Attachment A

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Technical Memorandum

Date:	18 October 2013
To:	Scott Maloni, Poseidon Water
From:	Gordon Thrupp, Geosyntec Consultants
Subject:	Response to Requests from California Coastal Commission Regarding Geosyntec' s Feasibility Assessment of Shoreline Subsurface Collectors Huntington Beach Seawater Desalination Project, September 2013

This memo provides responses to requests for additional information made by Coastal Commission (CCC) Staff[1] based on their review of Geosyntec's September 2013 Feasibility Assessment of Shoreline Subsurface Collectors, Huntington Beach Seawater Desalination Project (the Geosyntec Report). Each CCC staff request is provided below, followed by Geosyntec's response.

1. *All seismic reflection profile data, in both uninterpreted and interpreted versions (the report provided just a few of the survey runs).*

A portable hard drive is being provided to CCC Staff that includes all of the raw data from the seismic reflection survey (Geophysical Survey) conducted offshore of Huntington Beach on August 6-7, 2013, by EcoSystems Management Associates, Inc. (ECO-M). The hard disk also includes PDF files of migrated (FKmig_Profiles) and stacked profiles (Stack_Profiles) with ten times vertical exaggeration and seismic velocity of 5,000 ft/sec. The other folders on the portable hard drive include the navigation files (SEGP1), Observer's Logs from the Geophysical Survey, and USGS data for other seismic surveys previously conducted on the San Pedro Shelf.[2] **Attachment 1** provides two figures showing the location of the San Pedro Shelf.

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[1] Email dated 8 Oct 2013 from Tom Luster of the CCC to Scott Maloni with Poseidon Water and Phone call with Mark Johnson of the CCC on 10 Oct 2013 re: preliminary review of Sept 2013 Geosyntec report.

[2] The San Pedro Shelf is a broad extension of the continental shelf between Newport Beach and the Palos Verde Peninsula. Approximately 400 km^2 of the area has water depths that are less than 100 m. The San Pedro Sea Valley, San Gabriel Canyon, and Newport Canyon cut into the slope off San Pedro Shelf at the west, south, and southeast. Based on numerous sea-floor samples the majority of the sea floor of the San Pedro Shelf consists of muddy sand.

Interpreted profiles were provided as geological cross-sections in the Geosyntec Report (Figures 6 and 7). The cross-sections show the character of the sub seafloor geology in the region offshore of the proposed desalination facility. For the complex geology and dense sub seafloor data coverage, interpretation was accomplished using the Geographix interpretation software and the points ("picks") for the relevant sub seafloor horizons were exported as XYZ (ascii) files for contouring and hydrogeological modeling. Figures 8, 9 and 10 of the Geosyntec Report provide contours on the top, bottom and thickness of the Talbert Aquifer offshore, based on processing and interpretation of the Geophysical Survey data by Legg Geophysical. The portable hard drive also includes the data sets from the Geophysical Survey of approximately 11,000 points ("picks") that define the top and bottom of the Talbert Aquifer.

Interpreted profiles (cross-sections) were not prepared for all the seismic reflection lines because they were not needed for the feasibility assessment of offshore collectors.

2. *Justification of the K values used, especially for the Holocene sediments overlying the Talbert Aquifer offshore up to the seafloor.*

The Holocene sediments overlying the Talbert Aquifer are dominantly fine-grained and function as a confining unit because of their low hydraulic conductivity. The basis for Geosyntec's determination of the fine-grained nature and low hydraulic conductivity of these sediments includes several references that are summarized in Section 3 of the Geosyntec Report, some of which are discussed below. Figure ES-1 and Figure 5 from the Geosyntec Report, which is a map showing locations of the numerous geotechnical samples further discussed below, is provided as **Attachment 2** to this memo.

> USACOE, 1988. Santa Ana River Design Memorandum No. 1. Ten shallow soil borings were drilled in 1979 along the Santa Ana River between Hamilton Ave and PC Hwy. Table 7, which is provided as **Attachment 3** to this memo, summarizes geotechnical properties of 44 shallow borings drilled from 1980 to 1986. As summarized graphically by Figure 1 below, only 8% of the depth intervals logged in the ten borings are sand (USCS[3], SP or SW) and 92% of soil borings are fine-grained sediments of low-permeability, which is representative of the fine-grained sediments that overlie of function as confining layer above the Talbert Aquifer.

[3] **Unified Soil Classification System** (**USCS**) is a soil classification system used in engineering and geology to describe the texture and grain size of soil (e.g. ASTM, 1985). The classification system is a two-letter symbol. The first letters include G (gravel), S (sand), M (silt), C (Clay), and O (organic). The second letters include P (poorly graded=uniform grain size), W (well graded=diverse range of grain sizes), H (high plasticity), and L (low plasticity).

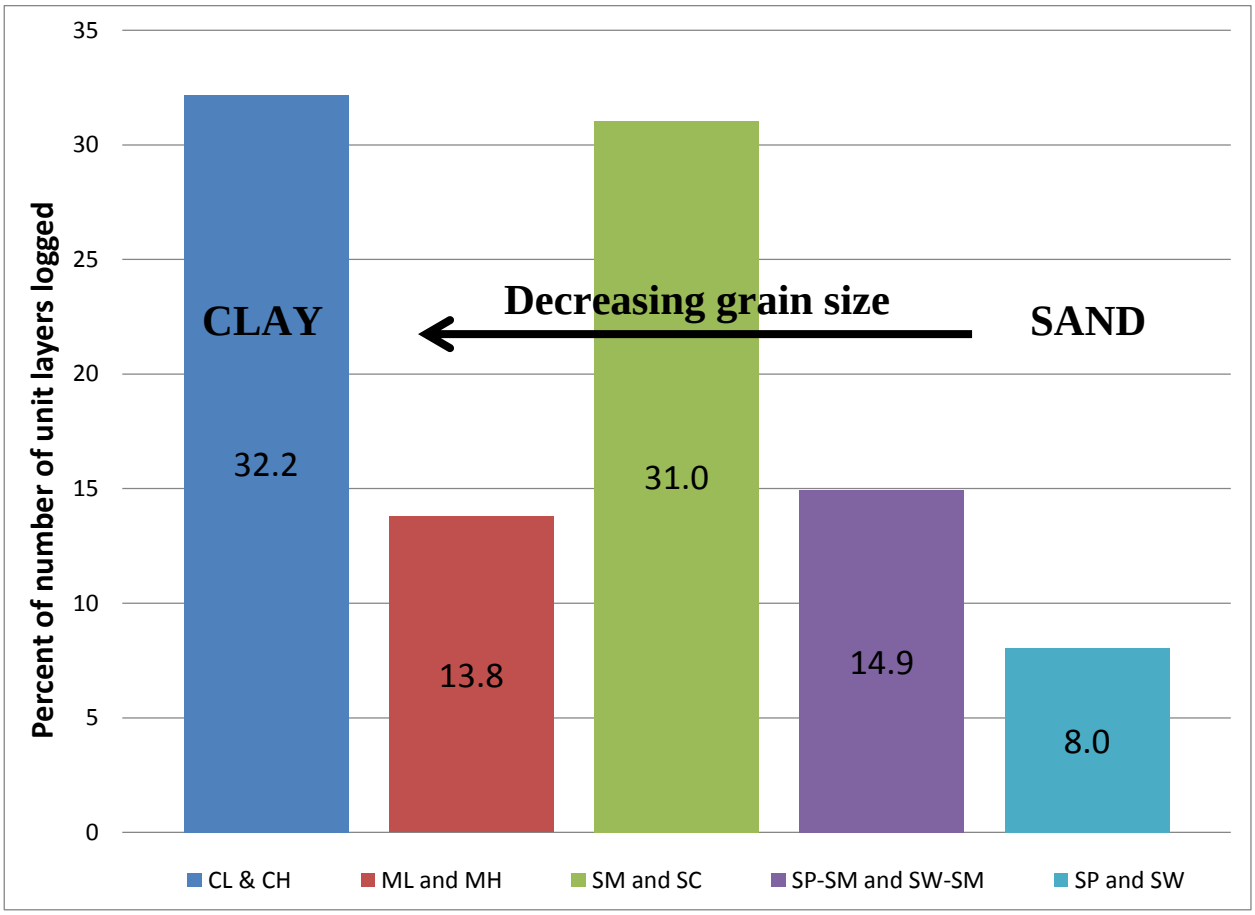

Figure 1. Compilation of soil types reported for ten shallow borings along the Santa Ana River (US ACOE, 1988)

GeoLogic Associates (GLA), May and November 2002, Geotechnical and Seismic Assessments for the Poseidon Desal Project. This investigation includes 21 cone penetrometer tests (CPTs) and 6 mud rotary borings to depths of approximately 90 ft on shore at the proposed Desal Facility Site. The report indicates that the Facility Site lies within a former estuarine environment in which deposition of dominantly fine-grained sediments is expected. The stratigraphy consists of approximately 9 ft fill / 4 ft clay / interbedded fine-grained sand with interbeds of clay and silt to depths of 72 ft (marine and estuarine) underlain by fluvial deposits (sand, silt & clay) from depths of 72 to 90 ft.

CDM 2000. Orange County Water District ("OCWD") Barrier System Modeling/Design Criteria. This report documents the design and application of a calibrated groundwater

model developed for OCWD to optimize operation of the Talbert Seawater Intrusion Barrier comprised of injection wells to both prevent seawater intrusion and replenish groundwater. The hydraulic conductivity assigned to the OCWD model for the aquifers is in part based on aquifer testing and boring logs of wells. The ECO-M Geophysical Survey justifies correlation of the offshore stratigraphy to the onshore geology and previous modeling efforts because it demonstrates continuity between onshore and offshore stratigraphy.

The properties of the OCWD model are based on aquifer testing and boring logs of many wells in the Orange County Groundwater Basin including the Talbert Gap. The top of the Talbert Aquifer near the Huntington Beach Coastline including the coastline adjacent to the proposed Desal Facility is approximately 90 feet deep and is overlain by a confining layer of fine-grained sediments with a reported range of hydraulic conductivity from 0.01 to 0.04 ft/d (Table 2-2, CDM, 2000; Figure 8 of the Geosyntec Report).

Tetra Tech, 2012, Site-Specific Hydraulic Conductivity Values. This report contains a compilation of site data and calculation of hydraulic conductivity for the Facility Site from GLA (2002) CPT data. Based on soil properties measured at hundreds of different points in 21 separate CPT soundings from the ground surface to depths of approximately 90 ft beneath the proposed Desal Facility Site. Tetra Tech calculated an average hydraulic conductivity (K) of 6 ft/d (2.1 x 10^{-3} cm/sec). The Geophsyical Survey conducted in August 2013 establishes that the onshore shallow stratigraphy beneath the coast, including the fine-grained sediments characterized by the CPT soundings at the Desal Facility Site, continues offshore. Therefore the geotechnical data collected onshore underneath the Project site are also applicable to the offshore sediments.

Osborne, et al., 1983, Documentation of borings offshore of Huntington Beach between the mouth of the Santa Ana River and the Huntington Beach Pier and within a distance of 10,000 ft from the beach indicates that shallow subsurface consists of silty very fine sand to very fine sand (USCS SM – SP). The sample locations are shown on Figure 5 of the Geosyntec Report, which is provided as **Attachment 2** to this memo.

US ACOE, 1988. Shallow seafloor sediments between the beach and 10,000 ft offshore of Huntington Beach and from the mouth of the Santa Ana River and the Huntington Beach Pier consist of silty sand, and silt or clay intervals with thickness of 0.5 to 6 ft depths of greater than 20 feet.

US ACOE, 2001. Offshore vibracore and diver-core samples offshore of the mouth of the Santa Ana River, southeast of the proposed Desal Facility Site are dominantly silty fine-

grained sand. Moreover, the sandy sediment is commonly micaceous, which reduces vertical hydraulic conductivity.

Wong et al, 2012. USGS publication on seafloor geology of the San Pedro Shelf. 182 grab sediment samples with grain-size analyses from the seafloor of the San Pedro Shelf. 22 samples are within the vicinity of Desal Facility area (see Figure 5 of Geosyntec Report, which also is included on **Attachment 1** with this memo). The majority are sandy silt or silty sand referred to by Wong et al. as "muddy sand."

Based on characterization of the sediments summarized above, the assigned values in the Geosyntec model of 10 and 1 ft/d for the horizontal and vertical hydraulic conductivity (Kv and Kh) of the fine-grained sediments overlying the Talbert Aquifer is conservatively high for the purpose of evaluating potential water production from the Talbert Aquifer beneath the shoreline. Heath (1989) reports that values for hydraulic conductivity of silty sand range from approximately 0.02 to 30 ft/d with a mean value of approximately 1 ft/d. Bear (1972) classifies very fine sand and silt as semi-pervious with hydraulic conductivity ranging from $1x\ 10^{-7}$ to $1x10^{-3}$ cm/sec, which is equivalent to a range of $3x10^{-4}$ to 3 ft/d. Moreover, as reported with the documentation for the OCWD groundwater model (Table 2-2, CDM 2000), values of hydraulic conductivity for the fine-grained material overlying the Talbert Aquifer are much lower, and range from 0.01 to 0.04 ft/d.

Because of the generally stratified nature of alluvium sediments, the hydraulic conductivity is lower across (perpendicular to) layering than parallel to it. Consequently, vertical hydraulic conductivity (Kv) is lower than horizontal conductivity (Kh) in alluvial sediments. The ratio of Kh to Kv is a function of scale, but values of this ratio in the range of 10 to 100 are common[4]. A ratio of Kh to Kv of 10 to 1, which was assigned to the model for this project, is a typical and scientifically appropriate "default" ratio in groundwater models.

To summarize, the Geosyntec model developed to evaluate the feasibility of subsurface offshore collectors is based on extensive onshore and offshore site-specific geotechnical data (See Figure 5 of the Geosyntec Report, also provided as **Attachment 2** to this memo). The Kh and Kv values of 10 and 1 ft/d are scientifically appropriate and optimistically high for alluvial sediments consisting dominantly of silty fine sand, termed "muddy sand" by Wong et al. (2012). On the scale of several tens of feet of thickness of the fine-grained sediment, the actual Kv value

[4] http://web.ead.anl.gov/resrad/datacoll/conuct.htm

of the sediments overlying the Talbert Aquifer is likely substantially lower due to the presence of intervals of clay and silt. As discussed above, CDM (2000) report a range of 0.01 to 0.04 ft/d for the hydraulic conductivity of the fine-grained sediments overlying the Talbert Aquifer, which is 25 to 100 times lower than the Kv used in the Geosyntec Model for the fine-grained sediments overlying the Talbert Aquifer.

Assigning a lower value of Kv than 1 ft/d for the fine-grained sediments overlying the Talbert Aquifer in the Geosyntec Model would be scientifically justifiable but would result in the model showing lower source water production potential from the offshore subsurface and greater lowering (drawdown) of the water table along the coast. Accordingly, the use of a Kh and Kv values of 10 and 1 ft/d for the fine-grained sediments overlying the Talbert Aquifer in the Geosyntec Model is optimistic because it results in a model showing higher source water production potential from the offshore subsurface. Kh and Kv values greater than 10 and 1 ft/d would not be scientifically justifiable because of the dominantly fine-grained texture of the sediments.

3. More complete justification for boundary conditions at the offshore end of the model.

The ocean boundary condition in Geosyntec's model is a specified constant hydraulic head (water pressure) boundary with an assigned elevation of 0.57 ft MSL. This water level is based on average water levels in monitoring wells near the coastline utilized for calibration of the OCWD model (CDM, 2000, OCWD, 2004). The offshore portion of the uppermost model layer in Geosyntec's model consists entirely of specified head with an assigned elevation of 0.57 ft MSL to represent the ocean. The value of 0.57 ft MSL for specified constant hydraulic head to represent the ocean results in a greater flow rate from the ocean to the subsurface than a value of 0 ft MSL. Accordingly, the conservative assumption behind the ocean boundary condition in the Geosyntec model is an additional reason that the model provides for an optimistically high estimate of the potential production rate of source water from the subsurface offshore of Huntington Beach.

At the margin of the Geosyntec model, approximately 4.3 miles feet offshore (see Figure 12 of the Geosyntec Report), all model layers are in direct connection with the sea. The distance to the seawater connection is generally consistent with the San Pedro Shelf geometry; the distance from the Huntington Beach coastline to the edge of the San Pedro Shelf is approximately 5.2 miles. If the Talbert Aquifer extends to the margin of the San Pedro Shelf, it likely would be exposed in the slope beyond the Continental Shelf.

Although the model represents the Talbert Aquifer as continuous offshore, the Geophysical Survey indicates that in reality, the Talbert Aquifer is not continuous but instead segmented. In addition, northwest of the Facility Site, the basal channel portion of the Talbert Aquifer appears to thin and even terminate approximately 1,000 feet offshore (see cross-sections on Figure 7 of the Geosyntec Report). Accordingly, because the Geophysical Survey demonstrates that the Talbert Aquifer actually is not continuous offshore, the model's representation of the Talbert Aquifer as continuous offshore results in overestimation of the potential production rate from the Talbert Aquifer.

4. Sensitivity analyses – i.e., multiple model runs with varying values of Kh, Kv, and boundary conditions.

Sensitivity analyses are not necessary to determine the feasibility of an offshore subsurface collector system because Geosyntec's model is designed as a conservative tool that over-predicts production potential from the Talbert Aquifer beneath the coastline. Further discussion regarding representation by the model of Talbert Aquifer and the overlying fine-grained sediments follows.

In the Geosyntec model, the Talbert Aquifer offshore, which underlies the fine-grained sediments beneath the seafloor, is assigned an optimistically high hydraulic conductivity and is represented as continuous and of constant thickness offshore. Uniform high values of 300 and 30 ft/d for Kh and Kv were assigned in the model to the Talbert Aquifer near the coast and offshore, which is consistent with the OCWD groundwater model (e.g. CDM, 2000), although in reality a general gradual decrease in grain size and permeability in the Talbert Aquifer is expected with distance offshore[5]. The zonally decreasing values of hydraulic conductivity assigned to the Talbert Aquifer in the OCWD groundwater model (CDM, 2000) are shown on Figure 13 of the Geosyntec Report. In addition, although Geosyntec's model represents the Talbert Aquifer as continuous and of constant thickness offshore, in reality, the Geophysical Survey shows that the Talbert Aquifer offshore actually is structurally segmented and includes localized channels (see Figures 6 - 10 of the Geosyntec Report).

Geometry of the Talbert Aquifer onshore and offshore is shown by contour maps provided by Figures 8, 9, and 10 of the Geosyntec Report. The offshore geometry is based on the

[5] In the Geosyntec Model, the Talbert Aquifer is represented by model layers 5 through 8 and the overlying fine-grained low permeability sediments are represented by model layers 2 through 4 (see Figures 12 and 14 in the Geosyntec Report). In the model, values of Kh and Kv for the Talbert Aquifer (Layers 5 – 8) are 300 and 30 ft/d and values of Kh and Kv for the overlying fine-grained sediments (Layers 2 – 4) are 10 and 1 ft/d.

Geophysical Survey; the contour maps of the top and bottom of the offshore Talbert Aquifer are each based on approximately 50,000 points ("picks") identified from the Geophysical Survey data by Legg Geophysical. Based on these detailed geophysical data, the average thickness of the Talbert Aquifer offshore in the surveyed area is 81 ft. A constant thickness of 90 feet is used for the Talbert Aquifer in the Geosyntec model, which also contributes to the conservatively high assessment by the model of source water production from the subsurface offshore of Huntington Beach because the rate of flow of water through an aquifer is proportional to its thickness (i.e., the source water production potential is greater for a thicker aquifer).

The hydraulic conductivity of the fine-grained sediments that overlay the Talbert Aquifer controls the degree of hydraulic connection between the sea and the Talbert Aquifer. As discussed above, the assigned horizontal and vertical hydraulic conductivity (Kh and Kv) values in the Geosyntec model of 10 and 1 ft/d are scientifically based, conservative maximum values for the fine-grained sediment. Accordingly, the model is designed to represent the maximum degree of hydraulic connection between the offshore Talbert Aquifer and the sea, thus eliminating the need for a sensitivity analysis. As discussed above, the actual Kh and Kv of the fine-grained sediment overlying the Talbert Aquifer are likely substantially lower than values of 10 and 1 ft/d that are used in the Geosyntec model. Additional model runs to provide a sensitivity analysis assuming higher values of Kh and Kv for the low permeability fine-grained sediment overlying the Talbert Aquifer would be scientifically inappropriate and produce highly unrealistic results. Model sensitivity simulations with lower Kh and Kv values for low permeability fine-grained sediment overlying the Talbert Aquifer would decrease the hydraulic connection to the sea and thus (1) reduce the model production rate from the Talbert Aquifer and (2) increase the drawdown (lowering) of the water table near the coastline.

In summary, potential sensitivity analyses including (1) lower Kh and Kv of the Talbert Aquifer offshore, (2) representation of discontinuities in the Talbert Aquifer offshore, (3) lower Kh and Kv for the fine-grained sediment overlying the Talbert Aquifer, would show lower production potential from the Talbert Aquifer and more drawdown of the water table near the coastline.

5. Explain the assumption that the Talbert Aquifer is the only potential alternative source of water for offshore subsurface collectors. Is production from deeper aquifers feasible?

On an October 10, 2013, phone call, CCC Staff requested justification from Geosyntec that the Talbert Aquifer is the only potentially viable offshore subsurface source of water for the proposed Desal Facility.

The Orange County Groundwater Basin includes three major aquifer systems commonly referred to as the Upper, Middle and Lower (e.g. OCWD, 2004; Edwards, 2009). The Newport-Inglewood Fault Zone (NI FZ) functions as an impermeable boundary along the coastline because consolidated non-water bearing bedrock is uplifted on the southwest (coastal) side of the fault zone. A generalized regional north-south geologic cross-section through the Santa Ana River portion of Orange County Groundwater Basin is provided as **Attachment 4** to this memo, and a cross-section showing the layers in the OCWD Talbert Gap groundwater model (CDM, 2000) is provided below (Figure 2). Both cross-sections illustrate that only the Upper Aquifer System extends to the coast and offshore. The Talbert Aquifer is the primary water bearing interval in the Upper Aquifer System; deeper sediments are reported to be semi-indurated and have lower permeability or consolidated non-water bearing bedrock (OCWD, 2004; Herndon and Bonsangue, 2006; Edwards et al., 2009).

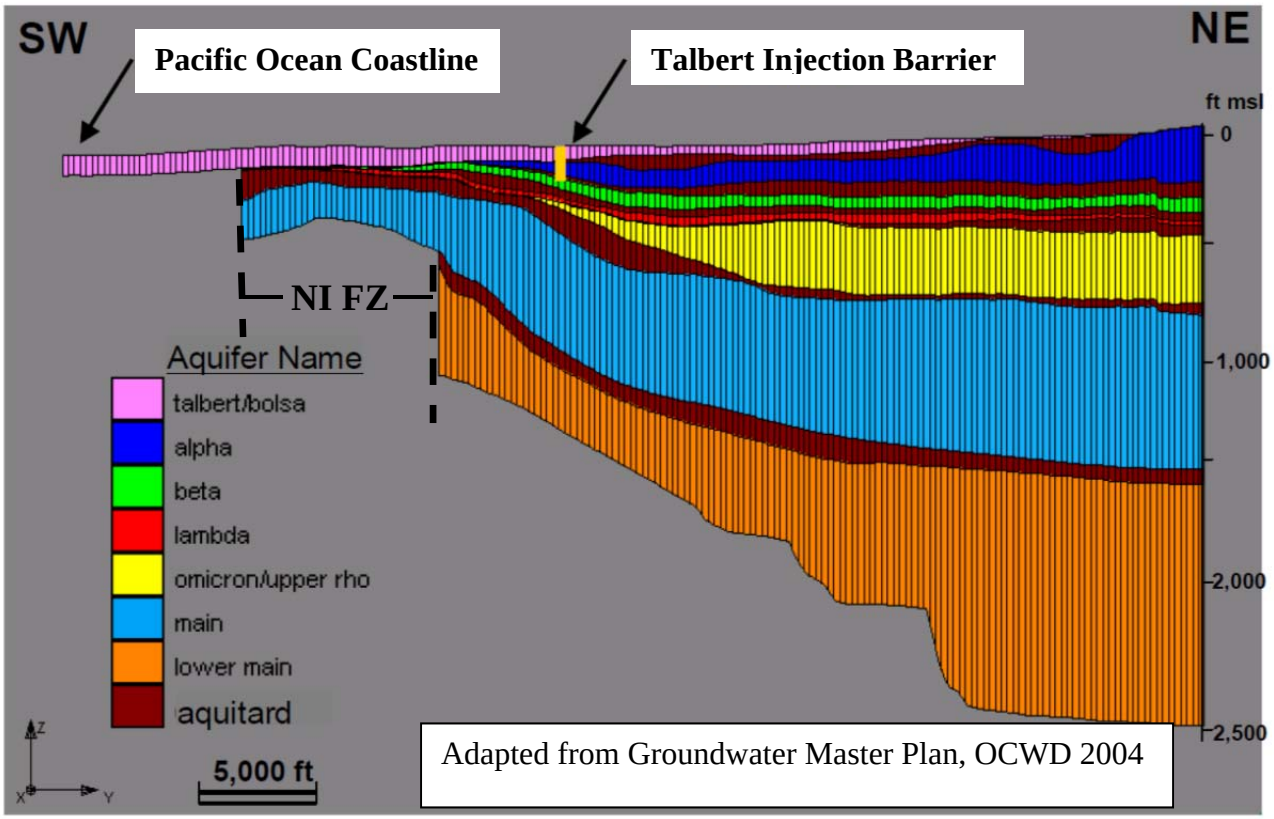

Figure 2. Layering of OCWD Groundwater Model (CDM, 2000; OCWD, 2004).

In summary, due to uplift of bedrock along the Newport Inglewood Fault, the Middle and Lower Aquifer systems of the Orange County Groundwater Basin do not exist offshore of Huntington Beach (see Figure 2 above, and **Attachment 4**). Due to more consolidation and induration at depth, the offshore subsurface deeper than the Talbert Aquifer is expected to have lower permeability and thus lower groundwater production potential than the Talbert Aquifer. Moreover, the deeper subsurface would have less hydraulic connection to the sea.

In addition, the bottom of the Talbert Aquifer, which reaches depths of approximately 200 feet offshore, is a reasonable practical technological limit for potential subsurface collector systems beneath the coastline (e.g. US Bureau of Reclamation, 2009). And, as addressed in the Geosyntec Report, offshore vertical wells connected with a deep infiltration gallery (DIG)[6] is not a feasible alternative offshore of Huntington Beach because of the offshore segmentation and complicated geometry of channels in the Talbert Aquifer revealed by the Geophysical Survey. . Moreover, permeability of the Talbert Aquifer is expected to generally decrease further offshore as does the subsurface below the Talbert Aquifer.

Hypothetically, even if the Talbert Aquifer was uniform and continuous offshore of Huntington Beach, the DIG tunnel likely would have to be dozens of feet in diameter and thousands of feet long to connect to tens of offshore vertical wells that would be necessary to achieve the necessary source water production rate. The engineering, construction, operation and maintenance of such an enormous system below the ocean floor has never been demonstrated and therefore constitutes a risky and unproven technology.

[6] A DIG is a tunnel in the seafloor extending offshore connecting a series of offshore vertical wells.

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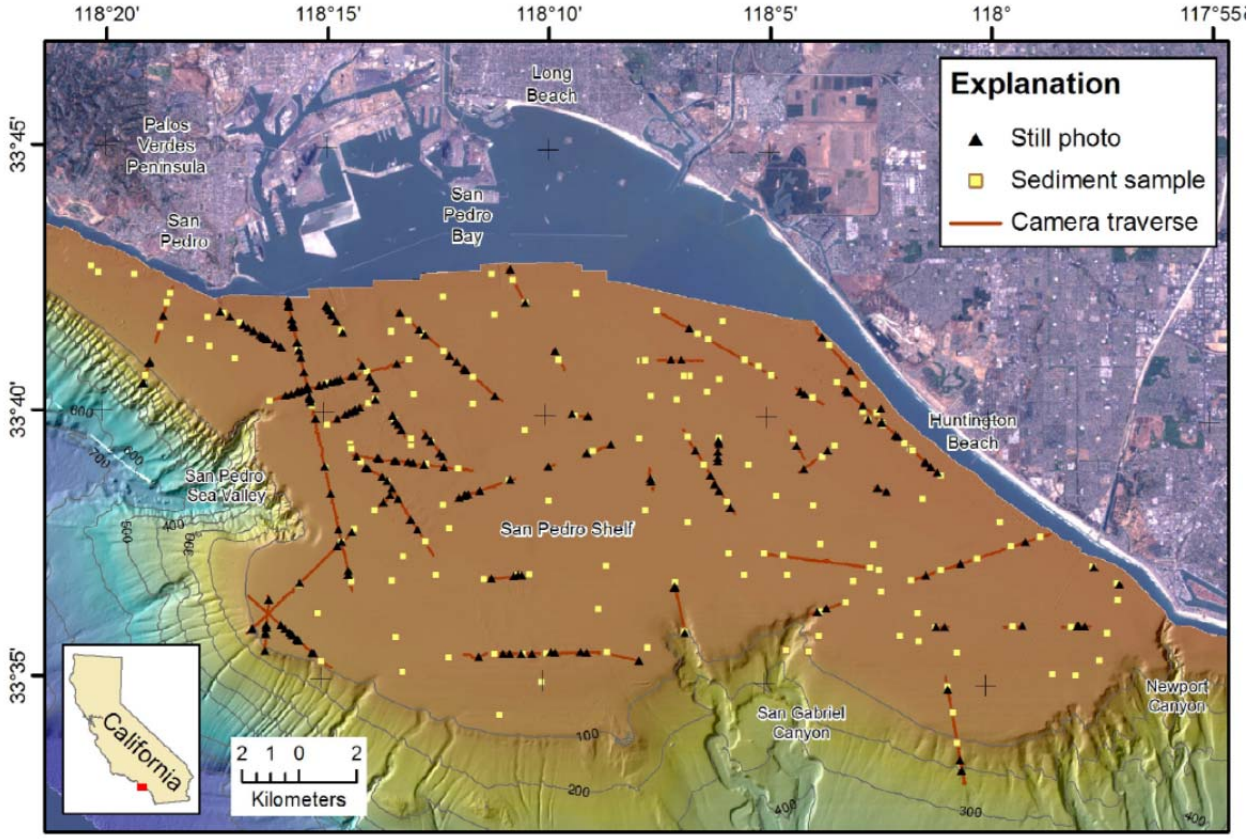
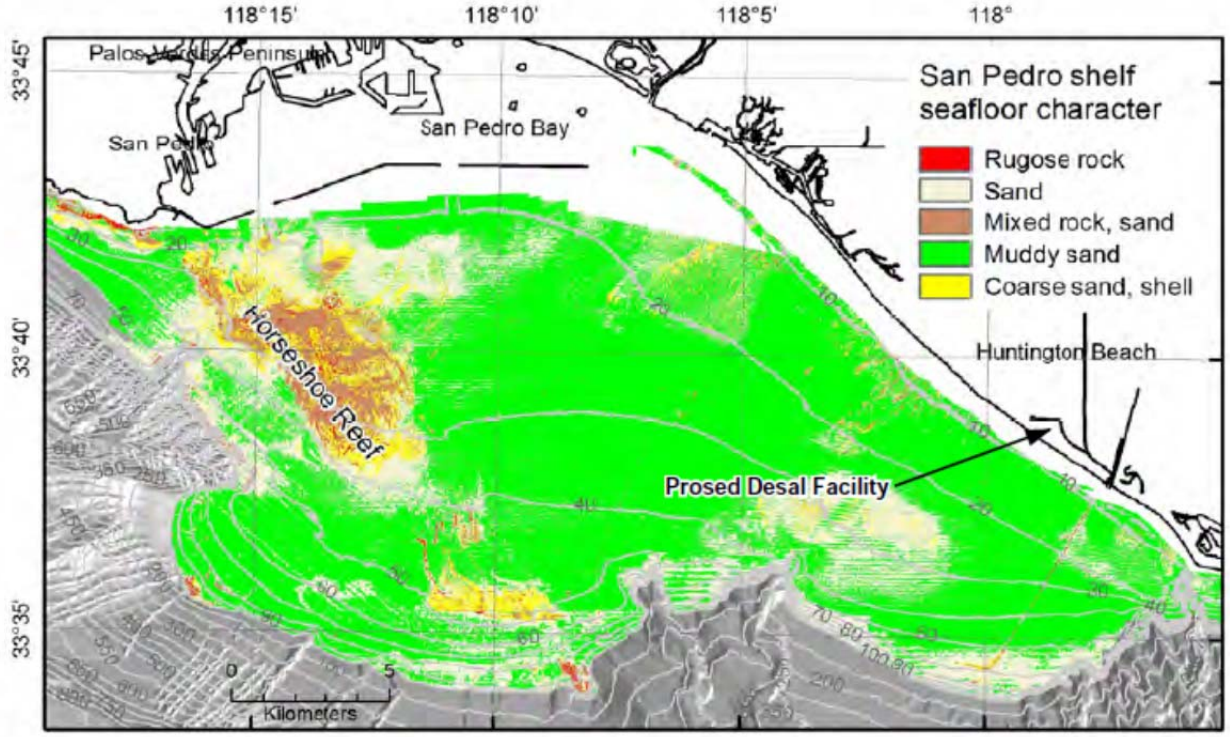
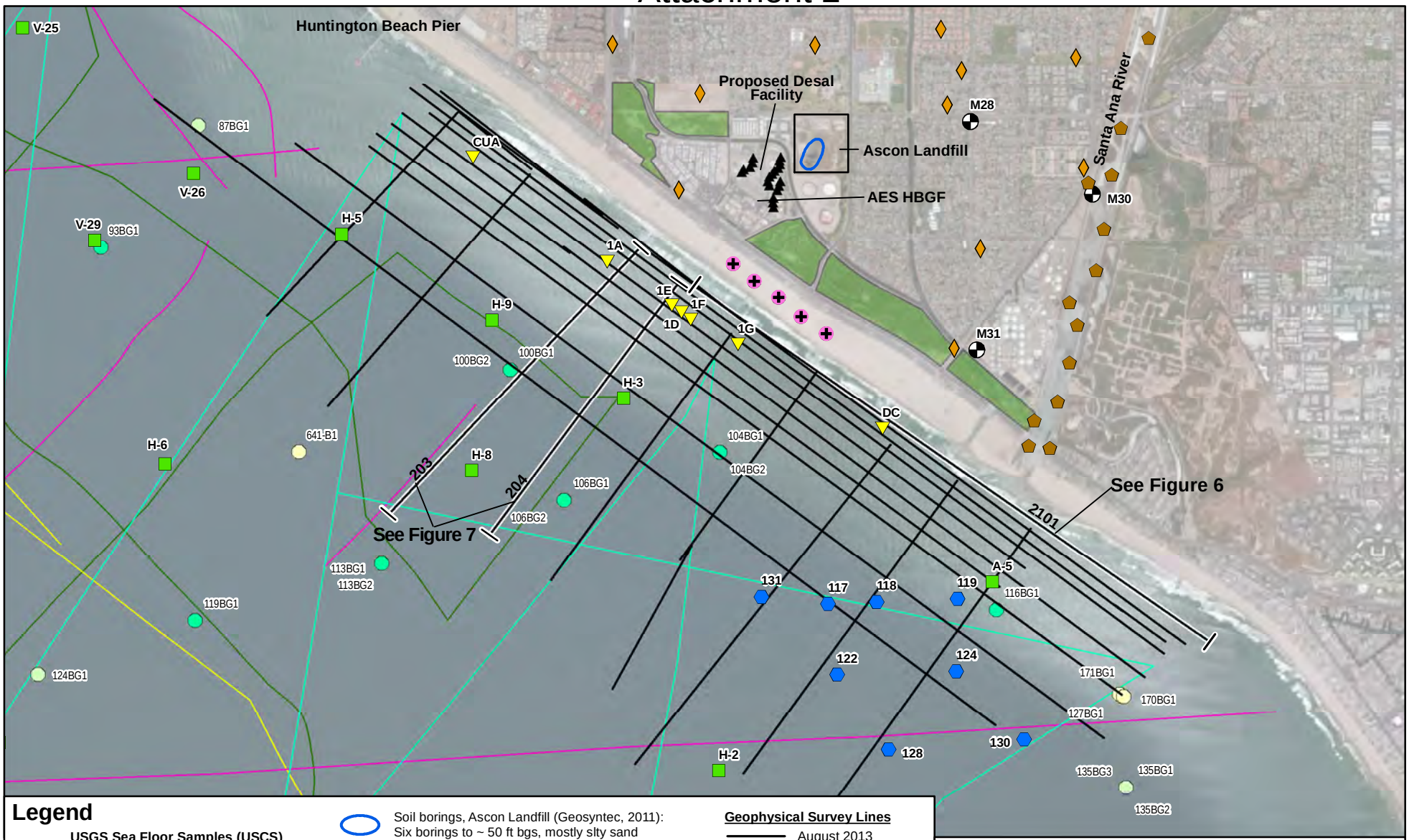
Attachment 1





Adapted from Wong et al., 2012

Attachment 2



Legend

USGS Sea Floor Samples (USCS)

Increasing Fines

- SW; SP; SW-SP; SP-SW
- SM; SM-SC; SP-SM; SP-SM; SP-SC
- SP-ML; SM-ML
- ML; ML-CL
- no data

Marsh and Wetland Area

- Soil borings, Ascon Landfill (Geosyntec, 2011): Six borings to ~ 50 ft bgs, mostly slty sand
- Boring and CPT Locations AES Facility, 2002, 2011
- OCWD MWs
- USGS OFR 81-966, Fuller et al., 1981
- US ACOE, 1988. Compilation of Soil Borings SAR Study
- Beach Sand Samples, Boehm et al., 2006
- Sea Floor Core Sample, ACOE, Osborne, 1983
- Sea Floor Core Samples, ACOE 2001
- Sea Floor Core Samples (AES NPDES Survey 2011)

Geophysical Survey Lines

- August 2013
- A-1-03-SC
- S-1-78-SC
- A-1-00-SC
- K-2-73-SC
- CSULB 2012

N

3,000 1,500 0 Feet

Notes:
All locations are approximate
Basemap source: ESRI 2013

Locations of Geotechnical Samples and Offshore Geophysical Survey

Feasibility Assessment of Shoreline Subsurface Collectors
Huntington Beach Seawater Desalination Project

Geosyntec consultants

WR1794 | September 2013

Figure 5

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Attachment 3

TABLE 7
LOWER SANTA ANA RIVER
SPD SOIL TEST RESULT SUMMARY

Station	Hole No.	Div. Serial No.	Report Date	Depth From	Depth To	Class	Mech. Analy. % finer sand #4	Mech. Analy. % finer fine #200	LL	PI	Densities Field dry PCF	Densities Field % Moist	Densities Compaction mth	Densities Compaction dry PCF	Densities Compaction max % Moist	% max den. test	Shear Strength U.U. samp	Shear Strength U.U. C tsf	Shear Strength U.D. O deg	Shear Strength U.D. C tsf	C.D. O deg	C.D. C tsf	Con-soli-datio Cc	Permea-bility ft/day
1207+00	801	91509	12-85	6.0	9.0	SM	86	24	23	3														
1207+00	"	91510	12-85	15.0	18.0	CL	96	67	41	17			Mo.	123.0	10.7	90	3-R		17	0.6	35	0.0		
1207+00	"	91511	12-85	24.0	25.0	SM	76	16		NP			Mo.	130.0	8.3	80	3-R		11	0.0	25	0.0		
1171+50	805	91512	12-85	3.0	9.0	SP	92	4		NP			Mo.	118.0	12.5	90	3-R		30	0.0	38	0.0		
1171+00	806	91513	12-85	21.0	24.0	SM	97	28		NP			Mo.	119.3	12.2	80	3-R		13	0.0	36	0.0		
1148+00	902	91043	12-85	33.0	37.0	CL	100	76	47	24	88.4	32.3					3-U		14	0.3	32	0.1		
1129+00	903	91514	12-85	3.0	6.0	SP	88	4		NP														
1129+00	"	91515	12-85	18.0	20.0	SP-SM	98	5		NP														
1129+00	"	91516	12-85	21.0	25.0	SP-SM	73	6		NP														
1080+00	1001	91517	12-85	12.0	15.0	SP	82	3		NP														
1080+00	"	91518	12-85	26.0	30.0	CL	86	56	42	20			Mo.	124.0	10.4	80	3-R		16	0.0	29	0.0		
1062+00	1004	91519	12-85	27.0	30.0	SW-SM	93	12		NP			Mo.	122.8	10.5	90	3-R		37	0.2	37	0.0		
1007+00	1103	91520	12-85	20.0	24.0	SP	92	4		NP														
1007+00	"	91521	12-85	27.0	30.0	SW	84	2		NP														
1007+00	"	91522	12-85	33.0	35.0	SP	95	7		NP														
0985+00	1106	91523	12-85	33.0	35.0	SC	85	28	34	12														
0950+00	1203	91524	12-85	21.0	24.0	SW-SM	68	6		NP														
0929+00	1206	91525	12-85	25.0	27.0	SC	93	37	28	10			Mo.	130.3	8.2	80	3-R		12	0.1	30	0.0		
0771+00	1503	91044	12-85	36.0	38.0	CL	100	82	34	19	117.3	10.8					1-U	3.2$						
0771+00	"	91045	12-85	38.0	40.0	CL	100	81	31	14	97.3	17												
0760+00	1504	91526	12-85	27.0	29.0	SM	99	21		NP														
0753+00	1506	91527	1-86	24.0	27.0	SM	99	28		NP			St.	117.2	12.0									2.1-15
0753+00	"	91528	12-85	40.0		CL	100	82	35	11			Mo.	114.8	11.5	80	3-R		14	0.3	33	0.0		
0740+00	1507	91529	12-85	24.0	27.0	CL	100	77	33	10			Mo.	123.5	11.5									
0719+00	1510	91046	12-85	15.0	18.0	CL-ML	100	23	21	4														
0719+00	"	91047	12-85	38.0	40.0	CL	100	80	33	18	114.4	16.6					1-U	0.7$						
0719+00	1509	91530	12-85	27.0	30.0	SM	97	22		NP			Mo.	119.4	9.3	90	3-R		25	1.8	36	0.0		
0710+00	1601	91531	1-86	21.0	22.0	SW-SM	97	7		NP			St.	113.2	12.4									15-180
0699+00	1602	91532	1-86	18.0	21.0	SP	99	3		NP			St.	107.1	15.3									25-150
0657+00	1607	91048	12-85	18.0		ML	100	58		NP	96.8	24.5					3-U		23	0.0	36	0.0		
0657+00	"	91049	12-85	30.0		CL	100	90	38	14	105.0	23												
0522+50	1811	91050	12-85	11.5		CL	100	86	36	15	100.9	21.3					1-U	1.0$						
0522+50	"	91051	12-85	15.0		CH	100	93	56	33	99.0	25.4											0.25	
0522+50	"	91052	12-85	20.0		CL	100	82	37	14	101.9	24												
0474+00	1905	91533	12-85	27.0	30.0	CL	100	79	30	9														
0310+00	2203	91534	1-86	27.0	30.0	ML	100	56	25	3			St.	111.5	13.5									.45-.6
0236+00	2301	82536	9-83	3.0	4.5	SP-SM	100	12		NP			St.	102.5	15.5									
0236+00	"	91053	12-85	10.0		SM	100	23		NP	92.1	26.3					3-U		28	1.0	35	0.0		
0236+00	"	91054	12-85	15.0		CL	100	75	43	26	91.5	28.3					1-U	0.4$						
0236+00	"	91055	12-85	20.0		CL	100	78	37	19	92.3	29.1											0.26	
0222+00	2305	82537	9-83	6.5	8.5	SP-SM	100	10		NP			St.	101.5	17.7									
0217+00	2307	82538	9-83	9.0	11.0	SM	99	32	19	1			St.	115.6	12.0	90	3-R		25	1.0	34	0.0		
0217+00	"	82539	9-83	14.0	16.0	SM	97	21	20	2			St.	119.4	11.0	90	3-R		27	1.2	32	0.0		
0217+00	"	82540	9-83	20.0	21.0	SM	99	22		NP			St.	115.0	11.7									
0217+00	"	82541	9-83	27.0	28.0	ML	100	56		NP			St.	101.5	18.2									
0200+00	2311	82542	9-83	4.0	6.5	SM	97	14		NP			St.	118.3	11.3									
0200+00	"	82543	9-83	6.5	9.5	SM	98	36		NP			St.	115.7	13.0									
0200+00	"	82544	9-83	20.0	22.5	SM	100	43		NP			St.	110.3	14.3									

Attachment 3 continued

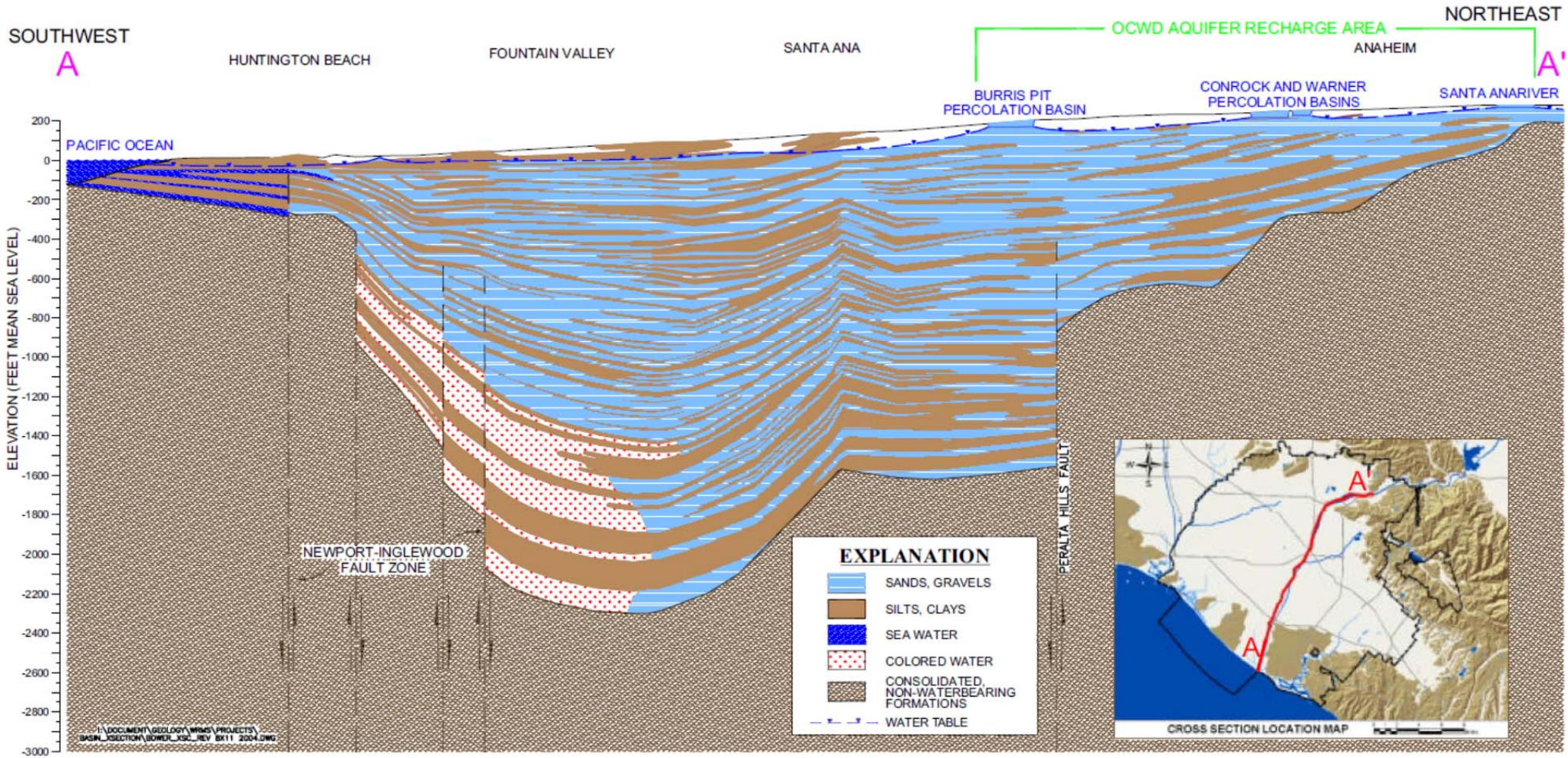
TABLE 7 (continued)
LOWER SANTA ANA RIVER
SPD SOIL TEST RESULT SUMMARY

Station	Hole No.	Div. Serial No.	Report Date	Depth From	Depth To	Class	Mech. Analy. % finer sand #4	Mech. Analy. % finer fine #200	LL	PI	Densities Field dry PCF	Densities Field % Moist	Densities Compaction mth	Densities Compaction dry PCF	Densities Compaction max % Moist	% max den. test	Shear Strength U.U. samp	Shear Strength U.U. C tsf	Shear Strength U.D. O deg	Shear Strength U.D. C tsf	C.D. O deg	C.D. C tsf	Con-soli-datio Cc	Permea-bility ft/day
0190+00	2401	82545	9-83	0.0	3.0	SM	99	30	21	2			St.	118.5	10.7									
0190+00	"	82546	9-83	-	-	SM	100	33	20	2			St.	116.6	12.0	90	3-R		25	1.0	34	0.0		
0177+50	2405	82547	9-83	6.5	13.0	SM	100	23		NP			St.	108.0	14.5									
0157+00	2407	82548	9-83	3.0	4.5	SC-SM	99	49	25	7			St.	118.0	12.5									
0157+00	"	82549	9-83	5.0	7.5	SM	99	17	18	1			St.	114.7	11.3	90	3-R		27	1.2	32	0.0		
0157+00	"	82550	9-83	20.5	21.0	SW-SM	98	9		NP			St.	111.5	13.3									
0157+00	2408	82551	9-83	4.5	5.0	SM	98	28		NP			St.	109.6	13.5									
0147+00	2409	82552	9-83	20.0	21.0	CL	100	72	40	20			St.	108.0	18.0									
0130+00	2501	82825	9-83			CH	100	99	76	43	81.4	39.6												
0130+00	"	82826	9-83			ML	100	77	32	7	93.9	29.7												
0125+00	2502	82827	9-83			CH	100	99	80	45	78.7	42.9												
0125+00	"	82828	9-83			SM	100	29		NP	97.6	26.3												
0120+00	2533	82829	9-83	13.5	16.5	CH	100	99	73	40	82.1	37.1												
0120+00	"	82830	9-83	18.5	21.5	CH	100	100	91	54	80.7	40.1												
0120+00	"	82831	9-83	21.5	24.5	ML	100	89	41	14	86.4	35												
0120+00	"	82832	9-83	24.5	27.5	SM	100	14		NP	93.7	26.7												
0120+00	"	82833	9-83	29.0	31.5	SP-SM	100	11		NP	103.1	14.8												
0117+00	T-79-2	71825	1-80	6.0	7.0	SP-SM	97	7		NP			St.	108.1	0.3		3-R				41*	0.0		
0115+00	2534	91056	12-85	12.0		CH	100	92	69	43	78.5	39.3					3-U		16	0.2	28	0.0		
0115+00	"	91057	12-85	15.0		ML	100	99	33	2	91.1	31.7					3-U	2.0						
0115+00	"	91058	12-85	20.0		SM	100	30		NP	103.2	21.4												
0098+00	T-79-1	71824	1-80	7.0	10.0	CL	100	96	44	19			St.	103.3	20.0	95	3-R				29*	0.0		
0082+00	79-10	71832	1-80	16.0	-	ML	100	55		NP	92.9	30.4					2-U		29	1.2	32	0.0	0.14	0.015
0070+50	2546	91062	12-85	4.5		CL	100	87	49	24	84.3	32.7					1-U	0.6$						
0070+50	"	91063	12-85	12.0		SM	100	30		NP	90.1	19.8											0.11	
0067+00	79-8	71822	1-80	0.0	5.0	CL	100	77	35	13			St.	103.3	19.5	95	3-R				35*	0.0		
0067+00	79-8	71823	1-80	9.0	15.0	SM	100	44	23	2			St.	110.5	14.5	94	3-R				38*	0.0		
0067+00	79-9	71830	1-80	15.0	-	ML	100	51		NP	95.9	28.1					2-U		25	1.0	35	0.0	0.13	0.005
0067+00	"	71831	1-80	30.0	-	ML	100	95	33	6	93.4	30.2					1-U		29	1.2	32	0.0	0.14	0.015
0060+00	2638	82836	9-83			MH	100	98	63	30	78.9	38.5												
0060+00	"	82837	9-83			SM	100	42	29	2	86.7	33.5												
0048+00	2632	82834	9-83	17.0	19.5	CH	100	52	59	35	83.9	34.1					1-U	0.4						
0047+00	79-6	71828	1-80	0.0	4.0	ML	100	93	43	15			St.	99.3	20.8	95	3-R		21	0.4	34	0.0		
0047+00	"	71829	1-80	5.0	10.0	CH	100	98	53	25			St.	99.2	21.6	95	3-R		18	0.1	28	0.1		
0030+00	2634	82835	9-83	20.0		MH	100	97	61	29	71.1	49.7					2-U	0.4						
0017+00	79-3	71826	1-80	1.0	4.0	CL	100	71	46	21			St.	106.1	20.5	95	3-R		19	0.3	28	0.2		
0017+00	"	71827	1-80	6.0	9.0	SC	100	23	28	11			St.	113.7	13.8	94	3-R				37*	0.0		
0012+00	2636	91059	12-85	13.0		SP-SM	100	11		NP	97.3	23.8											0.06	
0012+00	"	91060	12-85	16.0		SP-SM	100	7		NP														

NOTES: R - Remolded sample
U - Undisturbed sample
* - Direct shear test
$ - Unconfined Compression Test
T - Test trench
Permeabilities range from 80% to 95% of max. density

Attachment 4

GEOLOGIC CROSS SECTION THROUGH ORANGE COUNTY GROUNDWATER BASIN



From the Orange County Water District Groundwater Master Plan (OCWD, 2004) and Edwards et al., (2009)