2.2 Hydrogeologic Conceptual Model

This section describes the hydrogeologic conceptual model (HCM) for TBID, which provides information on the groundwater flow system within the TBID Plan Area. The HCM provides descriptions of the physical and geologic setting, geologic structure, boundary conditions, and principal aquifers and aquitards. Additionally, it provides the basis upon which water budgets, monitoring networks, and sustainable management criteria were developed. The HCM for TBID and the Tule Subbasin has been developed in accordance with the requirements of California Code of Regulations (CCR), Title 23, Division 2, Chapter 1.5, Subchapter 2, Article 5, Subarticle 2, Section 354.14, in consideration of DWR's BMPs.

The HCM was developed using information included in the *Tule Subbasin Setting* (**Appendix A-2**) of the Tule Subbasin Coordination Agreement (**Appendix A**), along with additional public and local data sets.

2.2.1 Topography

The terrain throughout the Subbasin is relatively level, with a gentle slope falling from east to west. The low-lying foothills of the Sierra Nevada Mountain Range in the east are the only major topographical feature within the Subbasin. Land surface elevation throughout the Subbasin ranges from approximately 850 feet above mean sea level (amsl), along the eastern edge, to approximately 200 feet amsl along the western edge (**Appendix A-2**).

A map of ground surface elevation across TBID is presented in **Figure 2-8**. TBID is characterized by an increasingly flat topography moving from east to west across the TBID Plan Area. In the eastern portion of TBID, adjacent to the foothills of the Sierra Nevada mountains, the land surface is approximately 800 feet above mean sea level (feet msl). Moving to the west, land surface elevations near the non-contiguous portion of the TBID Plan Area are approximately 400 feet. The average slope moving east to west across the TBID Plan Area is 1.8 percent.

2.2.2 Soils

Soil characteristics are described for the Subbasin in Section 2.1.6 of the *Tule Subbasin Setting* (**Appendix A-2**). A map of soils within the TBID Plan Area was developed from the USDA's Natural Resources Conservation Service (NRCS, 2025) and is contained in **Figure 2-9**. As part of the NRCS soil surveys, soil map units are defined to express similarities between soils within similar landform and landscape position. The dominant soil types within the TBID Plan Area include naturally fertile soils like Vertisols, Mollisols, and Alfisols. Soil series that dominate TBID include Centerville and Porterville clays, San Joaquin loam, and other loam to sandy loams.

2.2.2.1 Centerville Clay

The Centerville series, as per the USDA NRCS Official Soil Series Description, consists of deep, well-drained clay soils formed in granitic alluvium on alluvial fans and terraces near Terra Bella, California, supporting irrigated citrus and grains under a dry subhumid climate with 9-12 inches of annual precipitation. Classified as fine, smectitic, thermic Aridic Calcixererts, these soils have high clay content (35-60 percent), vertic properties with wide cracks and slickensides, a dark grayish brown Ap horizon (0-

12 inches, pH 8.0), and underlying Bss/Bk horizons (12-37 inches) of reddish brown clay with carbonates, slow permeability, high shrink-swell potential, and medium water capacity. The Centerville Clay has a relatively low permeability with an infiltration rate of approximately 0.06-0.2 inches/hour.

2.2.2.2 Porterville Clay

The Porterville series consists of deep, well-drained sandy clay loam soils formed in granitic alluvium on alluvial fans and terraces supporting irrigated citrus, grapes, and grains under a dry subhumid climate with 8-12 inches of annual precipitation. Classified as coarse-loamy, mixed, superactive, thermic Typic Haploxeralfs, these soils feature a brown A horizon (0-10 inches, pH 6.5-7.5), reddish brown Bt horizons (10-40 inches) with 20-35 percent clay and moderate blocky structure, slow to moderate permeability, low shrink-swell potential, and high water capacity, distinguishing them from Centerville soils by coarser texture and absence of vertic features or duripan (a hard, cement-like layer in the soil made of consolidated silica acting as a barrier that limits deep roots and percolating water). The Porterville clay has a slow to moderate infiltration rate of 0.2-0.6 inches/hour.

2.2.2.3 San Joaquin Loam

The Porterville series consists of deep, well-drained sandy clay loam soils formed in granitic alluvium on alluvial fans and terraces near Porterville in Tulare County, California, supporting irrigated citrus, grapes, and grains under a dry subhumid climate with 8-12 inches of annual precipitation. Classified as coarse-loamy, mixed, superactive, thermic Typic Haploxeralfs, these soils feature a brown A horizon (0-10 inches, pH 6.5-7.5), reddish brown Bt horizons (10-40 inches) with 20-35 percent clay and moderate blocky structure, slow to moderate permeability, low shrink-swell potential, and high water capacity, distinguishing them from Centerville soils by coarser texture and absence of vertic features or duripan. Similar to the Centerville Clay, the San Joaquin Loam has a relatively low permeability with an infiltration rate of approximately 0.06-0.2 inches/hour.

2.2.3 Geological and Structural Setting

The regional geologic and structural setting describing the entire Subbasin is described in Chapter 2.2.2 of the *Tule Subbasin Setting* (**Appendix A-2**).

TBID is located within California's Great Valley Geologic Province (**Figures 2-1** and **2-2**). A map of the surficial geology is presented in **Figure 2-10**. TBID Plan Area is almost entirely underlain by "Continental Sedimentary Rocks" (Qpc). This unit consists of Pleistocene continental deposits, primarily semi-consolidated gravel, sand, silt, and clay forming dissected alluvial fans and terraces derived from the Sierra Nevada by erosion. To the east of the TBID Plan Area, crystalline bedrock is present at the surface. The far eastern portions of the TBID Plan Area, including the non-contiguous area, are made up of "Alluvium" (Q). This unit is Quaternary in age and consists of unconsolidated to semi-consolidated sand, gravel, and clay, forming alluvial plains, fans, and terraces (**Appendix A-2**).

Five geologic formations have been identified across the Subbasin and under the TBID Plan Area. Descriptions of these geologic formations are provided below and are depicted in **Figures 2-11** through **2-12**.

2.2.3.1 Unconsolidated Continental Deposits

Sediment consisting of fluvial (i.e., streambed deposits), alluvial, flood plain, and lacustrine (i.e., lakebed) deposits. The deposits are estimated to range in thickness from approximately 200 feet to 350 feet (**Appendix A-2**). Subsurface alluvial sediments consist of highly stratified layers, with a boundary of the TBID Plan Area to approximately 350 feet near the eastern contact with the Sierra Nevada, based on lithologic data provided from DWR Well Completion Reports. Subsurface alluvial sediments consist of highly stratified layers of sand and gravel (relatively high permeability) interbedded with silt and clay (lower permeability). Correlation of individual sand and clay layers that extend laterally across the Tule Subbasin can be unclear due to the interbedded nature of the sediments.

The unconsolidated continental deposits form the primary groundwater reservoir in the Tule Subbasin, ranging in age from recent in near-surface stream channels to Upper Pliocene (approximately 2.6 million years ago) at depth. Near the TBID Plan Area within the eastern portion of the Tule Subbasin, Pleistocene sediments (2.6 million to 11,700 years before present) crop out at the land surface along the base of the Sierra Nevada Mountains, forming the dissected uplands (Lofgren and Klausing, 1969). The older continental deposits are semi-consolidated and contain a high percentage of clay; Therefore, they typically do not yield significant water to wells.

The lowermost portion of unconsolidated continental deposits is generally correlated with the Tulare Formation, which includes the regionally extensive confining Corcoran Clay layer, also referred to as the E-Clay (Frink and Kues, 1954), which is located west of the TBID Plan Area. The Corcoran Clay consists of a Pleistocene diatomaceous fine-grained lacustrine deposit (primarily clay; Faunt, 2009). In the Tule Subbasin, the Corcoran Clay is 150 feet thick at its maximum beneath the Tulare Lake, becomes progressively thinner to the east, and pinches out on the east side of Highway 99 (Lofgren and Klausing, 1969).

2.2.3.2 Pliocene Marine Deposits

Consolidated to loosely consolidated marine siltstone with minor interbedded sandstone beds that underlie the continental deposits. The marine siltstone unit ranges in thickness from approximately 150 feet along the eastern region of the TBID to greater than 250 feet near State Highway 65 adjacent to the western boundary of the TBID Plan Area (Lofgren and Klausing, 1969; **Appendix A-2**). The marine siltstone beds dip sharply from the base of the Sierra Nevada Mountains on the east to the central region of the valley in the west. The Pliocene marine strata do not yield significant water to wells due to their relatively low permeability.

2.2.3.3 Santa Margarita Formation

The formation underlies the Pliocene marine strata. It consists of Miocene (approximately 5.3 to 23 million years before present) sand and gravel that is relatively permeable and yields water to wells. The formation is approximately 200 to 250 feet thick, and its depth beneath the TBID Plan Area ranges from 1,200 feet near State Highway 65 to approximately 2,400 feet beneath the western boundary of the TBID Plan Area. The Santa Margarita Formation is a significant source of groundwater to wells in the southeastern region of the Tule Subbasin.

2.2.3.4 Tertiary Sedimentary Deposits

An interbedded assemblage of semi-consolidated to consolidated sandstone, siltstone, and claystone of Tertiary age (approximately 2.6 to 66 million years before present) that underlie the Santa Margarita Formation. Some irrigation wells in the southeastern region of the Tule Subbasin produce fresh water sourced from the Olcese Sand Formation (**Appendix A-2**). Most of the groundwater in the unit is not usable for crop irrigation or municipal supply, except near Highway 65, due to salinity that increases to the southwest.

2.2.3.5 Granitic Crystalline Basement

Basement rock consisting of Mesozoic granitic rocks that compose the Sierra Nevada batholith (Faunt, 2009) and are assumed to be relatively impermeable.

2.2.4 Lateral Basin Boundary

The lateral basin boundaries for the Subbasin, including natural and political boundaries, are described in DWR Bulletin 118 (DWR, 2016a). The eastern boundary of the TBID Plan Area is defined by the contact between the Sierra Nevada crystalline rocks and surficial alluvial sediments that form the groundwater basin (**Figure 2-10**). The TBID Plan Area northern boundary includes portions of Deer Creek and the Tule East GSA Plan Area, and the southern boundary is also defined by the Tule East GSA Plan Area. The TBID Plan Area western boundary is sectioned, and the primary boundaries are defined by State Highway 65, the Friant-Kern Canal, the Saucelito Irrigation District (SID) GSA, and the Tule East GSA Plan Areas. The TBID boundaries that are shared with neighboring GSAs are represented in **Figure 2-1**.

2.2.5 *Bottom of Basin*

The bottom of the Tule Subbasin and the TBID Plan Area are defined by the interface between the Tertiary sedimentary deposits and the underlying, relatively impermeable granitic basement rock (**Appendix A-2**) (**Figures 2-11** and **2-12**). Depths range from less than 600 feet below ground surface (bgs) east of State Highway 65 to greater than 2,000 feet bgs on the west side of the Friant-Kern Canal and TBID Plan Area (**Appendix A-2**).

The interface between freshwater and brackish water is thought to occur at depths ranging from less than 1,200 feet bgs in the northeastern region of the Tule Subbasin (north of the TBID Plan Area) to greater than 2,500 feet bgs near the Tulare/Kern County line (south of the TBID Plan Area). Groundwater quality parameters determine the efficacy of a fresh groundwater basin and determine if it is suitable for municipal, irrigation, or other uses. For example, a measure of the bottom of the basin is determined by an electrical conductivity of 3,000 micromhos per centimeter (µmohs/cm), which is approximately correlative to a total dissolved solids (TDS) concentration of 2,000 milligrams per liter (mg/L) (**Appendix A-2**). Aquifer groundwater quality of the TBID Plan Area is discussed in greater detail in **Section 2.3**, Groundwater Conditions, of this GSP.

2.2.6 Principal Aquifers and Aquitards

2.2.6.1 Aquifer Formations

Five aquifer and aquitard formations have been identified within the Subbasin's subsurface. These layers include the Upper Aquifer, Corcoran Clay, the Lower Aquifer, Pliocene Marine Deposits, and the Santa Margarita. All but the Corcoran Clay are present with the TBID Plan Area. A summary of the four aquifer/aquitard units that are present in TBID, as well as their approximate thicknesses, is described below, and they are represented as a cross-section in **Figure 2-11**. Descriptions are based on information presented in (**Appendix A-2**).

> **Upper Aquifer –** An unconfined to semi-confined aquifer occurring throughout the entire Subbasin, shallowing from west to east. The Upper Aquifer is generally considered unsaturated near the southern region of the Subbasin, with local areas of groundwater. Within the TBID Plan Area, the Upper Aquifer occurs within the upper 350 feet of sediment, which decreases to approximately 300 feet at the eastern boundary.

> **Lower Aquifer –** Confined beneath the Corcoran Clay, where it is present (west of Highway 99), and it is conceptualized to be semi-confined in the northeastern portion of the Subbasin. The Lower Aquifer is separated from the underlying Santa Margarita Formation Aquifer by a thick layer of Pliocene Marine Deposits. Within the eastern region of the TBID Plan Area, the Lower Aquifer has an approximate depth of 350 feet bgs and increases in depth westward to approximately 700 feet bgs near the western boundary of the TBID Plan Area.

> **Pliocene Marine Deposits –**A layer of marine deposits (confining unit) in the southeastern portion of the Subbasin that is considered an aquitard that separates the Lower Aquifer from the underlying Santa Margarita Aquifer. Due to its low permeability, the Pliocene marine deposits do not yield significant water to wells. The confining marine deposits are between 500 feet and 1,600 feet thick throughout the Subbasin.

> **Santa Margarita Formation and Olcese Formation –** Tertiary sedimentary deposits underly the Pliocene Marine Deposits, and the formation is conceptualized as hydrologically disconnected from the rest of the identified aquifers in the Subbasin. In the western half of the Tule Subbasin, the formation occurs at depths greater than 2,000 feet bgs, while it forms a localized aquifer in the southeastern portion of the Subbasin. It is relatively permeable and is a major water source for agricultural irrigation.

2.2.6.2 *Aquifer Physical Properties*

The principal water-bearing aquifers of the Tule Subbasin are formed from permeable sand and gravel layers that are interbedded with low-permeability silt and clay lenses. Shallower saturated sediments are generally unconfined to semi-confined, while confined aquifers in the western region of the basin occur beneath the Corcoran Clay, west of the TBID Plan Area. The ability of aquifer sediments to transmit and store water is based on the aquifer's transmissivity, hydraulic conductivity, and storativity. Aquifer parameters were derived using short-term pump tests and long-term pump tests (24 hours or more at a constant rate).

2.2.6.2.1 Transmissivity/Hydraulic Conductivity

Transmissivity is a measure of the ability of groundwater to flow within an aquifer. It is defined as the rate of groundwater flow through a unit width of an aquifer under a unit hydraulic gradient (Fetter, 1994), and it was estimated from short-term pumping test data based on Theis et al. (1963) and the following relationship:

$$T = \frac{S_c \, x \, 2{,}000}{E}$$

Where:

T = Transmissivity (gallons per day/foot);

S_c = Specific Capacity (gallons per minute/foot);

E = Well Efficiency (assumed to be 0.7)

The transmissivity values at individual wells within the Tule Subbasin were converted into hydraulic conductivity (i.e., aquifer permeability) by dividing by the aquifer thickness using the perforation interval of the well.

Horizontal hydraulic conductivity for the Upper Aquifer ranges from less than 20 feet/day in the southern half of the TBID Plan Area to 60-80 feet/day along the Deer Creek along its northern boundary. This range of K values is consistent with the rest of the Subbasin, with the exception of areas near Lake Success, where K values are between 100-150 feet/day (**Figure 2-13**). Whereas horizontal hydraulic conductivity values in the Lower Aquifer range from less than 20 feet/day through the majority of the TBID Plan Area to as high as 40 feet/day in the northeast portion of the TBID Plan Area near the Deer Creek (**Appendix 2-A**) (**Figure 2-14**). Higher hydraulic conductivity values in the northern region of the TBID Plan Area indicate that the sediments are more permeable than in the southern region, which resulted in lower conductivity values. This distribution of K is consistent with the location of wells with TBID, with a majority of wells located in the northern portion of the TBID Plan Area (**Figure 2-5**).

Additional details on hydraulic conductivity in the region are described in Chapter 2.1.7.2 of *the Tule Subbasin Setting* (**Appendix A-2**).

2.2.6.2.2 Specific Yield/Storativity

Specific yield refers to the ratio of the volume of water that sediment will yield by gravity drainage to the volume of the sediment. The majority of the Upper Aquifer is generally unconfined; therefore, its storage properties are expressed in terms of specific yield, and its values were assigned based on a USGS texture analysis published in Faunt (2009). Textural descriptions of sediment in terms of coarse-grain percentages were based on drillers' logs generated from boreholes or wells drilled within or immediately outside the Tule Subbasin. A higher percentage of coarse-grained sediment is directly proportional to higher specific yields (**Figure 2-15**).

In the Upper Aquifer of the TBID Plan Area, specific yield values range from approximately 0.05 to 0.25 (**Figure 2-15**), with areas of higher specific yield occurring near Deer Creek in the northeastern portion of the TBID Plan Area and areas of low specific yield in the southern and western portions (**Appendix A-2**).

The Lower Aquifer in the Tule Subbasin is confined to semi-confined; therefore, its storage properties are expressed in terms of storativity. Storativity is a measure of the volume of water that an aquifer can release from, or take into, storage per unit of aquifer surface area per unit change in hydraulic head. Storativity is based on long-term pumping tests, during which pumping interference is measured in a monitoring well located at a known distance from the pumping well. Pumping interference data for the Tule Subbasin is not available. Therefore, storativity values for the lower alluvial aquifer were originally based on values published in Faunt (2009) and were modified during calibration of the Tule Subbasin's numerical model. Storativity values in the lower aquifer under confined conditions range from 8.0e-06 to 3.6e-04 (**Appendix A-2**) (**Figure 2-16b**), which are indicative of confined aquifer conditions. The storativity values tend to increase from east to west.

2.2.7 Geologic Structures that Affect Groundwater Flow

Across the Subbasin, the Corcoran Clay confining unit is the most significant geologic feature within the Subbasin that affects groundwater flow. The unit is not within the TBID Plan Area, though localized confining beds may be present. Groundwater flow within the TBID Plan Area is described in **Section 2.4.2**.

No significant faults have been mapped within the TBID Plan Area that would affect groundwater flow. A concealed fault has been mapped at a northwest-southeast orientation adjacent to the northeastern boundary of the TBID Plan Area (**Appendix A-2**) (**Figure 2-10**).

2.2.8 Areas of Groundwater Recharge and Discharge

Groundwater recharge occurs primarily through deep percolation of applied irrigation water, precipitation, mountain-front recharge, or streambed infiltration. Deep percolation can occur over relatively permeable surface soils when there is a lack of subsurface impediments. Areas of recharge are identified for the Subbasin in Chapter 2.1.6 of the *Tule Subbasin Setting,* and generally occur along or within stream channels, unlined canals, in managed recharge basins, and on irrigated agricultural lands. Within the TBID Plan Area, areas suitable for recharge occur around Deer Creek and the Fountain Spring Gulch.

The Soil Agricultural Groundwater Banking Index (SAGBI) was developed by the University of California, Davis, and identifies effective recharge areas based on deep percolation potential, root zone residence time, topography, chemical limitations, and soil surface conditions. The SAGBI is intended to provide a preliminary indicator of potential recharge and where enhanced recharge could be implemented. SAGBI may not represent the complete view of recharge potential, and additional geotechnical studies should be conducted prior to the implementation of recharge projects. Classifications of potential recharge in the SAGBI include Very Poor, Poor, Moderately Poor, Moderately Good, Good, and Excellent, in order of increasing recharge potential.

Figure 2-17 shows the SAGBI rating of potential recharge within the TBID Plan Area, without consideration of soil modifications, such as deep tillage, that may have occurred historically or could occur. Based on the SAGBI Index, the TBID Plan Area generally consists of soils that are “very poor” for groundwater recharge. Areas of high recharge potential (excellent) are in the north, along Deer Creek, in the non-contiguous portions of the TBID Plan Area. The contiguous portion of the TBID Plan Area has an excellent classification for recharge potential along Fountain Spring Gulch, and from the south to the northwestern corner of the TBID Plan Area.

Groundwater discharge within the TBID Plan Area occurs through groundwater pumping and baseflow contributions to surface water systems (Deer Creek). No springs or wetlands are present within the TBID Plan Area.

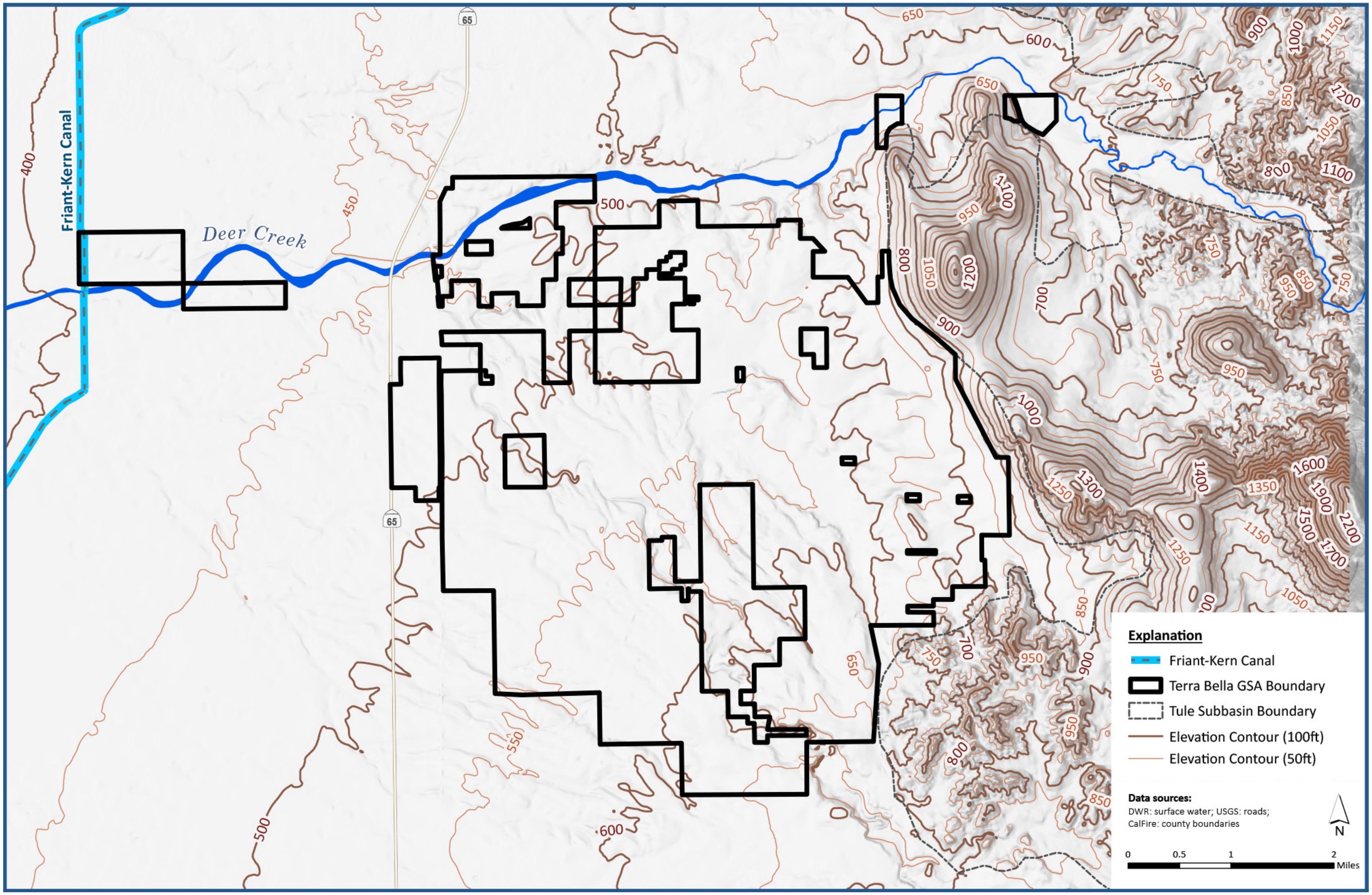

Figure 2-8. Map of Ground Surface Elevation

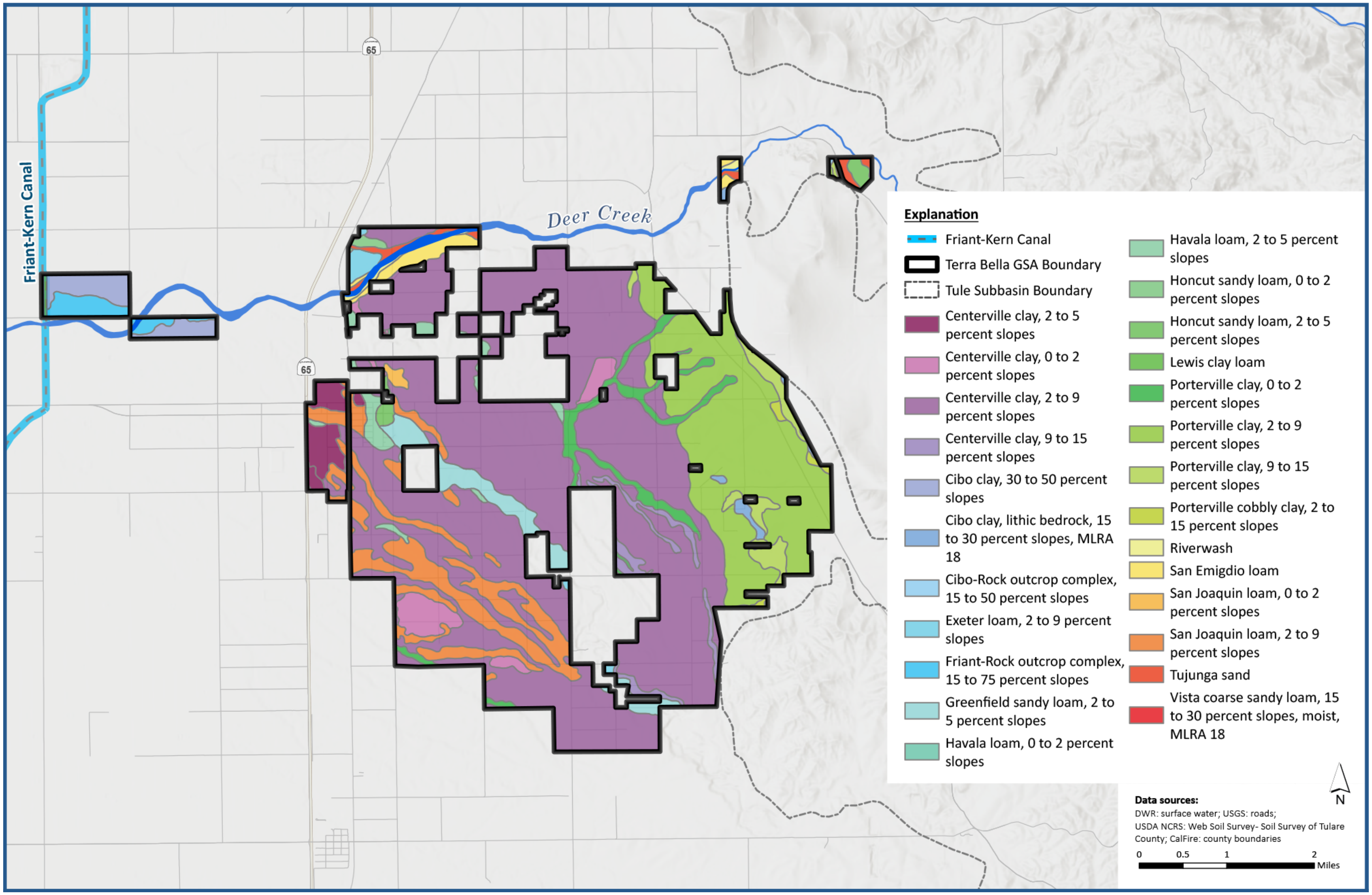

Figure 2-9. TBID Soils

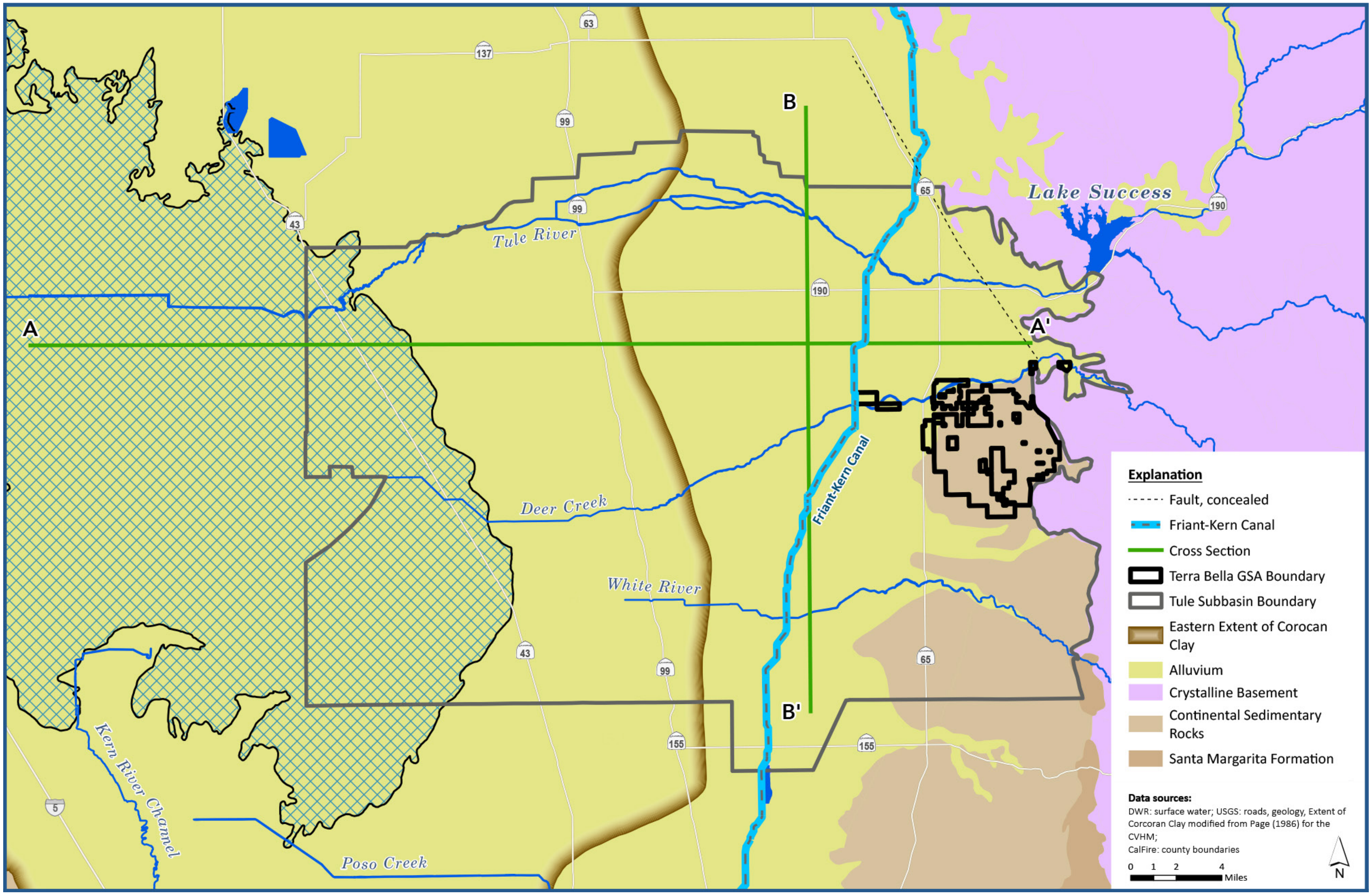

Figure 2-10. Surficial Geology and Cross-section Locations

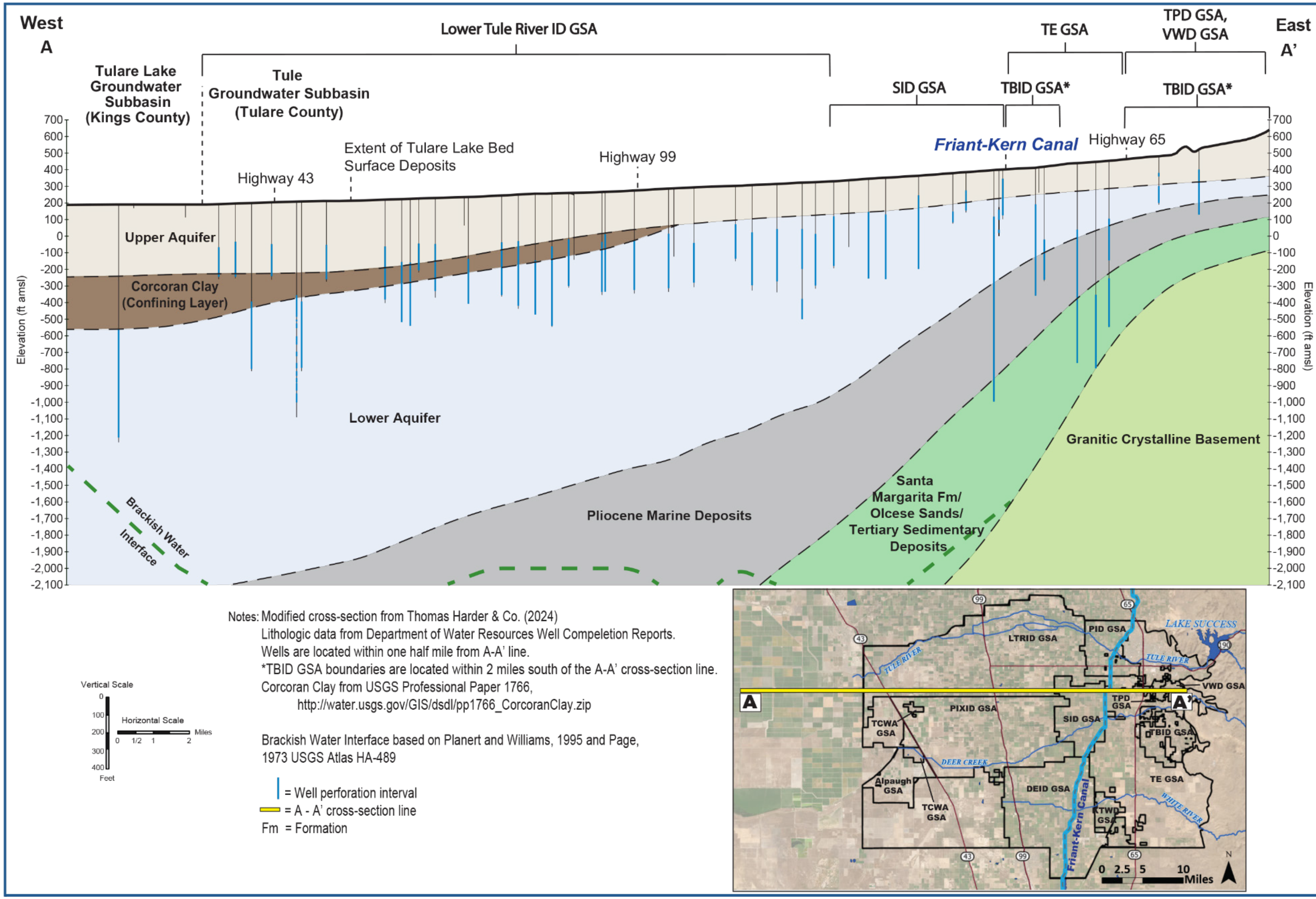

Figure 2-11. Geologic Cross-section A-A'

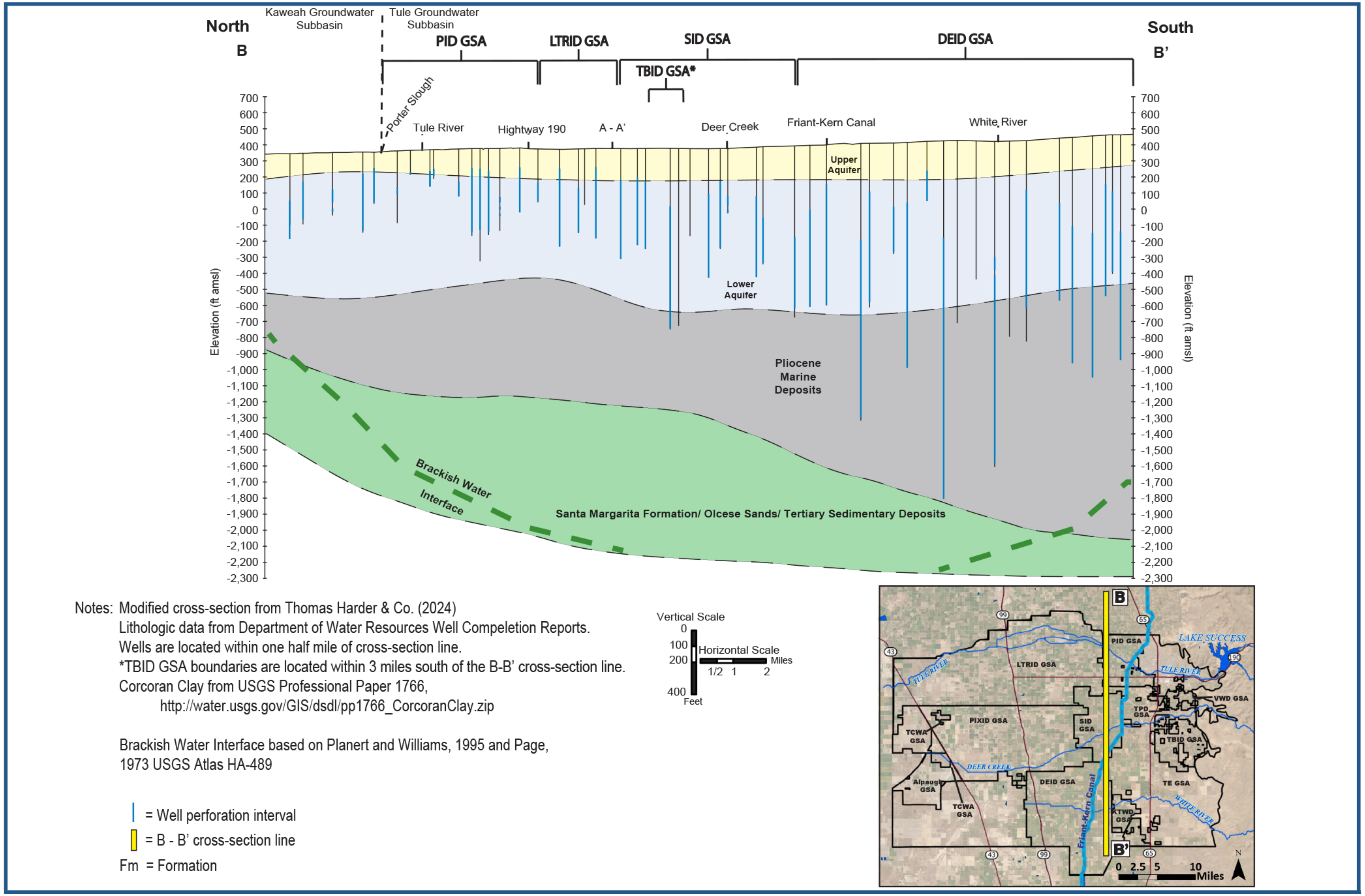

Figure 2-12. Geologic Cross-section B-B'

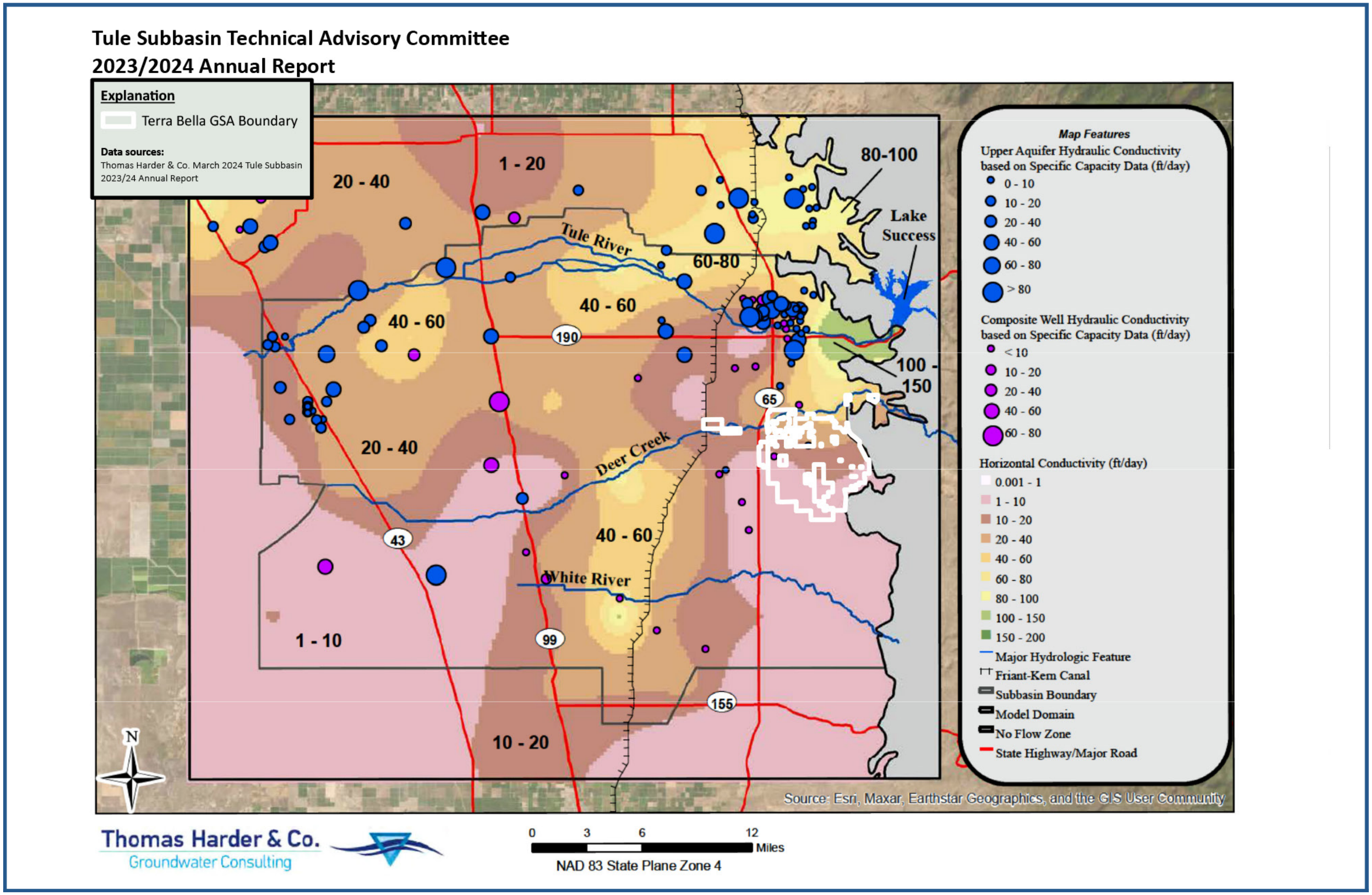

Figure 2-13. Upper Aquifer Horizontal Hydraulic Conductivity

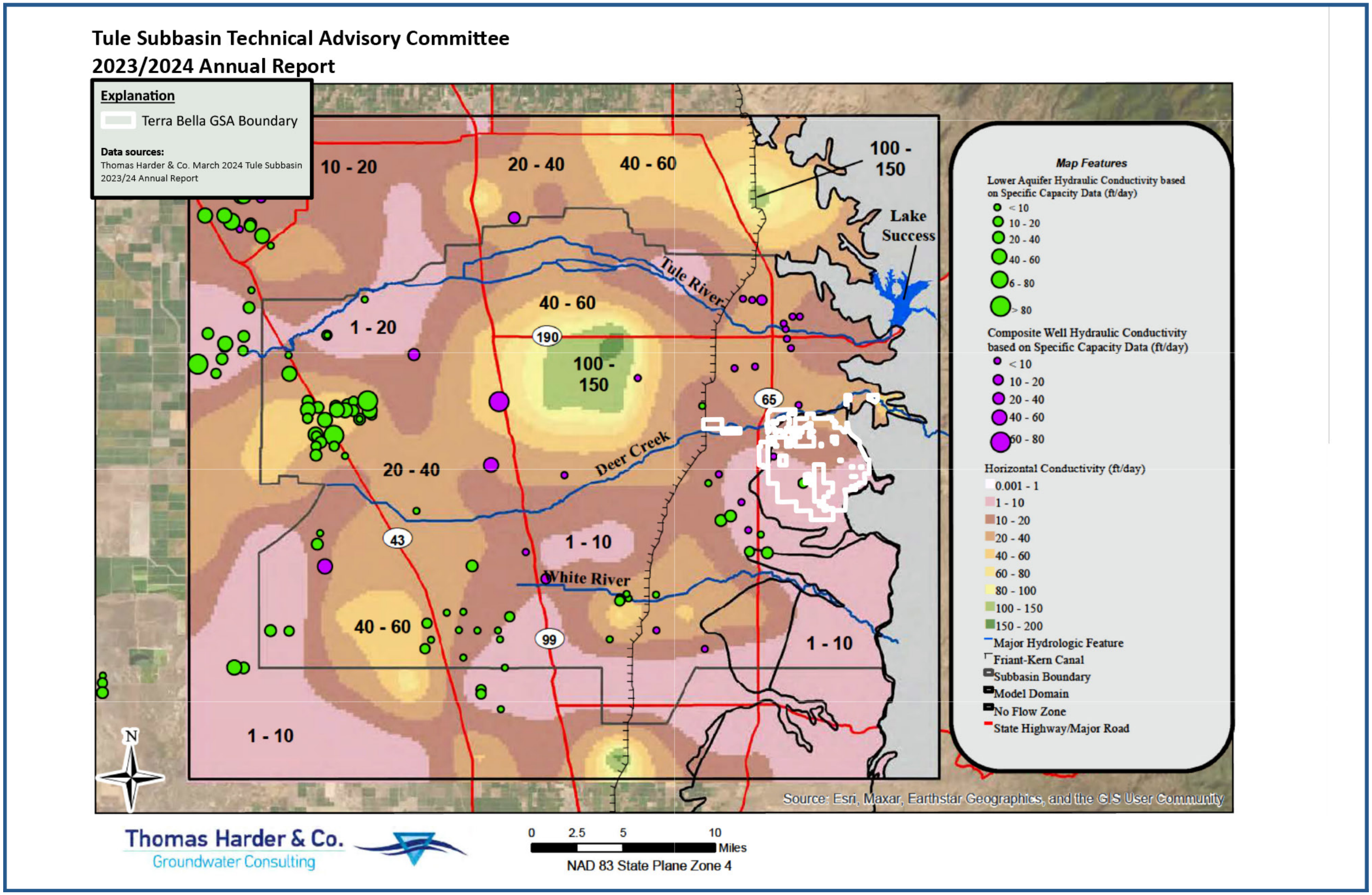

Figure 2-14. Lower Aquifer Horizontal Hydraulic Conductivity

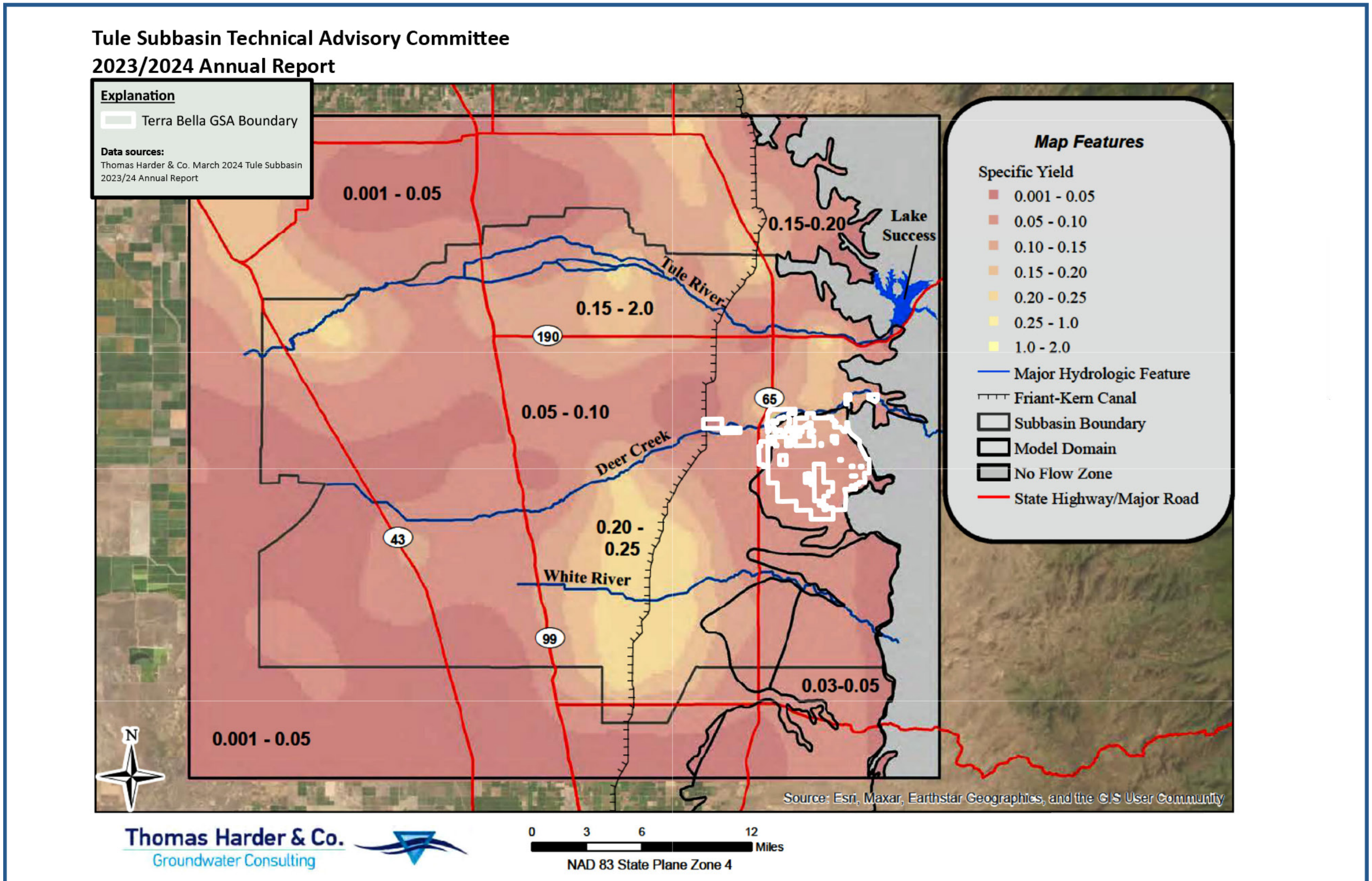

Figure 2-15. Upper Aquifer Specific Yield

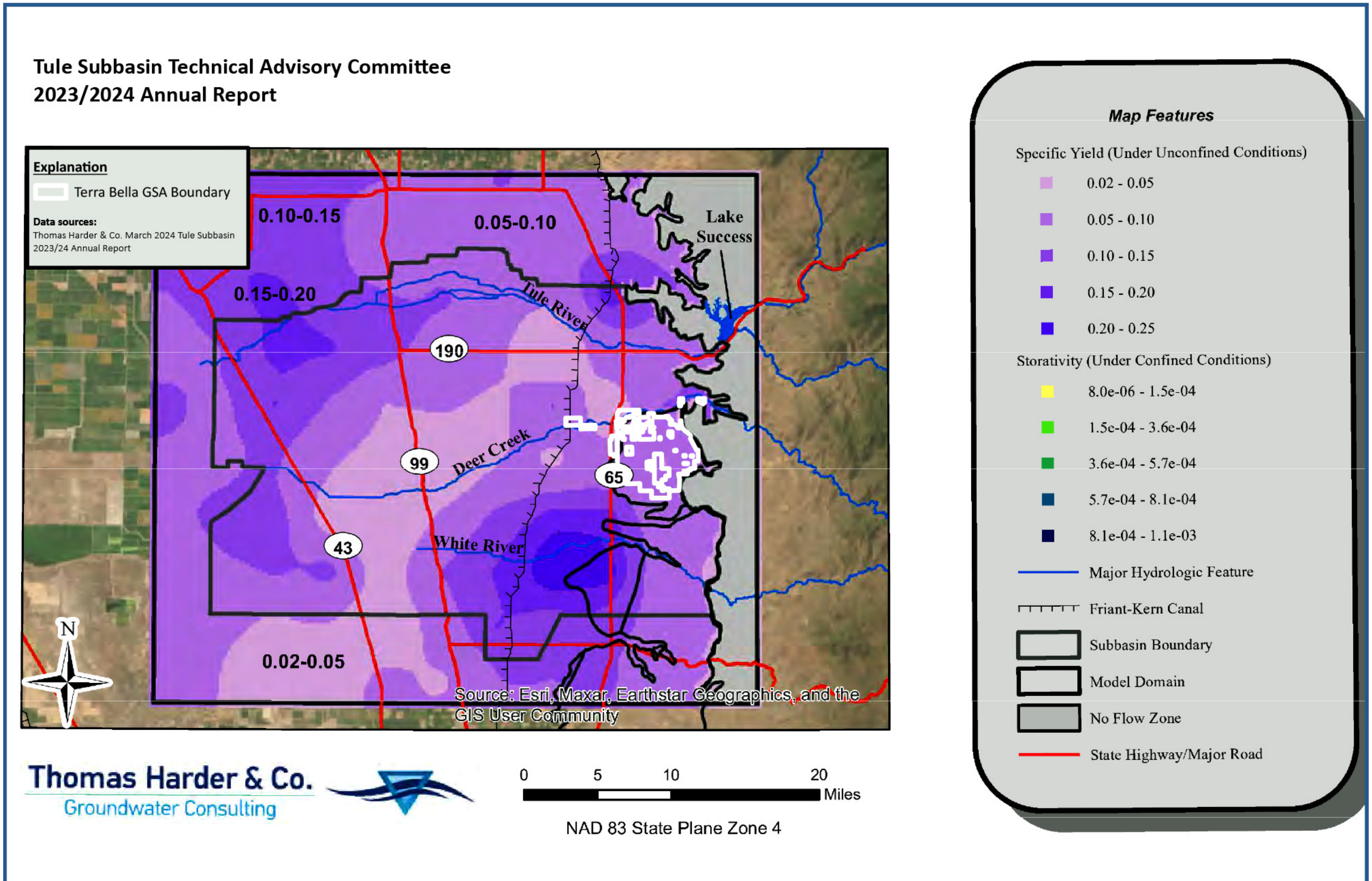

Figure 2-16a. Lower Aquifer Storage Properties: Specific Yield

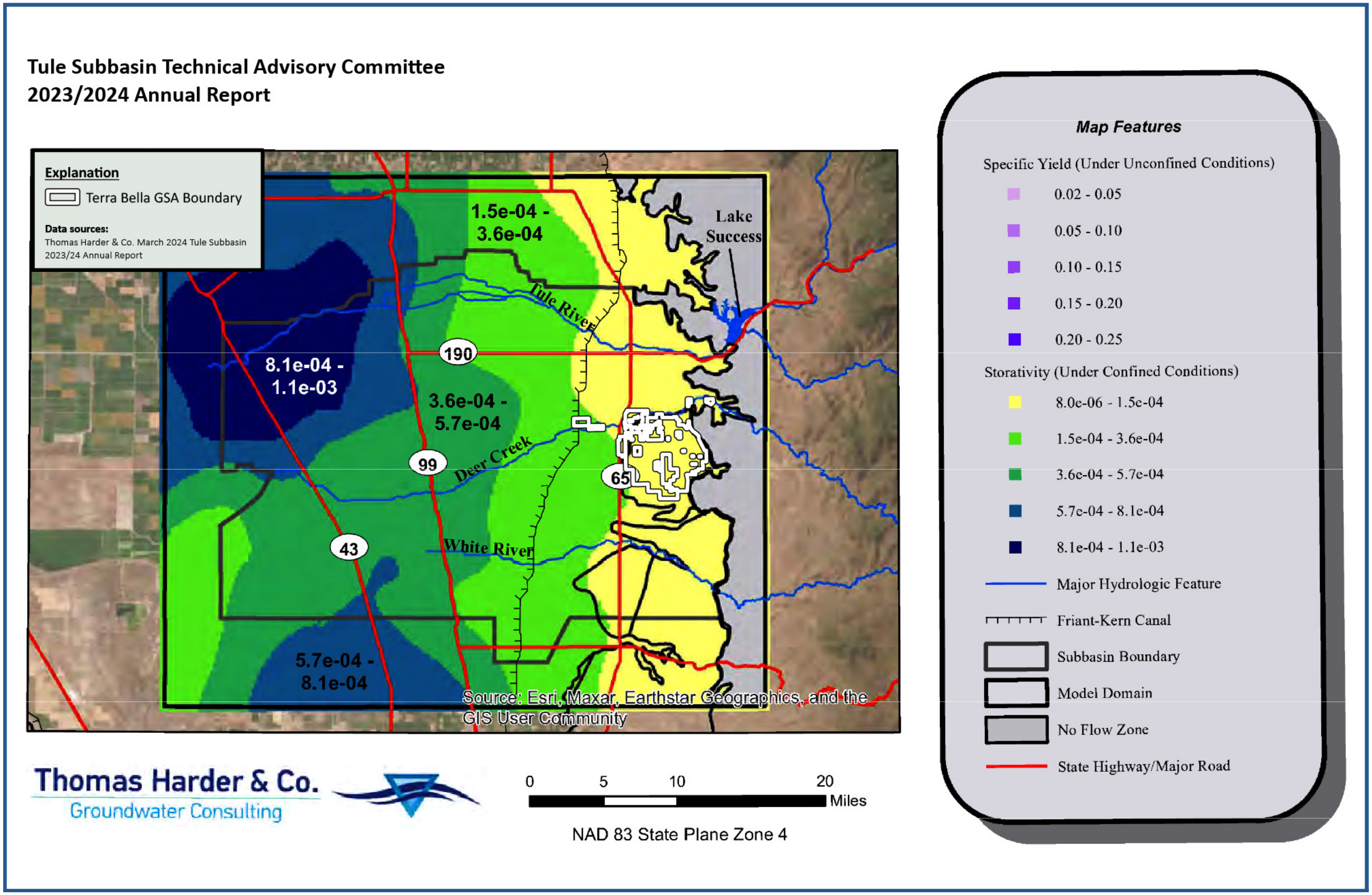

Figure 2-16b. Lower Aquifer Storage Properties: Storativity

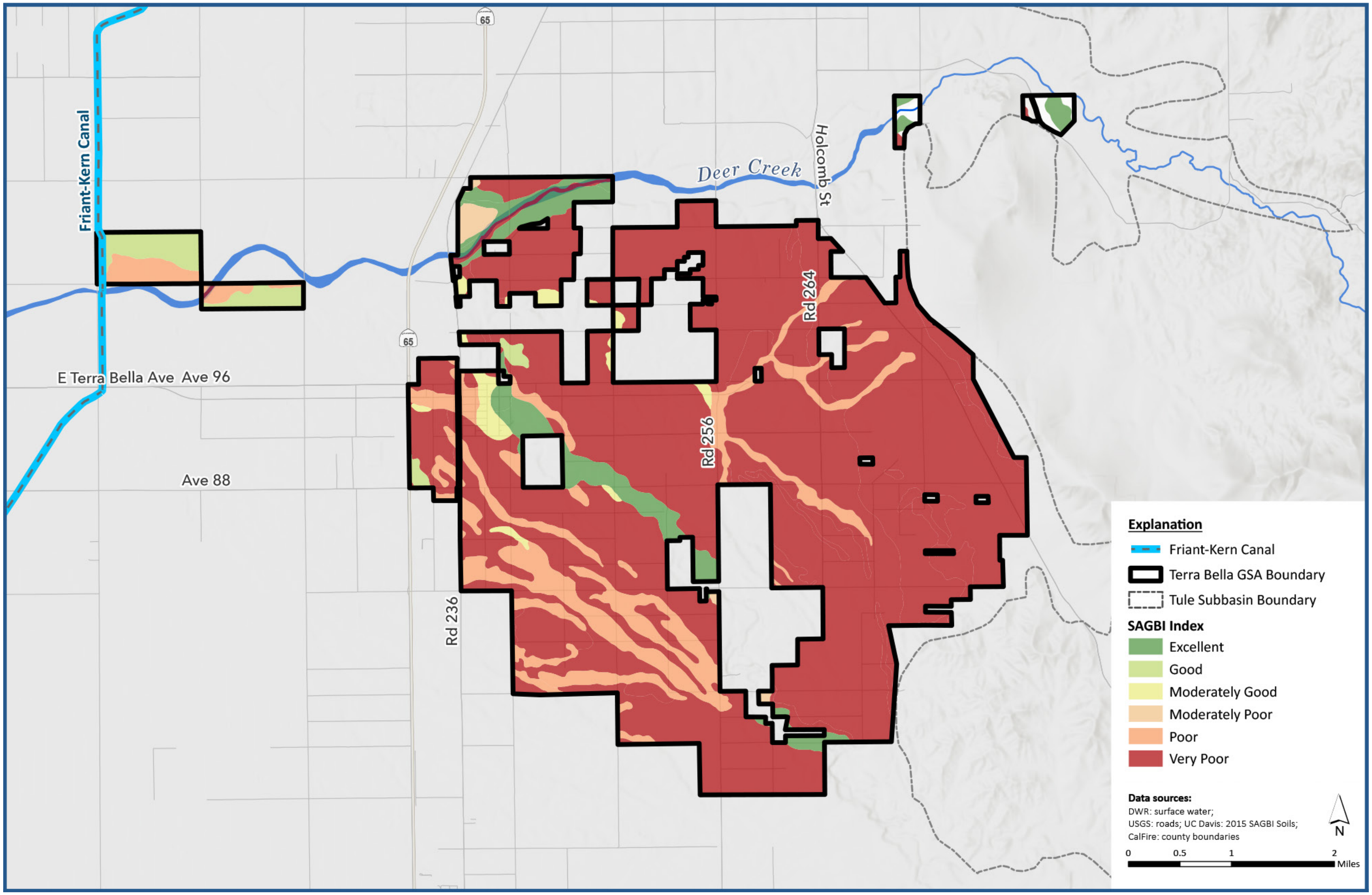

Figure 2-17. SAGBI Recharge Potential Map