Geologic Analysis, Ventura River Watershed

TO: Al Preston, PE, PhD, Geosyntec
Brandon Steets PE, MS, Geosyntec

CC: Kevin DeLano, GIT, MS, State Water Resources Control Board

FROM: Stephen J. Cullen, PG, PhD
Gregory Schnaar, PhD
Shannon Williams, CPG, MS

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BACKGROUND

This memorandum summarizes geologic analysis performed for the Ventura River Watershed (VRW) by Daniel B. Stephens & Associates, Inc. (DBS&A) in support of numerical model development. The geologic analysis presented herein will be used, in conjunction with other information as described in the project Study Plan (Geosyntec and DBS&A, 2019), to assign three-dimensional model layer geometry, initial model hydraulic properties (e.g., hydraulic conductivity), and the presence of boundary conditions. This geologic analysis is based on data available to DBS&A at the time the analysis was conducted. We anticipate that development of the VRW geologic conceptual model may be revised as additional data becomes available and as numerical model development proceeds.

GEOLOGIC ANALYSIS

The geologic analysis was performed by mapping the three-dimensional extent of surficial geologic units within the VRW, and results were plotted on a series of geologic cross-sections. Cross-section locations are shown on Figure 1 and were placed in order to be consistent with previous cross-sections developed in the VRW and follow the main surface-water bodies. The horizontal extent and depth of the geologic cross-sections were also determined based on the presence and depth of water supply wells in the watershed. Figure 2 displays the presence of, and indicates the depth of, wells within the VRW based on data received from VCWPD (2018). The geologic cross-sections are presented in Figures 3 through 8.

Specifically:

- Section A-A’, Figure 3, was located to follow the main stem of the Ventura River and continue to the north to the area of supply wells located along North Fork

Matilija Creek; within the Upper Ventura River Basin, this location is coincident with Section A-A’ from Kear Groundwater (KG, 2016a).

- Section B-B′, Figure 4, was located to pass through the Upper Ventura River Basin and into the Ojai Valley Basin; this section is coincident with Section B-B′ from KG (2016a) within the Upper Ventura River Basin and Section A-A′ from DBS&A (2011) within the Ojai Valley Basin.

- Section C-C′, Figure 5, was located to follow San Antonio Creek and is coincident with Section C-C′ from DBS&A (2011) within the Ojai Valley Basin.

- Section D-D′, Figure 6, was located to run south-to-north from the area south of the Upper Ojai Valley Basin (where several supply wells are located) to the Upper Ojai Valley Basin and then through the Ojai Valley Basin. This section is coincident with Section B-B′ from DBS&A (2011) within the Ojai Valley Basin.

- Section E-E′, Figure 7, was located to pass through the widest area of alluvium in the Lower Ventura River Basin and is also located based on availability of boring-log data.

- Section F-F′, Figure 8, was located to pass through the Upper Ventura River Basin and the areas of alluvium associated with San Antonio Creek, Lion Canyon Creek, and the Upper Ojai Valley Basin; this section is coincident with Section C-C′ from KG (2016a) within the Upper Ventura River Basin and the area around San Antonio Creek.

Geologic maps, boring logs, existing geologic studies and cross-sections, and the current Bulletin-118 Basin boundaries (DWR, 2016a) were reviewed in order to assess the extent of surficial geologic units. Previous studies of the extent and thickness of alluvium in the basins include Turner (1971), Staal Gardener & Dunne, Inc. (SGD, 1992), Fugro West, Inc. (Fugro, 2002), Hopkins Groundwater Consultants, Inc. (HGC, 2007), DBS&A (2011), and KG (2016a, 2016b). Previous studies of bedrock geology in the watershed consulted also included DWR (1933), Rockwell et al. (1984) and CDOG (1991).

Boring logs were available from DWR (2018), VCWPD (2017), HGC (2007), KG (2018), Numeric Solutions LLC (NS, 2018) and from Cleanup and Waste Discharge Sites on the GeoTracker website (SWRCB, 2018). Wells used in the geologic analysis are displayed on Figure 1 and Figure 9. Where multiple wells are present in the same general location and would overlap if projected onto the cross-sections, the well with the most detailed geologic log available was projected. All well logs used in this geologic analysis have been compiled and are available upon request. Two geophysical surveys in the vicinity of the Ventura River were also referenced (Fugro, 2002; Advanced Geoscience, Inc. [AGI], 2014) and locations are shown on Figure 9. Ground-surface elevation was based on Lidar data where available (VCPWA, 2005) and otherwise on digital-elevation data (USGS, 2018).

Geologic maps used in the analysis include the East Half Santa Barbara 30’ x 60’ Quadrangle prepared by the California Geologic Survey (Gutierrez et al., 2008; shown on Figures 10a and 10b), the Eastern Three-Quarters of the Cuyama 30’ x 60’ Quadrangle prepared by the U.S. Geologic Survey (Kellogg et. al, 2008; shown on Figures 11a and 11b), and a tectonic and physiographic map of the White Ledge Peak and Matilija Quadrangles prepared by the U.S. Geologic Survey (Minor and Brandt, 2015; shown on Figure 12). Geologic nomenclature used by the California Geologic Survey (Gutierrez et al., 2008) was used for the purpose of this memorandum, and descriptions are summarized in Table 1.

DBS&A received data from NS (2018) regarding the presence of tertiary bedrock outcrops (Pico Formation, Tp) in areas mapped as active wash deposits (Qw) and stream terrace deposits (Qht) on available geologic maps within the Lower Ventura River Basin. DBS&A observed these outcrops during a field survey in September 2018 and also at that time, observed tertiary bedrock outcrops (Rincon Shale, Tr) in an area of San Antonio Creek mapped as Qw in available geologic maps. DBS&A incorporated the presence of these tertiary bedrock outcrops in the geologic analysis, and locations are shown on Figure 9.

The first step in the geologic analysis was estimation of the horizontal extent and thickness of undifferentiated alluvium (excluding areas where alluvium is considered thin and non-water bearing and thin alluvial channels in bedrock areas). For the purpose of this memorandum, quaternary alluvial deposits (Qpa, Qoa), wash deposits (Qw), alluvial fan deposits (Qhfy, Qhf, Qf, Qpf), alluvial and colluvial deposits (Qha), stream terrace deposits (Qht), active beach deposits (Qb), active coastal estuarine deposits (Qes), paralic deposits (Qhps) and artificial fill (af) are considered as undifferentiated alluvium. The Saugus Formation (Qs) is also considered to be alluvial deposits based on its description as “weakly consolidated alluvial deposits composed of sandstone and siliceous shale, gravel and cobbles in sandy matrix” (Gutierrez et al., 2008; see Table 1).

The current Bulletin-118 groundwater basin boundaries are displayed on Figure 1 and are overlaid on geologic maps in Figures 10a, 11a, and 12. The Bulletin-118 boundaries largely correspond to the extent of surficial alluvium, excluding thin alluvial channels that underlie streams in the mountain bedrock areas, the area of Lake Casitas, various areas of landslide deposits throughout the VRW, and areas where alluvium is considered thin and non-water bearing (e.g., alluvium to the east of the Ventura River in the vicinity of Section F-F′ that was formally included in the Upper Ventura River Bulletin-118 boundary prior to basin boundary modification in 2016, see KG, 2016a; DWR, 2016b).

Alluvial sediment thickness was estimated from review of boring logs, geophysical logs, previous geologic studies, and the location of non-alluvial bedrock outcrops. SWRCB performed the first round of review of boring logs available from Ventura County Watershed Protection District (VCWPD) in the Upper Ventura, Lower Ventura, and Upper Ojai Valley Basins and estimated the depth of alluvium for each well (DeLano, 2017). DBS&A reviewed the SWRCB analysis against available boring logs and previous geologic studies. Within the Ojai Valley Basin, previous analysis of geophysical logs from wells located within the Basin was used to map alluvium thickness (DBS&A, 2011), and this previous mapping was updated based on newly received well logs. The geophysical log analysis also identified the presence of aquifer and semi-confining units within the Ojai Valley Basin.

Bottom-of-alluvium elevation was interpolated throughout the watershed using bedrock elevation data from each location for which lithologic data was present using a combination of manual contouring based on professional judgement and geostatistical (‘kriging’) methods. Previously developed maps of bottom-of-alluvium elevation within the VRW developed by Turner (1971) and SGD (1992) were also used to inform the bottom-of-alluvium elevation. Figure 13 presents the developed bottom-of-alluvium elevation contours. Figure 14 displays an isopach map of the resulting alluvium thickness at the scale of the 330-foot grid cells that are planned to be used for the numerical model.

Following mapping of undifferentiated alluvium, additional geologic analysis was conducted to map the three-dimensional extent of bedrock geologic units that are used for water supply in the VRW and to map the presence of structural features (i.e., faults). The bedrock geology analysis relied primarily on the available geologic maps (i.e., see Figures 10a, 11a, 12). When discrepancies in geologic interpretation occurred between the various maps, the newest geologic map covering an area was used. In cases where landslide deposits were mapped to cover bedrock on Gutierrez et al. (2008; see Figure 10a), older, preliminary geologic maps were referenced that did not include the landslide deposits (i.e., Dibblee, 1981, 1987a, 1987b). In addition, Gurrola (2018) and Rockwell et al. (1984) were referenced in regards to the orientation of the Arroyo Parida

Fault and other nearby faults located along the Ventura River. Well logs were also consulted where available to confirm bedrock lithology. Quaternary and Pleistocene alluvial deposits were delineated based on the age of mapped surface units on the respective geologic maps discussed above and also based on previous cross-sections developed by Turner (1971).

Apparent dips of bedrock units were calculated using bedding strike and dip measurements nearest the unit contact and the Visible Geology web application (Visible Geology, 2018), which uses strike, dip, and cross-section bearing to calculate apparent dip. When dip measurements on faults were available, apparent dip of the fault was calculated using the same method. If fault dip measurements were not available, faults were interpreted to have similar geometry to other nearby faults that did have direct measurements. Finally, when surface geology was covered by alluvium and no well logs were available, descriptions of general unit thickness, described in the Los Angeles 30' x 60' Quadrangle pamphlet (Campbell et al., 2014) were used to approximate unit contacts under the Ojai Valley and Upper Ojai Valley Basins.

REFERENCES

Advanced Geoscience, Inc. (AGI), 2014. Draft Report, Geophysical Surveys for Investigation of Subsurface Geologic Conditions Near Well Numbers 1-4 at VRCWD Facility. Submitted to Ventura River Water District, August 29, 2014.

California Department of Water Resources (DWR), 1933. Bulletin 46: Ventura County Investigation.

California Department of Water Resources (DWR), 2016a. Bulletin 118, Interim Update 2016. URL: https://water.ca.gov/Programs/Groundwater-Management/Bulletin-118

California Department of Water Resources (DWR), 2016b. Basin Boundary Modification Request System, 4-003.01 Ventura River Valley - Upper Ventura River.

California Department of Water Resources (DWR), 2018. Well Completion Reports, Well Completion Report Map Application.
URL: http://wdl.water.ca.gov/groundwater/wells/well_completion_reports.cfm

California Division of Oil and Gas (CDOG), 1991. Generalized Cross Section, Central Ventura River Basin, from California Oil and Gas Fields, Volume II: Southern, Central Coastal, and Offshore California. Publication No. TR12.

California State Water Resources Control Board (SWRCB), 2018. GeoTracker. URL: https://geotracker.waterboards.ca.gov/

Campbell, R.H., Wills, C.J., Irvine, P.J., and Swanson, B.J., 2014, Preliminary Geologic Map of the Los Angeles 30' x 60' quadrangle, California: Department of Conservation, California Geological Survey in cooperation with United States Geological Survey, 85 p., 1 sheet, 1:100,000. Digital preparation by Gutierrez, C.I. and O'Neal, M.D.

DBS&A, 2011. Groundwater Model Development, Ojai Valley Basin, Ventura County, California. November 15, 2011.

DeLano, K., 2017. Draft Analysis of Ventura River Well logs by K. DeLano (SWRCB), submitted to Gregory Schnaar (DBS&A).

Dibblee, T.W., Jr. 1981. Geologic Map of the Ojai Quadrangle, California. U.S. Geological Survey Open-File Report 82-74.

Dibblee, T.W., Jr., 1987a. Geologic Map of the Matilija Quadrangle, Ventura County, California: Dibblee Geological Foundation, Map DF-13 (Ehrenspeck, H.E., ed.), scale 1:24,000.

Dibblee, T.W., Jr., 1987b. Geologic Map of the Ojai Quadrangle, Ventura County, California: Dibblee Geological Foundation, Map DF-14 (Ehrenspeck, H.E., ed.), scale 1:24,000.

Fugro West, Inc. (Fugro), 2002. Geophysical and Geotechnical Study, Proposed Siphon Beneath the Ventura River, Meiners Oaks Area, Ventura County, California. Prepared for Ojai Valley Sanitary District, September 2002.

Geosyntec Consultants (Geosyntec) and Daniel B. Stephens & Associates, Inc. (DBS&A). 2019. Final Study Plan for the Development of Groundwater-Surface Water and Nutrient Transport Models of the Ventura River Watershed. Prepared for State Water Resources Control Board, December 2019. URL: https://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/cwap_enhancing/docs/vrw_sp_final.pdf

Gurrola, L. 2018. Personal communication to Stephen J. Cullen (DBS&A) describing the nature and orientation of the Arroyo Parida Fault zone based on fault investigations and engineering geological investigations performed in the Ojai valley and Matilija areas, letter dated June 18, 2018.

Gutierrez, C.I., Tan, S.S., and Clahan, K.B., 2008, Geologic Map of the east half Santa Barbara 30’ x 60’ quadrangle, California: Department of Conservation, California Geological Survey, 11 p., 1 sheet, 1:100,000. Digital preparation by Gutierrez, C.I. and Toman-Sager, K.

Hopkins Groundwater Consultants, Inc. (HGC), 2007. Preliminary Hydrogeological Study, Foster Park Wellfield Design Study, Ventura, California. Prepared for City of San Buenaventura, December 2007.

Kear Groundwater (KG), 2016a. Memorandum re: Basin Boundary Modification, Upper Ventura River Basin (DWR Basin No. 4-3.01). Submitted to Bert Rapp, Upper Ventura River Basin GSA Formation Committee.

Kear Groundwater (KG), 2016b. Memorandum re: Basin Boundary Modification, Ojai Valley Groundwater Basin (DWR Basin No. 4-2). Submitted to Jerry Conrow, President, Ojai Valley Basin Groundwater Management Agency.

Kear Groundwater (KG), 2018. Well logs and geophysical well-log interpretation provided by Jordan Kear, PG (Kear Groundwater) to SWRCB and DBS&A via email.

Kellogg, K.S., S.A. Minor and P.M. Cossette, 2008. Geologic Map of the Eastern Three-Quarters of the Cuyama 30’ x 60’ Quadrangle, California. U.S. Geologic Survey Scientific Investigations Map 3002.

Minor, S.A. and T.R. Brandt, 2015. Geologic Map of the Southern White Ledge Peak and Matilija Quadrangles, Santa Barbara and Ventura Counties, California. U.S. Geologic Survey Scientific Investigations Map 3321.

Numeric Solutions LLC (NS), 2018. Comment on SWRCB’s Draft Geologic Analysis of Ventura River Watershed in Support of Development of Groundwater-Surface Water and Nutrient Transport Models. Submitted to Kevin DeLano, SWRCB. November 1, 2018.

Rockwell, T.K., E.A. Keller, M.N. Clark, and D.L. Johnson, 1984. Chronology and rates of faulting of Ventura River terraces, California. Geological Society of America Bulletin, v. 95, p.1466-1474.

San Buenaventura Research Associates (SBRA). 2002. Historic resources evaluation, Avenue Water Treatment Plant, Ventura, California. May 14, 2002.

Staal Gardener & Dunne, Inc. (SGD). 1992. Hydrogeologic investigation: Ojai ground water basin Section 602 and 603 study tasks, Ventura, California. Prepared for Ojai Valley Basin Ground Water Management Agency. December 1992.

Turner, J.M. 1971. Ventura County Flood District Report on Ventura County Water Resources Management Study, Geohydrology of the Ventura River System: Ground Water Hydrology. Submitted to the Ventura County Board of Supervisors, May 1971.

U.S. Geological Survey (USGS). National Elevation Dataset (NED) 10m. 25 January 2018. https://www.usgs.gov/core-science-systems/national-geospatial-program/national-map

Ventura County Public Works Agency (VCPWA), 2005. Airborne Lidar Survey. Airborne 1 Corporation. February 2005.

Ventura County Watershed Protection District (VCWPD), 2017. Well logs provided by VCWPD to the State Water Resources Control Board.

Ventura County Watershed Protection District (VCWPD), 2018. Data on wells located within the Ventura River Watershed, provided via email by Barbara Council (VCWPD) to Gregory Schnaar (DBS&A), May 1, 2018.

Visible Geology Web Application (Visible Geology), 2018. URL: https://app.visiblegeology.com/

FIGURES AND TABLE

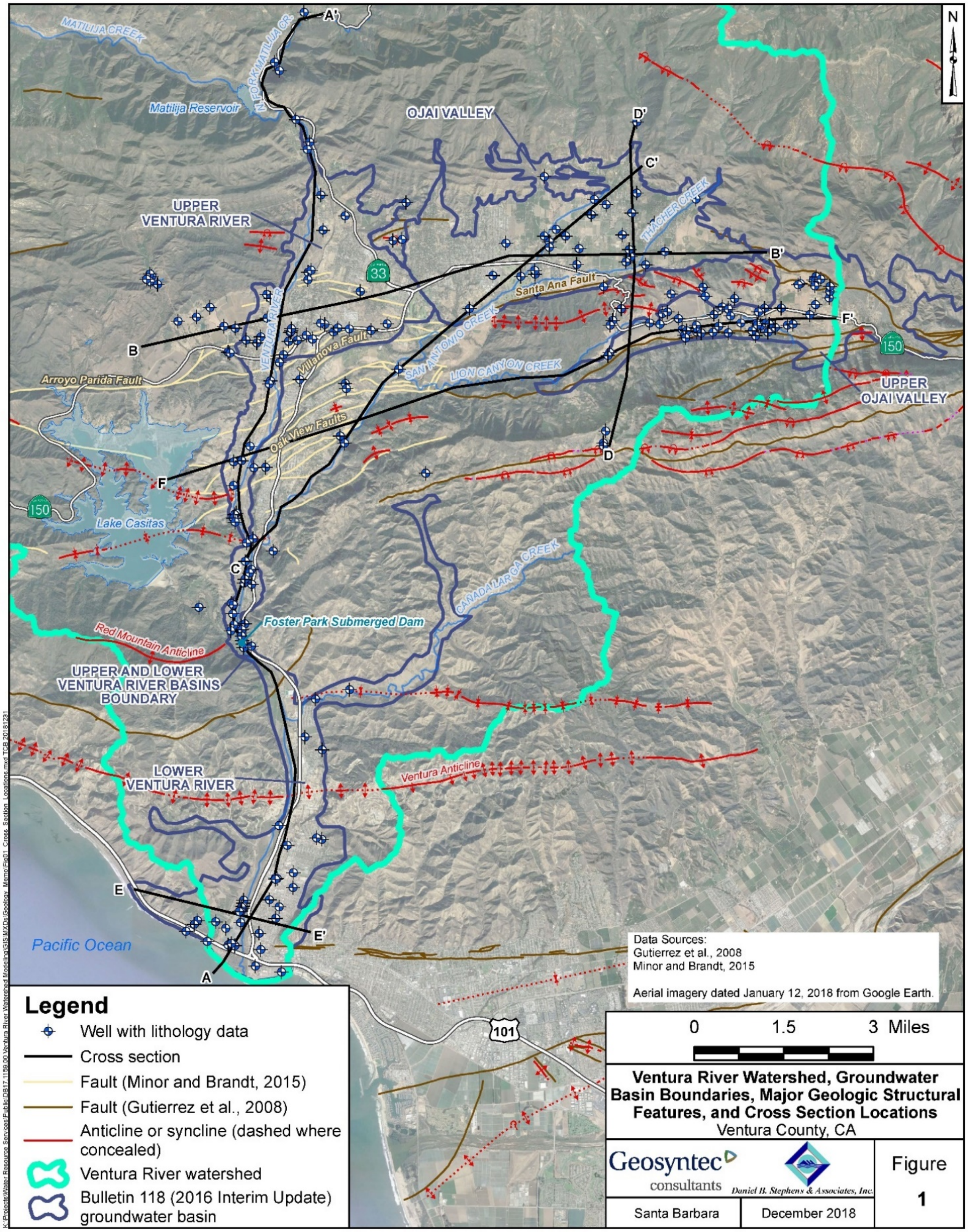

Figure 1: Ventura River Watershed, Groundwater Basin Boundaries, Major Geologic Structural Features, and Cross Section Locations.

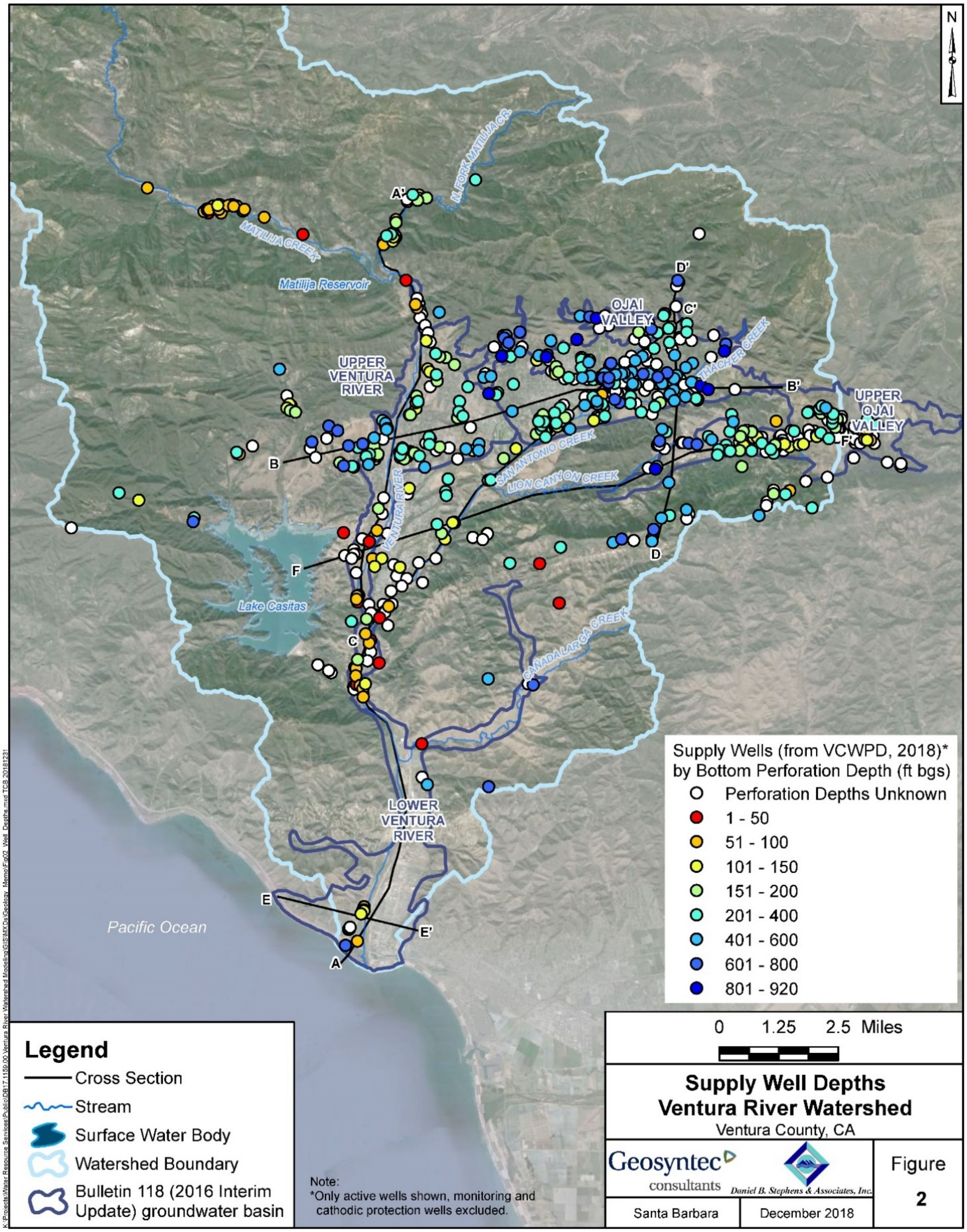

Figure 2: Supply Well Depths, Ventura River Watershed.

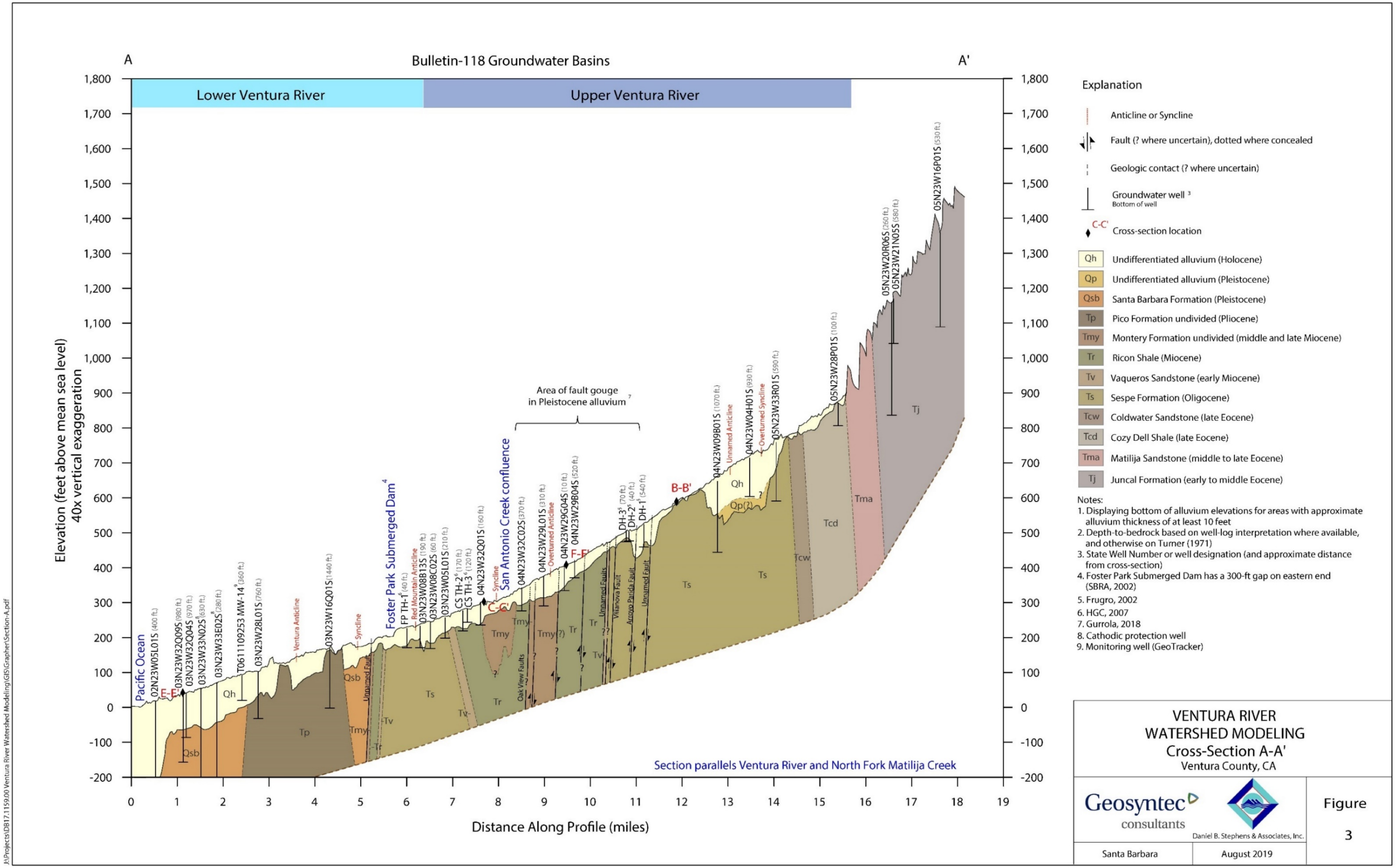

Figure 3: Ventura River Watershed Modeling: Cross-Section A-A'.

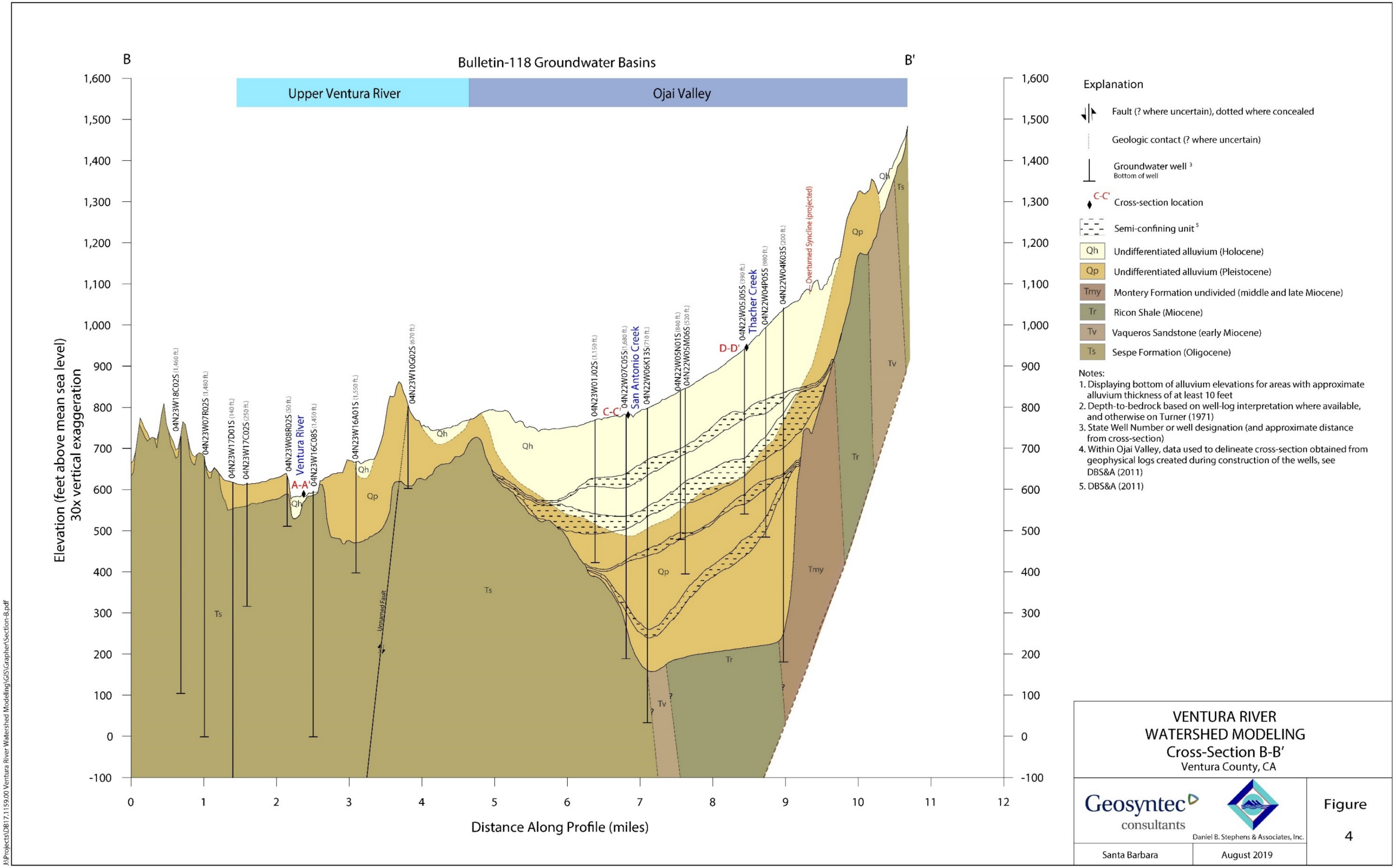

Figure 4: Ventura River Watershed Modeling: Cross-Section B-B'.

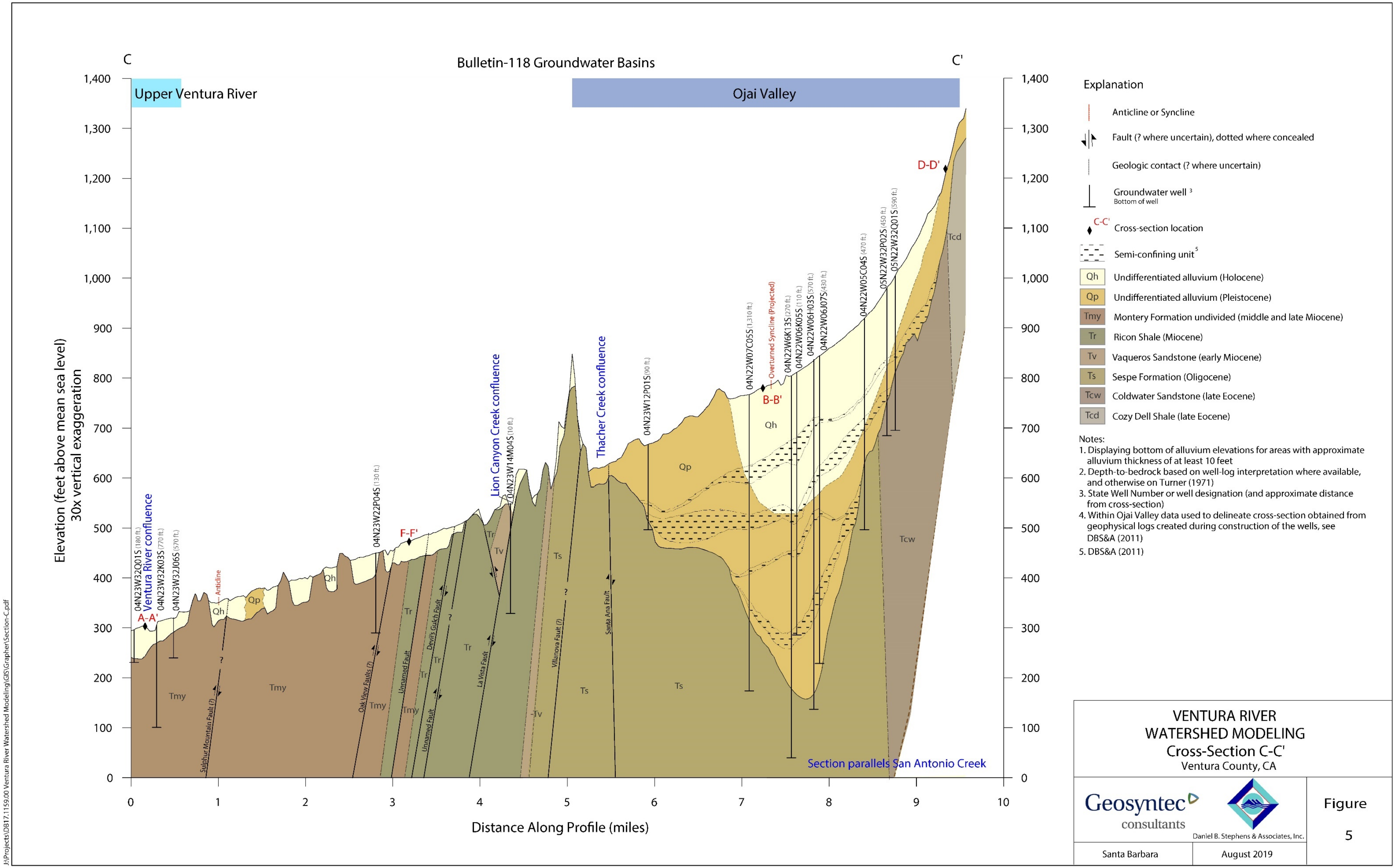

Figure 5: Ventura River Watershed Modeling: Cross-Section C-C'.

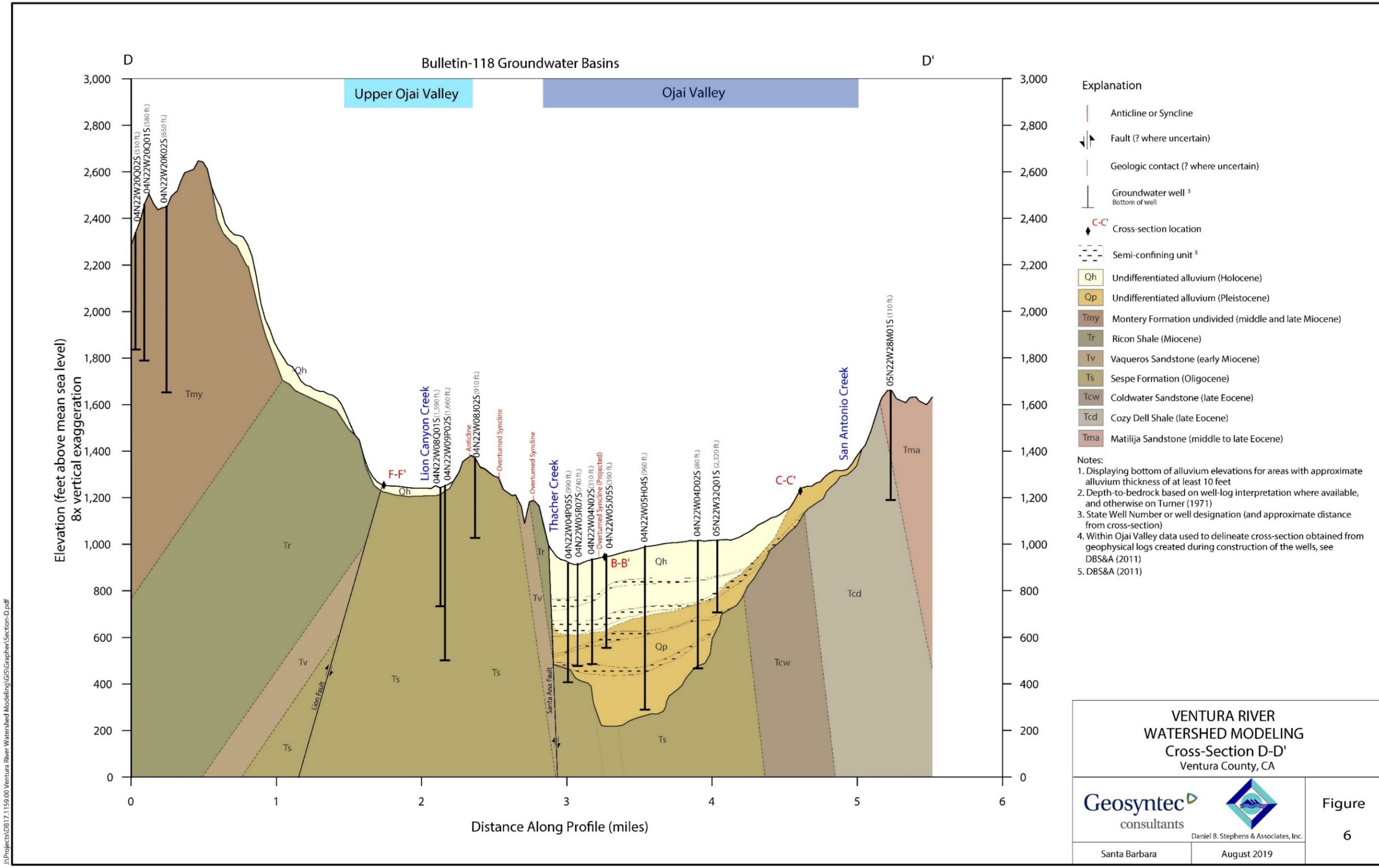

Figure 6: Ventura River Watershed Modeling: Cross-Section D-D'.

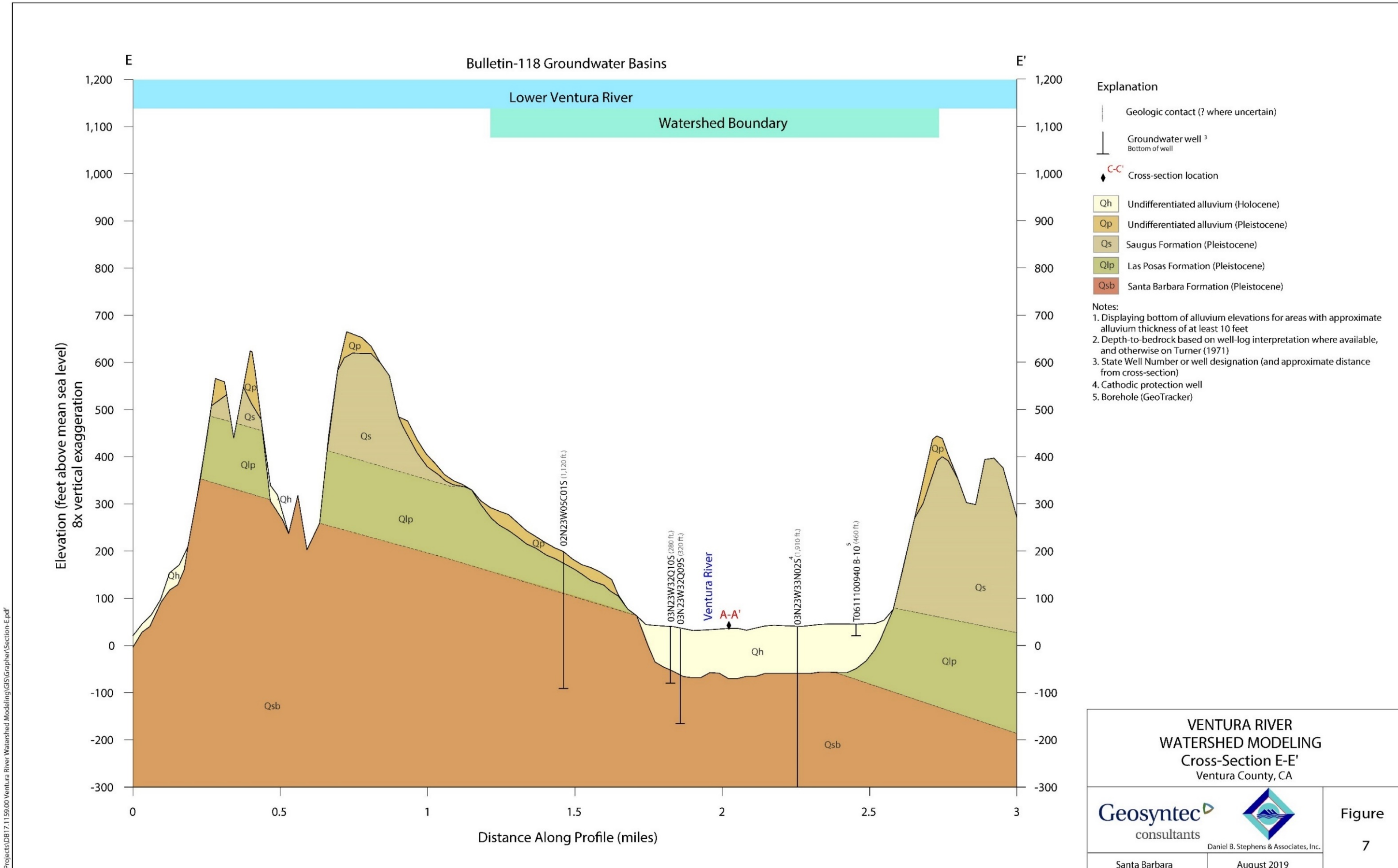

Figure 7: Ventura River Watershed Modeling: Cross-Section E-E'.

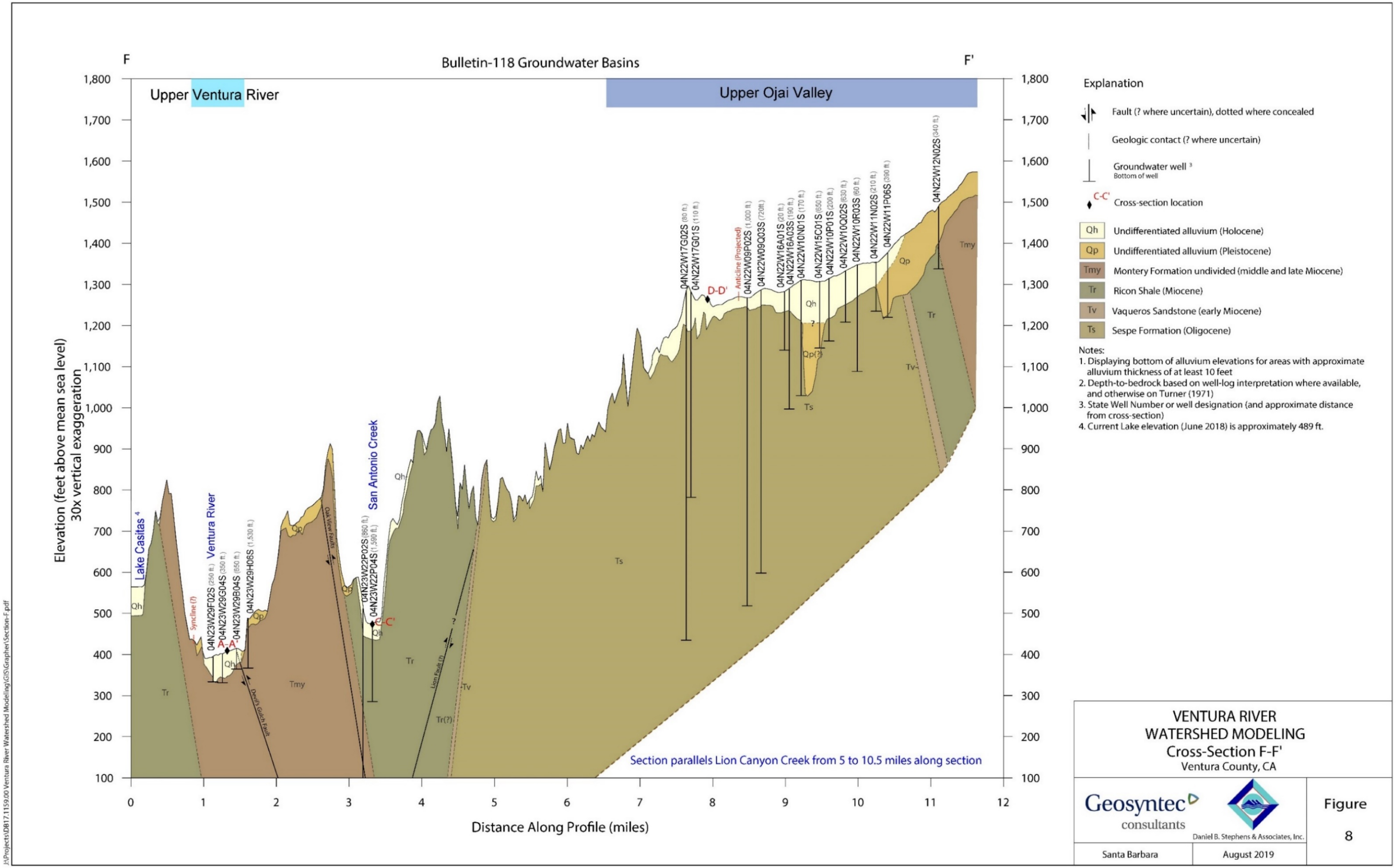

Figure 8: Ventura River Watershed Modeling: Cross-Section F-F'.

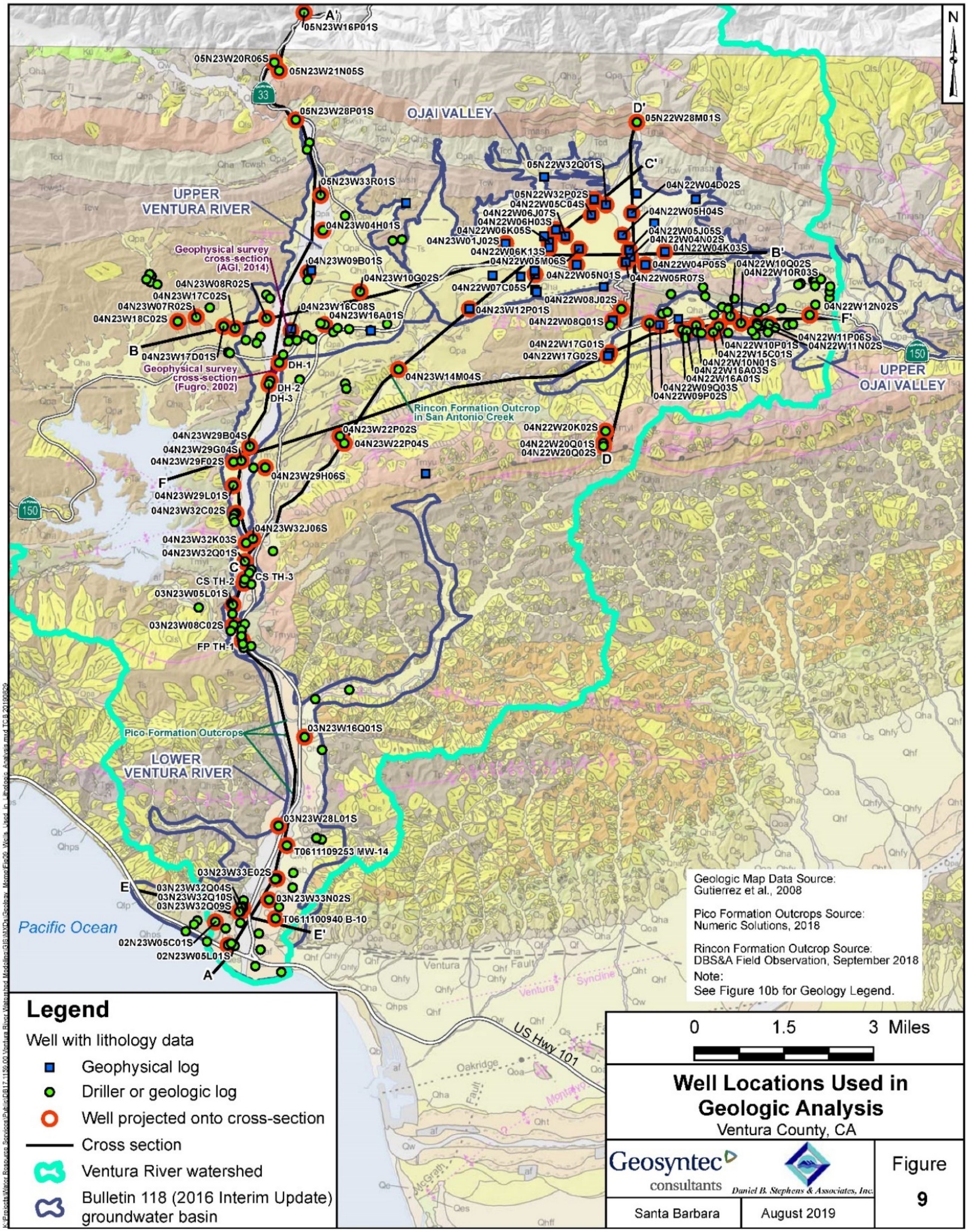

Figure 9: Well Locations Used in Geologic Analysis.

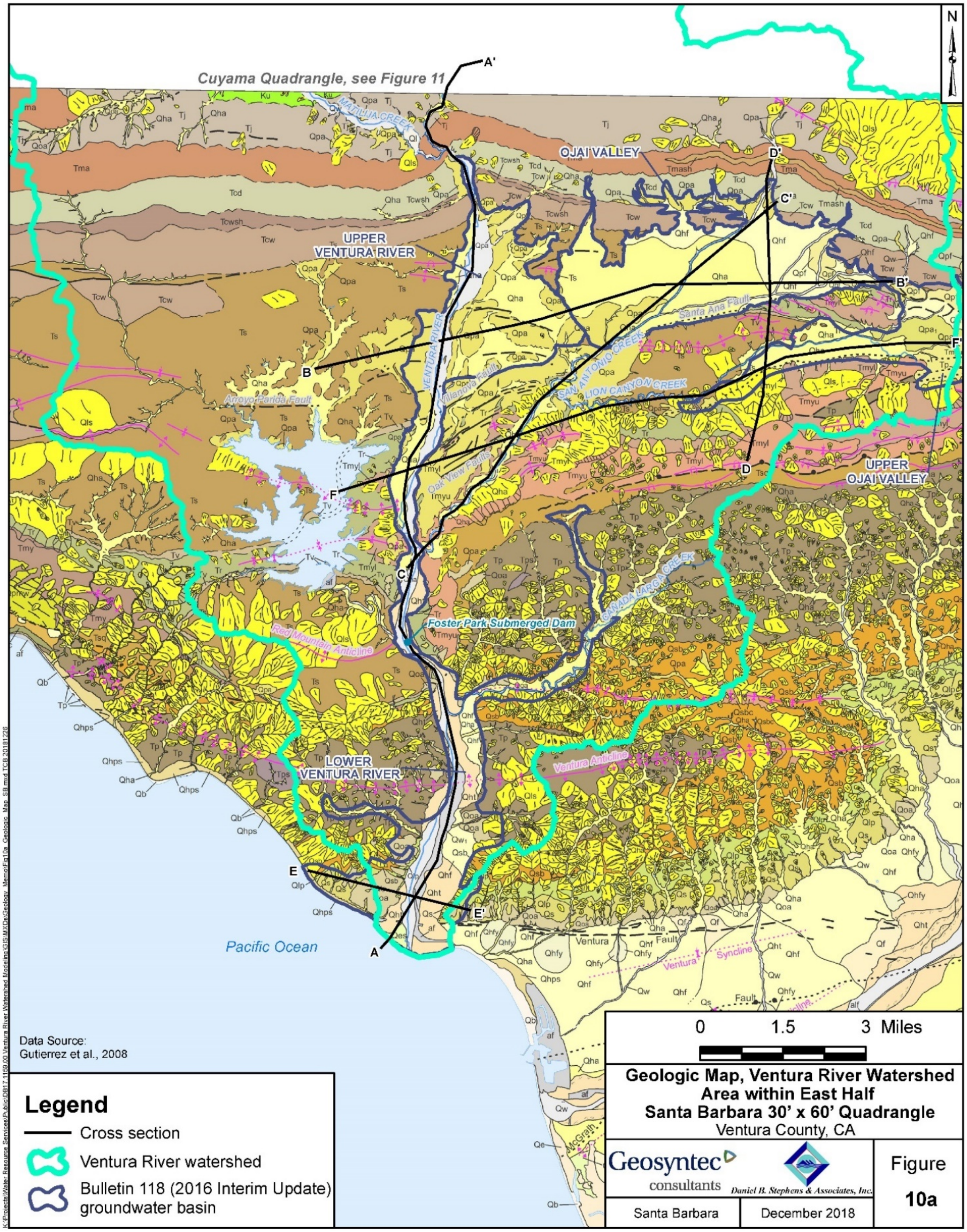

Figure 10a: Geologic Map, Ventura River Watershed Area within East Half Santa Barbara 30' x 60' Quadrangle.

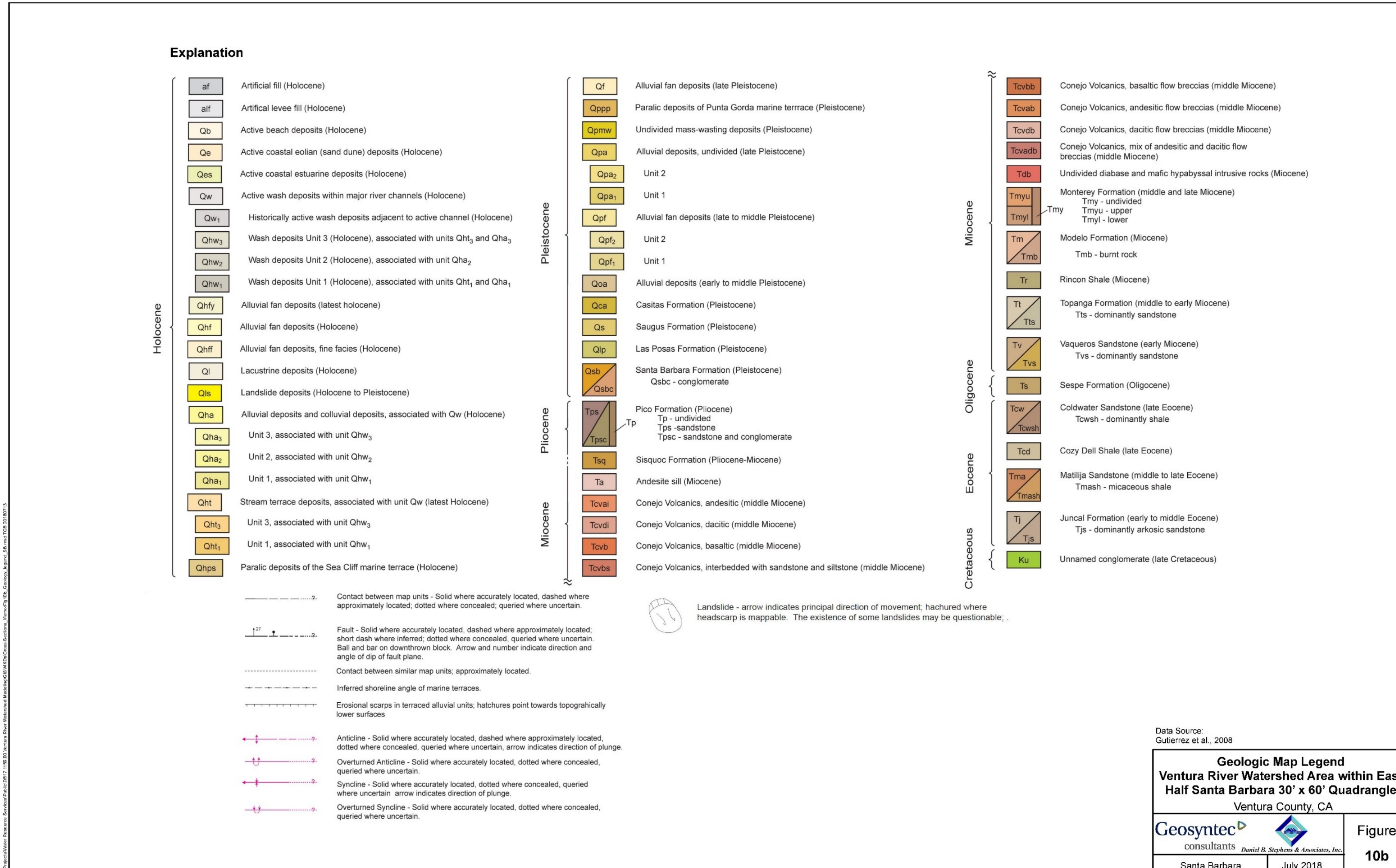

Figure 10b: Geologic Map Legend, Ventura River Watershed Area within East Half Santa Barbara 30' x 60' Quadrangle.

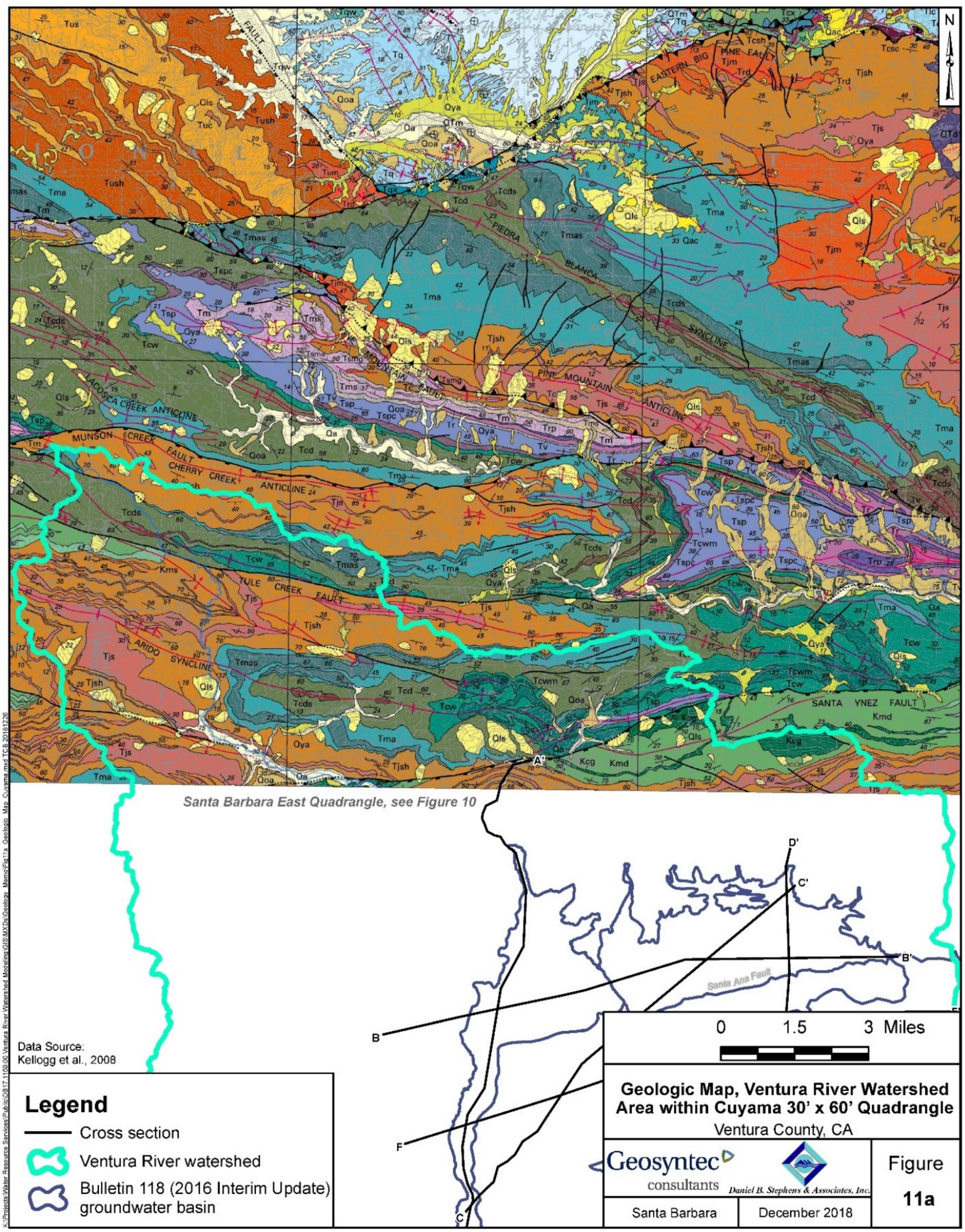

Figure 11a: Geologic Map, Ventura River Watershed Area within Cuyama 30' x 60' Quadrangle.

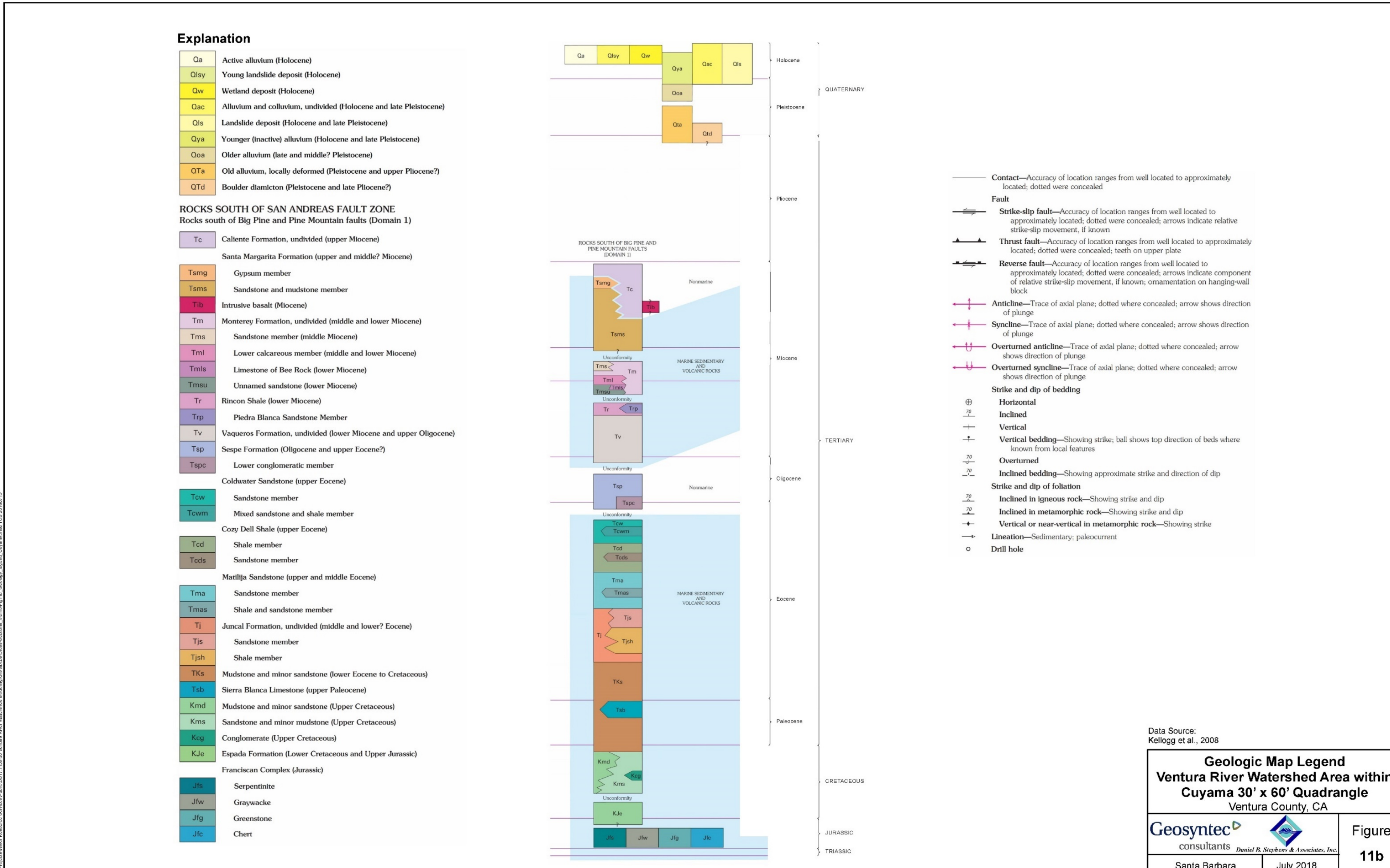

Figure 11b: Geologic Map Legend, Ventura River Watershed Area within Cuyama 30' x 60' Quadrangle.

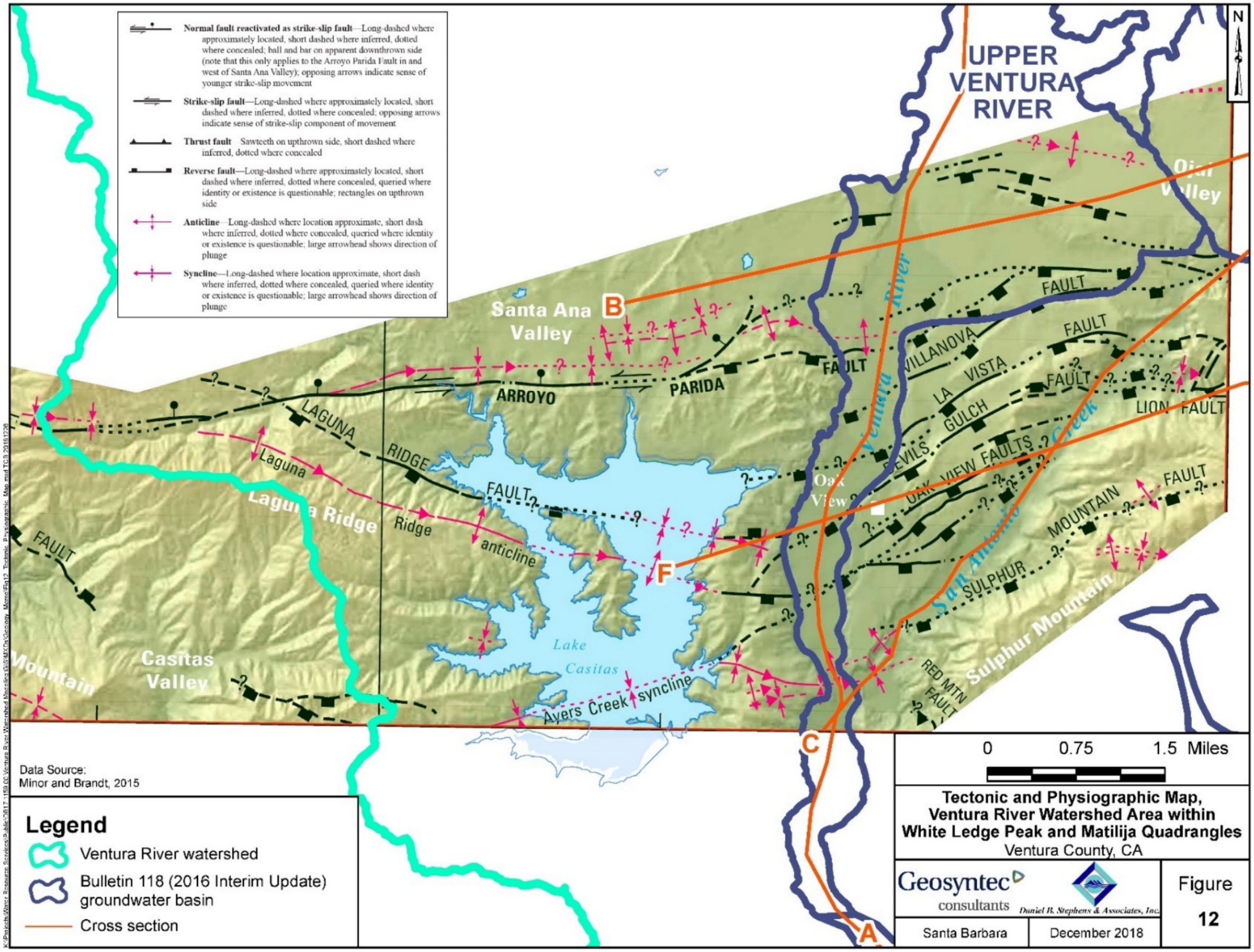

Figure 12: Tectonic and Physiographic Map, Ventura River Watershed Area within White Ledge Peak and Matilija Quadrangles.

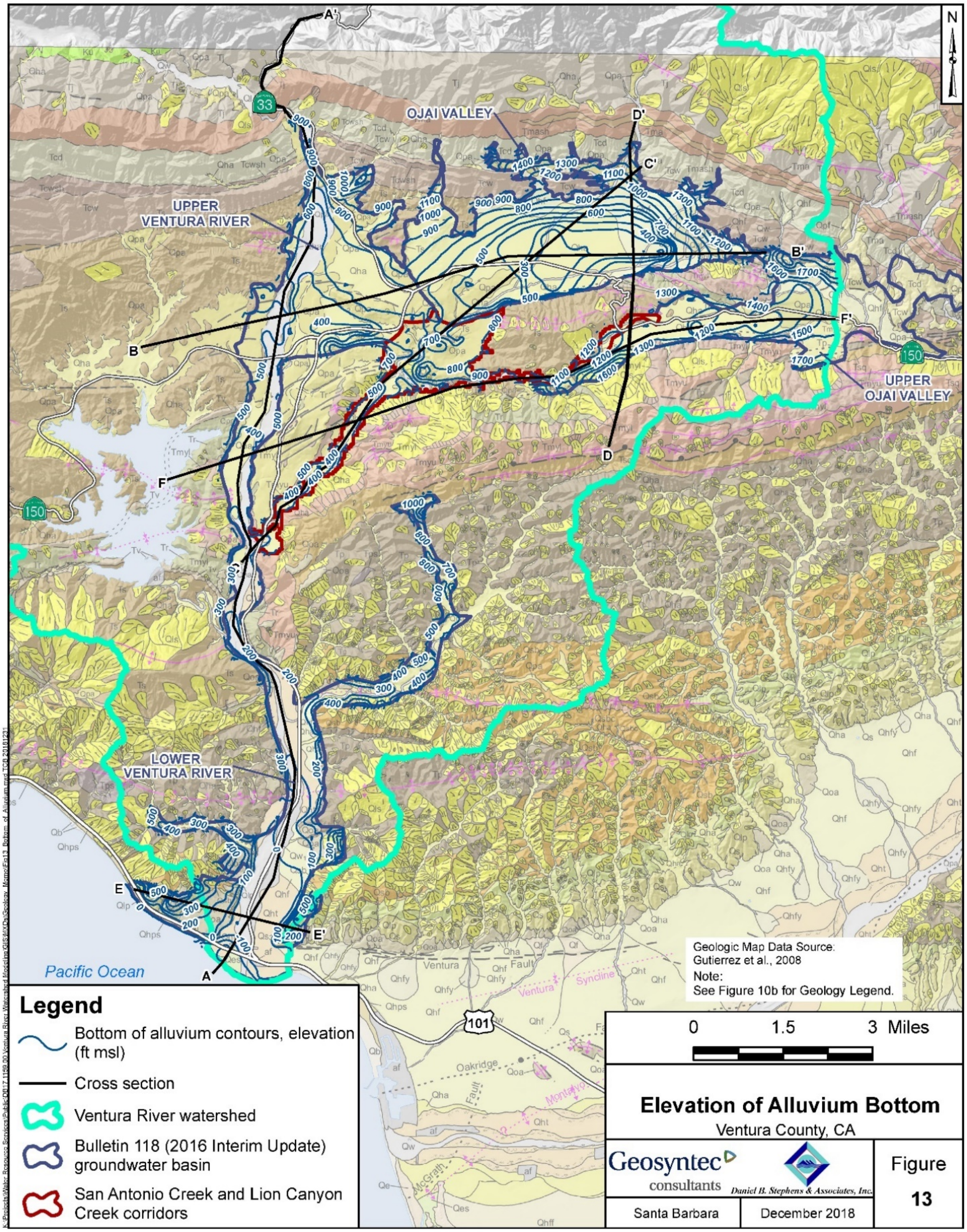

Figure 13: Elevation of Alluvium Bottom.

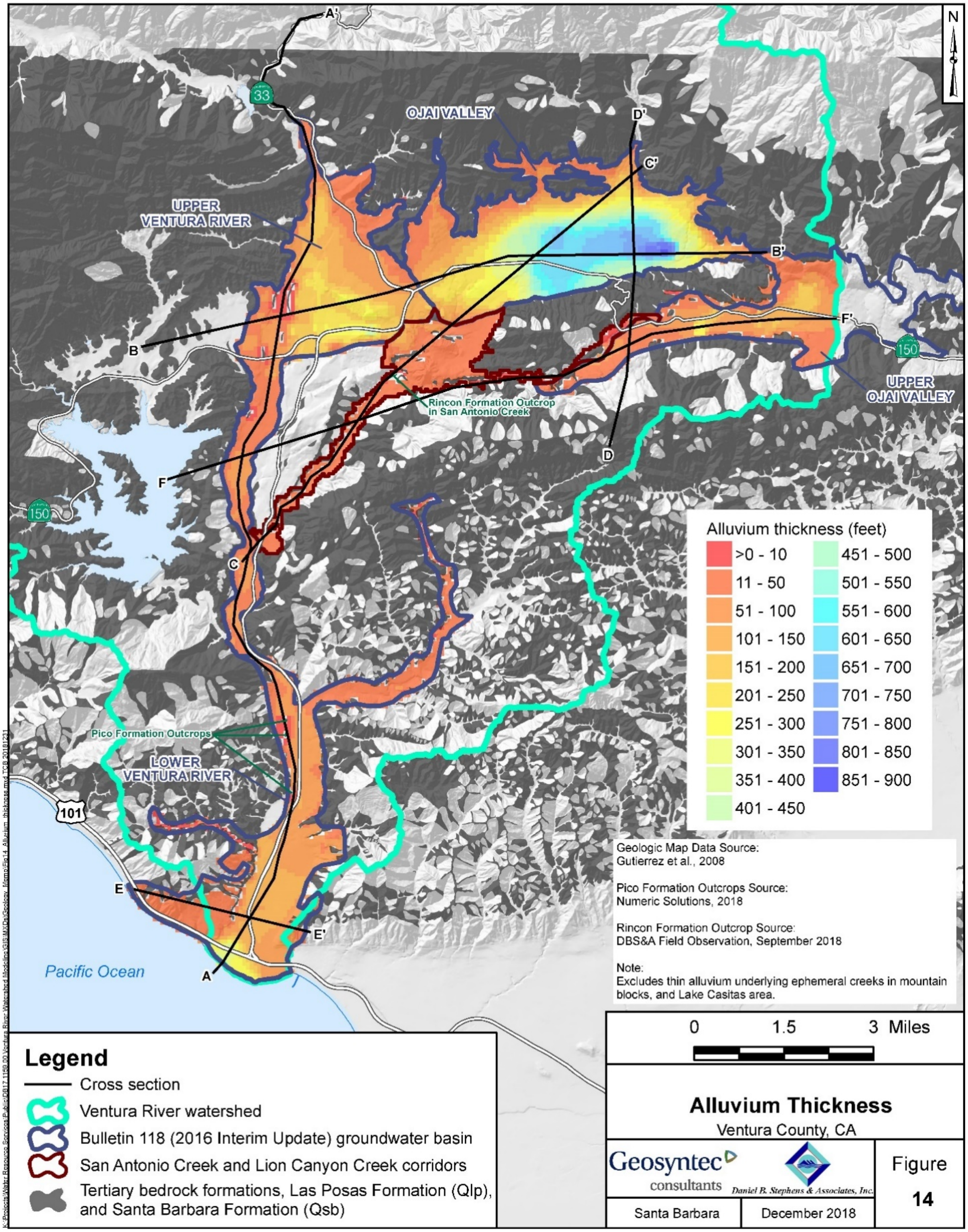

Figure 14: Alluvium Thickness.

Table 1: Geologic Unit Descriptions from Gutierrez et al., 2008.

Symbol	Name	Description
af	Artificial fill (Holocene)	May be engineered and/or non-engineered.
alf	Artificial levee fill (Holocene)	May be engineered and/or non-engineered.
Qb	Active beach deposits (Holocene)	Composed mainly of loose sand, well-sorted, fine- to coarse- grained. Includes coarse sand and volcanic cobble to boulder gravel along the beaches of Anacapa Island.
Qe	Active coastal eolian (sand dune) deposits (Holocene)	Composed of loose sand and silt.
Qes	Active coastal estuarine deposits (Holocene)	Composed of submerged/saturated silty clay.
Qw	Active wash deposits within major river channels (Holocene)	Composed of unconsolidated silt, sand, and gravel.
Qhw	Wash deposits (Holocene)	Composed of unconsolidated silt, sand, and gravel.
Qhfy	Alluvial fan deposits (latest Holocene)	Latest Holocene age indicated by historical inundation or the presence of youthful braid bars and distributary channels. Composed of moderately to poorly sorted and bedded gravel, sand, silt, and clay.
Qhf	Alluvial fan deposits (Holocene)	Includes active fan deposits, deposited by streams emanating from mountain canyons to the north onto the alluvial valley floor. Deposits originate as debris flows, hyperconcentrated mud flows, or braided stream flows. Composed of moderately to poorly sorted and moderately to poorly bedded sandy clay with some silt and gravel.
Qhff	Alluvial fan deposits, fine facies (Holocene)	Fine-grained alluvial fan and floodplain overbank deposits on very gently sloping portions of the valley floor. Composed predominantly of clay with interbedded lenses of coarser alluvium (sand and occasional gravel).

Symbol	Name	Description
Ql	Lacustrine deposits (Holocene)	Upstream of artificial dam, composed of moderately to poorly sorted and moderately to poorly bedded clayey silt and sand with some gravel.
Qls	Landslide deposits (Holocene to Pleistocene)	Includes numerous active landslides, composed of weathered, broken up rocks and soil; extremely susceptible to renewed landsliding.
Qha	Alluvial and colluvial deposits, (Holocene)	Deposited as overbank material associated with unit Qw, recognized by scour and incised channeling features. Composed of unconsolidated, poorly sorted sandy clay with some gravel. May include terrace deposits (Qht) and colluvium.
Qht	Stream terrace deposits (Holocene)	Deposited in point bar and overbank settings associated with unit Qhw1. Composed of unconsolidated, poorly sorted clayey sand and sandy clay with gravel.
Qhps	Paralic deposits of the Sea Cliff marine terrace (Holocene)	Composed of semiconsolidated sandy clay with some gravel; 1,800 to 5,800 years old
Qf	Alluvial fan deposits (late Pleistocene)	Deposited on gently sloping, relatively undissected alluvial surfaces where deposits might be of either late Pleistocene or Holocene age. Composed of moderately to poorly sorted sand, gravel, silt, and clay.
Qppp	Paralic deposits of Punta Gorda marine terrace (Pleistocene)	Consists of consolidated clayey sand with gravel lenses; 40,000 to 60,000 years old
Qpmw	Undivided mass-wasting deposits (Pleistocene)	Consists of unconsolidated and consolidated silt, sand, clay, and gravel.
Qpa	Alluvial deposits, undivided (late Pleistocene)	Consists of unconsolidated and consolidated silt, sand, clay, and gravel.
Qpf	Alluvial fan deposits (late to middle Pleistocene)	Semi-consolidated poorly sorted gravel, sand, silt and clay; often form elevated, slightly tilted terraces on hill slope areas.

Symbol	Name	Description
Qoa	Older Alluvial deposits (early to middle Pleistocene)	Moderately to deeply dissected undivided alluvial deposits where topography often consists of gently rolling hills with little or none of the original planar surface preserved, or tilted surfaces along active range fronts. Composed of moderately to poorly sorted and bedded gravel, sand, silt, and clay as well as some boulder size material. Includes older alluvial deposits of volcanic gravel deposited on wave-cut terraces on Anacapa Island.
Qca	Casitas Formation (Pleistocene)	Poorly consolidated sandstone and siltstone.
Qs	Saugus Formation (Pleistocene)	Weakly consolidated alluvial deposits composed of sandstone and siliceous shale, gravel, and cobbles in sandy matrix; moderately susceptible to landsliding.
Qlp	Las Posas Formation (Pleistocene)	Weakly consolidated sandstone, with some gravelly sand units; highly susceptible to landsliding.
Qsb	Santa Barbara Formation (Pleistocene)	Poorly consolidated claystone, locally contains Monterey Formation shale fragments; highly susceptible to landsliding.
Qsbc	Santa Barbara Formation, conglomerate (Pleistocene)	Portion of the Santa Barbara Formation consisting of conglomerate, sandstone, and claystone.
Tp	Pico Formation, undivided (Pliocene)	Composed of claystone, siltstone, and sandstone; locally pebbly. Generally susceptible to landsliding.
Tps	Pico Formation, sandstone (Pliocene)	Portion of Pico Formation containing sandstone; generally susceptible to landsliding.
Tpsc	Pico Formation, sandstone and conglomerate (Pliocene)	Contains sandstone and conglomerate; generally resistant to landsliding.
Tsq	Sisquoc Formation (Pliocene - Miocene)	Silty shale and claystone; generally susceptible to landsliding.
Ta	Andesite sill (Miocene?)	Composed of fractured volcanic breccia, andesite, silicified shale, sandstone, and breccia.

Symbol	Name	Description
Tcvai	Conejo Volcanics, andesitic (middle Miocene)	Intrusive andesitic rocks.
Tcvdi	Conejo Volcanics, dacitic (middle Miocene)	Intrusive dacitic rocks.
Tcvb	Conejo Volcanics (middle Miocene)	Basaltic flows with some flow breccias. Tcvbs – interbedded with sandstone and siltstone layers. Includes tuffaceous sandstone and siltstone on Anacapa Island.
Tcvbb	Conejo Volcanics (middle Miocene)	Basaltic flow breccias with some flows.
Tcvab	Conejo Volcanics (middle Miocene)	Andesitic flow breccias with some flows.
Tcvdb	Conejo Volcanics (middle Miocene)	Dacitic flow breccias with some flows.
Tcvadb	Conejo Volcanics (middle Miocene)	Mixture of andesitic and dacitic flow breccias with some flows. Includes basaltic and andesitic flows and breccias on Anacapa Island.
Tdb	Undivided diabase and mafic hypabyssal intrusive rocks (Miocene)	Hypabyssal intrusive rocks of gabbroic and dioritic composition.
Tmy	Monterey Formation (Miocene)	Consists of siliceous and diatomaceous shale and some sandstone and limestone, generally susceptible to landsliding. Tmyl - lower section, containing punky thin-bedded shale. Tmyu - upper section, composed of platy brittle siliceous thin- bedded shale.
Tm	Modelo Formation (Miocene)	Consists of siliceous and diatomaceous shale and some sandstone and limestone, generally susceptible to landsliding. Tmb - burnt rock of the Modelo Formation.
Tr	Rincon Shale (Miocene)	Composed of shale and siltstone; generally susceptible to landsliding.
Tt	Topanga Formation, undivided (middle to early Miocene)	Consists of interbedded siltstone, sandstone, and shale; generally susceptible to landsliding.
Tts	Topanga Formation (middle to early Miocene)	Composed predominantly of sandstone; generally resistant to landsliding.

Symbol	Name	Description
Tv	Vaqueros Sandstone, undivided (early Miocene)	Bedded siltstone, shale, and sandstone; consists of similar lithology as the Topanga Formation (Tt). Generally susceptible to landsliding.
Tvs	Vaqueros Formation, sandstone (early Miocene)	Portion of Vaqueros Formation mostly containing sandstone; similar lithology as the sandstone portion of the Topanga Formation (Tts). Generally resistant to landsliding.
Ts	Sespe Formation (Oligocene)	Composed of sandstone; locally pebbly, siltstone and claystone. Rocks are generally reddish in color.
Tcw	Coldwater Sandstone (late Eocene)	Composed of hard arkosic sandstone with siltstone and shale interbeds; locally reddish in color, similar to appearance of Sespe Formation. Tcwsh - consists predominantly of shale.
Tcd	Cozy Dell Shale (late Eocene)	Consists of micaceous shale with arkosic sandstone interbeds; generally susceptible to landsliding.
Tma	Matilija Sandstone (middle to late Eocene)	Composed of hard arkosic sandstone with micaceous shale interbeds. Tmash - consists predominantly of micaceous shale with thin sandstone interbeds.
Tj	Juncal Formation (early to middle Eocene)	Consists of micaceous shale with arkosic sandstone interbeds; generally susceptible to landsliding.
Tjs	Juncal Formation (early to middle Eocene)	Dominantly arkosic sandstone with minor shale interbeds.
Ku	Unnamed conglomerate (Late Cretaceous)	Conglomerate with arkosic sandstone and micaceous shale interbeds.