M & T Pump Station Intake Second Physical Model

Prepared by
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Introduction

• Since prior 2007 testing, bar migration and sedimentation at the current pump intake has continued

• TetraTech, Inc., working in coordination with Ducks Unlimited, Inc., funded a second physical model study in 2010

• Evaluate hydraulic, morphologic, and sedimentation patterns near the following sites:
  1. Current pump intake location
  2. Proposed Alternative 1 site, ~2,200 ft downstream of the current pump-intake location
  3. Proposed Alternative 2 site, ~3,500 ft downstream of the current pump-intake location

• Three channel configurations:
  1. Current field conditions (Baseline)
  2. Gravel-stockpile on the west floodplain
  3. Realigned section of the east bank with revetment for Proposed Alternative 2 site

Locus map illustrating the study reach
Physical Model

- 10,300-ft reach of the Sacramento River
- 1:100 Undistorted Froude-scale
- Sediment Scaling
  - Ratio of Shields parameter to critical Shields parameter
  - Ratio of flow velocity to critical flow velocity
  - Rouse number
- Scaled sediment sizing for mobile material within the channel
  - Model bed material $d_{50} = 0.15$ mm
  - Prototype bed material $d_{50} = 40$ mm
- 3 scaled discharges evaluated:
  - 145,000-cfs (10-yr recurrence interval flow)
  - 90,000-cfs (bankfull discharge)
  - 10,000-cfs (50% exceedance flow)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Symbol</th>
<th>Dimension</th>
<th>Similitude Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>$L$</td>
<td>$L$</td>
<td>$L_p = 100 \cdot L_m$</td>
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<tr>
<td>Time</td>
<td>$T$</td>
<td>$T$</td>
<td>$T_p = 10 \cdot T_m$</td>
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<tr>
<td>Velocity</td>
<td>$V$</td>
<td>$L/T$</td>
<td>$V_p = 10 \cdot V_m$</td>
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<tr>
<td>Shear Stress</td>
<td>$\tau$</td>
<td>$M/LT^2$</td>
<td>$\tau_p = 100 \cdot \tau_m$</td>
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<tr>
<td>Discharge</td>
<td>$Q$</td>
<td>$L^3/T$</td>
<td>$Q_p = 100,000 \cdot Q_m$</td>
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<tr>
<td>Unit Discharge</td>
<td>$q$</td>
<td>$L^2/T$</td>
<td>$L_p = 1,000 \cdot L_m$</td>
</tr>
</tbody>
</table>

Note: Subscripts m and p denote model and prototype, respectively.

Froude-scale conversions

Model extents identified on aerial photograph of the Sacramento River
Physical Model

Model construction started in the summer of 2010:

- 30 E-W soil-cement cross sections
- 1 N-S cross-section defining the downstream boundary
- Very fine sand material to model bed and floodplain sediment
- Cohesive soil to model cohesive stream banks along downstream east bank
- Mesh baffle to provide uniform flow entrance conditions
- Downstream gate to control backwater
- Sediment feed upstream of the test reach
- Installation of artificial trees and canopy

<table>
<thead>
<tr>
<th>Summary of Variables</th>
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<tbody>
<tr>
<td><strong>Variable</strong></td>
</tr>
<tr>
<td><strong>Hydraulic</strong></td>
</tr>
<tr>
<td>Elevation, Length</td>
</tr>
<tr>
<td>Flow Depth</td>
</tr>
<tr>
<td>Discharge</td>
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<tr>
<td>Flow Velocity</td>
</tr>
<tr>
<td>Shear Stress</td>
</tr>
<tr>
<td><strong>Sediment</strong></td>
</tr>
<tr>
<td>Sediment $d_{50}$</td>
</tr>
<tr>
<td>Time</td>
</tr>
</tbody>
</table>
Test Matrix

- **Baseline**
  - 10,000 cfs (8.5 hrs)
  - 90,000 cfs (143 hrs)
  - 145,000 cfs (7.5 hrs)

- **Gravel Stockpile**
  - 145,000 cfs (7.5 hrs)

- **Realigned Bank**
  - 10,000 cfs (4 hrs)
  - 90,000 cfs (148 hrs)
  - 145,000 cfs Test 1 (8 hrs)
  - 145,000 cfs Test 2 (8 hrs)
    - bed reset to original realigned-bank elevations between Test 1 and Test 2
  - 145,000 cfs Test 3 (8 hrs)
    - Bed elevations not reset between Test 2 and Test 3 resulting in 16 total hours of 145,000-cfs testing
Typical Testing Program

• Testing program:
  • Measure bed elevation before testing
  • Establish model discharge and backwater
  • “Begin” testing
    • Measure flow velocities
    • 10,000-cfs testing for ~8-hours
    • 90,000-cfs testing for ~140-hours
    • 145,000-cfs testing for ~8-hours
  • Slowly decrease the discharge and drain the model
  • Measure bed elevation after testing
Data Collection Locations
Comparison of Second Physical Model with the 2007 Model

Baseline Velocity Distribution of 2010 Model: 90,000-cfs Testing

Baseline Velocity Distribution of 2007 Model: 90,000-cfs Testing

Higher velocity at upstream end

Main channel velocity ~ 4 – 6 fps

90,000 cfs, Baseline

Prototype Velocity (ft/s)

- 0.0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- 4.1 - 5.0
- 5.1 - 6.0
- 6.1 - 7.0
- 7.1 - 8.0
- 8.1 - 9.0
- 9.1 - 10.0
- 10.1 - 11.0

Baseline Velocity Distribution of 2010 Model: 90,000-cfs Testing

Baseline Velocity Distribution of 2007 Model: 90,000-cfs Testing

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90,000 cfs, Baseline

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- 4.1 - 5.0
- 5.1 - 6.0
- 6.1 - 7.0
- 7.1 - 8.0
- 8.1 - 9.0
- 9.1 - 10.0
- 10.1 - 11.0
- 11.1 - 12.0
Baseline Testing: 90,000-cfs

90,000-cfs Baseline Flow Velocity Distribution

Elevation Difference between Post-90,000-cfs Baseline Testing and Pre-10,000 cfs

Note: Deep blues, reds, and missing colors outside of the river are trees and canopy within the model.
Baseline Testing: 145,000-cfs

145,000-cfs Baseline Flow Velocity Distribution

Elevation Difference between Post-145,000-cfs Baseline Testing and Pre-10,000 cfs

Note: Deep blues, reds, and missing colors outside of the river are trees and canopy within the model.
Baseline Testing Summary

• Current Pump Location
  • Continued trends of sedimentation near the pump
  • Agg. up to 5 ft (from 145,000-cfs test)
  • Lower flow velocities compared to the main channel promoting sedimentation

• Proposed Alternative 1 Site
  • Agg. up to 5 ft in the main channel (from 145,000-cfs test)
  • 2 to 5-ft strip of deg. along the bank (from 145,000-cfs test)

• Proposed Alternative 2 Site
  • Negligible agg. and deg. (from 145,000-cfs test)

• WPCP Outfall
  • Negligible agg. and deg. (from 145,000-cfs test)
Hydraulic Modeling – Gravel Stockpile

- Prototype Gravel Stockpile:
  - 1000’ Long x 300’ Wide x 10’ High
  - 1.5H:1V Side Slopes
  - To be constructed of dredged channel material from maintenance of current pump station

- Model Gravel Stockpile:
  - Scaled down prototype dimensions
  - Superimposed on baseline configuration topography
  - Used mobile sediment to construct
  - Significantly inundated only at model 145,000-cfs flow
Gravel Stockpile: Comparison

145,000-cfs with Stockpile Flow Velocity Distribution

145,000-cfs Baseline Flow Velocity Distribution
Gravel Stockpile: Comparison

Post-145,000-cfs Gravel-stockpile Testing Elevation Difference from Initial Gravel-stockpile Elevations

Post-145,000-cfs Baseline Testing Elevation Difference from Post-10,000-cfs Baseline

Note: Deep blues, reds, and missing colors outside of the river are trees and canopy within the model.
Hydraulic Modeling – Realigned Bank

- Prototype Bank realignment
  - Straightening of East bank near Proposed Alternative 1 Site
  - Riprap along east bank from current pump intake to downstream of Proposed Alternative 1 Site
  - Pea-gravel used to model riprap
  - Proposed Alternative 1 Site is no longer a potential relocation site with the bank realignment
Bank Realignment Testing: 90,000-cfs

Realigned Bank 90,000-cfs Flow Velocity Distribution

Elevation Difference between Post-90,000-cfs Realignment Testing and Pre-10,000 cfs

Note: Deep blues; reds; and missing colors outside of the river are trees and canopy within the model.
Bank Realignment Testing: 145,000-cfs

Realigned Bank 145,000-cfs Flow Velocity Distribution

Elevation Difference between Post-145,000-cfs Realignment Testing and Pre-10,000 cfs
Bank Realignment: Comparison

Realigned Bank 145,000-cfs Flow Velocity Distribution

Baseline 145,000-cfs Flow Velocity Distribution
Bank Realignment: Comparison

Post-145,000-cfs Realigned-bank Test 1
Elevation Difference from Pre-10,000-cfs Test

Post-145,000-cfs Baseline Testing Elevation Difference from Post-10,000-cfs Baseline
 Bank Realignment: Comparison

Realigned Bank 145,000-cfs Post-Test 2
Bed Elevation Difference from Pre-Test 2 (8 hrs)

Realigned Bank 145,000-cfs Post-Test 3
Bed Elevation Difference from Pre-Test 2 (16 hrs)
Bank Realignment: Comparison

145,000 cfs, Realigned Channel Bank, Test 3
Prototype Elevation Difference: Test 3 to Test 2 (feet)

-100 - 50
-49 - 20
-19 - 10
-9 - 0.5
-4 - 0.5
-0.1 - 10
0.1 - 10
1.1 - 20
2.1 - 50
5.1 - 10.0

Note: Deep blues, reds, and missing colors outside of the river are trees and canopy within the model.

Realigned Bank 145,000-cfs Post-Test 3
Bed Elevation Difference from Pre-Test 3 (8 hrs)

Realigned Bank 145,000-cfs Post-Test 3
Bed Elevation Difference from Pre-Test 2 (16 hrs)
Bank Realignment Testing Summary

- Hydraulic and sedimentation trends varied from Baseline and Gravel-stockpile trends
- Higher main-channel flow velocities compared to Baseline Testing
- Current pump location
  - Agg. up to 5 ft just northwest of current pump-intake (from 145,000-cfs test)
  - Negligible velocity difference compared to Baseline conditions
- Proposed Pump Alternative Location #1
  - Deg. up to 2 ft at 10,000 cfs and 90,000 cfs
  - Agg. up to 5 ft immediately upstream (from 145,000-cfs test)
  - Increased flow velocities compared to baseline conditions at 145,000 cfs
- Proposed Pump Alternative Location #2
  - Negligible agg. and deg. (from 145,000-cfs test)
  - Increase in velocity of main channel compared to Baseline
- WCPC Outfall
  - Agg. immediately upstream
  - Deg. immediately downstream
  - Measured upstream agg. suggests that a maximum of 2 ft of aggradation could be expected at the WPCP outfall
Summary Chart

Aggradation/Degradation at 145,000 cfs

<table>
<thead>
<tr>
<th></th>
<th>N/A</th>
<th>0</th>
<th>0</th>
<th>0</th>
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<tr>
<td>Current Pump Intake</td>
<td>2-5</td>
<td>2</td>
<td>2-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proposed Alternative #1</td>
<td>2-5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proposed Alternative #2</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>WPCP Outfall</td>
<td></td>
<td></td>
<td></td>
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<td>&lt;2</td>
</tr>
</tbody>
</table>

Prototype Bed elevation change (ft):
- Current Pump Intake: 2-5 ft
- Proposed Alternative #1: 2-5 ft
- Proposed Alternative #2: -(2-5) ft
- WPCP Outfall: <2 ft

Legend:
- Blue: Baseline
- Red: Gravel Stockpile
- Green: Realigned Bank Test 1
Summary Charts

**Baseline Testing**

- Current Pump Intake: 2.3 ft/s, Proposed Alternative #1: 3.5 ft/s, Proposed Alternative #2: 4.2 ft/s
- Current Pump Intake: 6.3 ft/s, Proposed Alternative #1: 3.7 ft/s, Proposed Alternative #2: 2.3 ft/s

**Gravel Stockpile Testing**

- Current Pump Intake: 6.6 ft/s, Proposed Alternative #1: 7.1 ft/s, Proposed Alternative #2: 4.4 ft/s

**Realigned Bank Testing**

- Current Pump Intake: 4.2 ft/s, Proposed Alternative #1: 3.7 ft/s, Proposed Alternative #2: 3.1 ft/s
- Proposed Alternative #1: N/A, Proposed Alternative #2: N/A
Conclusions from Hydraulic Model

- Continued sedimentation up to 5 ft is expected with existing field conditions near the current pump-intake location.
- Construction of the gravel stockpile on the west floodplain would have an insignificant effect on the hydraulics and erosion and sedimentation trends within the study reach.
- The Proposed Alternative 1 site may be suitable for pump-intake relocation because the model predicted degradation up to 5 ft near the Proposed Alternative 1 site for both the existing field conditions and with the construction of the gravel stockpile.
- The Proposed Alternative 2 site may be suitable for pump-intake relocation because:
  - The model indicated minimal aggradation and degradation near the Proposed Alternative 2 site.
  - The site experienced the most consistent bed elevations with minimal aggradation and degradation in the surrounding areas compared to the other evaluated pump location sites.
- The model indicated aggradation immediately upstream of the WPCP outfall and degradation immediately downstream of the WPCP outfall with the bank realignment for the Proposed Alternative 2 site.
  - The measured upstream aggradation suggests that a maximum of 2 ft of aggradation could be expected at the WPCP outfall.