Part III

Attachment III-E

GEOLOGY REPORT

Pescadito Environmental Resource Center

MSW No. 2374

Webb County, Texas

PESCADITO
ENVIRONMENTAL RESOURCE CENTER

Initial Submittal March 2015

Revised September 2015

Revised November 2015

Revised January 2016

Prepared for:

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1-20-2016

STATE OF TEXAS
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1.0 INTRODUCTION

The Pescadito Environmental Resource Center (PERC) is a 953 acre tract of land located in Webb County Texas owned by Rancho Viejo Waste Management LLC (RVWM). It is part of a larger approximately 12,000 acre Yugo Ranch owned by the parent company of RVWM, Rancho Viejo Cattle Company, Ltd. Webb County is located in a semi-arid part of the state with evaporation exceeding rainfall by approximately 40 inches per year. The PERC site is located on a "salt-flat' on the Yugo Ranch that historically has had no significant oil/gas resources and vegetation is quite sparse. See Photo 1 – view to the north from southeast corner of site.

Photo 1 - Looking North from B-21

The Geology Report for the Pescadito Environmental Resource Center is provided as a series of documents to meet the specific requirements of 30 TAC §330.63(e) and to provide additional information supporting the facility design and operation. Each of the documents has been prepared by a qualified groundwater scientist or professional engineer.

A description of the regional geology and hydrogeology and related information is provided in a document entitled *Regional Geology and Hydrogeology* prepared by H. C. Clark, PhD, P.G. A copy of Dr. Clark's report is included in Appendix III-E.1. This report is submitted to fulfill the requirements of 30 TAC §330.63(e)(1-3).

Site-specific subsurface investigation results and geotechnical data for the site are provided in multiple separate reports appended to this Report. Raba Kistner Environmental, Inc. prepared the *Subsurface Investigation Report* (SIR) included as Appendix III-E.2. Raba-Kistner Consultants, Inc. prepared the *Geotechnical Data Report* (GDR) included as Appendix III-E.3.

Those reports are submitted to fulfill the requirements of 30 TAC §330.63(e)(4)(A-H) and §330.63(e)(5)(A-E) and the requirements of the Soil Boring Plan (SBP) approved by TCEQ on April 11, 2011 (Appendix III-E.2, SIR Appendix A). It should be noted that subsequent to the approval of the SBP and preparation of the SIR and GDR, the permit boundaries were reduced. The revised boundary is enclosed entirely within the original boundary that was used when the SBP was approved. Figure III-E.0-1 within this Appendix shows the two permit boundaries.

Additional information on subsurface conditions has been obtained to support facility design and operation as well as to provide additional hydrogeologic characterization of the subsurface. This information consists of hydraulic testing of previously-installed piezometers to obtain field estimates of horizontal hydraulic conductivity. The information is provided in *Summary of Hydrogeologic Testing in Selected Piezometers*, prepared by Pierce L. Chandler, Jr., P.E. and is included in Appendix III-E.4.

Further subsurface investigation and testing has been performed to provide information useful for general landfill design as well as to provide additional hydrogeologic characterization of the subsurface. The information is provided in *Supplemental Subsurface Investigation Report – Phase V*, (SSIR) prepared by Michael W. Oden, P.E. and is included as Appendix III-E.5.

In addition to an extensive literature survey and conventional subsurface investigation techniques, i.e., boring, sampling, and lab testing; borehole geophysical logging was employed at several borings to assist in subsurface characterization. The borehole geophysical logs consisted of gamma, resistivity and caliper logs and are presented in Appendix C to Appendix III-E.2 (III-E.2-C). The borehole geophysical logging was not utilized to reduce the number of borings required in 330.63(e)(4)(B); and as allowed by 330.63(e)(4)(F).

As indicated in Appendix III-E.1 the natural gamma logs were reviewed in an attempt to locate the boundary between the Yegua and Jackson sediments. As no significant increase in background gamma radiation values could be determined from the geophysical logs, as would be expected if Jackson sediments were encountered, the boundary could not be established with geophysics. Subsequent additional investigation determined the boundary to generally be east of the site.

Further the resistivity borehole geophysical logs were used to assist in identifying the more transmissive zones for placement of additional piezometers at the site. There is not much sand in the subsurface (95% clays per the Geotechnical Data Report [III-E.3]), the sands are poorly graded and contain considerable amounts of clay. The transition from clay to sand is gradational. These factors lead to the geophysical logs not showing dramatic differences between the clays and sands and make it difficult to determine a change in the characterization of the subsurface soils.

As an example of the use of the resistivity borehole geophysical logs, look at boring B-124. Piezometers were desired in potentially more transmissive zones along the southern edge of the proposed facility. Upon a review of the boring log for B-124 (III-E.2-B) it was noted that thinly interbedded sandstone layers were found between 100 feet and 113 feet below ground surface (bgs). A review of the resistivity geophysical log (III-E.2-C) showed a slight increase in resistivity (sand is typically more resistive than clay) starting at about 95 feet bgs and ending at approximately 120 feet bgs. Consequently Piezometer B-124 was installed at that location with the screen interval from 110 feet to 113 feet bgs.

2.0 HYDROGEOLOGIC SETTING

All information compiled to-date has confirmed the siting evaluation, i.e., a semi-arid area with predominantly low-permeability clay subsurface materials and no shallow groundwater resource. Even deeper, available groundwater resources are slightly used due to water quality and depth considerations.

2.1 Uppermost Recognized Aquifer

The published documents and area well records summarized in the *Regional Geology and Hydrogeology* report established that the uppermost recognized aquifer at the facility is the regional Yegua-Jackson Aquifer. This uppermost aquifer is associated with basal Yegua sands located more than 300 feet below the deepest proposed excavation. Flow in the Yegua-Jackson Aquifer is to the east and appears to coincide with the regional dip of the Yegua-Jackson, which is approximately 50 feet to the mile. The Yegua-Jackson Aquifer is recharged from the outcrop miles to the west and northwest. Yegua-Jackson Aquifer water quality in the site area is brackish.

2.2 Aquiclude

The uppermost Yegua-Jackson Aquifer is under significant confining pressure due to the effective upper confining unit or "aquiclude" provided by hundreds of feet of low permeability Yegua-Jackson clays. The effectiveness of the upper confining unit is demonstrated by conditions at the nearby Ranch Well adjacent to the facility which shows a confining pressure, i.e., a static water level of approximately 220 feet bgs although the water-producing Yegua sands are hundreds of feet lower (see Table 3 in Appendix III-E.1).

The upper confining unit or "aquiclude" to the uppermost Yegua-Jackson Aquifer provides effective environmental protection to the aquifer. In addition to the confining performance demonstrated at the Ranch Well, the properties of the confining unit are well understood from a consensus of published documents and site-specific investigation and testing including a deep boring to 500 feet bgs. These properties include:

- Predominantly clays – less than 10% net sand (Knox, 2007) and less than 5% based on site-specific investigation (SIR, Raba-Kistner, 2015 [III-E.2]).
- Clay <u>vertical</u> hydraulic conductivities (permeabilities) are very low – average Yegua clay K_v = 10^{-4} ft/day or 3.5 x 10^{-8} cm/sec and decreasing with depth (Deeds, 2010). Site-specific testing, K_v =10^{-7} to 5 x10^{-11} cm/sec (SIR, Raba-Kistner, 2015 [III-E.2] and SSIR, CB&I, 2015 [III-E.5]).
- Clays are really dry – moisture levels predominantly 7-8 percentage points below the Plastic Limit, i.e., clays are not saturated (SIR, Raba-Kistner, 2015 [III-E.2] and SSIR, CB&I, 2015 [III-E.5]).
- Clays are highly plastic – Plasticity Indices are generally in the 20 to 60 range (SIR, Raba-Kistner, 2015 [III-E.2] and SSIR, CB&I, 2015 [III-E.5]).

Sands occur as isolated sand units and horizontal interbeds within the general clay matrix of the confining unit. This is consistent with the documented anisotropy of the Yegua-Jackson. To the depths explored by the site-specific investigations, the sand units are thin, isolated and laterally discontinuous (see Figures C-1 to C-10 in Appendix C to Appendix III-E.3 (III-E.3-C) and Figures 2 to 5 in Appendix III-D.2). There are also thin sandy interbeds or partings in the clay matrix. However, site-specific field testing of piezometers installed in these potentially more transmissive sandy intervals indicated low <u>horizontal</u> permeabilities, K_h = 3 x10^{-5} to 9 x10^{-8} cm/sec (Summary of Hydrogeologic Testing in Selected Piezometers, PLC 2015 [III-E.4] and SSIR, CB&I, 2015 [III-E.5]).

2.3 Shallow Subsurface Water

The various site-specific subsurface investigations encountered very limited quantities of very poor quality subsurface water at shallow depth – essentially at the top of the identified upper confining unit or upper "aquiclude" for the uppermost aquifer (basal Yegua sands of the Yegua-Jackson Aquifer). The shallow subsurface water, i.e., perched groundwater, is primarily associated with the relatively continuous contact zone consisting of a very thin layer of coarse-grained sediments occurring at shallow depth at the base of the surficial Recent-Pleistocene soils and above the underlying Eocene-age Yegua-Jackson sediments. The shallow subsurface water appears to be unconfined, i.e., under "water-table" conditions. The shallow subsurface water associated with the contact zone also appears to be present in the highly weathered and weathered stratum, i.e. Strata II and III as described in the SIR, GDR and SSIR (SIR, Raba-Kistner, 2015 [III-e.2], Summary of Hydrogeologic Testing in Selected Piezometers, PLC 2015 [III-E.4] and SSIR, CB&I, 2015 [III-E.5]). Within the Yegua-Jackson sediments, the shallow subsurface water appears to be located in transmissive secondary structure in the clays and the thin, isolated, shallow sand units. Site-specific piezometer information indicates that some very limited hydraulic communication with the contact zone may exist down to approximately sixty feet bgs. Piezometer readings below the sixty-foot depth show confining pressures, i.e., the deep piezometers indicate higher water levels than shallow piezometers (see Figures 20 to 23 in SIR [Appendix III-E.2]). Regardless of the shallow subsurface water presence, it should be noted that the degree of hydraulic communication that exists in Stratum II and III is comparable to what would be expected in a confining unit or "aquiclude" as commonly defined:

> "*Aquiclude - a hydrogeologic unit which, although porous and capable of storing water, does not transmit it at rates sufficient to furnish an appreciable supply for a well or spring (after WMO, 1974). See preferred term confining unit.*" From the U.S. Geologic Survey, ***Federal Glossary Of Selected Terms, Subsurface-Water Flow and Solute Transport*** (USGS, 1989).

Clays make up over 95% of Strata II and III. Horizontal permeability is in the 10^{-7} cm/sec range and vertical permeability would be even lower due to the anisotropy. It should also be noted that even in Strata II and III, the clays are unsaturated (i.e. very dry with moisture contents predominantly 7-8 percentage points below the Plastic Limit) (SIR, Raba-Kistner, 2015 [III-E.2] and SSIR, CB&I, 2015 [III-E.5]) Note that many of the sand units in the weathered Yegua-Jackson (Strata II and III) are also unsaturated. See Photo 2.

Photo 2 - Clayey Sandstone in B-52 at 10 to 13 feet bgs

Based on information in the *Subsurface Investigation Report*, inferred flow direction for the shallow subsurface water appears to mimic surface drainage patterns, i.e., to the south, with gradients ranging from 0.002 to 0.003. A maximum hydraulic conductivity (horizontal) of 2.01 x 10^{-6} cm/sec (5.7 x 10^{-3} ft/day) is given in the *Geotechnical Data Report*. Using these inputs, and conservatively using an average value for effective porosity for a sandy clay of 7%, a flow velocity of 5.94 x 10^{-2} to 8.92 x 10^{-2} ft/year is calculated.

Stratum IV is even more impermeable. Three test results on clay from Stratum IV indicate a vertical permeability (hydraulic conductivity) in the 10^{-9} to 10^{-11} cm/sec range at depth in Stratum IV or the unweathered Yegua-Jackson. A fourth test (PI = 42) result was in the 10^{-7} range; however, testing of that sample was delayed in the laboratory and micro-cracking was observed in the test specimen that could have affected the test result. (see Attachment F to Appendix III-E.5 [III-E.5-F]) SSIR, CB&I, 2015). At the very top of Stratum IV (Test Pit 2), vertical permeability was K_v = 1.2 x 10^{-7} cm/sec and horizontal permeability, K_H = 8.3 x 10^{-7} to 5.5 x 10^{-9} cm/sec (see Appendix B to Appendix III-E-3 [III-E.3-B], GDR, Raba-Kistner 2015). As with Strata II and III, Stratum IV clays predominate by over 95% and are not only unsaturated, they are very dry with moisture contents predominantly 7-8 percentage points below the Plastic Limit, i. e., the clays are not saturated (R-K & CBI, 2015). Note that many of the sand units in the unweathered Yegua-Jackson (Strata IV) are also unsaturated (see Photo 3). As you go deeper in Stratum IV, the geologic dip takes greater control in the water flow direction. Even though Stratum IV may contain very limited water, it still functions as an effective confining unit or "aquiclude" to the vertical migration of water.

Photo 3 - Clayey Sandstone in B-58 at 95' bgs

The results of the site investigations demonstrate that: (1) The shallow subsurface water in the contact zone at the base of the Recent-Pleistocene (Strata I) and the hydraulically connected secondary structure in the clays, thin sand units, and/or anisotropic, horizontal, more transmissive bedding characteristics in Strata II and III (highly weathered Y-J and weathered Y-J) down to about 60 feet; **and** (2) the deeper sand units and anisotropic, more transmissive horizontal bedding characteristics in Strata IV (unweathered Y-J) below 60 feet all the way down to the proposed depth of excavation; **together** represent the "potential migration pathways" for any release from the proposed landfill. Clearly, 30 TAC §330.63(f)(3) indicates that the contact zone, Strata II and III, and that portion of Stratum IV above the deepest proposed excavation are the logical groundwater monitoring interval for groundwater monitoring wells to ensure detection of any contamination released from a solid waste management unit

The obvious problem at this site is common to many landfills that are constructed in practically impervious clay-rich subsurface materials that would ordinarily be classified as "aquicludes" because of their impermeability characteristics. Such sites typically have some shallow subsurface water depending on season and precipitation. The most logical groundwater monitoring zone in such cases is to monitor the shallow subsurface water and extend the monitoring zone down to the bottom of the deepest proposed excavation. However, the monitored zone will rarely meet the regulatory definition of "aquifer" in 30 TAC §330.3(8).

> "***Aquifer***--*A geological formation, group of formations, or portion of a formation capable of yielding significant quantities of groundwater to wells or springs.*"

Nor will it meet the definition of "uppermost aquifer" in in 30 TAC §330.3(168).

> "***Uppermost aquifer***--*The geologic formation nearest the natural ground surface that is an aquifer; includes lower aquifers that are hydraulically interconnected with this aquifer within the facility's property boundary.*"

The shallow subsurface water at this site doesn't meet the regulatory definition of aquifer because it is not capable of "*yielding significant quantities of groundwater to wells or springs.*" The contact zone, transmissive secondary structure in the clays, thin sand units, and horizontal, more transmissive bedding characteristics represent very little saturated volume since low permeability clays make up about 95% of the subsurface. Further, for what limited quantity of water there is, the water quality is very poor – ranging from saline to brine (see SSIR, CBI, 2015). It should be noted that even if there were ample saturated material and good quality water, which the investigations prove there is not, subsurface conditions are so poorly transmissive, that wells cannot yield significant quantities of groundwater. Laboratory and field testing (GDR, Raba-Kistner, 2015 [III-E.3], Summary of Hydrogeologic Testing in Selected Piezometers, PLC 2015 [III-E.4] and SSIR, CB&I, 2015 [III-E.5]) shows that even the more transmissive zones encountered are poorly permeable to practically impervious.

To meet the regulatory requirements while simultaneously providing an effective groundwater monitoring system, it is proposed that the shallow subsurface water be considered the "regulatory uppermost aquifer" exclusively for complying with the requirements of 30 TAC §330.63(e)(4), 30 TAC §330.63(f)(3), and 30 TAC §330.403(a). The proposed monitoring system fully complies with the above stated rules; regardless the executive director could approve the proposed groundwater monitoring system under 30 TAC §330.403(c).

2.4 Summary

The subsurface conditions beneath the site are characterized as follows from the ground surface downward. See Figure 2 for a graphical representation:

- Stratum I is comprised of Recent-Pleistocene deposits with a coarse grained layer of sediments at the base of the Stratum. This zone typically transmits seasonal moisture from surface infiltration.

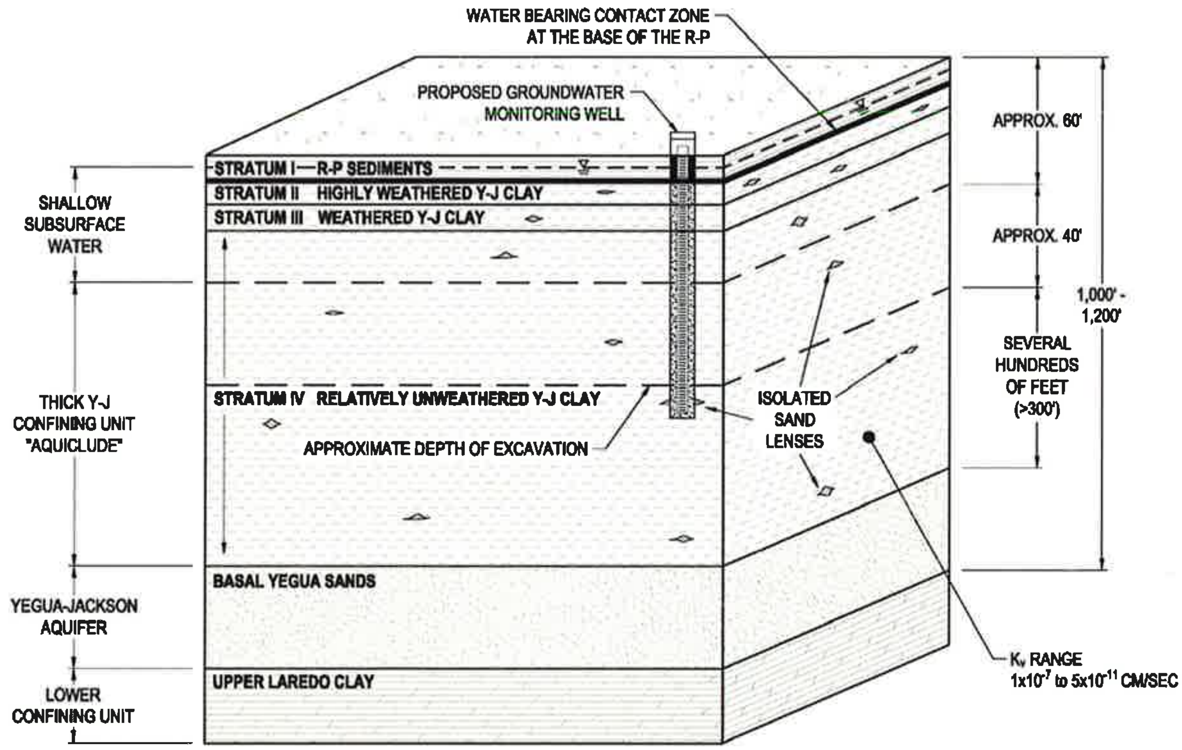


FIGURE 2
GENERALIZED CONCEPTUAL REPRESENTATION OF SITE HYDROLOGY
NTS

- Strata II, III and IV are predominately Eocene clay deposits of the Yegua-Jackson group and are subdivided as Highly Weathered (II), Weathered (III) and Relatively Unweathered (IV). These Strata contain 95% clay material that is overly consolidated and 7 to 8 percentage points dry of the plastic limit. Strata II, III and IV clays are practically impervious based on criteria established by Terzaghi and Peck in *Soil Mechanics in Engineering Practice* (1967). Vertical hydraulic conductivities of the clays ranged from approximately 1 x 10^{-7} cm/sec to less than 1 x 10^{-10} cm/sec. Isolated sandy intervals in Strata II, III, and IV are also poorly permeable to practically impervious with horizontal hydraulic conductivities ranging from approximately $1x10^{-5}$ cm/sec to less than 1 $x10^{-7}$ cm/sec.

- Strata II, III and IV contain isolated sand lenses that are discontinuous, poorly permeable to practically impervious but may be hydraulically connected to the contact zone to a depth of approximately 60-feet creating a shallow subsurface water bearing zone.

- The shallow subsurface water bearing zone has been designated as the "regulated uppermost aquifer" for groundwater monitoring purposes and extends to approximately 60 feet bgs and encompasses Stratum I, II, III and a portion of IV. This depth is based on the head difference in piezometers screened above 60-feet and those screened below 60-feet as discussed in Section 2.3 Shallow Subsurface Water.

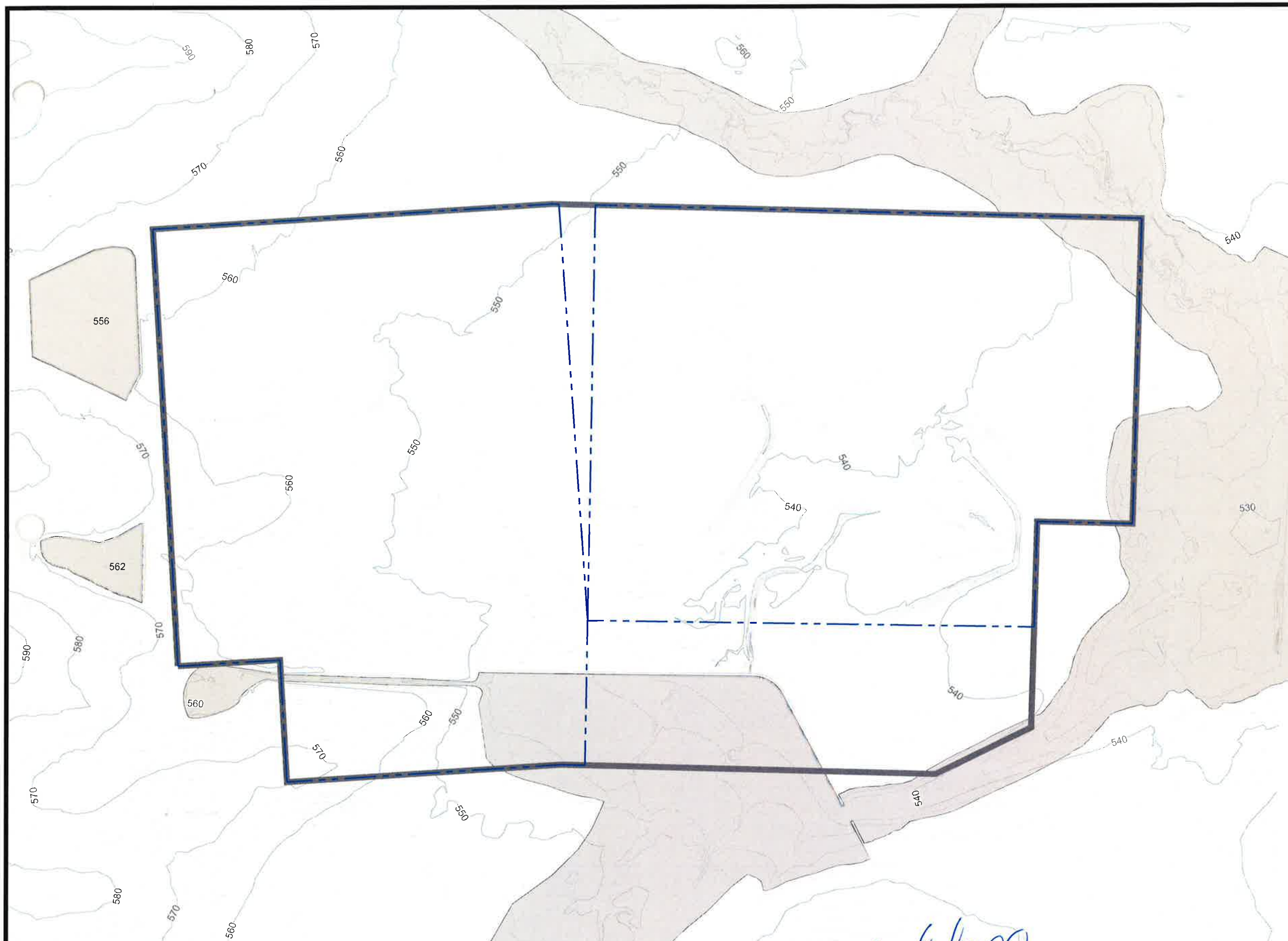
- Below approximately 60 feet and to several hundreds of feet (>300 feet below the deepest proposed excavation), Strata IV serves as the effective upper confining unit or aquiclude to the uppermost recognized aquifer beneath the site, i.e., the regional Yegua-Jackson Aquifer.

- Below approximately 60 feet, the water in Strata IV is very limited and under confined conditions.

- The uppermost recognized aquifer is comprised of the basal sands that occur near the bottom of the Yegua formation and is approximately 400-feet in thickness.

- The uppermost recognized aquifer exhibits confining pressures of several hundreds of feet.

- The upper Laredo Clays serve as the lower confining unit for the uppermost recognized aquifer, the regional Yegua-Jackson Aquifer (basal sands of the Yegua).



LEGEND

— · —	REVISED PERMIT BOUNDARY (2014)
▬	ORIGINAL PERMIT BOUNDARY (2011)
▭	CLOMR 100-YEAR FLOODPLAIN

NOTES

1. EXISTING CONTOURS DEVELOPED FROM SITE AERIAL TOPOGRAPHIC SURVEY BY DALLAS AERIAL SURVEYS ON FEBRUARY 15, 2010.
2. BOUNDARY AND IMPROVEMENT SURVEY DEVELOPED BY MEJIA ENGINEERING COMPANY ON AUGUST 15, 2011 AND JUNE 9, 2014.
3. FOR CLARITY, NOT ALL SITE FEATURES MAY BE SHOWN.
4. THE ORIGINAL PERMIT BOUNDARY WAS SUBMITTED IN 2011 AND WAS THE BASIS FOR THE APPROVED SOIL BORING PLAN. THE REVISED PERMIT BOUNDARY (2014) IS COMPLETELY WITHIN THE ORIGINAL BOUNDARY.

REV. NO.	DATE	DESCRIPTION

CB&I Environmental & Infrastructure, Inc.
TBPE FIRM F-5650

STATE OF TEXAS
MICHAEL W. ODEN
67165
REGISTERED PROFESSIONAL ENGINEER

THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF PERMITTING UNDER THE AUTHORITY OF MICHAEL W. ODEN, P.E. 67165.
9-18-2015

PESCADITO ENVIRONMENTAL RESOURCE CENTER
WEBB COUNTY, TEXAS
MSW 2374

ORIGINAL AND REVISED PERMIT BOUNDARIES

PROJ. NO.:	148866	DATE:	APRIL 2015
DESIGNED BY:	–	DRAWING NO.	III E.0-1
DRAWN BY:	MTE		
CHECKED BY:	RDS		
APPROVED BY:	MWO	1 OF 1 SHEETS	