2. BASIN SETTING

2.1 Hydrogeologic Conceptual Model

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

Much of the information in this section is from existing reports detailing the hydrogeology of the Sacramento Valley and the formations making up the aquifer systems in the groundwater basin. These reports by DWR include the Geology of the Northern Sacramento Valley, 2014 (DWR, 2014), the Butte County Groundwater Inventory Analysis, 2005 (DWR, 2005), and work by Blair et al. (1991). Better understanding the hydrogeology, aquifer dynamics, and recharge paths of the aquifer systems in the Northern Sacramento Valley region is an area of active research by local agencies, DWR, and others.

2.1.1 Basin Boundaries

2.1.1.1 Lateral Boundaries

The Wyandotte Creek Subbasin lies in the eastern central portion of the Sacramento Groundwater Basin. It is bounded on the west by the Feather River and Thermalito Afterbay; in the south by the Butte-Yuba County line (except for Ramirez Water District which is fully within the North Yuba Subbasin); and on the north and east by the edge of the alluvial basin as defined by DWR Bulletin 118 - Update 2003 (DWR, 2003). It is surrounded by the Butte Subbasin to the west, the Vina Subbasin to the north, the North Yuba Subbasin to the south and the foothills to the east.

2.1.1.2 Bottom of Basin

The definable bottom of the basin is described in Bulletin 118 subbasin report (DWR, 2006) as part of the North Yuba Subbasin (which at that time included what is now the Wyandotte Creek Subbasin) as follows:

> *The [Wyandotte Creek] Subbasin aquifer system is comprised of continental deposits of Quaternary to Late Tertiary (Pliocene) age. The cumulative thickness of these deposits increases from a few hundred feet near the Sierra Nevada foothills on the east to over 1,000 feet along the western margin of the basin.*

Groundwater occurs in the heterogeneous gravel and sand layers and the base of the Laguna Formation is generally accepted as the base of fresh water (Olmsted and Davis, 1961, as cited in DWR, 2014). However non-saline water has been observed in the underlying Ione formation (Dames and Moore, 1994) and Blair and others (1991) identified the base of the Mehrten Formation as the base of fresh water in portions of the Wyandotte Creek Subbasin.

Locally, the base of fresh groundwater fluctuates depending on local changes in the subsurface geology and geologic formational structure (DWR, 2005). In the DWR 2005 report, 600 feet was used as the average base of fresh water. In contrast, in an unpublished study by

Bookman -Edmonston Engineering, Inc (1992) a thickness of 200 feet was assumed for estimating groundwater storage capacity (as cited in DWR, 2006). Because of the inconclusive data on the location of the base of fresh groundwater, this remains an area requiring additional data to improve characterization of the aquifer system.

2.1.2 Topography, Surface Water and Recharge

2.1.2.1 Terrain and Topography

The Wyandotte Creek Subbasin lies southwest of Lake Oroville. The northeastern area of the subbasin has steeper and more varied terrain. Land surface elevation varies from approximately 90-100 feet above mean sea level (amsl) along the western edge near the Feather River and the southern edge along Honcut Creek, to over 200 feet amsl at the edge of the foothills on the eastern side. In general, the area slopes in a southwesterly direction toward the Feather River.

Figure 2-1 shows the surface topography of the Wyandotte Creek Subbasin.

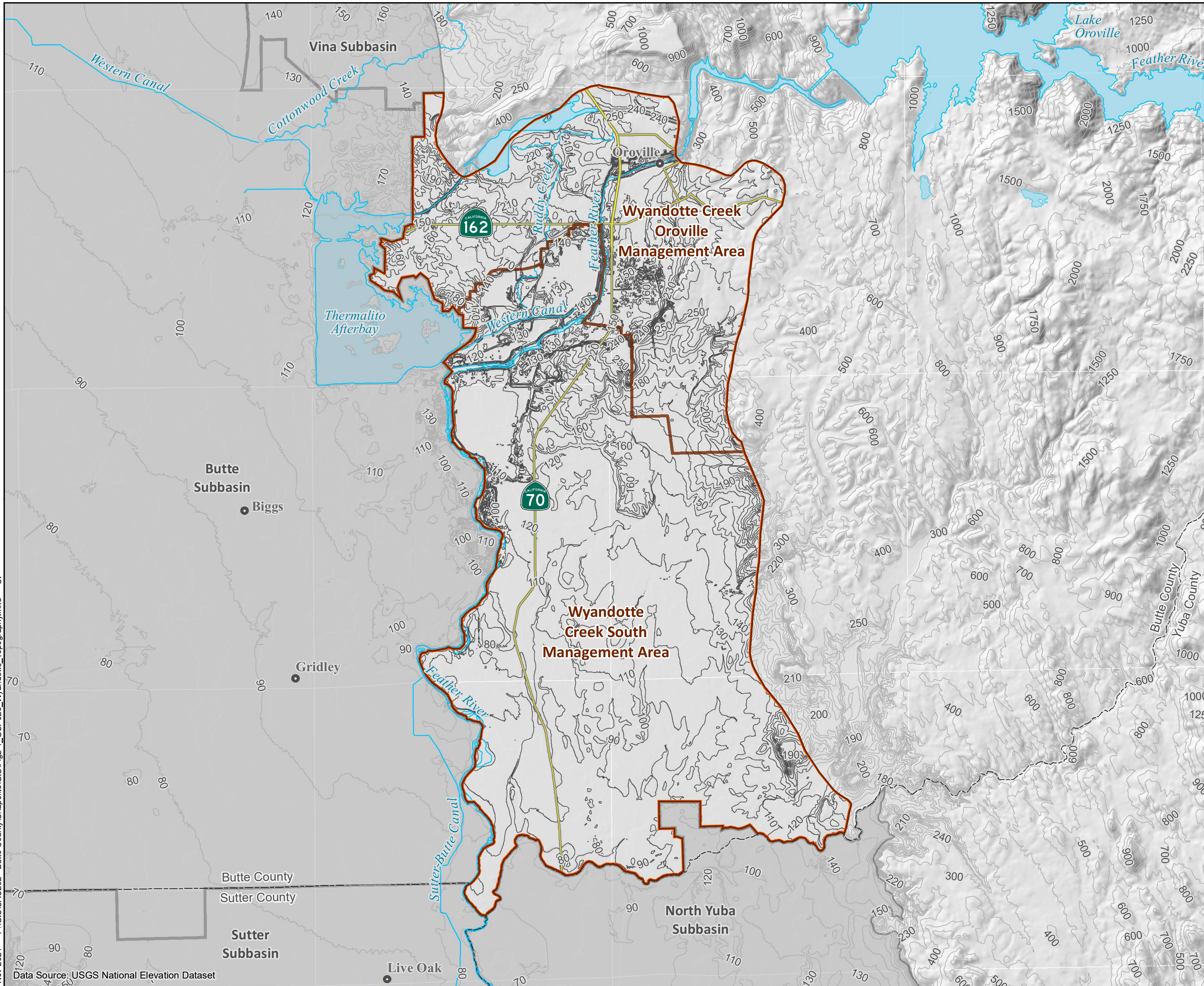
2.1.2.2 Soils

The area along the Feather River is underlain by lighter textured soils characterized by high infiltration rates. These areas correspond to land uses dominated by irrigated orchards. Most remaining areas of the subbasin has soils with slow to very slow infiltration rates. Soils with slow infiltration rates or a restrictive layer are well suited for growing rice. Figure 2-2 shows the distribution of Hydrologic Soil Groups for the Wyandotte Creek Subbasin. Soils designated as C/D are lands having soils that would have been classified as having very low infiltration (Group D) but have characteristics such as natural slope or management improvements that improved their drainage relative to that of similar soils.

Based on the Digital General Soil Map of the United States, or STATSGO2, soil data for the Wyandotte Creek Subbasin, the dominant soil mapping unit within the area is Redding-Corning, which is moderately well drained and represents approximately 64.3% of the subbasin. Other prominent soils within the subbasin include Riverwash-Dumps-Cortina (13.1% of area), and Tisdale-Kilaga-Conejo (13.6% of area). Characteristics of these soils are summarized in Table 2-1. The distribution of prominent soils (e.g., “map units”) in the subbasin is shown in Figure 2-3.

Table 2-1: STATSGO2 Soil Table for Wyandotte Creek Subbasin

Soil Map Unit	Percent of Area	Sum of Acres	Slope Range	Drainage
Wyandotte Creek Subbasin	100%	59,382		
Goulding-Auburn (s646)	0.7%	420	27.8	Well drained
Redding-Corning (s821)	64.3%	38,175	5.3	Moderately well drained
Riverwash-Dumps-Cortina (s648)	13.1%	7,783	2.6	Well drained
Stockton-Clear Lake-Capay (s824)	0.2%	108	1	Poorly drained
Sycamore-Shanghai-Nueva-Columbia (s855)	8.1%	4,822	1	Somewhat poorly drained
Tisdale-Kilaga-Conejo (s870)	13.6%	8,047	1	Well drained



SURFACE TOPOGRAPHY

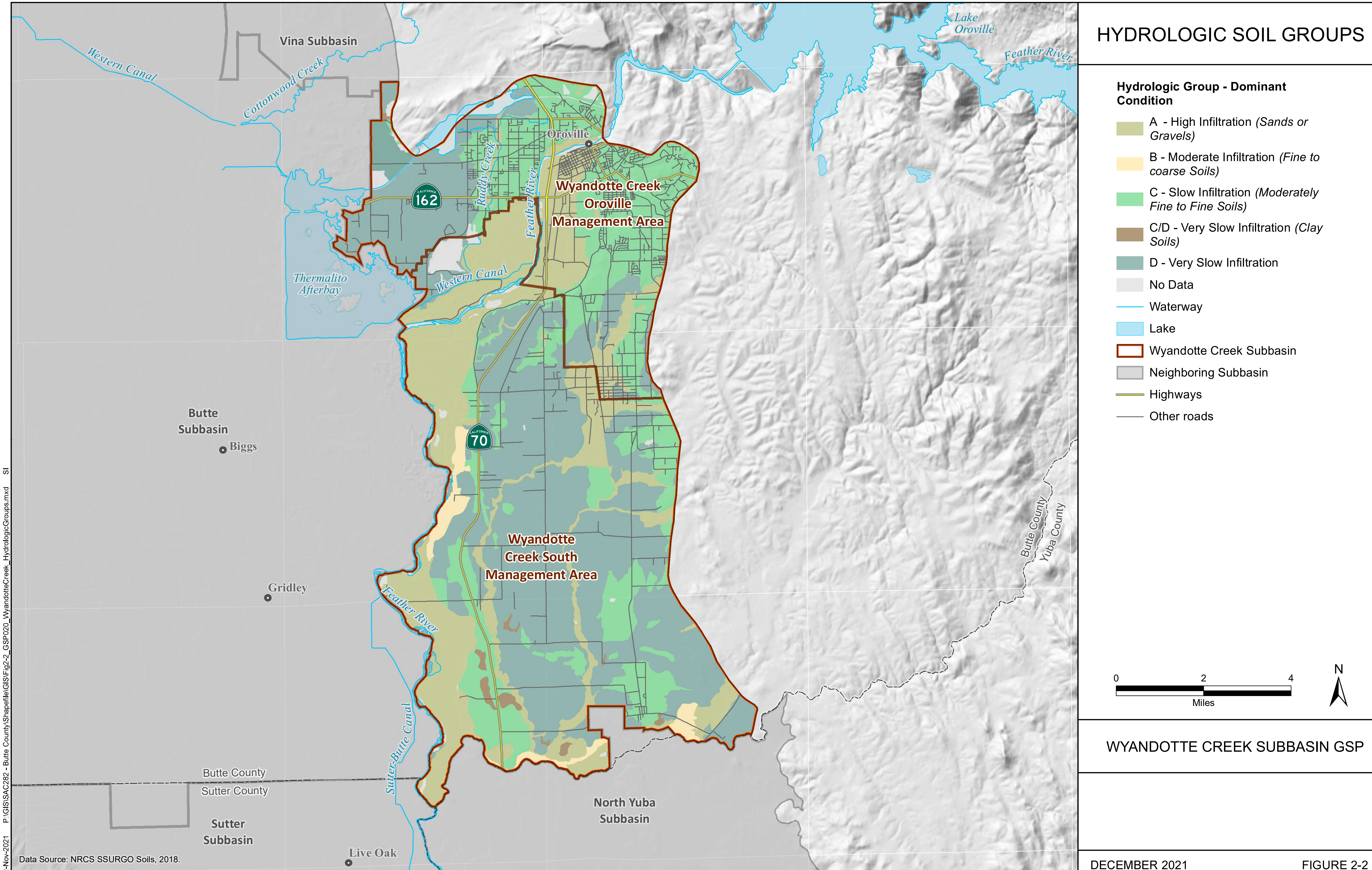
- Ground Surface Elevation Contours (10-ft interval at less than 250 ft msl; 100-ft interval between 250 ft and 1,000 ft msl, 250-ft interval at greater than 1,000 ft msl)
- Waterway
- Lake
- Wyandotte Creek Subbasin
- Neighboring Subbasin
- Highways

0 2 4
Miles

N

WYANDOTTE CREEK SUBBASIN GSP

DECEMBER 2021 FIGURE 2-1


HYDROLOGIC SOIL GROUPS
Hydrologic Group - Dominant Condition
A - High Infiltration (Sands or Gravels)
B - Moderate Infiltration (Fine to coarse Soils)
C - Slow Infiltration (Moderately Fine to Fine Soils)
C/D - Very Slow Infiltration (Clay Soils)
D - Very Slow Infiltration
No Data
Waterway
Lake
Wyandotte Creek Subbasin
Neighboring Subbasin
Highways
Other roads
0
2
4
Miles
N
WYANDOTTE CREEK SUBBASIN GSP
DECEMBER 2021
FIGURE 2-2
Vina Subbasin
Western Canal
Cottonwood Creek
Lake Oroville
Feather River
Oroville
Ruddy Creek
162
Wyandotte Creek Oroville Management Area
Thermalito Afterbay
Western Canal
Butte Subbasin
Biggs
70
Wyandotte Creek South Management Area
Gridley
Feather River
Butte County
Yuba County
Sutter-Butte Canal
Butte County
Sutter County
Sutter Subbasin
North Yuba Subbasin
Live Oak
Data Source: NRCS SSURGO Soils, 2018.
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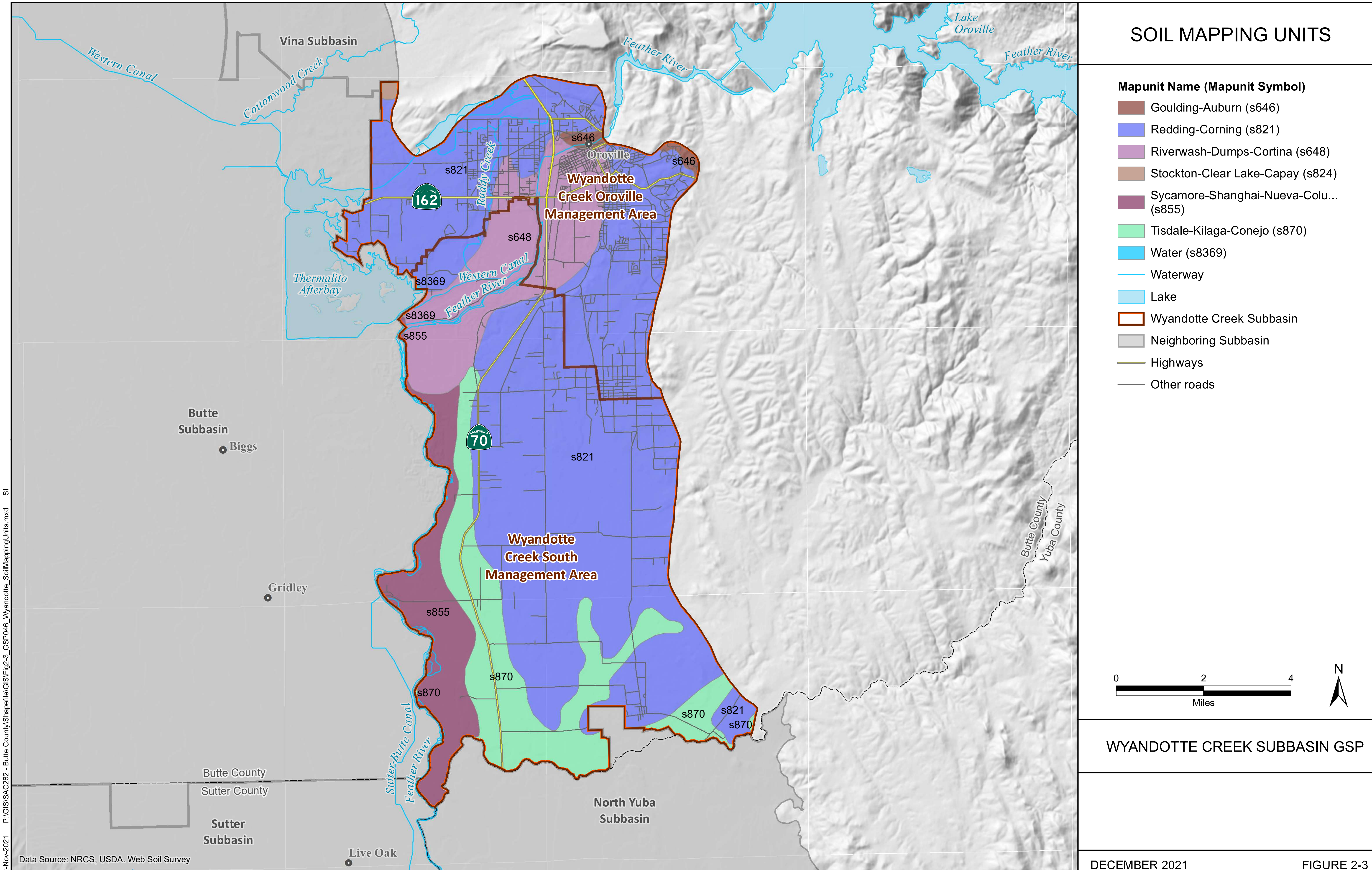
SOIL MAPPING UNITS
Mapunit Name (Mapunit Symbol)
Goulding-Auburn (s646)
Redding-Corning (s821)
Riverwash-Dumps-Cortina (s648)
Stockton-Clear Lake-Capay (s824)
Sycamore-Shanghai-Nueva-Colu... (s855)
Tisdale-Kilaga-Conejo (s870)
Water (s8369)
Waterway
Lake
Wyandotte Creek Subbasin
Neighboring Subbasin
Highways
Other roads
0 2 4
Miles
N
WYANDOTTE CREEK SUBBASIN GSP
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FIGURE 2-3
Vina Subbasin
Western Canal
Cottonwood Creek
Feather River
Lake Oroville
Oroville
Wyandotte Creek Oroville Management Area
Wyandotte Creek South Management Area
Ruddy Creek
Thermalito Afterbay
Butte Subbasin
Biggs
Gridley
Live Oak
Butte County
Sutter County
Yuba County
Sutter Subbasin
North Yuba Subbasin
Sutter-Butte Canal
162
70
s646
s821
s648
s8369
s855
s870
Data Source: NRCS, USDA. Web Soil Survey
22-Nov-2021 P:\GIS\SAC282 - Butte County\Shapefile\GIS\Fig2-3_GSP046_Wyandotte_SoilMappingUnits.mxd SI

2.1.2.3 Surface Water

The Feather River enters the subbasin in the northeast and then borders the subbasin on its western side. Other large surface water bodies bordering the subbasin include components of the Oroville Reservoir Complex including the Forebay and Thermalito Afterbay. The North, Middle, West and South Forks of the Feather River originate outside the subbasin and together supply water to Lake Oroville with a portion of flow routed through the Thermalito Forebay and Afterbay facilities to generate hydropower and deliver irrigation water supply to the Butte Subbasin, with the remaining water returning to the Feather River. The Feather River serves as a source of municipal and irrigation supply in the subbasin through diversions by the TWSD and SFWPA.

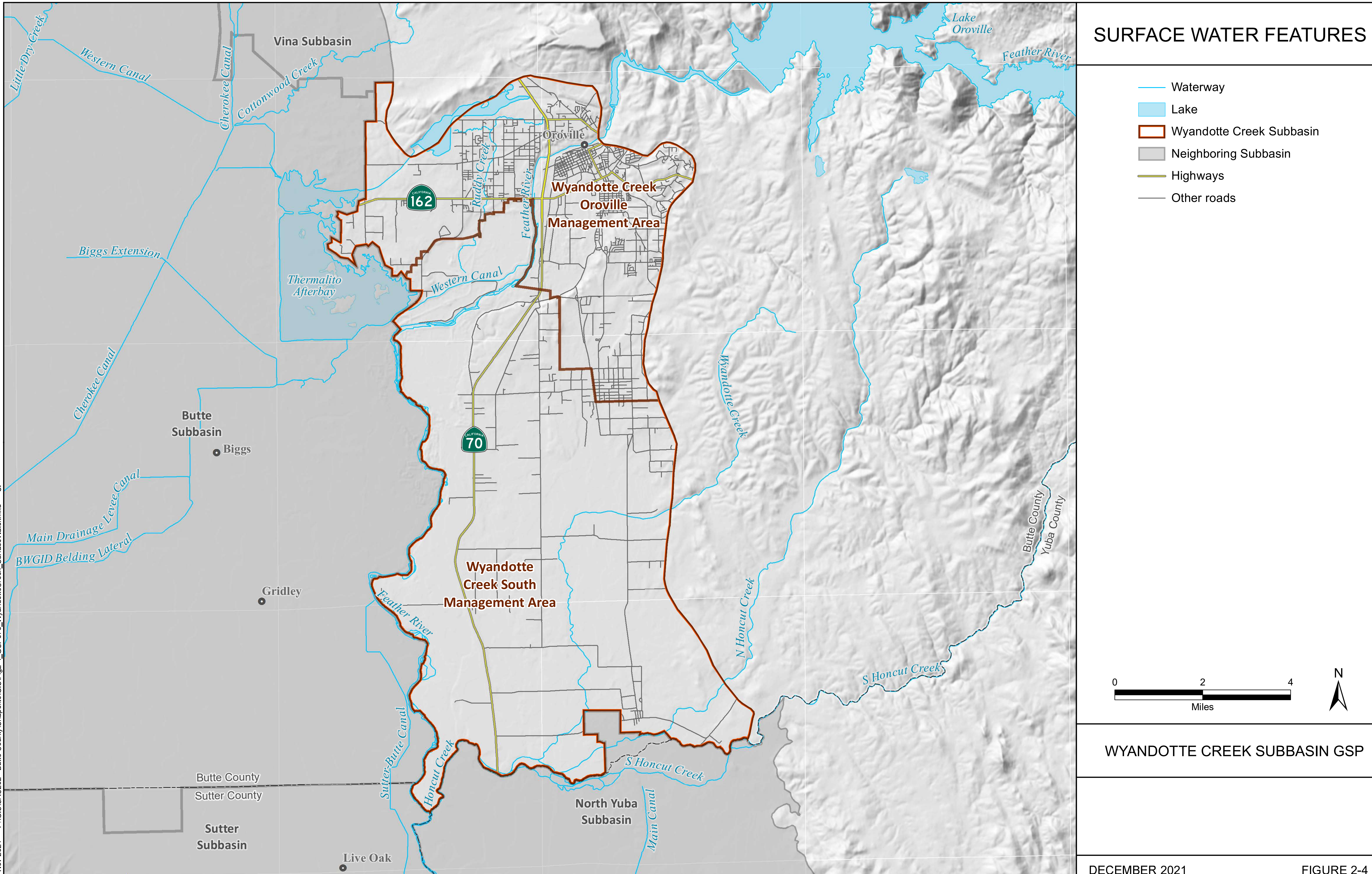
Smaller local or ephemeral streams entering and traversing the subbasin include North Honcut Creek, Wyandotte Creek, Wyman Ravine, Ruddy Creek, canals, and numerous unnamed waterways. Figure 2-4 shows prominent surface water features in the Wyandotte Creek Subbasin.

2.1.2.4 Groundwater Recharge Areas

Groundwater recharge is the downward movement of water from the surface to the groundwater system. Several water sources and mechanisms recharge the groundwater system in the Wyandotte Creek Subbasin. This includes percolation of water from rainfall, irrigation, or water bodies like the Feather River, streams and canals.

Figure 2-5 shows the relative rates of recharge as estimated by the Butte Basin Groundwater Model (BBGM) for the 2018 water year across the model elements (triangular areas) (BCDWRC, 2021). This is included as an indication of the variation in recharge in different areas due to the cumulative effects of varying factors including: soil characteristics, land use and irrigation water source, and precipitation. Areas with higher rates of recharge correspond in part to areas with soils having higher infiltration rates and areas receiving applied water for irrigation.

There is potential for additional recharge through management activities of flood flows or irrigation practices in the Wyandotte Creek Subbasin. The Soil Agricultural Groundwater Banking Index (SAGBI) is a suitability index for groundwater recharge on agricultural land based on five major factors: deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition. This dataset can serve as a starting point indication for areas conducive to natural or managed recharge. Large portions of the subbasin in its southern half received a moderately good to excellent rating in terms of being suitable for recharge (Figure 2-6). Additional considerations will be important for specific evaluation of any proposed recharge project. SAGBI data can be accessed at https:\\casoilresource.lawr.ucdavis.edu/sagbi.



DECEMBER 2021 FIGURE 2-4

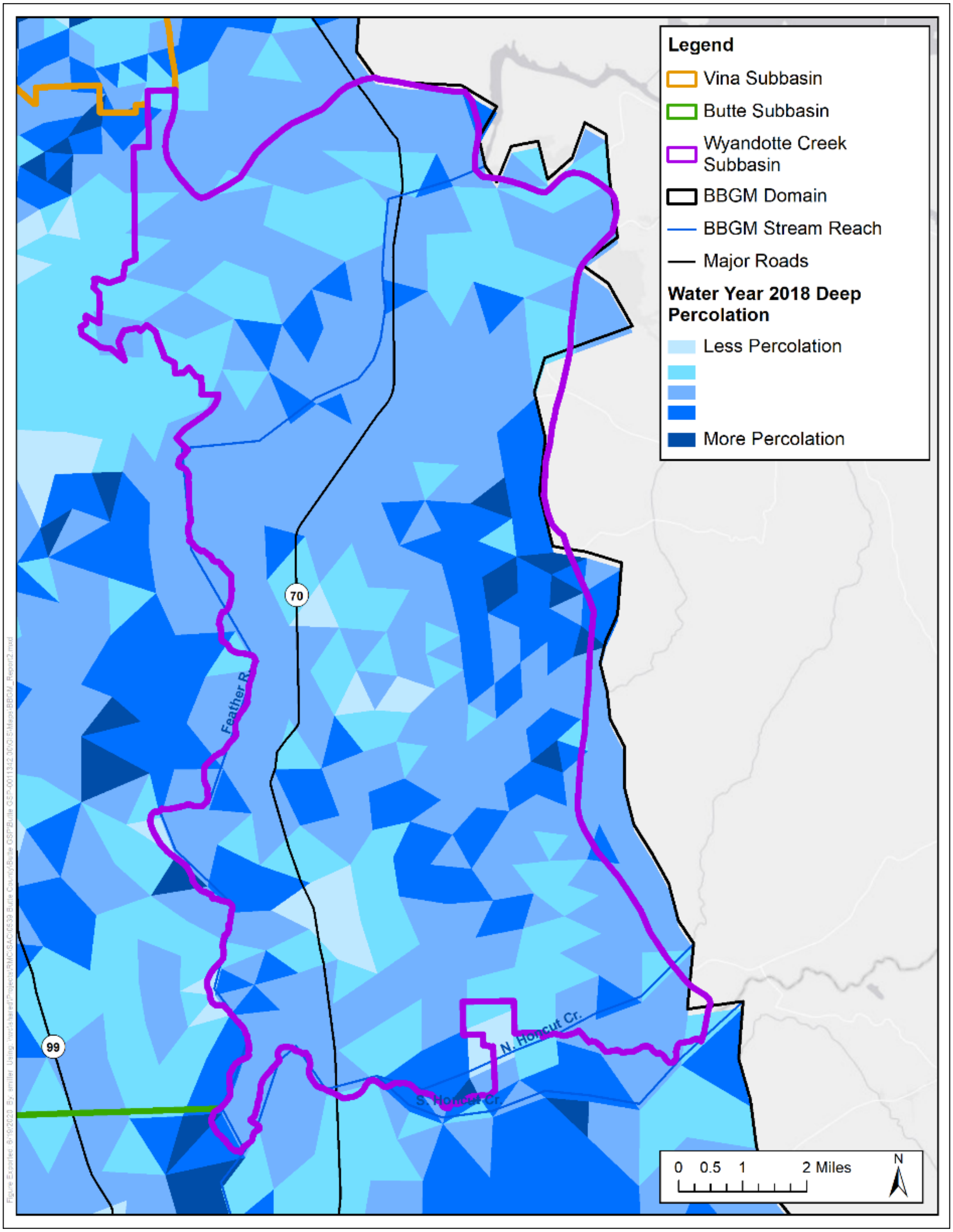
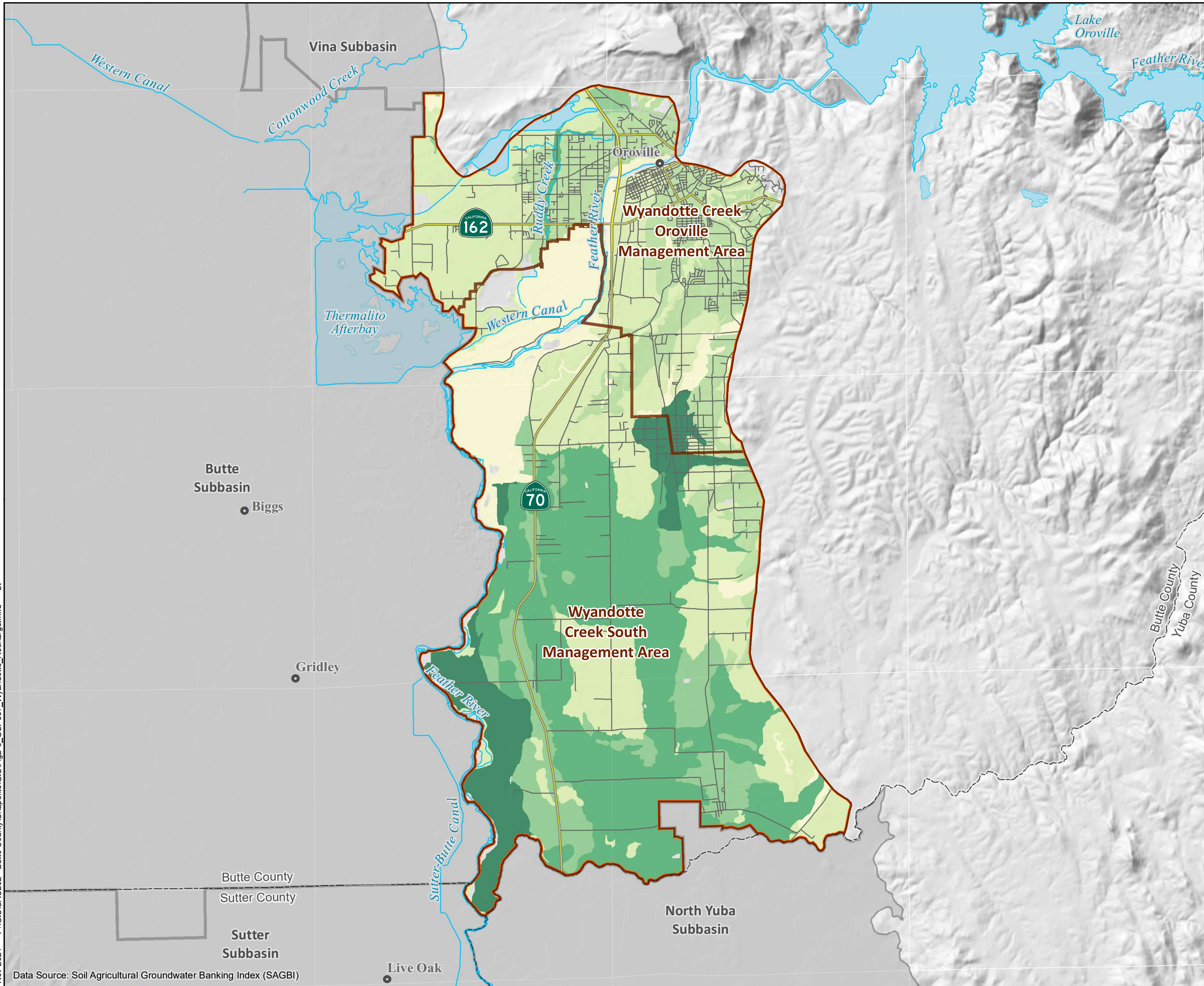


Figure 2-5: Relative Rates of Deep Percolation throughout the Wyandotte Creek Subbasin as Estimated by the Butte Basin Groundwater Model (BBGM)



SAGBI RECHARGE POTENTIAL

WYANDOTTE CREEK SUBBASIN GSP

DECEMBER 2021

FIGURE 2-6

2.1.3 Regional Geologic and Structural Setting

An inconsistent stratigraphic nomenclature has been established for the Cenozoic deposits in the Wyandotte Creek Subbasin (Blair et al., 1991). Many of these units are defined on the basis of gold content, buried soils, and geomorphic relationships or by the introduction of distant formation names without local verification. The stratigraphy of the Wyandotte Creek Subbasin, despite being finely divided, is further complicated by a lack of continuous exposure and by the fact that many of the units have inset relationships with older formations rather than superposed, layered relationships, owing to the sedimentologic behavior of the Feather River system. Using the nomenclature developed by Blair et al. (1991) and by adhering to the stratigraphic code (North American Commission on Stratigraphic Nomenclature, 2005), three formal stratigraphic units have been differentiated in the subbasin. These include, in ascending order, the Ione Formation, Mehrten Formation (designated by others as the Tuscan Formation), and Laguna Formation (designated by others as a combination of the Alluvium, Modesto, and Riverbank Formations).

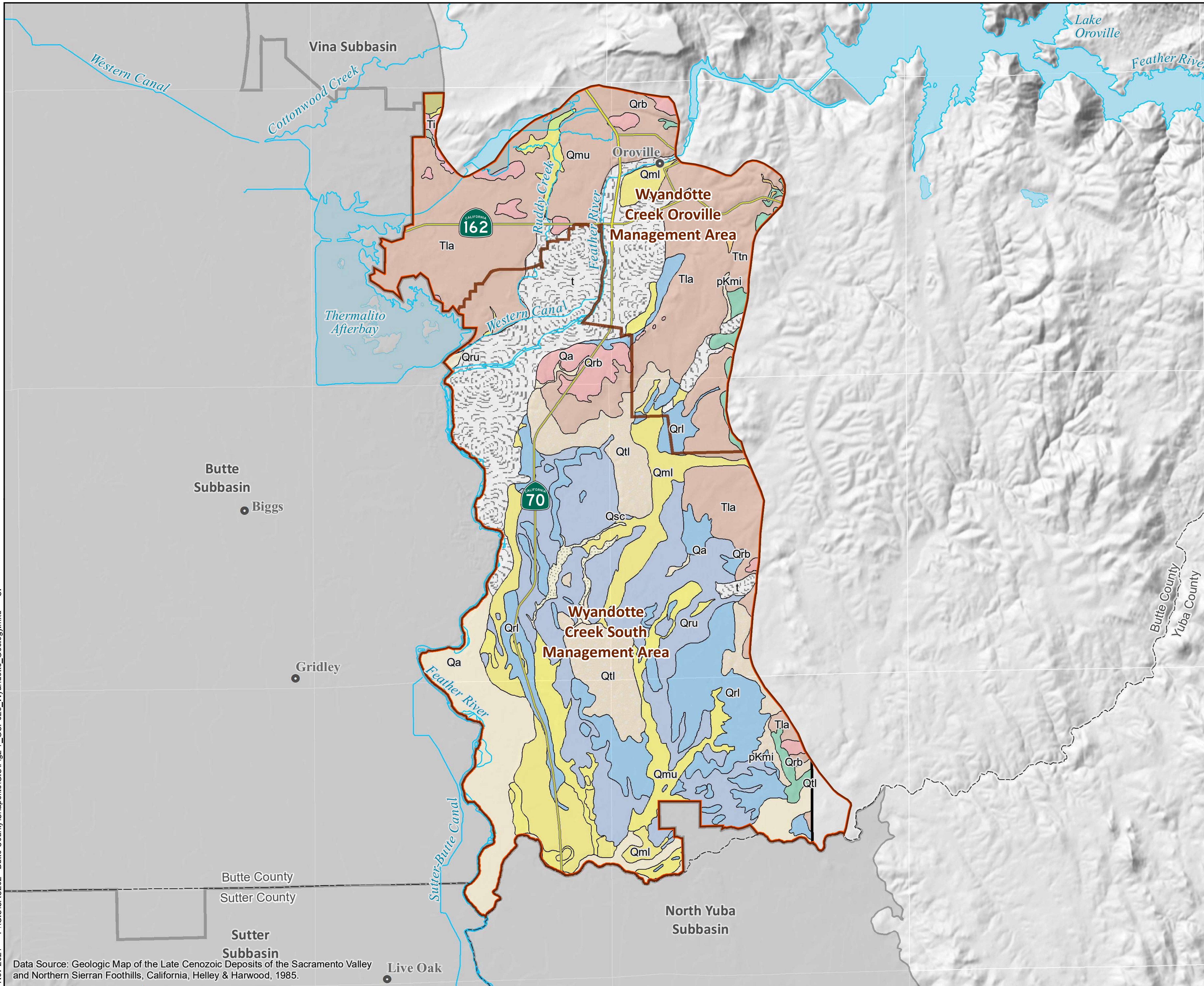
In the Oroville area, bedrock has been encountered as shallow as 283 feet below ground surface (bgs) and has been observed in outcrop adjacent to the Memorial Park Cemetery (Dames and Moore, 1994). Moving east from these areas, bedrock has been reported to occur at depths greater than 1,000 feet.

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

2.1.4 Geologic Formations

Groundwater occurs under both unconfined and confined conditions. Unconfined conditions are generally present in the surficial Quaternary deposits and in the Pliocene deposits that are exposed at the surface. Confined conditions exist where one or more confining layers rests above the underlying aquifer deposits.

Figure 2-7 is the Surficial Geologic Map for the Wyandotte Creek Subbasin, produced by DWR, which shows the surface distribution of geologic units. The surface geology is composed of the Laguna Formation in the north and eastern area, alluvium along the Feather River and predominantly Riverbank and Modesto Formations in the southern half of the subbasin. Tailings are mapped along the Feather River where it traverses the subbasin. These surficial deposits together are referred to as the Laguna Formation using the nomenclature of Blair et al. (1991).



SURFICIAL GEOLOGY

Geology Lines
- Contact, certain
- Map Boundary, exterior

Geology Polygons
- Stream Channel Deposits (Qsc)
- Alluvium (Qa)
- Basin Deposits, Undivided (Qb)
- Upper Member, Modesto Formation (Qmu)
- Lower Member, Modesto Formation (Qml)
- Upper Member, Riverbank Formation (Qru)
- Lower Member, Riverbank Formation (Qrl)
- Red Bluff Formation (Qrb)
- Turlock Lake Formation (Qtl)
- Nomlaki Tuff Member (Ttn)
- Tuscan Formation, Undifferentiated Unit A & B (Tta/b)
- Laguna Formation (Tla)
- Ione Formation (Ti)
- Metamorphic and Igneous Rocks (pKmi)
- Tailings (t)
- Waterway
- Lake
- Wyandotte Creek Subbasin
- Neighboring Subbasin
- Highways

0 2 4
Miles
N

WYANDOTTE CREEK SUBBASIN GSP

DECEMBER 2021 FIGURE 2-7

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The following is a discussion of groundwater producing geologic units found within the subbasin and region.

2.1.5 Groundwater Producing Formations

The majority of groundwater resources in the subbasin exist in spaces between gravel, sand, and clay particles of various formations that store and transmit water in the aquifer systems. Principal water bearing formations in the Wyandotte Creek Subbasin include the Ione, Mehrten, and Laguna Formations. These formations are discussed below.

2.1.5.1 Ione Formation

The Ione Formation is discontinuously exposed on the east side of the Sacramento Valley from near Deer Creek north of Chico to around Friant in the San Joaquin Valley (Creely, 1965 as cited in DWR, 2014). It is present in the subsurface in the Wyandotte Creek Subbasin and extends to the west toward the axis of the northern Sacramento Valley.

The Ione Formation consists of variably cemented, fine to coarse sandstone, siltstone, lignite, and claystone with variegated colors including red, yellow, white, blue, gray, orange, and black. Interbedded lenticular pebble-and-cobble “auriferous” or “greenstone” gravels are locally present and become more abundant eastwardly (Blair et al., 1991). In drill cuttings, the Ione Formation is easily identified from the overlying Mehrten Formation by its multicolored nature and volcanic-free composition.

2.1.5.2 Mehrten Formation

The Mehrten Formation includes a sequence of variably cemented, interbedded clay, sand, and gravel. This formation consists predominantly of purple volcanic debris flow deposits and interbedded water-lain fluvial deposits rich in volcanic detritus, but in many areas containing crystalline basement-derived clasts and rare tuff beds. The base of the Laguna Formation can easily be distinguished in drill cuttings where pumiceous materials of the tuff members are encountered. The reported occurrence of both channel-lain, clast supported, pebble- and cobble-gravel facies and interbedded volcanic-rich debris-flow facies in this formation suggests that debris flows related to volcanic events episodically choked the ancestral stream/river systems of the area. Blair et al. (1991) described the gravel and sand fractions, as well as many intervals of the Mehrten Formation in the Oroville area encountered in the subsurface consisting of porphyritic-dacite rock fragments and disaggregated quartz and plagioclase phenocrysts. The sand fraction of this area comprised a mixture of porphyritic-dacite rock fragments (36% to 37%), granitic rock fragments (32% to 49%), metamorphic rock fragments (4% to 7%), Quartz (10% to 19%), and feldspar (0% to 3%). This composition indicates that in the Wyandotte Creek Subbasin that the Mehrten Formation originated from the erosion of both Sierra Nevada crystalline rocks and a Mount Lassen-derived volcanic sequence.

2.1.5.3 Laguna Formation

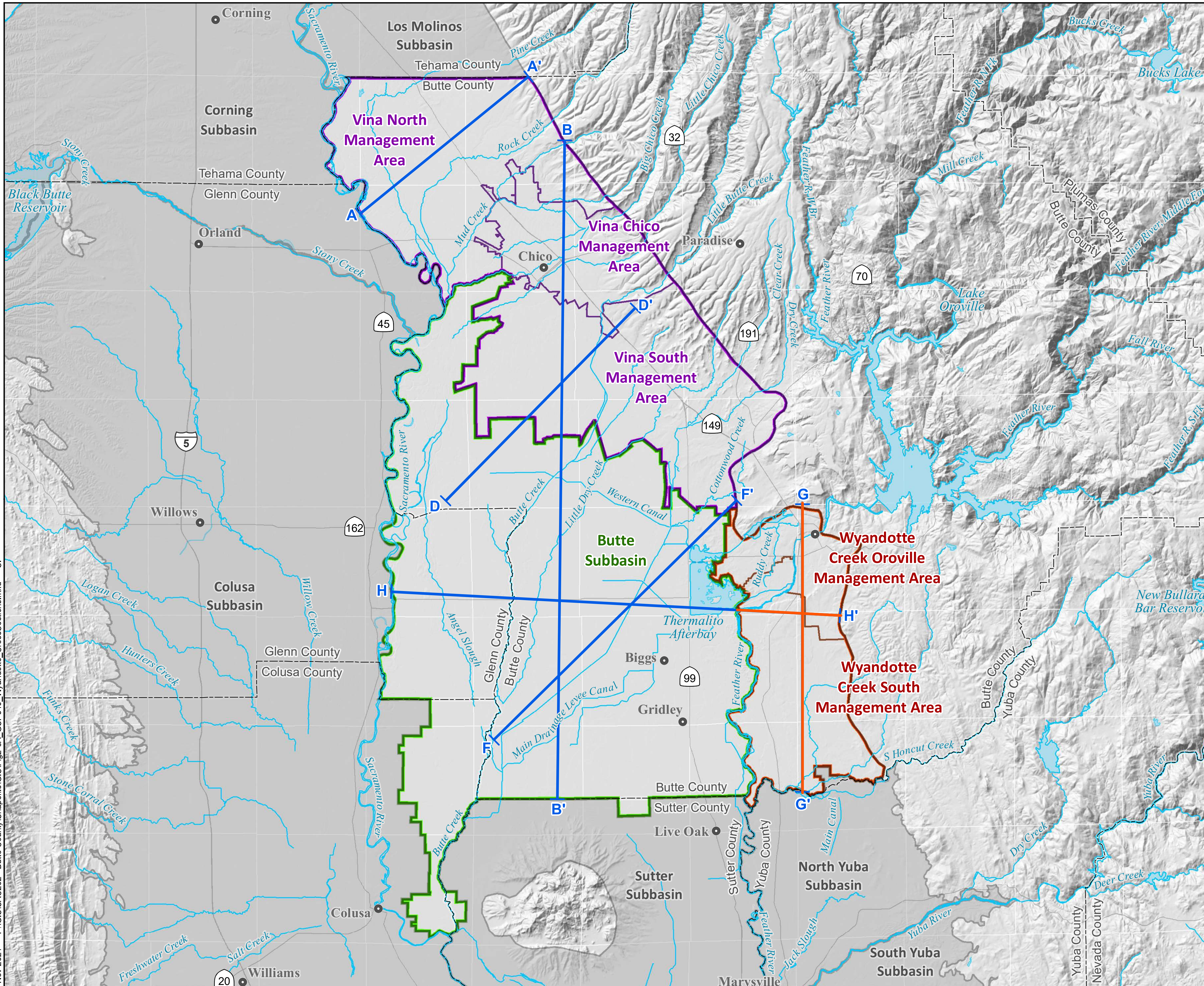
The Laguna Formation consists of sandy gravel channel, sandy channel facies, and sandy clay to clay floodplain facies and ranges in thickness in the northern part of the subbasin from 120 feet to 220 feet. The gravel deposits occur above sharp, scoured facies and are comprised of poorly to moderately sorted, sandy, clast-supported pebbles and cobbles. In the Oroville area, the Nomlaki Tuff Member, a white, pumice-rich, water-lain vitric tuff has been placed at the base of the Laguna Formation (Blair et al., 1991). If encountered, directly underlying this member is the

Mehrten Formation. Where the Nomlaki Tuff Member is not encountered, the base of the Laguna Formation is identified by the presence of gravel clasts and/or sand grains consisting of a composition greater than 50% andesite, andesitic basalt, and/or dacite.

The Laguna Formation was deposited by the ancestral Feather, and outside the subbasin by the Yuba, Bear, and American rivers to the south (Helley and Harwood, 1985). During the Pliocene and Pleistocene epochs, uplift of the Sierra Nevada increased the erosion of the plutonic and metamorphic rocks on the eastern side of the valley. Rivers and streams carried the eroded material westward to the valley floor, and as the water overtopped the banks, it spread out across the broad floodplains of the valley, depositing the sediments into broad alluvial fans (DWR, 2014).

2.1.6 Geologic Cross Sections

Figure 2-8A is a key which shows the orientation of geologic cross sections developed for the Wyandotte Creek Subbasin and relation of these cross sections to others in the adjacent Vina and Butte subbasins. Figures 2-8B and 2-8C are respectively north-south and east-west geologic cross sections for the Wyandotte Creek Subbasin. The north-south section was developed for this GSP, the east-west section is based on a section presented in the DWR report Geology of the Northern Sacramento Valley, California (DWR, 2014).



CROSS SECTION ALIGNMENTS

Cross Section Alignment
Relevant Cross Section Extent

Subbasins

Butte Subbasin
Vina Subbasin
Wyandotte Creek Subbasin
Neighboring Subbasin

All Other Features

Highway
Waterway
Lake

0 2.5 5 10
Miles

N

WYANDOTTE CREEK SUBBASIN GSP

DECEMBER 2021 FIGURE 2-8A

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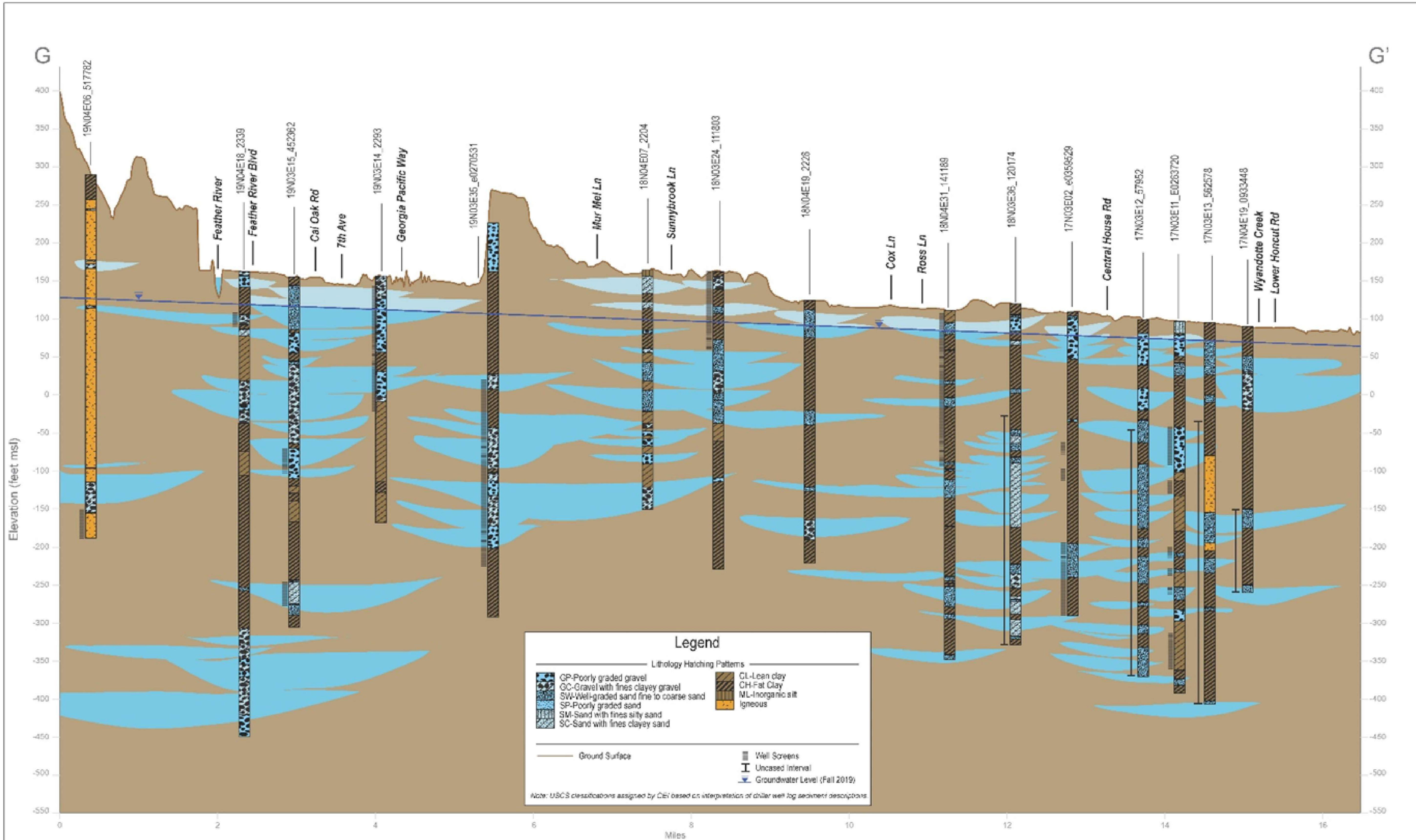


North-South Geologic Cross-Section G-G'
Wyandotte Creek Subbasin GSP

Project No.: SAC282 | December 2021

Figure **2-8B**

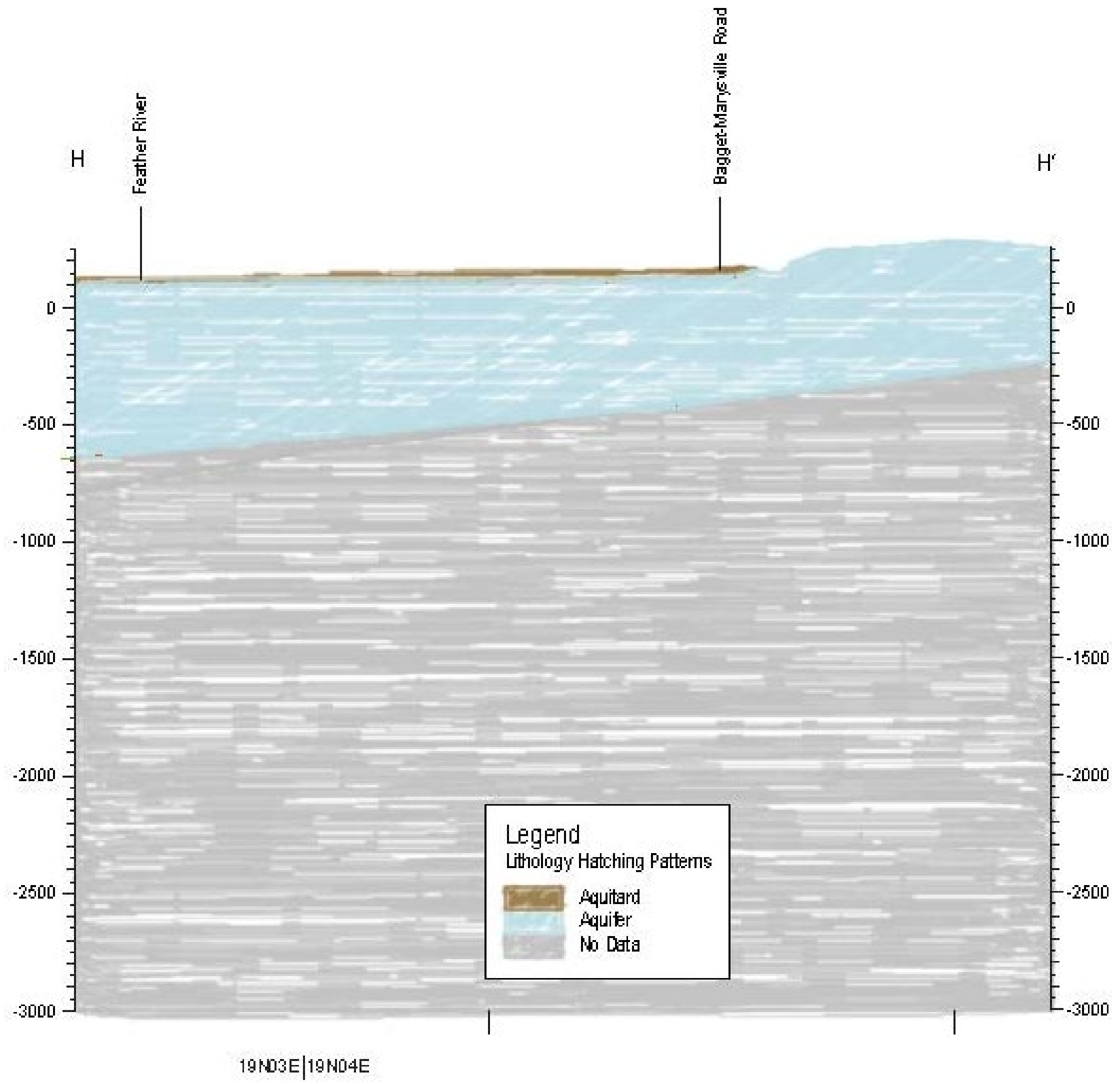


Figure 2-8C: East-West Geologic Cross Section H-H'

2.1.7 Principal Aquifers and Aquitards

DWR defines principal aquifers under SGMA as the "aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems" (California Code of Regulations [CCR], Title 23, § 351(aa)). A single principal aquifer in the subbasin consists predominantly of Ione, Mehrten, and Laguna Formations. There are no known structural properties that significantly restrict groundwater flow within the subbasin within the portion of the aquifer that stores, transmits, and yields significant quantities of water.

2.1.7.1 Primary Uses

Water produced from the principal aquifer is primarily used to meet irrigation, domestic and municipal water demand. Domestic supply is used to meet rural residential demands. Municipal supply is largely used to meet demand from the City of Oroville.

2.1.7.2 Specific Yield

Specific Yield or storativity quantifies the ability of the aquifer to hold or store water. Quantitative water-bearing data for the Laguna Formation is limited, especially in the area of the Wyandotte Creek Subbasin. Although the occurrence of thin sand and gravel zones is common, many of them have reduced permeability due to cementation. This, coupled with its fine-grained character, leads to an overall low permeability for the Laguna Formation. An unpublished study by Bookman-Edmonston Engineering, Inc. (1992) estimated groundwater storage based on an average specific yield of 6.9% and assumed thickness of 200 feet (DWR, 2006). The 2005 DWR report assumed a specific yield of 8.8%.

Values for specific yield and storativity used in the calibrated BBGM throughout the Wyandotte Creek Subbasin are 10% and 0.00001, respectively (BCDWRC, 2021).

2.1.7.3 Transmissivity

Transmissivity (T) quantifies the ability of water to move through aquifer materials. The aquifer hydraulic conductivity (K) quantifies the rate of groundwater flow and is related to the transmissivity and aquifer thickness (b) by the following formula: $T = K \times b$. Limited hydraulic conductivity data is available for the subbasin. The BBGM calibrated hydraulic conductivity ranges from 20-250 feet per day depending upon the location and depth within the subbasin (BCDWRC, 2021).

2.1.7.4 Water Quality

The primary water chemistry in the area indicates calcium magnesium bicarbonate or magnesium calcium bicarbonate groundwater. Some magnesium bicarbonate can be found in the northwest portion of the subbasin (DWR, 2006). The generally good water quality characteristics of the subbasin are apparent in the overall salinity of groundwater. In general, total dissolved solids (TDS) concentrations in the study area are below 500 milligrams per liter (mg/L) throughout the subbasin (Bookman-Edmonston Engineering, Inc. 1992). Data collected from DWR water quality wells indicate a TDS range of 149 to 655 mg/L and a median of 277 mg/L (DWR, 2006). Butte County's water quality trend monitoring program measures electrical conductivity in two wells in the subbasin. Data collected annually from 2002 through 2019 indicate a range of 132 to 374 microsiemens per centimeter (µS/cm), well below the secondary water quality threshold for drinking water of 900 µS/cm.

In the northern part of the subbasin, groundwater occurrence is saline to brackish except locally on the margins of the valley where the formational water has been flushed with newer fresh water. Non-saline water was also observed in deeper portions of the Ione Formation in the vicinity of Oroville (Dames and Moore, 1994). Sediments that were continentally derived contain fresh to brackish water and are poorly to moderately permeable (Olmsted and Davis, 1961). In the southern part of the subbasin, numerous wells appear to be completed within the Ione Formation (boring logs identify "blue clays" believed to be indicative of the Ione Formation) that produce fresh water.

2.1.8 Opportunities for Hydrogeologic Conceptual Model Improvements

2.1.8.1 Identify Areas Where Additional Monitoring Would Help Increase Understanding of the Aquifer

Determine the best approach for increasing monitoring in these areas, such as installation of new wells or increased monitoring at existing wells.

2.1.8.2 Expand Isotopic Analysis to Further Assess Groundwater Recharge

Future recharge and aquifer studies should include the collection and interpretation of stable isotope data. Methodology considerations include: 1) Seasonal sampling should be performed as part of future surface water and groundwater isotope studies for purposes of assessing groundwater recharge; 2) Monitoring wells with multiple screened intervals (multi-completion monitoring wells) are recommended to assess stable isotope data at different depths. Sampling locations with a single well-screen interval do not provide nearly as much insight as sampling locations with wells screened at multiple depths; and 3) Monitoring wells with relatively short screened zones (20 feet or less) are preferred to minimize mixing between aquifer zones or between aquifer zones and residual water retained within the aquitard zones between aquifers.

2.1.8.3 Characterize Recharge Source With General Water Quality

Conduct general mineral analysis on groundwater samples to evaluate whether elevated electrical conductivity values observed during sampling are due to irrigation influences (e.g., elevated nitrate, calcium, sulfate) or due to proximity to the Ione Formation (e.g., elevated sodium, chloride, and boron).

2.1.8.4 Recharge rate

Most monitoring well locations and depths should be sampled and analyzed for presence of tritium to help distinguish whether recharge to individual aquifer zones is occurring over periods shorter than about 60 years, or whether recharge is occurring over longer timeframes

2.1.8.5 Field Testing and Monitoring Equipment Installation to Understand the Recharge Rates and Stream Losses in the Recharge Zone

Expansion of stream gauging locations to document changes in stream-aquifer interactions should be conducted. In addition to the stream gauging, a series of shallow dedicated monitoring wells with temperature sensors installed along stream courses in the recharge corridor may help identify what sections of streams are losing or gaining.

2.1.8.6 Additional Aerial Electromagnetic Data Collection

Expanding the extent of aerial electromagnetic (AEM) surveys is recommended to support refinement of the 3D HCM of the subsurface. AEM data sets provide valuable insights on the lithology of the subbasin and therefore better understanding of connectivity between aquifer layers and recharge areas.

2.2 Groundwater Conditions

2.2.1 Description of Current and Historical Conditions

Groundwater conditions in the Wyandotte Creek Subbasin are continually monitored and are comprehensively described in the 2001 and 2016 Water Resource Inventory and Analysis Reports and Annual Groundwater Status reports produced by Butte County. These documents and other reports portray a subbasin that has adequate groundwater resources to meet demands under most hydrologic conditions. However, comparison of the reports illustrates how in the period between their issuance demand for groundwater has grown relative to the available supply. This trend, quantified below in the water budget section of this document, suggests that as forces ranging from population growth to climate change play out, the value of well-informed water management policies and practices is likely to increase. In short, as shown below, while groundwater conditions in the subbasin remain relatively stable, maintaining this posture in the future may become less the result of a state of nature and more the reward for thoughtful management. The water budget analysis presented in this section provides a quantitative assessment of how conditions have changed in the Wyandotte Creek Subbasin and an indication of how conditions may change in the future.

2.2.2 Groundwater Trends

2.2.2.1 Elevation and Flow Directions

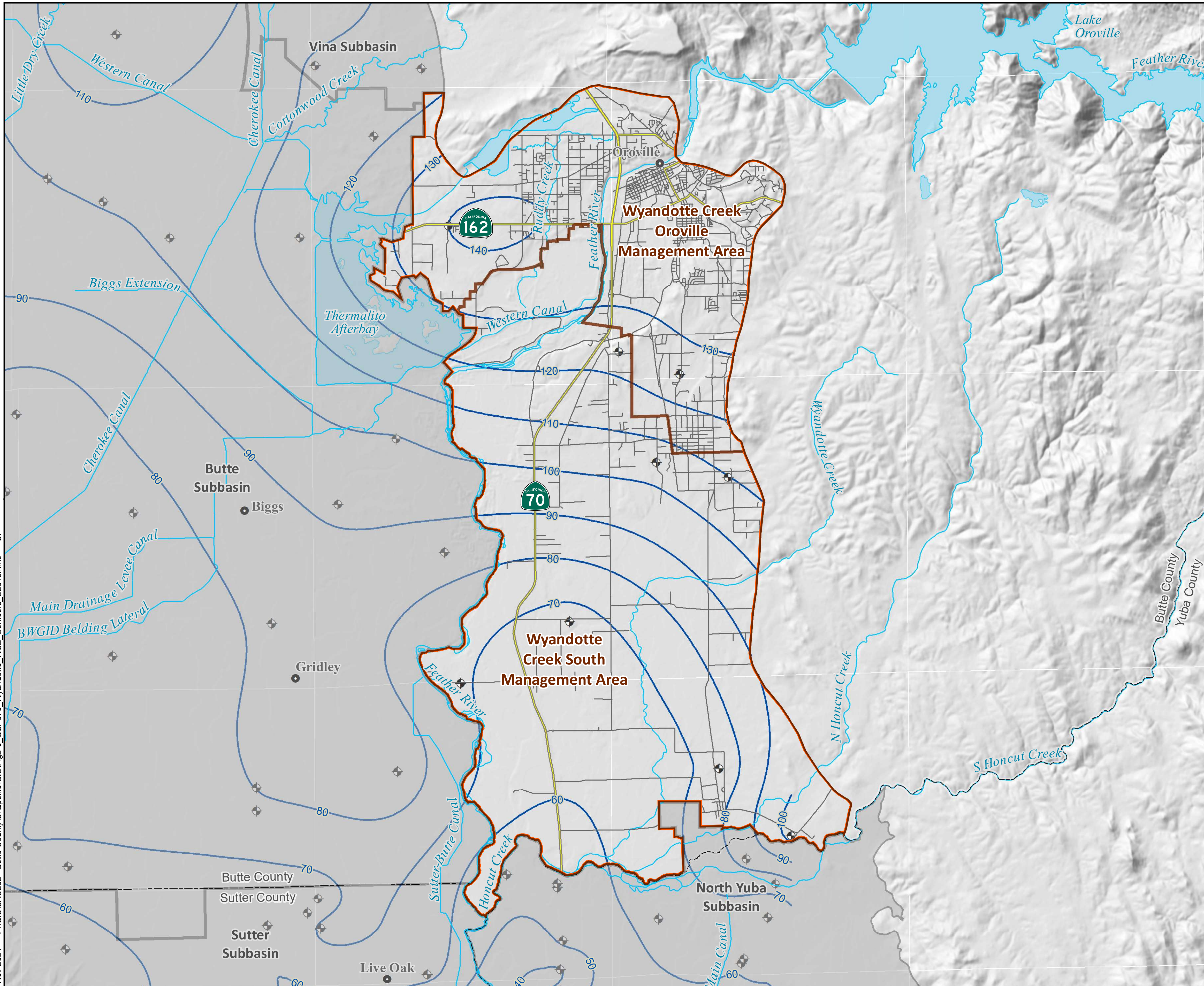
Figures 2-9 and 2-10 show groundwater elevation contours in the Wyandotte Creek Subbasin for the spring and fall of 2015 and Figures 2-11 and 2-12 show elevation contours for the spring and fall of 2019.

Contours plotted on these maps show first encountered groundwater as reported through the CASGEM Program. The data were processed as follows:

- Data from CASGEM were used to identify wells in the Wyandotte Creek Subbasin plus supplemental sites used to extend the contours to the west.
- Water level readings for 2015 and 2019 were then filtered for measurements taken between September 20th and October 30th for the fall contours and between March 20th and April 30th for the spring contours.
- Wells showing depths to first encountered groundwater deeper than 500 feet were eliminated from the data set. The remaining readings were sorted by well depth.

The four contour maps display groundwater elevations that are higher in the north of the subbasin than in the south indicating a general gradient that causes water to flow from north and from foothill recharge areas in the east toward the subbasin’s southeastern corner. Because of the influence of Thermalito Afterbay and the Feather River, groundwater elevations in the north are generally stable between the spring and fall observation periods, while elevations in the south tend to be lower in the fall than the spring, a pattern typical of valley floor locations distant from major sources of recharge.

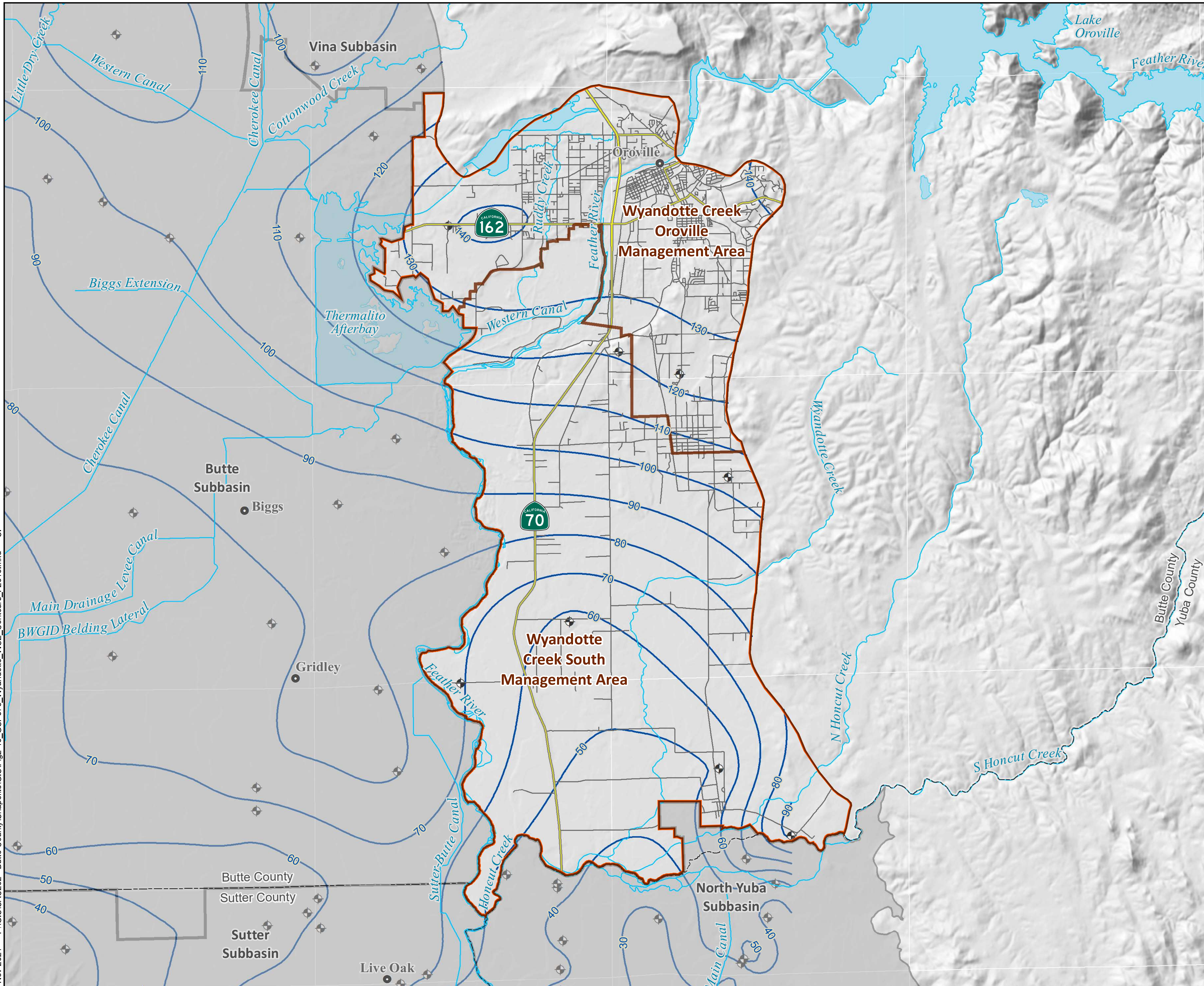
When comparing elevations reported in 2015 with those reported in 2019, the influence of stable water elevations in Thermalito Afterbay has resulted in a corresponding stability in neighboring groundwater elevations. However, elevations in the spring of 2015 observed in the south tend to be higher than those reported for the spring of 2019. Fall elevations in the north continue to show the stabilizing influence of Thermalito Afterbay. However, elevations to the south for 2015 are slightly lower than those observed in 2019. This may be an indication of an increase in the volume of water recharged from upland areas flowing into the subbasin’s principal aquifer.



WATER SURFACE ELEVATION SPRING 2015

WYANDOTTE CREEK SUBBASIN GSP

DECEMBER 2021 FIGURE 2-9



WYANDOTTE CREEK SUBBASIN GSP

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FIGURE 2-10

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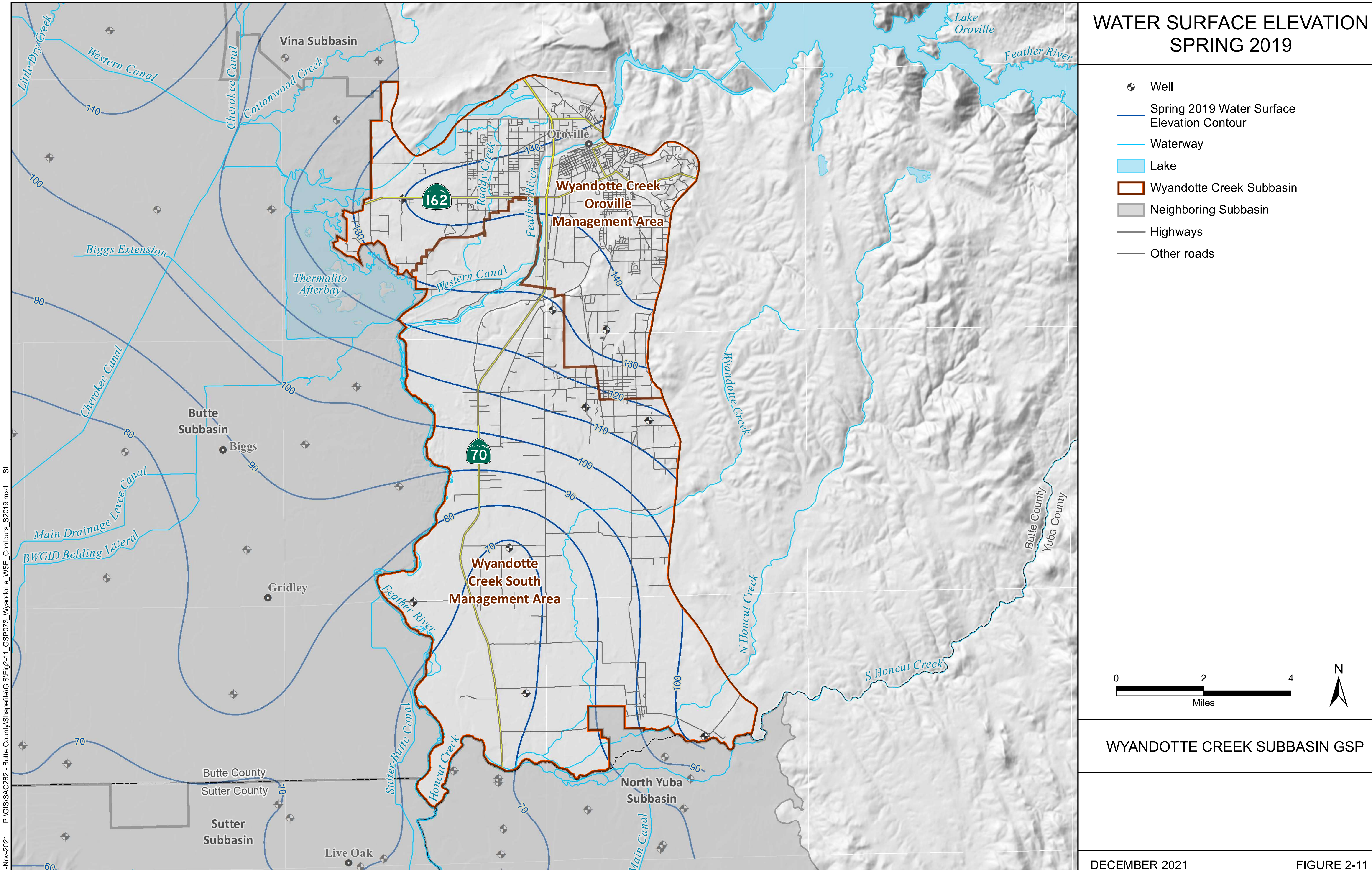
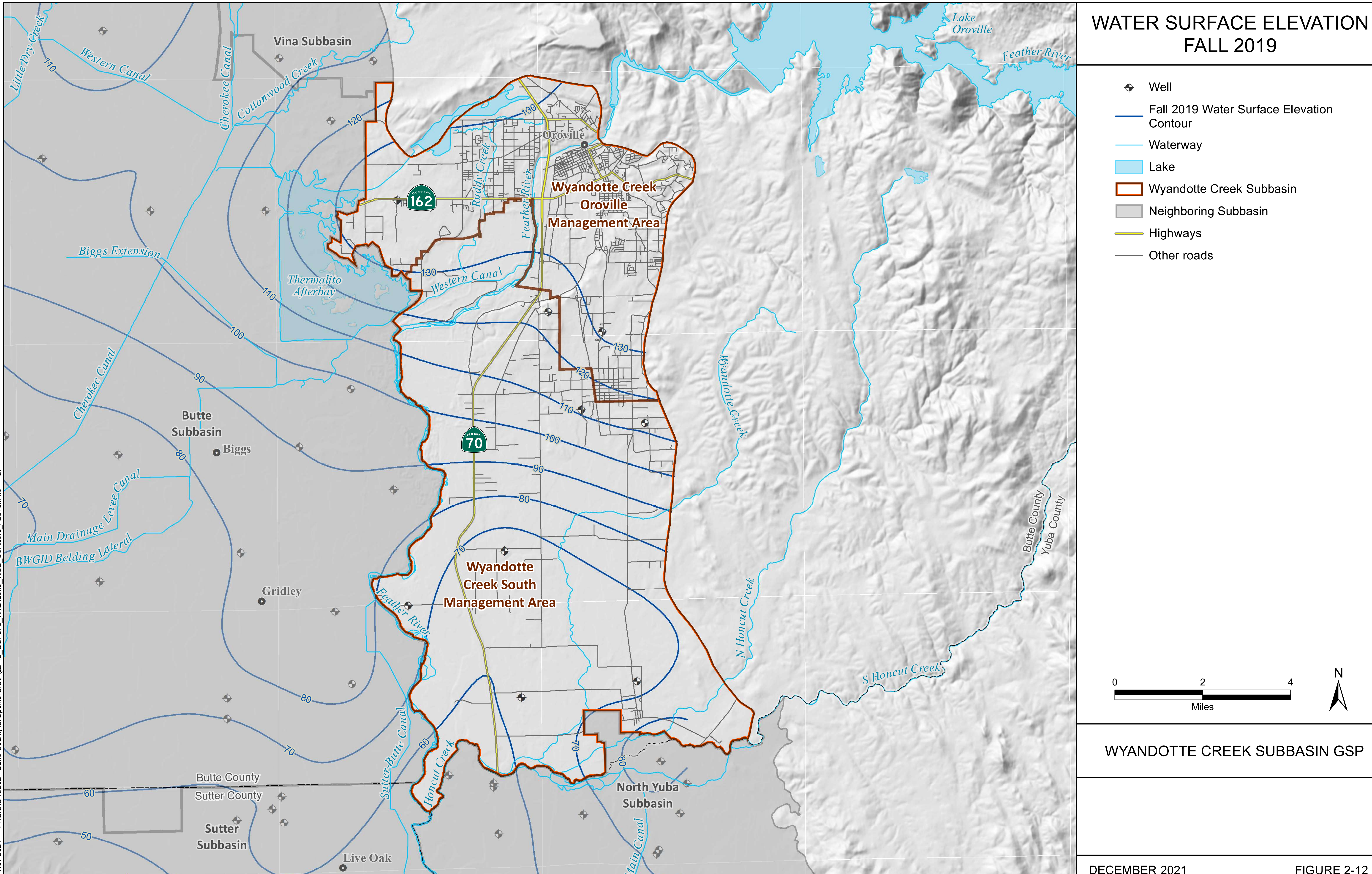

Vina Subbasin
Butte Subbasin
Sutter Subbasin
North Yuba Subbasin
Wyandotte Creek Oroville Management Area
Wyandotte Creek South Management Area
Oroville
Biggs
Gridley
Live Oak
Lake Oroville
Feather River
Thermalito Afterbay
Western Canal
Cherokee Canal
Cottonwood Creek
Little Dry Creek
Biggs Extension
Main Drainage Levee Canal
BWGID Belding Lateral
Sutter-Butte Canal
Honcut Creek
Wyandotte Creek
N Honcut Creek
S Honcut Creek
Main Canal
Ruddy Creek
Butte County
Sutter County
Yuba County
162
70
WATER SURFACE ELEVATION SPRING 2019
Well
Spring 2019 Water Surface Elevation Contour
Waterway
Lake
Wyandotte Creek Subbasin
Neighboring Subbasin
Highways
Other roads
0
2
4
Miles
N
WYANDOTTE CREEK SUBBASIN GSP
DECEMBER 2021
FIGURE 2-11
P:\GIS\SAC282 - Butte County\Shapefile\GIS\Fig2-11_GSP073_Wyandotte_WSE_Contours_S2019.mxd SI
22-Nov-2021



WYANDOTTE CREEK SUBBASIN GSP
DECEMBER 2021
FIGURE 2-12

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2.2.2.2 Lateral/vertical Gradients

Lateral groundwater gradients generally reflect ground surface topography. In the foothills east of the Wyandotte Creek Subbasin the gradient is steep, as high as 60 feet per mile. However, in most of the subbasin itself, the gradient is gradual at approximately 3 feet per mile, with the gradient influenced both by the terrain and by the groundwater mound fed by seepage from Thermalito Afterbay.

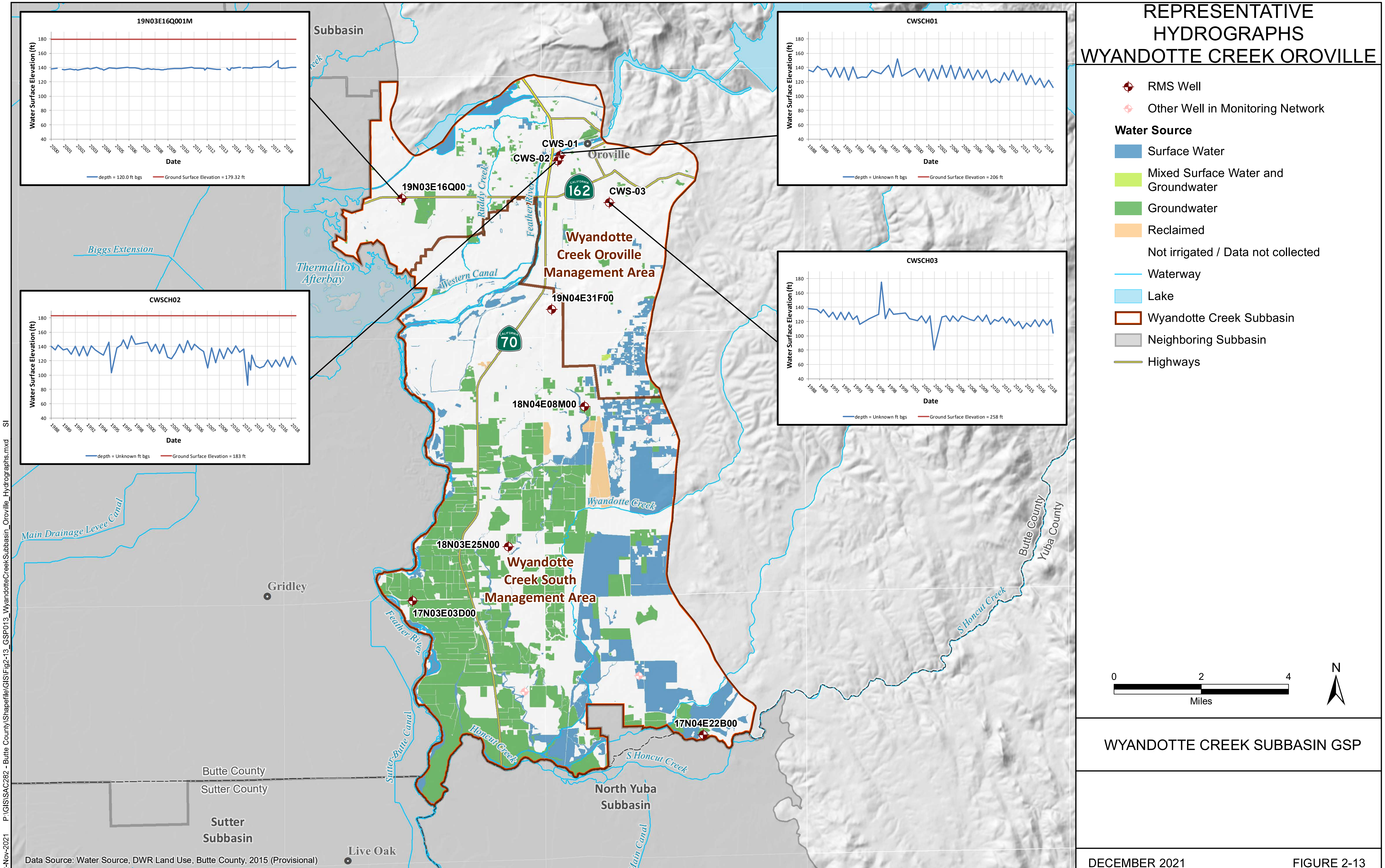
Figure 2-13 is a map of the Wyandotte Creek Subbasin's Oroville MA that displays hydrographs of selected monitoring wells, and Figure 2-14 is a similar map of the subbasin's South MA. Just as comparison of the spring and fall contours indicated the shift in groundwater elevations that typically occurs between the seasons, the hydrographs display annual oscillations in elevations as well as trends over the monitoring period, snapshots of which are captured in comparison between the 2015 and 2019 contours. Each of the hydrographs displays water surface elevations in feet amsl and also gives the depth of the bottom of the well which indicates the location of the zone being measured.

All of the hydrographs are taken from single completion wells where only one aquifer zone is screened. As discussed in Chapter 4, as part of the Technical Support Services program (TSS), DWR completed installation of a nested monitoring well (Figure 4-6). However, no water levels have been collected from this well for inclusion into the GSP.

Hydrographs for the selected wells in the Wyandotte Creek Subbasin are similar to the seasonal fluctuations illustrated in the contour maps with depths to groundwater at all locations being shallower in the winter and spring than in the summer and fall. Wells in the vicinity of Oroville tend to have higher groundwater elevations than those to the south and west because of higher ground surface elevations at those locations and because of recharge from the foothills. While wells in the eastern portion of the subbasin show periods when high levels of pumping cause water levels to drop during the summer, groundwater elevations tend to rebound to consistent elevations over the winter.

As would be expected, wells located near major water bodies such as the Thermalito Afterbay and the Feather River display stable groundwater elevations due to their proximity to these features. These hydrographs also display the strong gradient that exists between spring groundwater elevations observed in the northeastern quadrant of the subbasin, where elevations between 140 and 160 feet amsl are typical, and those observed in the southwestern quadrant, where groundwater elevations are near or shallower than 90 feet amsl.

Vertical groundwater gradients are typically measured by comparing groundwater elevations using multi-completion or nested wells that are designed to measure elevations from different aquifer zones. If groundwater levels in the shallower zone are higher than in the deeper ones, the gradient allows downward movement of groundwater. In locations where groundwater levels in the shallower zone are lower than in the deeper zones, the gradient encourages upward movement of groundwater. In locations where groundwater levels are similar in elevation and track each other in fluctuations across two or more zones, there is no vertical gradient and no vertical movement of groundwater. One of the data gaps observed in the Wyandotte Creek Subbasin is the lack of nested monitoring wells needed to observe and interpret vertical groundwater gradients in the subbasin.


REPRESENTATIVE HYDROGRAPHS WYANDOTTE CREEK OROVILLE
RMS Well
Other Well in Monitoring Network
Water Source
Surface Water
Mixed Surface Water and Groundwater
Groundwater
Reclaimed
Not irrigated / Data not collected
Waterway
Lake
Wyandotte Creek Subbasin
Neighboring Subbasin
Highways
0 2 4
Miles
N
WYANDOTTE CREEK SUBBASIN GSP
DECEMBER 2021
FIGURE 2-13
19N03E16Q001M
Water Surface Elevation (ft)
Date
depth = 120.0 ft bgs
Ground Surface Elevation = 179.32 ft
CWSCH01
depth = Unknown ft bgs
Ground Surface Elevation = 206 ft
CWSCH02
depth = Unknown ft bgs
Ground Surface Elevation = 183 ft
CWSCH03
depth = Unknown ft bgs
Ground Surface Elevation = 258 ft
CWS-01
CWS-02
CWS-03
19N03E16Q00
19N04E31F00
18N04E08M00
18N03E25N00
17N03E03D00
17N04E22B00
Oroville
Wyandotte Creek Oroville Management Area
Wyandotte Creek South Management Area
Subbasin
Biggs Extension
Thermalito Afterbay
Western Canal
Ruddy Creek
Feather River
Wyandotte Creek
Main Drainage Levee Canal
Gridley
Sutter-Butte Canal
Honcut Creek
S Honcut Creek
Butte County
Sutter County
Yuba County
Sutter Subbasin
North Yuba Subbasin
Live Oak
Main Canal
162
70
Data Source: Water Source, DWR Land Use, Butte County, 2015 (Provisional)
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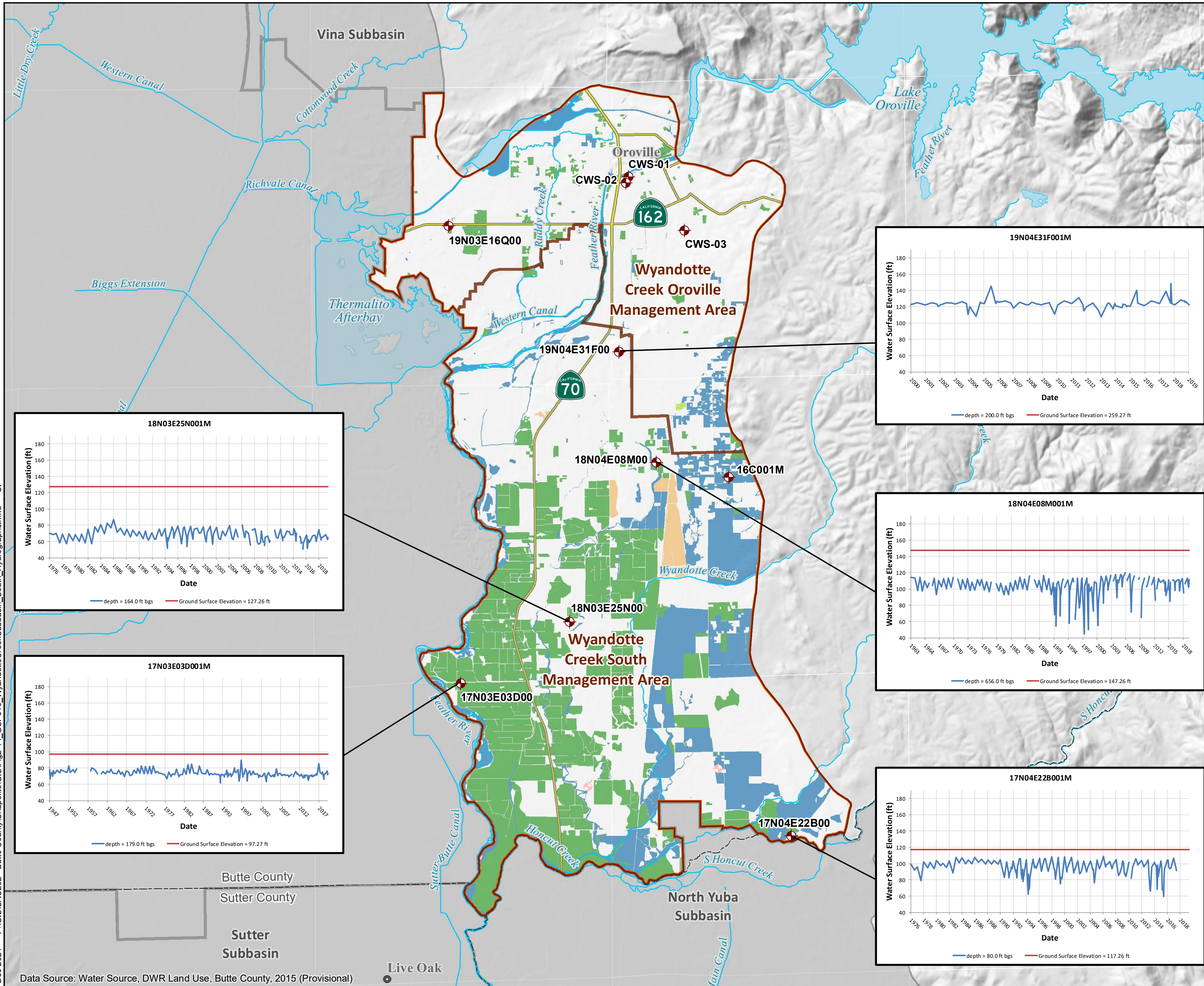
REPRESENTATIVE HYDROGRAPHS WYANDOTTE CREEK SOUTH



Data Source: Water Source, DWR Land Use, Butte County, 2015 (Provisional)

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WYANDOTTE CREEK SUBBASIN GSP

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FIGURE 2-14

2.2.2.3 Regional Patterns

The series of contour maps and hydrographs presented above complement each other in showing how groundwater levels respond to seasonal variations in demand and recharge and are affected by long-term events such as the recent drought. The patterns in groundwater conditions observed in the Wyandotte Creek Subbasin resemble those found throughout the region and are driven by similar forces. However, groundwater conditions in the Wyandotte Creek Subbasin tend to be moderated by recharge from precipitation, canal seepage and the proximity of Thermalito Afterbay and the foothills. Although the Wyandotte Creek Subbasin receives little groundwater inflow from the north, the subbasin does contribute groundwater to areas to its south.

2.2.2.4 Change in Storage

Change in groundwater storage is the product of the volume of aquifer material lying between groundwater elevations at the beginning and end of the period over which the change takes place and 'storage' values representing the storage capacity of a unit of aquifer material. The heterogeneity of the lithology of the shallow, unconfined, and confined zones results in a wide range of values for storage: specific yield for unconfined zones and coefficient of storage for confined zones.

Groundwater storage in the Wyandotte Creek Subbasin follows a pattern typical of much of the Sacramento Valley where during normal to wet years, water stored in the aquifer system is withdrawn over the summer when demand is high, and the main pathways for recharge are deep percolation of irrigation applications, canal seepage, and seepage from Thermalito Afterbay. As illustrated in the water budget, in many years, reductions in storage during the summer are replenished by precipitation over the winter allowing storage to rebound by the following spring.

Review of the hydrographs from monitoring wells in the Wyandotte Creek Subbasin demonstrates the influence of the Wyandotte Creek Subbasin's location with the foothills to the east, the Feather River to the west and Thermalito Afterbay to the northwest as factors that stabilize both groundwater elevations and groundwater storage. While the Afterbay, canal seepage and the foothills are important sources of recharge, the prevailing groundwater gradients allow groundwater to flow to the river and to subbasins to the south. Outflows to the river and to the south increase when inflows to the Wyandotte Creek Subbasin increase causing gradients to the south and to the river to steepen. The dynamics of the interaction between inflows, outflows, changes in groundwater elevations and changes in storage are captured in the water budget described later in the Basin Setting and by the BBGM.

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

[2] Additional details describing the Sacramento Valley Water Year Index are available from the California Data Exchange Center (https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST).

amounts. Groundwater pumping was estimated using the BBGM and is shown on a water year basis.[3] Values are reported in TAF.

As indicated in the figure, groundwater storage has generally decreased in dry and critical years and increased in wet years. In above normal and below normal years, changes in storage are smaller and less predictable, with increases in some years and decreases in others. For the recent historical period, which was marked by relatively dry conditions from 2007 to 2016, with the exception of the wet year of 2011, there has generally been a decline in groundwater storage within the subbasin. Historical and projected changes in storage are discussed in greater detail in Section 2.3, Water Budget.

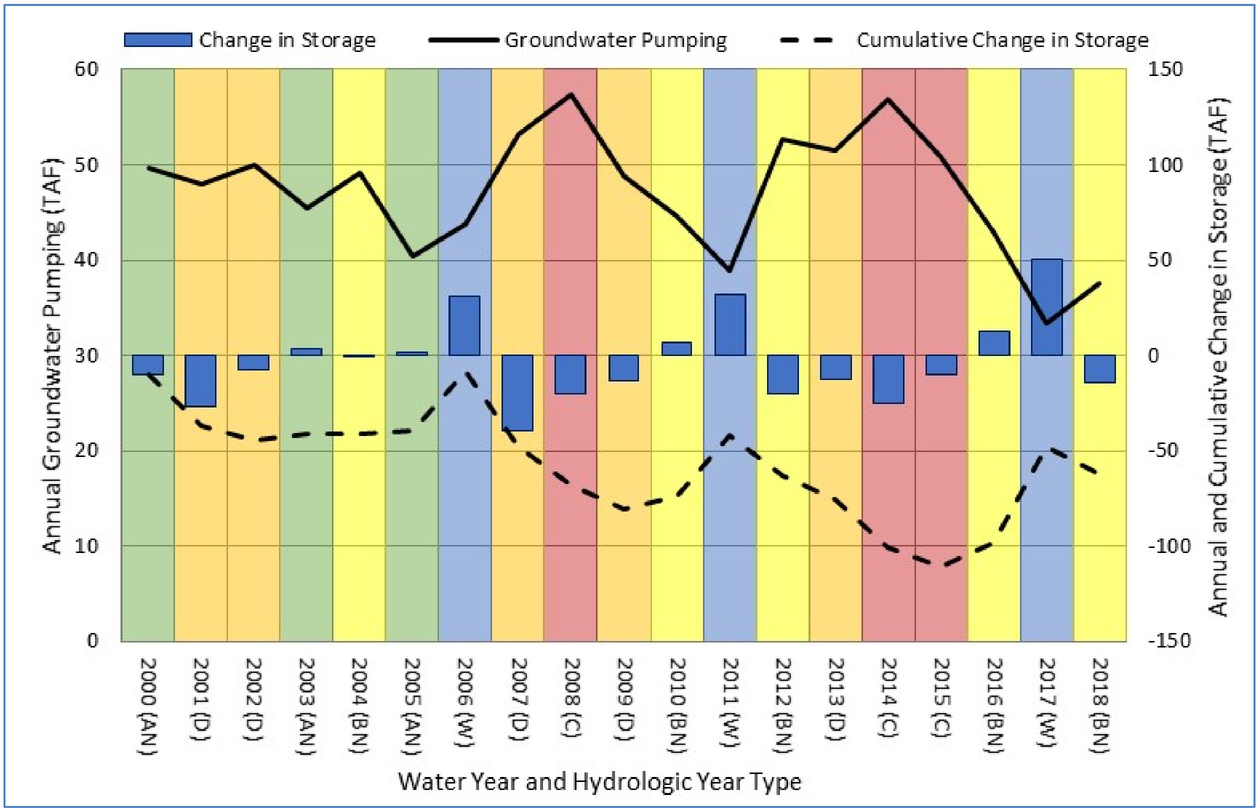


Figure 2-15: Change in Storage and Groundwater Pumping by Water Year Type. AN – above normal, D – dry, BN – below normal, W – wet, C – critical.

2.2.3 Seawater Intrusion

Intrusion of seawater is not a consideration in the Wyandotte Creek Subbasin because of the subbasin's location. For this reason, no monitoring of seawater intrusion is required nor is there a need for projects and management actions to mitigate seawater intrusion.

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

2.2.4 Groundwater Quality

2.2.4.1 General Water Quality of Principal Aquifers

The goal of groundwater quality management under SGMA is to supplement information available from other sources with data targeted to assist GSAs in the Wyandotte Creek Subbasin comply with the requirements of SGMA. Development of groundwater quality-related SMC for the Wyandotte Creek Subbasin is not intended to duplicate or supplant the goals and objectives of ongoing programs including Butte County, the SVWQC (SVWQC, 2016), the CRC (2019), and the State Drinking Water Information System (SDWIS).

Because irrigated agriculture is the predominant land use in the subbasin, monitoring of the groundwater quality data developed through the GQTMWP being implemented by the SVWQC and by the CRC for compliance with the CVRWQCB's ILRP will be an important source of information to GSAs in the Wyandotte Creek Subbasin. The SVWQC has identified one low priority High Vulnerability Area (HVA) in the South MA of Wyandotte Creek Subbasin (SVWQC, 2016). However, this area has been classified as an HVA because of conditions that make it susceptible to contamination and not due to contaminant levels observed in the area. Additional information on the ILRP is presented in the section describing the monitoring network.

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

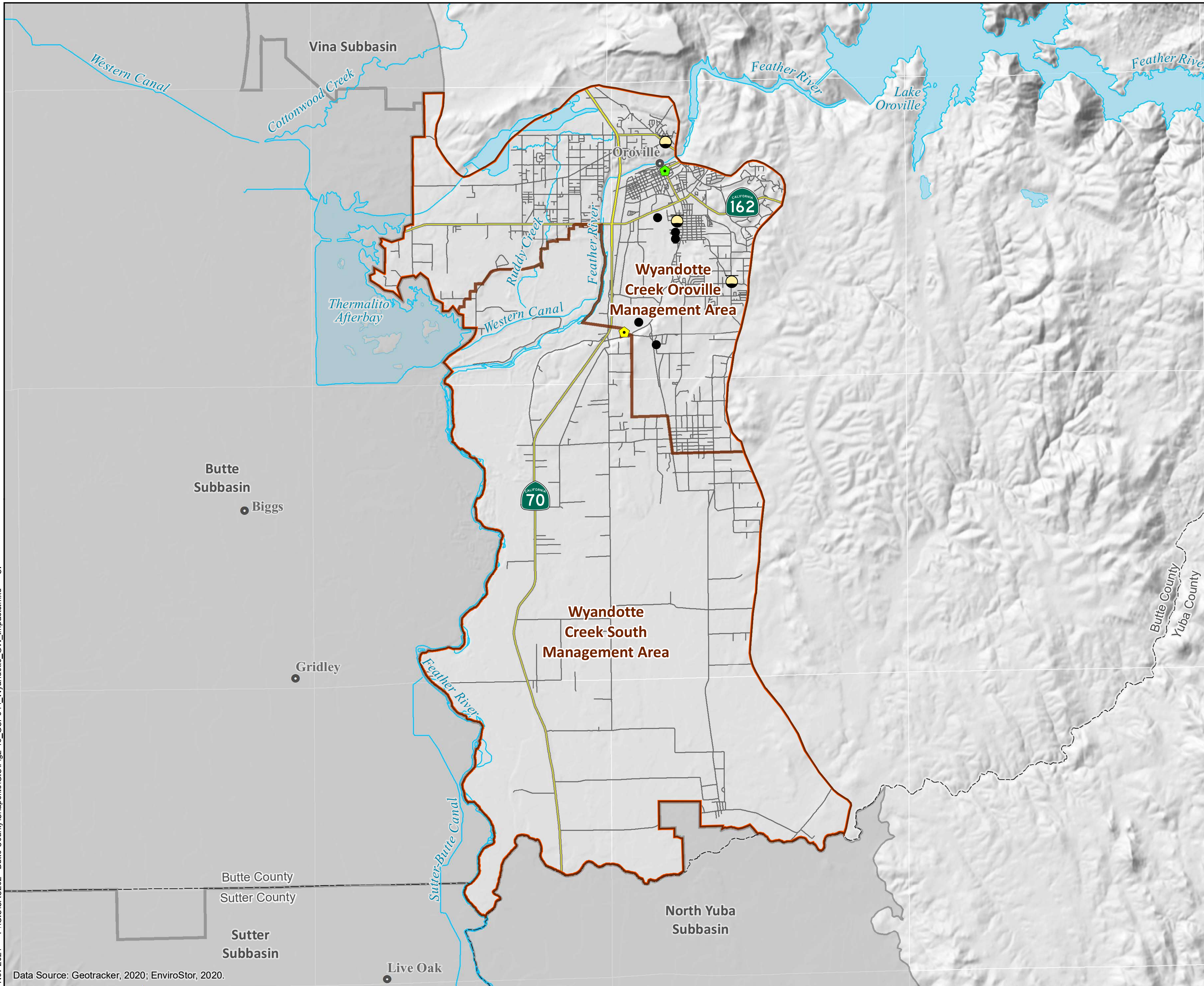
2.2.4.2 Description and Map of Known Sites and Plumes

The SGMA regulations require that GSPs describe locations, identified by regulatory agencies, where groundwater quality has been degraded due to industrial and commercial activity. Locations of impacted groundwater were identified by reviewing information available on the SWRCB Geotracker/GAMA website, the California Department of Toxic Substances Control (DTSC) EnviroStor website, and the Environmental Protection Agency's (EPA) National Priorities List (NPL). Cases that have been closed by the supervisory agency are not considered.

Figure 2-16, Active Contamination Remediation Sites, presents the locations of known impacted groundwater or potentially impacted groundwater in the Wyandotte Creek Subbasin. The sites were divided into the following categories based on regulatory designation:

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

ACTIVE CONTAMINATION REMEDIATION SITES



WYANDOTTE CREEK SUBBASIN GSP

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FIGURE 2-16

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Active DTSC Cleanup Program Sites in the Wyandotte Creek Subbasin include the following:

- No. 60000689 – Ophir Road Property:
  - Past use that caused contamination: junkyard, recycling, sand blasting
  - Potential contaminants of concern: metals, polychlorinated biphenyls (PCBs)
  - Potential Media affected: soil
- No. 60001282 – Pacific Gas and Electric Company (PG&E) Former Oroville Manufactured Gas Plant Site:
  - Past use that caused contamination: manufactured gas plant
  - Potential contaminants of concern: arsenic, cyanide, lead, polynuclear aromatic hydrocarbons (PAHs); total petroleum hydrocarbons (TPH)-diesel
  - Potential media affected: aquifer used for drinking water supply, soils, soil vapor
- No. 60002933 – St. Francis Mine – site under evaluation:
  - Past uses that caused contamination: none specified
  - Contaminants of concern: none specified
  - Potential media affected: none specified

Of the three open cases within the boundaries of the Wyandotte Creek Subbasin, only the former Oroville manufactured gas plant site has been confirmed as impacting groundwater. Information on these and other sites is available at www.envirostor.dtsc.ca.gov.

2.2.5 Land Subsidence

2.2.5.1 Rates and Locations

The SGMA regulations define the MT for significant and unreasonable land subsidence to be the “rate and the extent of land subsidence.” Unlike other sustainability indicators (SIs), the harmful effects of subsidence result from the damage it may cause to critical infrastructure and the costs of repairing or mitigating those damages. Critical infrastructure in the Wyandotte Creek Subbasin that could be affected by subsidence includes county, and state highways, power transmission lines and water conveyance and distribution facilities.

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

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

Subsidence has elastic and inelastic deformation components. As the head lowers in the aquifer, the load that was supported by the hydrostatic pressure is transferred to the granular skeletal framework of the formation. As long as the increased load on the formation does not exceed the pre-consolidation pressure, the formation will remain elastic. Under elastic conditions, the formation will rebound to its original volume as hydrostatic pressure is restored. However, when the head of the formation is lowered to a point where the load exceeds pre-consolidation pressure, inelastic deformation may occur. Under inelastic consolidation, the formation will undergo a permanent volumetric reduction as water is expelled from aquitards4.

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

Extensometers are installed in wells or boreholes and are a more site-specific method of measuring land subsidence as they can detect changes in the thickness of the sediment surrounding the well due to compaction or expansion. These instruments are capable of detecting very slight changes in land surface elevation on a continuous basis with an accuracy of +/- 0.01 feet or approximately 3 millimeters. The three extensometers in Butte County are all located outside of the Wyandotte Creek Subbasin.

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

2.2.5.2 Historical and Recent Cumulative Subsidence and Rates of Subsidence

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

Table 2-2: Cumulative Subsidence and Approximate Annual Rate of Subsidence

Subbasin Area (square miles)	Date Range	Cumulative Subsidence (feet)	Calculated Annual Rate of Subsidence (feet/year)	Source
93	2008-2017	0.038 to -0.015	0.004 to -0.002	Sac Valley
93	2015-2019	0.25 to -0.25	0.063 to -0.063	InSAR

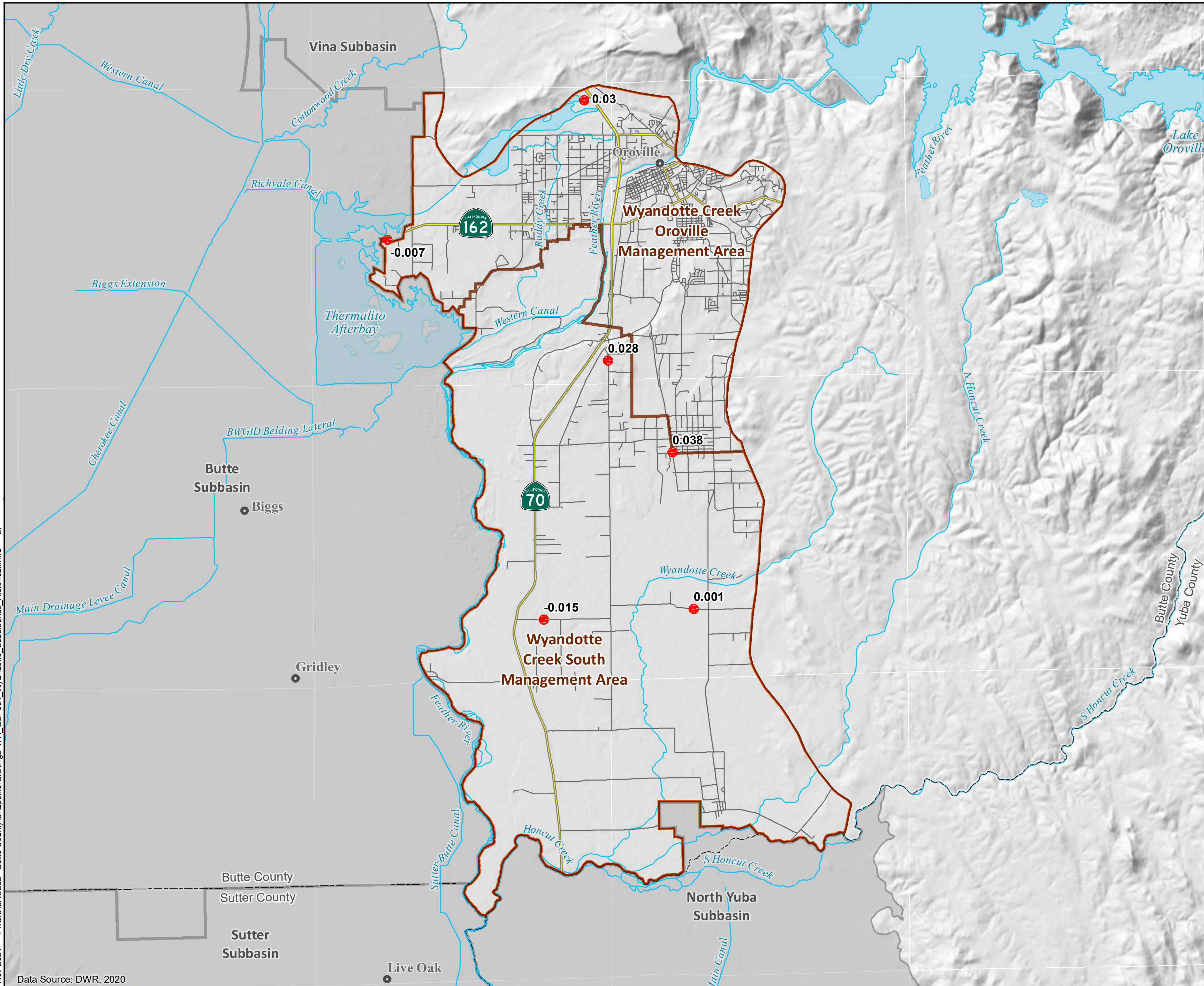
Figures 2-17A and 2-17B show historical and recent levels of subsidence within the Wyandotte Creek Subbasin. Historical levels for the period comparing 2008 to 2017 are shown in Figure 2-17A – Historical Subsidence and are the locations of subsidence monitoring network monuments used to measure subsidence. Recent levels for the period from 2015 through 2019 are presented in Figure 2-17B – Recent Subsidence. The values presented in Table 2-2 and in Figures 2-17A and 2-17B support the observation that inelastic land subsidence due to groundwater withdrawal is unlikely to result in an Undesirable Result in the Wyandotte Creek Subbasin, and both figures show subsidence to be uniform over the subbasin.

2.2.6 Interconnected Surface Water Systems

2.2.6.1 Streamflow Depletion and Accretion

The term interconnected surface water systems describes surface water features that are hydraulically connected by a continuous saturated zone to an underlying aquifer such that changes in elevations of either the aquifer or the surface water features propagate throughout the interconnected system. Within the Wyandotte Creek Subbasin, it is likely that surface water features are interconnected with shallow groundwater.

Interconnected surface waters are classified as either gaining or losing with respect to the condition of the surface water feature with gaining reaches gaining thorough accretion of groundwater and losing reaches losing through depletion to groundwater. It is important to recognize that these interconnections are dynamic and are affected by factors including variations in local geology, hydrology and water use.



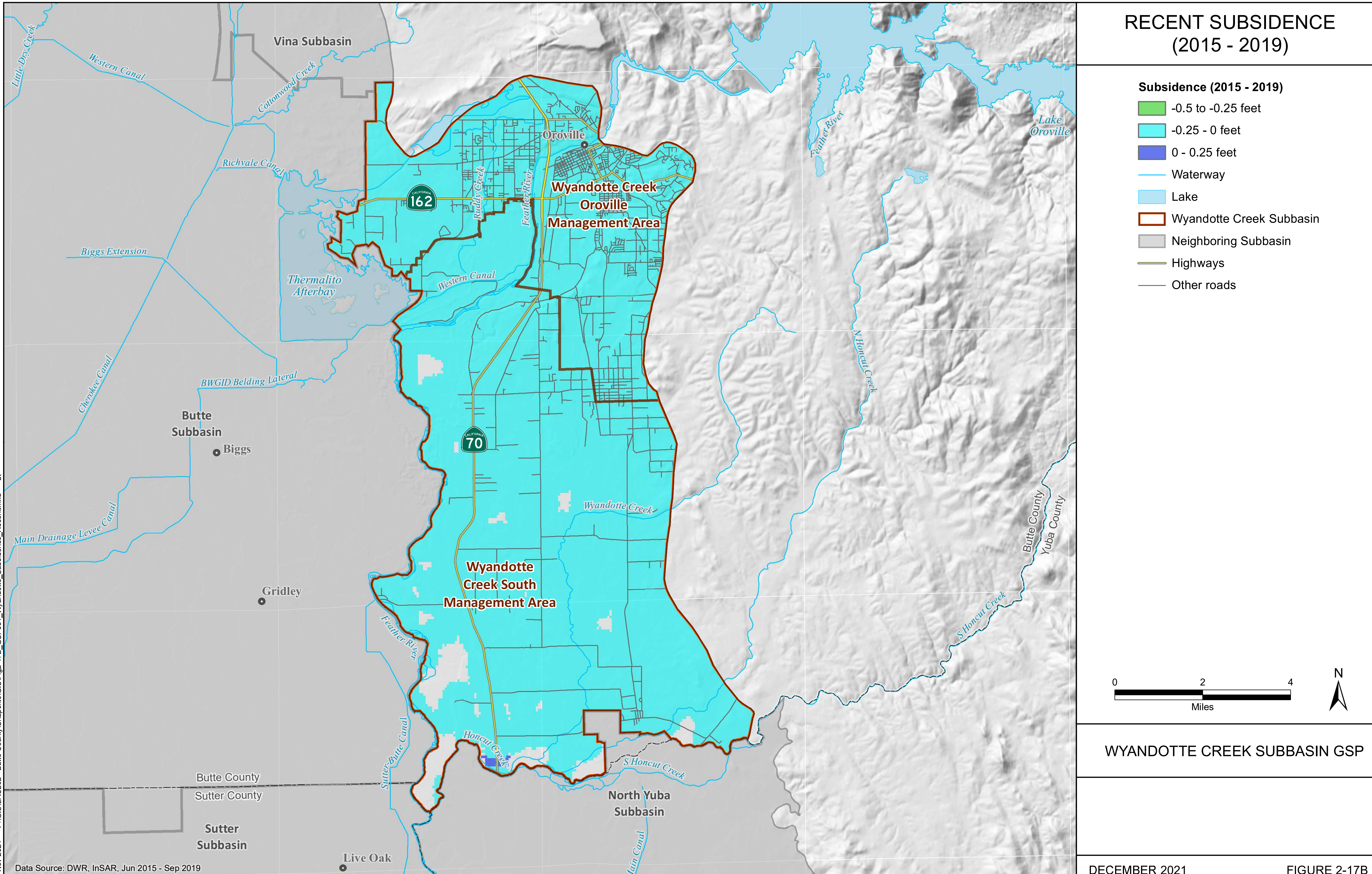
HISTORICAL SUBSIDENCE (2008 - 2017)

Subsidence Monument (units in feet)
Waterway
Lake
Wyandotte Creek Subbasin
Neighboring Subbasin
Highways
Other roads

0 2 4
Miles
N

WYANDOTTE CREEK SUBBASIN GSP

DECEMBER 2021 FIGURE 2-17A



WYANDOTTE CREEK SUBBASIN GSP

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FIGURE 2-17B

Thus, at a single point in time, a stream may have both gaining and losing reaches and reaches that are gaining under certain seasonal, or long-term hydrologic and water use conditions may become losing under others. Moreover, changes in water use or hydrology may cause interconnected surface water features to decouple from the groundwater system.

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

The difference between gaining and losing reaches is illustrated in Figure 2-18. For gaining reaches, the water table adjacent to the stream is above the elevation of water in the stream, resulting in flow of water from the groundwater system to the stream (gains or accretions). For losing reaches, the water table adjacent to the stream is below the elevation of water in the stream, resulting flow of water from the stream to the groundwater systems (losses or seepage). In both cases, flows in the stream are directly connected to the groundwater system, with no unsaturated zone present beneath the streambed.

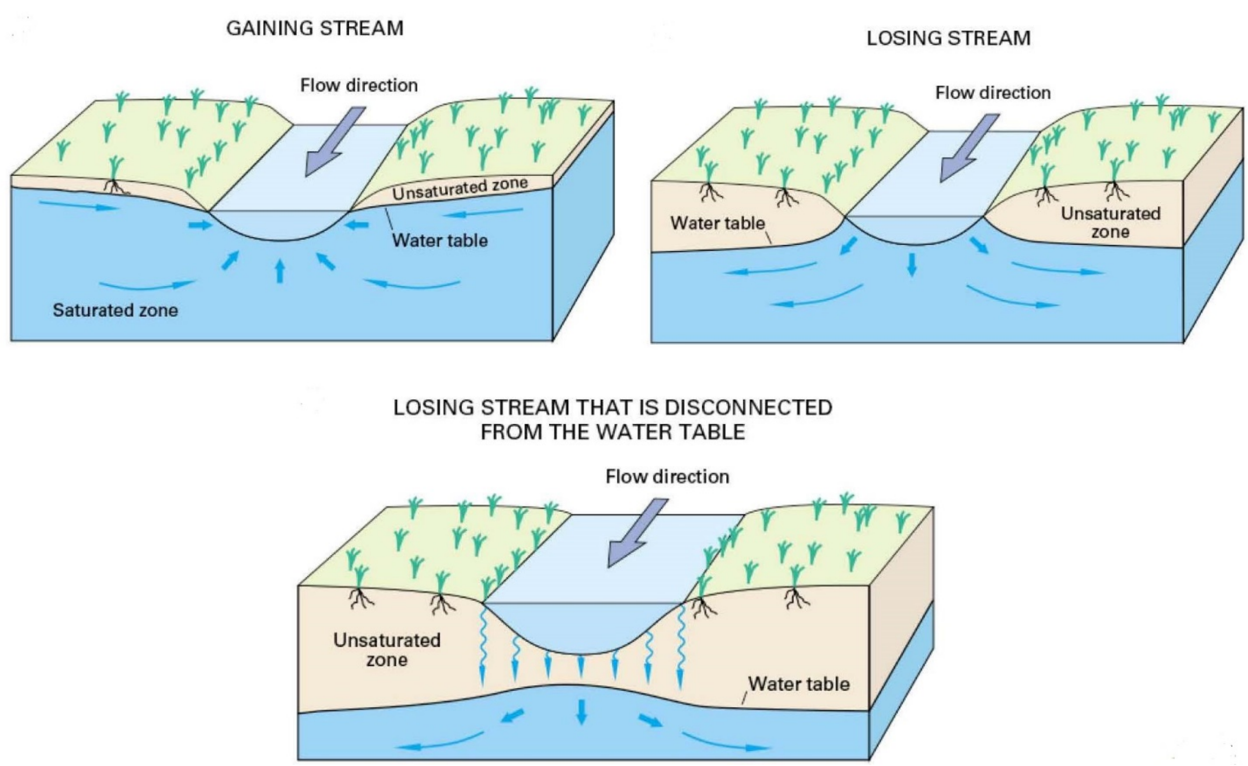

Figure 2-18: Illustration of Gaining and Losing Interconnected and Disconnected Stream Reaches (Source: USGS)

Direct measurement of interactions between groundwater systems and surface water features is difficult because of the need for a monitoring system that tracks both stream stage and groundwater elevations at nearby locations (see Section 4.2). Therefore, the interactions between groundwater systems and surface water features within the Butte Subbasin are estimated through use of the BBGM which integrates information from groundwater monitoring wells and stream stages to model gradients that control flow between surface water and groundwater.

The BBGM was utilized to evaluate stream segments within the subbasin and to classify them as being primarily gaining or losing over the historical period from water year 2000 to 2018. A total of seven stream segments traversing or bounding the subbasin with a total length of approximately 42 miles were defined. The segments range in length from 3.4 to 7.3 miles with an average length of 5.3 miles and are shown in Figure 2-19. The results of this analysis are shown in Figure 2-20. The figure shows the percent of months for the period from water year 2000 to 2018 with gaining conditions and classifies streams as primarily gaining (gaining conditions more than 80% of the time), primarily losing (losing conditions more than 80% of the time), or mixed. As indicated in Figure 2-20, stream segments representing the Feather River appear to be gaining more than 80% of the time. North Honcut Creek and South Honcut Creek both appear to experience gaining conditions less than 50% of the time.

To further evaluate the interconnectedness of streams with the groundwater system in the basin, streambed elevations at individual stream nodes from the BBGM were compared to groundwater elevations from spring groundwater level measurements provided by DWR as part of the SGMA Data Viewer.[4] Spring groundwater levels were available for 2014 to 2018. As indicated in Figure 2-21, the vast majority of stream nodes within the subbasin had spring groundwater levels within 10 feet of the estimated streambed elevation.

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

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

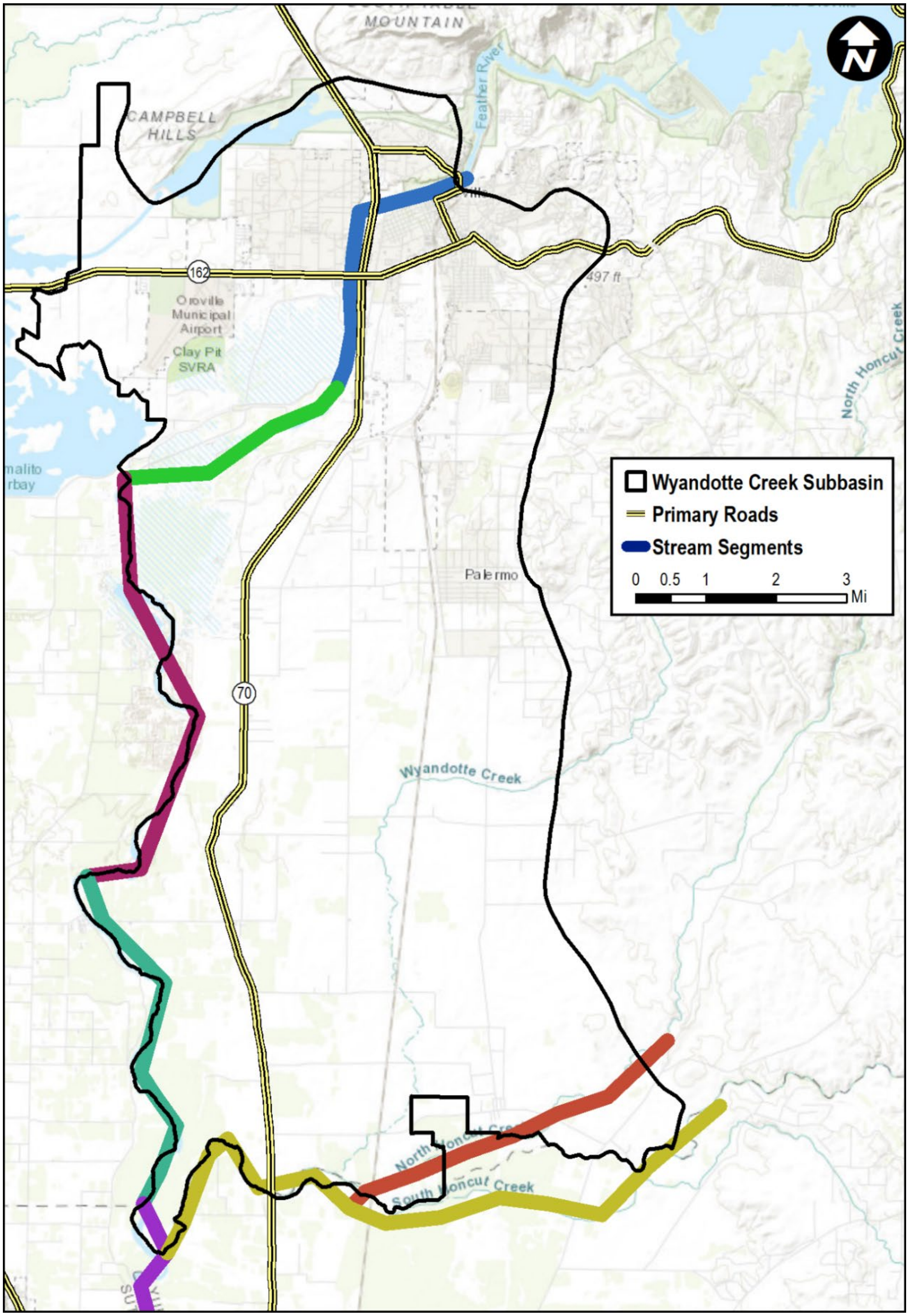

Figure 2-19: Wyandotte Creek Subbasin Stream Segments

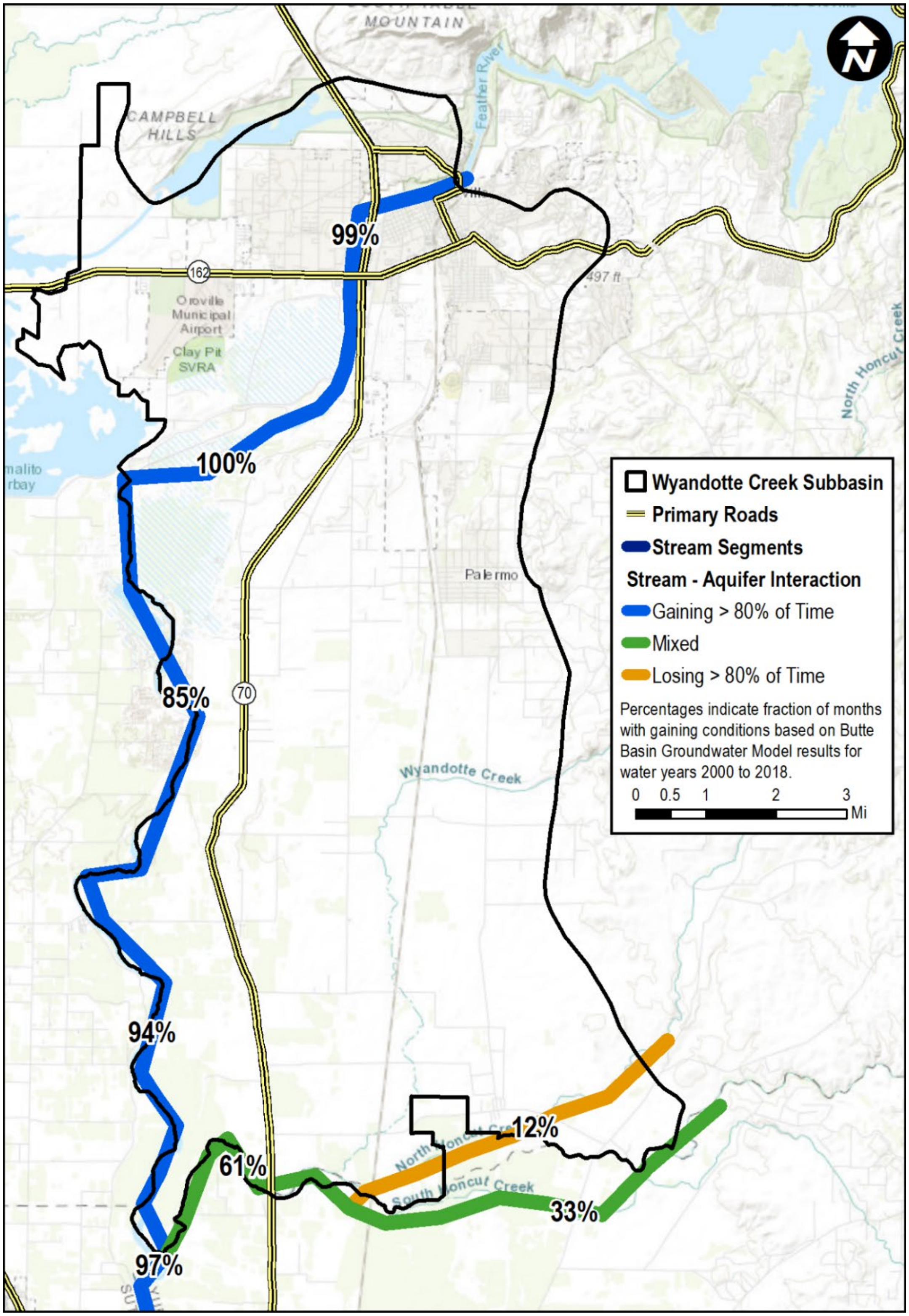

Figure 2-20: Wyandotte Creek Subbasin Gaining and Losing Stream Reaches Based on the BBGM, Water Years 2000 to 2018

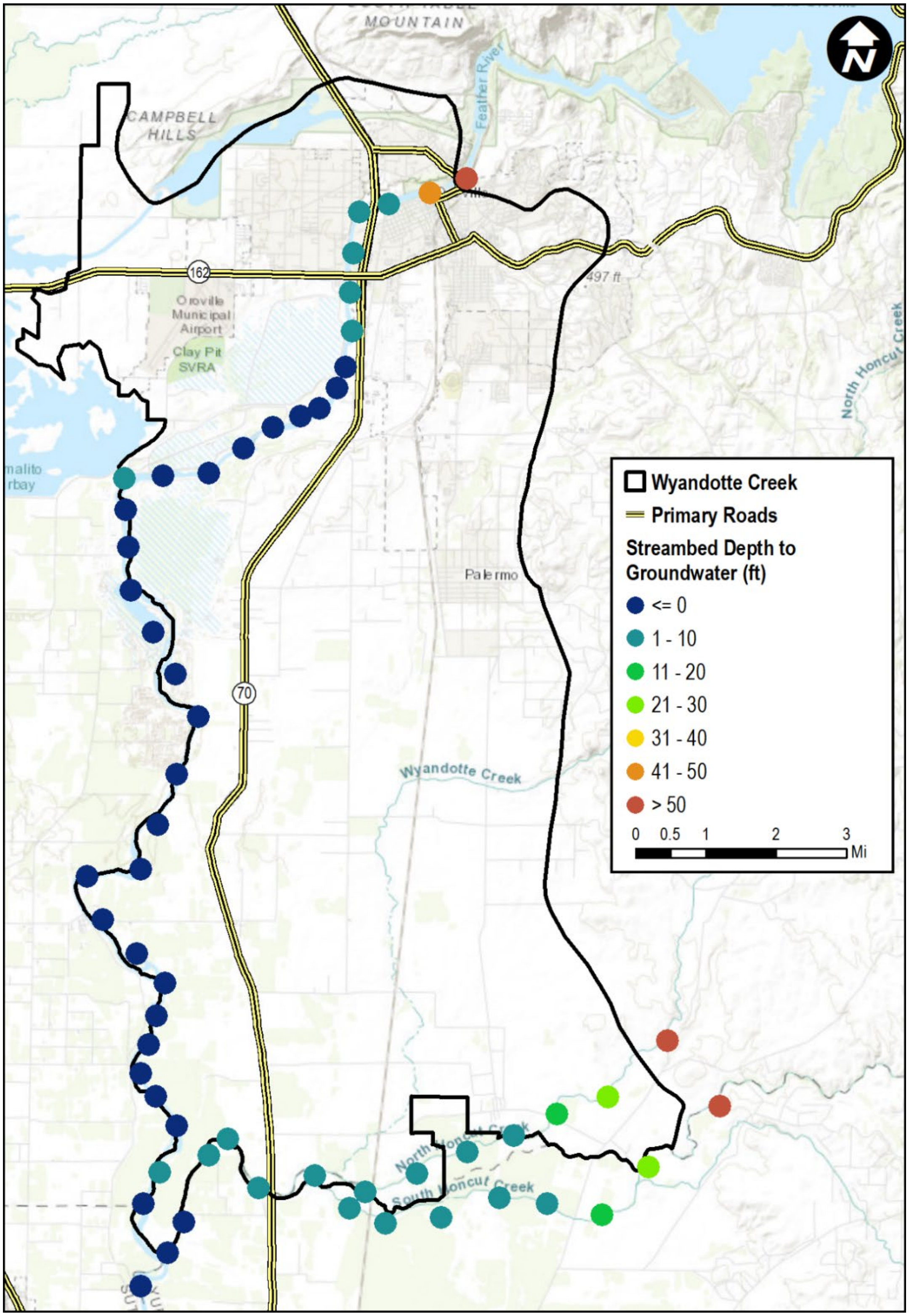

Figure 2-21: Wyandotte Creek Subbasin Average Spring Depth to Groundwater, 2014 to 2018

2.2.6.2 Timing and Amount of Surface Water – Groundwater Interaction

The timing and amount of surface water–groundwater interaction was estimated using the BBGM for the primary streams in the subbasin. Monthly net gains to streamflow from groundwater were estimated on a monthly basis for the historical period from water year 2000 to 2018 and are summarized in Table 2-3. Average monthly gains to streamflow are expressed in cubic feet per second (cfs). Negative values denote average losses from streamflow to groundwater (i.e., seepage or leakage).

Table 2-3: Average Monthly Gains to Streamflow from Groundwater, Water Years 2000 to 2018 (cfs)

Stream	Month												Average
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
Feather River	34	41	54	70	56	68	56	49	29	21	23	26	44
North Honcut Creek	-1	-1	-2	-1	-1	0	1	0	0	0	0	0	0
South Honcut Creek	0	0	0	2	2	3	3	2	0	0	0	0	1
Total	34	40	52	71	58	71	60	51	29	20	23	26	45

Average monthly gains from groundwater are greatest for the Feather River, at approximately 44 cfs. Gains are least between June and October, potentially due to relatively low groundwater elevations resulting from summer pumping. Gains tend to be greatest between late winter and spring (approximately December to May), potentially due to higher groundwater elevations relative to river stage. On average, streams traversing or bounding the subbasin are currently estimated to gain approximately 45 cfs on average, or approximately 32 TAF annually.

2.2.7 Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs) are defined in the SGMA regulations as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" (CCR, Title 23, § 351(m)). GDEs exist within the Wyandotte Creek subbasin largely where vegetation accesses shallow groundwater for survival; and in areas with streams and creeks where a connection to groundwater exists. Without access to shallow groundwater, these plants and the ecosystems supported by the hydrology would die.

2.2.7.1 NCCAG Database

The initial identification of GDEs for this GSP was performed by using the Natural Communities Commonly Associated with Groundwater (NCCAG) database to identify and map potential groundwater dependent ecosystems (iGDEs) in the Wyandotte Creek Subbasin. The NCCAG database was developed by a working group comprised of DWR, CDFW, and TNC by reviewing publicly available state and federal agency datasets that have mapped California vegetation, wetlands, springs and seeps and by conducting a screening process to retain types and locations of these commonly associated with groundwater. The results were compiled into the NCCAG database with two habitat classes defined. The first class includes wetland features commonly associated with the surface expression of groundwater under natural, unmodified conditions. The second class includes vegetation types commonly associated with the sub-surface presence of groundwater (phreatophytes). Figure 2-22 shows the locations of iGDEs identified by the NCCAG database within the Wyandotte Creek Subbasin.

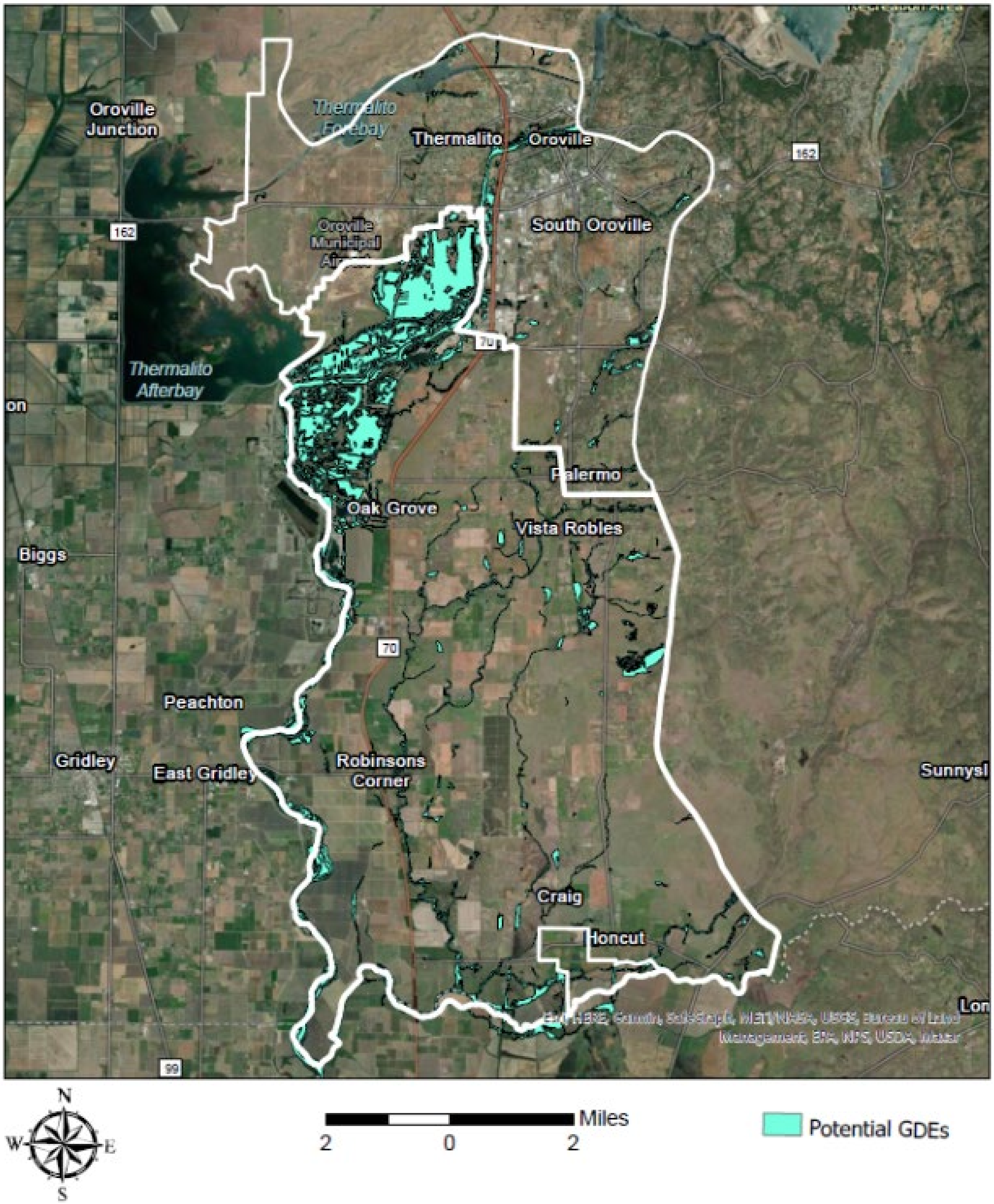

Figure 2-22: All Potential Groundwater Dependent Ecosystems in the Wyandotte Creek Subbasin as Identified in the Natural Communities Commonly Associated with Groundwater Database Hosted by The Nature Conservancy

The NCCAG dataset is based on 48 layers of publicly available data developed by state or federal agencies that map vegetation, wetlands, springs, and seeps in California (DWR, 2019a). A NCCAG technical working group with representatives from DWR, CDFW, and TNC reviewed the datasets compiled to assemble the NCCAG dataset. The NCCAG dataset attempts to extract mapped vegetation and wetland features that have indicators suggesting dependence on groundwater. The data presented in NCCAG dataset display vegetation polygons that have indicators of GDEs based on published and/or field observations of phreatophytic vegetation defined as a "deep-rooted plant that obtains water that it needs from the phreatic zone (zone of saturation) or the capillary fringe above the phreatic zone" (Rohde et al., 2018). The dominance of phreatophytic plant species in a mapped vegetation type is a primary indicator of GDEs. A list of plant species considered to be phreatophytes based on peer-reviewed scientific literature on rooting depths, published lists of phreatophytes, expert field observations, and vegetation alliance descriptions is publicly available (Klausmeyer et al., 2018; DWR, 2018a).

While developing the NCCAG dataset of areas with indicators of GDEs, the technical working group attempted to exclude vegetation and wetland types and polygons that are less likely to be associated with groundwater (Klausmeyer et al., 2018). The NCCAG working group attempted to remove any polygons that are not likely to be GDEs where they occurred in areas where they are likely to be supported by alternate artificial water sources (e.g. local seepage from agricultural irrigation canals), or where appropriate available data indicated the shallow groundwater depth is located well below the rooting zone (Klausmeyer et al., 2018).

The vegetation data presented in the NCCAG dataset is a latest available starting point for the identification of GDEs as the dataset includes the best available public datasets and has been screened to include only areas that have indicators of groundwater dependent vegetation. DWR has stated that use of the NCCAG dataset is not mandatory and does not represent DWR's determination of a GDE (DWR, 2018a). Rather, the NCCAG dataset can provide a starting point for the identification of GDEs within a groundwater basin.

Additional information, such as near surface groundwater depth obtained from piezometers, information about subsurface stratigraphy and geology on confining layers, and information on local land use and hydrology can be used to confirm whether vegetation in areas identified by the NCCAG as iGDEs is, in fact, reliant on groundwater.

2.2.7.2 Initial iGDE Analysis

GSA Managers from the subbasin used this database as a starting point to analyze a portion of the total iGDEs in the NCCAG database to evaluate local groundwater dependence. Specific criteria to each polygon to answer a series of questions led to an eventual characterization for each iGDE. These iGDEs were designated as either "Likely a GDE," "Not likely a GDE," or "Uncertain" based on evaluations. The criteria aimed at understanding each iGDE's dependence on groundwater including questions about land use changes, proximity to perennial surface water supplies, irrigated agriculture and agricultural dependent surface water, condition of vegetation during drought years and water applications to the iGDEs.

The first phase of the analysis was conducted by thorough review of aerial photographs from Google Earth across multiple years specifically focusing on the 2007, 2009, 2013, and 2015 drought years as well as use Managers' local knowledge of these areas.

2.2.7.3 iGDE Designations

While there were some areas identified as "Not likely a GDE" during this effort, Managers were also able to add any iGDEs into the map that were not captured in the original NCCAG database. NCCAG areas identified as "Not likely a GDE" from the initial analysis by Managers can be categorized as follows.

Not Likely a GDE Due to Significant Land Use Change

Some areas in the NCCAG database may have changed in land use since the database was published. Developed areas where there have been significant land use changes to the iGDE, i.e., land transitioned to cultivated irrigated agricultural lands, industrial or residential development occurred or lands had undergone man-made changes such as golf courses or other obvious anthropogenic changes were labeled as "Not likely a GDE."

Not Likely a GDE Due to Perennial Surface Water Supplies

Areas with perennial water supplies such as those subject to historical hydraulic gold mining runoff and dredging activities or those near reservoirs were labeled as "Not likely a GDE." In some areas historic mining activities have left tailings of cobbles and coarse gravel which rapidly transmit water. To some extent, it is assumed that pooled water in this area is tied to river stage through direct connections with the river with surface water bodies. Likewise, the reservoirs provide water year-round for adjacent ecosystems. If any iGDEs were located within 150 feet of reservoirs or mine tailings, they were assumed to be able to access the nearby surface water bodies and were labeled as "Not likely a GDE."

Not Likely a GDE Due to Supplemental Water Supplies

Irrigated agriculture, irrigated refuge / managed wetlands or irrigated urban areas with supplemental water deliveries were identified by Managers during the initial GDEs analysis effort. These areas are assumed to be accessing supplemental water supplies and not reliant on groundwater and were labeled as "Not likely a GDE."

Not Likely a GDE Due to Adjacency to Irrigated Agricultural Fields

Agricultural lands are dependent on reliable water supplies to ensure a successful harvest. Surface water and / or groundwater pumped from the aquifer is used to irrigate crops in the Wyandotte Creek subbasin. Such irrigation benefits not only the crops, but also surrounding vegetation. Potential GDEs further than 150 feet from irrigated rice fields and areas further than 50 feet from all other irrigated agriculture were assumed to be unable to access irrigation water. These distances are based on professional judgment, including past experience in the region and consideration of the physical characteristics of the Wyandotte Creek subbasin, such as hydraulic conductivity. Rice fields, along with other irrigated agriculture, are known to have percolation and lateral seepage, supplying water to the aquifer and into adjacent areas. Lateral seepage in Sacramento Valley rice areas has been estimated at between 1.0% and 1.9% of the total irrigation volume (LaHue and Lindquist, 2019). A larger distance was used for rice due to the long-term ponding of water and due to restrictive layers in the subsurface that result in the horizontal spreading of irrigation water. Potential GDEs near these irrigated areas are assumed to be accessing irrigation water through lateral movement through the soils, thus, they were labeled as "Not likely a GDE."

Not Likely a GDE Due to Dependence on Agricultural-dependent Surface Water
Similar to areas adjacent to reservoirs, iGDEs adjacent to surface water bodies that are perennial due to agricultural practices and those near drainage canals, are able to access surface water throughout the year. Agricultural water conveyance features, i.e., the Cherokee Canal is included in this definition; however, this does not include the Sacramento River, Butte Creek, or Honcut Creek because these natural waterways also convey non-agricultural water. Potential GDEs within 150 feet of these agricultural-dependent surface water bodies were assumed to be accessing water from them thus, they were labeled as "Not likely a GDE."

Not Likely a GDE Due to Non-Survival during Drought Conditions
To assess if the iGDE was groundwater dependent, Managers reviewed the condition of the iGDE over multiple dry drought years using aerial photographs from Google Earth. Specifically, the group focused on the drought years of 2007, 2009, 2013, and 2015 in addition to the Managers' local knowledge of these areas. Green vegetation over multiple drought years during summer months indicated survival of the iGDE as well as an assumed connection to groundwater. Potential GDEs which did not indicate any surviving conditions over multiple drought years were assumed to not be connected to groundwater and were labeled as "Not likely a GDE."

Uncertain – All Other Areas
The iGDEs analyzed by the Managers in this initial effort, which did not receive a designation as either "Not likely a GDE" or "Likely a GDE" based on the conclusions from the analysis above, were labeled as "Uncertain" and were analyzed as described below.

2.2.7.4 Additional GIS Analysis

Irrigated Agricultural Land Use
After the initial analysis was completed for a selection of the total iGDEs in the NCCAG database as described above, a geographical information systems (GIS) analysis was performed for all remaining iGDEs in this subbasin by Butte County staff to determine each iGDE's proximity to rice and other irrigated agriculture as described below. The DWR / Land IQ land use and crop mapping data for 2016 (DWR, 2019b) was used to determine the dominant crop type throughout the subbasin.

Land classified as "Rice" for the "Crop Type 2016" in the dataset was identified. Then all polygons in the TNC iGDEs dataset within 150 feet of land classified as rice were identified and designated as "Not likely a GDE near irrigated rice" for the same reasons as described above in the "Not Likely a GDE Due to Adjacency to Irrigated Agricultural Fields" section of this document above.

Land with "Crop Type 2016" classifications other than "Managed Wetland," "Urban," "Rice," and "Mixed Pasture" in the dataset were identified and for this purpose referenced as "Other Irrigated Agriculture" for this GIS analysis, as all other remaining irrigated crop types. All polygons in the NCCAG dataset within 50 feet of land classified as "Other Irrigated Agriculture" were designated as "Not likely a GDE near irrigated agriculture (Non-Rice)" for the same reasons as described above in the "Not Likely a GDE Due to Adjacency to Irrigated Agricultural Fields" section of this document.

Valley Oak Dominated Areas

The dataset provided by TNC indicates the dominant species of vegetation for each polygon, including Valley oak (*Quercus lobata*) in the Wyandotte Creek subbasin. Those polygons were classified as "Likely a GDE" due to feedback from TNC staff that this species can access groundwater over a wide range of depths (M. Rohde personal communication March 2, 2021).

2.2.7.5 Mapping

The map in Figure 2-23 show iGDEs classified as "Likely a GDE" or "Not Likely a GDE" for one of the reasons described above. The iGDEs classified as "Not Likely a GDE" in the Wyandotte Creek subbasin were designated this way due to either their proximity to irrigated agriculture as rice, proximity to irrigated agriculture other than rice, or for another reason as determined during the initial analyses performed by the GSA Managers.

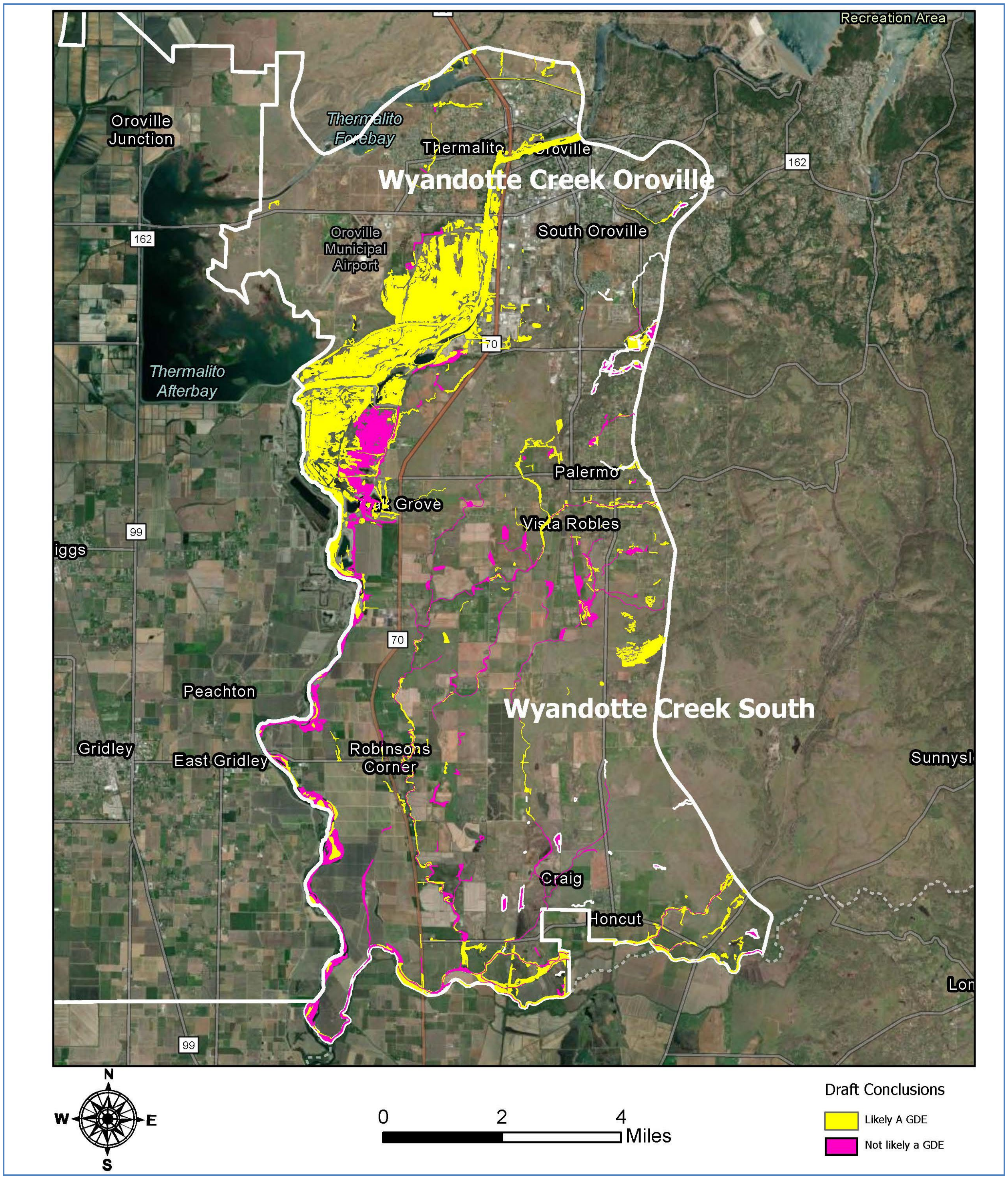

Figure 2-23: Potential Groundwater Dependent Ecosystems (iGDEs) Designations

2.3 Water Budget

This section describes historical, current, and projected water budgets in accordance with §354.18 of the GSP Emergency Regulations, including quantitative estimates of inflows to and outflows from the basin over time and annual changes in water storage within the basin. Components of the water budgets are depicted in Figure 2-24.

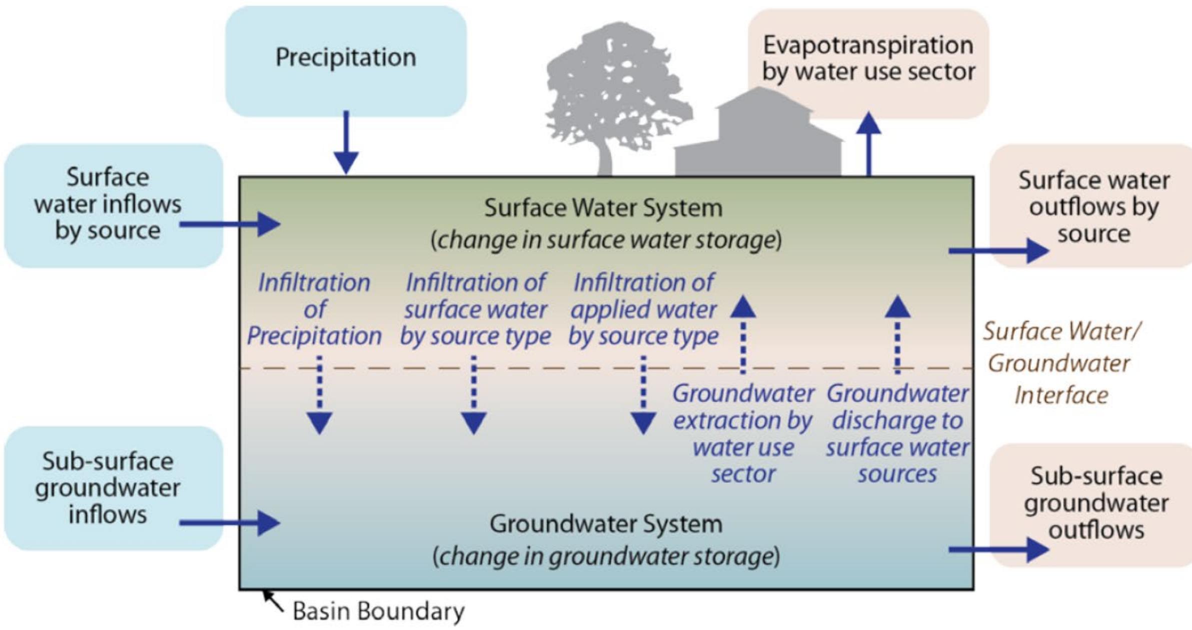

Figure 2-24: Water Budget Components (DWR, 2016)

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

2.3.1 Selection of Hydrologic Periods

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

- Historical – The 19-year period from water years[5] 2000 to 2018 was selected based on the level of confidence in historical information to support water budget development considering land use, surface water availability, hydrology, and other factors.
- Current Conditions – Historical water budget information for 2018 represents the most recent hydrology. To provide a broader basis for understanding current water budget conditions, a water budget scenario combining current land use and urban demands with 50 years of hydrology was selected. The period selected was 1971 to 2018 (48 years) with 2004–2005 (two relatively normal years) repeated at the end of the scenario. An advantage of evaluating the current conditions water budget over a representative 50-year period is that the results provide a baseline for evaluation of the projected water budgets. Results for 2018, the most recent available information, are provided in Appendix 2-A.
- Future Conditions – Consistent with the current conditions water budget, the period selected for the projected water budgets was 1971 to 2018 (48 years) with 2004–2005 repeated at the end of the scenarios to provide a full 50-year period as required by the GSP Emergency Regulations.
- Selection of the 50-year hydrologic period for the current and projected water budget scenarios was based primarily on three considerations:
    - The BBGM, the primary tool used to develop the water budgets, has a simulation period from water years 1971 to 2018.
    - The Sacramento Valley Water Year Index[6] over the period from 1971 to 2018 has an average of 8.0, as compared to 8.1 for the 103-year period from 1906 to 2018 (1906 is the first year for which the index is available) (Figure 2-25).
    - The selected period includes a combination of wet and dry cycles, including relatively wet periods in the early 1970s, mid 1980s, and late 1990s and dry periods in the late 1970s, early 1990s, and from approximately 2007 to 2015.
- Additionally, annual precipitation for the 1971 to 2018 period averaged approximately 26.3 inches per year, as compared to 24.8 inches for the 1906 to 2018 period indicating slightly drier conditions than the full period of record for the Sacramento Valley Index.

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[5] A water year is defined as the period from October 1 of the prior year to September 30 of the current year. For example, water year 2000 refers to the period from October 1, 1999, to September 30, 2000.
[6] The Sacramento Valley Water Year Index classifies water years as wet, above normal, below normal, dry, or critical based on Sacramento River unimpaired flows. Additional details describing the Sacramento Valley Water Year Index are available from the California Data Exchange Center (https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST).

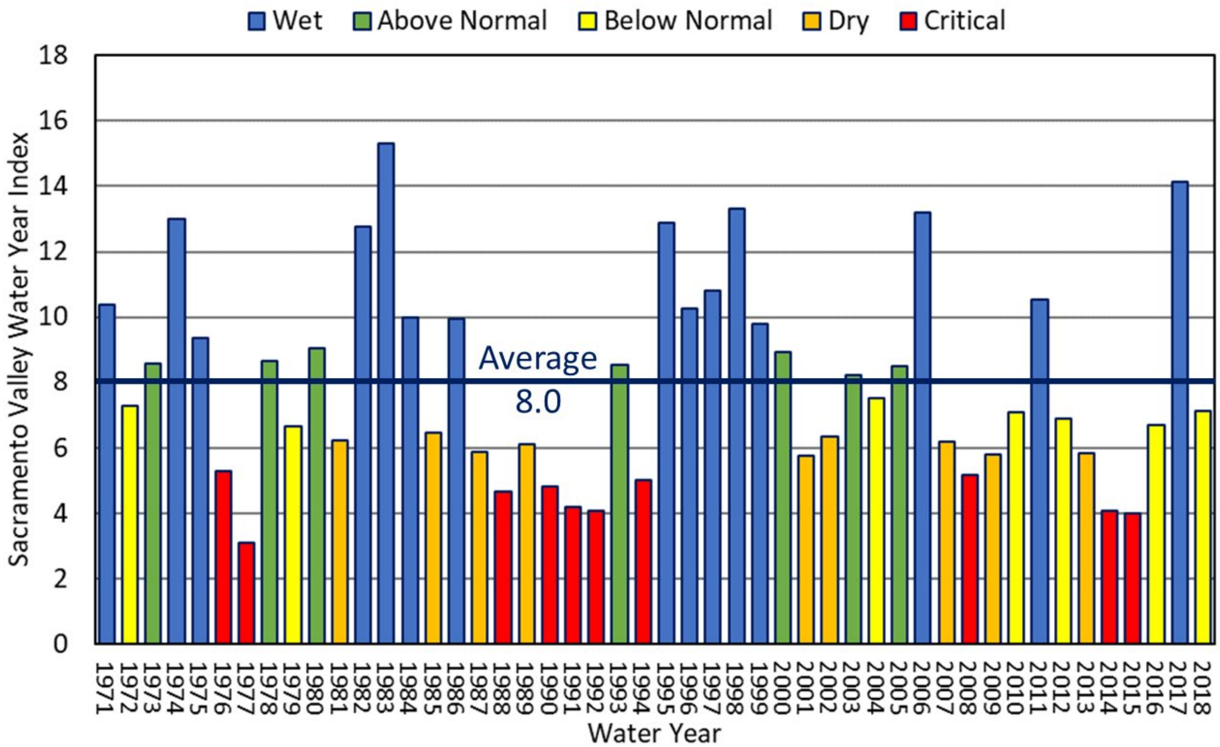

Figure 2-25: 1971 – 2018 Sacramento Valley Water Year Index and Water Year Types

2.3.2 Usage of the Butte Basin Groundwater Model

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

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

2.3.3 Water Budget Assumptions

Assumptions utilized to develop the historical, current, and projected water budgets are described below and summarized in Table 2-4.

Table 2-4: Summary of Water Budget Assumptions

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

2.3.3.1 Historical

A historical water budget was developed to support understanding of past aquifer conditions, considering surface water and groundwater supplies utilized to meet demands. The historical water budget was developed using the BBGM and incorporates the best available science and information. Historical water supplies and aquifer response have been characterized by water year type based on DWR's Sacramento Valley Water Year Index, which classifies water years as wet, above normal, below normal, dry, or critical based on Sacramento River unimpaired flows.

As described previously, water years 2000 to 2018 were selected to provide a minimum of 10 years across a range of hydrologic conditions. This period includes relatively wet years in 2006, 2011, and 2017 as well as dry conditions between 2007 and 2009 and between 2013 and 2015.

Information utilized to develop the historical water budget include:

- Analysis Period – Water years 2000 to 2018.
- Stream Inflows – Inflows of surface water into the basin were estimated based on stream gage data from USGS and DWR where available (e.g., Feather River and South Honcut Creek). For un-gaged streams, inflows were estimated using the Natural Resources Conservation Service (NRCS) rainfall runoff method applied at the watershed scale, considering precipitation timing and amount, soil characteristics, and other factors. Additional detail describing stream inflows is described in the BBGM model report (BCDWRC, 2021).
- Land Use – Land use characteristics for agricultural, native, and urban (including rural residential) lands were estimated annually based on a combination of DWR land use surveys and county agricultural commissioner cropping reports. DWR land use data were

available for 1994, 1999, 2004, 2011, 2014, 2015, and 2016. Additional detail describing the development of land use estimates can be found in the BBGM model report (BCDWRC, 2021).

- Agricultural Water Demand – Agricultural irrigation demands were estimated using the BBGM, which simulates crop growth and water use on a daily basis, considering crop type, evapotranspiration, root depth, soil characteristics, and irrigation practices. For ponded land uses (rice and managed wetlands), pond depths and pond drainage are also considered to simulate demands.
- Urban and Industrial Water Demand[7] – Urban and industrial demands were estimated based on a combination of pumping data provided directly by water suppliers (e.g., Cal Water) and estimates of population and per capita water use over time. Additional detail describing the development of urban demand estimates can be found in the BBGM model report (BCDWRC, 2021).
- Surface Water Diversions – Surface water diversions were estimated based on a combination of reported diversions by water suppliers (e.g., SFWPA) and, in some cases, agricultural water demand estimates for areas known to receive surface water but for which reported diversion data were not available.
- Groundwater Pumping – For urban water suppliers, historical pumping was estimated from reported pumping volumes over time. Pumping to meet agricultural and managed wetlands demands was estimated within the BBGM by first estimating the total demand and then subtracting surface water deliveries to calculate estimated groundwater pumping required to meet the remaining demand.

2.3.3.2 Current Conditions

The current conditions water budget was developed as a baseline to evaluate projected water budgets considering future conditions and is based on 50 years of hydrology along with the most recent information describing land use, urban demands, and surface water supplies. The 50-year hydrologic period was selected rather than the most recent year for which historical water budget information is available to allow for direct comparison of potential future conditions to current conditions. The use of a representative hydrologic period containing wet and dry cycles supports the understanding of uncertainty in groundwater conditions over time, establishment of SMC, and development of projects and management actions to avoid undesirable results.

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

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

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

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

2.3.3.3 Future Conditions

Three projected baseline water budget scenarios were developed considering a range of future conditions that may occur. The scenarios consider future planned land use changes (i.e., development) based on the Butte County 2030 General Plan, along with changes in climate, including precipitation, surface water inflows, and evapotranspiration. These baselines provide information regarding changes in basin conditions (e.g., groundwater storage) that may occur in the future over a series of wet and dry cycles.

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

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

- Analysis Period – 50-years of hydrology were utilized representing the period from 1971 to 2018, with 2004 and 2005 repeated following 2018.
- Stream Inflows:

- Future Conditions, No Climate Change – Inflows of surface water into the basin were estimated utilizing the same information as for the historical water budget.
- Future Conditions, 2030 Climate Change – Precipitation, evapotranspiration, and surface water supplies were adjusted to reflect climate change based on the 2030 Central Tendency climate change datasets provided by DWR to support GSP development.
    - For precipitation and evapotranspiration, monthly change factors were applied to historical values to estimate potential future conditions.

- For streamflows, DWR estimates of stream inflows were utilized where available; for streams without direct estimates of inflows, inflows were estimated using streamflow change factors applied at the watershed scale.
    - Future Conditions, 2070 Climate Change – Precipitation, evapotranspiration, and surface water supplies were adjusted to reflect climate change based on the 2070 Central Tendency climate change datasets provided by DWR to support GSP development:
        - For precipitation and evapotranspiration, monthly change factors were applied to historical values to estimate potential future conditions.
        - For streamflows, DWR estimates of stream inflows were utilized where available; for streams without direct estimates of inflows, inflows were estimated using streamflow change factors applied at the watershed scale.
- Land Use – Land use for agricultural, native, and urban (including rural residential) lands was estimated annually using the most recent land use information and modified based on planned development according to the Butte County 2030 General Plan. Specifically, 2015 and 2016 land use were mapped to the 50-year analysis period, with 2015 land use applied to extreme dry years and 2016 land use applied to all other years. 2015 and 2016 land use data were modified to reflect planned development, generally resulting in an increase in urban land through development of previously undeveloped (i.e., native) lands:
    - Future Conditions, No Climate Change – Land use was assumed to be similar to the current conditions water budget scenario.
    - Future Conditions, 2030 Climate Change – 2015 and 2016 land use data were mapped to the 50-year analysis period considering 2030 central tendency climate change projections, with 2015 land use used for extreme dry years and 2016 land use used for all other years.
    - Future Conditions, 2070 Climate Change – 2015 and 2016 land use data were mapped to the 50-year analysis period considering 2070 central tendency climate change projections, with 2015 land use used for extreme dry years and 2016 land use used for all other years.
- Agricultural Water Demand – Agricultural irrigation demands were estimated using the BBGM, in the same manner as the historical water budget.

- Urban and Industrial Water Demand – Urban and industrial demands were estimated based projected urban demands. Specifically, future urban demands were estimated based on preliminary draft demand estimates provided by Cal Water, a primary urban supplier in the basin, as part of 2020 UWMP development.
- Surface Water Diversions – Similar to land use, surface water diversions were estimated based on 2015 and 2016 conditions, with 2015 diversions assumed for extreme dry years and 2016 diversions assumed for other years. Extreme dry years are identified based on April to July unimpaired Feather River inflows into Lake Oroville.
- Groundwater Pumping – Pumping to meet urban demands was estimated based on draft projections from UWMPs currently under development, as described above. Pumping to meet agricultural and managed wetlands demands was estimated using the BBGM as described previously for the historical water budget.

2.3.4 Water Budget Estimates

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

- Inflows:
  - Surface Water Inflows – Inflows at the land surface through streams, canals, or other waterways. These inflows may also include overland flow from upslope areas outside of the basin. Although interactions with streams along the boundary of the basin (i.e., diversions and stream-aquifer interaction) are accounted for, the flow in the stream is not considered an inflow to the basin. Inflows from the Feather River, which traverses the basin, are accounted for explicitly.
  - Precipitation – Rainfall intercepting the ground surface within the basin boundary.
  - Groundwater pumping – Extraction of groundwater to meet agricultural, urban, managed wetlands, or other beneficial uses.
  - Stream Accretions – Gains in streamflow from shallow groundwater occurring when the water level in the aquifer adjacent to the stream is greater than the water level in the stream.
- Outflows:
  - Surface Water Outflows – Outflows at the land surface through streams, canals, or other waterways. These outflows may also include overland flow to downslope areas outside of the basin.
  - Evapotranspiration – Consumptive use of water including both evaporation and transpiration components from all land uses.
  - Deep Percolation – Recharge of the groundwater system through the vertical movement of precipitation and applied irrigation water below the root zone.
  - Seepage (Also referred to as Losses or Leakage) – Recharge of the groundwater system from streams, canals, or other water bodies.

- Change in Storage – Changes in soil moisture storage within the upper several feet of soil in the root zone, as well as changes in storage in surface water bodies within the basin. These changes are generally negligible on an annual basis but vary over the course of a year based on precipitation patterns and other factors.

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

- Inflows:
  - Deep Percolation – Described above.
  - Subsurface Inflows – Groundwater inflows from adjacent basins or from the foothill area north of the Wyandotte Creek Subbasin.
  - Seepage – Described above.
- Outflows:
  - Groundwater Pumping – Described above.
  - Subsurface Outflows – Groundwater outflows to adjacent basins.
  - Stream Accretions – Described above.
- Change in Storage – Changes in water storage in the aquifer system. These changes tend to be large compared to changes in root zone soil moisture storage and can vary substantially from year to year.

Many components of the water budget can be estimated based on measured data (e.g., precipitation, diversions, evapotranspiration, etc.) and are used to develop inputs to the BBGM to support water budget development. Other components are more difficult to measure or do not have measured values readily available (e.g., deep percolation, subsurface flows, groundwater pumping, surface water-groundwater interaction, etc.) and are estimated using the BBGM. Additional detail describing the BBGM is available in (BCDWRC, 2021).

Average annual water budget estimates for the historical water budgets and for the current and projected water budget scenarios are summarized in Table 2-5 for the land and surface water system and in Table 2-6 for the groundwater system. Additional information and discussion regarding the water budgets is provided in the following subsections. It is anticipated that the water budgets will be refined and updated over time as part of GSP implementation in the basin.

Table 2-5: Water Budget Summary: Land and Surface Water System

Component	Historical (AFY)	Current (AFY)	Future, No Climate Change (AFY)	Future, 2030 Climate Change (AFY)	Future, 2070 Climate Change (AFY)
Inflows					
Surface Water Inflows	**1,067,300**	**923,900**	**924,000**	**986,500**	**1,036,300**
Outside Diversions	5,700	5,600	5,700	5,700	5,700
Feather River	*1,019,200*	*874,500*	*874,500*	*933,800*	*981,400*
North Honcut Creek	*41,800*	*43,100*	*43,100*	*46,200*	*48,400*
Precipitation Runoff from Upslope Lands	*500*	*600*	*600*	*700*	*700*
Applied Water Return Flows from Upslope Lands	*100*	*100*	*100*	*100*	*100*
Precipitation	**130,800**	**136,100**	**136,100**	**141,500**	**144,900**
Groundwater Pumping	**47,100**	**43,100**	**45,000**	**46,600**	**48,700**
Agricultural	*39,300*	*36,200*	*35,800*	*37,400*	*39,300*
Urban and Industrial	700	500	2,800	2,700	2,700
Managed Wetlands	*7,100*	*6,400*	*6,400*	*6,500*	*6,700*
Stream Gains from Groundwater	**36,300**	**32,000**	**29,500**	**28,500**	**26,600**
Total Inflow	***1,281,500***	***1,135,100***	***1,134,600***	***1,203,100***	***1,256,500***
Outflows					
Evapotranspiration	**87,100**	**82,500**	**81,500**	**84,100**	**86,500**
Agricultural	*43,800*	*41,300*	*40,800*	*42,200*	*44,000*
Urban and Industrial	*8,600*	*8,700*	*11,800*	*12,000*	*12,200*
Managed Wetlands	*5,400*	*4,500*	*4,500*	*4,700*	*4,800*
Native Vegetation	*29,300*	*28,000*	*24,400*	*25,200*	*25,500*
Canal Evaporation	*0*	*0*	*0*	*0*	*0*
Deep Percolation	**70,700**	**69,600**	**67,300**	**69,900**	**70,700**
Precipitation	*47,000*	*48,800*	*45,300*	*49,100*	*47,000*
Applied Surface Water	*6,200*	*4,800*	*4,500*	*4,800*	*4,800*
Applied Groundwater	*17,500*	*16,000*	*17,500*	*16,000*	*18,900*
Seepage	**10,000**	**9,700**	**9,900**	**10,700**	**11,900**
Streams	*4,100*	*4,900*	*5,100*	*5,900*	*7,100*
Lakes	*3,600*	*3,600*	*3,600*	*3,600*	*3,600*
Canals and Drains	*2,300*	*1,200*	*1,200*	*1,200*	*1,200*
Surface Water Outflows	**1,113,500**	**973,200**	**975,600**	**1,038,600**	**1,087,400**
Precipitation Runoff	*17,800*	*19,200*	*21,600*	*23,200*	*24,800*
Applied Surface Water Return Flows	*1,700*	*1,200*	*1,300*	*1,300*	*2,600*

Component	Historical (AFY)	Current (AFY)	Future, No Climate Change (AFY)	Future, 2030 Climate Change (AFY)	Future, 2070 Climate Change (AFY)
Applied Groundwater Return Flows	*3,300*	*2,700*	*3,100*	*3,100*	*4,100*
Streams	*1,090,700*	*950,100*	*949,600*	*1,011,000*	*1,055,900*
Total Outflow	***1,281,300***	***1,135,000***	***1,134,300***	***1,203,300***	***1,256,500***
Change in Storage (Inflow - Outflow)	***200***	***100***	***300***	***-200***	***0***

Note: AFY = acre-feet per year
Totals are the sum of numbers in bold.

Table 2-6: Water Budget Summary: Groundwater System

Component	Historical (AFY)	Current (AFY)	Future, No Climate Change (AFY)	Future, 2030 Climate Change (AFY)	Future, 2070 Climate Change (AFY)
Inflows					
Subsurface Inflows	**24,900**	**22,500**	**22,500**	**22,100**	**22,200**
Butte Subbasin	*15,200*	*13,300*	*13,300*	*12,900*	*13,000*
North Yuba Subbasin	*2,700*	*2,500*	*2,500*	*2,300*	*2,100*
Sutter Subbasin	*700*	*500*	*500*	*600*	*800*
Vina Subbasin	*0*	*0*	*0*	*0*	*0*
Foothill Area	*6,300*	*6,200*	*6,100*	*6,300*	*6,300*
Deep Percolation	**70,800**	**69,600**	**67,300**	**69,900**	**70,700**
Precipitation	*47,000*	*48,800*	*45,300*	*46,900*	*47,000*
Applied Surface Water	*6,200*	*4,800*	*4,500*	*4,700*	*4,800*
Applied Groundwater	*17,500*	*16,000*	*17,500*	*18,300*	*18,900*
Seepage	**10,000**	**9,700**	**9,900**	**10,700**	**11,900**
Streams[1]	*4,100*	*4,900*	*5,100*	*5,900*	*7,100*
Lakes[2]	*3,600*	*3,600*	*3,600*	*3,600*	*3,600*
Canals and Drains[3]	*2,300*	*1,200*	*1,200*	*1,200*	*1,200*
Total Inflow	***105,700***	***101,800***	***99,700***	***102,700***	***104,800***
Outflows					
Subsurface Outflows	**26,000**	**26,700**	**25,600**	**27,600**	**29,900**
Butte Subbasin	*14,000*	*14,800*	*13,700*	*14,400*	*14,900*
North Yuba Subbasin	*10,500*	*10,500*	*10,700*	*11,800*	*13,600*
Sutter Subbasin	*400*	*300*	*300*	*300*	*200*
Vina Subbasin	*200*	*300*	*200*	*300*	*300*

Component	Historical (AFY)	Current (AFY)	Future, No Climate Change (AFY)	Future, 2030 Climate Change (AFY)	Future, 2070 Climate Change (AFY)
Foothill Area	*900*	*800*	*700*	*800*	*900*
Groundwater Pumping	**47,100**	**43,000**	**44,900**	**46,600**	**48,700**
Agricultural	*39,300*	*36,200*	*35,800*	*37,400*	*39,300*
Urban and Industrial	*700*	*500*	*2,800*	*2,700*	*2,700*
Managed Wetlands	*7,100*	*6,400*	*6,400*	*6,500*	*6,700*
Stream Gains from Groundwater	**36,300**	**32,000**	**29,500**	**28,500**	**26,600**
Total Outflow	***109,400***	***101,700***	***100,000***	***102,700***	***105,200***
Change in Storage (Inflow - Outflow)	***-3,700***	***100***	***-300***	***0***	***-400***

Note:
[1] Feather River and North Honcut Creek
[2] Thermalito Afterbay
[3] SFWPA
Totals are the sum of numbers in bold.

2.3.4.1 Historical

The historical water budget provides a foundation for how the basin has behaved historically, including insight into historical groundwater conditions (e.g., observed water levels). Also, in accordance with the GSP Regulations, the historical water budget covers a period of at least 10 years (19-year period from 2000 to 2018), is used to evaluate the availability and reliability of historical surface water supplies, and provides insight into the ability to operate the basin within the sustainable yield. The historical analysis period experienced somewhat less precipitation than the long-term average and included historic drought conditions from approximately 2007 to 2015.[8]

Average annual inflows to and outflows from the basin for the historical land and surface water system water budget were estimated to be 1.28 million acre-feet (MAF) per year. Average annual values were presented previously in Table 2-5 and are shown graphically in Figure 2-26.

Primary inflows to the land and surface water system include surface water inflows (1,067 thousand acre-feet per year [TAF/year]), precipitation (131 TAF/year), stream gains from groundwater (i.e., accretions) (36 TAF/year), and groundwater pumping (47 TAF/year). Surface water inflows consist primarily of the Feather River, which traverses the basin, as well as inflows from Honcut Creek and overland runoff of precipitation and applied water from upslope lands.

Primary outflows from the land and surface water system include surface water outflows (1,113 TAF/year), evapotranspiration (87 TAF/year), deep percolation (71 TAF/year), and stream losses

[8] For the 2000 to 2018 period, mean annual precipitation was 26.7 inches, compared to 23.1 inches for the 2007 to 2015 period.

(also referred to as seepage) (10 TAF/year). Surface water outflows include outflows through the Feather River and Honcut Creek, as well as overland runoff of precipitation and applied water to downslope lands. Evapotranspiration is primarily from agricultural lands but also from native vegetation, urban and industrial lands, and managed wetlands. Deep percolation is primarily from precipitation, but also from applied water. Stream losses include a combination of seepage from canals and drains, stream seepage, and seepage from Thermalito Afterbay.

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

Additional details describing the historical land and surface water system water budget are provided in Appendix 2-A.

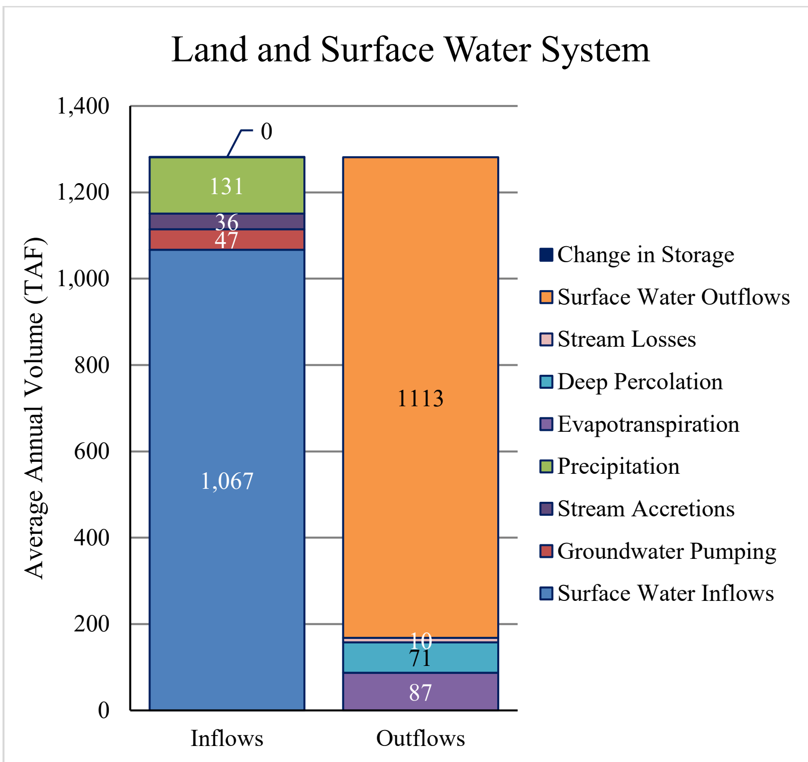

Figure 2-26: Average Annual Historical Land and Surface Water System Water Budget

Average annual inflows to and outflows from the groundwater system were estimated to be 106 TAF and 109 TAF, respectively, with an average decrease in groundwater storage of 4 TAF per year during the historical simulation period. Average annual values were presented previously in Table 2-6 and are shown graphically in Figure 2-27.

Inflows to the groundwater system include deep percolation (71 TAF/year); subsurface inflows from the Butte, North Yuba, Sutter, and Vina subbasins and from the foothill area (25 TAF/year); and stream losses (10 TAF/year). Outflows from the groundwater system include groundwater pumping (47 TAF/year); subsurface outflows to the Butte, North Yuba, Sutter, and

Vina subbasins and to the foothill area (26 TAF/year); and stream gains from groundwater (36 TAF/year).

Additional details describing the historical groundwater system water budget are provided in Appendix 2-A.

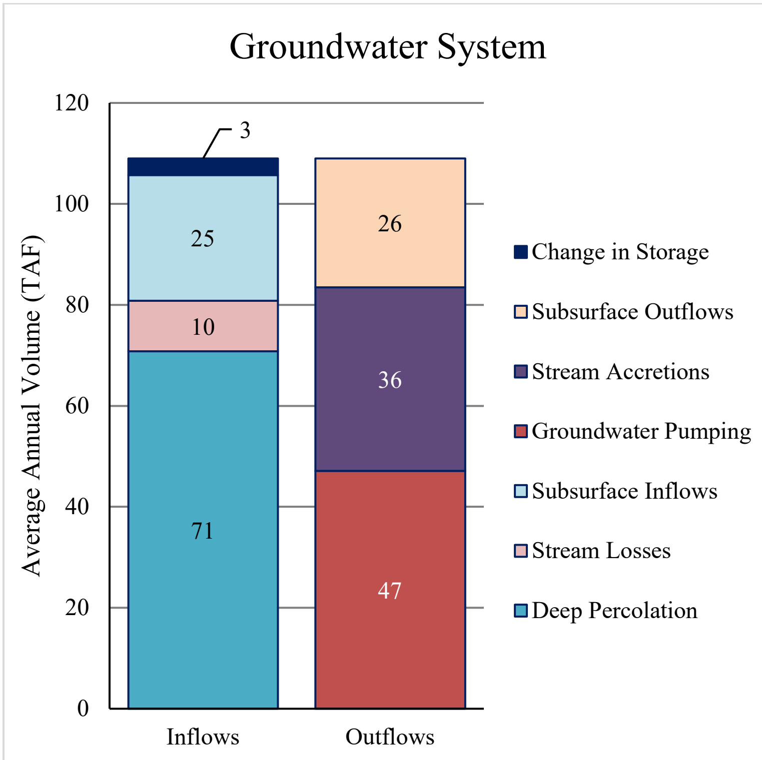

Figure 2-27: Average Annual Historical Groundwater System Water Budget

Historical water supplies and change in groundwater storage are summarized by water year type in Table 2-7 based on the Sacramento Valley Water Year Index. Between 2000 and 2018, there were three wet years, three above normal years, five below normal years, five dry years, and three critical years. Historical surface water deliveries were similar across year types, while groundwater pumping was greatest in critical years and least in wet years. Historically, groundwater storage in the basin has tended to increase in wet years and to decrease in above normal, below normal, dry, and critical years, with reductions in storage in above normal and below normal years less than reductions in dry and critical years. Surface water supplies are relatively reliable in the basin but currently represent only about 20% of total water supplies.

Table 2-7: Historical Water Supplies and Change in Groundwater Storage by Hydrologic Water Year Type

Water Year Type	Surface Water Deliveries (AFY)	Groundwater Pumping (AFY)	Total Supply (AFY)	Change in Groundwater Storage (AFY)
Wet	10,500	38,700	49,200	37,300
Above Normal	12,500	45,200	57,700	-2,000
Below Normal	11,100	45,400	56,500	-3,500
Dry	13,300	50,300	63,600	-20,300
Critical	9,900	55,000	64,900	-18,900

Availability or Reliability of Historical Surface Water Supplies

As indicated in Table 2-7, historical surface water supplies vary somewhat based on water year type with the primary water supply in the basin being groundwater. The primary source of surface water in the basin is the Feather River. Surface water supplies are relatively reliable in the basin and represent approximately 20% of total water supplies. Potential effects of climate change on surface water reliability are further evaluated as part of the projected water budgets in the following sections.

Suitability of Tools and Methods for Planning

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

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

Ability to Operate the Basin within the Sustainable Yield

Sustainable yield refers to the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin, and including any temporary surplus that can be withdrawn annually from a groundwater supply without causing an undesirable result. As a result, determination of sustainable yield requires consideration of SGMA's six SIs. Historical water budget estimates indicate an average annual decrease in storage of 3,700 TAF/year for the period from water year 2000 to 2018. Operation of the basin within the sustainable yield may require incorporation of projects and management actions into the GSP and implementation over the 50-year SGMA planning and implementation horizon. The estimated sustainable yield of the basin is described in greater detail in Section 2.3.5.

2.3.4.2 Current Conditions

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

Average annual inflows to and outflows from the basin for the current conditions land and surface water system baseline water budget were estimated to be 1.14 MAF per year. Average annual values were presented previously in Table 2-5 and are shown graphically in Figure 2-28.

Primary inflows to the land and surface water system include surface water inflows (924 TAF/year), precipitation (136 TAF/year), stream gains from groundwater (i.e., accretions) (32 TAF/year), and groundwater pumping (43 TAF/year). Surface water inflows consist primarily of the Feather River, which traverses the basin, as well as inflows from Honcut Creek and overland runoff of precipitation and applied water from upslope lands.

Primary outflows from the land and surface water system include surface water outflows (973 TAF/year), evapotranspiration (83 TAF/year), deep percolation (70 TAF/year), and stream losses (also referred to as seepage) (10 TAF/year). Surface water outflows include outflows through the Feather River and Honcut Creek, as well as overland runoff of precipitation and applied water to downslope lands. Evapotranspiration is primarily from agricultural lands but also from native vegetation, urban and industrial lands, and managed wetlands. Deep percolation is primarily from precipitation, but also from applied water. Stream losses include a combination of seepage from canals and drains, stream seepage, and seepage from Thermalito Afterbay.

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

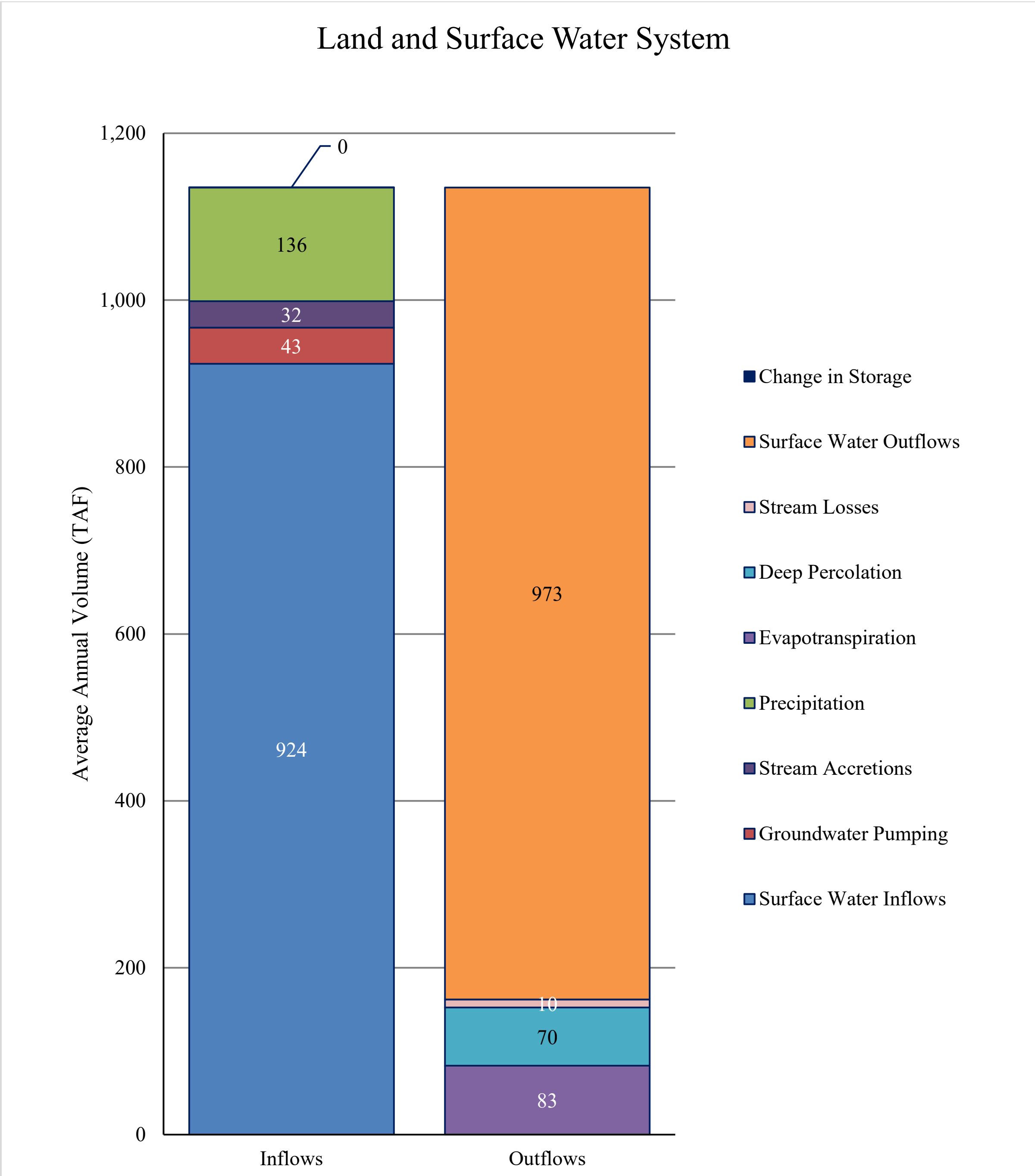

Figure 2-28: Average Annual Current Conditions Land and Surface Water System Water Budget

Average annual inflows to and outflows from the groundwater system were estimated to be 102 TAF, with limited average change in groundwater storage during the current conditions baseline simulation period. Average annual values were presented previously in Table 2-6 and are shown graphically in Figure 2-29.

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Inflows to the groundwater system include deep percolation (70 TAF/year); subsurface inflows from the Butte, North Yuba, Sutter, and Vina subbasins and from the foothill area (22 TAF/year); and stream losses (10 TAF/year). Outflows from the groundwater system include groundwater pumping (43 TAF/year); subsurface outflows to the Butte, North Yuba, Sutter, and Vina subbasins and to the foothill area (26 TAF/year); and stream gains from groundwater (32 TAF/year).

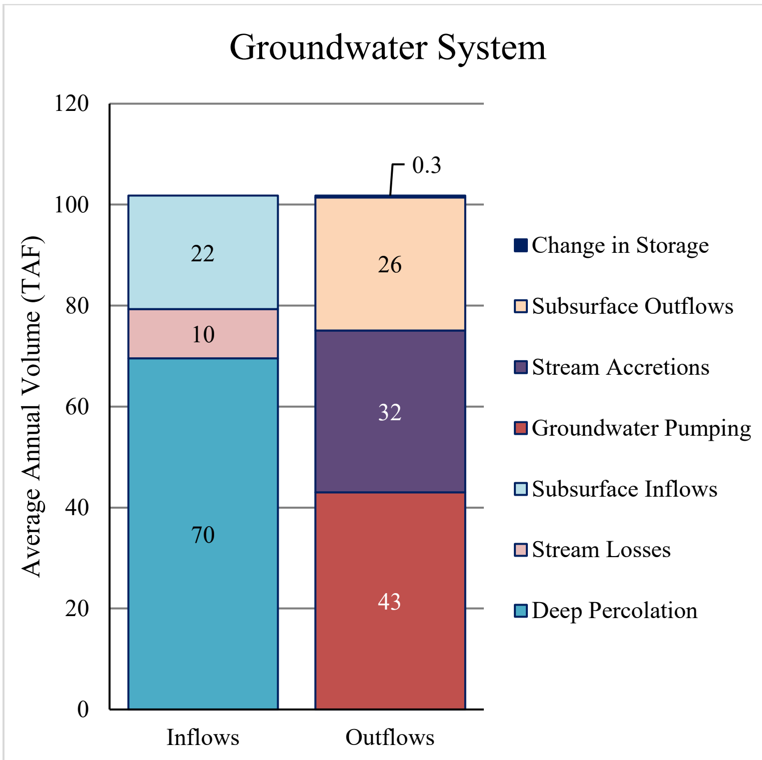


Figure 2-29: Average Annual Current Conditions Groundwater System Water Budget

2.3.4.3 Future Conditions

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

Future Conditions, no Climate Change

Average annual inflows to and outflows from the basin for the future conditions without climate change projected land and surface water system baseline water budget were estimated to be 1.13 MAF per year. Average annual values were presented previously in Table 2-5 and are shown graphically in Figure 2-30.

Primary inflows to the land and surface water system include surface water inflows (924 TAF/year), precipitation (136 TAF/year), stream gains from groundwater (i.e., accretions) (29 TAF/year), and groundwater pumping (45 TAF/year). Surface water inflows consist primarily of the Feather River, which traverses the basin, as well as inflows from Honcut Creek and overland runoff of precipitation and applied water from upslope lands.

Primary outflows from the land and surface water system include surface water outflows (976 TAF/year), evapotranspiration (82 TAF/year), deep percolation (67 TAF/year), and stream losses (also referred to as seepage) (10 TAF/year). Surface water outflows include outflows through the Feather River and Honcut Creek, as well as overland runoff of precipitation and applied water to downslope lands. Evapotranspiration is primarily from agricultural lands but also from native vegetation, urban and industrial lands, and managed wetlands. Deep percolation is primarily from precipitation, but also from applied water. Stream losses include a combination of seepage from canals and drains, stream seepage, and seepage from Thermalito Afterbay.

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

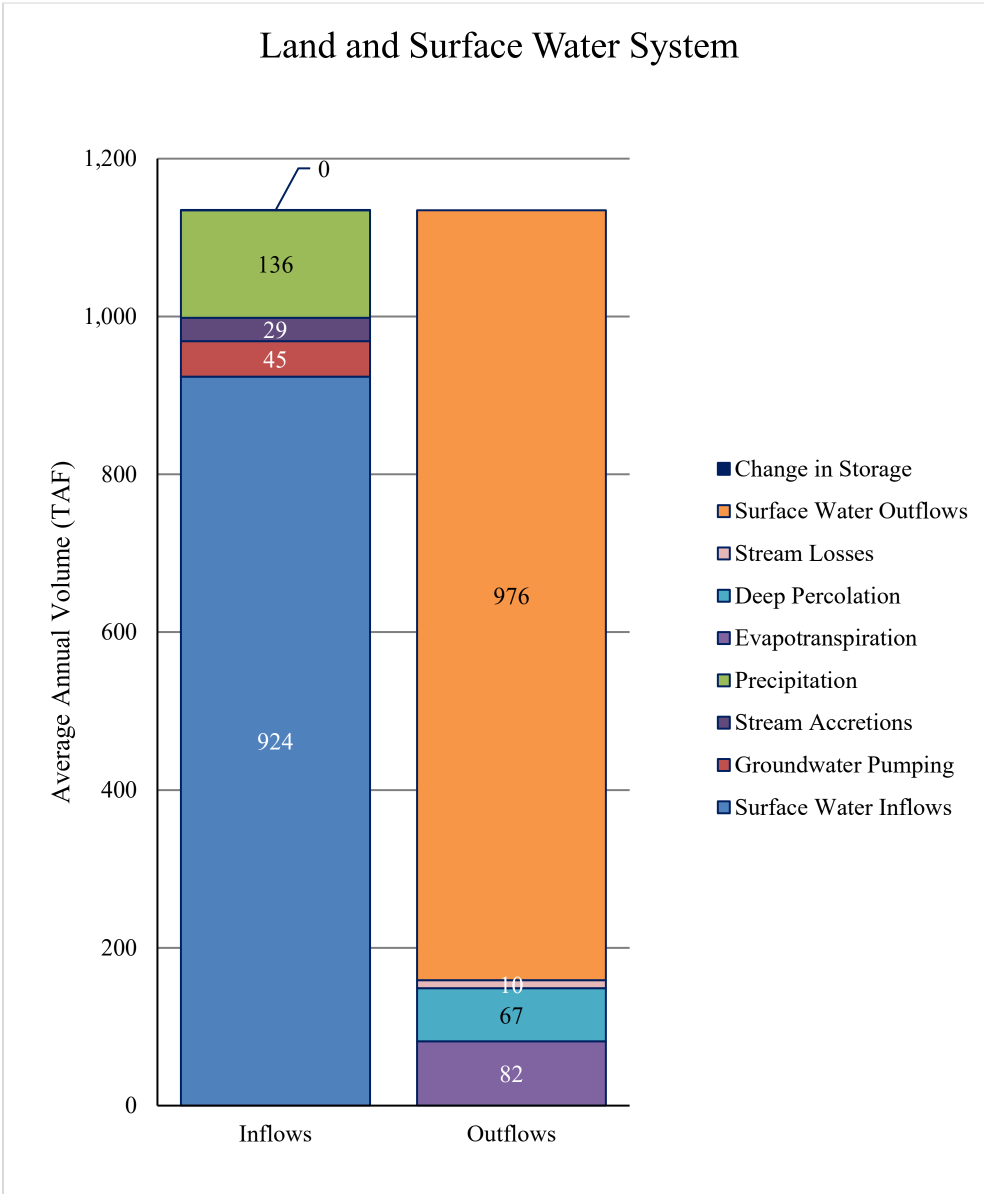


Figure 2-30: Average Annual Future Conditions without Climate Change Land and Surface Water System Water Budget

Average annual inflows to and outflows from the groundwater system were estimated to be 100 TAF, with limited average change in groundwater storage during the future conditions without climate change baseline simulation period. Average annual values were presented previously in Table 2-6 and are shown graphically in Figure 2-31.

Inflows to the groundwater system include deep percolation (67 TAF/year); subsurface inflows from the Butte, North Yuba, Sutter, and Vina subbasins and from the foothill area (22 TAF/year); and stream losses (10 TAF/year). Outflows from the groundwater system include groundwater pumping (45 TAF/year); subsurface outflows to the Butte, North Yuba, Sutter, and

Vina subbasins and to the foothill area (25 TAF/year); and stream gains from groundwater (29 TAF/year).

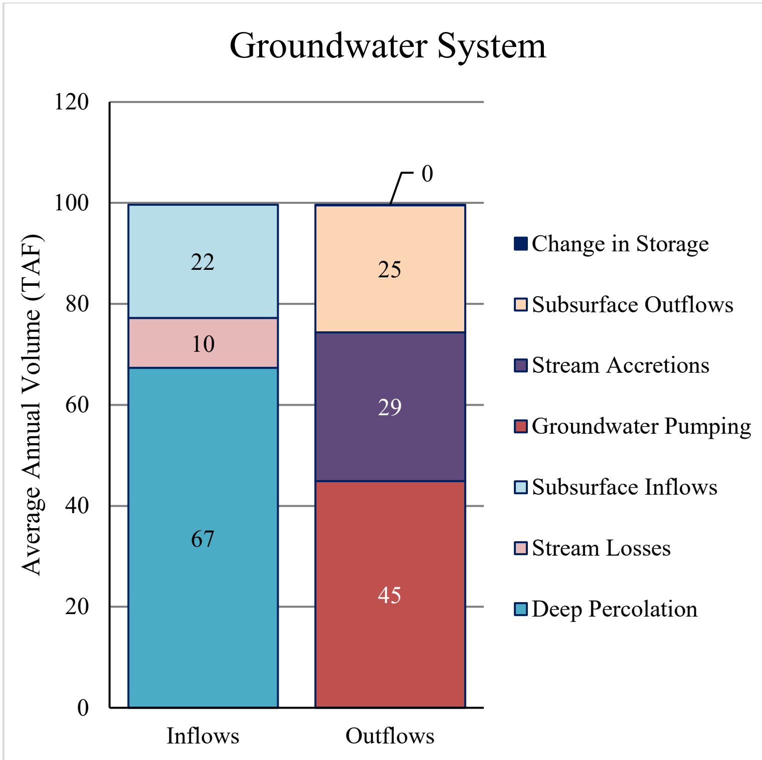


Figure 2-31: Average Annual Future Conditions without Climate Change Groundwater System Water Budget

Future Conditions, 2030 Climate Change

Average annual inflows to and outflows from the basin for the future conditions with 2030 climate change projected land and surface water system baseline water budget were estimated to be 1.20 MAF per year. Average annual values were presented previously in Table 2-5 and are shown graphically in Figure 2-32.

Primary inflows to the land and surface water system include surface water inflows (986 TAF/year), precipitation (142 TAF/year), stream gains from groundwater (i.e. accretions) (29 TAF/year), and groundwater pumping (47 TAF/year). Surface water inflows consist primarily of the Feather River, which traverses the basin, as well as inflows from Honcut Creek and overland runoff of precipitation and applied water from upslope lands.

Primary outflows from the land and surface water system include surface water outflows (1,039 TAF/year), evapotranspiration (84 TAF/year), deep percolation (70 TAF/year), and stream losses (also referred to as seepage) (11 TAF/year). Surface water outflows include outflows through the Feather River and Honcut Creek, as well as overland runoff of precipitation and applied water to downslope lands. Evapotranspiration is primarily from agricultural lands but also from native vegetation, urban and industrial lands, and managed wetlands. Deep percolation is primarily from precipitation, but also from applied water. Stream losses include a combination of seepage from canals and drains, stream seepage, and seepage from Thermalito Afterbay.

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

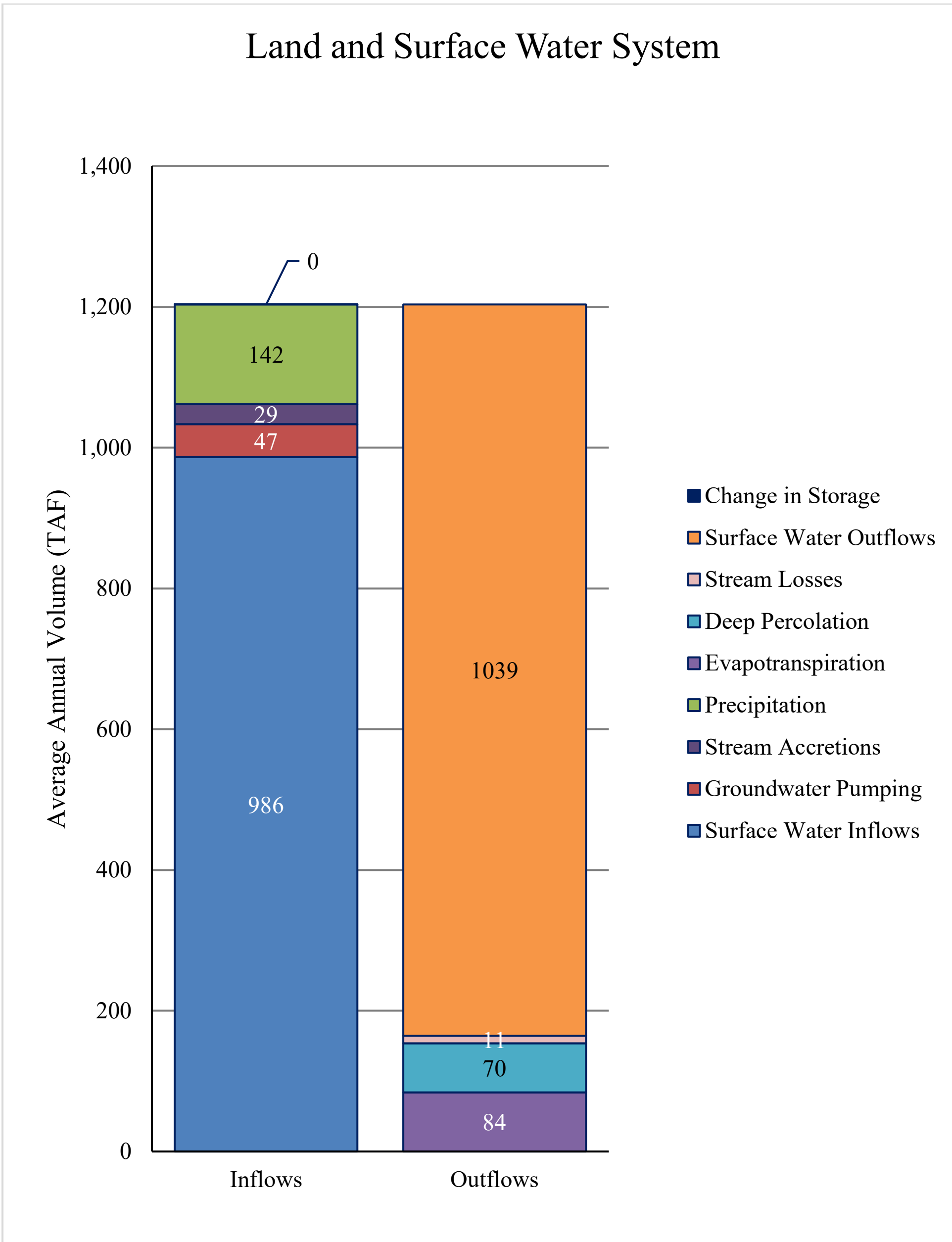


Figure 2-32: Average Annual Future Conditions with 2030 Climate Change Land and Surface Water System Water Budget

Average annual inflows to and outflows from the groundwater system were estimated to be 103 TAF, with limited average change in groundwater storage during the future conditions with 2030 central tendency climate change baseline simulation period. Average annual values were presented previously in Table 2-6 and are shown graphically in Figure 2-33.

Inflows to the groundwater system include deep percolation (70 TAF/year); subsurface inflows from the Butte, North Yuba, Sutter, and Vina subbasins and from the foothill area (22 TAF/year); and stream losses (11 TAF/year). Outflows from the groundwater system include groundwater pumping (47 TAF/year); subsurface outflows to the Butte, North Yuba, Sutter, and Vina subbasins and to the foothill area (27 TAF/year); and stream gains from groundwater (29 TAF/year).

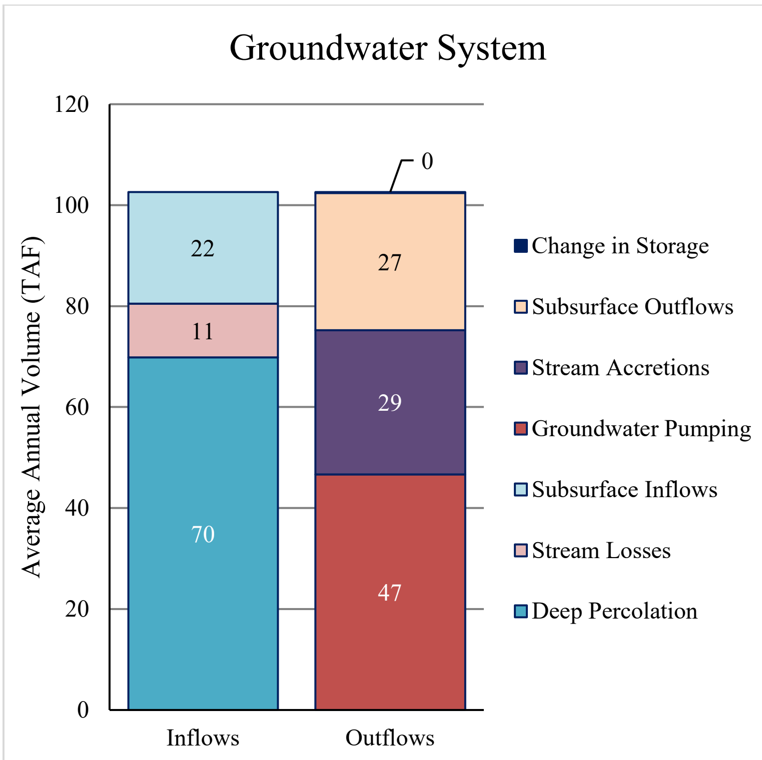


Figure 2-33: Average Annual Future Conditions with 2030 Climate Change Groundwater System Water Budget

Future Conditions, 2070 Climate Change

Average annual inflows to and outflows from the basin for the future conditions with 2070 climate change projected land and surface water system baseline water budget were estimated to be 1.26 MAF per year. Average annual values were presented previously in Table 2-5 and are shown graphically in Figure 2-34.

Primary inflows to the land and surface water system include surface water inflows (1,036 TAF/year), precipitation (145 TAF/year), stream gains from groundwater (i.e. accretions) (27 TAF/year), and groundwater pumping (49 TAF/year). Surface water inflows consist primarily of the Feather River, which traverses the basin, as well as inflows from Honcut Creek and overland runoff of precipitation and applied water from upslope lands.

Primary outflows from the land and surface water system include surface water outflows (1,087 TAF/year), evapotranspiration (87 TAF/year), deep percolation (71 TAF/year), and stream losses (also referred to as seepage) (12 TAF/year). Surface water outflows include outflows through the Feather River and Honcut Creek, as well as overland runoff of precipitation and applied water to downslope lands. Evapotranspiration is primarily from agricultural lands but also from native vegetation, urban and industrial lands, and managed wetlands. Deep percolation is primarily from precipitation, but also from applied water. Stream losses include a combination of seepage from canals and drains, stream seepage, and seepage from Thermalito Afterbay.

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

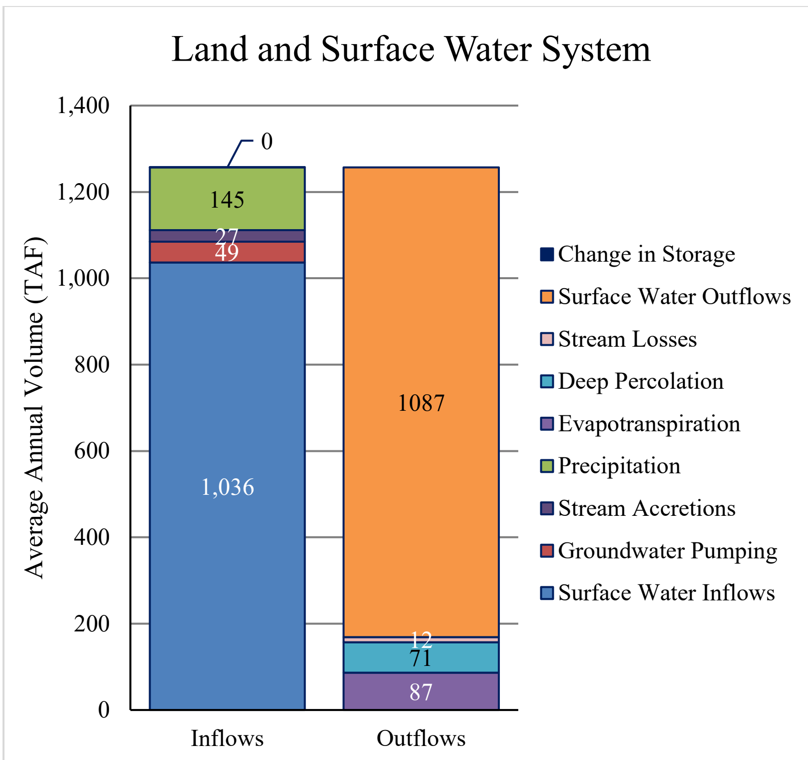


Figure 2-34: Average Annual Future Conditions with 2070 Climate Change Land and Surface Water System Water Budget

Average annual inflows to and outflows from the groundwater system were estimated to be 103 TAF, with limited average change in groundwater storage during the future conditions with 2030 central tendency climate change baseline simulation period. Average annual values were presented previously in Table 2-6 and are shown graphically in Figure 2-35.

Inflows to the groundwater system include deep percolation (71 TAF/year); subsurface inflows from the Butte, North Yuba, Sutter, and Vina subbasins and from the foothill area (22

TAF/year); and stream losses (12 TAF/year). Outflows from the groundwater system include groundwater pumping (49 TAF/year); subsurface outflows to the Butte, North Yuba, Sutter, and Vina subbasins and to the foothill area (29 TAF/year); and stream gains from groundwater (27 TAF/year).

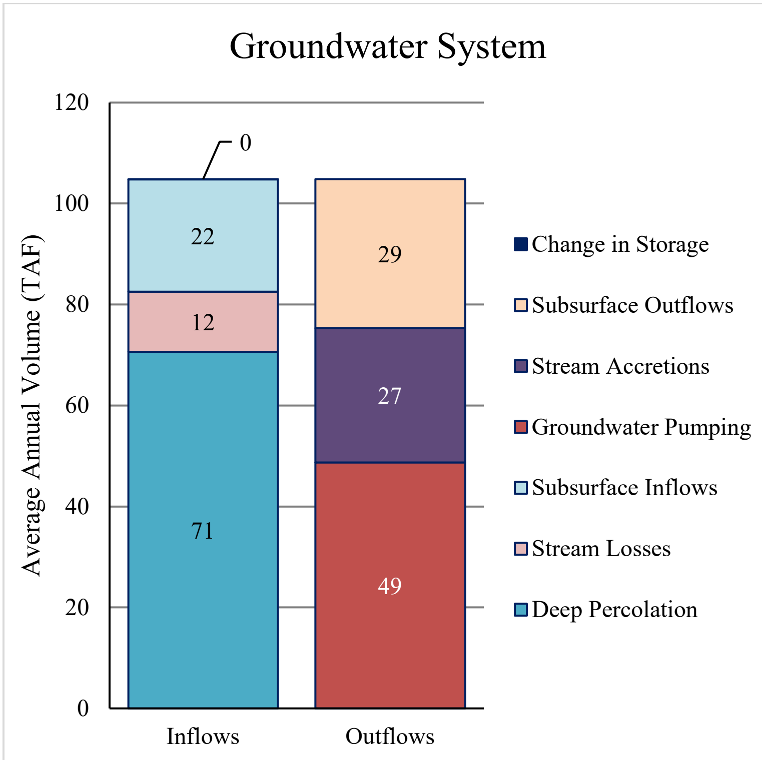
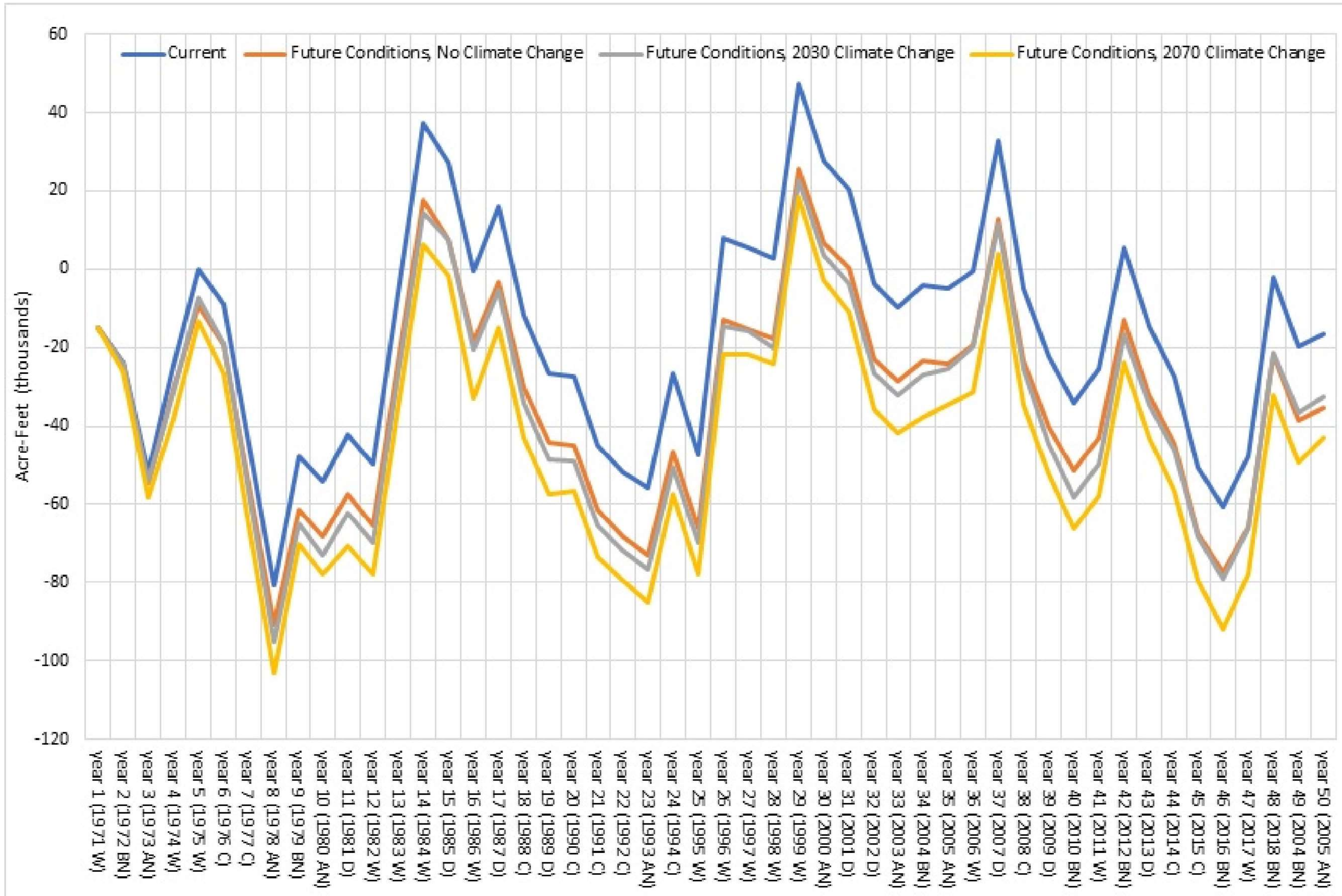


Figure 2-35: Average Annual Future Conditions with 2070 Climate Change Groundwater System Water Budget

Comparison of Water Budget Scenarios

A figure depicting cumulative change in storage for the current conditions and three future conditions baseline scenarios is provided on the following page (Figure 2-36). In the figure, the cumulative change in groundwater storage is shown for the 50-year hydrologic period. The x-axis (horizontal axis) is labeled with the historical reference year along with the corresponding water year type based on the Sacramento Valley Water Year Index. Years are identified as wet (W), above normal (AN), below normal (BN), dry (D), or critical (C).

There is a projected decrease in groundwater in storage for the future conditions scenarios relative to the current conditions scenarios likely resulting from a combination of increased urban and rural residential demands that may be met by groundwater and reduced recharge due to increased runoff on developed lands. Climate change may lead to additional reductions in storage due to increased temperatures and potential reductions in surface water availability.



Cumulative Change in Groundwater Storage for Current and Future Conditions Baseline Scenarios
Wyandotte Creek Subbasin GSP

Project No.: SAC282 | December 2021

Figure **2-36**

2.3.5 Water Budget Uncertainty

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

2.3.6 Sustainable Yield Estimate

Sustainable yield refers to the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin, and including any temporary surplus that can be withdrawn annually from a groundwater supply without causing an undesirable result. As a result, determination of sustainable yield requires consideration of SGMA's six SIs. Historical water budget estimates indicate an average annual decrease in storage of about 3,700 AFY for the period from 2000 to 2018. In general, decreased precipitation and increased groundwater pumping in dry years leads to decreases in groundwater levels and storage and may pose challenges to operating within the sustainable yield over multiple dry years. Operation of the basin within the sustainable yield will likely require incorporation of projects and management actions into the GSP and implementation over the 50-year SGMA planning and implementation horizon. The estimated sustainable yield of the basin is described in greater detail in Section 2.3.6.

Draft estimates have been developed for the basin for each scenario as the long-term annual groundwater pumping, minus the average annual decrease in groundwater storage, as summarized in Table 2-8. Ultimately, it is anticipated that other factors will be considered in refining these estimates as part of development of SMC for the basin.

Table 2-8: Estimated Groundwater Pumping, Decrease in Storage, and Change in Sustainable Yield

Baseline Scenario	Groundwater Pumping (AFY)	Decrease in Groundwater Storage (AFY)	Difference (AFY)
Current	43,000	-100	43,100
Future, No Climate Change	44,900	300	44,600
Future, 2030 Climate Change	46,700	200	46,500
Future, 2070 Climate Change	48,700	400	48,300

However, as discussed in Section 2.3.4, the decrease in groundwater storage is sensitive to the time period used to calculate this value. All of the scenarios presented in Table 2-8 are based on

50 years of data. As discussed in Section 2.3.6, a fifth scenario was used called historical that covers the period from 2000 to 2018 or 18 years. The groundwater pumping and decrease in storage for this scenario are 47,100 AFY and 3,700 AFY, respectively. Using these values, a sustainable yield of 43,400 AFY would be calculated similar to the current scenario.

For development of SMC as discussed in Chapter 3, the MO was developed to address the long-term trend of the "peaks and valleys" of the short-term cycles and stop the long-term decline in groundwater levels during dry years. Using this method, the average depth below the MO at compliance points (see Chapter 3 for discussion of representative monitoring sites [RMS]) if no actions are taken before the end of the implementation period in 2042 is about 5 feet. Using this value, a sustainable yield can be estimated based on the reduction in pumping needed to stop the observed decline in water levels across the subbasin. This value is sensitive to the specific storage. Specific storage is the parameter that translates the change in groundwater elevation to an associated change in volume (i.e. change in storage).

As discussed in Section 2.1.8.3, the average specific storage value used in the BBGM is 0.03967. Specific storage values estimated from pumping tests conducted in the Wyandotte Creek Subbasin ranged from 0.0002 to 0.00044 (Brown and Caldwell, 2013). Table 2-9 provides estimates of sustainable yield to maintain the MO in 2042 using this range of storativity values and the average decline in water levels across the subbasin in 2042. The groundwater pumping rate for the historical scenario is used for the calculation of sustainable yield.

Table 2-9: Estimated Sustainable Yield Using Average Depth Below Measurable Objective in 2042 and Range of Storativity Values

Feet Below MO in 2042	Specific Storage	Area of Subbasin (square miles)	Volume Storage Below MO in 2042 (acre-feet)	Average Change in Storage Between 2030 and 2042 (AFY)	Groundwater Pumping[1] (AFY)	Estimated Sustainable Yield (AFY)
5	0.03967	75	9,521	793	47,100	46,307
5	0.002	75	480	40	47,100	47,060
5	0.0002	75	48	4	47,100	47,096
5	0.0005	75	120	10	47,100	47,090

Using the information presented above, this GSP defines the estimate of the sustainable yield as 46,100 AFY based on groundwater pumping of 47,100 AFY and a decrease in storage of 1,000 AFY.

2.3.7 Opportunities for Improvement to the Water Budget

2.3.7.1 Refine Surface Water Diversion Estimates

While many of the large diversions are continuously monitored and recorded, limited information is available for others. It is recommended that the GSA in the basin work with local stakeholders to better document surface water diversions. Diversion estimates developed as part of the water budgets provide a good basis to support discussion with diverters.

2.3.7.2 Refine Groundwater Pumping Estimates
Groundwater pumping for irrigation has generally been estimated based on estimates of crop irrigation requirements in areas known to rely on groundwater. It is recommended that the GSA look for opportunities to verify and refine groundwater pumping estimates to support water budget validation and refinements by obtaining pumping data from cooperative landowners.

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

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

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

2.3.7.6 Land Use Changes Due to the Camp Fire
In 2018, the Camp Fire destroyed 18,000 structures in Butte County displacing over 27,000 residents. While the Town of Paradise, Concow and other areas destroyed by the Camp Fire rebuild, many residents have relocated to the City of Oroville and other portions of the Wyandotte Creek Subbasin. The existing General Plans may not fully account for the relocation of Camp Fire survivors. A focused accounting of changes to residential land use as a result of the Camp Fire should be conducted.