APPENDIX C

Geotechnical Report for Prado Basin Sediment Management Demonstration Project

Corona, California

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# Table of Contents

EXECUTIVE SUMMARY .......................................................................................................................... ES-1

1.0 INTRODUCTION .................................................................................................................................. 1
   1.1 Existing Site Conditions .................................................................................................................. 1
   1.2 Sediment Management Demonstration Project ............................................................................ 1
   1.3 Objective and Scope ..................................................................................................................... 1
       1.3.1.1 Data Review, Utility Clearance, and Permitting ................................................................. 1
       1.3.1.2 Field Exploration ................................................................................................................ 2
       1.3.1.3 Geotechnical Laboratory Testing ...................................................................................... 3
       1.3.1.4 Geotechnical Analyses ...................................................................................................... 3
       1.3.1.5 Environmental Testing ...................................................................................................... 3
       1.3.2 Report .................................................................................................................................... 4

2.0 GEOLOGIC SETTING .......................................................................................................................... 5
   2.1 Site Geology and Generalized Subsurface Conditions ................................................................. 5
       2.1.1 Very Young Wash Deposits, Unit 2 (Qw2) ............................................................................. 5
       2.1.2 Young Axial Channel Deposits (Qya2) .................................................................................. 6
       2.1.3 Generalized Subsurface Conditions ...................................................................................... 6
       2.1.4 Groundwater .......................................................................................................................... 6
   2.2 Regional Seismicity and Faults ........................................................................................................ 6
       2.2.1 Historical Seismicity .............................................................................................................. 6
       2.2.2 Active Faults Within 62 Miles (100 Kilometers) ..................................................................... 7
   2.3 Surface Fault Rupture .................................................................................................................... 8
   2.4 Landslide Hazards ......................................................................................................................... 10

3.0 DESIGN RECOMMENDATIONS ....................................................................................................... 11
   3.1 Geotechnical Feasibility ................................................................................................................ 11
   3.2 Seismic Design Considerations ..................................................................................................... 11
       3.2.1 Ground Shaking .................................................................................................................. 11
       3.2.2 Liquefaction ......................................................................................................................... 12
       3.2.3 Seismically-Induced Settlements ........................................................................................ 13
       3.2.4 Seismic Slope Instability ..................................................................................................... 13
       3.2.5 Tsunamis and Seiches ........................................................................................................ 13
   3.3 Environmental Testing ................................................................................................................... 13

4.0 CONSTRUCTION CONSIDERATIONS ............................................................................................. 16
   4.1 Excavation Characteristics ............................................................................................................. 16

5.0 LIMITATIONS ..................................................................................................................................... 17

6.0 CLOSING ........................................................................................................................................... 18

7.0 REFERENCES ..................................................................................................................................... 19
List of Tables
Table C-1  Major Active Faults within a 62 Mile (100-km) Radius of the Prado Basin
Table C-2  2007 California Building Code Seismic Design Parameters
Table C-3  Summary of Environmental Test Results

List of Figures
Figure C-1  Site Location Map
Figure C-2  Boring Location Plan
Figure C-3  Locations of Active Faults and Historical Seismicity

List of Appendices
Attachment A  Recent Borehole Logs
Attachment B  Previous Borehole Logs by Others
Attachment C  Geotechnical Laboratory Test Data
Attachment D  Environmental Laboratory Test Data
Attachment E  Important Information about your Geotechnical Report
1.0 INTRODUCTION

Golder Associates Inc. (Golder) presents this geotechnical report to HDR Inc. (HDR) with the results of our geotechnical investigation and environmental testing for the proposed Prado Basin Sediment Management Demonstration Project (SMDP). Our work was performed in accordance with the scope of work outlined in the Request for Proposals prepared by the Orange County Water District (OCWD) and the proposal dated November 23, 2009.

The Prado Dam was completed in 1941. The presence of the dam has altered the flow of sediment downstream of the dam. The Prado Basin SMDP will manually remove up to 500,000 cubic yards of sediment upstream of the dam for transport down the Santa Ana River below the dam within a one year time frame. The sediment will be removed below Elevation 505 feet.

1.1 Existing Site Conditions

The SMDP Site is located in the Prado Basin, upstream of the Prado Dam in Corona, California (See Figure C-1). The Prado Dam is an existing flood control dam located on the Santa Ana River. Existing ground surface elevations in Prado Basin range from approximately El 485 feet near the dam to elevation 535 feet upstream along the Santa Ana River. Water flows year round along the Santa Ana River into the basin. The largest flows into the basin occur in the rainy season (October 15th through April 15th) after storm events. During our investigation, the maximum allowable water elevation was El 505 feet.

1.2 Sediment Management Demonstration Project

The presence of the Prado Dam has altered the flow of sediment down the Santa Ana River. To restore the natural habitats downstream of the dam and increase the storage capacity of the dam, OCWMD plans to manually remove up to 500,000 cubic yards of sediment behind the for transport down the Santa Ana River.

1.3 Objective and Scope

The purpose of the geotechnical investigation was to collect soil samples for laboratory testing to characterize the geotechnical index properties (grain size and Atterberg limits) of the soils upstream of the dam. Soil samples were also collected for environmental testing to identify the presence of contaminants.

1.3.1.1 Data Review, Utility Clearance, and Permitting

The purpose of this task was to gather readily available geologic and geotechnical information for the Site and surrounding areas. Our scope of work for this task included:

- Reviewed geotechnical report for the Santa Ana Regional Interceptor Reaches IV-A and IV-B prepared by Ninyo and Moore
- Collect and review data on regional geology and seismicity.
Prepare a site-specific Health and Safety Plan (HASP) prior to performing investigation work at the Site. The HASP is not included in this report, but is available upon request.

Clear the proposed fault investigation trench and test pit locations of underground utilities through Underground Service Alert (USA) prior to excavating on Site.

### 1.3.1.2 Recent Field Exploration

Field exploration activities were performed at the upstream of the dam on March 17, 2010 and May 24, 2010. Approximately 30 potential borehole locations were identified for the Prado Basin SMDP. The large number of locations was selected because of access restrictions due to water storage behind the dam during the rainy season. The areas chosen for drilling were the least intrusive and had the lowest impacts on wildlife and habitat. The goal was to drill up to 12 of these 30 borings, however, because weather and water storage behind the dam, five borings were drilled for the SMDP. These five borings provided representative samples of the sediments within or near the potential removal alignments. The location of these five borings is shown on Figure C-2. The field exploration program consisted of mechanically drilling three (3) borings and two (2) hand auger boreholes upstream of the Prado Dam.

Prior to drilling, each of Golder’s proposed borehole locations was marked in the field and cleared of known existing utilities through Underground Service Alert (USA). An OCWD biologist was on site to assess the suitability of each borehole location from a wildlife and habitat perspective. A subsurface drilling permit was not required for this project.

The three mechanical borings were drilled to depths of approximately 31.5 feet below ground surface (bgs) using a CME 850 tracked rig equipped with a 7 inch diameter auger supplied by Layne Christen Company of Norco, California. The two hand auger borings were drilled with a 2-inch diameter auger. The borings were backfilled with the excavated soil cuttings. Soils encountered in the borings were visually logged in the field by a Golder engineer and geologist. Representative soil samples were collected from the borings and delivered to a laboratory for geotechnical testing. OCWD biologists and archeologist were onsite during drilling to monitor the drilling operations. The emphasis was placed on monitoring to preserve wildlife, habitat and cultural resources.

The boring logs are presented in Attachment A. The logs (Report of Borehole) describe the earth materials encountered and the soil samples obtained. The logs show the location, borehole number, drilling date, and the name of the person who logged the borehole. The soils were described in general accordance with ASTM D2488. The boundaries between different soil types shown on the logs are approximate because the actual transition between soil layers may be gradual.

In the mechanical borings, disturbed samples of representative earth materials were obtained from the borings at intervals of approximately 5 feet. Samples were primarily obtained using a three six inch brass sleeved driven a total of 18 inches into the soil at the bottom of the borehole. One six inch sleeve was used for environmental testing. In the hand auger borings, soil samples were primarily collected from the
auger cuttings. Two 6-inch brass sleeve samples (environmental samples) were collected per hand auger boring. After collecting each environmental sample, a label with an adhesive backing was affixed to the sample container. The label provided the sample identification number, project number, date and time of sampling, sample media, and the initials of the person collecting the sample. The sample was placed in a cooler for transport to a California-licensed hazardous materials testing laboratory. Chain-of-custody documentation was maintained and is included in Attachment C.

Steam cleaning of the augers between holes was not performed as cross contamination between holes in each zone is not a significant issue.

1.3.1.3 Previous Field Exploration

1.3.1.4 Geotechnical Laboratory Testing
Laboratory testing was performed by Hushmand Associates, Inc. of Irvine, California, on the representative bulk and disturbed samples for the purposes of:

- Substantiating field classifications; and
- Provide soil classifications for liquefaction analyses.

Geotechnical laboratory testing consisted of grain size distribution (ASTM D422), and Atterberg limits (ASTM D4318. Laboratory test results are presented in Attachment B.

1.3.1.5 Geotechnical Analyses
Field and laboratory data were analyzed in conjunction with the conceptual project plans provided by HDR. The conceptual plans included three potential sediment removal alignments and four potential sediment impoundment areas. Construction considerations specific to the project are identified. Potential geologic hazards such as ground shaking, liquefaction, ground rupture, and landsliding are discussed. We developed site-specific seismic parameters to for application of the California Building Code (CBC 2007) seismic design provisions.

1.3.1.6 Environmental Testing
Each soil sample was visually examined for evidence of staining and odor and environmental testing was performed on select soil samples. The environmental testing included total petroleum hydrocarbons, volatile organic compounds, organophosphorus pesticides, metals, PCBs, total inorganic nitrogen, chlorinated herbicides, total dissolved solids, and hexavalent chromium. The test types were selected after receiving recommendations from OCWD, the Army Corps of Engineers and the Orange County Regional Water Quality Control Board. Environmental test results are presented in Attachment C.
1.3.2 Report

The results of the geotechnical investigation and environmental testing are summarized in a report that presents the findings, conclusions, and recommendations of our study as follows:

- Geologic conditions.
- Evaluation of the potential for future surface fault rupture within the SMDP area;
- Other seismic hazards evaluation; and
- Construction considerations.
2.0 GEOLOGIC SETTING
The Site lies adjacent to the eastern flank of the Santa Ana Mountains within the Peninsular Range Geomorphic Province of California (California Geological Survey, 2002). The Peninsular Range Geomorphic Province is a physiological area that extends from the San Gabriel Mountains in the north to Baja California in the south. The province is characterized by northwest trending mountain ranges and alluvial filled basins separated by similar oriented faults. The Elsinore Trough is a northwest trending fault controlled depression (graben) associated with the Elsinore Fault Zone (EFZ). The Elsinore Trough contains thousands of feet of Tertiary and Quaternary sediments and extends from near Temecula in the southeast to near Chino in the Northwest. The Santa Ana Mountains are a southwesterly tilted uplifted block composed largely of Pre-Cretaceous metasedimentary and metavolcanic rocks and Cretaceous plutonic rocks of the Southern California Batholith.

In closer proximity, the Chino section of the EFZ extends below the Prado Basin. It crosses highway 71 approximately 2 miles north of SR-91 and extends toward the southeast with mapped strands near the eastern spillway area for Prado Dam. The site and its relationship to the EFZ can be seen on Figure C-2.

The “State of California Earthquake Fault Zones, Prado Dam Quadrangle revised Official Map” (CGS, 2003) shows the study zone boundary enclosing the Chino section of the Elsinore Fault extending through the Prado Basin. Figure C-2 indicates that a portion of the Site is located within the designated Alquist-Priolo (AP) Earthquake Fault Zone of the Elsinore fault.

2.1 Site Geology and Generalized Subsurface Conditions
Geologic mapping by Morton and Miller (2006) indicate that the Prado Basin is primarily underlain by young axial channel deposits (Qya2, Holocene) overlain by very young wash deposits (Qw2, Holocene). Descriptions of the geologic units encountered within the site are provided in the following sections.

2.1.1 Very Young Wash Deposits, Unit 2 (Qw2)
Morton and Miller (2006) describe the Qw2 sediments as “Unconsolidated sand and gravel deposits in active washes, ephemeral river channels of axial-valley streams, and in channels on active surfaces of alluvial fans; has fresh flood scours and channel-and-bar morphology. Essentially no soil development. Subject to localized reworking and introduction of new sediment mainly during winter months. In places, especially upper reaches of some drainages, contains clasts several meters across that were deposited by flash floods. Grain shape ranges from angular to rounded; larger clasts tend to be more rounded than smaller clasts. All sediment derived from local bedrock or reworked from local, older Quaternary deposits.”
2.1.2 Young Axial Channel Deposits (Qya₂)

“Slightly to moderately consolidated silt, sand, and gravel deposits. Units distinguished from each other on basis of soil-profile development, relative position in local terrace-riser succession, and degree of erosional dissection. Consists of pale brown and very pale brown, fine- to very coarse-grained sand and pebbly sand that coarsens upstream to poorly sorted sand and sandy pebble to small-cobble gravel” (Morton and Miller, 2006).

2.1.3 Generalized Subsurface Conditions

Golder’s subsurface exploration revealed the following general subsurface layer at the boring locations (from the existing ground surface down):

- **Alluvium**: Loose silty sands and sands with varying amounts of silt and clay. The sand is interbedded with lenses of silty clay and elastic silt. The soils are recent river sediments deposited since 1941. This layer was encountered to the full depth of the boreholes (approximately 31.5 feet bgs).

Subsurface conditions different from those described above may be encountered during site excavations due to the inherent variability in soil deposits and since only a very small fraction of the sub-soils were actually observed during the geotechnical field exploration. Because of the nearly random depositional environment of the river sediments, significant lateral variability in the soils should be anticipated. Well-defined subsoil layering may not be encountered.

2.1.4 Groundwater

Several active stream channels were traversed to access the boring locations. Ground water is controlled by the Santa Ana River and the elevation of the water stored behind the Prado Dam. Away from the dam groundwater was encountered in the borings at between 5 and 6 feet below ground surface. Closer to the dam, the soils are located underwater during and shortly after the rainy season (October 15 through April 15).

The depth to the groundwater table is expected to increase during after the rainy season. Ninio and Moore dilled five borings on October 13, 2009 and groundwater was encountered at depths ranging from 9 to 20 feet below ground surface in four of the borings. The fifth boring did not encounter groundwater at a depth of 21.5 feet below ground surface.

2.2 Regional Seismicity and Faults

2.2.1 Historical Seismicity

A review of available earthquake catalogs reveals that at least 501 earthquakes of M ≥ 4.0 have been recorded within about 62 miles (100 km) of the Site since the early 19th Century. Sixty-six earthquakes of M ≥ 5.0 have been recorded since the early 19th Century, and fourteen (14) of these earthquakes had reported magnitudes of M ≥ 6.0. Earthquake epicenter locations shown in Figure C-3 were taken from the...
California and Preliminary Determination of Epicenters (PDE) catalogs of the U.S. Geological Survey National Earthquake Information Center (http://neic.usgs.gov/). The large number of recorded earthquakes and their magnitudes indicates that the Site is located in an area of ongoing earthquake activity.

The largest historic earthquakes nearby the Prado Basin were the 1971 San Fernando earthquake (M 6.7), the 1994 Northridge earthquake (M 6.7), the 1992 Landers earthquake (M 7.3) and the 1999 Hector Mine earthquake (M 6.5). Figure C-3 shows the location of the epicenters of these earthquakes.

### 2.2.2 Active Faults Within 62 Miles (100 Kilometers)

All known major active faults located within about 62 miles (100 km) of the Site are listed in Table 1. Table 1 also provides the estimated maximum earthquake moment magnitude (\(M_{\text{max}}\)) associated with each fault as given by California Working Group (2007). They estimated the maximum earthquake using correlations among fault parameters such as slip rate, fault length, rupture area, and actual measured earthquake magnitudes.

The nearest Type-A active faults to the site are the Chino Section of the Elsinore Fault (Chino Fault per Working Group, 2007) located within the Prado Basin, and the Whittier Section of the Elsinore Fault located approximately 1.2 miles (1.9 km) southwest of the Site, at its closest approach (Table 1 and Figure C-3).

The Elsinore fault system is predominantly a right-lateral strike slip fault with some reverse displacement along secondary faults. The Elsinore fault system extends for about 190 miles (306 km) southeast along the northeastern side of the Santa Ana Mountains, with segments terminating at the north near Pomona and Whittier, respectively and into Baja California. The average horizontal fault slip rate is estimated at about 1 to 5 mm/year over the last several thousand years.

The San Andreas fault (SAF) zone is a major dextral strike-slip fault zone that extends for about 680 miles (1,100 km) along the western side of California. It is near the coast in northern California, but stays entirely inland to the south of San Francisco, extending all the way to the northern Gulf of California in Mexico. The SAF is the major fault in a network of dextral strike-slip faults that constitute the San Andreas fault system that collectively accommodates the majority of relative north-south motion between the Pacific and North American plates. In central California, the SAF traverses the length of the Coast Ranges geomorphic province and forms the boundary between the Transverse Range and Mojave Desert geomorphic provinces. The Mojave South and San Bernardino North segments of the SAF are the closest to the project site about 27 miles northeast of the Prado Basin. The average horizontal fault slip rate across both segments is estimated at 29 ± 7 mm/year and 19 ± 7 mm/year, respectively (2007 Working Group).
2.3 Surface Fault Rupture

The entire property lies within the boundaries of an Earthquake Fault Zone, as defined by the State of California, Alquist-Priolo Earthquake Fault Zoning Act. Our evaluation did not include field mapping. The maximum magnitude earthquake on the Elsinore fault system is $M_{\text{6.8}}$. This magnitude earthquake is large enough to result in ground surface rupture in the Prado Basin.
### TABLE 1 - MAJOR ACTIVE FAULTS WITHIN A 62-MILE (100-KM) RADIUS OF THE PRADO BASIN

<table>
<thead>
<tr>
<th>Faults and Fault Zones</th>
<th>Distance to Site(^{(1)}) (miles (km))</th>
<th>Earthquake Magnitude(^{(2)}) (M_{\text{MAX}})</th>
<th>Slip Rate(^{(3)}) (mm/yr) ± (mm)</th>
<th>Fault Movement Type(^{(4)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elsinore Fault (Chino Segment)</td>
<td>0.0 (0.0)</td>
<td>6.8</td>
<td>1.0 ± 1.0</td>
<td>r-r</td>
</tr>
<tr>
<td>Elsinore Fault (Whittier Segment)</td>
<td>1.2 (1.9)</td>
<td>6.8</td>
<td>2.5 ± 1.0</td>
<td>rl-ss</td>
</tr>
<tr>
<td>Elsinore Fault (Glen Ivy Segment)</td>
<td>3.8 (6.2)</td>
<td>6.8</td>
<td>5.0 ± 2.0</td>
<td>rl-ss</td>
</tr>
<tr>
<td>Sierra Madre FZ (Section E)</td>
<td>15.3 (24.5)</td>
<td>7.1</td>
<td>2.0 ± 1.0</td>
<td>r</td>
</tr>
<tr>
<td>Sierra Madre FZ (Cucamonga Section)</td>
<td>17 (27)</td>
<td>6.5</td>
<td>5.0 ± 2</td>
<td>r</td>
</tr>
<tr>
<td>San Jacinto Fault (San Bernardino Section)</td>
<td>19.5 (31)</td>
<td>6.7</td>
<td>6.0 ± 4.0</td>
<td>rl-ss, r-r</td>
</tr>
<tr>
<td>Sierra Madre FZ (Section D)</td>
<td>22 (35)</td>
<td>7.1</td>
<td>2.0 ± 1.0</td>
<td>r</td>
</tr>
<tr>
<td>Newport-Inglewood Fault</td>
<td>25 (40)</td>
<td>7.1</td>
<td>1.0 ± 0.5</td>
<td>rl-ss</td>
</tr>
<tr>
<td>Elsinore Fault (Temecula Section)</td>
<td>26 (42)</td>
<td>6.8</td>
<td>5.0 ± 2.0</td>
<td>rl-ss</td>
</tr>
<tr>
<td>San Andreas Fault (San Bernardino North + San Bernardino South Sections)</td>
<td>27 (44)</td>
<td>7.1</td>
<td>19 ± 6.0</td>
<td>rl-ss</td>
</tr>
<tr>
<td>San Andreas Fault (Mojave north + Mojave south Sections)</td>
<td>27 (44)</td>
<td>7.4</td>
<td>29 ± 7.0</td>
<td>rl-ss</td>
</tr>
<tr>
<td>Raymond Fault</td>
<td>29 (47)</td>
<td>6.5</td>
<td>1.5 ± 1.0</td>
<td>ll-ss</td>
</tr>
<tr>
<td>San Jacinto Fault (San Jacinto Valley Section)</td>
<td>30 (48)</td>
<td>6.7</td>
<td>18 ± 6.0</td>
<td>rl-ss, r-r</td>
</tr>
<tr>
<td>Palos Verdes Fault (San Pedro Shelf Section)</td>
<td>36.5 (59)</td>
<td>7.2</td>
<td>3.0 ± 1.0</td>
<td>r-r</td>
</tr>
<tr>
<td>Sierra Madre Fault (Section C)</td>
<td>36.5 (59)</td>
<td>7.1</td>
<td>2.0 ± 1.0</td>
<td>r</td>
</tr>
<tr>
<td>Hollywood Fault</td>
<td>39.5 (64)</td>
<td>6.5</td>
<td>1.0 ± 0.5</td>
<td>l-r</td>
</tr>
<tr>
<td>San Jacinto Fault (Anza Section)</td>
<td>45 (72.5)</td>
<td>7.2</td>
<td>18 ± 6.0</td>
<td>rl-ss, r-r</td>
</tr>
<tr>
<td>Sierra Madre Fault (San Fernando Section)</td>
<td>47 (75.5)</td>
<td>6.5</td>
<td>2.0 ± 1.0</td>
<td>r</td>
</tr>
<tr>
<td>Santa Monica Fault</td>
<td>47 (75.5)</td>
<td>6.6</td>
<td>1.0 ± 0.5</td>
<td>l-r</td>
</tr>
<tr>
<td>North Frontal Faults</td>
<td>47.5 (76.5)</td>
<td>7.1</td>
<td>1.0 ± 0.5</td>
<td>r</td>
</tr>
<tr>
<td>Elsinore Fault (Julian Section)</td>
<td>53 (86)</td>
<td>7.1</td>
<td>3.0 ± 1.0</td>
<td>rl-ss</td>
</tr>
<tr>
<td>Pinto Mountain fault zone</td>
<td>53 (86)</td>
<td>7.1</td>
<td>2.5 ± 2.0</td>
<td>ll-ss</td>
</tr>
<tr>
<td>Helendale-South Lockhart Fault</td>
<td>54 (87)</td>
<td>7.3</td>
<td>0.6 ± 0.4</td>
<td>rl-ss</td>
</tr>
<tr>
<td>Sierra Madre Fault (Santa Suzana Section)</td>
<td>58 (93)</td>
<td>6.7</td>
<td>5.0 ± 2.0</td>
<td>r</td>
</tr>
</tbody>
</table>

Footnotes:
1) Distances based on Site coordinates = 34.827N, 118.884W lat/long. Distances measured on Google Earth™.
4) From SCEC (2010b): r = reverse, r-r = right reverse; l-r = left reverse; rl = right lateral, ll= left lateral, ss= strike slip
2.4 Landslide Hazards

Most of the Prado Basin area is free from landslide hazards. The potential impoundment areas are adjacent to the Chino Hills. The Chino Hills area is comprised chiefly of Puente Formation siltstone and sandstone that has been tectonically faulted, folded and rotated by the interaction of the Whittier and Chino segments of the Elsinore Fault system. Ancient to recent landslides throughout the Chino Hills are common. The potential sediment impoundment areas, as defined by HDR, are located at the base of the southern margin of the Chino Hills at the mouth of Santa Ana Canyon. Local bedding is steeply (45-70 degrees) dipping to the north. A review of aerial imagery indicates that there is evidence of across bedding rotational or joint plane failures along the bluff faces, particularly in the area immediately west of Highway 71 where the bluff face is significantly higher and steeper than the hills further to the west. This portion of the Chino Hills is comprised of the Sycamore Canyon Member of the Puente Formation which is generally made up of a buff to brown to white pebble [rounded gravel to cobble-sized material] conglomerate and conglomeratic sandstone with some light-gray siltstone deposits (Durham and Yerkes, 1959). As such, these materials are susceptible to rapid erosion and incipient slope failures due to rapid bank undercutting by the Santa Ana River. This area is immediately adjacent to one of the potential impoundment areas. However, the impoundment area is separated from the slopes by an existing road.
3.0 DESIGN RECOMMENDATIONS

3.1 Geotechnical Feasibility

Based on the field exploration, laboratory testing, and geotechnical analyses conducted for this study, Golder believes that it is feasible from a geotechnical standpoint to remove the soils behind the Prado Dam. An economic feasibility analysis has not been conducted.

An analysis of the Prado dam structure, its foundation and other elements of dam stability, integrity, and safety have not been performed as a part of this study. The goal of the SMDP is to move approximately 500,000 cy of sediment downstream in one season. The current estimates of sediment being deposited behind the dam range from 500,000 cy to 1,000,000 cy per year. Therefore the SMDP will not reduce the elevation of the soil in the Prado basin. However, locally along the potential sediment removal alignments the elevations will be lowered. We recommend that the sediment removal activity be conducted at a safe distance from the dam. The current plan shows the start of the sediment removal alignments at distances of greater than 600 feet from the dam. This distance should be sufficient to not impact the dam.

The SMDP will be used to assess the feasibility of a long term sediment management solution for the Prado basin. We understand that this long term solution could result in a lowering of the sediment elevation behind the dam.

While it may be feasible to remove sediments to the original elevation of the Prado Basin, before proceeding with the project, we recommend that an analysis of the dam integrity including a seepage analysis be performed by an appropriate dam expert to determine the maximum depth to which the sediments may be removed behind the dam without compromising its safety. The analyses of the dam should be completed in accordance with the requirements of the California Division of Safety of Dams (DSOD). This study should be conducted as a part of the engineering for the long term sediment management solution for the Prado basin.

3.2 Seismic Design Considerations

The Site is located in the seismically active region of southern California. The Site can be expected to experience strong earthquake shaking during its design life. Potential seismic hazards include strong ground shaking, liquefaction and lateral spreading, ground surface rupture due to faulting, seismic settlement, slope instability, and tsunamis and/or seiches. The following sections discuss these potential seismic hazards with respect to the SMDP Site.

3.2.1 Ground Shaking

The basis for the 2007 California Building Code (CBC) seismic design are 5%-damped spectral accelerations for 0.2 seconds (S0) and 1 second (S1) at an outcropping rock site (Site Class B). These 5%-damped spectral accelerations are established for a Maximum Credible Earthquake (MCE).
Typically, the MCE spectral accelerations have a mean return period of 2,475 years (2% probability of being exceeded in 50 years). Site coefficients \( F_a \) and \( F_v \) are then used to scale the spectral accelerations as a function of Site Class to develop a site-specific, 5%-damped acceleration response spectrum. The values for \( S_0 \) and \( S_1 \) are selected from the 2008 model for the United States developed by the United States Geologic Survey (USGS). Table 2 provides the recommended 2007 CBC seismic design parameters for the Site based on the results of Golder’s geotechnical exploration and Section 1613 of the 2007 CBC. These parameters were established using the USGS ground motion calculator for a site located at 33.890N latitude, 117.641W longitude, not interpolation of the small-scale maps contained in the 2007 CBC.

### TABLE 2
**PRADO BASIN SMDP SITE, CORONA, CALIFORNIA**

<table>
<thead>
<tr>
<th>2007 CBC Seismic Design Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Class</td>
<td>D</td>
</tr>
<tr>
<td>Site Class B, 5%-damped, 0.2-sec spectral acceleration ( (S_0) )</td>
<td>2.43</td>
</tr>
<tr>
<td>Site Class B, 5%-damped, 1-sec spectral acceleration ( (S_1) )</td>
<td>0.76</td>
</tr>
<tr>
<td>Site Class</td>
<td>F</td>
</tr>
<tr>
<td>Site Coefficient, ( F_a ) †</td>
<td>0.9</td>
</tr>
<tr>
<td>Site Coefficient, ( F_v ) †</td>
<td>2.4</td>
</tr>
</tbody>
</table>

† Site Coefficients provided for Site Class E

#### 3.2.2 Liquefaction

When certain saturated soil deposits are subjected to shaking during an earthquake, excess pore water pressures build up within the soil mass and lead to a loss of the soil’s shear strength. A complete loss of shear strength in the soils is called liquefaction. The excess pore water pressure dissipates mainly toward the ground surface and is accompanied by a volume change of the soil deposit, which is manifested at the ground surface as settlement. A recent example is the 1989 Loma Prieta Earthquake, which caused extensive liquefaction and the associated ground surface settlements in the Marina District of San Francisco.

Liquefaction analyses at a site are often conducted in two stages: 1) liquefaction risk and 2) liquefaction hazard. Liquefaction risk analyses establish the likelihood that liquefaction will occur during the design earthquake event and the thickness of the potentially liquefiable layer(s). Liquefaction hazard analyses evaluate the consequences of liquefaction at the site. The distinction between liquefaction hazard and risk is subtle but important. For example, the liquefaction risk at a site may be low (i.e., a thin layer of liquefiable soil) but the liquefaction hazard may be high (e.g., several feet of lateral spreading). Conversely, the liquefaction risk at a site may be high (i.e., a thick deposit of liquefiable soil) but the liquefaction hazard may be low (e.g., little to no surface manifestation of ground settlement).
The analysis of liquefaction generally involves four considerations: 1) the location of the groundwater, 2) the magnitude of the design earthquake, 3) the intensity of ground acceleration during the design earthquake, and 4) the liquefaction resistance of the soils.

As discussed in Section 2.1.4, groundwater was is shallow and controlled by the Santa Ana River and water storage behind the Prado Dam. The liquefaction resistance of the soils was evaluated using the procedure developed by Youd and Perkins (1978). This procedure is based upon the geologic origin and age of the soils, the ground water depth, soil grain size distribution, soil relative density, and thickness of the deposit. The USGS ground motion calculator estimates a peak ground horizontal acceleration (PGA) of 0.48g at the Site with a return period of 475-years. Disaggregation of the seismic hazard indicates that this ground motion is associated with a M6.8 approximately 3.4 km from the site.

Since the soils upstream of the dam are recently deposited saturated sands and silty sands, these soils are very highly susceptible to liquefaction during the design earthquake (Youd and Perkins, 1978). Therefore, liquefaction of these soils is considered likely.

### 3.2.3 Seismically-Induced Settlements

Seismically-induced settlement within the Prado Basin was estimated using the procedure proposed by Ishihara (1996). The estimated settlement is approximately 12 to 30 inches. This settlement is based on the assumption that liquefaction occurs to a depth of 50 feet below ground surface within the basin.

### 3.2.4 Seismic Slope Instability

The Prado Basin is located level ground adjacent to the Santa Ana River. However, the potential impoundment areas are adjacent to the Chino Hills. A review of aerial imagery indicates that there is evidence of across bedding rotational or joint plane failures along some areas of the slopes. These areas of the slopes may be susceptible to additional failure during a seismic event.

### 3.2.5 Tsunamis and Seiches

Tsunamis are very large waves in the ocean caused by seismic events or volcanic eruptions. Seiches are waves in lakes, bays, or gulfs that result from seismic events or atmospheric disturbances. The elevation of the Site above sea level (over 400 feet amsl) and its distance to the ocean that adverse effects from tsunami will not affect the Site. The Prado Dam periodically stores water behind the dam. A seismic seiche is possible behind the dam particularly if the earthquake occurs along the Elsinore fault zone segment located in the Prado Basin. In the extreme case, water could overtop the dam.

### 3.3 Environmental Testing

Table 4 summarizes the results of the environmental testing. The complete laboratory test results are included in Attachment C. The results of the environmental testing indicate that the soils had non-detectible levels of total petroleum hydrocarbons, volatile organic compounds, organophosphorus
pesticides, PCBs, chlorinated herbicides, and hexavalent chromium. The total petroleum hydrocarbon testing covers the range carbon chain molecules from C6 to C40. For this screening level, testing was performed of certain ranges of the carbon chain. TPH-GRO covers the gasoline range (including jet fuel) for the carbon chain molecules (≈ C6 to C12). TPH-DRO/ORO covers the diesel and oil ranges of the carbon chain molecules (≈ C11 to C40). TPH-CCID covers the entire range of the carbon chain molecules (≈ C6 to C40). Low concentrations of some metals were detected however, these levels were well below the EPA Region 9 Regional Screening Levels (RSLs) published April 2009.
**TABLE 3**
SUMMARY OF ENVIRONMENTAL TEST RESULTS

<table>
<thead>
<tr>
<th>Boring</th>
<th>Depth</th>
<th>Test</th>
<th>Result</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>11-11.5</td>
<td>TPH-GRO</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>11-11.5</td>
<td>VOCs</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>21-21.5</td>
<td>Organophosphorus Pesticides</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>31-31.5</td>
<td>Metals</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>6-6.5</td>
<td>TPH-DRO/RO</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>11-11.5</td>
<td>PCBs</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>21-21.5</td>
<td>VOCs</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>25.5-26</td>
<td>TPH-DRO/RO</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>31-31.5</td>
<td>Total Inorganic Nitrogen</td>
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<td></td>
</tr>
<tr>
<td>16</td>
<td>5-5.6</td>
<td>VOCs</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>5.5-6</td>
<td>Organophosphorus Pesticides</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>16-16.5</td>
<td>Metals</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>16-16.5</td>
<td>Chlorinated Herbicides</td>
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</tr>
<tr>
<td>16</td>
<td>21-21.5</td>
<td>Total Dissolved Solids</td>
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</tr>
<tr>
<td>16</td>
<td>26-26.5</td>
<td>Hexavalent Chromium (CrVI)</td>
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</tr>
<tr>
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<td>30.5-31</td>
<td>Pesticides</td>
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<td></td>
</tr>
<tr>
<td>28</td>
<td>2.5</td>
<td>Metals</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>2.5</td>
<td>TPH-CCID</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>12.5</td>
<td>VOCs</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>12.5</td>
<td>Organophosphorus Pesticides</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>2.5</td>
<td>VOCs</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>2.5</td>
<td>Organophosphorus Pesticides</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>12.5</td>
<td>Metals</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>12.5</td>
<td>TPH-CCID</td>
<td>ND</td>
<td></td>
</tr>
</tbody>
</table>

*Low levels of some metals (arsenic, barium, chromium, cobalt, copper, lead, nickel, vanadium and zinc) were detected above PQL. Detectable concentrations of metals are well below EPA Region 9 Regional Screening Levels (RSLs) published April 2009.*
4.0 CONSTRUCTION CONSIDERATIONS
The Prado Basin SMDP will manually remove up to 500,000 cubic yards of sediment upstream of the dam for transport down the Santa Ana River below the dam within a one year time frame. The sediment will be removed below Elevation 505 feet. We anticipate that the sediment will be removed by dredging or mechanical excavation.

4.1 Excavation Characteristics
One of the five borings (B-29) hit an obstruction at 13.5 feet bgs (large tree root or branch), it is possible that during the excavation tree roots or branches will be encountered during the excavation.

The soils at the site consist of recent loose recent sediments deposited during periods of high flow along the Santa Ana River. During the recent geotechnical investigation, the boreholes were excavated by a CME-85 rig or by hand. Therefore, conventional earth moving and dredging equipment should be capable of performing the excavations upstream of the dam for the SMDP. Borehole B-29 encountered a root or tree branch at a depth of 13.5 feet bgs. It is possible that additional debris (trees, branches, roots, etc.) may be buried at upstream of the dam.

During excavation, we anticipate that the soils below water will flow into the excavation. We expect that that the slopes will stabilize at inclinations of 2H:1V (horizontal: vertical) or flatter.
5.0 LIMITATIONS

This report has been prepared for the exclusive use of HDR, OCWD and their agents for the specific application to the SMDP in Corona, California. The findings, conclusions, and recommendations presented in this report were prepared in accordance with generally accepted geotechnical engineering practice within the area at the time this study was performed. No other warranty, either expressed or implied, is made. Attachment D contains further detailed information regarding the proper use and interpretation of this geotechnical report.

HDR and OCWD have the responsibility to see that all parties to the project, including the designer, contractor, subcontractors, etc., are made aware of this report in its entirety. This report contains information that may be useful in the preparation of contract specifications. However, this report is not written as a specification document and may not contain sufficient information for this use without proper modification.
6.0 CLOSING

Golder appreciates the opportunity to be of service on this project. If you have any questions, please contact any of the undersigned at (714) 508-4400.

Sincerely,

GOLDER ASSOCIATES INC.

DRAFT

Donald Lowry, PG, CEG
Senior Project Geologist

DRAFT

Anthony Augello, PhD, PE
Senior Geotechnical Engineer
7.0 REFERENCES


Ninyo and Moore, 2009, Geotechnical Design Evaluation Santa Ana Regional Interceptor (SARI)/ Repairs to the Unlined Reinforced Concrete Pipe (RCP)/ Reaches IV-A and IV-B, San Bernardino and Riverside Counties, California, November.


