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HYDROGEOLOGIC CONCEPTUAL MODEL IN PASO ROBLES
TRADITIONAL HCM

RAMBOLL

HYDROGEOLOGIC CONCEPTUAL MODEL IN PASO ROBLES TRADITIONAL HCM

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Front page	**Photo of a Paso Robles Formation exposure taken along the roadside of the Robert and Pat Nimmo Memorial Hwy (41), Coordinates 35 33 41.85, -120 28 35.36,**

California Department of Water Resources (DWR)
Ministry of Environment and Food of Denmark – Eco-innovation (MUDP)
County of San Luis Obispo (SLO)

Stanford Groundwater Architecture Project (GAP) – Traditional Hydrogeologic Model Project 1690013412

Dear Sir / Madam.

Please find enclosed the report Hydrogeologic Conceptual Model in Paso Robles: Traditional HCM as prepared by Ramboll.

We would like to thank GSI Water Solutions (Paul Sorensen and Jeff Barry) for their valuable contributions provided during the status meetings.

We appreciate the staff from SLO for their support during the survey design and field operation.
We will remain available at your convenience to discuss this report or to answer any questions.

Yours sincerely,

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ABBREVIATIONS

AEM	Airborne Electromagnetic
APN	Assessor's Parcel Number
Bgs	Below ground surface
C	Celsius
CalGEM	California Geologic Energy Management Division
DEM	Digital Elevation Model
DOGGR	Division of Oil, Gas, and Geothermal Resources (now replaced by CalGEM, https://www.conservation.ca.gov/calgem)
DOI	Depth of Investigation
DWR	Department of Water Resources
EPSG	European Petroleum Survey Group – an international unique coding of coordinate systems
HCM	Hydrogeologic conceptual model
GAP	The Stanford Groundwater Architecture Project
GRS	Gamma-ray Spectrometer, e-log /geophysical wireline log
GSA	The Geological Society of America
GSP	Groundwater Sustainability Plan
km	Kilometers
LCI	Laterally Constrained Inversion
LN64	Long Normal Log – 64", e-log /geophysical wireline log
m	Meters
m a.m.s.l.	Meter Above Mean Sea Level
m b.m.s.l.	Meter Below Mean Sea Level
ms	Milliseconds
MS	Microsoft
MUDP	The Environmental Technology Development and Demonstration Program
MYBP	Million Years Before Present
NAD83	North American Datum of 1983 computed by the National Geodetic Survey
Ohmm	SI unit of electrical resistivity - ohm-meter (ohmm)
SGMA	Sustainable Groundwater Management Act
SN16	Short Normal Log - 16", e-log /geophysical wireline log
SI	International System of Units (SI, abbreviated from the French Système international (d'unités)
TDS	Total Dissolved Solids
TEM	Time-domain (transient) Electromagnetic
us	Microseconds
WCR	Well Completion Report
QC	Quality Control

1. INTRODUCTION

The Hydrogeologic Conceptual Model in Paso Robles Report (Report) was prepared for the County of San Luis Obispo to improve the understanding of the hydrology in the central portion of the Paso Robles Groundwater Subbasin (Paso Robles Subbasin). This Report provides a description of the basin setting, data collection, compilation and processes used to develop a 3D Hydrogeologic Conceptual Model (HCM). The HCM is part of the Stanford Groundwater Architecture Project (GAP). The GAP is a two-year pilot project that is providing critical information about how best to use the airborne electromagnetic (AEM) method to support groundwater management in California. The project lead is Stanford University, and major project funding partners are the California Department of Water Resources (DWR) and State Water Resources Control Board (SWRCB). Three local agencies, including the County of San Luis Obispo, were selected by the GAP to be part of this project.

1.1 Basin Setting

The Paso Robles Subbasin (DWR Bulletin 118 no. 3-004.06 - Figure 1-1) occupies the southern portion of the Salinas Valley Groundwater Basin in the Central Coastal region of California. It is bounded on the west by the Santa Lucia Range, on the south by the La Panza Range, and on the east by the Temblor and Diablo ranges. The Paso Robles Subbasin is located in northern San Luis Obispo County.

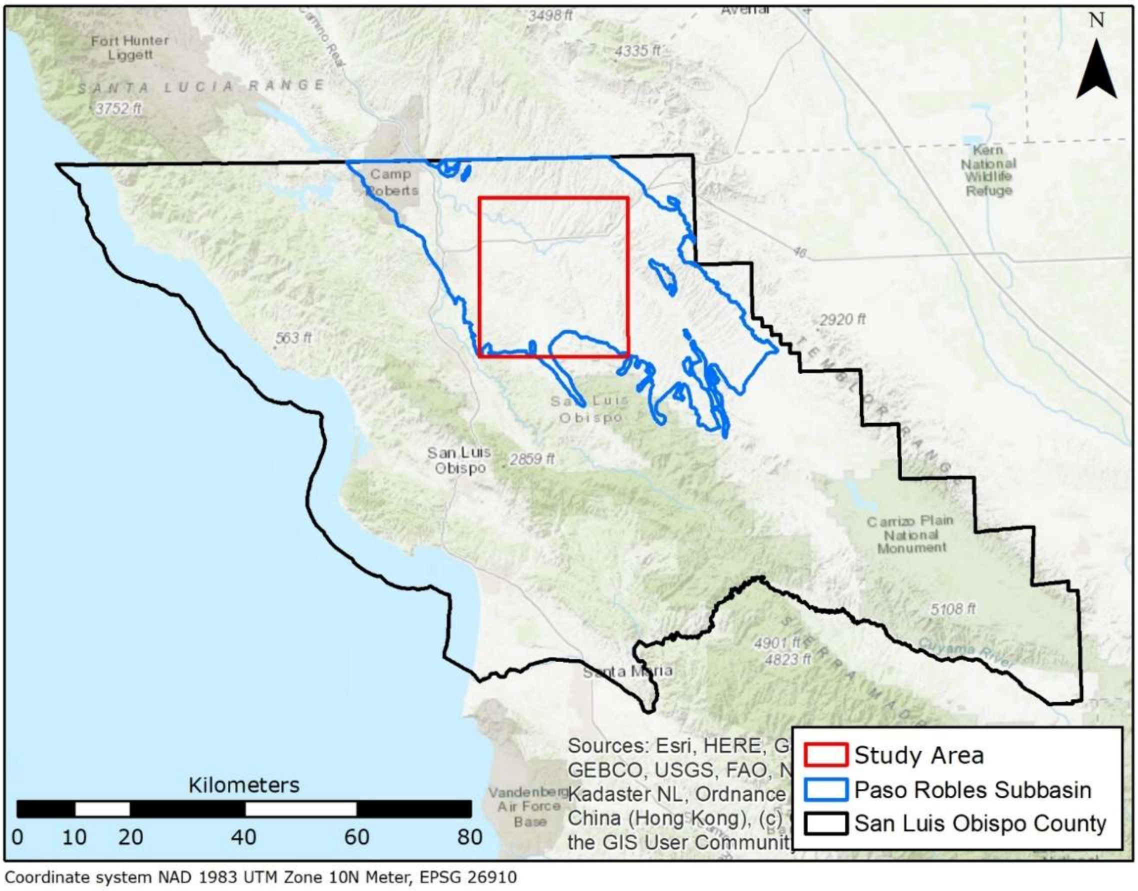


Figure 1-1. Paso Robles Subbasin and Study Area.

Figure 1-1 shows the AEM survey area (Study Area) over the central part of the Paso Robles Subbasin. The predominant land uses within the Study Area are small cattle ranches, farms, and a large number of vineyards typically located along river and creek corridors. The landscape of the northern and the eastern part of the Study Area is predominantly undisturbed open space with native vegetation. In the western part of the Study Area is an increase in urban land use and residential parcel density from communities.

This HCM supplements previous studies that have investigated the hydrogeologic and structural framework of the Paso Robles Subbasin. Significant contributions to the understanding of the hydrogeologic framework were developed by Fugro Consultants Inc. in 2002 and 2005. In the Fugro 2002 report, a set of geologic cross sections was established, as well as sections focusing on the hydrogeologic interpretation. The subsequent groundwater model update (Geoscience 2014) and refinement (Geoscience 2016) relied on the original geologic interpretation defined in the Fugro studies. Most recently, the groundwater model was adapted by Montgomery & Associates for use in the Paso Basin Groundwater Sustainability Plan which was developed in compliance with the State's SGMA requirements. In 2012, Colgan *et al.* (2012) provided new insight into the tectonic structures within the Paso Robles Subbasin by using geologic maps, wells, seismic-reflection profiles, field interpretations, and magnetic data.

The HCM project is co-funded through the Stanford Groundwater Architecture Project (GAP), through an agreement between the State of California Department of Water Resources, State Water Resources Control Board, Kingdom of Denmark, and three local agencies (Indian wells Valley Water District, Butte County, and County of San Luis Obispo).

1.2 Stanford Groundwater Architecture Project (GAP) – Workflow

The GAP is a two-year program designed to define the optimal workflow for the acquisition of aerial electromagnetic (AEM) data in California to support the development of more detailed and improved HCMs. Three local agencies (Butte County, Indian Wells Valley Water District, and the County of San Luis Obispo) were selected to participate in the GAP. In each of the three groundwater basin areas, the same workflow is used, identifying and addressing the challenges specific to working in the three different areas selected. What will emerge are processes and methodologies that will be transferrable to other regions throughout California.

The defined steps in the workflow are summarized below:

1. Project management and dissemination of results: development of a system for project management, allowing for the flow of information among all project members, tracking of progress, revision of timelines as needed, and dissemination of results.
2. Engagement: This step involves working closely with the County to clearly identify project objectives to improve the understanding of the HCM.
3. Project Geo Data Management System: A project GeoDMS enables data sharing between GAP members.
4. Compilation of existing data: Reports, drillers logs, geophysical logs, maps and other data were reviewed for the interpretation of the AEM data and integration with the AEM data to develop the conceptual model. Driller logs and geophysical logs were digitized for the conceptual model.
5. Identifying data gaps and AEM survey design: Using all available data and collaborate with the County to identify and plan where AEM survey can be performed to help define the hydrology of the subbasin.
6. Acquisition of AEM data: The AEM survey followed standard practices for data acquisition.
7. Data analysis and inversion: A robust data analysis and inversion was performed that provided large-scale mapping of subsurface properties to depths of ~500 m and a shallow mapping of properties with higher resolution was performed to guide recharge efforts.

8. Geophysics to hydrogeology transformation: A methodology was developed to transform the geophysical property measured with the AEM system (electrical resistivity) to the desired sub-surface information, e.g. mapping of aquifer and aquitard units, and any structural features.
9. Model development through data integration: A computational framework was required that integrated the AEM data with all other available data to generate a HCM to provide a better understanding for decisions in the subbasin within the Study Area.
10. Uncertainty analysis: There is the need to quantify uncertainty and rigorously account for its propagation through the workflow that leads to the development of the conceptual model. In general, the conceptual model is part of the development of the groundwater model, so uncertainty must be quantified in such a way that it helps inform decisions on the groundwater model.

This report provides geologic, geophysical and hydrogeologic interpretation to support the traditional HCM for the Paso Robles Subbasin. The overall GAP is expected to be completed in 2020.

2. WORK PROCESS

A Hydrogeologic Conceptual Model (HCM) is developed with the purpose of providing an understanding of the geometry and physical characteristics of the groundwater systems, which forms the basis for a numerical groundwater model. The HCM of the Paso Robles Subbasin is constructed following the phases:

Phase 1. Data acquisition
Phase 2. Defining the geologic settings
Phase 3. Development of the 3D geological model
Phase 4. Development of the HCM

A diagram illustrating the workflow is presented in Figure 2-1. Each phase is described in more detail in the following sections.

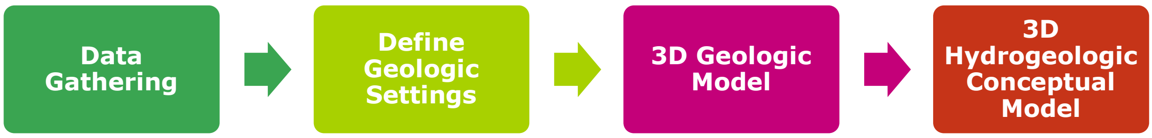


Figure 2-1. Workflow in the development of a HCM.

2.1 Data gathering

The first step in the development of the HCM is data gathering. Data are collected and processed, so they can be uploaded to the modelling software GeoScene3D. Data often used include digital elevation models, geological maps, geophysical surveys (e.g. seismic, AEM, gravity and aeromagnetic data), and borehole information (e.g. well logs, well screen, water level, water quality and electrical logs). Data used in the development of the Paso Robles HCM are described in Chapter 3.

2.2 Defining the geologic settings

The next step is to perform a review of the collected data, as well as previous studies on the subbasin’s geology and hydrogeology. The object of the review is to obtain an initial understanding of the area’s geology, a knowledge that will support construction of the 3D geological model and HCM. The review is performed by providing a description of the landscape, the geological units and important structural elements (*e.g.* faults). The text is often accompanied with illustrations (often as cross sections) showing the major architecture of the geological units and geological structures. The geological formations and the known tectonic structures within the Paso Robles Subbasin are described in Chapter 4.

2.3 Development of the 3D geological model

The third step is the construction of a 3D geological model using the modelling software GeoScene3D. In a 3D geological model, lithostratigraphic units (the basic geologic units described by physical properties and sequence) are correlated to known geological formations, which are then modelled. The result is a 3D rendering of the thickness and distribution of the individual geological units (*i.e.* geological formations) within the Study Area. In a 3D geological model, the accuracy and quality of the interpretations are dependent upon the amount of chronostratigraphic information (the relative age of rock strata in relation to time) available. The 3D geological model constructed for the Paso Robles Subbasin is described in Chapter 5.2.

2.4 Development of the HCM

The final step is the development of the HCM. The aim of the 3D geological model is to subdivide the geological strata into chronostratigraphic units (*i.e*. formations), and as a result, the geological units may contain a wide range of lithologies characterized by different hydraulic properties. In an HCM, the aim is to subdivide the geological strata into hydrostratigraphic units (i.e. aquifers and aquitards) using the interpretations from the 3D geological model. The hydrostratigraphic units define the groundwater system, and the HCM provides the foundation of the groundwater flow model. In addition, the HCM provides useful information on the location of groundwater recharge areas, and areas where groundwater resources may be most vulnerable to pollution. The HCM constructed for the Paso Robles Subbasin is described in Chapter 5.3.

3. AVAILABLE DATA

The following section provides a brief description of the data used in the development of the HCM.

3.1 Wells used in the development of the HCM

A total of 729 well completion reports (WCRs) were digitized and stored in a tabular format in a Microsoft Access database. The digitization of the WCRs was completed as a separate task by the company I-GIS (GAP member).

The borehole data used was from 729 wells selected from a total of 2538 WCRs provided by the County of San Luis Obispo and DWR. I-GIS digitized the WCRs, starting with the most recent and moving backwards in time. The geographical location of the wells was either provided by coordinates, or they were located based on a comparison of hand drawn maps as part of the WCRs with Google Maps.

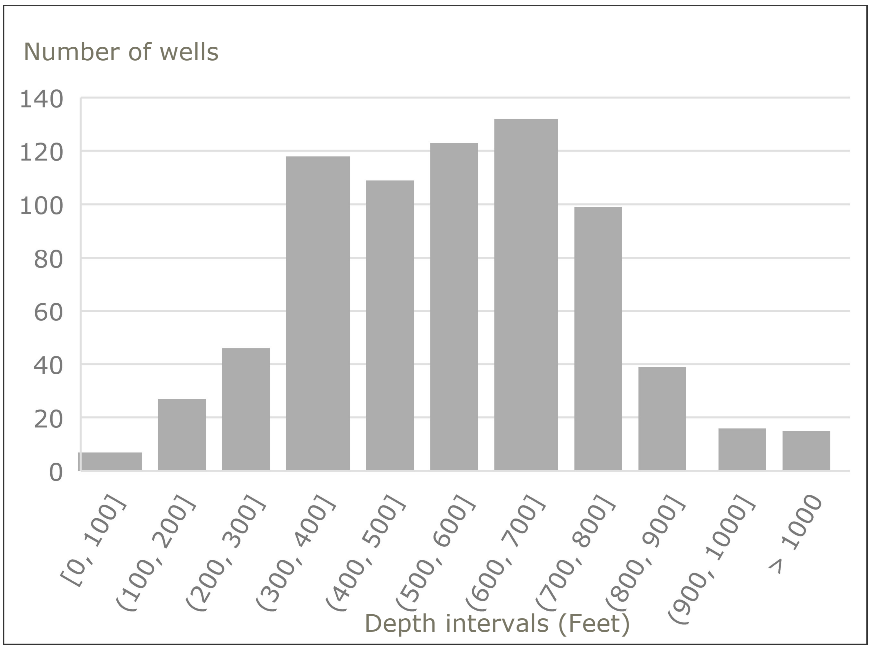
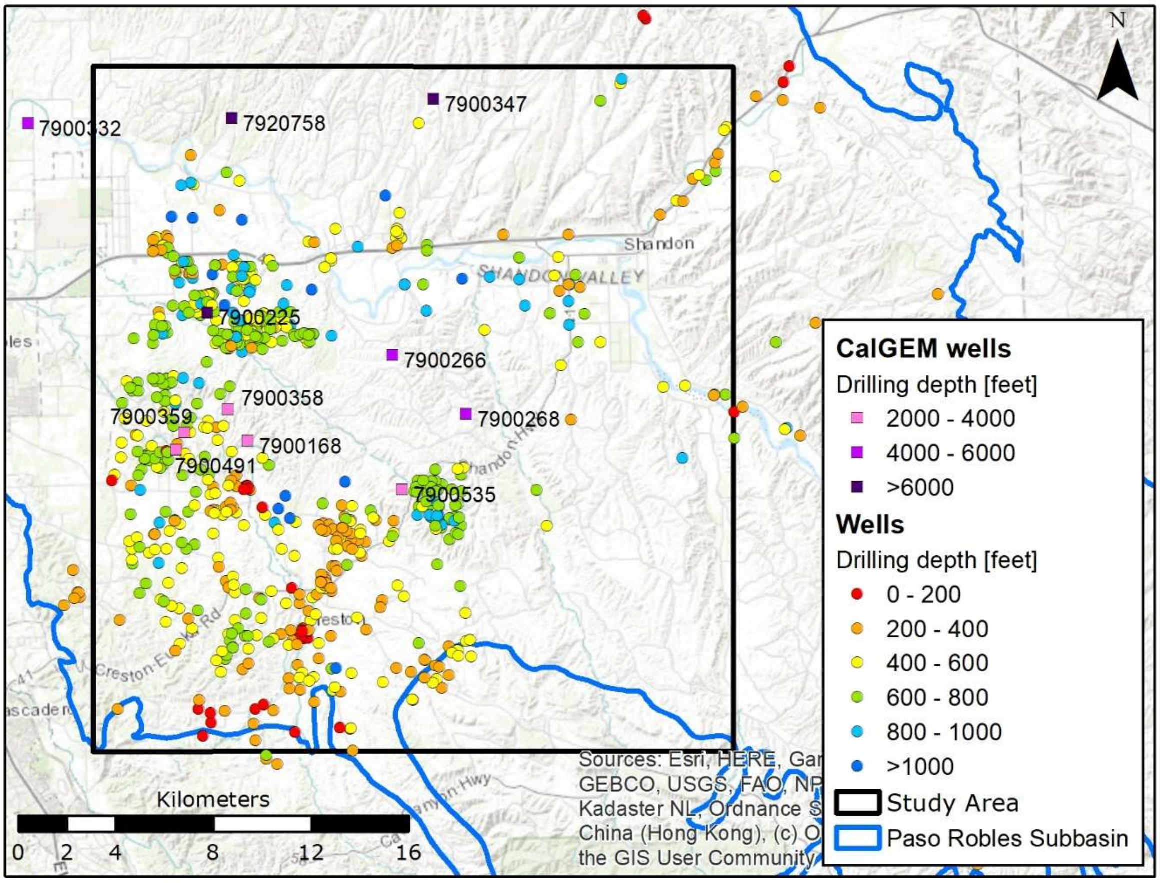


Figure 3-1. Histogram describing the distribution of the drilling depth.

The following parameters were digitized if available on the logs: WCR number, -X,-Y,-Z coordinates, well permit number, Township, Range, Section, APN, borehole diameter, drilling method, date of completion, type of casing, top and bottom of casing depth, type of seal, depth of seal, total boring depth, name of drilling company, lithological description, screen interval and water level measurement.

As shown in Figure 3-1, the typical drilling depth is from 90 to 244 m (300 to 800 feet) below groundwater surface (bgs) with only a few reaching more than 300 m (1,000 feet) bgs.



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 3-2. Map showing the location of the wells that were used in the interpretation of the HCM. Each dot represents the location of a well within a specified depth range. There may be several wells with the same coordinates. The borehole ID to the eleven CalGEM wells are shown on the map.

Ramboll digitized an additional 11 WCRs representing California Geologic Energy Management Division (CalGEM - formerly DOGGR Division of Oil, Gas, and Geothermal Resources) oil and gas exploration wells within the Study Area. The CalGEM wells are listed in Table 3-1, which provides information on well geographic location and depth. Stratigraphic markers identified in the wells are also shown in Table 3-1.

The geographic location of the 729 wells and 11 CalGEM wells are shown in Figure 3-2. The wells are themed based on the wells' depth. The figure shows that the wells are primarily located in the western and southwestern part of the Study Area.

The digitized well lithology descriptions were simplified into basic descriptors that include clay, sand, silt, gravel, sandstone, shale, and fill. The associated color scale is used to represent the lithology types.

Table 3-1. List of digitized CalGEM wells.

BOREHOLE NO	UTMX [Meter]	UTMY [Meter]	Depth [Feet]	Stratigraphic Markers* [depth in feet]
7900168	722252	3941275	3374	Top Santa Margarita (480) Monterey (1500-3150)
7900225	720588	3946530	6157	Top Santa Margarita (2142) Top Monterey (3435)
7900266	728182	3944787	5062	None
7900268	731209	3942363	4505	None
7900332	713235	3954286	5365	Top Santa Margarita (3380)
7900347	729873	3955289	7716	Top Santa Margarita (4130) Top Monterey (6090)
7900358	721427	3942544	2345	None
7900359	719650	3941611	2924	Top Monterey (2150)
7900491	719316	3940889	3576	None
7900535	728590	3939262	2803	Top Monterey (588)
7920758	721606	3954505	7350	Top Poncho Rico (970) Top Santa Margarita (4460) Top Monterey (5226)

Coordinate system: NAD 83 UTM Zone 10N Meter, EPSG 26910
**) The stratigraphic markers are listed if present for the geologic formations with a relevance for the development of the HCM*

Table 3-2. Interpreted lithology based upon the descriptions from the driller's logs and thematic color scale for the interpreted lithology used in the GeoScene3D software. The colors in this scale apply to all cross sections presented in this report.

Lithological description from the driller's logs	Interpreted lithology	Thematic color
Fill, Top	Fill	Dark gray
Clay, silt, siltstone or shale as the first descriptor. Sand, silt or gravel are secondary descriptor.	Clay, silt, siltstone or shale	Brown
Sand as the first descriptor, then followed by gravel, boulder or rock (coarse sediment types). The sand can contain silt or clay layers/clay stringers.	Sand	Yellow
Gravel as the first descriptor, then followed by sand, or rock (coarse sediments)	Gravel	Light red
Rock	Rock	Dark blue
Conglomerate	Conglomerate	Purple
Sandstone	Sandstone	Dark red
Chert and shale	Chert	Black
Chalk	Limestone	Green
Unknown	Unknown	White

3.2 Geophysical logs / e-logs

Geophysical wireline logs (e-logs) for five locations are shown in Table 3-3. The geophysical logging tools applied in the five wells listed in the table include natural gamma-ray spectrometer (GRS), short normal log (16 inch, SN16) and long normal log (64 inch, LN64) resistivity logs.

Table 3-3. List of wells with geophysical wireline logs.

BOREHOLE NO	UTMX [Meter]	UTMY [Meter]	Elevation [Meter]	Depth [Feet]	GRS	SN16	LN64
W4	716641	3939981	277.4	743	No	Yes	Yes
W9	725652	3940888	249.6	800	Yes	No	Yes
W37	736245	3948087	335.6	852	Yes	No	Yes
W47	735459	3947663	336.2	996	No	No	Yes
W48	735555	3941455	341.1	821	Yes	No	Yes

Note: Geophysical wireline logs (e-logs) were provided by Sunview Vineyards and digitized by Ramboll (GAP member).

The location of the wells with electric logs is shown in Figure 3-3.

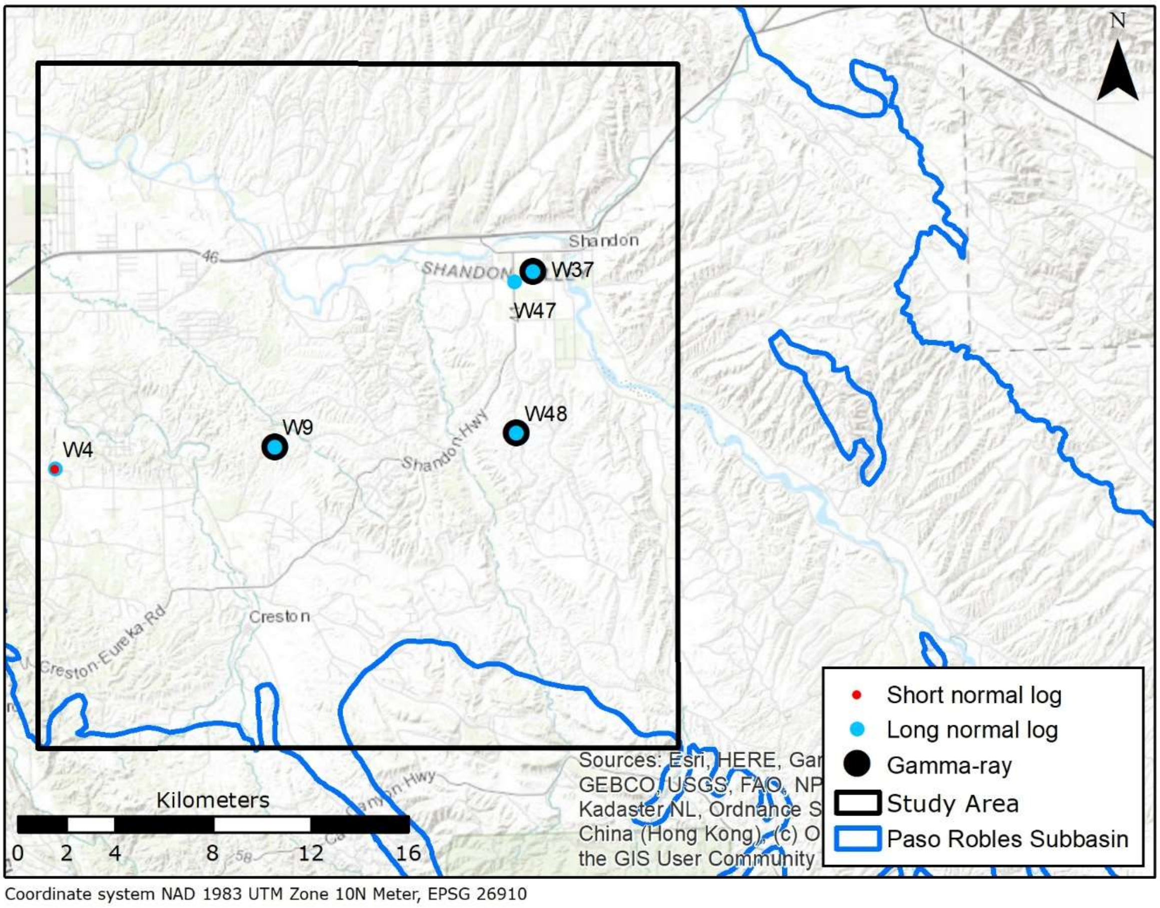
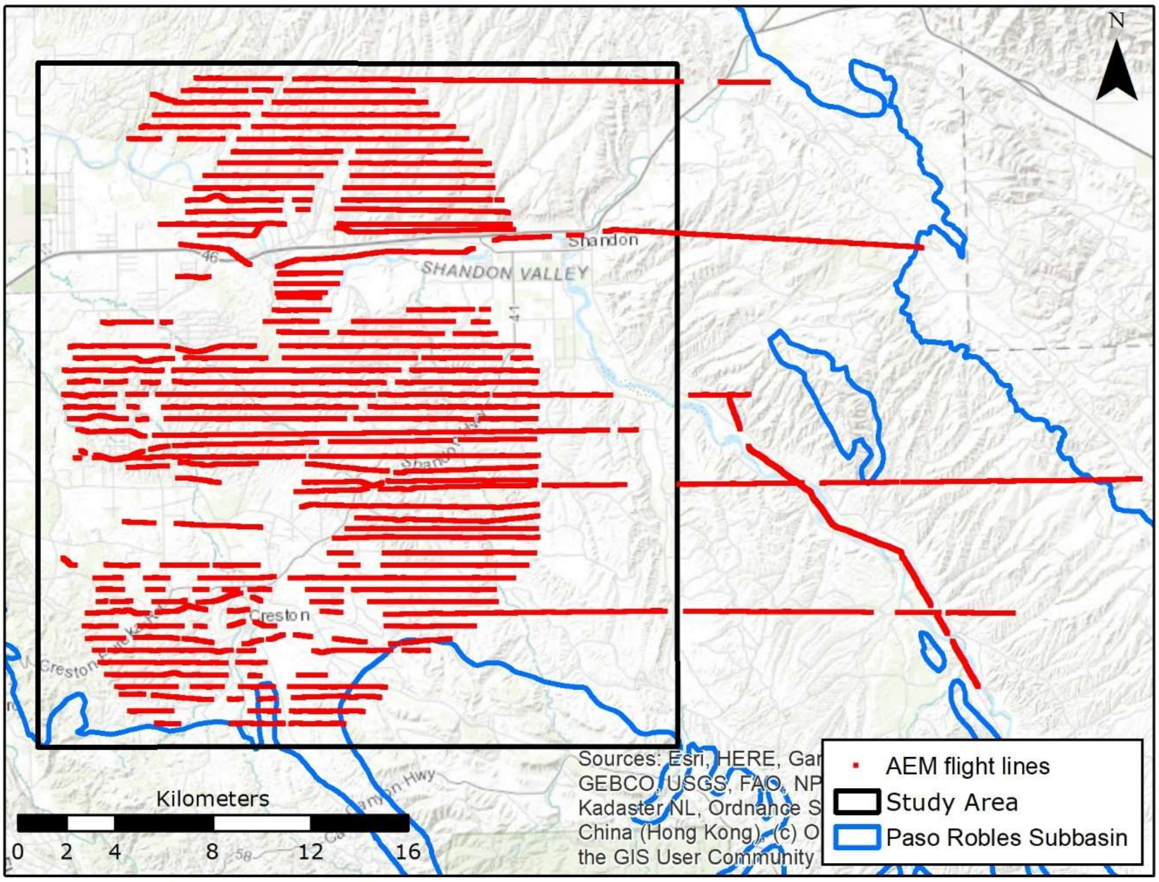


Figure 3-3. Location of the different E-logs: Borehole ID to the wells are shown on the map.

3.3 AEM Survey

The Paso Robles AEM survey was performed on November 5-7, 2019 with the SkyTEM 312M system attached to a helicopter. A total of 860-line km of data was collected by the system. The flight line spacing was 500 m apart with the majority of flight lines trending in the east-west direction as shown in Figure 3-4. The AEM flight lines (red lines) show the final data after processing that has been used to develop the geophysical resistivity model.



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 3-4. AEM data.

The line directions were chosen to cross the long axis of the main geologic structural features, and to achieve long straight AEM flight lines. To keep a safe distance from buildings, fences, and power lines, some lines were adjusted with curvatures incorporated. Additionally, several lines were adjusted and extended to get in close proximity to specific boreholes where water tables were measured by the County.

In the planning phase, portions of flight lines were removed within the Study Area due to the presence of structures and features that would interfere (*e.g.* powerlines, metal fences, *etc.*) with AEM data collection.

The company SkyTEM Surveys provided the data and documented the data collection in a technical report (SkyTEM Surveys, 2019). The data underwent quality control and an in-depth processing and modelling review process. Noisy data due to interference from man-made installations (*e.g.* powerlines, metal fences, *etc.*) were removed from the data set. The resulting dataset was then used as the basis for an inversion process where the obtained field data were modelled. A detailed description of this procedure can be found in the SkyTEM Technical Report (SkyTEM Surveys, 2019). The outcome of this procedure was used as the SkyTEM data in the development of the HCM.

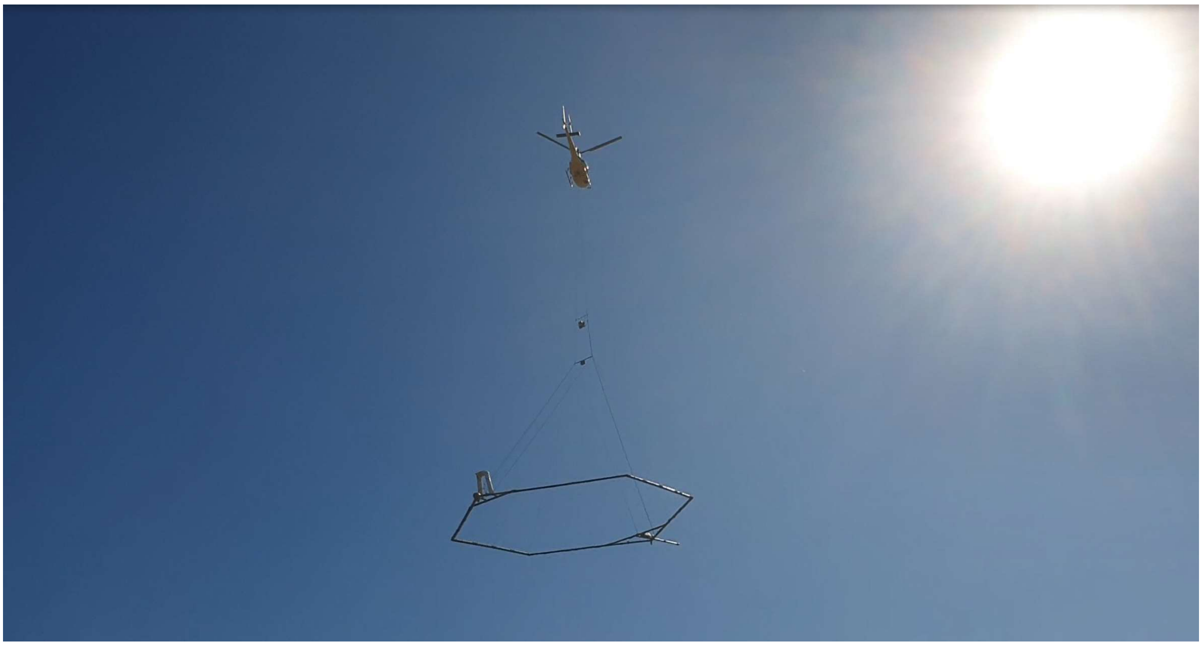


Figure 3-5. SkyTEM system: Take-off at Paso Robles Municipal Airport.

The color scale for the AEM data was optimized to heighten the resistivity contrasts seen in the unconsolidated sediments within the subbasin. It was found that a color scale representing the resistivity interval from 3 ohmm to 300 ohmm was well suited for representing the resistivities modelled across the survey area. The color scale for the AEM data is presented in Figure 3-6.

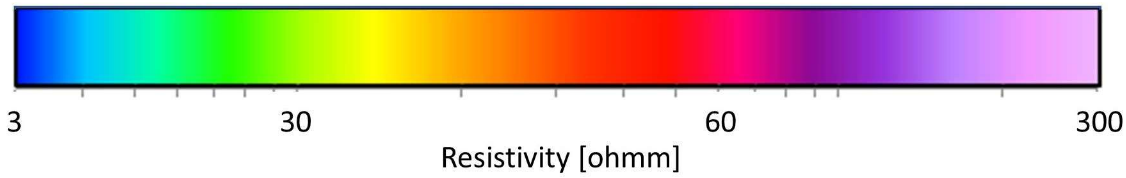
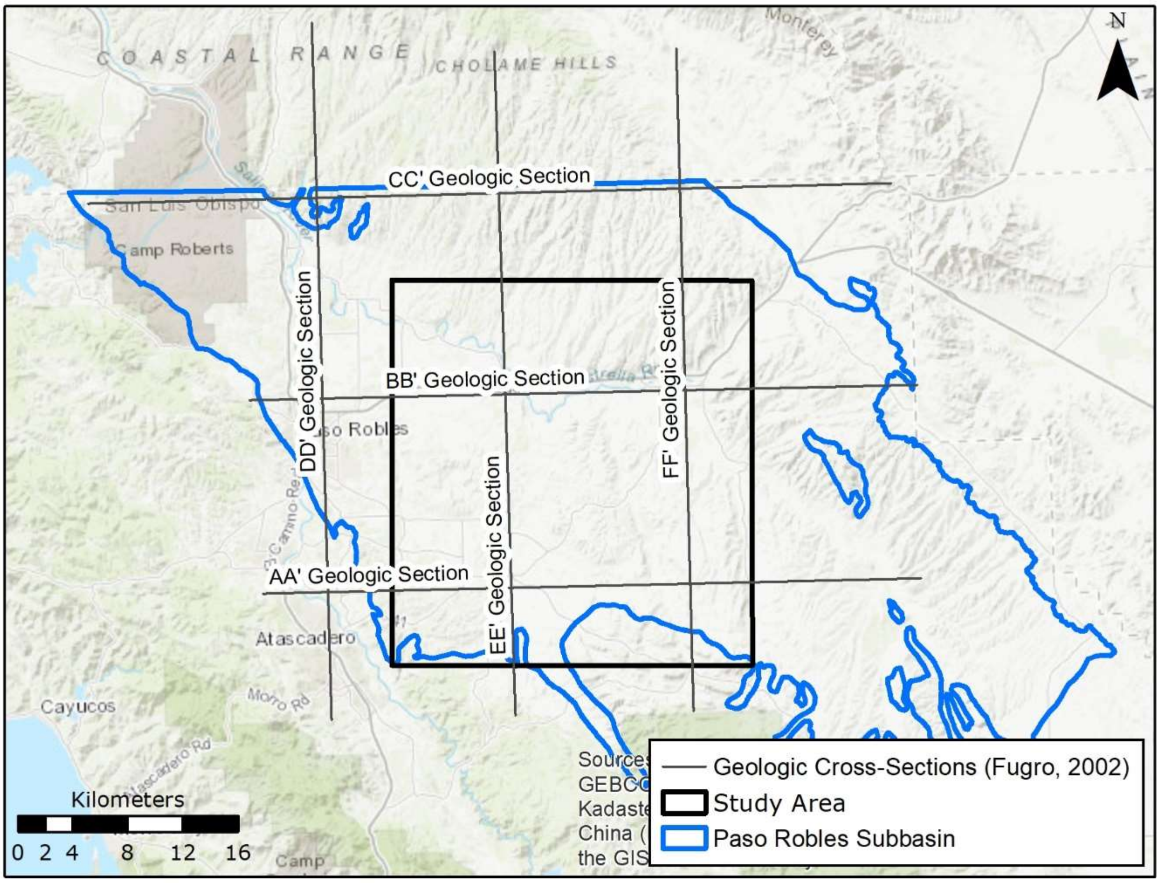


Figure 3-6. Thematic color scale for the AEM (SkyTEM) data.

3.4 Existing geologic and hydrogeologic sections

The general aquifer-aquitard system was interpreted from geologic logs, geophysical logs, groundwater levels, and water quality as reported by Fugro (2002) and Fugro (2005). The interpretations included information from a number of deeper wells (typically CalGEM wells), some of which are listed in Table 3-1. Unfortunately, not all the wells/well logs presented in the report by Fugro (2002) could be located for this effort. As a result, information from geologic cross sections from Fugro (2002) was used to support the development of the HCM. This was done by drawing the cross sections shown in Figure 3-7 in GeoScene3D, after which the images of the geologic cross sections from Fugro (2002) were uploaded to the drawn cross sections. This ensured that the previous interpretations were incorporated during HCM development.



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 3-7. Location of geologic cross sections from Fugro (2002).

3.5 Geologic framework from existing numerical flow model

The Fugro 2002 geologic interpretations were used to define the framework of the aquifers in the MODFLOW numerical flow model update and refinement (GSSI, 2014 and 2016), as well as the latest adaptation (Montgomery & Associates, 2020) developed for the Paso Robles Subbasin Groundwater Sustainability Plan.

The following grids were extracted from the numerical flow model and uploaded to GeoScene3D:

1. Lower boundary of each of the four layers used in the model
2. Horizontal and vertical hydraulic conductivity as 3D grids

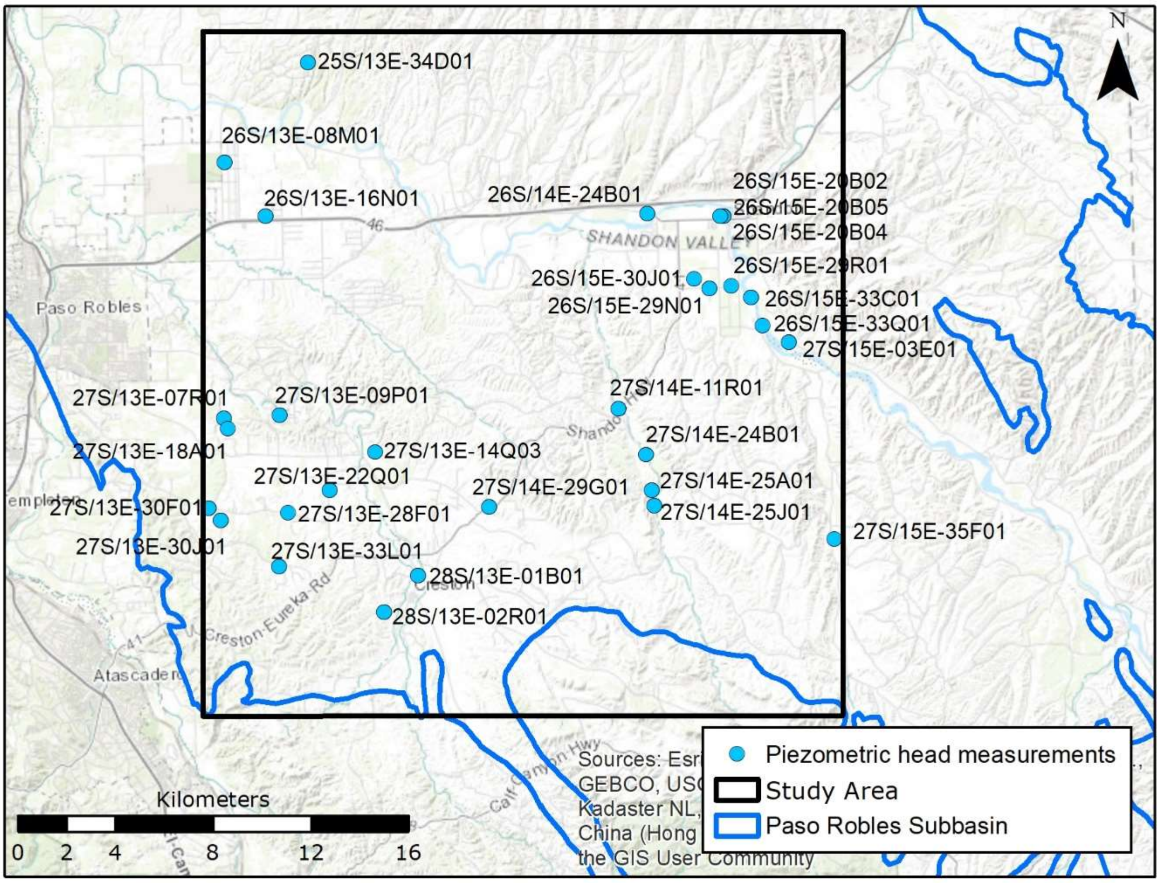
All units were converted to metric and to the coordinate system NAD83 UTM Z10N (EPSG:26910). The grid format used was defined by Golden Software (.grd).

As the hydraulic conductivity varies significantly within each layer, it is essential to take the hydraulic conductivity into account when using the model for geologic interpretations.

3.6 Piezometric head measurements

Water level measurements from wells within the Study Area were collected in a total of 29 wells during the period from October 8 to November 12, 2019. Measurements were taken just prior to, and concurrent with, the AEM geophysical survey to provide timely data on the location of the water table. The measurements were either based on simple tape measurements or data from automatic sounders.

A list of the wells and water level measurements are provided in Appendix 2. The water table elevations were measured concurrently with the AEM geophysical survey. The data were uploaded as points in GeoScene3D and are shown in Figure 3-8. The measurements were used to support the interpretation of changes in resistivities within the unconfined zone.



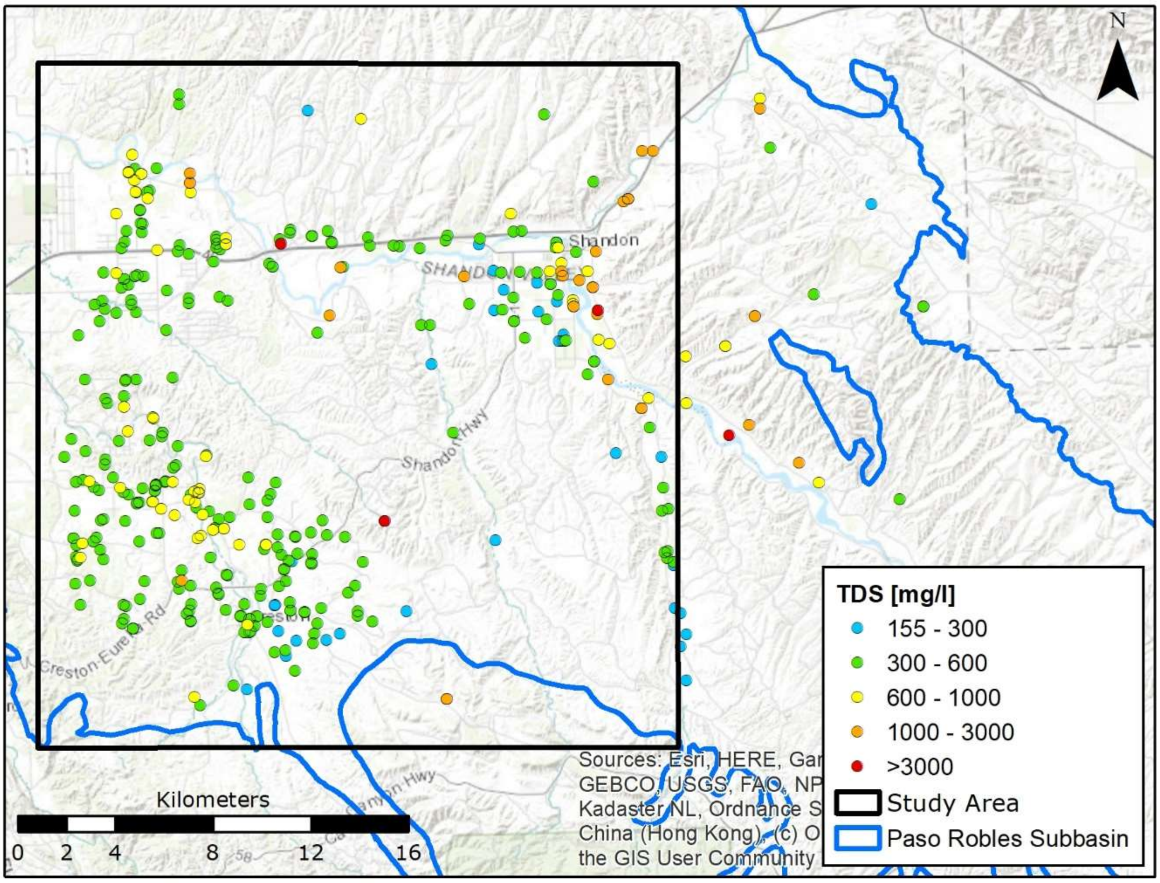
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 3-8. The location of the water table measurement wells.

3.7 Data from Geotracker

The latest total dissolved solids (TDS) analytical results from monitored wells within the Study Area were extracted from Geotracker[1] (see Figure 3-9). A number of locations show high TDS values in the groundwater. Brackish and saline water in the aquifers will influence the measured resistivities and should be considered when interpreting the AEM resistivities. Further information about water quality and saline content is available in the Salt/Nutrient Management Plan for the Paso Robles Groundwater Basin Report by RMC (2015), and in Section 6.3 of this report.

[1] https://geotracker.waterboards.ca.gov/



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 3-9. Total Dissolved Solids (TDS) measurements.

4. REGIONAL GEOLOGIC AND STRUCTURAL SETTING

4.1 Topography

The topography of the Paso Robles Subbasin, shown in Figure 4-1, is dominated by gently rolling hills of the Temblor Range to the east, foothill peaks of the Santa Lucia Mountain Range to the west, and La Panza Range to the south, separated by lowland areas of moderate relief. The Study Area of the subbasin lies entirely within uppermost drainages of the northwesterly flowing Salinas River, with relatively uniform hilltop topography dissected by streams, blanketed by chaparral grassland and oak woodland.

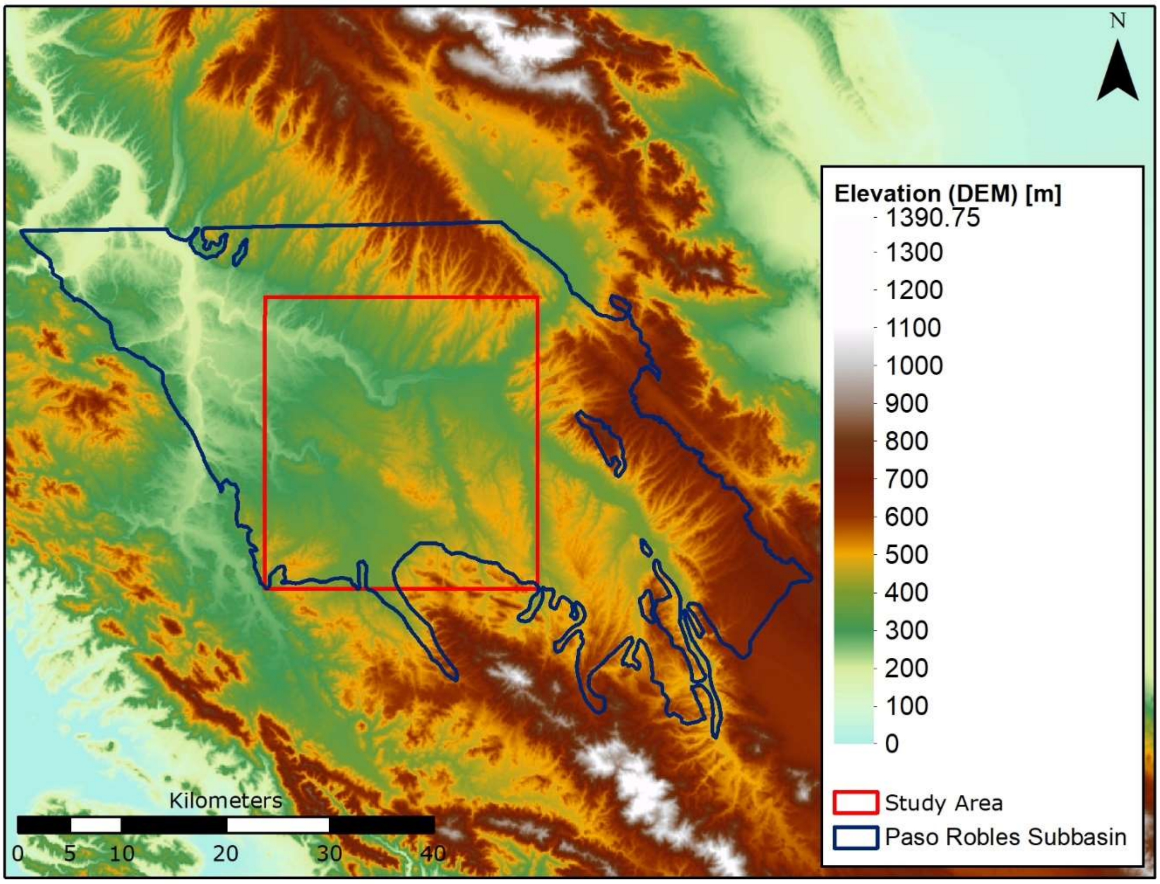


Figure 4-1. The topography of the Paso Robles subbasin.

4.2 Regional Geology and Structure

The Paso Robles Subbasin lies within the upper (southern) Salinas Valley basin, located in the south portion of the northwest trending Coast Ranges, a geomorphic province between the Central Valley and Pacific Ocean, California (Figure 1-1). The geologic history of the formation of the Coast Ranges and Paso Robles structural subbasin includes three different stress regimes. The first, which was dominant until about 20 million years ago, was an ancient period of tectonic subduction and mountain building. The second stress regime comprised early to middle Miocene extension and associated deformation accommodated by high angle normal faulting along the San Andreas fault zone and other nearby faults oriented approximately northwest to southeast, accompanied by movement of the Pacific plate northwest relative to the North American plate. This was followed by the third stress regime with little to no deformation in the Late Miocene with subsequent Pliocene and younger crustal shortening accommodated by new reverse faults and reactivation of older normal faults. The crustal shortening resulted from westward motion along the left lateral Garlock fault and associated westward motion of the Sierra Nevada-Great Valley block, as the Salinian block moved northward along the San Andreas (Colgan, 2012).These three stress regimes help provide an explanation of the complexity of the rocks and sediments making up the Paso Robles Subbasin and surrounding area, including the extensive folding and thrust faulting, and the significant bend in the San Andreas fault zone.

The Coast Ranges are primarily composed of late Mesozoic to Cenozoic age sedimentary rocks (250 million years old to present) (Figure 4-2). Franciscan Complex rocks formed where, working like a conveyor belt, heavier oceanic crust was drawn down below continental crust as massive marine sediments and submarine volcanics were scraped and piled up within an ancient subduction zone. This resulted in a somewhat chaotic distribution of sheared matrix with large blocks of various rock types and metamorphic histories known as mélange. Pieces of previously subducted oceanic plate known as ophiolite are also scattered throughout. These Franciscan Complex rocks rest on top of the older continental plate granitic and high-grade metamorphic rocks known as the Salinian block (Durham 1974). Overlying the Coast Range basement of Mesozoic sediments and granitics are mainly marine arkosic sandstone and organic mudstone and shale deposited as recently as Oligocene, upper Miocene to lower Pliocene, including the Vaqueros, Monterey and Santa Margarita formations.

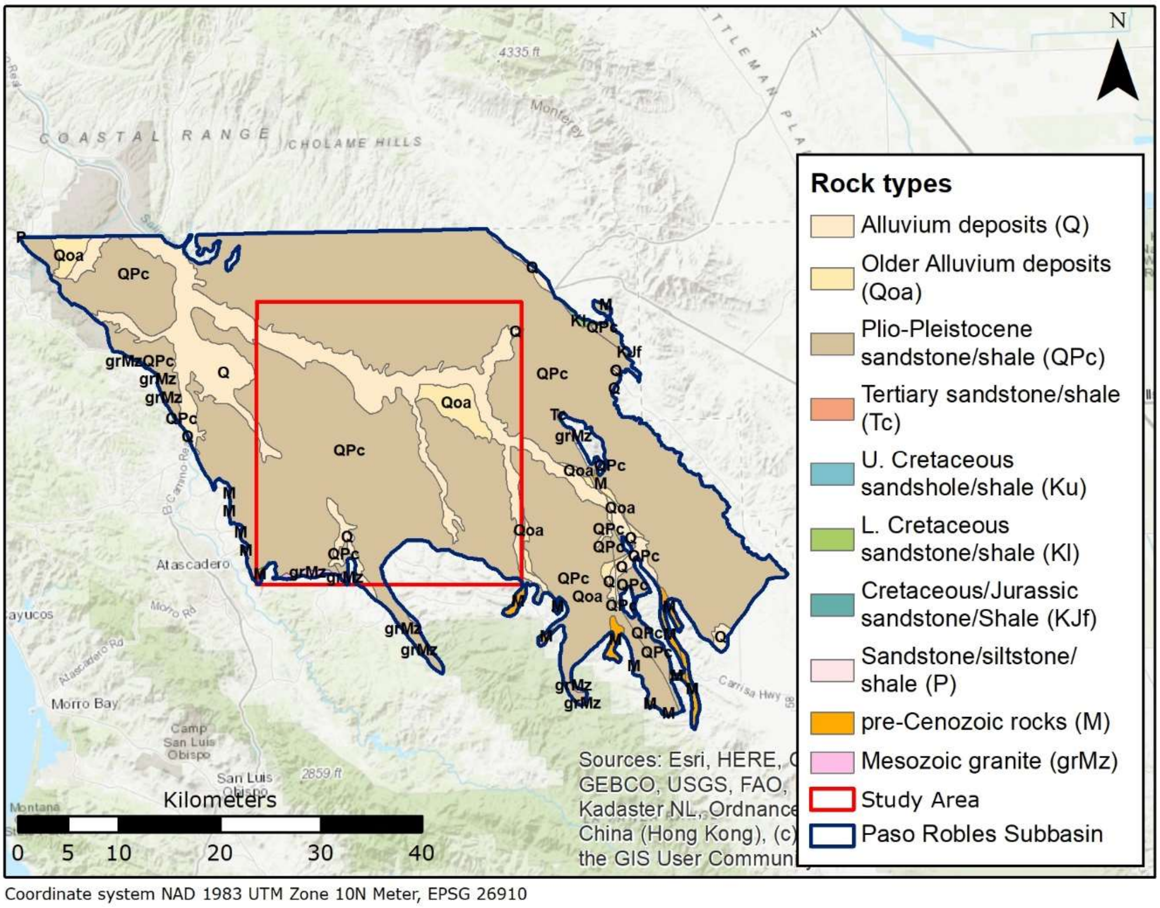


Figure 4-2. CGS Geologic map (Jennings *et al.*, 2010).

Within the confines of the Paso Robles Subbasin, the Franciscan Complex is largely absent, with the granitic rock of the Salinian block forming the basement. Folded and faulted Pliocene-Pleistocene and recent unconsolidated nonmarine sediments blanket the subbasin surface, including the above-named formations, Pancho Rico and Paso Robles formations, covering nearly all older marine and granitic rocks.

The subbasin is highly faulted with multiple mapped northwest-southeast trending faults associated with the east bounding San Andreas fault zone cutting through the subbasin, including the Red Hills, San Juan and White Canyon faults on the southeast, and Huerhuero fault on the south. The San Marcos-Rinconada fault system bounds the subbasin to the west. The degree of faulting is a result of the convergent and subsequent right lateral shearing tectonic imprints that have also folded and deformed mostly Pliocene and older geologic formations.

The Paso Robles, Santa Margarita and Monterey formations are all folded and deformed in synclinal and anticlinal forms with the folding axis generally paralleling the San Andreas and Rinconada fault zones bearing generally northwest to southeast, with deformation and folding more extensive with depth. The Paso Robles formation is mapped with a structure extending northwest-southeast across the Study Area and is moderately deformed into syncline and anticline forms with fold axis trending northwest southeast.

Table 4-1 provides a summary of the age, tectonic relationship, and formation thickness, general lithology, occurrence and hydrologic property descriptions. Significant work has been completed in the subbasin and surrounding area, and the majority of this summary has been transposed from Fugro (2002 and 2005).

Table 4-1. Stratigraphic age and regional structure.

Age: Mybp	Age: Era	Age: Period	Age: Epoch	Tec-tonics	Stratigraphic Units		Average Thickness (feet)	Lithology	Origin/Occurrence	Hydrologic Properties
0.01	Cenozoic	Quaternary	Holocene (Recent)	Extensional right-lateral strike slip faulting along the San Andreas and associated other faults during early to mid-Miocene, late Miocene quiescence, followed by Pliocene and younger crustal shortening perpendicular to the San Andreas fault zone.	Mostly unconsolidated rocks	Holocene alluvium	100	Unconsolidated gravel, sand and silt.	Nonmarine; largely fluvial with some dune, mudflow debris and lacustrine deposits. Covers most valley bottoms and along major stream drainages as stream bed and terrace deposits; older alluvium in bluffs along Salinas River.	Provides well yields that may exceed 1,000 gpm and has an estimated specific yield of 15 percent; groundwater is unconfined, is recharged by streamflow.
2.6	Cenozoic	Quaternary	Pleistocene		Mostly unconsolidated rocks	Paso Robles	1,000 (Up to +3,000)	Predominantly fine to coarse grained sandstone and conglomerate, some mudstone and limestone, with minor amounts of gypsum, and woody lignite. Conglomerate generally forms the base and is common throughout with Monterey clasts dominant in north and mixed clasts including Franciscan Complex in the south.	Nonmarine; largely fluvial and lacustrine. Present and exposed throughout the subbasin except where covered by recent alluvium. Generally, overlies the Pancho Rico, except where the Pancho Rico pinches out to the far south and instead directly overlies the Santa Margarita formation.	Provides well yields in 100's of gpm and has an estimated specific yield of 9 percent; is recharged by the overlying alluvium in stream beds where present.
5.0	Cenozoic	Tertiary: Neogene	Pliocene		Mostly unconsolidated rocks / Mostly consolidated rocks	Pancho Rico	1,000	Mainly fine, medium and pebbly coarse sandstone with calcareous fossiliferous beds, medium bedded massive conglomerate, siliceous poorly bedded mudstone with diatomites.	Marine; widespread in the subbasin and generally overlies the Santa Margarita formation, except where it pinches out to the south end and eastern portion of the subbasin.	Fine-grained units provide low quantities to wells.
	Cenozoic	Tertiary: Neogene	Miocene		Mostly consolidated rocks	Santa Margarita	1,400	Light colored, highly calcareous, massively bedded sandstone; may contain tuff beds at base.	Marine; occurs throughout the subbasin overlying and intertonguing with the upper portion of the Monterey formation.	Limited flow to domestic wells south of Templeton, expect in geothermal areas where flow exceeds 300 gpm of poor quality in Paso Robles City area.
23	Cenozoic	Tertiary: Neogene	Miocene		Mostly consolidated rocks	Monterey	2,500	A sequence of fine grained porcelaneous rocks, siliceous mudstone, shale, chert, and sands overlying a sequence of calcareous mudstone, shale and some chert, both highly deformed.	Marine; occurs throughout the subbasin area mostly underlying and in cases interfingering with the overlying Santa Margarita formation, with some minor exposures along the basin boundaries.	Water wells may be productive when completed in sufficient thickness of deformed siliceous shale.
66	Cenozoic	Tertiary: Paleogene	Oligocene (Paleocene, Eocene Absent)	Convergent tectonic margin with active subduction zone	Mostly consolidated rocks	Vaqueros	200	Cemented, fossiliferous, poorly bedded, fine to coarse grained sandstone with some massive mudstone and conglomerate.	Marine; generally mapped directly overlying granitic basement throughout most of the subbasin.	Spring flows of up to 25 gpm in canyons, with water wells producing about 20 gpm.
	Mesozoic	Jurassic-Cretaceous			Mostly consolidated rocks	Franciscan Complex		Heterogeneous assemblage of largely dismembered sequences of greywacke, shale, some mafic rocks, thin-bedded chert with minor limestone, found with serpentinite and blueschist in mélange zones.	Marine rocks that were deformed and metamorphosed in a subduction zone. Outcrops to the east and west of the subbasin.	Limited quantities of water produced sufficient for domestic wells, generally in fractured metavolcanics.
252	Mesozoic	Jurassic-Cretaceous			Mostly consolidated rocks	Salinan Block Basement Complex	10,000?	Primarily granite, tonalite to gabbro; may contain metamorphic rocks gneiss, granofels, quartzite, with minor schist and marble.	Intrusive; underlies subbasin sediments as basement rock - surface exposures along south and west portion of subbasin.	Generally impermeable unless fractured; weathering profile/regolith up to 80 feet thick where exposed at surface may provide limited water to wells.

**) Age reference: GSA Geologic Time Scale v. 5.0, The Geological Society of America (GSA), 2018*

5. HYDROGEOLOGIC CONCEPTUAL MODEL DEVELOPMENT

The hydrogeologic conceptual model (HCM) for the Paso Robles Subbasin has been further refined compared to existing geological models and aquifers and aquitards more accurately mapped in the subbasin using new available data. This chapter provides a detailed description of the HCM development and modelling results.

5.1 Model setup and concept

The modelling software GeoScene3D developed by I·GIS was used to construct the 3D geological model, as well as the HCM. The models are constructed using the spatial reference NAD38 UTM Zone 10N. All data (i.e. databases, GIS-files etc.) were imported using this coordinate system.

To construct the models, all available data described in Chapter 3 were uploaded to the software and visualized within a rectangular area, called Scene Extent. The Scene extent was specified by the modeler and in the Paso Robles project was defined by the coordinates:

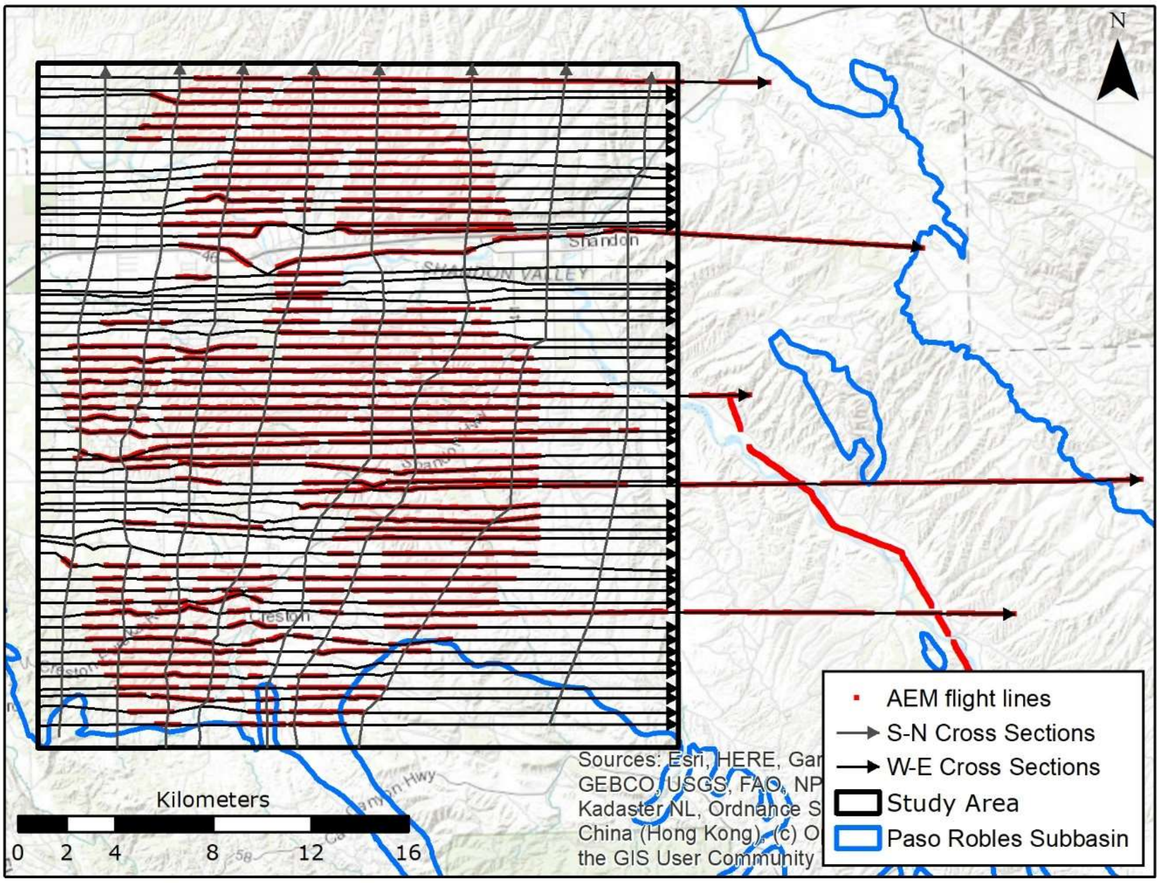
X_{min}=709,600; Y_{min}=3,925,800; and
X_{max}=761,900; Y_{max}=3,964,800.

The models are constructed as layer models. In a layer model, the boundaries between different layers are defined. Depending on the purpose, a layer may either represent a geologic formation or a hydrostratigraphic/hydrogeologic unit (i.e. aquifer or aquitard). In GeoScene3D, the lower or upper boundary of a layer is defined by a series of interpretation points (XYZ points), which are stored in a standard Microsoft-Access database.

A network of cross sections was drawn across the Study Area to assist in the interpretation of the geology (Figure 5-1). Data located within the user-defined distance from the cross sections, called the buffer-zone, were projected onto the cross sections. In constructing the cross sections, the following distances were used:

- a buffer-zone of 300 m (984 feet) was used for borehole data
- a buffer-zone of 100 m (328 feet) was used for the geophysical
- a buffer zone of 100 m (328 feet) was used for other data

A total of 62 cross sections were constructed across the Study Area within the Paso Robles Subbasin. A total of 54 cross sections run in a west-east direction along the AEM flight lines, with 8 cross sections that run south-north (see Figure 5-1). The west-east cross sections are sequentially named from south to north, starting with W-E Cross Section 1 and ending with W-E Cross Section 54 in the northern part of the Study Area. Likewise, the south-north cross sections are sequentially named from west to east, starting with S-N Cross Section 1 and ending with S-N Cross Section 8. Cross sections are provided in Appendix 3 and 4.



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 5-1. The location of the 64 cross sections in GeoScene3D.

The individual layers are defined by placing control points, based on interpretation, along the cross sections. When a layer boundary is identified in the geophysical data or well logs, the control points are snapped to data. This means the control points in the MS-Access database will contain the ID number of the geophysical data or the borehole number. In areas with no data available, the control points are placed on the cross sections based on the modeler's understanding of the geology. These points are often referred to as 'support-points', since they are placed on the cross sections to ensure that the layer boundaries are defined within the whole Study Area.

For each of the defined layers, the control points are used to create a 2D surface grid (Surfer® grid format by Golden Software), which depicts the spatial geometry of the individual boundaries. To create the surface grids, an interpolation algorithm for each of the layers is selected and configured in GeoScene3D. During the modelling process, the control points are continually gridded, so the modeler can visually check the results from the interpretations. In the Paso Robles HCM, the interpolation algorithm 'inverse distance weighting' is used to create the 2D surface grids.

To avoid surface grids overlapping each other, a grid adjustment routine is configured in GeoScene3D. For example, if a boundary surface crosses the terrain grid (DEM) (*i.e.* the boundary surface grid is located higher than the terrain grid), the routine ensures that the boundary surface grid is adjusted down, so it follows the terrain grid instead. All the surface grids are adjusted in the same way, so no surface grids overlap each other. The terrain grid is the only surface grid that is fixed, and is, therefore, not adjusted by the other surface grids.

Grid interpolation and adjustment are performed continuously during interpretation. This is done to check how well the interpolated, adjusted surfaces match the data in the model. The quality check of the interpolated surfaces is done on the west to east oriented cross section network, on which the interpretations took place, but also along the north-south trending cross sections. Quality control using north-south trending cross sections is particularly important to confirm that no significant offsets are in the interpolated surfaces perpendicular to the direction in which the interpretation took place. This ensures a more correct interpretation of the geologic or hydrogeologic unit boundaries.

When the interpolated surfaces do not fit the data, the surfaces are manually edited by either adding additional interpretation points or through a re-interpretation of the surface (*i.e*. moving interpreted points higher or lower). Once the manual editing of the interpretation points is complete, the surfaces are re-interpolated and checked. This is an iterative process, repeated until a reasonable fit between the data and the interpolated surfaces is achieved.

5.2 3D geological model

The 3D geological model was developed as a digital layer model in GeoScene3D. This section describes the framework of the 3D geologic model and shows the results from the geologic interpretations.

5.2.1 Geologic Units

The following geologic units have been identified.

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

5.2.2 The geologic framework

The 3D geological model was constructed by first defining a conceptual framework for the model. The framework defines the number of geologic formations, which are to be modelled within the Study Area. The framework of the 3D geological model was constructed based on evaluation of well lithology and geophysical data. In the evaluation, the data were compared and correlated with previous geologic studies to identify and define the geologic formations in the assembled data.

The AEM survey results, 5 E-logs, 11 CalGEM wells, 729 WCR wells, and a series of geologic cross sections from a previous study of the Paso Robles Subbasin (Fugro, 2002) were used in the construction of the 3D geological model. However, only 7 of the CalGEM wells and the geologic cross sections contain stratigraphic information that can be used to identify the geologic formations. These data, therefore, act as the primary data source for the 3D geological model. Since stratigraphic data are limited, correlation of AEM resistivity values with specific geologic formations during the modelling process were estimated to support the interpretation of the geology.

From the overview of the regional geology in Chapter 4 and the initial data screening, the geologic framework for the 3D geological model was defined in a downward sequence by the following geologic formations:

A. Paso Robles Formation
B. Pancho Rico Formation
C. Santa Margarita Formation
D. Monterey Formation

Each of the units is described below.

A. Paso Robles Formation

The Paso Robles Formation is an unconsolidated, sedimentary, fluvial unit deposited during Plio-Pleistocene time. The geologic unit comprises thin, discontinuous sand and gravel layers interbedded with thicker layers of silt and clay (Fugro, 2002). The formation is represented by resistivity values from 3 to 50 ohmm.

B. Pancho Rico Formation

The Pancho Rico Formation is a consolidated, sedimentary, marine unit deposited in the Pliocene (Fugro, 2002). The geologic unit comprises diatomaceous mudstones and is characterized by resistivity values from 3 to 15 ohmm.

C. Santa Margarita Formation

The Santa Margarita Formation is a consolidated, sedimentary, marine unit deposited in the Late Miocene. The geologic unit consists of white, fine-grained sandstone and siltstone (Fugro, 2002), and is represented by resistivity values from 25 to 100 ohmm.

D. Monterey Formation

The Monterey Formation is a consolidated, sedimentary, marine unit deposited in the Miocene. The geologic unit comprises interbedded argillaceous and siliceous shale, sandstone, siltstone and diatomite (Fugro, 2002). The formation is characterized by resistivity values from 3 to 15 ohmm.

In the southern part of the Study Area, high resistivities in the AEM data show that granitic bedrock is located 0-100 m below ground surface. The granite is represented by a resistivity higher than 100 ohmm.

5.2.3 Cross Sections

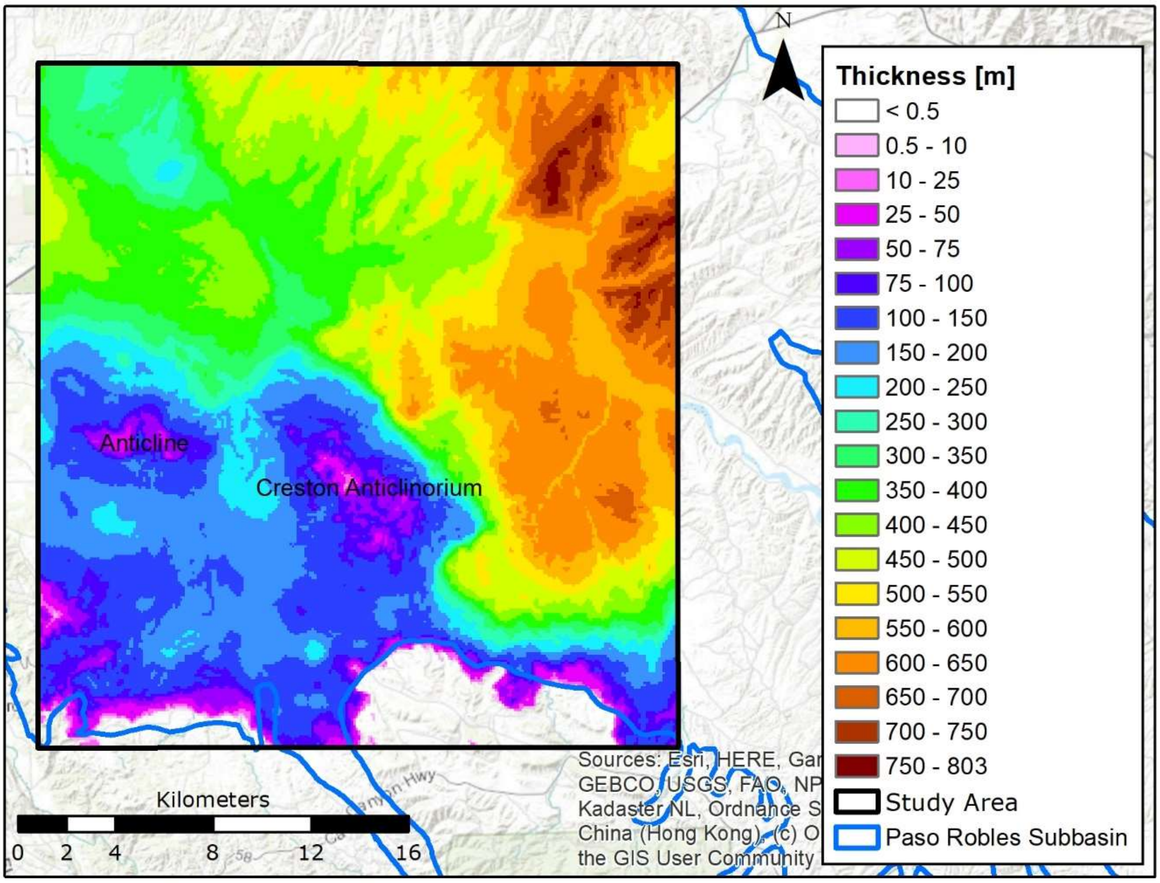
The interpretations from the 3D geological model are presented in Appendix 5 and 6, which contain the 62 cross sections drawn in GeoScene3D. The interpreted boundary surfaces of the four geologic units are shown on the cross sections together with AEM data and well logs. The cross sections also show the interpretation of faults as well as internal stratigraphic units in the Paso Robles Formation determined from the AEM data. These sections were drawn in Adobe Illustrator.

5.2.4 Extent and thickness of the geologic units

Maps showing the extent and thickness of the four geologic units are created from the adjusted surface grids interpreted in GeosScene3D. These maps are described in more detail in the following subsections.

5.2.4.1 Paso Robles Formation

The thickness of the Paso Robles Formation, as interpreted in the 3D geologic model, is shown in Figure 5-2. The greatest thickness is in the eastern and northern part of the Study Area where the Paso Robles Formation is estimated to be between 200-800 meters (650-2600 ft) thick. In the area between Paso Robles and Creston, the Paso Robles Formation is estimated to have a thickness between 25-200 meters (80-650 ft). The thinnest parts of the Paso Robles formation are generally over the Creston Anticlinorium and in the area named “Anticline” in Figure 5-2. The latter area is named Anticline because a series of shallow anticlines and synclines have previously been mapped in this area by Fugro (2002).



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 5-2. Thickness map of the Paso Robles Formation.

Figure 5-3 shows the elevation of the bottom of the Paso Robles Formation. The bottom ranges from approximately 100-500 m a.m.s.l. (300-1600 ft) in the southwestern part of the Study Area. In this area, the shallowest point occurs at the Creston Anticlinorium, where the bottom of the Paso Robles Formation is approximately 400-500 m a.m.s.l. (1300-1600 ft). Another shallow point is west of the Creston Anticlinorium where the bottom of the Paso Robles Formation is at 200-300 m a.m.s.l. (700-1000 ft). In the 3D geological model, the bottom of the Paso Robles Formation descends towards the north and east, where it is approximately 100-250 m b.m.s.l. (300-800 ft).

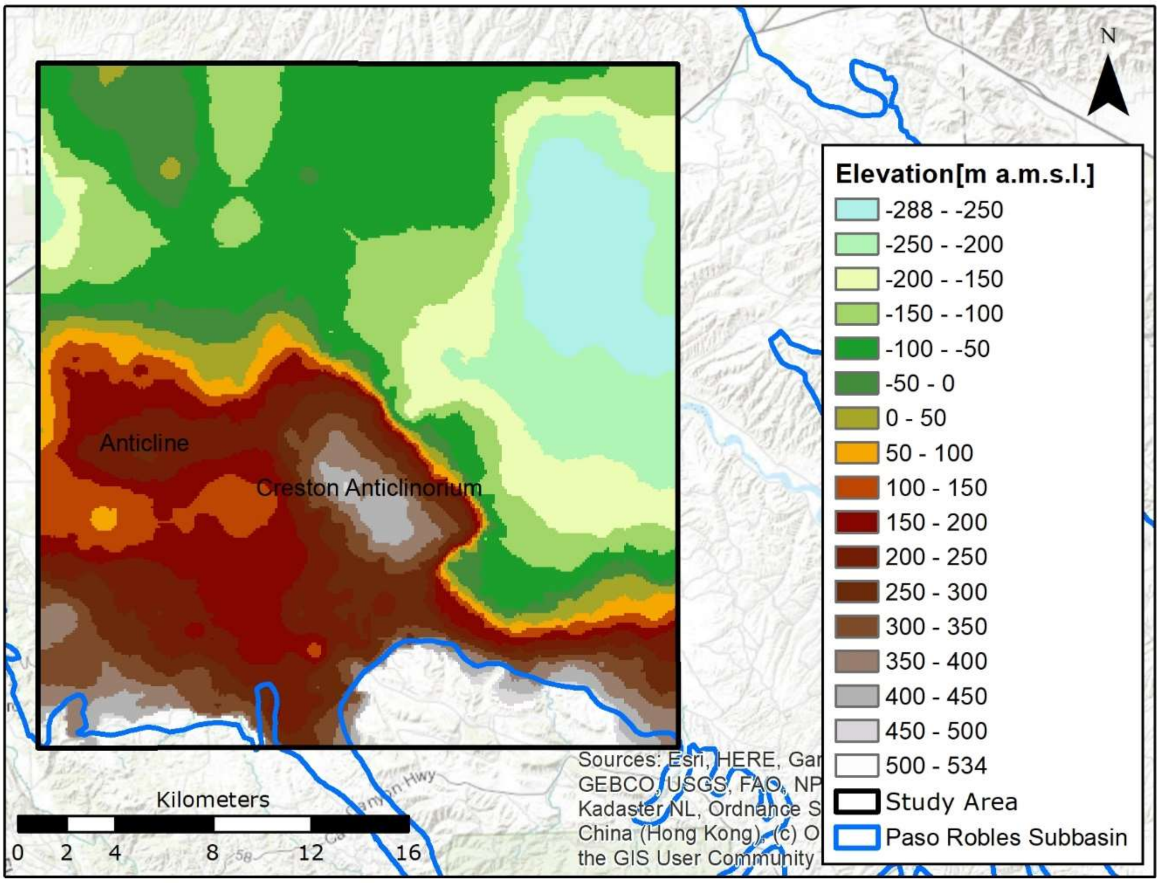
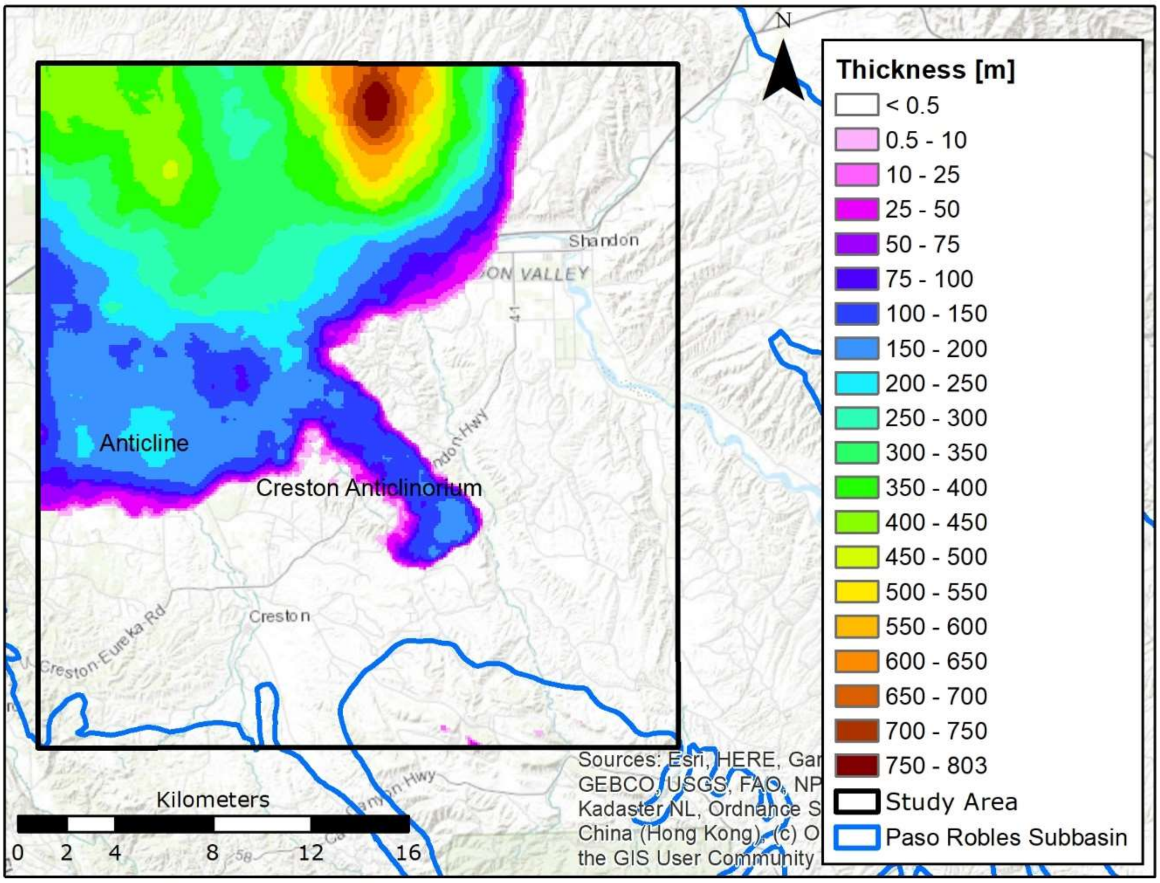


Figure 5-3. The elevation of the bottom of the Paso Robles Formation in meters above mean sea level.

5.2.4.2 Pancho Rico Formation

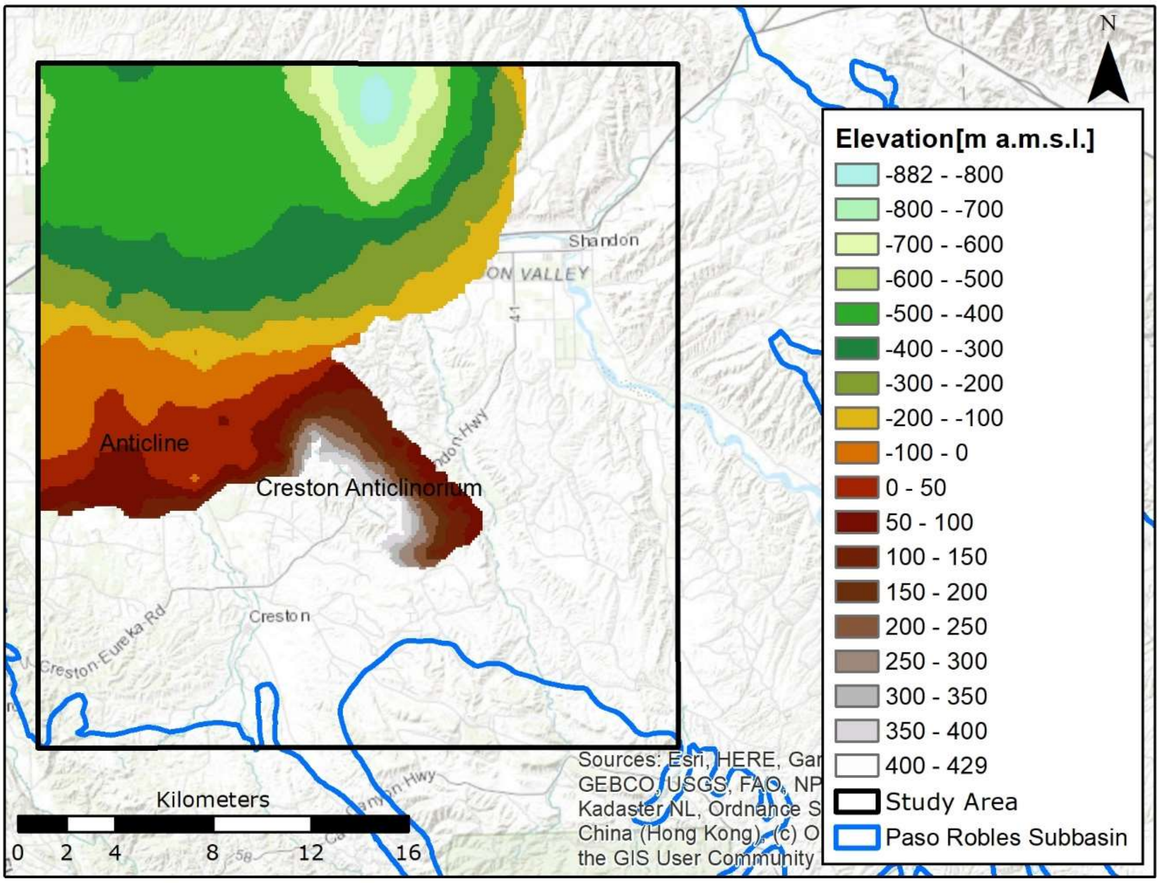
Figure 5-4 show the thickness of the Pancho Rico Formation as modelled in the 3D geological model. Here, the Pancho Rico Formation is primarily present in the northern and northwestern part of the Study Area. The thickness of the Pancho Rico Formation increases towards the north, from around 150 m (500 ft) to about 500 m (1600 ft). In the northern part of the Study Area, the formation locally has a thickness of 800 m (2600 ft), based on a single CalGEM well. In the central part of the Study Area, the Pancho Rico Formation is much thinner and is estimated to be about 100 m (300 ft), which is limited to an elongated area coinciding with the Creston Anticlinorium.



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 5-4. Thickness map of the Pancho Rico Formation.

The elevation of the bottom of the Pancho Rico Formation is shown in Figure 5-5. The shallowest point of the bottom of the Pancho Rico Formation is approximately 50-400 m a.m.s.l. (200-1300 ft) at the Creston Anticlinorium. The bottom of the Pancho Rico Formation slopes downwards from the Creston Anticlinorium and towards the north and northwest. Figure 5-5 shows that in the northern and northwestern part of the Study Area, the lower boundary is approximately 500-900 m b.m.s.l (1600-2900 ft).

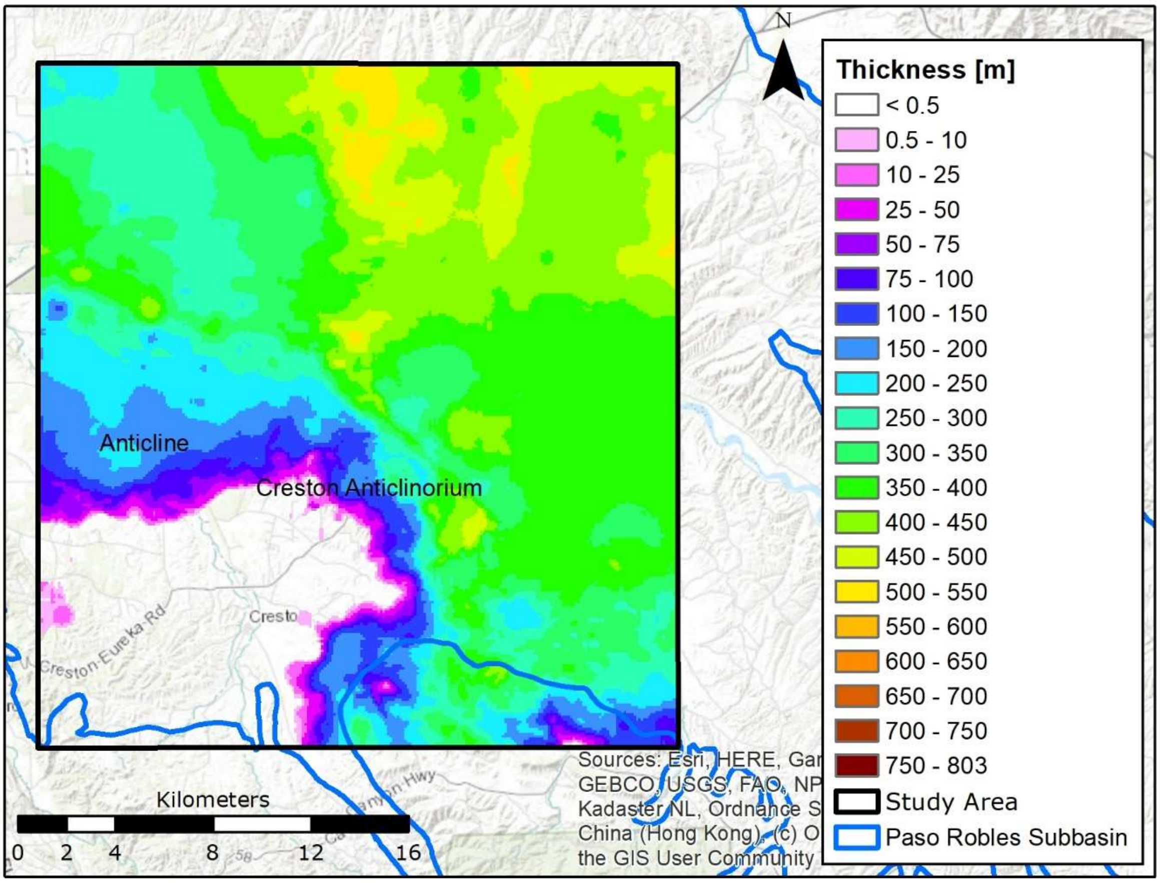


Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 5-5. The elevation of the bottom of the Pancho Rico Formation in meters above mean sea level.

5.2.4.3 Santa Margarita Formation

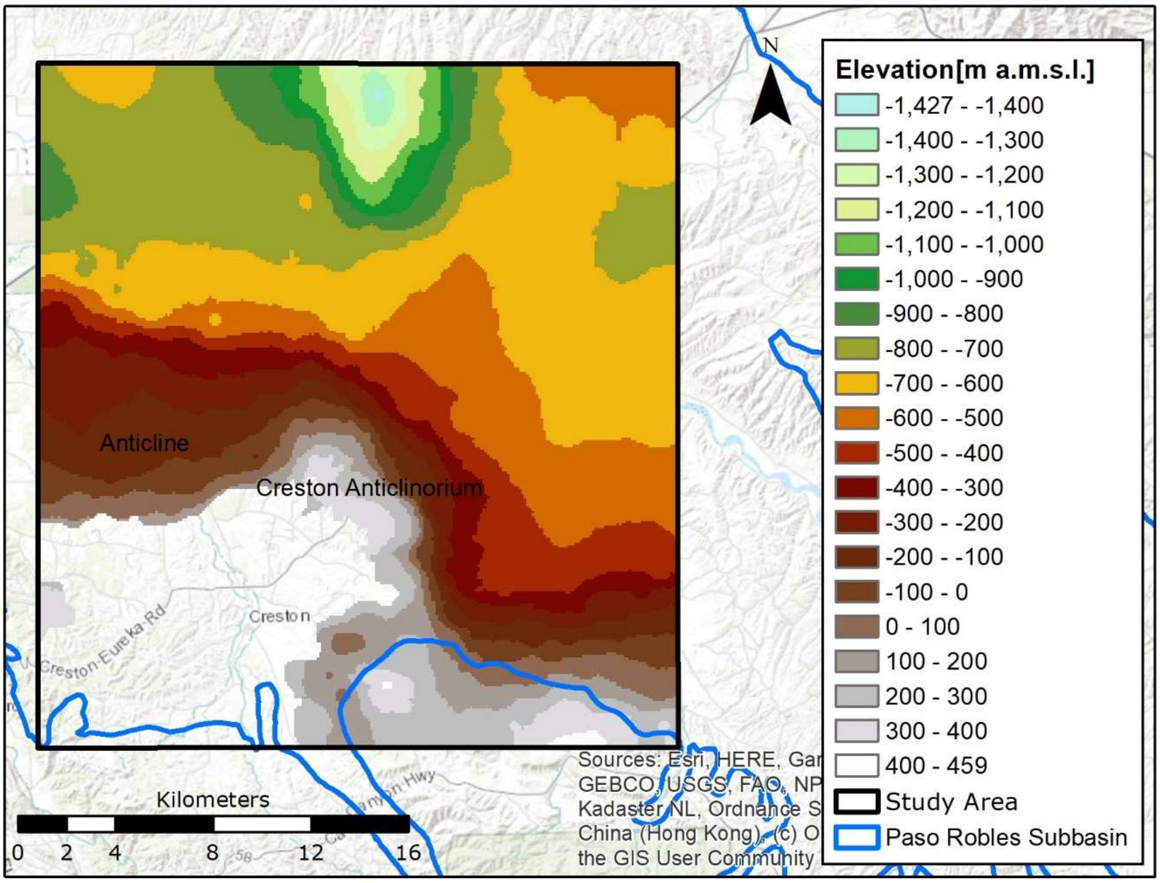
The thickness of the Santa Margarita Formation, as interpreted in the 3D geological model, is shown in Figure 5-6. The Santa Margarita Formation is interpreted to be present across the Study Area except in the Creston area and in the southwestern part of the Study Area (Figure 5-6). The thickness is modelled to increase towards northeast, from 100-200 m to 400-500 m (300-1600 ft).



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 5-6. Thickness map of the Santa Margarita Formation.

The elevation of the bottom of the Santa Margarita Formation as modelled in the 3D geological model is shown in Figure 5-7. The lower boundary of the Santa Margarita Formation is modelled to slope downward towards the north. The formation bottom is estimated to be approximately 300 a.m.s.l. (900 ft) to 400 m b.m.s.l. (1300 ft) in the central part of the Study Area, and approximately 600-1400 m b.m.s.l. (2000-4600 ft) the northern part of the Study Area.



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 5-7. The elevation of the bottom of the Santa Margarita Formation in meters above mean sea level.

5.2.4.4 Monterey Formation

In the 3D geological model, the Monterey formation is interpreted to be widespread in the Study Area except in the southwestern corner. This is seen in Figure 5-8, which shows the modelled thickness of the Monterey Formation in the 3D geological model. In the model, it is interpreted that the thickness increases to the northwest from around 200 m (600 ft) to 500-600 m (1600-1900 ft).

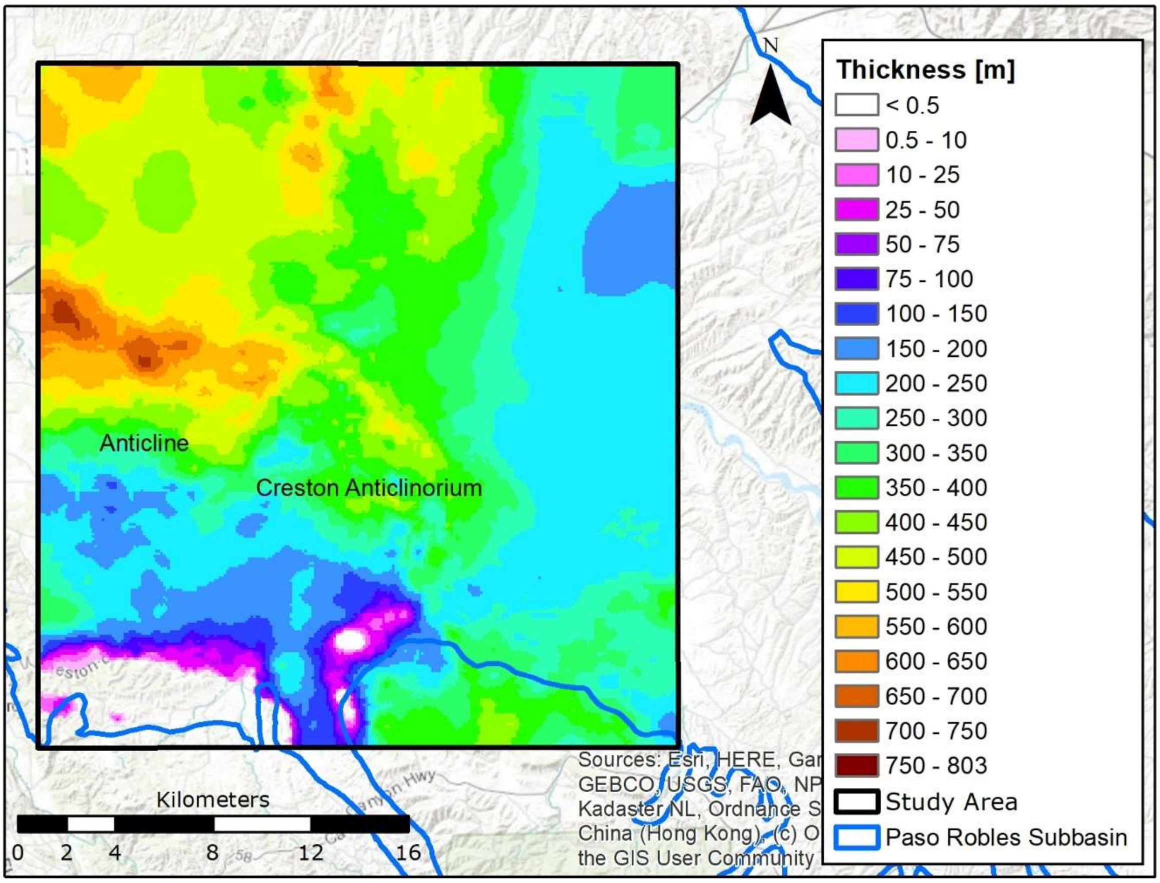
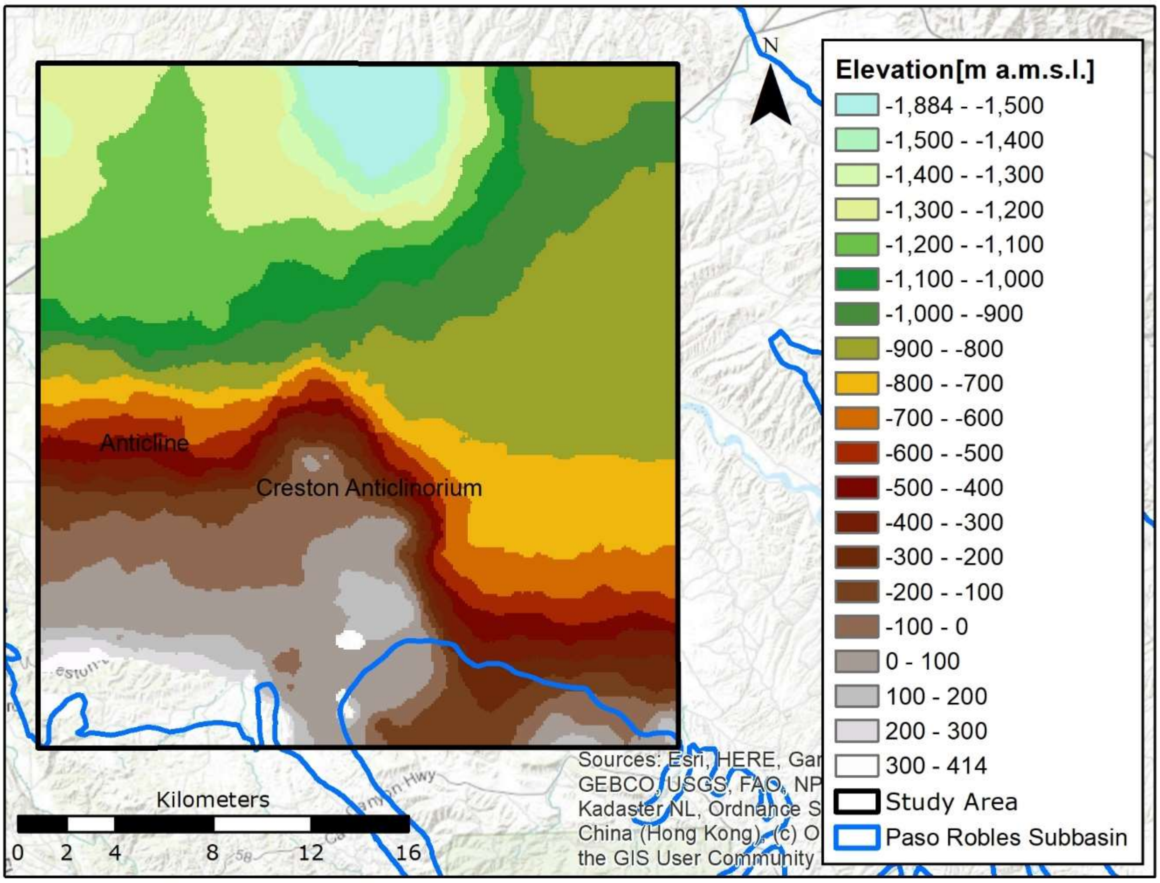


Figure 5-8. Thickness map of the Monterey Formation.

The elevation of the lower boundary of the Monterey Formation is shown in Figure 5-9. The lower boundary is modelled to be approximately 300 a.m.s.l. (900 ft) to 800 m b.m.s.l. (2600 ft) in the central and southwestern part of the Study Area. The bottom of the Monterey Formation slopes downwards from south to north, where the lower boundary is interpreted to be approximately 900-1800 m b.m.s.l. (2900-5900 ft).



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 5-9. The elevation of the bottom of the Monterey Formation in meters above mean sea level.

5.3 Hydrogeologic conceptual model

The HCM is developed following the 3D geological model and uses the 3D geological model as a foundation. In the HCM, only hydrogeologic zones within the Paso Robles Formation have been modeled. This is because the Paso Robles Formation is considered to be the primary water producing zone within the Study Area. The hydrogeologic zones in the HCM are interpreted by placing control points along the lower boundary of the individual hydrogeologic zones. Normally, the control points are used to create a 2D surface grid. A 2D surface grid was not created because of the area's geologic complexity (*i.e.* faults). The lower boundaries of the hydrogeologic zones are, therefore, visualized by point data themes (point cloud) and not as surface grids.

5.3.1 The HCM framework

The HCM framework conceptualizes the number of hydrogeologic zones (aquifers and aquitards) observed within the subbasin Study Area, with the general structure of the HCM determined based on the geology, data interpretation is used to map hydrogeologic zones.

As previously mentioned, the Paso Robles Formation is considered as the primary water-bearing formation within the Paso Robles Subbasin. Due to the highly alternating and heterogeneous nature of the sandy and clayey sediments, it is not possible to define individual, mappable aquifers and aquitards in the subbasin. However, it is possible to subdivide the Paso Robles Formation into hydrogeologic zones based on resistivity. The mapping of these zones will provide information on where, for example, the Paso Robles Formation is characterized by a higher sand content, which in turn would highlight areas with a higher permeability within the Paso Robles Formation.

Three hydrogeologic zones have been identified within the Paso Robles Formation using resistivity data. The three zones in a downward sequence are:

A. An upper high resistivity layer, generally interpreted as coarse sediments
B. An electrically conductive layer, generally interpreted as finer sediments
C. A lower high resistivity layer, generally interpreted as more coarse sediments

The three hydrogeologic zones are detailed described in the following subsections.

A. The upper layer of coarse sediments

In the AEM data, a high resistivity layer within the Paso Robles Formation is observed immediately beneath ground surface. The extent of the high resistivity layer is shown in Figure 5-10. The layer is characterized by resistivity values between 15 and 250 ohmm, and the thickness varies between 10 and 80 m. When compared with nearby well logs, there is no clear evidence that the high resistivity represents a dominance of coarse deposits. In some well logs subsurface sands are observed, while other well logs show clayey deposits with sand lenses. Therefore, the high resistivity does not necessarily indicate a dominance of coarse deposits, but in fact can indicate the presence of unsaturated zone. The high resistivity is underlain by the layer characterized by a low resistivity.

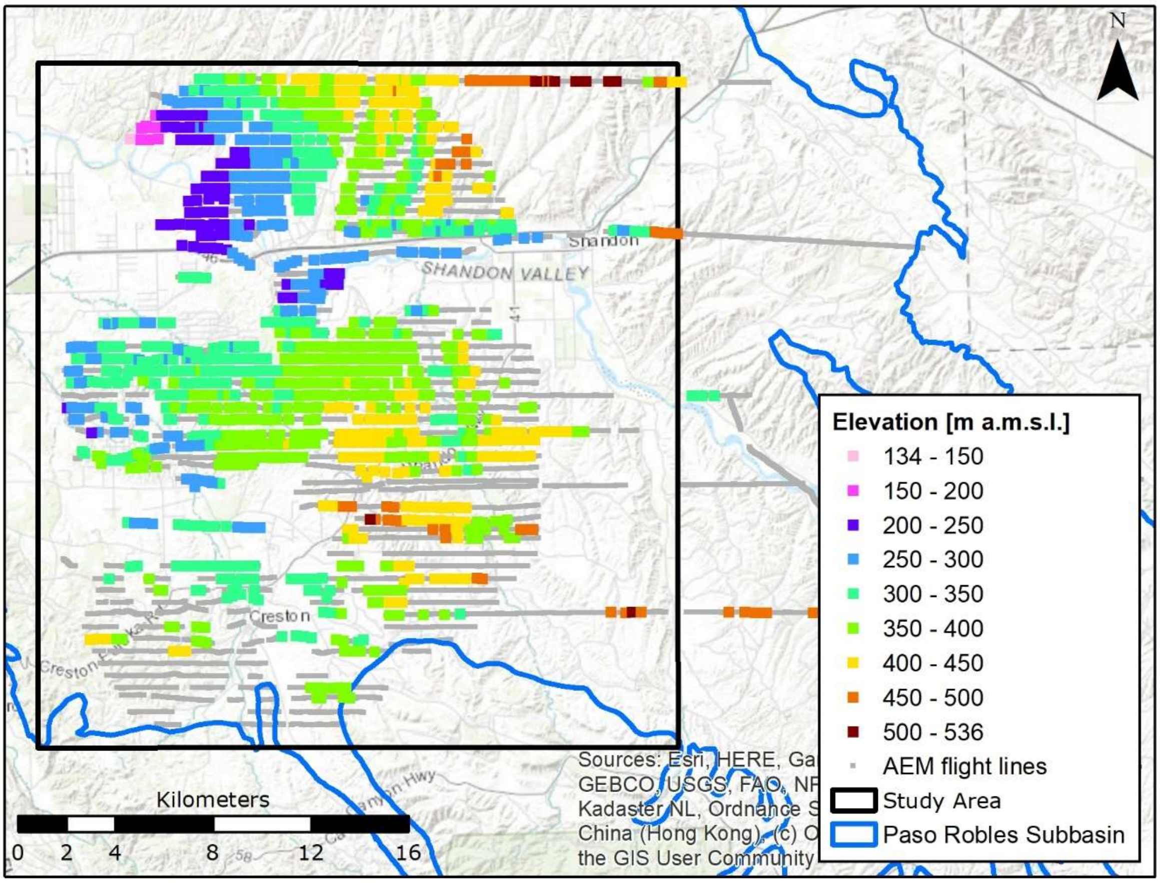
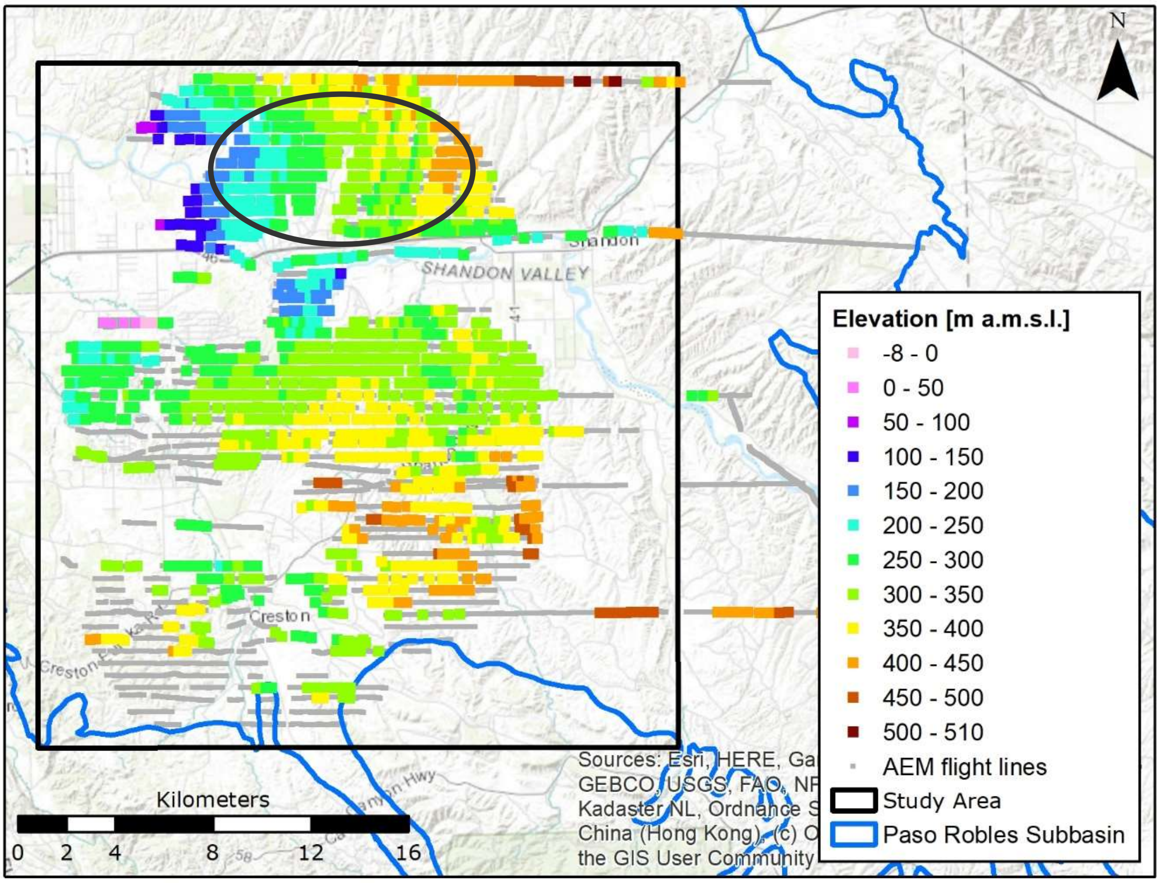


Figure 5-10. The elevation of the lower boundary of the upper layer of sediments within the Paso Robles Formation. The boundary is interpreted to reflect the water table (possibly perched) with an overlying unsaturated zone, or the contact between clays and overlying coarse sediments.

B. The layer of finer sediments

The AEM data has mapped a low resistivity layer between 3 and 15 ohmm within the Paso Robles Formation (see Figure 5-11). Depending on the thickness of the upper high resistivity layer, the low resistivity layer is generally located 10 to 50 m below ground surface. The lowest resistivities (<5 ohmm) are commonly observed in the area north of Estrella River, which is marked by the black ellipse in Figure 5-11. It is inferred that the low resistivity indicates clayey sediments, which is consistent with the lithological description in nearby well logs. The thickness of the layer generally varies between 10 and 50 m.



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 5-11. The elevation of the lower boundary of the finer sediment-low resistivity layer within the Paso Robles Formation. The black ellipse shows the area, where the layer is characterized by a resistivity <5 ohmm.

C. The lower layer of more coarse sediments

A high resistivity layer is mapped in the Paso Robles Formation by the AEM data. The extent of the layer is shown in Figure 5-12. The layer is generally characterized by a resistivity between 15 and 50 ohmm. The layer's thickness generally varies between 20 and 100 m. Lithologic descriptions from nearby well logs indicate that the layer is primarily composed of sand deposits interbedded with minor clay layers. The black ellipse in Figure 5-12 marks the area where the high resistivity layer has the greatest thickness. Here, well logs outside the Study Area of the AEM data also generally show a dominance of sandy sediments.

The high resistivity layer is generally overlain by the above-mentioned low resistivity layer, but areas where the high resistivity layer is in direct contact with ground surface are also observed. For example, this can be seen in the southern part of the Shedd Canyon, just east of the Creston Anticlinorium. Here the high resistivity layer is underlain by a low resistivity layer, and within the black ellipse in Figure 5-12, this layer generally has a resistivity between 5 and 15 ohmm.

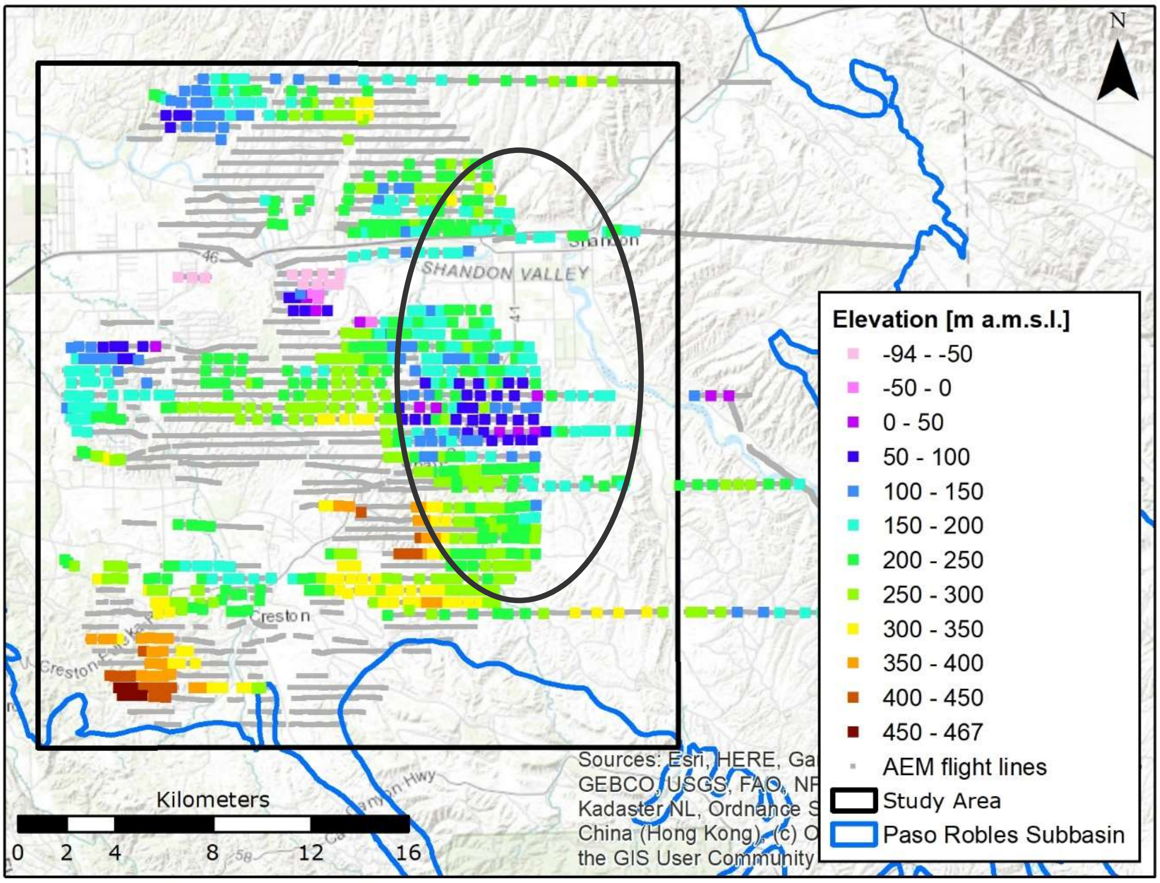


Figure 5-12. The elevation of the lower boundary of the layer of coarser sediments within the Paso Robles Formation. The black ellipse shows the area where the layer has the greatest thickness.

5.4 Resistivity-lithology relationship

Based on a thorough examination of specific boreholes near the AEM survey line data during development of the 3D geological model and HCM, a correlation between the AEM survey resistivity and lithology of geologic formations was established (Figure 5-13). This correlation indicates that the marine consolidated clay units, Monterey and Pancho Rico Formation, are generally characterized by resistivities below 15 ohmm, while the marine consolidated sand unit, Santa Margarita, is characterized by resistivities of 25-100 ohmm. The Paso Robles Formation resistivities range from 3 ohmm to 50 ohmm, indicating both clayey deposits and sandy deposits. However, resistivities above 15-20 ohmm appear generally to indicate coarse sediments (sand/gravel) in the Paso Robles Formation, while resistivities below 10 ohmm indicate clay-dominant sediments with possible sand-lenses present.

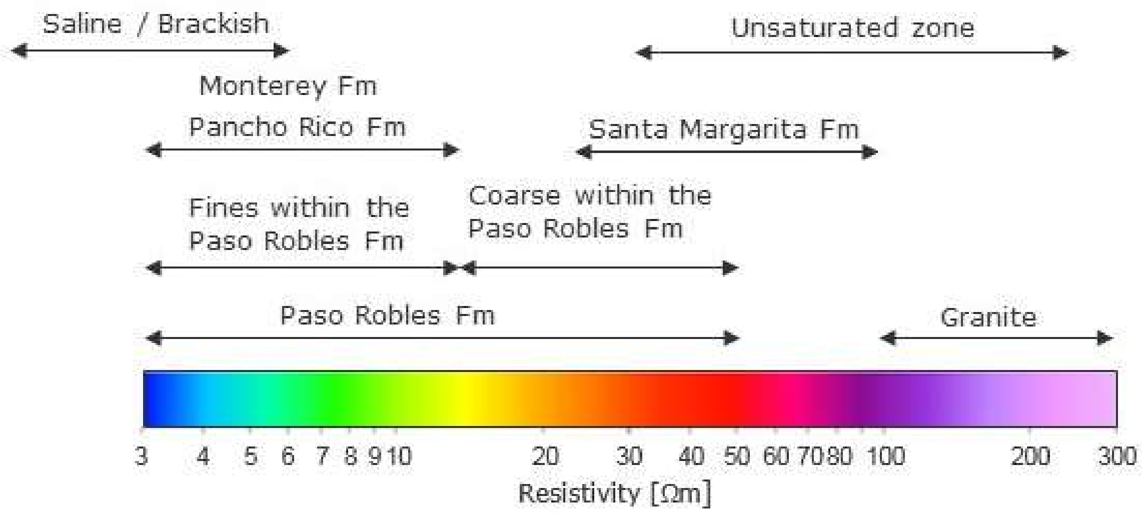


Figure 5-13. The color key showing the resistivity-lithology correlation in the interpretation of the AEM data for the geologic units.

6. GEOLOGIC INTERPRETATIONS WITHIN SPECIFIC AREAS

6.1 Faults

Colgan *et al.* (2012) mapped and described some of the major fault systems in the Paso Robles Subbasin using a variety of data including geologic maps, wells, gravity measurements and seismic-reflection profiles. The data were also used to construct cross sections through the La Panza Range and southern Salinas basin, which illustrate the stratigraphic and structural architecture of the geologic strata within the Salinas Basin. Two of the cross sections pass through the central part of the Paso Robles Subbasin (Figure 6-1), and the interpreted geology is provided in Figure 6-2.

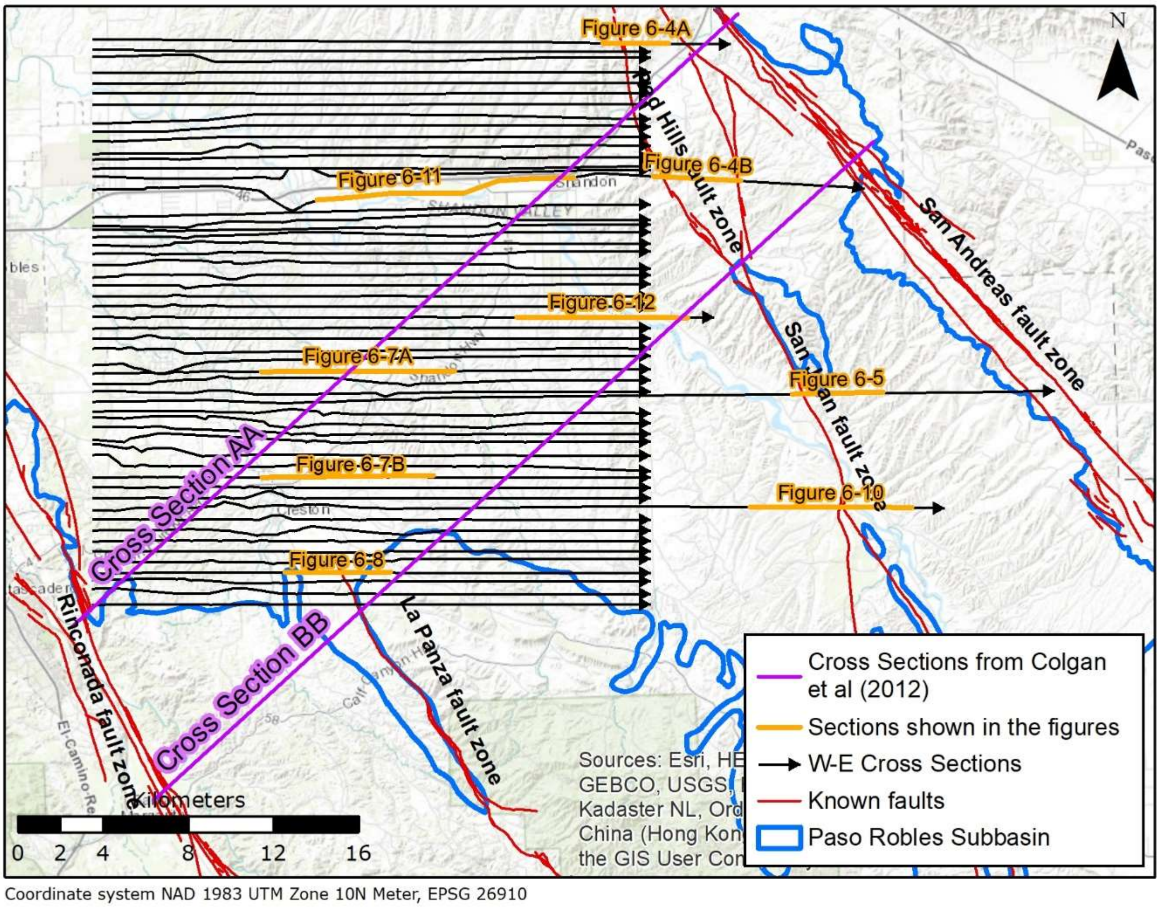


Figure 6-1. The location of the two cross sections from Colgan *et al.* (2012) and the location of the section of AEM data shown in the figures below. The cross sections from Colgan *et al.* (2012) are illustrated in Figure 6-2.

As illustrated by the cross sections, Colgan *et al.* (2012) identified that strike-slip faults and thrust faults formed during the deformation of the geologic strata within the Paso Robles Subbasin. These faults have also been observed in the AEM data. Furthermore, the AEM data have mapped other concealed faults, which have not been mapped in previous studies. In the following subsections, the faults mapped by the AEM data are described and compared with results from the Colgan *et al.* (2012).

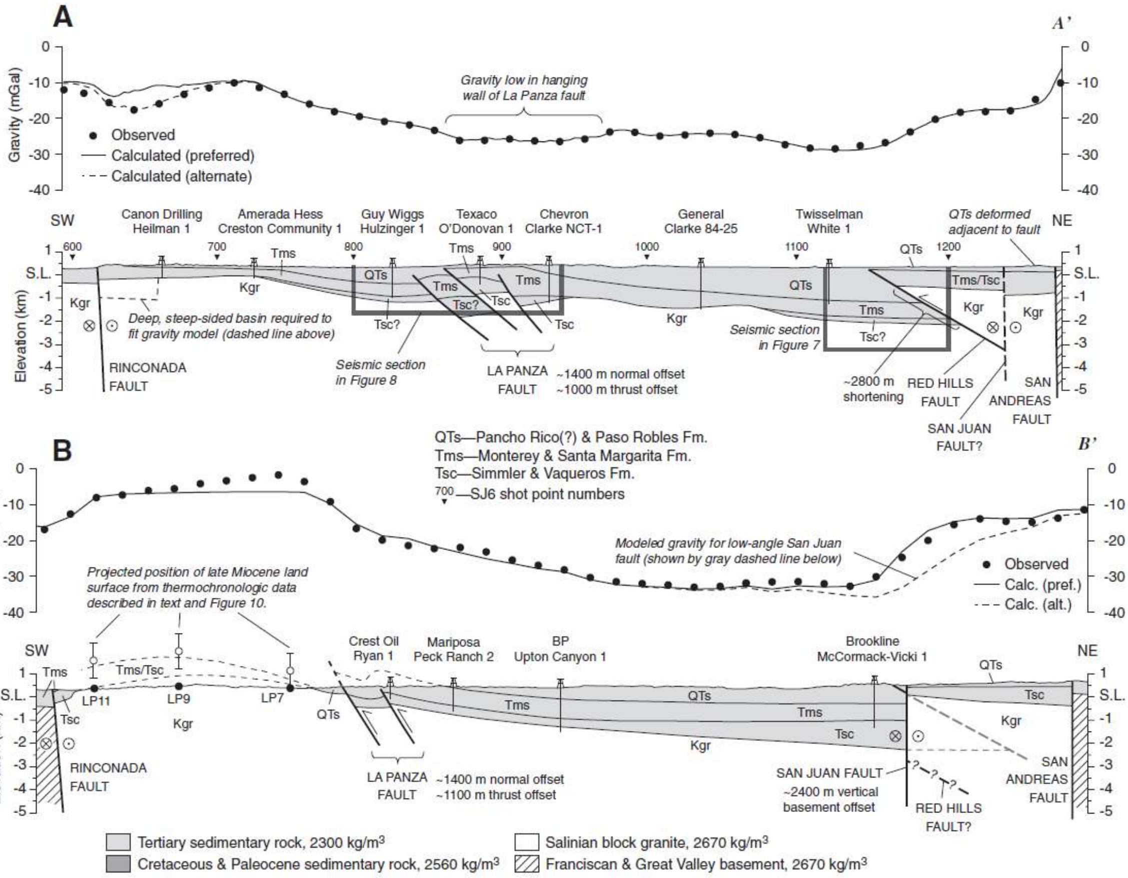


Figure 6-2. Geologic cross sections and modeled gravity profiles across the Paso Robles Subbasin (from Colgan *et al.* 2012). The approximate location of the two cross sections are shown in Figure 6-1.

6.1.1 San Juan and Red Hills fault

The San Juan and the Red Hills fault are in the eastern part of the Paso Robles Subbasin (see Figure 6-1). The two faults are considered to represent two separate phases of tectonic activity: (1) southwest compressional thrusting along the Red Hills associated with convergent tectonics, and (2) extension associated with transform tectonics in which the Red Hills fault is cut obliquely by the younger strike slip San Juan fault as part of the San Andreas fault zone.

The Red Hills Fault is mapped as a 30-35° northeast-dipping thrust fault. The seismic-reflection image in Figure 6-3 shows that the thrust fault consists of a hanging wall of Salinian Block granitic basement rock that has moved up and over a footwall composed of the Pancho Rico Formation and Paso Robles Formation.

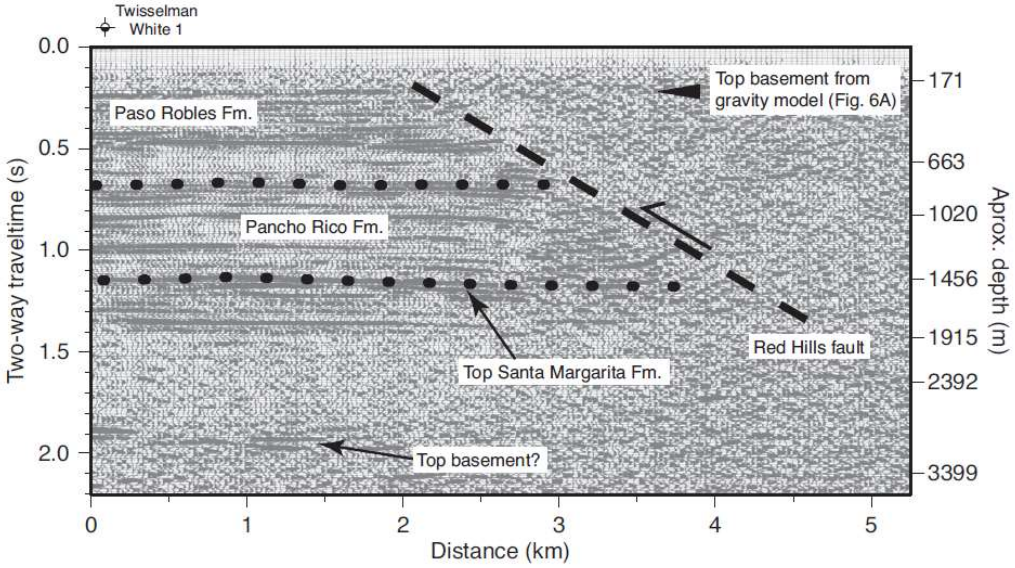


Figure 6-3. Seismic-reflection line across the Red Hills fault (from Colgan *et al.* 2012).

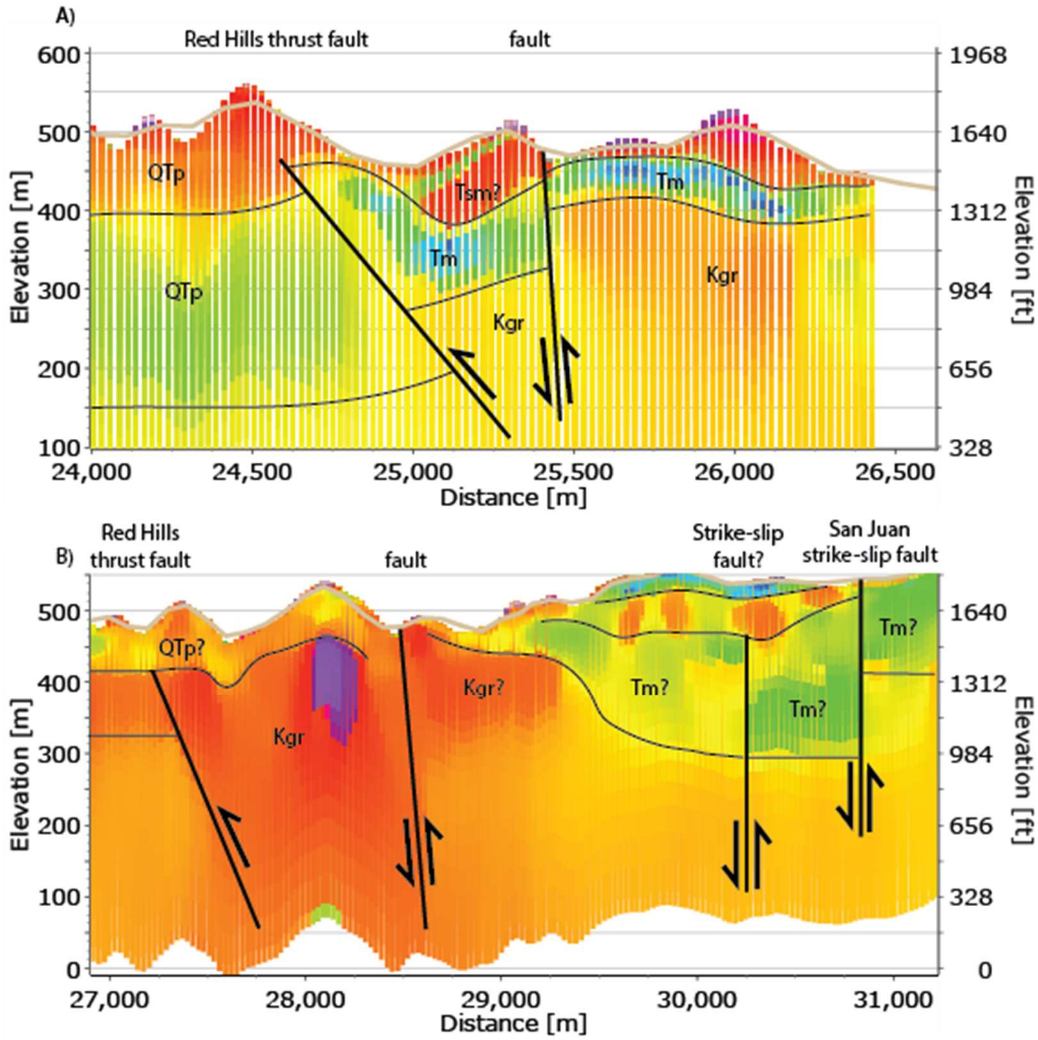


Figure 6-4. A section of the AEM data at the Red Hills fault. A) Resistivity data from W-E Cross Section 54 and B) Resistivity data from W-E Cross Section 40.

Two of the AEM flight lines cross the Red Hills fault, and the resistivity measurements from these flight lines are shown on W-E Cross Section 40 and 54 (Appendix 5). A close-up of the AEM data from the two cross sections at the Red Hills fault are shown in Figure 6-4. The Red Hills fault is best seen in the AEM data along W-E Cross Section 54 (Figure 6-4A) due to greater contrast in the resistivity measurements. On W-E Cross Section 54, the Red Hills faults is observed between the distance markers 24,500 m and 26,500 m. In the AEM data, a low resistivity layer is observed about 20-150 m below ground surface. The layer is characterized by a low resistivity of 3-10 ohmm. Directly below this layer, the resistivity is 14 to 20 ohmm, while resistivities of 20-40 ohmm are observed above the low resistivity layer. Based on the resistivity-lithology correlation, and a comparison of the structures observed in the resistivity data with the seismic-reflection image in Figure 6-3, it is interpreted that the low resistivity layer represents the Monterey Formation (Tm), while the layer with resistivities of 20-40 ohmm represents sandstone from the Santa Margarita Formation. This would mean that the hanging wall of the Red Hills thrust fault is composed of the Monterey Formation overlain by the Santa Margarita Formation. According to the gravity measurements (Figure 6-3), the top of the basement rocks within the hanging wall are located approximately 200 m below the ground surface. This would mean that the layer with resistivities of 14-20 ohmm represents Salinian Block granitic basement rocks (Kgr). These resistivities are very low for granite. This may be due to the weathered nature of the granitics associated with the fault zone and possibly pore water with increased salt content.

The footwall of the Red Hills fault is composed of a layer with resistivities of 9-15 ohmm (Figure 6-4A), which is interpreted to represent the Paso Robles Formation. This is consistent with the interpretations in the seismic-reflection image (Figure 6-3). The AEM data show an extra detail, which is not reported by Colgan *et al.* (2012). An additional fault is observed between the distance markers 25,500 m and 26,000 m in Figure 6-4A. The fault may either be a small thrust fault, or a vertical left lateral strike-slip fault associated with San Juan/San Andreas fault system.

The Red Hills fault is more difficult to discern from the AEM data on the W-E Cross Section 40, but the fault is interpreted to be visible in the AEM data between the distance markers 27,000 m and 28,000 m. From the resistivity measurements, it is inferred that the hanging wall of the Red Hills fault is composed of basement rocks (20-140 ohmm) overlain by a thin layer (10-15 ohmm), which may represent the Paso Robles Formation. The composition of the footwall is more uncertain, as the resistivities can indicate basement rocks, sandstone, or the Paso Robles Formation. Like the AEM data in Cross Section 54, an additional fault is visible east of the Red Hills fault. The fault may be a small thrust fault associated with the Red Hills fault zone or a vertical left lateral strike-slip fault associated with San Juan/San Andreas fault system (see Figure 6-4B).

The San Juan Fault is defined as a steeply dipping (vertical or near vertical) right-lateral strike-slip fault subparallel to and within the San Andreas fault zone (Colgan *et al.* 2012). Indication of the San Juan fault in the AEM data is primarily observed on Cross Section 40 and 20. In Figure 6-4B, the San Juan fault is seen between the distance markers 30,500 m and 31,000 m. Here, a 100 m thick layer characterised by low resistivity (5-10 ohmm) has been truncated, so there is a sharp boundary between the low resistivity layer and layer with a sligthly higher resistivity (10-20 ohmm) towards the east. On the eastern side of the San Juan fault, the low resistivity layer is shifted approximately 100 m above the low resistivity layer on the western side of the San Juan fault. The low resistivity layer may represent the Monterey Formation, while the layer with sligthly higher resistivity likely represents deposits older than the Monterey Formation (*e.g.* Vaqueros Formation).

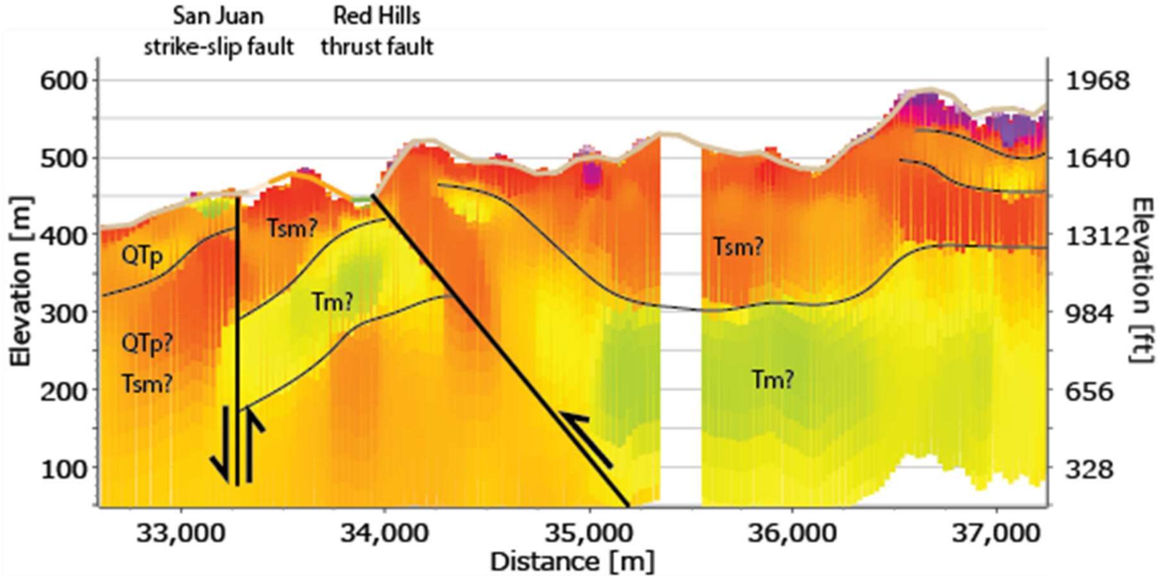


Figure 6-5. A section of AEM data at the San Juan fault from W-E Cross Section 20.

The AEM data on W-E Cross Section 20 (Figure 6-5) indicate the San Juan fault likely cuts through the strata at distance marker 33,500 m. Like the AEM data on W-E Cross Section 40, there is a change from a low resistivity layer (10-15 ohmm) to a layer with a slightly higher resistivity (20-25 ohmm). This contrast in resistivity is visible on W-E Cross Section 20 in Appendix 5. East of the San Juan fault, the resistivity measurements may also indicate the presence of a thrust fault. Colgan et *al.* (2012) mapped the Red Hills fault to be on the western side of the San Juan fault in the northern part of the Study Area. In the eastern part of the Study Area, the Red Hills fault is offset right laterally by the San Juan fault, so it is located on the eastern side of the San Juan fault (see Figure 6-11). Therefore, the thrust fault observed in the AEM data in Figure 6-5 is interpreted to be the Red Hills fault, which is consistent with the work of Colgan *et al.* (2012).

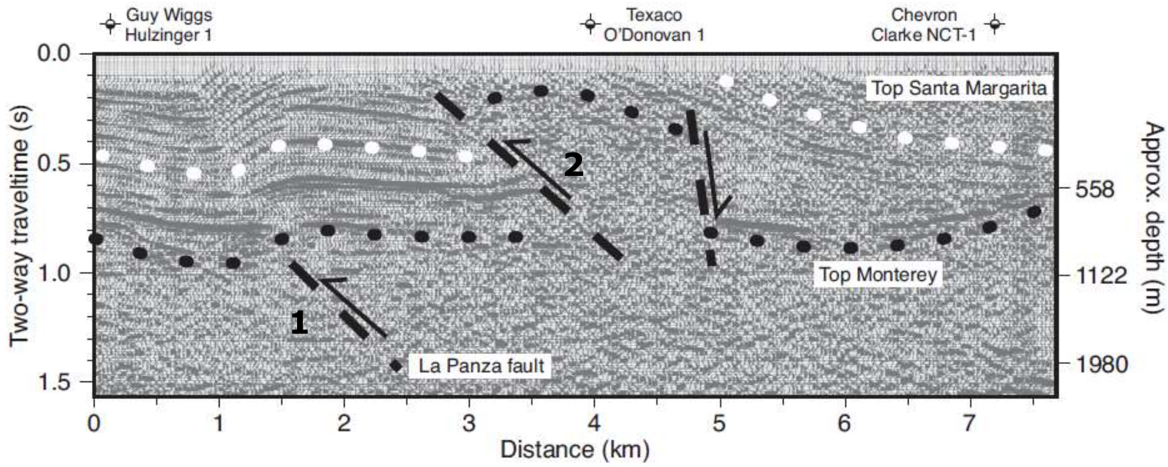


Figure 6-6. Seismic-reflection line across La Panza fault and the Creston anticline (from Colgan *et al.*, 2012). The numbers refer to the individual thrust faults that are interpreted to be part of the La Panza fault zone in Figure 6-7.

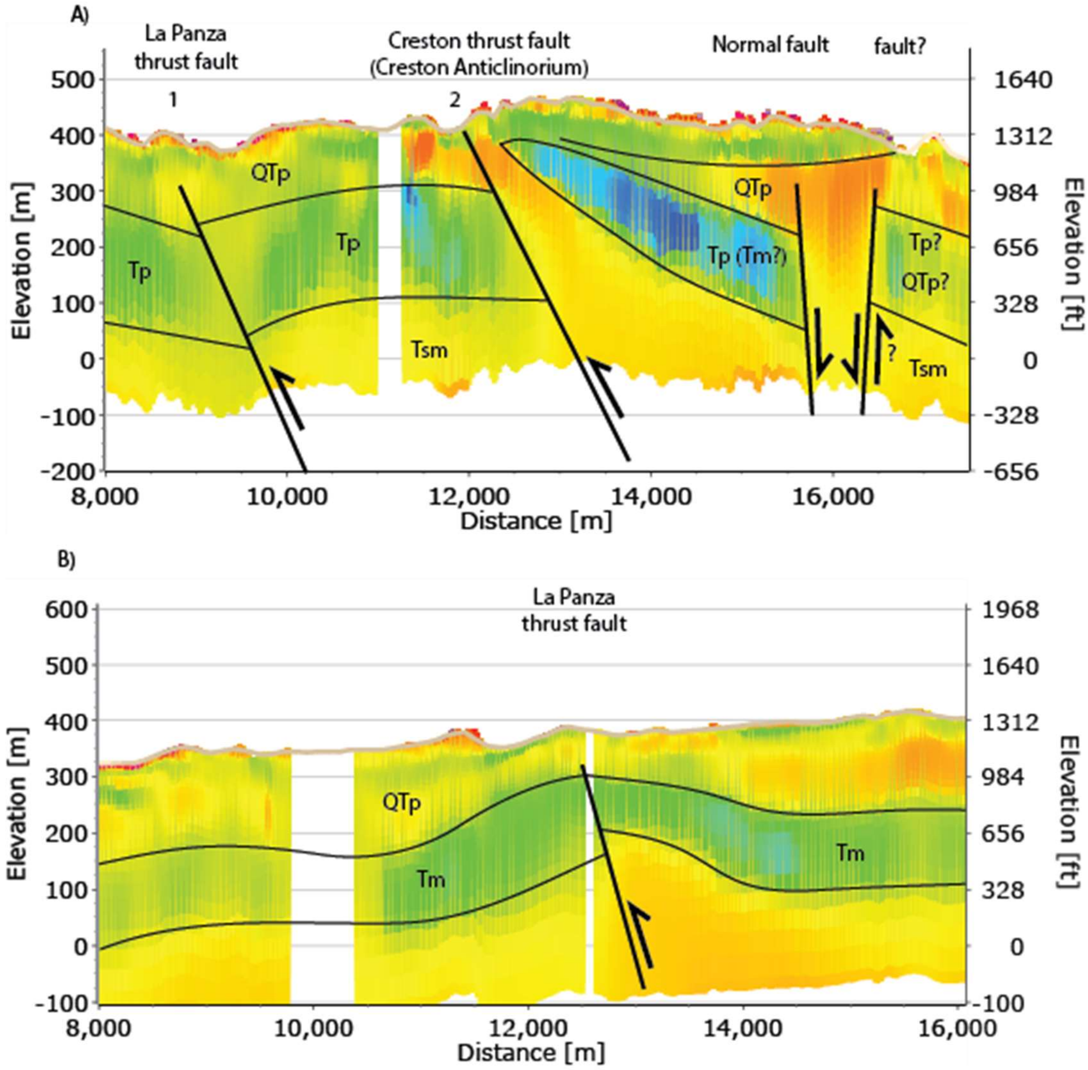


Figure 6-7. A section of the AEM data at La Panza thrust fault. A) Resistivity data from W-E Cross Section 23 and B) Resistivity data from W-E Cross Section 13.

6.1.2 La Panza fault and Creston Anticlinorium

The La Panza fault occurs in the western part of the Paso Robles Subbasin (see Figure 6-1). The fault is defined as a northeast-dipping thrust fault (Colgan *et al.*,2002). The seismic-reflection image in Figure 6-6 reveals that the La Panza fault is a blind thrust fault, which means that there is no indication of the fault at ground surface (see also Cross Section AA’ in Figure 6-2). The thrust fault is revealed in the seismic data by the folding of the Santa Margarita Formation and Pancho Rico Formation (Figure 6-6). The seismic reflection image also revealed an additional thrust fault approximately 2 km northeast of the La Panza fault. During the up-thrust of the hanging wall, the sediments were folded. The hanging wall is truncated by a normal fault to the northeast. Here the hanging wall has subsided, which resulted in a thick deposit of the Santa Margarita Formation (see Figure 6-6). Colgan *et al.* (2012) interpreted the two thrust faults to be part of the same fault zone.

When comparing the seismic reflection image in Figure 6-6 with the interpretations of the AEM data near the Creston Anticlinorium (Figure 6-7A), it is evident that thrust fault no. 2 in Figure 6-6 is the same structure as the Creston thrust fault (Creston Anticlinorium) in Figure 6-7A. This suggests that the same subduction zone compressional forces that caused the folding of the Monterey Formation, Santa Margarita Formation and the Pancho Rico Formation, also subsequently caused the formation of the thrust faulting. On the eastern side of the Creston Anticlinorium, the low resistivity layer, likely representing Pancho Rico Formation, is cut short. This is interpreted to be due to normal faulting as mapped by seismic reflection image in Figure 6-6.

The AEM data indicate that the Santa Margarita Formation and Pancho Rico Formation likely have been exposed to erosion at the top of the Creston Anticlinorium. Furthermore, the low resistivity layer interpreted to be part of the Paso Robles Formation seems to be draped over the Creston Anticlinorium. This may suggest an unconformable contact between the Paso Robles Formation and the underlying deposits, which in turn could indicate that the Creston Anticlinorium has been formed prior to the deposition of the Paso Robles Formation.

The La Panza thrust fault (thrust fault no. 1 in Figure 6-6) is difficult to discern in the AEM data. The fault is interpreted between the distance marker 9,000-10,000 m in Figure 6-7A, and is also interpreted to be visible in the AEM data between the distance markers 12,000 m and 14,000 m in Figure 6-7B. Here, the low resistivity layer, likely representing the Monterey Formation, seems to be folded by the La Panza thrust fault.

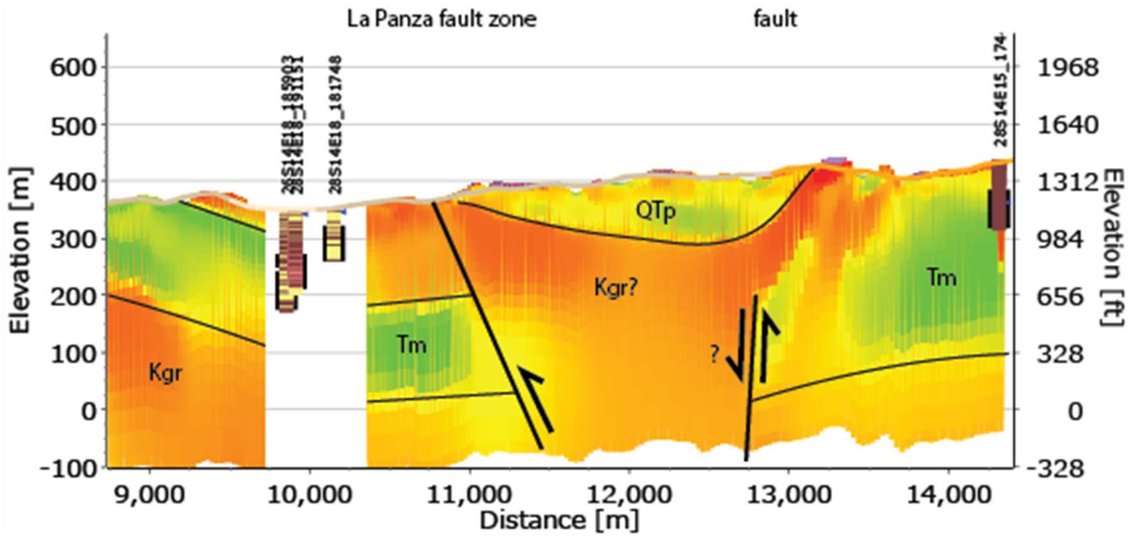


Figure 6-8. A section of the AEM data at La Panza fault zone from W-E Cross Section 4.

In the southern part of the Study Area, faults associated with the La Panza fault are easily seen in the AEM data because of greater resistivity contrasts. Figure 6-8 shows AEM data along W-E Cross Section 4. At the distance marker 11,000 m, there is a sharp boundary between a layer with low resistivity (5-10 ohmm) and a layer with a slightly higher resistivity (15-20 ohmm). This thrust fault is interpreted to be part of the La Panza fault previously mapped in the area (see Figure 6-1). At the distance marker 13,000 m in Figure 6-8, a similar change in resistivity is observed, which again indicates the presence of a fault. This type of fault is considered uncertain.

Along the west side of the Creston Anticlinorium, the Santa Margarita formation can be interpreted as reaching very close to ground surface or even outcropping, based on high electrical resistivities (20+ ohmm) characteristics from SkyTEM results. An example on Figure 6-9 is a close-up of geologic Cross Section 18 in Appendix 5 showing the Santa Margarita formation from 13,500 to 14,900 meters (distance along the section). The Santa Margarita formation is not shown on the Dibblee map in the area of the anticlinorium (Dibblee and Minch, 2004); Dibblee field mapped the entire land surface area as covered completely by the Paso Robles Formation. When interpreting the SkyTEM results, the Santa Margarita unit may extend near or all the way to ground surface in an area along the western side of the anticline. When it is not observed on the Dibblee maps it might be due to vegetation or a very thin sediment cover. On the east side of the Creston Anticlinorium, the geology is interpreted as the more conductive Paso Robles formation. The example refers to Cross Section 18, but similar observations can be seen on the neighboring sections 17, 19, 20 and 21 shown in Appendix 5.

Field mapping was not in the Study Area scope of work. Future field verification and scientific documentation could be conducted as a follow up to resolve the distribution of Santa Margarita and Paso Robles formations at the ground surface on the west side of the anticlinorium.

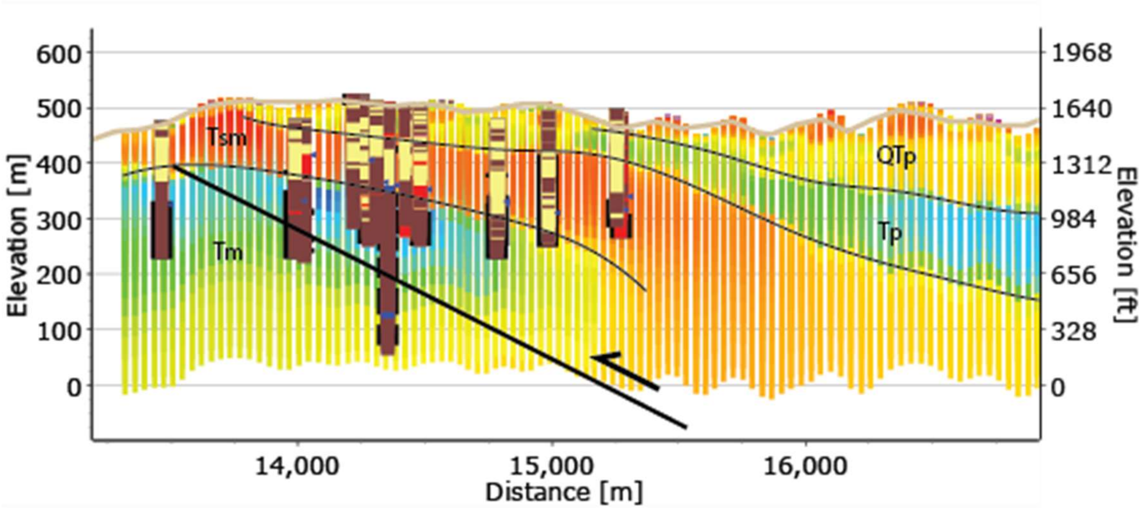


Figure 6-9. A section of the AEM data at Creston thrust fault from W-E Cross Section 18.

6.1.3 Newly Identified Concealed Faults

Besides the previously mapped faults, the AEM data also mapped additional, previously unknown, concealed faults. These faults were identified from terrain analysis, magnetic data and electromagnetic data. The newly identified faults are shown in Figure 6-10. Most of the previously and newly mapped faults are southwest-dipping faults. Among the SW-dipping faults are a northern extension of the La Panza fault, the Creston thrust fault and an unnamed normal fault that was developed as part of the Creston thrust fault complex. The locations of newly identified faults are highlighted with color in Figure 6-10.

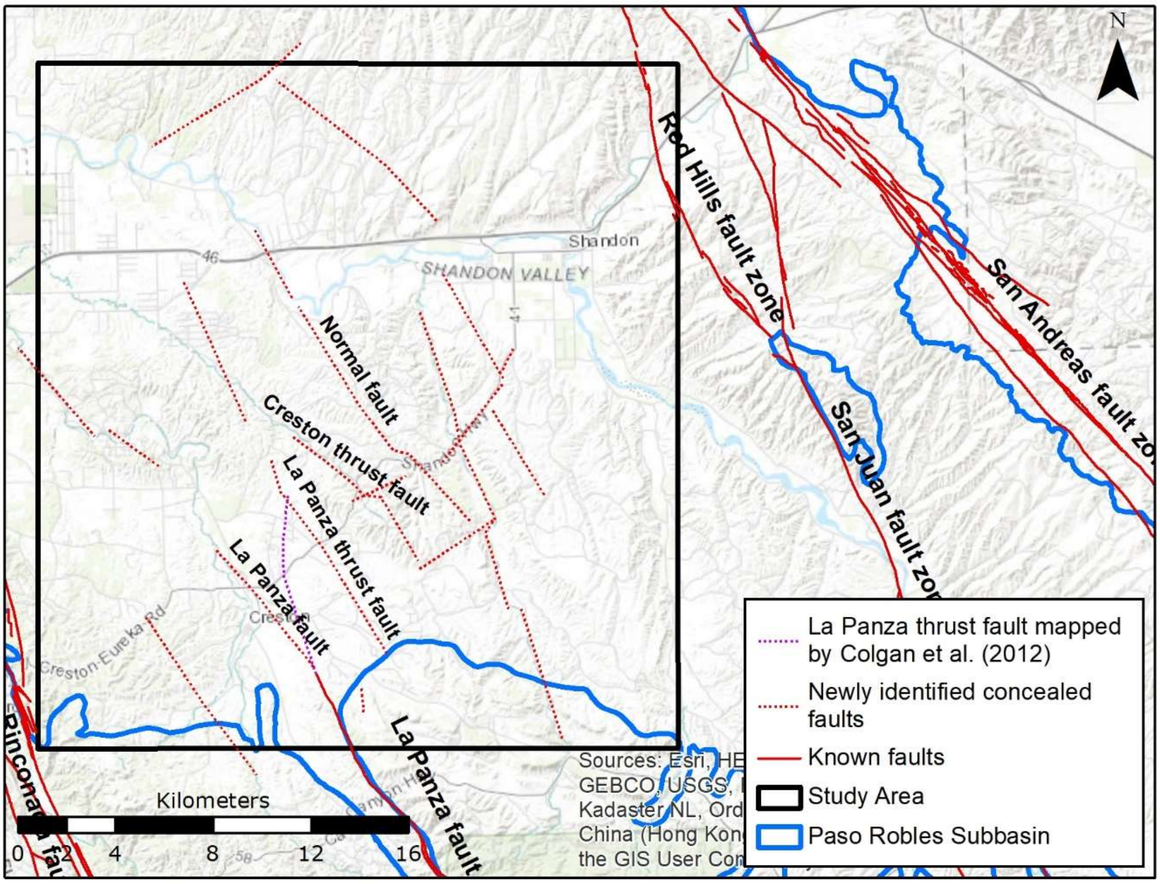


Figure 6-10. The location of newly mapped faults determined by terrain analysis, magnetic data and electromagnetic data.

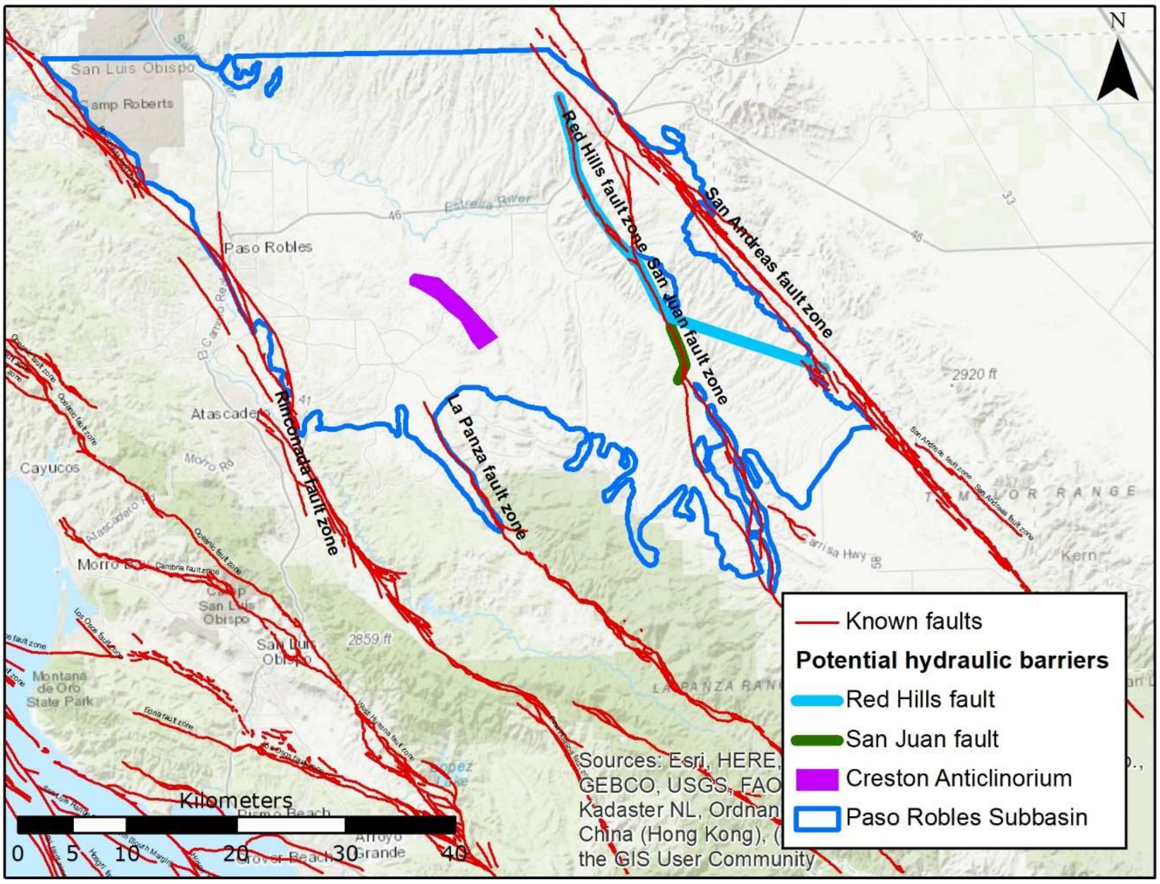
Colgan *et al.* (2012) interpreted the La Panza thrust fault (fault no. 2 in Figure 6-6) as an extension of the previously mapped La Panza fault, as illustrated by the purple dotted line in Figure 6-10. In this study, it is interpreted that the La Panza thrust fault is not a direct extension of the La Panza fault but is a separate fault system parallel to the La Panza fault (see Figure 6-10).

In the northern part of the Study Area, a series of northwest-dipping thrust faults was identified. These faults were mapped by the displacement of a distinctive clay layer (resistivity <5 ohmm) that was limited to this part of the study area (the layer of finer sediments in section 6.3.1). The faults are easily discernable in the AEM data because of resistivity contrasts. Figure 6-10 shows the location of these faults, and in Appendix 5, the interpretation of the individual thrust faults is shown along W-E Cross Section 41 to 54.

6.2 Faults and Groundwater Movement

Faults, several of which serve as Paso Robles groundwater subbasin boundaries, played a significant role in the development of inland California Coast Range valleys, including Paso Robles, and are probably responsible for the depth of some sediment filled basins within them. Faults also can affect groundwater flow and well production because groundwater movement may be inhibited or preferentially increased across or within faults and fault zones.

Faulting can break even very strong rocks, producing fracture zones that tend to increase permeability, and may provide preferential paths for groundwater flow. Conversely, some faults can form groundwater barriers if the faulting grinds the broken rock into fine-grained fault gouge with low permeability, or where chemical weathering and cementation of fractures over time have reduced permeability. The hydraulic characteristics of materials in a fault zone, and the width of the zone, can vary considerably so that a fault may be a barrier along part of its length but elsewhere allow or even enhance groundwater flow across it. Faults also may displace rocks or sediments so that geologic units with very different hydraulic properties are moved next to each other. Determining if faults act as conduits or barriers requires not only geologic but hydrologic and chemical information, such as water level measurements and/or aquifer tests from wells; groundwater chemistry on opposing sides of a fault can also help in making these determinations.



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 6-11. The approximate location of the Red Hills fault (light blue line), San Juan fault (green line) and Creston Anticlinorium (orange line), which could constitute a hydraulic boundary.

Paso Robles is well known historically for its thermal waters (See Section 6.3), with the alignments of thermal springs and wells (affected by waning granitic heat sources), along and near the western Paso Robles Subbasin-bounding Rinconada fault, indicate that some faults enable deep geothermal waters to move upward to the surface or into the Paso Robles formation (Chapman *et al.*, 1980). A similar but separate area southeast of Paso Robles suggests a similar and associated concealed fault may be present.

The San Andreas fault, considered a likely hydraulic barrier to groundwater flow (DWR, 2003), currently defines the eastern boundary of the Paso Robles Subbasin. The AEM data and the results from the study by Colgan *et al.* (2012) suggest that the Red Hills thrust fault, where basement rocks have been displaced over the Paso Robles Formation and the underlying deposits, may act as a hydraulic barrier. Additional hydrologic and water chemistry data would help to demonstrate the hydraulic nature of the Red Hills fault. Figure 6-11 shows the location of the Red Hills fault (thick light blue line) estimated using the AEM data and the study by Colgan *et al.* (2012).

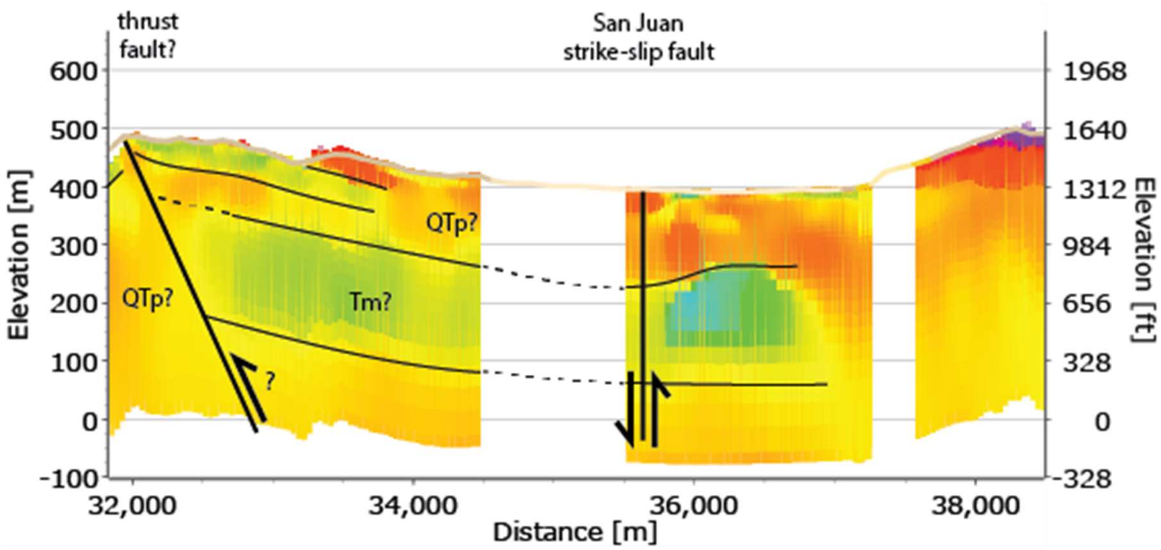


Figure 6-12. A section of the AEM data from W-E Cross Section 10.

The San Juan fault is a strike-slip fault related to the San Andreas fault zone, where displacement is primarily horizontal and not vertical. The San Juan fault is visible in the AEM data in Figure 6-5 (W-E Cross Section 20), but the fault is more difficult to discern in Figure 6-12 (W-E Cross Section 10). In both figures, the San Juan fault cuts through a layer with a resistivity generally below 10 ohmm. This layer is likely the Monterey Formation, but it could also be the Pancho Rico Formation. On the western part of the San Juan fault as seen in Figure 6-5 (W-E Cross Section 20), the AEM data show a layer with resistivities of 20-40 ohmm. Based on data from a nearby well lithologic log, the layer is composed of sand and gravel lenses within clay beds. The coarse sediments are presumably part of the Paso Robles Formation. At this location, on the east the Paso Robles Formation is truncated by the San Juan fault and abutted by the Monterey Formation, which is generally considered an aquitard or very small producer in fractures. Further to the south (Figure 6-12), the San Juan fault cuts through presumably the Monterey Formation and an overlying layer with resistivities of 10-30 ohmm. It is uncertain which formation this layer represents, but the resistivities suggest the Paso Robles Formation. It would, therefore, seem that there is no hydraulic barrier at this location, unless the San Juan fault acts as a barrier. However, the AEM data indicate that an hydraulic barrier may lie approximately 3 km west of the San Juan fault (Figure 6-12), where the Monterey Formation is interpreted to have been displaced on top of the Paso Robles

Formation along a thrust fault. Here, the Monterey Formation could potentially act as a hydraulic barrier.

Another potential hydraulic barrier within Paso Robles Subbasin is the Creston Anticlinorium. Along the Creston Anticlinorium (Creston thrust fault), the Pancho Rico, Santa Margarita and Monterey Formation have been displaced upward, and the displaced formations thereby reasonably could constitute a hydraulic barrier between Creston and San Juan Creek (see Figure 6-11). The hydraulic connection between Creston and San Juan Creek, therefore, seems likely to be limited by the presence of the Creston Anticlinorium (Creston thrust fault).

6.3 Saline Groundwater

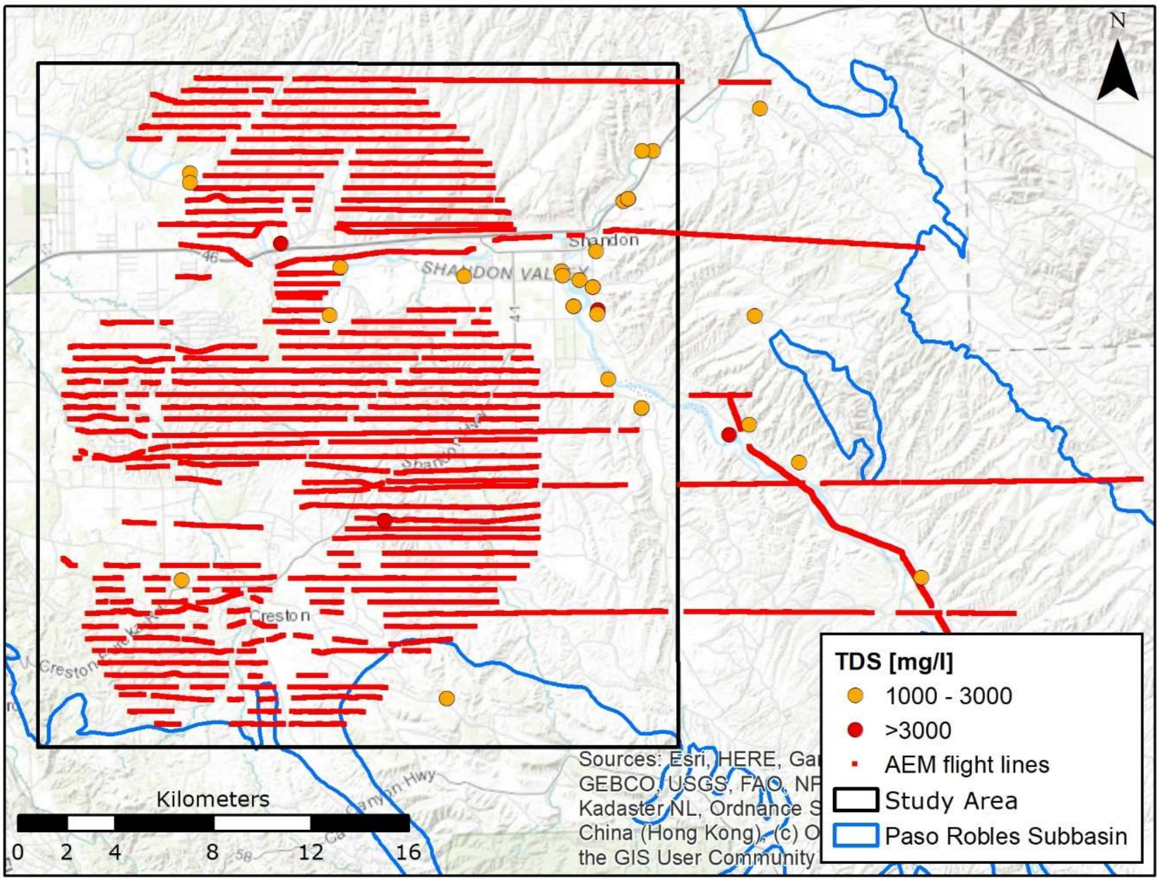
Numerous springs and wells over a large portion of the Paso Robles area have historically produced water at high flows and temperatures up to 47 degrees Celsius (C) (116.6 F). The artesian nature of the water and moderate groundwater temperatures have also historically made the Paso Robles area popular for its spas and mud-baths (CDMG, 1980). The popularity of spas waned in the mid-1900s, and the wells have been abandoned due to their hydrogen sulfide content and potential for pollution. Mineral chemistry of warm water wells in the area included sodium (300-645 mg/L), chloride (200-800 mg/L), sulfate (200-500 mg/L), and TDS (1100 to 2400 mg/L) (CDMG, 1980).

Geothermal (saline) water and springs appear to produce mainly from the Paso Robles formation and are generally associated with faults. This includes the area around the City of Paso Robles as well as the Shandon area to the southeast. Saline water southeast of Paso Robles has been found to have similar temperature and chemistry, and anecdotally according to local drillers, is generally associated with a blue clay (CDMG, 1980).

RMC (2015) mapped TDS and chloride distribution in the subbasin. In general, these mapped areas of higher TDS and chloride distribution appear to correlate with previously mapped geothermal areas by CDMG (1980), blue clays noted in drillers logs, and previously and recently mapped faults in this report.

Saline water is found in water samples at specific locations such as in the Pancho Rico formation on top of the anticline, which might stem from residual sea water in the formation. Along the San Juan Creek and the Cholame Creek TDS values in the range 1000-3000 mg/l are seen. The poor water quality in those areas might originate from the surrounding bedrocks. Along the anticline, very low resistivities are seen in the AEM data. The low resistivities within this area might reflect both the poor water quality and finer sediments.

Along the San Juan Creek and the Cholame Creek, low resistivity layers are not seen in the data collected in the areas. This may indicate that the saline water is localized to these areas.



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 6-13. AEM data and measurements of Total Dissolved Solids (TDS) over 1000 mg/l.

6.4 Near surface geology along Estrella River and San Juan Creek

Figure 6-14 shows a section of the AEM data along the Estrella River riverbed. The AEM data show that the geology beneath the Estrella River riverbed is composed of two hydrogeologic units, both interpreted to be part of the Paso Robles Formation.

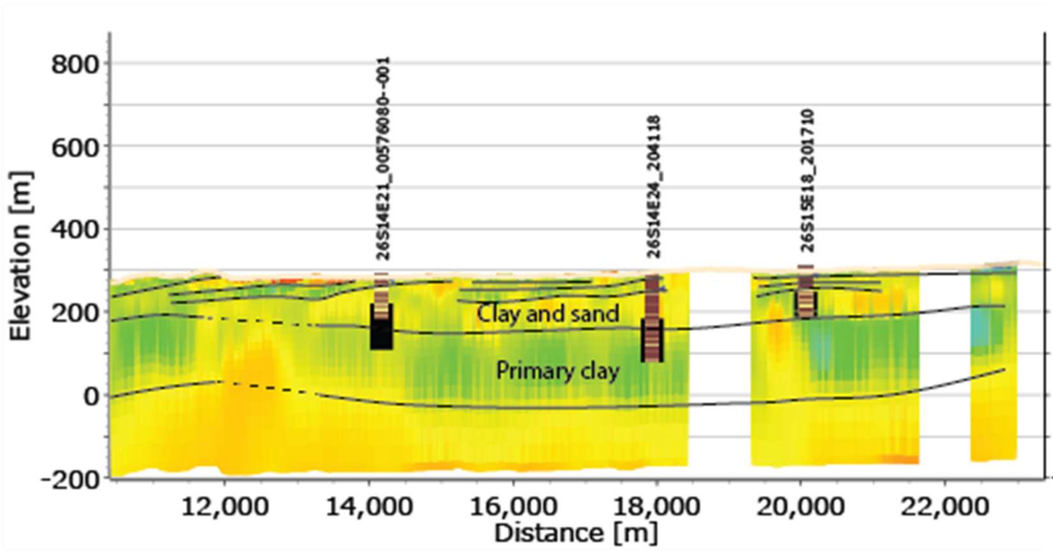


Figure 6-14. A section of the AEM data along the Estrella Riverbed from W-E Cross Section 40. Layers with predominantly clay are highlighted with black lines.

The uppermost unit is characterized by a resistivity of 3-20 ohmm and is estimated to be around 100 m thick (300 ft). Based on the lithologic description from wells and the AEM data, it is interpreted that the uppermost hydrogeologic unit consists of alternating layers of sand and clay. Beneath the terrain, 10-30 m (30-100 ft) thick layers are observed within the uppermost hydrogeologic unit. These layers have a resistivity below 10 ohmm, which correlate to clay layers in the nearby wells. This suggests that infiltration of surface water along the Estrella River may be impeded by these clay layers.

Beneath the uppermost unit, a second hydrogeologic unit is characterized by a resistivity below 15 ohmm. The boundary between the two hydrogeologic units is estimated to be around 100 m (328 ft) below ground surface. The lower hydrogeologic unit is approximately 200 m (650 ft) thick and consists of clay with sand lenses. The clay layer constitutes an aquitard, which would further impede any significant infiltration to potential aquifers below this layer.

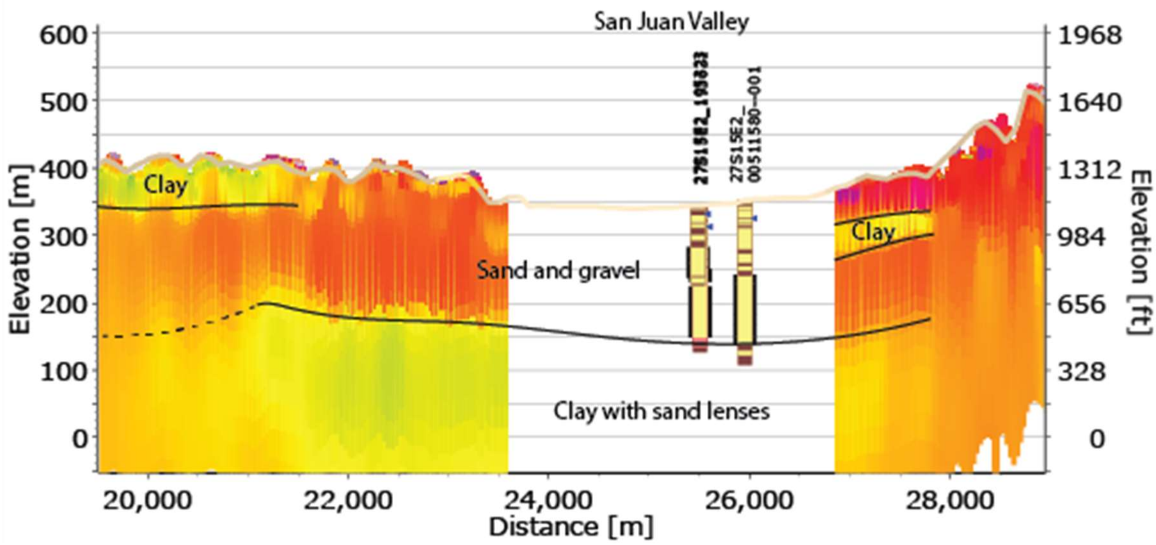


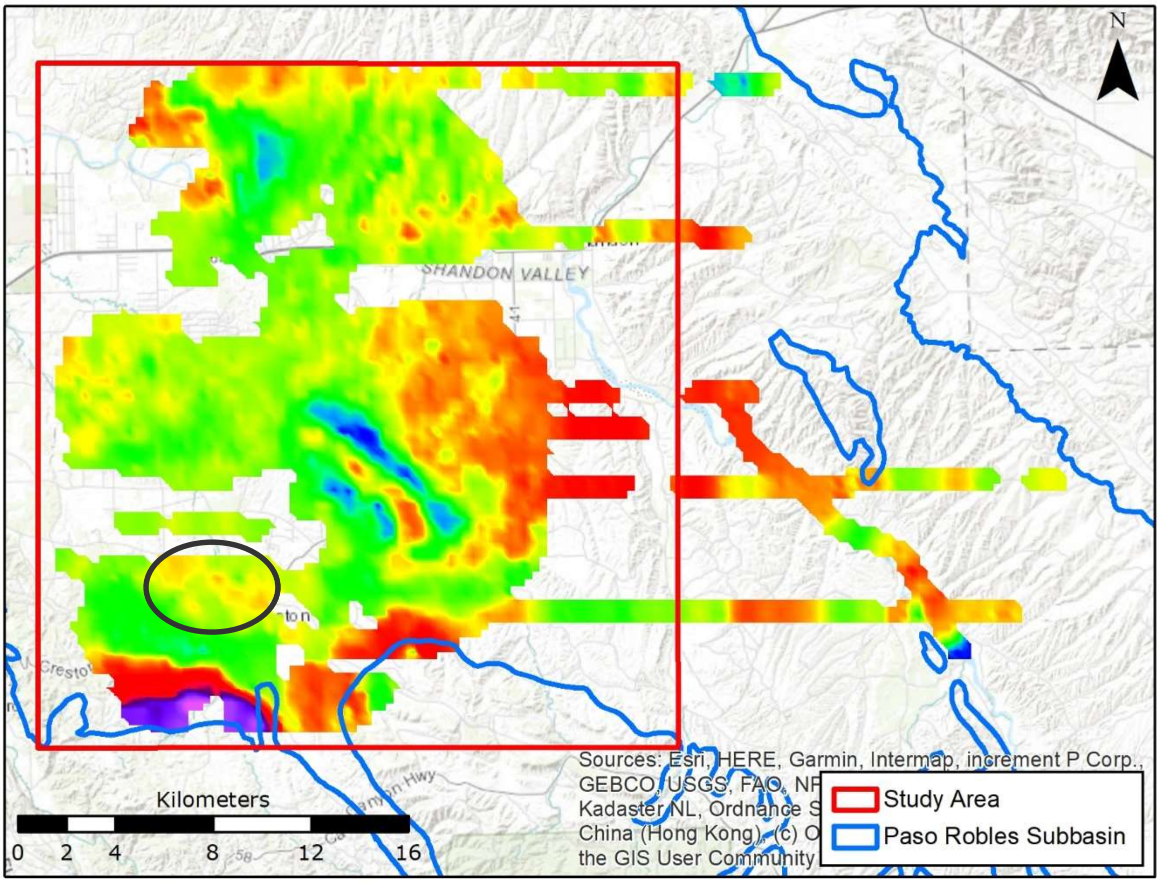
Figure 6-15. A section of the AEM data crossing the San Juan Valley from W-E Cross Section 28.

The AEM data indicate that there may be opportunities for groundwater recharge along the San Juan Creek in San Juan Valley. Figure 6-15 shows a section of the AEM data perpendicular to San Juan Valley. Both AEM data and wells within the valley indicate that the geology here is composed of an upper layer of coarse material, which is underlain by a layer of finer material. The upper layer has a resistivity of 20-40 ohmm, which according to nearby wells represent deposits of sand and gravel with a few minor clay lenses. The underlying layer has a resistivity below 15 ohmm, and according to nearby wells, the layer consists primarily of clay with perhaps minor sand lenses. Therefore, based on the AEM and well data, the San Juan Valley along San Juan Creek may be a good location for recharging the aquifers within the Paso Robles Formation and may benefit from further hydrogeologic evaluation.

6.5 Creston area

The Creston area is defined as the area between City of Paso Robles and the Creston Anticlinorium. Within this area, the well logs and the AEM data generally show a dominance of clayey deposits interbedded with minor sand beds. However, in southern Creston area, AEM data indicate higher resistivities and corresponding higher proportion of sandy deposits compared to the rest of the Creston area. The higher resistivity southern Creston area is highlighted by a black ellipse in Figure 6-16. In the northern Creston area, the resistivity is between 5 and 15 ohmm, and in the southern

Creston area, the resistivity is between 15 and 20 ohmm. Notably, the term 'Shale gravel' is often used in the well log lithologic description in the southern Creston area, and is generally interpreted as a relatively coarse horizon consisting of broken shale fragments within a matrix of clayey sand. This area may be suitable for groundwater recharge and may benefit from further hydrogeologic evaluation.

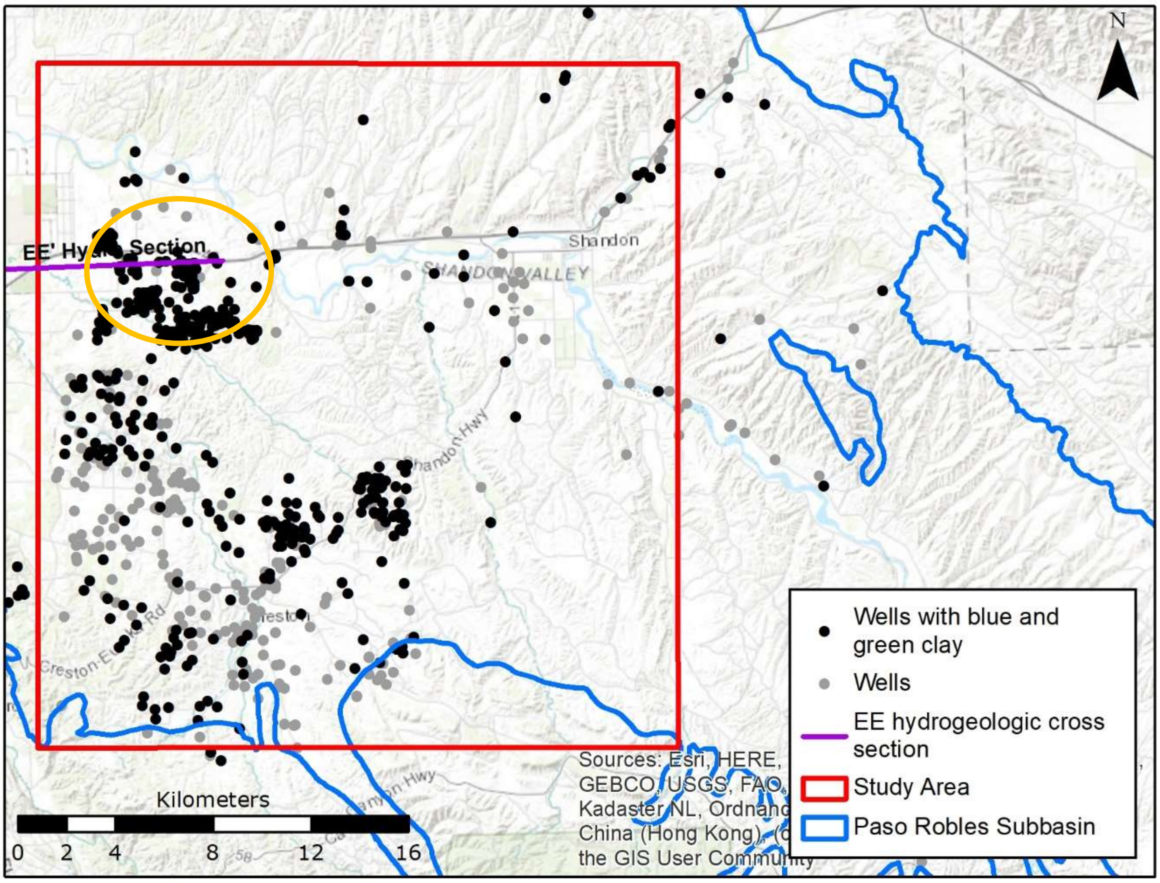


Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 6-16. Map of the mean resistivity within the elevation interval +240-260 m based on the AEM data. The black ellipse highlights an area within the Creston area with a high resistivity layer. See Figure 5-13 for the resistivity color scale.

6.6 Paso Robles – blue and green clays

More than 10,000 of the lithological descriptions of the sediments in the well completion reports are described by one or more colors and most of the lithologies (~9,000 samples) described by a color are clays. Brown is the most used color (~6,300 samples) and samples described as blue and/or green counts for more than 2,000 samples. The samples described as blue or green are of special interest as they indicate that the depositional environment most likely was anoxic/reducing. The location of wells with blue clay is shown in Figure 6-17. The figure shows that the wells with blue clay are primarily found in the area between Creston and the City of Paso Robles, the highest density area of wells in the subbasin.



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Figure 6-17. The location of wells with blue/green clay. The orange ellipse marks the area, where blue clay within the Paso Robles Formation is found.

In general, the blue clay is interpreted to be part of the marine Pancho Rico Formation and the Monterey Formation. However, a horizon of blue clay has also been observed in the Paso Robles Formation in the area south of the City of Paso Robles. Figure 6-18 shows an example horizon with blue clay within the Paso Robles Formation. The horizon is 40-50 m thick, and is located at a depth of 80-100 m. The origin of the blue clay within Paso Robles Formation is likely due to horizon-specific presence or predominance of Monterey formation derived shale fragments during deposition.

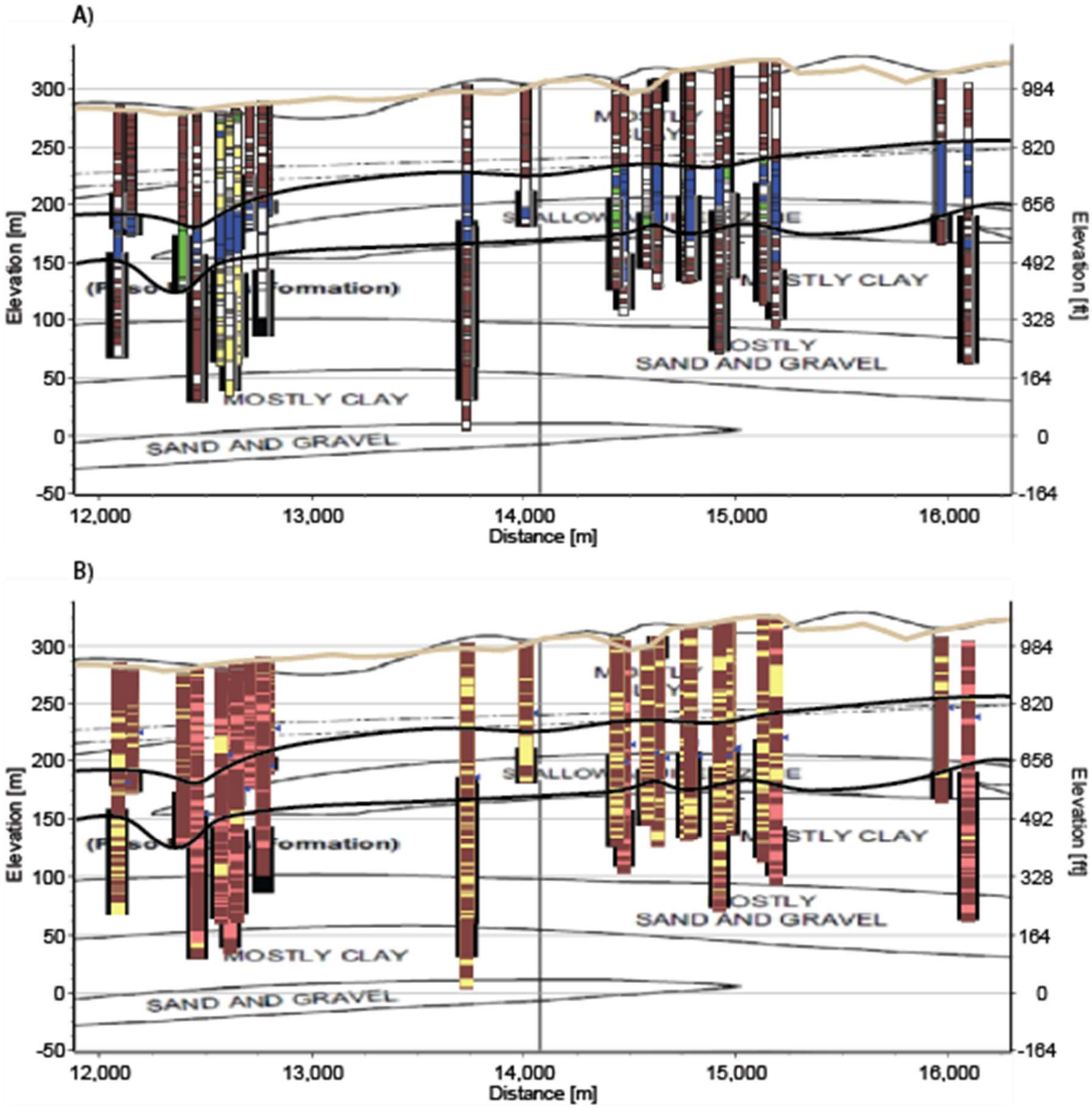


Figure 6-18. A section of the EE hydrogeologic cross section from Fugro (2002). The figure shows the horizon of blue and green clay within the Paso Robles Formation, which are observed in the WCR boreholes. The WCR boreholes are shown with A) the deposits' color and B) the deposits' lithology.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Data

7.1.1 AEM data

The AEM survey was conducted using a general line spacing of 500 m. The line spacing has proven to provide a reasonable ability to correlate the geologic and hydrogeologic interpretations from line to line. The 500 m line spacing is the maximum recommended spacing of flight lines when the Surface Constrained Inversion (SCI) inversion algorithm is applied. The AEM data provides information about the geology ranging from a couple of meters (6 feet) to a depth of up to 300 meters (1000 feet).

The flight lines were flown due west-east. Geologic structures that have the potential to affect groundwater flow trend northwest-southeast. Ideally the AEM lines would have been aligned perpendicular to geologic structures or northeast to southwest. However, the angle of flight appears not to have had significant effect on detecting and mapping the buried geologic structures and flying east-west aligned well with the Fugro geologic and hydrogeologic cross sections.

7.1.2 AEM data coverage

Certain portions of the study area are only sparsely covered with AEM data. This is typically in areas with vineyards where groundwater is supplied by wells along the Estrella River and San Juan Creek, and where the proximity of fences, powerlines and other man-made objects put a limitation on the ability to collect AEM data from the air. The use of ground-based geophysical techniques is recommended to achieve a better understanding of the vertical and lateral hydrologic connectivity within those riverbeds. In areas with vineyards, either electrical resistivity tomography (ERT) and/or seismic data can be recommended to support the HCM within those areas.

7.1.3 Water level

Water level measurements were collected contemporaneously with the AEM survey. Unfortunately, information on well screen intervals was limited, making the measurement density and depth insufficient to identify and separate shallow and deep aquifers in the hydrogeologic system. A higher-resolution aquifer depth specific groundwater level dataset would be needed to further refine the hydrogeology and could also play an important role in better understanding the role the numerous faults and geologic fabric play in the vertical and horizontal hydrologic connectivities.

7.2 Hydrogeologic conceptual model (HCM)

7.2.1 Borehole data

The density of boreholes varies significantly across the groundwater basin. Borehole information is scarce in the northern and eastern part of the Study Area. Most of the boreholes provide information on the Paso Robles Formation, but only a few boreholes were deep enough to provide information on the deeper formations such as Pancho Rico Formation, Santa Margarita Formation and Monterey Formation. Even though the Paso Robles Formation is considered the primary water bearing zone within the Study Area, it is important to have a complete understanding of the geology, especially related to groundwater flow within the complex folded and faulted hydrogeology.

It is recommended that more borehole information is collected either by reviewing existing borehole datasets or drilling new boreholes. If new boreholes are drilled, it is recommended that an onsite geologist describe the borehole lithology using standard nomenclature, and subsequently the depositional environment and relative age of observed geology. Stratigraphic information from boreholes would ensure a better correlation between resistivity and the geologic units, which in the end would ensure a better interpretation of the AEM data.

7.2.2 Detailed information derived from the AEM data

The AEM data provides very detailed information on the hydrogeologic conditions and tectonic structures. With this data, it is possible to map faults and aquifers within the Paso Robles Formation. In the southern part of the Study Area, the AEM data are ideal for mapping the lower boundary of the Paso Robles Formation. Towards the north, the AEM data are not able to map the lower boundary because the boundary is below the Depth of Investigation (DOI) for the AEM survey. In this area, seismic surveys would be a good supplement to the AEM data, evident in Colgan et. al. (2012), as seismic data would be able to map the lower boundary of Paso Robles, while the AEM data would map the internal hydrogeologic zones within the formation.

7.2.3 3D Geological model considerations

The 3D geological model has provided important information, in the form of surface grids, on the extent and thickness of the geologic formations within the Study Area. These surface grids, in combination with the hydrogeologic zones defined in the HCM, can be used as input to a groundwater model. The 3D geological model is constructed in the form of layers bounded by the surface grids, providing a generalized visualization of the geology. However, the AEM data provide very detailed mapping of the geology such as strata displaced along faults, which a layered conceptual model is not able to include. Because of the geologic complexity within the Study Area, it is recommended to consider the use of a voxel-based model. In a voxel model, a regular 3D grid is created, where each grid cell is defined as a voxel. During model construction, each voxel is assigned a specific lithology.

7.2.4 New boreholes, geophysical logs, and monitoring wells

The HCM can be used to site new boreholes, geophysical logs, and monitoring wells. The purpose of the boreholes and geophysical logs would be to confirm the presence of important hydrogeologic layers identified in the AEM data and completed wells for water quality and water level monitoring purposes.

7.3 Faults

The geology within the Paso Robles Subbasin contains numerous faults, mostly trending northwest-southeast, offsetting formations resulting in a complex geologic framework. In the eastern portion of the groundwater basin five AEM lines are flown across the mountain range. The lines were flown to provide insight on the hydrologic connectivity/dis-connectivity towards the east. The mapping of the faults is important in understanding the hydrogeologic conditions including groundwater flow and hydrologic connectivity between aquifers. Additional investigations could be conducted where more hydrogeologic data is desired, for example, in determining whether a fault acts a groundwater flow barrier or conduit to deeper geothermal water. Additional investigations could include but not be limited to boreholes, geophysical logging, monitoring well installations, groundwater level and quality data collection and aquifer testing.

7.4 Potential recharge areas

Several areas within the Paso Robles Study Area have been characterized with AEM and other available hydrogeologic information as having the potential for managed aquifer recharge projects (San Luis Obispo County Flood Control and Water Conservation District, 2008). These areas include the southern Creston area between the City of Paso Robles and the Creston Anticlinorium, and the San Juan Valley along San Juan and Shell Creeks. If other critical factors such as groundwater quality, water availability and conveyance are suitable, these areas would be recommended for additional investigation to further define the underlying hydrogeology, including but not limited to, ground-based geophysical surveys, shallow test pit exploration, infiltration tests, borings and well installations, water quality sampling and aquifer geochemistry, and aquifer testing.

8. REFERENCES

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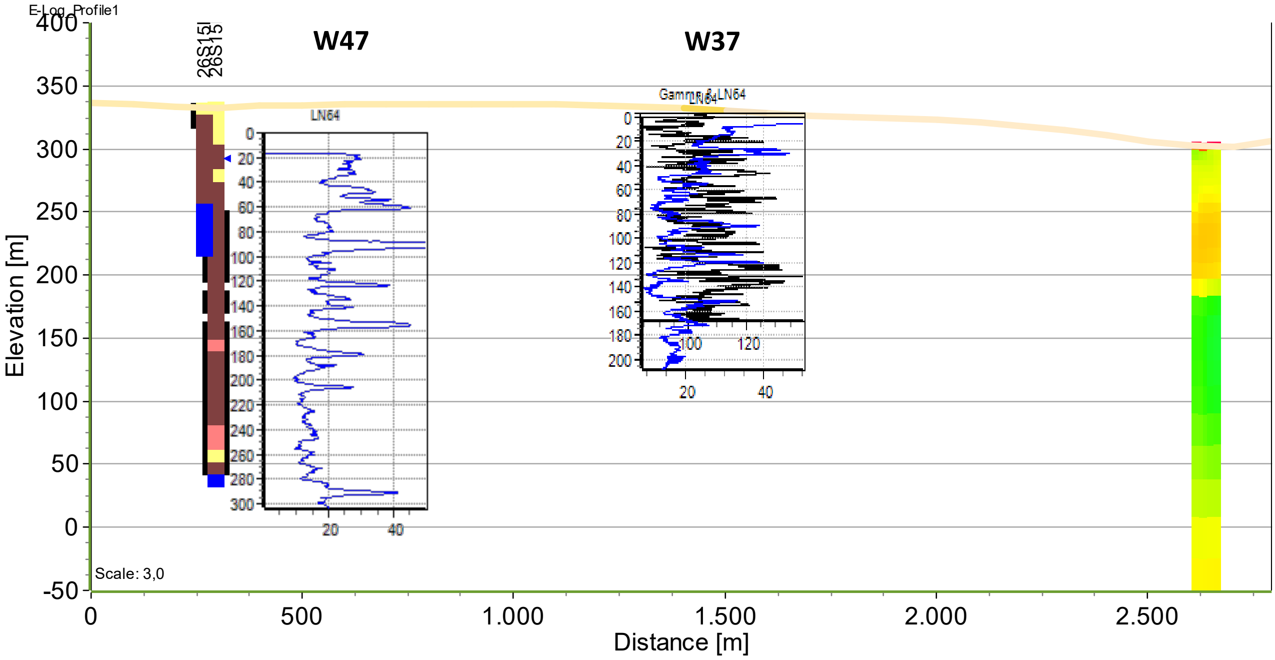
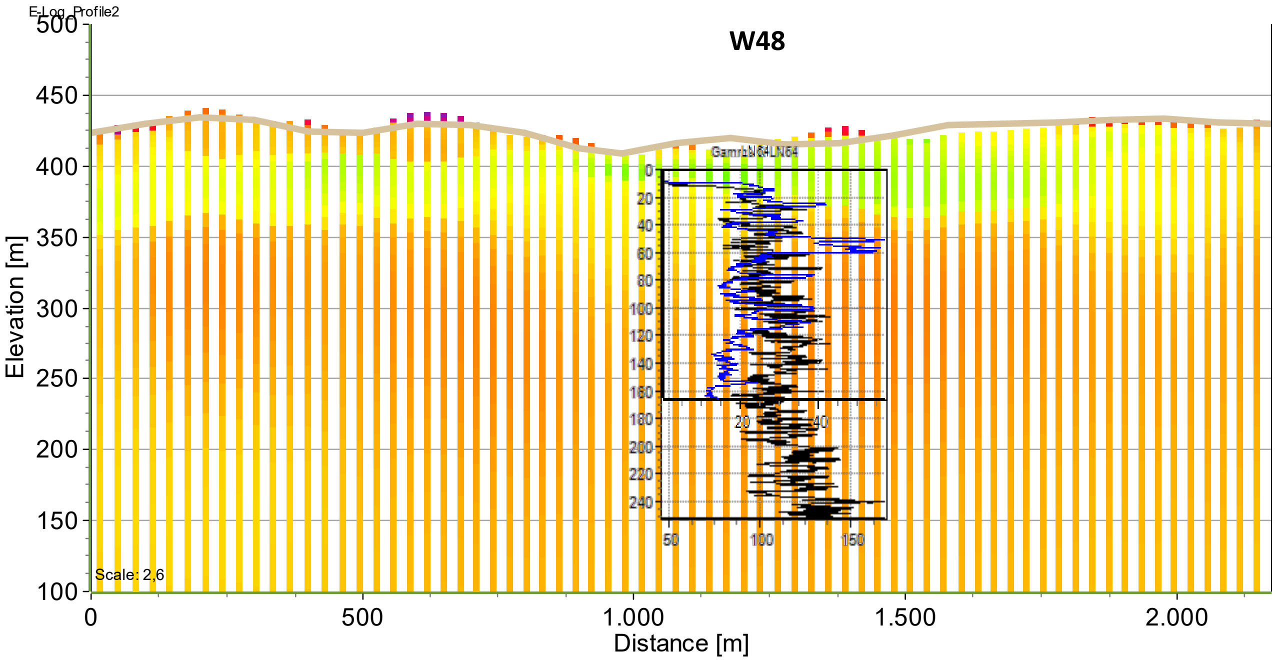
APPENDIX 1
WATER WELL GEOPHYSICAL LOGS

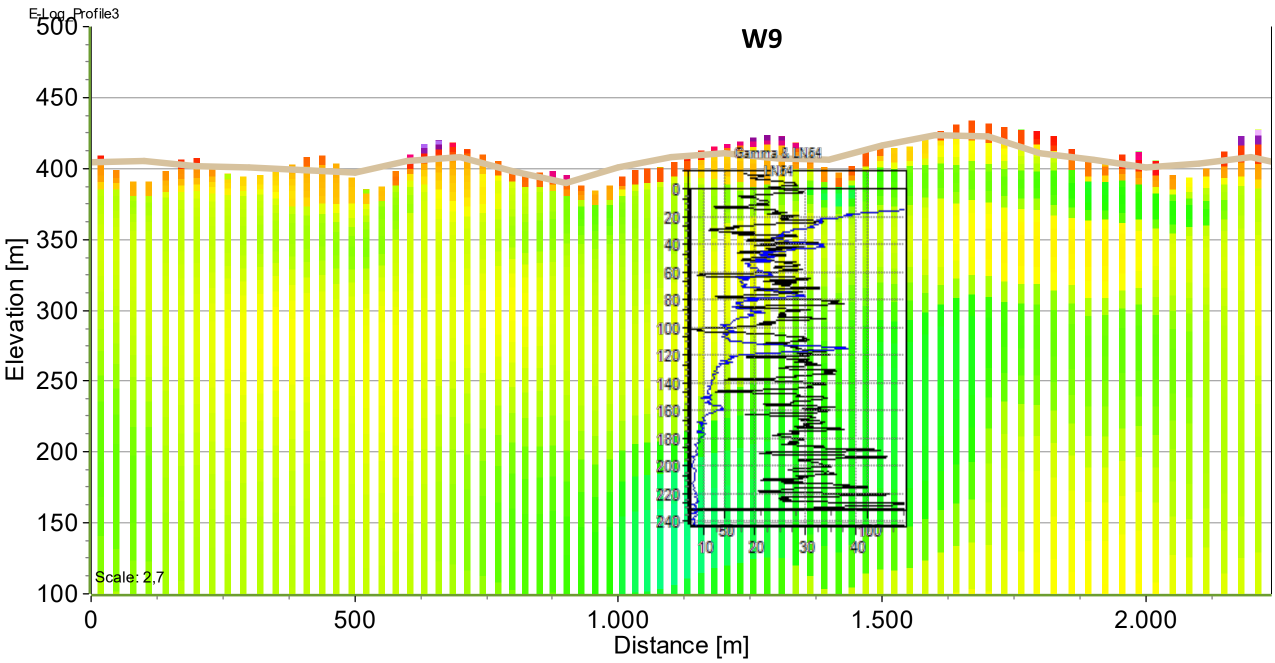
Geophysical logs



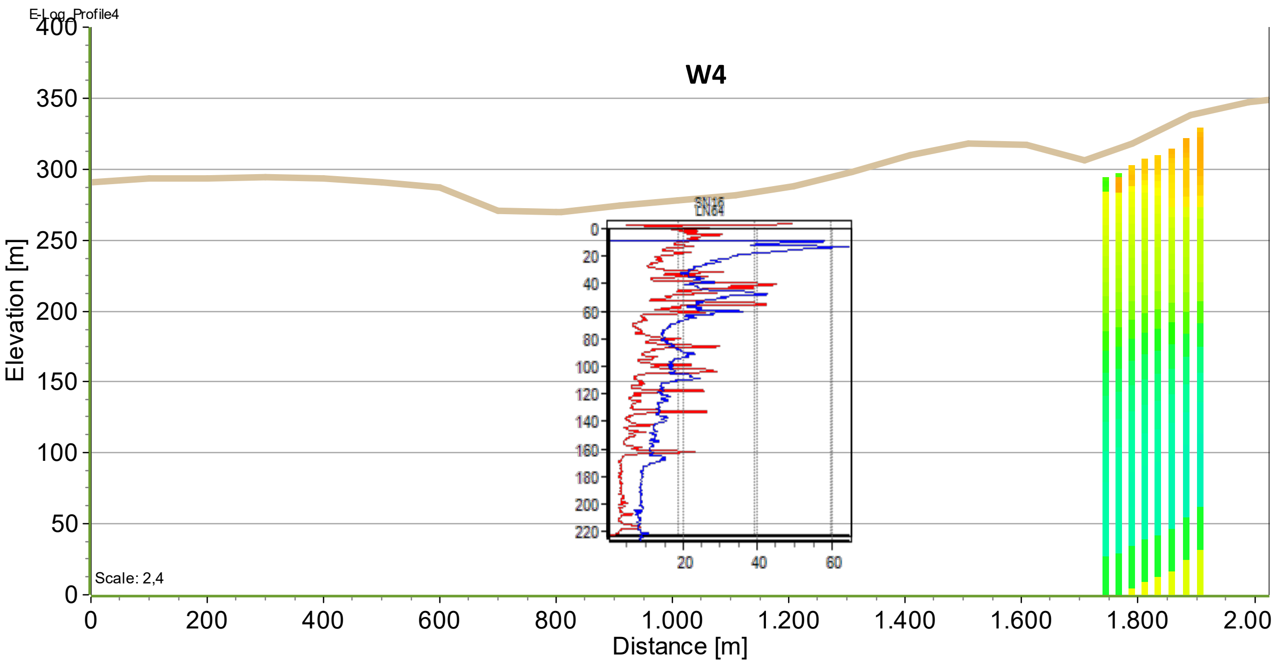
The above cross section shows E-logs from borehole W37 and W47. The blue colored line is long normal resistivity log (64 inch), while the black colored line is natural gamma-ray spectrometer.



The above cross section shows E-logs from borehole W48. The blue colored line is long normal resistivity log (64 inch), while the black colored line is natural gamma-ray spectrometer.



The above cross section shows E-logs from borehole W9. The blue colored line is long normal resistivity log (64 inch), while the black colored line is natural gamma-ray spectrometer.



The above cross section shows E-logs from borehole W4. The blue colored line is long normal resistivity log (64 inch), while the red colored line is short normal resistivity log (16 inch).

APPENDIX 2
WATER TABLE MEASUREMENTS

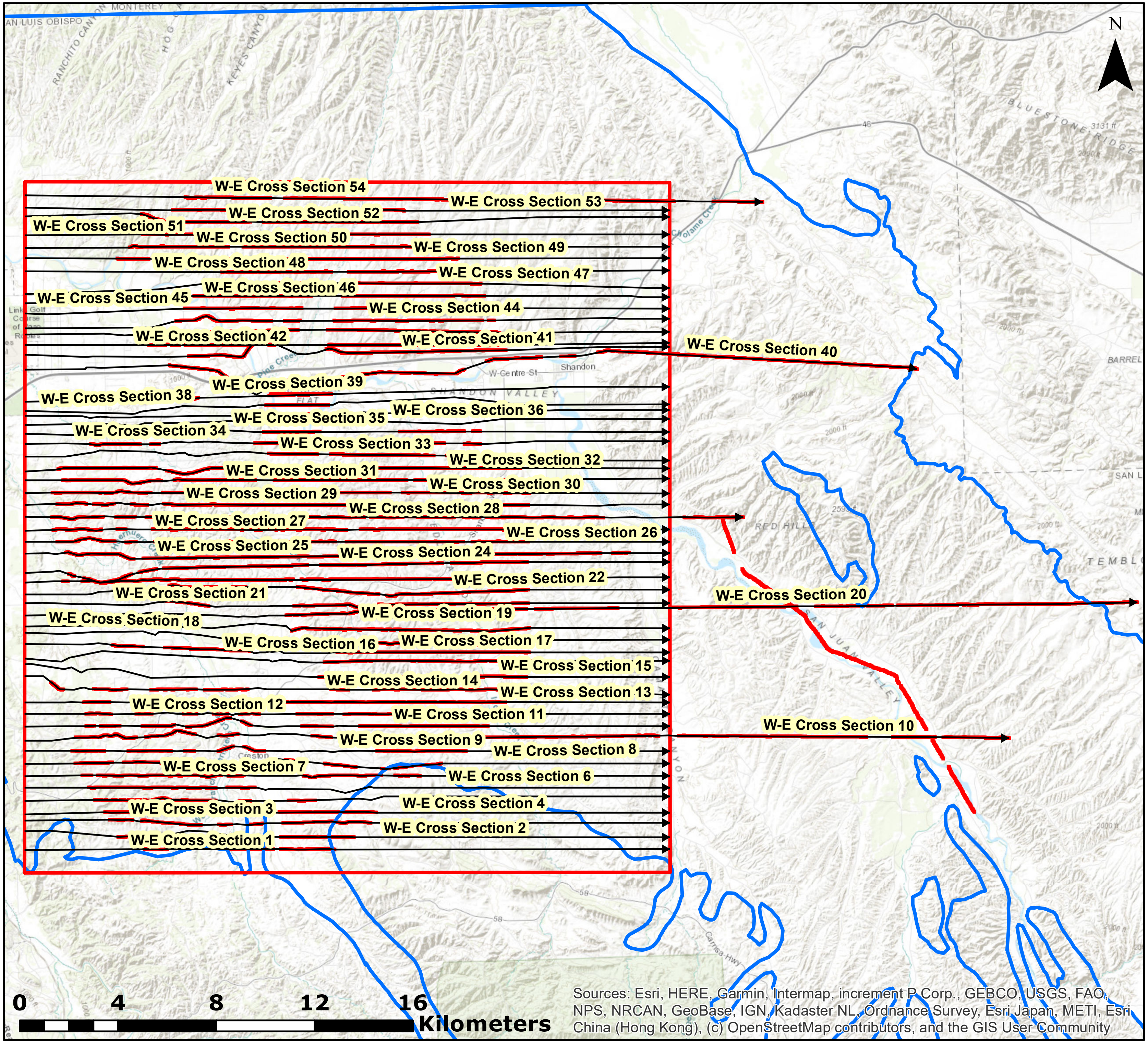
Appendix 2 - Paso Basin Water Table Measurements

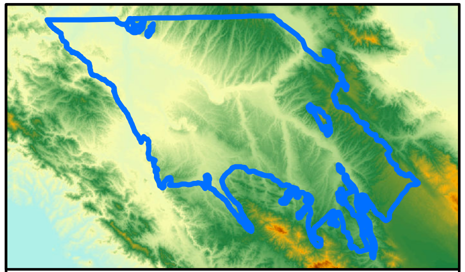
Borehole No	Depth Dis (Feet)	Data Entry	Tool	Tape Reading (Feet)	Reference (Feet)	Water AMSL (Feet)	Water AMSL (Meter)
25S/13E-34D01	436.92	20191104	Sounder	436.92	1081.37	644.45	196.42836
25S/13E-34D01	438	20191021	Sounder	438	1081.37	643.37	196.099176
26S/13E-08M01	218.95	20191104	Sounder	220.35	831.36	612.41	186.662568
26S/13E-08M01	218.9	20191008	Sounder	225	830	611.1	186.26328
26S/13E-16N01	312.8	20191104	Sounder	314.1	890.17	577.37	175.982376
26S/13E-16N01	307	20191008	Tape	315	890.17	583.17	177.750216
26S/14E-24B01	54	20191104	Sounder	55	1001	947	288.6456
26S/14E-24B01	62.9	20191018	Tape	70	1001	938.1	285.93288
26S/15E-20B02	72.2	20191104	Sounder	73.5	1036.87	964.67	294.031416
26S/15E-20B02	73.7	20191018	Sounder	75	1036.87	963.17	293.574216
26S/15E-20B04	68.8	20191105	Tape	80	1036.36	967.56	294.912288
26S/15E-20B04	74.35	20191018	Sounder	76.45	1036.36	962.01	293.220648
26S/15E-20B05	73.6	20191104	Sounder	75.35	1035	961.4	293.03472
26S/15E-20B05	75.1	20191018	Sounder	76.85	1035	959.9	292.57752
26S/15E-29N01	154.95	20191104	Sounder	155.3	1135	980.05	298.71924
26S/15E-29N01	150.35	20191018	Sounder	150.7	1135	984.65	300.12132
26S/15E-29R01	139.8	20191104	Sounder	139.8	1109.5	969.7	295.56456
26S/15E-30J01	171.2	20191104	Sounder	172.1	1123.3	952.1	290.20008
26S/15E-33C01	94.1	20191104	Sounder	94.1	1095	1000.9	305.07432
26S/15E-33C01	100.1	20191021	Tape	120	1095	994.9	303.24552
26S/15E-33Q01	111.7	20191106	Sounder	112.55	1102	990.3	301.84344
27S/13E-07R01	167.05	20191112	Tape	210	914.69	747.64	227.880672
27S/13E-07R01	172.95	20191024	Tape	200	914.69	741.74	226.082352
27S/13E-09P01	84.3	20191106	Sounder	84.8	900	815.7	248.62536
27S/13E-09P01	84.1	20191024	Tape	95	900	815.9	248.68632
27S/13E-14Q03	53.5	20191106	Sounder	54.2	1069.16	1015.66	309.573168
27S/13E-14Q03	53.3	20191024	Sounder	54	1069.16	1015.86	309.634128

Appendix 2 - Paso Basin Water Table Measurements

27S/13E-18A01	146.4	20191106	Sounder	148.6	918.76	772.36	235.415328
27S/13E-22Q01	122.7	20191106	Sounder	123.4	1044	921.3	280.81224
27S/13E-22Q01	124.7	20191028	Tape	130	1044	919.3	280.20264
27S/13E-28F01	227.4	20191024	Sounder	230	1072	844.6	257.43408
27S/13E-30F01	301.6	20191106	Sounder	303	1044.98	743.38	226.582224
27S/13E-30F01	301.8	20191024	Tape	315	1043.2	741.4	225.97872
27S/13E-30J01	307.4	20191108	Sounder	310	1092.49	785.09	239.295432
27S/13E-30J01	307.4	20191024	Tape	320	0	-307.4	-93.69552
27S/13E-33L01	187.3	20191106	Sounder	187.5	1180.5	993.2	302.72736
27S/13E-33L01	182.3	20191028	Sounder	182.5	1180.5	998.2	304.25136
27S/14E-11R01	132.55	20191105	Tape	140	1160.5	1027.95	313.31916
27S/14E-11R01	134.8	20191021	Tape	140	1160.5	1025.7	312.63336
27S/14E-24B01	186.05	20191105	Tape	200	1180.5	994.45	303.10836
27S/14E-24B01	192.4	20191023	Tape	265	1180.5	988.1	301.17288
27S/14E-25A01	96.7	20191105	Tape	105	1225	1128.3	343.90584
27S/14E-25A01	98.5	20191023	Tape	140	1225	1126.5	343.3572
27S/14E-25J01	112.65	20191105	Tape	125	1225.5	1112.85	339.19668
27S/14E-25J01	113.7	20191023	Sounder	115.5	1225.5	1111.8	338.87664
27S/14E-29G01	161.5	20191105	Tape	195	1201.5	1040	316.992
27S/14E-29G01	158	20191023	Tape	180	0	-158	-48.1584
27S/15E-03E01	83.2	20191104	Sounder	84	1120.8	1037.6	316.26048
27S/15E-03E01	83.6	20191030	Tape	105	1120.8	1037.2	316.13856
27S/15E-35F01	52.75	20191104	Sounder	52.75	1230	1177.25	358.8258
28S/13E-01B01	57.2	20191105	Tape	60	1099.42	1042.22	317.668656
28S/13E-01B01	56.7	20191021	Tape	70	1099.93	1043.23	317.976504
28S/13E-02R01	97.55	20191106	Sounder	98.05	1158.89	1061.34	323.496432
28S/13E-02R01	99.25	20191029	Tape	100	1158.89	1059.64	322.978272

APPENDIX 3
THE NAME OF THE W-E CROSS SECTIONS





Legend

- AEM data
- W-E Cross Sections
- Study Area
- Paso Robles Subbasin

Dato:	Tegning:	Kontrol:	Godkendt:
2020-09-23	TLM	MAXH	MAXH
Sag: 1690013412		Version: 1	

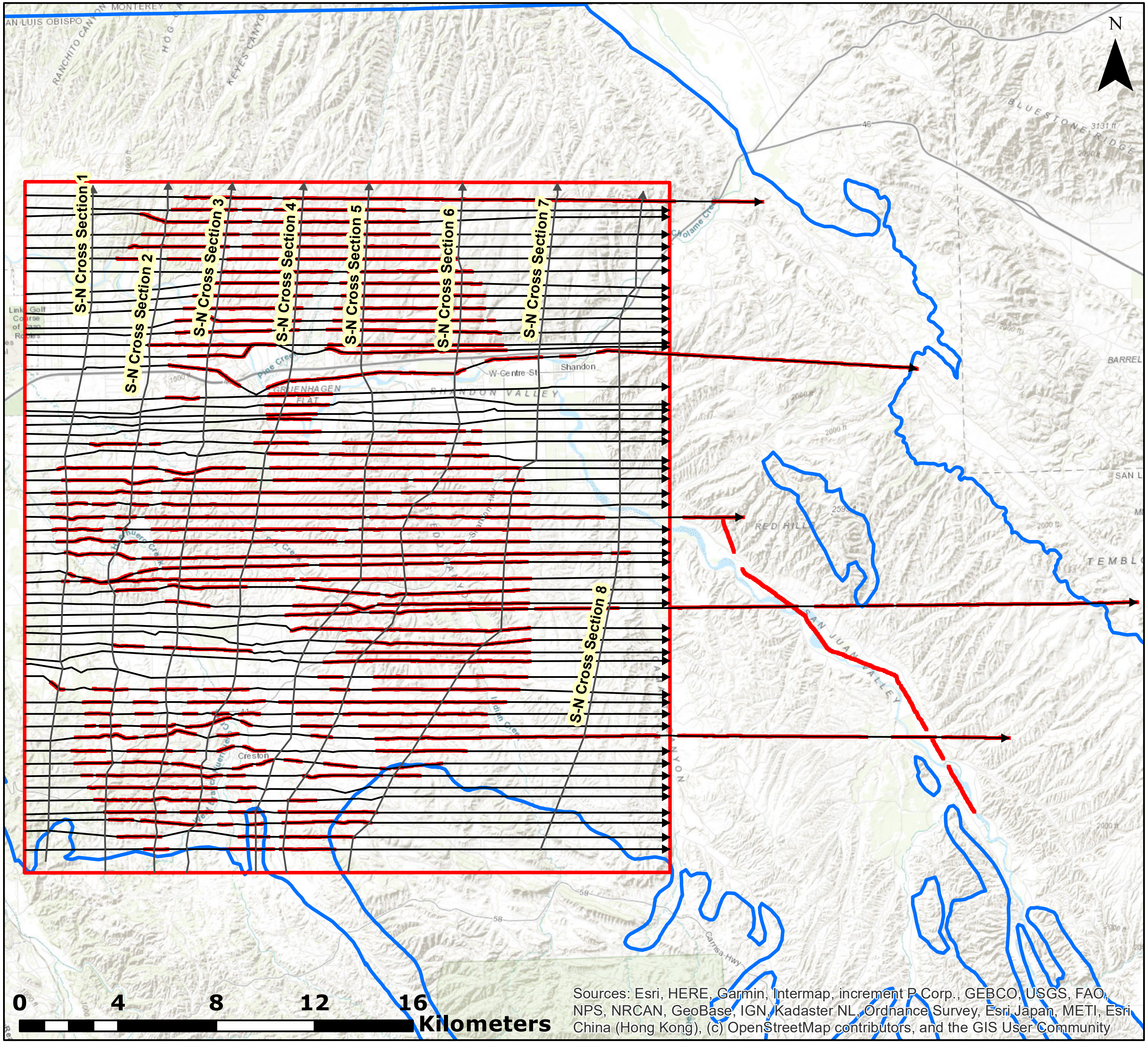
Paso Robles Subbasin

The name of the W-E Cross Sections

RAMBOLL

Appendix 3

APPENDIX 4
THE NAME OF THE S-N CROSS SECTIONS



Legend

- AEM data
- S-N Cross Sections
- W-E Cross Sections
- Study Area
- Paso Robles Subbasin

Dato:	Tegning:	Kontrol:	Godkendt:
2020-09-23	TLM	MAXH	MAXH

Sag: 1690013412 Version: 1

Paso Robles Subbasin

The name of the S-N Cross Sections

RAMBOLL

Appendix 4

APPENDIX 5
W-E CROSS SECTIONS WITH GEOLOGIC INTERPRETATION

Geologic Cross section 1

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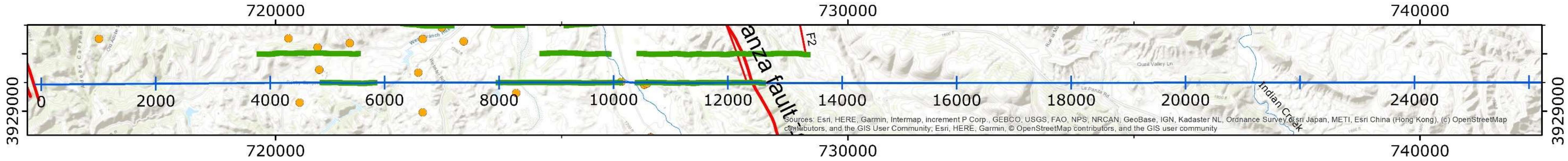
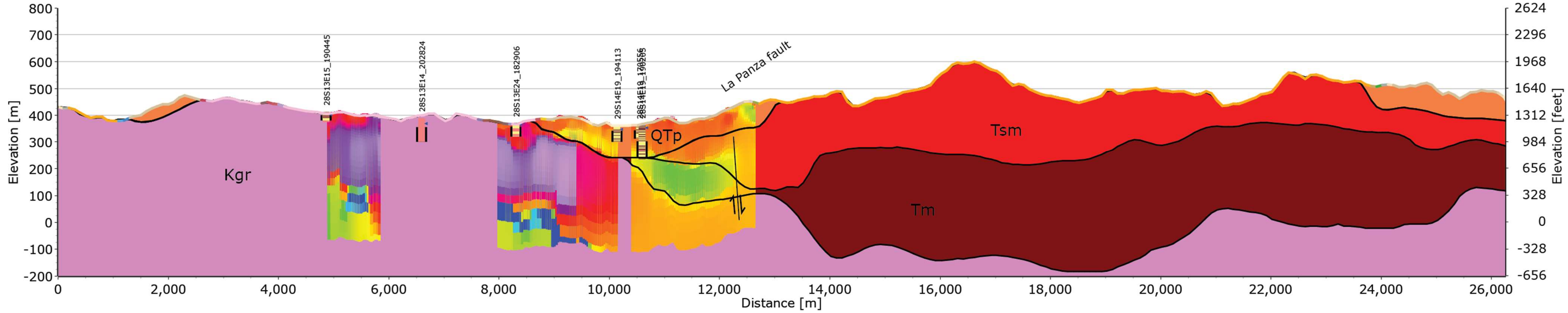




Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

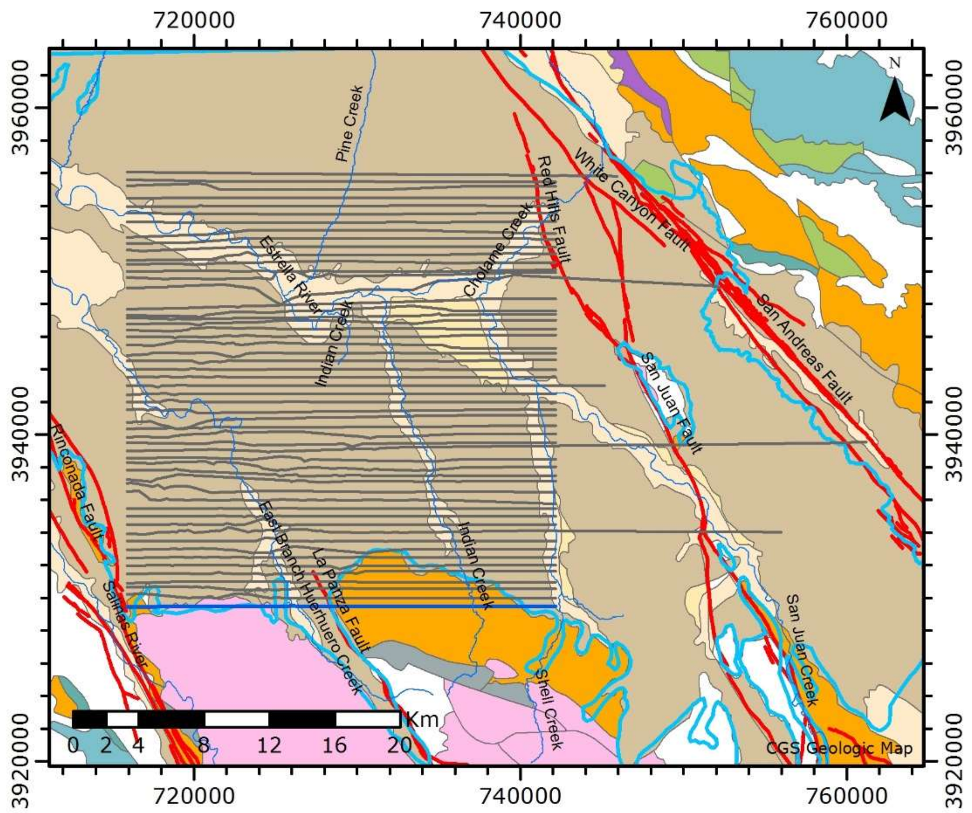
- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown

Saline/ Brackish
Clay/shale
Sand/Gravel
Sandstone
Granite

3 10 60 300
Resistivity [Ohmm]

Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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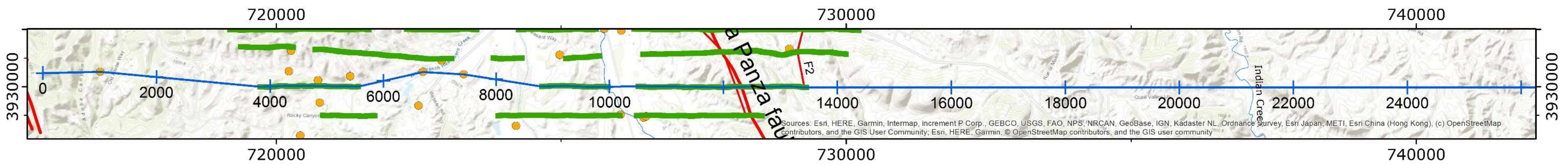
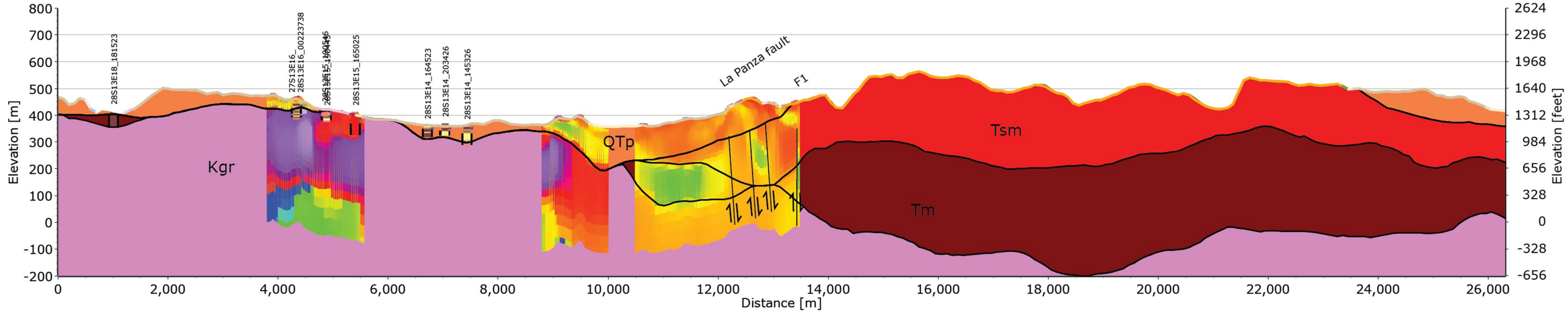
Geologic Cross section 2

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

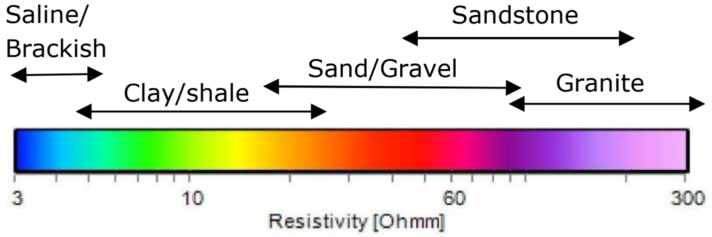
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



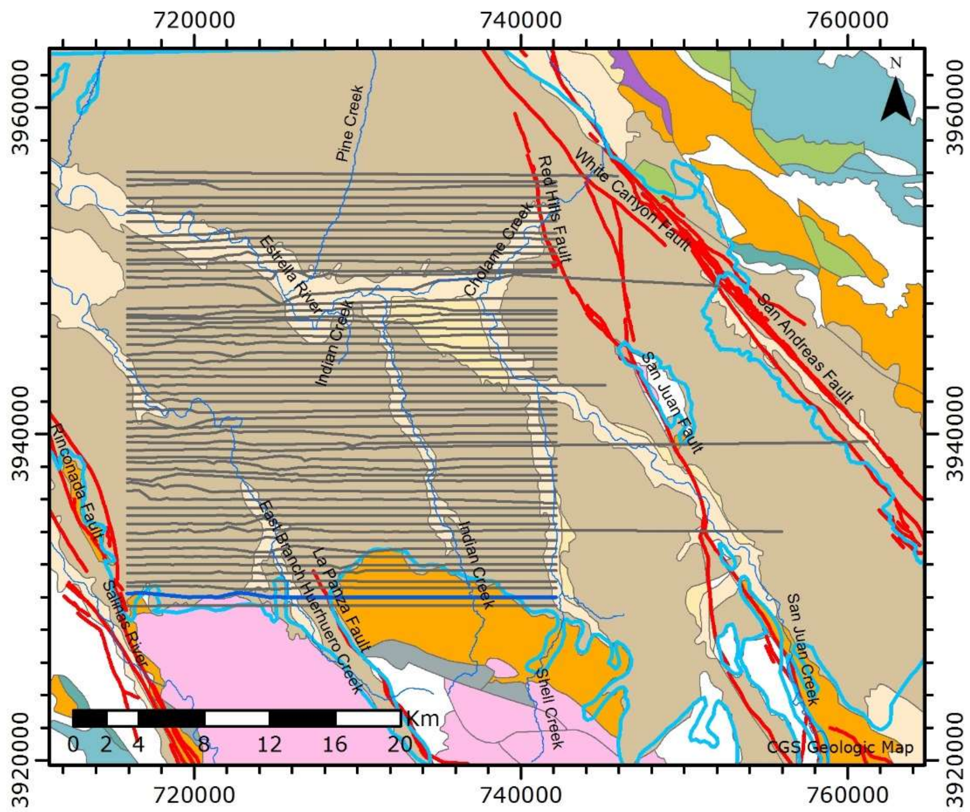
Borehole No.

Terrain/ CGS Geologic Map

Water level

Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412

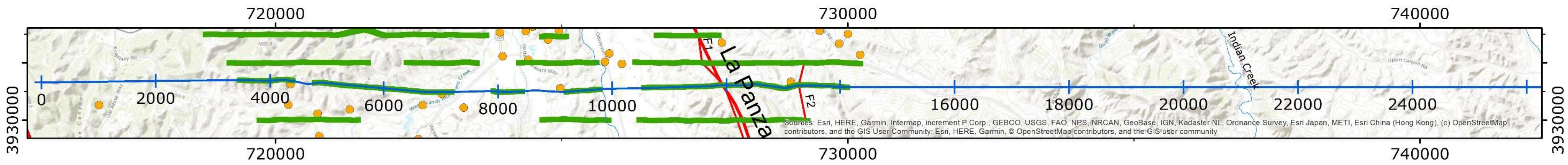


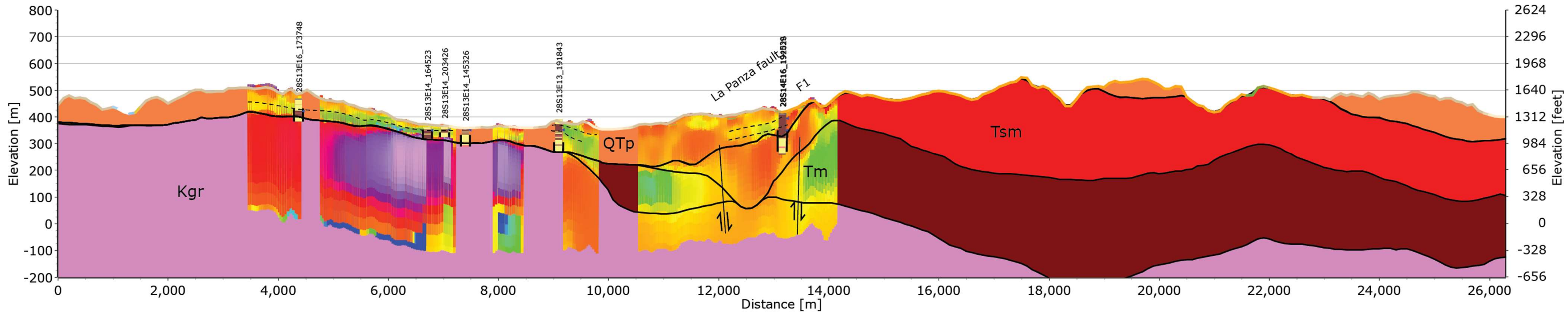
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 3

RAMBØLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

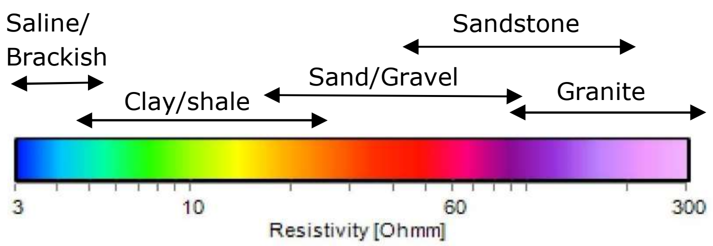
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

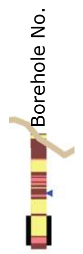
Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



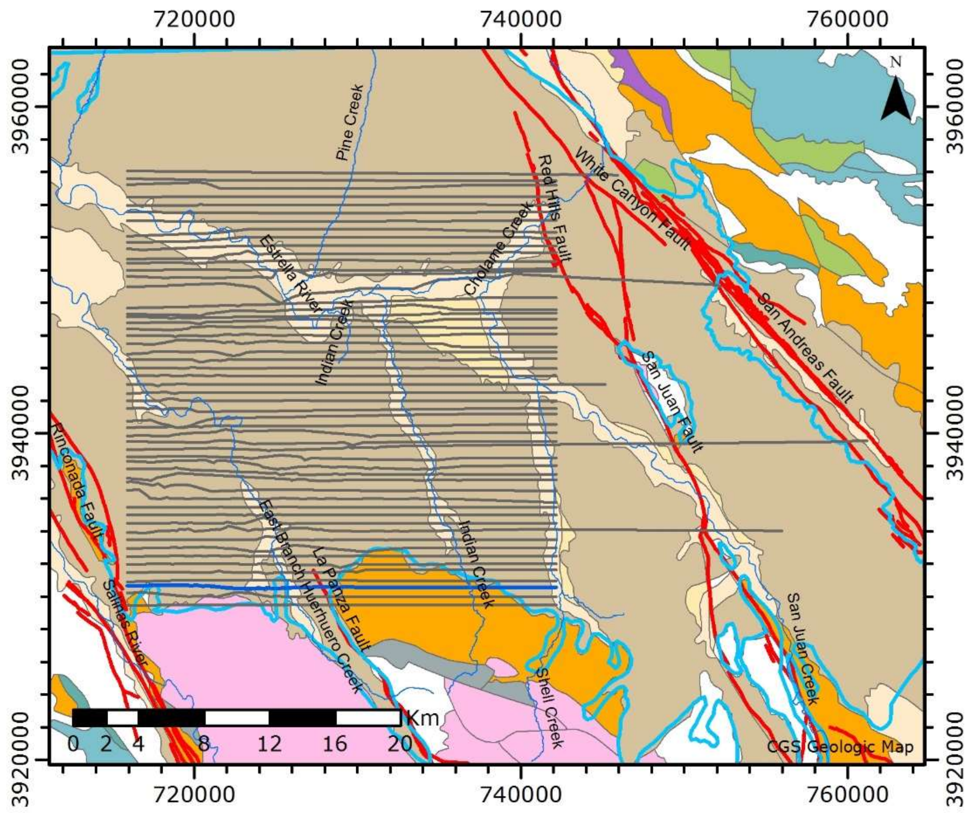


Terrain/ CGS Geologic Map

Water level

Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412



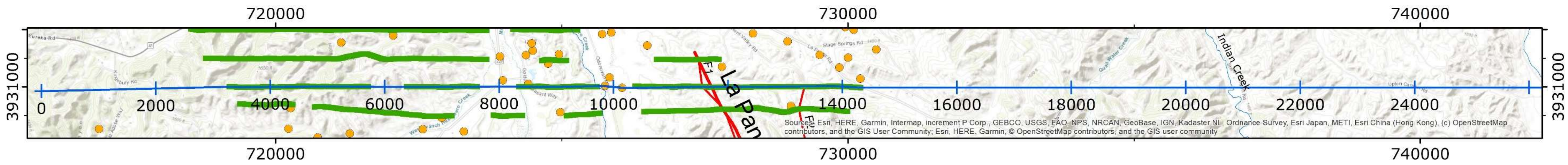
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

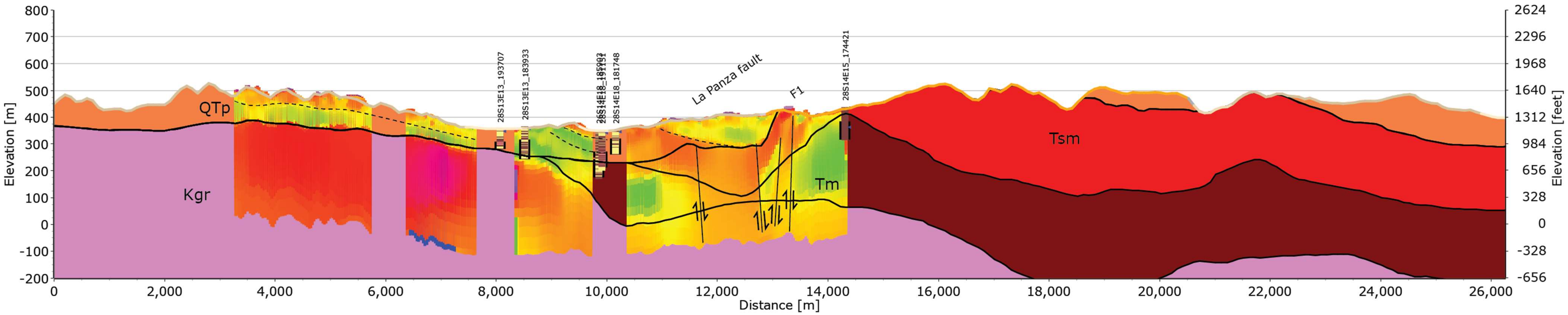
File: .\1690013412\plots\20200421\CrossSections

Geologic Cross section 4

Paso Robles Groundwater Basin, Hydrogeological Conceptual Model

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

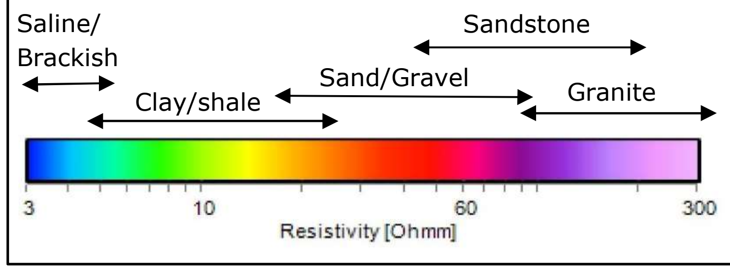
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.

Terrain/ CGS Geologic Map

Water level

Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
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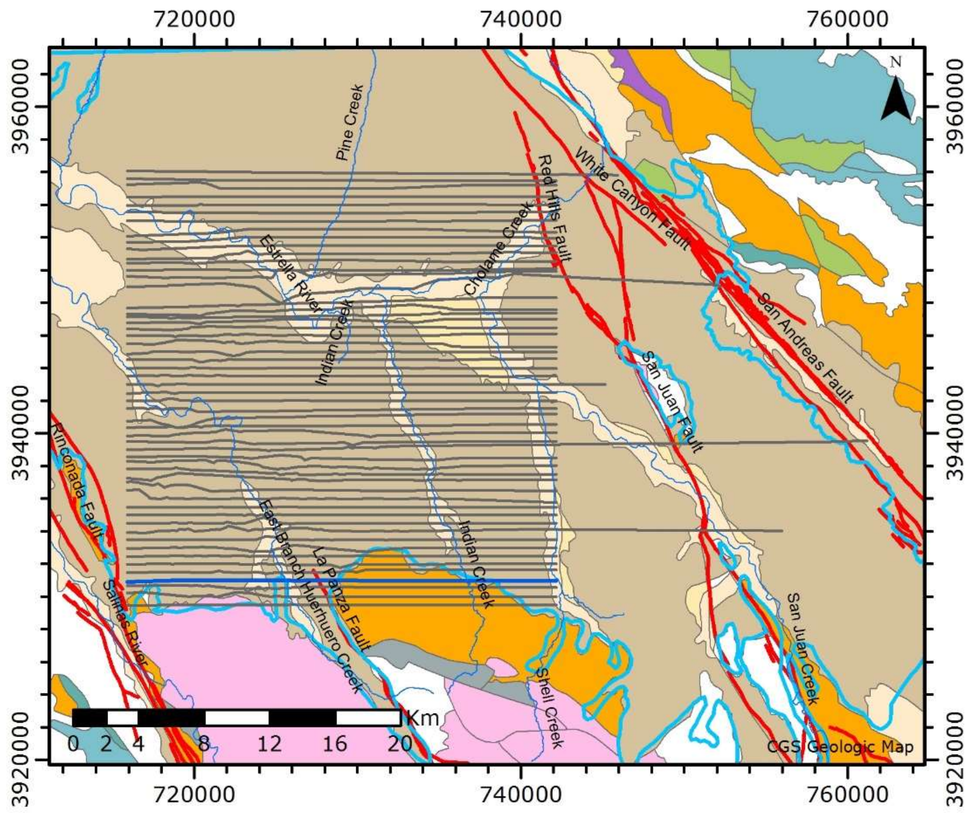

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Geologic Cross section 5

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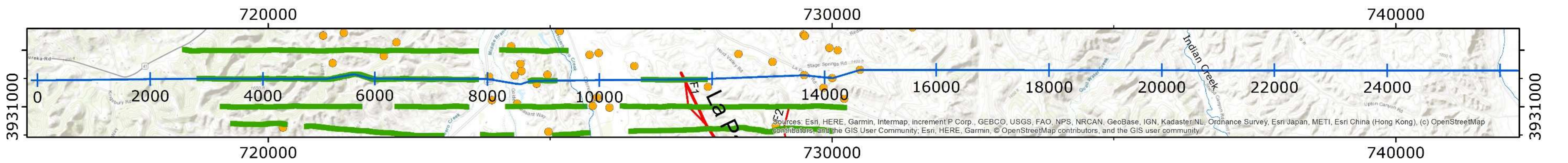
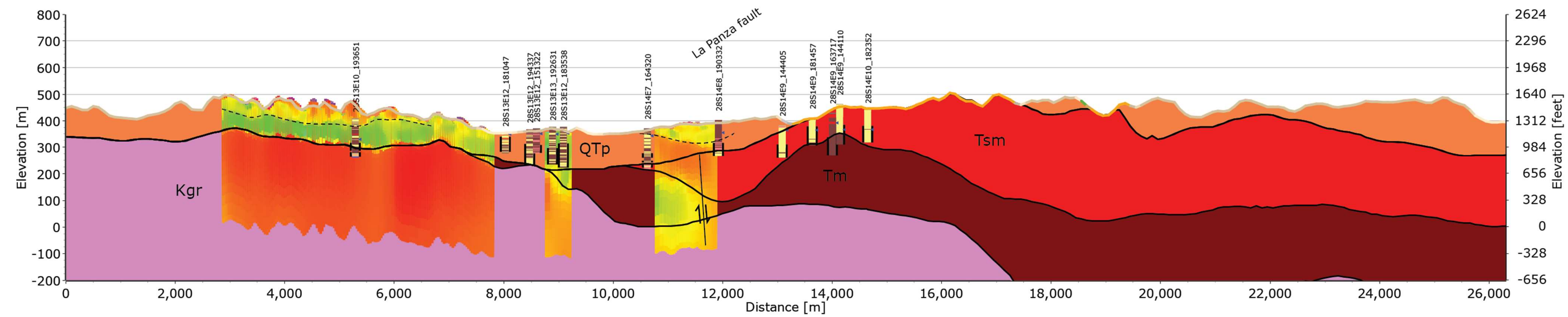




Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

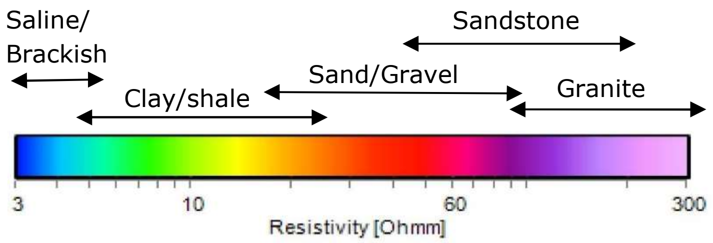
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.

Terrain/ CGS Geologic Map

Water level

Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
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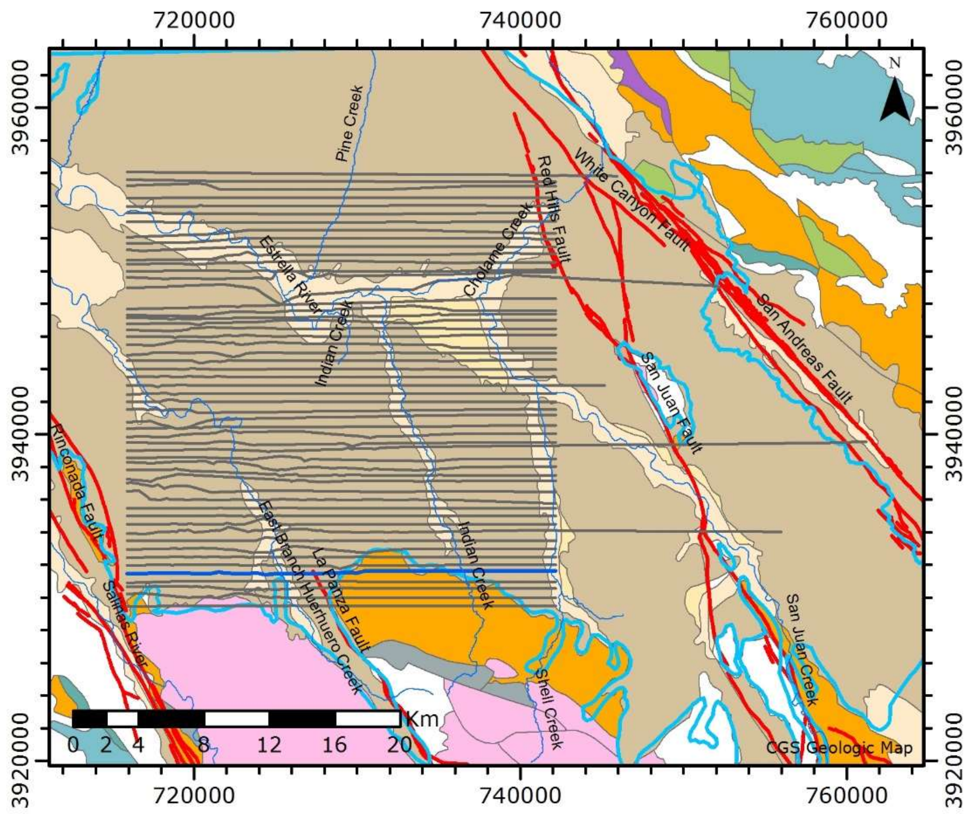

Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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Geologic Cross section 6

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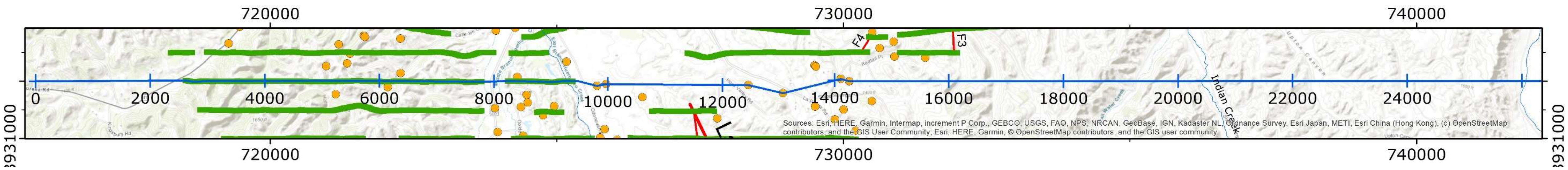
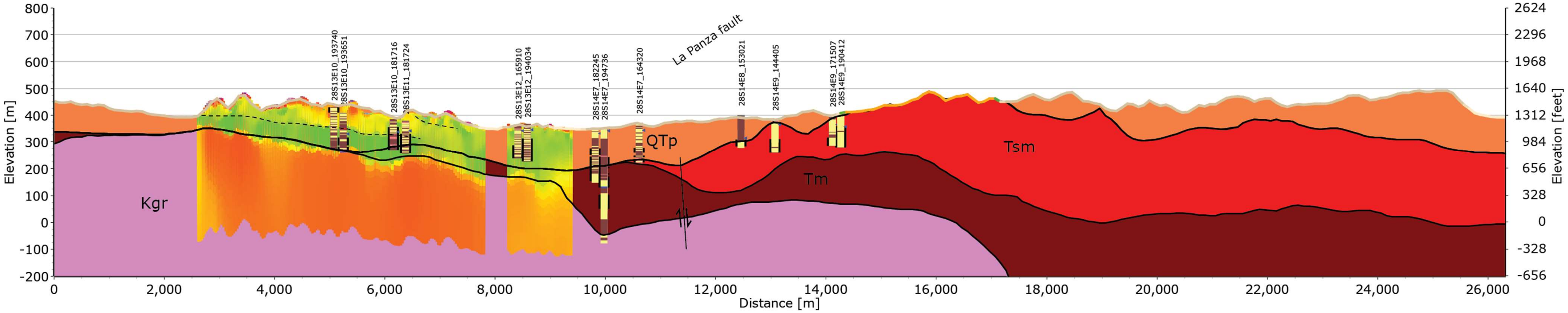




Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

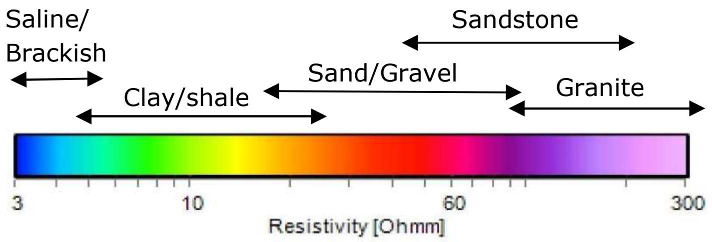
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.

Terrain/ CGS Geologic Map

Water level

Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
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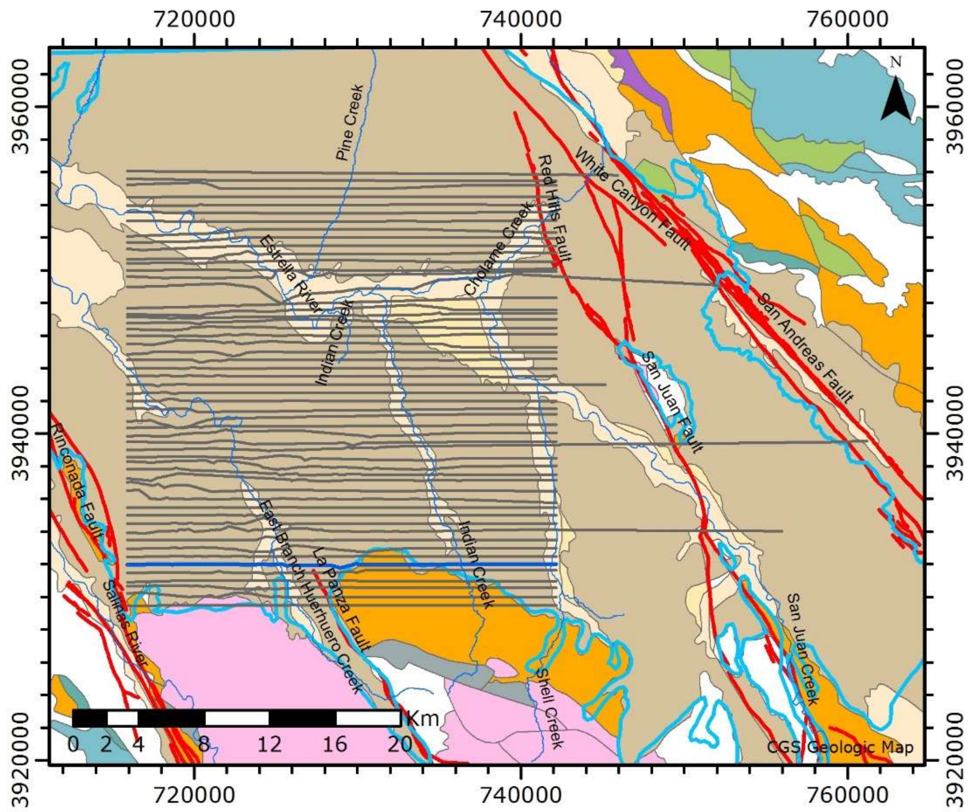

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Geologic Cross section 7

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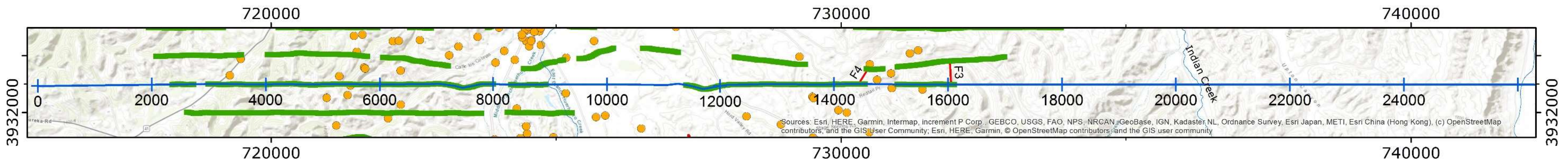
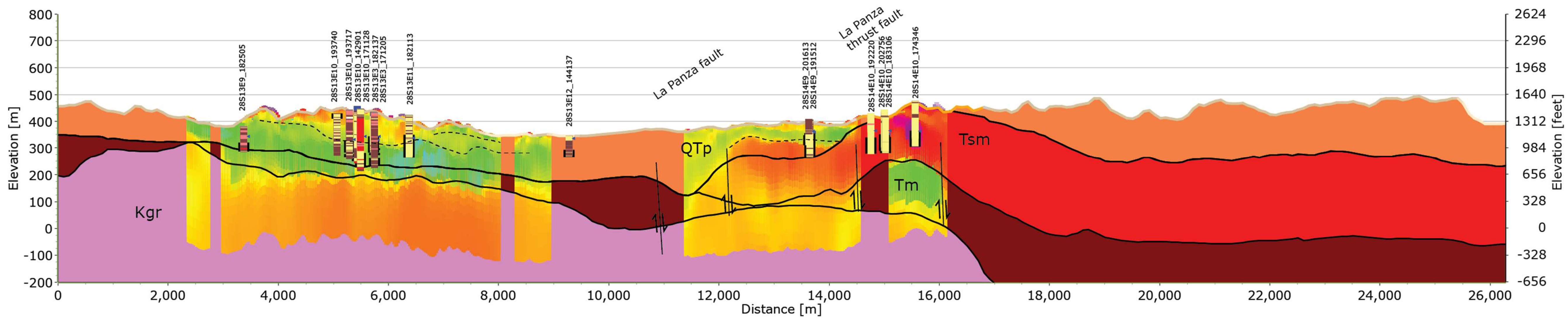




Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412

Cross section signatures

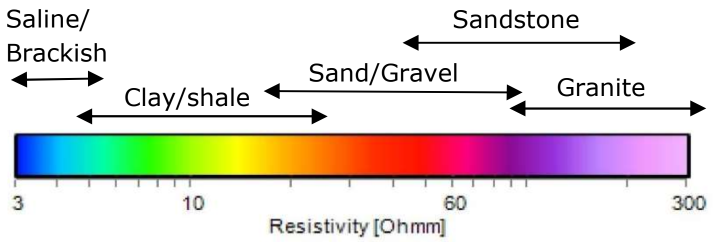
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown

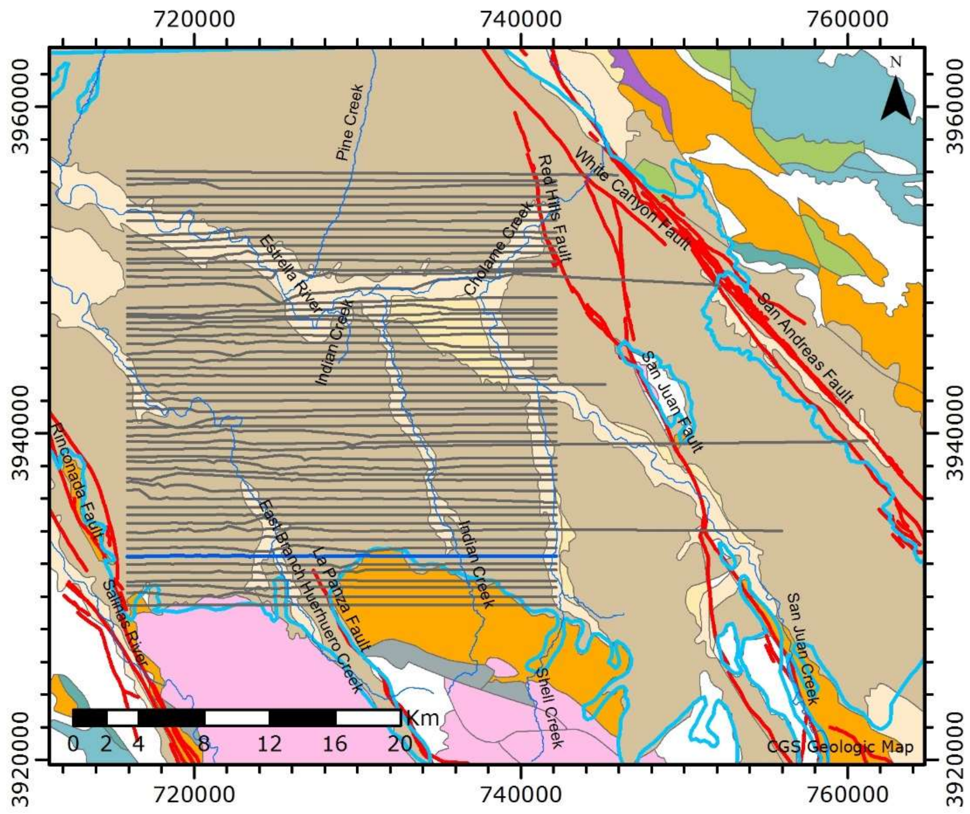


Borehole No.

Terrain/ CGS Geologic Map

Water level

Screen



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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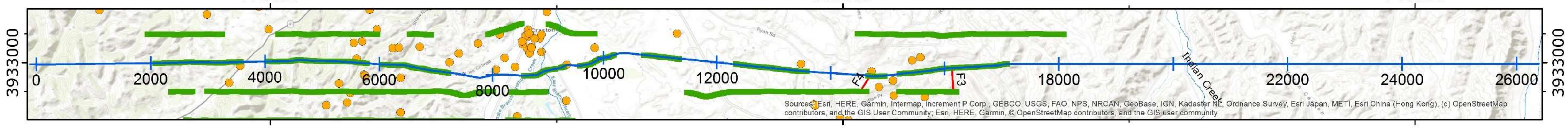
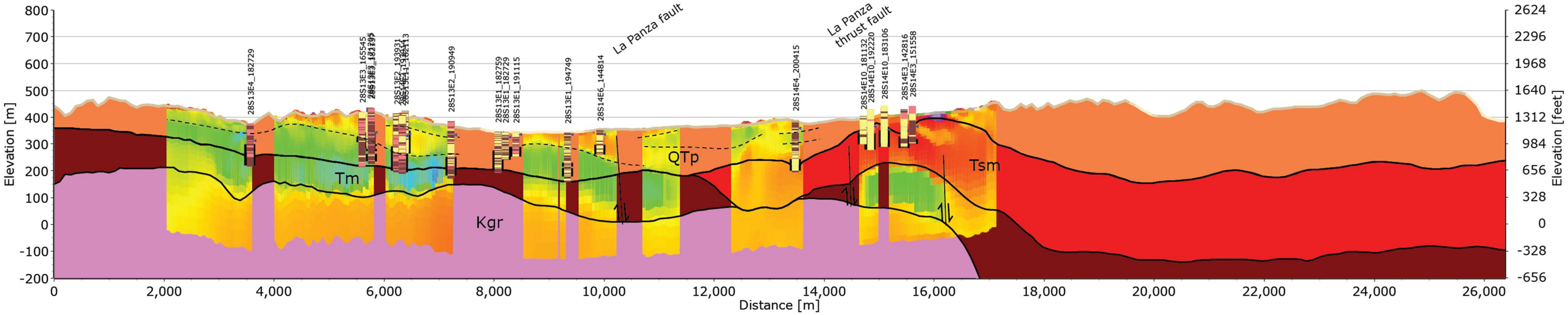
Geologic Cross section 8





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

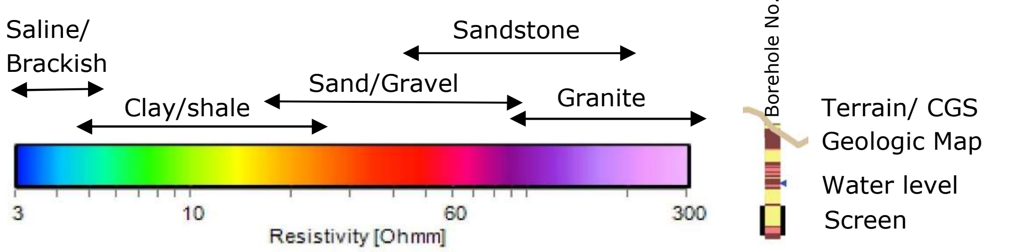
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Groundwater Architecture Project (GAP)
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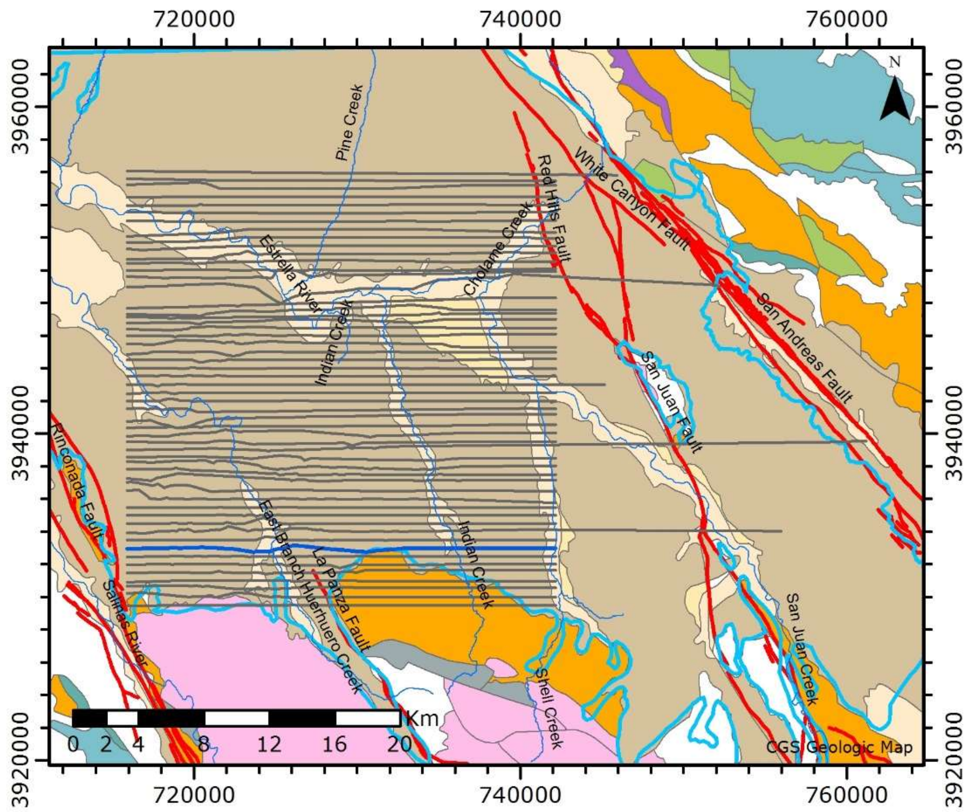

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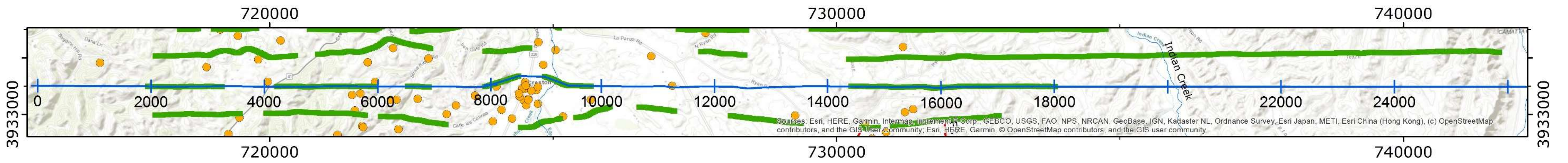
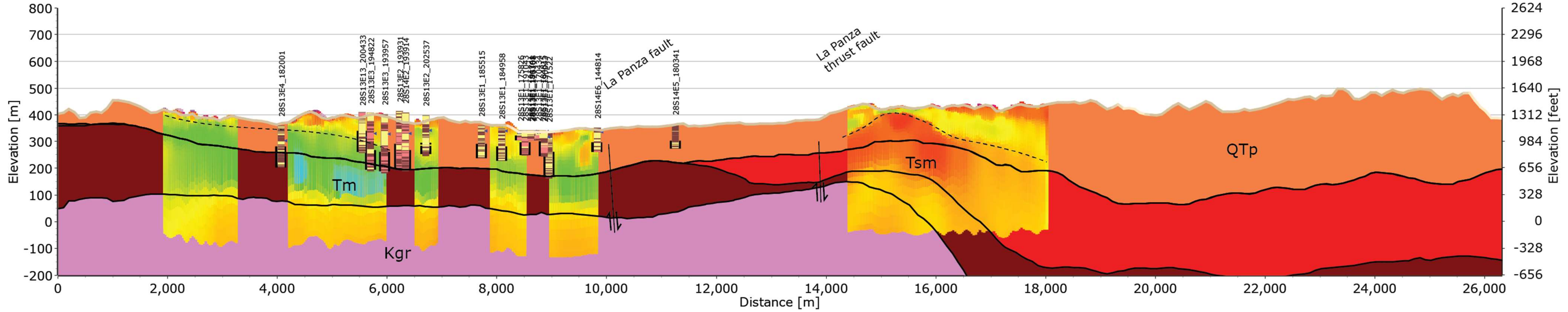
Geologic Cross section 9

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

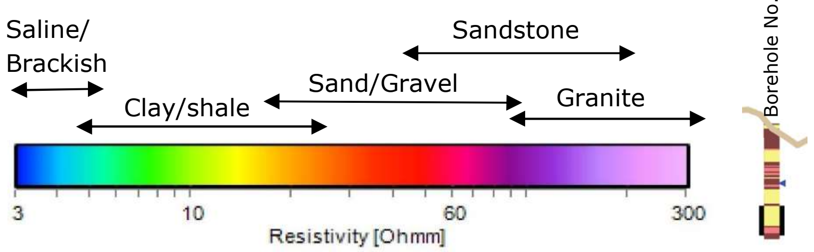
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Terrain/ CGS Geologic Map

Water level

Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
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Control: PATH
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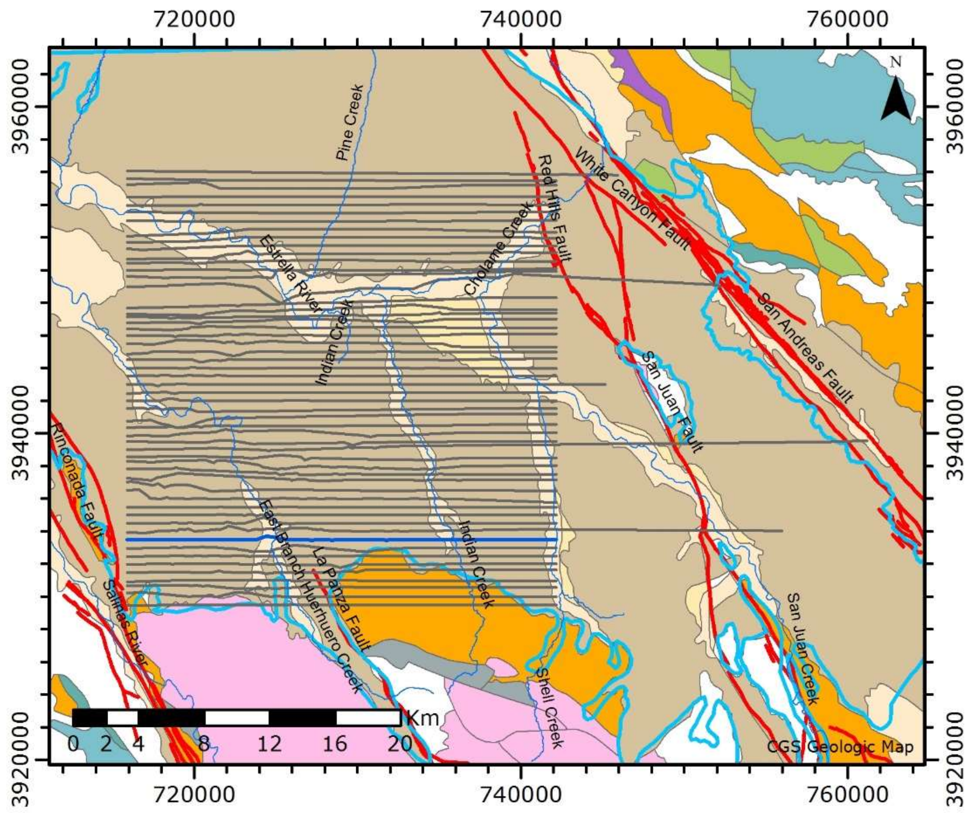

Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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Geologic Cross section 10

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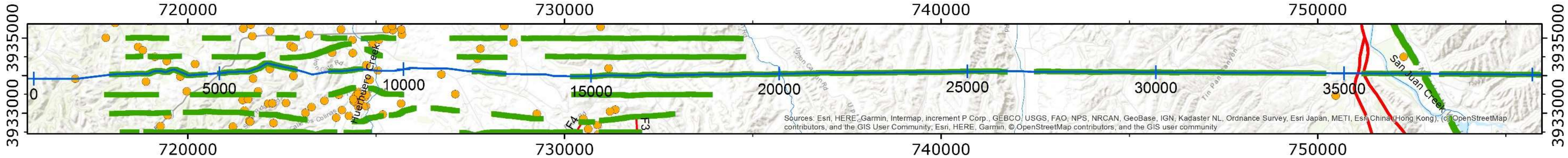

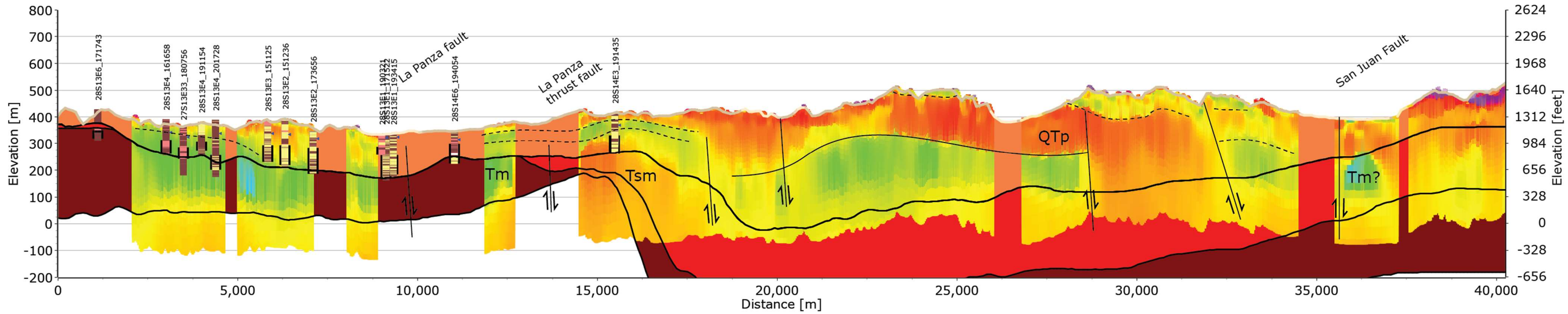

Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Groundwater Architecture Project (GAP)
San Luis Obispo County
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Control: PATH
Approved: MAXH
Project No. 1690013412

Cross section signatures

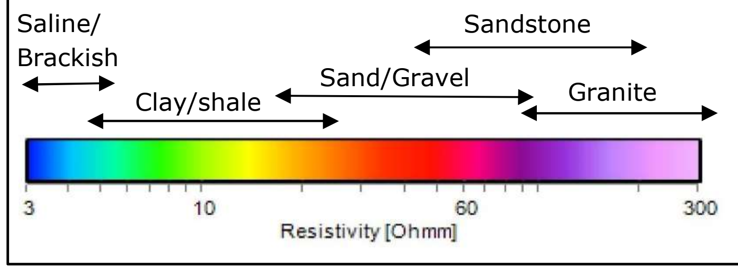
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

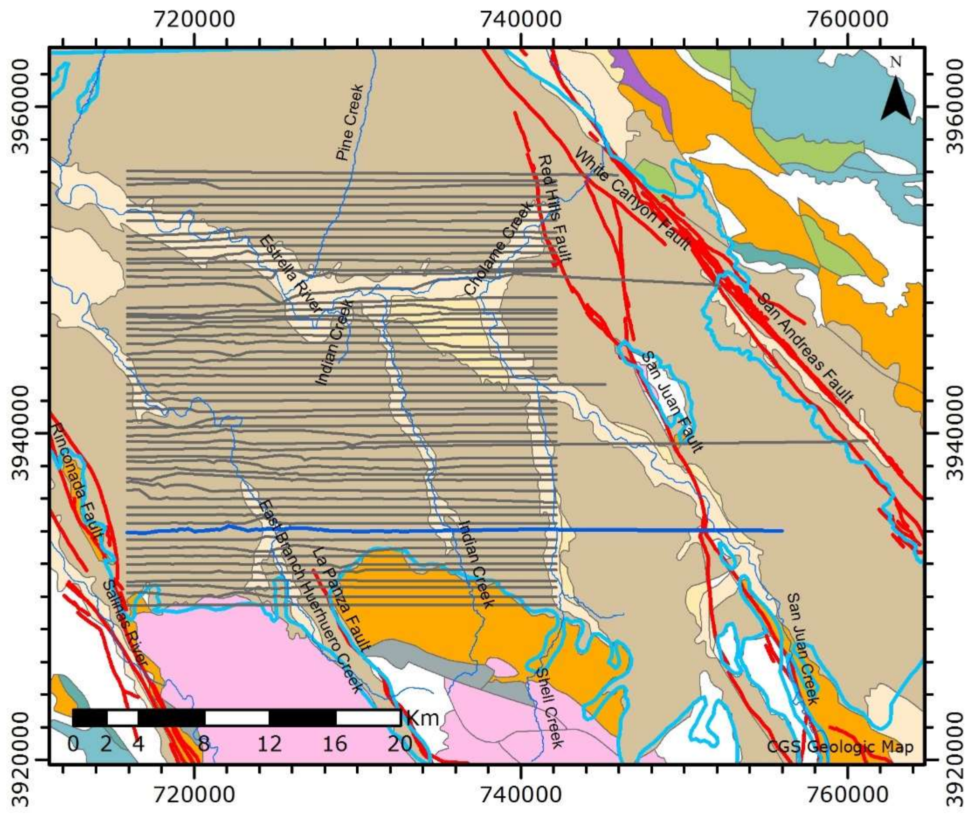
- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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Geologic Cross section 11

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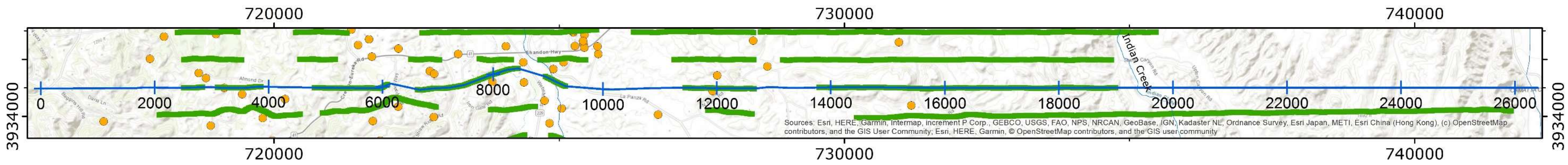

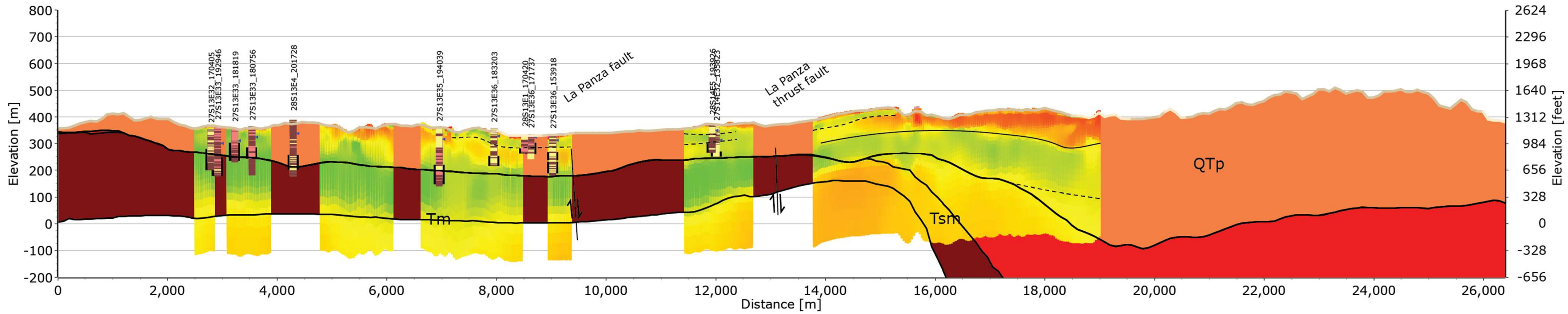

Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

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Control: PATH
Approved: MAXH
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Cross section signatures

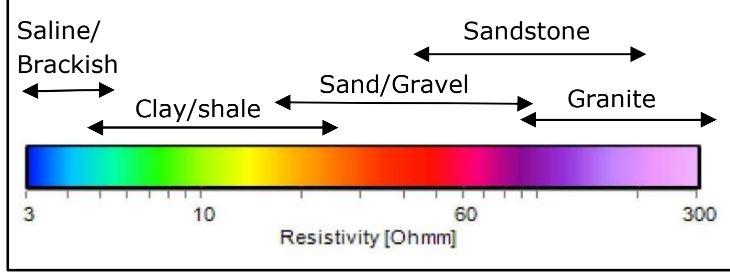
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

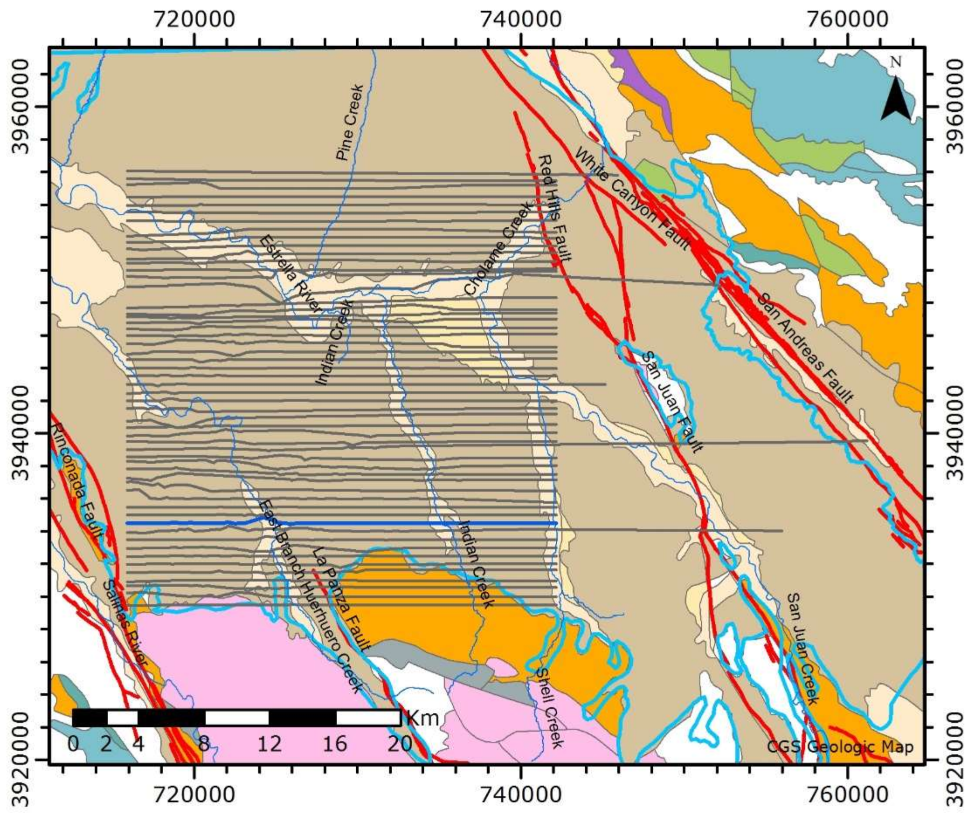
- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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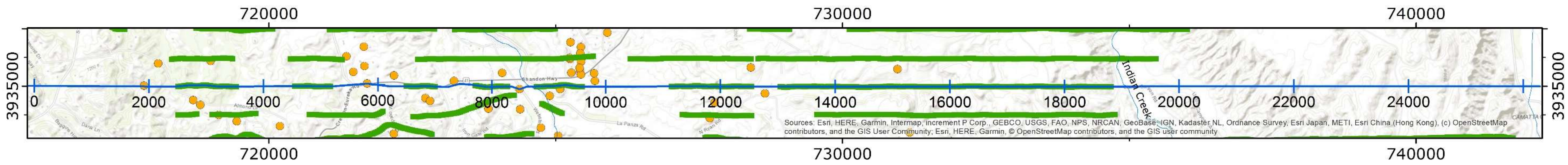
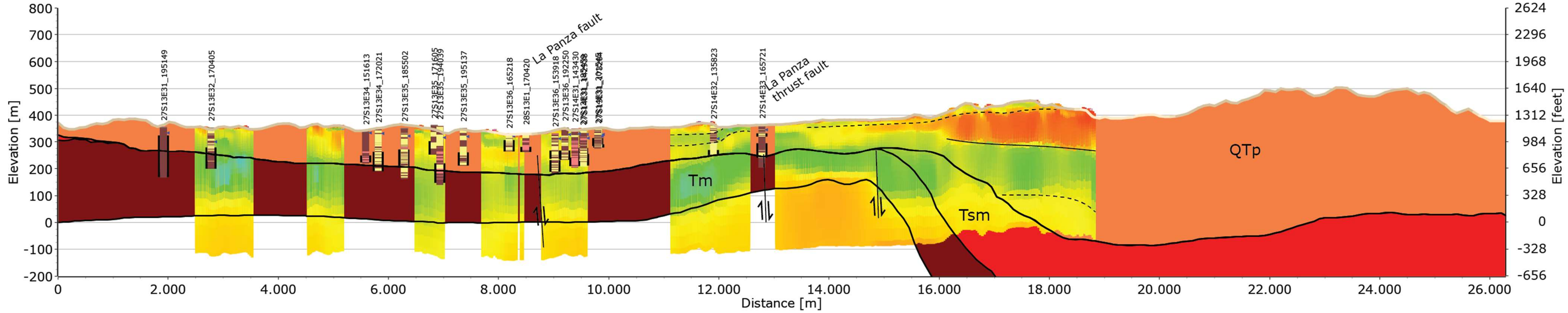
Geologic Cross section 12

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412

Cross section signatures

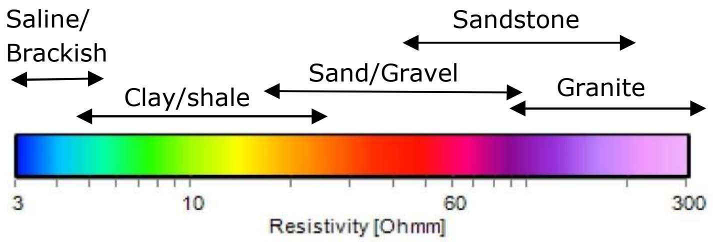
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

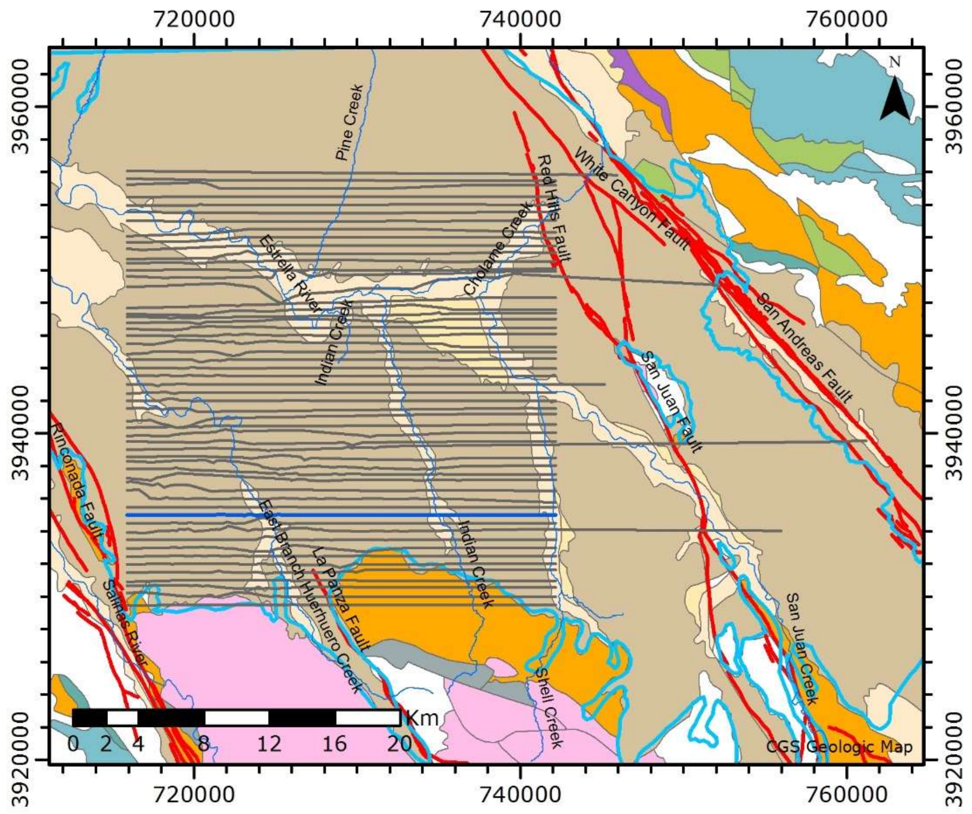
Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown





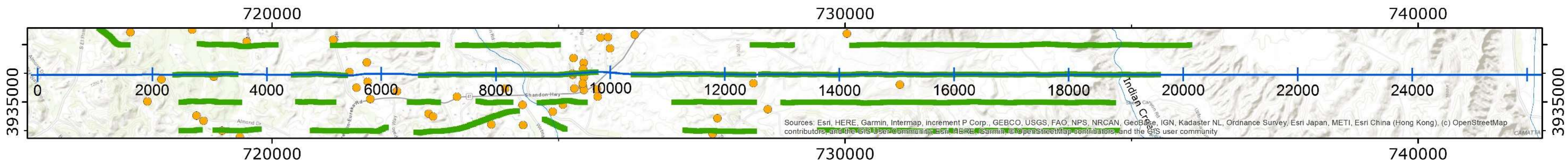
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

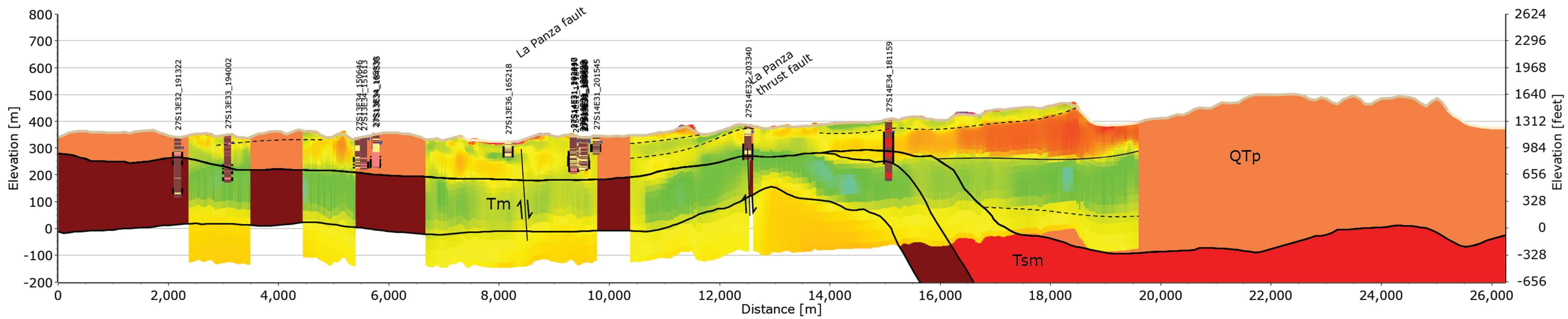
File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 13

Paso Robles Groundwater Basin, Hydrogeological Conceptual Model

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Groundwater Architecture Project (GAP)
San Luis Obispo County
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Approved: MAXH
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Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

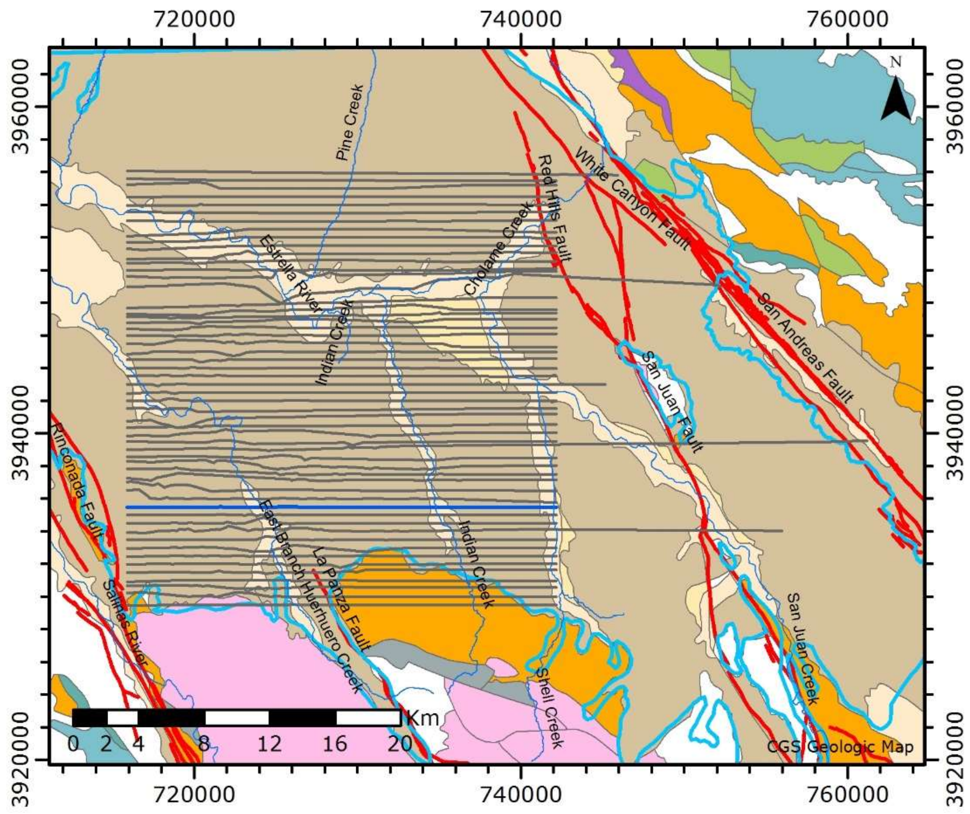
Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown

Saline/ Brackish
Clay/shale
Sand/Gravel
Sandstone
Granite

3 10 60 300
Resistivity [Ohmm]

Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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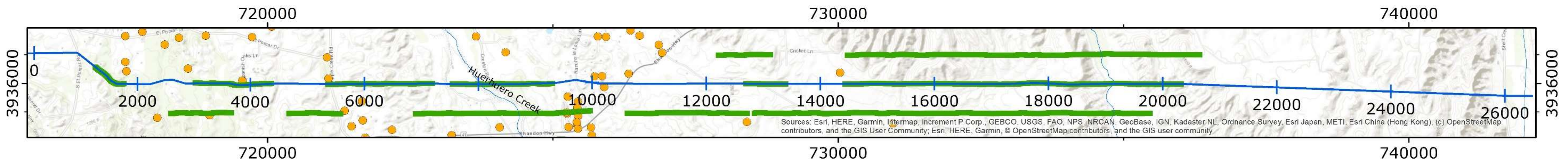
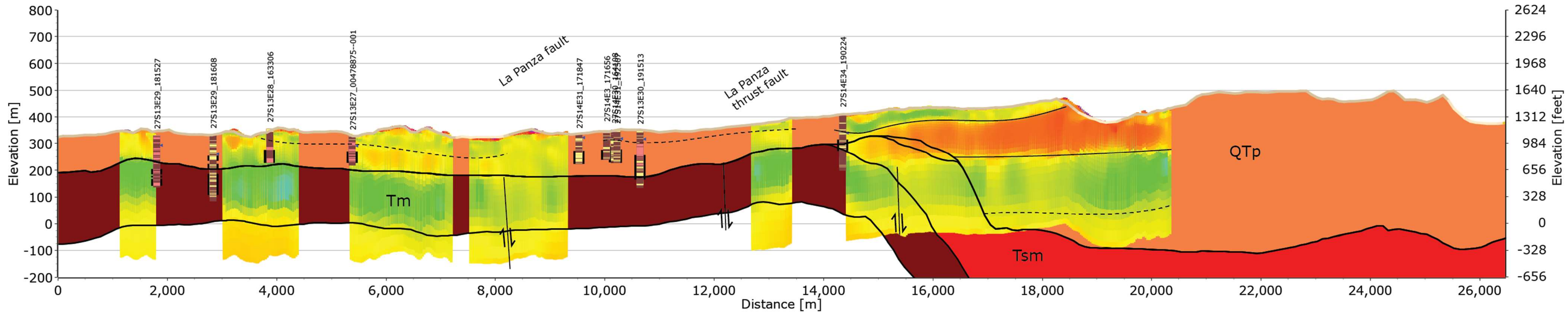
Geologic Cross section 14

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

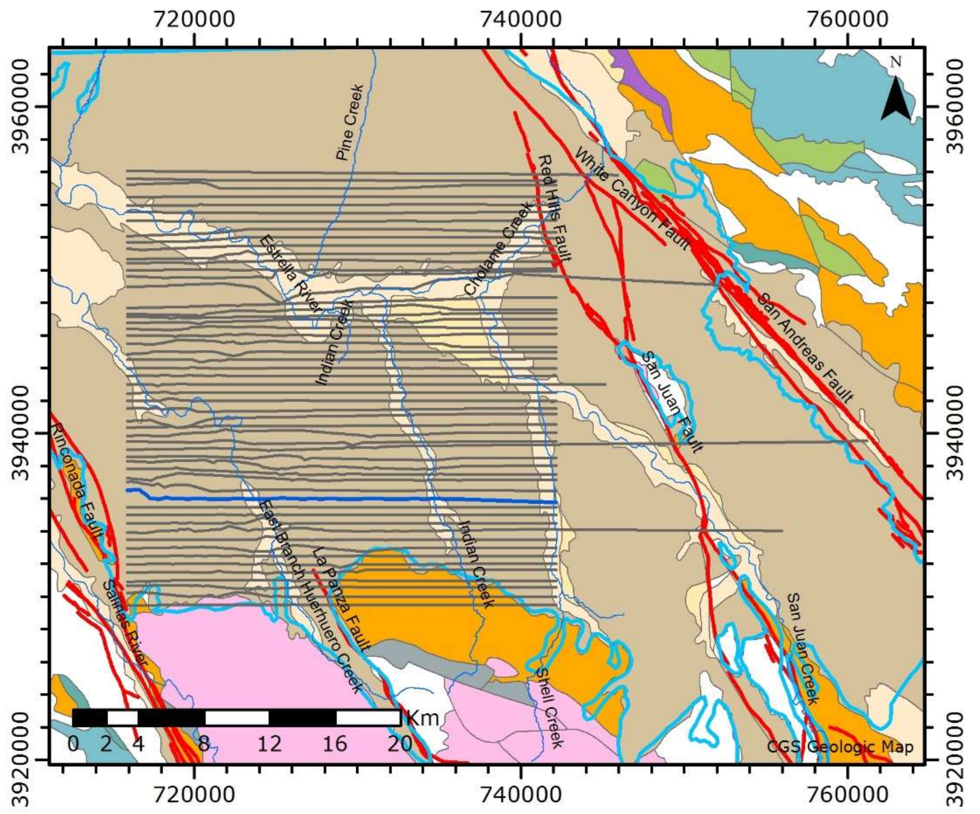
Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown

Saline/ Brackish
Clay/shale
Sand/Gravel
Sandstone
Granite

3 10 60 300
Resistivity [Ohmm]

Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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San Luis Obispo County
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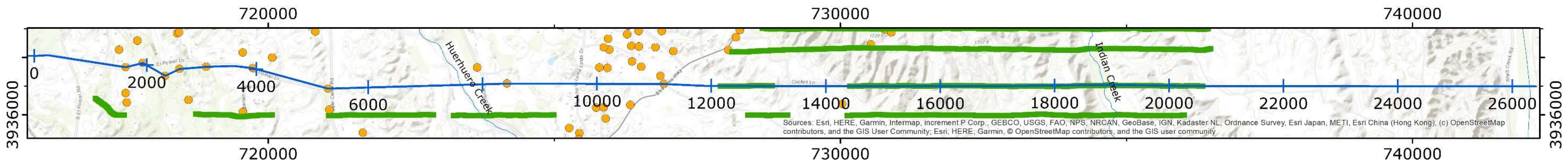
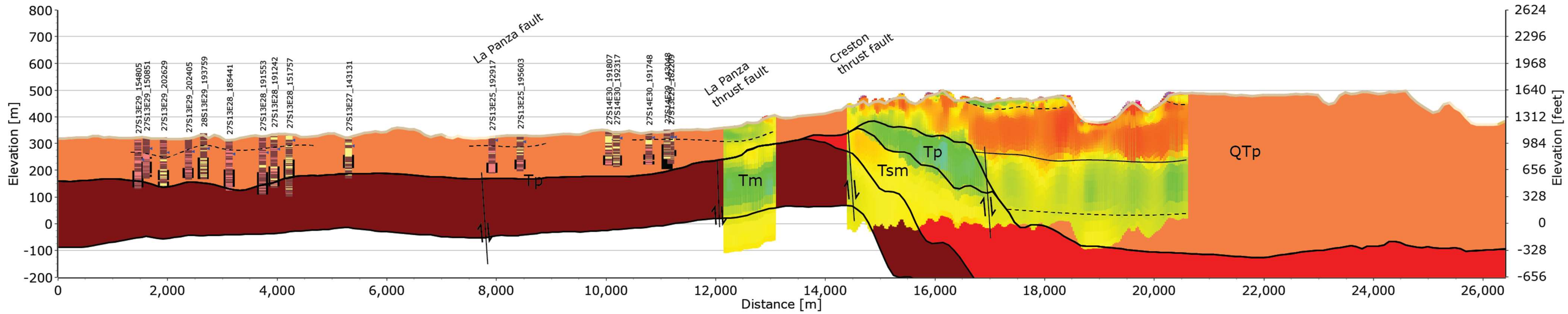
File: .\1690013412\plots\20200421\CrossSections

Geologic Cross section 15

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

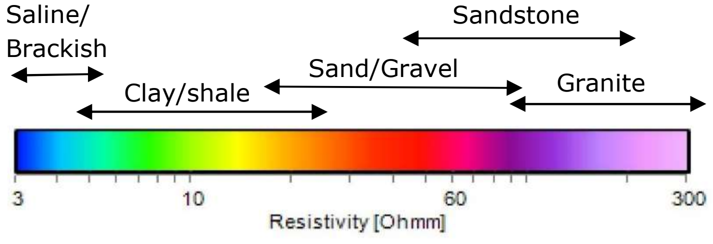
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen

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San Luis Obispo County
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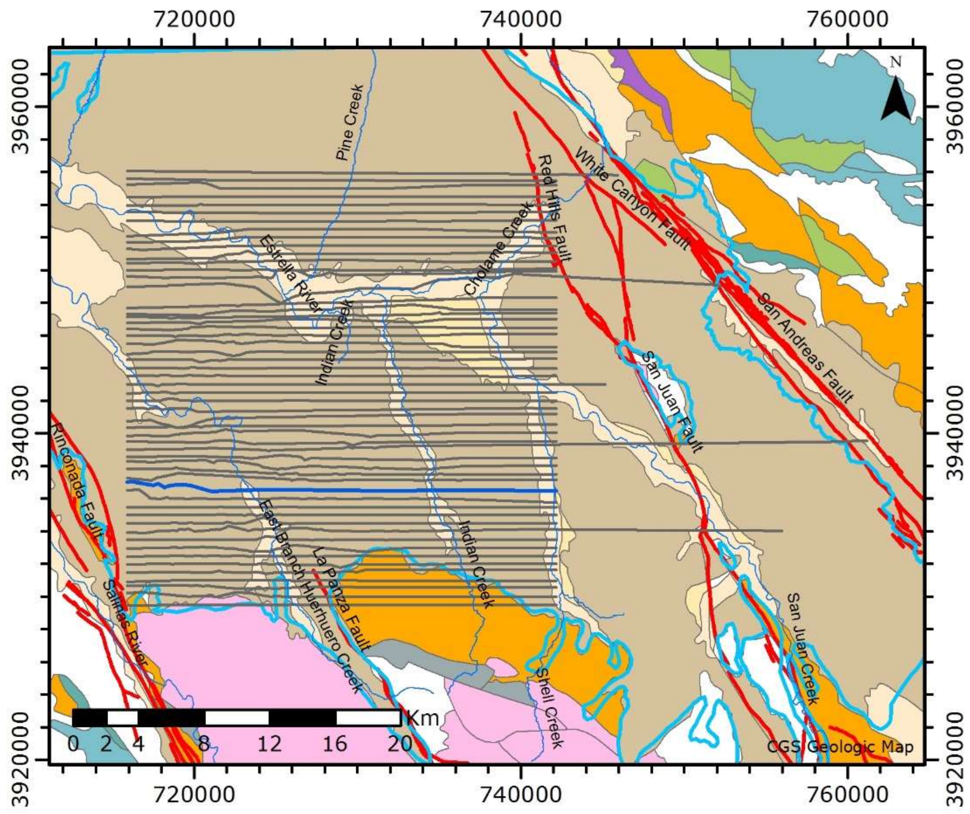
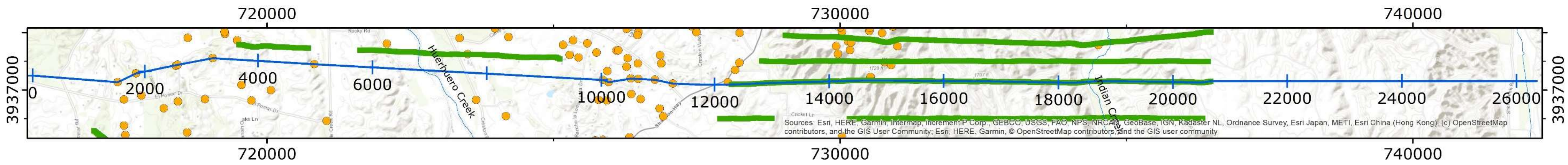


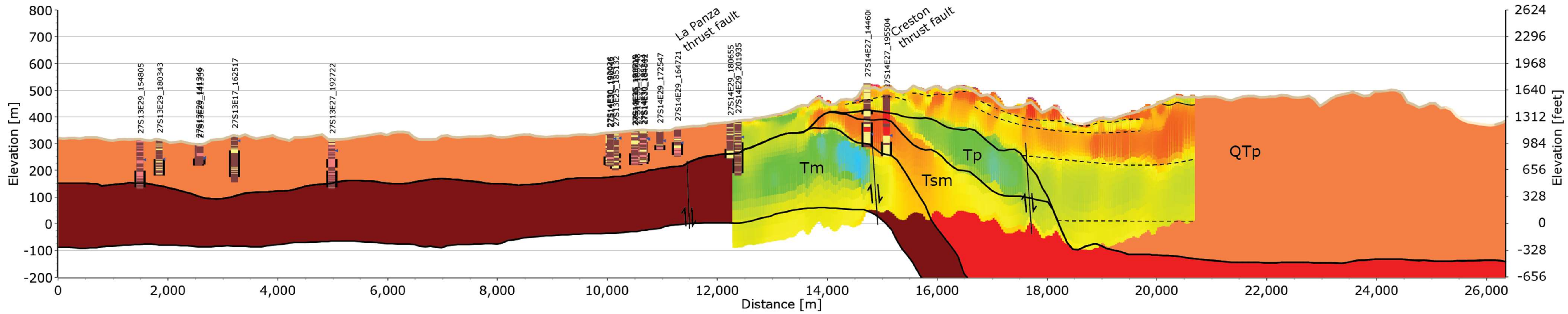
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: .\1690013412\plots\20200421\CrossSections

Geologic Cross section 16

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
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Approved: MAXH
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Cross section signatures

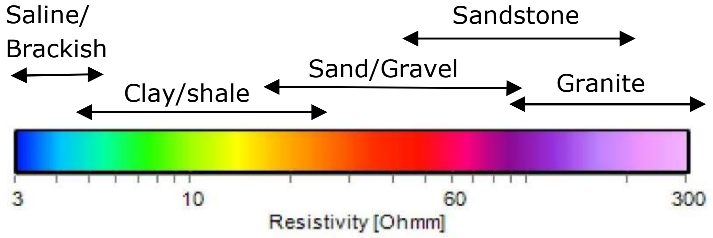
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

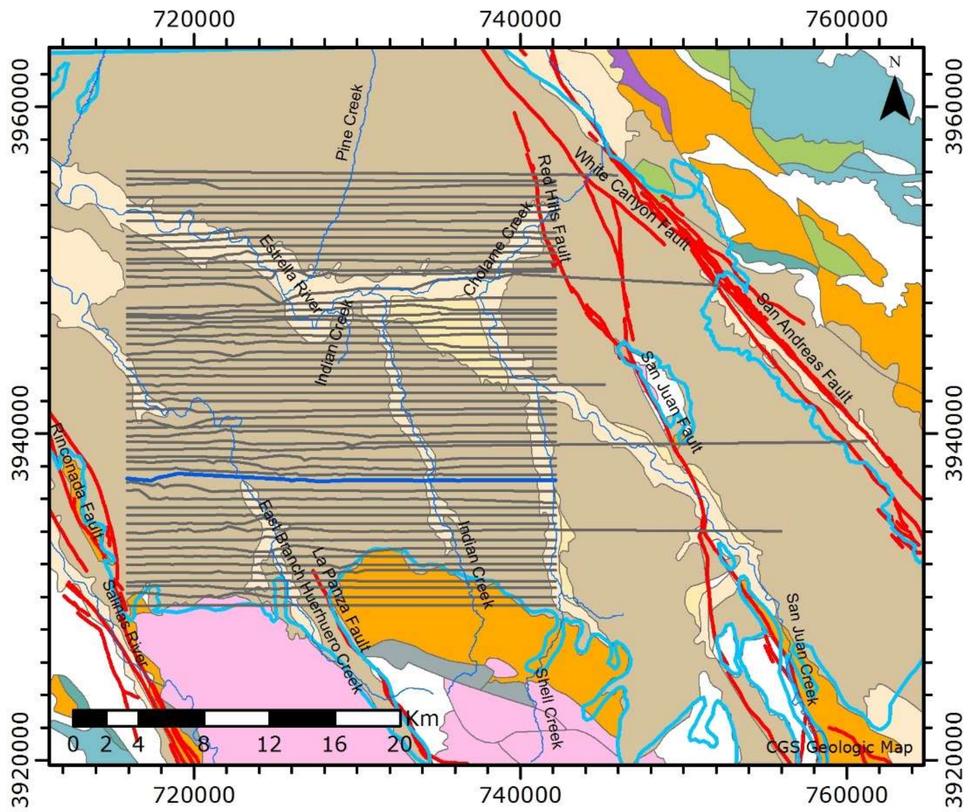
- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen

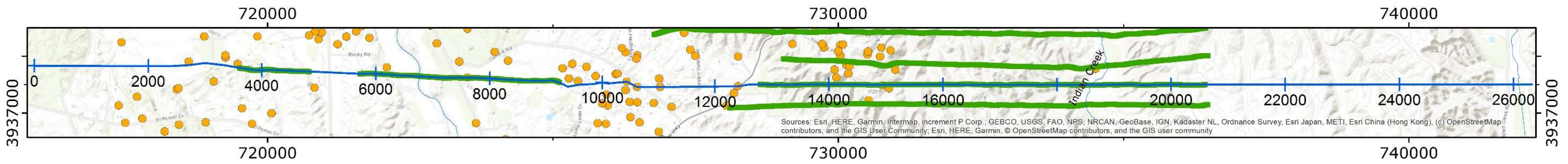


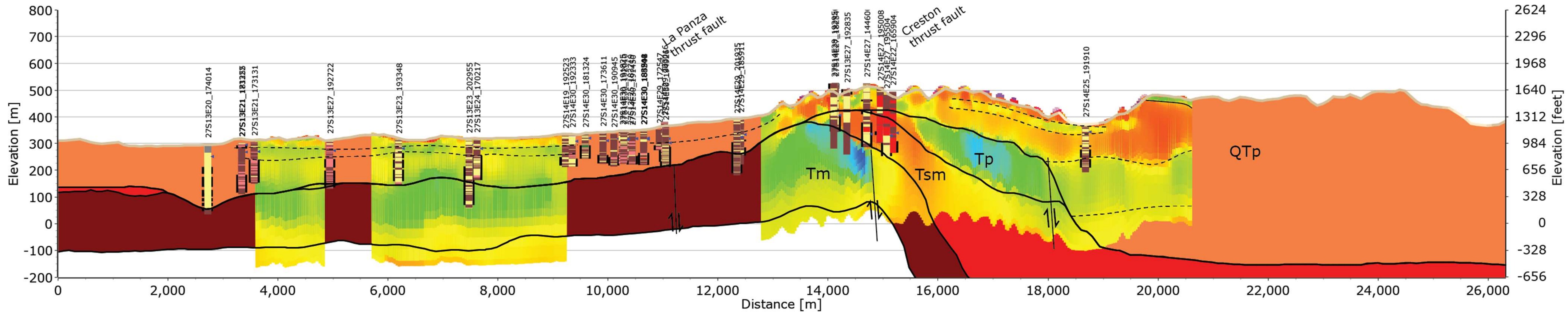
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 17

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

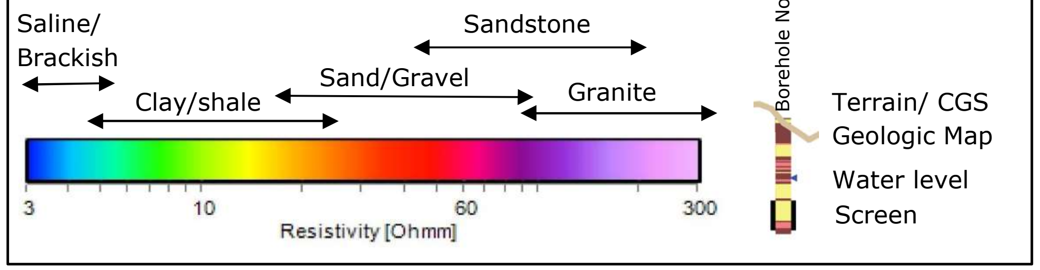
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Groundwater Architecture Project (GAP)
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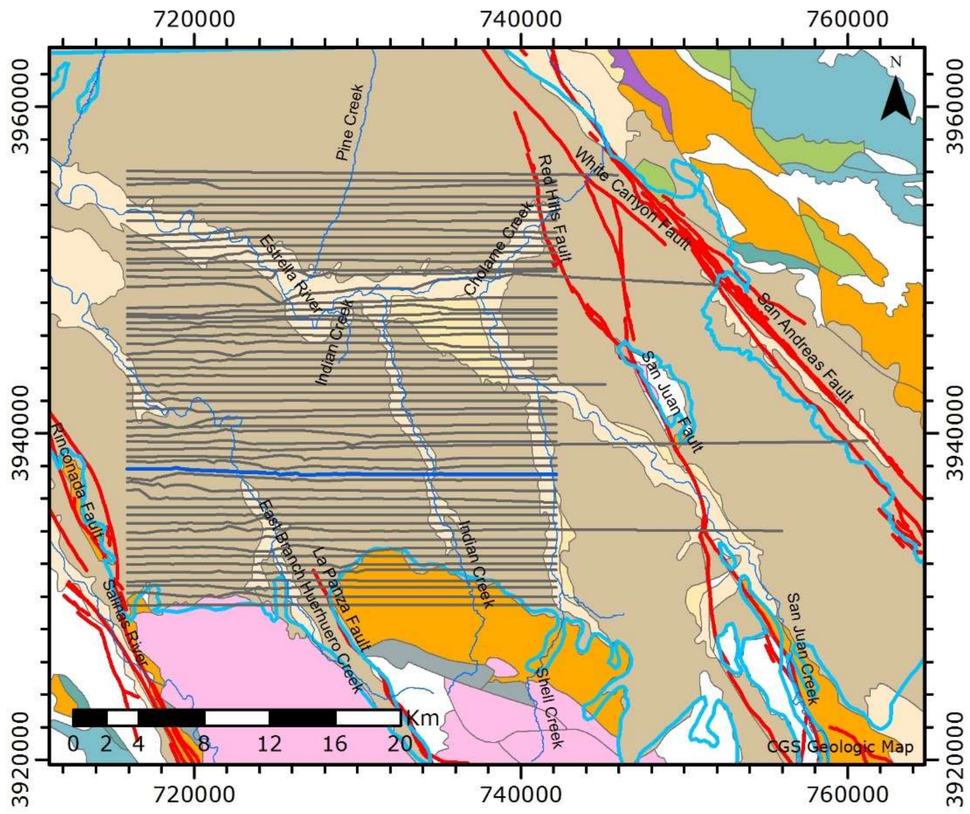
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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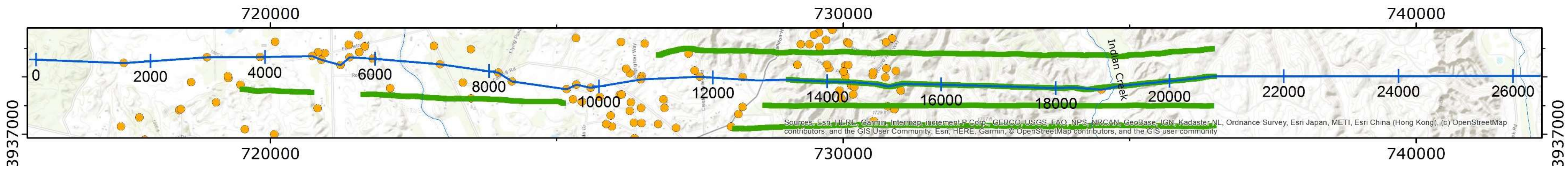
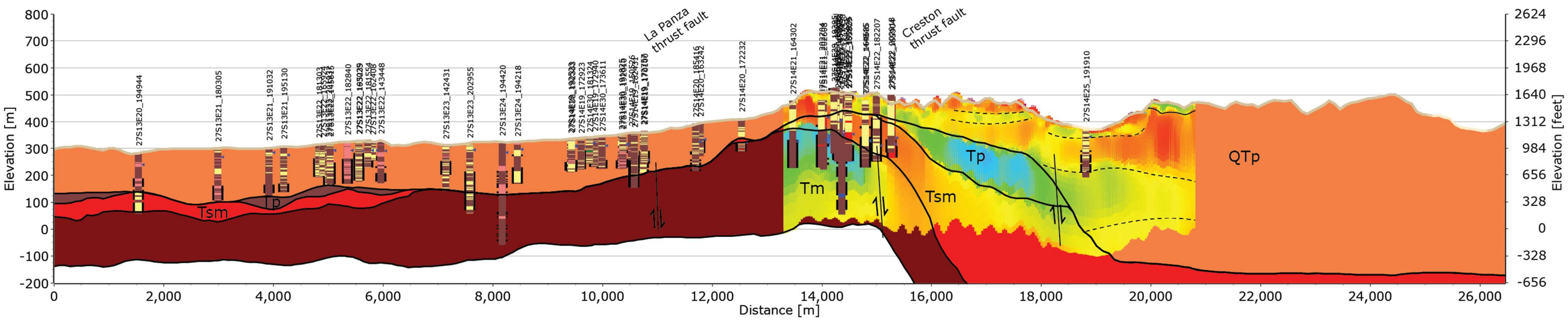
Geologic Cross section 18





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

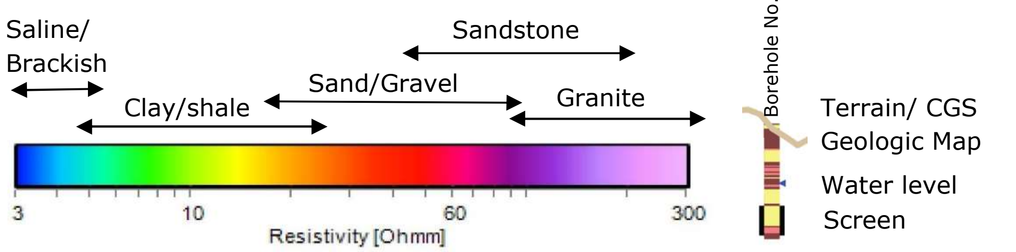
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

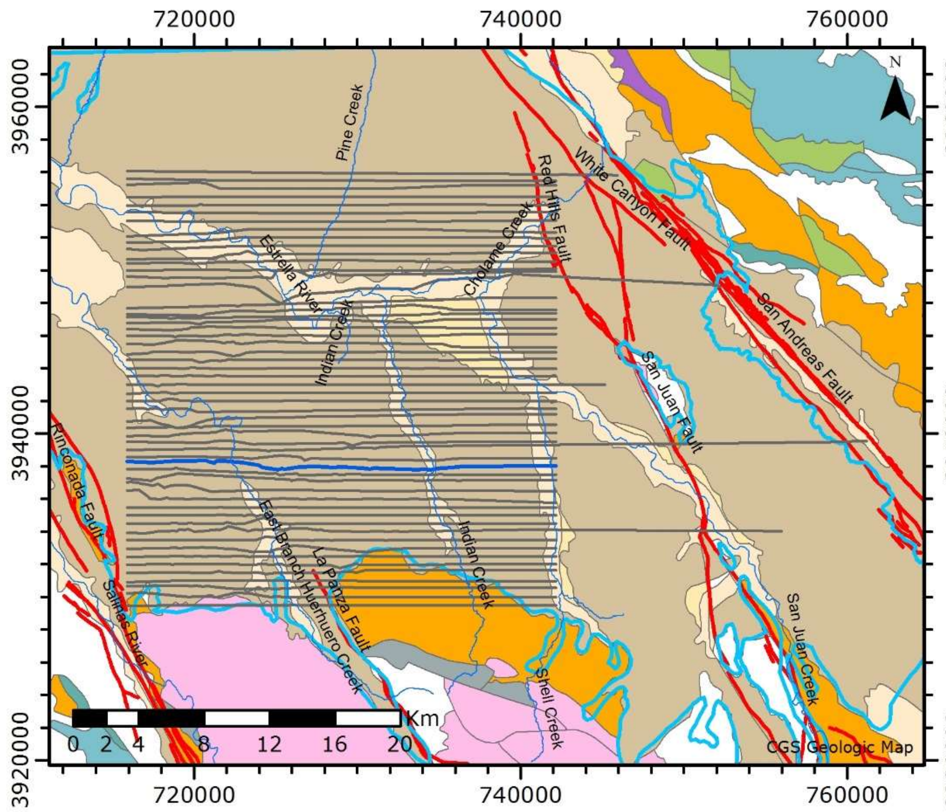
Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



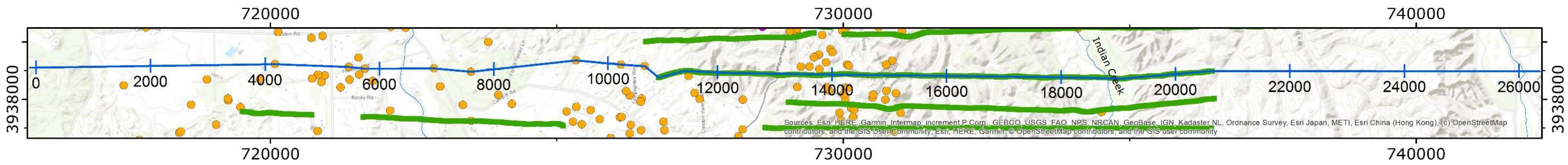


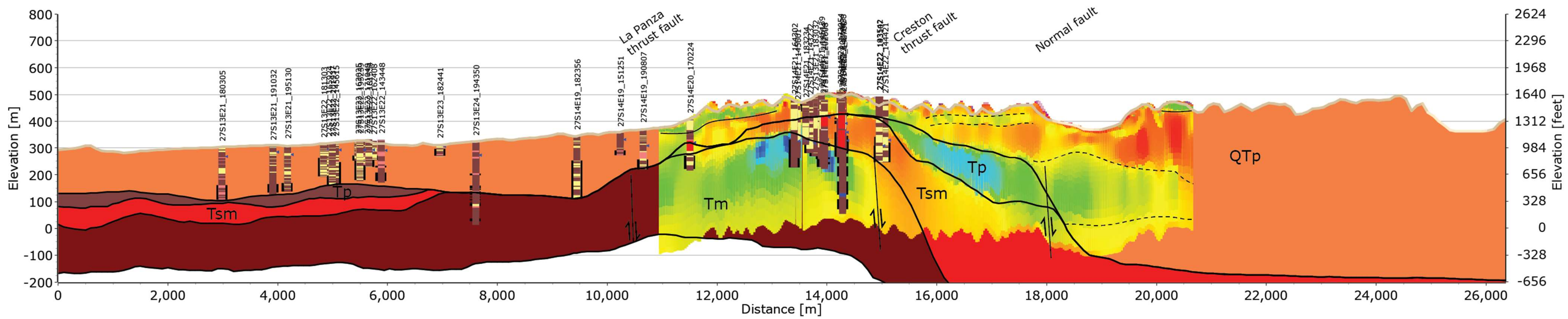
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412

Geologic Cross section 19

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
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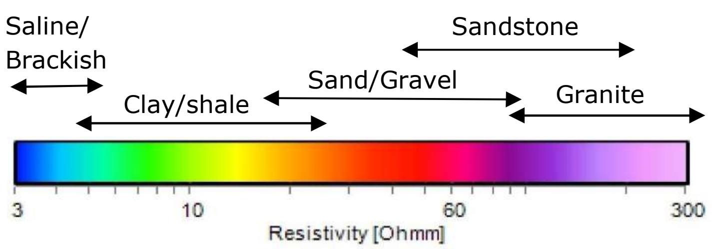
- Monterey Shale, Tm
- Granite rocks, Kgr

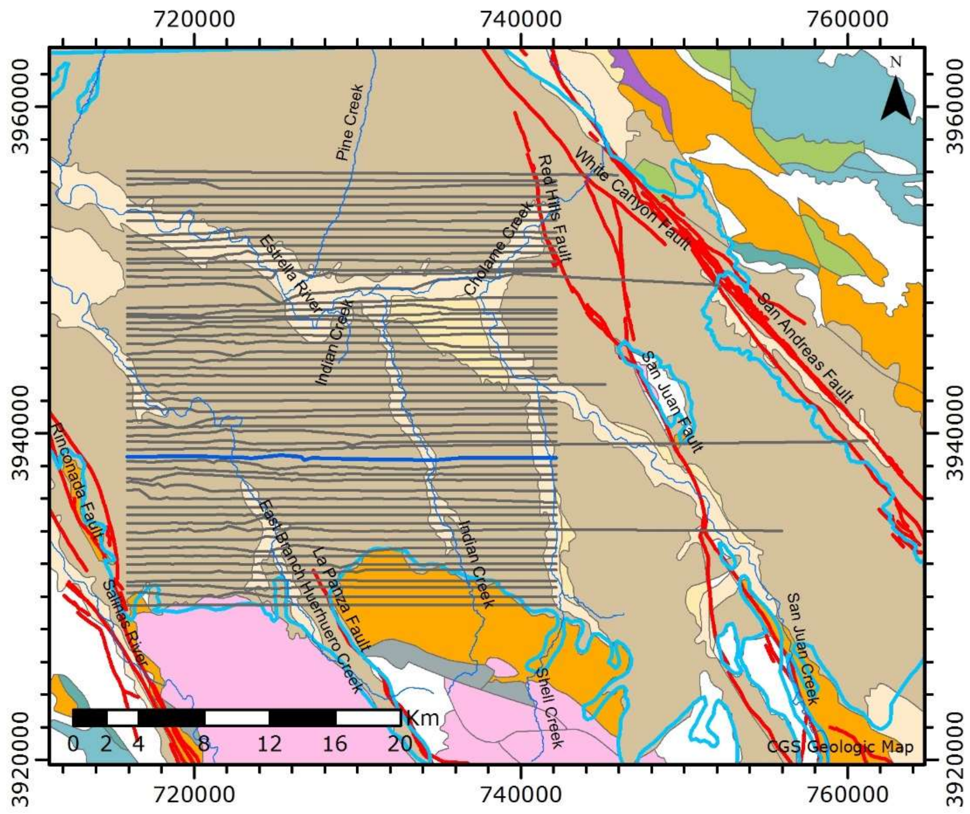
Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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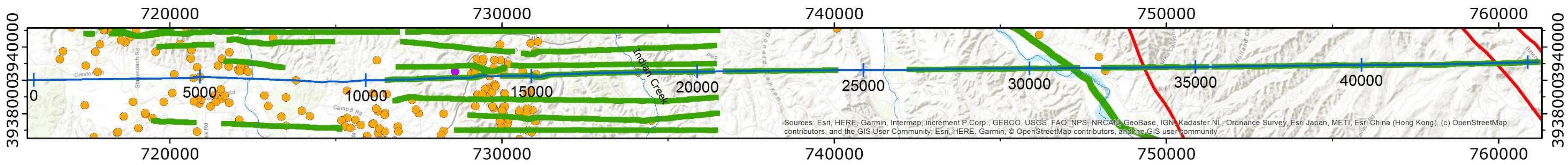
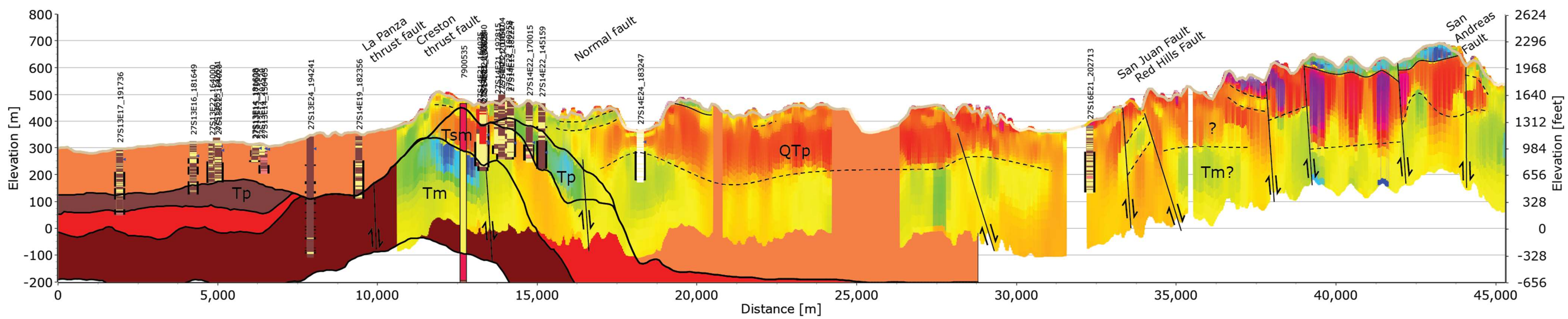
Geologic Cross section 20

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
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Groundwater Architecture Project (GAP)
San Luis Obispo County
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Control: PATH
Approved: MAXH
Project No. 1690013412

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
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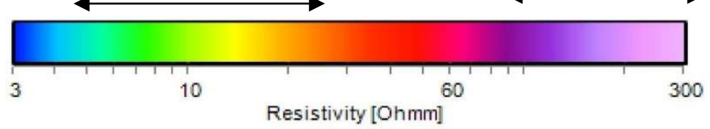
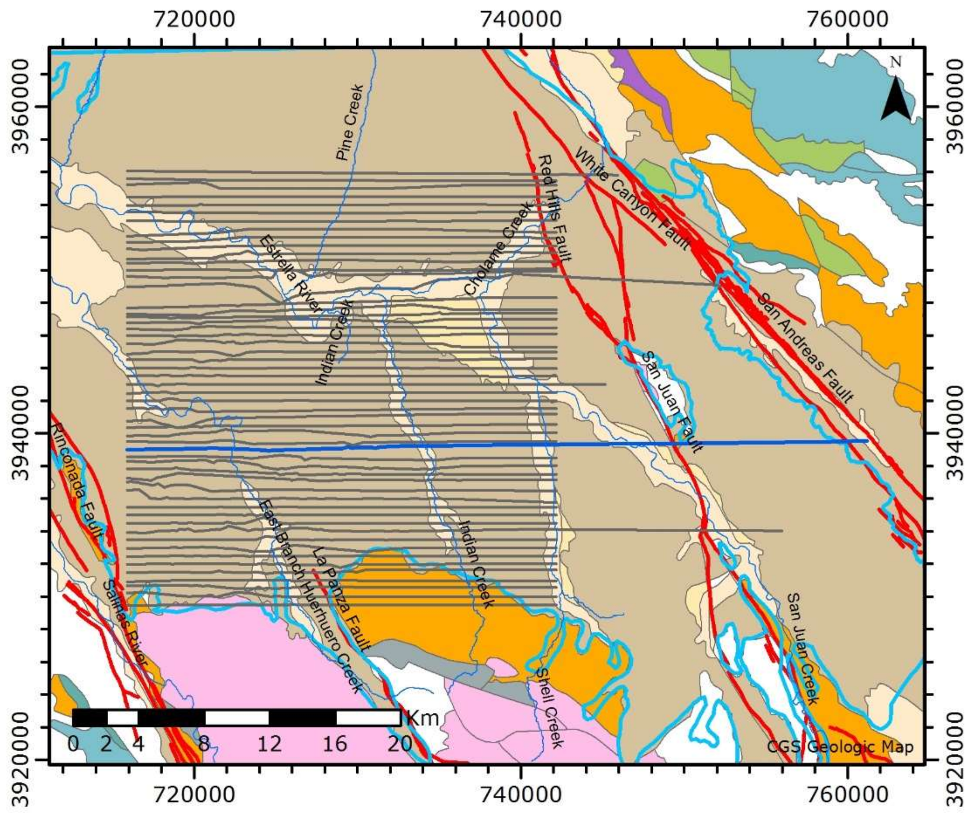
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen



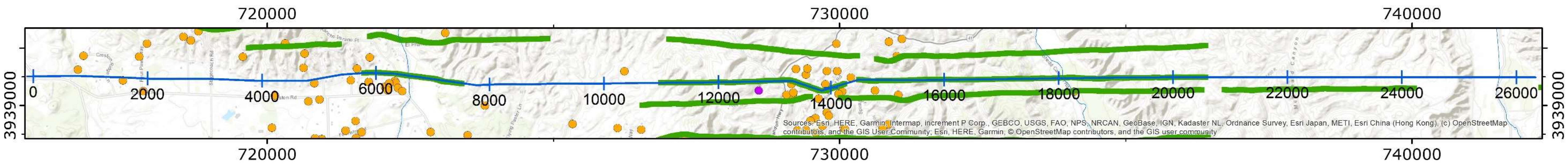
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

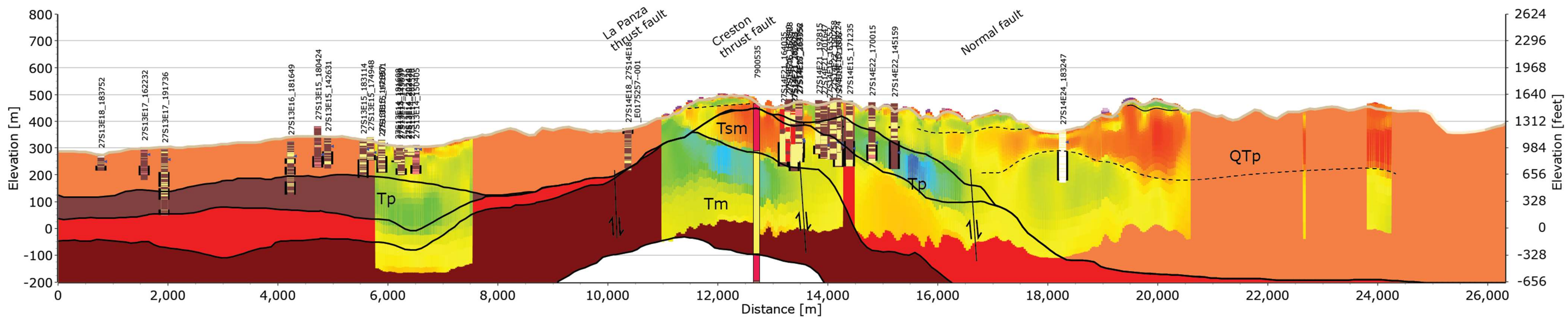
File: .\1690013412\plots\20200421\CrossSections

Geologic Cross section 21

Paso Robles Groundwater Basin, Hydrogeological Conceptual Model

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
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Groundwater Architecture Project (GAP)
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Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

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- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

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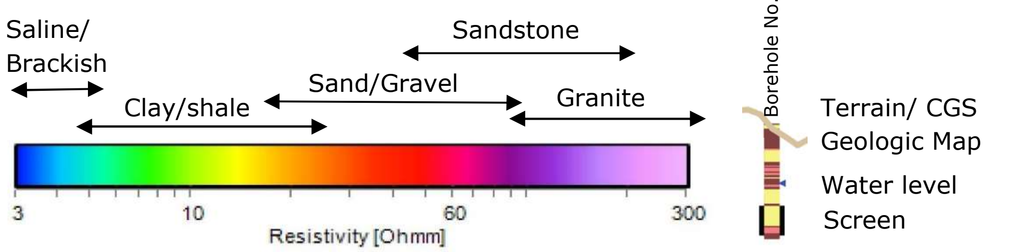
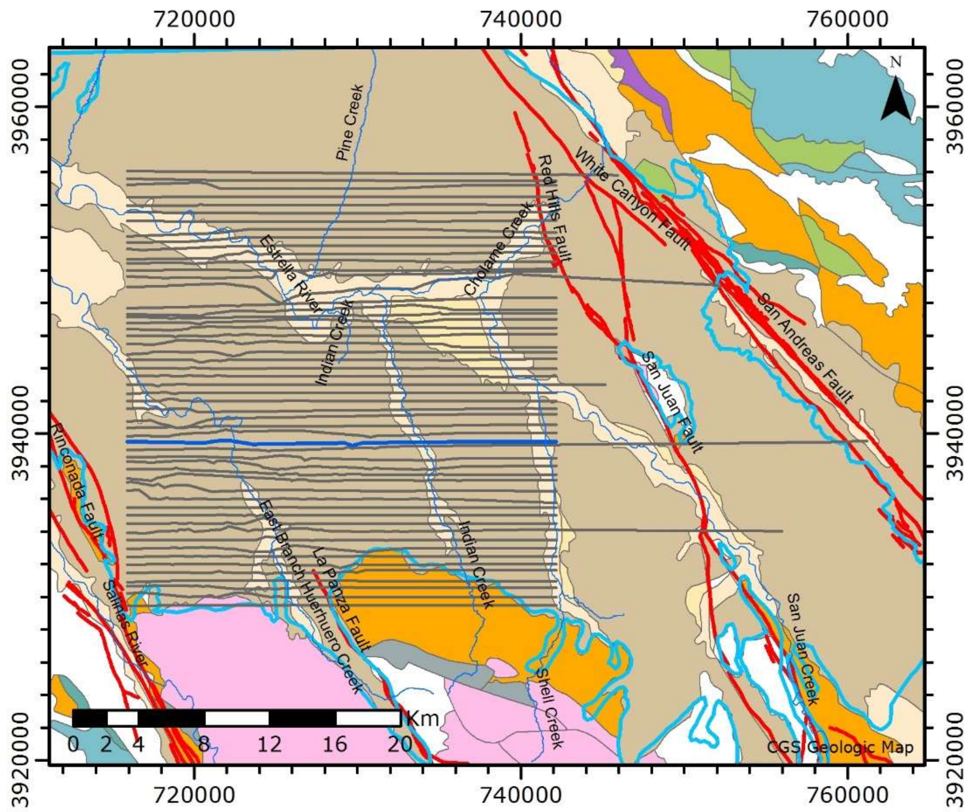
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown





Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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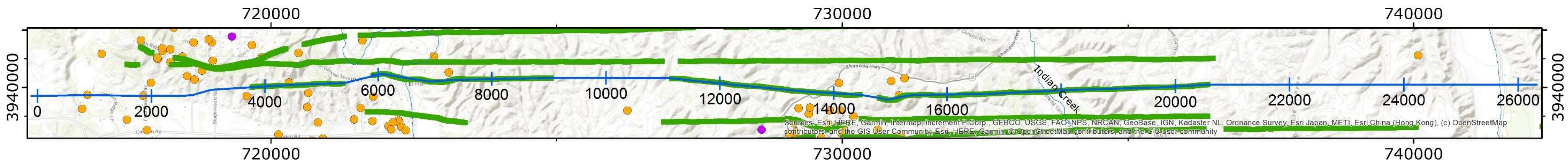
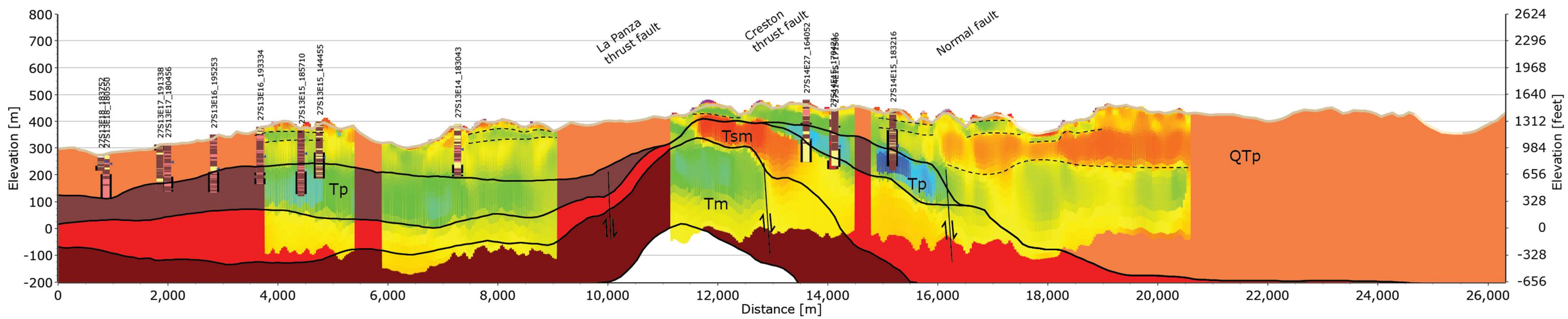
Geologic Cross section 22

Paso Robles Groundwater Basin, Hydrogeological Conceptual Model





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

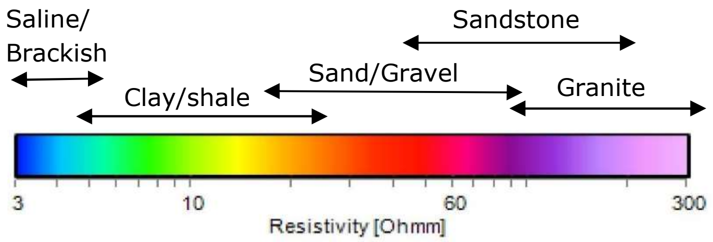
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.

- Terrain/ CGS Geologic Map
- Water level
- Screen

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San Luis Obispo County
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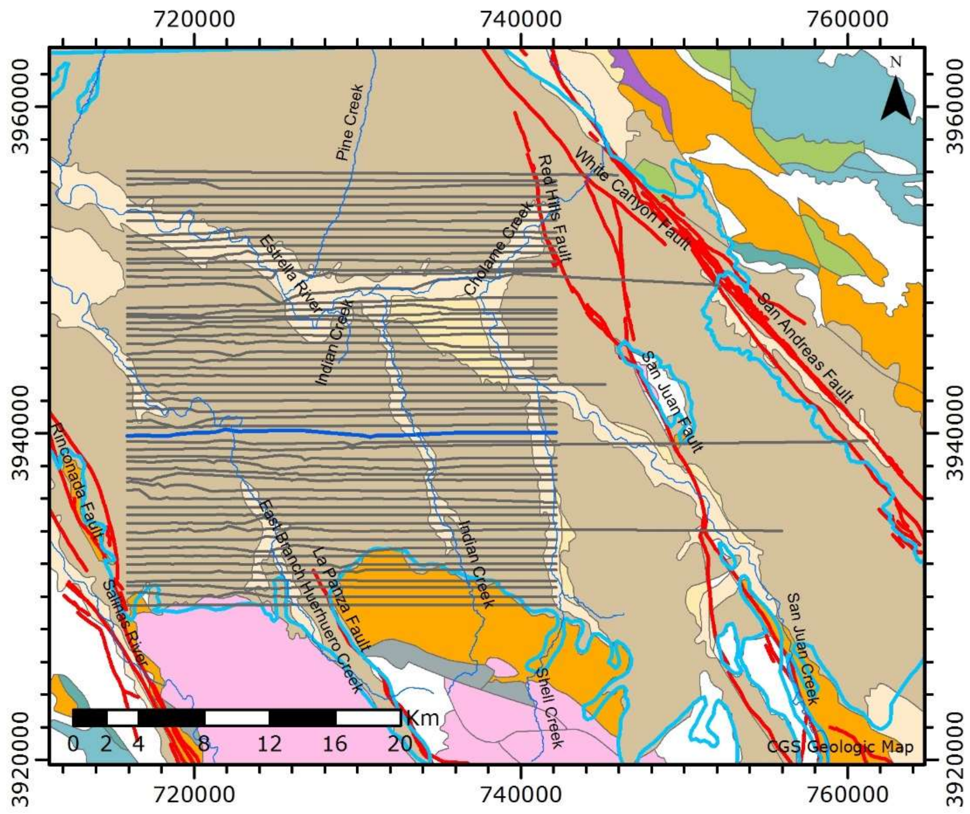
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412

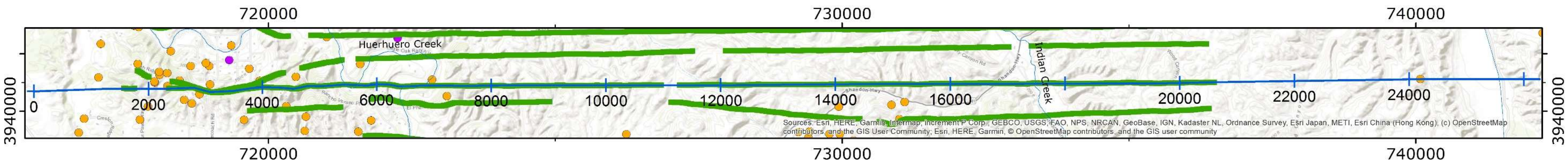


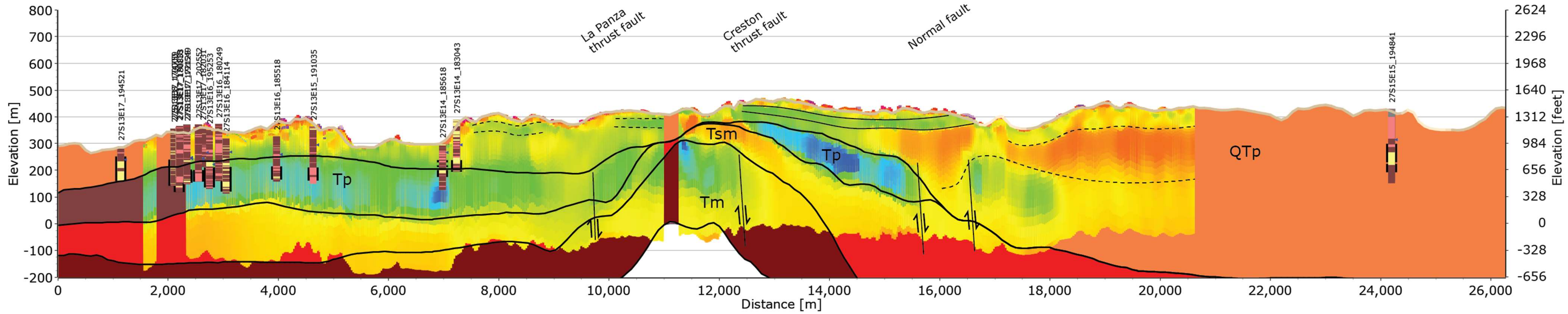
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 23

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

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Approved: MAXH
Project No. 1690013412

Cross section signatures

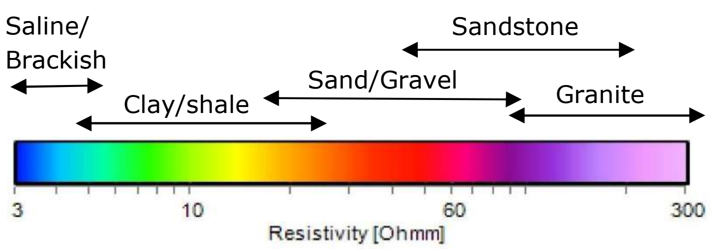
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

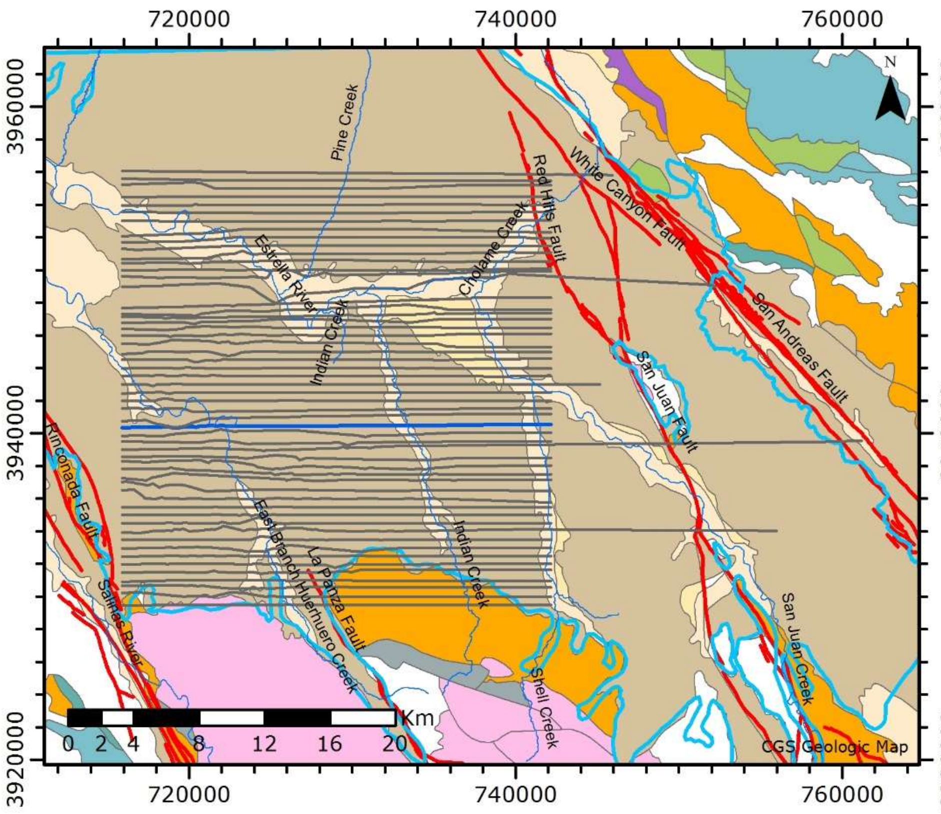
- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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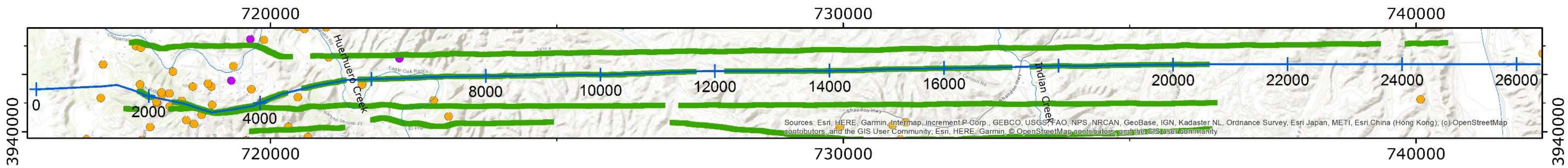
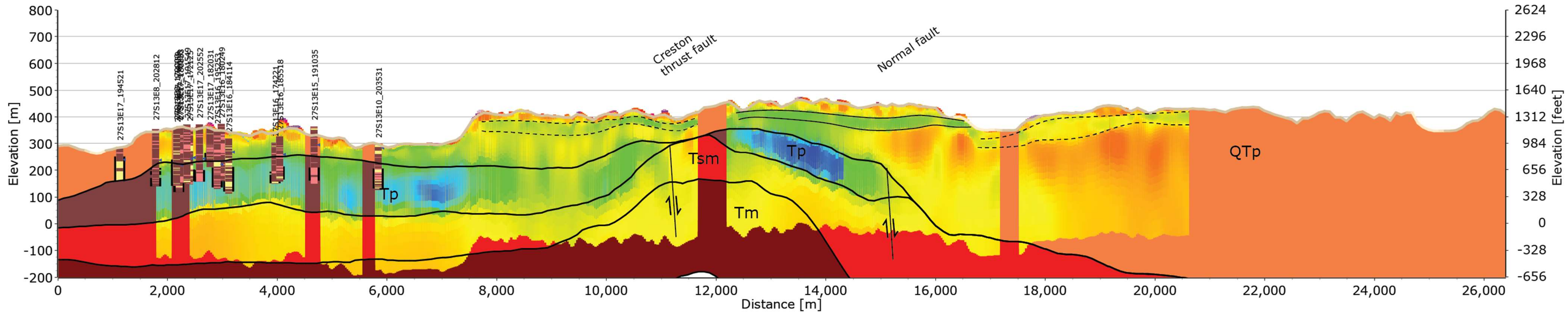
Geologic Cross section 24

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
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- Granite

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Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

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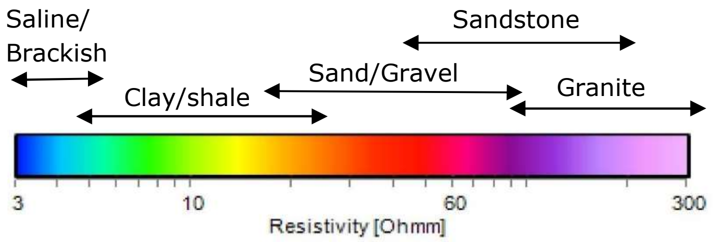
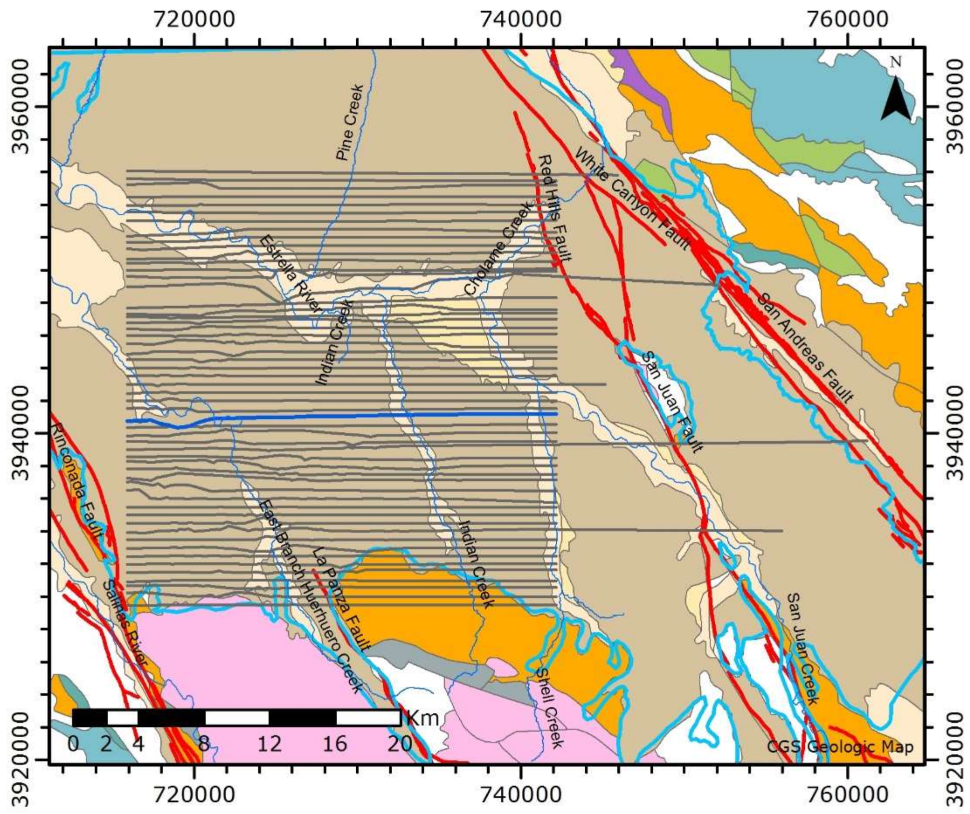
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen

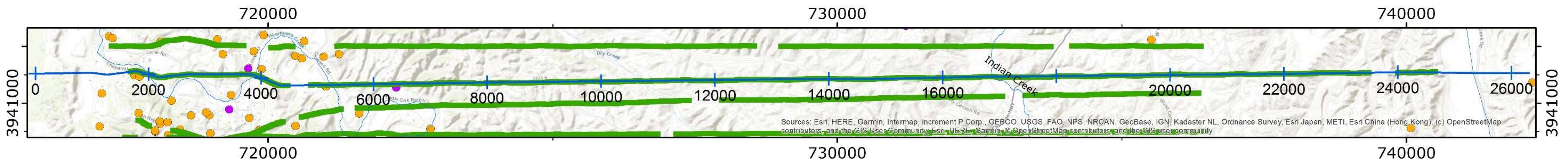


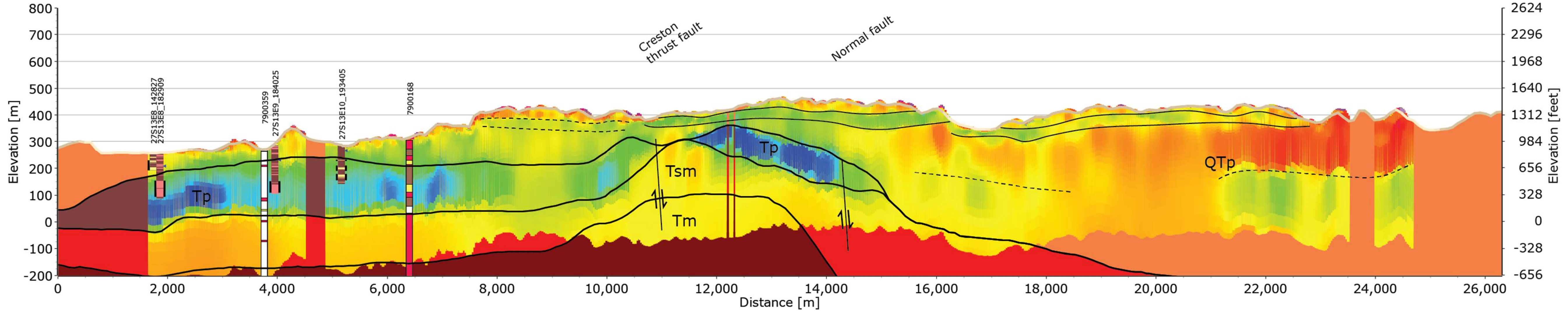
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: .\1690013412\plots\20200421\CrossSections

Geologic Cross section 25

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

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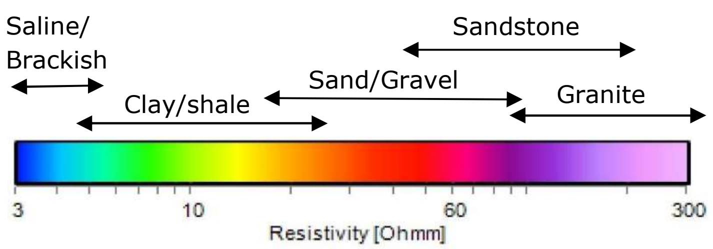
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen

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San Luis Obispo County
Date:2020.06.18
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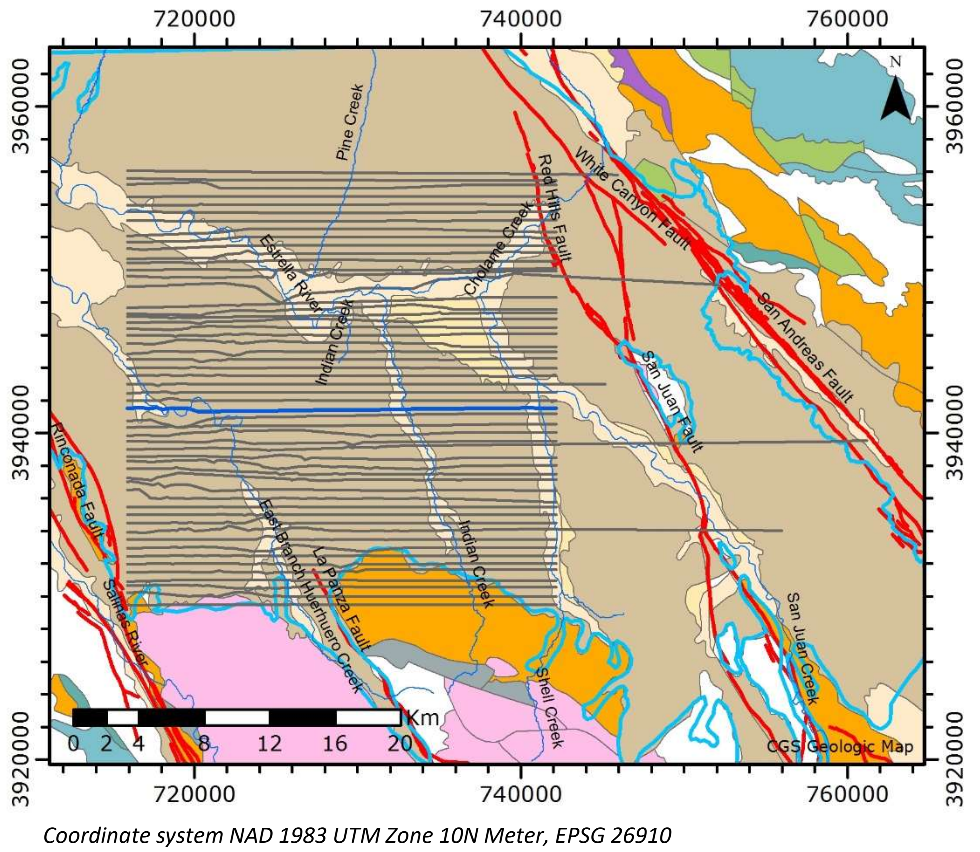

Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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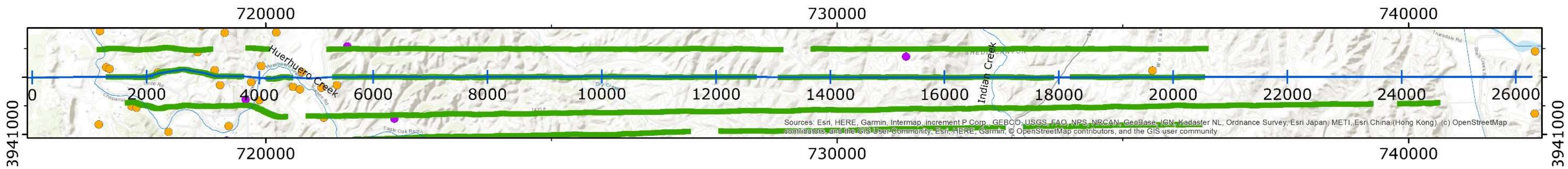
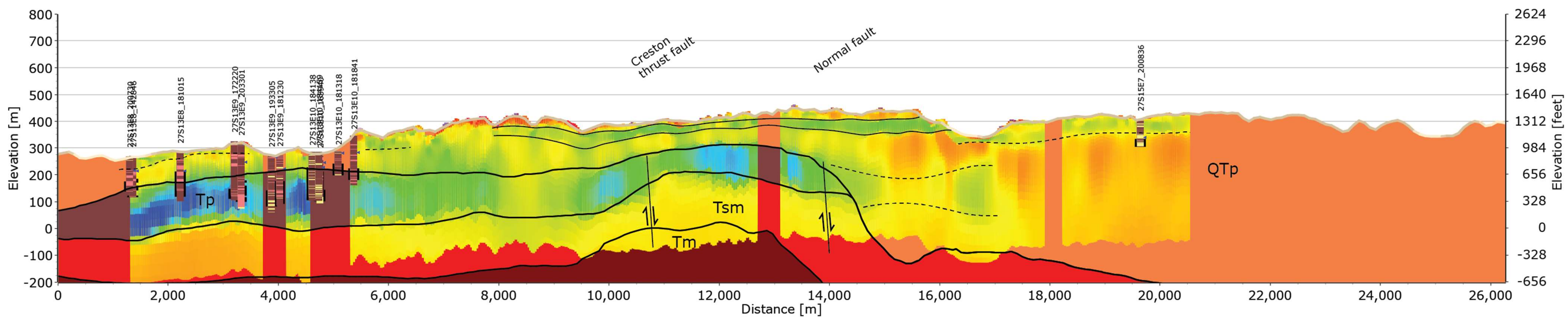
Geologic Cross section 26

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

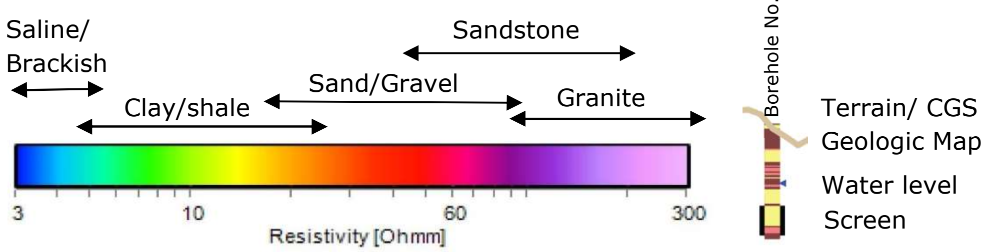
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Groundwater Architecture Project (GAP)
San Luis Obispo County
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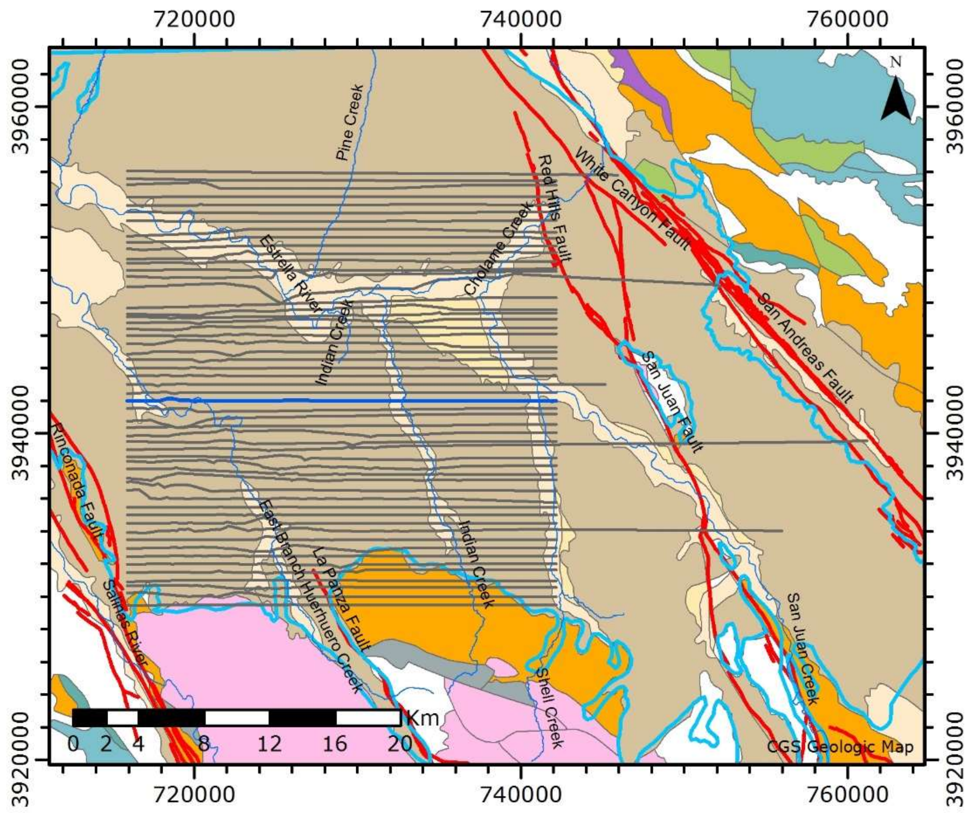


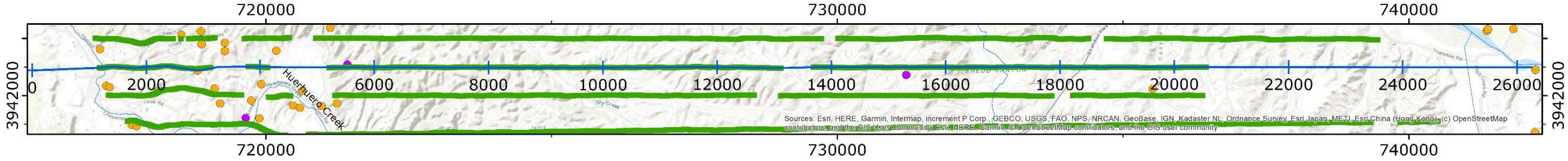
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

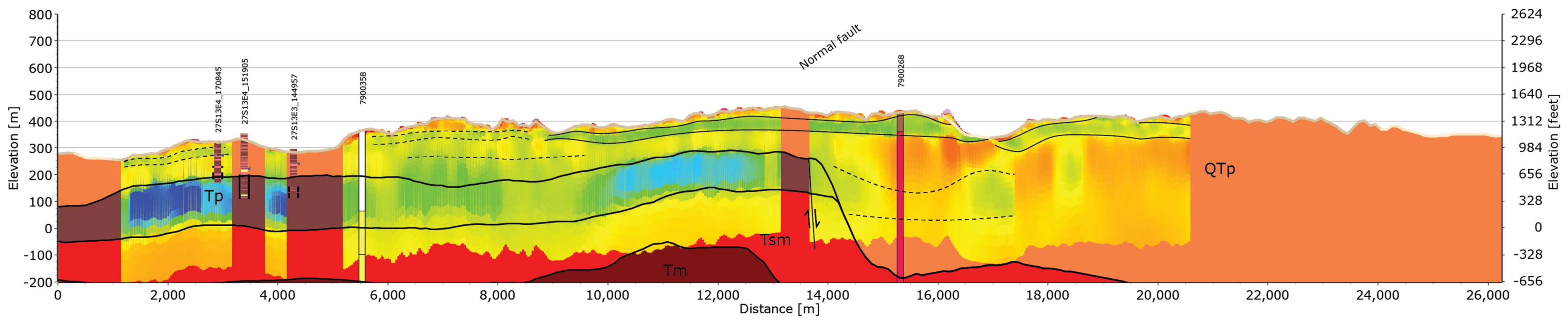
File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 27

Paso Robles Groundwater Basin, Hydrogeological Conceptual Model

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
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- Plio-Pleistocene sandstone/shale/gravel
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- Granite

Groundwater Architecture Project (GAP)
San Luis Obispo County
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Control: PATH
Approved: MAXH
Project No. 1690013412

Cross section signatures

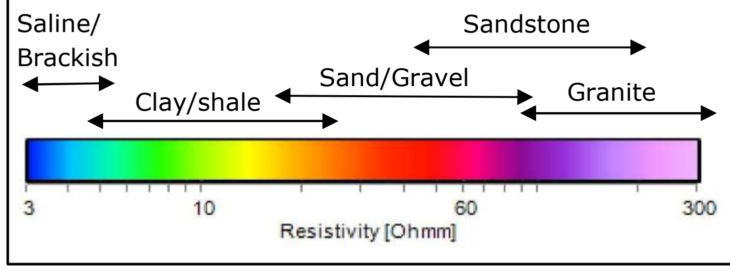
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown

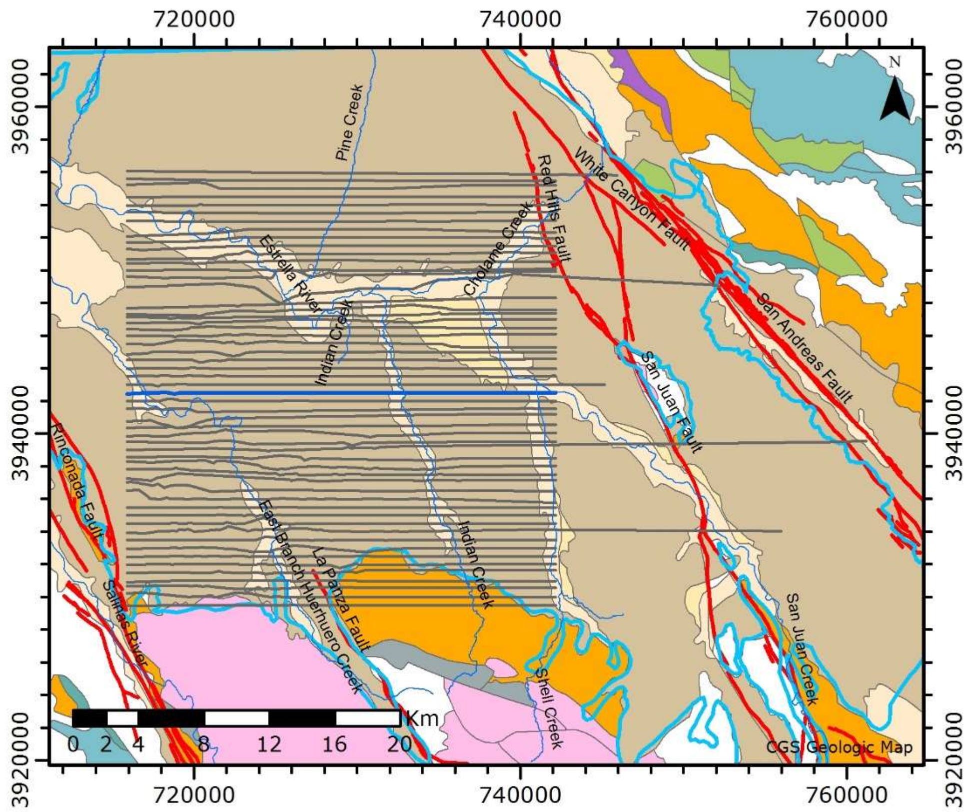


Borehole No.

Terrain/ CGS Geologic Map

Water level

Screen

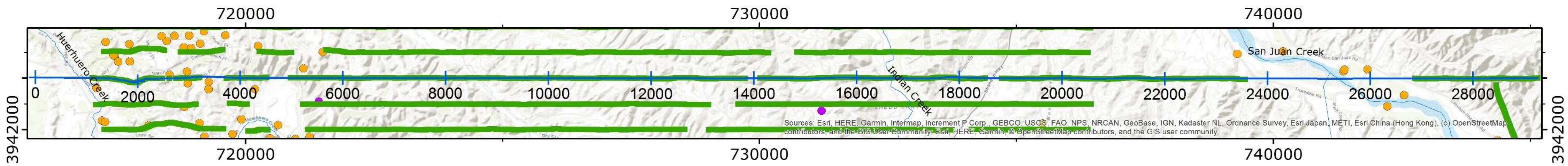


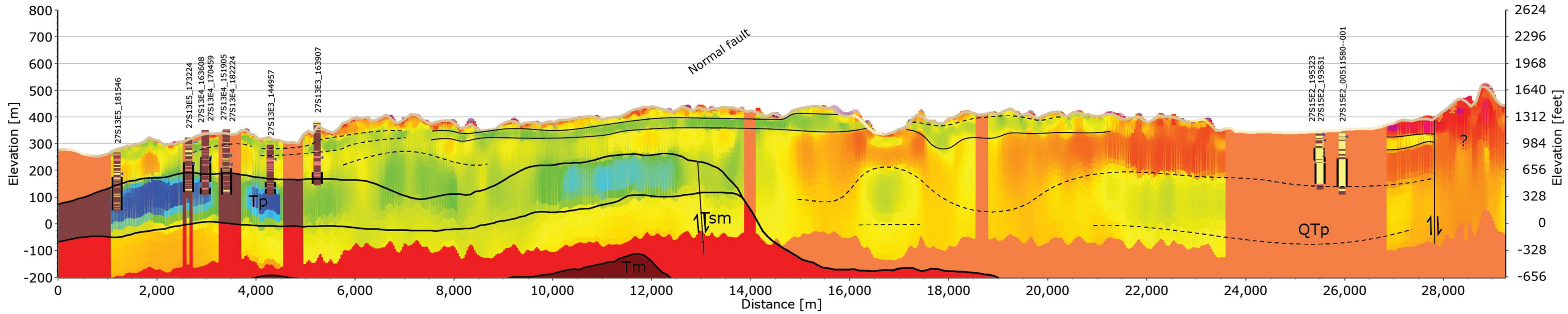
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 28

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

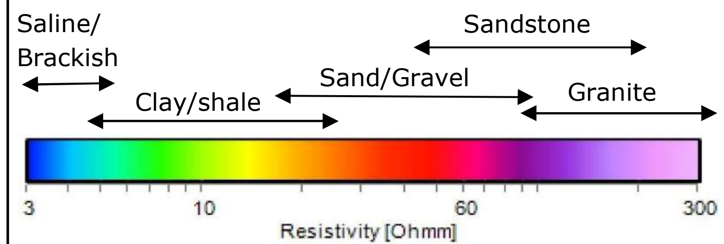
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown

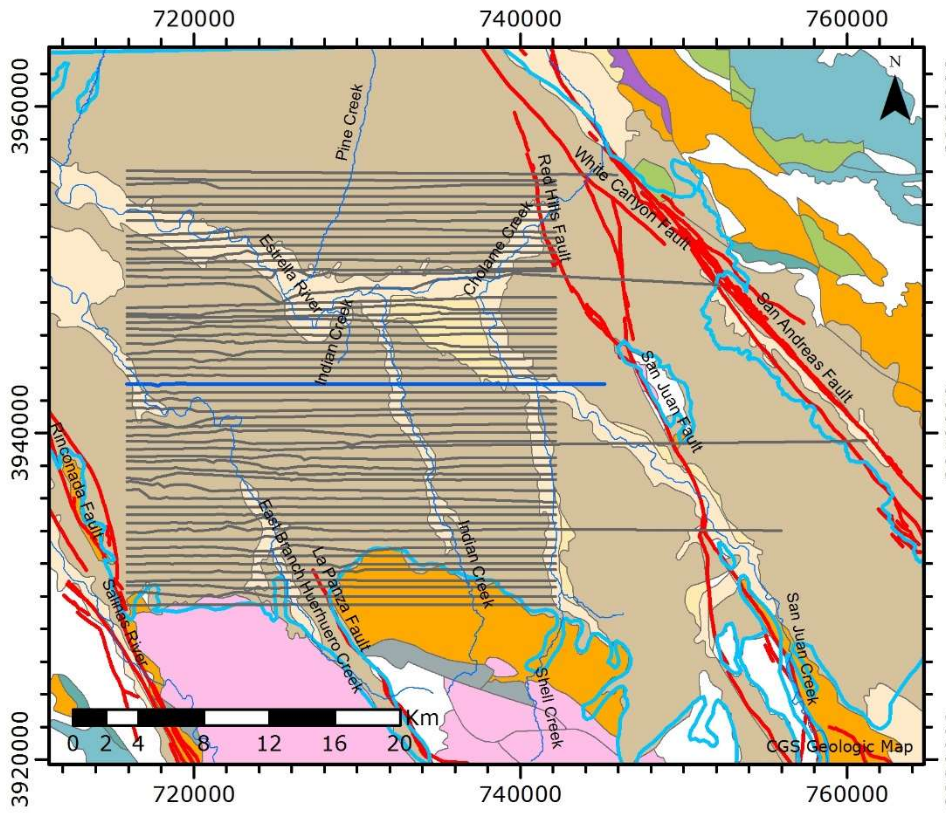


Borehole No.

Terrain/ CGS Geologic Map

Water level

Screen



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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San Luis Obispo County
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Control: PATH
Approved: MAXH
Project No. 1690013412

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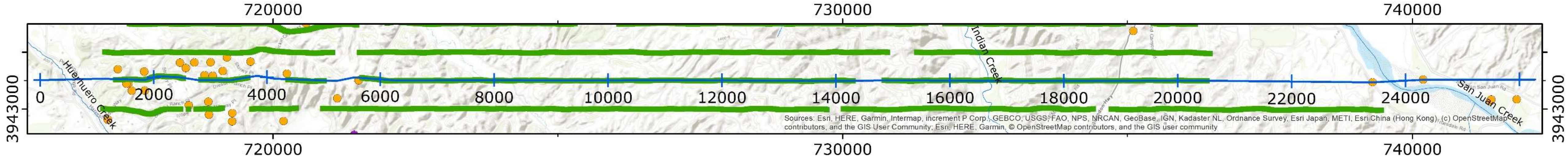
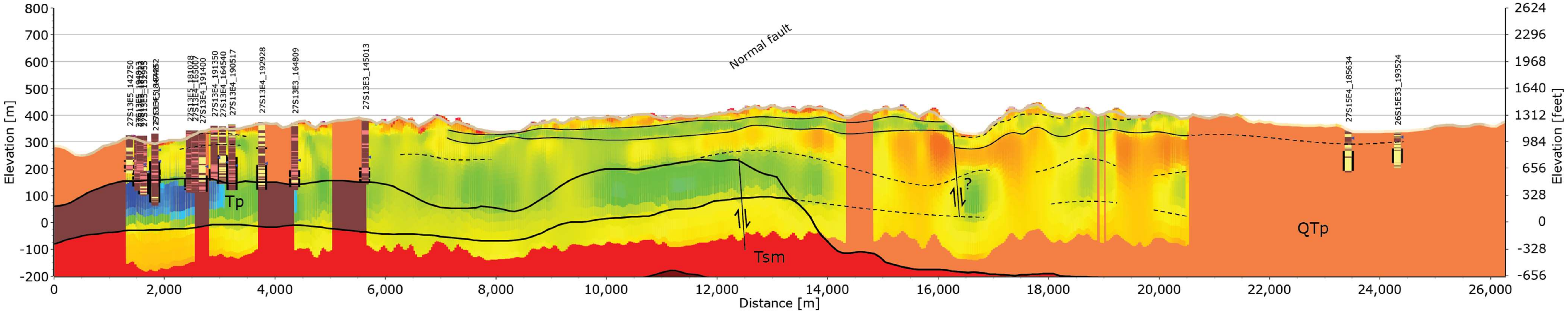
Geologic Cross section 29

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

- Geologic unit boundaries
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- Structural boundaries, uncertain
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Geologic Units

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Borehole lithology

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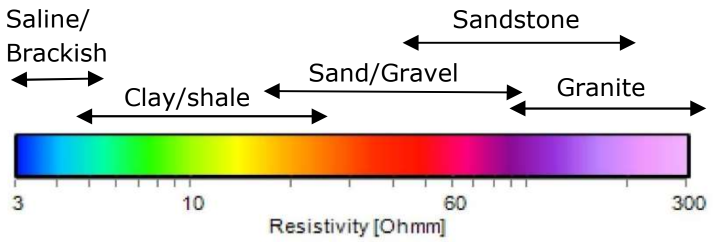
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.

Terrain/ CGS Geologic Map

Water level

Screen

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San Luis Obispo County
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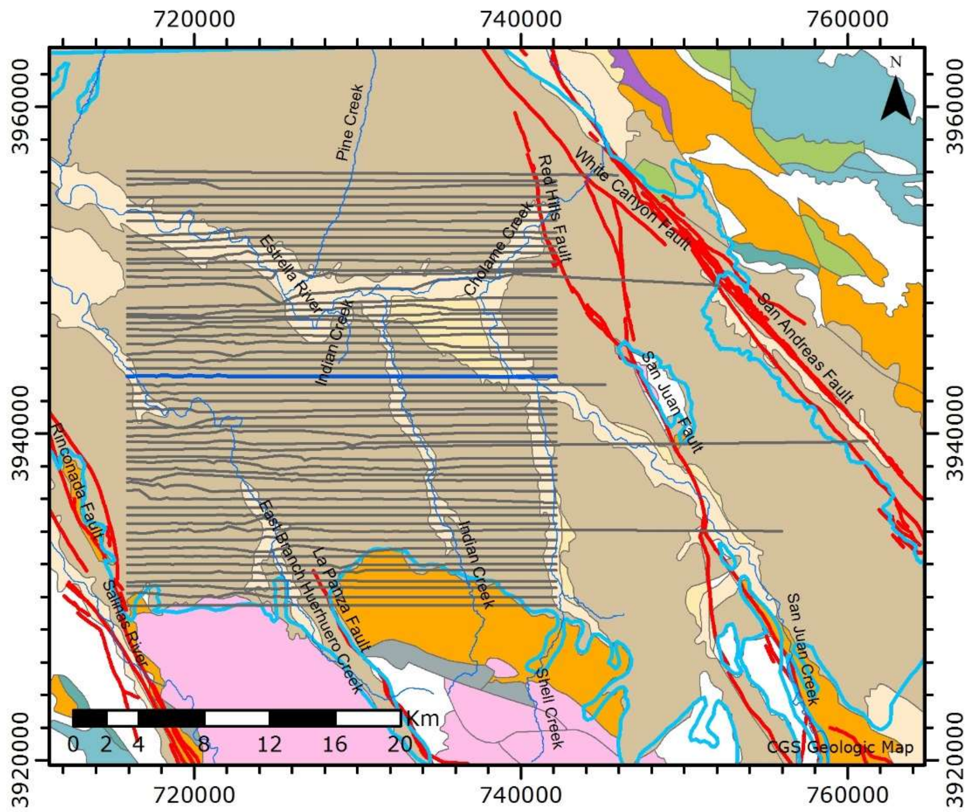
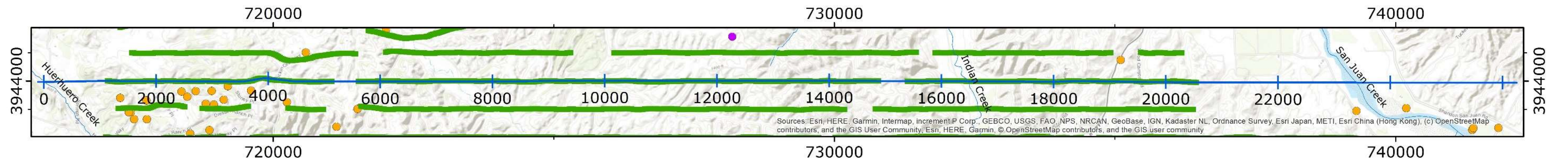


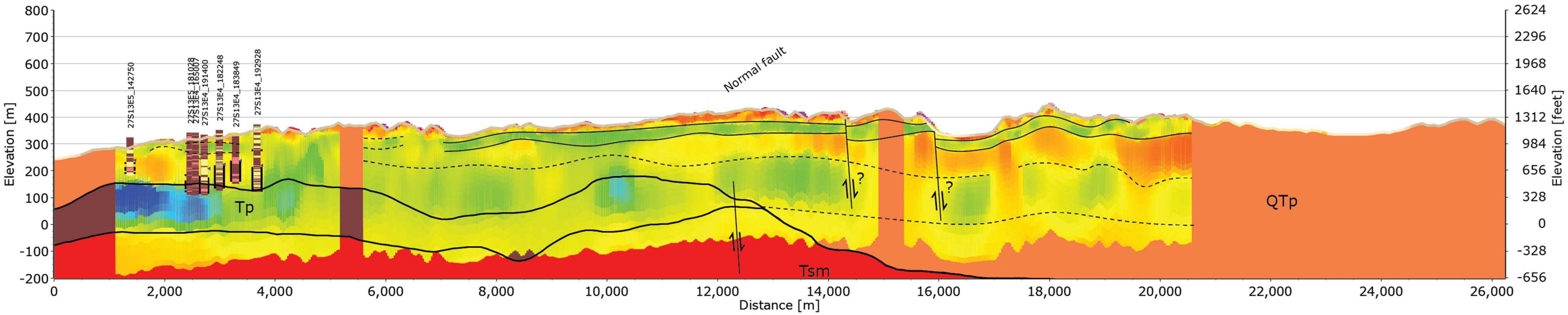
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Geologic Cross section 30

Paso Robles Groundwater Basin, Hydrogeological Conceptual Model

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
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Groundwater Architecture Project (GAP)
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Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

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- Santa Margarita Sandstone, Tsm
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Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown

Saline/ Brackish

Clay/shale

Sand/Gravel

Sandstone

Granite

3 10 60 300

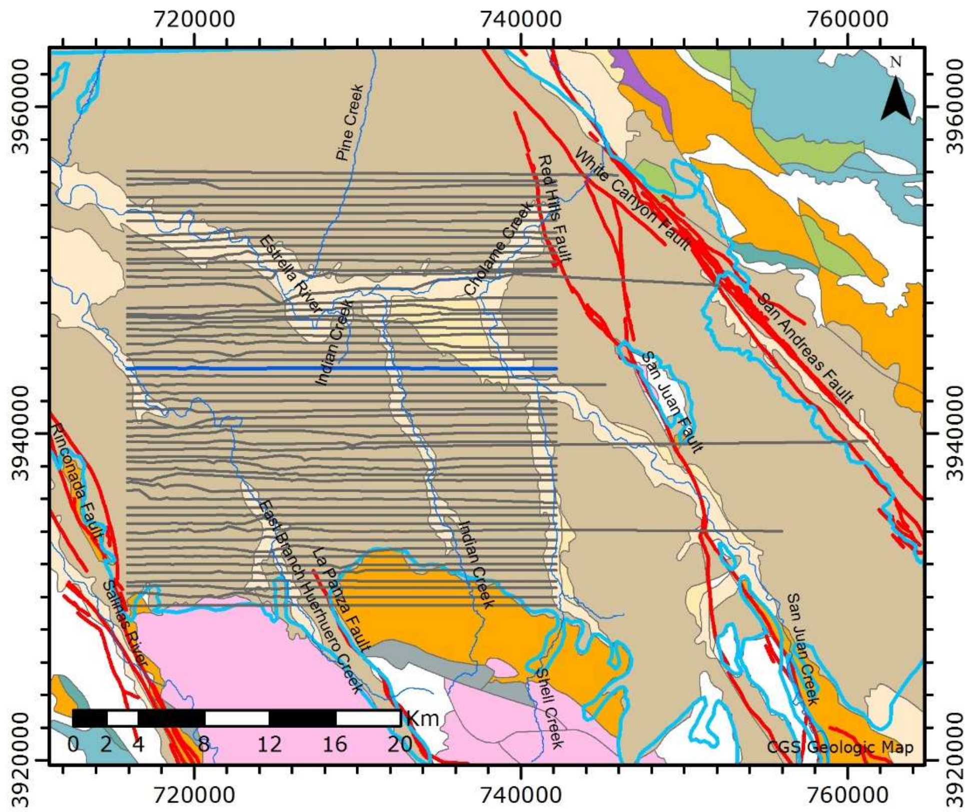
Resistivity [Ohmm]

Borehole No.

Terrain/ CGS Geologic Map

Water level

Screen

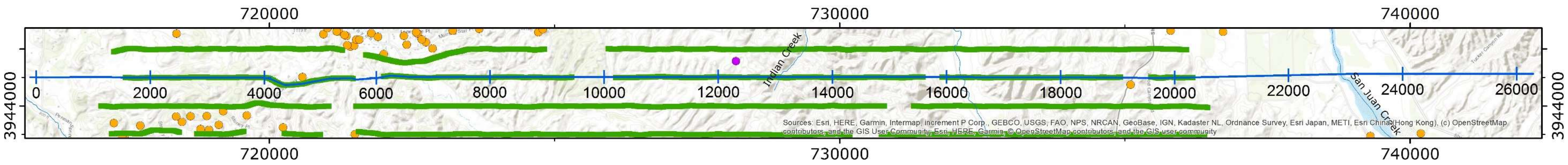


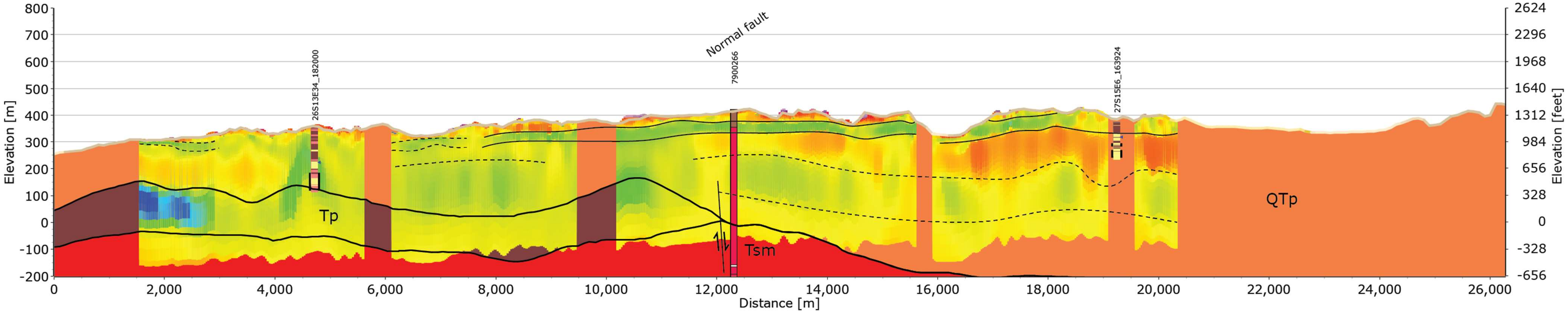
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 31

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

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Borehole lithology

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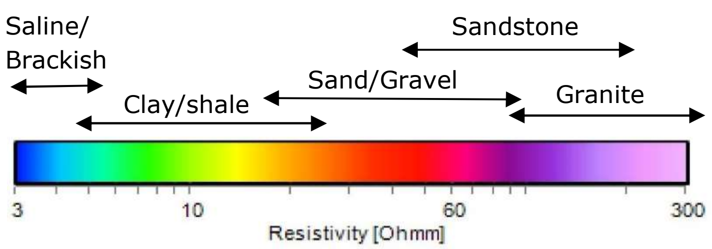
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen

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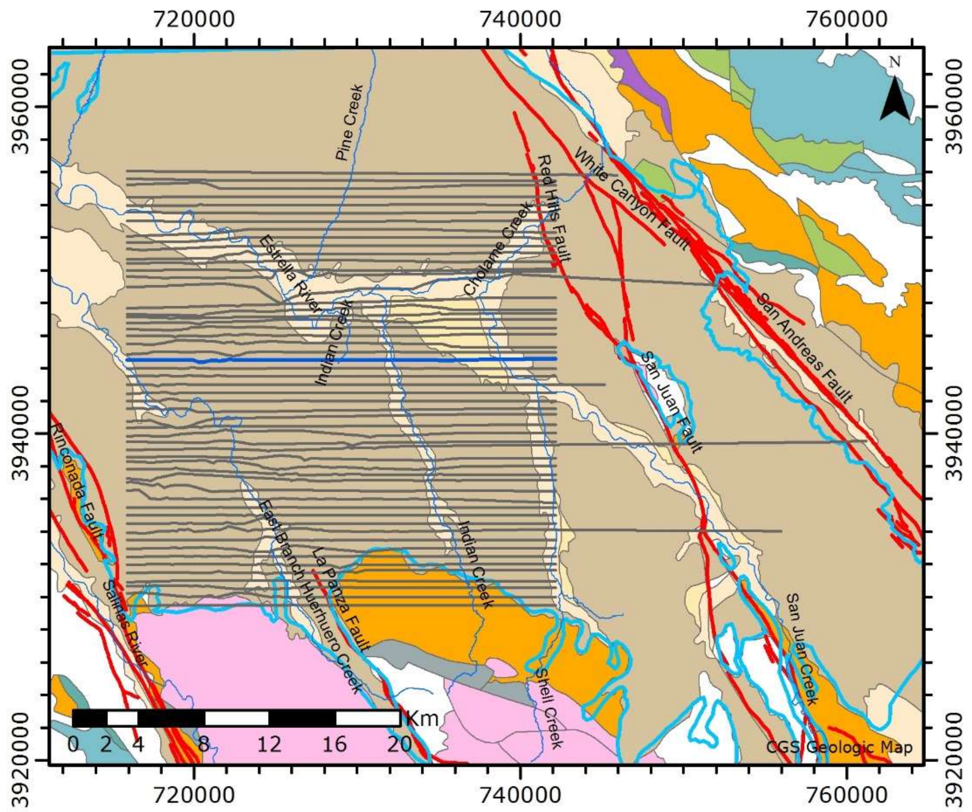

Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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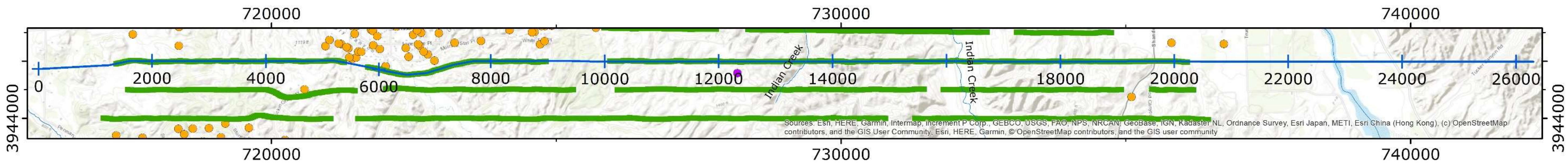
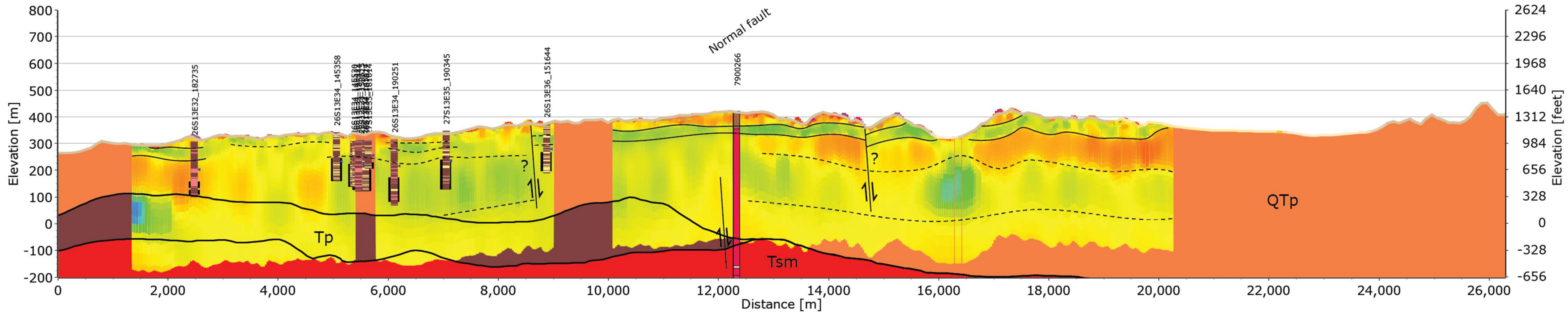
Geologic Cross section 32





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

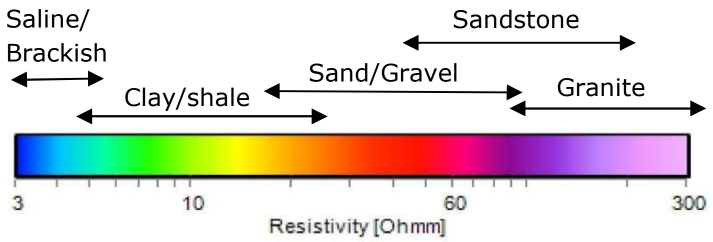
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.

Terrain/ CGS Geologic Map

Water level

Screen

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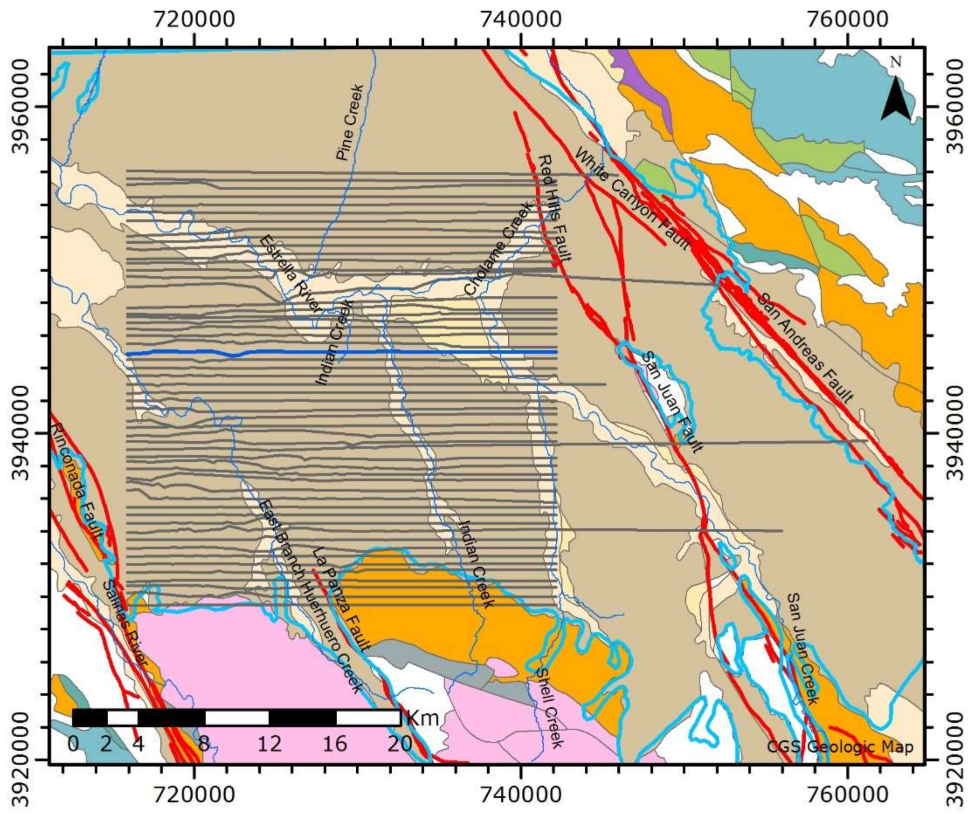
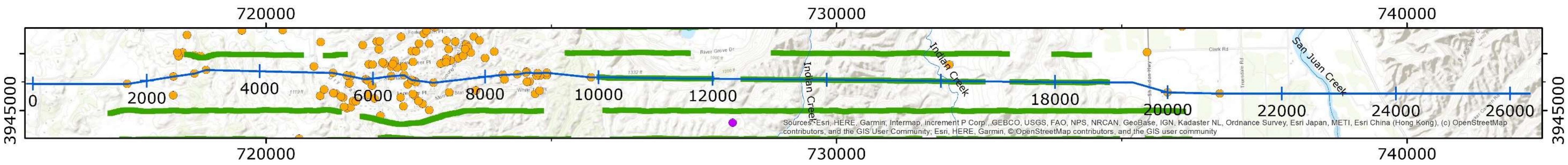
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412

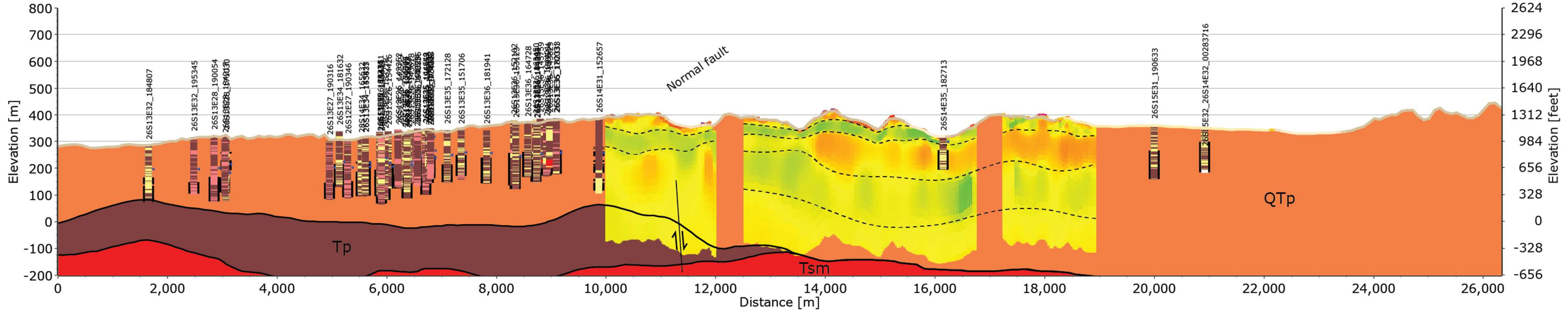


Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 33





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

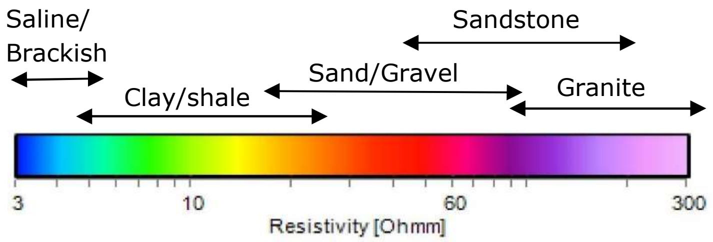
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

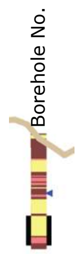
Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



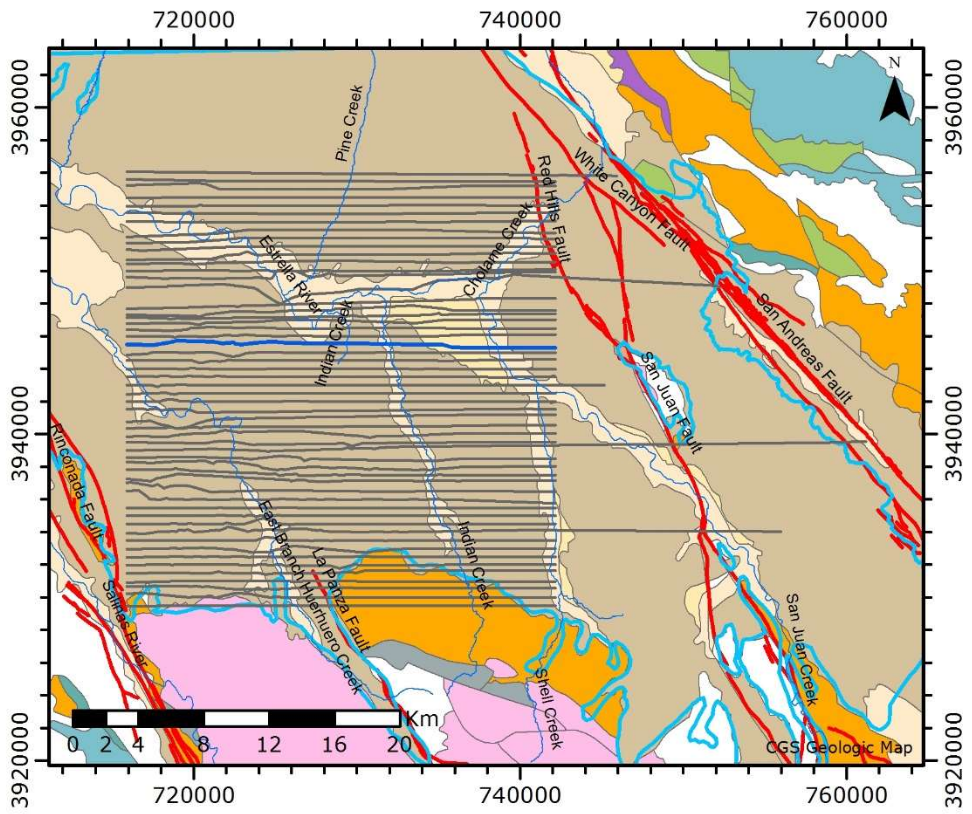


Terrain/ CGS Geologic Map

Water level

Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412



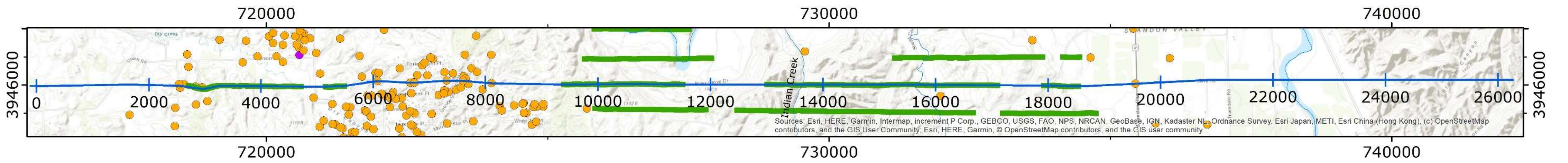
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

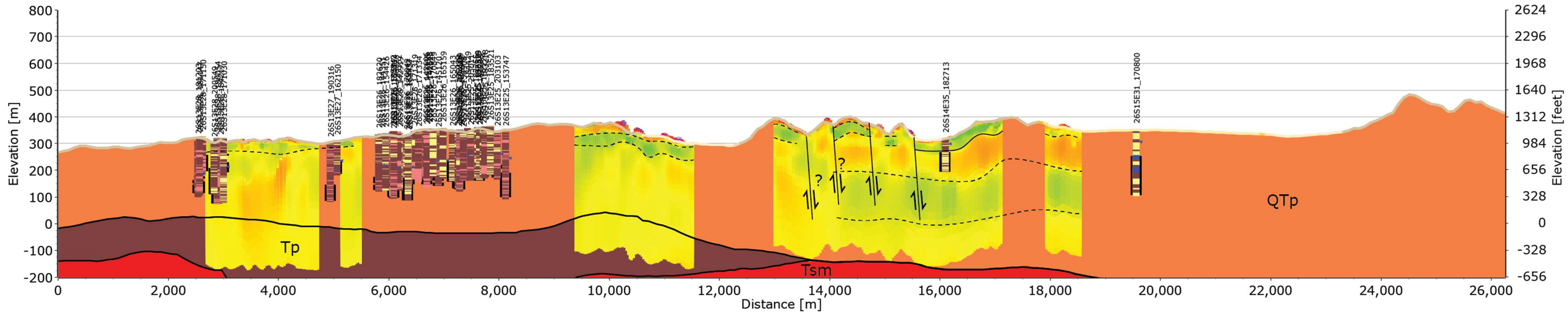
File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 34

Paso Robles Groundwater Basin, Hydrogeological Conceptual Model

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

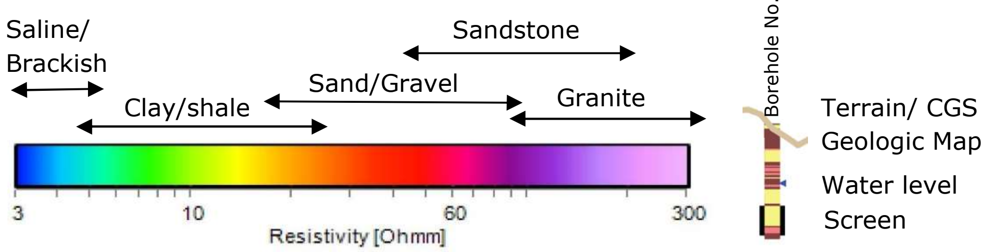
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

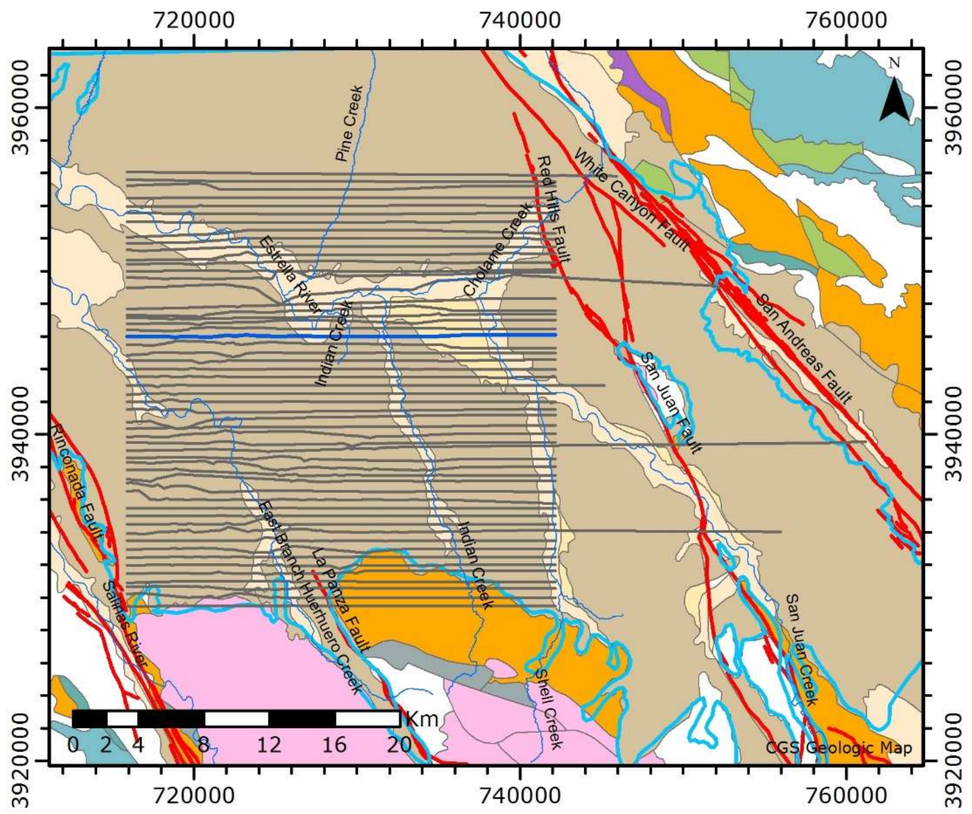
Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown





Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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San Luis Obispo County
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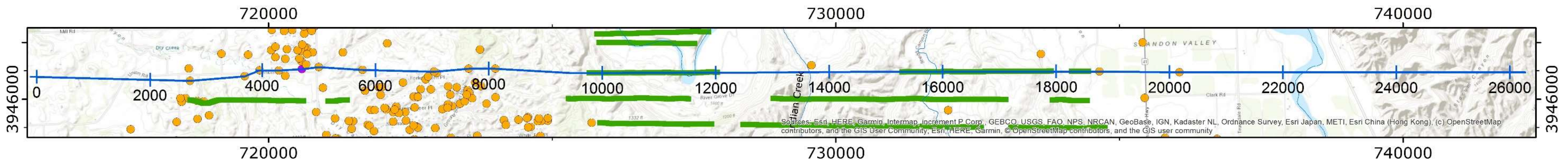
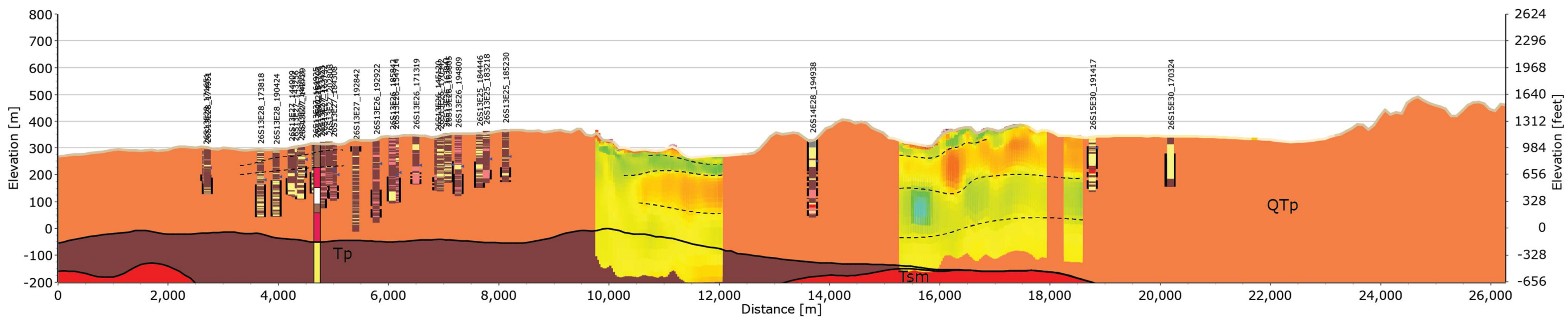
Geologic Cross section 35

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

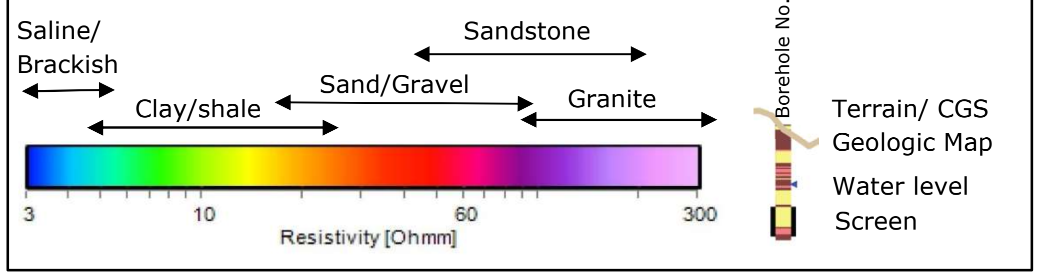
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
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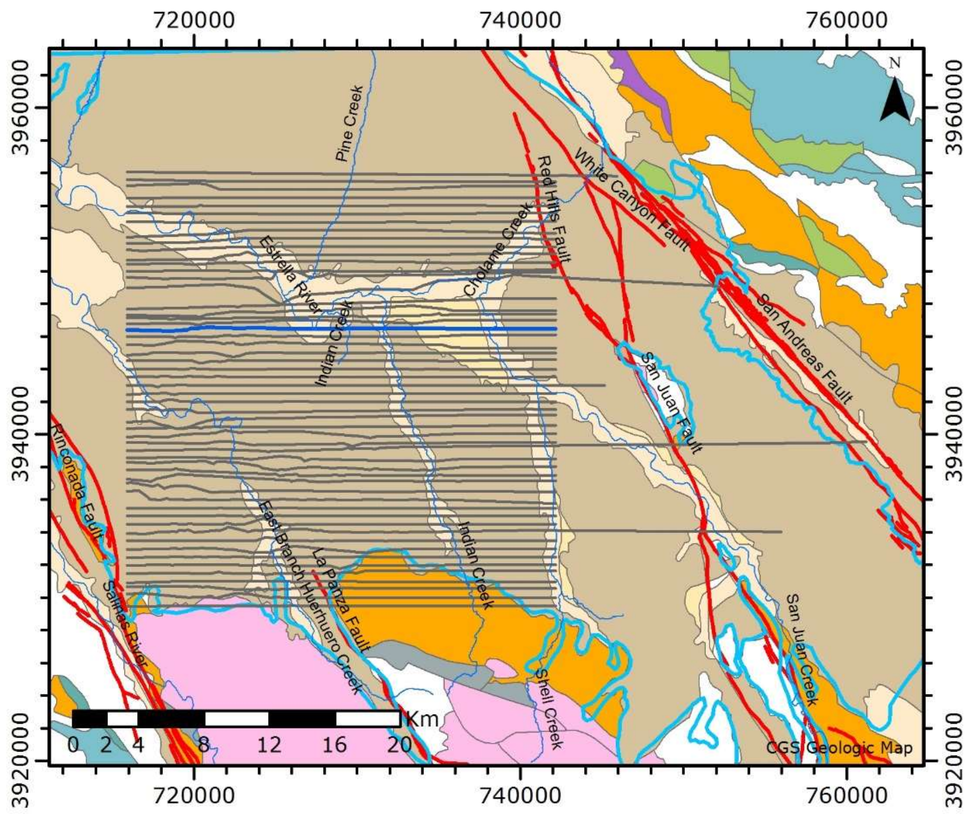
Approved: MAXH
Project No. 1690013412

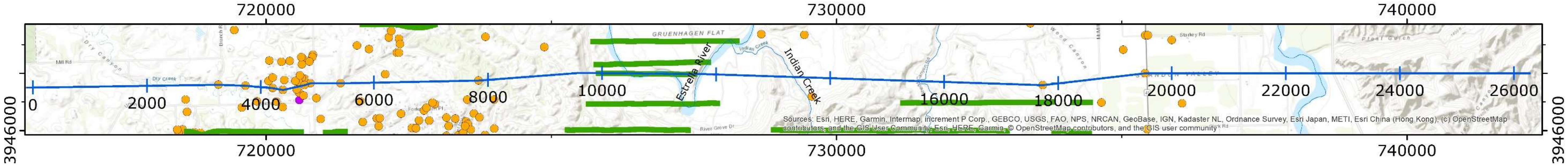


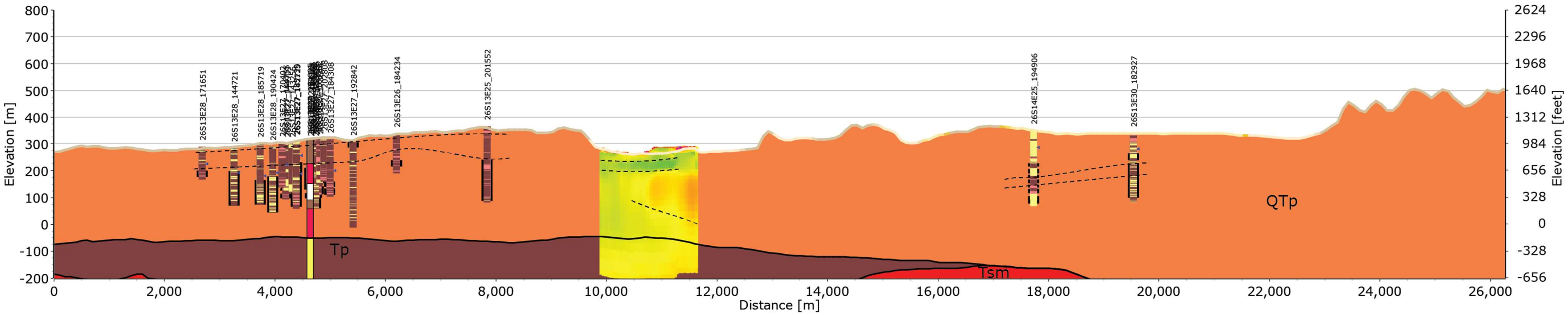
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: .\1690013412\plots\20200421\CrossSections

Geologic Cross section 36

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

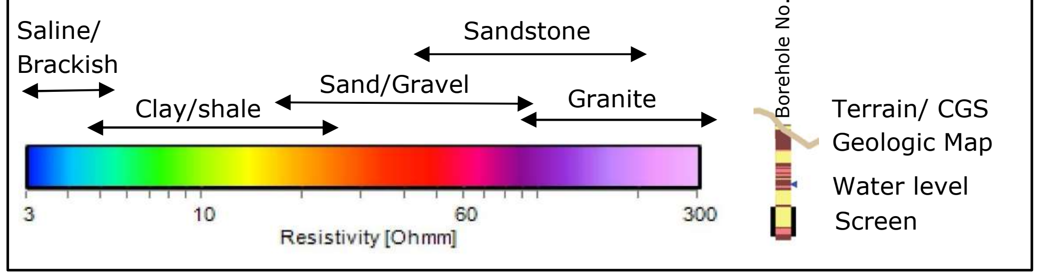
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

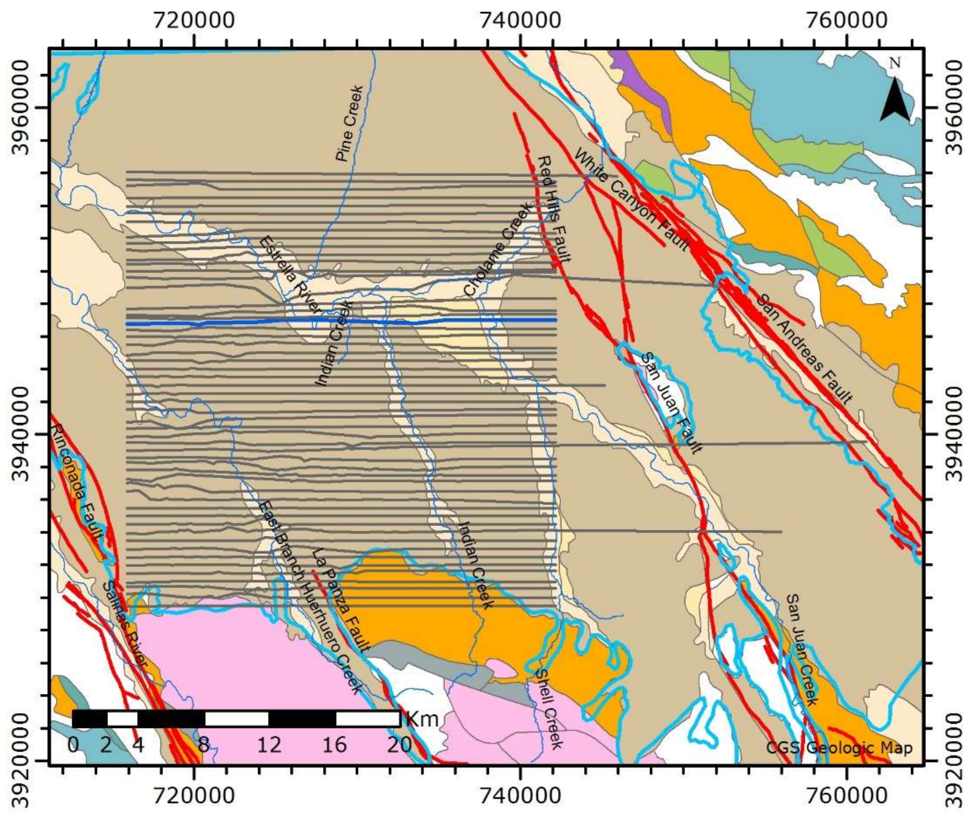
Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown





Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
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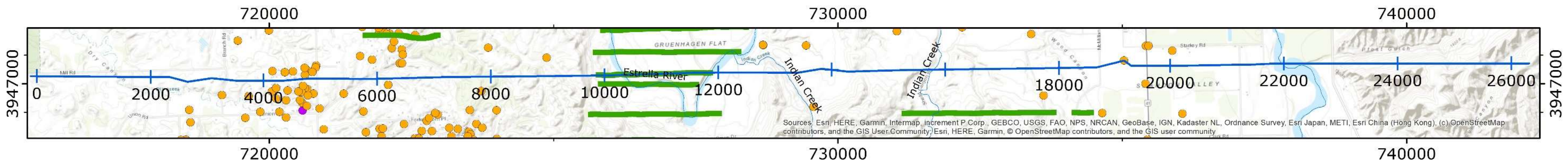
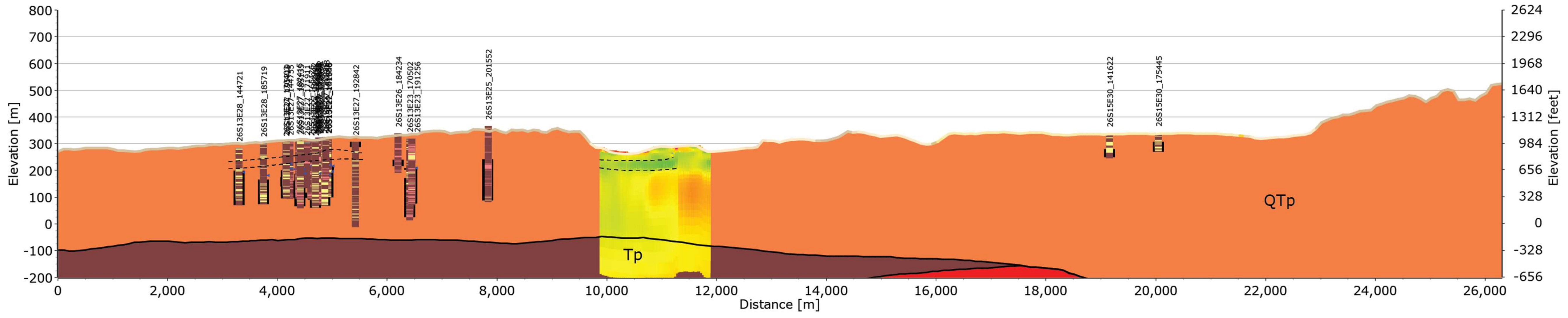
Geologic Cross section 37

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown

Saline/ Brackish

Clay/shale

Sand/Gravel

Sandstone

Granite

3 10 60 300

Resistivity [Ohmm]

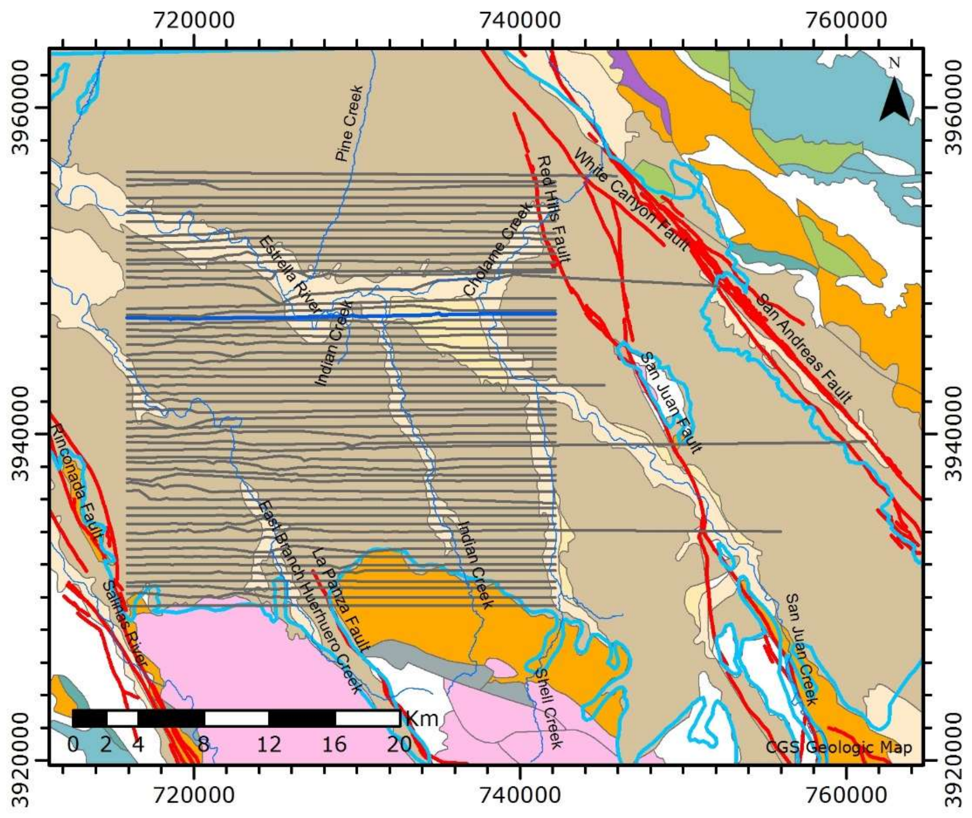
Borehole No.

Terrain/ CGS Geologic Map

Water level

Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412



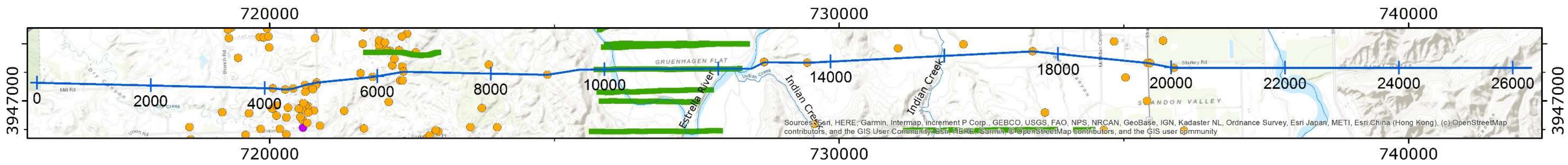
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

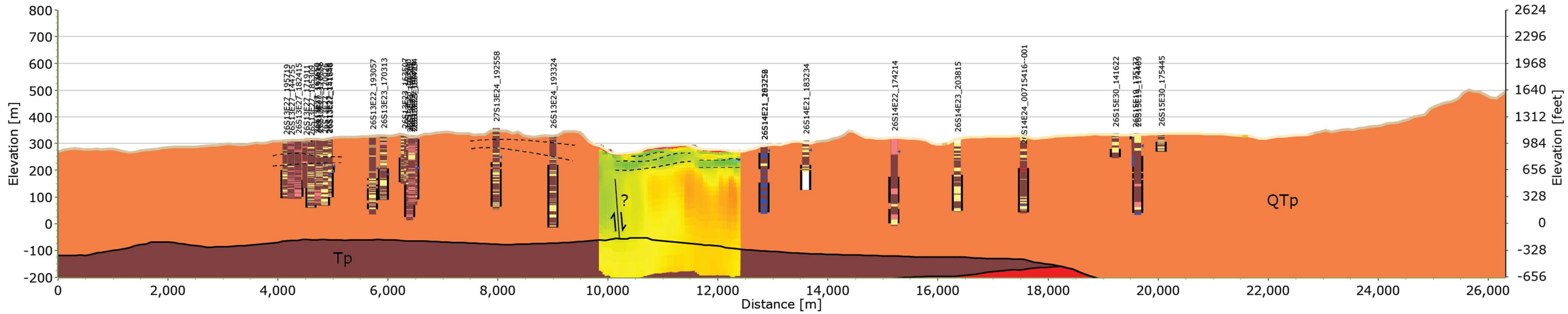
File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 38

Paso Robles Groundwater Basin, Hydrogeological Conceptual Model

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Groundwater Architecture Project (GAP)
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By: TLM, MAXH
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Approved: MAXH
Project No. 1690013412

Cross section signatures

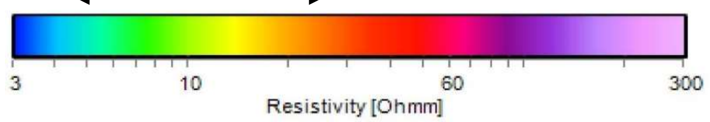
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

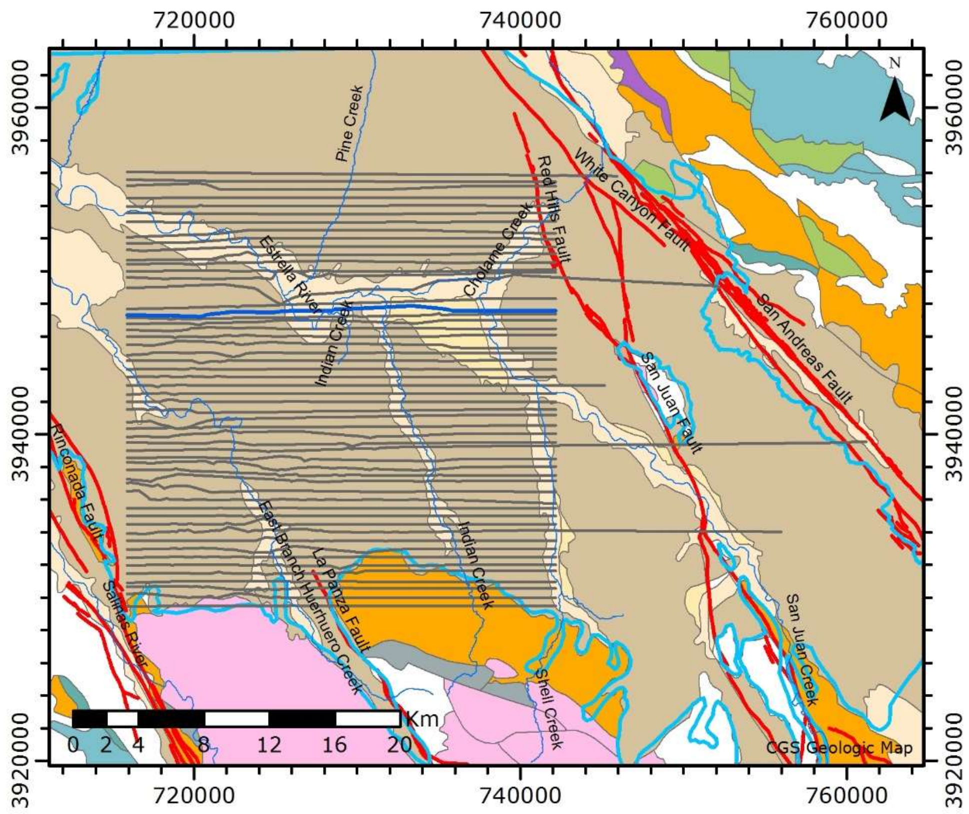
- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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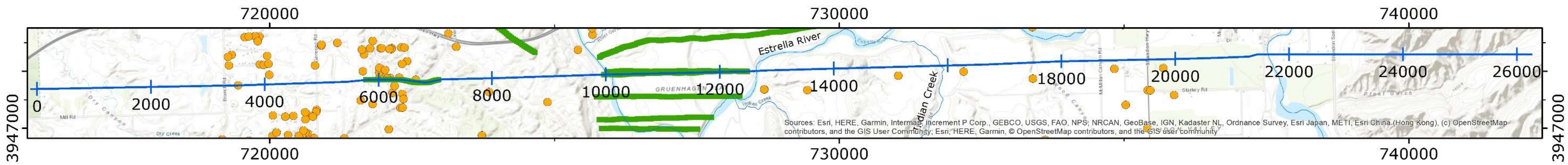
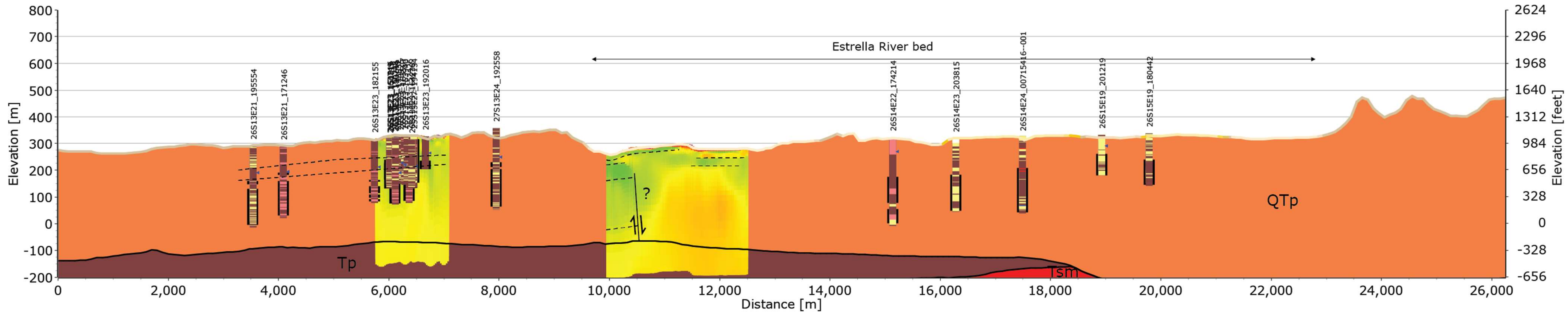
Geologic Cross section 39

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Groundwater Architecture Project (GAP)
San Luis Obispo County
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Control: PATH
Approved: MAXH
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Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

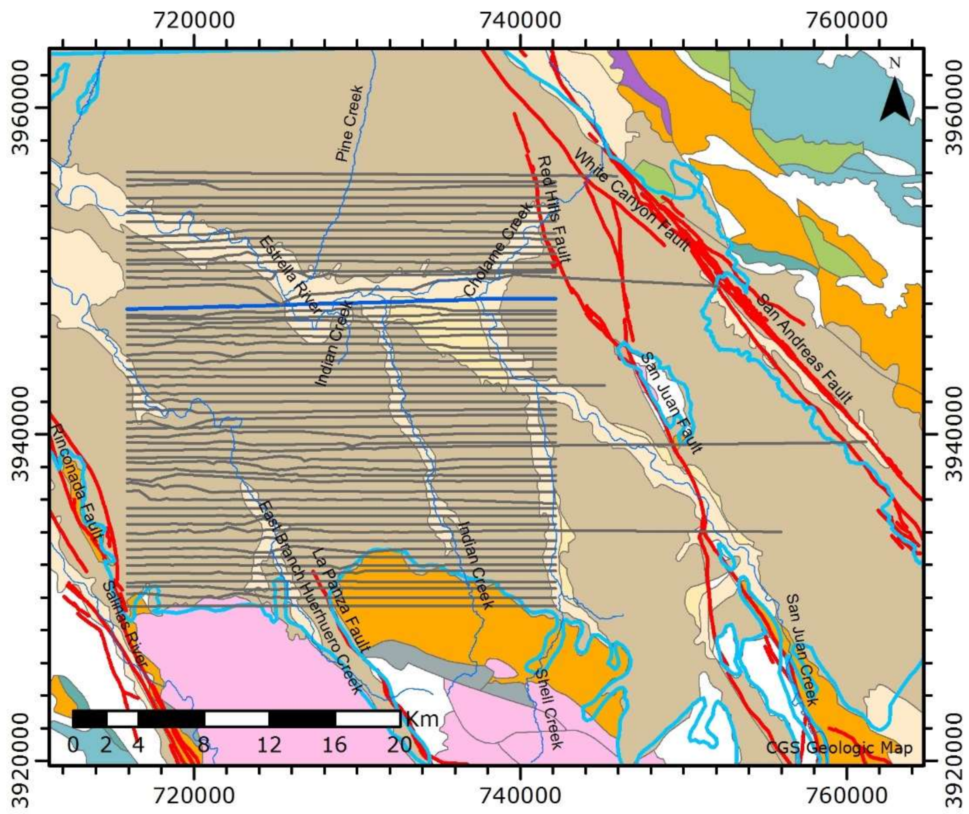
Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown

Saline/ Brackish
Clay/shale
Sand/Gravel
Sandstone
Granite

3 10 60 300
Resistivity [Ohmm]

Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen

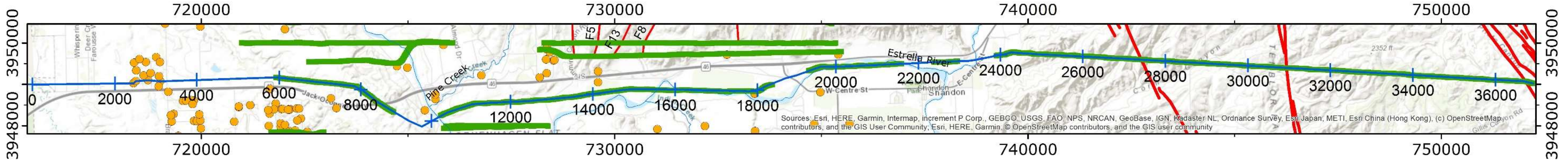


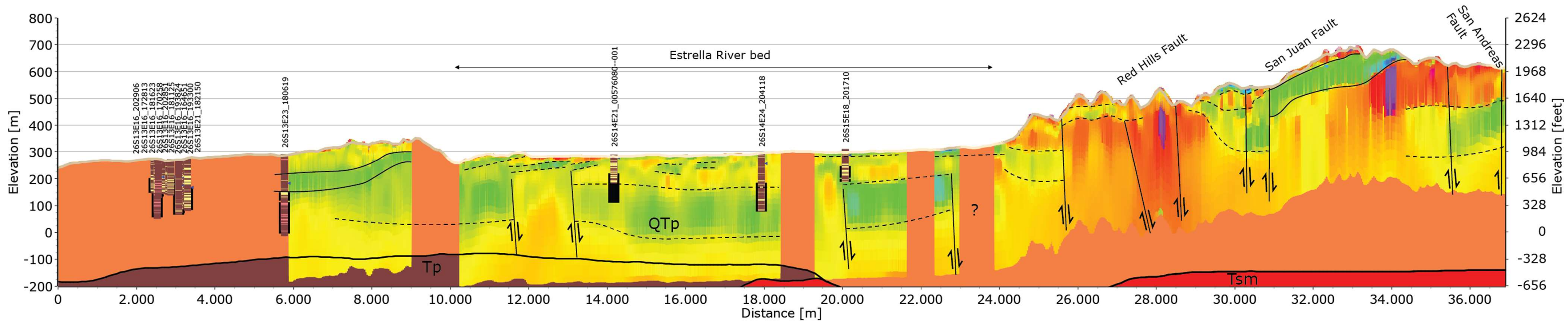
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 40

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Groundwater Architecture Project (GAP)
San Luis Obispo County
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Cross section signatures

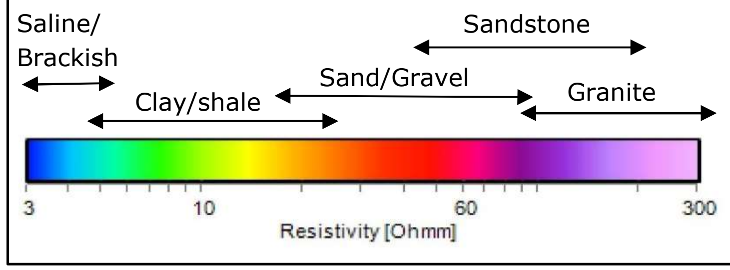
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

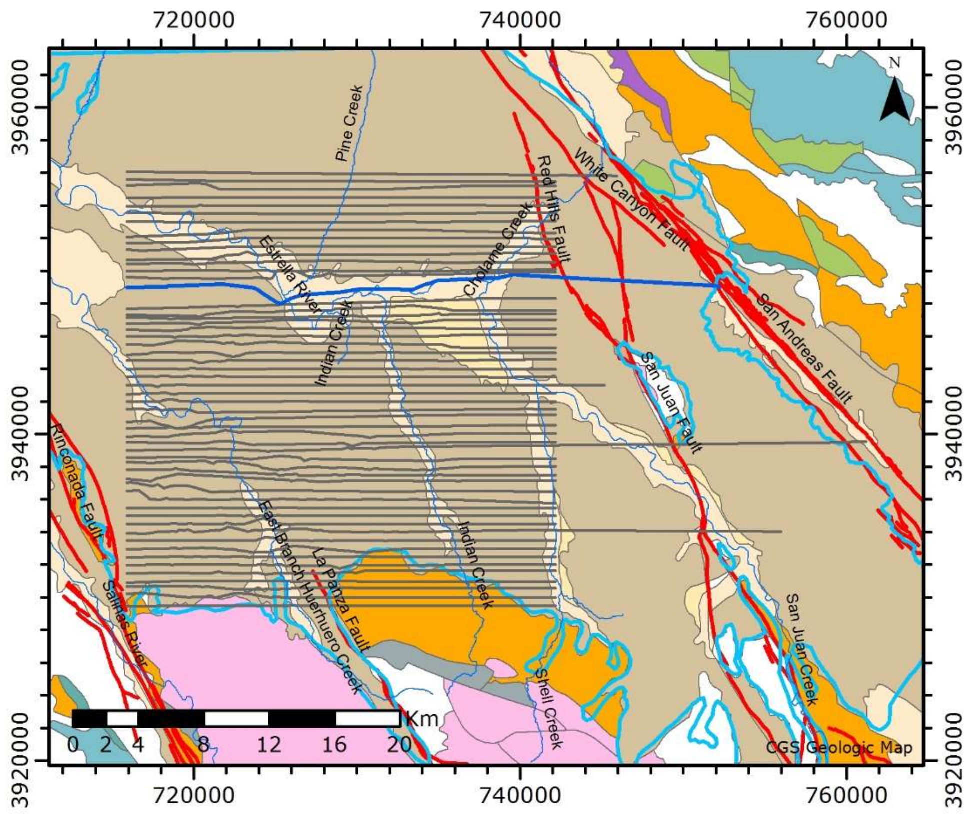
- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



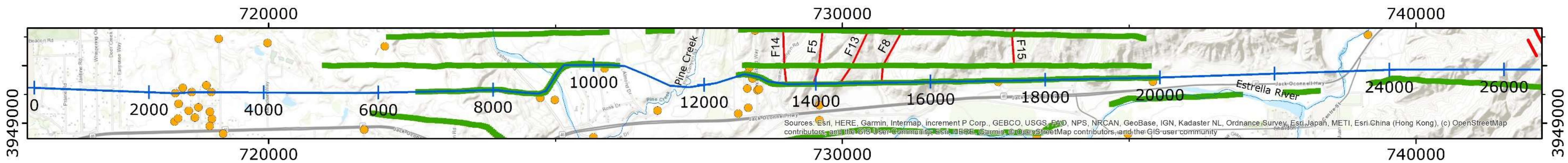
Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen

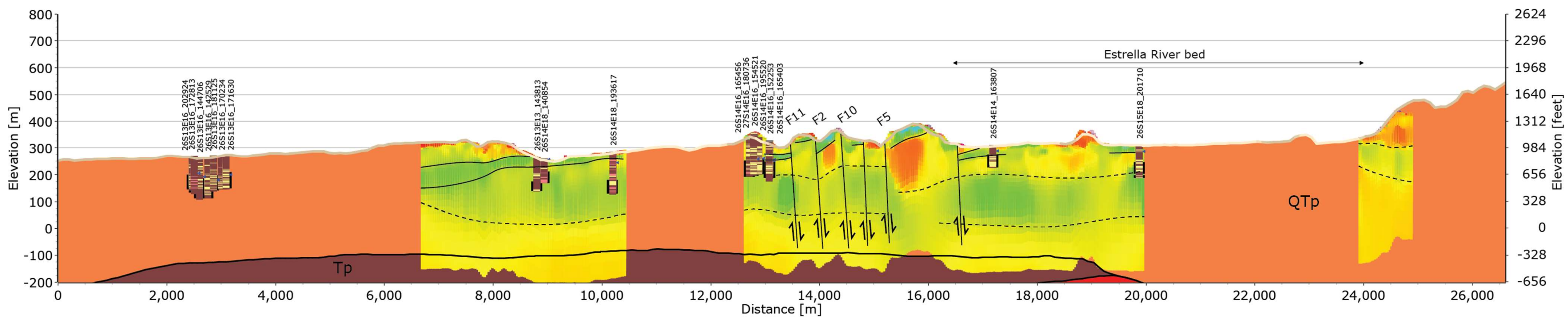


Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: .\1690013412\plots\20200421\CrossSections

Geologic Cross section 41





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Groundwater Architecture Project (GAP)
San Luis Obispo County
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Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

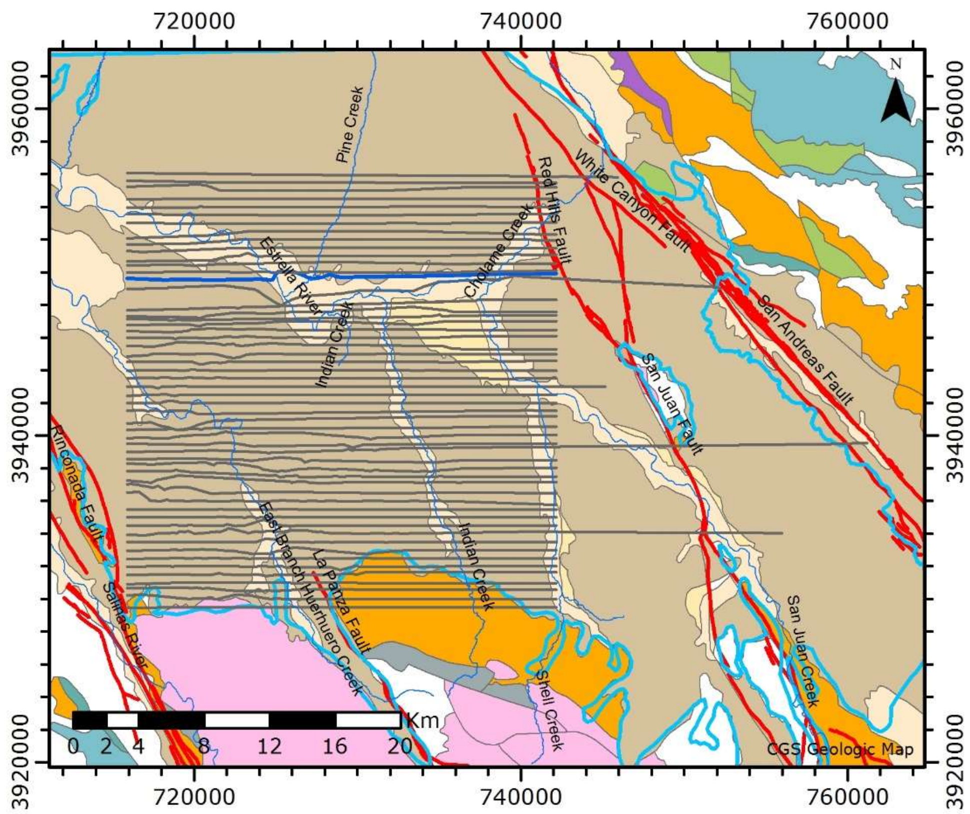
Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown

Saline/ Brackish
Clay/shale
Sand/Gravel
Sandstone
Granite

3 10 60 300
Resistivity [Ohmm]

Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen

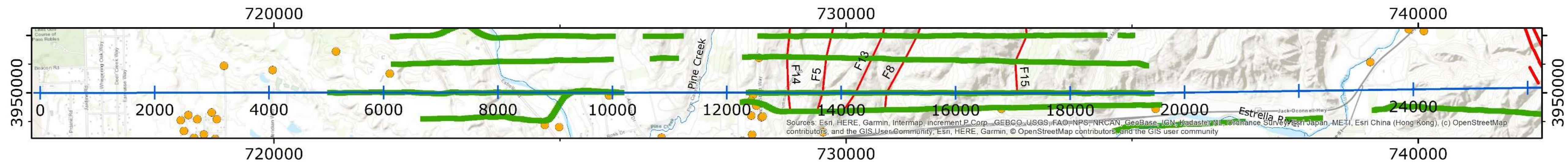


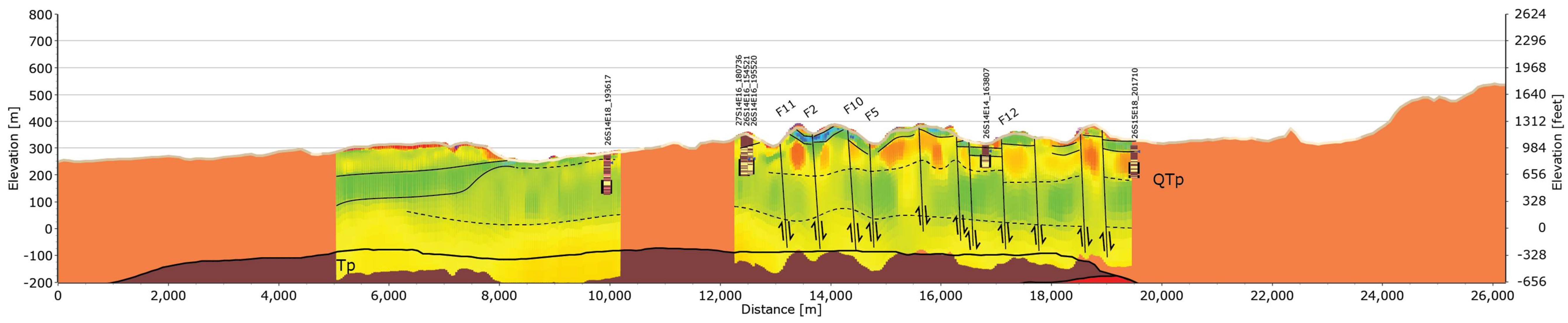
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 42

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

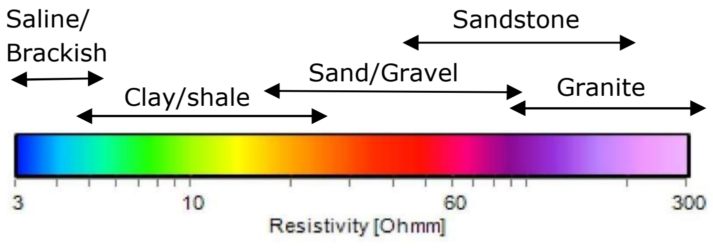
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

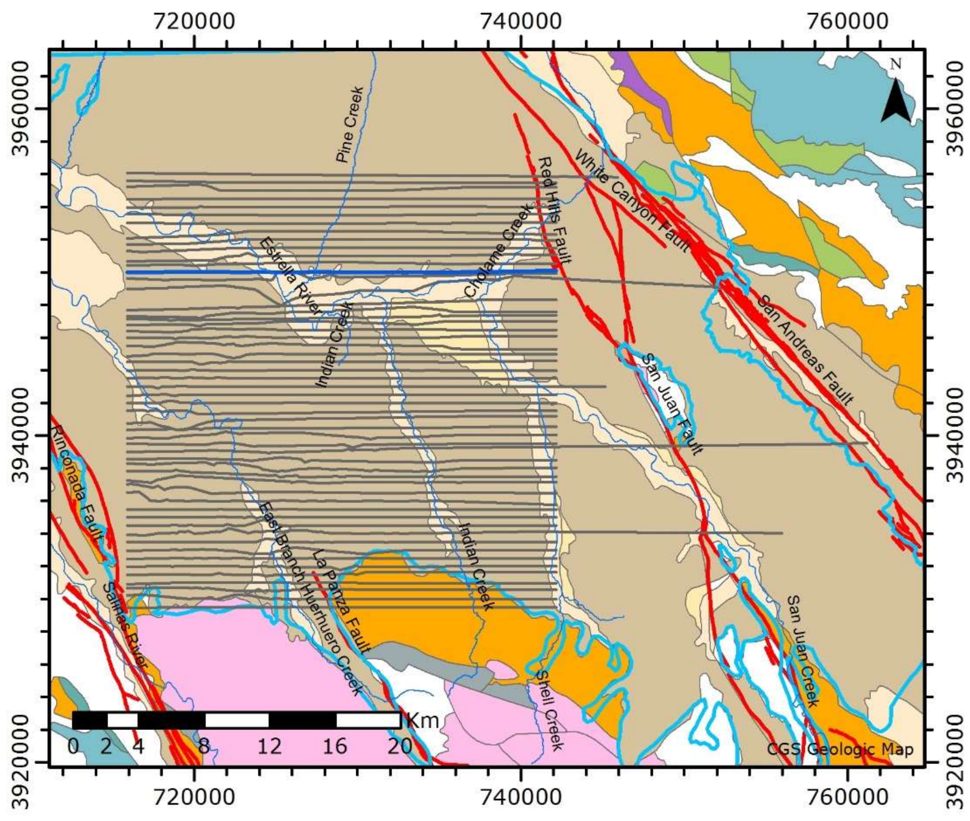
- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412

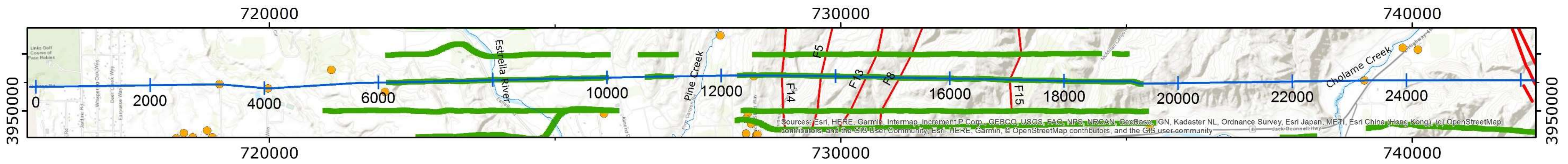


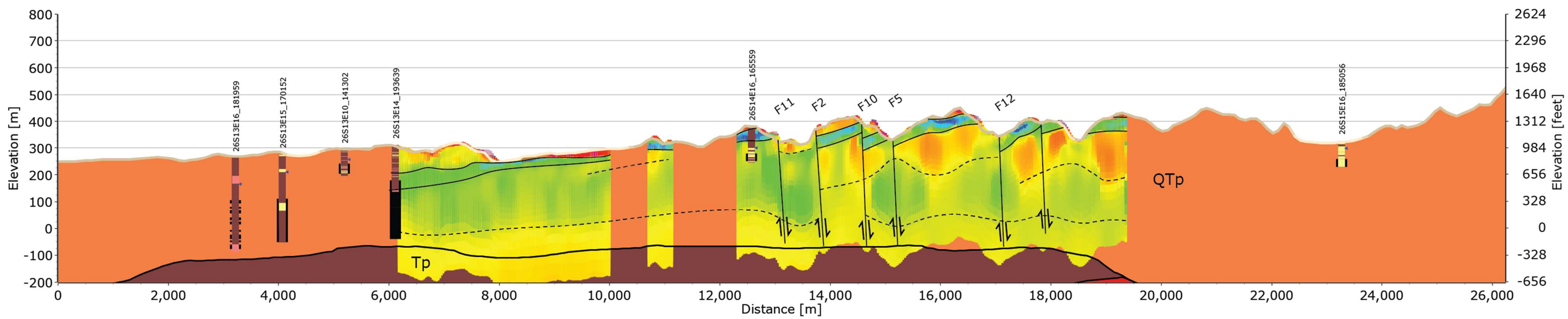
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: .\1690013412\plots\20200421\CrossSections

Geologic Cross section 43

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

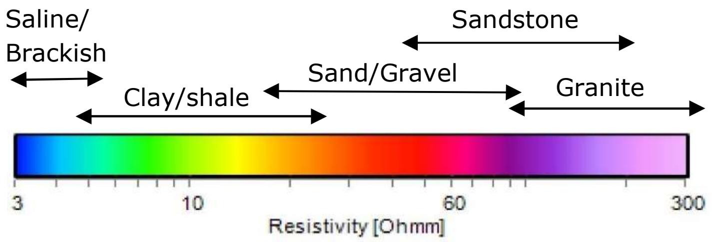
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

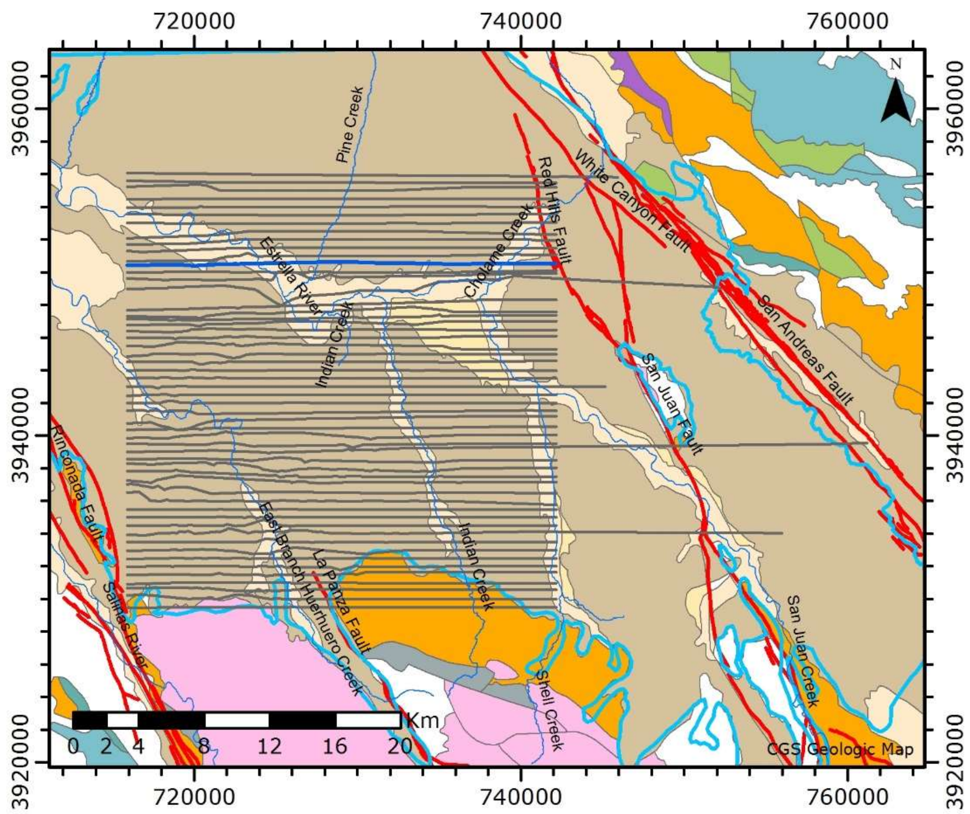
Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412



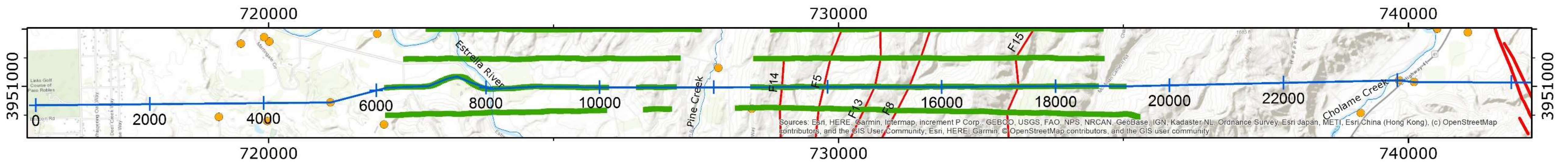
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

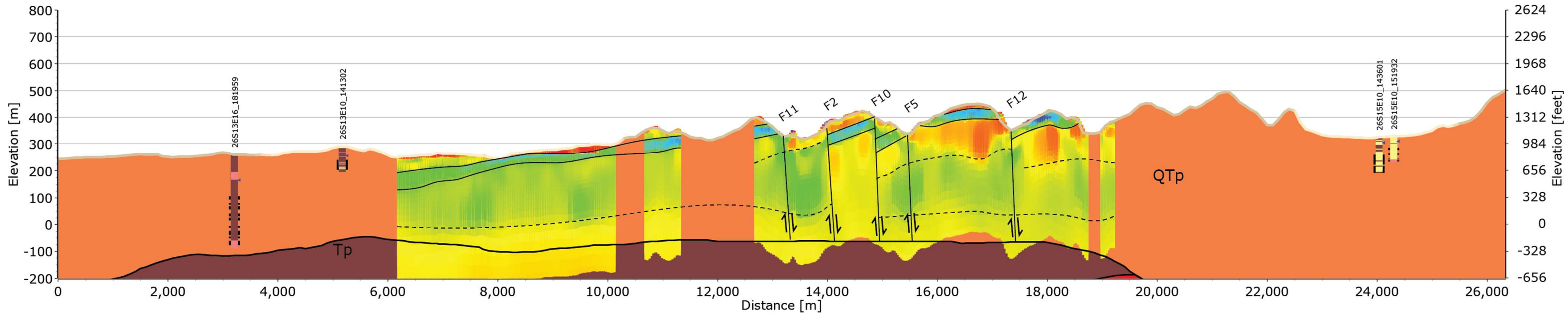
File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 44

Paso Robles Groundwater Basin, Hydrogeological Conceptual Model

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Groundwater Architecture Project (GAP)
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By: TLM, MAXH
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Approved: MAXH
Project No. 1690013412

Cross section signatures

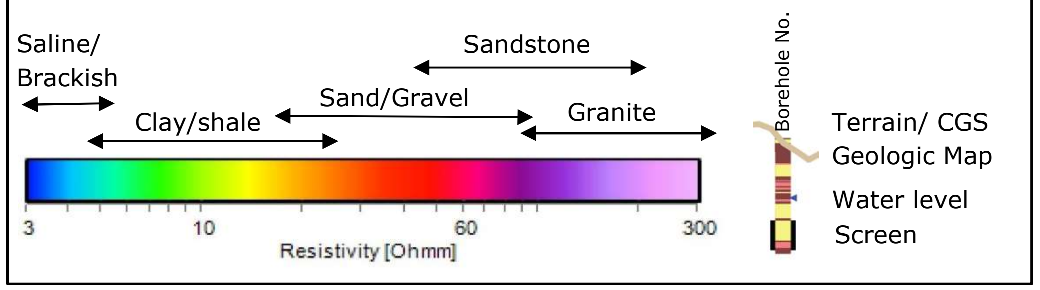
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

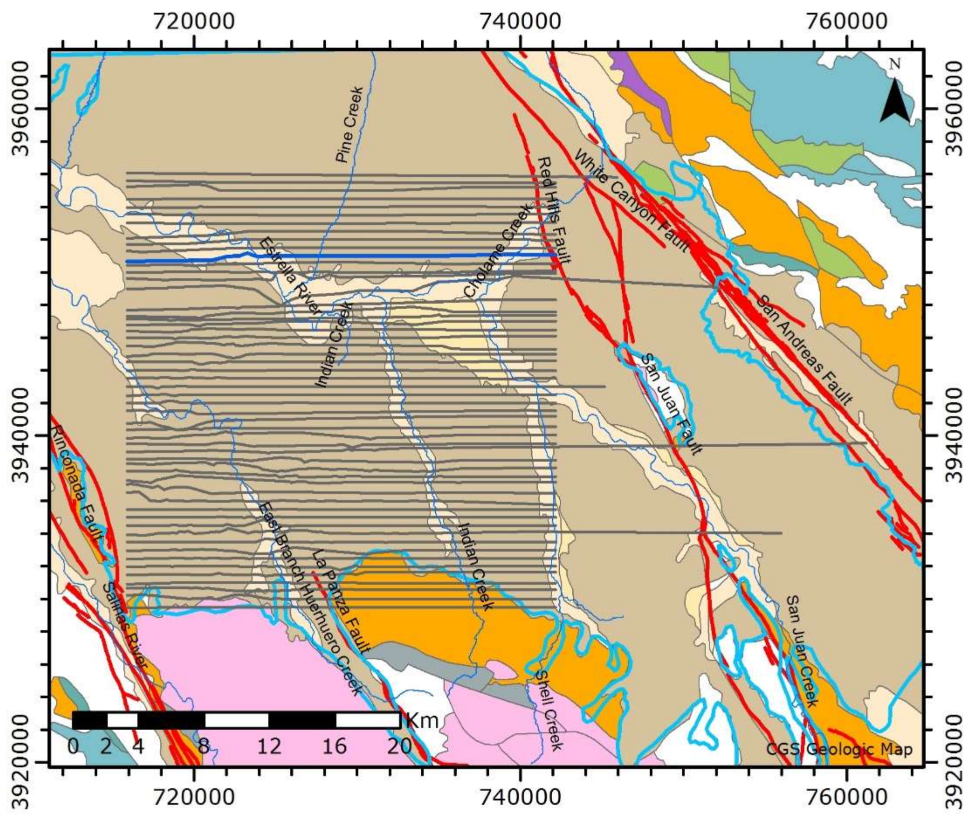
Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown

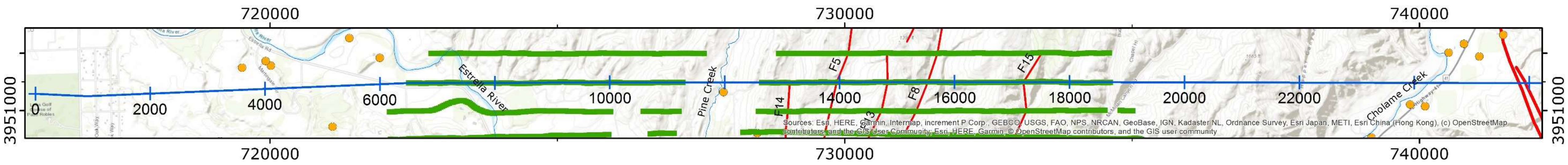


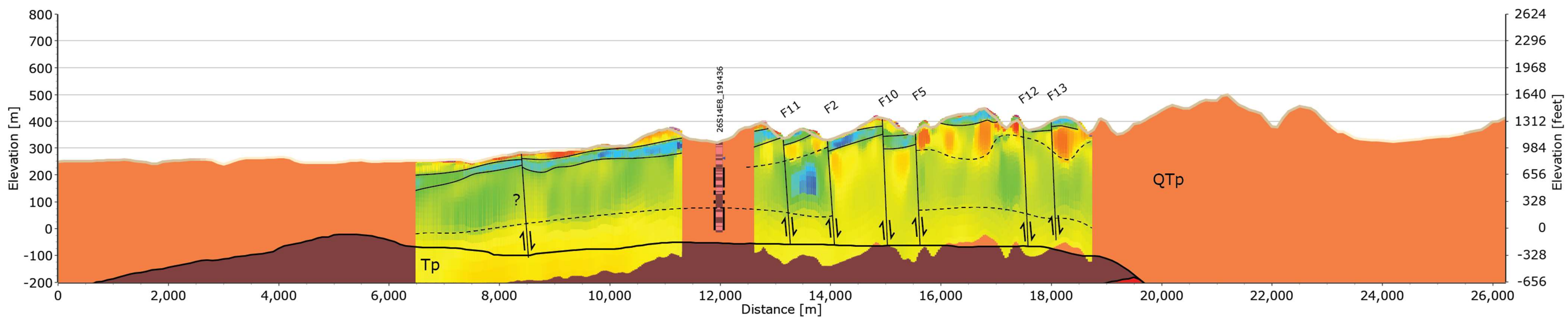


Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 45





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

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Control: PATH
Approved: MAXH
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Cross section signatures

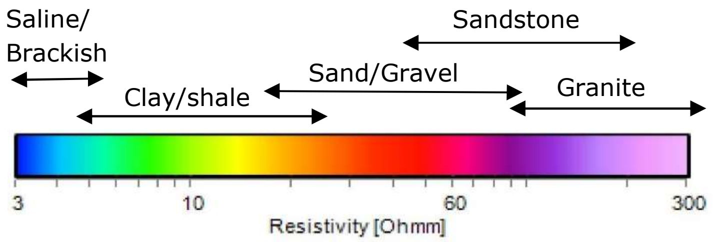
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

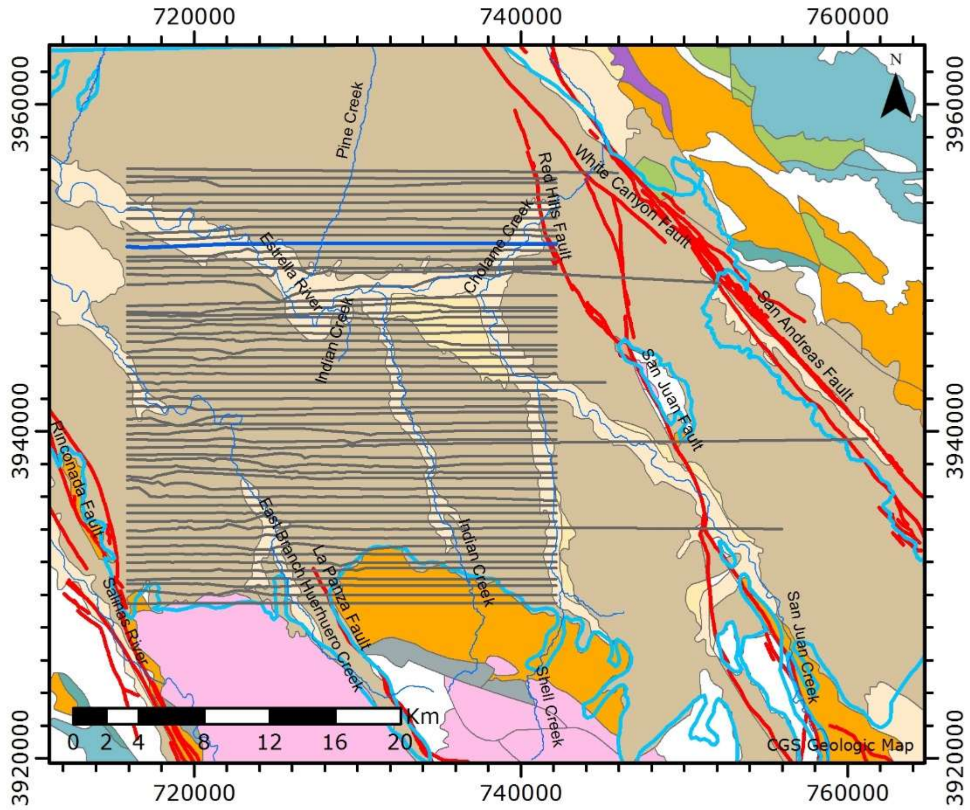
- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen



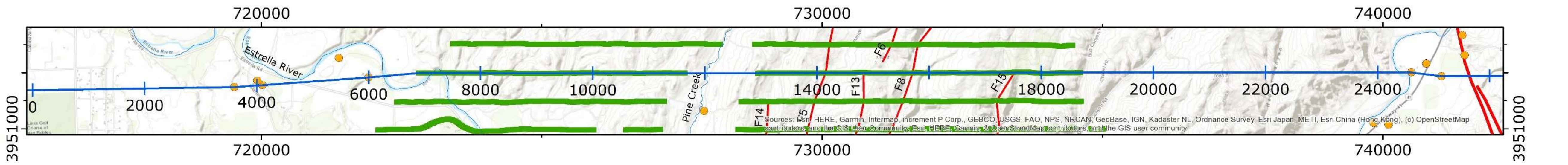
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

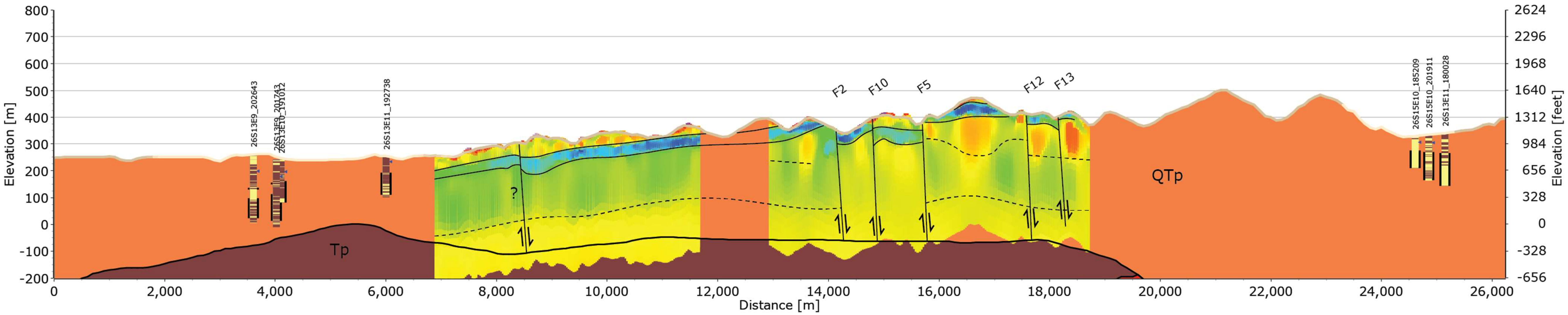
File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 46

Paso Robles Groundwater Basin, Hydrogeological Conceptual Model

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

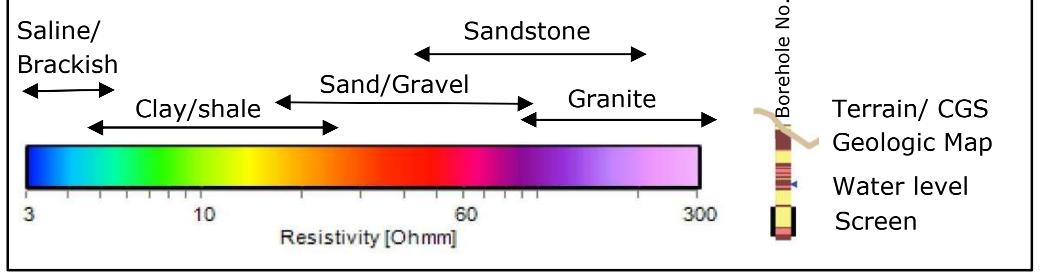
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Groundwater Architecture Project (GAP)
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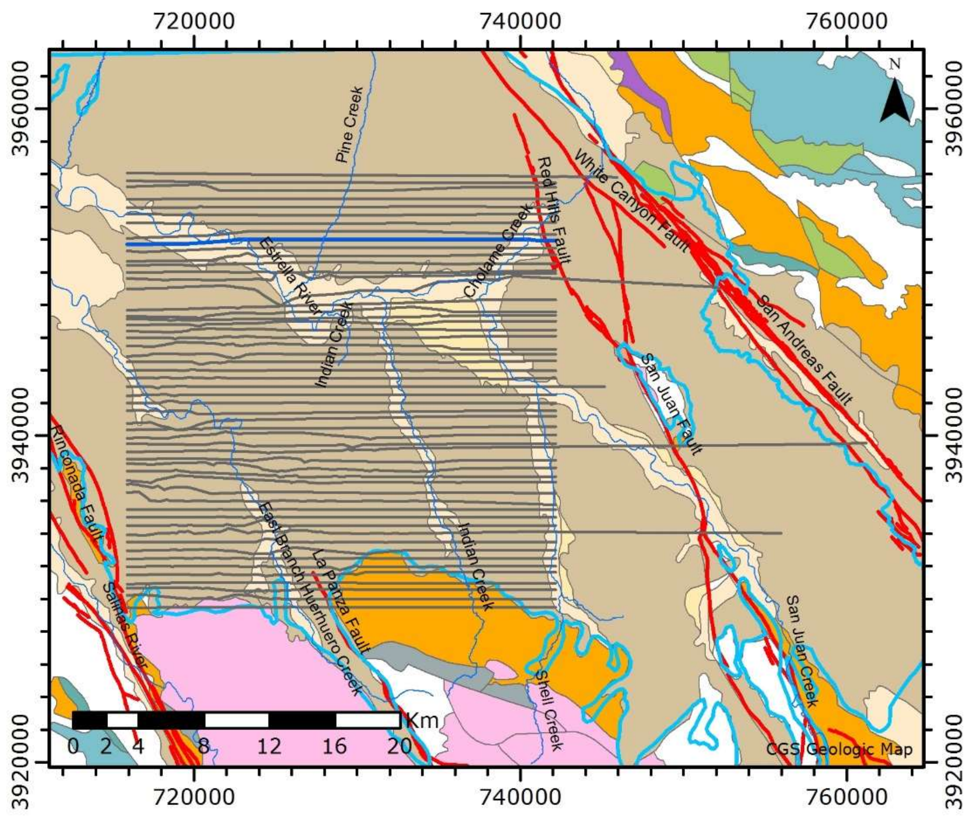
Approved: MAXH
Project No. 1690013412

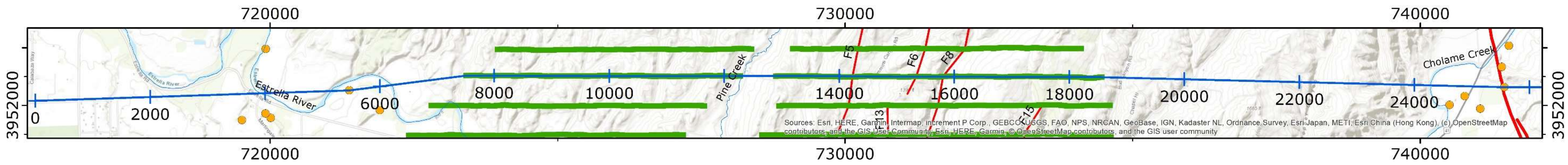


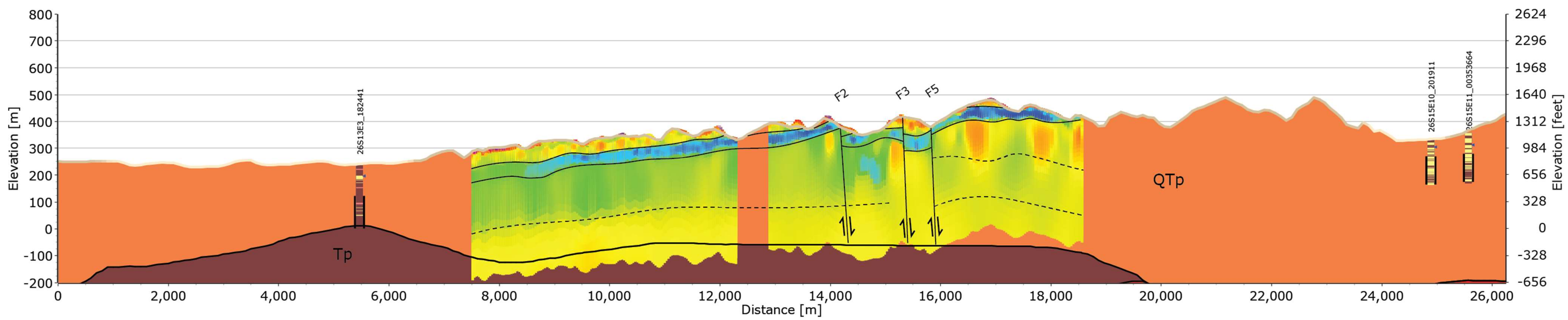
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: .\1690013412\plots\20200421\CrossSections

Geologic Cross section 47

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

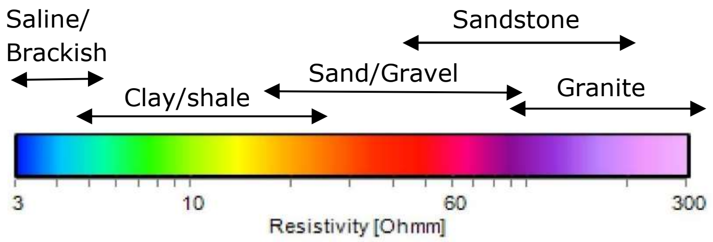
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

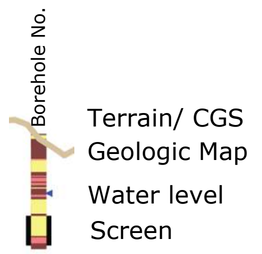
Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown





Groundwater Architecture Project (GAP)
San Luis Obispo County
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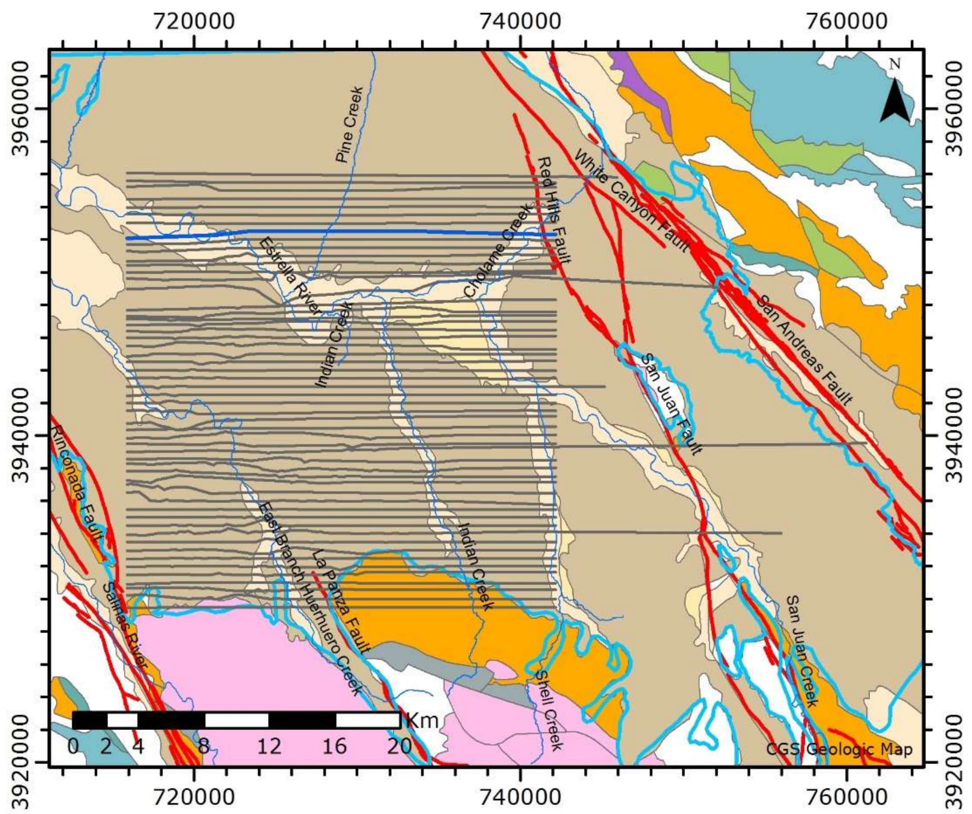
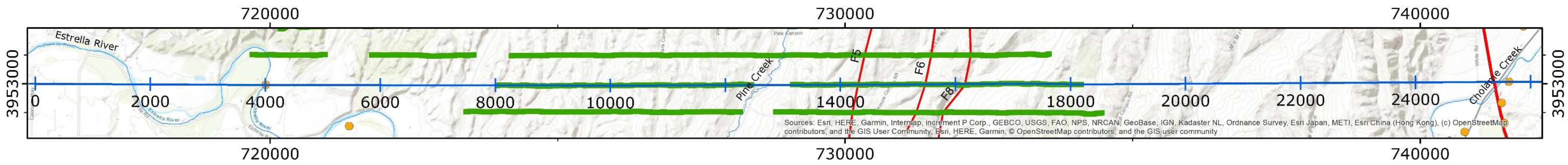


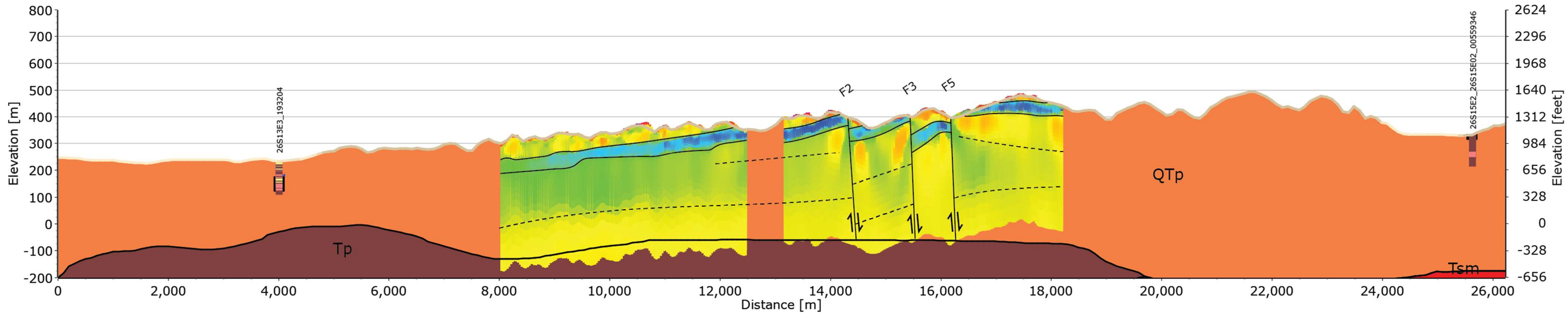
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 48

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

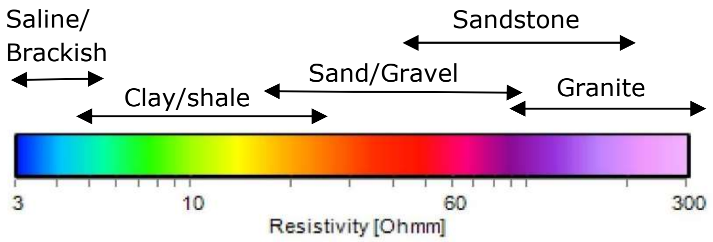
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.

Terrain/ CGS Geologic Map

Water level

Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
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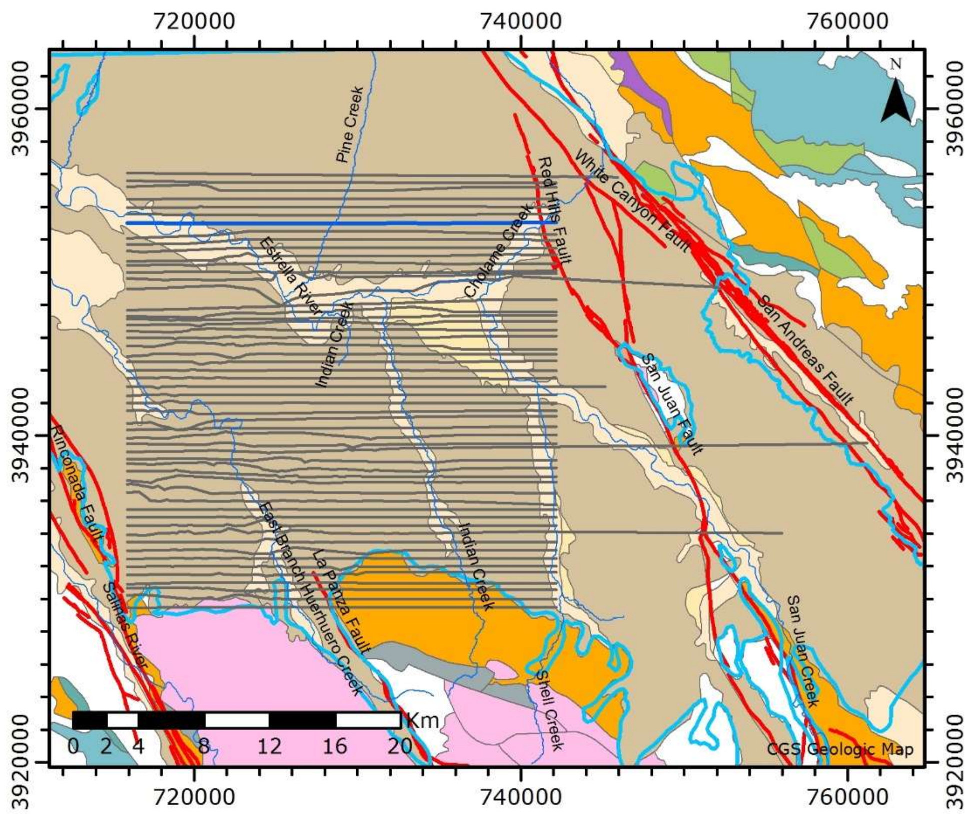
Project No. 1690013412

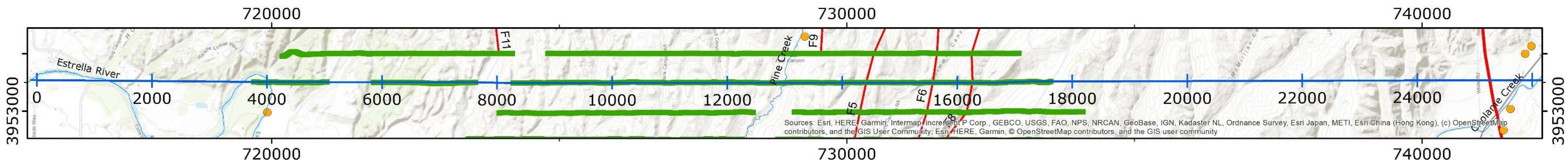


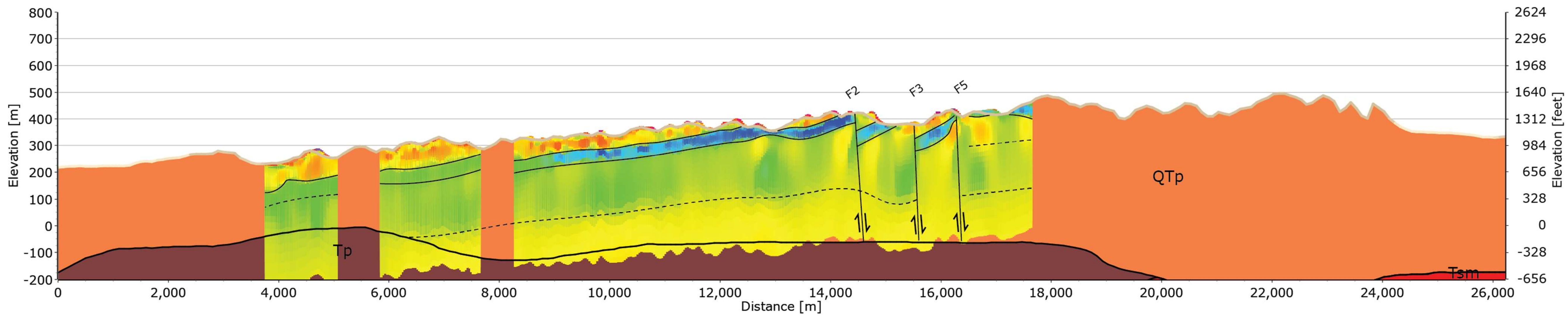
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: .\1690013412\plots\20200421\CrossSections

Geologic Cross section 49

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
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Borehole lithology

- Clay/Shale
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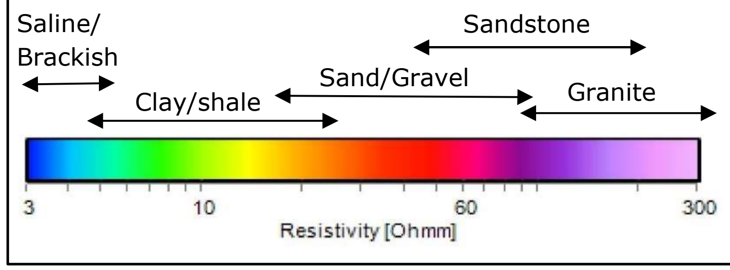
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown

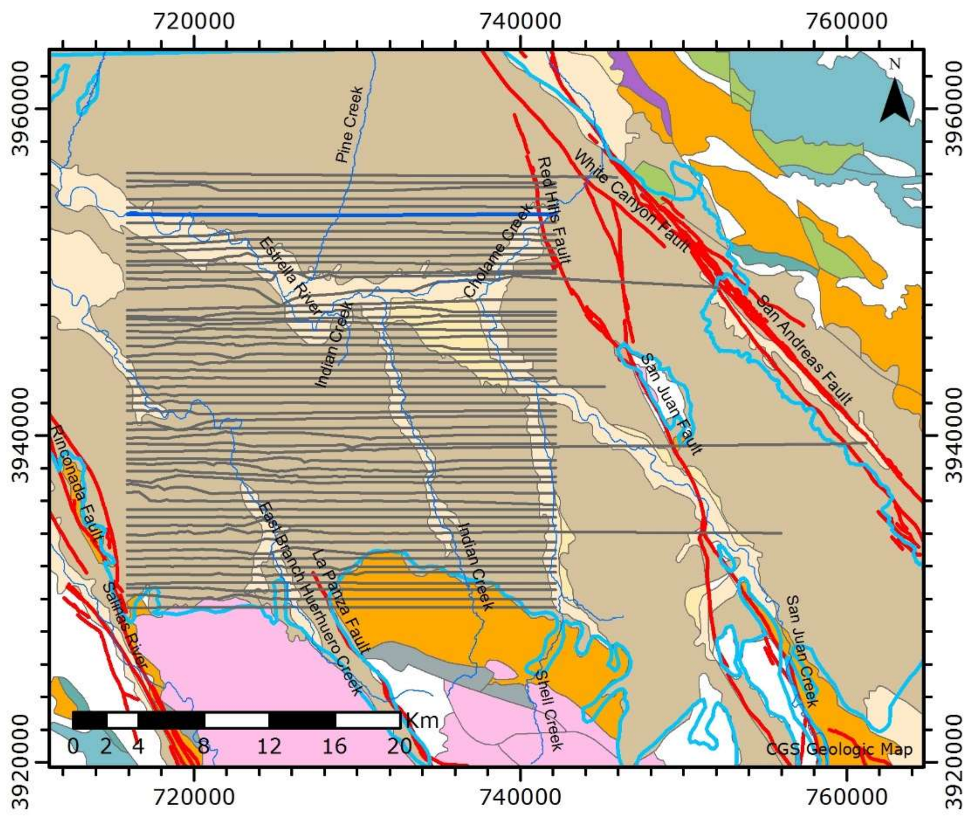


Borehole No.

Terrain/ CGS Geologic Map

Water level

Screen



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

Groundwater Architecture Project (GAP)
San Luis Obispo County
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By: TLM, MAXH
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Approved: MAXH
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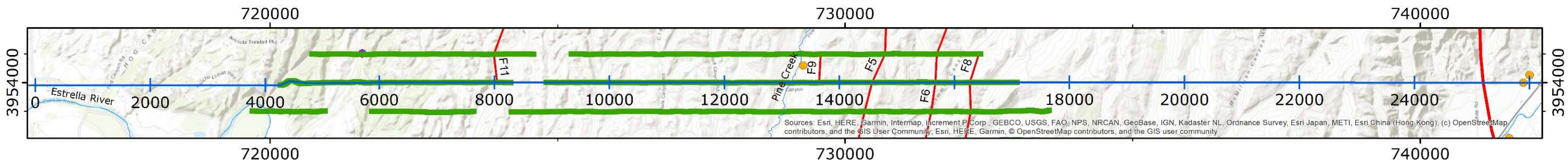
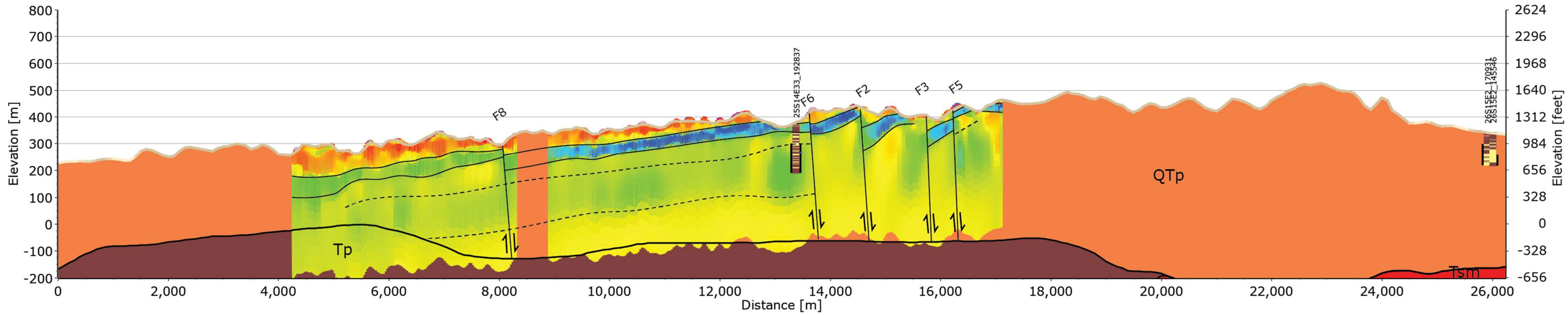
Geologic Cross section 50

Paso Robles Groundwater Basin, Hydrogeological Conceptual Model

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
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Borehole lithology

- Clay/Shale
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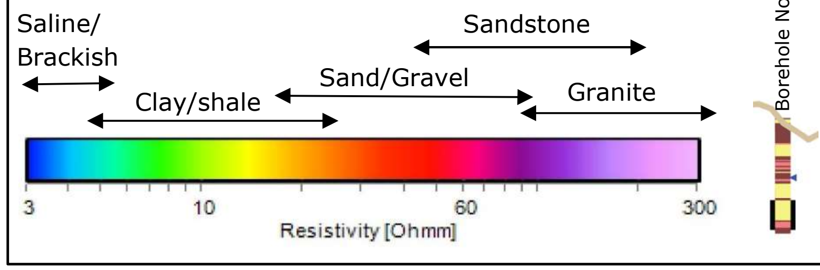
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Terrain/ CGS Geologic Map

Water level

Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
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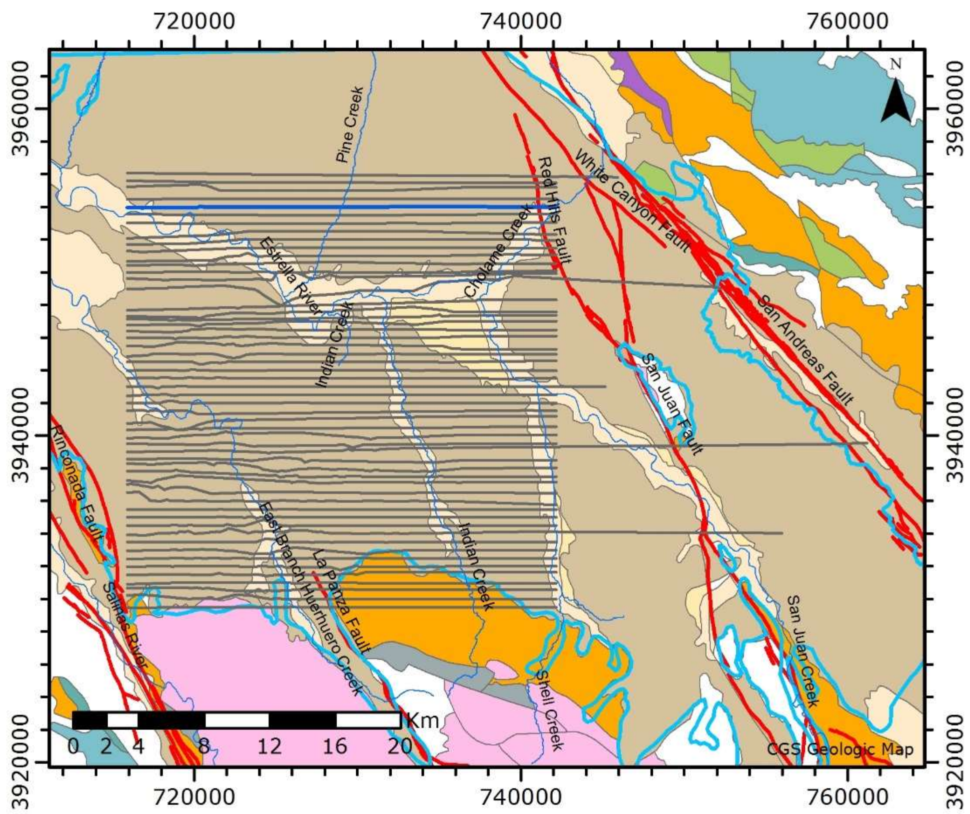
Control: PATH
Approved: MAXH
Project No. 1690013412

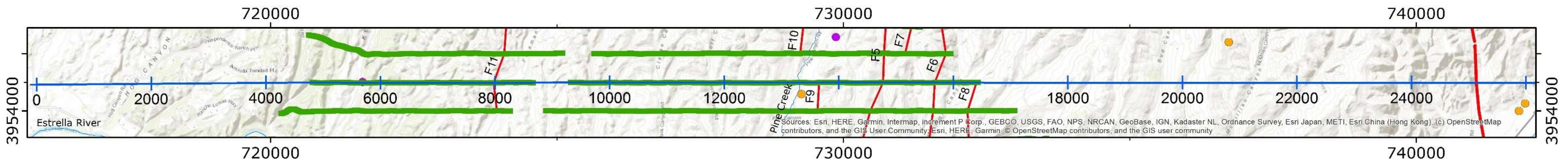


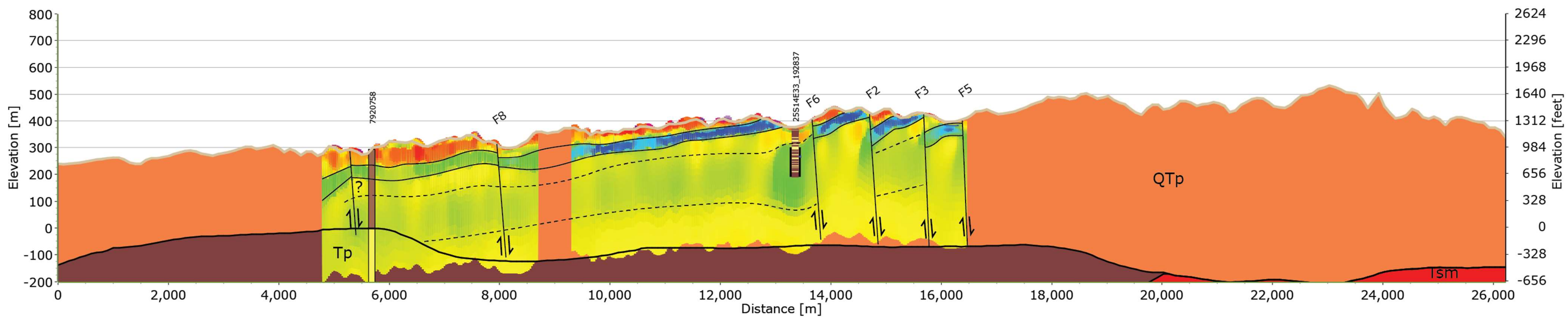
Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: ..\1690013412\plots\20200421\CrossSections

Geologic Cross section 51

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

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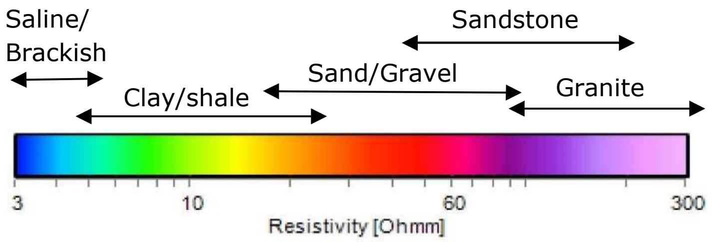
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

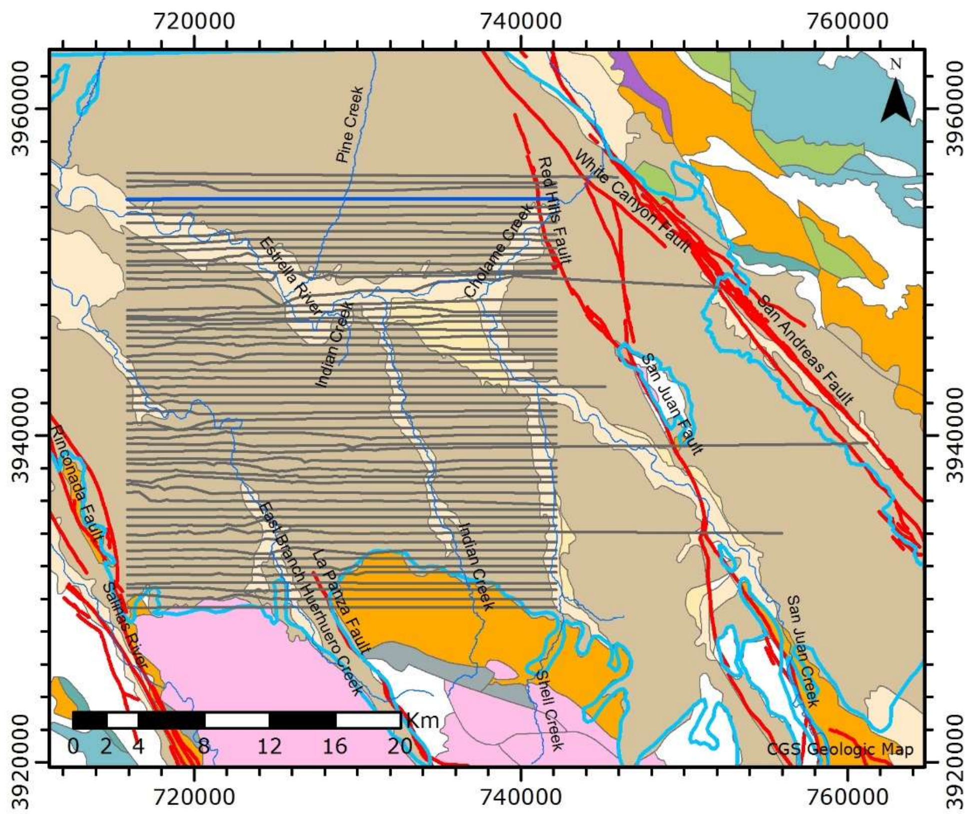
Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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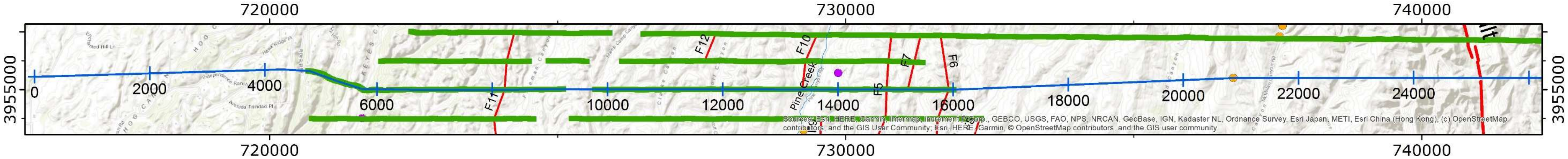
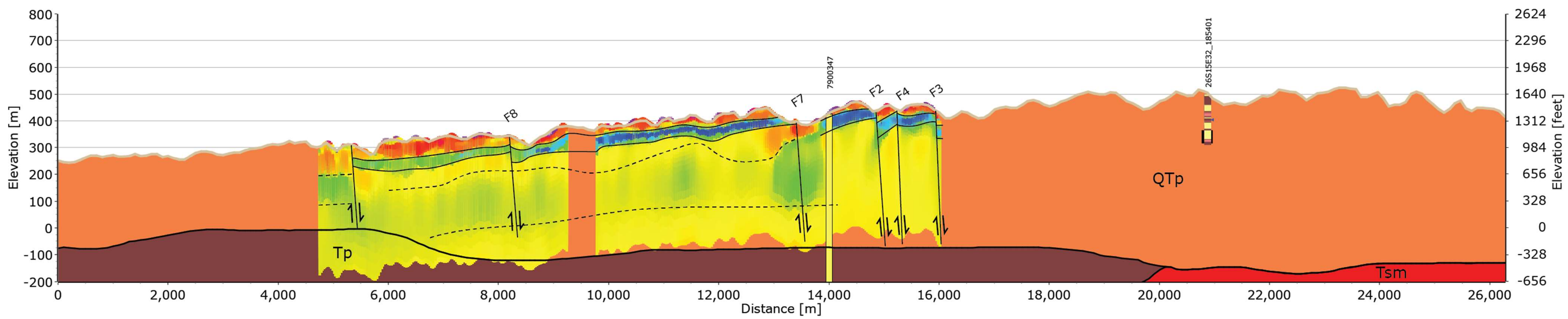
Geologic Cross section 52

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

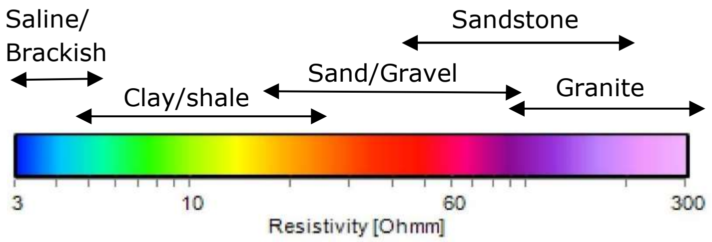
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
Control: PATH
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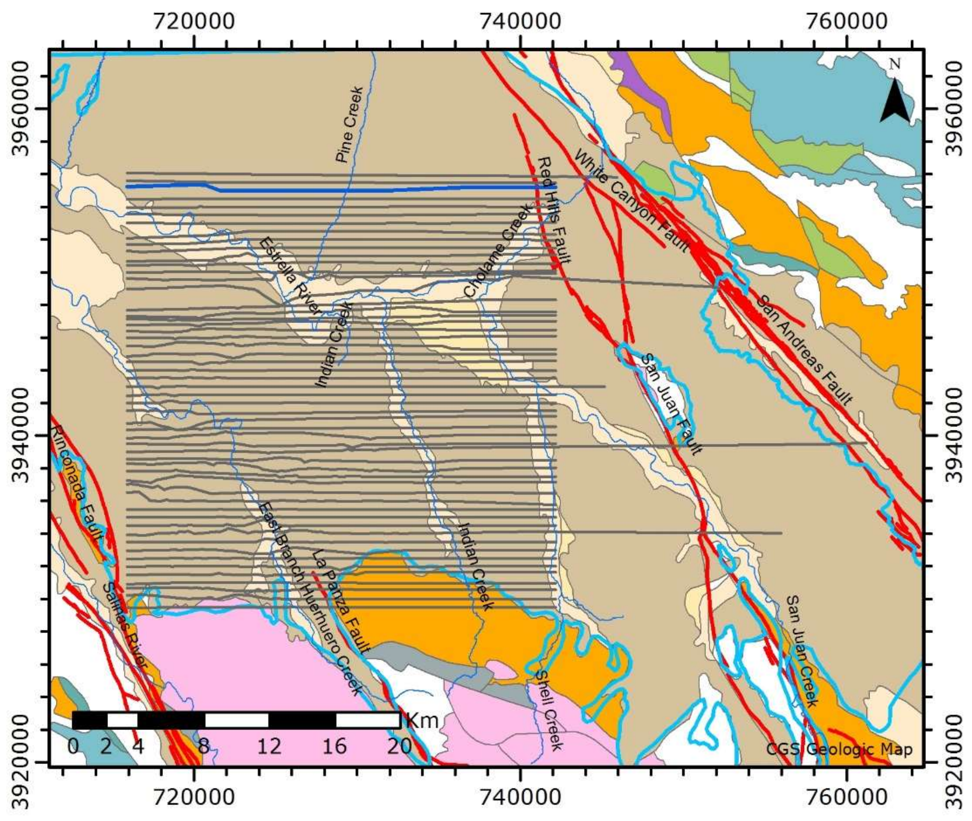
Project No. 1690013412



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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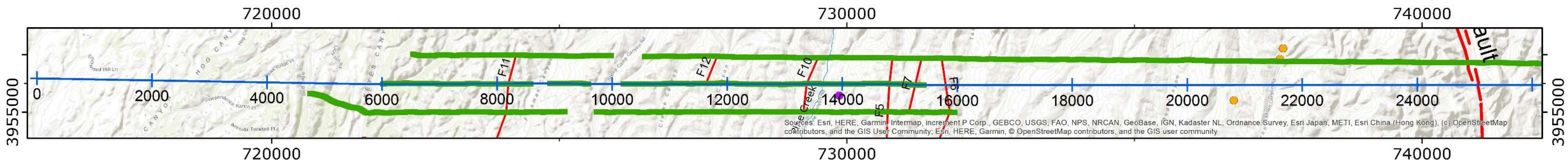
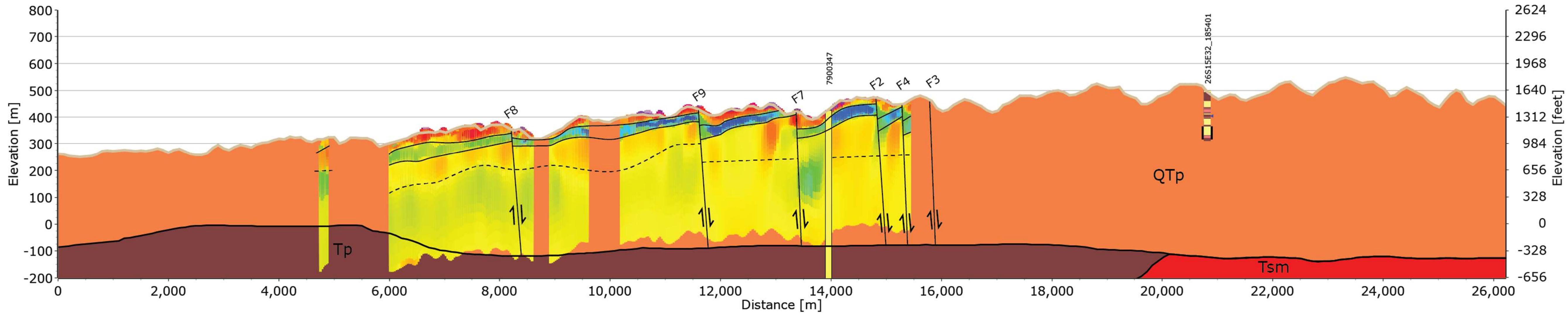
Geologic Cross section 53

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

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- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

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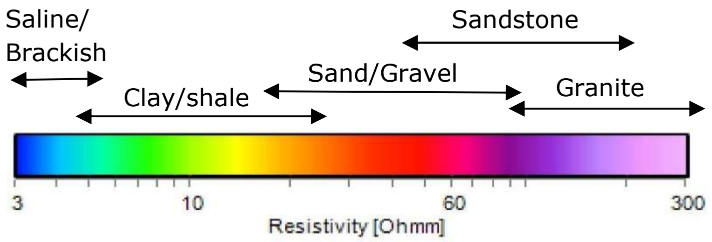
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
- Terrain/ CGS Geologic Map
- Water level
- Screen

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San Luis Obispo County
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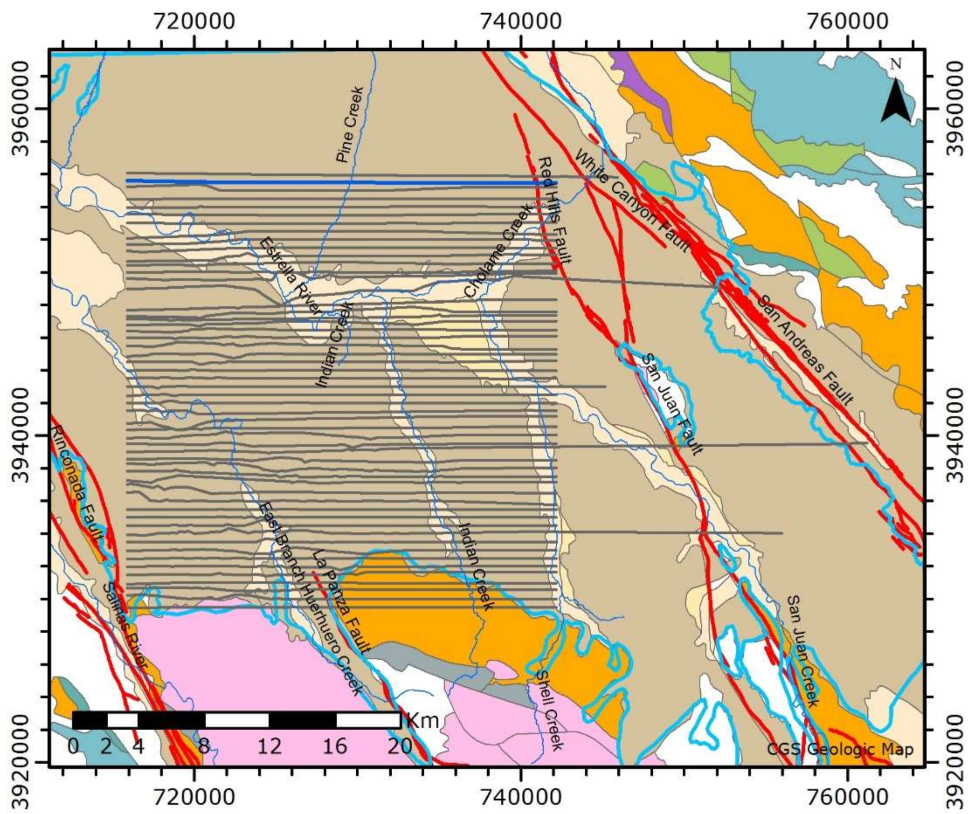

Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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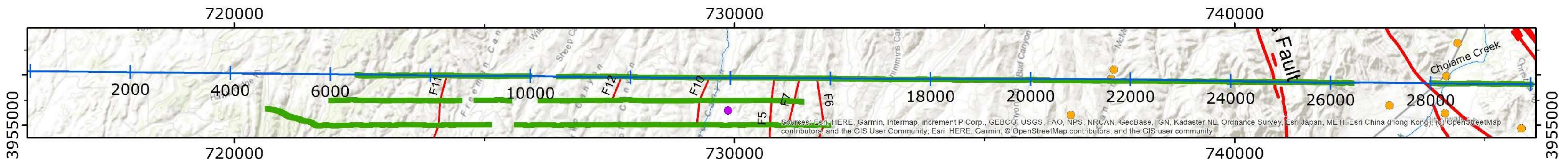
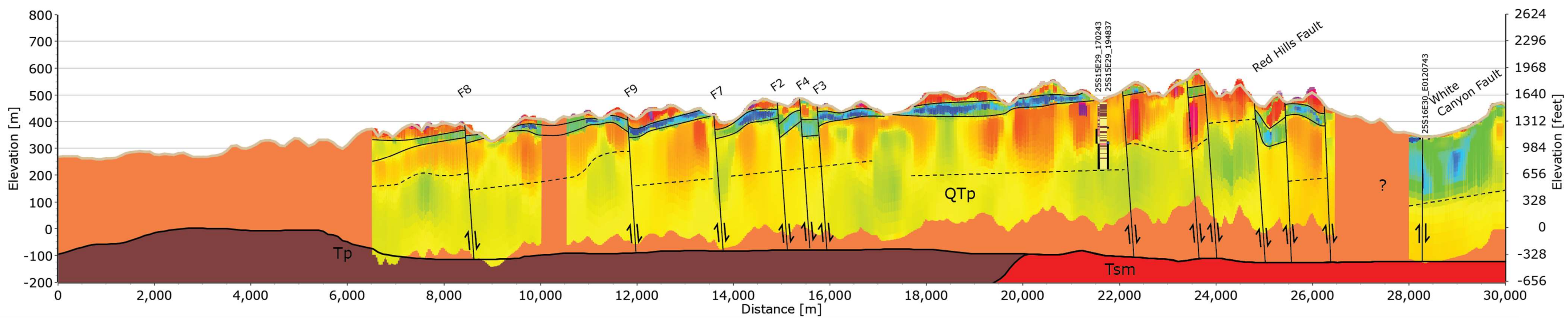
Geologic Cross section 54

RAMBOLL





Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
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- Granite

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Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
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- Monterey Shale, Tm
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Borehole lithology

- Clay/Shale
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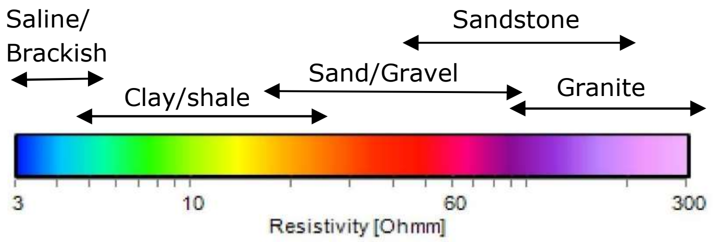
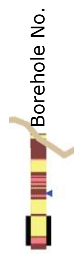
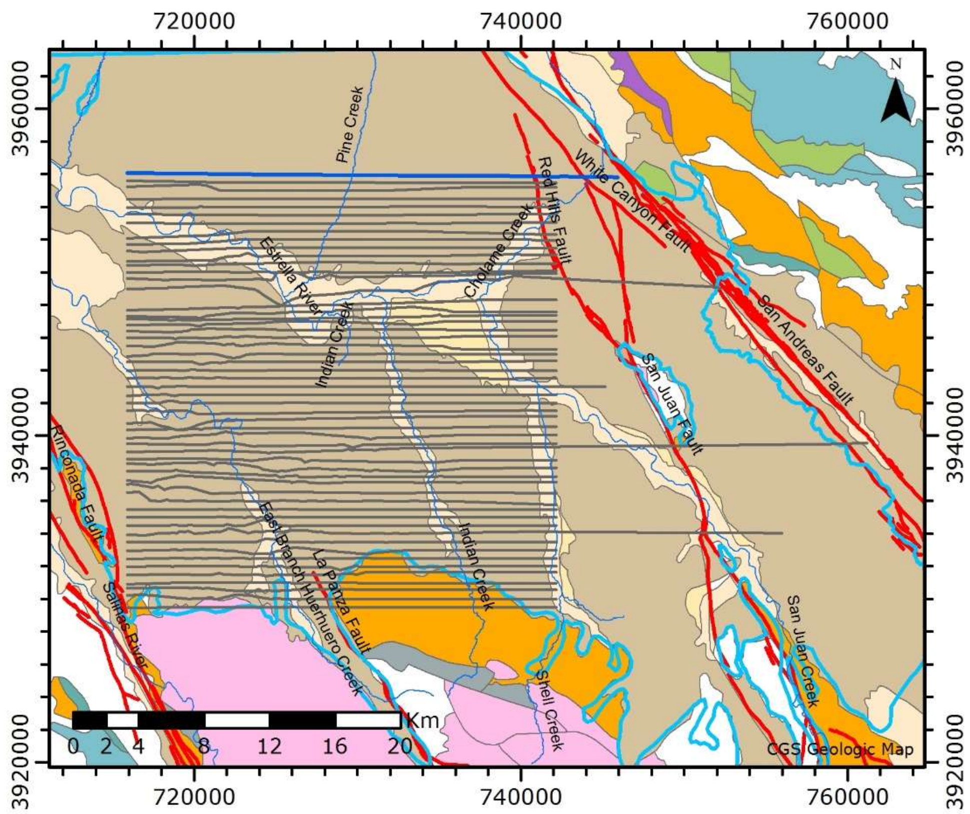
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown





Terrain/ CGS Geologic Map
Water level
Screen

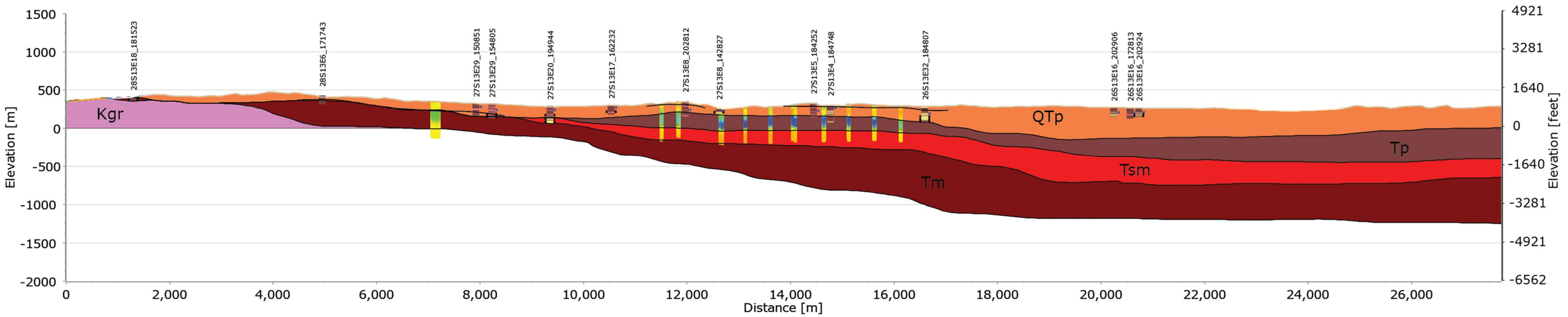


Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: ..\1690013412\plots\20200421\CrossSections

APPENDIX 6
S-N CROSS SECTIONS WITH GEOLOGIC INTERPRETATION

S-N Geologic Cross section 1



Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
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- Basin boundaries
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- Granite

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Cross section signatures

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- Structural boundaries
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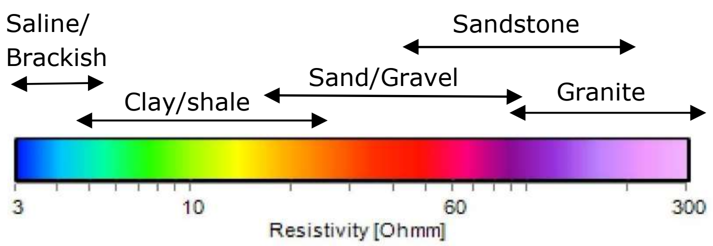
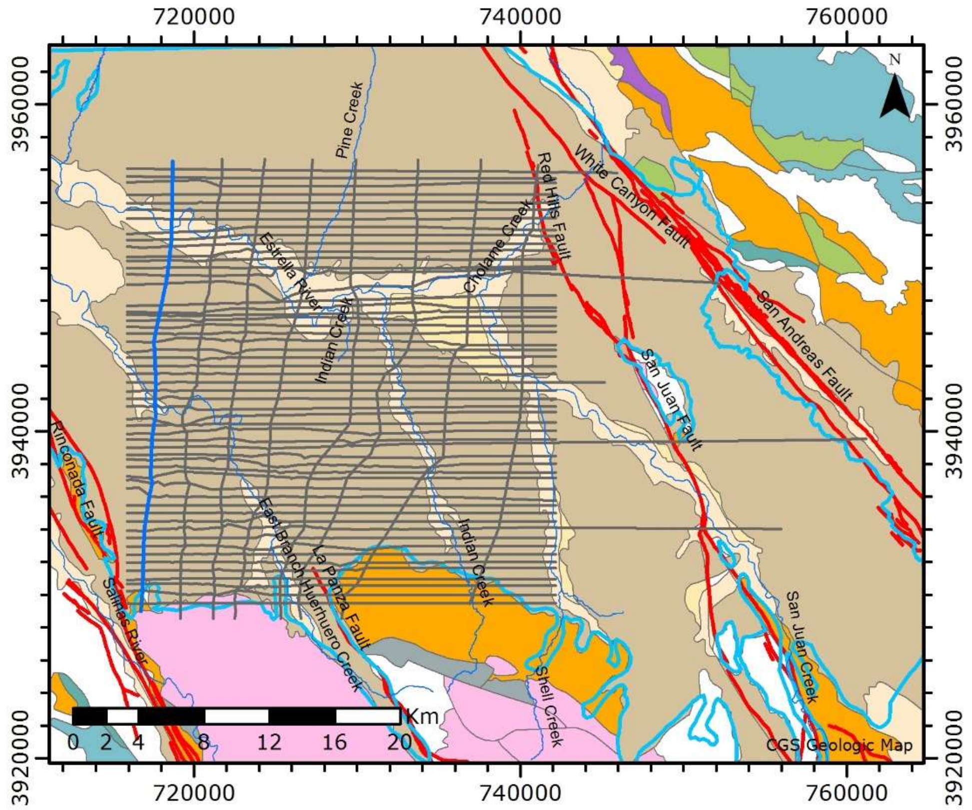
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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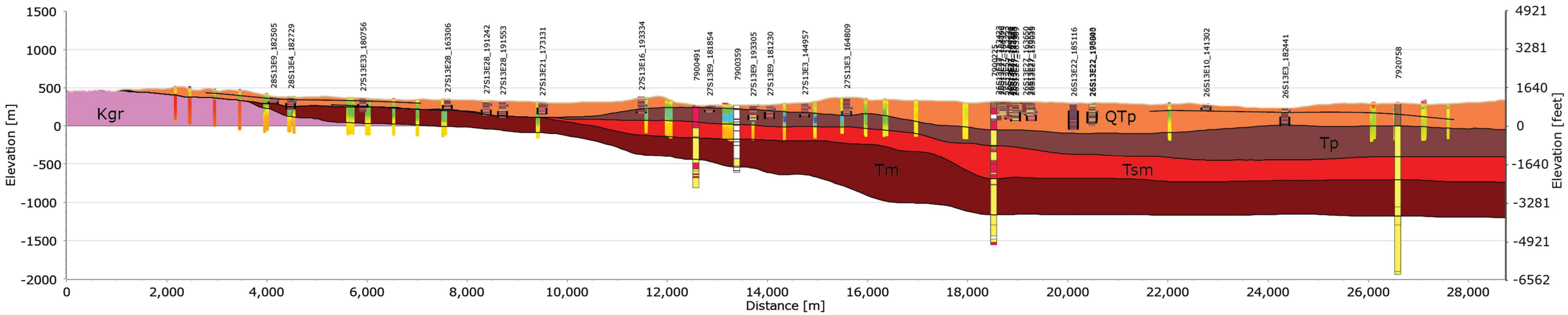
S-N Geologic Cross section 2



Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
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- Miocene marine sandstone
- Granite

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

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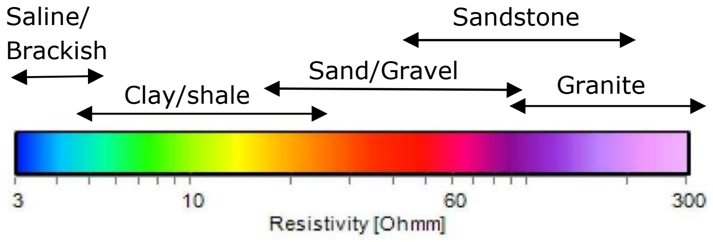
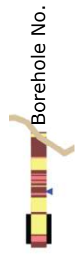
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown





- Terrain/ CGS Geologic Map
- Water level
- Screen

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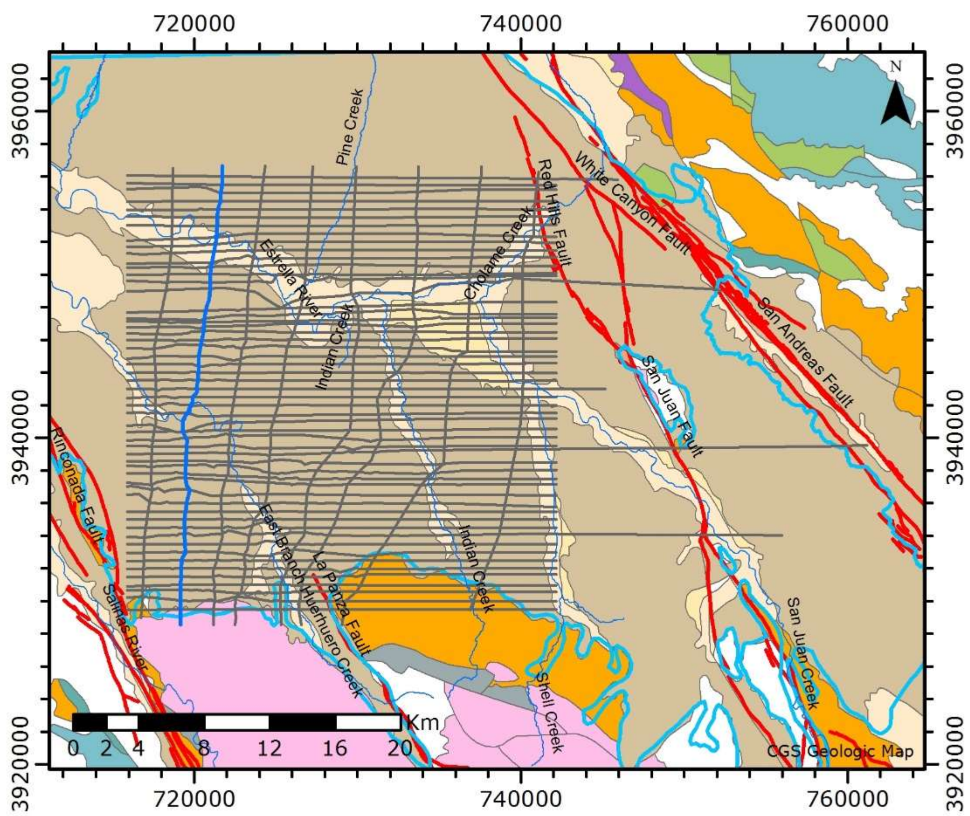
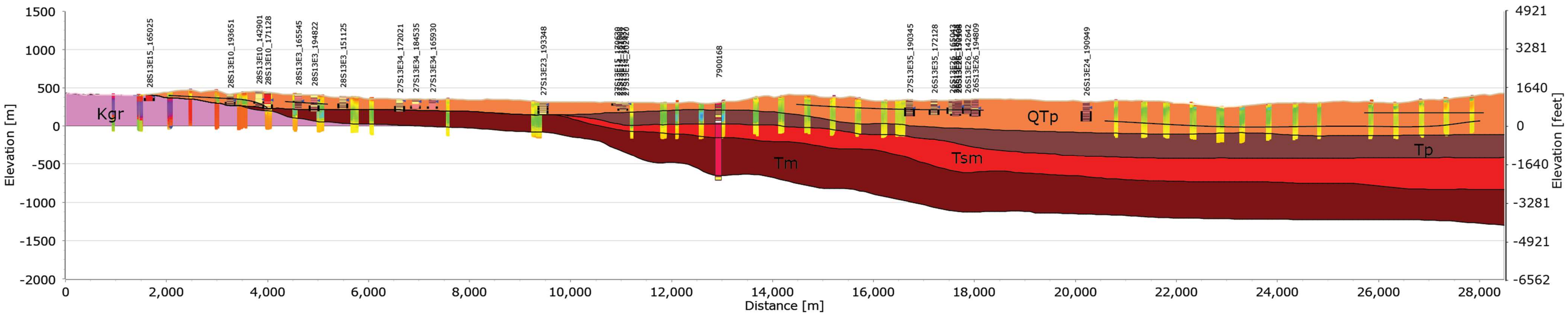


Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: ..\1690013412\plots\20200421\CrossSections

S-N Geologic Cross section 3



Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
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- Miocene marine sandstone
- Granite

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

- Paso Robles Form, QTp
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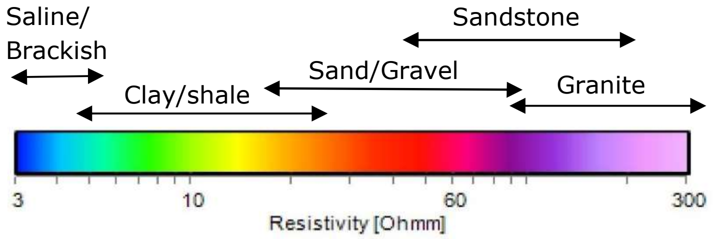
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.

Terrain/ CGS Geologic Map

Water level

Screen

Groundwater Architecture Project (GAP)
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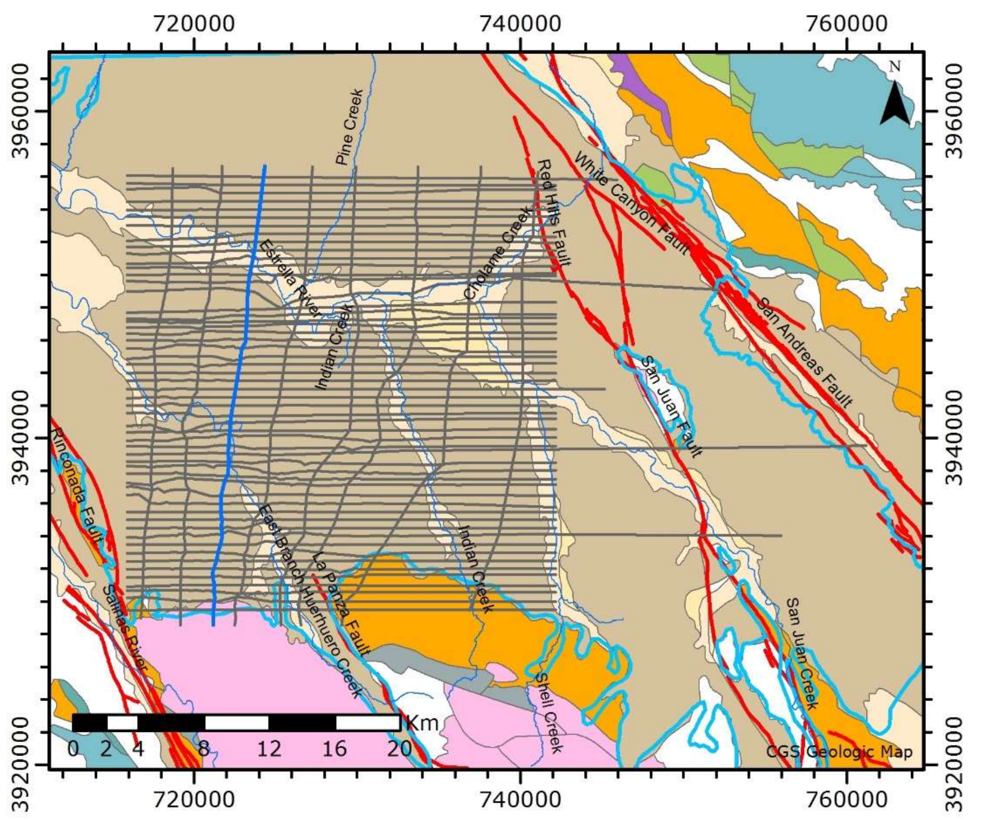
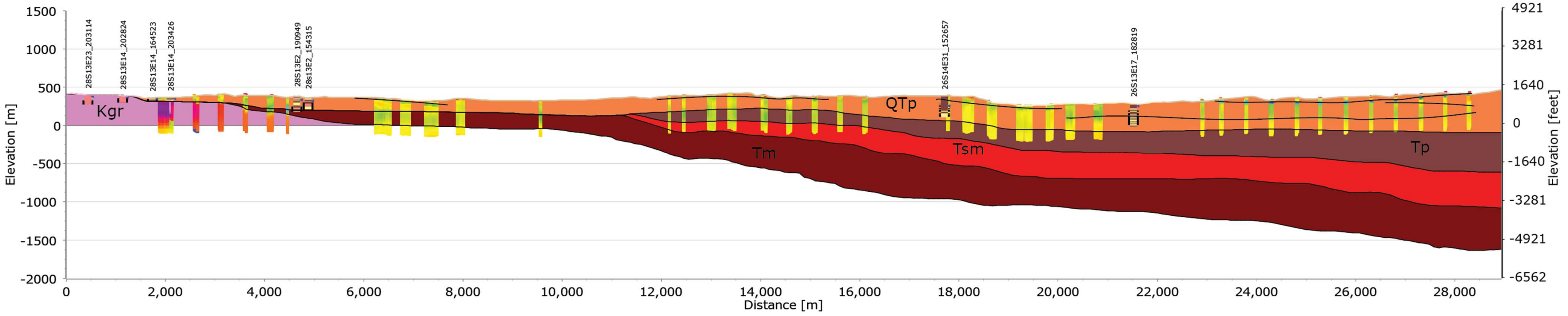


Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: ..\1690013412\plots\20200421\CrossSections

S-N Geologic Cross section 4

RAMBOLL



Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

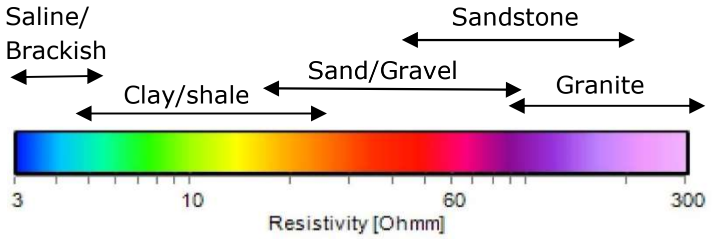
- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown



Borehole No.

Terrain/ CGS Geologic Map

Water level

Screen

Groundwater Architecture Project (GAP)
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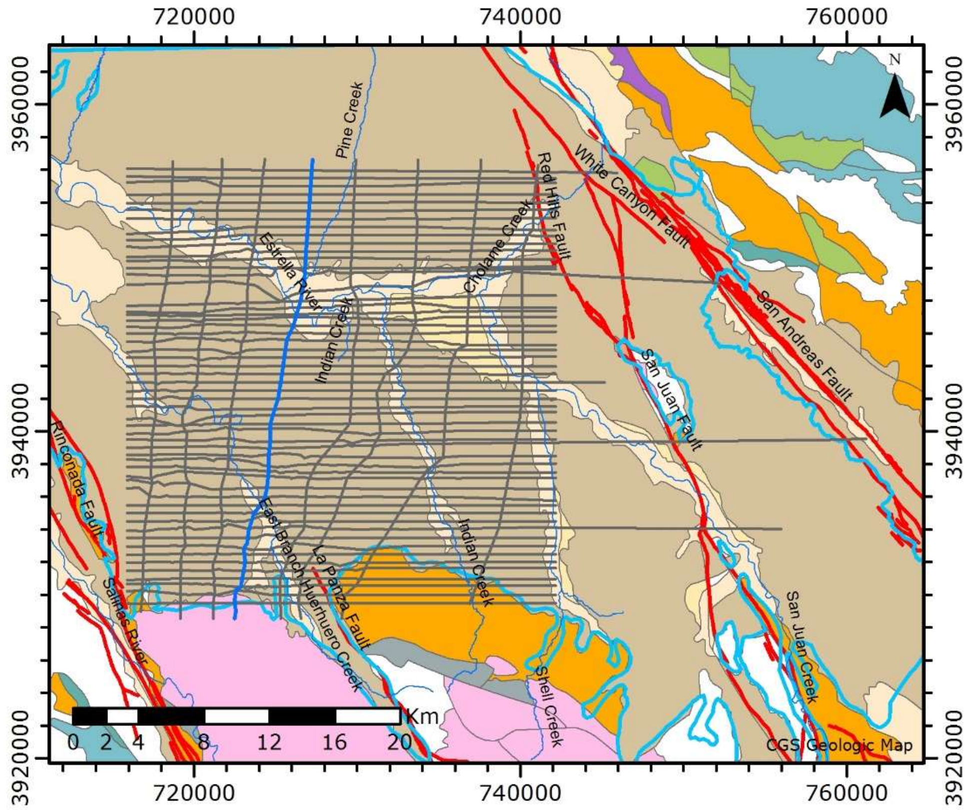

Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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S-N Geologic Cross section 5

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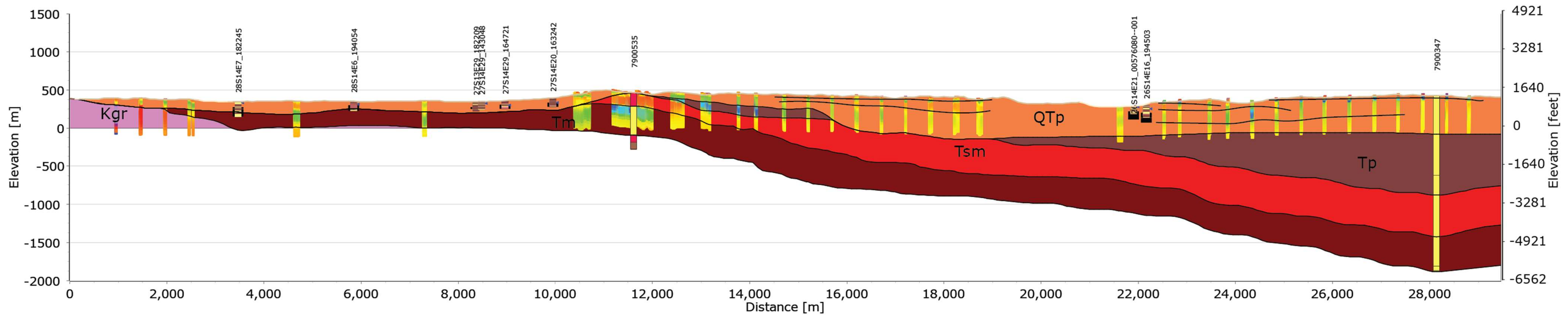

Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

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- Pancho Rico Formation, Tp
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- Granite rocks, Kgr

Borehole lithology

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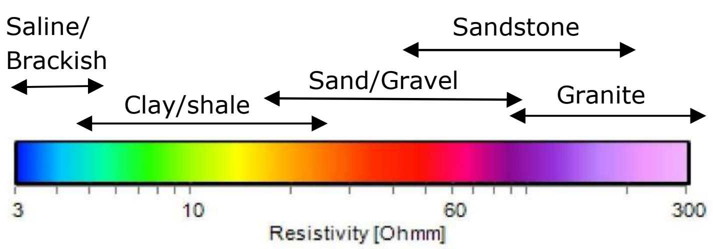
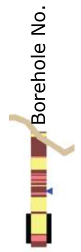
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown





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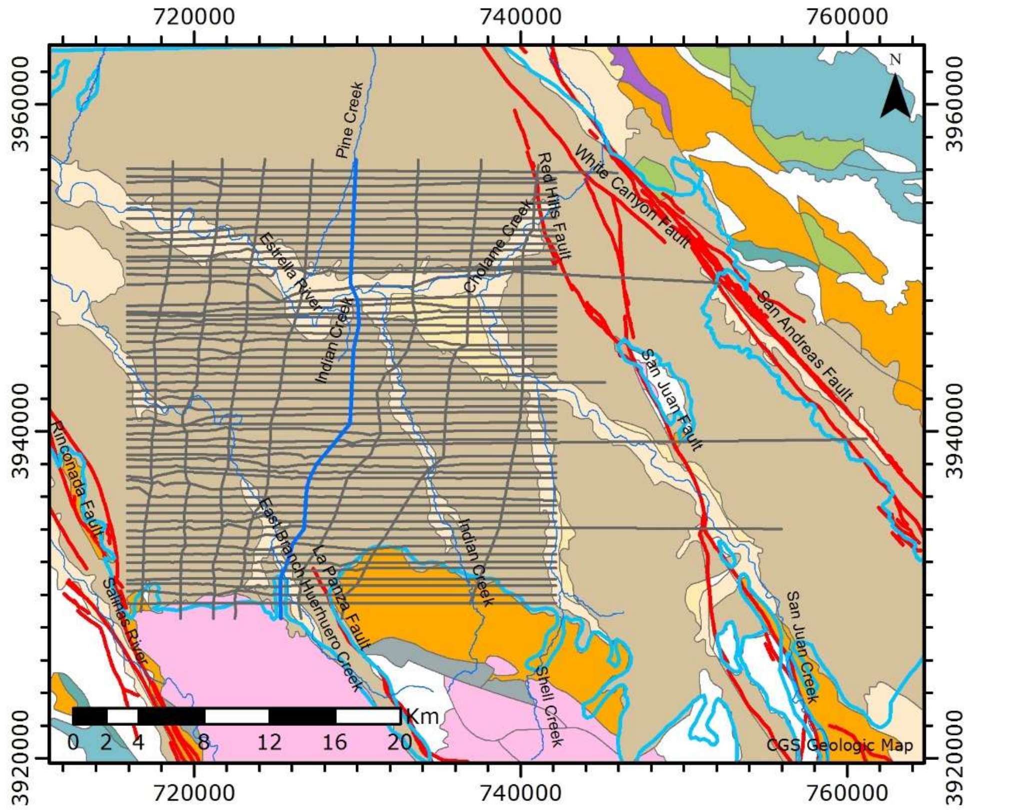

Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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S-N Geologic Cross section 6

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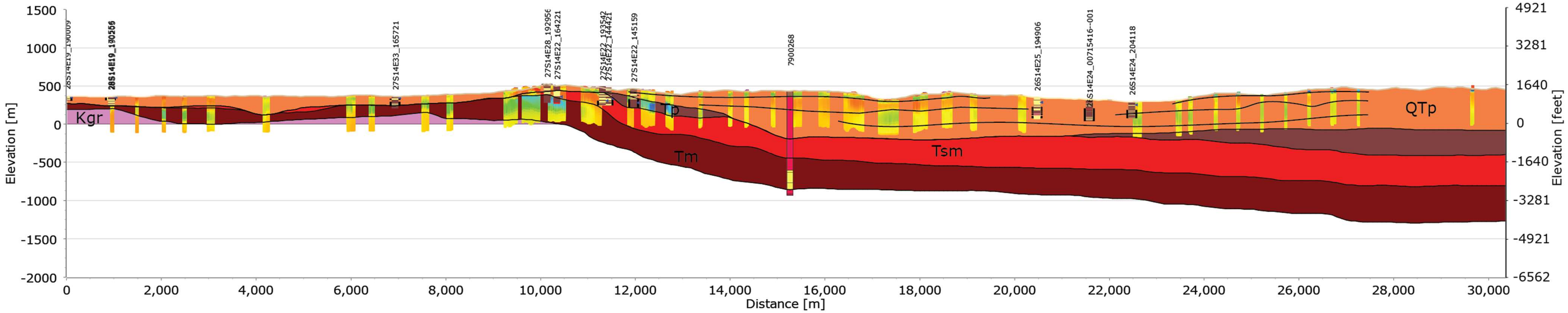

Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
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Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1...

Geologic Units

- Paso Robles Form, QTp
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Borehole lithology

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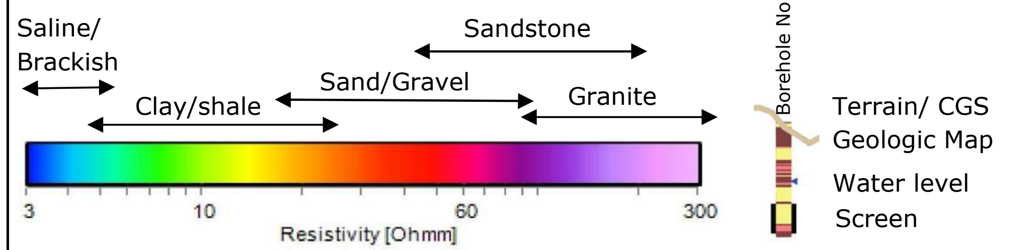
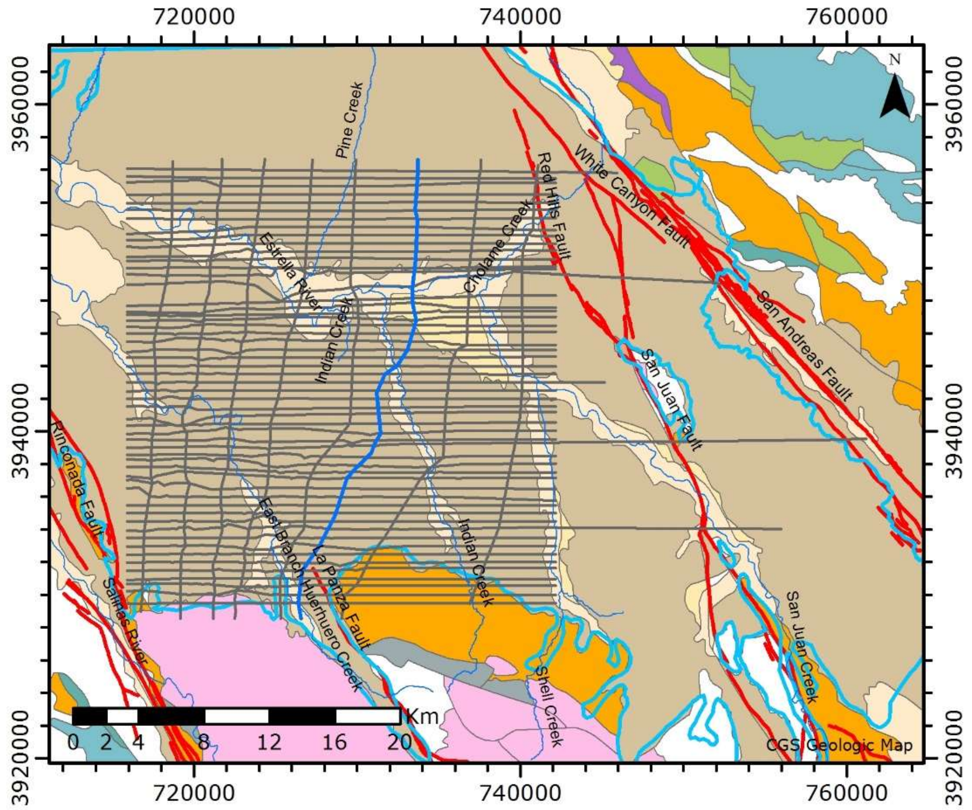
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown





Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

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S-N Geologic Cross section 7

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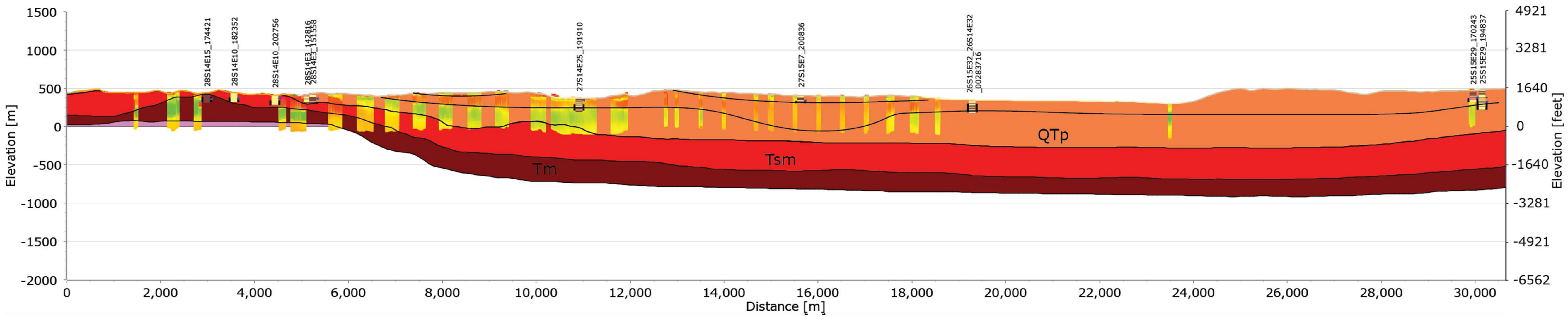

Map signatures

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- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
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- River/Creek
- Basin boundaries
- Quaternary alluvium
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- Granite

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

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- Rock
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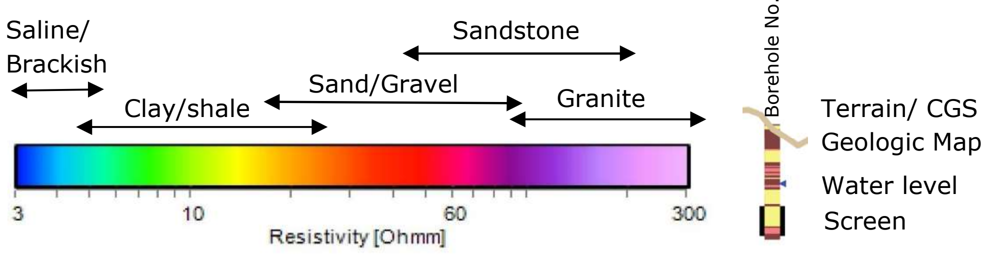
- Breccia
- Unknown



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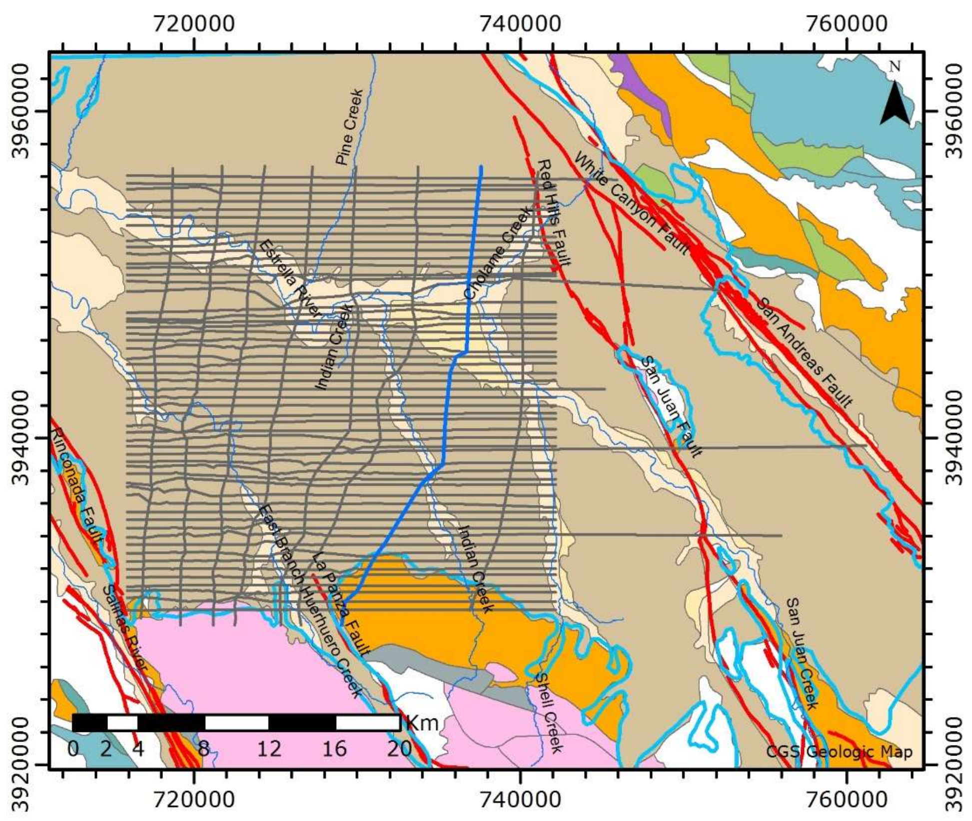
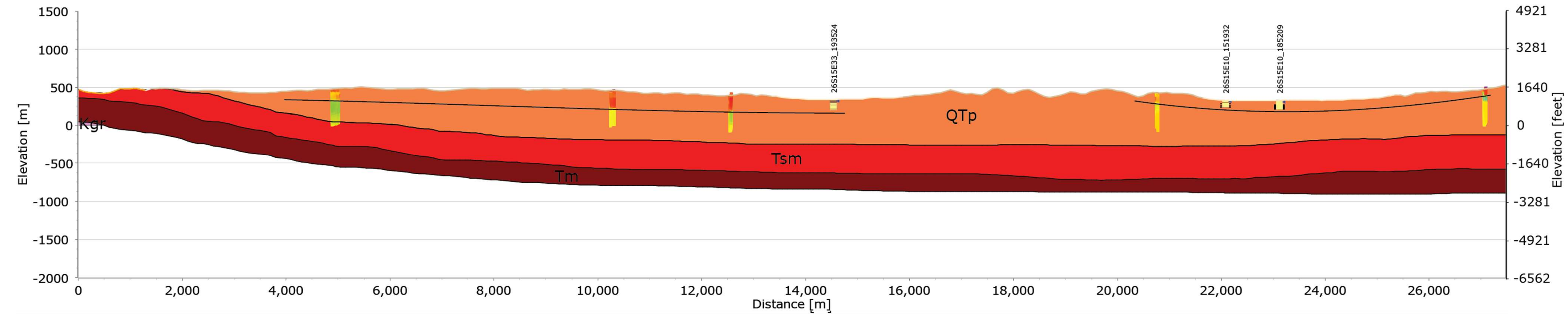


Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: .\1690013412\plots\20200421\CrossSections

S-N Geologic Cross section 8



Map signatures

- AEM data
- Boreholes
- DOGGR wells
- Cross Section
- Faults (known)
- Faults (interpreted)
- River/Creek
- Basin boundaries
- Quaternary alluvium
- Quaternary older alluvium
- Plio-Pleistocene sandstone/shale/gravel
- Miocene marine sandstone
- Granite

Cross section signatures

- Geologic unit boundaries
- Structural boundaries
- Structural boundaries, uncertain
- Fault, numbered F1…

Geologic Units

- Paso Robles Form, QTp
- Pancho Rico Formation, Tp
- Santa Margarita Sandstone, Tsm
- Monterey Shale, Tm
- Granite rocks, Kgr

Borehole lithology

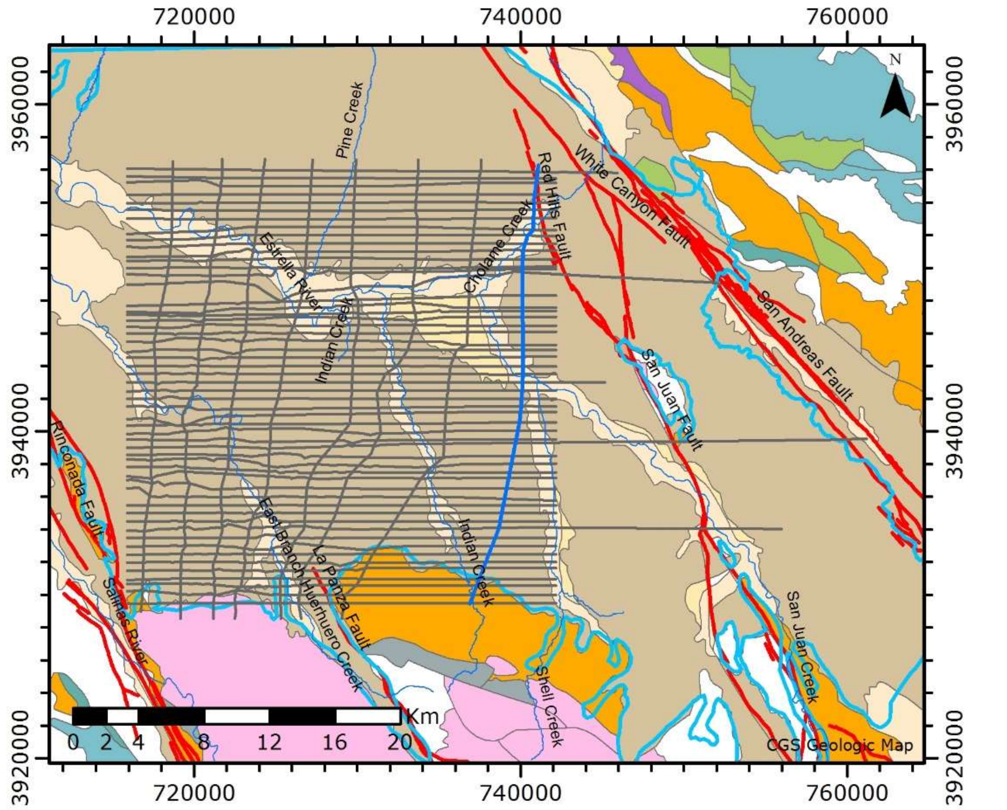
- Clay/Shale
- Gravel/shale gravel
- Sand/shale sand
- Silt/siltstone
- Sandstone
- Conglomerate
- Chert and shale
- Chalk rock
- Rock
- Topsoil
- Breccia
- Unknown

Saline/ Brackish
Clay/shale
Sand/Gravel
Sandstone
Granite

3 10 60 300
Resistivity [Ohmm]

Borehole No.
Terrain/ CGS Geologic Map
Water level
Screen

Groundwater Architecture Project (GAP)
San Luis Obispo County
Date:2020.06.18
By: TLM, MAXH
Control: PATH
Approved: MAXH
Project No. 1690013412



Coordinate system NAD 1983 UTM Zone 10N Meter, EPSG 26910

File: .\1690013412\plots\20200421\CrossSections