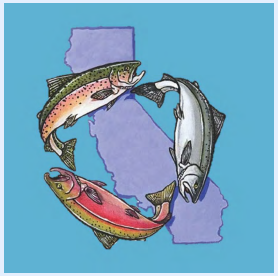
Approaches for Management and Restoration of Central California Coastal Lagoons

A Concurrent Session at the 39th Annual Salmonid Restoration Conference held in Santa Cruz, California from April 19 – 22, 2022.

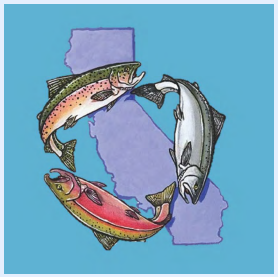
- **Session Coordinators:**
  - *Dane Behrens, ESA and*
    Jim Robins, Alnus Ecological



Coastal lagoons are a vital part of the California coastline, acting as links in the sediment supply chain that form sandy beaches along the shoreline, and as critical habitat for native species. Because of their location, they are frontlines for climate change impacts from both the coastal side (sea-level rise) and from the upstream side (increased runoff variability). Climate change is anticipated to create extensive change to the long-term function and fate of these systems. At the same time, the historical backdrop includes a host of legacy impacts to the hydrograph and sediment supply, as well as development encroachment within the floodplain. While this is the reality for most of coastal California, there is a particular urgency in central California, where a small number of coastal lagoon systems have disproportionate importance as homes for threatened and endangered species, such as the California Central Coast Steelhead, California Central Coast Coho salmon, and tidewater goby.

This session will showcase novel approaches for restoration, monitoring, and long-term management that are being developed in central California. Speakers will include: restoration practitioners that will highlight recent efforts to improve habitats and add long-term resilience to climate change, local fisheries biologists that will discuss recent advances in monitoring methods and how they are being implemented in the field local resource agency staff that will discuss how long-term planning approaches are evolving to meet the challenge of climate change. This session will integrate with site tours of local sites, including Scotts Creek and Pescadero.

Presentations



Slide 4 - **Considerations for Management of the Mouth State of California's Bar-built Estuaries**, Kevin O'Connor, *Moss Landing Marine Labs*

Slide 31 - **Logging,Leather, Lime and "Lost Boys": Reducing Limiting Factors for Anadromous Salmonids in the San Lorenzo River Lagoon**, Chris Berry, *City of Santa Cruz*

Slide 88 - **Lessons Learned from 8 Years of Lagoon Management of the San Lorenzo River,Santa Cruz, California: Using Sand to Balance Ecological Function and Social Demands**, David Revell, PhD, *Integral Consulting*

Slide 139 - **Butano Marsh Channel Reconnection and Resilience Project: Design,Implementation and Preliminary Results**, Chris Hammersmark, PhD, PE, and Ryan Dillar, *CA State Parks*

Slide 203 - **Pescadero Marsh: A Bar-Built Estuary's Importance to Steelhead**, Sean Cochran, *CDFW*, and Patrick Samuel, *Cal Trout*

Slide 226 - **Projecting Habitat Evolution in the Face of Sea Level Rise, a Case Study in Pescadero Marsh**,Matt Jamieson, MFA, *Integral Consulting*

Considerations for Management of the Mouth State of California's Bar-built Estuaries

Kevin O'Connor

John Largier & Ross Clark

2022 SRF
Santa Cruz, CA

April 21-22, 2022

NOAA FISHERIES

CCWG Central Coast Wetlands Group

Bodega Marine Laboratory — UC Davis Coastal & Marine Sciences Institute

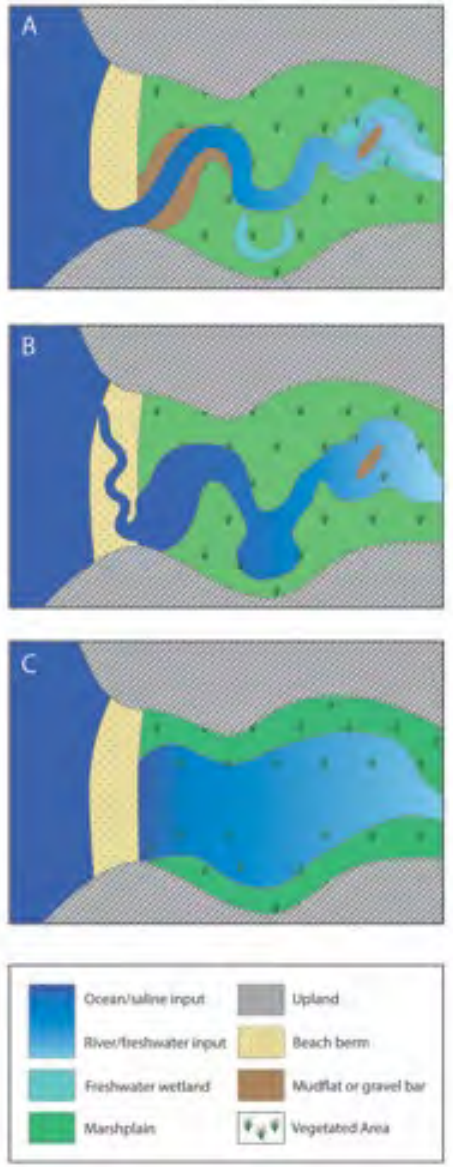
Bar-Built Estuaries (BBE)

-Seasonal closure of beach berm to the marine environment

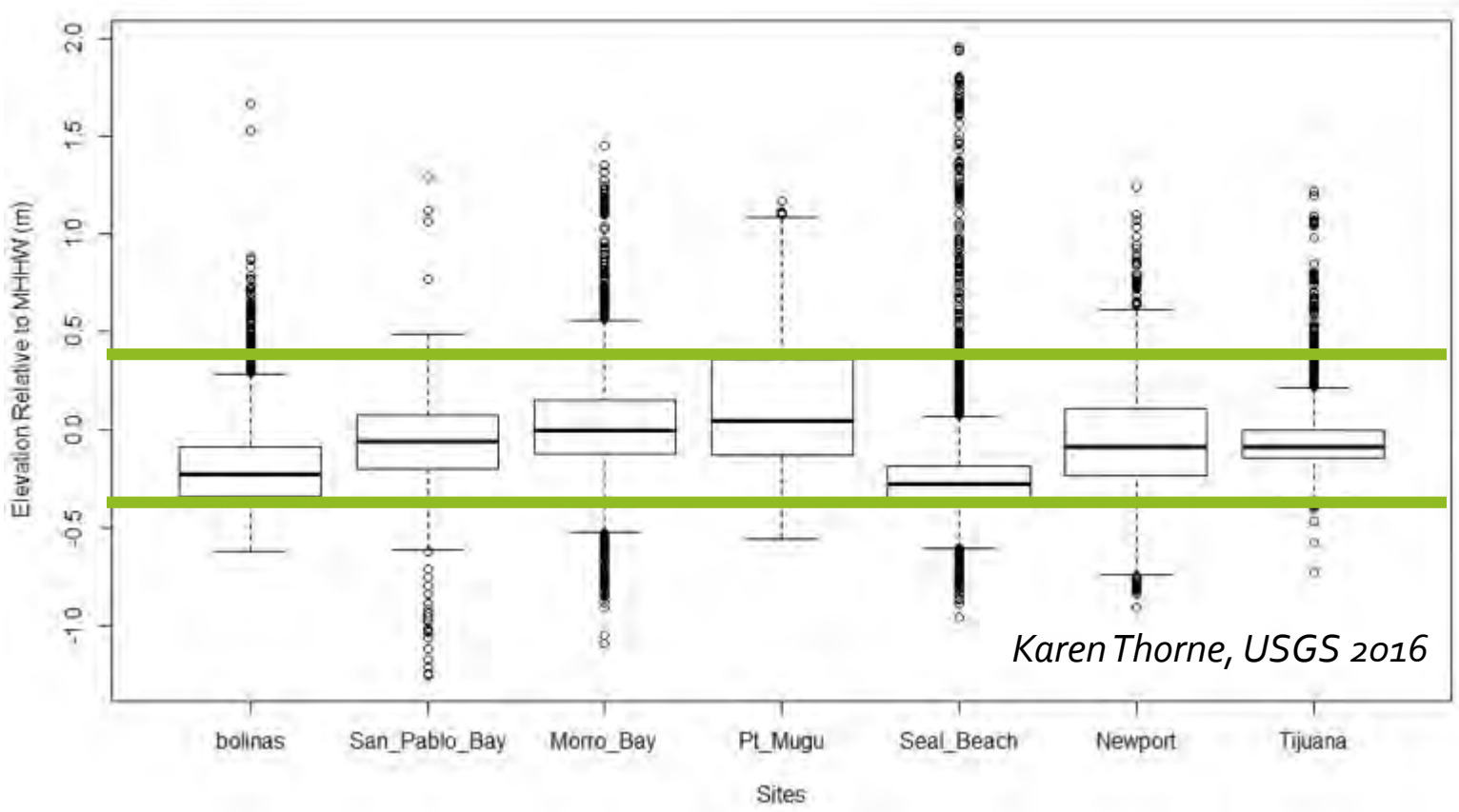
-Marsh plain linked to height of berm, freshwater inputs, and tidal height

-Highly dynamic
salinity, DO, temp, etc.

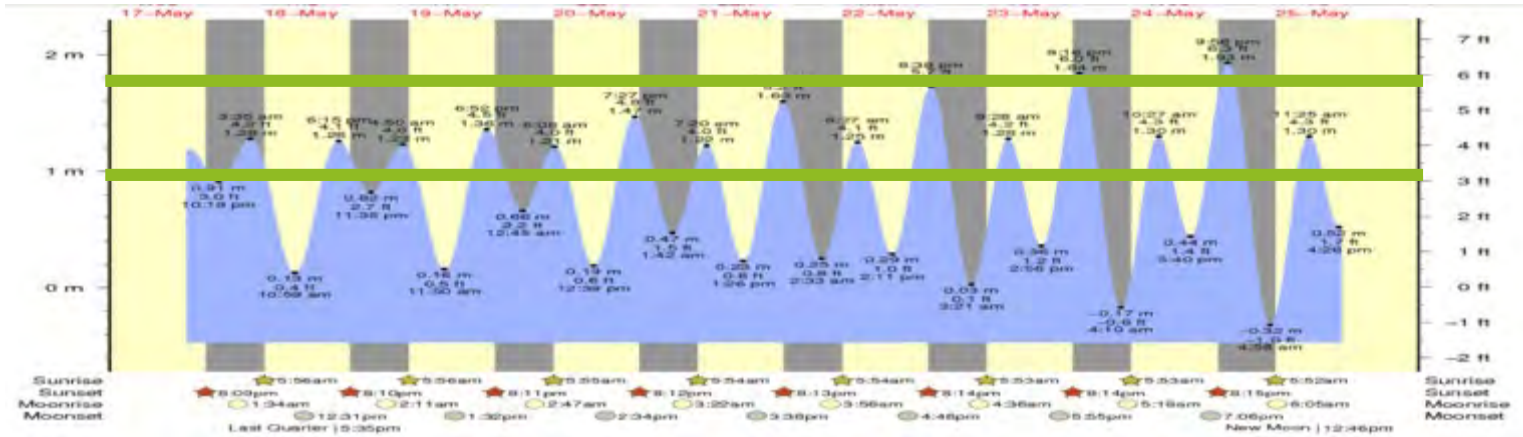
-Periodic flushing



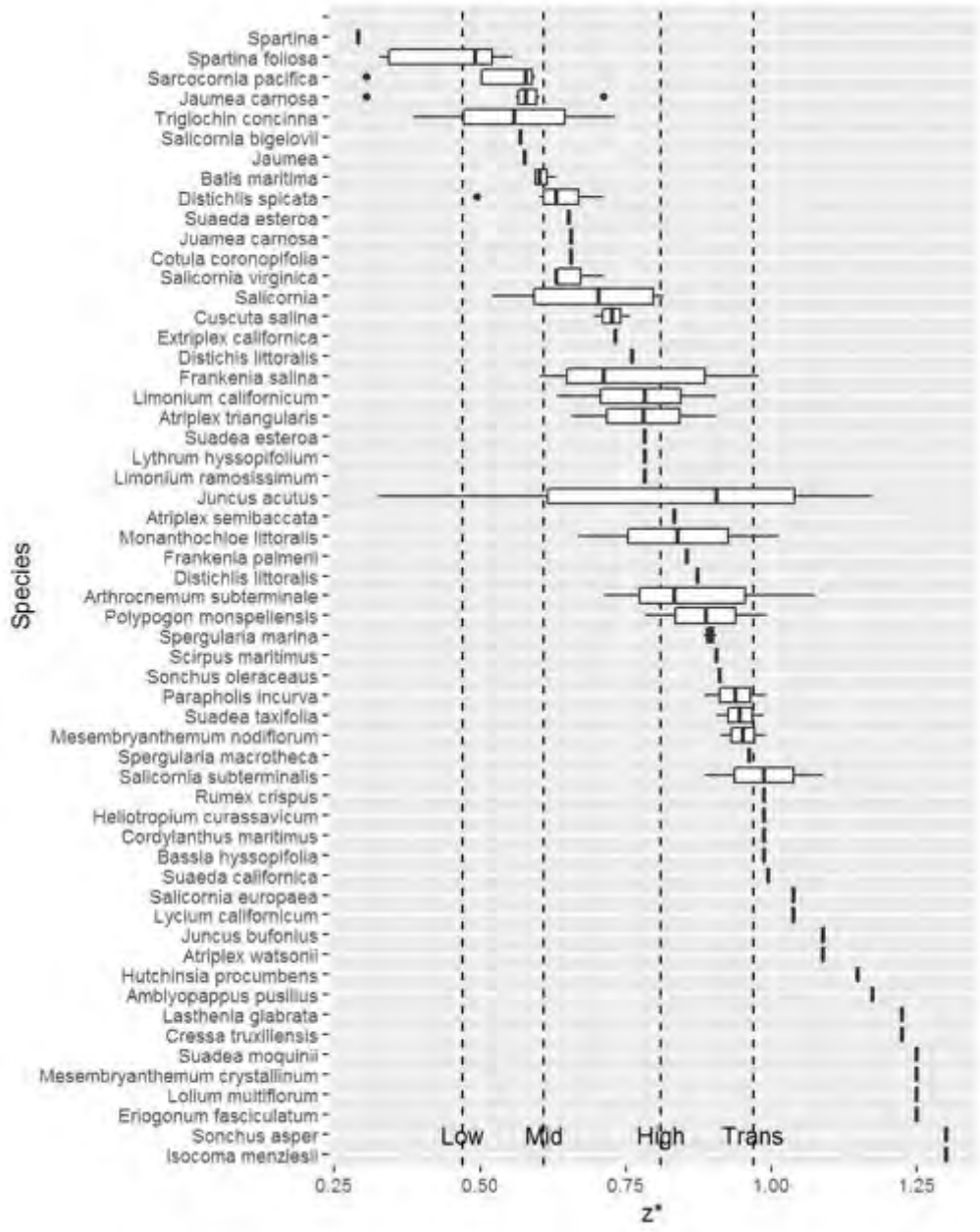
Perennial Coastal Salt Marsh elevations are typically within a tight range relative to local MHHW

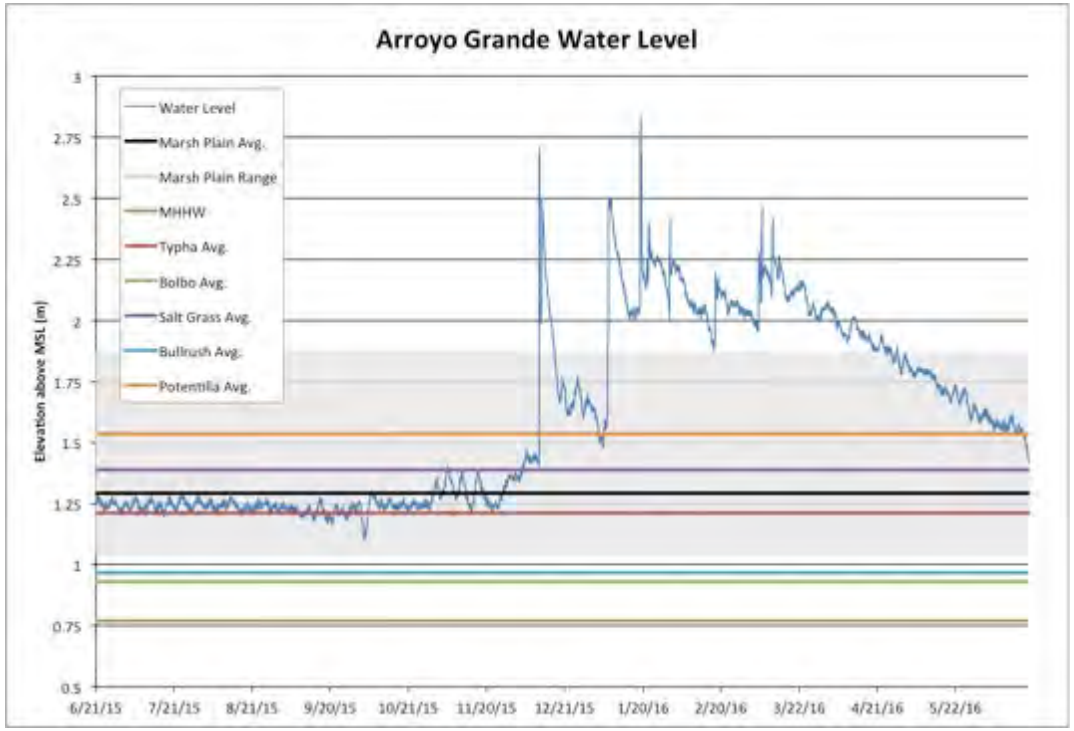


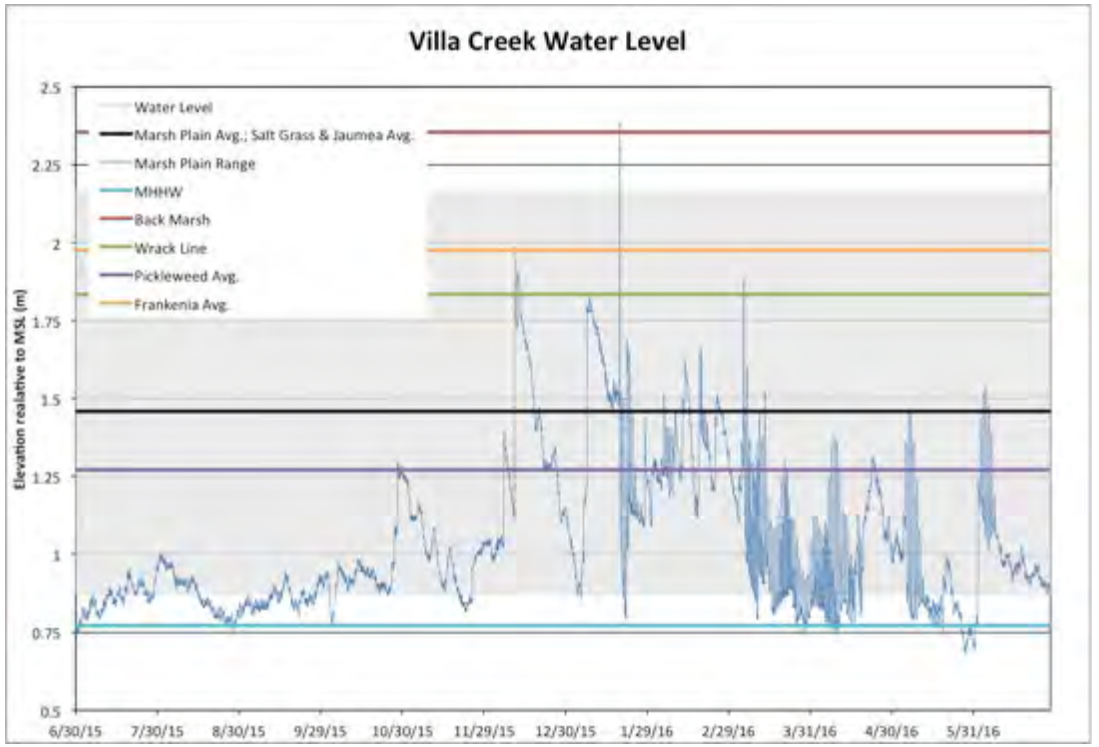
Karen Thorne, USGS 2016

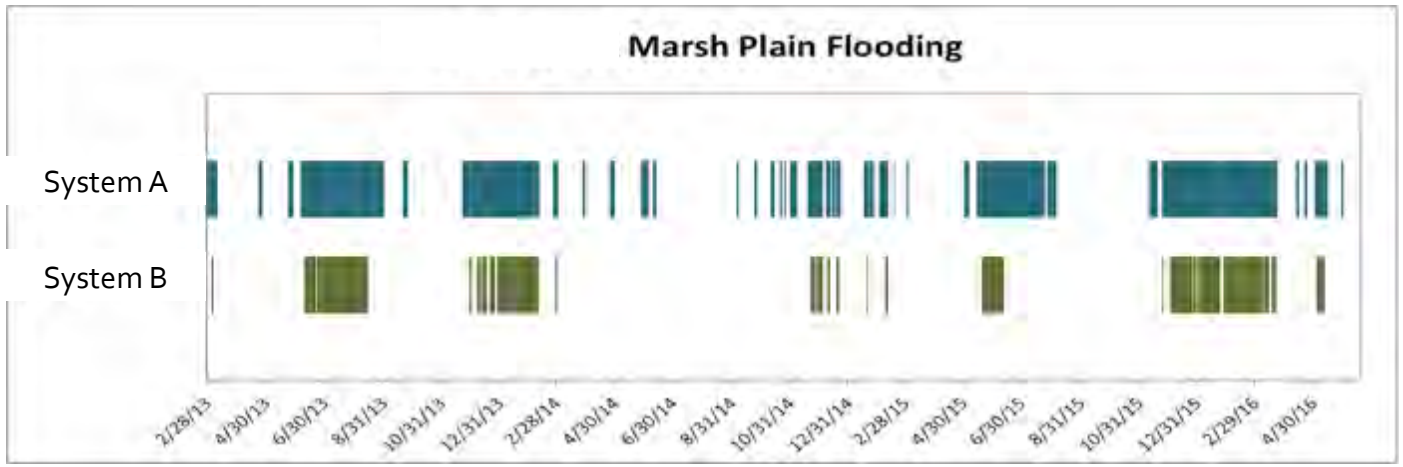


Plant Zonation relative to local tidal range

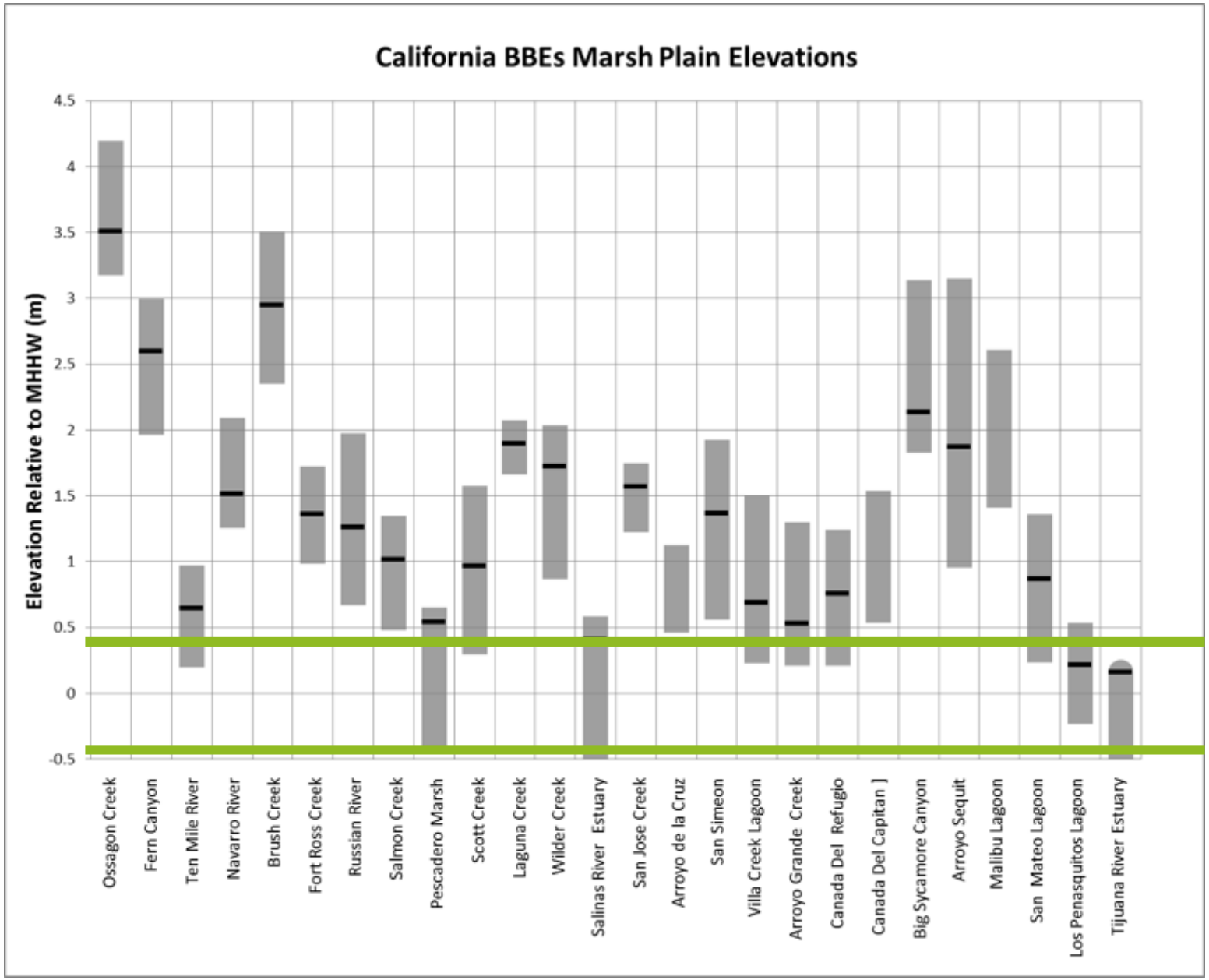



Arroyo Grande Water Level
Water Level
Marsh Plain Avg.
Marsh Plain Range
MHHW
Typha Avg.
Bolbo Avg.
Salt Grass Avg.
Bullrush Avg.
Potentilla Avg.
Elevation above MSL (m)
3
2.75
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
6/21/15
7/21/15
8/21/15
9/20/15
10/21/15
11/20/15
12/21/15
1/20/16
2/20/16
3/22/16
4/21/16
5/22/16

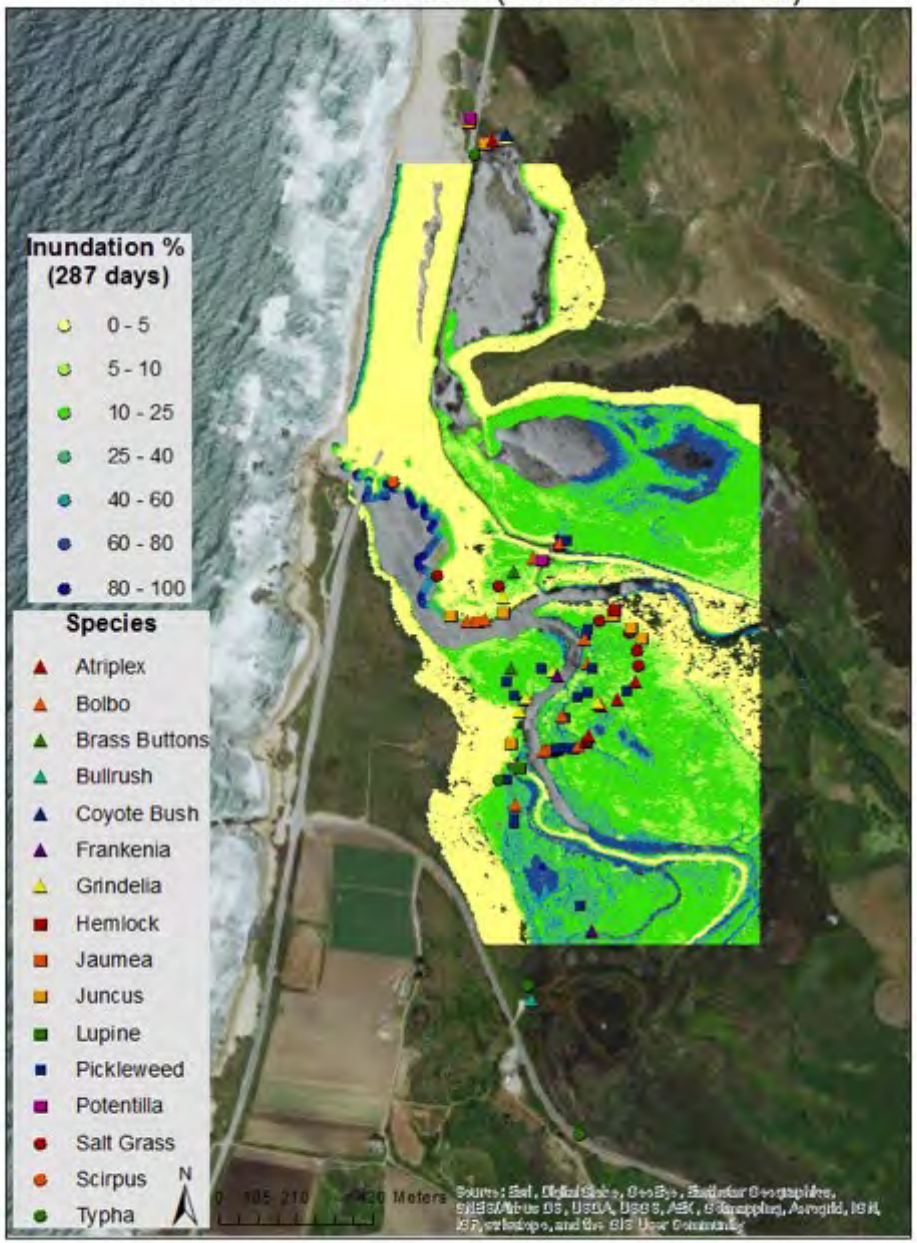

Villa Creek Water Level
Water Level
Marsh Plain Avg.; Salt Grass & Jaumea Avg.
Marsh Plain Range
MHHW
Back Marsh
Wrack Line
Pickleweed Avg.
Frankenia Avg.
Elevation realative to MSL (m)
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
6/30/15
7/30/15
8/30/15
9/29/15
10/30/15
11/29/15
12/30/15
1/29/16
2/29/16
3/31/16
4/30/16
5/31/16

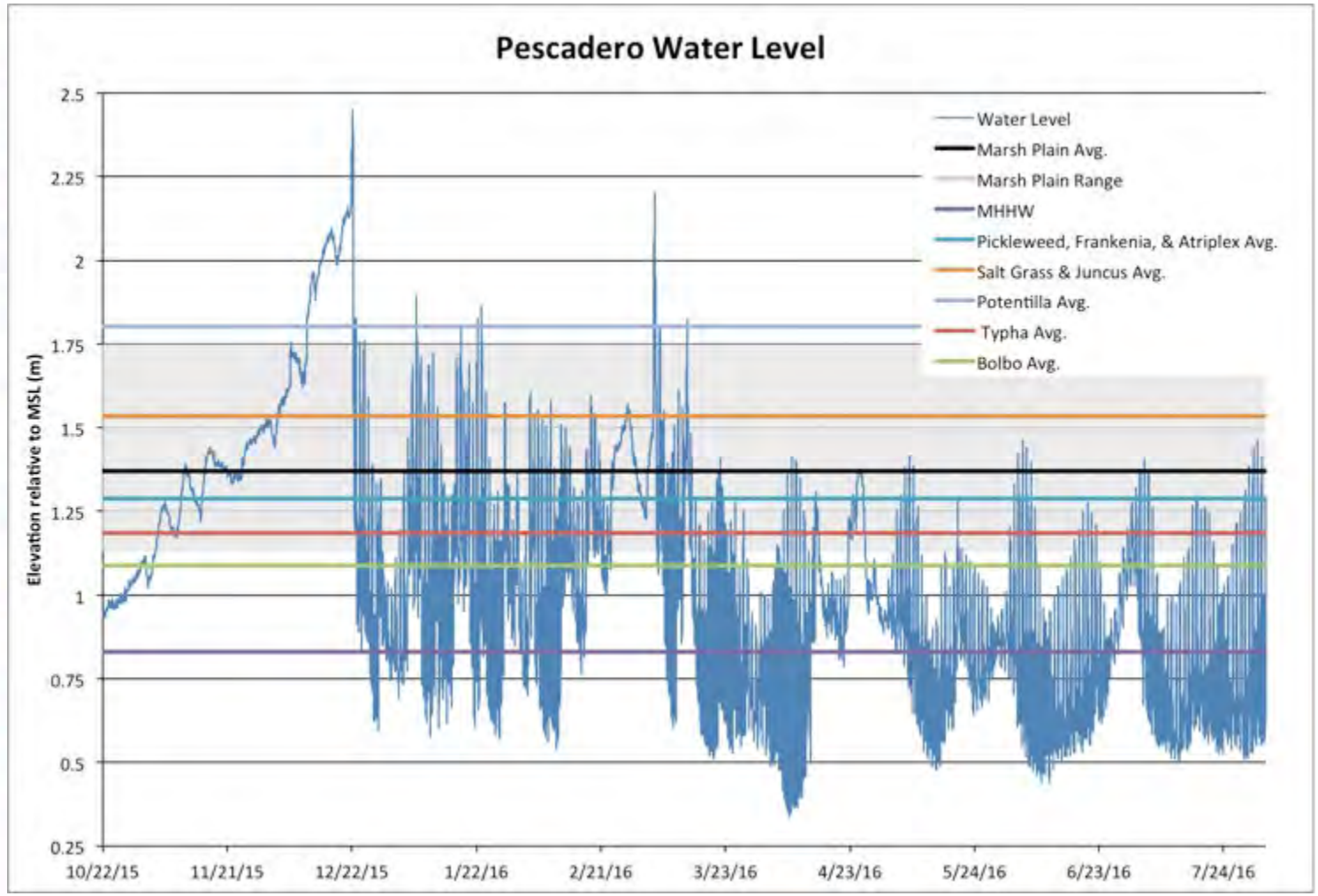

Marsh Plain Flooding
System A
System B
2/28/13
4/30/13
6/30/13
8/31/13
10/31/13
12/31/13
2/28/14
4/30/14
6/30/14
8/31/14
10/31/14
12/31/14
2/28/15
4/30/15
6/30/15
8/31/15
10/31/15
12/31/15
2/29/16
4/30/16

BBE Marsh plain's not linked with MHHW but with mouth bar formation dynamics

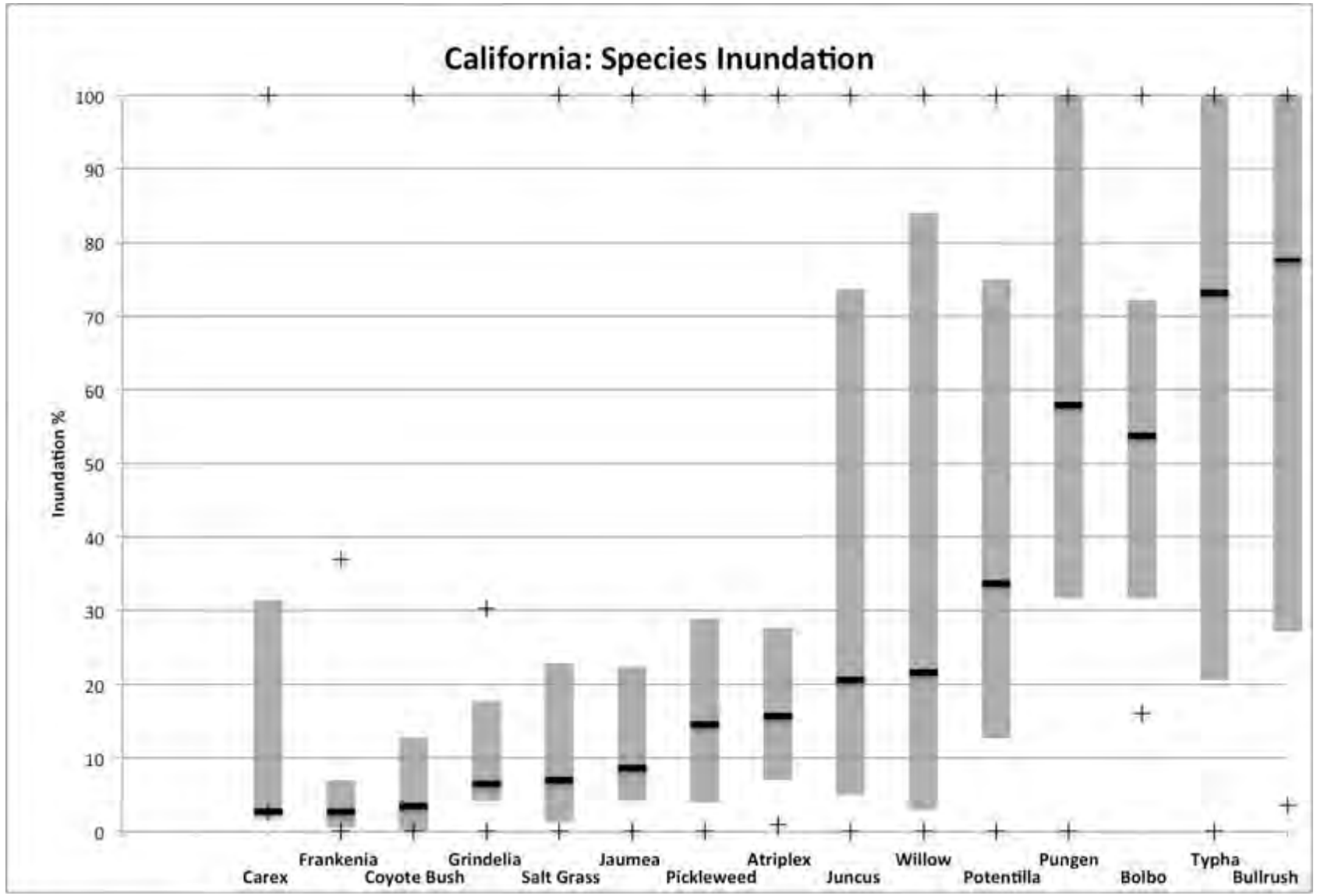


Pescadero Inundation (10.22.15 - 8.3.16)





Plant community reliance on mouth state N= 28 BBE



Considerations for Management of the Mouth State of California's Bar-built Estuaries

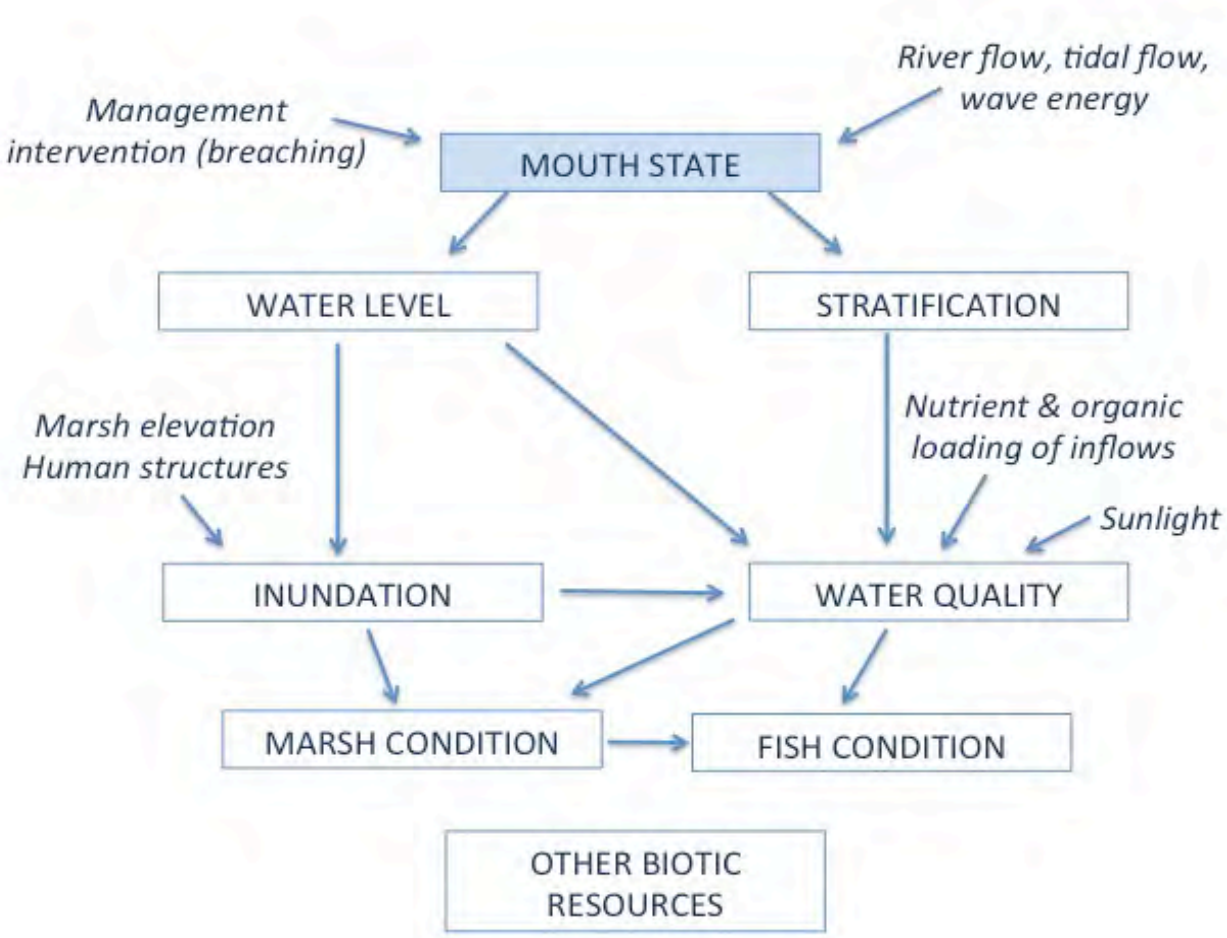
Report Contents

- Main Report
  - Approach
  - Effects of mouth state on estuary functions and conditions
  - Effects of managed breaching
  - Management decisions on estuary breaching
  - Recommendations for improved management
- Appendices:
  - Appendix 1: Focal Site #1: Russian River Estuary – Summary of Existing Data and Information
  - Appendix 2: Focal Site #2: Scott Creek Estuary – Summary of Existing Data and Information
  - Appendix 3: Focal Site #3: Los Peñasquitos Lagoon – Summary of Existing Data and Information
  - Appendix 4: Summary of California Rapid Assessment Method (CRAM)
  - Appendix 5: Permits needed to conduct Managed breaching of bar-built estuaries in California
  - Appendix 6: List of special conditions placed on breaching permits for BBEs throughout California

Approach

Responses of Parameters to Managed Breaching

Organized by Conceptual Model Boxes

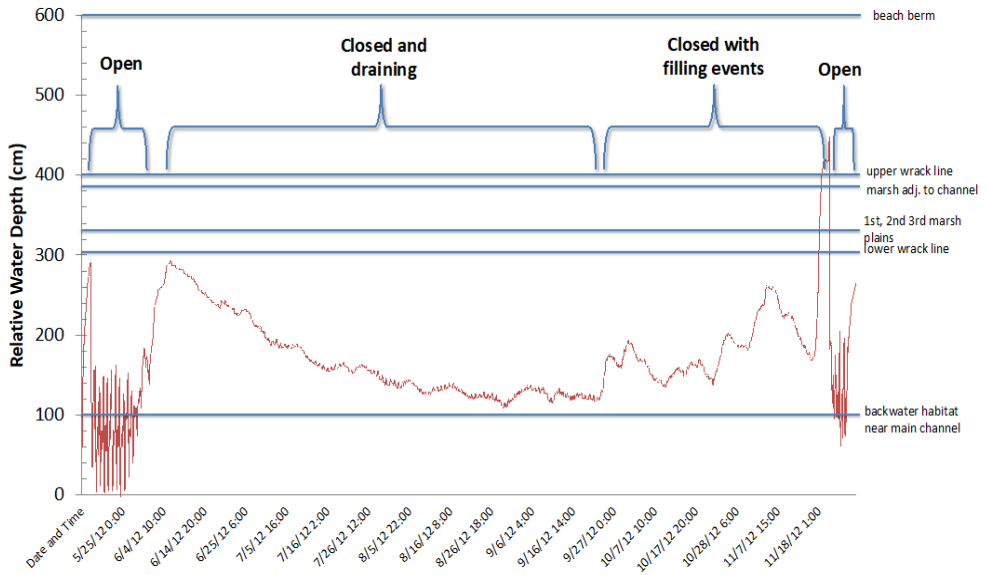


Approach

- Lists of abiotic and biotic factors in BBEs
- For each parameter (abiotic and biotic), narrative that examines the affect of mouth state
- Three focal systems were reviewed –
  - substantial environmental data from long-term monitoring programs
  - investigate changes in parameters before and after breaching events
- A set of response predictions drafted to inform breaching decisions
  - Not all responses observed in all systems
  - some are more certain and universal, others are more specific or hypotheses that are not fully tested
- Biophysical findings linked to management decisions
- Recommendations were developed to improve managed breaching activities
  - recommendations to avoid worst scenarios,
  - recommendations to improve biophysical expectations,
  - recommendations for monitoring for future decisions in specific systems.

General Effects of mouth state on estuary functions and conditions

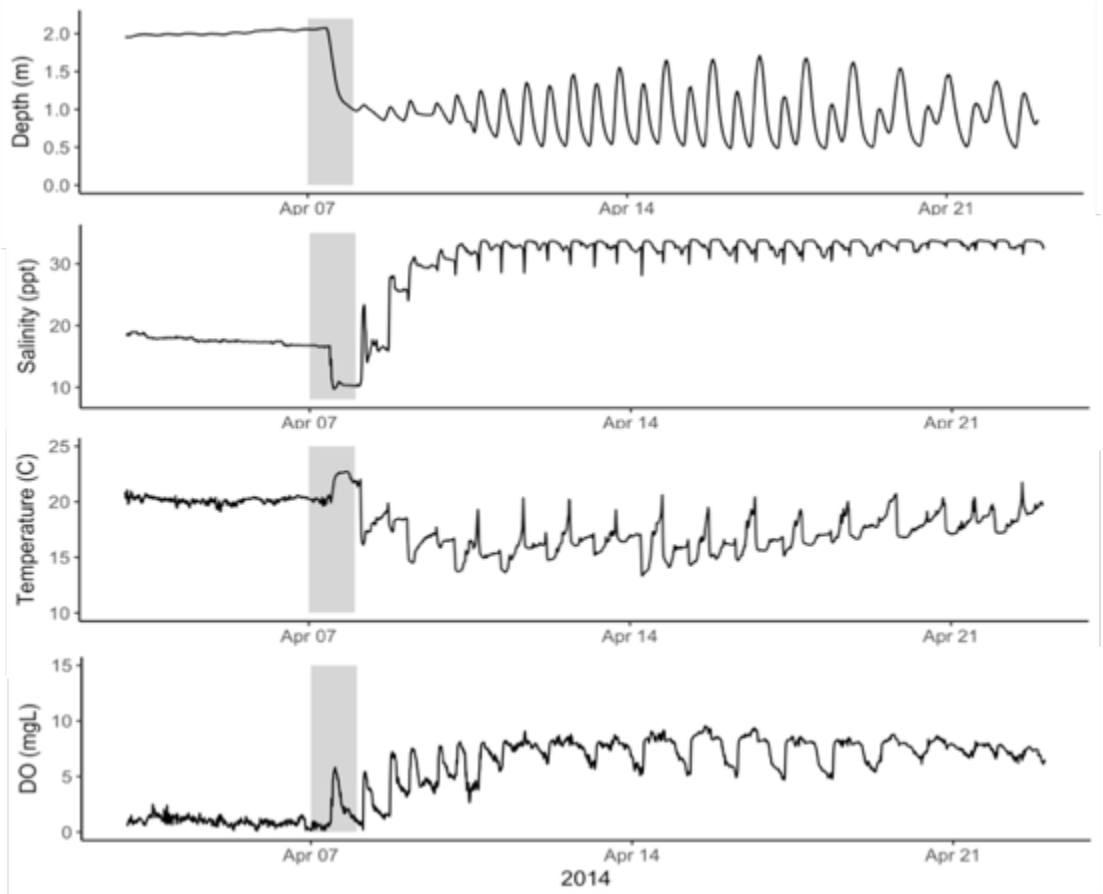
- Water elevation
  - Open=tidal, closed= + or 1- water balance, not black and white
- Stratification
  - Open=more salty less stratified, closed/muted=stratification can form
- Water quality
  - Open=cold O2 rich waters near mouth, closed=warmer reduced O2 waters
- Marsh plain condition
  - Open=intertidal marshes inundated, closed= perched marshes inundated
- Biotic condition of the channel
  - Open=fish passage ocean nutrients, closed=ideal fish rearing conditions and freshwater SAV



A typical breach event

- Sequence of reactions that initially follow removal of a portion of the sand barrier that retains water in the estuary:
  - Water flows out, possibly rapidly.
  - Channel is eroded deeper into sand barrier.
  - Water level drops in estuary.
  - Salinity decreases in estuary as shoreward saline water is replaced with low-salinity water from the back-basin.
  - Particulate organic material is re-suspended.
  - Plankton and weak-swimming biota are flushed from estuary.
  - Marginal habitats are disconnected.
  - Greater predator access to a smaller area of water habitat
- After a tidal cycle or two the estuary transitions to a tidal state, with further consequences:
  - Water level reaches an extreme minimum on low tide immediately after scour.
  - New seawater intrudes as net outflow recedes.
  - Salinity increases in estuary due to seawater inflow.
  - Water level varies tidally (often muted).
  - Waves enter outer estuary.

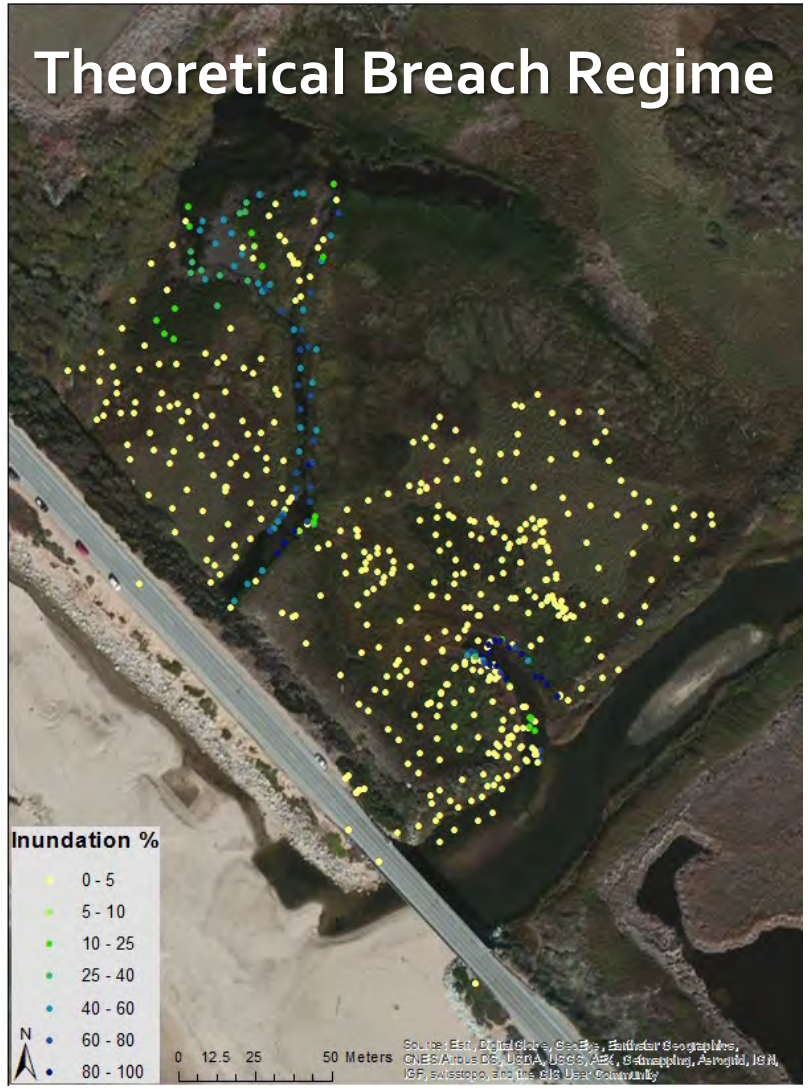
Managed Breach Event at LPL

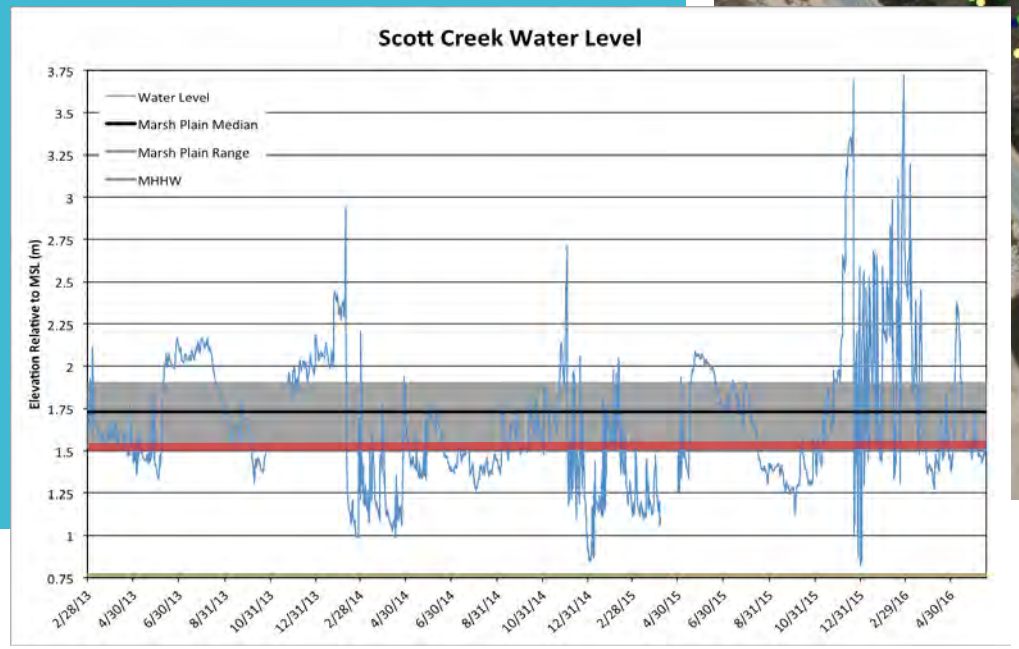


Effects of managed breaching

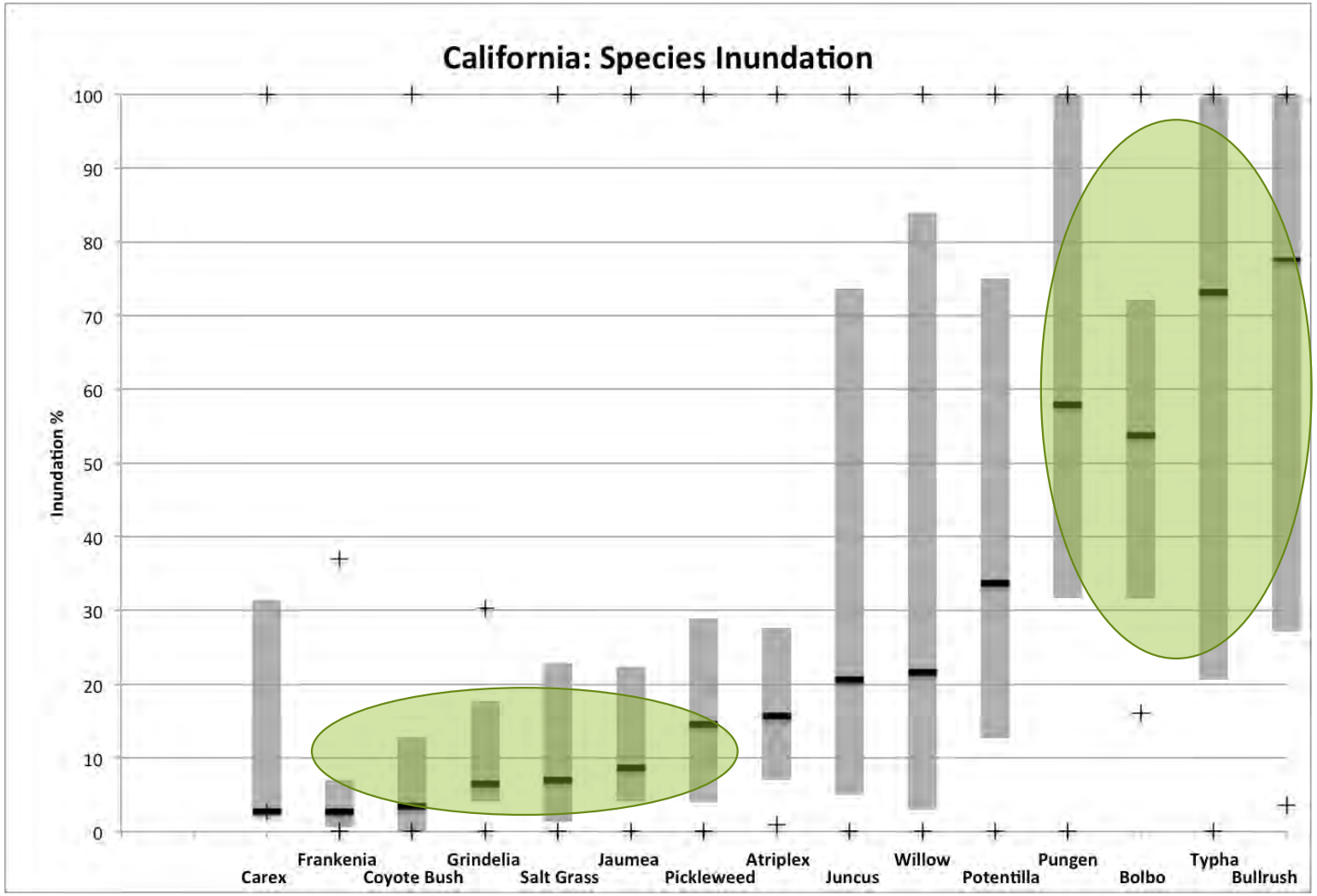
- In all systems there are both short-term and long-term effects:
  - Short-term:
    - transient conditions that typically last for less than a week
      - very strong currents
      - sudden change from freshwater to seawater salinity
  - Long-term effects
    - decrease in time that water levels are sustained at a high or more variable levels
      - Less marsh plain inundation
    - additive or chronic effects of multiple breaches
      - sedimentation of the outer estuary
    - conversion to an open system (type change)
      - increasing proportion of time that a BBE is open to seawater exchange
    - *These effects are not as well-known and typically observed through long-lived features like BBE morphology or marsh plain and channel condition*

Scott Creek Flood Plain Inundation





Managed breaching may lead to changes in natural marsh plain plant species diversity and abundance



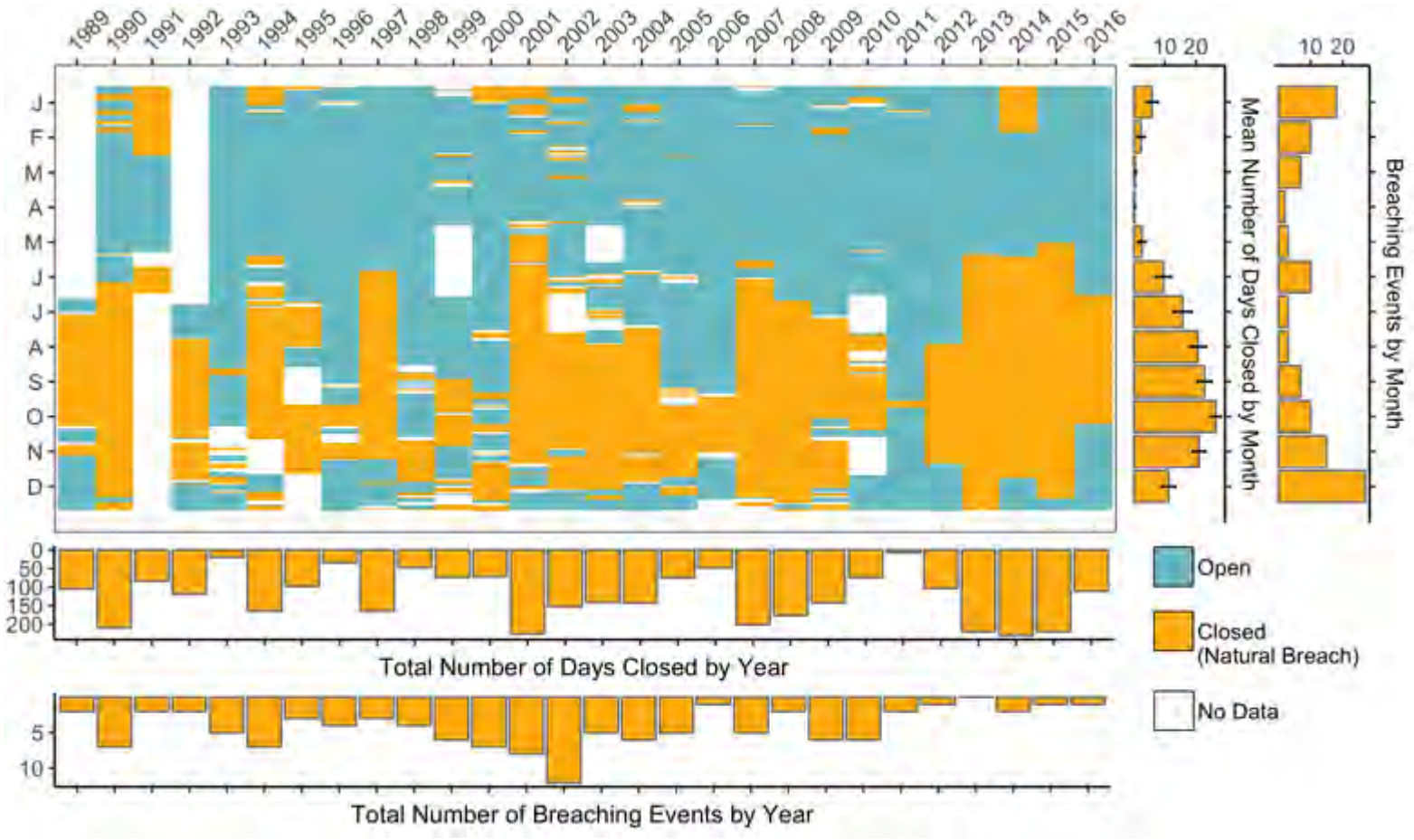
Study sites

Focal Site Name	Region of state	Watershed size (acres)	Annual precipitation	% watershed impervious
Russian River Estuary	North	949,807	45 inches	9.0
Scott Creek Estuary	Central	19,281	35 inches	1.1
Los Peñasquitos Lagoon	South	61,222	10 inches	64.5

- List of Characteristics of each Estuary important in comparing with other BBEs in California

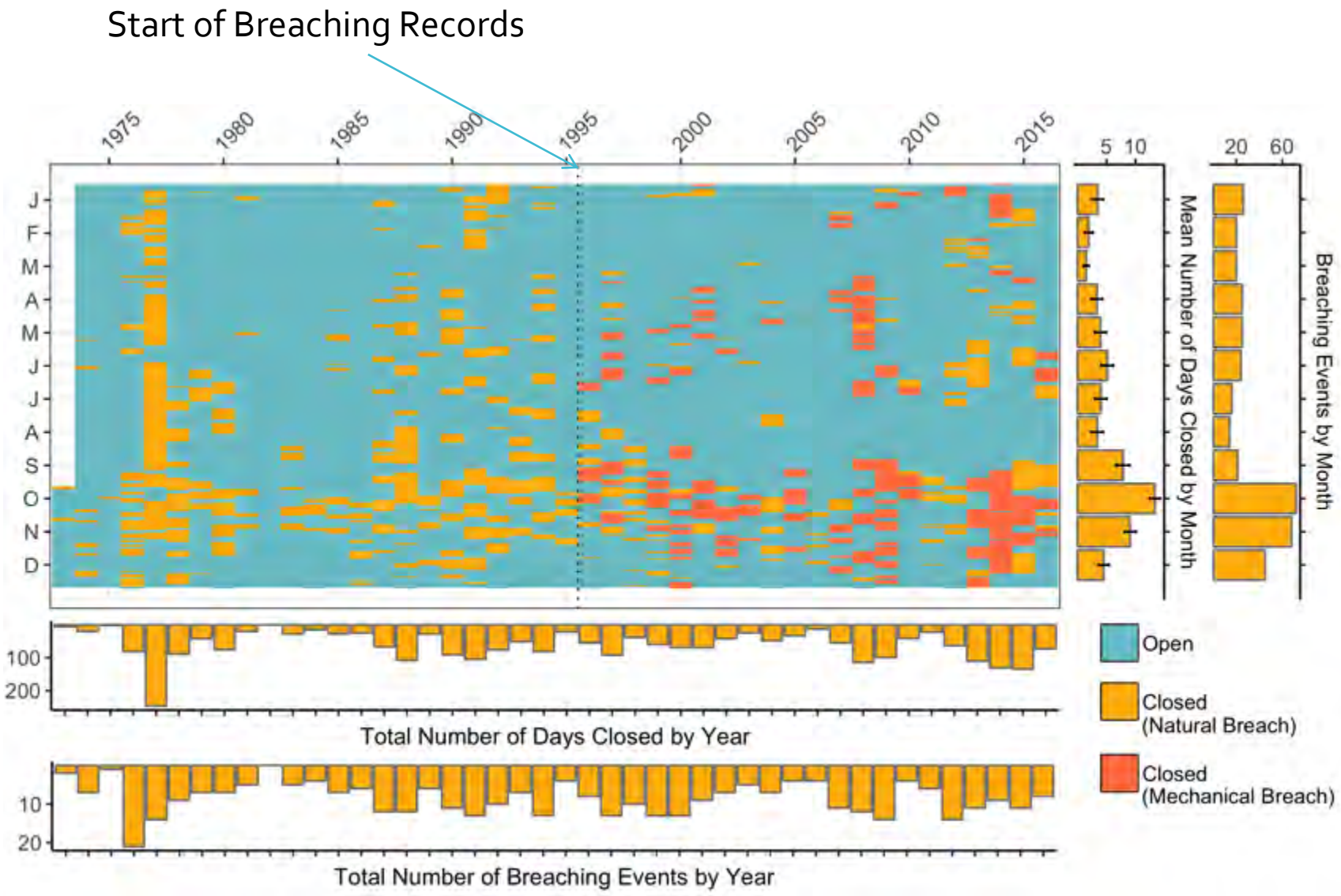
Mouth State

Scott Creek



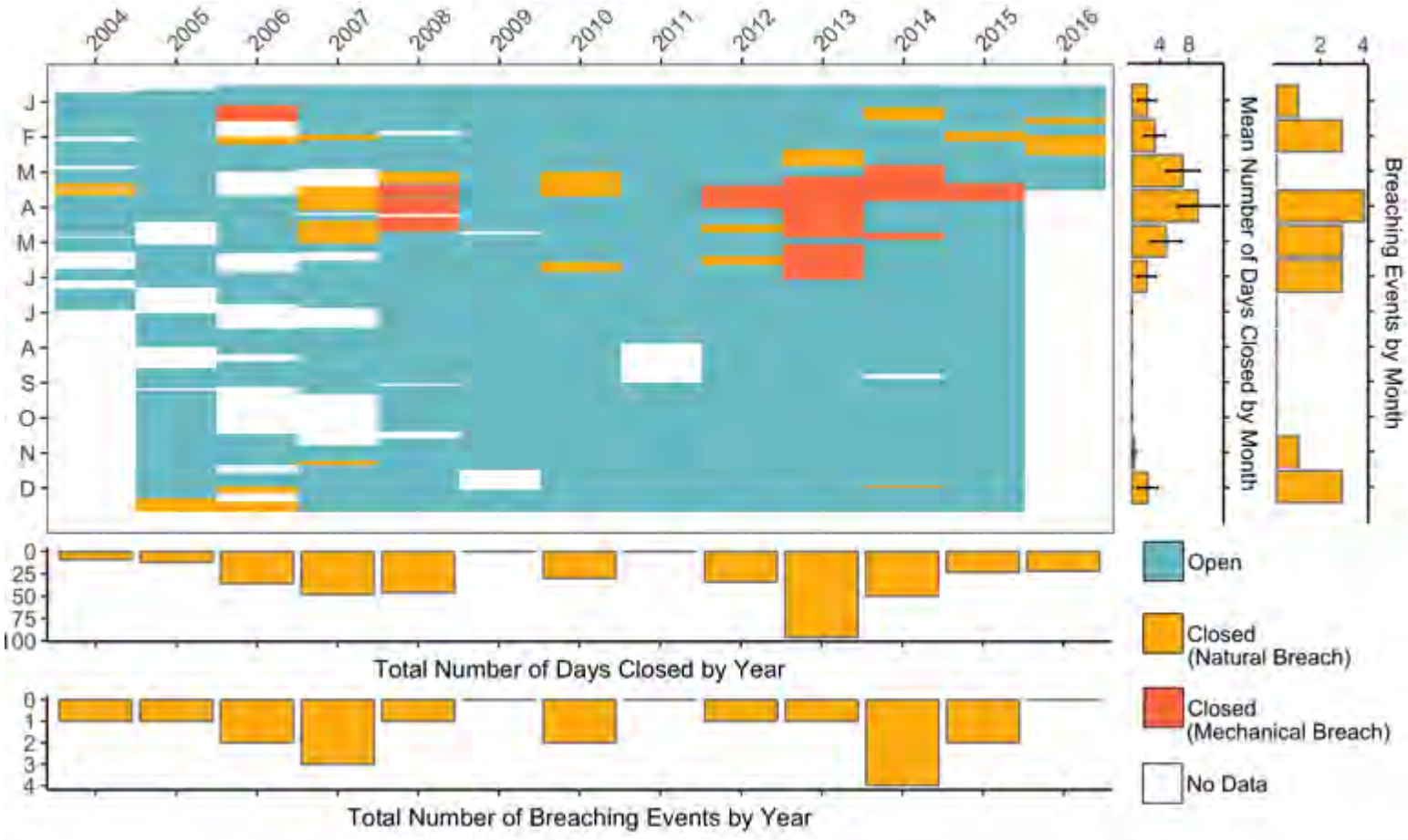
Mouth State

Russian River



Mouth State

Los Penasquitos Lagoon



BBEs with Recent permitted breaching activities

BBE Name	Reason for breach
Lake Earl and Lake Talawa Estuary	
Mattole River Estuary	Fish passage and WQ
Navarro River	
Russian River Estuary	
San Gregorio Creek	
Pescadero Marsh	Fish passage and WQ
Scott Creek Lagoon	Fish passage
San Lorenzo River Lagoon	Flooding
Corcoran Lagoon	Flooding
Soquel Creek Lagoon	Flooding
Aptos Creek Lagoon	Flooding
Pajaro River Estuary	Flooding
Salinas River Lagoon	Flooding
Carmel River Lagoon	Flooding
Pismo Creek	
Arroyo Grande Creek	
Santa Ynez River	
Goleta Slough	
Mission Creek	
Santa Clara River	
Malibu Creek Lagoon	water quality and flooding
Topanga Creek	water quality
Santa Ana River	
San Luis Rey River	
San Dieguito River	water quality
Tijuana River	
Los Penasquitos Lagoon	water quality
San Elijo Lagoon	water quality

Recommendations for improved management-

things to avoid

- partial managed breaches that evacuate the top freshwater layer if the system is stratified.
  - forces fish to enter the hypoxic near-bottom waters
- extreme evacuation of the estuary embayment and/or extreme high-velocity flows
  - flush fish and other key biota from the estuary
- breach early in juvenile steelhead rearing season
  - prevents fish from being exported from the estuary prior to being fully developed
- shock events that result in massive die-off of SAV
  - leads to severe eutrophication and hypoxia.
- large-scale mobilization of organic sediments without rapid and persistent flushing from high river flow
  - may release high loads of oxygen demand (chemical and biological), pollutants and nutrients.
- always conducting a managed breach before the marsh plain is inundated
  - periodic flooding of the marsh supports a diversity of habitats and ecological functions in marsh channels and on the marsh plain.

Standard data collection protocols

- *Water Level and Photographic Records*
- *Morphology surveys*
- *Stratification and Water Quality Records*
  - throughout lagoon waters (x, y & z) when open and closed
- *Marsh plain and Submerged Aquatic Vegetation (SAV) Condition Surveys*
- *Fish and other faunal surveys*
  - when open and closed.

- **Estuary MPA Monitoring Protocol**. Prepared by Central coast Wetlands Group for for the Ocean Protection Council and CDFW. **Available at: empa.sccwrp.org**
  - **California BBE Wetland Monitoring Manual.** Prepared by Central coast Wetlands Group for for the United States Environmental Protection Agency.
  - **California Estuarine Wetland Monitoring Manual (Level 3).** Prepared by The Bay Foundation for the United States Environmental Protection Agency.
  - **Evaluation and Regional Comparison of USEPA Intensive, Level-3 Monitoring: Consolidating Coastal Wetland Datasets and Programs.** Prepared by The Bay Foundation and partners for the United States Environmental Protection Agency.

Processed-Based Approach to Management

- **Know your estuary**
  - **Identify ecological costs and benefits** of different estuary states and of different breaching protocols to allow for informed decisions
  - Understand the **dynamic processes** that control observed conditions
  - Develop **quantitative conceptual models** that capture the processes and environmental variability of BBEs across seasons – and use these **models to inform management** decisions.
- **Plan regionally**
  - Adopt a **regional approach to maintaining habitat diversity** by ensuring a diverse combination of BBEs systems thrive (i.e., the regional portfolio approach).
  - Prioritize habitat enhancement and restoration activities within BBEs to **reestablish functions and services that have been regionally lost**.
- Advocate for a management strategy that **maintains environmental variability** and associated habitat diversity (including extreme events)

Access to the Report

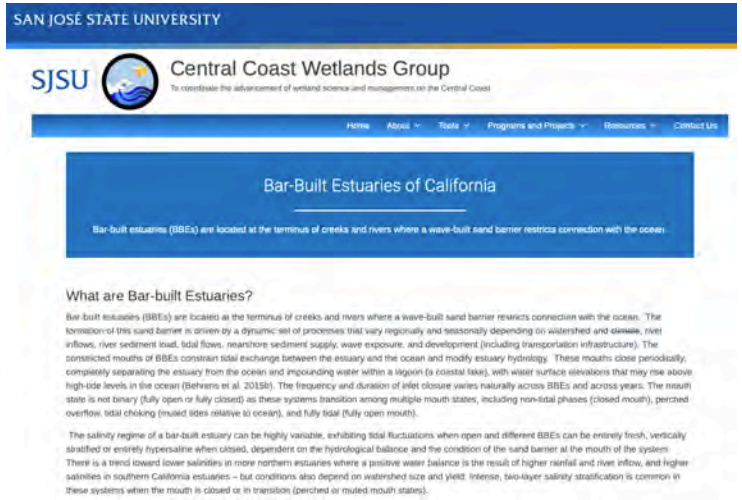
Report website:

https://www.fisheries.noaa.gov/resource/document/considerations-management-mouth-state-californias-bar-built-estuaries-o

CCWG BBE website:

www.centralcoastwetlands.org

->Tools
-> BBE Assessments
->bottom of page



More West Coast Estuary info: PMEP www.Pacificfishhabitat.org

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Moss Landing Marine Labs

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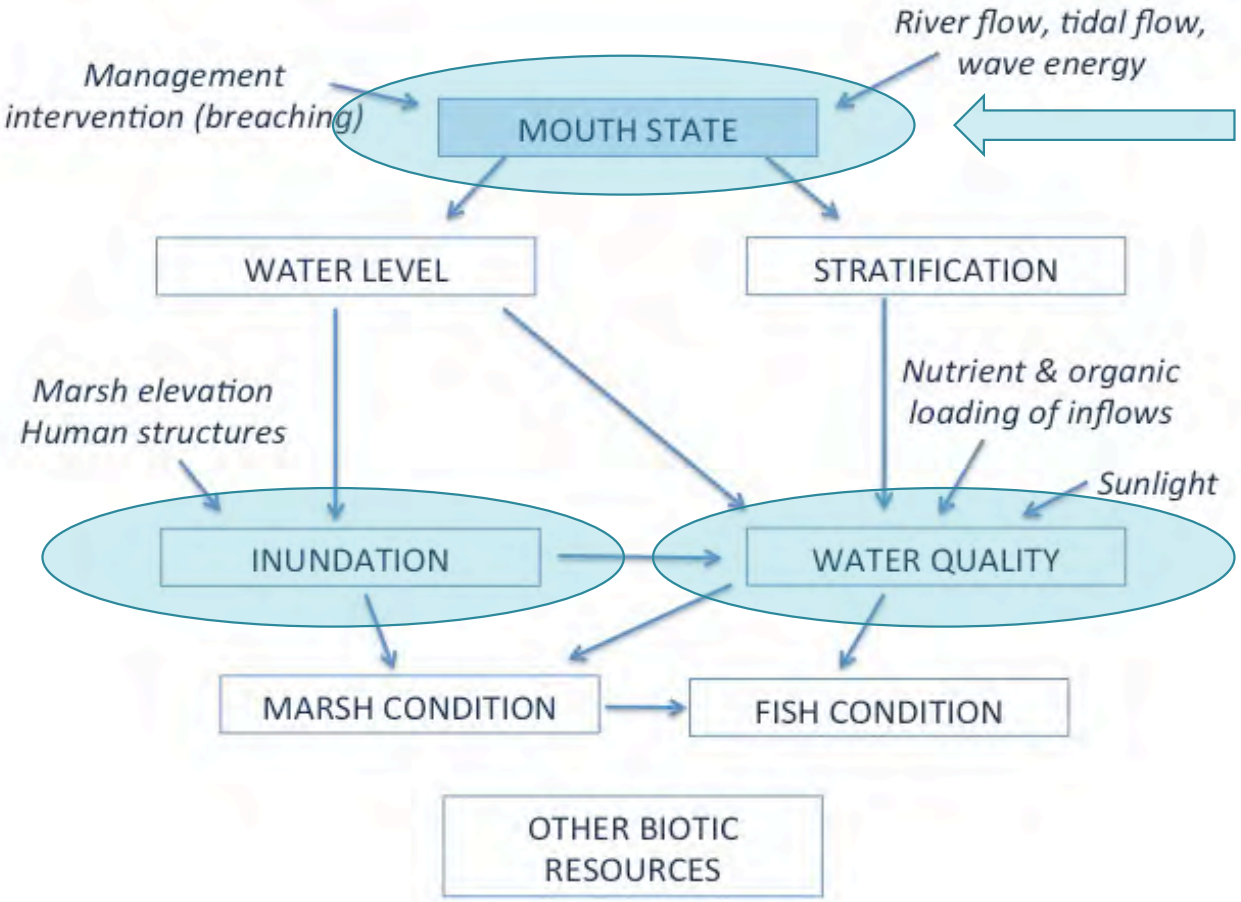
Responses of Parameters to Managed Breaching

Organized by Conceptual Model Boxes

In partnership with National Marine Fisheries Service



Fish Passage

Flood Management

Fish Kills / DO & Smell

Logging, Leather, Lime and "Lost Boys"
Reducing Limiting Factors for Anadromous Salmonids in the San Lorenzo River Lagoon

Salmonid Restoration Federation Annual Conference

April 21, 2022

Chris Berry, Santa Cruz Water Department –
Watershed Compliance Manager

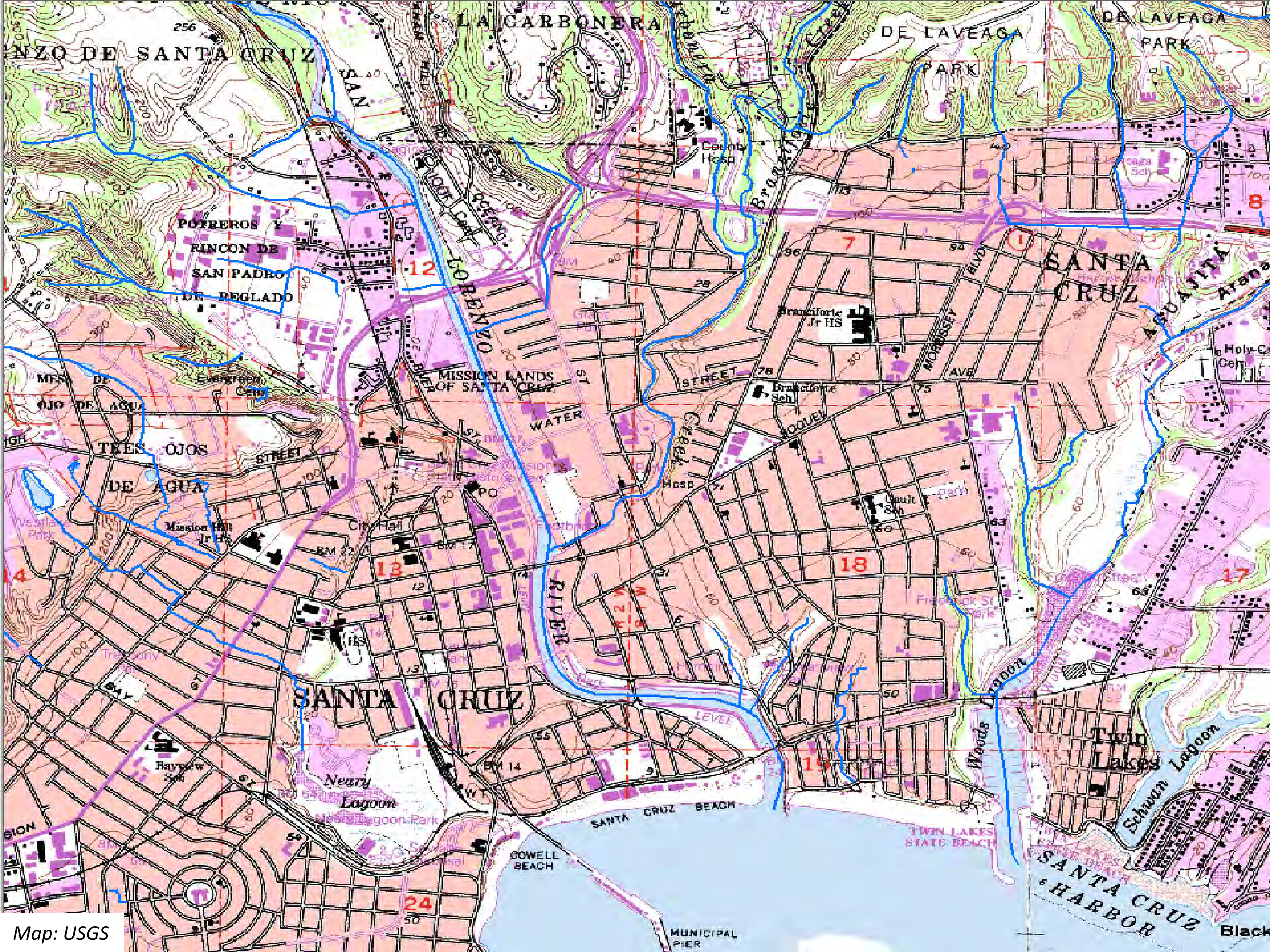
Our Water, Our Future

City of Santa Cruz Water Department

OUTLINE

- Historical background
- Limiting factors
- Solutions!

Image: City of Santa Cruz staff seining the San Lorenzo lagoon, 2018 – Chris Berry


LA CARBONERA
DE LAVEAGA PARK
NZO DE SANTA CRUZ
SAN LORENZO RIVER
POTREROS Y RINCON DE SAN PADRO DE REGLADO
MISSION LANDS OF SANTA CRUZ
MESA DE OJO DE AGUA
TRES OJOS DE AGUA
Evergreen Cem
Mission Hill Jr HS
City Hall
County Hosp
Branciforte Jr HS
Branciforte Sch
Branciforte Creek
WATER STREET
SOQUEL AVE
MORRISSEY BLVD
SANTA CRUZ
Holy Cross Cem
Arana
AGUA JITA
Hosp
PO
HS
Bayview Sch
Neary Lagoon
Neary Lagoon Park
BAY
SANTA CRUZ BEACH
COWELL BEACH
MUNICIPAL PIER
TWIN LAKES STATE BEACH
Woods Lagoon
Twin Lakes
Schwan Lagoon
SANTA CRUZ HARBOR
Black
12
13
7
18
15
17
24
8
14
Map: USGS

FLOOD MANAGEMENT

Image: Flood control channel upstream of Highway 1, late 1950s – Santa Cruz Public Libraries Archives

Image: Mission Santa Cruz, 1791 - California Mission Foundation

SAN LORENZO RIVER CONFIGURATION
AROUND THE TURN-OF-THE-CENTURY
MAP BY
ROSS ERIC GIBSON

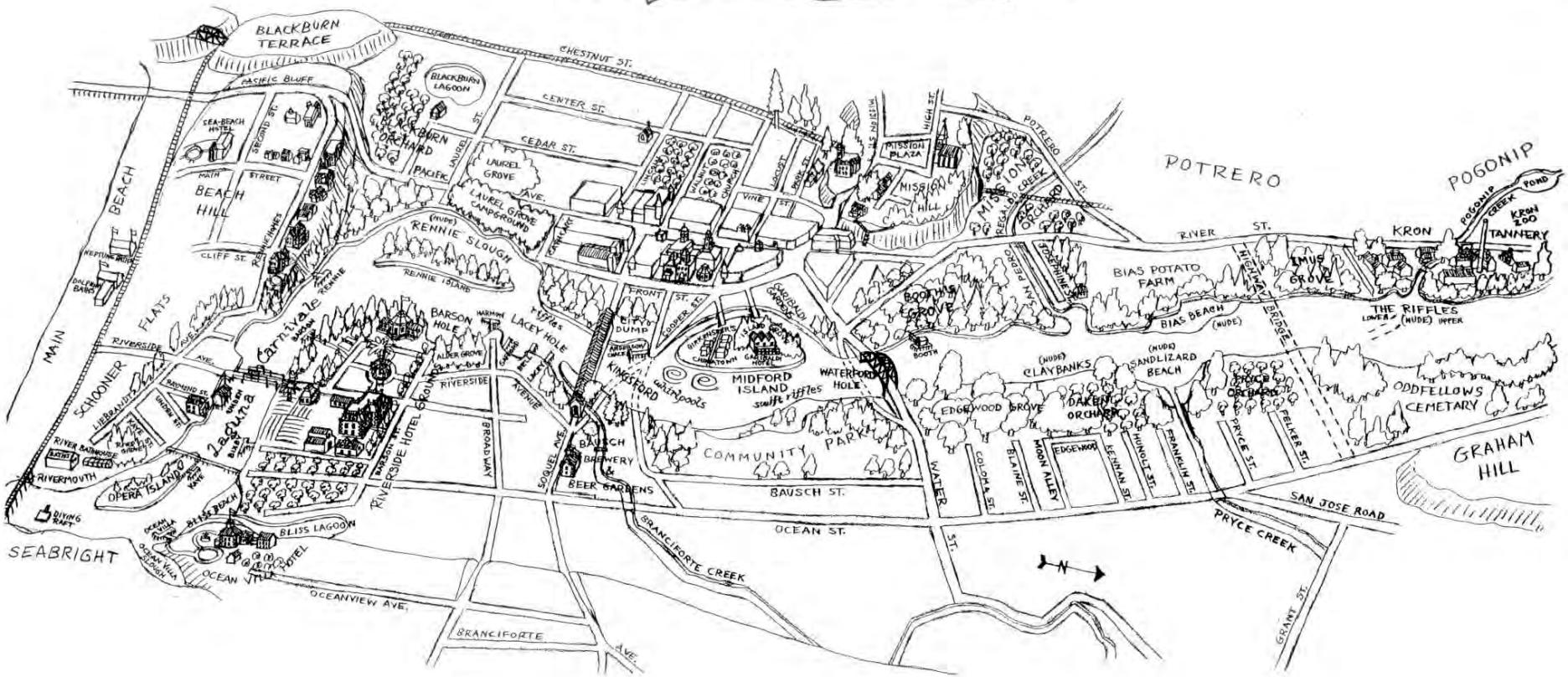
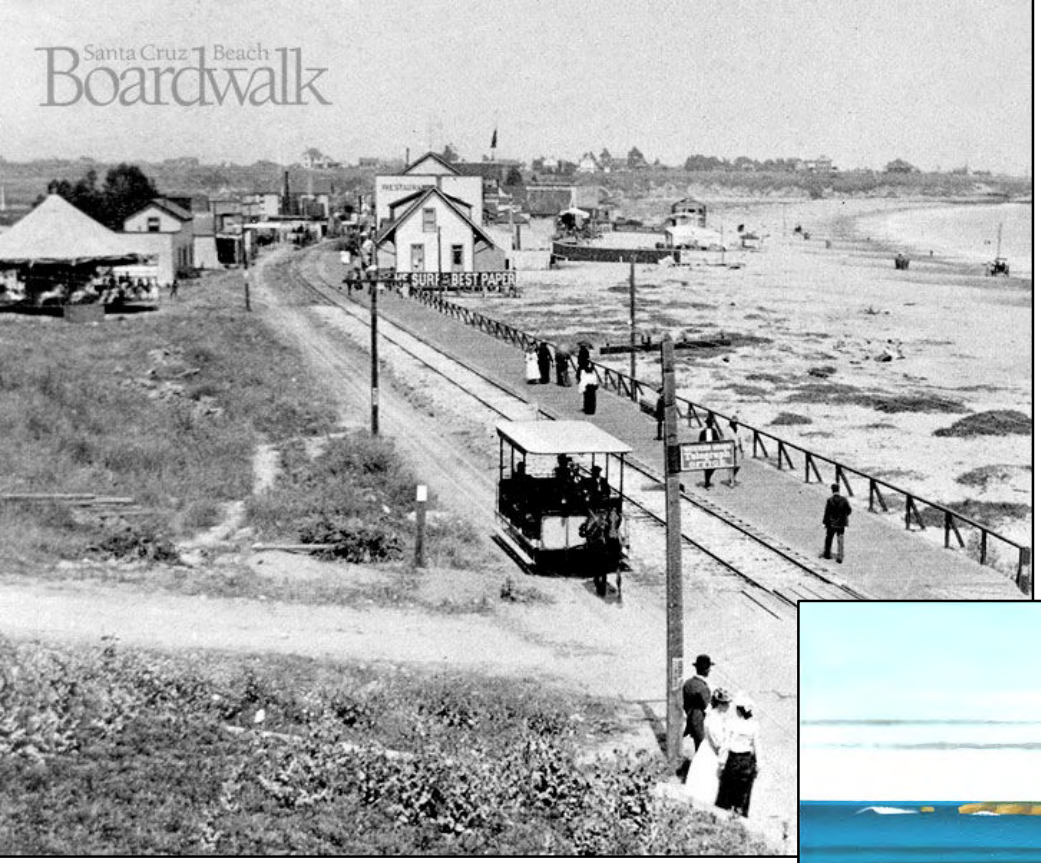


Image: Historic Main Beach, wharves and rivermouth, 1906 – George Lawrence

Image: 1955 flood - Santa Cruz Public Libraries

Image: 1955 flood - Santa Cruz Public Libraries

Image: San Lorenzo River flood control channel downstream of Water Street - Warner, Richard E., and Kathleen M. Hendrix, editors California Riparian Systems: Ecology, Conservation, and Productive Management. Berkeley: University of California Press, 1984.



RECREATION

Images: Hawaiian princes surfing at the San Lorenzo Rivermouth (bottom), 1885 - Jim Phillips, Historic Main Beach and Boardwalk (top), late 1800s - Santa Cruz Beach Boardwalk

Decorated boats and barges participate in the Venetian Water Carnival on the San Lorenzo River, 1890s. Courtesy Santa Cruz Public Libraries

Image: Boardwalk tent city,
1904 - Santa Cruz Trains

Image: Boardwalk tent city, 1911 - Santa Cruz Trains

Image: San Lorenzo River steelhead fishing, 1950s - Good Times

Image: Boardwalk wave inundation, 1926 - San Francisco Chronicle

HARBOR CONSTRUCTION AND COASTAL MORPHOLOGY

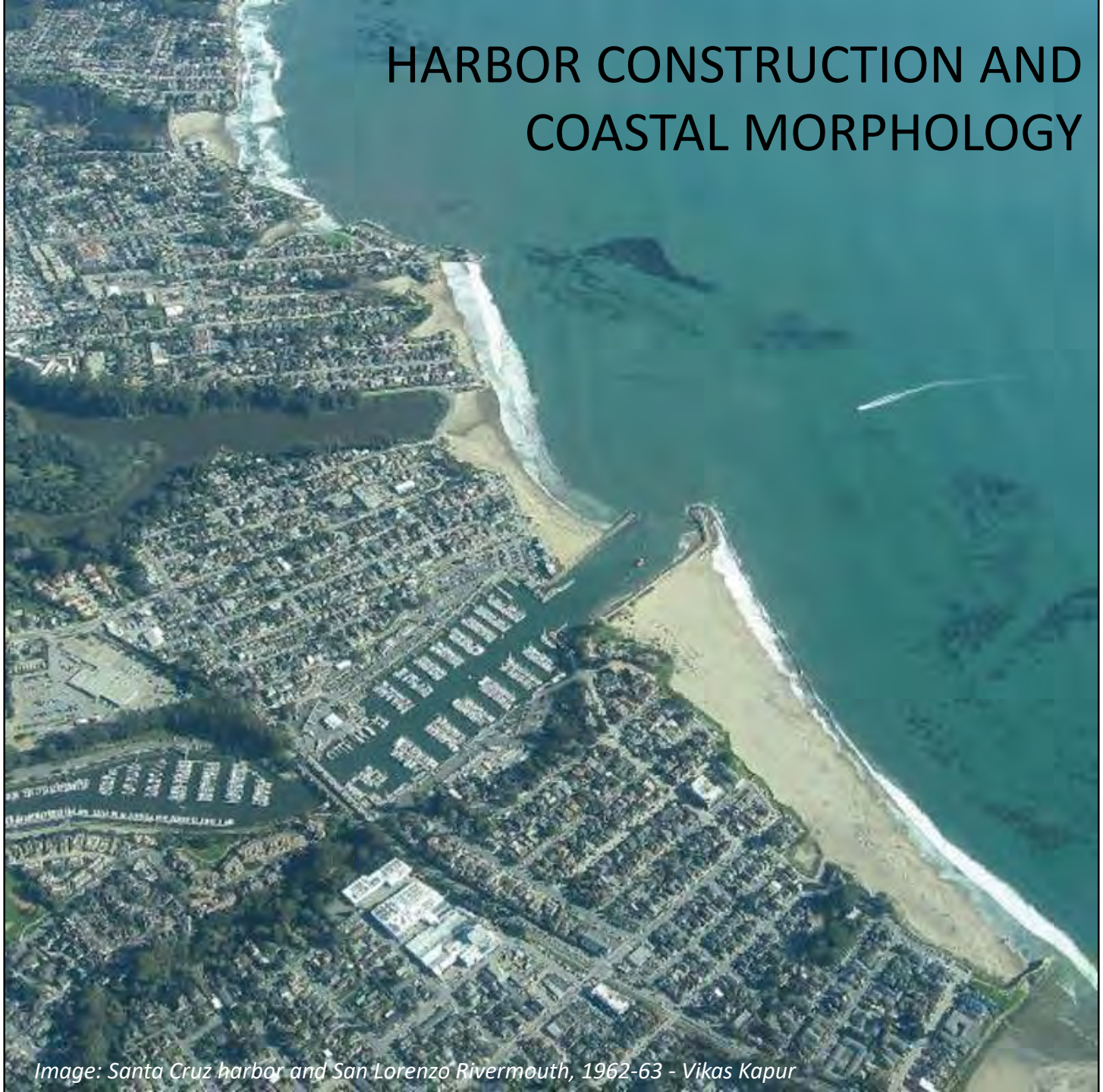


Image: Santa Cruz harbor and San Lorenzo Rivermouth, 1962-63 - Vikas Kapur

Image: Santa Cruz harbor and San Lorenzo Rivermouth, 1952

Image: Santa Cruz harbor and San Lorenzo Rivermouth, 1974

FISH & GAME
COMMISSION

COUNTY OF SANTA CRUZ

GOVERNMENTAL CENTER 701 OCEAN STREET SANTA CRUZ, CALIFORNIA 95060

(408) 425-2375

July 26, 1974

Colonel J. L. Lammie, District Engineer
San Francisco District Corps of Engineers
100 McAllister Street
San Francisco, Ca. 94102

RE: CORP. PUBLIC NOTICE 74-0-148 AND DRAFT ENVIRONMENTAL IMPACT REPORT, SANTA CRUZ HARBOR DREDGING

Dear Colonel Lammie:

Thank you for the opportunity to review the subject notice and draft Environmental Impact Report.

Santa Cruz Harbor was developed, and is maintained, with the loss of Woods Lagoon, a highly productive wildlife area. Your impact statement should note that annual maintenance dredging facilitates continued harbor use without the mitigation of related wildlife habitat losses. The long term progressive reduction of biological productivity caused by man's short term recreational gain in the use of this area should be noted.

It should be noted that investigations on ways to compensate for the wildlife loss at Woods Lagoon have been conducted by the California Departments of Fish and Game and Parks and Recreation, U. S. Fish and Wildlife Service, Santa Cruz Port District, and your agency. It was recommended that a replacement lagoon be constructed at Sunset State Beach. It seems appropriate to describe this item under mitigation measures considered to minimize project impact.

The Santa Cruz County Fish and Game Advisory Commission requests that the Corps of Engineers evaluate the relationship of continued dredgi-- operations funding to the still unresolved question of wildlife mitigatio.

Sincerely,

Robert Bromber

ROBERT BROMBER, Chairman
Santa Cruz County Fish and Game Commission

RB:RRJ:mb
cc: Senators Alan Cranston & John Tunney
California Representative Burt Talcott
State Senator Donald Grunsky
State Assemblyman Frank Murphy
Gerry Barney, Port Director
Board of Supervisors

Image: San Lorenzo Rivermouth, Spring 1983 -
Warner Brothers

Images (top): Illegal breaching, 2019 - Jane Mio

Images (bottom); Illegal breaching, 2012 (left) and 2007 (right) – City of Santa Cruz files

Image: Rivermouth surf, 2019 - Chris Berry

Image: Rivermouth surf, 2018 – Chris Berry

WATER SUPPLY

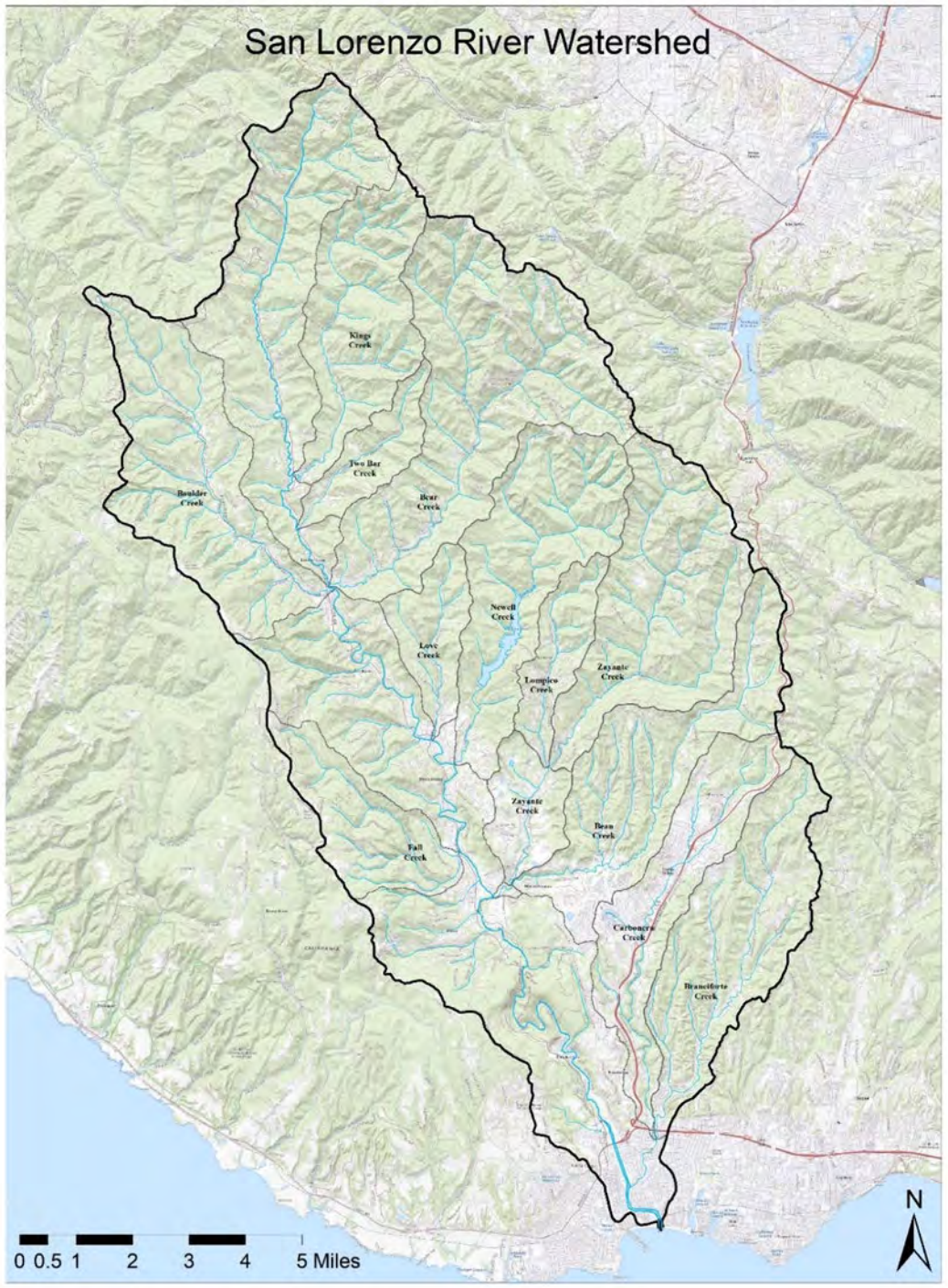
WATER WORKS.—Mr. Elisha Anthony is now busy repairing the main pipes and replacing new ones where needed, in the different streets. The connection crossing the river has been joined with iron pipes of large size and great strength, so as to be secure, in future, against floods. The reservoir has been cleaned out and thoroughly repaired. In cleaning out the reservoir several brook trout were taken, one of which weighed four pounds. The fish were placed in to keep the water clear of insects. Those desiring pure, fresh water, should make early application, so as to be served before the hot weather sets in and the ground is baked hard.

Source: Santa Cruz Sentinel, 1866

Image: Pogonip Spring- Mercury News

Images: Defunct Branciforte Creek diversion, 2013 (left) and San Lorenzo River diverstion, 2022 (right) – City of Santa Cruz files

IT TAKES A VILLAGE…AND A WATERSHED FOCUS…



Map: Ryan Bassett

- 138 square miles of watershed upstream
- Relatively dense residential land use currently served by onsite wastewater disposal systems
- High road density
- Natural geologic instability
- Extreme fuel loads
- Fully appropriated water rights status
- Flood hazards
- Several TMDLs
- Industrial land use history
- Historically regionally significant fishery…

Images: Looking upstream from Water Street Bridge (top), 2000's - City of Santa Cruz files, Snow up in the headwaters, 2019 (bottom) – Shmuel Thaler

LOGGING

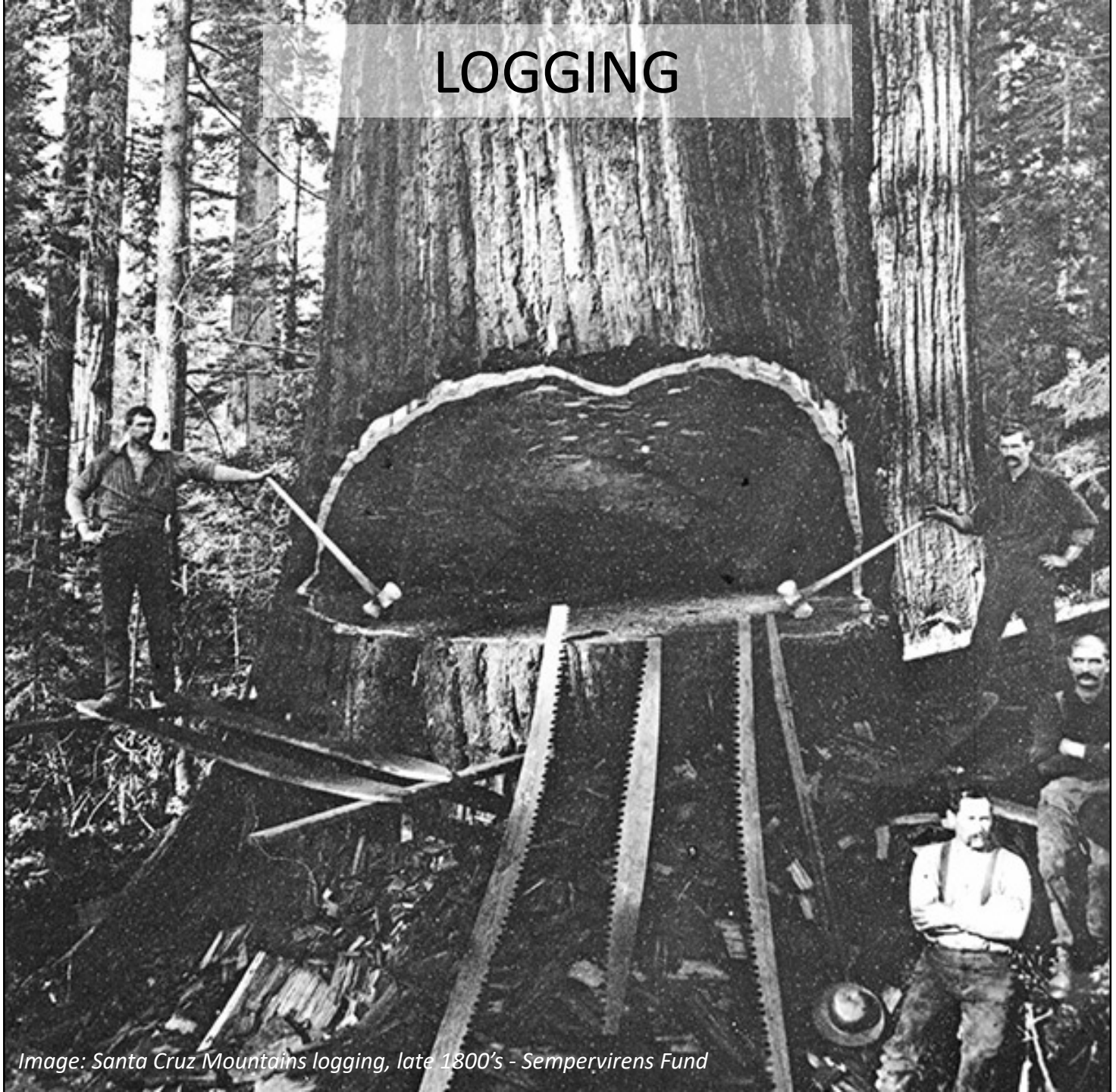
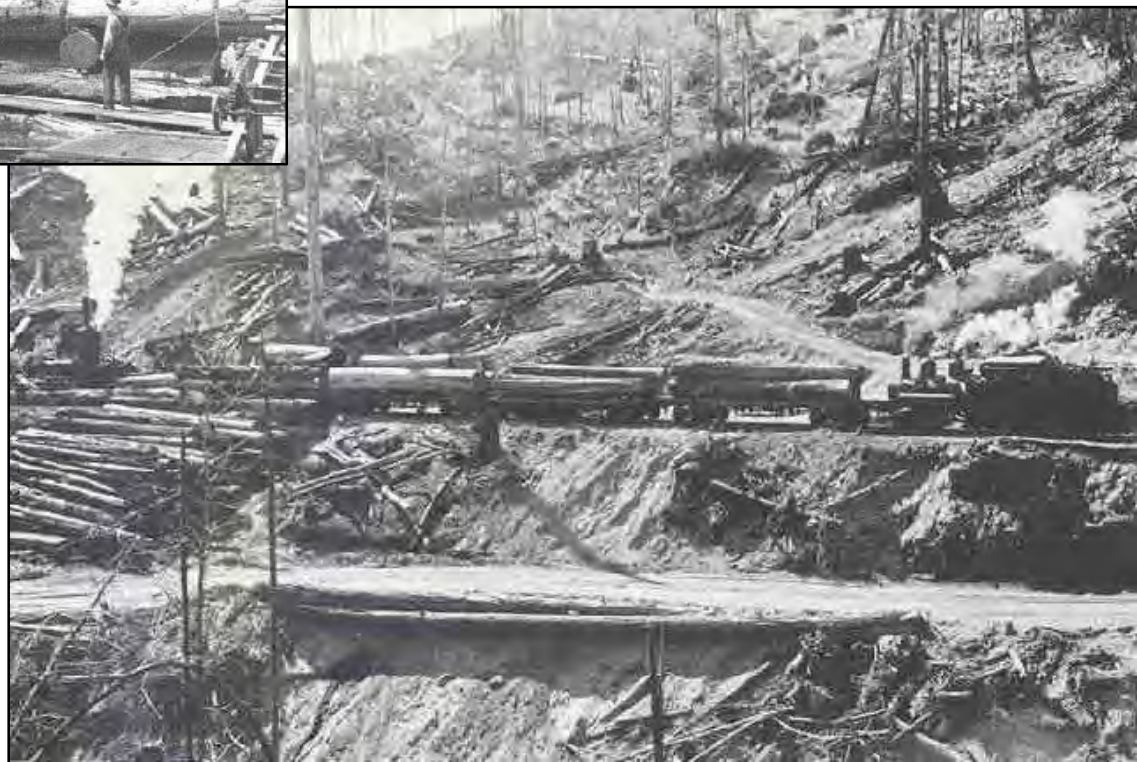


Image: Santa Cruz Mountains logging, late 1800's - Sempervirens Fund



Images: Santa Cruz Mountain logging, 1930s/1940s – Santa Cruz Trains

LEATHER

Image: Tanoak used for dyeing leather, 1955 - Ansel Adams

Old Santa Cruz

● ● ● By Ernest Otto

Santa Cruz, in the early days, had about the most industries in the state outside San Francisco.

There was water power, lumber and split stuff, cattle herds furnishing beef and hides in the Santa Cruz mountains and in connection with the bay and wharf there were fishing and shipping.

Of the 10 tanneries which were here in the '70s, only one remains. This is the former Kron tannery operated now by Salz, on River street near the San Lorenzo.

Tanneries were located on streams and throughout the county was the tanbark for the curing of the hides. Many of the hides came from within the county. The Kron tannery was by Pogonip creek. Adjoining it, also along Pogonip creek, was a smaller establishment, the Fischer tannery. Farther up beyond Crossing street was another tannery. It turned out another type of leather, for harnesses.

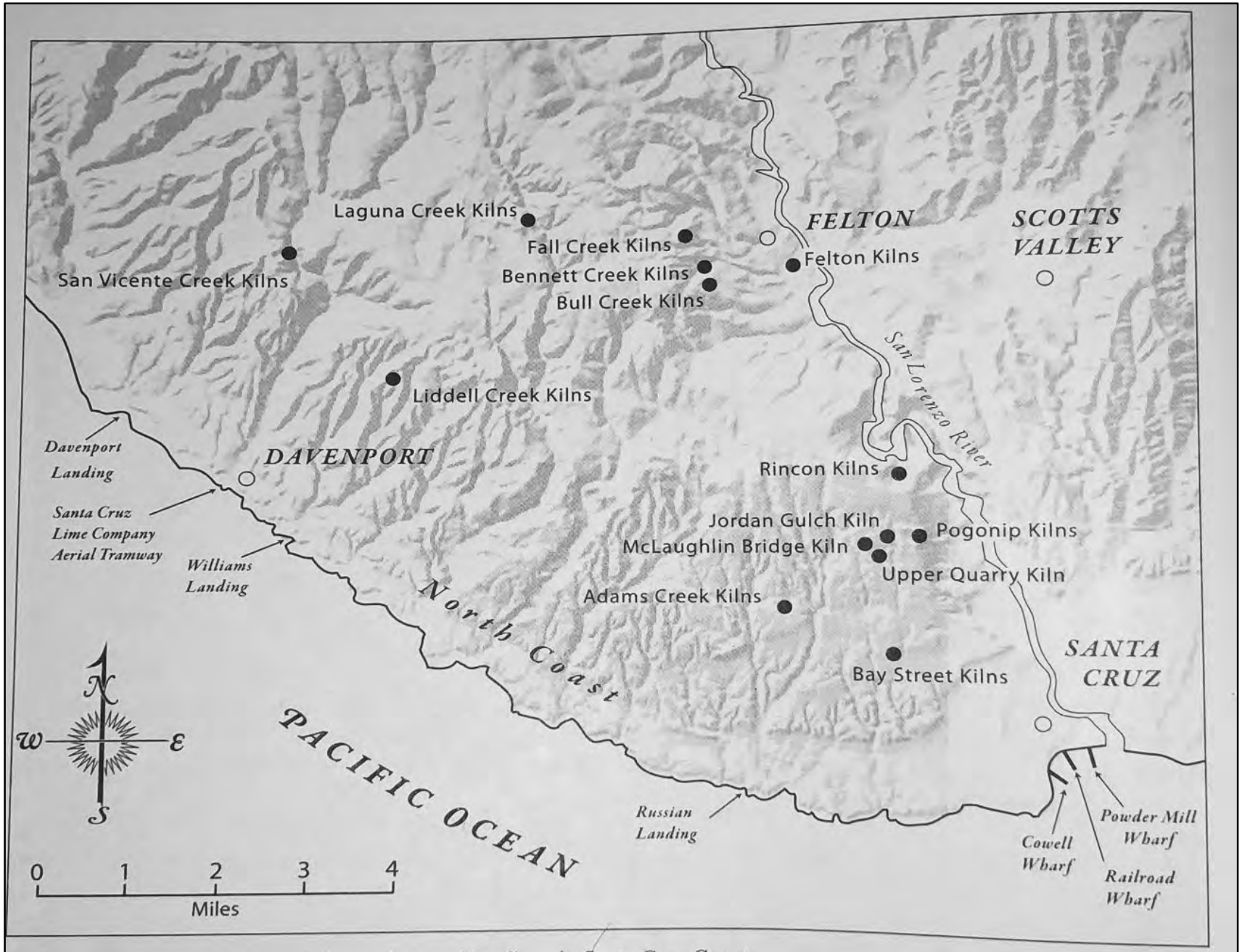
Two more stood for years as monuments of the early day industries.

Image: Tannery story, 1952 - Santa Cruz Sentinel archives

Image: Glazing leather at Salz Tannery, 1955 – Ansel Adams

LIME

Image: Fall Creek lime kilns, 2014 – Peter Gross



Map showing locations of lime kilns and coastal landings in Santa Cruz County.

Map: Limekiln Legacies

OTHER HISTORIC INDUSTRIES

Powder Mill and
Paper Mill

Images: Paper Mill Dam, 1861 – Bancroft Library (top) and Powder Mill Dam, mid-1860s – Peyton Family Collection (bottom)

…AND DON’T FORGET…“LOST BOYS”

Image: Filming of “Lost Boys”, April 1986 - Adrian Roe

Image: Lost Boys Bridge camp site, 2019 - Chris Berry

Image: Water Street bridge camp site – City of Santa Cruz files

Image: Lost Boys Bridge walker, 2020 - Michael Eckerman

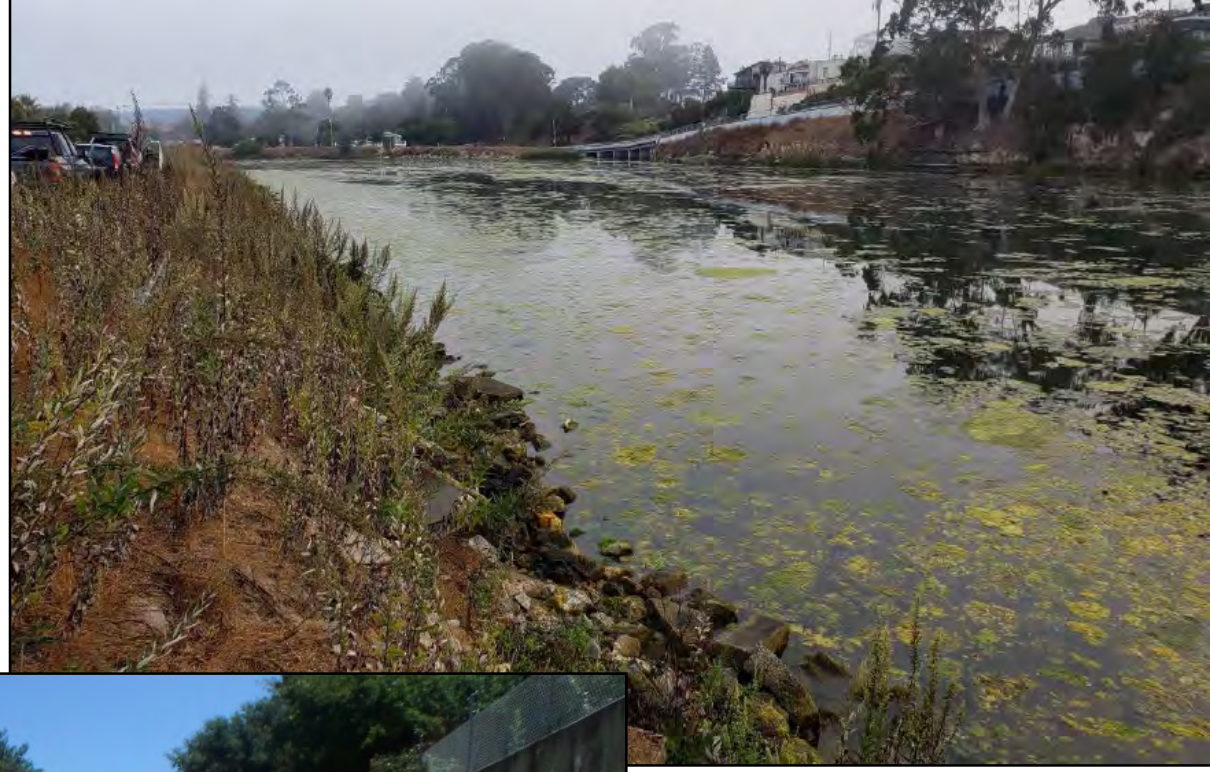
Image: Levee camper, mid-2000s - City of Santa Cruz files

Image: "Dakota Landing" flooding, 2021 – Bruce Ashley

LIMITING FACTORS

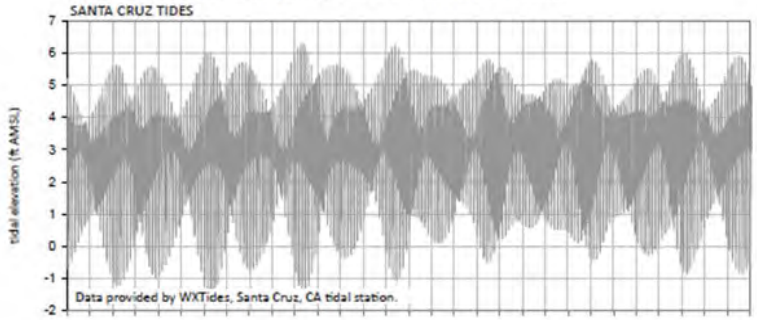
Summer steelhead rearing habitat!

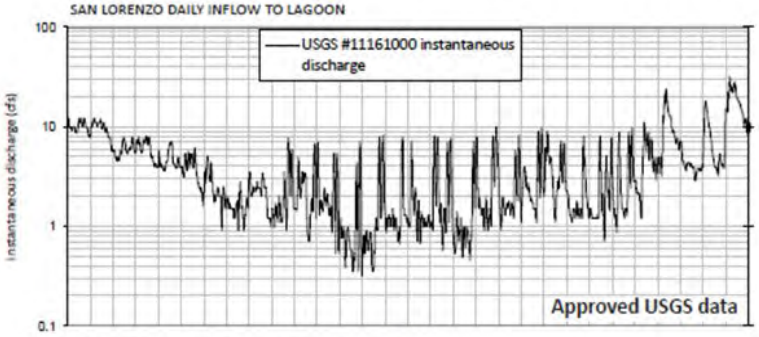
- Instream flow
- Water Quality
- Habitat Simplification

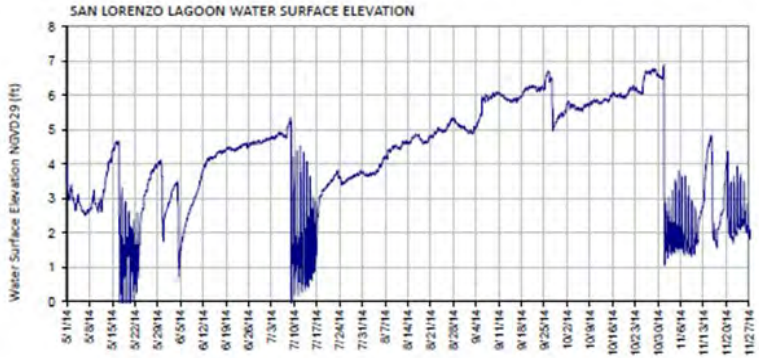


Photos: - Branciforte Flood Control Channel - City of Santa Cruz (bottom), ~2018, San Lorenzo River lagoon, 2020 - Hagar Environmental Science (top)

2014 SAN LORENZO LAGOON HYDROLOGY





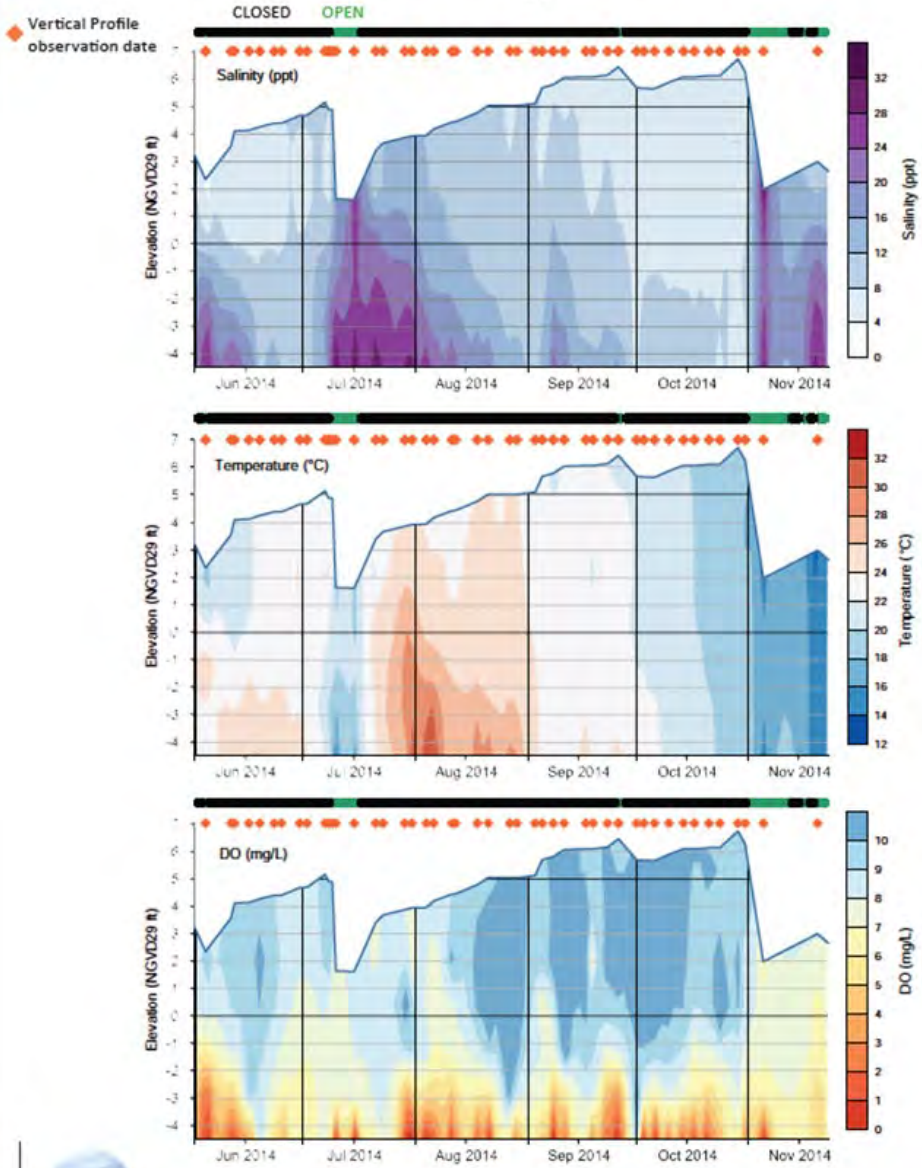


2NDNATURE | LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

SAN LORENZO HYDROLOGY AND LAGOON WATER BUDGET (2014)

FIGURE 7

2014 SAN LORENZO LAGOON VERTICAL PROFILE DATA:
SL3



2NDNATURE LLC
TEL: 831.426.9119 FAX: 831.426.7092
www.2ndnaturellc.com

2014 VERTICAL PROFILE MONITORING AT SL3

FIGURE 13

Table 8. Fish catch in San Lorenzo River Lagoon, September 2014

Species	South of Trestle (1)	Around Trestle (2)	Between Trestle and WQ Station (3)	Upstream of Riverside Bridge (5)	Bend near Laurel Ave. (6)	Downst ream of Water St. (8)	Grand Total
# Hauls	*1*	*5*	*1*	*2*	*2*	*7*	
Steelhead (*O.mykiss*)						8	**8**
Topsmelt	1	38	3		5	310	**357**
Threespine stickleback		3		11	2	6	**22**
Prickly sculpin					1	3	**4**
Staghorn sculpin				1			**1**
Shiner surfperch		1					**1**
Tidewater goby				1		4	**5**
Crab		7	1	2	3		**13**
Bullfrog tadpole						1	**1**
O. mykiss CPUE	*0*	*0*	*0*	*0*	*0*	*1.1*	

Source: Hagar Environmental Science, 2015

ATTACHMENT B

San Lorenzo River Watershed
Nitrate Total Maximum Daily Load
for
Santa Cruz, California

(Listed Waters: San Lorenzo River, Carbonera Creek, Shingle Mill Creek, and Lompico Creek)

Prepared by
Central Coast Regional Water Quality Control Board
September 15, 2000

San Lorenzo Nitrate Sources

Contribution to Summer Load at Felton:

• 1,400 Septic Systems in sandy areas	38%
• 10,500 Septic Systems in non-sandy areas	19%
• Natural sources in sandy areas	12%
• Sewer discharge from B.C. Country Club	10%
• Scotts Valley nitrate plume	9%
• Livestock and stables	6%
• Natural sources in non-sandy areas	4%
• Landscaping/fertilizer use	2%

Source: Ricker, 2015

Image: Pardise Park flooding, 2017 - Santa Cruz Sentinel

Image: San Lorenzo River, 1986 - California Coastal Records Project

- Routine sandbar breaching
- LWD removal
- Vegetation removal
- Low (not very high quality) inflows

SOLUTIONS!

Image: Coastal Watershed Council interpretive event on the San Lorenzo River, ~2015 - *Chris Berry*

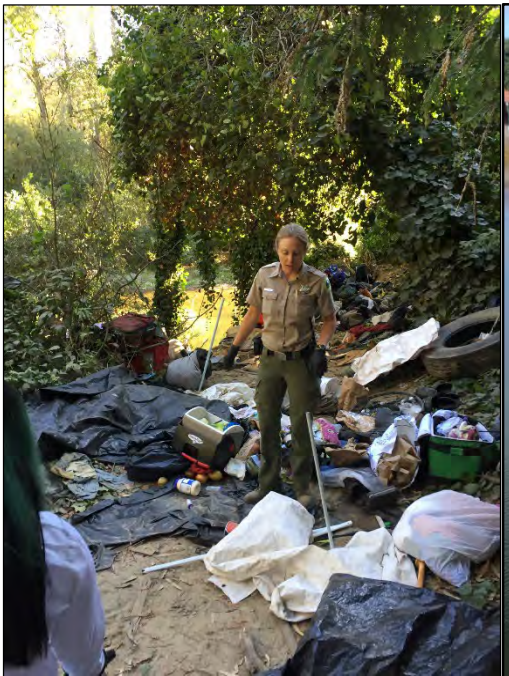
MONITORING

- Extensive flow, fisheries and water quality monitoring since 2002
    - 4 water quality sondes (top and bottom)
    - Multiple vertical profile sample sites from mouth to Water Street
    - Nutrient loading monitoring
    - Multiple seining events during peak rearing season
    - Multiple gaging sites including sponsoring USGS gages
    - And more!

Photos: Water quality and steelhead monitoring, 2018 (top) and 2019 (bottom) – City of Santa Cruz files

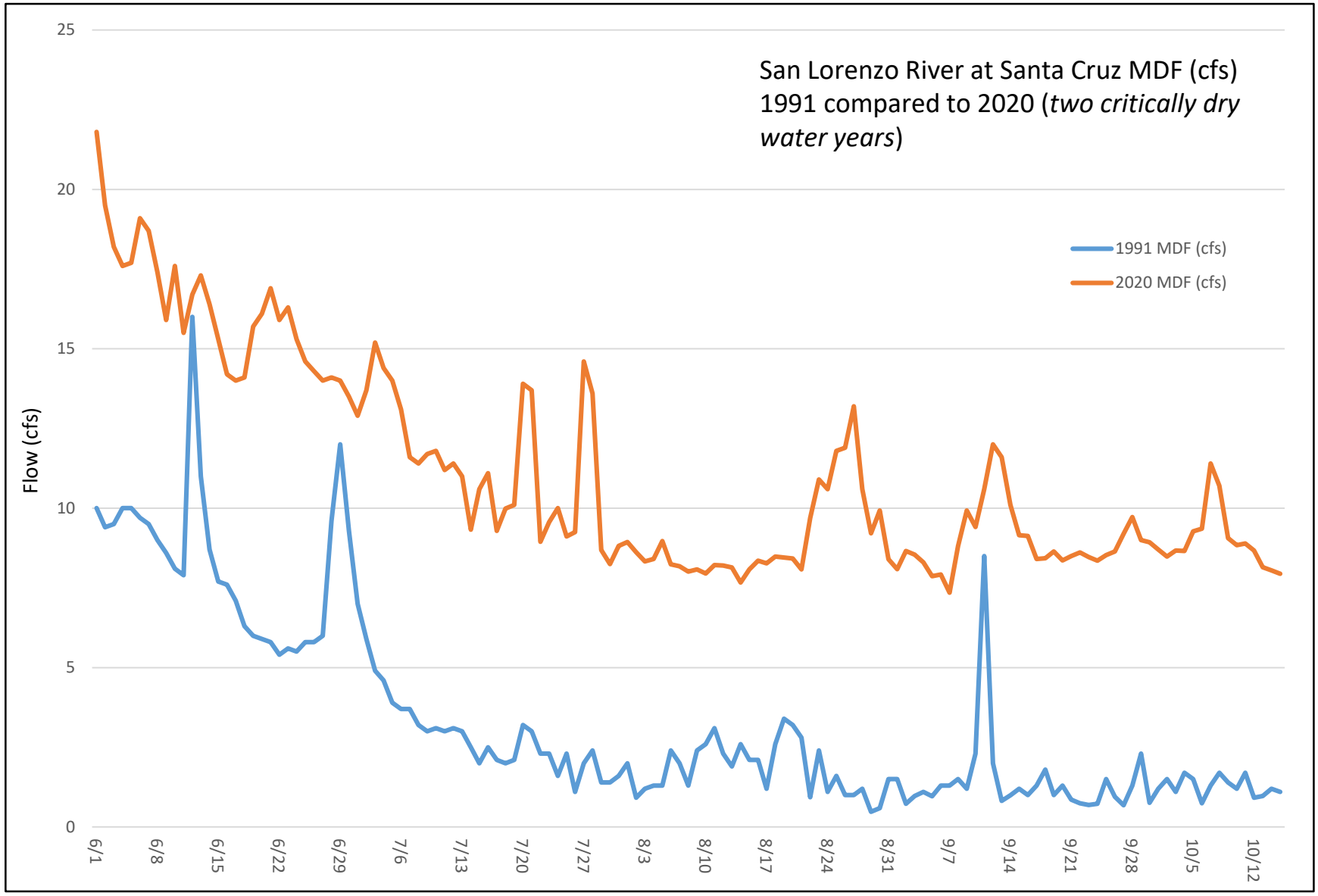
HABITAT IMPROVEMENTS

- LWD placement
- Native plant restoration
- Flood maintenance bmps
- Riparian protection/retention
- Trash removal
- IPM Program
- Stormwater program
- Improved instream flows
- Water level management
- Mitigation opportunities!



Photos: City of Santa Cruz files

INSTREAM FLOW IMPROVEMENTS



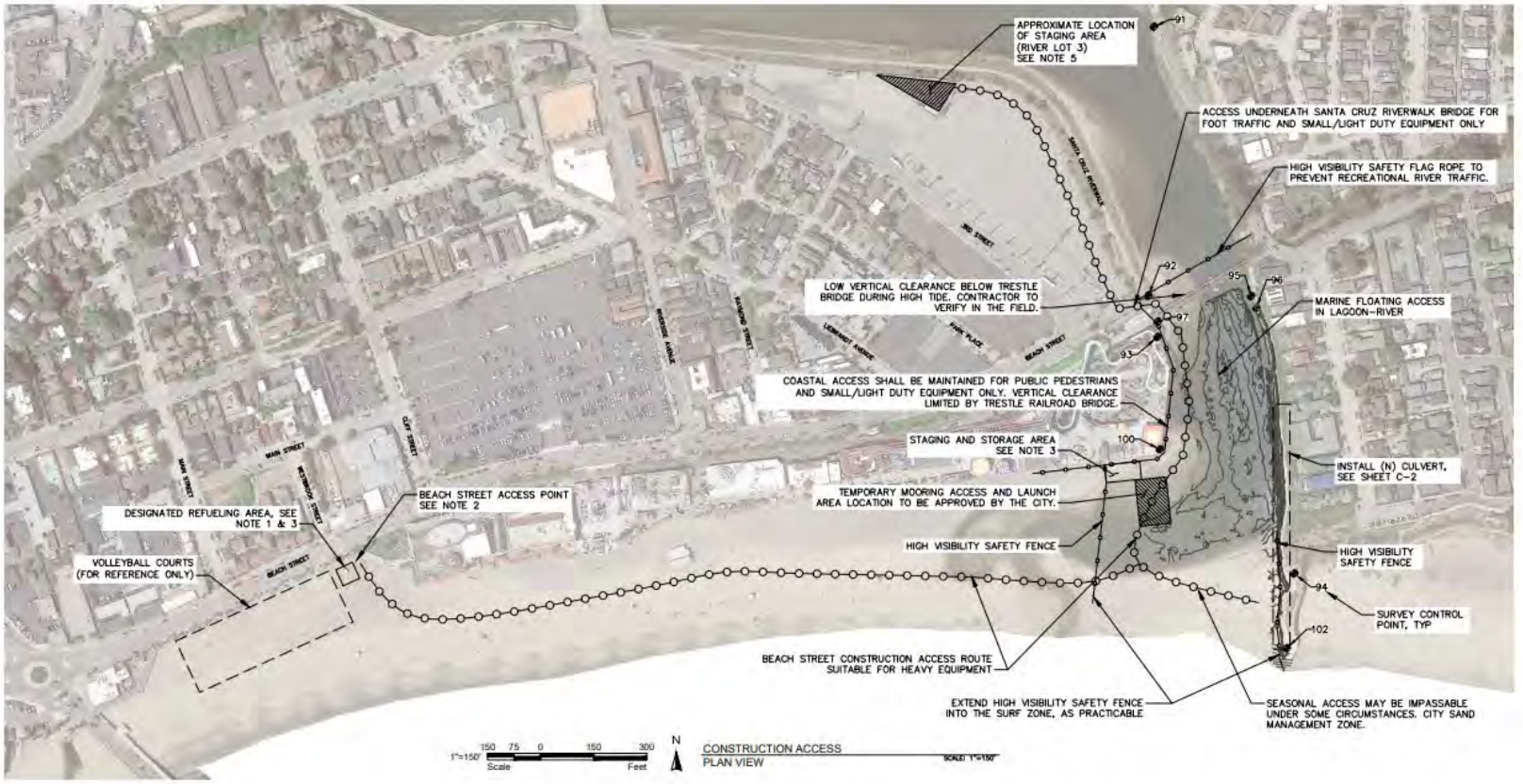
Source: USGS data

Table 11. Fish catch in San Lorenzo River Lagoon, September 2020

Species	South of Trestle (SL-1)	Around Trestle (SL-2)	Around Water Quality Station (SL-3)	Upstream of Riverside Bridge (SL-5)	Bend Downstream of Laurel Ave. (SL-6)	Grand Total
# Hauls	*7*	*7*		*4*	*5*	***23***
O. mykiss	1	211		76	419	**707**
Striped mullet		1			3	**4**
Topsmelt	1	55		8	11	**75**
Threespine stickleback	7	68		21	3	**99**
Staghorn sculpin		5				**5**
Tidewater goby		6			1	**7**
crab	1	9				**10**
shrimp				2		**2**
				76	419	
O. mykiss CPUE	*0.1*	*30.1*		*19.0*	*83.8*	***30.7***

Source: Hagar Environmental Science, 2021

WATER LEVEL MANAGEMENT



NOTES:

1. DAYTIME REFUELING SHALL BE COORDINATED WITH THE CITY AND CITY LIFEGUARD.
2. BEACH STREET ACCESS IS LIMITED TO 06:00 AM TO 08:00 AM WEEKDAYS. SEE GENERAL NOTES.
3. CONTRACTOR SHALL WORK WITH THE CITY TO CONFIRM EXTENT, LOCATION, HOUR RESTRICTIONS, AND ACCESS TO REFUELING AND TEMPORARY NIGHT TIME STAGING AREAS.
4. NIGHT TIME STORAGE OF EQUIPMENT SHALL BE RESTRICTED TO EQUIPMENT REQUIRED TO INSTALL THE CULVERT, UNLESS DIRECTED OTHERWISE BY THE CITY OR THE EOR.
5. ACTUAL STAGING AREA (APPROX. 10,000 SQUARE FEET) WILL BE LOCATED WITHIN LOT 3 AREA. EXACT LOCATION, LAYOUT, AND EXTENT TO BE PROVIDED BY THE CITY. CONFIRM WORK HOURS WITH THE CITY.

VERIFY SCALE

SURVEY CONTROL POINT TABLE:

NAD 83 / NAVD 88 POINT TABLE

POINT #	NAME	NORTHING	EASTING	NAVD88 ELEV	DESCRIPTION
91	SLR-M1	1814371.77	6119534.38	22.187	FD DISK SLR-M1
92	3B	1813611.29	6119518.91	15.267	CUT + ON CC
93	3A	1813495.37	6119544.65	19.119	SET DISC
94	2B	1812827.16	6119931.81	38.435	FD MAG NAIL TW
95	1A	1813610.86	6119809.60	9.931	SET DISC
96	1B	1813577.19	6119824.75	4.805	SET DISC
97	S-1237	1813539.01	6119545.39	26.815	FD DISK S1237
100	4	1813177.87	6119551.87	11.456	CENTER TARGET
102	2A	1812615.83	6119910.95	23.569	SET DISC

PREPARED BY: ESA

CONSTRUCTION ACCESS & STAGING AND SURVEY CONTROL

SAN LORENZO RIVER LAGOON CULVERT

PREPARED FOR: CITY OF SANTA CRUZ 809 CENTER STREET SANTA CRUZ, CA 95060

SANTA CRUZ

REGISTERED PROFESSIONAL ENGINEER JEAN G. TOTTEN C 77499 CIVIL STATE OF CALIFORNIA

APPROVED: B.BATTALIO
DESIGNED: ESA
DRAWN: S.CLARKE, S.SMITH
PM/CHARGE: J.TOLLIOU
SCALE: AS NOTED
REVISION:
DATE: FEBRUARY 2021
SHEET: G-3
03 OF 22

Image: Lagoon Culvert Plan, 2021 – City of Santa Cruz files

HOMELESSNESS POLICY

- Trash cleanups
- Downtown Streets Team
- Camping ordinance
- “River Health Days”
- Provision of sanitary facilities
- Routine patrols of riparian areas
- Benchlands Environmental Stewardship Team
- Development of shelter space!

https://www.cityofsantacruz.com/community/homelessness

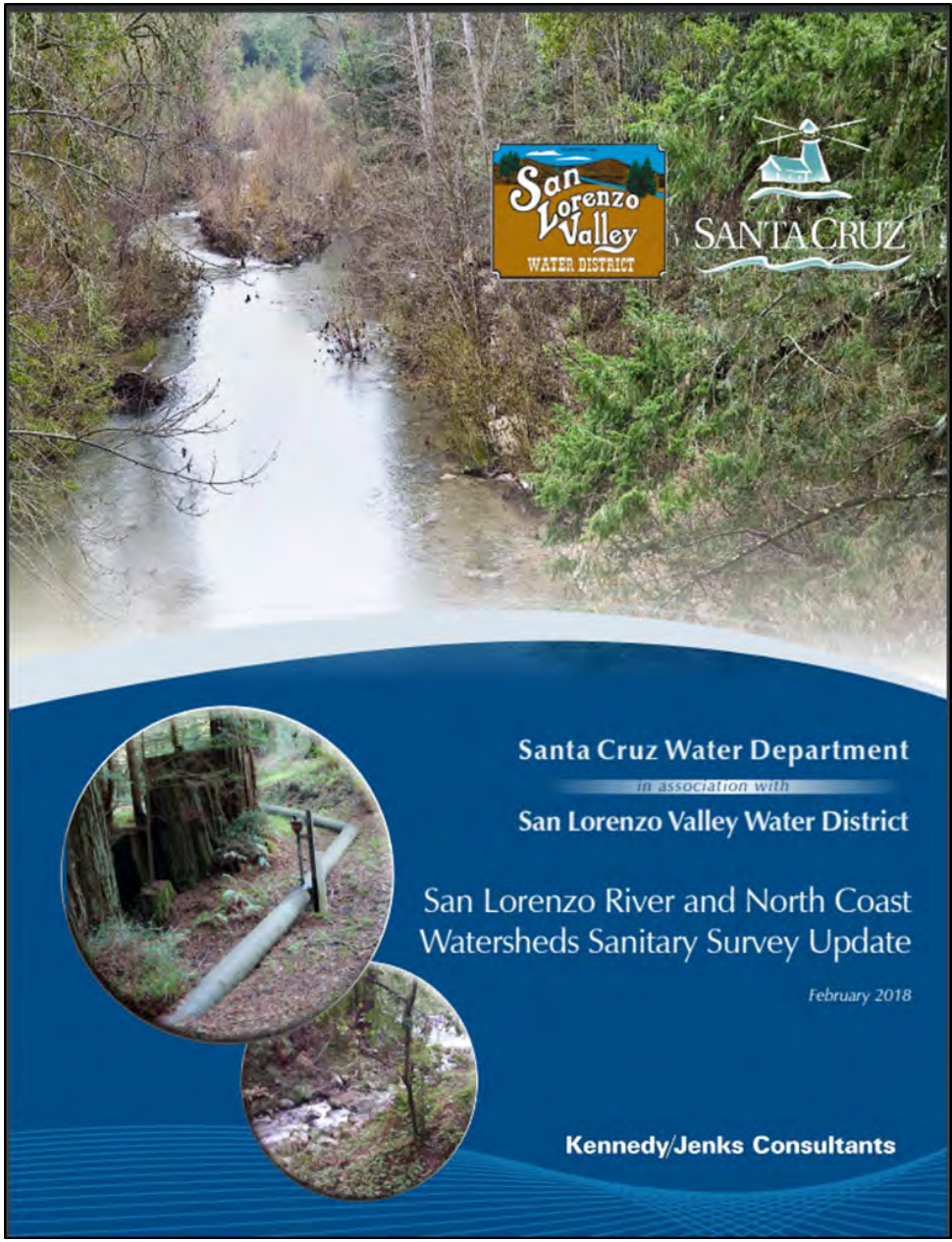
Above Photo: Benchlands camp, 2020 - “We are Santa Cruz”, Other photos – City of Santa Cruz files

INTERESTED PARTIES ENGAGEMENT

Photos Top and right: City of Santa Cruz files, bottom left, CWC

WATERSHED PROTECTION

- Development plan review
- Code compliance
- Property management
  - City watershed lands and riparian conservation lands
- Regional Planning
  - Karst Protection Zone
  - Onsite Wastewater Treatment Systems
  - Cannabis cultivation
  - Community Wildfire Protection
  - Riparian Conservation Plan
  - Regional Conservation Investment Strategy
  - Conservation Blueprint
  - Santa Cruz County General Plan update
  - Many others…



PROGRESS…NOT PERFECTION…

Year	*O. mykiss* Catch per Haul				
	June	July	August	September	October
2008	2.6				0.1
2009	0.3			1.0	0.5
2010	8.3	21.5			28.25
2011	13				2.5
2012	1.7			14.4	
2013	2	8.4		4.7	
2014	1.2	1.1		0.0	
2015	2.6	0	0		0
2016	39.7	1.0	2.0	7.8	
2017	134.4	452.0	272.0	328.5	
2018	23.3	2.5	6.4	6.3	
2019	92.2	53.4	277.7	228.2	
2020	146.1	120.6		31.0	

Source: Hagar Environmental Science, 2020

THANKS!

Image: San Lorenzo River steelhead, 2021 – Shmuel Thaler

CONTACT: cberry”@”cityofsantacruz.com

Lessons Learned from 8 Years of Lagoon Management of the San Lorenzo River, Santa Cruz, California

Using Sand to Balance Ecological Function and Social Demands

David Revell, Ph.D., Integral Consulting

drevell@integral-corp.com

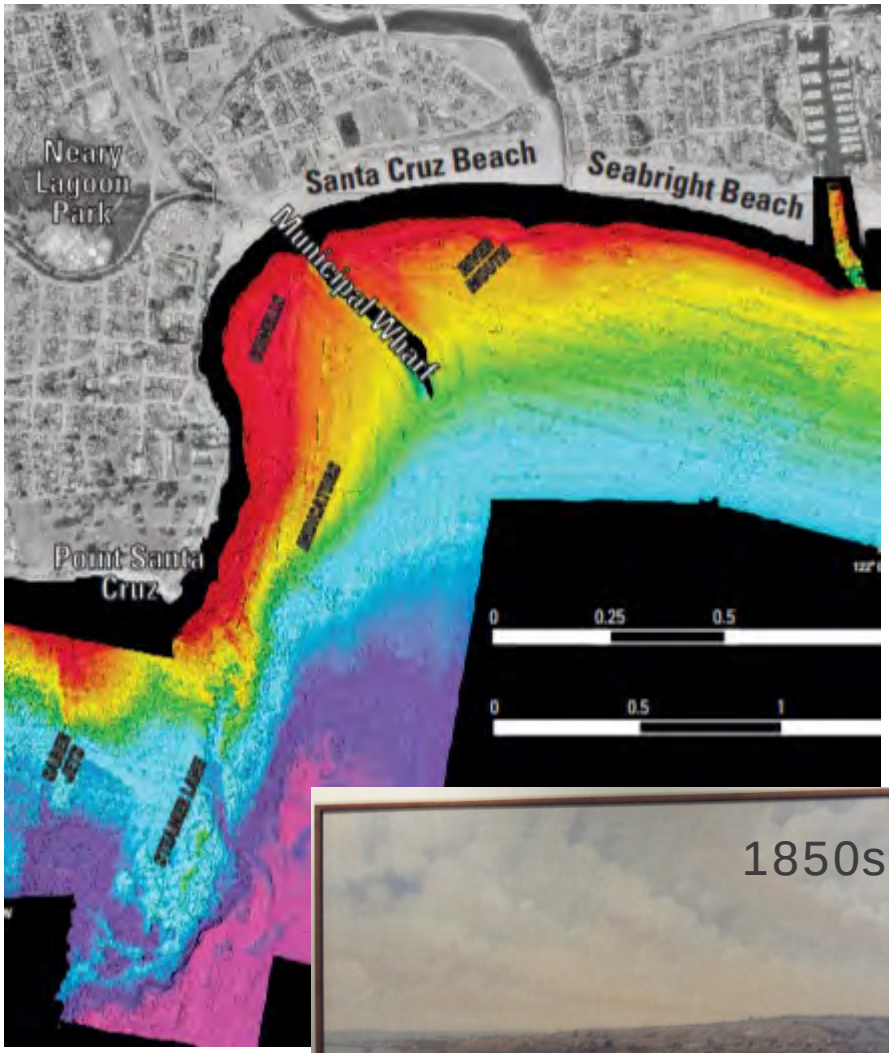
04/22/2022

integral consulting inc.

CITY OF SANTA CRUZ

Outline

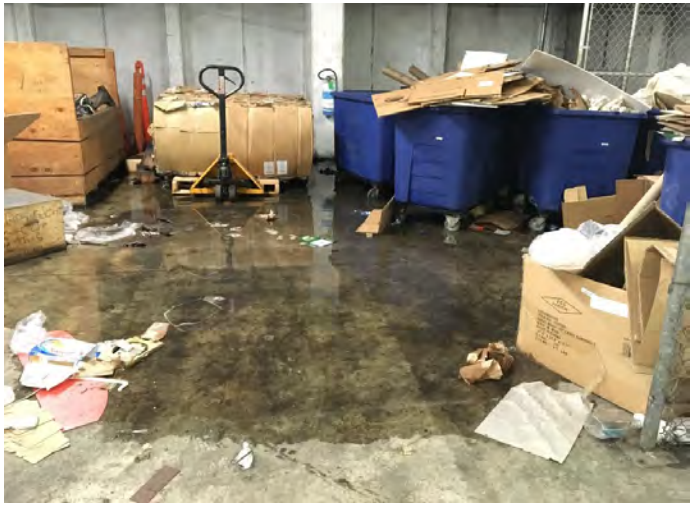
- Background
- Coastal Process Study
- Mouth Management
- Alternatives Considered
- Moving forward



Competing Priorities

- Endangered Species
- Public Safety
- Federal Historic Landmark
- Water Quality
- Nuisance Flooding
- Public Recreation in a World Surf Reserve

Flooding Impacts

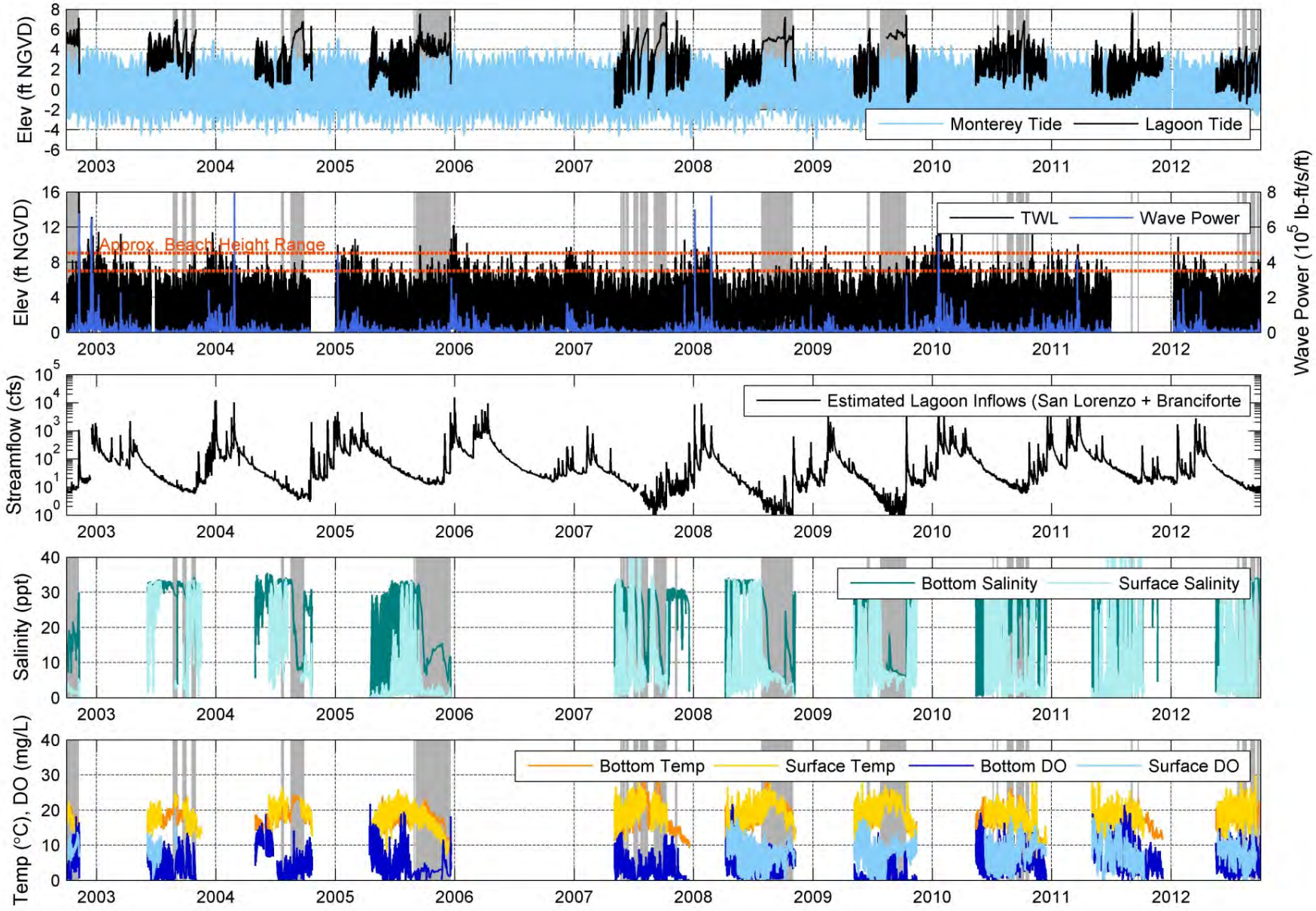


Sea Level Rise Coastal Hazard Zones

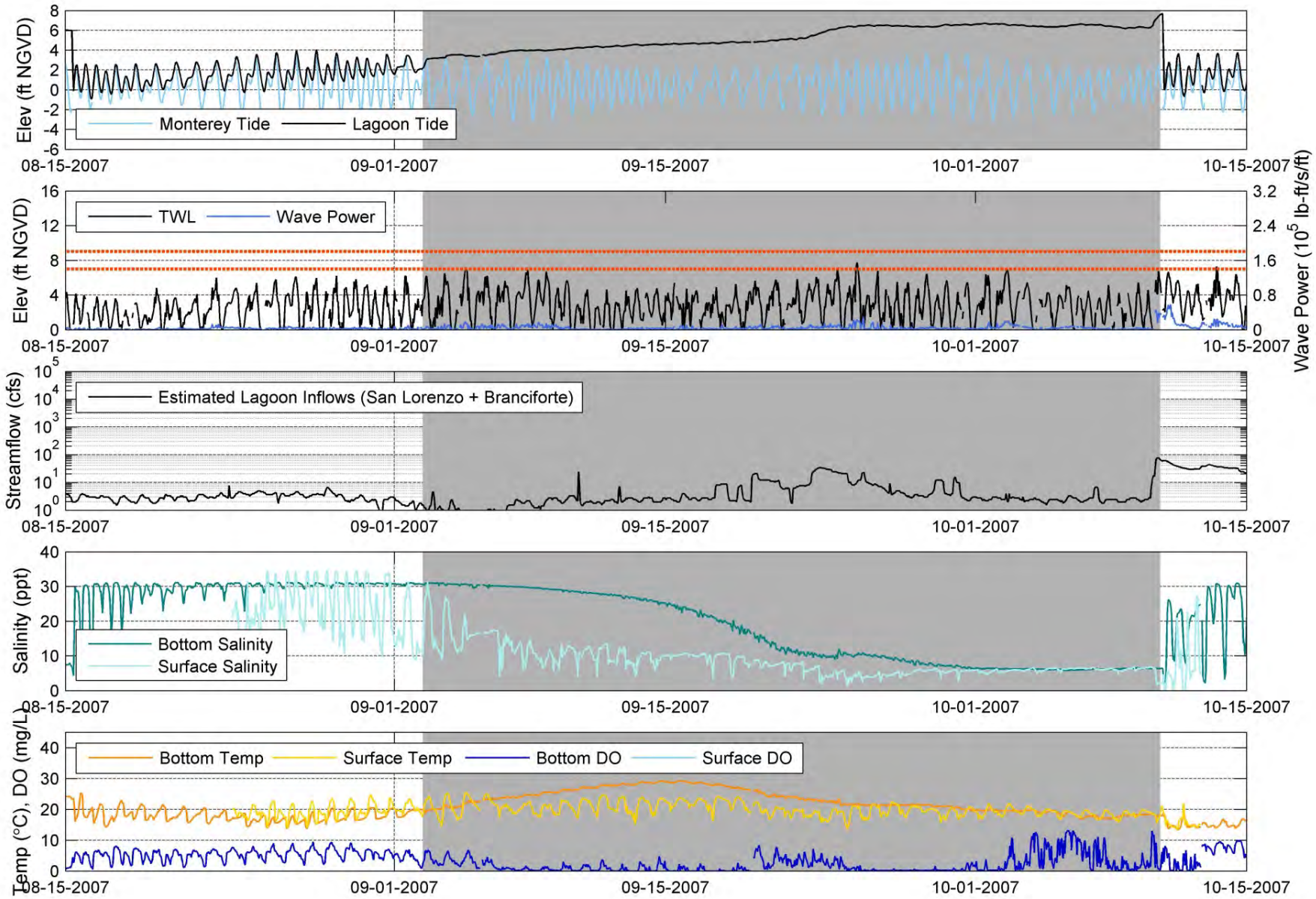
Background

Background

Coastal Processes Study 2002 - 2012



Close-up: 2007 Low Waves



Physical Processes

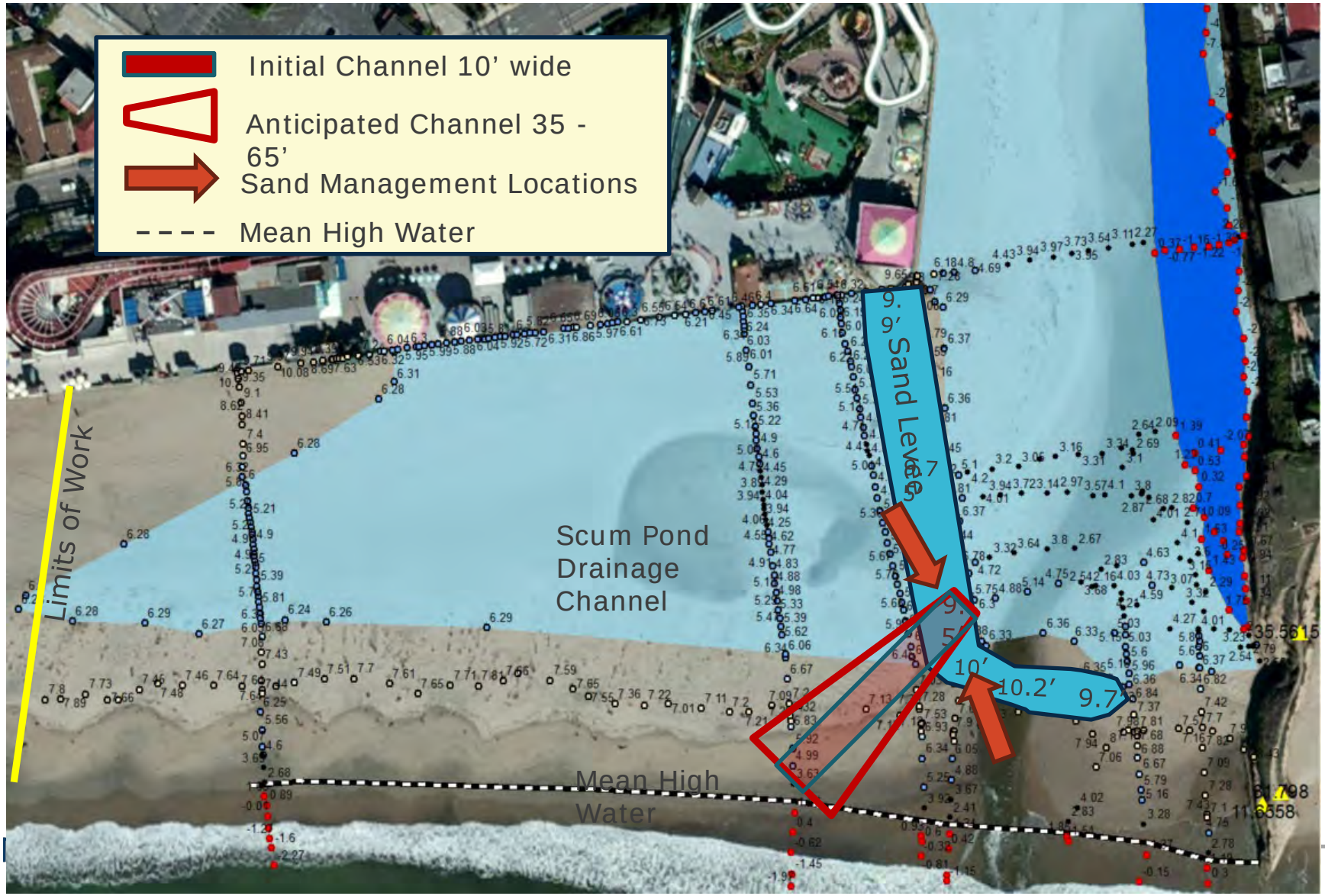
- Wave run-up affect salinity and water level in a closed lagoon
- Beach sill typically mutes tide below 2-3’ NGVD
- Bottom temperature high until lagoon freshens
- Lagoon freshens during closure (3 weeks no overtopping)
- DO generally low after inlet closure
- Wave overwash increases DO at bottom
- Closed beach berm crest elevation ranges from 6.5 to 10.5’
- Beach crest highest next to point varying by season and year
- Thalweg depth varies widely from beach to train trestle

Historic Management

- MECHANICAL BREACHING
- OPEN AT LOW TIDE
- MAXIMUM HYDRAULIC GRADIENT

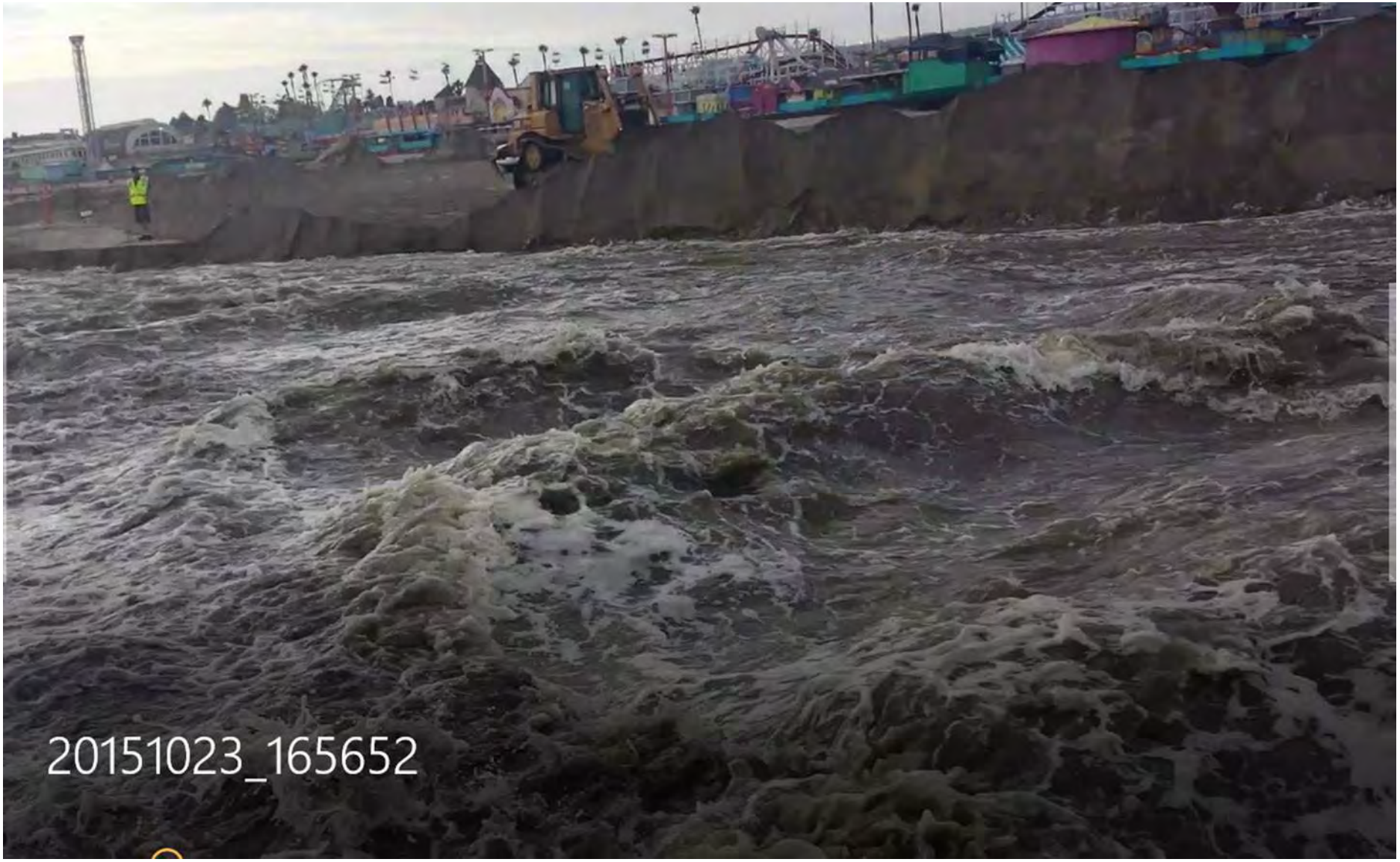
2012 - River almost destroyed the boardwalk

2014-15 MANAGEMENT
SCUM POND

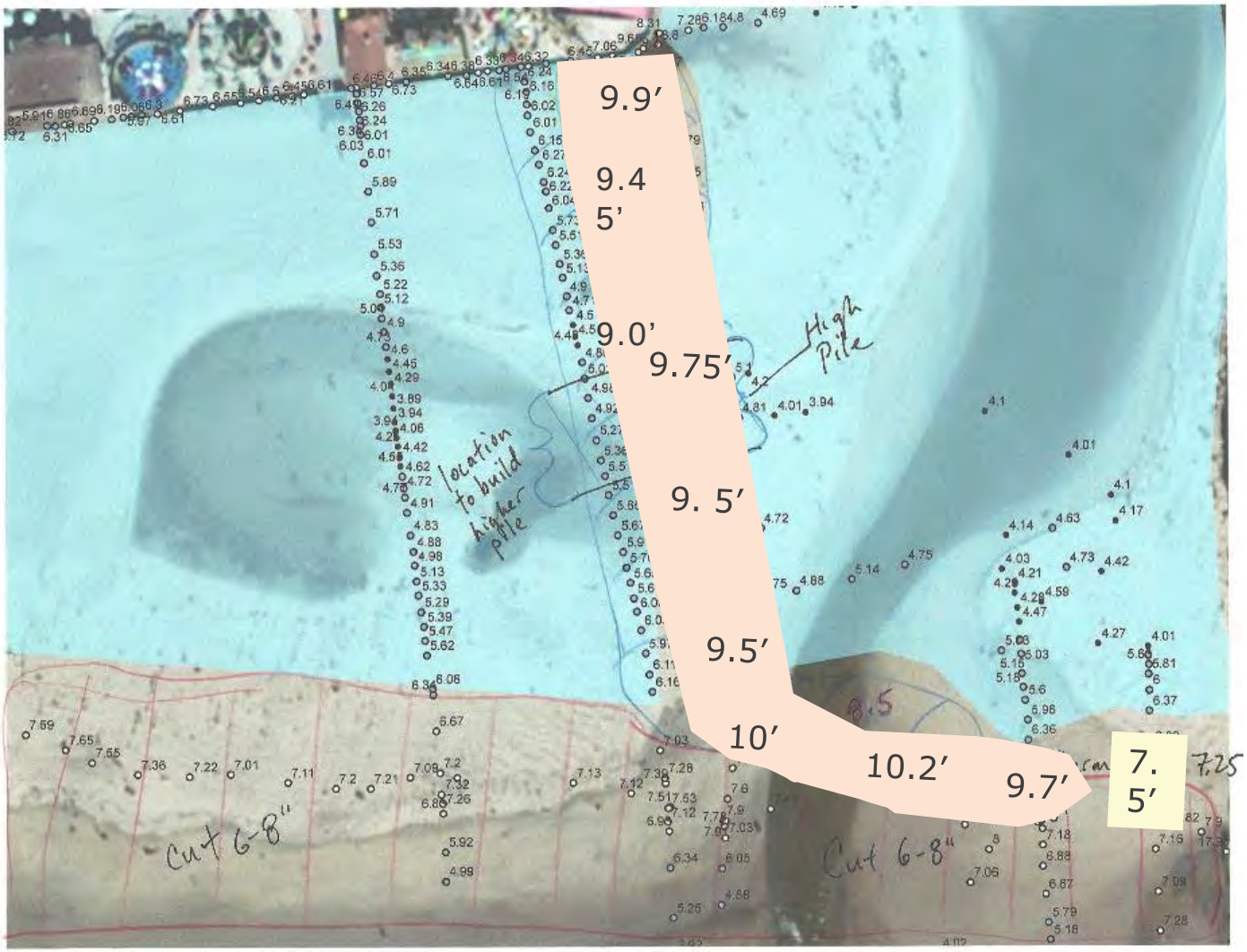



Warning
PEOPLE and PETS should avoid direct contact with water at this site.
The water in the San Lorenzo Lagoon may contain harmful compounds caused by algae.
Water smell is NOT an indication of safe water.
Aviso
Personas y animales domésticos deben evitar el contacto directo con el agua.

Breaches - Mechanical


20151023_165652

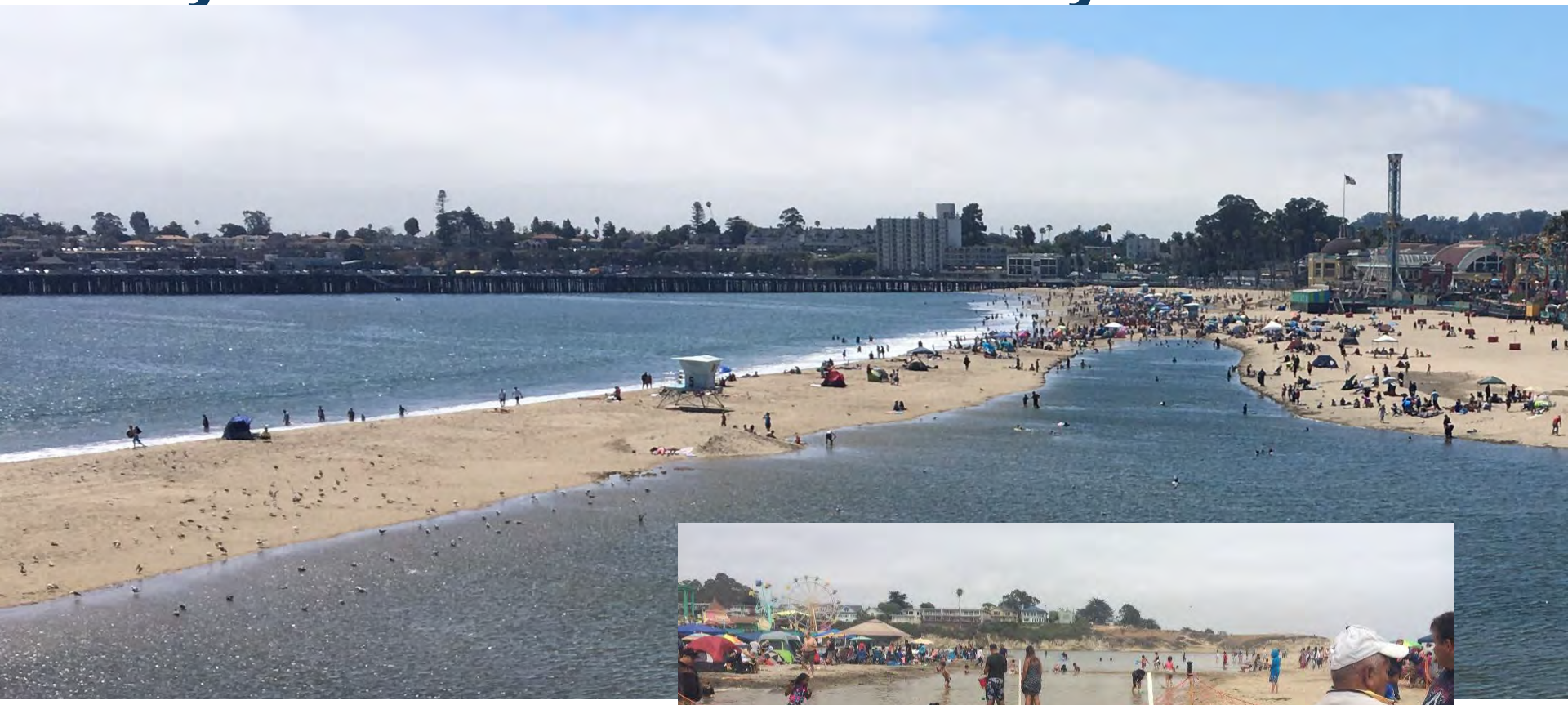

CAT


9.9′
9.4
5’
9.0’
9.75′
9. 5′
9.5′
10′
10.2′
9.7′
7.
5′
High Pile
location to build higher pile
Cut 6-8"
Cut 6-8"

9/27/15 – Vandal Breach of the Sand Levee

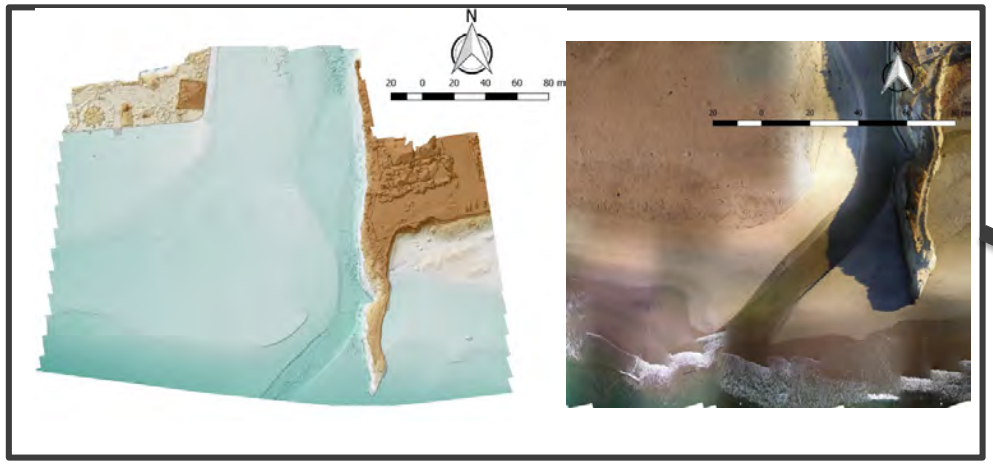
2016 – Migrating Mouth JULY 4th

City Closed Breach on July 4th

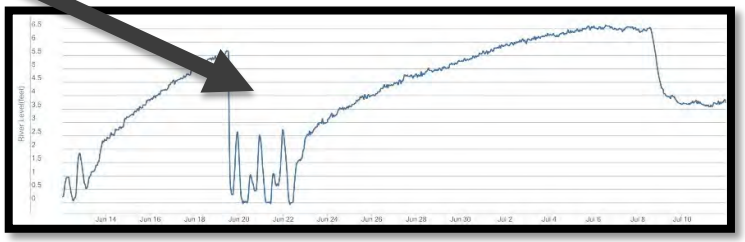


Relocated Mouth

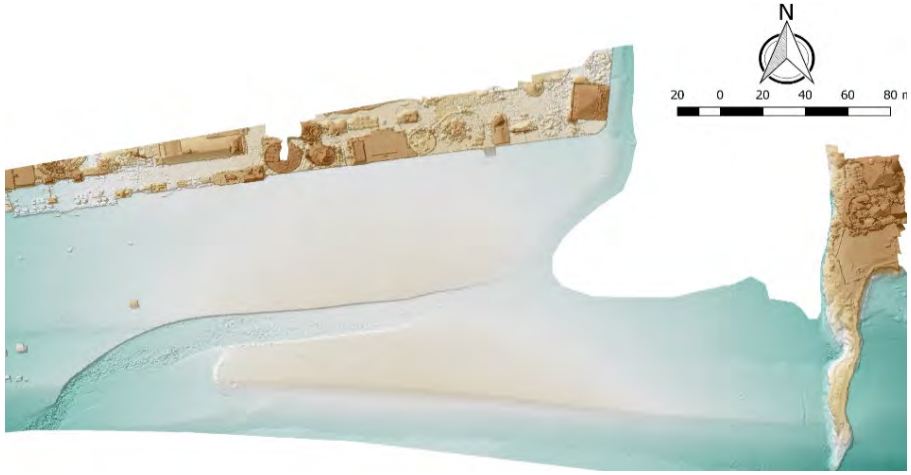
Mouth Relocated

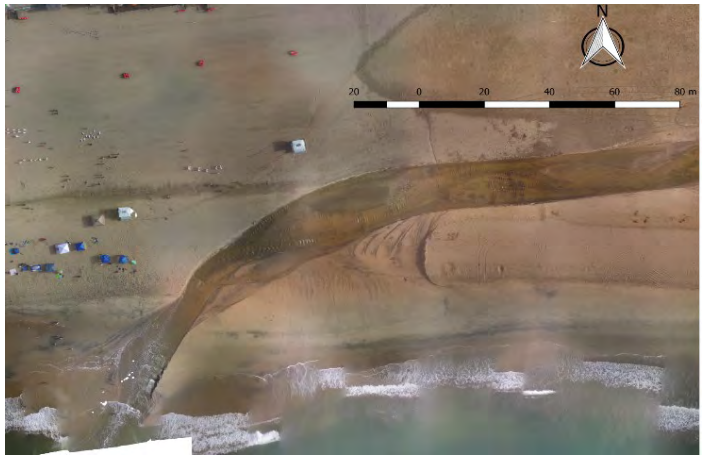


Starting June 22nd, a berm forms at the river mouth and the water levels in the lagoon begin to rise.



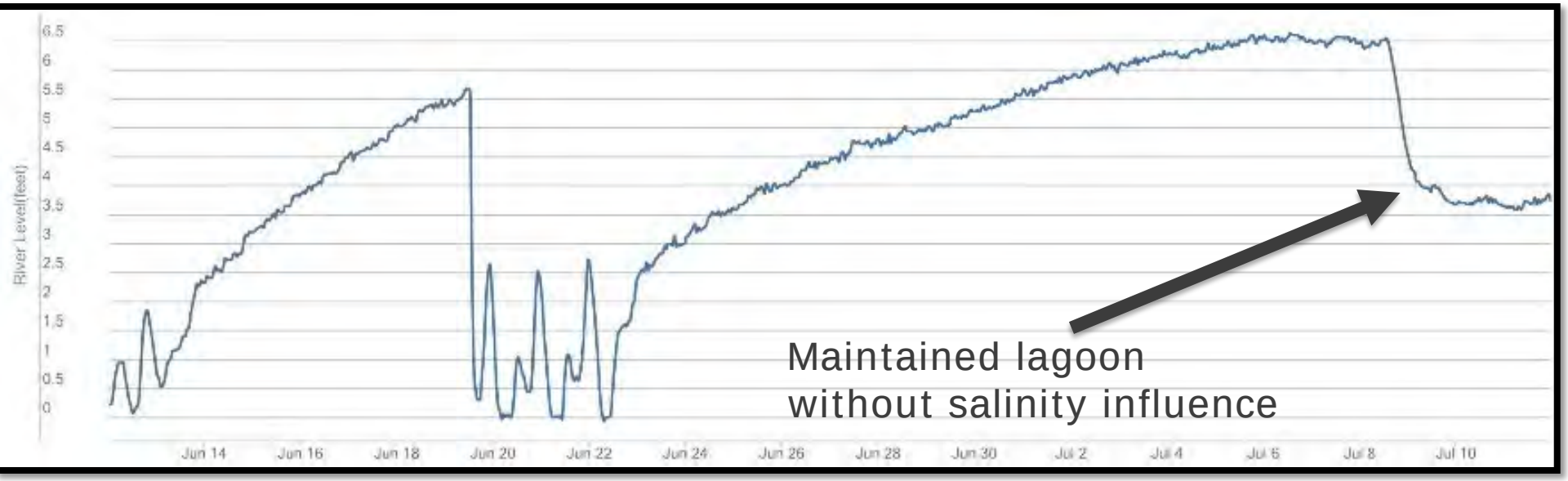
By July 8th , the water levels exceeded 6 ft causing public beach hazards, flooding, and water quality concerns.



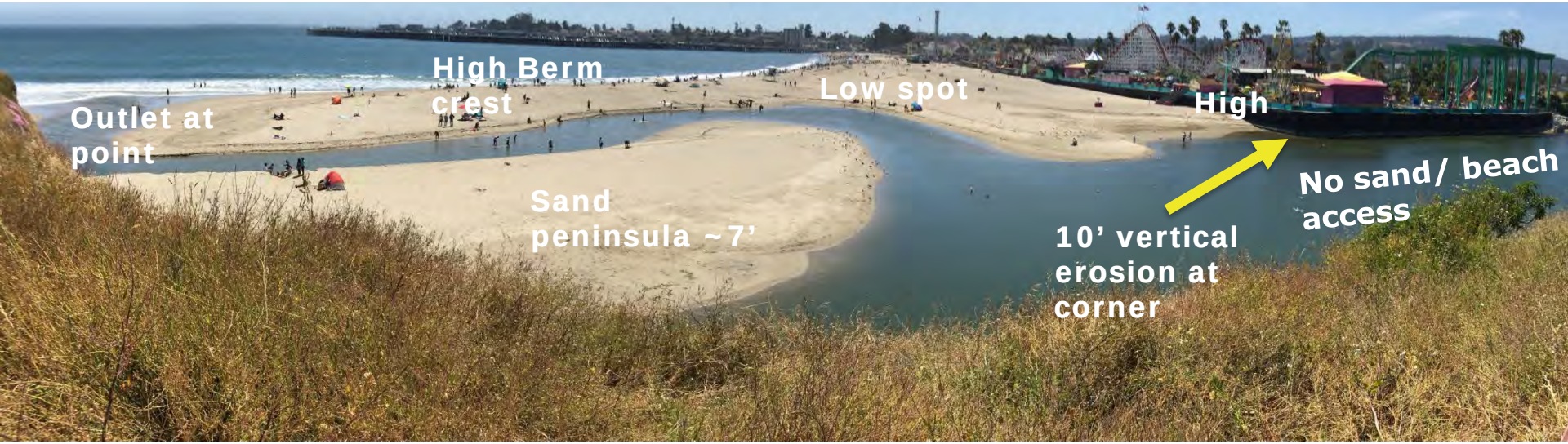


A controlled relocation of the mouth dropped the water levels in the lagoon by over 2 ft.

Geomorphic approach



2017 Management
Summer of Unpermitted Breaches



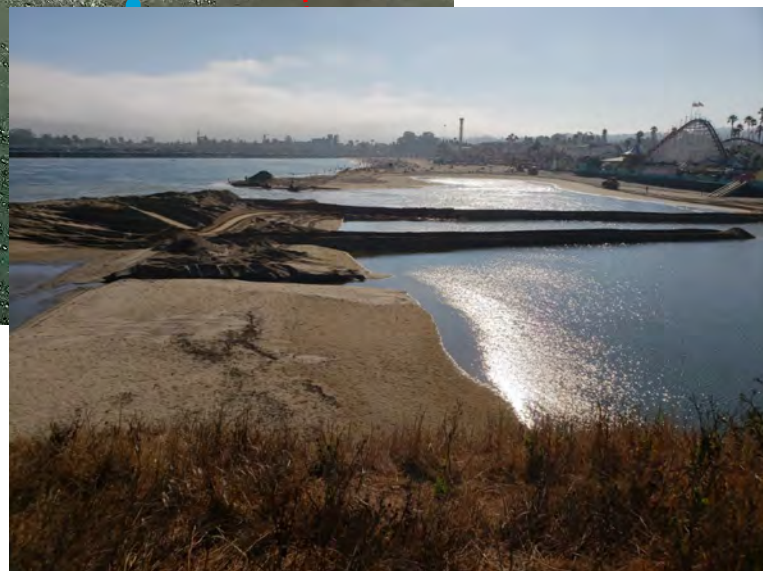
Reduce down the beach migration


AREA CLOSED
NO SWIMMING

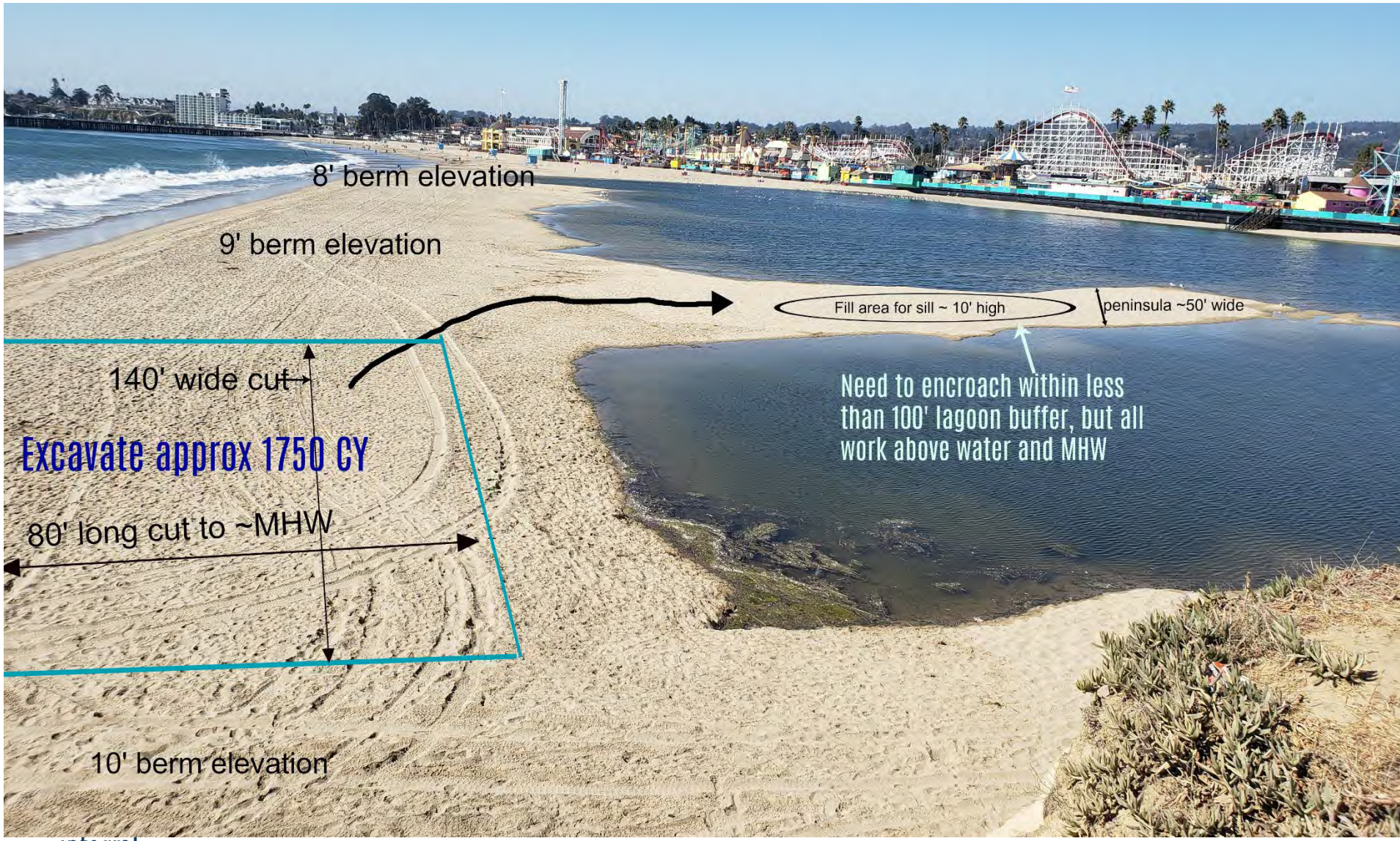
2018 Management - Sand Castles and Sills


Area A
Area B
Area C
Area D
thalweg
Limits of Work
Limits of Work
Sand Peninsula
Sand Stockpile
Sand Stockpile
100′
Limits of work and access
Lifeguard towers
Proposed Outlet
Sand Peninsula
Berm crest excavation
Sand Stockpile
© 2018 Google

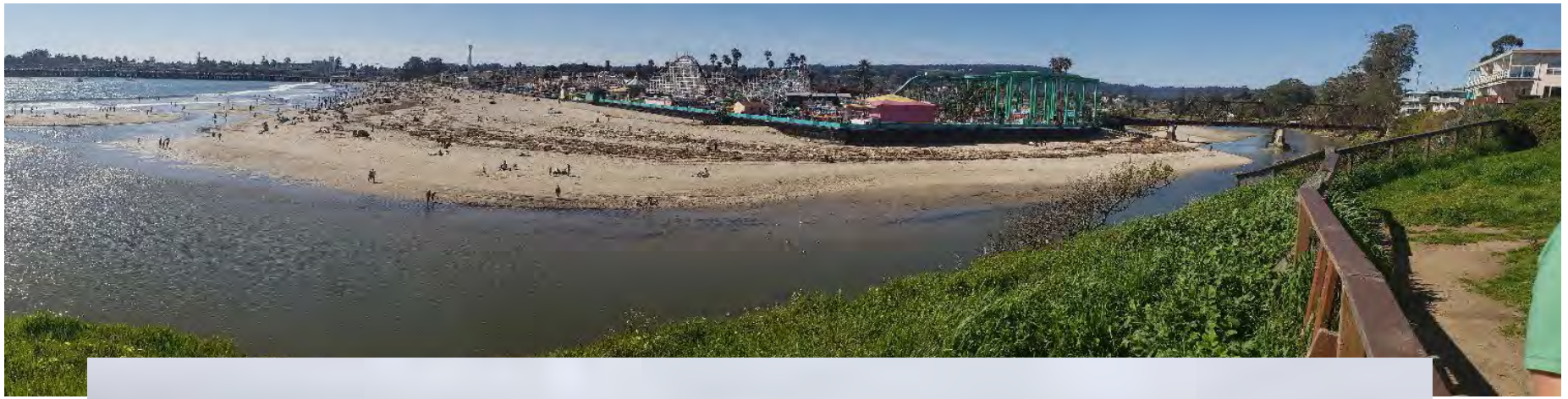
Sand Sills



Priming the Breach



2019 Management – Sand Access Berm



Engineering with Nature

The good and the bad

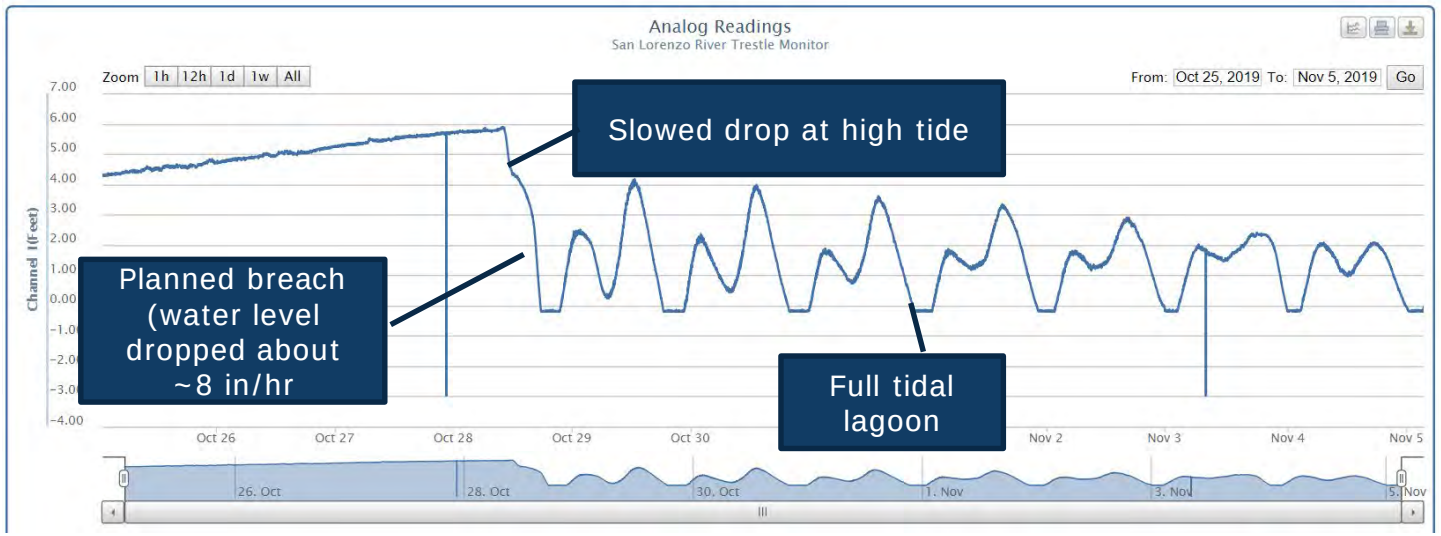
Good

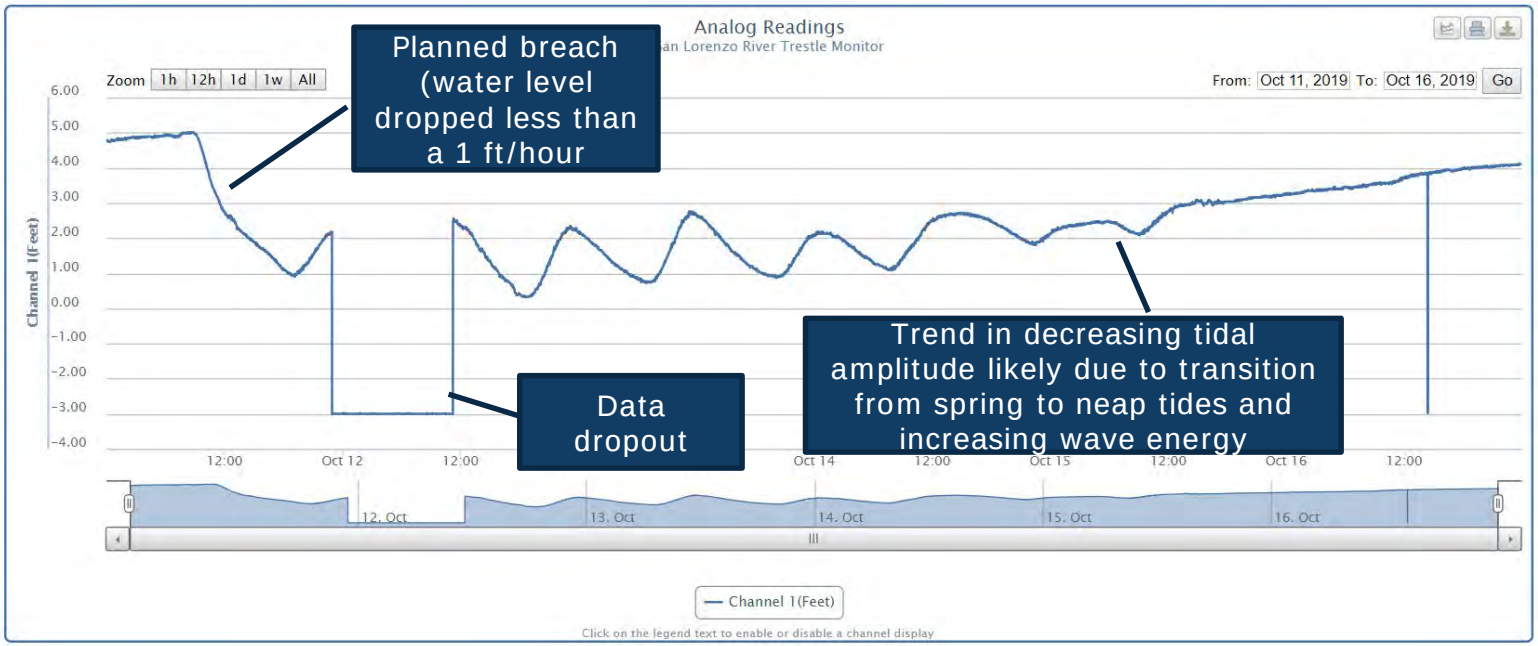
- 2019 the first pink salmon was documented in the San Lorenzo since 1915 (104 years!!!)

Bad

- Lagoon water levels reached 8.1’
- And …. The levee started to unravel through gopher holes
- Army Corp declared emergency

2019 to 2021 Low Flow Breaches





2022 - Head Driven Culvert

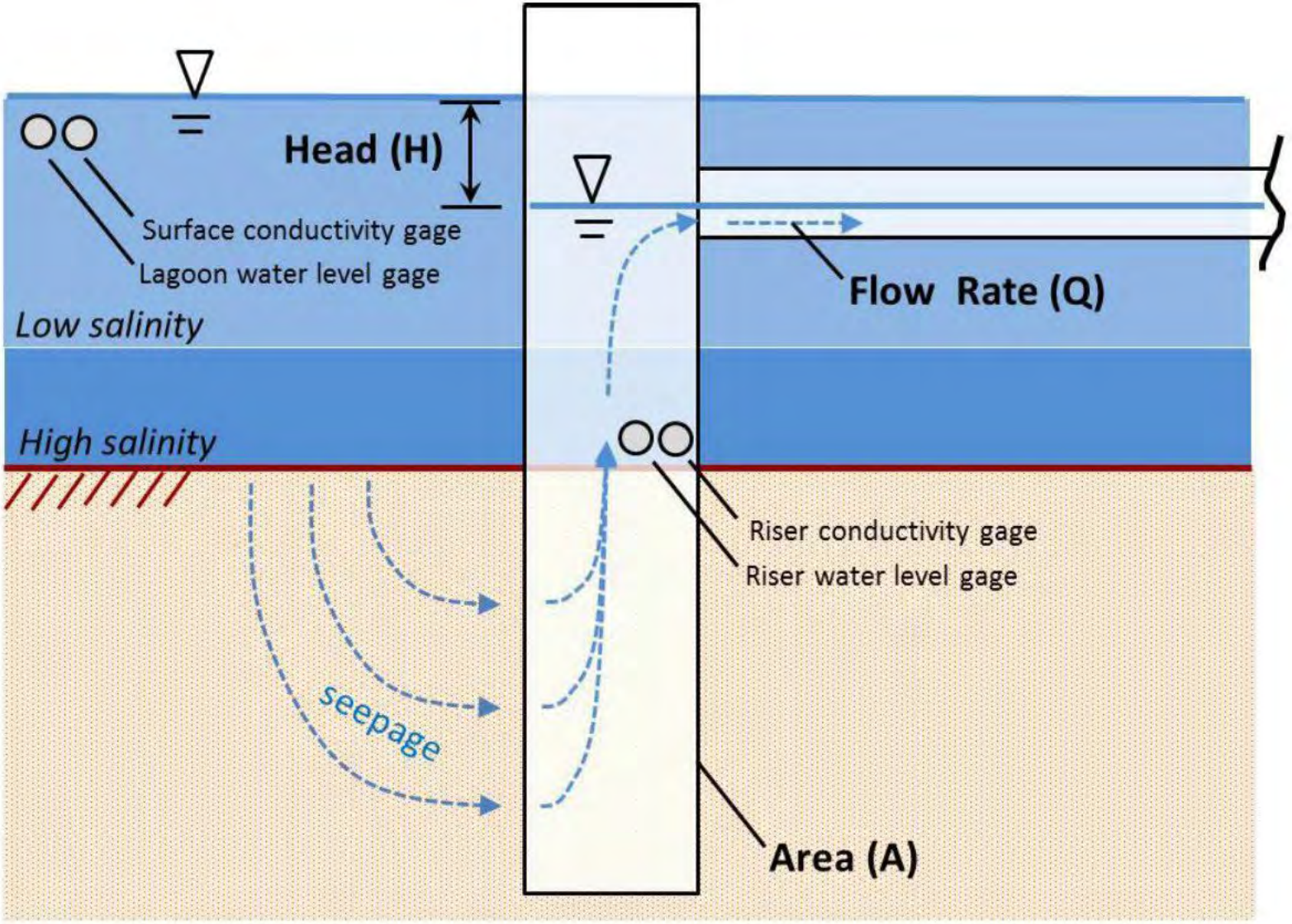


Figure 1 **Schematic of Seepage Measurement.**

Construction scheduled for this summer!!!

Stay tuned…

Regulatory Agency Partners

NOAA FISHERIES

CALIFORNIA COASTAL COMMISSION

Funding Partners

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

CALIFORNIA Water Boards

CITY OF SANTA CRUZ

PROP 1
GOVERNOR EDMUND G. BROWN, JR.
WATER BOND 2014
RELIABILITY | RESTORATION | RESILIENCE

WCB
State of California
Wildlife Conservation Board

Questions?

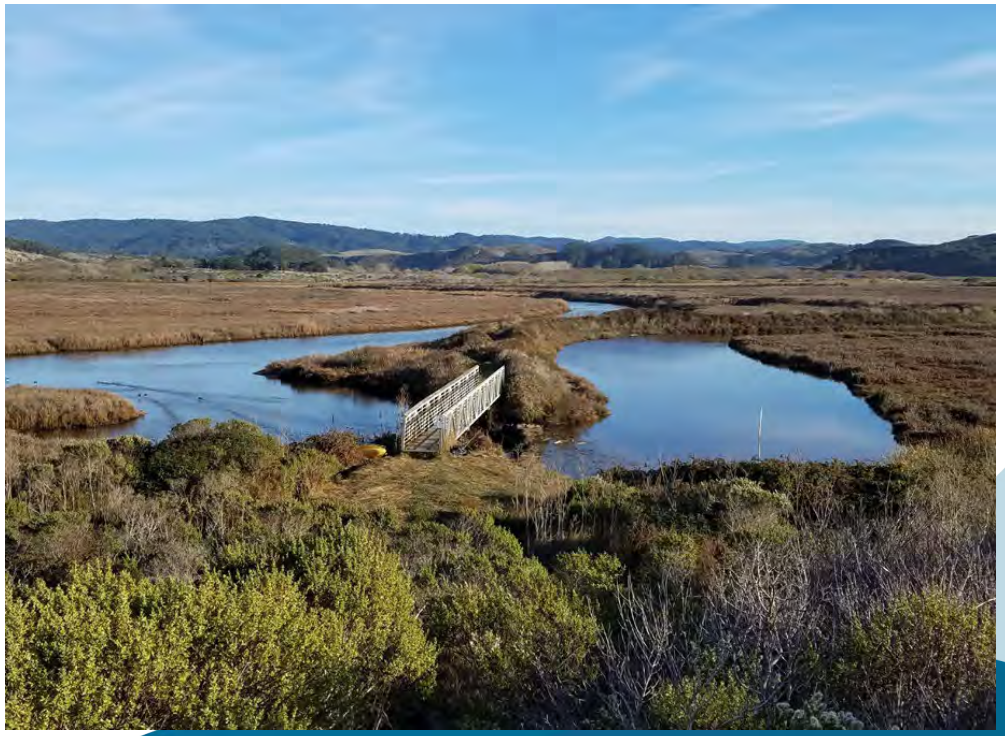
David Revell
drevell@integral-corp.com

Butano Creek Channel Reconnection and Resilience Project

Chris Hammersmark and Jai Singh
cbec eco engineering

Ryan Diller
California State Parks

Jim Robins
San Mateo Resource Conservation District



Stillwater Sciences ESA Pacific Crest Engineering Inc.

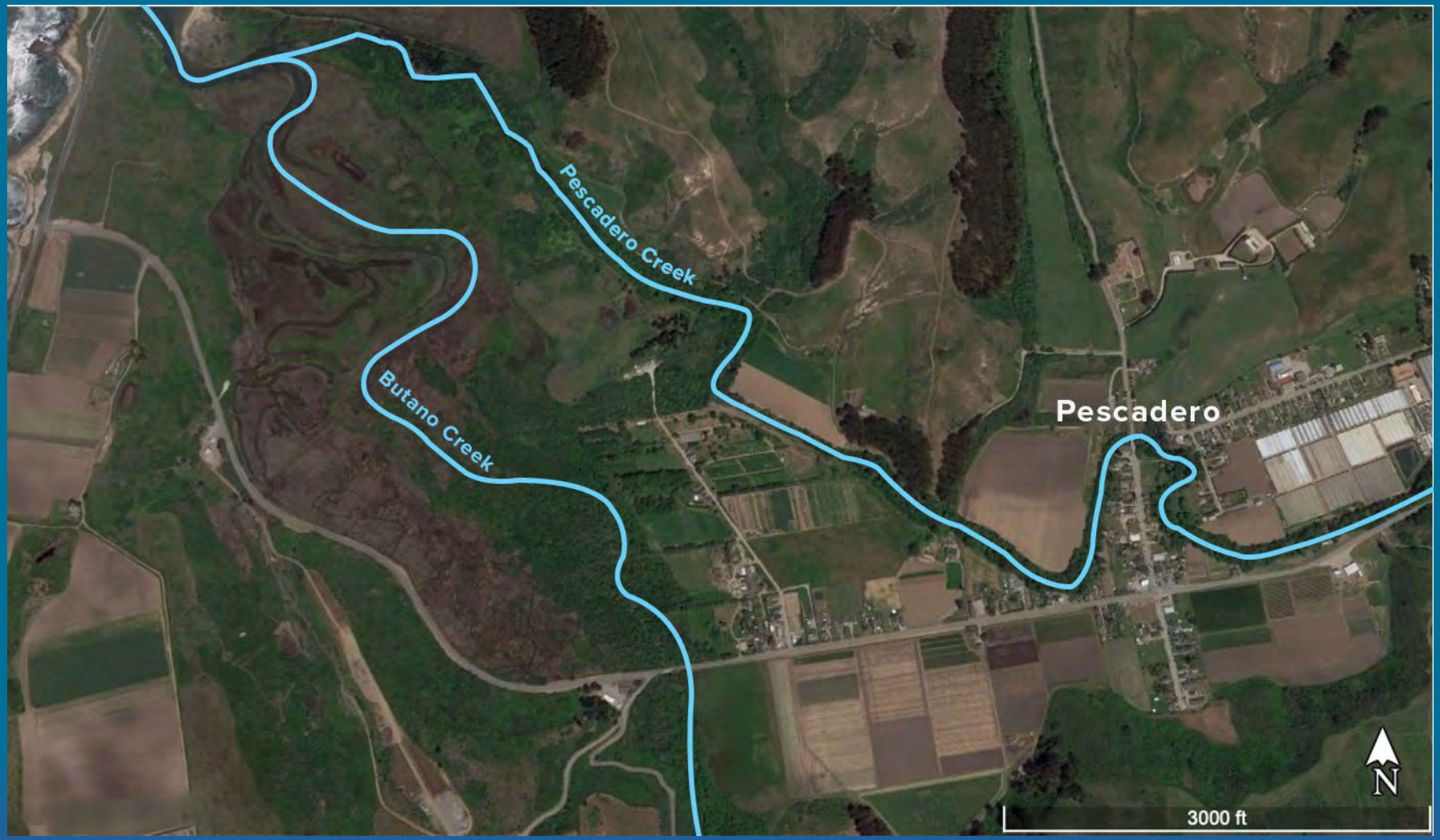
Project Location

- Butano Creek, largest tributary of Pescadero Creek
- Rural community of Pescadero in San Mateo County
- Landowners:
  - California Department of Parks and Recreation
  - Level Lea Farms
  - Peninsula Open Space Trust

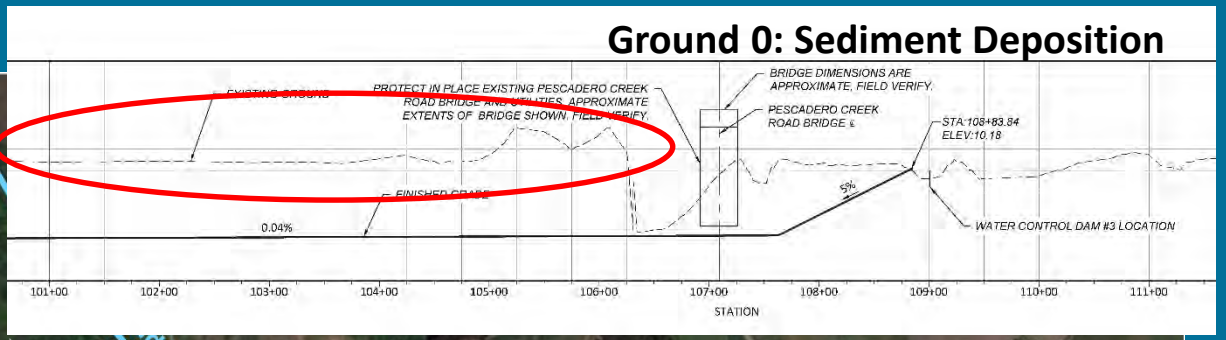
Project Context – Finite Solution Part of a Greater Effort

- History of stressors in the watershed and project area
- Butano Creek channel filled with sediment
- Numerous sensitive species
- Significant animosity among stakeholders
- Recent advances in scientific understanding of fish kills
- Opportunity to address a finite number of problems:
  1. Poor WQ and fish kills
  2. Fish passage
  3. Road flooding

Overview of Key Challenges

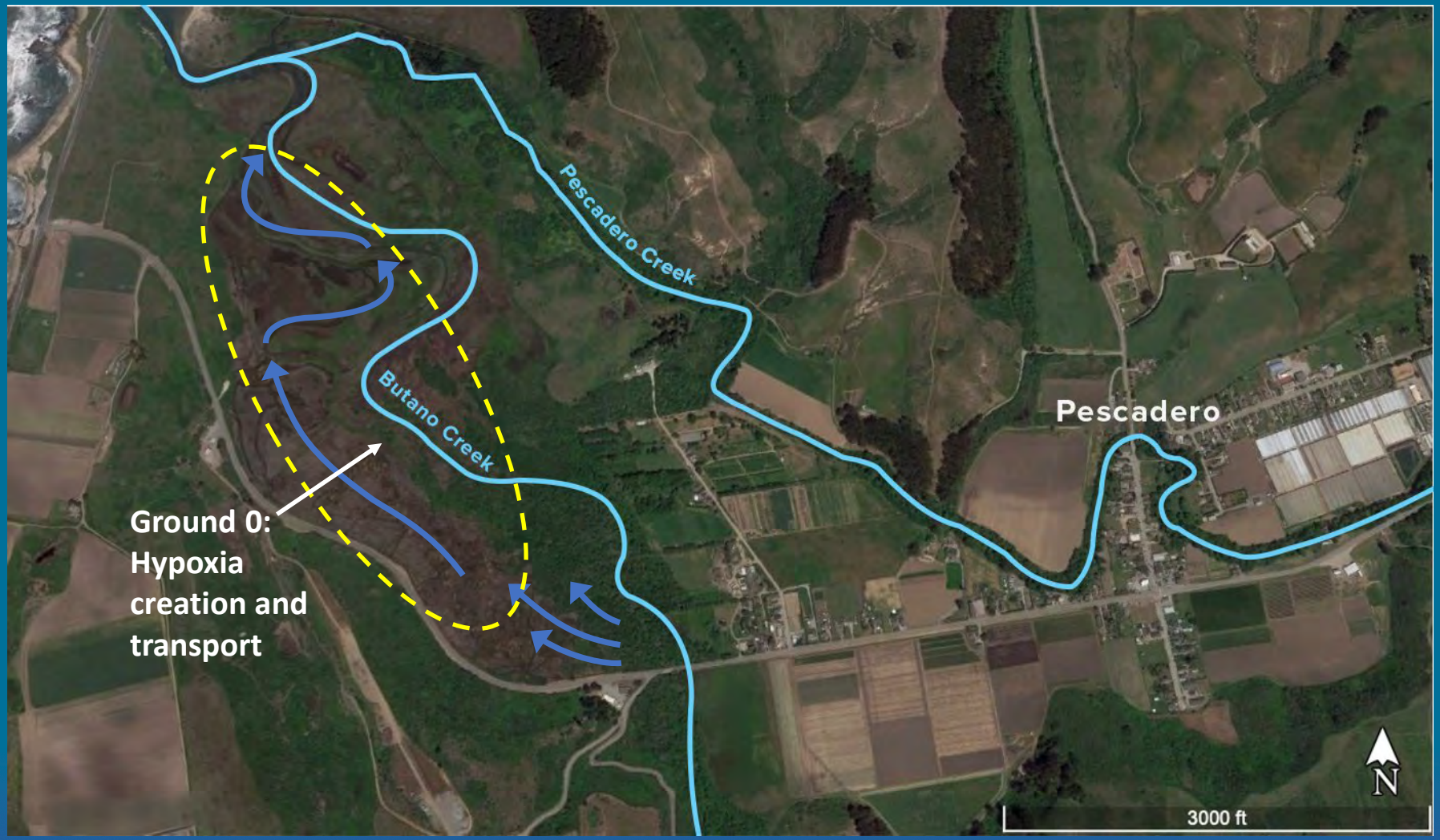


Heavy Sediment Loads Completely Filled Stream Channel

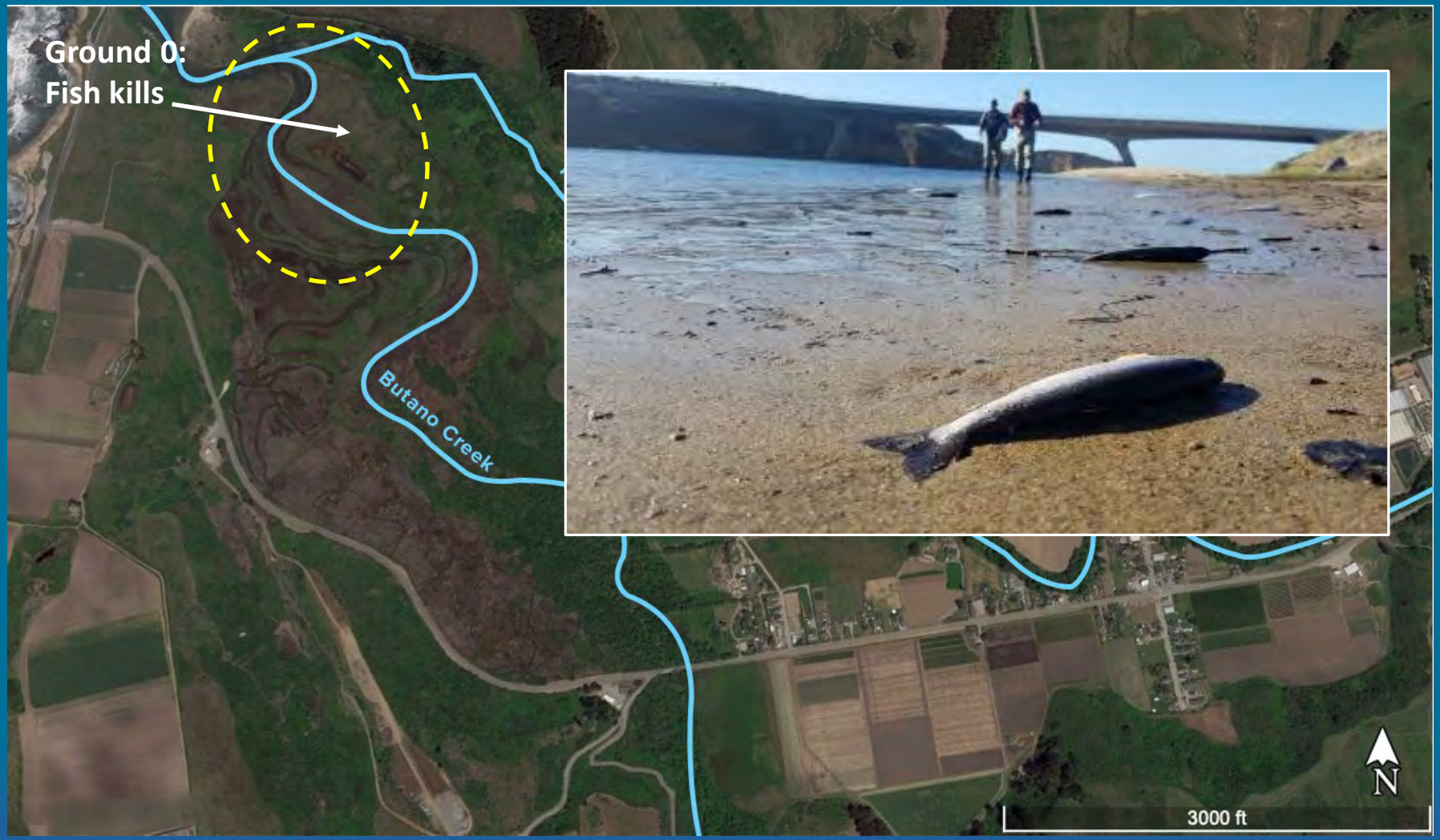


Routine Flooding of Pescadero's Primary Access Road

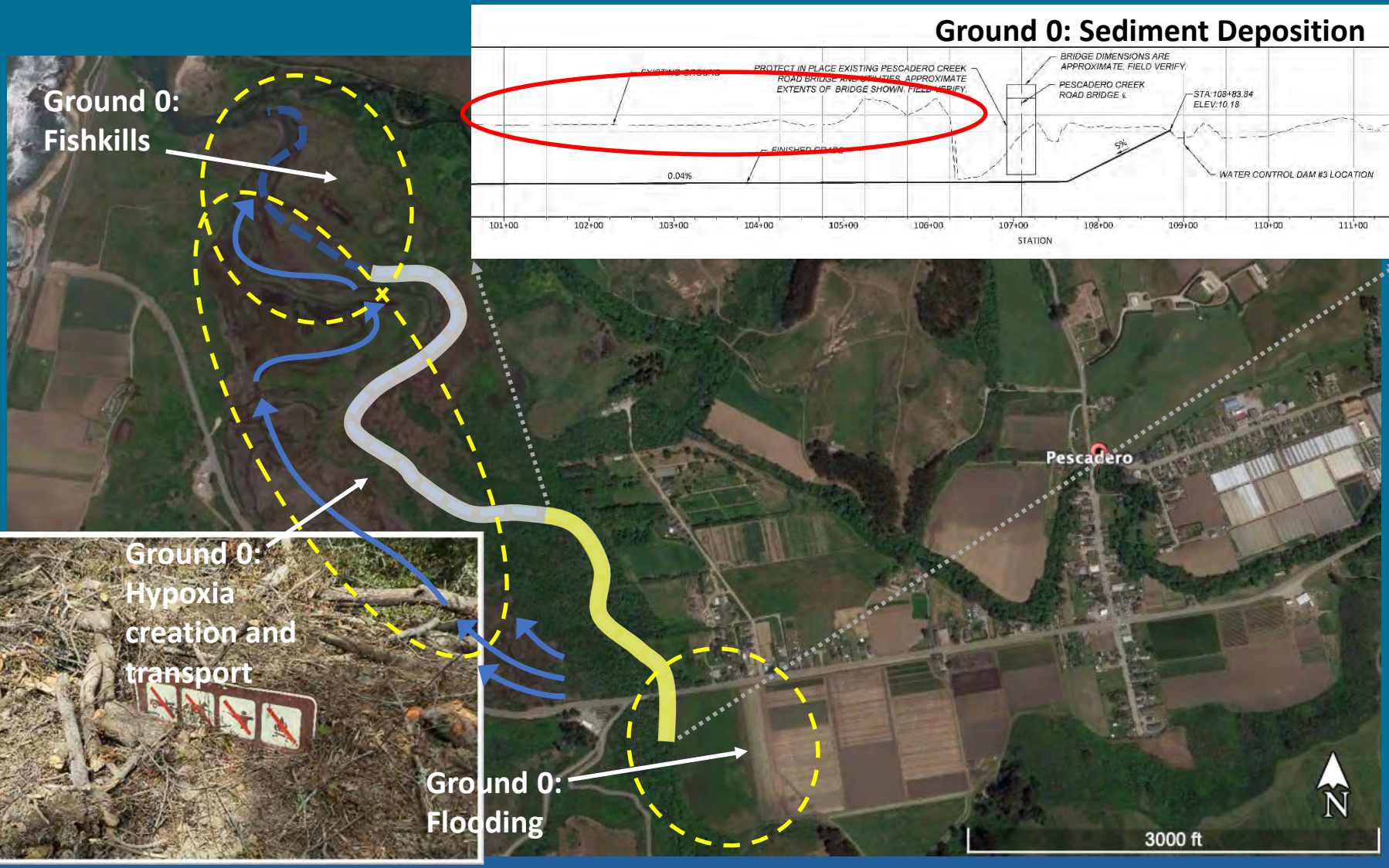
Generation of Anoxic Water Conditions in Butano Marsh



Anoxic Water Drove ~Annual Fish Kills



A Win-Win-Win Solution Might Actually Exist…



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- **Improve water quality and reduce likelihood and magnitude of fish kills**
- **Restore fish passage** to 10.1 miles of Butano Creek
- **Reduce the extent, duration and frequency of flooding** at Pescadero Creek Road.

This Project Will Not:

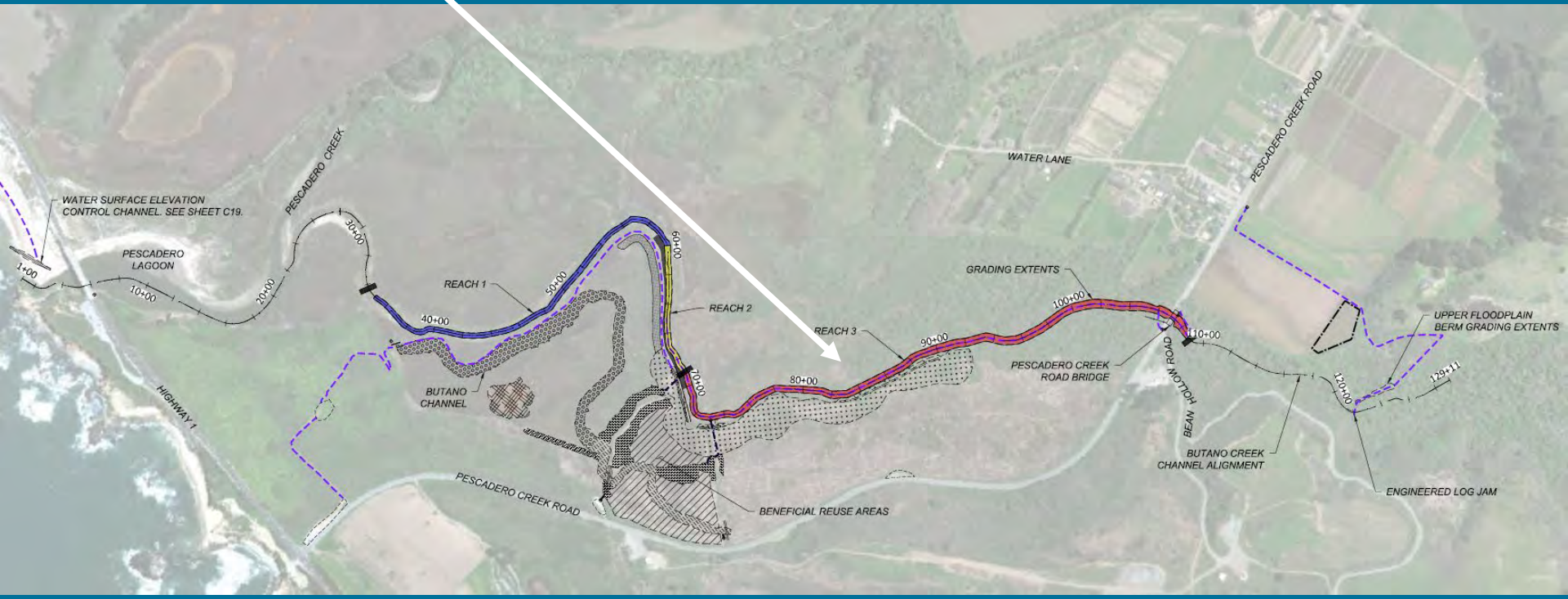
- Restore habitat for all species.
- Provide comprehensive ecosystem restoration.
- Remove the community from the floodplain or eliminate all flooding.

Key Components of Design Process

1. Build upon extensive research and monitoring efforts
2. Highly interdisciplinary approach
3. Leverage field sampling, numerical modeling and laboratory analysis
4. Bar-built estuary and considerations of mouth condition and lagoon level
5. **Beneficial sediment reuse**
6. **Emphasis on constructability**
7. Proactive permitting approach
   - Permits obtained in less than 5 months of 65% design completion

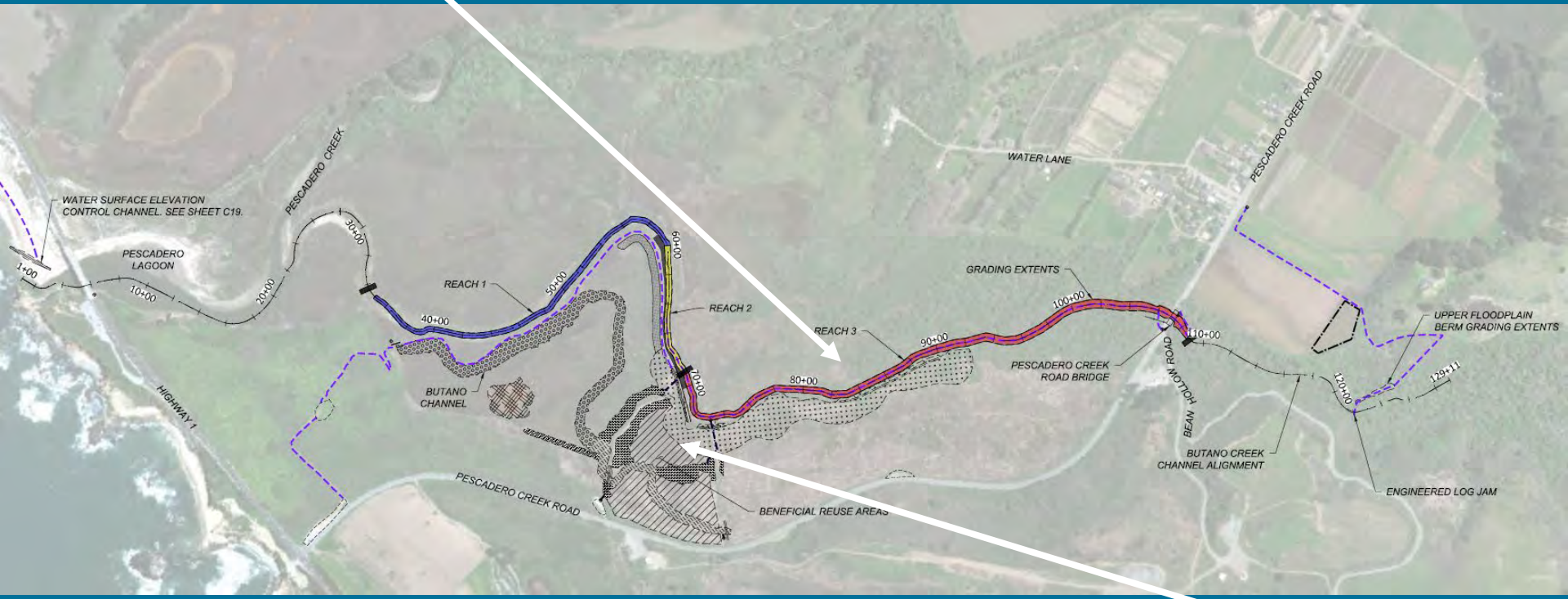
Key Project Elements

Butano Creek Channel Excavation



Key Project Elements

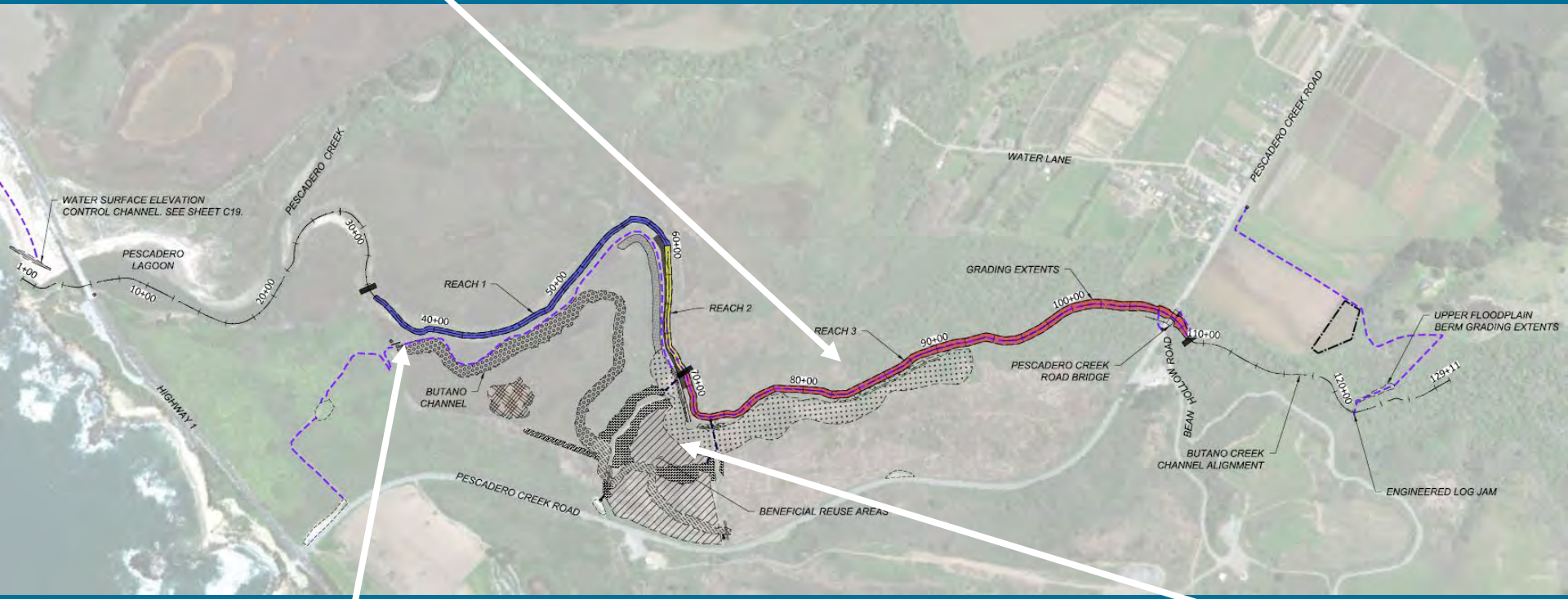
Butano Creek Channel Excavation



Beneficial Reuse of Sediment in Marsh

Key Project Elements

Butano Creek Channel Excavation



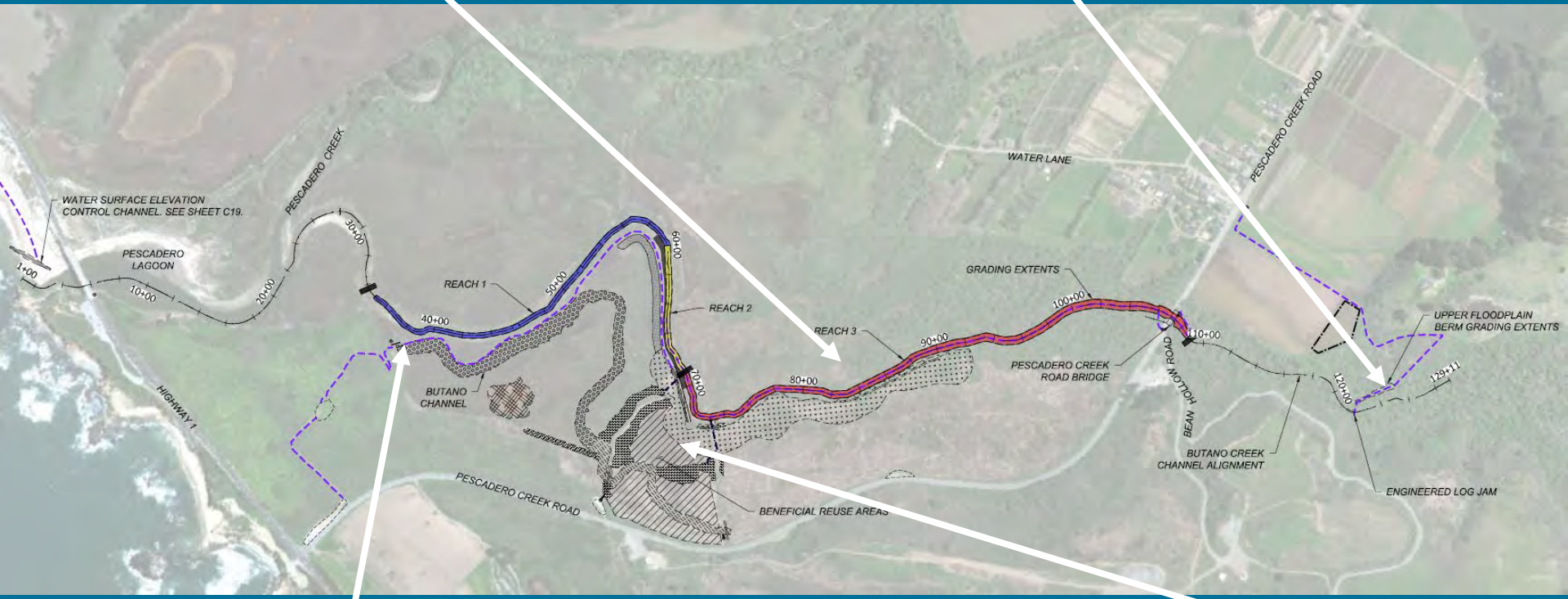
Marsh Control Structure

Beneficial Reuse of Sediment in Marsh

Key Project Elements

Butano Creek Channel Excavation

Upper Floodplain Berm & Engineered Log Jam



Marsh Control Structure

Beneficial Reuse of Sediment in Marsh

Constructability Considerations

- Quality of sediment for beneficial reuse
- Earthwork limited to one construction season
- Presence of sensitive species
- Mouth condition and water level control

Phase I – Vegetation Clearing along Reach 3 – Fall 2018

Phase I – Vegetation Clearing along Reach 3 – Fall 2018

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Phase I – Vegetation Clearing along Reach 3 – Fall 2018

Phase I – Vegetation Clearing along Reach 3 – Fall 2018

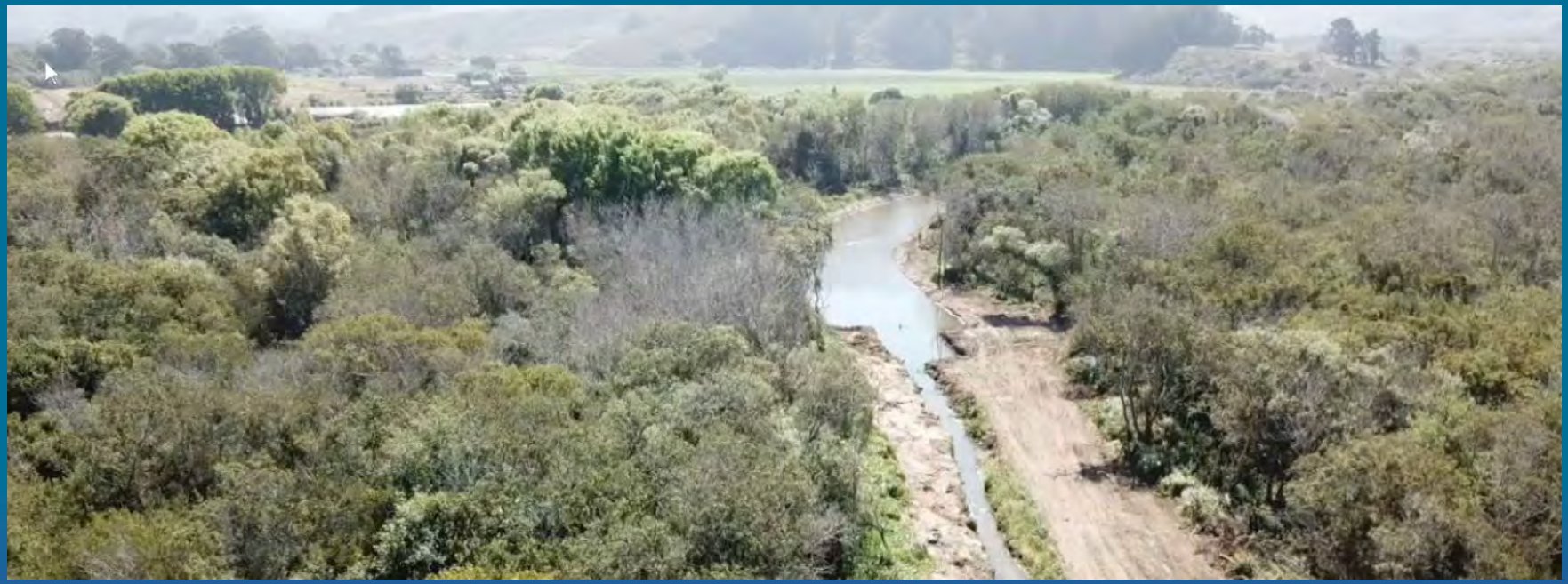
Phase I – Vegetation Clearing along Reach 3 – Feb 2019

Phase I – Vegetation Clearing along Reach 3 – April 2019

Phase II – Vegetation Flattening along Reach 2 – Feb 2019

Phase III – Earthwork and Construction Activities - 2019

1. Butano Creek channel excavation
2. Butano Marsh beneficial sediment reuse
3. Marsh Control Structure construction
4. Upper floodplain berm and ELJ construction
5. Revegetation efforts



Downstream Water Control

Downstream Water Control

Dredging Butano Creek Reach 1

Dredging Butano Creek Reach 1

Filling Butano Channel with Dredge Slurry

Filling Butano Channel with Dredge Slurry

Excavating Butano Creek Reach 3

Excavating Butano Creek Reach 3

Excavating Butano Creek Reach 3

Excavating Butano Creek Reach 3

Excavating Butano Creek Reach 3

Beneficially Reusing Sediment to Fill Butano Channel

Beneficially Reusing Sediment to Fill Butano Channel

Beneficially Reusing Sediment to Fill Butano Channel

Installing Marsh Control Structure to Maintain Grade

Installing Marsh Control Structure to Maintain Grade

Installing Marsh Control Structure to Maintain Grade

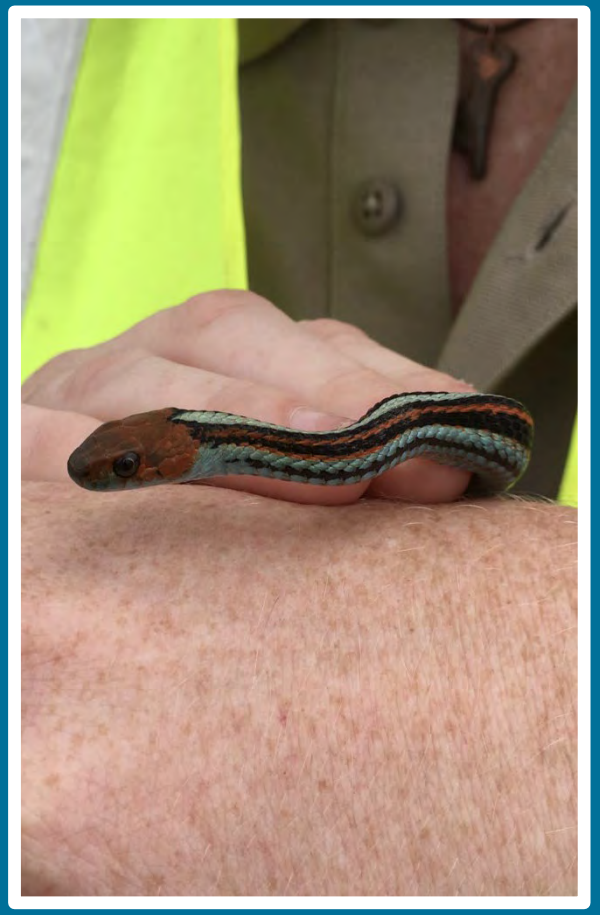
Installing Marsh Control Structure to Maintain Grade

Installing Marsh Control Structure to Maintain Grade

Installing Marsh Control Structure to Maintain Grade

Installing Marsh Control Structure to Maintain Grade

All while watching out for these critters…



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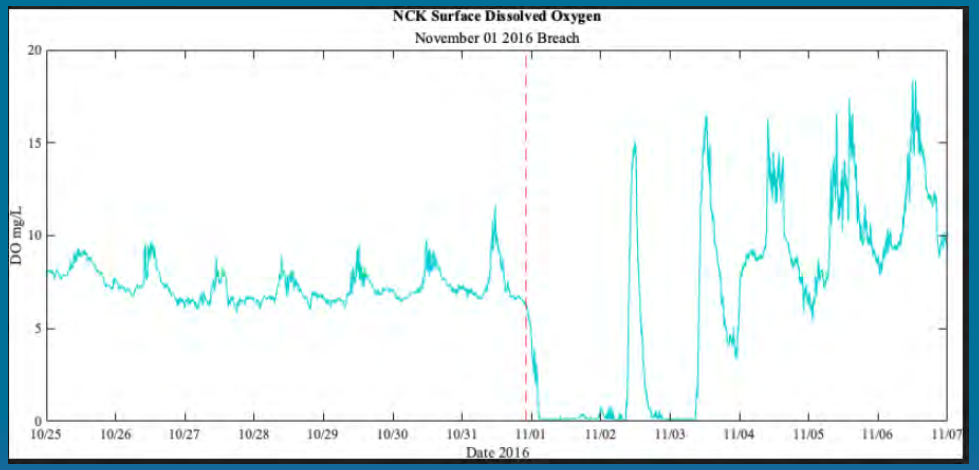
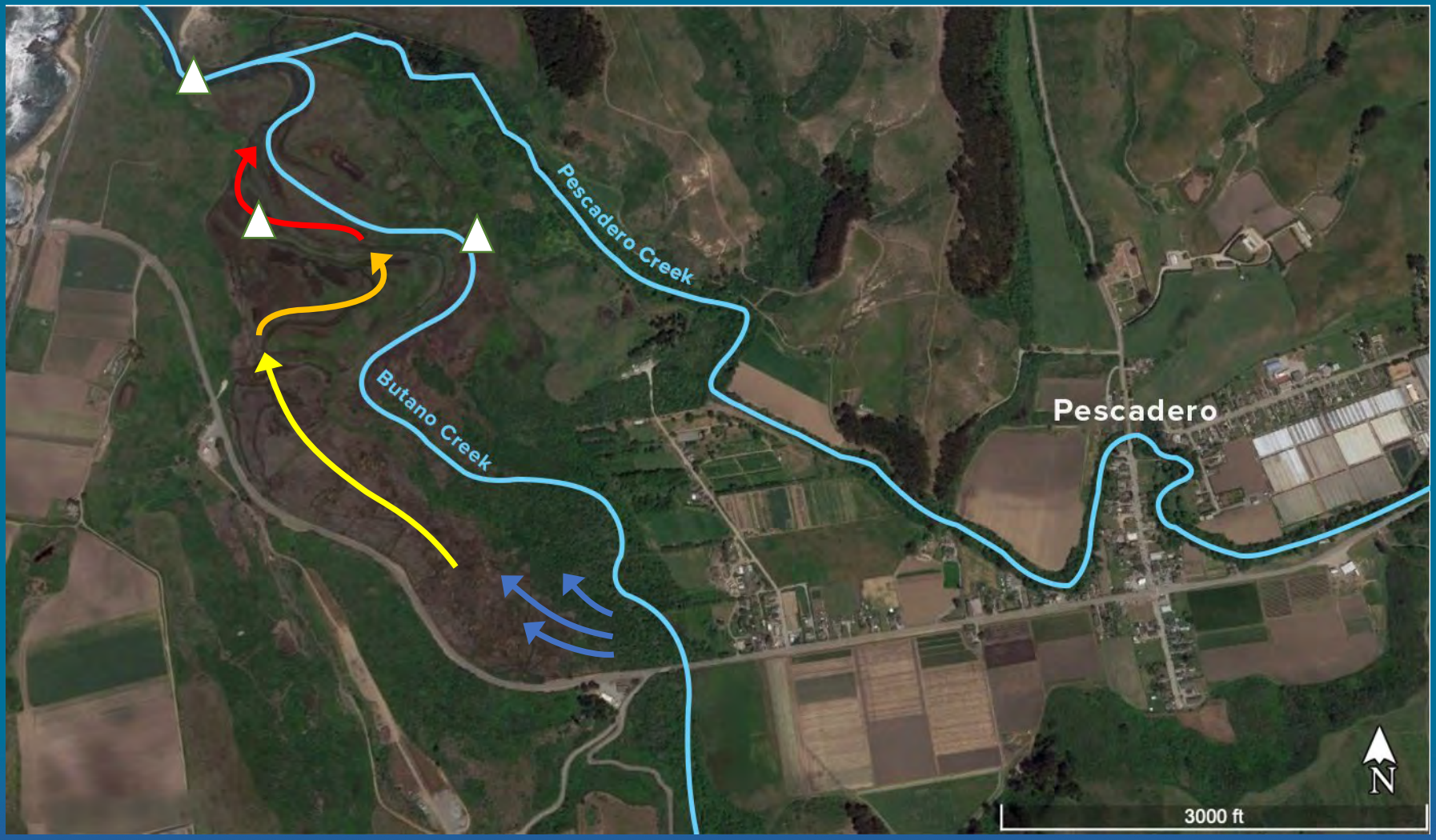


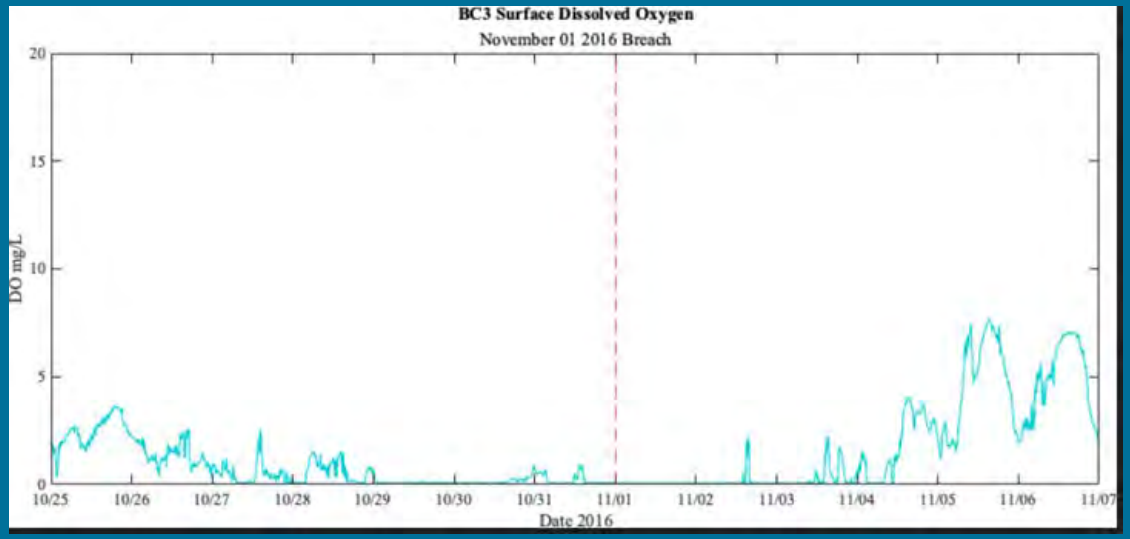
Generation of Anoxic Water Conditions in Butano Marsh



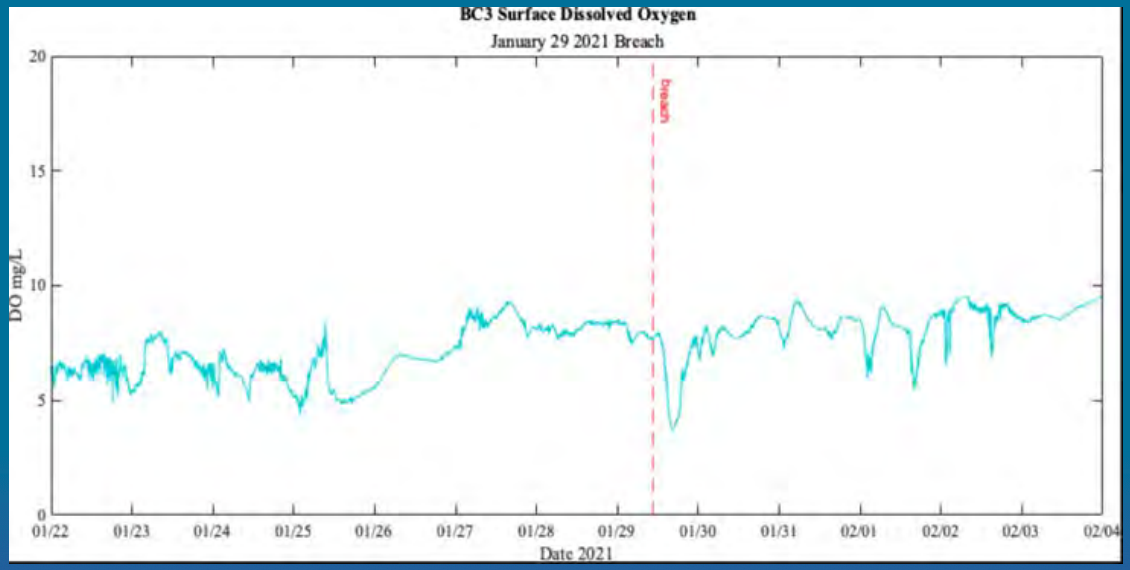
Results: Water Quality

Butano Creek

Before



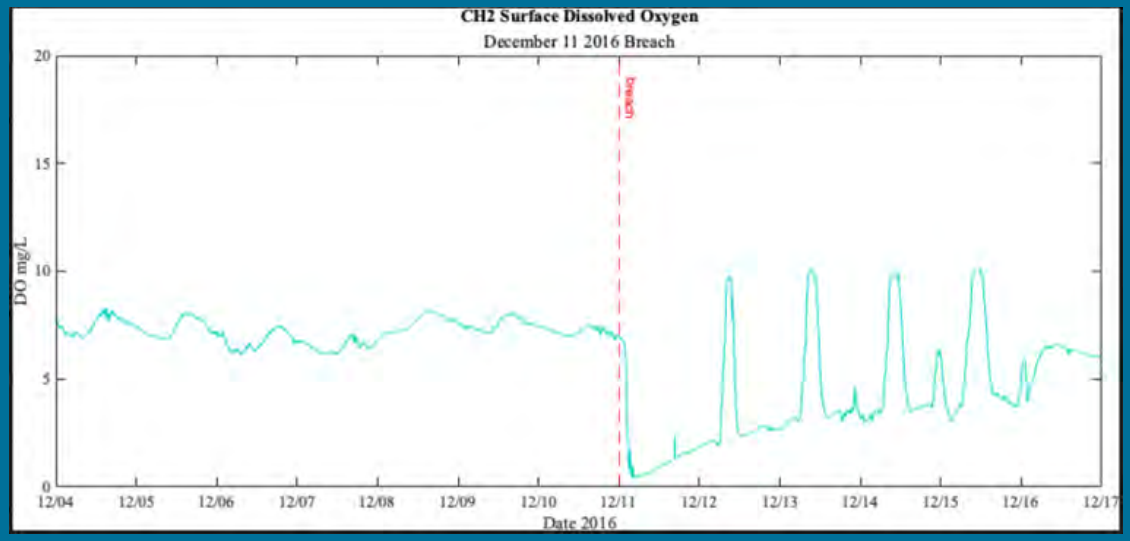
After



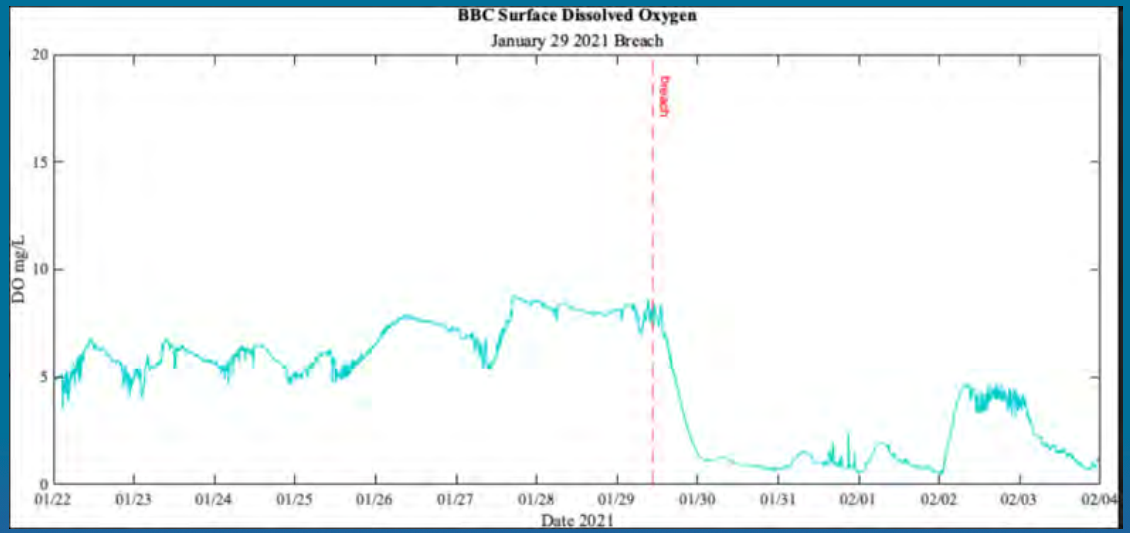
Results: Water Quality

Butano Channel

Before



After

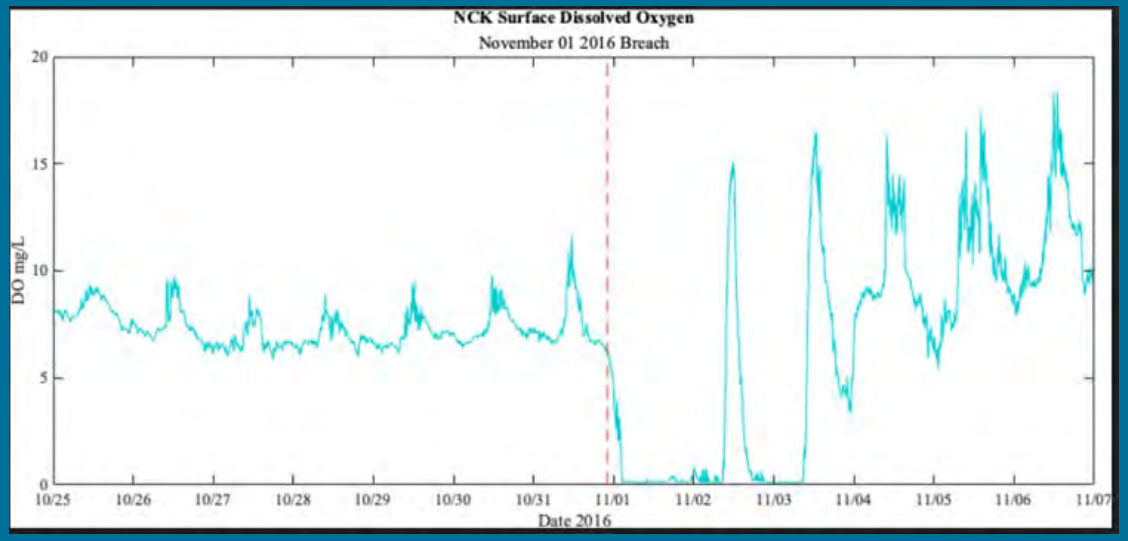


Results: Water Quality

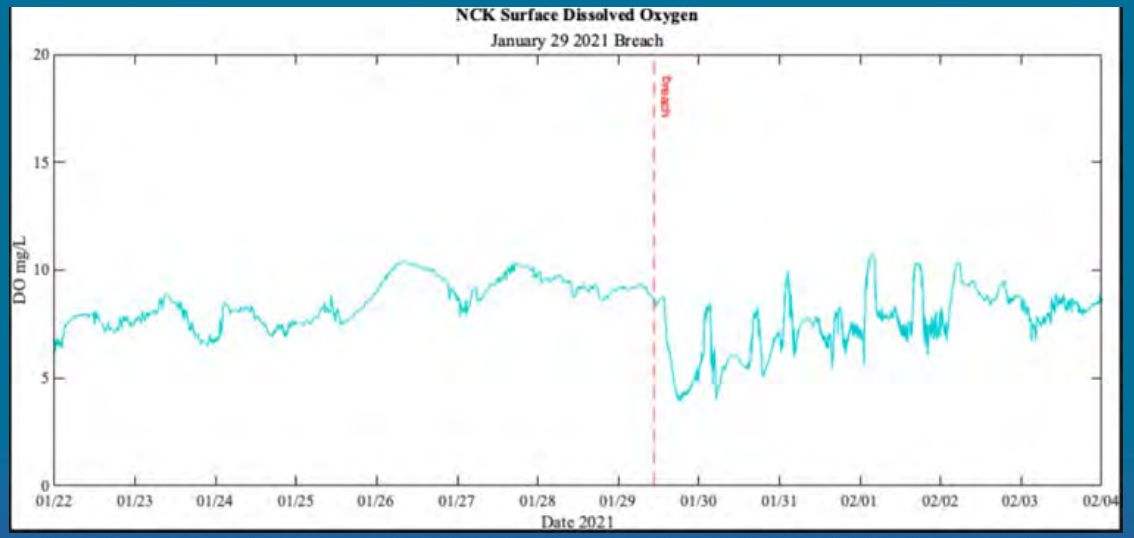
Results: Water Quality

Main Embayment

Before



After



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- **Restore fish passage to 10.1 miles of Butano Creek**
- Reduce the extent, duration and frequency of flooding at Pescadero Creek Road.

Results: Fish Passage

Results: Fish Passage

Project Goals

This Project Will:

- Improve water quality and reduce likelihood and magnitude of fish kills
- **Restore fish passage to 10.1 miles of Butano Creek**
- **Reduce the extent, duration and frequency of flooding at Pescadero Creek Road.**

Results: Flooding

Results: Flooding

Results: Flooding

Results: Flooding

Results Summary

Since construction in 2018-2019, what have we learned?

1. WQ has improved and fish kills have not occurred
2. Anadromous salmonids have been observed in Butano Creek within and upstream of the project area
3. Frequency and duration of Pescadero Creek Road flooding has been reduced, but does still flood for brief periods during larger events
4. Channel has not filled in, but deposition has occurred in areas where it was expected
5. Impacts of the CZU fire in 2000 are still being evaluated and will be covered in a future presentation!

Thank You!


Questions?
c.hammersmark@cbecoeng.com
ryan.diller@parks.ca.gov

Pescadero Marsh: A Bar Built Estuary's Importance to Steelhead

Sean Cochran, District Fisheries Biologist, CDFW

Patrick Samuel, Bay Area Regional Director, California Trout

CALIFORNIA TROUT

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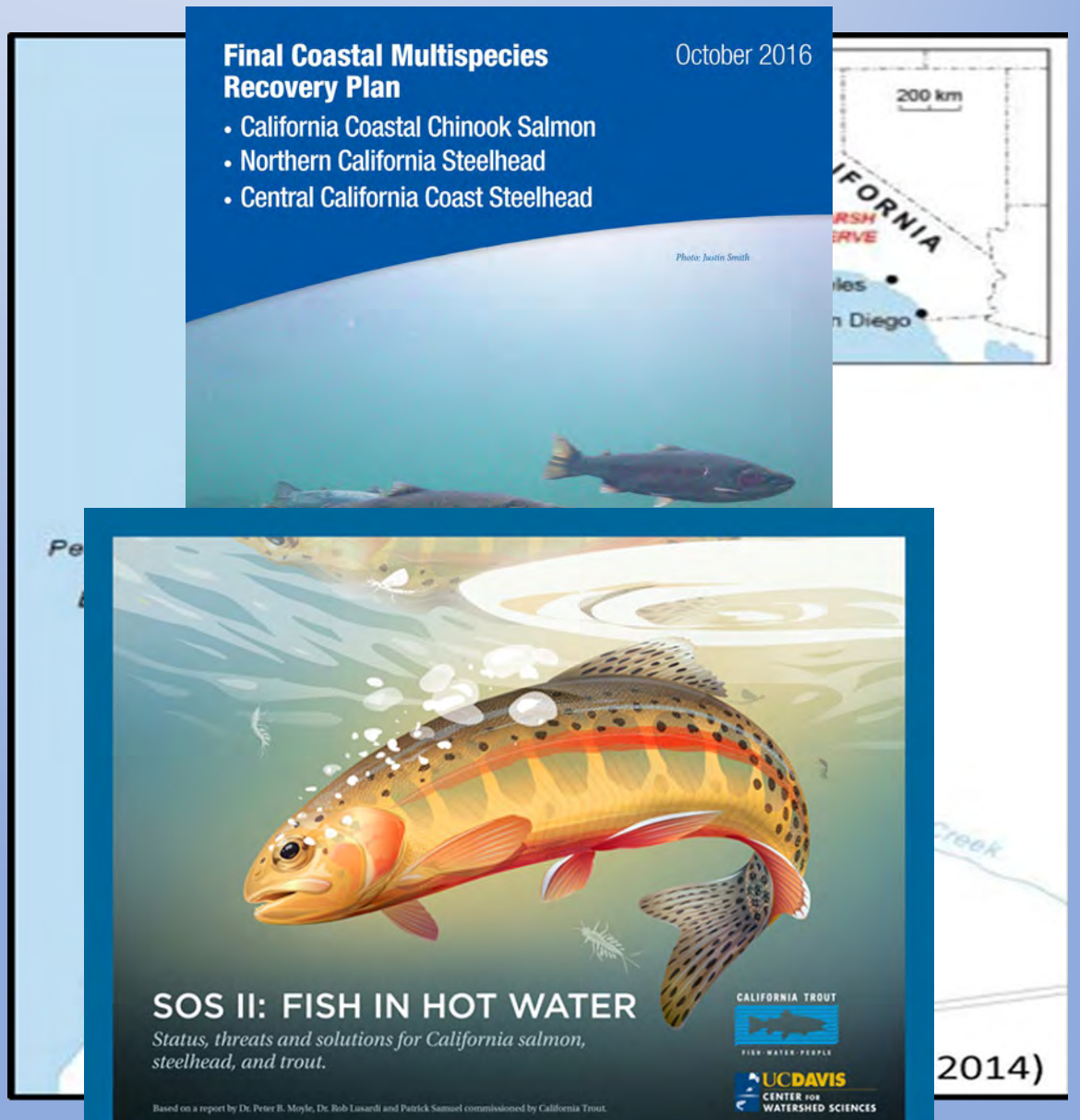
CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

Investing In Productive Habitats

- Watershed 81 square miles
- Largest estuary between Golden Gate and Elkhorn Slough
- Critical habitat for sensitive species: including **Central California Coast Steelhead Trout**; Central California Coast Coho Salmon; Tidewater Goby and California red-legged frog

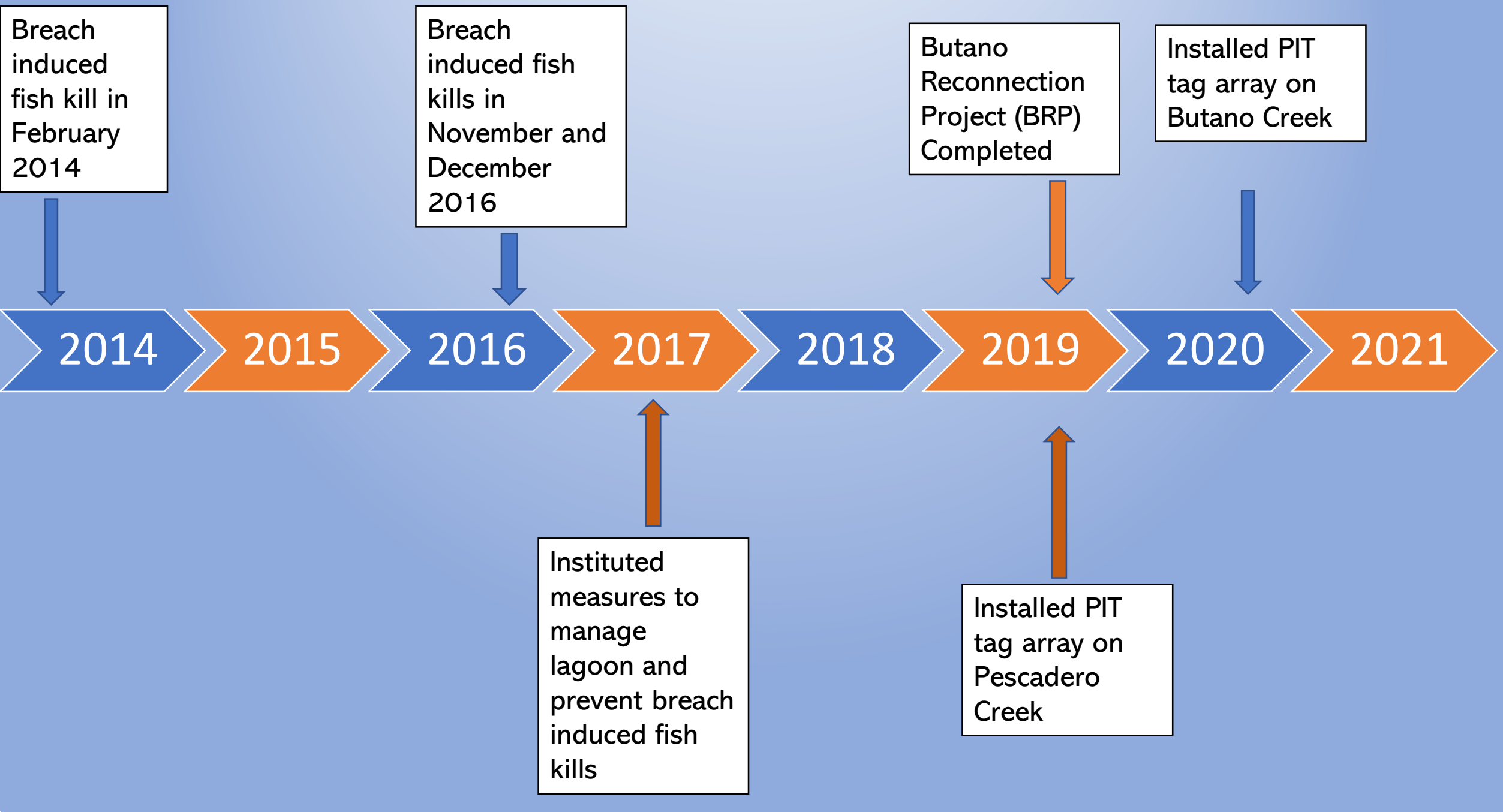


Monitoring Program

2014 to Present

- Water Quality (temperature, dissolved oxygen and salinity) monitored @ 10 stations using network of fixed sondes and periodic spot check profiles
- Juvenile steelhead trout Population Surveys
  - Sampling with 100' beach seine
  - Lagoon sampled twice monthly July - October
  - Switched to PIT tagging steelhead for mark-recapture in 2017
  - 2019 began operating first of two current PIT tag arrays

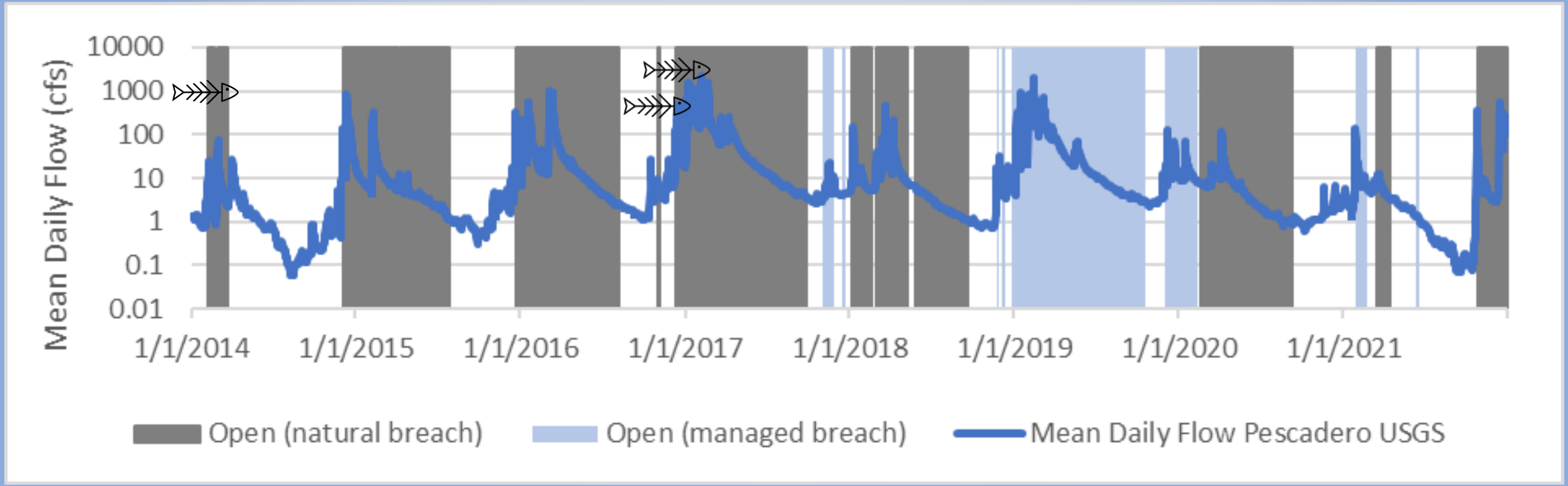
Monitoring Partners: CDFW, Caltrout, California Department of Parks and Recreation, UC Davis Bodega Marine Lab, San Mateo Resource Conservation District, Trout Unlimited, and NOAA Fisheries


Breach induced fish kill in February 2014
Breach induced fish kills in November and December 2016
Butano Reconnection Project (BRP) Completed
Installed PIT tag array on Butano Creek
2014
2015
2016
2017
2018
2019
2020
2021
Instituted measures to manage lagoon and prevent breach induced fish kills
Installed PIT tag array on Pescadero Creek

2017-2019 Efforts to Manage Lagoon Water Quality

Table 1. *Managed lagoon breaching criteria*

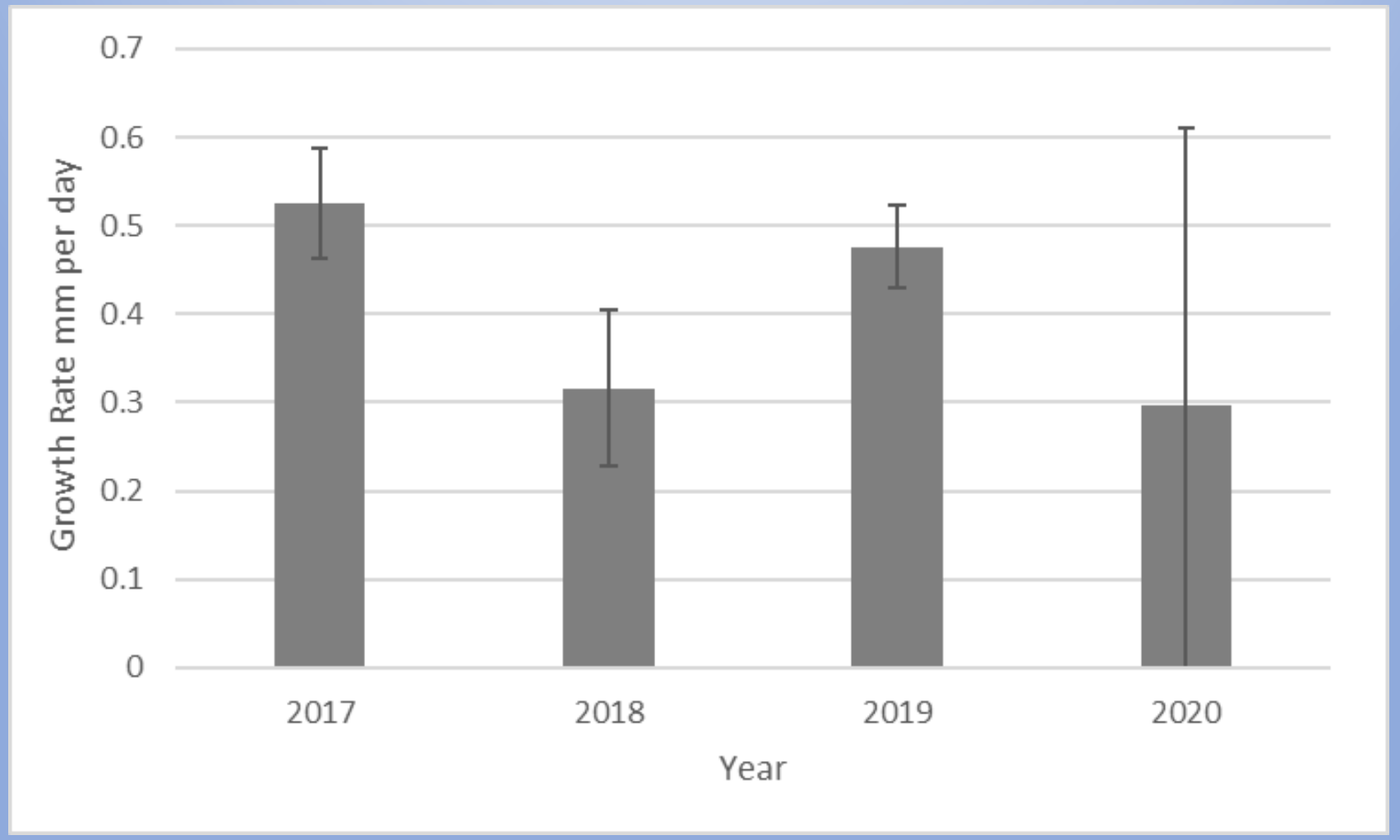
Managed Breach Triggers	States	Level
Inundation Level Conditions	Before full marshplain inundation, if feasible	6-8ft NAVD88 (Hwy 1 staff plate)
Stratification Conditions	Any monitoring site is vertically salinity stratified	When top 0.25m and bottom 0.25m are >5ppt different
Hypoxic Conditions	Any monitoring site has hypoxia midday 0.25m above bed	<1.5 mg/L
Sandbar Condition	Sandbar fully intact	Sandbar presence that eliminates tidal action or mixing
Wave Conditions	Minimal wave and swell states	
Tide Conditions	Near spring tide, if feasible	


Mean Daily Flow (cfs)
10000
1000
100
10
1
0.1
0.01
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018
1/1/2019
1/1/2020
1/1/2021
Open (natural breach)
Open (managed breach)
Mean Daily Flow Pescadero USGS

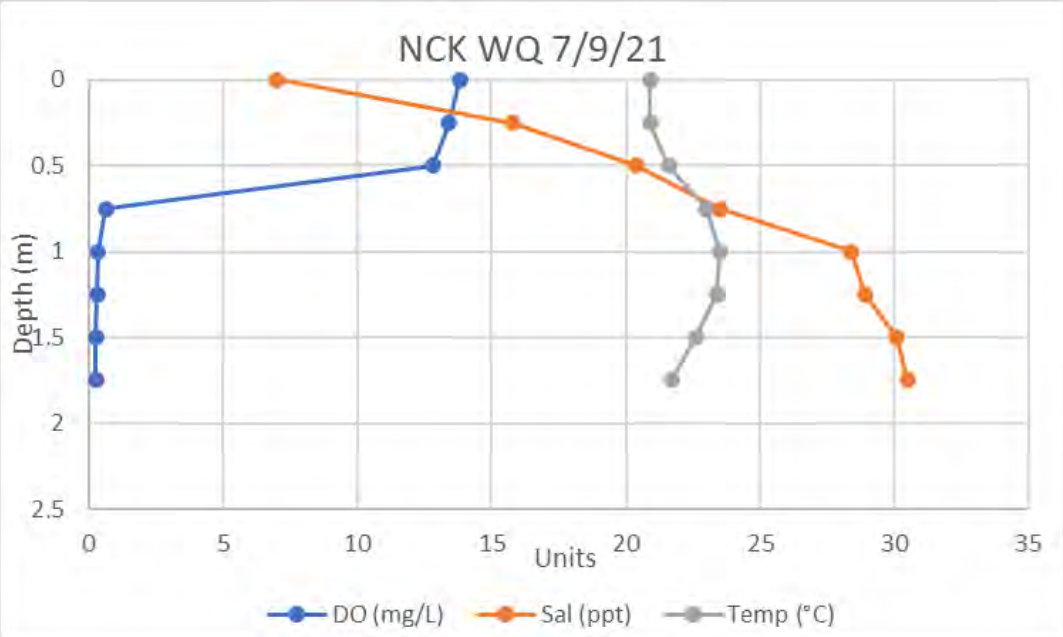
Mark-Recapture Steelhead Population Estimates

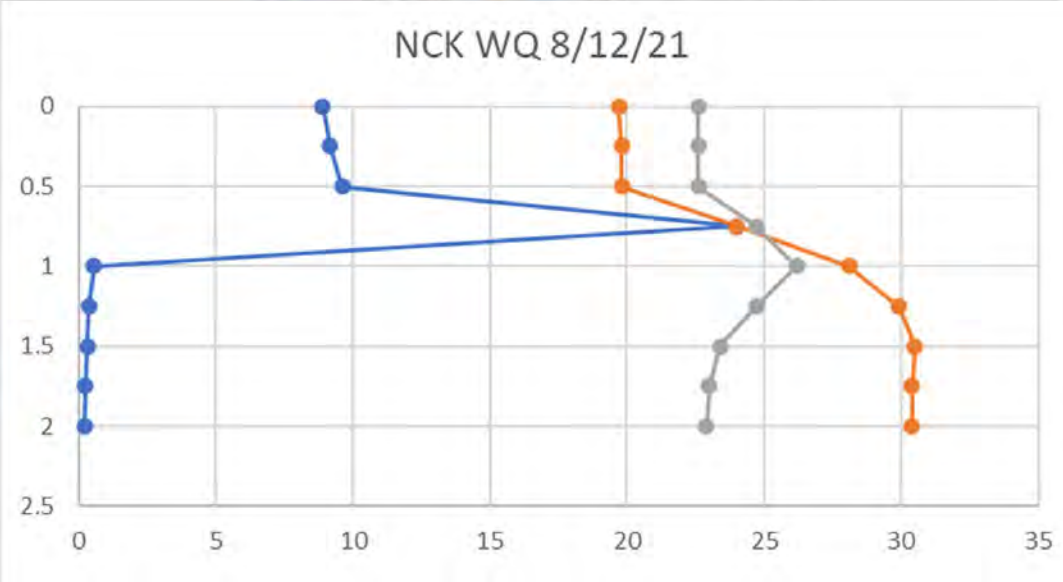
	July	August	September	October	November
2015	2345/-			0/-	
2016	4064/-			1577/-	
2017	2622/2400	4483/5966	6686/2856	3474/1674	2287/-
2018	2957/3941	7300/1229	2507/1772	914/-	
2019	4886/-	8638/3333	20800/8514	9156/-	
2020	-/5183	-/4561		-/562	
2021				-/0	

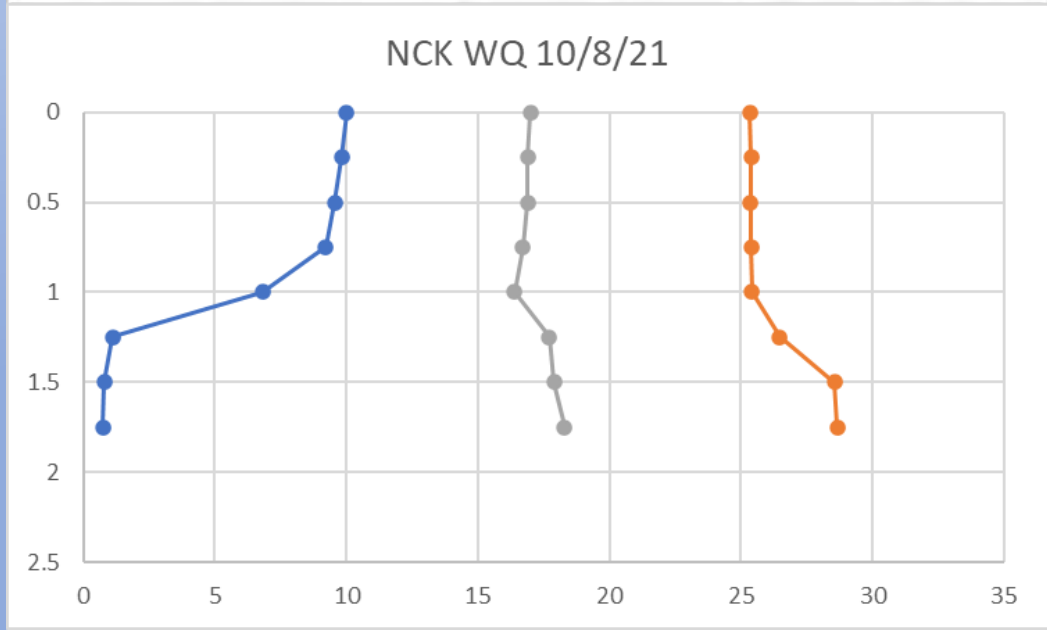
Mark-Recapture Based Growth Rates



Snapshot of 2021 Water Quality





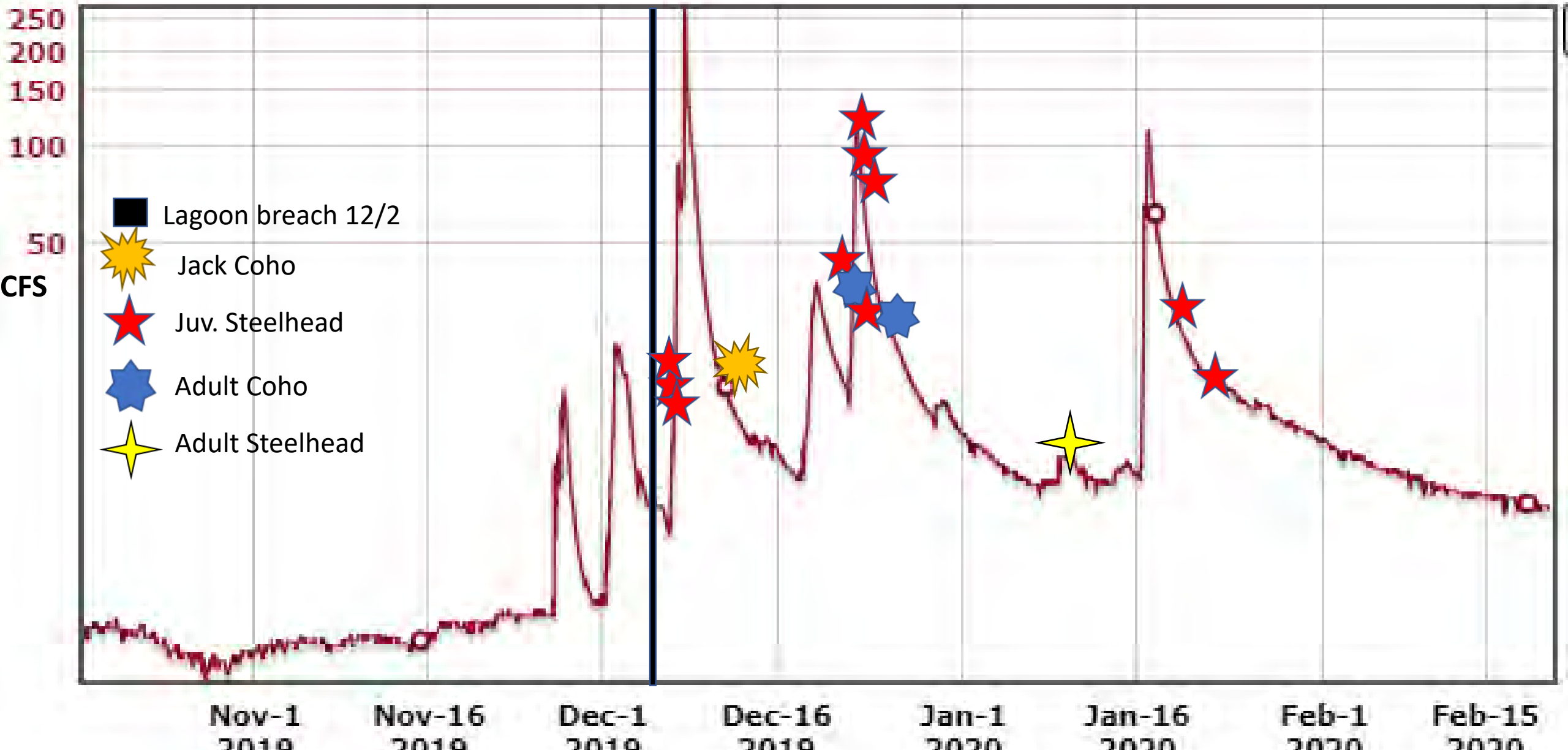


Pescadero PIT Antenna Pilot


HERTER'S


Main
Embayment
N
PITAA
Pescadero

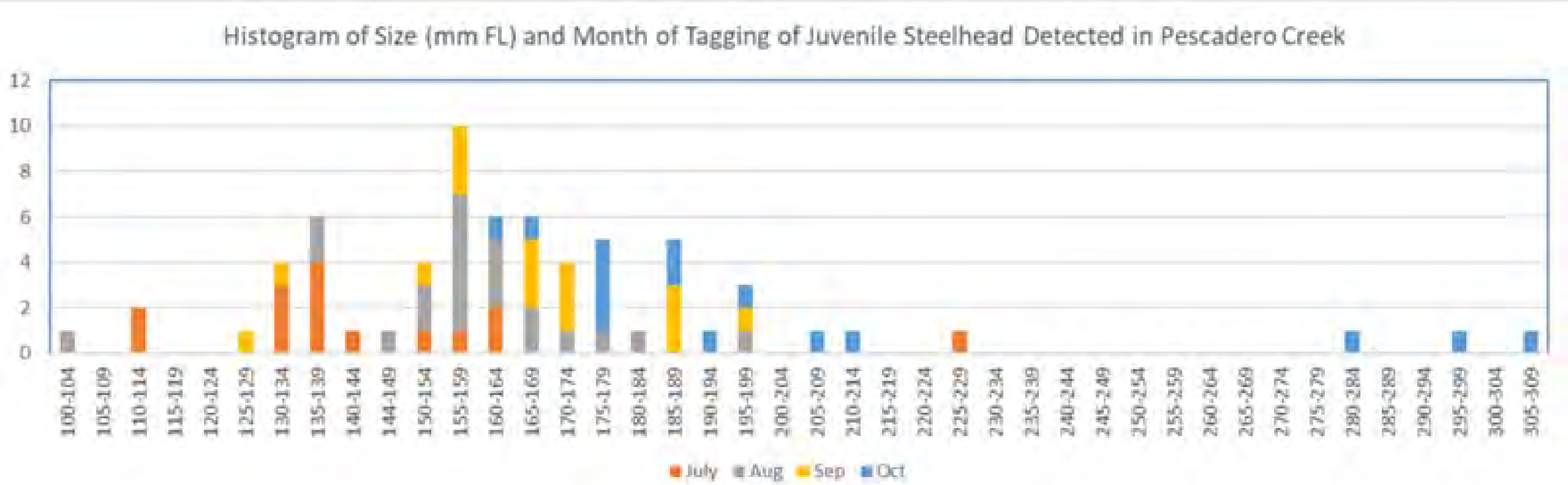
Pescadero Creek Flow and PIT Detections, October 17, 2019 – February 17, 2020



Fish Detections:
December 2, 2019 – March 28, 2020

CALIFORNIA TROUT
FISH · WATER · PEOPLE

- 73 total fish detected (63 juv. steelhead; 2 adult, 1 jack coho; 7 adult steelhead)
  ~ 50 juv. steelhead tagged last summer/fall moved upstream in March
- Expand to Butano Creek, new sites in Pescadero



Pescadero Creek: PIT Detections by Week, 2021

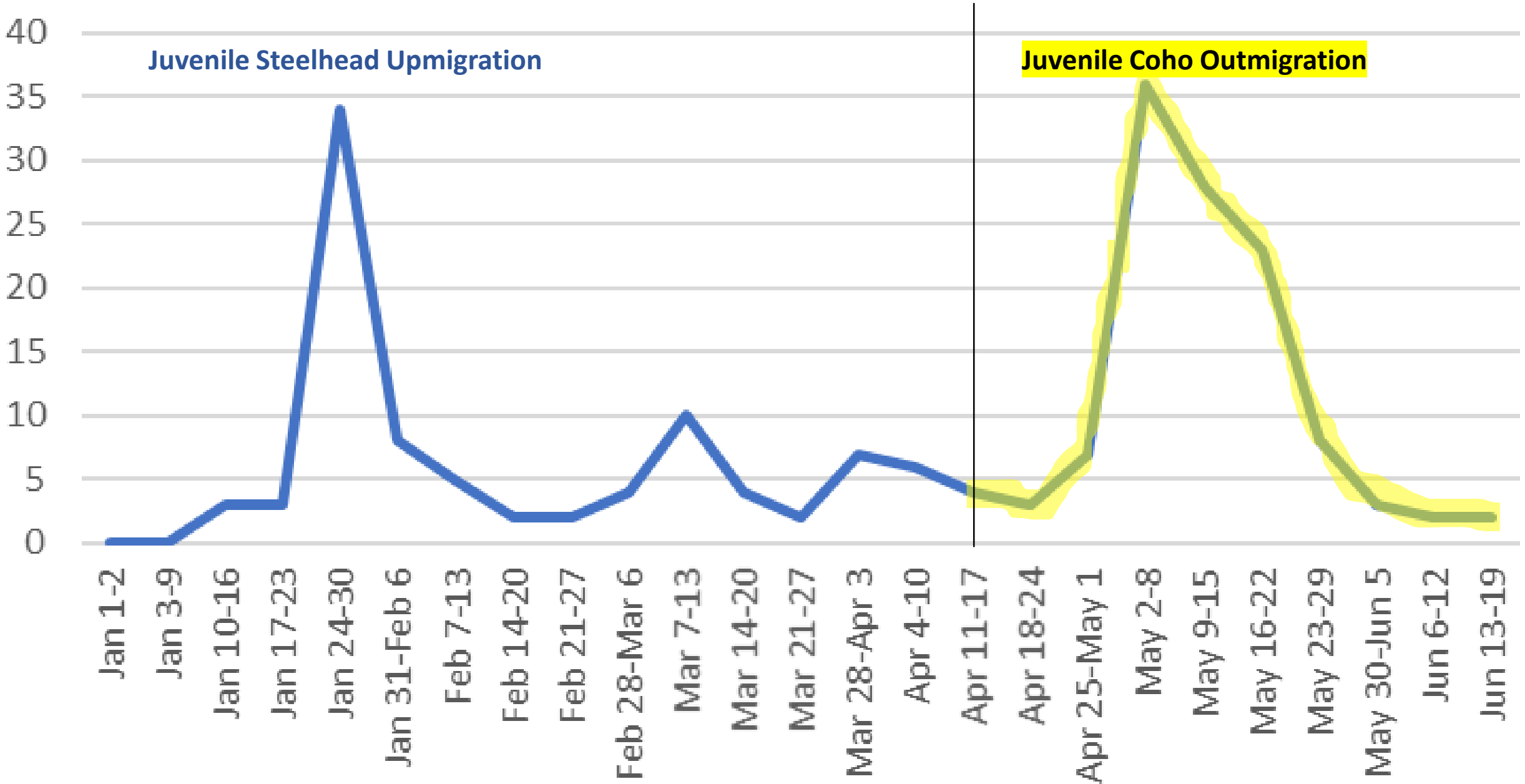


Photo credits: San Mateo RCD

Conclusions

- Pescadero lagoon presently is a high-risk vs. high-reward environment for juvenile steelhead.
- The BRP has improved water quality, reducing the quantity of anoxic water draining from Butano Marsh and providing adequate water quality refugia during breaches.
- Lagoon still functions poorly under closed conditions due to prolonged salinity stratification and inability to convert to a productive freshwater environment. **Under drought or dry water years conditions can be lethal!**

Conclusions Continued

- Findings from PIT tags and array network:

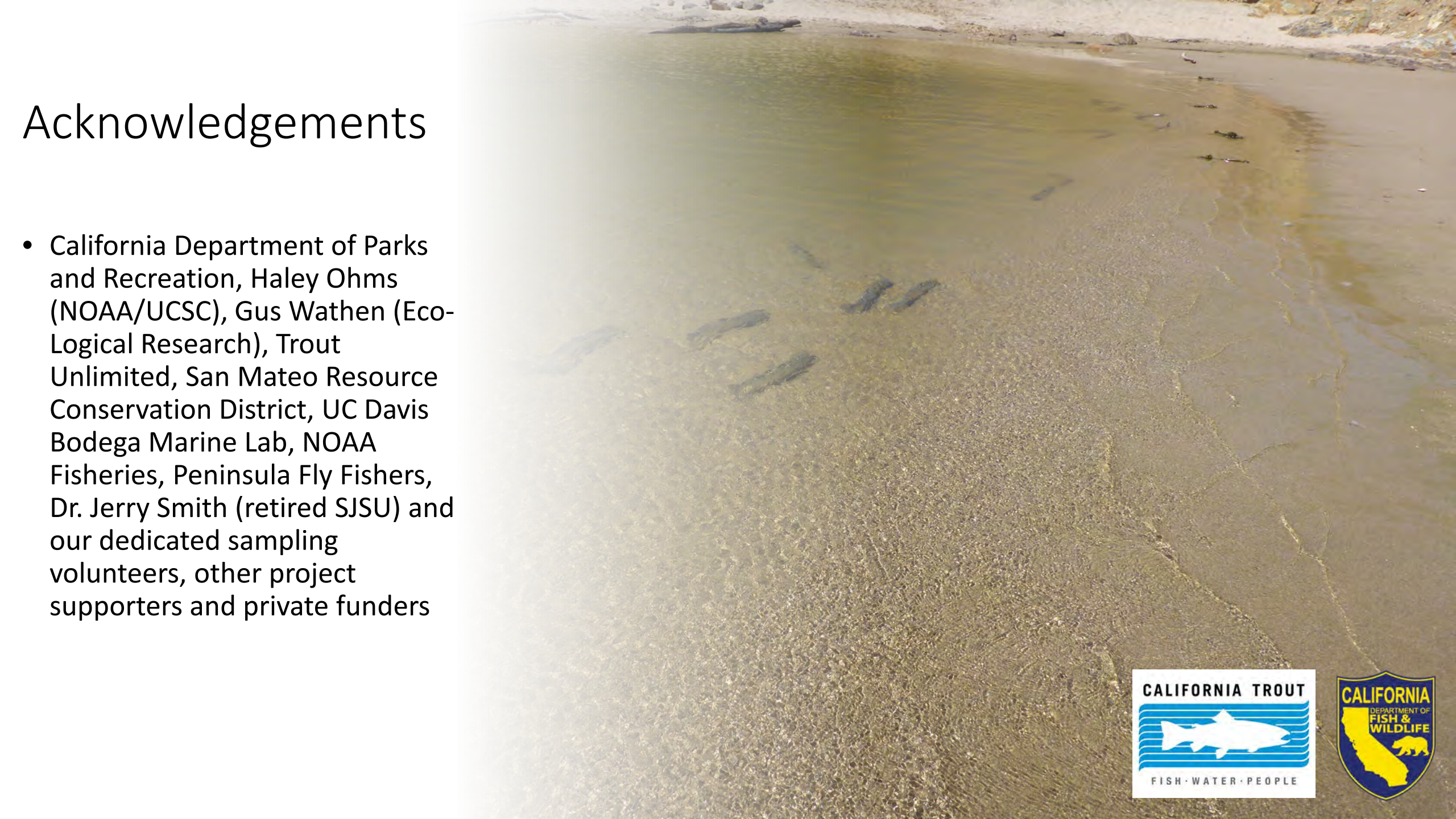
- Helped us understand how lagoon conditions influence productivity of the steelhead population in the lagoon.
- Helped shed light on life-history diversity that is present in Pescadero steelhead to cope with dynamic lagoon environment.
- Helped in decision making in managing the lagoon (artificial breaching).
- Provides an indication Coho Salmon from the King Fisher Flats Conservation Hatchery Program are straying into Pescadero relatively frequently.

Recommendations

- Intensive management of the lagoon, inclusive of artificial breaching is still necessary under current conditions.
- More restoration! Need to restore historic function and mosaic of habitats in lagoon.
- Reduce impacts of upstream water diversion on lagoon inflow.
- Continued investment in use of PIT tags and antenna arrays to understand how these fish respond to management and restoration efforts.

Acknowledgements

- California Department of Parks and Recreation, Haley Ohms (NOAA/UCSC), Gus Wathen (Eco-Logical Research), Trout Unlimited, San Mateo Resource Conservation District, UC Davis Bodega Marine Lab, NOAA Fisheries, Peninsula Fly Fishers, Dr. Jerry Smith (retired SJSU) and our dedicated sampling volunteers, other project supporters and private funders



Projecting Habitat Evolution in the Face of Sea Level Rise

A Case Study in Pescadero Marsh

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Contributors: David Revell, Sam McWilliams, Ross Clark, Kevin O' Connor, Jim Robins, and Andrew Hall

April 21, 2022

integral consulting inc.

Objectives

- Identify areas where the marsh and habitat zones will migrate with sea level rise

Constraints

- Relatively small budget and with a tight deadline for incorporation into a larger regional study

Project Goals

- Incorporate the most recent State Park water level data (to generate exceedance curves), site DEM, and provide a foundation to build on for the future

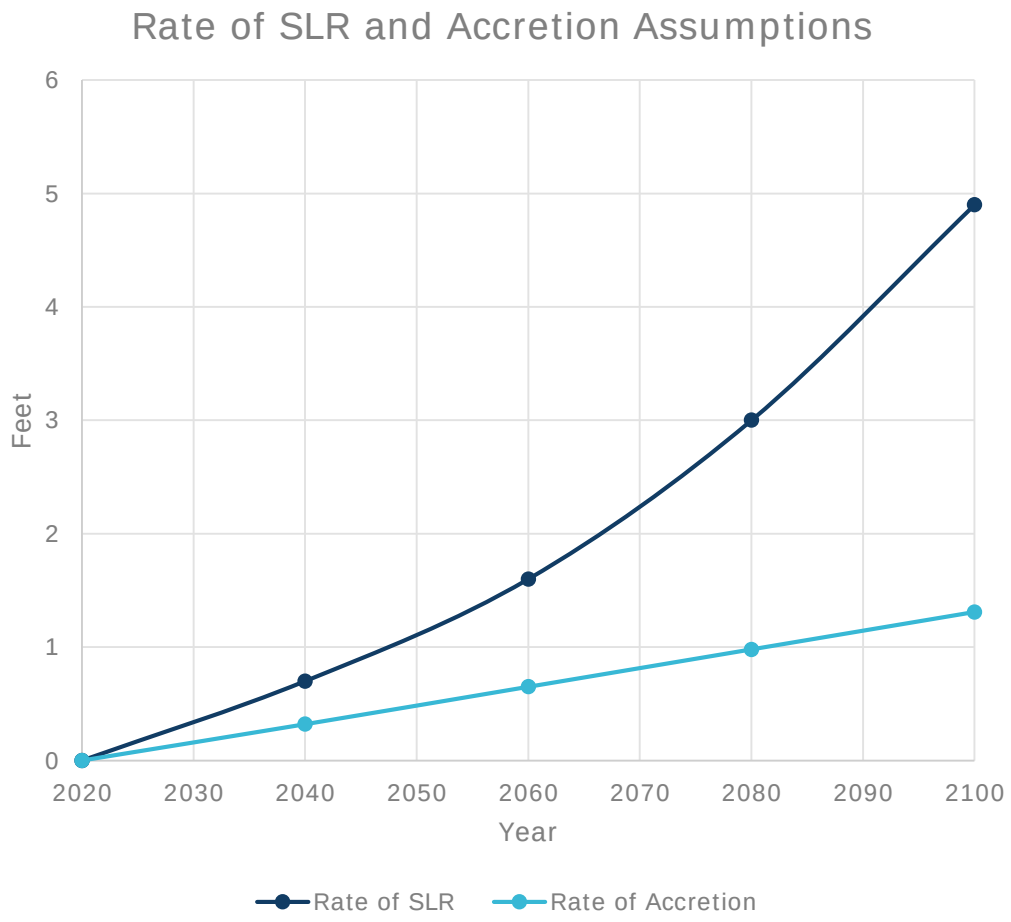
Pescadero Marsh

- Bar-built estuary system with both saltwater and freshwater marsh habitats. Mouth of the system affects the hydrology of the system and vegetative communities. Perched marsh on a high wave-energy coast.
- Subject to a range of tides when open, wave overtopping events when closed, and receives freshwater flows from Pescadero and Butano Creeks throughout the year
- The topography of the area is characterized by a relatively flat marsh plain surrounded by steep slopes

Project Goal in Integrating…

- Recently collected water levels across the marsh and lagoon: CA State Parks (2016-2017 and 2020-2021)
- Habitat mapping by CA State Parks (updated in 2018), based on field work and the National Wetlands Inventory (USFWS)
- Detailed topo/bathy DEM by by UC Davis (updated post-Butano restoration in 2020), 1m resolution
- Water level duration habitat assemblage relationships by the Central Coast Wetlands Group
- Regional SM South Coast study SLR horizons

Regional Sea Level Rise Assumptions



Year	SLR (ft.)	Accretion Elevation Gain (ft.)	Dif. SLR – Acc. (ft.)
2020	0	0	0
2040	0.8	0.3	0.5
2060	1.6	0.7	0.9
2080	3	1.0	2.0
2100	4.9	1.3	3.6

Based on the OPC 2018 publication, rates are in the 1-in-20 chance (5%) probability range.

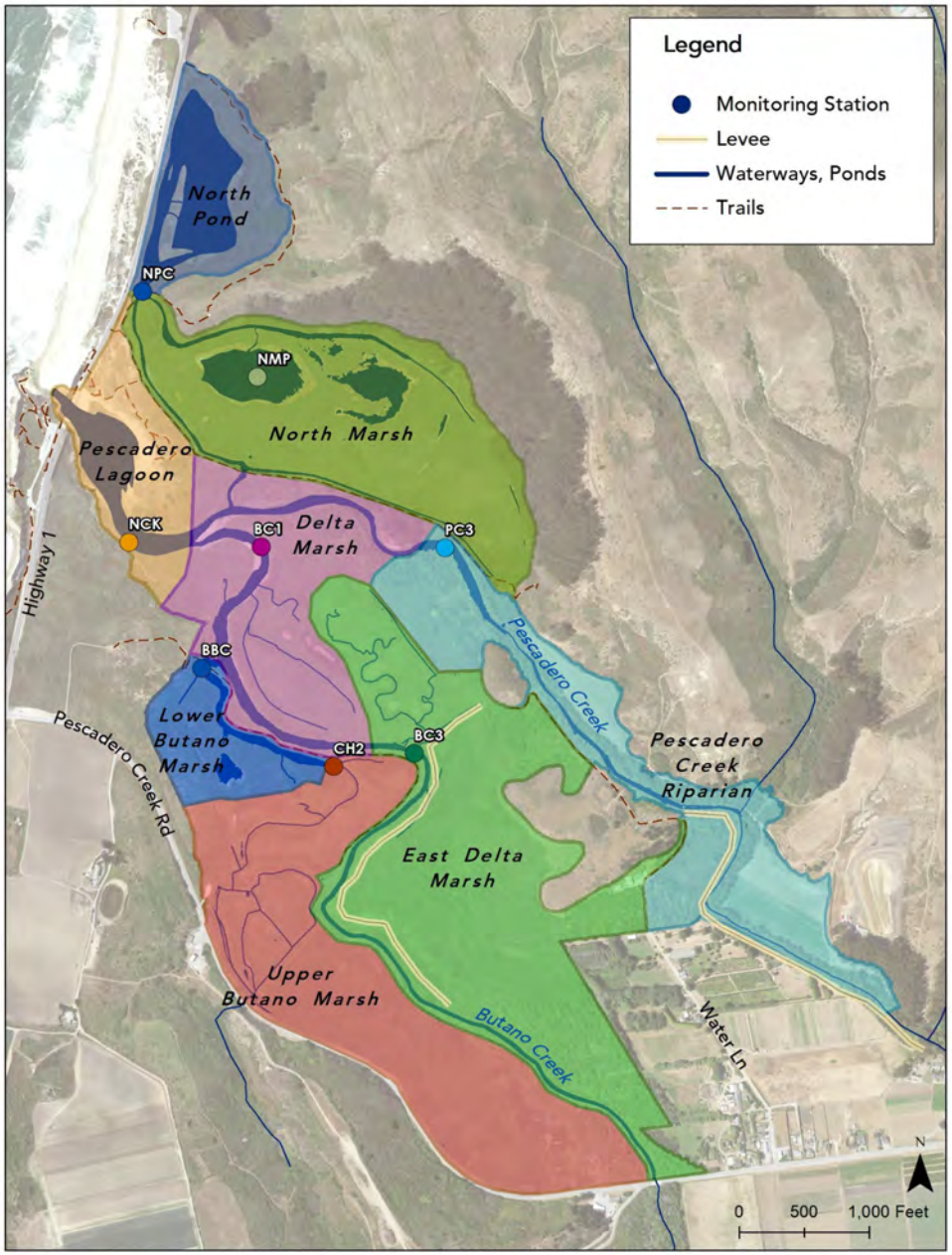
Rate of accretion is assumed to be 5mm/yr.

Assumptions

- Sediment is generally deposited in large episodic events, however the rate & timing was considered a consistent 5mm/yr.
- Deposition across the marsh plain was assumed to be even
- The relationships between habitat classifications and inundation percentage were assumed to stay consistent with sea level rise
- This rate was determined based on professional judgment by CCWG, and relies on a report by the Pescadero Lagoon Science Panel by John Largier et. al. in 2015. It was reported that in topographic surveys between 1987 and 2011, the East Butano Marsh accreted between 0.5 ft and 1.3 ft, and the North Pond has accreted ~1ft on average, while no accretion was observed in North Marsh. Taking these accretion rates in aggregate, a rate of 5 mm was assumed.

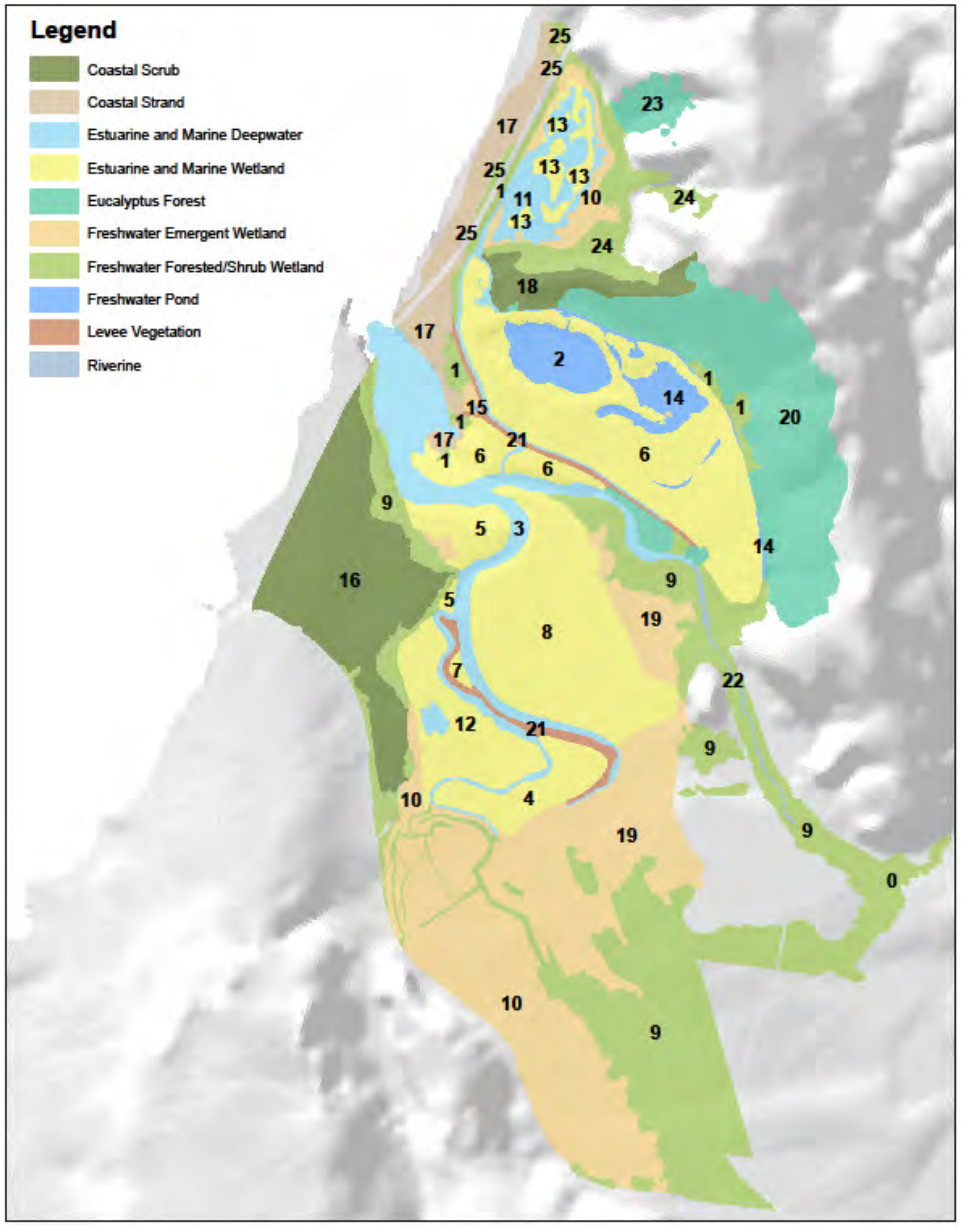
Processing: Classifying Marsh Sub Areas

- Defined by CA State Parks Monitoring Station Locations:
  - 8 monitoring
  - Divided in 8 sub regions or areas of influence
  - Divisions based on physical features such as levees whenever possible. When these features were not present, higher elevation areas represented by natural changes in the grade were used

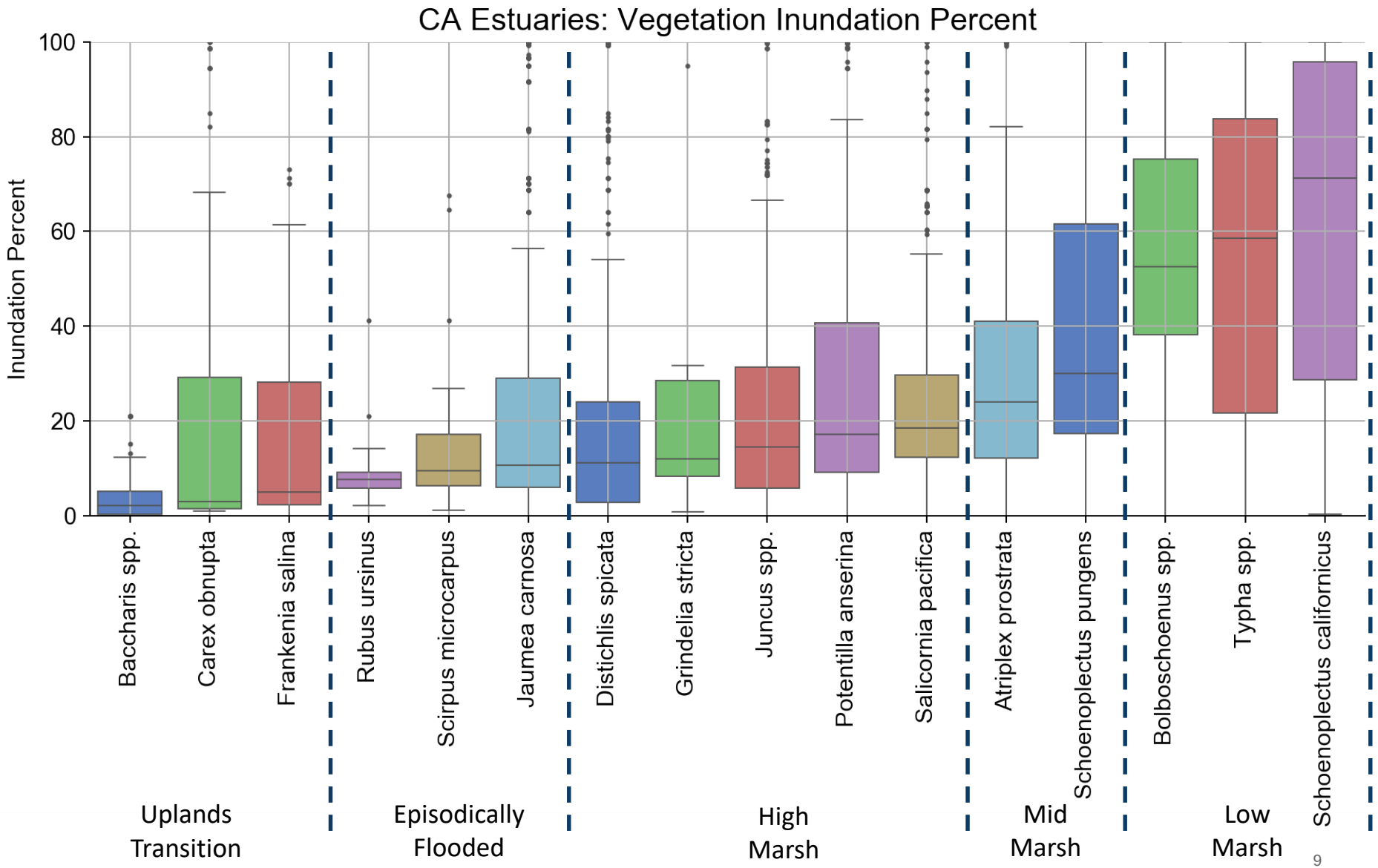


Understanding existing sub area habitat distributions by elevation

- Zonal statistics were generated to determine habitat and elevation relationships in the marsh

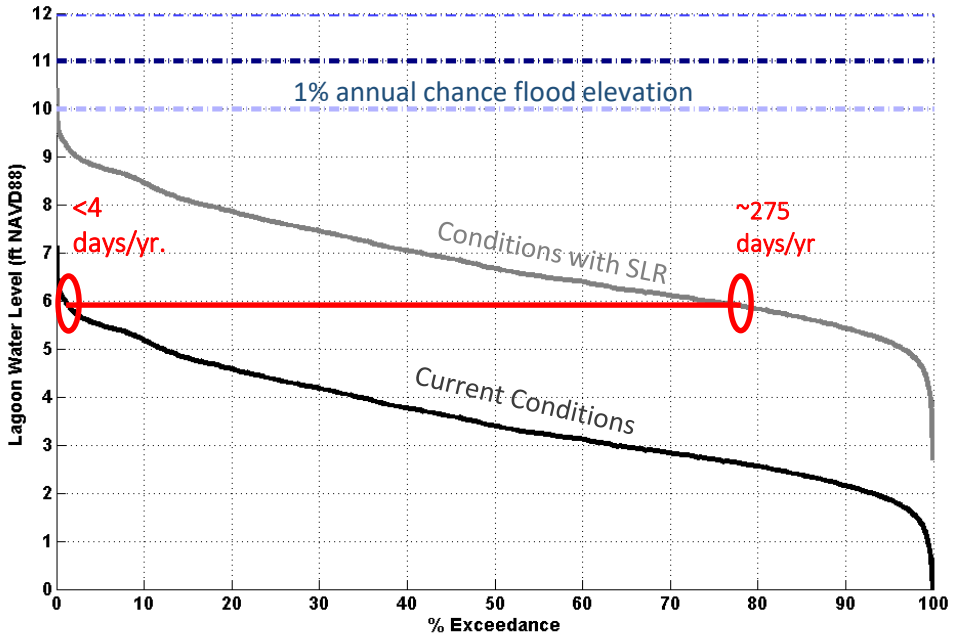


Central California Wetland Species by Inundation Percentage

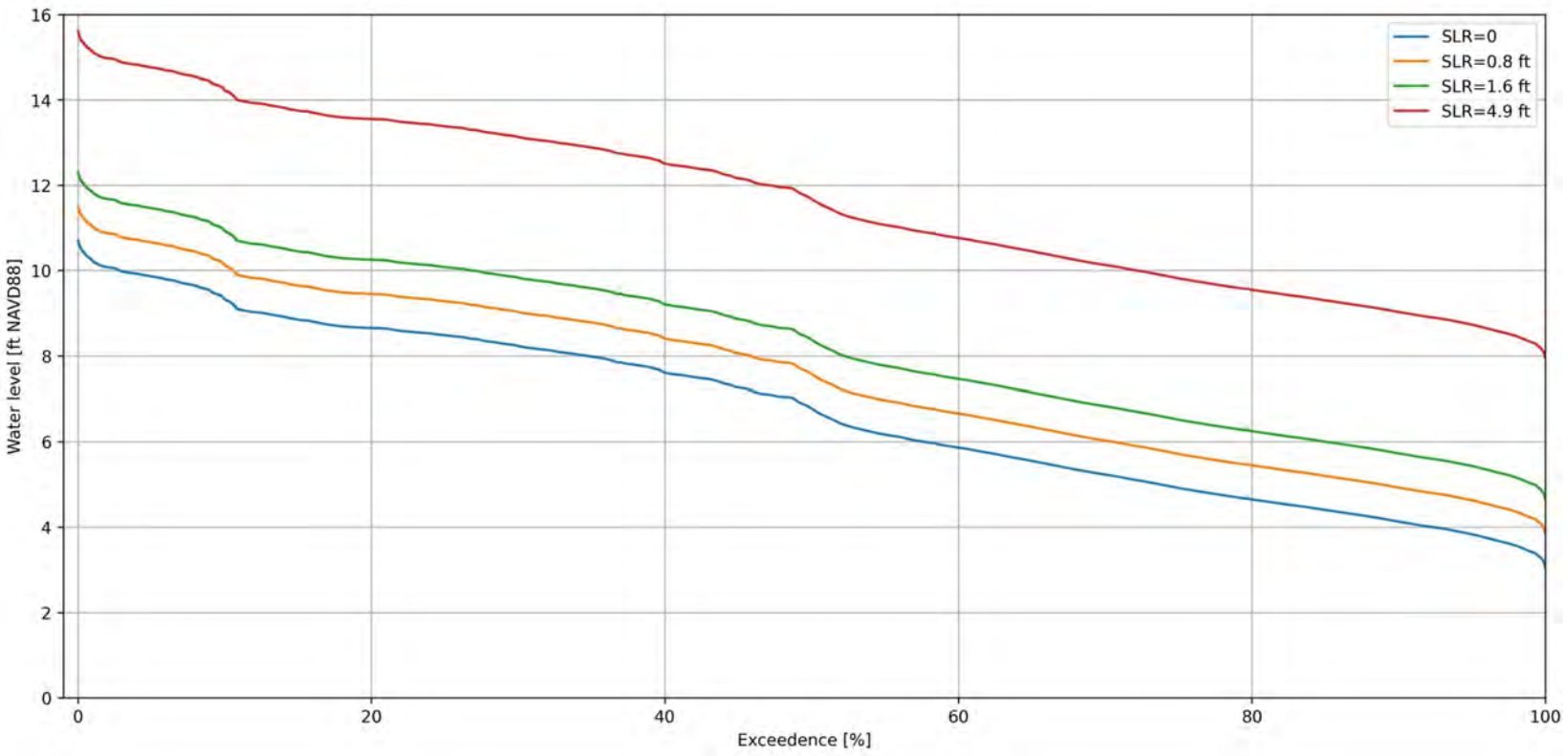


Generating Water Level Exceedance Curves

Example of an Exceedance Curve with Sea Level Rise



Exceedance Curve Example - Delta Marsh Sub Area

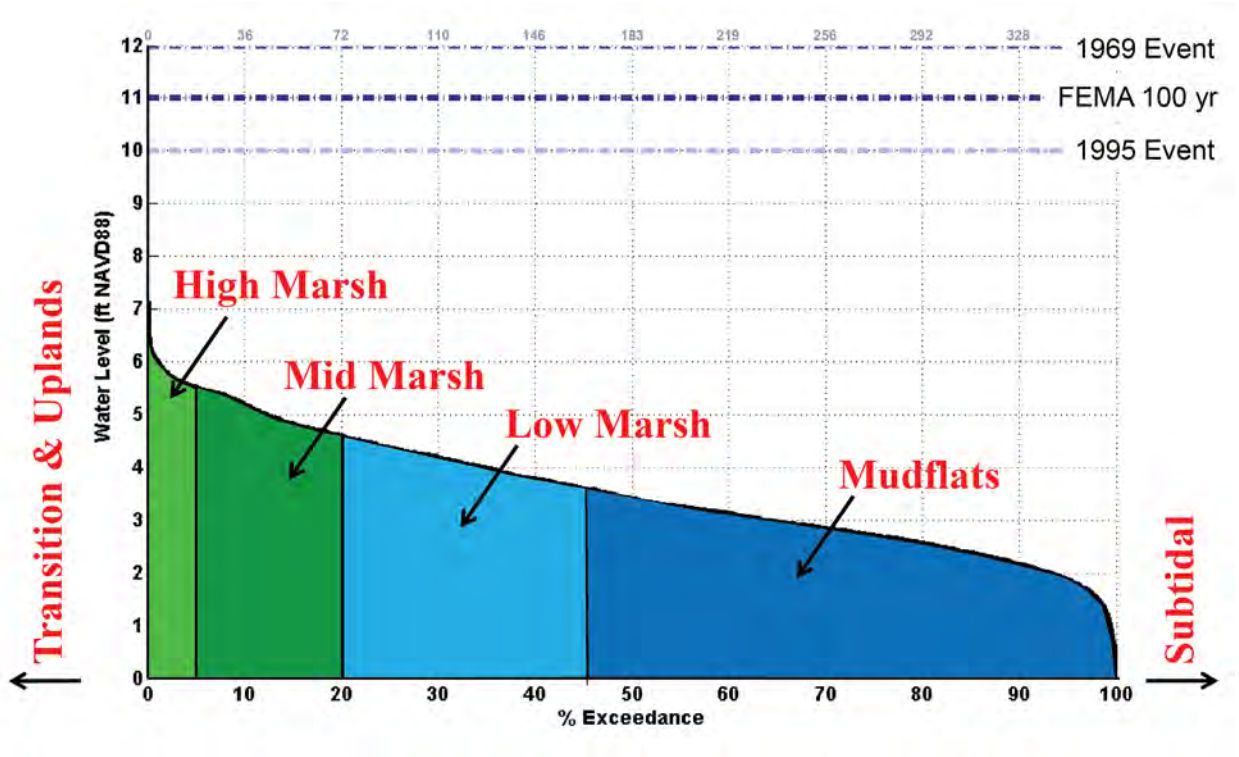


~4 years of data
Water levels were taken approx. once every 3 min.

Apply vegetation inundation percentages to general habitat classifications

Assumption:

Species occur along a gradient relative to percentage of inundation duration



Coastal Shrubland, Grassland, Dune

Estuarine Wetland

Tidal Flat, Pannes & Pools

Ponds, Riverine, Estuarine

Considerations

- Each sub area used custom habitat breakpoints depending on its location in the marsh and these were verified with habitat mapping from CA State Parks
- Station locations were not always representative of water levels throughout the station's area of influence, so adjustments were made
- Considerations were made where elevation gradients were more highly variable between upstream and downstream areas of the zone, this varied by sub area

Linking Habitat Type to Inundation Ranges - Delta Marsh Sub Area

Habitat Type	Inundation Percentage	Elevation (ft) of Habitat Type (NAVD88) by SLR Horizon			
		0	0.8’	1.6’	4.9’
Episodically flooded	5 - 10	9.86	10.47	11.27	14.57
High marsh	10 - 20	9.33	9.95	10.75	14.05
Mid marsh	20 - 45	8.65	9.27	10.07	13.37
Low marsh	45 - 75	7.26	7.88	8.68	11.98
Sand, mudflat, alkali flat	75 - 86	4.92	5.54	6.34	9.64
Estuarine, riverine	86 - 100	4.36	4.97	5.77	9.07

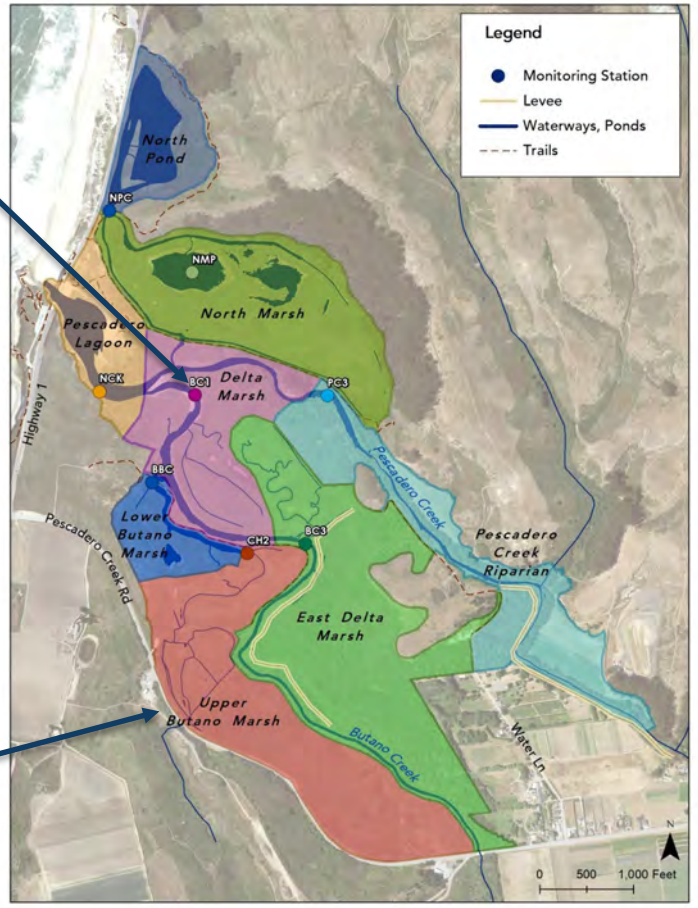
Hypsometry response varied throughout the marsh

Delta Marsh:

Habitat Type	Inundation Percentage	Elevation (ft) of Habitat Type (NAVD88) by SLR Horizon			
		0	0.8’	1.6’	4.9’
Episodically flooded	5 - 10	9.86	10.47	11.27	14.57
High marsh	10 - 20	9.33	9.95	10.75	14.05
Mid marsh	20 - 45	8.65	9.27	10.07	13.37
Low marsh	45 - 75	7.26	7.88	8.68	11.98
Sand, mudflat, alkali flat	75 - 86	4.92	5.54	6.34	9.64
Estuarine, riverine	86 - 100	4.36	4.97	5.77	9.07

Upper Butano Marsh:

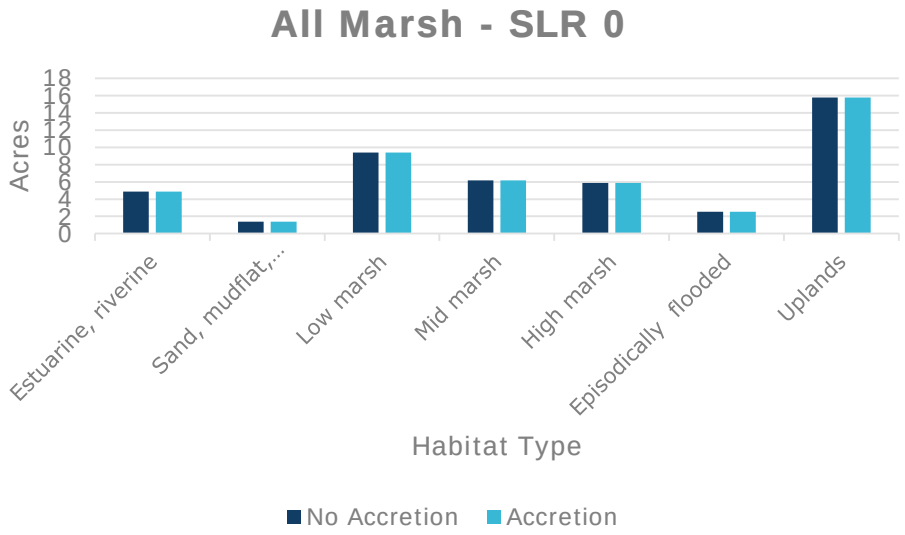
Habitat Type	Inundation Percentage	Elevation (ft) of Habitat Type (NAVD88) by SLR Horizon			
		0	0.8’	1.6’	4.9’
Episodically flooded	5 - 10	9.41	9.41	9.74	13.04
High marsh	10 - 20	8.59	8.59	8.93	12.23
Mid marsh	20 - 45	7.70	7.70	8.04	11.34
Low marsh	45 - 75	6.76	6.76	7.10	10.40
Sand, mudflat, alkali flat	75 - 86	5.81	5.81	6.14	9.44
Estuarine, riverine	86 - 100	5.43	5.43	5.77	9.07

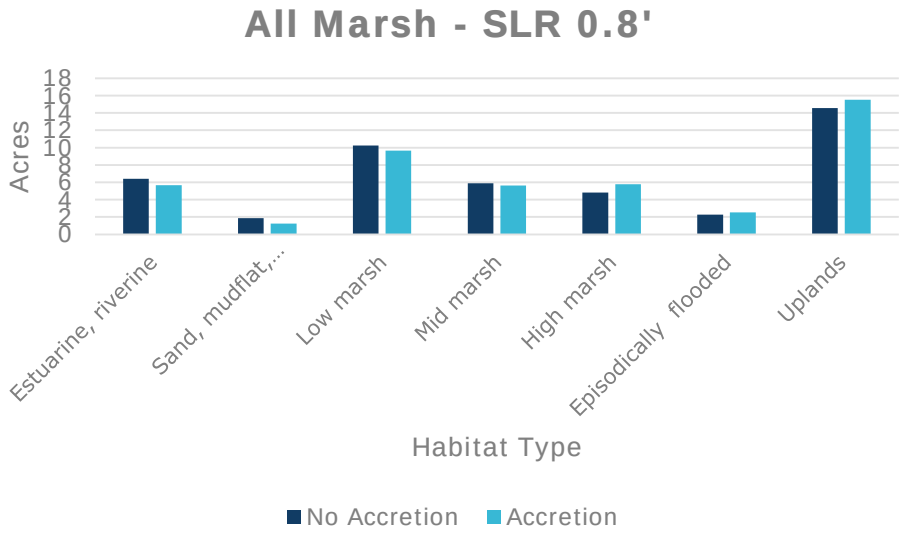


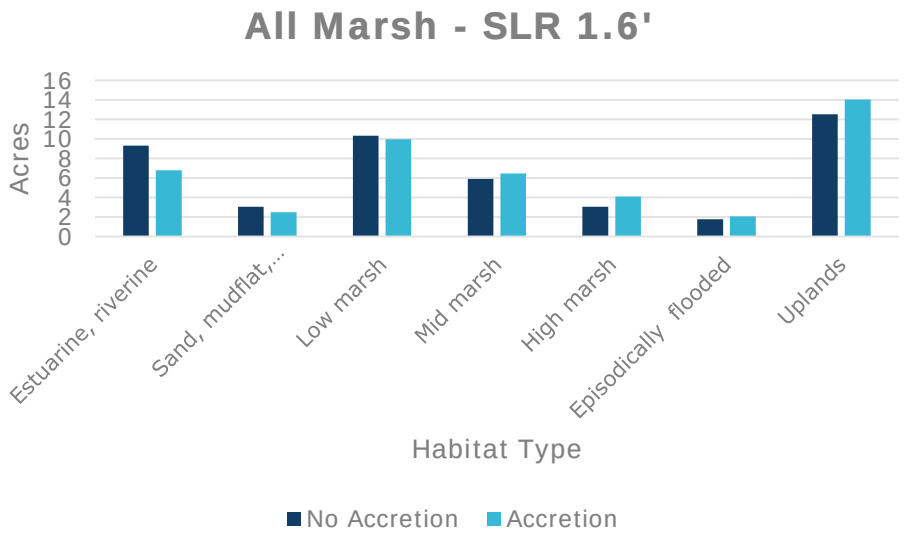
Linking habit types to locations

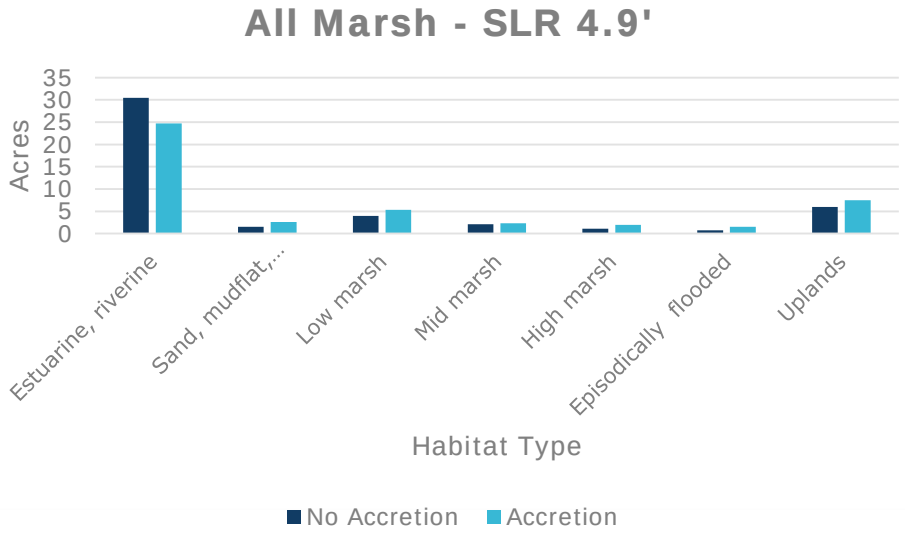
- Vector-based
- Filled contours every 0.2 ft
- One flat table to work with
- Pros & cons to this method
- Other strategies could include using many rasters or a multidimensional raster

Pescadero Marsh - Habitat Evolution Table

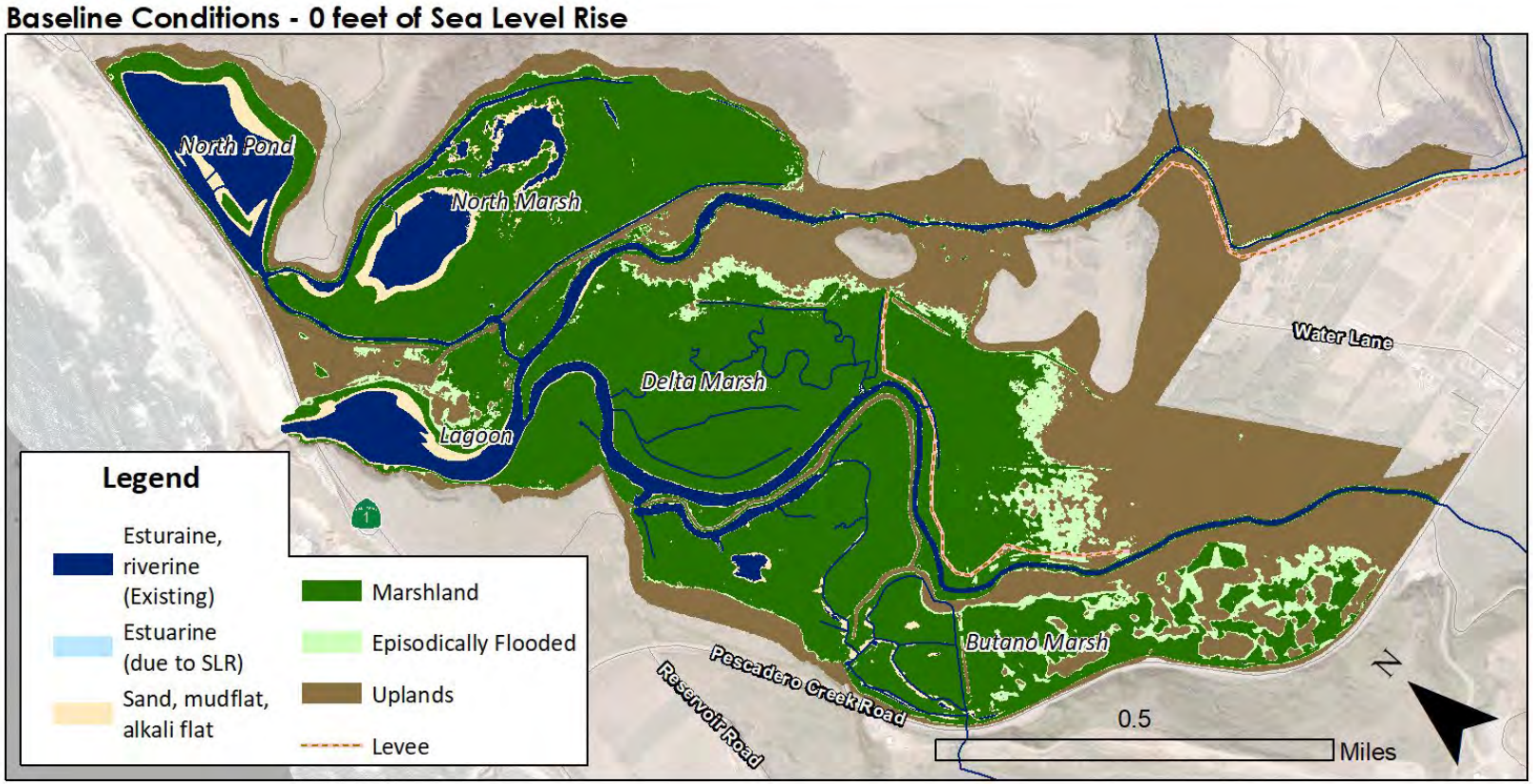






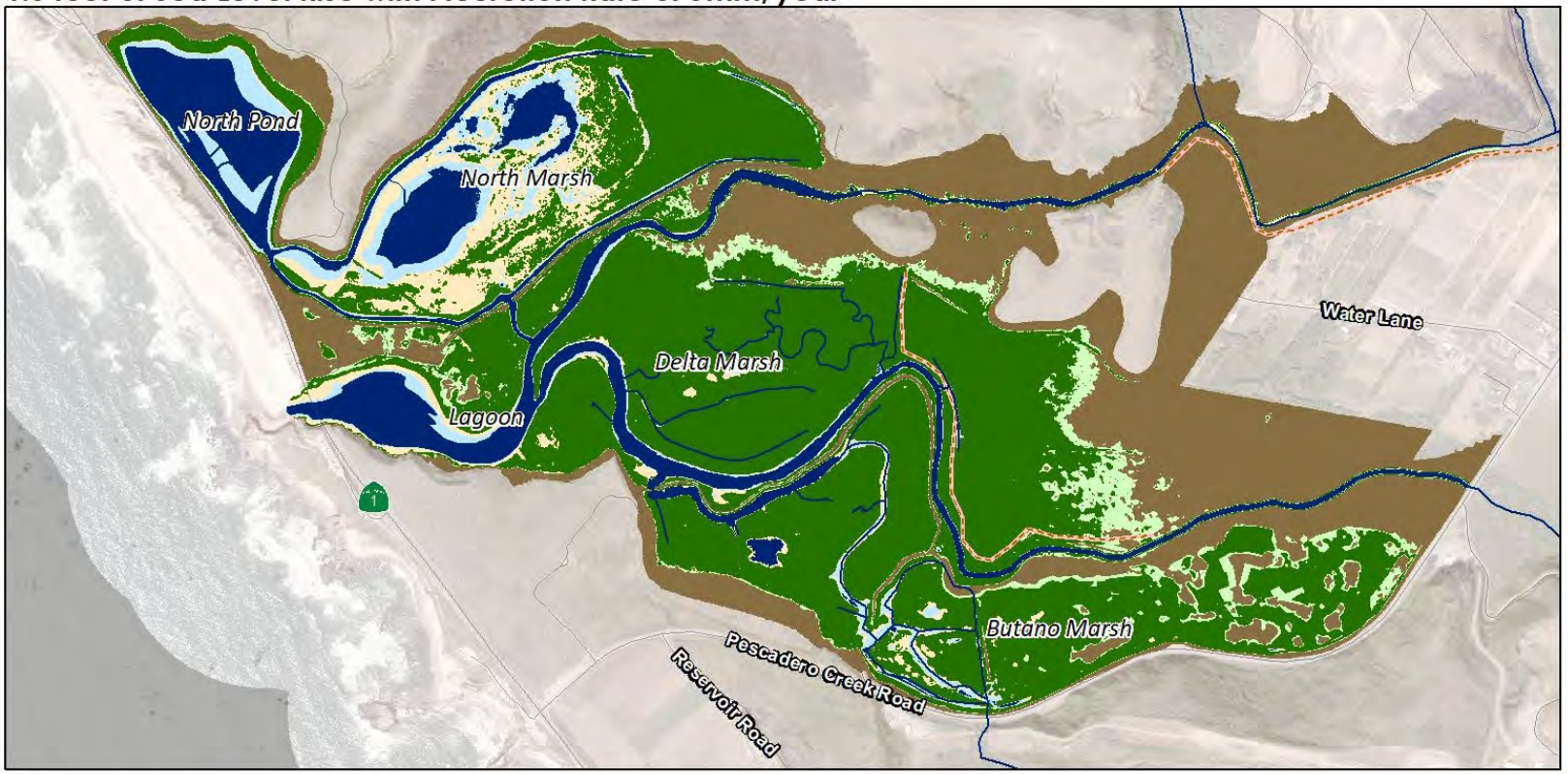


Baseline Conditions - 2020



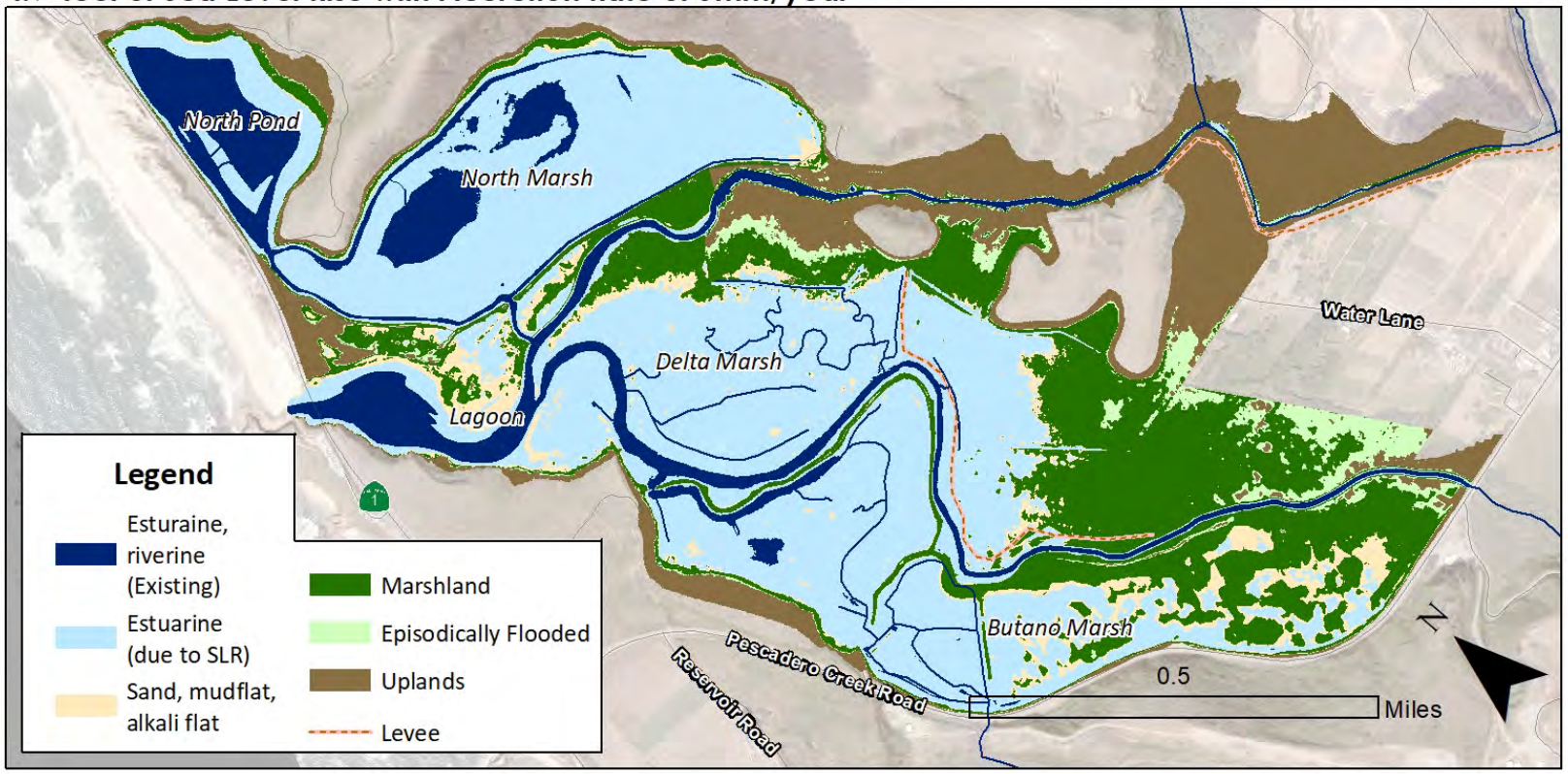
Mid-Term Conditions (~2060)

1.6 feet of Sea Level Rise with Accretion Rate of 5mm/year



Long-Term Conditions (~2100)

4.9 feet of Sea Level Rise with Accretion Rate of 5mm/year



Some preliminary findings

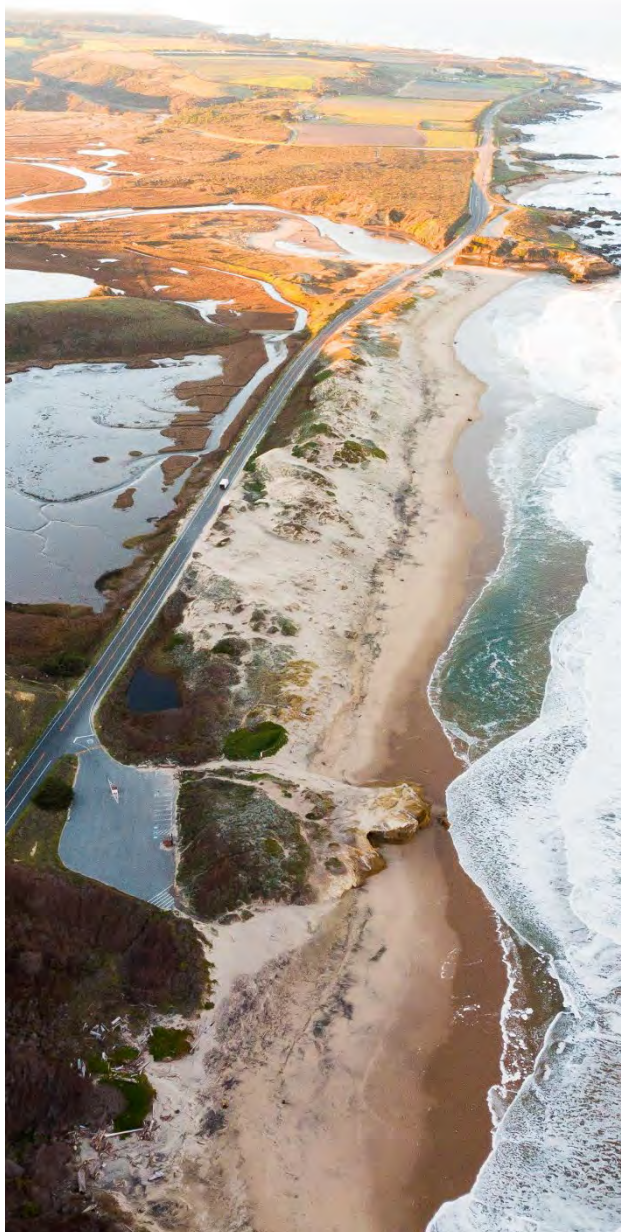
- Topography confines the suitable areas that marsh habitat can expand or migrate to in the future, both landward and upslope
- The zones of suitability for marsh habitat will increasingly become confined with accelerated SLR, with a substantial shift of marsh habitats toward subtidal habitats after 1.6 feet of sea level rise
- In the near term, rising sea levels may mean areas suitable for low and mid marsh habitat could expand, and areas of high marsh and edge-marsh uplands may become more confined. Over the long term, however, areas suitable for marsh expansion will decrease and the habitat zones between subtidal / estuary areas and uplands will narrow

Potential future work…

- Establishing sediment elevation markers which will allow us to determine the relative rates of accretion across the marsh
- Sediment mass balance models for response of the mouth to sea level rise. How will the barrier beach increase in elevation over time, and will the mouth be more open over time?

Future adaptation strategies

- Increasing the area available for marsh transition
- Increasing sediment supply/retention:
  - Altering the marsh levees to allow for more sediment deposition in the marsh plains as well as to reduce flow velocities during flood events
  - Reducing the tidal connectivity between some of the marshes and lagoon could reduce ebb-tidal scour within the tidal channels and promote sediment retention in the system
  - Highway 1 has fixed the position of the sand spit near the North Pond and is limiting sediment exchange between the marsh and open coast



Thank you!