Matilija Dam Ecosystem Restoration Project

Geotechnical and Concrete Field Investigations and Dam Structural Analysis

October 1, 2020 Update

Brian Person, PE
Field Investigations – Tasks and Timeline

• Objective
• Field Investigations Technical Memorandum – October 21, 2019
• Permitting by VCWPD
• Geotechnical Investigations
  • Boring – Gregg Drilling w/AECOM Oversight – August 2018
  • Geotechnical Testing – NV5 West – September-November 2018
  • Analytical Testing – Test America Laboratory – August 2018
• Concrete Investigations
  • Coring – Concrete Coring Company – August 2018
  • Physical Testing – NV5 West – September/October 2018
  • Petrographic Analysis – Analytical Consulting Group – October 2018
Geotechnical Investigations
Boring Locations
## Boring Summary

<table>
<thead>
<tr>
<th>Boring</th>
<th>Location</th>
<th>Depth (ft.)</th>
<th>Depth of methane (ft.)</th>
<th>Material boring terminated in</th>
<th>Approx. mudline elevation (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>Right abutment, 100ft upstream from dam</td>
<td>73</td>
<td>Not measured</td>
<td>Sandstone (Bedrock)</td>
<td>1085</td>
</tr>
<tr>
<td>B-2</td>
<td>Center of reservoir, 250ft upstream from dam</td>
<td>86.5</td>
<td>Not measured</td>
<td>Sandstone (Bedrock)</td>
<td>1085</td>
</tr>
<tr>
<td>B-3</td>
<td>Middle of reservoir</td>
<td>75.3</td>
<td>15</td>
<td>Alluvium (Qal)</td>
<td>1085</td>
</tr>
<tr>
<td>B-4</td>
<td>Left abutment, 200ft upstream from launch site</td>
<td>80.3</td>
<td>16</td>
<td>Alluvium (Qal)</td>
<td>1085</td>
</tr>
<tr>
<td>B-5</td>
<td>Left abutment, 300ft upstream from launch site</td>
<td>65.5</td>
<td>Not measured</td>
<td>Alluvium (Qal)</td>
<td>1085</td>
</tr>
<tr>
<td>B-6</td>
<td>Left abutment, upstream extent of reservoir</td>
<td>66.4</td>
<td>Not measured</td>
<td>Sandstone (Bedrock)</td>
<td>1085</td>
</tr>
</tbody>
</table>
Boring Results

- Water depth 9 – 10.5 feet across all borings
- MIP used in only two holes B-3 and B-4
- Very soft silts and lean clays – in several cases the drill stem weight advanced the sampler
- Occasional sandy layers; occasional organic material (leaves, roots, stems)
- Alluvial deposits comprised of very dense sand and coarse gravel
- Three borings encountered sandstone bedrock below alluvium
- Sampler refusal (>50 blow/1/2 ft.) in alluvium and bedrock
Physical Testing

- Grain size analysis – silts with layers of lean clays and sand, unit weights 68.0 to 85.8 pcf
Analytical Testing

- Total petroleum hydrocarbons
  - diesel range organics and motor oil organics above lab reporting limit, but well below Tier 1 Environmental Screening Levels

- Semi-volatile organic compounds
  - 65 compounds tested

- Title 22 metals (EPA method)
  - Concentrations either lower than or well within range of background levels reported in California by Kearney Foundation of Soil Science

- Organochlorine pesticides
  - no results above respective laboratory reporting limits

- Polychlorinated biphenyls
  - no analytes above respective laboratory reporting limit
Concrete Investigations
Core Hole Locations

Slide 10

Table 1 - Horizontal Core Details

<table>
<thead>
<tr>
<th>Core ID</th>
<th>Dia. (in.)</th>
<th>Depth (ft)</th>
<th>Location Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>0</td>
<td>4</td>
<td>Upstream Approximately 1.5 feet above spillway elevation</td>
</tr>
<tr>
<td>H2</td>
<td>0</td>
<td>4</td>
<td>Upstream Approximately 1.5 feet above spillway elevation</td>
</tr>
<tr>
<td>H3</td>
<td>0</td>
<td>4</td>
<td>Downstream, Approximately 2 feet left to the left (downstream convention) of 1068 coreholes</td>
</tr>
<tr>
<td>H4</td>
<td>0</td>
<td>20</td>
<td>Downstream, Approximately 2 feet left to the left (downstream convention) of 1068 coreholes</td>
</tr>
<tr>
<td>H5</td>
<td>0</td>
<td>4</td>
<td>Downstream</td>
</tr>
<tr>
<td>H6</td>
<td>0</td>
<td>20</td>
<td>Downstream</td>
</tr>
</tbody>
</table>

Approximate Horizontal Core Locations and ID
(See Table 1 for details)

Current Dam Crest (Overflow El. 1095 ft.)

Approximate Silt Level (El. 1070 ft - El. 1075 ft)

Year for Dam Section removal

Scale: 1in = 50ft
Concrete Coring – Upstream Face and Crest
Core Drilling
Upstream Face
And Crest
Core Drilling – Downstream Face
Test Results

- Compressive strength 1,490 to 8,610 psi
- Splitting tensile strength 110 to 550 psi
- Unit weight 153.6 to 165.1 lb/ft$^3$
- No evidence of excessive water:cement ratio
- ASR present in all samples
Matilija Dam Ecosystem Restoration Project

Updated Structural Analysis
October 1, 2020 Update
Brian Person, PE
Evaluation Components

• Structural integrity re-evaluation, with and without proposed orifices
  • Overstressing and sliding stability under static loading (normal and flood)
  • Stability under dynamic (earthquake) loading conditions
  • Utilized a three-dimensional linear finite element model based on a refined version of the model developed for the 2013 study

• Comparison of model results under current study to those of 2013
Results Comparison – Compressive Strength

- Shaded region represents estimated range of values over time.
- ASR-affected concrete at crest removed.

Legend:
- EL. 1000
- EL.1000 - EL.1050
- EL.1050 - EL.1100
- > EL.1100
- Unused Data
## Estimated Concrete Material Properties - 2020

<table>
<thead>
<tr>
<th>Properties</th>
<th>Upper Section (&gt;El. 1050)</th>
<th>Middle Section (El. 1000-1050)</th>
<th>Lower Section (&lt;El. 1000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit weight</td>
<td>145 lb/ft³</td>
<td>145 lb/ft³</td>
<td>145 lb/ft³</td>
</tr>
<tr>
<td>Unconfined Compressive Strength</td>
<td>1500 psi</td>
<td>2700 psi</td>
<td>4000 psi</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>130 psi</td>
<td>300 psi</td>
<td>500 psi</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustained</td>
<td>$0.2 \times 10^6$ psi</td>
<td>$1.0 \times 10^6$ psi</td>
<td>$2.9 \times 10^6$ psi</td>
</tr>
<tr>
<td>Instantaneous</td>
<td>$0.3 \times 10^6$ psi</td>
<td>$1.4 \times 10^6$ psi</td>
<td>$4.1 \times 10^6$ psi</td>
</tr>
<tr>
<td>Poisson’s Ratio</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>1.08 BTU / ft-hr.-°F</td>
<td>1.08 BTU / ft-hr.-°F</td>
<td>1.08 BTU / ft-hr.-°F</td>
</tr>
<tr>
<td>Specific Heat</td>
<td>0.22 BTU / lb.-°F</td>
<td>0.22 BTU / lb.-°F</td>
<td>0.22 BTU / lb.-°F</td>
</tr>
<tr>
<td>Coefficient of Thermal Expansion</td>
<td>0.000005 in / in / °F</td>
<td>0.000005 in / in / °F</td>
<td>0.000005 in / in / °F</td>
</tr>
</tbody>
</table>

psi = pounds per square inch
Adjustment for ASR Effects

• ASR typically effects concrete by causing expansion and cracking throughout the mass
• ASR effects modeled as a reduction in the stiffness in the concrete over the height of the dam
• Note - in an arch dam, would typically manifest by some degree of upstream deflection – but none noted in 20 years of monitoring
Dynamic (Earthquake) Evaluation Factors

- Used deterministic ground motion analysis in accordance with DSOD procedures
- Cited identified active faults (Santa Ynez, Mission Ridge, San Andreas)
- Developed earthquake evaluation response spectrum corresponding to controlling fault at statistical levels prescribed by DSOD
### Summary of Load Combinations for Analysis

<table>
<thead>
<tr>
<th>Loading Combination</th>
<th>Abbreviated Load Combination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usual Load Combination No. 1: Gravity, stress-free temperature, normal water surface El. 1095, sediment El. 1095, ASR effects, uplift pressure</td>
<td>USLC–1 (2020)</td>
</tr>
<tr>
<td>Usual Load Combination No. 2: Gravity, summer temperature, normal water surface El. 1095, sediment El. 1095, ASR effects, uplift pressure</td>
<td>USLC–2 (2020)</td>
</tr>
<tr>
<td>Usual Load Combination No. 3: Gravity, winter temperature, normal water surface El. 1095, sediment El. 1095, ASR effects, uplift pressure</td>
<td>USLC–3 (2020)</td>
</tr>
<tr>
<td>Unusual Load Combination No. 1: Gravity, stress-free temperature, PMF water surface El. 1111, sediment El. 1095, ASR effects, uplift pressure</td>
<td>UNLC–1 (2020)</td>
</tr>
<tr>
<td>Extreme Load Combination No. 1: Gravity, stress-free temperature, normal water surface El. 1095, sediment El. 1095, ASR effects, uplift pressure, hydrodynamic added mass, ground motions due to seismic event</td>
<td>EXLC–1 (2020)</td>
</tr>
</tbody>
</table>
FEA Plots

Left Thrust Block

Right Thrust Block

USLC-3 (With Uplift)
Evaluation Findings

• Conclusions drawn from the 2013 study confirmed
• Model results and trends compared favorably with those of the 2013 study
• Dam expected to have adequate structural capacity to safely withstand all design load cases for the current year
• Maximum compressive stresses are below allowable values, except at small areas around the left orifice.
• Tensile stresses are below the allowable values, with the exception of limited areas on the surface of the concrete near the slip joint and near the left abutment
• “Matilija Dam is concluded to have adequate safety against concrete overstressing, before and after installing the proposed orifices, for the assumed static and dynamic loading conditions.”
Recommendations

- Additional analysis to evaluate the planned construction method, sequence, and details of the orifices may be justified
- Evaluate the need for measures to mitigate localized stress concentrations (steel tunnel lining for example)
- Continue to monitor the concrete condition and deformation to identify changes in deterioration trends
- Promptly investigate any significant or unexplained changes
Coordination With California Department of Water Resources - Division of Safety of Dams (DSOD)

- May, 2018 initiated coordination including coring and core hole backfilling plan under Repair or Alteration of a Dam and Reservoir Permit
- February 28, 2019 meeting in DSOD offices to present approach, preliminary findings, conclusions, next steps
- DSOD modeling methods differ, and suggest that the dam may not be stable under all dynamic loading conditions
- Draft Stability Evaluation Report, Appendices, and Evaluation Figures provided to DSOD on September 26, 2019
- April 9, 2020 email from DSOD expressing general agreement with the dual orifice concept, but acknowledging that additional work is necessary to address tensile stress concentrations on the on limited portions of the orifice surfaces
- August 11, 2020 email from DSOD indicating they will soon be issuing a letter providing comment on the Draft Stability Evaluation Report
Questions?