WORKSHOP #2

Sea Level Rise Adaptation Plan for Eureka Slough Hydrographic Area, Humboldt Bay

March 17, 2021 1:00 pm – 3:00 pm

Project Team

- GHD Inc.
- Northern Hydrology & Engineering
- Environmental Science Associates
- GMA Hydrology, Inc.
- Trinity Associates (Aldaron Laird)
- Philip King & Kristina Kunkel, San Francisco State University
- Redwood Community Action Agency
- Ryan Rice
- Jerry Rohde

Funding

- Caltrans Adaptation Planning Grant Program
- County of Humboldt
- City of Eureka
- Humboldt County Association of Governments

(Total Budget = $480,000)

Study Period

October 2018 – March 2021

Workshop Agenda

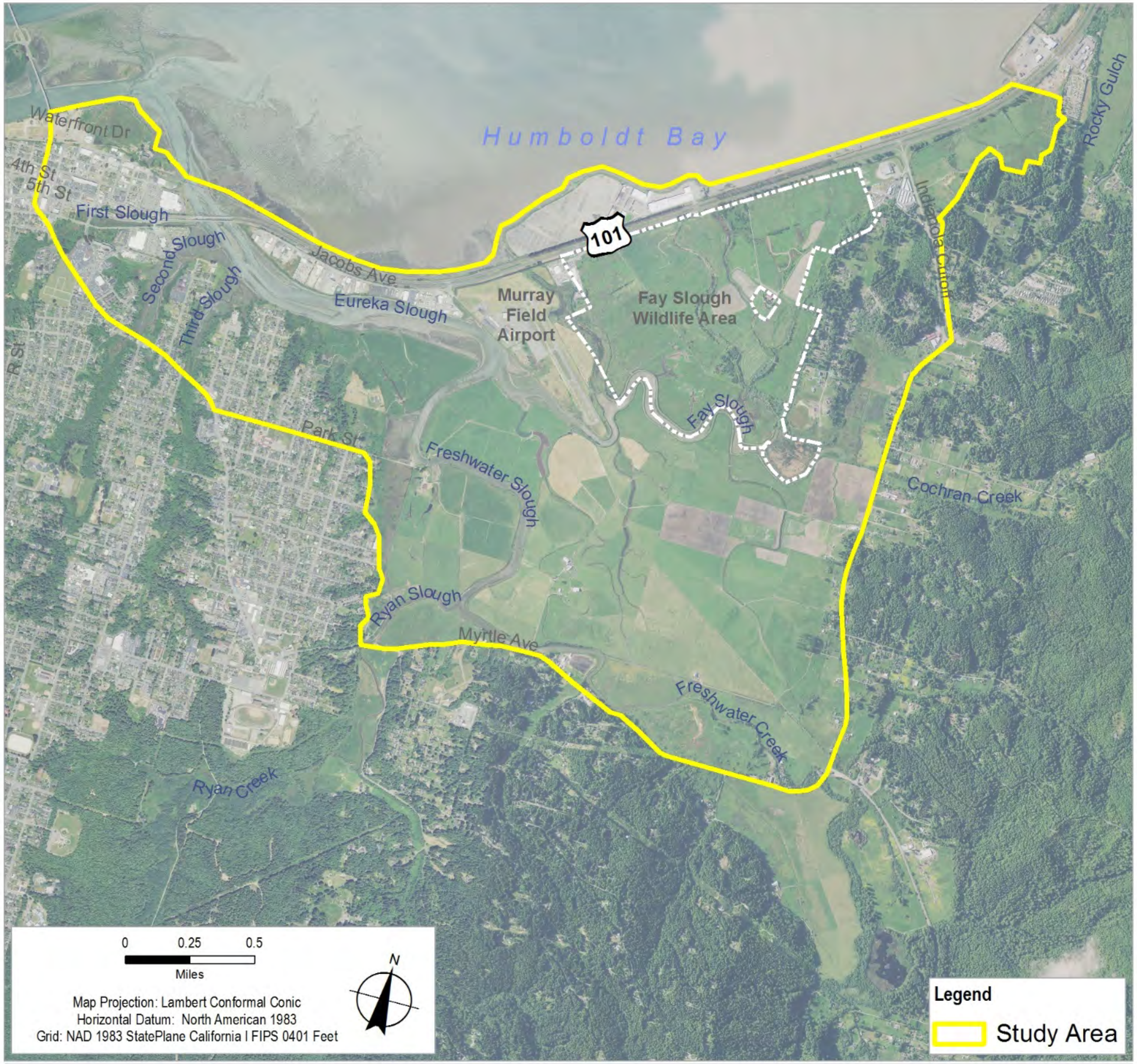
I. Planning Framework	1:00-1:20 pm
II. Vulnerability Assessment	1:20-1:50 pm
III. Adaptation Projects	1:50-2:20 pm
IV. Key Take-Aways & Strategies	2:20-2:30 pm
V. Discussion	2:30-3:00 pm

Today's Presenters:

- Hank Seemann, Deputy-Director, Humboldt County Public Works
- Jeremy Svehla, Senior Civil Engineer and Project Manager, GHD
- Brett Vivyan, Civil Engineer, GHD

I. Planning Framework


City of Arcata
101
255
101
101
Study Area
City of Eureka



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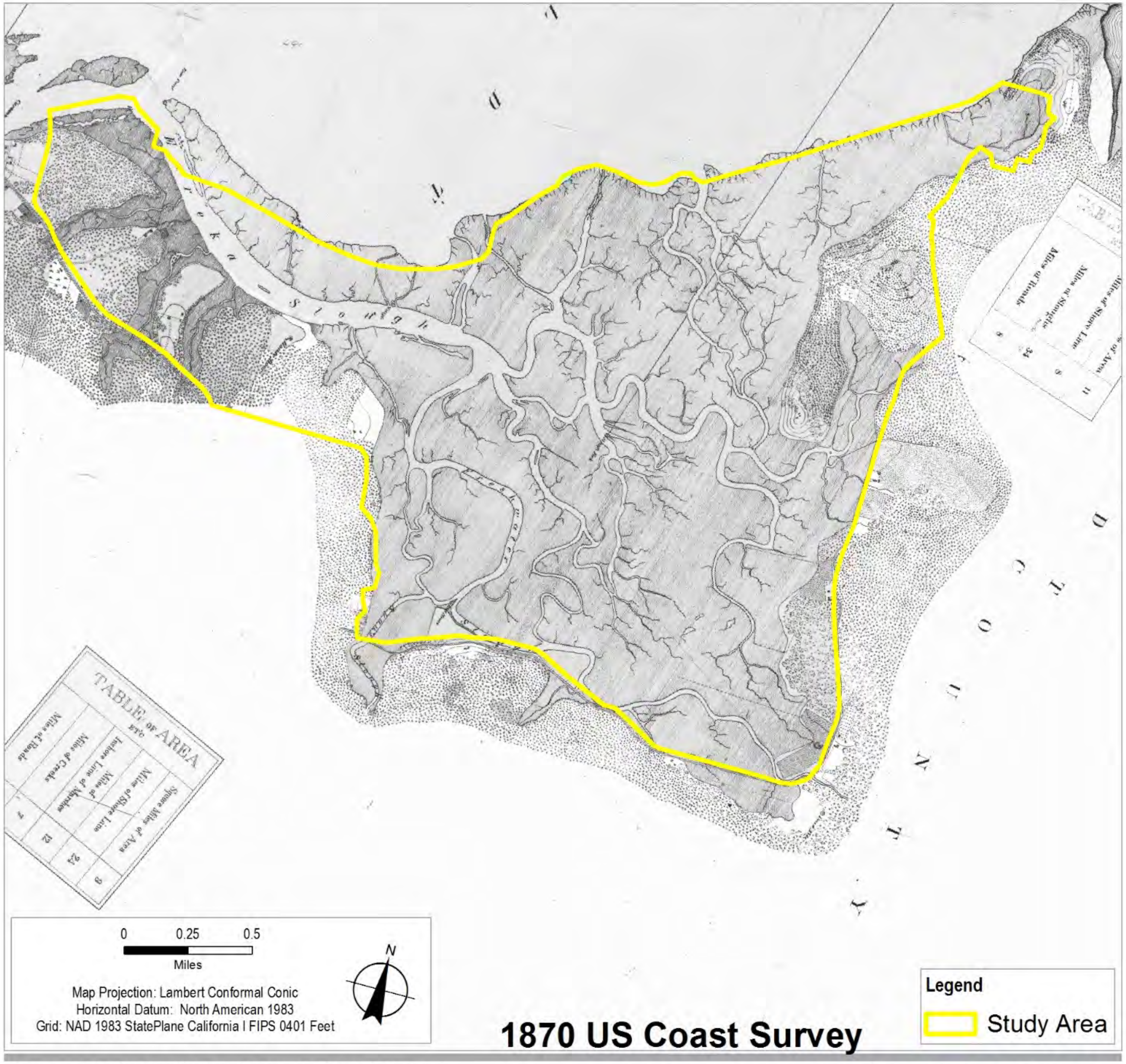
Data source: Study area, Humboldt County; Roads data, TIGER; Orthoimagery, 2016; NAIP; . Created by: ashows



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Data source: Study Area boundary, Humboldt County; City Boundary, City of Eureka, 4/3/2019; Coastal Zone boundary, Laird; Roads data, TIGER; Orthoimagery 2016, NAIP; . Created by: ashows

Overview

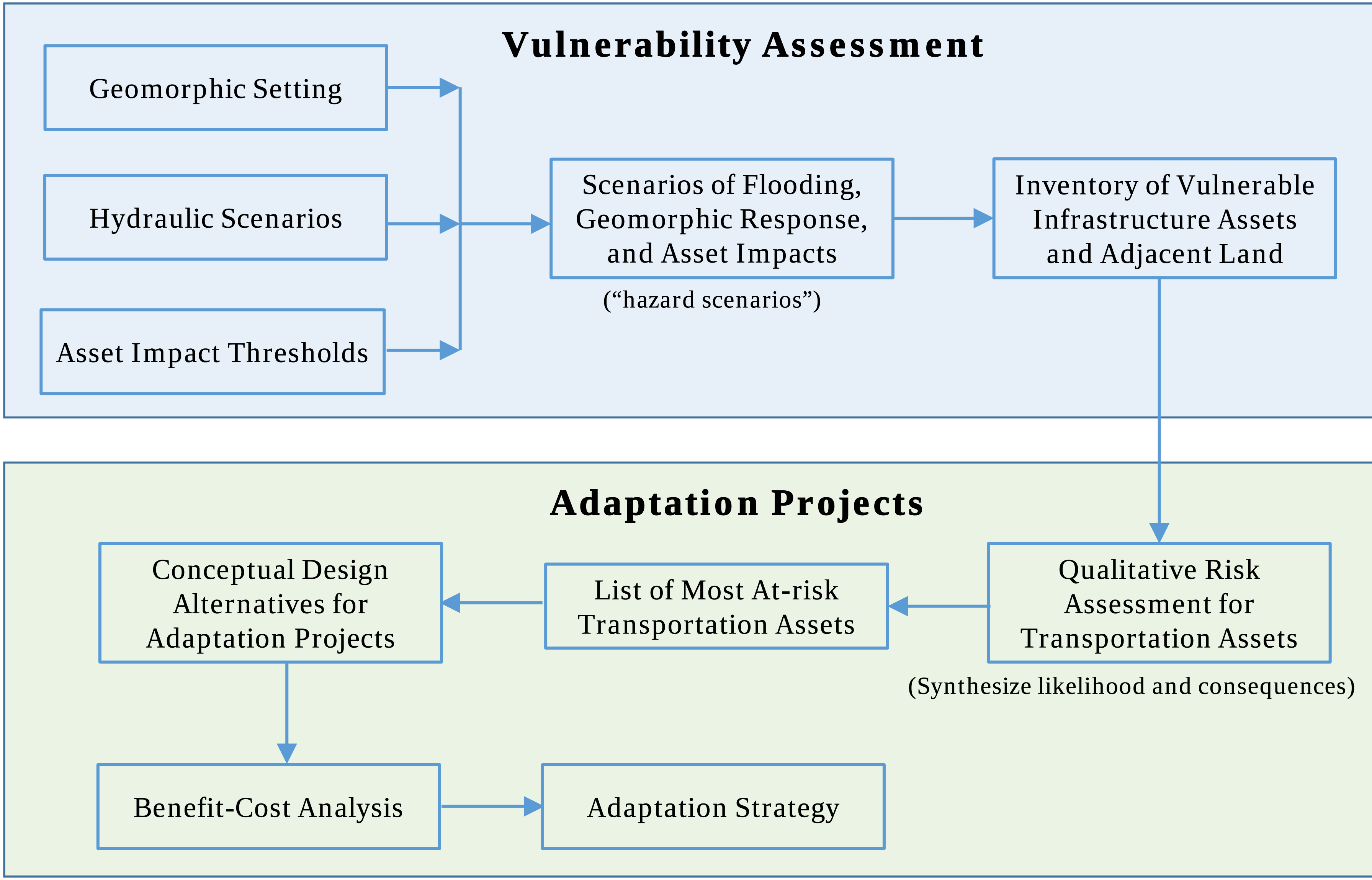
This Plan provides a framework for planning adaptation projects in the Eureka Slough hydrographic area:

1. Intended to support transition from vulnerability assessment to adaptation
2. Presents vision statement, key assumptions, guiding principles
3. Improves understanding of site-specific risks and physical processes
4. Identifies project concepts that could be feasible and effective
5. Selects four project concepts for more detailed analysis

This Plan does not:

1. Present policies or address land use designations
2. Contain a specific work plan or timeline
3. Analyze adaptation concepts for Highway 101

Sea Level Rise Adaptation Planning Flow Diagram



Vision Statement

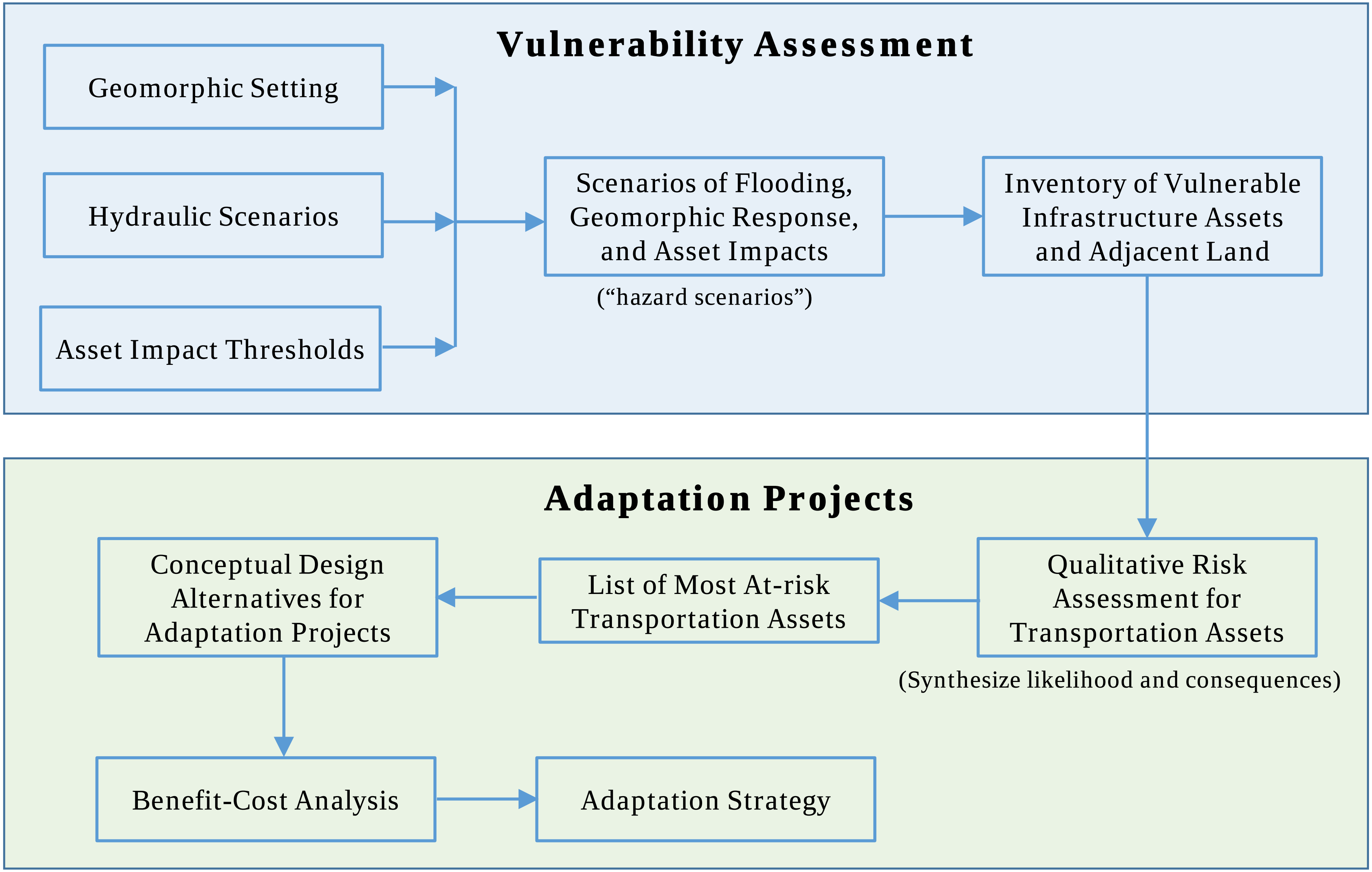
1. Landowners and managers collaborate on implementing an integrated strategy of short-term and long-term actions to build resilience to flood hazards and achieve an acceptable level of flood risk.
2. The critical resources of the Eureka Slough hydrographic area are protected from flooding hazards by multiple lines of defense including natural features (mud flats and salt marsh) and built structures (such as levees and embankments).
3. Public officials, landowners, and residents are aware of flood hazards associated with Humboldt Bay and freshwater tributaries and incorporate the goal of reducing flood risk into all pertinent planning and management decisions.
4. Diverse habitat types and healthy ecosystem functions are maintained.
5. Disadvantaged communities are not disproportionately impacted by flooding hazards or the costs of adaptation.
6. Adaptation projects are supported by federal and state funding.

Resilience

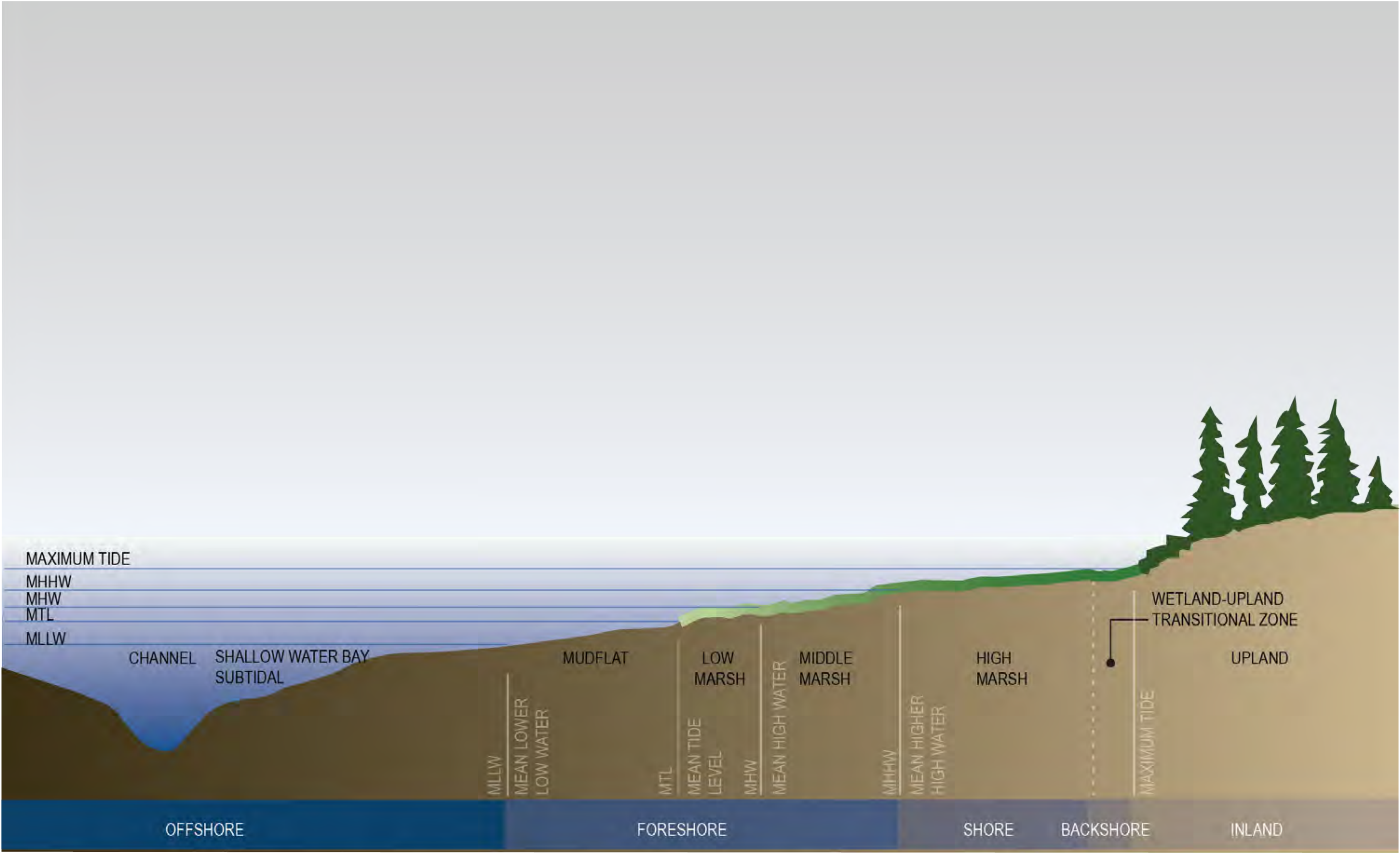
- The concept of resilience can be applied to human beings, communities, natural systems, and the built environment.
- Fundamentally, resilience is the capacity to:
  1. Absorb disturbance; and
  2. Recover from shocks and stresses while maintaining basic function and structure.
- One goal is to identify thresholds beyond which disturbance would be extremely damaging and potentially beyond recovery.
- In addition, human beings and communities can aspire to:
  3. Adapt and grow from disruptive experiences; and
  4. Seize opportunities for creative (even transformational) solutions.
- Resilience is a continuous practice, not an end-state.

II. Vulnerability Assessment

Sea Level Rise Adaptation Planning Flow Diagram

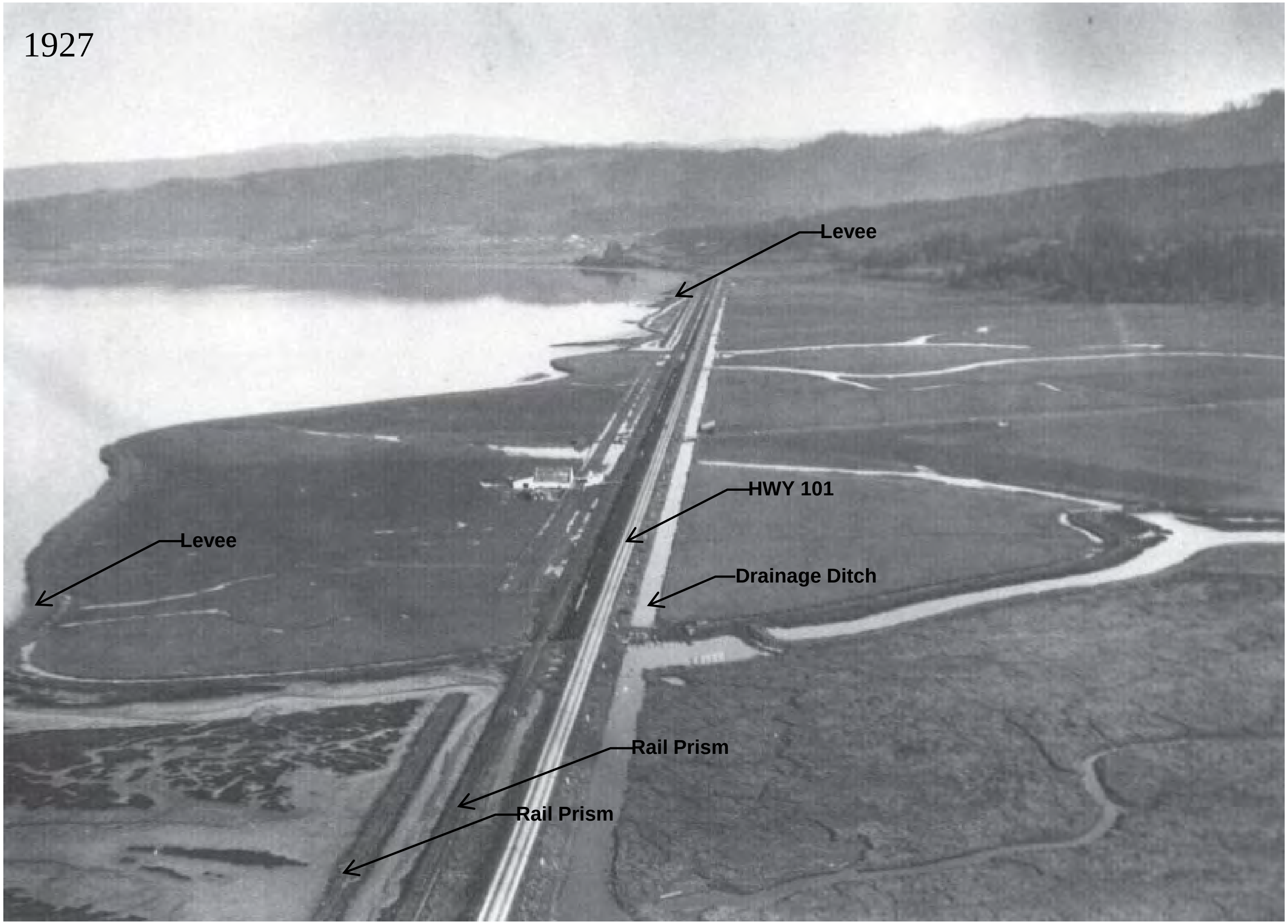


Geomorphic Setting: 1870 vs Present

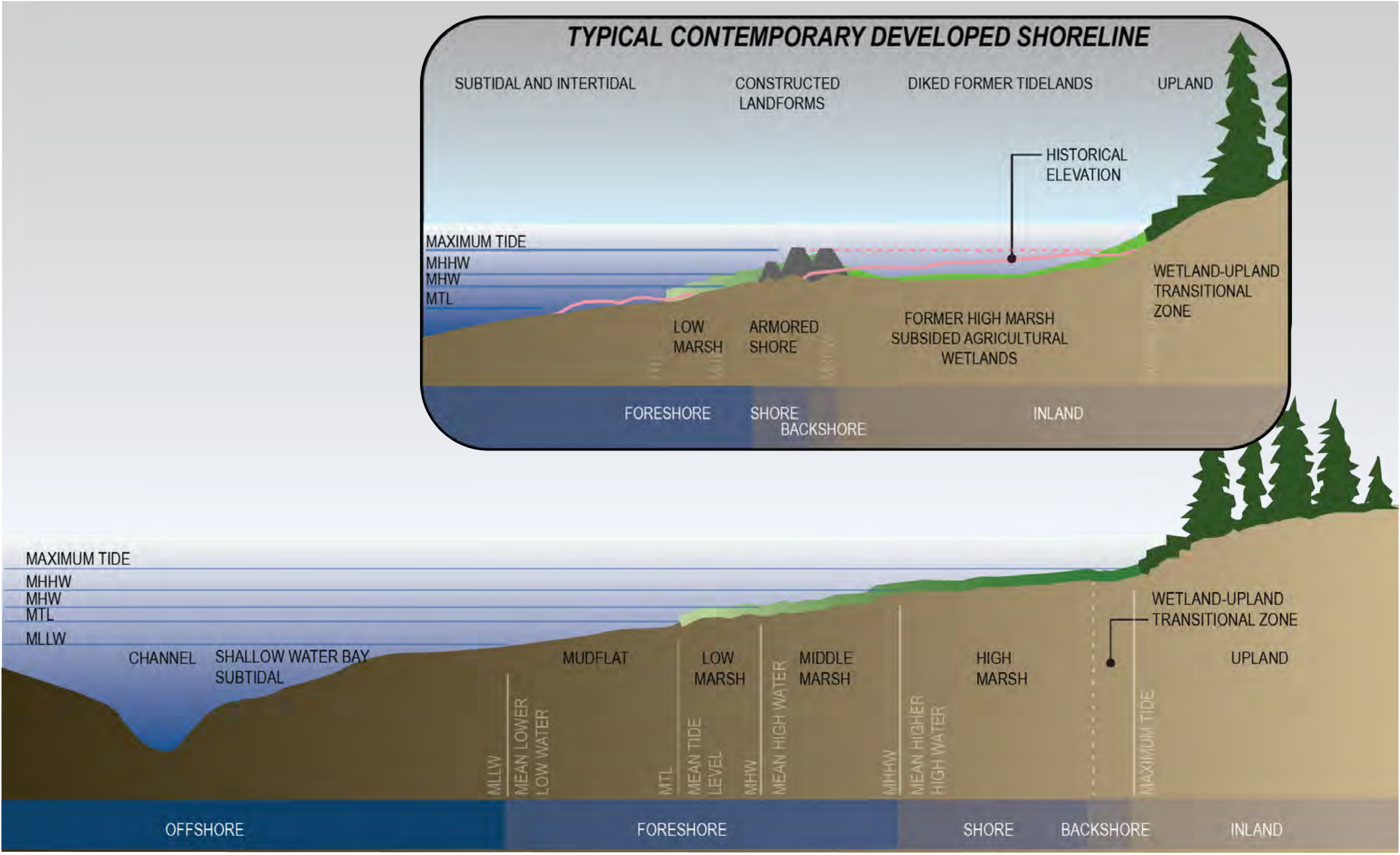


ARCATA BAY CONCEPTUAL SHORELINE, TIDAL WETLAND PRISM AND TIDES

Adapted from Barnhart (1992) and Monroe (1973)



Source: Roscoe (2007); Rohde (2020)



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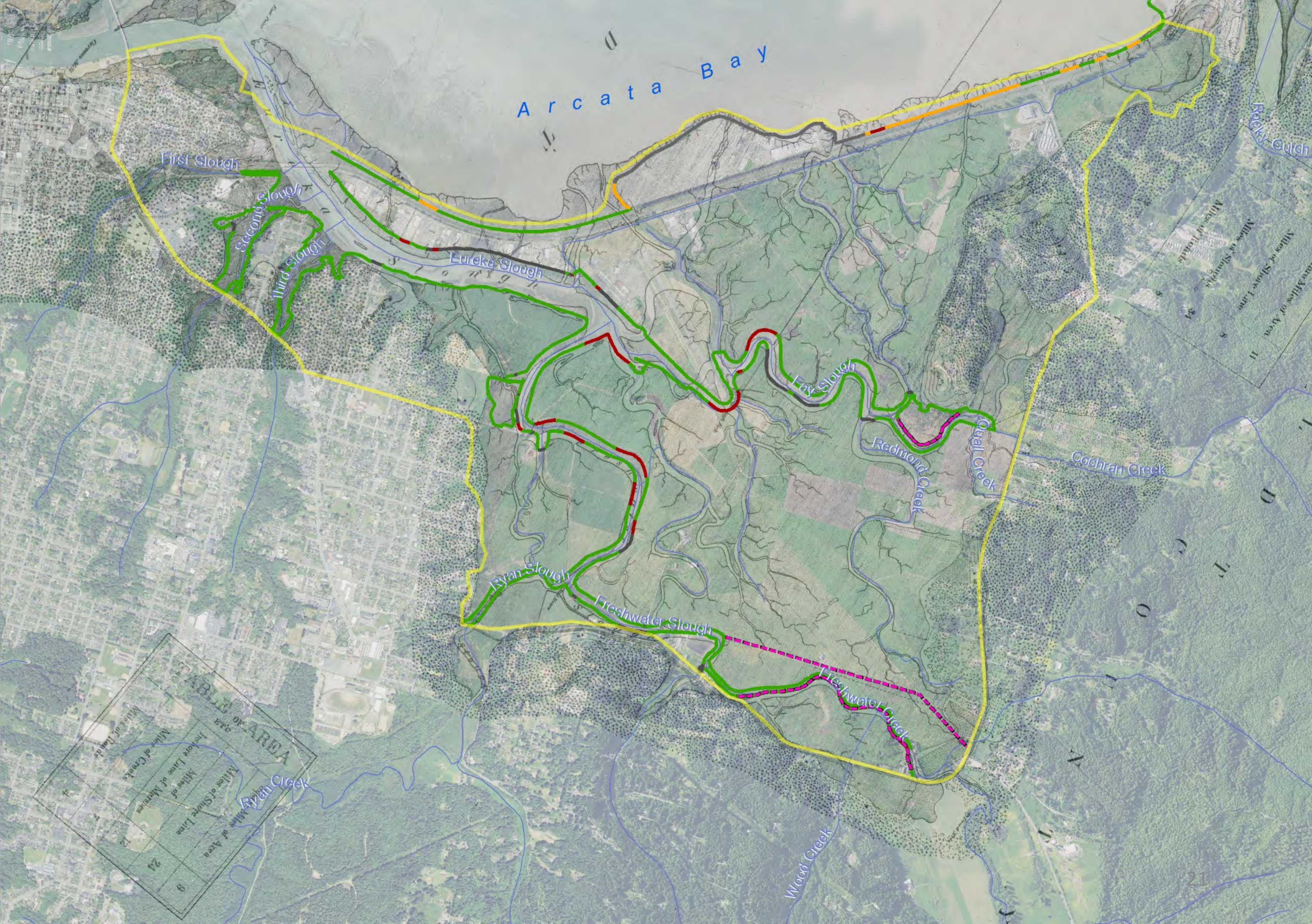
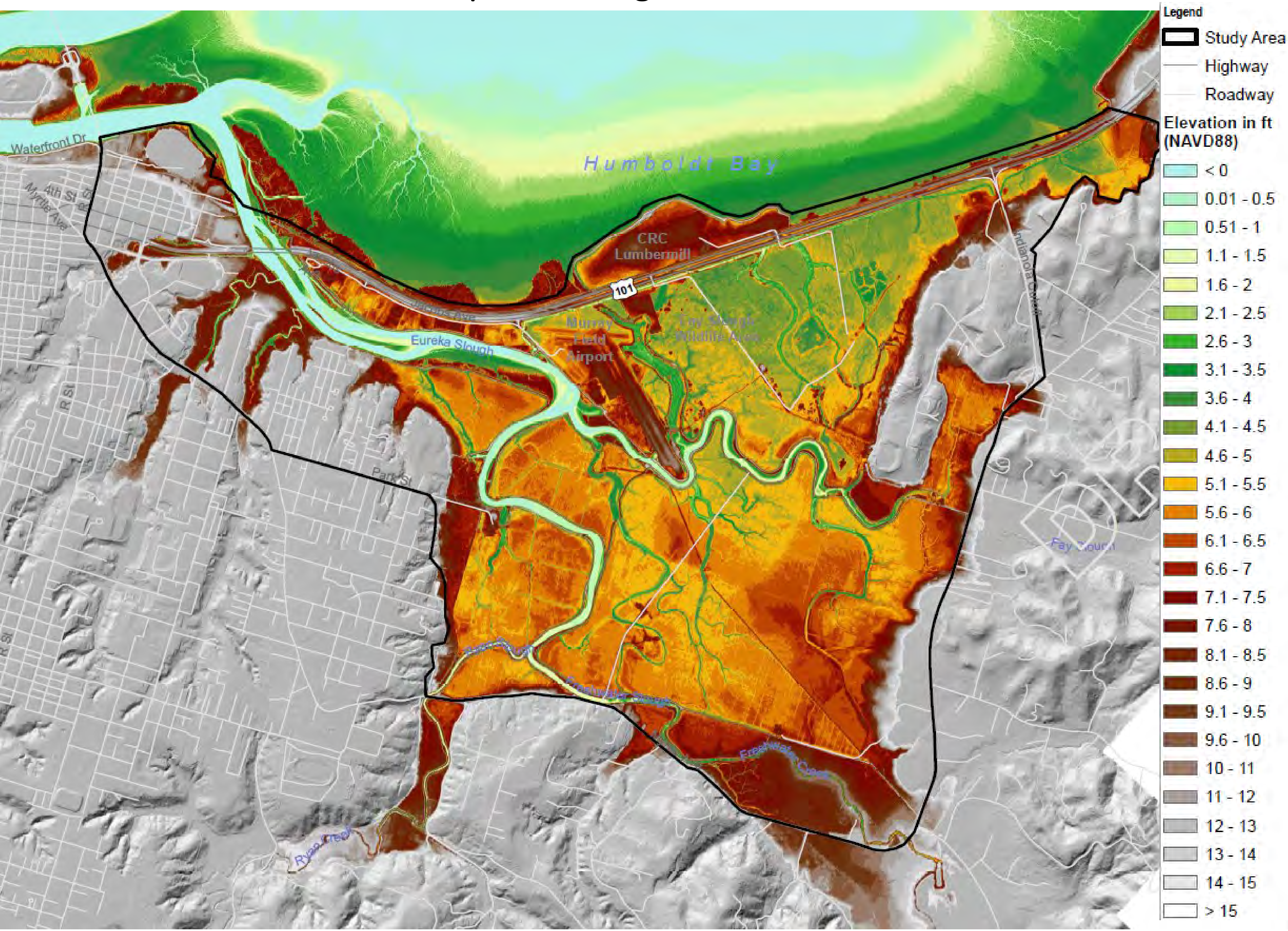
Geomorphic Setting: 1870 vs Present



Geomorphic Setting: Current Elevations



Flood Sources and Flood Risk Change with Sea Level Rise

Humboldt Bay

Attribute	Trend with SLR
Mean tide levels	Increasing
Extreme events	More intense/more frequent
Wave energy	Increasing

- *Tidal flooding*
- *Storm surge*
- *Wind waves*

Freshwater tributaries

Attribute	Trend with SLR
High-flow events	More intense/ More frequent
Downstream Boundary condition	Rising
Downstream Tidal extent	Increasing inland
Sediment supply	Variable

- *Fluvial flooding*

Landscape Features

- Sub-tidal and intertidal areas
- Constructed linear landforms (railroad, levees, Highway 101, other roads)
- Diked former tidelands
- Uplands

Groundwater

Attribute	Trend with SLR
Depth to water	Decreasing
Duration of Standing water	Increasing

- *Groundwater infiltration*

- *Flooding events/overtopping/overwash*
- *Erosion*
- *Sediment deposition*

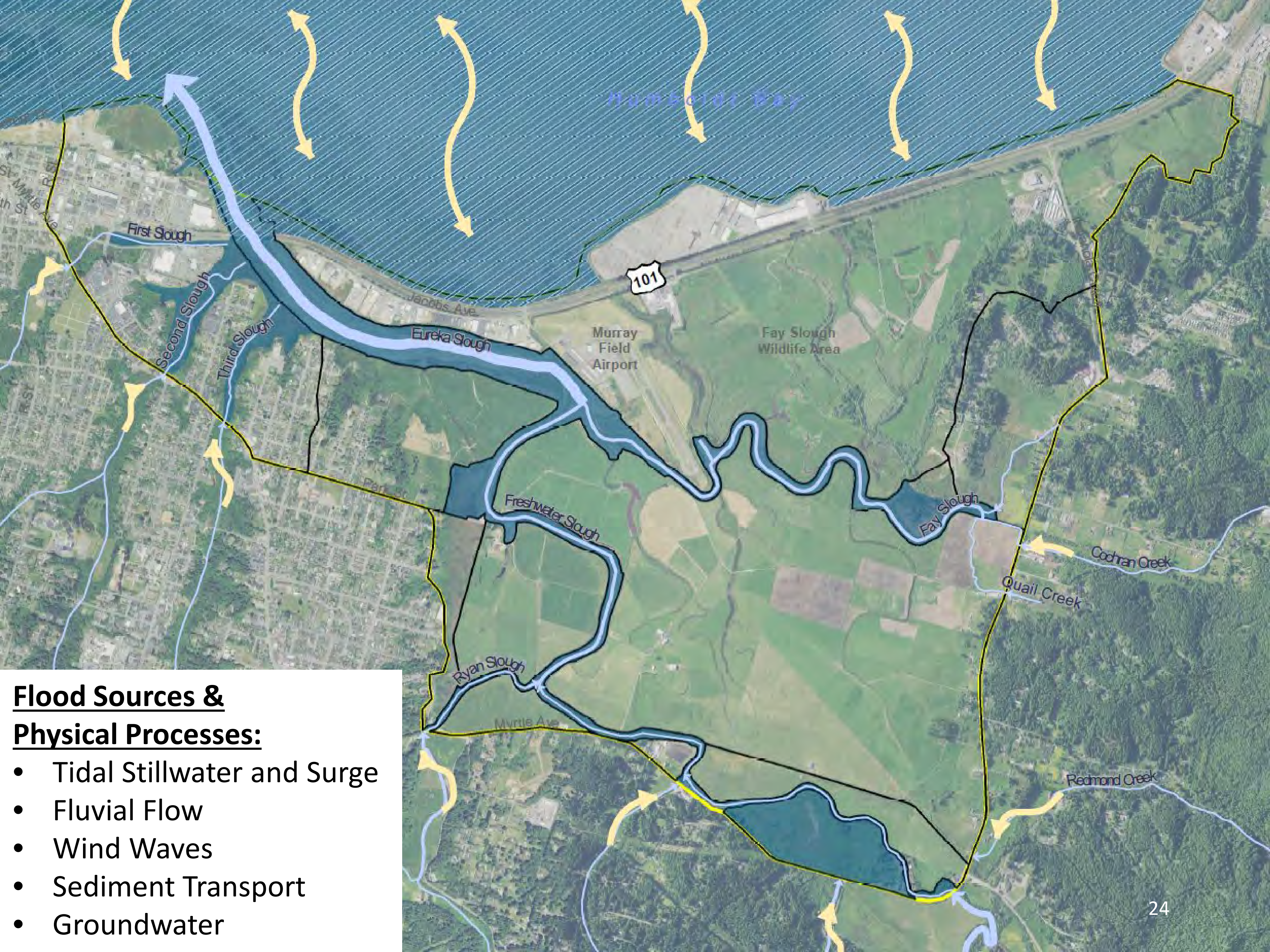
FLOOD RISK

Sources of uncertainty:

1. Global emissions and atmospheric/ocean response
2. Rate of relative sea level rise
3. Occurrence of extreme events is unpredictable
4. Potential clusters of extreme events
5. Future human interventions
6. Physical and ecological systems are dynamic and interact in complex ways
7. Limited knowledge and data
8. Potential major disturbance from seismic event/tsunami

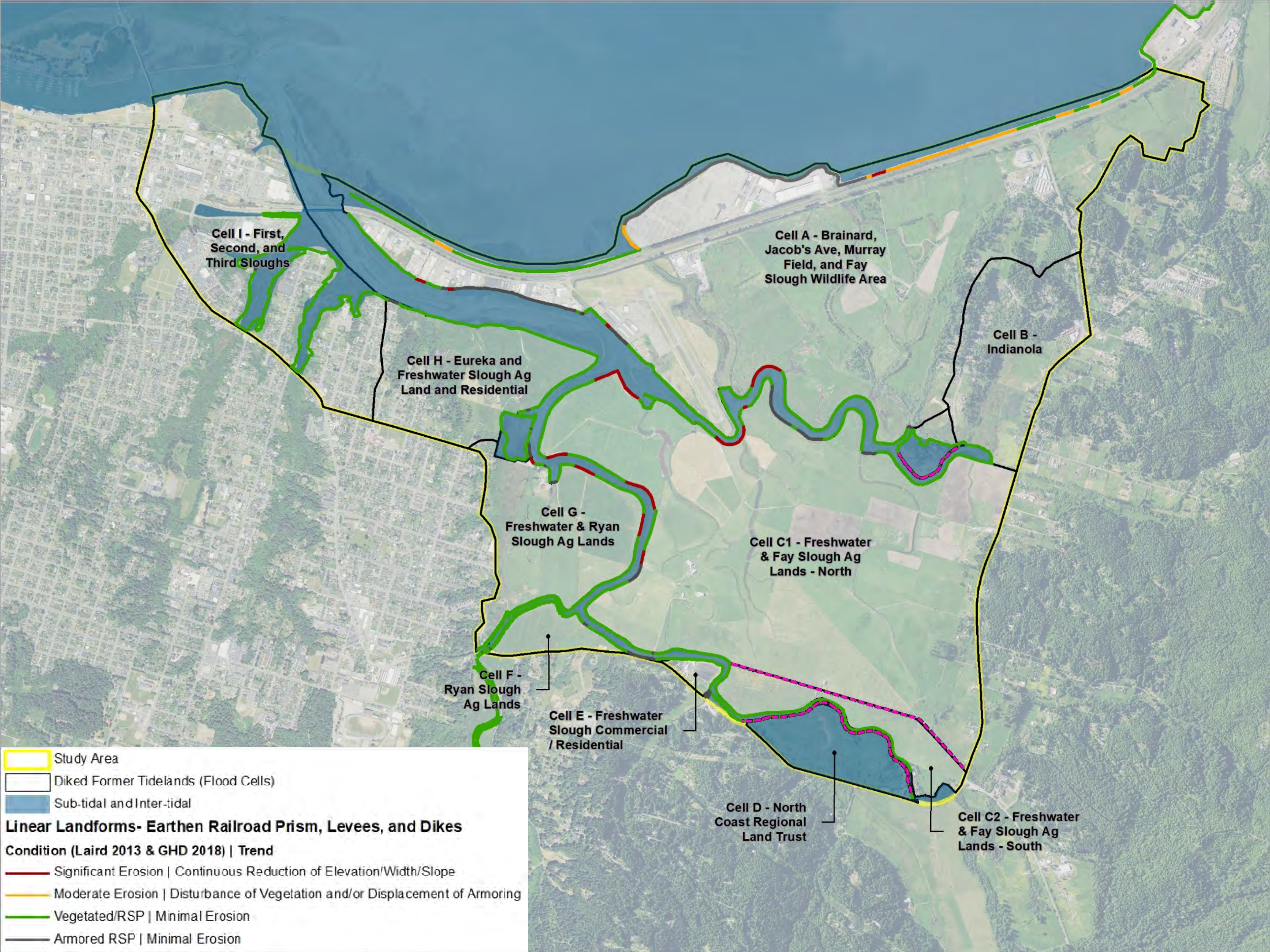
Potential Physical Impacts

- Displacement of rock slope protection
- Scour and erosion of landforms
- Damage to infrastructure
- Delayed drainage of floodwaters and stormwater
- New areas of regular inundation
- Habitat and vegetation changes
- Sediment deposition in channels
- Saltwater intrusion



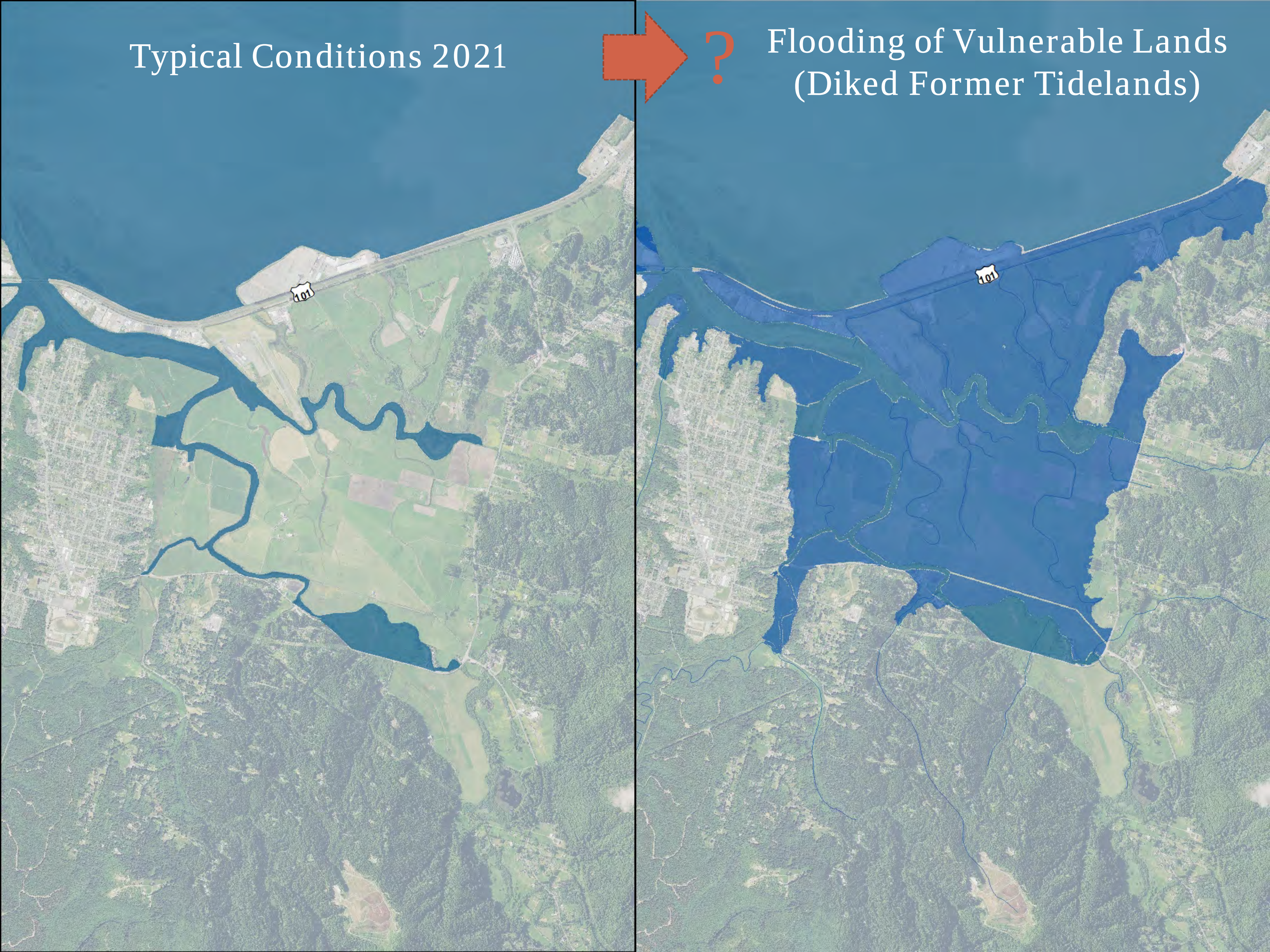
Flood Sources & Physical Processes:

- Tidal Stillwater and Surge
- Fluvial Flow
- Wind Waves
- Sediment Transport
- Groundwater

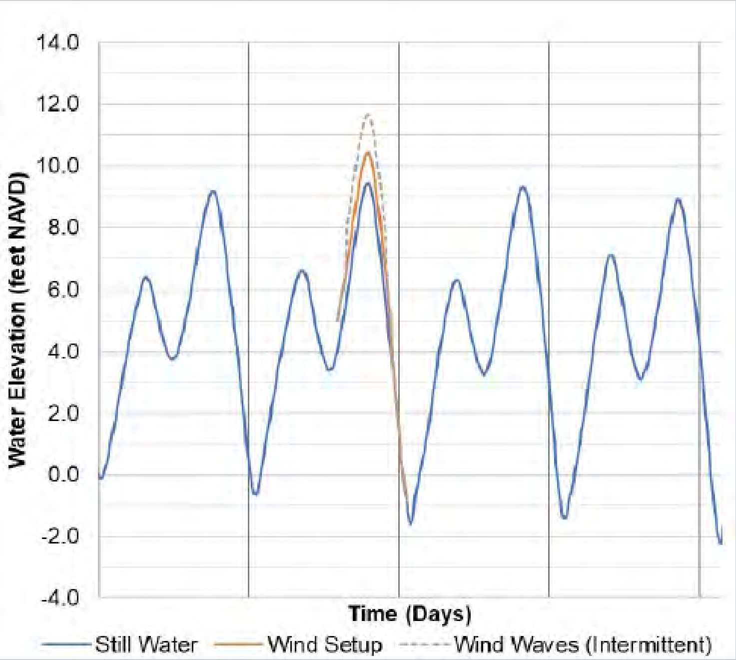

Cell I - First, Second, and Third Sloughs
Cell A - Brainard, Jacob's Ave, Murray Field, and Fay Slough Wildlife Area
Cell B - Indianola
Cell H - Eureka and Freshwater Slough Ag Land and Residential
Cell G - Freshwater & Ryan Slough Ag Lands
Cell C1 - Freshwater & Fay Slough Ag Lands - North
Cell F - Ryan Slough Ag Lands
Cell E - Freshwater Slough Commercial / Residential
Cell D - North Coast Regional Land Trust
Cell C2 - Freshwater & Fay Slough Ag Lands - South
Study Area
Diked Former Tidelands (Flood Cells)
Sub-tidal and Inter-tidal
Linear Landforms- Earthen Railroad Prism, Levees, and Dikes
Condition (Laird 2013 & GHD 2018) | Trend
Significant Erosion | Continuous Reduction of Elevation/Width/Slope
Moderate Erosion | Disturbance of Vegetation and/or Displacement of Armoring
Vegetated/RSP | Minimal Erosion
Armored RSP | Minimal Erosion

Hazard Scenarios for Flooding Impacts

- Scenario-based planning was applied at the scale of the hydrographic area
- Each scenario is a hypothesis about the potential cause-and-effect linkages between hydrologic and geomorphic processes and physical changes to the landscape and seascape
- 13 scenarios were developed for this study (11 existing conditions, 2 assuming Humboldt Bay Trail South project as designed)
- Objectives:
  1. Gain a better understanding of dynamic physical processes
  2. Interpret technical information to make flooding risks more understandable
  3. Explore thresholds and tipping points to gain a better understanding of site-specific vulnerabilities
  4. Inform the design objectives for adaptation projects to maximize effectiveness
  5. Increase the robustness of decisions


Typical Conditions 2021
?
Flooding of Vulnerable Lands
(Diked Former Tidelands)
101
101

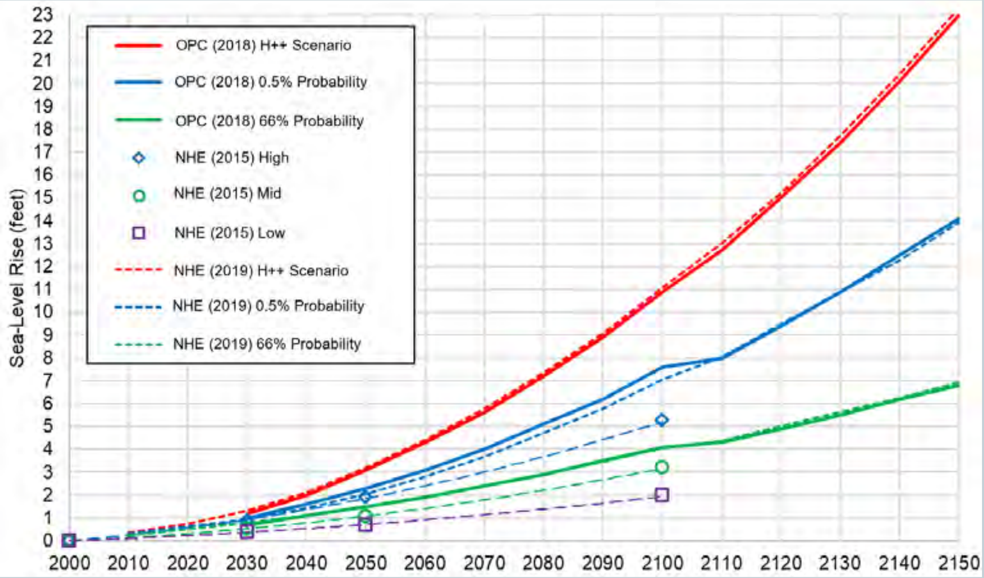
Hydraulics and Sea Level Rise



Tidal Still Water Level: 9.3 ft NAVD
Wind Set-up: 1 ft **(10.3 ft NAVD)**
Wind Wave Height: 2.4 ft
Wave Runup Range: 1.5 ft - 4.5 ft **(12 - 15 ft NAVD)**

Approx. Equivalent Still Water with Sea Level Rise (SLR)

50-yr + 0 ft SLR	MMMW + 2.0 ft SLR	
10-yr + 0.5 ft SLR	MHHW + 3.5 ft SLR	
2-yr + 1.0 ft SLR		



Conceptual Model to Characterize Landscape Response to Tidal and Fluvial Flooding

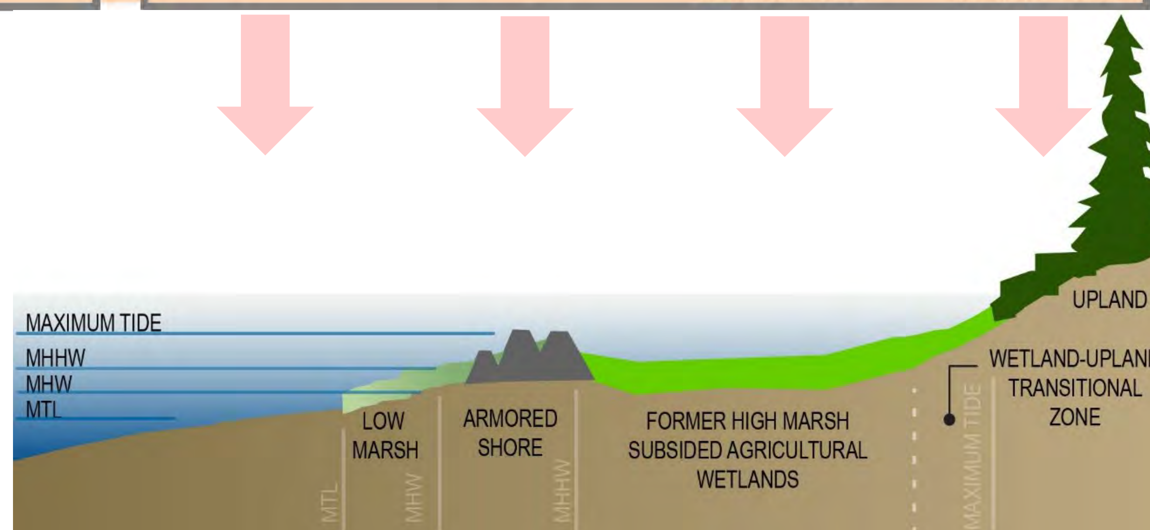
Physical Drivers

- **Relative Sea-Level Rise** (local SLR + vertical land motion)
- **Increased Precipitation Intensity**
- **Change in Sediment Supply**
- **Shoreline Interventions (Physical alterations)**

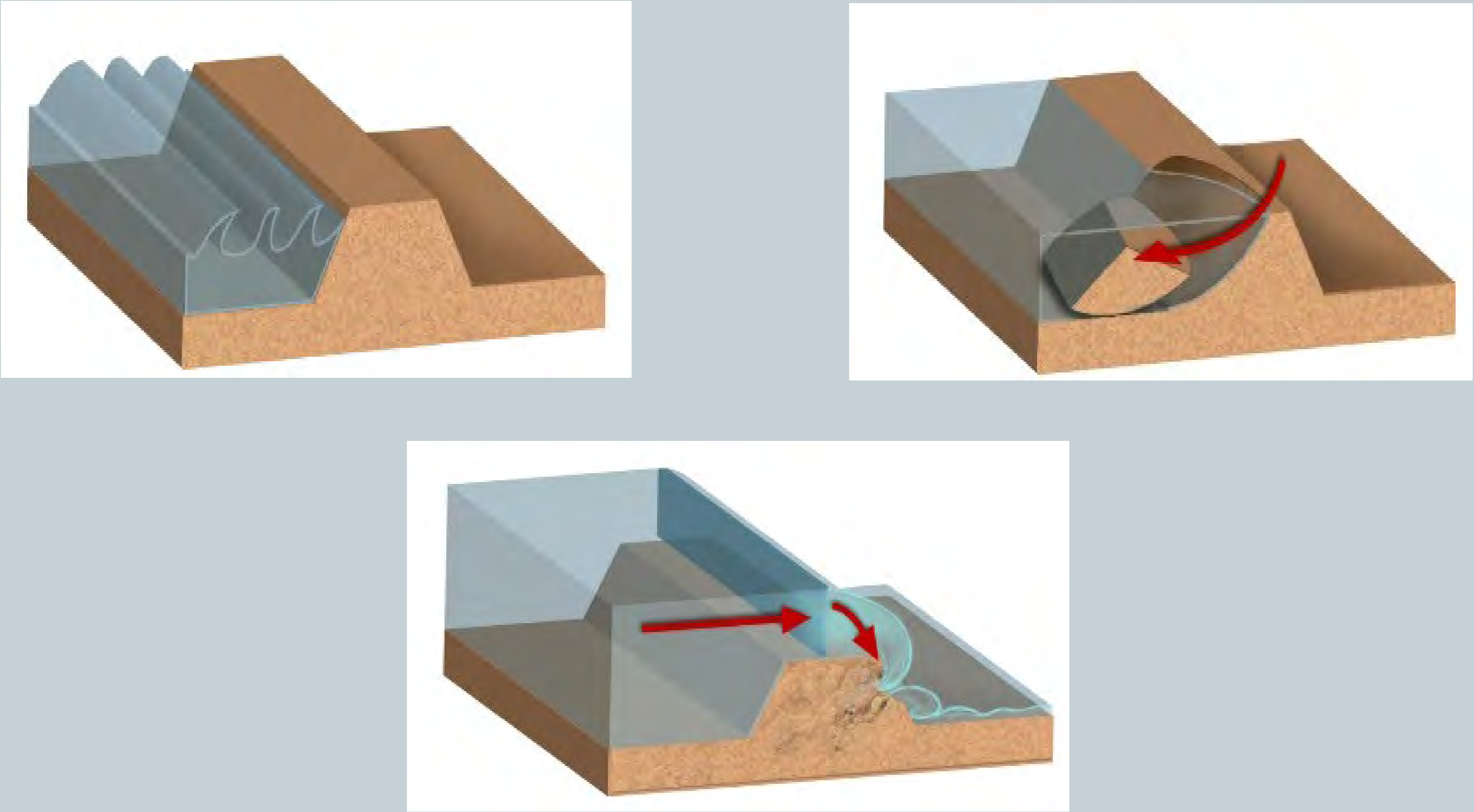
Physical Response of Geomorphic Units

Physical Processes	Sub-tidal and inter-tidal (mudflats, salt marsh and channels)	Linear Landforms (earthen levees, dikes, railroad prism)	Diked Former Tidelands (protected low-lying land and managed sloughs)	Uplands
Tidal still water and coastal storm surge	Change in elevation	Erosion, seepage, overtopping	Impede drainage	Erosion, impeded drainage
Fluvial flows	Erosion, accretion	Erosion, seepage, overtopping	Impeded drainage	Backwater, impeded drainage
Wind waves	Erosion, accretion	Erosion, overtopping	Overtopping	Erosion, impeded drainage
Sediment transport	Sediment source and sink	Sediment source, impedes transport	Sediment sink, sediment starved	Sediment source
Groundwater	Increase infiltration	Seepage	Alter groundwater table, salinization	Alter groundwater table, salinization

Adapted from IPCC, 2019



Shoreline Conditions and Geomorphic Response



Example Shoreline Structure Responses (National Science Foundation, 2020)

Resource Impact Thresholds

Asset Impacts		
Initiation of Impacts	Increasing	Most Severe
Increasing Water Levels →		

Infrastructure

- Levees, Rail Prism, Roads

Utilities

- Water, Sewer, Gas, Communications

Land Use

- Residential, Commercial, Industrial, Agricultural

Work Products

Case Studies

HAZARD SCENARIO 3

Tidal Still Water Level		Approximate Equivalent Still Water Event with Sea Level Rise		
10.3 feet NAVD	Existing (2012 baseline) ~50-year 2% chance per year	1 foot 2-year 50% chance per year	2 feet MMMW 5 to 6 events per year	3.5 feet MHHW Daily - Weekly

Introduction (See Exhibit HS 3-1):

This case study describes a scenario characterized by similar hydraulic conditions observed on December 31, 2005, the highest observed tide affecting the Study Area[1]. An extreme high tide coincided with a high wind event from the west-southwest. The strong winds elevated water levels (wind setup) along eastern Arcata Bay, in addition to producing waves. Water levels overtopped large sections of the rail prism, which exceeded the capacity of the adjacent drainage channel, flooding the southbound travel lanes of Highway 101. Flood waters entered the median drainage ditches and were conveyed into the drainage network east of the highway. Northbound travel lanes were not flooded. The storm impacts resulted in flooding throughout the Study Area; hazardous conditions for motorists traveling southbound on Highway 101 and eventual closure of the highway for multiple hours; damage to the rail prism requiring repairs to restore pre-event flood protection; and extensive post storm cleanup of roadways, drainage channels and flooded areas.

Photo of December 31, 2005 storm from Highway 101 Southbound.

Highlighted shoreline processes in this scenario include wave erosion, slope failure/erosion of bay- and slough-facing slopes, and overtopping with land-facing slope erosion. Conceptual examples shown below.

Wind Waves	Slope Failure/Erosion	Overtopping and Erosion
Arcata Bay Shoreline Erosion and Overtopping	Arcata Bay Shoreline Rail Prism	53% of Arcata Bay Shoreline 15% of Interior Slough Levees

Example Shoreline Structure Responses (National Science Foundation, 2020)

Hydraulics and Sea Level Rise:

This scenario combines extreme spring tides that typically occur in the months from November through January, with a low-pressure system (storm surge) that increases predicted tidal water levels entering Humboldt Bay and strong, continuous winds from the west that elevate water levels along the eastern shore of Arcata Bay and generate waves. Based on predicted tides leading up to a still water level event of 9.3 feet (NAVD), high tides exceed 9.0 feet (NAVD) the day prior to the peak and the day following[2]. On the day of the 9.3 foot (NAVD) peak tide, wind setup increases water levels by 1 foot throughout the Study Area, to 10.3 feet (NAVD). The wind produces a significant waves height of 2.4 feet, which intermittently increase water levels to between 12 and 15 with wave runup on the rail prism and levees. Based on modeled wind speeds of 45 mph from the west/southwest in Eureka Slough, wind waves in the sloughs are not a significant erosional process and are therefore not added

[1] NOAA 2020. Datums for 9418767, North Spit CA.

[2] NHE 2019. Draft -Hydraulic Modeling to Support the Sea Level Rise Adaptation Plan for Humboldt Bay Transportation Infrastructure (Phase 1) Project, Humboldt County, CA December 2019

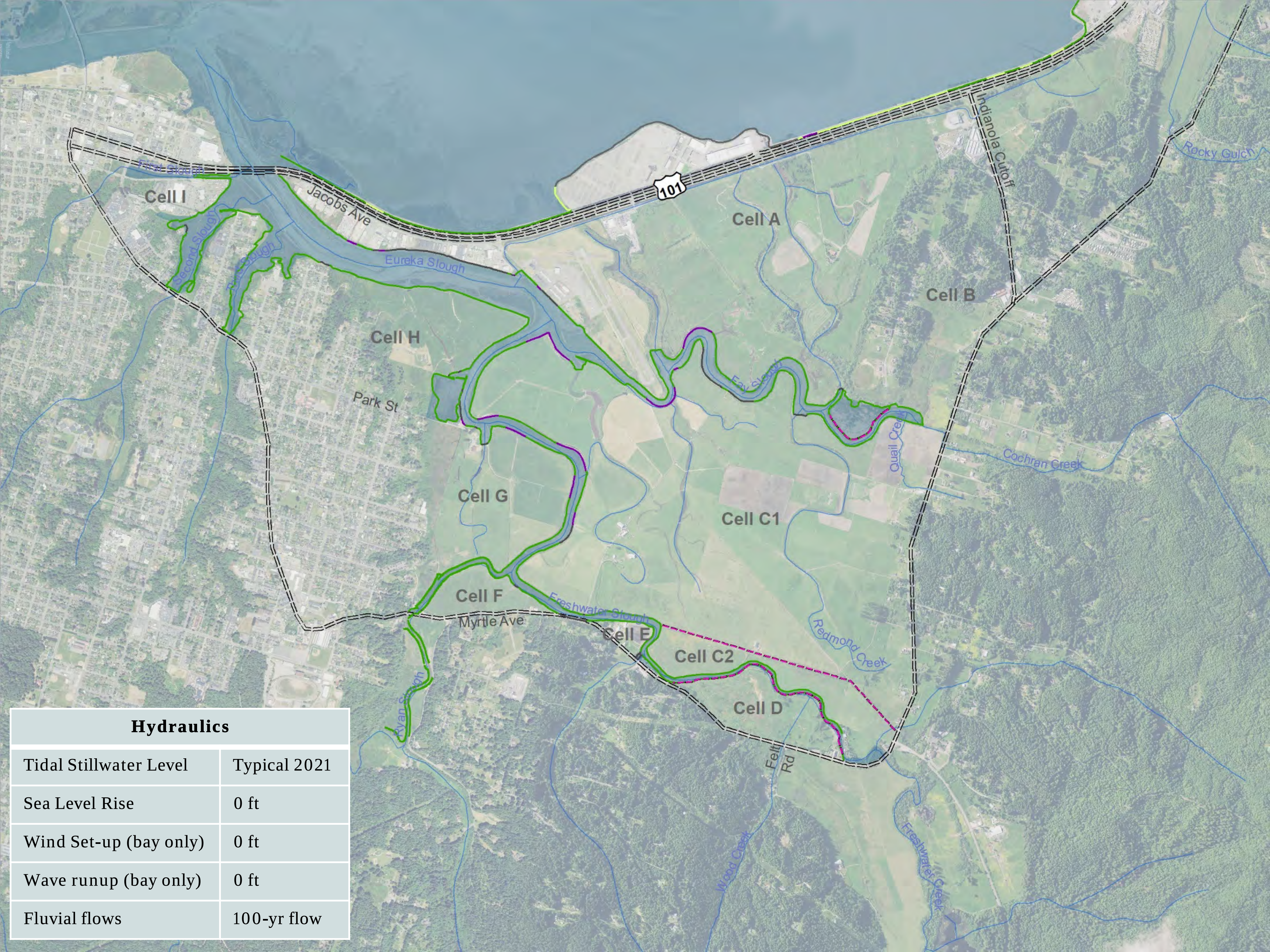
Inventory of Impacts

Table 4. Critical Resource Response and Impact Evaluation

Critical Resource		Physical Process	Location/Exposure	Flood Depth/Duration/ Extent	Impact to Resource
Shoreline Protection	Earthen Levees/ Dikes	Overtopping (depth and time)	Cell A	shallow (<1ft) and/or short (< 2hrs)	Top and Land-facing Slope Rill Erosion
			Cell B	>1ft and >2 hrs	Potential Failure
			Cell C	>1ft and >2 hrs	Potential Failure
			Cell E	>1ft and >2 hrs	Potential Failure
			Cell F	shallow (<1ft) and/or short (< 2hrs)	Top and Land-facing Slope Rill Erosion
			Cell G	>1ft and >2 hrs	Potential Failure
			Cell H	shallow (<1ft) and/or short (< 2hrs)	Top and Land-facing Slope Rill Erosion
	Rail Prism	Wind Waves (height)	Cell A- Arcata Bay	1.5-4.5 ft	Top and Land-facing Slope Rill Erosion
		Overtopping (depth and time)	Cell A- Arcata Bay	shallow (<1ft) and/or short (< 2hrs)	Top and Land-facing Slope Rill Erosion
Transportation	Hwy 101 Southbound	Surface Flooding (ft)	Cell A - Arcata Bay	2	Closure & Damage
	Hwy 101 Northbound		Cell A - Arcata Bay	none	none
	Jacobs Ave		Cell A (ft)	0.1	Shallow Flooding
	Airport Road		Cell A	2	Closure & Damage
	Indianola Cutoff		Cell A	-	none
	Park Street		Cell G	2	Closure & Damage
	Hoover Street		Cell I	0.9	Closure
	2nd and Y Streets		Cell I	0.5	Closure
	4th, 5th, 6th, V St		Cell I	-	none
	Myrtle Ave		Cells B, C, F, D	-	none
	Hwy 255 (Alternate Route)		Arcata Bay	-	none
Utilities	Sewer Lift Stations	Surface Flooding (ft)	City of Eureka Jacobs Ave #1	-	none
			City of Eureka Jacobs Ave #2	-	none
			City of Eureka Y Street	-	none
			City of Eureka Hill Street (Tydd Street)	0.5	Shallow Flooding
			Humboldt CSD Hoover Street	0.5	Shallow Flooding
			Humboldt CSD Edgewood	-	none
	Water Booster Station		City of Eureka Myrtle Ave	0.2	Shallow Flooding
	Sewer or Water Pressure Main		Cell A Jacobs Ave - COE	26	Limited Access Multiple Days

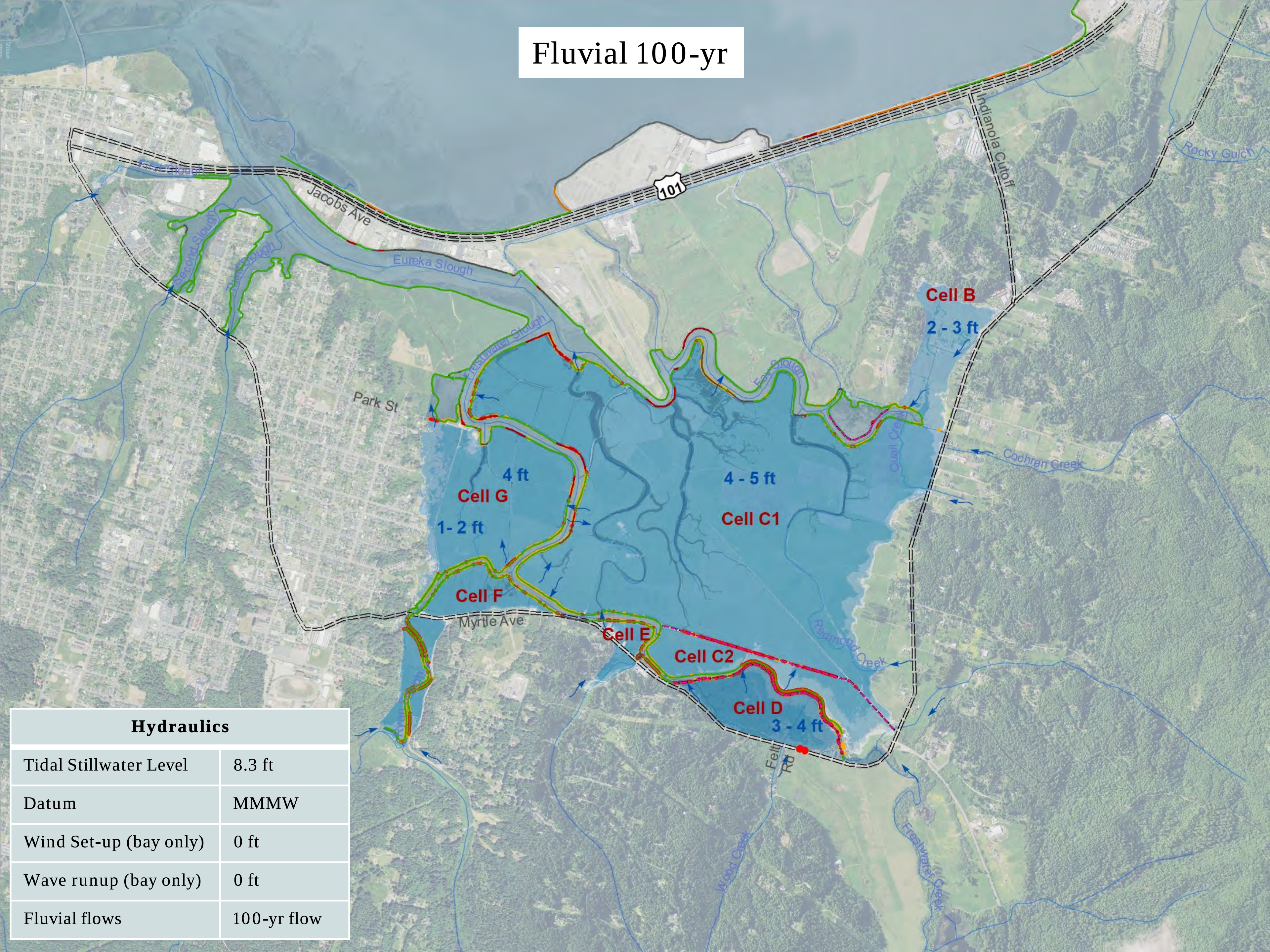
Summary

SCENARIO ELEMENTS		1 Typical King Tide with Wind	2 Extreme Tide
HYDRAULICS AND SEA LEVEL RISE (SLR)			
Tidal Still Water Level (NAVD)		8.3ft	9.3ft
Wind Set-up		0.5ft (8.8ft NAVD)	0
Wind Wave Height		1ft	0
Wave Runup		0.5ft – 1ft	0
Total Water Level (TWL) NAVD (Bay Shoreline)		9.3-10.3ft	9.3ft
Approximate Equivalent Still Water Event with SLR		King Tide + 0ft SLR 2-yr + 0.5ft SLR MHHW + 2ft SLR MHW + 3ft SLR	2-yr + 0ft SLR MMMW + 1ft SLR MHHW + 2.5ft SLR MHW + 3.5ft SLR
RESOURCE RESPONSE & IMPACT SUMMARY (see case study descriptions			
Overtopping		Limited, Select, Isolated Locations	Limited, Select, Isolated Locations
Cell A Bay Shoreline		< 0.1 mi, < 0.1 ac-ft	< 0.1 mi, < 0.1 ac-ft
Cell A Interior Shoreline		0	30 ft, 0.7 ac-ft
All other Cells		< 0.1 mi	0.5 mi
Shoreline Erosion Potential	Low	Wind Waves	N/A
	Moderate	Rill	Rill
	High	None	None
Transportation Resources Impacted		Usability Disruption: Park Street	Usability Disruption: Park Street
Other Critical Resources Impacted		No Significant, Observable Impacts	Minor: Underground Utilities Moderate: Agricultural Lands
Key Findings and Conclusions		No significant episodic impacts. Typical long-term erosion and geomorphic processes. Minor flooding of Park Street.	Approximate elevation when overtopping begins. Existing drainage infrastructure has capacity to convey overtopping flow.



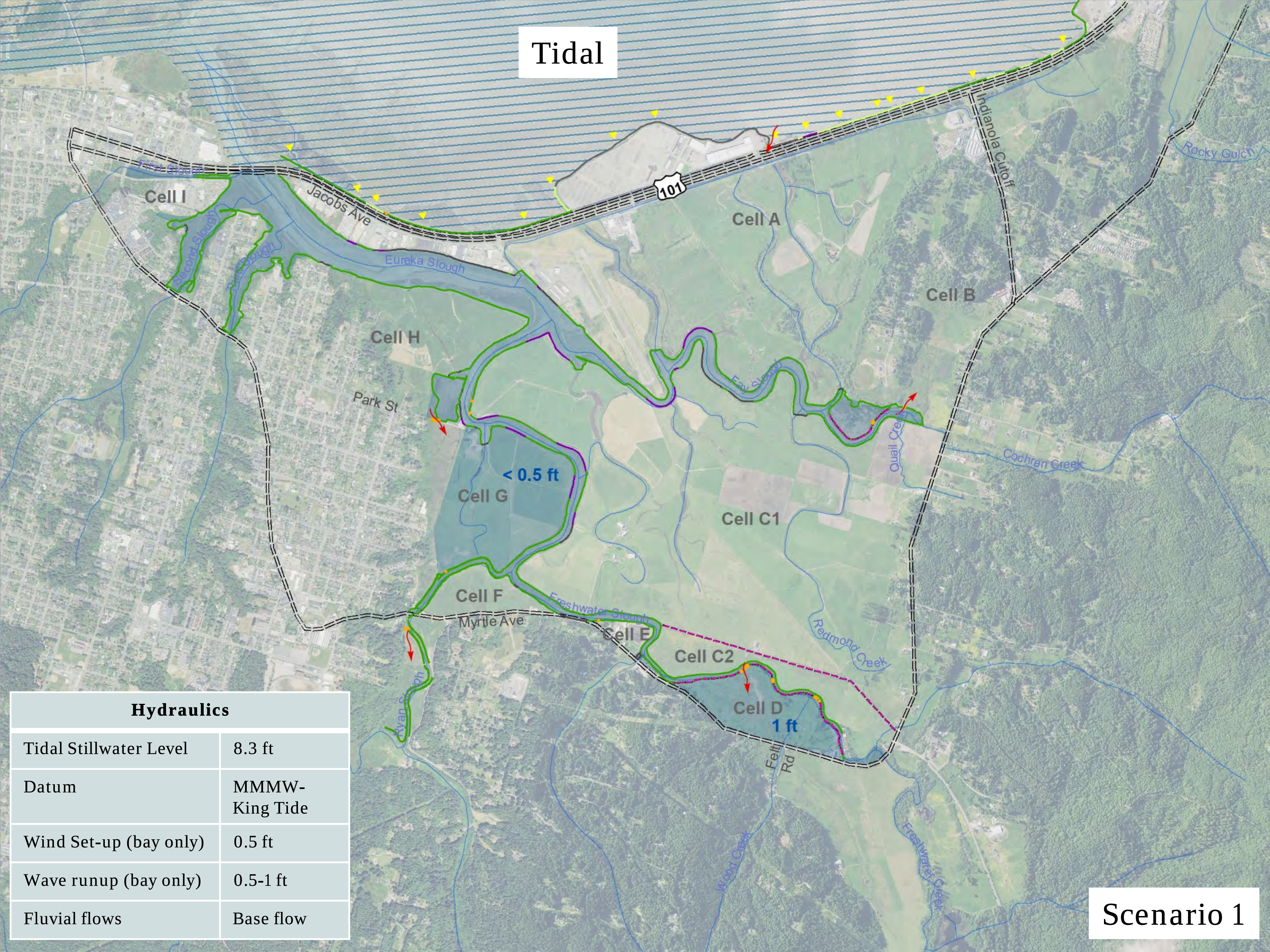
Hydraulics	
Tidal Stillwater Level	Typical 2021
Sea Level Rise	0 ft
Wind Set-up (bay only)	0 ft
Wave runup (bay only)	0 ft
Fluvial flows	100-yr flow

Fluvial 100-yr



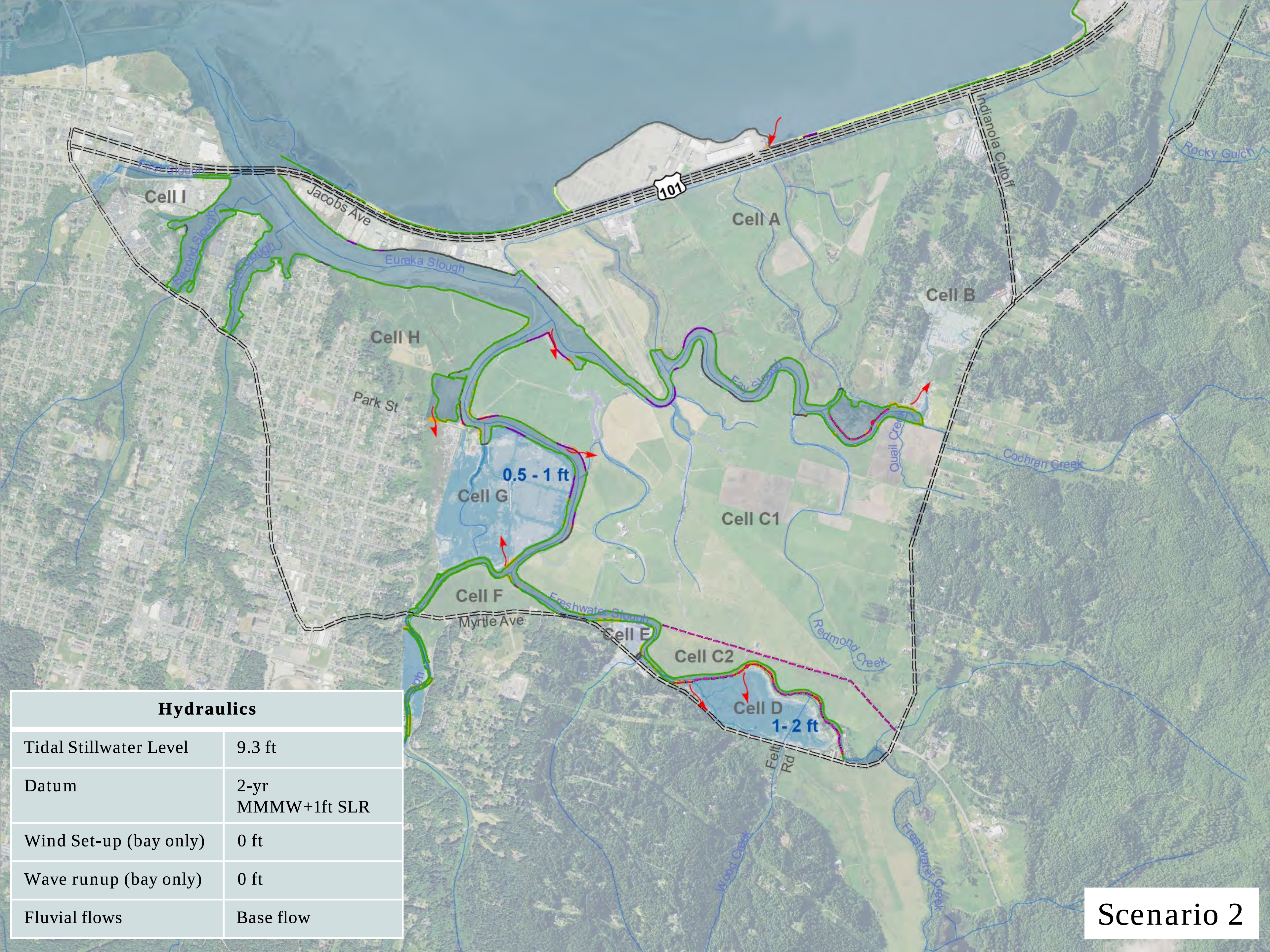
Hydraulics	
Tidal Stillwater Level	8.3 ft
Datum	MMMW
Wind Set-up (bay only)	0 ft
Wave runup (bay only)	0 ft
Fluvial flows	100-yr flow

Tidal



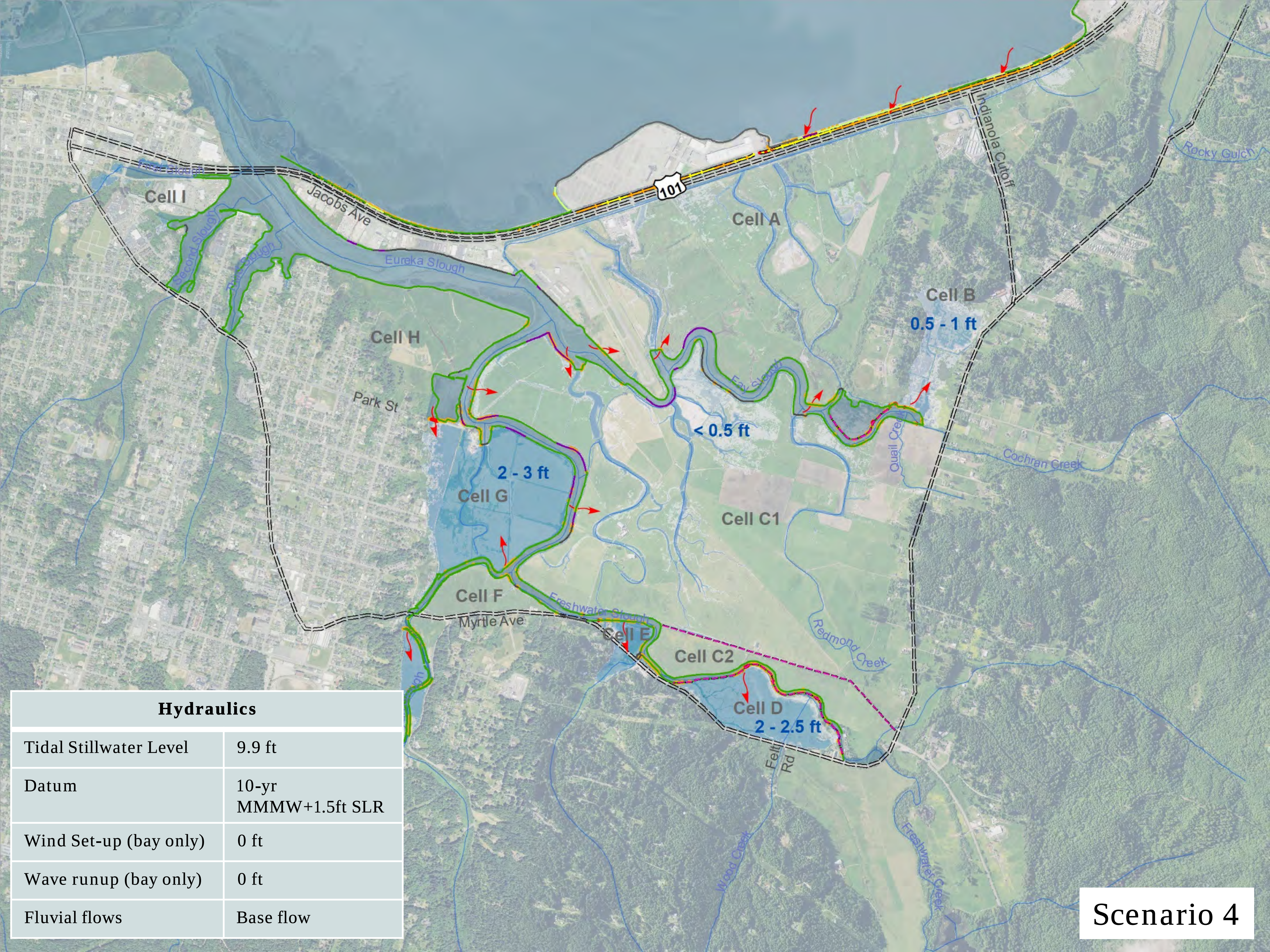
Hydraulics	
Tidal Stillwater Level	8.3 ft
Datum	MMMW- King Tide
Wind Set-up (bay only)	0.5 ft
Wave runup (bay only)	0.5-1 ft
Fluvial flows	Base flow

Scenario 1



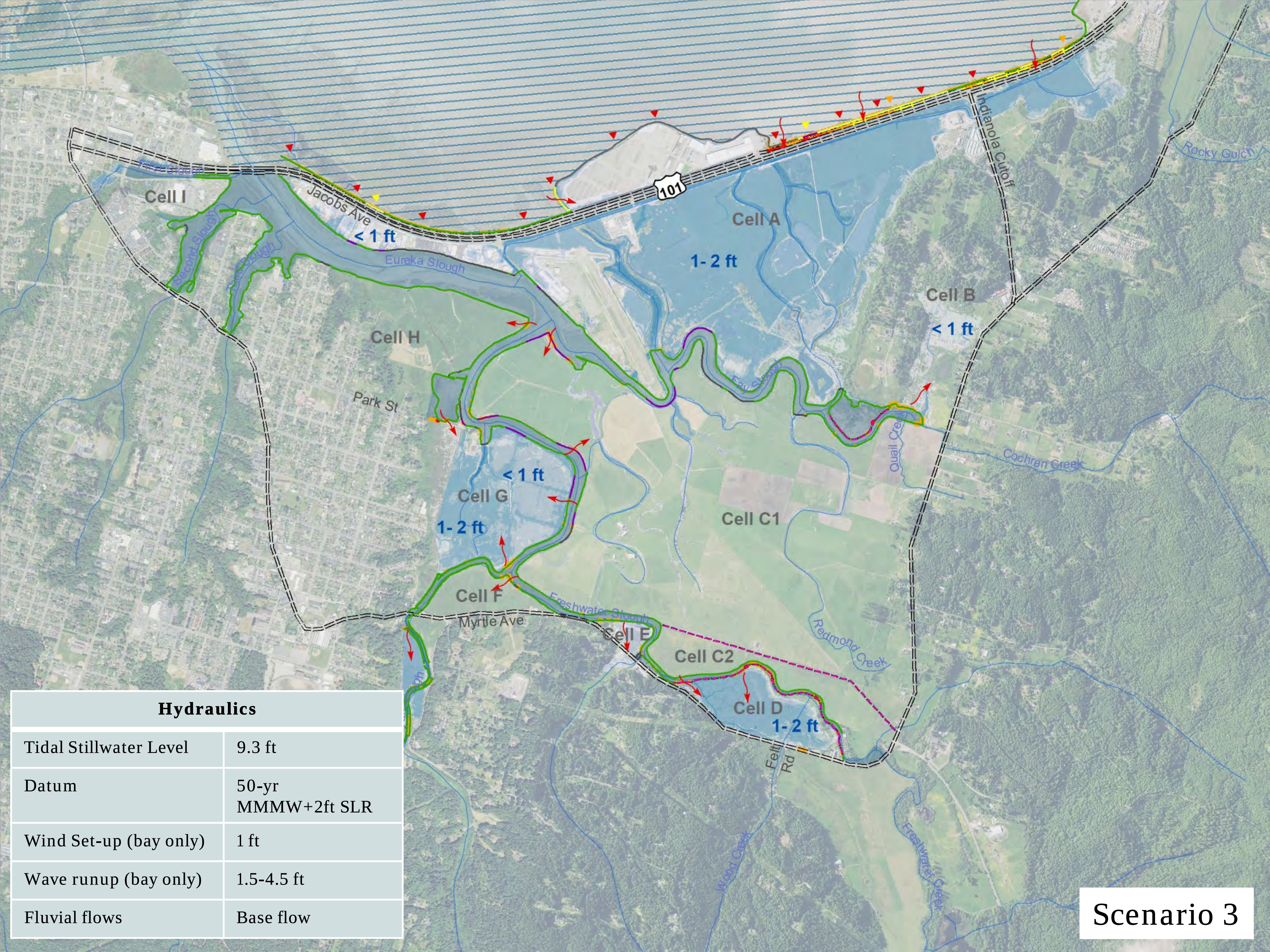
Hydraulics	
Tidal Stillwater Level	9.3 ft
Datum	2-yr MMMW+1ft SLR
Wind Set-up (bay only)	0 ft
Wave runup (bay only)	0 ft
Fluvial flows	Base flow

Scenario 2



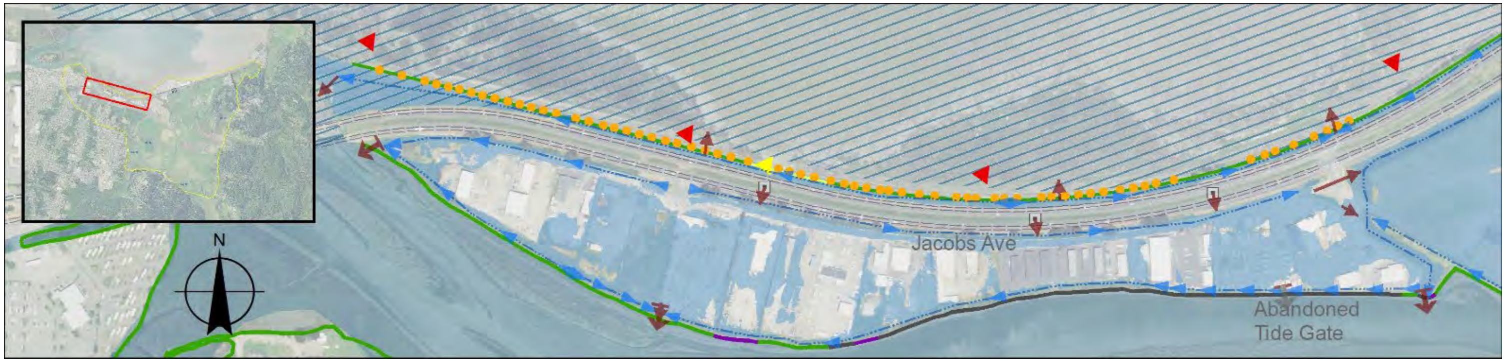
Hydraulics	
Tidal Stillwater Level	9.9 ft
Datum	10-yr MMMW+1.5ft SLR
Wind Set-up (bay only)	0 ft
Wave runup (bay only)	0 ft
Fluvial flows	Base flow

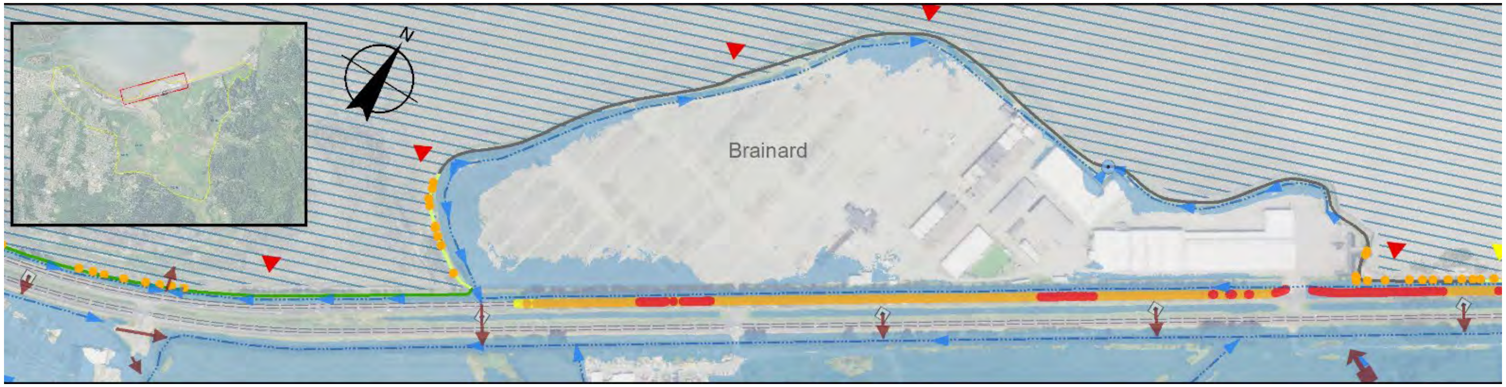
Scenario 4

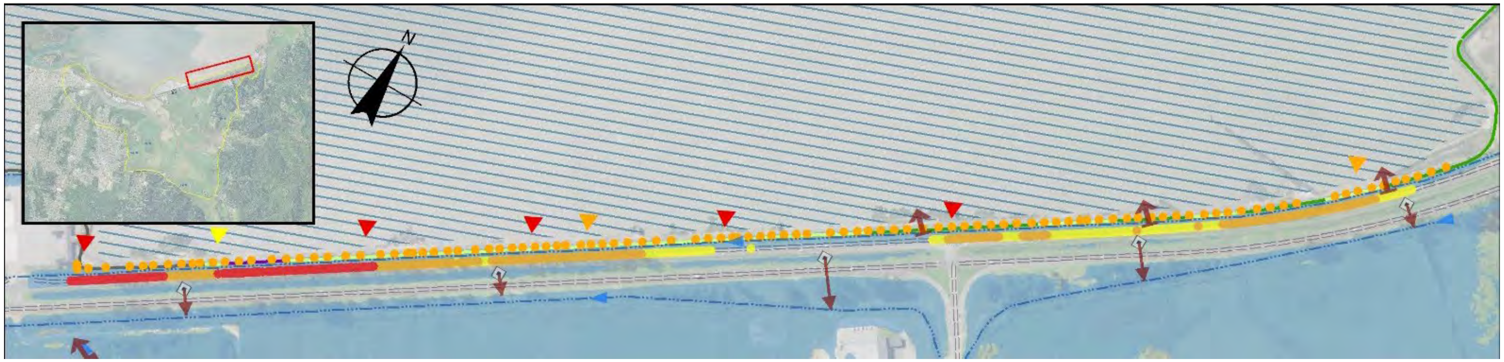


Hydraulics	
Tidal Stillwater Level	9.3 ft
Datum	50-yr MMMW+2ft SLR
Wind Set-up (bay only)	1 ft
Wave runup (bay only)	1.5-4.5 ft
Fluvial flows	Base flow

Scenario 3



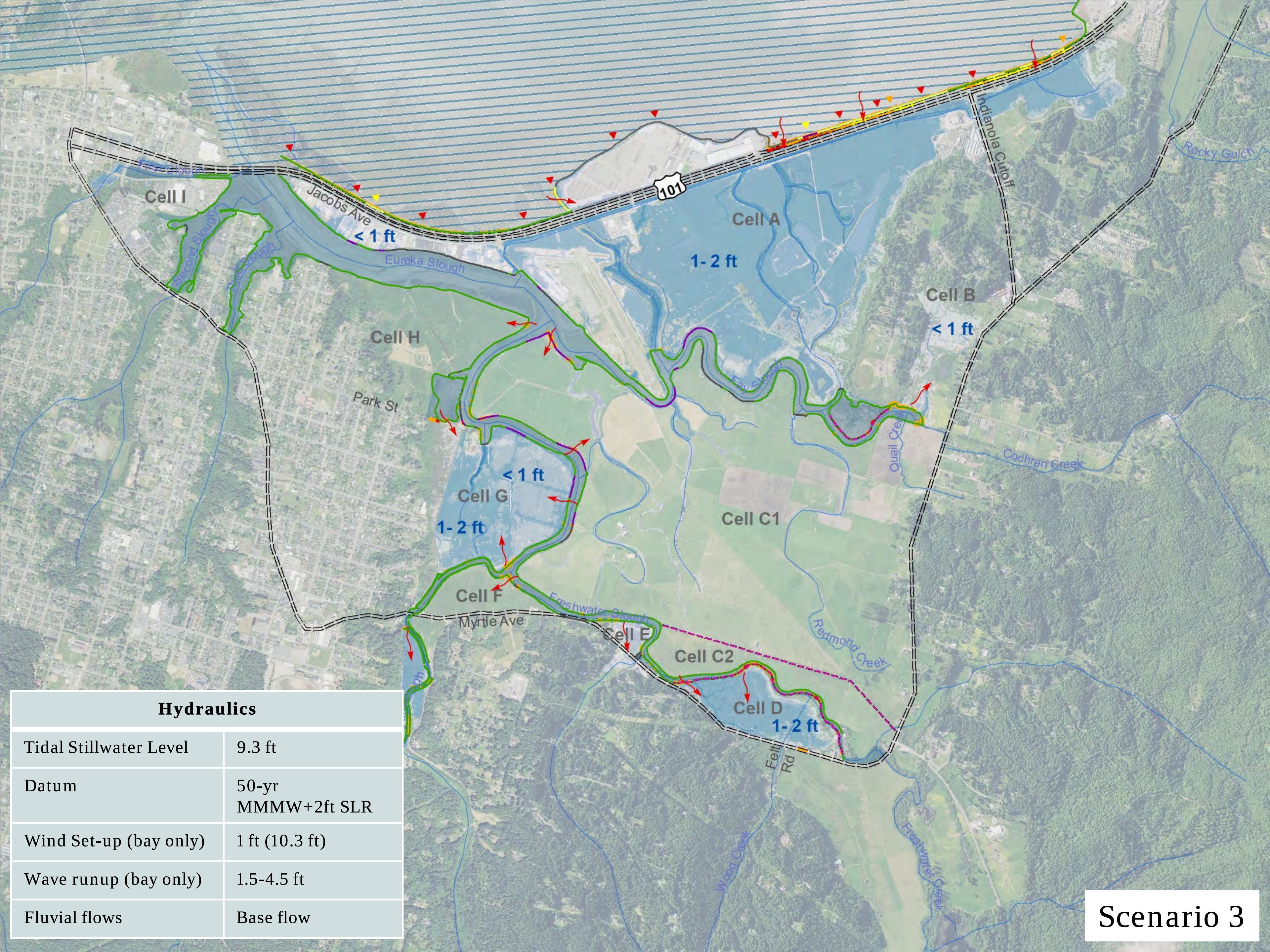




Scenario 3

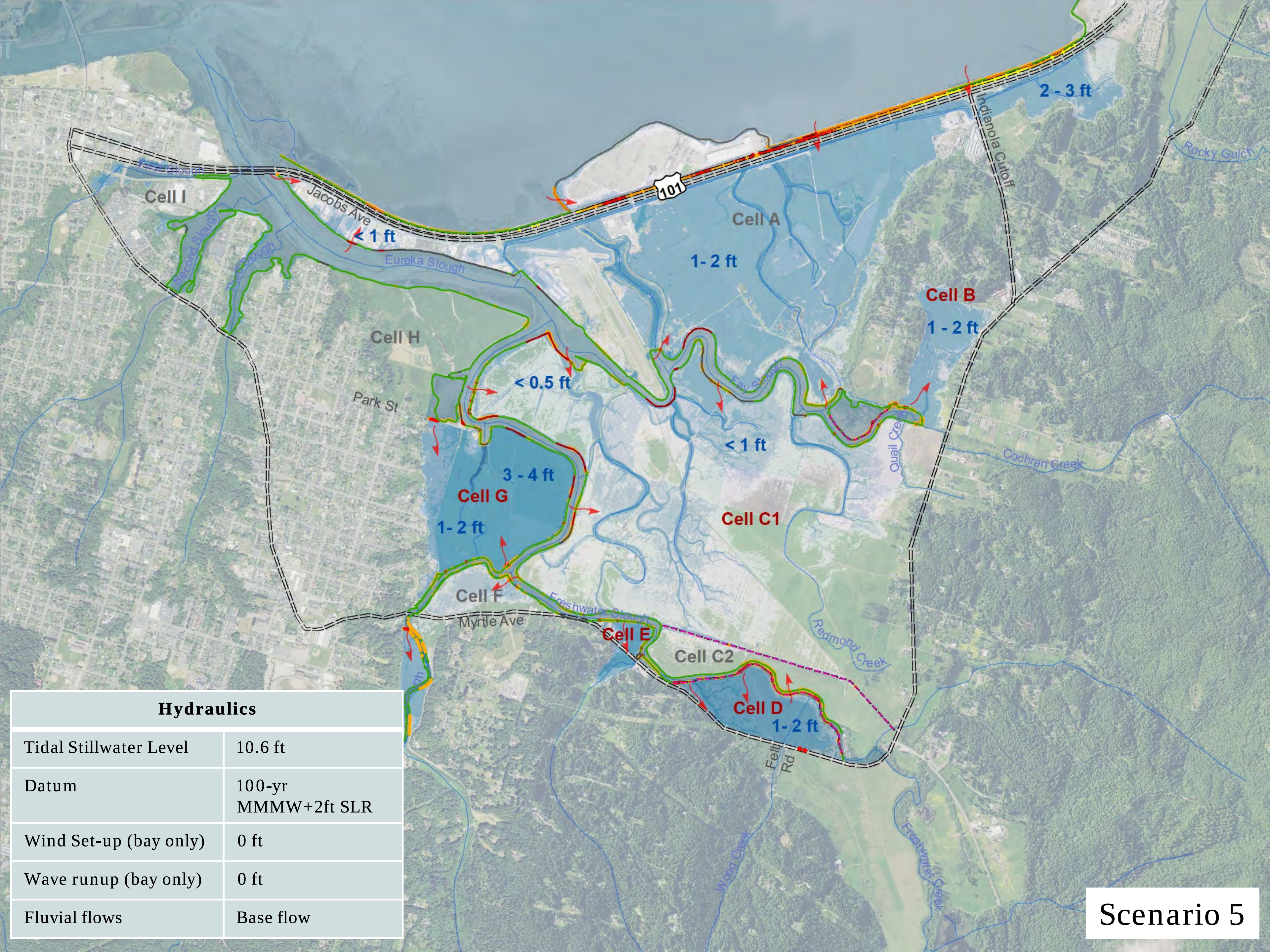
Eureka-Arcata Highway 101 Corridor: December 31, 2005

Eureka-Arcata Highway 101 Corridor: December 31, 2005



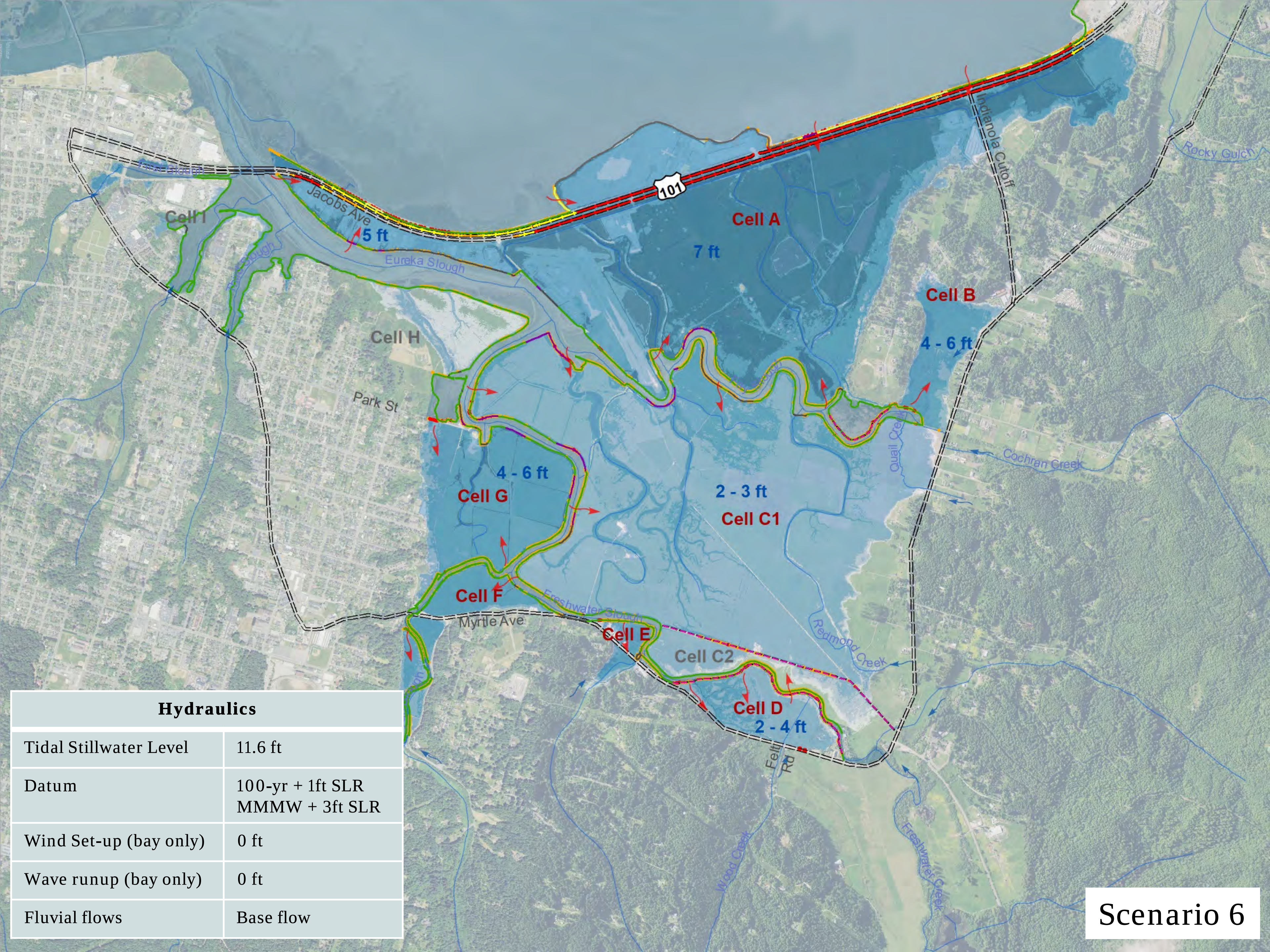
Hydraulics	
Tidal Stillwater Level	9.3 ft
Datum	50-yr MMMW+2ft SLR
Wind Set-up (bay only)	1 ft (10.3 ft)
Wave runup (bay only)	1.5-4.5 ft
Fluvial flows	Base flow

Scenario 3



Hydraulics	
Tidal Stillwater Level	10.6 ft
Datum	100-yr MMMW+2ft SLR
Wind Set-up (bay only)	0 ft
Wave runup (bay only)	0 ft
Fluvial flows	Base flow

Scenario 5



Hydraulics	
Tidal Stillwater Level	11.6 ft
Datum	100-yr + 1ft SLR MMMW + 3ft SLR
Wind Set-up (bay only)	0 ft
Wave runup (bay only)	0 ft
Fluvial flows	Base flow

Scenario 6

Hazard Scenarios: Key Findings

Asset Impacts		
Initiation of Impacts	Increasing	Most Severe
Increasing Water Levels →		

Water Level and Overtopping

10 ft → 10.5 ft → 11.5 ft

Salt Marsh and Wind Waves

Insignificant ← Overtopping & Erosion

Hazard Scenarios: Key Findings

Asset Impacts		
Initiation of Impacts	Increasing	Most Severe
Increasing Water Levels →		

Highway 101 Flooding

10 ft	→	11.6 ft
Shoulder Closure	Southbound Lanes	4 Lane Closure

Alternate Travel Routes

10 ft	10.6 ft	11.6 ft
Hwy 255	→	
Myrtle Ave	Myrtle Ave	Flooded

Hazard Scenarios: Key Findings

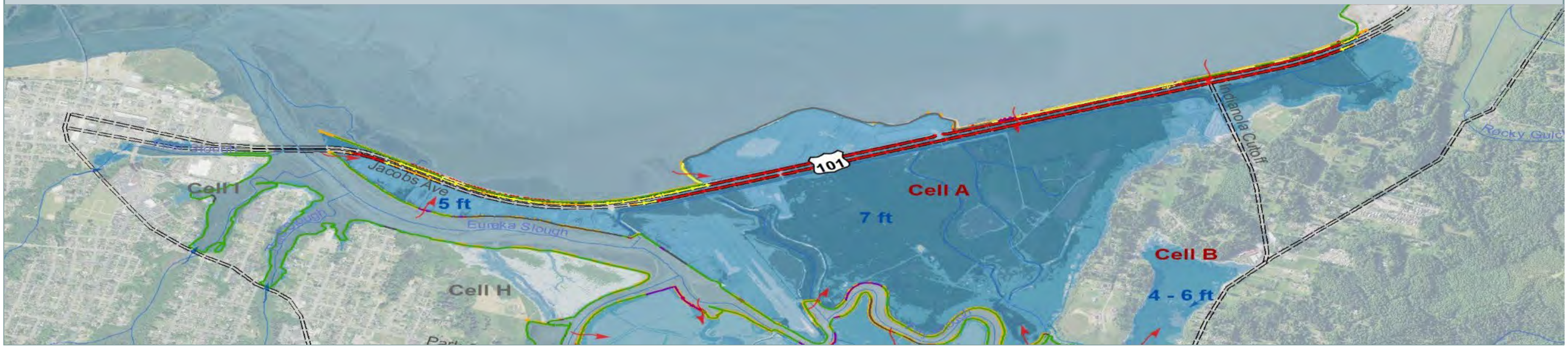
Asset Impacts		
Initiation of Impacts	Increasing	Most Severe
Increasing Water Levels →		

Inundation Pathways & Flood Reduction

Cell A Levees — **Brainard to Bracut**

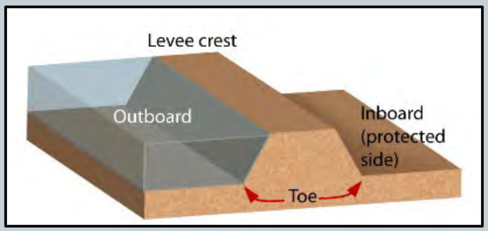
300 ac-ft ← **5,000 ac-ft**

11.6 ft Water Level

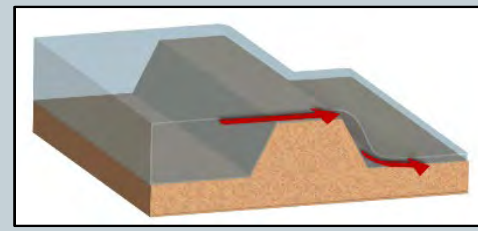


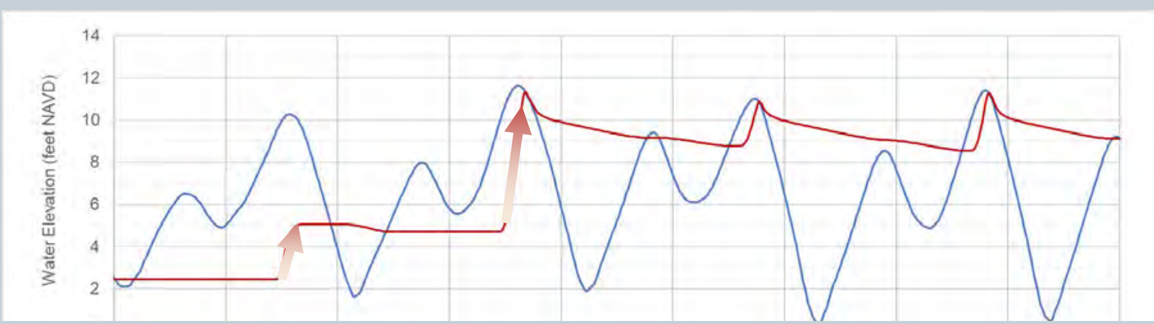
Hazard Scenarios: Key Findings

Asset Impacts		
Initiation of Impacts	Increasing	Most Severe
Increasing Water Levels →		



Jacobs Avenue & Fay Slough





Duration of Extreme Tides

Example Shoreline Structure Responses (National Science Foundation, 2020)

Hazard Scenarios: Key Findings

Asset Impacts		
Initiation of Impacts	Increasing	Most Severe
Increasing Water Levels →		

Utility Impacts - Access

10 ft	11.6 ft	12.6 ft
Hours	Days	Weeks

Qualitative Risk Assessment

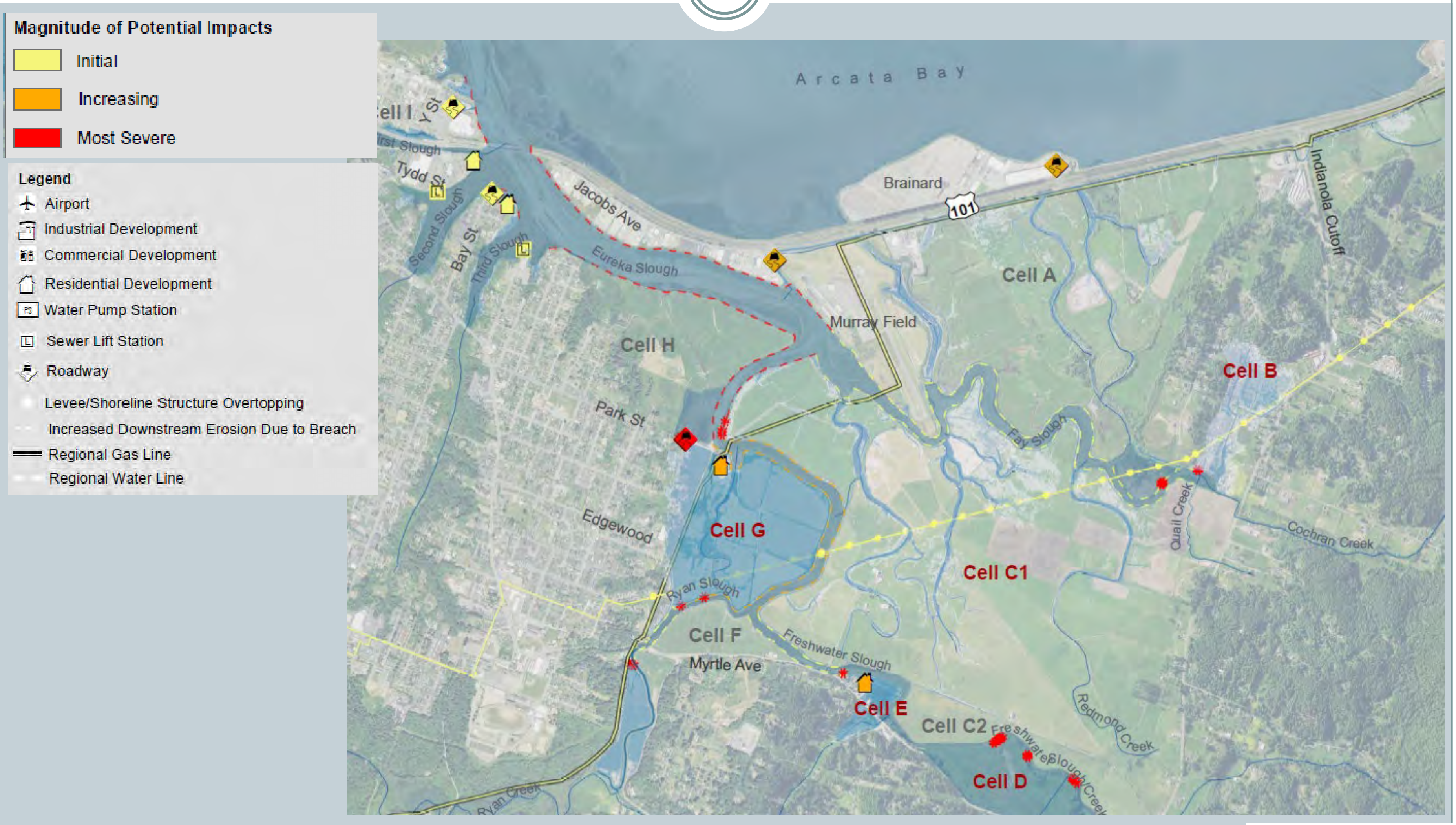
Evaluate public health and safety and economic consequences resulting from flooding and impacts to critical resources.

Risk:

Likelihood of Hazardous Flood Event 1% → 99%

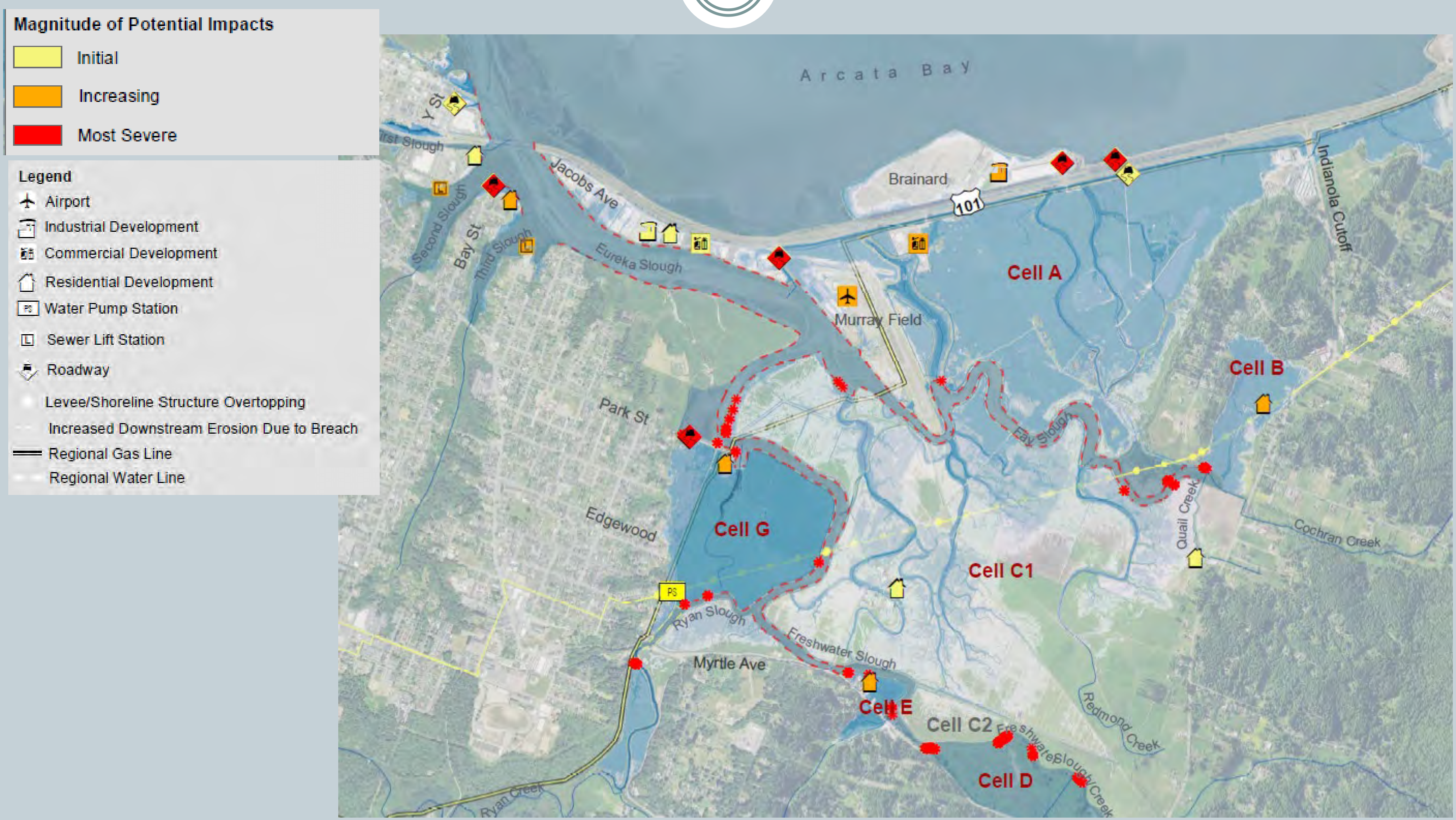
Magnitude of Consequence Nuisance → Life Safety

Mapped Qualitative Risk Assessment



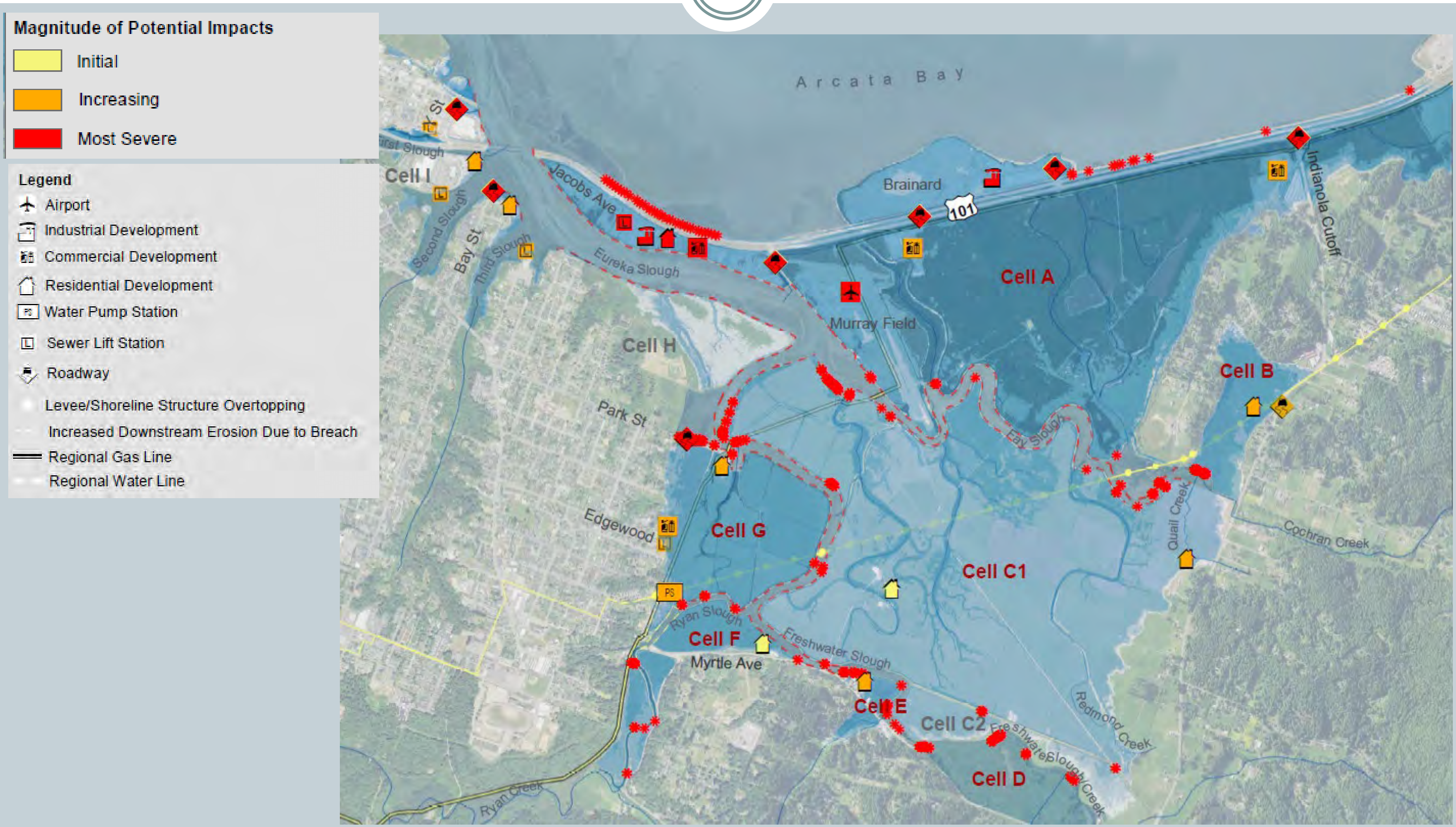
Scenario 4

Mapped Qualitative Risk Assessment



Scenario 5

Mapped Qualitative Risk Assessment



Scenario 6

Public Health & Safety

Death or Injury
- Flooding
- Ingress & Egress

Nuisance → Life Safety

Illness
- Exposure

Unknown → Multiple Known

Displacement
- Recovery

Recovery → Displacement/ Homelessness

Economic Loss

Services
- Disruption

Local → Regional

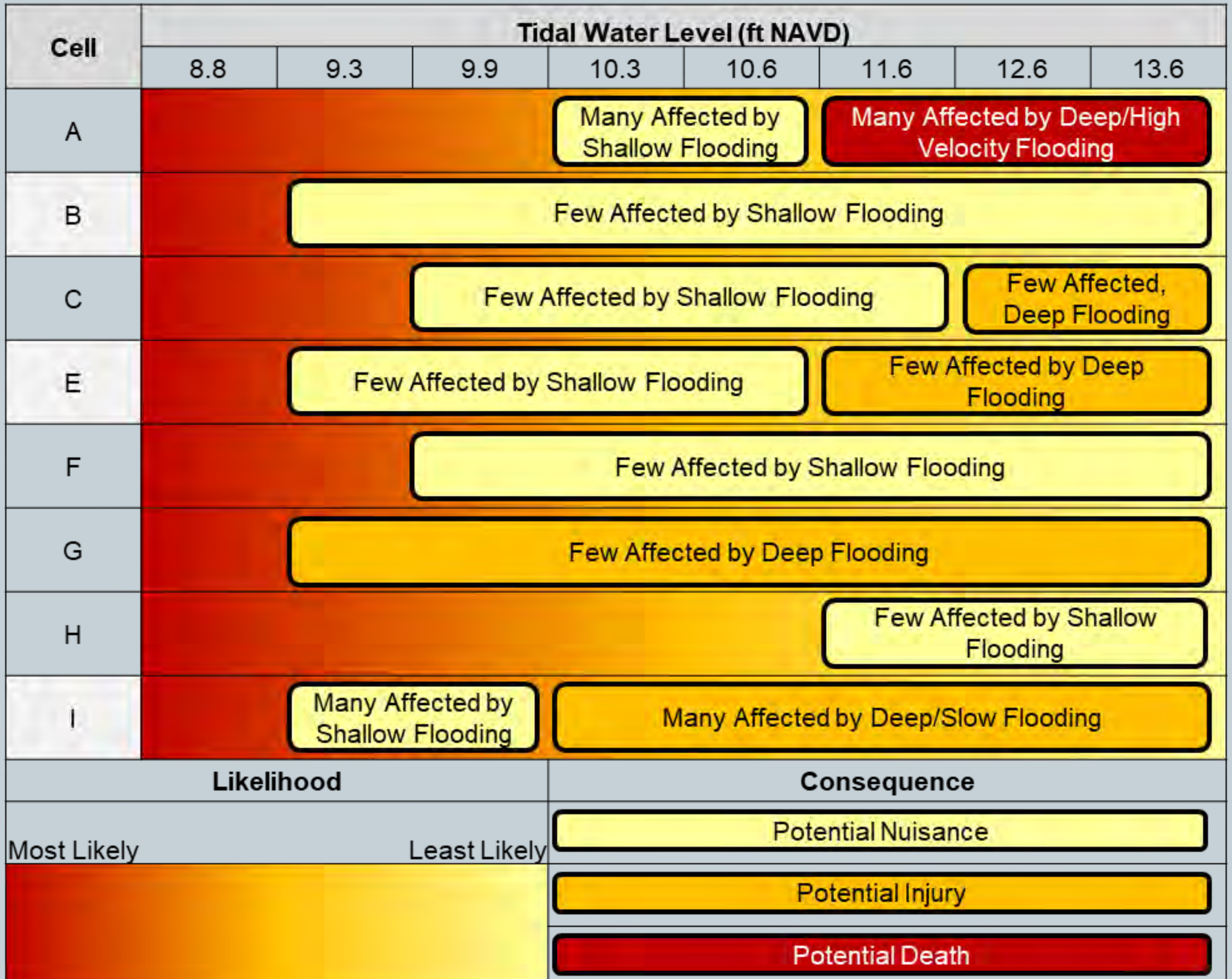
Structures, Goods, Services, Jobs
- Damage/Closure

Disruption → Long Term Closure

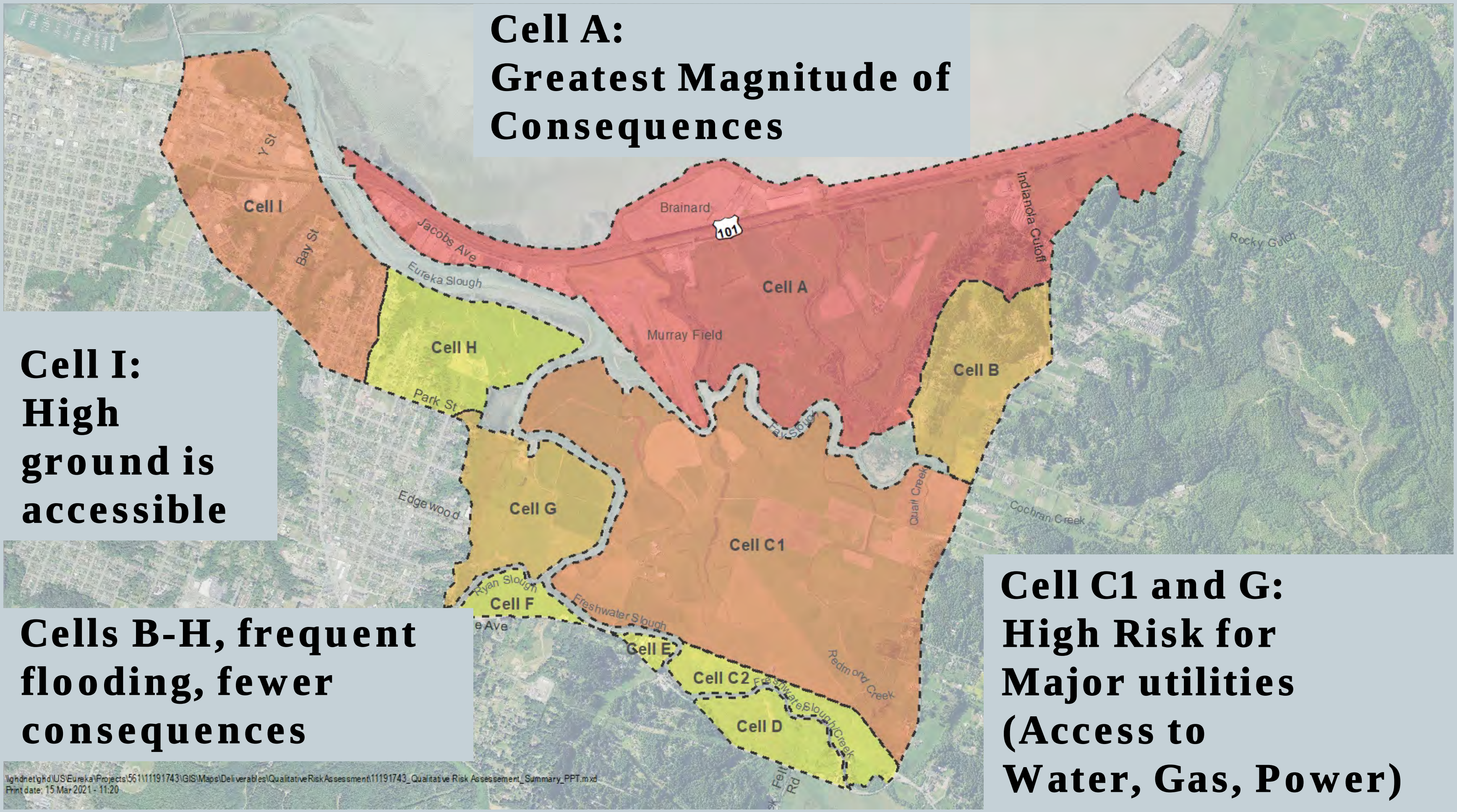
Agricultural Lands, Goods, Services
- Damage/Loss

Disruption → Land Use Changes

Example Evaluation



Qualitative Risk Assessment: Key Findings



Cell A:
Greatest Magnitude of Consequences

Cell I:
High ground is accessible

Cells B-H, frequent flooding, fewer consequences

Cell C1 and G:
High Risk for Major utilities (Access to Water, Gas, Power)

III. Adaptation Projects

Adaptation Project Development

- Driven by vision statement, key assumptions, guiding principles
- Fundamental goal is to reduce flood risk for critical resources during near-term planning horizon (current to mid-century)
- The long-range planning horizon (mid- to late-century) is opaque with uncertainty
- Aim for compatibility with future Caltrans Phased Adaptation Plan for Highway 101 (due 2025)
- Mix of nature-based and gray infrastructure project types
- Respond to stakeholder input and risk assessment (highest risk is Cell A)
- Think big at first; can scale down, refine, and value-engineer in future phases
- Did not identify near-term opportunities for managed retreat

Recommended Near-term Studies

Studies

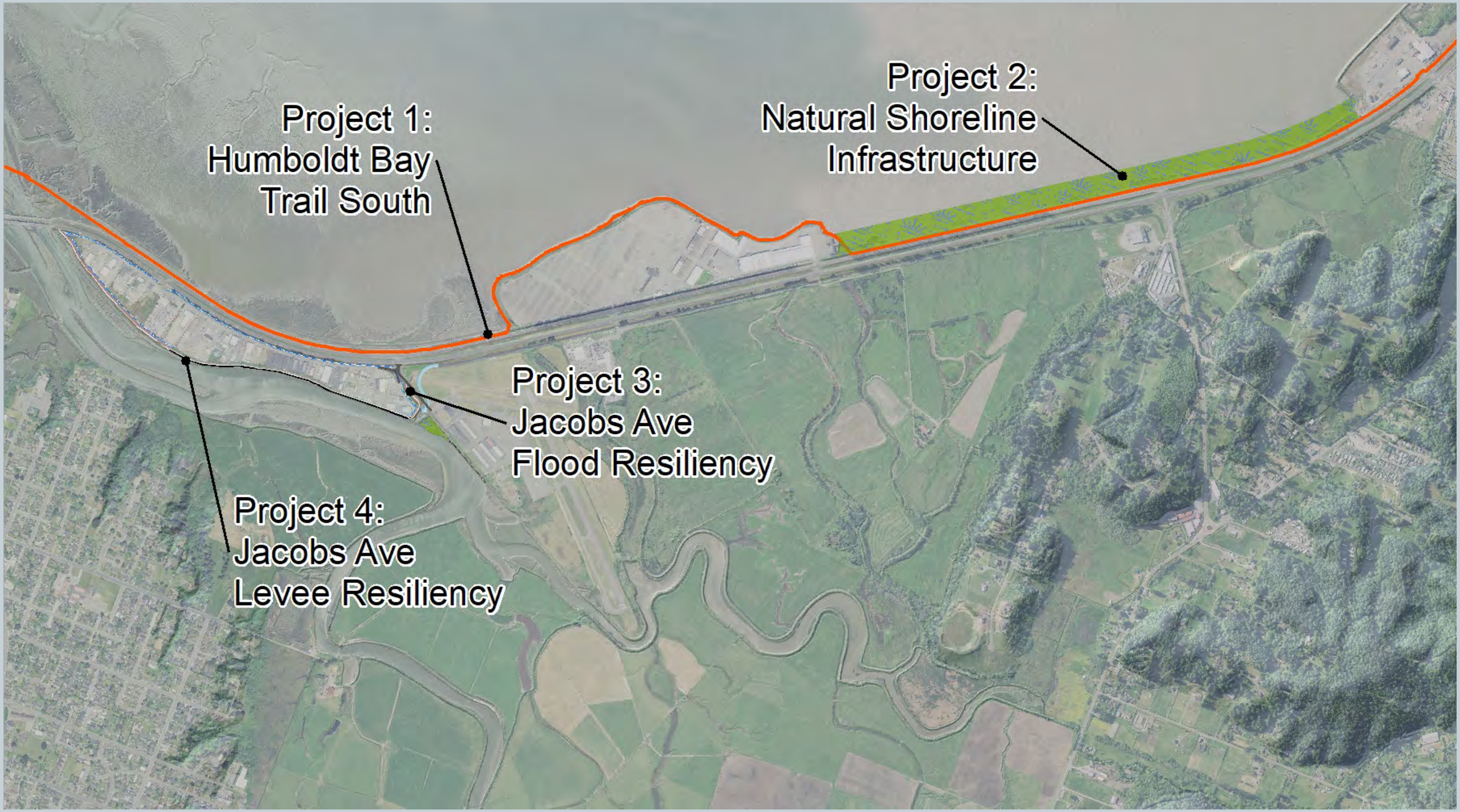
1. Develop an adaptation plan for the Jacoby Creek Hydrographic Area
2. Develop a salt marsh adaptation strategy
3. Prepare an emergency response and preparedness plan for Jacobs Avenue area
4. Assess opportunities to isolate and/or inter-connect the Cell A interior drainage network
5. Develop an adaptation feasibility study for the City of Eureka's water transmission line and water mains
6. Expand the Greater Eureka Area Traffic Model to include the Eureka-Arcata Highway 101 corridor, Highway 255, and Myrtle Avenue/Old Arcata Road and run closure scenarios
7. Other scientific and engineering studies that advance understanding of physical processes and critical resource response to sea level rise

Recommended Near-term Project Concepts

Project Concepts

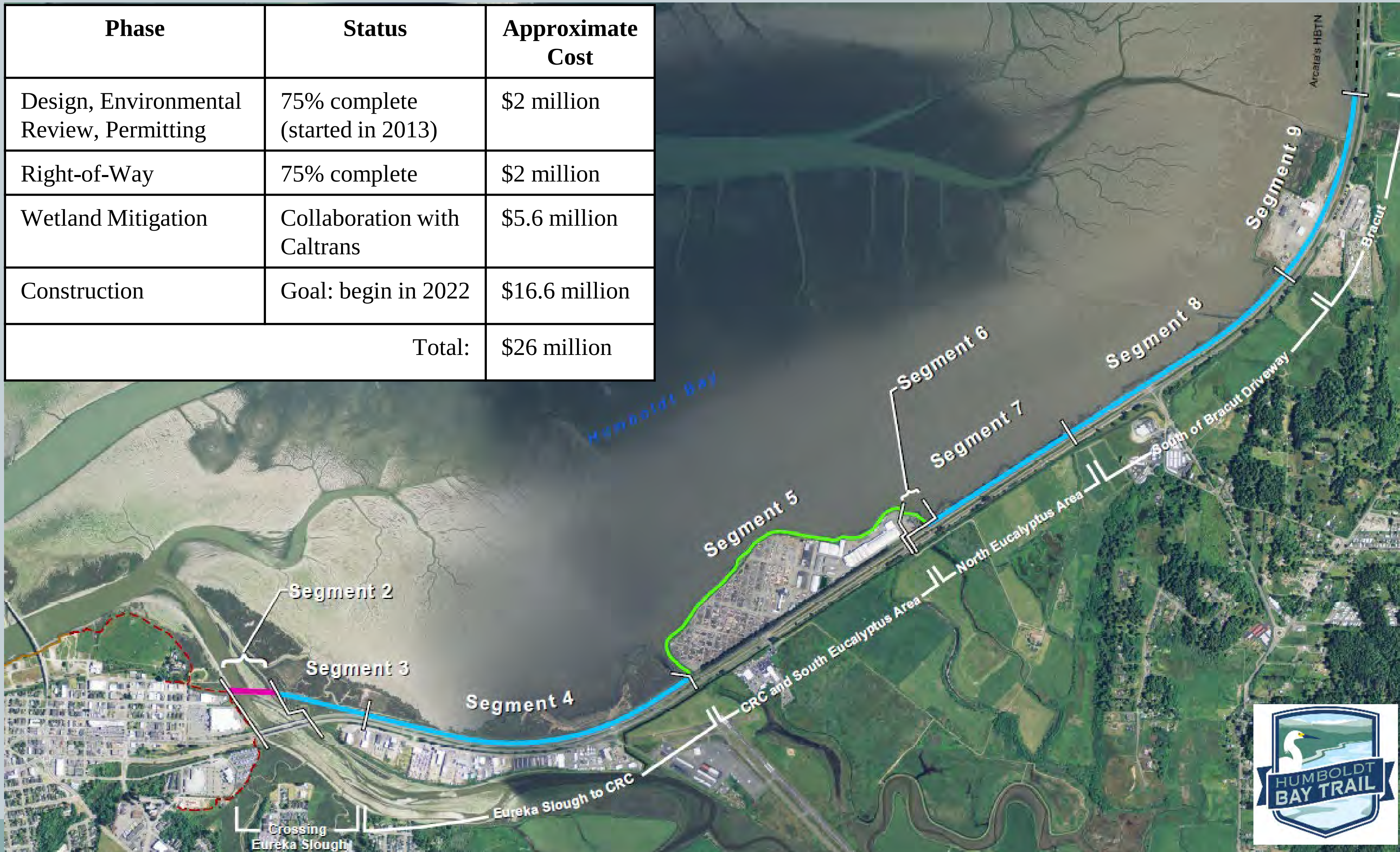
1. Humboldt Bay Trail South (*Implementation in progress)
2. Natural shoreline infrastructure between Brainard and Bracut (*Study in progress)
3. Isolate Jacobs Avenue area from interior flooding
4. Improve the Jacobs Avenue levee
5. Implement Highway 101 drainage improvement measures
6. Develop and implement interconnected drainage improvement projects within Cell A based on outcome of feasibility studies
7. Elevate, stabilize, or set back CDFW Fay Slough Wildlife Area levees and other agricultural levees based on outcome of feasibility studies
8. Flood-proof City of Eureka and Humboldt Community Services District sewer collection and water distribution facilities

Four Adaptation Projects Selected for Further Analysis



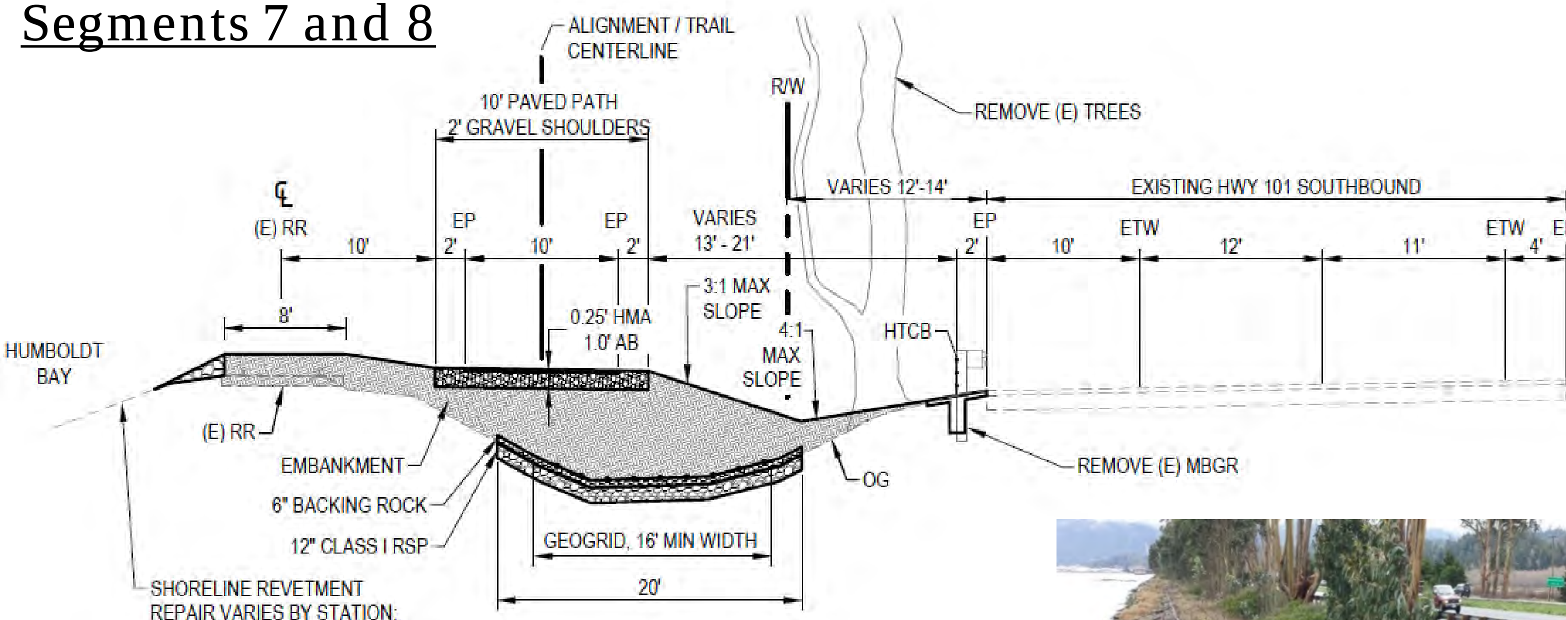
Project 1: Humboldt Bay Trail South

Phase	Status	Approximate Cost
Design, Environmental Review, Permitting	75% complete (started in 2013)	$2 million
Right-of-Way	75% complete	$2 million
Wetland Mitigation	Collaboration with Caltrans	$5.6 million
Construction	Goal: begin in 2022	$16.6 million
	Total:	$26 million



Project 1: Humboldt Bay Trail South

Segments 7 and 8

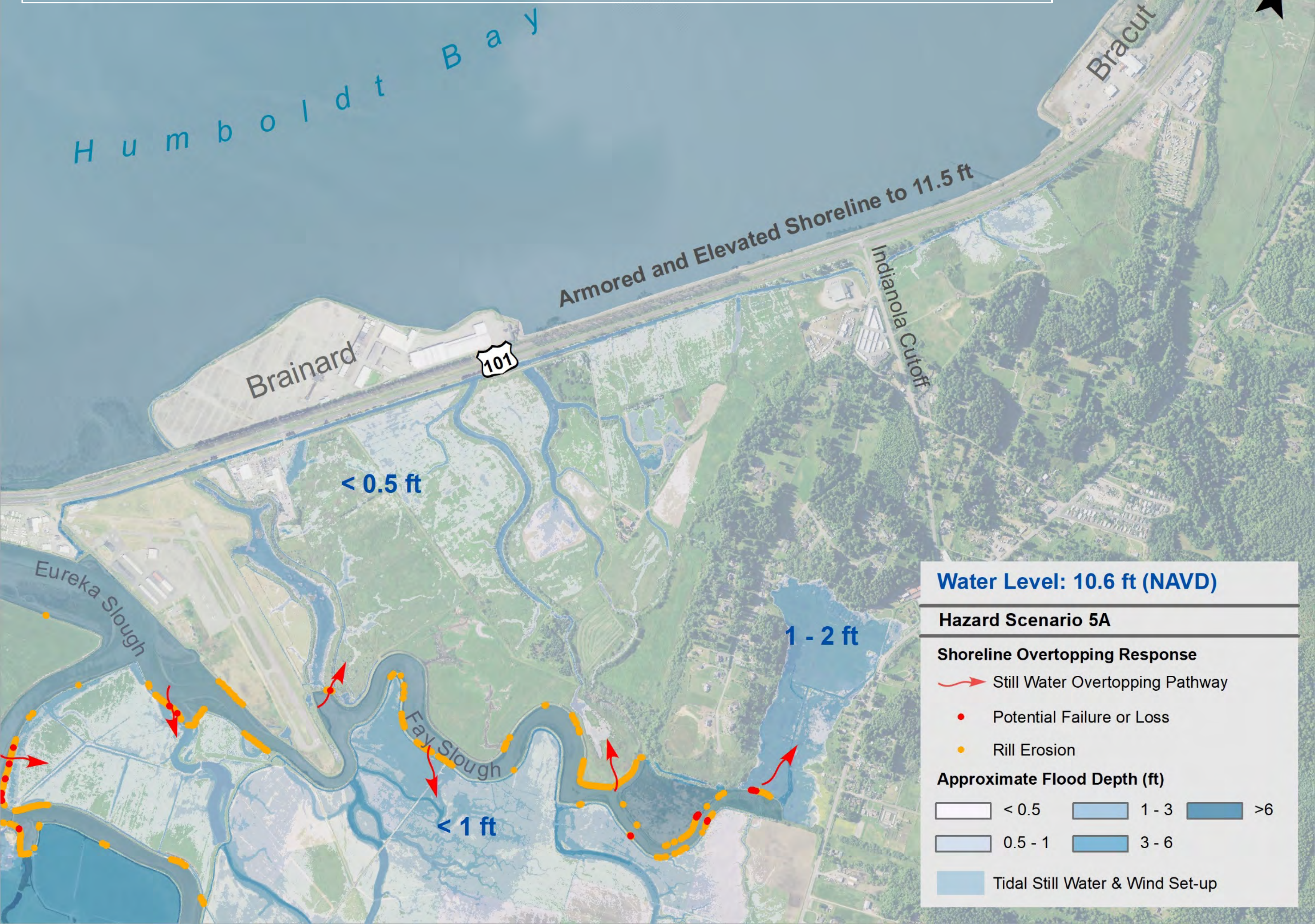


ELEVATIONS

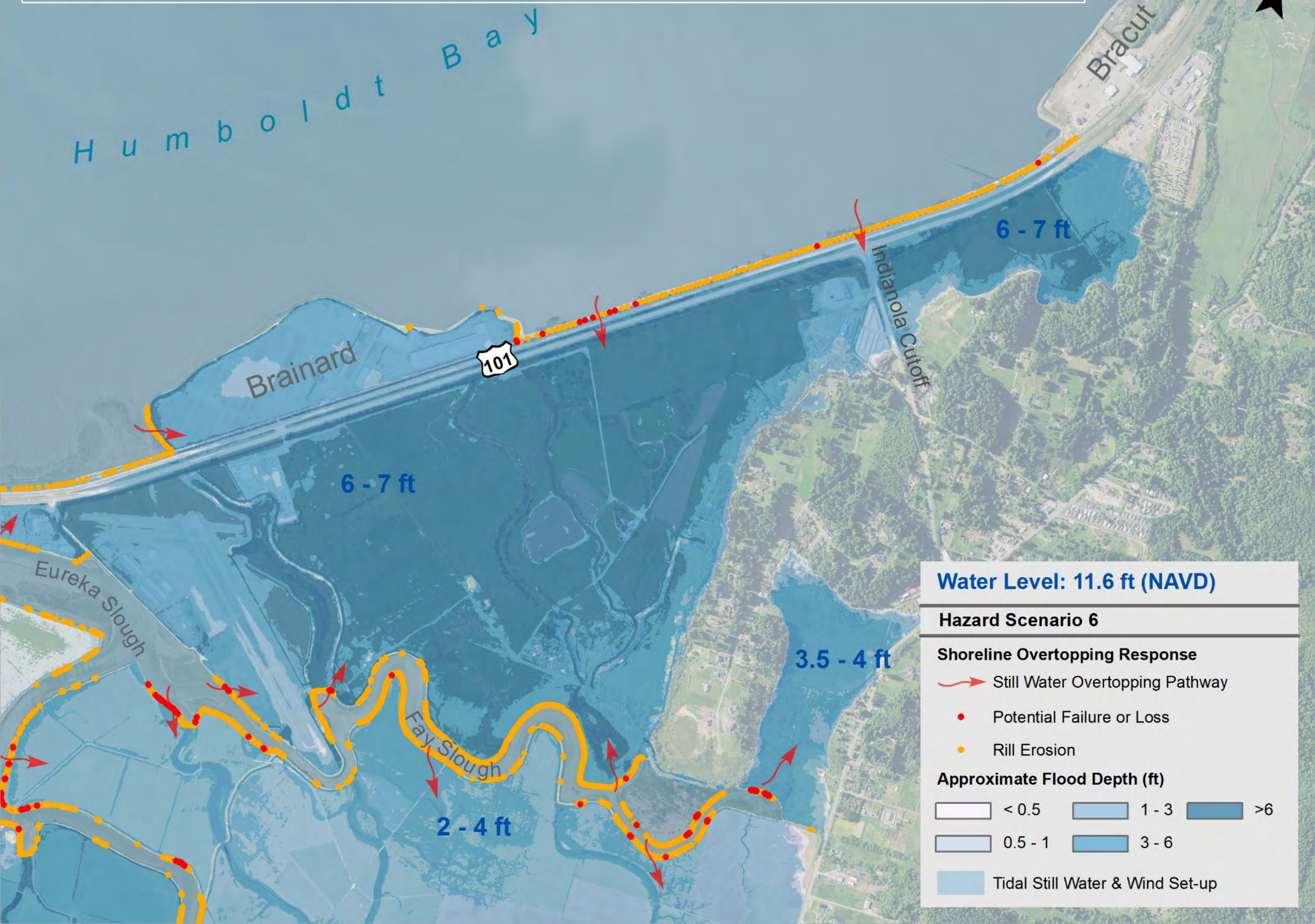
Feature	Existing	Future
Railroad	9.6-10.3 ft	11.5 ft
Trail	n/a	10.5 ft

1%-chance Tidal Stillwater: Existing Conditions

1%-chance Tidal Stillwater: with Humboldt Bay Trail South



1%-chance Tidal Stillwater + 1 foot SLR: Existing Conditions



1%-chance Tidal Stillwater + 1 foot SLR: with Bay Trail South

Project 1: Humboldt Bay Trail South

Key Features & Benefits:

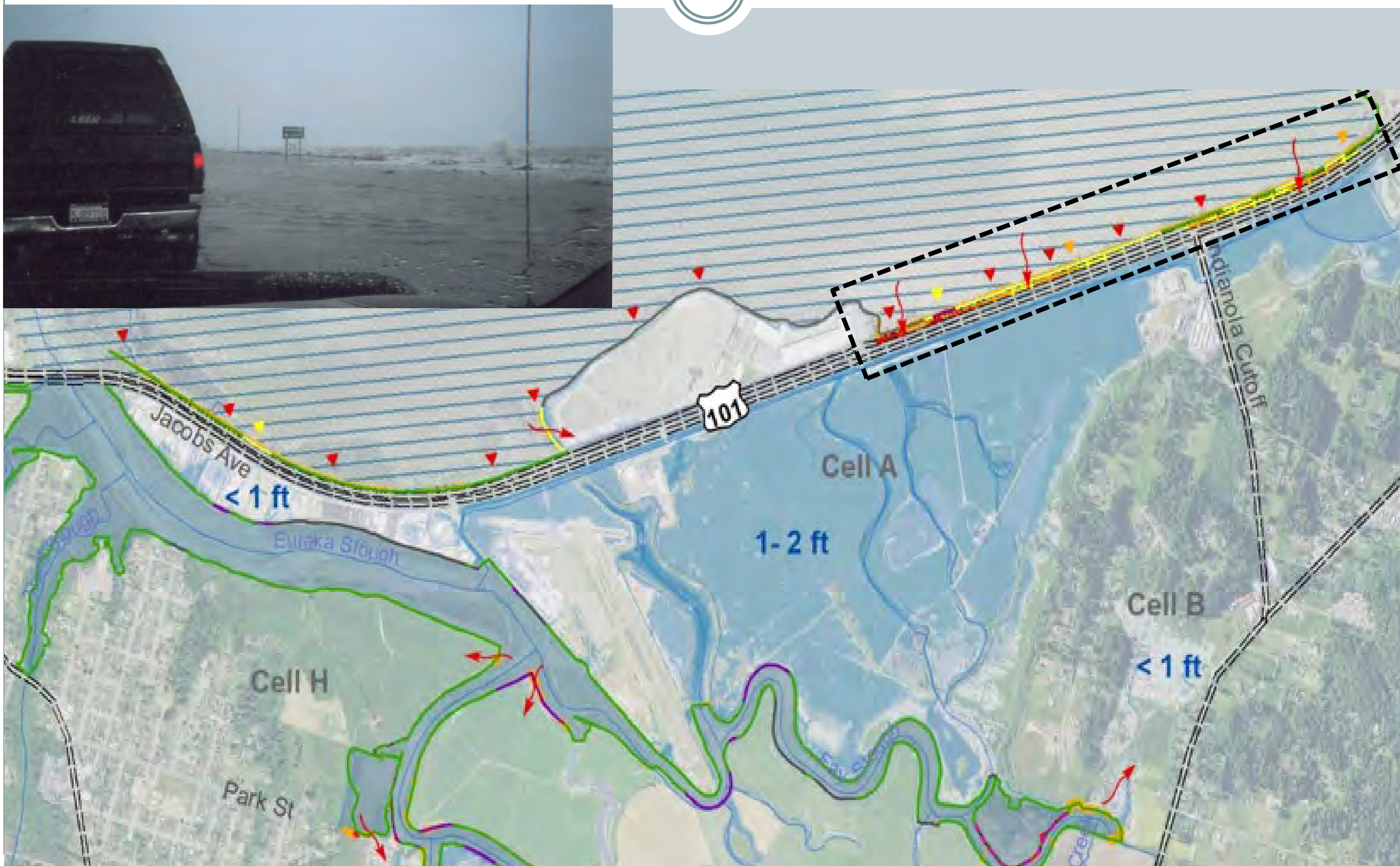
- 4.25 miles of Class I multi-use trail
- For highly vulnerable 1.25-mile section, elevates rail prism 1-2 feet and stabilizes areas of shoreline erosion (not full rehabilitation)
- Reduces shoreline overtopping and flooding for Highway 101 and Cell A
- Unique multi-objective project for providing greenhouse gas mitigation and sea level rise adaptation along with transportation and coastal access benefits

Project Cost: $16.6 million (Construction), $26 million (Total)

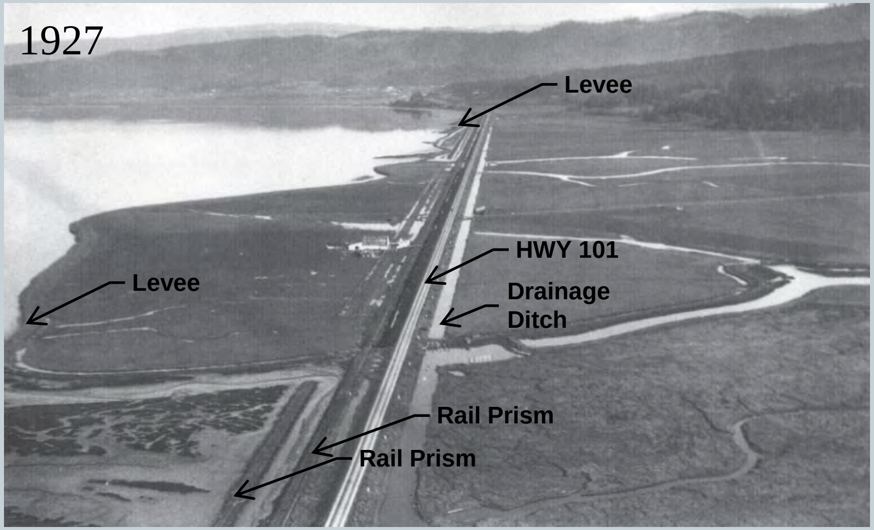
Next Steps:

- Right-of-way and permitting are still in progress (outcomes are not assured)
- Goal is to begin construction in 2022

Project 2: Natural Shoreline Infrastructure



Project 2: Natural Shoreline Infrastructure



Project 2: Natural Shoreline Infrastructure

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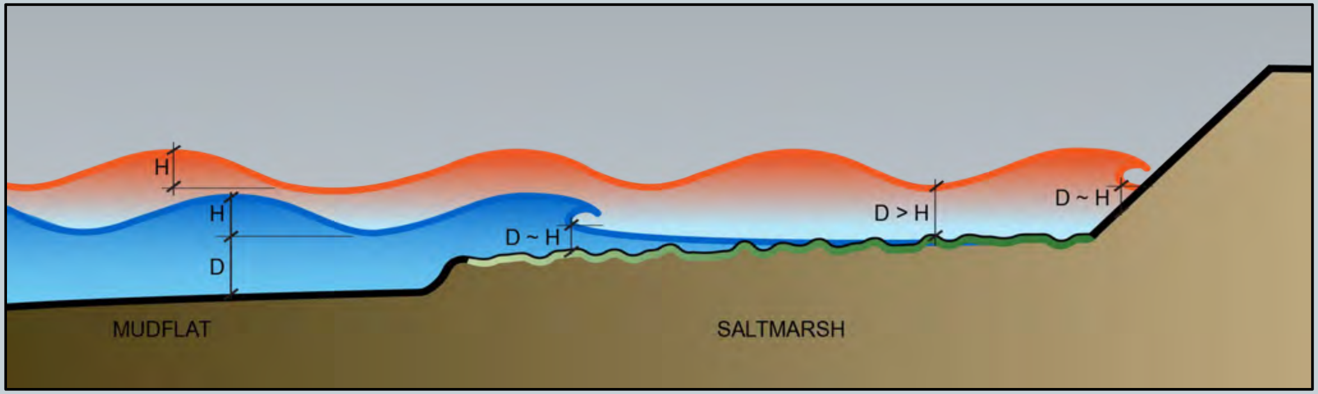
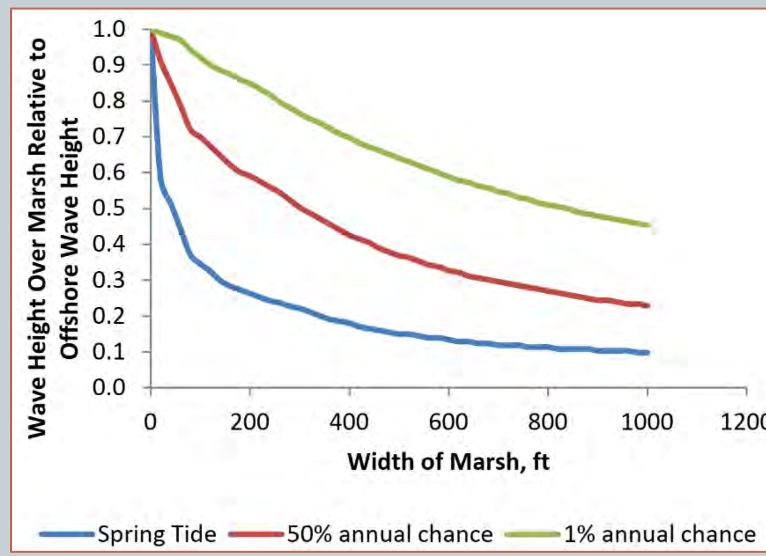
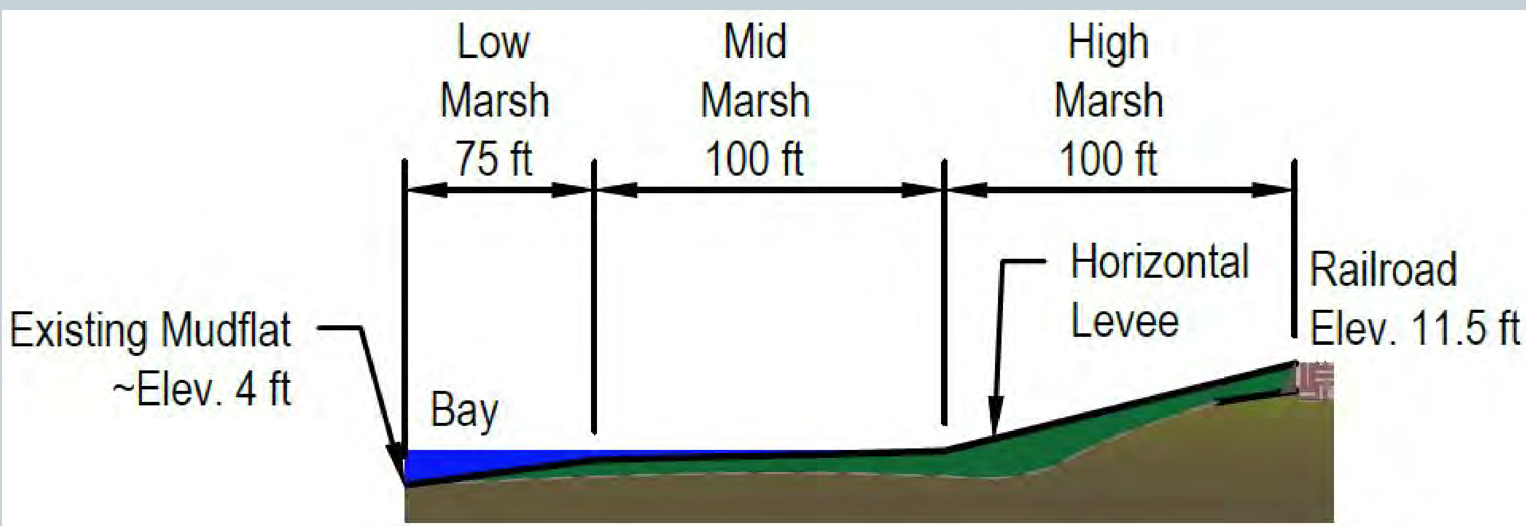


General diagram depicting effects of salt marsh on waves for two water level scenarios

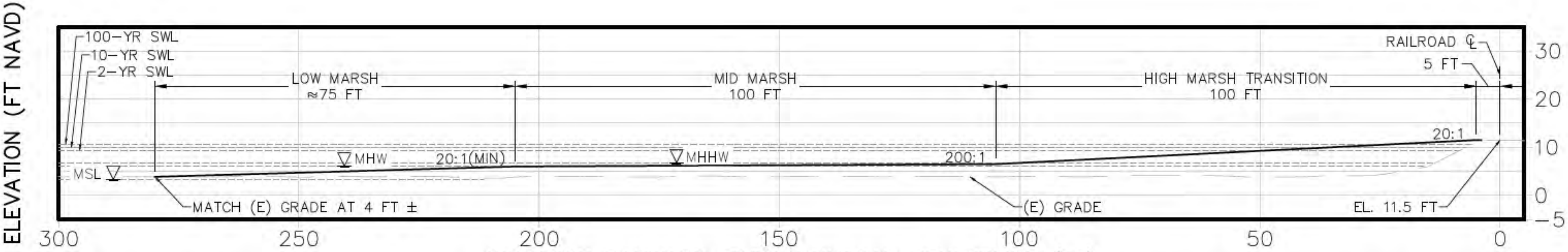
General relationship between marsh width and wave attenuation
(from studies in San Francisco Bay)



Project 2: Natural Shoreline Infrastructure

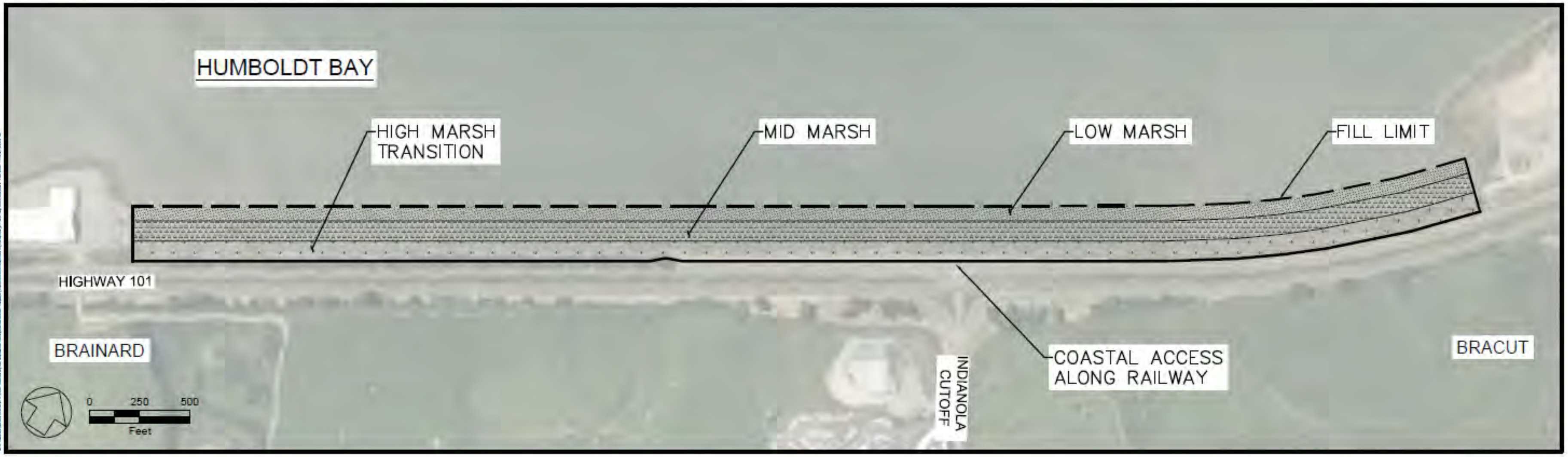


Project 2: Natural Shoreline Infrastructure



TYPICAL SECTION
PROJECT 2 CONCEPT

SCALE:
HORIZ. 1"=20'
VERT. 1"=20'



PLAN OVERVIEW
PROJECT 2 CONCEPT

Project 2: Natural Shoreline Infrastructure

Key Features & Benefits:

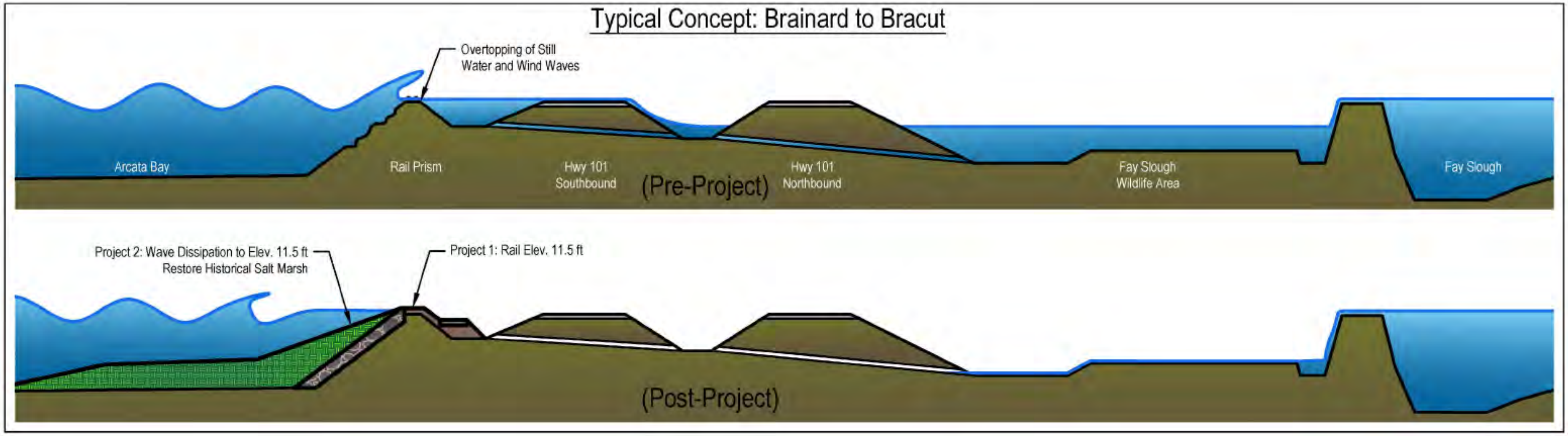
- Reduces erosion and flood hazard along 1.25 mile degraded shoreline
- Utilizes nature-based (living shoreline, green infrastructure) approach
- Initial (bold) concept is wide horizontal levee (ecotone levee) from mud flat to high marsh transition
- Would restore and diversify habitat types and allow for habitat migration with SLR
- Potential beneficial reuse of dredge spoils
- Can consider opportunities for reduced scale, alternative concepts

Opinion of Probable Cost: **$20-30 million (Total)**

Next Steps:

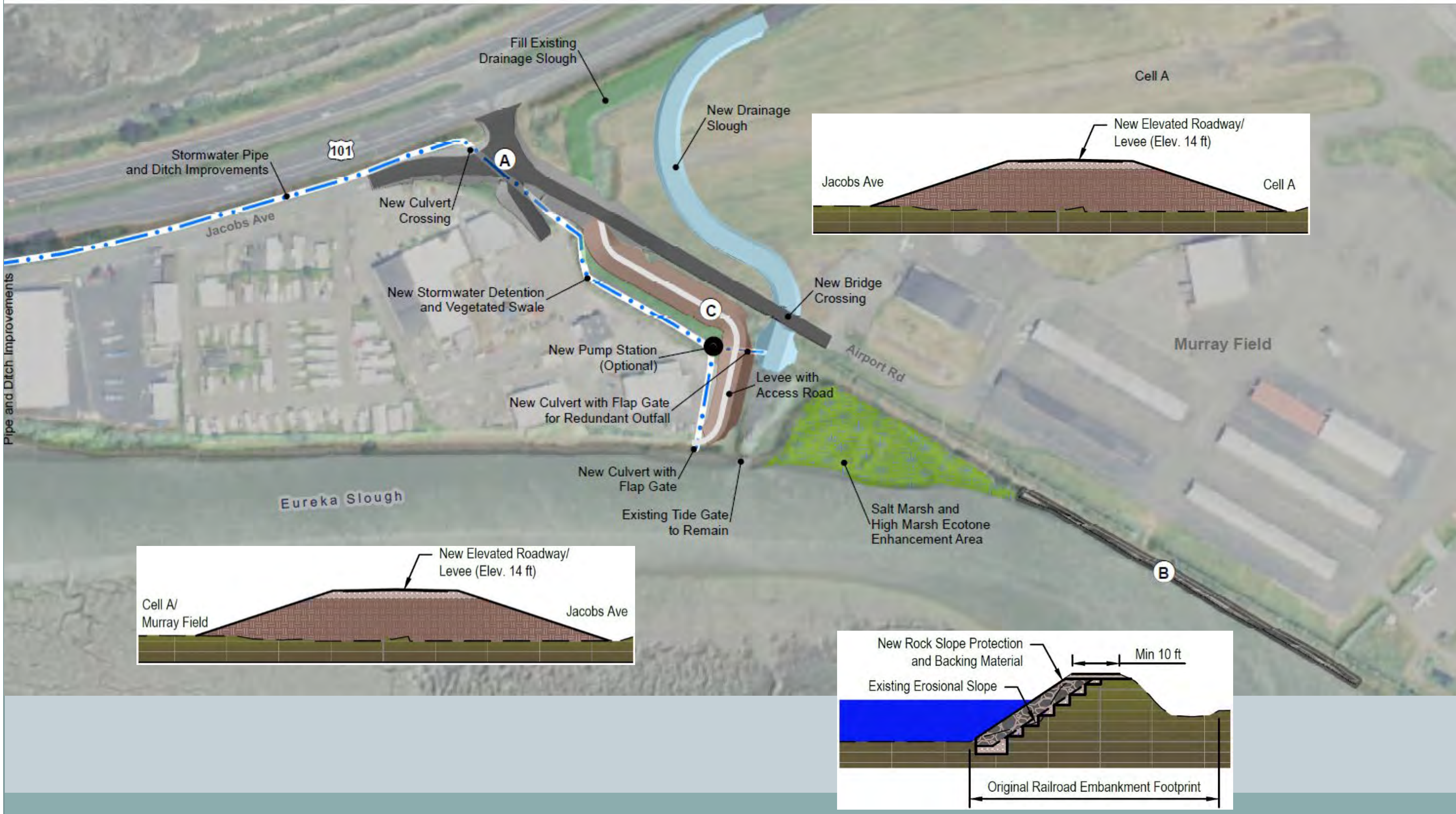
- Study in progress for site characterization and further conceptual design

Summary: Project Concepts 1 & 2



Project 3: Jacobs Avenue Flood Resiliency

Project 3: Jacobs Avenue Flood Resiliency



Project 3: Jacobs Avenue Flood Resiliency

Key Features & Benefits:

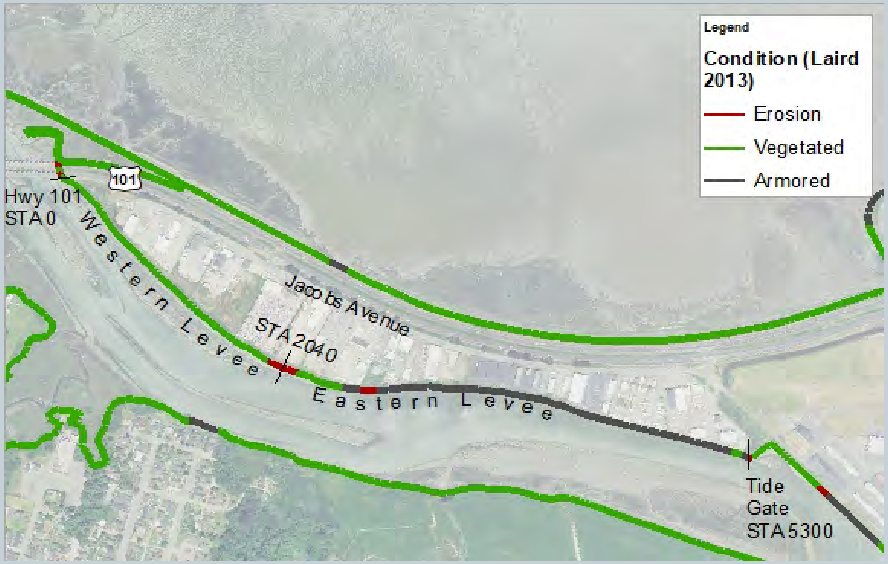
- Reduces flood pathways from vulnerable shorelines in Cell A to Jacobs Avenue
- Improves stormwater management/conveyance along Jacobs Avenue
- Stabilizes eroding Murray Field levee (former rail prism)
- Enhances salt marsh and creates a high marsh ecotone

Opinion of Probable Cost: **$9-$12 million**

Next Steps:

- Explore potential funding sources for feasibility study
- Determine project lead and organizational structure

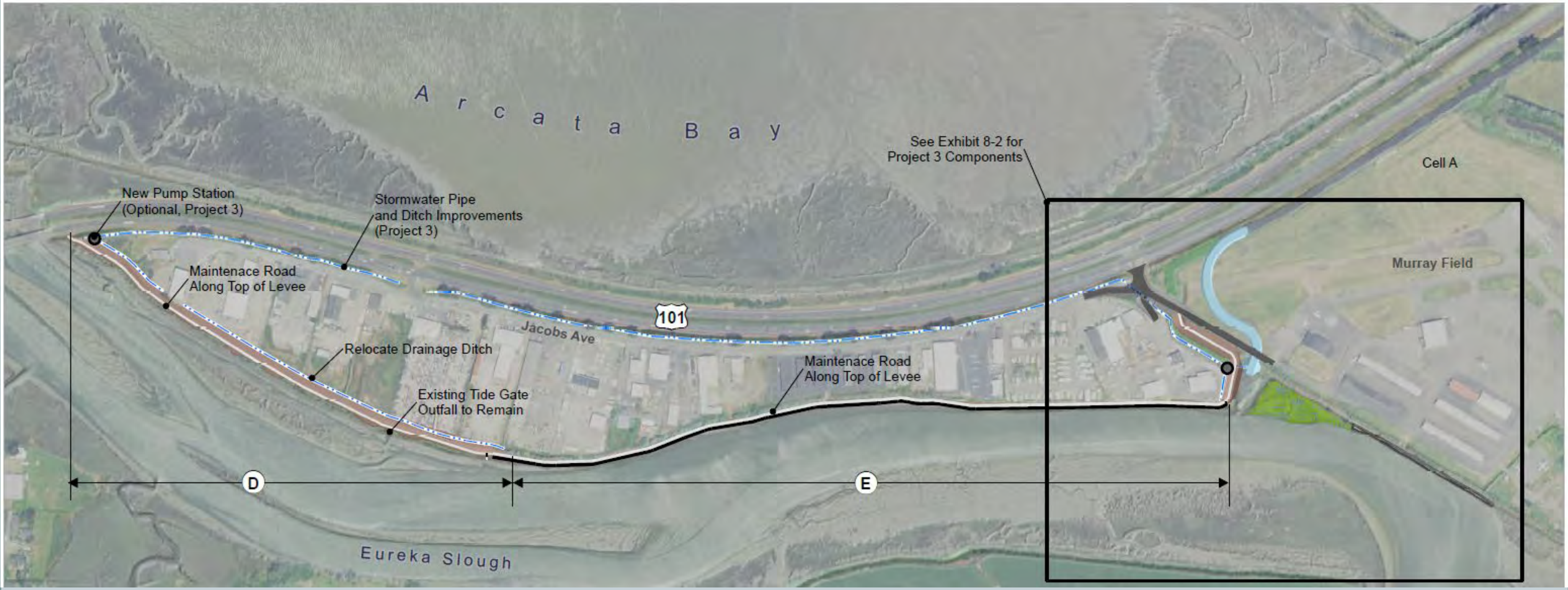
Project 4: Jacobs Avenue Levee Resiliency

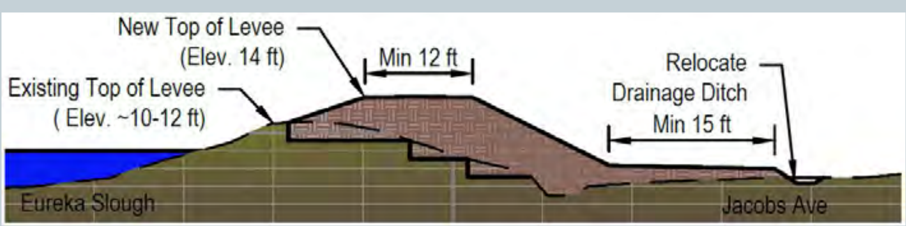


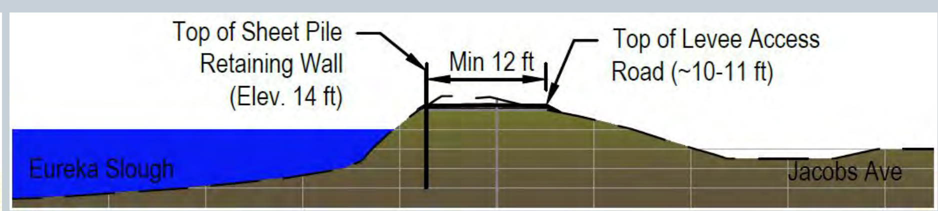
Levee Assessment

- Used available soil borings (CGI 2016)
- Assessed stability at various water levels
  - Slope stability
  - Underseepage
  - Overtopping
  - Erosion
- Western segment is more vulnerable to slope stability, underseepage, and overtopping relative to eastern segment

Project 4: Jacobs Avenue Levee Resiliency







Project 4: Jacobs Avenue Levee Resiliency

Key Features & Benefits:

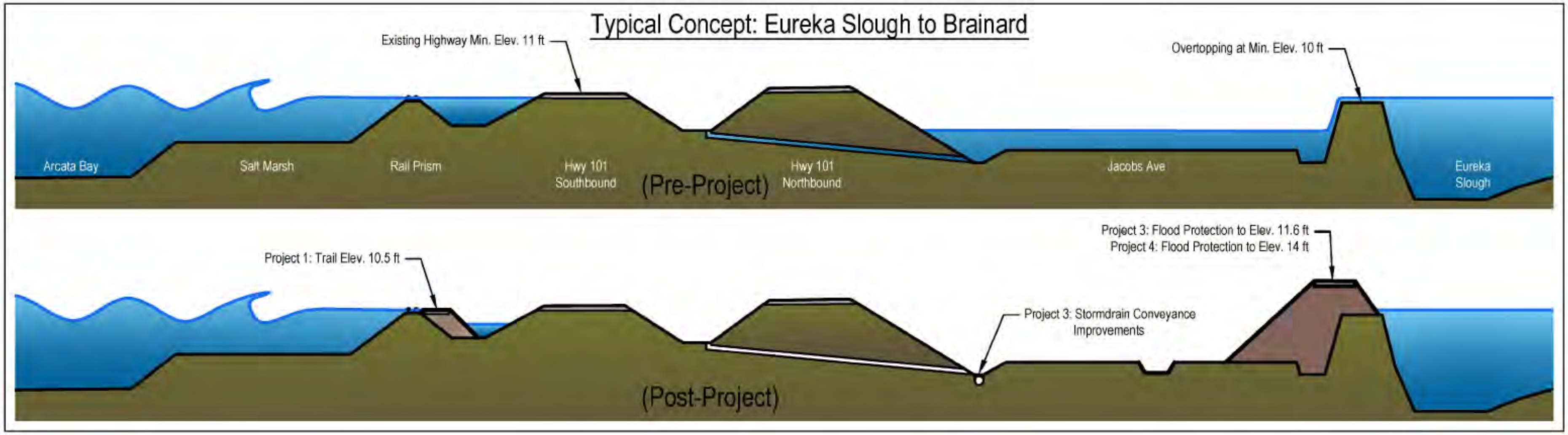
- Extends service life of existing levee
- Elevates levee to elevation 14ft (~3ft above current 100-year tidal still water)
- Reduces flood risk to Jacobs Avenue area
- Intended to not conflict with Caltrans' Eureka Slough Bridge Replacement

Opinion of Probable Cost: $7-$9 million

Next Steps:

- Explore potential funding sources for feasibility study
- Determine project lead and organizational structure
- Feasibility study would require additional sub-surface investigation, considerations for underseepage, define design criteria based on risk tolerance and available funding

Summary: Project Concepts 3 & 4



Benefit Cost Analysis

A technique for monetizing select benefits and avoided costs with implementation of a project and weighing these benefits against the costs of a project.

- Damages Under Existing Conditions
- Avoided Damages and Other Benefits of Project
- Project Construction Cost
- Probability of Flooding
- Time Value of Money

Costs and Benefits

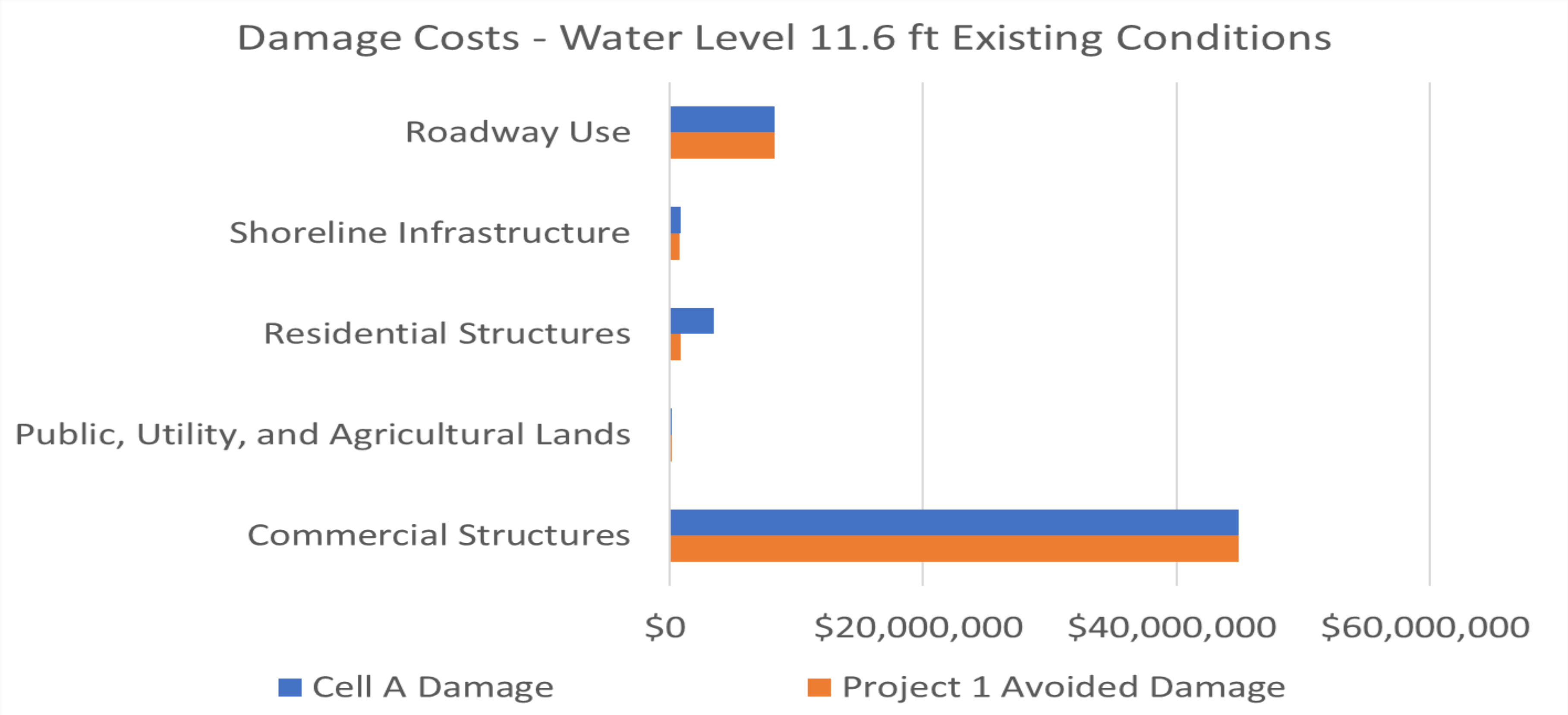
Evaluated

- Land Use by Parcel
  - Structures
  - Open Space and Ag Land
- Road Use
- Shoreline Infrastructure
  (Levees or Rail Prism)
- Trail Usage and Damage
- Utility Use and Disruption

Identified

- Indirect Economic Impacts
- Roadway Damage
- Public Health
- Safety
- Habitat Conversion
- Ecosystem Services

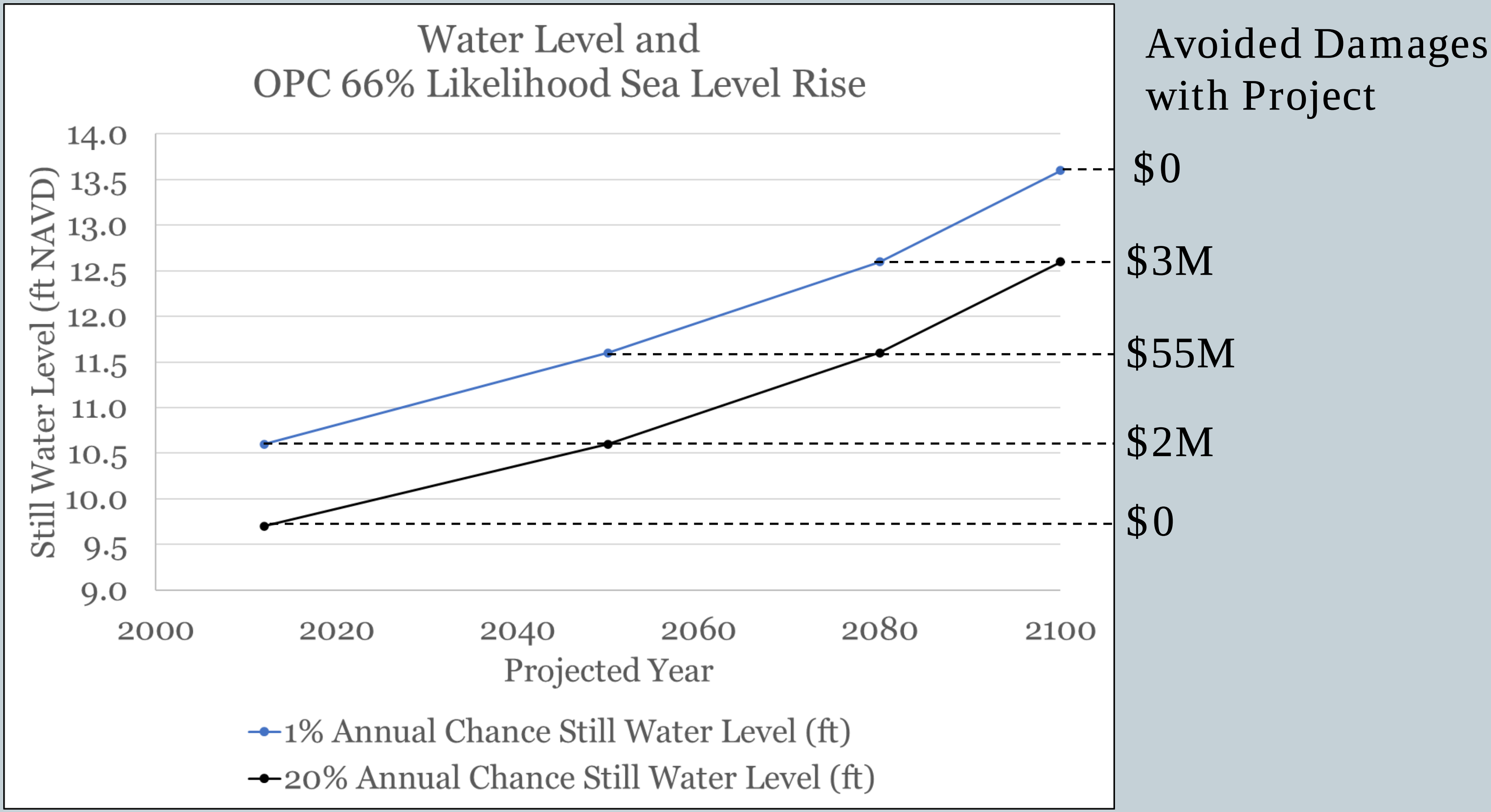
Example Damage Valuation



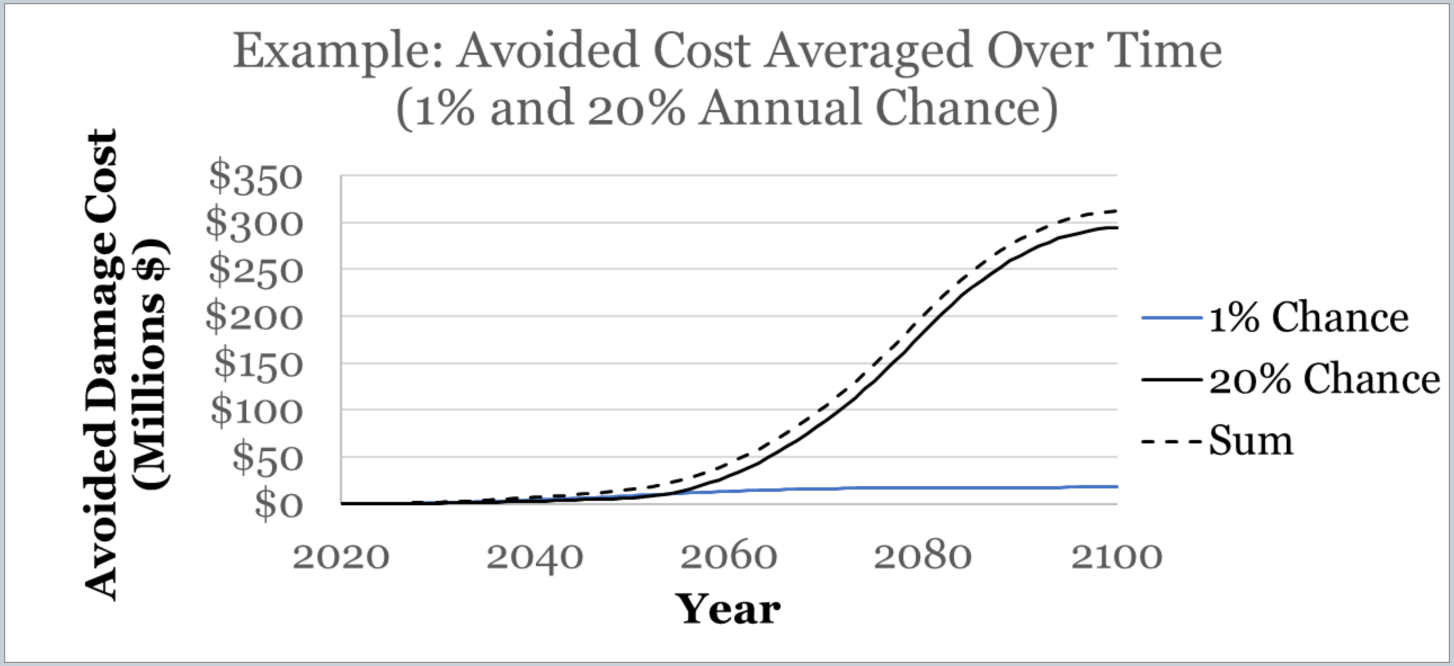
Existing: $58 M in Damages/Event

With Project: $55 M in Avoided Damages/Event

Probability of Flooding and Sea Level Rise



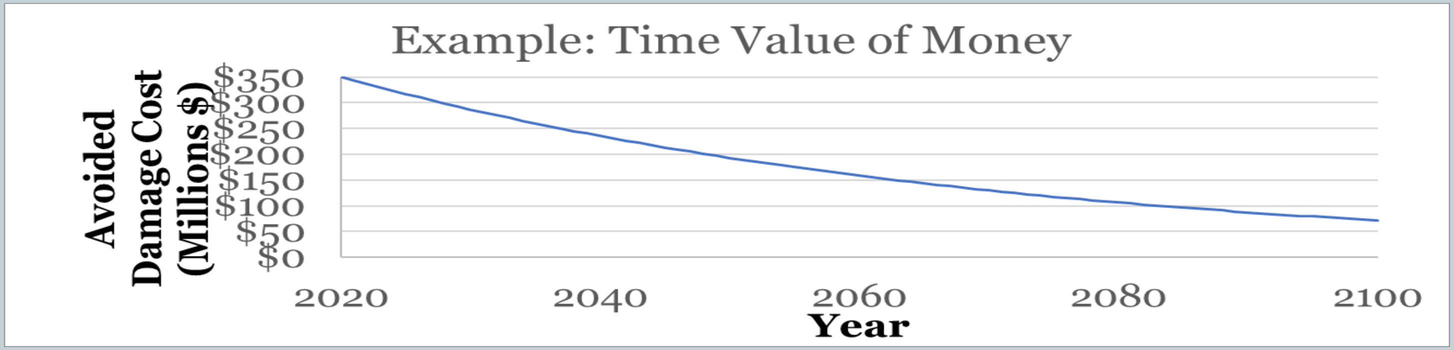
Flooding Cost Averaged Over Time

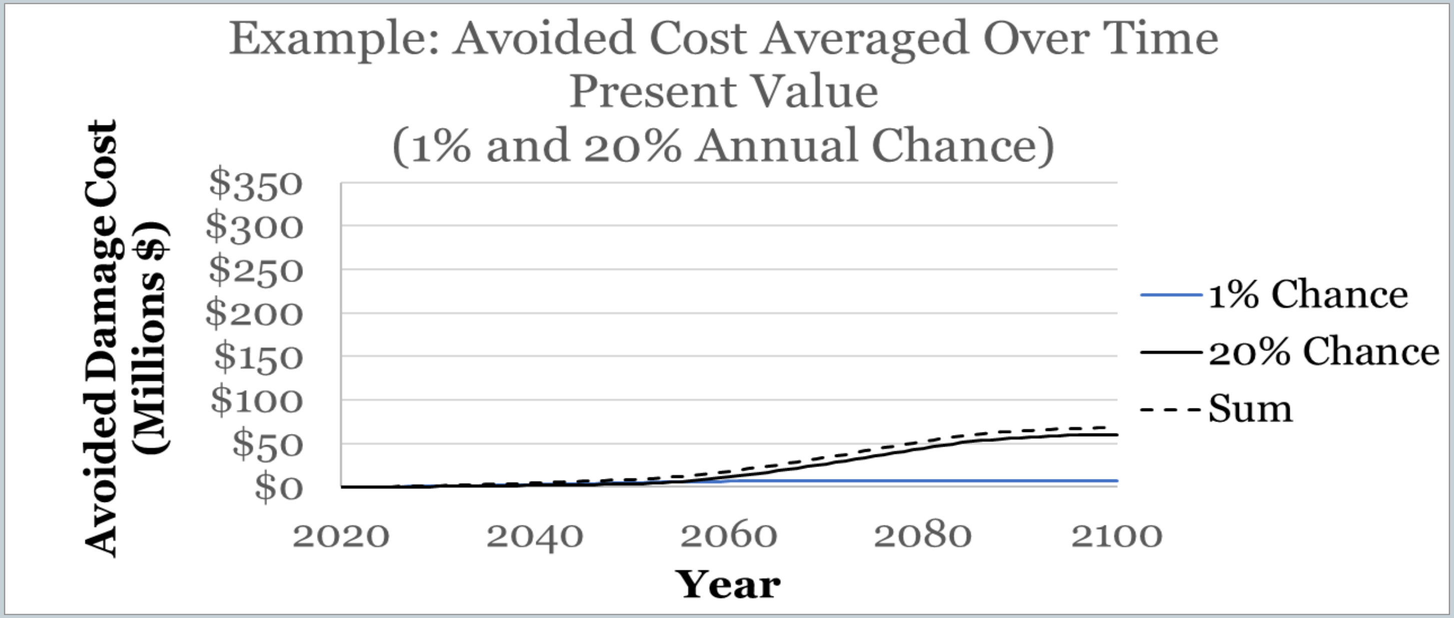


<u>Through 2100</u>

- 1% Annual Chance per Year : 1% of Cost per Year
- 20% Annual Chance per Year : 20% Cost per Year

Time Value of Money





Through 2100 Example

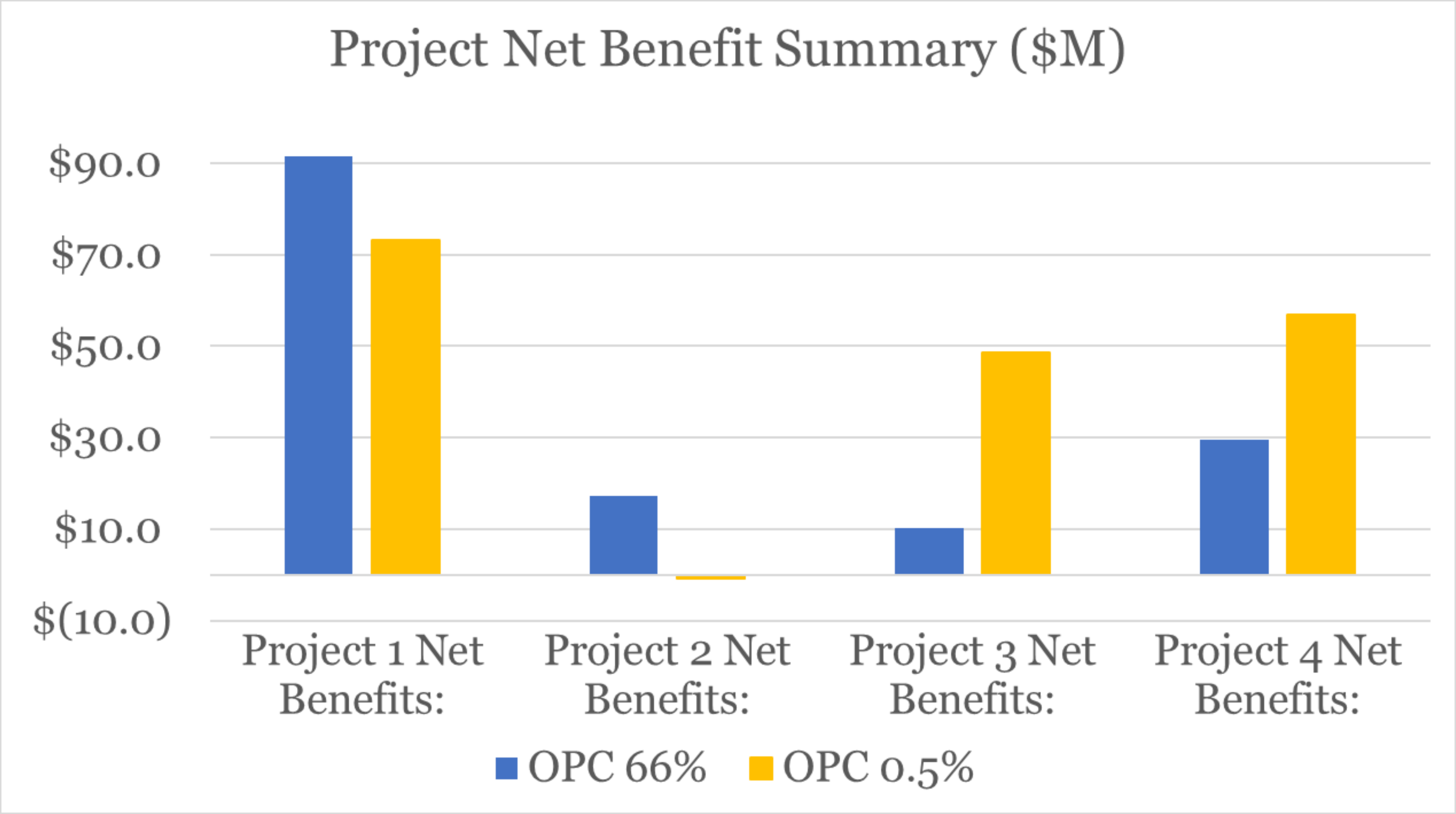
Costs and Benefits	OPC 66% SLR	OPC 0.5% SLR
Avoided Damages		
Commercial Structures	$	$
Public, Utility, and Agricultural Lands		
Residential Structures		
Roadway Use		
Levee Reconstruction Damage		
Key Avoided Damages Not Monetized	Loss of Life, Exposure to Hazardous Materials, Roadway Damage, vehicle accidents/damage	
Added Benefit Value		
Public Trail Use	$	$
Key Benefits Not Monetized	Non-motorized trips, safety, public health, tourism, habitat	
Total Benefits + Avoided Damages	$B	$B
Project Costs	$C	$C
Net Benefits:	$B-C	$B-C

Flooding Cost Scenarios

Scenario-Based 20-year and 50-year

Event	1	2	3	4	5
Year	2025	2030	2040	2050	2070
Water Level (ft NAVD)	9.9	9.9	11.6	10.6	11.6
SLR Projection (ft) (66% Probability)	0.25	0.5	0.8	1.1	1.7
Approx. Recurrence w/ SLR	5 to 10-yr	2-yr	100-yr	2-yr	10-yr
Avoided Damage Cost	-	-	$55M	$2M	$55M
Present Value	-	-	$	$	$
20 Year	Sum Events 1-3 Present Value				
50 Year	Sum Events 1- 5 Present Value				

Summary



Project Net Benefit Summary ($M)
$90.0
$70.0
$50.0
$30.0
$10.0
$(10.0)
Project 1 Net Benefits:
Project 2 Net Benefits:
Project 3 Net Benefits:
Project 4 Net Benefits:
OPC 66%
OPC 0.5%

Key Findings

<u>Damages and Project Benefits</u>

- Can be extremely difficult to monetize
- Depend on available models and site-specific information

<u>Traditional Methods</u>

- Heavily weighted toward flood benefit to structures and loss of service

<u>Alternative Approaches Needed</u>

- Innovative, experimental methods are needed to improve our understanding of adaptation project benefits

<u>Project Timing</u>

- With sea level rise, little benefit is achieved by waiting to implement a projects

IV. Key Take-aways and Strategies

Some Key Take-Aways

1. The railroad has become critical coastal protection infrastructure.
2. Salt marsh provides immensely valuable flood risk reduction benefits.
3. The hydrographic area provides a useful spatial framework for understanding geomorphic context, landscape history, physical processes, and flood risk.
4. Further dialogue is needed with stakeholders on risk tolerance/risk aversion.
5. The scale of adaptation projects is a big challenge and possible barrier.
6. Humboldt Bay Trail South is a unique opportunity to reduce short-term flood risks and provides a model for multi-objective projects.
7. Levees have limited adaptive capacity.
8. Scenario-based planning shows promise as a decision-support tool.
9. Applying benefit-cost analysis to sea level rise adaptation is effort-intensive, still a work in progress.
10. Caltrans Phased Adaptation Plan (2025) will inform view of long-term options.

Salt Marsh along the East Shoreline of North Bay

South of Jacoby Creek

Between Brainard and Bracut

South of Jacoby Creek

Northwest of Eureka Slough

Sea Level Rise Adaptation Strategies

1. Aim to maximize multi-benefit projects and nature-based solutions
2. Invest limited resources prudently
3. Look for cooperative funding opportunities
4. Expand and improve regional coordination on sea level rise planning and adaptation
5. Invest in our successors – find ways to involve younger generations
6. Find ways for the public to be involved in meaningful and effective action
7. Look for models of success to emulate

Sea Level Rise Work in Progress

- City of Eureka: SLR vulnerability and capital improvement program adaptation plan (2021)
- City of Arcata: Living shoreline pilot project (2021)
- Humboldt County: Pre-feasibility study for natural shoreline infrastructure along the Humboldt Bay shoreline between Brainard and Bracut (2021)
- USGS: Coastal Storm Modeling System applied to the North Coast (2021)
- Wiyot Tribe: Climate change adaptation plan (2022)
- Christina Bewley, HSU graduate thesis: Geologic hazards assessment of Highway 101 corridor (2022)
- Humboldt County: Sea level rise regional planning feasibility study (2022)
- Humboldt County: Humboldt Bay Area Plan update (2022)
- Humboldt County: Airport system wide study (2023)
- Jacoby Creek Land Trust: Jacoby Creek water sustainability and anadromous fish habitat enhancement feasibility study (2024)
- Caltrans: Highway 101 phase adaptation plan (2025)

Thank you

Opportunities for feedback:

Comments on draft report by March 26, 2021 (hseemann@co.humboldt.ca.us)

Topics for Discussion

1. Which tools or information appear to be the most useful?

2. Are there additional project concepts to consider?

3. Are there additional strategies to consider?

4. What are the desired outcomes for regional coordination?
   a) Information exchange
   b) Shared learning
   c) Coordination of studies, project development, monitoring
   d) Pooling resources
   e) Consistent policies
   f) Joint projects