

NHC Ref. No. 5006208

26 September 2023

Westervelt Ecological Services
600 North Market Blvd, Suite 3
Sacramento, CA
95834

Attention: Allegra Bukojemsky

Re: Background for the 65% Design of the Zacharias Ranch Restoration Site

Dear Ms. Bukojemsky:

Northwest Hydraulic Consultants (NHC) has completed the 65% Design for the Zacharias Ranch restoration site as a part of its contract with Westervelt Ecological Services (Westervelt). The work completed to date includes the evaluation of local tide gage data, development of a long-term tide model of the site, the design of two preliminary channel configurations to promote full tidal exchange once the site is breached, and the 65% design for the project.

The following data sets were used to complete the analyses described in this report:

1. Zacharias surface model provided by Westervelt in the CAD file "ZR_Surface.dwg"
2. 15-min Zacharias Ranch tide data provided by Westervelt in the Excel spreadsheet "ZR_Hyro-All To Date_2021-0813.xlsx"
3. 15-min tide data from USGS gage 11336600 DELTA CROSS CHANNEL NR WALNUT GROVE (https://waterdata.usgs.gov/ca/nwis/uv/?site_no=11336600&PARAMeter_cd=00065,00060)
4. 1-hour tide data from CDEC gage Mokelumne River at Benson's Ferry on Thornton Rd (BEN) (https://cdec.water.ca.gov/jspplot/jspPlotServlet.jsp?sensor_no=103&end=08%2F24%2F2021+12%3A09&geom=huge&interval=10&cookies=CDEC01)
5. Variable (about 20-min) tide data from Sacramento County Snodgrass at Lambert Road (https://sacflood.org/sensor/?time_zone=US%2FPacific&site_id=1130&site=b5e1d541-c031-4781-9e85-123d8ad12ada&device_id=1&device=3d480b55-87a5-42c4-93bb-40f3bb05ec57&bin=86400&range=Custom%20Range&markers=false&legend=true&thresholds=true&refresh=off&show_raw=true&show_quality=true&data_start=2021-04-08%2000%3A00%3A00&data_end=2021-08-13%2023%3A59%3A59)

The CAD surface file provided by Westervelt (ZR_Surface.dwg) was used to define the existing conditions topography of Zacharias Ranch and the surrounding flood protection levees. A recent 2022 survey at the proposed location of the Northern Breach was also included in the existing conditions surface. The other four data sets listed above were used to analyze local tides near the site and develop a historical tide model for defining tide levels as a part of the channel design. All tide data and elevations presented here use the NAVD88 vertical datum.

1.0 Zacharias Ranch Background

The Zacharias Ranch restoration site is located to the west of Highway 5 between Lambert Road and Twin Cities Road. The total property is about 600 acres in size and lies between Snodgrass Slough to the west and an abandoned railroad berm to the east. Zacharias Ranch is intended to be restored to tidal action by breaching the perimeter levee and re-connecting the site to Snodgrass Slough. Excluding the perimeter levees, topography of the site is mostly flat with elevations that generally range between 2.4 to 4 feet. Some higher ground exists in the northern regions of the site with elevations as high as 8 feet. The surrounding levee system has crest elevations that range between 13 feet along the west and southwest, 9.5 feet in the north, and up to 23 feet along the railroad berm to the east. Land use in Zacharias has generally been agricultural with crops cultivated throughout the spring through fall growing seasons. The site is drained by several small canals that run east and west and connect to a large canal on the eastern side that runs north and south, referred to as the Rail Road Cut. This canal was originally excavated for material to construct the railroad berm on the east side. The Rail Road Cut connects to Snodgrass Slough in the south by three 8-foot diameter culverts with tide gates that are generally closed. Two protected areas exist at the site that are to remain undisturbed by the proposed restoration works.

2.0 Available Tide Data

The observed Zacharias Ranch tide data provided by Westervelt was collected on-site from April 8 to August 13 in 2021. Data loggers were located at four locations: (1) in Snodgrass Slough to the south of the culverts (South Snodgrass), (2) in the Rail Road Cut canal north of the tide gates (South Canal), (3) in the Rail Road Cut canal in the north of the site (North Canal), and (4) in Snodgrass Slough near the north of the site (North Snodgrass). The data measurements were collected in 15-minute intervals and were ultimately converted to water surface elevation on the NAVD88 vertical datum.

Tide data from three nearby gaging stations were also analyzed during the same time period as the Zacharias data to determine which of these might have a reasonable correlation for developing a historical tide model at the site. The stations were located at the Delta Cross Channel (USGS 11336600), the Benson's Ferry Thornton Road Bridge over the Mokelumne River (CDEC BEN), and Snodgrass Slough at Lambert Road (Sacramento County). Figures 1 through 3 present comparisons of each data set to the Snodgrass Slough data collected by Westervelt at Zacharias. Figure 1 indicates a strong correlation between the USGS data at the Cross Channel and the South Snodgrass data. The high tide peaks are about equal and the low tide peaks are generally less than 0.5 feet higher at Zacharias. This is likely due to some tidal muting at Snodgrass Slough during the outflow tide cycle between the cross channel and the site. Figure 2 indicates that the high and low tide peaks at South Snodgrass station tend to be about 0.5 to 1.5 feet higher than at

the Benson's Ferry on the Mokelumne. Figure 3 shows that the North Snodgrass data has both higher high peaks and lower low peaks than the Lambert Road data set, likely due to tidal muting caused by the narrow channel on the north side of the site.

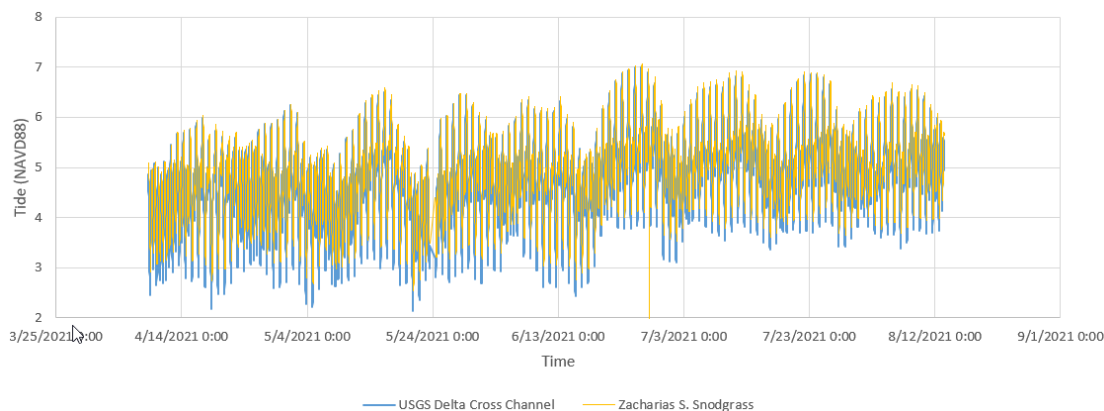


Figure 1. Comparison of tide levels at Delta Cross Channel and South Snodgrass data from April 8 to August 13, 2021.

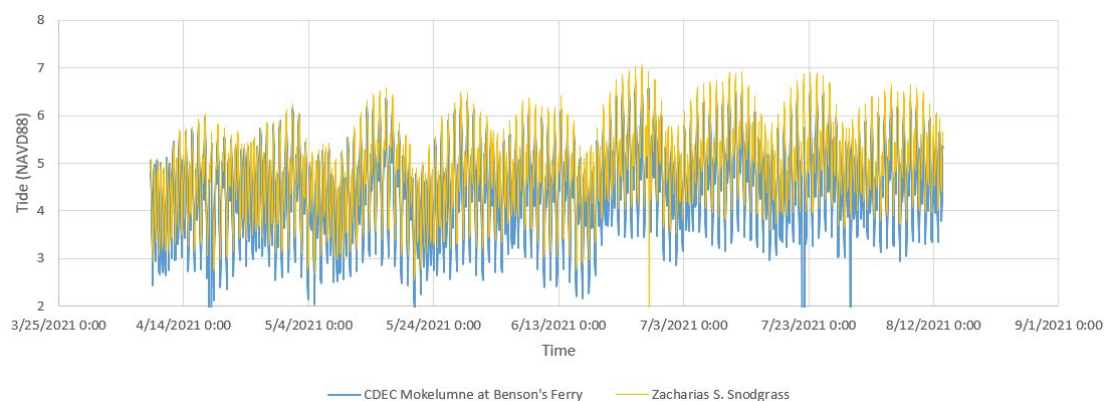


Figure 2. Comparison of tide levels on the Mokelumne River and South Snodgrass data from April 8 to August 13, 2021.

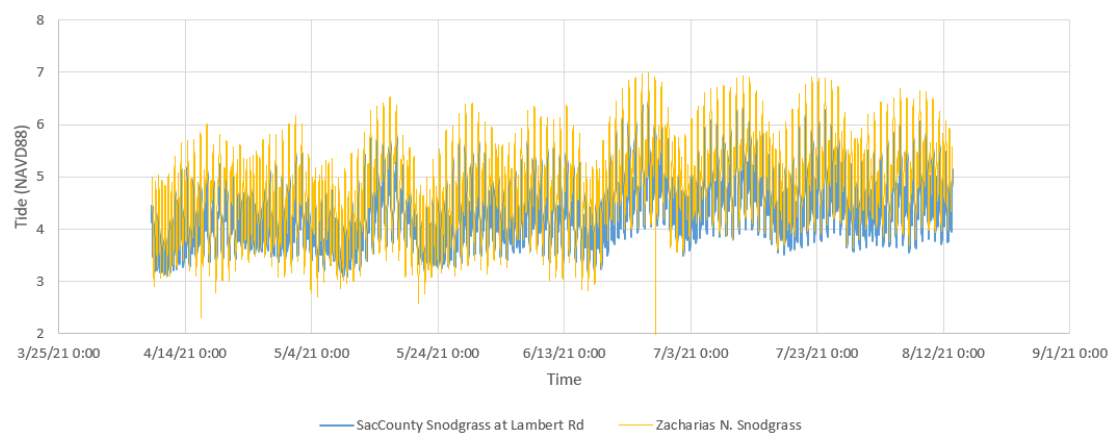


Figure 3. Comparison of tide levels in Snodgrass at Lambert and North Snodgrass data from April 8 to August 13, 2021.

Based on the evaluation of the tidal records of nearby gaging stations to Zacharias, the USGS gage at the Delta Cross Channel appeared to be most similar to the Westervelt data collected at both North and South Snodgrass locations. This data set was used, therefore, in the development of the Zacharias tide model.

3.0 Zacharias Ranch Historical Tide Model

Once the USGS Delta Cross Channel data was identified as closely approximating the tide at Zacharias, the entire available data set from 2007 to 2021 was downloaded from the USGS website. A simple tide model of Snodgrass Slough at Zacharias was developed by applying Equation 1 to the USGS data set.

$$T_z(t) = A \cdot T_{USGS}(t + t_o) + b \quad (1)$$

where: $T_z(t)$ is the tide at Zacharias in ft NAVD88 at time t
 $T_{USGS}(t+t_o)$ is the tide at the USGS Delta Cross Channel in ft NAVD88 at time $t+t_o$
 A , b , and t_o are best-fit coefficients

The coefficient t_o accounts for time lag between observed tide peaks at the two sites. Comparison of the data sets indicated a best-fit lag coefficient of $t_o = -1.25$ hours at Zacharias once the Pacific Daylight Time (PDT) data were converted to Pacific Standard Time (PST) to match the USGS data. The Solver function in Excel was then used to calculate the best-fit values for coefficients A and b , determined to be 0.934 and 0.475 for the South Snodgrass data and 0.908 and 0.555 for the North Snodgrass data. Figure 4 shows the original South Snodgrass data collected in the field and compares it to the model data based solely on the transformed USGS data set using Equation 1. The mean squared error between the observed and modeled tides is 0.02 feet.

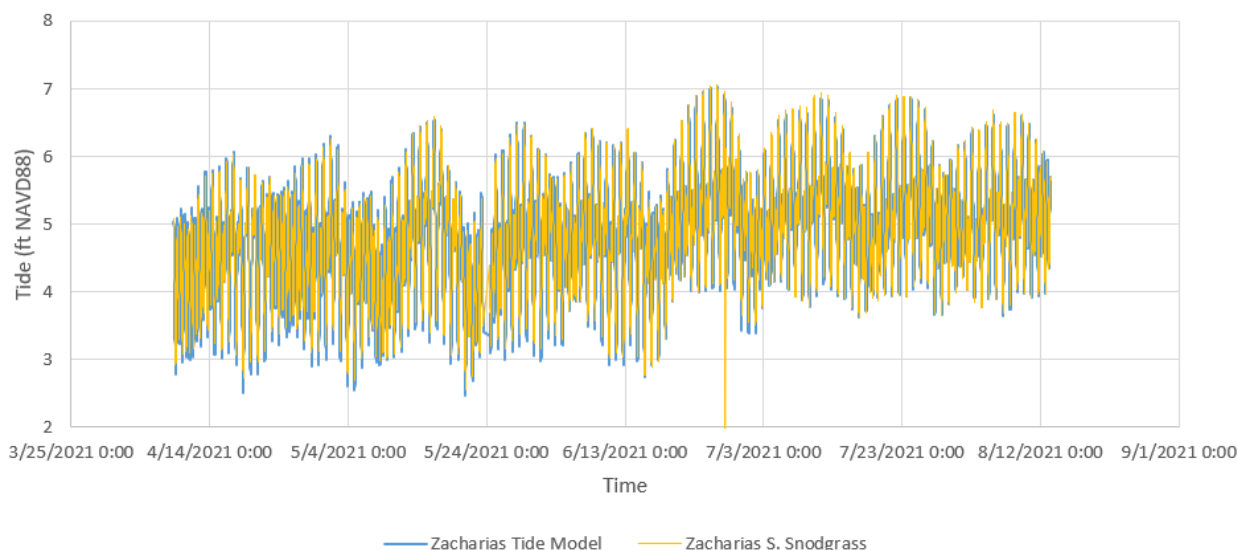


Figure 4. Comparison of modeled and observed tide levels at South Snodgrass from April 8 to August 13, 2021.

Once developed, the Zacharias tide model was used to estimate historical tides at the restoration site over the entire 14-year data set available from the USGS Delta Cross Channel gage station. The tide levels of

Mean Higher High Water (MHHW), Mean High Water (MHW), Mean Tide Level (MTL), Mean Low Water (MLW), and Mean Lower Low Water (MLLW) were then calculated for Zacharias using the modeled historical tide data. Table 1 presents the long-term tide levels modeled at the North and South Snodgrass stations together with the tide levels associated with the observed Westervelt data sets. The table shows that the modeled 14-year tide levels agree well with those collected for only 4 months at the site, indicating that the time window used for collecting data was representative of the long-term tide characteristics at Zacharias. Table 1 also shows that the tide levels calculated using the observed data from the North and South Snodgrass stations are nearly the equal, which demonstrates that tidal muting along Snodgrass Slough is generally minimal between stations under existing conditions. For reference, the tide levels calculated using data from the USGS Delta Cross Channel and CDEC Benson’s Ferry gaging stations are shown in Table 2.

Table 1. Modeled and observed tide levels at the North and South Snodgrass stations at Zacharias Ranch in feet NAVD88.

Tide Level	North Snodgrass Station		South Snodgrass Station	
	Modeled 2007-2014	Observed Apr-Aug 2021	Modeled 2007-2014	Observed Apr-Aug 2021
MHHW	6.1	6.1	6.1	6.2
MHW	5.7	5.7	5.7	5.7
MTL	4.9	4.8	4.9	4.9
MLW	3.9	3.9	3.9	4.0
MLLW	3.6	3.5	3.6	3.5

Table 2. Observed tide levels at the Delta Cross Channel and Mokelumne River at Benson’s Ferry in feet NAVD88.

Tide Level	USGS Delta Cross Channel Observed 2007-2021	CDEC Mokelumne R. at Benson’s Ferry Observed Apr-Aug 2021
MHHW	6.1	5.9
MHW	5.7	5.5
MTL	4.8	4.5
MLW	3.7	3.4
MLLW	3.3	2.9

4.0 FEMA Flood Levels and the 2023 Flood

Flood Risks at Zacharias Ranch and the surrounding area are shown in the Federal Emergency Management Agency’s (FEMA) Flood Insurance Rate Maps (FIRM) for Sacramento County. Table 3 provides the FIRM panel numbers covering the project area. The FIRMs show the site is designated an AE flood zone with a Base Flood Elevation of 18 feet NAVD88. Flooding at the site appears estimated from the North Fork

Mokelumne River Overflow Channel at the confluence with Snodgrass Slough. The site is not mapped within a floodway. Flood elevations for floods more frequent than the 100-year event are not provided in the FEMA data.

Table 3: Map numbers for FEMA FIRMs covering project location.

Community	Map Number	Effective Date
Sacramento County	06067C0420H	August 16, 2012
Sacramento County	06067C0450H	August 16, 2012

A significant flood event occurred in the North Delta during the first few days of 2023 that overtopped the levees at Zacharias Ranch. The flood had a peak water surface elevation of just over 15 feet and created two full breaches in the western levee and numerous small erosion sites. The two breaches were subsequently filled with granular material to close the connection to Snodgrass Slough and are to be filled on the top and landsides with fine material to discourage future breaching at the sites.

5.0 Conceptual Design Description

The conceptual design of Zacharias Ranch focused on the layout of interior drainage channels to promote full tidal exchange at the site based on the observed and calculated tide levels. Although regional modeling by MBK Engineers indicated that some muting of up to 10 inches might occur at the site when initially breached, the assumption of no muting was used in the design process to account for future erosion of slough channels and constrictions over time and that would eventually lead to a non-muted condition.

Two alternative channel layouts were considered for the conceptual design: (1) a branching pattern drainage network based on a single breach in the south and (2) a combination branching pattern and fringing pattern network based on three breaches in the western levee. Figure 5 shows a layout of the two alternatives. The single breach layout consisted of a main channel with three smaller branch channels. The channels were designed to follow local depressions and lower elevation areas to assist with drainage of the site and to reduce overall excavation volumes. The multiple breach layout included a large breach also in the south that connected Snodgrass Slough to the Rail Road Cut drainage canal on the eastern side of the site. Fringe channels were connected to the canal to drain the eastern half of the site. Two smaller breaches in the northern and mid regions of Zacharias were included in this alternative to drain the western side.

The geometric properties of the drainage channels were designed using guidance from Odell, Hall, and Brooks¹ (2008) that relates the hydraulic properties of depth, width, and side slope of slough channels in San Francisco Bay to their local drainage areas. The drainage subbasins associated with individual channels were delineated using existing topography provided by Westervelt with estimated channel layouts as shown in Figure 5. In Figure 5, subbasins are identified using letters and channel segments using numbers.

¹ Odell, Hall, and Brooks (2008). Conceptual Design and Modeling of Restored Coastal Wetlands. Intl. J. River Basin Management Vol. 6, No. 3 pp. 283-295.

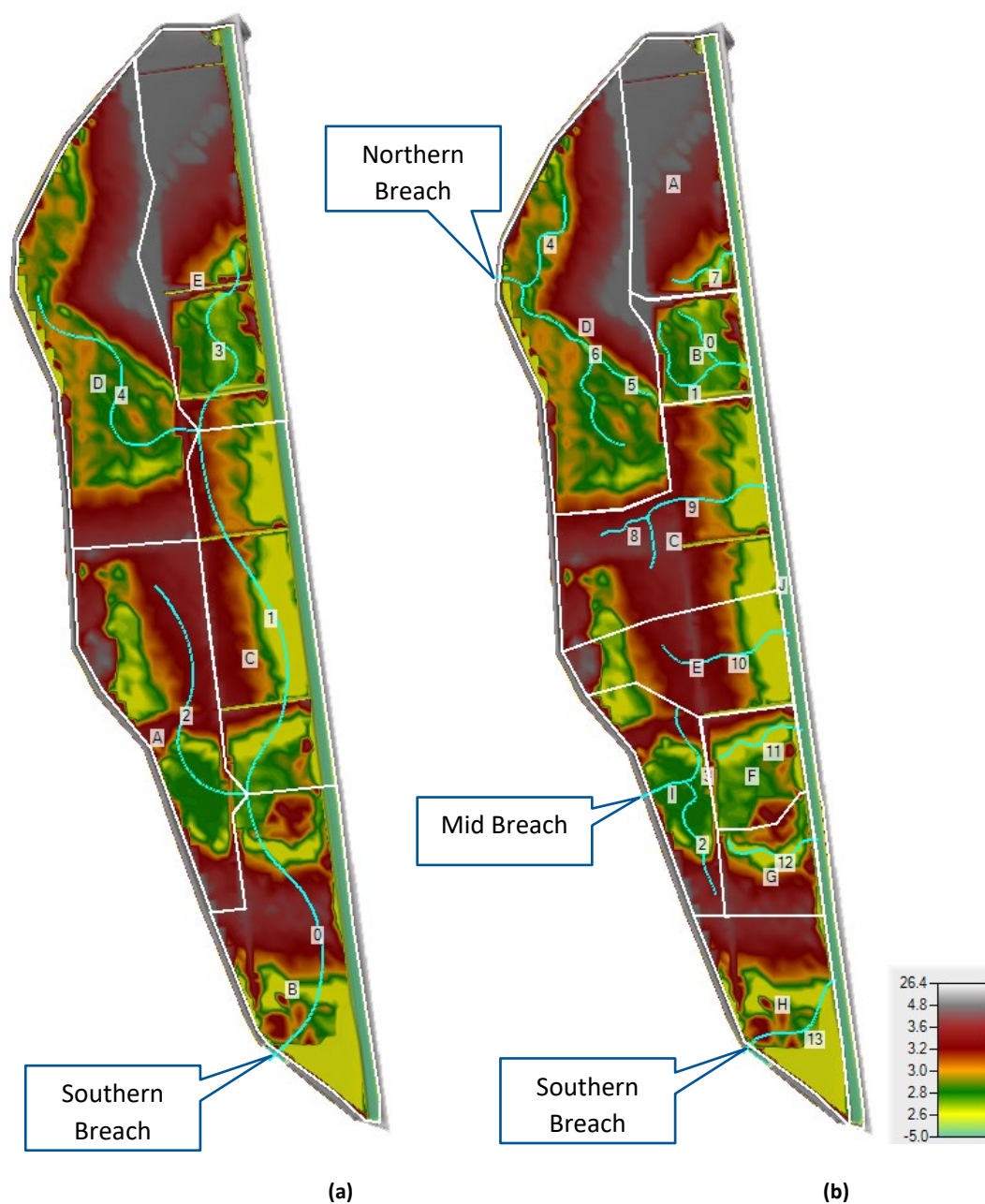


Figure 5. Drainage subbasins and design channels defined for the (a) Single Breach and (b) Multiple Breach concept alternatives. The color contours provide elevations relative to feet NAVD88. Channel centerlines are depicted with cyan lines and number labels, and drainage sub-basins extents are defined by white lines with letter labels.

The delineated subbasin areas were used to define appropriate dimensions for each drainage channel. Tables 4 and 5 summarize the channel properties calculated for the Single Breach and Multiple Breach design layouts. Odell, Hall, and Brooks describe an empirical method for sizing channel dimensions based on data from existing sites with typical marsh plain elevations at about MHW.

Table 4. Summary of preliminary design channel properties for the Single Breach alternative.

Channel ID	Drainage Subbasins		Channel Topwidth (ft)		Channel Bottom Width (ft)		Design Channel Invert (ft NAVD88)	Design Channel XS Area (sf)	Design Channel Length (ft)	Approx. Design Channel Volume (cy)
	Drainage Areas	Total Acreage	Odell et al.	Site Design	Odell et al.	Site Design				
0	A-E	558	229	200	114	100	-5	1200	3365	150,000
1	C,D,E	371	168	120	84	60	-5	702	4324	112,000
2	A	93	58	40	29	20	-5	240	2945	26,000
3	E	120	71	40	35	20	-5	234	2422	21,000
4	D	145	82	60	41	30	-5	351	3097	40,000

Table 5. Summary of preliminary design channel properties for the Multiple Breach alternative.

Channel ID	Drainage Subbasins		Channel Topwidth (ft)		Channel Bottom Width (ft)		Design Channel Invert (ft NAVD88)	Design Channel XS Area (sf)	Design Channel Length (ft)	Approx. Design Channel Volume (cy)
	Drainage Areas	Total Acreage	Odell et al.	Site Design	Odell et al.	Site Design				
0	B	14	14	10	7	5	-3	44	762	1,000
1	B	29	24	20	12	10	-3	87	1692	5,000
2	I	20	18	10	9	5	-3	45	1434	2,000
3	I	39	30	40	15	20	-3	180	1529	10,000
4	D	44	33	30	16	15	-3	131	1315	6,000
5	D	44	33	30	16	15	-3	131	797	4,000
6	D	131	76	60	38	30	-3	261	2863	28,000
7	A	34	27	10	14	5	-3	44	894	1,000
8	C	32	26	10	13	5	-3	49	579	1,000
9	C	97	61	40	30	20	-3	186	2070	14,000
10	E	52	38	20	19	10	-3	90	1606	5,000
11	F	29	24	10	12	5	-3	41	1078	2,000
12	G	13	13	10	7	5	-3	41	1188	2,000
13	A-C, E-H, J	391	175	180	87	90	-5	1053	1464	57,000

The total excavation required to create the drainage channels for the two conceptual layouts was estimated by summing the channel volumes listed in the last column of Tables 4 and 5. These were estimated to be 349,000 cy and 138,000 cy for the Single Breach and Multiple Breach concepts, respectively. In the conceptual design, it was proposed that the excavation spoils from the channels be used on site to build up high areas and islands within Zacharias with top elevations between 9 to 10 feet. These areas would encourage the creation riparian scrub and forest habitats in the site. The elevated islands were located over existing high areas to reduce the volume of material required to construct them. In addition, the spoils islands were generally located near the excavated channels to minimize haul distances and create shaded riverine habitat. Figure 6 presents the conceptual channel layout designs for the two alternatives that

include the islands. The islands were designed using a 5:1 slope up to about elevation 6 feet and 10:1 slope up to elevation 9.5 feet.

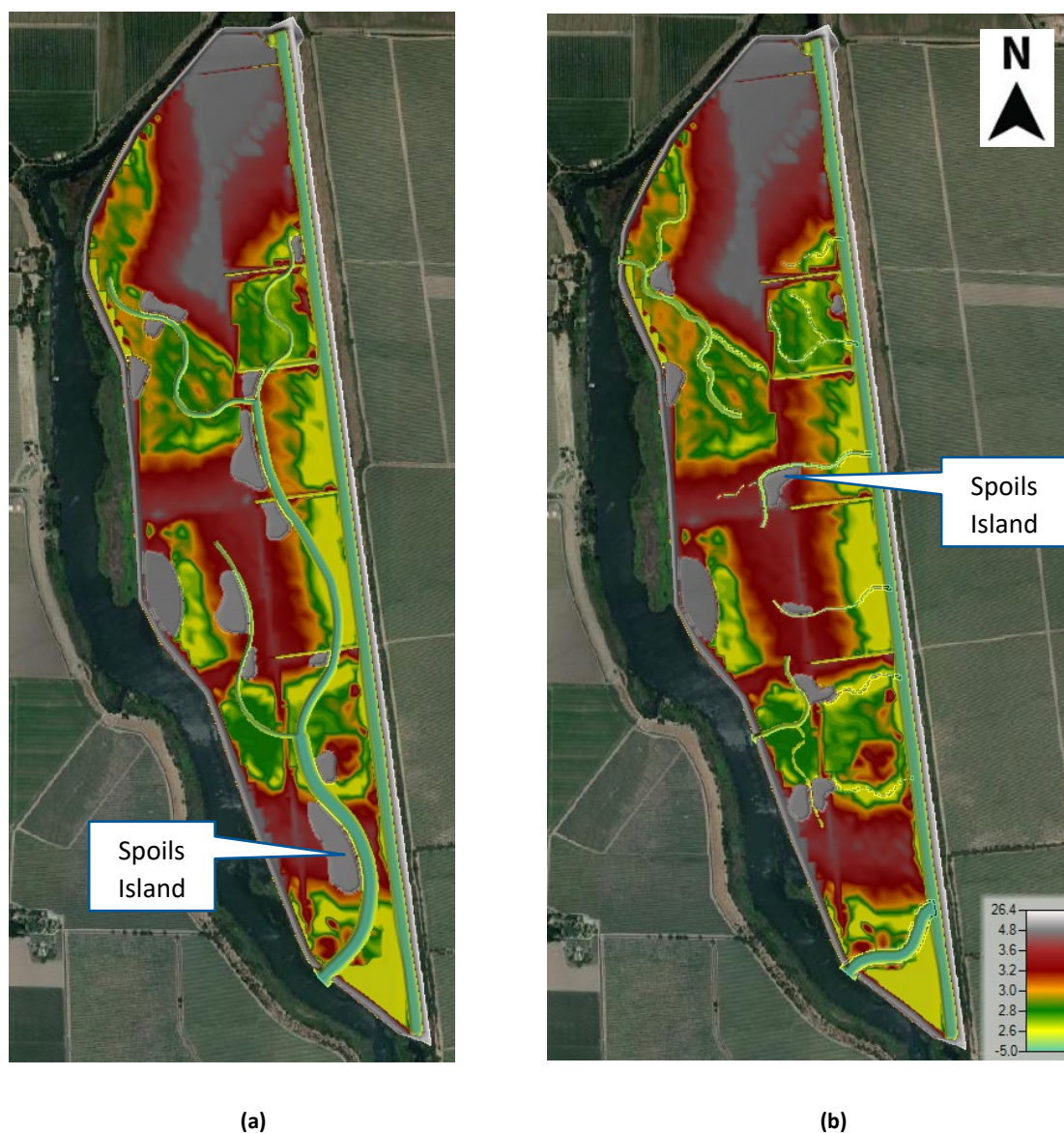


Figure 6. Conceptual design channel layouts for the (a) Single Breach and (b) Multiple Breach alternatives. The color contours provide elevation relative to feet NAVD88.

6.0 30% Design Description

Similar to the Conceptual Design, the 30% Design for Zacharias Ranch (Figure 7) included a network of excavated channels to promote flooding and draining during tidal cycles. The excavated channels were connected to Snodgrass Slough by two breaches: the Northern Breach and the Southern Breach. The following section describes additional details of the 30% Design submitted in June of 2023.

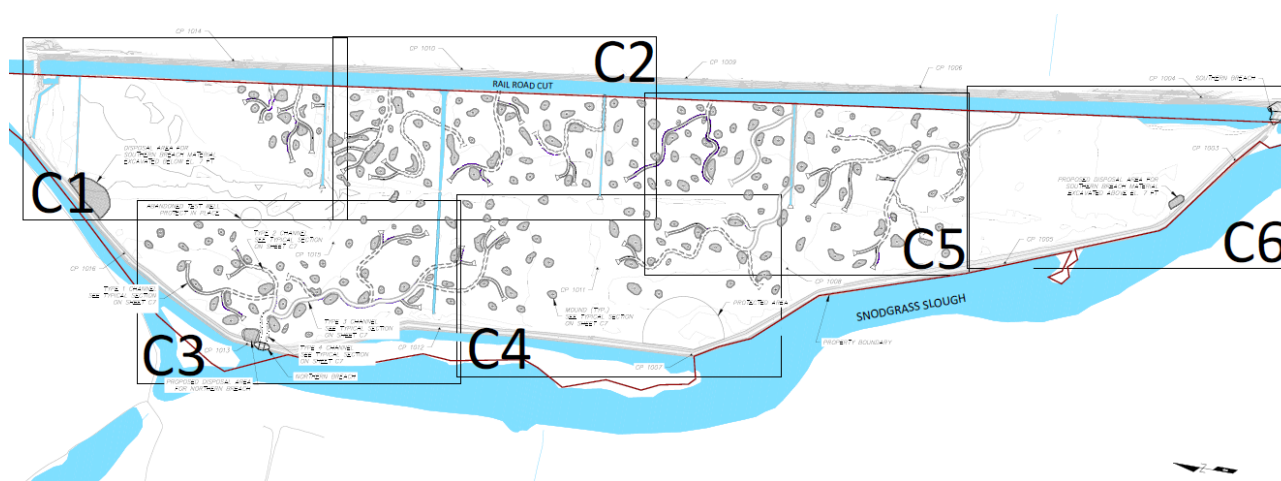


Figure 7. 30% Design plans developed for Zacharias Ranch.

6.1 Channel Design

The channels shown in the 30% Design plans were based on four cross section templates that defined prismatic channels between confluence points. These are referred to as channel Types 1 to 4, with Type 1 channels being the smallest and Type 4 channels being the largest. Generally, where two lower level channels joined, they flowed into a higher level channel downstream (in the draining direction). The channels have constant bottom widths and top widths with varying side slopes for ease of construction that range from about 2.3:1 to 3:1. Type 1, 2, and 3 channels have invert elevations of 0 feet, while the invert of Type 4 channels varies along its length from 0 to -4 feet. Table 6 presents the general dimensions of the four channel types. The sizes of the channels were designed to provide approximately 100,000 cy of material for the creation of the habitat mounds at the site and were checked against empirical relationships by Odell, Hall, and Brooks that correlate channel geometry to drainage basin area for sloughs in the North Delta. In general, the channels in the 30% Design were slightly oversized to allow for use of scrapers to grade the channels during construction and to achieve required excavation volumes. The terminal ends of channels included a transition zone to connect the channel invert to existing grade with an approximate 10:1 slope. The total volume of channels excavated in the 30% Design plans was estimated to be 104,000 cy.

Table 6. Summary of channel properties for the Zacharias Ranch preliminary design.

Channel Geometry	Top width (ft)	Bottom Width (ft)	Side Slope	Invert Elev. (ft NAVD88)	Approx. Total Length (ft)	Approx. Volume (cy)
Type 1	30	16	~ 2.3:1	0	12,120	33,000
Type 2	38	24	~ 2.3:1	0	14,090	44,000
Type 3	44	30	~ 2.3:1	0	6,170	22,000
Type 4	88 to 64	50	~ 2.3:1 to 3:1	-4 to 0	320	5,000

6.2 Habitat Mounds

The 30% Design plans included fill features called mounds to create higher elevation areas for the establishment of cattails and low marsh habitat. The mounds were smaller and lower than the spoils islands presented in the Conceptual Design. In all, 210 mounds were included in the 30% Design with a total volume of 96,000 cy. Many of the mound locations and sizes were based on a Westervelt concept design provide to NHC in November of 2022, with some additional mounds added throughout. The mounds were generally 2 feet higher than the surrounding ground, placed in areas where the topography was below 3.5 feet NAVD88, and had 3:1 side slopes. The 30% Design plans included tables that indicate the top elevation and volume of each mound to be constructed. The plans noted that the Engineer would indicate to the Contractor additional mound locations as required so that all excavated material was placed on site.

6.3 Levee Breaches

The 30% Design plans indicated that the excavated channels would be connected to Snodgrass Slough at two breaches in the perimeter levee: the Northern Breach and the Southern Breach. The Northern Breach, located on the northwest side of the site, was shown to have a bottom width of 50 feet at elevation -4 feet NAVD88. The breach included 3:1 side slopes on both sides. The Southern Breach reconnected the existing Rail Road Cut drainage canal along the east side, which connects to Snodgrass Slough in the south. The breach bottom width was 80 feet wide at an invert elevation of -4 feet to match the geometry of the canal. The Southern Breach had 3:1 side slopes on the west and conformed to existing levee grades on the east side. As a part of the Southern Breach connection, the three 8-foot culverts with tide gates were to be removed.

7.0 65% Design Description

The 65% Design plans (Figure 8), submitted in September of 2023, include minor adjustments to channel alignments and habitat mounds relative to the 30% Design. The following section provides additional design background information and details. A field visit was made on July 27, 2023 to observe the locations of proposed breaches and note existing structures to be demolished.

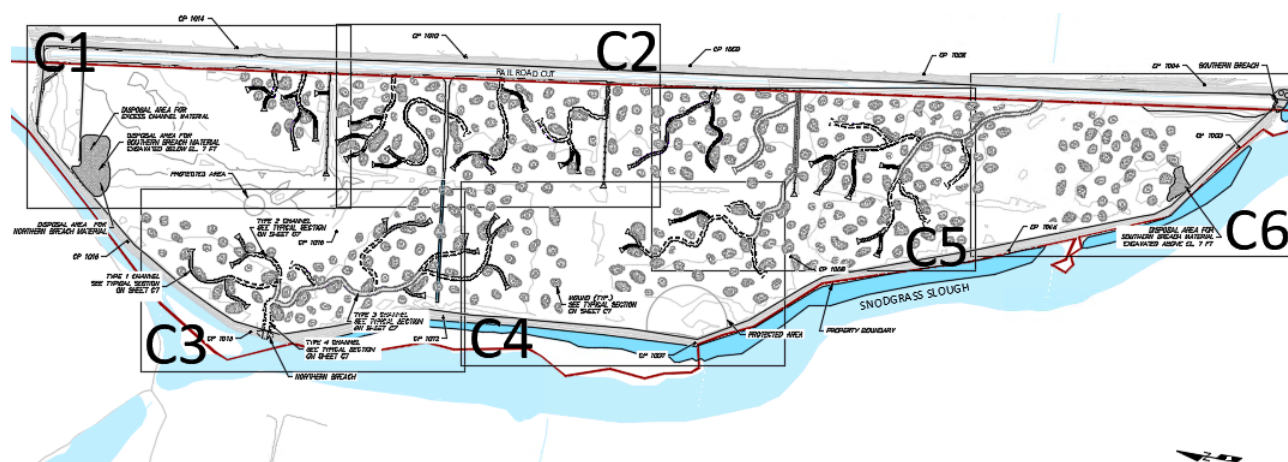


Figure 8. 65% Design plans developed for Zacharias Ranch.

7.1 Channel Design

The channels shown in the 65% Design plans are similar to those shown in the 30% Design. However, the southern-most channel connecting to the Rail Road Cut was moved further south to avoid impacts to existing trees. Total channel excavation volume is estimated to be about 105,000 cy.

7.2 Habitat Mounds

Based on design feedback from the 30% Design plans, the elevations of the habitat mounds have been reduced in height from 2 feet above existing ground to 1.25 feet. The top elevations of the mounds range between elevations 3.5 and 5 feet NAVD88 to more closely coincide with the observed elevations of cattails growing in analogue sites. A total of 357 habitat mounds are included in the 65% Design with a total volume of 95,000 cy. The plans note that the surfaces of the mounds should be flat but vary by +/- 0.5 feet to create a more natural and variable habitat area.

7.3 Levee Breaches and Disposal Areas

The geometries of the breaches shown in the 65% Design are similar to those presented in the 30% Design. The plans indicate that excavation of the Northern and Southern Breaches will likely occur in two stages: removal of material above 7 feet first, and then removal of material below elevation 7 feet. This will allow for the hauling of some material away from the breaches before the site is opened to tidal influence from Snodgrass Slough. Material excavated from the Northern Breach will be transported to the north of the site and placed in a large spoils area with a top elevation of 9 feet. Spoils from the Southern Breach will be disposed of at two locations. The dry material from the Southern Breach excavated above elevation 7 feet will be hauled away and placed in the south of the site near the existing levee road ramp. Wet material excavated below elevation 7 feet will be hauled to high ground at the northern spoils location along the eastern access route. The northern spoils area will also be used to dispose of any excess material from channel excavation that is not used to create habitat mounds. Table 7 summarizes levee the breach properties for the two breach sites.

Table 7. Summary of levee breach properties for the Zacharias Ranch preliminary design.

Breach Location	Top Width (ft)	Bottom Width (ft)	Side Slope	Invert Elev. (ft NAVD88)	Approx. Volume above 7 ft (cy)	Approx. Volume below 7 ft (cy)	Approx. Total Volume (cy)
Northern	155	50	3:1	-4	1,000	2,100	3,100
Southern	240	80	~3:1	-4	2,600	5,700	8,300

7.4 Access and Demolition

Access to the site is provided from the north along Lambert Road. Internal access routes are shown in the plans along the eastern levee road, the northwestern and southwestern levee roads, and through the center of the site. Multiple locations for construction staging are indicated that could potentially be used by the Contractor. The plans also show the boundaries of two protected areas in the north and on the west sides of the site. The plans clearly indicate that these areas must be fenced off to prevent accidental entry or disturbance during construction.

Several structures are to be removed according to the 65% Design plans. These include the North and Northwestern pump houses and associated appurtenances, abandoned powerlines and transformers (abandoned power poles to remain), and the culverts and tide gates in the south. Demolished material will be hauled offsite and disposed of at an appropriate facility.

7.5 Tree Survey

A tree survey was performed by Westervelt in August of 2023 at the breach locations and around the channel confluences at the Rail Road Cut canal. The survey indicated that 10 trees at the breach locations will have to be removed to accommodate project grading. This includes 6 trees at the Northern Breach and 4 trees at the Southern Breach with diameters greater than 6 inches. Figure 9 shows the locations of trees surveyed near the two breach sites. Table 8 lists the trees from Figure 9 to be removed and to be protected. It is noted in plans that three trees (numbers 105, 106, and 107) are currently listed as protected at the south breach. However, due to uncertainty in the plan topography, it is not known for sure if they can be saved. A reasonable effort will be made to protect these trees. However, if excavation is required within 10 feet of the trunks or more than 4 feet of soil must be placed around the trunks, these trees will also be removed.

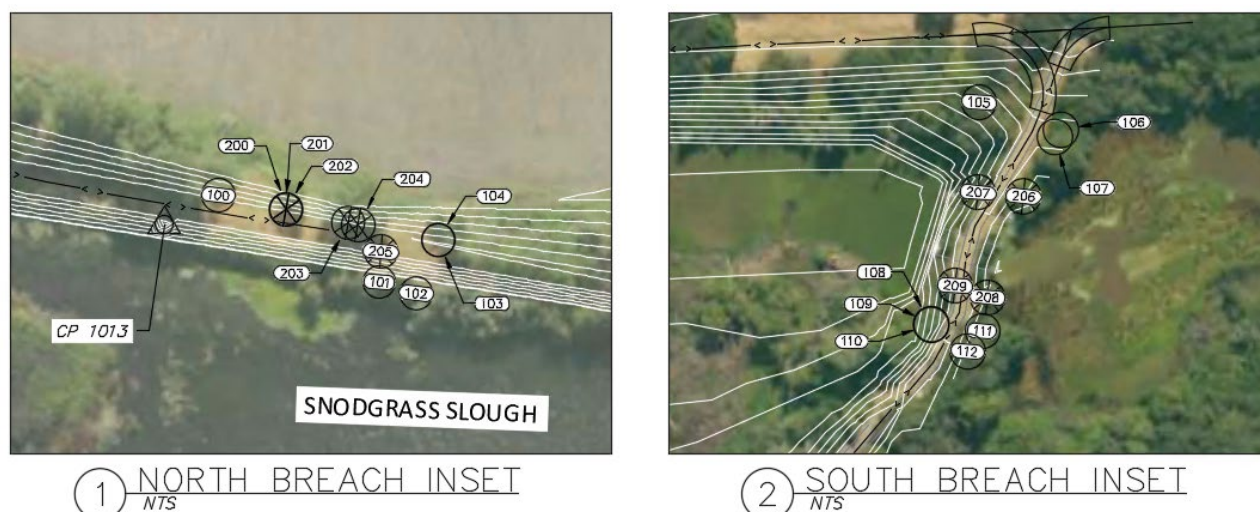


Figure 9. View from the 65% Design plans showing trees to be removed and protected near the breach sites.

Table 8. Table from the 65% Design plans listing trees to be removed and protected near the breach sites.

TREES TO BE PROTECTED		TREES TO BE REMOVED	
Tree #	Description	Tree #	Description
100	11" Fremont cottonwood	200	16" Fremont cottonwood
101	8" Valley oak	201	11" Fremont cottonwood
102	6" Valley oak	202	17" Fremont cottonwood
103	6" Fremont cottonwood	203	20" Fremont cottonwood
104	6" Red willow	204	20" Fremont cottonwood
105	40" Valley oak	205	6" Valley oak
106	30" Valley oak	206	12" Valley oak
107	18" Valley oak	207	10" Palm
108	7" Pacific willow	208	7" Valley oak
109	7" Pacific willow	209	7" Valley oak
110	7" Arroyo willow		
111	35" Valley oak		
112	35" Valley oak		

7.6 Boat Launch and Access Ramp

The 65% Design plans include the construction of a boat launch and access ramp in the north that provides access to the Rail Road Cut canal. The ramp and boat launch pad will be paved with 4" of compacted gravel.

7.7 Best Management Practices (BMPs)

The 65% Design plans indicate that the use of turbidity curtains or other sediment barriers around areas of excavation near Snodgrass Slough will be required. This includes the two breach sites as well as the locations of pipelines to be removed at the north and northwest pumphouses. The plans also call for the installation of construction fencing around protected areas and trees to be protected near breaches. Since the disposal of excavated material will be onsite, and no hauling traffic or egress BMPs will be required.

8.0 HEC-RAS Modeling of the 65% Design

8.1 Hydraulic Model of 65% Design With No Tidal Muting

A 2D HEC-RAS model of the 65% Design for Zacharias Ranch was developed to evaluate the hydraulics of the site over multiple tidal cycles. The model assumed no tidal muting in Snodgrass Slough, and used the Westervelt data collected in 2001 for the boundary conditions. The time period between June 13 to June 16, 2021 was selected for the simulation, since this period contained tide peaks that nearly matched MHHW and MLLW in Snodgrass Slough, as well as an extreme low tide of 2.78 feet. The results of the modeling indicated that the breaches and drainage channels as designed in the 65% Design were sufficiently large to allow for full tidal exchange inside Zacharias Ranch. Figure 10 presents the water surface elevations modeled inside the site at three locations under project conditions (southern, middle, and northern regions) and compares them to the tide in Snodgrass Slough. The figure shows full tidal exchange in the site for the entire period of the simulation.

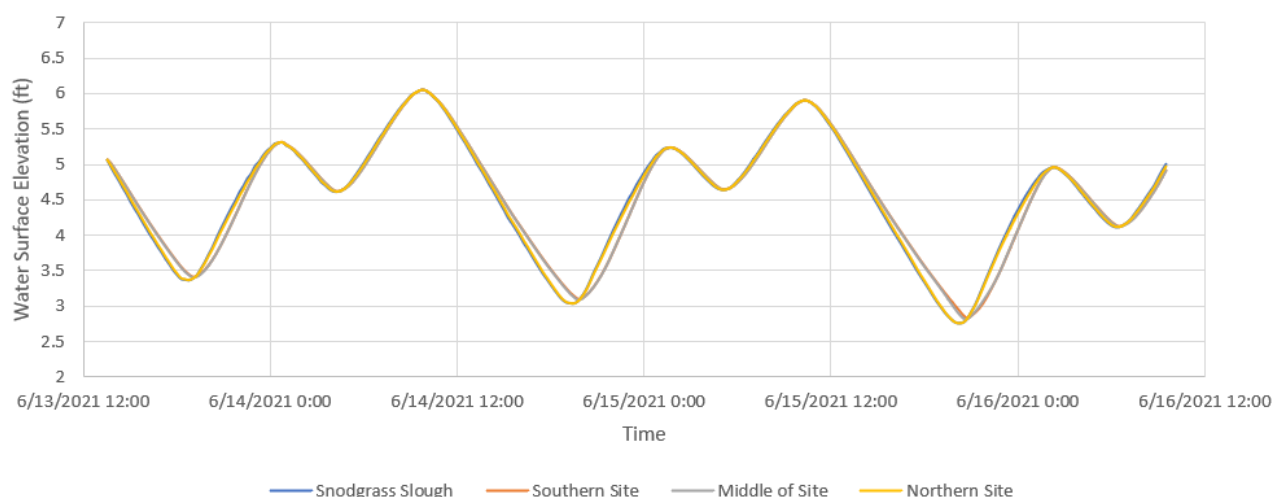


Figure 10. Sample locations showing modeled tides in Zacharias relative to Snodgrass Slough for the 65% Design.

The 2D HEC-RAS model was also used to evaluate peak velocities in the channels and floodplains over the period of simulation for the 65% Design. Figure 11 presents the peak velocities observed in the model for the same June 13 to 16, 2021 time period. The figure indicates that peak velocities in the Northern Breach ranged between 2 to 2.5 fps and in the Southern Breach between 1.5 to 2 fps. In the channels, peak velocities were lower and generally range between 0.5 to 1.5 fps. The safe non-eroding peak velocity for channels is a function of bed material and channel geometry, and generally ranges between 2 to 3 fps for sloughs in the North Delta. This indicates that the breach openings shown in the 65% Design are reasonably sized for full tidal exchange and to avoid erosion. The channel velocities are a bit lower than this range since they were oversized to provide sufficient material to build the habitat mounds. Peak velocities in the floodplains are generally less than 0.5 fps.

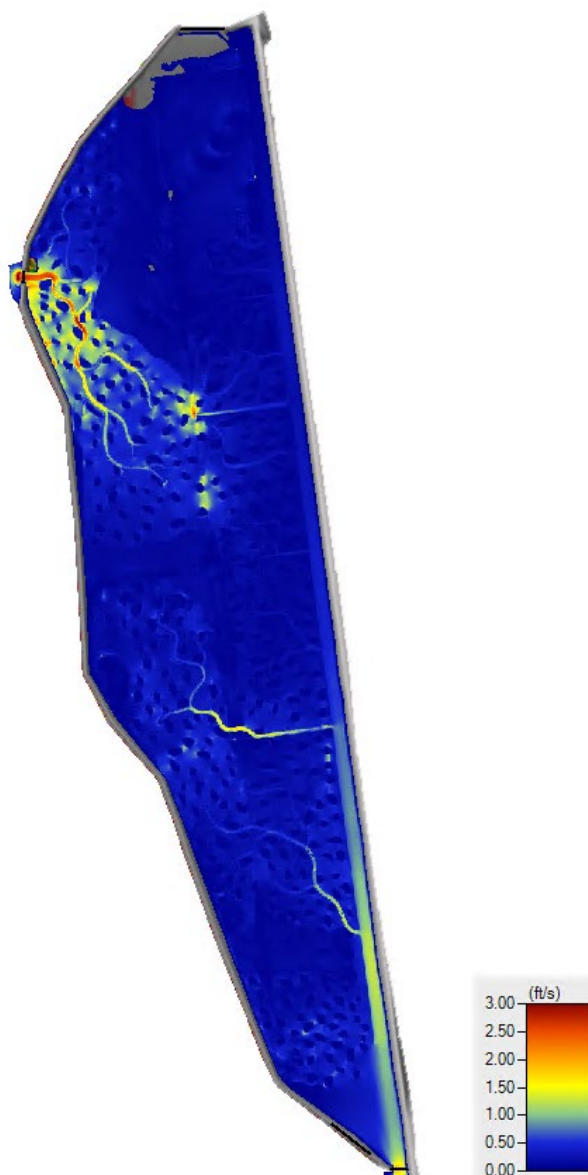


Figure 11. Modeled peak velocities simulated for the 65% Design during the typical June 13 to 16 time period.

8.2 Hydraulic Model to Evaluate Potential Muting in the Southern Rail Road Cut

The 65% Design plans show that that Southern Breach will connect Zacharias Ranch to Snodgrass Slough by re-connecting the Rail Road Cut canal that is currently blocked off by a levee. However, the bathymetry of the Rail Road Cut to the south of the site is unknown, and flow must pass through it for about a mile before it completely connects back to Snodgrass Slough. In order to determine if frictional losses in the southern reach of the Rail Road Cut could affect tide levels in Zacharias Ranch, a second HEC-RAS model was developed with an estimated terrain to the south, as shown in Figure 12. The invert of the reach near the Southern Breach was defined at 0 feet, the mid section was defined with an invert elevation at -2 feet, and the southern section near Snodgrass Slough was defined with an invert elevation at -6 feet NAVD88. Hydraulic connections to Snodgrass Slough were made at three locations based on aerial imagery. These are shown in the figure with blue arrows. The results of the simulation indicated that the frictional effects of the southern Rail Road Cut would be small and would not significantly affect tide levels in the site.

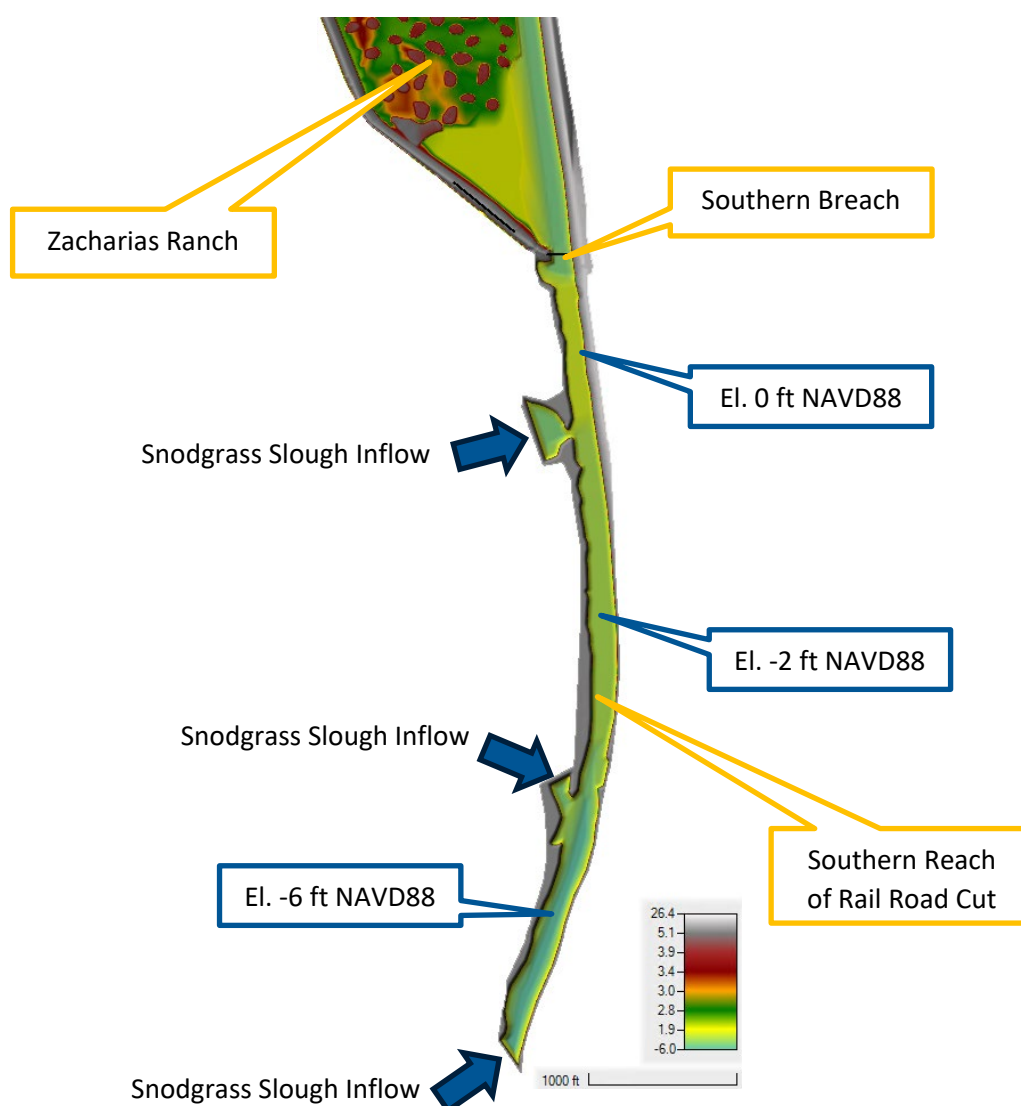


Figure 12. Assumed geometry of southern reach of the Rail Road Cut used to evaluate potential muting due to hydraulic friction.

9.0 Estimated Residence Time

The HEC-RAS model results were used to estimate the residence time of water in the Zacharias Ranch site. The same time period of June 13 to June 16 was used for this analysis. It is important to note that residence time is directly related to the height of tide peaks, which affects the total volume of water flooding the site on a given tide cycle. Therefore, residence times should be expected to vary when calculated using other tide cycles.

For this analysis, the discharge passing through each of the breaches was determined at 15-minute intervals for the two design alternatives. Starting with an initial water surface elevation equal to Mean Tide Level in the site, the total water volume and the flow in and out of the site was tracked. As flow entered the site, it was assumed that it instantly mixed with the original water on the site, which reduced the concentration of original water. As flow left the site, the total water volume (including original water) was reduced.

For the 65% Design layout, the amount of time to reduce the concentration of original water from 100% to 5% was 40 hours. To reduce the concentration of original water down to 1% took 58 hours. Table 9 summarizes the estimated residence times to achieve for various percentages of original water concentration on the site for the June 13 to 16, 2021 tides.

Table 9. Residence times to reduce concentration of original water in 65% Design layout.

Percent of original water remaining	Time (hours)
100	0
50	8
25	17
10	33
5	40
1	58

10.0 Conclusions and Summary

A historical tide model was developed for Snodgrass Slough at Zacharias Ranch based on data from the USGS Delta Cross Channel station. The model results indicated that the data collected by Westervelt from April 8 to August 13, 2021 produced similar tidal characteristics to the modeled record between 2007 and 2021. The tide levels of MHHW, MTL, and MLLW were estimated to be 6.1, 4.9, and 3.6 feet NAVD88, respectively, in Snodgrass Slough at Zacharias under current conditions. The Concept Design of Zacharias Ranch was based on two potential channel layouts that included a branched network with a single breach and a branched/fringe channel network with three breaches. The 30% Design used two breaches to connect excavated channels directly to Snodgrass Slough (Northern Breach) and to the Rail Road Cut channel in the south (Southern Breach). The sizes of the channels were oversized to provide full tidal exchange in the site and to produce sufficient material to create habitat mounds throughout the site. The 65% Design used a similar channel layout as the 30% Design, though the heights of the habitat mounds were reduced from 2 feet above existing grade to 1.25 feet. HEC-RAS modeling of the design indicated that the breaches and channels are sufficiently sized to promote full tidal exchange and avoid excessive scour at the breaches.

The results provided here are for informative purposes only and, if provided to a contractor, the contractor shall verify understanding, assumptions, and tidal values.

Sincerely,

Northwest Hydraulic Consultants Inc.



Robert Odell, PhD, P.E.
Senior Engineer



Brian Wardman, P.E.
Principal

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