PUBLIC REVIEW DRAFT
Section 3 –Basin Setting

Corning Subbasin
Groundwater Sustainability Plan

September 2021

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Appendix 3C. Groundwater Level Hydrographs

3 BASIN SETTING

3.1 Hydrogeologic Conceptual Model

3.1.1 Overview

This section describes the hydrogeologic conceptual model (HCM) of the Subbasin. The HCM "provides an understanding of the general physical characteristics related to regional hydrology, land use, geology, geologic structure, water quality and aquifers" (DWR, 2016b). As such, the HCM provides the necessary physical background information to develop integrated hydrologic computer models and compute water budgets.

The Corning Subbasin covers approximately 207,342 acres in the northern Sacramento Valley across northern Glenn County and southern Tehama County. As a portion of the Sacramento Valley Groundwater Basin, there are no dominant hydrogeologic barriers between the Subbasin and neighboring subbasins. Subbasin geology is largely consistent with the regional Sacramento Valley depositional environment, consisting of alternating and sometimes interbedded layers of conglomerate, sandstone, siltstone, mudstone, and lahars.

3.1.2 Subbasin Boundaries

The Subbasin's extent, identified by DWR and vetted by the GSAs, is bounded by geographic and geological (lateral), and hydrostratigraphic (vertical) features. Lateral boundaries of the Subbasin are displayed on Figure 3-1, showing the surface water features (creeks, rivers, and reservoirs). Lateral extents are also marked by regionally significant geologic formations, as further described in the following sections. Creeks and rivers are considered boundaries as they may cause or support divergent groundwater flow (DWR, 2006a). The lateral boundaries of geologic formations are used as they can affect the occurrence and distribution of groundwater.

Lateral boundaries include:

- **North** – Thomes Creek from around Flournoy in the east to its junction with the Sacramento River in the west. Here the Subbasin borders the Red Bluff Subbasin.
- **East** – The Sacramento River, beginning northeast of Corning down to just southeast of Hamilton City. Here the Subbasin borders the Los Molinos, Vina, and Butte Subbasins.
- **South** – Stony Creek from its junction with the Sacramento River near Hamilton City to just east of Black Butte Lake, where Stony Creek intersects the Glenn County-Tehama County border. This county border forms the Subbasin boundary from here to the edge of the Orland Buttes. The Subbasin boundary then follows the outline of the Black Butte Hills north to Black Butte Lake, which forms the southern Subbasin boundary where it is

present. West of Black Butte Lake, Stony Creek again forms the southern Subbasin boundary. Here the Subbasin borders the Colusa Subbasin.

- **West** – The surficial extent of the Tehama Formation, a regionally significant formation. Geology west of this extent is defined by pre-paleogene metamorphic, igneous, and sedimentary rocks (DWR, 2014). There is no subbasin bordering the western Corning Subbasin border. The Coastal Range foothills border the Subbasin to the west.

Hydrostratigraphic boundaries are defined using subsurface geology and groundwater chemistry. The three deepest formations in the Corning Subbasin (the Upper Princeton Valley Fill, the Lower Princeton Valley Fill, and the Great Valley Sequence) are brackish and/or saline (Redwine, 1984). Above these lie the Tehama and Tuscan Formations, which contain freshwater. The Tehama and Tuscan Formations are therefore considered the deepest freshwater-bearing formations, the lower boundaries of which define the vertical boundary of the Subbasin (DWR, 2014). The base of freshwater discussed below generally corresponds to the bottom of the Tehama and Tuscan Formations across the northern Sacramento Valley (DWR, 2014).

As defined by DWR, the base of freshwater can be considered the deepest point at which total dissolved solids (TDS) concentration is less than 1,000 mg/L. DWR considers groundwater containing TDS above this level to be brackish or saline, as treatment (desalination) is typically needed prior to use for agriculture or drinking water. Other communities in California do produce water from aquifers with groundwater above 1,000 mg/L TDS at added cost. However, due to the relative abundance of fresh groundwater in the Northern Sacramento Valley, groundwater with TDS above 1,000 mg/L is typically considered economically unviable. Accordingly, very few wells are screened at depths necessary to extract water below the Tehama and Tuscan Formations (Figure 3-2) (DWR, 2006a).

Therefore, the base of freshwater is considered the bottom boundary of the Subbasin, as shown on Figure 3-2.

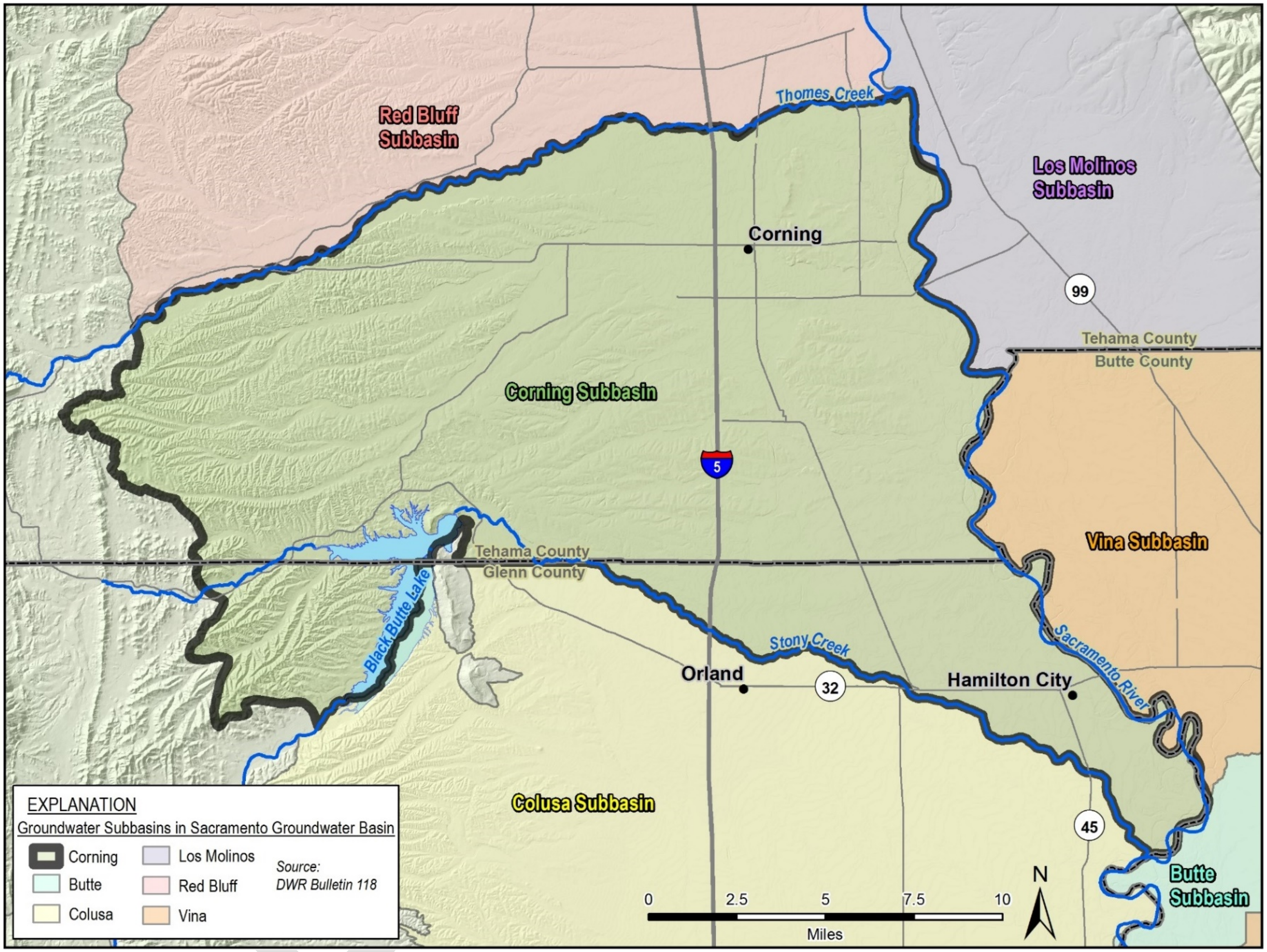

Figure 3-1. Corning Subbasin Lateral Boundaries

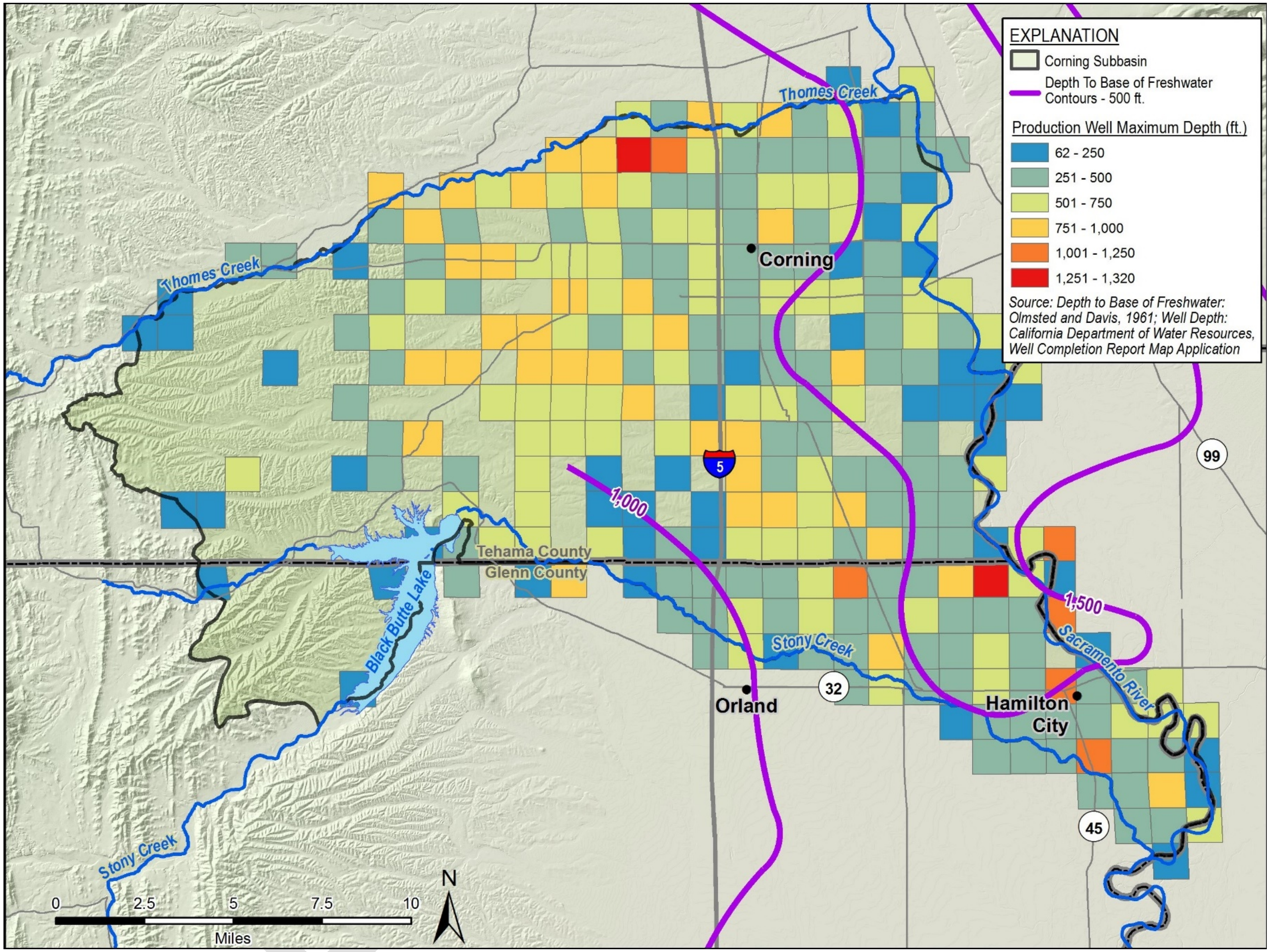

Figure 3-2. Corning Subbasin Vertical Boundaries

3.1.3 Surface Topography

Figure 3-3 displays USGS elevation contours in the Subbasin. Topography in the Subbasin generally slopes eastward from a high of over 1,000 feet above mean sea level (AMSL) bordering the Coastal Range foothills to a low of approximately 100 ft AMSL in the Sacramento Valley. Approximately two-thirds of the Subbasin's extent has an elevation between 100 and 500 ft AMSL. Overall, the range in elevation across the Subbasin is relatively minor, with a gradual sloping towards the valley floor, which encourages runoff and drainage toward the Sacramento River and to the southeast. Elevations in the Subbasin reflect a typical Sacramento Valley floor environment.

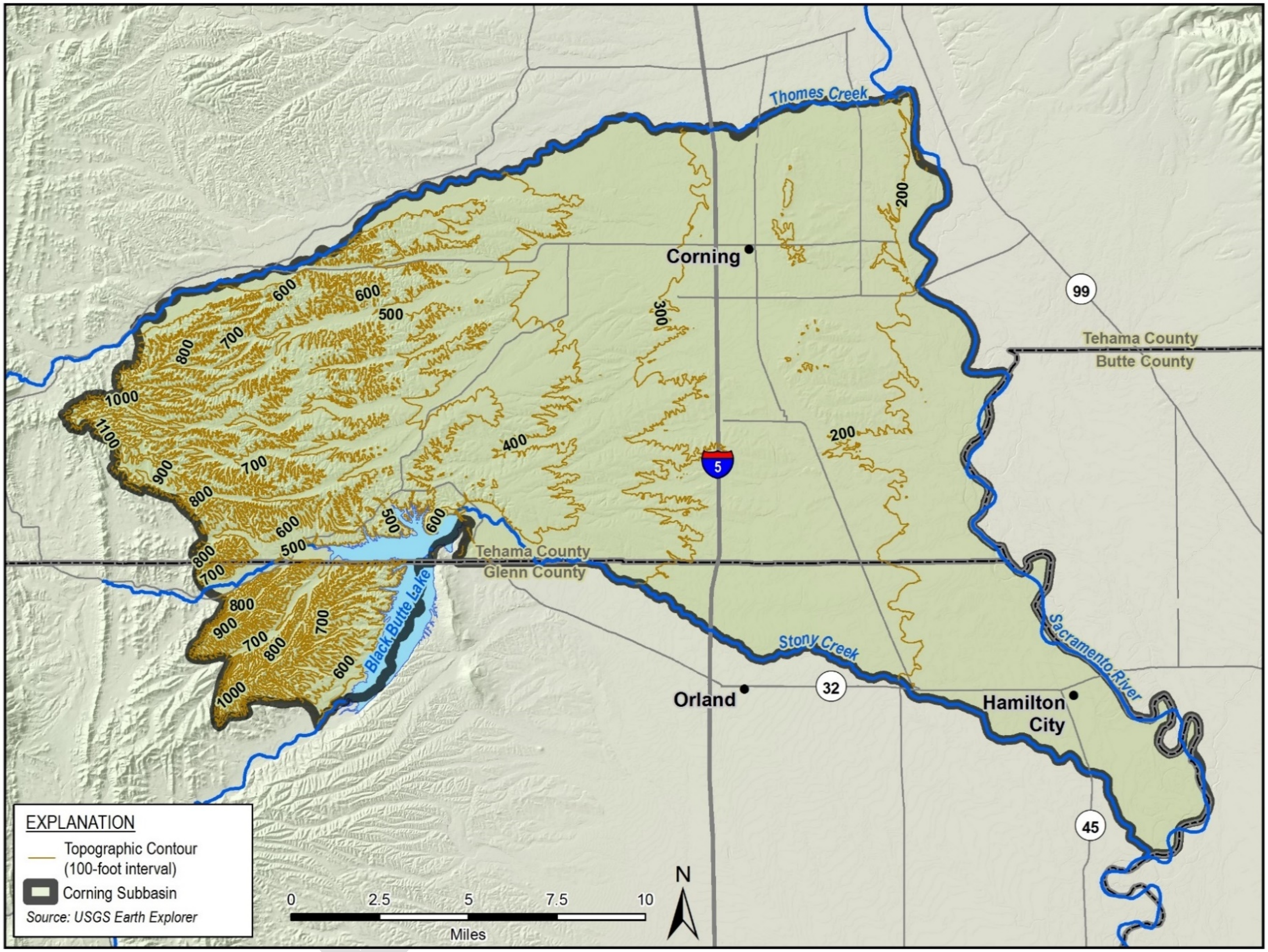

Figure 3-3. Surface Topography

3.1.4 Soil Characteristics

Soils can be classified according to soil type (based on multiple soil properties) and hydrologic soil group (based on infiltration and drainage ability of soils). USDA soil taxonomy designations are presented on Figure 3-4. Hydrologic soil group designations obtained from the Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) are presented on Figure 3-5. Both maps serve to describe Subbasin soils and identify potential effects on Subbasin hydrogeology.

The following soil types are present in the Corning Subbasin (Figure 3-4):

- Alfisols - soils with a clay-enriched B horizon
- Entisols - mineral soils that have not yet differentiated into distinct horizons
- Inceptisols - freely draining soils with poorly defined horizons
- Mollisols - identified by a deep layer of well decomposed and finely distributed organic matter
- Vertisols - clayey soil with little organic matter

Approximately 80% of surveyed areas in the Subbasin are covered by alfisols, which are fertile soils defined by a prominent clay layer (hardpan) and high base saturation and which may impede infiltration capacity (NRCS, 1999). The widespread presence of alfisols correlates with relatively low infiltration rates across much of the Subbasin (see Figure 3-4). Entisols, prevalent near rivers and creeks, are characterized by similarity to soil parent material, in this case coarse-grained and unconsolidated fluvial deposits. Infiltration rates are correspondingly higher near rivers and creeks, notably Thomes Creek, Stony Creek, and the Sacramento River. Inceptisols, mollisols, and vertisols are also present in the Subbasin, though their effects on Subbasin hydrogeology are less prominent. Overall, soil infiltration rates are generally higher in the eastern half of the Subbasin and near rivers and creeks, due to the presence of coarser fluvial deposits (Figure 3-5).

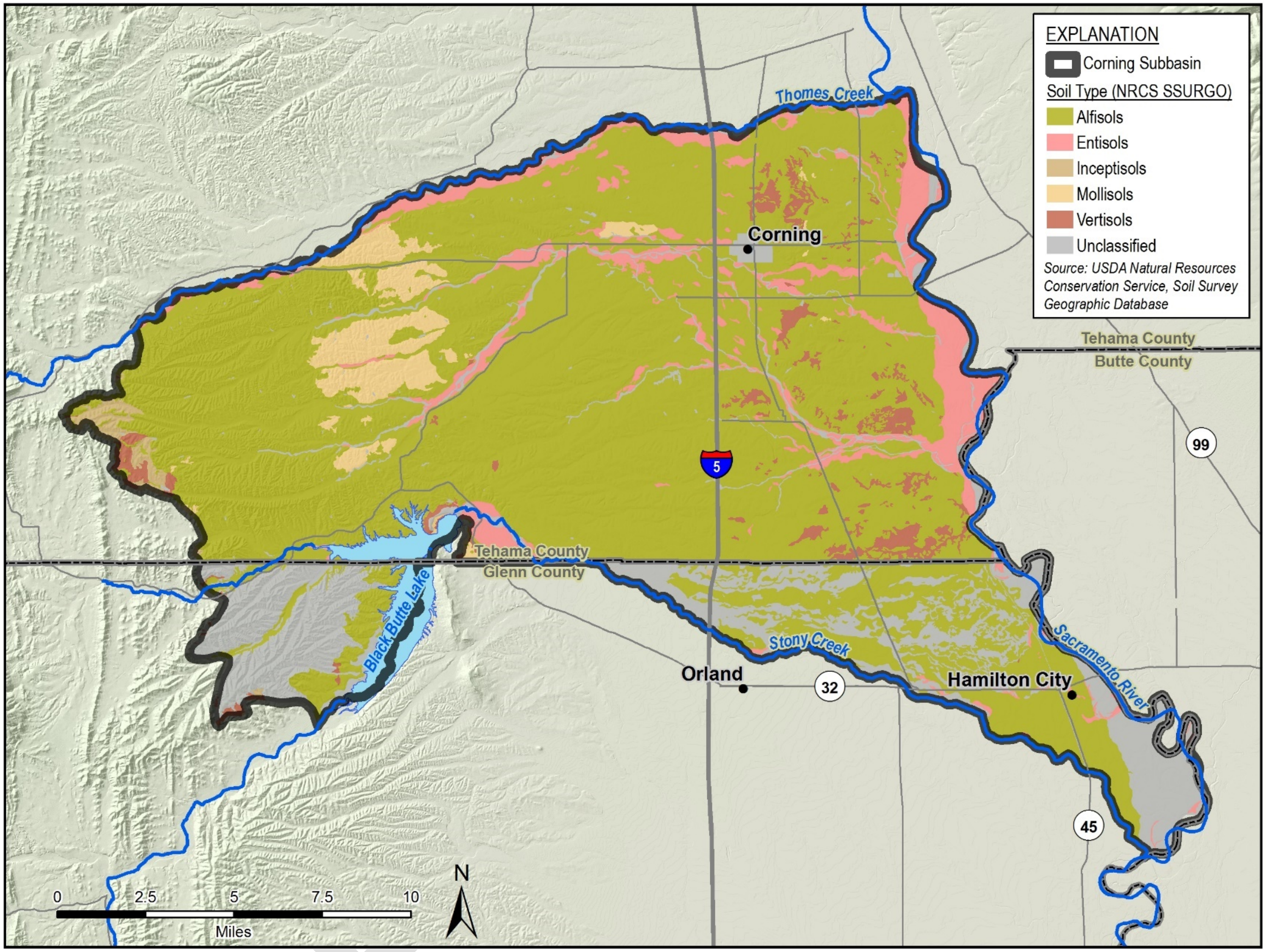

Figure 3-4. Soil Types

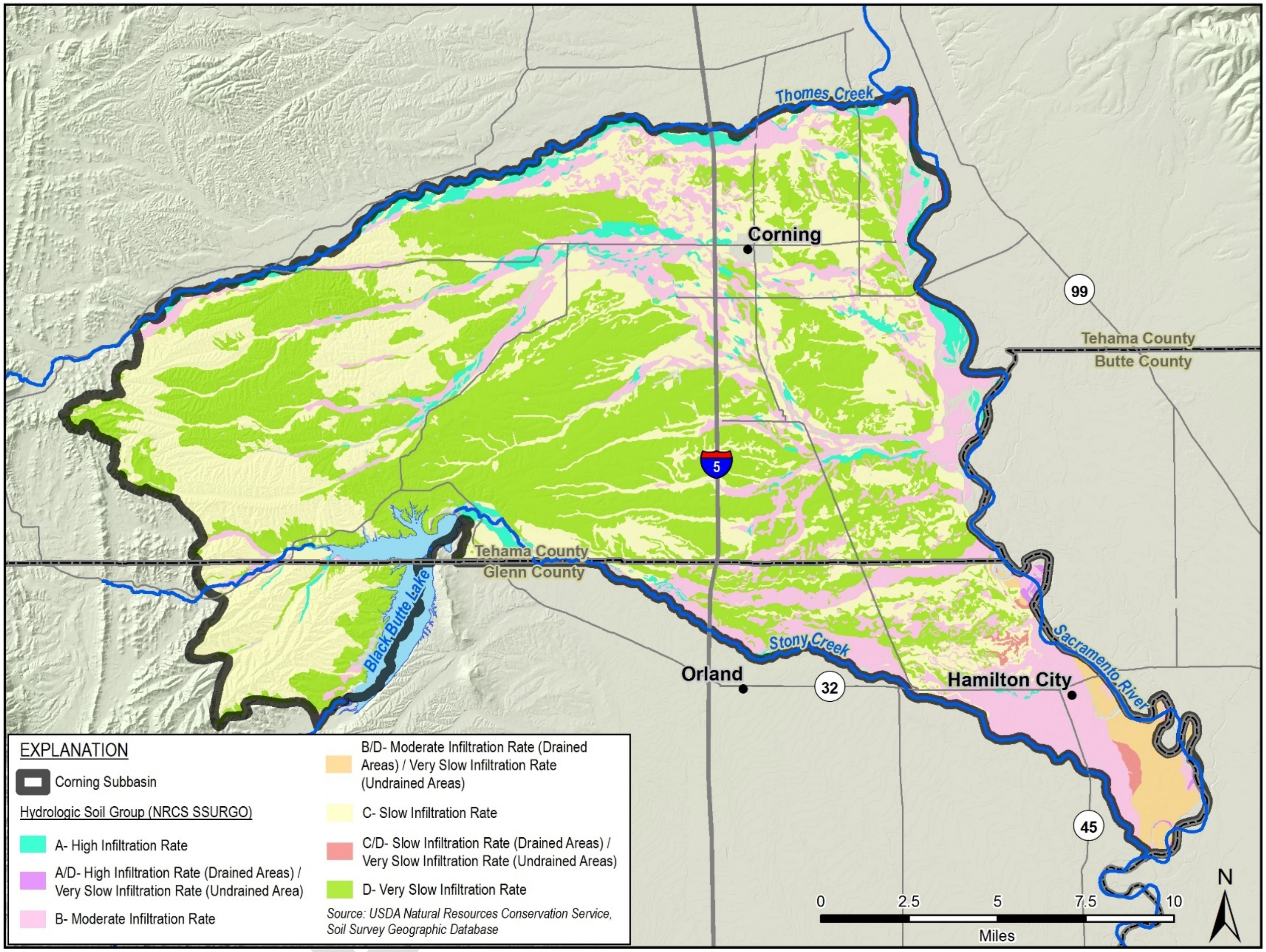

Figure 3-5. Hydrologic Soil Groups

3.1.5 Geologic Formations and Stratigraphy

Subbasin stratigraphy is marked by distinct depositional environments producing a diverse sequence of geologic formations including those of marine and continental origin. Marine formations were deposited early in the Subbasin's history, from the Jurassic through the Miocene. During this period, the majority of northern Sacramento Valley was a marine basin formed via action of the Pacific-North American plate subduction zone. Continental sedimentary formations and volcanic formations were deposited from the Pliocene onward, as uplift of the Coast Ranges created the Sacramento Valley as it stands today.

The following formations and units are present in the Corning Subbasin:

- Quaternary Alluvium (Qa)
- Tehama Formation (Tte)
- Tuscan Formation (Tt)
- Upper Princeton Valley Fill (Upvf)
- Lower Princeton Valley Fill (Lpvf)
- Great Valley Sequence (JKgvs)

Two other formations, the Lovejoy Basalt and the Ione Formation, have minor presence in the Subbasin at depth. Due to their limited presence, they are not discussed in detail in this section.

Figure 3-6 illustrates the Subbasin's surficial geology. Quaternary formations and deposits are displayed individually to detail surficial geology, though cross sections displayed in Section 3.1.6.3 group these as (Qa) for simplicity. Quaternary formations were similarly grouped in the Glenn-Colusa HCM, which covers the southern portion of Corning Subbasin in Glenn County (Davids Engineering and West Yost, 2018). Geologic formations present in the Subbasin area are presented stratigraphically on Figure 3-7 including age of deposition, lithology, and approximate maximum thickness in the Subbasin.

Hydrogeologic properties of freshwater-bearing units, as estimated through a variety of aquifer tests and hydrogeologic modeling are summarized in Table 3-1. The Quaternary Alluvium aquifer layers storage parameter is specific yield as this aquifer is primarily unconfined and the deeper aquifers, such as the Tehama and Tuscan aquifers, have storativity values as they are confined. This table shows that hydrogeologic parameter information is missing for several hydrogeologic units, and where available, data from different sources are not consistent. This points to a data gap that could be resolved during GSP implementation. Brief definitions of the aquifer parameter terminology used in this section are presented in the sections below.

Hydraulic Conductivity: Property of geologic materials that moderates the speed of groundwater flow. Higher hydraulic conductivity allows water to travel faster through media. Units with very low hydraulic conductivity slow or may prevent groundwater flow. Usually presented as [length/time].

Transmissivity: The hydraulic conductivity of an aquifer unit multiplied by its total thickness. High transmissivity may reflect units very conductive to groundwater flow, very thick units, or both. Usually presented as [length^2/time] or occasionally as [volume/length/time].

Storativity: The volume of water (i.e., cubic feet) released from a square unit of geologic material (i.e., square foot), given a unit decline in groundwater (i.e., foot). Storativity is applied to aquifers under local or regional confinement and is roughly equivalent to specific yield in an unconfined aquifer. High storativity suggests a productive aquifer unit. Storativity is a volumetric ratio and therefore unitless.

Specific Yield: The amount of water released from a cubic unit of geologic material if allowed to drain completely under force of gravity. Specific yield is used to characterize unconfined aquifers; high specific yield indicates a productive aquifer unit. Specific yield is a volumetric ratio and therefore unitless.

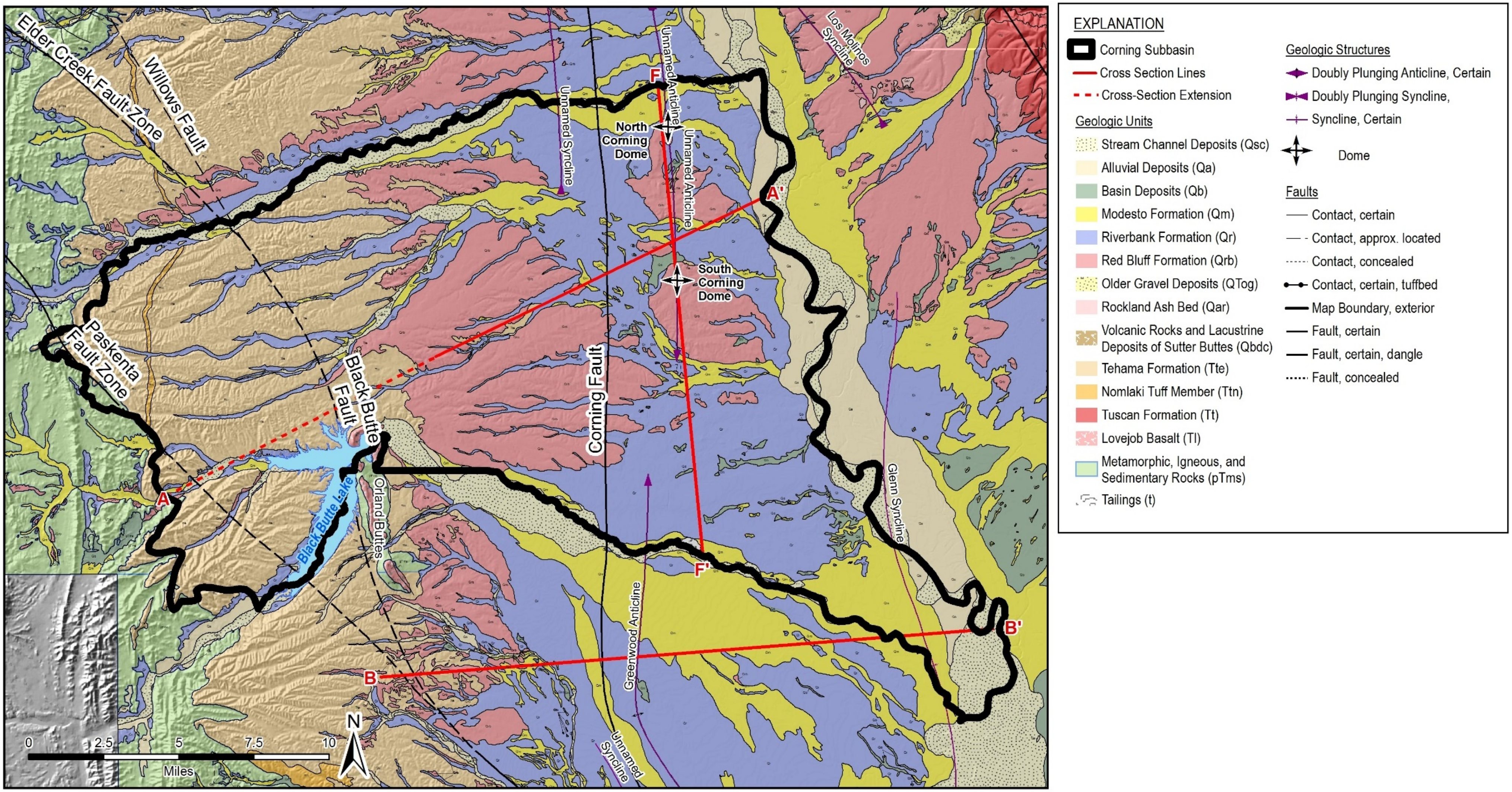

Figure 3-6. Surface Geology

Era	Period	Series	Geologic Formation		Lithology	Approximate Thickness in Subbasin (feet)
Cenozoic	Quaternary	Holocene	Alluvial Deposits and Stream Channel Deposits (Qa/Qsc)		Unconsolidated gravel, sand, silt, and clay	< 80
Cenozoic	Quaternary	Holocene	Basin Deposits (Qb)		Unconsolidated fine-grained silts and clays	< 150
Cenozoic	Quaternary	Pleistocene	Modesto Formation (Qm)		Poorly sorted unconsolidated gravel, sand, silt, and clay.	10-200
Cenozoic	Quaternary	Pleistocene	Riverbank Formation (Qr)		Poorly sorted, unconsolidated to semi-consolidated pebble and small cobble gravels inter-lensed with clay, silt, and sand.	1- 200
Cenozoic	Quaternary	Pleistocene	Red Bluff Formation (Qrb)		Highly weathered sandy gravels	< 33
Cenozoic	Quaternary / Tertiary	Pleistocene / Pliocene	Tehama Formation (Tte)*		Fluviatile moderately consolidated pale green, gray, and tan sandstone and siltstone containing lenses of sand and gravel, silt and gravel, and cemented conglomerate	< 2,000
Cenozoic	Tertiary	Pliocene	Tuscan Formation (Tt)*	Tuscan C (Ttc)	Low permeability lahars	< 300
Cenozoic	Tertiary	Pliocene	Tuscan Formation (Tt)*	Tuscan B (Ttb)	Volcanic conglomerate, sandstone, siltstone, and interbedded lahars overlain by tuffacous breccias, sandstone, and conglomerate	< 700
Cenozoic	Tertiary	Pliocene	Tuscan Formation (Tt)*	Tuscan A (Tta)		
Cenozoic	Tertiary	Miocene	Upper Princeton Valley Fill (UPvf)		Non-marine sandstone containing mudstone, conglomerate, and sandstone interbeds.	< 1,400
Cenozoic	Tertiary	Eocene	Lower Princeton Submarine Valley Fill (LPvf)		Marine conglomerate and sandstone interbedded wih silty shale	< 1,500
Mesozoic	Cretaceous		Great Valley Sequence (Jkgvs)		Marine siltstone, shale, sandstone, and conglomerate	< 45,000

** Tt and Tte were deposited concurrently during the late Pliocene and Pliestocene*

Low Permeability Unit

Unconformity

Freshwater Aquifer

Brackish Aquifer

Saline Aquifer

Figure 3-7. Geologic Formations Stratigraphic Column

Table 3-1. Freshwater Aquifer Hydrogeologic Properties

Principal Hydrogeologic Unit		Data Sources	Horizontal Hydraulic Conductivity (ft/day)	Vertical Hydraulic Conductivity (ft/day)	Transmissivity (ft^2/day)	Storativity	Specific Yield
Quaternary Alluvium (Qa)		Olmsted and Davis, 1961[1]	---	---	---	---	0.034 – 0.185
		WRIME, 2003[2]	10 – 299	---	---	---	---
Tehama Formation (Tte)		West Yost, 2012[3]	26.6	---	2,466 – 4,727	0.0003 – 0.001	---
Tuscan Formation (Tt)	Tuscan C (Ttc)	Brown and Caldwell, 2013a[3]	321 – 571	---	11,550 – 20,540	0.0003 – 0.0005	---
		West Yost, 2012[3]	---	0.0036	---	---	---
	Tuscan B (Ttb)	Brown and Caldwell, 2013a[3]	66 – 88	---	2,322 – 3,078	0.00004 – 0.00009	---
		West Yost, 2012[3]	11.4 – 13.2	---	2,705 – 8,902	0.0009 – 0.003	---
	Tuscan A (Tta)	Brown and Caldwell, 2013a[3]	41 - 79	---	12,230 – 23,650	0.00004 – 0.001	---
		West Yost, 2012[3]	11.4 – 13.2	---	2,705 – 8, 902	0.0009 – 0.003	---

1- Data from geologic sample analysis 2- Modeled data 3- Data from aquifer pump test analysis.

3.1.5.1 Quaternary Alluvium (Qa)

Quaternary Alluvium is composed of multiple formations and deposits presented individually on Figure 3-6. These are grouped by compositional similarity and limited thickness. Overall, Quaternary Alluvium is characterized by its young geologic age and unconsolidated nature. Besides some deposits of the Riverbank Formation which follow stream channels, Quaternary Alluvium is thickest in the portion of the Subbasin roughly east of Black Butte Fault, known as the Stony Creek Fan, where it ranges in total thickness up to roughly 300 feet. The Stony Creek fan lies unconformably over fine grained Tehama formation deposits.

Despite variation in geological characteristics between the constituent units, Quaternary Alluvium largely consists of geologically young, unconsolidated, and poorly to moderately sorted sediments ranging from clays to gravel. Units comprising Quaternary Alluvium range from poorly to highly permeable. Existing estimates of hydraulic conductivity in Quaternary Alluvium range widely from 10-299 feet/day (WRIME, 2003) reflecting variation between constituent units. Low thickness limits the overall transmissivity of Quaternary Alluvium. Where sufficiently thick, such as in the Stony Creek Fan, Quaternary Alluvium is pumped by shallow domestic and irrigation wells. Subbasin formations and deposits composing Quaternary Alluvium are discussed in further detail in the sub-sections below.

3.1.5.2 Stream Channel Deposits and Alluvial Deposits (Qsc and Qa)

Both Stream Channel Deposits and Alluvial Deposits are composed of sediments deposited within the past 10,000 years. Stream Channel Deposits are composed of unconsolidated sediments ranging from gravels to clays, derived from the erosion, reworking, and deposition of underlying formations by the Subbasin's rivers and creeks (DWR, 2006a). Alluvial Deposits are similarly composed of unconsolidated sediments and are typically unweathered. Both Alluvial Deposits and Stream Channel Deposits are present primarily near the Subbasin's three major watercourses: the Sacramento River, Stony Creek, and Thomes Creek. Thickness of these units is limited across the Subbasin, maxing out at roughly 80 feet (DWR, 2014; DWR, 2006a).

3.1.5.3 Basin Deposits (Qb)

Basin deposits are composed of fine silts and clays deposited by flooding of the Subbasin's rivers and creeks. Basin deposits are of limited thickness but can reach up to 150 feet in the eastern portion of the Subbasin near the Sacramento River. Basin Deposits are largely limited to small pockets in the eastern Subbasin, roughly southeast of Corning and northwest of Hamilton City. Due to their fine-grained nature and limited extent, basin deposits are not used extensively for groundwater production but provide limited groundwater to shallow wells (DWR, 2014).

3.1.5.4 Modesto Formation (Qm)

The Modesto Formation is composed of unconsolidated weathered gravel, sand, silt, and clay deposited by ancient river systems (DWR, 2014). The Modesto Formation occurs at surface in the northern and eastern Subbasin, particularly near Corning and Hamilton City. Thickness of the Modesto Formation ranges from 10 to roughly 200 feet across the northern Sacramento Valley. Where sufficiently thick, the Modesto Formation provides water for irrigation and domestic wells.

3.1.5.5 Riverbank Formation (Qr)

The Riverbank Formation consists of poorly to highly permeable weathered gravels with interbedded sand, silt, and clay. Riverbank Formation sediments are present at surface along the Subbasin's creek and rivers and over much of the eastern Subbasin. While very similar in appearance to the Modesto Formation, the Riverbank Formation is distinguished by its interbedded clay layers. Thickness of the Riverbank Formation ranges from 1 to over 200 feet across the northern Sacramento Valley, (DWR, 2014; DWR 2006a). Where sufficiently thick, the Riverbank Formation provides water for irrigation and domestic wells.

3.1.5.6 Red Bluff Formation (Qrb)

The Red Bluff Formation is composed of bright red, highly weathered sandy gravels deposited during floodplain or lacustrine conditions. Across the Northern Sacramento Valley, thickness of the Red Bluff Formation ranges from 3 to just over 33 feet (DWR, 2014). In some areas the coarse-grained Red Bluff Formation sits atop fine-grained Tehama or Tuscan deposits, creating discontinued localized areas of perched groundwater conditions (DWR, 2014). The Red Bluff Formation is present at surface over much of the central and northwestern Subbasin.

3.1.5.7 Tehama Formation (Tte)

The Tehama Formation is composed of moderately compacted layers of pale green, gray, and tan metamorphic sandstone and siltstone enclosing discontinuous sand and conglomerate lenses (DWR, 2014). These sediments originated in the Coast Ranges and were deposited under floodplain conditions. The Tehama Formation is present at surface across the western half of the Subbasin where it is also the primary freshwater bearing unit. To the east, the Tehama-Tuscan Transition Zone occurs where subsurface deposits of the Tehama interlayer with the Tuscan Formation due to their concurrent deposition. At its maximum thickness, the Tehama Formation is just under 2,000 feet thick (DWR, 2014).

While these Tehama Formation's sand and conglomerate lenses are typically isolated, they can be very thick and highly productive, yielding up to several thousand gallons per minute per well (DWR, 2006a). Hydraulic conductivity in the Tehama has been estimated at 26.6 ft/day, though the heterogenous nature of this formation suggest a wide range in conductivity values (West Yost, 2012; DWR 2006a; DWR, 2014). Transmissivity has been estimated to range from 2,466 – 4,727 ft^2/day, and storativity to range from 0.0003 – 0.001 (West Yost, 2012). As with conductivity, a wide range in these values is expected due to the formation's heterogenous nature. The Tehama Formation is the predominant freshwater bearing formation in the eastern Subbasin, where it is pumped by medium to deep agricultural and municipal wells.

3.1.5.8 Tuscan Formation (Tt)

The Tuscan Formation contains a series of lahars including volcanic conglomerate, breccia, sandstone, siltstone, and tuff derived from the Mt. Yana volcanic complex in the Cascade Mountains (Green and Hoover, 2014; DWR, 2014). The Tuscan Formation is present beneath the eastern portion of the Subbasin, where it represents a significant freshwater-bearing formation. Roughly east of Corning, the Tuscan interfingers with the Tehama Formation due to their concurrent deposition, in an area sometimes referred to as the 'Tehama-Tuscan Transition Zone' (Figure 3-8). The Tuscan is thickest in the northeastern portion of the Subbasin past the North Corning Dome, where thickness reaches up to 1,000 feet (DWR, 2014). South of the Corning Dome, thickness of the Tuscan is variable, though generally less than 500 feet. The Tuscan is typically described as containing four subunits: Tuscan A (Tta), Tuscan B (Ttb), Tuscan C (Ttc), and Tuscan D (Ttd) (Helly and Harwood, 1985; DWR, 2014). Tuscan units A-C are described in the following sections. The upper unit, Tuscan D, is not thought to be present in the study area and is therefore not discussed (DWR, 2006a).

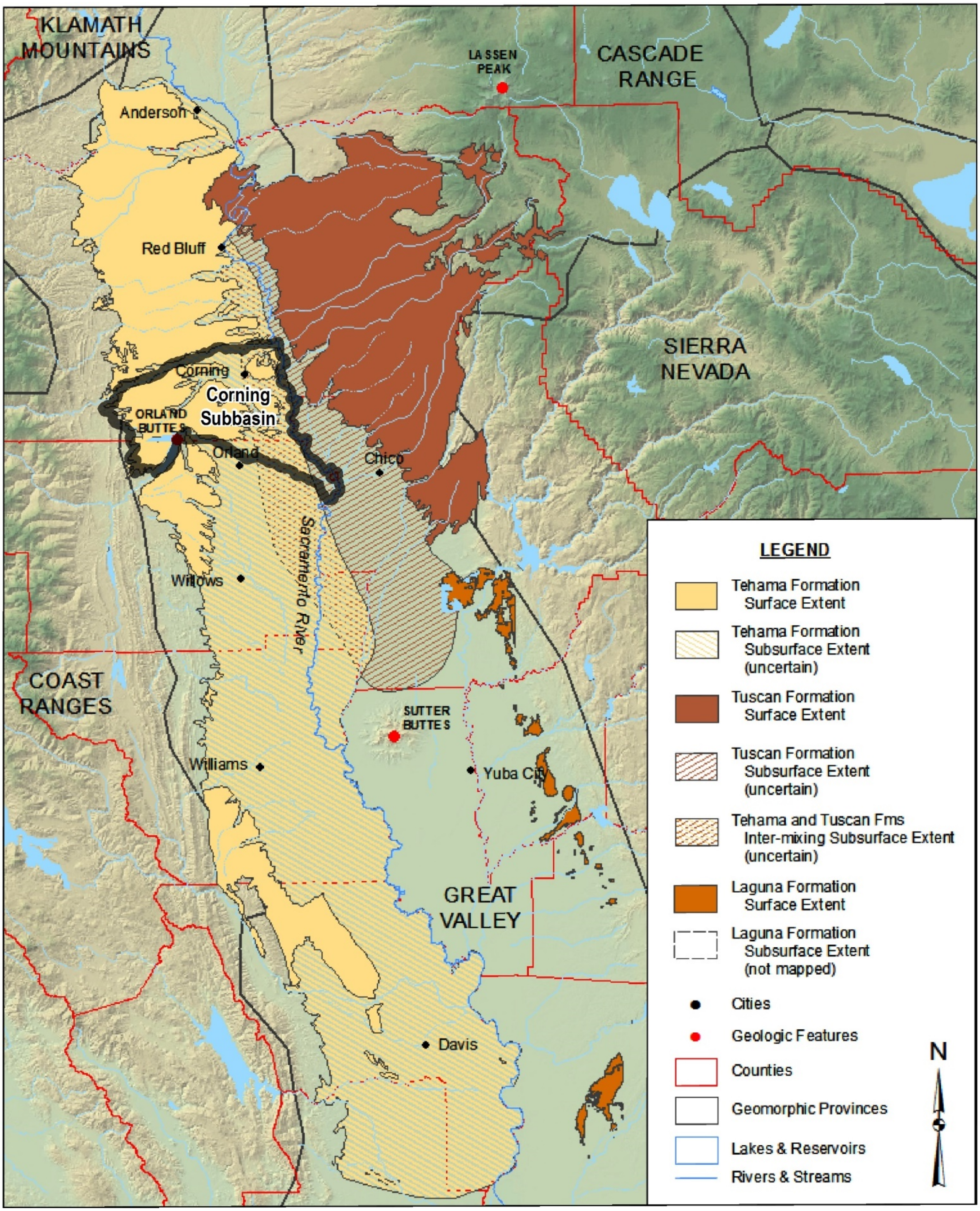

Figure 3-8. Tehama-Tuscan Transition Zone [DWR, 2009]

3.1.5.8.1 Tuscan C (TtC)

The Tuscan C is primarily a series of lahars with some interbedded volcanic conglomerate and sandstone. Despite the presence of these interbeds, the Tuscan C is characterized by low yield and can act as a localized confining unit to the underlying Tuscan A and B where present (Helly and Harwood, 1985; West Yost, 2012; DWR, 2014).

The Tuscan C's mudflow deposits are characterized by low vertical hydraulic conductivity in some areas (~ 0.0036 ft/day) and can confine groundwater where present (West Yost, 2012; DWR, 2014). However, confinement in the Corning Subbasin may be limited by the Tuscan Formation's irregular deposition (DWR, 2006a; DWR, 2014). The Tuscan C also contains irregular layers of highly conductive sand and gravel; at least one previous report has noted high horizontal hydraulic conductivities in the Tuscan C, up to 571 feet/day (Brown and Caldwell, 2013a). Aquifer testing preformed for this study was reported as taking place in a highly permeable sandy gravel layer (Brown and Caldwell, 2013a). Airborne-electromagnetic surveys have also indicated that the Tuscan is relatively coarse-grained where it exists within the Corning Subbasin (Aqua Geo, 2019). Hydrogeological analysis in the Tehama-Tuscan Transition Zone has indicated a high degree of spatial heterogeneity, potentially complicating interpretation of aquifer testing results (Greene and Hoover, 2014).

3.1.5.8.2 Tuscan B (TtB) and Tuscan A (TtA)

The Tuscan B is composed of interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone. The groundwater production portions of the Tuscan B (and Tuscan A) were formed by channelization of the lahars by ancient streams and rivers, which were then filled by reworked volcanic sediments (DWR, 2014).

Like the Tuscan B, The Tuscan A contains interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone. The Tuscan A is primarily differentiated from the Tuscan B by the presence of minor amounts of metamorphic rocks, and a lower degree of spatial heterogeneity (Helly and Harwood, 1985; DWR, 2014)

Current estimations of hydraulic conductivity in the Tuscan A and B units range from 11.4 to 88 feet/day, establishing these units as moderately to highly conductive. Storativity values obtained from aquifer testing of these confined units range from 0.00004 to 0.003 (Brown and Caldwell, 2013a; West Yost, 2012). Existing cross sections indicate the Tuscan Formation (units A-C) is present more than 500-600 feet below ground surface over most of where it occurs in the Subbasin, though depth of occurrence is as low as roughly 100 feet below ground surface near Hamilton City (DWR, 2014). It is therefore typically pumped by relatively deep agricultural and municipal wells.

3.1.5.9 Upper Princeton Valley Fill (UPvf)

The Upper Princeton Valley Fill is primarily composed of sandstone containing frequent interbeds of mudstone and infrequent interbeds of conglomerate and conglomeritic sandstone (DWR, 2014). Deposited unconformably atop the marine Lower Princeton Valley fill by an ancient equivalent to the Sacramento River, the Upper Princeton Valley Fill contains brackish to fresh interstitial water and is typically not used for groundwater supply (Redwine, 1984; DWR, 2014). The Upper Princeton Valley Fill is up to 1,400 feet thick in the Subbasin.

3.1.5.10 Lower Princeton Valley Fill (Tlpg)

The Lower Princeton Valley Fill, sometimes named the Lower Princeton Submarine Valley Fill, is composed of interbedded beds of shale and sandstone (DWR, 2014). Groundwater in the Lower Princeton Valley Fill is saline due to its marine depositional setting (Redwine, 1984). The Lower Princeton Valley Fill is up to 1,500 feet thick across the Subbasin.

3.1.5.11 Great Valley Sequence (JKgvs)

The Great Valley Sequence consists of deep-marine turbidites composed of interbedded marine siltstone, sandstone, and conglomerate. These were deposited in a deep ocean environment off the coast of the ancient continental shelf and accordingly contain saline interstitial water. The Great Valley Sequence is up to 45,000 feet thick across the north Sacramento Valley (DWR, 2014). The Sierran basement underlying the Great Valley Sequence is composed of metamorphosed igneous and sedimentary rocks with intruded igneous plutonic rocks. Due to its great depth and non-water bearing nature, the Sierran basement is not discussed further.

3.1.6 Geologic Structures

The following subsections describe faults and folds present in the Corning Subbasin. Description of geologic structures includes geologic age and the effect on geologic formations. Geologic structures are presented on Figure 3-6 and are visualized in the cross sections discussed in Section 3.1.6.3.

3.1.6.1 Faults

Faulting occurred in the Subbasin from the early Paleocene through the late Pleistocene, associated with the subduction and transformation processes that created the California Coast Ranges and closed the Sacramento Valley. Faults may affect the movement of groundwater by juxtaposing formations with differing hydraulic conductivity, by creating local fractures, or by otherwise providing physical conduits or barriers to flow. The Corning Fault, Black Butte Fault, Elder Creek Fault, Willows Fault, and Paskenta Fault Zone are presented on Figure 3-6 and discussed in the following subsections. The Stoney Creek fault is outside of the Subbasin in the Coast Range.

3.1.6.1.1 Willows Fault

The Willows Fault is a high-angle reverse fault with east-side-up movement that passes through a small portion of the northeastern Subbasin (Figure 3-6) (Redwine. 1984; DWR, 2014). Movement at the Willows Fault occurred from the Paleocene to the late Miocene (4-60 Ma) (DWR, 2014). While the Willows fault displaces the older cretaceous formations up to 1,600 feet, only a slight offset is inferred in the overlying Tehama Formation.

3.1.6.1.2 Elder Creek Fault Zone

The Elder Creek Fault Zone is present in a small area of northeastern Subbasin, consisting of several branching northwest-to-southeast trending faults (3.4-65 Ma) (DWR, 2014). Like the Willows Fault, the Elder Creek Fault Zone has limited presence in the Subbasin, diverging from the Black Butte Fault just south of the northern Subbasin boundary (Figure 3-6).

3.1.6.1.3 Paskenta Fault Zone

The Paskenta Fault Zone is a northwest-striking normal fault that trends through the Black Butte Reservoir area and proceeds roughly parallel to the western Subbasin boundary. Movement along the Paskenta Fault zone occurred from the early Paleocene to the mid Pliocene (3.3 – 65 Ma) and ceased before the deposition of the Tehama Formation (DWR, 2014).

3.1.6.1.4 Black Butte Fault

The Black Butte Fault has historically been mapped as a northwest-trending fault cutting through the eastern half of the Subbasin, with inferred movement occurring in the late Eocene to the Pliocene (Helly and Harwood, 1985). However, more recent investigations including analysis of seismic reflection data did not find compelling evidence supporting the existence of the Black Butte Fault. If present, the Black Butte Fault may be an inactive shallow bedding-parallel fault (DWR, 2014).

3.1.6.1.5 Corning Fault

The Corning Fault is a north-trending, steeply dipping, east-side-up reverse fault that crosses the eastern Subbasin with no superficial expression (DWR, 2014). Major fault movement occurred in the Pliocene and Pleistocene (1.0-2.5 Ma), causing deformation of the Tehama and Red Bluff Formations and significant displacement of the underlying Cretaceous Formations.

3.1.6.2 Folds

Various geologic folding events occurred in the Subbasin from the late Miocene through the mid Pleistocene, associated with the subduction and transformation processes that created the modern Sacramento Valley. In particular, northward migration of the Mendocino Triple Junction is correlated with the occurrence of folds in the northern Sacramento Valley (DWR, 2014). Folds influence the positioning of aquifer and aquitard layers, and therefore have the potential to influence groundwater flow and availability. Folds may also impact groundwater flow by increasing local hydrogeologic permeability, or by overturning naturally anisotropic units. The North Corning Dome, South Corning Dome, and Glenn Syncline are presented on Figure 3-6 and discussed in the subsections below, in addition to unnamed synclines and anticlines present within the Subbasin.

3.1.6.2.1 North and South Corning Domes

Domes exist where two anticlines intersect, creating a vaulted geological structure. The North and South Corning Domes are present in the eastern portion of the Subbasin and are associated with movement on the Corning Fault in the Pliocene and Pleistocene (Figure 3-6). Underneath both domes, the Tehama and Tuscan Formations are significantly thinner, and the Upper Princeton Valley Fill is encountered at shallower depth.

3.1.6.2.2 Glenn Syncline

The Glenn Syncline is a north-northwest trending syncline that crosses the southeastern portion of the Subbasin near Hamilton City. Like the Corning Domes, creation of the Glenn Syncline is associated with movement on the Corning Fault in the Pliocene and Pleistocene. Troughing created by the syncline locally controls the Sacramento River (DWR, 2014).

3.1.6.2.3 Orland Buttes

The Orland Buttes are structures present just outside of the Subbasin's southern boundary, on the eastern shore of Black Butte Lake (Figure 3-6). The Orland Buttes measure up to 1,037 feet at their maximum height and may have been uplifted via movement of the Black Butte fault or a blind west-dipping thrust fault (DWR, 2014).

3.1.6.2.4 Unnamed Synclines and Anticlines

As presented on Figure 3-6, an unnamed syncline and anticline are present in the eastern portion of the Subbasin. These are not indicated or apparent on cross sections presented in DWR's Geology of the Northern Sacramento Valley report (DWR, 2014). These two geologic features are only present in a smaller northern portion of the Subbasin and are not anticipated to have a significant effect on general groundwater flow.

3.1.6.3 Geologic Cross Sections

The following subsections describe the occurrence and orientation of geologic units in the Subbasin through the illustration of geologic cross sections. Cross sections A-A', B-B', and F-F' were created by DWR as part of their 2014 'Geology of the Northern Sacramento Valley' report (DWR, 2014). The cross-sections were developed using various sources of data such as: lithologic cutting descriptions and geophysical data from groundwater observation well drilling, geophysical data from the California Department of Conservation's Division of Oil, Gas, and

Geothermal Resources' natural gas well drilling for reference in identifying formational boundaries (DWR, 2014). The locations of these cross sections are presented in red on Figure 3-6. Some cross sections have been shortened to better reflect geology relevant to the Subbasin. The full DWR cross-sections are included in Appendix 2-A, along with resistivity logs used during cross section determination. Due to their limited depth at large scales, units comprising Quaternary Alluvium are grouped as Qa on cross sections for simplicity. Recent airborne electromagnetic (AEM) surveys of the southeastern Subbasin are also discussed and compared with the traditional cross sections.

3.1.6.3.1 Cross Section A-A'

Cross section A-A' is presented on Figure 3-9 below and its location is shown on Figure 3-6. This cross-section was extended from its original extent presented in DWR 2014 to the end of the Subbasin to improve understanding of hydrogeology in the western Subbasin. Details of cross-section extension development are presented in Appendix 2B, including methods utilized for drafting and data compilation. Overall, results from extension of cross-section A-A' present similar results to the extension of the nearby and similarly oriented cross-section B-B' shown in the Glenn-Colusa HCM (Davids Engineering and West Yost, 2018).

Beginning at the western edge of the Subbasin west of Black Butte Lake, A-A' extends northeast to the Sacramento River, displaying southwest-northeast trends in stratigraphy over the Subbasin. In the central and eastern portions of A-A' the Upper Princeton Valley Fill (UPvf) forms the bottom of the Subbasin, topped by the Tehama (Tte) and Tuscan (Tt) Formations. To the west, where the Princeton Valley Fill formations have pinched out, the Great Valley Sequence (JKgvs directly underlies the Tehama Formation and forms the bottom of the Subbasin.

Near the western boundary of the Subbasin, the Tehama Formation is present at limited thickness from less than 50 feet to roughly 250 feet. As shown at the western edge of A-A', the Tehama Formation may pinch out prior to the Subbasin boundary in places, causing Quaternary Alluvium to directly overlie the Great Valley Sequence. Despite the saline nature of Great Valley Sequence, well completion reports in this area report freshwater at shallow depths, potentially a result of flushing caused by surficial recharge (DWR, 2014).

As A-A' continues to the northeast, the Tehama Formation gradually thickens up to a maximum of roughly 1,500 feet thick in the center of the Subbasin. Movement caused by the Corning fault is visible in this portion of the Subbasin, displacing the Upper Princeton Valley Fill and Tehama Formations. Further to the northeast, the prominent effect of the Corning Domes is visible, which significantly decreases the total thickness of the Tehama Formation. In this portion of the cross section, the Tehama is roughly 800 feet thick. Around the same extent as the Corning Domes, the transition between the Tehama and Tuscan Formations becomes apparent as these interbedded formations transition from the Tehama in the west to the Tuscan in the east. As the section continues northeastward the Tehama gradually pinches out, the Tuscan deepens, and the effect of the Corning Domes lessens.

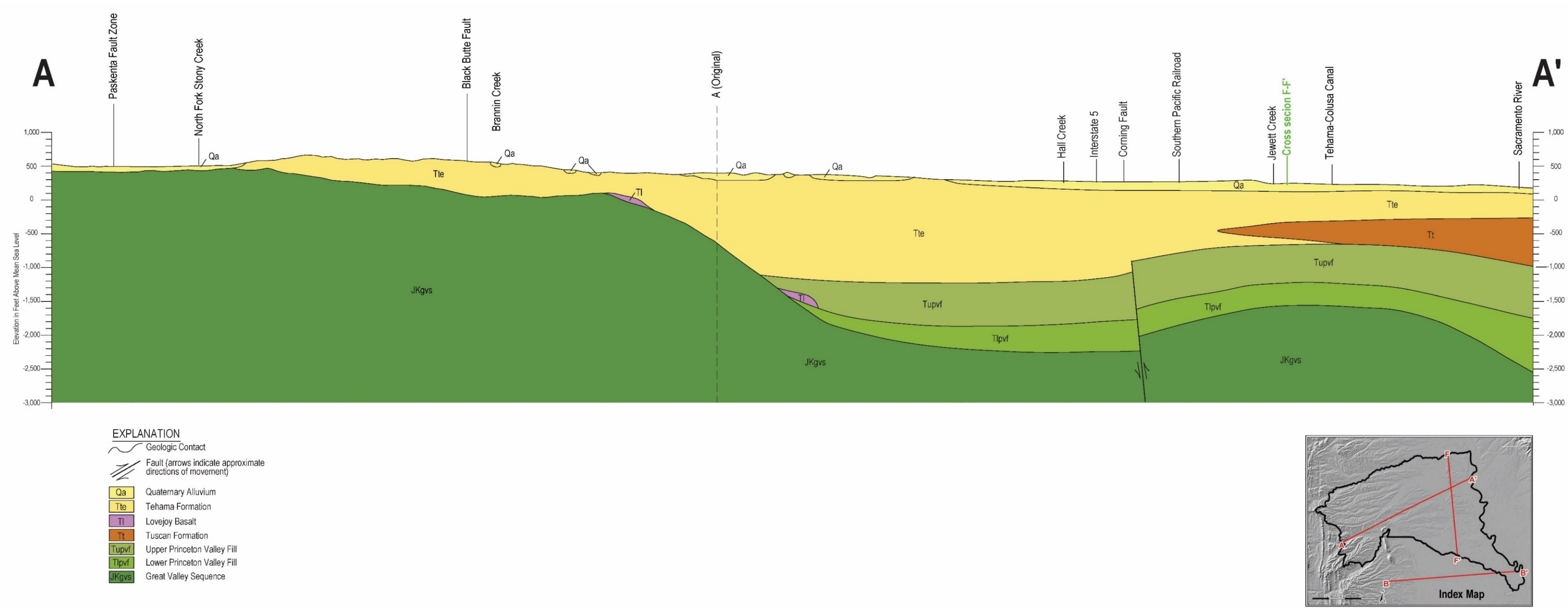

Figure 3-9. Cross Section A-A' [Adapted from DWR, 2014]

3.1.6.3.2 Cross Section F-F'

Cross section F-F' is presented on Figure 3-10 below and its location on the map on Figure 3-6. Beginning north of the Subbasin, F-F' crosses through the Corning Domes then continues southeast, displaying north-south trends in stratigraphy. At the northernmost extent of F-F' within the Subbasin, the Tuscan Formation is roughly 500 feet thick and is both overlain and underlain by the Tehama Formation. The overlying Tehama deposit is roughly 150-200 feet thick, while the underlying deposit is less than 100 feet thick. South of this point the effect of the North Corning Dome becomes apparent, greatly decreasing the overall thickness of the Tuscan and bringing the Princeton Valley Fill formations closer to surface. Here the Tehama Formation is briefly exposed at the surface before being overlain again by Quaternary Alluvium. Continuing along F-F', the South Corning Dome further elevates the Princeton Valley Fill Formations, pinching out the lower deposit of the Tehama Formation and bringing the Tuscan in direct contact with the underlying Upper Princeton Valley Fill. South of the two Corning Domes the Tuscan gradually transitions to the Tehama, where the Tehama is present up to 1,000 feet in thickness (DWR, 2014). This cross-section was shortened to be shown within the Corning Subbasin only but extends further south into the Colusa Subbasin where the Tehama Formation is present at more than 1,500 feet in thickness, as described in the Glenn-Colusa HCM (Davids Engineering and West Yost, 2018).

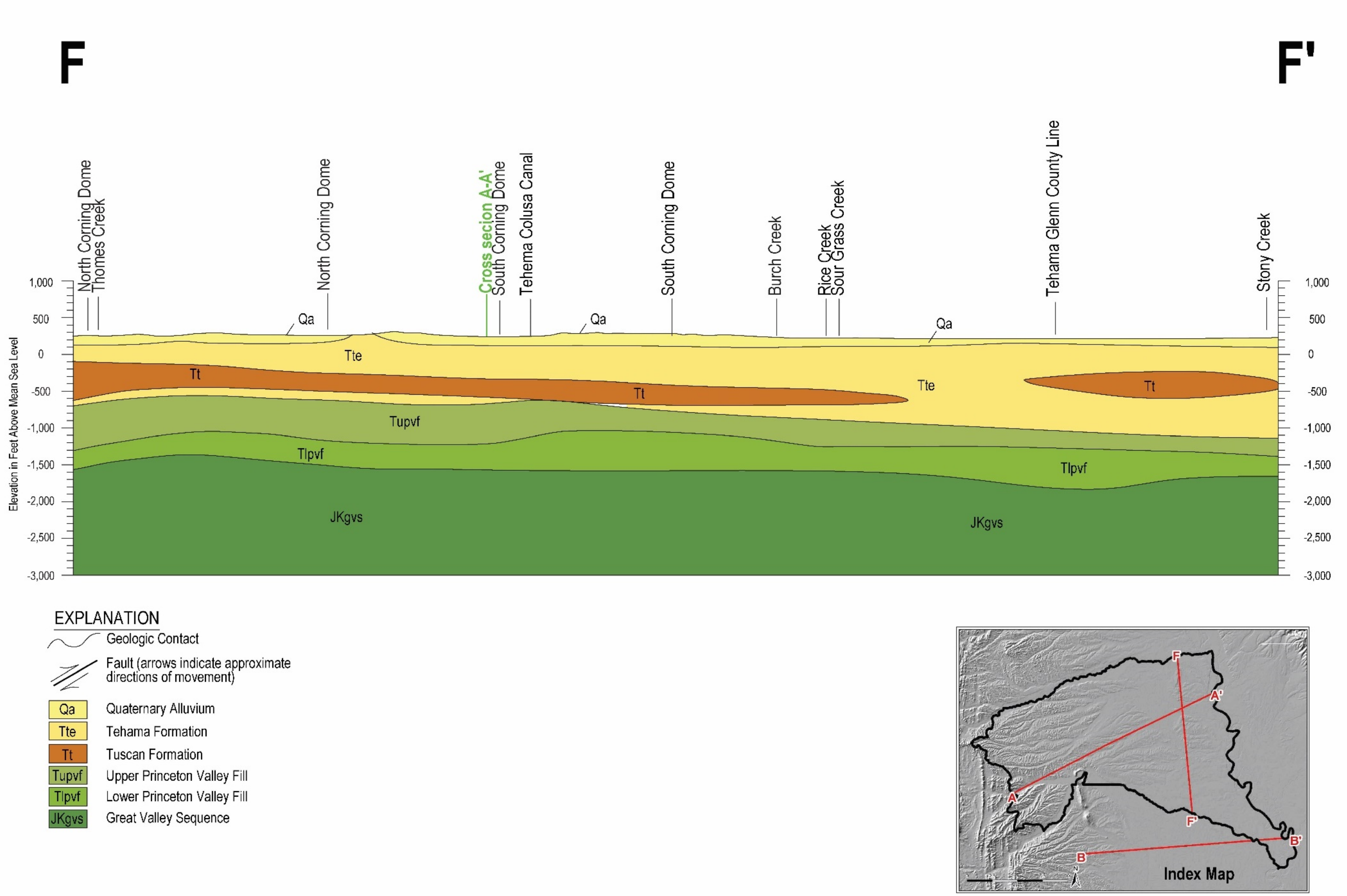

Figure 3-10. Cross Section F-F' [Adapted from DWR, 2014]

3.1.6.3.3 Cross Section B-B’

Cross Section B-B’ is presented on Figure 3-11 below and on the map on Figure 3-6. While B-B’ only crosses through a small portion of the southeastern Subbasin near Hamilton City, this section provides insight into the east-west trending stratigraphy in the southern portion of the Subbasin, which is also further described in the Glenn-Colusa HCM for the portions within the Colusa Subbasin (Davids Engineering and West Yost, 2018). Examination of B-B’ in conjunction with A-A’ and F-F’ also helps illustrate the Subbasin’s geology in three dimensions. Within the Subbasin (Stony Creek to the Sacramento River), B-B’ crosses the Tehama Tuscan Transition zone where the Tuscan Formation is overlain by the Tehama Formation and quaternary alluvium. Here the Tehama Formation is generally less than 400 feet thick, while the Tuscan reaches thicknesses greater than 1,300 feet. As was the case in A-A’ and F-F’, the Tuscan appears to be both overlain and underlain by the Tehama in places. Towards the eastern portion of the B-B’ cross-section, the saline Ione Formation is present at roughly 350 feet in thickness between the Upper and Lower Princeton Valley Fill.

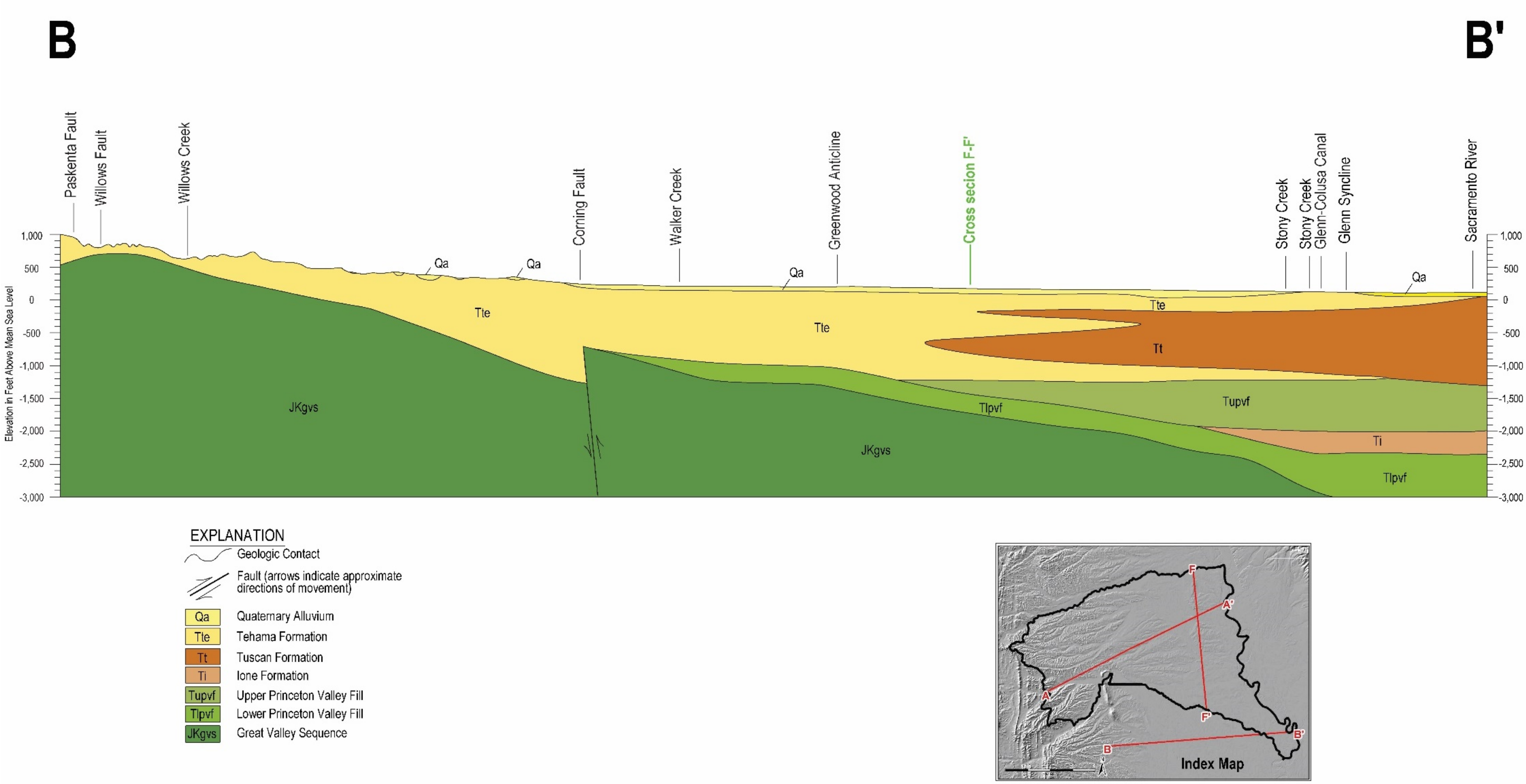

Figure 3-11. Cross Section B-B' [Adapted from DWR, 2014]

3.1.6.3.4 AEM Survey Results

AEM is a geophysical technology used to measure variations in physical subsurface parameters with the intent to map the distribution and composition of groundwater aquifers. In an AEM survey a helicopter takes multiple flight paths over the survey area carrying a sensor and instrument package roughly 100 feet off the ground. This instrument package transmits low-frequency radio waves into the ground and measures the response returning from the ground.

Figure 3-12 displays stratigraphy interpolated from results of recent AEM surveys that included a portion of the southeastern Subbasin: “approximately 361 line-miles were acquired by the SkyTEM312 over the Butte-Glenn counties AEM survey area west of Chico on November 30 through December 2, 2018. Then on December 3, 2018, approximately 138 line-miles were acquired by the SkyTEM304M southeast of Chico” (Aqua Geo, 2019). DWR cross sections B-B’ and E-E’ (which is in the Butte Subbasin, outside of the area of the Corning Subbasin) are also presented on Figure 3-12 for comparison with AEM interpretations. Cross section B-B’ runs through the southeastern portion of the Subbasin as described in Section 3.1.6.3.3. Cross section E-E’ does not intersect the Subbasin but can be used to further compare the AEM method with DWR cross sections.

One of the main objectives of this AEM surveying was to increase understanding of the Tehama Tuscan Transition Zone, an area where the Tehama and Tuscan Formations interlayer due to their cotemporaneous deposition. As presented on cross section B-B’, the Tuscan and Tehama Formations are interbedded from the Orland area past the eastern edge of the Subbasin (Figure 3-11). Overall, AEM interpretations are in general agreement with the DWR 2014 cross sections (Aqua Geo, 2019). AEM interpretations display similar trends with increased detail and in three dimensions, utilizing multiple flight paths. In the Corning Subbasin, interpolated AEM results suggest a greater overall thickness of the Tehama Formation. East of the Subbasin, AEM interpretations indicate the presence of the Tehama Formation where it is not mapped in DWR cross section B-B’ or E-E’. Example AEM cross-sections based on flights which took place over the Hamilton City area are provided on Figure 3-12 (east-west) and Figure 3-13 (north-south). Zones of high resistivity (generally infers highly permeable media) are shown in red, and zones of low resistivity (generally less permeable media or saltwater) are shown in blue. Across the survey lines, no significant continuous aquitard which would impair flow between units is present. AEM methods provide high density of data over a specific area by being able to incorporate interpretations from multiple flight paths.

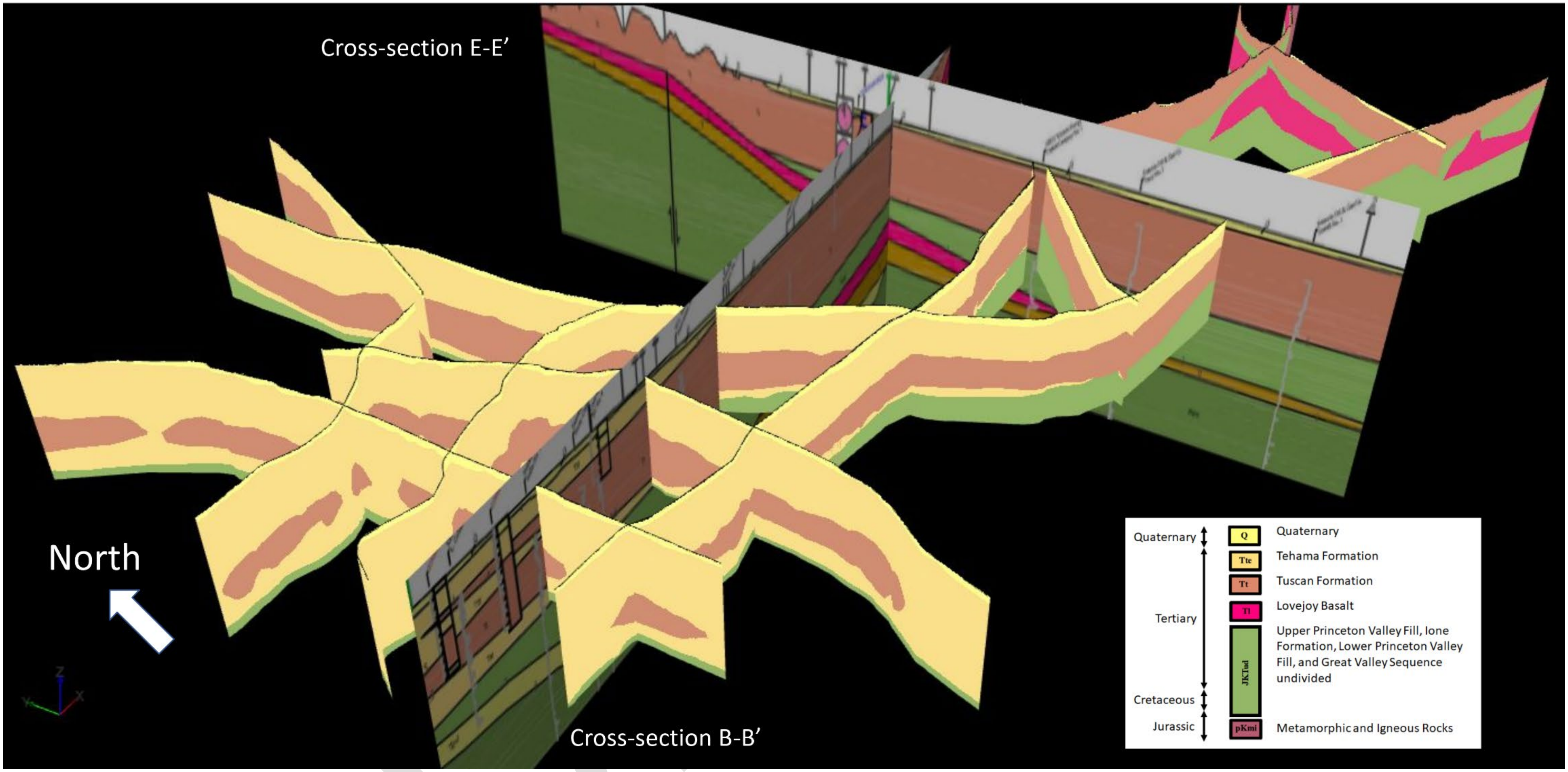

Figure 3-12. AEM Interpretaion with DWR Cross Sections [AGF, 2019]

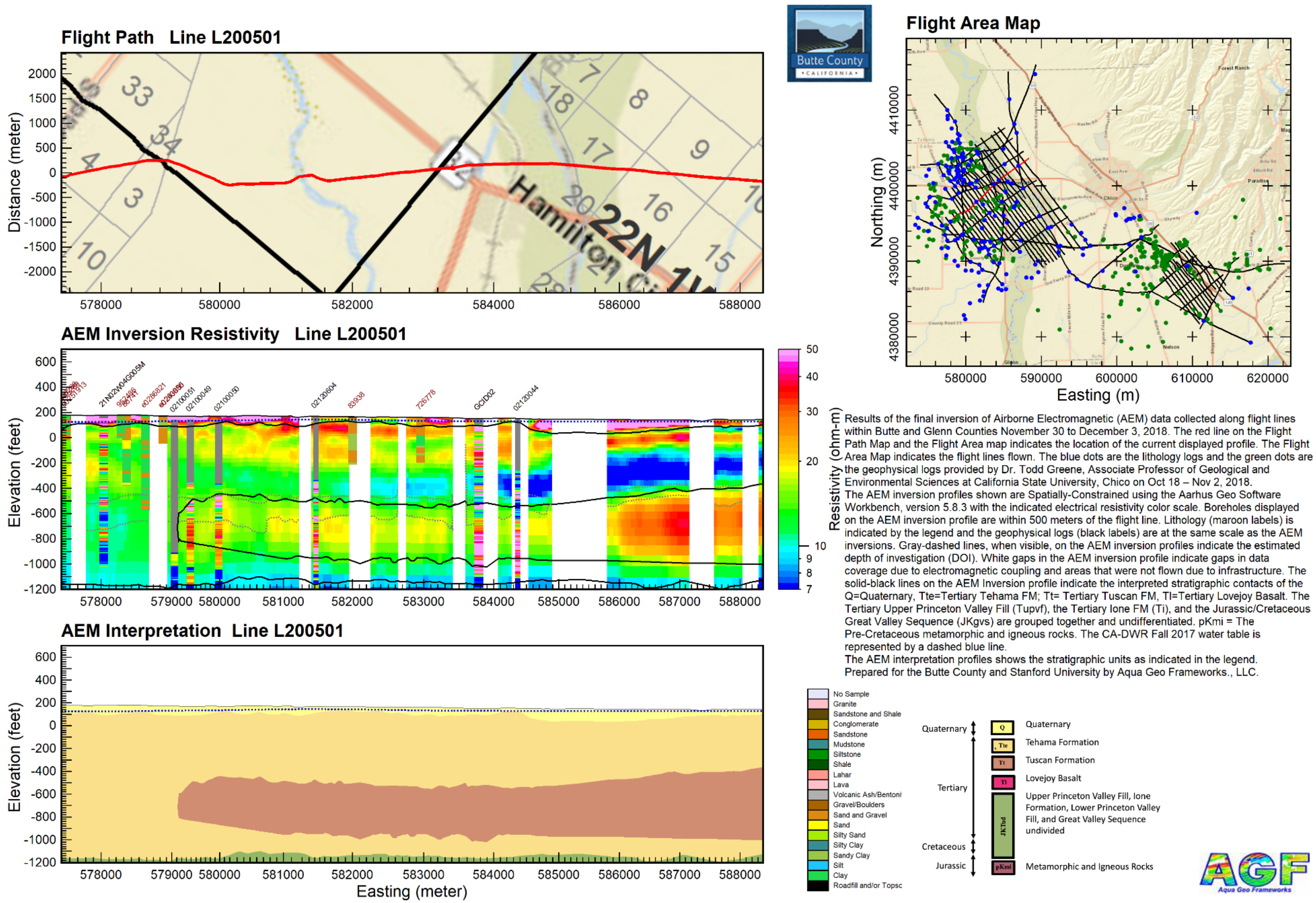

Figure 3-13. East-West AEM Cross Section in Eastern Corning Subbasin near Hamilton City

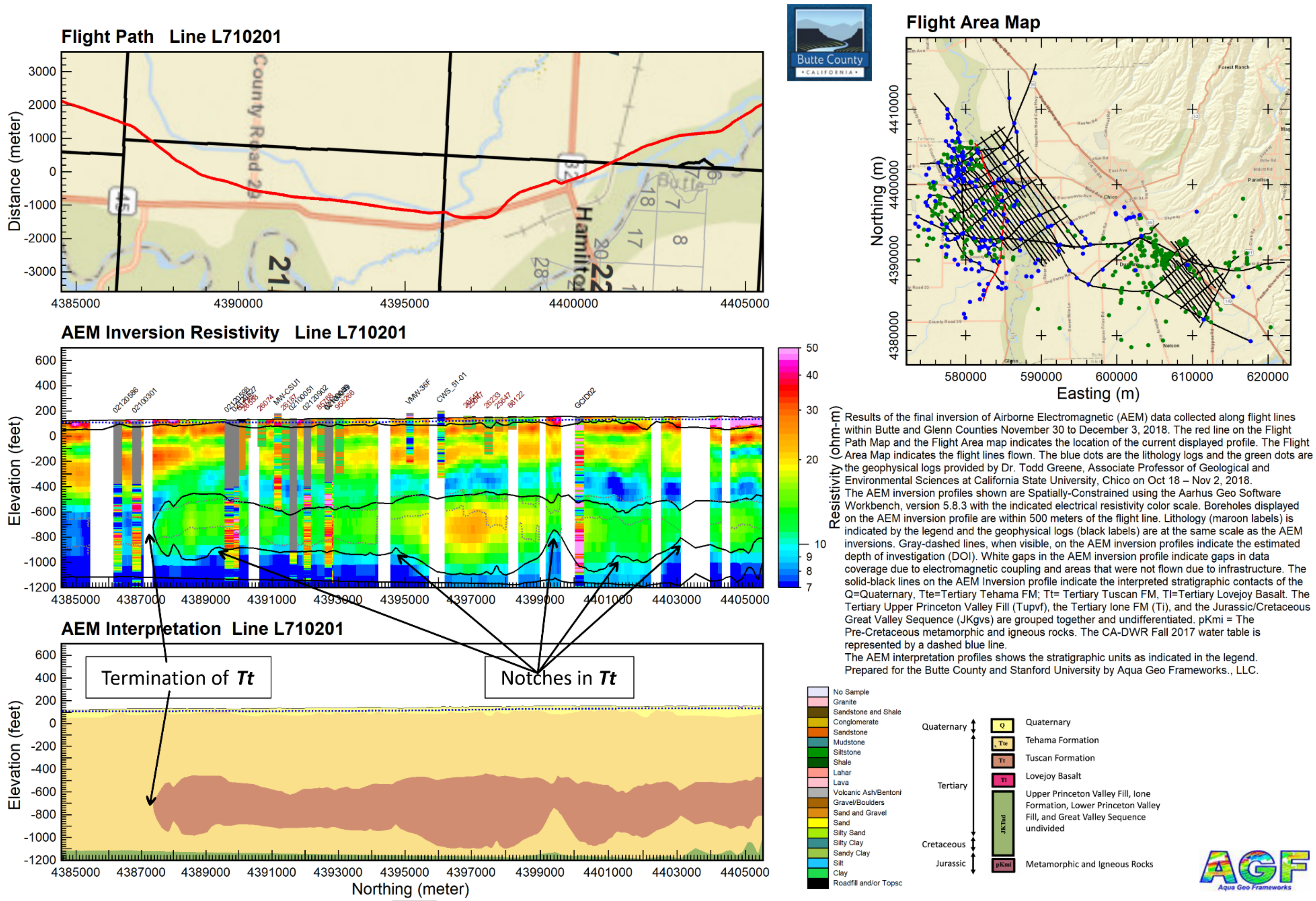

Figure 3-14. North-South AEM Cross Section in Eastern Corning Subbasin near Hamilton City

3.1.7 Designation of Principal Aquifer in Corning Subbasin

This section defines and describes the Subbasin's principal aquifer as defined by the GSP regulations [§ 351.aa]: *"principal aquifers refer to aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems."*

Aquifers are separated by continuous impervious layers (aquitards) that impede or slow flow between different main aquifers (as an example, the Corcoran Clay layer in the San Joaquin Valley constitutes such an aquitard).

The Subbasin's largest freshwater bearing formations were deposited contemporaneously, creating expansive zones of interlayering formations as discussed in Section 3.1.5. These were then overlain by conductive quaternary alluvial formations, which are unlikely to create boundaries to flow (DWR, 2014). Interlayering of these formations may facilitate groundwater flow between units by increasing the surface area at which units are in contact (DWR, 2009). Interlayering also increases the likelihood that wells are screened in multiple units, further facilitating vertical groundwater transmission. While some areas may experience localized differences in geology and groundwater flow patterns, the Subbasin does not contain expansive contiguous impervious aquitards that may cause regional differences in flow patterns and water quality.

This depositional history results in a hydrogeologically interconnected aquifer system where impacts to one unit have the potential to impact the larger aquifer network. Further, in this Subbasin, no regionally continuous impervious layers are found, wells are often screened within several geologic units, and water flows mostly freely between vertical aquifer units. As such, the Subbasin is best described as having one principal aquifer comprised of the interlayered freshwater bearing formations within the Subbasin. These are:

- Quaternary Alluvium,
- The Tuscan Formation, and
- The Tehama Formation.

This determination is based on the best available information at the time of GSP development. There is potential for data refinement and/or collection of additional information during GSP implementation to either more fully support or refine aquifer designation.

The hydrogeological properties, stratigraphic occurrence, and groundwater extraction patterns of these formations are described in detail in Section 3.1.5.

Groundwater quality in the Corning Subbasin principal aquifer is predominantly of a calcium-magnesium bicarbonate or magnesium-calcium bicarbonate type. There are also some localized areas of calcium bicarbonate groundwater near Stony Creek (DWR, 2006a). Overall, the Corning Subbasin contains groundwater that generally meets or exceeds primary and secondary water quality standards. Similarly, anthropogenic contamination of groundwater is not extensive in the Subbasin. However, there are some known areas of naturally occurring and non-point source groundwater quality constituents, including nitrate and salinity. Specific groundwater quality constituents of concern (COCs) are described in more detail in Section 3.2 of the groundwater conditions.

As further described in the Plan Area Section, beneficial uses of groundwater in the Corning Subbasin include agricultural (primary use), industrial (minor use), municipal (only two main areas), tribal use (one main area) and domestic use (widespread over the entire Subbasin). Groundwater also supports designated wildlife and habitat protection areas. Groundwater dependent ecosystems near the Sacramento River and other larger creeks are present in the Subbasin and are further described in the Groundwater Conditions Section.

3.1.8 Natural Groundwater Recharge and Discharge Areas

A robust understanding of groundwater recharge and discharge supports sustainable groundwater management by identifying key spatial and temporal patterns in groundwater flow entering and existing the Subbasin's aquifer system. Reductions in groundwater recharge can occur naturally as a result of drought, or as a result of changes in land use which impede natural infiltration and subsequent recharge. Reductions in groundwater discharge generally result from declines in the groundwater table and may be used as an indicator of local groundwater elevations. The following section discusses groundwater recharge and discharge areas as relevant to sustainable groundwater management.

3.1.8.1 Natural and Potential Recharge Areas

Groundwater recharge in this Subbasin occurs through the following processes:

- Natural areal infiltration of precipitation
- Deep percolation of excess irrigation water applied to crops
- Recharge occurring where the Subbasin's surface water bodies are interconnected with groundwater or where stream and canal seepage occurs to the underlying aquifer
- Subsurface inflow from areas outside of the Subbasin, including recharge from the foothills of the Coast Ranges

Infiltration of precipitation is influenced by the soil characteristics discussed in Section 3.1.4. Figure 3-15 displays an index of recharge suitability in the Corning Subbasin based on deep percolation, root zone residence time, topography, chemical limitations, and soil surface conditions (O'Geen *et al.*, 2015). Potential recharge is generally higher in the eastern Subbasin and near river and creek beds, roughly corresponding to the areas of high soil infiltration displayed on Figure 3-5. Strong correlations between potential recharge and the existence of intermittent or ephemeral streams suggest the presence of highly permeable alluvial sediments in and along the Subbasin's watercourses. Water distribution systems are generally known to recharge groundwater through canal seepage when those features are unlined.

Recent recharge studies by Glenn and Tehama Counties and AEM investigations have identified numerous potential recharge areas that could be used as managed aquifer recharge locations in the Subbasin (Brown and Caldwell, 2011; Brown and Caldwell, 2013a). The studies utilized surficial geology and soil mapping to target areas with high soil permeability. Both studies focused on areas near existing water conveyance infrastructure that had declining groundwater level trends that could benefit most from managed recharge. The Glenn County recharge study identified three promising areas in the Subbasin near the Tehama-Colusa Canal to the northwest of Hamilton City (Brown and Caldwell, 2013a). The Tehama County recharge study identified four promising areas in the Subbasin along the Corning and Tehama-Colusa Canals (Brown and Caldwell, 2011). The one promising area along the Corning Canal was to the northwest of Corning, and three areas along the Tehama-Colusa Canal were to the northeast and southeast of Corning and along the border of Tehama-Glenn County. The AEM survey overseen by Aqua Geo was limited in extent in the Subbasin, but indicated that the area northwest of Hamilton City along the Tehama-Colusa Canal and Tehama-Glenn County border had suitable surficial geology to allow for groundwater recharge (Aqua Geo, 2019). Further analysis will be required to determine the extent and speed that managed recharge at surface will percolate to the deeper portions of the aquifer.

Subsurface inflow originates in areas outside of the Subbasin, where formations outcrop at the surface. Isotopic analysis suggests the Tuscan Formation is recharged by infiltration occurring where it outcrops to the east, at the margins of the valley floor (Brown and Caldwell, 2013a). As the Tehama Formation pinches out at the Subbasin's western boundary, substantial subsurface inflow from that direction is unlikely. However, the Subbasin can receive subsurface inflow (and outflow) from the other adjoining Subbasins to the north, east, and south (Figure 3-15).

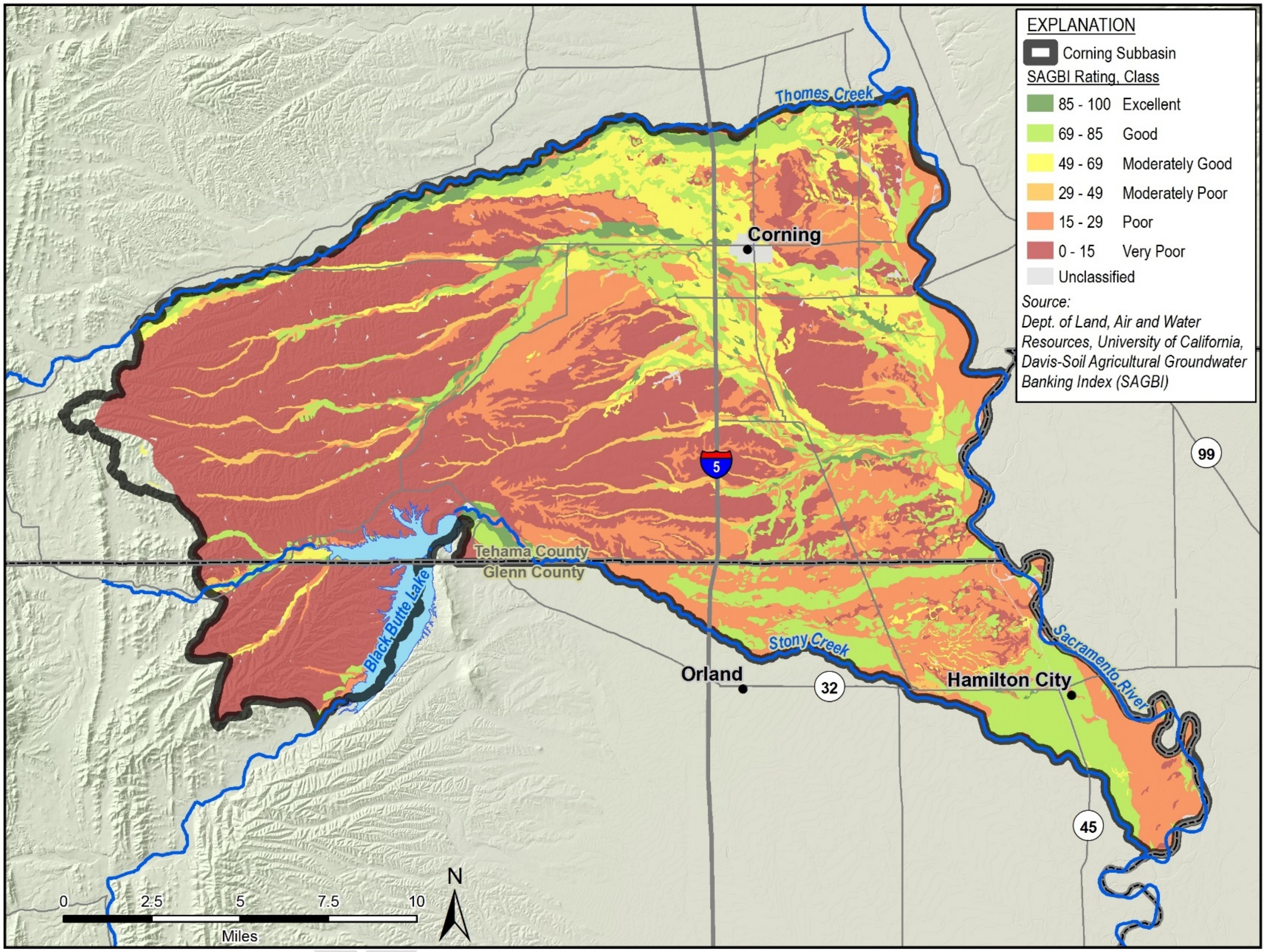

Figure 3-15. Potential Recharge Areas

3.1.8.2 Natural Discharge Areas

Natural discharge occurs where groundwater exits the aquifer system as either: discharge to springs and seeps, discharge to surface water bodies and wetlands, or as evapotranspiration (ET) when utilized by phreatophyte (consuming groundwater) plant species. Figure 3-16 displays mapped spring and seeps in addition to areas of potential groundwater-dependent wetlands and vegetation. The small number of springs and seeps within the Subbasin do not display obvious spatial patterns; these may be correlated with areas of locally low elevation or perched aquifer conditions.

Groundwater wetlands and areas of vegetation commonly associated with groundwater (visualized on Figure 3-16) are clustered along the Sacramento River, Stony Creek, and Thomes Creek. These areas indicate where groundwater may discharge from underlying formations to the surface or be utilized directly by groundwater-dependent vegetation. Groundwater-dependent ecosystems (GDEs) presented in Figure 3-16 are considered potential GDEs, as they show Natural Communities Commonly Associated with Groundwater (NCCAG) and this dataset is further refined and evaluated in the Groundwater Conditions Section. The proximity of these areas to the Subbasin's water bodies also suggests the presence of groundwater-surface water connection. Groundwater discharge to streams is further reviewed in the Groundwater Conditions section. As discussed above, the Subbasin may produce subsurface outflow to the adjoining Subbasins to the north, east, and south. The Water Budget section provides an analysis of the interaction of surface water and groundwater and the subsurface flow between adjacent subbasins.

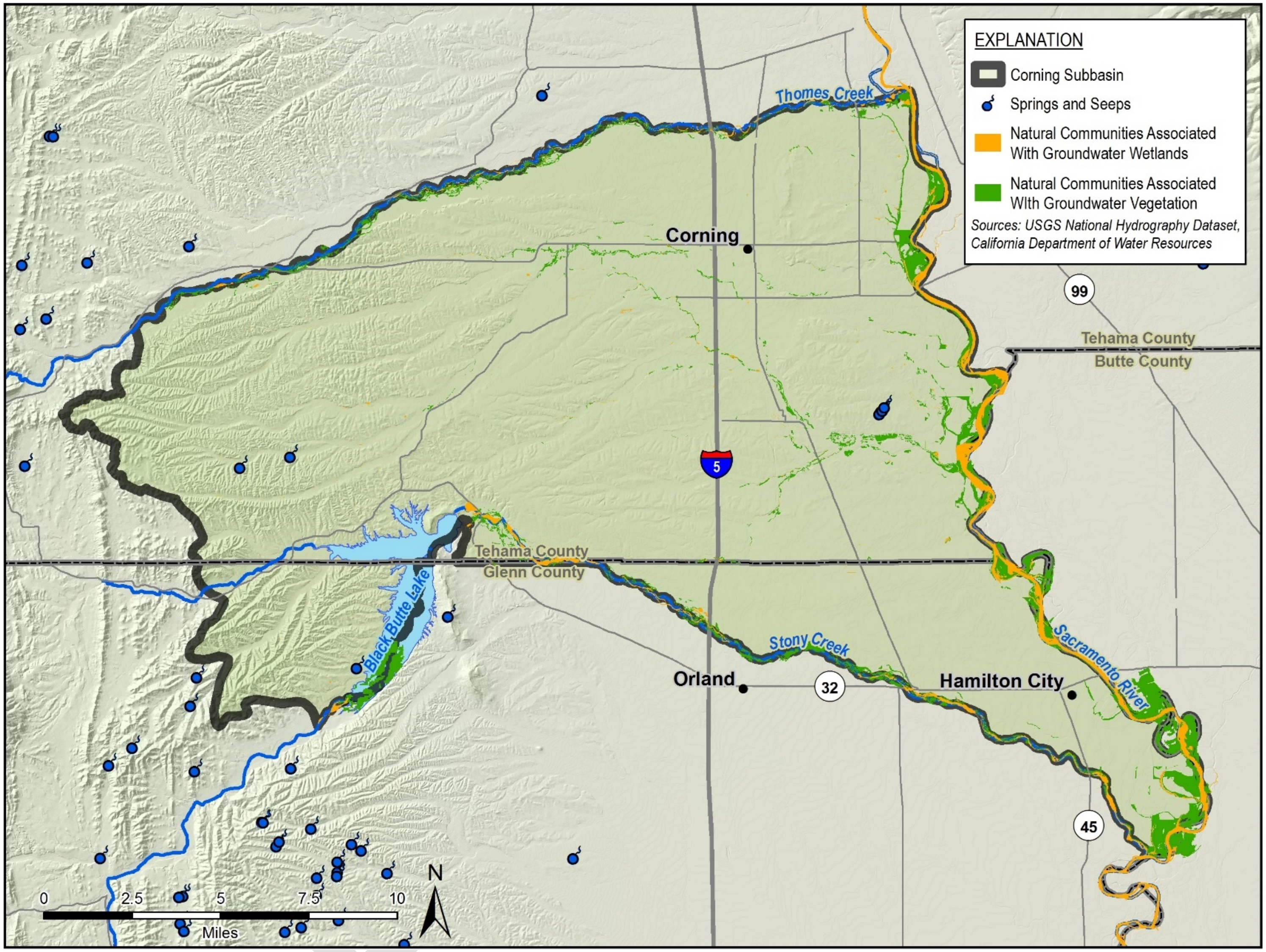

Figure 3-16. Natural Discharge Areas

3.1.8.3 Surface Water Bodies

Figure 3-17 displays rivers, creeks, reservoirs, major canals, and other bodies of water within the Corning Subbasin. These include perennial and ephemeral streams, lined channels, and a large surface water reservoir.

3.1.8.3.1 Rivers and Creeks

The Sacramento River is a defining surface water body that forms the Subbasin's eastern boundary. The river provides surface water for irrigation for a portion of the Subbasin, mainly via the Red Bluff diversion to the Corning Canal. However, very little surface water is currently being used in the subbasin, and levels of use have been declining with a change in cropping types and the unreliable and increased cost of surface water.

Available discharge measurements taken at a USGS streamflow gauge near Hamilton City (11383800) range from under 500 cubic feet per second (CFS) in the dry season (May-October) to over 15,000 CFS in the wet season (November-April). Total discharge is much higher during flood conditions, reaching well over 150,000 CFS. The Sacramento River is generally connected to groundwater, with the direction and magnitude of flow depending on climatic conditions and local hydrogeology. Sacramento River flows support agriculture and provide habitat for aquatic and groundwater dependent ecosystems across the Northern Sacramento Valley.

Stony Creek, which forms part of the Subbasin's southern boundary, is a typically perennial stream which flows eastward from Black Butte Lake to the Sacramento River. Runoff in Stony Creek peaks in the winter and is generally low in the summer, though flows are regulated by upstream storage in Black Butte Lake (Davids Engineering and West Yost, 2018) and releases from the Dam. Diversions on Stony Creek support agriculture in the southeastern Subbasin and in the Colusa Subbasin to the south.

Thomes Creek, which forms the Subbasin's northern boundary, flows eastward from the Coast Range foothills to the Sacramento River. Thomes Creek typically runs year-round in the western portion of the Subbasin, but often runs dry roughly east of Henleyville during the summer months (VESTRA, 2006). Diversions on Thomes Creek support agriculture in the northern portion of the Subbasin and in the Red Bluff Subbasin.

In addition to the major creeks and streams discussed above, numerous intermittent and ephemeral creeks flow eastward across the Subbasin in wet conditions. Flow in these streams typically occurs only during large storms or especially wet conditions; during normal conditions, these creeks generally do not contain flow. Due to their intermittent nature, these streams are not used as significant sources of water supply.

Surface water systems in Corning Subbasin are generally connected to groundwater, either in losing or gaining conditions depending on climactic conditions. Flow in the summer and fall is generally supported more by baseflow and less by stormflow, with the opposite relationship occurring in the winter and spring. The Subbasin's river and creeks generally support groundwater recharge, as they convey stormflow occurring at higher elevations into the Subbasin and support percolation into the Subbasin's aquifer system.

3.1.8.3.2 Canals and Reservoirs

Some of the agricultural water demand in the Corning Subbasin is supported by surface water deliveries which pass through a system of canals, dams, and other surface water conveyance infrastructure. Major canals are displayed on Figure 3-17; these are supported by a network of smaller canals maintained by irrigation and water districts for irrigation delivery to farms and fields.

Black Butte Lake is a large surface water reservoir located in the southwestern portion of the Subbasin, formed via the damming of Stony Creek. Construction of the Black Butte Dam and Reservoir was finalized by the USACE in 1963, as part of a regional flood protection strategy. This reservoir also functions as upstream storage and flow regulation for Stony Creek, with a total capacity estimated at 143,700 AF (CDM, 2003). The USACE manages releases in the winter for flood control and the USBR manages releases in the growing season for irrigation source water for the Orland Project (Davids Engineering, 2017).

The Tehama-Colusa Canal runs southward through the entire Subbasin, entering northeast of Corning and exiting northeast of Orland. The cement-lined canal originates north of the Subbasin at the Red Bluff Pumping Plant and Fish Screen on the Sacramento River near the City of Red Bluff and terminates southwest of Dunnigan in Yolo County. The Tehama-Colusa Canal provides only very limited surface water supplies in the Subbasin.

The Corning Canal likewise originates from the Sacramento River at the Red Bluff Pumping Plant and Fish Screen and flows southward into the Subbasin from the Red Bluff Subbasin to the north. The Corning Canal enters the Subbasin northwest of Corning and terminates near the center of the Subbasin, southwest of Corning. Operations and maintenance of the Tehama-Colusa Canal and the Corning Canal are handled by the Tehama-Colusa Canal Authority. Surface water supplies from the Corning Canal are utilized within the Corning Subbasin.

The Glenn-Colusa Canal originates from a diversion of the Sacramento River near Hamilton City in the southeastern portion of the Subbasin and terminates south of the Subbasin near Williams in Colusa County. The Glenn-Colusa Canal is owned and operated by the GCID, which provides water to agricultural users, protected federal wildlife areas, and private habitat land. The GCID also owns two groundwater production wells in the Subbasin adjacent to the Glenn-Colusa Canal to be utilized as a backup water source for export from the Subbasin during extreme drought or water shortages, such as in the 2012-2016 drought. The wells were not operated between 2016 and 2019. The Glenn-Colusa Canal does not supply water within the Corning Subbasin.

The OUWUA Orland Project canals displayed on Figure 3-17 are the main channels of the OUWUA Northside and Southside area distribution systems. Both canals begin as diversions on lower Stony Creek and provide water for agricultural users. The Northside distribution system supplies water within the Corning Subbasin, while the Southern distribution system supplies water to OUWUA managed areas in Colusa Subbasin to the south.

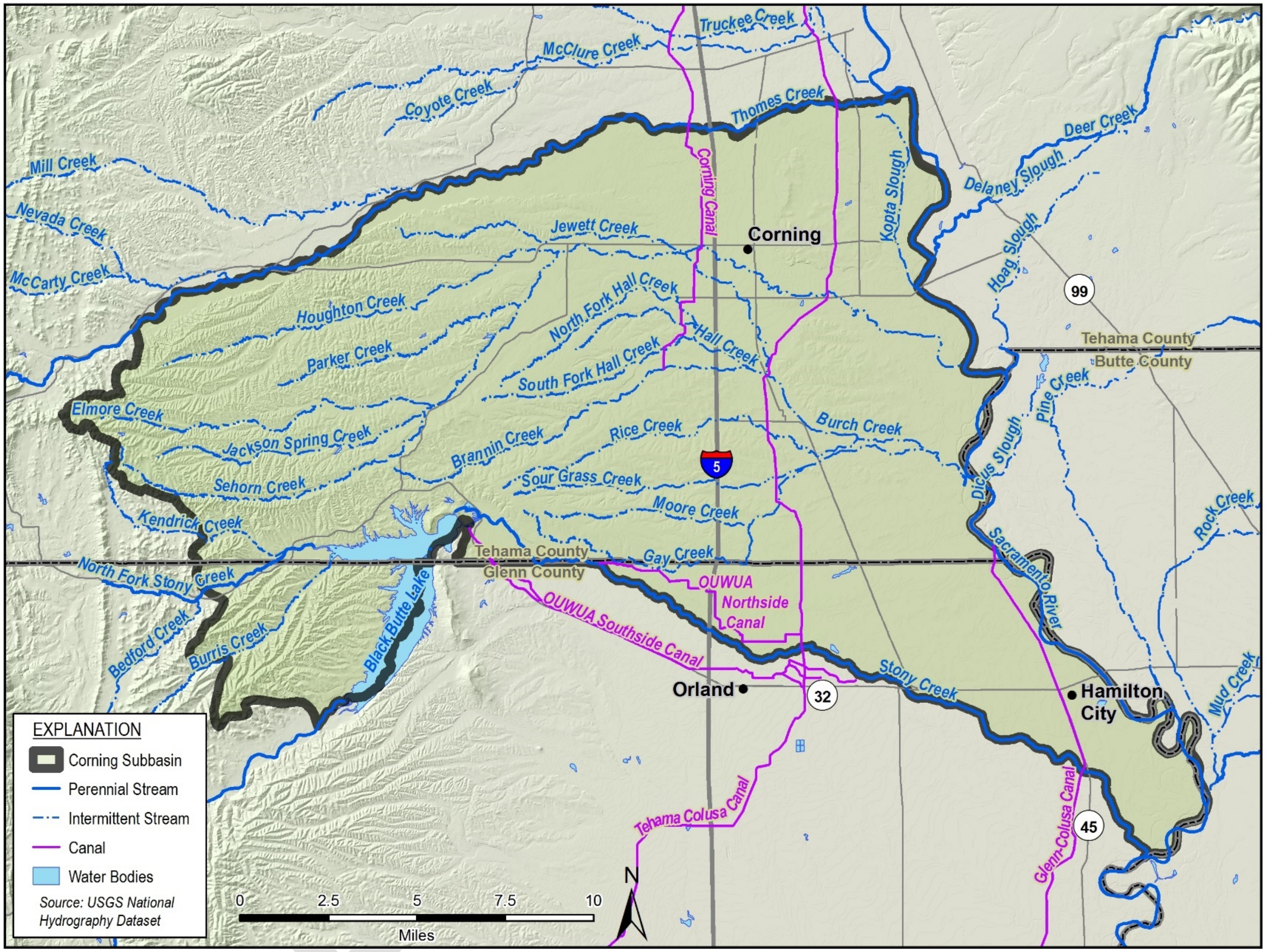

Figure 3-17. Surface Water Bodies

3.1.8.4 Imported Water Supply Sources and Deliveries

Beneficial users within the Subbasin utilize both surface water and groundwater supplies. The system of canals and other water conveyance infrastructure described in Section 3.1.8.3.2 provides water to agricultural users in addition to designated wildlife and habitat protection areas.

As described in Section 3.1.8.3.2, several canals exist within the Subbasin, but not all of them deliver surface water to users within the Subbasin. The Corning Canal imports water from the Sacramento River in the Red Bluff Subbasin into the Subbasin, which is primarily used for agriculture. Diversions on the Corning Canal provide surface water in the Subbasin, to Corning Water District and Thomes Creek Water District specifically.

3.1.9 HCM Data Gaps and Uncertainty

The following paragraphs discuss data gaps and uncertainty related to the HCM that could improve understanding of aquifer conditions and characteristics if resolved, but which need not be rectified to complete a robust GSP. A data gap plan is included in the GSP implementation section of this GSP.

Western Boundary of the Subbasin: there is some uncertainty as to the western boundary of the alluvial basin, as there is anecdotal evidence that some wells in this portion of the Subbasin are drilled into fractured rock and not alluvial aquifer. This information could be refined in the future with more in-depth hydrogeological studies and AEM data.

Tehama-Tuscan Transition Zone: The geologically complex environment created by the cotemporaneous deposition of the Tehama and Tuscan Formations is not perfectly represented by existing cross sections or other visualizations. While not a true data gap from the standpoint of groundwater sustainability planning and management, data obtained from future hydrogeologic investigations could inform detailed groundwater modeling, well design, and groundwater recharge projects. Previous analysis of the eastern Subbasin (West Yost, 2012; Brown and Caldwell, 2013a; Greene and Hoover, 2014) can be used as a framework for additional aquifer tests and resistivity mapping. Additional AEM or other geophysical surveys could also further depict the detailed formation layering, though portions of the deeper aquifer may not be penetrated by this technology

Hydrogeologic Parameters: Existing knowledge of aquifer parameters can be considered incomplete for some of the Subbasin's formations, namely the Tuscan and Tehama Formations. Existing aquifer testing results are limited and sometimes potentially misleading, as described in Section 3.1.5. Formations in the Subbasin are generally heterogenous; the Tehama Formation contains intermittent lenses, and the Tuscan contains subunits of differing properties which have not been robustly mapped at depth in the Subbasin. Further, aquifer testing which has taken place in the Tehama-Tuscan Transition Zone may have inadvertently occurred in multiple units. While not required by SGMA, additional aquifer testing could further the understanding of the Subbasin's aquifer system and improve the groundwater model for GSP updates.

3.2 Historical and Current Groundwater Conditions

3.2.1 Overview

The following sections summarize historical and current groundwater conditions in the Corning Subbasin. As defined by SGMA Regulations [§354.16] current conditions are those existing after January 1, 2015; therefore, historical conditions include all those existing prior to January 1, 2015. Organization of this section aligns with the 6 SGMA sustainability indicators listed below:

- Chronic lowering of groundwater levels (Section 3.2.2)
- Changes in groundwater storage (Section 3.2.3)
- Seawater intrusion (Section 3.2.4)
- Land Subsidence (Section 3.2.5)
- Groundwater quality (Section 3.2.6)
- Depletion of interconnected surface waters (Section 3.2.7)

As described in Section 3.1.8, the Corning Subbasin comprises a hydrogeologically interconnected aquifer system where impacts to one aquifer unit have the potential to impact the larger aquifer network. A single principal aquifer was identified in the HCM, and therefore, this section applies to groundwater conditions for the entire aquifer within the Subbasin. These sections discuss groundwater conditions in relation to spatial and temporal variables.

3.2.2 Groundwater Elevations

Groundwater elevations represent the height of the water table relative to mean sea level. Groundwater elevations change based on the amount of water that is recharged to the aquifer and the amount of water that is removed from the aquifer. For example, declines in groundwater elevation may result from reduced groundwater recharge or over-extraction of groundwater resources. Groundwater elevations can be measured at monitoring or pumping wells to assess the change in levels seasonally or over longer periods of time. While groundwater elevations in most wells fluctuate seasonally, long-term declines may result in a variety of impacts to beneficial users including but not limited to wells going dry, reduced available groundwater storage, and declines in interconnected surface water.

The following subsections describe current and historical groundwater elevations in the Corning Subbasin. Groundwater elevations can be described in terms of spatial variability of the Subbasin at a snapshot in time (elevation contours in Sections 3.2.1 and 3.2.2), and in terms of temporal variability with measurements taken at discrete wells over time.

The following data and general references were reviewed for this Section:

- DWR SGMA Data Viewer – contour maps
- CASGEM wells water levels
- Groundwater Management Plans for Glenn and Tehama Counties
- Agricultural Water Management Plans for Districts within Corning Subbasin

The Subbasin has experienced several periods of groundwater elevation decline as described further in the following subsections. These declining groundwater elevations may have resulted in some domestic well water supply shortages, as evidenced by reports filed with DWR's water supply shortage reporting system.[1] Household water supply shortages reported within the last month (red), last year (yellow), and since April 2013 (green) are presented on Figure 3-18 below for Glenn, Tehama, and Butte Counties.

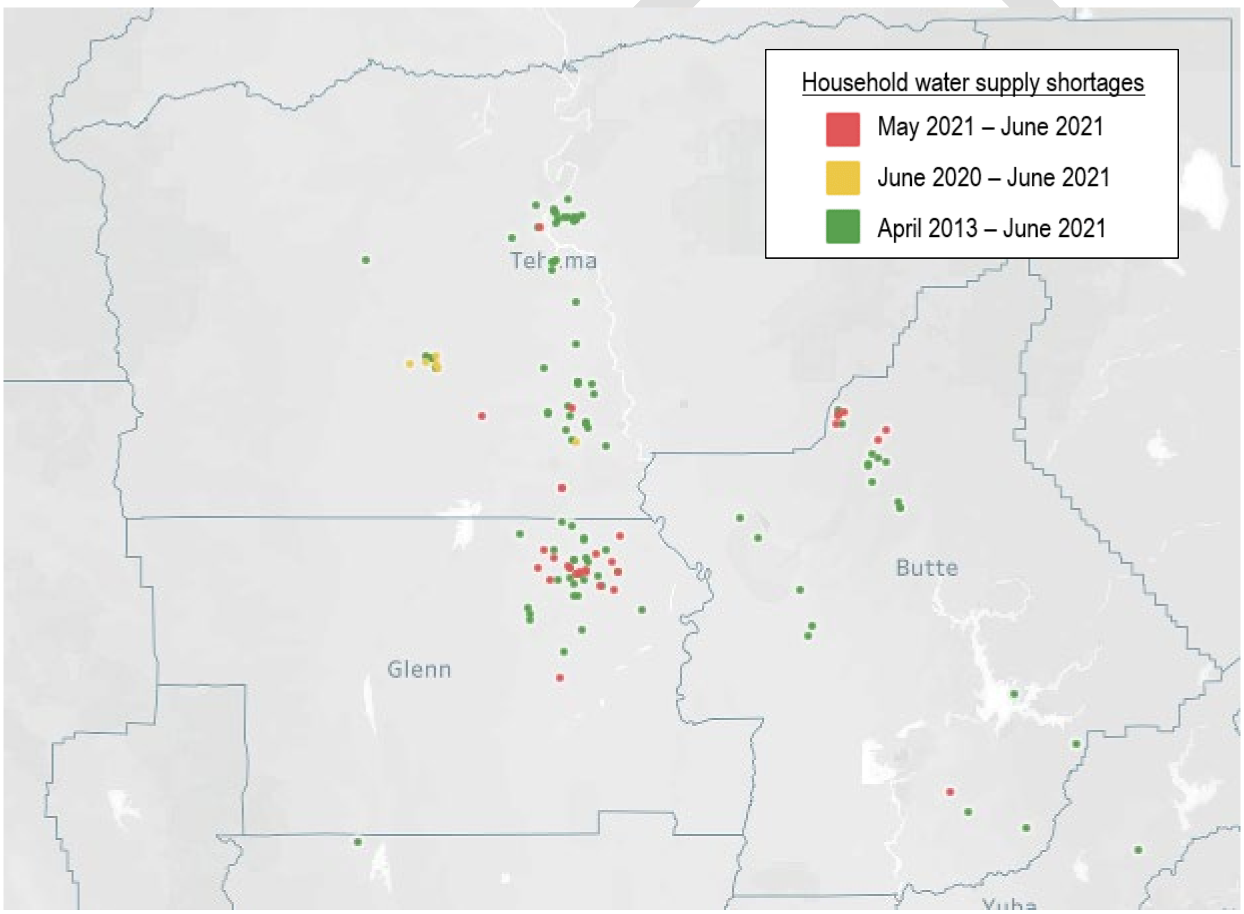

Figure 3-18. Reported Household Water Supply Shortages in Glenn and Tehama Counties
Accessed June 21, 2021 at: https://mydrywatersupply.water.ca.gov/report/publicpage

[1] https://mydrywatersupply.water.ca.gov/report/publicpage. Accessed June 21, 2021.

3.2.2.1 Current Groundwater Elevation Contours and Flow Direction

Groundwater elevation contours during the fall and spring of 2018, derived from groundwater levels measured at wells in the CASGEM monitoring program in the Corning Subbasin and surrounding areas, are displayed on Figure 3-19 and Figure 3-20, respectively. In general, groundwater elevations in spring reflect recharge received during the rainy season, while groundwater elevations in fall reflect the antecedent dry season and the tail end of the growing season for many crops in the Subbasin. The 2018 water year (WY) was classified as a below normal water year according to DWR's Sacramento Valley Water Year Index.

During both spring and fall, groundwater elevations are higher in the north and west of the Subbasin, reflecting regional gradients that drive groundwater toward the center of the valley. Here, groundwater elevations reach as high as 250 feet amsl in the spring and 240 feet amsl in the fall. In the southeastern Subbasin, where groundwater elevations are typically at their lowest, elevations range as low as 120 feet amsl in the spring and 110 feet amsl in the fall. Across much of the Subbasin, elevations display a roughly 10- to 20-foot difference in groundwater elevation between these 2 seasons. Contours near Stony Creek display up to a 40-foot difference in elevation, potentially due to differences in streambed recharge between the spring and fall. Flows in Stony Creek are known to be a significant source of aquifer recharge (DWR, 2006a); spring groundwater elevations shown on Figure 3-20 bend downstream, displaying apparent groundwater recharge along the length of the creek. Flood and furrow surface water applications for crop irrigation in this area also likely provide groundwater recharge (Davids Engineering and West Yost, 2018).

Groundwater elevation contours in the far western portion of the Subbasin are not available, due to the lack of wells that are monitored in this area. This is a data gap that will be identified in the data gap action plan in Section 8 – Plan Implementation.

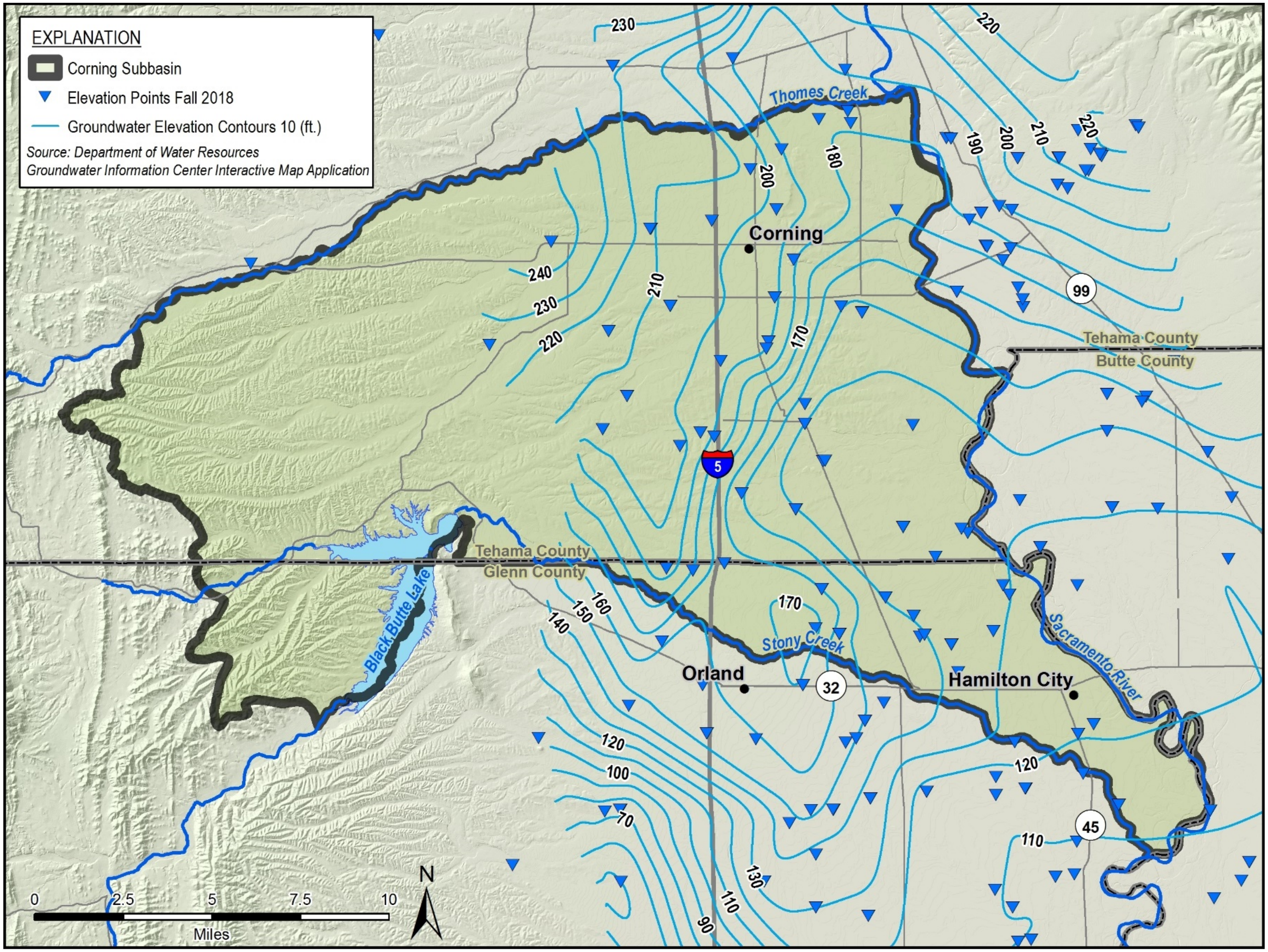

Figure 3-19. Fall 2018 Groundwater Contours

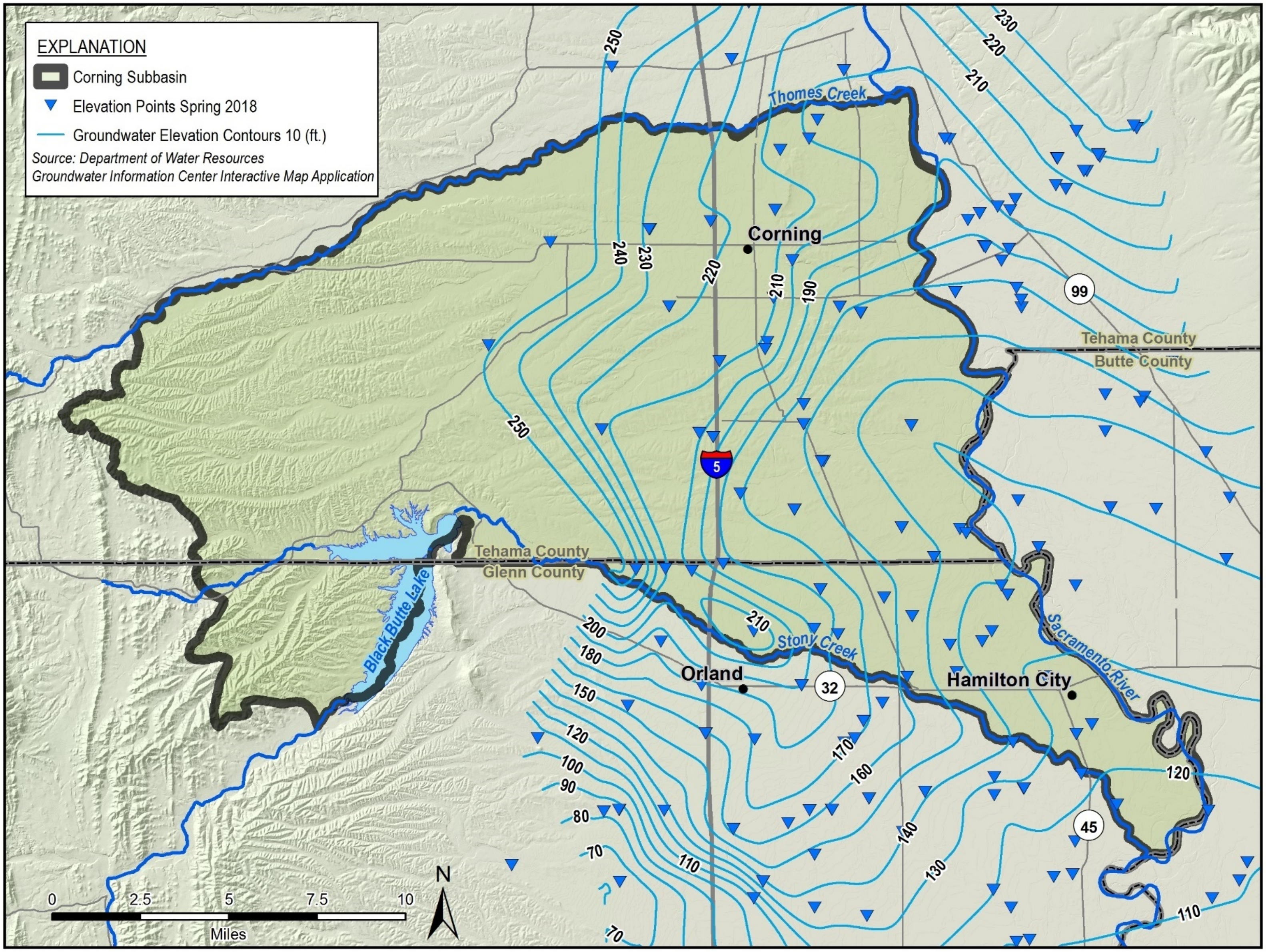

Figure 3-20. Spring 2018 Groundwater Contours

3.2.2.2 Subbasin-Wide Historical Groundwater Elevations

As compared to more recent conditions, historical groundwater elevation information can be assessed from maps of elevation contour changes between 2 distinct periods in time. Figure 3-21, Figure 3-22, and Figure 3-23 display changes in groundwater elevation as points and contours between 2004-2014, 2010-2015, and 2015-2018, respectively. These 3 periods compare the Subbasin's historical and current conditions with respect to portions of the recent historical record. Changes between the fall seasons of each year are presented on the figures to reflect when groundwater elevations are at their lowest. Groundwater elevation change maps were generated for these 3 periods by DWR to compare conditions during periods with distinct changes in climate, such as evaluating the effects of the 2012-2016 drought on overall water level trends. The period from 2004-2018 included some the most extreme wet and dry years in the climate record, including an extended drought between 2012-2016 and wet water years in 2006, 2011, and 2017. Since 2004, groundwater level declines have been exacerbated by expansion of irrigated farmland, conversion to groundwater-irrigated orchards, and surface water limitations. For discussion purposes below, "average" conditions include "above normal" and "below normal" water years, as there is no "normal" water year on the index. "Wet," "dry," and "critically dry" water years are representative of the extremes. Overall, the following trends can be observed from these data:

- **From 2004-2014:** This 10-year period reflects several generally average WYs, followed by several dry years in the beginning of the 2012-2016 drought. During this period, groundwater elevations experienced declines across the majority of the Subbasin (Figure 3-21). Elevations declined up to 30 feet near the City of Corning, in the western Subbasin, and in the southern Subbasin near Stony Creek. Elsewhere in the Subbasin, elevations declined roughly 5 to 10 feet. All measured wells in the Subbasin experienced a decline in groundwater elevation during this period of at least 5 feet. In addition to reduced infiltration of rainfall, these declines were likely influenced by increased reliance on groundwater extraction due to reduced diversion allocation availability from and flow in the Sacramento River, Stony Creek, Thomes Creek, and other seasonal streams. Reduced streamflow may have further affected groundwater elevations by reducing groundwater recharge from streambeds.
- **From 2010-2015:** This 5-year period reflects the last 2 years of wetter conditions, and 3 years of drought. During this period, changes in groundwater elevation reflect the influence of multiple drought years; elevations decreased by up to 30 feet in the western Subbasin, and up to 20 feet in the south (Figure 3-22). Overlap between this period and the 2004-2014 period (Figure 3-21) helps illustrate the significant influence of the recent drought on groundwater elevations. Beginning in 2012 and ending around 2016, the drought brought about reduced recharge and increased groundwater reliance, culminating in extensive groundwater level declines.

- **From 2015-2018:** water years alternated between wet and below normal and groundwater elevations began to show recovery in some areas from the recent drought, with elevation increases in the northern and southern Subbasin of up to approximately 10 to 11 feet. Despite recovery in many areas, elevations at some wells in the central Subbasin remained in decline during this period, with declines in groundwater elevation of between 3 and 10 feet. During the drought, surface water allocations from the CVP were severely limited, which resulted in greater groundwater pumping that lowered groundwater levels.

As a general frame of reference, DWR provided more recent regional groundwater elevation trends between spring measurements in 2019 and 2020 in their California Groundwater Conditions Update – Spring 2020 (DWR, 2020b). 2019 was a wet water year and 2020 was a dry water year. The Corning Subbasin areas in Glenn County and southern Tehama County generally had stable groundwater levels, with change of less than ±5 feet, while the wells in northern Tehama County typically declined by 5 to 25 feet between spring measurements. A more detailed analysis of 2020 and 2021 water level data in the Subbasin will be provided in the first annual report (due April 1, 2022).

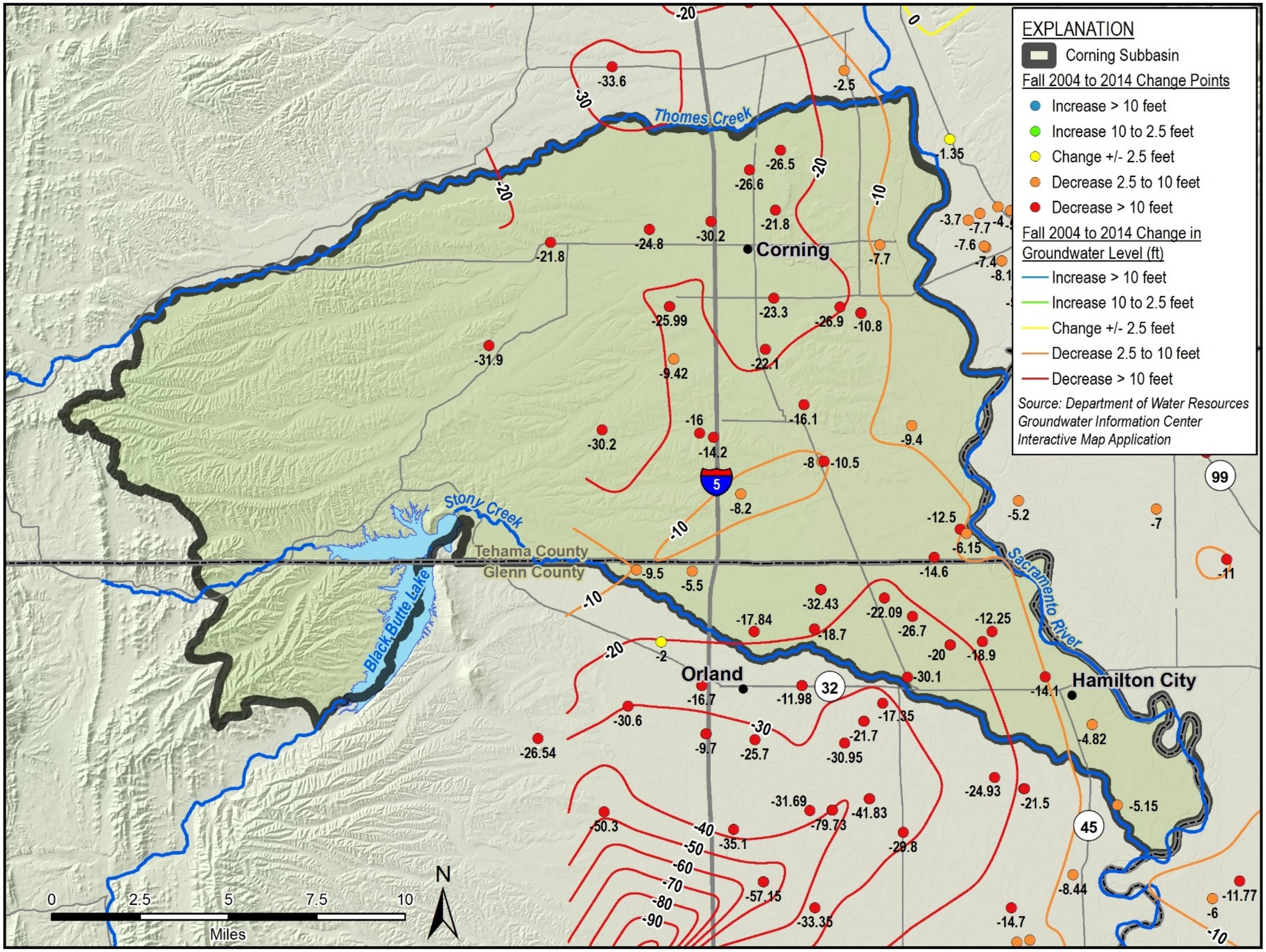

Figure 3-21. Change in Groundwater Elevations: Fall 2004 - Fall 2014

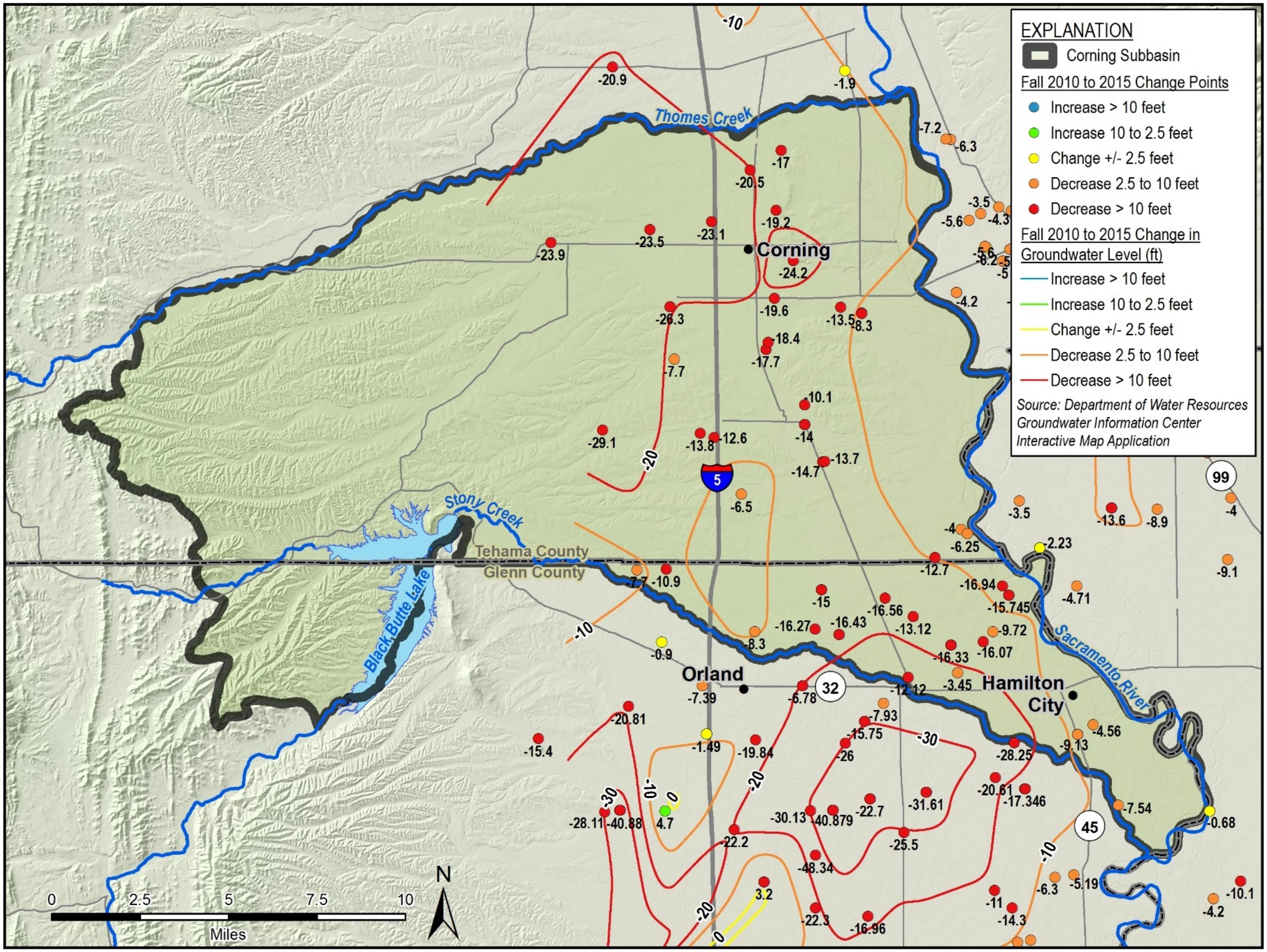

Figure 3-22. Change in Groundwater Elevations: Fall 2010 - Fall 2015

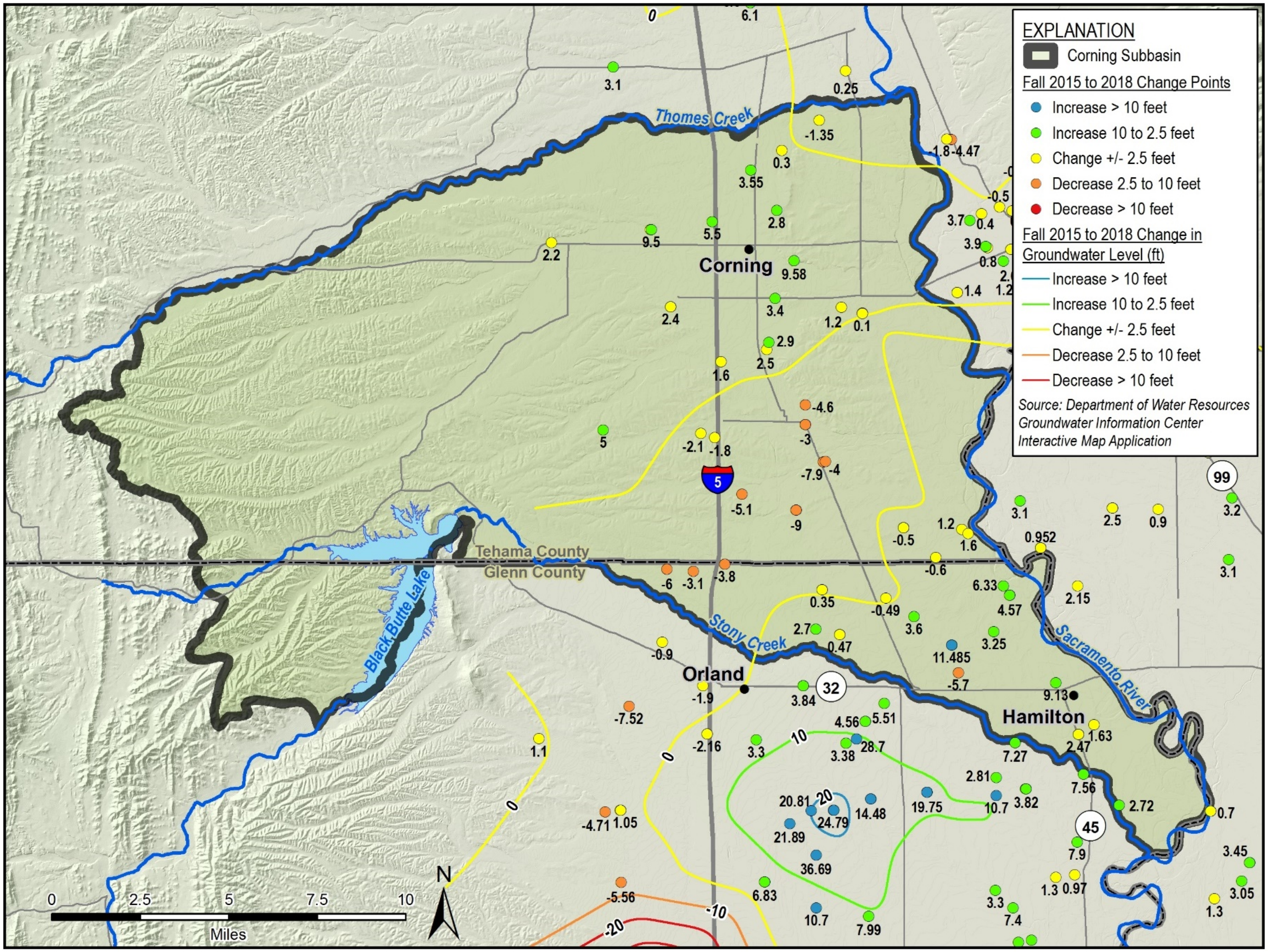

Figure 3-23. Change in Groundwater Elevations: Fall 2015 - Fall 2018

3.2.2.3 Hydrographs: Historical Groundwater Elevation Trends

There are a number of wells monitored regularly in the Subbasin that include groundwater elevation data since the 1970s. Appendix 3C provides a compilation of groundwater elevation hydrographs for wells within the Subbasin.

To facilitate the review of groundwater elevations, the Subbasin was divided into east, west, and south areas based on differences in land use, water supply sources, and geology, as discussed further in the sections below:

1. The east area - represented by the area of the Subbasin to the east of I-5 within Tehama County. The east area is predominantly agricultural. Growers in the east area rely mainly on groundwater to meet agricultural water demands, except for riparian surface water rights holders on the Sacramento River near Thomes Creek.
2. The west area – represented by the area of the Subbasin to the west of I-5 within Tehama and Glenn Counties. The northeast portion of this area, within the Thomes Creek WD and Corning WD jurisdiction to the west of the City of Corning, is used extensively for fruit, nut, and olive orchards. This portion has some access to surface water supplies from the Corning Canal. Collectively, the Corning Water District growers use about half surface water and half groundwater to irrigate crops. The rest of the growers in this area mainly use groundwater for irrigation. The southeast portion of this area has few irrigated crops and surface water is generally unavailable. An approximately 9,000-acre eucalyptus grove was established in 1993 and irrigated with groundwater until 2002 (CDM, 2003). The western portion within Tehama and Glenn Counties has more topographic relief, the aquifer is deeper, and the groundwater has higher salinity than in the rest of the Subbasin. Consequently, the land is typically used for livestock grazing. The western portion relies mostly upon groundwater as a water source, except for a few parcels along creeks with riparian surface water rights. The small portion to the west of Black Butte Lake within Glenn County is sparsely irrigated. As described in Section 2 Plan Area, land use continues to expand in this area. Expansion of orchards and other irrigated crops will continue to increase demand for groundwater and result in a decrease in groundwater levels in this area.
3. The south area – represented by the area of the Subbasin to the southeast within Glenn County. This area of the Subbasin is used mostly for deciduous fruit and nut crops to the east and pasture to the west. Surface water is available to growers within the OUWUA, while groundwater is mainly used in the rest of this area (Davids Engineering, 2018).

Characteristic wells were selected for historical groundwater trend analysis based on well location, well screen interval, length of historical water level record, and data quality.

Figure 3-5 displays the location of the wells used. Plots of groundwater elevation data over time (hydrographs) are provided on Figure 3-25 through Figure 3-30 and discussed in the following sections. The well construction information associated with each hydrograph is shown in Table 3-2 through Table 3-7, which are presented following the corresponding figure. DWR Sacramento Valley Water Year designations are shown on the background of all hydrographs to help illustrate the relationships between groundwater elevations and climate and hydrology.

As displayed on Figures 3-2 and 3-3, baseline differences in groundwater elevations between wells are the product of regional horizontal groundwater flow and gradients because groundwater elevations are generally higher in the northern part of the Subbasin and decrease to the south. Hydrographs display prominent seasonality, with groundwater elevations rising and falling by 10 to 30 feet annually. Variations in seasonal response between these wells may reflect spatial differences in groundwater recharge and use across the Subbasin.

Water levels in these hydrographs clearly follow climatic cycles with rising and falling water levels affected by droughts and wet cycles. Water level declined in the 1975-1977, 1986-1992, and 2012-2016 droughts. Generally, water levels recovered during subsequent wet years, with some exceptions, as noted for individual hydrographs below.

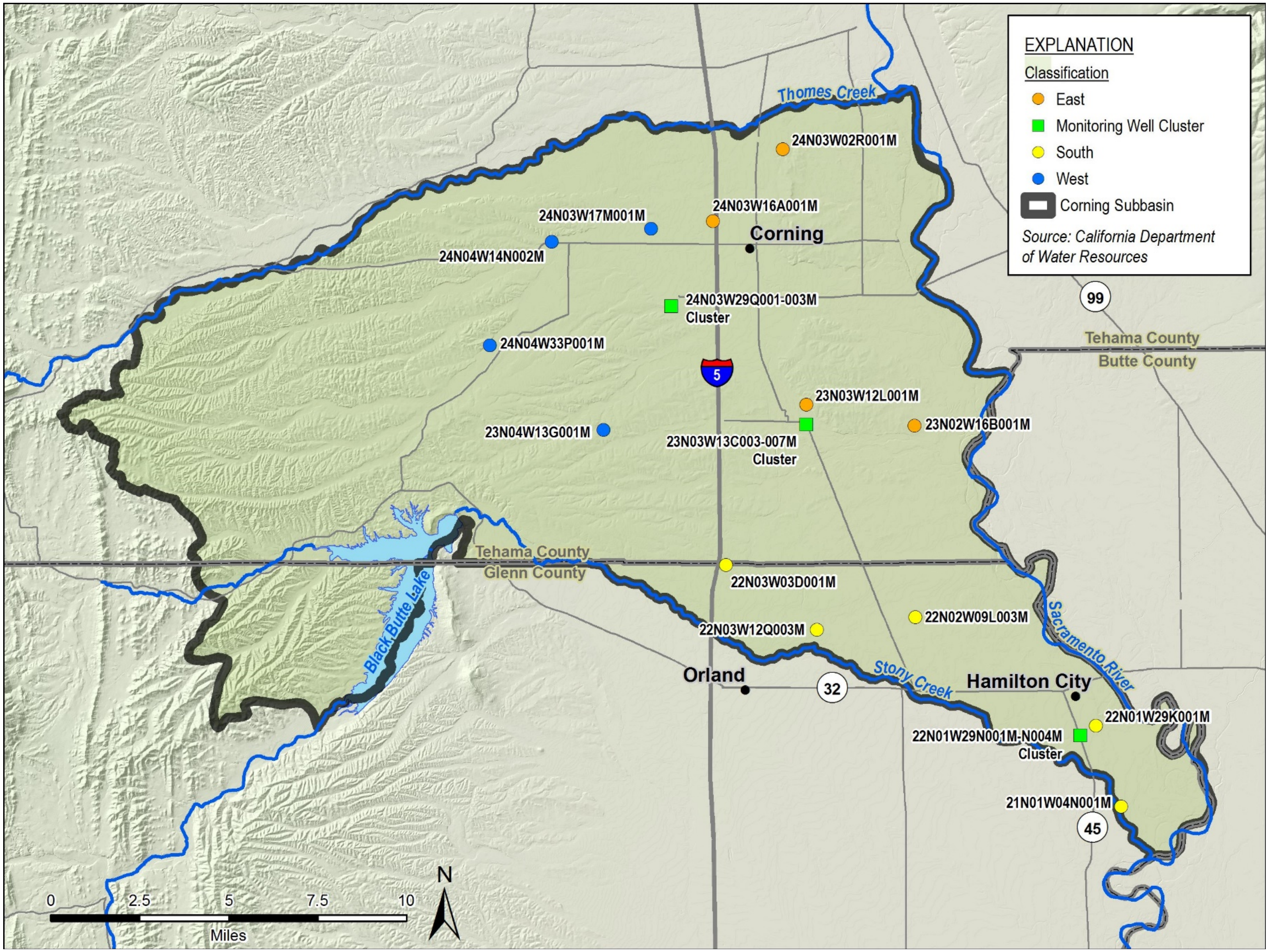

Figure 3-24. Characteristic Wells Used for Groundwater Elevation Assesments

3.2.2.4 East Area Groundwater Elevations

As displayed on Figure 3-21 through Figure 3-23, wells in the eastern area have generally experienced water level decline over the past 2 decades in the areas further from the Sacramento River, while water levels in wells near the Sacramento River have remained relatively stable. Wells located closer to the Sacramento River may benefit from a greater degree of applied surface water, direct recharge from the river, and direction of groundwater flow from east to west toward the Sacramento river.

Hydrographs on Figure 3-25 show groundwater elevation trends in 4 characteristic wells with historical water level measurements reflective of regional trends. Well construction information for each well is summarized in Table 3-2. The well screen intervals of the characteristic wells range from 120 to 295 feet below ground surface (bgs).

Historical groundwater elevation trends from roughly 1970-1995 show the effects of 2 climactic cycles (the 1976-77 drought and the 1987-1992 drought); groundwater elevation decreases of up to 20 feet are noted during dry periods, but the water levels recovered to pre-drought conditions in wells during wet periods. From 2005 through 2019, a net decrease in groundwater elevation of approximately 30 feet was noted in the wells further from the Sacramento River, partly in response to the recent 2012-2016 drought. Groundwater elevations recovered after the drought in the well closest to the river (23N02W16B001M in green below) but have not recovered entirely in wells further to the west or in the deeper wells.

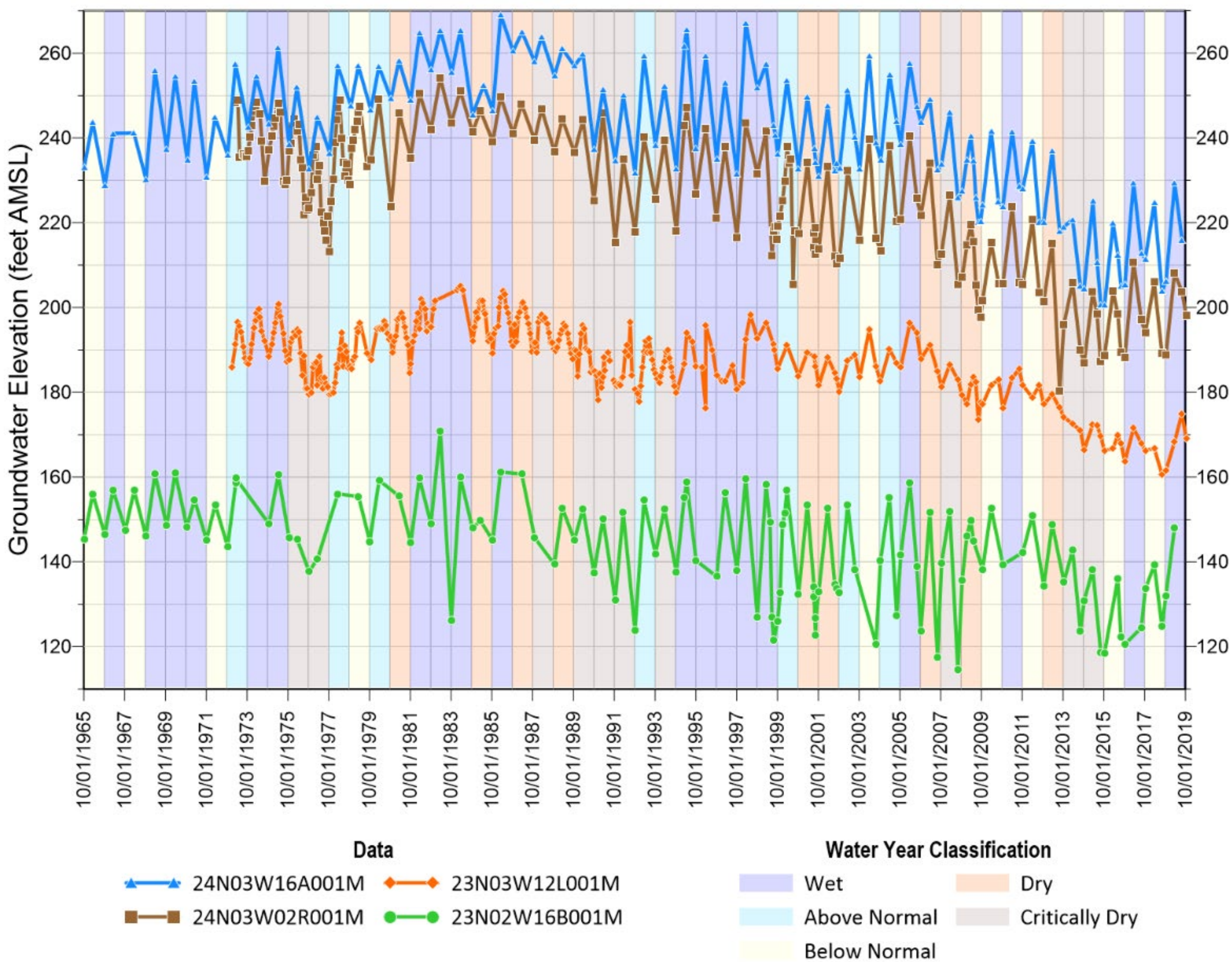

Figure 3-25. East Area Characteristic Hydrographs

Table 3-2. Screened Intervals and Total Depths of East Area Characteristic Hydrograph Wells

Well Name	Well Type	Screened Interval(s) (ft bgs)	Total Depth (ft bgs)
24N03W16A001M	Irrigation	Unknown	295
24N03W02R001M	Domestic	Unknown	270
23N03W12L001M	Irrigation	45-95, 132-148	150
23N02W16B001M	Irrigation	100-120	120

3.2.2.5 West Area Groundwater Elevations

Much of the agriculture in the west area relies entirely on groundwater supply for irrigation, with most production wells typically screened in the Tehama Formation. As seen on Figure 3-21 through Figure 3-23, wells in the western region have experienced historical declines in groundwater elevation since 2004, partially in response to groundwater pumping. Figure 3-7 displays hydrographs of 4 characteristic wells; Table 3-3 lists the well screen intervals and total depths. Well depths for the characteristic wells range from 108 to 780 feet bgs, representing an array of screened intervals.

As was the case in the east area, hydrographs for the characteristic wells demonstrate a strong response to extended dry and wet periods. However, the degree of groundwater elevation change is greater in the west area than in the other areas, with up to 40 feet of decline seasonally. The historical groundwater elevation record in west area wells demonstrates the effect of 2 climactic cycles. From roughly 1970 to 2006, annual water level declines during dry periods were followed by recovery during wet periods. Groundwater elevations in the western Subbasin have experienced continuous declines from 2006 until present. Deeper wells in this area tend to have a wider range of annual fluctuation, but the annual trends are relatively similar between wells installed at varying depths.

One hydrograph in the west region has a distinctly different trend from 1992 to 2002 than the other wells. 23N04W13G001M (in purple below) is located on the previously mentioned 9,000-acre eucalyptus farm that used groundwater supply from 1993 to at least 2002 (CDM, 2003). Groundwater pumping during the initial growth period is strongly reflected in the hydrograph for this well; groundwater elevations declined by 40 to 60 feet from 1993 to 2000, followed by partial recovery from 2000 to 2007. This decline occurred during a wet period and is not reflected in other hydrographs from the rest of the region, suggesting the influence of more intensive pumping in this portion of the western area. Since 2007, the water level trends in this well have tracked closely with other wells in the western area, following the recovery from the extensive pumping to support the eucalyptus grove (Figure 3-26).

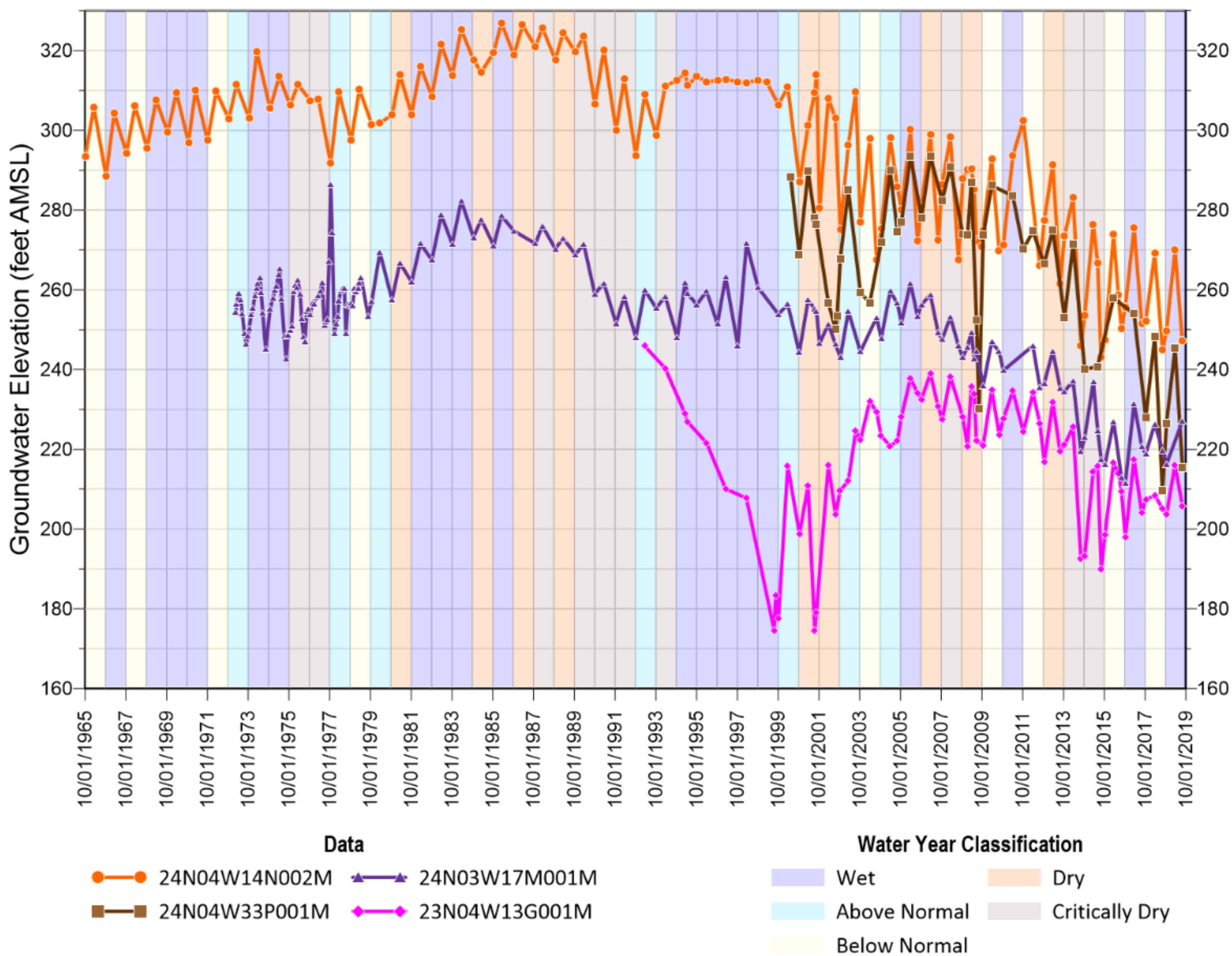

Figure 3-26. West Area Characteristic Hydrographs

Table 3-3. Screened Intervals and Total Depths for Western Subbasin Characteristic Hydrograph Wells

Well Name	Well Type	Screened Interval(s) (ft bgs)	Total Depth (ft bgs)
24N04W14N002M	Domestic	Unknown	180
24N04W33P001M	Irrigation	250-280, 300-350, 360-390, 420-440, 490-570, 650-690, 730-750, 760-780	780
24N03W17M001M	Domestic	100-108	108
23N04W13G001M	Irrigation	Unknown	560

3.2.2.6 South Area Groundwater Elevations

Figure 3-27 displays hydrographs for 5 characteristic wells in the south area of the Subbasin Table 3-4 summarizes the well construction information. In general, wells in the south area show similar trends to the east and west with historical fluctuations in groundwater elevation related to wet and dry climatic cycles. However, in contrast to the east and west areas, a declining water level trend has not been as pronounced during the past 2 decades (Figure 3-21 through Figure 3-23). This may be reflective of more surface water use for irrigation in this area, coupled with groundwater recharge from the Sacramento River and Stony Creek. Well screen interval does not appear to influence annual groundwater elevation changes in these wells, though the amplitude of change in deeper well (22N02W09L003M in green below) was greater compared to the other shallower wells shown on Figure 3-27. While groundwater elevation changes are seen in all wells from regional groundwater pumping during dry conditions, groundwater elevations in wells closer to Stony Creek and the Sacramento River (22N01W29K001M and 21N01W04N001M in blue and brown, below) exhibit more stable groundwater elevations with limited changes due to climate.

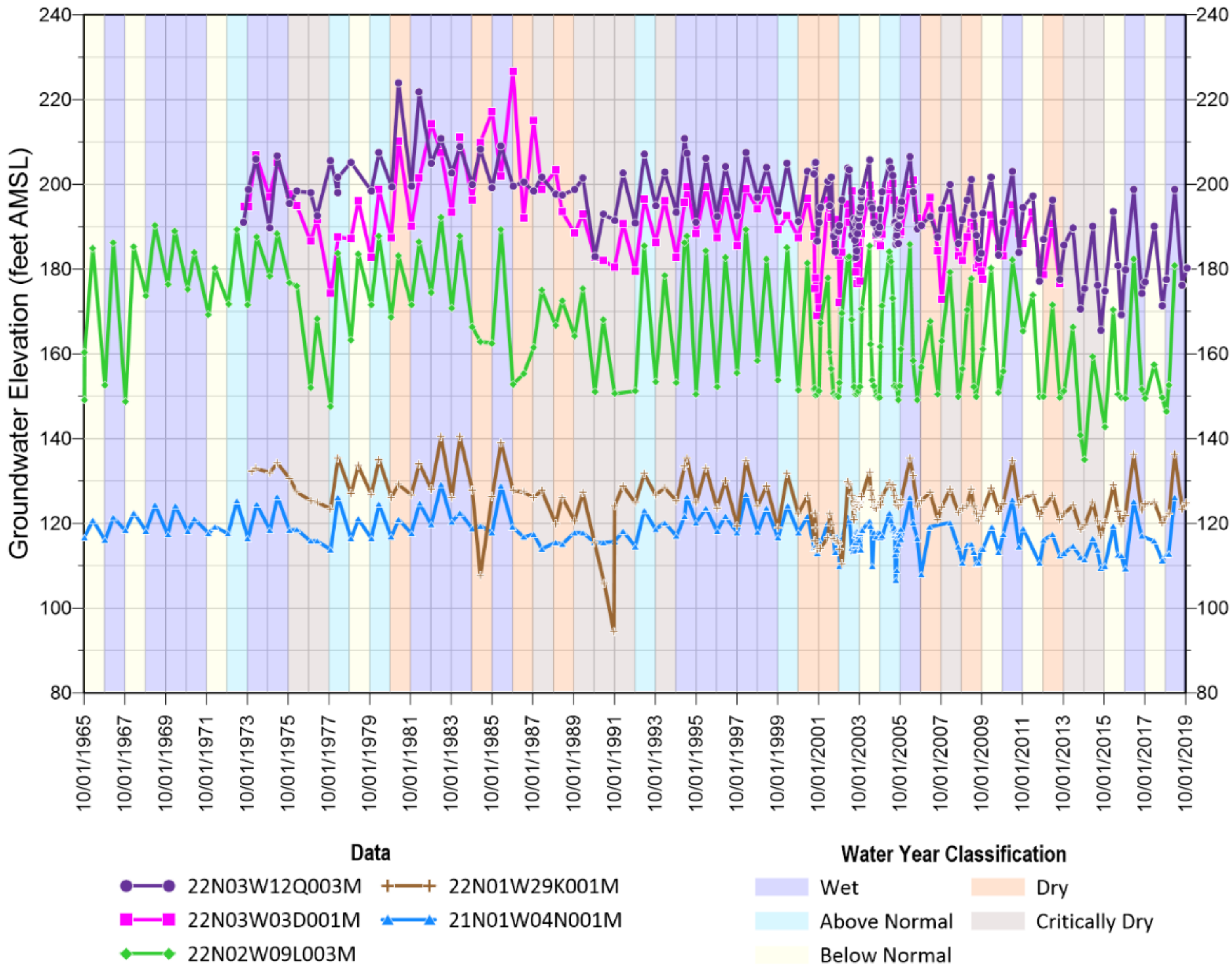

Figure 3-27. South Area Characteristic Hydrographs

Table 3-4. Screened Intervals and Total Depths for Southern Subbasin Characteristic Hydrograph Wells

Well Name	Well Type	Screened Interval(s) (ft bgs)	Total Depth (ft bgs)
22N03W12Q003M	Domestic	112-123	124
22N03W03D001M	Domestic	90-102	104
22N02W09L003M	Irrigation	40-53, 148-153, 180-219, 290-313, 358-366, 527-536	550
22N01W29K001M	Irrigation	Unknown	150
21N01W04N001M	Domestic	unknown	100

3.2.2.7 Vertical Groundwater Gradients

Clustered monitoring wells are 2 or more wells installed near to each other but with screens at different depths. Clustered wells can be used to identify differences in groundwater elevation by depth (or vertical zone), illustrating potential vertical groundwater gradient direction and magnitude. Figure 3-28, Figure 3-29, and Figure 3-30 display representative hydrographs for 3 well clusters in the east, west, and south areas of the Subbasin, respectively, in the locations shown on Figure 3-5. Table 3-5 through Table 3-7 list the well screen intervals and total depths for wells presented in these figures.

Vertical groundwater gradients occur due to pumping patterns at different depths in the aquifer. Groundwater always flows from high elevation to low elevation (similar to flow in a horizontal plane). When groundwater elevation in shallow wells is lower than groundwater elevation in deeper wells, groundwater flows upward through the aquifer, resulting in an upward vertical gradient. The opposite can also occur. Large vertical gradients at a cluster well can indicate that screened intervals are in hydrogeologically distinct aquifers, semi-confined, or perched areas, while hydrographs with similar groundwater elevation trends and small vertical gradients suggest that aquifer zones are likely hydrogeologically connected.

There are vertical hydraulic gradients associated with vertical groundwater flow in the Subbasin. Downward vertical gradients are prevalent in the east and south area well clusters, where the majority of the pumping occurs. In contrast, upward vertical gradients were common in the west area well cluster from the first measurement in 2004 through 2014 but have fluctuated in direction over seasonal timeframes since. In general, the Subbasin hydrographs reflect that groundwater elevation trends are similar across the thickness of the saturated aquifer over time, with variability related to local pumping effects, especially in the summer and fall. There are a few locations where more distinct trends are apparent at different depths in the aquifer (Figure 3-28), particularly in the eastern portion of the Subbasin where the Tehama and Tuscan formations interfinger. The extent of the Tuscan aquifer and degree of interconnection between the Tehama and Tuscan formations is not well refined and is a data gap that will be addressed during GSP implementation.

The hydrographs from the well cluster in the east area (Figure 3-28) typically indicate that groundwater elevations decrease with increasing screen depth from 2006 to 2019. There are 3 distinct trends for the shallow well with a screen from 25 to 35 feet bgs, the intermediate wells with screens from 95 to 355 feet bgs, and the deeper wells with screens from 815 to 970 feet bgs. The shallow well demonstrated a long-term stable water level, suggesting that it is not hydraulically connected with deeper wells that all had a long-term decreasing water level trend and is likely indicative of perched groundwater. Perched groundwater is found in some shallow wells less than 80 feet deep near ephemeral streams. Decreasing groundwater elevations at depth caused downward vertical gradients to increase in relation to the shallow well over time.

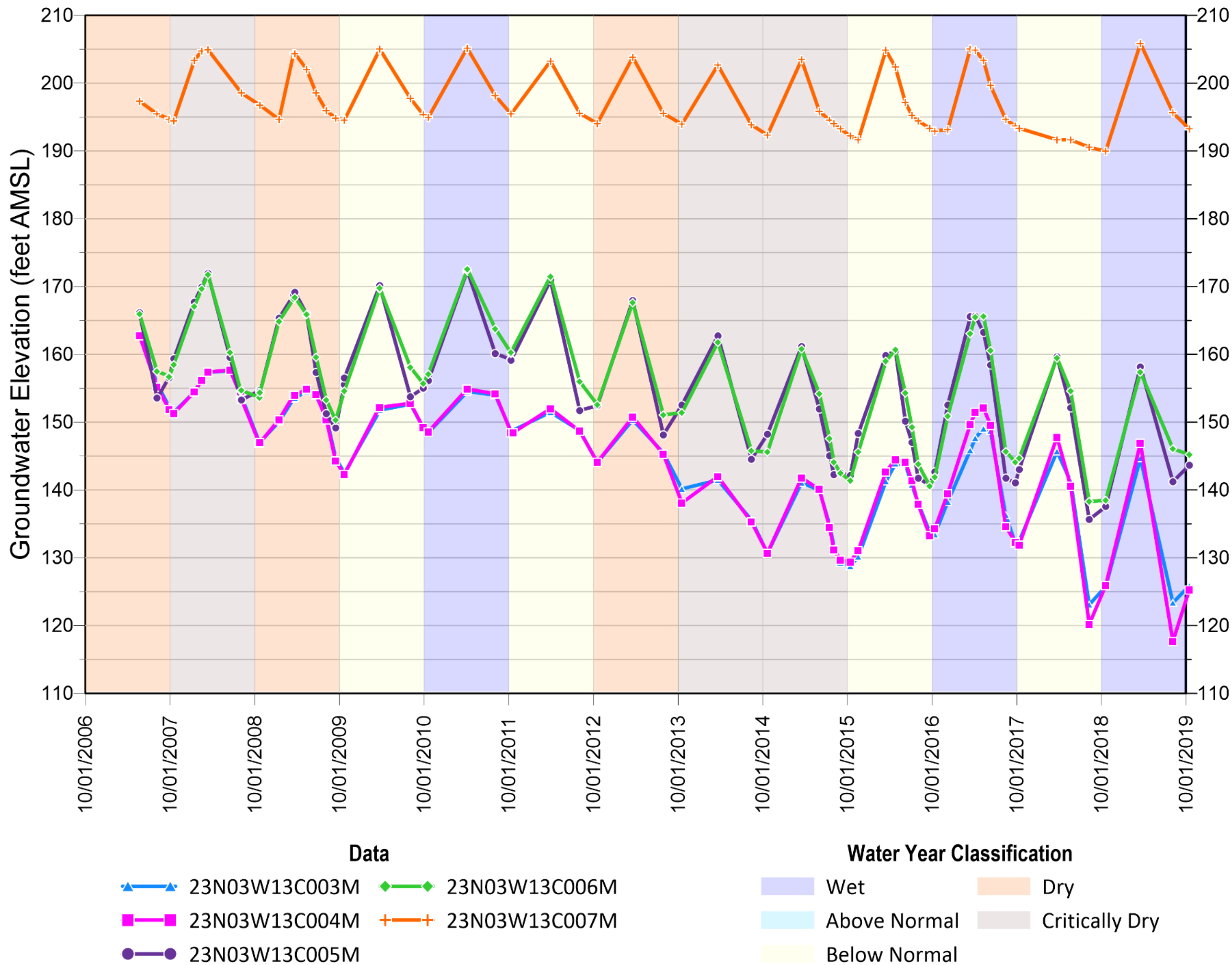

Figure 3-28. Groundwater Elevations in Clustered Wells 23N03W13C003M-C007M

Table 3-5. Screened Intervals for Clustered Wells 23N03W13C003M-C007M

Well Name	Well Type	Location	Screened Interval(s) (ft bgs)	Total Depth (ft bgs)
23N03W13C003M	Monitoring	East Area	900-910, 960-970	980
23N03W13C004M	Monitoring	East Area	815-825	835
23N03W13C005M	Monitoring	East Area	345-355	381
23N03W13C006M	Monitoring	East Area	95-105, 125-135	182
23N03W13C007M	Monitoring	East Area	25-35	71

In the well cluster in the west area the vertical gradient trends from 2004 to 2019 had notably different conditions before and after the 2013 to 2015 critically dry years (Figure 3-29). Prior to 2014, vertical gradients were consistently upward from deeper to shallower wells, while vertical gradients after 2014 generally fluctuated between upward in the fall and downward in the spring.

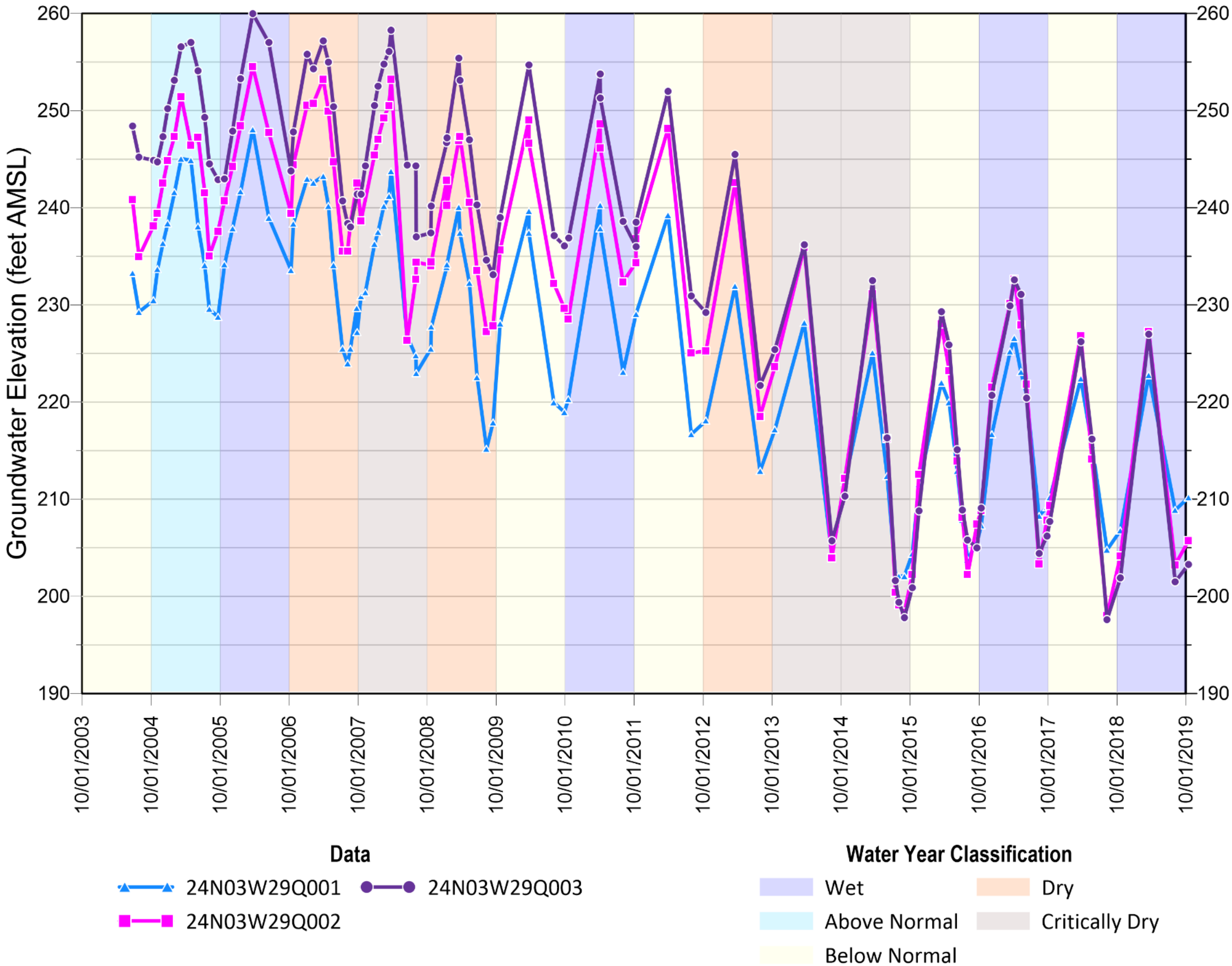

Figure 3-29. Groundwater Elevations in Clustered Wells 24N03W29Q001-Q003

Table 3-6. Screened Intervals for Clustered Wells 24N03W29Q001-Q003

Well Name	Well Type	Location	Screened Intervals (ft bgs)	Total Depth (ft bgs)
24N03W29Q001	Monitoring	West Area	130-140, 190-200, 230-40, 280-290, 350-360	372
24N03W29Q002	Monitoring	West Area	490-500, 540-550	575
24N03W29Q003	Monitoring	West Area	650-670, 700-710	844

The hydrographs from the well cluster in the south area near Hamilton City fluctuate over annual and long-term cycles from 2009 to 2019, but are predominantly downward with occasional observations with no gradient or an upward gradient (Figure 3-30). Vertical gradients are generally more negative (or downward) during the fall measurements than in the spring, likely as a result of greater groundwater pumping at depth during the growing season. During the spring, vertical gradients generally remained downward, but were smaller in magnitude than observations in the fall.

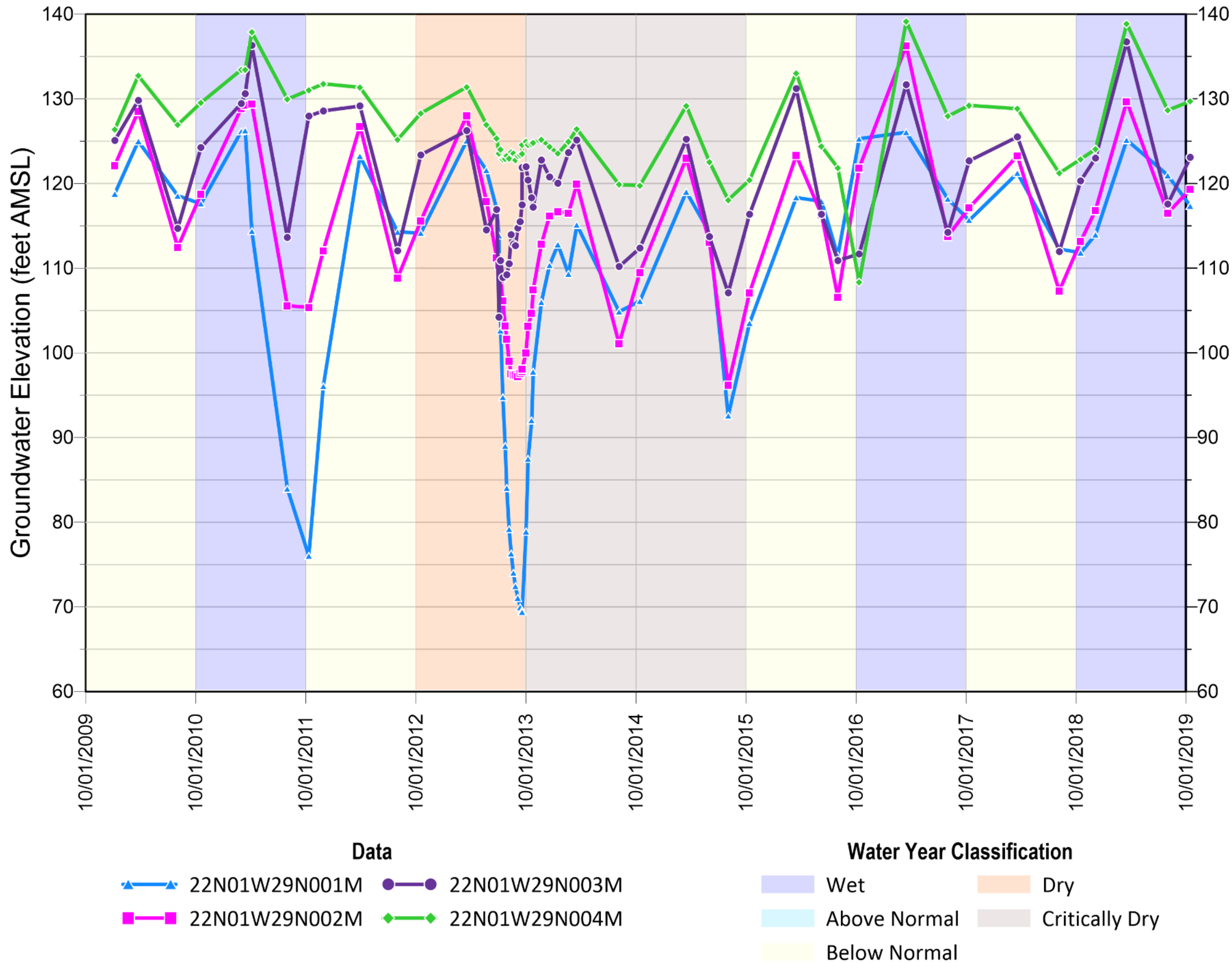

Figure 3-30. Groundwater Elevations in Clustered Wells 22N01W29N001M-N004M

Table 3-7. Screened Intervals and Total Depths of Clustered Wells 22N01W29N001M-N004M

Well Name	Well Type	Location	Screened Interval(s) (ft bgs)	Total Depth (ft bgs)
22N01W29N001M	Monitoring	South Area	859-879, 990-1010, 1116-1135	1204
22N01W29N002M	Monitoring	South Area	549-559, 595-605, 631-641	670
22N01W29N003M	Monitoring	South Area	189-199, 255-265, 320-330, 370-380	400
22N01W29N004M	Monitoring	South Area	89-99	120

3.2.3 Change in Groundwater Storage

Change in groundwater storage refers to the difference between the total amount of groundwater recharge and the total amount of groundwater withdrawals within the aquifer. Change in storage can be assessed on an annual basis to identify changes in the aquifer due to climate and water management in particular, or changes can be tracked over time, which leads to a cumulative change in storage. The cumulative change in storage provides longer-term overview and potential resiliency of the aquifer to changes over time.

As described in CDM, 2003:

> *Change in groundwater in storage is dependent on many factors, including climatic conditions, the annual rate of groundwater extraction, and the annual rate of groundwater recharge. Groundwater storage commonly fluctuates within a given year and from year to year. Groundwater in storage will typically decline during periods of drought and rebound during periods of above-normal precipitation. Within the same year, groundwater in storage will decline through the summer months as it is extracted for municipal and agricultural uses, then recover as extraction slows and seasonal precipitation increases recharge. In basins where the amount of annual groundwater extraction is at or below the amount of normal-year recharge, the long-term change in groundwater in storage will remain the same. In basins where the annual amount of groundwater extraction exceeds the amount of normal-year recharge, the long-term change in groundwater in storage will decline. Depletion of groundwater in storage is typically exhibited by a decline in groundwater levels during periods of normal precipitation.*

The C2VSim model is used to develop the complete water budget for the Corning Subbasin, as described in Section 4 – Water Budgets. Historical annual and cumulative change in groundwater storage over the historical period 1973-2015 is shown for the entire subbasin on Figure 3-31. The annual change in storage fluctuates with dry and wet climatic conditions. The average annual change in storage is 6,900 AF over the simulation period (water year 1974 to 2015), meaning that the Subbasin is gaining groundwater over this period (inflows to the subbasin exceed outflows, on average). The cumulative change in storage provides an overview of the total change in groundwater storage between 2 different points in time. It is obtained by adding the annual change in storage over the entire model simulation period to assess the long-term trend in groundwater storage change. The cumulative change in groundwater storage roughly corresponds to the average groundwater level change in the Subbasin over time. As shown on Figure 3-31, cumulative change in storage has generally increased between 1976 and 2005, recovering immediately after the initial drought of 1976-77. A second period of decrease occurring during the 1986-1992 drought. Since 2006, cumulative change in storage is declining, meaning more water is pumped out the aquifer than recharged, as evidenced in the hydrographs presented on Figure 3-25 and Figure 3-26. The cumulative change in storage between simulated year 2000 and 2015 is a net loss of 114,500 AF.

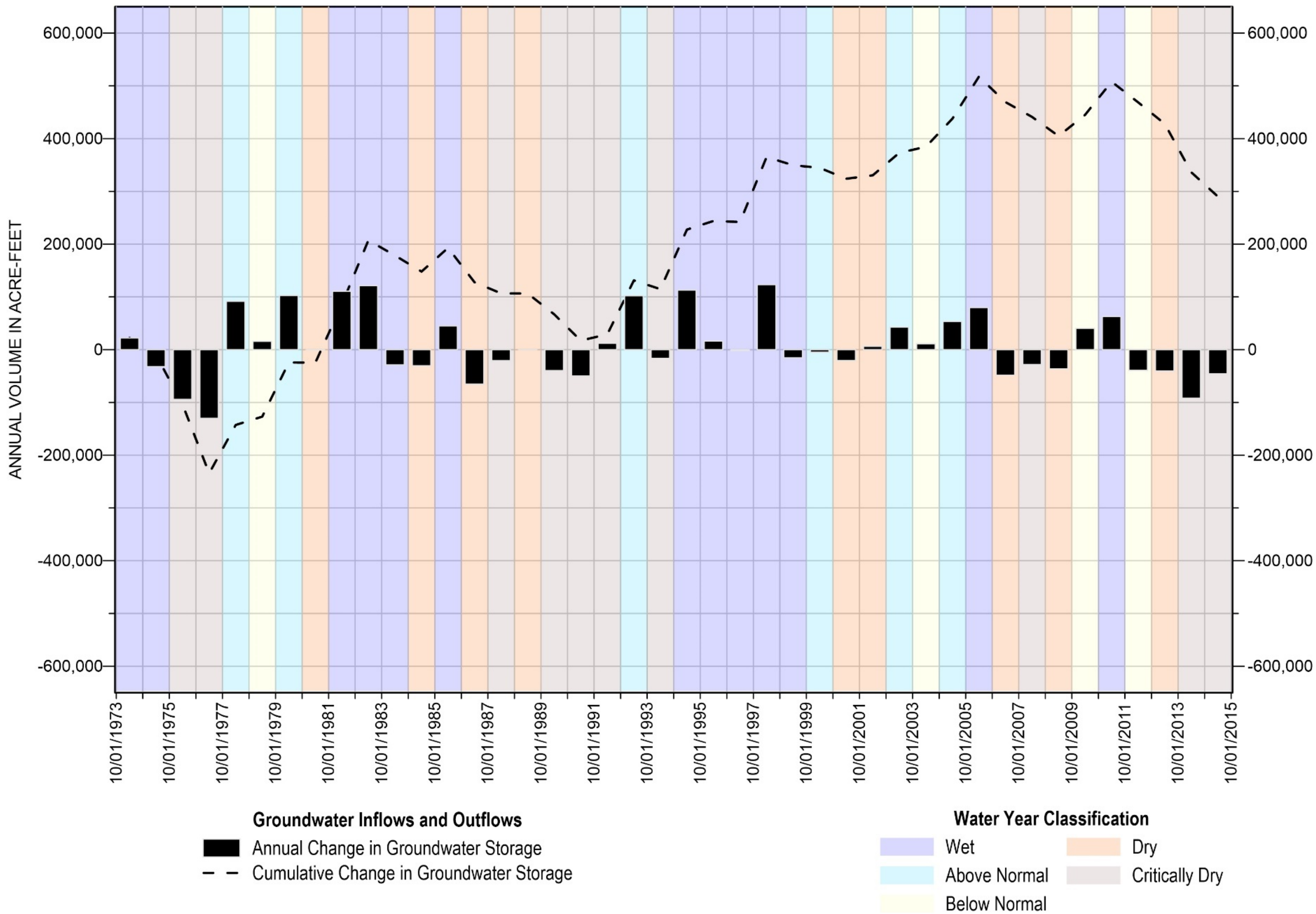

Figure 3-31. Historical Change in Groundwater Storage

3.2.4 Seawater Intrusion

Seawater intrusion is not an applicable sustainability indicator for the Corning Subbasin GSP, due to its distance from the Pacific Ocean, bays, deltas, or inlets. Therefore, seawater intrusion is not likely to occur in the Corning Subbasin.

The Corning Subbasin does not border any oceanic or deltaic environments and therefore seawater intrusion is not an applicable sustainability indicator in the Subbasin and is not further discussed in this GSP.

3.2.5 Land Subsidence

Land subsidence refers to the gradual lowering or sudden sinking of the land surface. There are many factors which can contribute to land subsidence, including groundwater pumping, drainage and decomposition of peatlands, underground mining, oil and gas extraction, hydrocompaction, natural compaction, sinkholes, and/or thawing permafrost. Amongst these causes of land subsidence, only aquifer-system compaction due to groundwater pumping is relevant to SGMA and is applicable to geology, water management, and land use in the Subbasin.

Aquifer-system compaction can occur in certain sedimentary basins where more groundwater is withdrawn than is being replenished, causing dewatering of sediments. Dewatering depressurizes the aquifer skeleton and compacts clay layering, leading to a decline in the ground surface. Aquifer-system compaction may be seasonal or otherwise non-permanent (elastic subsidence), or permanent (inelastic subsidence). Elastic subsidence is generally reversible while inelastic subsidence is generally irreversible and can lead to permanent land surface changes. Figure 3-32 illustrates the relationship between lowering groundwater elevation and land subsidence. Land subsidence occurs when groundwater elevations in an aquifer that contains clay layers fall below the previous lowest water levels, causing depressurization and compaction of clay layers.

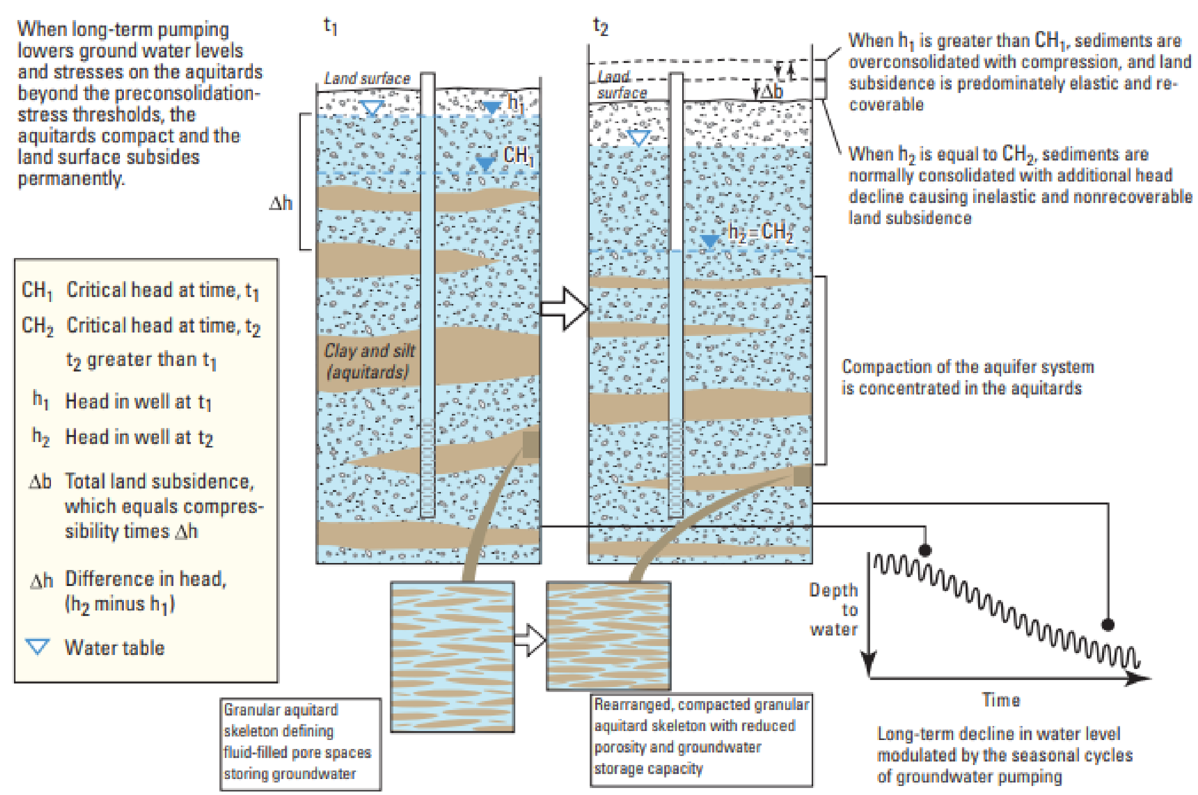

Figure B18. Relationship of water-level changes and critical heads to subsidence and inelastic compaction.

Figure 3-32. Illustration Showing Inelastic Subsidence (USGS, 2009)

Inelastic land subsidence can increase the risk of flooding, cause damage to overlying infrastructure, and reduce aquifer storage potential. Existing data presented in the following subsections suggest there is limited land subsidence in one area of the Corning Subbasin.

3.2.5.1 Sacramento Valley Subsidence Surveys

DWR and USBR jointly manage the Sacramento Valley Height-Modernization Project, which aims to characterize land subsidence due to groundwater withdrawal within the Sacramento Valley via survey benchmarks (DWR, 2008; DWR, 2018a). DWR performed extensive land surface elevation surveys in 2008 and 2017 over a network of survey monuments throughout the Sacramento Valley (DWR, 2018a) to identify any significant land subsidence between these 2 measurement timeframes. The network in the Subbasin includes 18 survey monuments spread across the portions of the Subbasin utilized for groundwater production (Figure 3-33).

Results displayed on Figure 3-33 indicate that only 1 monument (2966, 4 miles northwest of Orland) shows any statistically significant subsidence. From 2008 to 2017, the land surface elevation at this location decreased by approximately 0.3 foot. The stated uncertainty of these GPS measurements was 0.17 foot, meaning minor land surface elevation changes at other monuments in the Subbasin was essentially zero, or within the uncertainty bounds of the measurement device.

Additional limited measurements were collected at several of the Glenn County locations in 2004 and in 2015 (DWR, 2004a; DWR, 2015). The 2004 report included surveys of 3 of the 18 total monuments in the Subbasin (N852, HAMI, ORLA); between 2004 and 2008 the land surface elevation increased by 0.2 foot at N852 and HAMI, and the land surface elevation decreased at ORLA by 0.1 foot. These measurements were essentially within the range of uncertainty. In 2015, 2 of the 18 monuments were surveyed (ORLA and WILD). The measurement at ORLA was about equal to the measurement in 2008. The measurement at WILD was 1.32 feet less than in 2008. However, the reported elevation decrease at the WILD monument between the 2008 and 2017 valley-wide surveys was 0.117 foot (within the GPS measurement uncertainty), indicating no subsidence in this area. The result from WILD in 2015 appears to be an anomaly, particularly because this location is near the Sacramento River in an area with little groundwater use, stable groundwater levels, and no known historical land subsidence.

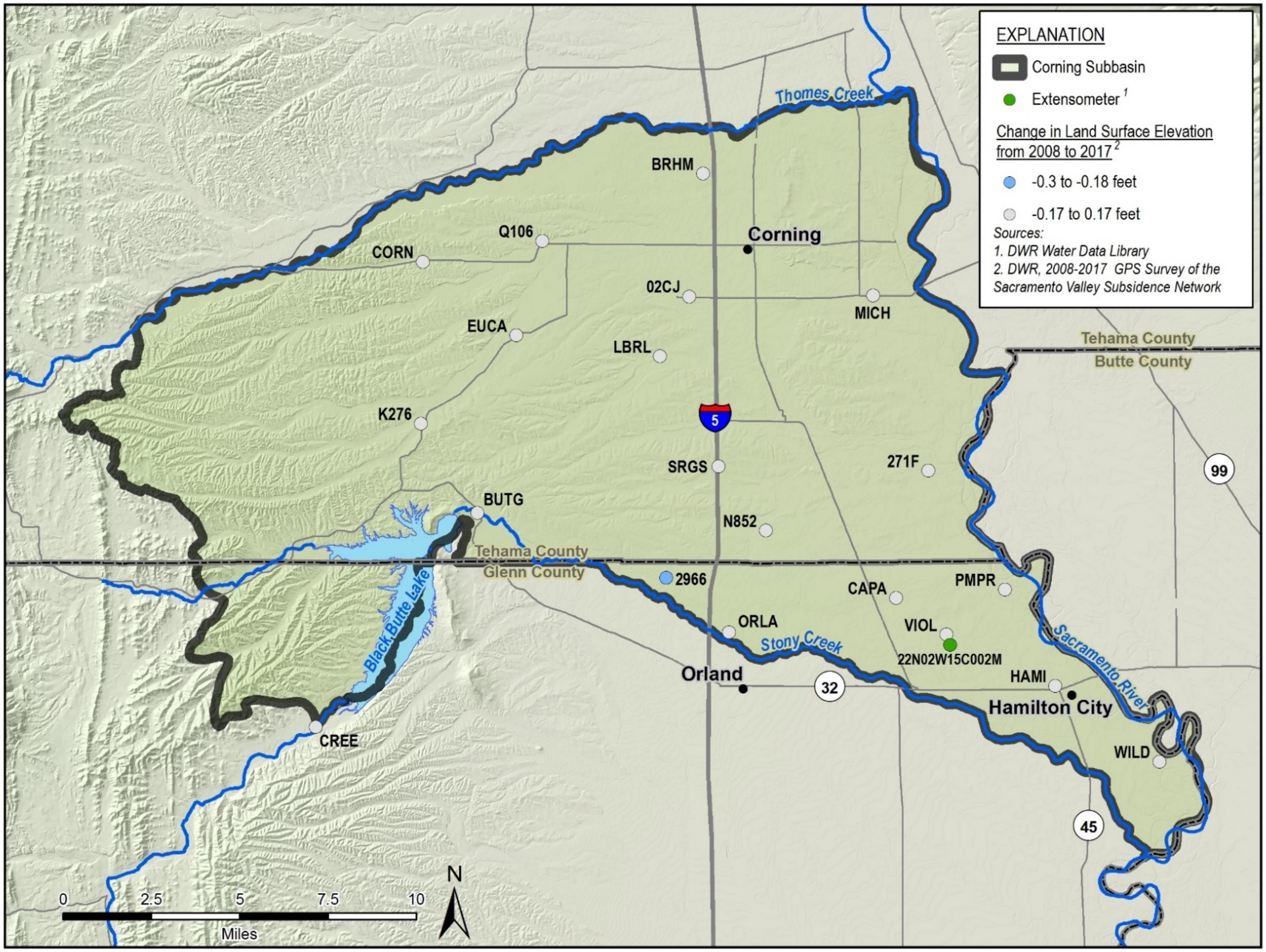

Figure 3-33. Subsidence Measurements Between 2008 and 2017 (DWR, 2018a)

3.2.5.2 DWR INSAR Subsidence Mapping

Interferometric Synthetic-Aperture Radar (InSAR) is a remote sensing technology that measures ground elevation using microwave satellite imagery data. DWR provides monthly InSAR data mapped over the entire state from June 2015 to June 2019.[2] The data were mapped for the Subbasin to compare the difference in land surface elevation between 2019 and 2015 (Figure 3-34). Over this period, land subsidence measured in the Subbasin was less than 0.1 foot. There are several small gaps in measurements adjacent to the Sacramento River, especially in the area near Hamilton City. Since groundwater levels fluctuate less near the Sacramento River than in other parts of the Subbasin, subsidence due to groundwater pumping in these areas are not as likely as in other areas of the Subbasin (Figure 3-21 through Figure 3-23).

As with any measurements, the InSAR data provided by DWR are subject to error. DWR has stated that, on a statewide level, the total vertical displacement measurements are subject to 2 error sources (DWR, 2019 and Towill, Inc., 2020):

1. The error between InSAR data and continuous GPS data is 16 mm (0.052 foot) with a 95% confidence level.
2. The measurement accuracy when converting from the raw InSAR data to the maps provided by DWR is 0.048 foot with 95% confidence level.

Simply adding the errors 1 and 2 results in a combined potential error of 0.1 foot (or 1.2 inches). While this is not a robust statistical analysis, it does provide an estimate of the potential error in the InSAR maps provided by DWR. A land surface change of less than 0.1 foot in the Subbasin between June 2015 and 2019 is within the noise of the data and is not considered statistically significant.

Figure 3-35. shows monthly subsidence measurements from this dataset at1 location near the Sacramento Valley Subsidence Survey monitoring location 2966. Monitoring location 2966 was the only location in the Subbasin with reported subsidence of 0.29 foot between 2008 and 2017 land elevation surveys (Figure 3-33; DWR, 2018a). The InSAR subsidence data from this location between June 2015 and June 2019 showed that approximately 0.1 foot of subsidence occurred during the timeframe. Some elastic subsidence is apparent from the displacement showing rebounding elevations in late 2016 and late 2017. But overall, the trend is downward, and this location will need to be monitored for future subsidence.

[2] https://data.cnra.ca.gov/dataset/tre-altamira-insar-subsidence/resource/2535a9b9-ed25-4b19-9734-4b1409e3fdce. Accessed February 19, 2020

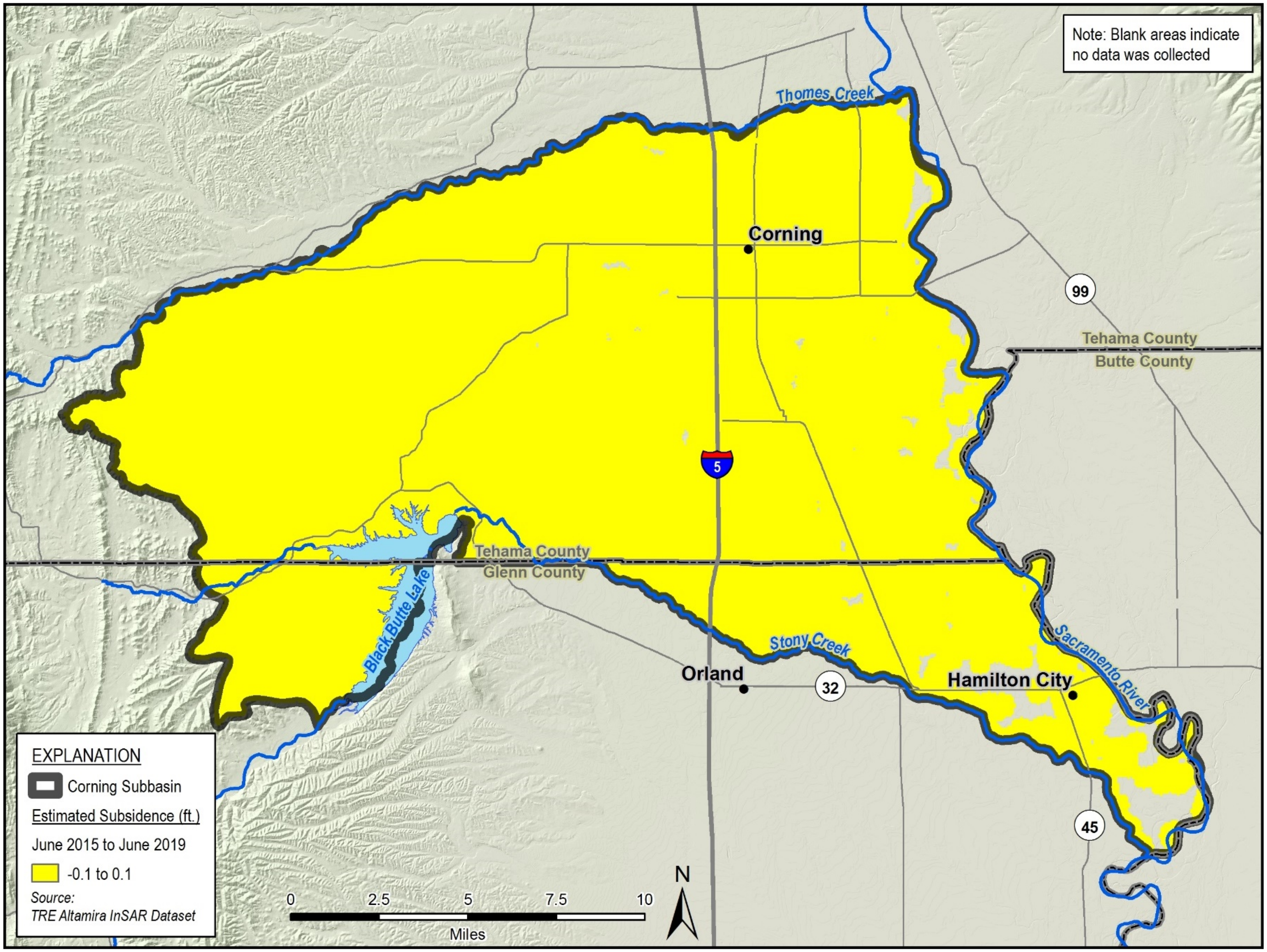

Figure 3-34. DWR InSAR Subsidence in Corning Subbasin, June 2015- June 2019

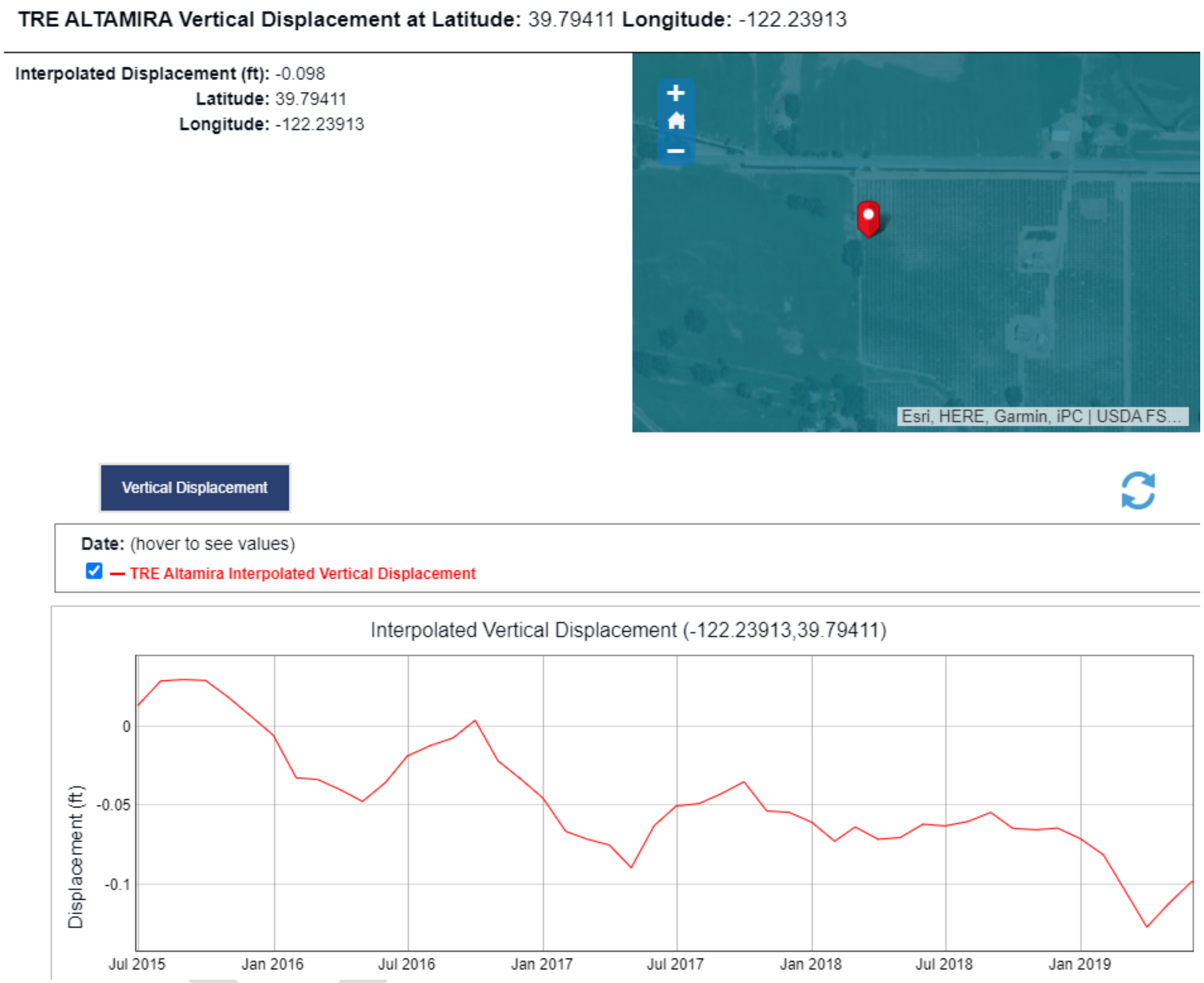

Figure 3-35. DWR InSAR Subsidence from June 2015 to June 2019 Near Sacramento Valley Subsidence Survey Location 2966.[3]

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

3.2.5.3 DWR Extensometer Measurements

An extensometer is an instrument consisting of a pipe or cable anchored at the bottom of a well casing and a recorder that measures the relative distance between the bottom of the borehole and the ground surface. Extensometers are used by DWR to measure aquifer-system expansion or compaction of the geologic material, measured as displacement at ground surface at 11 locations in the Northern Sacramento Valley.[4] Figure 3-35 shows the only extensometer location that the DWR has monitored in the Subbasin for this purpose. This well (22N02W15C002M) was installed with a screen from 759 to 780 bgs; therefore, the extensometer measures expansion and compression of the Quaternary alluvium and Tehama/Tuscan Formation aquifer systems at this location (Davids Engineering, 2018).

Land displacement and groundwater elevation data from the well and extensometer from 2004 to 2019 shown on Figure 3-35 suggest that the aquifer-system in this location is elastic. This means that the aquifer compacts slightly during the dry season when water levels are lower, but a relatively equal amount of expansion occurs in the following wet season when the water level is higher. The result of elastic expansion and compaction is that minimal net subsidence occurs over an annual cycle. Over the 14-year record, monthly ground surface elevation at the well fluctuated 0.12 foot from +0.08 and -0.04 foot. Between 2004 and 2019, the ground surface at the well rose about 0.05 foot in this location while the water table dropped by more than 10 feet. There are several small data gaps in the record, the longest of which spans 6 months from October 2012 to April 2013. Overall, the data display no inelastic subsidence in response to declines in groundwater elevation.

[4] https://data.cnra.ca.gov/dataset/wdl-ground-surface-displacement

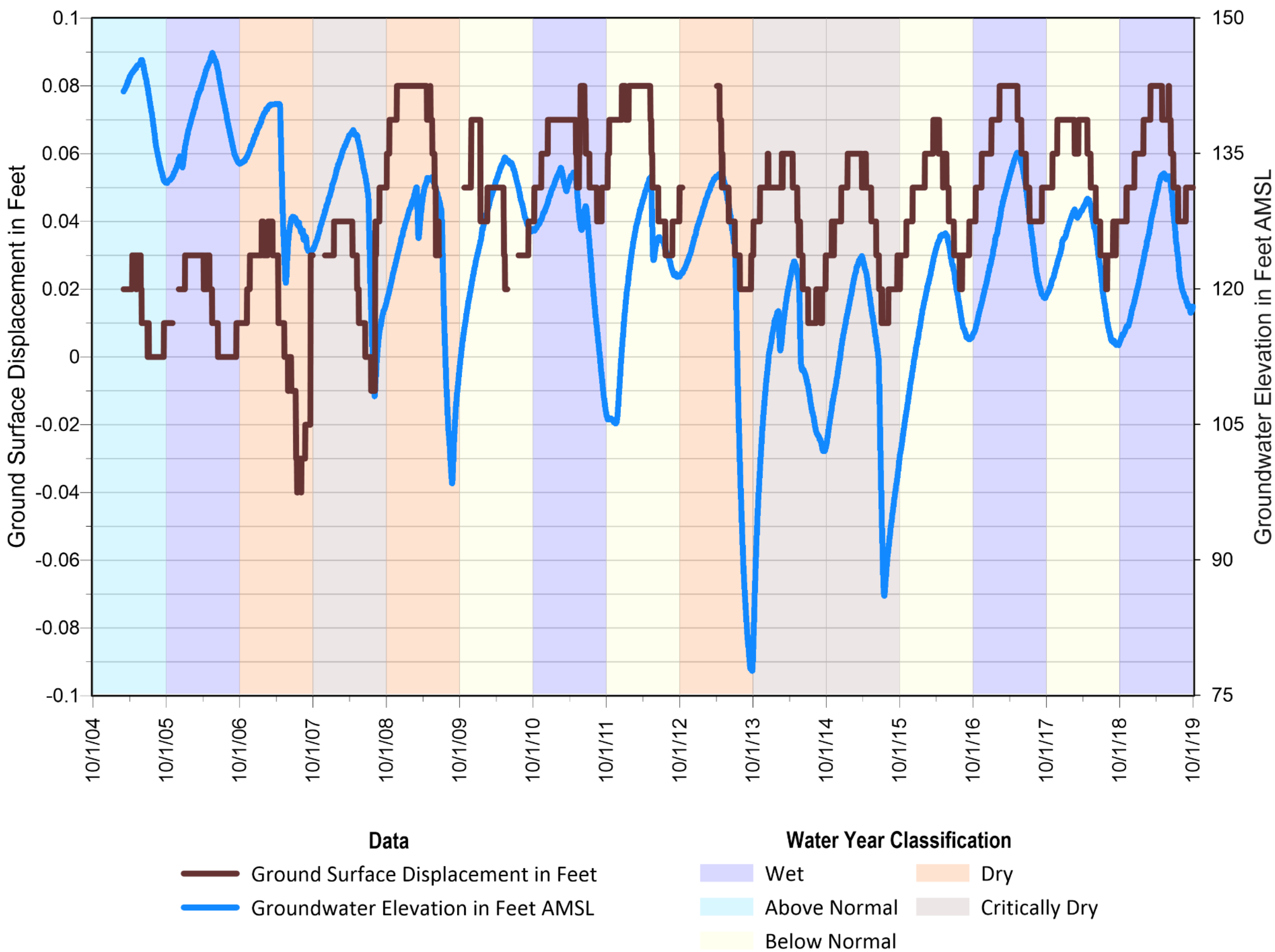

Figure 3-36. DWR Extensometer Measurements, 2004-2019

3.2.6 Groundwater Quality

Evaluation of groundwater quality conditions involves the observation and analysis of chemical concentrations in groundwater. Chemical concentrations are typically evaluated in regard to primary and secondary drinking water standards established by the U.S. Environmental Protection Agency (USEPA) and the California State Water Resources Control Board's DDW. These are also referred to as MCL and secondary maximum contaminant limits (SMCL). MCL are concentrations above which adverse effects on human health can occur. SMCL are concentrations above which aesthetic concerns for groundwater use can occur but are not health threatening. Aesthetic effects may include poor taste, odor, damage to pipes and pumps, and reduced effectiveness when treating for other constituents.

The following sections describe point source pollutants and non-point source groundwater constituents in the Corning Subbasin, focusing on constituents which have been detected above or near the MCL or SMCL. Point source pollutants are those which have1 isolated, typically well-defined anthropogenic source. Non-point source groundwater constituents occur over a wider potentially diffuse area and may be anthropogenic or naturally occurring. Anthropogenic pollutants are a result of human activities such as industry, agriculture, or home use while naturally occurring groundwater constituents are a result of natural geochemical conditions within the aquifer.

3.2.6.1 Point Sources of Groundwater Pollutants

Cleanup and monitoring of point source pollution may be overseen by either the Central Valley Regional Water Quality Control Board (Regional Board or CVRWQCB) or the California State Department of Toxic Substances Control (DTSC). These agencies make all related materials available to the public through 2 public portals: GeoTracker (https://geotracker.waterboards.ca.gov/) managed by the Regional Board and Envirostor (https://www.envirostor.dtsc.ca.gov/public/) managed by DTSC.

Figure 3-37 displays all historical cleanup sites in the Corning Subbasin, utilizing information from the GeoTracker database. These sites include leaking underground storage tank (LUST) sites, land disposal sites, dry cleaners, and agricultural facilities. Cleanup sites are generally clustered around the City of Corning and Hamilton City. Figure 3-38 shows cleanup sites within adjacent subbasins, close to the Corning Subbasin. Of a total of 51 sites in the Corning Subbasin, 7 sites remain open as of April 8, 2020. These sites are displayed on Figure 3-39, and summarized in Table 3-8. Open-case site designation indicates that some sort of contamination has occurred on site, and that remediation is ongoing. Six of the sites are in the northeastern potion of the Subbasin, while the seventh is located just east of Hamilton City. Figure 3-40 shows the only open cleanup cases adjacent to and near the Corning Subbasin are located in the Colusa Subbasin around the City of Orland.

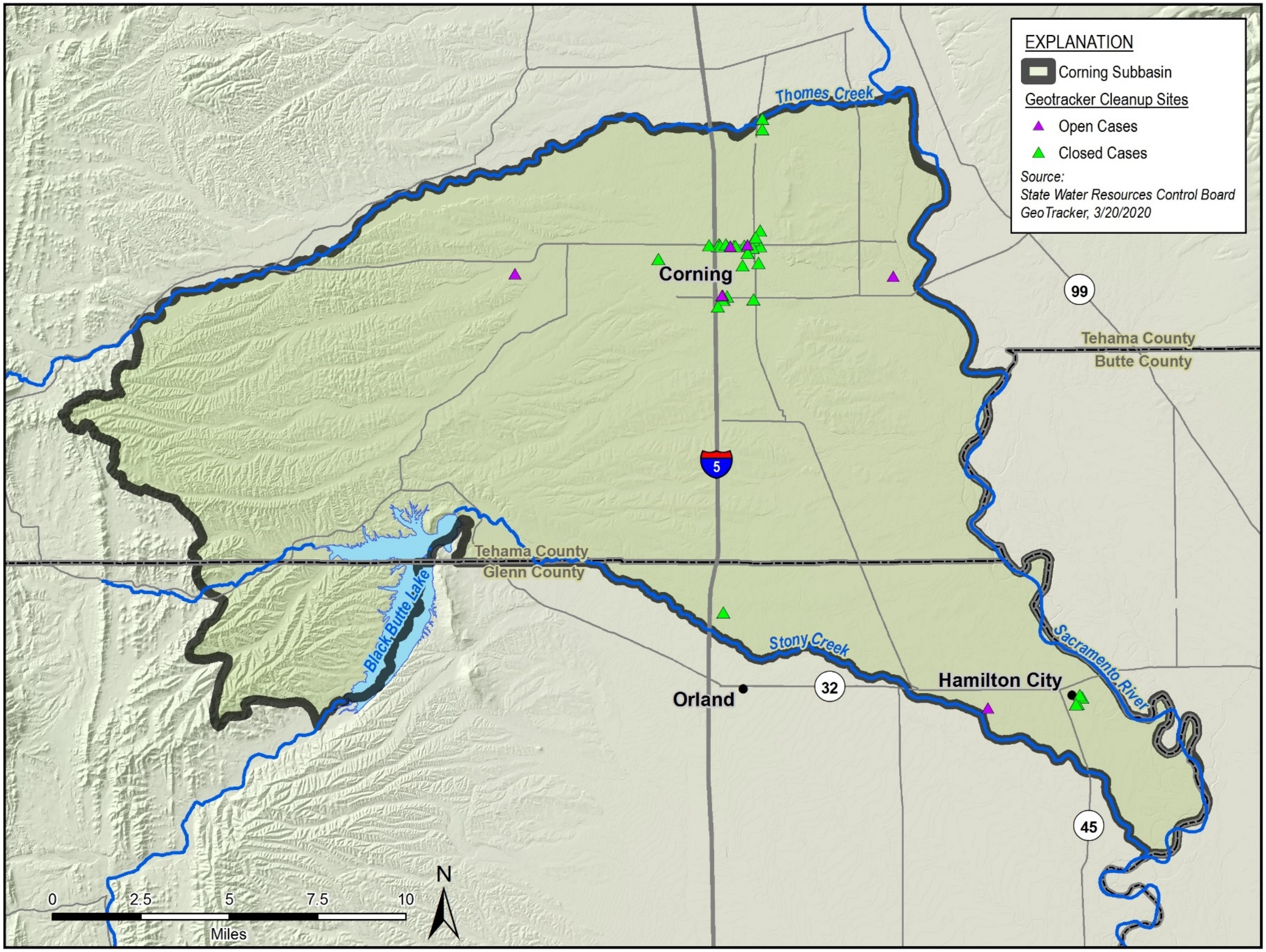

Figure 3-37. All Historic and Current Cleanup Sites within the Corning Subbasin

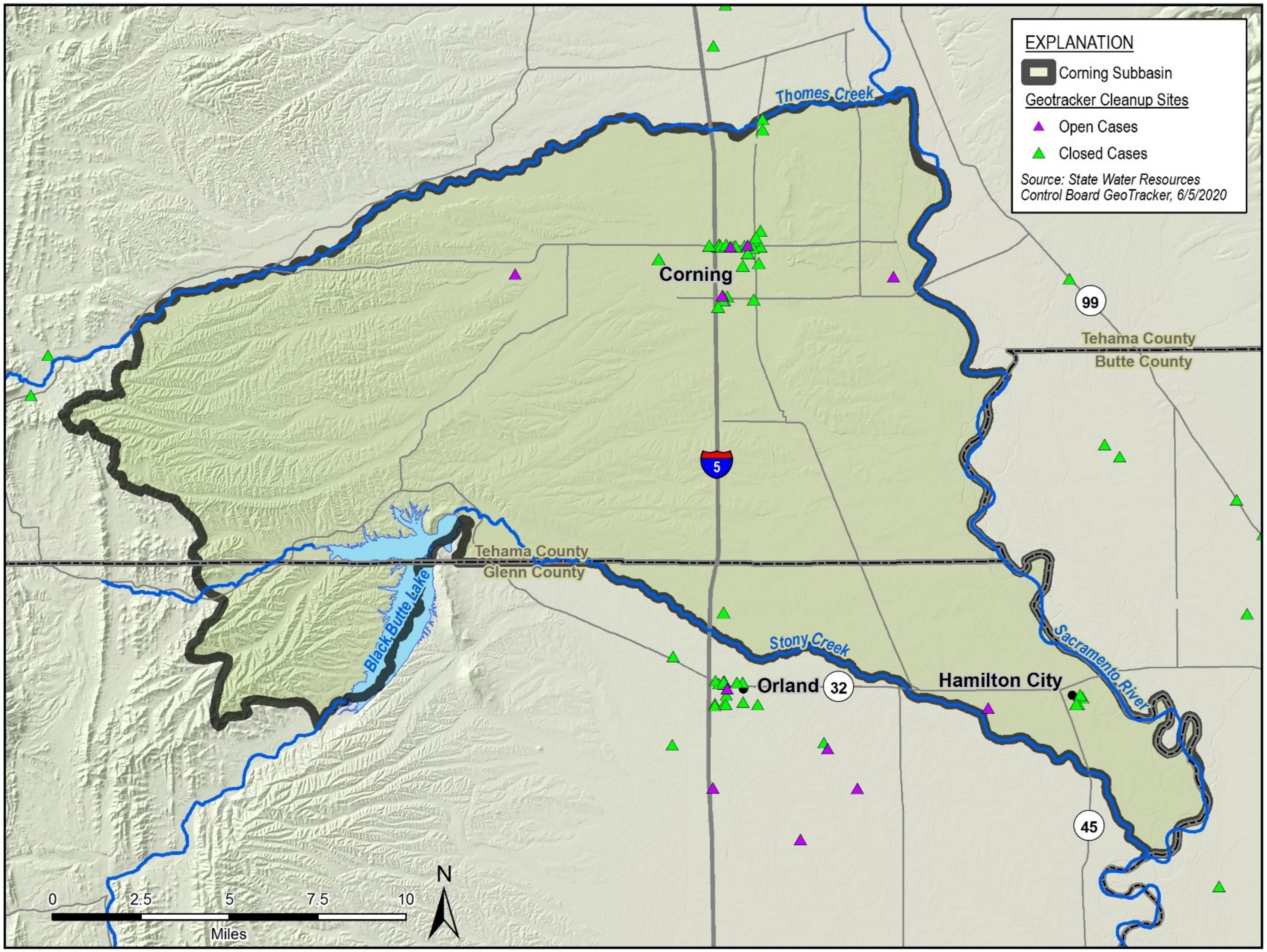

Figure 3-38. All Historical and Current Cleanup Sites within Adjacent Subbasins Close to the Corning Subbasin

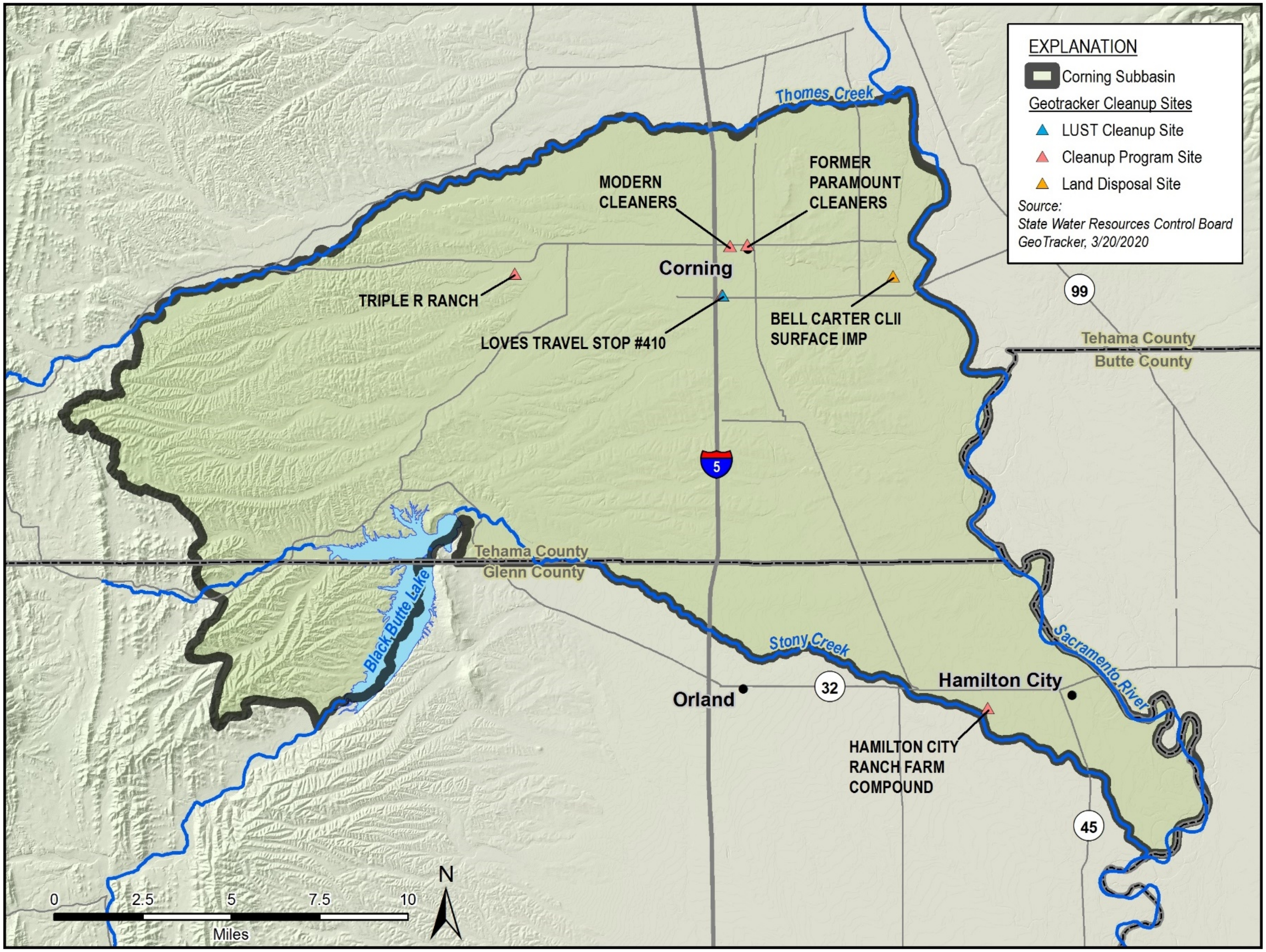

Figure 3-39. Open-Case Cleanup Sites Within the Corning Subbasin

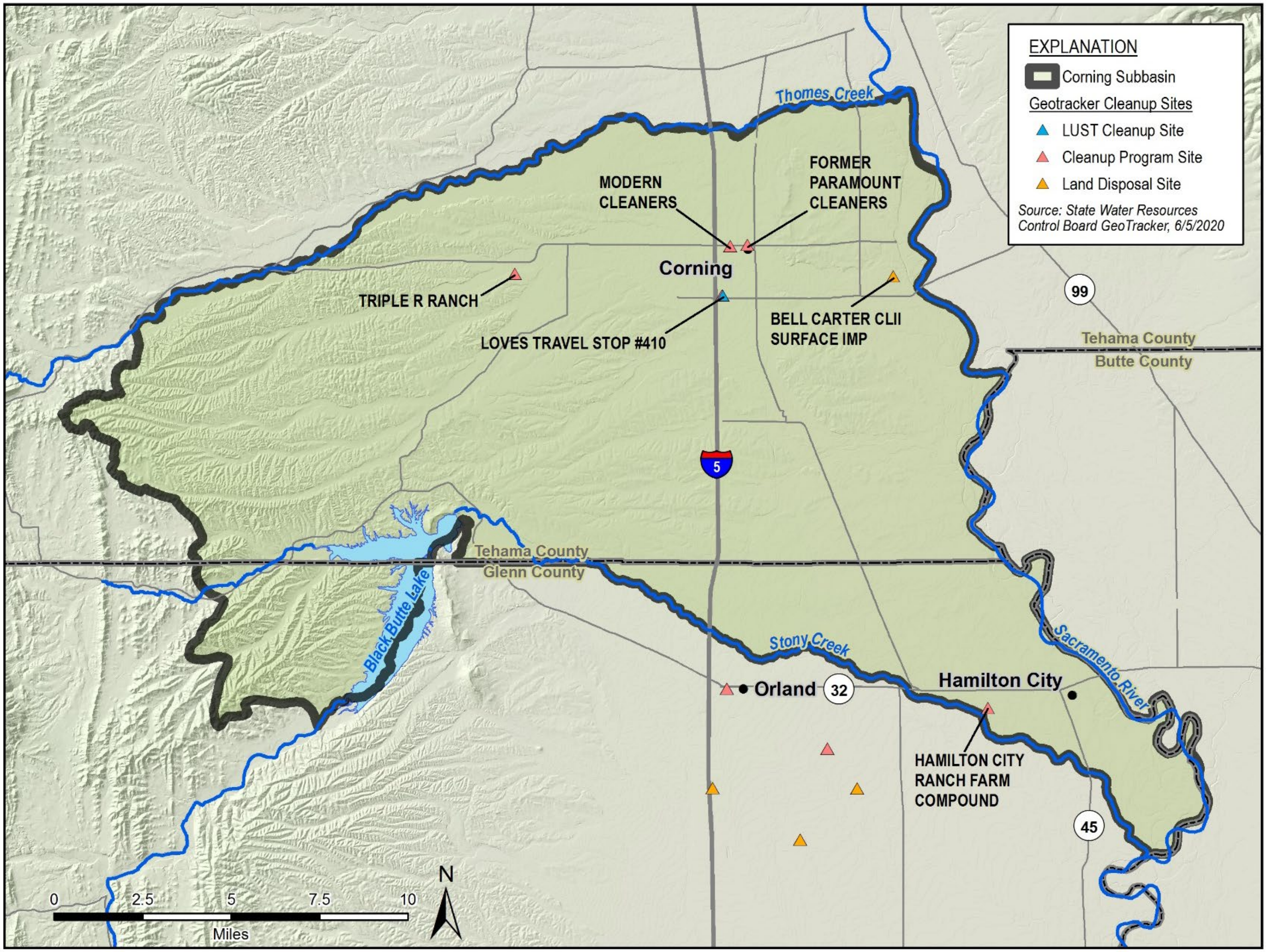

Figure 3-40: Open Case Cleanup Sites within Adjacent Subbasins Close to the Corning Subbasin

Table 3-8. Open-Case Cleanup Sites within the Corning Subbasin

Site	Site Type	Cleanup Status	Potential Constituents of Concern
Bell - Carter Olive Company, Inc.	Land Disposal Site	Operating	None Specified
Former Paramount Cleaners	Cleanup Program Site	Site Assessment	Tetrachloroethylene (PCE)
Hamilton City Ranch Farm Compound	Cleanup Program Site	Site Assessment	Diesel
Love's Travel Stop #410, Former Dudley and Petty	Cleanup Program Site	Site Assessment	Chlorinated Solvents - PCE, Chlorinated Solvents - TCE, Petroleum - Automotive gasolines, Petroleum - Diesel fuels
Love's Travel Stop #410, Former Dudley and Petty	LUST Cleanup Site	Verification Monitoring	Diesel, Gasoline, Tetrachloroethylene (PCE), Solvents, Trichloroethylene (TCE)
Modern Cleaners	Cleanup Program Site	Site Assessment	Tetrachloroethylene (PCE)
Triple R Ranch, Formerly Christian Boys Ranch	Cleanup Program Site	Inactive (Site Assessment complete, now inactive since 2016)	None Specified

Five open cleanup sites are located just south of the Corning Subbasin in the vicinity of Orland, as shown in Table 3-9 below. Because of their vicinity to the Corning Subbasin, pumping within the Corning Subbasin might affect the movement of these contaminants into the Subbasin.

Table 3-9. Open Cleanup Sites within City of Orland Vicinity

Site	Site Type	Cleanup Status	Potential Constituents of Concern
Compost Solutions Inc. Composting Facility	Land Disposal Site	Open - Operating	None Specified
Glenn County Airport - Orland	Cleanup Program Site	Open - Site Assessment	Other Insecticides / Pesticide / Fumigants / Herbicides, Toxaphene
K&S Spreading and Hauling, Inc.	Land Disposal Site	Open - Operating	None Specified
Orland Dry Cleaners	Cleanup Program Site	Open - Verification Monitoring	Tetrachloroethylene (PCE)
Sulara Enterprises Drilling Mud Disposal Facility	Land Disposal Site	Open - Closed/With Monitoring	None Specified

3.2.6.2 Distribution and Concentrations of Non-Point Source Groundwater Constituents

In addition to the point sources described above, the Regional Board monitors and regulates activities and discharges that can contribute to non-point source pollutants, which are constituents that are released to groundwater over large areas, such as from agricultural fields. The primary non-point source constituents of potential concern identified by prior studies in the Sacramento Valley are arsenic, boron, nitrate, and salinity. Of these, nitrate and salinity are the subject of most regional groundwater planning efforts. Arsenic and boron are naturally occurring COCs and are not commonly linked to groundwater management practices, but may affect drinking water supply and/or agricultural production.

Groundwater quality reports and databases reviewed to develop this section include the following:

- USGS summary of GAMA program comprehensive groundwater quality data collected in 2006 for the Middle Sacramento Valley Study Unit (USGS, 2008; USGS, 2011).
- NCWA and SVWQC summary of groundwater quality COC data from various sources collected between 1982 and 2012 for the 2014 Groundwater Quality and Assessment Report [(GAR), CH2M Hill, 2014] revised GAR in 2016 (CH2M, 2016), and Groundwater Quality Management Plan (CH2M, 2017).
- Water Board CV-SALTS program report summarizing nitrate and TDS high resolution maps for the Sacramento River Watershed, compiled from data collected from various sources between 2000 and 2016, including point source environmental assessment and remediation monitoring wells (LSCE, 2019b).
- Northern Sacramento Valley Dedicated Monitoring Well Groundwater Quality Assessment summary of data for a wide array of potential COCs and geochemical parameters collected by DWR from observation wells between 2015 and 2019 (DWR, 2020d).
- Water Board GeoTracker GAMA[5] groundwater information system geodatabase comprehensive groundwater quality data for public supply wells submitted to the Department of Drinking Water (DDW) downloaded on February 17, 2020.
- Water Board Drinking Water Needs Assessment webmap[6] compiles groundwater quality data between 1999 to 2019 and interpolates regional groundwater quality distribution maps for water quality constituents including nitrate and arsenic, but not TDS. The data is presented as a combination of 2 statistical analyses: 1) Public Land Survey System

[5] https://gamagroundwater.waterboards.ca.gov/gama/gamamap/public/
[6] https://gispublic.waterboards.ca.gov/portal/apps/webappviewer/index.html?id=292dd4434c9c4c1ab8291b94a91cee85

(PLSS) section average concentration between 1999 and 2019, and 2) PLSS section with MCL exceedances between 2016 and 2019. The analysis also uses a nearest neighbor approach to interpolate data in sections with no water quality data.

- Water Board Safe and Affordable Funding for Equity and Resilience (SAFER) aquifer risk webmap[7], that compiles groundwater quality data from the GAMA geodatabase collected between 2000 to 2020 and delineates water quality risk relative to domestic well locations for constituents including nitrate and arsenic.

In the early 2000's, the State Water Resources Control Board partnered with the USGS to monitor groundwater quality in the State, as part of the GAMA Program's Priority Basin Project. The Corning Subbasin was monitored in 2006, along with other subbasins (Colusa, Vina, East and West Butte, Sutter, North and South Yuba – from the Bulletin 118 basin determinations at the time the report was written) within the Middle Sacramento Valley Study Unit. This study provided a regional overview of groundwater quality and identified potential COCs for drinking water and agricultural use. Groundwater samples collected from 108 wells in this study were analyzed for up to 280 constituents, and 195 of those constituents were not detected in any of the samples (USGS, 2008).

The main conclusions of this comprehensive study are as follows (USGS, 2008):

> *Groundwater samples were analyzed for volatile organic compounds (VOCs), pesticides and pesticide degradates, constituents of special interest, pharmaceutical compounds, nutrients, major and minor ions, trace elements, radioactivity, and microbial indicators.*
>
> *Regulatory thresholds apply to treated water that is served to the consumer, not to raw ground water. However, to provide some context for the results, concentrations of constituents measured in the raw ground water were compared with health-based thresholds established by the U.S. Environmental Protection Agency (USEPA) and the California Department of Public Health (CDPH). All detections of VOCs, pesticides, and pesticide degradates were below health-based thresholds, and most were less than one-hundredth of the threshold values. All detections of perchlorate, and radioactive constituents were below established thresholds.* ***Arsenic, nitrate, and boron were the only constituents detected at concentrations above health-based thresholds****.* ***Total dissolved solids, specific conductance, pH, iron, chloride, sulfate, and manganese were detected at concentrations above the SMCL-CA, a non-enforceable threshold set for aesthetic concerns****.*

Arsenic and boron are generally considered to be naturally occurring within the aquifer sediments and might leach into groundwater under certain geochemical conditions, then are

[7] https://gispublic.waterboards.ca.gov/portal/apps/webappviewer/index.html?id=17825b2b791d4004b547d316af7ac5cb

pumped out via wells. Arsenic can be a health hazard at relatively low concentration of 0.01 milligram per Liter (mg/L). Boron is mostly of concern for irrigating crops, as many crops have a low tolerance to boron, at levels below human health hazard level of 1,000 mg/L. In the Corning Subbasin, boron was detected at low levels (USGS, 2011), and therefore is not a COC in the Subbasin.

Nitrate can be naturally occurring, but when encountered at higher than typical natural background concentrations (generally above 3 mg/L) human activity is often the source of the constituent in groundwater. Nitrate is considered a human health hazard, particularly for pregnant women and infants.

Salinity is not generally a high risk for drinking water and primarily affects taste, odor, damage to pipes and pumps, and reduced effectiveness when treating for other constituents. However, many crops have low tolerance for salinity, primarily tree crops such as almonds.

The primary non-point source COCs in the Central Valley, due to the intense agricultural practices, are salinity or TDS and nitrate. These constituents have been studied in the Central Valley as part of the CV-SALTS and summarized in a series of technical reports including the mapping report by LSCE (2019b) described above.

Salinity in the eastern portion of the Subbasin is generally low and meets the relevant drinking water standards for TDS. However, sufficient data are not available at this time to adequately delineate salinity in the western Subbasin. In general, TDS concentrations in the western Sacramento Valley are highest at the margin of the Coast Ranges and can naturally be above secondary drinking water standards due to local hydrogeologic factors and the presence of marine sediments (CH2M, 2016).

With respect to nitrate, the CV-SALTS technical analysis classifies the Corning Subbasin as a low priority Initial Analysis Zone[8] due to its overall low nitrate concentration in groundwater. The main source of nitrate in the Sacramento Valley is nitrogen fertilizers, however, septic systems and dairy farms are also potential sources (CH2M, 2017).

The Northern Sacramento Valley Dedicated Monitoring Well Groundwater Quality Assessment (DWR, 2020d) includes water quality analysis results from 2017 samples collected from 30 DWR observation wells in 7 clusters in the Corning Subbasin. Overall, the report finds that ambient groundwater quality in the Corning Subbasin is good as the water meets the regulatory requirements for drinking water supply. The report erroneously identified several locations in the Subbasin with nitrate results greater than the MCL, due to total dissolved nitrate being compared to the nitrate as nitrogen MCL of 10 mg/L (instead of comparing to the 45 mg/L nitrate MCL).

[8] https://www.cvsalinity.org/nitrate-control-program.html

The correct results are available through the SWRCB GAMA database and show that in fact, these values are below the nitrate as nitrogen MCL.

The GAMA geodatabase, Drinking Water Needs Assessment, and SAFER webmaps are based on the same data compiled by the Water Board used in many of the other regional studies. The data available through these sources have similar findings to the other regional studies. In general, groundwater quality in the Subbasin meets the regulatory drinking water limits with exception of a few isolated results for each constituent.

Beneficial uses that could be affected by non-point source groundwater pollution include municipal and domestic drinking water, agricultural irrigation, and industrial manufacturing and services.

3.2.6.3 Summary of the Major Groundwater Quality Concerns in the Subbasin

Major groundwater quality concerns are constituents with elevated or increasing concentrations, defined relative to the respective MCL and SMCL. Constituents identified as groundwater quality concerns within the Subbasin are identified in the bullets below and summarized in the following subsections.

- Salinity (EC and TDS)
- Nitrate
- Arsenic

3.2.6.3.1 Salinity (EC and TDS)

Elevated salinity in groundwater may occur from natural hydrogeologic factors or as a result of anthropogenic groundwater contamination. Salinity in groundwater is often measured using TDS, which is the measure of all dissolved substances in groundwater. TDS consist of inorganic salts and small amounts of organic matter, and are strongly correlated with electrical conductivity (EC, also referred to as specific conductance). TDS and EC are both used as indicators of salinity levels in groundwater. The recommended SMCL for TDS is 500 mg/L, and the upper limit SMCL is 1,000 mg/L. Beyond 1,000 mg/L, water is non-potable and requires significant desalinization treatment. Analysis of TDS data reviewed for the GAR found that wells located near the City of Corning had concentrations of TDS above the 500 mg/L recommended SMCL (CH2M, 2016). No wells exceeded the TDS upper limit SMCL of 1,000 mg/L.

Figure 3-41 and Figure 3-42 display the TDS concentration in the Subbasin's upper and lower groundwater zones showing some of the most recent available data in the Sacramento Valley based on CV-SALTS data analysis (LSCE, 2019b). These TDS maps were developed from average measured TDS data at wells located primarily within the eastern portion of the Subbasin and modeled ambient TDS concentrations throughout the entire Subbasin. The upper zone includes the production zones of most domestic wells, while the lower zone includes the production zones of most municipal and other production wells. While these upper and lower zones vary spatially, analysis of domestic well screens suggest the lower zone is generally no deeper than 250-300 feet bgs within the Subbasin.

Data collected in the eastern portion of the Subbasin had TDS concentrations generally less than the SMCL of 500 mg/L with slightly greater concentrations in the upper zone than in the lower zone. TDS concentrations were estimated up to 750 mg/L in the upper and lower zones of the western Subbasin, though model interpretation was based on TDS data from outside the Subbasin boundaries.

The DWR observation well monitoring report identified 2 observation wells in 1 well cluster with TDS results above the upper SMCL of 1,000 mg/L in the Glenn County portion of the Subbasin (DWR, 2020d). The results in this location appear to be anomalously high compared to other regional water quality data. This observation well is near an active dairy and could be influenced by its operations.

Historical data from public supply wells submitted to DDW correlate well with the information discussed above. Since 1990 almost all public supply well TDS data on the GAMA geodatabase are less than 400 mg/L (Figure 3-43). Over the last 20 years, TDS concentrations in City of Corning and Hamilton City municipal wells have been generally stable around 200 mg/L and 300 mg/L, respectively. Not every public supply well is routinely sampled for TDS and wells that are routinely sampled are done so infrequently at 3- or 9-year intervals.

In general, wells in the western area of the Subbasin are screened to shallow depths reflecting limited vertical extent of the Tehama Formation. Well depth decreases to the west, reflecting a thinning or 'pinching out' of the Tehama formation, consistent with the Subbasin HCM (see cross section A-A'). Beneath the Tehama lies the saline Great Valley Sequence. Screening in this sequence would yield saline water. If groundwater levels decline, or freshwater recharge is limited, pumping may result in upwelling of this saline water. TDS values in the western Subbasin at Black Butte Lake Recreation Area headquarters and campground are historically below the SMCL. Data from the Flournoy Elementary School exhibit stable detections of TDS around the SMCL of 500 mg/L (Figure 3-44); this school is in the Red Bluff Subbasin in the community of Flournoy, which is just north of the Corning Subbasin boundary formed by Thomes Creek. The following conclusions can be derived from available data in the western portion of the Subbasin:

- Salinity in the western area of the subbasin is naturally occurring, associated with saline formations underlying the Tehama Formation, particularly the Great Valley Sequence.
- Available salinity data does not display a significant increasing trend (Figure 3-43).

- Wells in the western area of the Subbasin are generally shallow, presumably to avoid being screened in the saline Great Valley Sequence, or the low-yielding and saline Sierran Basement.
- Based on hydrogeological understanding of the area, decreases in groundwater recharge or overpumping could result in upwelling of high salinity from the Great Valley Sequence into the Tehama Formation.

Overall, TDS in the Subbasin is below the upper SMCL and is generally below the lower SMCL. The western area of the Subbasin may contain elevated TDS above the lower SMCL resulting from natural geologic sources, but there is currently insufficient available data to delineate salinity in this area. Isolated shallow groundwater wells near the City of Corning and the Tehama and Glenn County line near Hamilton City may contain elevated TDS from anthropogenic point sources and dairies. The overall TDS trend in the Subbasin is slightly upward in recent history, which is potentially a result of changes in land use and increased irrigation with groundwater (Figure 3-43; CH2M, 2016).

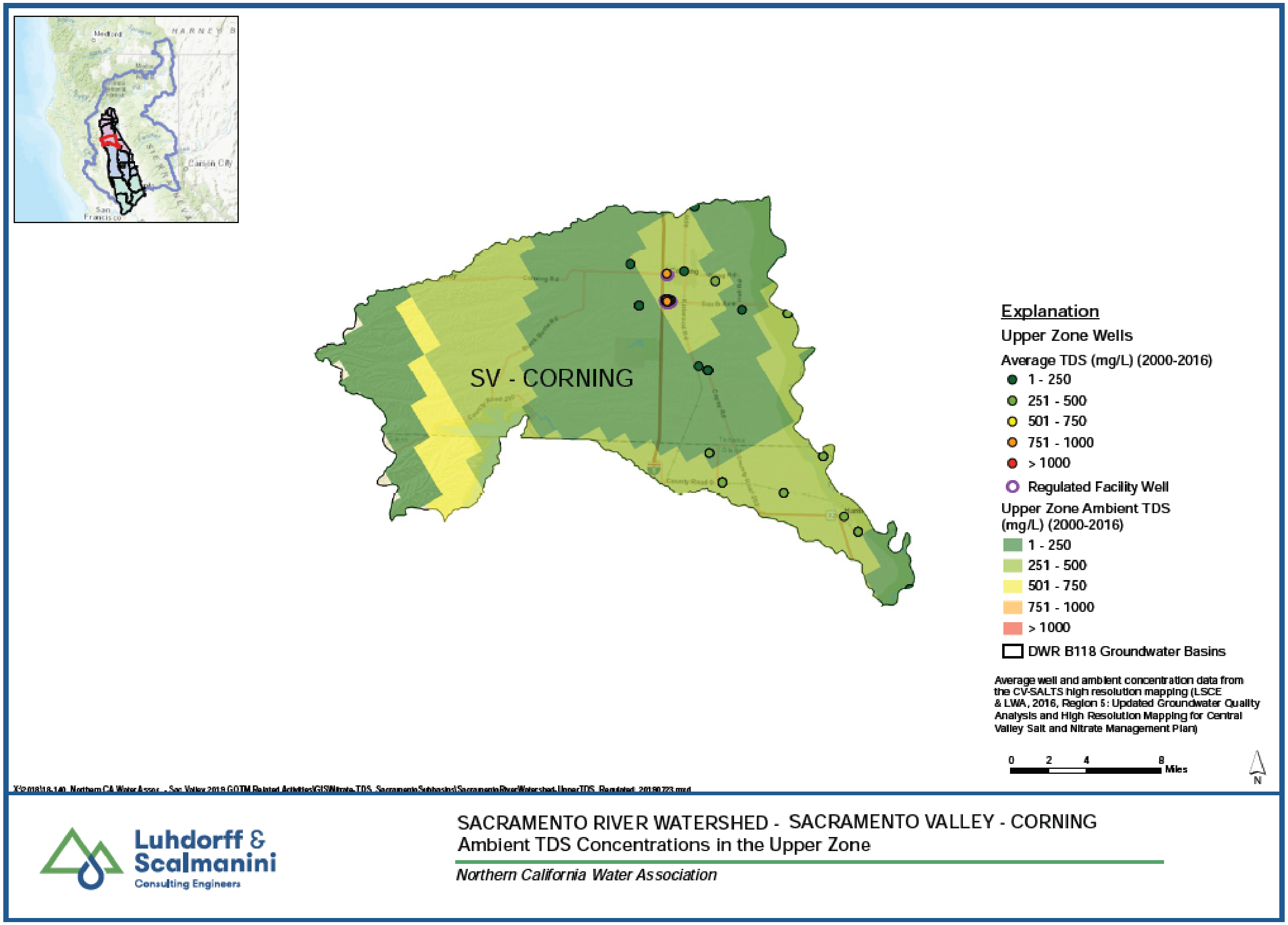

Figure 3-41. Upper Zone TDS Concentration in Corning Subbasin, 2000-2016

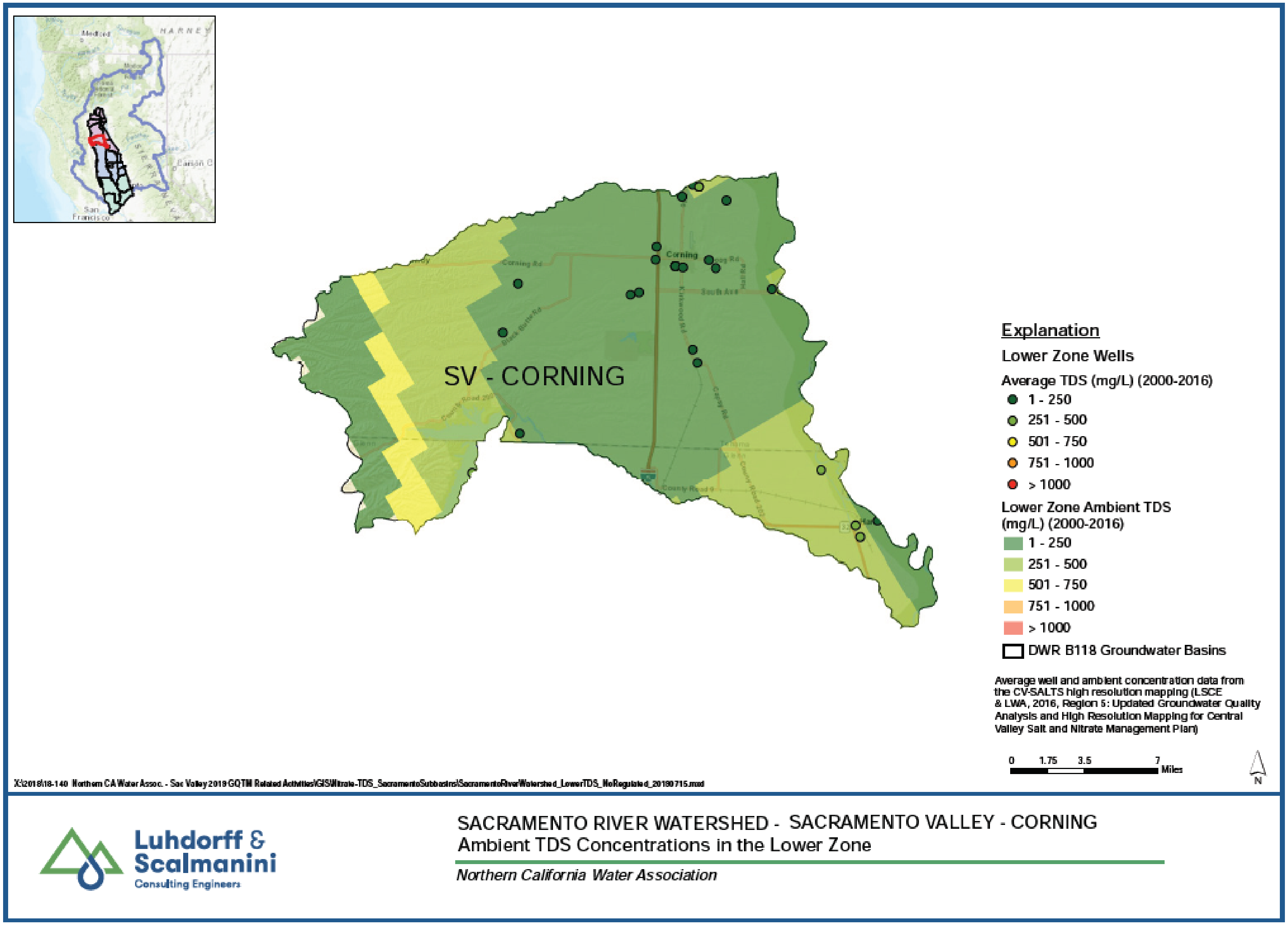

Figure 3-42. Lower Zone TDS Concentration in Corning Subbasin, 2000-2016

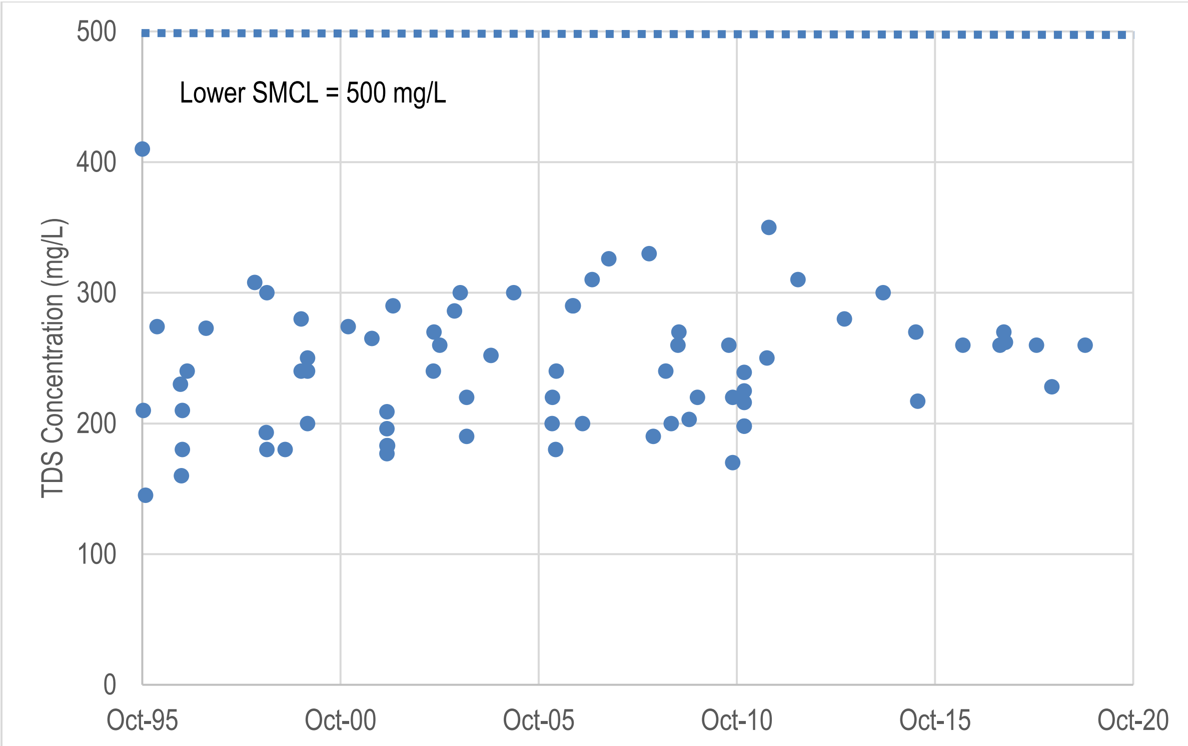

Figure 3-43. TDS Detections in Active Supply Wells (GAMA, 2020)

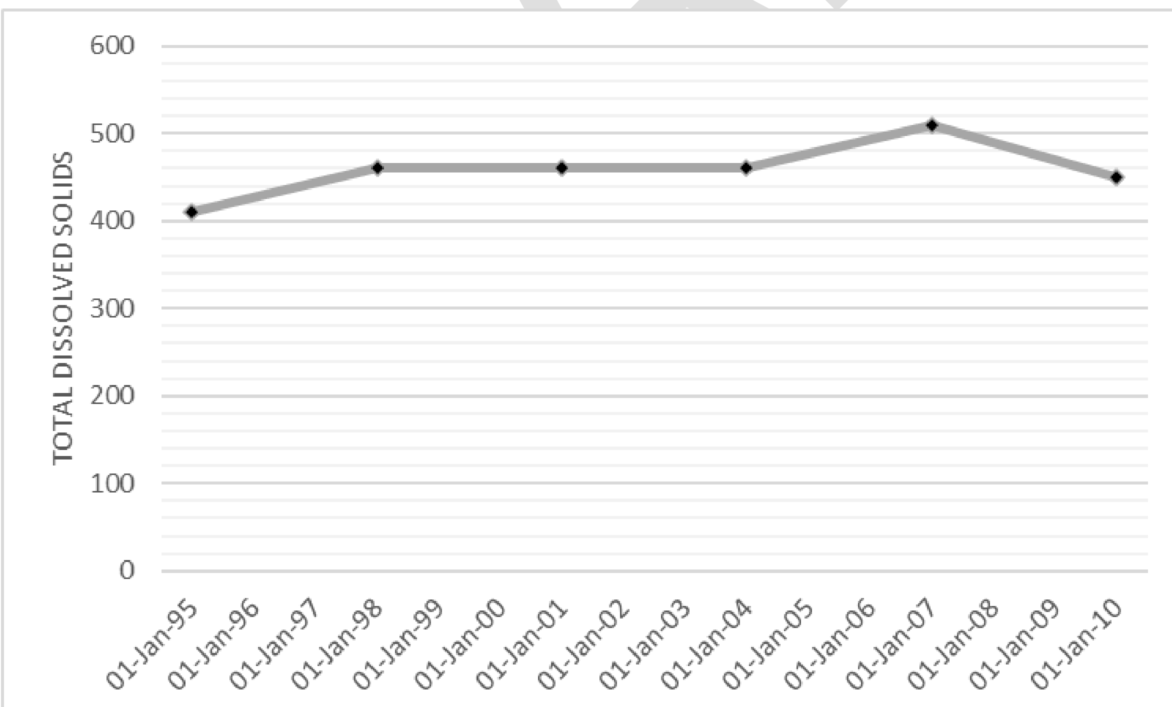

Figure 3-44. Flournoy Public School Well TDS Concentrations

3.2.6.3.2 Nitrate

Nitrate in groundwater is typically anthropogenic and can originate from nitrogen fertilizers, dairy farms, and septic systems. Nitrate may be a health hazard and may lead to over-nitrification of surface waters that promote the proliferation of nitrogen-tolerant plants. Some reports and data sources summarize nitrogen concentrations as NO3 (Nitrate-NO3) for which the MCL is 45 mg/L and other reports and data sources reviewed summarize nitrogen concentrations as N (Nitrate-N) for which the MCL is 10 mg/L.

Historical nitrate concentrations analyzed for the GAR indicate that nitrate concentrations are typically less than the MCL but that concentrations are slightly increasing within the Subbasin (CH2M, 2016). CV-SALTS program modeled ambient nitrate concentrations in the Subbasin's upper and lower groundwater zones show similar findings on Figure 3-45 and Figure 3-46, respectively (LSCE, 2019b). A few wells within the Subbasin in both the GAR and CV-SALTS analysis exceed the MCL for nitrate. The maximum nitrate concentration reported in the CV-SALTS assessment was 31.7 mg/L Nitrate-N (LSCE, 2019b), though this sample appeared to be from a shallow point source contaminant assessment and remediation well and therefore does not likely reflect nitrate conditions in the aquifer depths used for drinking water supply. Other wells with MCL exceedances screened in the upper zone near the City of Corning and in the upper and lower zones in northeastern Glenn County, appear to not reflect regional groundwater quality trends and are likely related to anthropogenic sources such as septic releases and dairies. Across the Subbasin, nitrate concentrations are generally higher in the upper zone.

Supply well data on the GAMA geodatabase shows that nitrate concentrations are below the MCL in active supply wells, but concentrations have a slight increasing trend over time. The maximum concentration for all samples collected from active public supply wells since 1990 is 8 mg/L as shown on Figure 3-47. Nitrate concentrations over time in representative City of Corning and Hamilton City wells are shown on Figure 3-48 and Figure 3-49. The nitrate concentration in the City of Corning wells is stable and the maximum concentration reported by DDW is less than 4 mg/L since 1995. In Hamilton City, the nitrate concentration was close to 7 mg/L in 1 well between 2006 and 2013, but has been less than 5 mg/L in recent years.

The Water Board Drinking Water Needs Assessment webmap uses the publicly available data on the GAMA geodatabase to assess drinking water risk. The webmap shows average nitrate concentrations by section using data collected over the past 20 years and also calls out locations with recent nitrate exceedances of the MCL in the past 3 years. The webmap shows 1 well in the Subbasin exceeded the nitrate MCL between 2016 and 2019. Apart from this one section with an MCL exceedance, average nitrate concentrations for PLSS sections are less than 5 mg/L. The well where the exceedance occurred is actively monitored by the Water Board under the jurisdiction of the ILRP and its maximum concentration reported on the GAMA geodatabase was 15 mg/L in July 2019.

The SAFER online webmap uses similar data to the Drinking Water Needs Assessment, but interpolates aquifer risk as low, medium, or high based on historical groundwater quality data and domestic well locations. The webmap shows that the aquifer risk for nitrate contamination of drinking water wells is low except for the area around the ILRP well to the northwest of Corning.

Overall, nitrate in the Subbasin is below 8 mg/L in public supply wells and is generally below the MCL in ambient groundwater with exception of some isolated shallow groundwater wells near the City of Corning and along the Glenn and Tehama County border. The areas with nitrate concentration greater than the MCL are likely related to anthropogenic point sources such as septic releases, dairies, and contaminant assessment and remediation sites regulated by various Water Board regulatory programs. The overall nitrate trend in the Subbasin is slightly upward in recent history, which may eventually pose a risk to water quality in some areas within the Subbasin should this trend continue (Figure 3-47; CH2M, 2016). Based on this information, nitrate is not a COC for the GSP, as it is rarely detected at concentration exceeding the MCL and where it is found, is monitored by other Water Board regulatory programs.

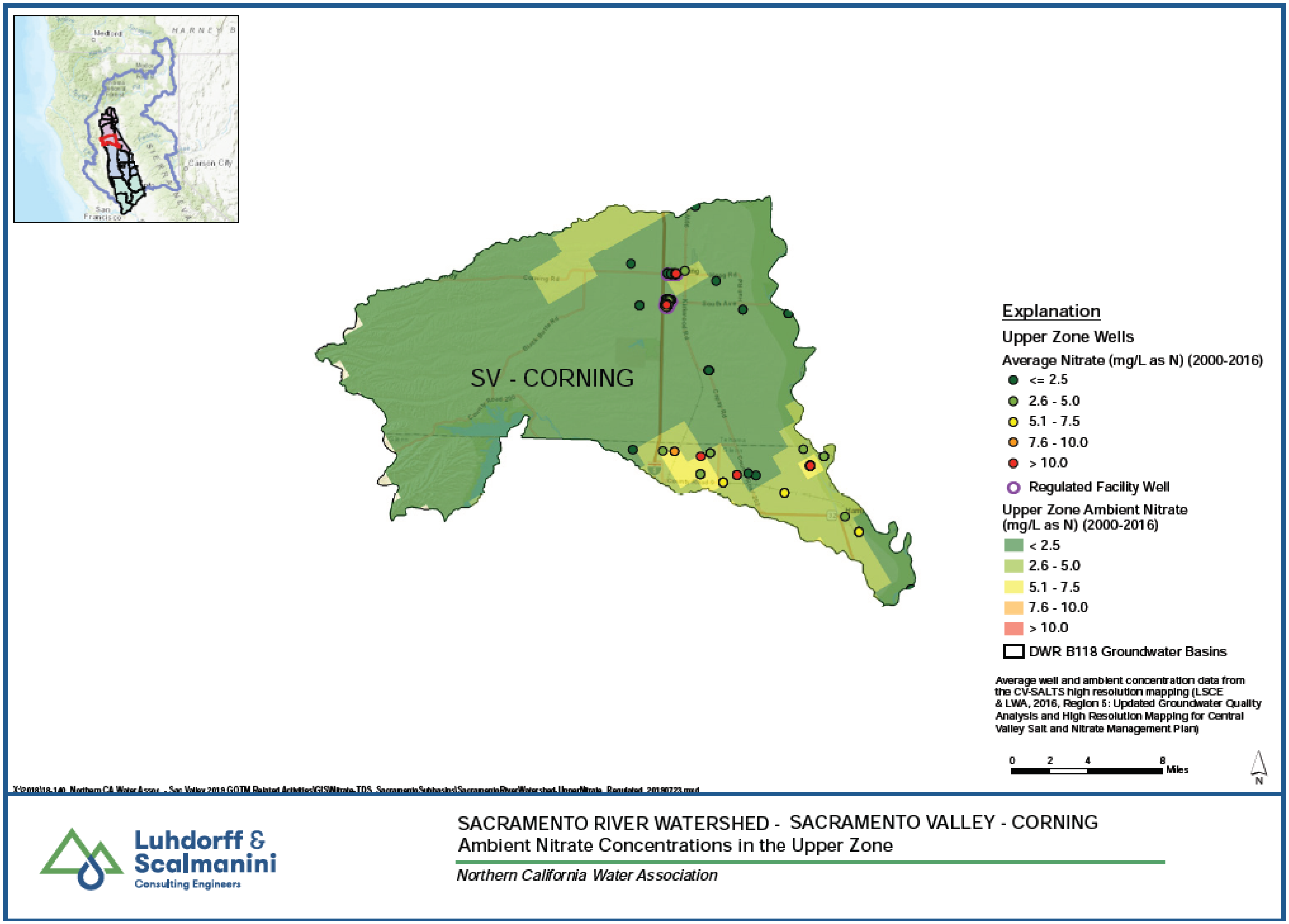

Figure 3-45. Upper Zone Nitrate Concentration in Corning Subbasin, 2000-2016

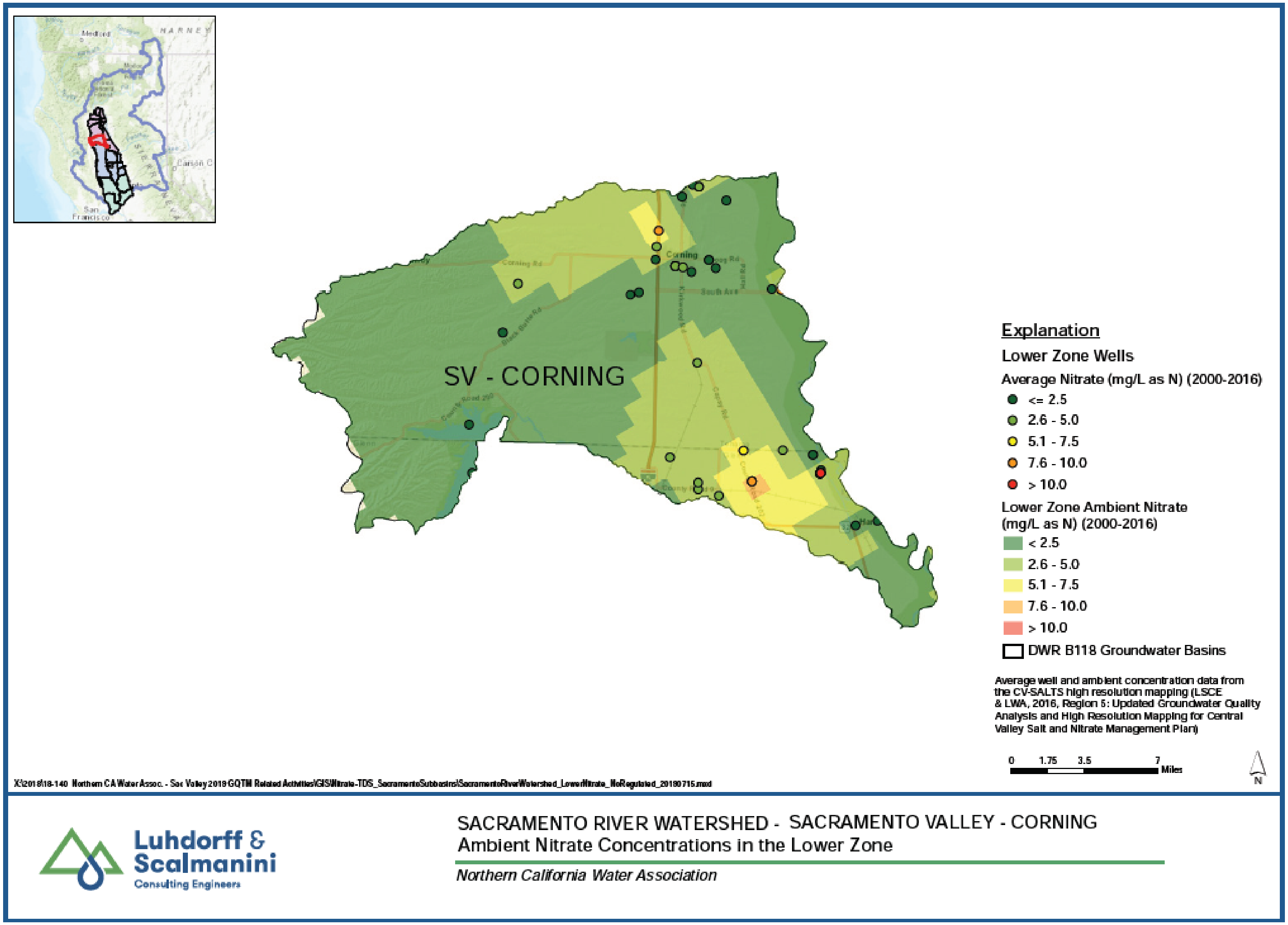

Figure 3-46. Lower Zone Nitrate Concentration in Corning Subbasin, 2000-2016

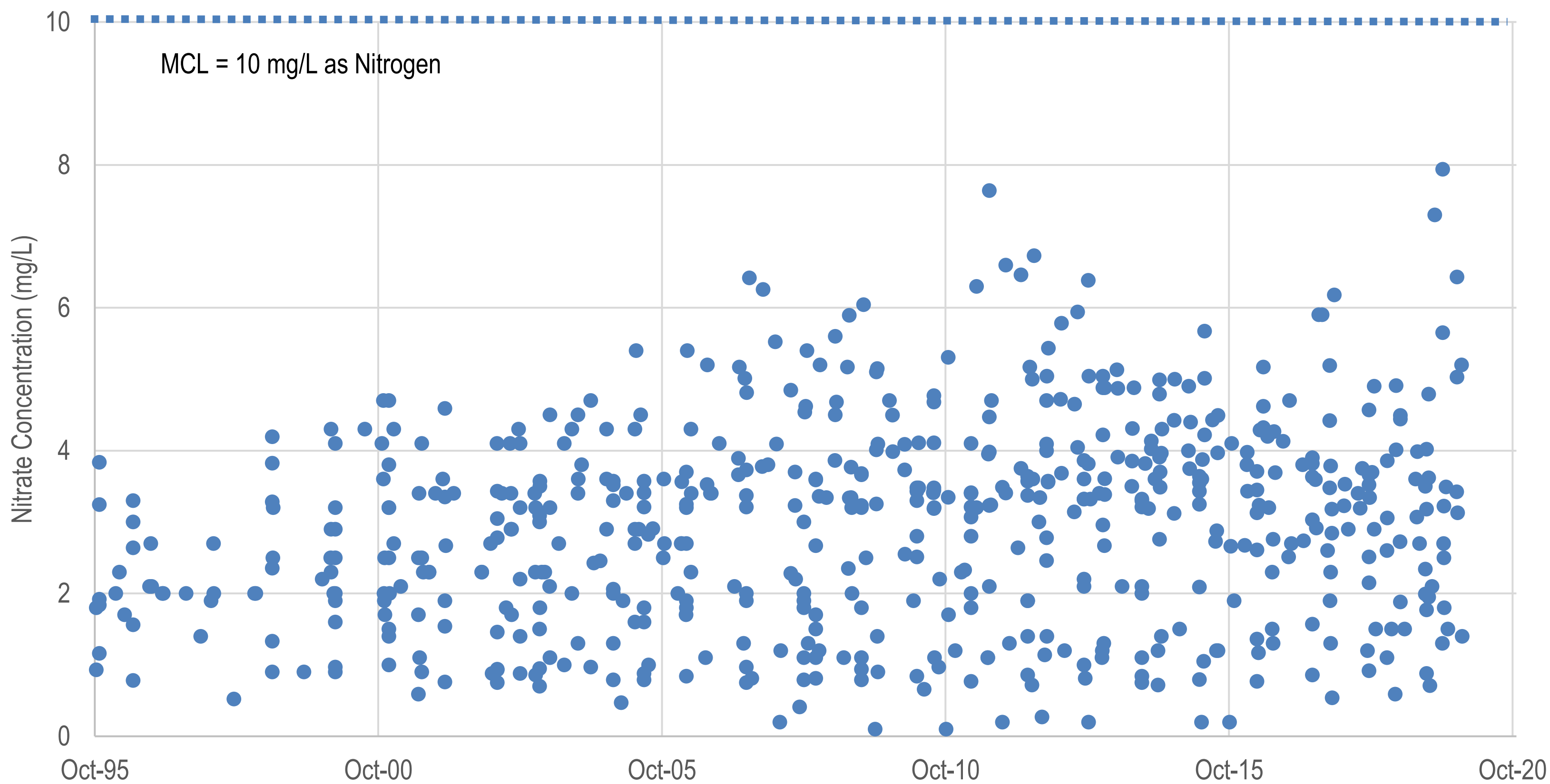

Figure 3-47. Nitrate Detection in Active Public Supply Wells (GAMA, 2020)

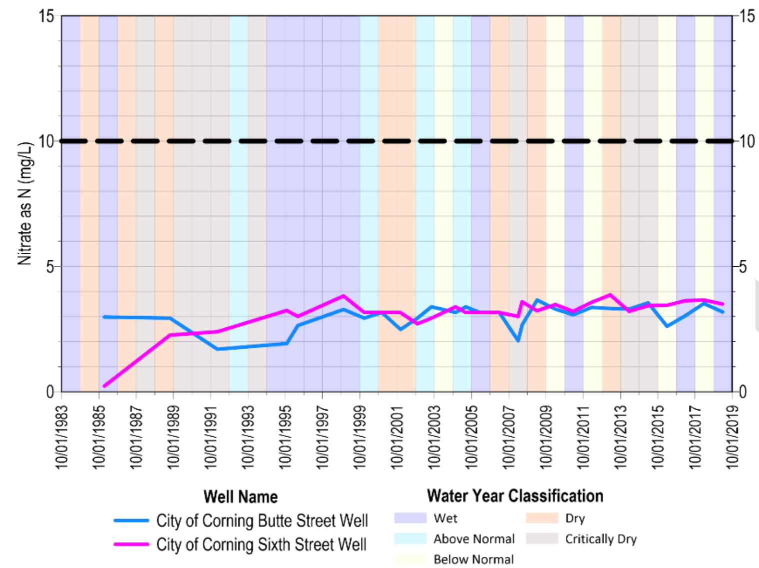

Figure 3-48. Historical Nitrate Concentrations in Municipal Wells in the City of Corning (dashed line shows 10 mg/L MCL)

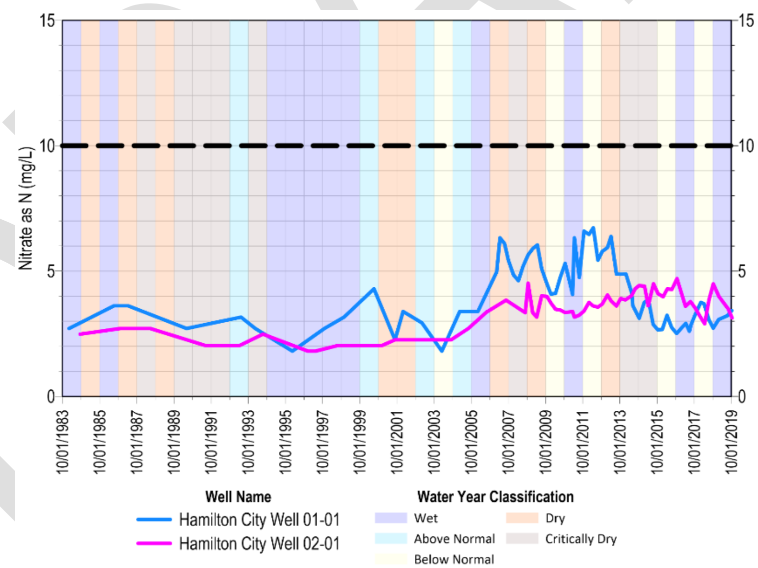

Figure 3-49. Historical Nitrate Concentrations in Municipal Wells in Hamilton City (dashed line shows 10 mg/L MCL)

3.2.6.3.3 Arsenic

Arsenic is a trace element that is often naturally present in groundwater and can negatively impact human health when consumed. Many drinking water sources in California contain arsenic at or above the MCL of 0.01 mg/L. Arsenic is commonly associated with deeper portions of sedimentary fill-basins throughout the western United States (Anning *et al.*, 2012). Arsenic is a commonly detected constituent in groundwater in Tehama County. It is a natural occurring element in groundwater from the Tuscan formation that originates from the pyroclastic rocks deposited by volcanic mudflows (Tehama County, 2012).

Arsenic has been detected historically in the eastern portion of the Subbasin, including occasional concentrations at or above MCL (USGS, 2011). Reported maximum arsenic concentrations by DDW for active supply wells in the GAMA geodatabase is 0.02 mg/L, which is above the MCL (Figure 3-50). One well near Richfield had 6 MCL exceedances prior to 2010, that have since been resolved by a well modification or replacement. Arsenic results in active supply wells since 2011 are less than or equal to 0.005 mg/L, which is half the MCL. The arsenic concentration trend over time is stable (Figure 3-50).

The DWR observation well monitoring report identified 3 observation wells in 2 well clusters with arsenic results above the MCL, at concentrations of 0.012, 0.014, and 0.025 mg/L, respectively. The wells with arsenic MCL exceedances were co-located with wells with nitrate exceedances, suggesting a possible anthropogenic source, or possibly an unrelated natural source.

The Water Board webmaps suggest that arsenic poses little water quality risk in the Subbasin. The Drinking Water Needs Assessment did not identify PLSS sections with recent MCL exceedances or 1999-2019 average arsenic concentrations greater than the MCL. The majority of sections had 20-year average concentrations less than 0.05 mg/L, which is half the MCL, with a few section average concentrations between 0.05 and 0.08 mg/L. Similarly, the SAFER webmap showed that arsenic was low risk for groundwater quality impairment in nearly all of the Subbasin except for a small area along the Tehama and Glenn County line that was considered medium risk based on the DWR observation well MCL exceedances summarized above.

In general, arsenic is detected at low concentrations below the MCL in most wells in the Subbasin. Active public supply well arsenic concentrations reported by DDW were less than half the MCL since 2010 and the concentration trend is stable. Arsenic has exceeded the MCL recently in isolated observation wells though these results appear to be isolated and not indicative of regional trends. Based on this information, arsenic is not a COC for the GSP.

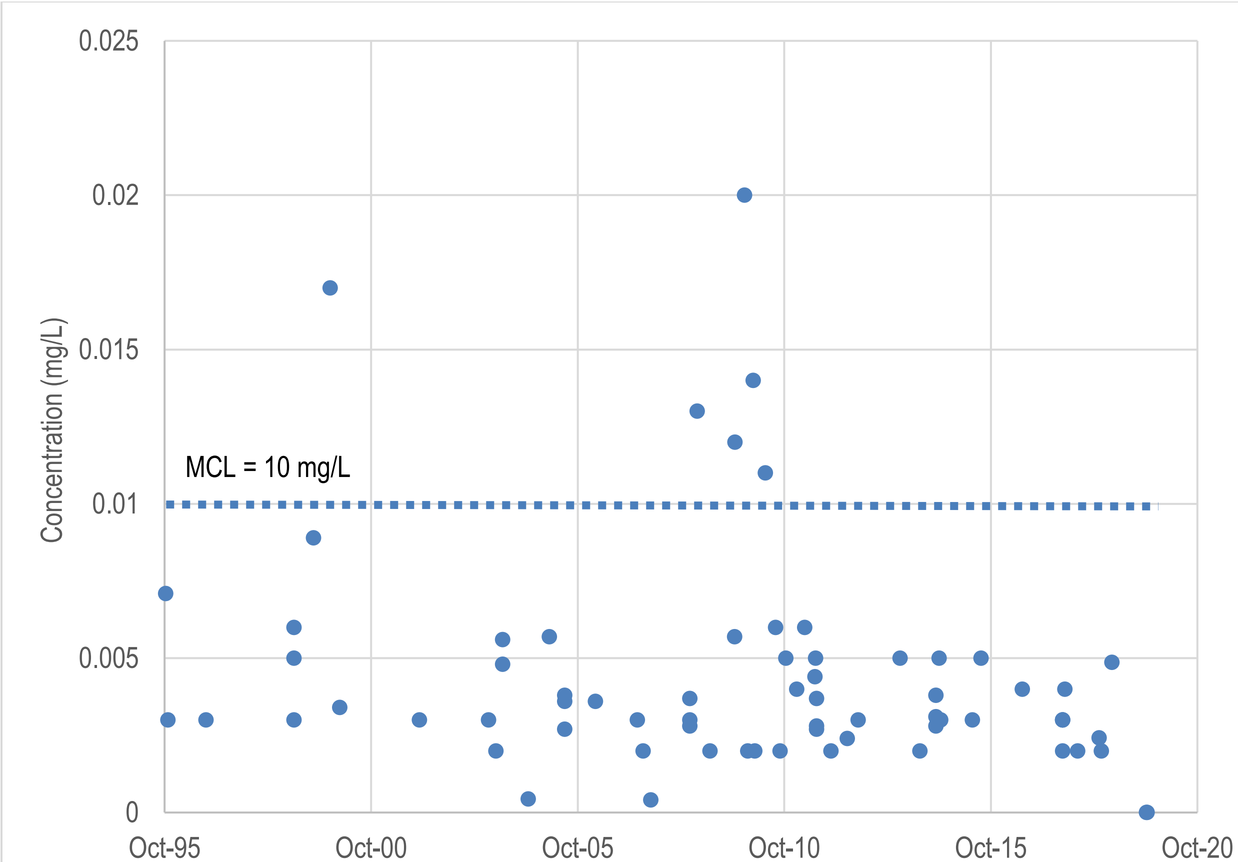

Figure 3-50. Arsenic Detection in Active Public Supply Wells (GAMA, 2020)

3.2.7 Interconnected Surface Water

Surface water that is connected to the groundwater flow system is referred to as interconnected surface water. If adjacent groundwater elevations are higher than the stream's water level, the stream is said to be gaining stream because it receives water from a connected aquifer. If the groundwater elevation is lower than the water level in the stream, it is termed a losing stream because it loses water to the surrounding groundwater flow system. If the groundwater elevation is below the streambed elevation, the stream and groundwater are considered to be disconnected. SGMA does not require that disconnected stream reaches be analyzed or managed. These concepts are illustrated on Figure 3-51.

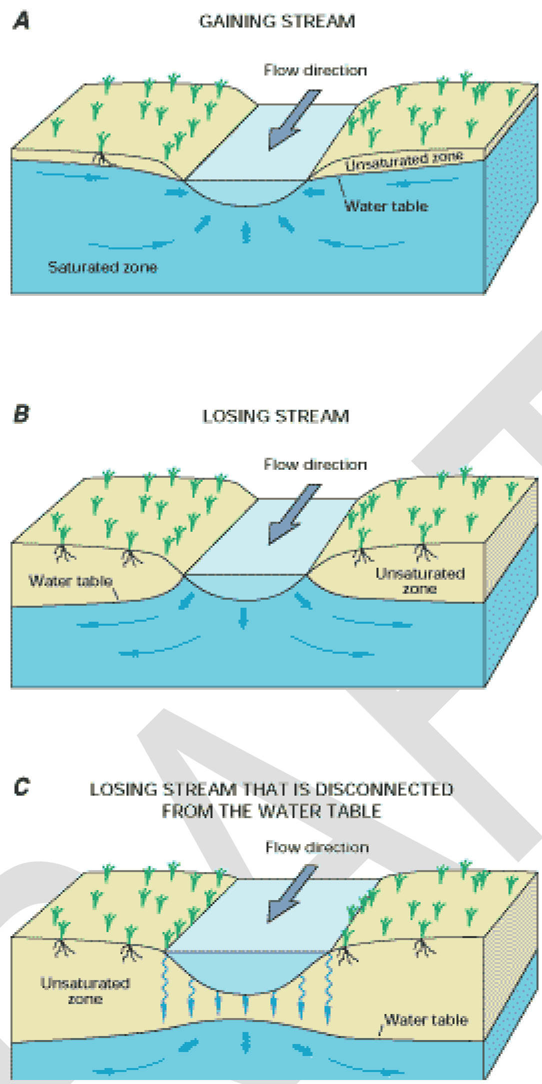

Figure 3-51. Conceptual Representation of Interconnected Surface Water (Source: USGS, 1999)

3.2.7.1 Analysis of Surface Water and Groundwater Interconnection

The Subbasin's surface water bodies are generally connected to groundwater intermittently throughout the year, as Subbasin geology does not support significant barriers between streams and surficial formations. Of all formations and deposits present at surface in the Subbasin, only the Red Bluff Formation is a potential barrier to connection between streams and groundwater. It is a thin layer of partially cemented sand and gravel, the cemented areas of which restrict vertical flow. However, streambed recharge is unaffected by the Red Bluff formation as streams have eroded through the cement into more permeable sediments below (TCFCWCD, 2012).

In absence of geologic barriers, surface water-groundwater connection is largely dependent on local groundwater elevations. If groundwater elevations are not sufficiently high the water table may become disconnected from streams, removing direct surface water-groundwater connection.

The magnitude and direction of flow between surface water and groundwater may therefore be dependent on seasonal or climatic variations in groundwater elevations and surface water discharge. Except for concrete-lined canals and temporary ponds trapped atop the Red Bluff Formation, it is reasonable to assume that every surface water feature in the Corning Subbasin is at least partially hydrogeologically connected to groundwater.

Using the North Sacramento IWFM Model (NSac) integrated hydrologic model, an analysis was conducted to determine where and when stream reaches (nodes in the model) are likely to be connected, and then where stream reaches are gaining or losing throughout the Subbasin. As shown on Figure 3-52, groundwater and surface water are interconnected year-round in the Sacramento River and parts of the year in some reaches of Stony Creek. Groundwater and surface water are likely disconnected in most of Thomes Creek. These model results largely correlate to previous studies and shallow groundwater data. There is a data gap for shallow groundwater monitoring near Thomes creek that will be addressed during GSP implementation.

The percentage of time that stream nodes in the groundwater model are simulated as gaining provides an understanding of the gaining and losing conditions of each stream, as shown on Figure 3-53. Losing conditions may or may not mean that surface water is connected to groundwater, depending on the groundwater level near the streams. There is not enough groundwater level data, particularly along Thomes Creek, to know with certainty if and when groundwater and surface water are interconnected.

A review of surface water-groundwater connection in the major surface water bodies in the Subbasin is presented in the paragraphs below.

Sacramento River: The Sacramento River is generally connected to shallow groundwater across the Northern Sacramento Valley Region. In the Corning Subbasin, the Sacramento River is typically gaining (Figure 3-53), meaning that groundwater levels are higher than the stream stage, resulting in groundwater discharge to the River. In periods of high river flows and in areas with lower groundwater elevations than the stream stage, the River provides an important source of groundwater recharge to the Subbasin. The Sacramento River is controlled upstream of the Subbasin at the Shasta Dam and has several diversions and canals that either provide surface water to the Subbasin or downstream areas. The diversions and canals are discussed in more detail in Section 3.1.8.3.2.

Thomes Creek: Thomes Creek is mostly disconnected from groundwater and mostly losing water to groundwater in the Subbasin (Figure 3-53). In the past, some water from Thomes Creek was diverted for irrigation by riparian users, but now water used for irrigation near Thomes Creek is either from the Sacramento River diversion in Red Bluff or groundwater pumping. Thomes Creek often runs dry seasonally to the east of Henleyville.

Stony Creek: Stony Creek is likely connected to shallow groundwater in most reaches and alternates seasonally between gaining and losing conditions (Figure 3-53). Stony Creek streamflow is regulated by Black Butte Dam for flood control and irrigation supply. Surface water is typically present year-round in upper reaches where the creek is used to convey irrigation releases to the OUWUA irrigation canal system. Lower reaches of Stony Creek closer to the Sacramento River are seasonally dry. The fan alluvium surrounding Stony Creek is very transmissive, and Stony Creek is known as a significant source of direct groundwater recharge, particularly in areas of heavy groundwater use (DWR, 2004b; DWR, 2006b). In general, Stony Creek potentially provides direct recharge in the area from the Tehama Colusa Canal to the Sacramento River where groundwater is used extensively for irrigation. Upstream of the Tehama Colusa Canal, where surface water is used for irrigation, the roles are reversed, and Stony Creek receives significant baseflow from groundwater. More information on the Black Butte Dam and OUWUA irrigation canal system in provided in Section 3.1.8.3.2.

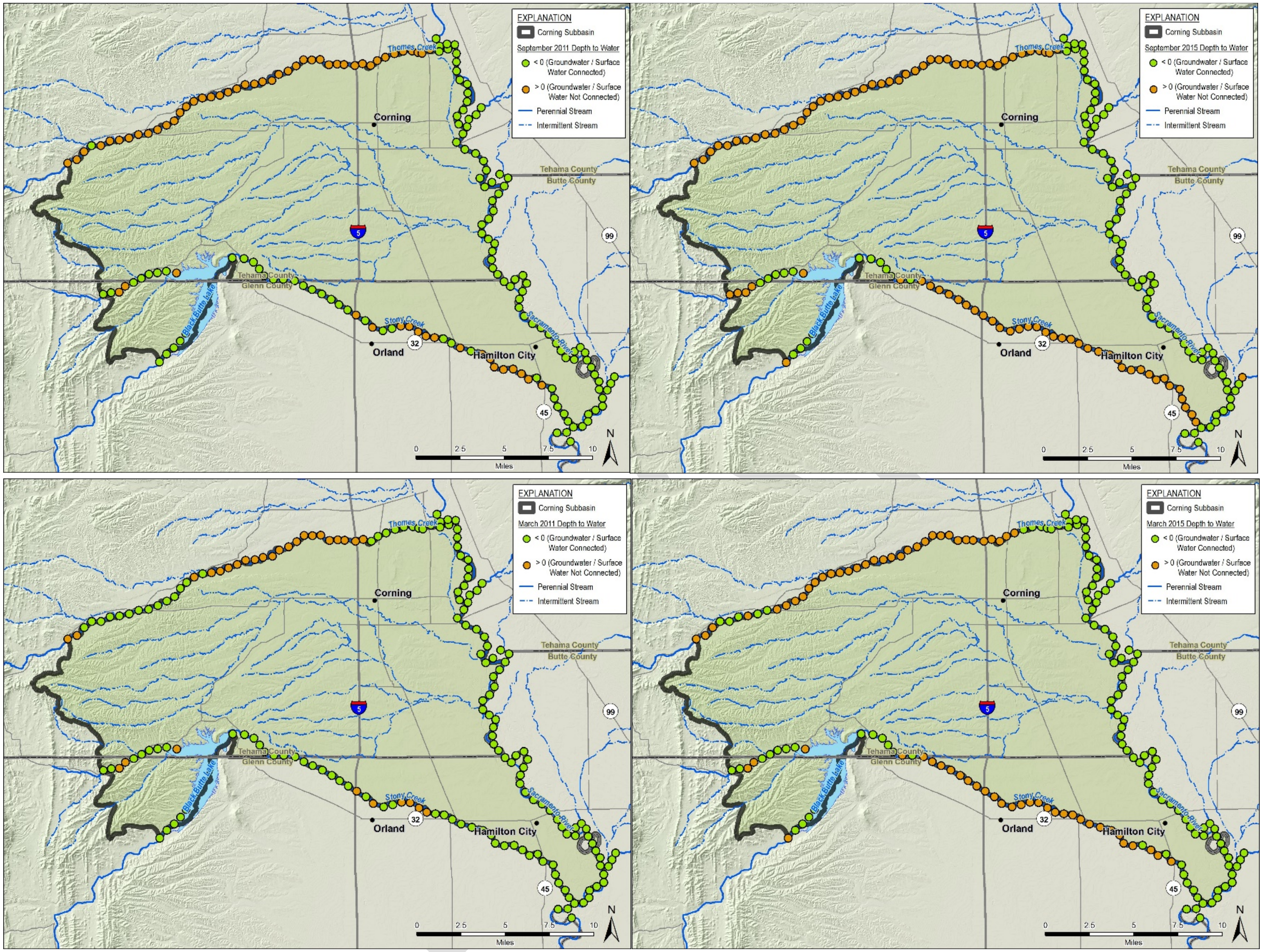

Figure 3-52. Simulated Depth to Water at Stream Nodes (NSac model)

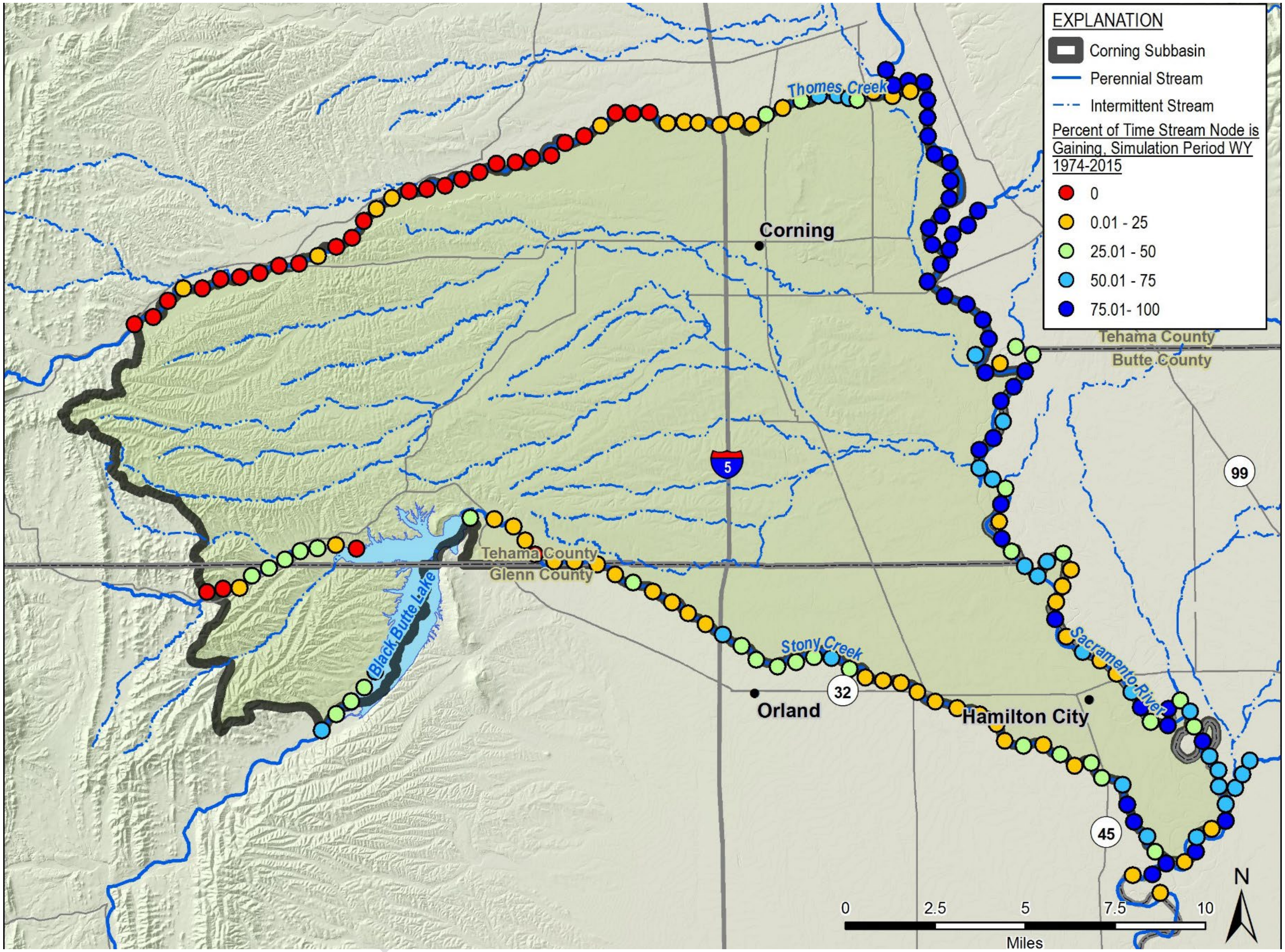

Figure 3-53. Percentage of Time Surface Water is Gaining in Groundwater Model Simulations

Figure 3-54 provides a screenshot in and around the Corning Subbasin of interconnected surface water locations, as developed by The Nature Conservancy (TNC).[9] This map categorizes the rivers and streams in the Central Valley on the likelihood that they are interconnected surface water, using groundwater depth as a proxy to determine if the surface water is hydraulically connected to groundwater. This map confirms the modeling results and general understanding of interconnected surface water in the Corning Subbasin. It shows the Sacramento River as likely connected and gaining, reaches of Thomes Creek and Stony Creek close to the Sacramento River as likely connected and losing, and reaches of Stony Creek and Thomes Creek further from the Sacramento River as likely disconnected or uncertain.

[9] https://icons.codefornature.org/

EXPLANATION

Corning Subbasin

Interconnected Surface Water Categories

- Likely Connected - Gaining
- Likely Connected - Losing
- Uncertain
- Likely Disconnected
- No Groundwater Data
- Canal, Ditch, or Pipeline*

Likely Connected - Gaining:
Groundwater depth is at or above stream surface levels and thus is likely flowing into the surface water body.

Likely Connected - Losing:
Groundwater depth is between 0 and 20 feet below the stream surface level and thus is likely receiving water from the water body through a continuous saturated zone.

Uncertain:
Groundwater depth is between 20 and 50 feet below the stream surface and may or may not be connected to surface water.

Likely Disconnected:
Groundwater depth is greater than 50 feet below the stream surface and is likely disconnected from surface water.

No Groundwater Data:
No groundwater depth data available from the California Department of Water Resources.

***Canal, Ditch, or Pipeline:**
Labeled as canal/.ditch or pipeline in NHDPlus.

Source data: The Nature Conservancy, California. ICONS: Interconnected Surface Water in California's Central Valley, Version 1.0.1. https://icons.codefornature.org/. March 2021.

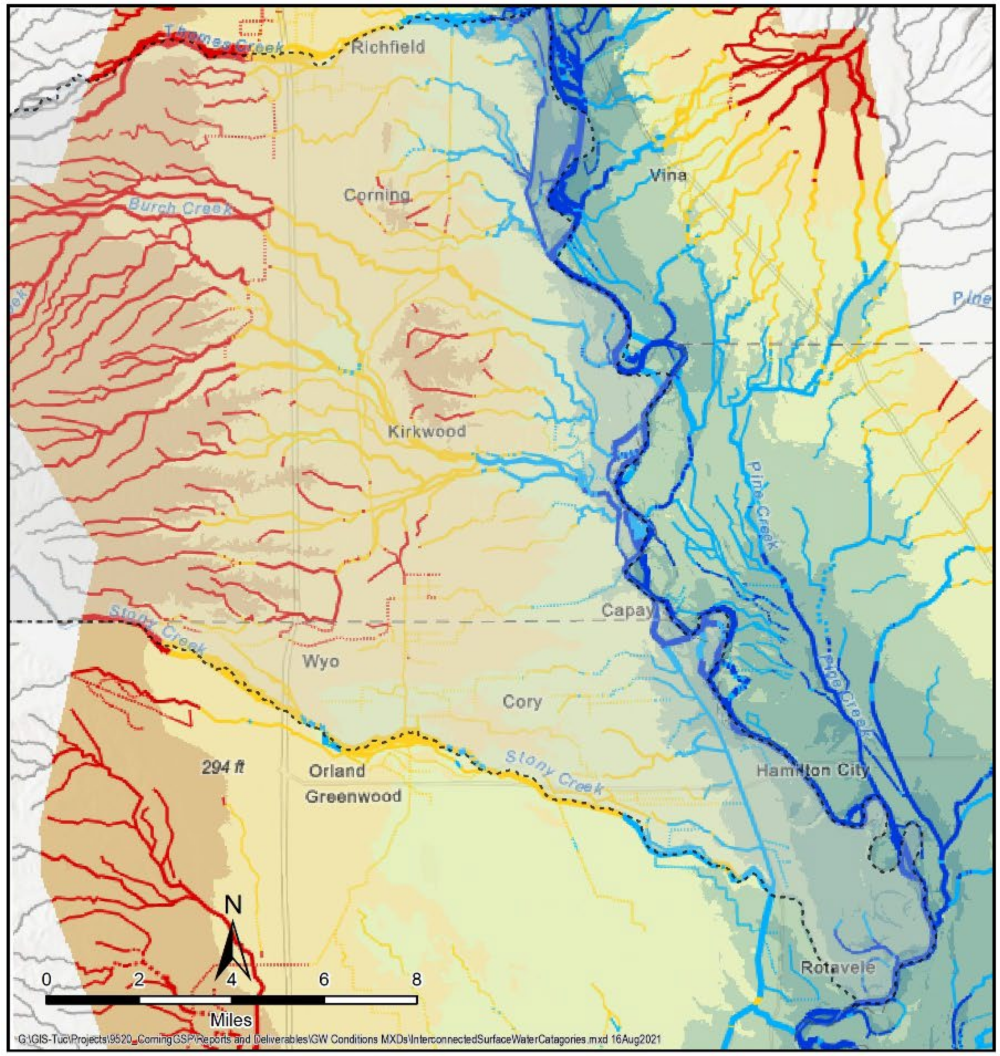

Figure 3-54. Interconnected Surface Water Locations (from TNC)

Figure 3-55 and Figure 3-56 below illustrate groundwater elevations and simulated monthly net groundwater discharge to streams in 2 wells near the Sacramento River. The seasonal rising and falling of groundwater elevations is coincident with fluctuations in net groundwater discharge to streams, indicating a high degree of groundwater-surface water interconnectivity in this area. In areas of groundwater-surface water interconnection, the relative height of the stream stage and groundwater elevation drives the directionality and volume of interaction. Other contributing factors include the hydraulic conductivity of the aquifer and the streambed.

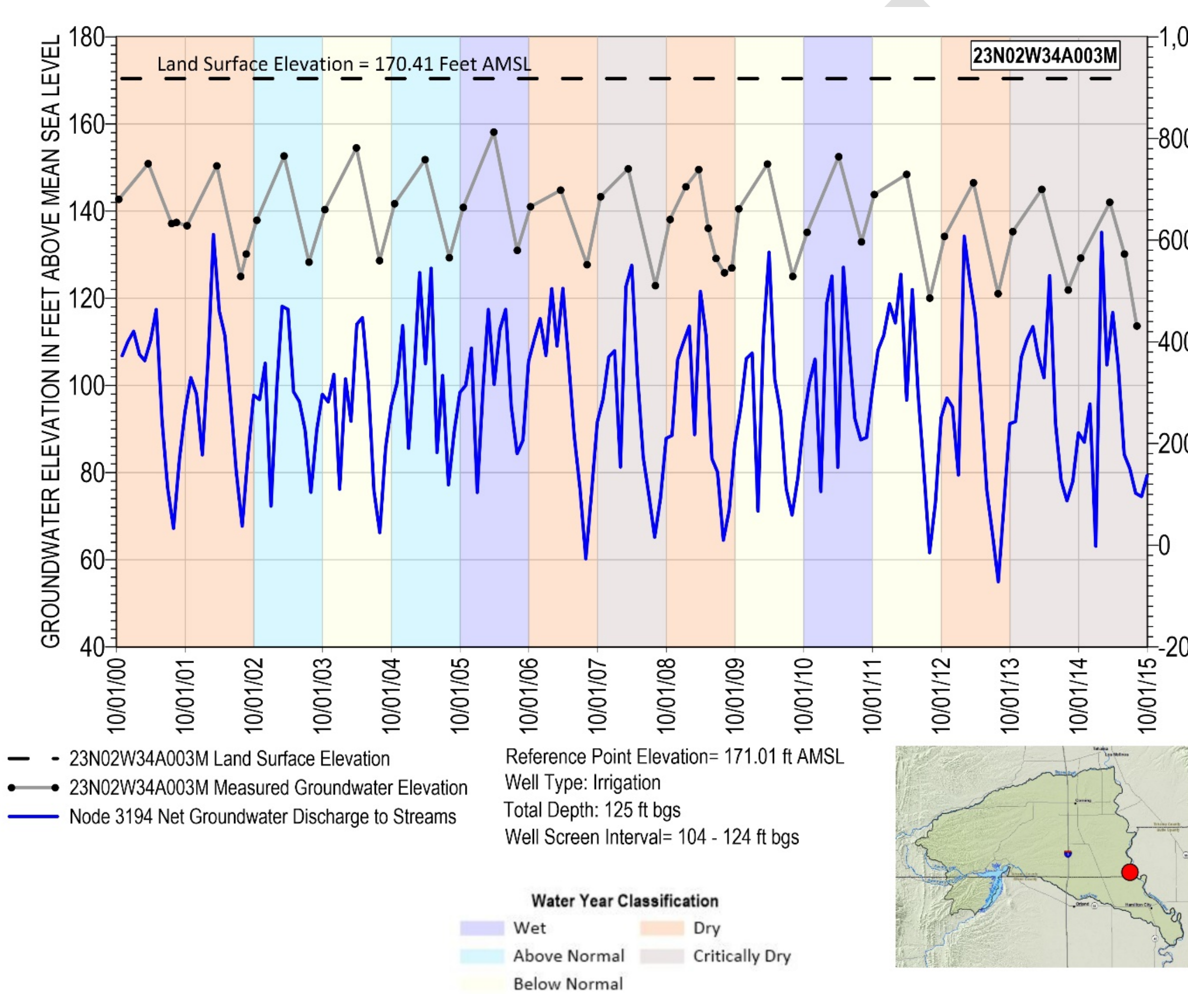

Figure 3-55. Shallow Groundwater Elevations and Monthly Net Groundwater Discharge to Sacramento River, 23N02W34A003M

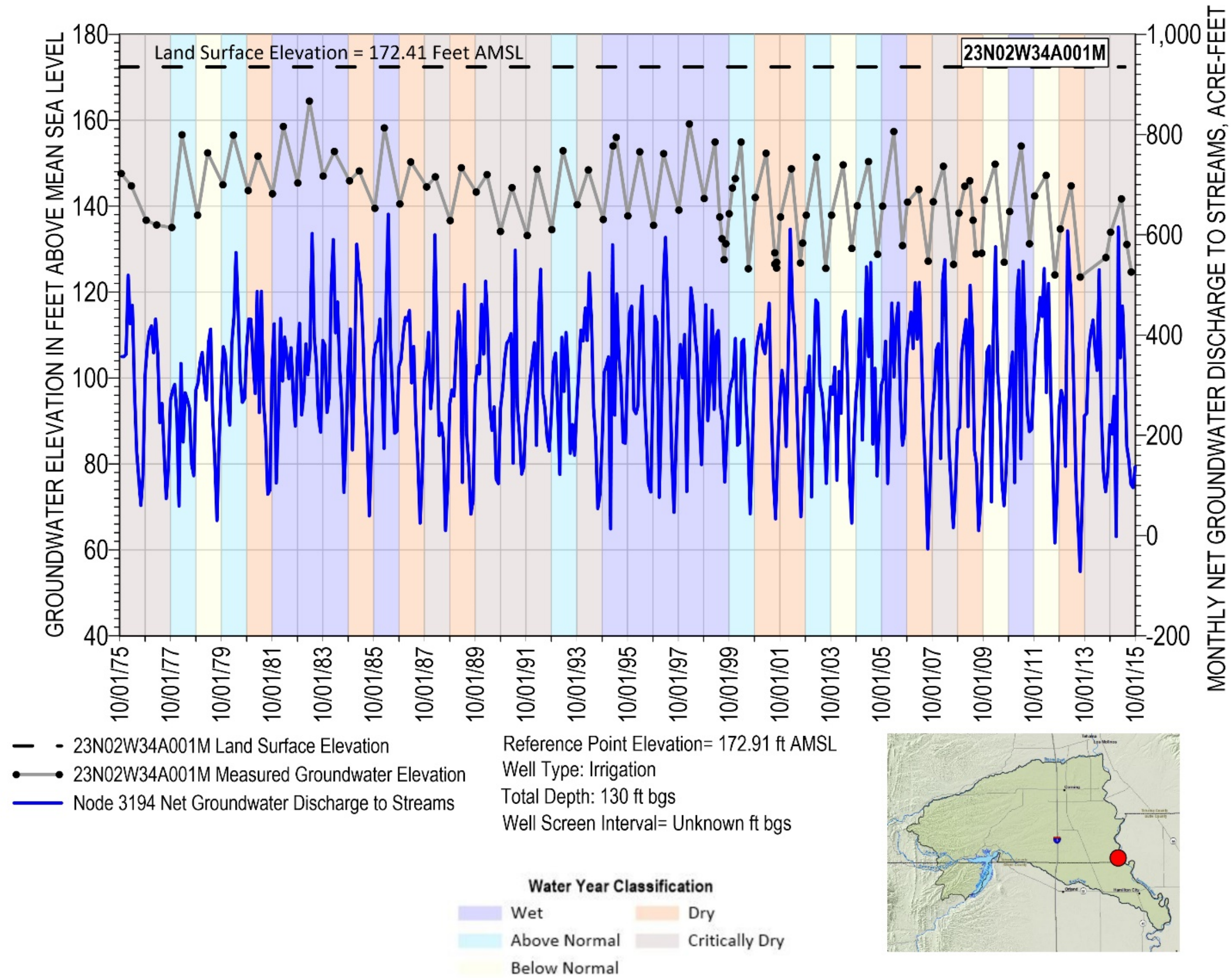

Figure 3-56. Shallow Groundwater Elevations and Monthly Net Groundwater Discharge to Sacramento River, 23N02W34A001M

3.2.7.2 Identification of Groundwater-Dependent Ecosystems

GDEs within Corning Subbasin are identified in accordance with §354.16(g) of the GSP Regulations. The procedure for identifying GDEs follows guidance developed by TNC and detailed in the *Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act: Guidance for Preparing Groundwater Sustainability Plans* report (Rohde *et al.*, 2018). This process differentiates between indicators of Groundwater Dependent Ecosystems (iGDEs), potential Groundwater Dependent Ecosystems, and true Groundwater Dependent Ecosystems.

- iGDEs were developed by TNC in partnership with the California Department of Fish and Wildlife (DFW) and DWR using the best available statewide data. The iGDEs are identified using locations of springs and seeps, wetlands, and vegetation known to rely on groundwater. The Nature Conservancy also uses the term "Natural Communities

Commonly Associated with Groundwater" to refer to these iGDEs. iGDEs in Corning Subbasin are presented on Figure 3-57.

- Potential GDE are iGDEs that, through mapping analyses, grow in areas that may be connected to shallow groundwater and therefore be relying on shallow groundwater for consumptive use. As such, potential GDEs are considered beneficial users of groundwater.
- True GDEs are potential GDEs that have been field-verified to establish that they are supported by groundwater. The methodology described herein does not identify true GDEs.

This section identifies potential GDEs using the following 3 criteria:

1. iGDEs exist as defined by The Nature Conservancy and DWR.
2. The area is near a riverine environment and existing data demonstrate surface water and groundwater are interconnected.
3. Water levels in this area are consistently less than 30 feet below ground surface, the maximum groundwater level thought to be accessible to the deepest root systems of GDE species. There is some anecdotal evidence that plants can extend roots to greater depths than 30 feet in some cases.

An area must meet all 3 criteria to be considered a potential GDE.

Figure 3-57 displays indicators of GDEs in the Subbasin. Along the boundaries of the Subbasin, Thomes Creek, Stony Creek, and the Sacramento River are identifiable as having potential GDEs by the presence of high density of groundwater dependent vegetation and potentially shallow water levels. In the central and eastern part of the basin, Burch Creek and Hall Creek also have characteristic vegetation associated with potential GDEs. The area near Burch and Hall Creek is known to have perched groundwater in at least 1 well (Figure 3-28). Groundwater dependent wetlands are mostly limited to the widest streams, those being the Sacramento River and where Stony Creek flows out from Black Butte Lake.

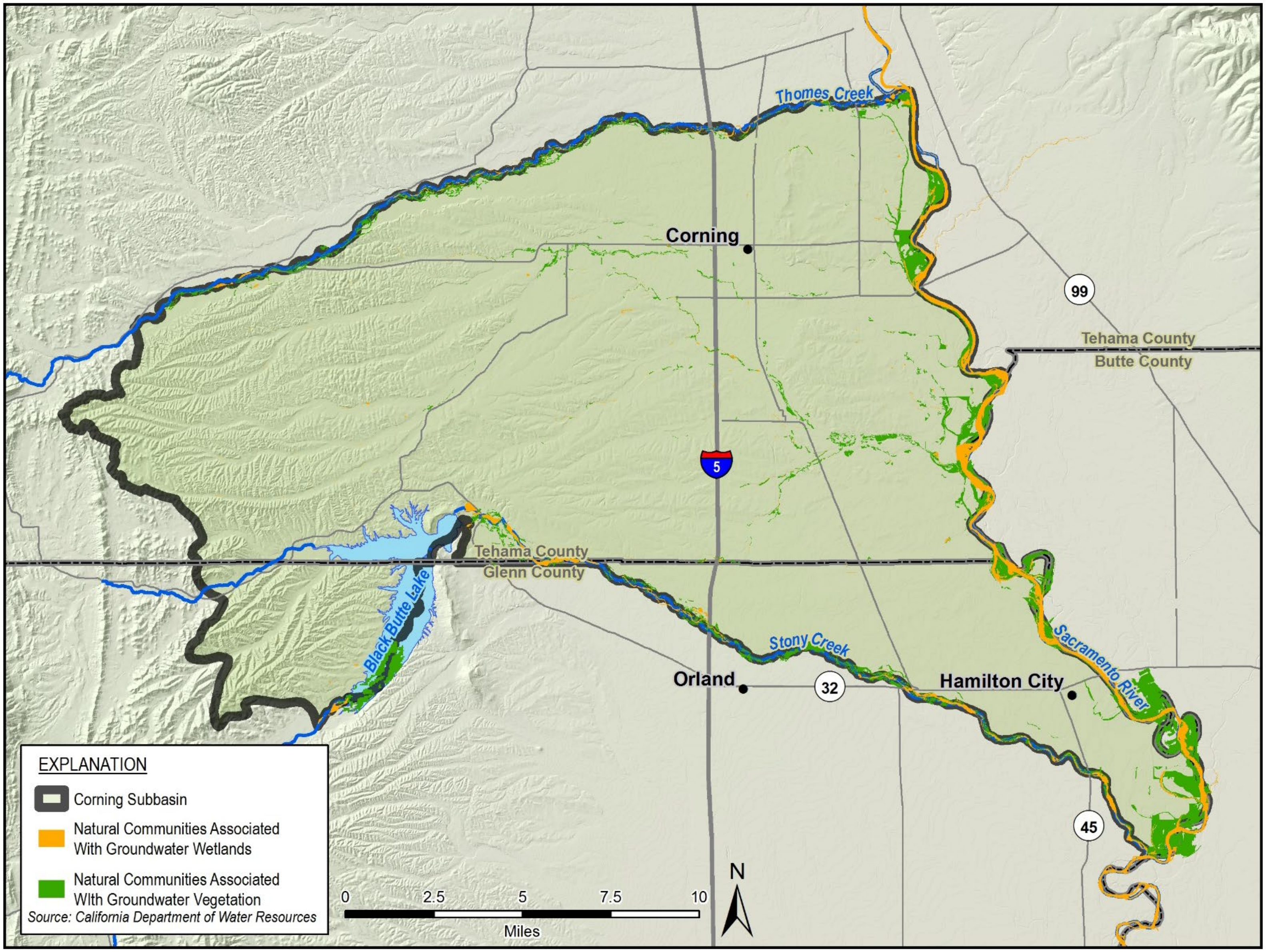

Figure 3-57. Indicators of Groundwater Dependent Ecosystems in Corning Subbasin

The maximum rooting depth for GDE plants identified by TNC that live in the Sacramento Valley is 30 feet bgs.[10] This depth was selected as a conservative screening level for potential GDE locations, as only a few of the mature plants in GDE communities could feasibly extend roots to this or greater depth. Areas where the potential GDEs are mapped, but the depth to groundwater is greater than 30 feet are likely not dependent on groundwater but have other sources of water such as perched water from surface water sources or irrigation canals. There is some evidence that the deepest roots of valley oaks and possibly other mature GDE species can reach depths up to 80 feet, though most vegetative species do not have this capacity, and it is not known if rooting depths deeper than 30 feet are found in the Subbasin.

Groundwater level data for Spring 2018 for CASGEM wells in the Subbasin with depths less than 150 feet bgs were reviewed and mapped with the iGDE areas on Figure 3-58. Spring 2018 was a relatively high groundwater level for many Subbasin wells, relative to the groundwater level records since SGMA was enacted on January 1, 2015. Almost all of the wells used in the shallow groundwater level analysis were installed with screened intervals between 50 and 150 feet bgs, though well screen and annular seal information was not available for all wells

In summary, plant communities indicative of potential GDEs are present in the Corning Subbasin shown on Figure 3-59. These are likely supported by groundwater found at depths less than 30 feet bgs in close proximity to the Sacramento River on the eastern Subbasin boundary and Stony Creek in the southeastern portion of the Subbasin near Hamilton City. Many of the stream reaches mapped as potential GDEs are overgrown with invasive species such as arundo and tamarisk. The GSAs do not intend to protect non-native invasive species habitat and in fact, intend to support arundo eradication efforts, as described in more detail in the Projects and Management Actions in Section 7 of this GSP. Shallow groundwater is found in some central portions of the Subbasin where Burch Creek and Hall Creek, which are ephemeral, merge before flowing into the Sacramento River; this could be due to perched groundwater fed by surface water runoff in this area.

GDE extent in general is not well refined in the Subbasin and is a data gap that will be addressed during GSP implementation with additional data collection and ground-truthing. For example, Thomes Creek does not have enough shallow groundwater level monitoring to evaluate changes in groundwater levels relative to GDE vegetation vigor. In addition, evidence reported by local stakeholders and farmers suggests that the central area of the Subbasin includes invasive species and is probably mostly fed by irrigation water runoff. GDE health over time can be assessed by the GSAs in the future relative to changes in groundwater elevation and streamflow using new remote sensing tools that evaluate changes in vegetation vigor such as the Nature Conservancy's GDE Pulse.[11] The GSAs plan to further refine GDE mapping and assess the impact on GDEs due

[10] https://groundwaterresourcehub.org/sgma-tools/gde-rooting-depths-database-for-gdes/
[11] https://gde.codefornature.org/#/home

to streamflow depletion and lowering groundwater levels, should these conditions occur during GSP implementation.

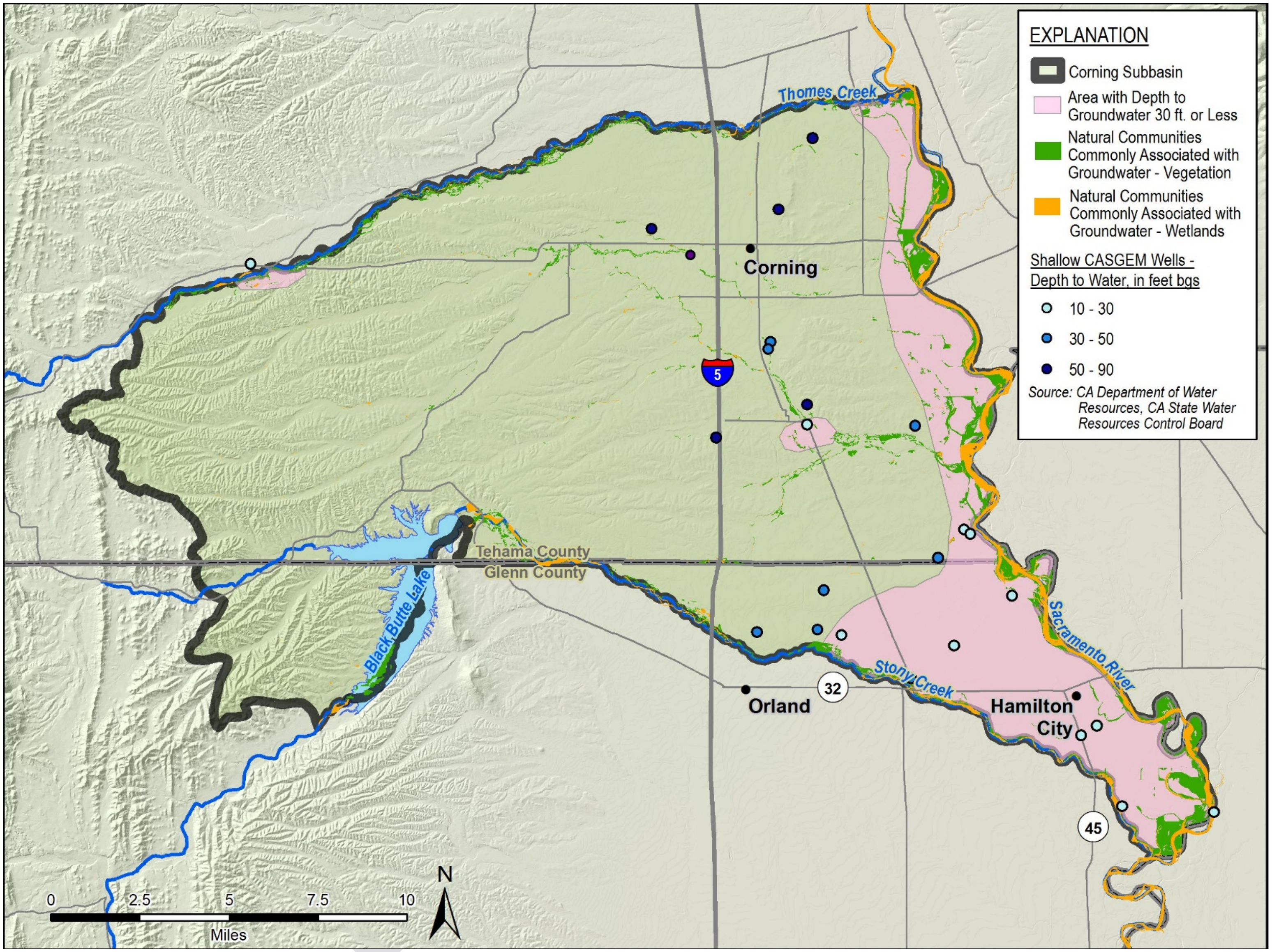

Figure 3-58. iGDEs and Depth to Groundwater

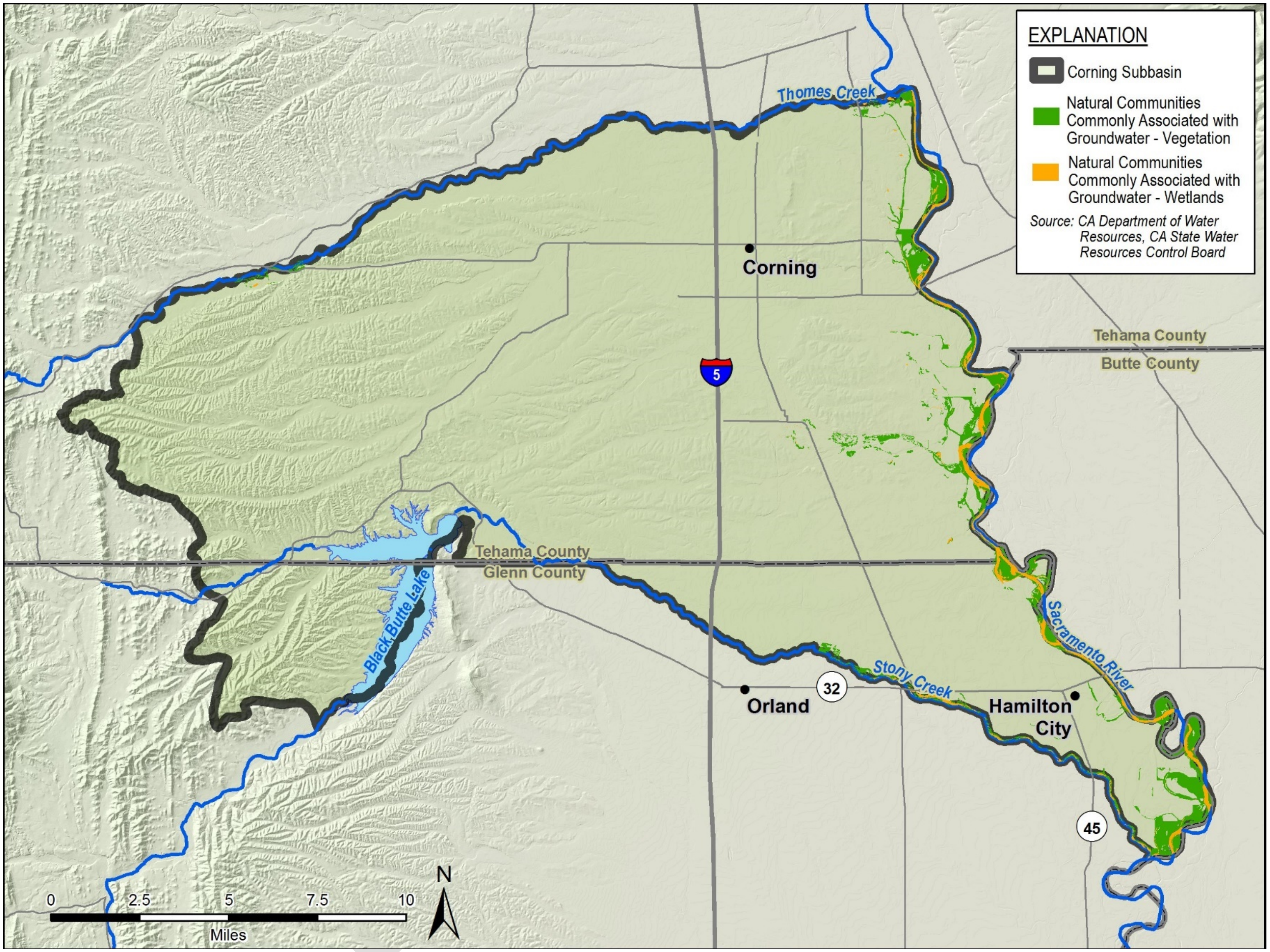

Figure 3-59. Potential GDEs Idenfitied in the Subbasin

3.2.7.3 Priority Species that Rely on Groundwater-Dependent Ecosystems

A list of threatened and endangered species that may rely on GDEs in the Subbasin was compiled using information available from the CDFW and TNC. Nine threatened and endangered species were identified that likely rely on GDE ecosystems in the Subbasin, summarized in Table 3-10.

Table 3-10. Critical and Threatened Species in the Subbasin that Rely on GDEs

Scientific Name	Common Name
Rana draytonii	California red-legged frog
Coccyzus americanus occidentalis	western yellow-billed cuckoo
Vireo bellii pusillus	least Bell's vireo
Branchinecta conservatio	Conservancy fairy shrimp
Acipenser medirostris	green sturgeon
Oncorhynchus mykiss irideus	steelhead
Oncorhynchus tshawytscha	chinook salmon
Desmocerus californicus dimorphus	valley elderberry longhorn beetle
Thamnophis gigas	giant garter snake

Several steps were taken to determine which threatened and endangered species were likely found in the Subbasin and of those, which were likely to rely on GDE habitat. First, a list of all critical species for Glenn and Tehama County was downloaded from the CDFW California Natural Diversity Database (CNDDB).[12] This list was filtered by state of California and Federal endangered, threatened, or proposed endangered or threatened species. This filtered list consisted of 40 species within the counties that make up the Corning Subbasin. The reduced list was cross-referenced with species-specific mapping information available from the CDFW and United States Fish and Wildlife Service in order to identify species that are likely to be found within the bounds of the Subbasin in areas where habitat is known to be groundwater dependent.[13] [14] Animals such as the gray wolf, Sierra Nevada red fox, and Humboldt marten that are only likely found at higher elevations of the counties outside of the bounds of the Subbasin were removed from the list. Similarly, plant species such as Hoover's spurge, hairy and slender Orcutt grasses, and Colusa grass that are found in vernal pools were also removed from the list, as these are not groundwater dependent ecosystems in the Subbasin. Finally, the list was cross-referenced with the TNC Critical Species "LookBook" in order to confirm that the priority species are likely reliant on GDEs (Rohde *et al.*, 2019).

[12] https://wildlife.ca.gov/Data/CNDDB/Maps-and-Data
[13] https://wildlife.ca.gov/Conservation/Plants/Endangered
[14] https://ecos.fws.gov/ipac/location/index

3.2.8 Groundwater Conditions Data Gaps and Uncertainty

Data gaps related to groundwater conditions are primarily related to lack of detailed information on groundwater elevations and groundwater quality in the west area of the Subbasin.

Groundwater Elevations in the Western Area of Subbasin:

Analysis of groundwater elevations in the western Subbasin is limited by the low number of wells screened and monitored in that area. The absence of this data is very apparent on the groundwater contours presented on

and Figure 3-20. Additional wells installed and/or monitored in this area could help resolve this data gap.

Groundwater Quality in the Western Area of Subbasin:

Groundwater quality is not measured in many wells in the western area as most of the wells are private domestic wells and are not part of groundwater quality monitoring programs.

Stream Gauge Data:

A number of stream gauges are no longer active in the Subbasin and are also considered a data gap in measuring stream flows on the lower portions of Thomes Creek. This data gap is further discussed in Section 5 on Monitoring Networks.

GDE Locations and Extent:

The location and extent of GDEs is estimated based on vegetation mapping and regional groundwater level data. Actual rooting depth data are limited and will depend on the plant species and site-specific conditions such as soil and aquifer types, and availability to other water sources. There are areas in the Subbasin with potential GDEs where insufficient data exist to say with certainty if GDE vegetation is supported by shallow groundwater or if vegetation is supported by surface water. This distinction is important as GDEs supported only by surface water are not subject to the depletion of interconnected surface water SMC. Priority species that are known to utilize specific GDE habitat are not well defined for the Subbasin.