Appendix H: 65% Southern Los Cerritos Wetlands Restoration, Phases 1 and 2 Hydraulic and Hydrology Modeling

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MEMORANDUM

To: LCW Design Team

From: Weixia Jin, Qing Wang and Chris Webb

Date: 1/31/2023

Subject: 65% Southern Los Cerritos Wetlands Restoration, Phases 1 and 2 Hydraulic and Hydrology Modeling, Updated for a Bridge-Type Crossing

M&N Job No.: 210644

1 Introduction

This updated version of the Hydrology/Hydraulics memorandum addresses minor modifications considered on the main channel to accommodate a bridge-type crossing on 1st Street. No other modifications are addressed, and the remaining portions of the memo are unmodified from the original.

The Southern Los Cerritos Wetland Restoration Project is focused on restoring 105 acres of tidal wetlands in Los Cerritos Wetland (LCW), Seal Beach California. Moffatt & Nichol (M&N) and its team partners have contracted with Los Cerritos Wetlands Authority (LCWA) to provide engineering services for the 65% design of the Southern LCW Restoration Project. This memorandum presents the hydraulic modeling of the 65% design of Phases 1 and 2 conditions. The hydraulic models were mainly developed to support the engineering design by providing inundation curves in the wetlands that serve to inform the grading plans, and to help quantify the areas inundated by the project. Figure 1 illustrates the project area of the Southern LCW Restoration.

Figure 1: Southern LCW Restoration Project Area

2 Existing Tidal Conditions

Existing tidal conditions in the marsh were measured in both 2011 and 2021 by M&N with a tide gage near First Street (just upstream). The tide gage was a calibrated RBR Solo pressure transducer. Tidal elevations are provided in feet relative to the vertical datum of National Geodetic Vertical Datum of 1929, or NGVD29. This datum is essentially equivalent to mean sea level in 1929, or MSL.

Data show that the existing tidal range is approximately 2 feet (2.1 feet in 2011 and 2.0 feet in 2021, while the San Gabriel River possessed a tidal range of 7.4 feet in 2011 and 6.9 feet in 2021). Variations in tidal range in the river and marsh are due to specific conditions occurring during the time of tidal measurements. Data in 2011 were obtained in July and August (summer) while data in 2021 were obtained in October (fall), and phases of the moon were different during both periods.

Tidal elevations in the wetland were approximately a high of 3.58 feet and a low of 1.57 feet in 2011 (tidal range of 2.1 feet), and a high of 3.67 feet and a low of 1.47 feet in 2021 (tidal range of 2.0 feet). Clearly, the marsh is muted compared to the river by effects of the existing 42-inch to 48-inch culvert. The culvert is slightly smaller on its upstream end at the marsh, and slightly larger on its downstream end at the river. It is composed of five segments connected in the shape of an inverted U when viewed in plan. The culvert's invert elevation is -1.0 feet NGVD29 at the upstream end and -1.1 feet NGVD29 at the downstream end.

3 Numerical Modeling to Predict Future Tides After Restoration

Two models were developed to analyze the different phases of construction due to different types of tidal connections proposed. Phase 1 assumes connection through the existing culvert and was analyzed using a link-node model, such as was used for the Los Cerritos Wetlands Conceptual Restoration Plan Project (CRP) in 2014 (M&N 2014) and for previous concepts proposed in the 1990s and early 2000s. Phase 2 assumes connection through a new open channel with a larger channel network and was analyzed using a two-dimensional (2-D) numerical model called Mike21. Each model is described below.

Based on the above background information, the following tasks were performed:

Phase 1

1. Develop the Phase 1 link-node model set up to cover the Phase 1 area with the proposed topography.
2. Calculate storage curves of water within the respective nodes and determine the cross-sectional areas and invert elevations for the links.
3. Perform numerical modeling for the following scenarios:
    - Typical spring tide condition with existing sea level,
    - 1.6-feet (0.5-m) sea level rise (SLR) together with typical spring tide condition, and
    - 3.3-feet (1-m) SLR together with typical spring tide condition.
4. Prepare inundation frequency curves for three scenarios modeled in Task 3.

Phase 2

1. Develop the 2-D numerical model mesh to cover Phase 2 area with the proposed topographic grading.
2. Perform numerical modeling for the following scenarios:
   - Typical spring tide condition with existing sea level,
   - 1.6-feet (0.5-m) SLR together with typical spring tide condition, and
   - 3.3-feet (1-m) SLR together with typical spring tide condition.
3. Prepare inundation frequency curves for three scenarios modeled in Task 6.

4 Numerical Model Development

4.1.1 Phase 1 Model Selection and Description

Phase 1 is a relatively simple wetland configuration that can be modeled using a one-dimensional (1-D) model called link-node. The model is an internally-developed lumped parameter type routine with a series of basins (nodes) interconnected by channels (links). Equations of motion and continuity are solved at successive time steps to give the water elevations at the nodes and the velocities at the links. The system is driven by a sequence of tide elevations applied at the downstream interface, which in this case is the San Gabriel River mouth. The model is capable of handling culverts and other special structures, as well as natural channels of approximately trapezoidal cross-section. A diagram of the model system representing the proposed wetland is provided in Figure 2. It consists of four nodes and three links.

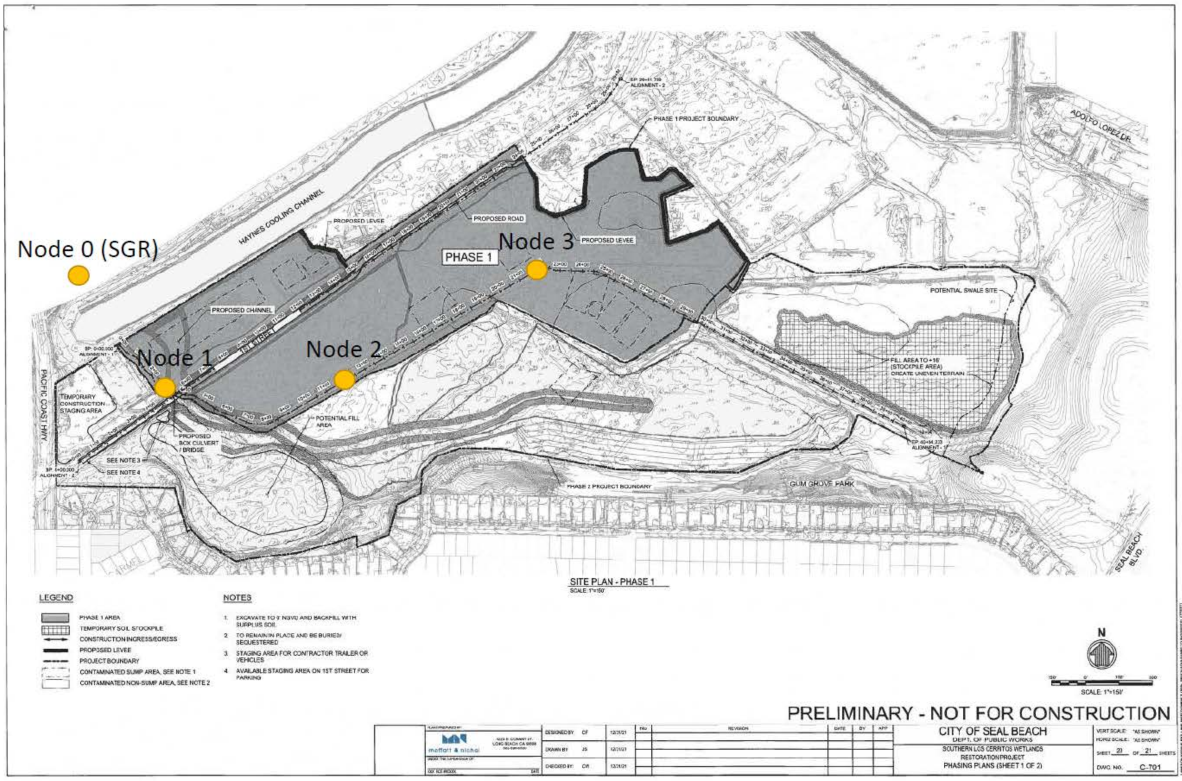

Figure 2: 30% Design of the Phase 1 Area

This model is simplified over the model used in Phase 2 and described below. The simplified link-node model was used for Phase 1 because the configuration of the wetland is more basic than in Phase 2 and the wetland is smaller, plus it is connected to the San Gabriel River by a culvert. Culvert connections are better approximated using the link-node approach, and this model has been used for three prior restoration planning efforts at this site in the past with success, including the LCWCRP (2014) as mentioned above. Also, the model was calibrated with the measured tidal data shown in Figure 3. The model-predicted water levels matched well with the recorded water levels. Therefore, it was selected for predicting Phase 1 hydrologic and hydraulic conditions to keep results consistent with the prior efforts.

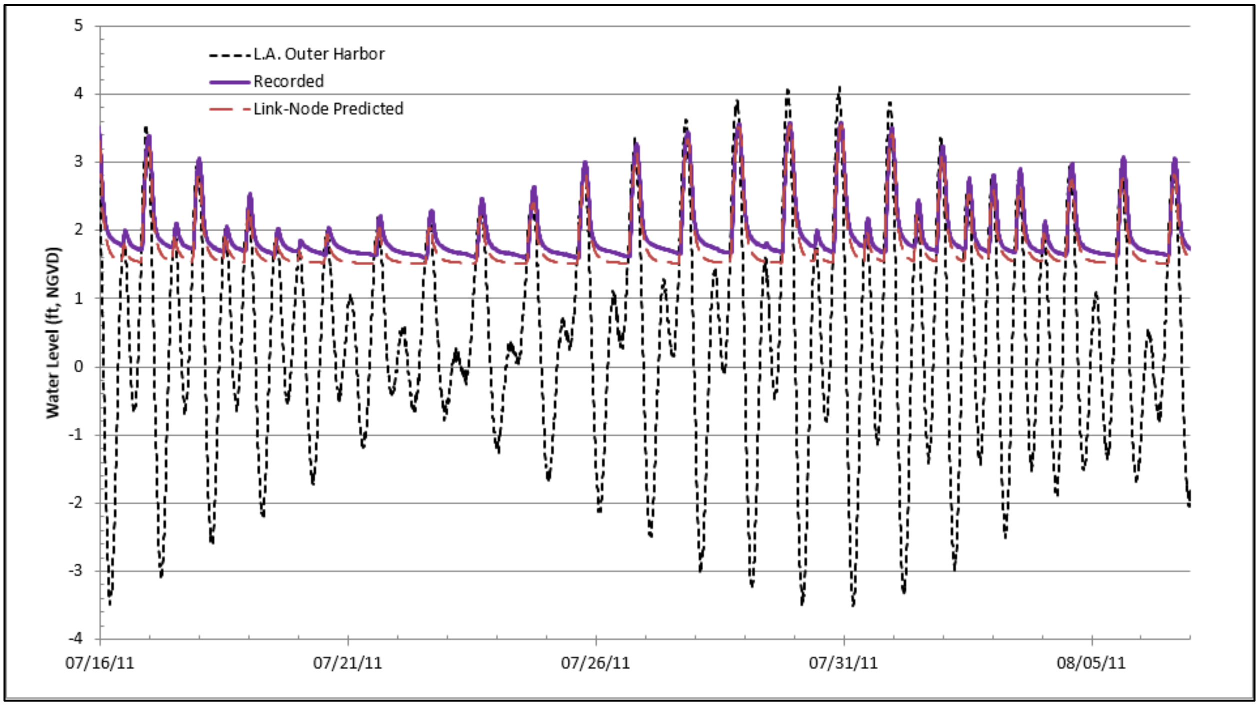

Figure 3: Calibration of Link-Node Model (Hellman Channel) with 2011 Data

4.1.2 Phase 2 Model Selection and Description

The hydraulic complexity introduced in the Phase 2 project design is more suitable to modeling using a 2-D model for increased resolution and probable accuracy, and the project requires simulations of hydrodynamics for the larger hydraulic system. In this study, the Mike21 Flexible Mesh (FM) Hydrodynamic (HD) model from DHI was used for hydraulic modeling. The model simulates the hydrodynamic flow system based on the finite volume method over an unstructured flexible mesh. It also contains other essential features such as wetting and drying, completely coupled sediment transport, constituents transport (temperature and salinity), and wind effects. It is a state-of-art tool for simulating flow conditions for coastal wetland systems.

This is the model that was used to test results of installing a new bridge-type crossing at 1st Street.

4.1.2.1 Mike21 Model Domain and Integrated Model Bathymetry and Topography

The model mesh for Phase 2 was developed based on the grading plan dated January 2022 (Figure 3). The elevation of the levee crest at the northern boundary of the project area is at +7.5 feet NGVD29. As shown in the Boundary Condition Section, the highest water surface elevation during typical spring tide is 4.1 feet NGVD29. The designed levee will not be overtopped under the considered 1.6-feet and 3.3-feet SLR scenarios. Therefore, the model domain for Phase 2 hydraulic modeling was set to be the same for all three modeling scenarios shown in Figure 4.

Figure 5 is the developed flexible model mesh for Phase 2. It includes 63,264 nodes and 125,296 elements. The element size varies from the longest element side length of 50 feet near the model boundary to less than 3 feet on channel slopes. Model elevations were based on the integrated elevation surface of the topographic survey by MDS Consulting completed in 1999 (MDS Consulting, Personal Communication 2021) and the proposed Phase 2 grading plan. Figure 4 demonstrates the integrated model elevations, and elevations of “no grading” areas were based on the existing topographic survey. The invert of the open channel that connects the marsh to Haynes cooling channel is set at an elevation of -4.5 feet NGVD29. The open channel shown in Figure 5 is sized to have a large cross-sectional area to convey the flow between the Haynes Channel and the wetland without causing tidal muting. Figure 6 shows the model domain and proposed elevations.

The model was modified at the location of 1st Street to simulate effects of installing a bridge-type crossing of the channel. The modifications made were to replace the reach of the channel under 1st Street with a box culvert that is 20 feet wide and 12 feet high, with a cross-sectional area of 240 square feet. This is a conservatively small representation of the proposed opening. The proposed opening will be a trapezoidal channel cross-section with 2:1 side slopes from slope toe to the top of the channel. Therefore, the actual proposed channel cross-sectional area under the bridge will be 528 square feet, or nearly twice the size of that modeled. This allows for reduced hydraulic impedance compared to a narrower channel, and maintenance of the tide and flow velocity condition throughout the entire channel reach. Figure 7 shows the model domain with the proposed new crossing.

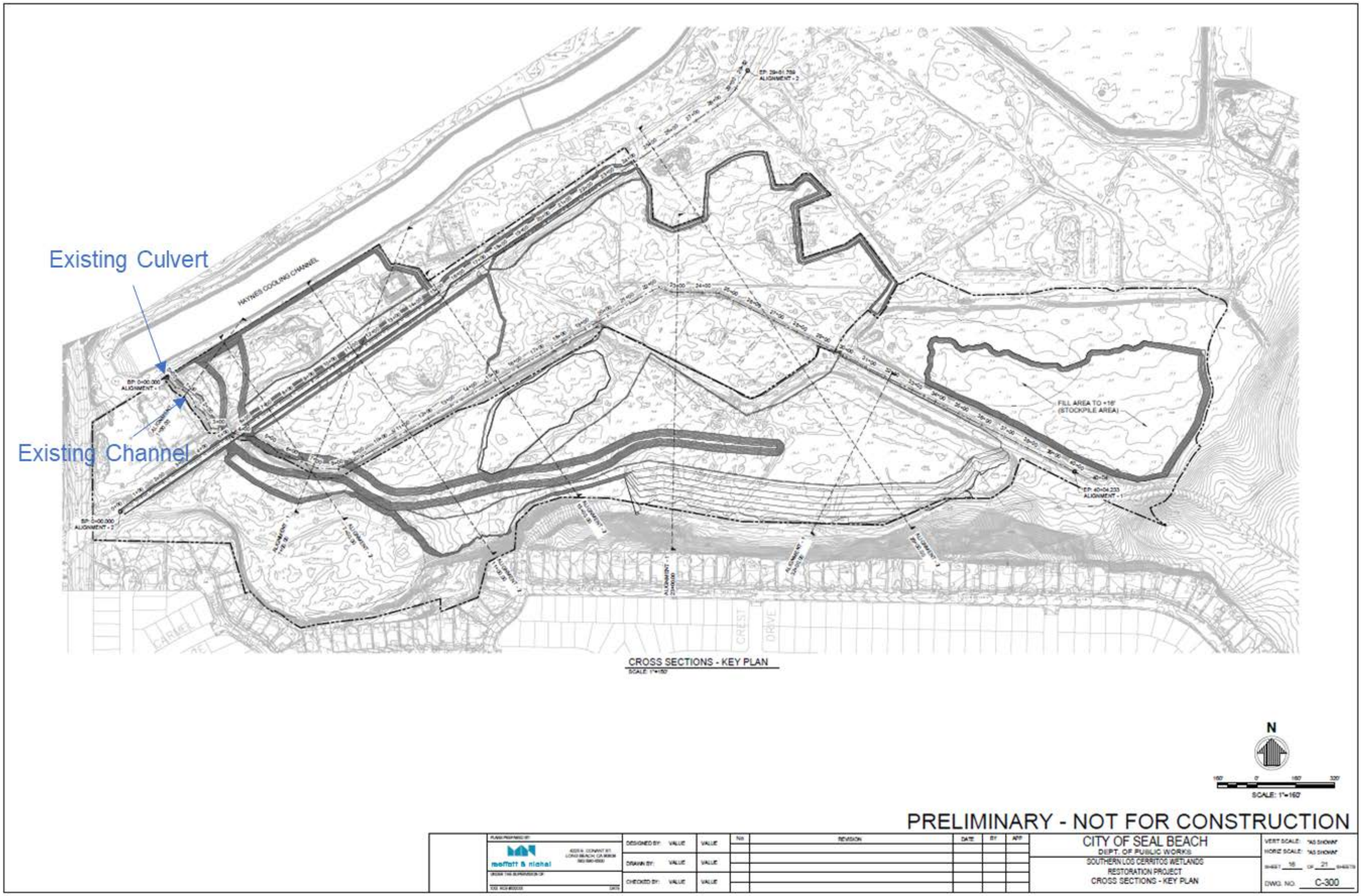
Existing Culvert
Existing Channel
HAYNES COOLING CHANNEL
FILL AREA TO +16' (STOCKPILE AREA)
CROSS SECTIONS - KEY PLAN
N
SCALE: 1"=160'
PRELIMINARY - NOT FOR CONSTRUCTION
moffatt & nichol
CITY OF SEAL BEACH
DEPT. OF PUBLIC WORKS
SOUTHERN LOS CERRITOS WETLANDS
RESTORATION PROJECT
CROSS SECTIONS - KEY PLAN
DWG. NO. C-300

Figure 4: 30% Design of the Phase 2 Area and Grading Plan

Figure 5: Model Mesh for the Southern LCW Restoration, Phase 2

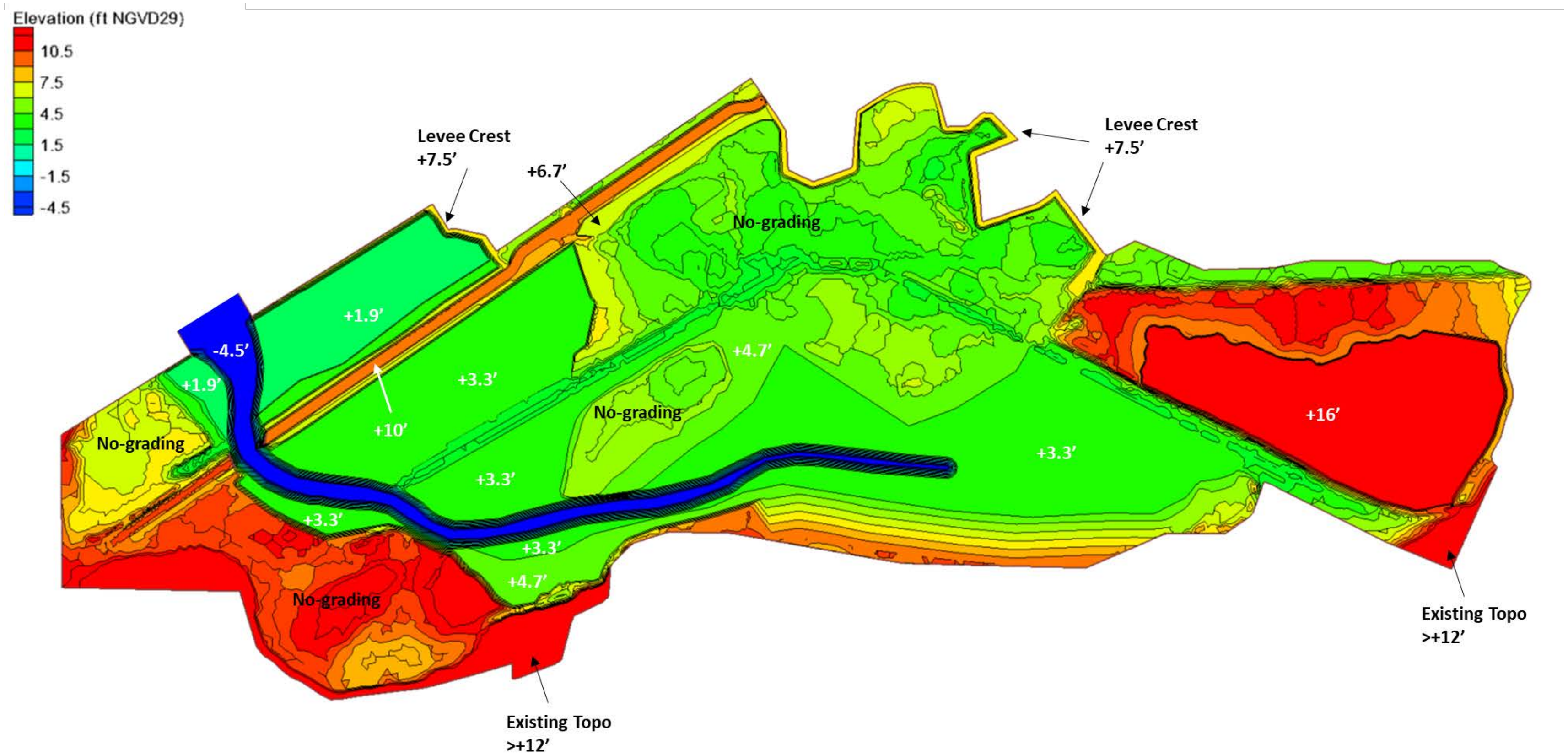

Figure 6: Model Domain and Proposed Elevations

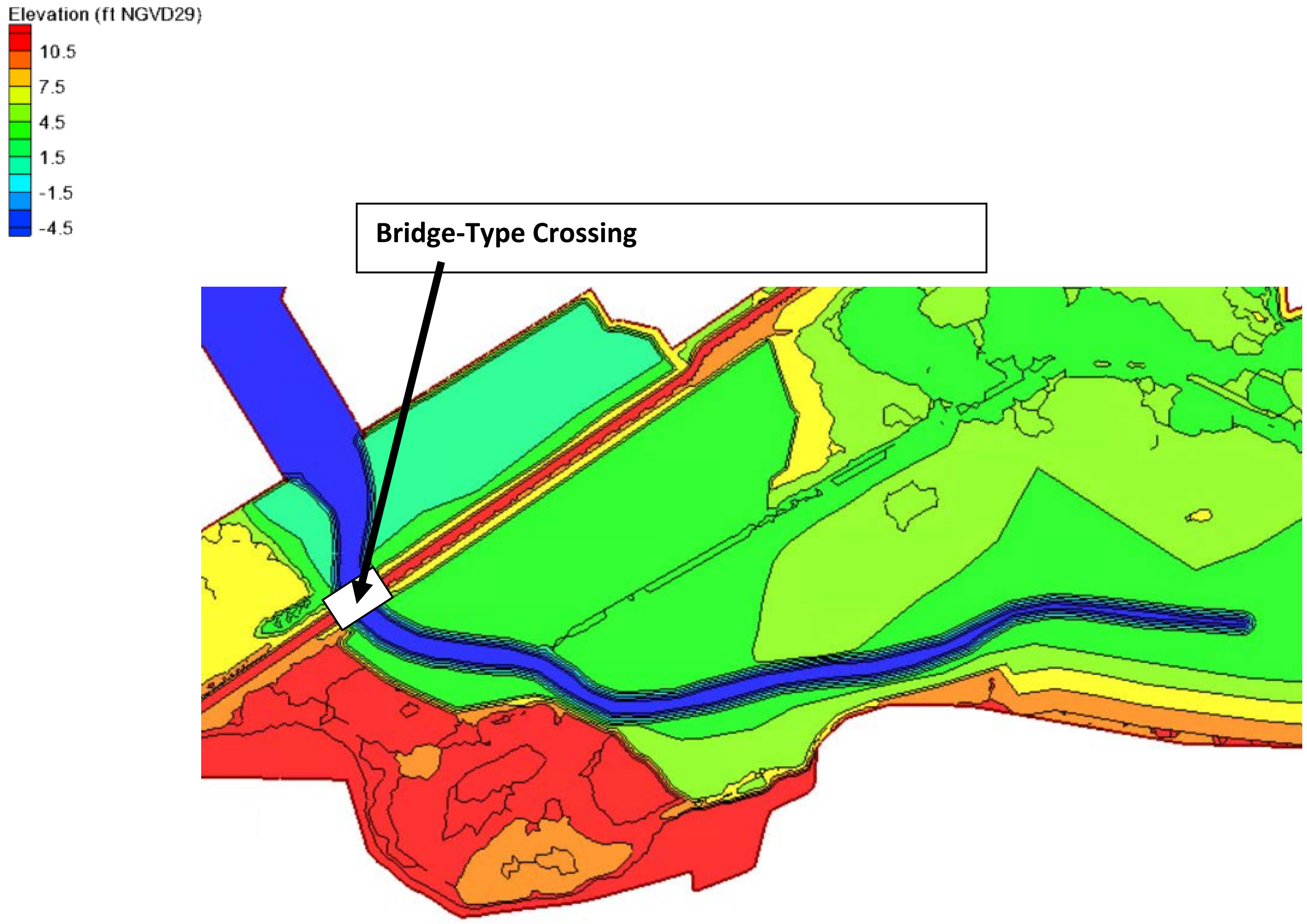

Figure 7: Updated Model Domain and Proposed Elevations With a Bridge-Type Crossing

4.1.3 Boundary Conditions for Phases 1 and 2

4.1.3.1 Tides

There are no tide stations within Alamitos Bay; the nearest tide station administered by National Oceanic and Atmospheric Administration (NOAA) at Los Angeles Outer Harbor is considered to be representative of the ocean boundary tidal conditions. A representative spring-neap tidal cycle (its spring high elevation, mean sea level, and low tide elevation are closest to the 19-year average values based on the latest 19-year monthly tidal elevation data) was selected and is presented in Figure 6. The highest water surface elevation in the tidal cycle (or average spring high tide) is 4.1 feet NGVD29, equivalent to 6.52 feet NAVD.

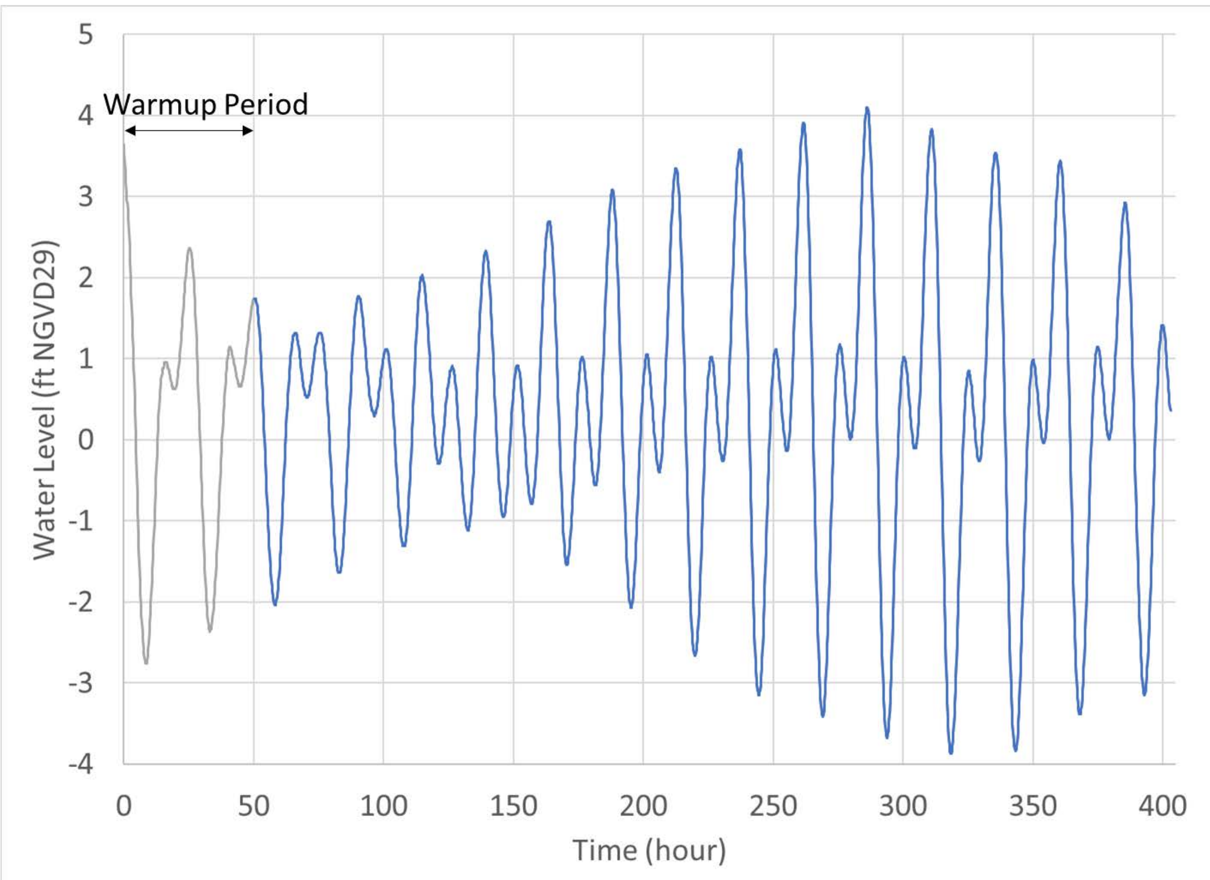

Figure 7: Typical Spring-Neap Tide Cycle

4.1.3.2 Sea Level Rise

Climate change with rising sea levels is expected to continue and worsen in the coming years. Ocean Protection Council (OPC) Guidance (2018) provides SLR projections for the Los Angeles area (Figure 7). Two SLR scenarios modeled for Southern LCW Restoration Phase 2 condition are 1.6 feet (0.5m) and 3.3 feet (1m). The 1.6-feet SLR falls in the “Likely Range” of OPC’s projections by 2070 under the Low Risk Aversion scenario, and 2050 under the Medium-High Risk Aversion scenario. The 3.3-feet SLR falls in the “Likely Range” of OPC’s projections by

2110 under the Low Risk Aversion scenario, and 2070 under the Medium-High Risk Aversion scenario. The SLR amount is added to the typical spring-neap tide cycle to evaluate the impacts of SLR.

		Probabilistic Projections (in feet) (based on Kopp et al. 2014)					H++ scenario (Sweet et al. 2017) *Single scenario
		MEDIAN	LIKELY RANGE		1-IN-20 CHANCE	1-IN-200 CHANCE	
		50% probability sea-level rise meets or exceeds...	66% probability sea-level rise is between...		5% probability sea-level rise meets or exceeds...	0.5% probability sea-level rise meets or exceeds...	
				Low Risk Aversion		Medium - High Risk Aversion	Extreme Risk Aversion
High emissions	2030	0.3	0.2 -	0.5	0.6	0.7	1.0
	2040	0.5	0.4 -	0.7	0.9	1.2	1.7
	2050	0.7	0.5 -	1.0	1.2	1.8	2.6
Low emissions	2060	0.8	0.5 -	1.1	1.4	2.2	
High emissions	2060	1.0	0.7 -	1.3	1.7	2.5	3.7
Low emissions	2070	0.9	0.6 -	1.3	1.8	2.9	
High emissions	2070	1.2	0.8 -	1.7	2.2	3.3	5.0
Low emissions	2080	1.0	0.6 -	1.6	2.1	3.6	
High emissions	2080	1.5	1.0 -	2.2	2.8	4.3	6.4
Low emissions	2090	1.2	0.7 -	1.8	2.5	4.5	
High emissions	2090	1.8	1.2 -	2.7	3.4	5.3	8.0
Low emissions	2100	1.3	0.7 -	2.1	3.0	5.4	
High emissions	2100	2.2	1.3 -	3.2	4.1	6.7	9.9
Low emissions	2110*	1.4	0.9 -	2.2	3.1	6.0	
High emissions	2110*	2.3	1.6 -	3.3	4.3	7.1	11.5
Low emissions	2120	1.5	0.9 -	2.5	3.6	7.1	
High emissions	2120	2.7	1.8 -	3.8	5.0	8.3	13.8
Low emissions	2130	1.7	0.9 -	2.8	4.0	8.1	
High emissions	2130	3.0	2.0 -	4.3	5.7	9.7	16.1
Low emissions	2140	1.8	0.9 -	3.0	4.5	9.2	
High emissions	2140	3.3	2.2 -	4.9	6.5	11.1	18.7
Low emissions	2150	1.9	0.9 -	3.3	5.1	10.6	
High emissions	2150	3.7	2.4 -	5.4	7.3	12.7	21.5

Figure 8: Projected Future SLR for Los Angeles (OPC 2018)

5 Modeling Results

Modeling results for both Phase 1 and Phase 2 are presented below. Results are in the form of tidal elevations, tidal inundation frequency, and tidal water residence times. Both phases included analyses of existing sea level, and SLR of 1.6 feet (0.5m) and 3.3 feet (1m). Table 1 lists the modeling scenarios. Each SLR condition was analyzed with the typical spring-neap tide cycle. For Phase 2, modeling is not required for the two SLR scenarios as the wetland will experience the full ocean tidal conditions. Hence, the tidal conditions in the wetland will be the same as those in the ocean. The results for the bridge-type crossing are presented in the Phase 2 section below because the modeling was intended to show the ultimate hydraulic condition. The crossing will be installed in Phase 1; however, when tidal flow and prism are smaller compared to Phase 2.

Table 1: SLR Scenarios

Scenario	SLR	Offshore Water Level
#1	No	Typical Spring-Neap Tide Cycle
#2	+1.6 ft	Typical Spring-Neap Tide Cycle
#3	+3.3 ft	Typical Spring-Neap Tide Cycle

6 Phase 1

6.1.1 Tidal Elevations and Ranges

The modeled water surface elevations at the three nodes (Node 1 through Node 3) shown in Figure 2 are compared with water levels in the San Gabriel River (assumed to be the same as those in the open ocean) during the typical spring-neap tidal cycle. As presented in Figure 9, the water levels at each node are muted compared to ocean (river) water levels: High tides in the wetland are predicted to reach maximum elevations of 2.90 feet relative to NGVD29, while ocean water levels reach up to 4.10 feet NGVD29. The low tide in the wetland will reach down to an elevation of 0.10 feet NGVD at Nodes 1 and 2 while the low tide in the ocean reaches down to -3.88 feet. As summarized in Table 2, the wetland tidal range is predicted to be approximately 2.80 feet while that in the ocean is approximately 7.98 feet. The farthest upstream node (Node 3) is more muted than the downstream nodes (Nodes 1 and 2) due to distance from the culvert and the constricted channel condition all the way to that node.

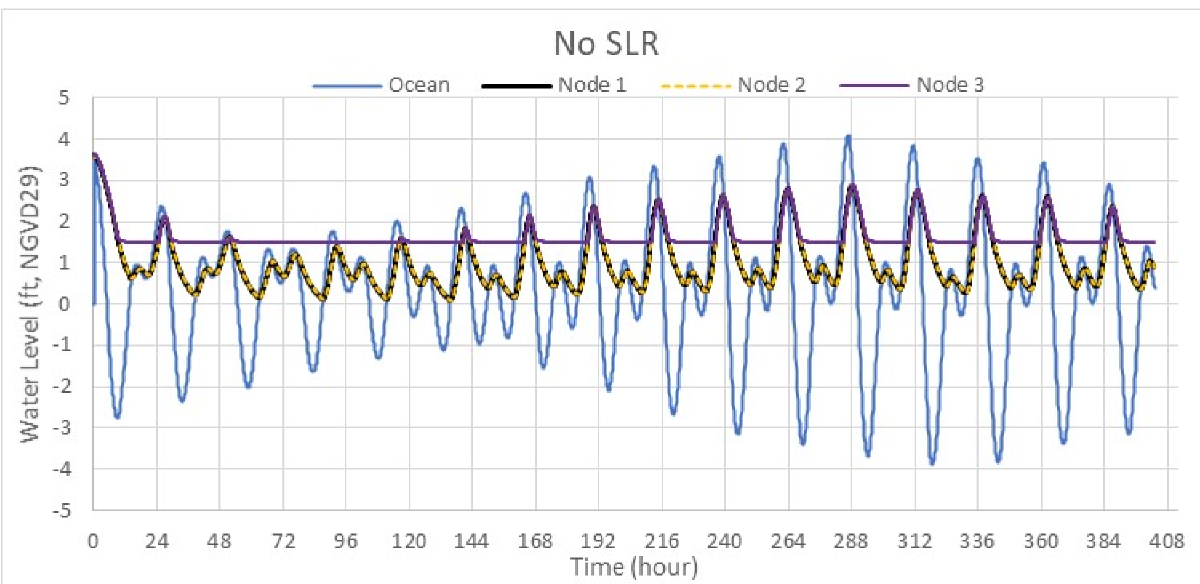

Figure 9: Modeled Water Levels at Phase 1 Marsh Under No SLR Scenario

Table 2: Comparison of Post-Phase 1 Restoration Average Spring High & Low Tides and Tide Ranges with No SLR

Locations	Offshore (Node 0)	Southern LCW		
		Node 1	Node 2	Node 3
Spring High Tide (ft NGVD29)	+4.10	+2.90	+2.90	+2.90
Spring Low Tide (ft NGVD29)	-3.88	+0.10	+0.10	+1.50
Spring Tide Range (ft)	7.98	2.80	2.80	1.40

Tidal muting in the wetland during Phase 1 is due to effects of the existing 42-inch culvert. The culvert limits the amount of water entering and exiting the marsh. The existing wetland area is approximately 38 acres (CRC 2021). The limited surface area of the Phase 1 restored marsh (40 acres) is similar to the existing condition, so the tidal storage capacity in the wetland and the tidal range should be similar. The model predicts the tidal range to be similar to existing conditions with a modest increase of approximately 0.6 feet, but the maximum and minimum tidal elevations are lower for future conditions compared to existing values. This is caused by the effect of the proposed grading (lowering) of the entrance channel down to -4 feet NGVD29, as compared to an existing marsh channel invert elevation of +1 foot NGVD29. Existing measured tides remain above the existing invert by 0.5 feet, so the existing low tide is +1.5 feet. The conveyance capacity of the culvert is sufficient to allow high tides to reach within 1.2 feet of the high tide in the river.

The existing culvert has sufficient conveyance capacity to provide tides to the site in Phase 1 in the near term so that it does not need to be replaced with a larger culvert, nor does the existing corroded flap gate on the river end need to be replaced. The only potential action that could occur is cleaning the culvert of sediment and debris to continue water conveyance. In conclusion for Phase 1, the tidal range will expand from approximately 2.0 feet to 2.8 feet (40% increase) but drop in elevation by approximately 1.5 feet due to the proposed channel grading. This effect may help to maintain existing salt marsh habitat on-site by not causing tidal inundation to occur more often than the existing marsh habitat can tolerate. No additional hydraulic changes to these results nor those presented below will occur from installing a bridge-type crossing at 1st Street. The bridge-type crossing is less influential on tides than the existing 42-inch culvert.

The predicted water levels under the 1.6-feet SLR scenario are shown in Figure 10. The high tide reaches the same elevation at all three nodes, but the low tide is still muted more at Node 3 compared to Nodes 1 and 2, as it is further away from the culvert near the end of a long and narrow channel.

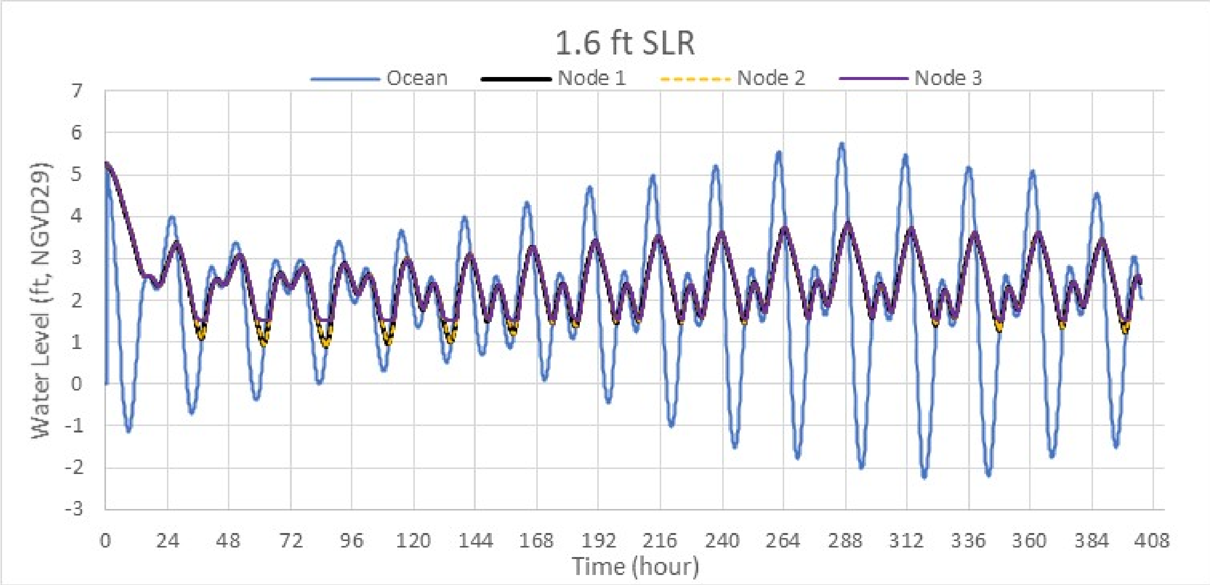

Figure 10: Modeled Water Levels at Phase 1 Marsh Under 1.6-ft SLR Scenario

Figure 11 shows predicted water levels under the 3.3-feet SLR scenario. All nodes, in other words the entire wetland, will experience a similar tidal range of 2.04 feet. Table 3 lists the high and low tidal elevations and tidal ranges at Node 1 by SLR scenario. The high and low spring tide elevations increase with SLR, but the tidal range decreases as SLR increases. This tidal range decrease likely occurs as the storage capacity of the marsh area increases and more water can be stored on-site during high tide, but that increased water volume cannot pass through the limited culvert cross-section during ebbing tides, thus limiting the low tide elevation. If Phase 1 is the only restoration to occur on-site, then one long-term objective could be to replace the culvert with a larger one or add additional culverts to the existing one. One possible future adaptation strategy during SLR would be to increase the size of the culvert.

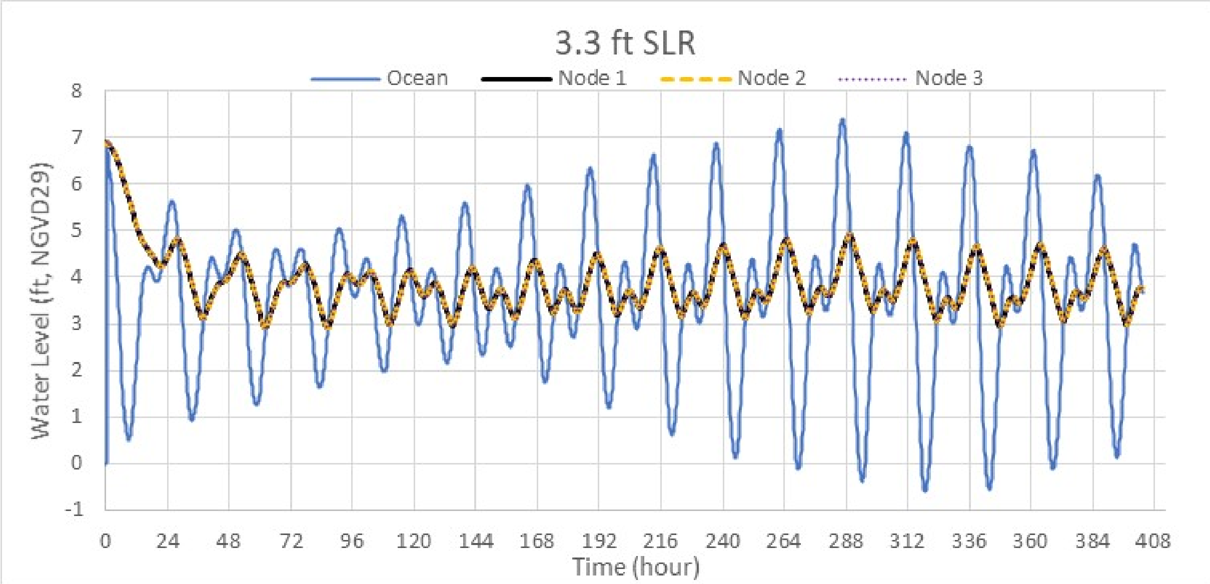

Figure 11: Modeled Water Levels at Phase 1 Marsh Under 3.3-ft SLR Condition

Table 3: Post-Phase 1 Restoration Average Spring High & Low Tides and Tide Ranges at Node 1 by SLR Scenarios[1]

Locations	Southern LCW [1]		
Scenarios	No SLR	+1.6 ft SLR	+3.3 ft SLR
Spring High Tide (ft NGVD29)	+2.90	+3.82	+4.93
Spring Low Tide (ft NGVD29)	+0.10	+1.52	2.89
Spring Tide Range (ft)	2.80	2.30	2.04

Note: [1] The results from Pt 1 are presented in this table, and the differences among Pt 1, Pt 2 and Pt 3 are less than 0.03 ft.

6.1.2 Tidal Inundation Frequency

The tidal inundation frequency analysis provides the frequency of inundation statistics over specific elevation thresholds at a given location. It is extremely beneficial in planning marsh restoration activities and habitat designs. The inundation frequency determines the elevations at which specific marsh habitats will be established and the area and distribution of wetland habitats. Figure 12 presents the predicted inundation frequencies at South LCW wetland for no SLR condition. There are no differences between the inundation curves at Nodes 1 and 2, but Node 3 is very different with a much more compressed range of tidal elevations and a compressed habitat establishment elevation range. There are three inundation percentage breaks, 4%, 20% and 40% for high marsh, mid marsh, low marsh and mudflat, respectively. Tidal elevations may generally be slightly lower than existing conditions and the inundation frequency may reflect that condition, so the team is considering lowering the target elevations of low marsh and mid-marsh in the 30% design by 0.5 feet to compensate.

Table 4 through Table 6 list the habitat break elevations at Node 1 through Node 3 in the southern LCW for three sea level scenarios, respectively. Due to the minimum differences in tidal range and high/low tide elevations at Nodes 1 and 2, the habitat break elevations at these two points are also very similar under the same SLR scenario. Node 3 has a very different range of habitat elevations due to its distance inland and low marsh is eliminated.

For SLR, Figure 13 and Figure 14 show the inundation frequency curves for 1.6 feet and 3.3 feet, respectively, although Node 3 varies from the other two at the low end of the tide for the 1.6 feet of SLR scenario. The sites take on similar traits with no significant difference between them. The curve is steep meaning that there is very little range of elevation between habitats, however, each habitat type may exist within its respective elevation band. Overall, the site is fairly resilient to SLR as habitat establishment becomes a bit more diverse as sea levels rise.

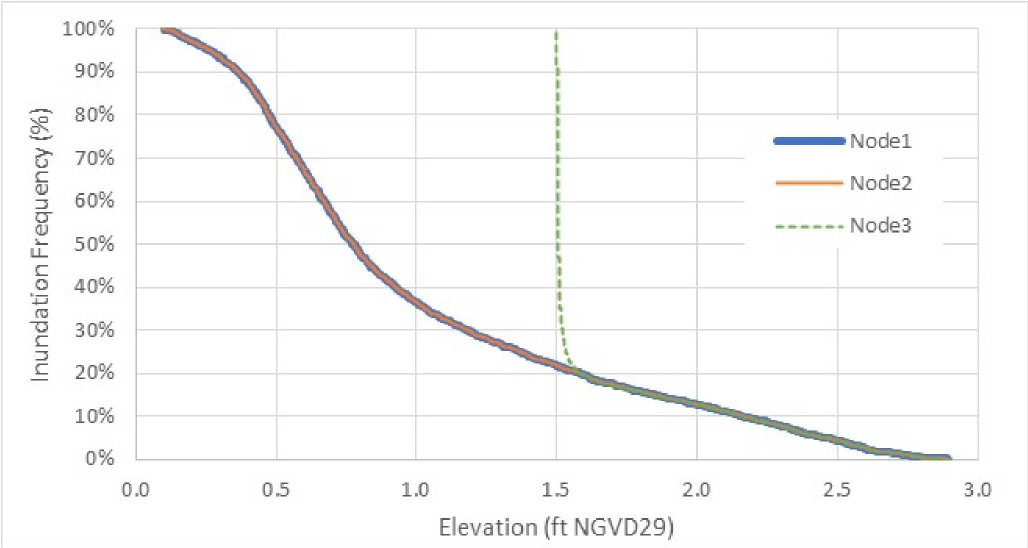

Figure 12: South LCW Wetland Inundation Frequency Curves, Phase 1 – No SLR Scenario

Table 4: Habitat Elevation Breaks in Southern LCW Phase 1 – No SLR Scenario

Habitat Type	Freq (%)	Habitat Breaks (WL, ft, NGVD29)		
		Node1	Node2	Node3
Transitional	0%	2.89	2.90	2.90
High- Marsh	4%	2.53	2.53	2.52
Mid-Marsh	20%	1.58	1.59	1.59
Low-Marsh	40%	0.93	0.92	1.51
Mudflat	100%	0.10	0.10	1.50

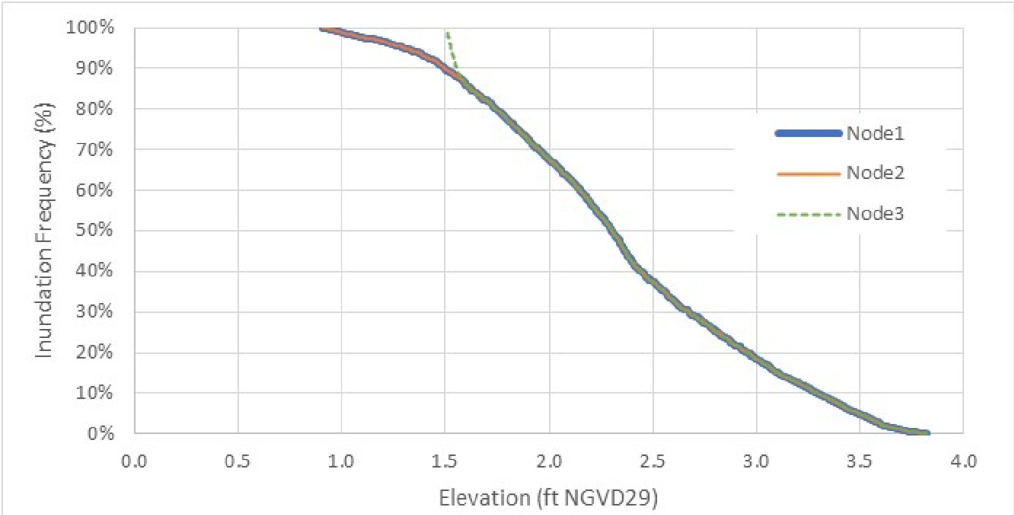

Figure 13: South LCW Wetland Inundation Frequency Curves, Phase 1 – 1.6 Feet of SLR Condition

Table 5: Habitat Elevation Breaks in Southern LCW Phase 1 – 1.6 Feet of SLR Scenario

Habitat Type	Freq (%)	Habitat Breaks (WL, ft, NGVD29)		
		Node1	Node2	Node3
Transitional	0%	3.82	3.82	3.82
High- Marsh	4%	3.54	3.54	3.54
Mid-Marsh	20%	2.96	2.96	2.96
Low-Marsh	40%	2.44	2.44	2.44
Mudflat	100%	0.91	0.90	1.51

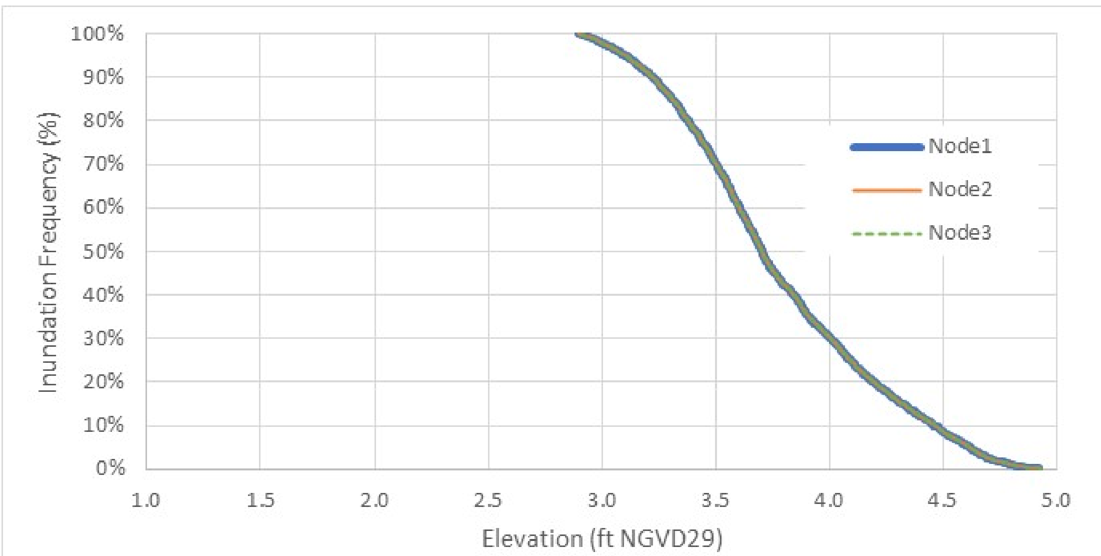

Figure 14: South LCW Wetland Inundation Frequency Curves, Phase 1 – 3.3 Feet of SLR Condition

Table 6: Habitat Elevation Breaks in Southern LCW Phase 1 – 3.3 Feet of SLR Scenario

Habitat Type	Freq (%)	Habitat Breaks (WL, ft, NGVD29)		
		Node1	Node2	Node3
Transitional	0%	4.92	4.93	4.93
High- Marsh	4%	4.65	4.65	4.65
Mid-Marsh	20%	4.20	4.20	4.20
Low-Marsh	40%	3.84	3.84	3.84
Mudflat	100%	2.90	2.90	2.89

7 Modeling Results – Phase 2

Figure 15 presents the three locations where tidal elevations and the tidal inundation frequency were analyzed based on the model water level outputs. The three points are all located within the proposed open channel and numbered Pt 1 through Pt 3 from west to east. Evaluation of the bridge-type crossing required analysis of an additional point, so Figure 16 shows the model output locations.

Figure 15: Location Map of Three Monitoring Points

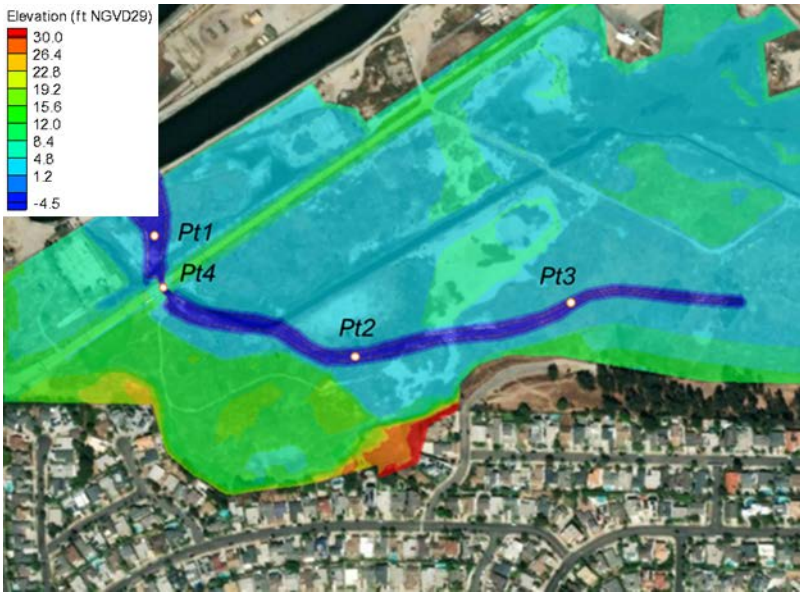

Figure 16: Location Map of Four Monitoring Points to Consider a Bridge-Type Crossing

7.1.1 Tidal Elevations and Ranges

The modeled surface elevations at the three monitoring points are compared with offshore water levels during the typical spring-neap tidal cycle. As presented in Figure 17, the water levels at Pt 1 are the same as offshore water levels: The highest spring tidal level is 4.10 feet above NGVD29, and the lowest is 3.88 feet below NGVD29, resulting in a spring tidal range of 7.98 feet. There is no “tidal muting” observed, nor tidal phase lag. This is due to the designed open channel in Phase 2 being wide enough to fully convey the tidal flow in and out of the State Lands Commission (SLC) wetland. Table 7 compares the high and low tide elevations and the associated tidal ranges among offshore and the three monitor points. The differences are less than 0.03 feet and are considered neglectable since such differences are within the model accuracy range.

Table 8 lists the high and low tidal elevations and tidal ranges at Pt 1 by SLR scenarios. The tidal range remains the same for all three SLR scenarios, and the high and low spring tide elevations increase linearly with the SLR amount. The results of Pt 2 and Pt 3 are the same as Pt 1, thus not presented in the table. Values at Pt 4 at the new bridge-type crossing is the same as Pt 1. Also, Pts 2 and 3 located upstream of the future bridge also possess the same values as originally modeled, so no upstream effects of the structure’s presence are predicted.

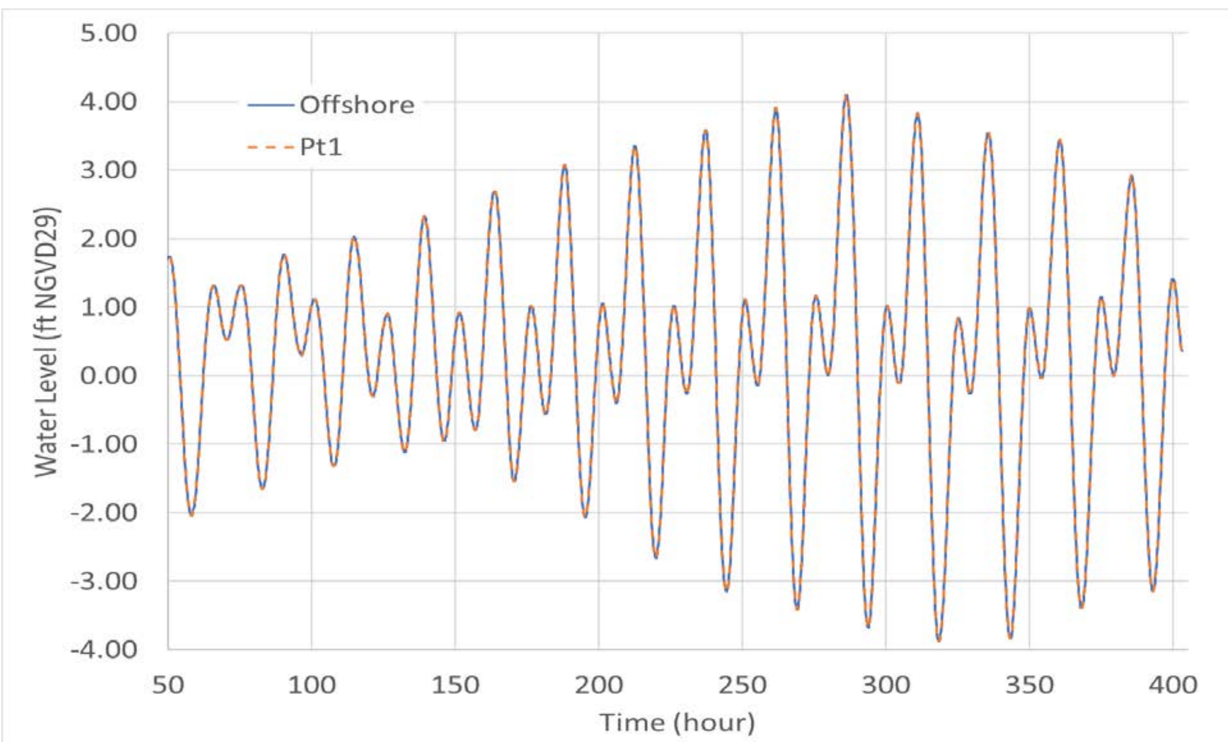

Figure 17: Modeled Water Levels at Pt 1 and Offshore During Typical Spring Tides

Table 7: Comparison of Post-Phase 2 Restoration Average Spring High & Low Tides and Tide Ranges with No SLR

Locations	Offshore	Southern LCW			
		Pt 1	Pt 2	Pt 3	Pt 4
Spring High Tide (ft NGVD29)	+4.10	+4.10	+4.12	+4.13	+4.10
Spring Low Tide (ft NGVD29)	-3.88	-3.87	-3.88	-3.88	-3.87
Spring Tide Range (ft)	7.98	7.97	8.00	8.00	7.97

Table 8: Average Spring High & Low Tides and Tide Ranges at Pt 1 by SLR Scenario[1]

Locations	Southern LCW [1]		
Scenarios	No SLR	+1.6 ft SLR	+3.3 ft SLR
Spring High Tide (ft NGVD29)	+4.10	+5.70	+7.40
Spring Low Tide (ft NGVD29)	-3.87	-2.27	-0.57
Spring Tide Range (ft)	7.97	7.97	7.97

Note: [1] The results from Pt 1 are presented in this table and the differences among Pt 1, Pt 2, and Pt 3 are less than 0.03 ft.

7.1.2 Tidal Inundation Frequency

The tidal inundation frequency analysis provides the frequency of inundation statistics over specific elevation thresholds at a given location. It is extremely beneficial in planning marsh restoration activities and habitat designs. The inundation frequency determines the elevations at which specific marsh habitats will be established and the area and distribution of wetland habitats. Figure 18 presents the predicted inundation frequencies at south LCW wetland for no SLR condition. There are no differences between the inundation curves at the four monitoring points, Pt 1 through Pt 4. There are three inundation percentage breaks, 4%, 20%, and 40% for high marsh, mid marsh, low marsh, and mudflat.

Table 9 through Table 11list the habitat break elevations at Pt 1 through Pt 4 in the southern LCW for three sea level scenarios, respectively. Due to the minimum differences in tidal range and high/low tide elevations at Pt 1 through Pt 4, the habitat break elevations at these four points are also very similar under the same SLR scenario. At a given location within the open channel in southern LCW, the habitat break elevation for certain habitat linearly increases with SLR.

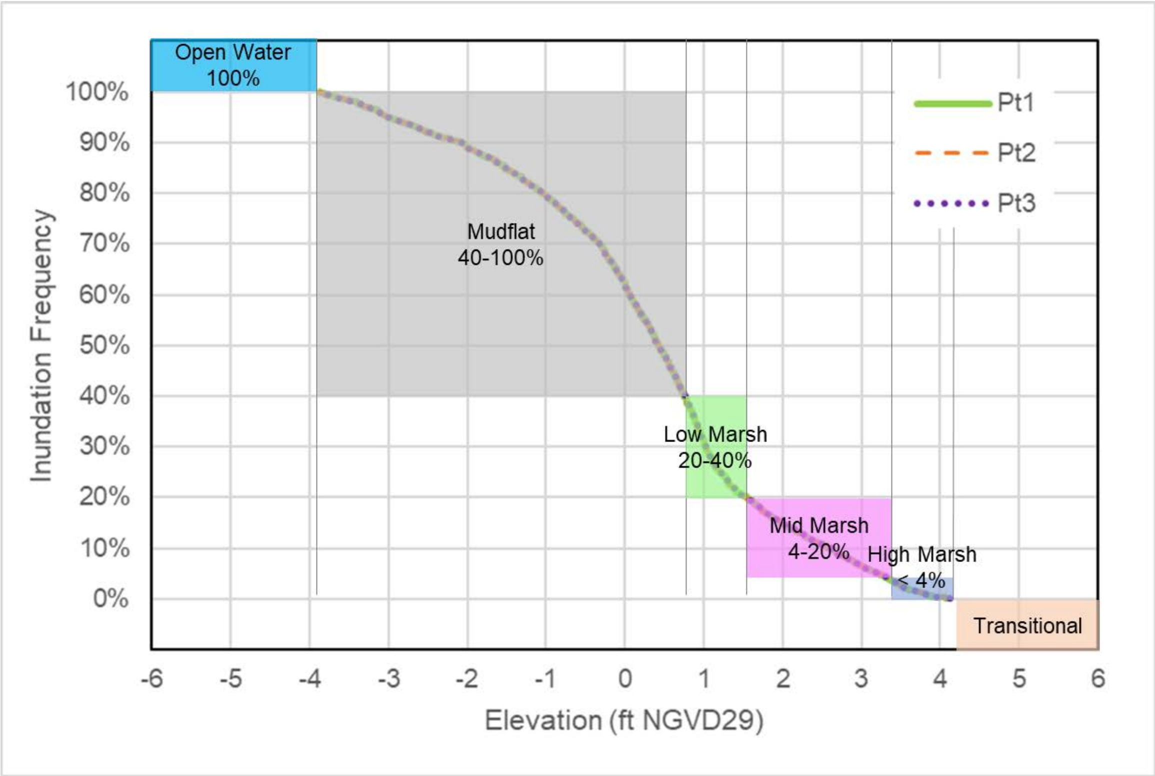

Figure 18: South LCW Wetland Inundation Frequency Curve – No SLR Condition

(Pts 1 and 4 Possess the Same Curves)

Table 9: Habitat Elevation Breaks in Southern LCW Phase 2 – No SLR Scenario

Habitat Type	Freq (%)	Habitat Elevation Breaks (ft NGVD29)		
		Pt1 and Pt 4	Pt2	Pt3
Transitional	0%	> 4.10	> 4.12	> 4.13
High- Marsh	4% - 0%	3.35 – 4.10	3.35 – 4.12	3.34 – 4.13
Mid-Marsh	20% - 4%	1.54 – 3.35	1.54 – 3.35	1.54 – 3.34
Low-Marsh	40% - 20%	0.76 – 1.54	0.76 – 1.54	0.76 – 1.54
Mudflat	100% - 40%	-3.87 – 0.76	-3.88 – 0.76	-3.88 – 0.76
Subtidal	100%	< -3.87	< -3.88	< -3.88

Table 10: Habitat Elevation Breaks in Southern LCW Phase 2 – 1.6-ft SLR Scenario

Habitat Type	Freq (%)	Habitat Elevation Breaks (ft NGVD29)		
		Pt1 and Pt 4	Pt2	Pt3
Transitional	0%	> 5.70	> 5.72	> 5.73
High- Marsh	4% - 0%	4.95 – 5.70	4.95 – 5.72	4.94 – 5.73
Mid-Marsh	20% - 4%	3.14 – 4.95	3.14 – 4.95	3.14 – 4.94
Low-Marsh	40% - 20%	2.36 – 3.14	2.36 – 3.14	2.36 – 3.14
Mudflat	100% - 40%	-2.27 – 2.36	-2.28 – 2.36	-2.28 – 2.36
Subtidal	100%	< -2.27	< -2.28	< -2.28

Table 11: Habitat Elevation Breaks in Southern LCW Phase 2 – 3.3-ft SLR Scenario

Habitat Type	Freq (%)	Habitat Elevation Breaks (ft NGVD29)		
		Pt1 and Pt 4	Pt2	Pt3
Transitional	0%	> 7.40	> 7.42	> 7.43
High- Marsh	4% - 0%	6.65 – 7.40	6.65 -7.42	6.64 -7.43
Mid-Marsh	20% - 4%	4.84 - 6.65	4.84 - 6.65	4.84 – 6.64
Low-Marsh	40% - 20%	4.06 – 4.84	4.06 – 4.84	4.06 – 4.84
Mudflat	100% - 40%	-0.57 – 4.06	-0.58 – 4.06	-0.58 – 4.06
Subtidal	100%	< -0.57	< -0.58	< -0.58

8 Conclusions

Conclusions from these hydraulic/hydrologic analyses are provided below.

8.1 Phase 1

1. The existing tide range is constricted to approximately 2.0 feet with a high tide elevation of 3.67 feet NGVD29 and a low of 1.47 feet NGVD29 as measured in 2021. Tidal muting is caused by the effects of a limited culvert cross-section area of 42 inches at the marsh and 48 inches at the San Gabriel River. Also, site topography and bathymetry within the main channel limits the existing low tide elevation because the bed elevation remains above +1.0 feet MSL.
2. The future tide range is predicted to expand from existing conditions but will still be muted and may range by approximately 2.80 feet, with high tide reaching 2.90 feet NGVD29 and low tide reaching 0.10 feet NGVD29. These tides are still determined to be sufficient to provide the desired habitat range within the site for Phase 1 restoration. The tide range will be limited by the size of the culvert. The range of tidal elevations will drop by nearly 1.5 feet from existing conditions because the elevation of the bed of the main channel is proposed to be lowered to -4 feet, which is below the elevation of the culvert invert. The proposed bridge-type crossing at 1st Street will have no effect on these tides because the tides are controlled by the existing 42-inch culvert.
3. For existing sea level, the existing culvert can remain as is with the only potential action to include cleaning. However, the culvert can still function acceptably without being cleaned. The culvert door to the San Gabriel River does not need to be removed, and the culvert does not need to be replaced with a larger one or supplemented with an additional one.

4. As sea level rises, the tidal range of the Phase 1 restored marsh will decrease due to increased storage capacity and the limited culvert. However, tidal elevations will shift up with the higher water levels in the river.
5. If Phase 1 restoration is the only project completed on the site, the long-term adaptation strategy to maximize tidal flushing and range during SLR is to either replace the culvert with a larger one or add another culvert to increase the hydraulic conveyance capacity.
6. Habitat elevations for low and mid-marsh may need to be reconsidered and lowered by 0.5 feet in the design to compensate for slightly lowered high and low tidal elevations with restoration.

8.2 Phase 2

1. Phase 2 results in a full tidal range in the marsh post-restoration without SLR, and also with SLR over time.
2. All tidal wetland habitats can be realized on-site with high quality and function for existing sea level.
3. As sea level rises, tidal elevations rise linearly with SLR, and the tide range remains as occurs with existing conditions.
4. Tidal wetland habitats can exist but will transition from the original distribution to a new mix of more subtidal, mudflat, and low marsh habitats, with less mid-marsh, high marsh, and transitional habitats over time.
5. Adaptation during SLR could consist of thin layer adaptation of adding sediment selectively to certain areas to maintain mid- and high marsh habitats over time.
6. The proposed bridge-type crossing at 1st Street has no effect on tides and the site will function similarly with the structure in place for existing sea level and for the SLR scenarios considered herein.

9 References

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