TEHAMA COUNTY
FLOOD CONTROL AND WATER CONSERVATION DISTRICT

Groundwater Sustainability Plan

Bowman Subbasin

JANUARY 2022

PREPARED BY

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Consulting Engineers

BOWMAN SUBBASIN
GROUNDWATER SUSTAINABILITY PLAN

ACKNOWLEDGMENTS

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TEHAMA COUNTY GROUNDWATER SUSTAINABILITY AGENCY BOARD OF DIRECTORS

The Tehama County Flood Control and Conservation District, a local and regional authority, serves as the exclusive GSA for the Red Bluff Subbasin. The GSA Board of Directors are same members of the Tehama County Board of Supervisors.

Bob Williams
Candy Carlson
Dennis Garton
John Leach
William Moule

GROUNDWATER SUSTAINABILITY PLAN GROUNDWATER COMMISSIONERS

In June 2016, the District established the Tehama County Groundwater Commission to serve as an advisory commission to the Tehama County Flood Control and Water Conservation District Board of Directors for GSA related matters. The Commission consists of 11 members. The Groundwater Commission provided input, review of draft GSP content, defined sustainable management criteria, and provided input on next steps for GSP implementation. Tehama County Groundwater Sustainability Agency appreciates the contributions of the 11 members listed below:

Kristina Miller, City of Corning
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Bill Borror, City of Tehama
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Martha Slack, Rio Alto Water District
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PLANNING, TECHNICAL, AND FACILITATION SUPPORT

Consensus Building Institute, Inc.
Davids Engineering
MBK Engineers
Water Resource Consulting
Pacific Agroecology

Luhdorff & Scalmanini Consulting Engineers performed modeling, planning, and other technical support for the Tehama County Groundwater Sustainability Agency in addition to composing the Red Bluff Subbasin Groundwater Sustainability Plan.

On behalf of the Tehama County Groundwater Sustainability Agency, thank you to all of the community members who participated in public meetings, information sessions, and various outreach events. Your input was vital to shaping this Plan.

FINAL REPORT

Bowman Subbasin

Sustainable Groundwater Management Act

Groundwater Sustainability Plan

January 2022

Prepared For:

Tehama County Flood Control and Water Conservation District

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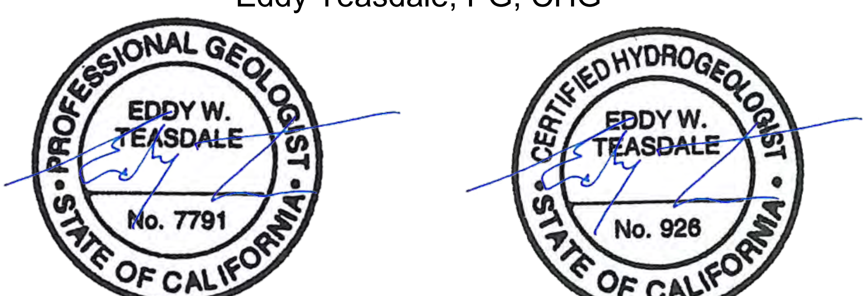

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LIST OF ACRONYMS & ABBREVIATIONS

µg/L	Micrograms per liter
µmhos/cm	Micromhos per Centimeter
AB	Assembly Bill
ACID	Anderson-Cottonwood Irrigation District
af	Acre-feet
AN	Above normal Sacramento Valley water year type
AWMP	Agricultural Water Management Plan
bgs	Below Ground Surface
BLM	Bureau of Land Management
BMP	Best Management Practices
BN	Below normal Sacramento Valley water year type
BOD	Board of Directors
C	Critical (dry) Sacramento Valley water year type
CalEPA	California Environmental Protection Agency
CalGEM	California Geologic Energy Management Division
CASGEM	California Statewide Groundwater Elevation Monitoring
CCR	California Code of Regulations
CDEC	California Data Exchange Center
CDFW	California Department of Fish and Wildlife
CDPH	California Department of Public Health
CE	Communications and Engagement
CFS	Cubic Feet per Second
CNRA	California Natural Resources Agency
CVP	Central Valley Project
CVRWQCB	Central Valley Regional Water Quality Control Board
CV-SALTS	Central Valley Salinity Alternatives
CWA	Clean Water Act
CWC	California Water Code
D	Dry Sacramento Valley water year type
DAC	Disadvantaged Community
DDW	Division of Drinking Water
DMS	Data Management System

DO	Dissolve Oxygen
DOI	Department of the Interior
DPR	Department of Pesticide Regulation
DQO	Data Quality Objective
dS/m	Deci-siemens per Meter
DTSC	Department of Toxic Substance Control
DTW	Depth to Water
DWR	Department of Water Resources
EC	Electrical Conductivity
ET	Evapotranspiration
ft bgs	Feet Below Ground Surface
ft msl	Feet Above Mean Sea Level
ft/d	Feet Per Day
ft/mile	Feet per Mile
ft/yr	feet per year
ft2/d	Square Feet Per Day
FTE	Full Time Equivalent
GAMA	Groundwater Ambient Monitoring and Assessment Program
GDE	Groundwater Dependent Ecosystem
GMP	Groundwater Management Plan
GPS	Global Positioning Systems
GQTM	Groundwater Quality Trend Monitoring
GSA	Groundwater Sustainability Agency
GSE	Ground Surface Elevation
GSP	Groundwater Sustainability Plan
GWE	Groundwater Elevation
GWMP	Groundwater Management Plan
GWS	Groundwater System
HCM	Hydrogeological Conceptual Model
iGDE	Indicators of Groundwater Dependent Ecosystems
ILRP	Irrigated Lands Regulatory Program
InSAR	Interferometric Synthetic Aperture Radar
IRWMP	Integrated Regional Water Management Plan

JPA	Joint Powers Authority
LLNL	Lawrence Livermore National Laboratory
LSCE	Luhdorff & Scalmanini, Consulting Engineers
MAs	Management Actions
MCL	Maximum Contaminant Level
mg/L	Milligrams per Liter
MO	Measurable Objective
MOA	Memorandum of Agreement
MT	Minimum Threshold
MTJ	Mendocino Triple Junction
MWELO	Model Water Efficient Landscape Ordinance
NAVD88	North American Vertical Datum of 1988
NCCAG	Natural Communities Commonly Associated with Groundwater
NDVI	Normalized Difference Vegetation Index
NRCS	Natural Resources Conservation Service
NWIS	National Water Information System
ORP	Oxidation-Reduction Potential
PBO	Plate Boundary Observatory
PMAs	Projects and Management Actions
QA	Quality Assurance
QC	Quality Control
RMS	Representative Monitoring Sites
RP	Reference Point
RPE	Reference Point Elevation
RWQCB	Regional Water Quality Control Board
SAGBI	Soil Agricultural Groundwater Banking Index
SB	Senate Bill
SGMA	Sustainable Groundwater Management Act
SMC	Sustainable Management Criteria
SMCL	Secondary Maximum Containment Level
SVWQC	Sacramento Valley Water Quality Coalition
SWP	State Water Project
SWRCB	State Water Resources Control Board

SWS	Surface Water System
TAC	Technical Advisory Committee
taf	Thousand acre-feet
TDS	Total Dissolved Solids
Tehama County FCWCD	Tehama County Flood Control and Water Conservation District
Tehama IHM	Tehama Integrated Hydrologic Model
TM	Technical Memorandum
UNAVACO	University NAVSTAR Consortium
USBLM	Bureau of Land Management
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UWMP	Urban Water Management Plan
UWMPA	Urban Water Management Planning Act
W	Wet Sacramento Valley water year type
WCR	Well Completion Report
WDL	Water Data Library
WDR	Waste Discharge Requirements
WMP	Water Management Plan

FINAL REPORT

Bowman Subbasin

Sustainable Groundwater Management Act

Groundwater Sustainability Plan

(Executive Summary)

January 2022

Prepared For:

Tehama County Flood Control and Water Conservation District

Prepared By:

Luhdorff & Scalmanini

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ES 1. INTRODUCTION

In 2014, the California legislature enacted three bills, AB 1739 (Dickinson), SB 1168 (Pavley), and SB 1319 (Pavley), collectively known as the Sustainable Groundwater Management Act (SGMA) in response to overdraft conditions of California's groundwater resources. Since 2016, the Tehama County Flood Control and Water Conservation District (Tehama County FCWCD) (District), a local and regional authority, is the exclusive GSA for the Bowman Subbasin. The Tehama County Groundwater Commission serves as an advisory commission to the Tehama County Flood Control and Water Conservation District Board of Directors for GSA related matters. Groundwater Commission meetings, which are open to the public, were held the 4th Wednesday of each month, except holidays.

The GSP provides information demonstrating that the past and present actions of the GSA have created a sustainably managed groundwater basin. The GSP outlines planned management oversight and activities that will result in continued sustainability of the groundwater resources in the Bowman Subbasin.

This Executive Summary and the companion GSP are organized as follows:

- Executive Summary
- Section 1 Introduction
- Section 2 Plan Area, Basin Setting and Water Budgets
- Section 3 Sustainable Management Criteria and Monitoring Network
- Section 4 Projects and Management Actions
- Section 5 Plan Implementation
- Appendices

The following sections provide factors about the Subbasin and an overview of technical content in the GSP.

The Bowman Subbasin (Subbasin) (DWR Subbasin No. 5-006.01) (**Figure ES-1**) has been identified by the California Department of Water Resources (DWR) as a high priority subbasin. Under SGMA high priority subbasins are required to prepare and be managed under a GSP by January 31, 2022. This GSP, prepared by the GSA, adequately defines groundwater conditions in the managed area and establishes criteria to maintain and/or achieve sustainability within 20 years of the GSP adoption.

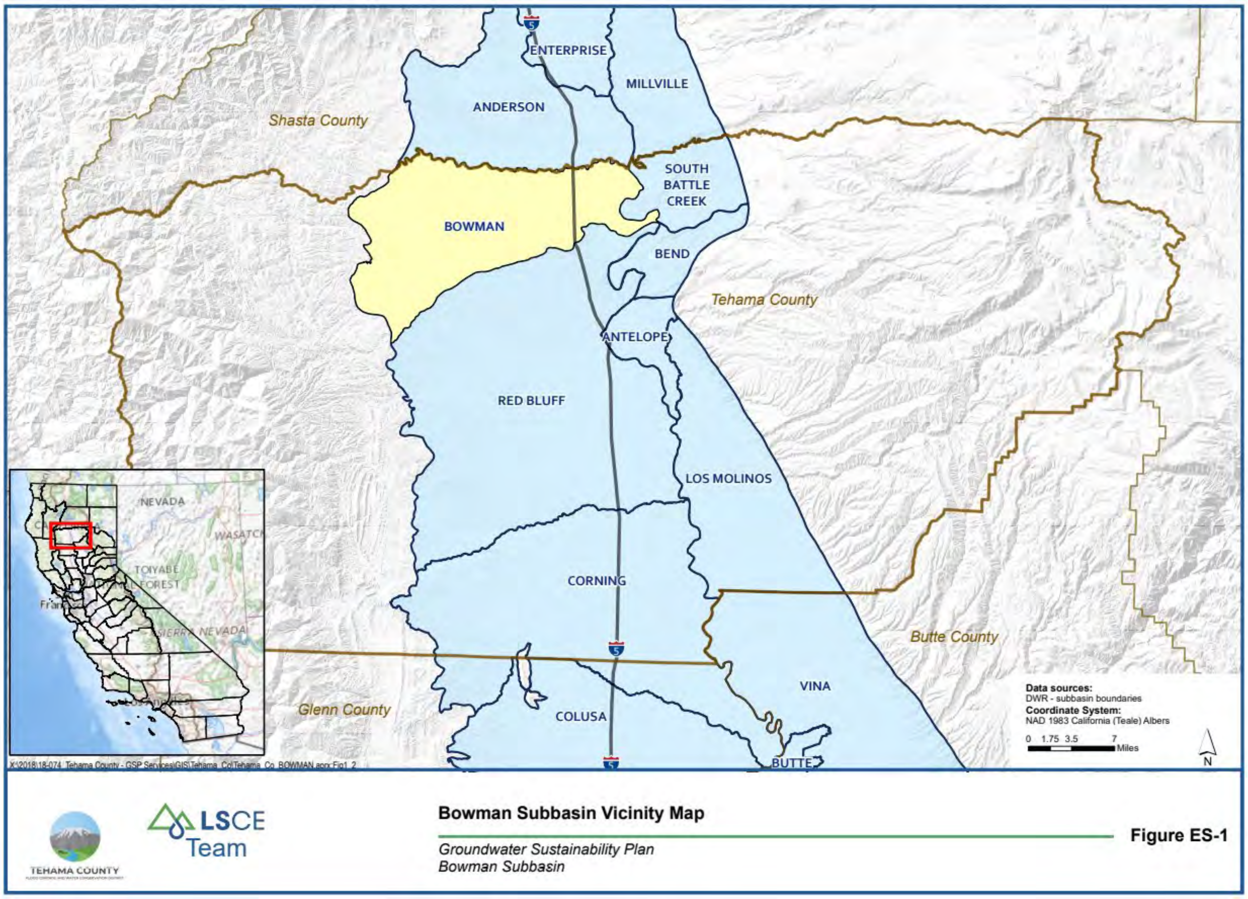

Figure ES-1. Bowman Subbasin Location Map

A Public Draft GSP was made available for public review and comment on September 24, 2021, for a period of 45 days. The GSA received comments, reviewed, and prepared responses to comments, and revised the Draft GSP. The Final GSP will include those revisions. Comment letters and responses will be included as GSP appendices.

ES 2. SUMMARY OF PLAN AREA

The Bowman Subbasin (DWR Subbasin No. 5-021.54) covers 122,500 acres and is Redding Area Groundwater Basin (**Figure ES-1**). Bowman is one of seven (7) subbasins within Tehama County. The Tehama County FCWCD is the exclusive GSA for six (6) of those subbasins: Antelope, Bend, Bowman, Los Molinos, Red Bluff, and South Battle Creek. The seventh, the Corning Subbasin, extends into Glenn County, and the GSP for that subbasin is being developed in a coordinated effort between the Tehama County FCWCD and Corning Sub-basin GSA.

The lateral extent of the Subbasin is consistent with Bulletin 118 (DWR, 2018). It is bounded on the north by the Anderson Subbasin, on the south by the Red Bluff Subbasin, on the east by the South Battle Creek Subbasin, and on the west by the Northern Coast Mountain Ranges. The northern and eastern boundaries of the Subbasin generally follow Cottonwood Creek and the Sacramento River, respectively, and the western boundary generally aligns with the Northern Coast Mountain Range. The vertical boundaries of the Subbasin are the land surface (upper boundary) and the definable bottom of the basin (lower boundary). The definable bottom is the base of fresh water located at approximately from 400 to 1,200 feet below ground surface (bgs) at different locations in the Subbasin.

Lands in the Bowman Subbasin are mostly privately owned with state and federal agencies owning a small portion. Private lands are majority farmland with nearly equal amounts riparian and other native vegetations. Over 2,500 groundwater wells exist in the Subbasin, and most are domestic wells. A few wells are operated for the public water supply and roughly five times that number of wells are maintained for agricultural production. Numerous monitoring programs are operated in the Subbasin by federal, state, and local public agencies including the EPA, USGS and DWR. Monitoring programs collect data on groundwater levels, groundwater quality, land subsidence and surface water conditions. Data from these programs were incorporated (as applicable) into the evaluation of basin conditions within this GSP and were part of previous management plans including the Tehama County AB3030 Groundwater Management Plan (GWMP) and the Northern Sacramento Valley Integrated Regional Water Management Plan (IRWMP). Components of these management plans were incorporated into this GSP.

ES 2.1. Basin Setting and Hydrogeologic Conceptual Model

The ground surface generally slopes from the west to east of the Subbasin and water generally flows eastward towards the Sacramento River. Recharge contributions to the deeper geologic formations occurs where the formations outcrop at the surface, however recharge of the Subbasin primarily occurs along Cottonwood Creek, the South Fork of Cottonwood Creek, and the Sacramento River, as well as perennial streams where saturated hydraulic conductivity of soils is high. Water flows downward in the upper aquifer driven by natural recharge. Gaining conditions along streams represent discharge from the aquifer to surface water and occur seasonally. Larger sources of discharge from the aquifer are likely from production of wells even though a portion returns to the aquifer via recharge from irrigations. Even with the noted groundwater withdraw there is little to no reported evidence of subsidence within the Subbasin.

Horizontal hydraulic gradients are approximately 16 ft/mile to 18 ft/mile in the eastern half of the Subbasin, and data are not available to estimate the gradient in the western half. Seasonal high historical water levels range between about 20 and 190 ft bgs, with shallower depths (about 20 – 30 bgs) close to the northeastern boundary of the Subbasin. Groundwater quality is good with no widespread presence of contaminants at undesirable levels.

The Subbasin is defined as a two-aquifer system with unconfined to semi-confined conditions in the Upper Aquifer and semi-confined to confined conditions in the Lower Aquifer. Fresh water occurs as groundwater to a maximum depth of over -1,200 ft msl in the west of the Subbasin. The major water bearing formations within the Subbasin are the Tuscan and Tehama Formations with some contribution from the shallower Quaternary sedimentary deposits. More recent geologic history is dominated by fluvial and alluvial deposition.

ES 2.2 Water Budget

In accordance with technical guidance documents provided by DWR, water budget scenarios were evaluated using a groundwater flow model that quantified historical, current, and projected groundwater budget conditions. The water budgets were developed through application of the Tehama Integrated Hydrologic Model (Tehama IHM), a numerical groundwater flow model that characterizes surface water and groundwater movement and storage across the entire Subbasin and extending outside of the Subbasin. The Tehama IHM is an integrated groundwater and surface water model developed for the purpose of conducting sustainability analyses within Tehama County. The model used foundational elements of DWR's SVSim regional model for the Sacramento Valley (DWR, 2021) and was refined locally for improved application in the Subbasin area. Use of publicly available modeling platforms is a guiding principle under DWR Best Management Practices and facilitates independent assessment of modeling results.

The model was calibrated using records from 1990-2019 (29 years). This period represents long-term average hydrologic conditions and is considered the historical water budget period. The current water budget presents information on the effects of recent hydrologic and water demand conditions on the groundwater system and spans five different recent periods. The historical and current water budget periods were selected to evaluate conditions over discrete representative periods considering the following criteria: Sacramento Valley water year type; long-term mean annual water supply; inclusion of both wet and dry periods, antecedent dry conditions, adequate data availability; and inclusion of current hydrologic, cultural, and water management conditions in the Subbasin. Water budgets were calculated for a projected 50-year period, 2022 through 2072. The 50-year projected water budget uses hydrologic conditions representative of the most recent 50 years of hydrology in the Subbasin, with adjustments applied in scenarios for evaluating the water budget under climate change and altered water supply and demand conditions.

Model results indicate that over the historical period the largest outflow from the groundwater system (GWS) comes from groundwater pumping (on average 13 thousand-acre feet (taf) per year). Groundwater discharge to the surface is 55 taf per year. Deep percolation is the largest net inflow to the GWS (12 taf per year). Subsurface inflows from adjacent subbasins and upland areas represents 50 taf per year gain to the GWS. Groundwater root uptake represents a small flux of 1.5 taf per year of the leaving the GWS. Over the 29-year historic period the average annual change in storage was around -610 af per year.

The recent three-year period from 2016 through 2018 is believed to provide a reasonable representation of the recent water budget conditions based on an evaluation of past water budgets and the hydrologic conditions over these recent periods. A comparison of several future modeled water budgets was made to define the possible effect of different climate change and management action scenarios. Overall projected storage change in the Subbasin is small and differs little between the different climate change conditions.

The sustainable yield was estimated to be 10,000 acre-feet per year, which is equal to the volume of groundwater extracted annually in the Subbasin (by pumping and by uptake) minus the simulated change in storage in the projected model scenario with future land use and 2070 climate change conditions. Under these conditions groundwater extractions total about 9,900 acre-feet per year on average. The change in storage is nearly zero which results in the sustainable yield equaling 10,000 acre-feet. Assuming potential uncertainty of 25 percent associated with the water budget estimates, an associated range of values for the estimated sustainable yield would be 7,500 to 12,500 acre-feet per year.

ES 3. SUSTAINABILITY MANAGEMENT CRITERIA

Sustainable management criteria include establishing a sustainability goal for the Subbasin, defining undesirable results, and quantifying minimum thresholds and measurable objectives.

The sustainability goal for the Bowman Subbasin GSP is to manage the groundwater Subbasin to:

- Protect and maintain safe and reliable sources of groundwater for all beneficial uses and users.
- Ensure current and future groundwater demands account for changing groundwater conditions due to climate change.
- Establish and protect sustainable yield for the Subbasin by achieving measurable objectives set forth in this GSP in accordance with implementation and planning periods.
- Avoid undesirable results defined in the GSP in accordance with SGMA.

Sustainable management criteria (SMC) also define the conditions that constitute sustainable groundwater management. Note that undesirable results have not occurred historically in the Bowman Subbasin and are not projected to occur in the future. The sustainable management criteria will commit the GSA to meeting the sustainability goal for the Subbasin.

Sustainability indicators are measurable indicators that are used to set Measurable Objectives (MO), interim milestones and Minimal Thresholds (MT) to ensure that the sustainability goals are met. Undesirable results occur when significant and unreasonable effects are caused by groundwater conditions for a given sustainability indicator. Sustainability indicators are listed in **Table ES-1** along with whether undesirable results occurred in the subbasin and if they are likely to occur in the future without GSP implementation. Sustainability indicators will be measured at representative monitoring sites (RMS) selected based on location, aquifer, and historical data. MOs, MTs and undesirable results are defined in **Table ES-2.**

Table ES-1: Summary of Undesirable Results Applicable to the Plan Area

SUSTAINABILITY INDICATOR	HISTORICAL PERIOD	EXISTING CONDITION	FUTURE CONDITIONS WITHOUT GSP IMPLEMENTATION
Chronic Lowering of Groundwater Elevations	No	No	No
Reduction of Groundwater Storage	No	No	No
Seawater Intrusion	Not Applicable	Not Applicable	Not Applicable
Degraded Water Quality	Limited	Limited	Limited
Land Subsidence	No	No	No
Depletion of Interconnected Surface Water	Data Gap	Data Gap	TBD

Table ES-2. Summary of MT, MO, and Undesirable Results

SUSTAINABILITY INDICATOR	MINIMUM THRESHOLD	MEASURABLE OBJECTIVE	UNDESIRABLE RESULT
Chronic Lowering of Groundwater Elevations	**Upper Aquifer:** Spring groundwater elevation where less than 10% or less than 20% of domestic wells could potentially be impacted. **Lower Aquifer:** Spring groundwater elevation minus 20 to 120 feet	**Upper & Lower Aquifer:** Spring 2015 groundwater elevation minus five feet (for wells with increasing or no groundwater trends) or projected Spring 2042 groundwater elevation minus five feet for wells with declining groundwater elevations	25% of groundwater elevations measured at same RMS wells exceed the associated MT for two consecutive measurements.
Reduction of Groundwater Storage	**Upper & Lower Aquifer:** Amount of groundwater in storage when groundwater elevations are at their minimum threshold	**Upper & Lower Aquifer:** Amount of groundwater storage when groundwater elevations are at their measurable objective	Same as chronic lowering of groundwater levels
Land Subsidence	Two feet over 20 years (i.e., no more than 0.5 feet of cumulative subsidence over a five-year period (beyond the measurement error), solely due to lowering of groundwater elevations	One foot over 20 years (Zero inelastic subsidence, in addition to any measurement error). If InSAR data are used, the measurement error is 0.1 feet and any measurement 0.1 feet or less would not be considered inelastic subsidence	50% of RMS exceed the minimum threshold over a 5-year period that is irreversible and is caused by lowering of groundwater elevations
Seawater Intrusion	Not Applicable	Not Applicable	Not Applicable

SUSTAINABILITY INDICATOR	MINIMUM THRESHOLD	MEASURABLE OBJECTIVE	UNDESIRABLE RESULT
Degraded Water Quality	**Upper & Lower Aquifer:** TDS concentration of 750 mg/L at all RMS wells	**Upper & Lower Aquifer:** California lower limit secondary MCL concentration for TDS of 500 mg/L measured at RMS wells	At least 25% of RMS exceed the minimum threshold for water quality for two consecutive years at each well where it can be established that GSP implementation is the cause of the exceedance
Depletion of Interconnected Surface Water	Same as chronic lowering of groundwater levels (Initial)	Same as chronic lowering of groundwater levels (Initial)	25% of groundwater elevations measured at RMS wells drop below the associated threshold during two consecutive years in the Upper Aquifer.

ES 3.1. Chronic Lowering of Groundwater Elevations

Groundwater levels declined over the historical period. This trend is expected to continue without GSP implementation. The MOs for Chronic Lowering of Groundwater Elevations indicator is defined at each of the RMS (wells) as that well's spring 2015 groundwater elevation minus five feet or projected 2042 groundwater elevation minus five ft for wells with declining groundwater elevations. MTs are defined as the groundwater level at RMS wells that are estimated to impact (potentially run dry) less than 10% or less than 20% of nearby domestic wells. It is considered an Undesirable Results for Chronic Lower of Groundwater Elevations if 25% of groundwater elevations measured at RMS wells exceed the associated MT for two consecutive measurements.

ES 3.2. Reduction of Groundwater Storage

The groundwater storage reduction sustainability indicator will be evaluated using groundwater levels as a proxy in conjunction with annual evaluations of monitored groundwater level changes. Based on considerations applied in developing the groundwater level minimum thresholds, reduction in groundwater storage minimum thresholds do not exceed any identified significant and unreasonable level of depleted groundwater storage volume.

ES 3.3. Subsidence

Land subsidence is not known to have occurred in the subbasin, is not occurring presently, and is not expected to occur without GSP implementation. MOs have been defined as a decline of one foot over 20 years. Subsidence is based on InSAR data. InSAR measurement error is 0.1 feet and any measurement 0.1 feet or less would not be considered inelastic subsidence. MTs are defined by a decline of two feet over 20 years. Undesirable Results are defined as 50% of RMS exceeding the minimum threshold over a 5-year period that is irreversible and is caused by lowering of groundwater elevations. RMS for subsidence are the InSAR pixels collocated or near the water level RMS wells.

ES 3.4. Degraded Water Quality

Groundwater quality in the Subbasin is generally good with a few exceptions. Present conditions are unchanged from conditions within the historical period however conditions could worsen without GSP implementation. MOs are defined by the California MCL for TDS of 500 mg/L measured at RMS wells. MTs are set at 750 mg/L measured at RMS wells. Undesirable Results occur if 25% of RMS exceed the minimum threshold for water quality for two consecutive years at an individual well where it can be established that GSP implementation is the cause of the exceedance.

ES 3.5. Seawater Intrusion

Due to the location of the Subbasin relative to any potential source of seawater this sustainability criterium is not applicable to this subbasin.

ES 3.6. Depletion of Interconnected Surface Waters

The interconnected surface water sustainability indicator could not be properly defined due to gaps in historical surface and groundwater monitoring programs. It is not known if conditions will worsen without GSP implementation without a reliable way to correlate the groundwater and surface water elevations. Due to the lack of data associated with this sustainability indicator the MOs and MTs are considered interim and will use the Chronic Lowering of Groundwater Elevations sustainability indicator as a proxy. An Undesirable Result is defined as 25% of groundwater elevations measured at upper aquifer RMS wells dropping below the associated threshold during two consecutive years.

ES 3.7. Monitoring Network

Monitoring networks are developed to quantify current and future groundwater conditions in the Bowman Subbasin, as well as within individual GSA jurisdictions. The monitoring network for sustainability indicators is summarized in **Figure ES-2.** There are a total of seven RMS wells in the Bowman Subbasin, four in the Upper Aquifer and three in the Lower Aquifer. The four Upper Aquifer RMS wells serves as the monitoring locations for the Chronic Lowering of Groundwater Elevations, Reduction of Groundwater Storage, Depletion of Interconnected Surface Water, and Water Quality indicators. The Lower Aquifer RMS wells are associated with the first three indicators, but not the Interconnected Surface Water Depletion indicator. The InSAR RMS are pixels collocated or near the water level RMS wells. Measured water level elevations will inform MO and MTs for Chronic Lowering of Groundwater Elevations, Reduction of Groundwater Storage, Depletion of Interconnected Surface Water indicators. Water quality samples taken from RMS wells will inform the MOs and MTs for the Degraded Water Quality indicator. Land Subsidence will be informed at RMS (select pixels) using satellite InSAR data. The monitoring network will be periodically reviewed and modified as needed; for instance, additional RMS wells may be added to better understand interconnected surface waters.

A Data Management System (DMS) was developed to store and analyze data collected as part of this GSP. With submittal and implementation of the Bowman Subbasin GSP, there will be a publicly accessible weblink to view reports, maps, graphs, and current data under the Subbasin monitoring plan.

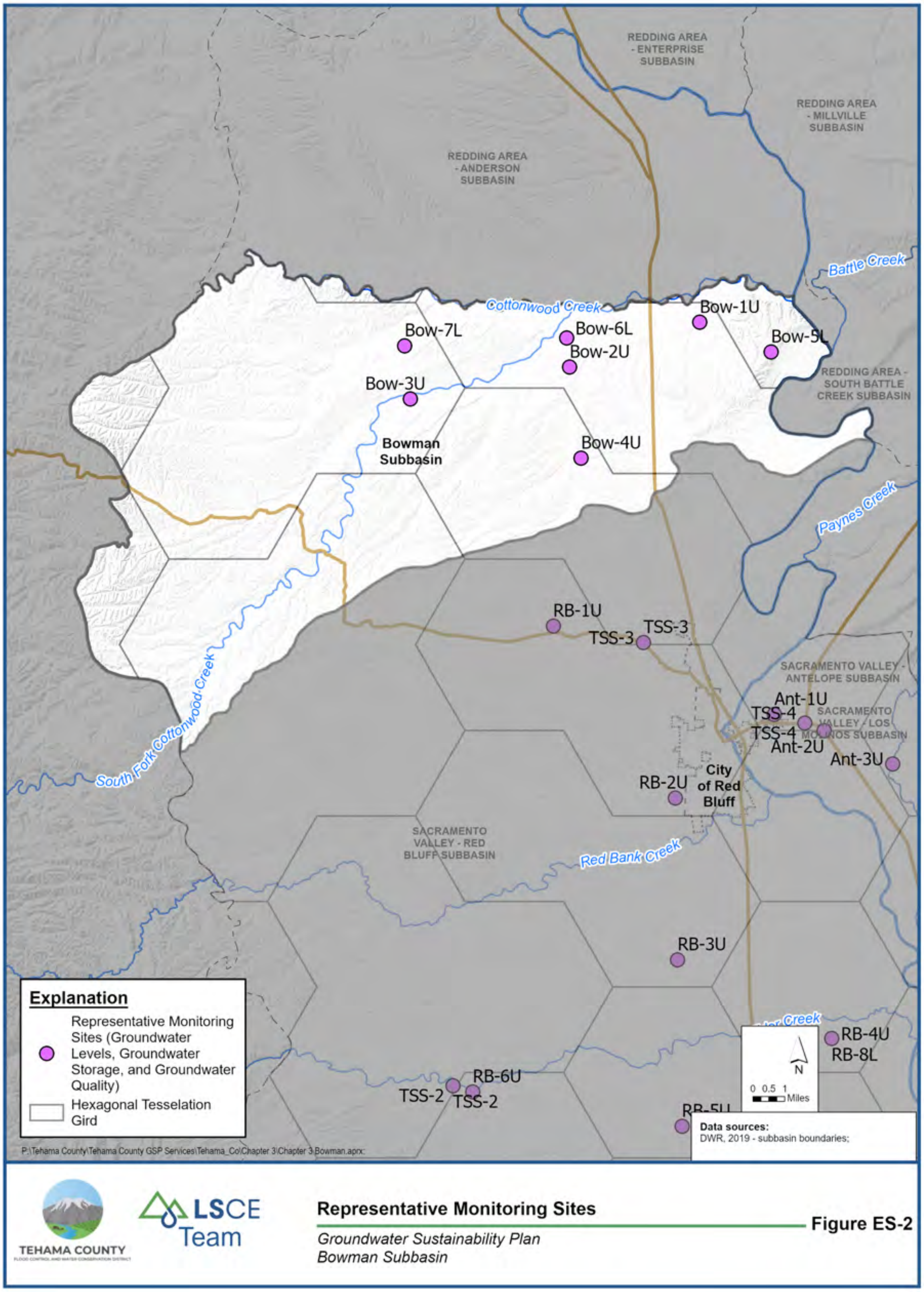

Figure ES-2. Representative Monitoring Sites

ES 4. OVERVIEW OF PROJECTS AND MANAGEMENT ACTIONS

In accordance with 23 CCR §354.44, Projects and Management Actions (PMAs) were developed to achieve and maintain the Subbasin sustainability goal by 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 support sustainable groundwater management. Because the Bowman Subbasin is currently and projected to be sustainable (i.e., no onset of undesirable results), PMAs are not expected to be essential for sustainability. However, future conditions are uncertain and PMAs will be employed through the principle of adaptive management on an as-needed basis.

Even so, the GSA plans to continue monitoring sustainability indicators throughout GSP implementation and will initiate and scale PMAs as needed to ensure that the measurable objectives are met. The following describes PMAs identified for the Bowman Subbasin.

ES 4.1. PMAs Planned for Implementation

The GSA has identified PMAs that are planned to be completed prior to 2042. These projects and management actions are expected to support the GSA in achieving the GSP sustainability goal and responding to changing conditions in the Subbasin.

ES 4.1.1. Multi-Benefit Groundwater Recharge Programs

A multi-benefit recharge program will provide groundwater recharge through normal farming operations while also providing critical wetland habitat for shorebirds migrating along the Pacific Flyway. The Nature Conservancy (TNC) has prepared guidance to assist GSAs in planning on-farm multi-benefit groundwater recharge programs.

ES 4.1.2. Grower Education and Outreach

This 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.

ES 4.1.2. Cottonwood Creek Invasives Control Follow Up & Riparian Habitat Restoration

This project would build on past similar projects by strategically removing known invasive plant species occurring within portions of Cottonwood Creek's South Fork located in Tehama County. The goal of this project would be to reduce demand on riparian and groundwater resources with the benefit of increased groundwater availability for all beneficial users of groundwater in the Subbasin and improved surface water conveyance and ground and surface water interactions.

ES 4.2. Proposed Potential PMAs

Projects and Management Actions in this category are proposed as potential options that GSAs may wish to implement, as needed, to support ongoing sustainability, to adapt to changing conditions in the Subbasin, and to achieve other water management objectives.

ES 4.2.1 Direct Groundwater Recharge

Potential projects would support efforts to recharge groundwater with excess surface water in wet years for use in dry years. Recharge may be done in conveyances such as unlined canal and laterals, natural drainages such as creek beds, recharge basins, agricultural fields, and aquifer storage and recovery (ASR) wells. Projects could also be directed at making improvements to stormwater management facilities to enhance groundwater recharge of stormwater, capture rainfall through modification of on-field conditions and facilitate use of recycled water for groundwater recharge.

ES 4.2.2. Groundwater Demand Reduction

Groundwater demand reduction can be achieved by conveyance improvements such as removal of invasive plants from creeks and irrigation canals. Plant removal would reduce conveyance issues, reduce evapotranspiration (ET), and allow for more water in the shallow groundwater areas, restoring conditions for GDEs and native riparian species.

ES 4.2.3. Surface Water Supply Augmentation & In-Lieu Groundwater Recharge

Programs directed at promoting inter-basin surface water transfers or exchanges can potentially subsidize surface water costs so that it is less expensive than groundwater. Construction, renovation, or conversion of flood control facilities to water supply reservoirs can increase available supply of surface water.

ES 4.2.4. Education/Outreach, In-Lieu Groundwater Recharge

This management action assist growers with conversion to efficient and dual-source irrigation systems, improve surface water conveyance and irrigation infrastructure to allow growers to utilize both surface water and groundwater for drip irrigation of orchards, assist growers with capital improvements to irrigation infrastructure, from use of groundwater to use of surface water or dual-source systems.

ES 4.2.5. Groundwater Demand Reduction.

Management actions aimed at reduction of groundwater demand may offer incentives for urban, residential, and commercial projects that improve water use efficiency, such as high efficiency appliance rebates and incentives for lawn removal, low-water landscape installation, rain barrels, graywater reuse, etc. Action may promote the conversion of agricultural lands to less water intensive crops to reduce water use while continuing to promote agriculture land use.

ES 4.2.6. In-Lieu Groundwater Recharge

Management actions aimed at increasing In-Lieu recharge may incentivize use of surface water for irrigation when available to allow groundwater levels to recover in between drought years when surface water is not available. Effective management actions may also increase use of surface water by creating a water market for exchanging surface water and groundwater.

ES 4.2.7. Monitoring to Fill Data Gaps & Programs to Support Wells

Several data gaps have been identified in this GSP. Additional studies of GDEs and groundwater surface water interactions, expanded subbasin monitoring and aquifer testing, install additional agroclimate stations, maintain and expand groundwater level monitoring network, and a one-time groundwater quality snapshot are all actions that can be taken to improve data gaps.

To support well owners and reduce impacts of potential undesirable results a county-wide system to tracking dry domestic wells will better inform and lead to better management of assistance to domestic well owners when water levels drop, and wells go dry.

ES 5. PLAN IMPLEMENTATION

This GSP will be implemented to achieve the Subbasin sustainability goal by 2042 and avoid undesirable results through 2070 as required by SGMA and GSP regulations. Implementation of this GSP includes PMAs in addition to on-going activities that will be completed by the GSA related to monitoring, management, administration, updates, reporting, and public outreach.

GSP implementation costs include both costs specific to projects and management actions and costs for the GSA to administer and operate all other tasks associated with the GSP over the 20-year implementation period. The total cost is estimated to be approximately $19,757,000.

These costs may be subject to change, as they are projections based on the time of development of this report. GSP implementation and GSA support costs are estimated on an annual basis and are described in further detail below.

Table ES-3. Estimated GSP Implementation Costs through 2042

FISCAL YEAR	GSA ADMINISTRATION	MONITORING	5-YEAR UPDATES	10% CONTINGENCY	TOTAL
2022	$470,000	$104,000	$0	$57,000	$631,000
2023	$484,000	$107,000	$0	$59,000	$650,000
2024	$499,000	$110,000	$0	$61,000	$670,000
2025	$514,000	$114,000	$0	$63,000	$690,000
2026	$529,000	$117,000	$150,000	$80,000	$876,000
2027	$545,000	$121,000	$150,000	$82,000	$897,000
2028	$561,000	$124,000	$0	$69,000	$754,000
2029	$578,000	$128,000	$0	$71,000	$777,000
2030	$595,000	$132,000	$0	$73,000	$800,000
2031	$613,000	$136,000	$169,000	$92,000	$1,010,000
2032	$632,000	$140,000	$174,000	$95,000	$1,040,000
2033	$651,000	$144,000	$0	$79,000	$874,000
2034	$670,000	$148,000	$0	$82,000	$900,000
2035	$690,000	$153,000	$0	$84,000	$927,000
2036	$711,000	$157,000	$196,000	$106,000	$1,170,000
2037	$732,000	$162,000	$202,000	$110,000	$1,205,000
2038	$754,000	$167,000	$0	$92,000	$1,013,000

FISCAL YEAR	GSA ADMINISTRATION	MONITORING	5-YEAR UPDATES	10% CONTINGENCY	TOTAL
2039	$777,000	$172,000	$0	$95,000	$1,044,000
2040	$800,000	$177,000	$0	$98,000	$1,075,000
2041	$824,000	$182,000	$227,000	$123,000	$1,357,000
2042	$849,000	$188,000	$234,000	$127,000	$1,397,000
Total	$13,478,000	$2,983,000	$1,502,000	$1,798,000	$19,757,000

Development of this GSP was funded through Proposition 1 and Proposition 68 Grants. Ongoing implementation, monitoring, and reporting are expected to be funded through fees and outside grants and funding. The GSA is currently developing a financing plan that will include one or more of the following financing approaches

- Grants and low-interest loans: GSA 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 all of the GSA operating costs for GSP implementation
- GSP Implementation Costs: Initial implementation costs not covered by grant funding will be assessed through either land-based charge or groundwater usage charge. In the future the GSA may adopt a volumetric charge on groundwater extracted from the Subbasin.
- Taxes: This could include general property related taxes that are not directly related to the benefit or cost of a service (ad valorem and parcel tax), or special taxes imposed for a specific purpose related to GSA activities.

The GSA is pursuing a combined approach, targeting available grants and low interest loans, and considering a combination fee and assessment to cover operating and program-specific costs. The GSA will comply with statutory and California constitutional requirements to adopt any rate, fee, charge, or assessment to fund implementation of the GSP.

This GSP will be adopted and submitted to DWR by January 31, 2022. The implementation timeline will begin thereafter and will allow the GSA to develop and implement projects and management actions to meet sustainability objectives by 2042. GSP implementation also includes annual and periodic evaluations and submittals to DWR. The full schedule for implementation is subject to change, will be evaluated, and updated as necessary based on implementation progress, sustainability goals, monitoring, and other factors that could affect implementation. The implementation timeline as presently described is outlined below in **Figure ES-3**.

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

Annual reports will be completed and submitted to DWR by April 1 of each year pursuant to GSP Regulation §356.2. Annual reports will include sections on general information, basin conditions, and plan implementation progress for the reporting period. The annual report submitted to DWR will comply with the requirements of §356.2. The GSA will evaluate the GSP every five years and whenever the plan is amended. The evaluation will be submitted to DWR and include the elements of the Annual Report, a summary of the GSP, project, and management action implementation progress, and progress toward meeting the sustainability goal of the Subbasin.

Figure ES-3. GSP Implementation Schedule

TASK NAME	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
Plan Implementation																					
GSP Submittal to DWR	x																				
Outreach and Communication																					
Monitoring and DMS																					
GSP Reporting																					
Annual Reports	x	x	x	x	x		x	x	x	x		x	x	x	x		x	x	x	x	
5-year GSP Evaluation Reports						x					x					x					x

x Indicates a submittal.
Indicates ongoing event.

ES 6. OVERVIEW OF GOVERNANCE

In adopting the Sustainable Groundwater Management Act ("SGMA"), the Legislature made clear that nothing in SGMA "determined or alters surface water of groundwater rights under common law or any provision of the law that determines or grants surface water rights. In other words, the Legislature intended that actions undertaken in accordance with SGMA to respect common law water rights.

This GSP established the objectives of maximizing the beneficial use of water with the Bowman Subbasin, without causing undesirable results. The powers of the GSA are set forth in SGMA. This GSP meets the requirements of SGMA and vests the management authority in the GSA. Authorities include Powers of the Board, Rules and Regulations, Committees, Specific Powers, Variances and Complaints.

FINAL REPORT

Bowman Subbasin

Sustainable Groundwater Management Act

Groundwater Sustainability Plan

(Chapter 1- Introduction)

January 2022

Prepared For:

Tehama County Flood Control and Water Conservation District

Prepared By:

Luhdorff & Scalmanini

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LIST OF ACRONYMS & ABBREVIATIONS

AB	Assembly Bill
CASGEM	California Statewide Groundwater Elevation Monitoring
CCR	California Code of Regulations
CWC	California Water Code
DWR	California Department of Water Resources
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
GWMP	Groundwater Management Plan
SB	Senate Bill
SGMA	Sustainable Groundwater Management Act
TAC	Technical Advisory Committee
Tehama County FCWCD	Tehama County Flood Control and Water Conservation District

1 INTRODUCTION

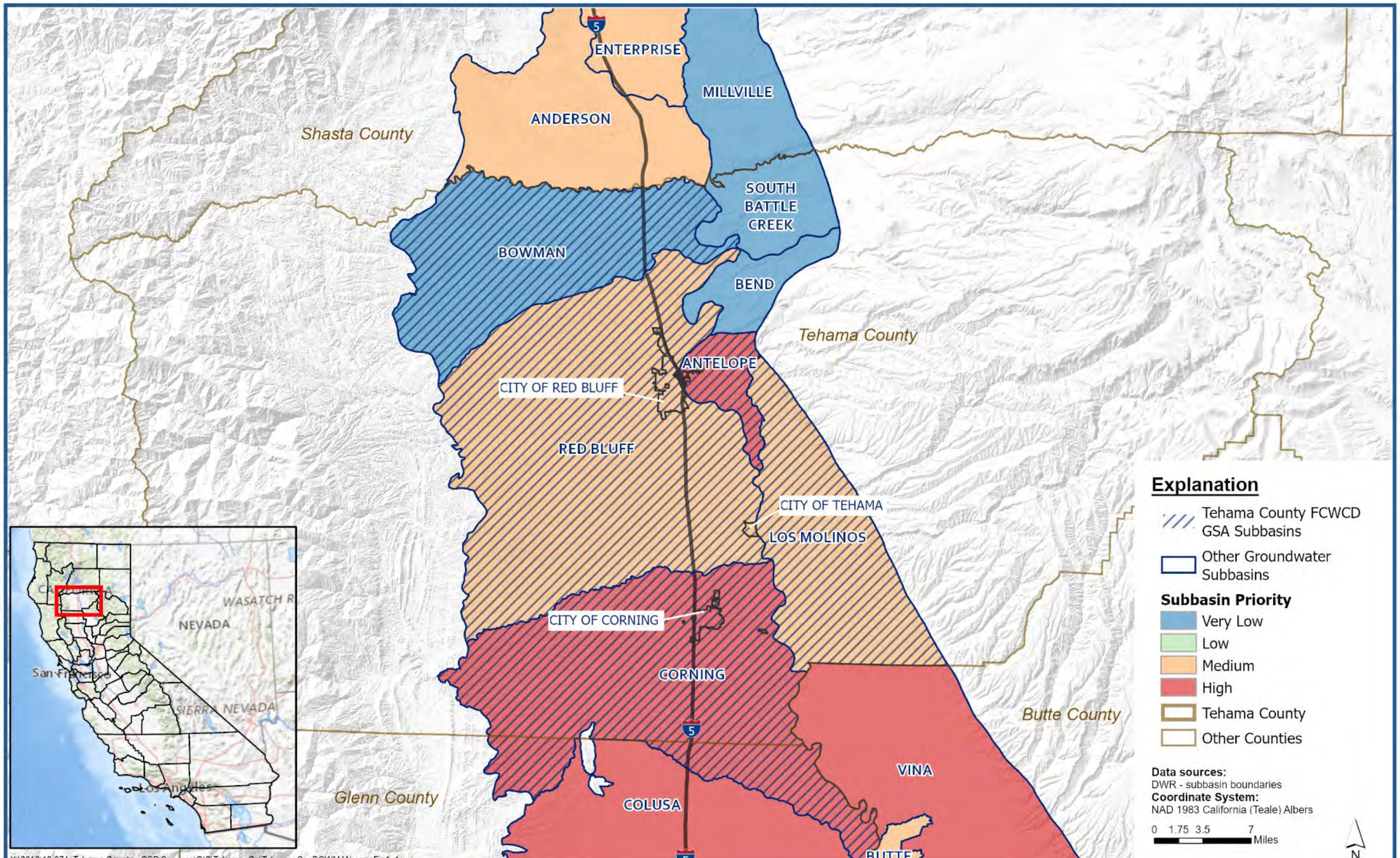
Groundwater serves as an important source of supply for agricultural, municipal, domestic, environmental, and industrial beneficial uses throughout Tehama County, which underlies approximately 1.9 million acres of the County. Agriculture in Tehama County relies on groundwater to produce an array of commodities that contribute to the agricultural economies of the County. Groundwater also supports the majority of domestic, municipal, and industrial water use in and around the City of Corning, City of Red Bluff, and City of Tehama. Thus, the sustainable management of groundwater in the County is important for long-term prosperity.

The Bowman Subbasin, which is entirely located within Tehama County, is comprised of approximately 122,500 acres, and relies on an average of approximately 5,200 acre-feet (AF) of groundwater annually for agriculture (1991-2019), has been identified by the California Department of Water Resources (DWR) as a very low priority subbasin. Under the Sustainable Groundwater Management Act (SGMA) of 2014, high or medium priority subbasins are required to prepare and be managed under a Groundwater Sustainability Plan (GSP, or Plan) by January 31, 2022 (California Water Code (CWC) Section 10720.7(a)(1)) (**Figure 1-1**). Although the Bowman Subbasin is not designated as a high or medium priority subbasin, the Groundwater Sustainability Agency (GSA) received funding to develop the GSP and is leading its development in conjunction with three other GSPs being developed by the GSA as described in **Section 1.1** below.

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 GSAs with the authority to develop, adopt, and implement a GSP. 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 without causing "undesirable results" as defined by SGMA: significant and unreasonable lowering of groundwater levels, loss of groundwater storage and supply, degradation of water quality, land subsidence, and surface water depletion. Sea water intrusion, while a SGMA-defined undesirable result, is not applicable to the Bowman Subbasin.

1.1 Purpose of Groundwater Sustainability Plan

The purpose of this GSP is to optimize groundwater use and groundwater storage in the Bowman Subbasin while meeting the regulatory requirements set forth in the three-bill legislative package, Assembly Bill (AB) 1739 (Dickinson), Senate Bill (SB) 1168 (Pavley), and SB 1319 (Pavley), collectively known as the Sustainable Groundwater Management Act which became effective in California in January 2015 (Water Code §§ et seq). Under SGMA, all high or medium priority groundwater basins or subbasins must form a GSA to represent the subbasin or a portion thereof and submit an adopted GSP to DWR) by January 31, 2022. The Bowman Subbasin (DWR Subbasin No.5-006.01) of the Sacramento Valley Groundwater Basin was assigned a very low priority designation by DWR, and the GSA is choosing to submit a GSP. The Tehama County Flood Control and Water Conservation District (Tehama County FCWCD) (District), a local and regional authority, serves as the exclusive GSA for the Bowman Subbasin.



TEHAMA COUNTY

LSCE Team

Tehama County FCWCD GSA Subbasins

Groundwater Sustainability Plan
Bowman Subbasin

Figure 1-1

There are seven (7) subbasins within Tehama County. The Tehama County FCWCD is the exclusive GSA for six (6) of those subbasins: Antelope, Bend, Bowman, Los Molinos, Red Bluff, and South Battle Creek **(Figure 1-2).** The seventh, the Corning Subbasin, extends into Glenn County, and the GSP for that subbasin is being developed in a coordinated effort between the Tehama County FCWCD and Corning Sub-basin GSA. Both GSAs retain jurisdictional authority over the portion of the Corning Subbasin that is within their county. Of the seven (7) subbasins in the County, the Antelope, Corning, Los Molinos, and Red Bluff Subbasins are designated as medium or high priority and required to submit a GSP in January 2022 **(Figure 1-1).** The Bowman Subbasin was initially designated as medium priority and the District was awarded funding for the Bowman Subbasin under the Proposition 1, Round 2 grant. The District has elected to lead development of a SGMA compliant Plan for the Bowman Subbasin (subsequently, the subbasin's prioritization was changed by DWR to a very low priority) to be submitted in January 2022.

The GSPs for the Antelope, Bowman, Los Molinos, and Red Bluff Subbasins are being developed concurrently, and will be submitted as four (4) separate GSPs. The Corning Subbasin GSP will be submitted in a coordinated effort between the District and the Corning Sub-basin GSA.

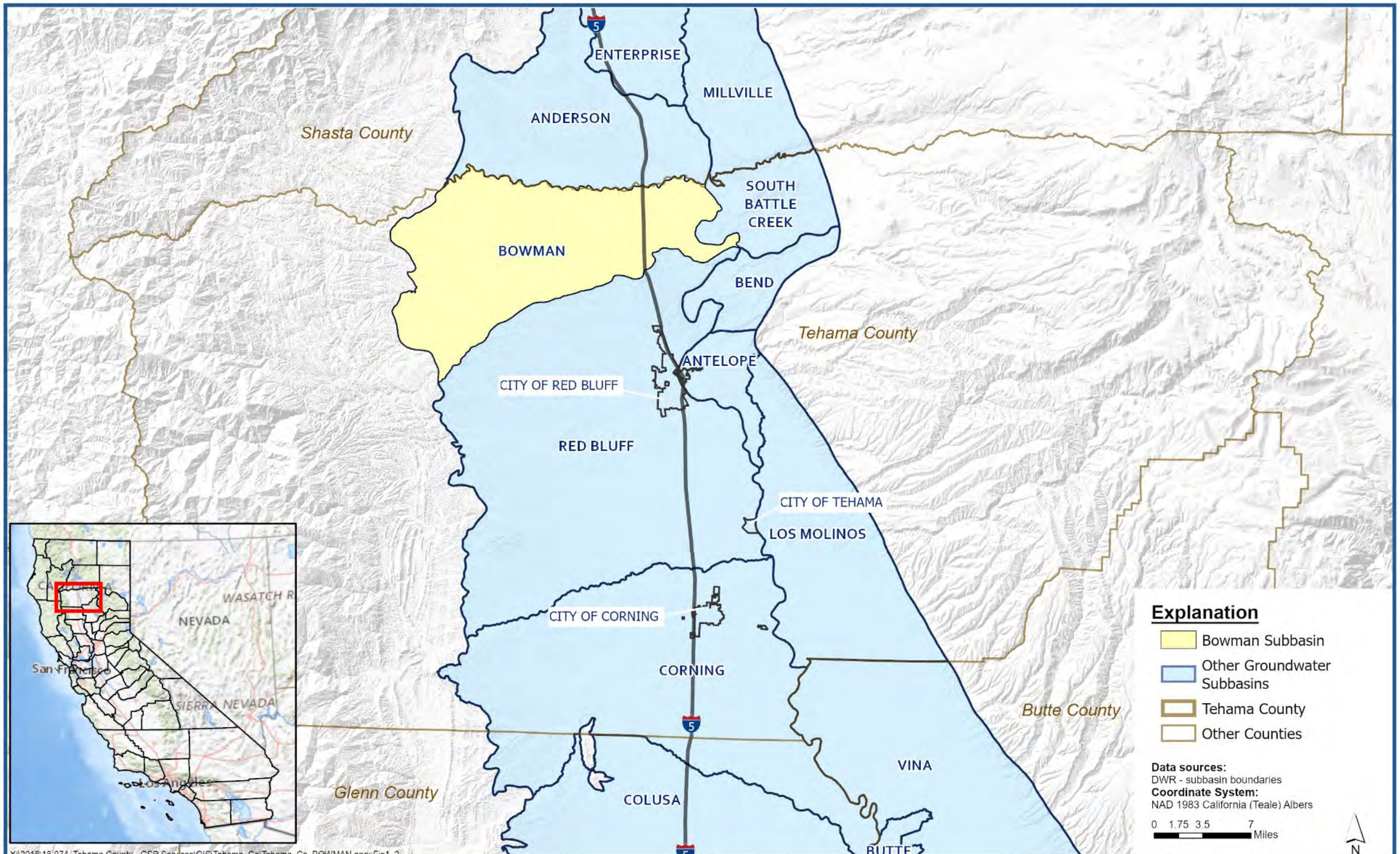
SGMA defines sustainable groundwater management as "management and use of groundwater in a manner that can be maintained during the planning and implementation horizon (50 years from 2022 through 2072) without causing undesirable results" (Water Code, § 10721(v)). Undesirable results, caused by groundwater pumping in the Subbasin, are recognized as:

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

Each applicable sustainability indicator will be addressed in this GSP and integrated into subbasin-wide monitoring programs based on existing hydrogeologic conditions and current management practices in the Subbasin. Measurable objectives and minimum thresholds have been set for each sustainability indicator based on an analysis of projected hydrologic conditions simulated by a numerical groundwater flow model. This GSP will be implemented over the next 20 years with the intention of establishing sustainable use of groundwater resources for all beneficial users in the Subbasin.

1.1.1 Justification for Management Area

Management areas are not being incorporated into this GSP for the Bowman Subbasin.



TEHAMA COUNTY

LSCE Team

Bowman Subbasin Vicinity Map

Groundwater Sustainability Plan
Bowman Subbasin

Figure 1-2

1.2 Sustainability Goal

The Tehama County FCWCD will manage groundwater resources responsibly and sustainably in order to maintain acceptable standards and prevent undesirable results, as defined by SGMA, while recognizing the importance of maintaining groundwater supplies and quality for the beneficial users of groundwater within the Subbasin over the 50-year planning and implementation horizon. As mandated under Title 23 of the California Code of Regulations (CCR) Section 354.24, the GSA within the Bowman Subbasin has established a "sustainability goal for the basin that culminates in the absence of significant and unreasonable undesirable results within 20 years of the applicable statutory deadline." Specifically, this sustainability goal establishes that the Bowman Subbasin will be operated within its sustainable yield by 2042, or 20 years following GSP adoption and 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.

To achieve the sustainability goal, this GSP details the accounting of the Subbasin's sustainable yield and establishes the sustainable management criteria to guide the District in sustainably managing the groundwater resources in the Subbasin. Monitoring networks, projects, and management actions are proposed to achieve and verify sustainable groundwater use. The GSA will review the progress of the GSP in meeting the sustainability goal during the five-year periodic reviews and update the GSP as needed to ensure the GSP will achieve subbasin sustainability. To facilitate review, **Table 1-1** aligns the regulations with this GSP's corresponding section.

Table 1-1. Sustainability 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	2.3
	§ 354.20	Management Areas	2.4
Establishment of Goal	§ 354.24	Sustainability Goal	3.1
	§ 354.26	Undesirable Results	3.4
	§ 354.28	Minimum Thresholds	3.3
	§ 354.30	Measurable Objectives	3.2
Measures of Ensuring Goal Achievement	§ 354.32	Introduction to Monitoring Networks	3.5
	§ 354.34	Monitoring Network	3.5
	§ 354.36	Representative Monitoring	3.6.8
	§ 354.38	Assessment and Improvement of Monitoring Network	3.6.9
	§ 354.44	Projects and Management Actions	4

1.3 Agency Information

The Bowman Subbasin is comprised of 122,533 acres within Tehama County in the southern portion of the Redding Area Groundwater Basin **(Figure 1-2)**. It is bordered by the Anderson Subbasin (DWR Basin 5-006.03) to the north, the Red Bluff Subbasin (DWR Basin 5-021.50) to the south, the South Battle Creek Subbasin (DWR Basin 5-006.06) to the east, and the Coastal Mountain Range to the west. The Tehama County FCWCD was formed in 1957 by the Tehama County Flood Control and Water Conservation District Act and is based in Gerber, California **(Appendix 1-A Act of District Formation)**. Upon formation, the Act defined the area of the District as "all that territory of the County of Tehama lying within the exterior boundaries thereof."

Tehama County FCWCD is responsible for disseminating drought information, levee system management, providing emergency flood information, water resource management, groundwater monitoring, and sustainable groundwater management. The District provides this information and management for public use within the County. Groundwater information maintained and managed by the District includes monitoring wells that are part of the California Statewide Groundwater Elevation Monitoring (CASGEM) program, a Groundwater Management Plan (GWMP), and compliance with SGMA.

1.3.1 Organization and Management Structure of the GSA

The Tehama County FCWCD is governed by a five-member Board of Directors, these five directors are the same five members of the Tehama County Board of Supervisors. The Board of Supervisors members are elected officials within Tehama County, serving 4-year terms. The Tehama County Flood Control and Water Conservation District Board of Directors meetings, which are open to the public, are held the 4th Wednesday of each month. Meeting agendas and minutes are available on the District's website (http://tehamacountywater.ca.gov/)

In June 2016, the District established the Tehama County Groundwater Commission to serve as an advisory commission to the Tehama County Flood Control and Water Conservation District Board of Directors for GSA related matters. The Commission consists of 11 members with one member from each of the following entities:

- City of Corning
- City of Red Bluff
- City of Tehama
- El Camino Irrigation District
- Los Molinos Community Services District
- Rio Alto Water District
- Five at-large members appointed by the Tehama County FCWCD Board of Directors

The five at-large commission members represent each of the five Supervisorial Districts, which include two private pumpers, two surface water agencies or districts, and one at large member within the County and are selected by the Tehama County FCWCD to represent various areas of groundwater interest. These five at-large members initially selected for the Commission had varying term expirations: two members with a one-year term, one member with a two-year term, one member with a three-year term, and one member with a four-year term. Thereafter, all positions are appointed for a term of four years. Members representing cities or districts were selected by their respective agencies and have no term expiration.

Groundwater Commission meetings, which are open to the public, are held the 4th Wednesday of each month, except holidays. Meeting agendas and minutes are available on the Tehama County meeting portal: https://tehamacountywater.org/meetings/groundwater-commission/#meetings.

The GSA Governing Body is the Tehama County FCWCD Board of Directors which has responsibilities that include, but are not limited to, the following:

1. Approve the final GSP and any future amendments, and all GSA ordinances, rules, regulations, and fees.
2. Provide primary responsibility for funding, resources, and staffing
    - Provide staff assistance to Groundwater Commission and Board of Directors throughout GSP development and implementation process
    - Where necessary, provide additional resources from FCWCD's existing funding or grant opportunities pursued by Tehama County FCWCD

- Apply for and receive grants to fund GSA activities (with the Commission's recommendation), including responsibility for executing and implementing grant contracts and associated requirements
- Further revenue measures, if any, would be reviewed by the Commission prior to adoption by the Board of Directors

3. Decide on appeals, if any, from decisions of the Groundwater Commission on permits, similar entitlements, and enforcement matters
4. Confirm appointments of the five "Supervisorial District Representative" members of the Groundwater Commission (upon recommendation of the Commission)

The Groundwater Commission's responsibilities include, but are not limited to, the following:

1. Develop GSP and any future amendments, and all GSA ordinances, rules, and regulations, including holding public hearings and making final recommendations to the Board of Directors.
2. Conduct investigations to determine the need for groundwater management, monitor compliance and enforcement, propose, and update fees, and make final recommendations to the Board of Directors.
3. Review all proposed grant applications and advise Board of Directors regarding grant funding opportunities.
4. Issue permits or similar entitlements issued by the GSA e.g., well spacing (with appeal).
5. Make quasi-judicial decisions in GSA enforcement matters (with appeal).
6. Provide recommendations to the Board of Directors for selection of the five (5) representatives from each County Supervisorial District

The AB3030 Technical Advisory Committee (TAC) also provides technical assistance as needed. The TAC provides input on groundwater management in Tehama County based on the District's AB3030 GWMP. The TAC consists of three agricultural pumpers, three water district representatives, one natural resources representative, and one representative each from the City of Corning, the City of Red Bluff, and the City of Tehama.

Contact information for the District's GSP Manager is provided below:

Agency: Tehama County Flood Control and Water Conservation District

Address: 9380 San Benito Avenue
Gerber, CA 96035-9701

Plan Manager: Justin Jenson, Deputy Director of Public Works – Water Resources

Phone: 530-385-1462

Email: jjenson @tcpw.ca.gov

1.3.2 Legal Authority of the GSA

Any local public agency that has water supply, water management, or land use responsibilities in a basin is eligible to become a GSA. A single local agency can decide to become a GSA, or a combination of local agencies can decide to form a GSA by using a joint powers authority, a memorandum of agreement, or other legal agreement (DWR, 2016c). A timeline of the authoritative actions by the District for GSA formation and GSP submission is provided in **Table 1-2** below. GSA formation documents are provided in **Appendix 1-B.**

Table 1-2. GSA Formation Timeline

DATE	EVENT
January 1, 2015	SGMA became effective
June 2, 2015	Public Hearing
November 3, 2015	Public Hearing
August 17, 2015 – December 18, 2015	**Letters of Support** were provided by local Cities and Districts: City of Corning, City of Red Bluff, City of Tehama, El Camino Irrigation District, Gerber Las Flores Community Services District, Los Molinos Community Services District, and Rio Alto Water District
November 3, 2015	**Resolution No. 05-2015 Adopted:** A Resolution of the Board of Directors of the Tehama County Flood Control and Water Conservation District Electing to be the Groundwater Sustainability Agency for all those Portions of the Rosewood, Bowman, South Battle Creek, Red Bluff, Bend, Antelope, Dye Creek, Los Molinos, Corning, Vina, and Colusa Subbasins Located within Tehama County
November 4, 2015	**Notice of Intent** to Become a Groundwater Sustainability Agency for all eleven (11) Groundwater Subbasins located within Tehama County was submitted to DWR
February 11, 2016	**Listing as an Exclusive GSA** for the following Subbasins or portions of Subbasins within Tehama County: Rosewood, Bowman, Red Bluff, Corning, Colusa, Vina, Los Molinos, Dye Creek, Antelope, Bend, and South Battle Creek
February 18, 2016	**Jurisdictional Consolidation** of portion of Colusa Subbasin within Tehama County into the Corning Subbasin
June 7, 2016	**Ordinance 2016-1 Adopted:** An Ordinance of the Tehama County Flood Control and Water Conservation District Board of Directors establishing the Tehama County Groundwater Commission
June 30, 2017	GSA establishment deadline
September 27, 2018*	**Jurisdictional Consolidation** of portion of Vina Subbasin within Tehama County and the Dye Creek Subbasin into the Los Molinos Subbasin
September 27, 2018*	**Jurisdictional Consolidation** of the Rosewood Subbasin into the Bowman Subbasin
September 27, 2018*	**Jurisdictional Consolidation** of portion of Millville Subbasin within Tehama County into the South Battle Creek Subbasin
January 31, 2022	Adopted GSP Due to DWR

*Following the consolidations on September 27, 2018, the number of subbasins in Tehama County was reduced from eleven (11) to seven (7).

1.3.3 Estimated Cost of Implementing the GSP

The GSA is responsible for the finances of GSP implementation, GSA staffing, contracting, and daily operations related to Bowman GSP implementation. The Antelope, Bowman, Los Molinos, and Red Bluff Subbasin GSP development costs were funded through Proposition 1 and 68 grants totaling $2,998,160 (Proposition 1, Round 2 total was $1,498,960 and Proposition 68, Round 3 total was $1,499,200). The grant funding represents the cost of GSP development. Funding for the development of the Corning Subbasin GSP (~$1 million) was awarded to Glenn County under Proposition 1, Round 2.

The GSP implementation estimated annual costs (in current dollars) are estimated to be $470,000 for GSA Administration, Management, and Operations of all five GSPs managed by the Tehama County FCWCD and $104,000 for annual monitoring associated with the Bowman GSP as described in Chapter 5. Plan updates are also expected to cost $300,000 (current dollars) every five years. Estimated annual operations and maintenance (O&M) costs for all Bowman GSP projects and management actions are described in Chapter 4. All costs are preliminary estimates that will be refined by the GSA as the GSP is implemented. The GSA will manage the financing of GSP implementation, GSA staffing, contracting, and daily operations related to Bowman GSP implementation. Additional information is provided in Chapter 5 of this GSP.

1.4 GSP Organization

This GSP is organized according to DWR's "GSP Annotated Outline" for standardized reporting (CA DWR SGMP, 2016d) and DWR's Elements Guide. To facilitate DWR review and assure compliance with all applicable GSP regulations, **Table 1-3** was prepared to cross-reference 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 California Water Code (CWC) Section 10721 and 23 CCR Section 351.These definitions are provided as **Appendix 1-C**. of this GSP. Refer to the Elements Guide in **Appendix 1-D** for a detailed breakdown of the required GSP elements and their location in this GSP. The structure of the GSP is as follows:

Executive Summary:

Provides a consolidated overview of the GSP.

Chapter 1 - Introduction:

describes the purpose of the plan, Subbasin sustainability goal, agency formation and contact information, and the organization of the GSP.

Chapter 2 - Subbasin Plan Area and Basin Setting:

Section 1 provides a general overview of the Plan Area including a summary of the jurisdictional areas, relevant water resource monitoring and management programs, description of applicable general plan elements, and GSP notification and communication.

Section 2 describes the hydrogeologic setting of the Subbasin, current and historic groundwater conditions, and provides details on groundwater modeling and the water budget.

Chapter 3 - Sustainable Management Criteria:

establishes the Subbasin sustainability goal to be achieved. This section also establishes measurable objectives, minimum thresholds, and undesirable results for each sustainability indicator, followed by a description of the proposed monitoring network to track and verify progress toward the Subbasin sustainability goal.

Chapter 4 - Projects and Management Actions:

describes the programs and management actions the Tehama County FCWCD has determined will achieve the sustainability goal for the Subbasin.

Chapter 5 - Plan Implementation:

includes an estimate of GSP implementation costs, schedule, and a plan for annual reporting and 5-year updates.

Chapter 6 - References

Table 1-3. Cross Reference of GSP Regulations 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	6
	6. Agency Information	-	Agency information pursuant to CWC Section 10723.8, along with:	App. 1
		(a)	Agency name and mailing address	1.3
		(b)	Agency organization and management structure, persons with management authority for Plan implementation	1.3.1
		(c)	Plan manager name and contact information	1.3
		(d)	Legal authority of agency	1.3.2
		(e)	Estimate of Plan implementation costs and description of how Agency plans to meet costs	1.3.3, 5.1
	8. Description of Plan Area	(a)	Maps of Plan area	2.1
		(b)	Written description of Plan area	2.1
		(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 Section 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
		(b)	List of public meetings	2.1.5
		(c)	Comments and responses regarding the Plan	2.1.5
		(d)	Description of communication procedures	2.1.5

SUBARTICLE	SECTION	PARAGRAPH	REQUIREMENT	GSP SECTION
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
	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	2.3
		(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	2.3

SUBARTICLE	SECTION	PARAGRAPH	REQUIREMENT	GSP SECTION
2. Basin Setting			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	
	20. Management Areas	(a)	Description of management areas	2.4
		(b)	Describe purpose, minimum thresholds, measurable objectives, monitoring, analysis	2.4
		(c)	Maps and supplemental information	2.4
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	3
	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	3.1
	26. Undesirable Results	(a)	Processes and criteria used to define undesirable results applicable to the Subbasin	3.4
		(b)-(c)	Description of undesirable results, including cause of groundwater conditions and potential effects on beneficial uses and users of groundwater	3.4

SUBARTICLE	SECTION	PARAGRAPH	REQUIREMENT	GSP SECTION
	28. Minimum Thresholds	(a)	Establish minimum thresholds to quantify groundwater conditions for each applicable sustainability indicator	3.3
		(b)-(d)	Describe information and criteria to select, establish, justify, and quantitatively measure minimum thresholds	3.3
	30. Measurable Objectives	(a)-(g)	Establish measurable objectives, including interim milestones in increments of five years, to achieve and maintain the Subbasin sustainability goal	3.2
4. Monitoring Networks	32. Introduction to Monitoring Networks	-	Description of monitoring network, monitoring objectives, monitoring protocols, and data reporting	3.5
	34. Monitoring Network	(a), (e)-(g)	Development of monitoring network to yield representative information about groundwater conditions	3.5.1
		(b)-(d)	Monitoring network objectives	3.5.1
		(h)	Maps and tables of monitoring sites	3.5.1
		(i)	Monitoring protocols	3.6
	36. Representative Monitoring	(a)-(c)	Designation of representative monitoring sites	3.6.8
	38. Assessment and Improvement of Monitoring Network	(a)-(d)	Evaluation of monitoring network, including uncertainty, data gaps, and efforts to fill data gaps	3.6.9
		(e)	Adjustment of monitoring frequency and density to assess management action effectiveness	3.6.9
	40. Reporting Monitoring Data to the Department	(f)	Copy of monitoring data from data management system	
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	4

FINAL REPORT

Bowman Subbasin

Sustainable Groundwater

Management Act

Groundwater Sustainability Plan

(Chapter 2A – Plan Area)

January 2022

Prepared For:

Tehama County Flood Control and Water Conservation District

Prepared By:

Luhdorff & Scalmanini

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LIST OF ACRONYMS & ABBREVIATIONS

AB	Assembly Bill
bgs	Below Ground Surface
BMP	Best Management Practice
CalEPA	California Environmental Protection Agency
CalGEM	California Geologic Energy Management Division
CASGEM	California Statewide Groundwater Elevation Monitoring
CCR	California Code of Regulations
CDFW	California Department of Fish and Wildlife
CNRA	California Natural Resources Agency
CV-SALTS	Central Valley Salinity Alternatives
CWA	Clean Water Act
CWC	California Water Code
DDW	Division of Drinking Water
DPR	Department of Pesticide Regulation
DTSC	Department of Toxic Substance Control
DWR	California Department of Water Resources
GAMA	Groundwater Ambient Monitoring and Assessment Program
GDE	Groundwater Dependent Ecosystem
GMP	Groundwater Management Plan
GQTM	Groundwater Quality Trend Monitoring
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
GWMP	Groundwater Management Plan
HCM	Hydrogeological Conceptual Model
ILRP	Irrigated Lands Regulatory Program
IRWMP	Integrated Regional Water Management Plan
MCL	Maximum Contaminant Level
MO	Measurable Objective
MT	Minimum Threshold
RWQCB	Regional Water Quality Control Board

SB	Senate Bill
SGMA	Sustainable Groundwater Management Act
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAC	Technical Advisory Committee
Tehama County FCWCD	Tehama County Flood Control and Water Conservation District
USBLM	Bureau of Land Management
USBR	United States Bureau of Reclamation
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WCR	Well Completion Report
WDR	Waste Discharge Requirements

2 SUBBASIN PLAN AREA AND BASIN SETTING (REG. § 354.8)

Per DWR GSP regulations section §354.8, this section of the GSP describes the components of the plan area of the Bowman Subbasin along with the basin setting. The plan area includes information on land use, existing groundwater wells, monitoring and management in the Subbasin, and notice and communication methods used during the GSP development and implementation process. The basin setting includes a description of the hydrogeologic conceptual model, groundwater conditions, and subbasin water budget.

2.1 Description of Plan Area

The Bowman Subbasin (DWR Subbasin No. 5-006.01) covers 122,500 acres and is located in the Redding Area Groundwater Basin (**Figure 2-1**). The lateral extent of the Subbasin is defined by the Subbasin boundaries provided in Bulletin 118 (DWR, 2018). It is bounded on the north by the Anderson Subbasin (DWR Subbasin No. 5-006.03), on the south by the Red Bluff Subbasin (DWR Subbasin No. 5-021.50), on the east by the South Battle Creek Subbasin (DWR Subbasin No. 5-006.06), and on the west by the Northern Coast Mountain Ranges. The northern and eastern boundaries of the Subbasin generally follow Cottonwood Creek and the Sacramento River, respectively, and the western boundary generally aligns with the Northern Coast Mountain Range. The vertical boundaries of the Subbasin are the land surface (upper boundary) and the definable bottom of the basin (lower boundary). The definable bottom is the base of fresh water located at approximately 400-1,200 feet below ground surface (bgs) and was established as part of the development of the hydrogeologic conceptual model (HCM) discussed in the Basin Setting section of this GSP (Section 2.2).

2.1.1 Summary of Jurisdictional Areas and Other Features

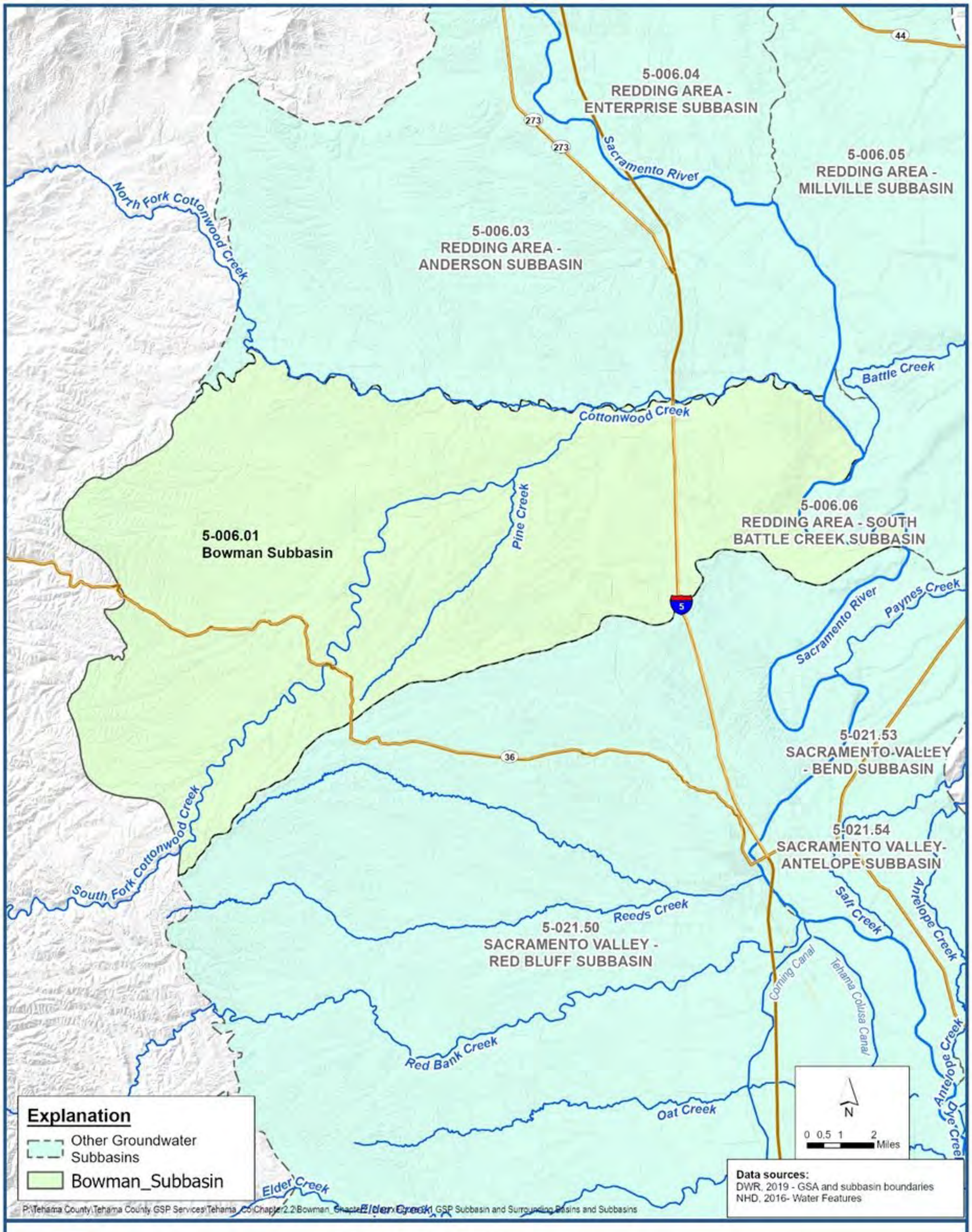
2.1.1.1 Land Ownership

This GSP covers the entire Subbasin, all of which falls within the jurisdictional boundaries of Tehama County. There are no known adjudicated areas within or surrounding the Subbasin.

State and federal agencies with land ownership in the Subbasin comprise a very small portion of the Subbasin. Federal and state land ownership includes:

- State Lands (0.07%, 85 acres)
- United States Bureau of Land Management (USBLM) (0.15%, 190 acres)

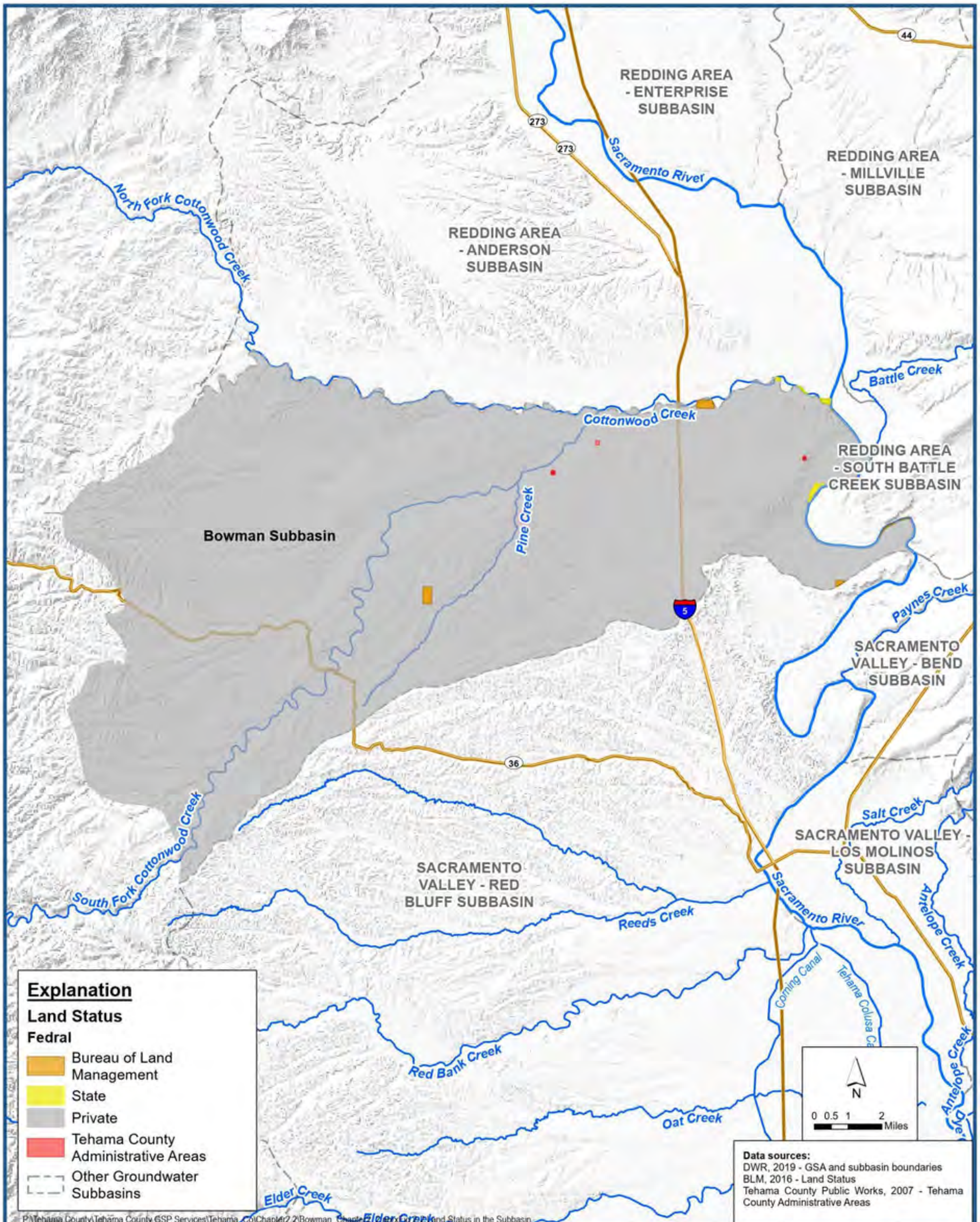
The remaining 99.8% of land is privately owned (**Figure 2-2**).



Bowman Subbasin and Surrounding Groundwater Subbasins

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-1



Land Status in the Subbasin

Figure 2-2

Groundwater Sustainability Plan
Bowman Subbasin

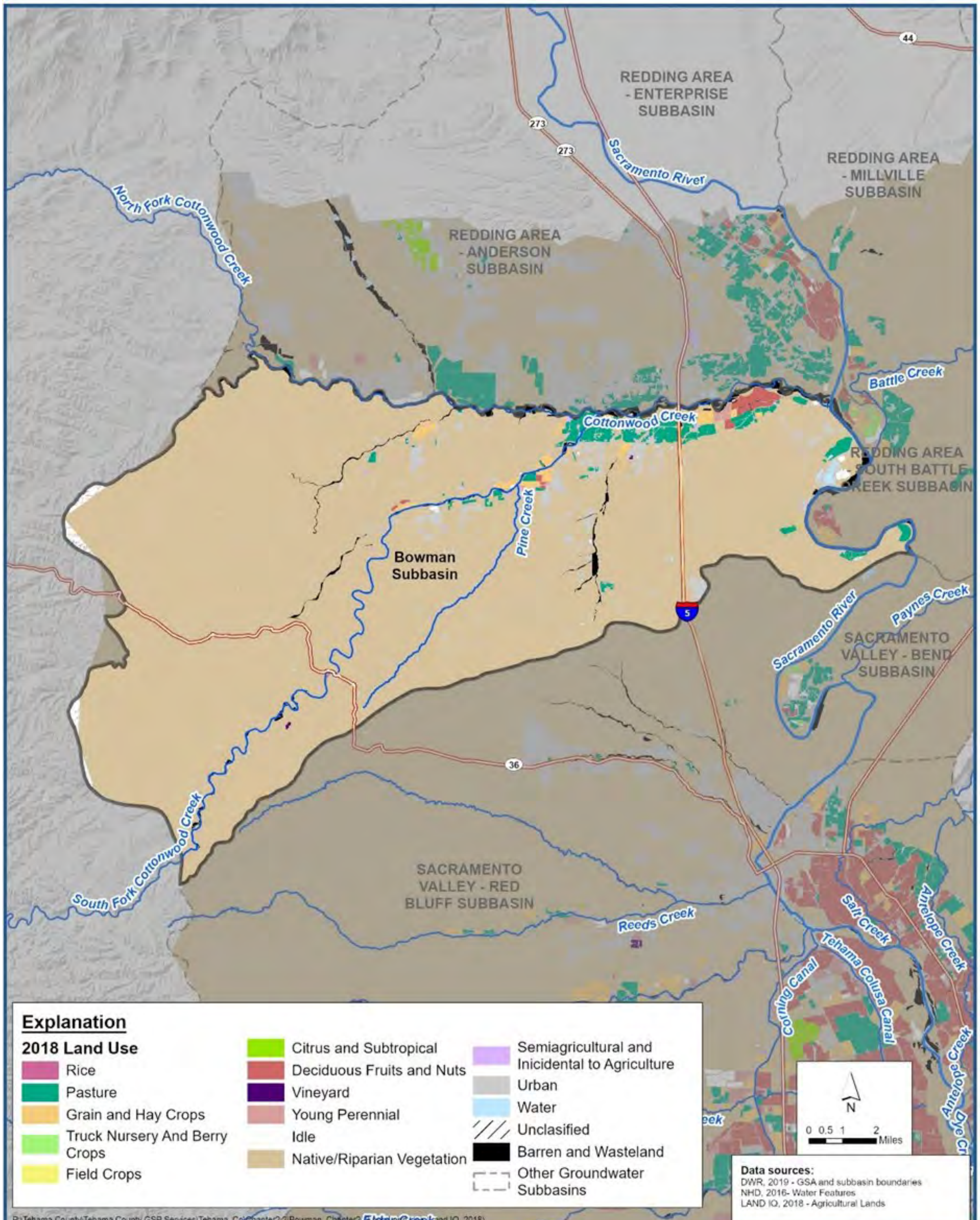
2.1.1.2 Land Use

Land use in the Bowman Subbasin was categorized as: agricultural, urban, and native and riparian vegetation based on the Land IQ dataset which primarily focuses on irrigated lands:

- Agricultural: includes all agricultural crops reported in the Subbasin: rice, pasture, grain and hay crops, truck nursery, and berry crops, field crops, citrus and subtropical, deciduous fruits and nuts, vineyards, young perennial crops, and idle land/land that was cultivated but is now in a state of disuse/abandoned.
- Native Vegetation: includes all land covered by native vegetation, riparian vegetation, and water surfaces.
- Refuge Area: includes managed wetlands in the Subbasin.
- Urban: includes lands classified as urban and semi-agricultural to incidental to agriculture. The only significant urbanized area in the Subbasin is Lake California which is located in the northeast portion of the Subbasin.

Figure 2-3 displays the land use in the Bowman Subbasin as reported in 2018 through Land IQ-remotely-sensed land use data.

Annual land use (acres) within each of the four main land use sectors**:** agriculture, urban, refuge area, and native and riparian vegetation are depicted in **Figure 2-4** and **Table 2-1** for the Bowman Subbasin from 1985 to 2019. The data from 1985-2017 and 2019 came from the model generated as part of this GSP; the 2018 data is from Land-IQ. The total land use acreage (122,670 acres) shown in **Figure 2-4** and **Table 2-1** varies slightly (0.11%) from the total subbasin acreage and 2018 data (122,500 acres) due to the depiction of the model domain. As displayed in the table, native and riparian vegetation (94%) is the leading source of land use within the Subbasin with approximately 5% and 1% dedicated to agriculture and urban use, respectively. Agricultural land use categories are further detailed in **Figure 2-5** and **Table 2-2**.



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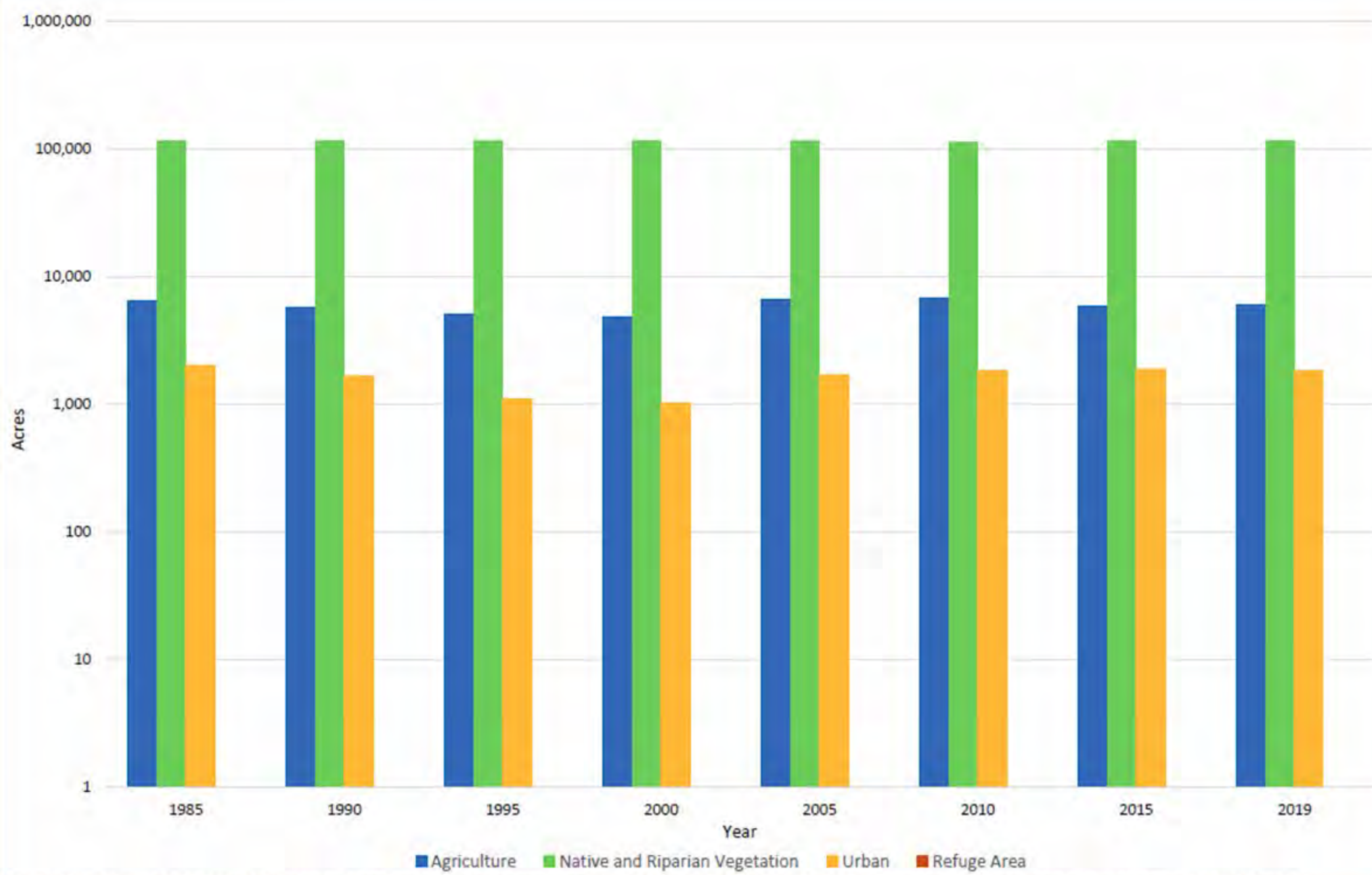
2018 Land Use

Figure 2-3

Groundwater Sustainability Plan
Bowman Subbasin



Note: Data is plotted on a logarithmic scale. 1978-2013 total Subbasin acreage = 122,667 and 2018 total Subbasin acreage = 121,803. This is due to different data sources

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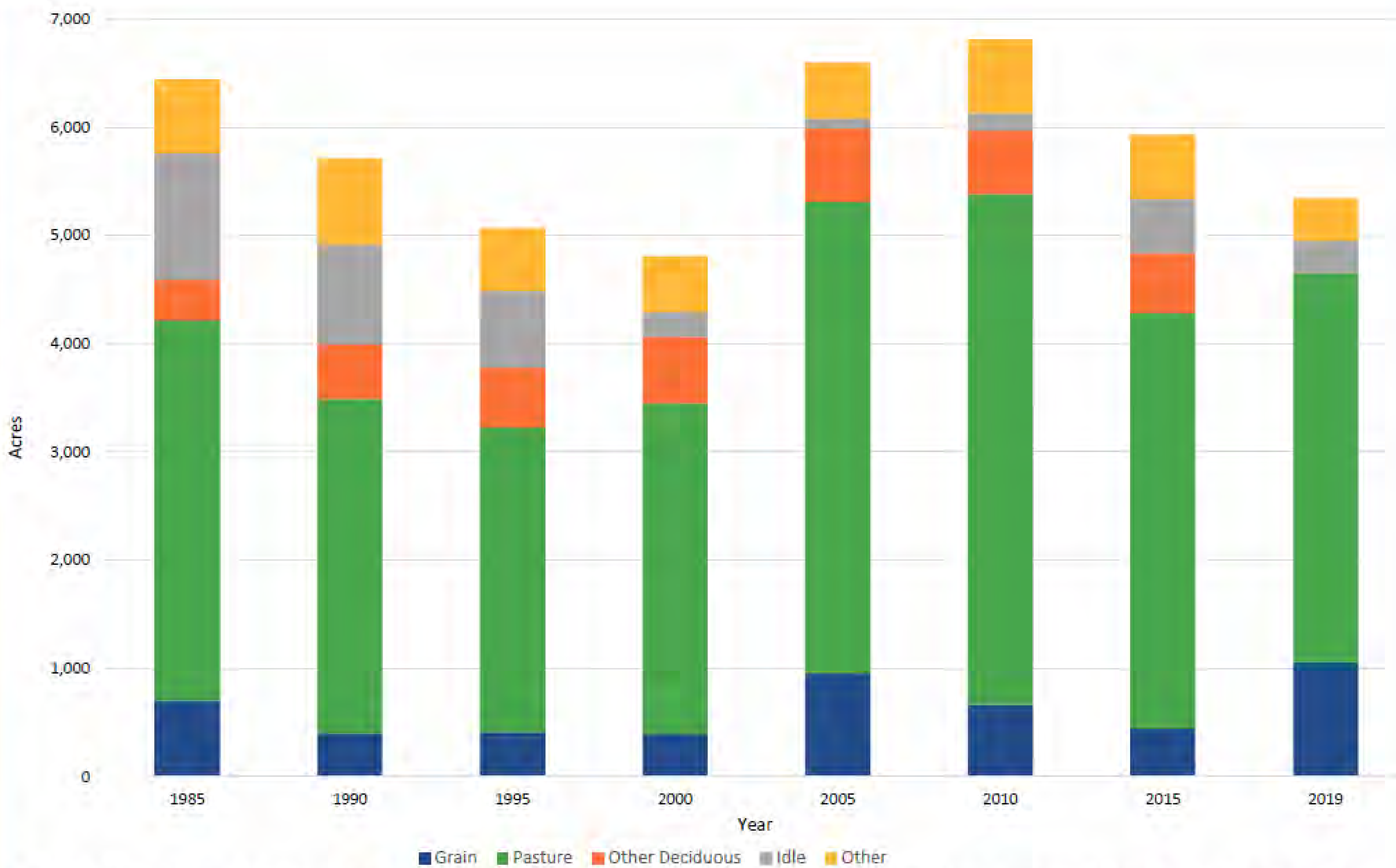
Bowman Subbasin Land Use

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-4



Note: "Other" includes agricultural land use that is less than 5% of the total: sugar beets, corn, dry beans, safflower, other field, alfalfa, other truck crops, curcurbits, almonds & pistachios, citrus & subtropical, and vineyards

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Bowman Subbasin Agricultural Land Use

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-5

Table 2-1. Bowman Subbasin Land Use (Acres)

YEAR	AGRICULTURE	NATIVE VEGETATION	REFUGE AREA	URBAN	TOTAL
1985	6,450	114,210	0	2,010	122,670
1986	6,200	114,500	0	1,960	122,660
1987	5,990	114,770	0	1,900	122,660
1988	6,130	114,700	0	1,840	122,670
1989	5,910	115,000	0	1,760	122,670
1990	5,710	115,280	0	1,670	122,660
1991	5,510	115,600	0	1,560	122,670
1992	5,430	115,800	0	1,430	122,660
1993	5,610	115,730	0	1,330	122,670
1994	5,820	115,640	0	1,210	122,670
1995	5,070	116,480	0	1,110	122,670
1996	5,220	116,350	0	1,100	122,670
1997	5,730	115,900	0	1,030	122,670
1998	5,180	116,510	0	970	122,670
1999	4,520	117,220	0	920	122,670
2000	4,820	116,830	0	1,020	122,670
2001	5,780	115,720	0	1,170	122,670
2002	5,690	115,680	0	1,300	122,670
2003	5,830	115,420	0	1,420	122,670
2004	6,450	114,690	0	1,530	122,670
2005	6,600	114,380	0	1,690	122,670
2006	5,940	115,040	0	1,690	122,670
2007	6,050	114,890	0	1,720	122,670
2008	5,670	115,280	0	1,710	122,670
2009	6,000	114,900	0	1,760	122,670
2010	6,810	114,020	0	1,830	122,670
2011	6,360	114,460	0	1,850	122,670
2012	5,630	115,170	0	1,870	122,670
2013	5,700	115,100	0	1,860	122,670
2014	5,800	115,030	0	1,840	122,670
2015	5,930	114,880	0	1,860	122,670
2016	6,110	114,700	0	1,860	122,670
2017	6,260	114,480	0	1,920	122,670
2018	6,060	114,050	0	1,950	122,670
2019	6,060	114,750	0	1,850	122,670

*Values were rounded to the nearest 10 acres. These totals differ from the Subbasin acreage (122,500) due to the depiction of the model domain.

Table 2-2. Bowman Subbasin Agricultural Land Use (Acres)

AGRICULTURAL LAND USE TYPE	1985	1990	1995	2000	2005	2010	2015	2019
Grain	708	400	413	393	955	666	445	1,059
Pasture	3,511	3,090	2,814	3,060	4,359	4,719	3,841	3,592
Other Deciduous	376	503	552	608	674	585	553	691
Idle	1,166	919	708	234	92	161	502	299
Other*	685	801	582	511	519	683	593	396

*"Other" includes agricultural land use that is less than 5% of the total: sugar beets, corn, dry beans, safflower, other field, alfalfa, other truck crops, cucurbits, citrus & subtropical, vineyards, and almonds & pistachios

2.1.1.3 Well Distribution and Density

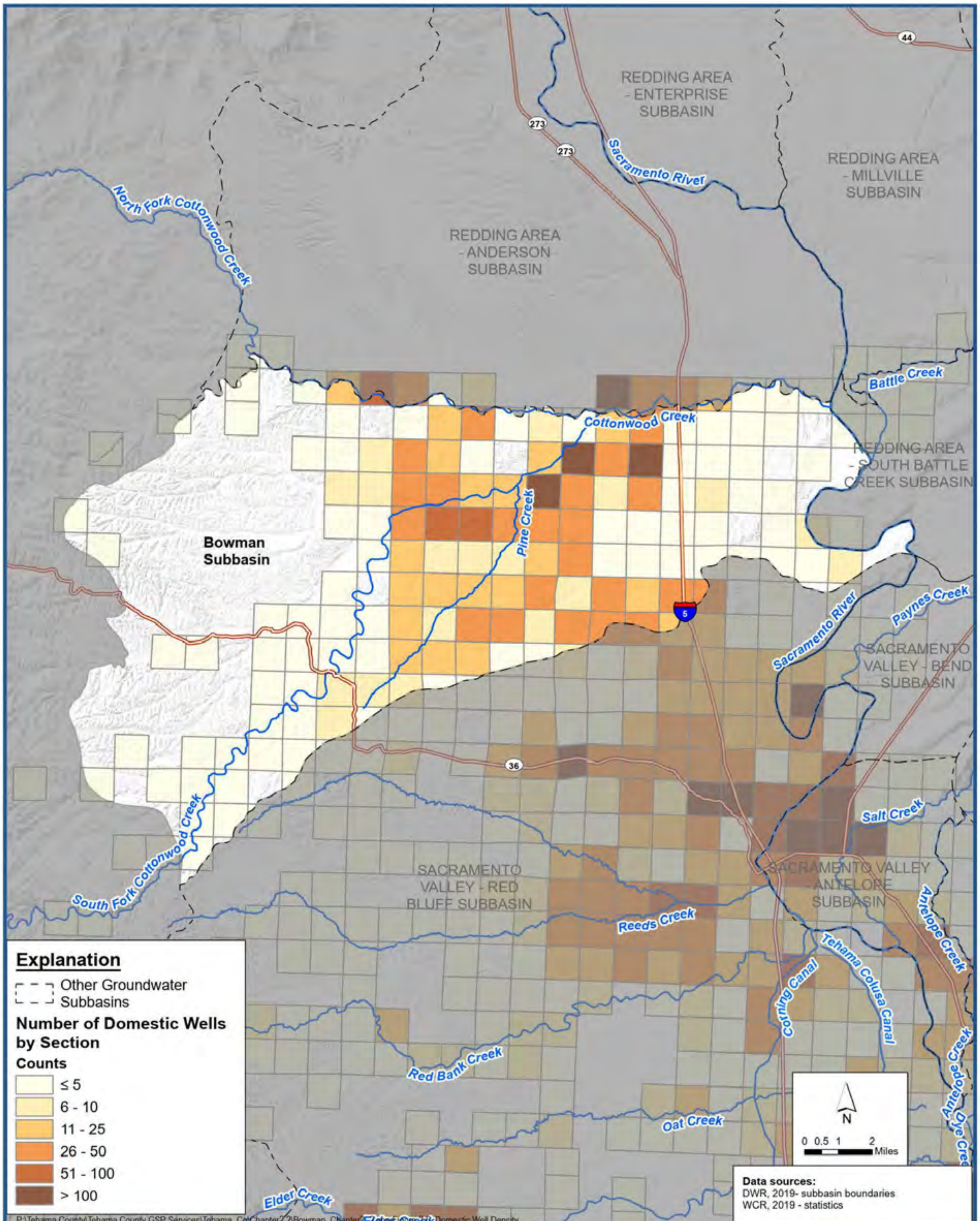
Well construction, type, and distribution for wells in the Subbasin were obtained from Tehama County, DWR's Well Completion Report Map Application (DWR, 2018), the Groundwater Ambient Monitoring and Assessment Program (GAMA), and the CASGEM program.

Wells within the Subbasin are categorized as domestic, production, and public supply. These categories are based on the well use information submitted with the well logs to DWR (**Table 2-3**):

Table 2-3. Well Density

TYPE OF WELL	WELL COUNT
Domestic	2,428
Production	124
Public Supply	25
TOTAL	**2,577**

Well density maps were prepared to illustrate the distribution of these wells (**Figures 2-6, 2-7, and 2-8**). The well distribution may not reflect the total number of existing or active wells in the Subbasin. The highest concentration of domestic wells is centered around Cottonwood, California, production wells are generally scattered throughout the Subbasin, and there are few public supply wells located in the Subbasin. A detailed analysis of domestic well depths and distribution is included as **Appendix 2-A**.



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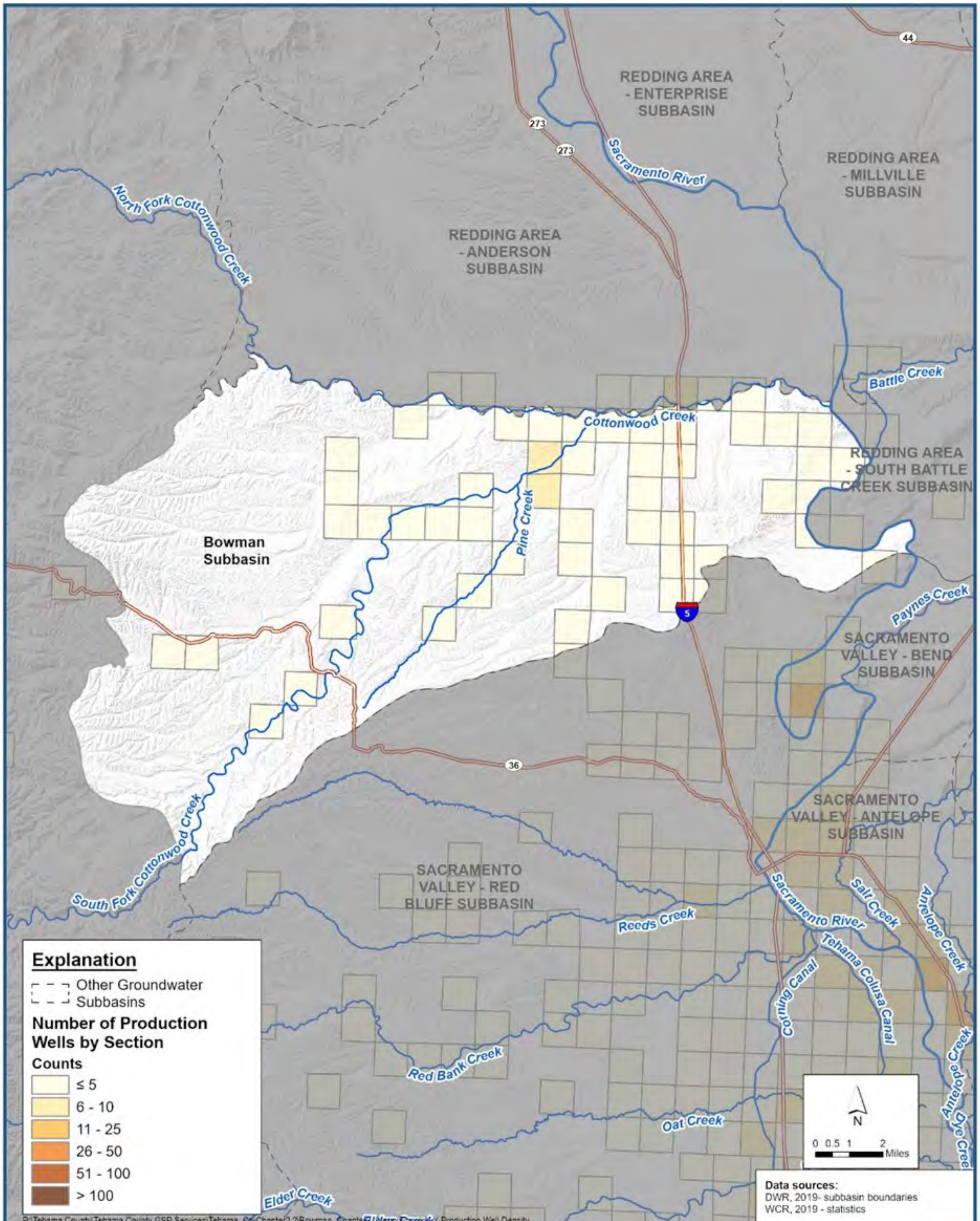
Domestic Well Density by Section

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-6



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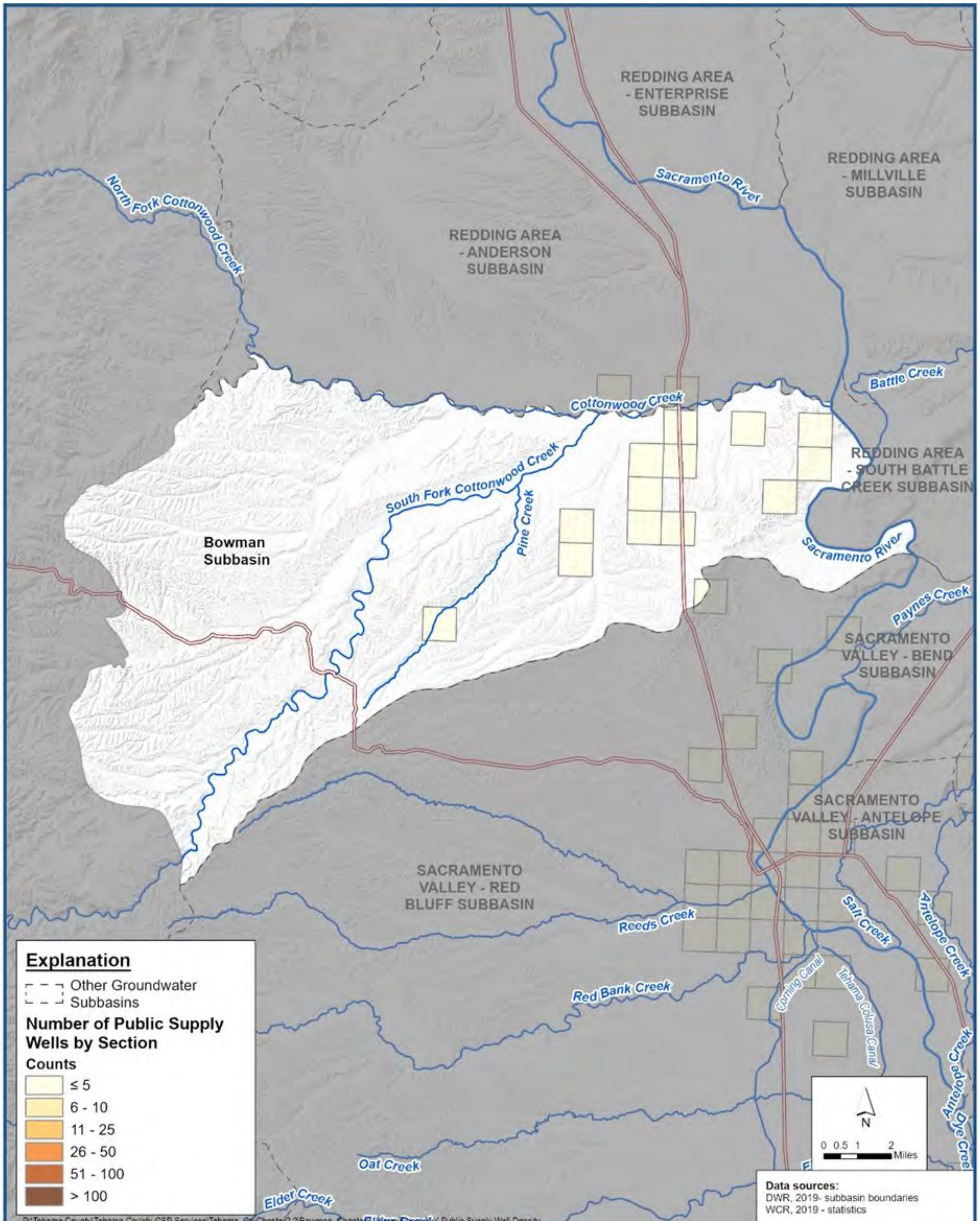
Production Well Density by Section

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-7



Public Supply Well Density by Section

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-8

2.1.2 Water Resource Monitoring Entities, Management Programs, and Data Sources

The Tehama County FCWCD is responsible for surface water and groundwater resource management in Tehama County, including the Bowman Subbasin. The District has been attempting to manage groundwater resources through existing monitoring, management, and regulatory programs in the Subbasin. These existing programs also support the development of the GSP and monitoring network (described in Chapter 3). Each of these programs and a summary of the water planning documents applicable to the GSA are detailed below.

Existing monitoring programs within the Plan area include those implemented by federal, state, and local public agencies to meet regulatory requirements. Data from these programs and associated projects were incorporated (as applicable) into the evaluation of basin conditions and the GSP monitoring network described in Section 3. These entities, programs, and data sources include:

- United States Environmental Protection Agency (USEPA)
- United States Geological Survey (USGS)
- California Natural Resources Agency (CNRA)
- California Geologic Energy Management Division
- DWR
- CASGEM
- California Environmental Protection Agency (CalEPA)
- California Department of Pesticide Regulation (DPR)
- California Department of Toxic Substances Control (DTSC)
- California State Water Resources Control Board (SWRCB)
- Surface Water Monitoring Programs
- Division of Drinking Water (DDW)
- GAMA
- Central Valley Regional Water Quality Control Board (RWQCB)
- Other Existing Management Programs and Plans
- Existing Regulatory Programs
- Conjunctive Use Programs

Local monitoring programs include municipal water system Supervisory Control and Data Acquisition data, monthly pumping records, and surface water delivery data. Existing monitoring entities and programs are described in further detail below. Data from these programs was incorporated as applicable into the development of this GSP.

2.1.2.1 United States Environmental Protection Agency (USEPA)

The USEPA administers the Clean Water Act (CWA) for surface water and wetlands in coordination with state and tribal governments. The CWA designates the SWRCB and RWQCBs as the responsible agencies for water quality, safe and reliable drinking water, and water rights. In addition to water quality oversight, the federal Comprehensive Environmental Response, Compensation and Liability Act established a program to clean up uncontrolled or abandoned hazardous waste sites, accidents, spills, and other emergency releases of pollutants and contaminants. The USEPA seeks cooperation and funding from parties potentially responsible for contaminated "Superfund" sites. Both state and federal Superfund programs maintain a list of sites, with the federal list referred to as the USEPA's National Priority List and the state list referred to as the "Hazardous Waste and Substances Site List."

2.1.2.2 United States Geological Survey (USGS)

The USGS works with state, federal, and local agency data providers to monitor groundwater levels using the framework of the National Groundwater Monitoring Network. The USGS maintains a publicly accessible database (National Water Information System) of water quality and groundwater level information which has undergone QA/QC by the USGS.

2.1.2.3 California Natural Resources Agency (CRNA)

California Geologic Energy Management Division (CalGEM)

CalGEM (previously the Division of Oil, Gas, and Geothermal Resources) regulates the drilling, operation, maintenance, and abandonment of oil, gas, and geothermal wells in California. Through Waste Discharge Requirements (WDRs), RWQCBs regulate well development drilling fluid, mud disposal, and produced water disposal and reuse, which includes disposal discharge to ponds, roads, and the use of produced water as irrigation water. Water quality is also monitored through the Water Quality in Areas of Oil and Gas Production – Regional Groundwater Monitoring Program undertaken by the SWRCB, which serves to improve the understanding of threats posed to groundwater resources by oil and gas operations.

California Department of Water Resources (DWR)

DWR is responsible for the management and regulation of water usage throughout the state. DWR implements the State Water Project (SWP) which is the nation's largest state-built water conveyance system and manages the submission of Well Completion Reports (WCRs) for construction, alteration, or destruction of water wells, monitoring wells, cathodic protection wells, and geothermal heat exchange wells. WCRs are added to the statewide dataset by the CNRA, made publicly available with private information redacted, and included in DWR's web application. DWR further maintains a variety of databases that contain hydrologic data for the State of California, including the Water Data Library, the Water Data Information System, SGMA Data Viewer and database, and the CASGEM program.

DWR also collects and maintains monitoring data and assists GSAs in the implementation of SGMA through various technical, financial, and planning services. Technical services provided by DWR include offering statewide data and tools for water levels, WCRs, and climate change, publishing best management practices (BMPs), guidance documents, and technical reports. Financial services provided by DWR include the Sustainable Groundwater Planning Grant Program to assist local agencies in the development of GSPs.

The development of this GSP includes DWR monitoring data, technical tools, and guidance documents. Financial assistance was also attained through DWR Grant programs, Proposition 1 and Proposition 68 funding, Technical Support Services, and Facilitation Support Services.

CASGEM

In 2009, Senate Bill SBX7-6 established that all subbasins need to collect and report groundwater elevations to track seasonal and long-term trends in California's groundwater basins and subbasins. To participate in CASGEM, well owners are minimally required to measure and report groundwater levels annually. DWR maintains this data and allows it to be publicly accessible.

2.1.2.4 California Environmental Protection Agency (CalEPA)

CalEPA maintains regulatory jurisdiction over safe drinking water quality requirements, hazardous waste management and remediation requirements, and pesticide use and reporting requirements. These requirements are maintained under the California DPR, DTSC, and the SWRCB. CalEPA maintains the Regulated Site Portal, a website (https://siteportal.calepa.ca.gov/nsite) that combines data from a variety of state and federal databases from these environmentally regulated sites and facilities in California into a single, searchable database. Regulated activities include hazardous materials and waste, state, and federal cleanups, impacted groundwater and surface waters, and toxic materials. The portal integrates data from the following entities:

- CalEPA's California Environmental Reporting System, which tracks hazardous materials and waste
- SWRCB's California Integrated Water Quality System, which manages information pertaining to sites discharging to surface water
- EnviroStar system, which tracks hazardous waste facilities and sites with known or suspected contamination
- SWRCB's GeoTracker sites, which track sites that impact or have the potential to impact water quality in California with an emphasis on groundwater
- SWRCB's Stormwater Multiple Application and Report Tracking System, which collects information on industrial and construction stormwater management
- Toxics Release Inventory which contains information on chemicals managed by industrial or other facilities in California

California Department of Pesticide Regulation (DPR)

The DPR is responsible for enforcing state laws and regulations consistent with the Federal Insecticide, Fungicide, and Rodenticide Act, which mandates regulation of pesticide distribution, sale, and use. County agricultural commissioners are responsible for enforcement and permitting the use of restricted pesticides. DPR conducts regular surface water and groundwater sampling to monitor for pesticide contamination. Additionally, the Pesticide Contamination Prevention Act requires the DPR to protect groundwater from pesticide pollution through its groundwater protection program. This program includes thresholds for pesticides posing risks to groundwater, a database of wells sampled for pesticides, identification of areas sensitive to pesticide contamination (known as groundwater protection areas), and mitigation measures developed to prevent pesticide transport to groundwater in those areas. DPR maintains databases of groundwater pesticide testing results and provides summaries of annual sampling and test results to the state legislature.

California Department of Toxic Substances Control (DTSC)

The DTSC regulates hazardous wastes through enforcement of the federal Resource Conservation and Recovery Act and California's Hazardous Waste Control Law. Through DTSC's Hazardous Waste Management Program and Site Mitigation and Restoration Program, groundwater is protected through the oversight of hazardous waste management and remediation. DTSC maintains an online database of permitted hazardous waste sites, corrective action facilities, and information regarding site cleanup. DTSC enforces the Toxic Injection Well Control Act and the Toxic Pit Cleanup Act, both of which require monitoring and hazardous waste containment. DTSC shares toxic site cleanup responsibilities with California's RWQCBs.

California State Water Resources Control Board (SWRCB)

SWRCB is responsible for the management of WDRs, underground storage tanks, groundwater cleanup programs, and groundwater and surface water quality policies and enforcement. The SWRCB administers water rights, water pollution control and water quality functions for the state. Through California's Porter-Cologne Water Quality Control Act (Porter-Cologne Act), the SWRCB shares authority with the RWQCBs to implement the federal CWA. The SWRCB provides policy guidance and budgetary authority to the RWQCBs, who adopt Water Quality Control Plans. The Bowman Subbasin is located within the jurisdictional area of the Central Valley RWQCB.

SWRCB and RWQCB enforce groundwater quality protection through WDRs which have control over the following:

- agricultural runoff
- domestic septic systems
- injection wells
- wastewater recycled for reuse or discharged to land
- dairy operations
- timber harvesting

If contamination occurs in violation of any WDR, the State and Regional Boards are responsible for cleanup and abatement of groundwater sites impacted by the contamination. SWRCB maintains an online database containing records of investigations, actions related to cleanup activities, identified known contaminant cleanup sites, and permitted underground storage tanks.

SWRCB maintains environmental data for their regulated facilities in their GeoTracker database. GeoTracker was initially developed in 2000 pursuant to a mandate by the California State Legislature (AB 592, SB 1189 (Stats. 1997, Chapter 814 and 185). Data from these regulated facilities typically includes groundwater level measurements and samples from groundwater monitoring wells at each regulated site.

SWRCB Surface Water Monitoring Programs

In collaboration with the RWQCBs, the SWRCB also implements the National Pollution Discharge Elimination System, stormwater permitting requirements, and the Surface Water Ambient Monitoring Program. The NPDES program was introduced in 1972 and aims to control water pollution by regulating point sources that discharge pollutants, such as rock, sand, dirt, and agricultural, industrial, and municipal waste. Stormwater permitting is managed under General Permits which regulate stormwater discharges and authorized non-stormwater discharges and enforce implementation of Stormwater Pollution Prevention Plans to monitor surface water runoff and pollutants during construction activities. The Surface Water Ambient Monitoring Program conducts monitoring and assessment of water quality in all of California's surface waters to support water resource management in the state.

SWRCB Division of Drinking Water (DDW)

DDW is responsible for enforcing the Safe Drinking Water Act in California. DDW ensures safe access to drinking water through water quality regulations and monitoring requirements for regulated public water systems. Beginning in 2001, Title 22 of the California Code of Regulations Sections 64469 and 64819 established requirements and the format for reporting public water systems' water quality analyses results. All public water systems, certified drinking water analytical laboratories, including those that are subcontractors of other laboratories, are required to submit water quality data directly to the SWRCB DDW in digital, electronic form (Electronic Data Transfer). The Electronic Data Library supplies links to water quality monitoring schedules, files for the DDW water quality database, and houses county small water system water quality data files. All drinking water quality data of public water supply systems submitted to DDW through the Electronic Data Transfer portal can be accessed through the SWRCB DDW Safe Drinking Water Watch Program. Title 22 also includes designated Maximum Contaminant Levels (MCLs) for constituents to ensure water quality meets drinking water standards.

Groundwater Ambient Monitoring and Assessment Program (GAMA)

SWRCB created GAMA in 2000 to house groundwater elevation and groundwater quality data. SWRCB works with agencies from the State and Regional Water Boards, DWR, DPR, USGS, Lawrence Livermore National Laboratory, water agencies, and private owners to provide groundwater data to the public. Data collected by regulatory agencies that submit reports to SWRCB are made accessible through the GeoTracker GAMA database. This differs from the GeoTracker database used for environmental sites. GAMA data was an important source of data used in the development of this GSP. Goals of the GAMA Program include:

- Improve statewide comprehensive groundwater monitoring
- Increase the availability to the public of groundwater quality and contamination information
- Establish ambient groundwater quality on a basin-wide scale

- Continue periodic groundwater sampling and groundwater quality studies in order to characterize chemicals of concern and identify trends in groundwater quality
- Centralize the availability of groundwater information to the public and decision makers to better protect groundwater resources.

Central Valley Regional Water Quality Control Board (RWQCB)

The RWQCB regulates water quality in groundwater and surface water in the Central Valley of California. The RWQCB is responsible for developing Water Quality Control Plans, governing requirements for WDRs, issuing WDRs, taking enforcement action against dischargers who violate permits or otherwise harm water quality in surface waters, and monitoring water quality. The RWQCB's overall mission is to protect surface waters and groundwater in the region through the following tasks:

- Addressing region-wide water quality concerns through the creation and triennial update of a Water Quality Control Plan (Basin Plan)
- Preparing new or revised policies addressing region-wide water quality concerns
- Adopting, monitoring compliance with, and enforcing waste discharge requirements and NPDES permits
- Maintaining the 303(d) list of impaired surface water bodies and administering oversite of Total Maximum Daily Loading projects
- Providing recommendations to the SWRCB on financial assistance programs, proposals for water diversion, budget development, and other statewide programs and policies
- Coordinating with other public agencies that are concerned with water quality control
- Informing and involving the public on water quality issues.

The Basin Plan contains descriptions of the legal, technical, and programmatic bases of water quality regulation for the region. At the regional level, the Basin Plan outlines water quality objectives to define the appropriate levels of environmental quality and to control activities. The Basin Plan provides a definitive program of actions designed to preserve and enhance water quality and to protect beneficial uses in a manner that will result in maximum benefit to the people of California. The Basin Plan fulfills the following:

- Conformance to USEPA requirements in order to allocate federal grants to cities and districts for construction of wastewater treatment facilities
- Provides a basis for establishing priorities as to how both state and federal grants are disbursed for constructing and upgrading wastewater treatment facilities
- Meets the requirements of the Porter-Cologne Act that call for water quality control plans in California
- Provides a basis for the RWQCB to establish or revise waste discharge requirements and for the SWRCB to establish or revise water rights permits
- Establishes conditions for discharge prohibitions that must be met at all times
- Establishes or indicates water quality standards applicable to waters of the Region, as required by the federal CWA
- Establishes water quality attainment strategies, including Total Maximum Daily Loads required by the CWA, for pollutants and impaired water bodies.

The RWQCB also manages the Irrigated Lands Regulatory Program (ILRP) which includes the Sacramento Valley Groundwater Quality Trend Monitoring Program (GQTM). RWQCB *Order No. R5-2014-0030-R1 Waste Discharge Requirements General Order for Growers in the Sacramento River Watershed that are Members of the Third-Party Group* requires the Sacramento Valley Water Quality Coalition to develop and implement a the GQTM program. The GQTM program involves groundwater quality sampling through a network of wells to monitor regional and long-term trends in groundwater quality in relation to agricultural practices as outlined in Coalition GQTM Workplan submittals to the RWQCB.

2.1.2.5 Groundwater Level Monitoring

Groundwater levels are monitored in the Subbasin and reported from the various sources and programs listed above. A significant amount of the existing groundwater level monitoring information included in the development of this GSP originated from GAMA and CASGEM data sets.

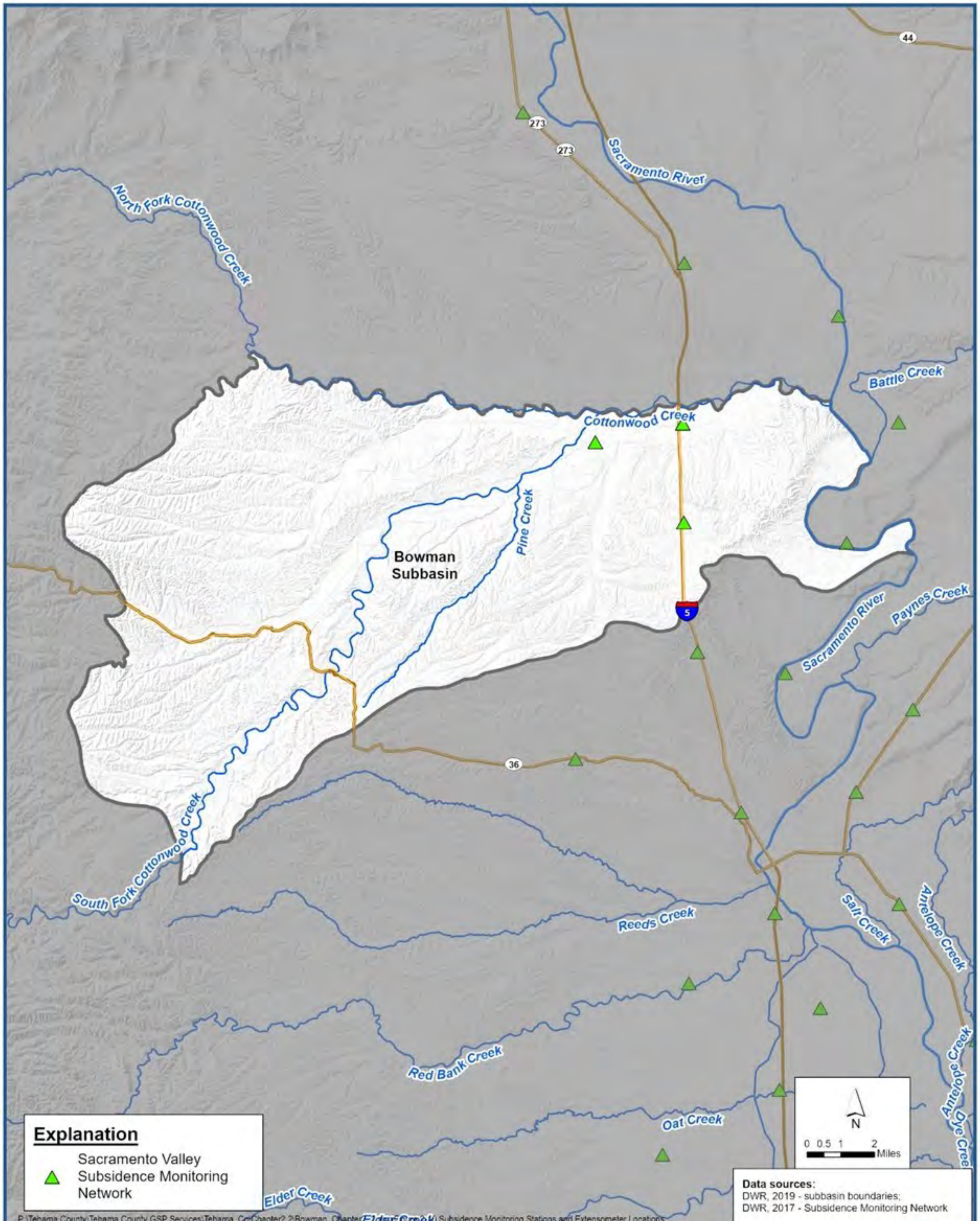
Tehama County has 52 wells that are part of the CASGEM program. Eight (8) of these wells are located in the Bowman Subbasin. Groundwater elevations have generally been reported 2-3 times per year with measurements dating back to the early 1970's. Measurements are typically taken during March/April (Spring), July/August (Summer), and October/November (Fall). CASGEM monitoring wells were incorporated into this Plan's groundwater monitoring network as needed.

2.1.2.6 Groundwater Quality Monitoring

Groundwater quality monitoring in the Subbasin has been conducted by a variety of entities. As described in the AB3030 GWMP (Section 253), the Tehama County FCWCD worked with USGS, SWRCB, DWR, California Department of Public Health, and the U.S. Department of the Interior to complete extensive water quality monitoring of wells in Tehama County as part of the GAMA program from 2005-2007. Water quality monitoring is also completed as part of the ILRP, the Sacramento Valley Water Quality Coalition GQTM, and other DWR and Central Valley RWQCB programs (Tehama County, 2012) as described above.

2.1.2.7 Land Subsidence Monitoring

The Tehama County FCWCD established 34 GPS land surface elevation benchmarks in 2008 for use in land subsidence monitoring as part of the Sacramento Valley Subsidence Project. These benchmarks are approximately 3-5 miles apart, covering the valley floor. There are three benchmark locations within the Bowman Subbasin and three additional benchmarks within two miles of the Subbasin boundary. These benchmark locations are shown on **Figure 2-9**. When this project was completed, it was anticipated that land elevations would be measured at each benchmark every 5 years to monitor potential changes in land surface elevation and land subsidence (Tehama County, 2012). These benchmarks were resurveyed in 2017 and exhibited little to no change in subsidence (DWR, 2017).



TEHAMA COUNTY
LSCE Team

Subsidence Monitoring Stations

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-9

2.1.2.8 Surface Water Monitoring

Surface water monitoring is completed through the various federal, state, regional, and local programs listed above. Surface monitoring stations located within the Subbasin are shown in **Table 2-4** and on **Figure 2-10**. The points of surface water diversion, which are the locations where water may be diverted from surface water sources by the water right holders, are also shown on **Figure 2-10**. Water right holders that use diverted surface water are required to file an annual statement of water diversion with the SWRCB. Most individual diverters use all diverted water in areas close to the source, while water diverted under the Central Valley Program may be delivered to distal areas from the source.

Table 2-4. Surface Water Monitoring Stations

WATERWAY	SOURCE	SITE ID	AVAILABLE DATA PERIOD
Cottonwood Creek	USGS	11375815	1981-1985
South Fork Cottonwood Creek	USGS	11375820	1962-1978
South Fork Cottonwood Creek	USGS	11375870	1976-1986
South Fork Cottonwood Creek	USGS	11375900	1981-1985

2.1.2.9 Other Existing Management Programs and Plans

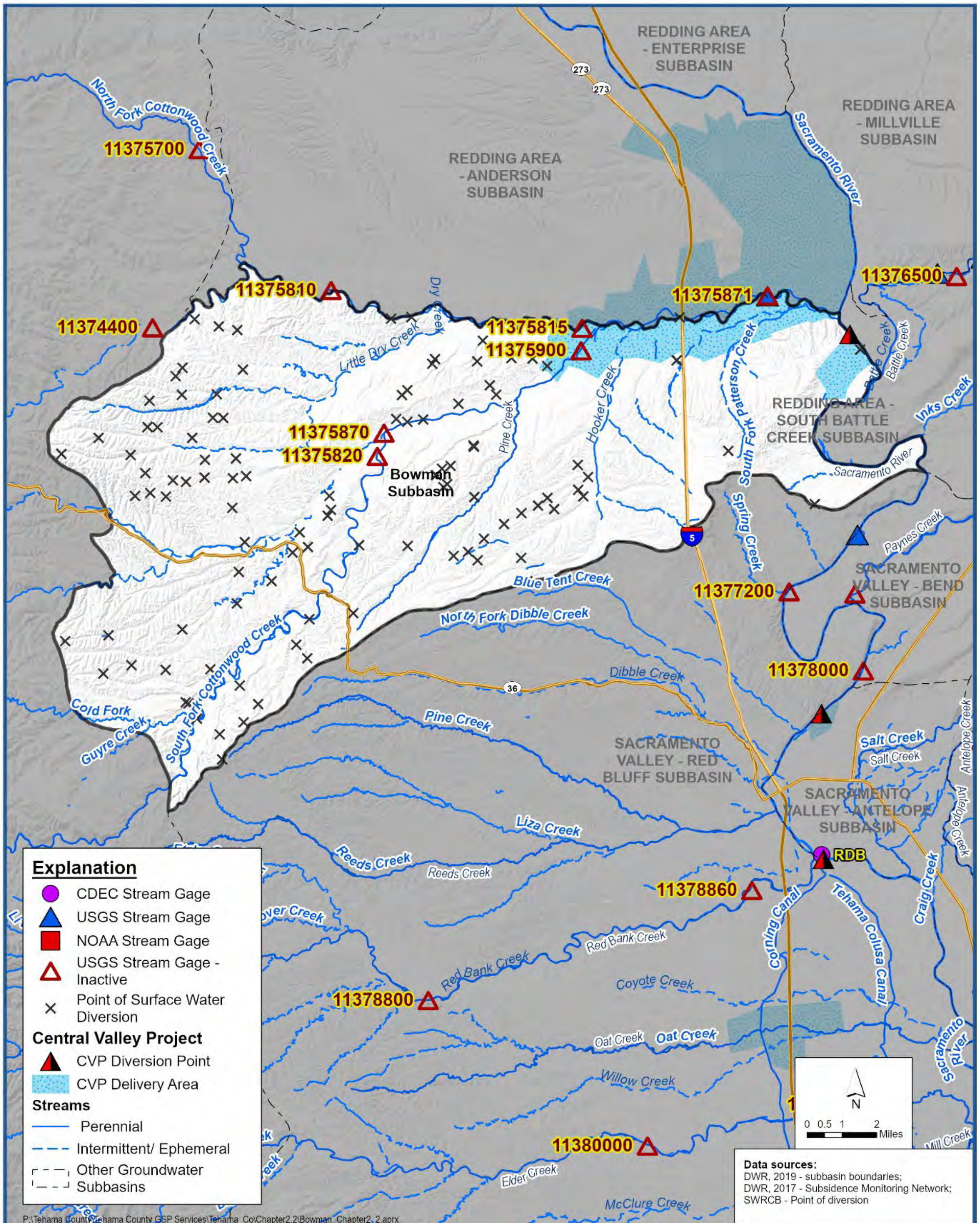
State Water Use Efficiency Programs

The California Irrigation Management Information System hosts a network of automated weather stations owned and operated by DWR and local agencies. These stations provide "real-time" weather data to estimate crop and landscape evapotranspiration rates for irrigation management decisions.

DWR also conducts land use and water use data collection activities in support of statewide water planning. The program includes land use surveys, public water system statistics surveys, statewide irrigation methods surveys, agricultural land and water use estimates, agricultural water use models, and the California Seasonal Application Efficiency Program.

Tehama County AB3030 Groundwater Management Plan (GWMP)

The Tehama County GWMP was first adopted in November 1996 to comply with California Assembly Bill 3030 (AB3030). An update to the GWMP was provided in 2012 through a collaborated effort among the Tehama County FCWCD TAC, the University of California Cooperative Extension, and DWR. Prior to the completion of the AB3030 GWMP, background documents and technical memoranda were developed: Water Inventory and Analysis (2003) and Proposed Groundwater Trigger Levels and Awareness Actions (2008). Separate proposed Groundwater Trigger Levels and Awareness Actions technical memoranda were written for the Subbasins of Tehama County: Antelope, Bend, Bowman, Corning East, Corning West, Dye Creek, Los Molinos, Red Bluff East, Red Bluff West, Rosewood, South Battle Creek, and Vina. Some of the subbasins have since been consolidated (**Section 1.3.2, Table 1-2**).



TEHAMA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

LSCE Team

Surface Water Monitoring Stations

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-10

The purposes of the AB3030 GWMP include:

- Sustain groundwater levels that balance long-term extraction and replenishment
- Sustain groundwater levels in a manner that allows existing groundwater well infrastructure within Tehama County to remain operational over a long period of time
- Develop a comprehensive groundwater management program to ensure sufficient groundwater supplies of useable quality are maintained for reliable, efficient, and cost-effective extraction
- Implement the GWMP through the development of county-wide consensus where possible

The AB3030 GWMP includes a description of the study area within Tehama County, which includes location, geology, climate, population, economy, local GWMP interest, groundwater basin conditions, existing monitoring, historic groundwater levels and pumpage, groundwater recharge, and groundwater quality issues. It also provides a three-phase approach to achieving the elements of the plan purpose that includes:

- Phase I – Passive Management
    - data inventory and evaluation
    - monitoring strategies and coordination
    - TAC
    - public education
- Phase II – Tasks
    - water conservation
    - coordination with local land use planning agencies
    - identification and management of wellhead protection areas
    - identification of well construction policies
    - protection of beneficial uses
    - conjunctive management operations
    - development of relationships with state and federal regulatory agencies
- Phase III – Activities
    - construction and operation of groundwater management facilities
    - regulation of contaminated groundwater migration
    - control of saline water intrusion and other contaminants

Many of these actions, assessments, and data are useful in the development of the GSP and align with the GSP requirements under SGMA. Components and data from the AB3030 GWMP were incorporated into the development and implementation of this GSP, as necessary.

Northern Sacramento Valley Integrated Regional Water Management Plan (IRWMP)

The IRWMP was developed in 2006 to guide water management policies, programs, and projects in the Sacramento Valley. It was intended to serve as a platform for coordination to allow improved water management to occur at the local, regional, and state level. The main objectives of the development and implementation of the IRWMP are to improve the economic health of the region, improve water supply reliability, improve flood protection and floodplain management, improve, and protect water quality, and to protect and enhance the ecosystem. These objectives were developed based on existing water management plans in the Sacramento Valley to ensure mutual objectives are developed for stakeholders and enhanced coordination can be obtained. The IRWMP includes a summary of the Tehama County local setting, current and future land and water use, and recommendations. The highest priority land use/water related issues identified in the County include:

- Potential groundwater impacts from urban development and protection of county groundwater resources
- Lack of baseline groundwater information and need for more monitoring
- Potential development of the Lower Tuscan and Tehama Formations and funding needed for further study and peer review of existing hydrogeologic data
- Continued protection of water quality

Recommendations listed in the IRWMP include: implementation of the Lower Tuscan Recharge Investigation Program, creation of a database, exploration of funding opportunities for a subsidence monitoring network, exploration of research and funding opportunities to expand knowledge base for the Tehama Formation, continued cooperation with nearby counties, encouragement of agricultural uses and development through land use planning policies, support of efforts to evaluate flood potential, coordination with the Tehama County Planning Department, and support of IRWMP proposed projects (NCWA, 2006).

Issues identified in Tehama County related to land and water use and efforts to integrate and implement the IRWMP were included in the development of this GSP, as necessary.

2.1.2.10 Existing Regulatory Programs

Tehama County Groundwater Ordinances

Three applicable ordinances related to groundwater management have been enacted in the County:

- Tehama County Board of Supervisors Ordinance No. 1617 –limits the export of groundwater for use in areas outside of Tehama County
- Tehama County Board of Supervisors Ordinance No. 2006 – amends Titles 9 and 10 of the Tehama County Code relating to groundwater aquifer protection and water wells to require a permit for extraction of groundwater use off-parcel, amend well permitting requirements, and provide requirements for maintenance of dormant wells
- Tehama County Flood Control and Water Conservation District Board of Directors Ordinance No. 2016-1 – establishes the Tehama County Groundwater Commission

Irrigated Lands Regulatory Program (IRLP)

The ILRP was created to mitigate impairment of surface water and groundwater due to waste discharges (sediments, pesticides, nitrates) from irrigated land runoff in the Central Valley of California. The Central Valley RWQCB manages the program and requires irrigated landowners to verify effective water quality protection practices and submit information to their coalition or the RWQCB. Irrigated landowners must adhere to WDRs under this program (California Waterboards, 2020). Components of this program and water quality data were considered in the development of this GSP, as necessary.

Central Valley – Salinity Alternatives for Long-Term Sustainability (CV-SALTS)

CV-SALTS is a collaborative stakeholder managed program aimed to develop sustainable salinity and nitrate management planning in the Central Valley. CV-SALTS is in the process of developing scientific and regulatory tools to create a management plan to minimize the impacts of salt and nutrients on water quality. Data from CV-SALTS monitoring was included in the development of this GSP, as necessary.

2.1.2.11 Conjunctive Use Programs

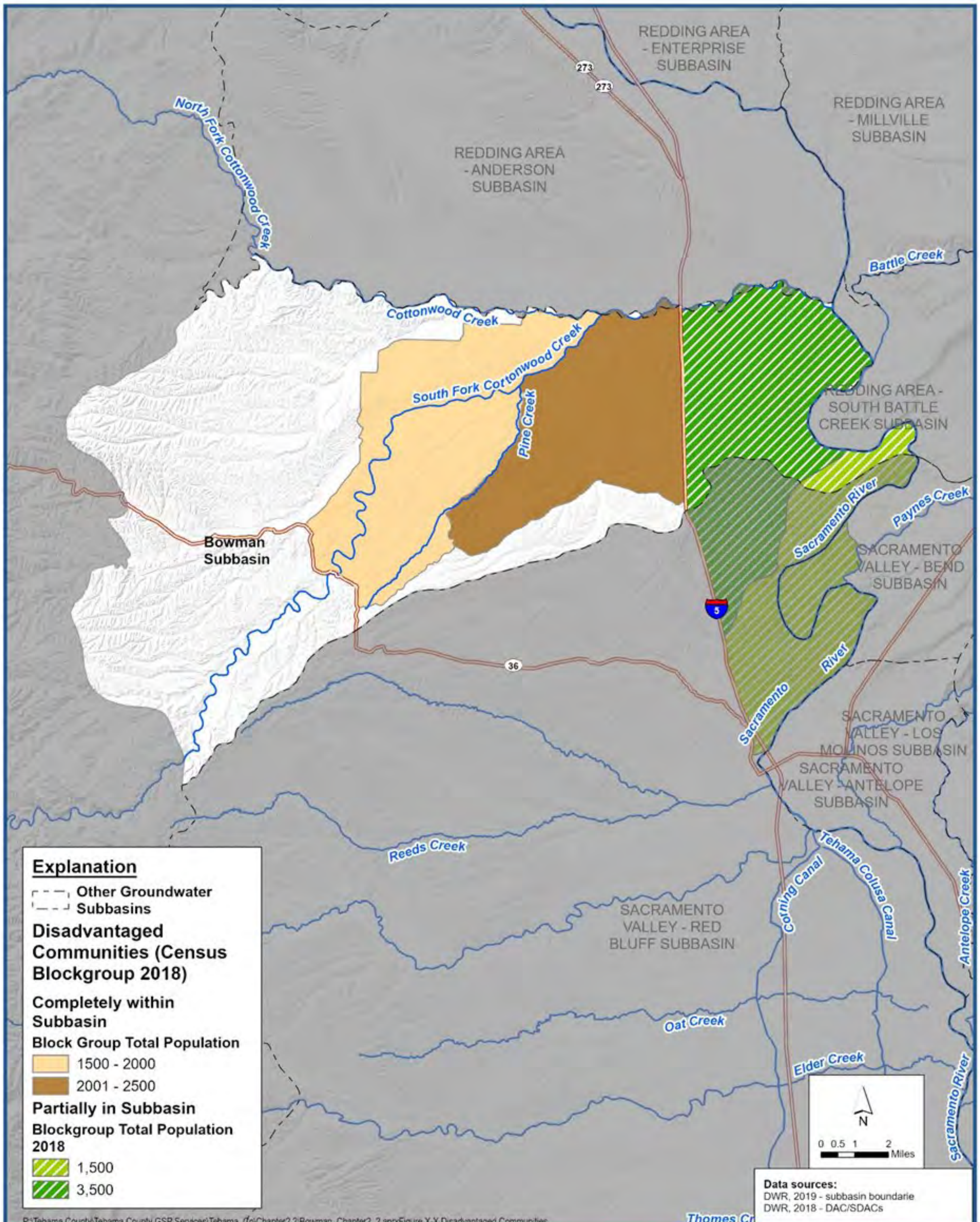
There are no formal conjunctive use programs in the Subbasin.

2.1.2.12 Water Planning Documents

Several water planning documents have been prepared and adopted on a County and region-wide basis to support water and resource management. There have also been several reports and analyses generated to aid in water monitoring and management. These include:

- Regional Plans
  - Northern Sacramento Valley Drinking Water Quality Strategy Document (2005)
  - Sacramento River Basin-wide Water Management Plan (2004)
  - Sacramento Valley Integrated Regional Water Management Plan (2006)
  - Tehama, Butte, Glenn, and Colusa Four-Counties Memorandum of Understanding (2006)
- Tehama County Groundwater Management Plan
  - AB3030 Groundwater Management Plan (Adopted in 1996, Updated 2012)
- Tehama County Groundwater Ordinances
  - No. 1617
  - No. 2006
  - No. 2016-1
- General Plans
  - Tehama County General Plan (2009)
- Applicable Studies
  - Redding Basin Water Resources Management Plan Environmental Impact Report (2007)

Information included in these plans and applicable studies completed in Tehama County regarding surface water, groundwater, land use, and monitoring has been included in the development of this GSP, as necessary. Development and implementation of the GSP will continue to consider the interests of all beneficial uses and users of groundwater including agricultural users, municipal water users, domestic users, disadvantaged communities (**Figure 2-11**), groundwater dependent ecosystems (GDEs), and other stakeholders.



TEHAMA COUNTY

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Disadvantaged Communities

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-11

2.1.3 Land Use Elements or Topic Categories of Applicable General Plans

The Bowman Subbasin lies entirely in Tehama County, in which the Tehama County General Plan is applicable. No other General Plans or Urban Water Management Plans apply to the Bowman Subbasin jurisdiction.

The development and implementation of this GSP will support all goals, policies, and implementation measures described in these general plans, in conjunction with SGMA and GSP regulations, while considering the beneficial uses and users of groundwater.

2.1.3.1 Tehama County General Plan

The Tehama County General Plan, updated in 2009 and in effect until 2029, provides structure for the "physical development of the county or city, and any land outside its boundaries which bears relation to its planning." It creates guidelines for future development and decision-making, and it is detailed in the General Plan that "agriculture remains one of the primary uses of land in Tehama County." The General Plan is comprised of the following elements:

- Land Use (LU)
- Transportation and Circulation (CIR)
- Public Services (PS)
- Economic Development (ED)
- Open Space and Conservation (OS)
- Agriculture and Timber (AG)
- Safety (SAF)
- Noise (N)

All elements focus on the protection and enhancement of agricultural land within the County, as agriculture is depicted as "a way of life and the foundation of the quality of life in Tehama County."

The Tehama County General Plan contains goals, policies, and implementation measures relating to surface water and groundwater resource protection (**Table 2-5**).

Table 2-5. Tehama County General Plan Relevant Goals, Policies, and Implementation Measures

GOAL OR POLICY	DESCRIPTION
Goal ED – 7	Protect and enhance environmentally sensitive lands and natural resources while, at the same time, promoting business expansion, retention, and recruitment.
Goal OS – 1	To ensure that water supplies of sufficient quality and quantity will be available to serve the needs of Tehama County, now and into the future.
Goal OS – 3	To protect, preserve, and enhance fish and wildlife species by maintaining healthy ecosystems.
Goal PS – 4	To promote development in areas where existing water districts have available resources to accommodate development or where existing districts may be expanded to serve new development in a cost-effective manner.
Policy ED – 7.1	The County shall continue to preserve Tehama County's natural resources including agriculture, timberlands, water and water quality, wildlife resources, minerals, natural resource lands, recreation lands, scenic highways, and historic and archaeological resources. The protection of natural resources is of the utmost importance and promoting business expansion, retention, and recruitment should complement and enhance the natural resources while reducing negative impacts.
Policy LU – 10.1	The County shall actively promote the implementation of the County's Groundwater Management Plan: implement the recommended management and monitoring actions of the GWMP and identify and quantify the water production, water quality, and groundwater recharge activities occurring within the County.
Policy OS – 1.1	The County shall protect and conserve water resources and supply systems through sound watershed management: • Maintain local water ordinances to protect the integrity of water supplies in Tehama County (Implementation Measure 1.1a) • Consider and evaluate the need for a Water Conservation Ordinance (Implementation Measure 1.1b) • Ensure that projects adhere to the regulations of the State of California Reclamation Board, California Department of Fish and Game, Regional Water Quality Control Board, and U.S. Government (Implementation Measure 1.1c) • Continue to maintain and implement the Adopted AB3030 GWMP to protect and preserve water supplies and water quality in Tehama County (Implementation Measure 1.1e) • Encourage involvement in Local, Regional, and Statewide Water Resource coordination, cooperation, and collaboration to protect and

GOAL OR POLICY	DESCRIPTION
	preserve water supplies and water quality (Implementation Measure 1.1f) • Discourage the export of water from Tehama County (Implementation Measure 1.1h)
Policy OS – 1.2	The County shall work to ensure continued reasonable alternate water supplies: • Encourage water supply agencies and companies in the County to identify and develop water supply sources, other than groundwater, where feasible (Implementation Measure 1.2a) • Require development project approvals to include a finding that all feasible and cost-effective options for conservation and water reuse are incorporated into project design (Implementation Measure 1.2b) • Encourage the use of treated wastewater to irrigate parks, golf courses, and landscaping (Implementation Measure 1.2c) • Promote the installation of sufficient groundwater monitoring wells and data collection facilities to assure non-injury to surrounding areas in the development of community and specific plan projects (Implementation Measure 1.2d)
Policy OS – 1.3	Surface water quality and stream flows for water supply, water recharge, recreation, and aquatic ecosystem maintenance shall be protected while respecting adjudicated and appropriated (California recognized water rights) rights of use: • Protect surface and ground water from major sources of pollution, including hazardous materials contamination and urban runoff (Implementation Measure 1.3a) • Restrict hazardous materials storage in the 100-year floodplain to prevent surface water contamination (Implementation Measure 1.3b) • Educate the community on laws governing the proper handling of hazardous materials, especially those laws which pertain to discharging materials into creeks (Implementation Measure 1.3c) • Require clean-up of contaminated ground and surface water by current and/or past owners or polluters (Implementation Measure 1.3e) • Require development to incorporate runoff control measures into their site design or to participate in an area-wide runoff control management effort consistent with standards developed by the Public Works Department (Implementation Measure 1.3f) • Establish and require the use of best management practices to protect receiving waters from the adverse effects of construction activities, sediment, and urban runoff (Implementation Measure 1.3g)
Policy OS – 1.4	The County shall encourage development of land for the purposes of improving groundwater recharge:

GOAL OR POLICY	DESCRIPTION
	• Consistent with the General Plan, development pattern and where deemed a reasonable on- or off-site improvement by the Advisory Agency, division of lands within all water district or County Service Area boundaries shall be conditioned based on maintaining right-of-way access to irrigation infrastructure and the continued use of open irrigation ditches (Implementation Measure 1.4a)
Policy OS – 1.5	The County shall ensure the high quality of groundwater by emphasizing programs that minimize erosion and prevent the intrusion of municipal and agricultural wastes into water supplies: • Natural Resource Lands land use subcategories shall be used to indicate areas essential to the recharge of groundwater and to afford protection from stream bank erosion (Implementation Measure 1.5a) • The Regional Water Quality Control Board shall monitor irrigation runoff to prevent infiltration of herbicides/fertilizers/pesticides and municipal wastes into streams and rivers of the groundwater basin. The County shall also encourage irrigation water recycling (Implementation Measure 1.5b) • As appropriate and feasible, the County shall install water-conserving landscaping and irrigation on County-owned facilities (Implementation Measure 1.5c)
Policy OS – 1.6	The County shall explore and encourage new water projects that are of local benefit: • Work with local, regional, and state water suppliers to determine the necessary water storage required for projected growth in the County. Investigate potential federal and state funding opportunities related to water infrastructure. Apply for funding to establish water storage facilities (Implementation Measure 1.6a).
Policy OS – 1.7	The County shall encourage new development to incorporate water conservation measures.
Policy OS – 3.1	The County shall preserve and protect environmentally-sensitive and significant lands and water valuable for their plant and wildlife habitat, natural appearance, and character.
Policy PS – 3.2	The County shall ensure that water supply and delivery systems are available in time to meet the demand created by new development or are guaranteed to be built through the use of bonds or other financial sureties.
Policy PS – 4.1	The County shall encourage future development to be located with respect to type and intensity/density of land use in order to ensure the long-term, economically feasible and environmentally sound provision of adequate water supply and quality.

GSP Implementation Effects on Water Demands and Sustainability

Implementation of the proposed land use developments under the General Plan are not expected to greatly affect water demands due to the nature of the land use and efficient water management practices encouraged in the County. Policies included in the Tehama County General Plan encourage the implementation of urban water conservation measures (Policy OS-1.7), groundwater recharge (Policy OS-1.4), consideration of reasonable alternate supplies, and water resource management. According to the Tehama County General Plan, population growth within the County can be described as "slow to moderate," and urban growth that occurs is generally limited to areas with access to resources and services which typically occur around the major transportation corridors in Tehama County. The majority of the land use in the County is agricultural, and the County has policies related to the protection of resource lands for agricultural and other beneficial uses. Therefore, it is not expected that land use changes based on the Tehama County General Plan will have a significant impact on the implementation of this GSP. Additionally, consistent with GSP regulations, minimum thresholds (MTs) and measurable objectives (MOs) established in this GSP were based on long-term planning water and land use assumptions established in the Tehama County General Plan.

GSP Implementation Effects on Water Supply Assumptions

Projects and management actions (Chapter 4) may result in changes in pumping and groundwater recharge to ensure the Subbasin operates within its sustainable yield over its implementation horizon. Expected changes in agricultural water use are described in Chapter 4. Urban water use is not expected to be significantly impacted by the implementation of this GSP, as the majority of water use in the Subbasin is agricultural, and there are not any significant expected changes in land use. Efficient urban water use is also encouraged by the General Plan and regulated by other statutory requirements such as the Urban Water Management Planning Act and the Model Water Efficient Landscape Ordinance. Goals and policies related to land use, water supply, water resources, wetlands, native/riparian areas, and open spaces were considered in the development of this GSP and are expected to align with GSP implementation efforts to achieve Subbasin sustainability.

2.1.4 Additional GSP Elements

2.1.4.1 Well Construction, Destruction, and Abandonment Policies

Well construction, rehabilitation, repair, and destruction policies are described in Section 9.42 of the Tehama County Municipal Code and permitting is under the jurisdiction of the Tehama County Environmental Health Department. The Municipal Code includes requirements for: well location, annular seal, surface construction features, well labeling, disinfection, and sanitary requirements, sealing off strata, casing, well development, redevelopment, well conditioning, water quality testing, large-diameter shallow wells, driven wells, rehabilitation, repair, deepening of wells, inspection, well driller's reports, and well maintenance. To obtain a permit to construct a well, a plot plan showing the location of the proposed well, shall be filled out and submitted to the Tehama County Environmental Health Department. Public supply wells must also undergo a DWR review and approval process. Review may be required by additional Tehama County entities if necessary: Planning Department (applies to zoning), Building Department (applies to flood hazard areas), and/or the fire department (applies to parcels formed after 1992).

Abandoned or unused wells in the County, including exploration and test holes, are required to be properly destroyed to assure that the groundwater supply is protected and preserved for future use and to eliminate potential physical hazards. Wells shall be destroyed and/or abandoned per Section 9.42 of the Tehama County Municipal Code which includes requirements for: preliminary work, filling and sealing conditions, materials, placement of materials, and temporary covers.

In response to drought conditions prior to 2015, the Tehama County Board of Supervisors adopted Ordinance No. 2006, "An Ordinance of the Board of Supervisors of the County of Tehama Amending Titles 9 and 10 of the Tehama County Code Relating to Groundwater Aquifer Protection and Water Wells." This ordinance included permit requirements for extraction of groundwater use off parcel, changes to well permitted use, maintenance of dormant wells, and administrative civil penalties. These changes were made to decrease potential impacts of well construction, use, destruction, and abandonment on the groundwater aquifer.

2.1.4.2 Efficient Water Management Practices

Tehama County promotes water conservation through both urban and agricultural efficient water management practices. As described in the AB3030 GWMP, these practices include:

- Coordination with the Tehama County Planning Department to provide groundwater conservation information to prospective developers in the County
- Coordination with the Tehama County Department of Building and Safety to provide groundwater conservation information to builders in the County
- Encouragement of recycled water use
- Collaboration with the Cities of Corning, Red Bluff, and Tehama to support activities that promote urban water conservation
- Providing educational materials to assist agriculture operations to become as efficient as possible
- Providing references to public and private programs and materials designed to improve agricultural efficiency
- Coordination with DWR, Tehama County Farm Bureau, University of California Cooperative Extension, Shasta Tehama Watershed Education Coalition, Tehama County Cattlemen's Association, and the various agricultural water districts in the County to expand upon and further support agriculture efficiency and water conservation programs

County Irrigation systems for agriculture have transitioned to primarily drip- and microsprinkler- type for efficient water management. Additionally, the Tehama County Resource Conservation District offers a free Mobile Irrigation Lab which provides on-site evaluations of agricultural irrigation systems to allow producers to receive comments, suggestions, and recommendations related to the performance of their irrigation systems.

2.1.4.3 Impacts on Groundwater Dependent Ecosystems

Potential impacts on GDEs are described in detail in Section 2.2.2.7.

2.1.4.4 Control of Saline Water Intrusion

Due to the significant distance of the Bowman Subbasin from the Pacific Ocean, seawater intrusion is not a concern. As noted in the AB3030 GWMP, the potential for saline water intrusion into freshwater aquifers exists in some areas from vertical migration via unsealed or improperly sealed natural gas wells and associated test holes that are no longer active. This is not a significant concern in the Bowman Subbasin. Well construction, protection, and abandonment standards and regulation by CalGEM exists for natural gas wells to best mitigate saline water intrusion.

2.1.4.5 Wellhead Protection and Recharge Areas

As identified in the AB3030 GWMP and 1986 Safe Water Drinking Act, a wellhead protection area is "the surface and subsurface area surrounding a water well or wellfield supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water well or wellfield." Therefore, wellhead protection can refer to both the immediate location of the well and the broader surrounding area.

Wellhead protection is attained for drinking water systems through the completion of Drinking Water Source Assessments and Source Protection Assessments. Municipalities and community services districts use these assessments to identify potential sources of contamination and potential management practices for mitigating such contamination. Drinking water supply wells are also protected by completion requirements regulated by DDW. Wellhead protection for agricultural wells is managed by the DPR Groundwater Protection Program which focuses on preventing potential contamination of groundwater recharge areas by farming activities.

2.1.4.6 Migration of Contaminated Groundwater

Potential groundwater contaminants identified in the AB3030 GWMP include saline water, pesticides, nitrate from sewage systems, and fertilizer practices, organic compounds from industrial activities, and naturally occurring elements in underlying soil and rock formations. As described in the AB3030 GWMP, contaminants have the potential to enter the groundwater system as result of lateral or vertical migration through abandoned wells, wells with long screens, and unsealed or improperly sealed wells. These wells can be active or abandoned wells, water supply wells, and associated test holes. Water quality results for non-drinking water wells in the Subbasin associated with regulated sites have exhibited DDW primary drinking water MCL exceedances for arsenic, chromium, and nitrate, synthetic organic compounds such as 1,2,3-TCP, Heptachlor, Heptachlor Epoxide, Dibromochloropropane, and Dinoseb, and volatile organic compounds such as benzene, 1,3 Dichloropropene, and MTBE. Secondary MCL exceedances have occurred for manganese and iron in wells in the Subbasin.

Regulation and oversight for contaminants is provided by CalGEM, SWRCB, the Tehama County Environmental Health Department, the Tehama County Department of Agriculture, and other federal, state, and regional agencies. Identified sources of control for upward migration of contaminants include enforcement of well construction policies, extraction reduction, artificial recharge, and coordination with regulatory agencies. Identified sources of control for downward seepage of sewage, agricultural, or industrial contaminants include coordination with land use planning agencies, coordination with the regulatory agencies discussed above, and public education. Identified sources of control for inter-aquifer migration of contaminated groundwater include enforcement of well construction and abandonment standards.

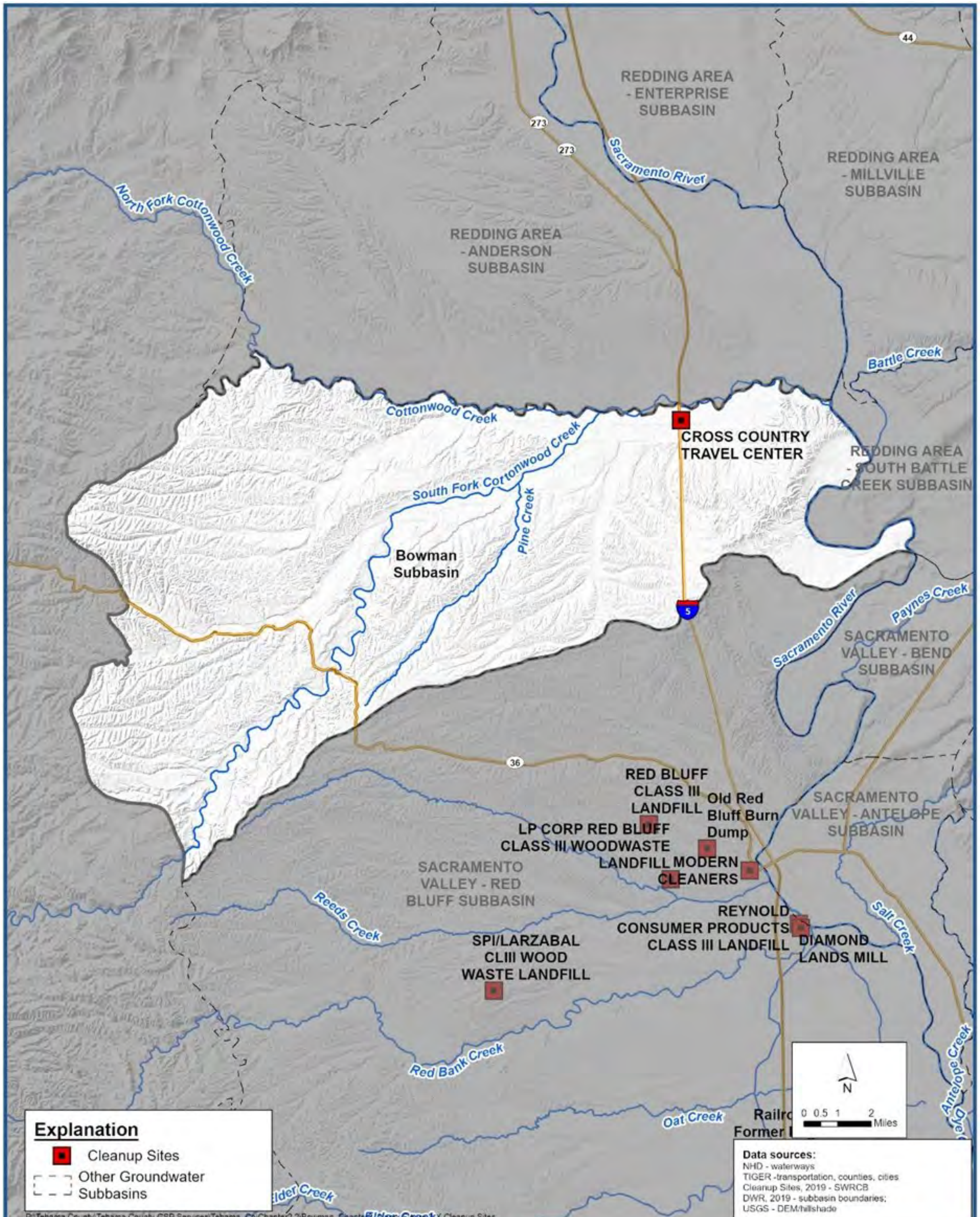
Groundwater cleanup sites are identified on the GeoTracker database which includes leaking underground storage tank sites, Department of Defense Sites, and Cleanup Program Sites. As displayed in **Figure 2-12**, there is one cleanup site located within the Bowman Subbasin. This site is located at an active gas station and is designated as a remediation site for a dissolved-phase MTBE plume that has been monitored since 1996. As reported on GeoTracker, this MTBE plume extends from former underground storage tank and pump locations at the northern end of the site toward an Anderson Cottonwood Irrigation District canal and domestic well on the adjoining northern property. This site is regulated by SWRCB.

2.1.4.7 Relationships with State and Federal Regulatory Agencies

The GSA has developed relationships with state and federal interests in the Bowman Subbasin to ensure the proper communication of GSP information and allow stakeholder input on the development of the GSP. **Table 2-6** identifies state and federal agencies with beneficial use and/or users in the Subbasin.

2.1.4.8 Consideration of Existing Land Use Plans

The GSA considered the land use policies of Tehama County in the development of this GSP. Land use plans are described in Section 2.1.3 (Land Use Elements or Topic Categories in Applicable General Plans).



TEHAMA COUNTY

LSCE Team

Cleanup Sites

Groundwater Sustainability Planning
Bowman Subbasin

Figure 2-12

2.1.5 Notice and Communication

GSP Regulations Section 354.10 requires that the GSA consider the interest of all beneficial groundwater users. Under the requirements of SGMA, GSAs must encourage diverse, social, cultural, and economic elements of the population to be actively involved in GSP development. Cooperation and engagement of all beneficial users (described below) of groundwater will assist in the successful implementation of the GSP and sustainable management of groundwater in the Subbasin on the path forward.

To facilitate stakeholder involvement in the GSP development process and ensure interested parties could participate in the development of the GSP, a Communication and Engagement Plan (**Appendix 2-A**) was created to:

- Enhance understanding and inform the public about water and groundwater resources in the District subbasins, the purpose and need for sustainable groundwater management, the benefits of sustainable groundwater management, and the need for GSPs.
- Engage a diverse group of interested parties and stakeholders and promote informed feedback from stakeholders, the community, and groundwater-dependent users throughout the preparation and implementation process of the GSPs.
- Coordinate communication and involvement between the subbasins and other local agencies, elected and appointed officials, and the general public.
- Utilize the District Board of Directors and Groundwater Commission meetings to facilitate a public engagement process.
- Employ a variety of outreach methods that make public participation accessible and that encourage broad participation.
- Respond to public concerns and provide accurate and up-to-date information.
- Manage communications and engagement in a manner that provides maximum value to the public and constitutes an efficient use of the GSA's resources.

In addition, the Tehama County FCWCD will coordinate with neighboring GSAs through GSP implementation as part of the Northern Sacramento Valley Inter-basin Coordination Report (**Appendix 2-B**).

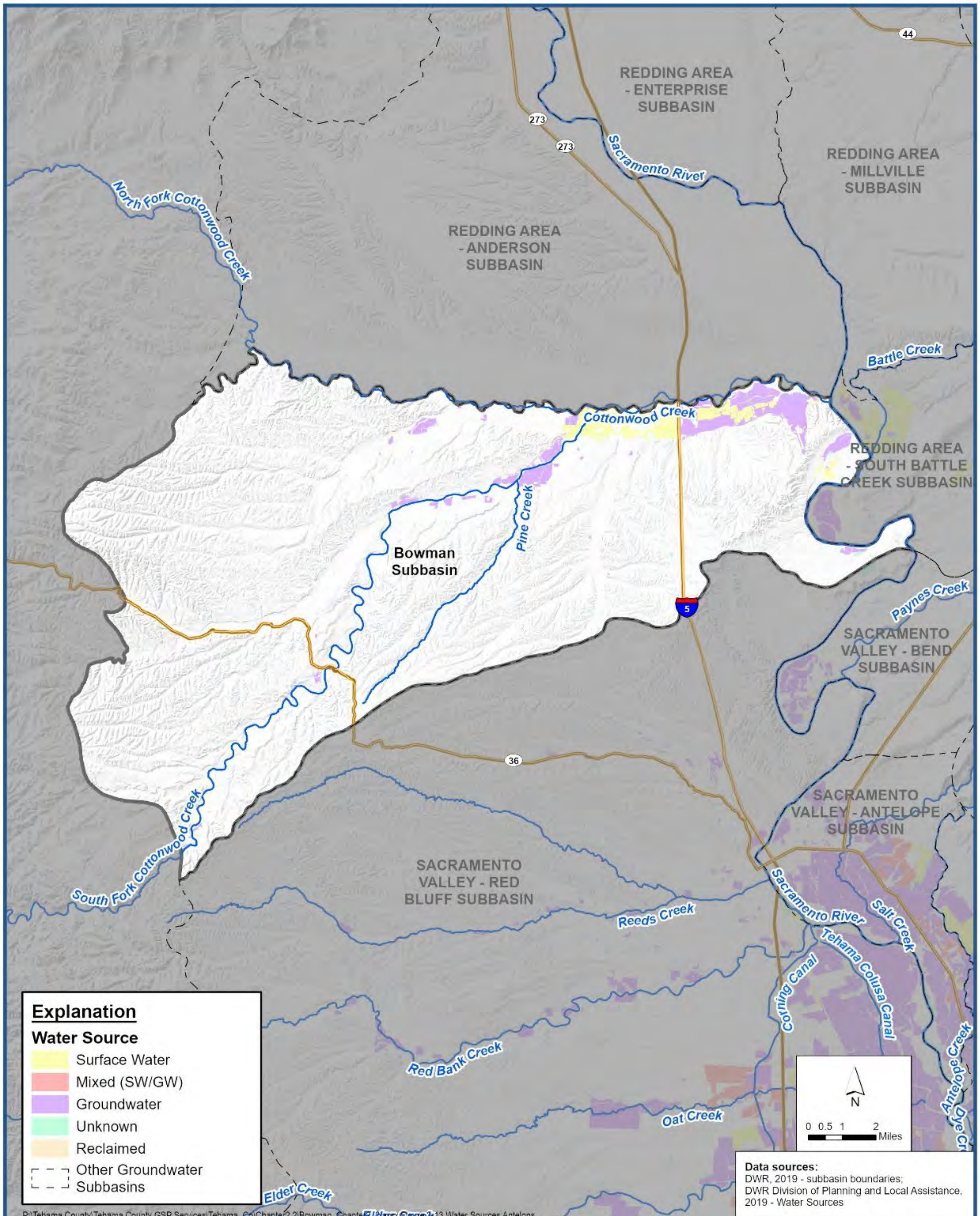
2.1.5.1 Beneficial Uses and Users of Groundwater

Under the requirements of SGMA, all beneficial uses and users of groundwater in the Subbasin must be considered in the development and implementation of the GSP, and the GSA must encourage the active involvement of such parties. In the Bowman Subbasin, beneficial users include any stakeholders that have interest in groundwater use and/or management in the Subbasin. Beneficial uses and users, as identified in the Communication and Engagement Plan are displayed in **Table 2-6** below. Subbasin water sources are shown in **Figure 2-13** and public water districts are shown in **Figure 2-14.**

Table 2-6. Beneficial Uses and Users of Groundwater

CATEGORY OF INTEREST	STAKEHOLDER GROUPS
General Public	• Interested individuals or interested parties • Tehama County School District • Latino Outreach of Tehama County • University of California Cooperative Extension • Tehama County Board of Supervisors • Shasta College • Red Bluff-Tehama County Chamber of Commerce • Lake California Property Owners Association • Evergreen Union School District • Sunset Hills Development
Land Use	• Tehama County Planning Department • Tehama County Planning Commission • Tehama County Environmental Health Department • Tehama County Department of Agriculture
Urban/ Commercial & Non-Commercial Agricultural	• Tehama County Farm Bureau • Tehama County Cattlemen’s Association • Tehama County Cattlewomen’s Association • Tehama County Agricultural Commissioner • University of California Cooperative Extension • Resource Conservation District of Tehama County • Shasta Tehama Watershed Education Coalition • Rio Alto Water District • Anderson Cottonwood Irrigation District • Bengard Ranch
Other Commercial/Municipal Users	• Renewable Power Companies • CAL FIRE Stations • Crain Processing Plants • Sierra Pacific Industries • Tehama County
Environmental and Ecosystem	• Audubon Society • The Nature Conservancy • California Department of Fish and Wildlife • United State Fish and Wildlife Service • United States Bureau of Reclamation • United States Bureau of Land Management

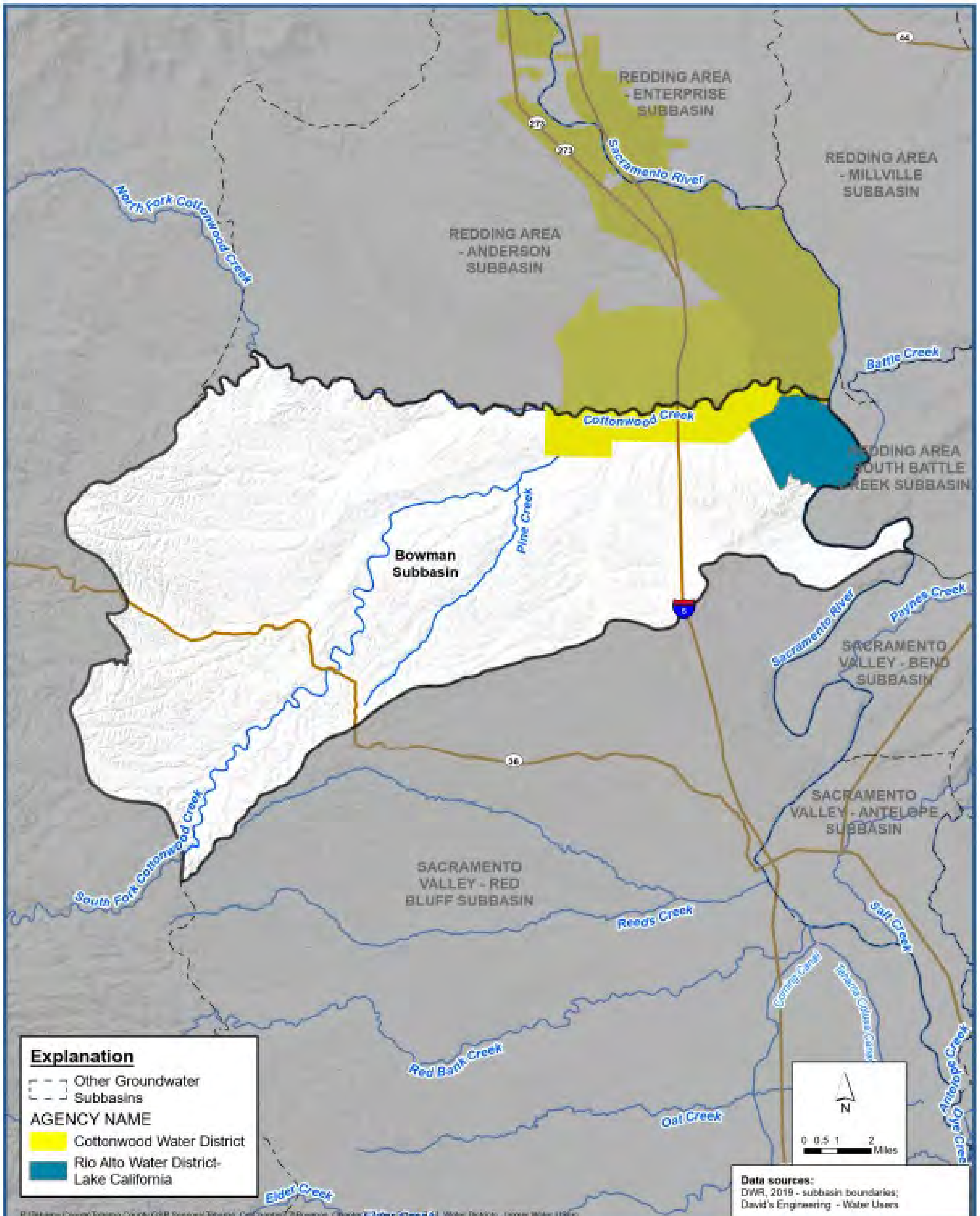
	• United States Forest Service • Natural Resources Conservation Service • DWR • California State Parks • Fire Safe Councils (Tehama Glenn FSC)
Surface Water	• Mutual Water Companies • Water Districts • Agricultural Users • Riparian Water Right Holders • Anderson Cottonwood Irrigation District • Lake California Property Owners Association
Economic Development	• Tehama County Board of Supervisors • James Gallagher (SA) • Jim Neilson (Senator) • Tehama County Planning Commission • Red Bluff-Tehama County Chamber of Commerce • U.S. Economic Development Administration
Human Right to Water	• Private Well Owners • Small Water Systems • Disadvantaged Communities • Lake California • Unincorporated County (Bowman Area) • Rio Alto Water District • Saddleback Mutual Water Company
Tribes	• California Indian Water Commission • Greenville Rancheria
Integrated Water Management	• IRWMP Stakeholders • Mid Upper Sacramento Regional Flood Management Group



Water Sources

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-13



Public Water Districts

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-14

2.1.5.2 Opportunity for Public Engagement

Involvement of social, cultural, and economic elements and interested parties was encouraged through public meetings and workshops, public availability of SGMA, GSA, and GSP information, public comment opportunities, and collaboration with cities, districts, state and federal agencies, neighboring GSAs, and stakeholders in the Subbasin. SGMA, GSA, and GSP information was made available to the public through the Tehama County FCWCD website, public hearings, meetings, and workshops.

The Groundwater section of the Tehama County Flood Control and Water Conservation District website (tehamacountywater.org) provides: Groundwater Commission Bylaws and general information, GSA formation documents including: notices of public hearings, resolutions, notices of intent, ordinances, letters of support, formation notifications, basin boundary modification documents, groundwater monitoring data, groundwater related resource materials, and information on the Tehama County Groundwater Commission. The website also includes meeting dates and links to agendas and meeting minutes for Groundwater Commission and Board of Directors meetings and Groundwater Sustainability presentations. Additionally, the public may register for the interested parties list, via the website or by contacting GSA staff, to receive information and notices concerning SGMA, GSP development, and the GSA. The list of GSA outreach events and current list of interested parties is included as **Appendix 2-D**.

Active involvement of the public and stakeholders was encouraged in a variety of ways:

- Public Meetings - Groundwater Commission and District Board of Directors meetings were open to the public and followed the requirements of the Brown Act. The public had opportunities to provide comments on programs, plans, and proposals at these meetings.
- Public Hearings - Public hearings were held prior to the adoption of any fees, GSP elements, and the final GSP.
- Public Workshops – These included all educational opportunities where the public could learn about SGMA, GSA, and GSP elements. These events were typically held as tailgates and webinars.
- Public Notices – Notices were sent to the public prior to the initial development of the GSP and to inform the public of ways in which they could be involved in the GSP development and implementation process.
- Stakeholder Briefings – Groundwater Commission members regularly communicated with and disseminated information to the stakeholder groups they represent.
- Newsletters - Quarterly newsletters were provided to update the public and stakeholders on GSP development.

A full list of meetings, public hearings, and workshops during which the public had the opportunity to be engaged is included in **Table 2-7**. Additionally, presentations were provided to stakeholder groups as listed in **Appendix 2-D**.

Table 2-7: Opportunities for Public Engagement

EVENT NAME	DATE	LOCATION
Tehama County FCWCD Board of Directors Meeting	January 22, 2015, 10:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	May 14, 2015, 10:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Public Hearing TCFCWCD Board of Directors (GSA Formation)	June 2, 2015, 1:30 PM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	August 13, 2015, 10:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Public Hearing TCFCWCD Board of Directors (Notice of Intent)	November 3, 2015, 1:30 PM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	December 10, 2015, 10:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	January 27, 2016, 10:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	March 23, 2016, 10:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County Public Meeting	April 4, 2016	
Tehama County FCWCD Board of Directors Meeting Public Meeting	May 25, 2016, 10:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA

EVENT NAME	DATE	LOCATION
Tehama County Public Meeting	June 27, 2016	
Tehama County FCWCD Board of Directors Meeting	July 27, 2016, 10:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	August 2, 2016, 2:00 PM	Tehama County Dept. of Agriculture 1834 Walnut Street Red Bluff, CA
Groundwater Commission Meeting	September 12, 2016, 9:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	September 26, 2016, 2:00 PM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	November 9, 2016, 10:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	December 14, 2016, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	January 23, 2017, 10:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	February 22, 2017, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	March 20, 2017, 10:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA

EVENT NAME	DATE	LOCATION
Groundwater Commission Meeting	March 22, 2017, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	April 26, 2017, 2:00 PM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	May 15, 2017, 10:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County Public Meeting	May 30, 2017	
Groundwater Commission Meeting	June 28, 2017, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	July 17, 2017, 10:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County Public Meeting	August 9, 2017	
Groundwater Commission Meeting	September 27, 2017, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	October 24, 2017, 10:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	October 25, 2017, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	December 4, 2017, 2:00 PM	Board of Supervisors Chambers 727 Oak Street

EVENT NAME	DATE	LOCATION
		Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	March 19, 2018, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	April 25, 2018, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	May 21, 2018, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	June 14, 2018, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	June 19, 2018, 1:30 PM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	August 22, 2018, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	September 17, 2018, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	October 24, 2018, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	November 19, 2018, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA

EVENT NAME	DATE	LOCATION
Groundwater Commission Meeting	January 23, 2019, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	March 18, 2019, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	April 24, 2019, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	May 20, 2019, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	May 22, 2019, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	August 28, 2019, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	September 16, 2019, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	October 23, 2019, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	November 18, 2019, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	December 18, 2019, 11:00 AM	Board of Supervisors Chambers 727 Oak Street

EVENT NAME	DATE	LOCATION
		Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	January 7, 2020, 10:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	January 27, 2020, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	February 26, 2020, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	March 16, 2020, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	April 22, 2020, 8:30 AM	Virtual
Groundwater Commission Meeting	May 27, 2020, 8:30 AM	Virtual
Groundwater Commission Meeting	June 24, 2020, 8:30 AM	Virtual
Tehama County FCWCD Board of Directors Meeting	July 20, 2020, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	August 26, 2020, 8:30 AM	Virtual
Tehama County FCWCD Board of Directors Meeting	September 23, 2020, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	September 23, 2020, 8:30 AM	Virtual
Regional Public Meeting	October 8, 2020, 6:00 PM	Virtual

EVENT NAME	DATE	LOCATION
Public Outreach Series (Bowman) SGMA and GSP Overview	October 15, 2020, 5:30 PM	Tailgate outdoor meeting Evergreen Middle School 19500 Learning Way, Cottonwood, CA
Tehama County FCWCD Board of Directors SGMA Presentation	October 20, 2020, 1:30 PM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	October 28, 2020, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	November 16, 2020, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	December 9, 2020, 8:30 AM	Virtual
Regional Public Webinar Progress Update on GSP Development	December 9, 2020, 6:00 PM	Webinar
Tehama County FCWCD Board of Directors Meeting	January 25, 2021, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	January 27, 2021, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	February 24, 2021, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	March 15, 2021, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	March 24, 2021, 8:30 AM	Board of Supervisors Chambers

EVENT NAME	DATE	LOCATION
		727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	April 19, 2021, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Public Outreach Series (Bowman) Plan Area and Basin Setting, SMC	April 19, 2021	Virtual
Groundwater Commission Meeting	April 28, 2021, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	May 17, 2021, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	May 26, 2021, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	June 23, 2021, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	June 28, 2021, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	July 28, 2021, 8:30 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	August 16, 2021, 11:00 AM	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA

EVENT NAME	DATE	LOCATION
Public Outreach Series (Bowman) **SMCs, PMAs, Public Review Schedule**	August 17, 2021, 6:00 PM	Virtual
Groundwater Commission Meeting	*September 22, 2021, 8:30 AM*	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Regional Public Webinar	*September 29, 2021, 6:00 PM*	Virtual
Tehama County FCWCD Board of Directors Meeting	*October 18, 2021, 11:00 AM*	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Regional Public Webinar	*October 20, 2021, 6:00 PM*	Virtual
Groundwater Commission Meeting	*October 27, 2021, 8:30 AM*	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	*November 15, 2021, 11:00 AM*	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Regional Public Workshop	November 15, 2021, 6:00	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Groundwater Commission Meeting	*December 8, 2021, 8:30 AM*	Board of Supervisors Chambers 727 Oak Street Red Bluff, CA
Tehama County FCWCD Board of Directors Meeting	*December 20, 2021, 11:00 AM*	Board of Board of Supervisors Chambers 727 Oak Street

2.1.5.3 Comments on the Plan

Comments that the Tehama County FCWCD received on the GSP were considered in the preparation of the GSP by the GSA and consultants. Copies of comment letters received are provided in **Appendix 2-E**.

2.1.5.4 Agency Decision Making Process

The Tehama County FCWCD is the GSA for the Bowman Subbasin and has the final decision-making authority for the Subbasin. To assist in the development of the GSP, meetings were held with the Groundwater Commission, Tehama County FCWCD Board of Directors, Tehama County Board of Supervisors, ad hoc committees, and AB3030 TAC to discuss GSP elements as needed. As discussed in Section 1.3.1, the Board of Directors/Board of Supervisors is the five-member elected governing body of the Tehama County FCWCD, the Groundwater Commission is an eleven-member advisory committee for the Board of Directors for GSA related matters, and the AB3030 TAC consists of stakeholders with various interests: agricultural pumpers, water district representatives, a natural resource representative, and city representatives. The ad hoc committees consist of a smaller group of Groundwater Commission members that assemble when needed to address specific topics, make recommendations, and report information back to the full Groundwater Commission for direction or recommendation to the FCWCD Board of Directors. Once the specific topic was addressed, the committee would dissolve. These committees formed and met throughout the development of the GSP to ensure specific topics were addressed. Final decisions were then made by the GSA and in coordination with stakeholders and with input from consultants and advisory committees as needed.

2.1.6 References

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FINAL REPORT

Bowman Subbasin

Sustainable Groundwater Management Act

Groundwater Sustainability Plan Chapter 2B Basin Setting

January 2022

Prepared For:

Tehama County Flood Control and Water Conservation District

Prepared By:

Luhdorff & Scalmanini, Consulting Engineers

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LIST OF ACRONYMS & ABBREVIATIONS

AB	Assembly Bill
bgs	Below Ground Surface
BLM	Bureau of Land Management
BOD	Board of Directors
BLM	Bureau of Land Management
CASGEM	California Statewide Groundwater Elevation Monitoring
CCR	California Code of Regulations
CDEC	California Data Exchange Center
CDFW	California Department of Fish and Wildlife
CDPH	California Department of Public Health
CE	Communications and Engagement
CFS	Cubic Feet per Second
CV-SALTS	Central Valley Salinity Alternatives
CVRWQCB	Central Valley Regional Water Quality Control Board
CWC	California Water Code
dS/m	Deci-siemens per Meter
DAC	Disadvantaged Community
DDW	Division of Drinking Water
DOI	Department of the Interior
DWR	California Department of Water Resources
DPR	Department of Pesticide Regulation
EC	Electrical Conductivity
ft^2/d	Square Feet Per Day
ft/d	Feet Per Day
ft/mile	Feet per Mile
ft bgs	Feet Below Ground Surface
ft msl	Feet Above Mean Sea Level
GAMA	Groundwater Ambient Monitoring and Assessment Program

GDE	Groundwater Dependent Ecosystem
GMP	Groundwater Management Plan
GPS	Global Positioning Systems
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
HCM	Hydrogeologic Conceptual Model
iGDE	Indicators of Groundwater Dependent Ecosystems
ILRP	Irrigated Lands Regulatory Program
InSAR	Interferometric Synthetic Aperture Radar
IRWMP	Integrated Regional Water Management Plan
JPA	Joint Powers Authority
LLNL	Lawrence Livermore National Laboratory
LSCE	Luhdorff & Scalmanini, Consulting Engineers
MCL	Maximum Contaminant Level
mg/L	Milligrams per Liter
MO	Measurable Objective
MOA	Memorandum of Agreement
MT	Minimum Threshold
MTJ	Mendocino Triple Junction
MWELO	Model Water Efficient Landscape Ordinance
NCCAG	Natural Communities Commonly Associated with Groundwater
NRCS	Natural Resources Conservation Service
NWIS	National Water Information System
SAGBI	Soil Agricultural Groundwater Banking Index
SB	Senate Bill
SGMA	Sustainable Groundwater Management Act
SVWQC	Sacramento Valley Water Quality Coalition
SWRCB	State Water Resources Control Board
TAC	Technical Advisory Committee
TDS	Total Dissolved Solids

Tehama County FCWCD	Tehama County Flood Control and Water Conservation District
TM	Technical Memorandum
USDA	United States Department of Agriculture
USBR	United States Bureau of Reclamation
USFS	United States Forest Service
USFWS	United States Fish & Wildlife Service
USGS	United States Geological Survey
UWMPA	Urban Water Management Planning Act
WDL	Water Data Library
WDR	Waste Discharge Requirements
μg/L	Micrograms per liter
μmhos/cm	Micromhos per Centimeter

2 SUBBASIN PLAN AREA AND BASIN SETTING (REG. § 354.8)

2.1 Description of Plan Area

2.2 Basin Setting

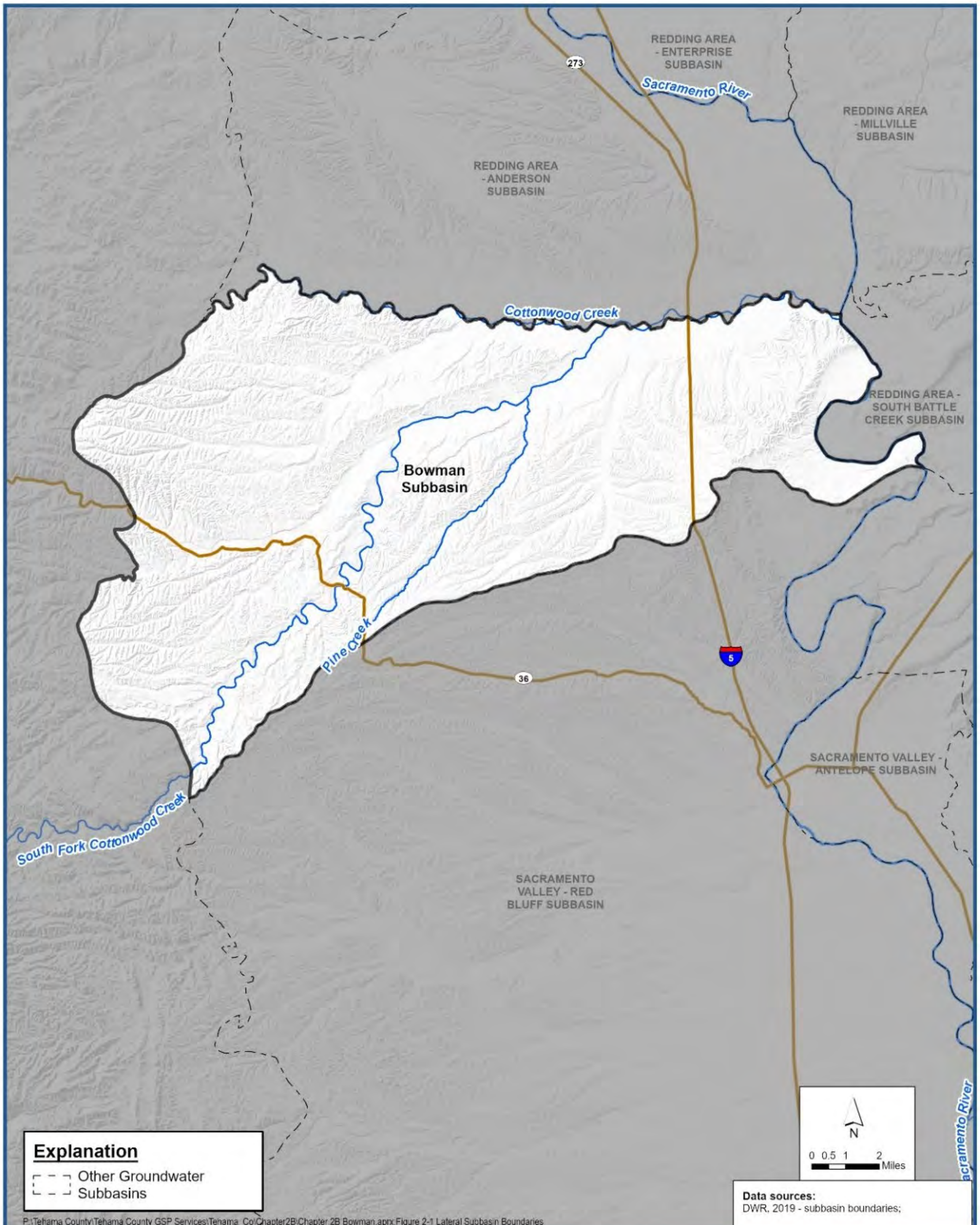
The Basin Setting section is a description of available information used as a background to develop the sustainability criteria for the Subbasin. It includes a detailed review of studies and historic groundwater conditions in the Subbasin. This information provides context about the quantity and movement of water in the Subbasin. The Basin Setting supports numerical modeling used to define groundwater budgets.

2.2.1 Hydrogeologic Conceptual Model

The Hydrogeologic Conceptual Model (HCM) is the framework for the movement of water in the Subbasin. An HCM is developed through the use and interpretation of historical geologic, hydrogeologic, and hydrologic data and investigations to describe the geologic features, the water sources, and movement of surface and groundwater. The HCM also describes groundwater quality and the origin and migration of chemicals of concern to beneficial users. The development of the HCM is based on the availability of data and is updated periodically as new hydrogeologic data is collected, analyzed, and interpreted. The development of an HCM begins with a review of historical reports and available data. The HCM presented herein of the Bowman Subbasin is the result of updating previous HCMs. The HCM is also the foundation for the numerical model used to produce the historic and current water budgets and the future projections of groundwater use. The components of the HCM including the Subbasin's lateral boundaries, topography, geologic setting, soil characteristics, principal aquifers, definable bottom of the aquifer system, surface water features, and recharge areas, are presented in the following sections.

2.2.1.1 Subbasin Boundaries

The lateral extent of the Bowman Subbasin is defined in the DWR Bulletin 118 and based on surface water and geologic features. Initial subbasin boundaries for California were published in 2004 with updates published in 2016 and 2018. The Bowman Subbasin boundary descriptions were updated to incorporate the preexisting Rosewood Subbasin in the 2018 Bulletin 118 update. Surface water and geologic features are used as lateral bounds as they often control divergent groundwater flow (DWR, 2004). The Subbasin is bordered to the north by Cottonwood Creek (county border). The western boundary is defined as the Coast Ranges and the eastern boundary is defined as the Sacramento River (DWR, 2004). The Red Bluff Arch separates the Subbasin from the Red Bluff Subbasin to the south (DWR, 2004). The bottom of the Subbasin is defined as the base of the post-Eocene continental deposits where the transition from marine derived sediments to terrestrial derived sediments corresponds to the transition from saline/brackish groundwater to fresh groundwater. Fresh groundwater is defined as water with an electrical conductivity of less than 3,000 micromhos per centimeter (µmhos/cm) as mapped by Berkstresser (1973) (DWR, 2014). This depth is corroborated by DWR's review of geophysical logs and water quality samples (DWR, 2014). The lateral subbasin boundaries are presented in **Figure 2-15** and the bottom of the basin is discussed further in section 2.2.1.6 and presented in **Figure 2-16** and **Figure 2-17**.



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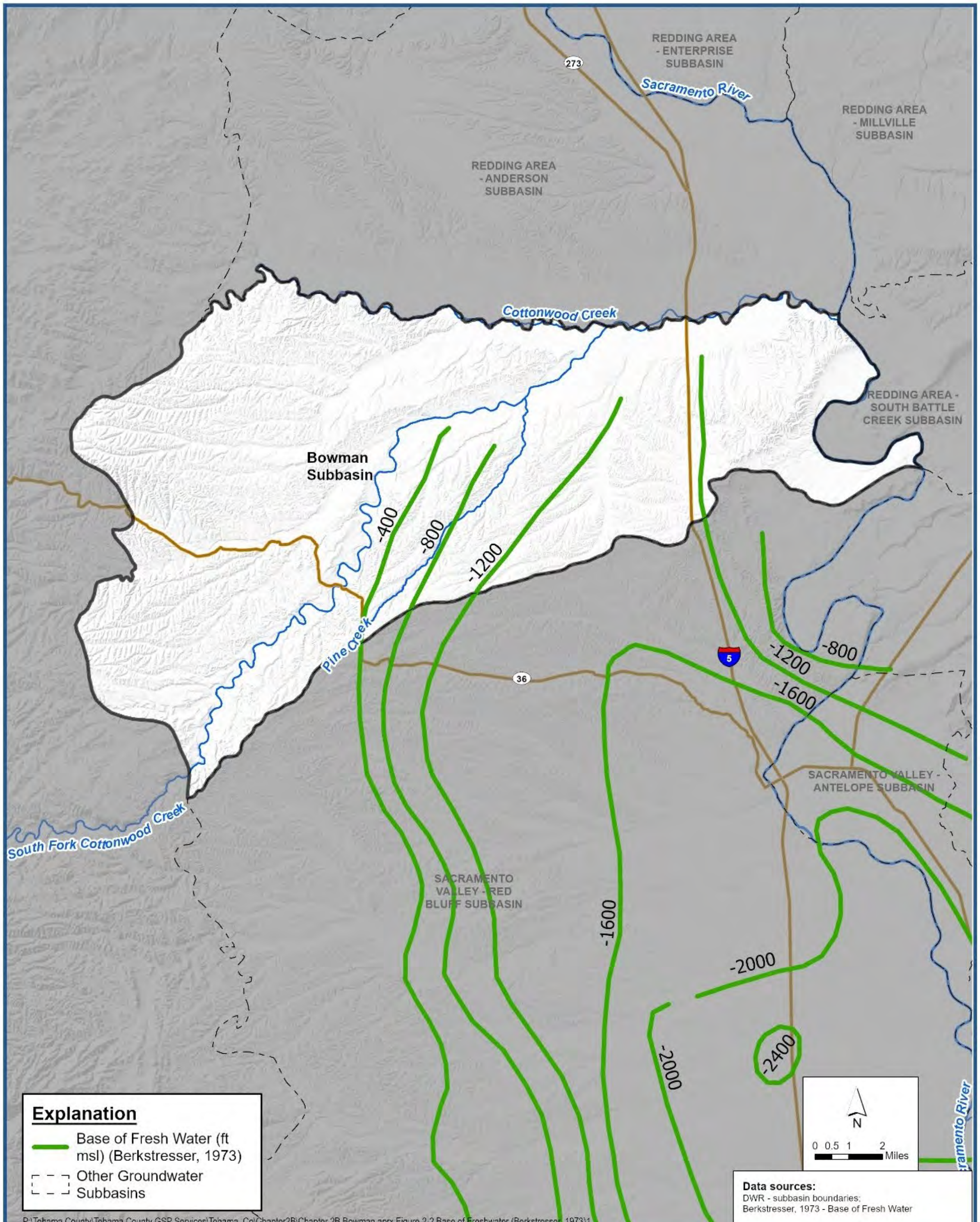
Lateral Subbasin Boundary

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-15



Contours of Equal Groundwater Elevation, Base of Freshwater

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-16

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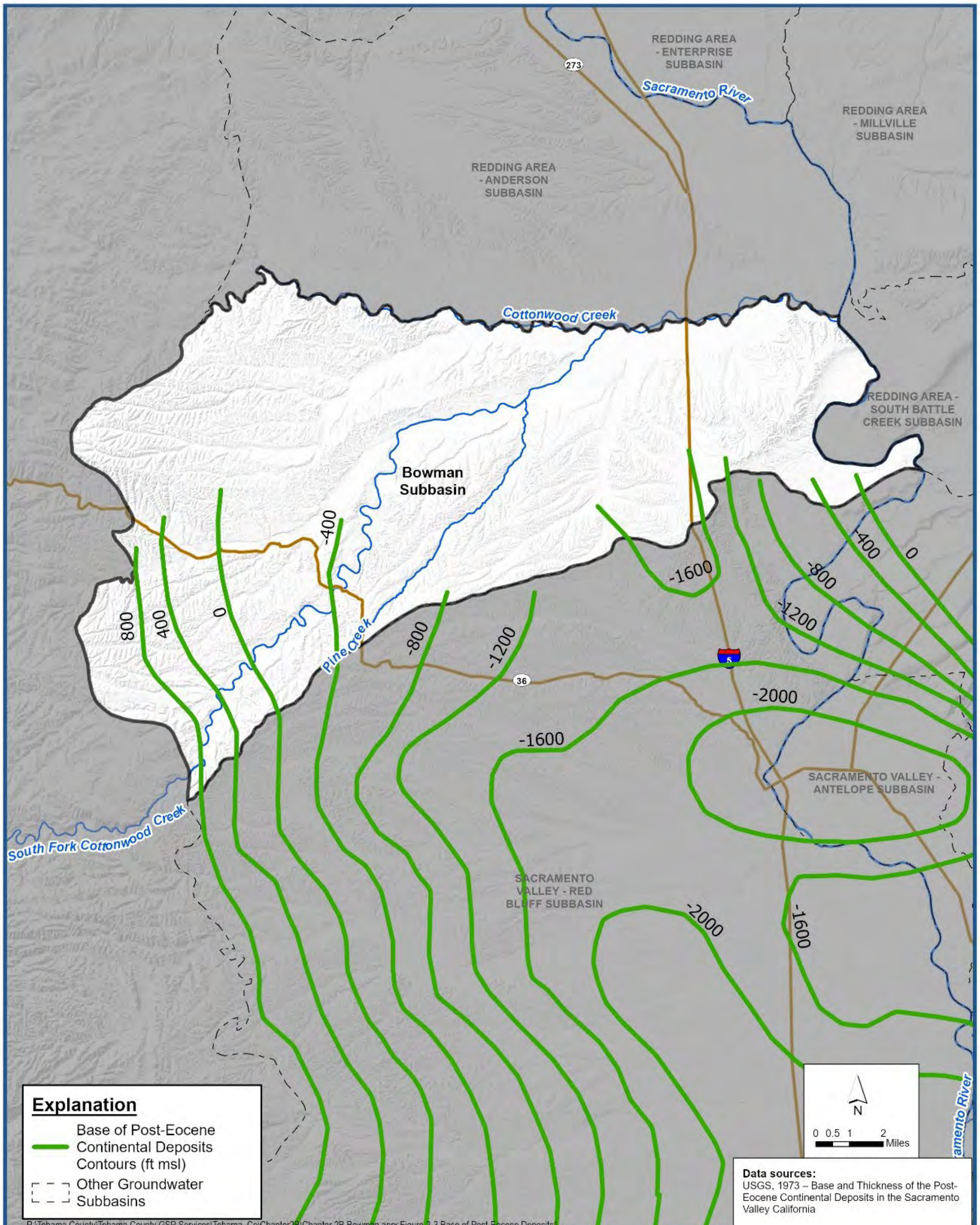

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Contours of Equal Elevation, Base of Post-Eocene Deposits

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-17

2.2.1.2 Topographic Information

The Bowman Subbasin is characterized by a relatively sloped topographic setting along the western side of the Redding Area groundwater basin. Topography is highest along the western border of the Subbasin where the Coast Ranges foothills transition to the valley floor. The topographic slope is steep in the west (10% - >50%) and is generally shallow in the northern and eastern areas of the Subbasin (<2%) (**Figure 2-18**). The ground surface elevation ranges from over 1,000 feet above mean sea level (ft msl) in the west and southwest parts of the Subbasin to less than 400 ft msl in the majority of the Subbasin (**Figure 2-19**).

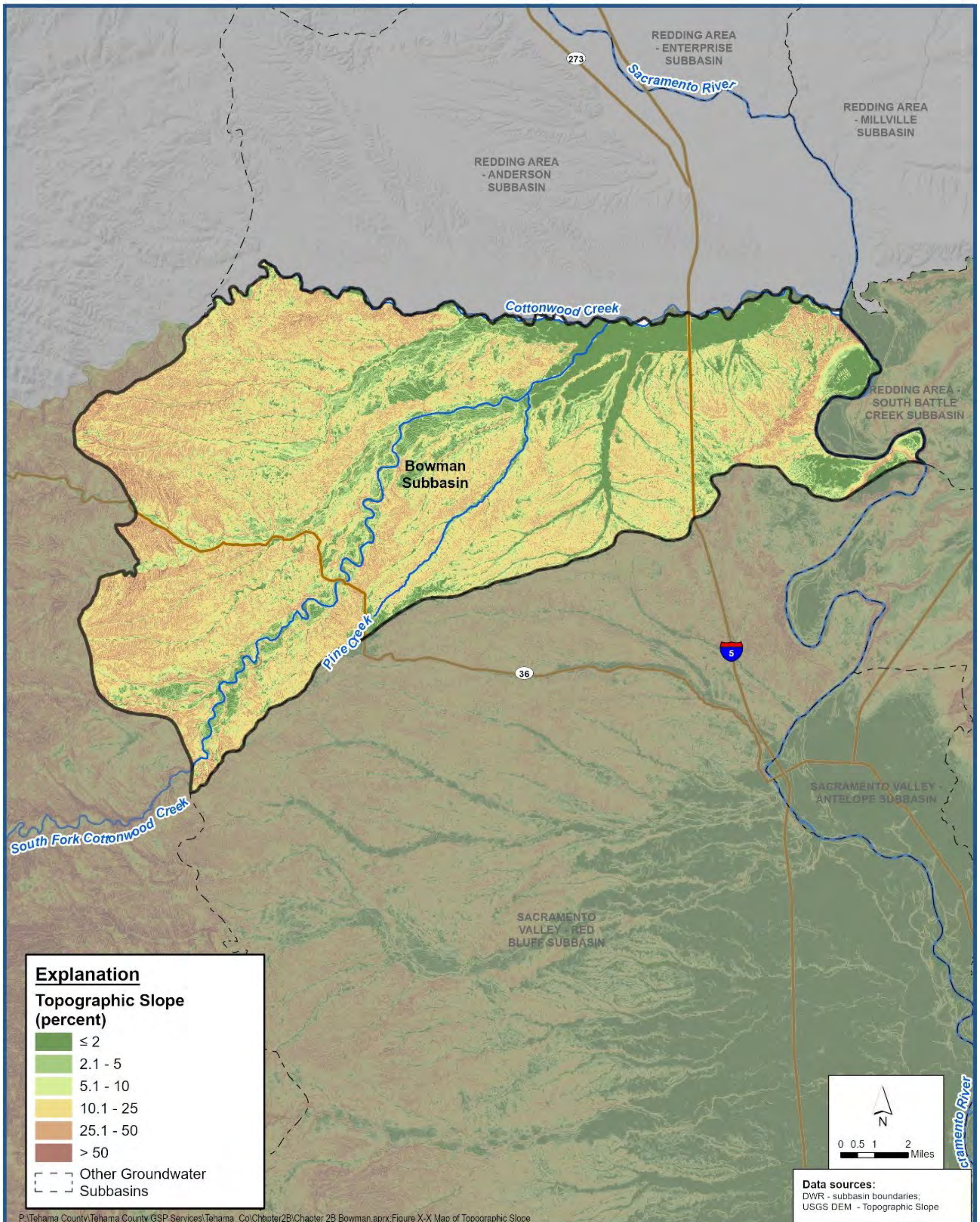
2.2.1.3 Geologic Setting

In the 1960s and 1970s, early studies of the geology in the northern Sacramento Valley were conducted for oil and gas exploration and characterization of geologic resources like groundwater. Studies by the USGS and independent researchers consolidated earlier work and conflicting nomenclature into more standardized and agreed upon definitions and characterized the water bearing potential and origin of the younger geologic units in the Sacramento Valley (Olmstead and Davis, 1961; Lydon, 1968; Ojakangas 1968). Depositional environments and geologic history of the older and deeper rocks were also characterized during the same period for oil and gas resources and academic purposes (Garrison, 1962; Bailey et al., 1970; Redwine, 1972; Dickinson and Rich, 1972; Mansfield, 1979).

In the 1980s and 1990s, further research was conducted on the older Great Valley Sequence geologic units (Ingersoll and Dickinson, 1981; Bertucci, 1983). Extensive mapping and seminal studies of the younger geologic formations were conducted by the USGS that further defined and separated the distribution and lithologic character of the geologic units in the Sacramento Valley (Marchand and Allwardt, 1981; Harwood et al., 1981; Helley and Jaworowski, 1985; Helley and Harwood, 1985; Harwood and Helley, 1987; Blake et al., 1999).

More recent studies in the 2000s and 2010s have attempted to further characterize the geologic material and contextualize the information as it relates to groundwater resources (DWR, 2004; DWR, 2008; Gonzalez, 2014). DWR conducted an extensive literature review and study to compile the most current geology and groundwater information in a 2014 report (DWR, 2014).

The geologic history of the northern Sacramento Valley, where the Subbasin is located, is dominated by a series of mountain building events leading to provenance changes in basin sedimentation. During the Mesozoic, a subduction zone created the plutonic emplacement of the Sierra Nevada. The uplift of the Sierra Nevada isolated the Pacific Ocean from its previous extent, moving the shoreline west (DWR, 2014). The uplifting mountains created a source of sediment that filled the forearc basin through erosional processes (Olmstead and Davis, 1961). On the western boundary of the forearc basin, the eastward dipping subduction resulted in accretionary forces forming the metamorphic rocks that would later make up the Franciscan Formation and Coast Range Ophiolite (DWR, 2014).



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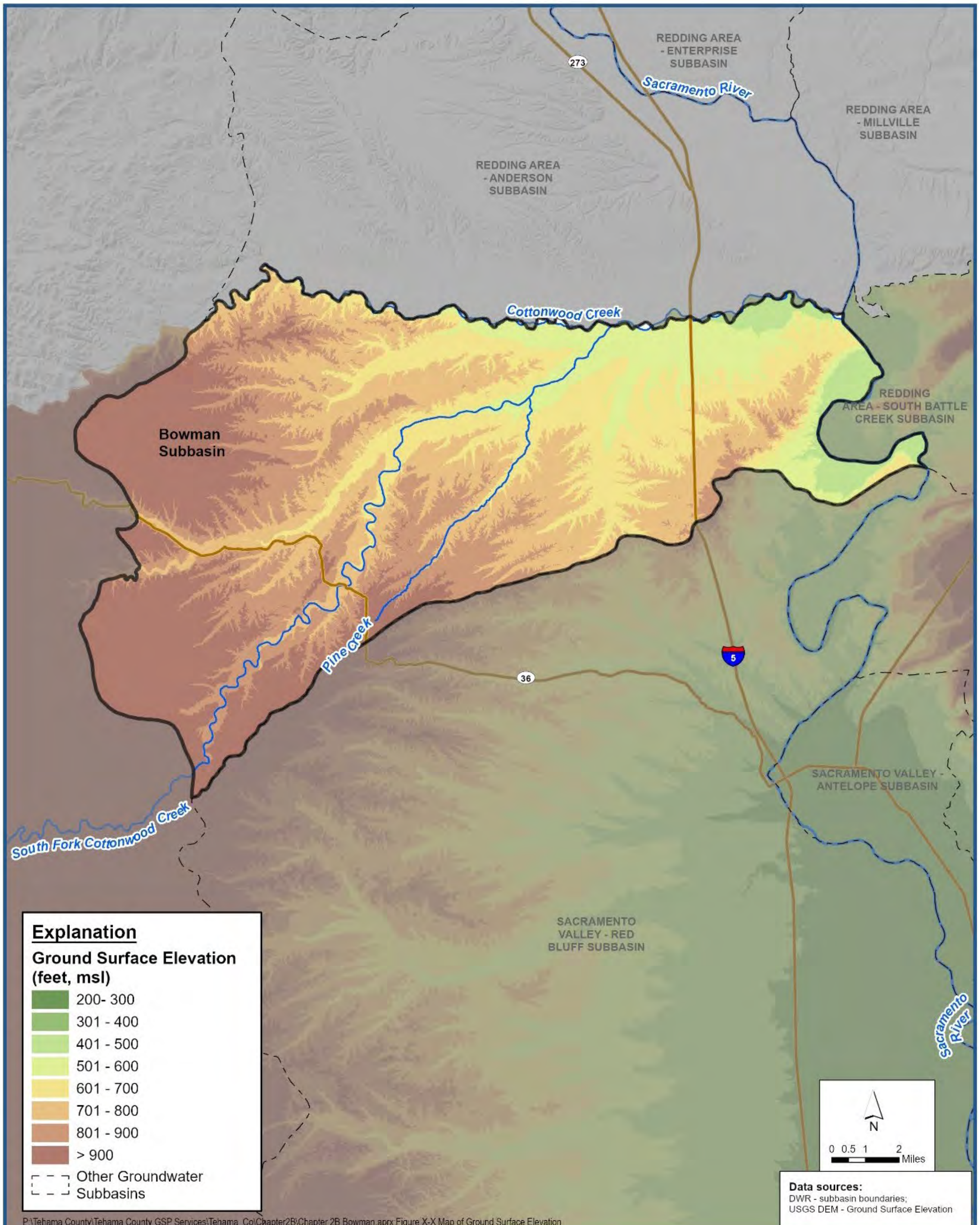
Map of Topographic Slope

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-18



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Map of Ground Surface Elevation

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-19

During the early part of the Cenozoic Era in the Paleogene Period, the tectonic forces that dominated during the Mesozoic were still present (DWR, 2014). These tectonic forces resulted in periods of marine regression and transgressions that carved and subsequently filled a large canyon known as the lower Princeton Submarine Valley (DWR, 2014). Marine transgressions and regressions continued throughout the Paleogene and into the Miocene while older Cascade volcanism occurred on the eastern margins of the valley (DWR, 2014).

Continued sedimentation filled the valley throughout the Paleogene until a marine regression and sediment accumulation caused a transition from a marine to terrestrial depositional environment in the Neogene. During this period sedimentation sourced from the uplifting coast ranges, Klamath Mountains, and ancestral Cascades filled the basin (DWR, 2014). Throughout the Neogene epoch the tectonic regime was transitioning from subduction to transverse in a northward pattern until the present day where it is expressed as the Mendocino Triple Junction (MTJ). Tectonic forces associated with the northward migration of the MTJ resulted in geologic structures in the valley like the Chico Monocline, Red Bluff and Corning Faults, and the Los Molinos Syncline (DWR, 2014).

2.2.1.3.1 *Regional Geology*

The terrane surrounding the Subbasin is the source for the sediments that are deposited in and comprise the Sacramento Valley. It is important to understand the surrounding geologic provinces to properly characterize and contextualize the stratigraphy of the Subbasin. The northern portion of the Sacramento Valley where the Subbasin is located is bordered on the east by the Cascade Range Province and the Klamath and Coast Range Geologic Provinces are to the west (**Figure 2-20**).

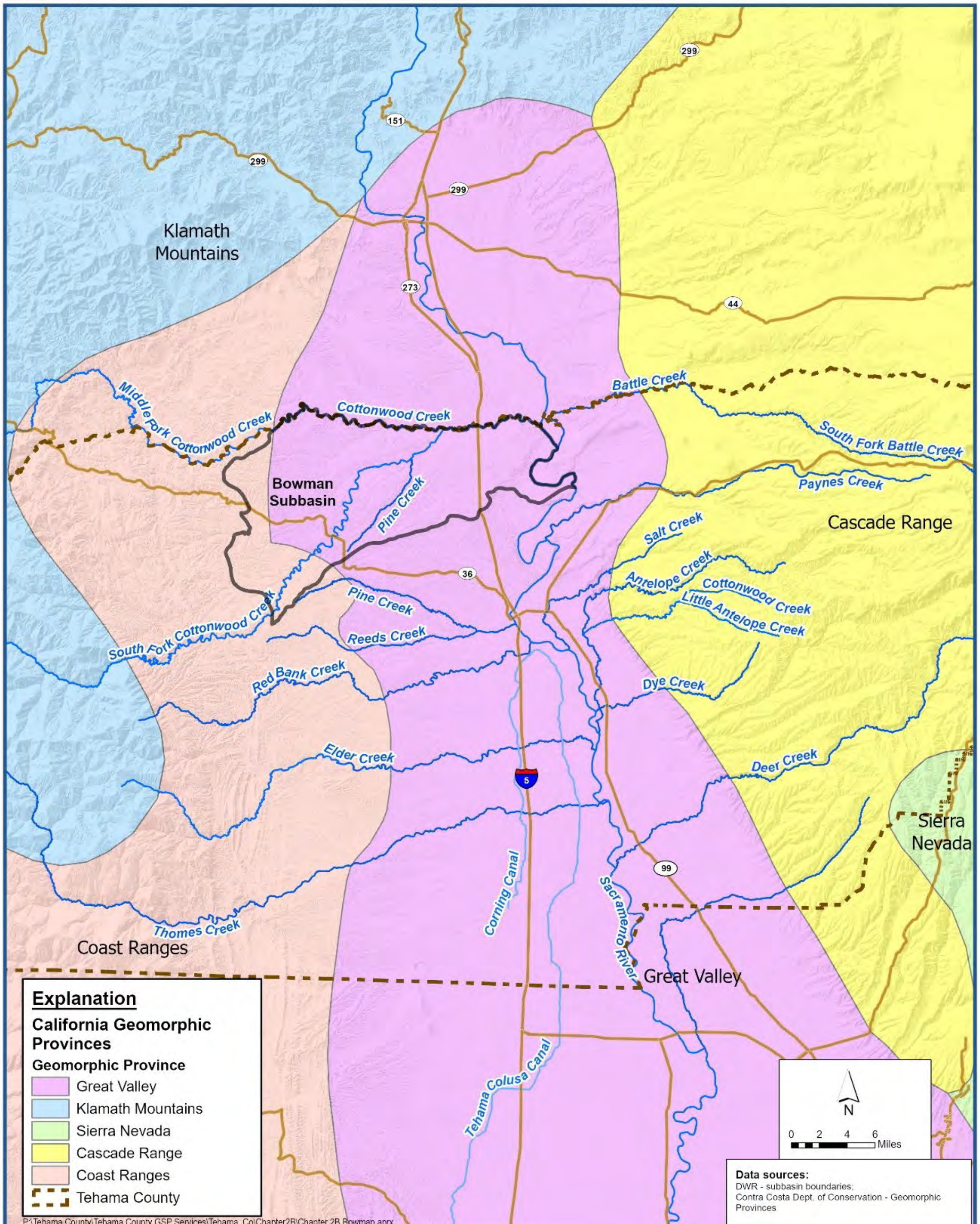
Klamath Geologic Province

The mountains to the northwest of the Subbasin make up the Klamath Geologic Province. The mountain range is steep with peaks of approximately 6,000 ft to 8,000 ft. The Klamath Mountains are comprised of accreted terranes consisting of oceanic crust and accreted island arcs (Blake et al., 1999). To the northwest of the Subbasin, the province consists of Jurassic and older metamorphic-plutonic basement overlain by the east to southeast dipping Great Valley Sequence (Blake et al., 1999). Some streams and tributaries drain the Klamath Geologic Province in the vicinity of the Subbasin.

Coast Range Geologic Province

West of the Sacramento Valley and the Subbasin lies the northern portion of the Coast Range Geologic Province. The northern Coast Range Geologic Province in the vicinity of the Subbasin is steeply sloped with peaks around 5,700 ft.

The mountains here form the boundary between the northern Sacramento Valley and the California Coast. Major creeks that flow through the Subbasin that feed the Sacramento River drain this area of the Coast Ranges.



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Map of Geologic Provinces

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-20

The rocks exposed in the western area of the Coast Range Province are composed of metamorphosed deep sea marine sedimentary rocks (Franciscan Complex). The Franciscan rocks are subdivided into two separate terranes, the Pickett Peak terrane and the Yolla Bolly terrane, which are further divided into sub-groups separated by thrust faults (Blake, 1999). The Franciscan Complex is separated from Jurassic and Cretaceous sedimentary rocks of the Sacramento Valley western foothills by the Coast Range Fault.

The recent and Quaternary history of the basin is similar to present day conditions. The MTJ continued its migration north to its present location causing flexural structures to form like the Inks Creek Fold system (DWR, 2014). Sedimentation continues to occur along stream channels that feed the Sacramento River and is sourced from the surrounding terrane and reworking of emplaced sediment.

Sacramento Valley western foothills

Along the west side of the Sacramento Valley are the foothills of the Coast Ranges and the Klamath Mountains. These foothills form a transition from the steeply sloped peaks of the Coast Ranges to the shallower slopes of the Sacramento Valley. Many streams drain the western foothills and feed the streams and channels in the Sacramento Valley.

The Jurassic and Cretaceous rocks of the Great Valley sequence that are exposed in the western portion of the province consist of marine sourced sedimentary rocks (DWR, 2014). These deposits are exposed due to folding and tilting and form the west limb of a structural trough (DWR, 2014). In the northwest of the province the outcrops are in depositional contact with the Coast Range Ophiolite and in the southwest they are in fault contact (Blake, 1999). In the most northern areas of the western foothills the Great Valley Sequence is in contact with the Klamath Mountains (Blake, 1999). The marine origin of the Great Valley sequence causes the groundwater contained therein to be saline and brackish (connate water).

Cascade Range Province

The Cascade Range Province borders the northern Sacramento Valley to the east. The Cascade Range is a series of andesitic and basaltic-andesite volcanic cones that extend from Lassen Peak in the south through Washington and Oregon in the north (USGS, 2002; Clynne and Muffler, 2010). The ancestral southernmost volcano of the Cascade Range, Mt. Yana, was the principal source of sediment for the Tuscan Formation (Lydon, 1968). The Cascade Range is an active volcanic arc that is driven by the eastward subduction off the coast of Washington, Oregon, and Northern California. No streams and rivers currently drain the Cascade Range in the vicinity of the Subbasin. Eastern fluvial systems feed the Sacramento River and transport sediment to the Sacramento Valley Groundwater Basin.

Great Valley Province (Sacramento Valley Province)

The Great Valley Province encompasses the entire central valley of California. The northern region of the Great Valley Province where the Subbasin is located is referred to as the Sacramento Valley Province. The Sacramento Valley Province (Great Valley Province on **Figure 2-20**) is relatively flat and gently slopes on either side toward the south draining Sacramento River. Stream channels, flood plains, and natural levees dominate the interior of the province which is bordered by the Coast Ranges to the west and the foothills of the Cascades to the east. The underlying sediments are dominated by the freshwater bearing Tehama Formation in the west and the Tuscan Formation in the east (Blake et al., 1999).

The alluvial plains of the western side of the province were formed by the ancestral Sacramento River and its tributaries. The streams deposited large amounts of sediment sourced from the uplifting Coast Ranges and to a lesser extent, the Klamath Mountains, during the Pliocene (Blake et al., 1999). These Pliocene sediments were later cut and filled by younger streams and tributaries (Blake et al., 1999). Outcrops of these younger sediments often occupy currently active streams and tributaries (Blake et al., 1999).

The topography on the east side of the Province is similar to that of the west. It has steeply sloping drainages in the east that shallow into alluvial fans in the vicinity of the Sacramento River. The major difference between the west and the east side is the provenance of the Pliocene sediments. The Pliocene sediments of the east side were sourced from the Cascade Range (DWR, 2014).

2.2.1.3.2 *Geologic Formations*

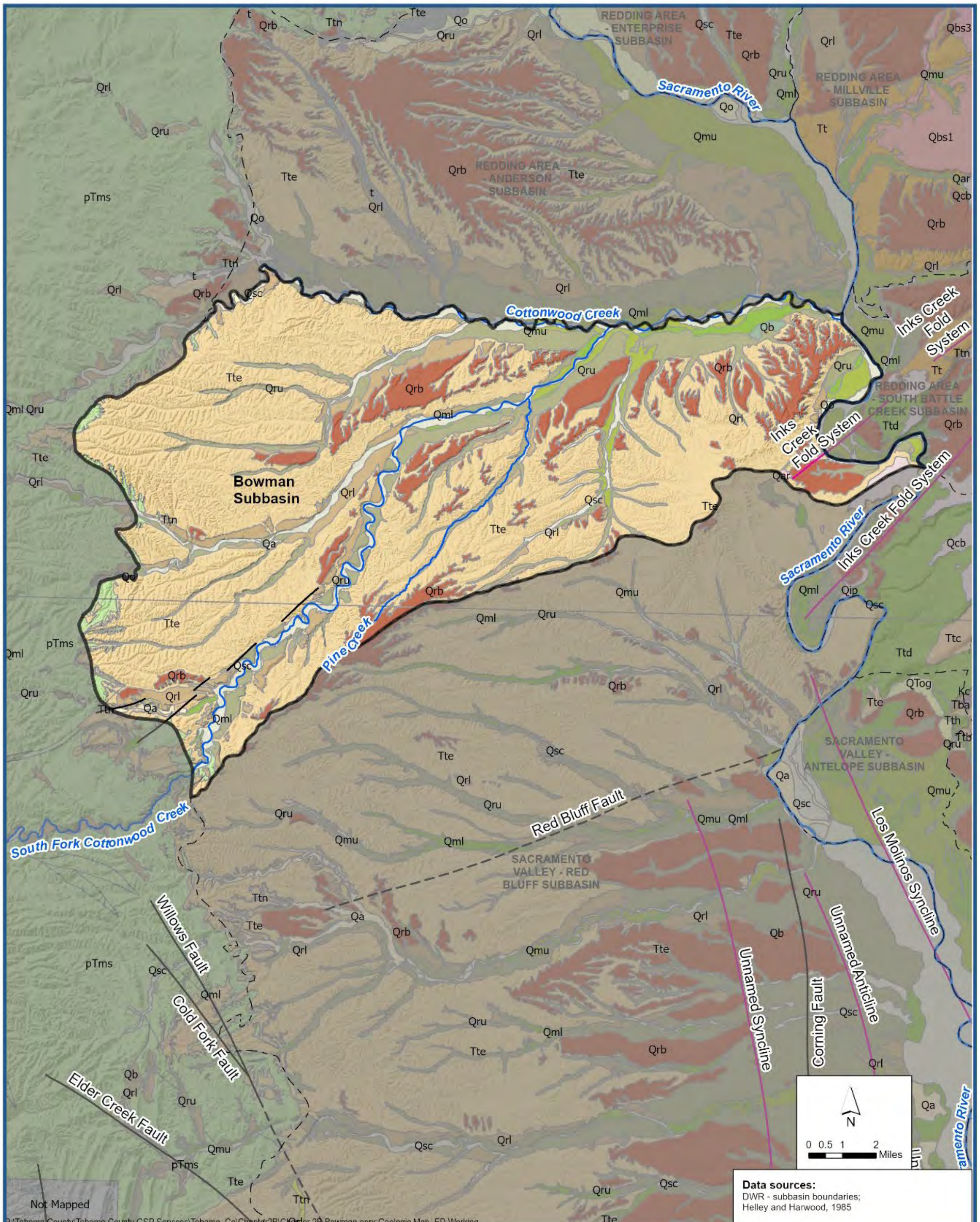
Geologic formations were mapped by Helley and Harwood (1985) and digitized by DWR (2014). The digitized maps were modified and are presented as **Figure 2-21** and **Figure 2-21B**. Geologic Cross sections were constructed using available data, locations of cross sections are presented as **Figure 2-22** and **Figure 2-22B,** and cross sections are presented as **Figure 2-23** and **Figure 2-24**. In addition, a DWR cross section (DWR, 2003) that includes the Subbasin and extends into the Red Bluff Subbasin, is presented as **Figure 2-25** and **Figure 2-25B**. A summary of stratigraphic relationships and water bearing character is presented as **Table 2-8**.

Great Valley Sequence

The Great Valley sequence (pTms on **Figure 2-21**) is characterized by Late Jurassic and Cretaceous deep-marine turbidites comprised of interbedded marine sandstone, siltstone, and conglomerate (Bailey et al. 1970; Bertucci, 1983; DWR, 2014). The Great Valley sequence can be seen on the east and west edges of the northern Sacramento Valley and underly the younger deposits throughout the Subbasin. The deposits have been observed to be 45,000 feet thick (Ingersoll and Dickinson, 1981). The depth to the top of the Great Valley Sequence can be up to 2,700 ft bgs in the Subbasin (**Figure 2-25**). The source material was the ancestral Sierran-Klamath terrane (Ojakangas, 1968; Dickinson and Rich, 1972; Mansfield, 1979; Ingersoll and Dickinson, 1981; DWR, 2014). The eroded sediments were deposited off the continental shelf as turbidity flows and submarine fans. The groundwater contained in the Great Valley sequence is primarily saline due to the marine depositional environment (DWR, 2014).

Lower Princeton Submarine Valley Fill

The lower Princeton Submarine Valley fill is composed of Eocene aged interbedded marine shale and sandstones (DWR, 2014; Redwine, 1972). The formation is not visible at the surface but has been observed to be approximately 1,500 ft deep in the Sacramento Valley based on the interpretation of lithologic logs from oil and gas wells (Redwine, 1972). The extent of the lower Princeton Submarine Valley fill within the Subbasin is limited to the subsurface in the southeast and pinches out in the north (**Figure 2-25**). The formation was deposited under marine conditions therefore formation groundwater is saline (Redwine, 1972). The formation is unconformably overlain by the upper Princeton Valley fill in the Subbasin (DWR, 2014).



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Geologic Map with Faults

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Bowman Subbasin

Figure 2-21

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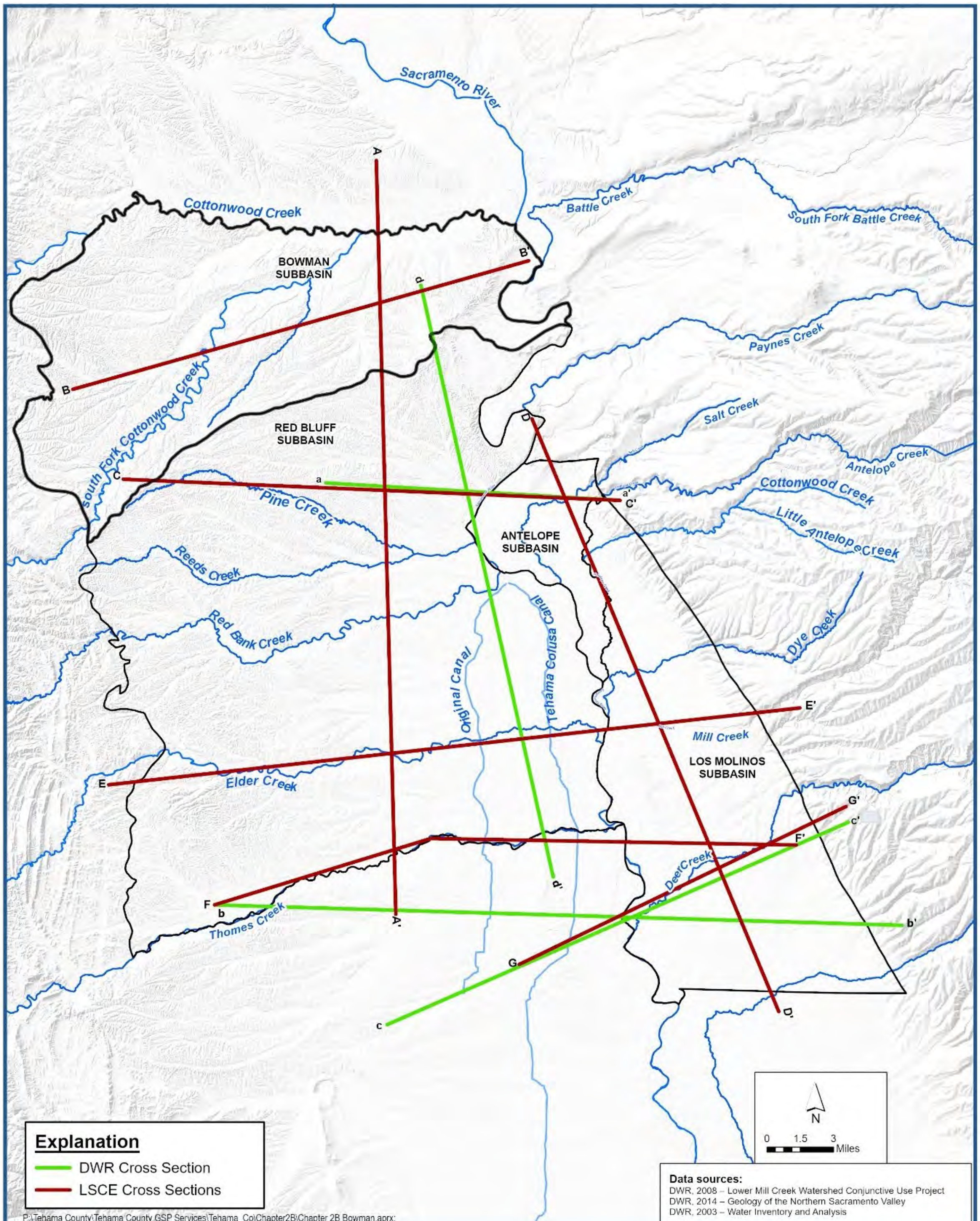
Geologic Map with Faults

Groundwater Sustainability Plan
Bowman Subbasin

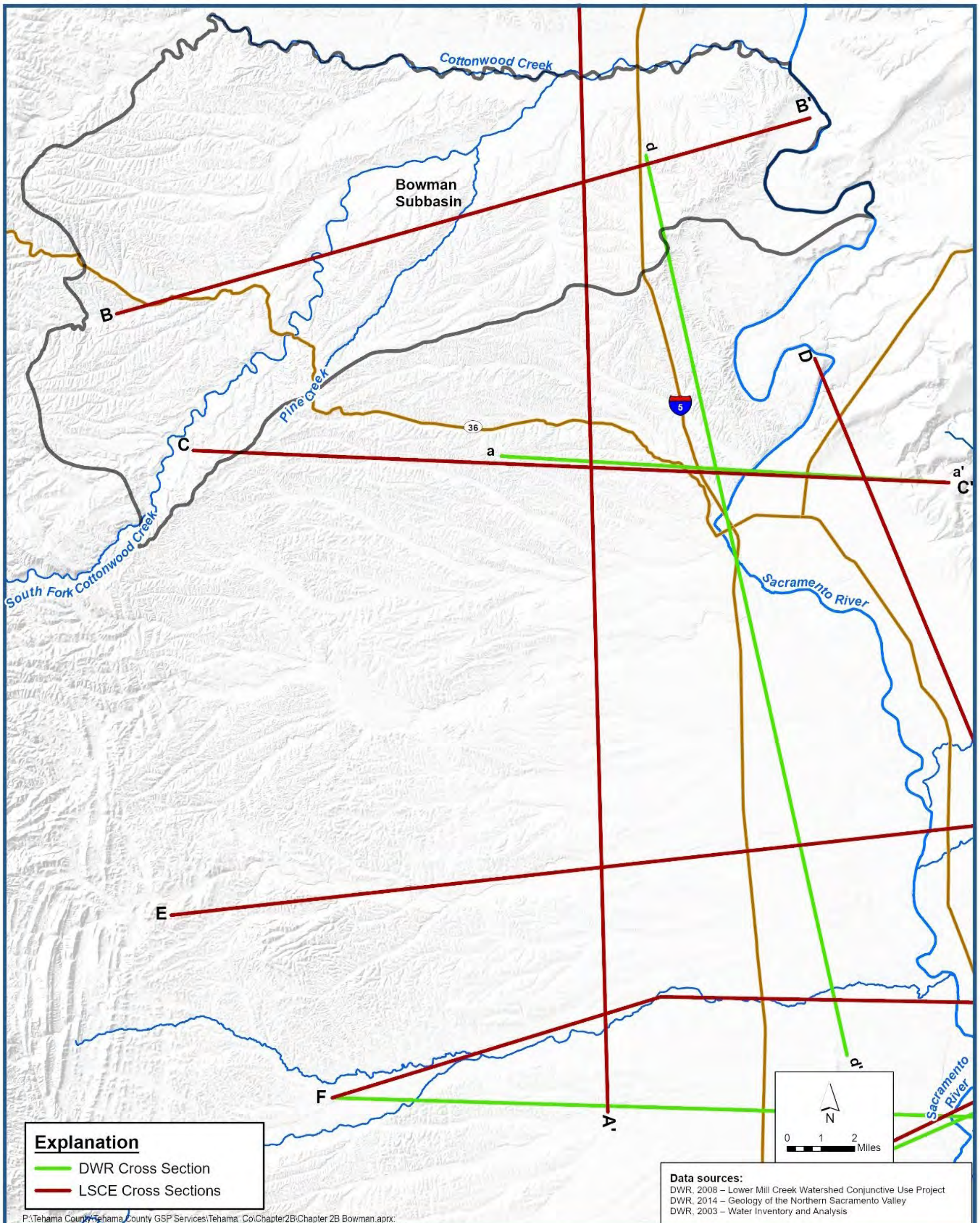
Figure 2-21B



Map of Cross Section Locations

Groundwater Sustainability Plan
Bowman Subbasin

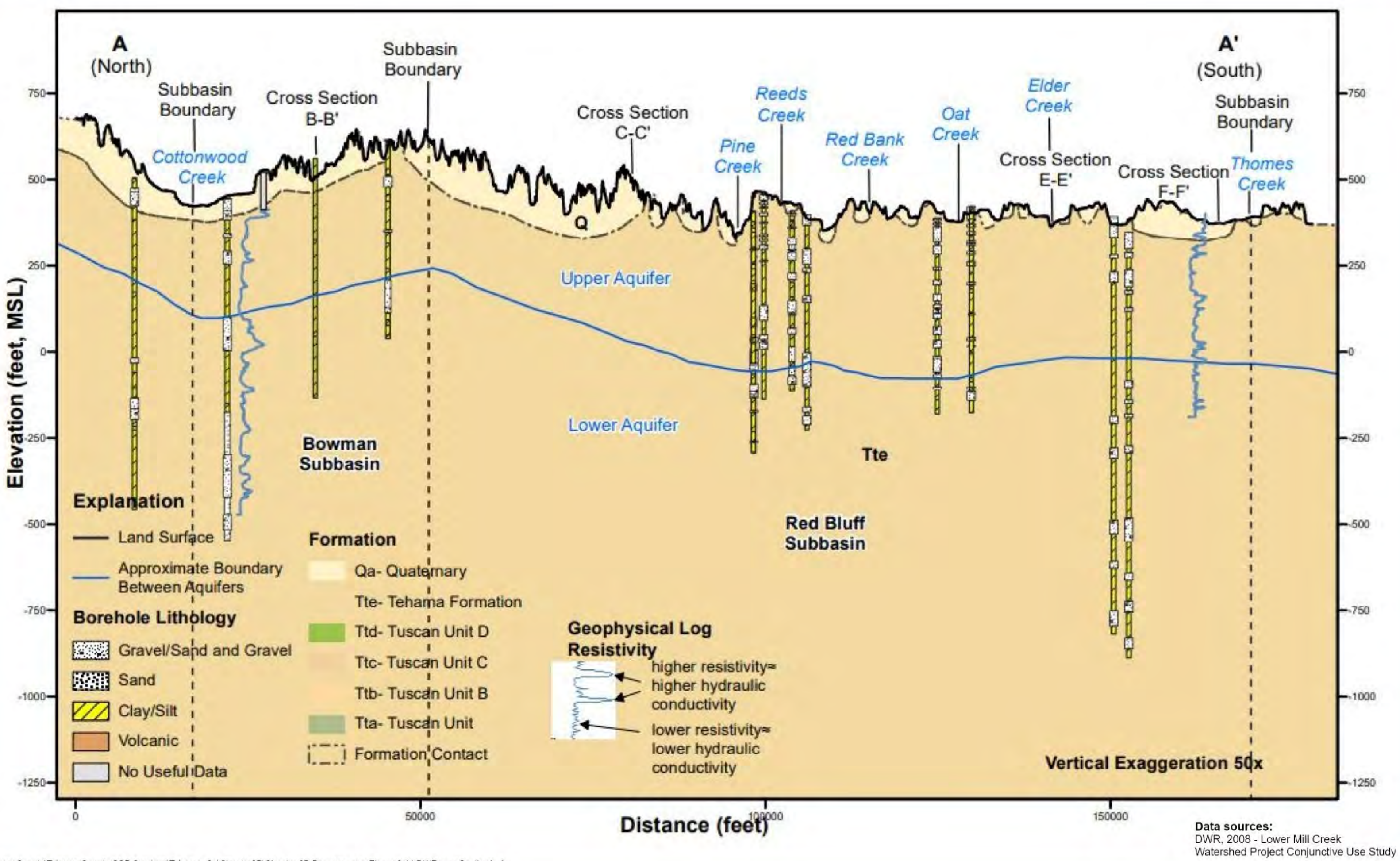
Figure 2-22



Map of Cross Section Locations

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-22B



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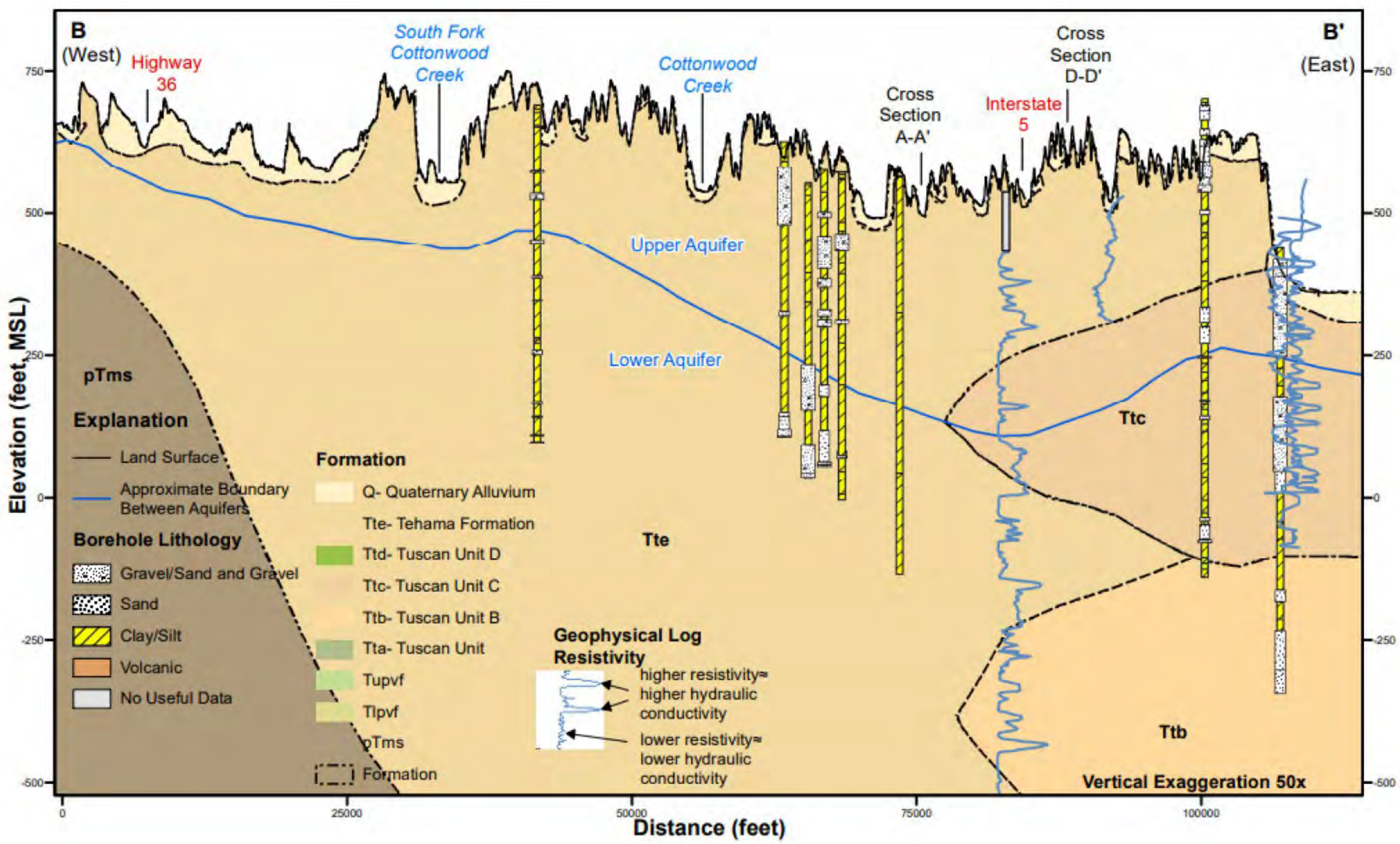
Cross Section A-A'

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-23



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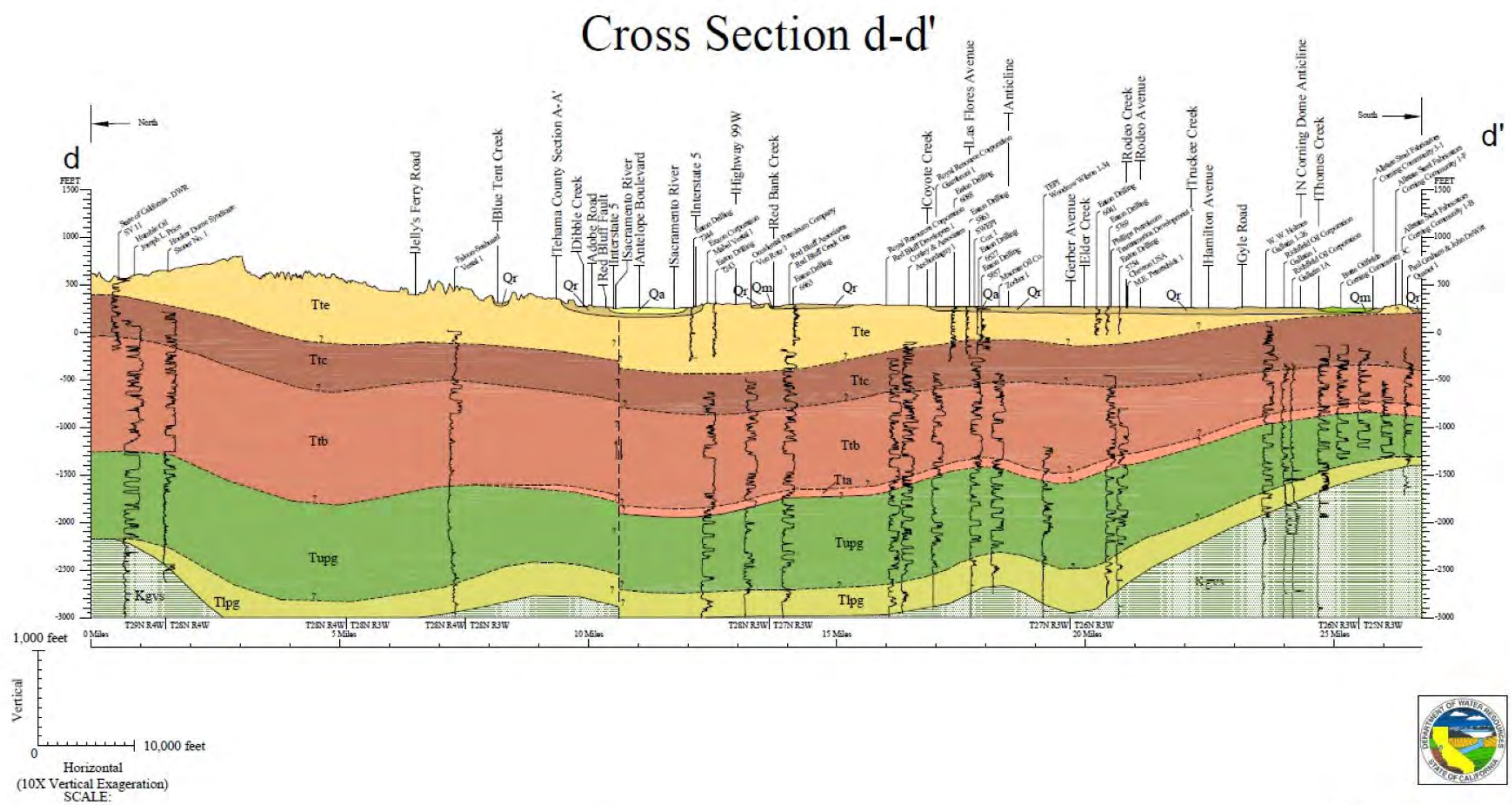
Cross Section B-B'

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-24

DRAFT



Data source:
DWR, 2003 - Water Inventory and Analysis

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Cross Section d-d'

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-25A

DESCRIPTION OF MAP UNITS

Unit	Description
Qa	**Alluvium** (Holocene)-Includes surficial alluvium and stream channel deposits of unweathered gravel, sand and silt, maximum thickness 80 ft. *(adapted from Helley & Harwood, 1985)*.
Qb	**Basin Deposits** (Holocene)-Fine-grained silt and clay derived from adjacent mountain ranges, maximum thickness up to 200 ft. *(adapted from Helley & Harwood, 1985)*.
Qm	**Modesto Formation**, undifferentiated (Pleistocene)-Alluvial fan and terrace deposits consisting of unconsolidated weathered and unweathered gravel, sand, silt and clay; maximum thickness approximately 200 ft. *(adapted from Helley & Harwood , 1985).*
Qr	**Riverbank Formation**, undifferentiated (Pleistocene)-Alluvial fan and terrace deposits consisting of unconsolidated to semi-consolidated gravel, sand and silt; maximum thickness approximately 200 ft. *(adapted from Helley & Harwood, 1985).*
Tte	**Tehama Formation** (Plio-Pleistocene)-Includes Red Bluff Formation on west side. Pale green, gray and tan sandstone and siltstone with lenses of pebble and cobble conglomerate; maximum thickness 2,000 ft. *(adapted from Helley & Harwood, 1985).*
Ttd	**Tuscan Unit D** (Plio-Pleistocene)-Fragmental flow deposits characterized by monolithic masses containing gray hornblende and basaltic andesites and black pumice, maximum thickness 160 ft. *(adapted from Helley & Harwood, 1985).*
Ttc	**Tuscan Unit C** (Plio-Pleistocene)-Includes Red Bluff Formation on east side. Volcanic lahars with some interbedded volcanic conglomerate and sandstone, and reworked sediments; maximum thickness 600 ft. *(adapted from Helley & Harwood, 1985, DWR Bulletin 118-7, 2001, draft report).*
Ttb	**Tuscan Unit B** (Pliocene)-Layered, interbedded lahars, volcanic conglomerate, volcanic sandstone and siltstone; maximum thickness 600 ft. *(adapted from Helley and Harwood, 1985; DWR Bulletin 118-7, 2001, draft report).*
Tta	**Tuscan Unit A** (Pliocene)-Interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone containing metamorphic rock fragments; maximum thickness 400 ft. *(adapted from Helley & Harwood, 1985; DWR Bulletin 118-7 (in progress), 2001).*
Tl	**Lovejoy Basalt** (Miocene)-Black, dense, hard microcrystalline basalt; maximum thickness 65 ft. *(adapted from Helley & Harwood, 1985).*
Tupg	**Upper Princeton Valley Fill** (Late Oligocene to Early Miocene)-Non-marine sediments composed of sandstone with interbeds of mudstone and occasional conglomerate and conglomerate sandstone; maximum thickness 1,400 ft. *(adapted from Redwine, 1972).*
Ti	**Ione Formation** (Eocene)-Marine to non-marine deltaic sediments, light colored, commonly white conglomerate, sandstone and siltstone, which is soft and easily eroded; max. thickness 650 ft. *(adapted from DWR Bulletin 118-6, 1978; Creely, 1965).*
Tlpg	**Lower Princeton Submarine Valley Fill** (Eocene)-includes Capay Formation. Marine sandstone, conglomerate and interbedded silty shale, maximum thickness 2,400 ft. (*adapted from Redwine, 1972*)
JKgvs	**Great Valley Sequence** (Late Jurassic to Upper Cretaceous)-Marine clastic sedimentary rock consisting of siltstone, shale, sandstone and conglomerate; maximum thickness 15,000 ft.
JKf	**Franciscan Formation** (Jurassic to Cretaceous)-Dominated by greenish-grey greywackes with lesser amounts of dark shale, limestone and radiolarian chert, maximum thickness up to 25,000 ft. *(adapted from strand, 1962 and Norris & Webb, 1990).*

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DWR Cross Section Legend

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-25B

Table 2-8 Stratigraphic Summary with Hydrogeologic Properties

Age: Period	Age: Epoch	Geologic Unit	Lithology Description	Approximate Thickness Interpreted in Subbasin	Aquifer Unit	Hydrogeologic Character
Quaternary	Holocene	Surficial Alluvium	Unweathered gravel, sand, and silt (DWR, 2014)	30 ft (DWR, 2004)	Upper	Moderately permeable but not a significant source of groundwater in the Subbasin due to limited extent (DWR, 2004)
Quaternary	Pleistocene & Pliocene	Modesto Formation	Alluvial fan and terrace deposits consisting of unconsolidated to semi-consolidated gravel, sand, silt, and clay (DWR, 2014)	50 ft (DWR, 2004)	Upper	Moderately to highly permeable. Limited source of groundwater due to limited thickness and extent in the Subbasin (DWR, 2004).
Quaternary	Pleistocene & Pliocene	Riverbank Formation	Alluvial fan and terrace deposits consisting of unconsolidated to semi-consolidated gravel, sand, and silt (DWR, 2014)	50 ft (DWR, 2004)	Upper	Moderately to highly permeable. Limited Source of groundwater due to limited thickness and extent in Subbasin (DWR, 2004)
Quaternary	Pleistocene & Pliocene	Red Bluff Formation	Thin veneer of highly weathered, bright red gravels (DWR, 2014)		Upper	Water is available only where local perched conditions exist. Provides limited water due to limited extent and thickness in the Subbasin (DWR, 2004).
Neogene	Pleistocene & Pliocene	Tehama Formation	Pale green, gray, and tan sandstone, and siltstone with lenses of pebble and cobble conglomerate (DWR, 2014)	2,500 ft (DWR, 2004)	Upper/Lower	Low to moderate permeability with localized areas of high permeability (DWR, 2003). Well yields can range from 475 gpm to 950 gpm (DWR, 2003)
Neogene	Pleistocene & Pliocene	Tuscan Formation	Interbedded lahars, volcanic conglomerate, volcanic sandstone, siltstone, and pumiceous tuff (DWR, 2014)	1,600 ft (DWR, 2003)	Upper/Lower	Low to high permeability and is the main water-bearing formation in the Subbasin (DWR, 2004)
Paleogene	Miocene	Upper Princeton Valley Fill	Non-marine sediments composed of sandstone with interbeds of mudstone, occasional conglomerate, and conglomerate sandstone (DWR, 2014)	1,000 ft (DWR, 2003)	Brackish	
Paleogene	Eocene	Lower Princeton Submarine Fill	Marine Sandstone, conglomerate, and interbedded silty shale (DWR, 2014)	350 ft (DWR 2003)	Saline	
Cretaceous		Great Valley Sequence	Marine clastic sedimentary rock consisting of siltstone, shale, sandstone, and conglomerate (DWR, 2014)	1,500 ft (DWR, 2003)	Saline	

Upper Princeton Valley Fill

The upper Princeton Valley Fill is composed of Miocene-age sandstone with frequent interbeds of pelite (mudstone) and occasional conglomerate (Redwine, 1972). The formation is not observed on the surface but extends throughout the northern Sacramento Valley from Red Bluff to the Sutter Buttes with maximum thicknesses of 1,400 ft (DWR, 2014; Redwine 1972). The formation sandstone contains interstitial brackish water and occasionally fresh water (DWR, 2014; Redwine, 1972). The formation sediments were deposited by a meandering stream, following a similar trajectory to the modern Sacramento River (Redwine 1972).

Tuscan Formation

The late Pliocene Tuscan Formation (Tt on **Figure 2-21**) is comprised of interbedded lahars, volcanic conglomerate, volcanic sandstone, siltstone, and pumiceous-tuff sourced from ancestral Cascade Volcanoes (DWR, 2014; Helley and Harwood, 1985; Lydon 1968). The formation can be seen in outcrops along the eastern side of the Sacramento Valley from the Redding area in the north to near Oroville in the south (DWR, 2014). In the subsurface, the volcanic sourced deposits of the Tuscan interfinger with the metamorphic sourced sediments of the Tehama Formation in the vicinity of the Sacramento River, forming the western extent of the Tuscan Formation (Garrison, 1962; Lydon, 1968). The westward extent of this interfingering can be west of the Sacramento River (DWR, 2014). Beneath the valley sediments, the Tuscan Formation is relatively flat lying, dipping 2 to 3 degrees on the western side of the valley (Olmstead and Davis 1962). Thicknesses of the formation ranges from 300 ft at the westward extent to 1,700 ft in the east (Lydon, 1968). In the Subbasin, the thickness can be 1,600 ft (**Figure 2-25**).

The Tuscan Formation was deposited by volcanic mudflows and stream channels carrying debris from the ancestral Cascade volcanic centers (Lydon, 1968). These volcanic mudflows and stream channels flowed westward and fanned out in the valley resulting in variation of the formation thickness (DWR, 2014). The volcanic mudflow deposits were cut over time by streams flowing from the east (DWR, 2014). Lastly, the stream channels were subsequently filled by reworked volcanic sand and gravel that now contain fresh groundwater in pore spaces (DWR, 2014; Lydon, 1968).

The depositional history resulted in a formation that is heterogeneous and is divided into four units (oldest to youngest: Unit A, Unit B, Unit C, and Unit D). Tuscan Unit A is composed of metamorphic clasts in interbedded lahars, volcanic conglomerate, volcanic sandstone and siltstone, and fractured tuff breccia (DWR, 2004). Groundwater in Unit A is associated with sandstone and conglomerate layers as well as the fractured tuff breccia (DWR, 2003). Unit B (Ttb on **Figure 2-21**) similarly yields water readily. Unit B is composed of lahars, tuffaceous sandstone, and conglomerate (DWR, 2004). Groundwater in Unit B is contained in the reworked sand and gravel layers and is the main source for Tuscan Formation groundwater in Tehama County (Tehama County FCWCD, 2003). Unit C (Ttc on **Figure 2-21**) mainly consists of low permeability volcanic mudflow deposits that act as confining layers for groundwater contained in Unit B (DWR, 2004). Unit D (Ttd on **Figure 2-21**) is characterized by masses of andesite, pumice, and fragments of black obsidian in a mudstone matrix (Gonzalez, 2014). In the Subbasin, the Tuscan formation’s extent is limited to the subsurface in the vicinity of the Sacramento River.

Tehama Formation

The Tehama Formation (Tte on **Figure 2-21**) is composed of Pliocene-age noncontiguous layers of sandstone and siltstone, with lenses of pebble and cobble conglomerate (Blake et al., 1999; Helley and Harwood, 1985). The sandstone and siltstone are predominately composed of metamorphic clasts with some volcanic clasts (Blake et al., 1999; Helley and Harwood, 1985). The formation is present from the foothills of the Coast Ranges in the west to the vicinity of the Sacramento River in the east where the Tehama Formation intermixes with the Tuscan Formation in the Subsurface (DWR, 2014). The northern-most outcrops of the Tehama Formation can be seen near Redding and stretch as far south as Vacaville (DWR, 2014). The Tehama Formation outcrops in the majority of the Subbasin (**Figure 2-21**). Thickness of the Tehama Formation can be 500 ft in the Subbasin (**Figure 2-25**).

The Tehama Formation was deposited by streams flowing eastward off the Coast Ranges and, to a lesser extent, south from the Klamath Mountains (DWR, 2014). The streams flowed and deposited sediment under floodplain conditions (DWR, 2014). This depositional environment resulted in non-continuous series of poorly sorted sediments cut by non-lenticular channels of coarser sediments (DWR, 2014; Russell, 1931). The Tehama Formation's maximum thickness over its entire mapped extent is 2,000 ft (Olmstead and Davis, 1961).

Saturated groundwater conditions exist in the gravel and sand layers of the Tehama Formation (DWR, 2014; Olmstead and Davis, 1961). The base to fresh water is widely reported to be at the base of the Tehama Formation or sometimes within the Tehama Formation (DWR, 2014; Olmstead and Davis, 1961; Springfield and Hightower, 2012). The Tehama Formation is overlain and cut by the younger Modesto, Red Bluff, and Riverbank Formations (DWR, 2014).

Red Bluff

The Red Bluff Formation (Qrb on **Figure 2-21**) is composed of sandy gravels on 0.45- to 1.08-million-year-old pediment surfaces. The Red Bluff Formation weathers to a bright-red color (Helley and Harwood, 1985; Helley and Jaworowski, 1985). The formation is discontinuously exposed in the northern Sacramento Valley overlying the Tehama and Tuscan Formations from the Redding area to the vicinity of Cache Creek (DWR, 2014; Russell, 1931; Olmstead and Davis, 1961; Helley and Harwood, 1985). Studies propose that the Red Bluff Formation is the result of alluvial fans depositing reworked metamorphic (Klamath origin) and volcanic (Cascade origin) sediments upon a pediment (Gonzalez, 2014; Harwood et al., 1981; Helley and Jaworowski, 1985). The pediment deposition has resulted in sparce perched aquifer conditions in the 3 ft to 33 ft thick formation (DWR, 2014; Olmstead and Davis, 1961). In the Subbasin, the Red Bluff Formation's extent is mainly limited to the north and east (**Figure 2-21**).

Riverbank

The Riverbank Formation is composed predominately of gravel, sand, and silt deposits that were deposited unconformably on the Tehama, Tuscan, and Red Bluff Formations (DWR, 2014; Marchand and Allwardt, 1981). The formation extends from Redding to Merced discontinuously (Marchand and Allwardt, 1981). It is generally found along higher-elevation terraces beneath the pediment surface of the western tributary systems including the Thomes, Elder, Oat, and Cottonwood Creeks (Tehama County FCWCD, 2012). The thickness varies from 1 ft to over 200 ft (Helley and Harwood, 1985). In the Subbasin the Riverbank Formation is predominately in the east and on the banks of the creeks and streams that feed the Sacramento River (**Figure 2-21**).

It is divided into upper and lower members that are lithologically similar but differ in stratigraphic position and degree of soil development (Helley and Harwood, 1985; Blake et al., 1999). Both members contain gravel, sand, silt, and clay derived from the surrounding mountain ranges (Klamath, Coast Ranges, and Cascades). The upper member (Qru on **Figure 2-21**) occupies the lower terrace positions while the lower member (Qrl on **Figure 2-21**) occupies the higher positions (Helley and Harwood, 1985). The upper member consists of semi-consolidated sediments while the lower consists of unconsolidated but compact alluvium (Helley and Harwood, 1985). Both members display soil development with B horizons and local hardpans however, the soils are more developed in the lower member (Blake et al., 1999). The Riverbank formation yields limited water due to its aerial extent and limited thickness (1 to 200 feet) (Helley and Harwood, 1985). The thickness in the Subbasin has been interpreted to be up to 50 ft (DWR, 2004). The Formation is overlain by the younger Modesto Formation, basin deposits, or surficial alluvium (DWR, 2014).

Modesto

The Modesto Formation is composed of 0.14 to 0.42 Ma stream channel deposits that were laid down in a manner similar to the Riverbank Formation (Marchand and Allwardt 1981). It can be seen on the ground surface from Redding to the San Joaquin Valley (DWR, 2014). The formation ranges in thickness from less than 10 ft to 200 ft (Helley and Harwood, 1985). The Modesto Formation is present at the surface along streams and creeks within the Subbasin and at thicknesses up to 50 ft (**Figure 2-21;** DWR, 2004). Groundwater occurs in the formation under unconfined conditions (DWR, 2014).

The Modesto Formation consists of a lower member (Qml on **Figure 2-21**) occupying higher topographic areas and an upper member (Qmu on **Figure 2-21**) visible at lower topographic areas (Helley and Harwood, 1985). Both the lower and the upper members are composed of unconsolidated gravel, sand, silt, and clay. The main difference between the two is that the lower member is slightly more weathered (Helley and Harwood, 1985). The Modesto Formation sedimentary deposits often border currently active stream channels and were likely deposited by the same streams they border (Helley and Harwood, 1985).

Surficial Alluvium

The surficial alluvium (QTog, Qa, Qo, and Qsc on **Figure 2-21**) is the youngest of the geologic units in the Subbasin. The alluvium consists of gravel, sand, and silt sourced from the Klamath, Coast Range, Cascade, and Sierra Nevada ranges and transported and deposited by modern streams and rivers (Helley and Harwood, 1985). It is present throughout the northern Sacramento Valley forming natural levees and along current rivers and streams (DWR, 2014). The maximum thickness of the surficial alluvium has been observed up to 30 feet (Helley and Harwood, 1985). The maximum thickness in the Subbasin is interpreted to be up to 30 ft (DWR, 2004). It is not a major source of water due to its limited thickness and extent (DWR, 2014).

2.2.1.3.3 *Geologic Structures*

Geologic structures are a result of tectonic forces leading to deformation in the geologic material. The deformation can control direction and rate of groundwater flow. This section is a description of major geologic structures in the area. The Red Bluff Arch is present in the Subbasin, and the other structures are discussed for regional context (**Figure 2-21**).

Los Molinos Syncline

The Los Molinos Syncline is a 1.0- to 2.5-million-year-old north northwest-trending syncline that locally controls the Sacramento River (Blake et al., 1999). The syncline generally follows the topographically low elevations and lies between the Chico Monocline and the Corning Fault. The Los Molinos Syncline may influence the direction of groundwater flow.

Elder Creek Fault

The Elder Creek Fault is a northwest-trending reverse fault that lies south of the Willows fault (Helley and Harwood, 1985). The fault converges with the Stony Creek Fault at the Coast Range Ophiolite (DWR, 2014). Estimated movement along the fault is as recent as 3.4 Ma (DWR, 2014).

Red Bluff Fault

The Red Bluff Fault is a 15-mile-long south-dipping normal fault that has surface expressions northeast of the City of Red Bluff (DWR, 2014). Strike is generally 60 degrees east and has been observed to have late Cenozoic displacement as it affects the base of the Pliocene rocks, offsetting them about 500 feet (Blake et al., 1999).

Willows Fault

The Willows Fault is a north-trending high-angle reverse fault with no surface expression (DWR, 2014). The main evidence for the fault is subsurface surveys in previous studies (Redwine, 1972; Harwood and Helley, 1987). The fault has been observed at a dip of over 74 degrees east with greater degrees of offset on older rocks (DWR, 2014).

Corning Fault

The Corning Fault is a north-trending reverse fault with no surface expression. It branches off the Willows Fault south of Tehama County. The main evidence for the fault is subsurface surveys performed by Harwood and Helley (1987). The fault has been observed at a dip of 74 degrees east with greater degrees of offset on older rocks (DWR, 2014; Helley and Harwood, 1985). The fault generally follows the trend of Interstate 5 until its terminus at the Red Bluff Fault and Chico Monocline north of Red Bluff (DWR, 2014).

Inks Creek Fold System

The Inks Creek Fold System is a series of northeast-trending folds that occur to the north of the Subbasin (DWR, 2004). The fold system is composed of a dome on the west side of the Sacramento River, and a southwest-plunging anticline and syncline that locally control the major bends in the Sacramento River (Harwood and Helley, 1987). The system is a hydrologic drainage divide that separates the Red Bluff Arch in the west from the Chico monocline in the east (DWR, 2014). The system is a part of the Red Bluff Arch, a hydrologic drainage divide that separates the Redding Area groundwater basin and the Sacramento Valley groundwater basin (DWR, 2014).

Chico Monocline

The Chico Monocline is a flexure feature in the east side of the Subbasin that roughly follows the boundary of the valley. It is a northwest-trending feature that deforms the Tuscan Formation in the east, causing the beds to increase from a dip of 2 to 5 degrees in the middle of the valley to 25 degrees in the east (DWR, 2014).

Red Bluff Arch

The Red Bluff Arch is an area of regional compression that encompasses multiple tectonic features in the area (DWR, 2014). It is a northeast-trending feature that is made up of a collection of smaller geologic structures. Major structures that encompass the Red Bluff Arch are the Red Bluff fault, the Inks Creek Fold System; and the Seven Mile, Tuscan Springs, Salt Creek, and Hooker Creek domes (DWR, 2014). The collection of features regionally creates a barrier to groundwater flow separating the Sacramento Valley groundwater basin from the Redding Area groundwater basin (DWR, 2014).

2.2.1.4 Soil Characteristics

The characteristics of a soil influence the movement of surface water (e.g., water sourced from rainfall, stream flow, or anthropogenic activities such as irrigation). Coarse, porous soils promote infiltration of surface water, while relatively impermeable soils promote surface runoff. Chemical properties of a soil (e.g., salinity and pH) can alter the chemistry of water that percolates through it. Therefore, understanding of the spatial variability of soil characteristics is important to conceptualize the hydrogeologic system of the Subbasin. Surficial soil property data were obtained from the US Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS). NRCS soil surveys use soil "map units" to delineate geographical areas that have soils with similar characteristics. A "soil series" is a unique collection of map units. It represents a three-dimensional soil body that is composed of soils that have a relatively narrow range of properties. Detailed descriptions of soil map units and series are available in USDA Soil Survey Manual, Handbook No. 18 (Soil Science Division Staff, 2017).

Soils – Type

Surficial soil types that are present in the Bowman Subbasin belong to 94 unique map units. These soil types are grouped into 31 soil series and shown in **Figure 2-26** and **Figure 2-26B**. The most dominant soil series in the Subbasin is the Newville series. The Newville Series is abundant in uplands across the Subbasin covering about 55% of the Subbasin. These soils are moderately deep, well drained and formed from weathering of calcareous shale and sandstone. The Arbuckle series soils occur throughout the Subbasin in narrow terraces along drainages. These soils are very deep, well drained and formed in alluvium from sedimentary and metamorphic rocks. The Dibble series soils occur on foothills and fan remnants. These soils are moderately deep, well drained and formed in from shale, sandstone, and semi consolidated dense materials. Other dominant soil series in the Subbasin are the Red Bluff, Redding, Perkins, and Riverwash series soils. These soils collectively account for about 15% of the Subbasin area. All other soil series that exist in the Subbasin collectively cover about 30% of the land surface, and the contribution of each series varies from less than 1% to 2%.

Soil Texture

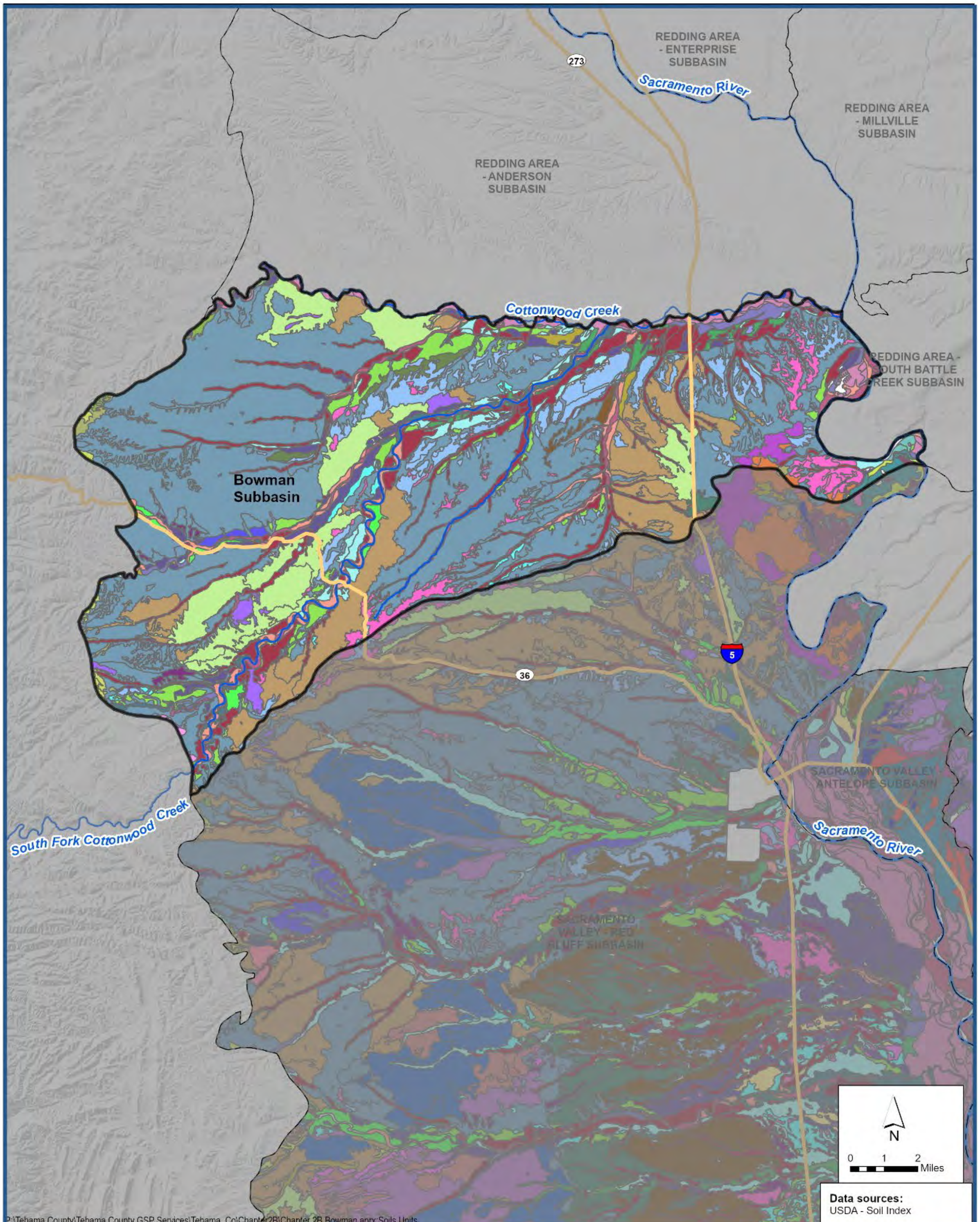
Soil textural classes are defined based on relative percentages of sand, silt, and clay (Soil Science Division Staff, 2017). Spatial distribution of soil textural classes in the Bowman Subbasin are shown in **Figure 2-27**. Loam (a soil composed mostly of sand and silt with a small amount of clay), and different variations of loam are the dominant surficial soil textures in the Subbasin. Gravelly loam soil (loam soil with abundant gravel) covers about 77% of the surface area and exists throughout the Subbasin. Silty clay loam (loam soil with abundant silt and clay) covers about 8% of the Subbasin. Clay loam (loam soil with abundant clay) covers about 5% of the surface.

Hydraulic Conductivity

The saturated hydraulic conductivity of surficial soils, which is a measure of a soil's ability to transmit water under a hydraulic gradient, ranges from approximately 0.3 ft/d to 35 ft/d in the Bowman Subbasin (**Figure 2-28**). The spatial distribution of hydraulic conductivity throughout the Subbasin is related to the distribution of soil texture. Relatively fine texture soils such as clays, clay loam and loam have low hydraulic conductivities. Coarse texture soils such as sandy, gravelly, or cobbly loams, and gravelly sand have high hydraulic conductivities. Hydraulic conductivities over 2.0 ft/d are limited to areas along active streams, where soils with gravelly sand texture are common (about 12% of the Subbasin area). About 88% of the Subbasin area has surficial soils with hydraulic conductivities of less than 1.0 ft/d, most likely due to the presence of low-permeability, fine-textured soil horizons.

Drainage

Soil drainage classes indicate the ability of a soil to drain water. Spatial distribution of soil drainage properties in the Bowman Subbasin closely resembles the distribution of saturated hydraulic conductivity and soil texture (**Figure 2-29**). About 88% of the Subbasin area is categorized as well drained soils, while about 7% of the area is categorized as moderately well drained soils. Somewhat excessively drained and excessively drained soils occur adjacent to drainage ways, where coarse soils are abundant, covering a total of about 5% of the area. Small patches of poorly drained soils cover less than 1% of the Subbasin.



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Soils - Type by Soil Series

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-26

TEHAMA COUNTY

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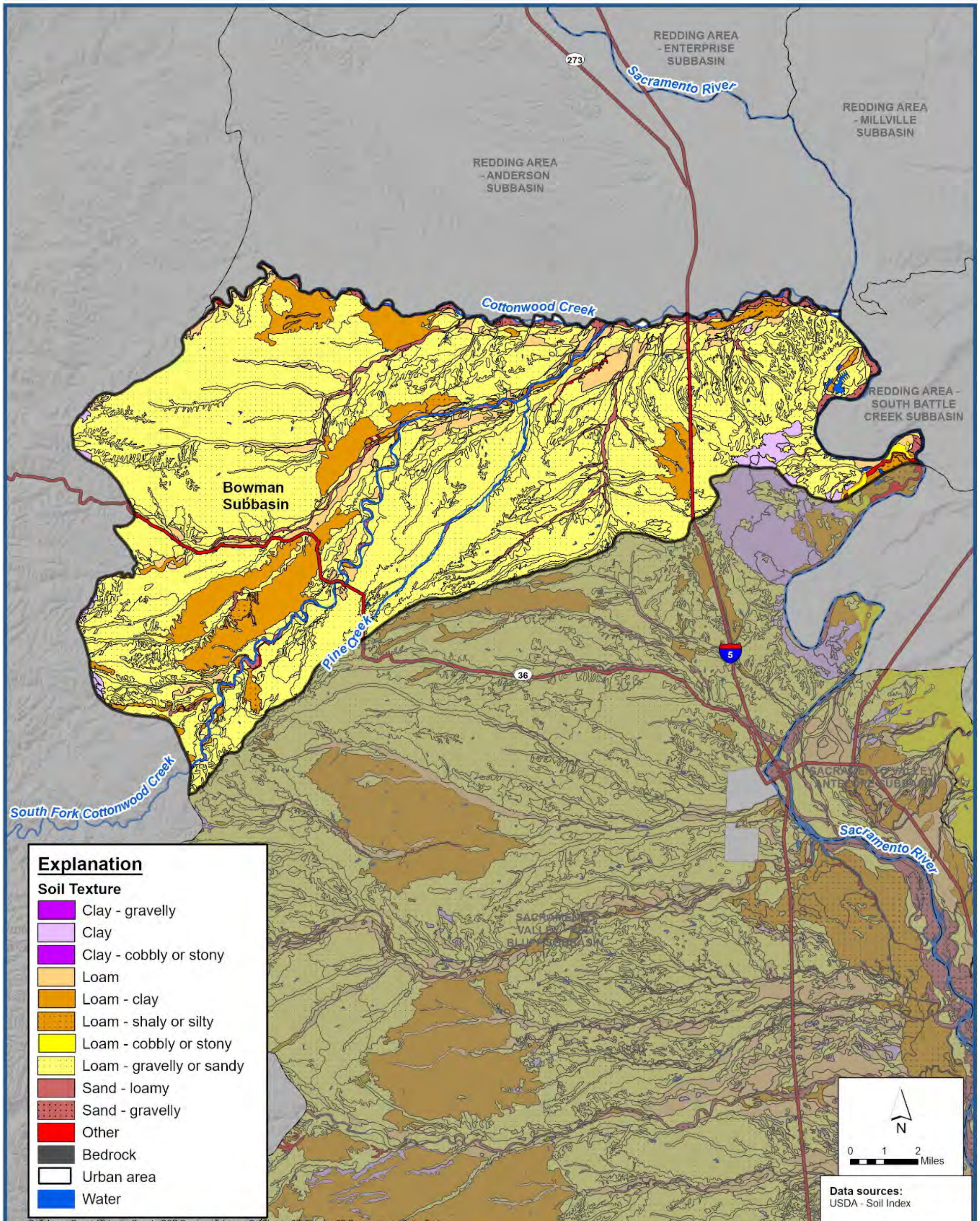
Soils - Type by Soil Series

Groundwater Sustainability Plan
Bowman Subbasin

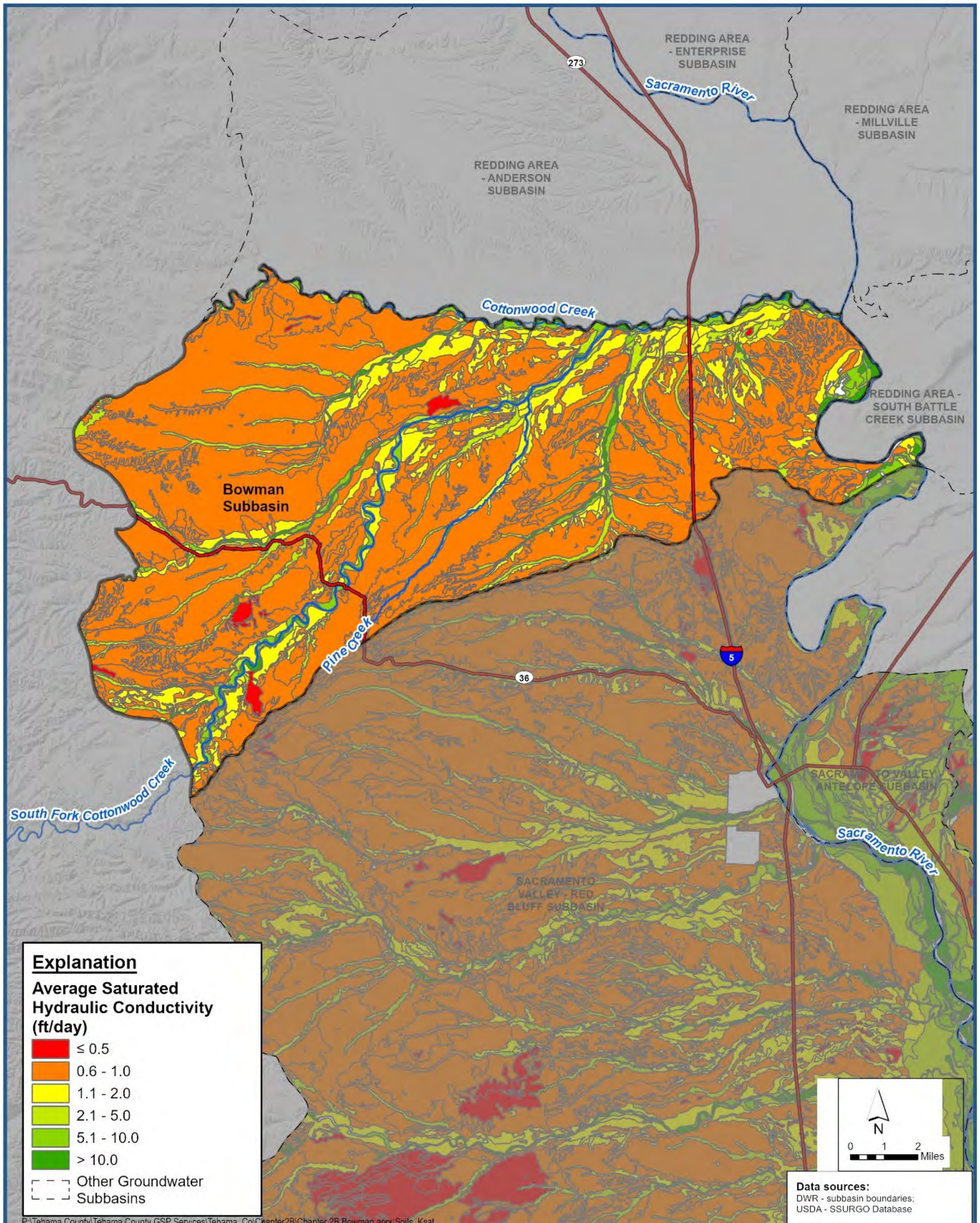
Figure 2-26B



Soils - Texture

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-27



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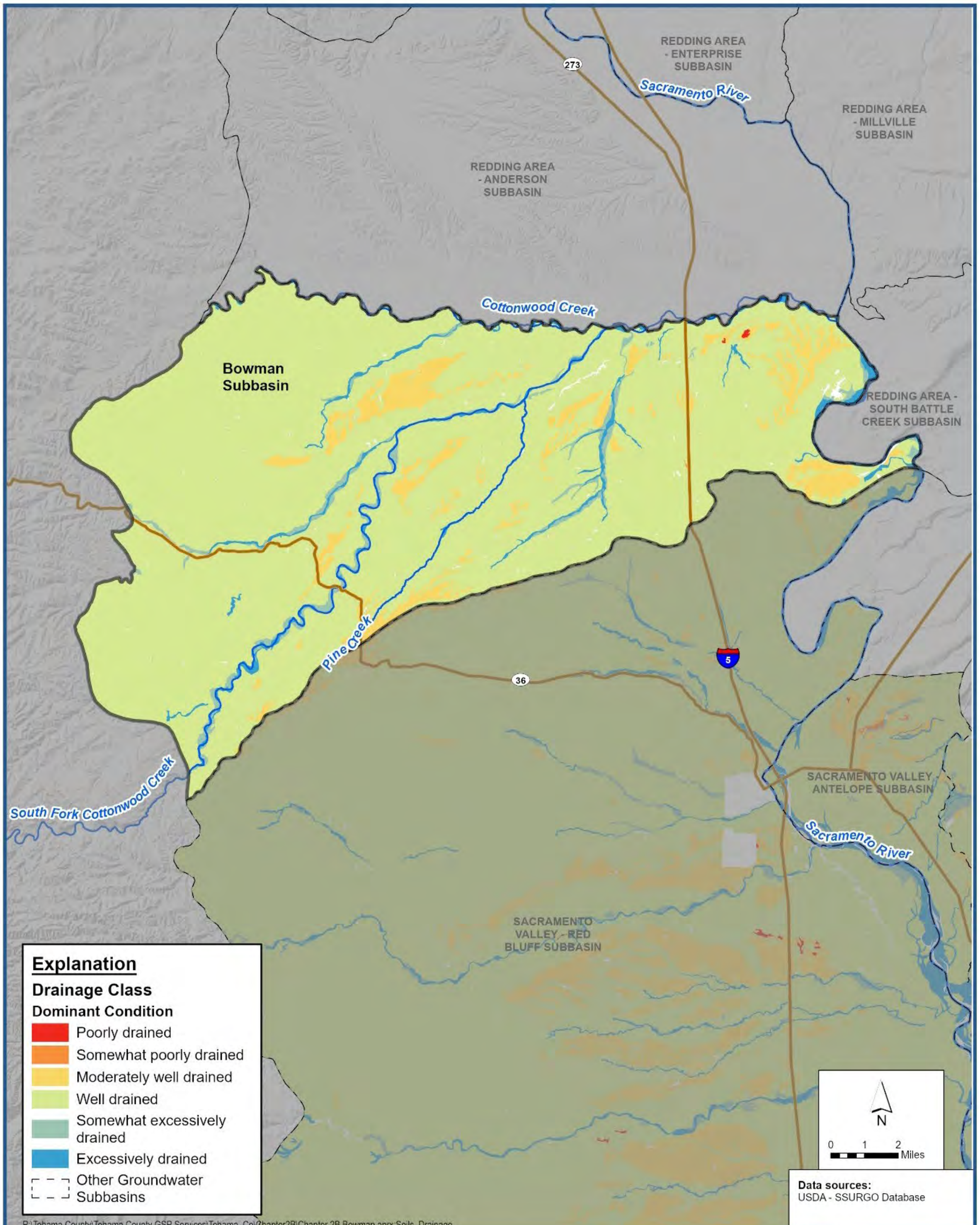
Soils - Saturated Hydraulic Conductivity

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-28



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Soils - Drainage Class

Groundwater Sustainability Plan
Bowman Subbasin

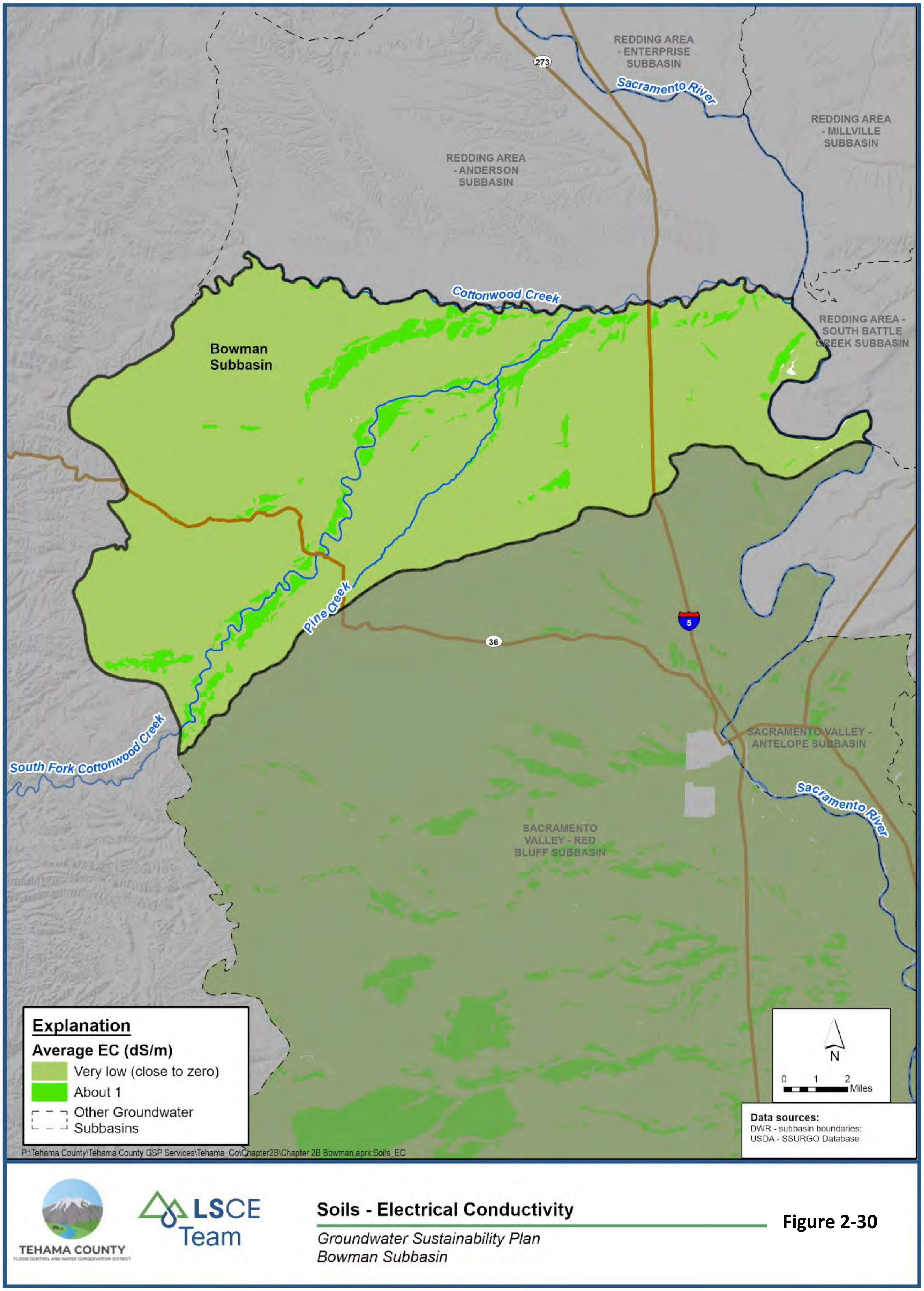
Figure 2-29

Electrical Conductivity

Electrical Conductivity (EC) of a soil is an indirect measure of the amount of salt present in that soil. Percolating water can leach and transport salts from saline soils to groundwater, resulting in the increase of the salinity of groundwater. All surficial soils in the Bowman Subbasin fall into non-saline class, where EC values are less than two decisiemens per meter (dS/m) (2,000 µmhos/cm). As per NRCS soil data, EC of surficial soils in more than 90% of the Subbasin is zero dS/m, while that of soils in the remaining areas is 1 dS/m (1,000 µmhos/cm) (**Figure 2-30**).

pH

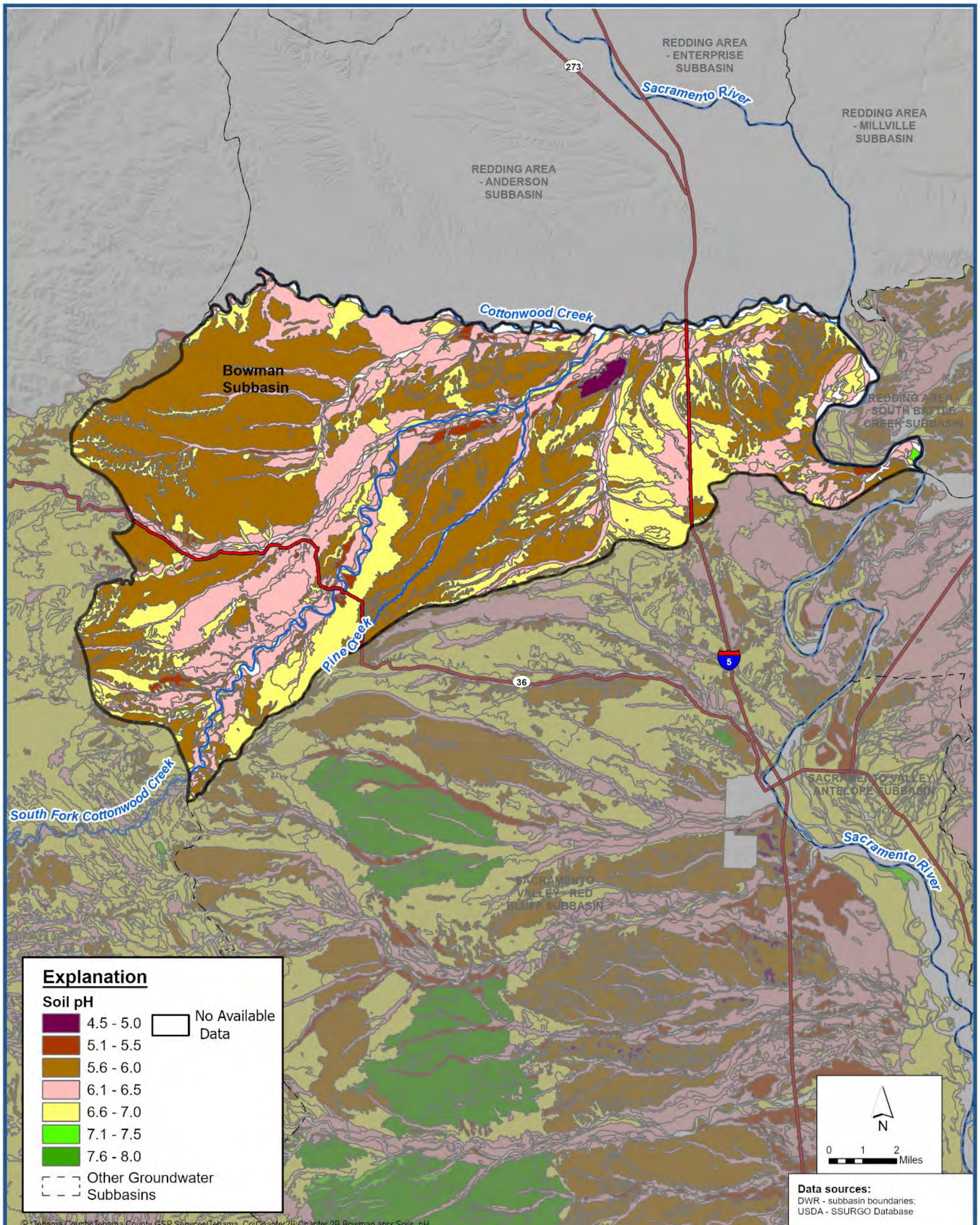
Soil pH is a measure of the acidity or alkalinity of that soil, which influences chemical interactions between soil minerals and percolating water. A pH of 7 is considered neutral. Increasing pH values indicate more alkaline soil conditions and decreasing pH values indicate more acidic soil conditions. Soil pH in the Bowman Subbasin ranges between 5.0 and 7.9, but the range is between 5.6 and 7.0 in about 99% of the area (**Figure 2-31**). Soils with pH values less than 5.6 occur throughout the Subbasin in small patches (about 1% of the area). In general, solubility of minerals increases with acidity of the soil and water. Acidity or alkalinity of surficial soils in the Subbasin are not expected to adversely alter water quality.



Soils - Electrical Conductivity

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-30



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Soils - pH

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-31

2.2.1.5 Identification/Differentiation of Principal Aquifers

Two principal aquifer units are defined in the Subbasin: Upper Aquifer and Lower Aquifer. The two-aquifer designation is based on an examination of time-series groundwater elevation hydrographs, electric resistivity data from geophysical logs, lithologic logs, well construction details, and review of previous studies in the Subbasin. The northern Sacramento Valley depositional environment is dominated by fluvial and alluvial deposition after the Eocene marine depositional environment transitioned to a subaerial one. The Pliocene depositional environment is similar to the current depositional conditions, with eastern depositional streams sourced from the Cascade Range and western depositional streams sourced from the Coast Ranges draining onto a central floodplain. This depositional environment resulted in a complex and varied series of water bearing sedimentary deposits and the Tuscan/Tehama Formations that collectively form a two-aquifer system in the Subbasin and beyond. Within singular water bearing formations there are areas where confined or unconfined conditions can be dominant. Generally, confined aquifer conditions are encountered at depth and unconfined conditions are seen in the shallower porous media. The complexity of the geologic materials and similarly among the formations makes it difficult to define a singular widespread aquitard or distinctive change in geologic materials separating an upper and lower aquifer. To delineate between areas with a higher likelihood of confined conditions, well construction data throughout the Subbasin were examined. Most of the wells in the Subbasin are screened or completed above 400 feet below ground surface (ft bgs). The bottom of numerical model layer 5 best corresponds with this depth. The bottom of model layer 5 is used as the delineation between the Upper and the Lower Aquifer (**Figure 2-23 and Figure 2-24**). Lastly, the degree of heterogeneity and anisotropy (directional preferable flow) is likely significant, but not easy to define based on current information.

Upper Aquifer

The Upper Aquifer is defined as the water bearing material from ground surface to the bottom of model layer 5 (approximately 350-450 ft bgs in the majority of the Subbasin). The aquifer has unconfined to semi-confined water conditions. Water bearing geologic units in the Upper Aquifer include the Quaternary formations and the upper portions of the Tehama and Tuscan Formations. Wells screened in the Upper Aquifer are largely for domestic purposes. The depth to the bottom of the Upper Aquifer is approximately 350-450 ft bgs (**Figure 2-23 and Figure 2-24**).

Site-specific aquifer properties obtained from aquifer tests are available for localized areas of the Subbasin. In addition, aquifer tests were conducted in surrounding subbasins. Hydraulic conductivity (rate at which water moves through an aquifer), transmissivity (hydraulic conductivity multiplied by aquifer thickness), and storage coefficients (ability of the aquifer to store water, commonly expressed as specific yield for water table/unconfined aquifers and storativity for confined aquitards) have been estimated at the Holiday Ranch Site south of Cottonwood and in neighboring subbasins. Aquifer tests were conducted in a well screened from 140 ft bgs to 520 ft bgs at the Holiday Ranch Site near Cottonwood (Lawrence and Associates, 2007). Transmissivity at the Holiday Ranch Site is 90,000 ft^2/d and hydraulic conductivity is 450 to 500 ft/d with a storage coefficient of 0.00025 (Lawrence and Associates, 2007). As the test well spans both the Upper Aquifer and Lower Aquifer horizons the aquifer parameter values represent a combination of both aquifers.

The Tehama Formation has an average transmissivity of approximately 4,000 ft^2/d, an average storativity of 0.00089, and an average hydraulic conductivity of 120 feet per day (ft/d) based on a 1989 constant discharge aquifer test at the Rancho Tehama Reserve in the Red Bluff Subbasin (McManus, 1993; DWR, 2003). In the Vina Subbasin to the southeast, the transmissivity of the upper portion of the Tuscan Formation (70-530 ft bgs) is estimated to be approximately 14,000 square feet per day (ft^2/d) to approximately 55,000 ft^2/d (DWR, 2003).

Lower Aquifer

The Lower Aquifer is defined as the freshwater bearing geologic units throughout the Subbasin from the bottom of model layer 5 at approximately 350-450 ft bgs, to the bottom of the Subbasin. The aquifer has confined to semi-confined conditions. Water bearing geologic units include the lower portions of the Tehama and Tuscan Formations. Lack of a continuous confining layer in the Subbasin creates challenges for defining the top of the Lower Aquifer.

The lack of wells screened in the Lower Aquifer in the Subbasin creates a data gap for hydraulic properties. Hydraulic properties of the Tehama Formation have been characterized in the Subbasin but are not specific to the Lower Aquifer. In a well screened from 200-500 ft bgs, average transmissivity is 90,000 ft^2/d, hydraulic conductivity is 450-500 ft/d, and the storage coefficient is 0.00025 at the Holiday Ranch Site near Cottonwood in the Subbasin (Lawrence and Associates, 2007). As the test well spans both the Upper Aquifer and Lower Aquifer horizons the aquifer parameter values represent a combination of both aquifers.

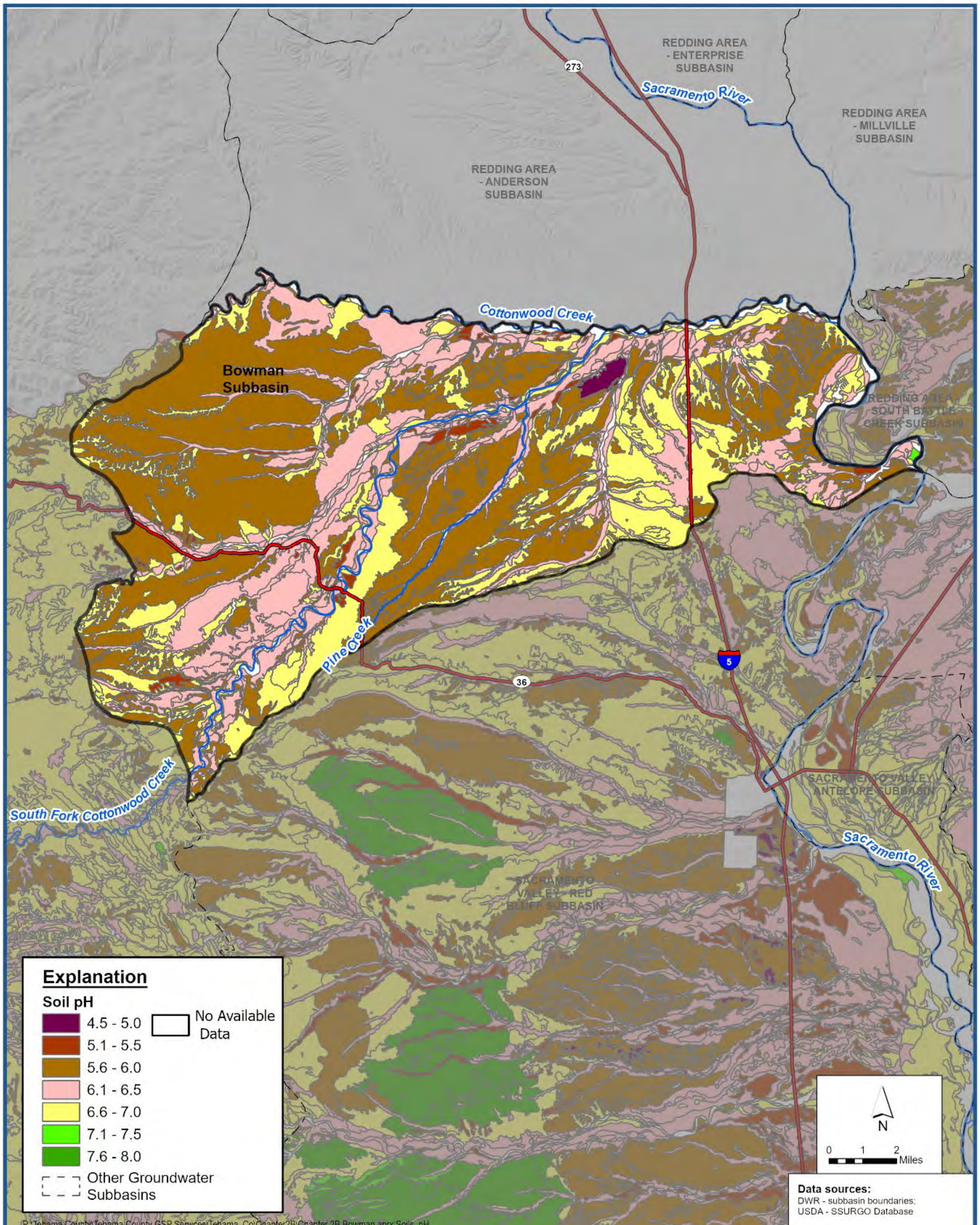
The Tehama Formation has an average transmissivity of 4,000 ft^2/d, an average storativity of 0.00089, and an average hydraulic conductivity of 120 feet per day (ft/d) based on a 1989 constant discharge aquifer test at the Rancho Tehama Reserve in the Red Bluff Subbasin (McManus, 1993; DWR, 2003). The Tuscan Formation has not been directly characterized in the Subbasin; however, the lower Tuscan Formation (Units A and B) has a hydraulic conductivity estimate (via an aquifer test south of Deer Creek and North of Little Chico Creek) of 41-88 ft/d (Brown and Caldwell, 2013). Transmissivity of the lower parts of the Tuscan Formation (340-920 ft bgs) ranges from 5,415 ft^2/d to 49,986 ft^2/d in the Los Molinos Subbasin (DWR, 2003). Storativity in the Los Molinos Subbasin is estimated to be 0.0025 and hydraulic conductivity is estimated to be 40 ft/d to 60 ft/d (Harrison, 1989; Ely, 1994; DWR, 2003).

2.2.1.6 Definable Bottom of Basin

The base of the post-Eocene continental deposits is defined as the bottom of the basin. The post-Eocene deposits are the deepest locations where fresh water may exist. Contours of the base of post-Eocene deposits (**Figure 2-17**) are on the base of the upper Princeton Valley Fill in the majority of the Subbasin. The upper Princeton Valley fill is a transitional formation from marine to terrestrial deposition. Interstitial fresh and brackish water is contained in the upper Princeton Valley Fill and fresh water can intersect with the formation in places (USGS, 1974; Tehama County FCWCD, 2012). Fresh water is defined as having a maximum electrical conductivity (EC) of 3,000 micromhos per centimeter (µmhos/cm) (Berkstresser, 1973). The base of fresh water is the shallowest in the west at elevations above -400 ft mean sea level (msl) and deepest in the east at elevations deeper than -1,200 ft, msl (**Figure 2-16;** Berkstresser, 1973). Fresh water depth based on electrical conductivity is corroborated by studies by DWR (2014).

2.2.1.7 Surface Water Features and Areas of Recharge

The primary surface water features in the Subbasin are the Sacramento River, Cottonwood Creek (including the South Fork), Little Dry Creek, Hooker Creek, Patterson Creek, and Pine Creek (**Figure 2-32**). The Sacramento River and Cottonwood Creek flow throughout the year (perennial), but the remaining streams flow seasonally. The Sacramento River flows southward along the eastern boundary of the Subbasin. The other streams flow northward draining the Subbasin and feeding Cottonwood Creek. Cottonwood Creek flows eastward where it enters the Sacramento River at the eastern boundary. Several small seasonal ponds (surface area less than 10 acres) occur along streams, but there are no natural lakes or reservoirs within the Subbasin.



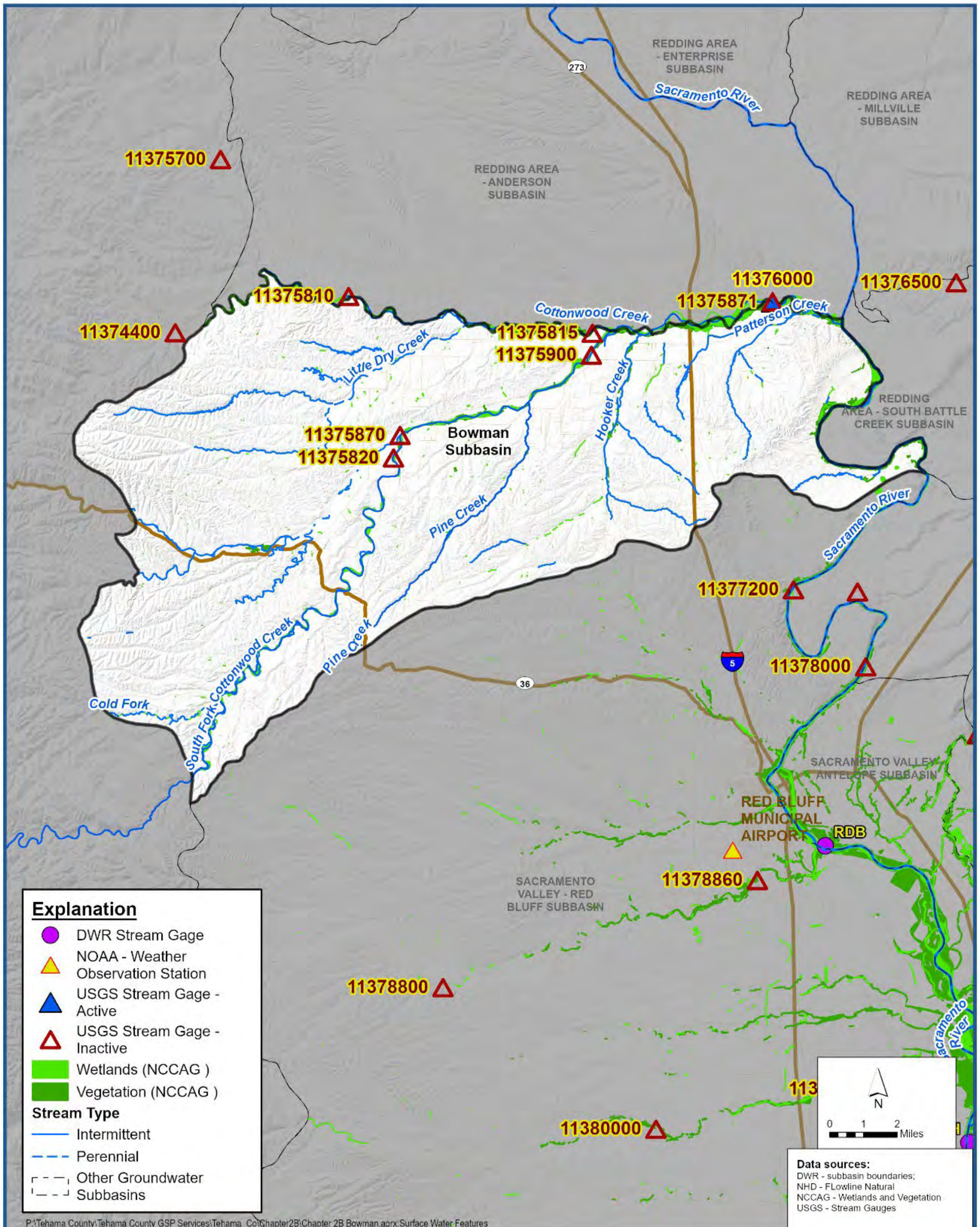
TEHAMA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

LSCE Team

Soils - pH

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-31



Map of Surface Water Features

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-32

Groundwater recharge of the Subbasin primarily occurs from the flow of the Sacramento River and the other streams and tributaries in the Subbasin (DWR, 2004). Some of the groundwater recharge contributions from smaller streams and tributaries likely supports low flow conditions in the Sacramento River as baseflow. Relatively high hydraulic conductivity of streambeds and soils located adjacent to these streams create favorable conditions for percolation of surface water (**Figure 2-28**). However, the Soil Agricultural Groundwater Banking Index (SAGBI; O'Geen et al., 2015), which indicates the suitability of land for groundwater recharge by flooding, gives “poor” deep percolation rating to many areas of flood plains and natural levees of streams despite the presence of highly conductive surficial soils (**Figure 2-33**). The poor rating in these areas can be attributed to the presence of low-permeable soil layers and a relatively shallow groundwater table, which are unfavorable for groundwater banking operations or managed aquifer recharge. Lastly, recharge likely also occurs along 1) the hill front due to runoff and groundwater movement down into the valley, 2) disperse aerial recharge from natural precipitation, and 3) irrigation water.

Seasonal wetlands exist adjacent to many streams, and most notably along the Sacramento River, Cottonwood Creek, and the South Fork of Cottonwood Creek (**Figure 2-34**). These wetlands may indicate the seasonal occurrence of groundwater discharge when the groundwater table rises to the land surface. However, data are not available to distinguish between wetlands fed by groundwater and those fed by surface water (from streams and precipitation run-off).

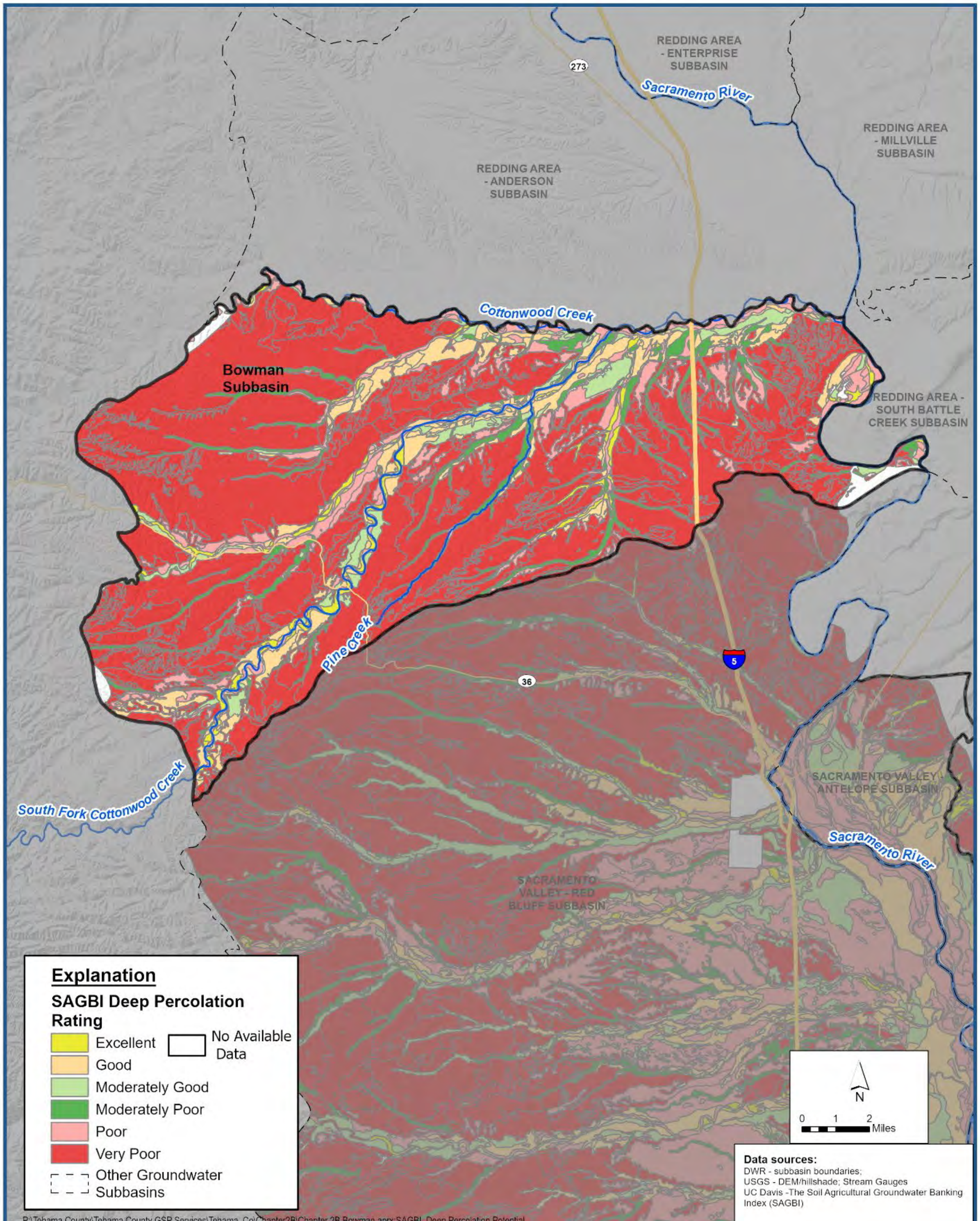
2.2.1.8 Data Gaps and Uncertainty

Stratigraphy

The general stratigraphy of the subsurface within the Subbasin is characterized based on past studies and LSCE’s interpretation of well completion reports and geophysical logs, however, specific thicknesses and lateral extent of formations is poorly understood. The western extent of the Tuscan Formation in the vicinity of the Sacramento River is poorly defined and the extent of the interfingering between the Tuscan and Tehama Formations in the subsurface is not known. The Hydrogeologic properties differ between the two formations, and it would be beneficial to know where the properties change so aquifer zones could be better constrained and future wells could be screened in targeted intervals.

Hydrogeologic Parameters

Estimates of hydrogeologic parameters are available for site-specific areas in the Subbasin. Parameters have been estimated for geologic formations within the Subbasin at localized sites; however, the formations vary with extent and may be different in different areas of the Subbasin. Parameters like storativity, transmissivity, and hydraulic conductivity can be estimated based on geology however, without field and lab measurements the range of values is significant. Future pump tests and testing of soil collected from drilling will help characterize the parameters specific to the Subbasin.



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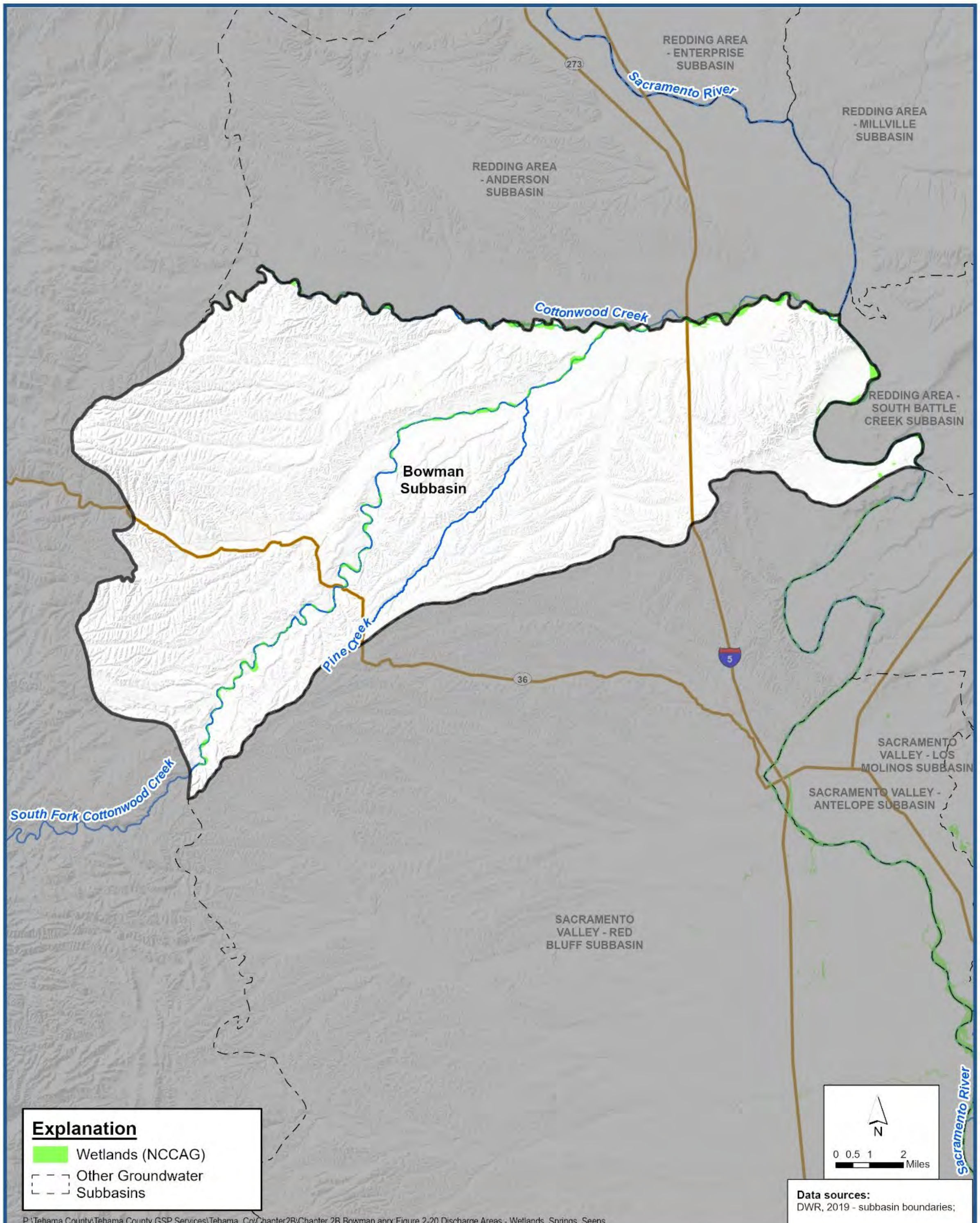
SAGBI Groundwater Recharge Rating

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-33



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Map of Discharge Areas – Wetlands, Springs, Seeps **Figure 2-34**

Groundwater Sustainability Plan
Bowman Subbasin

Surface Water and Recharge

Surface water and groundwater interconnectivity is based on observable relationships between streams and shallow groundwater. There is a lack of shallow wells near active stream gages, a condition needed to establish the relationship. Future frequent monitoring from the existing- and from new- stream gauges along the major waterways and from new proximal shallow monitor wells would help to describe interaction between surface water and groundwater.

2.2.2 Current and Historical Groundwater Conditions

An understanding of groundwater levels and the direction of flow is essential to sustainable groundwater management. This includes both the spatial and temporal variation of groundwater levels which are a function of geology, groundwater management, land use, and climatic conditions. Historical and current groundwater levels of the Subbasin were evaluated using data obtained from public databases (DWR, SWRCB, and USGS) and information available in the literature. LSCE performed a quality assurance/quality control (QA/QC) process on compiled data, which included evaluation of data for completeness and duplication, as well as identification of questionable data.

2.2.2.1 Groundwater Levels and Flow Direction

2.2.2.1.1 *Groundwater Levels*

To gain a historical perspective of trends in groundwater levels, hydrographs were generated for wells with historical time series data of sufficient period of record. Representative hydrographs and the locations of corresponding wells are shown in **Figure 2-35**, while all hydrographs used for the groundwater level evaluation are in **Appendix 2-F**. A graphical illustration that describes information shown on a hydrograph is also included in **Appendix 2-F**. Trends of groundwater levels can be observed over various time periods when data is available. The time-series data also show seasonal variations and changes that correspond to wet and dry periods of the Subbasin. The total annual precipitation measured at the Red Bluff Municipal Airport (about 10 miles south from the southern boundary of the Subbasin) shows a strong positive correlation with the Sacramento Valley Water Year Index (Pearson's correlation coefficients of 0.72). **Figure 2-36** shows the annual precipitation and cumulative departure curve of precipitation at Red Bluff Municipal Airport. Sacramento Valley hydrology between water years of 1990 and 2018 (representative base period of this GSP which represents long-term average annual hydrologic conditions) indicate multi-year wet periods occurred in 1995-1999, while multi-year dry periods occurred in 1990-1992 (started in 1987), 2007-2009 and 2013-2015 (**Table 2-9**).

Table 2-9. Sacramento Valley Water Year Types since 1980

Water Year	Water Year Index	Water Year Type
1980	9.04	Above Normal
1981	6.21	Dry
1982	12.76	Wet
1983	15.29	Wet
1984	10.00	Wet
1985	6.47	Dry
1986	9.96	Wet
1987	5.86	Dry
1988	4.65	Critical
1989	6.13	Dry
1990	4.81	Critical
1991	4.21	Critical
1992	4.06	Critical
1993	8.54	Above Normal
1994	5.02	Critical
1995	12.89	Wet
1996	10.26	Wet
1997	10.82	Wet
1998	13.31	Wet
1999	9.80	Wet
2000	8.94	Above Normal
2001	5.76	Dry
2002	6.35	Dry
2003	8.21	Above Normal
2004	7.51	Below Normal
2005	8.49	Above Normal
2006	13.20	Wet
2007	6.19	Dry
2008	5.16	Critical
2009	5.78	Dry
2010	7.08	Below Normal
2011	10.54	Wet
2012	6.89	Below Normal
2013	5.83	Dry
2014	4.07	Critical
2015	4.00	Critical
2016	6.71	Below Normal
2017	14.14	Wet
2018	7.14	Below Normal
2019	10.34	Wet

Source- https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST
Accessed in January 2021

Upper Aquifer

Seasonal high-water levels in the Upper Aquifer (in winter/spring seasons) during wet periods range between about 20 and 190 ft bgs. Depth to water is shallower (about 20 - 30 ft bgs) close to the northeastern boundary of the Subbasin (close to the Cottonwood Creek in areas east of the Little Dry Creek) compared to that in the other areas of the Subbasin. Local topography is also a major factor that determines the depth to water at a location. Groundwater levels decreased during dry periods likely due to the combined effect of increased withdrawal from wells and reduction in recharge. The lowest groundwater levels in recent history (since 1980) occurred during the 2013-2015 drought. During that period, seasonal high-water levels decreased by up to about 5 ft in most areas of the Subbasin. Recent data indicate that the groundwater levels partially or completely recovered to pre-drought levels since then. Seasonal water level fluctuations of most wells during a water year are less than five feet.

Lower Aquifer

Depth to water in the Lower Aquifer ranges from about 40 ft bgs to 140 ft bgs in the northeastern portion of the Subbasin (measured at three locations). Seasonal fluctuations, as well as fluctuations that correspond to wet and dry climatic conditions, are less than 10 ft in this area. Historical water level data in other parts of the Subbasin are not available.

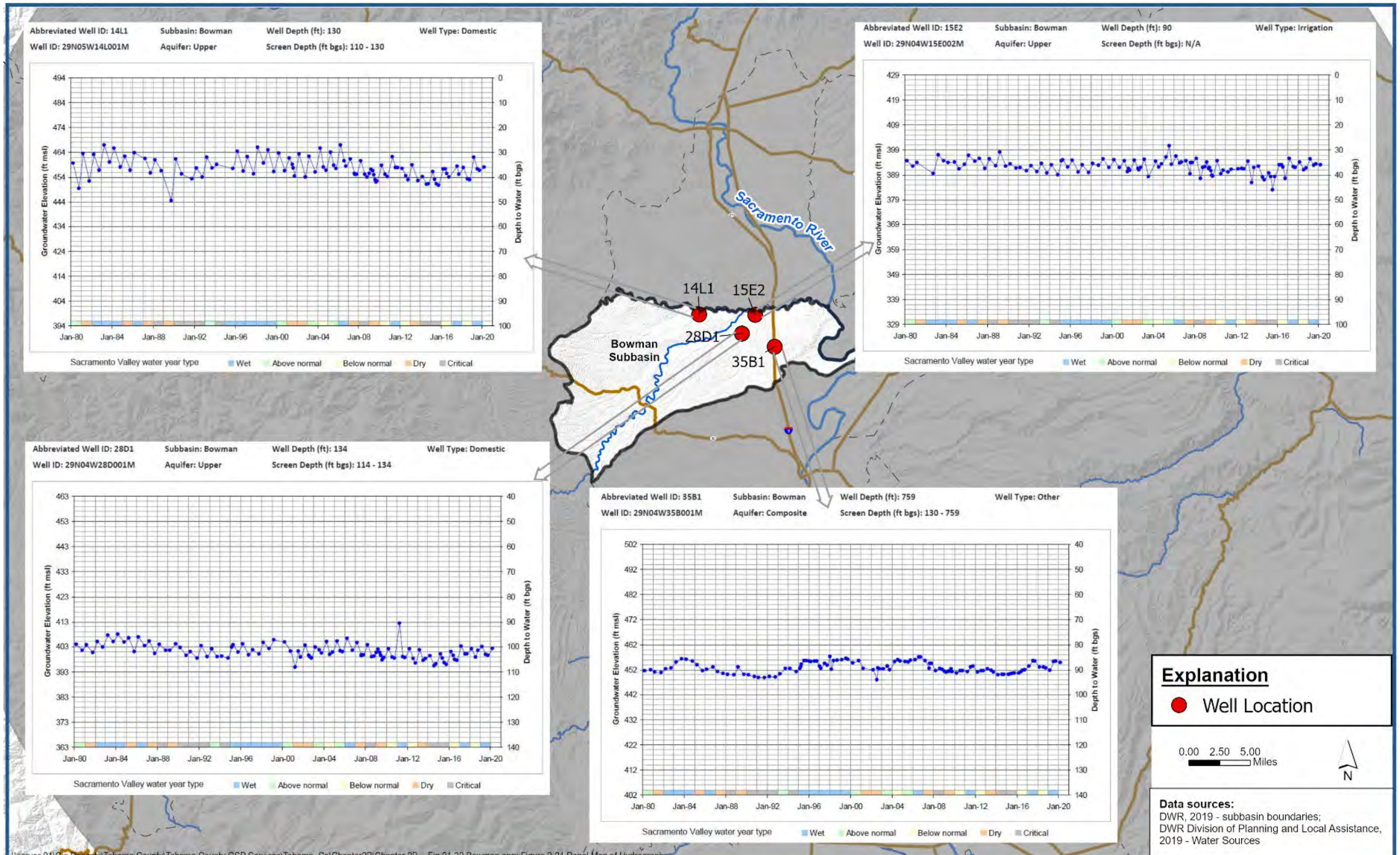
Trends in Groundwater Levels

Statistical analysis of data from four wells, which have records spanning the entirety of the 1990 through 2018 hydrologic base period, show stable groundwater levels. Three of these four wells are screened in the Upper Aquifer, and the other well is screened in both aquifers (a composite well). Seasonal high water levels of two Upper Aquifer wells and the composite well do not show a significant trend of change during this period. Water levels of the other Upper Aquifer well show a very small declining rate of about 0.2 feet per year. Lower Aquifer wells with water level data that span the entirety of the 1990-2018 period do not exist in the Subbasin. However, data collected from few wells since 2000 show stable water levels in the Lower Aquifer during the last two decades. Results of the groundwater level trend analysis, which used both parametric (Ordinary least squares regression) and nonparametric (Mann-Kendall and Theil–Sen) methods, are included in **Appendix 2-F**.

2.2.2.1.2 *Groundwater Elevation Contours and Flow Directions (§354.16(a)(1))*

Groundwater elevation contour maps were created to evaluate general groundwater flow directions in the Upper Aquifer. Seasonal high and seasonal low water elevations of Upper Aquifer wells were used to develop contours of equal groundwater elevation ("Contours"). Water levels of wells that are entirely screened within the top 50 ft bgs and wells without construction details were excluded from contouring, since these wells are likely not representative of the areas of the aquifer where groundwater pumping occurs. Contours were initially developed using spatial analyst tools in ArcGIS software, and then modified based on professional judgement. Contours were not developed for areas where data was lacking (mainly the western half of the Subbasin). Also, contours were not created for the Lower Aquifer because of the lack of data.

Contour maps were created to evaluate seasonal high and seasonal low groundwater conditions in multiple years that included wet, dry, and critical water year types between 1990 and 2019. Contours of current groundwater conditions are represented using the seasonal high and seasonal low groundwater elevation of water year 2019 (**Figures 2-37 and 2-38**). After evaluation of groundwater level hydrographs with long-term data and the Sacramento Valley water year type record (**Table 2-9**), water years 2017, 2013 and 2015 were considered to represent groundwater conditions in wet, dry, and critical years, respectively (**Figures 2-39 through 2-44**).



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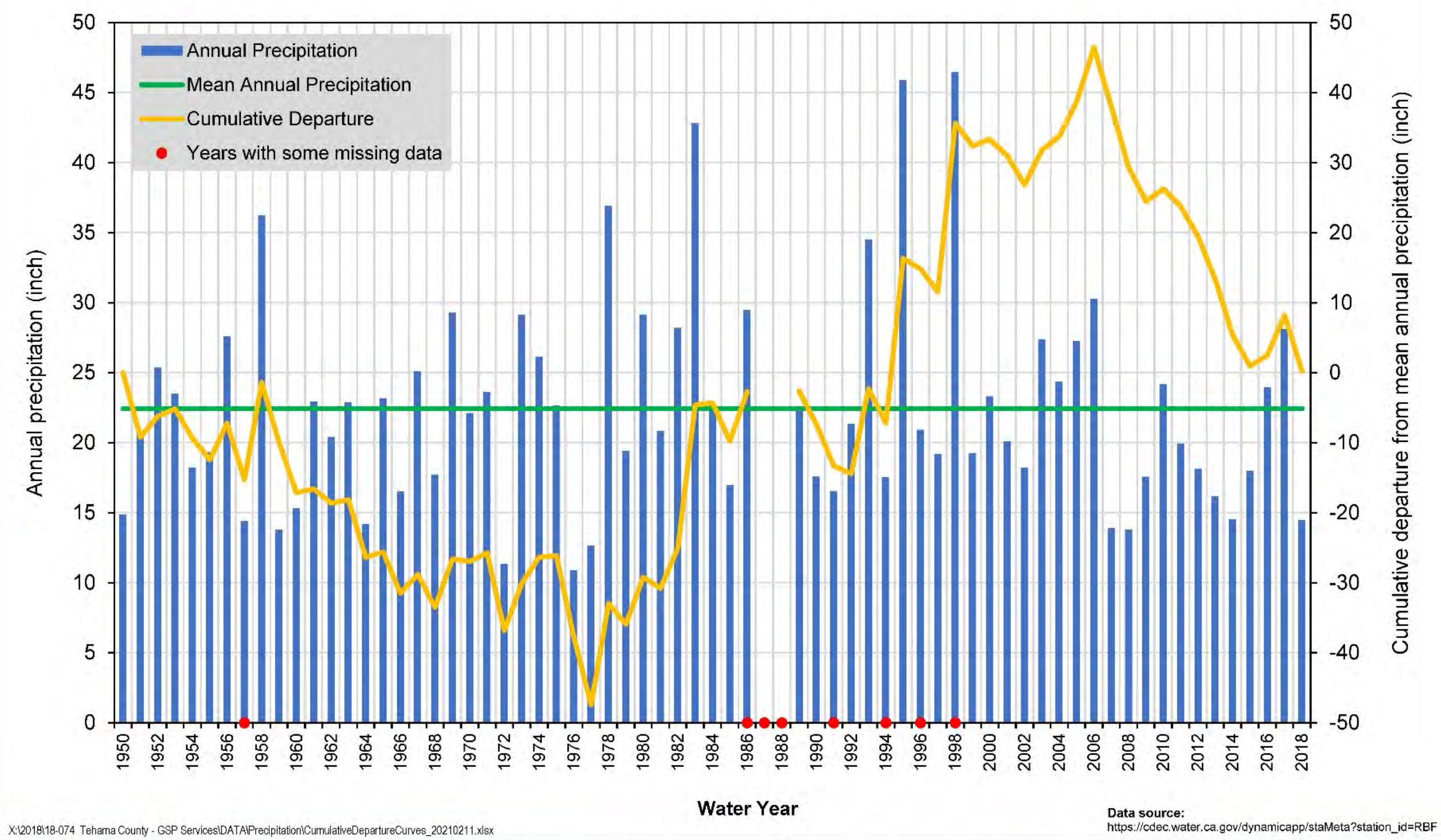
Panel Map of Selected Groundwater Elevation Hydrographs

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-35



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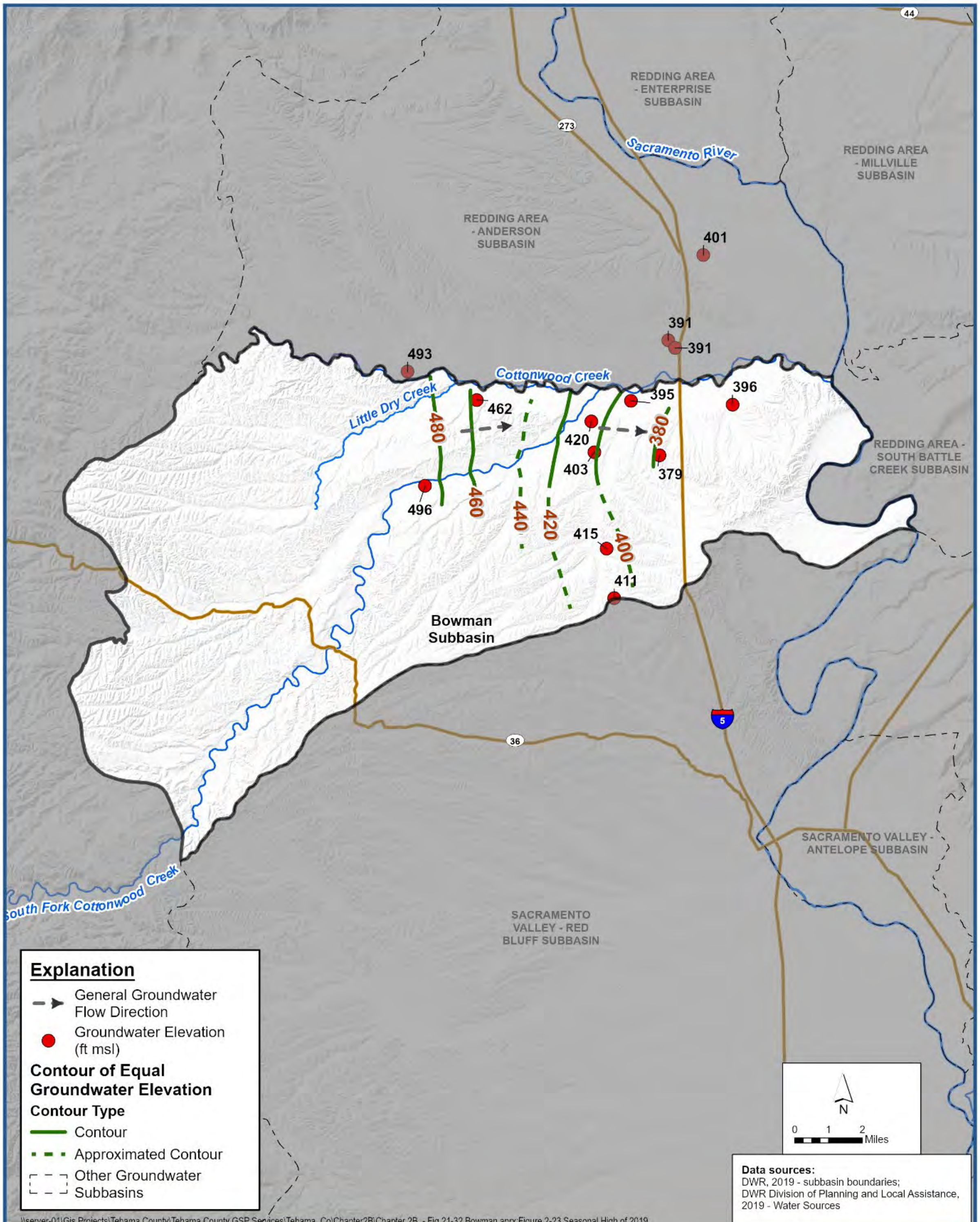
Annual Precipitation and Cumulative Departure at Red Bluff Municipal Airport

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-36



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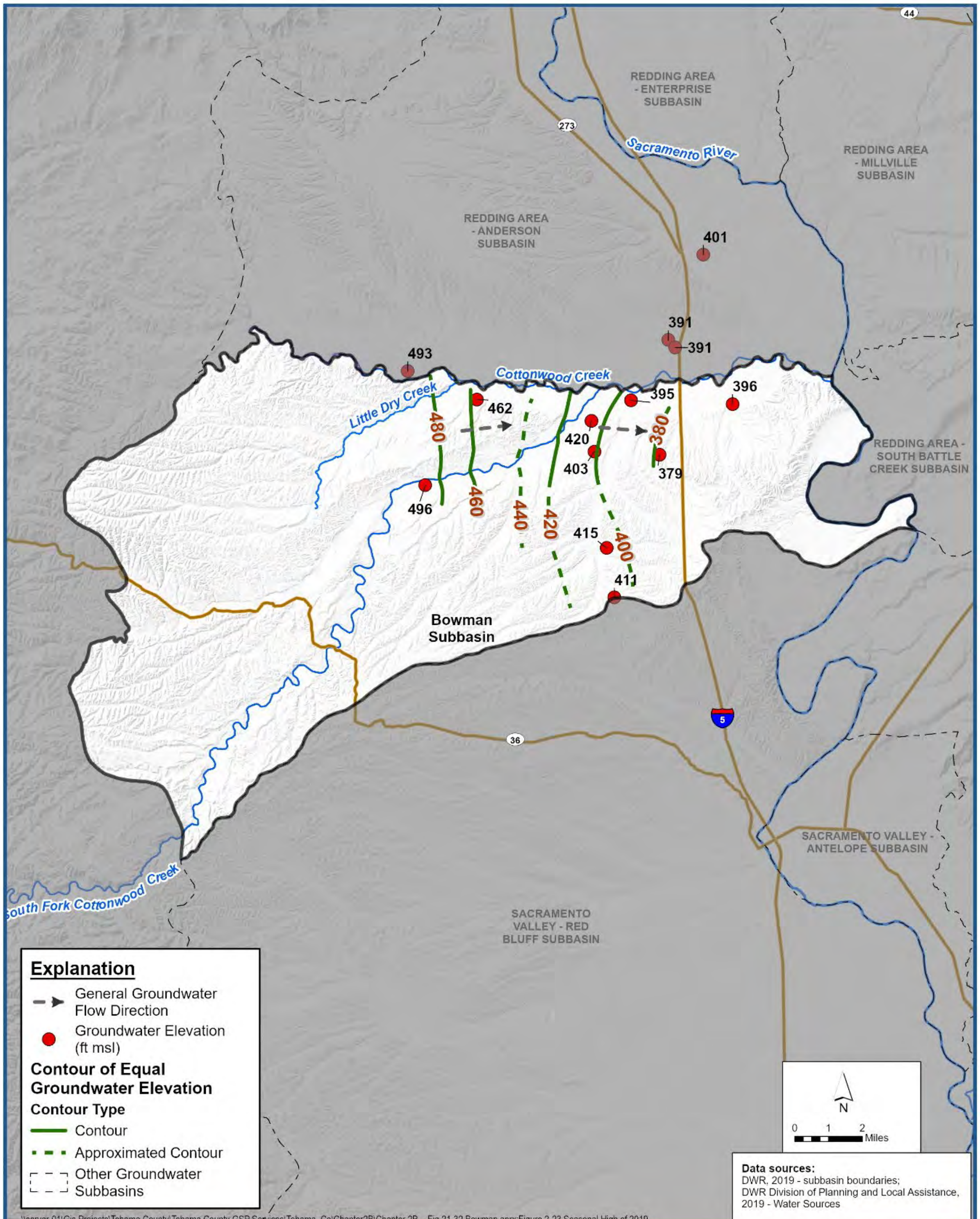
Contours of Equal Groundwater Elevation Upper Aquifer - Seasonal High of 2019

Groundwater Sustainability Plan
Bowman Subbasin

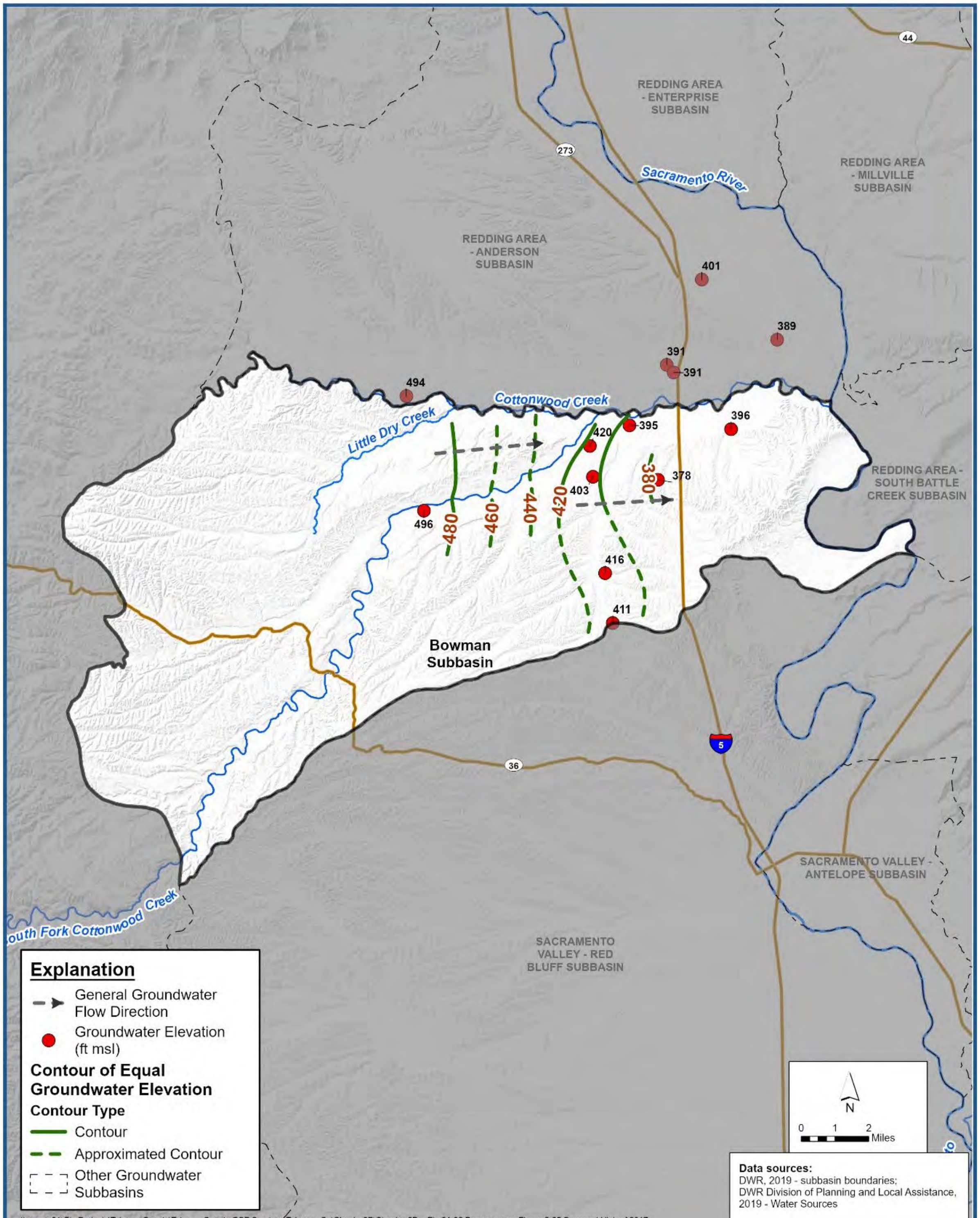
Figure 2-37



Contours of Equal Groundwater Elevation Upper Aquifer - Seasonal High of 2019

Groundwater Sustainability Plan
Bowman Subbasin

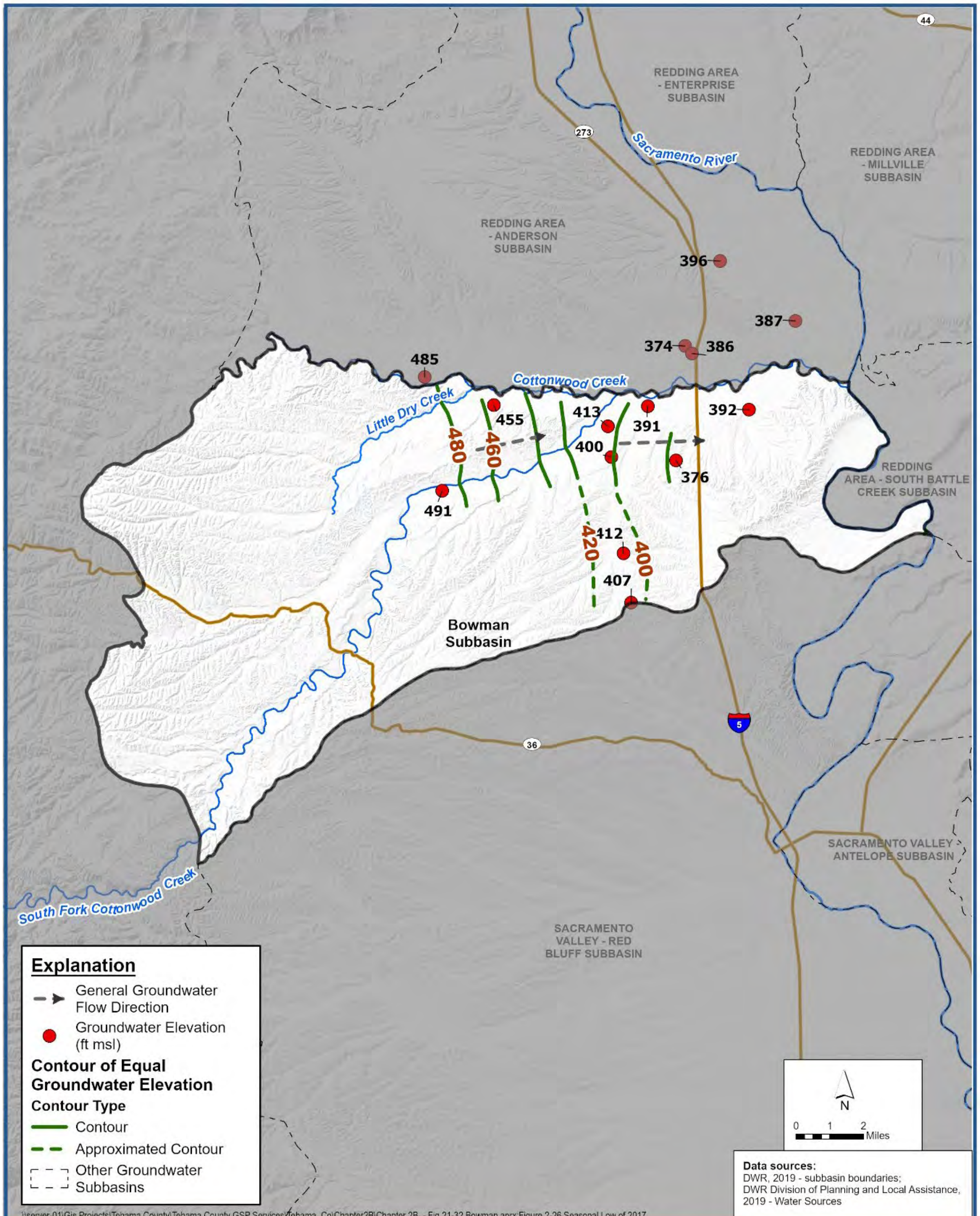
Figure 2-38



Contours of Equal Groundwater Elevation Upper Aquifer - Seasonal High of 2017

Groundwater Sustainability Plan
Bowman Subbasin

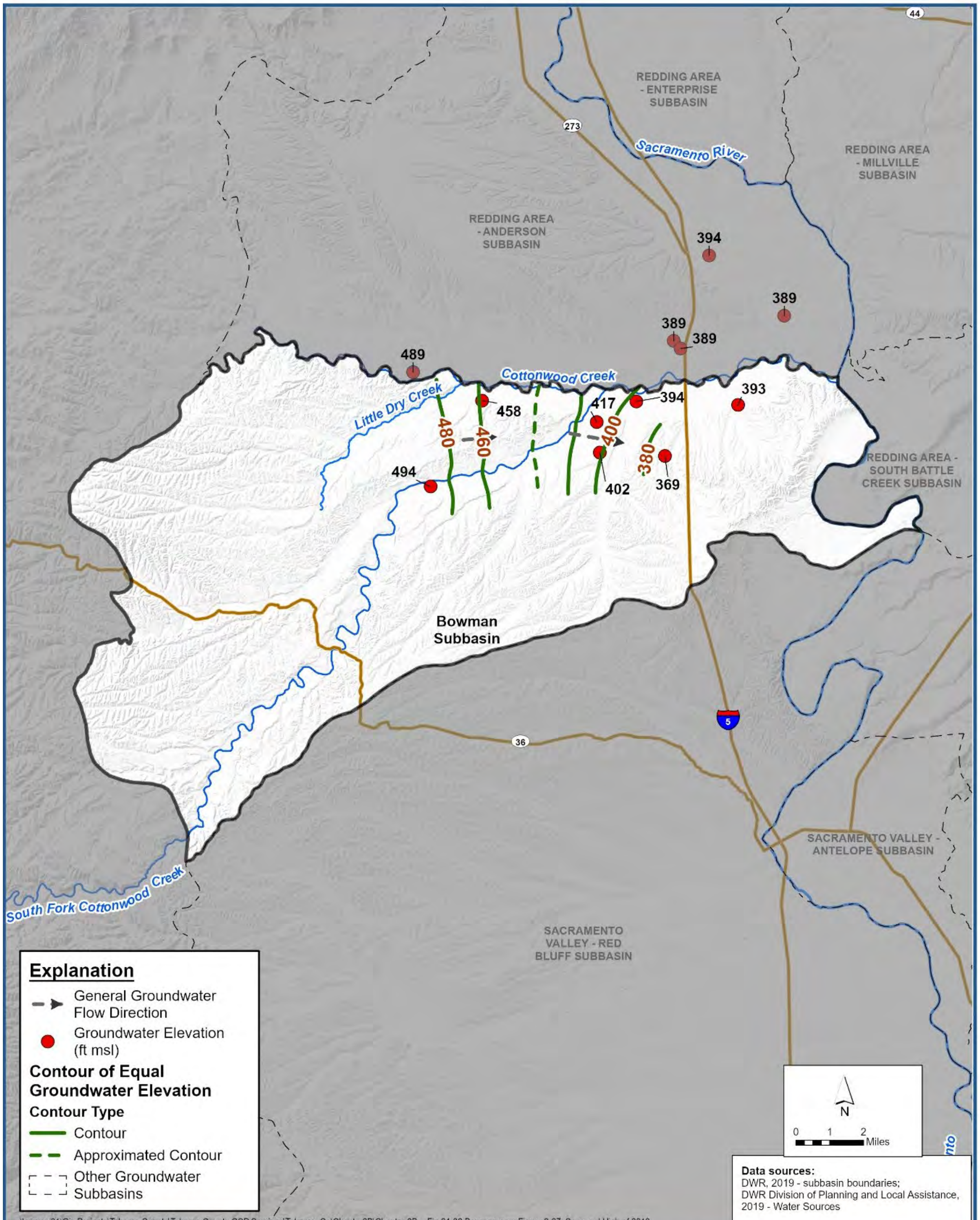
Figure 2-39



Contours of Equal Groundwater Elevation
Upper Aquifer - Seasonal Low of 2017

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-40



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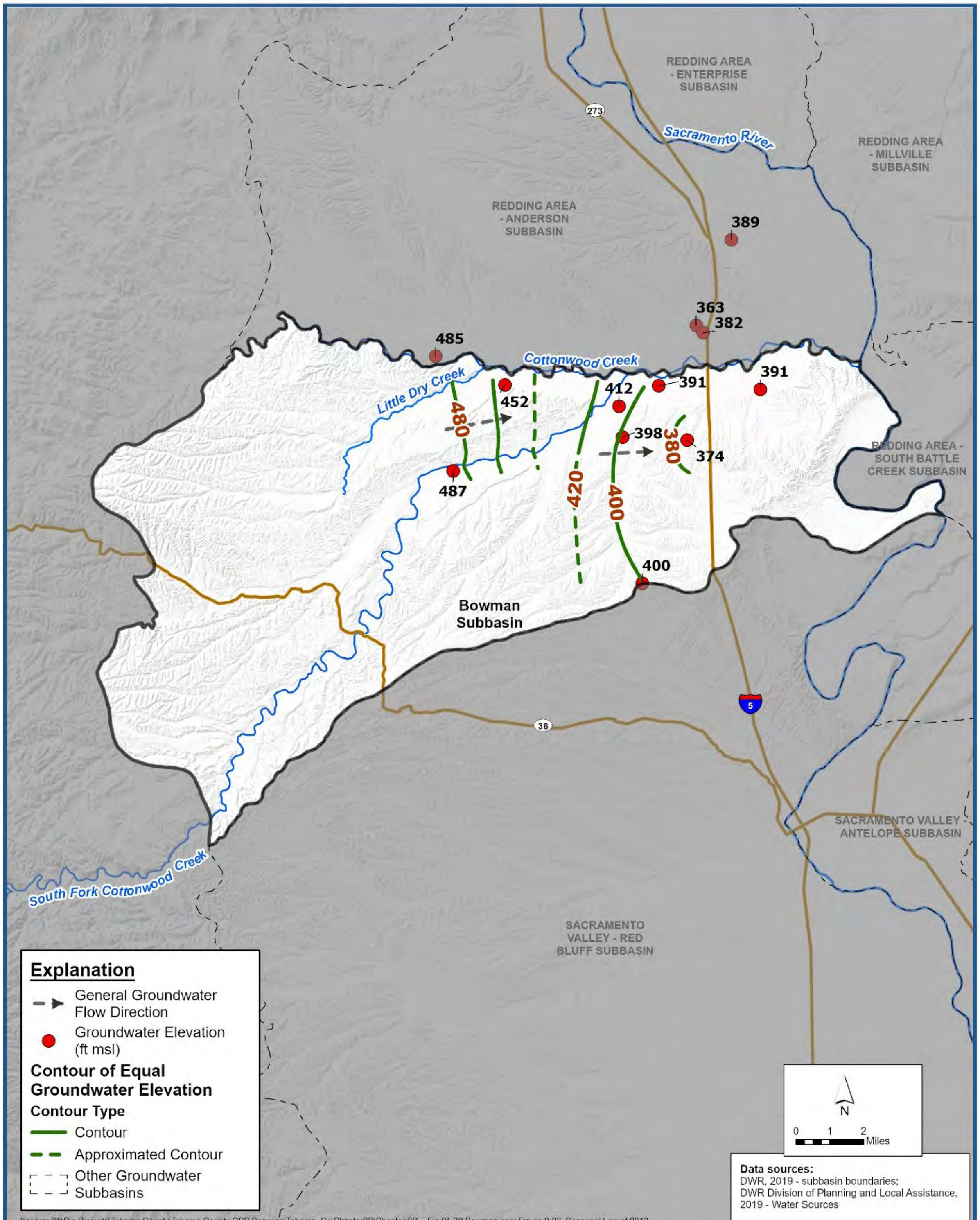
Contours of Equal Groundwater Elevation
Upper Aquifer - Seasonal High of 2013

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-41



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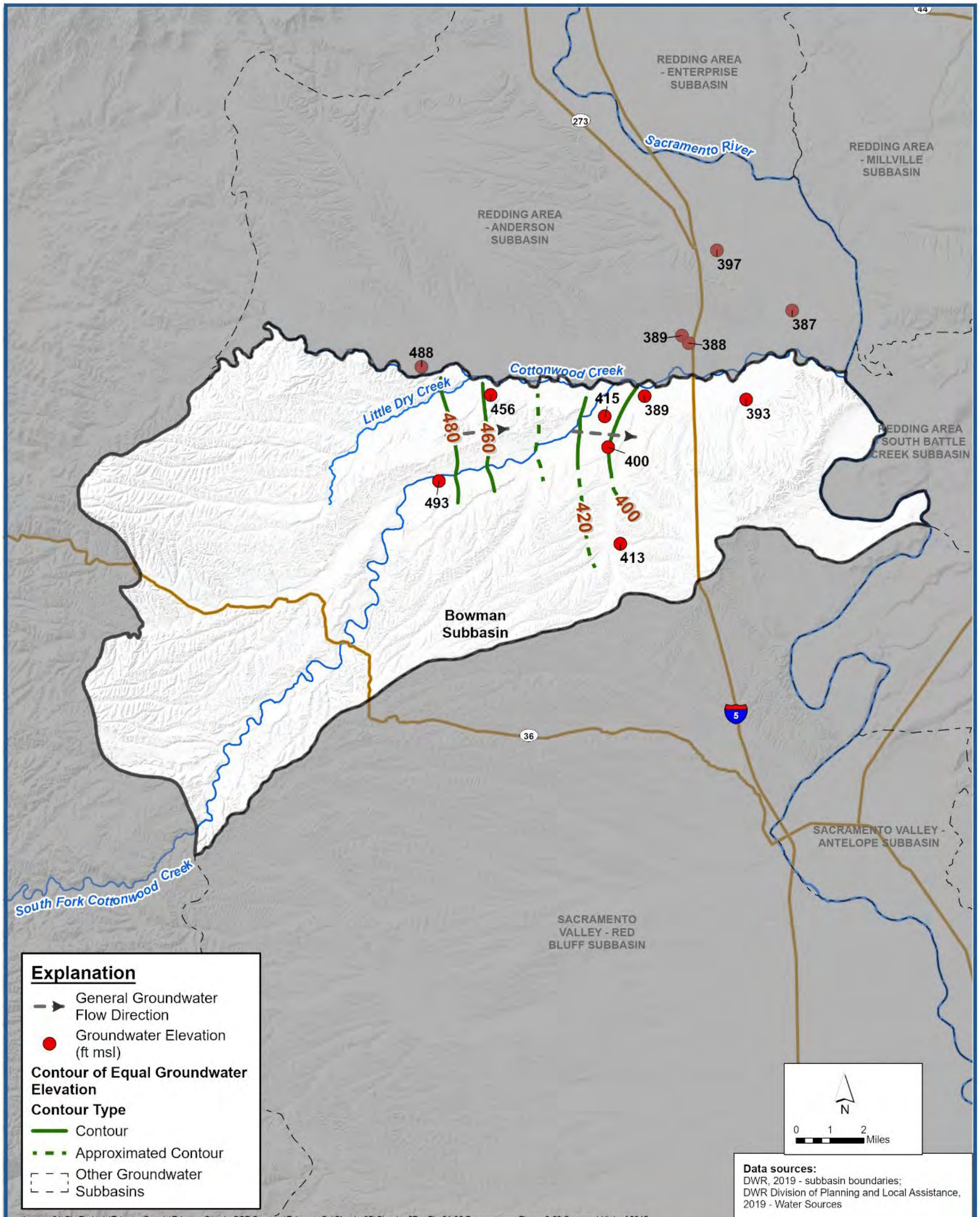
Contours of Equal Groundwater Elevation
Upper Aquifer - Seasonal Low of 2013

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-42



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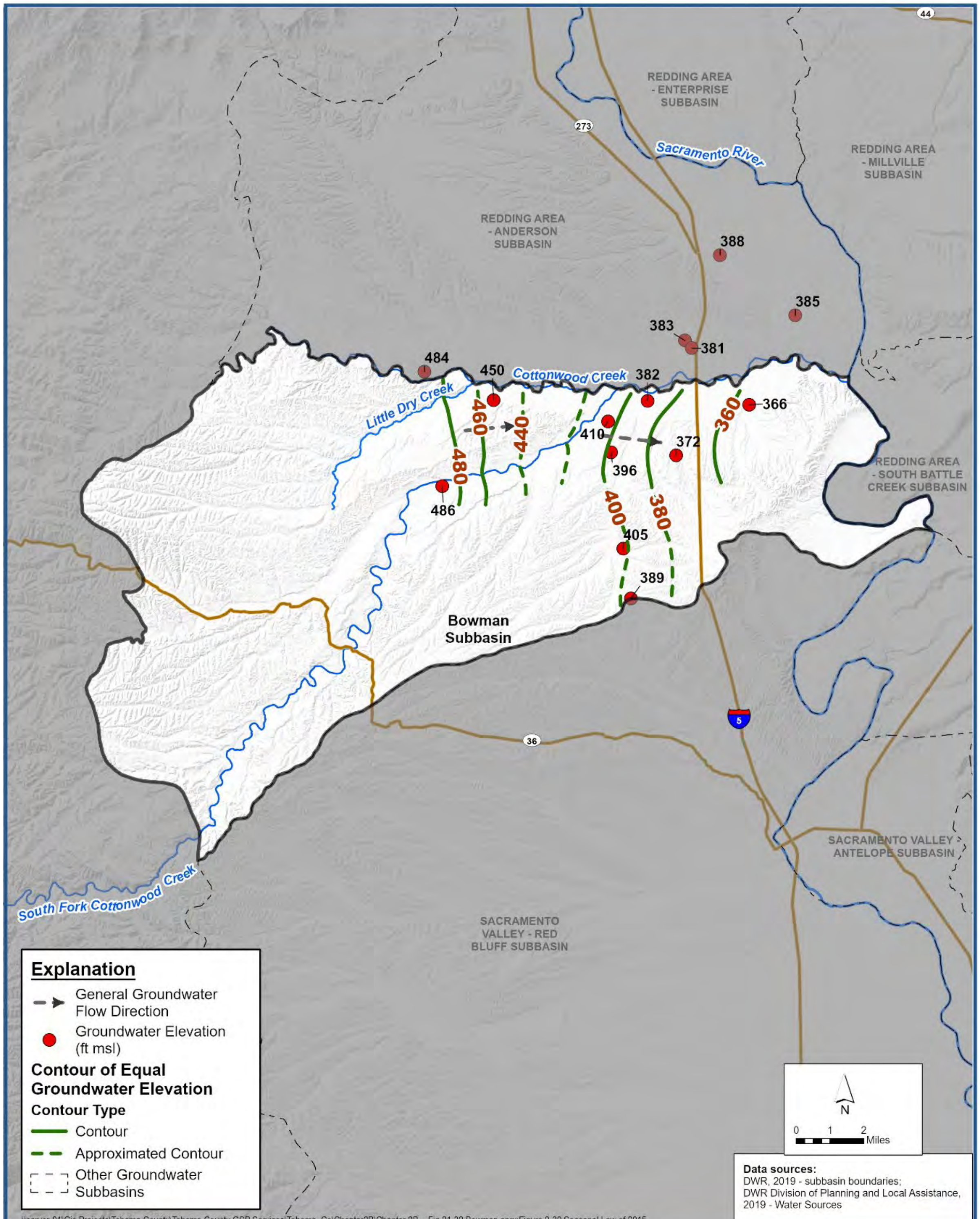
Contours of Equal Groundwater Elevation Upper Aquifer - Seasonal High of 2015

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-43



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Contours of Equal Groundwater Elevation
Upper Aquifer - Seasonal Low of 2015

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-44

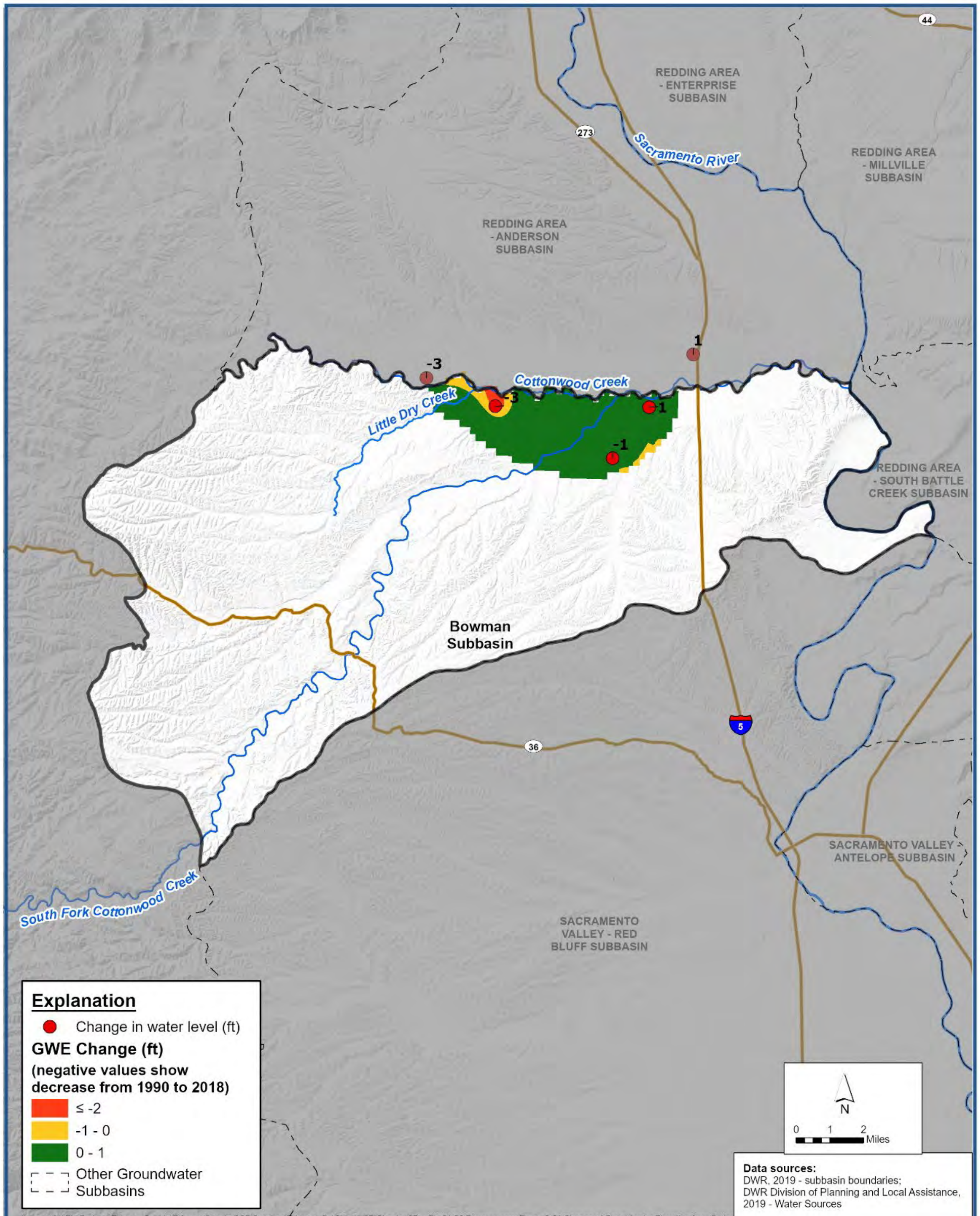
Upper Aquifer contour maps show that the water levels in the Subbasin are relatively unchanged between winter/spring and fall seasons, as well as between current conditions and different water year types. Groundwater elevations are lowest in the eastern side of the Subbasin, and gradually increase towards west. Historically, elevations remained between about 370 ft in the east (around Interstate-5) and 500 ft in the central area of the Subbasin with few feet of seasonal and annual fluctuations. Groundwater flow is generally towards the Sacramento River at the eastern Subbasin boundary, with a lateral hydraulic gradient that historically remained between 16 and 18 feet per mile. A northeasterly groundwater flow is expected in the southwestern portion of the Subbasin, because of the groundwater divide at the southern boundary of the Subbasin. Water level data from two separate sets of nested/clustered wells indicate consistently downward hydraulic gradients (0.01 to 0.06) within the Upper Aquifer and between the Upper Aquifer and Lower Aquifer. Direction of the vertical gradient in the Lower Aquifer changed from downward (up to 0.01) to upward (up to 0.02) at different times. Water level hydrographs of nested/clustered wells (shown in **Appendix 2-F**) indicate weak hydraulic separation between the Upper Aquifer and Lower Aquifer. Temporal fluctuations of water levels in both aquifers have similar patterns and comparable magnitudes.

2.2.2.2 Change in Groundwater Levels and Storage

Change in seasonal high groundwater elevations (spring to spring) from 1990 to 2018 was estimated to evaluate changes in groundwater storage during the hydrologic base period. Groundwater elevation surfaces of the Upper Aquifer for 1990 and 2018 were separately created by interpolating available water levels in each year. Then the difference between these two surfaces (**Figure 2-45**), which encompasses a volume of both water and porous media, was calculated. Sufficient water level data were available to evaluate groundwater level changes only in a northern portion of the Subbasin shown in **Figure 2-45**. Between 1990 and 2018, groundwater elevations, thus the groundwater storage, in this area did not change considerably. The area where groundwater elevation change was estimated is approximately 8,900 acres, which is about 7% of the Subbasin area. However, this area includes about 40% of all irrigated lands in the Subbasin (2018 land use data). The specific year-to-year historical groundwater storage changes are also estimated using a surface water-groundwater flow model discussed in the Chapter 2B.

2.2.2.3 Groundwater Quality

The evaluation of groundwater quality in the Subbasin included a literature review (e.g., Bennett et al., 2011; DWR, 2020; SWRCB, 2009 and Tehama County FCWCD, 2012) and evaluation of groundwater quality data collected from SWRCB GeoTracker and GeoTracker GAMA databases. SWRCB GeoTracker database identifies one currently open groundwater clean-up site (a leaking underground storage tank site with active monitoring) within the Subbasin (shown in **Figure 2-12** in Chapter 2.1). Occurrence of synthetic organic compounds and volatile organic compounds associated with industrial products and pesticides at concentrations higher than their Maximum Contaminant Levels have been reported in the Subbasin. These contaminants are listed in Chapter 2.1. Widespread presence of contaminants at undesirable levels has not been reported in groundwater samples in the Subbasin. The following discussion focuses on total dissolved solid (TDS), nitrate, and arsenic concentrations in the Subbasin.



Change of Groundwater Elevation - Upper Aquifer from Spring 1990 to Spring 2018

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-45

Total Dissolved Solid (TDS)

The occurrence of Total Dissolved Solids (TDS) at undesirable concentrations is not a concern at present. A total of 442 groundwater samples were tested for TDS since 1957, and results of only one sample exceeded the Secondary Maximum Contaminant Level of 500 mg/L (a concentration of 3,300 mg/L in a 10 ft deep well in 1995). Only three other samples from three different wells had results over 400 mg/L (**Figure 2-46, Appendix 2-G**). TDS concentrations of all other samples (from 147 wells) indicate stable TDS levels between 100 and 400 mg/L in the Subbasin. Test results of all 19 samples collected from seven Lower Aquifer wells between 1991 and 2017 ranged from 100 to 200 mg/L.

Nitrate

Occurrence of nitrate (nitrate, expressed as nitrogen) concentrations that exceed the Maximum Contaminant Level (MCL) of 10 mg/L is not a concern at present (**Figure 2-47**). DWR (2020) identified one shallow well with a nitrate concentration of 27.3 mg/L. However, all other sample results (382 samples from 129 wells) tested since 1955 were below the MCL. One sample with a concentration of 10 mg/L was reported in 1979 (the maximum concentration in the Subbasin). Test results of seven samples from different wells had concentrations between 5.0 mg/L and 7.0 mg/L, while all other 374 samples had concentrations less than 4.0 mg/L. Test results of all 75 of the Lower Aquifer samples were less than 3.1 mg/L.

Arsenic

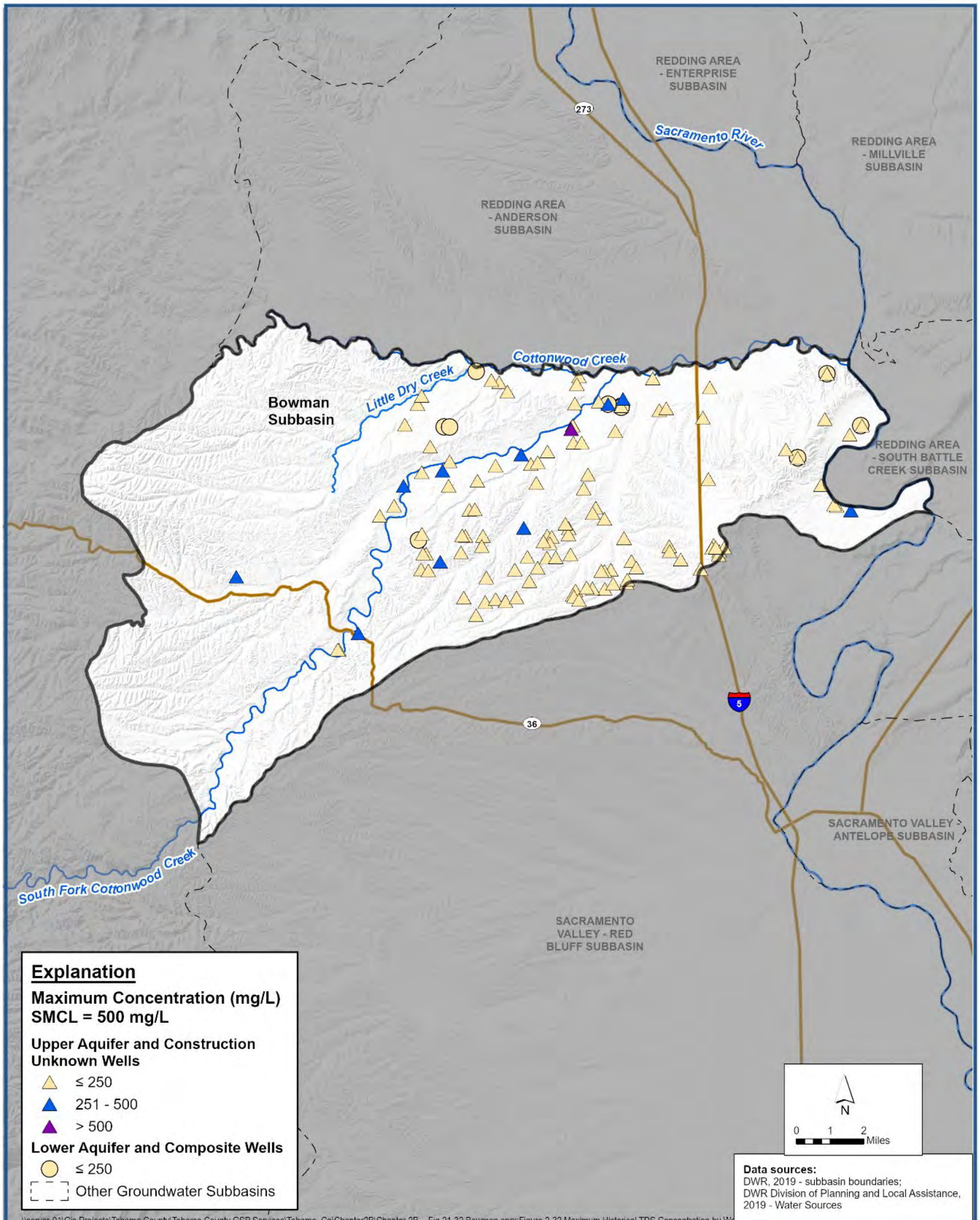
The occurrence of arsenic at concentrations exceeding the MCL of 10 micrograms per liter (µg/L) is not a widespread groundwater quality concern in the Subbasin. Since 1956, 240 samples collected from 86 wells were tested and only four samples from four wells exceeded the MCL (**Figure 2-48)**. The highest historical arsenic concentration in the Subbasin, 20 µg/L, was reported in 1976. All other samples had test results below 6.0 µg/L, and results of all 31 samples collected from seven Lower Aquifer wells had results below 2.5 µg/L. Arsenic is a naturally occurring chemical that originates from volcanic rocks of the Tuscan formation (Tehama County FCWCD, 2012).

2.2.2.4 Seawater Intrusion

Seawater intrusion is not an applicable sustainability indicator for the Bowman Subbasin because it is not likely to occur in the Subbasin due to its distance from the Pacific Ocean (about 90 miles).

2.2.2.5 Subsurface Compaction and Land Subsidence

Bowman Subbasin has little to no reported evidence of subsidence. Subsidence occurs when groundwater is extracted from the pore spaces in the geologic material leading to compaction. The compaction causes the ground surface elevation to drop. In addition to groundwater extraction, oil and gas extraction can lead to subsidence. There are no active oil or gas wells in the Subbasin (**Figure 2-49**). Subsidence monitoring in the Subbasin is available from two surveys conducted by DWR. The subsidence measured in these studies is likely elastic, meaning the land surface can recover (rise) if groundwater is recharged and again fills the pore spaces. Negative subsidence measurements indicate a downward vertical movement of the land surface and positive values indicate an upward movement.



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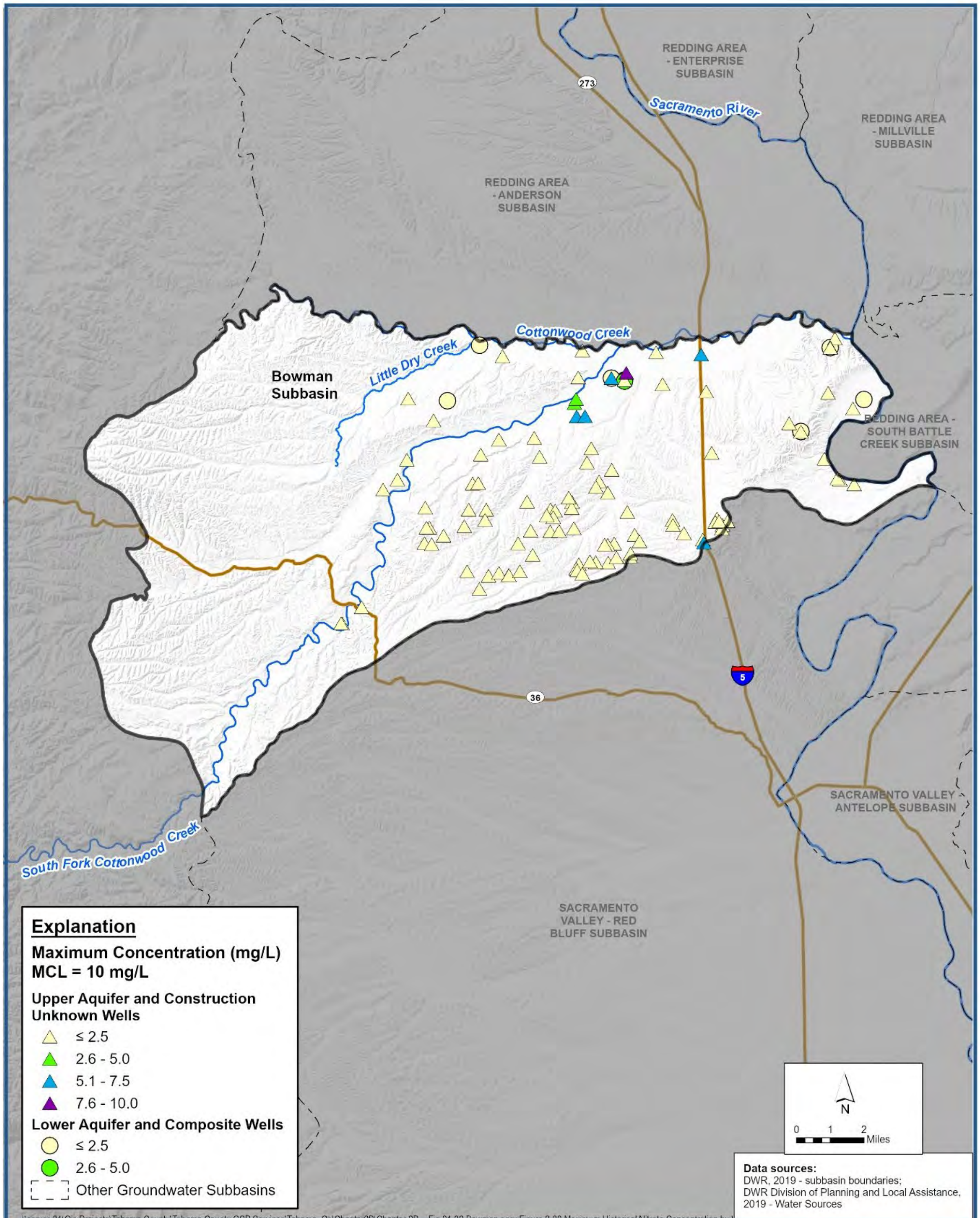
Maximum Historical TDS Concentration by Well

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-46



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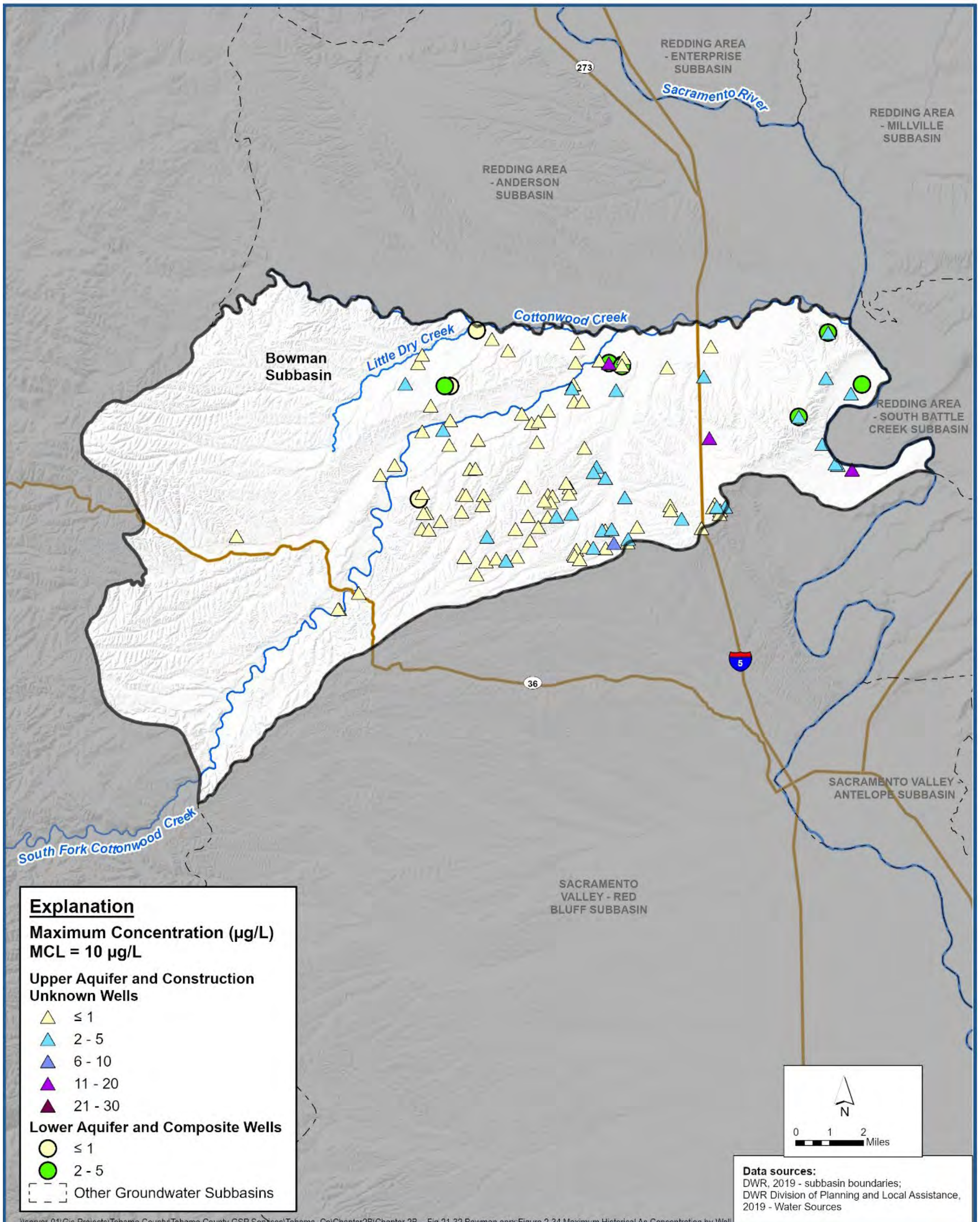
Maximum Historical Nitrate Concentration by Well

Figure 2-47

Groundwater Sustainability Plan
Bowman Subbasin



TEHAMA COUNTY

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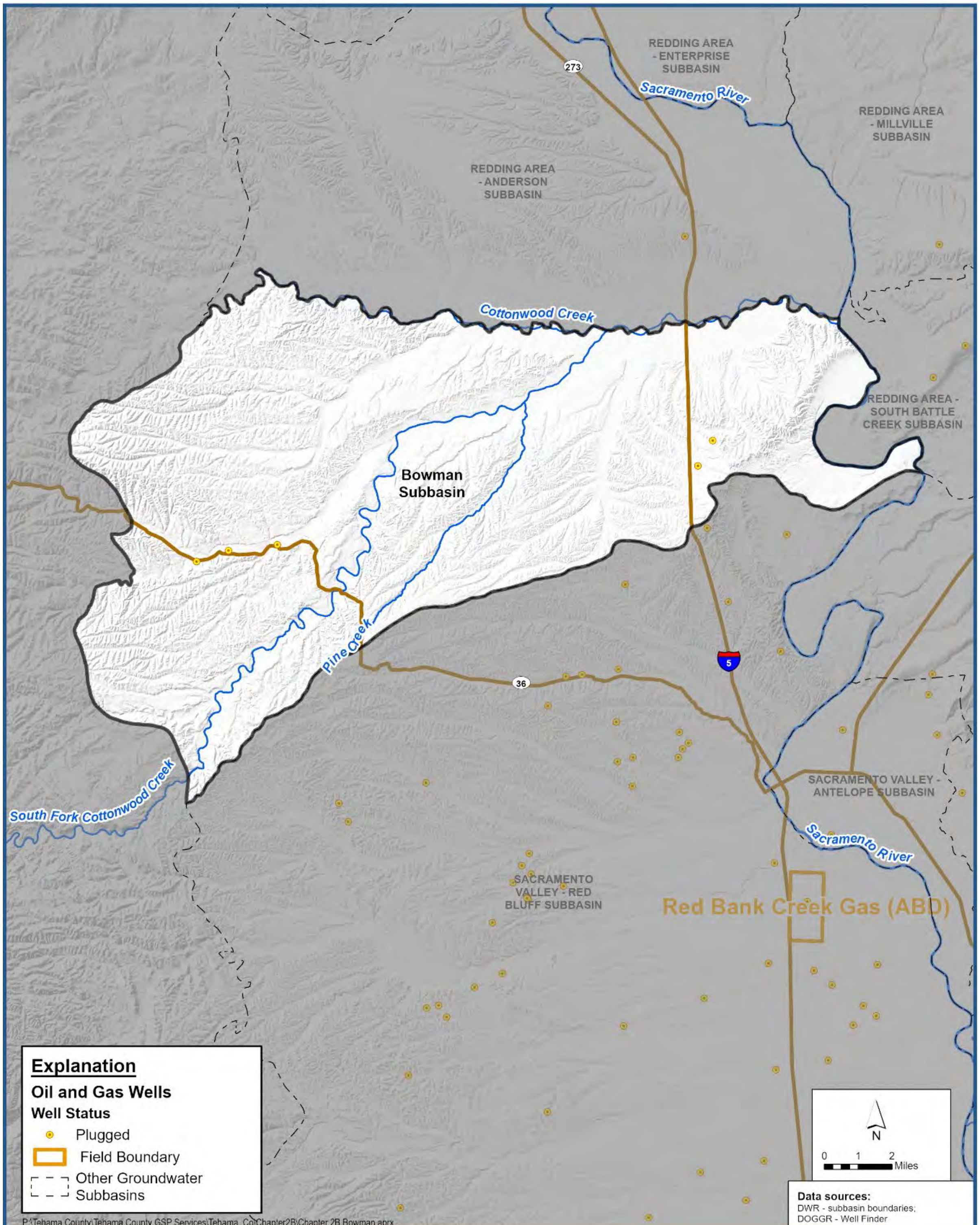
Maximum Historical Arsenic Concentration by Well

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-48



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Map of Oil and Gas Fields and Wells

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-49

In 2018 DWR released a report on land subsidence from 2008-2017 using Global Positioning systems (GPS) survey methods. In 2008, DWR contracted the installation of a series of survey monuments across 11 counties; 3 survey monuments are within the Subbasin boundaries (**Figure 2-50**). These monuments were surveyed to establish a baseline elevation and then resurveyed in 2017. Results from 2008 and 2017 were compared to establish an average change in ground surface elevation over the almost ten-year study period. In the Subbasin, measured ground surface elevation ranged from -0.129 ft at the station near I-5 and Cottonwood Creek to -0.073 ft at the southernmost station (**Figure 2-50**). On average, subsidence in the Subbasin was approximately -0.011 feet per year over the duration of the study.

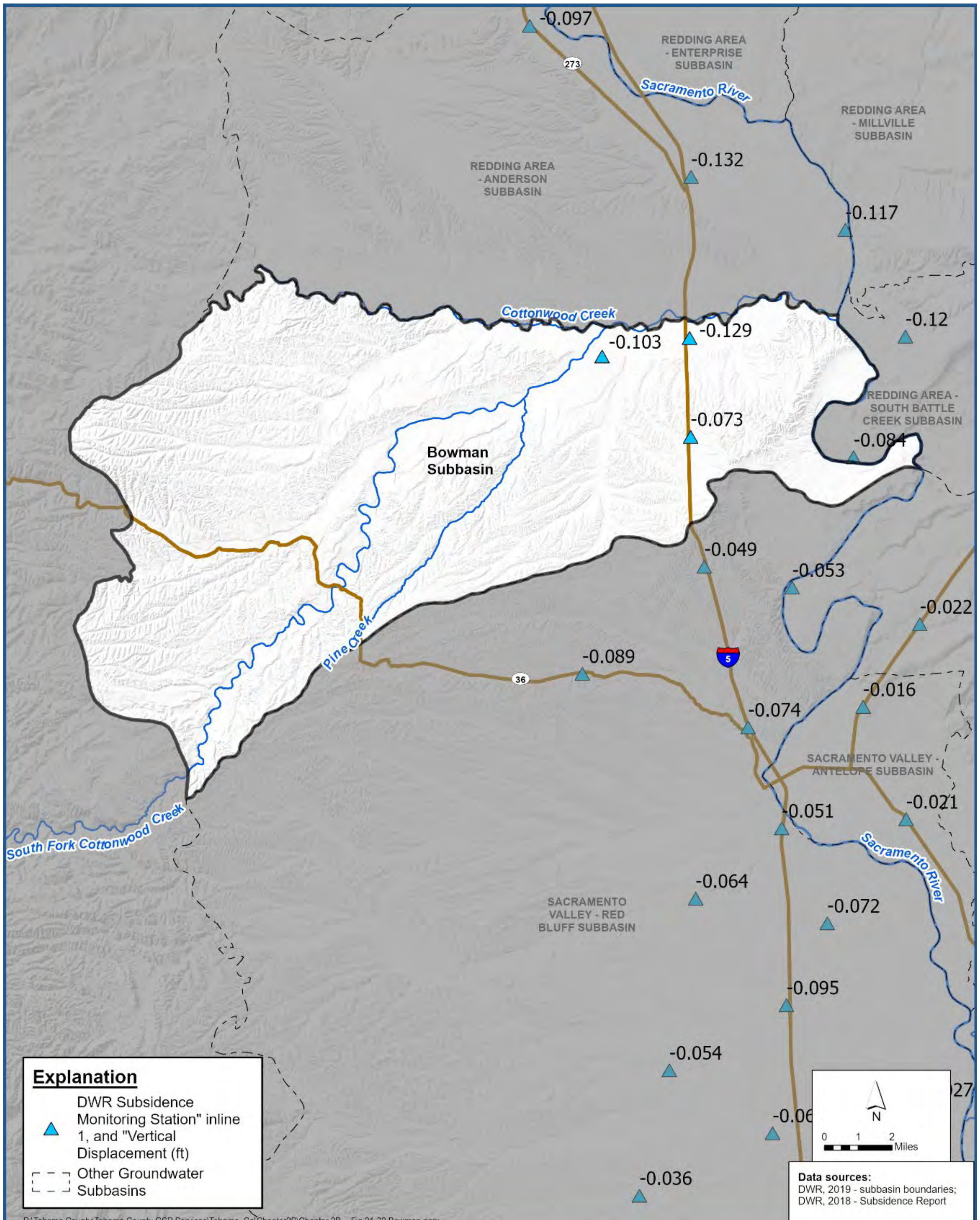
In 2015 DWR began reporting Interferometric Synthetic Aperture Radar (InSAR) surveys to assist with subsidence studies related to SGMA. Vertical measurements are collected by the European Space Agency Sentinal-1A satellite and compared to previous measurements to establish a change in surface elevation. The vertical measurements are collected as point data sets that represent 100-meter by 100-meter areas and are used to interpolate GIS rasters (**Figure 2-51**). Vertical displacement measured using the InSAR approach from July 2015 to June 2019 was between -0.09 ft to 0.05 ft in the Subbasin over the entire period of study (**Figure 2-51**). Average annual subsidence rate within the Subbasin based on InSAR data is -0.02 ft/year to 0.01 ft/year.

2.2.2.6 Surface Water Conditions

Historic and current surface water flow data is limited in the Subbasin. As discussed in Section 2.2.1.7, the Sacramento River, Cottonwood Creek, the South Fork of Cottonwood Creek, Pine Creek, Hooker Creek, and Little Dry Creek are the main surface water features. The Sacramento River and Cottonwood Creek flow throughout the year (perennial), but the remaining creeks flow seasonally. Only Cottonwood Creek has active stream gages within the Subbasin (**Figure 2-32**). The Sacramento River has a currently active gaging station approximately 2.5 miles to the south of the Subbasin boundary (**Figure 2-32**).

The Sacramento River has one currently active gaging station close to the Subbasin; USGS/USBR station #11377100 at Bend Bridge (BND). USGS/USBR station BND is located about 2.5 miles downstream of the southern boundary of the Subbasin (**Figure 2-32**) with a daily record since 1963. Based on historical data from BND, the mean annual flow rate is about 12,500 cubic feet per second (CFS) with highest flows from January through March (historical mean over 16,800 CFS), and lowest flows in October (historical mean about 7,000 CFS) (USGS NWIS stream flow data).

Flow of Cottonwood Creek has been measured since 1941 at USGS station #11376000 at Cottonwood Creek near Cottonwood about two miles upstream of the Sacramento. The mean annual flow rate is about 858 CFS with highest flows in January and February (mean of over 2,000 CFS), and lowest in August and September (mean of less than 75 CFS). In addition, there are five inactive USGS stream gages on Cottonwood Creek and the South Fork of Cottonwood Creek. The most recent records available from these stations are from 1986.



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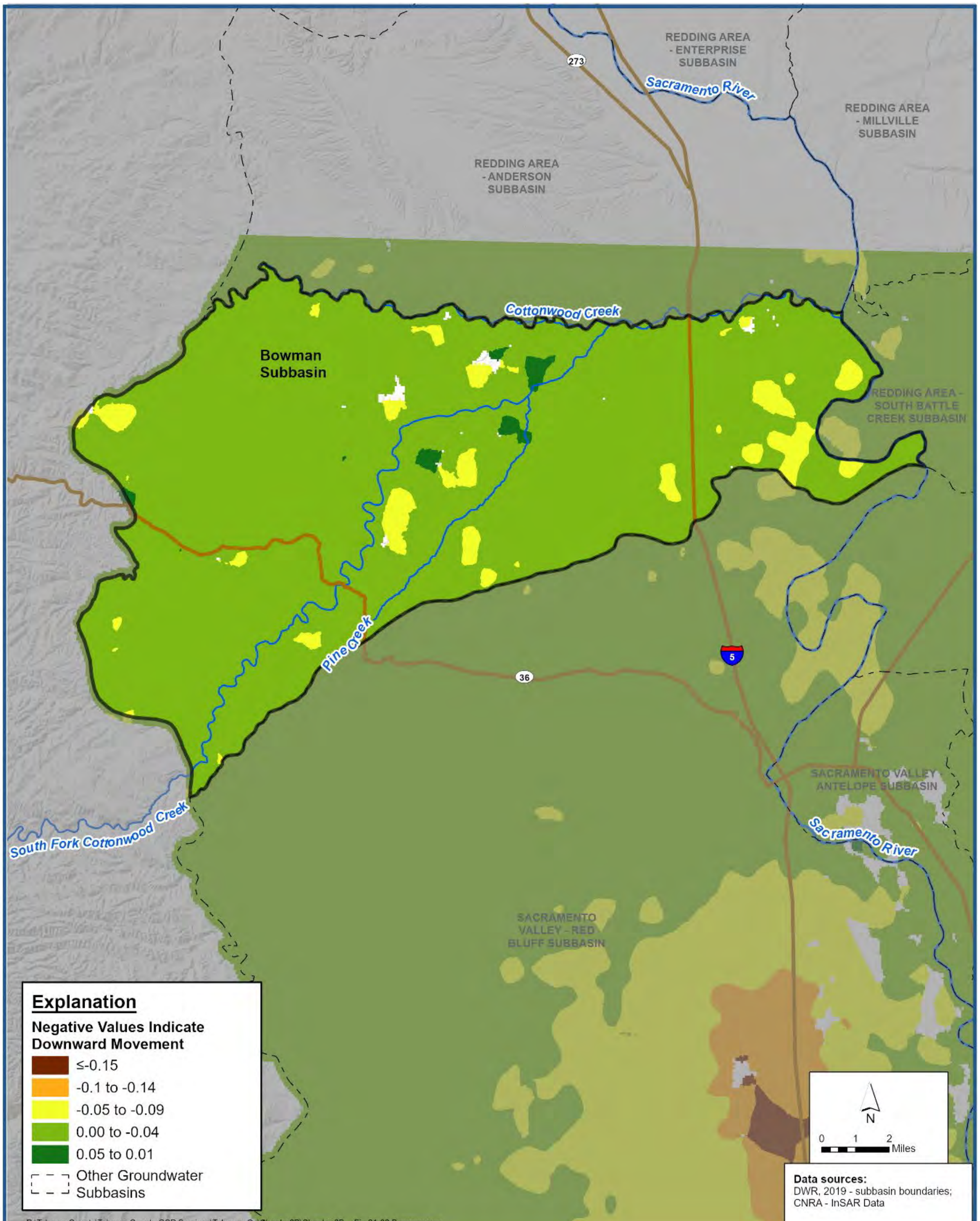
Subsidence Measurements Between 2008 and 2017

Figure 2-50

Groundwater Sustainability Plan
Bowman Subbasin



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DWR InSAR Subsidence Map

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-51

2.2.2.6.1 *Interconnected Surface Water Systems*

Characterizing the connectivity of the surface water systems in the Subbasin is challenging due to the limited data. Modeling surface water and groundwater interaction will also be a means to address the connectivity and is discussed in Chapter 2B. When a stream stage is higher than that of the groundwater table the stream will lose water to the ground via infiltration of water through the streambed (losing conditions). If losing conditions are present but the depth of the water table is too deep, the stream is considered losing and disconnected. Losing conditions with groundwater just below the stream are connected. When the water table elevation is higher than the stream stage, groundwater will infiltrate into the stream causing the stream to gain water (gaining conditions). Groundwater and surface water are always connected under gaining conditions. To establish if streams are connected, stream data like flow magnitude or stage height coupled with shallow groundwater elevation or flow direction is needed.

The Subbasin does not contain active stream gages near shallow monitoring wells needed to accurately define interconnectivity of surface water and groundwater (**Figure 2-52)**. As discussed in section 2.2.2.6, USGS station #11376000 is the only currently active source of stream stage data within the Subbasin. There are three currently monitored shallow CASGEM wells in the Subbasin. The closest CASGEM well to an active station is four miles away from USGS station #11376000. Installation of shallow monitor wells near the currently active gage station would help to characterize the interconnectivity of the Sacramento River and the groundwater in the Subbasin. There are several inactive stream gages near shallow monitoring wells, however records are not overlapping **Table 2-10**.

Figure 2-52 shows likely interconnected, likely disconnected and interconnectivity uncertain stream reaches based on a dataset developed by The Nature Conservancy (TNC, 2021). This dataset categorizes the likelihood of the interconnectivity based on approximated streambed elevation at a selected point and the minimum depth to groundwater at a nearby well recorded between 2011 and 2018. A stream segment that was hydraulically connected to groundwater at any time during that period is categorized as likely interconnected. Therefore, a large uncertainty exists about the seasonal and year-to -year variability of interconnectivity of streams. Losing and gaining stream segments categorized using the calibrated Tehama Integrated Hydrologic Model are included in **Sub-appendix G** of **Appendix 2-J.**

Table 2-10 List of Currently Inactive Stream Gages Close to Shallow Monitoring Wells

Stream Gage			Groundwater Monitoring Well		
Station Number	Start Year	End Year	State Well Number	Start Year	End Year
11375870	1976	1986	29N05W33A005M	2000	2020
11375815	1981	1985	29N04W20A004M	2007	2020
11375900	1981	1985	29N04W20A004M	2007	2020

2.2.2.7 Identification of Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs) are defined in the GSP regulations as, "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" (23 CCR § 351(m)). Freshwater species in Bowman Subbasin are listed in **Appendix 2-H.** These species were geographically selected from the California Freshwater Species Database (CDFW, 2015). The approach used to both identify and prioritize GDE's was modified from the guidance document *Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act – Guidance for Preparing Groundwater Sustainability Plans* (The Nature Conservancy, 2018. The guidance document was produced by The Nature Conservancy (TNC), an environmental stakeholder who has been actively involved in GSP development and review throughout the state. The dataset of Natural Communities Commonly Associated with Groundwater (NCCAG) provides indicators of potential groundwater dependent ecosystems (iGDEs). This dataset, provided by DWR, is a compilation of 48 publicly available state and federal agency datasets that map vegetation, wetlands, springs, and seeps in California (Klausmeyer et al., 2018). NCCAG data show the occurrence of iGDEs adjacent to perennial and intermittent streams, as well as seasonally flooded wetlands in the Subbasin (**Figure 2-52**). The process used to identify potential GDEs in the Subbasin was accomplished by:

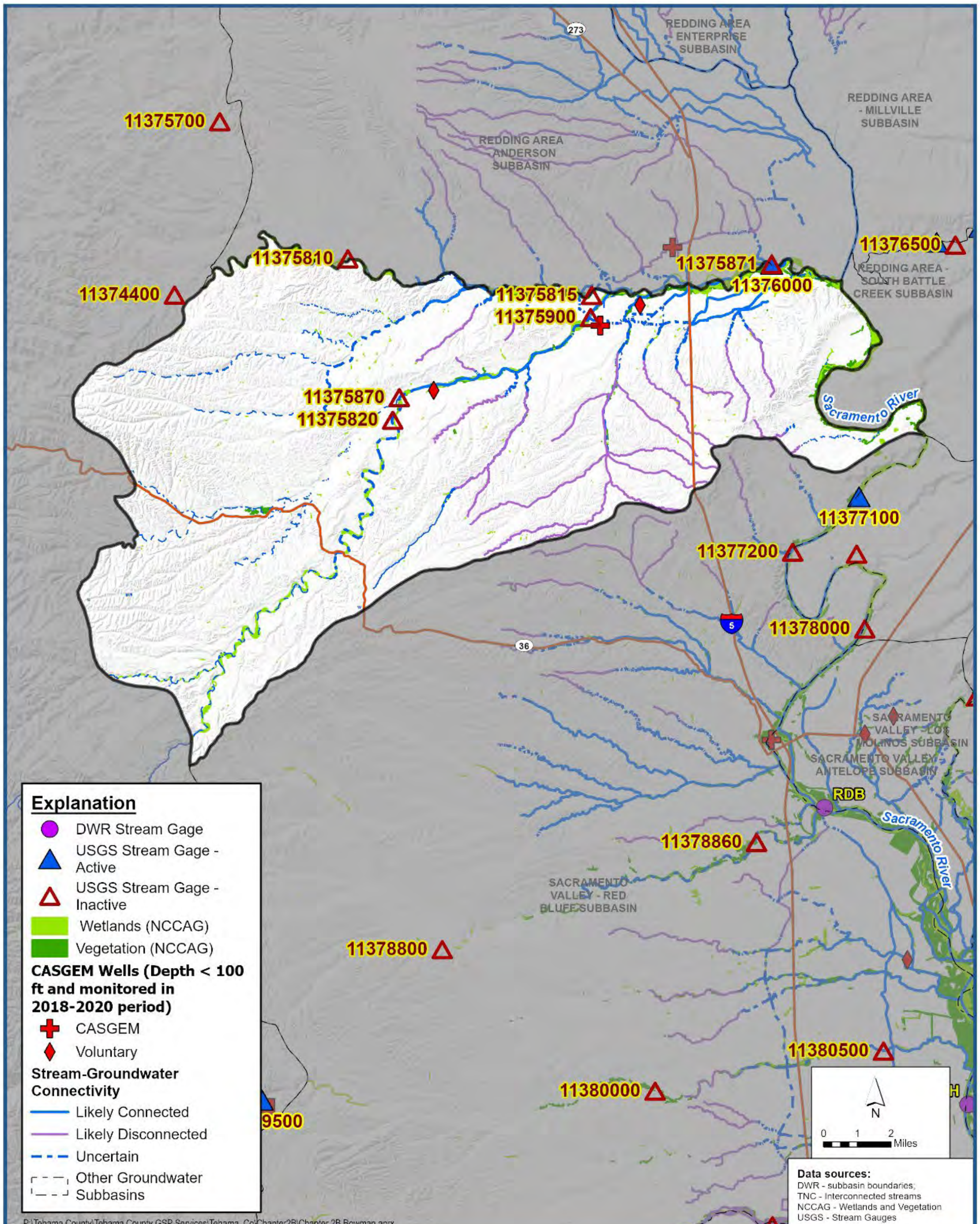
- a comparison of iGDEs with recent land cover data to update the map of iGDEs. This step is required because some iGDEs given in the NCCAG dataset are sourced from datasets mapped many years before 2015, which is the baseline year of SGMA. IGDEs found to exist within developed or irrigated lands were excluded during this step.
- an evaluation of groundwater conditions that can support GDEs. GDEs are likely to exist in areas where the seasonal high groundwater levels do not fall deeper than 30 ft bgs (TNC, 2019). Therefore, identifying areas with shallow groundwater that can support GDEs is important to identify GDEs. IGDEs within 1 mile of wells and with 2015-seasonal-high water deeper than 30 ft were excluded in this step.

A detailed description of methodology of GDE identification and prioritization is presented in a separate Technical Memorandum in **Appendix 2-I**Surface Water Depletion and GDE Methodology and Analysis. The steps above reduce the original NCCAG dataset of iGDEs from an area of 894 acres to 882 acres of GDEs, a reduction of 1.5%.

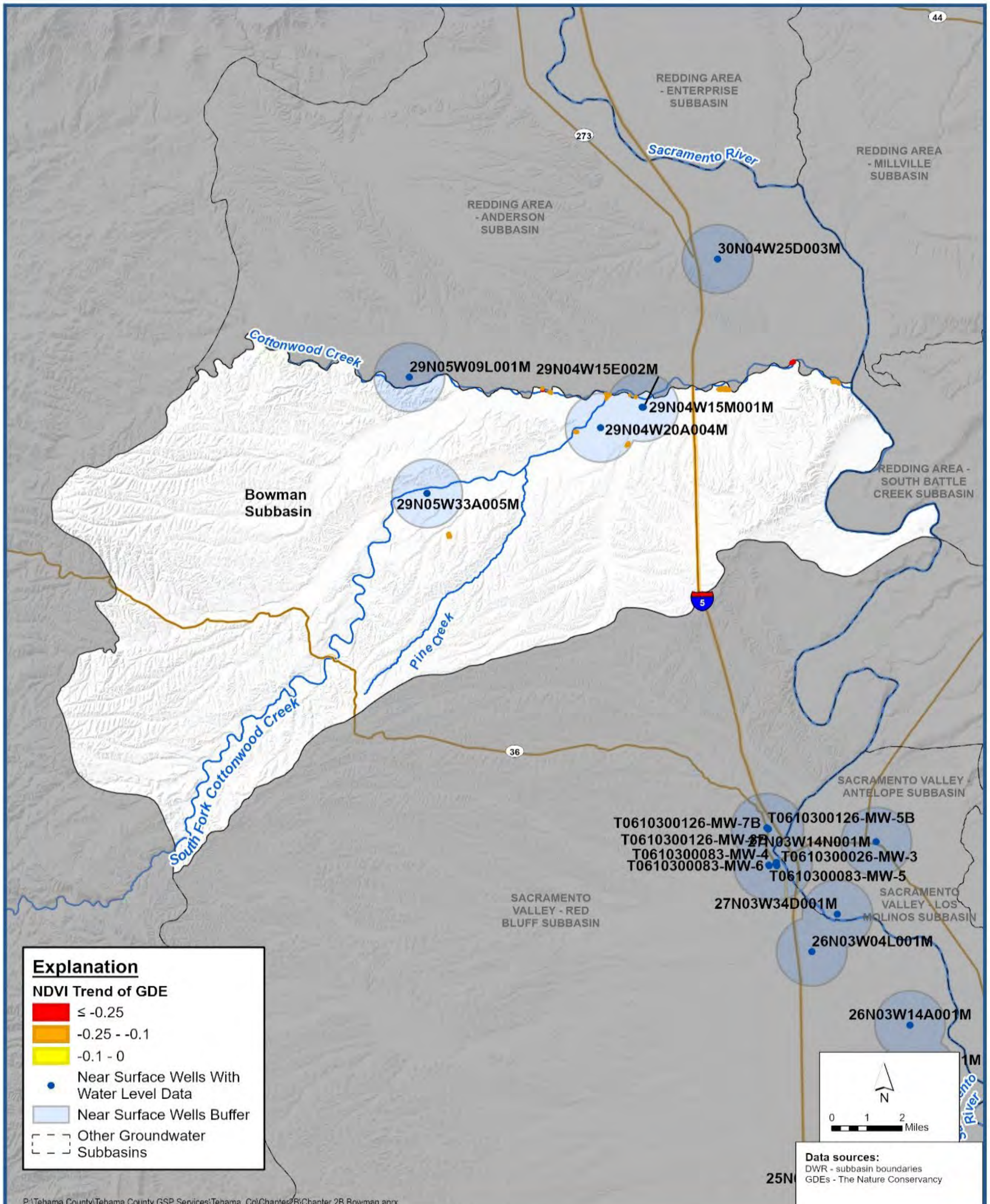
Identified GDEs were then prioritized for future monitoring using two vegetation metrics available at the GDE Pulse web application developed by TNC; Normalized Derived Vegetation Index (NDVI) that indicates vegetation greenness and Normalized Derived Moisture Index (NDMI) that indicates vegetation moisture (Klausmeyer et al., 2019). An annual NDVI value based on summer conditions was assigned to each individual GDE. Then a linear regression was performed to determine the trend of NDVI values between 1990 and 2018 (representative base period of this GSP). A negative trend of NDVI indicates a decrease in vegetation greenness during this period. GDEs with negative NDVI trends were classified as high priority (trend less than -0.1) and low priority (trend between -0.1 and zero) for future monitoring. High priority GDEs cover an area of about 30 acres within the Subbasin

(**Figure 2-53**). In the future, low priority GDEs will be observed outside of the established monitoring program and may be reclassified as high priority depending on future conditions.

High priority GDEs were further evaluated to determine if temporal changes of vegetation metrics and local groundwater levels were correlated. Identifying such correlations would be useful to establish groundwater levels that can sustain GDEs. Only wells that were perforated within the top 100 feet below ground surface (near surface wells) and located within approximately one mile from the GDEs were included in this analysis. Vegetation metrics of high priority GDEs and groundwater levels of four wells that met above criteria (**Figure 2-53**) were analyzed, but three of these wells did not have sufficient water level data to identify correlations. Water levels of the other well (29N04W15E002M in **Figure 2-53**) and vegetation metrics of an adjacent GDE had a very poor (insignificant) correlation (**Figure 2-54**). Considering the lack of groundwater level monitoring close to high priority GDEs at present, installation of shallow groundwater monitoring wells near or within these GDEs is recommended.



Surface water and Shallow Groundwater Monitoring Stations
Groundwater Sustainability Plan
Bowman Subbasin
Figure 2-52



TEHAMA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

LSCE Team

NDVI Trend of GDEs

Groundwater Sustainability Plan
Bowman Subbasin

Figure 2-53

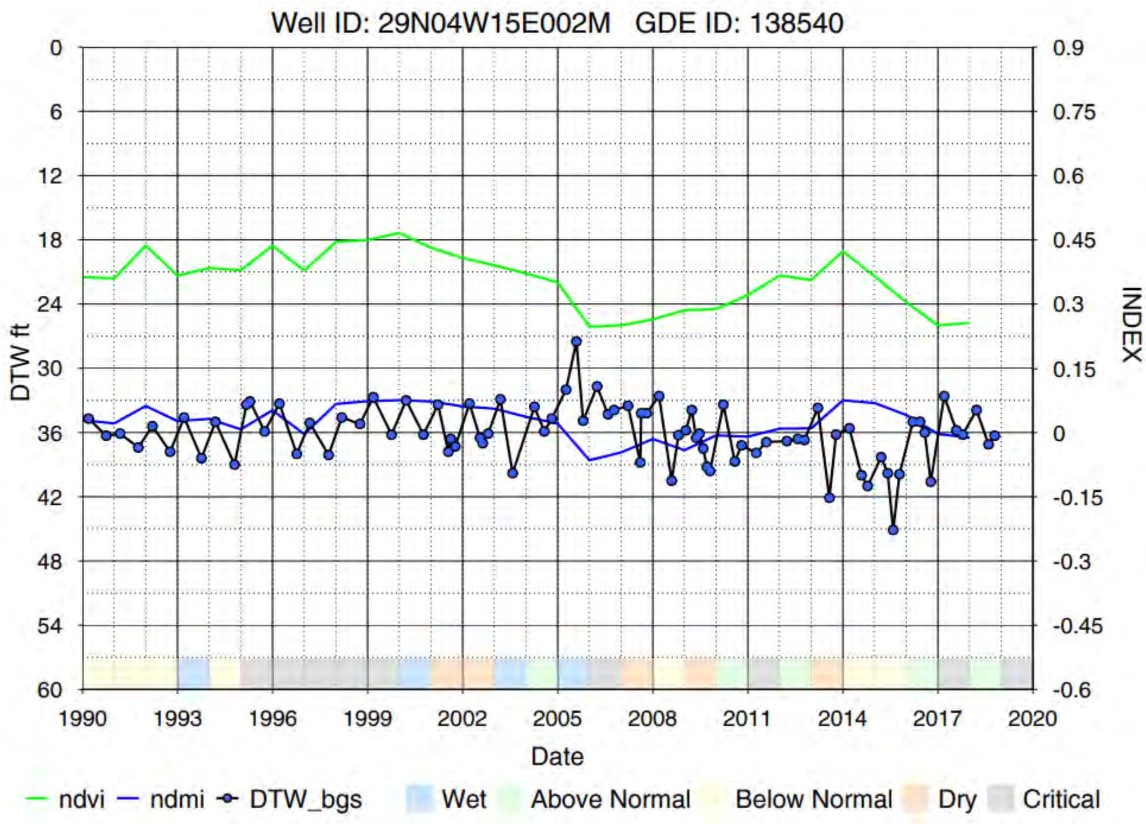


Figure 2-54. Timeseries graph of NDVI and NDMI of a GDE and depth to water at an adjacent well

2.2.3 Basin Setting Summary

In the Bowman Subbasin, groundwater generally flows eastward towards the Sacramento River with downward vertical movement in the Upper Aquifer driven by natural recharge. Water typically follows topography flowing from high elevation areas in the south and west toward low elevations near Cottonwood Creek and the Sacramento River in the north and east. Recharge contributions to the deeper geologic formations occurs where the formations outcrop at the surface. Aquifer recharge also generally occurs along Cottonwood Creek, the South Fork of Cottonwood Creek, and the Sacramento River, as well as perennial streams where saturated hydraulic conductivity of soils is high. Proximal to these surface water features groundwater likely flows outward when groundwater elevations are lower (losing conditions). Discharge from the groundwater also occurs in these areas when the water table rises to the ground surface elevation (gaining conditions). The larger source of discharge is likely from production of water wells. A portion of applied water (irrigation) also contributes to recharge. There is a two-aquifer system in the Subbasin with unconfined to semi-confined conditions in the Upper Aquifer and semi-confined to confined conditions in the Lower Aquifer.

The concepts discussed in Section 2.2 will be further discussed and refined in Chapter 2.3, the Water Budget. Section 2.2 provided basic concepts needed to understand the geometry of the Subbasin, distribution and character of water bearing material, distribution and movement of groundwater and surface water, and historic and current groundwater conditions including water quality. Basic physical Properties of the Subbasin include:

- The Bowman Subbasin is bounded to the north by Cottonwood Creek, to the east by the Sacramento River, to the south by the Red Bluff Arch, and to the west by the Coast Ranges Geologic Province.
- Fresh water occurs as groundwater to a maximum depth of over -1,200 ft msl in the west of the Subbasin.
- The bottom of the Subbasin is defined as the base of the post-Eocene continental deposits.
- The more recent geologic history is dominated by fluvial and alluvial deposition.
- The major water bearing formations are the Tuscan and Tehama Formations with some contribution from the shallower Quaternary sedimentary deposits.
- The ground surface generally slopes from the west to east with steeper slopes in the east of the Subbasin.
- Widespread presence of contaminants at undesirable levels have not been reported in groundwater samples in the Subbasin.
- The Bowman Subbasin has little to no reported evidence of subsidence, with recent rates of -0.02 feet/year or less.

Based on available data, a two-aquifer system is defined in the Subbasin. Groundwater conditions in the Subbasin include:

- The Upper Aquifer is defined as model layers 1-5 (approximately 350-450 ft bgs) and the Lower Aquifer is defined as model layers 6-9. The model layers will be further discussed in Chapter 2B.
- Recharge of the Subbasin primarily occurs from the flow of Cottonwood Creek, the South Fork of Cottonwood Creek, the Sacramento River and the other streams and tributaries in the Subbasin.
- Subsurface geologic formations can be recharged directly where they outcrop in the Subbasin.
- Groundwater contour maps of the Upper Aquifer indicate an easterly general flow from the elevated areas of the valley towards Cottonwood Creek and the Sacramento River in the valley floor.
- Horizontal groundwater gradient magnitude ranges from about 16 ft/mile to 18 ft/mile in the eastern half of the Subbasin, and data are not available to estimate the gradient in the western half.
- Seasonal high-water levels in the Upper Aquifer during wet periods range between about 20 and 190 ft bgs, with shallower depths (about 20 – 30 bgs) close to the northeastern boundary of the Subbasin.
- Depth to water in the Lower Aquifer ranges from about 40 ft bgs to 140 ft in the northeastern portion of the Subbasin, and historical data are not available from other areas.
- Seasonal water fluctuations, as well as fluctuations between dry and wet climatic periods, are generally less than five feet and 10 feet in the Upper Aquifer and Lower Aquifer, respectively.
- Vertical hydraulic gradient within the Upper Aquifer, as well as between the Upper Aquifer and Lower Aquifer consistently remains downward (0.01 to 0.06).
- Direction of the vertical gradient in the Lower Aquifer can change from downward (up to 0.01) to upward (up to 0.02) at different times.
- Wells with long-term water level data show stable groundwater levels in the Subbasin.
- At present, groundwater quality in the Subbasin is good with no widespread presence of contaminants at undesirable levels.

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FINAL REPORT

Bowman Subbasin

Sustainable Groundwater Management Act

Groundwater Sustainability Plan (Chapter 2C Water Budget)

January 2022

Prepared For:

Tehama County Flood Control and Water Conservation District

Prepared By:

Luhdorff & Scalmanini, Consulting Engineers

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Appendix 2-J Tehama Integrated Hydrologic Model Documentation Report

Appendix 2-K Detailed Water Budget Results

LIST OF ACRONYMS & ABBREVIATIONS

ACID	Anderson-Cottonwood Irrigation District
af	Acre-feet
AN	Above normal Sacramento Valley water year type
AWMP	Agricultural Water Management Plan
BMP	Best Management Practice
BN	Below normal Sacramento Valley water year type
C	Critical (dry) Sacramento Valley water year type
CCR	California Code of Regulations
CVP	Central Valley Project
D	Dry Sacramento Valley water year type
DWR	Department of Water Resources
ET	Evapotranspiration
GMP	Groundwater Management Plan
GSP	Groundwater Sustainability Plan
GWS	Groundwater System
Maf	Million acre-feet
SWS	Surface Water System
taf	Thousand acre-feet
Tehama IHM	Tehama Integrated Hydrologic Model
UWMP	Urban Water Management Plan
W	Wet Sacramento Valley water year type
WMP	Water Management Plan

2 SUBBASIN PLAN AREA AND BASIN SETTING (REG. § 354.8)

2.1 Description of Plan Area

2.2 Basin Setting

2.3 Water Budget (Reg. § 354.18)

An integral component of the GSP is the quantification of the water budget, which is an accounting of water movement and storage between the different systems of the hydrologic cycle (**Figure 2-55**). The Subbasin water budget includes an accounting of all inflows and outflows to the Subbasin. The difference between the volume of inflow and outflow to the Subbasin is equal to the change in storage as illustrated in **Equation 2-1**.

$$\text{Inflows} - \text{Outflows} = \text{Change in Storage}$$

Equation 2-1. Water Budget Equation

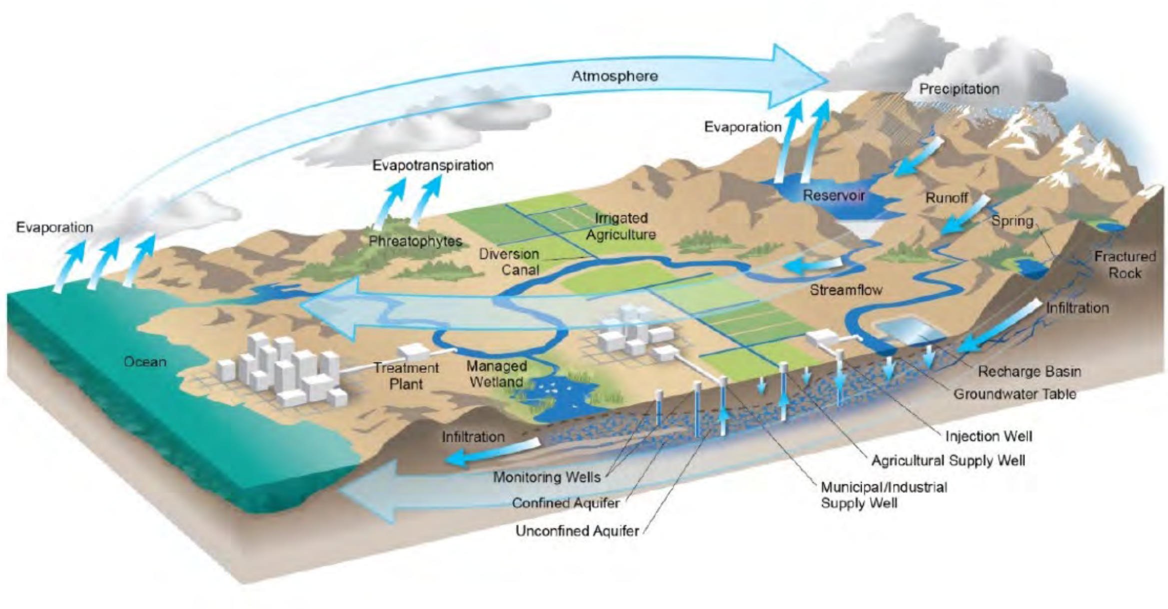
DWR has published guidance and Best Management Practice (BMP) documents related to the development of GSPs, including Water Budget BMPs (DWR, 2016a). The Water Budget BMPs recommend a water budget accounting structure, or conceptual model, which distinguishes the subbasin surface water system (SWS) and groundwater system (GWS). The SWS represents the land surface down to the bottom of plant root zone[1], 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. The complete Subbasin water budget is a product of the interconnected SWS and GWS water budgets. The lateral and vertical boundaries of the Subbasin are described in **Section 2.2** of the GSP.

Consistent with these BMPs, this section presents the methodology and results for the historical, current, and projected water budgets of the Bowman Subbasin. The water budgets were developed through application of the Tehama Integrated Hydrologic Model (Tehama IHM), a numerical groundwater flow model developed for the Subbasin area that characterizes surface water and groundwater movement and storage across the entire Subbasin, including extending into areas extending outside of the Subbasin. The Tehama IHM is an integrated groundwater and surface water model developed for the purpose of conducting sustainability analyses within Tehama County, including for the Bowman Subbasin. The model utilized foundational elements of DWR's SVSim regional model for the Sacramento Valley (DWR, 2021) and was refined locally for improved application in the Subbasin area. Key model refinements made during development of the Tehama IHM include, but are not limited to, extending of the simulation period through water year 2019, refinement of land use conditions based on recent land use mapping information, review and modification to land use crop coefficients based on local remote sensing energy balance data, refinement of surface water supplies and diversions, and enhancements to the sediment textural model used for aquifer parameter. After conducting refinements, the Tehama IHM was calibrated using local groundwater level and streamflow data. The Tehama IHM has a historical simulation period

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

spanning from water year 1985 through 2019, although the calibration period is 1990-2019. Detailed documentation associated with the development of the Tehama IHM is included in **Appendix 2-J.**

This section presents the historical, current, and projected water budget results for the Bowman Subbasin. Water budget results for the SWS and GWS are presented individually and as part of a complete water budget for the Subbasin. This section describes the different water budget components and the results of water budget estimates derived from the Tehama IHM. The section includes discussion of the estimated uncertainties associated with the water budget analysis, data sources, and results with additional details related to these topics also described in the model documentation included as **Appendix 2-J**. The water budget results presented in this section are rounded to two significant digits consistent with the typical uncertainty associated with the methods and sources used in the analysis. Water budget component results may not sum to the totals presented because of rounding.



2.3.1 Water Budget Conceptual Model

A water budget is defined as a complete accounting of all water flowing into and out of a defined volume[2] over a specified period of time. When the water budget is computed for a 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 volume of water stored within the subbasin.

[2] 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.

2.3.1.1 Water Budget Structure

For accounting purposes, the Subbasin's water budget is divided into the surface water system (SWS) and groundwater system (GWS), described above. These systems are referred to as *accounting centers*. Flows between accounting centers and storage within each accounting center are water budget *components*. A schematic of the general water budget accounting structure is provided in **Figure 2-56**.

The conceptual model (or structure) for the Subbasin water budget is presented in **Figure 2-57**, including presentation of terms used in the following section to describe individual aspects of the water budget. The required components for each accounting center are listed in **Table 2-11**, along with the corresponding section of the GSP Regulations (California Code of Regulations Title 23[3] (23 CCR) §354). Separate but related water budgets were prepared for each accounting center that together represent the overall water budget for the Subbasin.

This section discusses the inflows and outflows from each of the SWS and GWS parts of the Subbasin. The water budgets are calculated using the Tehama IHM, which integrates flows between the SWS and GWS. The GWS water budget incorporates all inflows and outflows from the SWS into an accounting of the net effect of the hydrology and water use on groundwater storage in the Subbasin.

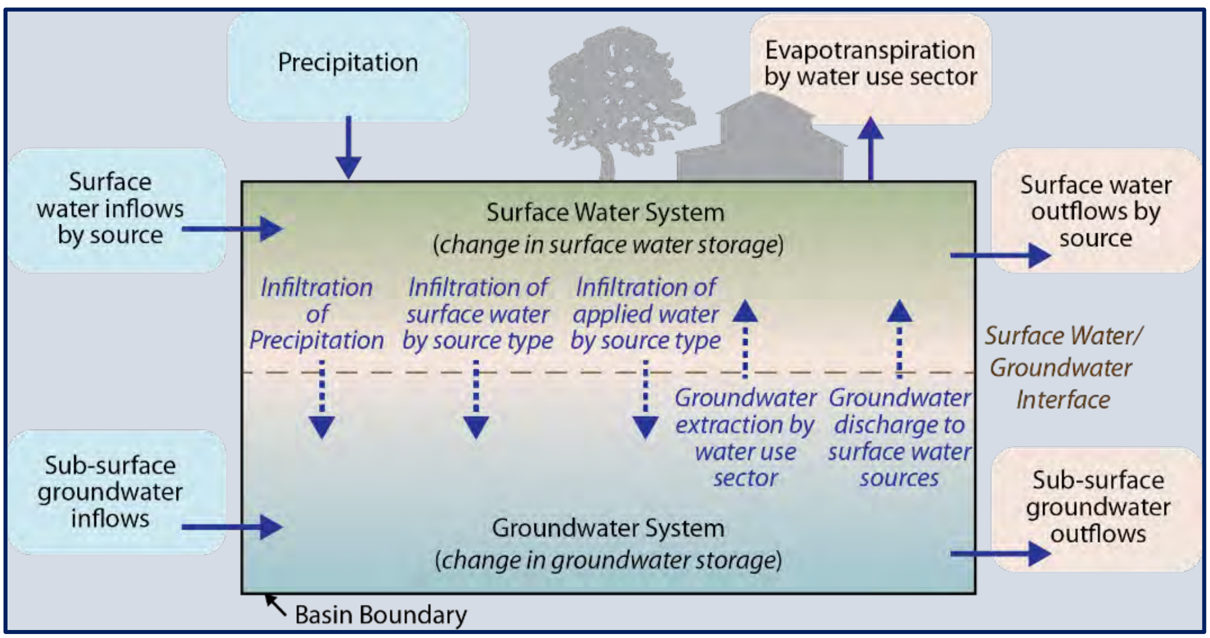
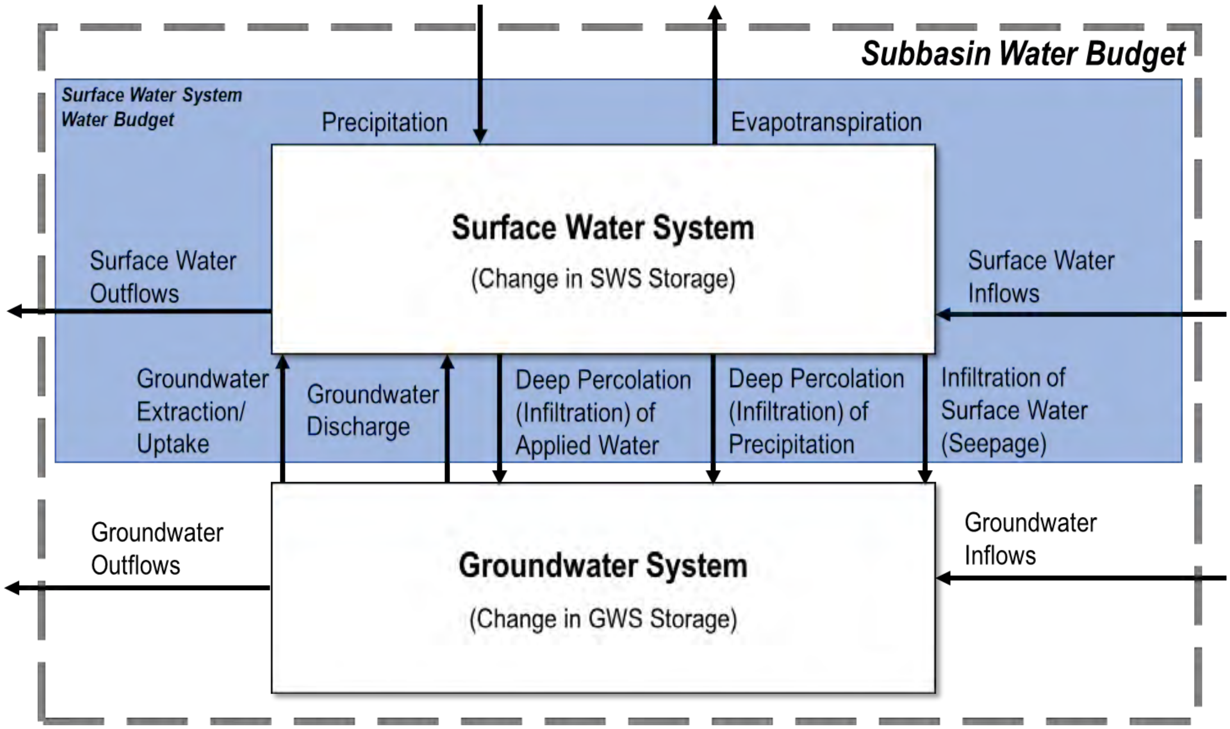


Figure 2-56. Water Budget Accounting Structure (Source: DWR, 2016a)

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



Net Recharge from the SWS =
(Deep Percolation of Applied Water + Deep Percolation of Precipitation + Infiltration of Surface Water) – Groundwater Extraction/Uptake

Figure 2-57. Subbasin Water Budget Conceptual Model

Table 2-11. Water Budget Components by Accounting Center and Associated GSP Regulations

Accounting Center	Water Budget Component (flow direction)	GSP REGULATION SECTION[1]
Basin	Surface Water Inflow[2] (+)	§354.18(b)(1)
	Precipitation (+)	Implied
	Subsurface Groundwater Inflow (+)	§354.18(b)(2)
	Evapotranspiration[3] (-)	§354.18(b)(3)
	Surface Water Outflow[2] (-)	§354.18(b)(1)
	Subsurface Groundwater Outflow (-)	§354.18(b)(3)
	Change in Storage	§354.18(b)(4)
Surface Water System	Surface Water Inflow[2] (+)	§354.18(b)(1)
	Precipitation (+)	Implied
	Groundwater Extraction (+)	§354.18(b)(3)
	Groundwater Discharge (+)	§354.18(b)(3)
	Evapotranspiration[3] (-)	§354.18(b)(3)
	Surface Water Outflow[2] (-)	§354.18(b)(1)
	Infiltration of Applied Water[4,5] (-)	§354.18(b)(2)
	Infiltration of Precipitation[4] (-)	§354.18(b)(2)
	Infiltration of Surface Water[6] (-)	§354.18(b)(2)
	Change in SWS Storage[7]	§354.18(a)
Groundwater System	Subsurface Groundwater Inflow (+)	§354.18(b)(2)
	Infiltration of Applied Water[4,5] (+)	§354.18(b)(2)
	Infiltration of Precipitation[4] (+)	§354.18(b)(2)
	Infiltration of Surface Water[6] (+)	§354.18(b)(2)
	Subsurface Groundwater Outflow (-)	§354.18(b)(3)
	Groundwater Extraction (-)	§354.18(b)(3)
	Groundwater Discharge (-)	§354.18(b)(3)
	Change in GWS Storage	§354.18(b)(4)

1. California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2 Groundwater Sustainability Plans, Article 5 Plan Contents
2. By water source type.
3. Evapotranspiration includes total evapotranspiration and evaporation, by water use sector. Total evapotranspiration includes the combined evaporation from the soil and transpiration from plants, resulting from both applied water and precipitation. In this context, evaporation is the direct evaporation from open water surfaces.
4. Synonymous with deep percolation.
5. Includes infiltration of applied surface water, groundwater, and reused water
6. Synonymous with seepage. Includes infiltration of lakes, streams, canals, drains, and springs.
7. Change in storage of root zone soil moisture, not groundwater.

2.3.2 Water Budget Analysis Periods

Per 23 CCR §354.18, each GSP must quantify the historical, current, and projected water budget conditions for the Subbasin.

2.3.2.1 Historical and Current Water Budget Periods

The historical water budget for the Subbasin must quantify all required water budget components starting with the most recently available information and extending back a minimum of 10 years, or as is sufficient to calibrate and reduce the uncertainty of the water budget (23 CCR § 354.18(c)(2)(B)). The historical water budget period effectively represents long-term average historical hydrologic conditions. The current water budget must include the most recent hydrology, water supply, water demand, and land use information (23 CCR § 354.18(c)(1)). The historical water budget enables evaluation of the effects of historical hydrologic conditions and water demands on the water budget and groundwater conditions within the Subbasin over a period representative of long-term hydrologic conditions. The current water budget presents information on the effects of recent hydrologic and water demand conditions on the groundwater system.

The historical and current water budget periods were selected to evaluate conditions over discrete representative periods considering the following criteria: Sacramento Valley water year type; long-term mean annual water supply; inclusion of both wet and dry periods, antecedent dry conditions, adequate data availability; and inclusion of current hydrologic, cultural, and water management conditions in the Subbasin. Water years, as opposed to calendar years, are used as the time unit for defining analysis, following the DWR standard water year period (October 1 through September 30). Unless otherwise noted, all years referenced in this section are water years.

Based on these criteria, the following periods were identified for presentation of historical and current water budgets:

- **Historical Water Budget Period**: Water years 1990-2018 (29 years) using historical hydrologic, climate, water supply, and land use data.
- **Current Water Budget Periods**: Consideration of five different recent water year periods (listed below) using the historical hydrologic, climate, water supply, and land use data over each period.
  - Recent 10 years (2009-2018)
  - Recent 5 years (2014-2018)
  - Recent 3 years (2016-2018)
  - Recent 1 year (2018)
  - Recent 1 year (2019)

For the historical water budget, the period from 1990-2018 was selected to represent long-term average historical hydrologic conditions following evaluation of precipitation records and DWR Sacramento Valley water year type classification (**Table 2-12**). Further information and discussion of the historical water budget period, including discussion of historical hydrology and the base period selection process, are presented in **Section 2.2** of this GSP. Discussion of the historical water budget water results is included in **Section 2.3.5**

Table2-12. Sacramento Valley Water Year Type Classification during the Historical Water Budget Period (1990-2018)

SACRAMENTO VALLEY WATER YEAR TYPE	ABBREVIATION	NUMBER OF YEARS, 1990-2018	PERCENT TOTAL YEARS, 1990-2018
Wet	W	8	28%
Above Normal	AN	4	14%
Below Normal	BN	5	17%
Dry	D	5	17%
Critical	C	7	24%
Total		29	100%

For consideration in estimating the current water budget, the results for several recent periods were presented, including recent 1-year, 3-year, 5-year, and 10-year periods. These various periods result in widely varied inflows and outflows, much of which is attributed to varied precipitation and water supplies in individual years (see results in **Section 2.3.6**). Although the model simulations were run for the 1990-2072 period, results for 2019 are only shown in the current water budget comparison table for the purpose of considering variability in water budget over different recent time periods. The water budget for year 2019 is not explicitly included in the historical, current, or projected water budgets for the Subbasin although it was simulated in the model to span the years between historical (1990-2018) and projected (2022-2072) water budget periods. Details of model inputs are presented in **Appendix 2-J**. Because of the year-to-year variability in water budget results, the current water budget summarizes results from the various recent periods considered to provide an appropriate and reasonable representation of the current water budget based on recent conditions.

2.3.2.2 Projected 50-Year Hydrology and Water Budget Period (§354.18c3)

The projected water budget is intended to evaluate the effects of anticipated future conditions of hydrology, water supply availability, and water demand over a 50-year GSP planning period on the Subbasin water budget and groundwater conditions. The projected water budget incorporates consideration of potential climate change and water supply availability scenarios and evaluation of the need for and benefit of any projects and management actions to be implemented in the Subbasin to maintain or achieve sustainability. The 50-year projected water budget uses hydrologic conditions representative of the most recent 50 years of hydrology in the Subbasin, with adjustments applied in scenarios for evaluating the water budget under climate change and/or altered water supply and demand conditions.

To evaluate projected water budgets, fifty years of future hydrology inputs to the Tehama IHM were developed through consideration of the historical hydrology from 1968 to 2018. Because of the availability of higher quality data and characterization of conditions in the Subbasin during more recent years spanning the historical base period (1990-2018), the projected water budget analyses used surrogate years from the historical period to construct a future hydrology and water budget period representative and consistent with hydrologic conditions over a historical 50-years period from 1968 to 2018. Surrogate years from the historical period were assigned to represent 50 years of future hydrology based on 1) the Sacramento Valley water year index from DWR for each year, 2) mimicking variability (wet and dry) in the historical precipitation conditions in the Subbasin and replicating precipitation consistent with the annual average historical precipitation, and (3) replicating regional streamflow conditions based on flows in the Sacramento River. The frequency of water year types used in the projected hydrology is representative of the 50 years of hydrology for the period 1969-2019 and includes approximately equal proportions of water years with above normal (wet and above normal; 48%) and below normal (below normal, dry, critical; 52%) hydrologic conditions (**Table 2-13**).

The approach and inputs used in development of the projected water budget are described in greater detail in the Tehama IHM documentation included as **Appendix 2-J**.

Table 2-13. Sacramento Valley Water Year Type Classification Over the Projected Water Budget Period (2022-2072)

SACRAMENTO VALLEY WATER YEAR TYPE	ABBREVIATION	NUMBER OF YEARS, 2022-2072	PERCENT TOTAL YEARS, 2022-2072
Wet	W	18	35%
Above Normal	AN	7	14%
Below Normal	BN	7	14%
Dry	D	9	18%
Critical	C	10	20%
Total		51	100%

2.3.3 Surface Water System (SWS) Water Budget Description

Water budgets for the SWS were developed to characterize historical and current conditions in the Subbasin relating to the individual inflows and outflows and overall SWS water budget. The general approach used in the SWS water budget calculations is described in **Section 2.3.3.1**. **Section 2.3.5** presents the results of the historical SWS water budgets within the boundary of the Subbasin and **Section 2.3.6** presents results for current SWS water budget analyses. The analyses and results relating to the projected water budget are presented in **Section 2.3.7** through **2.3.9**. Additional detailed discussion of the procedures and results of the SWS water budgets is included in documentation of the Tehama IHM development and results presented in **Appendix 2-J.**

2.3.3.1 General SWS Water Budget Components and Calculations

SWS inflows and outflows were quantified on a monthly basis, including accounting for any changes in SWS storage, such as changes in water stored in the root zone (**Equation 2-2**).

Total SWS Inflows – Total SWS Outflows = Change in SWS Storage (monthly)

Equation 2-2. Equation for Bowman Subbasin SWS Water Budget Analysis

As shown in **Figure 2-56** and **Table 2-11**, inflows to the SWS include surface water inflows (in various rivers, streams, and canals), precipitation, groundwater extraction (pumping and groundwater uptake), and groundwater discharge to surface water sources (from areas of high groundwater levels). Outflows include evapotranspiration (ET), surface water outflows (in various rivers, streams, and canals), infiltration of applied water (deep percolation from irrigation), infiltration of precipitation (deep percolation from precipitation), and infiltration of surface water (seepage).

The ET outflow component includes the following: ET of applied water (ET from soil and crop surfaces, of water that is derived from applied surface water, groundwater, and reused water); ET of precipitation (ET from soil and crop surfaces, of water that is derived from precipitation); and evaporation from rivers, streams, canals, reservoirs, and other water bodies. 'ET of applied water' differs from 'applied water' in that applied water is the volume of water that is directly applied to the land surface by irrigators (from all water sources), whereas ET of applied water is the volume of that applied water that is consumptively used by crops, vegetation, and soil surfaces.

Change in SWS storage is also depicted in **Figure 2-57** and **Table 2-11**. This represents the change in root zone soil moisture throughout the year. This is different from change in groundwater storage.

Net recharge from the SWS is defined as the total groundwater recharge (total infiltration from all sources) minus groundwater outflows to the surface water system, including both groundwater extraction and groundwater uptake by crops and vegetation.[4] Groundwater discharge to the SWS is not included in the net recharge term but is summarized separately as an exchange between the SWS and GWS. Net recharge from the SWS is a useful metric that equates only the impacts of the SWS on recharge and extraction from the GWS, providing valuable insight to the combined effects of land surface processes on the underlying GWS.

However, it should be recognized that net recharge from the SWS does not account for the complete GWS water budget, including subsurface groundwater flows. Thus, net recharge from the SWS is not meant to evaluate overdraft, but rather is most useful for evaluating how management of the surface layer impacts the GWS in the Subbasin. Net recharge from the SWS does not precisely express the effective availability of recharge in upgradient areas, which would be unable to utilize recharge that occurs in the downgradient

[4] Groundwater discharge to surface water is not included in the calculation of net recharge from the SWS, as groundwater discharge is more dependent on shallow groundwater and soil characteristics along waterways and is much less dependent on the management of the surface layer. Net recharge from the SWS is intended to describe the impacts of the SWS on the GWS, but groundwater discharge is more reflective of the GWS effects on the SWS.

areas of the Subbasins. More information about the net exchanges of surface water and groundwater in the Subbasin is provided below in the describing of components of the GWS water budget.

2.3.3.2 Detailed SWS Water Budget Accounting Centers and Components

To estimate the water budget components required by the GSP Regulations (**Table 2-11**), the SWS water budget accounting center is subdivided into detailed accounting centers representing the Land Surface System, the Canal System, and the Rivers, Streams, and Small Watersheds System (waterways conveying natural flow and surface water supplies into the Subbasin).

The Land Surface System represents inflows and outflows from irrigated and non-irrigated land. The Canals System represents flows through the canals and conveyance systems of diverters with access to surface water. The Rivers, Streams, and Small Watershed Systems represent inflows and outflows through waterways that convey natural flow, upgradient runoff, and drainage.

The Land Surface System is further subdivided into water use sectors, defined in the GSP Regulations as "categories of water demand based on the general land uses to which the water is applied, including urban, industrial, agricultural, managed wetlands, managed recharge, and native vegetation" (23 CCR Section 351(al)). Principal water use sectors in the Subbasin include Agricultural (irrigated crop land and idle agricultural land), Native Vegetation (native and riparian vegetation), and Urban (urban, residential, industrial, and semi-agricultural[5]).

2.3.3.2.1 *SWS Inflows*

2.3.3.2.1.1 Surface Water Inflow by Water Source Type

Per the GSP Regulations, surface inflows must be reported by water source type. According to the Regulations (23 CCR § 351(ak)):

> *"Water source type" represents the source from which water is derived to meet the applied beneficial uses, including groundwater, recycled water, reused water, and surface water sources identified as Central Valley Project, the State Water Project, the Colorado River Project, local supplies, and local imported supplies.*

Major surface water inflows to the Bowman Subbasin are summarized below according to water source type. Additionally, runoff of precipitation from upgradient areas adjacent to the Subbasin represents a potential source of SWS inflow.

Local Supplies

Local supply inflows to the Bowman Subbasin predominantly include runoff from upgradient small watersheds adjacent to the Subbasin and surface inflows along Cottonwood Creek. A portion of the local supplies are diverted by local water rights users for beneficial use within the Subbasin. There are about 140

[5] As defined in the DWR crop mapping metadata, semi-agricultural land includes farmsteads and miscellaneous land use incidental to agriculture (small roads, ditches, etc.) (DWR, 2016b).

riparian diverters in the Subbasin with active water rights. These water rights users divert water primarily from Cottonwood Creek and its tributaries, but there are a few diversions along the Sacramento River.

Central Valley Project

Central Valley Project (CVP) inflows to the Bowman Subbasin primarily include surface water diverted from the Sacramento River by the Anderson-Cottonwood Irrigation District (ACID). ACID holds the third oldest water rights on the Sacramento River and has a total Settlement Contract of more than 100,000 AF per year. While the majority of the ACID service area overlies the Anderson Subbasin, a portion of ACID's CVP supplies are delivered to parcels that overlie the Bowman Subbasin. Surface water is also diverted by small CVP contractors to irrigated land along the Sacramento River.

2.3.3.2.1.2 Precipitation

Precipitation falling on the landscape within the Subbasin is an inflow to the SWS. Precipitation inflows are accounted for by the land use (water use sector) on which they occur.

2.3.3.2.1.3 Groundwater Extraction and Uptake

Groundwater extraction is an inflow to the SWS (an outflow from the GWS). Groundwater extraction is accounted for by agricultural and urban (urban, residential, semi-agricultural, industrial) water use sectors. Urban groundwater pumping includes domestic well pumping. Groundwater uptake is water taken up by plant roots directly from the GWS.

2.3.3.2.1.4 Groundwater Discharge to Surface Water

Groundwater discharging to surface water features can occur where groundwater is very shallow and where groundwater levels are higher than the stage in surface water bodies. Groundwater discharge to surface water represents an inflow to the SWS (an outflow from the GWS).

2.3.3.2.2 SWS Outflows

2.3.3.2.2.1 Evapotranspiration

Evapotranspiration (ET) is accounted for by water use sector (urban, agriculture, native) and according to the source water (applied water or precipitation). ET from land includes from applied water and precipitation sources. Evaporation also occurs from rivers, streams, canals, and drains throughout the Subbasin.

2.3.3.2.2.2 Infiltration

Infiltration (deep percolation) is water that infiltrates below the root zone and recharges the GWS. Infiltration can occur from applied water (e.g., irrigation) or precipitation occurring on the landscape within the Subbasin. Alternatively, infiltration of surface water (stream seepage) can occur from surface water that seeps through the bottom of surface water features and recharges the GWS.

2.3.3.2.2.3 Surface Water Outflow

In the Bowman Subbasin, surface water outflows consist entirely of local supplies that traverse the Subbasin, or that drain from lands within the Subbasin or runoff into the Subbasin from upland areas outside the Subbasin. As described above, substantial local supply volumes enter the Bowman Subbasin along Sacramento River and tributary waterways, although much of this water passes through the Subbasin.

2.3.3.3 SWS Water Budget Overview

Water budget components are defined for each detailed accounting center in **Table 2-14 through Table 2-16**. Within the Land Surface System accounting center, water budget components are also defined for each water use sector. These detailed water budget accounting centers and components are quantified based on the best available data and science, including information from water management plans (WMPs), groundwater management plans (GMPs), agricultural water management plans (AWMPs), urban water management plans (UWMPs), and other sources.

Each detailed accounting center was computed for the Subbasin. The Subbasin boundary SWS water budget components are identified in **Table 2-17**. The water budget includes the crop demands, available water supplies, and other characteristics specific to the Subbasin, including diversions, evaporation, and infiltration of surface water within the Subbasin.

Table 2-14. Land Surface System Water Budget Components

DETAILED ACCOUNTING CENTER	DETAILED COMPONENT	FLOW DIRECTION	DESCRIPTION
	Deliveries	Inflow	Deliveries of surface water supply for use within the Subbasin.
	Groundwater Extraction	Inflow	Groundwater pumping to meet water demands, and groundwater uptake by crops and vegetation.
	Precipitation	Inflow	Direct precipitation on the land surface.
	Reuse	Inflow	Reuse of percolated water from the unsaturated zone[1].
	ET of Applied Water	Outflow	Consumptive use of applied irrigation water.
	ET of Groundwater Uptake	Outflow	Consumptive use of shallow groundwater uptake.
	ET of Precipitation	Outflow	Consumptive use of infiltrated precipitation.
	Net Return Flow	Outflow	Net runoff of applied irrigation water, accounting for reuse[2].
	Runoff of Precipitation	Outflow	Direct runoff of precipitation.
	Infiltration of Applied Water	Outflow	Deep percolation of applied water below the root zone.
	Infiltration of Precipitation	Outflow	Deep percolation of precipitation below the root zone.

[1] "The unsaturated zone is below the land surface system and represents the portion of the basin that receives percolated water from the root zone and either transmits it as deep percolation to the GWS or to reuse within the land surface system, or both." (DWR, 2016a).

[2] Includes tailwater and pond drainage for ponded crops.

Table 2-15. Canal System Water Budget Components

DETAILED ACCOUNTING CENTER	DETAILED COMPONENT	FLOW DIRECTION	DESCRIPTION
Canal System	Diversions	Inflow	Diversions of surface water supply from waterways, a portion of which is delivered and used within the Subbasin.
	Deliveries	Outflow	Deliveries of surface water supply for use within the Subbasin.
	Infiltration of Surface Water (Seepage)	Outflow	Seepage from canals to the GWS.
	Evaporation	Outflow	Direct evaporation from canal water surfaces.
	Spillage	Outflow	Spillage from canals used for conveyance.

Table 2-16. Rivers, Streams, and Small Watersheds System Water Budget Components

DETAILED ACCOUNTING CENTER	DETAILED COMPONENT	FLOW DIRECTION	DESCRIPTION
Rivers, Streams, and Small Watersheds System	Stream Inflows	Inflow	Surface water inflows at the upstream boundary of waterways that traverse the Subbasin; includes natural flow and spillage, drainage, and runoff from canals and land surfaces upgradient of the Subbasin.
	Small Watershed Inflows	Inflow	Surface water inflows of drainage from upgradient small watersheds.
	Groundwater Discharge	Inflow	Discharge from shallow groundwater into rivers and streams.
	Spillage	Inflow	Spillage from canals used for conveyance.
	Stream Outflows	Outflow	Surface water outflows at the downstream boundary of waterways that traverse the Subbasin; includes natural flow and spillage, drainage, and runoff from canals and land surfaces.
	Small Watershed Outflows	Outflow	Surface water outflows of drainage from upgradient small watersheds at the downgradient boundary of the Subbasin.
	Diversions	Outflow	Diversions of surface water supply from waterways, a portion of which is delivered and used within the Subbasin.
	Infiltration of Surface Water (Seepage)	Outflow	Seepage from rivers, streams, and small watershed inflows to the GWS.
	Evaporation	Outflow	Direct evaporation from river and stream water surfaces.

Table 2-17. Subbasin Boundary Surface Water System Water Budget Components

DETAILED ACCOUNTING CENTER	DETAILED COMPONENT	FLOW DIRECTION	DESCRIPTION
Rivers, Streams, and Small Watersheds System	Stream Inflows	Inflow	Surface water inflows at the upstream boundary of waterways that traverse the Subbasin; includes natural flow and spillage, drainage, and runoff from canals and land surfaces upgradient of the Subbasin.
	Small Watershed Inflows	Inflow	Surface water inflows of drainage from upgradient small watersheds.
	Groundwater Discharge	Inflow	Discharge from shallow groundwater into rivers and streams.
Canal System	Diversions *(in select cases)*	Inflow	Diversions of surface water supply from waterways *at a point outside or along the boundary of the Subbasin*, a portion of which is delivered and used within the Subbasin
Land Surface System *Water Use Sectors: Agricultural, Native Vegetation, Urban*	Groundwater Extraction	Inflow	Groundwater pumping to meet water demands, and groundwater uptake by crops and vegetation.
	Precipitation	Inflow	Direct precipitation on the land surface.
	ET of Applied Water	Outflow	Consumptive use of applied irrigation water.
	ET of Groundwater Uptake	Outflow	Consumptive use of shallow groundwater uptake.
	ET of Precipitation	Outflow	Consumptive use of infiltrated precipitation.
	Runoff of Applied Water	Outflow	Direct runoff of applied irrigation water[2].
	Runoff of Precipitation	Outflow	Direct runoff of precipitation.
	Infiltration of Applied Water	Outflow	Deep percolation of applied water below the root zone.
	Infiltration of Precipitation	Outflow	Deep percolation of precipitation below the root zone.
	Change in SWS Storage	Storage	Change in root zone soil moisture throughout the year; (not change in groundwater storage)
Canal System; and Rivers, Streams, and Small Watersheds System	Infiltration of Surface Water (Seepage)	Outflow	Seepage from canals, streams, and small watershed inflows to the GWS.
	Evaporation	Outflow	Direct evaporation from canals, rivers, and streams.
Canal System	Spillage	Outflow	Spillage from canals used for interior conveyance.
Rivers, Streams, and Small Watersheds System	Stream Outflows	Outflow	Surface water outflows at the downstream boundary of waterways that traverse the Subbasin; includes natural flow and spillage, drainage, and runoff from canals and land surfaces.
	Small Watershed Outflows	Outflow	Surface water outflows of drainage from upgradient small watersheds at the downgradient boundary of the Subbasin.

2.3.4 Groundwater System (GWS) Water Budget Description

Water budgets for the GWS were developed to characterize historical and current conditions in the Subbasin utilizing the Tehama IHM for different historical and current time periods described above. **Sections 2.3.5** and **2.3.6** present the results of the historical and current GWS water budgets within the lateral and vertical boundaries of the Subbasin. Discussion of the general approach used in developing model scenarios to evaluate projected GWS water budgets for the Subbasin with the Tehama IHM and the results from these projected water budget analyses are included in **Sections 2.3.7** through **2.3.9**. More detail related to the procedures and results of the GWS water budgets are also included in documentation of the Tehama IHM development presented in **Appendix 2-J.**

2.3.4.1 GWS Water Budget Components and Calculations

Inflows and outflows of the GWS were quantified on a monthly basis, including accounting for any changes in GWS storage (**Equation 2-3**).

Total GWS Inflows – Total GWS Outflows = Change in GWS Storage (monthly)

Equation 2-3. Equation for Bowman Subbasin GWS Water Budget Analysis

As shown in **Figure 2-56** and **Table 2-18**, inflows to the GWS include some of the outflow components from the SWS including infiltration (deep percolation) of precipitation and applied water and infiltration (seepage) of surface water. Additional GWS inflows include lateral subsurface groundwater inflows from adjacent subbasins and from adjacent upland or foothill areas outside the Subbasin (small watersheds). GWS outflows include exchanges with the SWS including groundwater discharge to surface waterways, groundwater extraction through pumping, and root water uptake by plants occurring directly from shallow groundwater. Lateral subsurface groundwater flows to adjacent subbasins represent additional GWS outflows. Water budget components representing exchanges between the GWS and the SWS are also included in discussions and presentations of the SWS conceptual water budget and results.

2.3.4.1.1 *Lateral Subsurface Flows*

Subsurface groundwater flows to and from the Bowman Subbasin occur between the Anderson Subbasin to the north, the Red Bluff Subbasin to the south, and the South Battle Creek Subbasin to the east. Additional subsurface groundwater inflows occur from the upland (small watershed) areas adjoining the Bowman Subbasin.

2.3.4.1.2 *Deep Percolation From the SWS*

Deep percolation from the SWS includes infiltration of water below the root zone (deep percolation) from precipitation and applied water. These two water budget components represent inflows to the GWS and are also included in the SWS water budget as outflows from the SWS.

2.3.4.1.3 *Net Stream Seepage/Groundwater Discharge to Surface Water*

The flow of water between the GWS and SWS through seepage of water from streams and canals and groundwater discharging into streams is discussed as part of the SWS water budget. These components are combined in the GWS water budget as a net volume of stream seepage. Positive total net seepage values represent a net inflow of water from the SWS to the GWS via stream and canal seepage indicating that the overall volume of stream seepage is greater than the volume of any groundwater discharging into surface waterways. Negative net seepage values represent a net outflow of groundwater from the GWS to the SWS through groundwater discharge to surface water. When net seepage is negative, it means that more groundwater is discharging into the surface waterways than is seeping from surface waterways into the GWS.

2.3.4.1.4 *Groundwater Extraction and Uptake*

Groundwater extractions and groundwater uptake are exchanges that occur between the GWS and the SWS and represent an outflow from the GWS. Groundwater extraction from the GWS occurs through groundwater pumping to meet water demands for urban and agricultural needs whereas groundwater uptake occurs through uptake of water by plants directly from the GWS.

2.3.4.2 GWS Water Budget Overview

Change in GWS storage as represented by change in groundwater storage is also depicted in **Figure 2-56** and **Table 2-18**. The change in groundwater storage represents the total change in the volume of water in storage in the groundwater system as a result of exchanges between the GWS and the SWS and the balance of all inflows and outflows of the GWS. The change in groundwater storage is directly related to changes in water levels in the groundwater system, both of which are sustainability indicators to be considered during development of a sustainable yield for the Subbasin. Each of the detailed components of the Subbasin boundary GWS water budget are identified in **Table 2-18** and were computed for the Subbasin to develop a complete GWS water budget. The HCM discussed in **Section 2.2** identifies two principal aquifers within the GWS: an Upper Aquifer and Lower Aquifer. Vertical groundwater flow does occur between these aquifers and change in storage of the entire GWS and also within each principal aquifer zone are considerations for sustainable groundwater management.

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Table 2-18. Subbasin Boundary Groundwater System Water Budget Components

ACCOUNTING CENTER	DETAILED COMPONENT	FLOW DIRECTION	DESCRIPTION
Groundwater System	Lateral Subsurface Groundwater Flows Between Adjacent Subbasins	Inflow	Lateral subsurface groundwater inflow from adjacent subbasin.
	Lateral Subsurface Groundwater Flows Between Adjacent Upland or Foothill Areas	Inflow	Lateral subsurface groundwater inflow from adjacent upland or foothill areas.
	Infiltration of Surface Water (Seepage)	Inflow	Seepage from canal, streams, and small watershed inflows from the SWS.
	Infiltration (Deep Percolation) of Applied Water	Inflow	Deep percolation of applied water below the root zone from the SWS.
	Infiltration (Deep Percolation) of Precipitation	Inflow	Deep percolation of precipitation below the root zone from the SWS.
	Lateral Subsurface Groundwater Flows Between Adjacent Subbasins	Outflow	Lateral subsurface groundwater outflow to adjacent subbasin.
	Groundwater Extraction	Outflow	Groundwater pumping to meet water demands, and groundwater uptake by crops and vegetation.
	Groundwater Discharge	Outflow	Discharge from shallow groundwater into rivers and streams.
	Vertical Subsurface Groundwater Flows within the GWS	Storage	Vertical subsurface groundwater flows between the Upper and Lower Aquifers within the GWS
	Change in GWS Storage	Storage	Change in volume of water stored within the groundwater system, representative of total accrual or depletion of groundwater storage.

2.3.5 Historical Water Budget

The following section summarizes the analyses and results relating to the historical SWS water budget for the Subbasin. Detailed descriptions and presentation of results for each of the individual water budget components, and the processes and data sources used in their development are included in **Appendices 2-J and 2-K**.

2.3.5.1 Land Use

Characterizing historical land use is foundational for accurately quantifying how and where water is beneficially used. Land use areas are also used to distinguish the water use sector in which water is consumed, as required by the GSP Regulations. **Figure 2-58** and **Table 2-19** summarize the annual land use areas over the historical period (1990-2018) in the Bowman Subbasin by water use sector, as defined by the GSP Regulations (23 CCR § 351(al)). In the Bowman Subbasin, water use sectors include agricultural, urban, and native vegetation land uses. The urban water use sector covers all urban, residential, industrial, and semi-agricultural[6] land uses. See Plan Area section 2.1.1.2, Land Use.

Agricultural, urban, and native vegetation land uses covered an average of 5,800 acres, 1,500 acres, and 115,100 acres, respectively, between 1990 and 2018. Since 1990, approximately 1,200 acres of native vegetation in the Bowman Subbasin has been converted to agricultural and urban land uses.

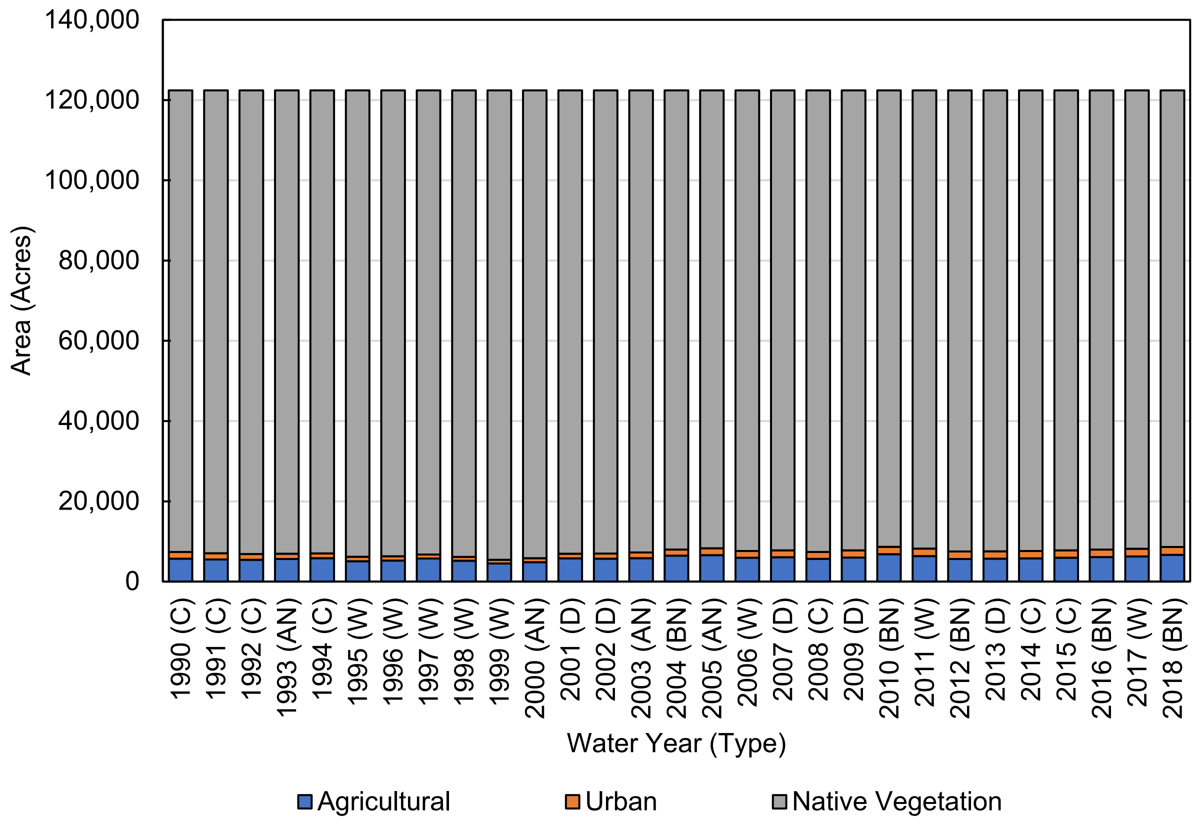

Figure 2-58. Bowman Subbasin Land Use Areas, by Water Use Sector

[6] As defined in the DWR crop mapping metadata, semi-agricultural land use subclasses include farmsteads, livestock feed lot operations, dairies, poultry farms, and miscellaneous semi-agricultural land use incidental to agriculture (small roads, ditches, non-planted areas of cropped fields (DWR, 2016b).

Table 2-19. Bowman Subbasin Land Use Areas, by Water Use Sector

WATER YEAR (TYPE)	AGRICULTURAL	URBAN[1]	NATIVE VEGETATION	TOTAL
1990 (C)	5,713	1,670	115,042	122,425
1991 (C)	5,506	1,559	115,360	122,425
1992 (C)	5,430	1,432	115,563	122,425
1993 (AN)	5,613	1,324	115,488	122,425
1994 (C)	5,821	1,208	115,396	122,425
1995 (W)	5,070	1,111	116,245	122,425
1996 (W)	5,219	1,095	116,110	122,425
1997 (W)	5,728	1,033	115,664	122,425
1998 (W)	5,178	973	116,274	122,425
1999 (W)	4,523	923	116,979	122,425
2000 (AN)	4,817	1,019	116,589	122,425
2001 (D)	5,775	1,167	115,482	122,425
2002 (D)	5,692	1,293	115,440	122,425
2003 (AN)	5,828	1,418	115,179	122,425
2004 (BN)	6,448	1,523	114,453	122,425
2005 (AN)	6,601	1,683	114,141	122,425
2006 (W)	5,936	1,683	114,805	122,425
2007 (D)	6,054	1,719	114,652	122,425
2008 (C)	5,671	1,711	115,043	122,425
2009 (D)	6,004	1,757	114,663	122,425
2010 (BN)	6,813	1,825	113,787	122,425
2011 (W)	6,357	1,842	114,226	122,425
2012 (BN)	5,626	1,869	114,930	122,425
2013 (D)	5,701	1,858	114,866	122,425
2014 (C)	5,798	1,839	114,788	122,425
2015 (C)	5,935	1,852	114,638	122,425
2016 (BN)	6,108	1,860	114,457	122,425
2017 (W)	6,263	1,917	114,245	122,425
2018 (BN)	6,663	1,947	113,815	122,425
Average (1990-2018)	5,789	1,521	115,115	122,425

[1] Area includes land classified as urban, residential, industrial, and semi-agricultural.

Agricultural land uses are further detailed in **Figure 2-59** and Table **2-20**. Historically, irrigated pasture has been the predominant agricultural land use in the Bowman Subbasin. Other irrigated crops include mainly alfalfa, grain, and various orchard crops, especially walnuts, almonds, and prunes. Flood irrigation is typically used to support pasture, alfalfa, and grain crops in the Bowman Subbasin.

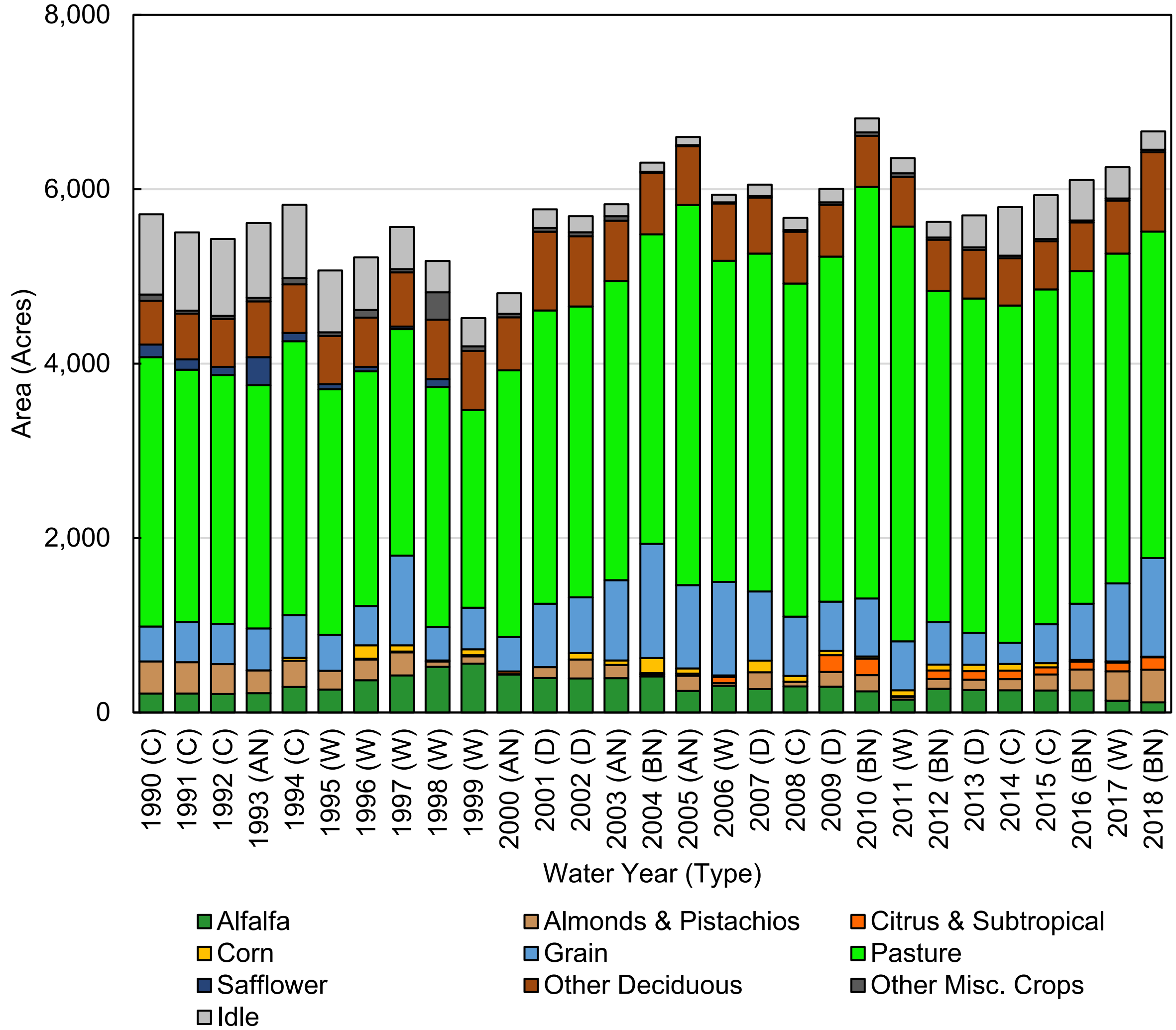

Figure 2-59. Bowman Subbasin Agricultural Land Use Areas

Table 2-20. Bowman Subbasin Agricultural Land Use Areas (acres)

WATER YEAR (TYPE)	ALFALFA	ALMONDS & PISTACHIOS	CITRUS & SUBTROPICAL	CORN	GRAIN	PASTURE	PONDED (RICE)	SAFFLOWER	OTHER DECIDUOUS[1]	OTHER MISC. CROPS[2]	IDLE	TOTAL
1990 (C)	217	369	0	0	400	3,090	0	144	503	71	919	5,713
1991 (C)	217	361	0	0	463	2,890	0	119	523	35	898	5,506
1992 (C)	214	341	0	0	461	2,853	0	95	549	36	881	5,430
1993 (AN)	223	261	0	0	479	2,790	0	322	639	42	856	5,613
1994 (C)	294	300	0	33	491	3,139	0	96	556	71	841	5,821
1995 (W)	262	217	0	0	413	2,814	1	59	552	43	708	5,070
1996 (W)	371	237	9	154	450	2,692	0	51	564	86	604	5,219
1997 (W)	426	264	9	72	1,028	2,597	161	29	621	37	483	5,728
1998 (W)	525	61	2	9	382	2,754	0	90	682	314	360	5,178
1999 (W)	561	84	13	67	478	2,267	0	0	677	54	323	4,523
2000 (AN)	434	5	32	0	393	3,060	10	0	608	40	234	4,817
2001 (D)	397	124	0	0	727	3,363	5	0	901	44	214	5,775
2002 (D)	390	219	0	73	638	3,337	0	0	804	46	185	5,692
2003 (AN)	394	152	0	51	920	3,428	0	2	691	53	137	5,828
2004 (BN)	412	25	16	172	1,310	3,549	144	0	704	14	103	6,448
2005 (AN)	248	173	25	59	955	4,359	2	0	674	14	92	6,601
2006 (W)	307	30	73	15	1,073	3,682	0	0	656	16	85	5,936
2007 (D)	271	191	0	134	793	3,875	0	0	640	19	132	6,054
2008 (C)	300	52	0	68	680	3,819	0	0	593	20	139	5,671
2009 (D)	296	170	192	49	563	3,958	0	0	593	30	153	6,004
2010 (BN)	243	186	188	25	666	4,718	0	0	585	41	161	6,813
2011 (W)	148	32	8	69	561	4,754	0	0	570	42	174	6,357
2012 (BN)	272	112	97	69	487	3,798	0	0	585	27	179	5,626
2013 (D)	259	117	100	72	368	3,832	1	0	558	29	367	5,701
2014 (C)	256	127	97	78	242	3,867	1	0	540	32	557	5,798
2015 (C)	253	183	82	49	445	3,841	2	0	553	27	502	5,935
2016 (BN)	254	239	89	21	644	3,813	1	0	558	24	464	6,108
2017 (W)	135	337	98	15	895	3,782	12	0	605	26	357	6,263
2018 (BN)	117	374	144	6	1,132	3,741	0	0	911	28	211	6,663
Average (1990-2018)	300	184	44	47	639	3,464	12	35	627	47	390	5,789

[1] Includes primarily walnuts and prunes.
[2] Area includes land classified as cotton, cucurbits, dry beans, onions & garlic, potatoes, sugar beets, tomatoes, vineyards, other field crops, and other truck crops.

2.3.5.2 Historical Surface Water System Water Budget Summary

Annual inflows, outflows, and change in SWS root zone storage during the historical water budget period (1990-2018) are summarized in **Figure 2-60** and **Table 2-21**. Inflows in **Figure 2-60** are shown as positive values, while outflows and change in SWS root zone storage are shown as negative values. Review of the variability in component volumes across years provides insight into the impacts of hydrology on the SWS water budget.

Of particular note in the historical SWS water budget results are the volume of precipitation that makes up a large part of the Subbasin SWS inflows averaging about 290 taf per year over the historical period. By comparison, other SWS inflows in the Subbasin are relatively smaller. Surface water inflows average about 81 taf per year. Groundwater extraction and uptake represents a relatively small SWS inflow averaging about 9.1 taf per year, and groundwater discharge to surface water is negligible over the historical water budget period.

Among the outflows from the Subbasin SWS, ET of precipitation makes up a large fraction of the total Subbasin SWS outflows averaging about 160 taf per year over the historical period. The surface water outflows total about 110 taf per year on average, a value that corresponds with the large volumes of precipitation and surface water inflow (a total of about 370 taf per year). By comparison, other SWS outflows in the Subbasin are relatively smaller, with values for deep percolation of precipitation about 44 taf per year and infiltration (seepage) of surface water about 43 taf per year on average. ET of applied water, and deep percolation of applied water are about 11, 8.6, and 10.5 taf per year on average, respectively. The outflows of ET of groundwater uptake and evaporation from surface water average about 3.0 and 0.7 taf per year, respectively.

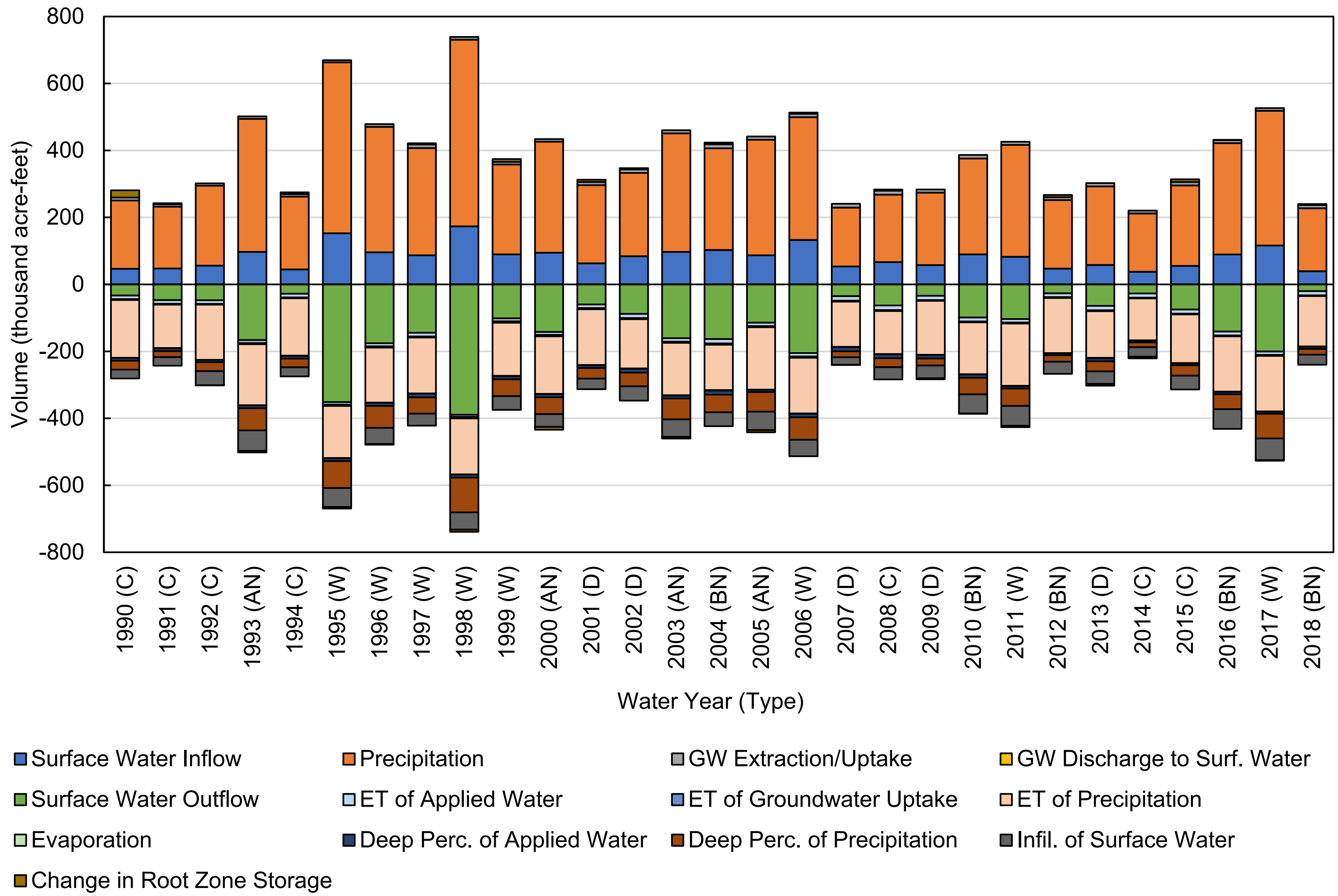

Figure 2-60. Bowman Subbasin Surface Water System Historical Water Budget, 1990-2018

Table 2-21. Bowman Subbasin Surface Water System Historical Water Budget, 1990-2018 (acre-feet)

WATER YEAR (TYPE)	INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
	SURFACE WATER INFLOW	PRECIPI-TATION	GROUND-WATER EXTRACTION / UPTAKE	GROUND-WATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUND-WATER UPTAKE	ET OF PRECIPI-TATION	EVAPO-RATION	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPI-TATION	INFIL. OF SURFACE WATER	
1990 (C)	47,000	200,000	8,600	0	33,000	11,000	3,000	170,000	330	7,900	27,000	26,000	-22,000
1991 (C)	48,000	180,000	7,300	0	47,000	11,000	2,300	130,000	330	8,400	18,000	26,000	-3,200
1992 (C)	56,000	240,000	7,100	0	47,000	11,000	2,200	160,000	330	6,800	27,000	42,000	620
1993 (AN)	97,000	400,000	7,200	0	170,000	9,200	3,100	180,000	330	8,700	66,000	61,000	5,100
1994 (C)	45,000	220,000	7,600	0	28,000	11,000	2,400	170,000	320	8,400	26,000	27,000	-5,100
1995 (W)	150,000	510,000	6,700	0	350,000	8,000	3,300	160,000	390	8,400	80,000	57,000	4,600
1996 (W)	96,000	370,000	8,200	0	180,000	9,200	3,600	160,000	490	9,000	66,000	48,000	2,100
1997 (W)	87,000	320,000	10,000	0	140,000	11,000	3,500	170,000	600	11,000	49,000	35,000	-3,900
1998 (W)	170,000	560,000	8,000	0	390,000	6,900	4,400	170,000	500	8,900	100,000	52,000	6,500
1999 (W)	90,000	270,000	7,700	0	100,000	8,800	4,300	160,000	740	9,500	50,000	41,000	-8,800
2000 (AN)	95,000	330,000	7,800	0	140,000	8,800	4,100	170,000	710	9,200	50,000	38,000	8,600
2001 (D)	63,000	230,000	9,300	0	60,000	11,000	3,300	170,000	760	7,900	32,000	31,000	-7,100
2002 (D)	84,000	250,000	11,000	0	88,000	13,000	3,400	150,000	850	11,000	41,000	43,000	-3,700
2003 (AN)	97,000	350,000	9,000	0	160,000	10,000	3,500	160,000	780	8,500	63,000	52,000	4,600
2004 (BN)	100,000	300,000	12,000	0	160,000	13,000	3,700	140,000	970	12,000	53,000	41,000	-4,600
2005 (AN)	87,000	340,000	9,800	0	110,000	9,900	3,600	190,000	780	6,300	58,000	55,000	6,700
2006 (W)	130,000	370,000	9,800	0	200,000	10,000	4,100	170,000	830	10,000	67,000	49,000	-3,700
2007 (D)	54,000	180,000	11,000	0	35,000	13,000	3,100	130,000	970	12,000	18,000	23,000	170
2008 (C)	66,000	200,000	12,000	0	63,000	14,000	2,900	130,000	960	11,000	27,000	36,000	-4,000

WATER YEAR (TYPE)	INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
	SURFACE WATER INFLOW	PRECIPITATION	GROUNDWATER EXTRACTION / UPTAKE	GROUNDWATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUNDWATER UPTAKE	ET OF PRECIPITATION	EVAPORATION	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPITATION	INFIL. OF SURFACE WATER	
2009 (D)	58,000	220,000	9,300	0	34,000	13,000	2,400	160,000	950	10,000	21,000	38,000	2,600
2010 (BN)	90,000	290,000	10,000	0	99,000	12,000	2,700	150,000	890	9,800	49,000	57,000	1,300
2011 (W)	83,000	330,000	9,400	0	100,000	10,000	3,200	190,000	760	7,000	52,000	59,000	4,000
2012 (BN)	47,000	200,000	8,300	0	27,000	11,000	2,300	160,000	820	6,100	19,000	36,000	-7,000
2013 (D)	58,000	230,000	10,000	0	64,000	14,000	2,300	140,000	960	9,200	30,000	37,000	5,600
2014 (C)	38,000	170,000	8,700	0	27,000	13,000	1,700	130,000	820	5,400	14,000	28,000	4,800
2015 (C)	55,000	240,000	11,000	0	75,000	13,000	1,700	150,000	770	5,900	31,000	42,000	-7,900
2016 (BN)	89,000	330,000	8,900	0	140,000	12,000	2,300	170,000	830	6,900	44,000	59,000	-710
2017 (W)	120,000	400,000	8,200	0	200,000	10,000	2,800	170,000	760	6,000	73,000	65,000	1,700
2018 (BN)	39,000	190,000	9,700	0	20,000	13,000	1,900	150,000	820	6,300	17,000	30,000	-3,000
Average (1990-2018)	81,000	290,000	9,100	0	110,000	11,000	3,000	160,000	700	8,600	44,000	43,000	-870
1990-2018 W	120,000	390,000	8,600	0	210,000	9,300	3,700	170,000	630	8,800	68,000	51,000	300
1990-2018 AN	94,000	360,000	8,500	0	150,000	9,600	3,500	170,000	650	8,200	59,000	52,000	6,300
1990-2018 BN	74,000	260,000	9,900	0	90,000	12,000	2,600	150,000	870	8,300	37,000	45,000	-2,800
1990-2018 D	63,000	220,000	10,000	0	56,000	13,000	2,900	150,000	900	10,000	28,000	34,000	-480
1990-2018 C	51,000	210,000	8,800	0	46,000	12,000	2,300	150,000	550	7,700	24,000	32,000	-5,200

2.3.5.3 Historical Groundwater Budget Summary

Summarized results for major components of the historical water budget as they relate to the GWS are presented in **Figure 2-61** and **Table 2-22**. Deep percolation represents the largest inflow averaging nearly 53 taf per year while net seepage represents an inflow of about 43 taf per year. Net subsurface flows (combined subsurface flows with adjacent subbasins and upland areas) represent the largest net outflow totaling about -88 taf per year of outflow from the Bowman Subbasin on average. Groundwater pumping (on average -6.1 taf per year) and groundwater (root water) uptake directly from shallow groundwater (on average -3.0 taf per year) represent smaller outflows from the GWS. Overall, the water budget results for the 29-year historical period indicate a cumulative change in groundwater storage of about -50 taf, which equals an average annual change in groundwater storage of only about -1.7 taf per year. These changes in storage estimates equate to total decreases in storage in the Subbasin of about 0.41 acre-feet per acre over the 29 years and an annual decrease of less than 0.01 acre-feet per acre across the entire Subbasin (approximately 122,425 acres). **Figure 2-61** provides a conceptual illustration of the historical water budget. **Figure 2-62** highlights the cumulative change in groundwater storage that has occurred over the 1990-2018 period, with a notable decline in storage over the generally dry period since the mid-2000s. The decrease of groundwater storage during relatively dry years is not an indication of overdraft, but likely due to removal of temporary surplus of groundwater. Temporary surplus removal is the extraction of a volume of aquifer storage to enable the capture of recharge and reduction in subsurface outflow from the subbasin without impacting beneficial users of groundwater creating unreasonable results. In contrast, overdraft is defined as “the condition of a groundwater basin or subbasin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions. Overdraft can be characterized by groundwater levels that decline over a period of years and never fully recover, even in wet years. If overdraft continues for a number of years, significant adverse impacts may occur, including increased extraction costs, costs of well deepening or replacement, land subsidence, water quality degradation, and environmental impacts” (DWR, 2003).

Additional details on the historical GWS water budget results are presented in **Appendix 2-K**.

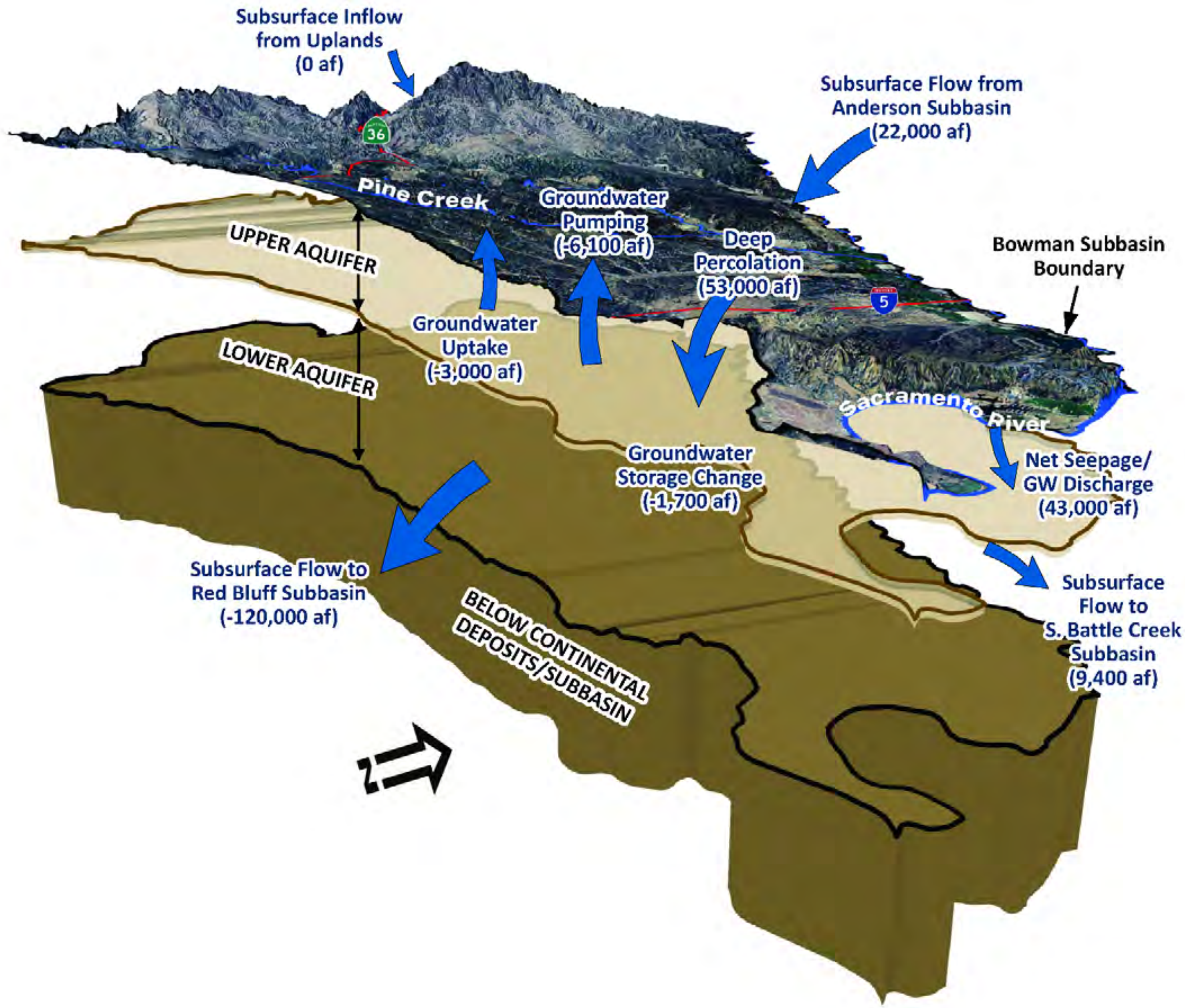

Figure 2-61. Diagram of the Bowman Subbasin Historical Average Annual Water Budget (1990-2018)

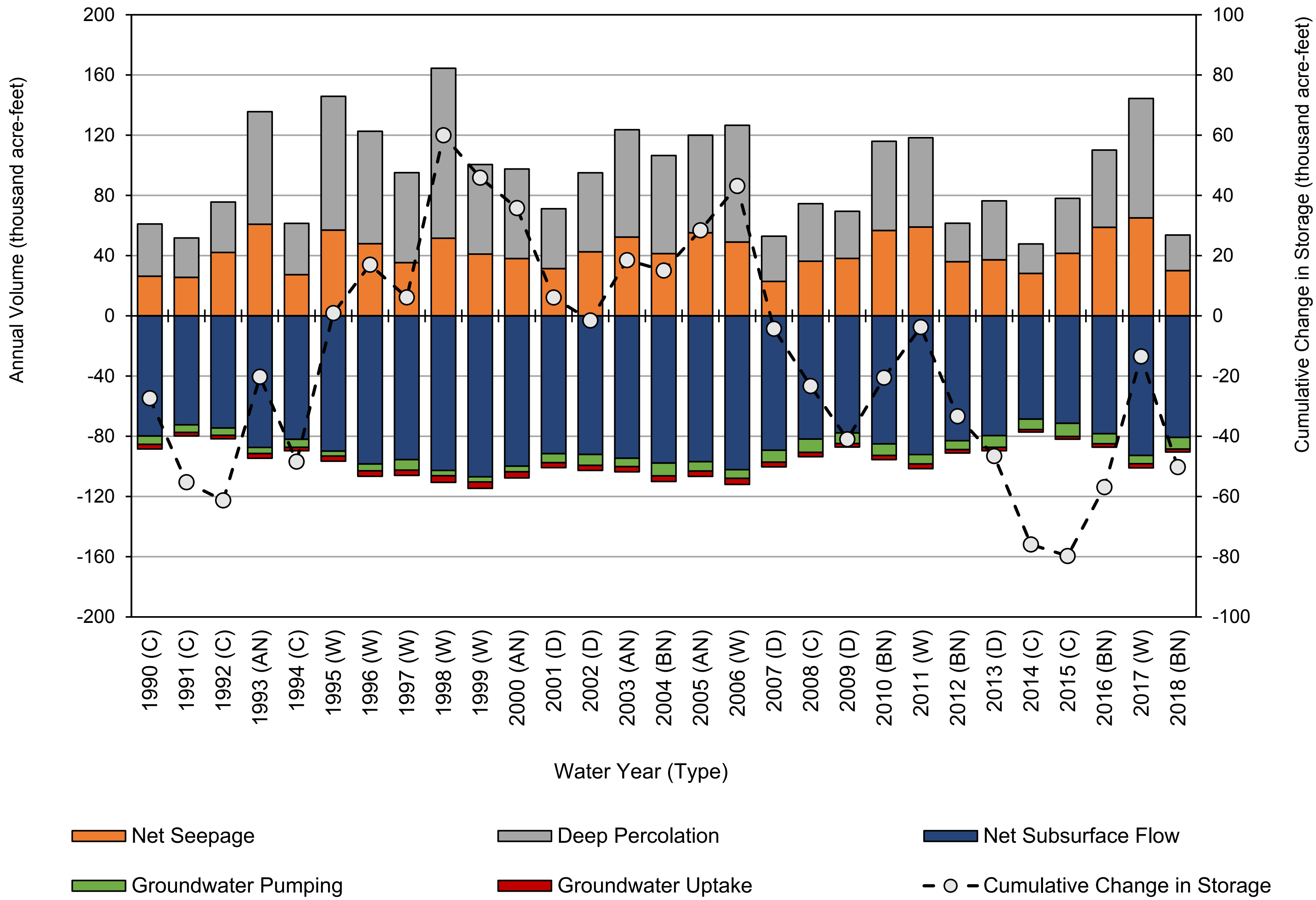

Figure 2-62. Bowman Subbasin Historical Water Budget Summary

Table 2-22. Bowman Subbasin Historical Water Budget Summary (acre-feet)

WATER YEAR (TYPE)	NET SEEPAGE	DEEP PERCOLATION	NET SUBSURFACE FLOWS	GROUND-WATER PUMPING	GROUND-WATER UPTAKE	ANNUAL GROUNDWATER STORAGE CHANGE	CUMULATIVE GROUNDWATER STORAGE CHANGE
1990 (C)	26,000	35,000	-80,000	-5,600	-3,000	-27,000	-27,000
1991 (C)	26,000	26,000	-72,000	-5,100	-2,300	-28,000	-55,000
1992 (C)	42,000	33,000	-75,000	-4,900	-2,200	-6,000	-61,000
1993 (AN)	61,000	75,000	-87,000	-4,100	-3,100	41,000	-20,000
1994 (C)	27,000	34,000	-82,000	-5,300	-2,300	-28,000	-48,000
1995 (W)	57,000	89,000	-90,000	-3,300	-3,300	49,000	910
1996 (W)	48,000	75,000	-98,000	-4,500	-3,600	16,000	17,000
1997 (W)	35,000	60,000	-96,000	-7,000	-3,500	-11,000	6,100
1998 (W)	52,000	110,000	-100,000	-3,600	-4,400	54,000	60,000
1999 (W)	41,000	59,000	-110,000	-3,400	-4,300	-14,000	46,000
2000 (AN)	38,000	59,000	-100,000	-3,800	-4,000	-10,000	36,000
2001 (D)	31,000	40,000	-92,000	-5,900	-3,300	-30,000	6,100
2002 (D)	43,000	53,000	-92,000	-7,200	-3,400	-7,600	-1,500
2003 (AN)	52,000	71,000	-95,000	-5,500	-3,500	20,000	19,000
2004 (BN)	41,000	65,000	-98,000	-8,500	-3,700	-3,500	15,000
2005 (AN)	55,000	65,000	-97,000	-6,300	-3,600	13,000	28,000
2006 (W)	49,000	78,000	-100,000	-5,700	-4,000	15,000	43,000
2007 (D)	23,000	30,000	-89,000	-8,000	-3,100	-47,000	-4,300
2008 (C)	36,000	38,000	-82,000	-8,900	-2,900	-19,000	-23,000
2009 (D)	38,000	31,000	-78,000	-6,900	-2,400	-18,000	-41,000
2010 (BN)	57,000	59,000	-85,000	-7,700	-2,700	21,000	-20,000
2011 (W)	59,000	59,000	-92,000	-6,200	-3,200	17,000	-3,700
2012 (BN)	36,000	26,000	-83,000	-6,000	-2,300	-30,000	-33,000
2013 (D)	37,000	39,000	-80,000	-7,700	-2,300	-13,000	-47,000
2014 (C)	28,000	20,000	-69,000	-6,900	-1,700	-29,000	-76,000
2015 (C)	42,000	37,000	-71,000	-8,800	-1,700	-3,800	-80,000
2016 (BN)	59,000	51,000	-78,000	-6,700	-2,300	23,000	-57,000
2017 (W)	65,000	79,000	-93,000	-5,400	-2,800	43,000	-13,000
2018 (BN)	30,000	24,000	-81,000	-7,800	-1,900	-37,000	-50,000
Average (1990-2018)	43,000	53,000	-88,000	-6,100	-3,000	-1,700	
1990-2018 W	51,000	76,000	-98,000	-4,900	-3,700	21,000	
1990-2018 AN	56,000	70,000	-93,000	-5,300	-3,400	25,000	
1990-2018 BN	47,000	46,000	-84,000	-7,200	-2,500	-590	
1990-2018 D	34,000	39,000	-86,000	-7,200	-2,900	-23,000	
1990-2018 C	32,000	32,000	-76,000	-6,500	-2,300	-20,000	

Note: positive values indicate inflows/increasing storage, negative values indicate outflows/decreasing storage.

2.3.6 Current Water Budget

As described above in **Section 2.3.2**, several recent water budget periods have been considered for use in representing the current water budget. Because the hydrology and land use conditions can vary year to year, estimating the current water budget can be challenging. To evaluate the current water budget, water budget results from the historical model run were summarized for five different recent time periods to evaluate variability and trends. The five different recent water budget periods evaluated include the following:

- Most recent 10 years (2009-2018)
- Most recent 5 year (2014-2018)
- Most recent 3 years (2016-2018)
- Recent single year 2018
- Recent single year 2019

Comparison of these recent water budget periods provides a representation of how water use varies with precipitation and water supply conditions from year to year. Based on these comparisons and consideration of the hydrologic conditions over these recent periods, the recent three-year period from 2016 through 2018 is believed to provide a reasonable representation of the recent water budget conditions. For reporting a current water budget in the GSP, the average water budget for the three-year period between 2016 and 2018 is considered to be representative of the current water budget and representative of current hydrologic and land use conditions. This period incorporates recent land use conditions and spans three years (two below normal years and one wet year) that collectively have precipitation and hydrology similar to the long-term average. Although the 2016 through 2018 period provides a summary of the water budget for recent years that appear to be reasonably representative of recent typical conditions, it is not necessarily representative of any longer-term average conditions. Understanding the recent water budget years is helpful in anticipating longer-term conditions under a scenario where current land uses are maintained in the Subbasin (see **section 2.3.7**). The results from comparisons of the recent water budget periods evaluated are presented below, including the results and discussion of the selected current water budget period of 2016-2018.

2.3.6.1 Surface Water System Water Budget Summary

The comparison of the different recent SWS water budget periods provides a representation of how individual SWS water budget components vary from year to year depending on water demands, precipitation, and water supply conditions. The SWS water budget results for these different recent time periods are presented in **Table 2-23**. The single year SWS water budget results highlight the high variability between these two years, which included a below normal year in 2018 and a wet year in 2019. The water budget inflows and outflows from the SWS vary by about 300 taf between these two single years. Most of the variability in the total SWS inflows and outflows is a result of variability in precipitation, surface water inflow and surface water outflow. When comparing the average annual water budget results for recent multi-year periods, the variability is considerably reduced with a maximum difference in both inflows and outflows of about 60 taf per year between the three different recent multi-year periods evaluated.

The selected current water budget period of 2016-2018 (highlighted blue in **Table 2-23**) has total SWS inflows and outflows of about 400 taf per year with the largest SWS inflows being precipitation (310 taf per year) and the largest SWS outflow being the ET of Precipitation (160 taf per year). Current SWS water budget inflows also include 82 taf per year of surface water inflow and 9.0 taf per year of groundwater extraction and uptake. Groundwater discharge to surface water is negligible. Other SWS outflows in the current SWS water budget include 120 taf per year surface water outflow, 51 taf of infiltration (seepage) of surface water, 45 taf per year deep percolation of precipitation, 12 taf per year ET of applied water, 6.4 taf per year of deep percolation of applied water, and additional smaller outflows for ET of groundwater uptake, and evaporation from surface water.

Table 2-23. Comparison of Recent SWS Water Budget Periods (acre-feet).

FLOW PATH		RECENT WATER BUDGET PERIOD				
		RECENT 10 YEARS	RECENT 5 YEARS	RECENT 3 YEARS	RECENT 1 YEAR	RECENT 1 YEAR
		(2009-2018)	(2014-2018)	(2016-2018)	2018	2019
Inflow	Surface Water Inflow	67,000	68,000	82,000	39,000	100,000
	Precipitation	260,000	270,000	310,000	190,000	420,000
	Groundwater Extraction/Uptake	9,300	9,200	9,000	9,700	8,900
	Groundwater Discharge to Surface Water	0	0	0	0	0
	Total Inflows	***340,000***	***340,000***	***400,000***	***240,000***	***540,000***
Outflow	Surface Water Outflow	79,000	93,000	120,000	20,000	210,000
	ET of Applied Water	12,000	12,000	12,000	13,000	10,000
	ET of Groundwater Uptake	2,300	2,100	2,300	1,900	2,900
	ET of Precipitation	160,000	150,000	160,000	150,000	180,000
	Evaporation	840	800	800	820	740
	Deep Percolation of Applied Water	7,300	6,100	6,400	6,300	7,100
	Deep Percolation of Precipitation	35,000	36,000	45,000	17,000	65,000
	Infiltration of Surface Water (Seepage)	45,000	45,000	51,000	30,000	60,000
	Change in Root Zone Storage	140	-1,000	-670	-3,000	6,600
	Total Outflows	***340,000***	***340,000***	***400,000***	***240,000***	***540,000***

2.3.6.2 Groundwater System Water Budget Summary

Comparing the different recent water budget periods provides a representation of how the overall GWS water budget components vary from year to year depending on conditions including inflows/outflows between the SWS and subsurface flows. The GWS water budget results for these different recent time periods are presented in **Table 2-24**. As with the results for the current SWS water budget summaries, the single year results for the GWS water budget highlight the high variability between the two individual years of 2018 and 2019, which included a below normal year (2018) and a wet year (2019). Although some of the individual water budget components are relatively stable between the two different recent water budget years, the total change in groundwater storage varied by about 73 taf ranging from a decrease in storage of about -37 taf in 2018 (a below normal year) to an increase in storage of nearly 36 taf in 2019 (a wet year). There is considerably less variability in most of the different water budget components when comparing between the three different recent multi-year periods, although the net seepage and net subsurface flows do show relatively higher differences between the three recent periods. Average annual change in storage varies between -2.7 and -0.7 taf per year for the recent 10-year and 5-year periods, respectively, and indicates an average increase in storage of about 9.8 taf per year for the recent three-year period. This difference is likely attributable to the drought years consisting of dry and critical years that occurred between 2013 and 2015, which are included in the recent five- and ten-year periods, but not included in the most recent three-year period from 2016 to 2018.

The selected current water budget period of 2016-2018 (highlighted blue in **Table 2-24**) has total net seepage of about 51 taf per year, indicating net contribution of surface water to the GWS through exchanges occurring in surface waterways. Deep percolation also averages about 51 taf per year. Net subsurface flows total about -84 taf per year on average over the current water budget period occurring as outflow. Groundwater pumping is an outflow from the GWS and averages about -7.8 taf per year during the current water budget period while groundwater uptake represents an additional GWS outflow of about -1.9 taf per year.

Table 2-24. Comparison of Recent GWS Water Budget Periods (acre-feet)

GWS WATER BUDGET COMPONENT	RECENT WATER BUDGET PERIODS				
	RECENT 10 YEARS	RECENT 5 YEARS	RECENT 3 YEARS	RECENT 1 YEAR	RECENT 1 YEAR
	(2009-2018)	(2014-2018)	(2016-2018)	2018	2019
Net Seepage	45,000	45,000	51,000	30,000	60,000
Deep Percolation	42,000	42,000	51,000	24,000	72,000
Net Subsurface Flows	-81,000	-78,000	-84,000	-81,000	-87,000
Groundwater Pumping	-7,000	-7,100	-6,600	-7,800	-6,000
Groundwater Uptake	-2,300	-2,100	-2,300	-1,900	-2,900
Annual Groundwater Storage Change	***-2,700***	***-700***	***9,800***	***-37,000***	***36,000***

Note: positive values indicate inflows/increasing storage, negative values indicate outflows/decreasing storage.

2.3.7 Projected Water Budgets

To evaluate projected water budgets in the future, projected model runs were developed using Tehama IHM. The projected model runs are intended to evaluate the effects of anticipated future conditions of hydrology, water supply availability, and water demand on the Bowman Subbasin water budget and groundwater conditions over a 50-year GSP planning period. The projected model runs also incorporate consideration of potential climate change and water supply availability scenarios and evaluation of the need for and benefit of any projects and management actions to be implemented in the Subbasin to maintain or achieve sustainability. The projected model runs use hydrologic conditions representative of the most recent 50 years of hydrology in the Subbasin, with adjustments applied in scenarios for evaluating the water budget under climate change and/or altered water supply and demand conditions. A number of projected future scenarios were simulated in Tehama IHM to compare possible outcomes, including different projected land uses and potential climate change impacts. Additional information about the development of the projected model scenarios is provided in **Appendix 2-J**.

2.3.7.1 Projected (Current Land Use) Water Budget

This section presents the results of the Projected (Current Land Use) scenario. The Current Land Use scenario assumes constant land use conditions based on 2018 conditions.

2.3.7.1.1 *Projected (Current Land Use) Surface Water System Water Budget Summary*

Annual inflows, outflows, and change in SWS root zone storage during the projected (current land use) water budget period (2022-2072) are summarized in **Figure 2-63** and **Table 2-25.** Inflows in **Figure 2-63** are shown as positive values, while outflows are shown as negative values. Review of the variability in component volumes across years provides insight into the impacts of hydrology on the SWS water budget.

Of particular note in the projected (current land use) SWS water budget results is the volume of precipitation that makes up the largest part of the Subbasin SWS inflows averaging about 300 taf per year over the projected period. By comparison, other SWS inflows in the Subbasin are relatively smaller. Surface water inflows average about 83 taf per year. Groundwater extraction and uptake represents a relatively small SWS inflow averaging about 9.1 taf per year, and groundwater discharge to surface water is negligible over the projected (current land use) water budget period.

Among the outflows from the Subbasin SWS, ET of precipitation makes up a large fraction of the total Subbasin SWS outflows averaging about 160 taf per year over the projected (current land use) period. The surface water outflows total about 120 taf per year on average, a value that corresponds with the large volumes of precipitation and surface water inflow (a total of about 380 taf per year). By comparison, other SWS outflows in the Subbasin are relatively smaller, with values for each deep percolation of precipitation and infiltration (seepage) of surface water totaling about 43 taf per year on average. ET of applied water, and deep percolation of applied water are about 11 and 7.3 taf per year on average, respectively. The outflows of ET of groundwater uptake and evaporation from surface water average about 2.9 and 0.85 taf per year, respectively.

Detailed results for the projected (current land use) SWS water budget are presented in **Appendix 2-K**.

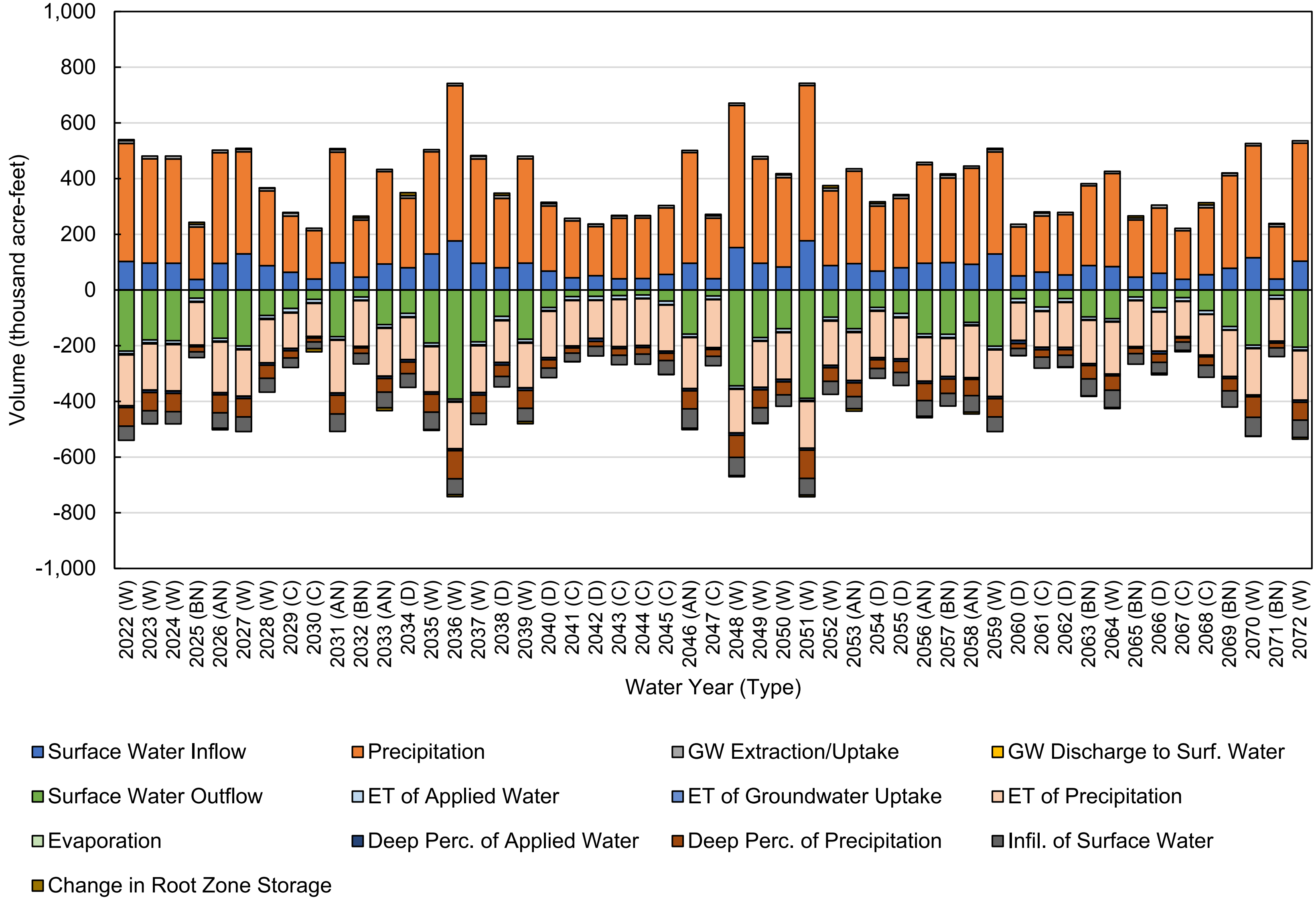

Figure 2-63. Bowman Subbasin Surface Water System Projected (Current Land Use) Water Budget, 2022-2072

Table 2-25. Bowman Subbasin Surface Water System Projected (Current Land Use) Water Budget, 2022-2072 (acre-feet)

WATER YEAR (TYPE)	INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
	SURFACE WATER INFLOW	PRECIPI-TATION	GROUND-WATER EXTRACTION / UPTAKE	GROUND-WATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUND-WATER UPTAKE	ET OF PRECIPI-TATION	EVAPO-RATION[1]	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPI-TATION	INFIL. OF SURFACE WATER	
2022 (W)	100,000	420,000	10,000	0	220,000	9,900	3,900	180,000	730	6,600	67,000	51,000	-3,500
2023 (W)	96,000	370,000	10,000	0	180,000	10,000	3,900	170,000	810	8,300	65,000	47,000	640
2024 (W)	96,000	370,000	10,000	0	180,000	10,000	4,000	170,000	810	8,300	65,000	44,000	0
2025 (BN)	38,000	190,000	9,700	0	29,000	12,000	2,900	150,000	800	5,800	18,000	21,000	-7,300
2026 (AN)	96,000	400,000	9,100	0	170,000	10,000	3,500	180,000	860	7,000	65,000	55,000	5,800
2027 (W)	130,000	370,000	8,800	0	200,000	9,800	3,800	170,000	790	7,600	66,000	53,000	-3,500
2028 (W)	87,000	270,000	9,600	0	92,000	11,000	3,700	160,000	940	7,700	47,000	50,000	-1,700
2029 (C)	64,000	200,000	11,000	0	66,000	13,000	3,000	130,000	1,000	7,800	26,000	34,000	-2,200
2030 (C)	39,000	170,000	8,700	0	33,000	13,000	2,000	120,000	830	5,200	14,000	24,000	12,000
2031 (AN)	98,000	400,000	8,800	0	170,000	9,900	3,000	190,000	850	7,800	67,000	63,000	-4,300
2032 (BN)	46,000	200,000	7,800	0	25,000	11,000	2,200	160,000	820	5,200	19,000	38,000	-6,400
2033 (AN)	93,000	330,000	8,000	0	120,000	10,000	2,900	170,000	850	8,000	49,000	56,000	10,000
2034 (D)	80,000	250,000	10,000	0	84,000	12,000	2,800	150,000	960	8,300	42,000	49,000	-10,000
2035 (W)	130,000	370,000	8,300	0	190,000	10,000	3,200	160,000	790	7,500	64,000	62,000	3,200
2036 (W)	180,000	560,000	8,400	0	390,000	7,100	3,900	170,000	650	6,300	100,000	57,000	7,300
2037 (W)	96,000	370,000	10,000	0	190,000	10,000	3,900	170,000	810	8,300	66,000	40,000	-2,300
2038 (D)	80,000	250,000	11,000	0	95,000	12,000	3,500	150,000	960	8,500	41,000	38,000	-8,200
2039 (W)	96,000	370,000	9,700	0	180,000	11,000	3,500	160,000	810	8,500	64,000	47,000	8,200
2040 (D)	68,000	230,000	8,900	0	63,000	11,000	3,000	170,000	890	7,400	30,000	34,000	-4,600
2041 (C)	44,000	200,000	9,500	0	24,000	12,000	2,500	160,000	920	6,400	19,000	30,000	540

WATER YEAR (TYPE)	INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
	SURFACE WATER INFLOW	PRECIPI-TATION	GROUND-WATER EXTRACTION / UPTAKE	GROUND-WATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUND-WATER UPTAKE	ET OF PRECIPI-TATION	EVAPO-RATION[1]	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPI-TATION	INFIL. OF SURFACE WATER	
2042 (D)	52,000	180,000	8,900	0	23,000	13,000	2,100	140,000	950	11,000	18,000	34,000	-510
2043 (C)	40,000	220,000	8,600	0	20,000	12,000	1,900	170,000	830	6,300	24,000	34,000	-2,200
2044 (C)	41,000	220,000	8,500	0	18,000	12,000	1,800	170,000	830	6,700	24,000	36,000	-10
2045 (C)	56,000	240,000	8,700	0	40,000	12,000	1,800	170,000	870	6,700	26,000	50,000	270
2046 (AN)	96,000	400,000	8,100	0	160,000	10,000	2,500	180,000	860	7,200	65,000	70,000	4,900
2047 (C)	41,000	220,000	8,600	0	22,000	12,000	1,900	170,000	830	6,200	24,000	34,000	-5,100
2048 (W)	150,000	510,000	8,200	0	340,000	9,400	2,900	160,000	760	8,100	79,000	65,000	4,500
2049 (W)	96,000	370,000	9,300	0	170,000	10,000	3,000	170,000	800	8,200	65,000	54,000	2,100
2050 (W)	83,000	320,000	11,000	0	140,000	12,000	2,900	170,000	930	8,000	47,000	41,000	-4,000
2051 (W)	180,000	560,000	8,300	0	390,000	7,300	3,800	170,000	650	6,600	100,000	60,000	6,400
2052 (W)	88,000	270,000	9,800	0	97,000	11,000	3,800	160,000	950	7,700	49,000	47,000	-8,900
2053 (AN)	95,000	330,000	8,800	0	140,000	10,000	3,600	170,000	860	8,200	49,000	43,000	8,800
2054 (D)	68,000	230,000	8,900	0	63,000	11,000	3,000	170,000	890	7,200	31,000	35,000	-6,700
2055 (D)	80,000	250,000	10,000	0	84,000	13,000	3,000	150,000	960	8,400	40,000	47,000	-3,700
2056 (AN)	96,000	350,000	8,200	0	160,000	10,000	3,100	160,000	820	7,300	62,000	56,000	4,700
2057 (BN)	99,000	300,000	9,800	0	160,000	12,000	3,300	140,000	970	8,800	52,000	45,000	-4,600
2058 (AN)	92,000	340,000	8,000	0	120,000	8,900	3,200	190,000	770	5,700	58,000	59,000	7,000
2059 (W)	130,000	370,000	8,700	0	200,000	9,900	3,600	170,000	800	7,400	66,000	53,000	-3,900
2060 (D)	51,000	180,000	9,400	0	31,000	12,000	2,700	130,000	950	10,000	18,000	25,000	430
2061 (C)	64,000	200,000	11,000	0	61,000	14,000	2,500	130,000	990	8,000	26,000	40,000	-4,400
2062 (D)	54,000	220,000	8,100	0	31,000	12,000	2,100	160,000	940	7,100	20,000	42,000	2,700

WATER YEAR (TYPE)		INFLOWS				OUTFLOWS								CHANGE IN ROOT ZONE STORAGE
		SURFACE WATER INFLOW	PRECIPI-TATION	GROUND-WATER EXTRACTION / UPTAKE	GROUND-WATER DISCHARGE	SURFACE WATER OUTFLOW	ET OF APPLIED WATER	ET OF GROUND-WATER UPTAKE	ET OF PRECIPI-TATION	EVAPO-RATION[1]	DEEP PERC. OF APPLIED WATER	DEEP PERC. OF PRECIPI-TATION	INFIL. OF SURFACE WATER	
2063 (BN)		88,000	290,000	7,700	0	97,000	9,800	2,500	160,000	860	6,800	48,000	61,000	1,800
2064 (W)		84,000	330,000	7,900	0	100,000	9,000	2,900	190,000	750	5,900	52,000	62,000	3,900
2065 (BN)		46,000	200,000	7,800	0	25,000	11,000	2,100	160,000	820	5,300	19,000	38,000	-7,300
2066 (D)		60,000	230,000	10,000	0	64,000	13,000	2,200	140,000	960	9,500	30,000	39,000	5,800
2067 (C)		38,000	170,000	8,800	0	27,000	12,000	1,700	130,000	830	4,900	14,000	30,000	4,900
2068 (C)		55,000	240,000	10,000	0	74,000	12,000	1,700	150,000	770	5,700	31,000	43,000	-8,000
2069 (BN)		78,000	330,000	8,900	0	130,000	12,000	2,100	170,000	830	6,800	44,000	58,000	-720
2070 (W)		120,000	400,000	8,100	0	200,000	9,700	2,700	170,000	750	5,800	73,000	67,000	1,700
2071 (BN)		39,000	190,000	8,800	0	19,000	12,000	1,900	150,000	800	6,400	17,000	31,000	-3,100
2072 (W)		100,000	420,000	8,900	0	210,000	10,000	2,800	180,000	740	7,000	65,000	62,000	6,700
Average (2022-2072)		83,000	300,000	9,100	0	120,000	11,000	2,900	160,000	850	7,300	46,000	46,000	-70
2022-2072	W	110,000	390,000	9,200	0	200,000	9,900	3,500	170,000	790	7,400	67,000	53,000	940
2022-2072	AN	95,000	370,000	8,400	0	150,000	9,900	3,100	180,000	840	7,300	59,000	58,000	5,300
2022-2072	BN	62,000	240,000	8,700	0	69,000	11,000	2,400	160,000	840	6,400	31,000	42,000	-4,000
2022-2072	D	66,000	220,000	9,500	0	60,000	12,000	2,700	150,000	940	8,600	30,000	38,000	-2,800
2022-2072	C	48,000	210,000	9,300	0	39,000	12,000	2,100	150,000	870	6,400	23,000	35,000	-460

1 Diversions for some years were estimated based on average monthly data, resulting in a generally constant evaporation volume for some years.

2.3.7.2 Projected (Current Land Use) Groundwater System Water Budget Summary

Summarized results for major components of the projected (current land use) water budget as they relate to the GWS are presented in **Figure 2-64** and **Table 2-26**. Deep percolation represents the largest inflow averaging nearly 53 taf per year while net seepage represents an inflow of about 46 taf per year. Net subsurface flows (combined subsurface flows with adjacent subbasins and upland areas) represent the largest net outflow totaling about -90 taf per year of outflow from the Bowman Subbasin on average. Groundwater pumping (on average -6.2 taf per year) and groundwater (root water) uptake directly from shallow groundwater (on average -2.9 taf per year) represent smaller outflows from the GWS.

Overall, the water budget results for the projected period indicate a cumulative change in groundwater storage of about -11 taf, which equals an average annual change in groundwater storage of about -0.2 taf per year. These changes in storage estimates equate to decreases in storage in the Subbasin of about 0.1 acre-feet per acre over the 51 years across the entire Subbasin (approximately 122,425 acres). **Figure 2-64** provides a conceptual illustration of the projected (current land use) water budget. **Figure 2-65** highlights the cumulative change in groundwater storage that would occur during anticipated multi-year wet and dry periods within the projected period.

Detailed results for the projected (current land use) GWS water budget are presented in **Appendix 2-K**.

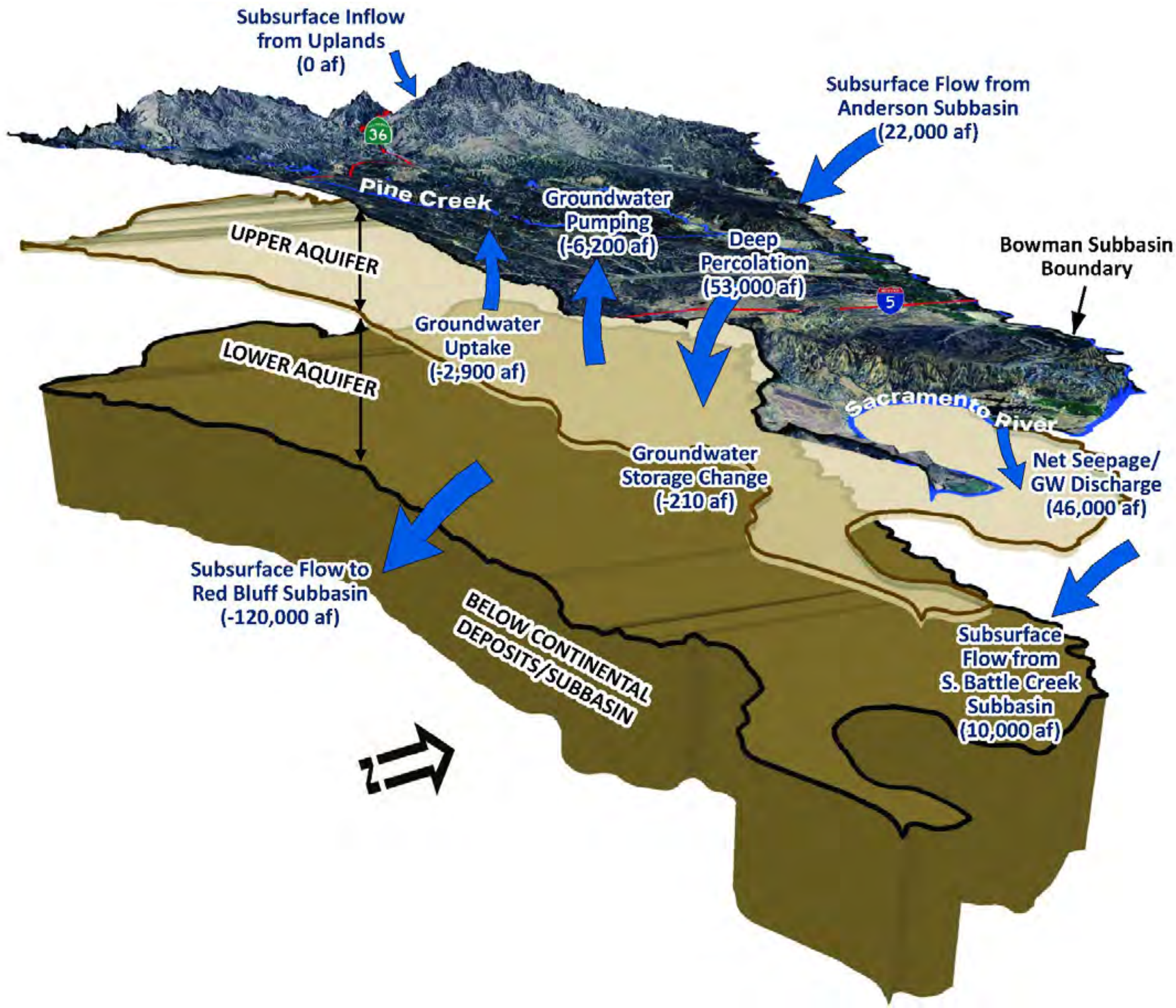

Figure 2-64. Diagram of the Bowman Subbasin Projected (Current Land Use) Average Annual Water Budget, 2022-2072