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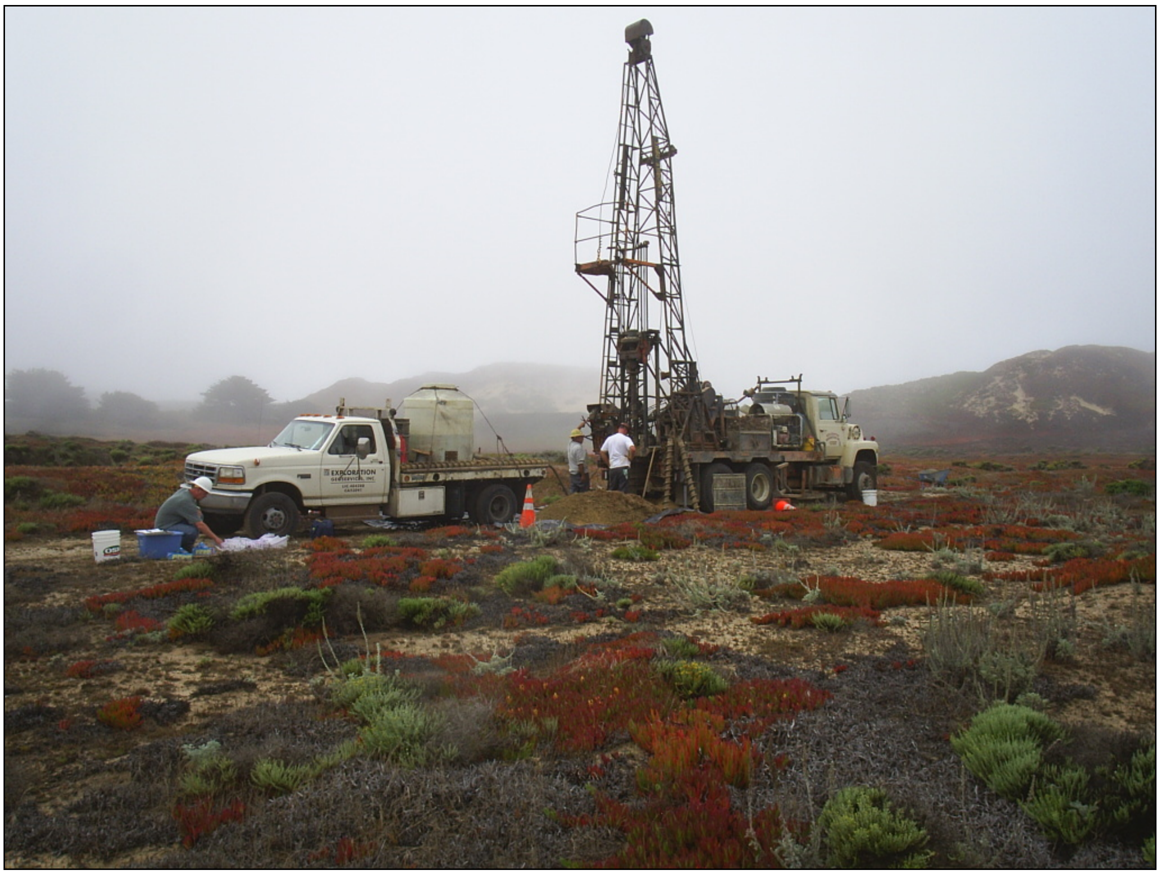
Monterey Peninsula Water Management District
95-10 DESALINATION PROJECT
Hydrostratigraphic Investigation

For
Monterey Peninsula Water Management District



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INTRODUCTION

BACKGROUND

The Monterey Peninsula Water Management District (District) has been investigating the possibility of developing a desalination facility to provide additional water supply for the Peninsula. This project is referred to as the MPWMD 95-10 Desalination Project. The project, if feasible, would be proposed to produce up to 8,400 acre-feet per year (AF/Y). Seawater feedwater requirements for a facility of this size would be approximately 11,570 gallons per minute (gpm)[1]. This feedwater would be developed from the shallow aquifers in hydraulic communication with the ocean.

The idea of utilizing the shallow dune sand aquifer adjacent to the ocean for a source of feedwater is not without precedent. Beginning in the early 1990's, the District investigated the feasibility of collector wells at locations both north and south of Fort Ord (Marina and Sand City). These investigations established the feasibility of the shallow aquifer to provide desalination feedwater. Perhaps most importantly, both of these investigations identified a low-permeability layer at the base of the dune sands that isolated the underlying aquifers. These materials have been documented at an elevation of approximately 40 to 50 feet below sea level (-40 to -50 feet, msl). This is generally accepted as the approximate top of the underlying freshwater aquifer systems in the areas investigated in these earlier studies.

2008 Constraints Analysis

An initial investigation of the feasibility of the 95-10 Desalination project was performed by the project team of ICF Jones & Stokes/Camp, Dresser & McKee in 2008 (JSA/CDM 2008). This initial investigation, was a constraints analysis and built on the work performed by CDM for the District from 2002 to 2004. The earlier work focused on analysis of the feasibility of developing desalination feedwater from the shallow aquifer system in Sand City. The conclusion of these earlier studies was that development of the required amount of feedwater from the Sand City area was technically challenging, but feasible. However, since 2004 the City of Sand City has moved ahead with permitting and construction of their desalination facility in the coastal portion of Sand City. The development of this facility limits, for several reasons, the District's access and use of the shallow aquifer system in this area.

Consequently, the Constraints Analysis report looked at the feasibility of developing desalination feedwater from the coastal portion the former Fort Ord. This area, which has now been converted into Fort Ord Dunes State Park (Park), was inferred to have similar hydrogeologic conditions and might be suitable for development of feedwater from the shallow sediments in hydraulic communication with the ocean. The Constraints Analysis performed a reconnaissance-level assessment of the hydrogeologic conditions of the area utilizing existing data, reviewed the land-use constraints within the Park, and prepared an inventory of potential permitting challenges. Specific feedwater development schemes focused on: a) conventional wells, b) slant wells and c) collector wells. For clarity, each of these approaches is described below:

- Conventional Wells – Conventional wells are vertical boreholes into which a casing has been installed. The lower portion of the well has a well screen to allow water to move into the well while retaining aquifer materials. At the depths and assumed discharge rates proposed in the Phase I study, construction costs for vertical wells would be less than $100,000 per well.

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[1] Project Size= 8,400 AF/Y = 23 AF/D = 5,200 gpm. 50% recovery, 90% on-line factor => 11,570 gpm

- Slant Wells –Slant wells are essentially conventional (vertical) wells that have been drilled at some angle less than 90 degrees to ground surface. Currently, the shallowest angle that can be achieved is 22.5 degrees from horizontal. The slant wells have two advantages over conventional wells that can be important depending on the hydrogeologic setting. At 22.5 degrees, the perforated section of casing adjacent to the aquifer is approximately 2.6 times longer in length than would be in a vertical well penetrating the same aquifer. This can marginally improve well performance if aquifer conditions are good and screen open area is the limiting factor. The other advantage is that because the well is constructed at an angle it moves the point of intake away from the location of the well head. At 22.5 degrees, for every foot in depth the well path moves 2.6 feet away from the point of entry. This can be advantageous if it is desired to move the point of extraction away from the surface location of the well as in a coastal setting with permitting setbacks or to move point of extraction toward a boundary condition such as the ocean. However, at 22.5 degrees and a suggested Coastal Commission setback from the ocean of 300 feet, the well bore is at a depth of 125 feet lower in elevation than the entry point when reaching the coastline. Depending on the ground surface elevation at the point of entry, this can be significantly below the shallow deposits in communication with the ocean and into the underlying aquifer system. Construction techniques are similar to conventional wells. However, at approximately $1M per well, slant wells cost ten times that of vertical wells.
- Collector Wells – Collector Wells, or Ranney Wells, consist of an approximately 15-foot in diameter caisson that has been installed to 40 to 50 feet below the water table. From this caisson, smaller perforated horizontal casings are advanced 300 feet or more toward a water body. In the best hydrogeologic settings a single collector well can produce as much as 28,000 gpm. However, collector wells are expensive, typically costing several million dollars. The Constraints Analysis study deemed collector wells not practical for several reasons: 1) the existing data revealed the aquifer materials, while permeable, to be not permeable enough to justify the cost of the collector; 2) Collector wells perform best when immediately adjacent to a water body. With the assumed erosional setbacks required by the Coastal Commission, siting collector wells any closer than 300 feet was considered unlikely. As such, collector wells were determined to be not suitable or cost-effective for the proposed setting.

These approaches to developing feedwater from the groundwater system were evaluated in terms of technical performance, siting criteria and permitability. Combinations of the approaches deemed feasible were utilized to develop concepts that included networks of conventional and/or collector wells at several locations in the Park. The conceptual plans were discussed with representatives of both the Monterey County Water Resources Agency (MCWRA) and the Seaside Groundwater Basin Watermaster (Watermaster). Both of these entities expressed conditional approval of the proposal with the proviso that the extraction of feedwater (saline groundwater from the ocean) from the proposed areas did not adversely affect the underlying groundwater resources in their respective jurisdictions. Additionally, the project team met with State Department of Parks and Recreation (State Parks) representatives to understand the land use limitations associated with the siting of the proposed feedwater system infrastructure, assuming it was feasible.

Using the conclusions of the reconnaissance-level hydrogeologic assessment and, as constrained by land-use plans of the Park, the Constraints Analysis report identified three potential locations for the siting of feedwater extraction facilities in the Park. These three locations were as follows:

1. The so-called Bunker Site: The report suggested that this site might be capable of developing between 4,000 gpm and 6,000 gpm (Project yield 2,900 to 4,350 AF/Y) from the shallow dune sand deposits, depending on the type of extraction facilities.

2. The former Fort Ord wastewater facility plant site: The report suggested that wells in the intruded 180-foot aquifer would be capable of developing as much as 4,000 gpm (Project yield 2,900 AF/Y) at this location.
3. The former Stilwell Hall site: The report suggested that between 2,000 and 3,000 gpm could be developed from the shallow aquifer at this location. Possibly 4,000 gpm could be developed from the intruded 180-foot aquifer at this location.

The Constraints Analysis report concluded that a project providing the desired 8,400 AF/Y could only be assembled utilizing wells that were in the 180-foot aquifer. The report pointed out that locations 2 and 3 are geographically outside of the Seaside Groundwater Basin and in the Salinas Groundwater Basin. In addition, by definition, the 180-foot aquifer is part of the Salinas Basin. Utilizing these locations and the 180-foot aquifer would constitute an inter-basin transfer and was considered extremely challenging politically.

SUBJECT INVESTIGATION

Given the conclusions of Constraints Analysis, the District decided to move forward to further evaluate the identified areas. The previous effort had included only a reconnaissance-level evaluation of the hydrogeology. Additional understanding of the hydrogeologic conditions was considered essential to complete the evaluation of the feasibility and impacts of developing feedwater from coastal Fort Ord.

Subsequent to the completion of the Constraints Analysis report, several fundamental questions were identified that need to be answered to establish the feasibility of the feedwater system. These questions are prioritized in order of significance to the feasibility of the project and are presented in this order below. These questions are a logical progression. If the first question cannot be answered favorably, the subsequent questions would not need to be explored and resolved. The questions, listed in order of importance, are presented below. A decision tree showing the overall approach is presented as Figure 1.

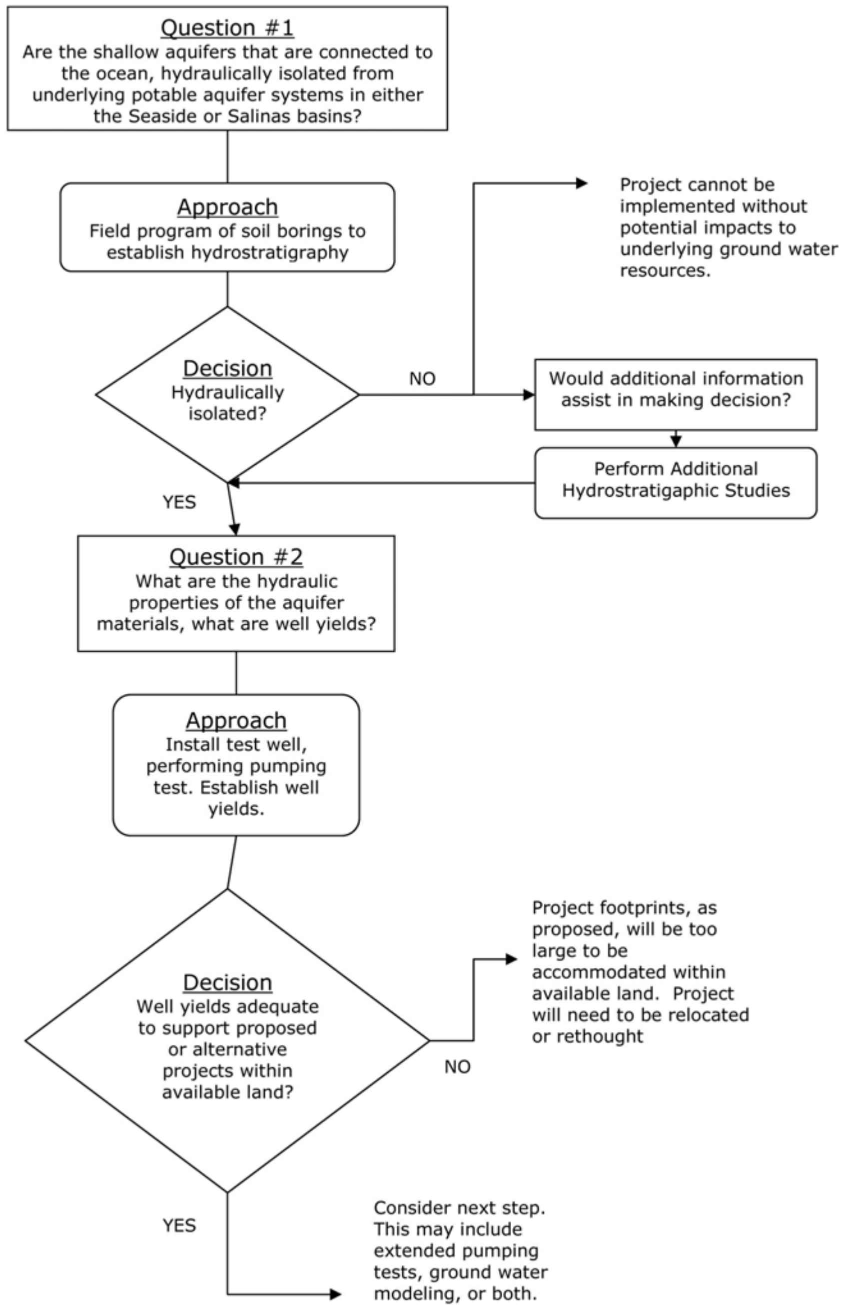
1. The operation of a feedwater collection system that produces groundwater from the shallow dune sand aquifer will, by intent and design, induce seawater intrusion into the shallow aquifer system. It has been postulated that the shallow aquifer system in the proposed area is underlain by low permeability materials that would provide hydraulic separation between the shallow aquifer system and the underlying aquifer systems of either the Salinas Valley Basin or Seaside Basin. This low permeability layer would protect the underlying aquifers from infiltration of seawater from the shallow aquifer system. Both the MCWRA and Watermaster have indicated that demonstrating the presence and extent of this low permeability layer is fundamental to the project's feasibility and permitability.

2. In estimating individual well yields the Constraints Analysis report project utilized hydraulic performance data derived from local studies performed much closer to the ocean than the locations currently proposed in the Park. The proximity to the ocean likely resulted in better well performance than will be possible at greater distances from the ocean. If the performance of the wells is reduced, the proposed number of wells will increase and, accordingly, the footprint of the feedwater system infrastructure will be larger than originally proposed. This increase in the number of wells and footprint may impact the ability to site the required facilities in areas acceptable to State Parks. Alternatively, the project yield could be reduced to fit the available areas.

3. If adequate hydrogeologic separation can be demonstrated and the individual well yields are high enough that siting sufficient well capacity is doable within the available areas in the Park, the project will need to demonstrate that the source of supply is ultimately seawater rather than a limited perched water supply. MCWRA has suggested that their acceptance of the project may require demonstration of the production of seawater.

As such, the District undertook this subject hydrogeologic investigation to start the evaluation of these questions. The project approach was to investigate the hydrogeologic setting of the areas only as far as could be supported by continuing positive results regarding the feasibility of developing saline groundwater from the shallow dune sand aquifer system. If investigation of a particular area identified fatal flaws, technical, political or permitting, the area was removed from further consideration.

Figure 1 - 95-10 Desalination Project Decision Tree



SCOPE OF WORK

The scope of work for the project was phased. The initial work was focused on assessing the existence and continuity of isolating layers. This work included data collection and review, and field exploration. If the initial work demonstrated the presence of a defendable isolating strata, the work would be continued and would focus on quantifying the hydraulic properties of the aquifer system. The subsequent work would include test well installation and aquifer testing.

FINDINGS

Hydrogeologic Setting

Fort Ord Dunes State Park overlies both the Seaside and Salinas Groundwater Basins, straddling the boundary located just south of the new shopping center on the former Fort Ord in Marina (The Dunes). The hydrogeology of these two groundwater basins is similar, but with significant differences. In the project area, the surficial deposits consist to older dune sands and Aromas Red Sand deposits. These deposits overlie a sequence of water-bearing deposits that are utilized for water supply in both basins. The generalized hydrostratigraphy is presented below.

Hydrostratigraphic Unit	Seaside Groundwater Basin	Salinas Groundwater Basin
Surficial Deposits	Older Dunes/Aromas Red Sands	Older Dunes/Aromas Red Sands
Upper Aquifer System	Continental Deposits “Paso Robles Aquifer”	River Alluvium “180-foot Aquifer” “ 400-foot aquifer”
Lower Aquifer System	Marine Deposits “Santa Margarita Aquifer”	Continental Deposits “Paso Robles Aquifer”/Marine Deposits “Purisima Formation” (“deep aquifer”)

The top of the upper aquifer system in the Salinas Basin in the project area is generally assigned at an elevation of approximately -10 feet, msl, based on hydrogeologic work performed as part of the base-wide clean-up of the former Fort Ord. In the Seaside Basin, the average elevation of the top of the Paso Robles Formation is approximately -50 feet, msl.

Data Inventory

Prior to the design of the hydrogeologic exploration program, available lithologic data from monitoring wells and borings in the coastal portion of former Fort Ord were assembled and tabulated to assist in designing the exploration program. This effort was documented in a progress report technical memorandum in July 2009 (Feeney, 2009). Many of the existing monitoring wells were installed as part of environmental assessment and clean-up activities associated with the closing of Fort Ord. Other monitoring wells were installed as part of basin management activities of the District and the Watermaster. Although there are more than 40 wells in the study area, many of the wells are too shallow to provide useful hydrostratigraphic information. The deeper more useful wells are summarized on Table 1– Well Inventory – Coastal Fort Ord. Table 1 presents details of well completions including elevation, total depth, perforated interval, water-level data, and relevant hydrostratigraphic data. The locations of the wells are shown on Figure 2 - Well/Boring Location Map.

Figure 2 - Well/Boring Location Map

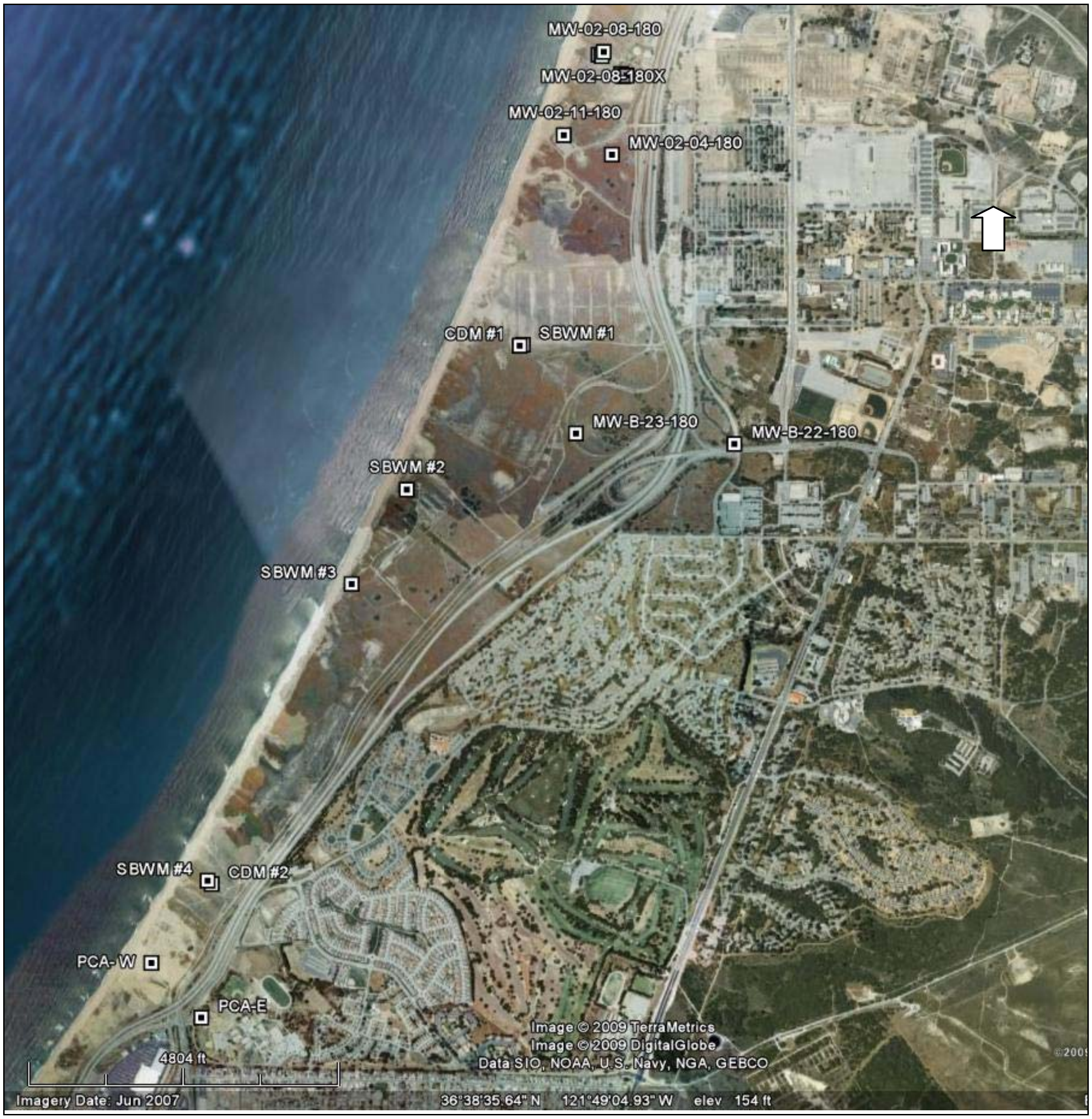


Table 1 - Well Inventory – Coastal Fort Ord

X-Section No.	Well Name	Lat.	Log	Date Drilled	Elev. (ft, msl)	Depth (feet)	Btm Elev. (ft., msl)	Top of Perfs (feet)	Btm of Perfs (feet)	Elev. Top of Perfs (ft, msl)	Elev. Btm of Perfs (ft, msl)	Recent DTW (feet)	Recent WSE (ft, msl)	Date of WL meas.	Available Data	Depth to Sig. Clay (feet)	Elev. of Sig. Clay (ft, msl)
	MW-02-08-180	36°39'52.39"N	121°49'8.50"W	1993	50.7	66	-15.3	37	57	13.7	-6.3	47.45	3.25	Mar-03	l	*NE*	
7	PZ-02-02-180U	36°39'51.99"N	121°49'9.49"W	1994	47.5	250	-202.5	37	52	10.5	-4.5	47.25	0.25	Mar-03	l	*NE*	
	PZ-02-02-180M	36°39'51.99"N	121°49'9.49"W	1994	47.5	250	-202.5	90	100	-42.5	-52.5	47.04	0.46	Mar-03	l	*NE*	
	PZ-02-02-180L	**36°39'51.99"N**	**121°49'9.49"W**	**1994**	**47.5**	**250**	**-202.5**	**165**	**175**	**-117.5**	**-127.5**	**50.14**	**-2.64**	**Mar-03**	**l**	***NE***	
	MW-02-08-180X	36°39'51.75"N	121°49'8.86"W	1995	48.1	84	-35.9	48	78	0.1	-29.9	47.6	0.5	Dec-05	l	*NE*	
	PZ-02-01-180U	36°39'49.13"N	121°49'5.20"W	1992	65.04	184	-118.96	38.7	68.7	26.34	-3.66	61.6	3.44	Sep-03	l	*NE*	
	PZ-02-01-180M	36°39'49.13"N	121°49'5.20"W	1992	65.04	184	-118.96	102.7	112.7	-37.66	-47.66	61.5	3.54	Sep-03	l	*NE*	
	PZ-02-01-180L	**36°39'49.13"N**	**121°49'5.20"W**	**1992**	**65.04**	**184**	**-118.96**	**142.7**	**152.7**	**-77.66**	**-87.66**	**65**	**0.04**	**Sep-03**	**l**	***NE***	
	MW-02-07-180	**36°39'48.84"N**	**121°49'4.18"W**	**1992**	**61.19**	**133.69**	**-72.5**	**110**	**130**	**-48.81**	**-68.81**	**56.63**	**4.56**	**Dec-08**	**l**	***NE***	
	MW-02-09-180	36°39'48.78"N	121°49'4.81"W	1993	59.5	80	-20.5	52	72	7.5	-12.5	57.08	2.42	Dec-08	l	*NE*	
6	MW-02-11-180	36°39'39.70"N	121°49'16.02"W	1994	95.67	101.4	-5.73	80	100	15.67	-4.33	91.69	3.98	Dec-08	l	*NE*	
	MW-02-04-180	36°39'36.72"N	121°49'6.95"W	1992	99.3	110.9	-11.6	87.7	107.7	11.6	-8.4	94.82	4.48	Dec-08	l	*NE*	
5	SBMW #1	36°39'07.93"N	121°49'23.67"W	2007	96	1500	-1404	1130	1490	-1034	-1394	na	na	na	l,gp,	*NE*	
	CDM MW #1	**36°39'07.79"N**	**121°49'24.25"W**	**2003**	**93.53**	**161.5**	**-67.97**			**93.53**	**93.53**	**90.02**	**3.51**	**Jul-08**	**l,gp,gs**	***NE***	
	MW-B-23-180	**36°38'54.54"N**	**121°49'13.71"W**	**1977**	**113.4**	**150**	**-36.6**	**90**	**140**	**23.4**	**-26.6**	**na**	**na**	**na**	**l**	***NE***	
	MW-B-22-180	36°38'52.91"N	121°48'44.01"W	1977	169.07	172	-2.93	117	167	52.07	2.07	165.53	3.54	Dec-08	l	*NE*	
4	SBWM #2	36°38'46.08"N	121°49'45.52"W	2007	73.7	1500	-1426.3	990	1480	-916.3	-1406.3	na	na	na	l,gp,	125	-51.3
3	SBWM #3	36°38'31.81"N	121°49'55.92"W	2007	59.5	1310	-1250.5	860	1290	-800.5	-1230.5	na	na	na	l,gp,	100	-40.5
2	SBWM #4	36°37'46.94"N	121°50'22.96"W	2007	62.4	920	-857.6	705	920	-642.6	-857.6	na	na	na	l,gp,	100	-37.6
	CDM MW #2	36°37'46.41"N	121°50'22.23"W	2003	63.83	105	-41.17			63.83	63.83	60.46	3.37	Jul-08	l,gp,gs	97	-33.17
1	PCA-W-S	36°37'34.59"N	121°50'33.40"W	1990	64.22	585	-520.78	525	575	-460.78	-510.78	62.2	2.02	Oct-08	l,gp,	140	-75.78
	PCA-E-S	36°37'26.29"N	121°50'24.07"W	1990	68.51	410	-341.49	350	400	-281.49	-331.49	68.12	0.39	Oct-08	l,gp,	160	-91.49

NE =	Not Encountered	gp =	geophysical log
l =	lithologic log	p=	permeability
na=	Not Available	gs=	grain size
bold face=	Clay not encountered		

Exploration Program

The information presented in Table 1 provides a basis for the design of an exploration program to further delineate the hydrostratigraphy of the coastal portion of former Fort Ord. Due to the absence of evidence for a significant clay (i.e., low-permeability) layer at the so-called Stilwell Hall and Fort Ord wastewater treatment plant sites, the originally proposed field program was, after discussions with District staff, reduced from the originally scoped ten borings to seven borings. The locations of the borings are shown on Figure 3 - Boring Location Map. The siting criterion for the borings was to develop data in areas with limited data. These locations were presented to District staff. However, in response to findings upon drilling the first three borings, two of the remaining borings were relocated during field operations to provide better resolution. The locations, ground surface elevation, and explored depth elevation are summarized on Table 2 – Exploratory Borings.

Table 2 – Exploratory Borings

Boring	Depth	Elevation*	Btm Elevation	Depth to Water	Top of Significant Clay	Elevation of Significant Clay	Notes
1	151	60.8	-90.2	57.8		below boring bottom	
2	161	76	-85	73		below boring bottom	
3	161	90.5	-70.5	87.5	158	-67.5	
4	151	74.3	-76.7	71.3	130	-55.7	
5	151	81.8	-69.2	78.8	124	-42.2	Shells
6	161	89.4	-71.6	86.4	125	-35.6	QTp
7	141	53	-88	50	127	-74	

* Calculated from water surface of 3 feet.

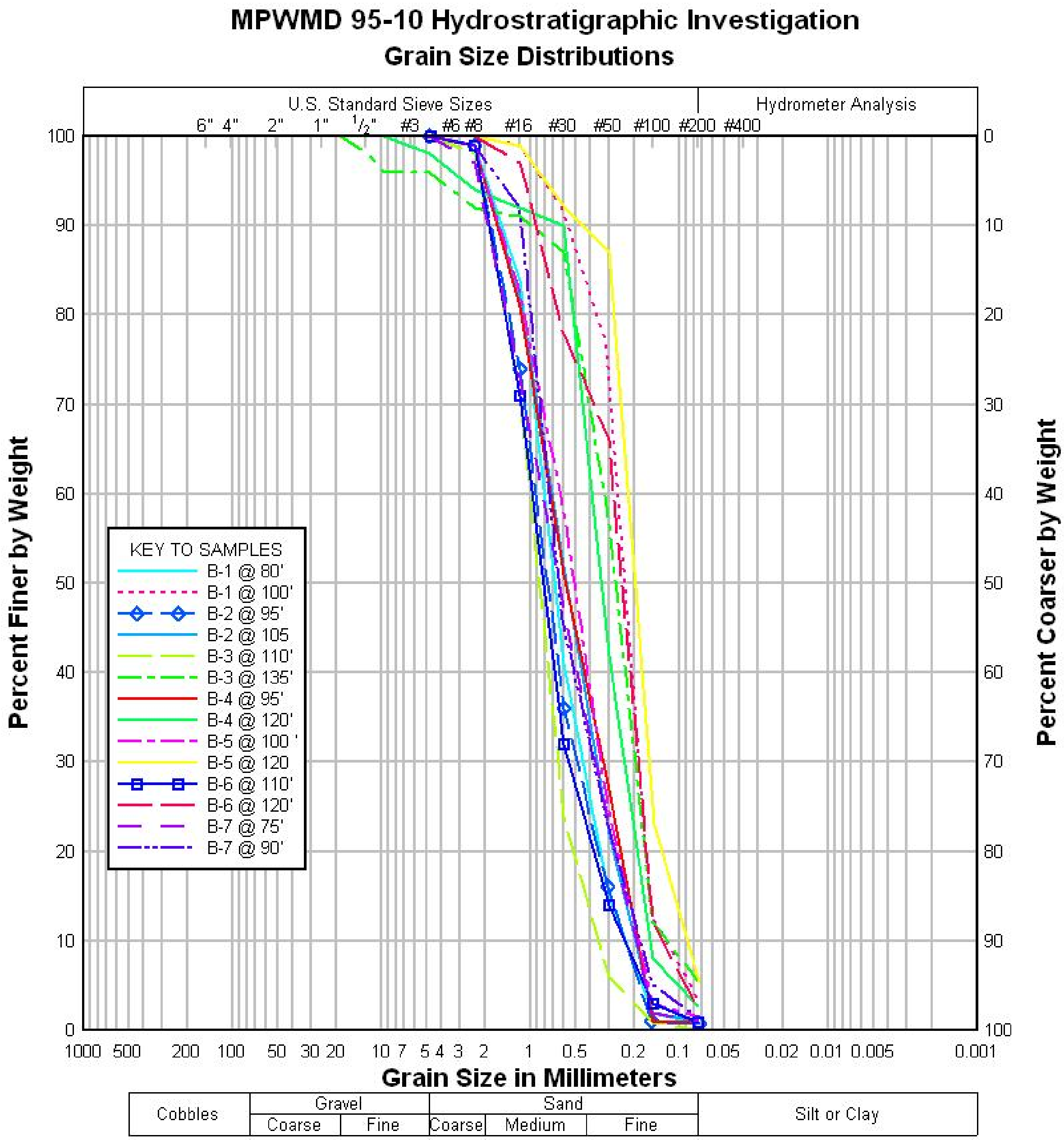
Figure 3 - Boring Location Map

The borings were drilled by the hollow-stem method to depths ranging from 141 to 161 feet below ground surface (bgs). The drilling contractor was Exploration GeoServices, Inc. of San Jose, California. During drilling, lithologic samples were taken on a continuous basis and logged by a Professional Geologist. Below the water table, samples were collected with the Standard Penetration Sampler and were bagged for laboratory analysis. After reaching final depth, each boring was backfilled with cuttings and, as needed, bentonite pellets to restore the original stratigraphy. The lithologic logs of the seven borings are presented in Appendix A - Boring Logs.

Laboratory Work

Lithologic samples were collected from each boring between the elevations of approximately sea level and -50 below sea level. Feedwater wells, if feasible, would be constructed such that the perforations would start 10 to 20 feet below the static water level, allowing for drawdown during operation. Water-level elevations at the site are approximately at sea level. An elevation of -50 feet, msl had been previously specified as the approximate top of the underlying aquifer system. As such, two samples from the interval between -20 and -50 feet below sea level from each borehole were submitted for laboratory testing. The two samples from each boring were selected by visual assessment to be the most permeable samples in that interval. Samples were tested to determine grain-size distribution. In general, the laboratory data allow classification of the materials as fine to medium sand. The grain-size curves for these samples are presented in Figure 4 - Grain Size Distributions.

Figure 4 - Grain Size Distributions



ANALYSIS

Hydrostratigraphic Interpretations

Ten of the wells on Table 1 extend to elevations below -50 feet, msl. All of the borings on Table 2 extended below -50 feet msl. Of these wells and borings, seven encounter low-permeability material above or near the elevation of -50 feet, msl, the adopted top of the freshwater aquifer system. The remaining wells either do not encounter low-permeability materials or encounter them at significantly different elevations.

Seven of the wells listed in Table 1 were utilized to construct a cross-section of the shallow hydrostratigraphy of the entire study area. The cross-section is presented as Figure 5 – Hydrogeologic cross section A-A' and the orientation and location of the cross-section is presented on Figure 6. As can be seen in the cross-section, most of the material encountered in the borings is clean to silty sand. Some discontinuous clay lenses are encountered at relatively shallow depths in the southern portion of coastal former Fort Ord. In the northern portion of the study area, these clay layers have not been encountered.

Figure 7 - Bunker Area Cross-Section (location of Figure 8) provides more detail of the subsurface conditions to the Bunker site based on the borings performed as part of this investigation. Again, most of the material is clean to silty sand. Apparent on Figure 7 is presence of discontinuous clay lenses occurring at differing elevations. In the three most northerly boring locations, low-permeability materials are either not of significant thickness or are entirely absent.

The collected data document a hydrostratigraphy that is areally and vertically discontinuous. The discontinuous nature of the low-permeability layers strongly suggests that, in most of the boring locations, the surficial deposits which comprise the upper shallow aquifer are likely in some degree of hydraulic communication with the underlying aquifer system.

Figure 5 - Hydrogeologic Cross-Section A-A'-

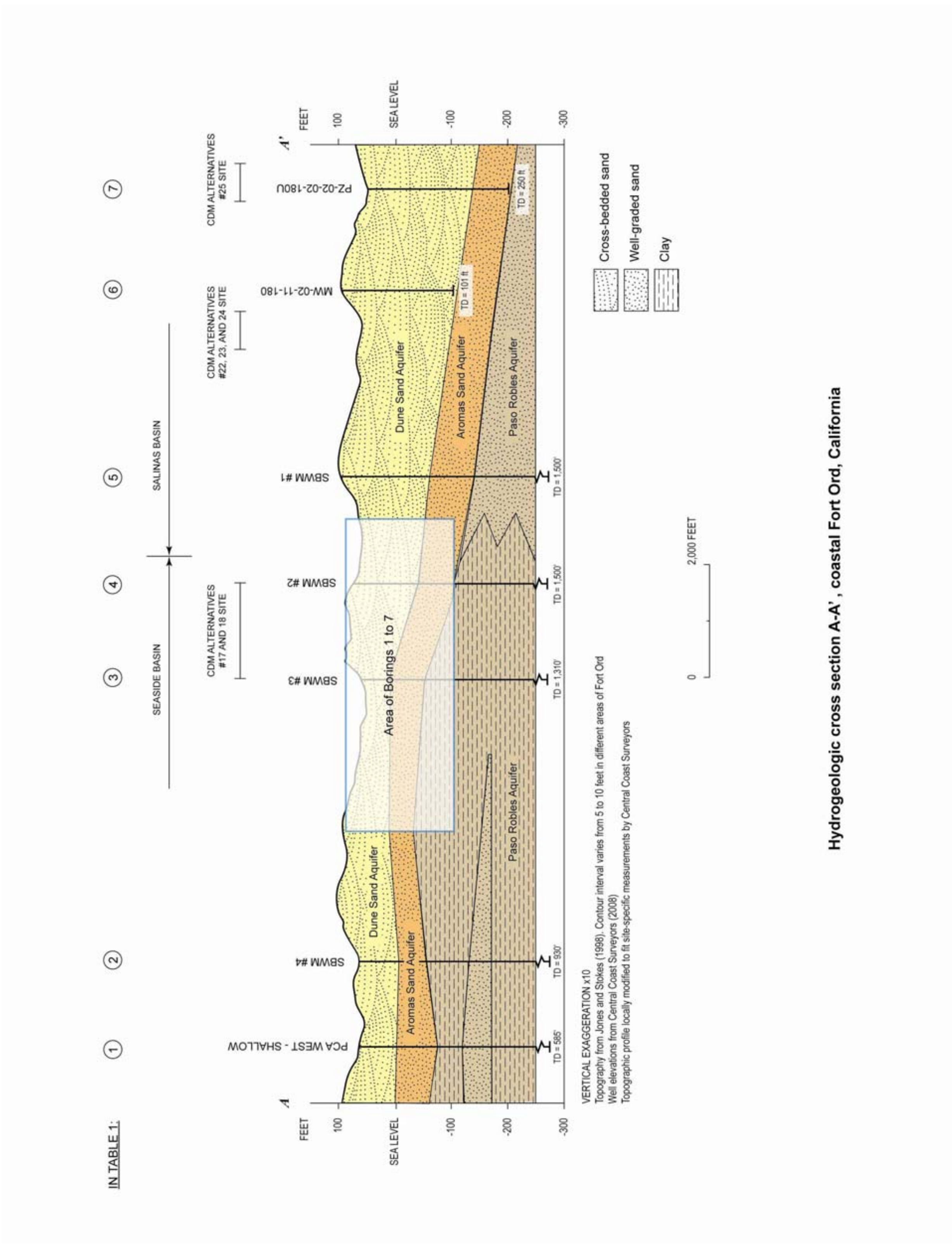


Figure 6 - Cross-Section Location Map

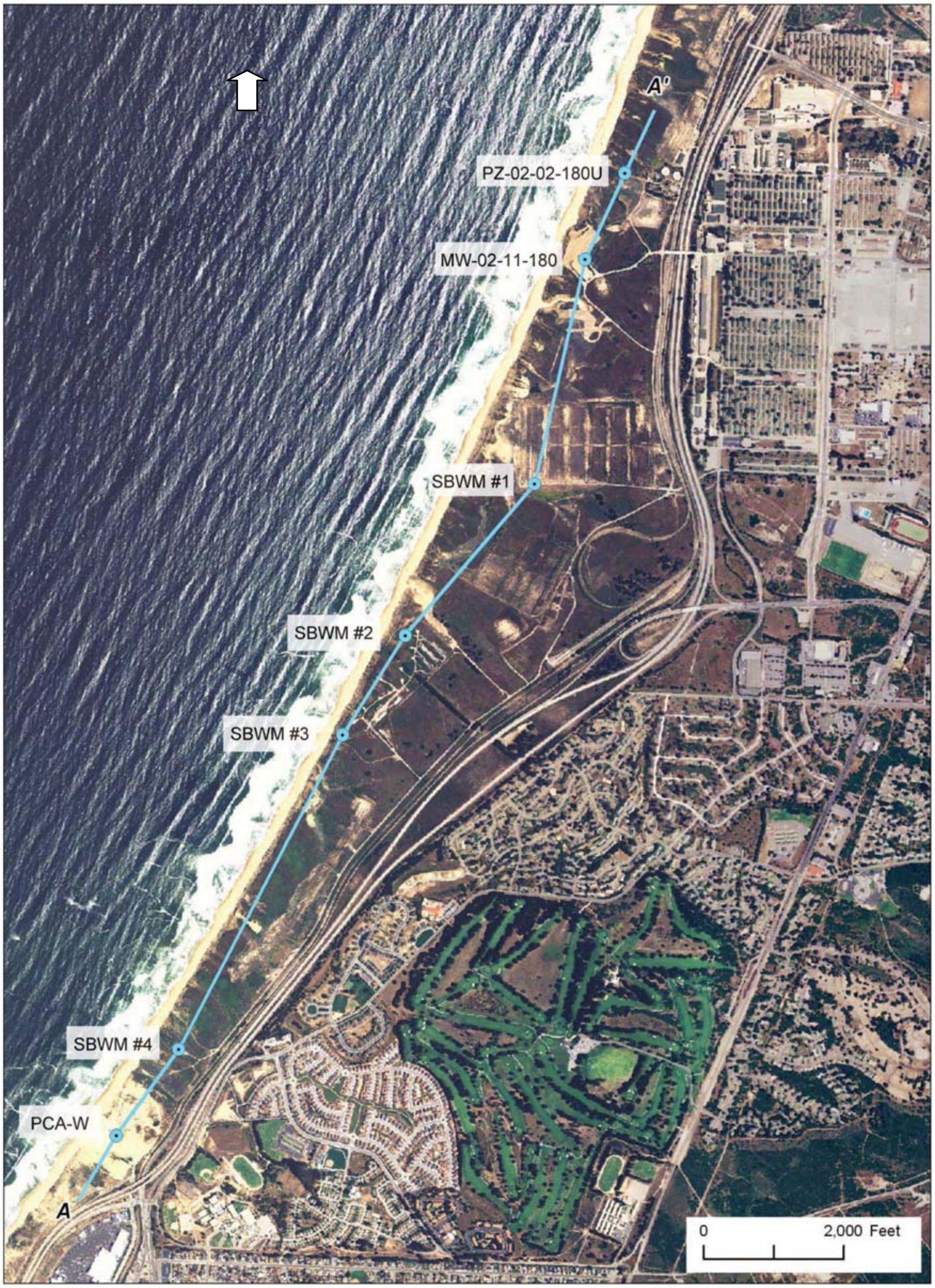


Figure 7 - Bunker Area Cross Section

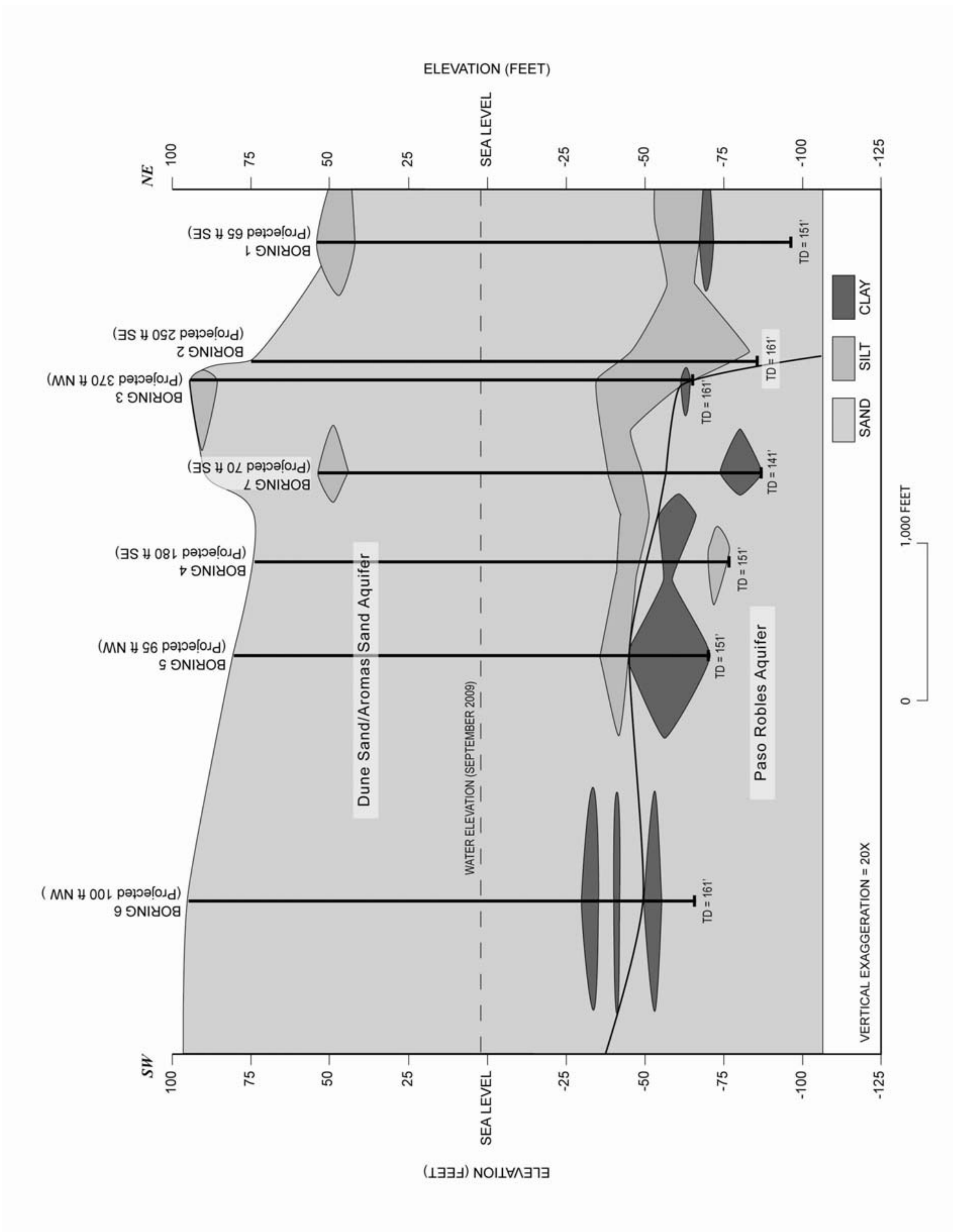
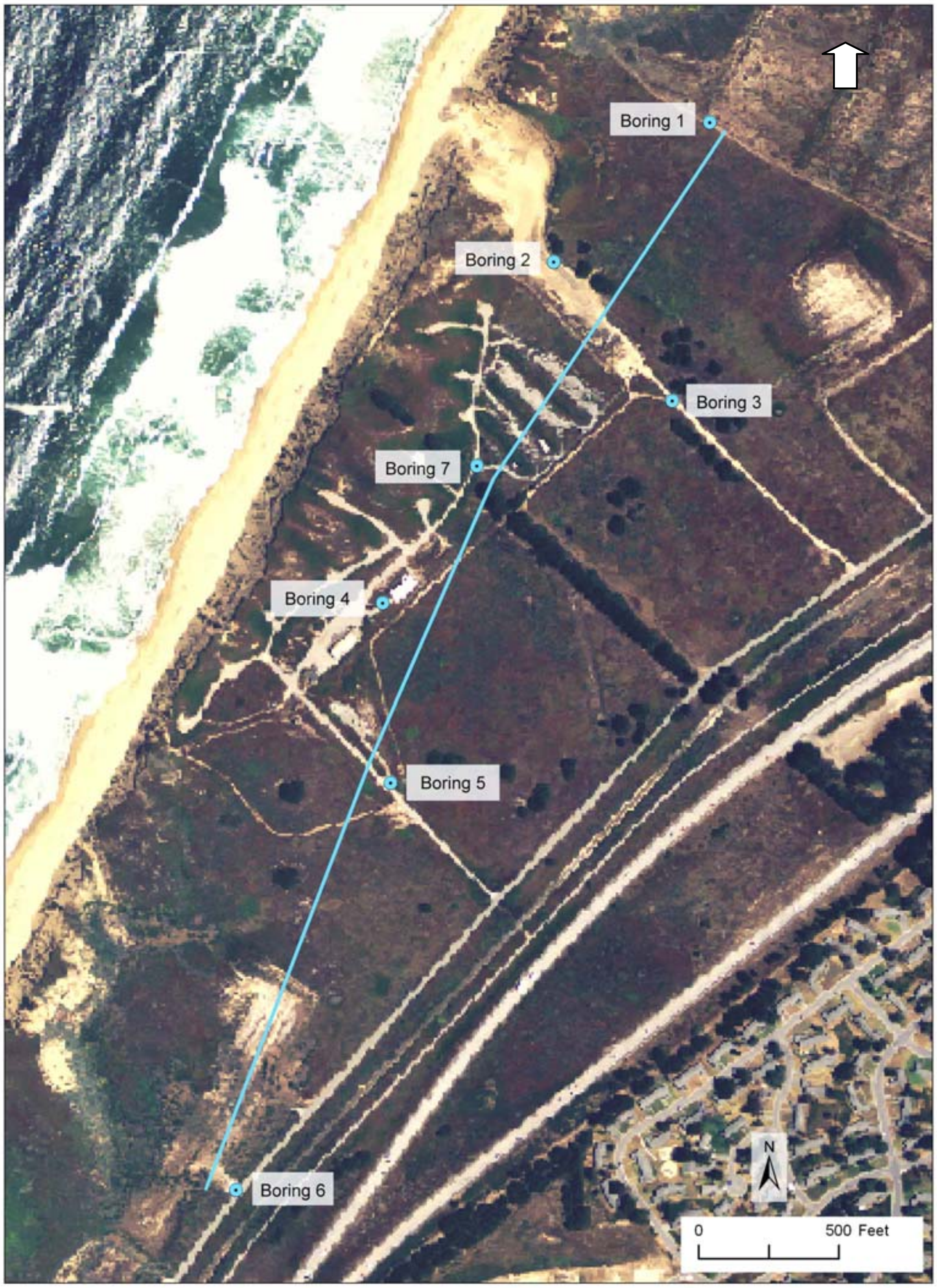


Figure 8 - Bunker Area Cross-Section Location Map



Estimated Well Yield/Well-Field Yield

Grain-size distribution data from the borings were used to estimate permeability through use of the Hazen method as presented in Fetter (1988). This analysis is presented in Table 3 - Permeability from Grain-Size Distribution. The laboratory data are included in Appendix B - Laboratory Data.

Table 3 - Permeability from Grain-Size Distribution

Hazen Method (for use in sands where d_{10} is 0.1 to 3.0 mm)

$K=C(d_{10})^2$

Boring	Depth	Elevation (feet, msl)	Description	C	d10 (mm)	K (cm/s)	K (feet/min)	K (feet/day)	ln K (cm/s)
1	80	-19.2	fn-md sd (SW)	80	0.23	0.042	0.083	120.053	-3.162495
1	100	-39.2	fn sd (SW)	60	0.12	0.009	0.017	24.510	-4.751353
2	95	-19	md sand (SW)	100	0.23	0.053	0.104	150.067	-2.939352
2	105	-29	md-fn sd (SW)	80	0.195	0.030	0.060	86.295	-3.492655
3	110	-19.5	md sn (SW)	100	0.343	0.118	0.232	333.747	-2.14005
3	135	-44.5	sd (SW-SM)	60	0.12	0.009	0.017	24.510	-4.751353
4	95	-20.7	md sd (SW)	100	0.195	0.038	0.075	107.869	-3.269511
4	120	-45.7	fn sand (SW)	80	0.16	0.020	0.040	58.098	-3.888306
5	100	-18.2	md sd (SW)	100	0.19	0.036	0.071	102.408	-3.321462
5	120	-38.2	sd (SW-SM)	60	0.09	0.005	0.010	13.787	-5.326717
6	110	-20.6	md sand (SW)	100	0.23	0.053	0.104	150.067	-2.939352
6	120	-35.6	md sd (SW)	80	0.13	0.014	0.027	38.354	-4.303585
7	75	-22	md sand (SW)	100	0.2	0.040	0.079	113.472	-3.218876
7	90	-37	fn-md sd (SW)	80	0.176	0.025	0.049	70.298	-3.697686

	ln mean		-3.65734
	exp		0.025801
Geometric Mean	2.580E-02	cm/s	
Arithmetic Mean	3.509E-02	cm/s	
Geometric Mean	74.3071	ft/day	
Arithmetic Mean	101.0540	ft/day	

C = Coefficient based on

Very fine sand, poorly sorted 40-80
Find sand with appreciable fines 40-80
Medium sand, well sorted 80-120
Coarse sand, poorly sorted 80-120
Coarse sand, well sorted, clean 120-150
(from Fetter, 2001)

T=kB

k=	555.817	gpd/ft
B=	50	feet
T=	27790.8	gpd/ft
SC=	13.8954	gpm/ft

The analysis results in a geometric mean permeability of 0.026 centimeters per second (cm/s) or about 75 feet per day (feet/day). Assuming a saturated thickness of approximately 50 feet (sea level to -50 feet, msl) a value for transmissivity (T=k*b) of 27,800 gpd/ft can be calculated. From the calculated transmissivity value, the Logan (1964) approximation can be used to estimate a value for specific capacity[2] resulting in a value of about 14 gpm/ft. This is considered a best-case value as it is supported by a coefficient of permeability derived from the most permeable samples from each borings. In many of the borings, much of the material was visibly less permeable.

Best practice for well operation is limiting drawdown to one third of the saturated thickness of the aquifer. In this case, the saturated thickness is 50 feet limiting drawdown to about 17 feet. With a specific capacity of 14 gpm/ft and drawdown of 17 feet, a well yield is estimated at about 240 gpm.

The well yield estimate presented above is for a single well operating alone, pumping from an infinite aquifer system. For the proposed project, a couple other factors influence well performance. The proposed project would utilize a series of wells that would be spaced along a line parallel with the coastline. The spacing of the wells will be dictated by well interference effects – the drawdown in a given well caused from the operation of an adjacent well. This impact is mutual in that two operating wells impact each other, reducing each well's yield. Using the estimates for aquifer properties calculated above and a 400-foot spacing and an assumed storage coefficient of 0.01, the mutual interference effects between two pumping wells are estimated at 7.5 feet after one year and would reduce individual well yield by about 100 gpm. The drawdown impacts would be even greater for interior wells (wells flanked on either side by a pumping well).

However, with the proposed well-field located 300 feet from the coastline, drawdown interference would be moderated, or perhaps completely negated, by the recharge boundary effect of the ocean which would maintain water levels. The recharge boundary effect would increase significantly if the well-field could be moved closer to the coastline.

Based on the discussion above, an estimate of the yield of a conventional well-field at the Bunker site can be developed. The Bunker site extends approximately 2,000 feet along the former Fort Ord coastline. Conceptually, assuming a well spacing of 400 feet, approximately 6 wells could be established in this area. Assuming a well discharge rate of 240 gpm per well, this well-field would be capable of developing 1,440 gpm. Assuming a desalination recovery of 50 percent, and an on-line factor of 90 percent, the well-field would be capable of supporting a desalination facility sized to produce approximately 1,050 acre-feet per year (AF/Y).

A well-field consisting of six slant wells would produce more than the conventional well-field as a result of moving the points of extraction closer to the recharge boundary. However, the permeability of the aquifer materials is relatively low. It is unlikely that slant wells could achieve discharge rates much more than 500 gpm. In this case, annual project yield would increase to 2,180 AF. However, installation of slant wells would increase well-field costs by a factor of 10.

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[2] Specific Capacity is the ratio of discharge to drawdown. The conventional units are gallons per minute per foot of drawdown (gpm/ft). A well with a specific capacity of 10 gpm/ft will produce 10 gpm with 1 foot of drawdown and 100 gpm with 10 feet of drawdown. A well with a specific capacity of 1 gpm/ft will produce 10 gpm with 10 feet of drawdown and 100 gpm with 100 feet of drawdown.

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this investigation was to further evaluate the feasibility of developing a source of saline feedwater on the coastal portion of former Fort Ord for a proposed desalination facility. The project concept had been developed as part of previous work for the District by the team of ICF Jones and Stokes/CDM. The conceptual plans developed as part of this work raised several fundamental questions on which the feasibility of developing the proposed feedwater turns. The most important of these questions are as follows:

- Because the operation of a feedwater collection system that produces groundwater from the shallow dune sand aquifer will, by intent and design, induce seawater intrusion into the shallow aquifer system, it must be demonstrated that the upper aquifer system is isolated from the underlying fresh-water aquifer system. It has been postulated that the shallow aquifer system in the proposed area is underlain by low-permeability materials that would provide hydraulic separation between the shallow aquifer system and the underlying aquifer systems of either the Salinas Valley Basin or Seaside Basin. This low-permeability layer would protect the underlying aquifers from infiltration of seawater from the shallow aquifer system. Both the MCWRA and Watermaster indicated that demonstrating the presence and extent of this low-permeability layer is fundamental to the project's feasibility and permitability.

- Well yield estimates used in the Constraints Analysis report utilized hydraulic performance data derived from local studies performed much closer to the ocean than the locations proposed in the Constraints Analysis. The proximity to the ocean likely resulted in better well performance than will be possible at greater distances from the ocean. If the expected yield of the well is less than assumed, the proposed number of wells will increase and, accordingly, the footprint of the feedwater system infrastructure will be larger than originally proposed. This increase in the number of wells and footprint may impact the ability to site the required facilities in areas acceptable to State Parks. As such, developing better estimates of well yield is considered a fundamental question in assessing the feasibility.

CONCLUSIONS:

This investigation has focused on addressing the above questions. The findings are as follows:

- The Constraints Analysis report recommended three possible areas based on a reconnaissance-level hydrogeologic assessment and integration of this assessment with State Parks land use plans. Two of these areas were located outside of the Seaside Groundwater Basin and it was acknowledged that development of these areas would be politically challenging.
- Review of available subsurface data revealed the lack of an isolating strata between the uppermost aquifer system and the underlying freshwater system at the two northern locations. This fact, combined with the fact that these sites were in the Salinas Basin, led to the elimination of these two northern sites.
- This hydrogeologic investigation, therefore, focused on the so-called "Bunker Site." Review of the existing hydrogeologic data suggested that an areally extensive low-permeability layer overlying the regional aquifer system may exist in this area and could serve to isolate the seawater brought in during extraction activities from the underlying freshwater aquifer system.
- Subsurface investigation of the Bunker Site revealed the presence of clay layers in some of the borings and not in others. Low-permeability strata encountered were areally discontinuous and occurred at differing elevations.

- Soil samples collected from the borings allowed estimation of the potential yield of a well-field at the Bunker Site. Based on the analysis, a well-field consisting of six conventional wells could be established, given the site constraints imposed by State Parks. Assuming that the boundary condition of the ocean negates the mutual interference between the wells at a discharge rate of 240 gpm per well, the yield of the well-field would be 1,440 gpm. Assuming a desalination recovery efficiency of 50 percent and an on-line factor of 90 percent, the annual yield of a desalination facility supported by such a well-field would be approximately 1,050 AF/Y. This yield could likely be increased if the conventional wells were replaced with slant wells, but it is unlikely that yield would be more than 2,000 AF/Y and would be at significant additional infrastructural cost.

In summary, the data do not support the feasibility of developing a source of subsurface feedwater on coastal Fort Ord. The development of a well-field to extract seawater from the shallow aquifer would cause migration of seawater inland. Due to the lack of an areally extensive low-permeabilty layer in the project area, this seawater could migrate down contaminating the underlying fresh water aquifer system. This is considered a fatal flaw from an environmental and permitting perspective.

Even if there were evidence for an extensive low-permeability layer, or the potential environmental impacts considered acceptable, the siting constraints of both the Coastal Commission and the State Parks, combined with the relatively low-permeability sands limit the potential amount of feedwater that could be developed and thusly limit project size to a maximum of about 2,000 acre-feet per year.

RECOMMENDATIONS:

It is recommended that the District terminate further investigation of this project at this juncture. The primary goal of the investigation was to demonstrate the presence of low-permeability strata isolating the shallow aquifer from the underlying freshwater aquifer system. The available data do not support the presence of such a layer in the area investigated. The remaining scope of work involves installing a test well and associated monitoring wells and performing a long-term pumping test to better estimate well yields. However, even if potential environmental impacts could be ignored and the well yields turn out to be twice as much as the existing data suggest, the project size is likely too small to be cost-effective.

CLOSURE

This report has been prepared for the exclusive use of Monterey Peninsula Water Management District for the specific application to the former Fort Ord coastal area. The findings, conclusions, and recommendations presented were prepared in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing under similar conditions in the fields of engineering geology and hydrogeology. No other warranty, express or implied, is made.

We appreciate the opportunity to be of service. Please call if you have any questions.

Sincerely,

Martin B. Feeney

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APPENDIX A - BORING LOGS

MPWMD 95-10 #1

Fort Ord Dunes State Park — Seaside, CA

Project Number		Drill Rig	Mobile B61
Geologist	Robert Marks	Ground Elevation	60.8 Feet
Date Drilled	9/17/09	Total Depth of Borehole	151 Feet
Borehole Diameter	6 Inches	Depth to Water	57.8 Feet

Graphic Log	Description	Depth	Sample	Undefined	Undefined	Undefined	Completion
	SANDY SILT - dk reddsih brn, loose, dry, w/very fine to medium sand	5					
	SILTY SAND - yellowish org/brn, very fine to med, moderately well graded, Water @ 57.8 feet	10					
		15					
		20					
		25					
		30					
		35					
		40					
		45					
		50					
		55					
	SAND- Yellowish org-gry, very fine to coarse, well graded, ang-subrnded, pred. SiO2 w/ multi colored grains	60					
		65					
		70					
		75					
		80					
		85					

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MPWMD 95-10 #1

Fort Ord Dunes State Park — Seaside, CA

Project Number		Drill Rig	Mobile B61
Geologist	Robert Marks	Ground Elevation	60.8 Feet
Date Drilled	9/17/09	Total Depth of Borehole	151 Feet
Borehole Diameter	6 Inches	Depth to Water	57.8 Feet

Graphic Log	Description	Depth	Sample	Undefined	Undefined	Undefined	Completion
		95					
	SILTY SAND - yellowish gray, very fine to med, mod well graded w/ micaeous silt	100					
	SAND SILT - gray, loose abundant mica, w/ very fine sand	105					
		110					
		115					
	SANDY CLAY - soft reddish brn, no sticky, slightly plastic, very fine to fine and w/silt	120					
	SANDY SILT- rd brn - dk brn, loose, w/ very fine to fine sand	125					
		130					
		135					
		140					
	SANDY SILT - dk brn w/ rd brn mottling, slightly sandier	145					
		150					
		155					
		160					
		165					
		170					
		175					

MPWMD 95-10 #2

Fort Ord Dunes State Park | Seaside, CA

Project Number		Drill Rig	Mobile B61
Geologist	Mike Burke	Ground Elevation	76 Feet
Date Drilled	9/21/09	Total Depth of Borehole	161 Feet
Borehole Diameter	6 Inches	Depth to Water	73 Feet

Graphic Log	Description	Depth	Sample	Undefined	Undefined	Undefined	Completion
	SILTY SAND- yellowish org/brn, well sorted, f. grained, dry, some base rock at surface.	5 10 15					
	SAND - Yellowish brown, fine grained, well sorted, silty, damp	20 25 30 35 40 45 50					
	SAND - Yellow-org brown, pred. fine grained, w/ some medium grains, common org staining, moist to wet WATER @ 73 feet	55 60 65 70					
	SAND - gry brn - ylw brn, fine to coarse grained, poorly sorted, SiO2 rich, abundant org staining,wet	75 80 85					

MPWMD 95-10 #2

Fort Ord Dunes State Park — Seaside, CA

Project Number		Drill Rig	Mobile B61
Geologist	Mike Burke	Ground Elevation	76 Feet
Date Drilled	9/21/09	Total Depth of Borehole	161 Feet
Borehole Diameter	6 Inches	Depth to Water	73 Feet

Graphic Log	Description	Depth	Sample	Undefined	Undefined	Undefined	Completion
	SILTY SAND - brnish gray, abundant mica, w/ very fine sand	95					
		100					
		105					
		110					
		115					
	SILT - dk gray-dk brwn micaceous w/ fine sand	120					
	SANDY SILT - gray,abundant mica, w/ very fine sand	125					
		130					
		135					
		140					
		145					
		150					
		155					
	SILTY SAND - /Sand Silt - v. dk orn brn, f. sand	160					
		165					
		170					
		175					

MPWMD 95-10 #3

Fort Ord Dunes State Park Seaside, CA

Project Number		Drill Rig	Mobile B61
Geologist	Robert Marks	Ground Elevation	90.5 Feet
Date Drilled	9/16/09	Total Depth of Borehole	160 Feet
Borehole Diameter	6 Inches	Depth to Water	87.5 Feet

Graphic Log	Description	Depth	Sample	Undefined	Undefined	Undefined	Completion
	SANDY SILT- reddish brn, v. fine to fine, mod. well graded, dry	5					
	SILTY SAND- org/brn, very fine to med, moderately well graded	10					
	SAND- Yellowish org-brn, very fine to coarse, mod. to well graded, subang-subrnded, minor silt WATER @ 87.5 feet	15 20 25 30 35 40 45 50 55 60 65 70 75 80 85					

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MPWMD 95-10 #3

Fort Ord Dunes State Park — Seaside, CA

Project Number		Drill Rig	Mobile B61
Geologist	Robert Marks	Ground Elevation	90.5 Feet
Date Drilled	9/16/09	Total Depth of Borehole	160 Feet
Borehole Diameter	6 Inches	Depth to Water	87.5 Feet

Graphic Log	Description	Depth	Sample	Undefined	Undefined	Undefined	Completion
	SAND- Pale yellowish org-brn, very fine to med occ. coarse, well graded, ang-subrnded, pred. SiO_2	90–113					
	SILTY SAND - grayish brn, v. fine to coarce, mod. well graded, w/ micaceous silt, dk. gray	113–128					
	SANDY SILT - dk grayish brn, abundant mica w/ poorly graded v. fine to fine sand, loose abundant mica, w/ very fine sand	128–158					
	SANDY CLAY - org- brn, hard, slight sticky, mod. plastic, w/ very fine to fine sand, minor silt	158–161					

Depth scale: 95, 100, 105, 110, 115, 120, 125, 130, 135, 140, 145, 150, 155, 160, 165, 170, 175

MPWMD 95-10 #4

Fort Ord Dunes State Park — Seaside, CA

Project Number		Drill Rig	Mobile B61
Geologist	Robert Marks	Ground Elevation	74.3 Feet
Date Drilled	9/14/09	Total Depth of Borehole	151 Feet
Borehole Diameter	6 Inches	Depth to Water	71.3 Feet

Graphic Log	Description	Depth	Sample	Undefined	Undefined	Undefined	Completion
	Asphalt/Base Rock						
	SILTY SAND - gry/brn, very fine to med, moderately well graded, loose, dry	5 10					
	SAND - Reddish orn/brn to yellowish brn, very fine to med grained, well graded, minor silt	15 20 25 30 35 40 45					
	SAND- a/a, becoming coarser	50 55 60					
	SAND- tannish brn, v. fine to med, mod. graded, minor silt, loose WATER @ 71.3 feet	65 70 75 80 85					

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MPWMD 95-10 #4

Fort Ord Dunes State Park — Seaside, CA

Project Number		Drill Rig	Mobile B61
Geologist	Robert Marks	Ground Elevation	74.3 Feet
Date Drilled	9/14/09	Total Depth of Borehole	151 Feet
Borehole Diameter	6 Inches	Depth to Water	71.3 Feet

Graphic Log	Description	Depth	Sample	Undefined	Undefined	Undefined	Completion
		95					
		100					
		105					
		110					
	SANDY SILT - brn-gray, loose abundant mica, w/ variable amounts of very fine to fine sand	115					
		120					
	SAND - dk reddish brn, very fine to med grained, poorly graded, minor silt	125					
	SANDY CLAY - orng brn, hard, slightly sticky, highly plastic, w/ v. fine to med sand , poorly graded	130					
		135					
	SILTY SAND - org-brn, very fine to fine, mod. well graded, loose	140					
	CLAYEY SILT - org/brn, firm, v. slightly plastic, minor v. fine sand	145					
		150					
		155					
		160					
		165					
		170					
		175					

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MPWMD 95-10 #5

Fort Ord Dunes State Park — Seaside, CA

Project Number		Drill Rig	Mobile B61
Geologist	Robert Marks	Ground Elevation	81.8 Feet
Date Drilled	9/15/09	Total Depth of Borehole	151 Feet
Borehole Diameter	6 Inches	Depth to Water	78.8 Feet

Graphic Log	Description	Depth	Sample	Undefined	Undefined	Undefined	Completion
	SILTY SAND- reddsih brn, very fine to med, well graded, loose, dry, abundant mica	0–15					
	SILTY SAND - a/a color change to org-brn, coarser	15–25					
	SILTY SAND - a/a color change to yellowish brn	25–80	Samples at 60, 65, 70, 75				
	SAND- pale yelowish brn, fine to med., well graded, ang-subrnded, pred. SiO_2 w/ multi colored grains, wet WATER @ 78.8 feet	80–	Samples at 80, 85				

Depth scale: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85

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MPWMD 95-10 #5

Fort Ord Dunes State Park — Seaside, CA

Project Number		Drill Rig	Mobile B61
Geologist	Robert Marks	Ground Elevation	81.8 Feet
Date Drilled	9/15/09	Total Depth of Borehole	151 Feet
Borehole Diameter	6 Inches	Depth to Water	78.8 Feet

Graphic Log	Description	Depth	Sample	Undefined	Undefined	Undefined	Completion
	SAND - a/a, slightly coarser	95					
	SAND - a/a becoming finer, increasing silt	100					
		105					
		110					
	SANDY SILT - brnish-gray, loose, abundant mica, w/ very fine to fine sand	115					
		120					
	SANDY CLAY - grayish orgn-brn, slighty sticky, slightly plastic, very fine to fine sand and lenses of gray micaceous silt with shells	125					
	CLAY -org brn w/ gray mottling, hard, slightly sticky, mod. plastic, w/ very fine sand	130					
		135					
		140					
		145					
	CLAY - a/a, clor change to greenish/bluish w/ gray mottling, hard, brittle, non-plastic	150					
		155					
		160					
		165					
		170					
		175					

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MPWMD 95-10 #6

Fort Ord Dunes State Park Seaside, CA

Project Number		Drill Rig	Mobile B61
Geologist	Robert Marks	Ground Elevation	89.4 Feet
Date Drilled	9/18/09	Total Depth of Borehole	161 Feet
Borehole Diameter	6 Inches	Depth to Water	86.4 Feet

Graphic Log	Description	Depth	Sample	Undefined	Undefined	Undefined	Completion
	SILTY SAND - dk brn, very fine to med, moderately well graded, loose, dry	5 10					
	SAND- reddish brn, very fine to fine, well graded,	15 20 25 30					
	SAND - yellowish brn, fine to med., mod well graded	35 40 45 50 55 60 65					
	SAND - tannish brn, med to occ. coarse WATER @ 86.4 feet	70 75 80 85					

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MPWMD 95-10 #6

Fort Ord Dunes State Park — Seaside, CA

Project Number		Drill Rig	Mobile B61
Geologist	Robert Marks	Ground Elevation	89.4 Feet
Date Drilled	9/18/09	Total Depth of Borehole	161 Feet
Borehole Diameter	6 Inches	Depth to Water	86.4 Feet

Graphic Log	Description	Depth	Sample	Undefined	Undefined	Undefined	Completion
	SAND- tannish gry, very fine to coarse, mod. well graded, ang-subrnded, pred. SiO2 w/ multi colored grains,	95, 100, 105, 110					
	SILTY SAND- brownish gray, very fine to med, poorly graded w/ soft gray micaeous silt	115, 120					
	SILTY CLAY - greenish gray, v. firm, slightly sticky, mod. plastic, w/minor mica and v. fine sand	125					
	SILTY SAND - gray, very fine to coarse, poorly graded w/ clasts (porcelaneous chert) of gravel to 1/2" dia., minor micaceous silt	130					
	SANDY CLAY - gray, very firm, slightly sticky, slightly plastic, w/v. fine sand , minor clasts of gravel	135					
	GRAVELEY SAND - tannish gray, v. fine to coarse sand, fime to coarse gravel, poorly graded, ang-subrnd, porcelaneous chert clasts	140					
	SANDY CLAY - light to dark greenish gray, very firm, slightly sticky, slightly plastic, w/v. fine sand , minor clasts of gravel	145					
	GRAVELEY SAND - light gray, v. fine to coarse sand, w/ fine to coarse gravel, poorly graded, ang-subrnd, porcelaneous chert clasts. Clasts up to 1" diam	150, 155, 160					
		165, 170, 175					

MPWMD 95-10 #7

Fort Ord Dunes State Park — Seaside, CA

Project Number		Drill Rig	Mobile B61
Geologist	Mike Burke	Ground Elevation	53 Feet
Date Drilled	9/22/09	Total Depth of Borehole	141 Feet
Borehole Diameter	6 Inches	Depth to Water	50 Feet

Graphic Log	Description	Depth	Sample	Undefined	Undefined	Undefined	Completion
	SANDY SILT- dk brn, w/very fine to medium sand, dry	5					
	SILTY SAND - dk org/brn, fine grained, damp	10					
	SAND - Yellowish org-gry, very fine to coarse, well graded, ang-subrnded, occ. thin strks of brn silt, damp become wet at 50 feet. WATER @ 50 feet	15 20 25 30 35 40 45					
	SAND - dk brn to gray brn, very fine to coarse, well graded, ang-subrnded, saturated	50 55 60 65 70 75 80 85					

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MPWMD 95-10 #7

Fort Ord Dunes State Park — Seaside, CA

Project Number		Drill Rig	Mobile B61
Geologist	Mike Burke	Ground Elevation	53 Feet
Date Drilled	9/22/09	Total Depth of Borehole	141 Feet
Borehole Diameter	6 Inches	Depth to Water	50 Feet

Graphic Log	Description	Depth	Sample	Undefined	Undefined	Undefined	Completion
	SANDY SILT- dk. brnish gray, loose abundant mica, w/ very fine sand	95					
	SILT - reddish/orgn brown, sandy, clayey	100					
	SILTY SAND - dk brn to gry brn, v. fine to fine grained	105					
		110					
		115					
		120					
		125					
	SILTY CLAY - yellowish brown, very stiff/hard	130					
		135					
		140					
		145					
		150					
		155					
		160					
		165					
		170					
		175					

APPENDIX B - LABORATORY DATA

95-10 Field Program
Summary of Boring Data

Boring	Depth	Elevation*	Btm Elevation	Depth to Water	Top of Significant Clay	Elevation of Significant Clay	Notes
1	151	60.8	-90.2	57.8		below boring bottom	
2	161	76	-85	73		below boring bottom	
3	161	90.5	-70.5	87.5	158	-67.5	
4	151	74.3	-76.7	71.3	130	-55.7	
5	151	81.8	-69.2	78.8	124	-42.2	Shells
6	161	89.4	-71.6	86.4	125	-35.6	QTp
7	141	53	-88	50	127	-74	

* Calculated from water surface of 3 feet.

** Google Earth

Elev.	*60.8*	*90.5*	*74.3*	*81.8*	*89.4*	*53*
Boring	**1**	**3**	**4**	**5**	**6**	**7**
50	10.8	40.5	24.3	31.8	39.4	3
55	5.8	35.5	19.3	26.8	34.4	-2
60	0.8	30.5	14.3	21.8	29.4	-7
65	-4.2	25.5	9.3	16.8	24.4	**-12**
70	-9.2	20.5	4.3	11.8	19.4	**-17**
75	**-14.2**	15.5	-0.7	6.8	14.4	**-22**
80	**-19.2**	10.5	-5.7	1.8	9.4	**-27**
85	**-24.2**	5.5	**-10.7**	-3.2	4.4	**-32**
90	**-29.2**	0.5	**-15.7**	-8.2	-0.6	**-37**
95	**-34.2**	-4.5	**-20.7**	**-13.2**	-5.6	**-42**
100	**-39.2**	-9.5	**-25.7**	**-18.2**	**-10.6**	**-47**
105	**-44.2**	**-14.5**	**-30.7**	**-23.2**	**-15.6**	**-52**
110	**-49.2**	**-19.5**	**-35.7**	**-28.2**	**-20.6**	-57
115	-54.2	**-24.5**	**-40.7**	**-33.2**	**-25.6**	-62
120	-59.2	**-29.5**	**-45.7**	**-38.2**	**-30.6**	-67
125	-64.2	**-34.5**	**-50.7**	**-43.2**	**-35.6**	-72
130	-69.2	**-39.5**	-55.7	**-48.2**	**-40.6**	-77
135	-74.2	**-44.5**	-60.7	-53.2	**-45.6**	-82
140	-79.2	**-49.5**	-65.7	-58.2	**-50.6**	-87
145	-84.2	-54.5	-70.7	-63.2	-55.6	-92
150	-89.2	-59.5	-75.7	-68.2	-60.6	-97
155	-94.2	-64.5	-80.7	-73.2	-65.6	-102
160	-99.2	-69.5	-85.7	-78.2	-70.6	-107

Shaded Samples Selected for Grain-size Distribution Analysis

BUREAU VERITAS NORTH AMERICA, INC.
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October 8, 2009

File No: -
DSA/OSHPD No: -
BVNA JOB No: **09-000755**
LAB No: 81589

Martin B. Feeney
P.O Box 23240
Ventura, CA 93002

Project: Feeney - Misc. Testing
Material: Light brown well graded medium grain Sand (SW)
Location: B-8 @ 75'
Sampled By: Client

SIEVE ANALYSIS

(ASTM C136)

Sieve Size	% Passing	Specifications
100mm (4")		
90mm (3 1/2")		
75mm (3")		
63mm (2 1/2")		
50mm (2")		
37.5mm (1 1/2")		
25mm (1")		
19mm (3/4")		
12.5mm (1/2")		
9.5mm (3/8")		
4.75mm (#4)	100	
2.36mm (#8)	97	
1.18mm (#16)	73	
600 um (#30)	47	
300 um (#50)	23	
150 um (#100)	2	
75 um (#200) washed	1.0	

N/AVA: Not Available.

Reviewed By: ______________

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October 8, 2009

Martin B. Feeney
P.O Box 23240
Ventura, CA 93002

File No: -
DSA/OSHPD No: -
BVNA JOB No: **09-000755**
LAB No: 81589

Project: Feeney - Misc. Testing
Material: Light brown well graded medium grain Sand (SW)
Location: B-5 @ 100'
Sampled By: Client

SIEVE ANALYSIS

(ASTM C136)

Sieve Size	% Passing	Specifications
100mm (4")		
90mm (3 1/2")		
75mm (3")		
63mm (2 1/2")		
50mm (2")		
37.5mm (1 1/2")		
25mm (1")		
19mm (3/4")		
12.5mm (1/2")		
9.5mm (3/8")		
4.75mm (#4)	100	
2.36mm (#8)	99	
1.18mm (#16)	83	
600 um (#30)	58	
300 um (#50)	25	
150 um (#100)	3	
75 um (#200) washed	1.5	

N/AVA: Not Available.

Reviewed By: ______________

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October 8, 2009

Martin B. Feeney
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Ventura, CA 93002

File No: -
DSA/OSHPD No: -
BVNA JOB No: **09-000755**
LAB No: 81589

Project: Feeney - Misc. Testing
Material: Light brown well graded medium-fine grain Sand (SW)
Location: B-8 @ 90'
Sampled By: Client

SIEVE ANALYSIS
(ASTM C136)

Sieve Size	% Passing	Specifications
100mm (4")		
90mm (3 1/2")		
75mm (3")		
63mm (2 1/2")		
50mm (2")		
37.5mm (1 1/2")		
25mm (1")		
19mm (3/4")		
12.5mm (1/2")		
9.5mm (3/8")		
4.75mm (#4)	100	
2.36mm (#8)	99	
1.18mm (#16)	92	
600 um (#30)	46	
300 um (#50)	23	
150 um (#100)	5	
75 um (#200) washed	1.4	

N/AVA: Not Available.

Reviewed By: ______________

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October 8, 2009

File No: -
DSA/OSHPD No: -
BVNA JOB No: **09-000755**
LAB No: 81589

Martin B. Feeney
P.O Box 23240
Ventura, CA 93002

Project: Feeney - Misc. Testing
Material: Light brown well graded medium grain Sand (SW)
Location: B-7 @ 95'
Sampled By: Client

SIEVE ANALYSIS
(ASTM C136)

Sieve Size	% Passing	Specifications
100mm (4")		
90mm (3 1/2")		
75mm (3")		
63mm (2 1/2")		
50mm (2")		
37.5mm (1 1/2")		
25mm (1")		
19mm (3/4")		
12.5mm (1/2")		
9.5mm (3/8")		
4.75mm (#4)	100	
2.36mm (#8)	99	
1.18mm (#16)	74	
600 um (#30)	36	
300 um (#50)	16	
150 um (#100)	1	
75 um (#200) washed	0.7	

N/AVA: Not Available.

Reviewed By: _______________

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October 8, 2009

File No: -
DSA/OSHPD No: -
BVNA JOB No: **09-000755**
LAB No: 81589

Martin B. Feeney
P.O Box 23240
Ventura, CA 93002

Project: Feeney - Misc. Testing
Material: Light brown well graded medium grain Sand (SW)
Location: B-6 @ 110'
Sampled By: Client

SIEVE ANALYSIS

(ASTM C136)

Sieve Size	% Passing	Specifications
100mm (4")		
90mm (3 1/2")		
75mm (3")		
63mm (2 1/2")		
50mm (2")		
37.5mm (1 1/2")		
25mm (1")		
19mm (3/4")		
12.5mm (1/2")		
9.5mm (3/8")		
4.75mm (#4)	100	
2.36mm (#8)	99	
1.18mm (#16)	71	
600 um (#30)	32	
300 um (#50)	14	
150 um (#100)	3	
75 um (#200) washed	0.9	

N/AVA: Not Available.

Reviewed By: _______________

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October 8, 2009

File No: -
DSA/OSHPD No: -
BVNA JOB No: **09-000755**
LAB No: 81589

Martin B. Feeney
P.O Box 23240
Ventura, CA 93002

Project: Feeney - Misc. Testing
Material: Light brown well graded fine grain Sand (SW)
Location: B-1 @ 100'
Sampled By: Client

SIEVE ANALYSIS

(ASTM C136)

Sieve Size	% Passing	Specifications
100mm (4")		
90mm (3 1/2")		
75mm (3")		
63mm (2 1/2")		
50mm (2")		
37.5mm (1 1/2")		
25mm (1")		
19mm (3/4")		
12.5mm (1/2")		
9.5mm (3/8")		
4.75mm (#4)		
2.36mm (#8)	100	
1.18mm (#16)	99	
600 um (#30)	92	
300 um (#50)	77	
150 um (#100)	13	
75 um (#200) washed	3.6	

N/AVA: Not Available.

Reviewed By: ______________

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October 8, 2009

File No: -
DSA/OSHPD No: -
BVNA JOB No: **09-000755**
LAB No: 81589

Martin B. Feeney
P.O Box 23240
Ventura, CA 93002

Project: Feeney - Misc. Testing
Material: Light brown well graded medium grain Sand (SW)
Location: B-6 @ 120'
Sampled By: Client

SIEVE ANALYSIS

(ASTM C136)

Sieve Size	% Passing	Specifications
100mm (4")		
90mm (3 1/2")		
75mm (3")		
63mm (2 1/2")		
50mm (2")		
37.5mm (1 1/2")		
25mm (1")		
19mm (3/4")		
12.5mm (1/2")		
9.5mm (3/8")		
4.75mm (#4)		
2.36mm (#8)	100	
1.18mm (#16)	97	
600 um (#30)	78	
300 um (#50)	66	
150 um (#100)	12	
75 um (#200) washed	2.4	

N/AVA: Not Available.

Reviewed By: ______________

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October 8, 2009

File No: -
DSA/OSHPD No: -
BVNA JOB No: **09-000755**
LAB No: 81589

Martin B. Feeney
P.O Box 23240
Ventura, CA 93002

Project: Feeney - Misc. Testing
Material: Light brown well graded medium grain Sand (SW)
Location: B-4 @ 95'
Sampled By: Client

SIEVE ANALYSIS

(ASTM C136)

Sieve Size	% Passing	Specifications
100mm (4")		
90mm (3 1/2")		
75mm (3")		
63mm (2 1/2")		
50mm (2")		
37.5mm (1 1/2")		
25mm (1")		
19mm (3/4")		
12.5mm (1/2")		
9.5mm (3/8")		
4.75mm (#4)	100	
2.36mm (#8)	99	
1.18mm (#16)	81	
600 um (#30)	51	
300 um (#50)	27	
150 um (#100)	1	
75 um (#200) washed	0.9	

N/AVA: Not Available.

Reviewed By: ______________

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October 8, 2009

File No: -
DSA/OSHPD No: -
BVNA JOB No: **09-000755**
LAB No: 81589

Martin B. Feeney
P.O Box 23240
Ventura, CA 93002

Project: Feeney - Misc. Testing
Material: Light brown well graded medium-fine grain Sand (SW)
Location: B-7 @ 105'
Sampled By: Client

SIEVE ANALYSIS

(ASTM C136)

Sieve Size	% Passing	Specifications
100mm (4")		
90mm (3 1/2")		
75mm (3")		
63mm (2 1/2")		
50mm (2")		
37.5mm (1 1/2")		
25mm (1")		
19mm (3/4")		
12.5mm (1/2")		
9.5mm (3/8")		
4.75mm (#4)	100	
2.36mm (#8)	99	
1.18mm (#16)	82	
600 um (#30)	52	
300 um (#50)	22	
150 um (#100)	2	
75 um (#200) washed	1.0	

N/AVA: Not Available.

Reviewed By: _______________

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October 8, 2009

File No: -
DSA/OSHPD No: -
BVNA JOB No: **09-000755**
LAB No: 81589

Martin B. Feeney
P.O Box 23240
Ventura, CA 93002

Project: Feeney - Misc. Testing
Material: Light brown well graded medium-fine grain Sand (SW)
Location: B-1 @ 80'
Sampled By: Client

SIEVE ANALYSIS

(ASTM C136)

Sieve Size	% Passing	Specifications
100mm (4")		
90mm (3 1/2")		
75mm (3")		
63mm (2 1/2")		
50mm (2")		
37.5mm (1 1/2")		
25mm (1")		
19mm (3/4")		
12.5mm (1/2")		
9.5mm (3/8")		
4.75mm (#4)	100	
2.36mm (#8)	99	
1.18mm (#16)	84	
600 um (#30)	41	
300 um (#50)	15	
150 um (#100)	2	
75 um (#200) washed	0.8	

N/AVA: Not Available.

Reviewed By: _______________

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October 8, 2009

File No: -
DSA/OSHPD No: -
BVNA JOB No: **09-000755**
LAB No: 81589

Martin B. Feeney
P.O Box 23240
Ventura, CA 93002

Project: Feeney - Misc. Testing
Material: Grayish brown well graded fine grain Sand (SW)
Location: B-4 @ 120'
Sampled By: Client

SIEVE ANALYSIS
(ASTM C136)

Sieve Size	% Passing	Specifications
100mm (4")		
90mm (3 1/2")		
75mm (3")		
63mm (2 1/2")		
50mm (2")		
37.5mm (1 1/2")		
25mm (1")		
19mm (3/4")		
12.5mm (1/2")		
9.5mm (3/8")	100	
4.75mm (#4)	98	
2.36mm (#8)	94	
1.18mm (#16)	94	
600 um (#30)	90	
300 um (#50)	42	
150 um (#100)	8	
75 um (#200) washed	2.7	

N/AVA: Not Available.

Reviewed By: ____________

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October 8, 2009

File No: -
DSA/OSHPD No: -
BVNA JOB No: **09-000755**
LAB No: 81589

Martin B. Feeney
P.O Box 23240
Ventura, CA 93002

Project: Feeney - Misc. Testing
Material: Reddish Brown well graded Sand with silt (SW-SM)
Location: B-3 @ 135'
Sampled By: Client

SIEVE ANALYSIS

(ASTM C136)

Sieve Size	% Passing	Specifications
100mm (4")		
90mm (3 1/2")		
75mm (3")		
63mm (2 1/2")		
50mm (2")		
37.5mm (1 1/2")		
25mm (1")		
19mm (3/4")	100	
12.5mm (1/2")	98	
9.5mm (3/8")	96	
4.75mm (#4)	96	
2.36mm (#8)	92	
1.18mm (#16)	91	
600 um (#30)	87	
300 um (#50)	57	
150 um (#100)	12	
75 um (#200) washed	5.5	

N/AVA: Not Available.

Reviewed By: ______________

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October 8, 2009

File No: -
DSA/OSHPD No: -
BVNA JOB No: **09-000755**
LAB No: 81589

Martin B. Feeney
P.O Box 23240
Ventura, CA 93002

Project: Feeney - Misc. Testing
Material: Light brown well graded medium grain Sand (SW)
Location: B-3 @ 110'
Sampled By: Client

SIEVE ANALYSIS

(ASTM C136)

Sieve Size	% Passing	Specifications
100mm (4")		
90mm (3 1/2")		
75mm (3")		
63mm (2 1/2")		
50mm (2")		
37.5mm (1 1/2")		
25mm (1")		
19mm (3/4")		
12.5mm (1/2")		
9.5mm (3/8")		
4.75mm (#4)	100	
2.36mm (#8)	98	
1.18mm (#16)	71	
600 um (#30)	24	
300 um (#50)	6	
150 um (#100)	<1	
75 um (#200) washed	0.2	

N/AVA: Not Available.

Reviewed By: _______________

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October 8, 2009

File No: -
DSA/OSHPD No: -
BVNA JOB No: **09-000755**
LAB No: 81589

Martin B. Feeney
P.O Box 23240
Ventura, CA 93002

Project: Feeney - Misc. Testing
Material: Grayish Brown well graded fine Sand with silt (SW-SM)
Location: B-5 @ 120'
Sampled By: Client

SIEVE ANALYSIS

(ASTM C136)

Sieve Size	% Passing	Specifications
100mm (4")		
90mm (3 1/2")		
75mm (3")		
63mm (2 1/2")		
50mm (2")		
37.5mm (1 1/2")		
25mm (1")		
19mm (3/4")		
12.5mm (1/2")		
9.5mm (3/8")		
4.75mm (#4)		
2.36mm (#8)	100	
1.18mm (#16)	99	
600 um (#30)	92	
300 um (#50)	87	
150 um (#100)	23	
75 um (#200) washed	5.4	

N/AVA: Not Available.

Reviewed By: _______________

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