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5 February 2019

Scott Maloni
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Subject: 5th Generation of Modeling of Coastal Margin Slant Wells
Huntington Beach Seawater Desalination Project

Dear Mr. Maloni:

On January 16, 2019, State and Regional Water Board staff requested that Poseidon prepare a 5th Generation of the Talbert Gap groundwater model of slant well subsurface intakes at Huntington Beach with an expanded sensitivity analysis.

The purpose of the 5th Generation groundwater model updates and sensitivity analyses presented herein is to provide:

1. An estimate of potential maximum hydraulic production from slant wells sited in the Talbert Aquifer that would not exceed a 1,000 acre-foot per year impact to Orange County's groundwater basin, and;

2. A revised calculation of possible impacts to wetlands based on data supported by scientific literature characterizing local wetlands conditions and a revised approach to represent specific properties of sediments immediately beneath the wetlands.

PREVIOUS GENERATIONS OF THE GROUNDWATER MODEL

A summary follows of the previous generations of subsurface intake groundwater models for the proposed Huntington Beach Desal Project. **Attachment 1** provides summary tables of results including sensitivity analyses from previous generations of the model.

Generation 1: The Geosyntec groundwater model of subsurface intakes at Huntington Beach was first developed in September 2013 at the request of the California Coastal Commission staff as part of its evaluation of the feasibility of slant wells as an alternative seawater intake for the Huntington Beach Project (**Regional Board Application Appendix K**).

Generation 2: In November 2015, the model was revised to include sensitivity analyses at the request of the Coastal Commission's Well Investigation Team ("WIT"). The model was revised to include representation of the wetlands area with a portion of the coastal marsh and wetland areas assigned a constant sea-level water table. Eight model sensitivity analyses evaluated different slant well locations, variation of horizontal hydraulic conductivity (Kh) and vertical hydraulic conductivity (Kv), and pumping rate (Q) (**Regional Board Application Appendix A3**). The revised model properties, assumptions and conclusions underwent additional independent 3rd party peer review by the Coastal Commission's Dr. Detwiler **(Regional Board Application Appendix L)** and the Orange County Water District (OCWD) hydrogeologist Roy Herndon **(Regional Board Application Appendices L2 and L3 and L4).**

Generation 3: In January 2017, the model was revised at the request of the State and Regional Water Board staff hydrogeologists (**Regional Board Application Appendix III**). Six additional model sensitivity analyses concluded that variation in the number, location and length of the slant wells by a several hundred feet has very little influence on the sea and inland aquifer portions of source water pumped by the slant wells.

Generation 4: In July 2017, the Talbert Gap model was revised again to evaluate the feasibility of subsurface seawater intake wells for alternative sites along the coastline at the Bolsa, Sunset, and Alamitos Gaps (**Regional Board Application Appendix QQQQ**). The models were similar to the Talbert Gap model but with hydrostratigraphy, subsurface geometry, hydraulic properties, and groundwater conditions adjusted for each specific setting. The models used a range of assigned properties to derive a calculation of the maximum sustainable pumping from slant wells including an estimated calculation of the portion of source water that would come from the sea, local wetlands and inland aquifers. The revised alternative sites model underwent independent 3rd party peer review by Orange County Water District hydrogeologist Roy Herndon (**Regional Board Application Appendix L4**).

Generation 5: Geosyntec's 5th generation Talbert Gap groundwater model and sensitivity analyses presented below updates the previous analyses of possible impacts to wetlands near the Huntington Beach coast margin based on local available data, scientific literature characterizing wetlands conditions, and a revised approach to represent specific properties of sediments immediately beneath the wetlands.

GENERATION 5 MODEL UPDATES

Representation of Wetlands with MODFLOW River Package

Prior to running the 5th Generation groundwater model update Poseidon received concurrence from the State and Regional Water Board hydrogeologists to explicitly account for the hydraulic properties of the sediments immediately below the wetlands by using MODFLOW River Package (e.g. Harbaugh, et al., 2000) to represent the wetland areas. Flow of water out of, or into, the wetland cells through the wetland sediments (riverbed) s is calculated by MODFLOW as follows:

$$\mathbf{Q = C\ (Hr\text{-}Hcell)}$$

Where C = conductance through the riverbed (wetland sediments)

= (Kv/b') (Area of model grid cell),

Kv = vertical hydraulic conductivity of riverbed (wetland sediments),

b' = thickness of riverbed (wetland sediments),

Hr = Head in river (wetlands), and

Hcell = Head in grid cell, or elevation of base of riverbed if the head in the grid cell is below the base of the riverbed.

Wetland Sediment Properties

The Huntington Beach Wetlands complex is an approximately 200-acre remnant of a 2900-acre wetland area that historically existed at the mouth of the Santa Ana River in Huntington Beach. The area consists of restored salt marsh and coastal dune habitat, and is bisected by roadways into four distinct sections, including the Talbert, Brookhurst, Magnolia, and Newland marshes. The marshes are hydraulically linked to each other and to the Pacific Ocean by a flood control channel running along the northeastern border of the marsh areas. Additional projects restored tidal flow to Brookhurst Marsh (67 acres) in 2009 and Magnolia Marsh (41 acres) in 2010 (Allen et al., 2011).

Water Board Staff's hydrogeologists and Poseidon have agreed that the base case conductivity values assigned to the local Huntington Beach Wetland's complex are to be based on currently available data characterizing the wetlands' geologic and hydrogeologic conditions.

Based on review of boring log data in the vicinity of the Huntington Beach wetlands (Poland and Price, 1956; CDM, 2000; Geosyntec, 2011), near-surface fine-grained (clayey and silty) sediments range in thickness from less than one foot to 12 feet with measured and estimated hydraulic conductivity ranging from 0.01 to 0.1 ft/d ($3.5x10^{-6}$ to $3.5x10^{-5}$ cm/sec).

Laboratory testing of shallow sediments beneath lagoons in within the Ascon Landfill Area (Geosyntec, 2011) indicates hydraulic conductivity of 0.28 ft/d ($1.00x10^{-5}$ cm/sec) and thickness of fine-grained sediments of up to five feet. On a larger regional scale, hydraulic conductivity is reported to range from 0.01 to 0.04 ft/d ($3.5x10^{-6}$ to $1.4x10^{-5}$ cm/sec) which gives an average of 0.25 ft/d ($8.8x10^{-6}$ cm/sec), for the intervals of fine-grained, low-permeability sediments that cumulatively function as a confining layer above the Talbert Aquifer.

Logs for a series of five shallow borings reported by Poland and Piper (1956), which span a distance from the margin of the beach to a couple miles inland, show an average of 6.5 feet for total thickness of fine-grained intervals in the upper 10 to 20 feet of sediment. The one boring closest to the coastal margin and at the edge of a current marshy area has only 0.6 ft of fine-grained sediment (silt in this case).

A monitoring well installation report documents clayey silt to silty clay with trace to 10% fine sand at few ft bgs and a thickness of ~2 to 8 ft with a thickness of approximately 2 to 8 feet within the a few feet of the ground surface at the Magnolia Tank Farm Facility, which is close to the current wetlands near the Huntington Beach coastal margin (Tait Environmental Services, 2018).

Available information specifically on the Huntington Beach Wetlands sediments indicate a high proportion of sand. Sediment samples taken near vegetated areas of the wetland waterways were reported to have higher silt/clay content (~85% sand, ~15% silt/clay) than unvegetated areas (~95% sand, ~5% silt/clay). Mapping for the Huntington Beach Wetlands Restoration Project shows that muddy sediment varies in density in the wetland channels, which indicates that the wetland areas are not consistently floored by a low-permeability layer.

Note also that portions of the sediments in the wetland areas are reported to have peat deposits, however, based on review of scientific literature, peats are commonly quite hydraulically conductive. Compilation from literature shows a range of 0.03 to 14.17 ft/d ($1x10^{-5}$ to $5x10^{-3}$ cm/sec). And laboratory testing of downward flow through peat deposits gave a mean of 0.24 ft/d ($8.25x10^{-5}$ cm/sec) (Meyers, 1999).

Attachment 2 provides a summary of review of data from boring logs and sediment samples in the vicinity of the Huntington Beach wetlands and some data for marsh and peats from scientific literature.

Based on the Regional Board's direction that we review and incorporate site-specific data and scientific literature, for the base case of the 5th Generation Model we have assigned an average vertical hydraulic conductivity (Kv) of 0.03 ft/d (1 x 10^{-5} cm/sec) and a thickness of 5 feet for the sediments that floor the wetland areas. Because a five-feet thickness is likely on the high side and results in a conservatively high representation of hydraulic resistance between water in the wetlands and groundwater beneath, the calculated flow of water from the wetlands to the pumping wells is likely on the low side for the base case. However, we have also conducted sensitivity analyses using Kv values of 0.01 and 0.1 ft/d. Note that 0.03 ft/d is the antilog of the mean of the log values of the 0.01 to 0.1 ft/d range that we have considered for the wetland sediments.

The base of the riverbed (wetland sediments) cells in the model are assigned an elevation of -5 ft. The water level ("river stage") at the wetlands grid cells is assigned a constant head of 0.57 ft MSL, as are grid cells with constant head at the ocean boundary in the OCWD model (CDM, 2000). A constant head of 0.57 ft MSL is also specified for all cells in the offshore portion of Layer 1, which represents the ocean in all generations of the model.

The distribution of the assigned wetland grid cells for the MODFLOW River Package is based on the location and area of the wetlands visible on aerial photos. Figure 1 shows the general wetland and marsh areas, the GIS delineation of visible water in these areas, and the wetland grid cells assigned in the updated model. The total area of wetland cells assigned in the model is 2,385,587 ft^2 (~54.8 acres). And the respective areas west and east of Santa Ana River are 1,616,587 ft^2 (37.1 acres) and 769,000 ft^2 (17.7 acres)

<u>Other Updates to the Model</u>

In addition to the updated representation of the wetlands in the Generation 5 Model, we have updated the upgradient boundary conditions in general accordance with 2017 groundwater levels in the Talbert Aquifer reported by OCWD (2018b) in the vicinity of the Talbert Barrier. The specified groundwater levels at the upgradient margin range from approximately 3 to 11 ft above mean sea level (MSL). As for previous generations of the model, the sequence of shallow sediments (Layers 2 through 4) are assigned the same constant head boundary conditions at the upgradient margin as the Talbert Aquifer (Layers 5 through 8) with the exception of a few of the upper layers where the elevation of the bottom of the grid cells are above the specified water level. No groundwater level is specified at the upgradient margin for these grid cells.

In previous generations of the model the upgradient boundary for Model Layer 10, which represents the Lower Aquifer System was assigned a uniform groundwater level of 10 feet above sea level. This intentionally provided an upward gradient to the Talbert Aquifer from below to contribute to the optimistic production potential from the Talbert Aquifer as is discussed in more detail in documentation of previous generations of the model (e.g. Geosyntec 2013, 2015, 2017a,b**: Regional Board Application Appendices K, A3, III and QQQQ).** However, the upward gradient results in model groundwater levels for simulations *without* slant well pumping that are higher than actual conditions within the Talbert Aquifer and shallow sediments near coastal margin. This is not important for the previous generations of the model that were used to simulate high rates of slant well pumping and evaluate portions of flow from the ocean and inland. However, for the Generation 5 Model, which is designed to simulate much lower rates of pumping from slant wells, more realistic groundwater levels for non-pumping conditions is needed to estimate:

- Maximum pumping that does not exceed the inland impact threshold of 1000 AFY;
- Portion of the pumping that comes from the wetlands, and;
- Drawdown of the water table caused by low rates of pumping compared to non-pumping conditions.

A uniform constant head of 10 ft below MSL is assigned to the upgradient boundary for Layer 10 (Lower Aquifer System). Also, a small area of Layer 10 about a mile south of the Talbert barrier near the Santa Ana River where new injection wells are operating is assigned a constant head of 11 ft above MSL based on OCWD maps groundwater levels (OCWD, 2018b). Also, no groundwater levels are specified at the upgradient boundary in the aquitard (Layer 9) between the Talbert Aquifer and the Lower Aquifer System, and the aquitard horizontal and vertical hydraulic conductivities (Kh and Kv) were decreased from the previous values of 5 & 0.5 ft/d to 2.5 & 0.25 ft/d to facilitate a more muted hydraulic connection between these Aquifers, as is observed.

The Generation 5 model also includes representation of a mergence zone between the Talbert and Lower Aquifer System within the Layer 9, where the aquitard is not present, or less significant, as was discussed with Water Board staff for the Generation 4 models (Geosyntec, 2017b) **(Regional Board Application Appendix QQQQ)** based on maps by OCWD (2018b). Within the mergence zone in Layer 9, values of horizontal and vertical hydraulic conductivity are assigned at 20 and 2 ft/d, respectively. The updates to the constant heads at the inland boundary and new injection barrier locations, and updates to the hydraulic conductivities in Layer 9 achieve an improved match for non-pumping conditions near the coast within the Talbert Aquifer and shallow sediments.

Table 1 provides a summary of assigned properties for each of the ten model layers. A uniform recharge rate of 1 in/yr, based on the OCWD model (CDM, 2000) is assigned to the uppermost active layer in the model as for previous generations of the model.

Slant Wells Design Considerations

Prior to assigning slant wells in the 5th Generation Model, the ball-park pumping rate was estimated by scaling down the pumping rate used for slant well simulations in order to decrease the portion of inland flow so it does not exceed the 1,000 AFY OCWD threshold (OCWD, 2018a). Based on scaling down the pumping rates from the previous models, preliminary estimates for the maximum allowable pumping rate were in the range of 3 to 5 mgd.

Based on the hydraulic properties of the Talbert Aquifer, previous site-specific modeling, consideration hydrogeologic conditions, and pumping rates and geometry of trial slant wells at Doheny Beach and the coast of Monterey Bay (US Bureau of Reclamation, 2009; ESA, 2018), for Huntington Beach we recommend approximately 1,000 gpm as a reasonable extraction rate per slant well, spacing of 300 to 400 feet between the wells, an angle of ~25 degrees below horizontal, and maximum total length of ~700 ft[1]. In accordance with these considerations, three slant wells were assigned to the 5th Generation model, with an angle of ~26 degrees below horizontal, a total length of ~500 ft, spacing of approximately 380 feet, and pumping rate per well in the range of 700 to 1,200 gpm.

Pumping, for example, at 1,000 gpm from a 26-degree angled well (i.e., slant well) completed in the Talbert Aquifer beneath the shoreline would be represented in the model by assigned extraction at 250 gpm from each of four adjacent progressively deeper cells (Layers 5 to 8) along one column in the Talbert Aquifer. Figure 2 is a cross-section view illustrating the representation of a slant well in the model. The total length of each hypothetical slant well is ~425 ft, of which the lower ~250 ft is screened. The vertical depth is ~180 ft.

As previously reported (Geosyntec, 2017a) for the Generation 3 modeling **(Regional Board Appendix III),** six additional model sensitivity analyses concluded that variation in the number, location and length of the slant wells by a several hundred feet has very little influence on the sea and inland aquifer portions of source water pumped by the slant wells. Extending the slant wells to a length of 1,000 feet at a potentially technically feasible angle of 25 degrees in an attempt to locate more of the screened portion of the well beneath the sea is not beneficial

[1] Note that several previous model sensitivity analyses concluded that variation in the specific location, length, and angle of hypothetical slant wells at Huntington Beach has very little influence on the sea and inland aquifer portions of source water that would be pumped by the slant wells (Geosyntec, 2017a and Attachment 1 to this letter).

because it would result in pumping from deeper strata below the aquitard beneath the Talbert Aquifer and thus a greater vertical separation between of the lower portion of a slant well and the sea. Due to depositional fabric and stratigraphic layering within the Talbert and Lower Aquifers, the vertical hydraulic conductivity is significantly lower than the horizontal hydraulic conductivity.

For the purposes of the Generation 5 model the hypothetical slant well design (e.g., well diameter, length, pumping capacity and location) is based on local hydrogeologic conditions and industry knowledge gleaned from test wells previously operated in Monterey Bay and Doheny Beach. The detailed design of a slant well system and supporting infrastructure would be affected by technical, environmental, social and economic considerations like beach access, sea level rise and other coastal hazards that is beyond the scope of this report.

GENERATION 5 MODEL RESULTS

Multiple model runs were conducted to estimate the pumping rate from the slant wells that would not exceed the Orange County Water District's 1,000 AFY threshold for the inland portion of flow (OCWD, 2018a). Table 2 summarizes the water balance results for the base case model and for sensitivity analyses using lower and higher hydraulic conductivity for the sediments immediately below the wetlands. The assigned pumping rates were adjusted so the portion of flow from inland aquifers is below the threshold criteria of 1,000 AFY. The calculated flow to the slant wells from the coastal margin wetlands is approximately 24 to 68 gpm, or approximately 1% to 3% of the total pumping rate. The portion of flow from the ocean ranges from approximately 74 to 75% of the total pumping, which is approximately 2.8 mgd. And the portion from inland aquifers ranges from 23 to 24% of the total pumping, which is approximately 0.9 mgd.

Figures 3a and 3b show the contours of the water table and groundwater level in the Talbert Aquifer, respectively, for the base case model with no slant well pumping.

Figures 4a and 4b show the results for the base case model properties with pumping from three slant wells at 872 gpm, for a total of 2,615 gpm (3.77 mgd). Figure 4a shows the model drawdown of the water table and pathlines of water that flow down through the bottom of the wetlands, into groundwater and to the slant wells in the Talbert Aquifer. Figure 4b shows contours of groundwater level in the Talbert Aquifer and pathlines of groundwater that flow to the slant wells from inland and from the ocean. On both Figures 4a and 4b the space between the arrows on the pathlines represents the calculated distance groundwater flows in five years.

CONCLUSIONS

The results of analyses using the 5th Generation groundwater model indicates that to comply with the 1000 AFY threshold stipulated by Orange County Water District for tolerable impact to its managed groundwater basin (OCWD, 2018a), the maximum pumping rate from a small-scale slant well system on Huntington Beach is approximately 3.8 mgd.

Note that the estimated maximum pumping rate for slant wells that would comply with the 1000 AFY threshold for tolerable impact to inland aquifers stipulated by OCWD would provide only approximately 3.5% of the design intake flow of 106.7 mgd required for the proposed desalination facility at Huntington Beach.

With pumping from three slant wells at a total of 3.8 mgd, the modeling with sensitivity analyses for the wetland sediment properties indicates that the portion of flow from the coastal margin wetlands would be in the range of 1% to 3% of the total pumping rate. Although for pumping at 3.8 mgd this equates to only approximately 24 to 68 gpm, the continuous draw of water through sediments at the bottom of the wetlands by the slant well pumping could potentially impact the wetland ecosystem by altering the geochemistry and nutrients in both the wetlands water and the porewater in the wetland sediments.

Sincerely

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Attachments:
- References
- Tables
- Figures
- Attachment1 Summary of Previous Generation Model Results
- Attachment 2 Summary Compilation of Wetland Sediment Properties

Copy to Roy L. Herndon, Chief Hydrogeologist, Orange County Water District

Scott Maloni
5 February 2019

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TABLES

Table 1
Summary of 5th Generation Model Aquifer Properties
Additional Modeling of Coastal Margin Slant Wells
Huntington Beach Seawater Desal Project

Hydrostratigraphic Unit	Layer(s)	Hydraulic Conductivity				Approximate Thickness
		Kh (ft/d)	Kv (ft/d)	Kh (cm/sec)	Kv (cm/sec)	(ft)
Ocean[1]	1	1000	100	3.5E-01	3.5E-02	120 - 10
Wetland Sediments[2]	2*	na	0.03	na	1.1E-05	5
Confining Sequence above Talbert Aquifer[3]	2 - 4	1	0.1	3.5E-04	3.5E-05	50 - 100
Talbert Aquifer[4]	5 - 8	300	30	1.1E-01	1.1E-02	90 - 100
Aquitard between Talbert and Lower Aquifer System[5]	2.5	2.5	0.25	8.8E-04	8.8E-05	10 - 20
Lower Aquifer System[6]	10	300	30	1.1E-01	1.1E-02	50

Notes:

1. Ocean portion of Layer 1 has specified sea level head Inland portion of Layer 1 is inactive
2. Wetland Sediments are represented by MODFLOW River Package, which does not represent Horizontal flow.
3. Layers 2 to 4 are a simplified representation of a heterogeneous sequence of interbedded sand, silt and clay, including some of which were deposited in marsh, wetland and estuary environments. Cumulatively the sequence functions as a semi-confining unit above the Talbert Aquifer.
4. Assigned Kh & Kv for the Talbert Aquifer increase to 325 and 32.5 ft/d inland of the coast based on the OCWD model. And assigned Kh & Kv is lower (30 & 10 ft/d) along the margins of the Talbert Gap to represent decreased transmissivity instead of decreasing thickness.
5. Assigned Kh & Kv is higher (20 & 2 ft/d) in an inland portion of Layer 9 where due absence or less development of an aquitard where the Talbert Aquifer locally merges with the Lower Aquifer (OCWD, 2018).
6. The Lower Aquifer System is simplified representation of sequence of aquifers and aquitards that have little relevance to modeling of the coastal margin slant wells.

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Table 2
Results of Fifth Generation of Modeling of Coastal Margin Slant Wells

Additional Modeling of Coastal Margin Slant Wells

Huntington Beach Seawater Desal Project

Description	Model Run	Total Pumping		Percent of Design Intake Rate (106.7 mgd)	Number of Active Wells*	Pumping Rate per Well	Hydraulic Conductivity of Wetland Seds		Flow from Ocean		Flow from Inland Aquifers**			Flow from Wetlands		
	ID	MGD	gpm			gpm	Kv (ft/d)	Kv (cm/sec)	MGD	% of Pumping	MGD	AFY	% of Pumping	MGD	gpm	% of Pumping
Base Case	V19-1K	3.77	2615	3.53%	3	872	0.03	1.1E-05	2.810	74.6%	0.89	**999**	23.7%	0.064	44.6	1.7%
More Permeable Wetland Sediments	V19H-1K	3.78	2627	3.55%	3	876	0.1	3.5E-05	2.799	74.0%	0.89	**994**	23.4%	0.097	67.6	2.6%
Less Permeable Wetland Sediments	V19L-1K	3.75	2603	3.51%	3	868	0.01	3.5E-06	2.825	75.4%	0.89	**997**	23.7%	0.034	23.6	0.9%

Notes:

* The model represents pumping from three wells simultaneously, however two standby wells are recommended to allow production to continue with interruption when maintenance is required.

** The flow from inland portion includes approximately 1 mgd aerial recharge to the uppermost active model layer (1 inch/year).

FIGURES

Legend

- Wetted Areas (Based on Aerial Photo Review)
- Wetland Grid Cell
- Marsh and Wetland Area
- Modeled Slant Well Screened Interval
- Modeled Slant Well

N

1,800 900 0 Feet

Note:
Imagery source: ESRI, 2016

Coastal Margin Wetland and Marsh Areas

Fifth Generation Modeling of Coastal Margin Slant Wells
Huntington Beach Seawater Desalination Project

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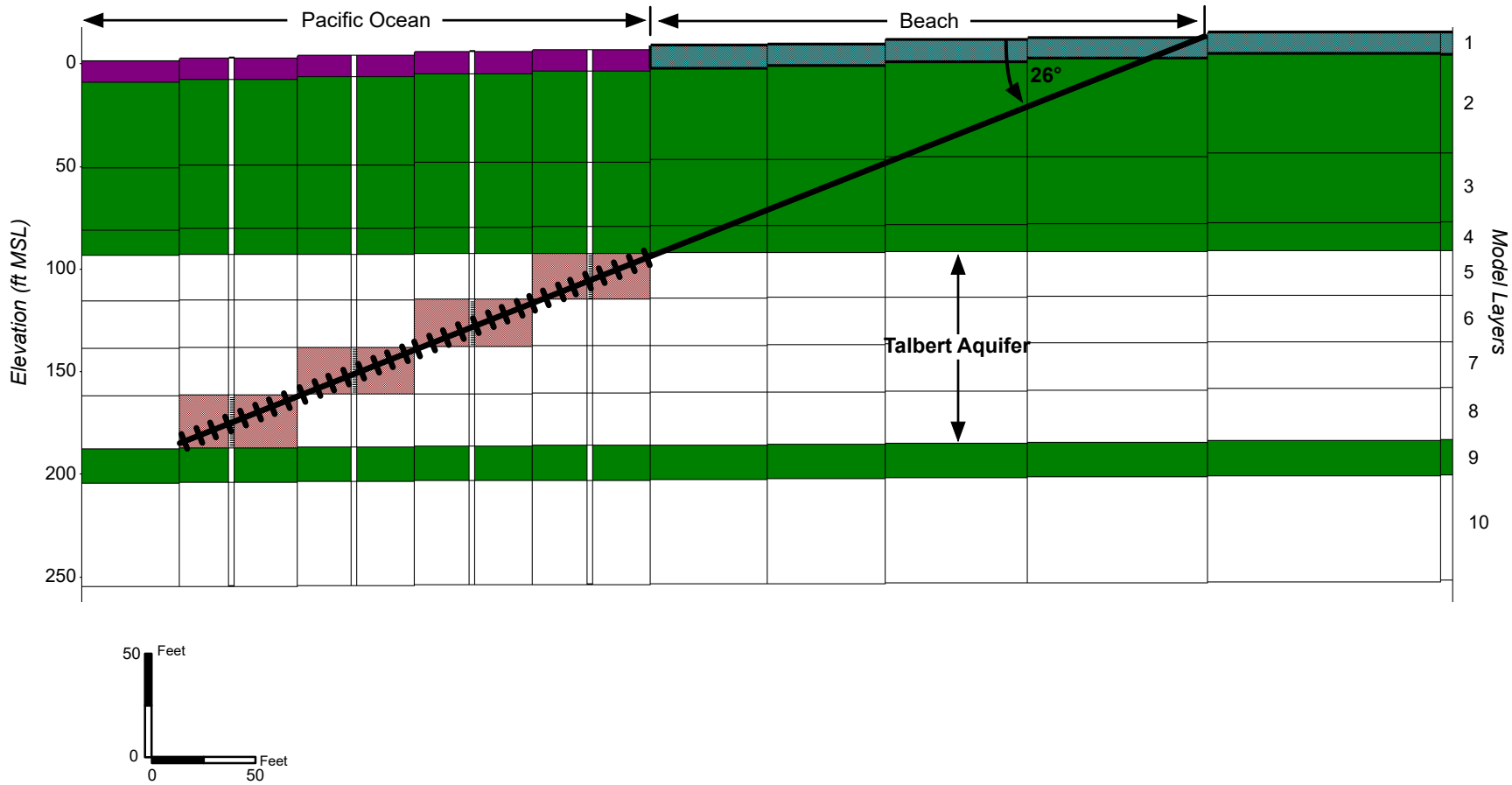
Figure 1

D:\GIS\HuntingtonBeach\Project\2019Feb\Fig01_CoastalWetlands.mxd



Notes:
The cross-section shows the representation of a slant well in the MODFLOW numerical groundwater model.
In the model each of the hypothetical slant wells is represented by pumping from 4 consecutive cells in Layers 5 – 8, which is the Talbert Aquifer.
The slant well begins at the upper portion of the beach and is drilled at an angle of 26 degrees to a total vertical depth of ~200 ft.
The length of each slant well would be approximately 500 ft. The lower 250 ft is screened in the Talbert Aquifer.

Model Representation of Slant Well

Fifth Generation Modeling of Coastal Margin Slant Wells
Huntington Beach Seawater Desalination Project

Geosyntec consultants

WR1794-04	February 2019	Figure 2

P:\GIS\HuntingtonBeach\Project\2019Feb\Fig02_SlantWell.ai

Legend

- Slant Well (yellow represents screened interval)
- Shallow Groundwater Levels (Model Layer 2) - [ft MSL]
- Inactive Area of Model
- Wetland Grid Cell

N

3,000 1,500 0 Feet

Imagery source: ESRI, 2016

Modeled Shallow Groundwater Levels Without Slant Well Pumping

Fifth Generation Modeling of Coastal Margin Slant Wells
Huntington Beach Seawater Desalination Project

Geosyntec consultants

WR1794-04	February 2019	Figure 3a

D:\GIS\HuntingtonBeach\Project\2019Feb\Fig03a_ModelResultsNPShallow_ZoomOut.mxd

Legend

- Slant Well (yellow represents screened interval)
- Groundwater Levels in Talbert Aquifer (Layer 7) - [ft MSL]
- Constant Head (Injection Barrier)
- Inactive Area of Model
- Wetland Grid Cell

N

3,000 1,500 0 Feet

Imagery source: ESRI, 2016

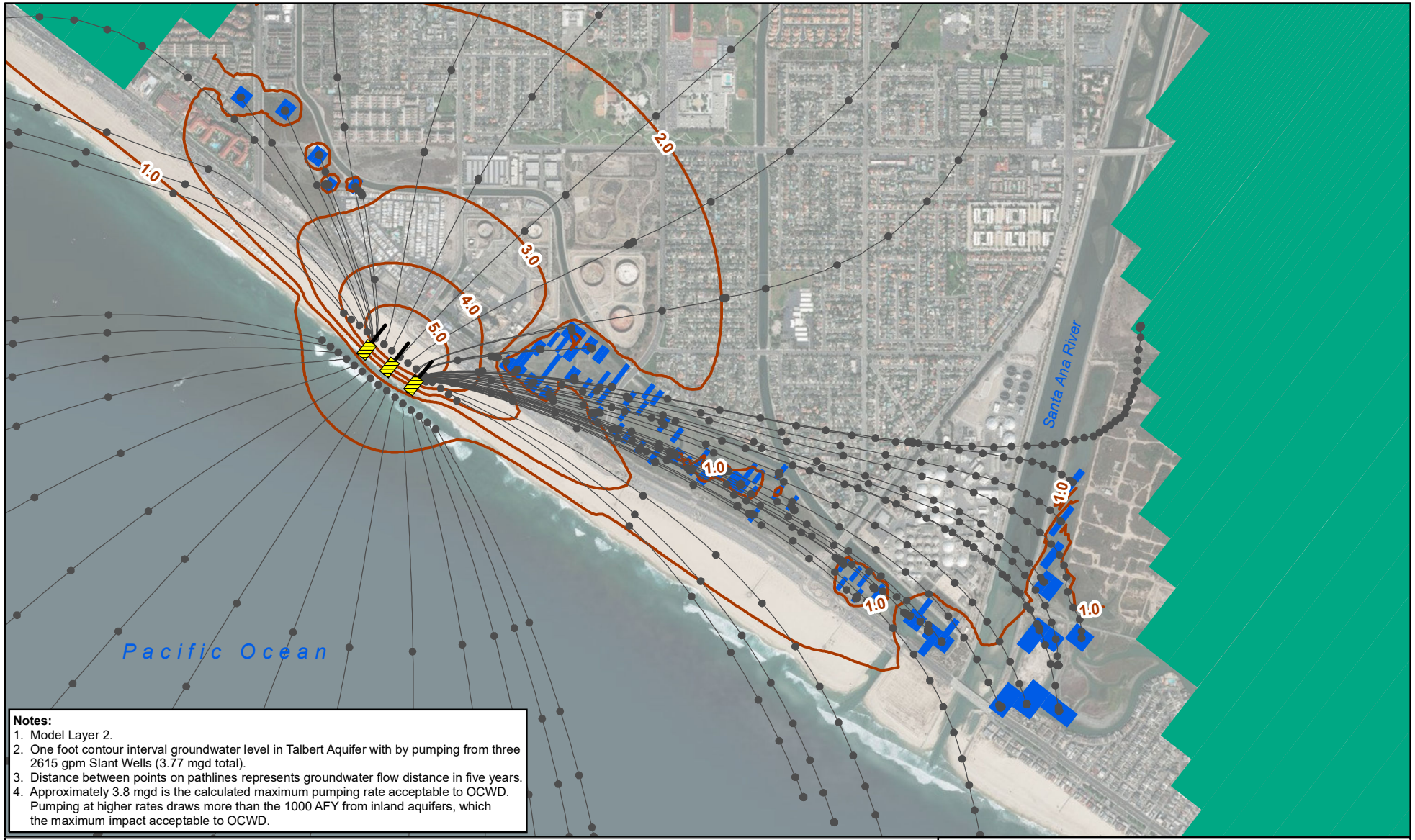
Modeled Groundwater Levels in Talbert Aquifer Without Slant Well Pumping

Fifth Generation Modeling of Coastal Margin Slant Wells
Huntington Beach Seawater Desalination Project

Geosyntec consultants

WR1794-04	February 2019	Figure 3b

D:\GIS\HuntingtonBeach\Project\2019Feb\Fig03b_ModelResultsNPTalbert_ZoomOut.mxd



Notes:
1. Model Layer 2.
2. One foot contour interval groundwater level in Talbert Aquifer with by pumping from three 2615 gpm Slant Wells (3.77 mgd total).
3. Distance between points on pathlines represents groundwater flow distance in five years.
4. Approximately 3.8 mgd is the calculated maximum pumping rate acceptable to OCWD. Pumping at higher rates draws more than the 1000 AFY from inland aquifers, which the maximum impact acceptable to OCWD.

Legend

- Slant Well (yellow represents screened interval)
- Groundwater Flow Pathline (space between dots represents distance groundwater flows in five years)
- Drawdown In Shallow Groundwater (Model Layer 2) - [ft MSL]
- Inactive Area of Model
- Wetland Grid Cell

N

1,800 900 0 Feet

Imagery source: ESRI, 2016

Model Groundwater Drawdown and Flowpaths in Shallow Groundwater with Slant Well Pumping of ~3.8 MGD

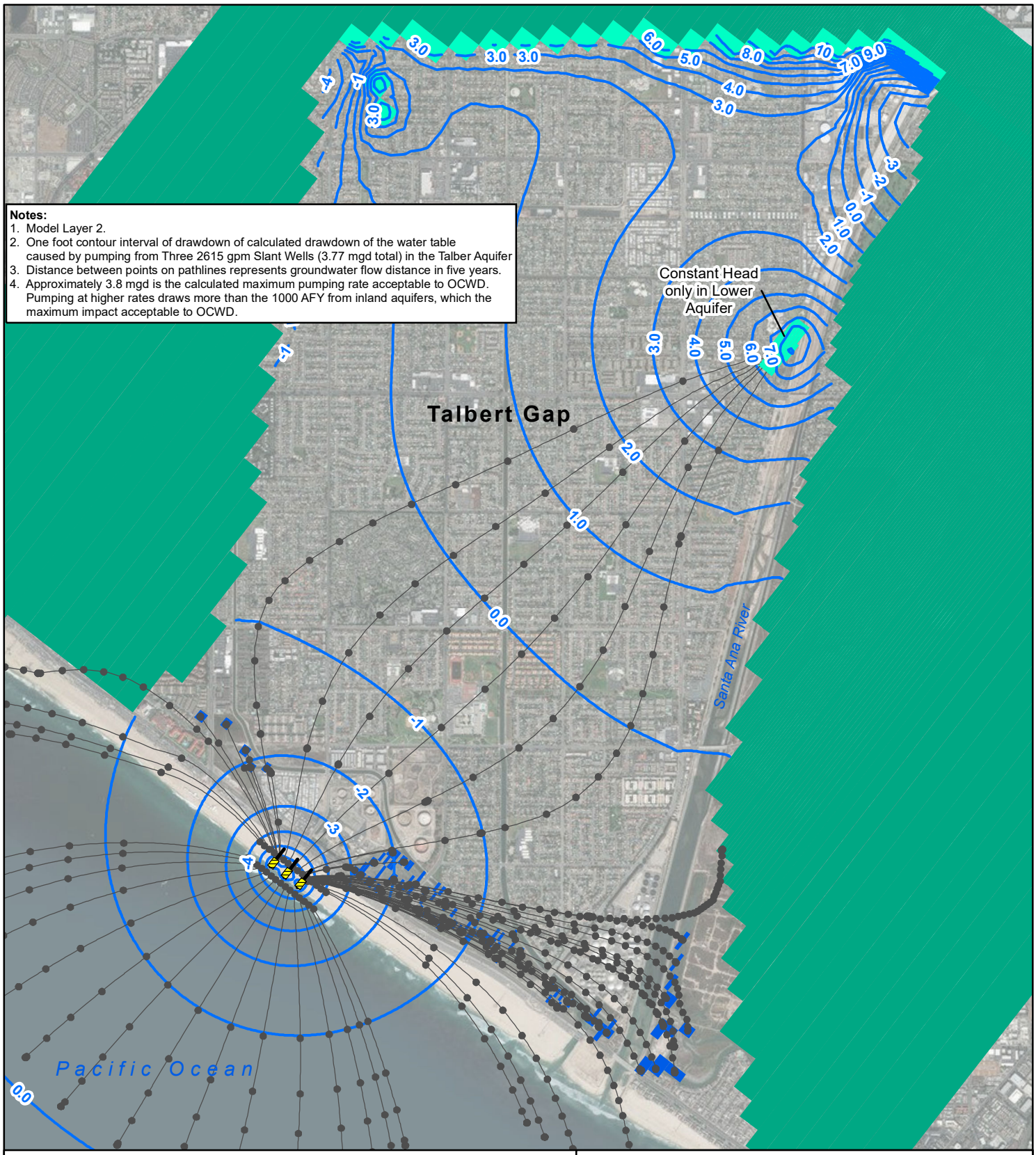
Fifth Generation Modeling of Coastal Margin Slant Wells
Huntington Beach Seawater Desalination Project

Geosyntec consultants

WR1794-04 | February 2019

Figure 4a

D:\GIS\HuntingtonBeach\Project\2019Feb\Fig04a_ModelResultsShallow_ZoomIn.mxd



Legend

Imagery source: ESRI, 2016

- Slant Well (yellow represents screened interval)
- Groundwater Flow Pathline (space between dots represents distance groundwater flows in five years)
- Groundwater Elevation (one foot contour interval) - [ft MSL]
- Constant Head (Injection Barrier)
- Inactive Area of Model
- Wetland Grid Cell

N

3,000 1,500 0 Feet

Modeled Groundwater Levels and Flow Pathlines in the Talbert Aquifer with Slant Well Pumping of ~3.8 MGD

Fifth Generation Modeling of Coastal Margin Slant Wells
Huntington Beach Seawater Desalination Project

Geosyntec consultants

WR1794-04 | February 2019

Figure 4b

D:\GIS\HuntingtonBeach\Project\2019Feb\Fig04b_ModelResultsTalbert_ZoomOut.mxd

ATTACHMENT 1
Summary of Previous Generation Model Results

Geosyntec consultants

from Geosyntec 2015

Table 1
Summary of Sensitivity Analysis of Modeled Coastal Margin Slant Wells
Feasibility Assessment of Shoreline Subsurface Collectors
Huntington Beach Seawater Desal Project

Description	Model Run	Q from Sea		Q from Wetlands		Q from Recharge		Q from Inland BC	
	ID	MGD	%	MGD	%	MGD	%	MGD	%
Original Model	V5	112.7	89	na	na	1	0.8	13	10
Add Wetland Constant Sea Level Heads	V6	110.5	87	2.6	2	1	0.8	12.6	10
Moved Slant Wells 240 ft landward	V7	109	86	2.9	2	1	0.8	13.8	11
Moved Slant Wells 240 ft seaward	V8	133.3	89	2.1	2	1	0.8	10.3	8
Reduced Kh & Kv of overlying strata (Layers 2-4) from 10 & 1 to 1 & 0.1 ft/d	V6A	85.6	75	2.4	2	1	0.8	25.8	22
Reduced Kh & Kv of overlying strata (Layers 2-4) from 10 & 1 to 0.2 & 0.02 ft/d	V6B	56.9	62	0.4	0.5	1	0.8	32.8	36
Reduced Kh and Kv of Talbert Aquifer (Layers 5-8) from 300 & 30 ft/d to 150 and 15 ft/d	V6C	110.5	87	3	2	1	0.8	12.3	10
Increased Kh and Kv of Talbert Aquifer (Layers 5-8) from 300 & 30 ft/d to 600 and 60 ft/d	V6D	93.3	74	2.3	2	1	0.8	30.1	24
Reduced pumping rate by factor of 2 (twenty instead of forty 2200 gpm wells, 63.5 mgd total)	V6Qhalf	53.7	85	1.3	2	1	1.6	7.3	12
Reduced pumping rate by factor of 4 (twenty 1100 gpm wells: 31.75 mgd total)	V6Qqtr	25.2	80	0.6	2	1	3.2	4.8	15

*The flow from inland portion includes approximately 1 mgd aerial recharge to the uppermost active model layer (1 inch/year).

For non-pumping conditions the total model flow to the ocean from the constant head boundary at the Injection Barrier is approximately 2.3 mgd.

from Geosyntec 2017a

Table 1
Results of Additional Sensitivity Analysis of Modeled Coastal Margin Slant Wells
Feasibility Assessment of Shoreline Subsurface Collectors
Huntington Beach Seawater Desalination Project

Description	Model Run		Total Pumping	Number of Wells	Pumping Rate per Well	Hydraulic Conductivity Shallow Sediments		Hydraulic Conductivity Lower Aquifer		Flow from Sea		Flow from Wetlands		Flow from Inland Aquifers*			Flow from Inland Talbert Aquifer*			Flow from Inland Lower Aquifer*		
	Case	ID	MGD		gpm	Kh (ft/d)	Kv (ft/d)	Kh (ft/d)	Kv (ft/d)	MGD	% of Pumping	MGD	% of Pumping	MGD	% of Pumping	% of Injection Rate**	MGD	% of Pumping	% of Water Injected into Talbert Aquifer**	MGD	% of Pumping	% of Water Injected into Lower Aquifers**
25 deg angle, 425 ft Screened in Talbert Only (Original Slant Well Geometry)	**1a**	V10AP1	106.7	40	1,852	10	1	30	3	96.4	**90.4%**	2.8	2.6%	6.4	6.0%	**21.4%**	1.9	1.8%	**25.7%**	4.5	4.2%	**10.0%**
25 deg angle, 1,000 ft Screened in Talbert and Lower Aquifer	**2a**	V10	106.7	40	1,852	10	1	30	3	96.6	**90.6%**	2.8	2.6%	6.3	5.9%	**21.0%**	1.8	1.7%	**24.0%**	4.5	4.2%	**10.0%**
12 deg angle, 1,000 ft, Screened in Talbert Aquifer Only	**3a**	V11	106.7	40	1,852	10	1	30	3	96.9	**90.9%**	2.6	2.5%	6.1	5.7%	**20.3%**	1.7	1.6%	**22.7%**	4.4	4.1%	**9.8%**
25 deg angle, 425 ft Screened in Talbert Only (Original Slant Well Geometry)	**1b**	V10AK1P2	72	27	1,852	1	0.1	100	10	53.9	**77.1%**	1.9	2.8%	14.6	20.8%	**48.6%**	1.2	1.7%	**16.2%**	13.4	19.1%	**29.7%**
25 deg angle, 1,000 ft Screened in Talbert and Lower Aquifer	**2b**	V10K1	69.3	26	1,852	1	0.1	100	10	53.5	**77.2%**	1.9	2.8%	14.4	20.8%	**48.0%**	1.2	1.7%	**16.0%**	13.2	19.1%	**29.3%**
12 deg angle, 1,000 ft, Screened in Talbert Aquifer Only	**3b**	V11K1	69.3	26	1,852	1	0.1	100	10	53.6	**77.5%**	1.9	2.8%	14.2	20.6%	**47.3%**	1.1	1.6%	**14.7%**	13.1	19.0%	**29.1%**

Notes:
Horizontal and Vertical Hydraulic Conductivity (Kh and Kv) assigned to Talbert Aquifer at coastal margin and offshore: Kh = 300 ft/d, Kv = 30 ft/d for all the model versions summarized above. This is based on the OCWD model (CDM, 2000)
For Model Cases 1a, 2a, and 3a, the assigned values Kh and Kv of 10 and 1 ft/d for the shallow sediments that overly the Talbert Aquifer are the same as the original model (Geosyntec, 2013). These values are consistent with local estimates based on CPT data (GLA, 2002, TetraTech, 2012, Geosyntec 2013), but on a larger-scale are optimistically high (likely unrealistic). The lower Kh and Kv values (1 and 0.1 ft/d) assigned to the shallow sediments for Models Cases 1b, 2b, adn 3b) are considered more realistic based on the muddy character of the shallow sediments (Wong et al., 2012) and stratigraphic layering of the shallow sediments documented by the offshore geophysical surveys.
Kh and Kv of 30 and 3 ft/d asssigned to the Lower Aquifer for Model Cases 1a, 2a and 3a is consistent with values assigned to the Main Aquifer in OCWD model, which underlies the Talbert Aquifer at the coast (Table 4-1 and Figure 3-1, CDM, 2000).
Higher values of Kh and Kv (100 and 10 ft/d) assigned to the Lower Aquifer for Model Cases 1b, 2b, and 3b, provide a more optimistic respresentation of production capability from the Lower Aquifer for Model Case 2b that include pumping from the Lower Aquifer, and an optimistic contribution of from the Lower Aquifer upwater into the Talbert Aquifer for Model Cases 1b and 3b, which do not include pumping from the Lower Aquifer.
The assigned Kh value of 100 ft/d for the Lower Aquifer, results in the same transmissivity (15,000 ft2/d) as the Kh value of 300 ft/d in the original model because the thickness is 150 ft in the revised model, but was 50 ft in the original model.
We are not aware of any precedence for a 1000 ft long slant well at a 12 degree angle (likely not technically feasible)
* The flow from inland portion includes approximately 1 mgd aerial recharge to the uppermost active model layer (1 inch/year).
** Typical total injection rate is 30 MGD, of which 25% (7.5 MGD) is into the Talbert Aquifer and 75% (22.5 MGD) is into the Lower Aquifers
The entire length of the model inland constant head boundary for the Talbert Aquifer represents the Injection Barrier
Approximately half of the length of the inland constant head boundary for the Lower Aquifers represents the Injection Barrier. Consequently the percentage of pumping derived from the Injection Barrier in the Lower Aquifers is divided by two.

From Appendix QQQQ. Geosyntec, 2017b

Table 2
Model Results Summary
Alternative Sites Analysis
Huntington Beach Seawater Desalination Project

	Alamitos Gap				Sunset Gap			Bolsa Gap			
Pumping Well Design											
	Base Case	High K	Mergence	Low K	Base Case	High K	Low K	Base Case	High K	Mergence	Low K
Width of Coastline with Wells (ft)	8,000				9,400			8,000			
Number of Wells along Coastline	22				31			18			
Pumping Rate per Well (gpm)	316			221.2	208		143	570			
Estimated Sustainable Production (MGD)	10			7	9		6	15			
Portions of Source Water Pumped by Slant Wells											
	Base Case	Sensitivity Analysis			Base Case	Sensitivity Analysis		Base Case	Sensitivity Analysis		
		High K	Mergence	Low K		High K	Low K		High K	Mergence	Low K
Portion of Pumping from Sea	79%	81%	78%	76%	78%	77%	70%	79%	80%	79%	64%
Portion of Pumping from Wetlands	12%	15%	12%	3%	9%	19%	3%	3%	15%	3%	0%
Portion of Pumping from Inland	9%	4%	10%	21%	13%	5%	27%	18%	5%	18%	36%

Notes:
Pumping rate per well and estimated sustainable production are approximate.

Base Case: Kh of upper aquitard = 1 ft/d; Kv of upper aquitard = 0.1 ft/d
High K: Kh and Kv of upper aquitard = 1 ft/d
Low K: Kh of upper aquitard = 0.1 ft/d; Kv of upper aquitard = 0.01 ft/d

ft = feet
ft/d = feet per day
gpm = gallons per minute
Kh = horizontal hydraulic conductivity
Kv = vertical hydraulic conductivity
MGD = million gallons per day

Summary of Submittals Addressing Model Sensitivity Analyses
Feasibility of Subsurface Seawater Intakes
Huntington Beach Desalination Project

Geosyntec, 2013a, Feasibility Assessment of Shoreline Subsurface Collectors, Huntington Beach Seawater Desalination Project, Huntington Beach, California, September 2013, 79 pp.

Geosyntec 2013b, Response to Requests from California Coastal Commission Regarding

Geosyntec's Feasibility Assessment of Shoreline Subsurface Collectors, Huntington Beach Seawater Desalination Project, September, Technical Memorandum to Scott Maloni, Poseidon Water, 17 pg, 18 October 2013.

Geosyntec, 2015, Revision and Sensitivity Analyses of Slant Well SSI Model Feasibility Assessment of Shoreline Subsurface Collectors Huntington Beach Seawater Desalination Project, Technical Memorandum to Scott McCreary, Concur, 9 November, 34 pp. *[additional model sensitivity requested by Coastal Commission and the Well Investigation Team (WIT). Provided as an attachment to Geosyntec, 2017a]*

Geosyntec, 2017a, Additional Sensitivity Analyses of Slant Well SSI Feasibility Modeling: Variation in The Location and Length of The Slant Wells Has Very Little Influence on the Portions of Source Water Pumped by the Slant Wells, letter to Scott Maloni, Poseidon Resources, 18 January 2017, 64 pp.

Appendix QQQQ. Geosyntec, 2017b, Groundwater Modeling to Evaluate Feasibility of Subsurface Seawater Intakes in Bolsa, Sunset, and Alamitos Gaps, Water Board Request RCF 23, Alternative Sites Evaluation for the Proposed Desalination Project at Huntington Beach, letter to Scott Maloni, Poseidon Resources, 25 July 2017, 47 pp. *Includes Appendix A. Remaining Outstanding Requests for RCF23 Alternative Sites Evaluation for the Proposed Desalination Project at Huntington Beach.*

Poseidon, 2018, Huntington Beach Desalination Project Slant Well Analyses, letter to Hope Smythe, CARWQCB, Santa Ana, 11 Dec 2018, 13 pp.

ATTACHMENT 2
Summary of Compilation of Wetland Sediment Properties

ATTACHMENT 2

Summary Compilation of Wetland Sediment Properties

Proposed Desalination Facility, Huntington Beach, CA

See Psomas, 2007

Compilation and of shallow seds characteristics in vicinity of wetlands from Reported Hydraulic Conductivity of shallow fine-grained seds in vicinity of wetlands.

Ascon LF Shallow Seds beneath Lagoons Geosyntec, 2011						
		Lab Tests				
		cm/s	ft/d	thickness		
		1.00E-05	**0.028**	**up to 5 ft**		
Hydraulic Conductivity of low K shallow seds, OCWD Model, CDM 2000						
			ft/d	cm/sec		
			0.010	3.5E-06		
			0.040	1.4E-05		
		avg	**0.025**	**8.8E-06**		

Geosyntec consultants

Poland and Piper, 1956, Ground-water Geology of the Coastal Zone Long Beach-Santa Ana Area, California, USGS WS Paper 1109

TABLE 4.—*Materials penetrated by typical shallow observation wells in the coastal zone of the Long Beach-Santa Ana area*—Continued

SANTA ANA GAP—Continued

6/10–19L1. Orange County. About 0.45 mile west of Santa Ana River and 0.15 mile northeast of the Pacific Ocean. Altitude 6.9 feet.

Material	Thickness (feet)	Depth (feet)
Shoreline and lagoonal deposits:		
Fine to medium sand, pebbly, with shells	2	2
Silt, yellowish-gray	.6	2.6
Medium to fine sand	8.6	11.2

SANTA ANA GAP

6/10–7L4. Orange County. About 0.85 mile west of Santa Ana River and 0.5 mile north of Atlanta Avenue. Altitude 8.4 feet.

Flood-plain deposit:		
Silt	5	5
Silty clay	1	6
Clay, gray, plastic	6	12
Very fine sand, blue	6	18

6/10–18C5. Orange County. About 0.7 mile west of Santa Ana River and 18 feet south of Atlanta Avenue. Altitude 7.8 feet.

Flood-plain and lagoonal deposits:		
Silt	4	4
Clay, silty, plastic, with peat layers at 6.5 feet	5	9
Sand, silty, gray	5	14
Sand, gray, with shells abundant	2	16

6/10–18L1. Orange County. About 0.6 mile west of Santa Ana River and 10 feet south of Hamilton Street, projected. Altitude 7.2 feet.

Flood-plain and lagoonal deposits:		
Sand and silt, gray	4	4
Clay, plastic	4	8
Fine sand, silty, gray	1.5	9.5
Clay, plastic	1	10.5
Sandy silt, blue, with shells abundant	2.5	13
Sand with shells	2	15

6/10–19C1. Orange County. About 0.5 mile west of Santa Ana River and 0.6 mile northeast of the Pacific Ocean. Altitude 6.0 feet.

Lagoonal and flood-plain deposits:		
Silt	2.5	2.5
Clay, plastic	3.5	6
Sandy silt, light-gray, with shells	5	11
Fine sand, silty, dark-gray, with shells abundant	4	15

	Kv/b base case		0.001	1/d	
	b tot ft	100			
	Kv base	0.1	ft/d		
Material	est (K ft/d)	b (ft)	b/Kv (d)	Kv/b (1/d)	fraction of base case
THIS BORING IS CLOSEST TO THE WETLANDS					
see map on next page.					
ML	0.1	0.6	6		
		0.6	shallowKv/b=	1.7E-01	
			total Kv/b=	1.0E-03	1.0
b tot ft	100				
Material	est (K ft/d)	b (ft)	b/Kv (d)	Kv/b (1/d)	
ML	0.1	5	50		
ML-CL	0.05	1	20		
CL	0.01	6	600		
		12	shallowKv/b=	1.5E-03	
			total Kv/b=	6.5E-04	0.6
Material	est (K ft/d)	b (ft)	b/Kv (d)	Kv/b (1/d)	
ML	0.1	4	40		
ML-CL	0.05	5	100		
		9	shallowKv/b=	7.1E-03	
			total Kv/b=	9.5E-04	1.0
Material	est (K ft/d)	b (ft)	b/Kv (d)	Kv/b (1/d)	
CL	0.01	4	400		
CL	0.01	1	100		
		5	shallowKv/b=	2.0E-03	
			total Kv/b=	6.9E-04	0.7
Material	est (K ft/d)	b (ft)	b/Kv (d)	Kv/b (1/d)	
ML	0.1	2.5	25		
CL	0.01	3.5	350		
		6	shallowKv/b=	2.7E-03	
			total Kv/b=	7.6E-04	0.8
		average thickness of shallow low K seds	6.52		

Map with approximate locations of shallow borings from Table 4 of Poland and Piper, 1956 addressed on previous page.

N

3,000 1,500 0 Feet

EIR Magnolia Tank Farm Facility near HB coastal margin, Psomas, 2018
https://www.huntingtonbeachca.gov/government/departments/planning/major/major-projects-view.cfm?ID=62

Fill was generally encountered to a depth of approximately 2 feet, NAVD, but may extend deeper in localized areas of the site. Fill is described as very moist, grey-brown silty clay, elastic silt, and sandy silt with clay. The fill was found to be loose, and very soft to stiff, increasing in relative density with
depth.

Quaternary-age young axial channel deposits (Qya) extend from the bottom of the artificial fill to the maximum depth explored of 51.5 feet below the ground surface. These deposits consist of an upper layer of clay, silty clay, and silt, which was found be approximately 7 to 12 feet in thickness, the bottom of this layer is approximately located between -4 and -8 feet, NAVD, and described as very soft to stiff, and very moist to saturated.
Below this is a thicker layer of interbedded sand and silt, which extends to the maximum depth explored. This layer was found to be loose near the top, transitioning to dense with depth.

EnvApps Monintoring well install report July 2018 to DTSC documents clayey silt to silty clay with trace to 10% fine sand at few ft bgs with a thickness of ~2 to 8 ft

Radian 1988 Site Charc of Ascon LF.

Native silty clay 2 to 10 ft thick grades to clayey silt at base

HB Wetlands Restoration Project: Monitoring Final Report. CSULB 2013

Figure 67. Major habitat types (sediment and vegetation) within the Brookhurst Marsh during summer 2011. Colors correspond to benthic habitat types. This marsh was the focus of our mapping effort because the patches within the tidal channel did not change significantly over the monitored period.

Reported hydraulic conductivity for peat deposits

Meyers, 1999.
Hydraulic Properties of South Florida Wetland Peats, Master's Thesis, University of Florida

			cm/s	ft/d
range from lit (field tests)			1.00E-05	0.03
			5.00E-03	14.17
thesis mean downward flow (lab)			8.32E-05	0.24

Huntington Beach Wetlands Restoration Project Report (HBWRP) on marshes is at the following online link (pdf too large to email) Pages 18-32 of report discuss tidal monitoring of marshes
http://hbwetlands.org/pdfs/HBW%20Restoration%20Project_finalreport_Oct2013.pdf/HBW%20Restoration%20Project_finalreport_Oct2013.pdf

Allen et al., 2011, HB Wetlands Restoration

The Huntington Beach Wetlands (HBW) complex is an approximately 200-acre remnant of a 2900-acre wetland area which historically existed at the mouth of the Santa Ana River in Huntington Beach, Orange County, California (33° 39' N, 117° 59' W; Fig. 1). This area consists of restored salt marsh and coastal dune habitat, and is bisected by roadways into four distinct sections, including the Talbert, Brookhurst, Magnolia, and Newland marshes.

This area consists of restored salt marsh and coastal dune habitat, and is bisected by roadways into four distinct sections, including the Talbert, Brookhurst, Magnolia, and Newland marshes. These marshes are hydraulically linked to each other and to the Pacific Ocean by a flood control channel running along the northeastern border of the site.

Additional projects restored tidal flow to Brookhurst Marsh (67 acres) in 2009 and Magnolia Marsh (41 acres) in 2010; tidal flow has not yet been restored to Newland Marsh.

The eelgrass beds within the Tidal Channel have created small pockets of low flow, enabling the settlement of finer-grain sediments that juvenile halibut < 20 cm TL are known to associate with (Ginsburg and Lowenstam 1958; Fonseca et al. 1982; Heiss et al. 2000). Sediment samples taken near vegetated areas of the HBW had higher silt/clay content (~85% sand, ~15% silt/clay) than unvegetated areas (~95% sand, ~5% silt/clay).

Moffat and Nichol 2004 Sediment disposal options HBW restoration

Material within the unrestored HB wetlands is silts and clays in the upper layers to depths of 10 to 15 feet below ground in most areas, and sand in lower layers.

Brookhurst Marsh

The material is alluvial silt from 5 feet depth below the levee crest to a depth of 11 feet. Fine sand exists from depths of 11 feet below ground to a depth of 41 feet (bottom of borehole). This general vertical section of soil stratigraphy is consistent throughout the HB wetlands.

Magnolia Marsh

The data indicate that the top 13 to 15 feet of soil below levee crest is fill and alluvial silt and clay, with material below 15 feet being fine sand to the depths of the borings which was 50 feet (Shannon & Wilson, Inc., 1973; GeoSoils, Inc., 1991; and Southern California Edison, 2001).

Newland Marsh

The borings are on north levee of the Huntington Beach Channel and show sand/silt/clay fill for the top 5 to 7 feet below ground with silt down to 12 to 13 feet below ground, and sand to depths of 30 to 40 feet borings (GeoSoils, Inc., 1991).