Prospect Island Tidal Restoration Project
Hydrodynamic Modeling Analysis for 100-year and 200-year Flood Events
Technical Memorandum

DWR Task Order SS-02 – Amendment 07, Contract No. 4200009291

November 2016
Executive Summary

A tidal habitat restoration project is being proposed for Prospect Island in the northern Sacramento-San Joaquin Delta (DWR, 2016). A numerical model analysis was performed to assess the potential hydrodynamic impacts of the project on the surrounding channels during times of high flood flow conditions. Model evaluations were previously performed for the CEQA “Proposed Project” configuration (RMA, 2015). The current study is for the evaluation of the CEQA “Alternative 2” restoration configuration.

The Alternative 2 configuration breaches the island to Miner Slough at two locations; a central breach and a south breach. An additional component is a north Miner overflow weir (+7 ft NAVD88 elevation) located at the northeast corner of Prospect Island.

The two principal objectives of the hydrodynamic analysis were to evaluate the impacts with development of the project for high flow conditions (100-year and 200-year flood events):

1) Evaluate potential changes to peak water surface elevation in the surrounding north Delta region.
2) Evaluate the potential for scour in the adjacent Miner Slough.

The flood flow analysis employed a one and two dimensional hydrodynamic model (RMA2) of Prospect Island and the north Delta region. Downstream model stage and upstream inflow boundary conditions were supplied from the MBK Engineers HEC-RAS model for the Sacramento River system.

Computed stage increases at peak flood in the channels surrounding the Prospect Island site were small, at most +0.01 feet for few a locations of Miner Slough adjacent Prospect Island. Additionally, the model results indicated a small reduction in peak water surface elevation (WSE) for Miner Slough upstream of Prospect Island. Peak WSE for Miner Slough at the Hwy 84 bridge was reduced -0.08 feet for the 100-year event and -0.04 feet for the 200-year event.

The velocity analysis compared Baseline and Alternative 2 velocity magnitude at time of peak flood stage. Increases in Miner Slough velocities with the Alternative 2 were limited to < 0.1 fps for both the 100-year and 200-year events during peak flood. Computed Miner Slough velocities immediately downstream of the north Miner weir decreased.
# Table of Contents

**EXECUTIVE SUMMARY** ......................................................................................................................... 1

**INTRODUCTION** ......................................................................................................................................... 1

- ALTERNATIVE 2 CONFIGURATION ................................................................................................................. 1
- RMA2 .............................................................................................................................................................. 2

**MODEL CONFIGURATION** ............................................................................................................................ 6

- MANNING’S FRICTION COEFFICIENTS ....................................................................................................... 7

**100-YEAR AND 200-YEAR FLOOD FLOW ANALYSIS** .................................................................................. 13

- INTRODUCTION ............................................................................................................................................ 13
- MODEL BOUNDARY CONDITIONS ................................................................................................................... 13
- MODEL RESULTS .......................................................................................................................................... 20
  - Stage Analysis ....................................................................................................................................... 20
  - Miner Slough Velocity Analysis ............................................................................................................. 21
- RMA2, HEC-RAS MODEL COMPARISON ....................................................................................................... 41

**REFERENCES** .............................................................................................................................................. 45

**TABLE OF FIGURES**

- **FIGURE 1** LOCATION OF THE PROSPECT ISLAND TIDAL HABITAT RESTORATION SITE IN THE NORTHERN DELTA. ................................................................. 4
- **FIGURE 2** (LEFT) EXISTING TOPOGRAPHY FOR THE PROSPECT ISLAND RESTORATION SITE (DATA FROM STILLWATER SCIENCES).  (RIGHT) DESIGN FEATURES FOR ALTERNATIVE 2. ......................................................................................... 5
- **FIGURE 3** RMA2 GRID DEVELOPED IN SUPPORT OF THE CENTRAL VALLEY PROTECTION PLAN (CVFPP) MODELING ANALYSIS.  THE NORTH DELTA PORTION OF THE GRID WAS EXTRACTED AND USED FOR THE FLOOD FLOW (100-YEAR AND 200-YEAR) PROSPECT ISLAND RESTORATION ANALYSIS. ............................................................................................................. 8
- **FIGURE 4** MODEL NETWORK DETAIL NEAR PROSPECT ISLAND FOR THE CEQA ALTERNATIVE 2 HIGH FLOW GRID. ................................................................. 9
- **FIGURE 5** BASE AND ALTERNATIVE 2 MANNING’S “n” VALUE CLASSIFICATION FOR THE PROSPECT ISLAND INTERIOR. ......................................................... 10
- **FIGURE 6** MANNING’S FRICTION COEFFICIENTS USED FOR THE FLOOD EVENT ANALYSIS FOR THE CHANNELS AND FLOOD BYPASS AREAS OF THE NORTH DELTA.  FRICTION COEFFICIENTS FOR THE OVERBANK AREAS (SEE FIGURE 8) WERE SET TO 0.040. ......................................................................................................................... 11
- **FIGURE 7** MANNING’S FRICTION COEFFICIENTS USED FOR THE FLOOD EVENT ANALYSIS FOR THE LOWER SACRAMENTO RIVER REGION. ............. 12
- **FIGURE 8** BOUNDARY CONDITION LOCATIONS FOR 100-YR AND 200-YR EVENT RUNS.  THE OVERBANK AREAS CAN RECEIVE FLOW FROM LEVEE OVERTOPPING OF MAIN CHANNELS AND BYPASS. ................................................................................................. 15
- **FIGURE 9** COMPARISON OF SACRAMENTO RIVER MODEL FLOWS AT FREEPORT (RM 46.4198) FOR THE 100-YEAR EVENT.  THE PLOT SHOWS THE HEC-RAS HYDROGRAPH AT FREEPORT (BLUE), THE RMA2 COMPUTED FLOW AT FREEPORT (GREEN) USING A TIME SHIFTED BOUNDARY CONDITION AND THE RMA2 COMPUTED FLOW AT FREEPORT WITH NO TIME SHIFTED BOUNDARY CONDITION (RED). ................................................................................................................................. 16
- **FIGURE 10** COMPARISON OF LOWER YOLO BYPASS MODEL FLOWS JUST ABOVE CACHE SLOUGH (RM 20.839) FOR THE 100-YEAR EVENT.  THE PLOT SHOWS THE HEC-RAS HYDROGRAPH (BLUE), THE RMA2 COMPUTED FLOW (GREEN) USING A TIME SHIFTED YOLO INFLOW BOUNDARY CONDITION AND THE RMA2 COMPUTED FLOW WITH NO TIME SHIFTED BOUNDARY CONDITION (RED). ............. 17
FIGURE 11 100-YEAR AND 200-YEAR INFLOW BOUNDARY CONDITIONS FOR THE SACRAMENTO RIVER AND GEORGIANA SLOUGH……..18
FIGURE 12 100-YEAR AND 200-YEAR INFLOW BOUNDARY CONDITIONS FOR THE YOLO BYPASS…………………………………….18
FIGURE 13 100-YEAR AND 200-YEAR DOWNSTREAM STAGE BOUNDARY CONDITIONS FOR THE SACRAMENTO RIVER AT COLLINSVILLE AND THREEMILE SLOUGH AT THE SAN JOAQUIN RIVER. .................................................................19
FIGURE 14  LOCATIONS FOR STAGE COMPARISONS…………………………………………………………………………………………24
FIGURE 15 BASE AND ALTERNATIVE 2 COMPUTED STAGE (TOP) AND FLOW (BOTTOM) FOR THE MINER SLOUGH AT HWY 84 BRIDGE LOCATION FOR THE 100-YEAR EVENT FLOWS. ..................................................................................................................25
FIGURE 16 BASE AND ALTERNATIVE 2 COMPUTED STAGE (TOP) AND FLOW (BOTTOM) FOR THE MINER SLOUGH AT HWY 84 BRIDGE LOCATION FOR THE 200-YEAR EVENT FLOWS. ..................................................................................................................26
FIGURE 17 100-YEAR EVENT. (LEFT) COMPUTED CHANGE IN PEAK WATER SURFACE ELEVATION NEAR PROSPECT ISLAND FOR THE ALTERNATIVE 2 RESTORATION CONFIGURATION. (RIGHT) COMPUTED PEAK WATER SURFACE ELEVATIONS NEAR PROSPECT ISLAND FOR THE ALTERNATIVE 2 CONFIGURATION. …………………………………………………………..27
FIGURE 18 100-YEAR EVENT. COMPUTED CHANGE IN PEAK WATER SURFACE ELEVATION IN THE NORTH DELTA NEAR PROSPECT ISLAND FOR THE ALTERNATIVE 2 RESTORATION CONFIGURATION. …………………………………………………………..28
FIGURE 19 200-YEAR EVENT. (LEFT) COMPUTED CHANGE IN PEAK WATER SURFACE ELEVATION NEAR PROSPECT ISLAND FOR THE ALTERNATIVE 2 RESTORATION CONFIGURATION. (RIGHT) COMPUTED PEAK WATER SURFACE ELEVATIONS FOR THE NORTH DELTA NEAR PROSPECT ISLAND FOR THE ALTERNATIVE 2 CONFIGURATION. …………………………………………………………..29
FIGURE 20 200-YEAR EVENT. COMPUTED CHANGE IN PEAK WATER SURFACE ELEVATION IN THE NORTH DELTA NEAR PROSPECT ISLAND FOR THE ALTERNATIVE 2 RESTORATION CONFIGURATION. …………………………………………………………..30
FIGURE 21 COMPUTED VELOCITY MAGNITUDE FOR THE BASE AND ALTERNATIVE 2 100-YEAR FLOOD FLOW SIMULATIONS NEAR THE TIME OF PEAK STAGE ON JANUARY 20 @ 21:30………………………………………………………………………………………..31
FIGURE 22 COMPUTED CHANGE FROM BASE VELOCITY MAGNITUDE FOR ALTERNATIVE 2 FOR THE 100-YEAR FLOOD FLOW SIMULATION NEAR TIME OF PEAK STAGE ON JANUARY 20 @ 21:30. …………………………………………………………………………………………..32
FIGURE 23 THE COMPUTED FLOW REGIME AT THE SOUTH END OF PROSPECT ISLAND AND MINER SLOUGH FOR THE 100-YEAR FLOOD SIMULATION NEAR PEAK STAGE (JAN 20 @ 21:30) FOR THE ALTERNATIVE 2 CONFIGURATION. THE RED BAR INDICATES THE MINER SLOUGH CHANNEL SECTION FOR COMPUTING THE SECTION-AVERAGE VELOCITIES. THE VELOCITY MAGNITUDE (LEFT) AND AERIAL IMAGE (RIGHT) SHOW THE AVERAGING IS COMPUTED OVER THE MAIN PART OF THE MINER SLOUGH CHANNEL. …………………………………………………………………………………………..33
FIGURE 24 MINER SLOUGH CROSS-SECTION LOCATIONS FOR VELOCITY ANALYSIS………………………………………………………..34
FIGURE 25 BASE AND ALTERNATIVE 2 CHANNEL AVERAGED VELOCITY FOR THE MINER SLOUGH ABOVE THE ARROWHEAD MARINA LOCATION. RESULTS ARE FOR THE 100-YEAR FLOOD FLOW SIMULATION. …………………………………………………………………………………………..35
FIGURE 26 BASE AND ALTERNATIVE 2 CHANNEL AVERAGED VELOCITY FOR THE MINER SLOUGH CENTER LOCATION. RESULTS ARE FOR THE 100-YEAR FLOOD SIMULATION. …………………………………………………………………………………………..35
FIGURE 27 BASE AND ALTERNATIVE 2 CHANNEL AVERAGED VELOCITY FOR THE MINER SLOUGH BELOW CENTRAL BREACH LOCATION. RESULTS ARE FOR THE 100-YEAR FLOOD SIMULATION. …………………………………………………………………………………………..36
FIGURE 28 BASE AND ALTERNATIVE 2 CHANNEL AVERAGED VELOCITY FOR THE MINER SLOUGH BELOW SOUTH BREACH LOCATION. RESULTS ARE FOR THE 100-YEAR FLOOD SIMULATION. …………………………………………………………………………………………..36
FIGURE 29 COMPUTED VELOCITY MAGNITUDE FOR THE ALTERNATIVE 2 CONFIGURATION FOR THE 200-YEAR FLOOD FLOW SIMULATION NEAR THE TIME OF PEAK STAGE ON JANUARY 20 @ 20:15………………………………………………………………………………………..37
FIGURE 30 COMPUTED CHANGE FROM BASE VELOCITY MAGNITUDE FOR ALTERNATIVE 2 FOR THE 200-YEAR FLOOD FLOW SIMULATION NEAR TIME OF PEAK STAGE ON JANUARY 20 @ 20:15. …………………………………………………………………………………………..38
FIGURE 31 BASE AND ALTERNATIVE 2 CHANNEL AVERAGED VELOCITY FOR THE MINER SLOUGH ABOVE THE ARROWHEAD MARINA LOCATION. RESULTS ARE FOR THE 200-YEAR FLOOD FLOW SIMULATION. …………………………………………………………………………………………..39
FIGURE 32 BASE AND ALTERNATIVE 2 CHANNEL AVERAGED VELOCITY FOR THE MINER SLOUGH CENTER LOCATION. RESULTS ARE FOR THE 200-YEAR FLOOD SIMULATION. …………………………………………………………………………………………..39
FIGURE 33 BASE AND ALTERNATIVE 2 CHANNEL AVERAGED VELOCITY FOR THE MINER SLOUGH BELOW CENTRAL BREACH LOCATION. RESULTS ARE FOR THE 200-YEAR FLOOD SIMULATION. …………………………………………………………………………………………..40
FIGURE 34  Base and Alternative 2 channel averaged velocity for the Miner Slough below South Breach location. Results are for the 100-year flood flow simulation. .................................................................40

FIGURE 35  Comparison of RMA 2 and HEC-RAS computed flow just upstream of Rio Vista (top) and stage at Rio Vista (bottom) for the 100-year event. .........................................................................................43

FIGURE 36  Comparison of RMA 2 and HEC-RAS computed flow just upstream of Rio Vista (top) and stage at Rio Vista (bottom) for the 200-year event. .........................................................................................44

LIST OF TABLES

TABLE 1. Channel and breach dimensions for the Alternative 2 configuration .................................................................2

TABLE 2  Comparison of HEC-RAS flow hydrograph locations to RMA2 boundary condition locations for the Sacramento River and Yolo Bypass inflows. .........................................................................................13

TABLE 3  Flows at max stage for the Sacramento River, Yolo Bypass and Georgiana Slough for the 100-year and 200-year flood flow events. Provided by MBK HEC-RAS model. .........................................................................................14

TABLE 4  Computed Miner Slough and North Delta peak water surface elevation and stage change with development of the Prospect Island restoration project for locations shown in Figure 14. .........................................................................................21

TABLE 5  Computed channel averaged velocities for the Miner Slough locations shown in Figure 24. Results are for time of peak stage for the 100-year and 200-year events. .........................................................................................23

TABLE 6  Comparison of RMA2 and HEC-RAS computed peak water surface elevations for selected North Delta stations (see Figure 14). .........................................................................................42
Introduction

The Prospect Island Tidal Habitat Restoration Project is an approximately 1600-acre site (DWR, 2016) located in the northern Sacramento-San Joaquin Delta, bounded by Miner Slough on the east and the Sacramento Deep Water Ship Channel (DWSC) on the west (Figure 1). The restoration project entails the breaching to Miner Slough at two locations to provide tidal flow onto the site. Currently the site is divided by an internal east-west cross levee into a south property and a north property.

RMA performed an earlier high flow analysis for the “Proposed Project” configuration in 2015 (RMA, 2015). The Proposed Project included a breach to Miner Slough near the northwest end of the site, and a second breach to be constructed on the south property to the spur channel connecting to Miner Slough. The interior cross levee would be partially breached to hydraulically connect the north and south Prospect Island.

The modeling analysis presented in this document is for the CEQA Alternative 2 configuration. Similar to the “Proposed Project” design, the Alternative 2 configuration includes the south property breach to the spur channel and the breach of the cross levee to connect the north and south Prospect Island properties. The north breach is replaced by a “central” Miner Slough breach, located a short distance north of the cross-levee.

The purpose of the current analysis is to evaluate the potential changes in the surrounding North Delta stage and potential scour in Miner Slough during high flow events (100-year and 200-year) with the Alternative 2 restoration design. The analysis was performed applying the RMA2 hydrodynamic numerical model program for a north Delta model network. This report provides a detailed description of numerical modeling performed and the results of the analysis.

Alternative 2 Configuration

Figure 2 presents the existing Prospect Island topography and the planned breaching and interior modifications associated with the Alternative 2 design. The features of the restoration project designed to enhance the tidal exchange to the site include (DWR, 2016):

1) Construct a “Central” breach to Miner Slough sited just north of the interior cross-levee.
2) Construct a “South” breach connecting the south property to the spur channel to Miner Slough.
3) Breach or partial removal of interior cross-levee to connect the north and south properties.
4) Excavate tidal channels to increase internal tidal circulation and external connectivity.

Additional project items include (Figure 2):

5) Construction of a high stage overflow weir in the far northeast corner of the island near the Arrowhead Marina (“North Miner Weir”).

6) Placement of excavated material on the interior side of the eastern levee (“Toe Berms”).

The dimensions and elevations for the breaches, tidal channels and north Miner weir are listed in Table 1.

Table 1. Channel and breach dimensions for the Alternative 2 configuration

<table>
<thead>
<tr>
<th>Feature</th>
<th>Width at Invert</th>
<th>Elevation at Invert</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Breach</td>
<td>400 ft</td>
<td>- 4 ft NAVD88</td>
</tr>
<tr>
<td>Central Breach</td>
<td>490 ft</td>
<td>- 1 ft NAVD88</td>
</tr>
<tr>
<td>Cross-Levee Breach</td>
<td>220 ft</td>
<td>- 4 ft NAVD88</td>
</tr>
<tr>
<td>Tidal Channels</td>
<td>50 ft</td>
<td>- 3 ft NAVD88</td>
</tr>
<tr>
<td>North Miner Weir</td>
<td>Approx. 700 ft at invert</td>
<td>+ 7 ft NAVD88</td>
</tr>
<tr>
<td></td>
<td>Approx. 900 ft at top</td>
<td></td>
</tr>
</tbody>
</table>

Channel and breach side slopes, H:V = 2.5:1
South breach and the Interior Cross-Levee breach taper into tidal channels.

RMA2

The hydrodynamic simulation program used is the RMA2 finite element based program for the computation of two-dimensional depth-averaged steady and unsteady flow. The model computes water surface elevations and horizontal flow velocity in one and two dimensions. The RMA2 engine supports combining two-dimensional depth-averaged (2-D) computational elements and one-dimensional cross-sectionally averaged (1-D) elements in a single mesh. Generally large channels, bays and floodplains are represented by 2-D elements and narrower channelized flows are modeled with the 1-D elements.

Two versions of the RMA2 program are discussed, the United States Army Corps of Engineers (USACE) version of the RMA2 program (RMA2 WES) and RMA’s in-house version of RMA2. The RMA2 WES is maintained and supported by the USACE at its Engineer Research and Development Center (ERDC). The RMA2 WES v. 4.5 is commercially distributed with the Surface Water Modeling System (SMS) package from Aquaveo, LLC. The governing equations and the
model use are documented in detail in the “Users Guide to RMA2 WES Version 4.5” (USACE, 2011). The RMA2 WES version of the program has been applied to portions of the Lower Sacramento Basin system in other flood studies. For example, an RMA2 based model system has been developed for the Yolo Bypass by the USACE (2007).

The version of the RMA2 program applied to the current analysis is the Resource Management Associates, Inc. (RMA) in-house version of the numerical model program. At its core, RMA’s version of the RMA2 program is the same as the RMA2 WES. RMA has updated the equation solver to use the PARDISO solver available in the Intel Fortran package. The PARDISO module is an efficient parallel direct sparse solver that is many times faster than the standard RMA2 solver for the size system of the study. The in-house version of the RMA2 program includes 2-D flow control structure element types. These are employed in the model to simulate flow for weirs, levees and gates. In particular, the 2-D levee elements are used for representing many of the levees in the flood flow model analysis. Similar 2-D flow control elements are enabled with the RMA2 WES version available to the USACE, but not in the publicly distributed version of the program.
Figure 1 Location of the Prospect Island tidal habitat restoration site in the northern Delta.
Figure 2  (left) Existing topography for the Prospect Island restoration site (data from Stillwater Sciences).  (right) Design features for Alternative 2.
Model Configuration

This section provides a brief description of the RMA north Delta model network used for the analysis. The north Delta RMA2 model network and 100-year and 200-year boundary conditions are similar to those applied to a recent flood flow analysis for the Decker Island Restoration study (RMA, 2016).

The 100-year and 200-year flow events were modeled using a subset of the Bay-Delta RMA2 grid (Figure 3) developed in support of the Central Valley Flood Protection Plan (CVFPP). This is a high flow network that accommodates the flood water filling of the lower Yolo Bypass, including Little Egbert Tract and Prospect Island. The model grid includes the overbank areas adjacent the Delta channels and permits the simulation of levee overtopping flow and levee failure. The model domain was limited to the North Delta to fit the locations of the available 100-year and 200-year flood flow boundary conditions provided by MBK Engineers from their HEC-RAS Sacramento Basin system model. The downstream boundaries of the HEC-RAS model are located on the lower Sacramento River near Collinsville and Threemile Slough at the junction with the San Joaquin River (Figure 3).

The grid for the lower Yolo Bypass and Cache Slough Complex were originally extracted from the USACE’s (2007) Yolo Bypass RMA2 model. These areas were updated with more recent topography information and refined in the development of the Lower Sacramento Bypass RMA2 2-D Model (2013). Representation of the restricted height levees for Little Egbert Tract bordering Cache Slough and for Prospect Island were updated to use 2-D levee/weir elements. Flow over the levee elements is free flow, submerged flow or flow with simple friction loss. Free flow and submerged flow are modeled based on methods developed by Kindsvater (1964) for embankment shaped weirs with correction to the discharge coefficient for submerged flow. Under certain submerged flow conditions such as a small upstream/downstream head differential, shallow depth of flow and a wide crest, the head loss reduces to a simple Manning’s friction equation. Overall the 2-D levee/weir elements provide some additional numerical stability at the onset of levee overtopping flow onto dry land.

Flow from the river channels and flood bypasses to the overbank areas (Figure 8) can occur by levee overtopping or levee failure. No levee failure was modeled for the flood flow analysis, but some levee overtopping flow in to the Delta islands did occur for the 200-year simulation and a small amount for the 100-year run.

The north Delta grid used in the present evaluation also carries over grid refinement added for the Miner Slough velocity and scour analysis associated with the 2015 study for the Prospect Island Tidal Restoration Project (RMA, 2015) and the 2016 high flow analysis for the Decker
Island Restoration Project (RMA, 2016). Levee crest elevations for Prospect Island were set using the Prospect Island DEM provided by Stillwater Sciences for the 2015 study. Other north Delta levee, island and flood plain elevations were set by applying the LiDAR data collected and processed for the CVFED project or from the DWR 2007 Delta LiDAR survey.

Detailed models grids of the Prospect Island interior for the Base and Alternative 2 geometries were developed from DEM and CAD files provided by Stillwater Sciences for the current study. The north Delta RMA2 high flow grid is primarily that used for the Decker Island flood flow analysis (RMA, 2016), with the above updates to the Prospect Island representation. Figure 4 shows detail of the Alternative 2 model grid for the Prospect Island region.

Manning’s Friction Coefficients

The Manning’s friction coefficients assigned for the Prospect Island interior can be viewed in Figure 5. The friction type classifications generally followed those identified for the 2015 high flow analysis (RMA, 2015). The interior island areas from 0 to 6 feet NAVD88 were classified as shallow subtidal and intertidal emergent wetland. For the high flood-flow conditions of the analysis, this area type was modeled with an “n” value of 0.06. This was the value calibrated for the tules and reeds of northern Liberty Island for the Lower Sacramento Bypass 2-D RMA2 flood flow model (RMA, 2013)1. Island regions below 0 ft NAVD88 were classified as moderate subtidal (tidal, perennial aquatic) and were modeled using an “n” value of 0.035, similar to the value used for the shallow open water areas in other parts of the grid. The excavated tidal and breach channels are modeled using an “n” value of 0.032.

The Manning’s friction coefficients applied for the overall model are shown in Figure 6 and Figure 7.

Figure 3  RMA2 grid developed in support of the Central Valley Protection Plan (CVFPP) modeling analysis. The north Delta portion of the grid was extracted and used for the flood flow (100-year and 200-year) Prospect Island restoration analysis.
Figure 4  Model network detail near Prospect Island for the CEQA Alternative 2 high flow grid.
“n” Value Classification

- **Emergent Wetland, Intertidal and shallow subtidal**, 0.060
- **Tidal, Perennial Aquatic**
  - 0.035
- **Tidal Channels and Breaches**, 0.032
- **Riparian**, 0.120
- **Grassland**
  - 0.040 – 0.045
- **Old South Breach Rock Weir (Base)**, 0.080

**Figure 5** Base and Alternative 2 Manning’s “n” value classification for the Prospect Island interior.
Figure 6  Manning’s friction coefficients used for the flood event analysis for the channels and flood bypass areas of the north Delta. Friction coefficients for the overbank areas (see Figure 8) were set to 0.040.
Figure 7  Manning’s friction coefficients used for the flood event analysis for the lower Sacramento River region.
100-Year and 200-Year Flood Flow Analysis

Introduction

100-year and 200-year flow and stage boundary conditions were applied to the north Delta RMA2 network for the purpose of evaluating the flow and stage impacts of the Prospect Island tidal restoration following the Alternative 2 configuration. The RMA2 model simulations were performed in dynamic or unsteady flow mode with time varying inflows and downstream stage boundary conditions.

Model Boundary Conditions

Time varying 100-year and 200-year flow and stage boundary conditions for the flood flow analysis were provided by MBK Engineers from HEC-RAS model simulation output. The primary model inflow boundary conditions were the Sacramento River below the American River confluence and the Yolo Bypass a distance above Liberty Island (Figure 8). The other major flow boundary condition to the model was the downstream outflow from Georgiana Slough. Separate downstream stage boundary conditions were applied to the lower Sacramento River above the confluence with the San Joaquin near Collinsville and to the Threemile Slough channel above the junction with the San Joaquin River.

The RMA2 model flow boundary locations for the Sacramento River and the Yolo Bypass are offset some from the HEC-RAS flow time series locations. The HEC-RAS computed flow reported at RM 46.4198, near Freeport, was applied for the RMA2 Sacramento River inflow. The RMA2 Yolo Bypass inflow applied the HEC-RAS hydrograph output from a location somewhat further upstream on the Yolo Bypass. A comparison of the RMA2 and HEC-RAS hydrograph locations for the Sacramento River and Yolo Bypass inflow boundary conditions are provided in Figure 8 and Table 2.

Table 2  Comparison of HEC-RAS flow hydrograph locations to RMA2 boundary condition locations for the Sacramento River and Yolo Bypass inflows.

<table>
<thead>
<tr>
<th>Flow Boundary Condition</th>
<th>HEC-RAS Model Flow Location River Mile</th>
<th>RMA2 BC, HEC-RAS River Mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yolo Bypass</td>
<td>38.522</td>
<td>31.554</td>
</tr>
<tr>
<td>Sacramento River</td>
<td>46.4198</td>
<td>60.3928</td>
</tr>
</tbody>
</table>

Following the procedure developed in the Decker Island restoration flood flow analysis (RMA, 2016), the Sacramento River and Yolo Bypass boundary conditions were shifted slightly in time to correct for the difference in the HEC-RAS and RMA2 boundary locations. The HEC-RAS...
Hydrograph used for the Sacramento River boundary condition was advanced 3 hours before applying to the RMA2 boundary location to adjust for the travel time between the HEC-RAS Freeport location (RM 46.4198) and the RMA2 Sacramento River inflow location below the American River confluence. Figure 9 illustrates that the 3-hour time shift of the HEC-RAS flow can correct for the difference between the HEC-RAS flow location and the RMA2 inflow boundary location (RMA, 2016).

Similarly, the HEC-RAS hydrograph used for the Yolo Bypass inflow was from a location upstream of the RMA2 Yolo Bypass inflow boundary location (Figure 8). In this case the HEC-RAS hydrograph was lagged 3 hours before applying to the RMA2 model. Figure 10 compares 100-year event HEC-RAS and RMA2 computed flows further down in the Yolo Bypass, just above Cache Slough. The plot shows the improved timing match at the peak flow when using the lagged Yolo inflow hydrograph.

Figure 11 and Figure 12 present the 100-year and 200-year boundary inflows for the Sacramento River and the Yolo Bypass. The Georgiana Slough flow in Figure 11 represents outflow from the network. The Georgiana Slough outflow was derived by differencing the HEC-RAS Sacramento channel flows just upstream and just downstream from the confluence with Georgiana Slough. The boundary condition flows at peak stage for the 100-year and 200-year flood events are summarized in Table 3.

Nominal 100 cfs constant inflows were applied to the Cache Slough and Lindsey Slough inflows (Figure 8) to match the MBK HEC-RAS model.

Dynamic stage boundary conditions were provided in the MBK data set for the lower Sacramento River at Collinsville and Threemile Slough at the San Joaquin River (Figure 13). The hourly interval stage data provided by MBK were cubic spline interpolated to a 5-minute interval for simulations. Notable is that the time of peak downstream stage precedes the time of the peak inflows.

Table 3 Flows at max stage for the Sacramento River, Yolo Bypass and Georgiana Slough for the 100-year and 200-year flood flow events. Provided by MBK HEC-RAS model.

<table>
<thead>
<tr>
<th>Locations</th>
<th>MBK Model Locations</th>
<th>Flow at Max Stage (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>100-year</td>
</tr>
<tr>
<td>Yolo Bypass near Yolano</td>
<td>Yolo Bypass/Putah to Cache S/30.981</td>
<td>550,900</td>
</tr>
<tr>
<td>Sac R at Freeport</td>
<td>Sac River/DS American/46.4177</td>
<td>117,800</td>
</tr>
<tr>
<td>Georgiana</td>
<td>Georgiana Slough/12.3652</td>
<td>22,250</td>
</tr>
</tbody>
</table>
Figure 8 Boundary condition locations for 100-yr and 200-yr event runs. The overbank areas can receive flow from levee overtopping of main channels and bypass.
Figure 9  Comparison of Sacramento River model flows at Freeport (RM 46.4198) for the 100-year event. The plot shows the HEC-RAS hydrograph at Freeport (blue), the RMA2 computed flow at Freeport (green) using a time shifted boundary condition and the RMA2 computed flow at Freeport with no time shifted boundary condition (red).
Figure 10  Comparison of Lower Yolo Bypass model flows just above Cache Slough (RM 20.839) for the 100-year event. The plot shows the HEC-RAS hydrograph (blue), the RMA2 computed flow (green) using a time shifted Yolo inflow boundary condition and the RMA2 computed flow with no time shifted boundary condition (red).
Figure 11  100-year and 200-year inflow boundary conditions for the Sacramento River and Georgiana Slough.

Figure 12  100-year and 200-year inflow boundary conditions for the Yolo Bypass.
Figure 13  100-year and 200-year downstream stage boundary conditions for the Sacramento River at Collinsville and Threemile Slough at the San Joaquin River.
*Model Results*

Model results are presented that examine the changes in peak stages near Prospect Island and current velocities in Miner Slough with development of the Prospect Island restoration project with the Alternative 2 configuration. Figure 15 compares the Base and Alternative 2 computed stage and flow time series for Miner Slough at the Hwy 84 Bridge location (Figure 14) just upstream of Prospect Island for the 100-year event. The time series for the 200-year event is presented in Figure 16. The plots show development of the Prospect Island restoration with the Alternative 2 design leads to a small decrease in upstream peak stage and a small increase in the flow at time of peak stage. Prior to the time of peak stage, the stage decrease and flow increase are more visible. The Alternative 2 configuration includes a north Miner overflow weir (Figure 2). A trial run of the Alternative 2 configuration without the north Miner weir indicated most of the described stage and flow changes are related to the presence of the weir.

*Stage Analysis*

Computed results are presented as spatial plots and tables of change in peak flood water surface elevation (WSE) with development of an Alternative 2 Prospect Island restoration project. Locations referenced in the discussion are indicated in Figure 14.

Figure 17 presents a spatial plot of the computed stage change and peak water surface elevation near Prospect Island for the 100-year event with the Alternative 2 project. The computed change in 100-year peak WSE for north Delta locations further out from Prospect Island is shown in Figure 18. The plots indicate the Alternative 2 project slightly reduces stage in Miner Slough upstream of Prospect Island (Figure 15) and at some other north Delta channels. The computed peak WSE increased by +0.01 ft for Miner Slough near the south end of Prospect Island. Figure 17 indicates for the land immediately north of Prospect Island, the peak water surface elevation increases +0.08 ft. However, this parcel is shown to be part of the Yolo Bypass floodway (DWR, 2016) and the land does not become fully filled with flood water, with the peak computed water surface elevation limited to +7.87 ft NAVD88.

Figure 19 and Figure 20 present similar result plots of change in computed peak water surface elevation for the 200-year event. The increase in peak WSE for Miner Slough near the south end of Prospect Island is <0.01 ft. The computed peak WSE decreases slightly in Miner Slough upstream of Prospect Island, but less than for the 100-year event simulations. Changes in WSE (primarily decreases) in the other north Delta channels are also less for the 200-year event versus the 100-year event.

Figure 19 shows for the 200-year model results there was some overtopping flow into Hastings Tract and Egbert Tract, west of the Yolo floodway. Computed inundation increased very slightly, +0.01 ft for Egbert Tract and +0.02 ft for Hasting Tract (Figure 20).
The change in peak water surface elevations tabulated for selected Miner Slough and north Delta locations (Figure 14) are presented in Table 4. For both the 100-year and 200-year event flows, maximum increase in peak WSE for Miner Slough is +0.01 feet or less. Upstream of Prospect Island, the computed peak WSE decreases for Miner Slough.

Table 4 Computed Miner Slough and north Delta Peak Water Surface Elevation and stage change with development of the Prospect Island restoration project for locations shown in Figure 14.

<table>
<thead>
<tr>
<th>Location</th>
<th>100-year Event</th>
<th>200-year Event</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peak WS Elevation (feet NAVD88)</td>
<td>D WSE (feet)</td>
</tr>
<tr>
<td></td>
<td>Base</td>
<td>Alt2</td>
</tr>
<tr>
<td>Miner Sl below South Breach</td>
<td>18.240</td>
<td>18.250</td>
</tr>
<tr>
<td>Miner Slough Center</td>
<td>18.717</td>
<td>18.719</td>
</tr>
<tr>
<td>Miner Sl at Hwy 84 Bridge</td>
<td>18.947</td>
<td>18.863</td>
</tr>
<tr>
<td>Rio Vista</td>
<td>10.792</td>
<td>10.792</td>
</tr>
<tr>
<td>Steamboat Sl below Sutter</td>
<td>16.830</td>
<td>16.803</td>
</tr>
<tr>
<td>Sac R at Walnut Grove</td>
<td>17.331</td>
<td>17.311</td>
</tr>
<tr>
<td>Sac R above Sutter Sl</td>
<td>21.153</td>
<td>21.126</td>
</tr>
</tbody>
</table>

Figure 17 and Figure 19 indicate little change in the peak WSE inside Prospect Island. A small increase of +0.02 ft occurs in the spur channel just outside the south breach, with all other changes in the area +0.01 ft or less.

Miner Slough Velocity Analysis
Computed results are presented as spatial plots of velocity magnitude at peak stage and velocity time series at selected locations.

Figure 21 shows the computed velocity field at peak stage (Jan 20 @ 21:30) for the 100-year event in and around Prospect Island for the Base and Alternative 2 configurations. The Alternative 2 velocity magnitude was differenced from Base and the change plotted in Figure 22. The figure shows the computed current velocities in Miner Slough decreased with the project just downstream of the north Miner weir, with the velocity differences disappearing further downstream. Some small velocity increases occurred inside Prospect Island adjacent...
the north Miner weir. However, the absolute magnitude was at the most around 1 fps (Figure 21). The Alternative 2 project produced a small velocity increase in the spur channel just outside the south breach of about 1.2 fps. The overall velocity here was less than 2 fps with the project.

Velocity time series plots were produced for channel averaged velocities across the main Miner Slough flow channel as illustrated in Figure 23. The four Miner Slough locations plotted are indicated in Figure 24 and the time series plots presented in Figure 25 to Figure 28 for the 100-year event. Peak flood conditions developed primarily after 12:00 Jan 19. After that time, Base and Alternative 2 project velocities were nearly the same, with velocities at the Miner Slough Center location somewhat lower. For the Miner Slough Center and Miner Slough below Central Breach locations, Alternative 2 velocities were more visibly lower for the time preceding peak flood (before 12:00 Jan 19). The Alternative 2 velocities were higher for Miner Slough above Arrowhead Marina (about 1 fps) and Miner Slough below South Breach locations preceding the peak flood.

Results for the 200-year event simulation runs are presented with the spatial plot of velocity magnitude change shown in Figure 30 and the time series plots of Miner Slough channel averaged velocities in Figure 31 to Figure 34. The velocity magnitude and current vectors at time of peak stage, Jan 20 @ 20:15, in the vicinity of Prospect Island is shown in Figure 29 for the Alternative 2 simulation. Overall, the velocity magnitude differences between Base and the Alternative 2 project for the 200-year event were similar in character to the 100-year event. Miner Slough current velocities downstream of the north Miner weir were reduced with the Alternative 2 configuration for the 200-year event, but somewhat less so than for the 100-year event. Velocity change in the spur channel outside the south breach was somewhat higher at 1.6 fps for the 200-year event results versus the 1.2 fps for the 100-year event. However, absolute current velocities at peak stage outside the south breach were less than 2 fps (Figure 29).

The channel averaged velocities at peak stage for the four velocity cross section locations (Figure 24) are summarized in Table 5. For both the 100-year and 200-year event flows, the velocity increases with the Alternative 2 are < 0.1 fps during the time of peak flood stage.
Table 5  Computed channel averaged velocities for the Miner Slough locations shown in Figure 24. Results are for time of peak stage for the 100-year and 200-year events.

<table>
<thead>
<tr>
<th>Location</th>
<th>100-year Event</th>
<th></th>
<th>200-year Event</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Channel Velocity at Peak Stage&lt;sup&gt;1&lt;/sup&gt; (fps)</td>
<td>D Vel (fps)</td>
<td>Channel Velocity at Peak Stage&lt;sup&gt;2&lt;/sup&gt; (fps)</td>
<td>D Vel (fps)</td>
</tr>
<tr>
<td></td>
<td>Base</td>
<td>Alt2</td>
<td></td>
<td>Base</td>
</tr>
<tr>
<td>Miner Slough above Arrowhead Marina</td>
<td>2.052</td>
<td>2.116</td>
<td>+0.07</td>
<td>1.940</td>
</tr>
<tr>
<td>Miner Slough Center</td>
<td>0.422</td>
<td>0.176</td>
<td>-0.25</td>
<td>0.396</td>
</tr>
<tr>
<td>Miner Slough Below Central Breach</td>
<td>0.890</td>
<td>0.908</td>
<td>+0.02</td>
<td>1.582</td>
</tr>
<tr>
<td>Miner Slough below South Breach</td>
<td>3.185</td>
<td>3.190</td>
<td>+0.01</td>
<td>3.228</td>
</tr>
</tbody>
</table>

<sup>1</sup> JAN 20 @ 21:30

<sup>2</sup> JAN 20 @ 20:15
Figure 14. Locations for stage comparisons.
Figure 15  Base and Alternative 2 computed stage (top) and flow (bottom) for the Miner Slough at Hwy 84 Bridge location for the 100-year event flows.
Figure 16  Base and Alternative 2 computed stage (top) and flow (bottom) for the Miner Slough at Hwy 84 Bridge location for the 200-year event flows.
Figure 17  100-year event.  (left) Computed change in peak water surface elevation near Prospect Island for the Alternative 2 restoration configuration.  (right) Computed peak water surface elevations near Prospect Island for the Alternative 2 configuration.
Figure 18  100-year event. Computed change in peak water surface elevation in the north Delta near Prospect Island for the Alternative 2 restoration configuration.
Figure 19  200-year event. (left) Computed change in peak water surface elevation near Prospect Island for the Alternative 2 restoration configuration. (right) Computed peak water surface elevations for the north Delta near Prospect Island for the Alternative 2 configuration.
Figure 20  200-year event. Computed change in peak water surface elevation in the north Delta near Prospect Island for the Alternative 2 restoration configuration.
Figure 21 Computed velocity magnitude for the Base and Alternative 2 100-year flood flow simulations near the time of peak stage on January 20 @ 21:30.
Figure 22  Computed change from Base velocity magnitude for Alternative 2 for the 100-year flood flow simulation near time of peak stage on January 20 @ 21:30.
Figure 23  The computed flow regime at the south end of Prospect Island and Miner Slough for the 100-year flood simulation near peak stage (Jan 20 @21:30) for the Alternative 2 configuration. The red bar indicates the Miner Slough channel section for computing the section-average velocities. The velocity magnitude (left) and aerial image (right) show the averaging is computed over the main part of the Miner Slough channel.
Figure 24  Miner Slough cross-section locations for velocity analysis.
Figure 25  Base and Alternative 2 channel averaged velocity for the Miner Slough above the Arrowhead Marina location. Results are for the 100-year flood flow simulation.

Figure 26  Base and Alternative 2 channel averaged velocity for the Miner Slough Center location. Results are for the 100-year flood flow simulation.
Figure 27  Base and Alternative 2 channel averaged velocity for the Miner Slough below Central Breach location. Results are for the 100-year flood flow simulation.

Figure 28  Base and Alternative 2 channel averaged velocity for the Miner Slough below South Breach location. Results are for the 100-year flood flow simulation.
Figure 29 Computed velocity magnitude for the Alternative 2 configuration for the 200-year flood flow simulation near the time of peak stage on January 20 @ 20:15.
Figure 30  Computed change from Base velocity magnitude for Alternative 2 for the 200-year flood flow simulation near time of peak stage on January 20 @ 20:15
Figure 31  Base and Alternative 2 channel averaged velocity for the Miner Slough above the Arrowhead Marina location. Results are for the 200-year flood flow simulation.

Figure 32  Base and Alternative 2 channel averaged velocity for the Miner Slough Center location. Results are for the 200-year flood flow simulation.
Figure 33  Base and Alternative 2 channel averaged velocity for the Miner Slough below Central Breach location. Results are for the 200-year flood flow simulation.

Figure 34  Base and Alternative 2 channel averaged velocity for the Miner Slough below South Breach location. Results are for the 100-year flood flow simulation.
**RMA2, HEC-RAS Model Comparison**

As a check of the RMA2 model, computed stage and flow for the RMA2 (Base condition) and HEC-RAS MBK models are compared for the lower Sacramento River. Figure 35 and Figure 36 present the computed flow and stage near Rio Vista for the two models for the 100-year and 200-year events respectively. For the location just above Rio Vista, the RMA2 computed stage and flow track the HEC-RAS computed values up to Jan 19 @ 21:00 for the 100-year event and Jan 19 @ 13:45 for the 200-year event. Afterwards, the RMA2 flow exceeds the HEC-RAS flow. These RMA2 flow increases occur when the Little Egbert Tract completely fills and water flowing into and through the tract return back to the Sacramento River, whereas the HEC-RAS computed flows indicate continued filling of overbank storage.

For the 100-year event, computed peak WSE at Rio Vista was 10.79 ft NAVD88 for the RMA2 model and 10.65 ft NAVD88 for the HEC-RAS result. Similarly, the 200-year event computed peak WSE at Rio Vista was 11.86 ft NAVD88 for the RMA2 model and 11.34 ft NAVD88 for the HEC-RAS model. As Figure 35 and Figure 36 indicate, the model peak WSE difference at Rio Vista reflects the increased peak flow for the lower Sacramento River with the RMA2 runs.

Table 6 compares the RMA2 and HEC-RAS computed peak stage for 100-year and 200-year event flows for Miner Slough upstream of Prospect Island and four other north Delta locations (Figure 14). For the 100-year event, RMA2 computed peak stage was 0.16 feet higher than the HEC-RAS value for the Miner Slough location. Similarly, the RMA2 model was 0.14 feet higher at the Rio Vista location and 0.18 feet higher for the Sacramento River above Sutter Slough. The model differences at the Walnut Grove and Steamboat Slough locations were more notable.

For the 200-year event run, the RMA2 model peak WSE at the Miner Slough locations was 0.67 ft above the HEC-RAS value, and at least partially reflects the higher peak flow in lower Cache Slough and the lower Sacramento River as seen at Rio Vista in the RMA2 model (Figure 36).
Table 6  Comparison of RMA2 and HEC-RAS computed peak water surface elevations for selected north Delta Stations (see Figure 14).

<table>
<thead>
<tr>
<th>Location</th>
<th>100-yr Peak WS Elev (feet NAVD88)</th>
<th>200-yr Peak WS Elev (feet NAVD88)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RMA2</td>
<td>HEC-RAS</td>
</tr>
<tr>
<td>Miner Slough at Hwy 84 Bridge</td>
<td>18.95</td>
<td>18.79</td>
</tr>
<tr>
<td>Sac R at Rio Vista (RM 12.8815)</td>
<td>10.79</td>
<td>10.65</td>
</tr>
<tr>
<td>Sac R above Sutter Slough</td>
<td>21.15</td>
<td>20.97</td>
</tr>
<tr>
<td>Steamboat Slough below Sutter</td>
<td>16.83</td>
<td>15.90</td>
</tr>
<tr>
<td>Sac R at Walnut Grove</td>
<td>17.33</td>
<td>16.85</td>
</tr>
</tbody>
</table>
Figure 35  Comparison of RMA 2 and HEC-RAS computed flow just upstream of Rio Vista (top) and stage at Rio Vista (bottom) for the 100-year event.
Figure 36  Comparison of RMA 2 and HEC-RAS computed flow just upstream of Rio Vista (top) and stage at Rio Vista (bottom) for the 200-year event.
References

Department of Water Resources and Department of Fish and Wildlife (DWR). 2016. *Prospect Island Tidal Habitat Restoration Project Draft Environmental Impact Report*. Prepared by the California Department of Water Resources, Fish Restoration Program, Division of Environmental Services, West Sacramento, CA and California Department of Fish and Wildlife, Fish Restoration Program, Bay Delta Region (Region 3), Stockton, CA. August.


