2. BASIN SETTINGS: OVERVIEW

This Cuyama Valley Groundwater Basin (Basin) Settings chapter contains three main sections as follows:

- **Hydrogeologic Conceptual Model (HCM)** – The HCM section (Section 2.1) provides the geologic information needed to understand the framework that water moves through in the Basin. It focuses on geologic formations, aquifers, structural features, and topography.
- **Groundwater Conditions** – The Groundwater Conditions section (Section 2.2) describes and presents groundwater trends, levels, hydrographs and level contour maps, estimates changes in groundwater storage, identifies groundwater quality issues, addresses subsidence, and addresses surface water interconnection.
- **Water Budget –** The Water Budget section (Section 2.3) describes the data used to develop the water budget. Additionally, this section discusses how the budget was calculated, provides water budget estimates for historical conditions, and current conditions and projected conditions.

2.1 Basin Settings: HCM

This section of Chapter 2 describes the HCM for the Basin. Additionally, this HCM section satisfies Section 354.8 of the Sustainable Groundwater Management Act (SGMA) regulations. As defined in the regulations promulgated by the Department of Water Resources (DWR), the HCM:

1. "Provides an understanding of the general physical characteristics related to regional hydrology, land use, geologic structure, water quality, principal aquifers, and principal aquitards of the basin setting;
2. Provides the context to develop water budgets, mathematical (analytical or numerical) models, and monitoring networks, and
3. Provides a tool for stakeholder outreach and communication."

This HCM was developed to understand and then convey information about the physical conditions by which water moves through the Basin. This information is also used to support development of water budgets (Section 2.3).

2.1.1 Useful Terms

This chapter includes descriptions of geologic formations and structures, aquifers, and properties of geology related to groundwater, among other related components. A glossary of technical terms is below. The terms listed here are intended as a guide for readers and are not a definitive definition of any term.

- **Formation –** A formation, or geologic formation, is a unit of rock of similar properties, such as grain size, mineral composition, or depositional environment. Geologic formations are distinct from surrounding rock types and are large enough to be mapped regionally. If the formation contains a dominant rock type, such as sandstone, it may be included in the name of the formation.

- **Basement rocks –** Basement rocks are the oldest and deepest rocks in the subsurface. Basement rocks are typically crystalline and metamorphic or igneous in origin, and groundwater generally only moves through fractures in the rock instead of pore spaces like in sedimentary rocks. No sedimentary layers are found below the basement rocks.
- **Water bearing formation –** A water bearing formation is a rock formation that is saturated and contains water within the pores or fractures of the unit. One or more water bearing formations compose an aquifer.
- **Aquifer –** An aquifer is an underground reservoir of water stored within the pores and fractures of rocks and sediments.
- **Unconfined aquifer –** An unconfined aquifer is an aquifer that does not have an impermeable layer above it (such as a clay layer). With an unconfined aquifer, the upper water surface is defined as the water table and is at atmospheric pressure. Water seeps from the ground surface directly into the aquifer, as there are not impermeable layers to prevent the water from entering the aquifer.
- **Cross section –** A cross section is a diagram that identifies subsurface layers located beneath a surficial trend. Stratigraphic cross sections depict geologic formations in the subsurface in relation to elevation. Cross sections are useful tools to interpret geology in the subsurface and visualize the relative thickness and distribution of geologic formations. Cross sections are often presented with an accompanying map that acts as a reference to spatially locate the trend of the cross section at the surface. To read cross sections, use the location and trend of the surficial lines on the location map as a key. For instance, where A-A' is marked on the map represents where the cross section named A-A' is located spatially
- **Hydraulic conductivity** – Hydraulic conductivity is defined as the "measure of a rock or sediment's ability to transmit water," typically measured in feet or meters per unit of time (day, hour, minute) (DWR, 2003). Rocks and sediments with high values of conductivity, such as gravels or coarse sands, are able to sustain groundwater flow better than rocks and sediments with low values of conductivity. Rocks and sediments with near zero values of hydraulic conductivity, such as very fine-grained sandstones, shale, or granites, do not transmit groundwater and are barriers to flow. Values of conductivity are used in the groundwater model to determine how quickly formations transmit groundwater and where barriers to groundwater flow (i.e., formations with very low values of conductivity) exist.
- **Hydrogeology** – The study of groundwater and aquifers.
- **Primary aquifer –** According to SGMA regulations, primary aquifers must be identified. In the Groundwater Sustainability Plan (GSP), aquifers requiring specific monitoring and management must also be identified. Primary aquifers are regionally extensive and are sources of groundwater used for beneficial uses.

- **Aquitard –** An aquitard is a layer of strata that has a low conductivity that groundwater flows very slowly through. Aquitards can be regional in the San Joaquin Valley, where it prevents flow from upper strata to lower strata across the western side of the valley, or it can be localized, which is common in most alluvial settings. Localized aquitards restrict vertical flow in a small region of an aquifer, and water will generally move laterally around localized aquitards as it flows by gravity toward the bottom of the aquifer.
- **Piper diagram** – A Piper diagram is used to characterize the chemical quality of a water sample and involves plotting the relative proportions of major ions. Piper diagrams show the relative abundance of major cations (e.g., sodium, potassium, calcium, magnesium) and anions (e.g., bicarbonate, carbonate, sulfate, chloride, fluoride) commonly found in water on a charge equivalent basis, as a percentage of the total ion content of the water. Piper diagrams are useful for understanding what kind of salts make up the total dissolved solids (TDS) in a location.

2.1.2 Regional Geologic and Structural Setting

The Basin is located at the southeastern end of the California Coast Ranges and north of the Western Transverse Ranges (Figure 2-1) and is in an area of high tectonic activity. The Basin is bounded on the north and south by faults and is located near major fault zones such as the San Andreas and Santa Maria River fault zones. Because the Basin is located in a mountainous region with high tectonic activity, it has a number of structural features generated by this activity. The Basin has been deformed by this tectonic activity, and is generally a synclinal basin, with multiple synclines that are oriented to the northwest and a number of faults within the Basin.

Tectonic activity from the northwest movement of the San Andreas Fault system has led to the development of a fold and thrust belt, which has driven the deformation of the Cuyama Valley for the past four million years (United States Geological Survey [USGS], 2013c). The Cuyama Valley was formed by a downfaulted block of the earth’s crust called a graben. This block is bordered on the north by the Morales and Whiterock faults and on the south by the South Cuyama and Ozena faults. Along these borders the faults have thrust older rocks of pre-Pliocene age over the rocks of Pliocene age and younger. In the eastern part of the valley the north-bordering faults approach the San Andreas Fault zone and the south-bordering faults approach the Big Pine Fault zone. (Singer and Swarzenski, 1970)

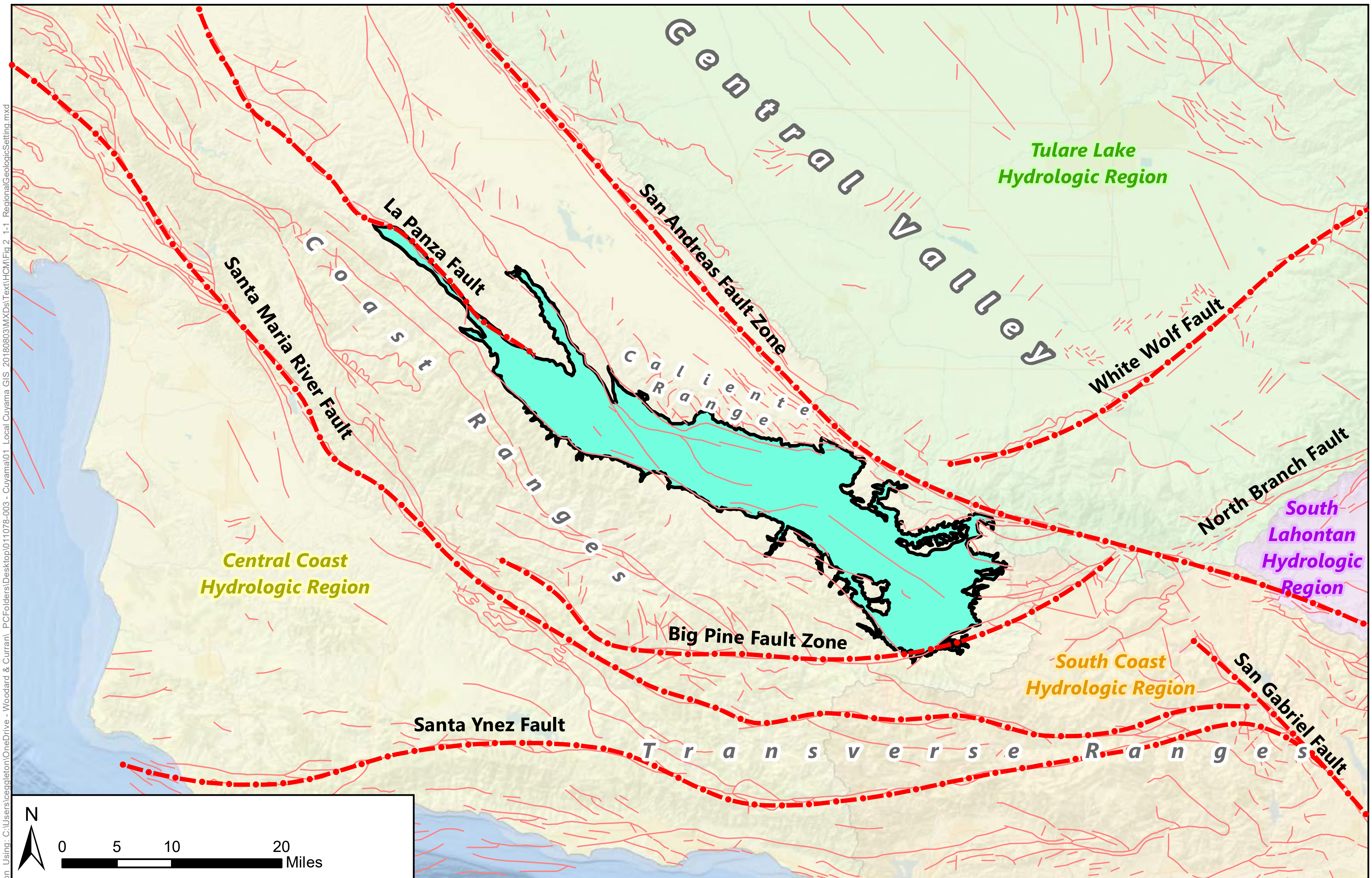

Figure 2-1: Regional Geologic Setting

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

December 2019

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Legend

Cuyama Basin

Faults and Folds

Fault Data Sources:
Fault Activity Map of California (2010) from the California Department of Conservation. Retrieved 6/13/2018.
<http://maps.conservation.ca.gov/cgs/fam/>
California Geologic Map Data from United States Geologic Survey. Retrieved 2/8/2018.
<https://mrdata.usgs.gov/geology/state/state.php?state=CA>

Figure Exported: 10/18/2018 By: ceggleton Using: C:\Users\ceggleton\OneDrive - Woodard & Curran_PCFolders\Desktop\011078-003 - Cuyama\01_Local Cuyama GIS_20180803\MXDs\Text\HCM\Fig 2_1-1_RegionalGeologicSetting.mxd

2.1.3 Geologic History

The Basin has a long history of deformation and deposition, most of this influenced by tectonic activity and cycles of marine transgression and regression. Formations in the Basin reflect variable depositional environments, from the middle bathyal shales and siltstones to the nonmarine sandstone, conglomerate, and mudstones. Marine rocks are dominant in the western part of the Basin and interfinger to the east with nonmarine rocks (Ellis, 1994).

A major late Eocene/early Oligocene (38 to 28 million years (Ma)) unconformity affected all regions south of the San Andreas Fault, shown in the geologic record by nonmarine Oligocene (23 Ma) rocks overlying a thick section (i.e., several kilometers) of upper Eocene (56 Ma) marine rocks (Kellogg et al., 2008; Ellis, 1994). This unconformity is a result of the Ynezian orogeny (around 30 Ma) during which pre-Oligocene marine rocks were folded and uplifted above younger, Oligocene-age sediments (Kellogg et al., 2008).

Following a period of orogeny, deformation changed to extension from the late Oligocene and early Miocene (around 23 Ma) and the Basin became a major extensional basin (Ellis, 1994). This period also correlated with two transgressive-regressive cycles, where the sea advanced and retreated over geologic time over the sediments now in the Basin due to tectonic subsidence (Bazeley, 1988). Sediments deposited during this period reflect the cyclical nature of sea-level rise and are generally categorized by marine strata in the west and nonmarine strata to the east. Formations deposited during ocean transgression are thick marine sediments, including the Vaqueros Formation, Monterey Formation, Branch Canyon Sandstone, and Santa Margarita Sandstone (Kellogg et al., 2008; Lagoe, 1981). Many of the marine units interfinger with terrestrial units and eventually pinch out to zero thickness in the east. During the late Miocene (8 Ma), the sea regressed from the western part of the region, evident in the geologic record where the nonmarine Caliente Formation interfingers with the similarly aged marine Santa Margarita Sandstone and unconformably overlies the Branch Canyon Sandstone (Kellogg et al., 2008). By the middle Miocene (15 Ma), the eastern Cuyama Valley area was characterized by a shelf and nonmarine deposition. Deformation by the middle Miocene changed from extension to right-lateral strike slip motion, resulting in the development of the Russell Fault.

Deformation from Oligocene extension and Miocene strike-slip faulting regimes was buried by the folding, uplift, and thrust faulting during the Pliocene through Pleistocene compression (beginning around 4 Ma) (Ellis, 1994). Compression led to the uplift of the Coast and Transverse mountain ranges surrounding the current topographic valley and the converging thrust faults that surround the present day topographic basin, including the Whiterock, Morales, and South Cuyama Faults (USGS, 2013b). The transition to a predominantly compressional system led to the development of a thrust system across the older extensional basin and began thrusting older sediments above younger sediments through the Cuyama Valley (Davis et al., 1988). Older, inactive faults and rocks were buried by the deposition of the younger Morales Formation, Older Alluvium, and Younger Alluvium. Thrust and compression continued into the Quaternary (3 to 2.5 Ma) and uplifted the Caliente Range and thrusted Miocene-aged rocks of the Caliente Range southward over Quaternary alluvium on the Morales Fault (USGS, 2013b; Ellis, 1994).

The Morales Formation and Older Alluvium are folded into synclines along the north and south margins of the valley near the bounding thrust faults (USGS, 2013b). The end of the Pliocene (around 2 Ma) marks the complete withdrawal of the sea from the area and the final sea regression marks the change in deposition of marine sediments to the continental clay, silt, sand, and gravel of the Morales Formation and alluvium (Singer and Swarzenski, 1970; Ellis, 1994). Fluvial deposits of claystone, sandstone, and conglomerate became the primary forms of sedimentation.

2.1.4 Geologic Formations/Stratigraphy

The Basin is composed of a sequence of unconsolidated to partly consolidated nonmarine deposits of Pliocene to Pleistocene age unconformably overly consolidated marine and nonmarine sedimentary rocks of late Cretaceous to middle Cenozoic age on top of Mesozoic crystalline granitic and gneissic bedrock (Davis et al., 1988). The unconsolidated to partly consolidated nonmarine deposits are the primary water-bearing units in the Basin and are described in further detail in Section 2.1.7. Individual geologic units found in the Basin are described in detail below, in order of youngest to oldest in deposition. Geologic units mapped at the surface are shown in. Figure 2-2. A generalized stratigraphic column of the Cuyama Valley is shown in Figure 2-3.

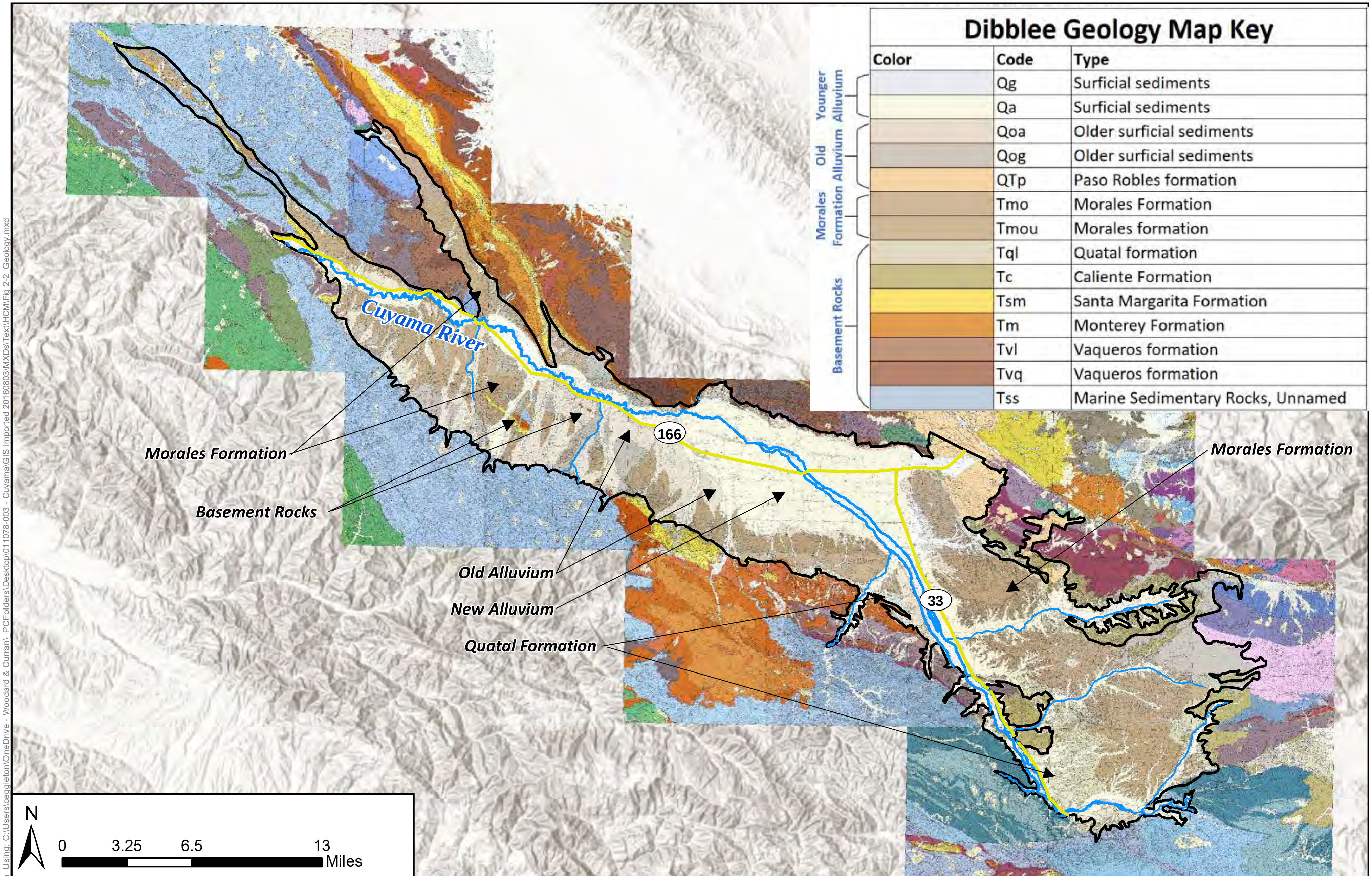

Figure 2-2: Geologic Map

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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Legend

- Cuyama Basin
- Cuyama River
- Streams
- Highways

Data Source: Thomas W. Dibblee, Jr., Dibblee Foundation Relased in June 2012, Purchased from AAPG as GeoTIF 28 March 2018.

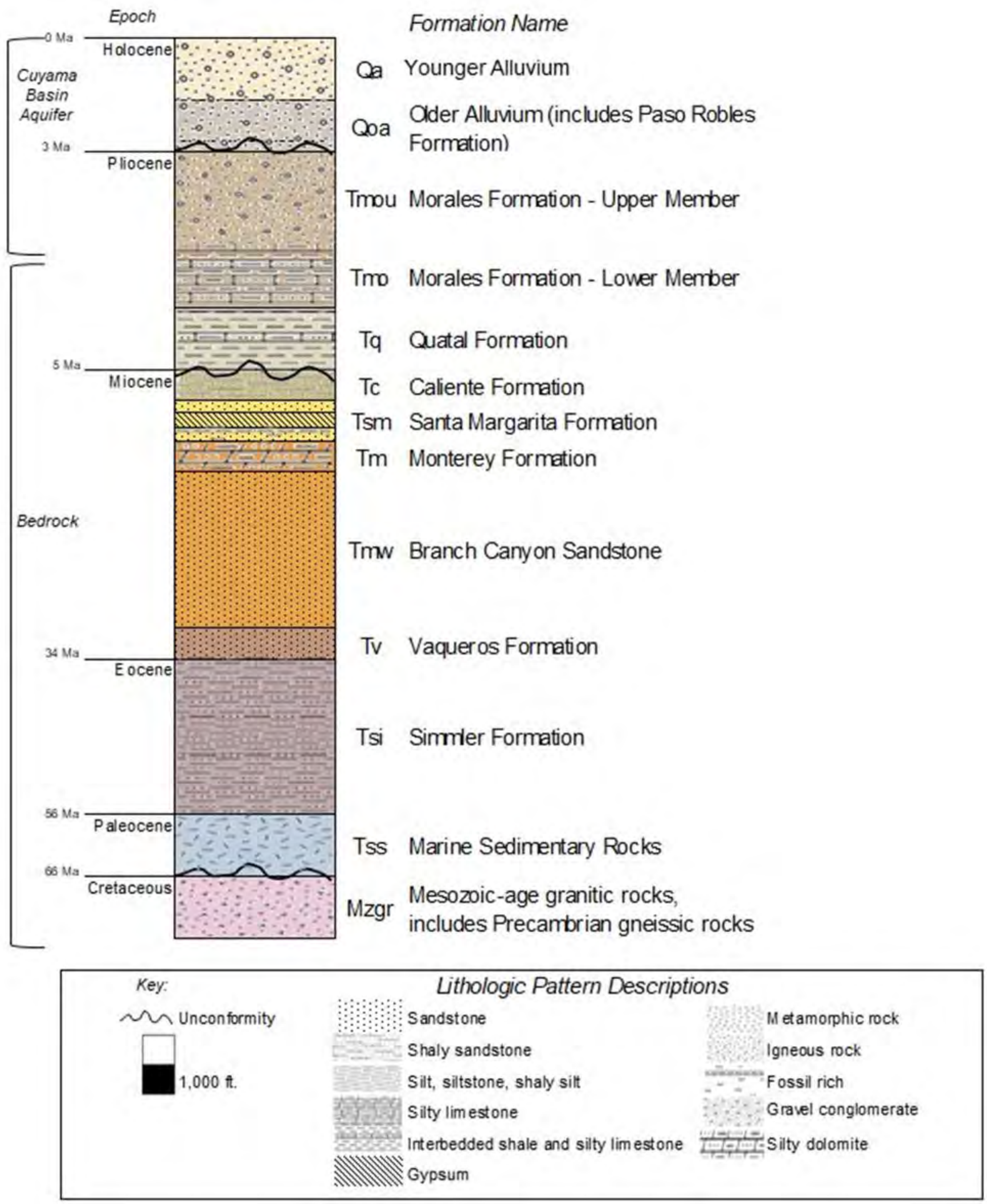
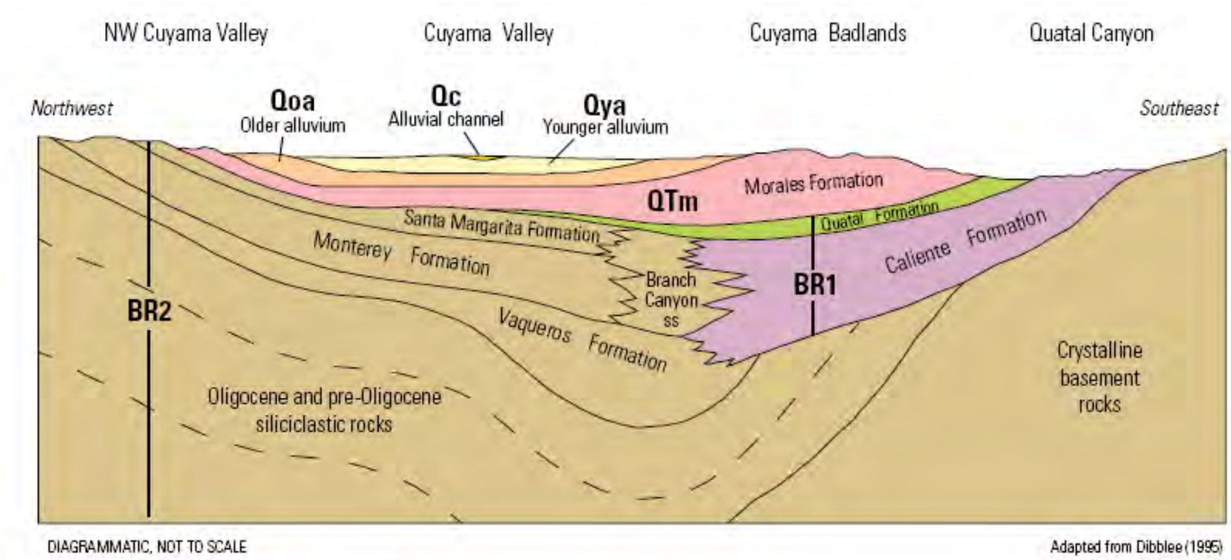


Figure 2-3: Generalized Stratigraphic Column of the Cuyama Valley

Stratigraphic Units of the Cuyama Basin Aquifer

Stratigraphic units in this section are presented in order from youngest to oldest. The USGS prepared a generalized stratigraphic diagram of the Basin and surrounding area (2013a, Figure 2-4). The diagram shows the relationship of the Young Alluvium, Older Alluvium, Morales Formation, and basement rocks in and near the Basin. The diagram shows that the Morales formation is thicker to the east, and that the Caliente Formation is interfingered with a number of other basement rock formations (Santa Margarita, Monterey, Vaqueros) beneath the Basin (USGS, 2013a). This diagram shows the general relationship of formations in the Cuyama area and is not a precise representation of unit thickness.



Source: USGS, 2013a.

Figure 2-4: Generalized Stratigraphic Diagram

Recent and Younger Alluvium

The youngest deposit in the Basin is the Recent and Young Alluvium. Recent alluvium is made up of active fluvial channel deposits associated with the Cuyama River and other active channels. Deposits include river-bed gravels and grain sizes ranging from silt to boulder size and are found along active fluvial channels in the Basin. The Younger Alluvium is inactive fluvial deposits consisting of unconsolidated to partly consolidated sand, gravel, and boulders, with some clay deposited as part of stream channels, floodplains, alluvial fans, or stream terraces (USGS, 2013c). Younger Alluvium is exposed throughout the central portion of the Central Valley and along the active channels and flood plains of the Cuyama River and other streams. The deposits thicken to the east, typically ranging from 5 to 50 feet in the west and to possibly as much as 1,100 feet in the east (Singer and Swarzenski, 1970). Recent and Younger Alluvium are primarily Holocene in age, but the Younger Alluvium can date back to the Pleistocene (USGS, 2013c).

Older studies do not distinguish Younger Alluvium from Older Alluvium (Upson and Worts, 1951; Singer and Swarzenski, 1970), but more recent studies (Kellogg et al., 2008) mapped the two alluvium units as distinguishable mappable units at the surface, and in 2013, the USGS identified differences in the two units using electric log signatures (2013a). A greater degree of consolidation, dissection, and local deformation distinguishes the Older Alluvium deposits from the Younger Alluvium.

Older Alluvium

Older Alluvium is primarily Pleistocene in age and is composed of unconsolidated to partly consolidated sand, gravel, and boulders with some clay (USGS, 2013a). The percentage of clay increases in the western part of the Cuyama Valley. Older Alluvium deposits are typically more consolidated and deformed than Younger Alluvium deposits and contain a higher clay content. The Older Alluvium is dissected alluvial fans, colluvial deposits and sediments on multiple terraces and alluvial surfaces and is found exposed on uplifted alluvial surfaces along the south side of the Cuyama Valley and on the caps of the Turkey Trap and Graveyard ridges (USGS, 2013a). Older Alluvium is typically 400 to 600 feet thick but increases in thickness up to 1,000 feet near the axis of the Cuyama Valley and decreases in thickness west of the Russell Fault (USGS, 2013a; Cleath-Harris, 2018). The Older Alluvium overlies the Morales Formation unconformably, west of the Cuyama Badlands (Ellis, 1994).

Paso Robles Formation

The Paso Robles Formation is part of the Quaternary alluvium series and is commonly grouped with the Older Alluvium. The Paso Robles Formation is a gray, crudely bedded alluvial gravel derived from Miocene rocks and basement rocks of western San Emigdio Mountains east of San Andreas Fault (Davis et al., 1988). The Formation is composed of pebbles, gravel, sand, and some cobbles. The Paso Robles Formation is sandwiched between two unconformities; it rests unconformably below the Older Alluvium and with angular discordance above the Morales Formation (Davis et al., 1988; Ellis, 1994). The Paso Robles Formation is present only in a small northeastern portion of the Basin.

Morales Formation

The Pliocene to Pleistocene-aged Morales Formation (Morales) is divided into two members, the upper and lower. The Morales Formation is the oldest formation to respond to the modern topography of the Basin, indicating its deposition simultaneous to acceleration of tectonic-driven subsidence (Yeats et al., 1989). The contact between the upper and lower members of the Morales is used to define the base of water-bearing units of the Basin (USGS, 2013a). The Younger and Older Alluvium, and Upper Morales Formation are the principal water-bearing formations in the Basin.

The Morales is massively bedded and ranges from 1,000 to 5,000 feet in thickness east of the Russell Fault and up to 1,200 feet thick west of the Russell Fault (USGS, 2013a; Cleath-Harris, 2018). The thickness of the Morales Formation is disputed amongst published references. In 1970, Singer and Swarzenski reported the Morales Formation to be up to 10,000 feet in thickness along the northern margin of the Valley (1970). The Morales Formation is found throughout the Valley and is widely exposed to the east of the Cuyama River near Ventucopa and the Cuyama Badlands. Its lateral extent is generally limited by faults. The Morales Formation is overlain unconformably by the older and Younger Alluvium (Hill, 1958).

Upper Morales

The upper member of the Morales is composed of partly consolidated, poorly sorted deposits of gravelly arkosic sand, pebbles, cobbles, siltstone, and clay of Pleistocene age (Davis et al., 1988). The upper Morales is a water-bearing unit and the base of this member marks the base of aquifer materials in the Basin. The upper Morales is thickest to the east near the Cuyama Badlands, approximately 2,200 feet, and shallows to the west, less than 800 feet west of the Russell Fault (Hill, 1958; Cleath-Harris, 2018). In the central portion of the Basin, south of the Cuyama River, the upper Morales is around 1,500 feet thick (Ellis, 1994). In some areas, such as near Ballinger Canyon, the Morales shows some degree of angular unconformity (Ellis, 1994).

Stratigraphic Units Below the Basin Aquifer

Lower Morales

The lower member of the Morales consists of clay, shale, and limestone with lacustrine clay beds with distinct coarse-grained intervals, boulder trains, and gravelly channel deposits (USGS, 2013a). The lower member of the Morales is finer grained than the upper Morales and is less permeable. The lower Morales is not considered a water bearing unit. South of the Cuyama River, the lower part of the Morales consists of about 1,300 feet of gray, gypsiferous, lacustrine claystones (Hill, 1958). The lower Morales lies conformably on the Quatal Formation and, in western areas of the Basin, unconformably on other marine units (Ellis, 1994).

Quatal Formation

The Quatal Formation is a sequence of fluvial and lacustrine claystone, siltstone, and sandstone which unconformably underlies the Morales Formation. Near the Cuyama Badlands, the formation is up to 820 feet of gypsiferous claystone while in other areas the unit is nonmarine sandstones interbedded with claystone (USGS, 2013a). The Quatal Formation thins to the west and pinches out to zero in thickness near the town of Cuyama. In the eastern and central parts of the Basin, the Quatal Formation is a distinct stratigraphic marker that defines the bottom of the Morales Formation (USGS, 2013a). The Quatal Formation is not a water bearing unit and is not considered a part of the Basin groundwater system.

Caliente Formation

The Caliente Formation is composed of nonmarine sandstones, claystones, and conglomerates of Miocene age (Davis et al., 1988). Layers of volcanic ash and basalt sills and dikes are commonly found in the formation and tertiary basalt is found interbedded with the formation in the Caliente Range (Davis, 1988;

Dudek, 2016). The formation is exposed in the eastern half of the Valley, along the Basin edge in the Caliente Range and in a footwall block of the Pine Mountain Fault (Kellogg et al., 2008). The fluvial Caliente Formation was deposited in the east at the same time the marine Branch Canyon Sandstone and Santa Margarita Formation were being deposited to the west (Ellis, 1994). The Caliente Formation conformably overlies and interfingers with the marine sedimentary rocks of the Santa Margarita Formation and pinches out to zero thickness to the west (Kellogg et al., 2008; Davis et al., 1988).

Santa Margarita Formation

The Santa Margarita Formation is composed of shallow-marine, consolidated sandstones from the middle to late Miocene (USGS, 2013b). The formation contains a gypsum member and a sandstone-mudstone member. The gypsum member consists of a greenish-gray, medium to thin bedded gypsum, up to 82 feet thick (Kellogg et al., 2008). The sandstone and mudstone member consists of interbedded layers of arkosic sandstone, mudstone, and siltstone, up to 400 feet thick (Kellogg et al., 2008). The sandstone sequence is rich in shallow marine molluscan fossils. The formation unconformably underlies the Morales Formation in the northwest of the Valley and grades into the Caliente Formation to the east (Hill, 1958). Locally, the formation contains layers of volcanic ash, basalt sills, dikes and flow units (Davis et al., 1988). The Santa Margarita Formation is the youngest marine unit in the Basin and marks the final phase of marine sedimentation and sea transgression (Lagoe, 1981).

Monterey Formation

The Monterey Formation consists of intervals of dolomitic marine shale, mudstone, and siltstone. The formation is subdivided into two members: the upper Whiterock Bluff Shale member and the lower Saltos Shale member (Davis et al., 1988). The Whiterock Bluff Shale is calcareous in the lower two-thirds and becomes gradually siliceous in the upper one-third and is found up to 1,200 feet in thickness (Bazeley, 1988; Hill, 1958). The Saltos Shale member is a calcareous shale with turbiditic sandstones and was deposited at the same time as the fluvial Caliente Formation, but in the western, bathyal portion of the Basin (Davis et al., 1988; USGS, 2013b). The Saltos Shale member is found up to 2,250 feet thick (Hill, 1958). The formation is middle Miocene in age and is cut with layers of volcanic ash and Miocene-age basalt sills (Davis et al., 1988). In the Caliente Mountain Range, Tertiary basalt is found interbedded with the Monterey Formation (Davis et al., 1988). To the east, the Monterey Formation grades into the Branch Canyon Sandstone. The formation is conformably overlain by the Santa Margarita Formation.

Branch Canyon Sandstone

The Branch Canyon Sandstone is Middle Miocene in age and is a shallow marine sandstone (Davis et al., 1988). Like the Monterey and Santa Margarita formations, the Branch Canyon Sandstone contains layers of volcanic ash and is cut by basalt sills and dikes (Davis et al., 1988). The sandstone grades into the Caliente Formation to the east and is up to 2,500 feet thick (Kellogg et al., 2008). The easternmost extent of the Branch Canyon Sandstone represents an early Miocene wave-dominated shoreline and is defined by the gradational change into the nonmarine Caliente Formation to the east (Davis et al., 1988; Bazeley, 1988).

Vaqueros Formation

Most of the oil produced in the Basin comes from the Vaqueros Formation. The formation is late Oligocene to early Miocene in age and is a marine clastic unit that is subdivided into three members: the upper, shallow-marine Painted Rock Sandstone member, the middle, bathyal Soda Lake Shale member, and the lower, shallow-marine Quail Canyon Sandstone member (Davis et al., 1988). The Vaqueros Formation represents a shallow-marine, high-energy, shoreface environment where the lower half represents a transgressive environment and the upper half represents a regressive environment (Bazeley, 1988). To the east, the Vaqueros Formation grades into the lower part of the nonmarine Caliente Formation. In the Cuyama Badlands, the Vaqueros Formation rests on the Simmler Formation and crystalline basement rocks, while in the central portion of the Basin, the Vaqueros Formation rests on Paleogene sedimentary rocks (Ellis, 1994). The Branch Canyon Sandstone and Monterey Formation are conformably above the Vaqueros Formation (Davis et al., 1988).

Simmler Formation

The Simmler Formation is a terrestrial sandstone, siltstone, and conglomerate of the Oligocene epoch (Davis et al., 1988). The Simmler Formation contains a shale member with intervals of claystones and siltstones interbedded with coarse sandstones and a sandstone member containing sandstones interbedded with siltstones and claystones (Kellogg et al., 2008). The formation is as thick as 2,800 feet and overlies the Eocene-Oligocene unconformity (Kellogg et al., 2008). To the east, the Simmler Formation interfingers with a thin section of the marine Vaqueros Formation, marking the beginning of marine regression in the early to middle Miocene (Kellogg et al., 2008). Sediments of the Simmler Formation were sourced from the erosion of the Santa Barbara Canyon area and were deposited on a wide, delta plain (Bazeley, 1988). Though rare, the Simmler Formation can contain interbedded mafic volcanics (Yeats et al., 1989).

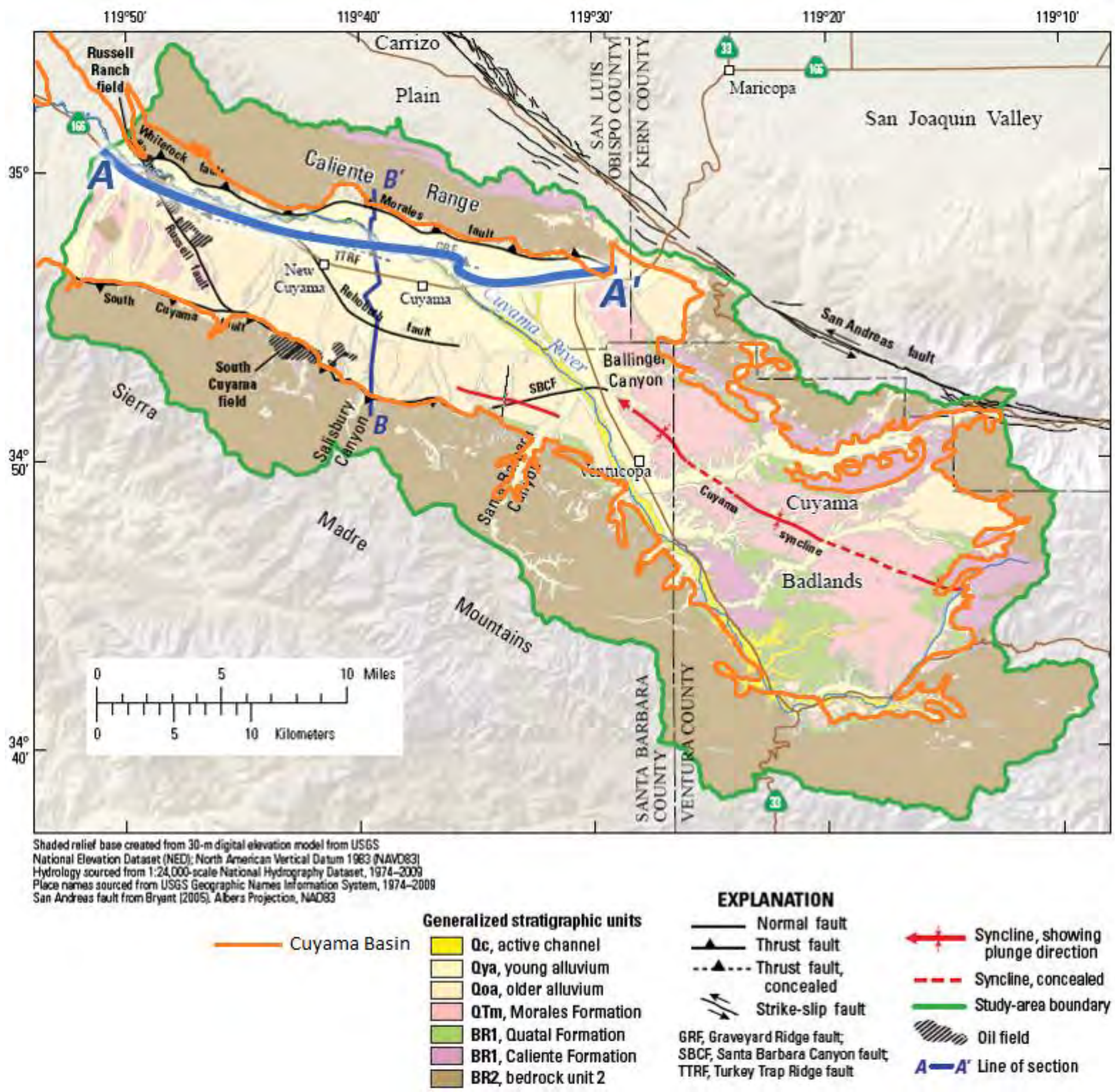
Marine Sedimentary Rocks

Late Cretaceous to Eocene marine rocks are unnamed but are part of the crystalline basement of the Cuyama Valley (Davis et al., 1988). The strata are unconformably overlain by a thick section of middle and upper Cenozoic rocks and are primarily exposed in the La Panza and Sierra Madre ranges and the hanging walls of the South Cuyama, La Panza, and Ozena faults (Davis et al., 1988).

Formations Older than Marine Sedimentary Rocks

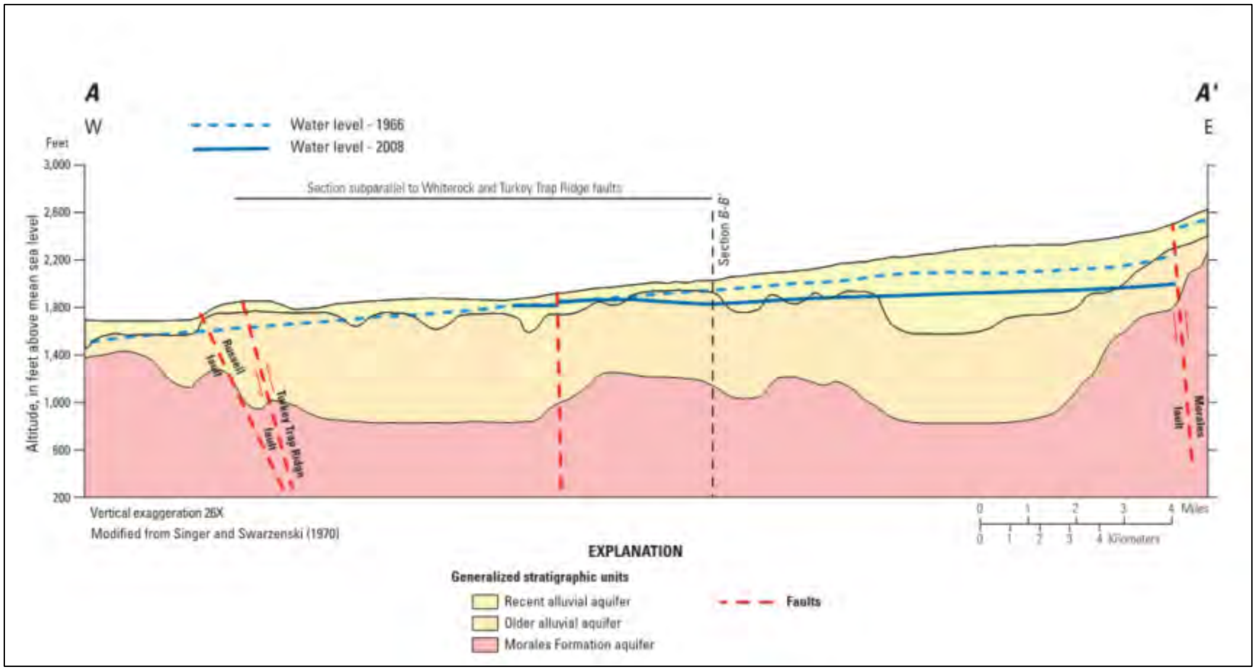
The crystalline rocks of the Cuyama Valley are composed of Mesozoic-age granitic rocks and Precambrian-age gneissic rocks (Davis et al., 1988). Cretaceous granitic rocks are exposed in the La Panza Range and near the San Andreas Fault, 12 to 18 miles southeast of the Cuyama Valley (USGS, 2013b). Precambrian granitic gneissic rocks outcrop east of the Cuyama Badlands and the La Panza Range (USGS, 2013b). Total thickness is unknown.

Figure 2-5 shows the locations of cross sections across the central portion of the Basin prepared by the USGS (2013a). Figure 2-5 shows a west-east cross section that runs near the towns of New Cuyama and Cuyama labeled A-A', and a south-north cross section labeled B-B'. Figure 2-6 shows the A-A' cross section and Figure 2-7 shows the B-B' cross section. Cross-section A-A' shows the layering of Recent and Old alluvial aquifers and the Morales Formation aquifer. It also shows where the Russell Fault and Turkey Trap Ridge Fault cross the cross section and shows groundwater elevation. Cross section B-B' shows layering of the aquifers and the locations where the Rehoboth and Graveyard Ridge fault cross the cross section.



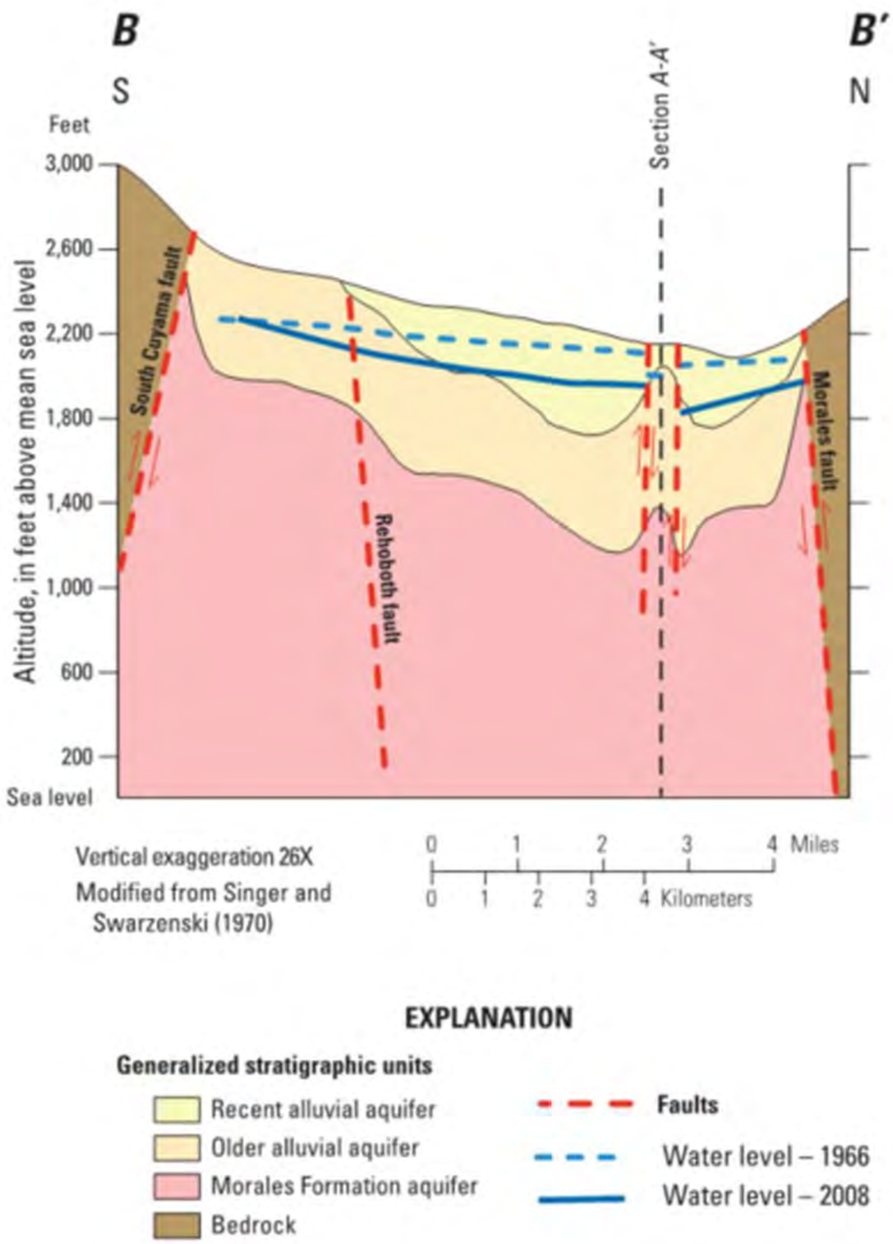
Source: USGS, 2015.

Figure 2-5: Location of USGS 2015 Cross Sections



Source: USGS, 2015

Figure 2-6: USGS Cross Section A-A'



Source: USGS, 2015

Figure 2-7: USGS Cross Section B-B'

2.1.5 Faults and Structural Features

The Basin is bounded by faults and contains a number of tectonic features including synclines, faults, and outcrops of basement rocks in the Basin. Major faults and synclines are shown in Figure 2-8. Outcrops of basement rocks are shown on available geologic maps (and Figure 2-5).

Synclines

There are a number of synclines in the Basin; they are generally oriented to the northwest/southeast consistent with how the majority of the Basin is oriented.

Cuyama Syncline

The Cuyama Syncline is located in the southeastern portion of the Basin. It stretches from the Ballinger Canyon south into the Cuyama Badlands, ending along the Cuyama River. The Cuyama Syncline plunges from the Ventucopa area northwestward to beneath the valley from the Ventucopa area to the southeast. The syncline is known from subsurface data from oil exploration wells beneath the valley and exposures near the town of Ventucopa and in the Cuyama Badlands. (USGS, 2013a). The axis of the syncline strikes roughly parallel to the San Andreas Fault (N50ºW) and plunges to the northwest (13ºNW) (Singer and Swarzenski, 1970; Ellis, 1994). The Cuyama syncline was a depocenter (a site of sediment accumulation) during the deposition of the Morales Formation (Ellis, 1994). The syncline has folded water and non-water bearing formations and is favorable to the transmission of water from the southeast end of the valley but otherwise has no pronounced effect on the occurrence of groundwater (Upson and Worts, 1951).

Syncline Near the Santa Barbara Canyon Fault

Near the Santa Barbara Canyon Fault, a syncline is indicated by the USGS (2013a). The syncline runs generally east-west and is roughly five miles long. It ends near the southern edge of the South Cuyama Fault.

Syncline in the Southwestern Portion of the Basin

There is a syncline in the western portion of the Basin that roughly follows a west-northwest direction near the southern border of the Basin, located southwest of the Russel Fault, near an outcrop of the Santa Margarita formation (Cleath-Harris, 2018). The full extent of this syncline, and its length are not documented at this time, but likely extends 5 to 10 miles, which is the length of documented Faults in the area, as mapped by Dibblee (2005).

Major Faults

There are a number of faults within the Basin, many of which take the form of 'fault zones' where there are multiple individual faults close together oriented in the same direction. This section describes each major fault individually, with consideration that there are often additional small faults near each major fault. Major faults are shown in Figure 2-8.

Russell Fault

The Russell Fault is a subsurface, right lateral, strike-slip fault that is seven miles long and runs roughly parallel to the Russell Ranch oil field through the western portion of the Basin.

The Russell Fault offsets the top of bedrock by as much as 1,500 feet (Nevins, 1982). The NW-striking fault in the northwestern part of the Cuyama Valley has had approximately 18 miles of right-lateral offset that occurred between 23 and 4 Ma (USGS, 2013a; Ellis, 1994). The fault is referred to as strike-slip by several authors, and normal fault by others, and is sometimes referred to as both strike-slip and normal fault in the same document (USGS, 2013a). Water bearing units on the western (upthrown) side of the Russell Fault become thinner to the west and become thicker to the east due to this uplift. Alluvium is generally limited to stream channels and the Cuyama River bed on the western side of the fault.

The Russell Fault has been analyzed by a number of authors who have come to different conclusions regarding the fault's potential to be a barrier to groundwater flow. In 1989, Yeats stated that "the base of the Morales Formation is not cut by the fault" (1989). Using tectonic activity and decreasing offset of younger beds, Yeats concluded that the Vaqueros Formation is primarily impacted as it was deposited during the fault's most active period and that by the time the Morales Formation was deposited 19 million years later, activity on the fault had ceased (Yeats et al., 1989). In 2013, the USGS studied the fault using interferometric synthetic-aperture radar (InSAR) data and concluded that "the Russell Fault did not appear to be acting as a barrier to groundwater flow" (USGS, 2013c). In 2015, the USGS identified the Russell Fault as a barrier to flow and used it as a no flow boundary in the Cuyama Valley Hydrologic Model (CUVHM) (USGS, 2015). Based on the conclusions of the USGS, Dudek stated that the fault has indicators that it obstructs groundwater flow due to truncation of older geologic formations and standing moisture near the fault and prepared a basin boundary modification request based on the conclusion that the fault is a barrier to flow (Dudek, 2016). In addition, Cleath-Harris Geologists concluded that the fault is a barrier to flow and prepared a technical memorandum to document their study of the fault's behavior (Cleath-Harris, 2018). In 2016, DWR denied a request for a Basin boundary modification based on claims that the Russell fault is a barrier to groundwater flow and divides groundwater in the central portion of the Basin from groundwater in the west, citing a lack of hydrogeologic data that supported evidence of barrier. EKI Environment & Water, Inc. (EKI) reviewed the USGS's work in 2017 and concluded the fault potential to be a barrier is not understood and recommended additional study to refine the fault's properties (EKI, 2017).

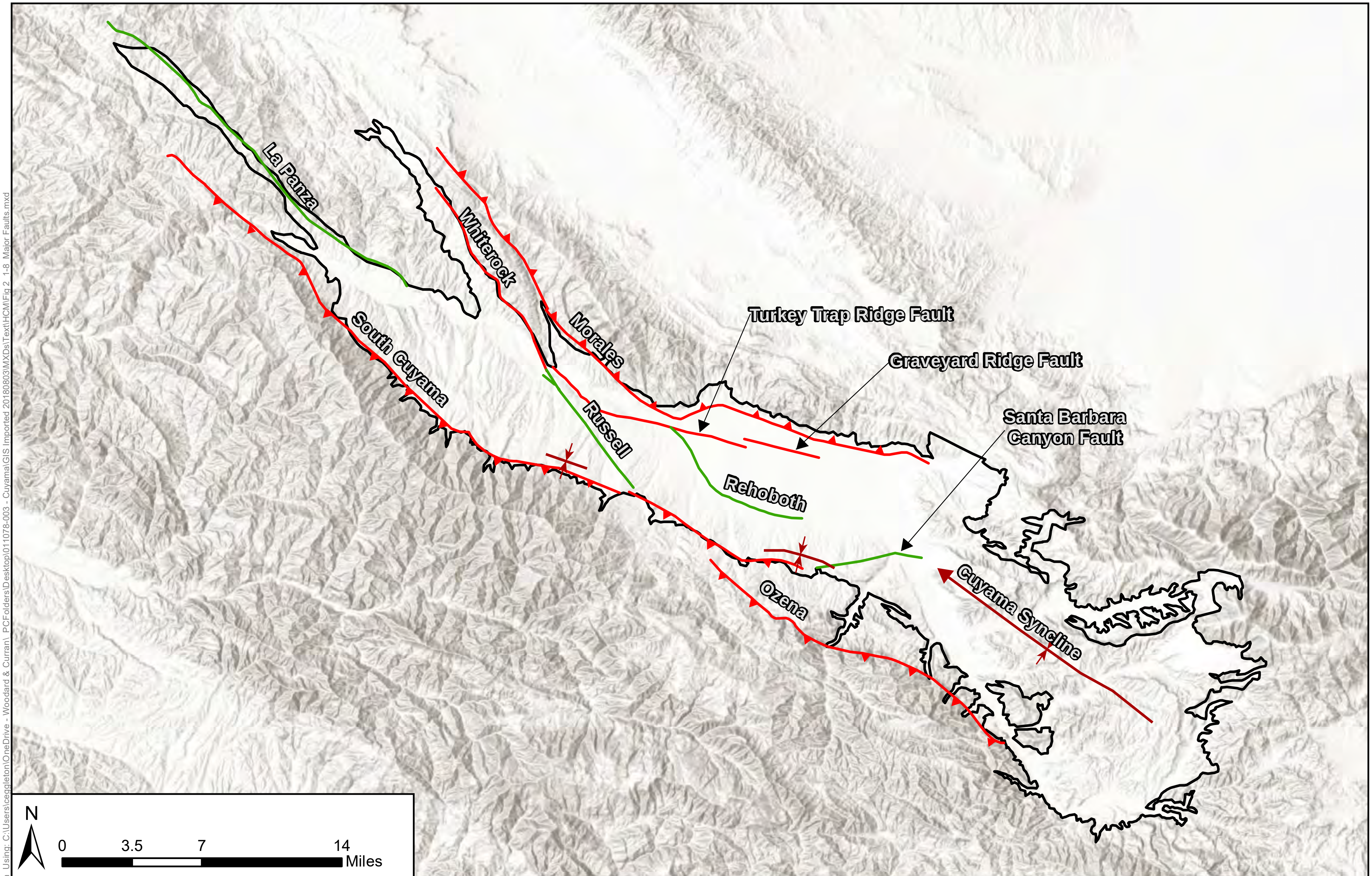


Figure 2-8: Major Faults

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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Legend

Fault Types

- Normal
- Syncline
- Thrust
- Thrust Fault, Concealed

Cuyama Basin

Figure Exported: 8/21/2018 By: ceggleton Using: C:\Users\ceggleton\OneDrive - Woodard & Curran\ PCFolders\Desktop\011078-003 - Cuyama\GIS Imported 20180803\MXDs\Text\HCM\Fig 2_1-8_Major Faults.mxd

Rehoboth Fault

The Rehoboth Fault is a normal, subsurface fault that bisects the central portion of the Basin. The fault is approximately eight miles long and trends to the east-southeast. The USGS concluded that evidence of the fault is inferred based on water level-changes in the west-central part of the valley and offset of the Morales Formation (USGS, 2013b; USGS, 2013a). The top of the Morales Formation is offset 160 feet on the northeast side of the fault and the offset increases with depth (USGS, 2013a). Surface exposures of the Older Alluvium do not appear to be offset along the trace of the fault, indicating the motion of the Rehoboth Fault ceased prior to the deposition of the Older and Younger Alluvium (USGS, 2013a).

Despite stating that the Rehoboth Fault does not "have a discernible effect on the elevation" of the Older and Younger Alluvium and that the fault was "not a significant barrier to groundwater flow" as symmetrical subsidence and uplift was observed on both sides of the fault, the USGS included the Rehoboth Fault as a leaky, horizontal barrier to groundwater flow in the CUVHM (USGS, 2013a; USGS, 2013b; USGS, 2015). In the CUVHM, the Rehoboth Fault impedes underflow in the Older Alluvium and Morales Formation along the Sierra Madre Foothills region (USGS, 2015). The USGS also listed the Rehoboth Fault as affecting the Younger and Older Alluvium and the Morales Formation in a summary table of "Geologic Units affected by Cuyama Valley faults" (USGS, 2013a).

Whiterock Fault

The Whiterock Fault is a surface and subsurface thrust fault that runs along the northern finger in the western part of the Cuyama Basin. The fault can be traced further south under the Basin near the Cuyama River and the Russell Fault and State Route (SR) 166, though it is buried (Calhoun, 1985). The fault dips northeast and is late Oligocene to early Miocene in age (Davis et al., 1988). The Whiterock Fault is exposed at the surface where it thrusts the Monterey Formation over the Morales Formation (Davis et al., 1988). Activity along the fault began after movement ceased on the Russell Fault and tectonically overrides the Russell Fault (Nevins, 1982; Calhoun, 1985). The fault cuts the Morales Formation south of the Cuyama River but does not affect the Younger or Older Alluvium (DeLong et al., 2011; Nevins, 1982).

Turkey Trap Ridge Fault and Graveyard Ridge Fault

The Turkey Trap Ridge Fault and the Graveyard Ridge Fault are normal, subsurface faults that trend slightly north of west in the west-center part of the Cuyama Valley (USGS, 2013a). The primary difference between the two faults is that the Turkey Trap Ridge Fault is 11 miles long and located southwest of the Graveyard Ridge Fault; the Graveyard Ridge Fault is four miles long. Both faults are located north of SR 166 and are oriented in a "left-stepping, echelon pattern" (USGS, 2013a). Seismic reflection profiles collected along the ridges indicate they are bounded by north-dipping, south-directed, reverse faults along the south sides (USGS, 2013a). Both faults are considered to be barriers to groundwater flow. Evidence of the faults and their no-flow zones include springs and seeps along the base of the faults in the 1940-50s and water-level changes across the faults of 80 to 100 feet in the area near these ridges (Upson and Worts, 1951; Singer and Swarzenski, 1970).

Singer and Swarzenski (1970) reported that water removed by pumping from this region was slow to replenish because the faults restrict movement of water from neighboring areas. The impediment to flow could be related to the hydraulic properties of the faults themselves or fault juxtaposition of older, slightly less permeable Older Alluvium to the north against Younger Alluvium to the south of the faults (USGS, 2013a).

South Cuyama Fault

The South Cuyama Fault is a surficial, thrust fault that defines a 39-mile stretch of the Basin's southwestern boundary. The fault thrusts the Eocene-Cretaceous aged marine sediments against the Older Alluvium and Morales Formation and impedes groundwater flow across the fault zone.

Ozena Fault

The Ozena Fault is a 17-mile long surficial, thrust fault located three miles south of the Cuyama Basin and locally cuts through the southeastern canyons of the Basin. Less than one mile of the Ozena Fault is within the Basin boundary. The fault trends west to northwest and runs parallel to the Basin boundary.

Santa Barbara Canyon Fault

The Santa Barbara Canyon Fault is a normal, subsurface fault with a northeast strike near the opening of the Santa Barbara Canyon. The fault offsets Basin deposits with impermeable Eocene-Cretaceous marine rocks (typically the Simmler and Vaqueros Formations) (Bazeley, 1988). Evidence of the fault comes from reported seasonal springs, a steep hydraulic gradient in the southeastern part of the Cuyama Valley near the fault, and the truncation of distinct gravel beds (Singer and Swarzenski, 1970). Groundwater elevations in the Ventucopa area have been reported 110 feet higher than water levels to the north (Singer and Swarzenski, 1970). In 2013, the USGS concluded that the Santa Barbara Canyon Fault was a barrier to groundwater flow, "Relatively small amount of vertical offset in the Santa Barbara Canyon Fault indicates changes in water levels across the fault documented in previous studies are perhaps the result of distinct fault-zone properties rather than juxtaposition of units of differing water-transmitting ability" (USGS, 2013a). In 2015, the USGS also considered the fault to be a barrier as it prevents groundwater flow from moving across the boundary bounded by the marine rocks (2015).

La Panza Fault

The La Panza Fault is a surficial thrust fault that trends west to northwest along 22 miles of the western margin of the Basin (USGS, 2013b). The present day thrust fault is a reactivated Oligocene extensional fault that was once part of the same system with the Ozena Fault (USGS, 2013b; Yeats et al., 1989). The fault defines the west-central margin of the Basin as it juxtaposes older non-water bearing Eocene to

Cretaceous marine rocks and the Simmler Formation against the younger, water bearing alluvium and Morales Formation, impeding groundwater flow across the fault.

Morales Fault

The Morales Fault is a 30-mile-long thrust fault that forms the boundary along the north-central portion of the Basin. The Morales thrust fault has a dip of approximately 30 degrees (Davis et al., 1988).

Unnamed Fault Near Outcrop of Santa Margarita Formation

A fault located southwest of the Russell Fault runs southeast to northwest and is located next to an outcrop of the Santa Margarita Formation inside the Basin (Dibblee, 2005). The fault runs parallel to the long side of the outcrop and bounds the syncline that is to the south of the outcrop. The fault's extent is not well documented, and its surficial exposure is roughly five miles long.

Outcrops of Bedrock Inside the Basin

There are a number of outcrops of non-aquifer material within the Basin. The outcrops occur primarily in the eastern upland portion of the Basin and the western portion, near and to the west of the Russell Fault. Outcrops of basement rock in the western portion of the Basin occur in a different manner than those in the eastern portion, outcrops in the eastern portion are likely depositional contacts with the Morales formation that were missed during basin delineation by DWR.[5] Outcrops in the western portion are likely tied to tectonic activity and faulting.

Outcrops of basement rock in the eastern upland portion of the Basin are shown in Figure 2-2. The Quatal Formation and the Caliente Formation are present within the Basin boundary near the edges of the Basin. The Quatal Formation is exposed at the surface near the Cuyama River, and at the higher elevations of the Basin, and in a band near the Quatal Canyon. The Caliente Formation is exposed at the surface within the Basin in the northeast portion of the Basin, near and along the Quatal Canyon. Another outcrop of Caliente Formation is present near the Cuyama River, but that outcrop has been excluded from the Basin during the Basin's delineation by DWR and is visible in Figure 2-2. Outcrops of basement rock in the western portion of the Basin are exposed at the surface in limited areas and are tied to tectonic activity in the area.

[5] DWR delineates basins based on the type of restrictions to groundwater flow. The boundaries of the Cuyama Basin were delineated by DWR because they were the boundary between permeable sedimentary materials (within the Basin) and impermeable bedrock (outside the Basin). DWR defines this boundary as "Impermeable bedrock with lower water yielding capacity. These include consolidated rocks of continental and marine origin and crystalline/or metamorphic rock."

Figure 2-9 shows the outcrops of bedrock near the Russell Fault with an overlay of areas identified by DeLong as “Tr,” or out of basin bedrock, overlain on the geologic mapping performed by Dibblee. In general, the outcrops identified by DeLong and Dibblee largely overlap and indicate that in separate field study efforts, the outcrops were identified independently by different geologists. As shown in Figure 2-9 outcrops of non-aquifer materials are present near the Russell Fault, next to the Cuyama River, as well as to the south of the Cuyama River, both in small outcrops that are partially linear in nature, and larger outcrops that are located next to faults, such as where the Santa Margarita and Monterey Formations and Marine Sedimentary Rocks are present. The presence of these non-aquifer materials in this area likely restricts groundwater movement by limiting the extent of permeable materials in this portion of the Basin.

Data Sources:
De Long: Climate change triggered sedimentation and progressive tectonic uplift in a coupled piedmont–axial system: Cuyama Valley, California, USA.
Stephen B. DeLong, Jon D. Pelletier, and Lee J. Arnold
Earth Surface Processes and Landforms
Earth Surf. Process. Landforms 33, 1033–1046 (2008)
Published online 13 September 2007 in Wiley InterScience (www.interscience.wiley.com) DOI: 10.1002/esp.1600
Dibblee: Thomas W. Dibblee, Jr., Dibblee Foundation, Relased in June 2012, Purchased from AAPG as GeoTIF 28 March 2018.

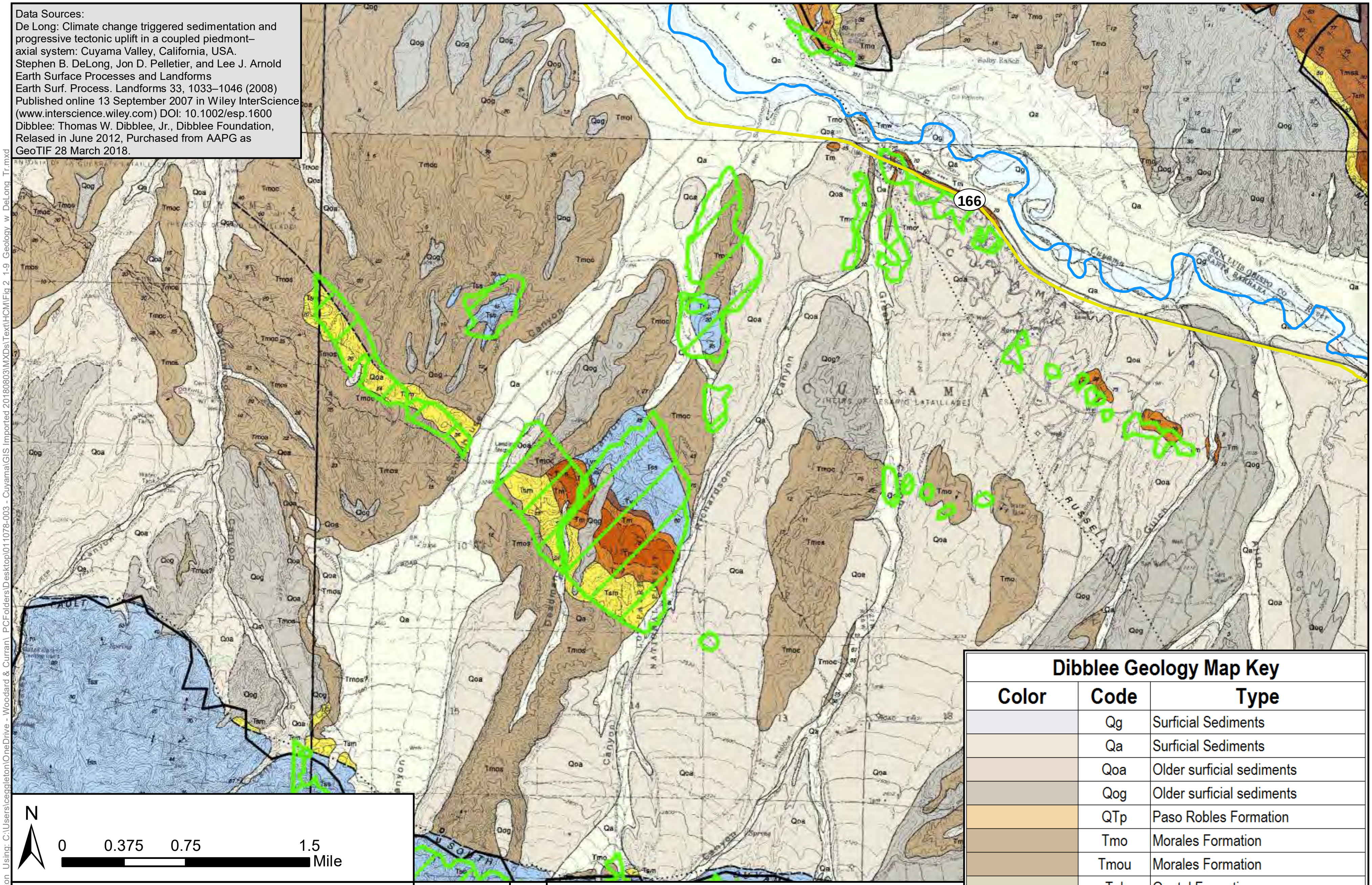

Figure 2-9: Geology with De Long "Tr" Overlay

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Legend

- Cuyama Basin
- De Long Geology "Tr" - Out of Basin Bedrock
- Highways
- Cuyama River

Dibblee Geology Map Key

Color	Code	Type
	Qg	Surficial Sediments
	Qa	Surficial Sediments
	Qoa	Older surficial sediments
	Qog	Older surficial sediments
	QTp	Paso Robles Formation
	Tmo	Morales Formation
	Tmou	Morales Formation
	Tql	Quatal Formation
	Tc	Caliente Formation
	Tsm	Santa Margarita Formation
	Tm	Monterey Formation
	Tvl	Vaqueros Formation
	Tvq	Vaqueros Formation
	Tss	Marine Sedimentary Rocks,

Additional Analysis Since GSP was Submitted

Airborne Electromagnetic Surveys

In order to better characterize the subsurface hydrogeology in the Basin, DWR coordinated a regional Airborne Electromagnetic Survey (AEM). This survey was performed in August 2021 and involved scanning the Basin with helicopter-mounted geophysical equipment to measure electrical resistivity at depths of up to 1,500 feet bgs. Twenty-three survey lines were flown with one line generally parallel to the Cuyama River and the remaining lines perpendicular to the river valley in order to generate a 3-D cross sectional model of the Basin. Figure 2-10 shows the AEM survey flight lines over the Basin.

The raw survey data was processed by Ramboll on behalf of DWR and provided to the public. The released data was provided in cross sectional resistivity as well as interpreted ratios of the texture of the subsurface materials (coarse vs fine grained). Woodard & Curran staff analyzed the public AEM data in both formats to generate a more refined conceptual model of the Basin. The AEM data were used to improve the design of the layering in the CBWRM Model, as well as model parameterization and calibration. Lithology data gathered from well logs were correlated with the AEM data as well as general knowledge of the geology of the Basin from previous USGS work was also used. Faults were also identified in the AEM data and were taken into consideration in refining model layering and hydraulic conductivity. Figure 2-11 shows several flight lines in the southeastern portion of the Basin as red lines on an aerial photograph. The figure also shows the 3-D representation of resistivity along those lines to the depth of investigation. The resistivity scale indicates low readings in blue and high readings in red.

CBGSA Investigation of Russell and Santa Barbara Canyon Faults

The CBGSA authorized Woodard & Curran to conduct a streamlined investigation of the Santa Barbara Canyon Fault in the southeastern portion of the Basin and the Russell Fault in the western portion of the Basin. These faults have been analyzed by a number of authors who have come to different conclusions regarding the potential of the faults to be a barrier to groundwater flow. The investigation consisted of several components with surface geophysical surveys being the primary component. Spectrum Geophysics of Huntington Beach, California was retained to conduct the surveys and analyze the data.

The surface geophysical surveys were designed to evaluate the depth of the buried faults since both are reportedly inactive and buried by alluvium after movement ceased, the orientation and historic movement (i.e., normal, strike-slip, or thrust), the juxtaposition of formations with different water transmitting capacities resulting from past movement, and evidence of the presence of groundwater on both sides of the faults.

The study consisted of two transects (or lines) across the mapped locations of the faults with lengths of 3,000 to 3,600 feet to achieve investigation depths of 600 to 800 feet bgs. The linear transects were laid out roughly perpendicular to the faults, subject to land access (private and government) and terrain. Electrodes were attached to steel stakes that were spaced 10 meters (roughly 30 feet) apart and driven about 18 inches into the ground. The surveys were conducted using direct current (DC) electrical resistivity (ER) and induced polarization.

The transects for the Santa Barbara Canyon Fault are shown in Figure 2-12. Line 1 was oriented southeast to northwest and located on the east side of Highway 33 in the right-of-way. The work was conducted under an encroachment permit from Caltrans. Line 2 was oriented south to north and located in the floodplain and bed of the Cuyama River. The work was conducted pursuant to a Categorical Exemption from the U.S. Bureau of Land Management. Profiles of ER for Line 1 and Line 2 are shown in Figure 2-13. Similarly, profiles of induced polarization for both lines are shown in Figure 2-14.

The ER data on Line 1 shows relatively laterally continuous lithology across the profile. The inferred location of the fault by the USGS was not present. Depth to groundwater was about 600 feet bgs based on information from monitoring well MW-H (Opti 915 and 916) that was recently constructed within Line 1. In contrast, the ER data on Line 2 shows abrupt lateral changes that are interpreted to be faults. The Santa Barbara Canyon Fault was identified as a vertical/subvertical north-dipping fault near the mid-point of the transect at a depth of about 212 feet bgs. A younger, unnamed south-dipping thrust fault was detected a short distance to the south. This younger fault appears to be thrusting Lower Morales over the Upper Morales. Depth to groundwater south of this fault is 50 to 100 feet bgs and markedly lower to the north. Water bearing zones were not observed north of the buried Santa Barbara Canyon Fault to the investigation depth of about 600 feet bgs.

The locations of these faults on Line 2 are shown in Figure 2-12. It appears the Santa Barbara Canyon Fault extends further to the northeast rather than bend distinctly to the east as inferred by the USGS. Interpretation of this data set indicates that the fault zone/system offsets both the Lower and Upper Morales as well as deep alluvium, contrary to published literature.

The transects for the Russell Fault are shown in Figure 2-15. Locations of the transects were restricted to avoid bedrock outcrops, the deeply incised and meandering Cuyama River channel, and oil field operations immediately east of the fault. Line 1 and Line 2 were oriented southeast to northwest oblique to the mapped location of the fault. The transects extended from the Russell Ranch east of the fault to the North Fork Ranch to the west. Natural vegetation was more extensive on the North Fork Ranch that prevented the collection of induced polarization on Line 2. Cultural interferences included a barbed wire fence between the private properties, oil wells, and pipelines. The ER profiles for Line 1 and Line 2 are shown in Figure 2-16. The induced polarization profile for Line 1 is shown in Figure 2-17.

The ER data on Line 1 shows abrupt lateral changes in resistivity that are interpreted to be faults. The vertical anomaly at the mid-point of the transect is interpreted to be the vertical Russell Fault that extends upward to a depth of about 50 feet bgs. A likely younger, apparent east-dipping thrust fault east of the Russell Fault is interpreted to be the Turkey Trap Ridge Fault. This interpretation is consistent with mapping of the Russell, Turkey Trap Ridge, and Whiterock faults in this area by the USGS (2015). The Lower Morales has been mapped east of the Russell Fault. A similarly very low resistivity unit is interpreted to be the Lower Morales west of the fault overlying the older Monterrey Formation. The younger Turkey Trap Ridge Fault appears to be trusting the older Monterrey Formation over the Lower Morales west of the fault. Groundwater appears to be about 50 feet bgs across the profile. The thickness of saturated alluvium is greater east of the fault zone/system.

Abrupt lateral changes in resistivity are also observed on Line 2. The vertical Russell Fault and apparent east-dipping thrust fault east of the Russell Fault interpreted to be the Turkey Trap Ridge Fault are shown. Another thrust fault appears to be thrusting the Lower Morales over the more deeply buried Russell Fault and Monterrey Formation west of the fault. Groundwater appears to be about 40 feet bgs across Line 2 which is closer to the Cuyama River.

The locations of these faults on Line 1 and Line 2 are shown in Figure 2-15. Interpretation of this data set indicates that the Russell Fault offsets the Morales and deep alluvium, contrary to published literature. The Turkey Trap Ridge Fault offsets both the Upper and Lower Morales and deep alluvium. Similar to the investigation of the Santa Barbara Canyon Fault, this geophysical survey identified a more complex fault system than previously reported in published literature.

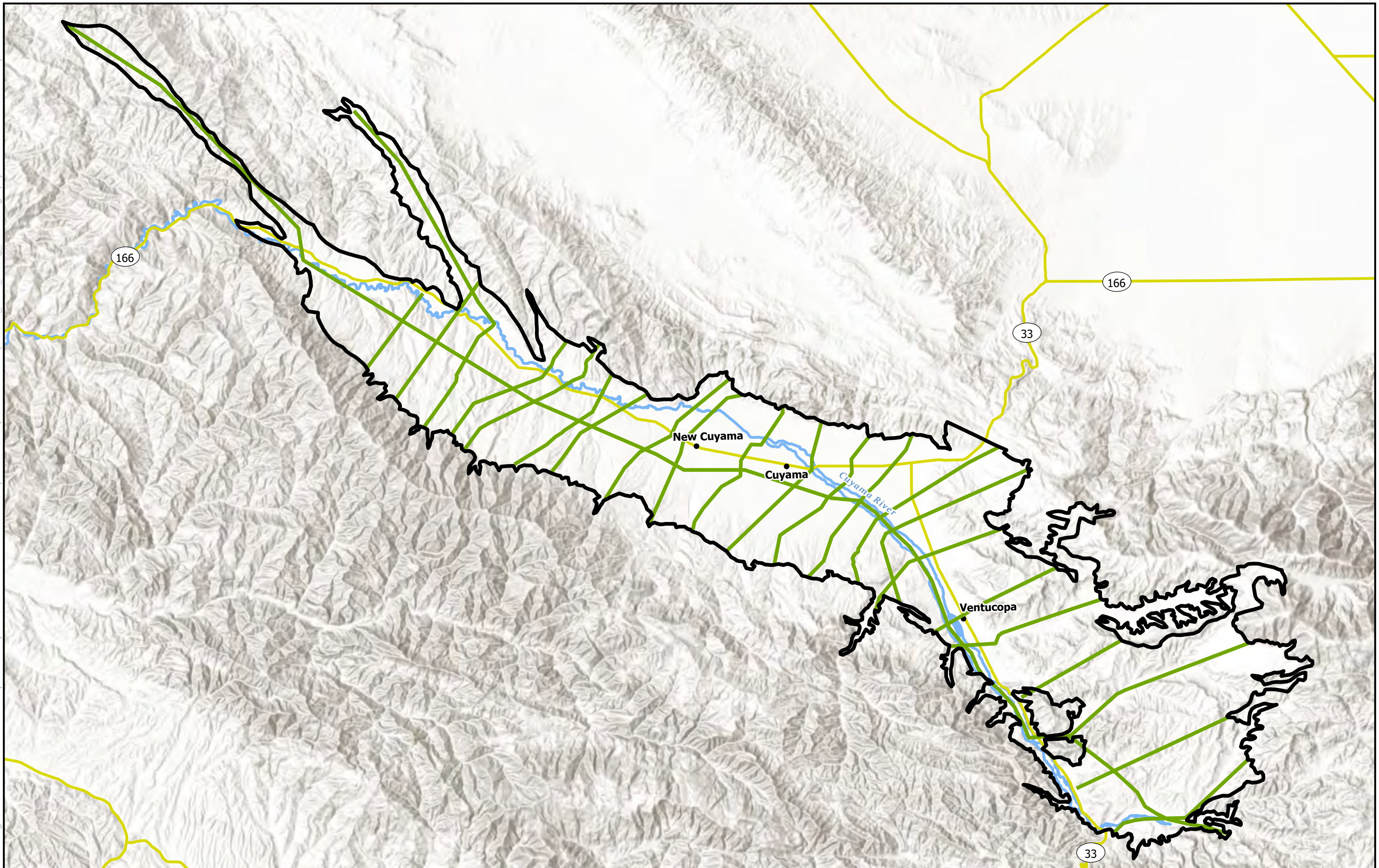


Figure 2-10: Distribution of AEM Flight Lines

Cuyama Valley Groundwater Basin

Legend

- Highway
- Town
- Cuyama River
- Cuyama Basin
- AEM Flight Lines

Woodard & Curran

Cuyama Basin Groundwater Sustainability Agency

Map Created: July 2024

Figure Exported: 7/10/2024 By: ACamille Using: \\woodardcurran.net\shared\Projects\CA Cuyama Basin GSA\0011078.01 GSP\wip\Z_GIS\2_Maps\3_2025 GSP Update\02_Basin_Setting_Overview\geophysical\AEM lines\AEMlines.aprx

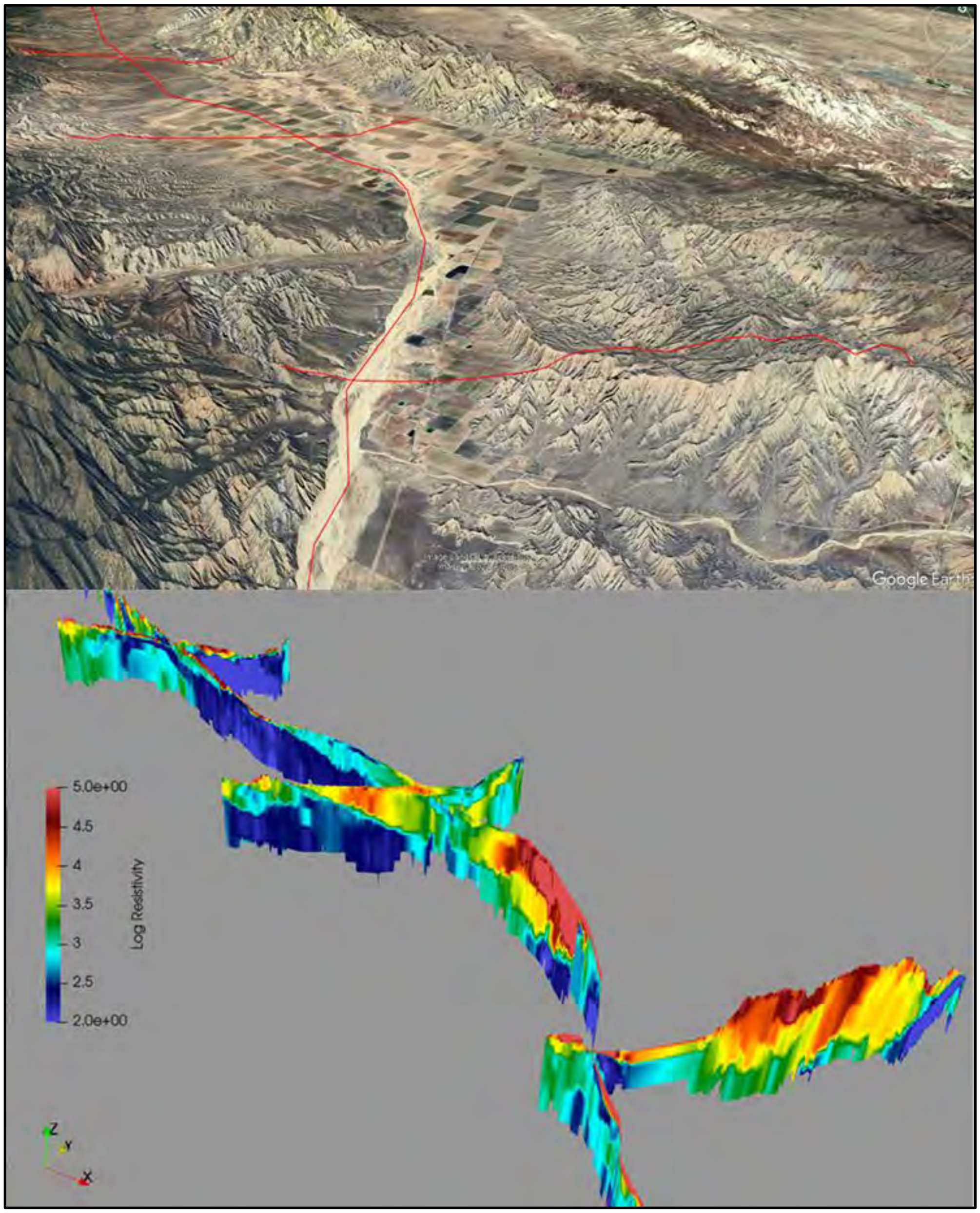


Figure 2-11: DWR AEM Survey Transect

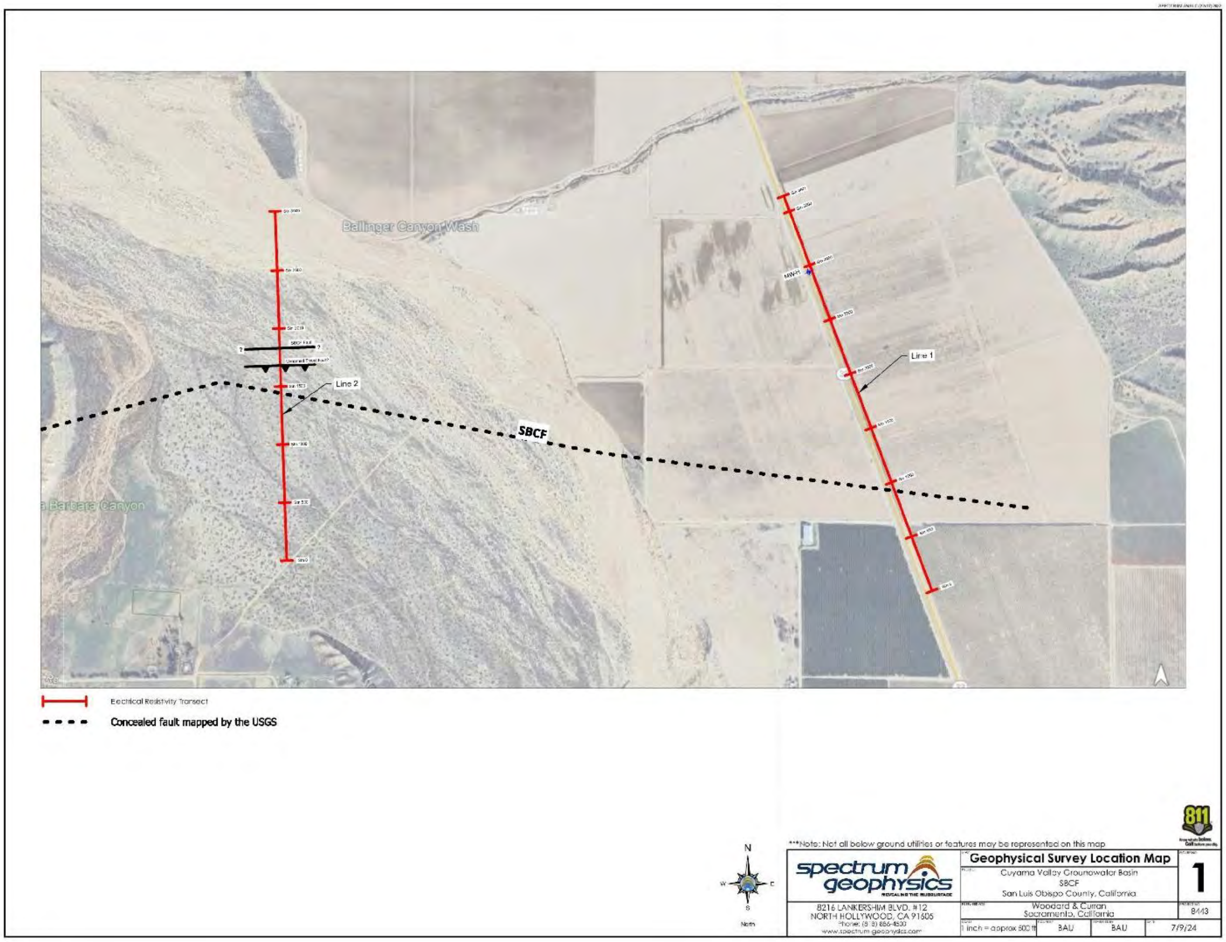


Figure 2-12: Location of Transects for Santa Barbara Canyon Fault

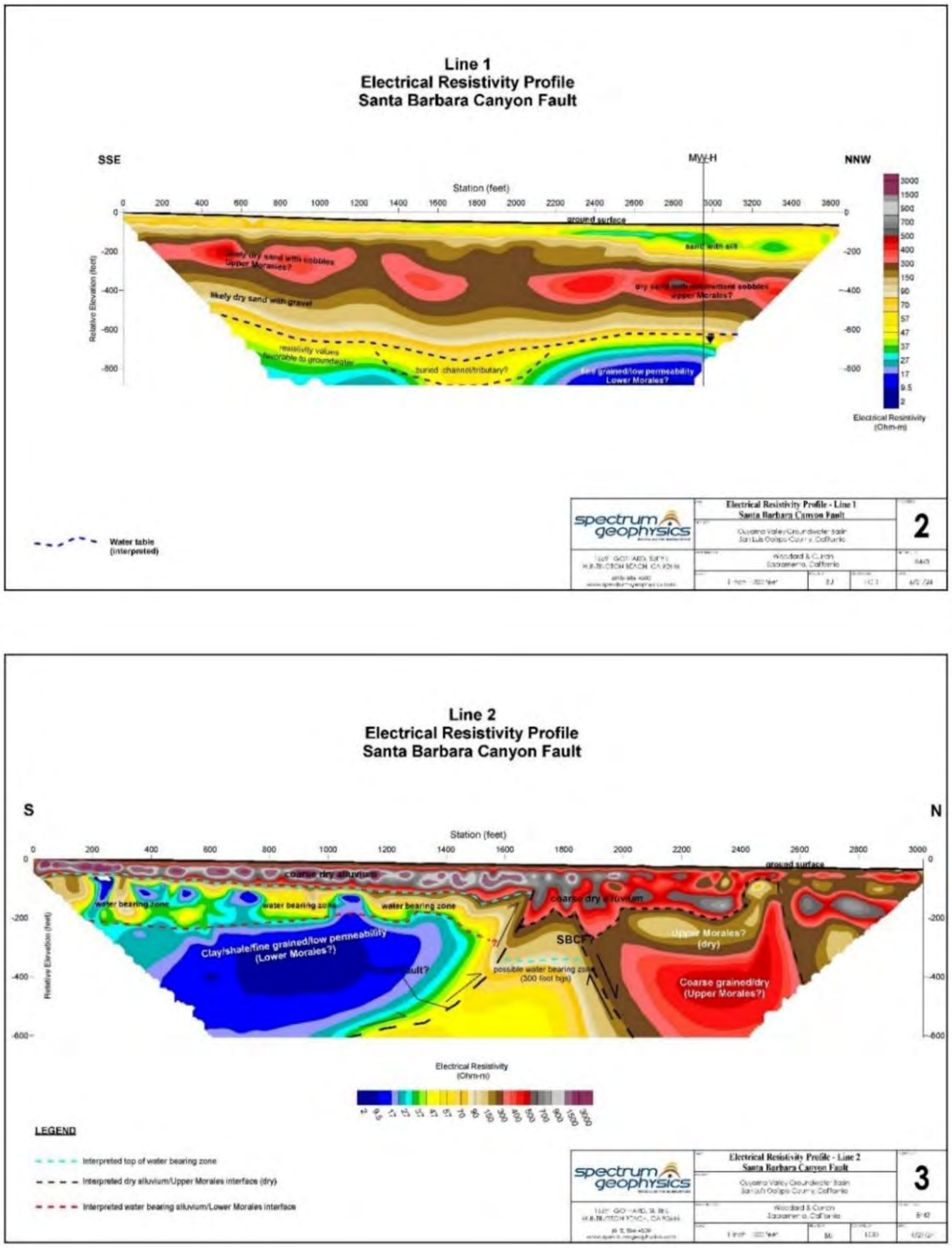
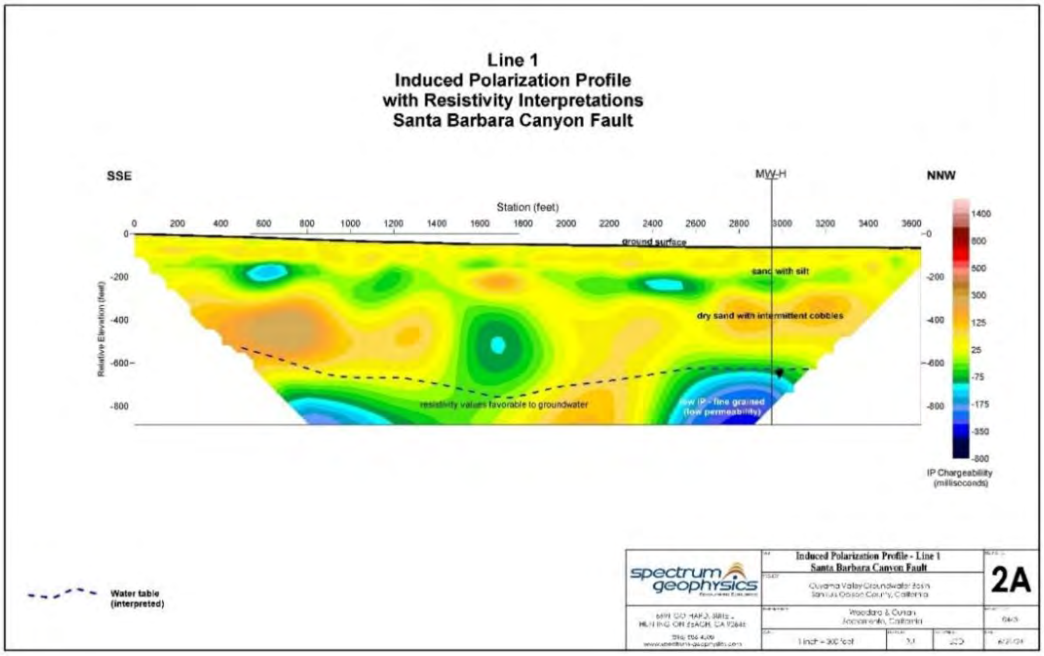


Figure 2-13: Resistivity Profiles for Santa Barbara Canyon Fault



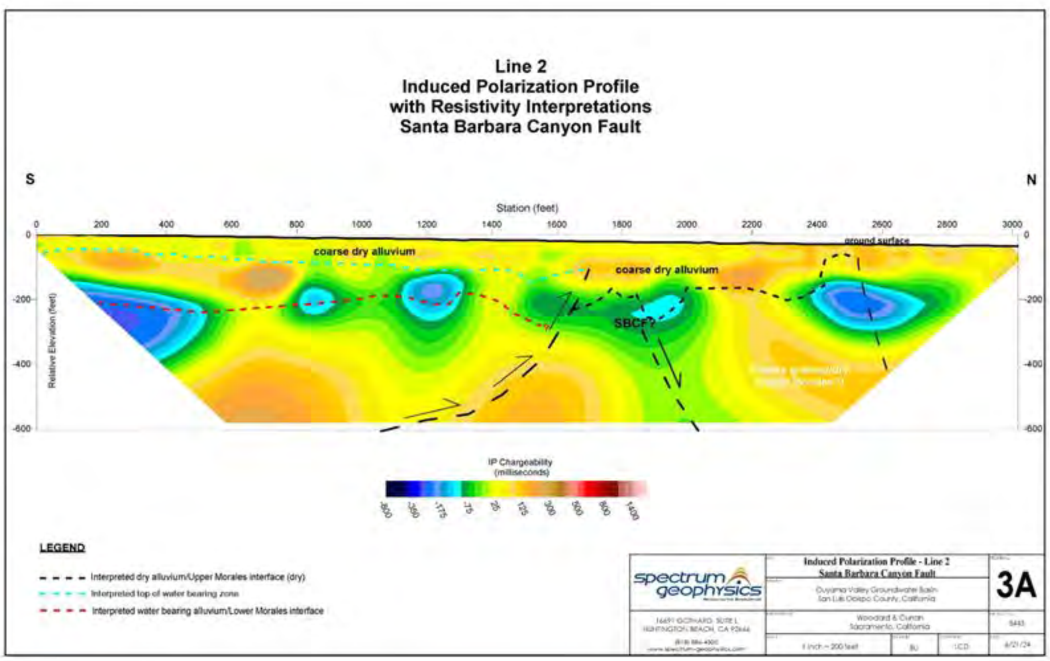


Figure 2-14: Induced Polarization Profiles for Santa Barbara Canyon Fault

Figure 2-15: Location of Transects for Russell Fault

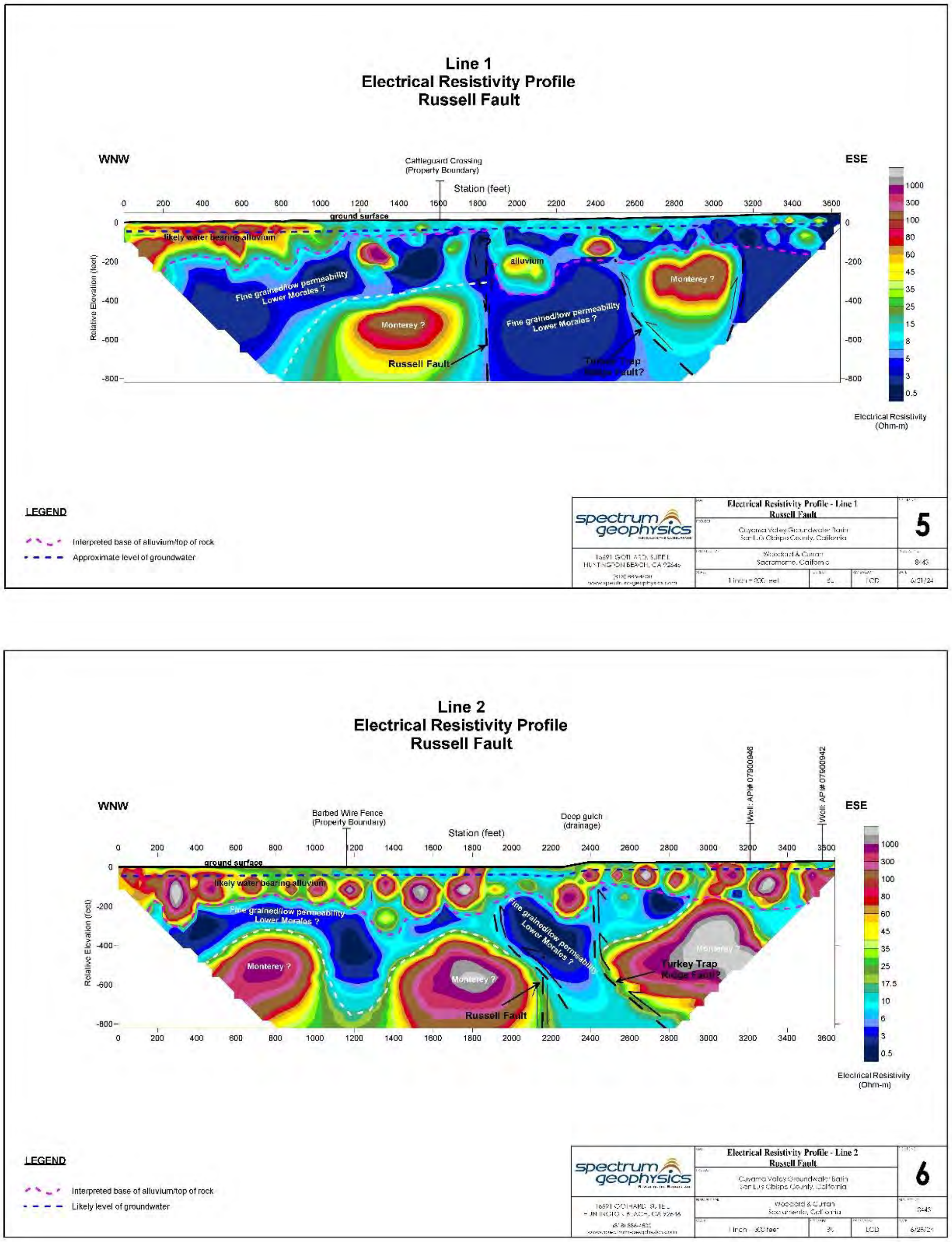


Figure 2-16: Resistivity Profiles for Russell Fault

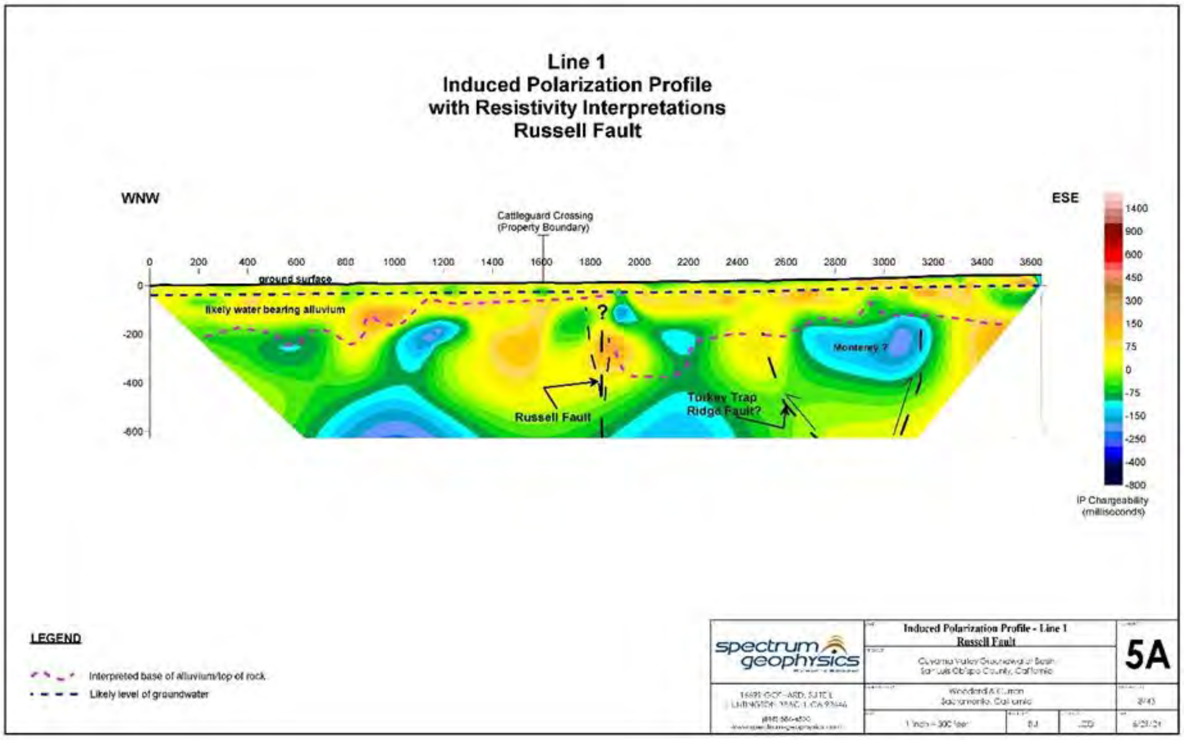


Figure 2-17: Induced Polarization Profile for Russel Fault

2.1.6 Basin Boundaries

The Basin has multiple types of basin boundaries. The majority of the boundaries are in contact with impermeable bedrock and faults, and a small portion is bounded by a groundwater divide between this Basin and the Carrizo Plain groundwater basin.

Lateral Boundaries

The Cuyama Basin is geologically and topographically bounded to the north by the Morales and Whiterock faults and the Caliente Range, to the west by the South Cuyama and Ozena faults and the Sierra Madre Range, to the east within the Los Padres National Forest and Caliente Range, and to the south by the surface outcrops of Pliocene and younger lithologies, which are surrounded by Miocene and older consolidated rocks (Dudek, 2016). The boundaries of the Cuyama Basin were delineated by DWR in Bulletin 118 because they were the boundary between permeable sedimentary materials and impermeable bedrock. DWR defines this type of boundary as, "Impermeable bedrock with lower water yielding capacity. These include consolidated rocks of continental and marine origin and crystalline/or metamorphic rock" (DWR, 2003). The thrust faults bounding the Cuyama Basin juxtapose younger, water-bearing lithologies against older, impermeable rocks. The consolidated continental and marine rocks and shales of the bordering mountain ranges mark a transition from the permeable aquifer sediments to impermeable bedrock.

Boundaries with Neighboring Subbasins

The Cuyama Basin shares a boundary to the east with the Carrizo Plain Groundwater Basin (Carrizo Plain Basin) and the Mil Potrero Area Groundwater Basin. The Cuyama and Carrizo Plain basins share a 4-mile boundary along the Caliente Range, which is a groundwater divide basin boundary. DWR defines this type of boundary as, "A groundwater divide is generally considered a barrier to groundwater movement from one basin to another for practical purposes. Groundwater divides have noticeably divergent groundwater flow directions on either side of the divide with the water table sloping away from the divide" (DWR, 2003).

The Cuyama and Mil Potrero basins share less than a one-mile boundary along the San Emigdio Canyon. The division between the Cuyama and Mil Potrero basins is also a groundwater divide basin boundary.

Bottom of the Cuyama Basin

The bottom of the Basin is generally defined by the base of the upper member of the Morales Formation (USGS, 2015). The lower member of the Morales Formation is composed of clay, shale, and limestone and is less permeable than the upper member of the Morales Formation (USGS, 2013a). The USGS describes the Morales Formation (both the upper and lower member combined) as up to 5,000 feet thick (USGS, 2013a). The top of the Morales Formation is generally encountered 750 feet below ground surface (bgs) but ranges up to 1,750 feet bgs in the Sierra Madre Foothills (USGS, 2013a). When referring to the Morales Formation in the context of the Cuyama aquifer, only the upper member of the Morales Formation is considered.

2.1.7 Principal Aquifers and Aquitards

There is one principal aquifer in the Basin. DWR's *Groundwater Glossary* defines an aquifer as "a body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant or economic quantities of groundwater to wells and springs" and an aquitard as "a confining bed and/or formation composed of rock or sediment that retards but does not prevent the flow of water to or from an adjacent aquifer." Most of the water pumped in the valley is contained in the Younger and Older Alluvium. These two units are indistinguishable in the subsurface and are considered, hydrologically, one unit. There are no major stratigraphic aquitards or barriers to groundwater movement, amongst the alluvium and the Morales Formation. The aquifer is considered to be continuous and unconfined with the exception of locally perched aquifers resulting from clays in the formations.

Aquifers

The aquifers making up the principal aquifer in the Cuyama Basin are Younger Alluvium, Older Alluvium, and the Upper Member of the Morales Formation. These units consist of unconsolidated to partly consolidated sand, gravel, silt, clay, and cobbles within alluvial fan and fluvial deposits and in total range from 3,000 to 4,000 feet in thickness (Upson and Worts, 1951). Rocks older than the upper Morales Formation are generally considered either non-water bearing or contain water that is released too slowly or of quality that is too poor for domestic and irrigation uses (USGS, 2013a).

Recent and Younger Alluvium

Historically, most of the water pumped in the Cuyama Basin was sourced from the saturated portions of the Younger and Older alluvium (Singer and Swarzenski, 1970). Groundwater is found in the permeable Holocene alluvial fill and in the underlying, less permeable, Pliocene-Pleistocene continental alluvial deposits. Younger Alluvium deposits thicken to the east, typically ranging from 5 to 50 feet in the west and thicken from 630 to 1,100 feet in the east (Singer and Swarzenski, 1970).

The Younger Alluvium varies compositionally across the Basin (Upson and Worts, 1951). The Recent and Younger Alluvium is the primary source of groundwater on the western side of the Basin. In the west, Younger Alluvium consists of interbedded layers of sand and gravel and thick beds up clay (ranging from 1 to 36 feet thick) (Upson and Worts, 1951). Clay beds, found 100 to 150 feet bgs, define the base of the Younger Alluvium (Upson and Worts, 1951). Wells in the western part of the Basin that are screened in the Younger Alluvium are shallow but have moderately large yields, as the sands and gravels have high permeabilities (Singer and Swarzenski, 1970).

In the south-central part of the Basin, the alluvium contains more gravel and is less fine-grained compared to western alluvium. The alluvium is predominantly sand and silt with some beds of gravel and clay, though no continuous layers of any material exist (Upson and Worts, 1951).

Older Alluvium

Older Alluvium consists of unconsolidated to partly consolidated sand, gravel, boulders, and some clay. Similar to the Younger Alluvium, clay content increases to the west (Upson and Worts, 1951). Like the Younger Alluvium, historically most of the water pumped in the Cuyama Basin was sourced from the saturated portions of the Younger and Older Alluvium (Singer and Swarzenski, 1970). More wells are perforated in the Older Alluvium in the western portion of the Basin than to the east (USGS, 2013c). In most regions of the Basin, the top of the saturated zone (the water table) is either deep in the alluvium or below its base (Upson and Worts, 1951).

Upper Morales Formation

The Pliocene to Pleistocene-aged Morales Formation is divided into two members, the upper and lower. The upper member of the Morales Formation is composed of partly consolidated, poorly sorted deposits of gravelly arkosic sand, pebbles, cobbles, siltstone, and clay and is considered water bearing (USGS, 2013a). Water bearing properties of the Morales Formation are not well defined, but available data indicate that the hydraulic conductivity of the formation varies greatly laterally and with depth (USGS, 2013c). The highest values occur in the syncline beneath the central part of the valley and decrease to the west (Singer and Swarzenski, 1970). In the east and southeastern parts of the valley where the Morales Formation crops out, the formation is coarse grained and moderately permeable, but land is topographically unsuited to agricultural development and few wells have been installed.

Aquifer Properties

The highest yielding wells are screened in the alluvium and located in the north-central portion of the Basin. Pumping in the alluvium also occurs in the eastern part of the Cuyama Valley, along the Cuyama River and its tributary canyon as far as a few miles upstream from Ozena (Singer and Swarzenski, 1970).

Hydraulic Conductivity

DWR defines hydraulic conductivity as the “measure of a rock or sediment’s ability to transmit water” (DWR, 2003). Hydraulic conductivity is variable within the principal aquifer, varying laterally, vertically, and amongst the three aquifer formations. In general, hydraulic conductivity is highest near the center of the Basin and decreases to the west and east with the highest values associated with the Younger Alluvium and the Upper Morales Formation with the lowest. Hydraulic conductivity data are widely available for the central portion of the Basin (near the towns of New Cuyama and Cuyama) and near the western vineyards but data are sparse elsewhere.

Available data from field tests (including pump and slug tests) were reviewed from the following sources:

- Three multi-completion USGS wells (USGS, 2013c)
- 51 PG&E wells (USGS, 2013c)
- 66 private landowner wells in the central portion of the Basin
- Two private landowner wells in the western portion of the Basin

Figure 2-18 shows the locations of these wells. Dates of field tests range from 1942 (PG&E tests) to 2022 (Woodard & Curran test). Test wells are screened in all three of the main aquifer formations, including the Younger Alluvium, Older Alluvium, and Upper Morales Formation. Additional sources of hydraulic conductivity include the *Hydrologic Models and Analysis of Water Availability in Cuyama Valley, California (USGS, 2015),* which describes conductivity values used in the CUVHM, along with Singer and Swarzenski (1970), and a USGS study (2011). The CUVHM characterizes the Recent and Younger Alluvium as having the highest hydraulic conductivity of the three aquifer formations (USGS, 2015). Hydraulic conductivity values calculated from field tests are used to characterize these aquifer formation, as described below and summarized in Table 2-1.

Recent and Younger Alluvium

Table 2-1 shows wells screened exclusively in the Younger Alluvium in the central portion of the Basin have hydraulic conductivities ranging from 1 to 32feet per day with a median value of about 10 feet per day. Wells screened in both the Younger and Older Alluvium in the central portion of the Basin had a comparable median value. Field tests are lower than those reported by the USGS (2015). For the Recent and Younger Alluvium, the range is about5 to 85 feet per day (USGS, 2015). Within the Recent and Younger Alluvium, the highest horizontal conductivity estimates are at wells constructed near the Cuyama River. Calculations of vertical hydraulic conductivity range from 0.2 feet per day in tributaries crossing the Alluvium in areas west of the Russell Fault up to 49 feet per day near the Cuyama River in the Ventucopa Uplands (USGS, 2015).

In March 2022, Woodard & Curran conducted a 72-hour constant rate test on a private agricultural well located several miles south of Ventucopa. Estimated values of hydraulic conductivity at the pumping well and several observation wells ranged from 145 to 407 feet per day with a geometric mean of 278 feet per day. These values are within the range of hydraulic conductivities for coarse sand and gravel.

Older Alluvium

In the central portion of the Basin, hydraulic conductivity in the Older Alluvium ranges up to about 81 feet per day, with a median hydraulic conductivity of 16 feet per day. Field tests are also higher than those reported by the USGS (2015 and 2011) that range from 0.3 to 28 feet per day. West of the Russell Fault, near the vineyards, hydraulic conductivity reportedly ranges from about 0.8 to 1.8 feet per day with a median value of 1.2 feet per day. Field data show that the range in hydraulic conductivity for wells screened in both the Older Alluvium and Morales Formation is lower than wells screened exclusively in the Older Alluvium. Estimates range up to 61 feet per day with a median value of 21 feet per day.

Morales Formation

The Upper Morales Formation has the lowest hydraulic conductivity of the aquifer units. In the central portion of the Basin, the hydraulic conductivity at wells only screened in the Morales Formation ranges from 1.6 to 10 feet per day, with a median value of 3.2 feet per day. Two wells were interpreted to be screened only in the Morales Formation west of the Russell Fault. The hydraulic conductivity for these wells ranges from 1.6 to 2 feet per day. The hydraulic conductivity of the Upper Morales Formation decreases with depth. The highest values of hydraulic conductivity in the Morales Formation occur in the central portion of the Basin and decrease to the west (Singer and Swarzenski, 1970).

Table 2-1: Summary of Hydraulic Conductivities in Aquifer Formations

Well Owner	Number of Wells	Formation(s) Well is Screened In	Conductivity Range (feet/day)	Median Conductivity (feet/day)
USGS	6[a]	Older Alluvium	1.5 – 18.1	15
	6[a]	Upper Morales Formation	1.6 – 9.9	3.15
PG&E[b]	22	Younger Alluvium	1 - 30	9
	19	Younger and Older Alluvium	0.1 - 37	4.5
	8	Older Alluvium	0.1 – 17	4
	2	Older Alluvium and Upper Morales Formation	0.1 – 4	2
Private Landowners, Central Portion of the Basin[c]	2	Younger Alluvium	28.9 – 31.9	30.4
	19	Younger Alluvium and Older Alluvium	3.9 – 68.6	17.1
	6	Younger Alluvium and Upper Morales Formation	1 – 21.3	12
	16	Older Alluvium	3.2 – 81.2	17.15
	23	Older Alluvium and Upper Morales Formation	3.6 – 61.2	23
Private Landowners, Western Portion of the Basin[c]	4	Older Alluvium	0.77 – 1.79	1.47
	6	Older Alluvium and Upper Morales Formation	0.64 – 1.59	1.22
	2	Upper Morales Formation	1.6 – 1.98	1.79
Private Landowners, Southeast Portion of the Basin[c]	1	Younger Alluvium and Older Alluvium	145 - 407	278

Notes:
[a]Three well locations with four completions each; each well completion is reported as a single well (12 total).
[b]Conductivity estimated using estimates of transmissivity from field tests.
[c]Conductivity estimated using estimates of specific capacity from field tests.

Specific Yield

DWR defines specific yield as the "amount of water that would drain freely from rocks or sediments due to gravity and describes the portion of groundwater that could actually be available for extraction" (DWR, 2003). Specific yield is a measurement that applies only to unconfined aquifers, which is the primary aquifer in the Cuyama Basin.[6] The Alluvium has an average specific yield of 0.15 (Singer and Swarzenski, 1970). The USGS estimated the specific yields of the three aquifer formations during CUVHM calibration. The Recent and Younger Alluvium had the lowest specific yield ranging from 0.02 to 0.14, the Older Alluvium had a slightly higher range of 0.05 to 0.19, and the Morales Formation had the highest specific yield ranging from 0.06 to 0.25 (USGS, 2015).

Specific Capacity

Specific capacity is defined as "the yield of the well, in gallons per minute, divided by the pumping drawdown, in feet" (Singer and Swarzenski, 1970). Specific capacity of the aquifer varies laterally and vertically but is typically highest in the Younger Alluvium and lowest in the Morales Formation. Wells screened in the Younger Alluvium have a median specific capacity of 60 gallons per minute (gpm) per foot (USGS, 2013c). Wells screened in both the Younger and Older alluvium have a lower median specific capacity of 40 gpm per foot. Wells screened in the Older Alluvium have a median specific capacity of 20 gpm per foot (USGS, 2013c). The silt and clay content of the Older Alluvium increases to the west and corresponds to a decrease in specific capacity; specific capacities are less in the western portion of the Basin compared to the eastern portion. However, a greater percentage of wells in the western portion are screened in the Older Alluvium (USGS, 2013c). The specific capacity of the Morales Formation also varies laterally but is generally less than the specific capacity of the Younger and Older Alluvium. In the western part of the Basin, the Morales Formation has a specific capacity ranging from 5 to 25 gpm per foot. In the north to north-central portion of the Basin the specific capacity increases to 25 to 50 gpm per foot (Singer and Swarzenski, 1970).

Transmissivity

DWR defines transmissivity as the "aquifer's ability to transmit groundwater through its entire saturated thickness" (DWR, 2003). Using aquifer tests at the 64 wells shown in Figure 2-18, estimates of transmissivity ranged from 560 to 163,400 gallons per day per foot (gpd/foot) and decreased with depth (USGS, 2013c). Among the aquifer units, wells screened in the Younger Alluvium had the highest transmissivity, with a median value of 15,700 gpd/foot (USGS, 2013c). The aquifer test conducted by Woodard & Curran in 2022 provided an estimated range of 100,000 to 270,000 gpd/foot.

Wells screened in Older Alluvium had a transmissivity three times lower than the Younger Alluvium wells, with a median value of 5,000 gpd/foot (USGS, 2013c). Wells screened in both the Younger and Older Alluvium had a median transmissivity of 11,300 gpd/foot (USGS, 2013c). Estimates of transmissivity from two wells screened in both the Older Alluvium and Morales Formation averaged

[6] For confined aquifers, the measurement of "storativity" is used instead of specific yield.

4,900 gpd/foot (USGS, 2013c). No values are available for only the Morales Formation. Using groundwater level contours, Singer and Swarzenski (1970) determined the range of transmissivity values in the Morales Formation are more variable than transmissivity values for the Younger and Older Alluvium. In general, values of transmissivity are highest in the central portion of the Basin and decline to the west as the thicknesses of the Younger and Older Alluvium decreases.

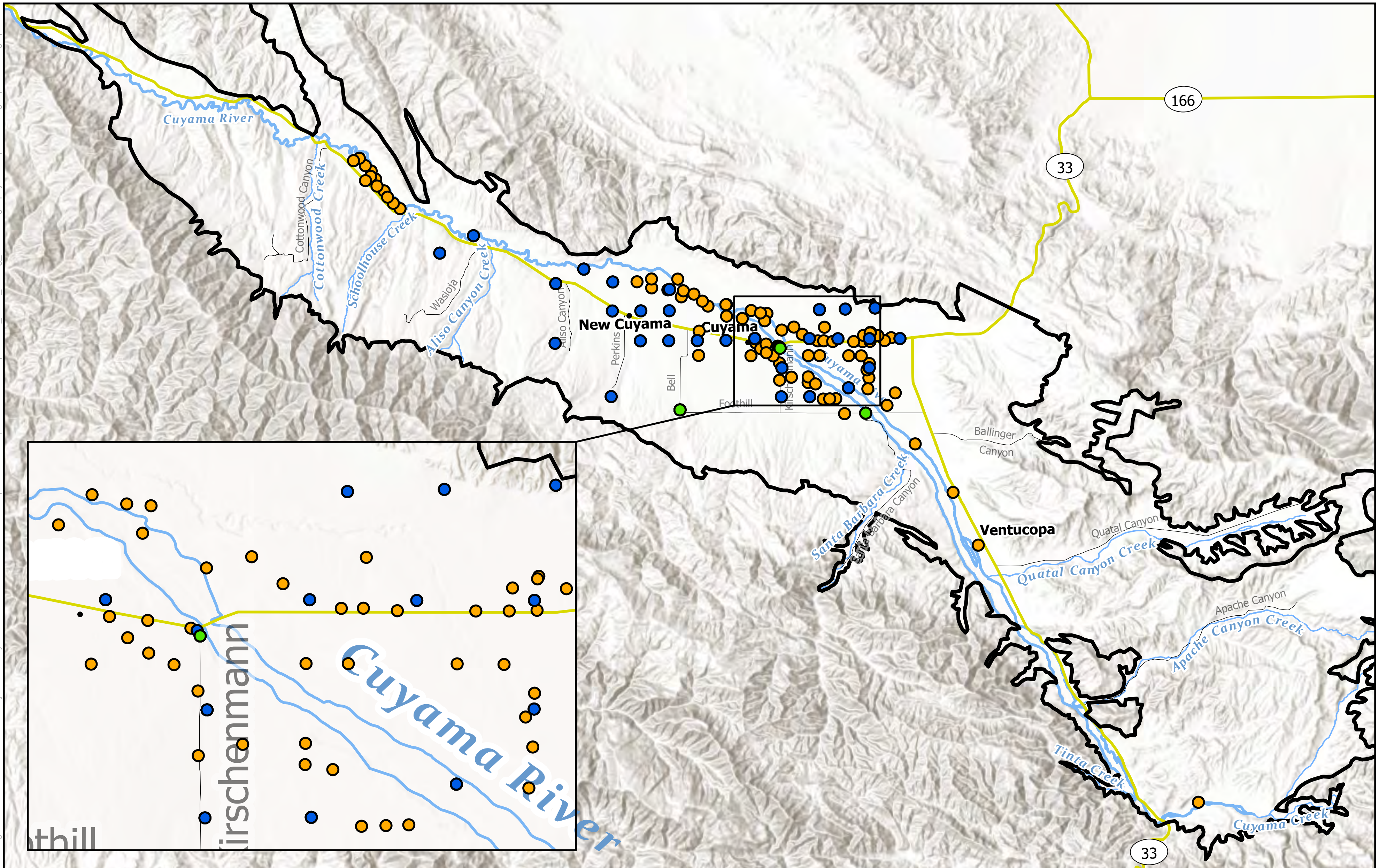


Figure 2-18: Location of Aquifer Testing Wells

Cuyama Valley Groundwater Basin

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2.1.8 Natural Water Quality Characterization

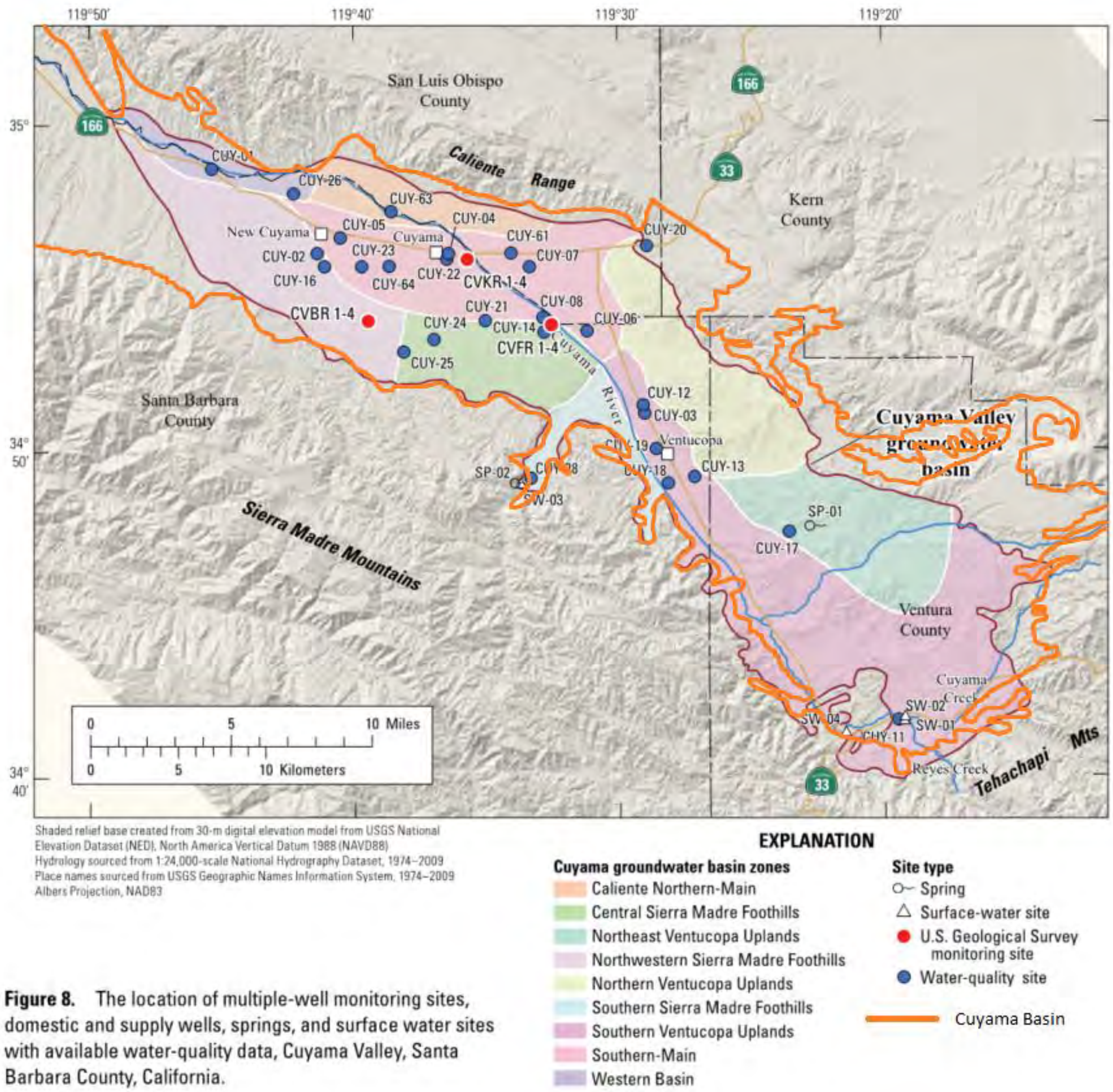
Water quality in the Basin has historically had a high level of TDS and sulfates. High concentrations of other constituents, such as nitrate, arsenic, sodium, boron, and hexavalent chromium are localized (USGS, 2013c). Locations where water quality measurements were taken by the USGS are shown in Figure 2-19.

Singer and Swarzenski studied groundwater in the Basin in 1970. Groundwater ranged from hard to very hard and is predominantly of the calcium-magnesium-sulfate type (Singer and Swarzenski, 1970). Averages of concentrations include 30 milligrams per liter (mg/L) chloride, 0.20 mg/L of boron, and 1,500 to 1,800 mg/L TDS (Singer and Swarzenski, 1970). Along the periphery of the Basin, groundwater quality is variable. Along the southern boundary and near the eastern badlands, the groundwater quality reflects the recharge from springs and runoff from the Sierra Madre Mountains; TDS concentrations range from 400 to 700 mg/L and most of the water is sodium calcium bicarbonate (Singer and Swarzenski, 1970). Along the eastern edge of the valley, near the Caliente Range, water quality declines as concentrations of sodium, chloride, TDS, and boron increase. Concentrations of boron range up to 15 mg/L, concentrations of chloride increase up to 1,000 mg/L, and TDS concentrations range from 3,000 to 6,000 mg/L (Singer and Swarzenski, 1970).

Singer and Swarzenski in 1970 also concluded that the Basin's water quality potentially results from the mixing of water from the marine rocks: "This water quality presumably results from the mixing of water from the marine rocks of Miocene age with the more typical water from the alluvium and is characterized by increased sodium, chloride, and boron. Although chloride and boron concentrations commonly are less than 30 and 0.20 mg/L, respectively, in the central part of the valley, the water from many wells close to the Caliente Range contains several hundred to nearly 1,000 mg/L of chloride and as much as 15 mg/L of boron." (Singer and Swarzenski, 1970). Singer and Swarzenski did not provide a map showing their sampling locations.

In 2011, the USGS published the *Kirschenmann Road Monitoring Well Site Open File Report* (USGS, 2011), which included analysis of major-ion composition for samples collected from the multiple-well monitoring site CVKR, and samples from selected water supply and irrigation wells in the Cuyama Valley. Figure 2-20 shows a Piper diagram of the major-ion analysis. Figure 2-20 shows that groundwater in the central portion of the Basin shares similar major-ions, and is largely chloride, fluoride, sulfate and calcium magnesium type water. Figure 2-21 shows the locations USGS sampled to perform this analysis.

In 2017 EKI compiled water quality data contained in the appendices of the USGS report *Geology, Water-Quality, Hydrology, and Geomechanics of the Cuyama Valley Groundwater Basin, California, 2008-12* (USGS 2013c). and prepared a Piper diagram with the data (Figure 2-22). The locations of the data used in this Piper diagram are shown in Figure 2-23. The Piper diagram shows the majority of samples indicate that water in the Basin can be characterized as calcium-magnesium sulfate waters, which agrees with conclusions made by USGS in 2013.



Source: USGS, 2013c.

Figure 2-19: Location of USGS 2013 Groundwater Quality Sampling Sites

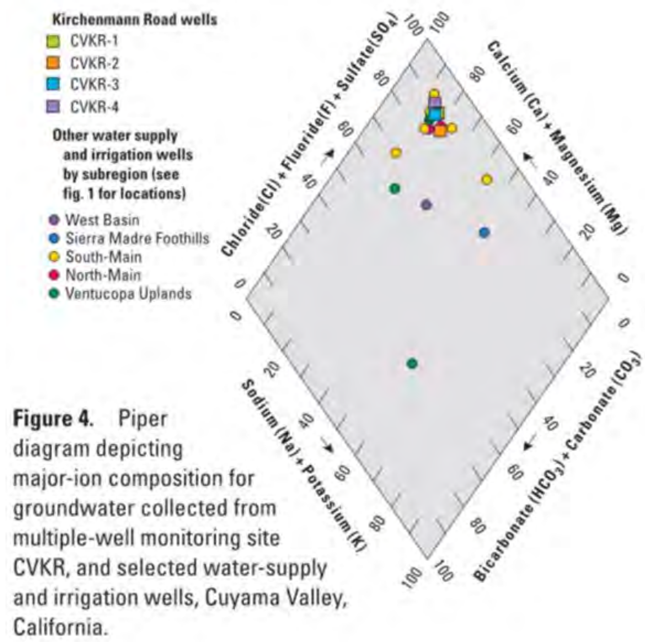


Figure 2-20: Piper Diagram for Well CVKR1-4

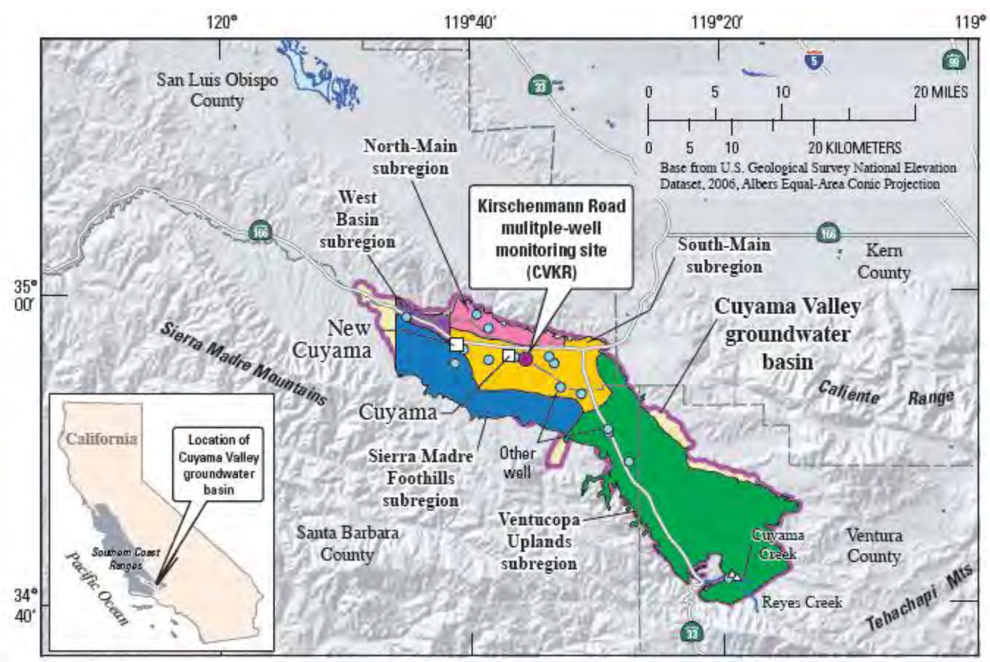


Figure 2-21: Location Map for Samples Used in Figure 2-20

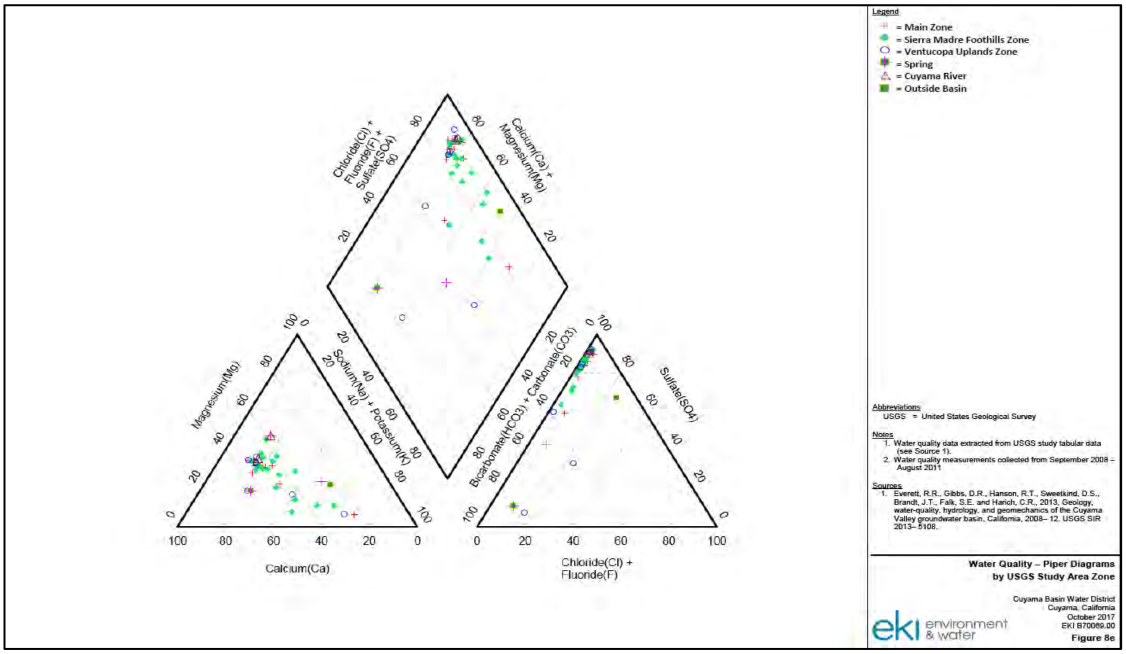


Figure 2-22: Piper Diagram of USGS 2013 Water Quality Sampling

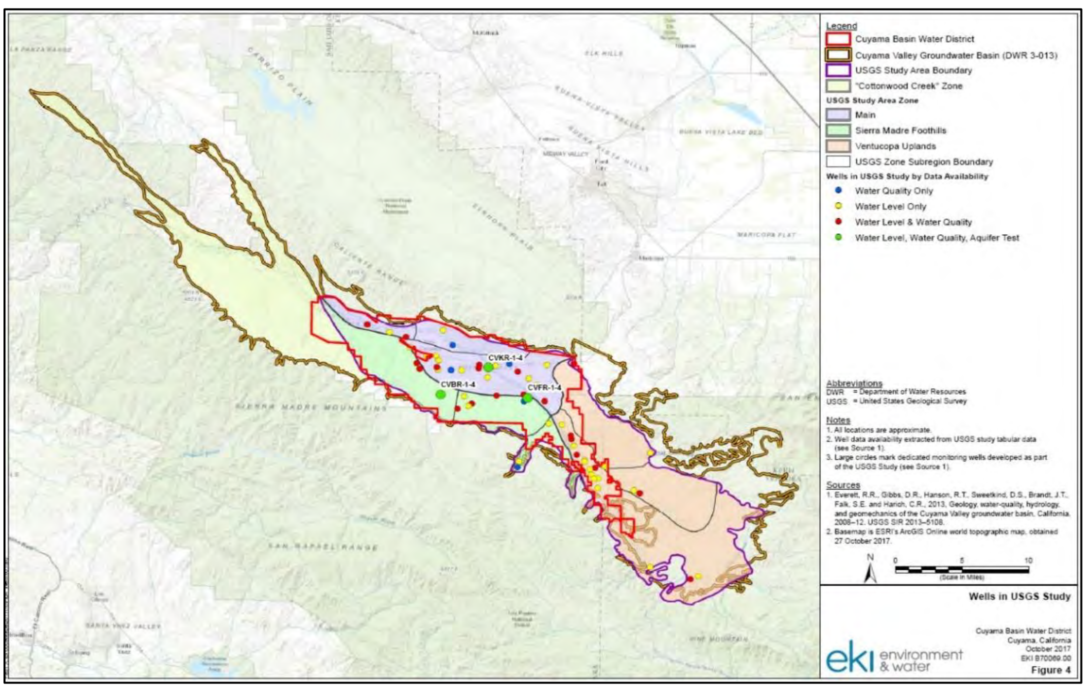


Figure 2-23: Location Map of USGS 2013 Sampling

Aquifer Use

The Cuyama Valley is dependent on groundwater as its sole source of supply. Groundwater is used for irrigation, domestic and municipal use (USGS, 2013c). The majority of agricultural activity occurs between the New Cuyama and Ventucopa areas, and west of the Russell Fault.

2.1.9 Topography, Surface Water and Recharge

This section describes the topography, surface water, soils, and groundwater recharge potential in the Basin. There are no imported water supplies to the Cuyama Basin and are not discussed in this section.

Topography

The Basin is lowest in the northwest, and highest in the southeast. The lowest elevation in the Basin is located at the west edge where the Cuyama River exits at approximately 1,300 feet, while the highest point is approximately 7,250 feet on the eastern boundary. Figure 2-24 shows the topographic characteristics of the Basin. The south facing northern slopes of the valley are generally steeper than the north facing south slopes. The eastern portion of the Basin along the valley walls becomes steep, characterized by mountainous runoff-cut topography.

Surface Water Bodies

The Cuyama River is the primary surface water feature in the valley and flows from an elevation of 3,800 feet on the eastern side to 1,300 feet at the western outlet of the Basin. The Cuyama River travels approximately 55 miles through the Basin and has a slope ratio of approximately 1:125. The river is perennial, with most dry seasons seeing little to no flows. Large flows usually occur in flashes due to the small watershed and storms that provide precipitation onto the surrounding Coastal Range Mountains. Peak flows through the Cuyama River, dated between 1929 and 2023, range from approximately 6,000 cubic feet per second to the highest recorded flow of 15,500 cubic feet per second on February 18, 2017 (National Watershed Information System [NWIS], 2018). There are approximately four main perennial streams that feed the Cuyama River: Aliso Canyon Creek, Santa Barbara Creek, Quatal Canyon Creek, and Cuyama Creek. However, during precipitation events many more smaller streams flow from the valley walls and surrounding mountains. Figure 2-25 shows the locations of surface water bodies in the Basin. Downstream on the Cuyama River lies Twitchell Reservoir, however this is an artificial body of water outside of the Basin.

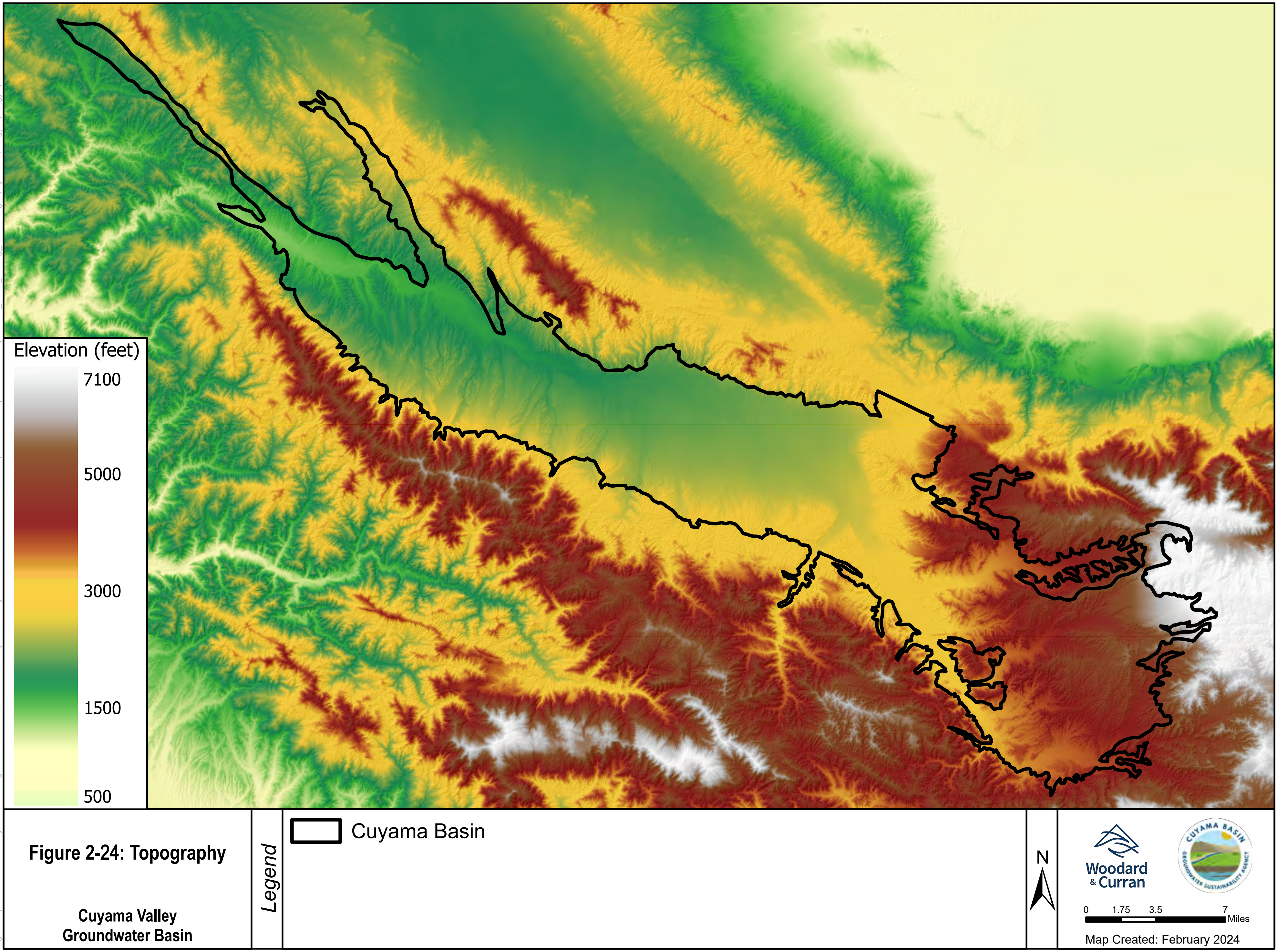


Figure 2-24: Topography

Cuyama Valley
Groundwater Basin

Woodard & Curran

Map Created: February 2024

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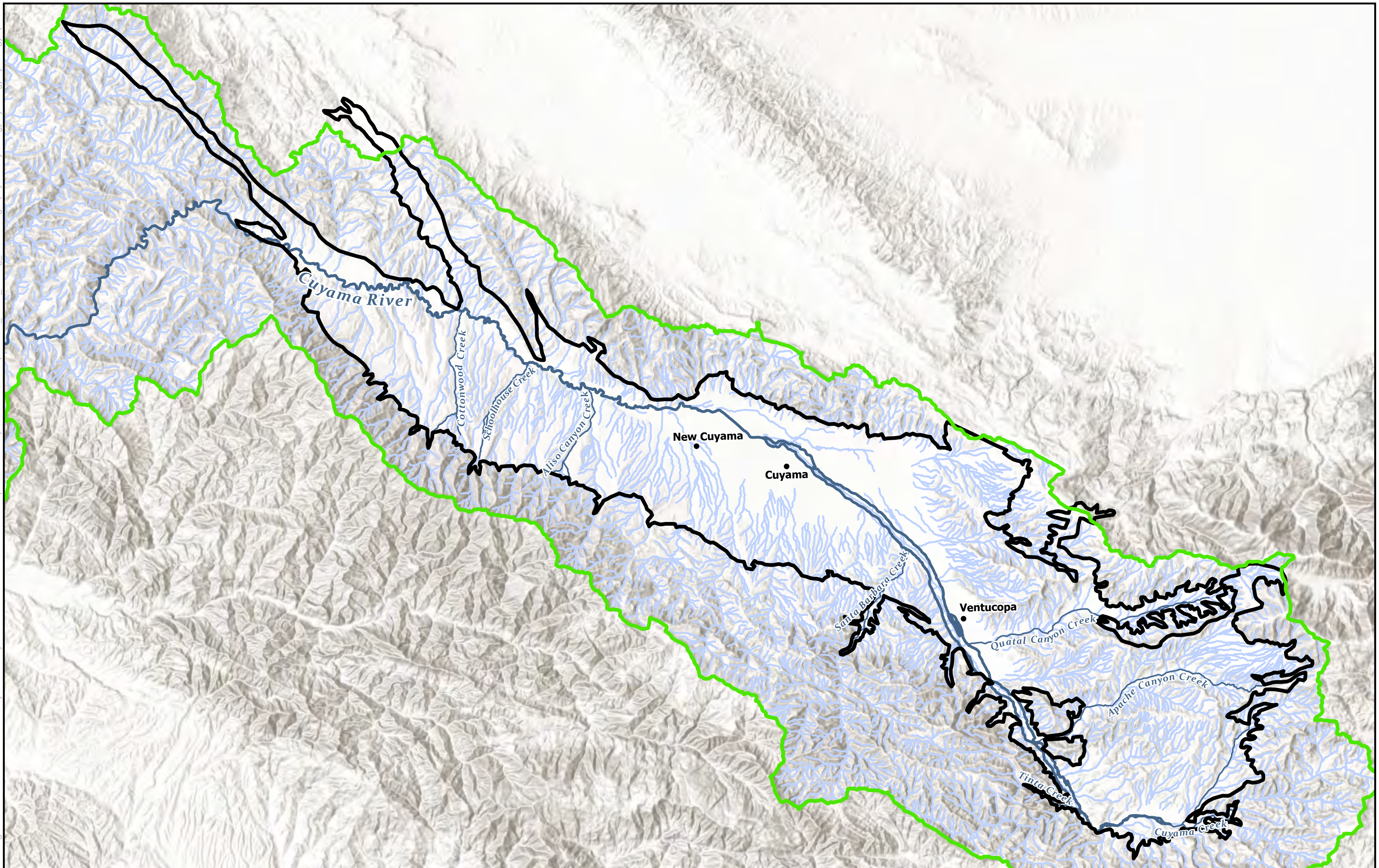

Figure 2-25: Surface Water

Cuyama Valley Groundwater Basin

Legend

Cuyama River	Town
Notable Creeks	Cuyama Watershed (HUC8)
NHD Flowlines	Cuyama Basin

N

0 1.75 3.5 7 Miles

Map Created: April 2024

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Areas of Recharge, Potential Recharge, and Groundwater Discharge Areas

Areas of recharge and potential recharge lie primarily within the central and low-lying areas of the Cuyama Valley. Agricultural and open space lands are considered areas of potential recharge. Figure 2-26 shows areas with their potential for groundwater recharge, as identified by the Soil Agricultural Groundwater Banking Index (SAGBI). SAGBI provides an index for the groundwater recharge for agricultural lands by considering deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition. SAGBI data categorizes 22,675 acres out of 37,568 acres (60 percent) of agricultural and grazing land within the Basin as moderately good, good, or excellent for groundwater recharge (University of California, Davis, 2018). SAGBI data shown in Figure 2-26 is derived from "modified" SAGBI data. "Modified" SAGBI data show higher potential for recharge than unmodified SAGBI data because the modified data assume that the soils have been or will be ripped to a depth of 6 feet, which can break up fine grained materials at the surface to improve percolation. Groundwater discharge areas are identified as springs located within the Basin. Figure 2-26 shows the location of historical springs identified by the USGS (NWIS, 2018). The springs shown represent a dataset collected by the USGS and are not a comprehensive map of springs in the Basin.

Soils

Soils in the Basin were categorized by the National Resource Conservation Service (NRCS). The Basin is comprised mostly of fine- to coarse-loamy soils (NRCS STATSGO2, 2018). As shown in Figure 2-27, the valley bottom and primary soil surrounding the Cuyama River and its tributaries is primarily fine-loamy soils, while the northern boundary of the Basin has coarse-loamy soils.

Figure 2-28 shows soils by hydrologic soil group. Hydrologic soil groups were calculated by the NRCS on a by-county basis. As shown in Figure 2-28, interpretations of soil groups varied by county in each study. In general, hydrologic soil groups are sorted by permeability, with class A being the most permeable and class D being the least permeable. Figure 2-28 shows that in general most of the soils in the Basin have lower permeabilities and are listed as class C or D, with higher permeabilities being located near streams and rivers.

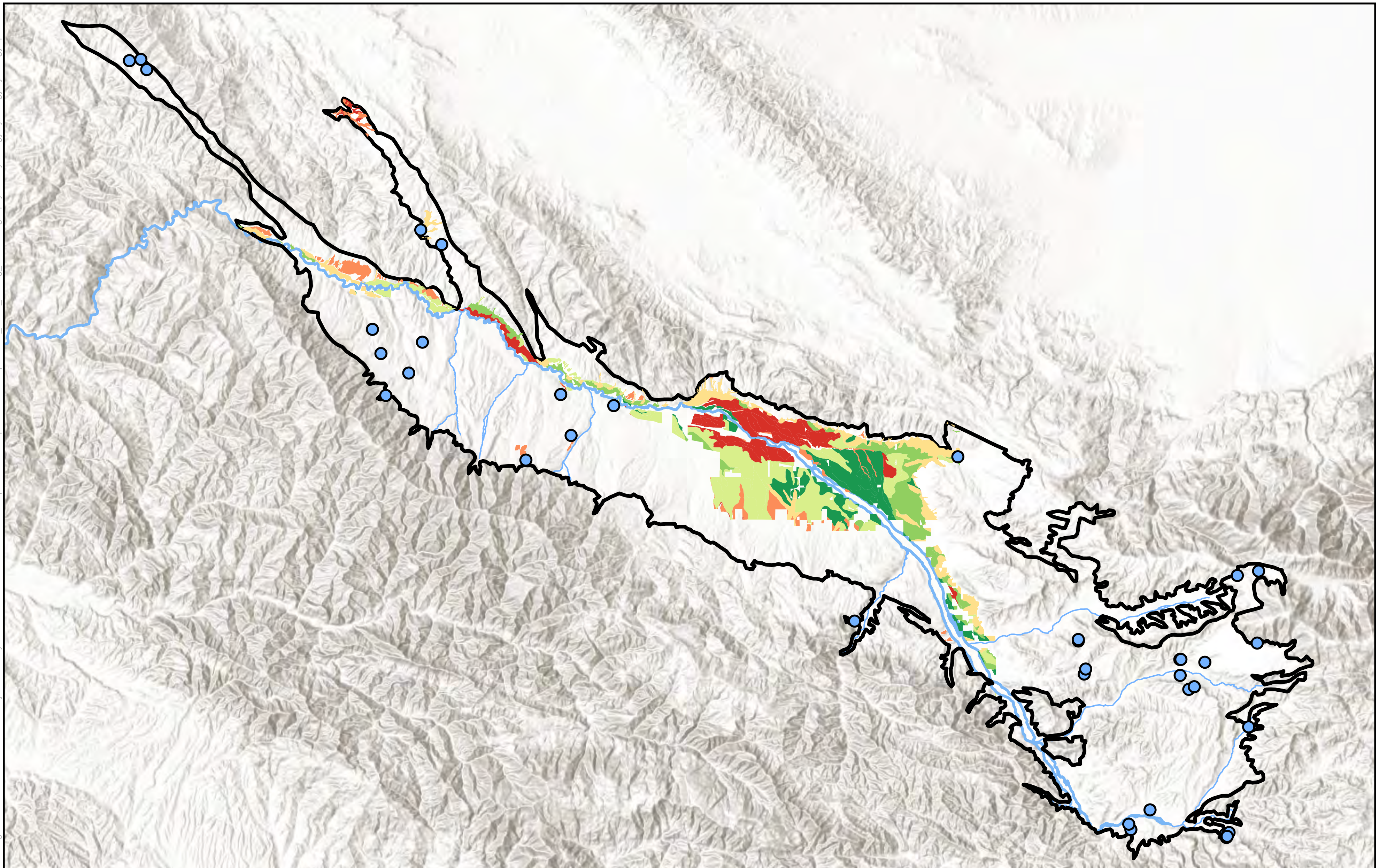

Figure 2-26: Recharge Areas, Springs, and Seeps

Cuyama Valley Groundwater Basin

Legend

Modified SAGBI Score
- Excellent (100 - 85)
- Good (85 - 69)
- Moderately Good (69 - 49)
- Moderately Poor (49 - 29)
- Poor (29 - 15)
- Very Poor (15 - 0)

- NHD Springs and Seeps
- Creek
- Cuyama River
- Cuyama Basin

N

0 1.75 3.5 7 Miles

Woodard & Curran

CUYAMA BASIN GROUNDWATER SUSTAINABILITY AGENCY

Map Created: February 2024

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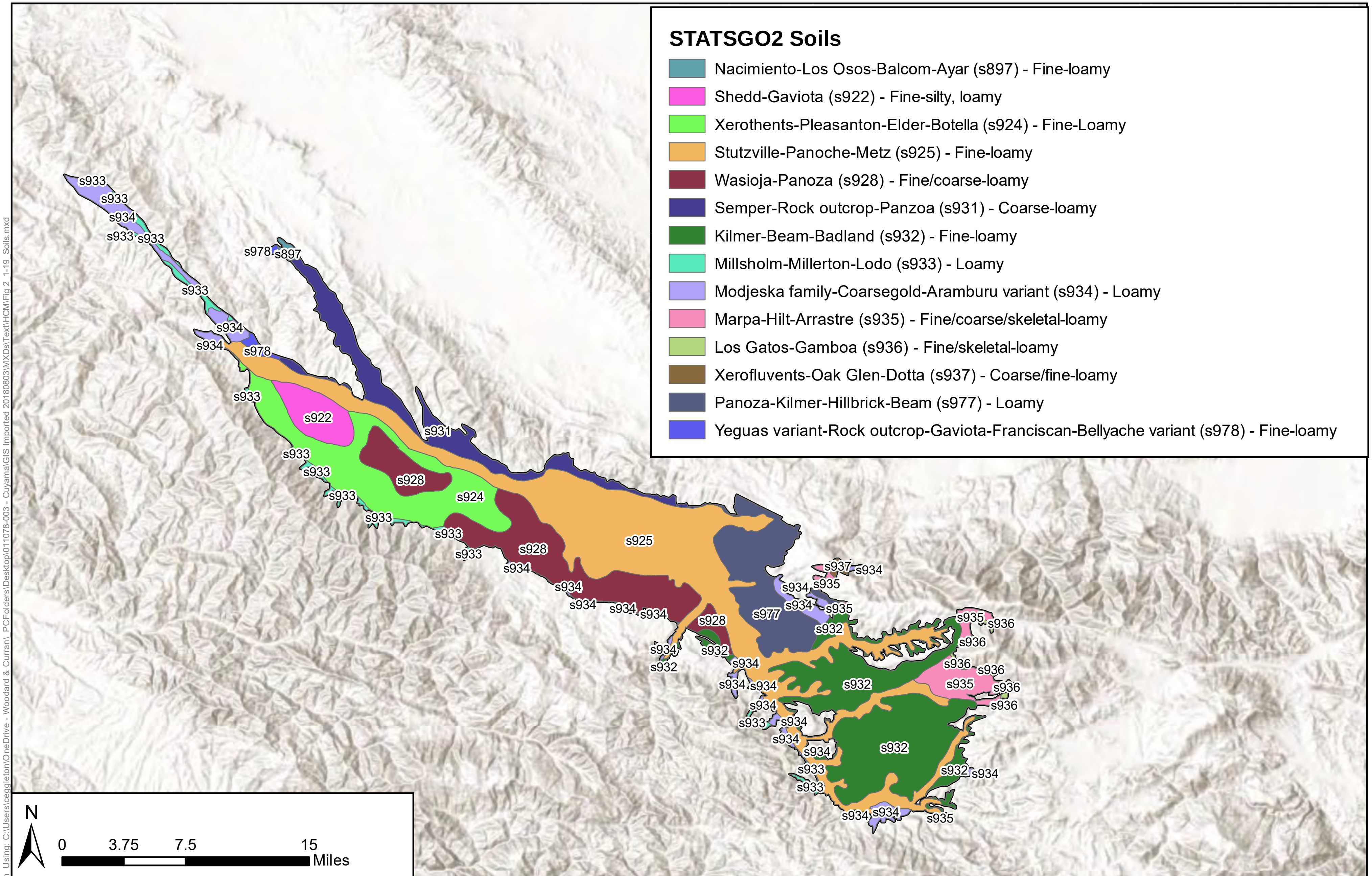

Figure 2-27: Soils

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

December 2019

Legend

Cuyama Basin

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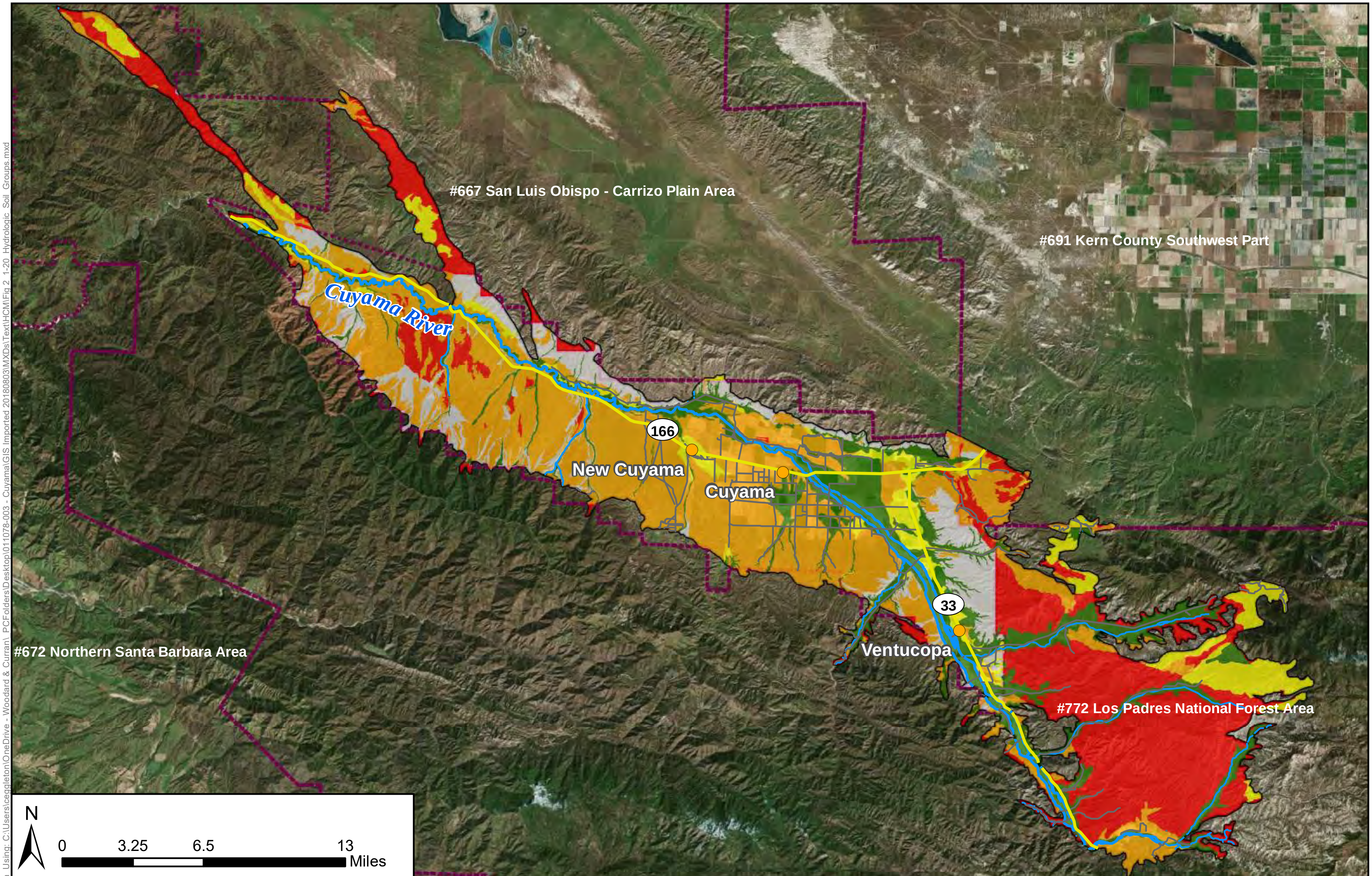

Figure 2-28: Hydrologic Soil Groups

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

December 2019

WOODARD & CURRAN

Legend

- Cuyama Basin
- Cuyama River
- Streams
- Towns
- Highways

Hydrologic Soil Group

- A
- B
- C
- D
- Not classified

Soil Survey Boundary

Soil Survey Key:

#772 Los Padres National Forest Area

Soil Survey Number — Survey Name

2.1.10 Hydrogeologic Conceptual Model Data Gaps

The following are the HCM data gaps that were identified during the development of this amended GSP. The surface geophysical survey of the subsurface Santa Barbara Canyon Fault confirmed its presence in the Cuyama River channel near its inferred location. The survey also confirmed the fault does not extend to the east as reported. It is uncertain whether the fault extends to the northeast from the location identified by the geophysical survey and, if so, where it crosses SR 33 to the north of Line 1. However, the possible northeast extension of the fault would not resolve the significant change in groundwater elevations that occurs further to the south of Line 1, namely between TSS #3 and MW-H (i.e., Opti wells 903-905 and 915 and 916). These data gaps may be resolved with an additional surface geophysical survey with transects extending to the north and to the south of Line 1 on or near SR 33. A continuing data gap is aquifer properties in areas where aquifer testing has not been conducted. These aquifer properties are not well defined and are estimated. Lastly, the extent of brackish groundwater discovered in the TSS #1 wells east of the Russel Fault is unknown and potential impacts to nearby groundwater is not understood. Other data gaps may be discovered during implementation of the GSP.

2.2 Basin Settings: Overview

This Cuyama Valley Groundwater Basin (Basin) Settings chapter contains three main sections as follows:

- **Hydrogeologic Conceptual Model (HCM)** – The HCM section (Section 2.1) provides the geologic information needed to understand the framework that water moves through in the Basin. It focuses on geologic formations, aquifers, structural features, and topography.
- **Groundwater Conditions** – The Groundwater Conditions section (Section 2.2) describes and presents groundwater trends, levels, hydrographs and level contour maps, estimates changes in groundwater storage, identifies groundwater quality issues, addresses subsidence, and addresses surface water interconnection.
- **Water Budget –** The Water Budget section (Section 2.3) describes the data used to develop the water budget. Additionally, this section discusses how the budget was calculated, provides water budget estimates for historical conditions, and current conditions and projected conditions.

2.2.1 Basin Settings: Groundwater Conditions

This section of Chapter 2 satisfies Section 354.8 of the SGMA regulations and describes the historical and current groundwater conditions in the Basin. Water budget components follow in Section 2.3.

As defined by the SGMA regulations, this section does the following:

- Defines current and historical groundwater conditions in the Basin
- Describes the distribution, availability, and quality of groundwater
- Identifies interactions between groundwater, surface water, groundwater-dependent ecosystems, and subsidence
- Establishes a baseline of groundwater quality and quantity conditions that will be used to monitor changes in the groundwater conditions relative to measurable objectives and minimum thresholds
- Provides information to be used for defining measurable objectives to maintain or improve specified groundwater conditions
- Supports development of a monitoring network to demonstrate that the Cuyama Basin Groundwater Sustainability Agency (CBGSA) is achieving Basin sustainability goals

The majority of published information about groundwater in the Basin is focused on the central part of the Basin, roughly from an area a few miles west of New Cuyama to roughly Ventucopa. The eastern uplands and western portion of the Basin have been studied less, and consequentially, fewer publications have been written about those areas, and less historical information is available in those areas.

The groundwater conditions described in this section are intended to convey the present and historical availability, quality, and distribution of groundwater and are used elsewhere in the GSP to define measurable objectives, identify sustainability indicators, and establish undesirable results.

Groundwater conditions in the Basin vary by location. To assist in discussion of the location of specific groundwater conditions, Figure 2-29 shows selected landmarks in the Basin to support the discussion of the location of specific groundwater conditions. Figure 2-29 shows major faults in the Basin in red, highways in yellow, towns as orange dots, and canyons and Bitter Creek in purple lines that show their location. The map calls out the Russell Ranch and South Cuyama oil fields in red.

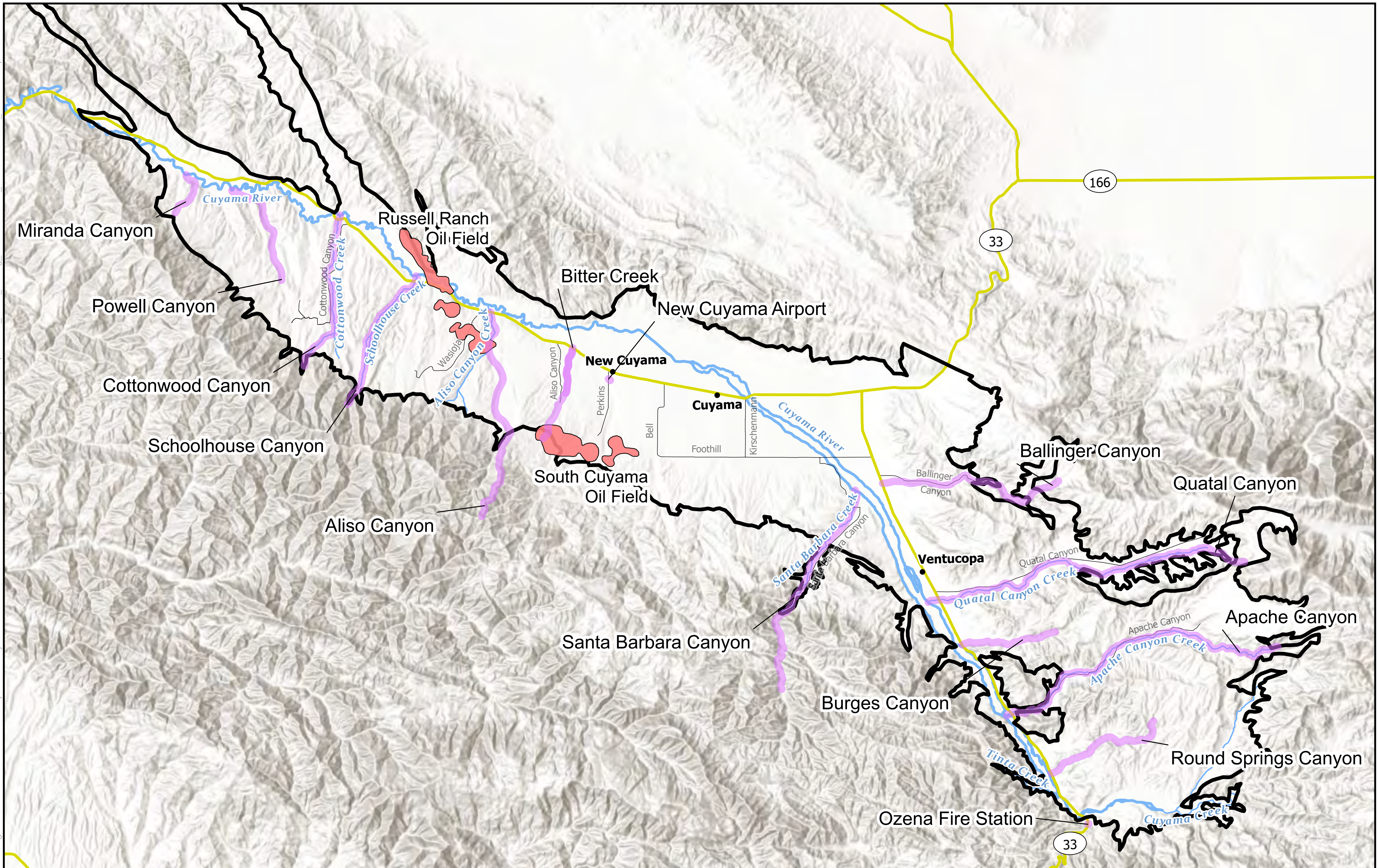

Figure 2-29: Landmarks

Cuyama Valley Groundwater Basin

Legend

Oil Field
Landmark
Highway
Local Road
Town
Creek
Cuyama River
Cuyama Basin

N

0 1.5 3 6 Miles

Map Created: April 2024

Figure Exported: 4/30/2024 By: DHunt Using: \\woodardcurran.net\shared\Projects\CA Cuyama Basin GSA\0011078.01 GSP\wip\Z_GIS\2_Maps\3_2025 GSP Update\02_Basin_Setting_Overview\basin_landmarks.aprx

2.2.2 Useful Terms

This section of Chapter 2 includes descriptions of the amounts, quality, and movement of groundwater, among other related components. A list of technical terms and their definitions are below. These definitions are given to guide readers through the section and are not a definitive definition of any term.

- **Depth to groundwater –** This is the distance from the ground surface to groundwater, typically reported at a well.
- **Horizontal gradient** – The horizontal gradient is the slope of groundwater from one location to another when one location is higher, or lower than the other. The horizontal gradient is shown on maps with an arrow showing the direction of groundwater flow in a horizontal direction.
- **Vertical gradient** – A vertical gradient describes the movement of groundwater perpendicular to the ground surface. Vertical gradient is measured by comparing the elevations of groundwater in wells that are of different depths. A downward gradient is one where groundwater is moving down into the ground, and an upward gradient is one where groundwater is upwelling towards the surface.
- **Contour map –** A contour map shows changes in groundwater elevations by interpolating groundwater elevations between monitoring sites. The elevations are shown on the map with the use of a contour line, which indicates that at all locations that line is drawn, it represents groundwater being at the elevation indicated. There are two versions of contour maps shown in this section as follows:
  - Elevation of groundwater above mean sea level, which is useful because it can help identify the horizontal gradients of groundwater, and
  - Depth to water (i.e. the distance from the ground surface to groundwater), which is useful because it can help identify areas of shallow or deep groundwater.
- **Hydrograph –** A hydrograph is a graph that shows the changes in groundwater elevation over time for each monitoring well. Hydrographs show how groundwater elevations change over the years and indicate whether groundwater is rising or descending over time.
- **Maximum contaminant level (MCL)** – An MCL is a standard set by the State of California regarding drinking water quality. An MCL is the legal threshold on the amount of a substance that may appear in public water systems. MCLs are different for different constituents in drinking water.
- **Elastic land subsidence** – Elastic land subsidence is the reversible and temporary fluctuation in the earth's surface in response to seasonal periods of groundwater extraction and recharge.
- **Inelastic land subsidence** – Inelastic land subsidence is the irreversible and permanent decline in the earth's surface resulting from the collapse or compaction of the pore structure within the fine-grained portions of an aquifer system.

2.2.3 Historical Groundwater Elevation Data Processing

Prior to GSP adoption in January 2020 groundwater well information and groundwater level monitoring data were compiled from four public sources, with additional data compiled from private landowners. . These sources include the following:

- DWR
- USGS
- Santa Barbara County Water Agency (SBCWA)
- San Luis Obispo County
- Private landowners

Data provided by these sources included well information such as location, well construction, well owner, ground surface elevation and other related components, as well as groundwater elevation data including information such as date measured, depth to water, groundwater surface elevation, questionable measurement code, and comments. At the time that this analysis was performed, groundwater elevation data was available for the time period from 1949 to June 2018.[7] There are many wells with monitoring data from some time in the past, but no recent data, while a small number of wells have monitoring data recorded for periods of greater than 50 years. Figure 2-30 through Figure 2-33 show well locations with available monitoring data, and the entity that maintains monitoring records at each well. These figures also show in a larger, darker symbol if the monitoring well has been measured in 2017 or 2018.

Figure 2-30 shows the locations of well data received from the DWR database. As an assessment of which wells have been monitored recently, the wells with monitoring data collected between January 2017 and June 2018 were identified. Roughly half of the wells from DWR's database contain monitoring data in 2017-18, with roughly half the wells having no monitoring data during this period. Wells in DWR's database are concentrated in the central portion of the Basin, east of Bitter Creek and north of the Santa Barbara Canyon Fault (SBCF). Many wells in DWR's database have been typically measured bi-annually, with one measurement in the spring, and one measurement in the fall.

Figure 2-31 shows the locations of well data received from the USGS database. Many of these wells are duplicative of wells contained in the DWR database. The majority of wells from the USGS database were not monitored in 2017-18. Wells that were monitored in 2017-18 are concentrated in the western portion of the Basin, west of New Cuyama, with a small number of monitoring wells in the central portion of the Basin and near Ventucopa. Many wells in the USGS database have been typically measured bi-annually,

[7] The analysis shown in this section was performed in the summer of 2018 and does not reflect data that may have been collected after June 2018. In addition, the analysis reflects the available data as provided by each entity - an assessment has not been performed on the standards and protocols followed by each entity that compiles and maintains the available datasets.

with one measurement in the spring, and one measurement in the fall. Figure 2-32 shows the locations of well data received from Santa Barbara and San Luis Obispo counties. Wells from both counties were monitored in 2017-18. Wells monitored by Santa Barbara County are concentrated in the western portion of the Basin west of Bitter Creek. The two wells monitored by San Luis Obispo County are in the central portion of the Basin; these wells also appear in the USGS database. Data are collected in many of these wells on a bi-annual basis, with one measurement in the spring, and one measurement in the fall, with some measurements at some wells occurring on a quarterly basis.

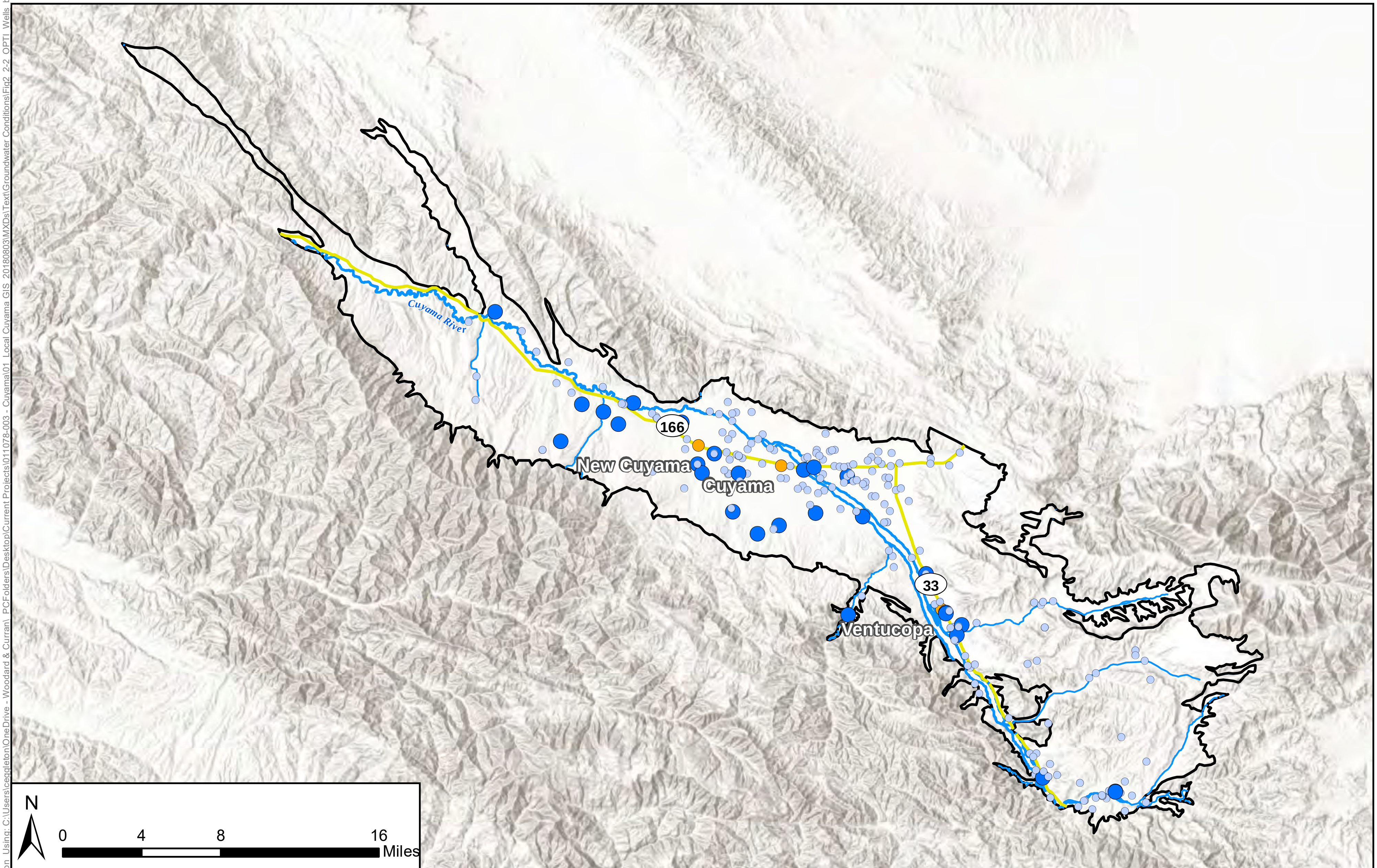

Figure 2-30: Cuyama GW Basin Wells with Monitoring Data Provided by DWR

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

December 2019

WOODARD & CURRAN

Legend

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- DWR Database Wells Last Measured in 2017-2018
- DWR Database Wells Last Measured 2016 and Earlier

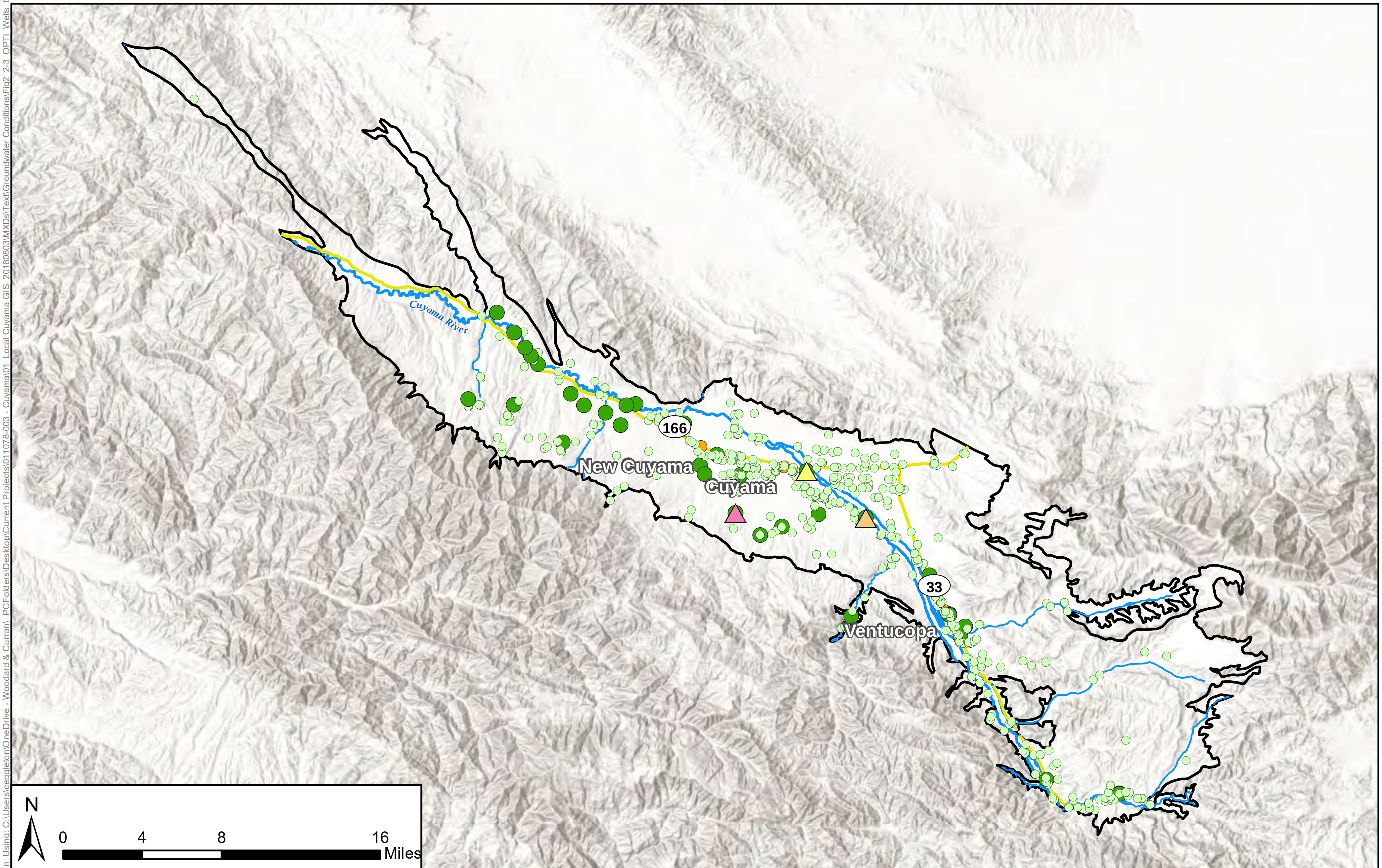

Figure 2-31: Cuyama GW Basin Wells with Monitoring Data Provided by USGS

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

December 2019

WOODARD & CURRAN

Legend

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- USGS Database Wells Last Measured in 2017-2018
- USGS Database Wells Last Measured 2016 or Earlier
- CVBR Multi-Completion Well
- CVFR Multi-Completion Well
- CVKR Multi-Completion Well

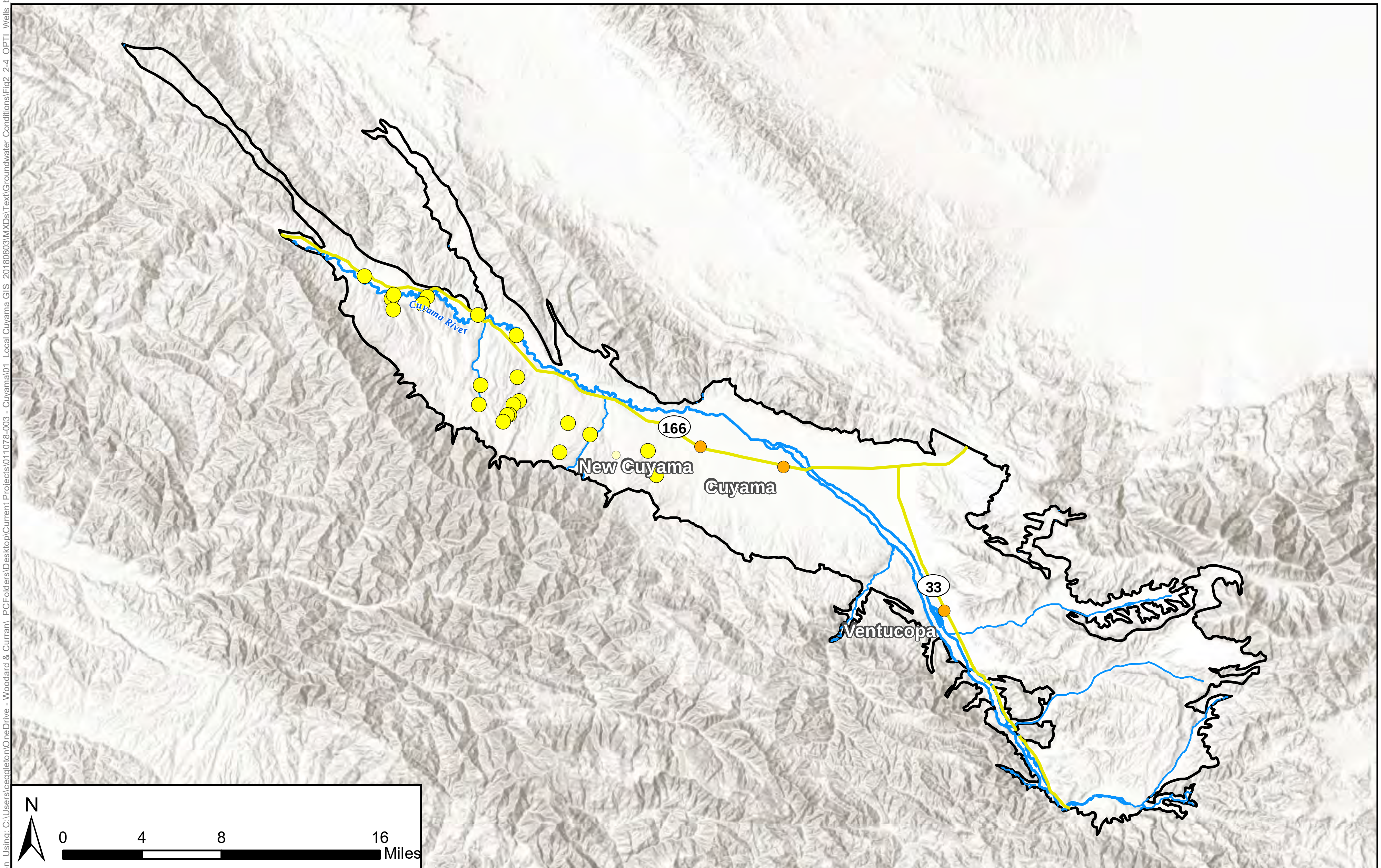

Figure 2-32: Cuyama GW Basin Wells with Monitoring Data Provided by Local Agencies

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

December 2019

WOODARD & CURRAN

Legend

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- County Database Wells Last Measured in 2017-2018
- County Database Wells Last Measured 2016 or Earlier

Figure 2-33 shows the locations of well data received from private landowners. The majority of wells provided by private landowners are located in the central portion of the Basin, between the Cuyama River and Highway 33, generally running along SR 166. Additional wells provided by private landowners are located along the Cuyama River and SR 166, west of the Russell Fault. Associated data provided with private landowners varies by source. Some data and measurements were taken annually, while other well owners recorded data biannually or quarterly.

Figure 2-34 shows the locations of collected data from all entities by their last measured date prior to the GSP 2020 submittal. Wells with monitoring data in 2017-2018 are shown in green triangles. There are recent measurements in many different parts of the Basin as follows:

- Near the Cuyama River in the eastern uplands and near Ventucopa
- In the central portion of the Basin, especially north of SR 166 but with some wells located in the southern portion of the central basin
- In the western portion of the Basin east of Aliso Canyon. An additional concentration of recent monitoring points is present along the Cuyama River east of the Russell Fault.

Figure 2-35 shows a comparison of data provided by private landowners and data compiled from the DWR, USGS, and county databases in the central portion of the Basin. This figure was developed to provide information on the consistency between data from these differing sources. The figure shows the location of compared wells, and the measurements on those wells by source. The measurements of groundwater elevation among the wells shown indicate that the monitoring by the private landowners and agencies approximately match in tracking historical trends from the public databases.

Figure 2-36 shows a comparison of data collected from other private landowners, and data collected from SBCWA. This figure was developed to provide information on the consistency between data from these differing sources. The figure shows the location of compared wells, and the measurements from those wells by source. A long-term comparison is not possible due to the shorter measurement period of the Santa Barbara County wells, but the measurements of groundwater elevation among the measured wells indicate that the monitoring by private landowners in the western portion of the Basin and the county are similar in elevation, with the county's data showing slightly higher elevations.

2.2.4 Processing of Groundwater Elevation Data Since GSP Submittal

Since 2020, the CBGSA has performed monitoring of groundwater levels on a quarterly basis through the development of its own monitoring network. This network is described in detail in Chapter 4 of this GSP. Data collection was begun in August 2020. Additional efforts have improved understanding of the wells in the monitoring network, including a well survey that was completed in 2021, which surveyed the latitude, longitude, and elevation of each monitoring network well. In addition, in October 2022, a well information survey was sent to all landowners in the Basin. This survey provided information on well ownership, location, and completion information, well type (irrigation, residential, etc.), and well status (pumping vs not pumping).

Processing of these data has been refined as additional information on wells from landowners has been received. This information has been included in the public Opti data management system (DMS) for review by Cuyama Basin Stakeholders. In addition to collecting data on wells already identified during GSP development, the CBGSA has constructed three new piezometers near mapped GDE locations and new multi-completion nested monitoring wells at six locations using grant funding from DWR. In addition, DWR constructed three new multi-completion nested wells under its Technical Support Services program. These new wells are located in areas that were identified by the CBGSA as spatial data gaps in the 2020 GSP. They are described in more detail in sections 2.2.4 and 2.2.10.

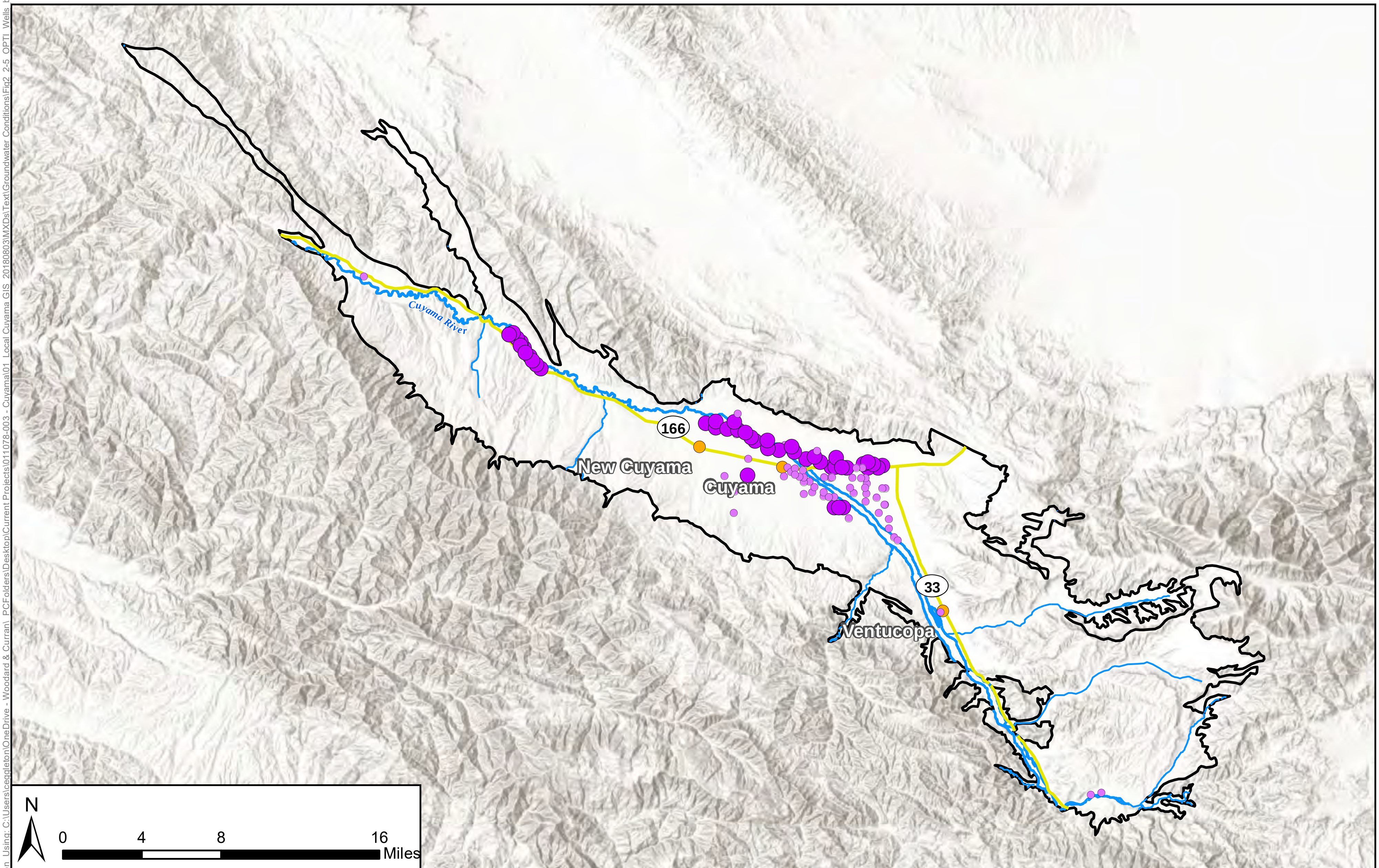

Figure 2-33: Cuyama GW Basin Wells with Monitoring Data Provided by Private Landowners

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

December 2019

WOODARD & CURRAN

Legend

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- Private Landowners Reported Wells Last Measured in 2017-2018
- Private Landowners Reported Wells Last Measured 2016 and Earlier

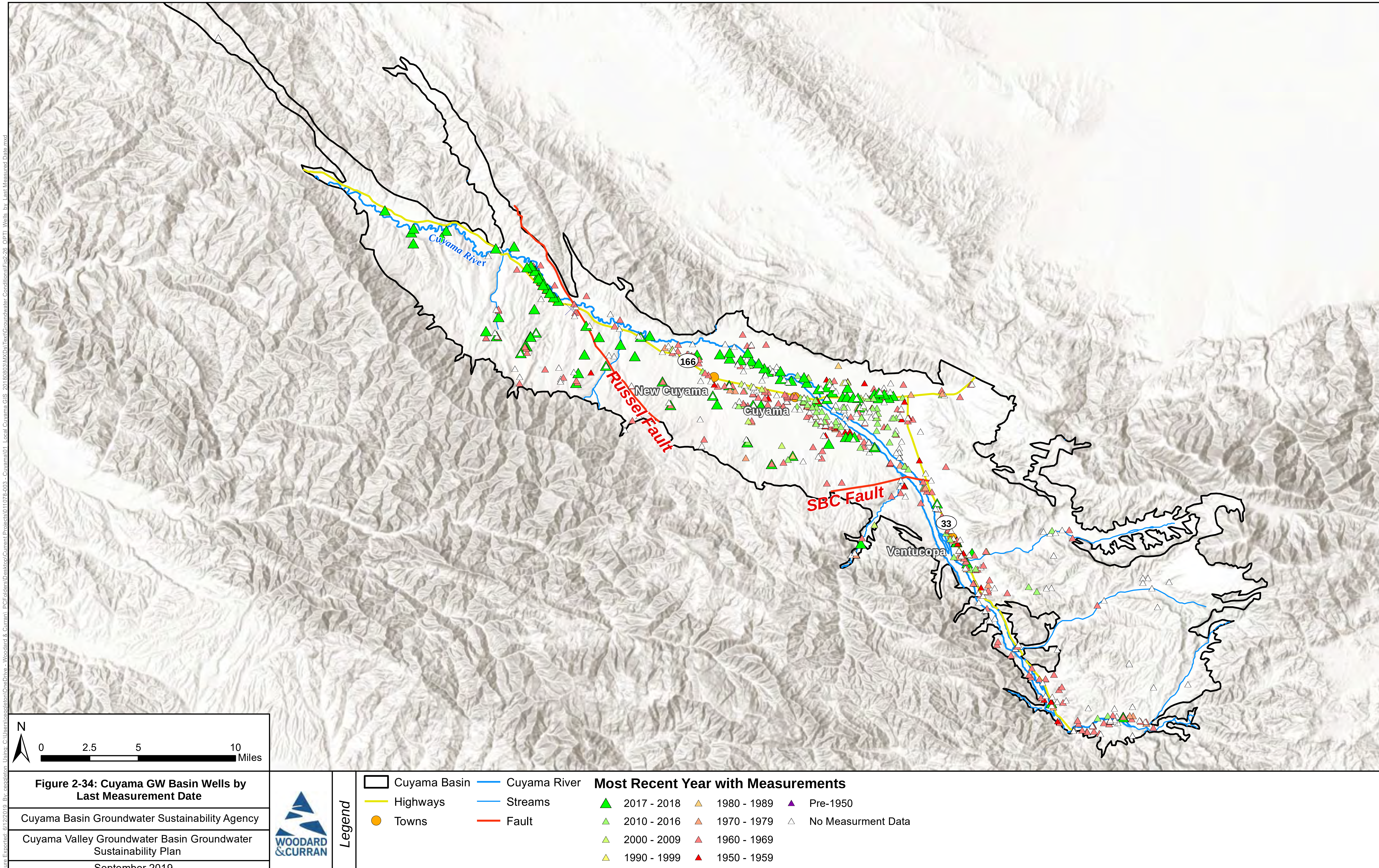

Figure 2-34: Cuyama GW Basin Wells by Last Measurement Date

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

September 2019

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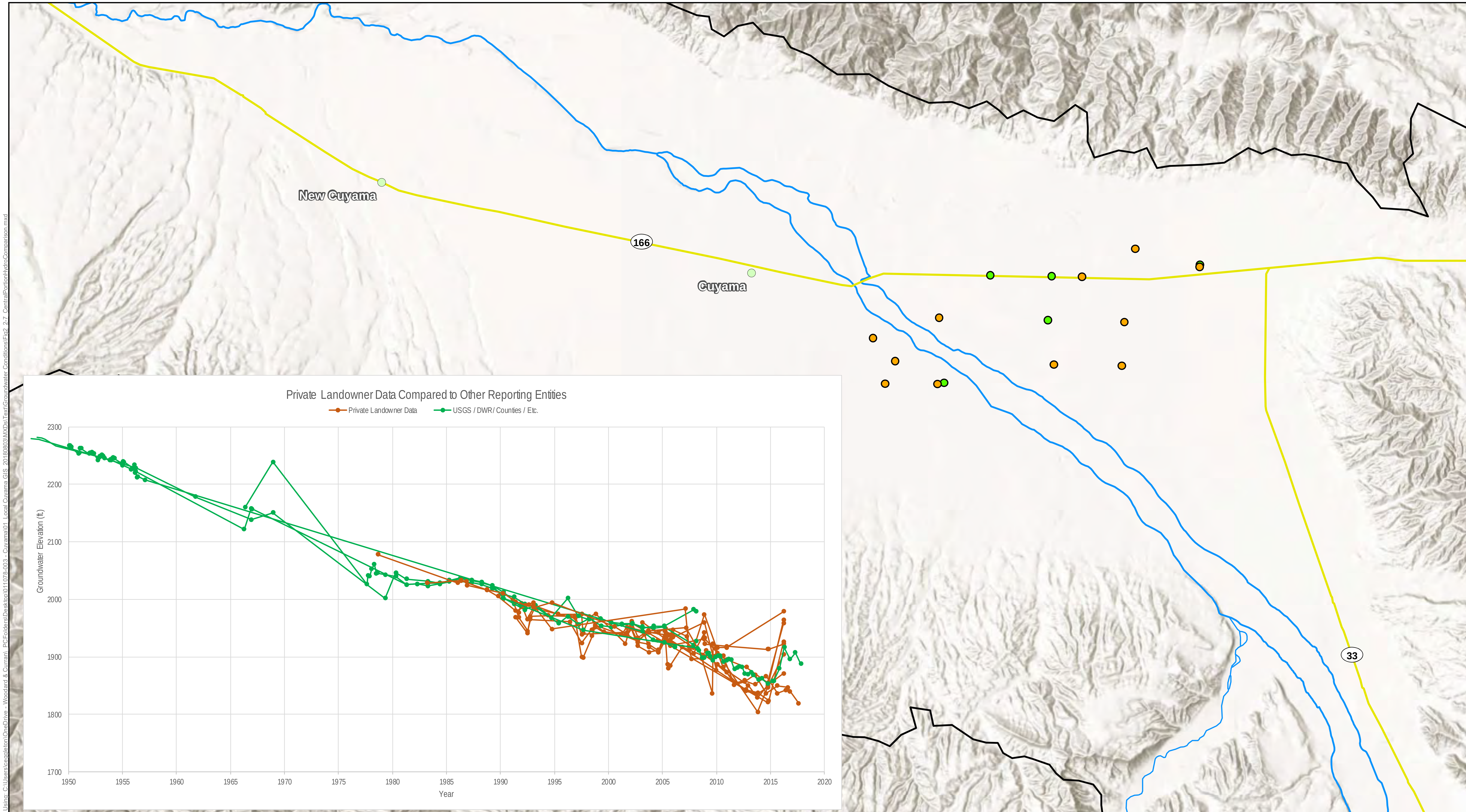


Figure 2-35: Central Cuyama GW Basin Wells and Hydrographs by Data Source

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

December 2019

WOODARD & CURRAN

Legend

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- USGS, DWR, County, Etc., Wells
- Private Landowners

N

0 0.5 1 2 Miles

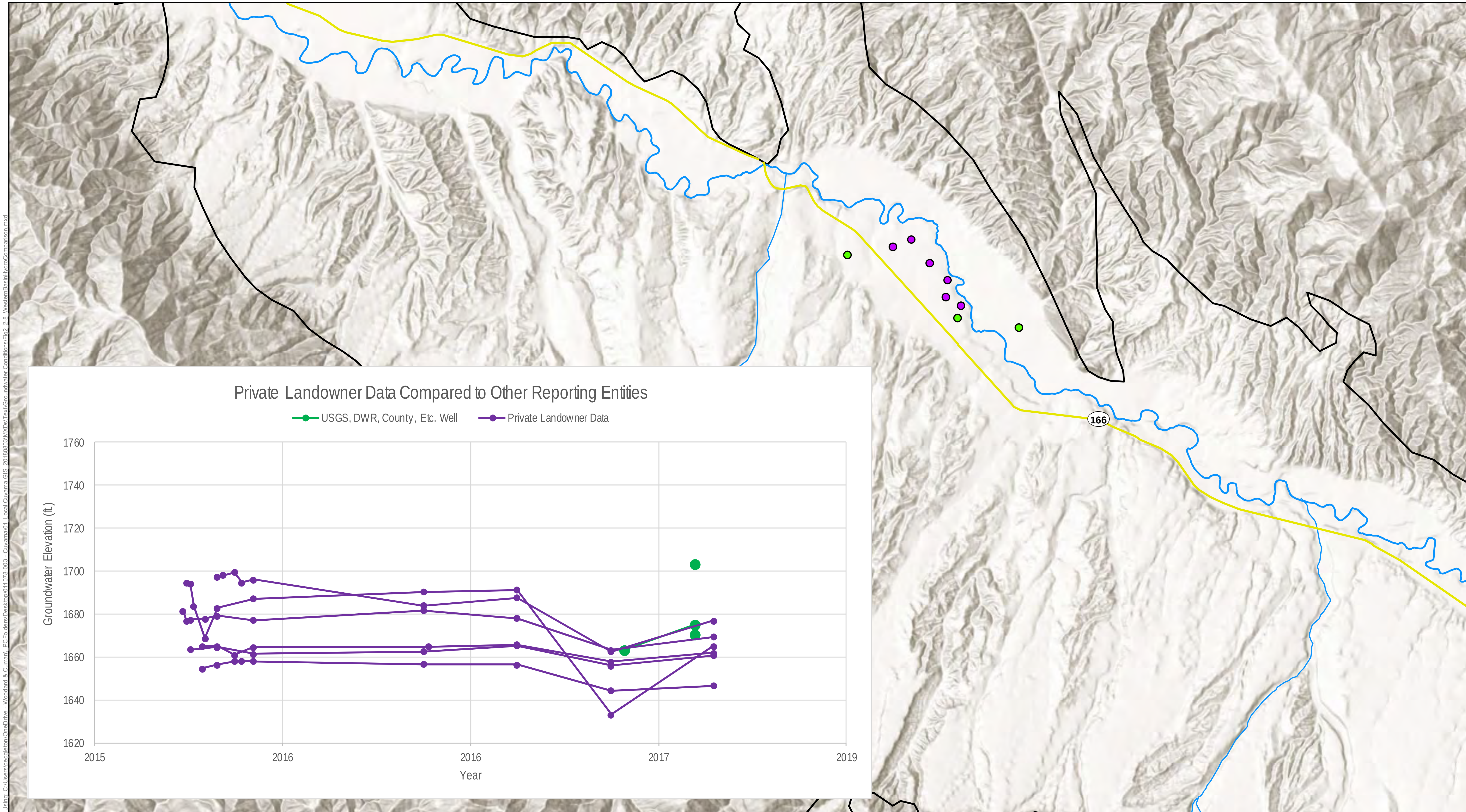


Figure 2-36: Western Cuyama GW Basin Wells and Hydrographs by Data Source

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

December 2019

WOODARD & CURRAN

Legend

Cuyama Basin

Highways

Cuyama River

Streams

USGS, DWR, County, Etc. Wells

Private Landowner Wells

N

0 0.5 1 2 Miles

2.2.5 Groundwater Trends

This section describes groundwater trends in the Basin generally from the oldest available studies and data to the most recent. Groundwater conditions vary widely across the Basin. In the following sections, historical context is provided by summarizing information from relevant studies about conditions from 1947 to 1966, followed by discussion of how groundwater conditions have changed based on available historical groundwater level monitoring data.

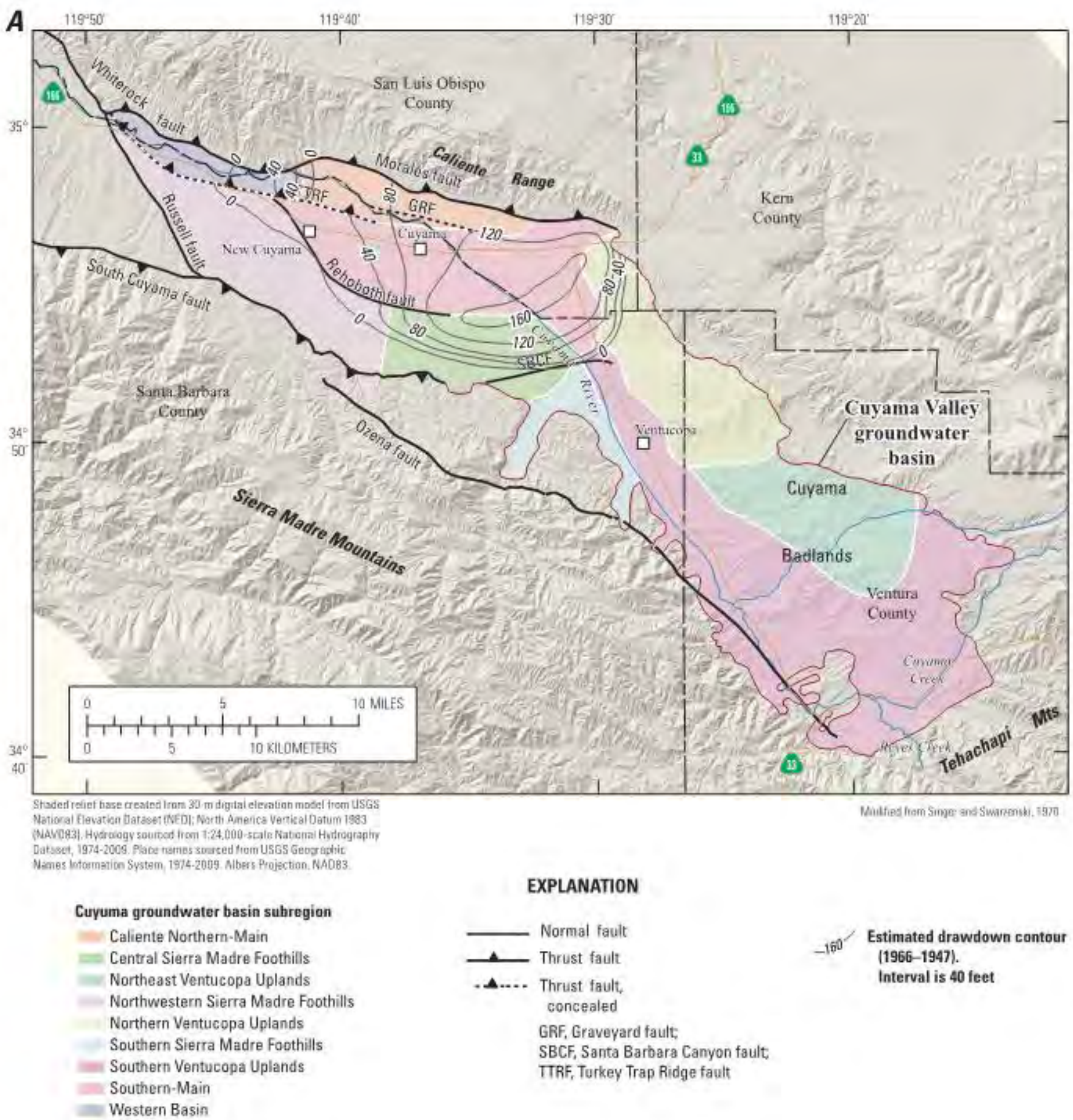
Historical Context – 1947 to 1966 Groundwater Trends

This section discusses public reports about conditions from 1947 to 1966. Information about groundwater conditions in the Basin during this period are limited to reports that discuss the central portion of the Basin and scattered groundwater elevation measurements in monitoring wells.

A USGS report titled *Water Levels in Observation Wells in Santa Barbara County, California* (USGS, 1956) discussed groundwater elevation monitoring in the Basin. The report states that, prior to 1946, there was no electric power in the Cuyama Valley, which restricted intensive irrigation, and that groundwater levels in the central portion of the Basin remained fairly static until 1946. The report states that: "Declines in groundwater began after 1946," and that groundwater declined "as much as 8.8 feet from the spring of 1955 to 1956; the average decline was 5.2 feet. The decline of water levels at the lower and upper ends of the valley during this period was not so great as in the middle portion and averaged 1.7 and 2.2 feet respectively. Since 1946, water levels in observation wells have declined on the average of about 27 feet" (USGS, 1956).

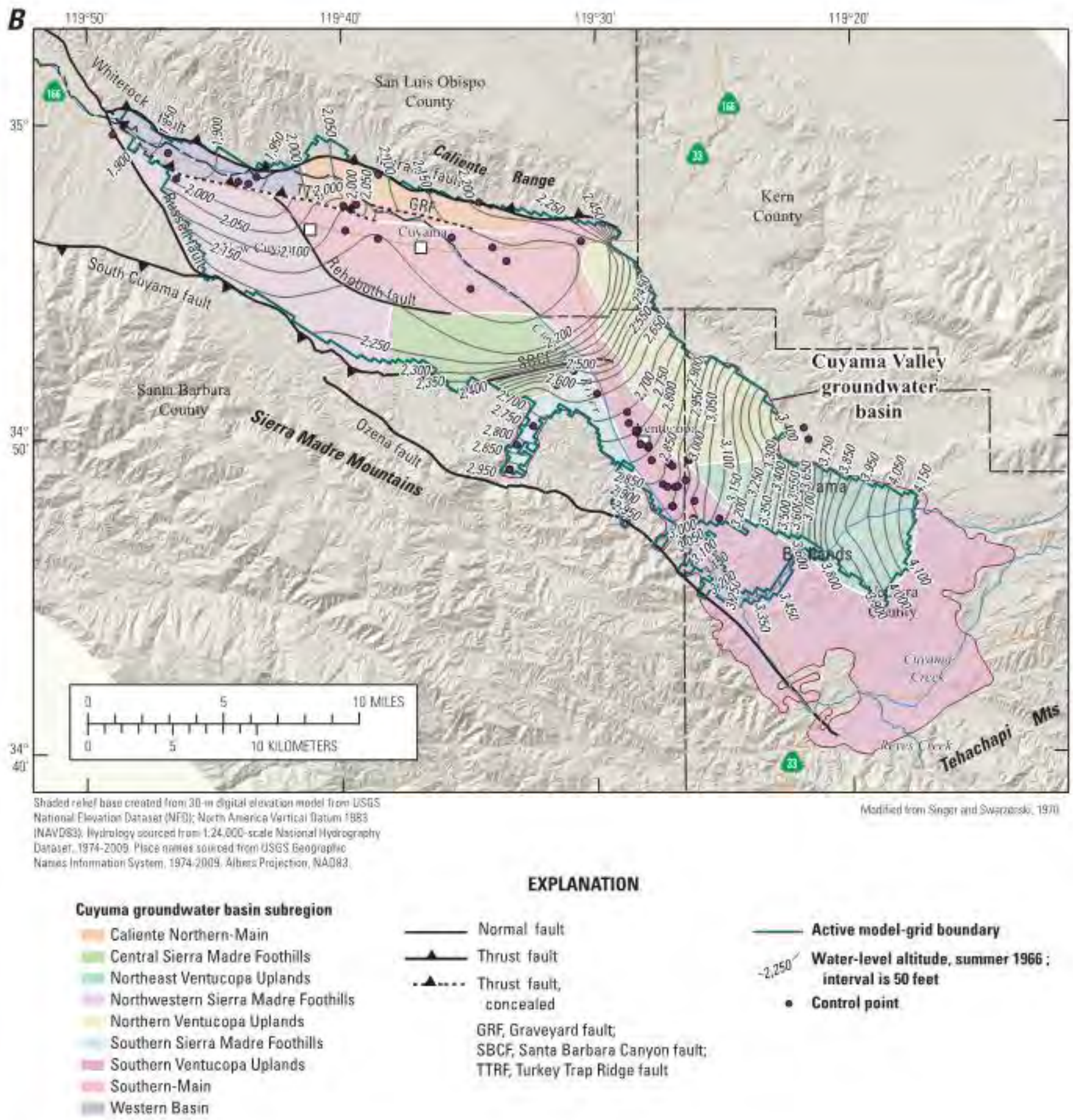
A USGS report titled *Hydrologic Models and Analysis of Water Availability in the Cuyama Valley, California* (USGS, 2015) presents two maps generated by using CUVHM simulated data. Figure 2-37 shows the estimated drawdown in the central portion of the Basin from 1947 to 1966. Figure 2-37shows that estimated drawdown ranged from zero at the edges of the central portion of the Basin to over 160 feet in the southeastern portion of the central portion of the Basin.

Figure 2-38 shows the estimated contours of groundwater elevation for summer 1966. These contours show a low area in the central portion of the Basin, and a steep groundwater gradient in the southeast portion near Ventucopa and in the highlands. A gentle groundwater gradient occurs in the southwestern portion of the central portion of the Basin, generally matching topography. Few wells are located in this area and groundwater elevation contours were estimated over large distances by the USGS.



Source: USGS, 2015

Figure 2-37: Water Level Drawdown Contours, 1947 to 1966



Source: USGS, 2015

Figure 2-38: 1966 Water Level Contours

Groundwater Trends According to Available Monitoring Data

To understand how groundwater conditions have changed in the Basin in recent decades, analysts developed and analyzed groundwater elevation hydrographs and contour maps, and horizontal and vertical hydraulic gradients, which are discussed below. Since the GSP was approved, the CBGSA has implemented its own monitoring program to monitor groundwater trends. The CBGSA publishes quarterly groundwater conditions reports that provide groundwater trends from the Basin's groundwater monitoring network (described in detail in Chapter 4). All data are published on the CBGSA's online public Opti DMS.

Groundwater Hydrographs

The DMS contains water level measurements from wells the CBGSA has identified in the Basin. Groundwater hydrographs were developed for a subset of the wells that are part of the monitoring network. These wells are measured more frequently, and the hydrographs provide indicators of groundwater elevation trends throughout the Basin. All historical measurements were compiled and shown in one hydrograph for each well. These hydrographs are presented in Appendix A.

In many cases, changes in historical groundwater conditions at particular wells have been influenced by climactic patterns in the Basin (Section 2.3). Historical precipitation is highly variable, with several relatively wet years and some multi-year droughts.

Figure 2-39 shows the current monitoring network that has been updated with this GSP submittal. Subsequent maps show different parts of the Basin starting in the west and moving to the eastern portion of the Basin to show specific groundwater conditions in selected areas.

Figure 2-40 shows hydrographs for each region of the Basin. These wells were selected because they broadly represent Basin conditions in their areas. More information about these conditions is summarized below.

- In the southeast region near Round Springs Canyon, near the Ozena Fire Station (Well 89), groundwater levels have been fluctuating by about 20 feet throughout the measurement period except for larger declines in about 1997 and 2017. On average, groundwater levels have remained stable. This well is not pumped, and the measurements represent static water levels. In the eastern region in the City of Ventucopa (Well 62), groundwater levels have declined from the early 1990's to about 2018 when they stabilized for several years. A recent increase in groundwater levels started at the end of 2023. This well is not pumped and the measurements represent static water levels.
- In the central region of the Basin (Well 91), groundwater levels have been declining from 2009 to 2024. The net decline over this period is about 100 feet bgs. This well is not pumped and the measurements represent static water levels.

- Also, in the central region (Well 77), groundwater levels have shown a steady decline since 2009 with seasonal fluctuations during most years. The net decline has been about 100 feet bgs.
- In the western portion of the Basin (Well 118), groundwater levels have been generally stable since 2016 with groundwater levels within about 60 feet of ground surface. These levels increased by 10 feet in recent years. This well is not pumped and the measurements represent static water levels.

Figure 2-41 shows hydrographs for six wells in the western part of the Basin located adjacent to the Cuyama River with water levels within 100 feet of ground surface. Wells 836 and 830 show a similar trend of stable water levels. A slight decline in water levels occurred in late 2022 followed by a rebound through 2023 due to the wet hydrologic conditions. The hydrograph for Well 833 shows a sharp water level decline in late 2020 with variable recovery through 2023 with water levels fluctuating 20 feet over this period. Wells 841 and 845 show seasonal fluctuations that reflect seasonal pumping for irrigated agriculture and an overall decline although Well 841 shows some recovery since mid-2022.

Figure 2-42 shows hydrographs for six other wells in the western portion of the Basin that are not adjacent to the Cuyama River. However, only Wells 117 and 106 are dedicated monitoring wells with no pumping. Water levels in Well 117 have been stable other than a sharp increase in early 2017. Wells 573, 118, and 106 have had stable water levels throughout the period of record at approximately 70 feet bgs, 55 feet bgs, and 140 feet bgs, respectively. At Well 571, groundwater levels were stable from 2016 to about 2020. Through 2022, the fluctuating levels ranged from 120 to 140 feet bgs. In early 2023, the measurements indicate an abrupt increase of about 80 feet. Since then, groundwater levels have declined from 40 to 80 feet bgs but remain notably higher than pre-2022 levels.

Figure 2-43 shows hydrographs for four wells in the west-central part of the Basin at variable distances from the Cuyama River. Wells 114 and 112 are active pumping wells. Well 114 was measured in 1968 but not again until 2016. The absence of data during this period indicates a decline from 30 to about 44 feet bgs. Well 112 has a similar data gap from 1968 to 2016 but shows a net increase in water levels from about 112 feet up to 83 feet bgs. Since 2016, the water level has declined to about 87 feet bgs. Well 568, also an active pumping well, has a data gap from 1967 to about 2009. During this period, water declines had a net decline of 10 feet. Water levels continued to decline until early 2022 when measurements show an abrupt decline of 40 feet. Subsequent water levels indicate the decline recovered just as abruptly, suggesting a possible measurement error. Water levels were steady for the remainder of 2023 at about 40 feet bgs, lower than historical measurements. Well 474 is a monitoring well with a decline in water levels of about 20 feet from 1955 to about 1967. Subsequent measurements show a partial recovery followed by steady conditions until mid-2019 with depth to water of about 185 feet bgs. Since that time, water levels have sharply increased to 135 feet bgs.

Figure 2-44 shows hydrographs for three wells in the north-central portion of the Basin. Wells 72, 74, and 604 are all active pumping wells. Well 72 had fluctuating water levels from about 55 to 80 feet bgs from 1981 to 2008. Since then, the water levels have fluctuated more frequently and show a net decline to about 130 feet bgs. The water level measurements show several significant short-term declines from 2009 to 2021. Water levels in Well 74 have slowly declined from 2008 to 2024 with levels decreasing from 220 to 250 feet bgs. An abrupt short-term decline is indicated by the data in 2009. Water levels in Well 604 had a net decline from 1995 to mid-2017. Since then, the water levels have increased to about 450 feet bgs.

Figure 2-45 shows selected hydrographs also in the central portion of the Basin. Well 103 is a dedicated monitoring well while Wells 608 and 609 are active pumping wells. Water levels in Well 103 have fluctuated above and below 300 feet bgs from 2012 to 2022, likely due to nearby pumping for irrigation. Since that time, water levels have increased to about 240 feet bgs. Wells 608 and 609, both close to the Cuyama River, had net water level declines from 1995 to 2024. At Well 608, water levels have declined from 290 to about 430 feet bgs. At Well 609, water levels have declined from about 280 to about 440 feet bgs.

Figure 2-46 shows selected hydrographs in the central portion of the Basin further east of those noted above. Well 96 is a monitoring well, while Wells 612 and 615 are active pumping wells. Water levels in Well 96 have declined from 1983 to 2024 from about 295 to about 340 feet bgs. Water levels in Well 612, close to the Cuyama River, have declined from 1995 to 2024 from 330 to about 475 feet bgs. Water levels in Well 615 were steady from 1995 to 200 at 360 feet bgs. Since then, water levels have declined to about 520 feet bgs.

Figure 2-47 shows selected hydrographs also in the central portion of the Basin further to the east. Wells 95, 610, 629, and 633 are active pumping wells. Wells 610, 629, and 633 have net declines since the first measurements in the late 1990's and mid-2000's. Depth to water in Wells 629 and 633 are currently about 560 to 570 feet bgs and 630 feet bgs in Well 610. Whereas it ranges from below 550 to about 650 feet bgs in the other wells. Water levels in Well 95 slightly declined from 2009 to 2023 to greater than 600 feet bgs. The well was reportedly rehabilitated and the pump set a new depth. The measurement of roughly 70 feet bgs is assumed to be a measurement error.

Figure 2-48 is the final hydrograph map in this series, showing selected hydrographs for the southeastern portion of the Basin. Wells 85, 100, and 101 are active pumping wells, while Wells 62 and 89 are monitoring wells. These five wells span a large area of the Basin. At Well 85, water levels have fluctuated significantly since 1950 with a net increase from 170 to 160 feet bgs. At Well 100, water levels had a net decline from 130 to 160 feet bgs from 2010 to 2022. In 2023, water levels sharply rose to 70 feet bgs. At Well 101, water levels had a net decline from 70 to about 108 feet bgs from 2008 to 2023. Since then, water levels have increased to 90 feet bgs. At Well 62, water levels declined from about 65 to about 165 feet bgs from in the mid 1990's to 2023. Since then, water levels have sharply increased to about 115 feet bgs. At Well 89, water levels have fluctuated since 1980 within the range of 20 to 40 feet bgs. The measurements indicate sharp declines in water levels in 1995 and 2016.

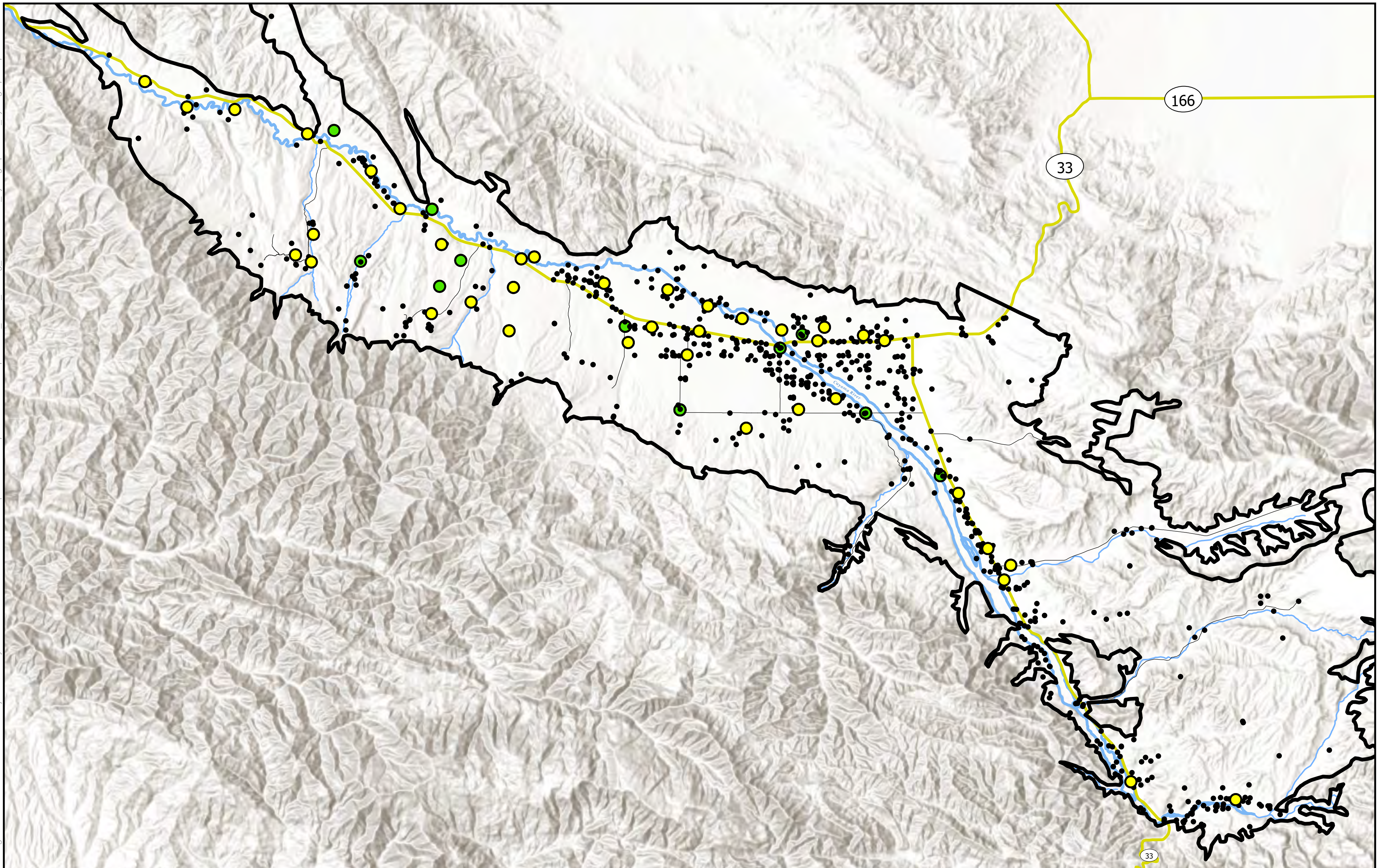


Figure 2-39: Monitoring Well Locations

Cuyama Valley Groundwater Basin

Legend

- ● (yellow) Well with Hydrograph
- ● (green) Well without Hydrograph
- • Well not Monitored
- Highway
- Local Road
- Creek
- Cuyama River
- Cuyama Basin

N

0 1.25 2.5 5 Miles

Map Created: July 2024

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions.
Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data sources: CA DWR, Esri, USGS**

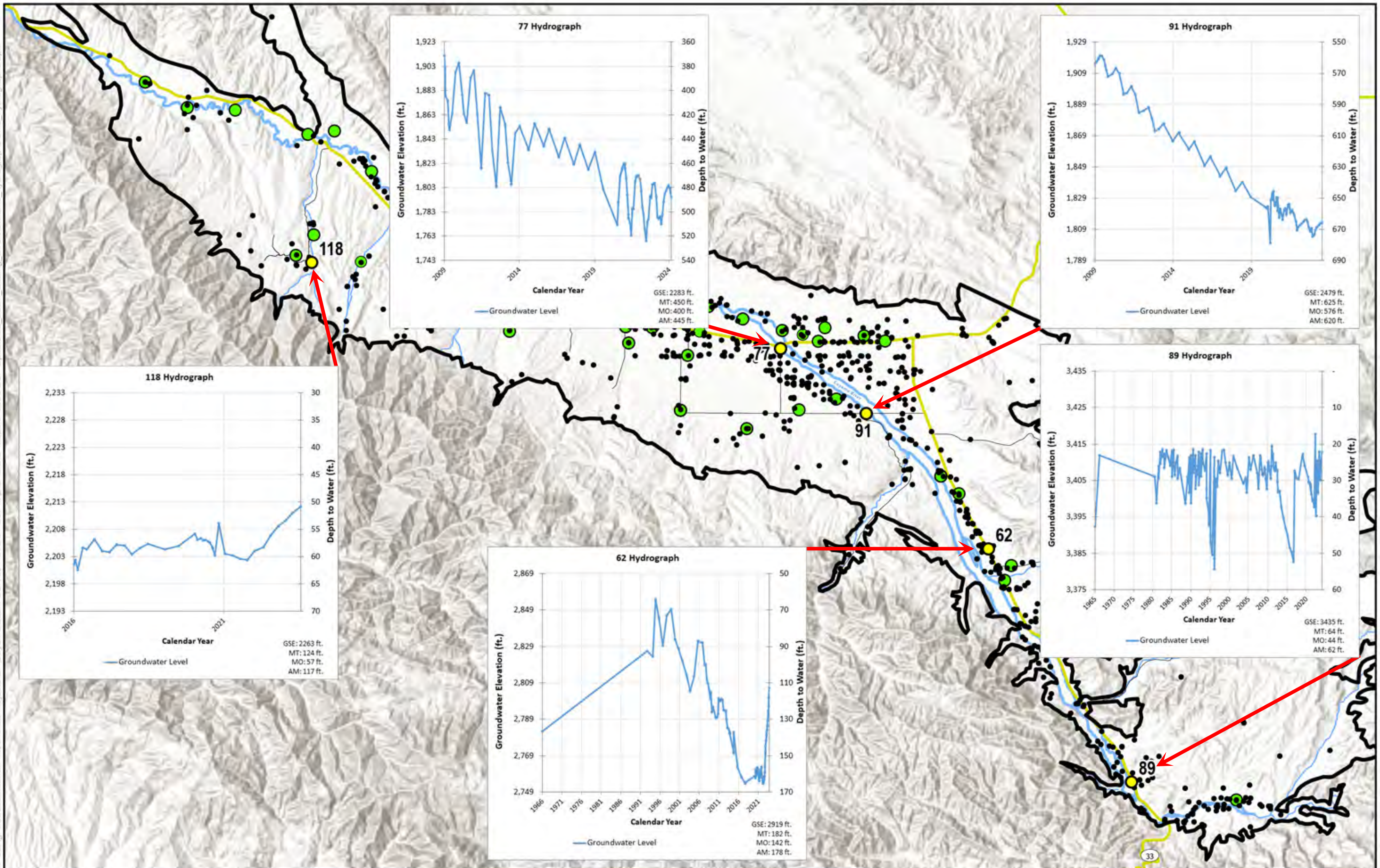


Figure 2-40: Monitoring Well Network Hydrographs

Cuyama Valley Groundwater Basin

Legend

- Well with Hydrograph
- Well without Hydrograph
- Well not Monitored
- Highway
- Local Road
- Creek
- Cuyama River
- Cuyama Basin

N

0 1.25 2.5 5 Miles

Woodard & Curran

Cuyama Basin Groundwater Sustainability Agency

Map Created: August 2024

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data sources: CA DWR, Esri, USGS**

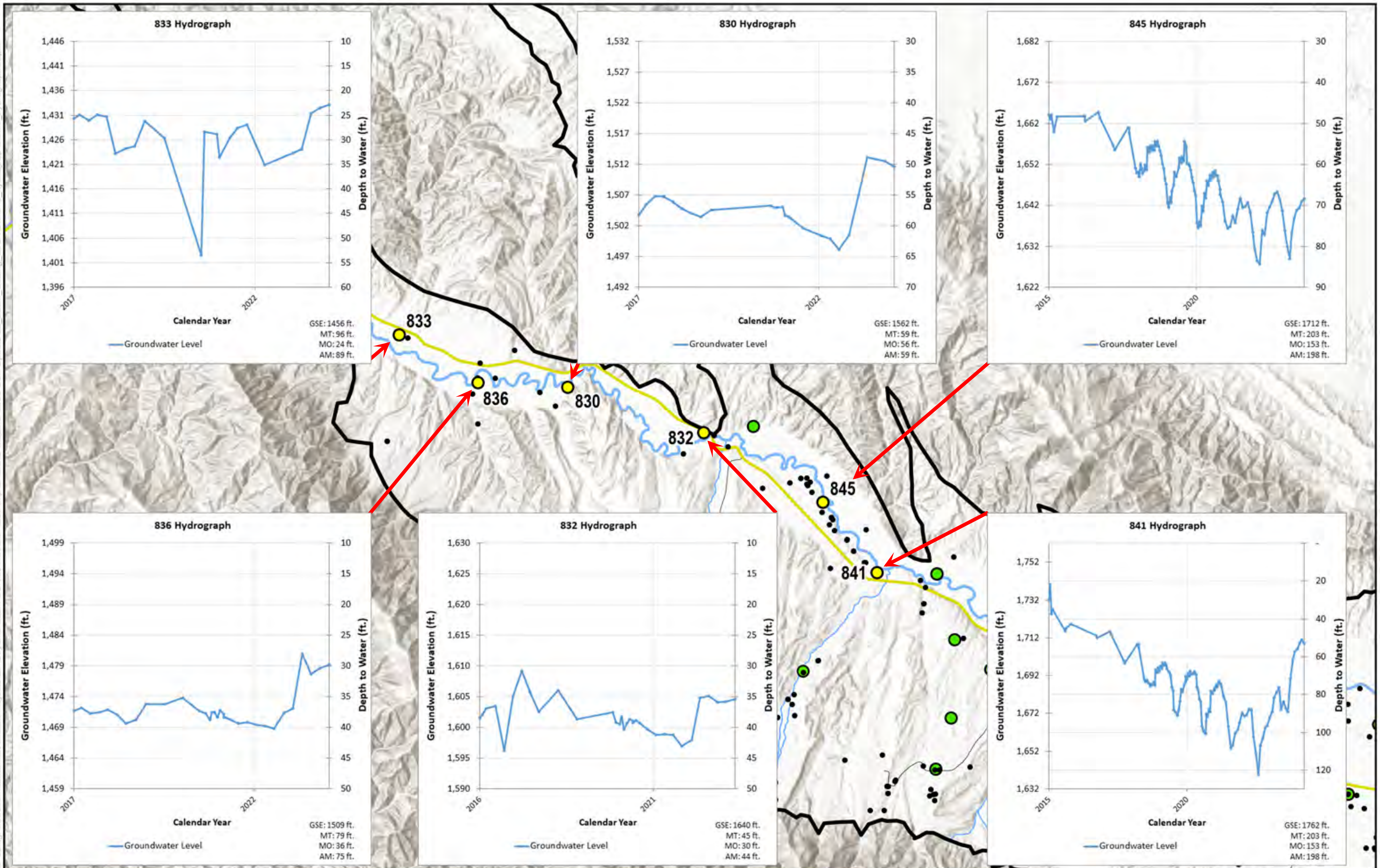


Figure 2-41: Monitoring Well Network Hydrographs

Cuyama Valley Groundwater Basin

Legend

- Well with Hydrograph
- Well without Hydrograph
- Well not Monitored
- Highway
- Local Road
- Creek
- Cuyama River
- Cuyama Basin

N

0 0.5 1 2 Miles

Woodard & Curran

Cuyama Basin Groundwater Sustainability Agency

Map Created: August 2024

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data sources: CA DWR, Esri, USGS**

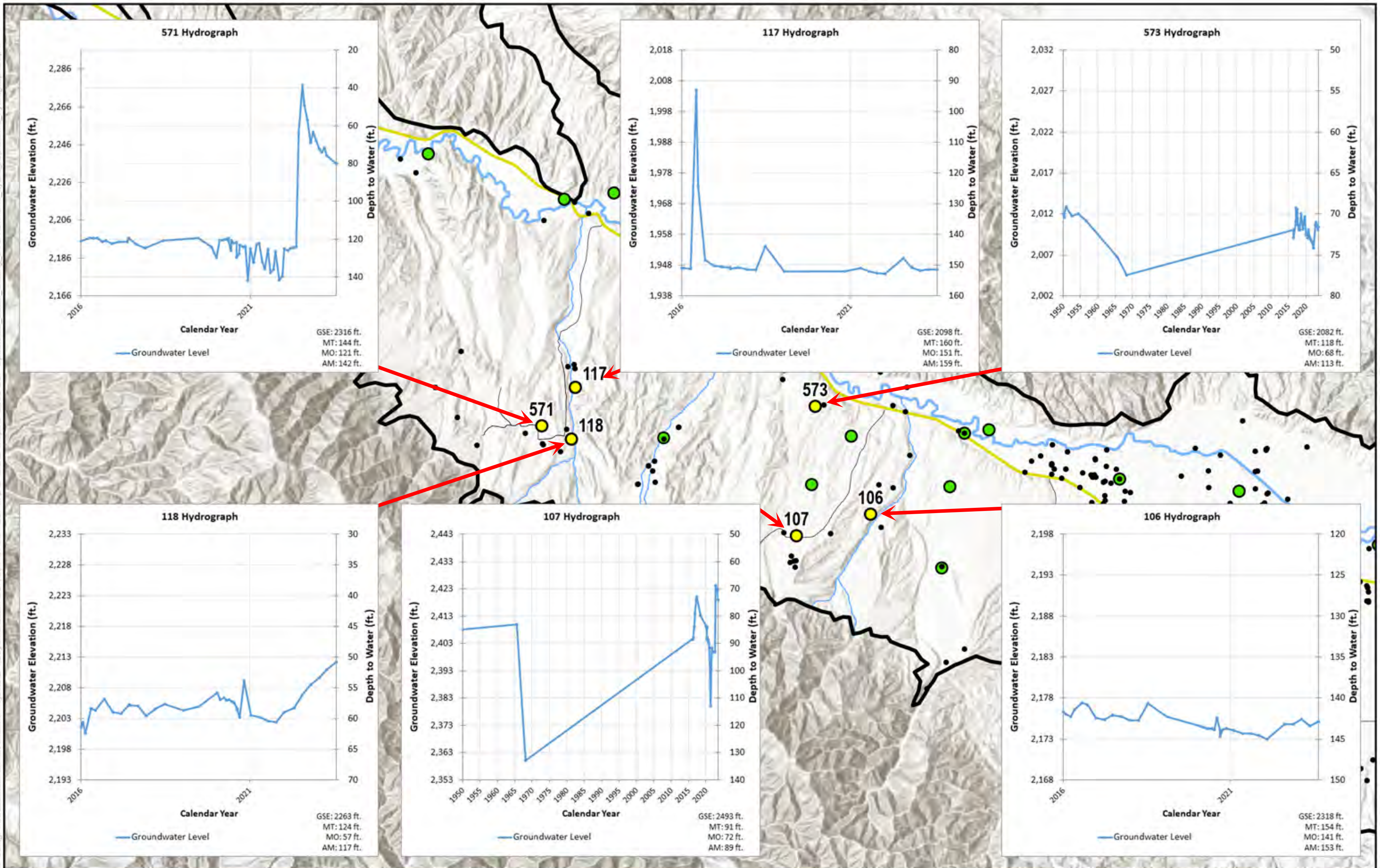


Figure 2-42: Monitoring Well Network Hydrographs

Cuyama Valley Groundwater Basin

Legend

- Well with Hydrograph
- Well without Hydrograph
- Well not Monitored
- Highway
- Local Road
- Creek
- Cuyama River
- Cuyama Basin

N

0 0.5 1 2 Miles

Map Created: August 2024

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data sources: CA DWR, Esri, USGS**

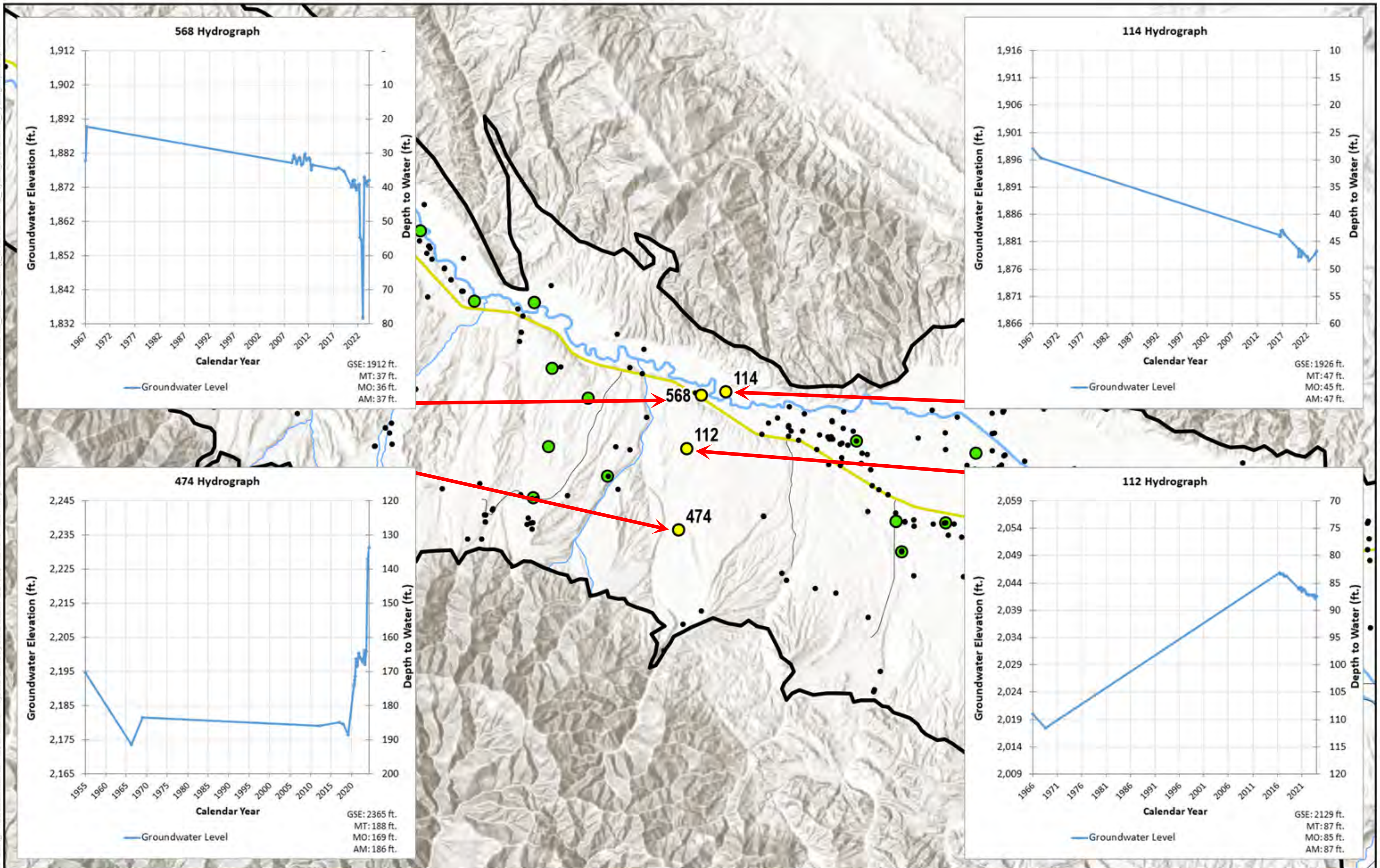


Figure 2-43: Monitoring Well Network Hydrographs

Cuyama Valley Groundwater Basin

Legend

- Well with Hydrograph
- Well without Hydrograph
- Well not Monitored
- Highway
- Local Road
- Creek
- Cuyama River
- Cuyama Basin

N

0 0.5 1 2 Miles

Map Created: August 2024

Woodard & Curran

Cuyama Basin Groundwater Sustainability Agency

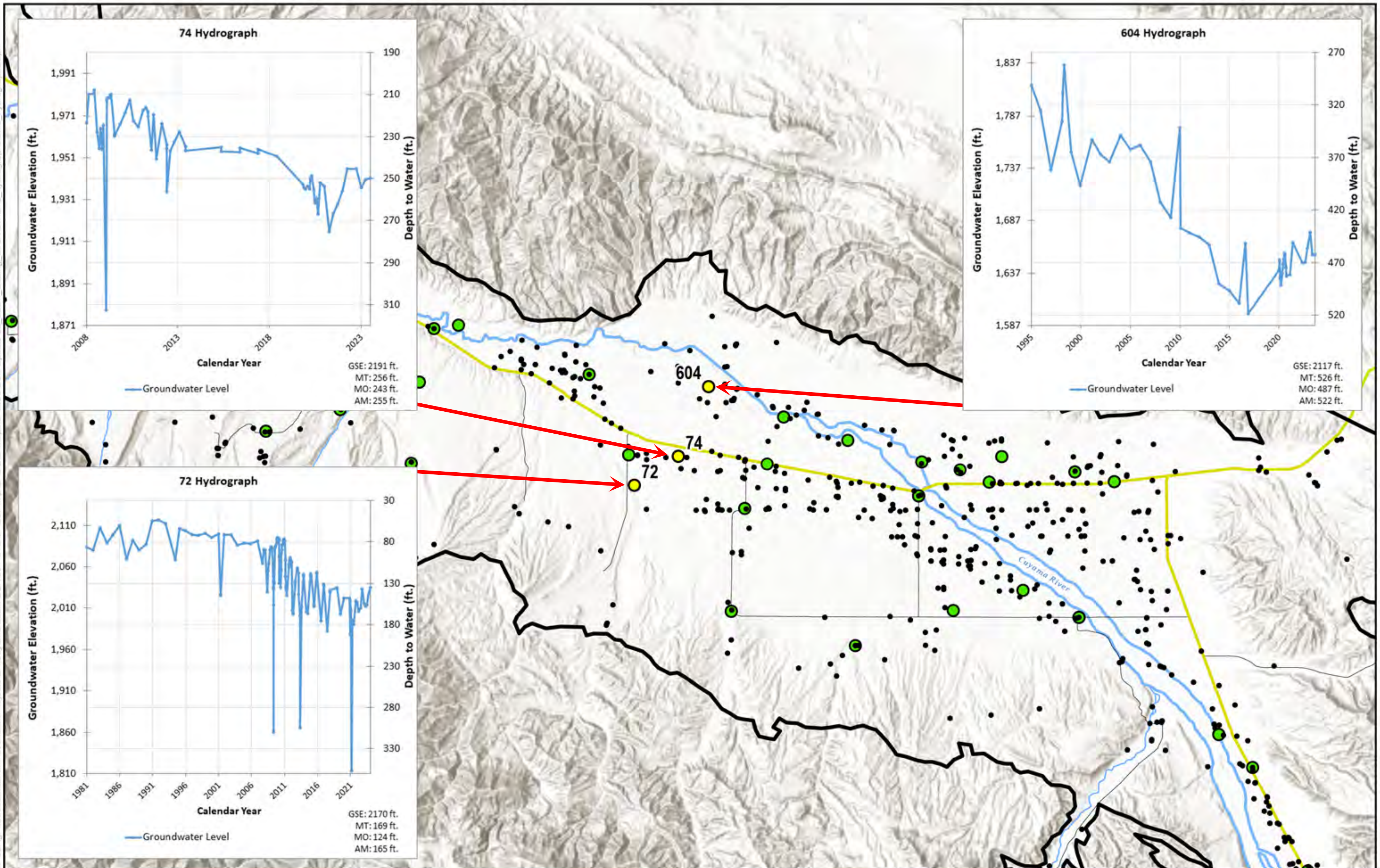


Figure 2-44: Monitoring Well Network Hydrographs

Cuyama Valley Groundwater Basin

Legend

- Well with Hydrograph
- Well without Hydrograph
- Well not Monitored
- Highway
- Local Road
- Creek
- Cuyama River
- Cuyama Basin

N

0 0.5 1 2 Miles

Woodard & Curran

Cuyama Basin Groundwater Sustainability Agency

Map Created: August 2024

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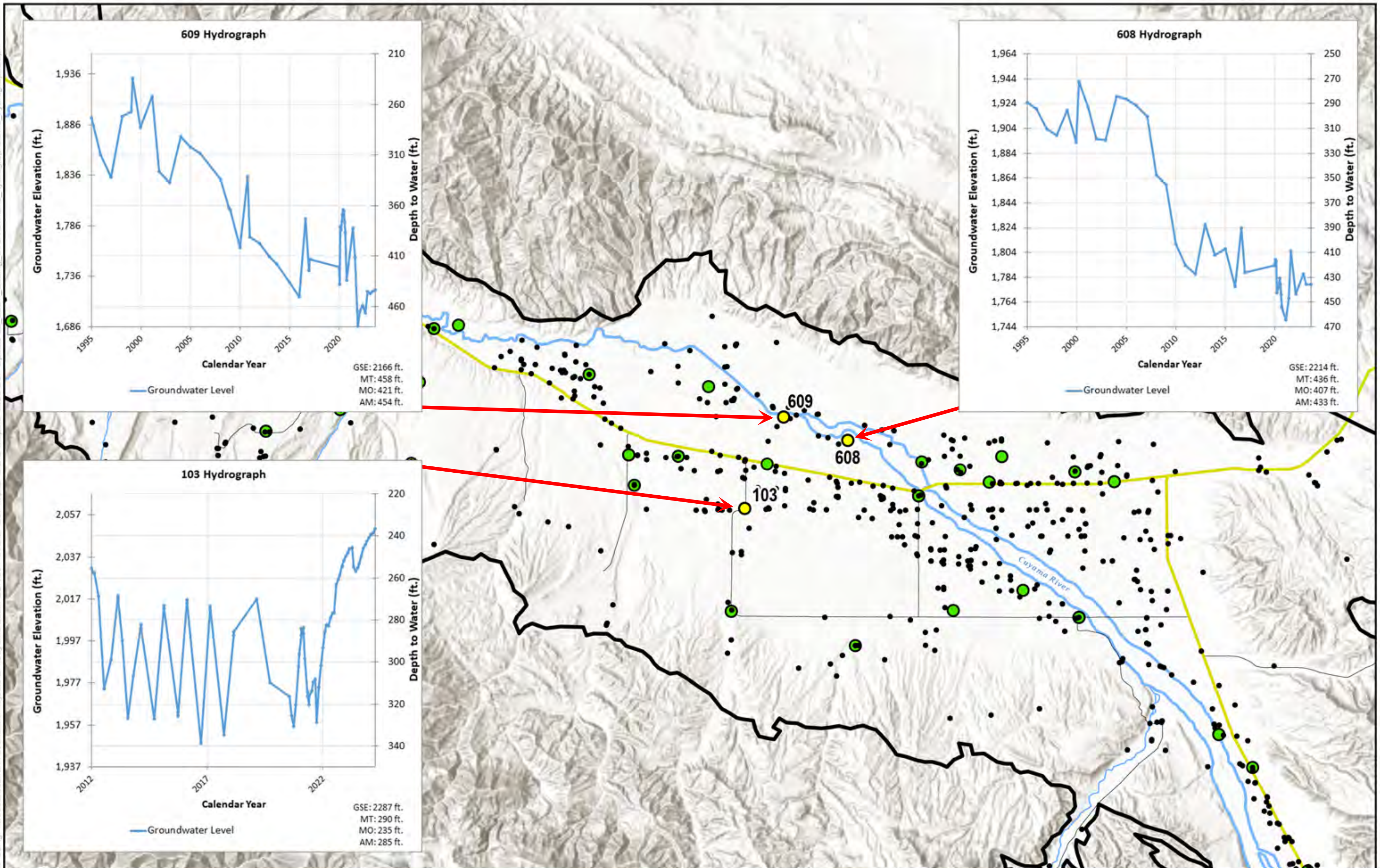

Figure 2-45: Monitoring Well Network Hydrographs

Cuyama Valley Groundwater Basin

Legend

- Well with Hydrograph
- Well without Hydrograph
- Well not Monitored
- Highway
- Local Road
- Creek
- Cuyama River
- Cuyama Basin

N

0 0.5 1 2 Miles

Map Created: August 2024

Woodard & Curran

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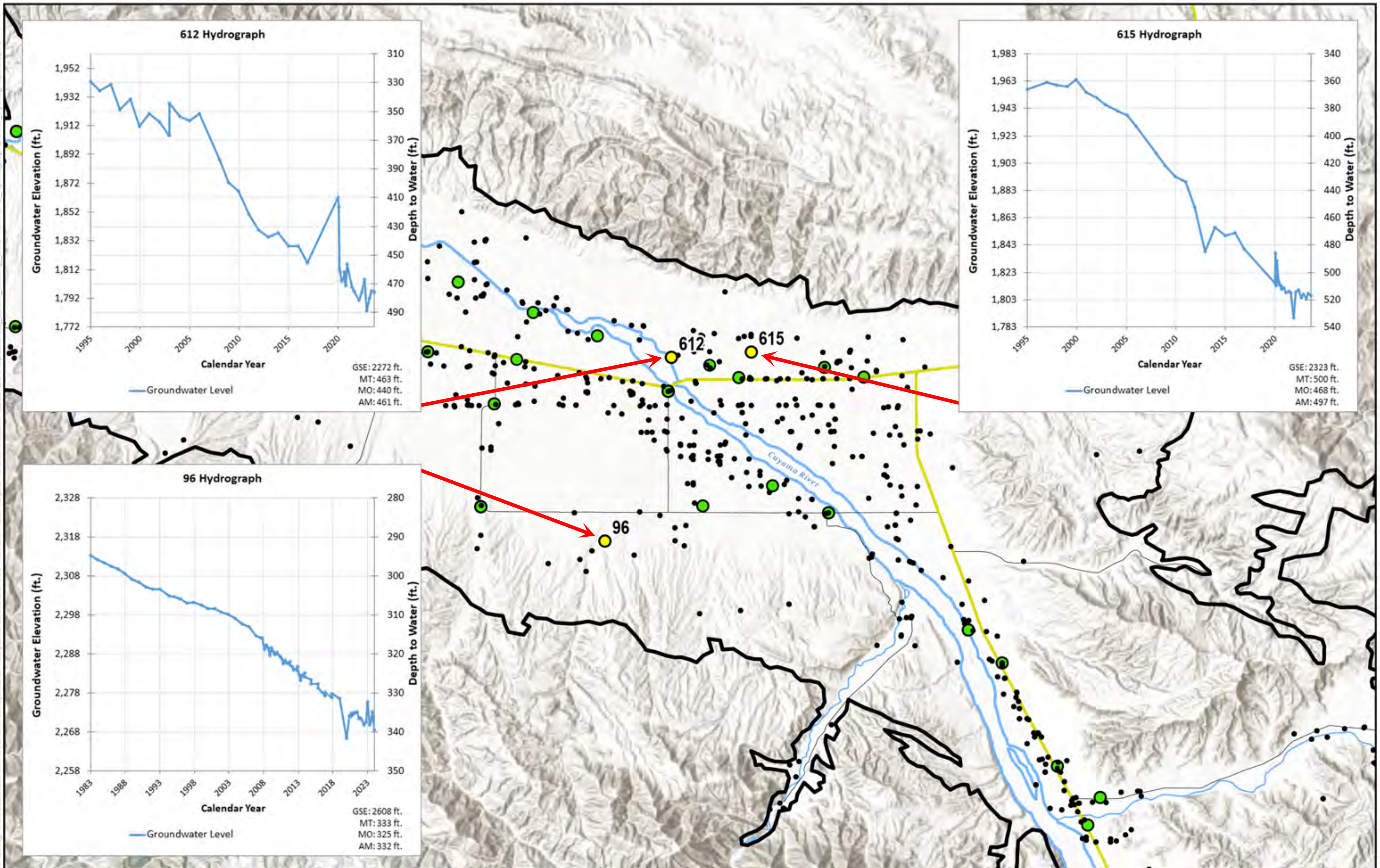

Figure 2-46: Monitoring Well Network Hydrographs

Cuyama Valley Groundwater Basin

Legend

- Well with Hydrograph
- Well without Hydrograph
- Well not Monitored
- Highway
- Local Road
- Creek
- Cuyama River
- Cuyama Basin

N

0 0.5 1 2 Miles

Map Created: August 2024

Woodard & Curran

Cuyama Basin Groundwater Sustainability Agency

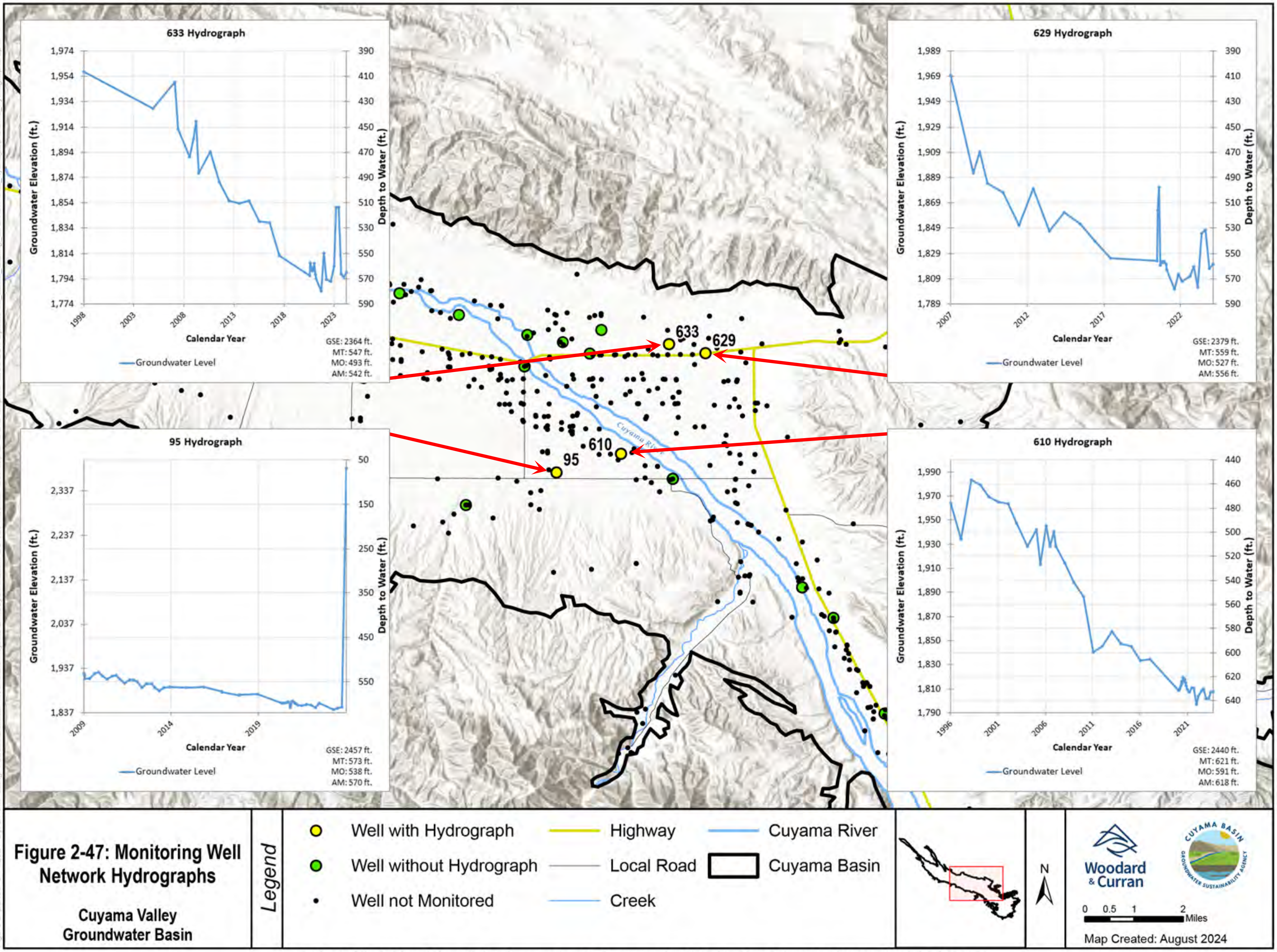

Figure 2-47: Monitoring Well Network Hydrographs

Cuyama Valley Groundwater Basin

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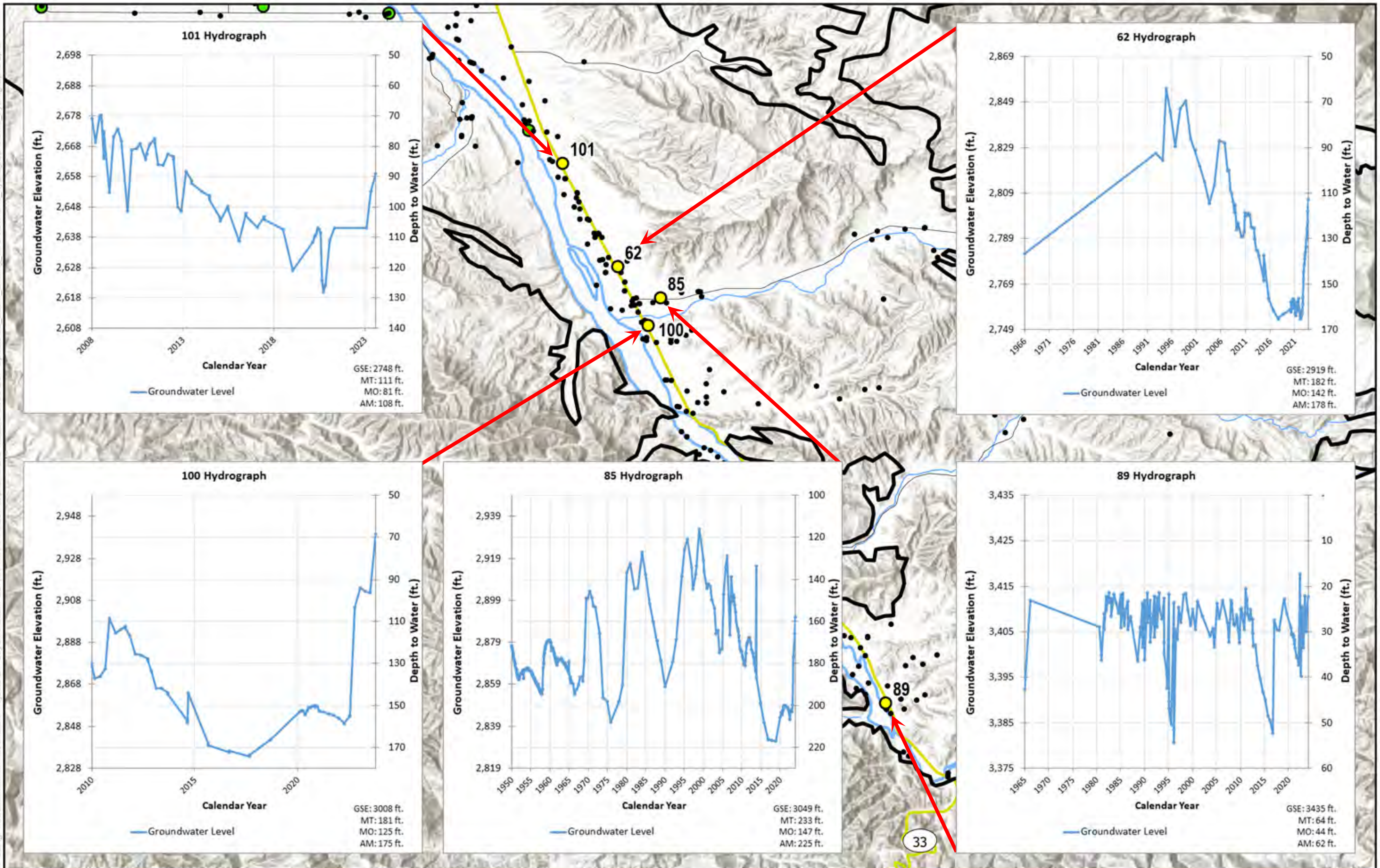

Figure 2-48: Monitoring Well Network Hydrographs

Cuyama Valley Groundwater Basin

Legend

- Well with Hydrograph
- Well without Hydrograph
- Well not Monitored
- Highway
- Local Road
- Creek
- Cuyama River
- Cuyama Basin

N

0 0.5 1 2 Miles

Map Created: August 2024

Woodard & Curran

Cuyama Basin Groundwater Sustainability Agency

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data sources: CA DWR, Esri, USGS**

Vertical Gradients

A vertical hydraulic gradient represents the movement of groundwater perpendicular to the ground surface and may be up or down. A vertical gradient is calculated by comparing the elevations of groundwater in wells with different screen depths. If groundwater elevations in the shallower well are higher than in the deeper well, the gradient is downward, corresponding to downward groundwater flow. If groundwater elevations in the shallower well are lower than in the deeper well, the gradient is upward, corresponding to upward groundwater flow. If groundwater elevations are similar, the vertical gradient is insignificant. An understanding of the Basin's vertical gradients is required by Section 354.16(a) of the SGMA regulations, and this understanding further describes how groundwater moves in the Basin.

There are 11 multiple completion nested wells in the Basin. At these locations, individual wells are constructed in the same borehole with different screen intervals. The depth between the screen intervals is sealed to prevent groundwater flow from one screen to another in the borehole. The USGS constructed nested monitoring wells at three locations in Cuyama Valley known as CVFR, CVBR, and CVKR. These nests are named after their location on Foothill Road, Bell Road, and Kirschenmann Road, respectively. Each location consists of four individual nested wells.

Three additional multi-completion nested well locations were constructed by DWR under its Technical Support Services (TSS) program. Each location consists of three individual nested wells with Opti numbers 900-902 at TSS #1, 903-905 at TSS #3, and 906-908 at TSS #2 (numbering according to DWR). The CBGSA received additional grant funding through the SGMA implementation grant and has installed five multi-completion wells (Opti wells 912 to 920). However, since these wells are newly constructed and do not yet have a record of groundwater level measurements, discussions of vertical gradients for these wells are not included. Figure 2-49 shows the locations of these 11 multi-competition wells. Opti well 914 was drilled in a location that was identified as a potential multi-completion well, but due to the geology encountered during drilling, only one well was constructed. Multi-completion nested wells at the MW-D location have not been constructed yet but will be completed prior to the GSP 2025 submittal.

Figure 2-50 shows the combined hydrograph for the multi-completion well CVFR, which was constructed by the USGS.[8] The first measurements were recorded on October 27, 2009. CVFR is comprised of four wells with different screen depths as follows:

- Opti well 91 (CVFR-1) is the deepest completion with a screened interval from 960 to 980 feet bgs.
- Opti well 316 (CVFR-2) is the second deepest completion with a screened interval from 810 to 830 feet bgs.

[8] All three multiple-completion wells were constructed by the USGS as part of the Cuyama Valley Water Availability Study in cooperation with SBCWA

- Opti well 317 (CVFR-3) is the third deepest completion with a screened interval from 680 to 700 feet bgs.
- Opti well 318 CVFR-4 is the shallowest completion with a screened interval from 590 to 610 feet bgs. Water level measurements for this well stopped in 2014 when the depth to water dropped below 610 feet bgs (i.e., the well is dry).

The hydrograph of the four wells shows similar groundwater elevations, with a difference of only three feet on the last recorded measurement date of April 26, 2024. Therefore, the vertical gradient is very low at this location. Figure 2-51 is scaled to show more detail for the years 2020-2024 to differentiate variations in recent water levels. The hydrograph shows consistent water levels for the wells prior to mid-2022. Afterwards, the third deepest well, 316, had the lowest water levels by several feet. Presumably, measurement errors in late 2020 at well 91 and mid-2023 at well 317 cause the anonymous water levels shown on the hydrograph.

Figure 2-52 shows the combined hydrograph for the multi-completion well CVBR. The first water level measurements were recorded on September 29, 2009. CVBR is comprised of four wells with different screen depths as follows:

- Opti well 99 (CVBR-1) is the deepest completion with a screened interval from 830 to 850 feet bgs.
- Opti well 322 (CVBR-2) is the second deepest completion with a screened interval from 730 to 750 feet bgs.
- Opti well 324 (CVBR-3) is the third deepest completion with a screened interval from 540 to 560 feet bgs.
- Opti well 325 (CVBR-4) is the shallowest completion with a screened interval from 360 to 380 feet bgs.

Historical measurements in the four wells indicate that water levels are typically lowest in the deepest well and highest in the shallowest well, indicating a downward vertical gradient. However, beginning in 2023, water levels in the deepest and shallowest wells have been about the same, with a difference of only about two feet. These recent measurements indicate a very low vertical gradient. Figure 2-53 is scaled to show more detail for the years 2020-2024 to differentiate variations in recent water levels. The hydrograph shows consistent water levels at wells at the beginning of each year. At mid-year, the deepest well, 325, had the shallowest water level and the third deepest well, 322, had the deepest water level.

Figure 2-54 shows the combined hydrograph for the multi-completion well CVKR. The first measurements were recorded on March 3, 2009. CVKR is comprised of four wells with different screen depths as follows:

- Opti well 77 (CVKR-1) is the deepest completion with a screened interval from 960 to 980 feet bgs.

- Opti well 420 (CVKR-2) is the second deepest completion with a screened interval from 760 to 780 feet bgs.
- Opti 421 (CVKR-3) is the third deepest completion with a screened interval from 600 to 620 feet bgs.
- Opti 422 (CVKR-4) is the shallowest completion with a screened interval from 440 to 460 feet bgs.

Similar to CVBR, the hydrograph of these four wells indicates that water levels are typically lowest in the deepest well and highest in the shallowest well, indicating a downward vertical gradient. The hydrograph also shows an apparently erroneous measurement in the shallowest well in mid-2023. Figure 2-55 is scaled to show more detail for the years 2020-2024 to differentiate variations in recent water levels. The hydrograph shows consistent water levels at the wells during this period except for presumed measurement error in mid-2022 at well 420.

Figure 2-56 shows the combined hydrograph for the multi-completion wells at TSS #1, Opti numbers 900-902. These three wells have different screen depths as follows:

- Opti well 902 is the deepest completion with a screened interval from 325 to 365 feet bgs.
- Opti well 901 is the second deepest completion with a screened internal from 165 to 205 feet bgs
- Opti well 900 is the shallowest completion with a screened interval from 50 to 60 feet bgs.

The combined hydrograph shows that the deepest well typically has the highest water level, indicating a small upward vertical gradient. However, the latest measurement, recorded on April 24, 2024, shows only a two-foot variation between the three wells.

Figure 2-57 shows the combined hydrograph for the multi-completion wells at TSS #3, Opti numbers 903-905. These three wells have different screen depths as follows:

- Opti well 905 is the deepest completion with a screened interval from 540 to 570 feet bgs.
- Opti well 904 has the second deepest completion with a screened interval from 360 to 400 feet bgs.
- Opti well 903 has the shallowest completion with a screened interval from 265-305 feet bgs.

Similar to TSS #1, the hydrograph shows the deepest well typically has the highest water level, indicating a small upward vertical gradient. This vertical gradient has remained consistent throughout the monitoring period from July 2022 to the latest measurement recorded on April 24, 2024.

Figure 2-58 shows the combined hydrograph for the multi-completion wells at TSS #2, Opti numbers 906-908. These three wells have different screen depths as follows:

- Opti well 908 is the deepest completion with a screened interval from 650-660 feet bgs.

- Opti well 907 is the second deepest completion with a screened interval from 515-525 feet bgs.
- Opti well 906 is the shallowest completion with a screened interval from 130-150 feet bgs.

The combined hydrographs for these wells show an upward vertical gradient with the highest water levels in the deepest well followed by the intermediate depth well, and the shallowest well, respectively. The differences in groundwater elevation indicate the upward vertical gradient between the intermediate and deepest wells is higher than the vertical gradient between the shallowest and intermediate wells. These water level differences are generally consistent throughout the monitoring period.

Table 2-2 shows the screen depths for multi-completion wells recently constructed by the CBGSA under the SGMA grant and initial groundwater levels.

Table 2-2: CBGSA Nested Wells

Nested Well	Deep Completion (feet bgs)	Shallow Completion (feet bgs)	Water Level Measurements (feet btoc)
Opti well 912-913 (MW-F)			
Opti 913	350-370		39.29 (6/5/2024)
Opti 912		180-200	8.05 (6/5/2024)
Opti 915-916 (MW-H)			
Opti 916	880- 900		507.82 (5/15/2024)
Opti 915		660-680	574.67 (5/15/2024)
Opti 917-918 (MW-E)			
Opti 918	720-740		386 (7/1/2024)
Opti 917		610- 630	381 (7/1/2024)
Opti Well 919-920 (MW-G)			
Opti 920	420-440		370.65 (8/2/2024)
Opti 919		280-300	196.10 (8/2/2024)
Opti 914 (MW-C)			
Opti 914	500-520 (Only one completion due to the geology encountered during drilling)		481.15 (4/11/2024)
Opti 921 (MW-D)			
Opti 921	820-840 (Only one completion due to the geology encountered during drilling)		Not available at the time of GSP Development

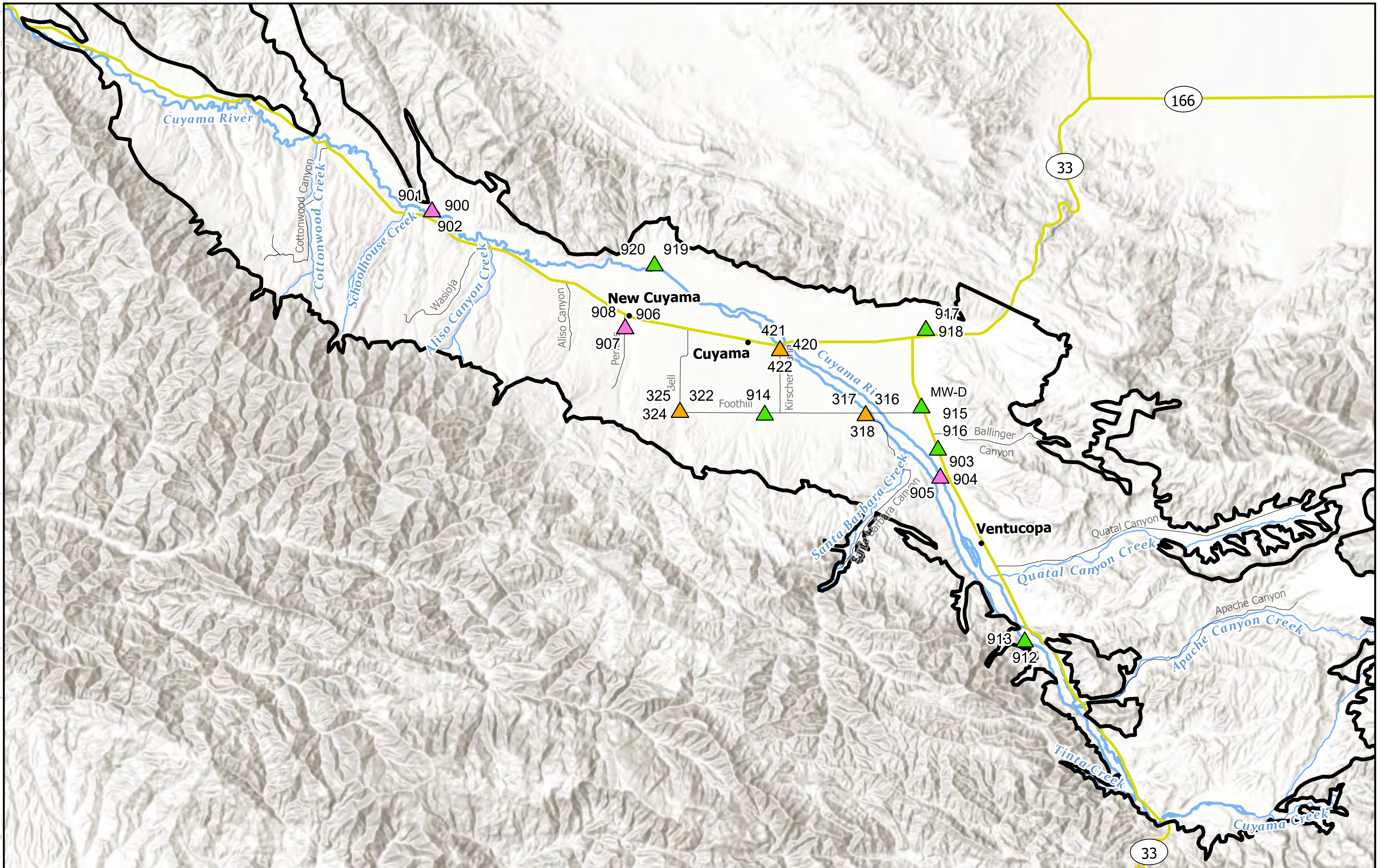

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Figure 2-49: Multi Completion And Nested Wells

Cuyama Valley Groundwater Basin

Legend

- CBGSA
- TSS
- USGS
- Highway
- Local Road
- Town
- Creek
- Cuyama River
- Cuyama Basin

N

0 1.25 2.5 5 Miles

Map Created: July 2024

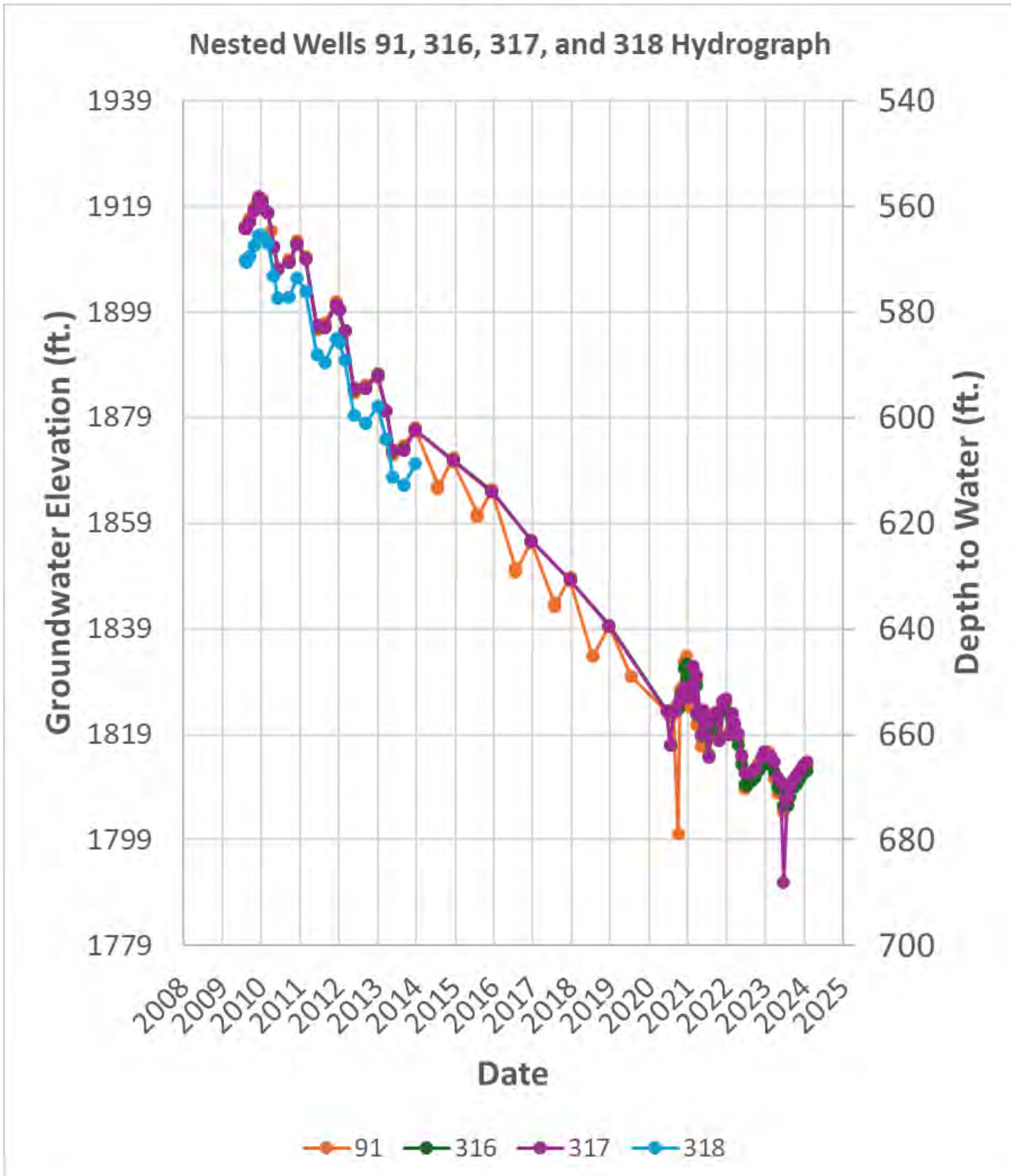

Figure 2-50: Hydrographs of Opti well 91, 316, 317, 318 (USGS Well CVFR)

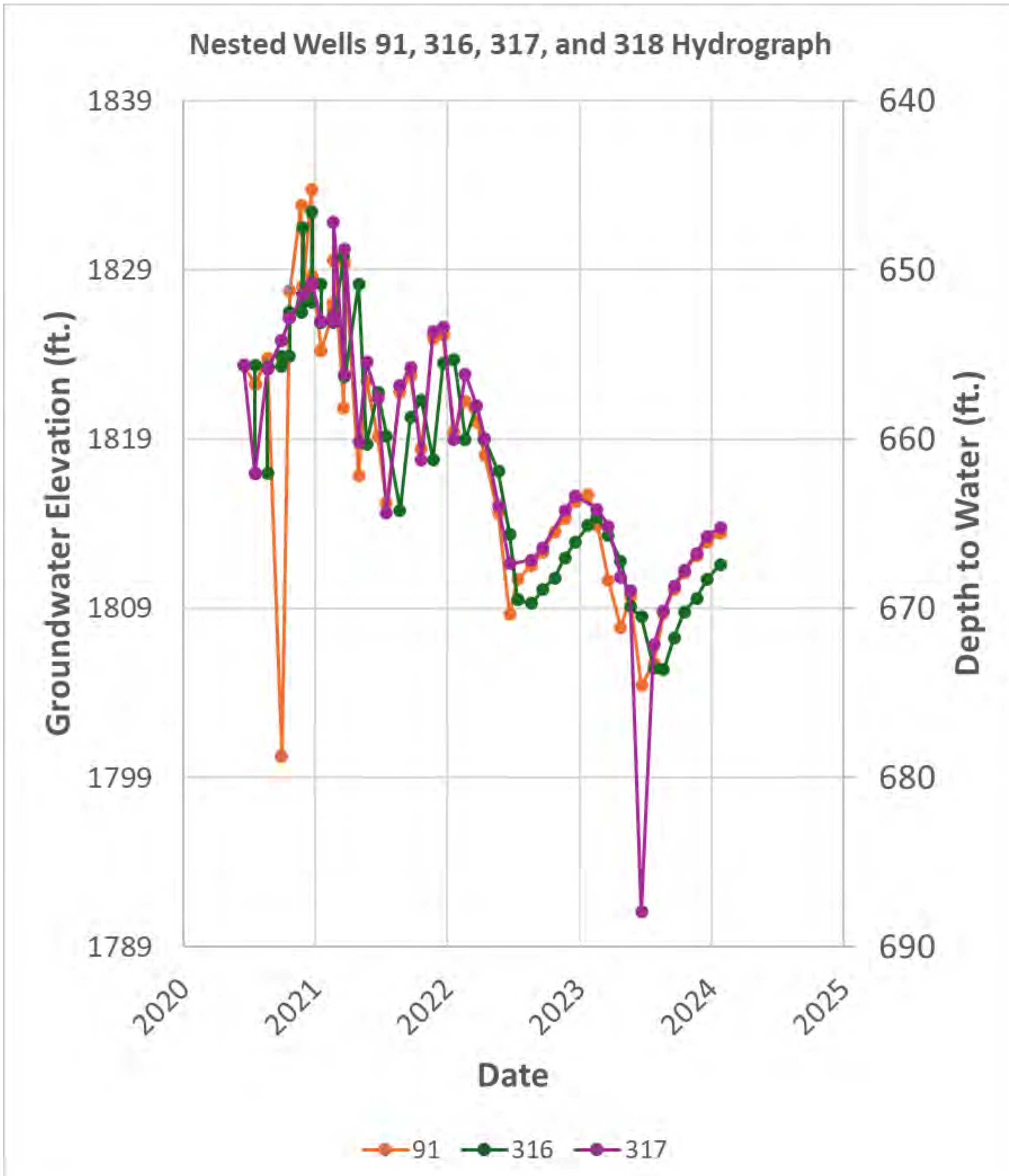

Figure 2-51: Hydrographs of Opti well 91, 316, 317, and 318 (USGS Well CVFR) 2020 - 2024 Only

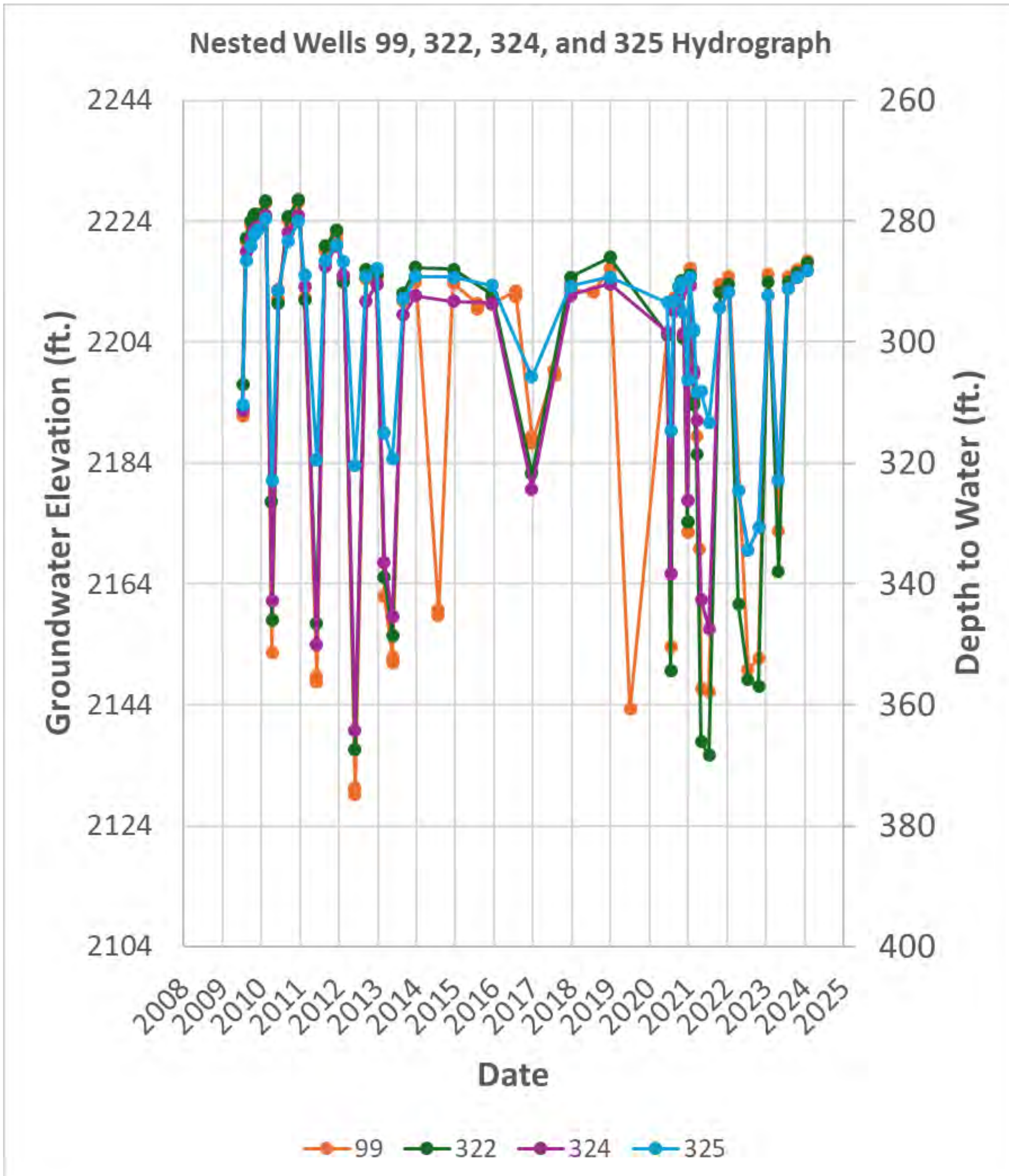

Figure 2-52: Hydrographs of Opti well 99, 322, 325, and 325 (USGS Well CVBR)

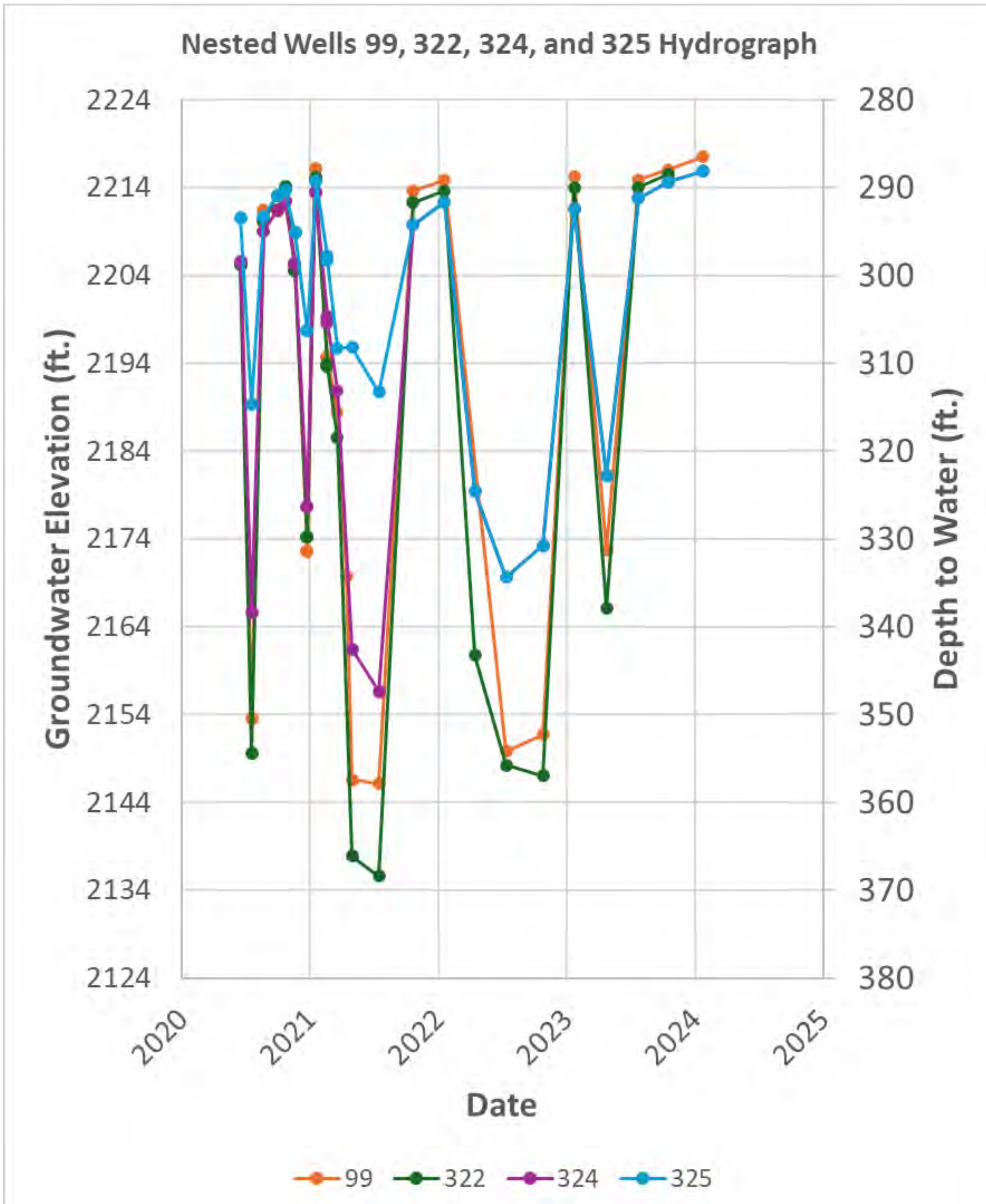

Figure 2-53: Hydrographs of Opti well 99, 322, 325, and 325 (USGS Well CVBR) 2020 - 2024 Only

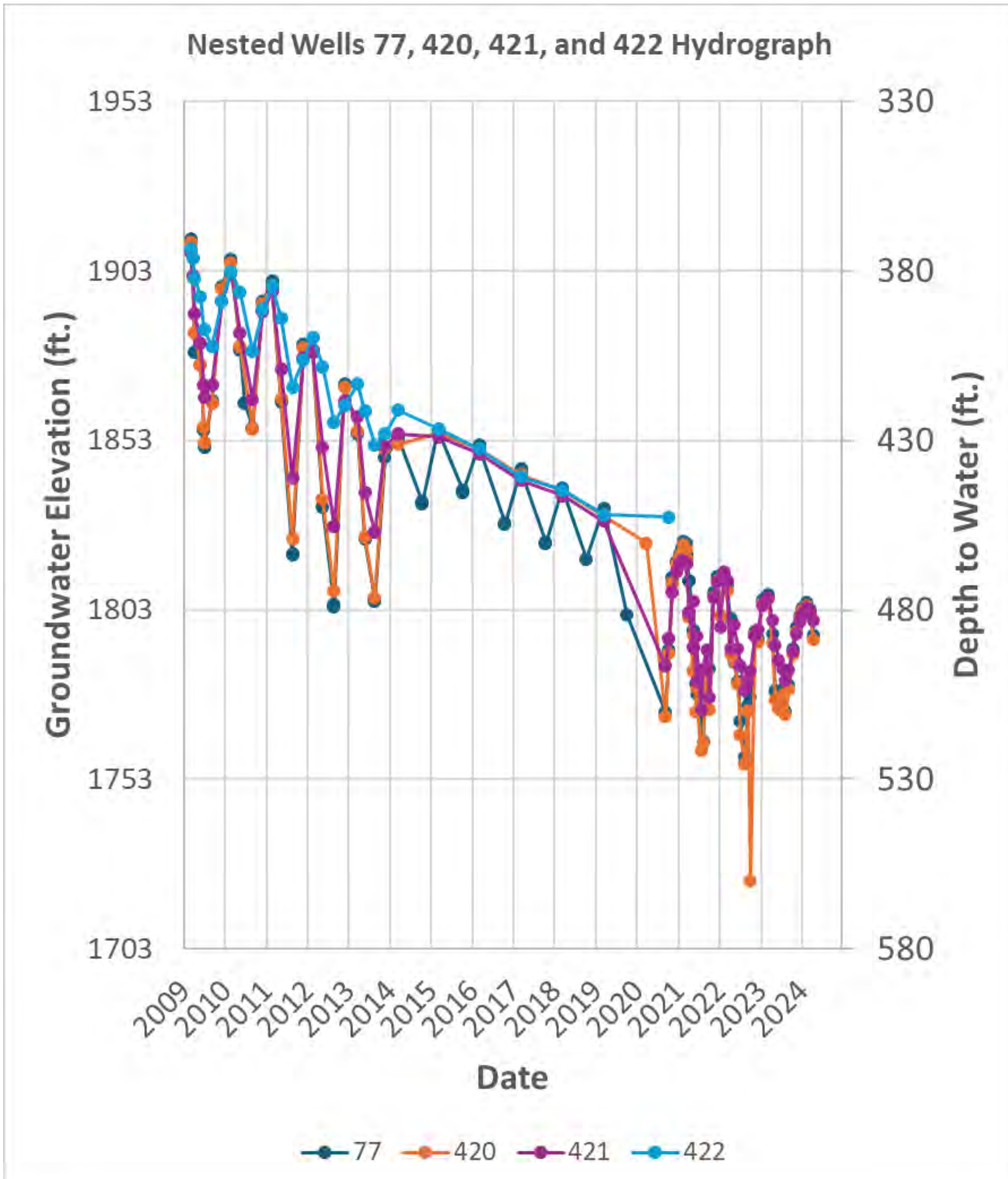

Figure 2-54: Hydrographs of Opti well 77, 420,421, and 422 (USGS well CVKR)

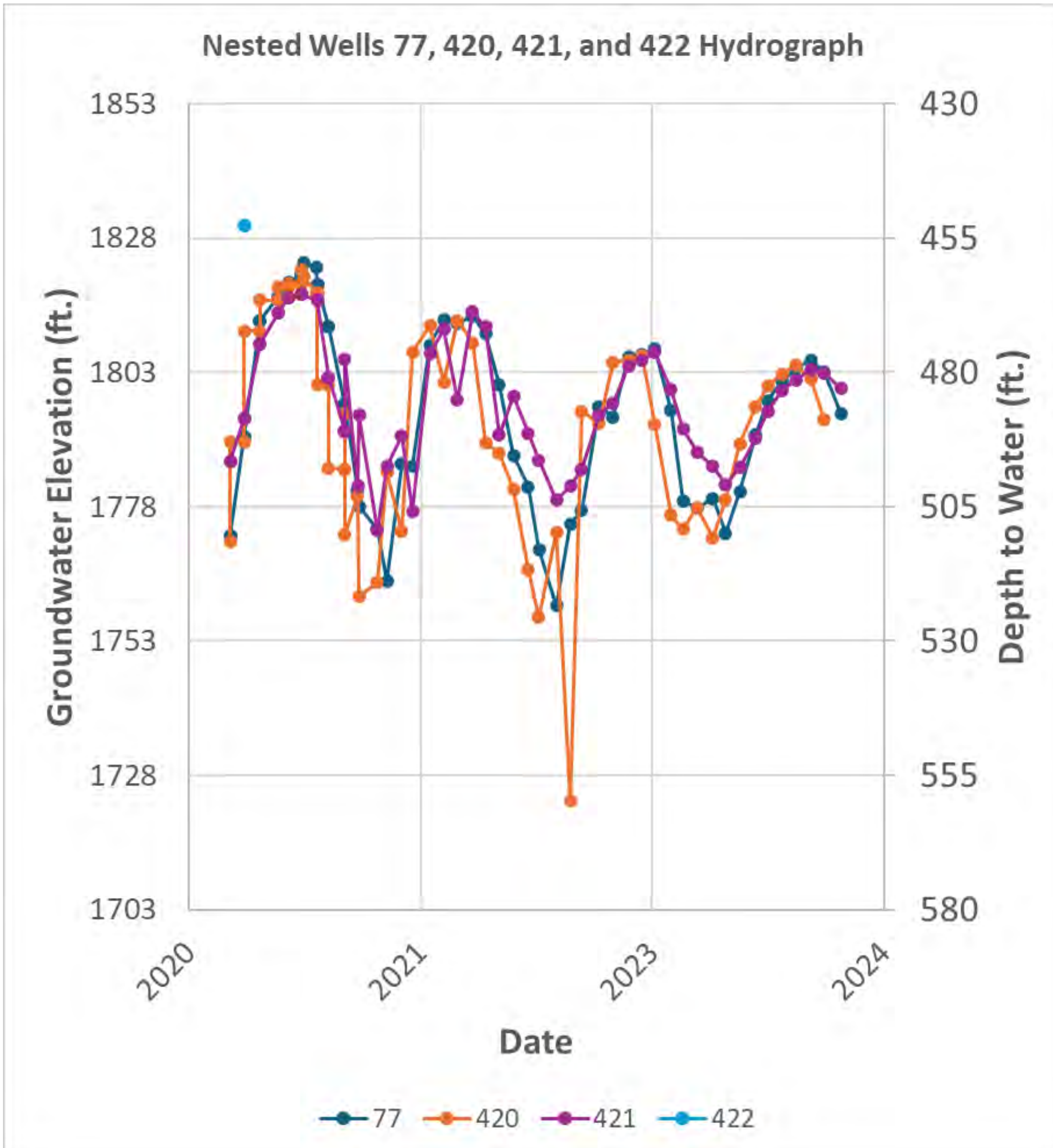

Figure 2-55: Hydrographs of Opti well 77, 420,421, and 422 (USGS well CVKR) 2020-2024 Only

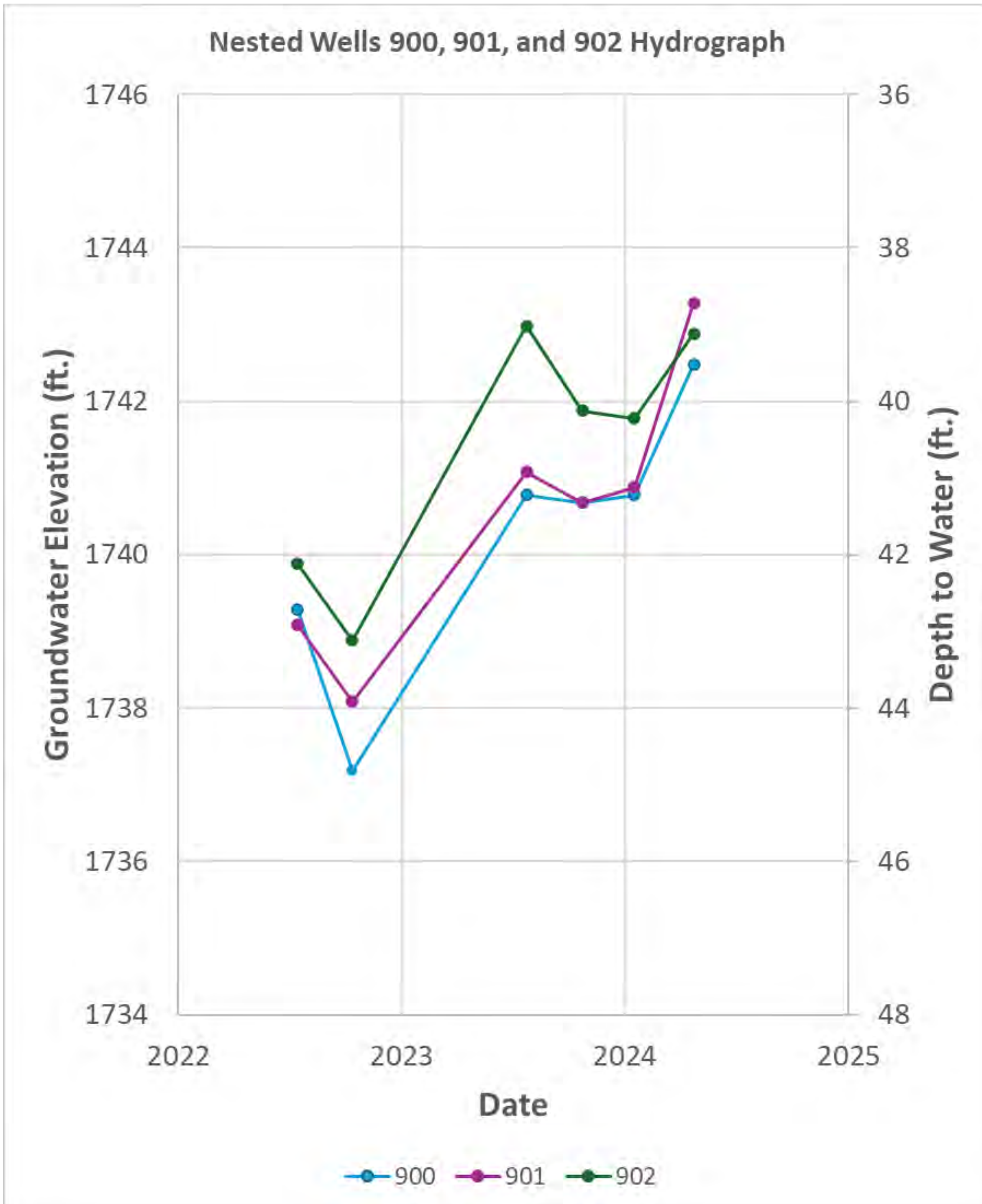

Figure 2-56: Hydrographs Opti well 900, 901 and 902 (TSS Well #1)

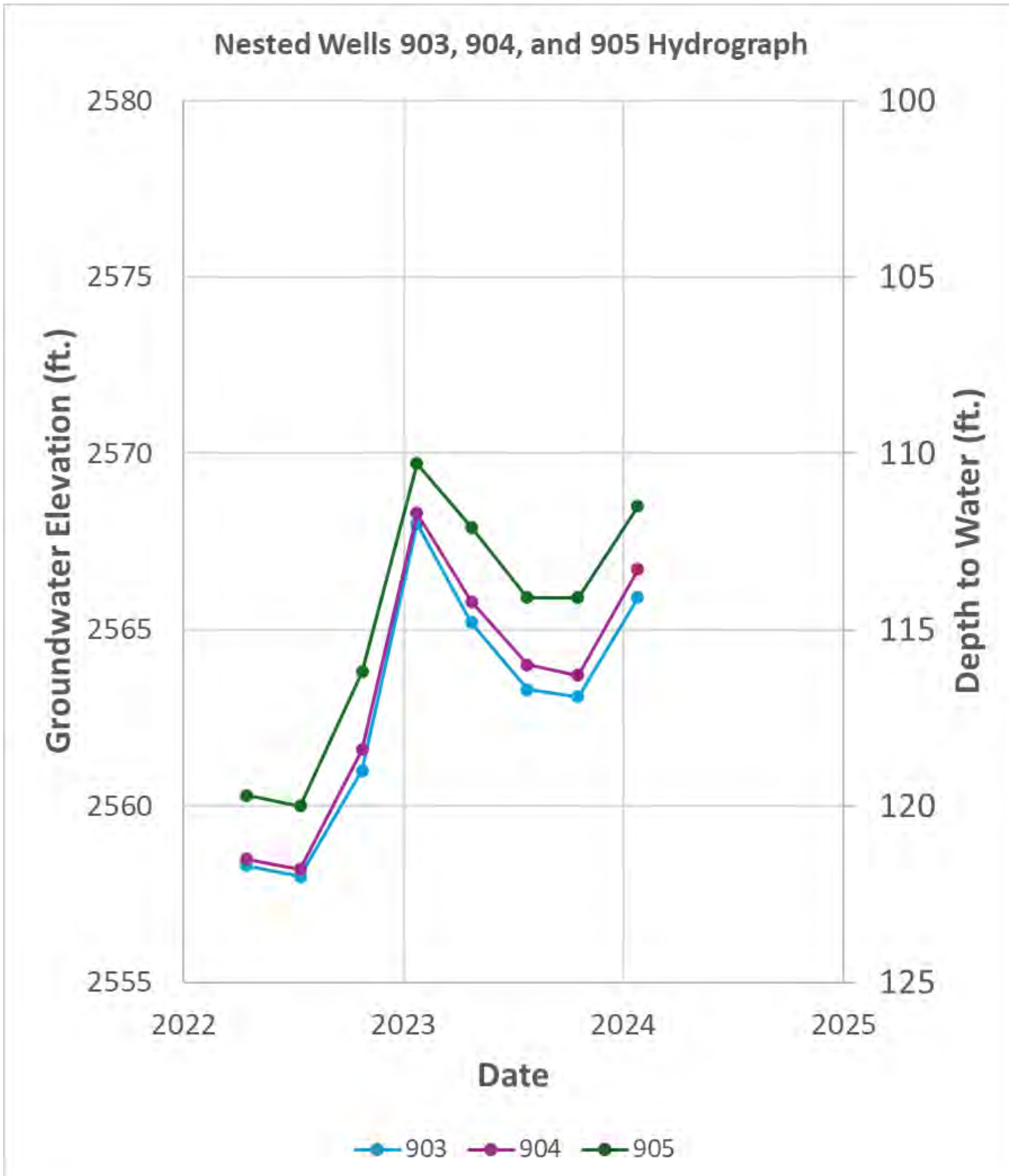

Figure 2-57: **Hydrograph Opti wells 903, 904, and 905 (TSS Well #3)**

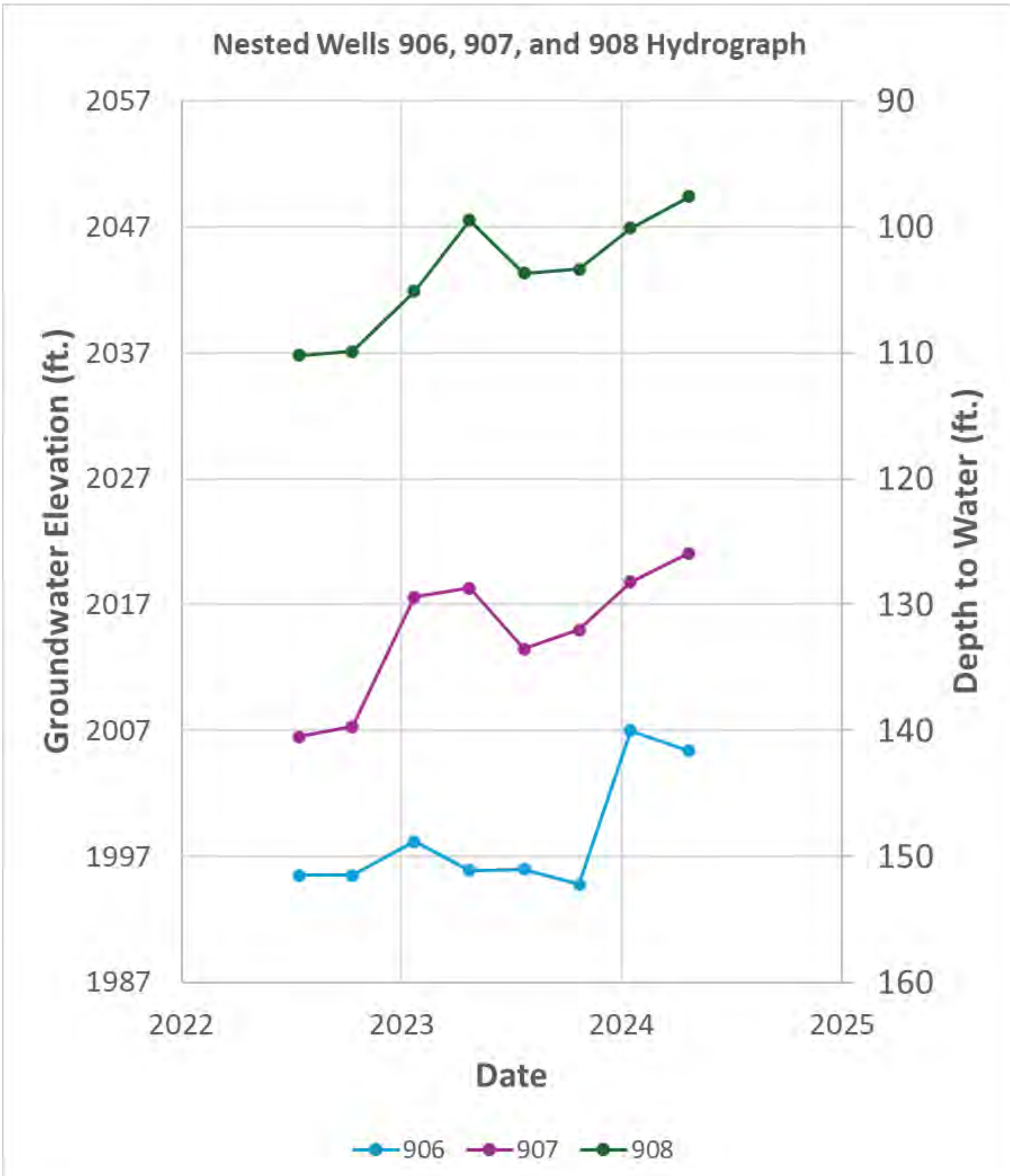

Figure 2-58: Hydrograph for Opti wells 906, 907, and 908 (TSS Well #2).

Groundwater Contours

Analysts prepared groundwater contour maps to improve understanding of recent groundwater trends in the Basin. Analysts used the data collected and described in Sections 2.2.3 and 2.2.4 to develop these maps. A contour map shows changes in groundwater elevations by interpolating groundwater elevations between monitoring sites. The elevations are shown on the map with the use of a contour line, which indicates that at all locations that line is drawn, the line represents groundwater at the elevation indicated. There are two versions of contour maps used in this section: one that shows the elevation of groundwater above mean sea level, which is useful because it can be used to identify the horizontal gradients and groundwater flow directions, and one that shows contours of depth to water, the distance from the ground surface to groundwater, which is useful because it can identify areas of shallow or deep groundwater.

Methodology

To complete the groundwater elevation maps in the 2020 GSP an inverse distance weighting (IDW) interpolation was conducted and then manually adjusted to meet expected conditions. The new methodology interpolates groundwater elevation using a specialized algorithm to create a 'hydrologically connected' potentiometric surface (ArcGIS Topo to Raster tool). This best represents the groundwater elevations as it helps to reduce depressions and variance in areas with limited data. The resulting interpolation and contours were then cropped within the bounding area of available data using a concave hull. Some minor manual adjustments were applied to the Basin boundary to reduce or remove areas with sparse data. Contours greater than one mile away from any well were labeled as 'approximate.' Conceptual flowlines were added based on the interpolated groundwater elevation contours to represent generalized groundwater flow directions.

To visualize the depth to groundwater in the Basin and areas with localized drawdown, an IDW was used for interpolation of depth to water measurements. Resulting rasters and contours were then cropped using the same procedure described above.

The new methodology is an improvement over the original methodology because it does not rely on manual contouring. Data can be processed following a set protocol, producing consistent results.

Analysts prepared groundwater contour maps for both groundwater elevation and depth to water for the following periods:

- Spring 2024
- Fall 2022
- Fall 2020
- Spring 2018
- Fall 2017
- Spring 2017

- Spring 2015

These years were selected for display because they are representative of current conditions and seasonal patterns. The contour maps are described below.

Each contour map follows the same general format using a 100-foot contour interval, with contour elevations indicated in white numeric labels, and measurements at individual monitoring points indicated in black numeric labels. Areas where the contours are dashed and not colored between are inferred because the available data are spaced far apart and are included for reference only. The groundwater contours were also based on certain assumptions in order to accumulate enough data points to generate useful contour maps. Assumptions are as follows:

- Measurements from wells of different depths are representative of conditions at that location and there are no vertical gradients. Due to the limited spatial amount of monitoring points, data from wells of a wide variety of depths were used to generate the contours.
- Measurements from dates that may span up to three months are representative of conditions during the spring or fall season, and conditions have not changed substantially from the time of the earliest measurement used to the latest within that season.

These assumptions allow for the generation of contours that are useful at the planning level for understanding groundwater levels across the Basin, and to identify general horizontal gradients and regional groundwater level trends. The contour maps are not indicative of exact values across the Basin because the interpolated groundwater contours reflect approximate conditions between measurement points. The contours do not account for topography or bedrock outcrops within the Basin. Therefore, a well on a ridge may have a greater depth to groundwater than a well in a canyon, and the contour map will not reflect that level of detail.

Figure 2-59 shows groundwater elevation contours for spring of 2024. In the southeastern portion of the Basin near the Ozena fire station, the groundwater gradient appears to indicate flow that follows the Cuyama River. The contour map shows a steep gradient across the SBCF and groundwater flow to an area of lower groundwater elevation northeast of the town of Cuyama. From the town of New Cuyama to the west, the groundwater elevation contours reflect a gradient and flow to the north-northeast, from areas with higher land surface elevations towards areas with lower land surface elevations and towards the Cuyama River.

Figure 2-60 shows depth to groundwater contours for spring of 2024. South of the SBCF, depth to groundwater is about 100-200 feet bgs. North of the SBCF, depth to groundwater declines rapidly to over 600 feet bgs. Depth to groundwater decreases (i.e., is closer to ground surface) to the west towards New Cuyama, where the depth to groundwater is around 200-300 feet bgs. West of Bitter Creek, groundwater is shallower than 200 feet bgs in many locations and shallower than 100 feet bgs at some well locations.

Figure 2-61 shows groundwater elevation contours for fall of 2022. The contour map shows a steep gradient across the SBCF and groundwater flow to an area of lower groundwater elevation northeast of the town of Cuyama. From the town of New Cuyama to the west, the groundwater gradient reflects generalized flow to the north-northeast, from topographically higher areas towards areas with lower topography and the Cuyama River.

Figure 2-62 shows depth to groundwater contours for fall of 2022. North of the SBCF, depth to groundwater declines rapidly to over 600 feet bgs. Depth to groundwater decreases (i.e., is closer to ground surface) to the west towards New Cuyama, where groundwater is around 300 feet bgs. West of Bitter Creek, groundwater is shallower than 200 feet bgs in many locations and shallower than 100 feet bgs in some well locations.

Figure 2-63 shows groundwater elevation contours for fall of 2020. Much like the maps for 2024 and 2022, the contour map shows a steep gradient across the SBCF and groundwater flow to an area of lower groundwater elevation northeast of the town of Cuyama. From the town of New Cuyama to the west, the groundwater elevation contours reflect a gradient and flow to the north-northeast, from areas with higher land surface elevations towards areas with lower land surface elevations and towards the Cuyama River.

Figure 2-64 shows depth to groundwater contours for fall of 2020. North of the SBCF, depth to groundwater declines rapidly to over 600 feet bgs. Depth to groundwater decreases (i.e., is closer to ground surface) to the west towards New Cuyama, where groundwater is around 300 feet bgs. West of Bitter Creek, groundwater is shallower than 100 feet bgs in most well locations.

Figure 2-65 shows groundwater elevation contours for spring of 2018.In the southeastern portion of the Basin near Ventucopa, groundwater flows to the northwest. The gradient increases in the vicinity of the SBCF and groundwater flows to an area of lower groundwater elevation southeast of the town of Cuyama. Lower groundwater elevations in this area are also associated with a flow gradient to the southeast from the town of Cuyama. From the town of New Cuyama to the west, the groundwater elevation contours reflect a gradient and flow to the northeast, from areas with higher land surface elevations towards areas with lower land surface elevations and towards the Cuyama River.

Figure 2-66 shows depth to groundwater contours for spring of 2018. Just south of the SBCF, depth to groundwater is about 100 feet bgs. North of the SBCF, depth to groundwater declines rapidly to over 600 feet bgs. Depth to groundwater decreases (i.e., is closer to ground surface) to the west towards New Cuyama, where groundwater is around 200 feet bgs. West of Bitter Creek, groundwater is shallower than 100 feet bgs in most locations.

Figure 2-67 shows groundwater elevation contours for fall of 2017. The contour map shows a steep gradient across the SBCF and groundwater flow to an area of lower groundwater elevations northeast of the town of Cuyama. From the town of New Cuyama to the west, the groundwater elevation contours reflect a gradient and flow to the northeast, from areas with higher land surface elevations towards areas with lower land surface elevations and towards the Cuyama River.

Figure 2-68 shows depth to water contours for fall of 2017. There is a steep gradient near the SBCF, and depth to groundwater is below 600 feet bgs immediately northwest of the SBCF. The central portion of the Basin generally has a depth to water between 400 and 500 feet bgs, with depth to groundwater decreasing (i.e., shallower) to the west of New Cuyama. West of Bitter Creek, groundwater is generally shallower than 100 feet below bgs.

Figure 2-69 shows groundwater elevation contours for spring of 2017. The contour map shows a steep gradient across the SBCF and groundwater flow to an area of lower groundwater elevation northeast of the town of Cuyama. From the town of New Cuyama to the west, the groundwater elevation contours reflect a gradient and flow to the northeast, from areas with higher land surface elevations towards areas with lower land surface elevations and towards the Cuyama River.

Figure 2-70 shows depth to water contours for spring of 2017. Depth to groundwater near Ventucopa is between 150 and 200 feet bgs. There is a steep gradient near the SBCF, and depth to groundwater is below 600 feet bgs immediately northwest of the SBCF. The central portion of the Basin generally has a depth to water between 350 and 500 feet bgs, with depth to groundwater decreasing to the west of New Cuyama. West of Bitter Creek, groundwater is generally shallower than 100 feet below bgs.

Figure 2-71 shows groundwater elevation contours for spring of 2015. Data for this year is more limited but the groundwater gradient indicates flow that follows the Cuyama River and from areas with higher land surface elevations towards areas with lower land surface elevations towards the central portion of the Basin.

Figure 2-72 shows depth to water contours for spring of 2015. Data indicates a steep gradient near the SBCF, and depth to groundwater is below 600 feet bgs immediately northwest of the SBCF. The central portion of the Basin generally has a depth to water between 300 and 600+ feet bgs, with groundwater levels rising to the west of New Cuyama. These depths are in general less severe than those shown for the spring of 2017, reflecting deepening depth to groundwater conditions in the central portion of the Basin. Interpretation from New Cuyama to monitoring points in the northwest is hampered by a limited set of data points.

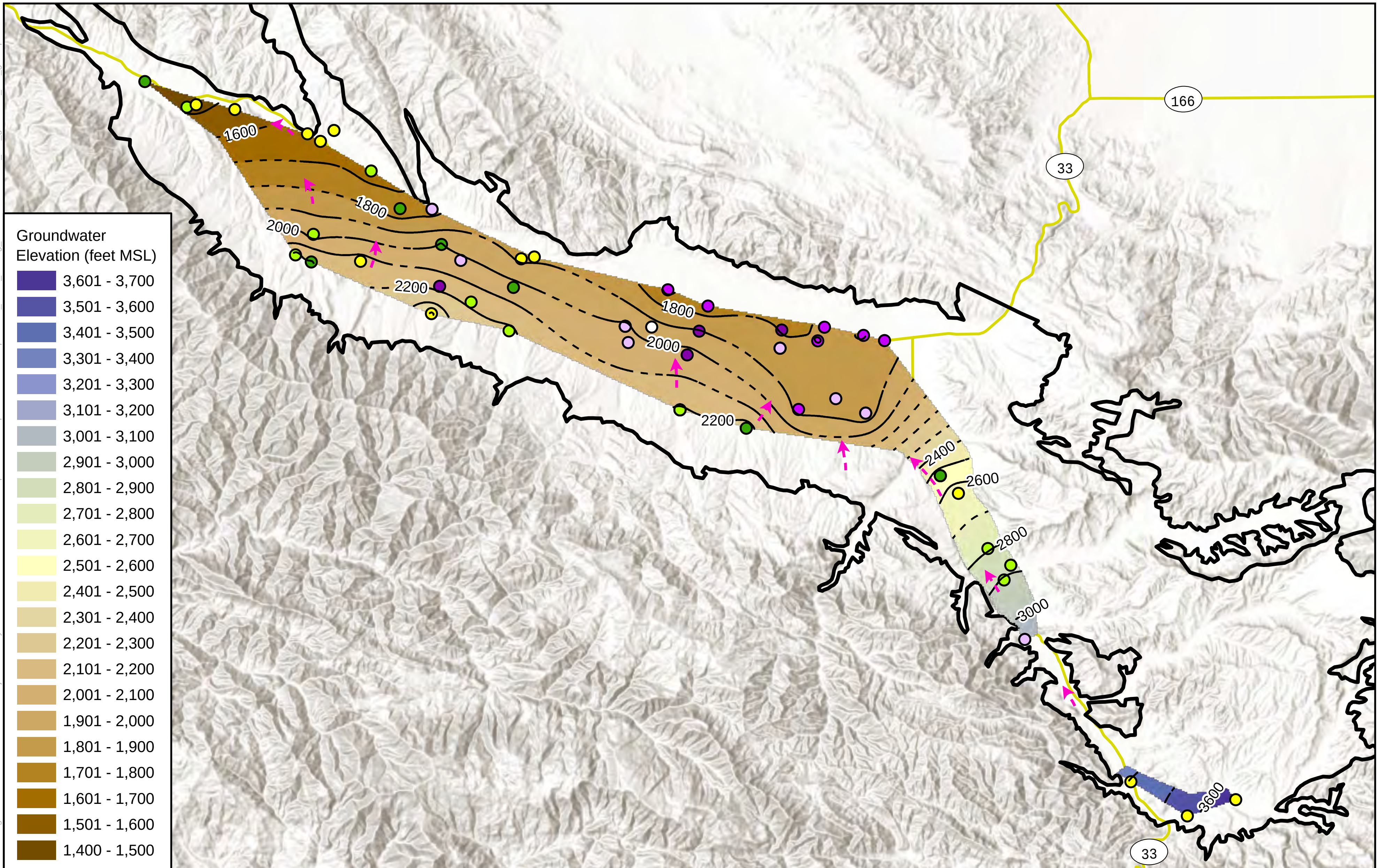

Figure 2-**59**: Spring 2024 Groundwater Elevation

Cuyama Valley Groundwater Basin

Legend

- Groundwater Elevation Contour
- Approximate Contour
- Conceptual Flowline
- Highway
- Cuyama Basin

Well Depth (feet)

- Unknown
- 0 - 200
- 201 - 400
- 401 - 600
- 601 - 800
- 801 - 1000
- 1001 - 1200

N

0 1.25 2.5 5 Miles

Map Created: July 2024

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data sources: CA DWR, Esri, USGS**

Figure Exported: 7/18/2024 By: ceggleton Using: \\woodardcurran.net\shared\Projects\CA Cuyama Basin GSA\0011078.01 GSP\wip\Z. GIS\2. Maps\3. 2025 GSP Update\02_Basin_Setting_Overview\GSP2025_dtw_gwe\2025_dtw_gwe.aprx

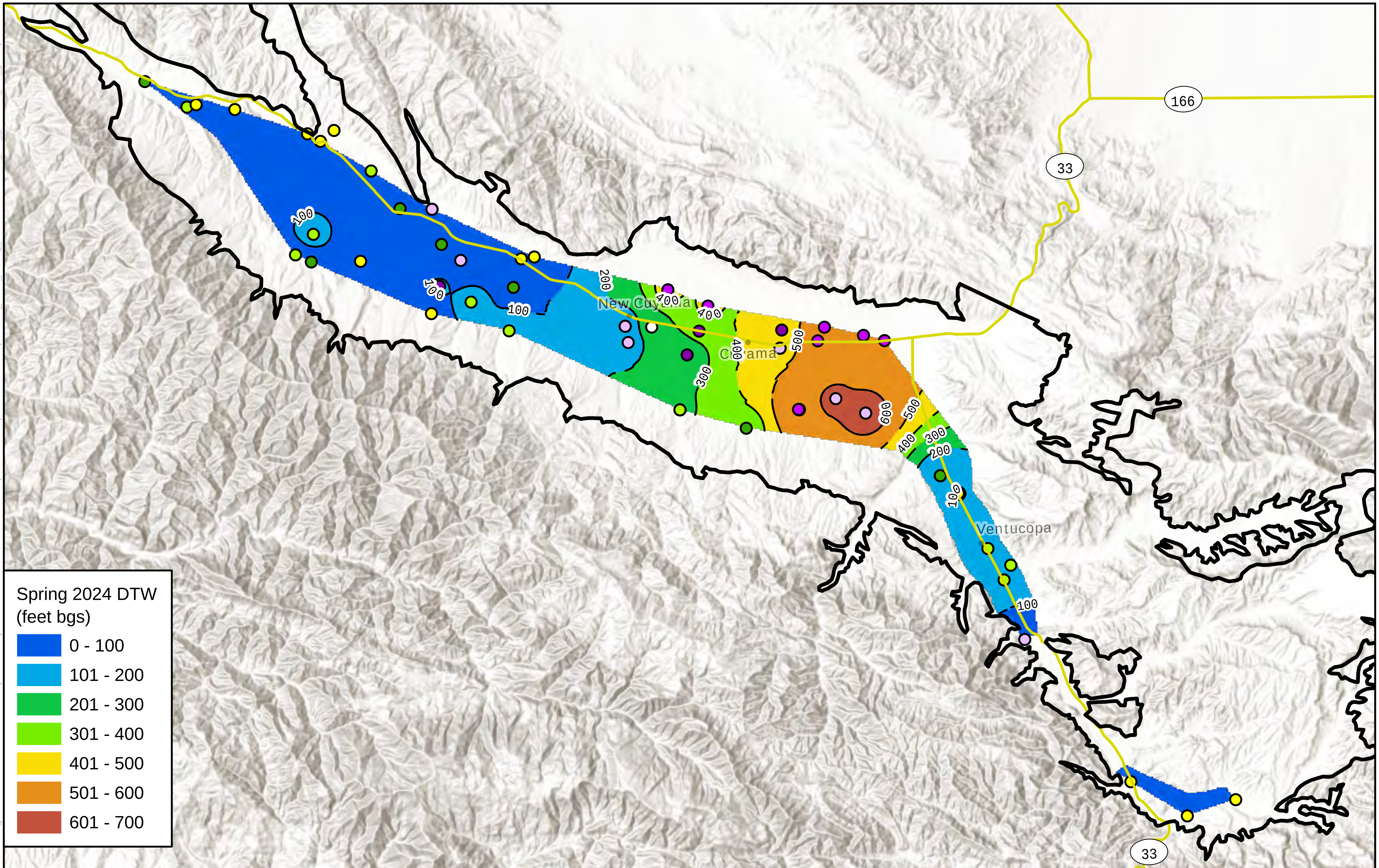

Figure 2-60: Spring 2024 Depth to Water

Cuyama Valley Groundwater Basin

Map Created: July 2024

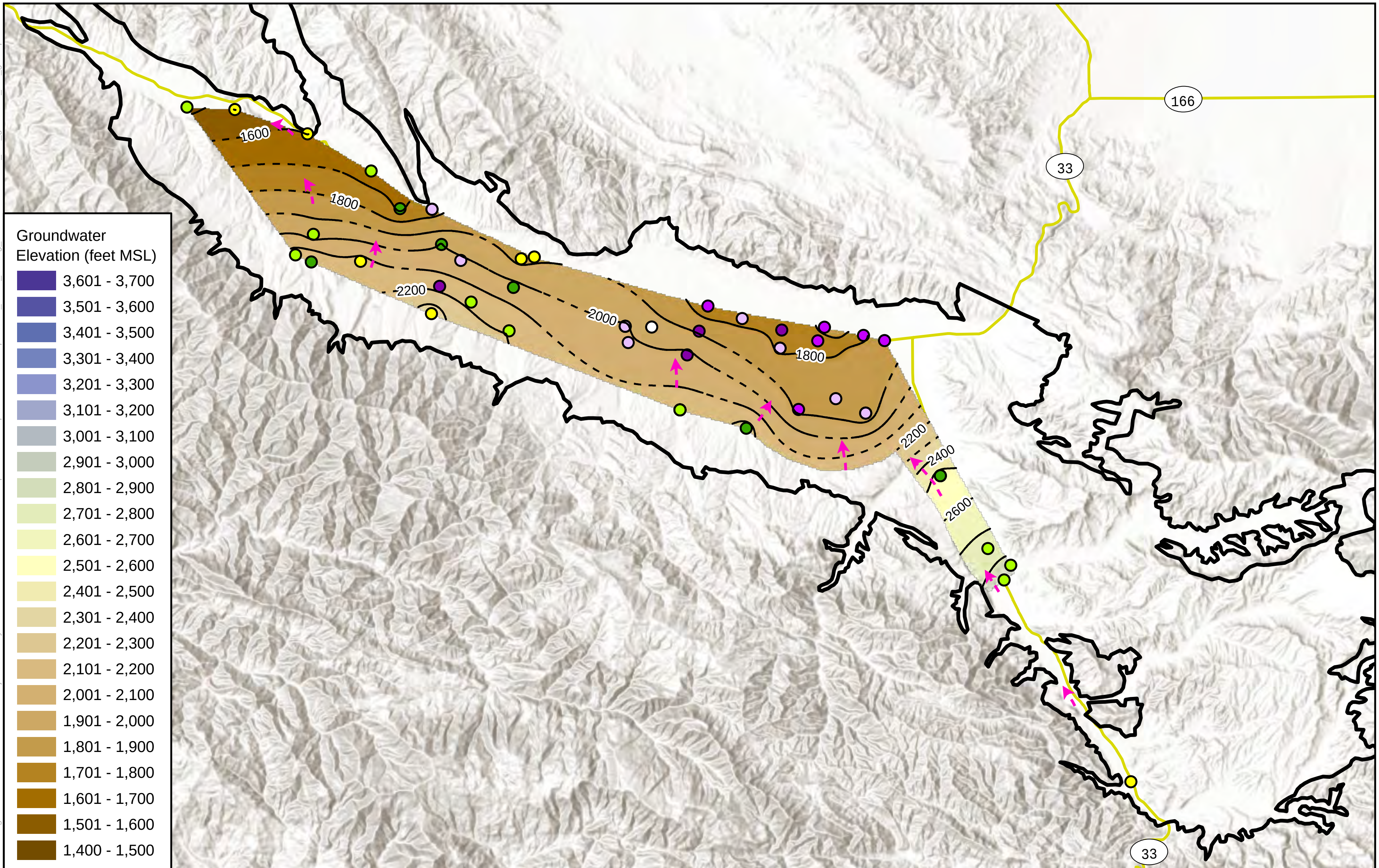

Figure 2-**61**: Fall 2022 Groundwater Elevation

Cuyama Valley Groundwater Basin

Legend

- Groundwater Elevation Contour
- Approximate Contour
- Conceptual Flowline
- Highway
- Cuyama Basin

Well Depth (feet)

- Unknown
- 0 - 200
- 201 - 400
- 401 - 600
- 601 - 800
- 801 - 1000
- 1001 - 1200

N

0 1.25 2.5 5 Miles

Map Created: July 2024

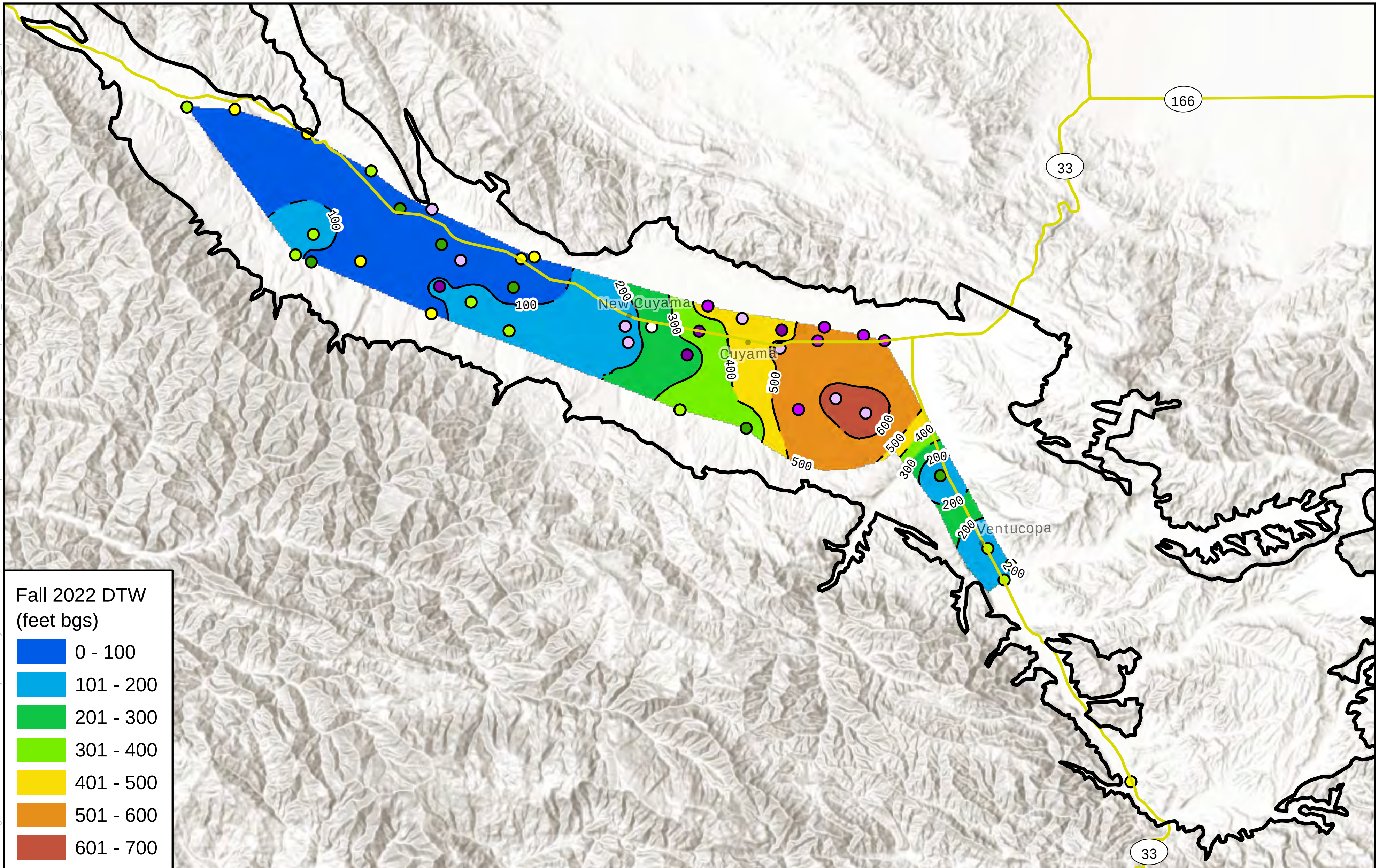

Figure 2-**62**: Fall 2022 Depth to Water

Cuyama Valley Groundwater Basin

Map Created: July 2024

Figure Exported: 7/18/2024 By: ceggleton Using: \\woodardcurran.net\shared\Projects\CA\Cuyama Basin GSA\0011078.01 GSP\wip\Z. GIS\2. Maps\3. 2025 GSP Update\02_Basin_Setting_Overview\GSP2025_dtw_gwe\2025_dtw_gwe.aprx

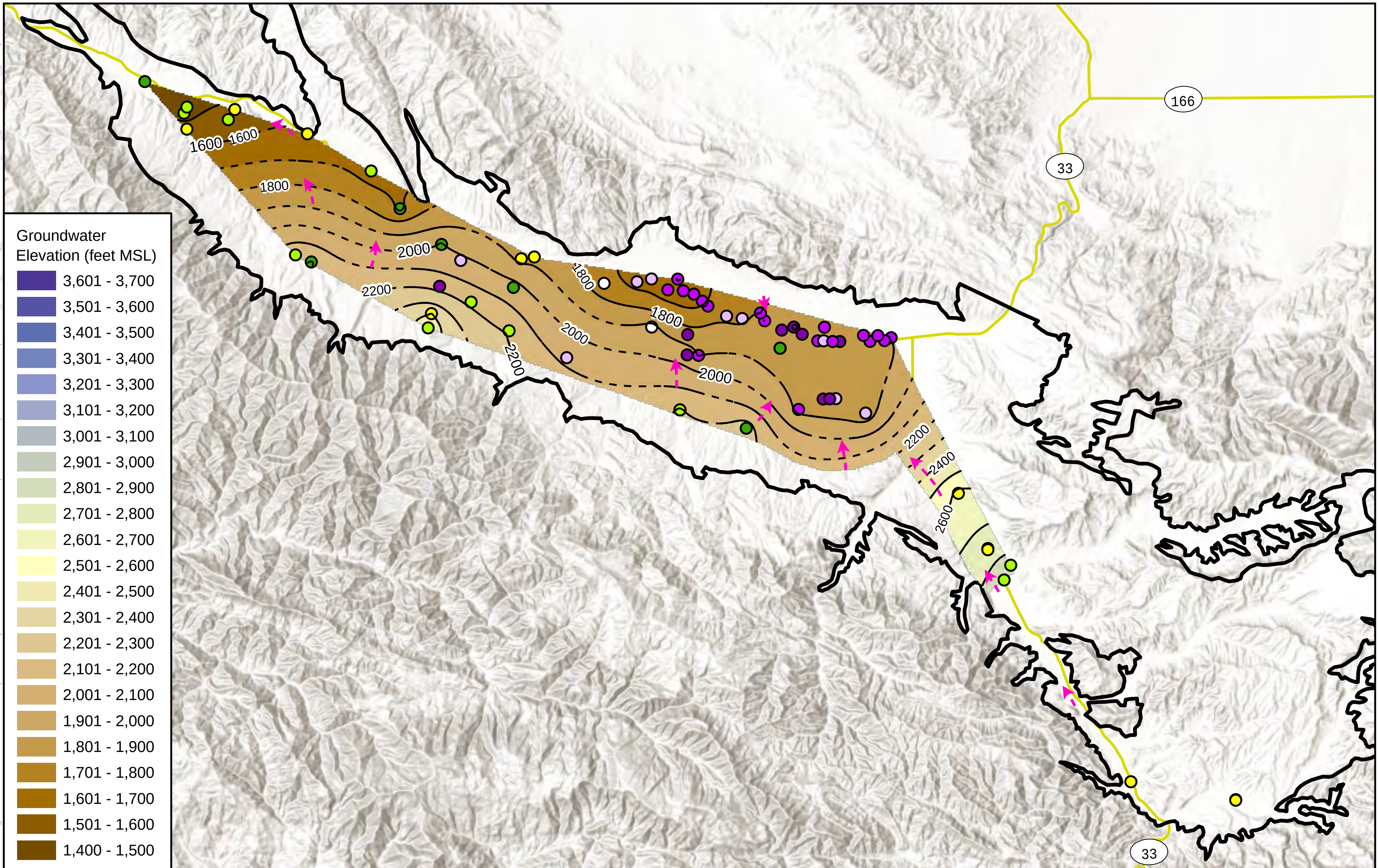

Figure 2-63: Fall 2020 Groundwater Elevation

Cuyama Valley Groundwater Basin

Legend

- Groundwater Elevation Contour
- Approximate Contour
- Conceptual Flowline
- Highway
- Cuyama Basin

Well Depth (feet)

- Unknown
- 0 - 200
- 201 - 400
- 401 - 600
- 601 - 800
- 801 - 1000
- 1001 - 1200

N

Woodard & Curran

CUYAMA BASIN GROUNDWATER SUSTAINABILITY AGENCY

0 1.25 2.5 5 Miles

Map Created: July 2024

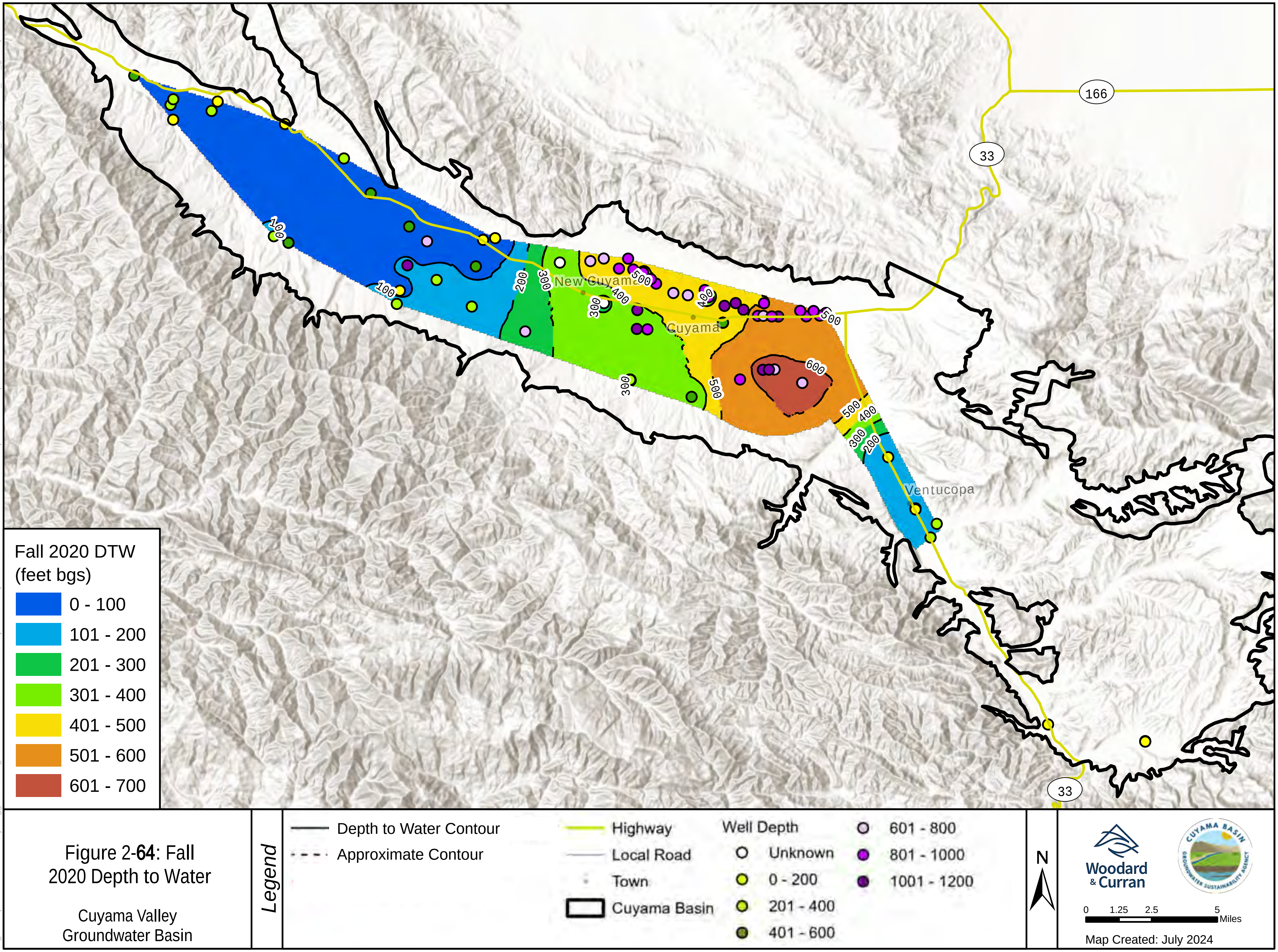

Figure 2-**64**: Fall 2020 Depth to Water

Cuyama Valley Groundwater Basin

Woodard & Curran

Cuyama Basin Groundwater Sustainability Agency

Map Created: July 2024

Figure Exported: 7/18/2024 By: ceggleton Using: \\woodardcurran.net\shared\Projects\CA Cuyama Basin GSA\0011078.01 GSP\wip\Z. GIS\2. Maps\3. 2025 GSP Update\02_Basin_Setting_Overview\GSP2025_dtw_gwe\2025_dtw_gwe.aprx

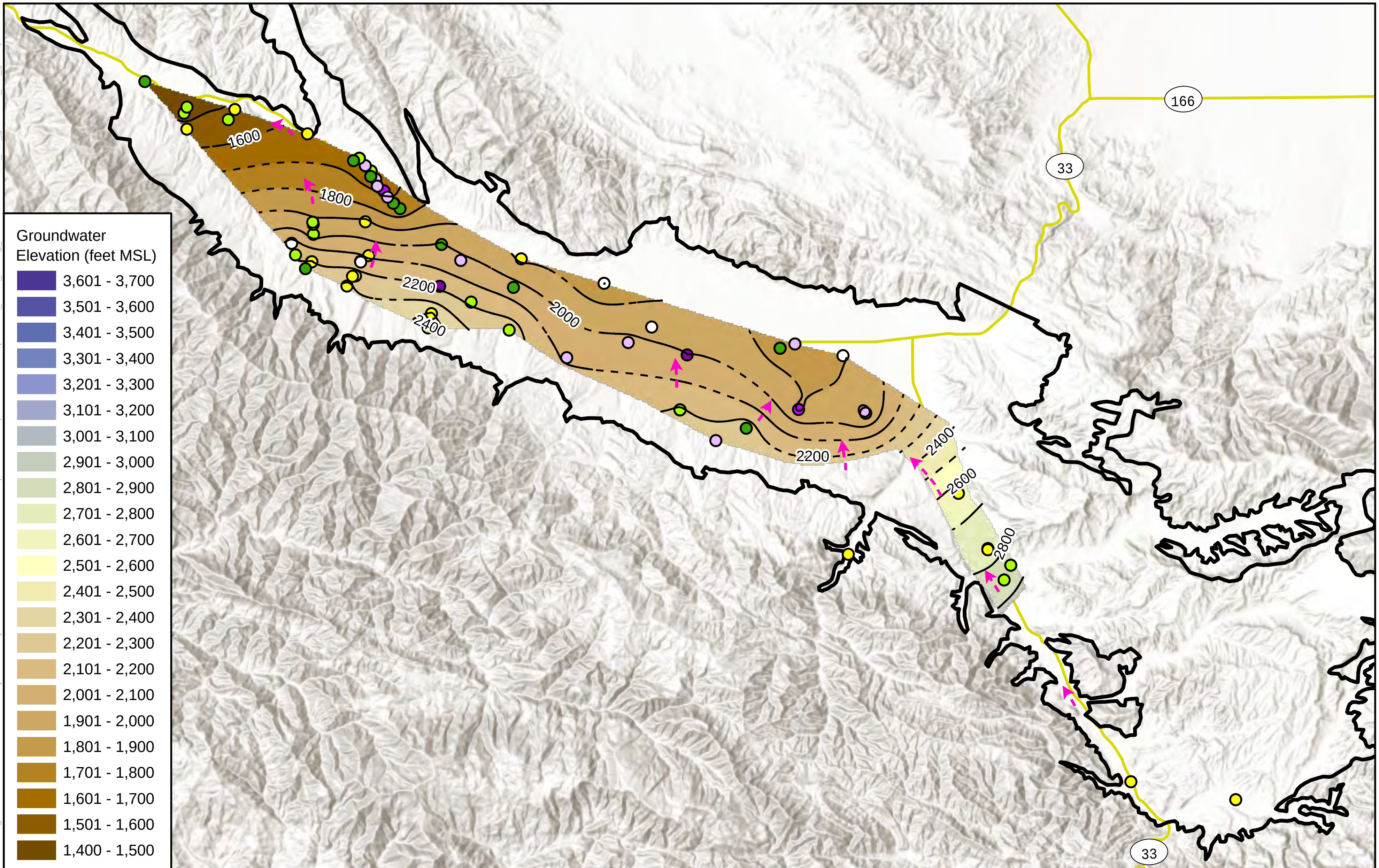

Figure 2-**65**: Spring 2018 Groundwater Elevation

Cuyama Valley Groundwater Basin

Legend

Groundwater Elevation Contour
Approximate Contour
Conceptual Flowline
Highway
Cuyama Basin

Well Depth (feet)
Unknown
0 - 200
201 - 400
401 - 600
601 - 800
801 - 1000
1001 - 1200

N

Woodard & Curran

CUYAMA BASIN GROUNDWATER SUSTAINABILITY AGENCY

0 1.25 2.5 5 Miles

Map Created: July 2024

Figure Exported: 7/18/2024 By: ceggleton Using: \\woodardcurran.net\shared\Projects\CA Cuyama Basin GSA\0011078.01 GSP\wip\Z. GIS\2. Maps\3. 2025 GSP Update\02_Basin_Setting_Overview\GSP2025_dtw_gwe\2025_dtw_gwe.aprx

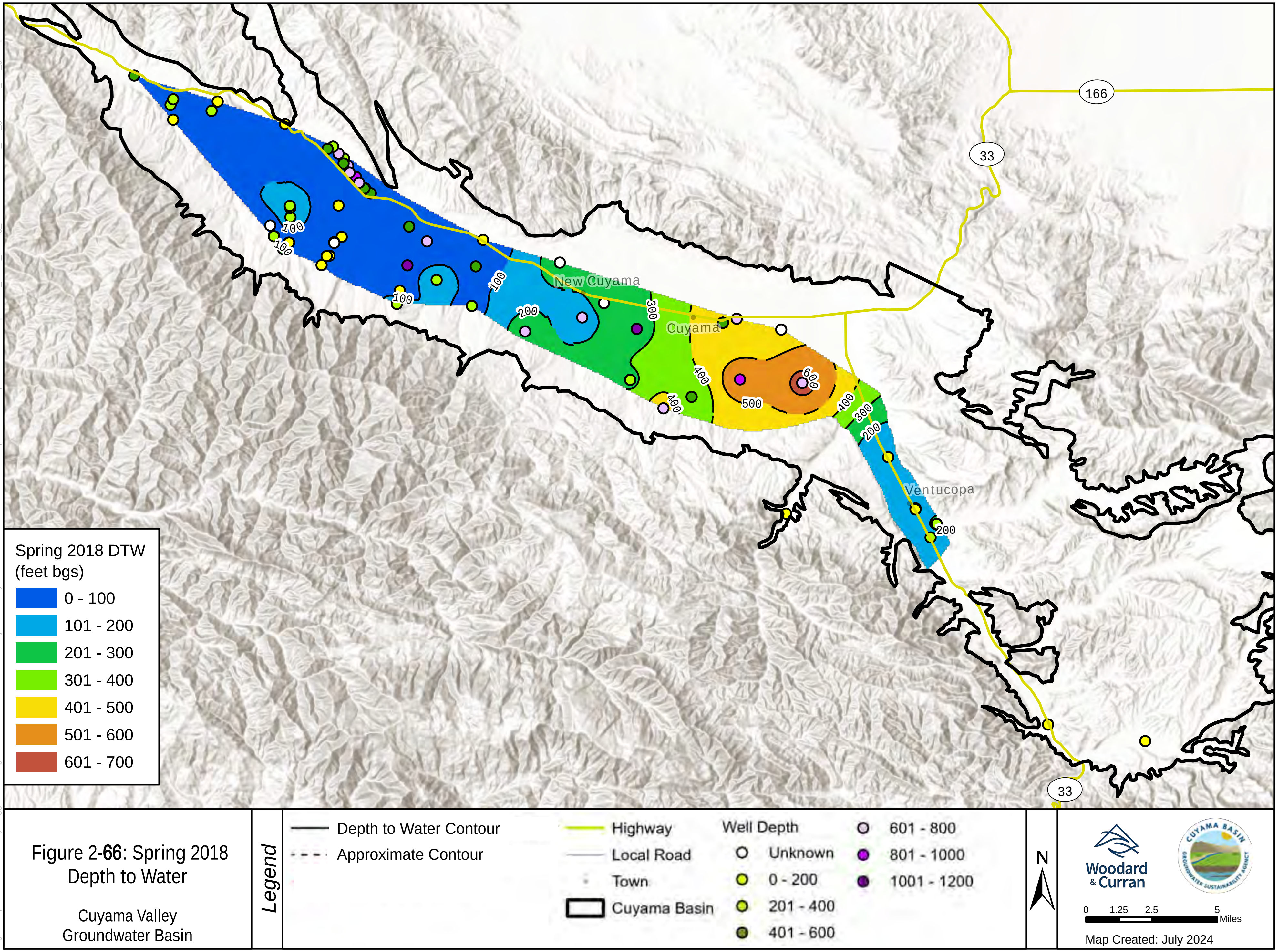

Figure 2-66: Spring 2018 Depth to Water

Cuyama Valley Groundwater Basin

Map Created: July 2024

Figure Exported: 7/18/2024 By: ceggleton Using: \\woodardcurran.net\shared\Projects\CA Cuyama Basin GSA\0011078.01 GSP\wip\z. GIS\2. Maps\3. 2025 GSP Update\02_Basin_Setting_Overview\GSP2025_dtw_gwe\2025_dtw_gwe.aprx

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data sources: CA DWR, Esri, USGS**

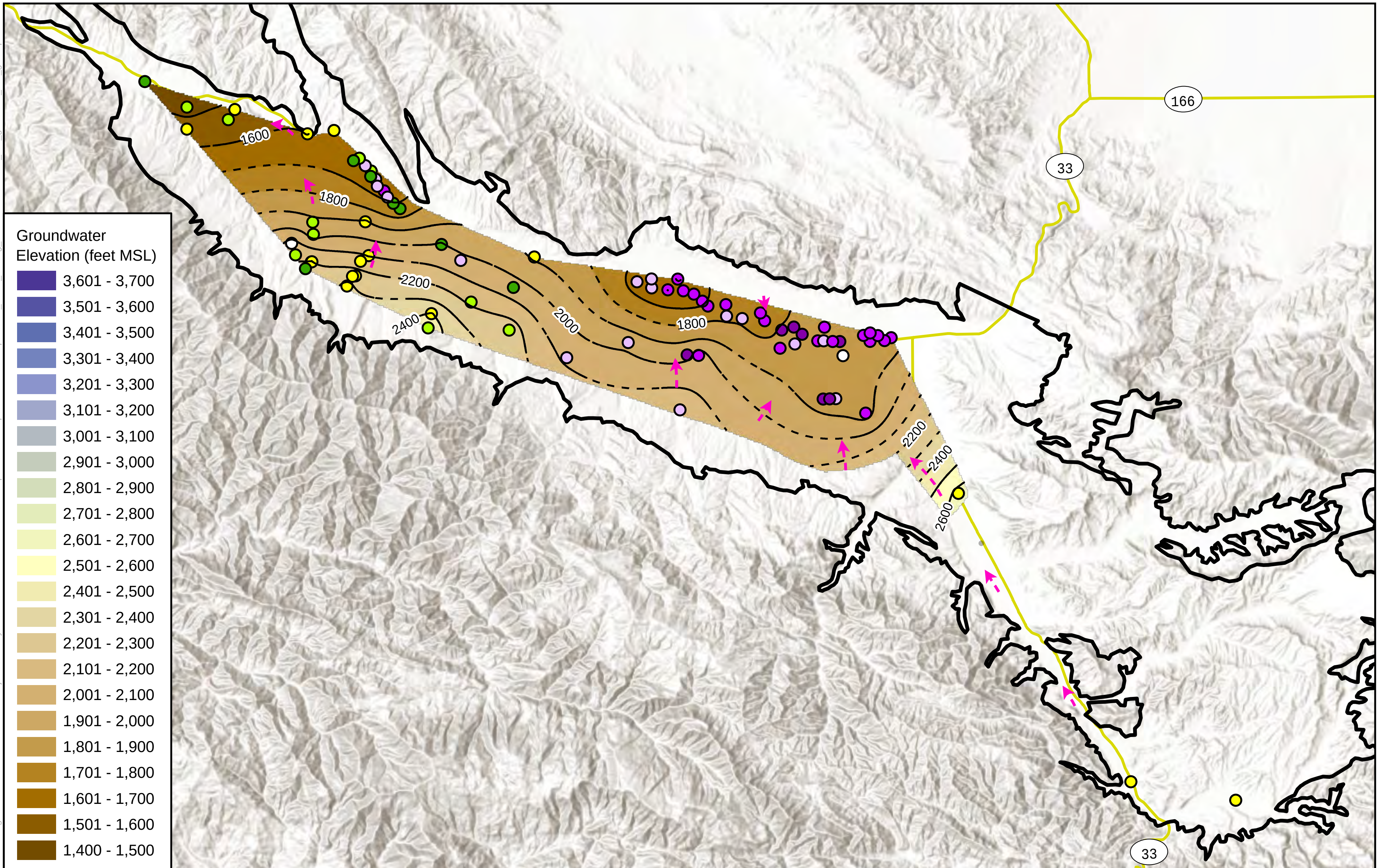

Figure 2-**67**: Fall 2017 Groundwater Elevation

Cuyama Valley Groundwater Basin

Legend

Groundwater Elevation Contour
Approximate Contour
Conceptual Flowline
Highway
Cuyama Basin

Well Depth (feet)
Unknown
0 - 200
201 - 400
401 - 600
601 - 800
801 - 1000
1001 - 1200

N

Woodard & Curran

Cuyama Basin Groundwater Sustainability Agency

0 1.25 2.5 5 Miles

Map Created: July 2024

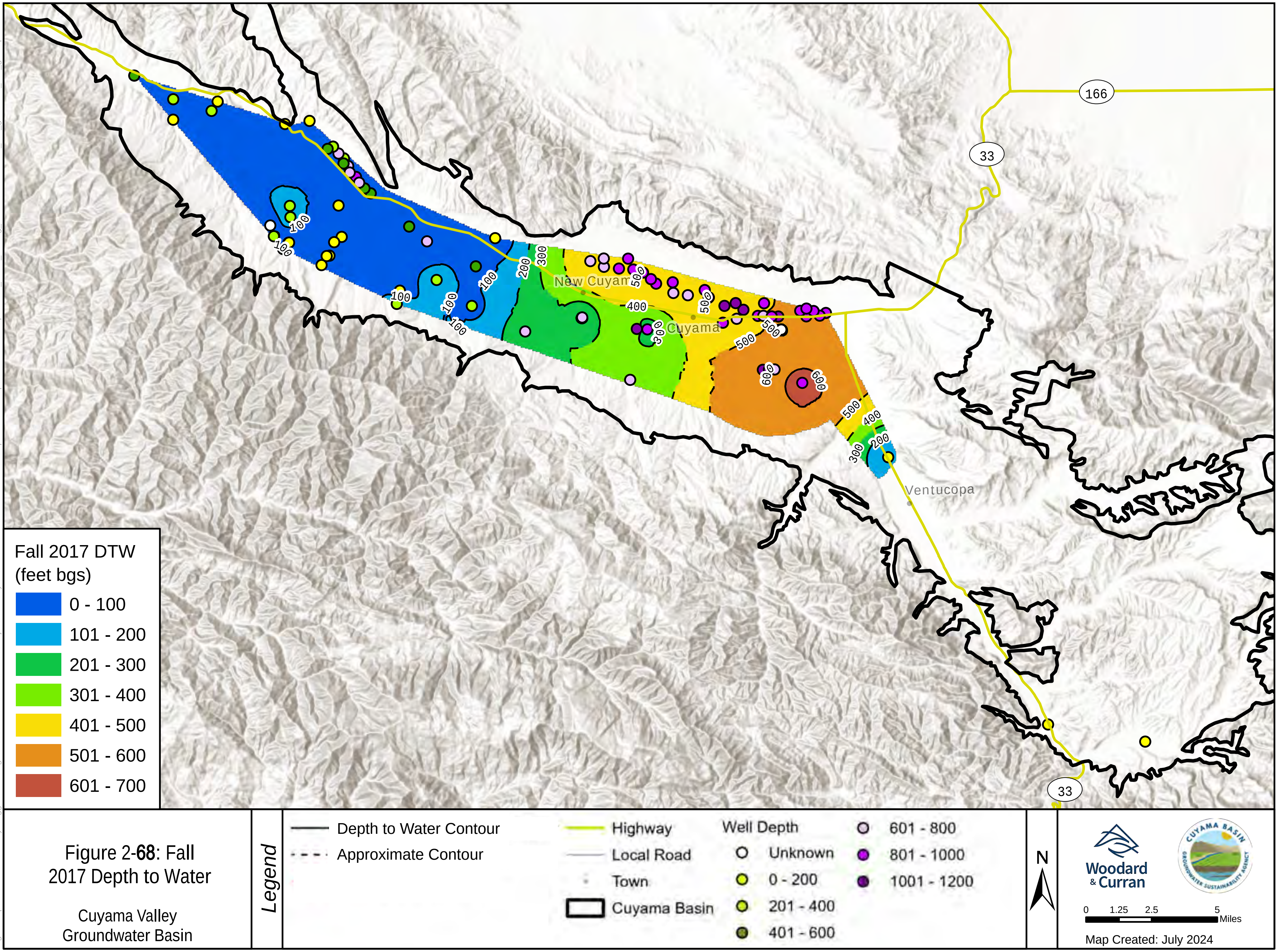

Figure 2-68: Fall 2017 Depth to Water

Cuyama Valley Groundwater Basin

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data sources: CA DWR, Esri, USGS**

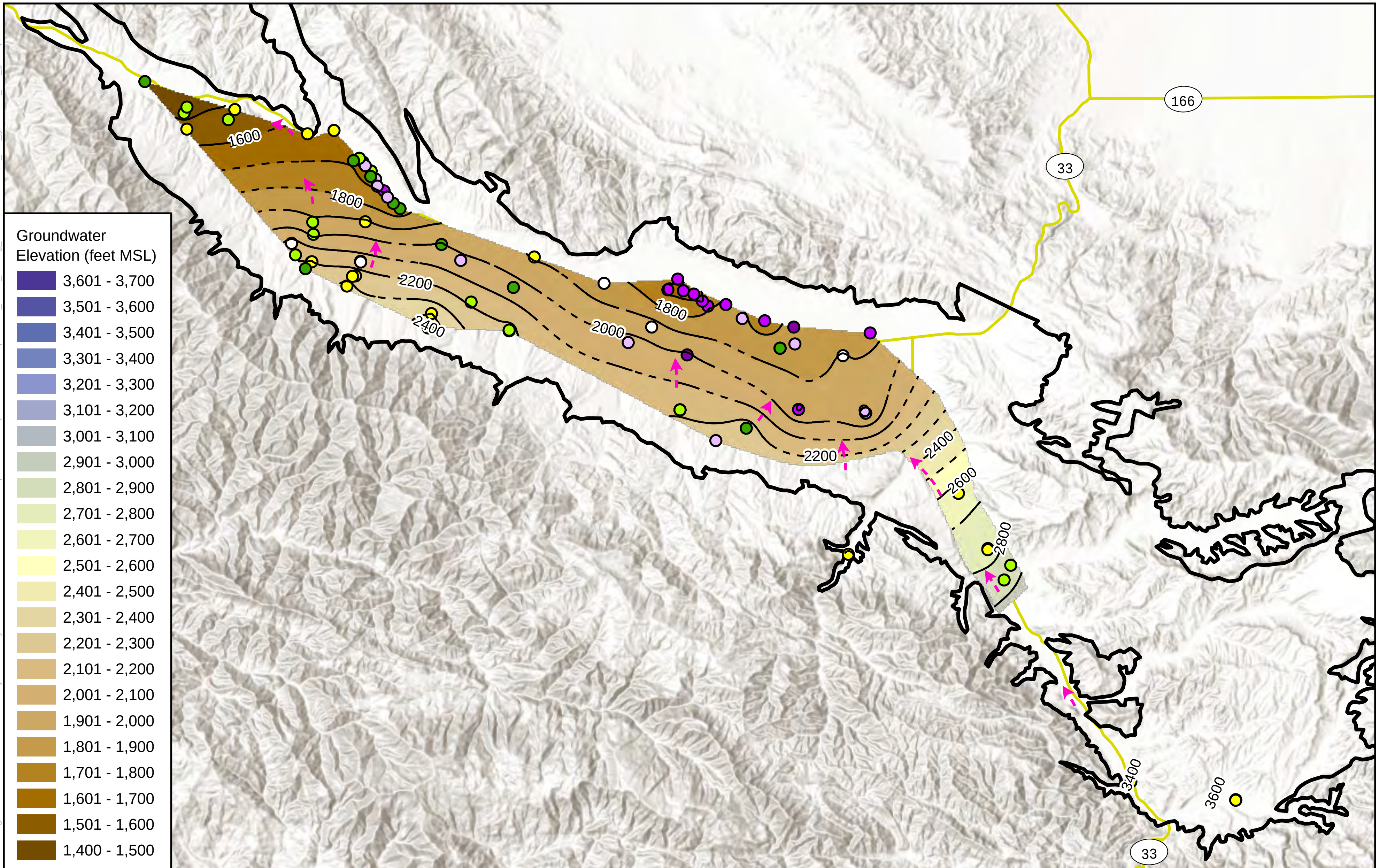

Figure 2-**69**: Spring 2017 Groundwater Elevation

Cuyama Valley Groundwater Basin

Legend

- Groundwater Elevation Contour
- Approximate Contour
- Conceptual Flowline
- Highway
- Cuyama Basin

Well Depth (feet)

- Unknown
- 0 - 200
- 201 - 400
- 401 - 600
- 601 - 800
- 801 - 1000
- 1001 - 1200

N

Woodard & Curran

CUYAMA BASIN GROUNDWATER SUSTAINABILITY AGENCY

0 1.25 2.5 5 Miles

Map Created: July 2024

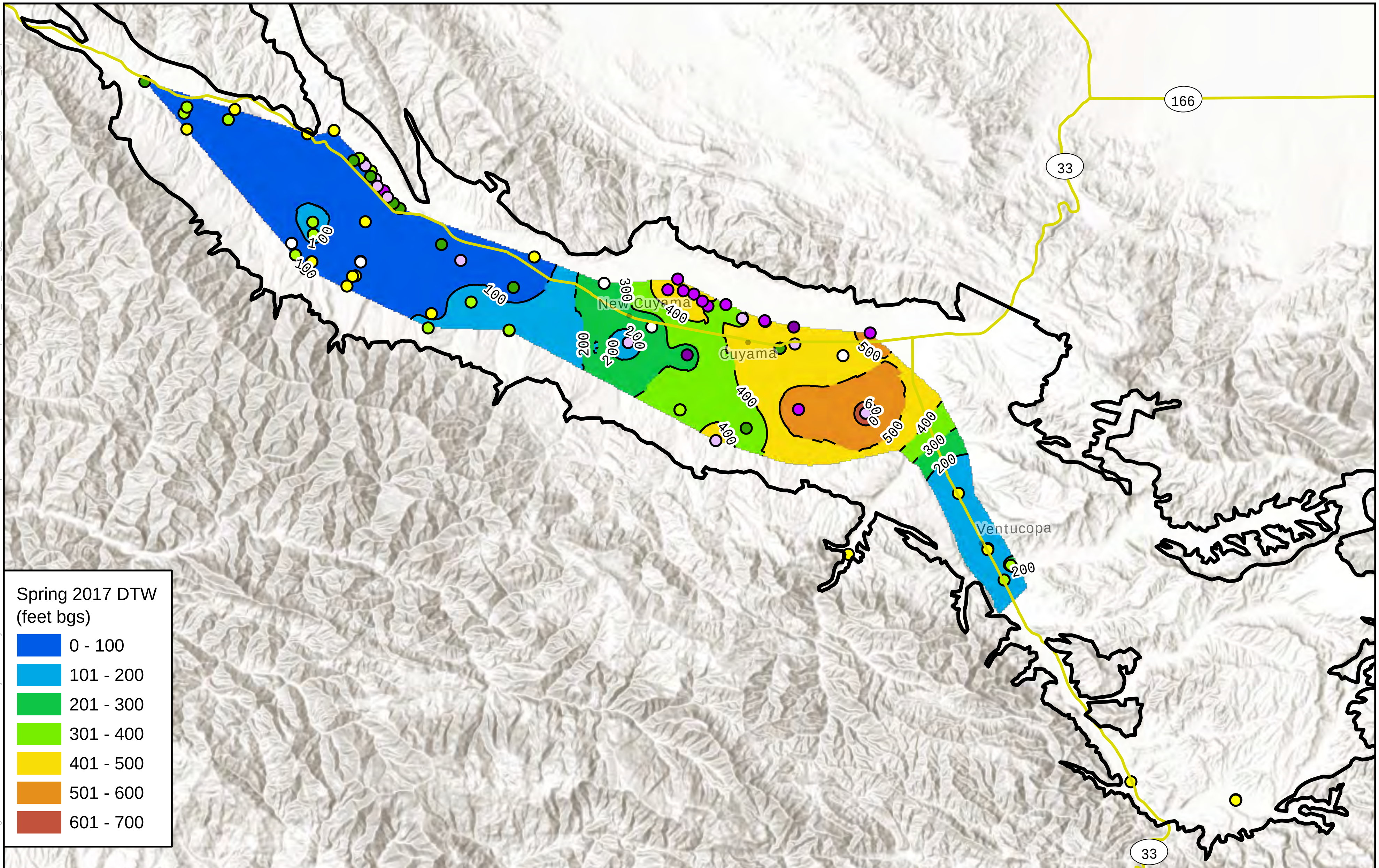

Figure 2-**70**: Spring 2017 Depth to Water

Cuyama Valley Groundwater Basin

Legend

Depth to Water Contour
Approximate Contour
Highway
Local Road
Town
Cuyama Basin

Well Depth
Unknown
0 - 200
201 - 400
401 - 600
601 - 800
801 - 1000
1001 - 1200

N

Woodard & Curran

CUYAMA BASIN GROUNDWATER SUSTAINABILITY AGENCY

0 1.25 2.5 5 Miles

Map Created: July 2024

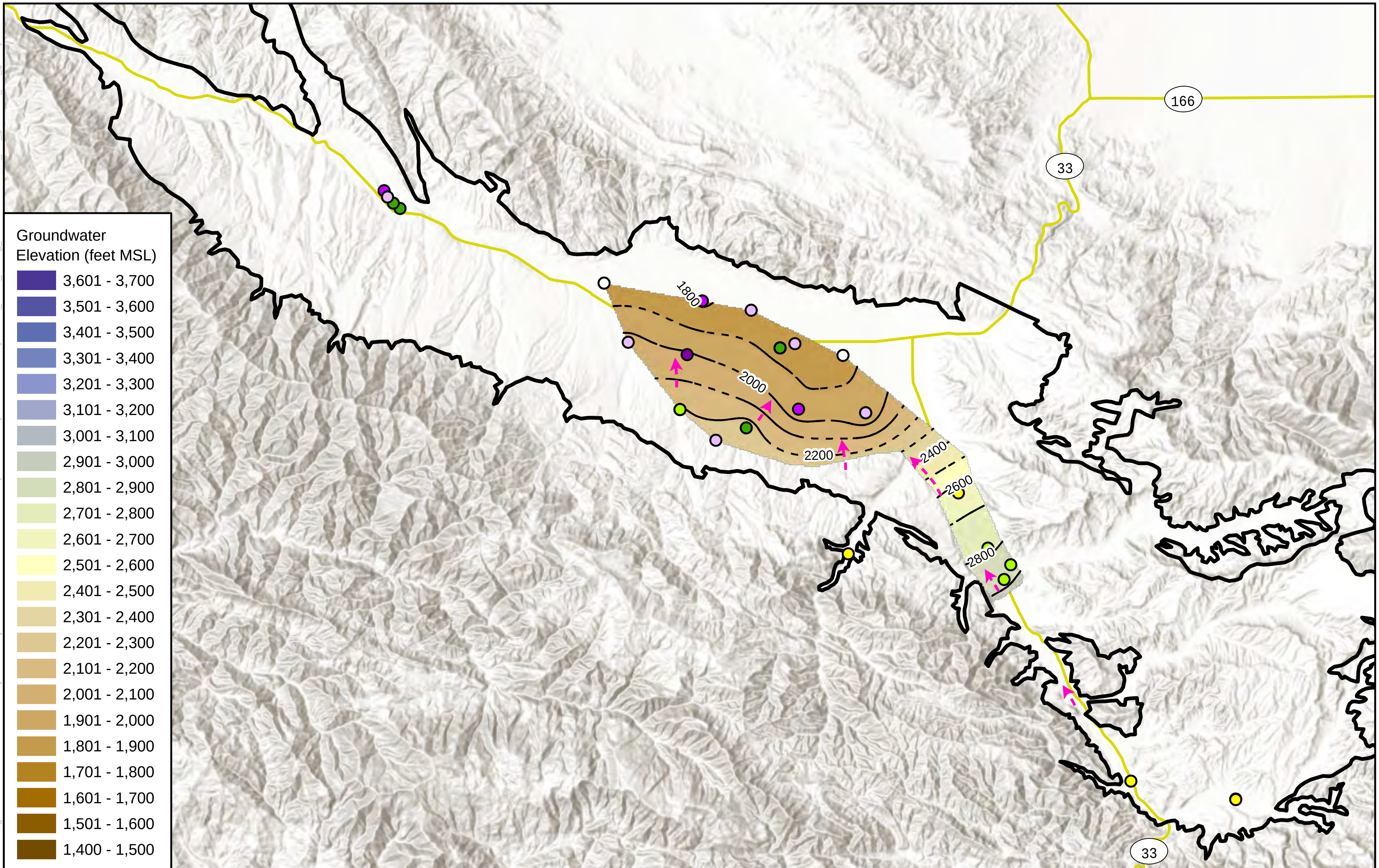

Figure Exported: 7/18/2024 By: ceggleton Using: \\woodardcurran.net\shared\Projects\CA Cuyama Basin GSA\0011078.01 GSP\wip\Z. GIS\2. Maps\3. 2025 GSP Update\02_Basin_Setting_Overview\GSP2025_dtw_gwe\2025_dtw_gwe.aprx

Figure 2-**71**: Spring 2015 Groundwater Elevation

Cuyama Valley Groundwater Basin

Legend

Groundwater Elevation Contour
Approximate Contour
Conceptual Flowline
Highway
Cuyama Basin

Well Depth (feet)
Unknown
0 - 200
201 - 400
401 - 600
601 - 800
801 - 1000
1001 - 1200

N

Woodard & Curran

CUYAMA BASIN GROUNDWATER SUSTAINABILITY AGENCY

0 1.25 2.5 5 Miles

Map Created: July 2024

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data sources: CA DWR, Esri, USGS**

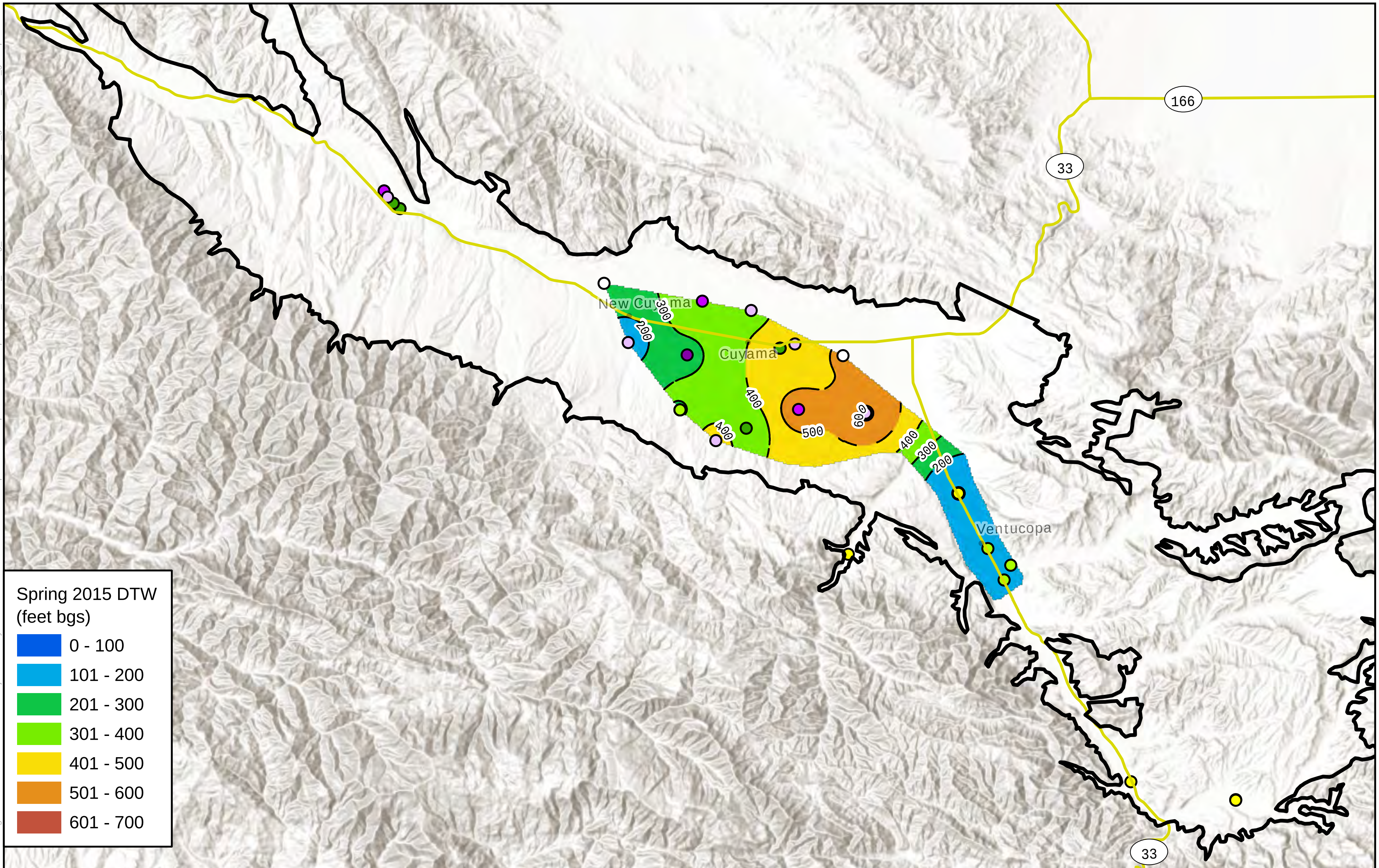

Figure 2-**72**: Spring 2015 Depth to Water

Cuyama Valley Groundwater Basin

Legend

Depth to Water Contour

Approximate Contour

Highway

Local Road

Town

Cuyama Basin

Well Depth

Unknown

0 - 200

201 - 400

401 - 600

601 - 800

801 - 1000

1001 - 1200

N

0 1.25 2.5 5 Miles

Map Created: July 2024

Figure Exported: 7/18/2024 By: ceggleton Using: \\woodardcurran.net\shared\Projects\CA Cuyama Basin GSA\0011078.01 GSP\wip\Z. GIS\2. Maps\3. 2025 GSP Update\02_Basin_Setting_Overview\GSP2025_dtw_gwe\2025_dtw_gwe.aprx

2.2.6 Change in Groundwater Storage

Historical change in Basin groundwater storage has shown a consistent decline. Figure 2-73 shows change in storage by year, water year type,[9] and cumulative water volume for the last 26 years. Change in storage was calculated using the Cuyama Basin Water Resources Model (CBWRM). Average annual depletion of groundwater storage over the 26-year period was -20,300 acre-feet. The color of bar for each year of change in storage correlates a water year type defined by Basin precipitation. Change in storage is negative in 22 of the 25 years, and was positive during three of the four wet years, as designated by the water year type.

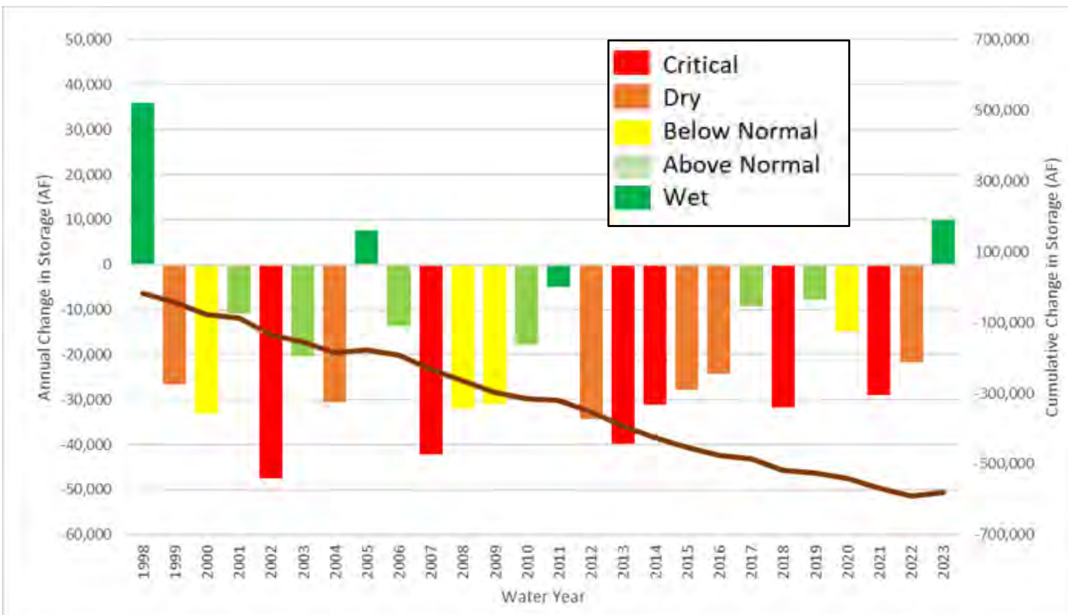

Figure 2-73: Cuyama Groundwater Storage by Year, Water Year Type, and cumulative Water volume

[9] Water year types are customized for the Basin watershed based on annual precipitation as follows:

- Wet year = more than 19.6 inches
- Above normal year = 13.1 to 19.6 inches
- Below normal year = 9.85 to 13.1 inches
- Dry year = 6.6 to 9.85 inches
- Critical year = less than 6.6 inches.

2.2.7 Seawater Intrusion

Seawater intrusion is not an applicable sustainability indicator, because seawater intrusion is not present in the Basin and is not likely to occur due to the distance between the Basin and the Pacific Ocean, its bays, deltas, or inlets.

2.2.8 Land Subsidence

In 2015, USGS measured land subsidence as part of its technical analysis of the Cuyama Valley. USGS used two continuous global positioning systems (GPS) sites and five reference point InSAR sites, shown in Figure 2-74 (USGS, 2015). There are 308 monthly observations from 2000 to 2012, and total subsidence from 2000 to 2012 ranged from 0.0 to 0.4 feet. USGS simulated subsidence using the CUVHM and estimated that inelastic subsidence began in the late 1970s (USGS, 2015).

Subsidence data were collected from the University NAVSTAR Consortium (UNAVCO) database. UNAVCO maintains data on five GPS monitoring stations in the area in and around the Basin. Figure 2-75 shows the monitoring stations and their measurements since 1999. Three stations (P521, OZST, and BCWR) are located just outside the Basin. The three stations' measurements show ground surface level as either staying constant or slightly increasing. The increase is potentially due to tectonic activity in the region. Two stations (VCST and CUHS) are located within the Basin. Station VCST is located near Ventucopa and indicates that subsidence is not occurring in that area. Station CUHS indicates that 339 millimeters (approximately 1.1 feet of subsidence have occurred in the vicinity of New Cuyama over the 25 years that were monitored (1999 - 2023). The subsidence at this station increases in magnitude following 2010, and generally follows a seasonal pattern. The seasonal pattern is possibly related to water level drawdowns during the summer, and elastic rebound occurring during winter periods.

In the fall of 2024, an investigation was completed of the Cuyama Valley High School (CUHS) station. This station is currently operated and maintained by USGS. An onsite inspection was performed and USGS staff were contacted to investigate the construction, sort term and seasonal fluctuations in all position's displacement components. USGS regularly reviews the data collected and did not identify any data quality issues and the site inspection did not identify any potential issue. It was concluded that the longer-term subsidence is occurring consistent with groundwater pumping and drought. Seasonal fluctuations are likely due to rainfall and possible the absence of bedrock anchoring allowing the station to move up and down on a titled axis.

A white paper that provides information about subsidence and subsidence monitoring techniques is in Appendix B.

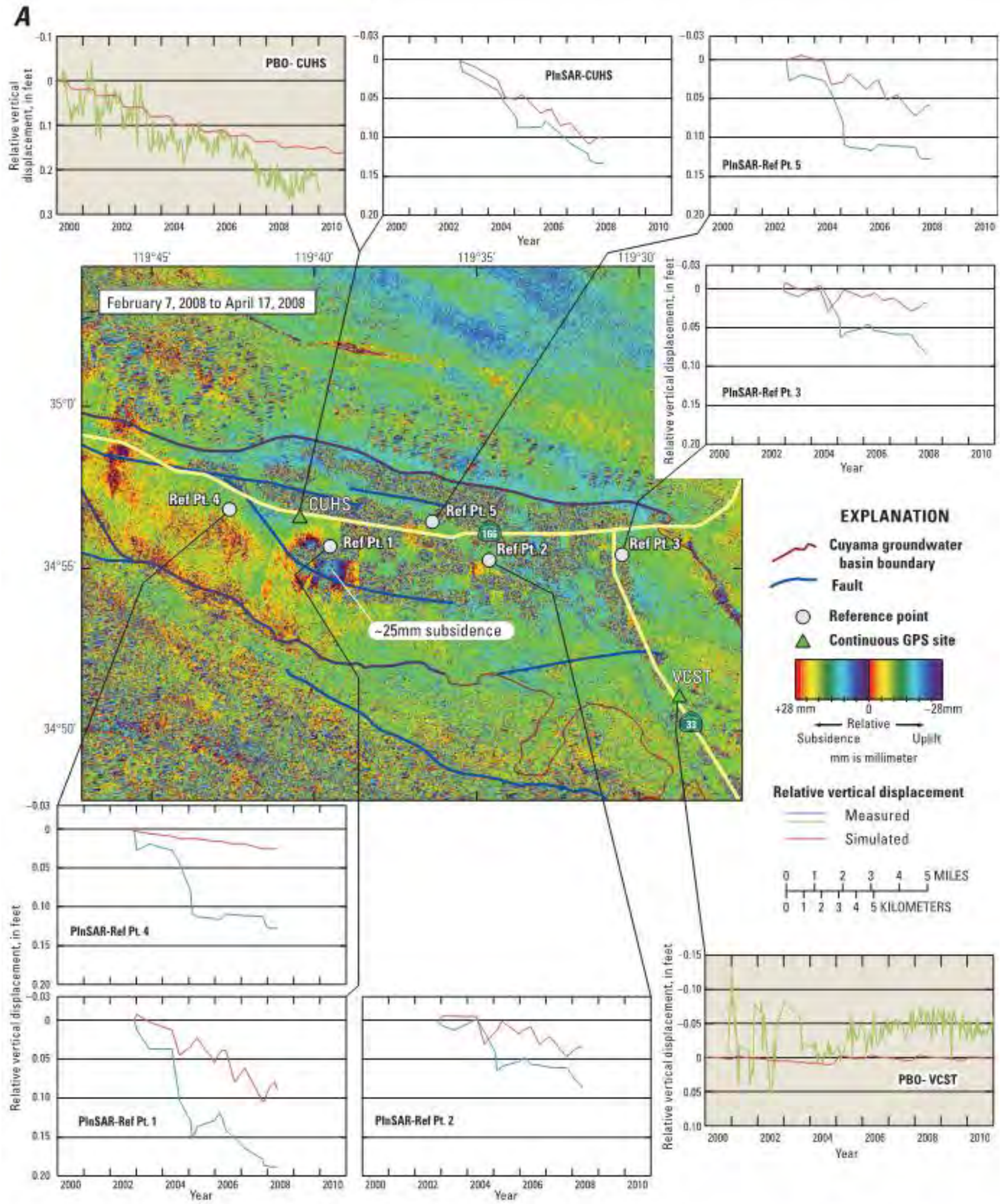

Figure 29. Historical subsidence as *A*, map of seasonal InSAR with graphs of simulated and measured time series for selected locations of relative land-surface deformation from Plate-Boundary Observation (PBO) sites and Point InSAR targets, and *B*, simulated total subsidence 1950–2010 for the calibrated hydrologic flow model, Cuyama Valley, California.

Source: USGS, 2015

Figure 2-74: Locations of Continuous GPS and Reference InSAR Sites in the Cuyama Valley

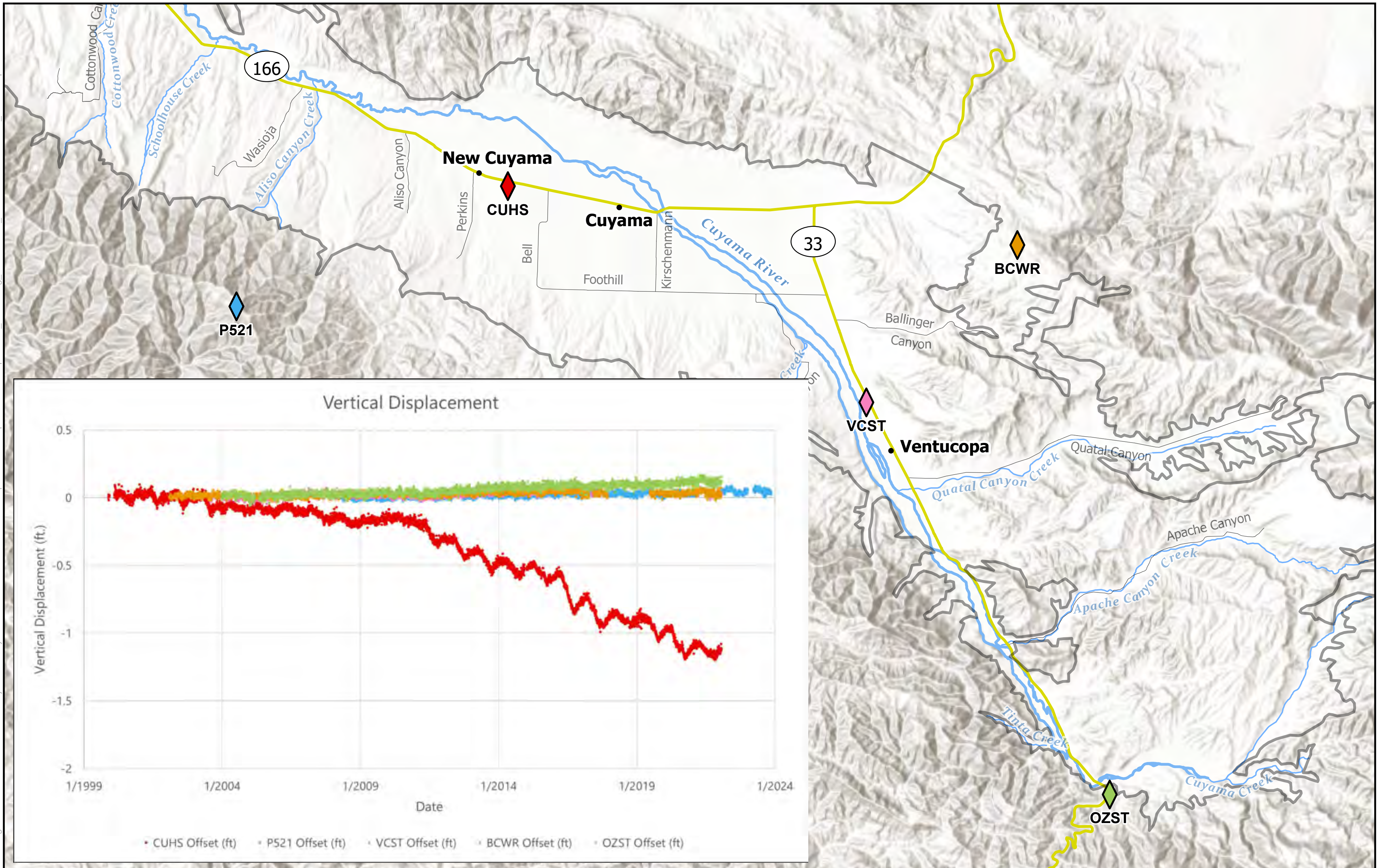

Figure 2-75: Subsidence Monitoring Network

Cuyama Valley Groundwater Basin

Legend

- Plate Boundary Observatory GPS Station
- Highway
- Local Road
- Town
- Cuyama River
- Creek
- Cuyama Basin

N

0 1 2 4 Miles

Map Created: December 2023

Woodard & Curran

Cuyama Basin Groundwater Sustainability Agency

Figure Exported: 12/27/2023 By: DHunt Using: \\woodardcurran.net\shared\Projects\CA Cuyama Basin GSA\0011078.01 GSP\wip\z_GIS\2_Maps\2025 GSP Update\04_Monitoring_Networks\22_subsidence\subsidence_network.aprx

2.2.9 Groundwater Quality

This section presents Basin groundwater quality information, including a discussion of available water quality data and references, results of water quality data analysis performed for the GSP, and a literature review of previous studies about water quality in the Basin.

Reference and Data Collection

Data collection was completed as part of the 2020 GSP compilation. References and data related to groundwater quality were collected from the following sources:

- USGS National Water Quality Monitoring Council. Downloaded data from June 1, 2018 from https://www.waterqualitydata.us/portal/
- DWR GeoTracker California Groundwater Ambient Monitoring and Assessment (GAMA) Program. Downloaded data on June 5, 2018 for each county, from http://geotracker.waterboards.ca.gov/gama/datadownload
- DWR California Natural Resources Agency data. Downloaded on June 14, 2018 from https://data.cnra.ca.gov/dataset/periodic-groundwater-level-measurements
- County of Ventura
- Private landowners

In addition to accessing the public portals for each program, CBGSA staff coordinated with RWQCB staff to ensure that all publicly available data was collected. It was confirmed by RWQCB staff that all available data for the ILP program was included in the online GAMA data portal download. Some of these public portals have overlapping data that, where possible, were removed, to develop a comprehensive data set for the Basin. Data were then compiled into a database for analysis.

Analysts also compiled references containing groundwater quality information. The information included in these references was used to enhance understanding of groundwater quality conditions beyond available data. References used in this section include the following:

- Singer and Swarzensky. 1970. *Pumpage and Ground-Water Storage Depletion in Cuyama Valley, 1947-1966*. This report focuses on groundwater depletion, but also includes information about groundwater quality.
- USGS. 2008 *Groundwater-Quality Data in the South Coast Interior Basins Study Unit, 2008: Results from the California Groundwater Ambient Monitoring and Assessment (GAMA) Program*. This study summarizes water quality testing on 12 wells in the Cuyama Valley; wells were tested for a variety of constituents.

- SBCWA. 2011. *Santa Barbara County 2011 Groundwater Report.* This report provides groundwater conditions from throughout the county and provides water quality information for the Cuyama Valley.
- USGS. 2013c. *Geology, Water-Quality, Hydrology, and Geomechanics of the Cuyama Valley Groundwater Basin, California, 2008-12*. This report investigates a wide variety of groundwater components in the Cuyama Valley, including water quality.

Historical Data Analysis

Collected data were analyzed for TDS, nitrate, and arsenic. These three constituents were included in analysis because they were cited in previous studies of the Basin, and they were discussed during public meetings as being of concern to stakeholders in the Basin. The Figures below show historical measurements of TDS nitrate and arsenic collected prior to GSP development as well as also recent sampling results from the CBGSA's monitoring network and collected from public portals described earlier in this chapter.

Figure 2-76 shows TDS of groundwater measured in wells in 1966. In 1966, TDS was above the MCL of 1,500 micrograms per liter (mg/L) in over 50 percent of measurements. TDS was over 2,000 mg/L near the Cuyama River in the southeast portion of the Basin near the Ozena Fire Station, Santa Barbara Canyon, and upper Quatal Canyon, indicating that high TDS water was entering the Basin from the watershed above these measurement points. TDS measurements were over the MCL throughout the central portion of the Basin, where irrigated agriculture was operating, near the towns of Cuyama and New Cuyama, and along the Cuyama River to the northwest of New Cuyama. TDS was less than 500 mg/L in a number of measurements between Bitter Creek and Cottonwood Canyon, indicating that lower TDS water was entering the Basin from the watersheds in this area.

Figure 2-77 shows TDS of groundwater measured in wells between 2011 and 2018. Multiple years of collected data were used to generate enough mapped data density for comparison to 1966 data. From 2011 to 2018 period, TDS was above the MCL in over 50 percent of measurements. TDS was over 1,500 mg/L near the Cuyama River in the southeast portion of the Basin near the Ozena Fire Station, and in Santa Barbara Canyon, indicating that high TDS water was entering the Basin from the watershed above these measurement points. TDS measurements were over the MCL throughout the central portion of the Basin where irrigated agriculture was operating. A number of 500 to 1,000 mg/L TDS concentrations were measured near New Cuyama and in upper Quatal Canyon, and along the Cuyama River between Cottonwood Canyon and Schoolhouse Canyon.

Figure 2-78 shows measurements of TDS for selected monitoring points over time. Monitoring points were selected by the number of measurements, with higher counts of measurements selected to be plotted. The charts indicate that TDS in the vicinity of New Cuyama has been over 800 mg/L TDS throughout the period of record, and that TDS has either slightly increased or stayed stable over the period of record. The chart for Well 85 at the intersection of Quatal Canyon and the Cuyama River is generally below 800 mg/L TDS with rapid spikes of TDS increases above that level. The timing of rapid increases in measured TDS corresponds with Cuyama River flow events, indicating a connection between rainfall and stream flow and an increase in TDS. This is the only location where this trend was detected.

Figure 2-79 shows measurements of nitrate in 1966. This figure also shows that data collected in 1966 shows the Basin was below the MCL of 10 mg/L throughout, with some measurements above the MCL in the central portion of the Basin where irrigated agriculture was operating.

Figure 2-80 shows the locations of wells with monitoring measurements for nitrates during the 2010-2020 period and the average concentrations measured in each well. For nitrate, 41 of the 102 wells recorded MCL exceedances from 2010-2020. A review of the data for wells with measurements both before and after 2015 showed little change in concentrations, with no wells showing water quality degradation for nitrate or arsenic.

Figure 2-81 shows the locations of wells with monitoring measurements for arsenic during the 2010-2020 period and the average concentrations measured in each well. For arsenic, five of the 23 wells with measurement recorded a measurement exceeding the MCL of 10 μg/L. A review of the data for wells with measurements both before and after 2015 showed little change in concentrations, with no wells showing water quality degradation for arsenic.

Figure 2-82 shows the results of a query using the Regional Water Quality Control Board (RWQCB)'s GeoTracker website. GeoTracker documents RWQCB contaminant concerns and mitigation projects. As shown in the figure, most GeoTracker sites show that gasoline, oil and/or diesel fuel have been cited as the contaminant of concern.

Analysis of Recent Data

Since the GSP adoption, the CBGSA has started collecting its own water quality results through the development of a water quality monitoring network. The CBGSA conducts its own sampling for TDS annually and samples for nitrate and arsenic once every five years. In the interim years, the CBGSA leverages existing monitoring programs for nitrate and arsenic through the California State Water Resource Control Board Groundwater Ambient Monitoring and Assessment (GAMA) Database, which includes data from the Central Coast Regional Water Board's Irrigated Lands Program for nitrates as part of its database.

Figure 2-83 shows TDS measurements as part of the water quality monitoring network sampled by the CBGSA in 2023. TDS ranges from less than 500 in the eastern part of the Basin to over 1700 in the central part of the Basin, where most of the agricultural production is located.

Figure 2-84 shows nitrate concentrations from 2022 and 2023 from the CBGSA monitoring and results from the GAMA database. Nitrate concentrations over the MCL are located in the central part of the basin where most of the agricultural production is located.

Figure 2-85 shows arsenic concentrations from 2022 and 2023 from CBGSA monitoring and results from the GAMA database. All wells with arsenic concentrations exceeding MCLs are located in the Central Threshold Region. The locations of high arsenic concentrations are focused south of New Cuyama near the existing Cuyama Community Services District (CCSD) well. This is a known issue for the CCSD that has been mitigated by the construction of a replacement well for the district, which is included as a project in the GSP (see Chapter 7).

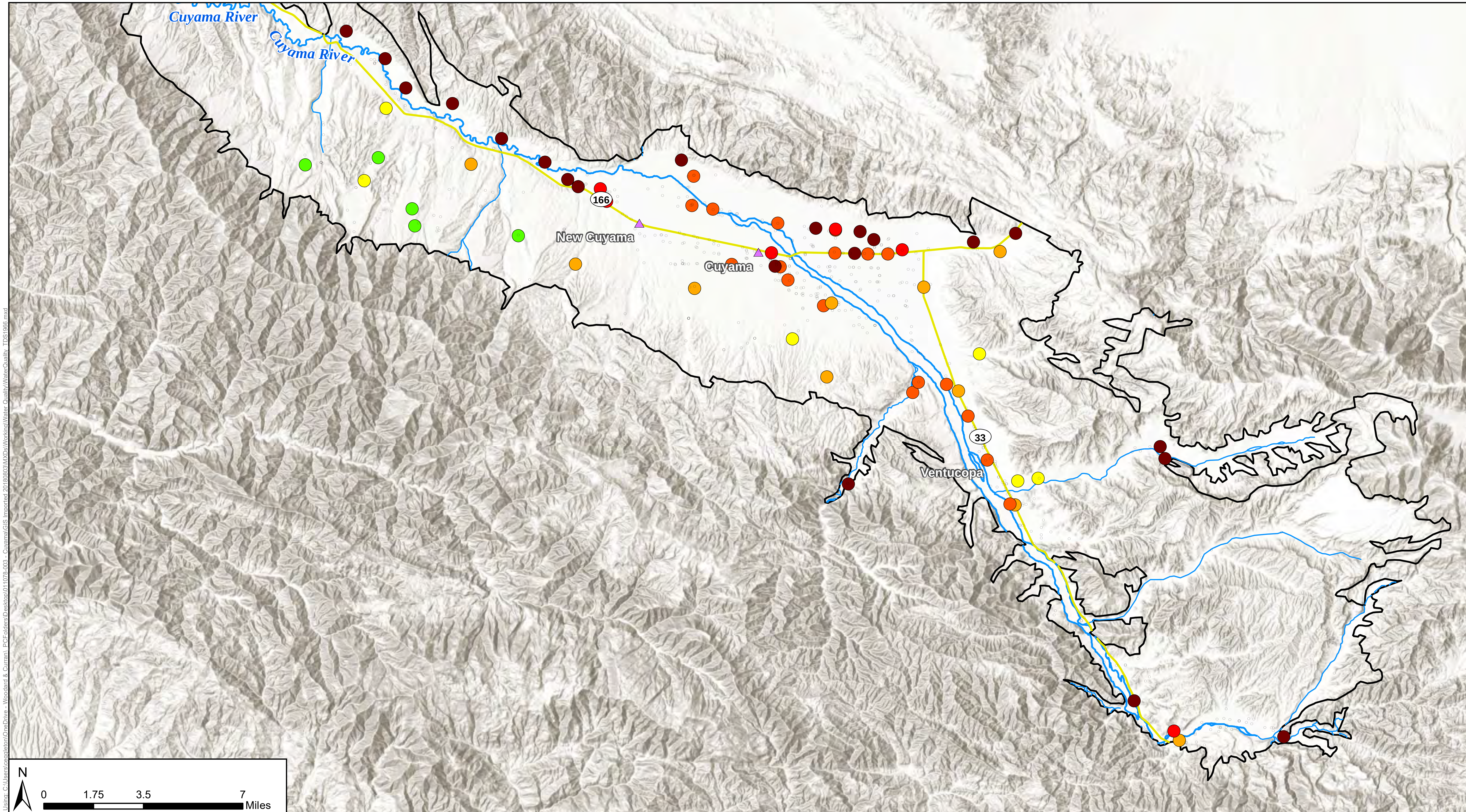

Figure 2-76: 1966 Average Well Measurements of Total Dissolved Solids, mg/L

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

December 2019

WOODARD & CURRAN

Legend

TDS, mg/L

- No Measurements
- < 500 mg/L
- 500 - 1,000 mg/L
- 1,000 - 1,500 mg/L
- 1,500 - 1,750 mg/L
- 1,750 - 2,000 mg/L
- >2,000 mg/L

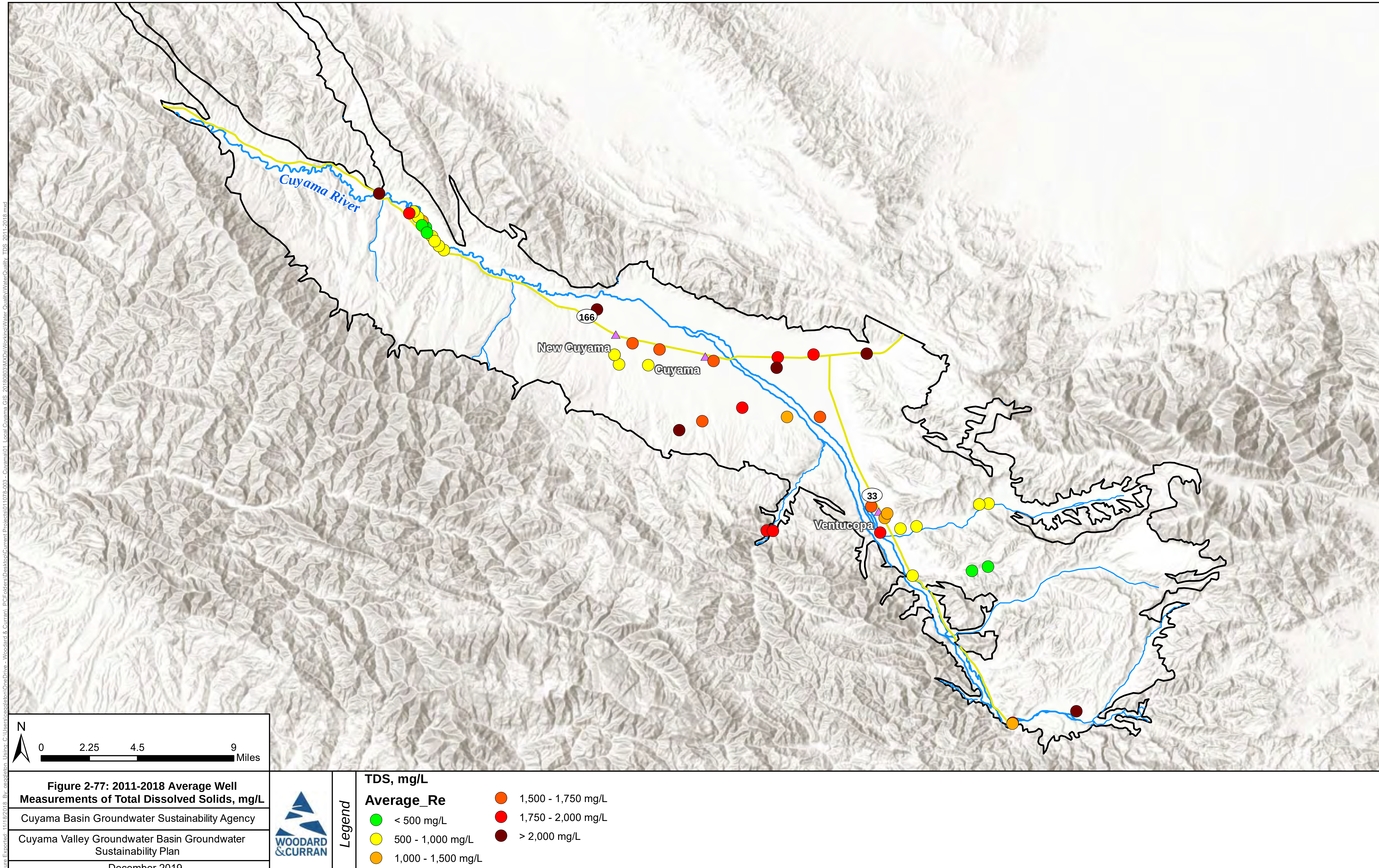

Figure 2-77: 2011-2018 Average Well Measurements of Total Dissolved Solids, mg/L

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

December 2019

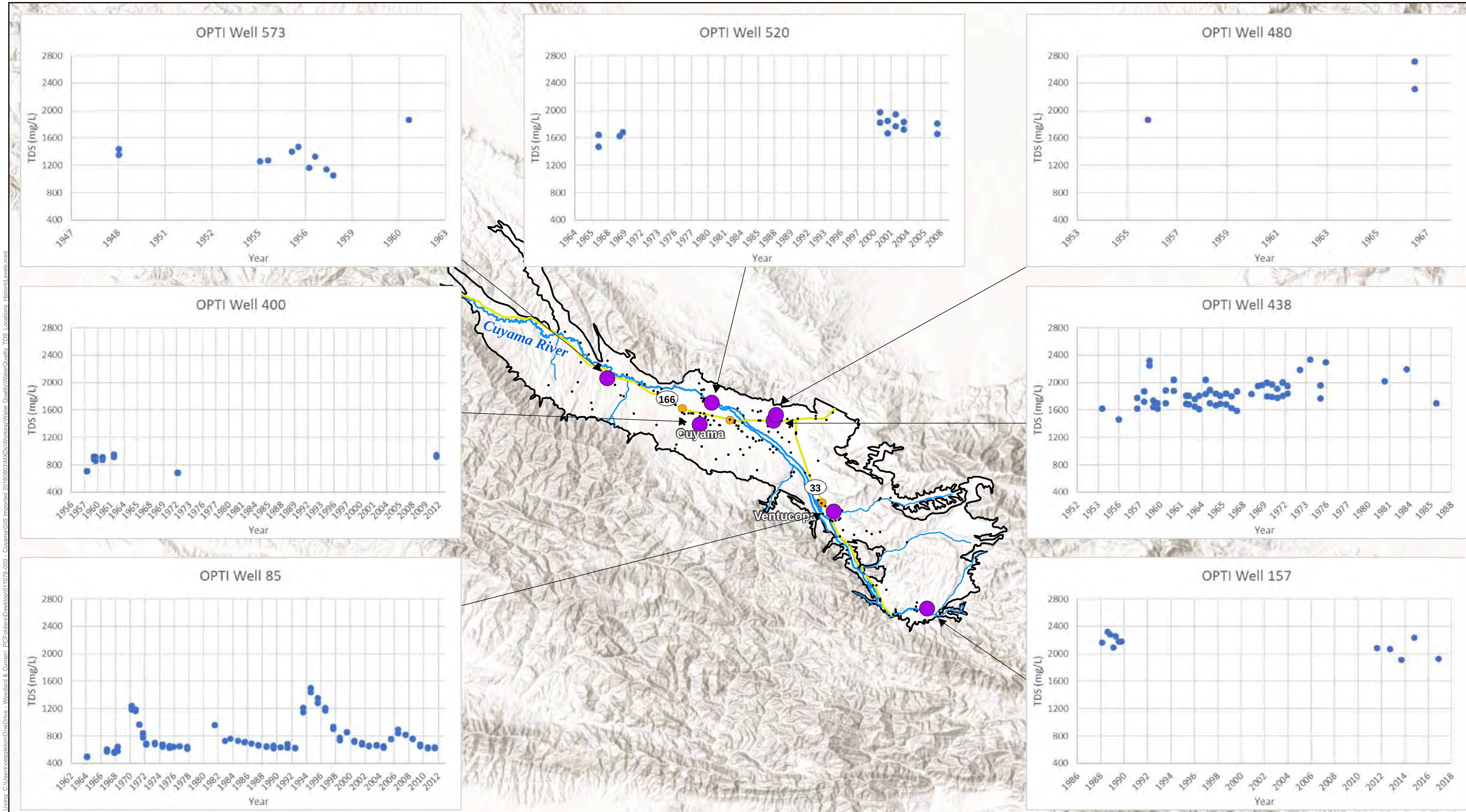

Figure 2-78: Cuyama Groundwater Basin Historic TDS Levels in Selected Wells

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

December 2019

WOODARD & CURRAN

Legend

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- Wells with Graphed Data
- Location of TDS WQ Measurements

N

0 4.5 9 18 Miles

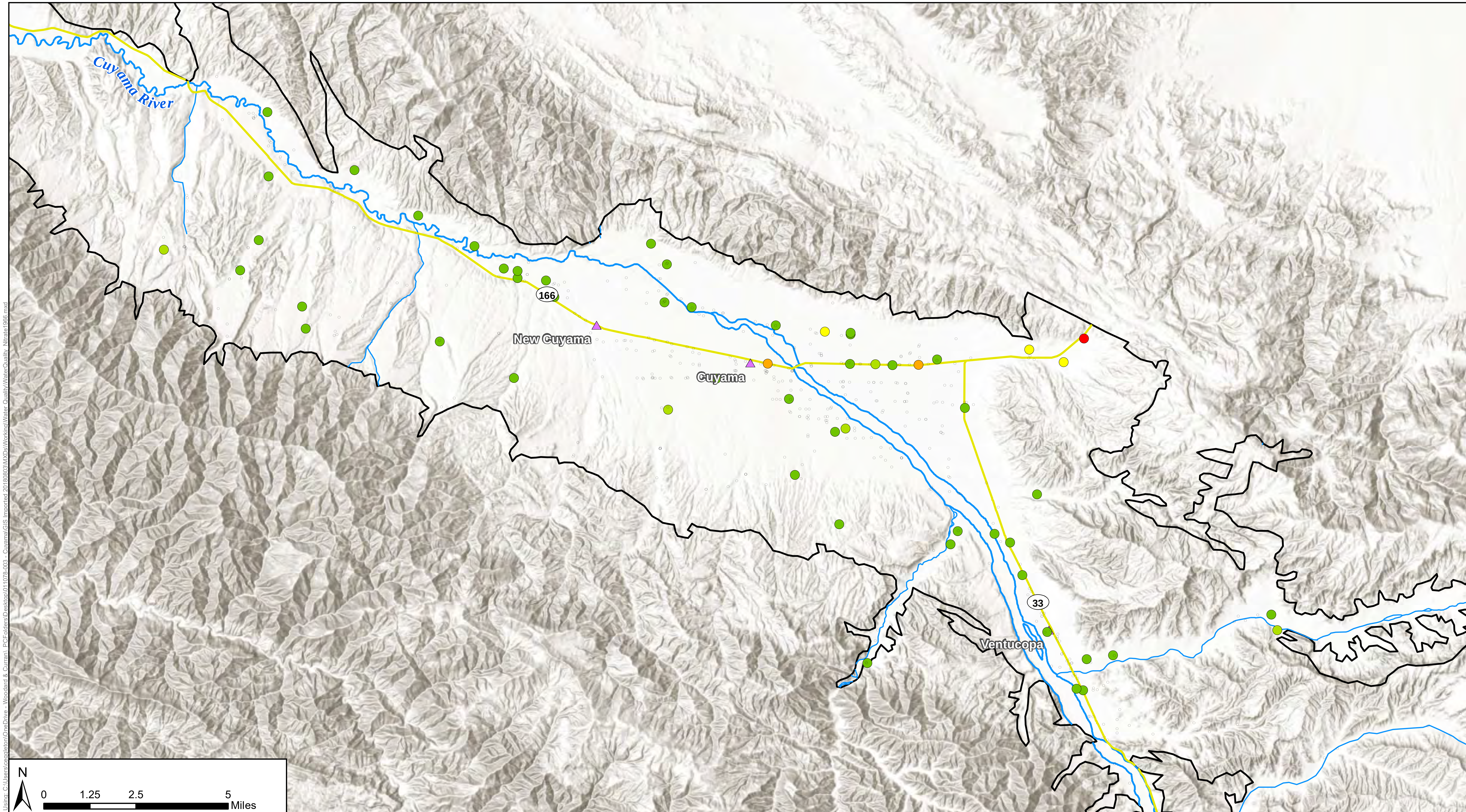

Figure 2-79: 1966 Average Well Measurements of Nitrate (NO3) as Nitrogen

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

December 2019

WOODARD & CURRAN

Legend

Nitrate (NO3) as N, mg/L

- No Measurements
- < 5 mg/L
- 5 - 8 mg/L
- 8 - 10 mg/L
- 10 - 15 mg/L
- 15 - 20 mg/L
- > 20 mg/L

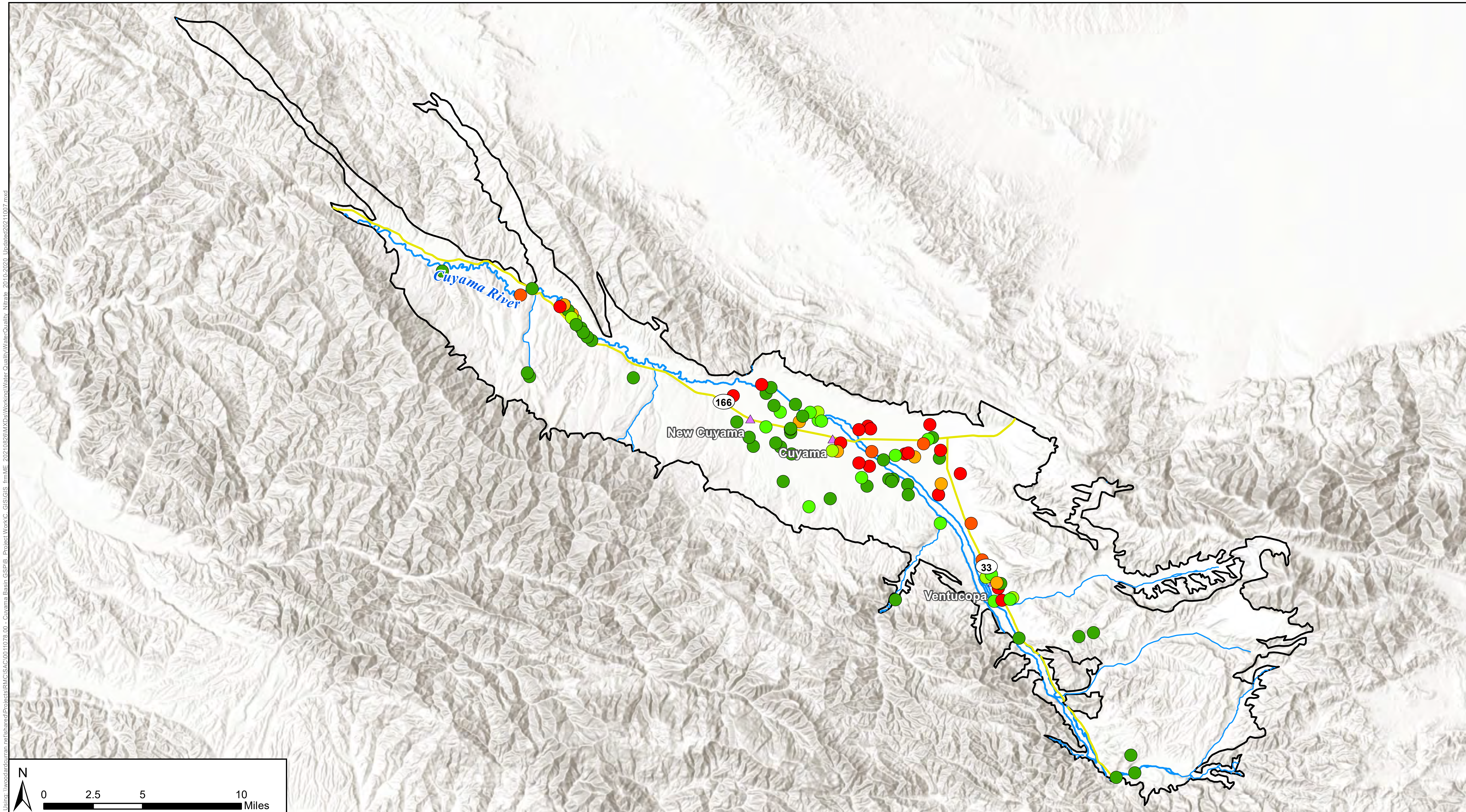

Figure 2-80: 2010-2020 Average Well Measurements of Nitrate (NO3) as Nitrogen

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

October 2021

WOODARD & CURRAN

Legend

Nitrate (NO3) as N, mg/L

- < 5 mg/L
- 5 - 8 mg/L
- 8 - 10 mg/L
- 10 - 15 mg/L
- 15 - 20 mg/L
- > 20 mg/L

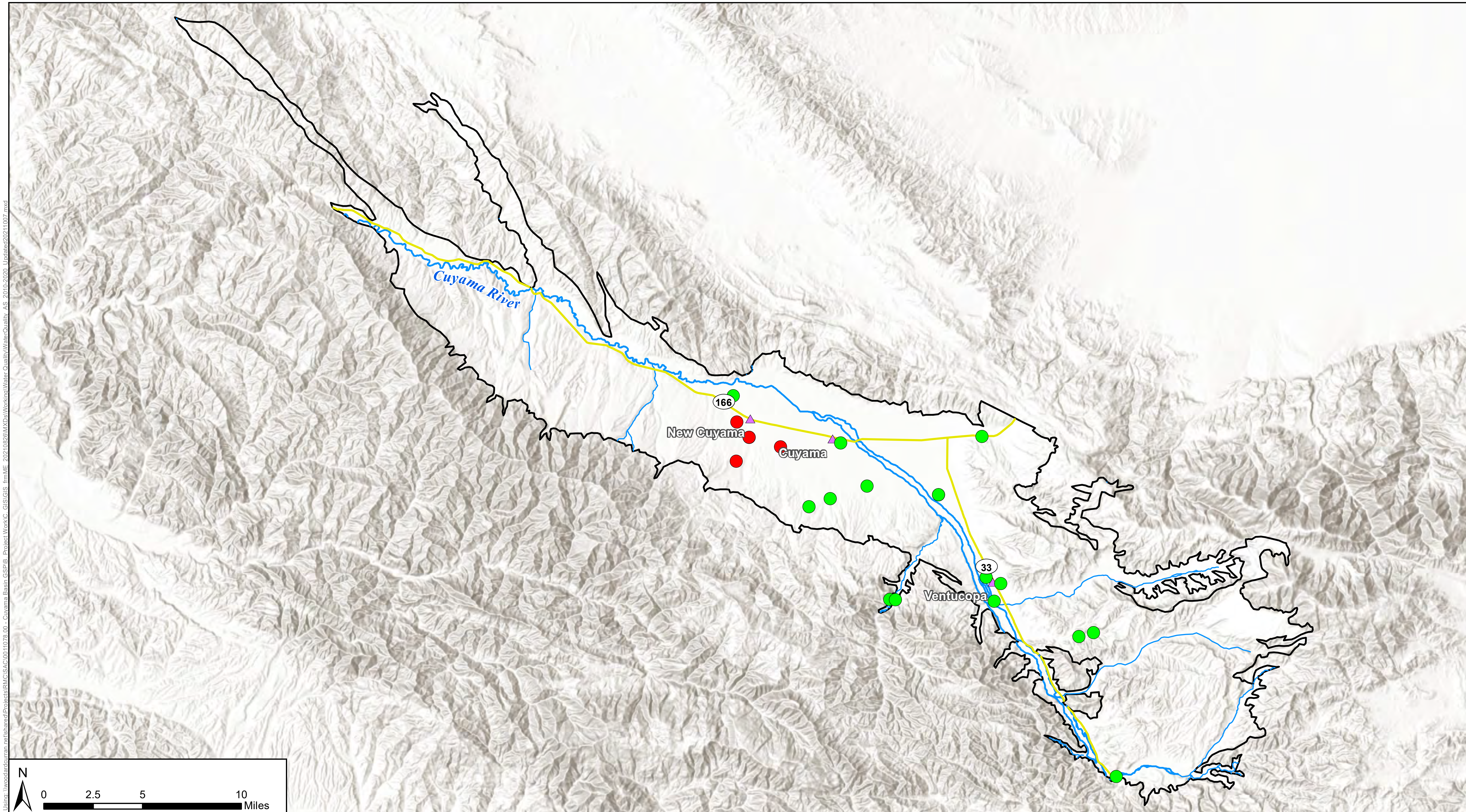

Figure 2-81: 2010-2020 Average Well Measurements of Arsenic, µg/L

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

October 2021

WOODARD & CURRAN

Legend

Aresenic (As), ug/L

- < 5 ug/L
- 5 - 10 ug/L
- 10 - 20 ug/L
- > 20 ug/L

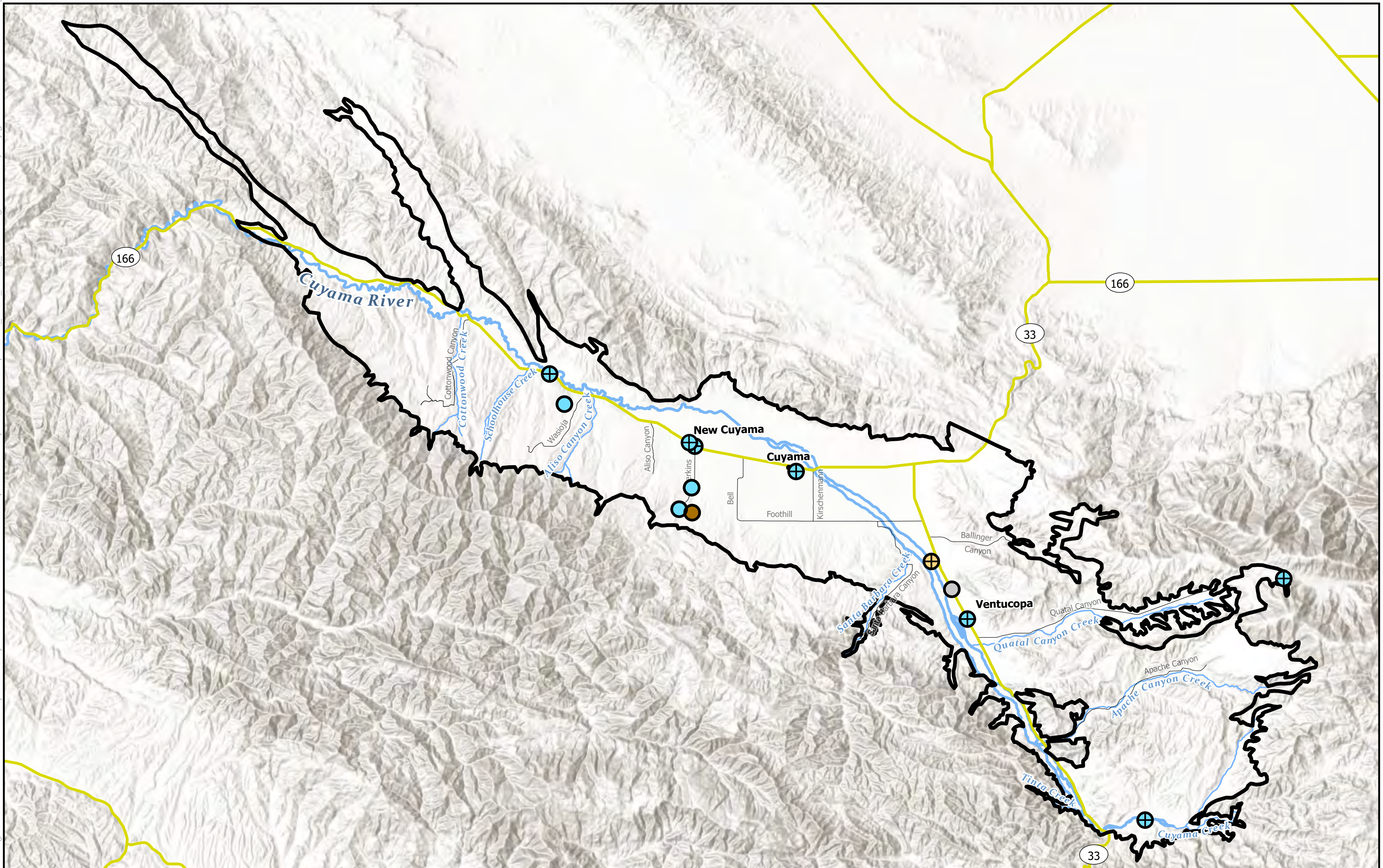

Figure 2-82: Sites with Water Quality Concerns

Cuyama Valley Groundwater Basin

Legend

Contaminant of Concern
- Alcohol
- Gas
- Lead
- Oil

Site Status
- Closed
- Open

- Highway
- Local Road
- Town
- Creek
- Cuyama River
- Cuyama Basin

N

0 1.75 3.5 7 Miles

Map Created: April 2024

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Cuyama Basin Groundwater Sustainability Agency

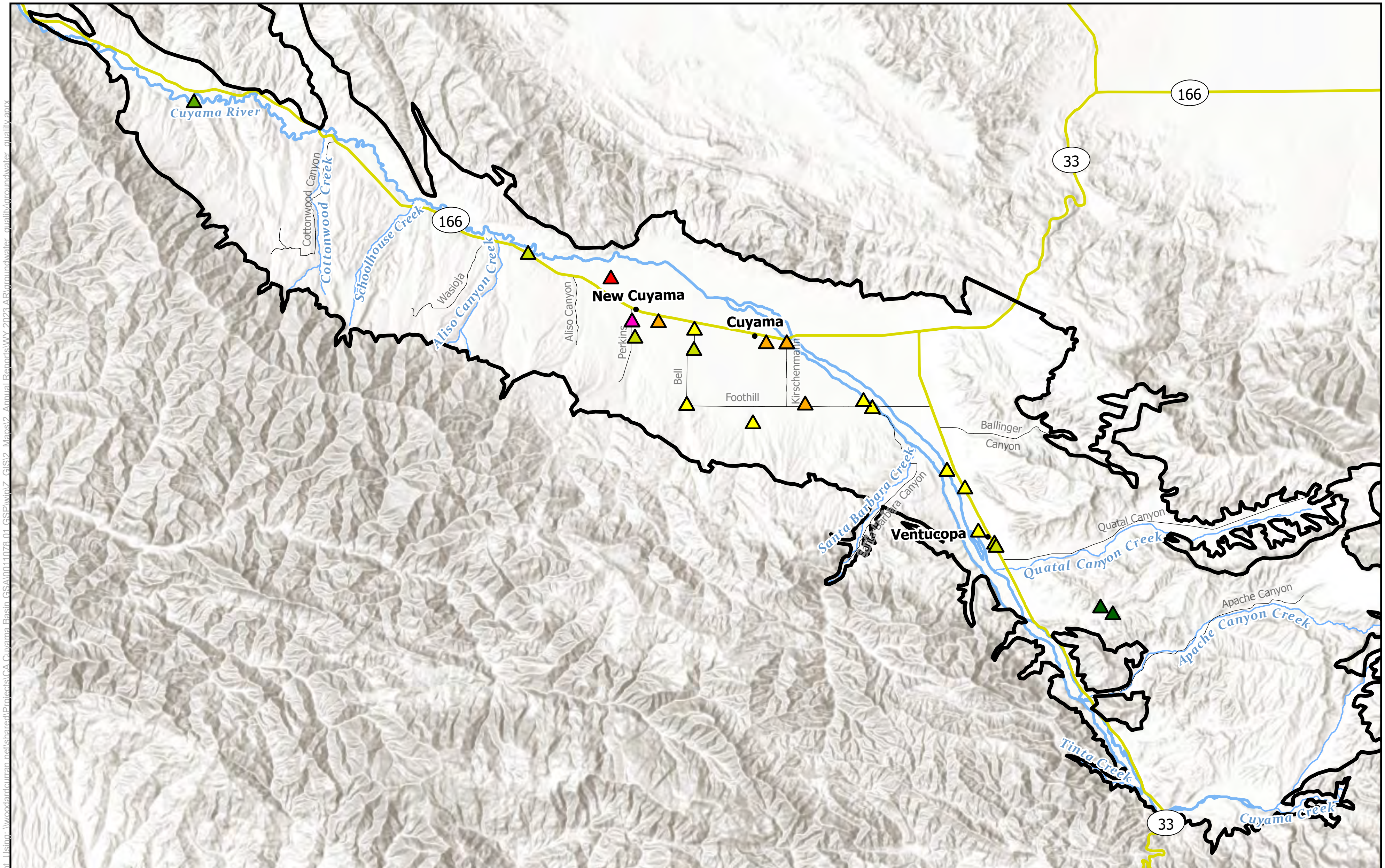

Figure 2-83: Groundwater Quality Measurements - TDS

2023 Data

Cuyama Valley Groundwater Basin

Legend

- < 500 mg/L
- 501 - 750 mg/L
- 751 - 1,000 mg/L
- 1,001 - 1,250 mg/L
- 1,251 - 1,500 mg/L
- 1,501 - 1,750 mg/L
- 1,751 - 2,000 mg/L
- 2,001 - 2,250 mg/L
- Highway
- Local Road
- Town
- Creek
- Cuyama River
- Cuyama Basin

N

0 1.25 2.5 5 Miles

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Cuyama Basin Groundwater Sustainability Agency

Map Created: March 2024

Figure Exported: 3/13/2024 By: DHunt

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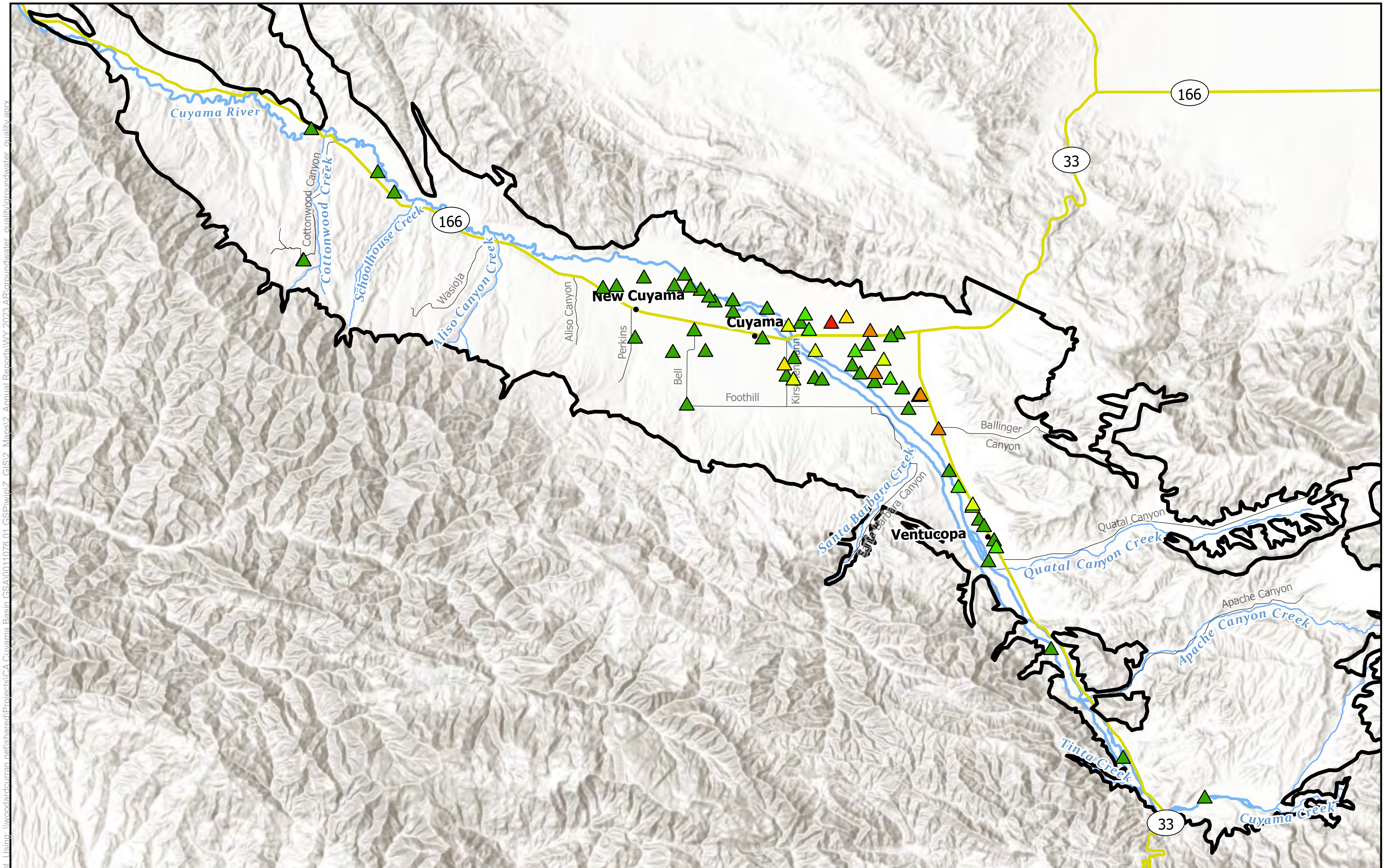


Figure 2-84: Groundwater Quality Measurements - Nitrate

Years 2022 and 2023

Cuyama Valley Groundwater Basin

Legend

- ▲ < 5 mg/L
- ▲ 5 - 8 mg/L
- ▲ 8 - 10 mg/L
- ▲ 10 - 15 mg/L
- ▲ 15 - 20 mg/L
- ▲ > 20 mg/L
- Highway
- Local Road
- • Town
- Creek
- Cuyama River
- Cuyama Basin

*Values from monitoring wells with multiple observations were averaged with respect to year sampled. **Nested well at this location.

N

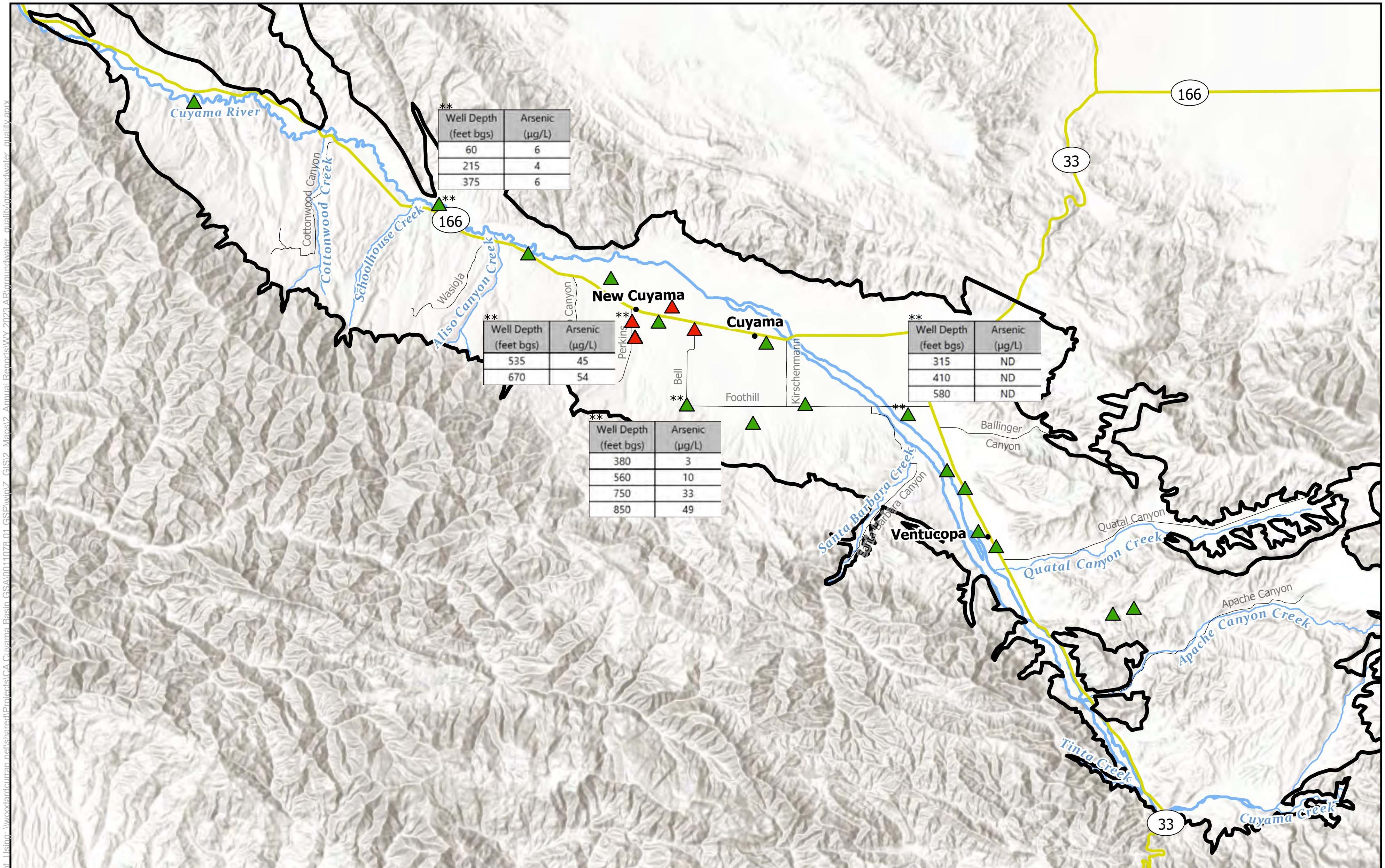
0 1.25 2.5 5 Miles

Map Created: April 2024

Woodard & Curran

Cuyama Basin Groundwater Sustainability Agency

Figure Exported: 4/30/2024 By: DHunt Using: \\woodardcurran.net\shared\Projects\CA Cuyama Basin GSA\0011078.01 GSP\wip\Z_GIS\2_Maps\2_Annual Reports\WY 2023 AR\groundwater_quality.aprx



Well Depth (feet bgs)	Arsenic (μg/L)
60	6
215	4
375	6

Well Depth (feet bgs)	Arsenic (μg/L)
535	45
670	54

Well Depth (feet bgs)	Arsenic (μg/L)
380	3
560	10
750	33
850	49

Well Depth (feet bgs)	Arsenic (μg/L)
315	ND
410	ND
580	ND

Figure 2-85: Groundwater Quality Measurements - Arsenic

Years 2022 and 2023

Cuyama Valley Groundwater Basin

Legend

- < 5 μg/L
- 5 - 8 μg/L
- 8 - 10 μg/L
- 10 - 15 μg/L
- 15 - 20 μg/L
- > 20 μg/L
- Highway
- Local Road
- Town
- Creek
- Cuyama River
- Cuyama Basin

*Values from monitoring wells with multiple observations were averaged with respect to year sampled. **Nested well at this location.

N

0 1.25 2.5 5 Miles

Woodard & Curran

Cuyama Basin Groundwater Sustainability Agency

Map Created: April 2024

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Figure Exported: 4/30/2024 By: DHunt Using: \\woodardcurran.net\shared\Projects\CA\Cuyama Basin GSA\0011078.01 GSP\wip\Z_GIS\2_Maps\2_Annual Reports\WY 2023 AR\groundwater_quality.aprx

Literature Review

The information contained in this literature review was compiled during the development of the GSP. In 1970, Singer and Swarzenski reported that TDS in the central portion of the Basin was in the range of 1,500 to 1,800 mg/L TDS, and that the cations that contributed to the TDS and the amount of TDS varied by location in the Basin. They also reported that TDS was lower (i.e., from 400 to 700 mg/L) in areas downstream from the Sierra Madre Mountains where TDS was made up of sodium or calcium bicarbonate, and higher (i.e., from 3,000 to 6,000 mg/L) in wells close to the Caliente Range and in the northeastern part of the valley. Singer and Swarzenski stated that the high TDS was generated by the mixing of water from marine rocks with more recent water from alluvium. They determined that groundwater movement favors movement of brackish water from the north of the Cuyama River toward areas of groundwater depletion, and that return of some water applied during irrigation and needed for leaching the soil carries dissolved salts with it to the water table (Singer and Swarzensky, 1970).

In 2008, USGS reported GAMA Program results. The GAMA Program sampled 12 Basin wells for a wide variety of constituents. Figure 2-86 shows the location of GAMA Program wells. The GAMA Program identified that specific conductance, which provides an indication of salinity, ranged from 637 to 2,380 microsiemens per centimeter (µS/cm) across the study's 12 wells. The GAMA Program study reported that the following constituents were not detected at levels above the MCL for each constituent in any samples for the following constituents:

- Pesticides or pesticide degradates
- Gasoline and refrigerants
- Aluminum, antimony, barium, beryllium, boron, cadmium, copper, iron, and lead
- Ammonia and phosphate
- Lithium, molybdenum, nickel, selenium, strontium, thallium, tungsten, uranium, vanadium, and zinc
- Bromide, calcium, chloride, fluoride, iodide, magnesium, potassium, silica, and sodium

The GAMA Program reported that there were detections at levels above the MCL for the following constituents:

- Manganese exceeded its MCL in two wells
- Arsenic exceeded the MCL in one well
- Nitrate exceeded the MCL in two wells
- Sulfate exceeded its MCL in eight wells
- TDS exceeded its MCL in seven wells
- VOCs detected in one well

In 2011, SBCWA reported that TDS in the Basin typically ranged from 1,500 to 1,800 mg/L in the main part of the Basin, while the eastern portion of the Cuyama Badlands near Ballinger, Quatal, and Apache Canyons had better water quality with TDS typically ranging from 400 to 700 mg/L. SBCWA noted spikes in TDS in a Badlands well following the wet rainfall years of 1969 and 1994 and stated that the spikes are attributable to overland flow from rainfall which is flushing the upper part of the Basin after dry periods.

SBCWA reported that boron is generally higher in the upper part of the Basin and is of higher concentration in the uplands than in the deeper wells in the central part of the Basin. Toward the northeast end of the Basin at extreme depth there exists poor quality water, perhaps connate (trapped in rocks during deposition) from rocks of marine origin.

SBCWA also reported: "There was little change in TDS, calcium, magnesium, nitrates and sulfates during the 2009- 2011 period. In some cases, concentrations of these nutrients actually fell during the period, most likely due to a lack of rainfall, recharge and flushing of the watershed. As the Cuyama watershed is mostly dry, water quality data must be examined with caution as sometimes overland flow from rainfall events "flushes" the watershed and inorganic mineral concentrations actually peak during storm flows. Typically, in other areas of Santa Barbara County mineral concentrations are diluted during widespread storm runoff out of natural watersheds."

In 2013, USGS reported that they collected groundwater quality samples at 12 monitoring wells, 27 domestic wells, and two springs for 53 constituents including: field parameters (water temperature, specific conductance, pH, DO, alkalinity), major and minor ions, nitrate, trace elements, stable isotopes of hydrogen and oxygen, tritium and carbon-14 activities, arsenic, iron, and chromium. Figure 2-87 shows the USGS sampling locations, which were presented in a figure from their report. The USGS reported sampling result as follows:

- Groundwater in the alluvial aquifer system has high concentrations of TDS and sulfate
- 97 percent of samples had concentrations greater than 500 mg/L for TDS
- 95 percent of samples had concentrations greater than 250 mg./L for sulfate
- 13 percent of samples had concentrations greater than 10 mg/L for nitrate
- 12 percent of samples had concentrations greater than 10 ug/L for arsenic
- One sample had concentrations greater than the MCL for fluoride
- Five samples had concentrations greater than 50 mg/L for manganese
- One sample had concentration of iron greater than 300 mg/L for iron
- One sample had concentration of aluminum greater than 50 mg/L

USGS reported that nitrate was detected in five locations above the MCL of 10 mg/L. Four wells where nitrate levels were greater than the MCL were in the vicinity of the center of agricultural land-use area. Irrigation return flows are a possible source of high nitrate concentrations. There was a decrease in concentrations with depth in the agricultural land use area which indicated the source of higher nitrate concentrations likely to be near the surface. The lowest nitrate levels were outside the agricultural use area, and low concentrations of nitrate (less than 0.02 mg/L) in surface water samples indicated surface water recharge was not a source of high nitrate

The USGS reported that arsenic was found in greater concentration than the MCL of 10 ug/L in four of the 33 wells sampled, and samples of total chromium ranged from no detections to 2.2 ug/L, which is less than the MCL of 50 ug/L. Hexavalent chromium ranged from 0.1 to 1.7 ug/L which is less than the MCL of 50 ug/L.

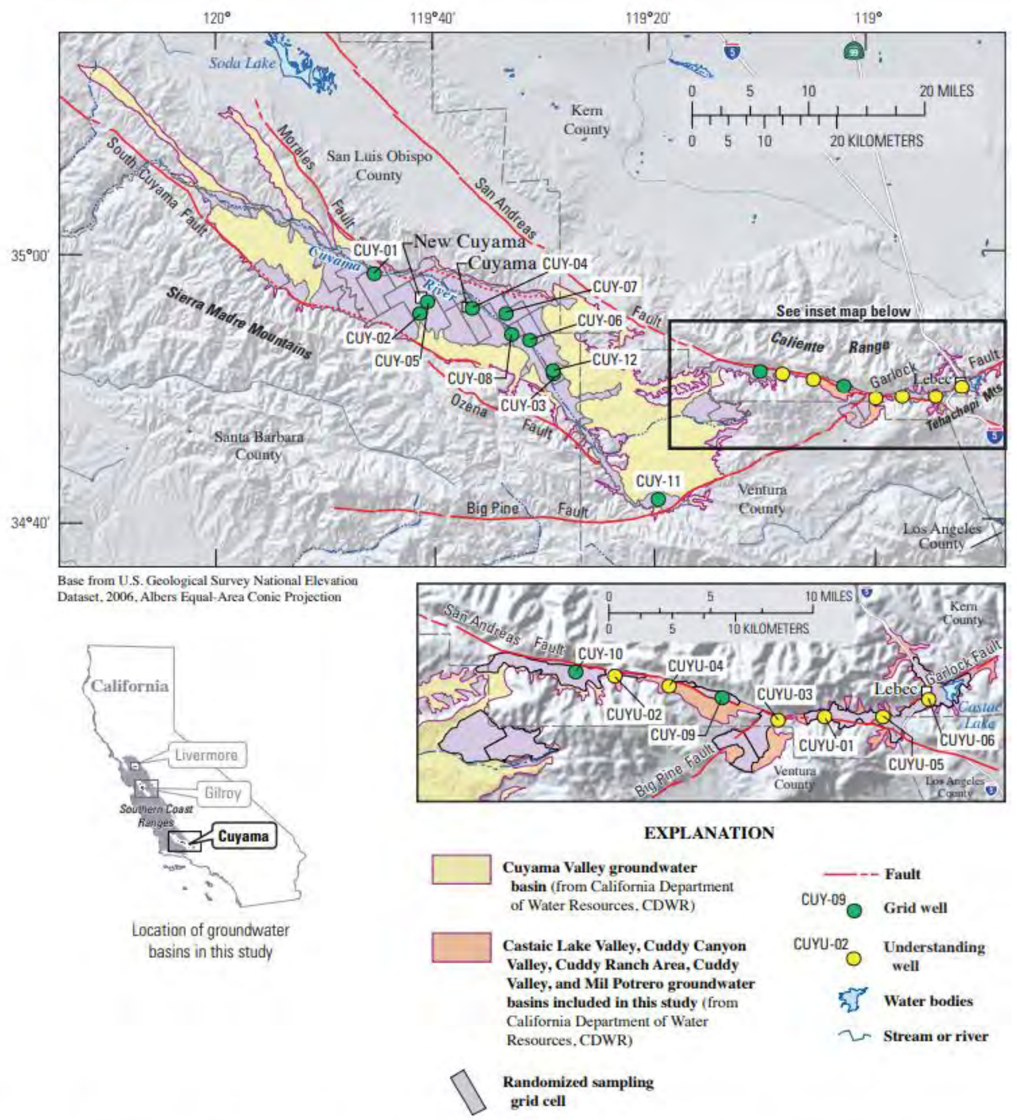

Figure 5. The South Coast Interior Basins Groundwater Ambient Monitoring and Assessment (GAMA) study unit showing the distribution of the Cuyama study-area grid cells, the location of sampled grid wells and understanding wells, the Cuyama Valley, Castaic Lake Valley, Cuddy Canyon Valley, Cuddy Ranch Area, Cuddy Valley, and Mil Potrero groundwater-basin boundaries (as defined by the California Department of Water Resources, CDWR), major cities, major roads, topographic features, and hydrologic features. Alphanumeric identification numbers for grid wells

Source: USGS, 2008

Figure 2-86: Locations of GAMA Sample Locations

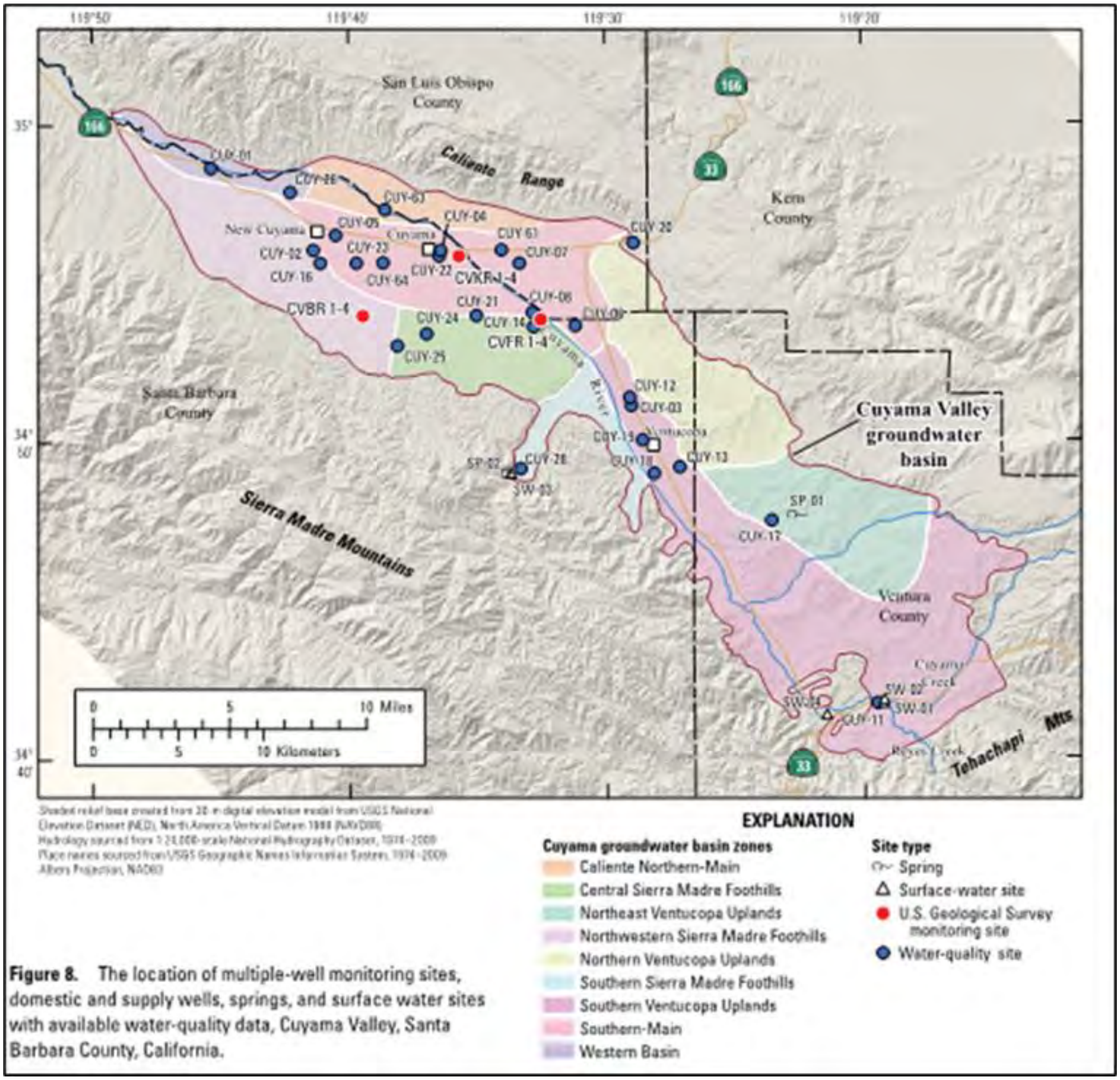

Figure 8. The location of multiple-well monitoring sites, domestic and supply wells, springs, and surface water sites with available water-quality data, Cuyama Valley, Santa Barbara County, California.

USGS 2013c

Figure 2-87: USGS 2013c Water Quality Monitoring Sites

2.2.10 Interconnected Surface Water Systems

The following content reflects what was included in the 2020 GSP. DWR is in the process of developing additional guidance documents to assist GSAs in addressing the interconnected surface waters sustainability indicator. At this time, those guidance documents have not been published, but the CBGSA plans to utilize those resources when they become available for future updates to the GSP and for future ISW implementation.

The CBWRM, described in Appendix C, was used to analyze interactions between surface water flows in the Basin. Surface water flows in the model were assigned reaches, five on the Cuyama River, and four for creeks that run off into the river. These reaches are shown in Figure 2-88, with each reach assigned a number. Results of the analysis are shown in Table 2-3 in AF for each reach. Seven years had higher total depletions than 2017, which had a depletion estimate of 5,016 AF. Reach characteristics are listed below.

Reach 1 – Alamo Creek: This reach was gaining in each year analyzed, with an average gain of 380 AF per year. The highest gain of 692 AF was in 1998, and the lowest gain was 192 AF in 2016.

Reach 2 – Cuyama River, from edge of basin to Alamo Creek: This reach was losing in each year analyzed, with an average loss of 26 AF. The smallest loss was 1 AF in 2007, and the largest loss was -109 AF in 2005.

Reach 3 – Cuyama River from Alamo Creek, to Quatal Canyon Creek: This reach was mostly gaining in each year and lost in one year. The average of gains and losses was a gain of 931 AF. The highest gain of 2,781 was in 1998, and the loss of 300 AF occurred in 2017.

Reach 4 – Quatal Canyon Creek: This reach was losing in each year analyzed, with an average loss of 83 AF. The smallest loss was 1 AF in 2007, and the largest loss was -347 AF in 1998.

Reach 5 – Cuyama River from Quatal Canyon Creek to Santa Barbara Canyon Creek: This reach was losing in each year analyzed, with an average loss of 926 AF. The smallest loss was 180 AF in 2013, and the largest loss was 2,394 AF in 2005.

Reach 6 – Santa Barbara Canyon Creek: This reach was gaining in each year analyzed, with an average gain of 95 AF per year. The highest gain of 222 AF was in 1999, and the lowest gain was 222 AF in 2016.

Reach 7 – Cuyama River from Santa Barbara Canyon Creek to Schoolhouse Canyon Creek: This reach was losing in each year analyzed, with an average loss of 5,218 AF. The smallest loss was 797 AF in 2013, and the largest loss was 16,472 AF in 1998

Reach 8 – Schoolhouse Canyon Creek: This reach was gaining in each year analyzed, with an average gain of 175 AF/year. The highest gain of 249 AF was in 1998, and the lowest gain was 134 AF in 2017.

Reach 9 – Cuyama River west of Schoolhouse Canyon Creek: This reach was gaining in each year analyzed, with an average gain of 1,333 AF/year. The highest gain of 2,743 AF was in 1998, and the lowest gain was 750 AF in 2015.

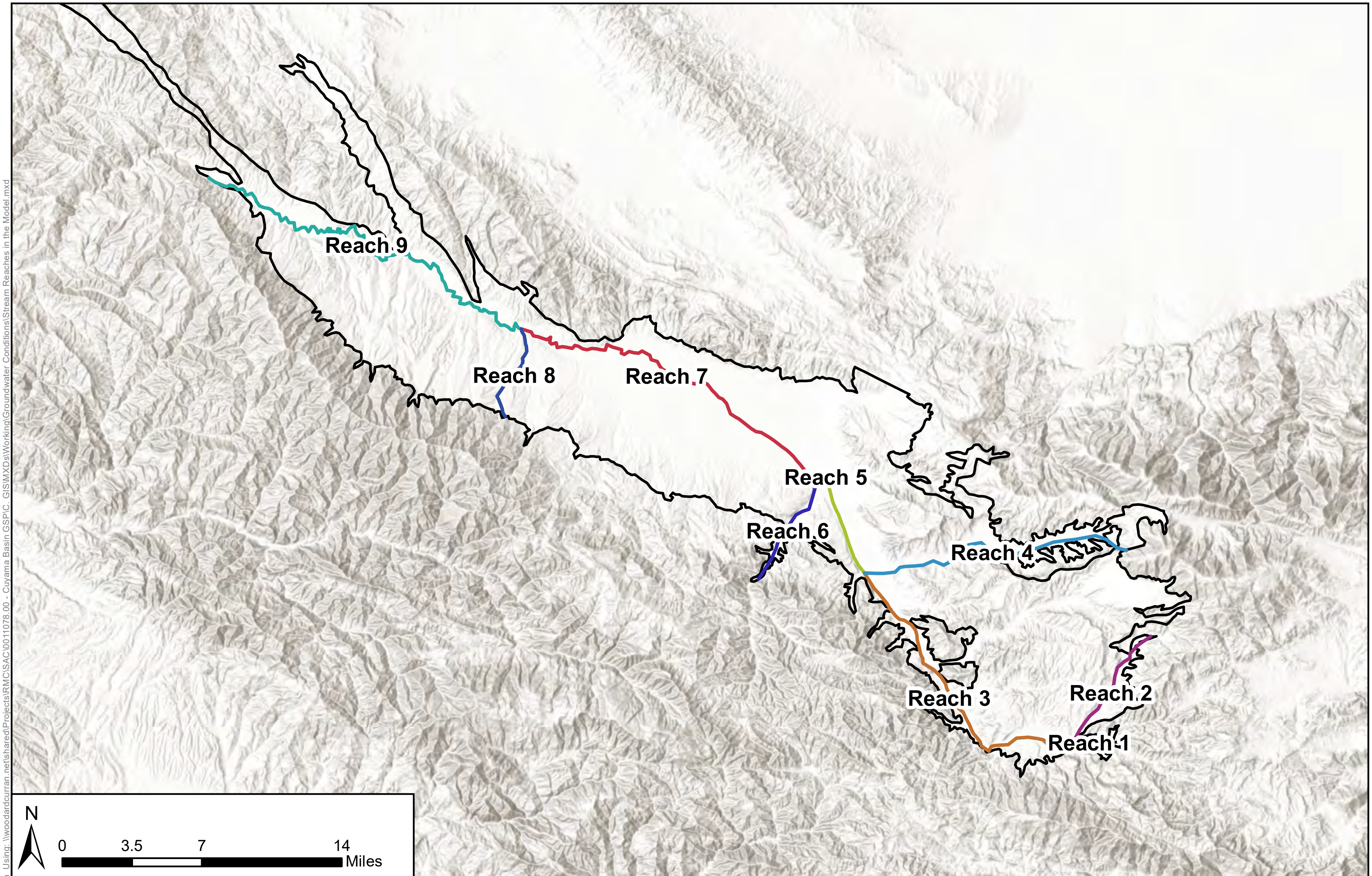

Figure 2-88: Stream Reaches Used in Cuyama Groundwater Model

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

April 2019

WOODARD & CURRAN

Legend

Cuyama Basin

Stream Reach

1
2
3
4
5
6
7
8
9

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Table 2-3: Stream Depletion by Reach

Year	Reach 1 (AF)	Reach 2 (AF)	Reach 3 (AF)	Reach 4 (AF)	Reach 5 (AF)	Reach 6 (AF)	Reach 7 (AF)	Reach 8 (AF)	Reach 9 (AF)	Total (AF)
1998	692.9	-100.7	2780.8	-346.8	-2182.5	164	-16471.5	249.3	2742.9	-12471.6
1999	547.1	-4.3	2636.1	-15.1	-561.3	222.1	-3060.8	234.1	2383.5	2381.4
2000	492.6	-19.3	1915.6	-60.8	-973.6	150	-4602.7	218.3	2152.4	-727.5
2001	460.6	-55.1	1300.5	-194.6	-1369.1	134	-7776	197.8	1906.3	-5395.6
2002	376.6	-1.2	1519.8	-2	-268.8	99.3	-1215.9	198.7	1783.1	2489.6
2003	340	-25.8	463.2	-78	-1247.9	75.8	-6156.6	189.6	1320.9	-5118.8
2004	293	-13.5	706.4	-37.2	-711.3	61.6	-3370.3	183.1	1447.5	-1440.7
2005	525.5	-109	668.7	-254.7	-2394	152.8	-14950.5	178	1115.9	-15067.3
2006	583.8	-23	1112.7	-106.3	-1302.3	155.6	-7026.4	172.2	1089.5	-5344.2
2007	455.6	-0.7	1542.1	-0.8	-269.9	114.1	-1327.9	172.3	1328.8	2013.6
2008	426.3	-26.6	797.8	-92.4	-1204.7	103.2	-5902.4	160.6	1105.7	-4632.5
2009	361.8	-8.3	956.6	-33.7	-540.2	77.5	-3191.7	164.2	997.3	-1216.5
2010	347.2	-29.4	294.2	-74.9	-1091.6	72.6	-5843.1	158.2	836	-5330.8
2011	332.3	-48.6	397.4	-191.5	-1518.5	79.5	-7937.3	143.2	899.7	-7843.8
2012	274.1	-7.7	650.6	-28.2	-457.8	60.6	-2720.4	153.9	1091.8	-983.1
2013	244.9	-0.9	768.7	-4.7	-180.2	46.9	-797.2	150.9	1169	1397.4
2014	226.4	-11	183.1	-31.2	-548	37	-2429.6	147.9	971.8	-1453.6
2015	211.9	-7.7	211.7	-16.5	-350.6	30.2	-1968.7	143.9	749.5	-996.3
2016	191.5	-8.6	16.8	-23	-447.1	27.1	-2713	141.1	766.7	-2048.5
2017	208.2	-19.9	-300.4	-67.8	-906	34.5	-4900.3	133.7	801.8	-5016.2
Annual Average	379.6	-26.1	931.1	-83.0	-926.3	94.9	-5218.1	174.6	1333.0	-3340.3

2.2.11 Groundwater Dependent Ecosystems

A groundwater dependent ecosystem (GDE) is defined by SGMA emergency regulations in Section 351(m) as referring "to ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface." Section 354.16(g) of the same regulations requires identification of GDEs in the Basin using data available from DWR, or the best available information. GDEs are not mentioned elsewhere in the emergency regulations. Because the Natural Communities Commonly Associated with Groundwater (NCCAG) dataset includes a number of estimates, DWR recommends the verification of NCCAG-identified locations by a licensed biologist.

DWR provided the NCCAG dataset through the SGMA data portal at https://gis.water.ca.gov/app/NCDatasetViewer/ . The NCCAG dataset was compiled using a set of six pre-existing dataset sources and is explained in detail at: https://gis.water.ca.gov/app/NCDatasetViewer/sitedocs/# . Figure 2-89 shows the locations of areas identified as NCCAG in the dataset.

A Woodard & Curran licensed wetlands biologist verified the NCCAG dataset using remote sensing techniques supported by in-person field verification. This work is documented in a Technical Memorandum (Appendix D). The analysis was performed by groupings, and the results of analysis at the groupings level is shown in Figure 2-90. Analysis concluded that there were 123 probable GDEs and 275 probable non-GDEs in the Basin.

Since the GSP was adopted, the CBGSA has installed 3 new wells in the vicinity of GDEs to measure groundwater levels and their impact on beneficial users. These are shallow wells, which are often called piezometers. These wells include:

- Opti well 911 is completed to a depth of 45 feet bgs with a screen interval from 10-40 feet bgs.
- Opti well 910 is completed to a depth of 50 feet bgs with a screen interval from 25-45 feet bgs.
- Opti well 909 is completed to a depth of 90 feet bgs with a screen interval from 50-80 feet bgs.

Figure 2-91 shows the well locations of these new GDE wells. Additionally, this figure shows seven representative monitoring wells identified as wells that monitor groundwater levels near GDEs and have minimum thresholds based on a GDE protection depth as described in Section 5.2.2. These wells were identified because they fall within 2000 feet of potential GDEs, with some exceptions for topography. These representative monitoring wells are Opti wells 2, 114, 568, 830, 832, 833, and 836.

The CBGSA now uses these 10 wells (three new wells and seven existing groundwater level representative monitoring wells) to monitor groundwater levels that help identify potential impacts to groundwater dependent ecosystems. Through these monitoring wells and the results of the fieldwork and analysis conducted by the licensed wetlands biologist, the CBGSA no longer relies on the NCAA remote sensing database for estimating or monitoring probable GDE locations.

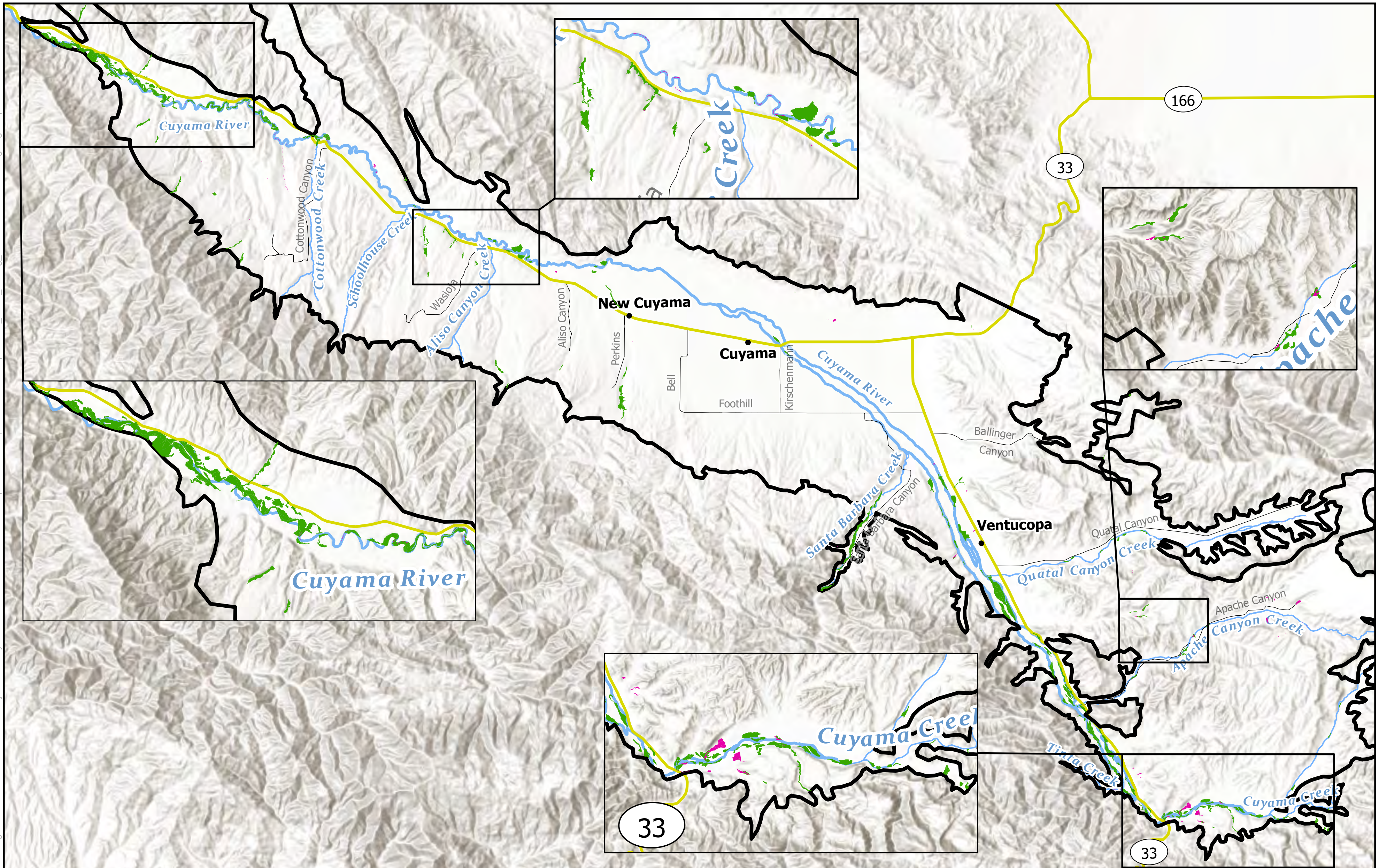

Figure 2-89: Potential GDEs Identified

2018 i02 NCCAG

Cuyama Valley Groundwater Basin

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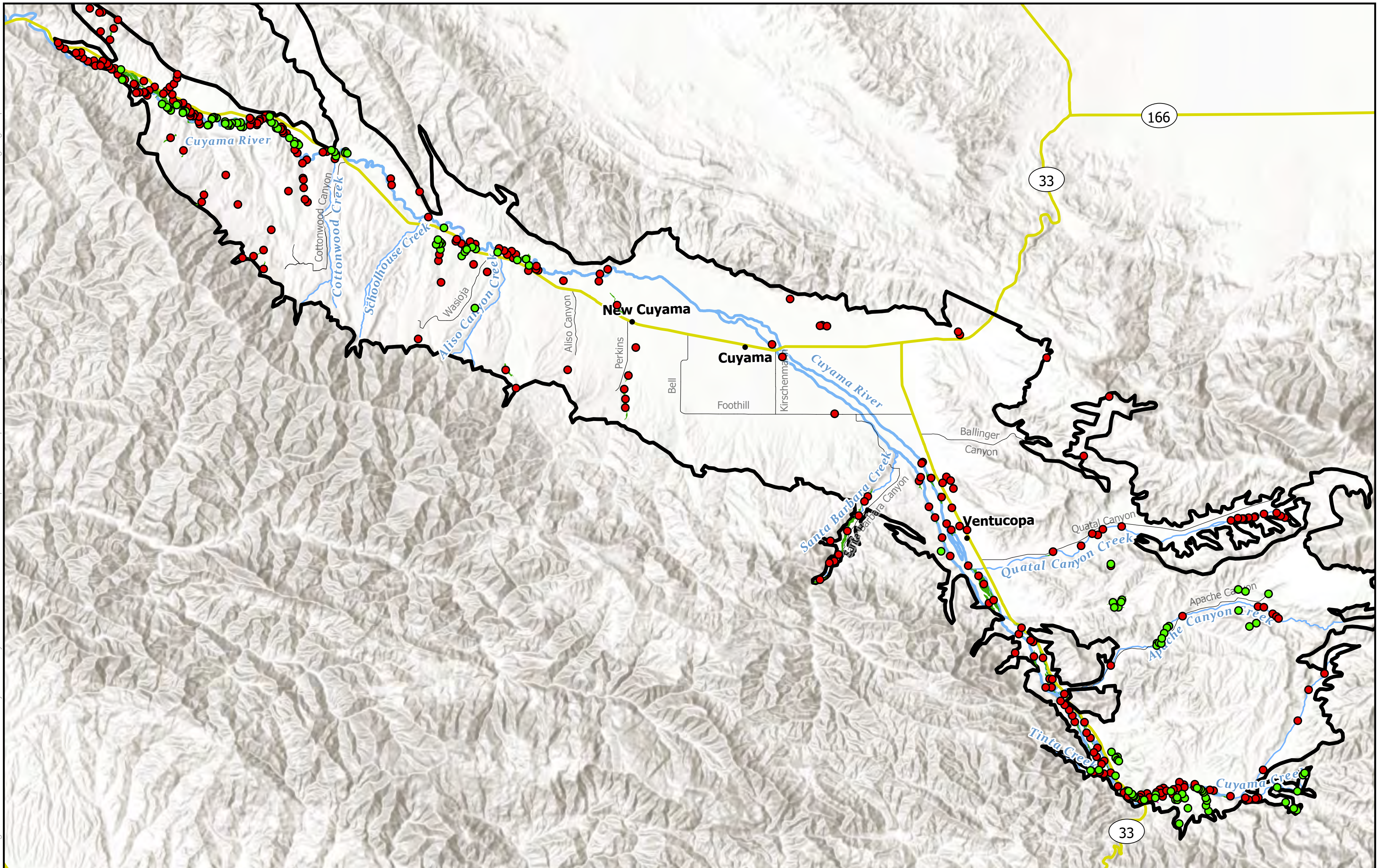

Figure 2-90: GDE Ground Truthing Analysis Results

Cuyama Valley Groundwater Basin

Legend

- Probable GDEs
- Probable Non-GDEs
- GDE Vegetation
- GDE Wetland
- Highway
- Local Road
- Town
- Creek
- Cuyama River
- Cuyama Basin

N

0 1.25 2.5 5 Miles

Woodard & Curran

Cuyama Basin Groundwater Sustainability Agency

Map Created: March 2024

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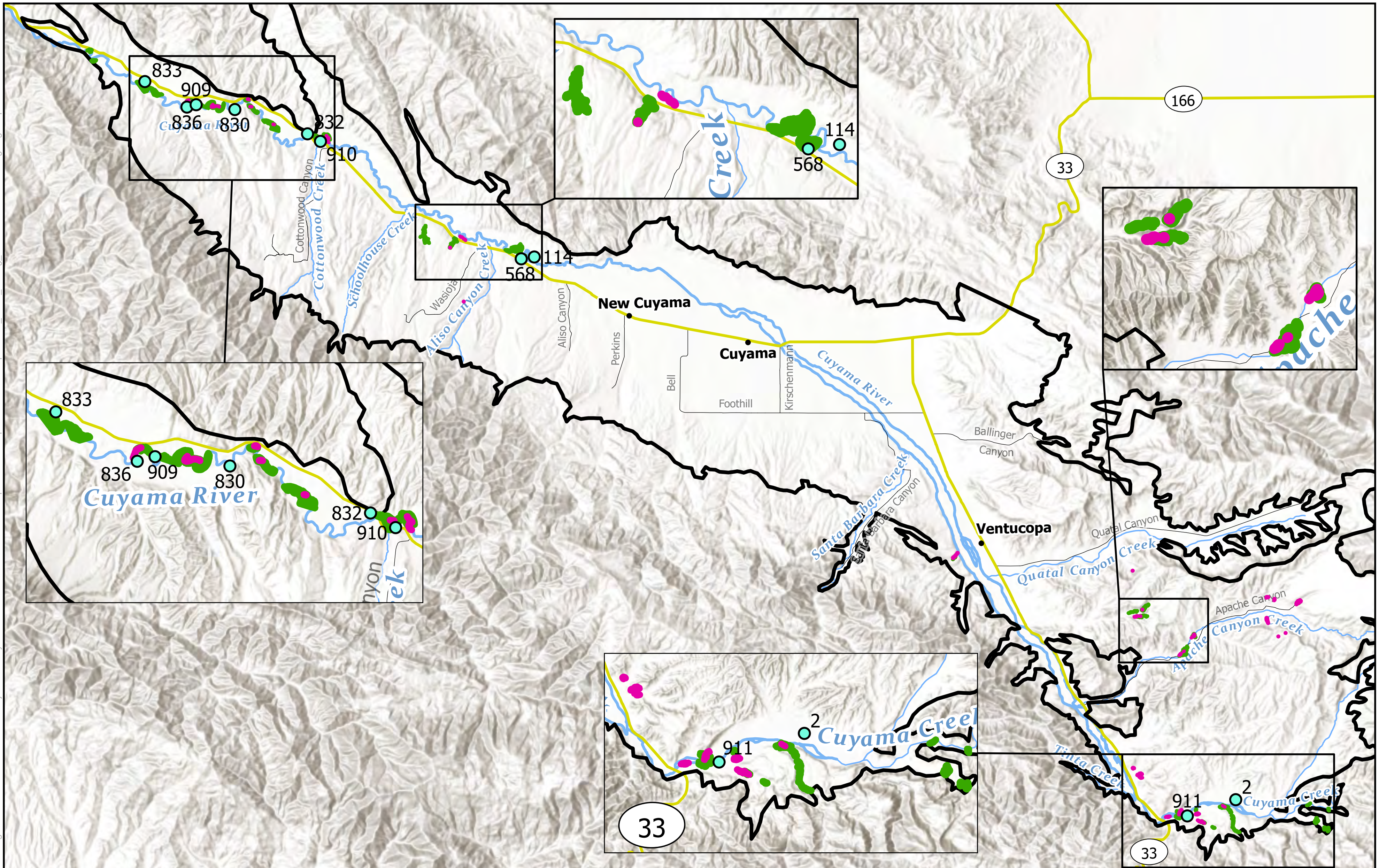


Figure 2-91: Probable GDEs Based on Analysis

Cuyama Valley Groundwater Basin

Legend

- Monitoring Well
- GDE Vegetation*
- GDE Wetland*
- Highway
- Local Road
- Town
- Creek
- Cuyama River
- Cuyama Basin

*GDE Vegetation and Wetland boundaries have been buffered 300 feet to improve visibility.

N

0 1.25 2.5 5 Miles

Map Created: June 2024

2.2.12 Data Gaps

Groundwater conditions data gaps were identified during the development of this GSP, and when additional questions were asked by stakeholders during GSP development. Since that time, many of these data gaps have been addressed. This section summarizes the data gaps that were described in the GSP and subsequent CBGSA actions to address them.

- Due to sporadic monitoring by a variety of monitoring entities, a long period of record of monitoring for groundwater levels does not exist in many areas in the Basin.
    - The CBGSA has implemented a quarterly monitoring program for the measurement of groundwater levels throughout the Basin. This program allows the CBGSA to have consistent and regular monitoring going forward. This data gap has been addressed to the extent possible. The monitoring program is described in Chapter 4. Additionally, the CBGSA has reclassified the lack of historical data as a data limitation, but not a data gap. As outlined in the SGMA regulations, a "data gap" must be addressed by a GSA. However, historical data is out of the CBGSA's ability to rectify, and therefore, it is inappropriate to label a lack of historical data as such
- The depths where arsenic occurs are not known, making setting sustainability thresholds for arsenic not feasible.
    - There is limited information on depth and location of elevated arsenic in the Basin. The one public water supply well owned and operated by CCSD, which has levels of arsenic above the EPA standards, is currently in the process of being replaced with a new in a location where arsenic concentrations are much lower. The CCSD is also looking at implementing treatment options for the current municipal water supply well. Through these changes, arsenic is not impacting beneficial uses or users within the Basin and therefore the CBGSA is not setting sustainability thresholds for arsenic.
- The Cuyama River is not gaged inside the Cuyama Basin, so flows of the river in the Basin have been estimated based on available precipitation data and flow measurements at downstream gages.
    - The CBGSA has installed a new stream gage on the Cuyama River and worked to re-activate an additional gage located within the Basin. Data is currently being collected by the USGS and monitored by the CBGSA.
- Subsidence in the central portion of the Basin where groundwater levels are lowest is not monitored nor understood.
    - The state provides InSAR data that can now be used to monitor subsidence within the Basin. Additionally, there are several CGPS stations in and around the Basin, with one in the central portion near the Cuyama High School which was verified in 2024 as active and accurate. After additional analysis during GSP implementation, results indicated that there were no impacts to critical infrastructure in the Basin due to subsidence, nor impact to any other beneficial uses or users of groundwater in the Basin. While additional monitoring in the

central portion of the Basin is expected to occur in the future, the CBGSA does not see an immediate need for the installation of additional subsidence monitoring stations.

- Vertical gradients in the majority of the Basin are not understood due to the lack of wells with completions of different depths located near each other.
    - As described in Section 2.2.3, DWR installed multi-completion (or nested) wells at three locations and the CBGSA has installed multi-completion wells at six additional locations throughout the Basin. These nested wells are completed at different depths to evaluate vertical gradients. Some of the USGS wells have been equipped with pressure transducers to automatically record groundwater levels on a programmed time interval. Readings are downloaded quarterly. The CBGSA also plans to equip the new multi-completion wells that have been drilled with grant funding from DWR with transducers. Other wells are monitored manually at a quarterly frequency. These wells allow the CBGSA to document and monitor changes in vertical gradients at multiple locations.
- Groundwater salinity in the Basin has a number of natural sources, but these sources are not discreetly identified.
    - The CCSD has installed a new well that monitors TDS quarterly and the CBGSA has measured TDS in a number of wells as part of its fault investigation, as described in Section 2.1.5. Natural sources of TDS are still not discreetly identified throughout the Basin, but additional work has been done to monitor salinity in groundwater. While additional data may be helpful, the CBGSA has determined through its data analysis during GSP implementation that regulating TDS and setting thresholds for TDS falls outside of the GSA's authority.
- GDEs could be evaluated in greater detail.
    - Section 2.2.9 describes the groundwater dependent ecosystem studies that were completed historically utilizing the NCCAG database. Since that time, the CBGSA has installed three new wells (piezometers) and monitored an additional seven groundwater level representative wells at locations identified as at or near groundwater dependent ecosystems. These 10 wells help the CBGSA understand groundwater levels near the identified potential GDEs throughout the Basin and their potential impact on GDEs.
- Faults are not well understood with regard to the degree they represent a barrier to flow and at what depth below the surface.
    - The CBGSA completed an investigation of the Russell and Santa Barbara Canyon Faults/fault zones as described in Sections 2.1.5. These are the two major faults identified by USGS as impacting groundwater flow. The Santa Barbara Canyon Fault zone includes an unnamed thrust fault and together they juxtapose formations with different water-bearing capacity that results in a significant difference in groundwater elevation across the fault zone. The fault zone is thought to restrict groundwater flow but is not literally a barrier to groundwater flow. Groundwater quality to the south and north of the fault zone is very similar. The Russell Fault zone does not appear to restrict groundwater flow. Depth to groundwater is consistent to the east and west of the fault zone. While the impact on

groundwater flow is not fully understood for the Santa Barbara Canyon fault zone in particular, a significant investigation was completed to better understand impacts of both faults. The CBGSA may consider an additional investigation in the future.

- The size of the Basin regarding groundwater in storage is not well understood.
    - The CBGSA has undertaken a complete update of the water resources model, which uses groundwater levels to predict storage. Significant progress has been made in identifying the storage capacity of each layer and calibrating it to current groundwater level trends. This analysis has been addressed to the extent possible, given the data available in the Basin.
- Information about many of the wells in the Basin is incomplete, and additional information is needed regarding well depths, perforation intervals and current status.
    - Several data collection efforts by the CBGSA have yielded additional information about wells within the Basin. The CBGSA conducted a well survey in 2021 on its groundwater level representative network yielding more accurate and updated construction and survey data such as ground surface elevations and reference point elevations. Additionally, the CBGSA has sent out surveys and worked with Basin stakeholders and landowners to get as much construction information as possible and categorize all wells in the Basin as either inactive or active to use in all future analyses. This information has been updated in the CBGSA's online Opti DMS.

2.3 Basin Settings: Water Budget

This section describes the historical, current and projected water budgets for the Basin. As defined by SGMA regulations, this section quantifies the following:

- Total surface water entering and leaving a basin by water source type
- Inflow to the groundwater system by water source type
- Outflows from the groundwater system by water use sector
- The change in the annual volume of groundwater in storage between seasonal high conditions
- If overdraft conditions occur, a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions
- The water year type associated with the annual supply, demand, and change in groundwater stored
- An estimate of sustainable yield for the Basin

2.3.1 Useful Terms

This section of Chapter 2 describes components of water budgets in the Basin. The terms listed here are intended as a guide for readers and are not a definitive definition of any term.

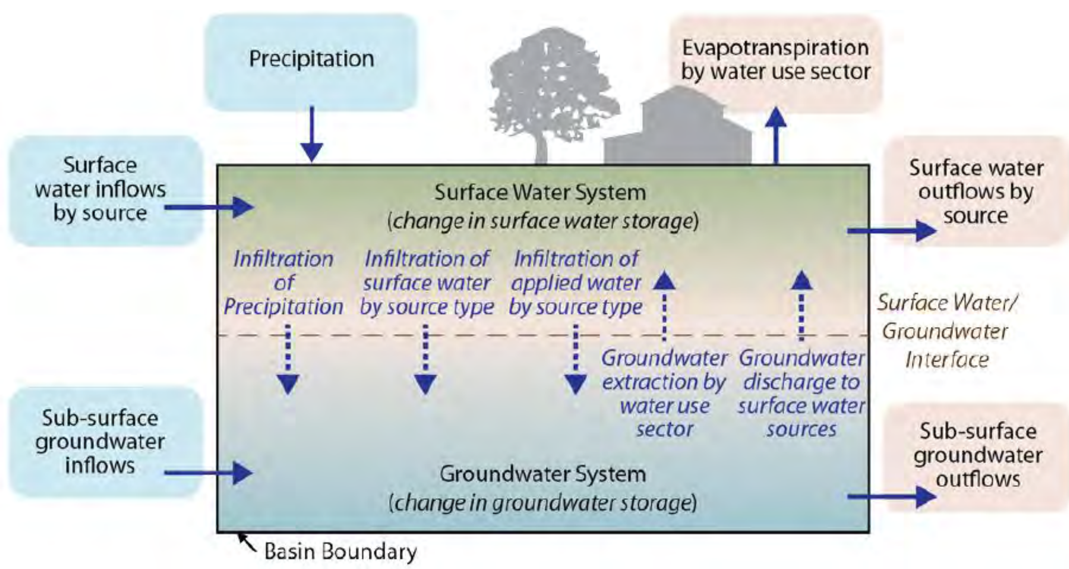
- **Precipitation** – Precipitation is the volume of rainfall that travels from the soil zone to the unsaturated (vadose) zone of the groundwater aquifer.
- **Applied Water** – Applied water is the volume of water that is applied by an irrigation system to assist crop and pasture growth.
- **Evapotranspiration** – Evapotranspiration is the volume of water entering the atmospheric system through the combined process of evaporation from soil and plant surfaces and transpiration from plants.
- **Domestic Water Use** – Domestic water use is the volume of water used for indoor household purposes, including potable and non-potable water provided to households by a public water supplier (domestic deliveries) and self-supplied water.
- **Deep Percolation** – Deep percolation is the volume of applied water and precipitation that travels from the soil zone to the unsaturated (vadose) zone of the groundwater aquifer.
- **Runoff** – Runoff is the volume of water flowing into the surface water system in a water budget zone from precipitation over the land surface.
- **Stream Seepage** – Stream seepage is the volume of water entering the groundwater system from rivers and streams.
- **Subsurface Inflow** – Subsurface inflow is the volume of water entering as groundwater into the groundwater system through its subsurface boundaries.

- **Change in Storage** – Change in storage is the net change in the volume of groundwater stored in the underlying aquifer.
- **Overdraft –** Overdraft is the long-term negative net change in volume of groundwater stored in the underlying aquifer.
- **Sustainable Yield** – Sustainable yield is the average annual groundwater pumping that can be sustained without any long-term negative net change in groundwater storage.

2.3.2 Water Budget Information

This water budget was developed to provide a quantitative accounting of water entering and leaving the Basin. Water entering the Basin includes water entering at the surface and entering through the subsurface. Similarly, water leaving the Basin leaves at the surface and through the subsurface. Water enters and leaves naturally, such as through precipitation and streamflow, and through human activities, such as pumping and recharge from irrigation. Figure 2-92 presents a vertical slice through the land surface and aquifer to summarize the water balance components used during analysis.

The values presented in the water budget provide information about historical, current, and projected conditions as they relate to hydrology, water demand, water supply, land use, population, climate change, sea-level rise (which is not applicable in the Basin), groundwater and surface water interaction, and subsurface groundwater flow. This information can help manage groundwater om the Basin by identifying the scale of different uses, highlighting potential risks, and identifying potential opportunities to improve water supply conditions, among other elements.



(Source: DWR)

Figure 2-92: Generalized Water Budget Diagram

Water budgets can be developed on different spatial scales. In agricultural use, water budgets may be limited to the root zone in soil, improving irrigation techniques by estimating the inflows and outflows of water from the upper portion of the soil accessible to plants through their roots. In a strictly groundwater study, water budgets may be limited to water flow in the subsurface, helping analysts understand how water flows beneath the surface. Global climate models simulate water budgets that incorporate atmospheric water, allowing for simulation of climate change conditions. In this document, consistent with the SGMA regulations, water budgets investigate the combined surface water and groundwater system in the Basin.

Water budgets can also be developed at different temporal scales. Daily water budgets may be used to demonstrate how evaporation and transpiration increase during the day and decrease at night. Monthly water budgets may be used to demonstrate how groundwater pumping increases in the dry, hot summer months and decreases in the cool, wet winter months. In this section, and consistent with SGMA regulations, this water budget focuses on the full water year (i.e., the 12 months spanning from October of the previous year to September of the current year), with some consideration to monthly variability.

The SGMA regulations require that annual water budgets are based on three different conditions: historical, current, and projected. Water budgets are developed to capture typical conditions during these time periods. Typical conditions are developed through averaging over hydrologic conditions that incorporate droughts, wet periods, and normal periods. By incorporating these varied conditions in the budgets, an analysis of the water system under certain hydrologic conditions such as drought can be performed along with an analysis of long-term average conditions. Information is provided below about the hydrology dataset used to identify time periods for budget analysis, the use of the CBWRM and associated data in water budget development, and about budget estimates.

2.3.3 Identification of Hydrologic Periods

Hydrologic periods were selected to meet the needs of developing historical, current, and projected water budgets. The SGMA regulations require that the projected water budget reflect 50 years of historical hydrology to reflect long-term average hydrologic conditions. Historical precipitation data for the Basin was used to identify hydrologic periods that would provide a representation of wet and dry periods and long-term average conditions needed for budget analyses. Analysis of a long-term historical period time provides information that is expected to be representative of long-term future conditions.

Figure 2-93 shows annual precipitation in the Basin for water years 1968 to 2023. The chart includes bars displaying annual precipitation for each water year and a horizontal line representing the mean precipitation of 13.0 inches. Rainfall data for the Basin are derived from the Parameter-Elevation Regressions on Independent Slopes Model (PRISM) dataset of DWR's California Simulation of Evapotranspiration of Applied Water (CALSIMETAW) model. Analysts identified periods with a balance of wet and dry periods using the cumulative departure from mean precipitation method. Under this method, the long-term average precipitation is subtracted from annual precipitation in each water year to develop the departure from mean precipitation for each water year. Wet years have a positive departure and dry years have a negative departure; a year with exactly average precipitation would have zero departure. Starting at the first year analyzed, departures are added cumulatively for each year. So, if the departure for Year 1 is 5 inches and the departure for Year 2 is -2 inches, the cumulative departure would be 5 inches for Year 1 and 3 inches (i.e., 5 plus -2) for Year 2.

The cumulative departure of the spatially averaged rainfall in the Basin is shown on Figure 2-93. The cumulative departure from mean precipitation is based on the PRISM dataset, and is displayed as a line that starts at zero and highlights wet periods with upward slopes and dry periods with downward slopes. More severe events are shown by steeper slopes and greater changes. The period from 2013 to 2016 illustrates a short period with dramatically dry conditions (i.e., a 16-inch decline in cumulative departure over four years). The decline in cumulative departure continued in the later years including 2022. The wet period in 2023 brings the cumulative departure back to the zero line.

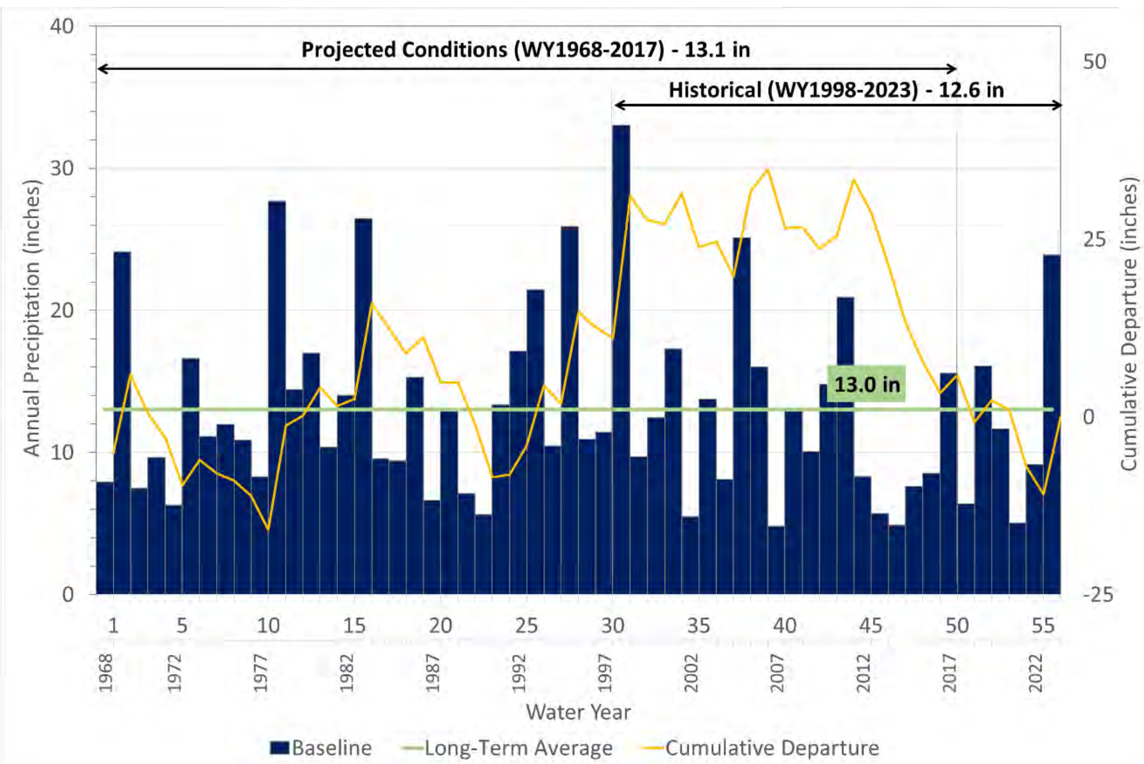


Figure 2-93: 50-Year Historical Precipitation and Cumulative Departure from Mean Precipitation

2.3.4 CBWRM Model Use and Associated Data for Water Budget Development

Water budgets were developed using the CBWRM model, which is a fully integrated surface and groundwater flow model covering the Basin. The CBWRM was developed in consultation with members of the Technical Forum, which includes technical staff and consultants representing a range of public and private entities in the Basin. Participants on the Technical Forum are shown in Chapter 1 Section 1.3. The Technical Forum held 14 monthly conference calls over the course of model development for the 2020 GSP. Additional Technical Forum calls have occurred as the model has been updated for the 2025 GSP Update. These calls provided opportunities for Technical Forum members to review and comment on all major aspects of model development.

The CBWRM integrates the groundwater aquifer with the surface hydrologic system and land surface processes and operations. The CBWRM was calibrated for the hydrologic period of October 1995 to September 2023 by comparing simulated evapotranspiration, groundwater levels, and streamflow records with historical observed records. Development of the model involved study and analysis of hydrogeologic conditions, agricultural and urban water demands, agricultural and urban water supplies, and an evaluation of regional water quality conditions.

The updated model used for the 2025 GSP Update was developed based on the best available data and information as of September 2023. This version of the model includes substantial data changes compared to the version that was released in 2020, reflecting additional data and information that was not available at that time. The data changes include the following:

- Updated geologic representation developed using:
    - The results of a fault investigation conducted by the CBGSA for the Santa Barbara Canyon and Russell faults
    - Airborne Electromagnetic (AEM) survey data collected by the California Department of Water Resources
    - Well log data from new monitoring wells installed in the Basin
- Updated pumping well locations using data provided by landowner surveys
- Updated land use using data and designations of non-irrigated land areas based on in information provided by landowners
- Updated evapotranspiration estimates calibrated to better match metered reporting data provided by landowners for 2022 and 2023
- Calibration period extended to incorporate groundwater level measurements taken by the GSA's monitoring program up through WY 2023

It is expected that the model will continue to be refined in the future as improved and updated monitoring information becomes available for the Basin. These refinements may result in changes in the estimated water budgets described in this section.

Additional information on the development and calibration of the CBWRM is included in Appendix C.

CBWRM simulations were developed to allow for the estimation of water budgets. Model simulations were used to develop the water budgets for historical, current, and projected conditions, which are discussed in detail below:

- The **historical water budget** was based on a simulation of historical conditions in the Basin.
- The **current water budget** was based on a simulation of current (2023) land and water use over historical hydrologic conditions, assuming no other changes in population, water demands, land use, or other conditions.
- The **projected water budget** was based on a simulation of future land and water use over the historical hydrologic conditions. Since future land and water use in the Cuyama Basin is assumed to be the same as current conditions, the projected water budget is the same as the current water budget.

Water Budget Definitions and Assumptions

Definitions and assumptions for the historical, current, and projected water budgets are provided below. Table 2-4 summarizes these assumptions.

Historical Water Budget

The historical water budget is intended to evaluate availability and reliability of past surface water supply deliveries, aquifer response to water supply, and demand trends relative to water year type. The hydrologic period of 1998 through 2023 was selected for the historical water budget to provide a period of representative hydrology while capturing recent Basin operations. The period 1998 through 2023 has an average annual precipitation of 12.6 inches, 0.4 inches less than the long-term average of 13.0 inches and includes the 2012 to 2017 drought, the wet years of 1998, 2005, and 2023, and periods of normal precipitation.

Current and Projected Water Budget

While a budget indicative of current conditions could be developed using the historical calibration model, like the historical water budget, such an analysis would be difficult to interpret due to the extreme weather conditions of the past several years and its effect on local agricultural operations. Instead, to analyze the effects of current land and water use on groundwater conditions, and to accurately estimate current inflows and outflows for the Basin, a current and projected conditions baseline scenario was developed using the IWFM. This baseline uses current land and water use conditions approximating year 2023 conditions with a historical precipitation sequence and a year-to-year variance in cropping patterns that matches the historical variability. Because there is no basis to assume any changes in Basin population or land use in the future as compared to current conditions (in the absence of projects or actions), a single baseline has been developed that reflects both current and projected conditions.

The current and projected conditions baseline includes the following conditions:

- Hydrologic period:
  - Water years 1968 to 2017 (i.e., a 50-year hydrology)
- Precipitation is based on:
  - PRISM dataset for the period from 1968 to 2017
- Land use is based on:
  - Land use information for historical years was developed from private landowner provided data, and the remote sensing data provided by DWR and the CBGSA.
  - Permanent crop acreage from 2023 was maintained, while the annual crop pattern was varied from year-to-year similar to the historical data.
- Domestic water use is based on:
  - Current population estimates
  - Cuyama Community Services District delivery records
- Agricultural water demand is based on:
  - The IWFM Demand Calculator in conjunction with historical remote sensing technology, Mapping Evapotranspiration at High Resolution and Internalized Calibration (METRIC)

Table 2-4: Summary of Groundwater Budget Assumptions

Water Budget Criteria	Historical	Current and Projected
Scenario	Historical simulation	Current and projected conditions baseline
Hydrologic Years	Water years 1998 to 2023	Water years 1968 to 2017
Development	Historical	Current
Agricultural Demand	Historical land use	Current conditions
Domestic Use	Historical records	Current conditions

Projected Water Budget with Climate Change

A second projected level water budget has been developed that incorporates the projected effects of climate change. The projected conditions with climate change baseline are the same as the current and projected conditions baseline, except that adjustments have been made to estimated precipitation and agricultural and native vegetation evapotranspiration during the 50-year hydrologic period. The estimated precipitation and evapotranspiration from 1968 to 2023 were adjusted using perturbation factors developed from the Central Tendency climate scenario data provided by DWR. On average, the perturbation factors for this scenario result in an increase in precipitation of about 1.4 percent and in an increase in crop evapotranspiration of about 5.4 percent. Additional information about how precipitation and evapotranspiration were adjusted for climate change can be found in the IWFM documentation in Appendix C.

Water Budget Estimates

Land surface and groundwater budgets are reported for the historical period, for current and projected conditions, and for projected conditions with climate change.

The following components are included in the land surface water budget:

- Inflows:
  - Precipitation
  - Applied Water
- Outflows:
  - Evapotranspiration
    - Agriculture
    - Native vegetation
  - Domestic water use
  - Deep percolation
    - From precipitation
    - From applied water
  - Runoff
    - Stream seepage to groundwater
    - Flow out of Basin

The following components are included in the groundwater budget:

- Inflows:
  - Deep percolation
  - Stream seepage
  - Subsurface inflow
- Outflows:
  - Groundwater pumping
- Change in storage (where negative values reflect overdraft conditions)

The estimated average annual water budgets are provided in Table 2-5 and Table 2-6 for the historical period and for current and projected conditions. The following sections provide additional information regarding each water budget.

Table 2-5: Average Annual Land Surface Water Budget

Component	Historical Water Volume[a] (AFY)	Current and Projected Water Volume[b] (AFY)	Projected Water Volume With Climate Change[b] (AFY)
Inflows			
Precipitation	223,600	231,100	236,400
Applied water	46,100	45,100	46,100
Total Inflow	**269,700**	**273,500**	**282,400**
Outflows			
Evapotranspiration			
Agriculture	49,300	51,100	54,600
Native vegetation	169,700	178,300	180,300
Domestic water use	400	400	400
Deep Percolation			
Precipitation	4,300	5,100	4,900
Applied water	14,700	11,600	11,900
Runoff	31,600	26,900	30,200
Total Outflow	**270,000**	**273,400**	**282,300**

Notes:
AFY = acre-feet per year
[a]From water years 1998 to 2023
[b]Based on 50-year hydrology

Table 2-6: Average Annual Groundwater Budget

Component	Historical Water Volume[a] (AFY)	Current and Projected Water Volume[b] (AFY)	Projected Water Volume with Climate Change[b] (AFY)
Inflows			
Deep percolation	19,000	16,700	16,800
Stream seepage	4,000	5,400	6,000
Subsurface inflow	2,800	2,800	3,200
Total Inflow	**25,800**	**24,900**	**26,000**
Outflows			
Groundwater pumping	46,200	42,400	46,000
Total Outflow	**46,200**	**42,400**	**46,000**
Change in Storage	**(20,400)**	**(17,500)**	**(20,000)**

Notes:
AFY = acre-feet per year
[a]From water years 1998 to 2023
[b]Based on 50-year hydrology

2.3.5 Historical Water Budget

The historical water budget is a quantitative evaluation of the historical surface and groundwater supply covering the 26-year period from 1998 to 2023. This period was selected as the representative hydrologic period to calibrate and reduce the uncertainty of the IWFM. Proper analysis and calibration of water budgets within IWFM ensures the hydrologic characteristics of the groundwater basin are accurately represented. The goal of the water budget analysis is to characterize the supply and demand, while summarizing the hydrologic flow within the Basin, including the movement of all primary sources of water such as rainfall, irrigation, streamflow, and subsurface flows.

Figure 2-94 summarizes the average annual historical land surface inflows and outflows in the Basin. Figure 2-95 shows the annual time series of historical land surface inflows and outflows.

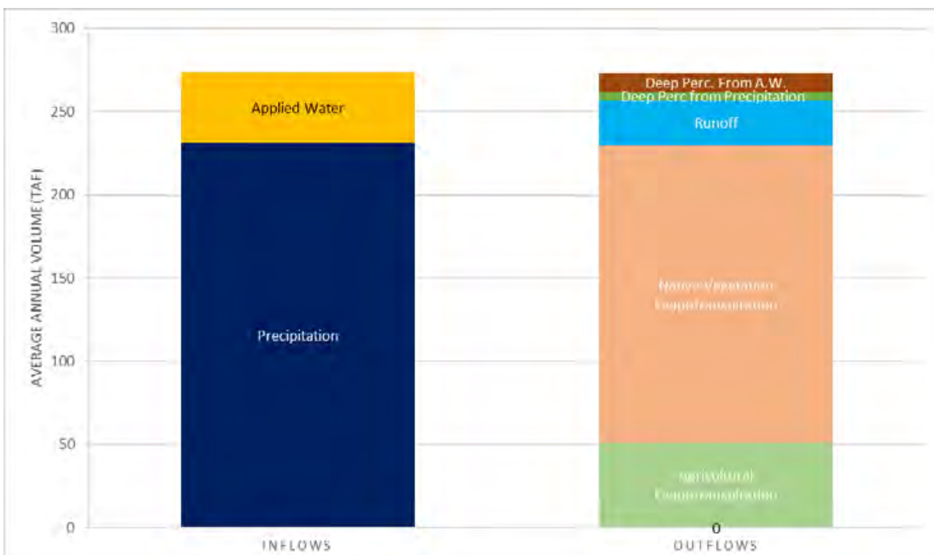


Figure 2-94: Historical Average Annual Land Surface Water Budget

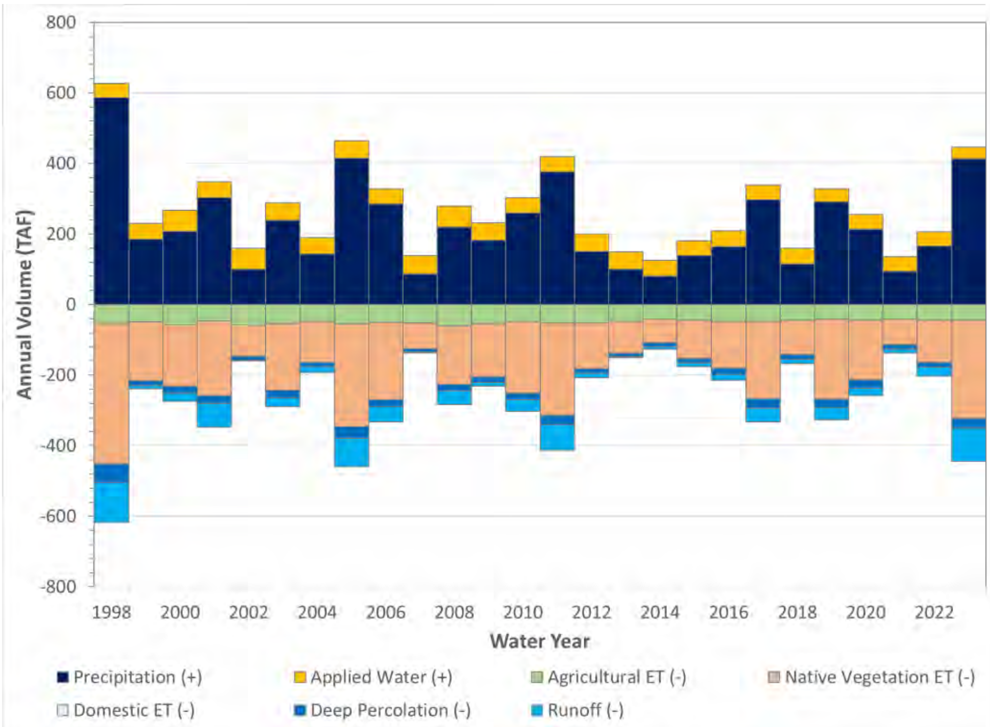


Figure 2-95: Historical Land Surface Water Budget Annual Time Series

The Basin experiences about 269,000 AF of land surface inflows each year, of which 224,000 AF is from precipitation and the remainder is from applied water. About 219,000 acre-feet per year (AFY) is consumed as evapotranspiration or domestic use, with the remainder either recharging the groundwater aquifer as deep percolation or stream seepage or leaving the Basin as river flow.

The annual time series shows large year-to-year variability in the availability of water, with land surface inflows ranging from a low of about 125,000 AF to a high of 626,000 AF. These year-to-year changes in inflows result in corresponding differences in outflows, with total annual agricultural, native vegetation and domestic evapotranspiration ranging from 108,000 to 345,000 AF.

Figure 2-96 summarizes the average annual historical groundwater inflows and outflows in the Basin. Figure 2-97 shows the annual time series of historical groundwater inflows and outflows. The Basin average annual historical groundwater budget has greater outflows than inflows, leading to a projected average annual decrease in groundwater storage (i.e., overdraft) of 20,000 AF. Note that with metered pumping data now available to calibrate the CBWRM the estimated pumping and reduction in storage are both now lower than what was estimated by the CBWRM in the 2020 GSP. Accounting for potential uncertainties in numerical model parameters (as described in Appendix C), the projected average annual overdraft could range from 19,000 to 22,000 AF. The groundwater storage decreases consistently over time, despite year-to-year variability in groundwater inflows.

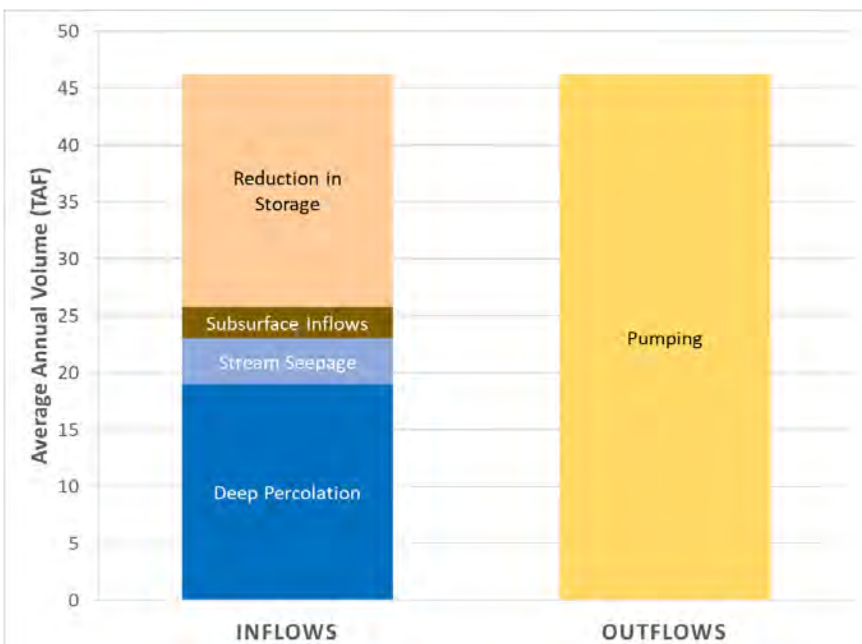


Figure 2-96: Historical Average Annual Groundwater Budget

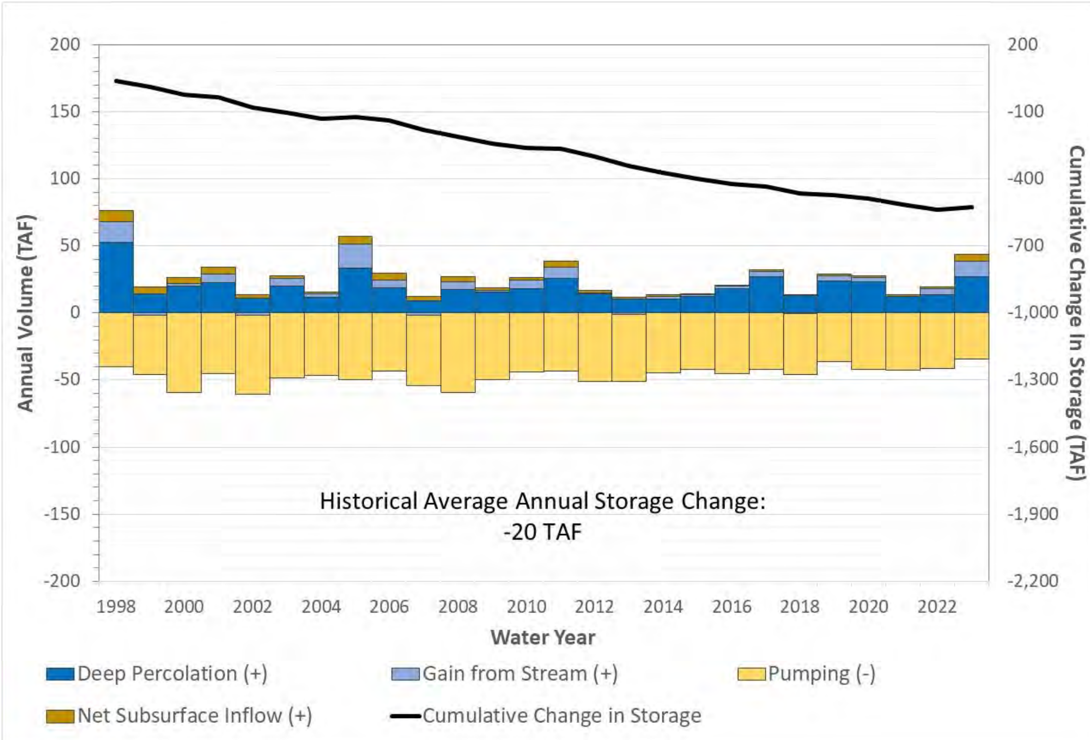


Figure 2-97: Historical Groundwater Budget Annual Time Series

2.3.6 Current and Projected Water Budget

The current and projected water budget quantifies inflows to and outflows from the Basin using 50 years of hydrology in conjunction with 2020 population, water use, and land use information.

Figure 2-98 summarizes the average annual current and projected land surface inflows and outflows in the Basin. Figure 2-99 shows the annual time series of current and projected land surface inflows and outflows.

Figure 2-98: Current and Projected Average Annual Land Surface Water Budget

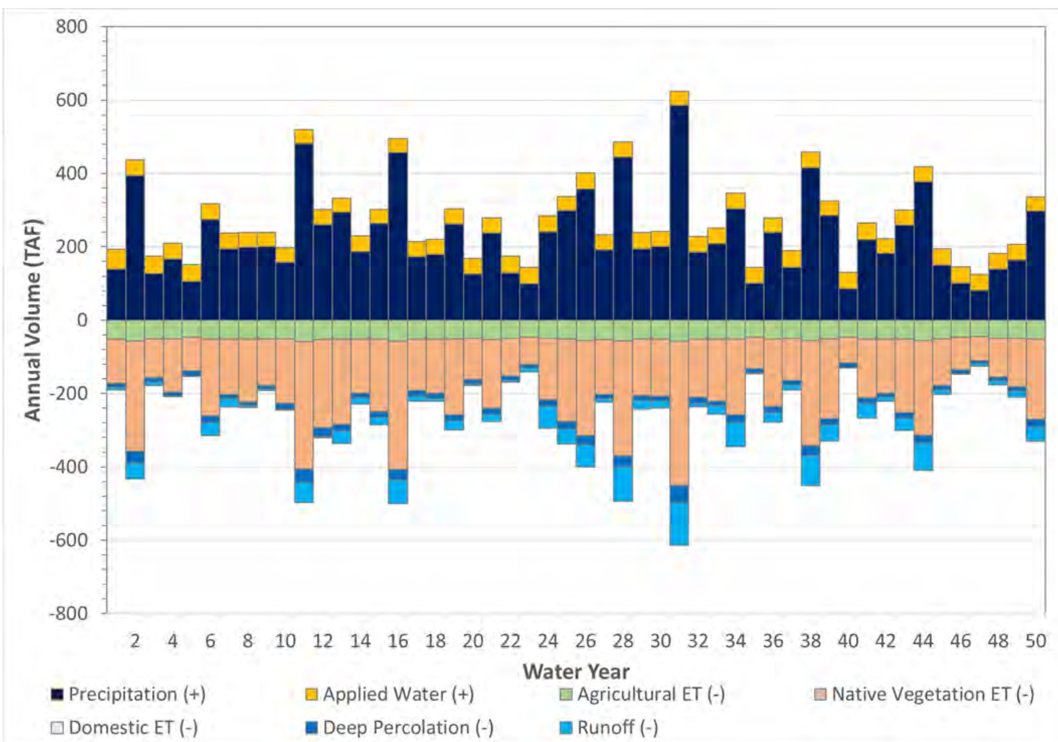


Figure 2-99: Current and Projected Land Surface Water Budget Annual Time Series

Under current and projected conditions, the Basin experiences about 274,000 AF of land surface inflows each year, of which 231,000 AF is from precipitation and the remainder is from applied water as shown in Table 2-5. About 230,000 AFY is consumed as evapotranspiration or domestic use, with the remainder either recharging the groundwater aquifer as deep percolation or stream seepage or leaving the Basin as river flow.

The annual time series shows the year-to-year variability in the availability of water, with land surface inflows ranging from a low of about 126,000 AF to a high of 624,000 AF. These year-to-year changes in inflows result in corresponding differences in outflows, with total annual agricultural, native vegetation and domestic evapotranspiration ranging from 111,000 to 451,000 AF.

Figure 2-100 summarizes the average annual current and projected groundwater inflows and outflows in the Basin. Figure 2-101 shows the annual time series of current and projected groundwater inflows and outflows. The Basin average annual current and projected groundwater budget has greater outflows than inflows, leading to an average annual decrease in groundwater storage (i.e. overdraft) of 18,000 AF. Similar to the historical water budget, the estimated pumping and reduction in storage are both now lower than what was estimated by the CBWRM in the 2020 GSP. Accounting for potential uncertainties in numerical model parameters (as described in Appendix C), the projected average annual overdraft could range from 17,000 to 20,000 AF. As with the historical conditions, the groundwater storage decreases consistently over time, despite year-to-year variability in groundwater inflows.

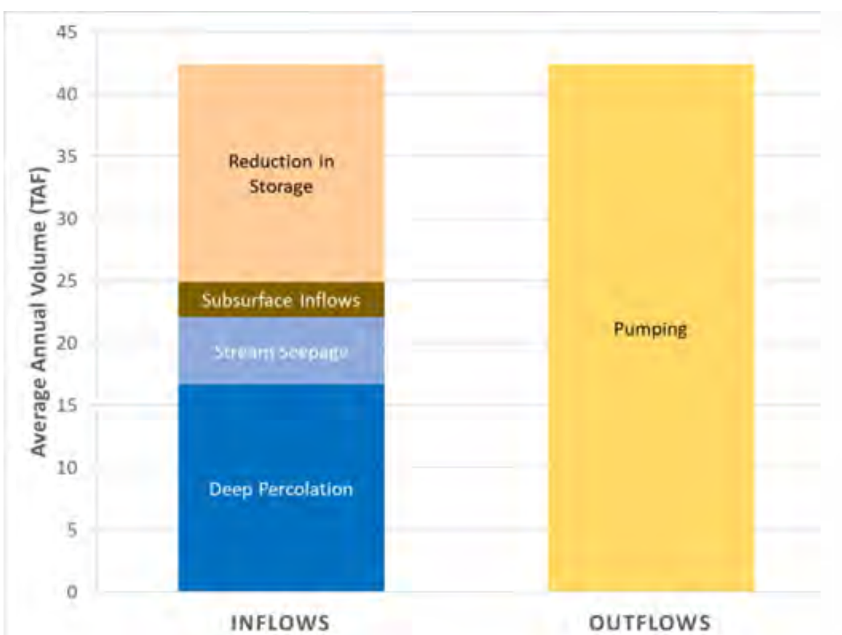


Figure 2-100: Current and Projected Average Annual Groundwater Budget

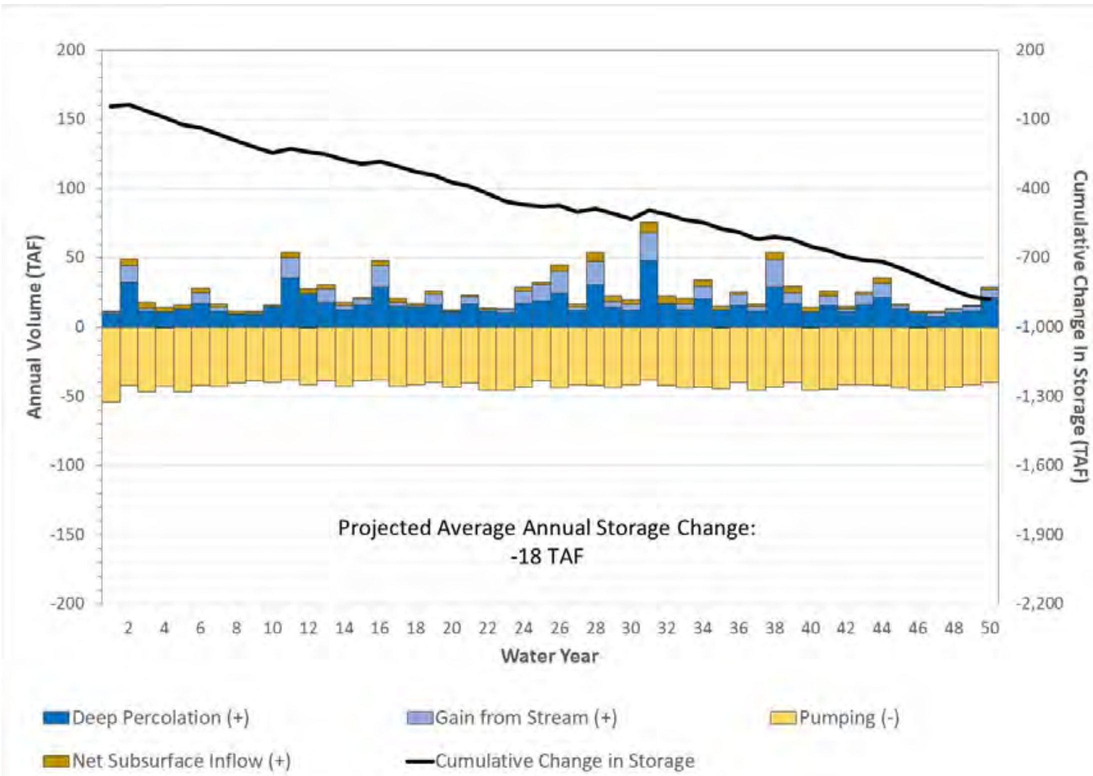


Figure 2-101: Current and Projected Groundwater Budget Annual Time Series

The current and projected water demand, water supply, and change in groundwater storage vary by water year type[10], as shown in Table 2-7. In wet years, precipitation meets a relatively high proportion of the water demand, which reduces the need for groundwater. By contrast, in drier years more groundwater pumping is required to meet the agricultural demand not met by precipitation. This leads to an increase in groundwater storage in wet years and a decrease in all other year types.

[10] Water year types are customized for the Basin watershed based on annual precipitation as follows:

- Wet year = more than 19.6 inches
- Above normal year = 13.1 to 19.6 inches
- Below normal year = 9.85 to 13.1 inches
- Dry year = 6.6 to 9.85 inches
- Critical year = less than 6.6 inches

Table 2-7: Current and Projected Average Annual Supply, Demand, and Change in Groundwater Storage by Water Year Type

Component	Water Year Type				
	Wet	Above Normal	Below Normal	Dry	Critical
Water Demand					
Agricultural Evapotranspiration (AFY)	56,700	50,800	51,100	50,300	46,100
Domestic Use (AFY)	200	200	200	200	200
Total Demand	**56,900**	**51,000**	**51,300**	**50,500**	**46,300**
Water Supply					
Groundwater Pumping (AFY)	41,000	40,500	42,100	44,100	45,100
Total Supply	**41,000**	**40,500**	**42,100**	**44,100**	**45,100**
Change in Storage	**11,000**	**(12,300)**	**(23,100)**	**(28,100)**	**(32,000)**

2.3.7 Projected Water Budget with Climate Change

The projected water budget with climate change quantifies inflows to and outflows from the Basin using 50-years of hydrology in conjunction with 2017 population, water use, and land use information, with historical precipitation and evapotranspiration values modified for climate change.

Figure 2-102 summarizes the average annual current and projected land surface inflows and outflows in the Basin. Figure 2-103 shows the annual time series of current and projected land surface inflows and outflows.

Figure 2-102: Projected Average Annual Land Surface Water Budget with Climate Change

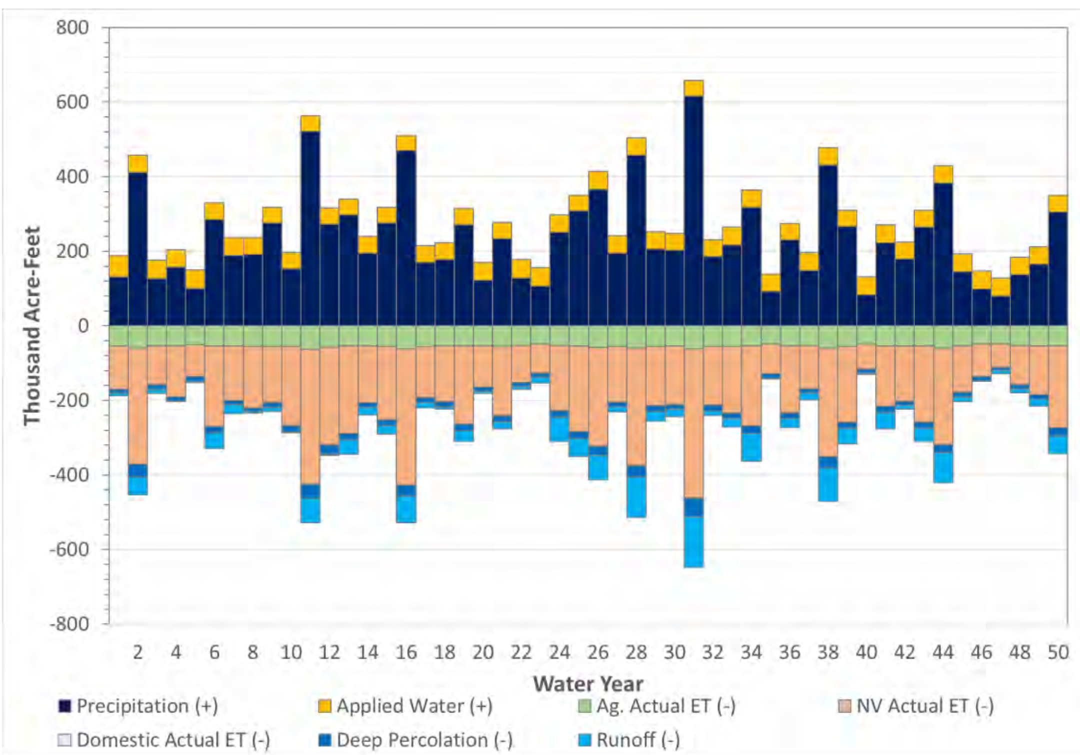


Figure 2-103: Projected Land Surface Water Budget with Climate Change Annual Time Series

Under projected conditions with climate change, the Basin experiences about 282,000 AF of land surface inflows each year, of which 236,000 AF is from precipitation and the remainder is from applied water as shown in Table 2-5. About 235,000 AFY is consumed as evapotranspiration or domestic use, with the remainder either recharging the groundwater aquifer as deep percolation or stream seepage or leaving the Basin as river flow.

The annual time series shows the year-to-year variability in the availability of water, with land surface inflows ranging from a low of about 129,000 AF to a high of 658,000 AF. These year-to-year changes in inflows result in corresponding differences in outflows, with total annual agricultural, native vegetation and domestic evapotranspiration ranging from 112,000 AF to 462,000 AF.

Figure 2-104 summarizes the average annual projected groundwater inflows and outflows with climate change in the Basin.

Figure 2-105 shows the annual time series of projected groundwater inflows and outflows with climate change. The Basin average annual current and projected groundwater budget has greater outflows than inflows, leading to an average annual decrease in groundwater storage (i.e., overdraft) of 20,000 AF. Similar to the historical water budget, the estimated pumping and reduction in storage are both now lower than what was estimated by the CBWRM in the 2020 GSP. As with the historical conditions, the groundwater storage decreases consistently over time, despite year-to-year variability in groundwater inflows.

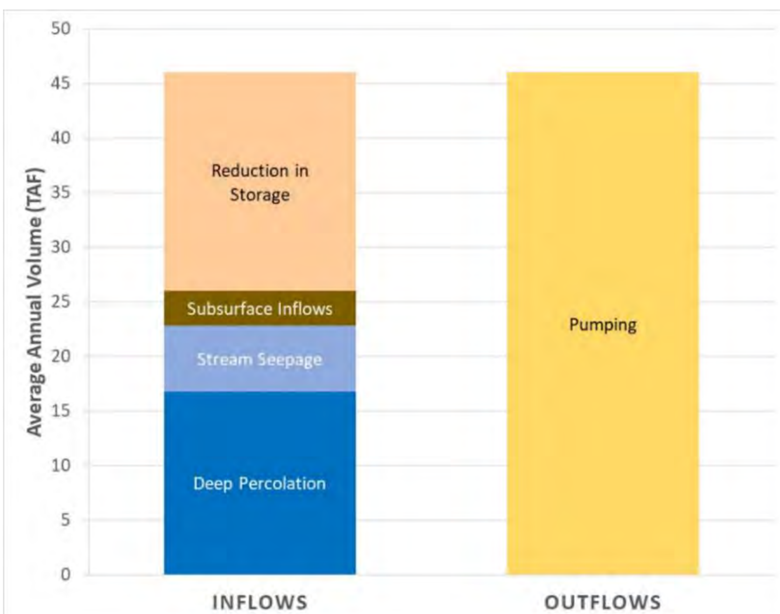


Figure 2-104: Projected Average Annual Groundwater Budget with Climate Change

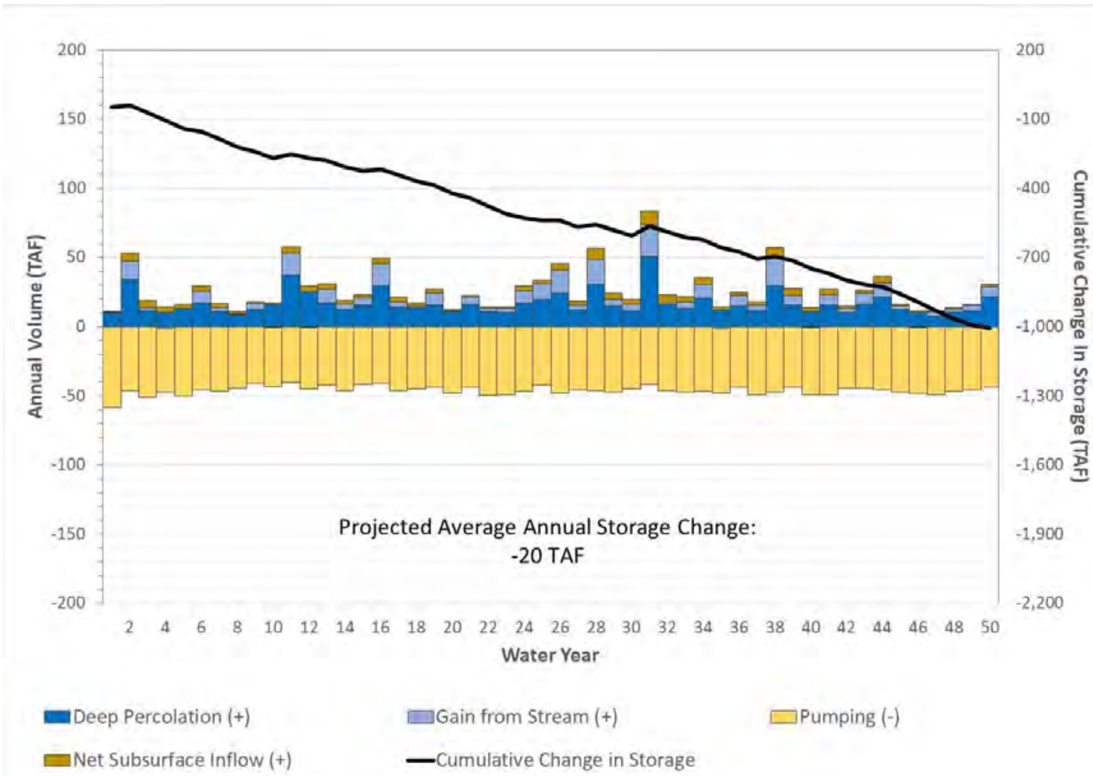


Figure 2-105: Projected Groundwater Budget with Climate Change Annual Time Series

2.3.8 Sustainable Yield Estimates

Four sustainability scenarios were analyzed with the updated version of the model to estimate the sustainable yield in the Basin as follows:

- Current and projected conditions sustainability with pumping reductions only
- Current and projected conditions sustainability with pumping reductions and water supply projects
- Projected sustainability with climate change with pumping reductions only
- Projected sustainability with climate change with pumping reductions and water supply projects

These estimates were developed using the current and projected conditions and projected conditions with climate change baseline models described above, with projects and pumping reductions implemented so as to achieve an exact balance between supplies and demands in the Basin-wide groundwater budget on average over the 50-year simulation period.

As noted above, the baseline models were developed using the best available data and information as of June 2024. It is expected that the model will continue to be refined in the future as improved and updated monitoring information becomes available in the Basin. These refinements will result in changes in the sustainable yield estimates described in this section.

Table 2-8 shows the groundwater budget for each sustainability scenario. Because there is no long-term average change in groundwater storage in these scenarios, the groundwater pumping represents the overall estimated sustainable yield in each scenario. Without water supply projects, the Basin sustainable yield is estimated to be about 16,800 AFY without climate change (i.e., a 60 percent reduction in groundwater pumping compared to baseline) and about 17,700 AFY with climate change (i.e., a 62 percent reduction in groundwater pumping compared to baseline). With water supply projects, the Basin sustainable yield is estimated to be about 21,100 AFY without climate change and about 22,000 AFY with climate change.

Table 2-8: Average Annual Groundwater Budget for Sustainability Scenarios

Component	Current and Projected Conditions with Pumping Reductions Only (AFY)	Projected Conditions with Climate Change with Pumping Reductions Only (AFY)	Current and Projected Conditions with Pumping Reductions and Water Supply Projects (AFY)	Projected Conditions with Climate Change with Pumping Reductions and Water Supply Projects (AFY)
Inflows				
Deep percolation	8,700	8,700	10,000	10,000
Stream seepage	5,300	5,800	5,300	5,800
Boundary and Other	2,800	3,200	2,800	3,200
Recharge from Projects	0	0	3,000	3,000
Total Inflow	**16,800**	**17,700**	**21,100**	**22,000**
Outflows				
Groundwater pumping	16,800	17,700	21,100	22,000
Total Outflow	**16,800**	**17,700**	**21,100**	**22,000**
Change in Storage	**(0)**	**(0)**	**(0)**	**(0)**
Reduction in groundwater pumping relative to Baseline	**(25,600)**	**(28,300)**	**(21,300)**	**(24,000)**
Percent reduction	**-60%**	**-62%**	**-50%**	**-52%**
Notes: All sustainability scenarios are simulated using the 1968 to 2017 hydrologic period.				

2.4 References

2.4.1 HCM References

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