveries not recorded in subbasin-level data sources)
- **Deliveries**: Water district delivery data managed in a database structure and used to quantify surface water supply utilized for irrigation

All GSAs will manage data related to GSP project implementation within their boundaries. GSAs are continually working to refine data, identify data gaps, and incorporate additional information characterizing groundwater conditions in the Subbasin.

GSAs are currently planning a GSP study (previously described) to review, update, and refine the current DMS to improve organization and more efficiently store, manage, and retrieve data. This will formalize the DMS, which will be developed to meet the requirements in the GSP Regulations, including § 352.4, § 352.6, and § 354.4. As described previously, the data will be managed so that appropriate tables, graphs, and maps supporting the GSP annual reports and periodic evaluations can be queried and provided to DWR.

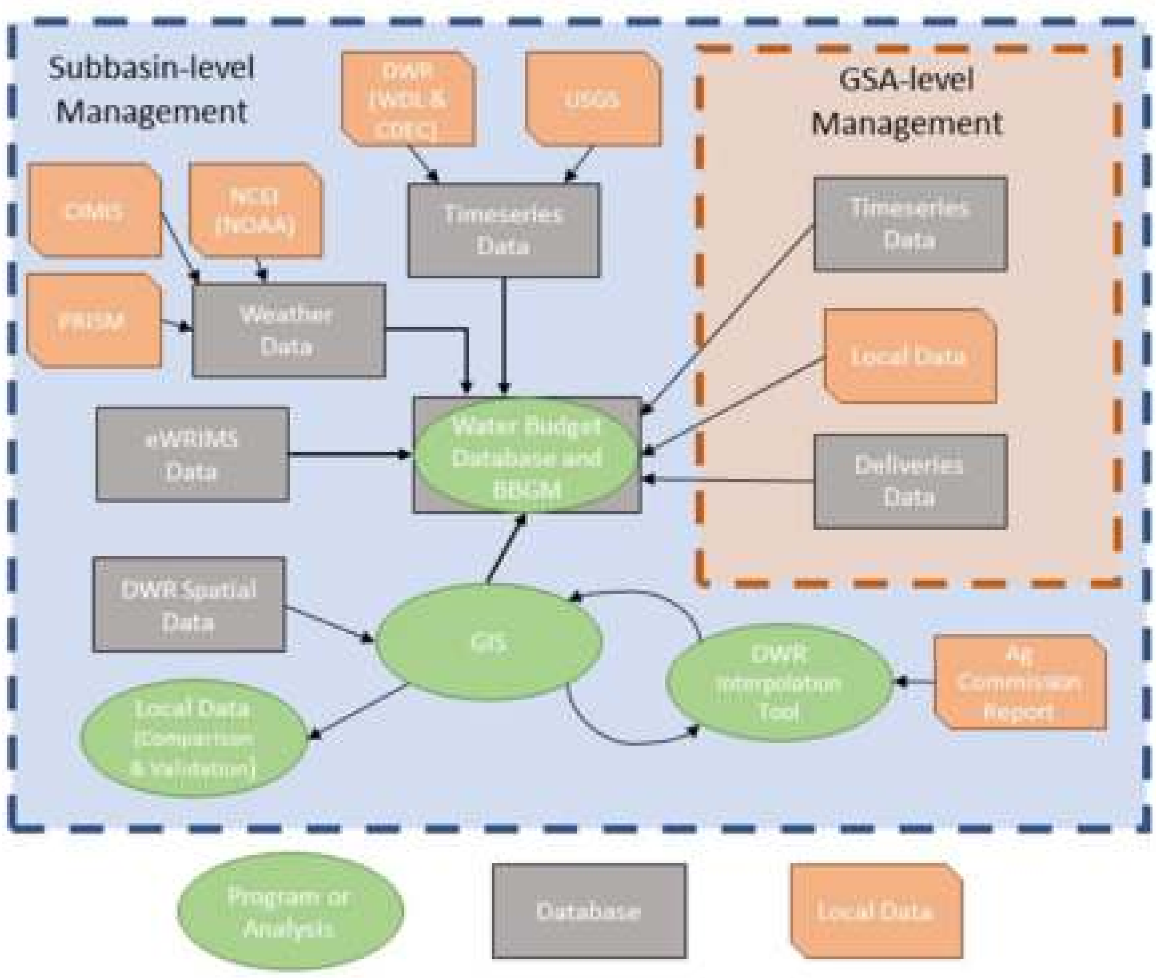


Figure 6-3. Butte Subbasin Data Management System Structure

7. References and Technical Studies *(Reg. § 354.4)*

American Society of Civil Engineers (ASCE). 2016. Evaporation, Evapotranspiration and Irrigation Water Requirements. Manual 70. Second Edition. M. E. Jensen and R. G. Allen (eds). Am. Soc. Civ. Engrs., 744 pp.

Barlow, P.M., Leake, S.A. and Fienen, M.N., 2018. Capture versus capture zones: Clarifying terminology related to sources of water to wells. *Groundwater*, *56*(5), pp.694-704. Available from: https://ngwa.onlinelibrary.wiley.com/doi/full/10.1111/gwat.12661.

Bredehoeft, J.D., Papadopulos, S.S. and Cooper, H.H., 1982. Groundwater: The water budget myth. Scientific basis of water resource management, 51, p.57. Available from: https://www.eqb.state.mn.us/sites/default/files/documents/The_Water-budget_Myth.pdf

Brouwer, C., Prins, K. and Heibloem, M., 1989. Annex I: Irrigation Efficiencies. In Irrigation Water Management: Irrigation Scheduling. Food and Agriculture Organization (FAO) of the United Nations. Training Manual, 4. Available from: http://www.fao.org/3/t7202e/t7202e08.htm#TopOfPage.

Butte County Department of Water and Resource Conservation (BCDWRC). March 2001. Water Inventory and Analysis Report. Technical Memorandum. (BCDWRC 2001)

Butte County Department of Water and Resource Conservation (BCDWRC). June 2016. Water Inventory and Analysis. (BCDWRC 2016)

Butte County Department of Water and Resource Conservation (BCDWRC). 2021. Model Documentation. Butte Basin Groundwater Model. Under Development. (BCDWRC 2021)

California Department of Water Resources (DWR). 2017. Draft Sustainable Management Criteria Best Management Practices. Accessed on May 10, 2021. Available online at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/BMP-6-Sustainable-Management-Criteria-DRAFT_ay_19.pdf

California Department of Water Resources (DWR). 2018. 2017 GPS Survey of the Sacramento Valley Subsidence Network. Accessed on June 11, 2021. Available online at: http://www.yolowra.org/documents/2017_GPS_Survey_of_the_Sacramento_Valley_Subsidence_Network.pdf

California Department of Water Resources, 2016, BMP 2 Monitoring Networks and Identification of Data Gaps.

California Department of Water Resources, 2018, 2017 GPS Survey of the Sacramento Valley Subsidence Network Report.

California Natural Resources Agency (CNRA). 2020. Northern Sacramento Valley Dedicated Monitoring Well Groundwater Quality Assessment. CNRA Northern Region Office. January 2020.

California Rice Commission, 2016, Groundwater Trend Monitoring Workplan and Data Gap Assessment Plan.

California Rice Commission, 2019, Waste Discharge Requirements for Sacramento Valley Rice Growers – 2019 Annual Monitoring Report.

CNRA, See California Natural Resources Agency

Dudley, T. and Fulton, A., 2006. Conjunctive Water Management: What is it? Why consider it? What are the challenges? University of California. Available from: https://ucanr.edu/sites/Tehama/files/20596.pdf.

DWR, See California Department of Water Resources

EDF, See Environmental Defense Fund

Environmental Defense Fund (EDF). 2018. Addressing Regional Surface Water Depletions in California: A Proposed Approach for Compliance with the Sustainable Groundwater Management Act. Accessed June 30, 2021. Available online at: https://www.edf.org/sites/default/files/documents/edf_california_sgma_surface_water.pdf

Gleick, P.H., Christian-Smith, J. and Cooley, H., 2011. Water-use efficiency and productivity: rethinking the basin approach. Water International, 36(7), pp.784-798.

https://www.edf.org/sites/default/files/documents/edf_california_sgma_surface_water.pdf
https://www.eqb.state.mn.us/sites/default/files/documents/Source_of_Water_Derived_from_Wells.pdf.

Land IQ. 2021. Statewide Crop Mapping 2018. Available from: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#waterbudget.

Lankford, B., Closas, A., Dalton, J., Gunn, E.L., Hess, T., Knox, J.W., van der Kooij, S., Lautze, J., Molden, D., Orr, S. and Pittock, J., 2020. A scale-based framework to understand the promises, pitfalls and paradoxes of irrigation efficiency to meet major water challenges. Global

Environmental Change, 65, p.102182. Available from: https://www.sciencedirect.com/science/article/pii/S0959378020307652.

Leake, S.A., 2011. Capture—Rates and directions of groundwater flow don't matter!. Groundwater, 49(4), pp.456-458. Available from: https://ngwa.onlinelibrary.wiley.com/doi/full/10.1111/j.1745-6584.2010.00797.x

Northern California Water Association, Sacramento Valley Water Quality Coalition, Draft Comprehensive Groundwater Quality Management Plan CH2M November 2016; Appendix B: Subwatershed Action Plans (SVWQC 2016)

Perry, C., 2007. Efficient irrigation; inefficient communication; flawed recommendations. Irrigation and Drainage: The journal of the International Commission on Irrigation and Drainage, 56(4), pp.367-378. Available from: https://onlinelibrary.wiley.com/doi/epdf/10.1002/ird.323.

Sanden, B.L., Prichard, T.L., and Fulton, A.E., 2016. Assessing And Improving Water Penetration. In L. Ferguson and D.R. Haviland (Eds.), Pistachio Production Manual, Publication 3545. University of California Agriculture and Natural Resources (UCANR) Publications.

Schmitt S., M Fram, B Milby Dawson. 2008. Results from the California GAMA Program. USGS Data Series 385.

Sears, L., Caparelli, J., Lee, C., Pan, D., Strandberg, G., Vuu, L. and Lin Lawell, C.Y.C., 2018. Jevons' paradox and efficient irrigation technology. Sustainability, 10(5), p.1590. Available from: https://www.mdpi.com/2071-1050/10/5/1590/htm.

Theis, C.V., 1940. The source of water derived from wells. *Civil Engineering*, *10*(5), pp.277-280. Available from: https://www.eqb.state.mn.us/sites/default/files/documents/Source_of_Water_Derived_from_Wells.pdf.

UC Davis. 2021. SAGBI: Soil Agricultural Groundwater Banking Index Spatial Dataset. California Soil Resource Lab at UC Davis and UC-ANR. Available at: https://casoilresource.lawr.ucdavis.edu/sagbi/.

United States Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS), 2014. Soil Infiltration: Soil Health – Guides for Educators. May 2014. Available from: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_051576.pdf.

Wood Rogers, 2012, Sutter County Groundwater Management Plan.