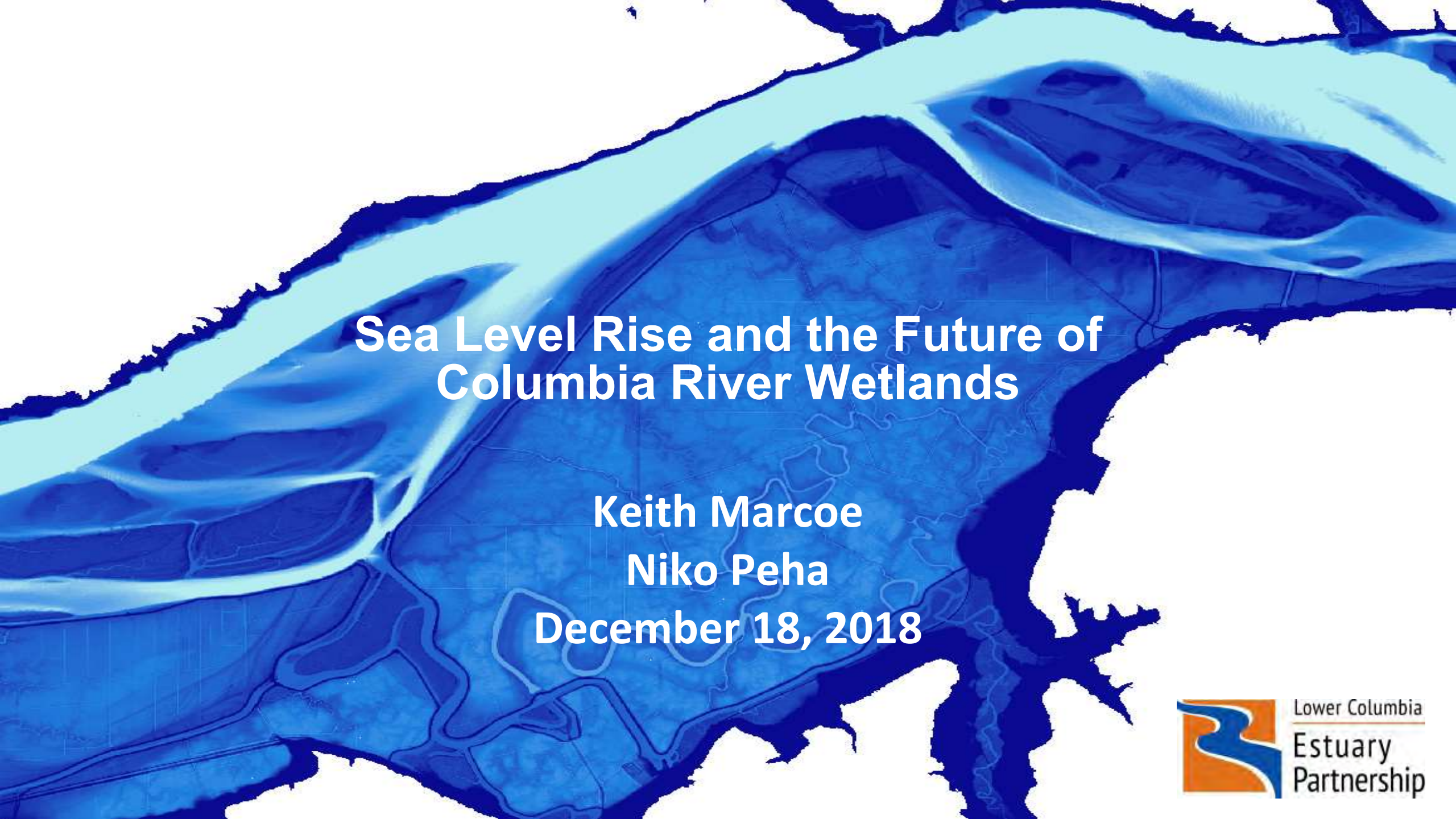


Sea Level Rise and the Future of Columbia River Wetlands

Keith Marcoe
Niko Peha

December 18, 2018

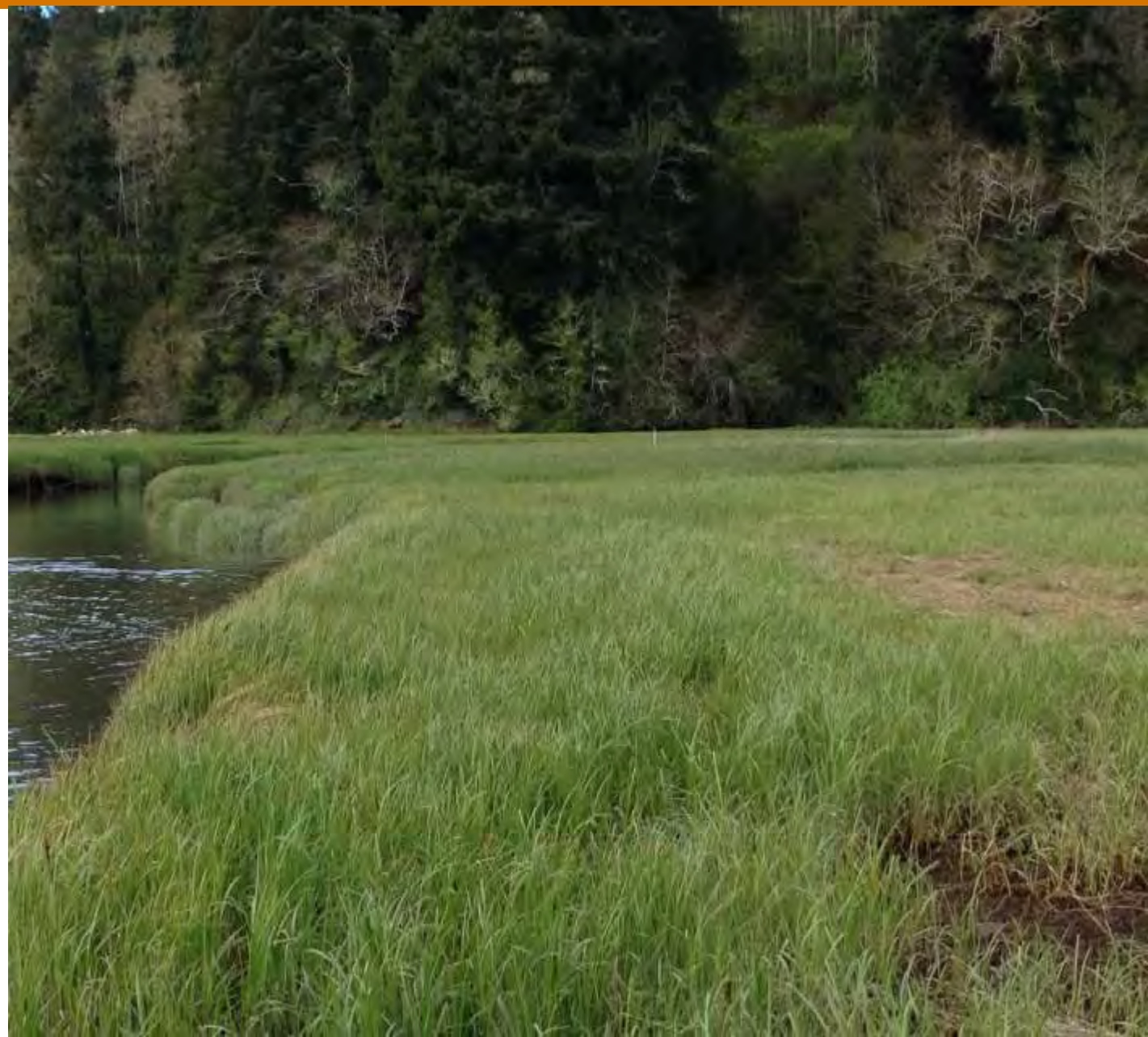
Lower Columbia Estuary Partnership

Project Background

- EPA funded study to map changes to lower Columbia R. wetlands that may be expected due to climate induced sea level rise (SLR)
- Map changes for three SLR scenarios: **0.5, 1.0, 1.5 meters**
- Scenarios were selected based on available hydraulic information: **USACOE lower Columbia R. Adaptive Hydraulic Model**

Lower Columbia Tidal Wetlands

- Flooded by tides/fluvial discharge typically daily to monthly
- Multiple functions
  - **Support a variety of species**
  - **Carbon storage**
  - **Flood reduction**
  - **Water quality**
  - **Recreation**
- Roughly 68% loss since late 1800's
- Important to assess SLR impacts
  - how much more will be lost?
  - where will restoration be most effective?



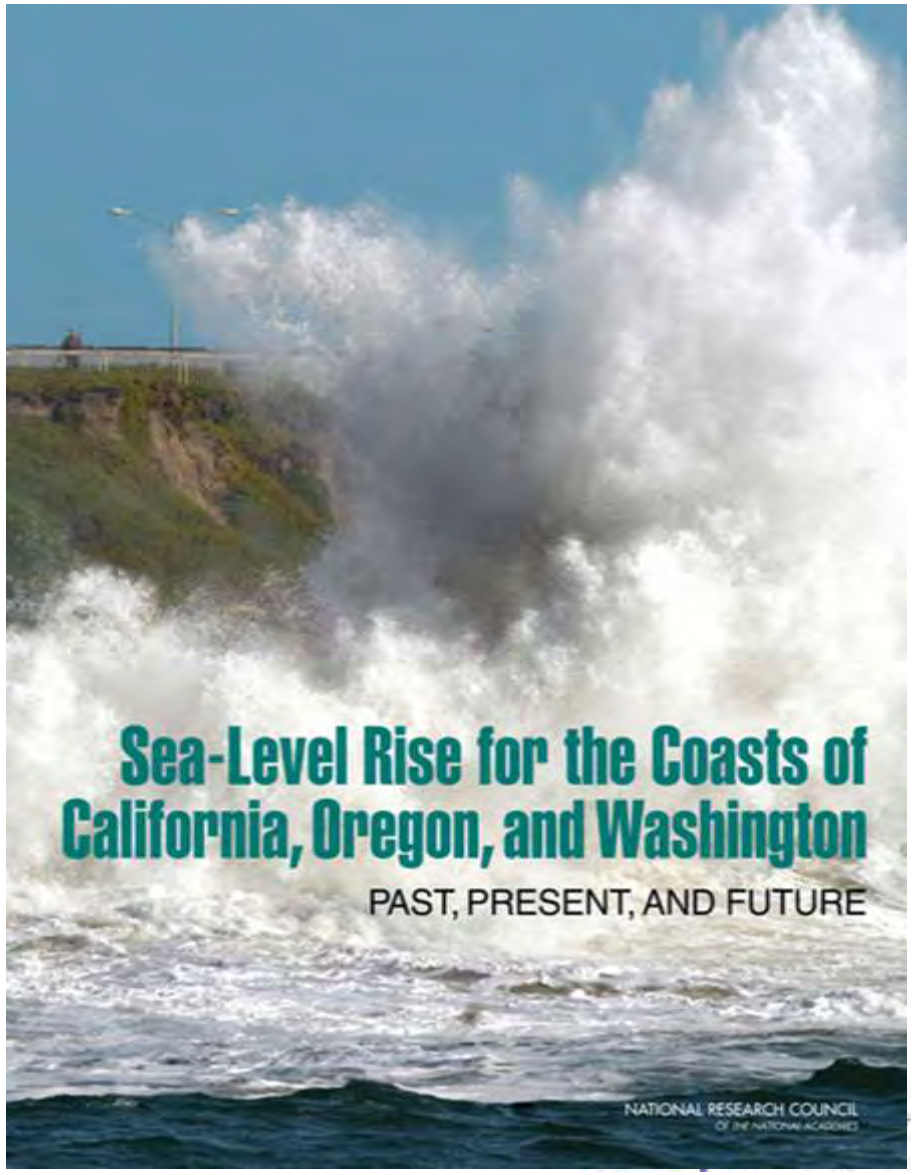
Objectives

- Map future lower Columbia wetlands for three sea level rise ('SLR') scenarios: 0.5 m, 1.0 m, 1.5 m
- Quantify impacts to existing wetlands by Hydrogeomorphic Reach
- *Assess impacts on available Recoverable Habitats and Recovery Targets
- Coarse assessment of risk (i.e. levee overtopping/infrastructure)
- Provide tool to incorporate climate change effects into action planning

* = still in progress

SLR on the West Coast

- 2012 National Academy of Sciences Report



SLR on the West Coast

- Large uncertainty in SLR projections based on contributing factors:

Global SLR

- Emissions scenarios
- Glaciers, Ice Caps, Sheets
- Terrestrial Water Storage

Local SLR

- Ocean circulation
- Short term SLR, storm surges
- Tectonic Land Motion

TABLE 5.3 Regional Sea-Level Rise Projections (in cm) Relative to Year 2000

	2030		2050		2100	
Component	Projection	Range	Projection	Range	Projection	Range
Steric and dynamic ocean[a]	3.6 ± 2.5	0.0–9.3 (B1–A1FI)	7.8 ± 3.7	2.2–16.1 (B1–A1FI)	20.9 ± 7.7	9.9–37.1 (B1–A1FI)
Non-Alaska glaciers and ice caps[b]	2.4 ± 0.2		4.4 ± 0.3		11.4 ± 1.0	
Alaska, Greenland, and Antarctica with sea-level fingerprint effect[c]						
Seattle, WA	7.1	5.4–9.5	16.0	11.1–22.1	52.7	32.7–74.9
Newport, OR	7.4	5.6–9.5	16.6	11.7–22.2	54.5	34.1–75.3
San Francisco, CA	7.8	6.1–9.6	17.6	12.7–22.3	57.6	37.3–76.1
Los Angeles, CA	8.0	6.3–9.6	17.9	13.0–22.3	58.5	38.6–76.4
Vertical land motion[d]						
North of Cape Mendocino	-3.0	-7.5–1.5	-5.0	-12.5–2.5	-10.0	-25.0–5.0
South of Cape Mendocino	4.5	0.6–8.4	7.5	1.0–14.0	15.0	2.0–28.0
Sum of all contributions						
Seattle	6.6 ± 5.6	-3.7–22.5	16.6 ± 10.5	-2.5–47.8	61.8 ± 29.3	10.0–143.0
Newport	6.8 ± 5.6	-3.5–22.7	17.2 ± 10.3	-2.1–48.1	63.3 ± 28.3	11.7–142.4
San Francisco	14.4 ± 5.0	4.3–29.7	28.0 ± 9.2	12.3–60.8	91.9 ± 25.5	42.4–166.4
Los Angeles	14.7 ± 5.0	4.6–30.0	28.4 ± 9.0	12.7–60.8	93.1 ± 24.9	44.2–166.5

[a] Projection indicates the mean and ± standard deviation computed for the Pacific coast from the gridded data presented in Pardaens et al. (2010) for the A1B scenario. Ranges are the means for B1 and A1FI using the scaling in Table 10.7 of IPCC (2007; see also Table 5.1 of this report): (B1/A1B) = (0.1/0.13); (A1FI/A1B) = (0.17/0.13).

[b] Extrapolated based on ice loss rates for glaciers and ice caps except Alaska, Greenland, and Antarctica. No ranges are given because these sources are assumed to have a small or uniform effect on the gradient in sea-level change along the U.S. west coast (see "Sea-Level Fingerprints of Modern Land Ice Change" in Chapter 4).

[c] Extrapolation based on ice loss rates and gravitational attraction effects for Alaska, Greenland, and Antarctica. Ranges reflect uncertainty in ice loss rates.

[d] Assumes constant rates of vertical land motion of 1.0 ± 1.5 mm yr^{-1} for Cascadia and -1.5 ± 1.3 mm yr^{-1} for the San Andreas region. The signs were reversed to calculate relative sea level. Uncertainties are 1 standard deviation.

SLR on the West Coast

- Range of SLR predictions for West Coast report and others
  - SLR projections considered in our LCR study (0.5, 1.0, 1.5 m)

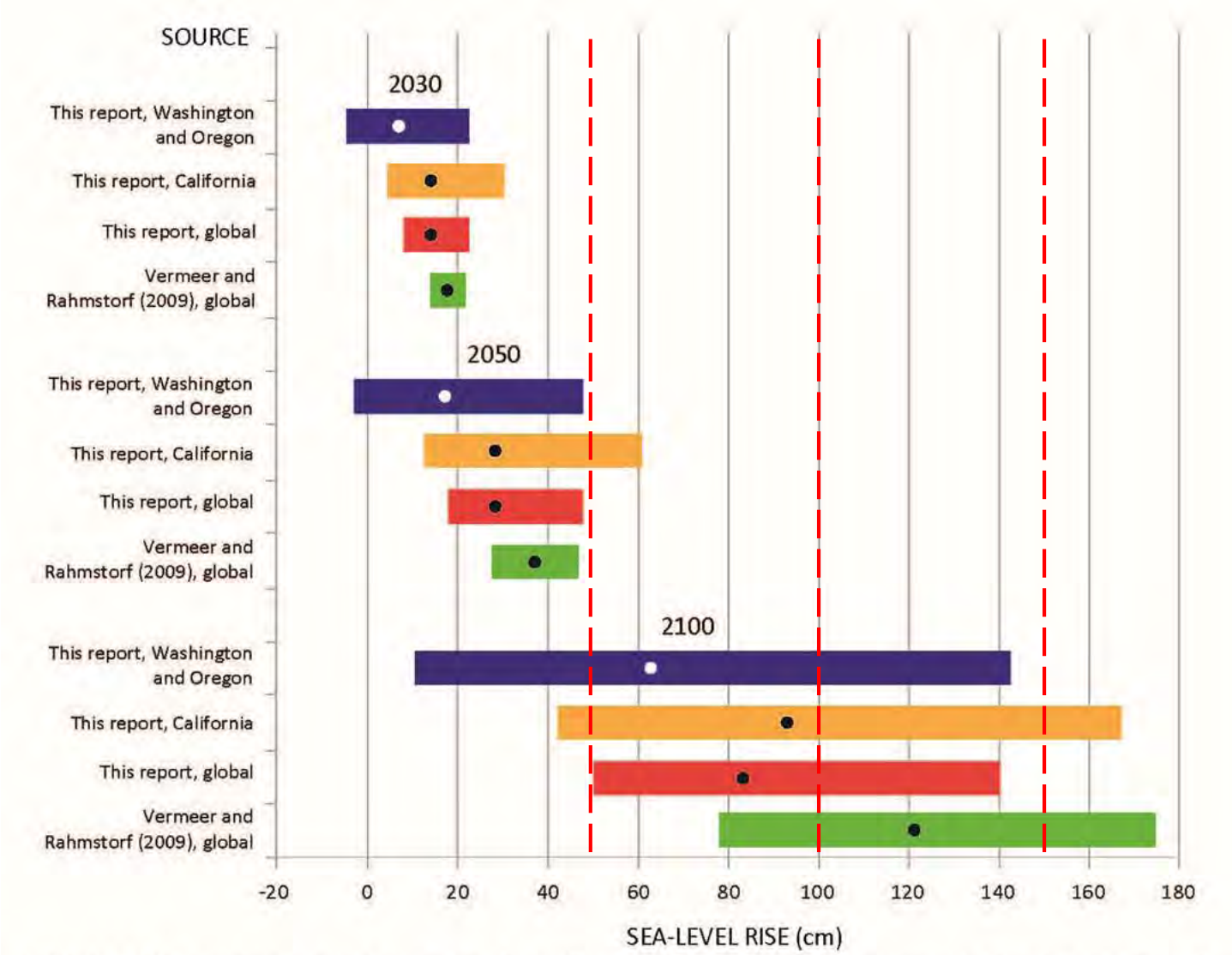
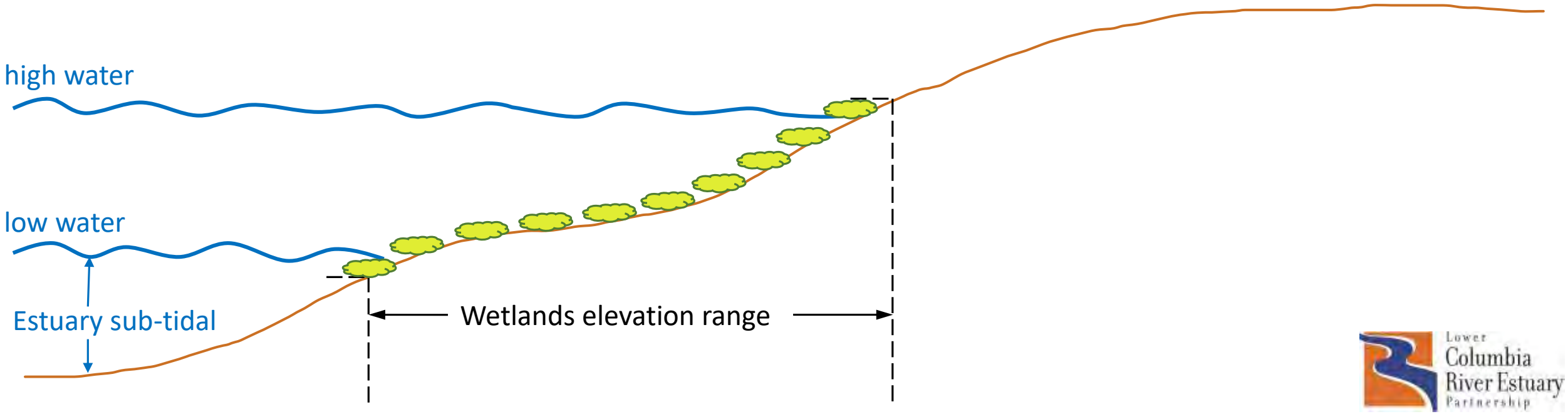


FIGURE 5.10 Committee's projected sea-level rise for California, Oregon, and Washington compared with global projections. The dots are the projected values and the colored bars are the ranges. Washington and Oregon = coastal areas north of Cape Mendocino; California = coastal areas south of Cape Mendocino.

SLR and Wetlands Change

Estuarine wetlands occupy a narrow range of elevations that is closely tied to fluctuating water levels

Estuary Cross Section



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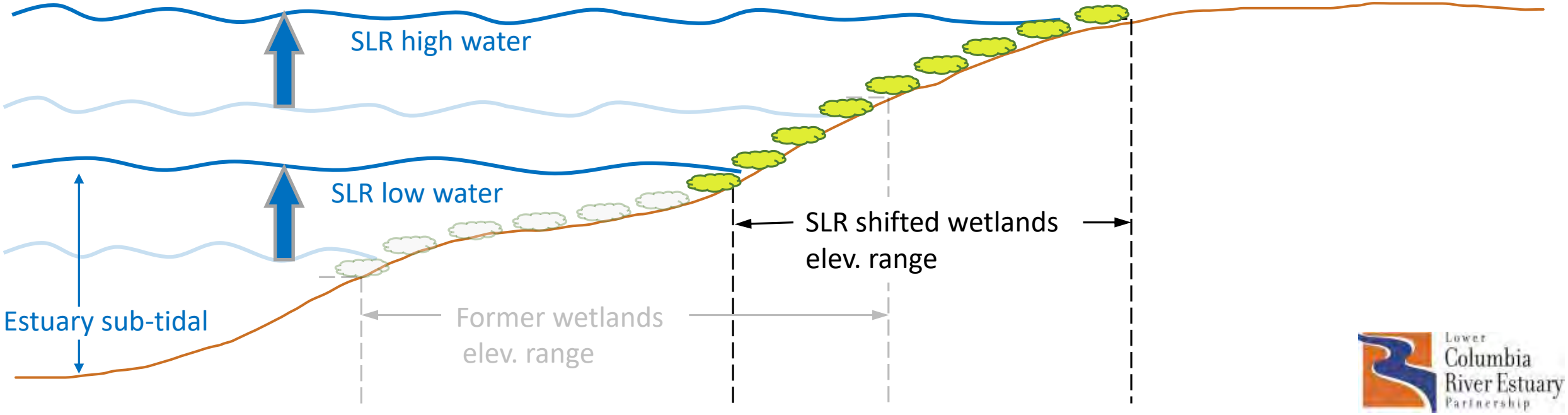
SLR and Wetlands Change

As water levels rise as a result of increased SLR, we assume the range of wetlands rises by the same amount

Magnitude of SLR induced water level increase

Estuary Cross Section



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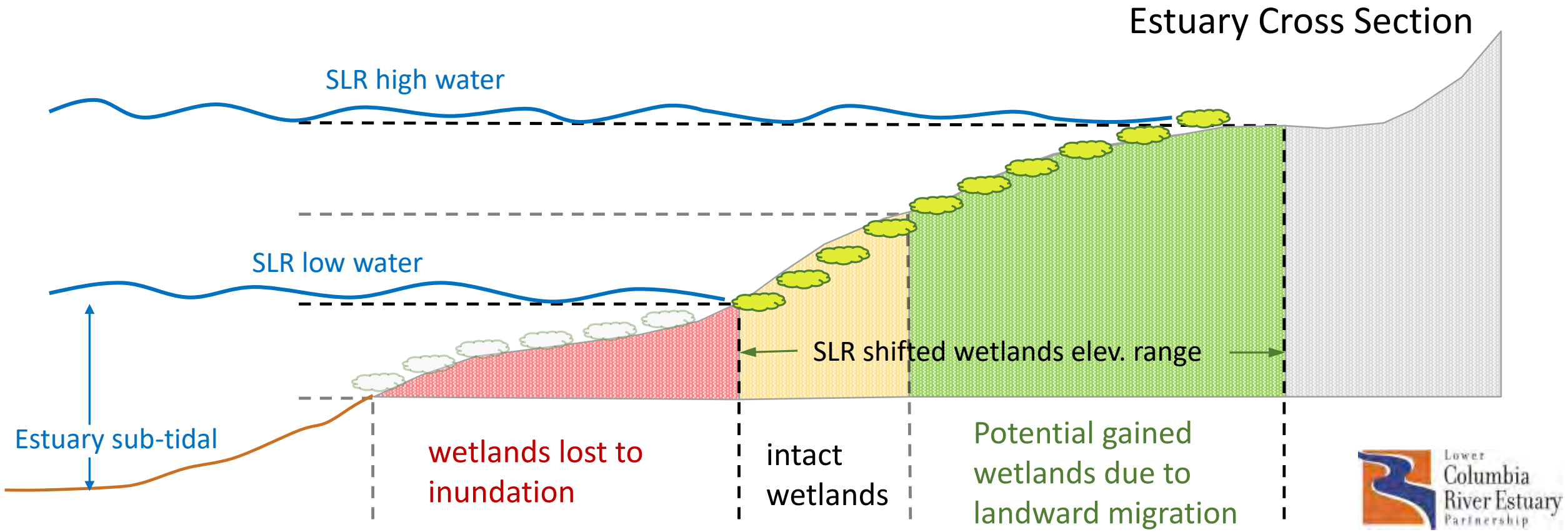
SLR and Wetlands Change

Resulting impacts to wetlands include areas of loss due to inundation, intact areas, and areas of potential gain. Relative amounts depend on the topography (i.e. slope)



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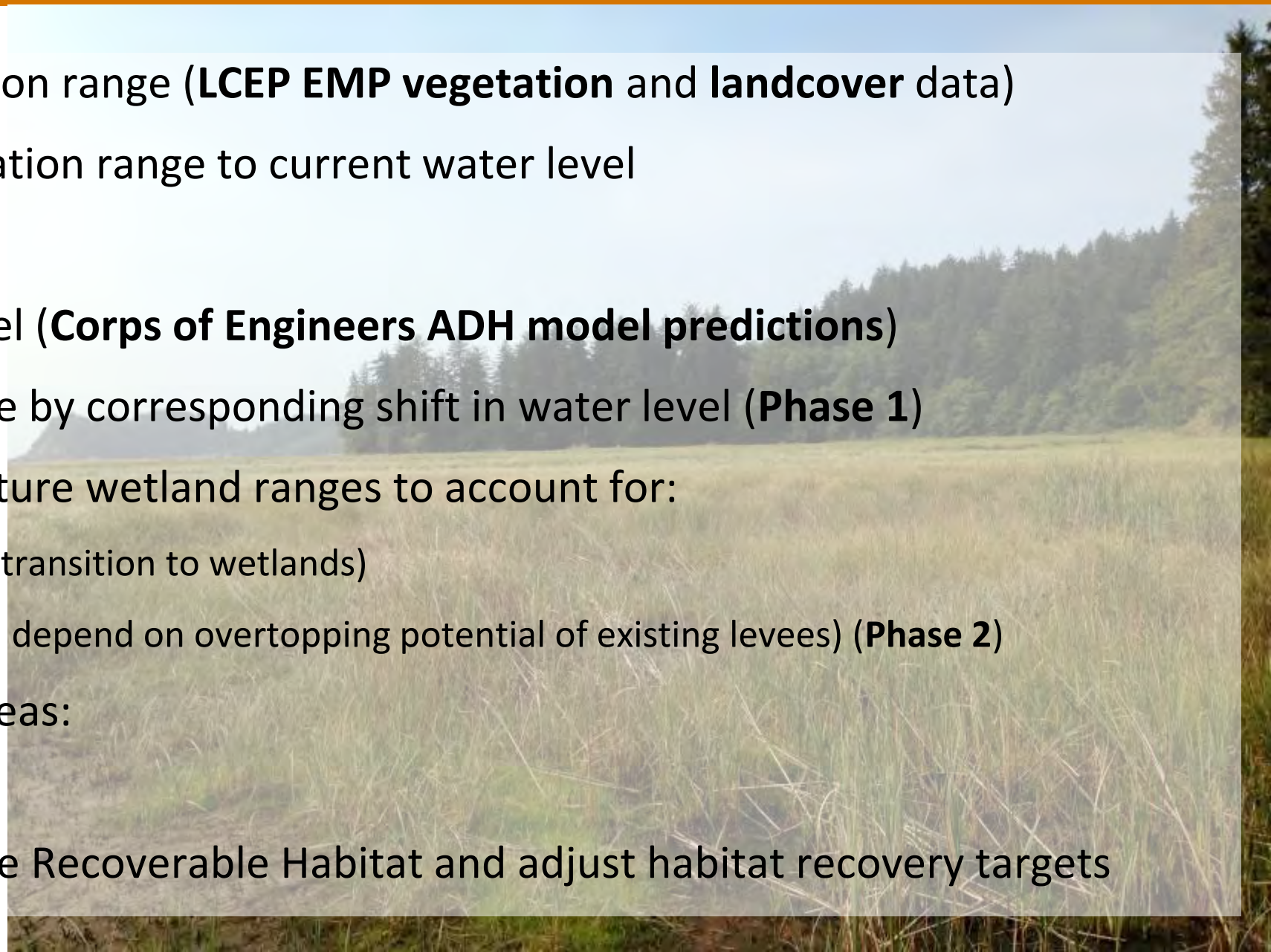
SLR and Wetlands Change

- Other factors that are not being considered in this study:
  - **Sediment accretion** (could offset SLR impacts by ~1-10 mm/yr)
  - **Localized tectonic adjustments** (uplift or subsidence. ~1-2 mm/yr)
    WA Coastal Resiliency Project provides estimates for areas in the estuary
  - **Other climate variables** (effects of precipitation and temperature changes on wetland vegetation)

Mapping SLR Impacts to Wetlands (Elevation Based Mapping)



- Map current wetland elevation range (**LCEP EMP vegetation** and **landcover** data)
- Relate current wetland elevation range to current water level

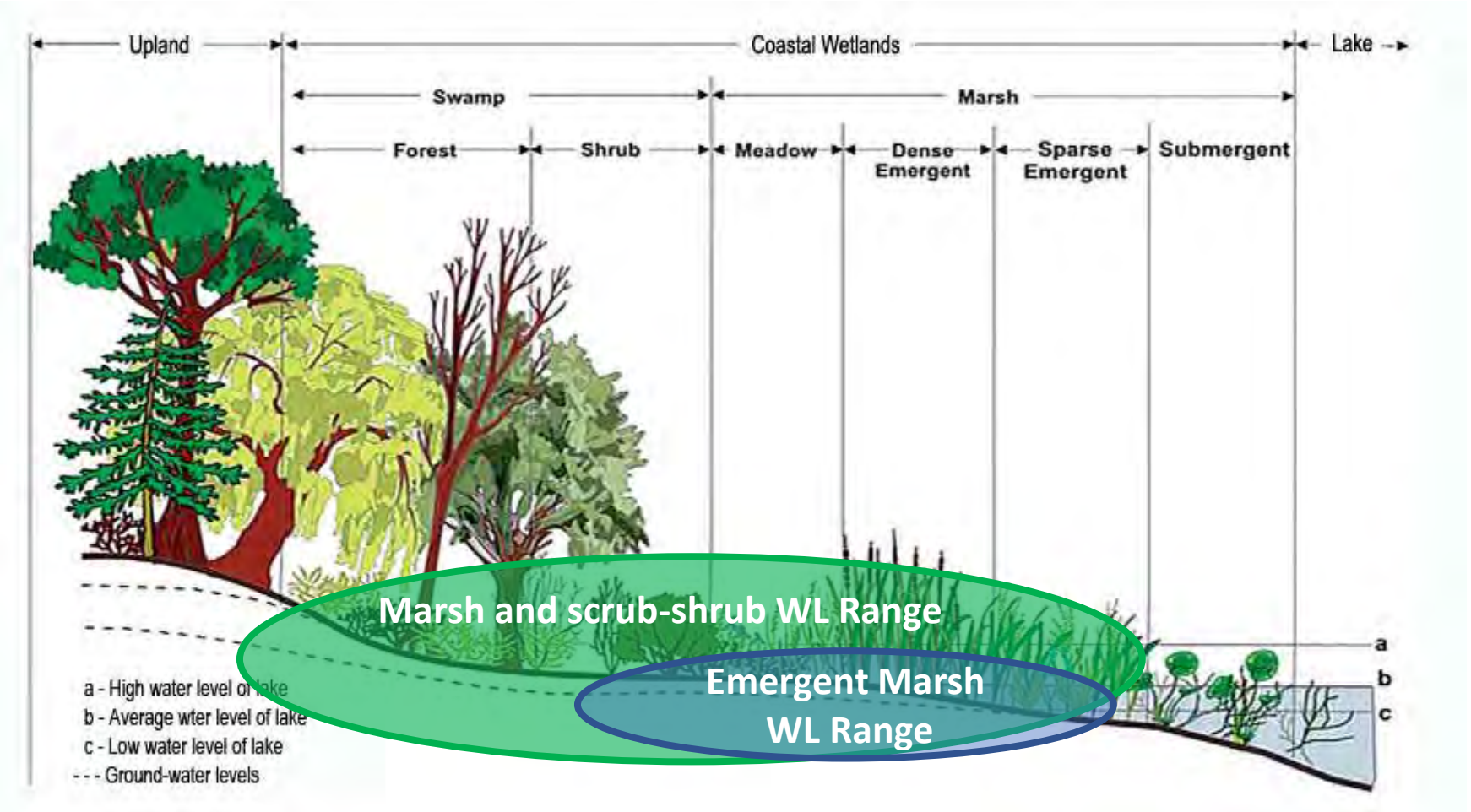
For each SLR scenario:

- Determine shift in water level (**Corps of Engineers ADH model predictions**)
- Shift wetland elevation range by corresponding shift in water level (**Phase 1**)
- Adjustments to predicted future wetland ranges to account for:
  - Developed lands (not likely to transition to wetlands)
  - Diked wetlands (transition will depend on overtopping potential of existing levees) (**Phase 2**)
- Treatment of special case areas:
  - Subsided areas
- Quantify changes to available Recoverable Habitat and adjust habitat recovery targets

Current LCR Wetland Elevation Range

Establish initial wetland elevation range by river kilometer

- Include emergent and scrub-shrub wetlands
- Data sources
  - Primary: emergent marsh elevation data at 136 sites from LCEP Ecosystem Monitoring Program and Kidd (2005–2017)
  - Supplement with LCEP 2010 landcover polygons for higher elevation scrub-shrub areas



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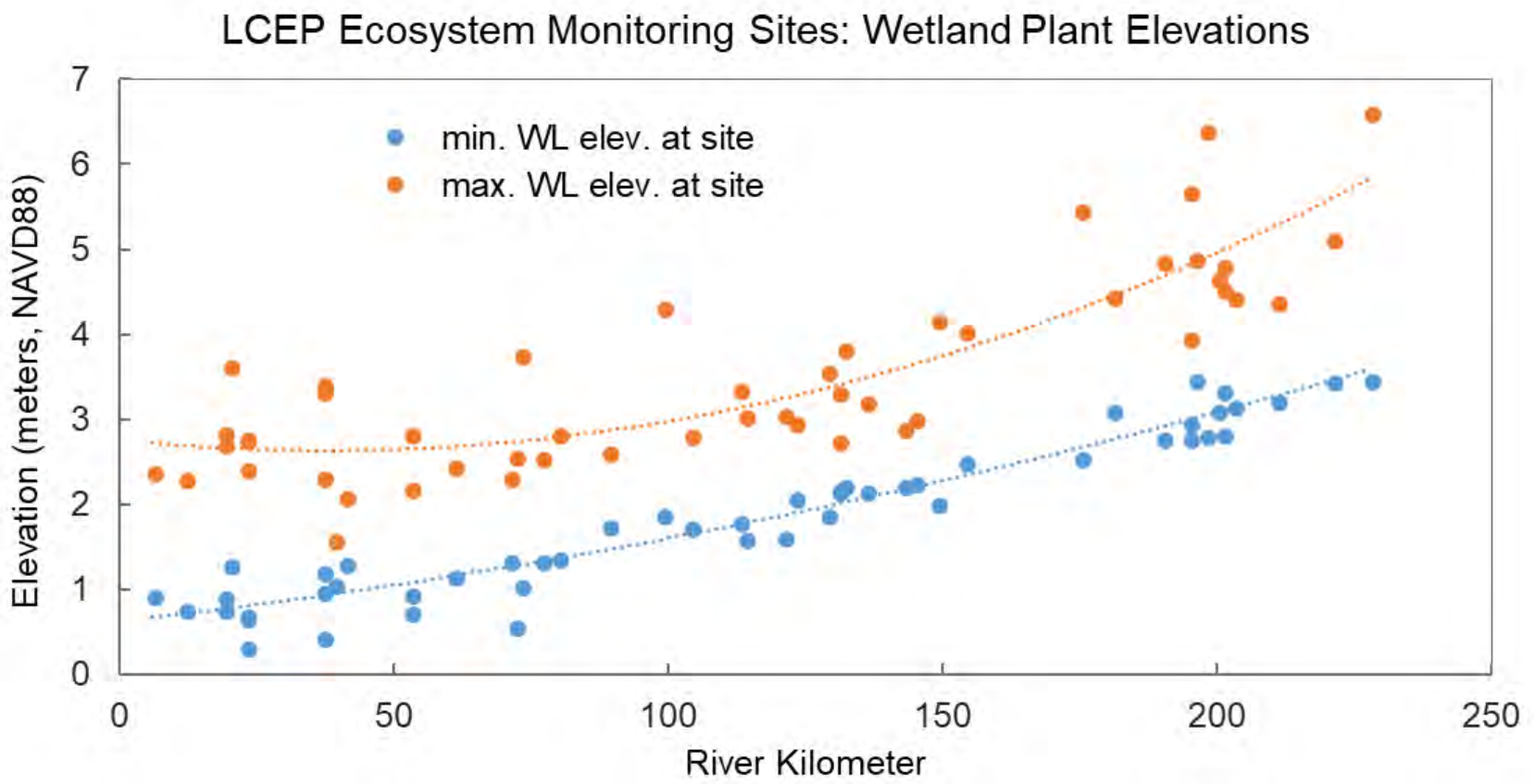
Current LCR Wetland Elevation Range

Establish initial wetland elevation range by river kilometer

- Upper limit defined by scrub shrub wetlands
- Lower limit defined by emergent wetlands



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Current LCR Wetland Elevation Range

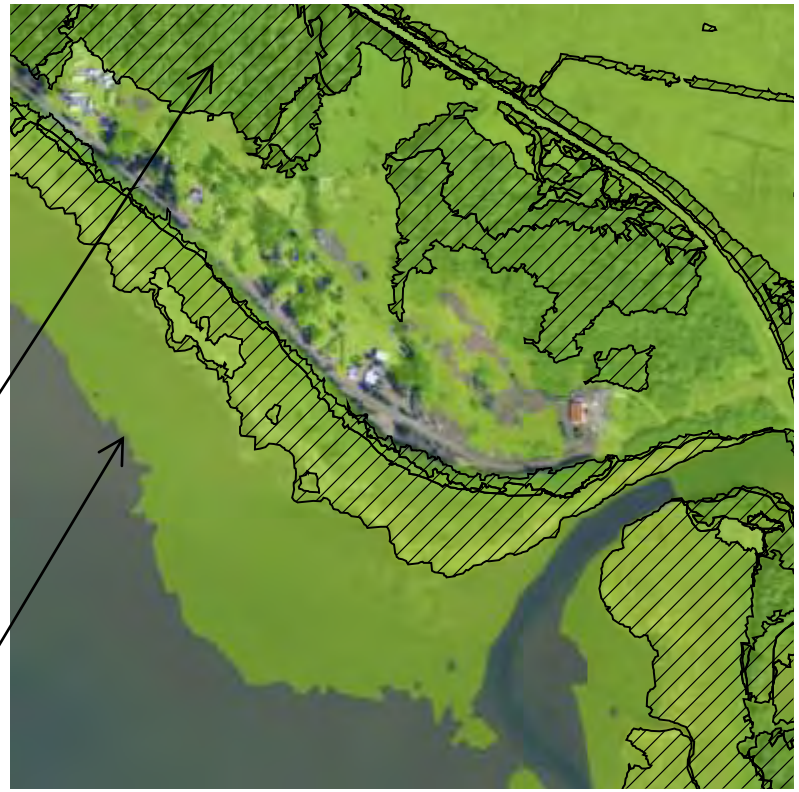
Local Ground truthing

- Adjust local elevations as needed based on imagery and landcover data (for scrub shrub max. elevations)

Initial too high

Initial too low

Initial Result



Adjusted Range

predicted wetland extent

2010 Landcover wetlands

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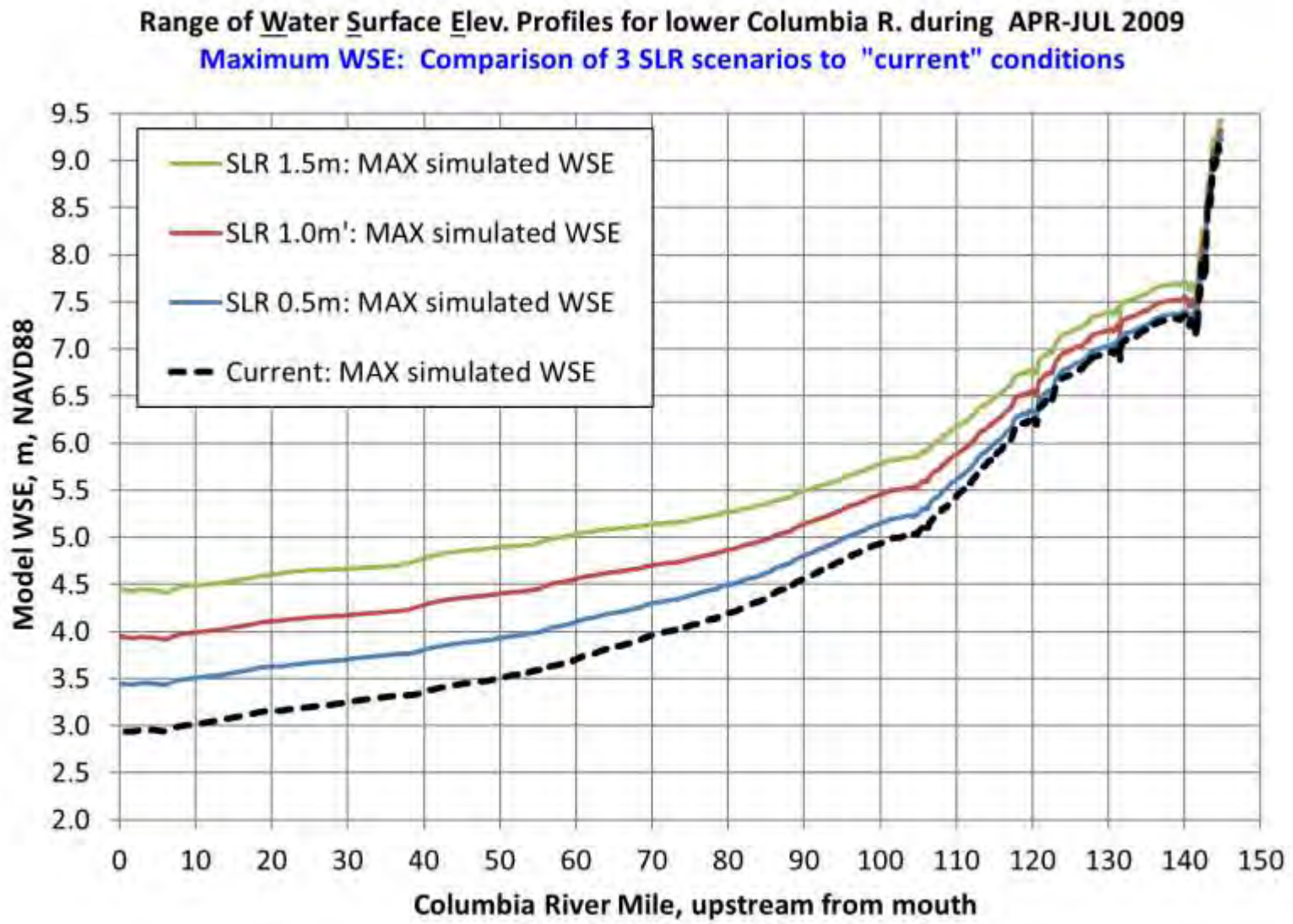
Current Water Level and SLR predictions

Water surface elevation (WSE) data from Corps of Engineers ADH Model simulations

- Includes WSE profiles at:
  - **max. high water (shown)**
  - **max. low water**
  - **avg. water**

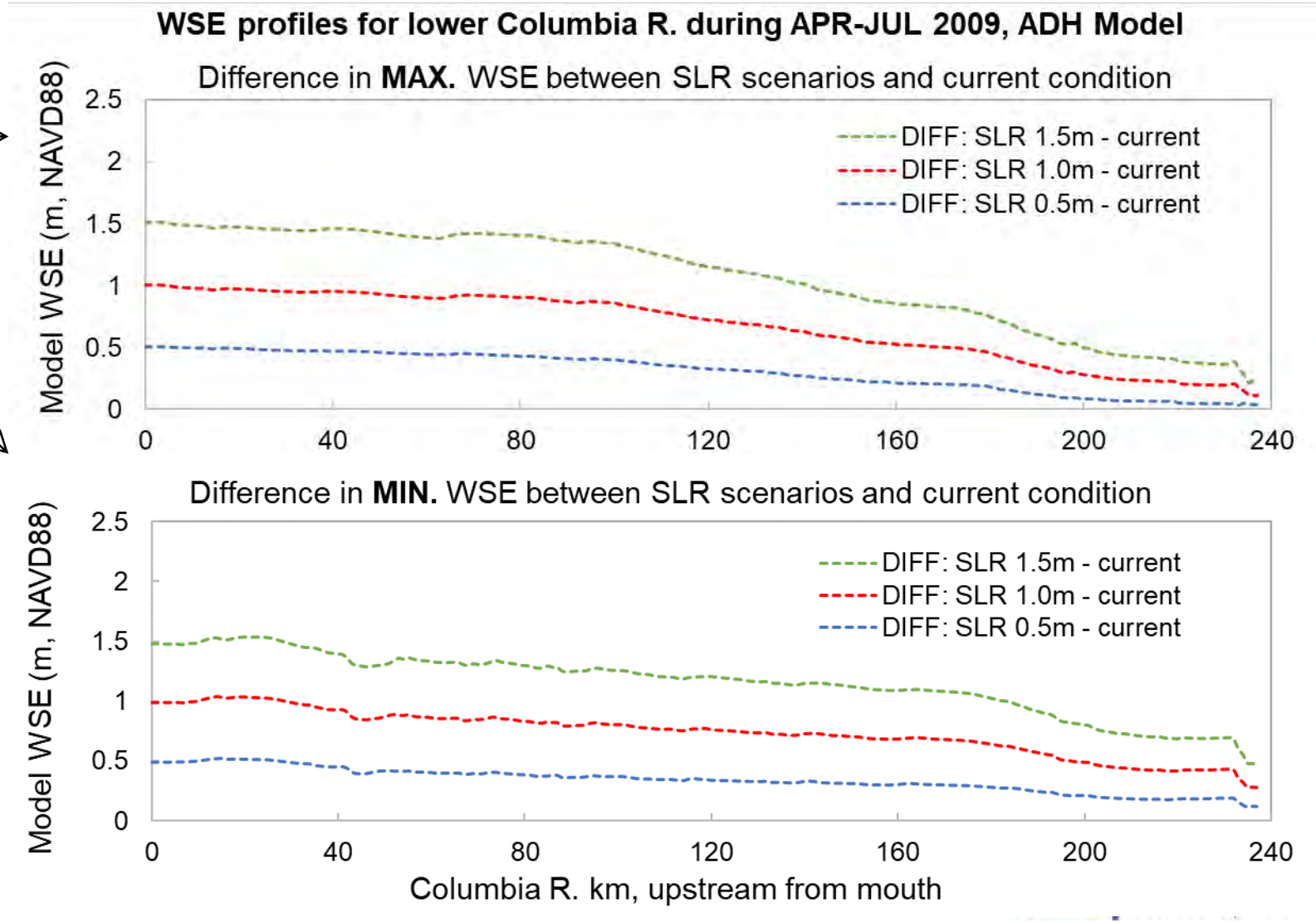
  for current conditions and 3 SLR scenarios (0.5,1.0,1.5 m)
- **Water level does not increase uniformly throughout river when SLR value is applied at ocean boundary!**



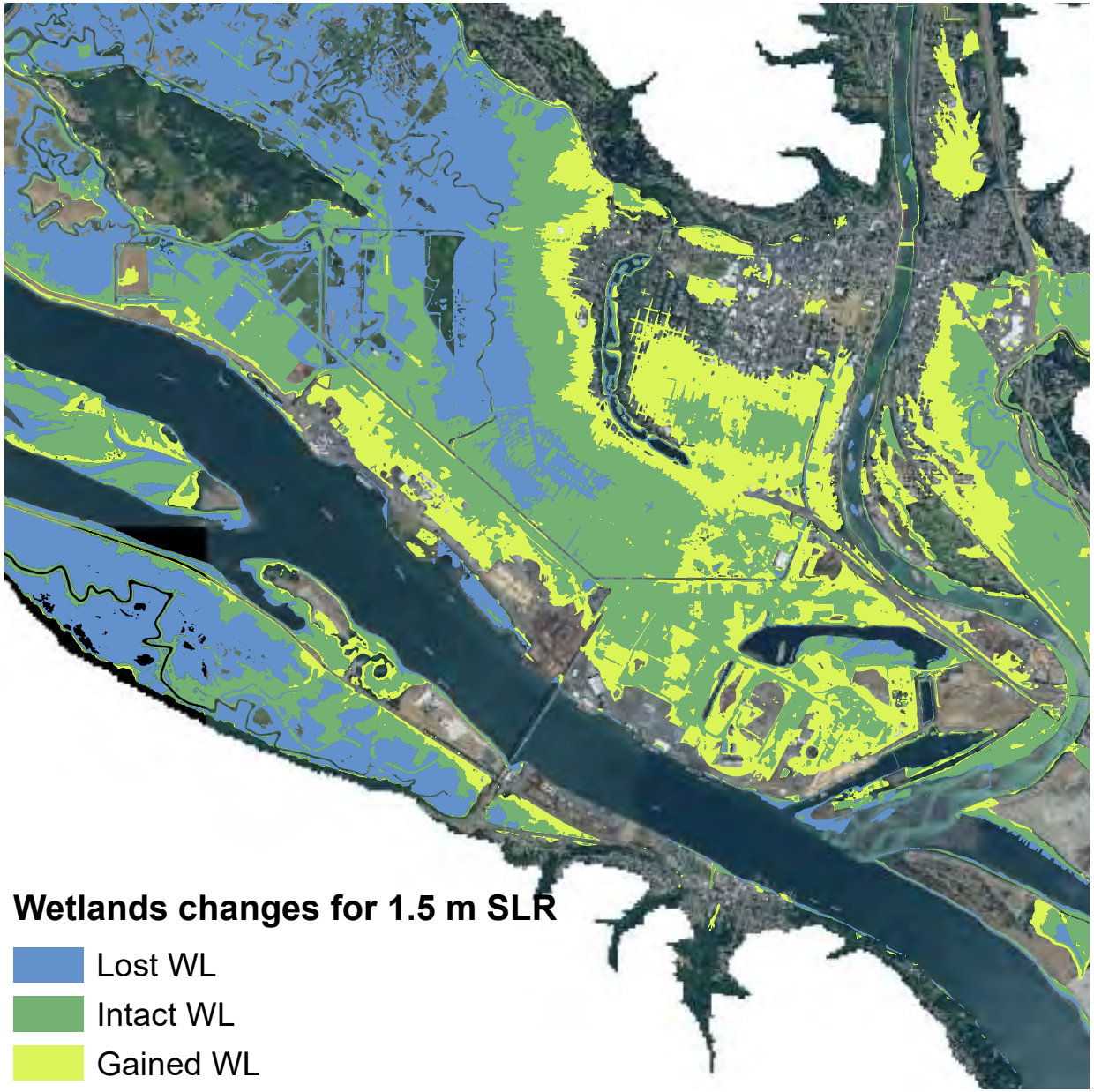
Wetlands Elevation Range Adjustment for SLR

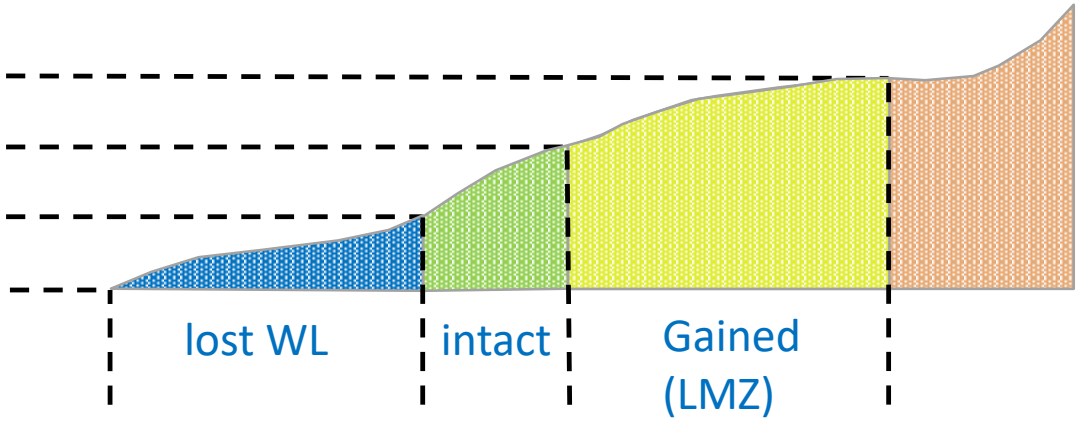
Basic assumption: wetland range will shift the same amount as the local water level

- Shift upper WL range according to MAX. WSE shift
- Shift lower WL range according to MIN. WSE shift
- Model uncertainty:
  - Assumes present day values for **Bonneville discharge** (2009)
  - We do not know how this will change in the future
  - Lower uncertainty below Longview, where ocean tide is dominant. Higher upstream



Future Wetlands Adjusted for SLR, Phase 1 Results





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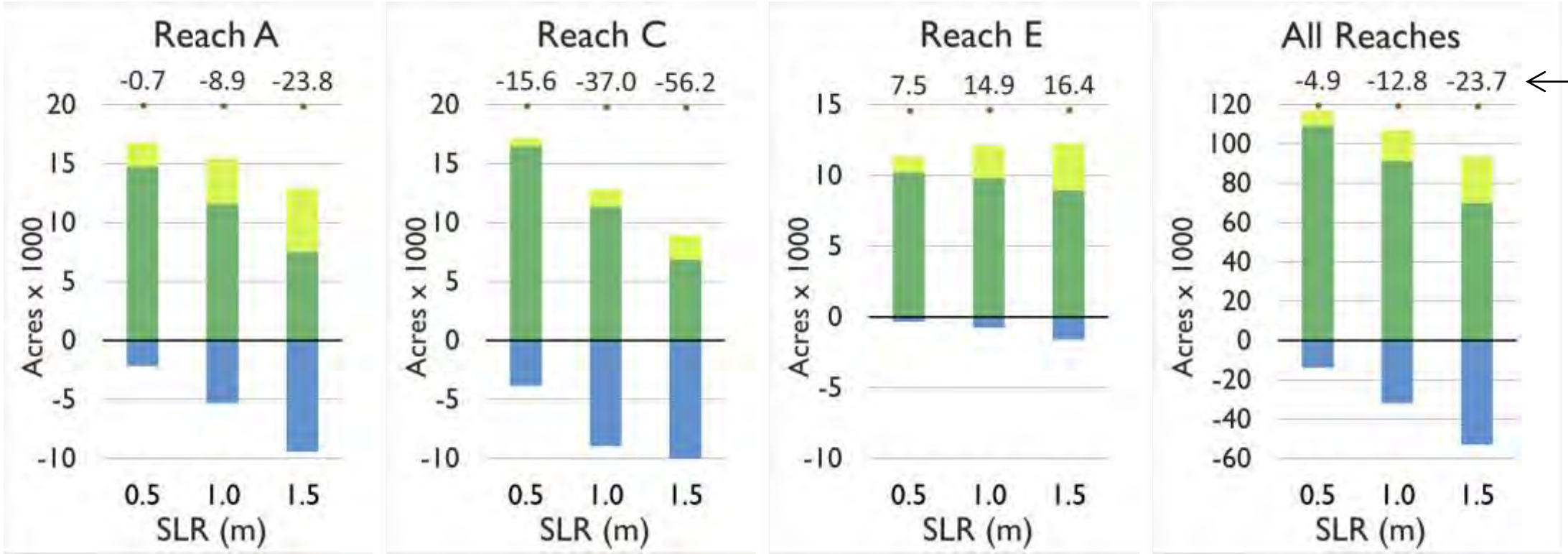
Future Wetlands Adjusted for SLR, Phase 1 Results

Net changes in wetland area by Hydrogeomorphic Reach



← Net change (% of current WL)

- Issues:
  - **Developed lands (not likely to become WL)**
  - **Levees (isolate diked WL from rising water levels)**
  - **Subsided areas**

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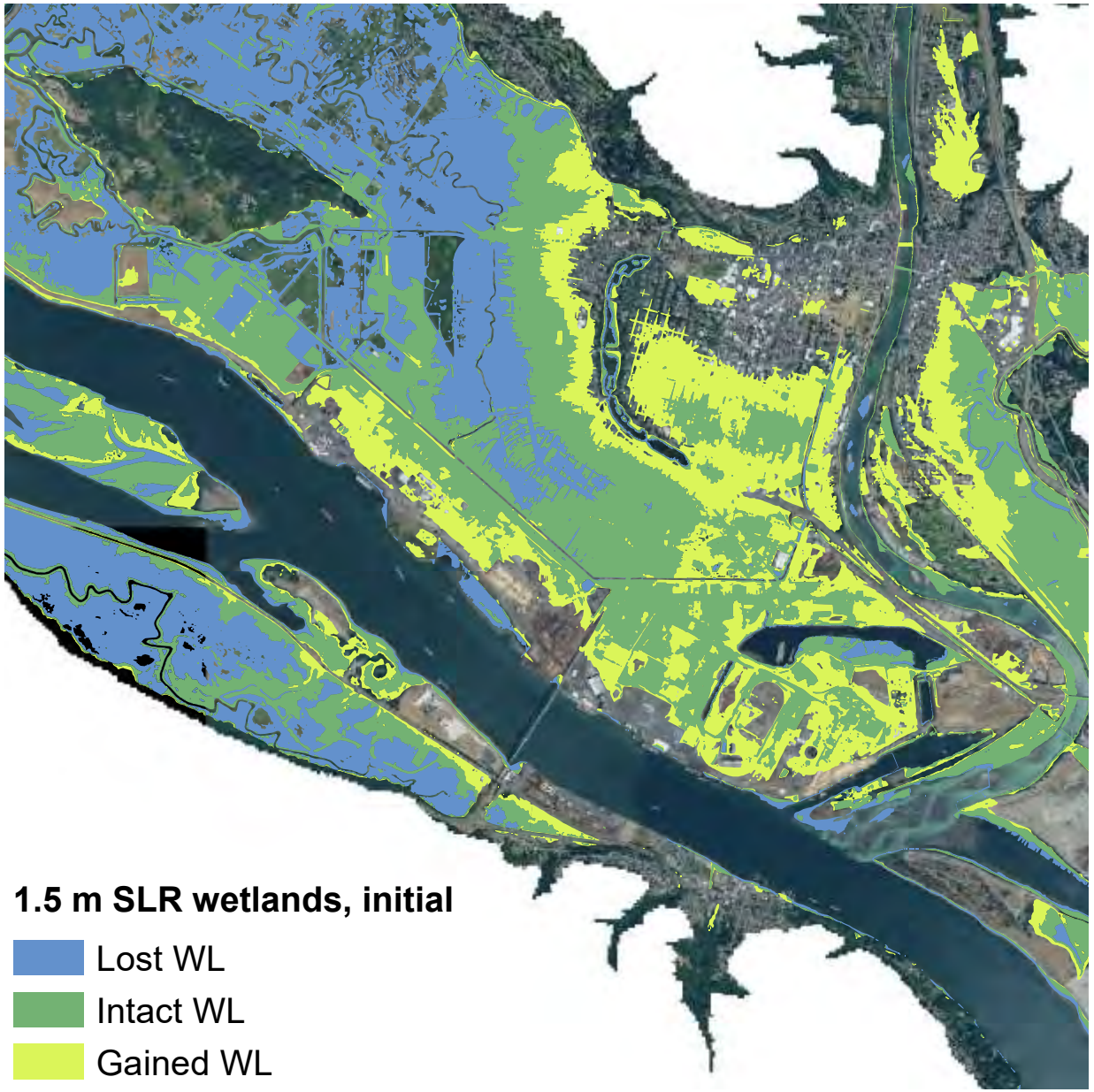
Remove Developed Lands From Analysis



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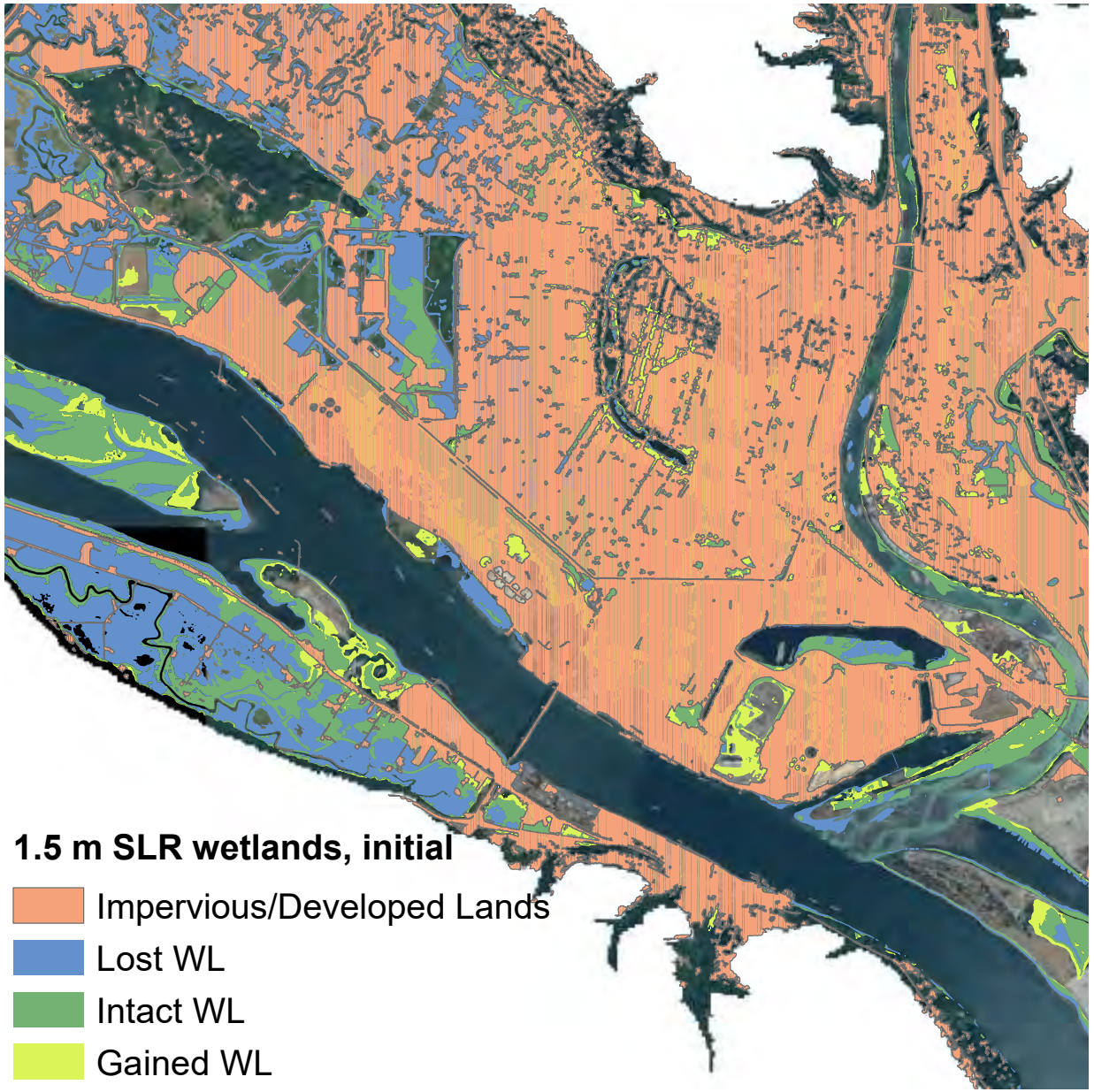
Remove Developed Lands From Analysis

Apply LCEP landcover Developed classes mask:



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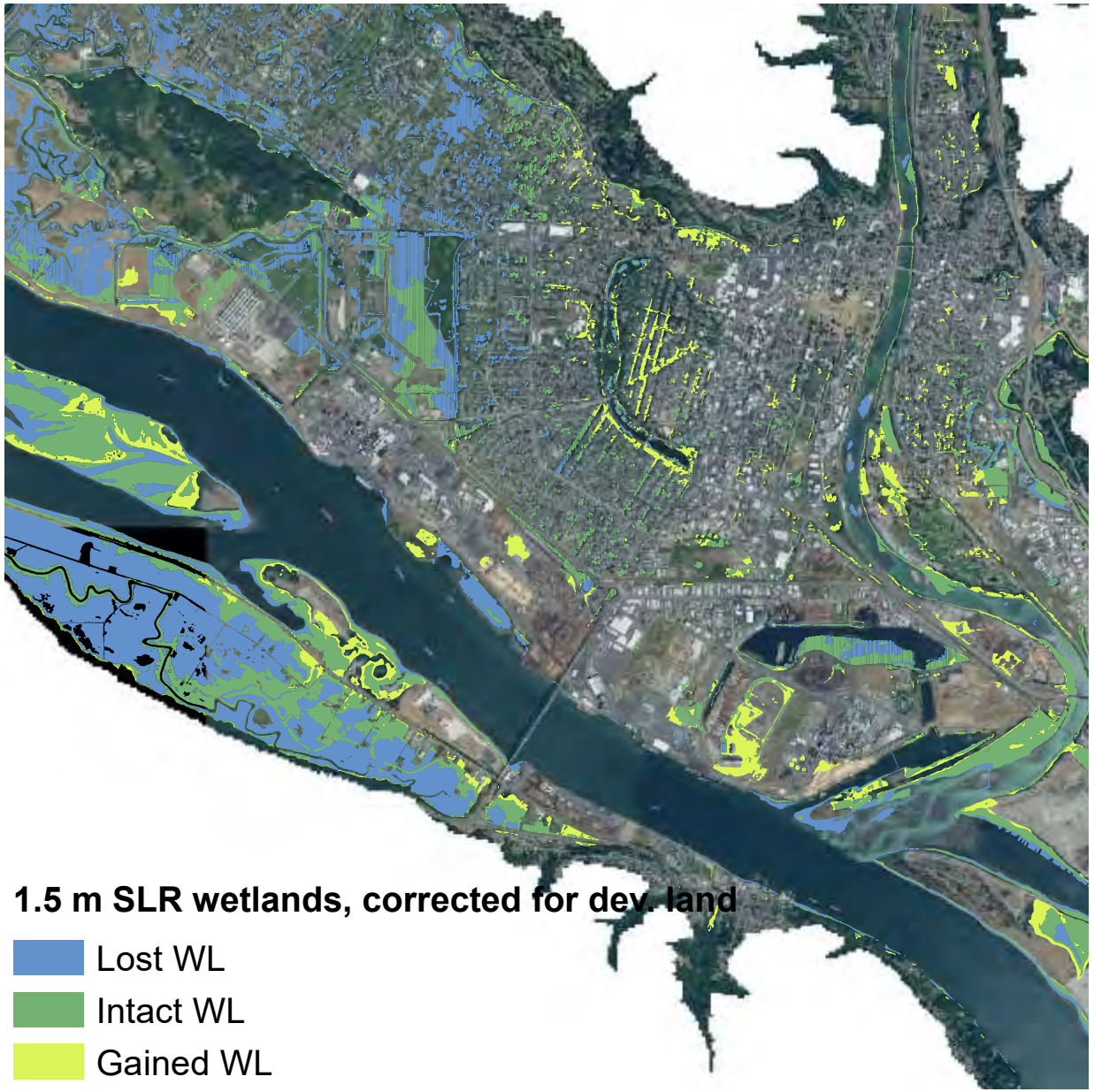
Remove Developed Lands From Analysis

Wetlands changes for 1.5 m SLR scenario with Developed lands removed



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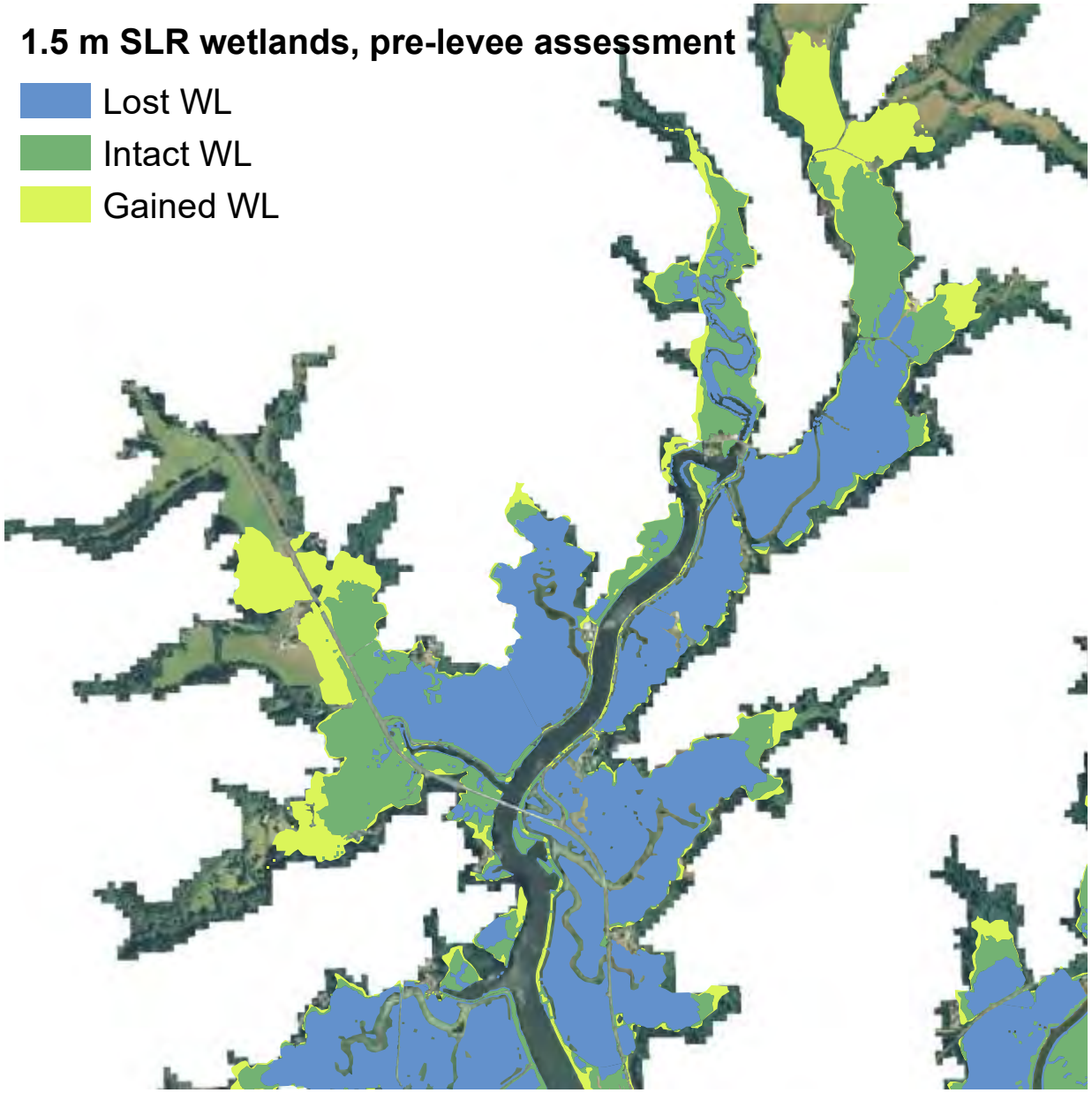
Levee Impacts

Wetlands changes for 1.5 m SLR scenario with Developed lands removed



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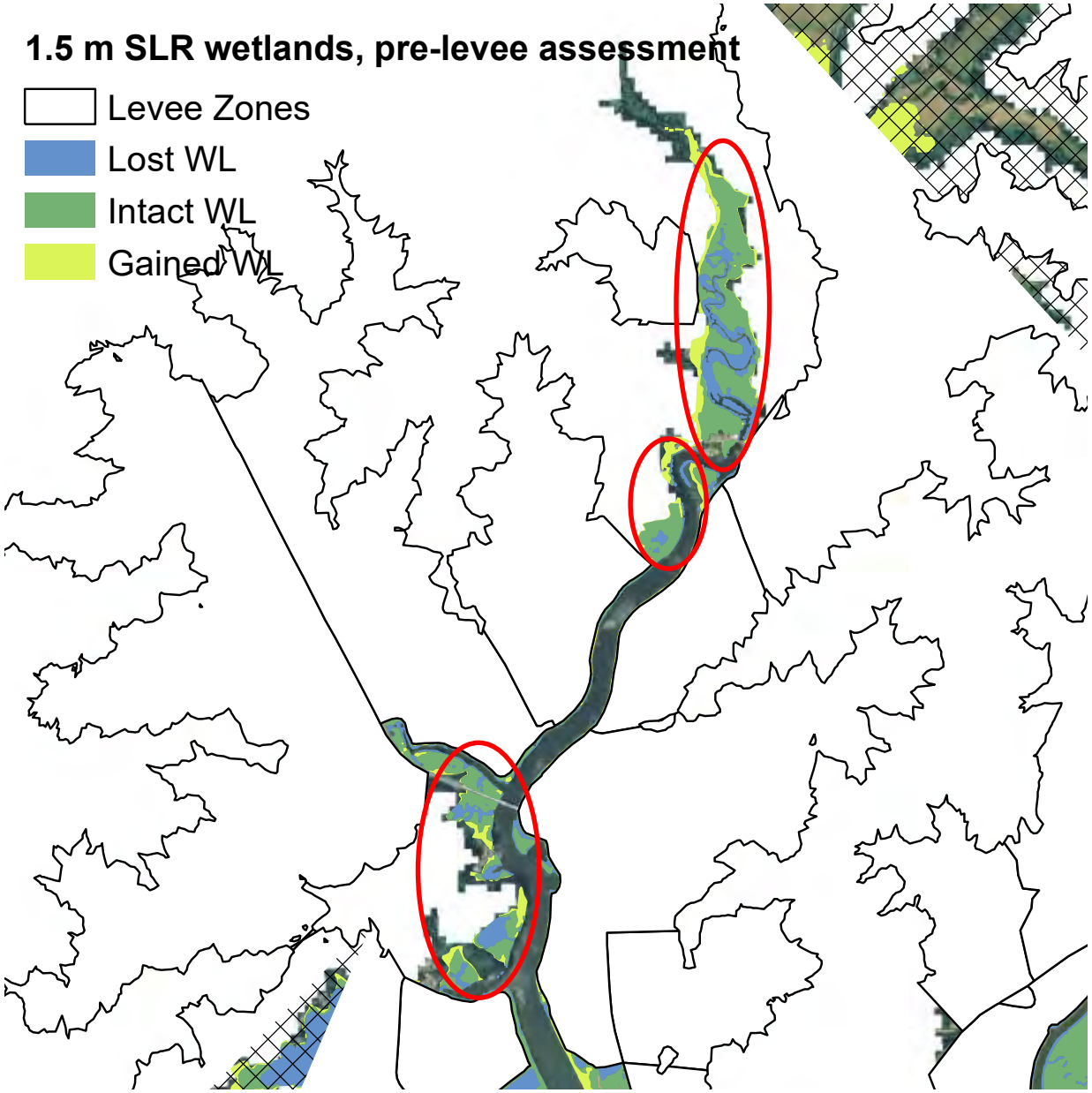
Levee Impacts

Diked wetlands (within Levee Zones shown) will only be impacted by SLR if the surrounding levee overtops

Tidal wetland areas. All other wetlands in this area are diked



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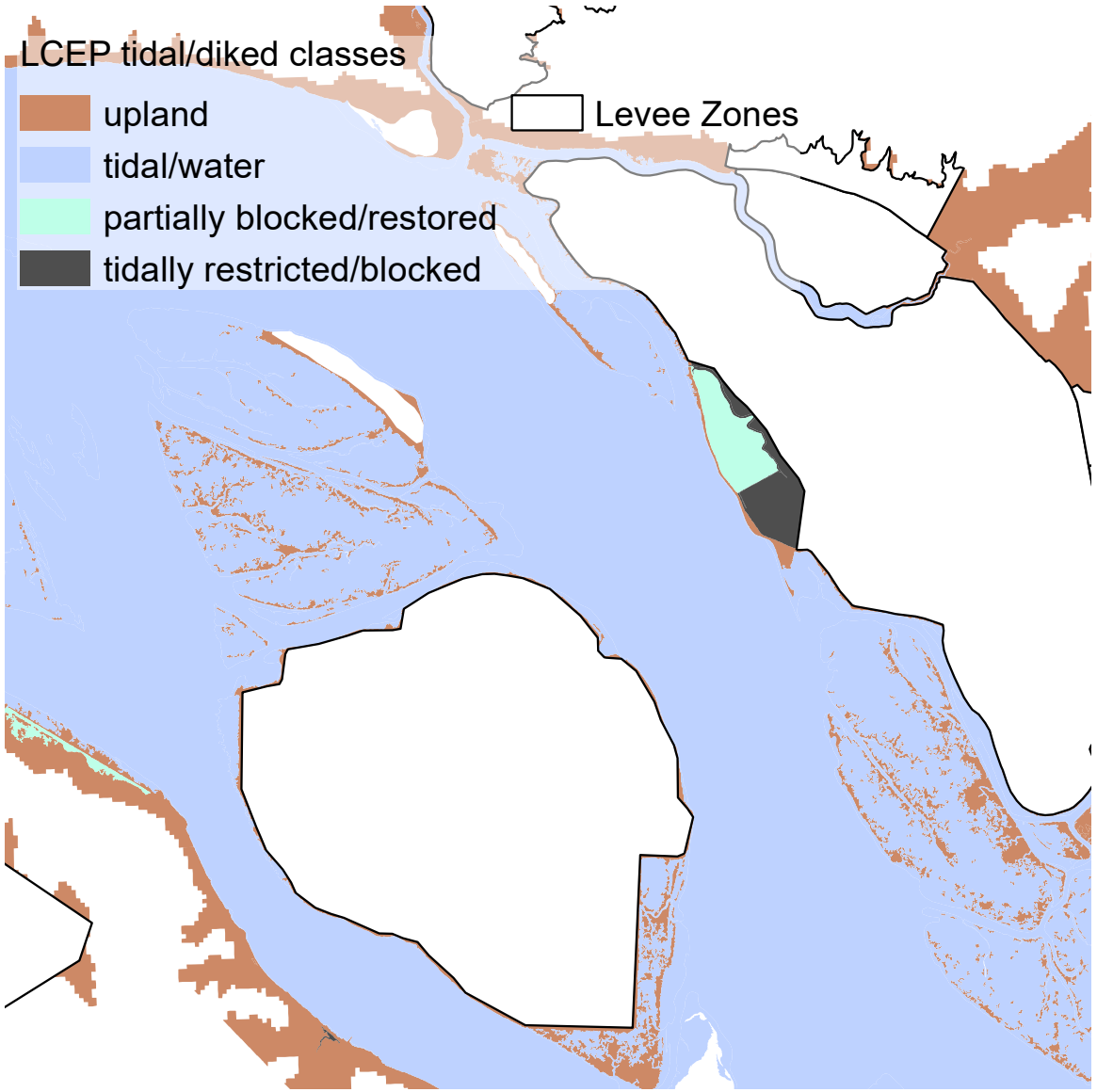
Levee Impacts – Assessing overtopping

- **Isolate Levee Zones using existing LCEP tidal/diked wetlands layer**



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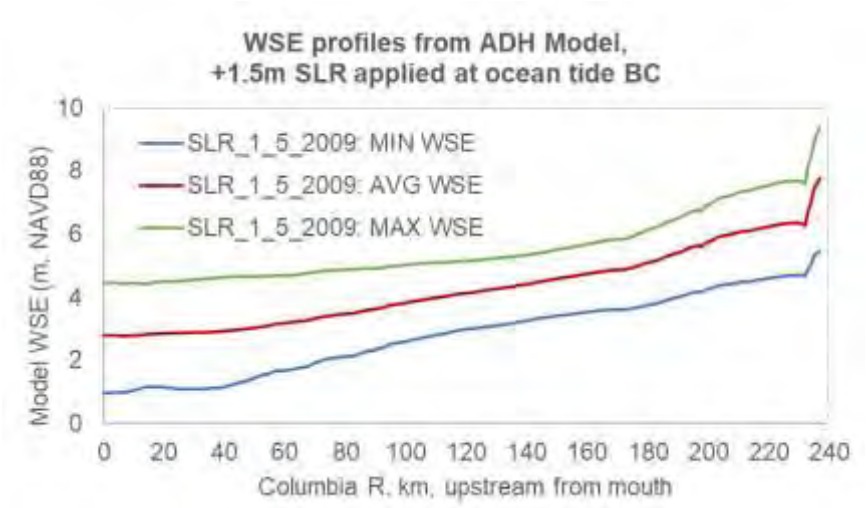
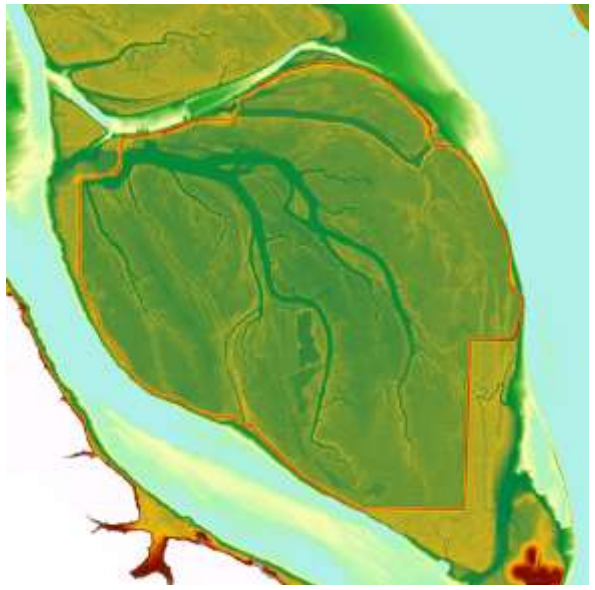
Levee Impacts – Assessing overtopping

- Isolate Levee Zones using existing LCEP tidal/diked wetlands layer
- **Compare Corps of Engineers ADH water level data for SLR scenarios to DEM to identify overtopping areas**
  - **Overtop criteria: 10 m long x 0.2 m depth**





Overtopping
Dike/levee
Diked Zones
Mainstem Columbia

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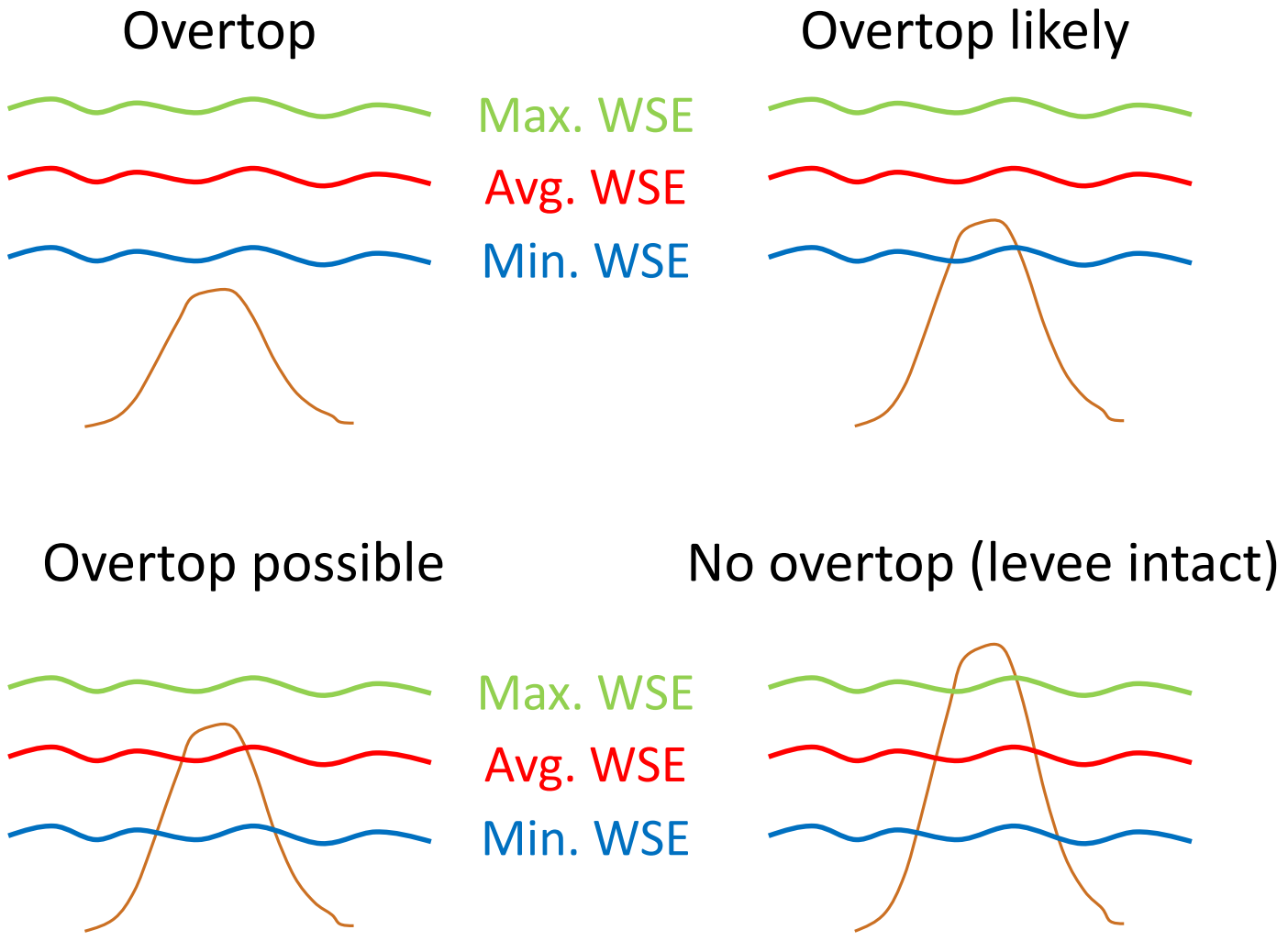
Levee Impacts – Assessing overtopping

- Isolate Levee Zones using existing LCEP tidal/diked wetlands layer
- Compare Corps of Engineers ADH water level data for SLR scenarios to DEM to identify overtopping areas
  - **Overtop criteria: 10 m long x 0.2m deep**
- **Apply range of uncertainty for overtopping**



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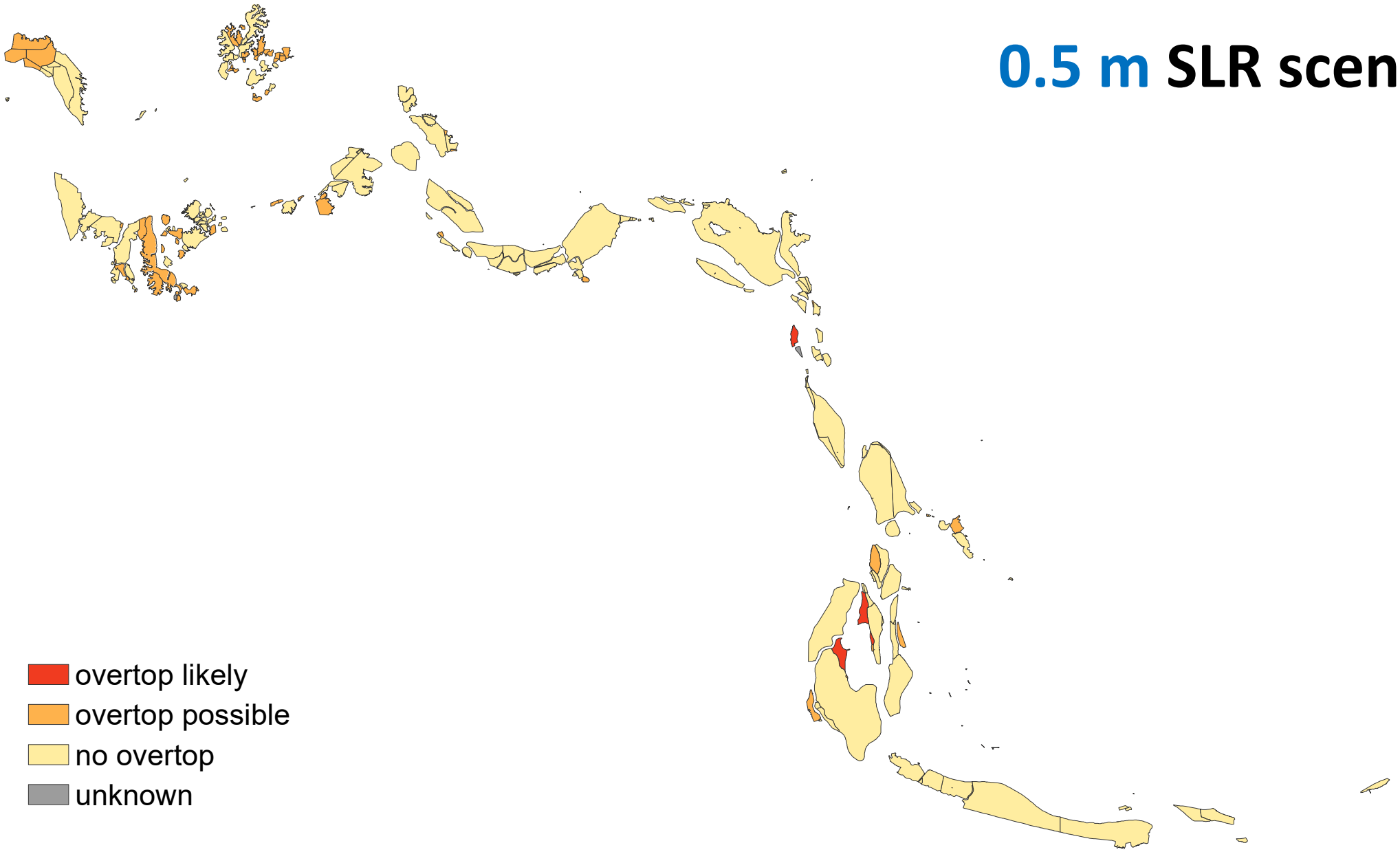
Levee Impacts – overtopping potential

0.5 m SLR scenario



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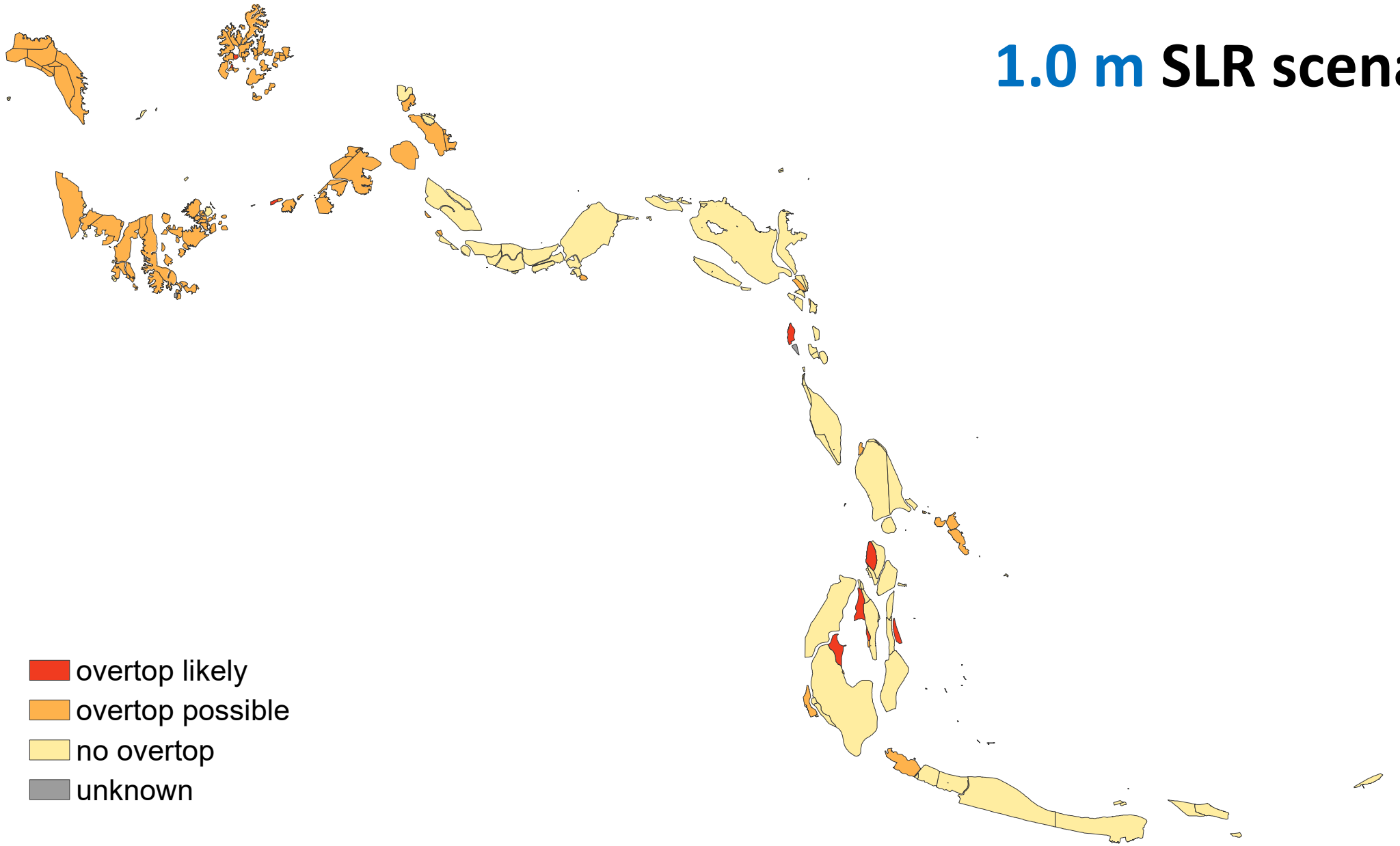
Levee Impacts – overtopping potential

1.0 m SLR scenario



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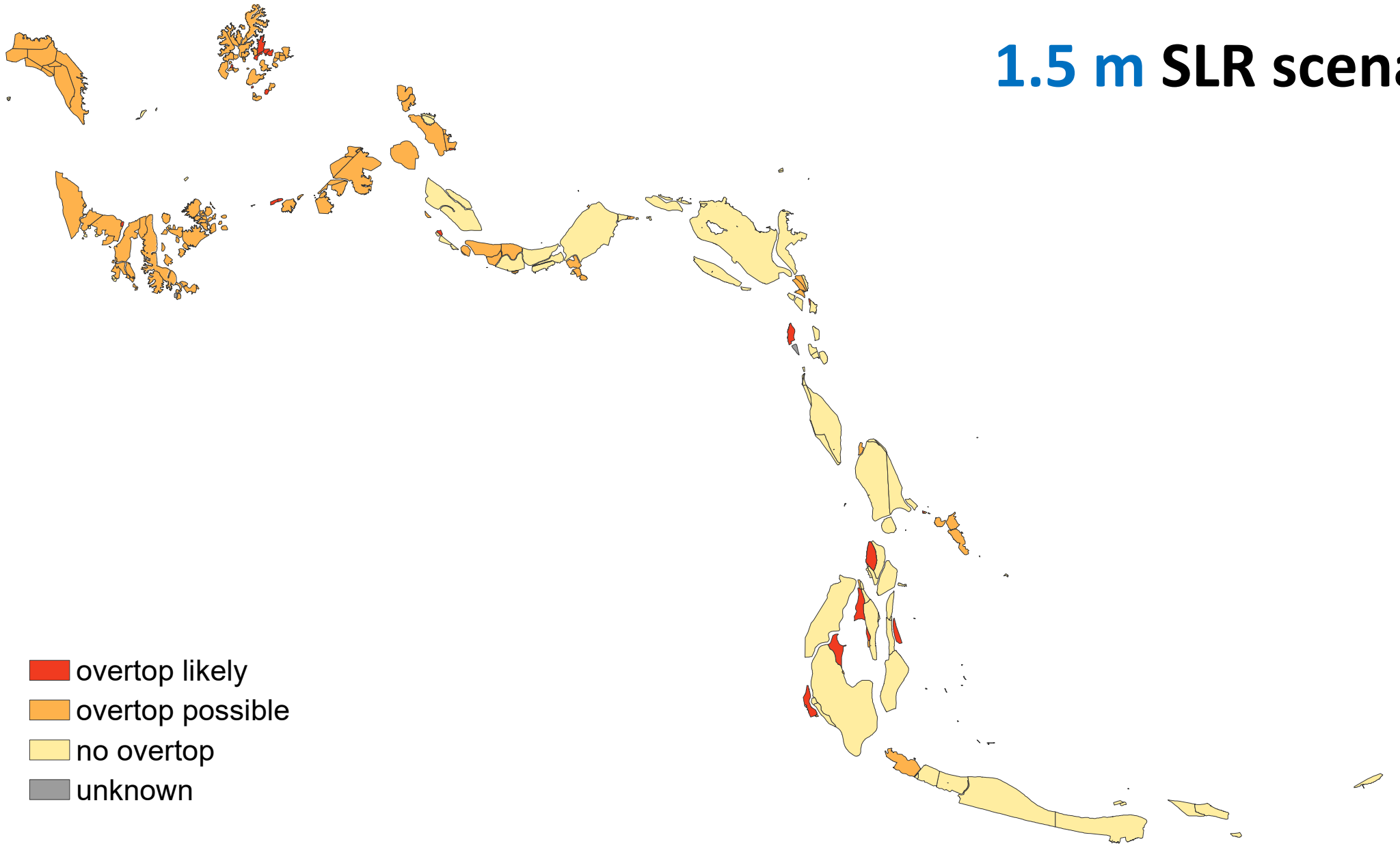
Levee Impacts – overtopping potential

1.5 m SLR scenario



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Levee Impacts – wetlands re-classification

Inputs	Phase 1 Action	Phase 1 Classes	Phase 2A Action	Phase 2A Classes					Phase 2B Action	Phase 2B Classes				
				no levee	levee present, overtop potential:					no levee	levee present, overtop potential:			
					overtop	overtop Likely	overtop Possible	No overtop			overtop	overtop Likely	overtop Possible	No overtop
Current WL Range	Apply SLR shift	Lost WL	Assess over-topping	Lost TWL	Lost DWL	Lost DWL - likely	Lost DWL – possible	Intact DWL	---	---	---	---	---	---
		Intact WL		Intact TWL	Gained TWL	Gained TWL - likely	Gained TWL - possible	Intact DWL		---	---	---	---	---
		Gained WL		Gained TWL	Gained TWL	Gained TWL - likely	Gained TWL - possible	Intact DWL		---	---	---	---	---
Subsided WL (Ag/WL in Land-cover)		Lost WL		not likely to occur	Lost DWL	Lost DWL - likely	Lost DWL - possible	Intact DWL		---	---	---	---	---
Developed areas extracted from Phase1 future WL	---	---	---	---	---	---	---	---	Assess over-topping	High risk	High risk	Mod. risk	Low risk	Intact

Mapping Future Wetlands - Process Summary

1.5 m SLR scenario

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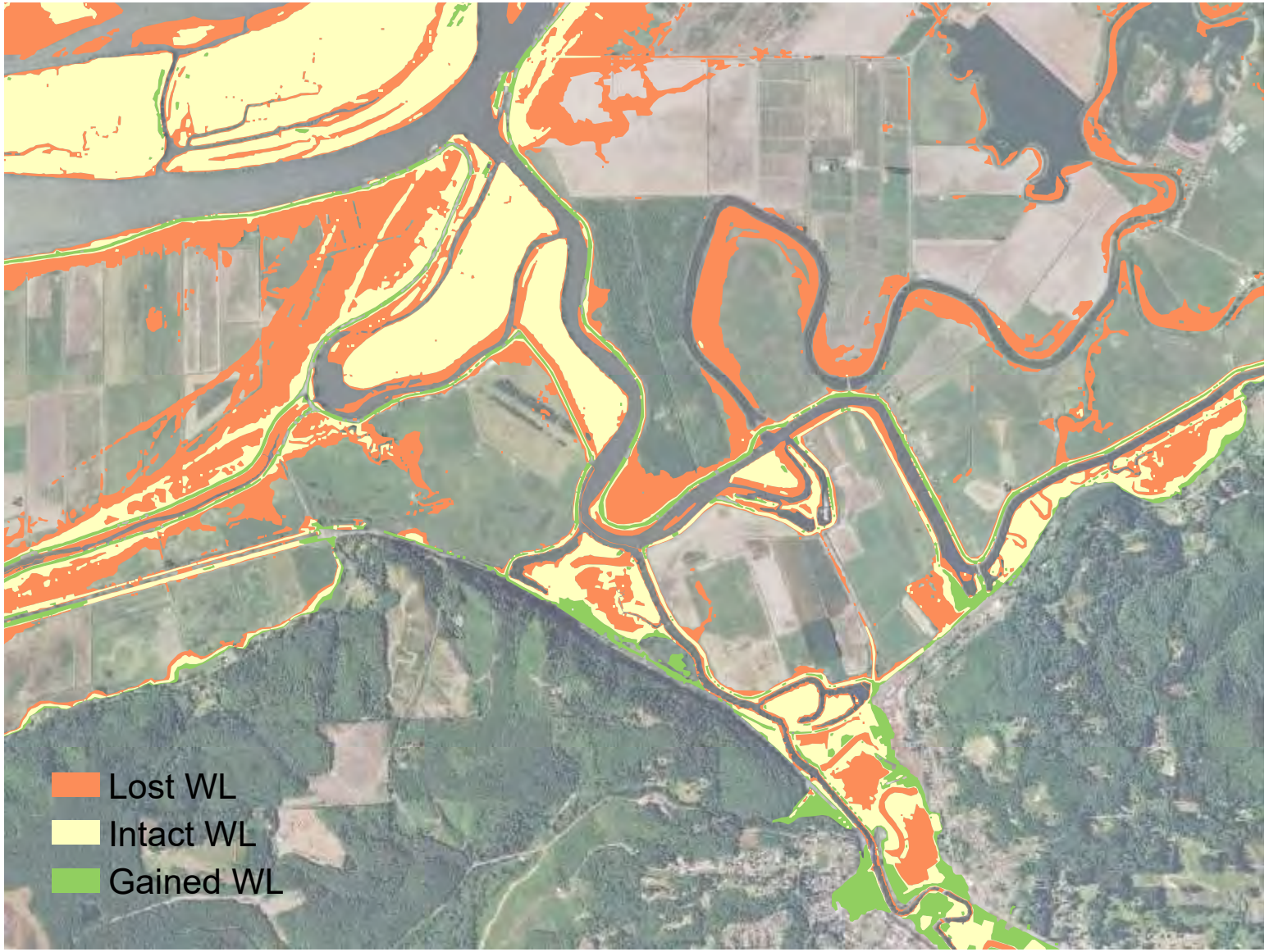
Mapping Future Wetlands - Process Summary



1.5 m SLR scenario

Apply SLR shift to predict future WL range (Phase 1)

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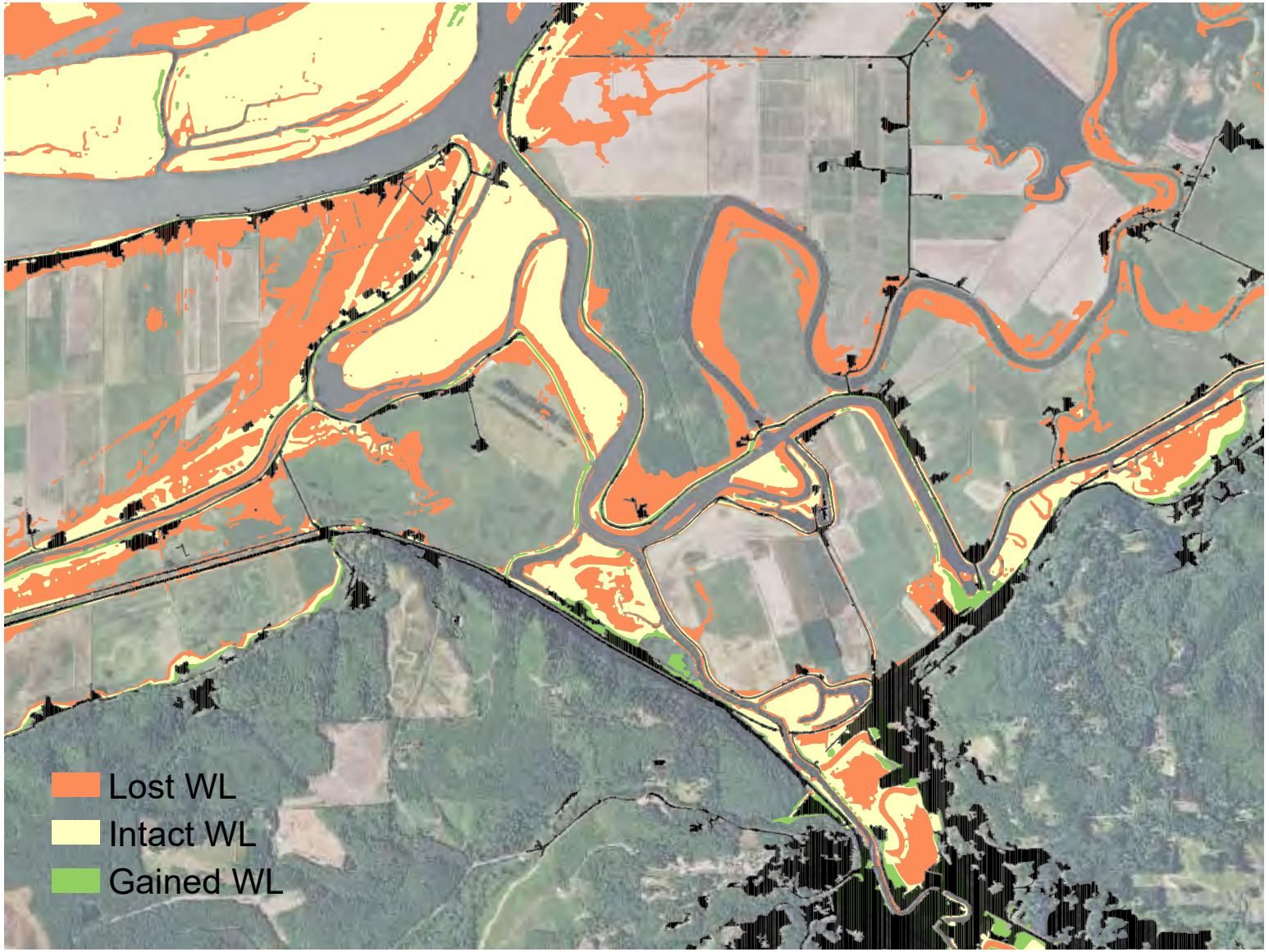
Mapping Future Wetlands - Process Summary



1.5 m SLR scenario

Apply Developed Areas Mask

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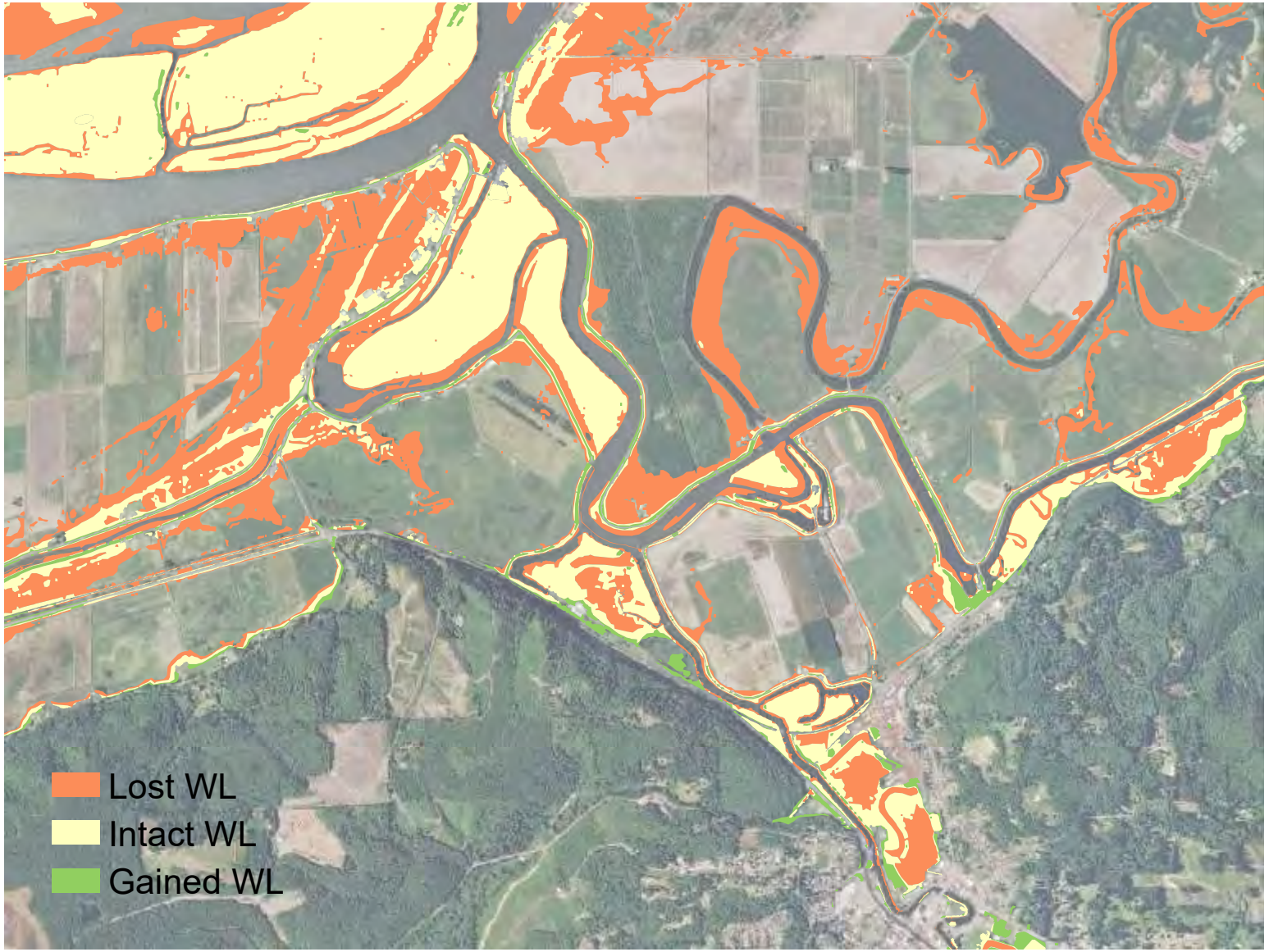
Mapping Future Wetlands - Process Summary



1.5 m SLR scenario

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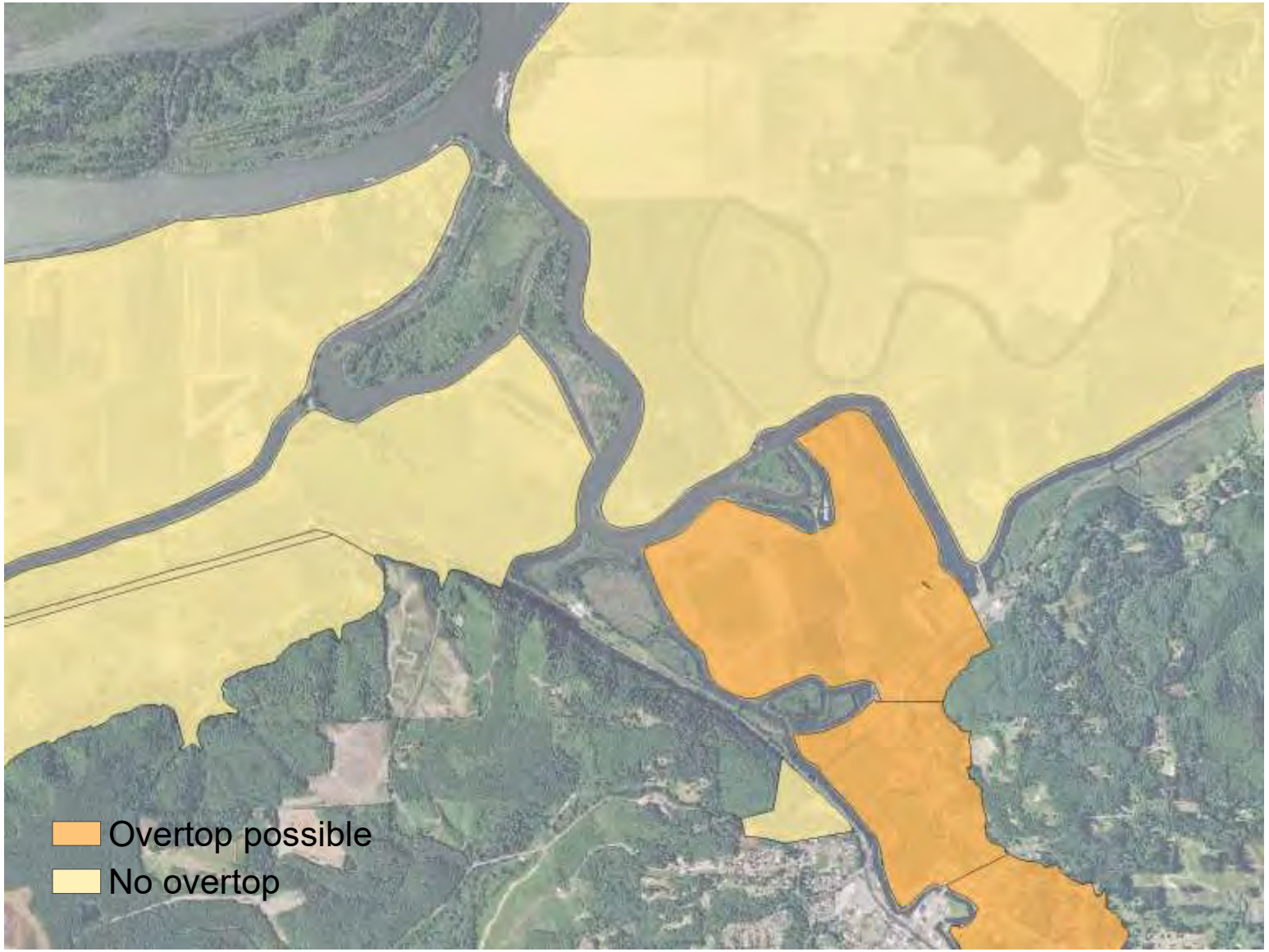
Mapping Future Wetlands - Process Summary



1.5 m SLR scenario

Assess levee overtopping potential

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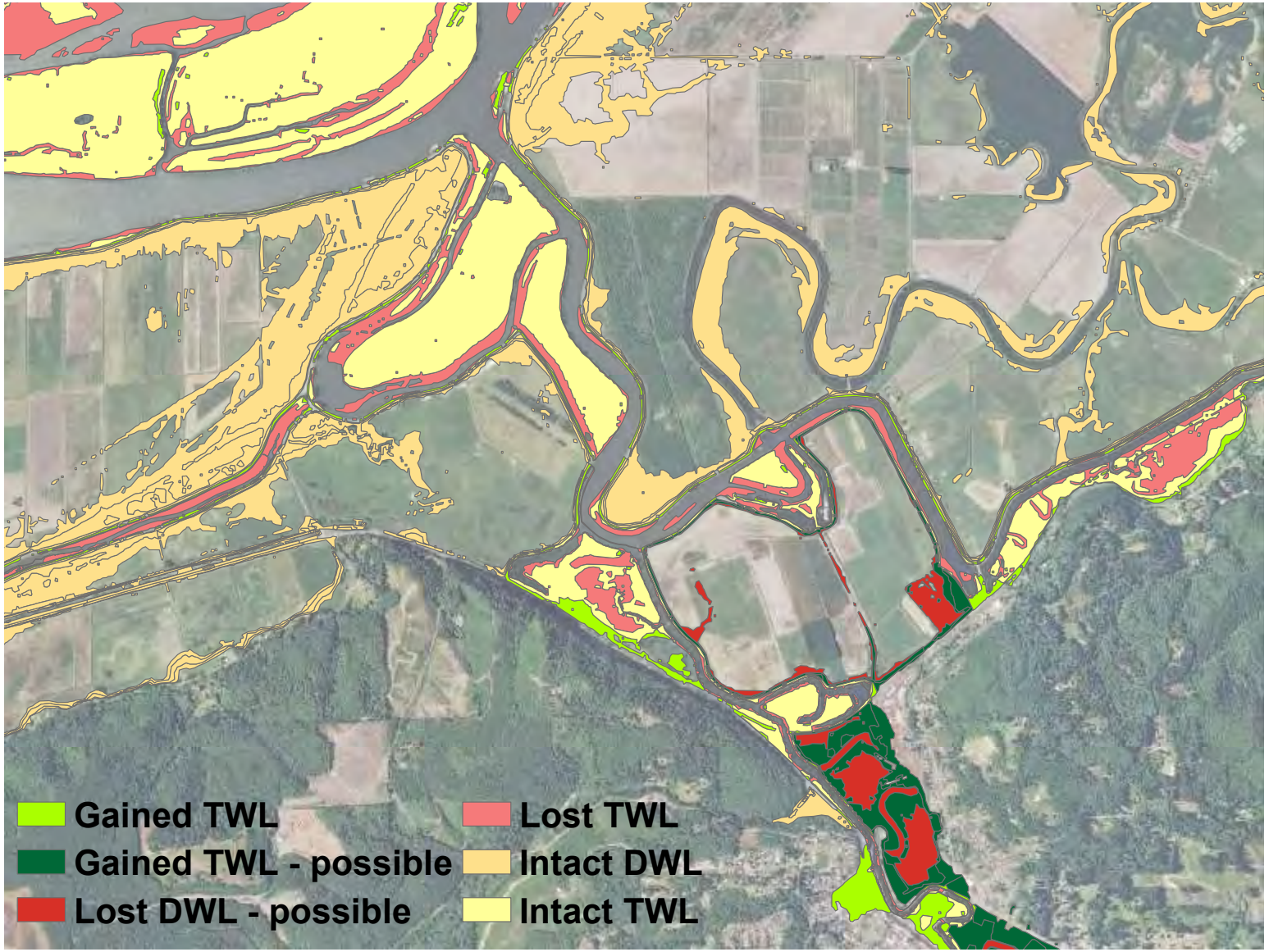
Mapping Future Wetlands - Process Summary



1.5 m SLR scenario

Apply levee assessment to refine future wetlands impacts classes

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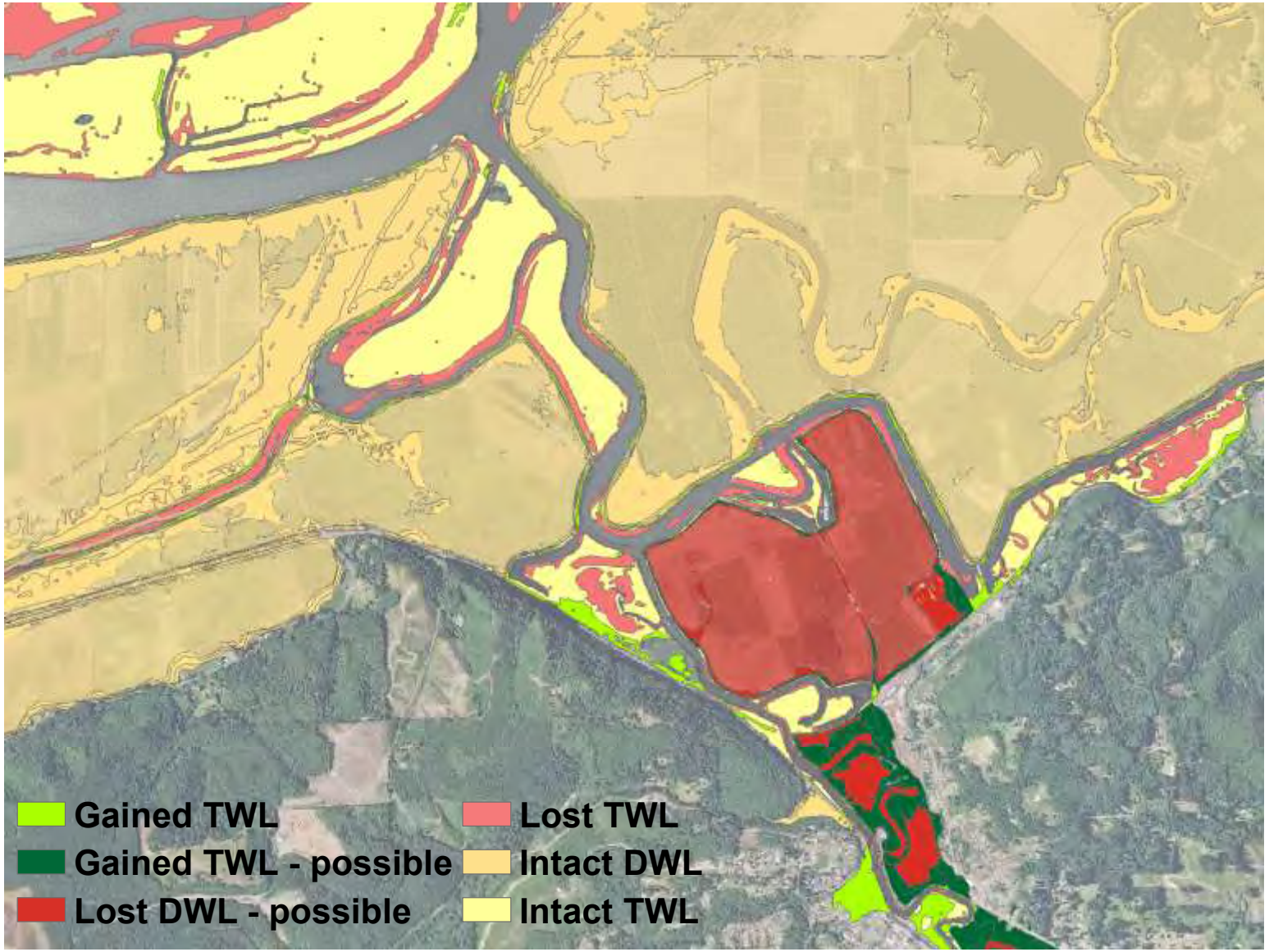
Mapping Future Wetlands - Process Summary



1.5 m SLR scenario

Include subsided areas

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Future Wetlands Adjusted for SLR, Phase 2 Results

Two outcomes based on levee overtopping predictions:

Possible wetland transitions:

SLR	Lost DWL-poss.	Lost DWL-likely	Lost TWL	Intact DWL	Intact TWL	Gained TWL-poss	Gained TWL-likely	Gained TWL
0.5	-902	0	-6,521	69,809	43,422	5,609	875	3,113
1.0	-8,850	-166	-11,762	55,376	38,181	14,589	1,221	6,409
1.5	-17,648	-473	-19,073	53,656	30,858	9,599	1,474	9,506

1. Wetland transitions grouped for the likely outcome for the SLR scenario (minimal predicted overtopping):

SLR	Lost DWL	Lost TWL	Intact DWL	Intact TWL	Gained TWL	Net change TWL
0.5	0	-6,521	76,321	43,422	3,988	-5
1.0	-166	-11,762	78,814	38,181	7,630	-8
1.5	-473	-19,073	80,903	30,858	10,980	-16

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Future Wetlands Adjusted for SLR, Phase 2 Results

Two outcomes based on levee overtopping predictions:

Possible wetland transitions:

SLR	Lost DWL-poss.	Lost DWL-likely	Lost TWL	Intact DWL	Intact TWL	Gained TWL-poss	Gained TWL-likely	Gained TWL
0.5	-902	0	-6,521	69,809	43,422	5,609	875	3,113
1.0	-8,850	-166	-11,762	55,376	38,181	14,589	1,221	6,409
1.5	-17,648	-473	-19,073	53,656	30,858	9,599	1,474	9,506

1. Wetland transitions grouped for the likely outcome for the SLR scenario (minimal predicted overtopping):

SLR	Lost DWL	Lost TWL	Intact DWL	Intact TWL	Gained TWL	Net change TWL
0.5	0	-6,521	76,321	43,422	3,988	-5
1.0	-166	-11,762	78,814	38,181	7,630	-8
1.5	-473	-19,073	80,903	30,858	10,980	-16

2. Wetland transitions grouped for the possible outcome for the SLR scenario (increase in predicted overtopping):

SLR	Lost DWL	Lost TWL	Intact DWL	Intact TWL	Gained TWL	Net change TWL
0.5	-902	-6,521	69,809	43,422	9,597	6
1.0	-9,016	-11,762	55,376	38,181	22,219	21
1.5	-18,121	-19,073	53,656	30,858	20,579	3

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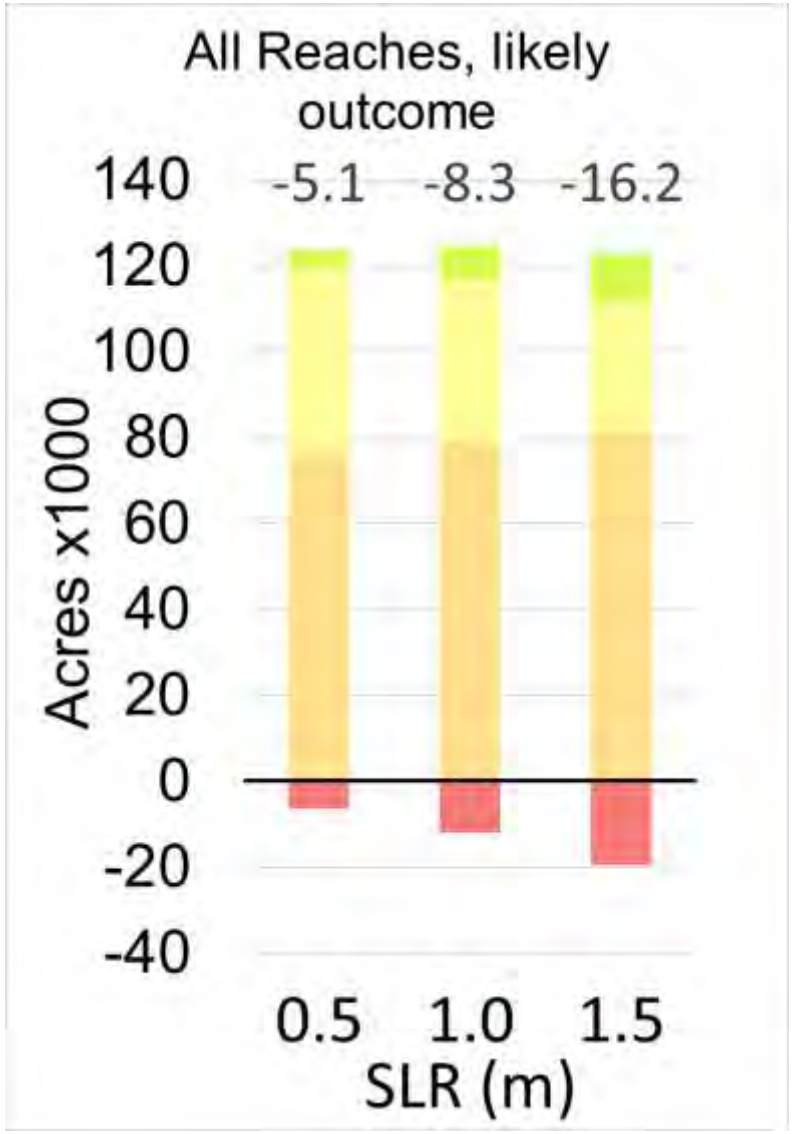
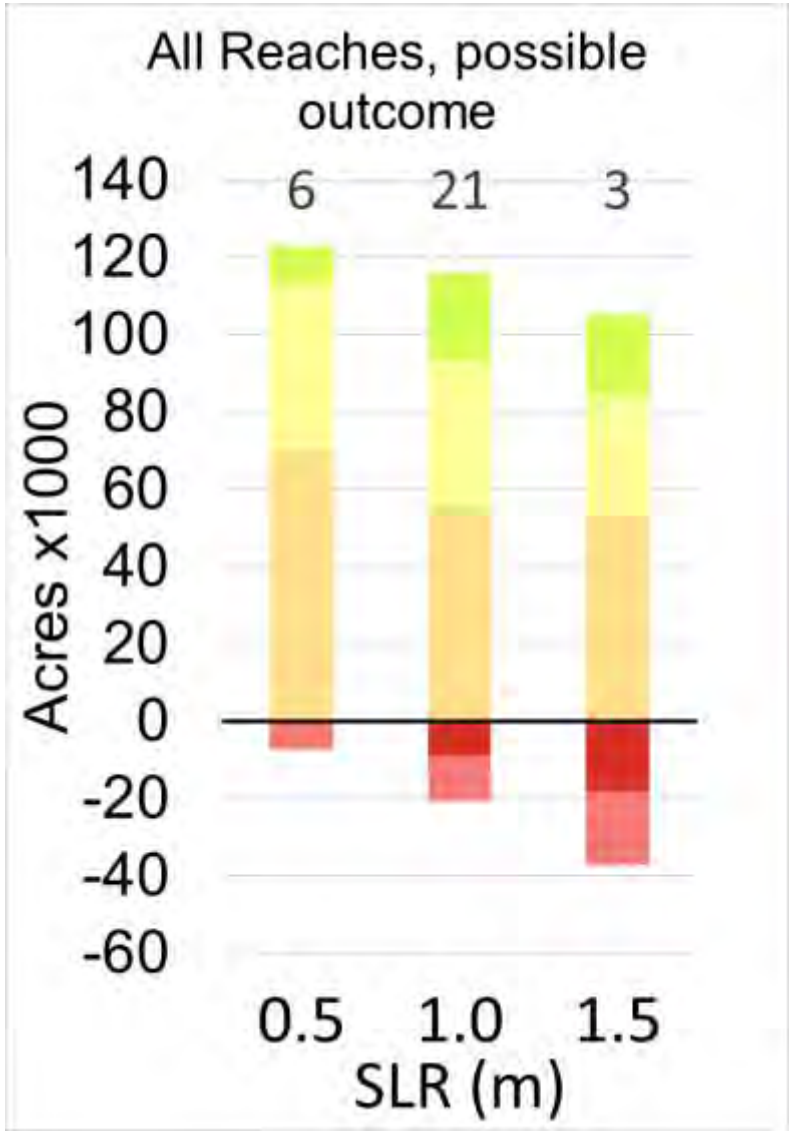
Future Wetlands Adjusted for SLR, Phase 2 Results





← Net change (% of current WL)

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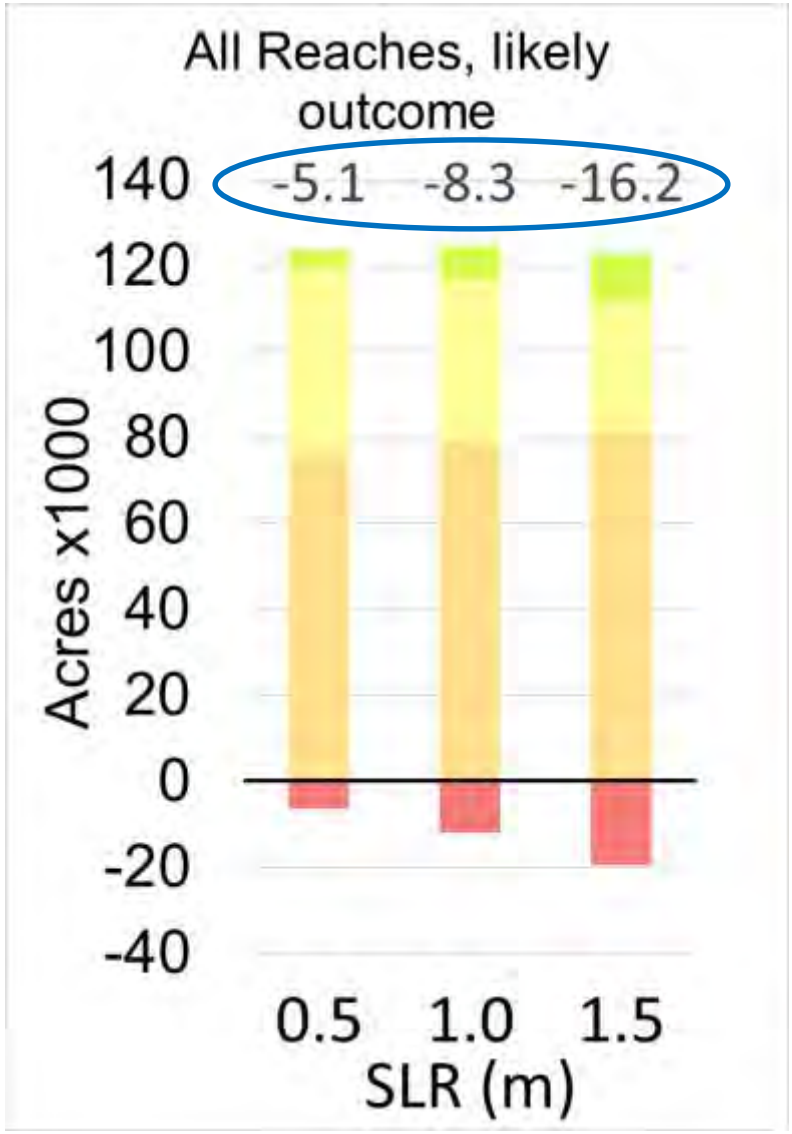
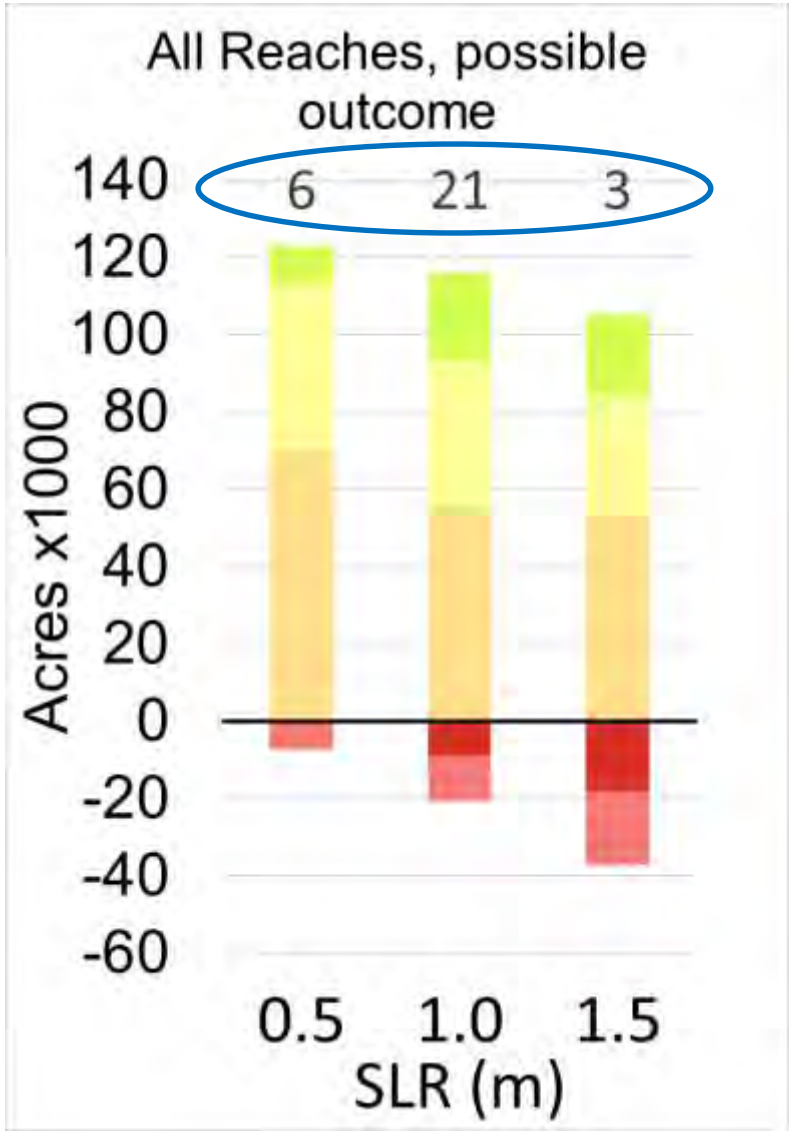
Future Wetlands Adjusted for SLR, Phase 2 Results





← Net change (% of current WL)

- **Future impacts will depend largely on the response of levees**
  - **conservative** estimate of overtopping (left): **net WL losses**
  - **Less conservative** estimate of overtopping (right): **potential WL gains**

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Recoverable Habitats and Habitat Targets

- LCEP has identified priority habitat types and target quantities for restoration based on Historical Land Cover Change Analysis
- SLR considerations for habitat targets:
  - **How much 'priority recoverable habitat' (PRH) will become unavailable?**
  - **Will enough PRH remain to meet targets (balance of gains and losses)?**
  - **Re-evaluate meaning of priority habitat. Historical basis of location may not be valid in future!**

Reach	Current Recoverable Habitat available (ac.)	Restoration Target for 30% Priority Habitat Recovery (acres)	Restoration Target for 40% Priority Habitat Recovery (acres)
A	10,062	1,784	2,945
B	10,417	0	1,195
C	18,837	4,110	6,673
D	1,098	1,177	1,708
E	9,173	1,690	2,511
F	24,567	939	4,721
G	2,510	683	2,524
H	546	0	205

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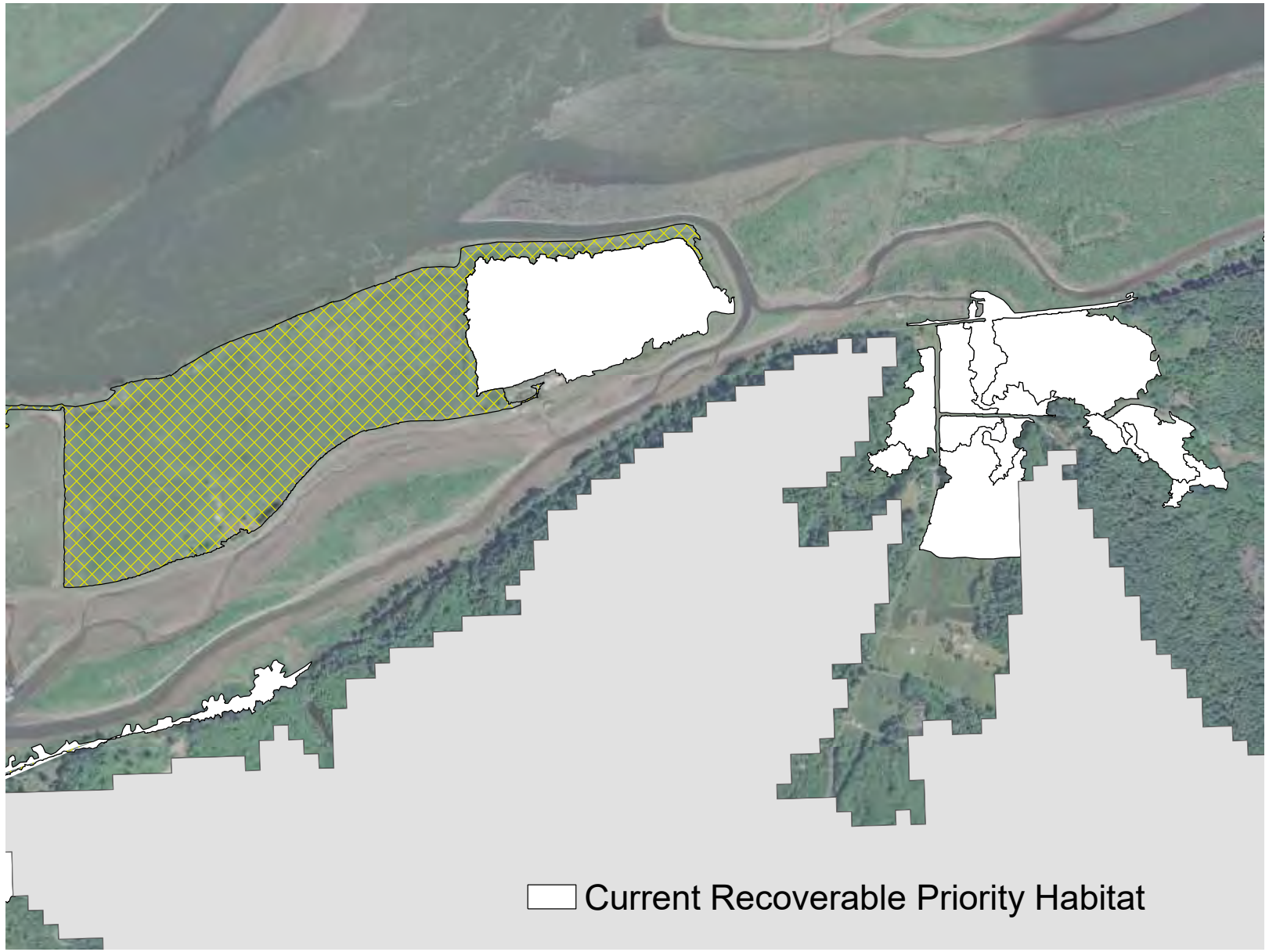
Recoverable Habitat Example



Current Recoverable
Priority Habitat: 154 acres

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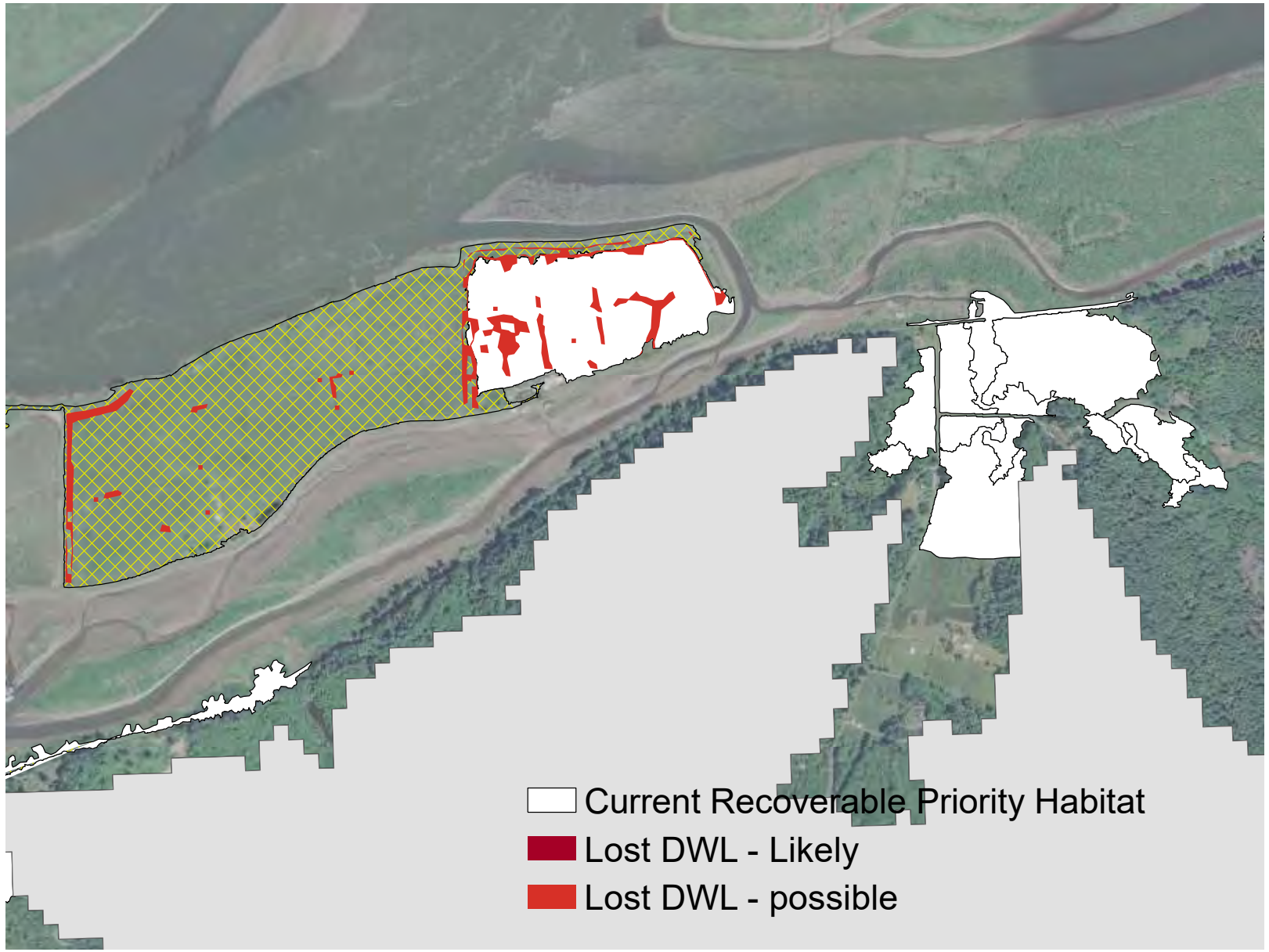
Recoverable Habitat Example



Current Recoverable
Priority Habitat: 154 acres

0.5 m SLR scenario

Likely PRH loss: 0 acres
Possible PRH loss: 6 acres

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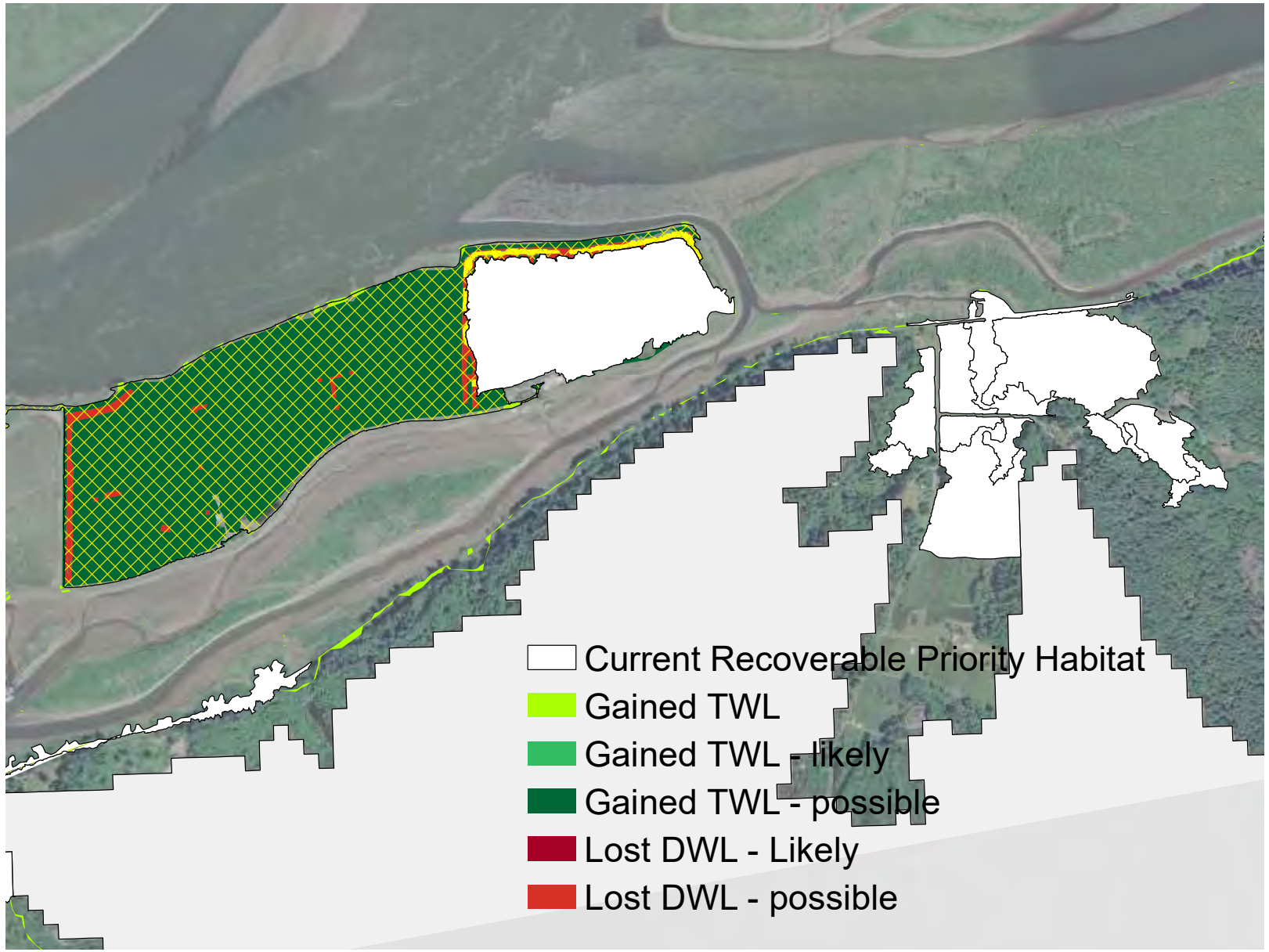
Recoverable Habitat Example



Current Recoverable
Priority Habitat: 154 acres

0.5 m SLR scenario

Likely PRH loss: 0 acres
Possible PRH loss: 6 acres

Likely Gained TWL: 0 acres
Possible Gained TWL: 95 acres
These do not contribute to PRH since already in PRH zone. So..

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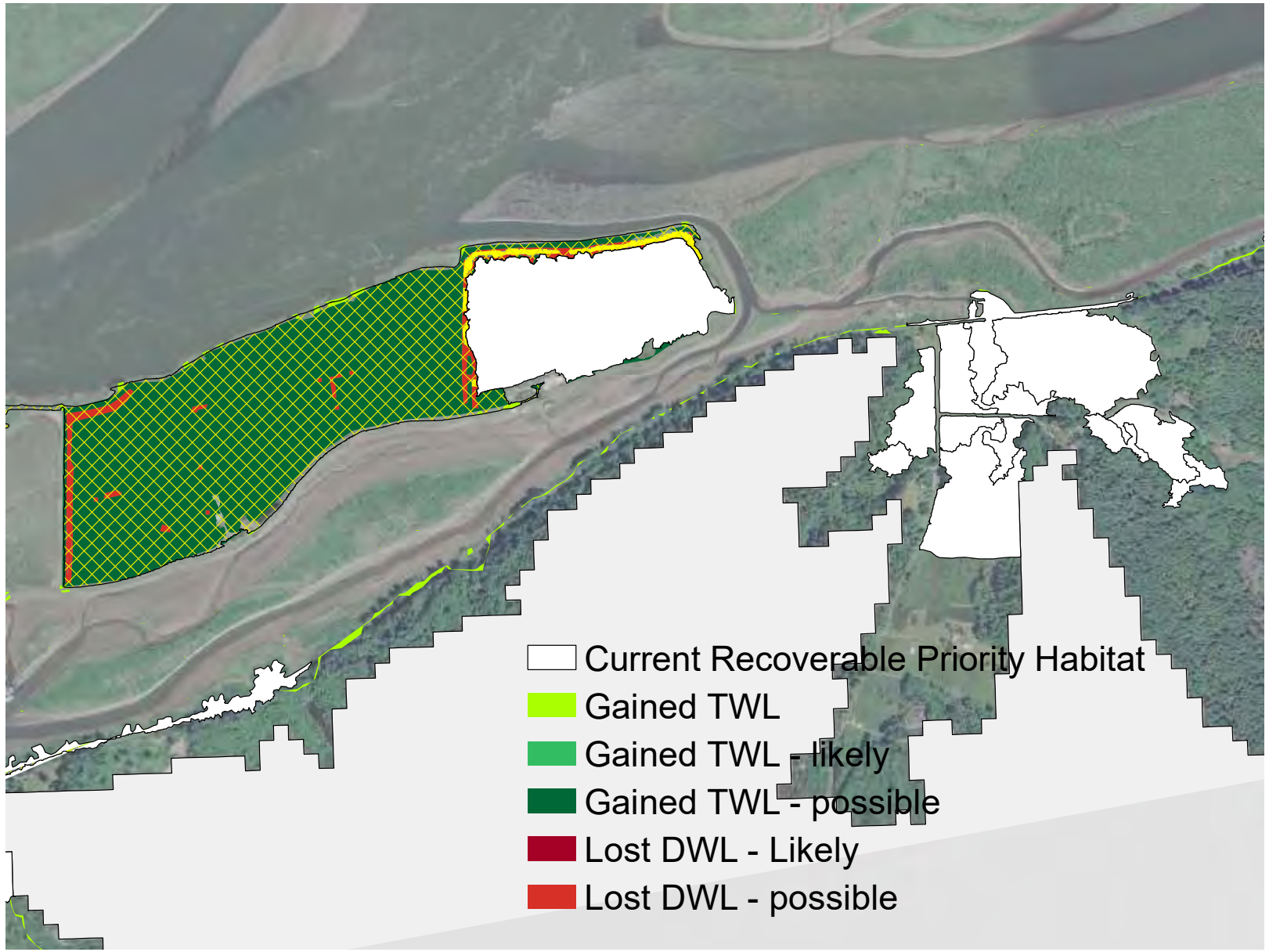
Recoverable Habitat Example



Current Recoverable
Priority Habitat: 154 acres

0.5 m SLR scenario

Likely PRH loss: 0 acres
Possible PRH loss: 6 acres

Likely Gained TWL: 0 acres
Possible Gained TWL: 95 acres
These do not contribute to PRH since already in PRH zone. So..

Net change in PRH: -6 acres

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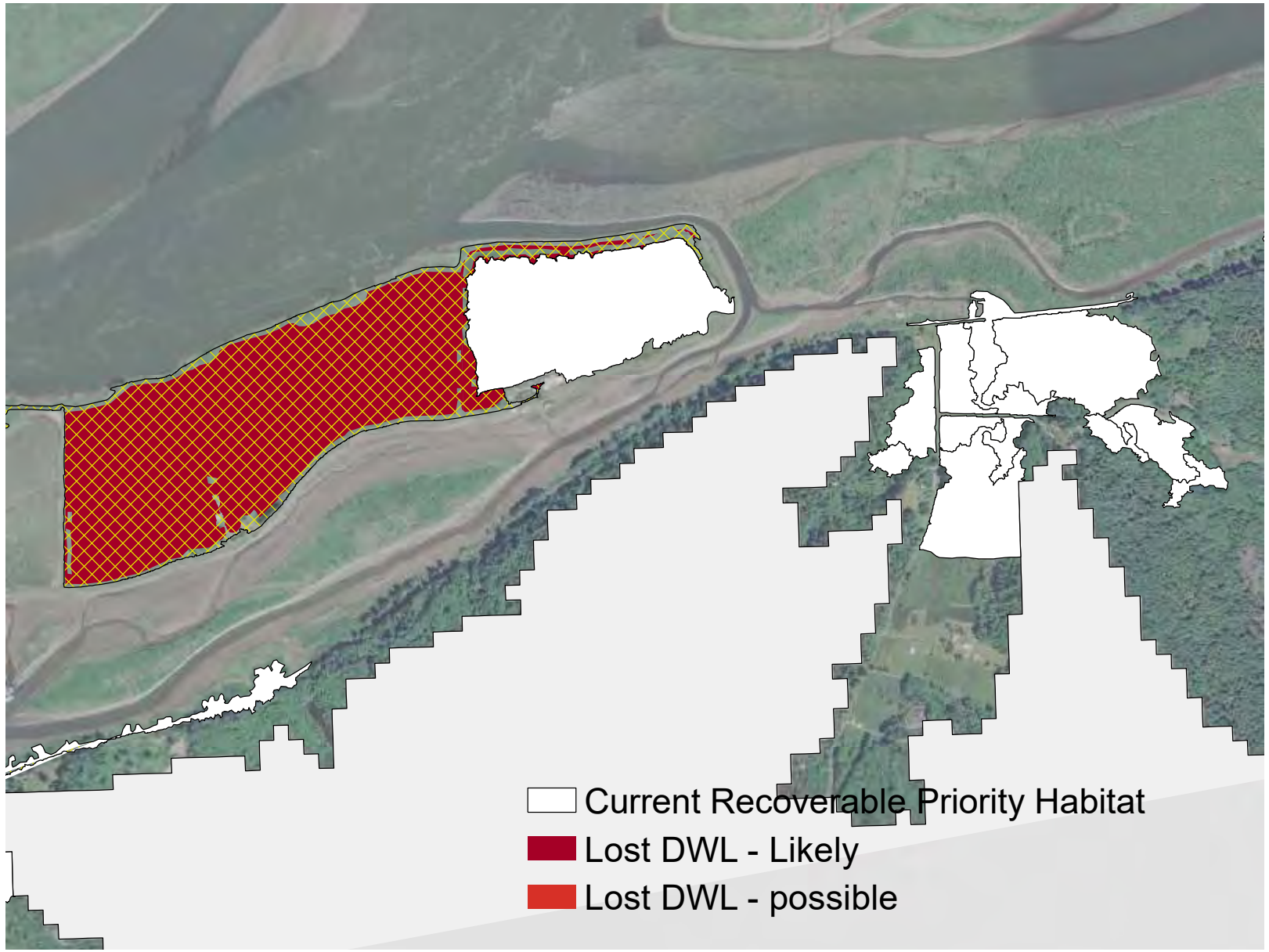
Recoverable Habitat Example



Current Recoverable
Priority Habitat: 154 acres

1.5 m SLR scenario

Likely PRH loss: 97 acres
Possible PRH loss: 44 acres

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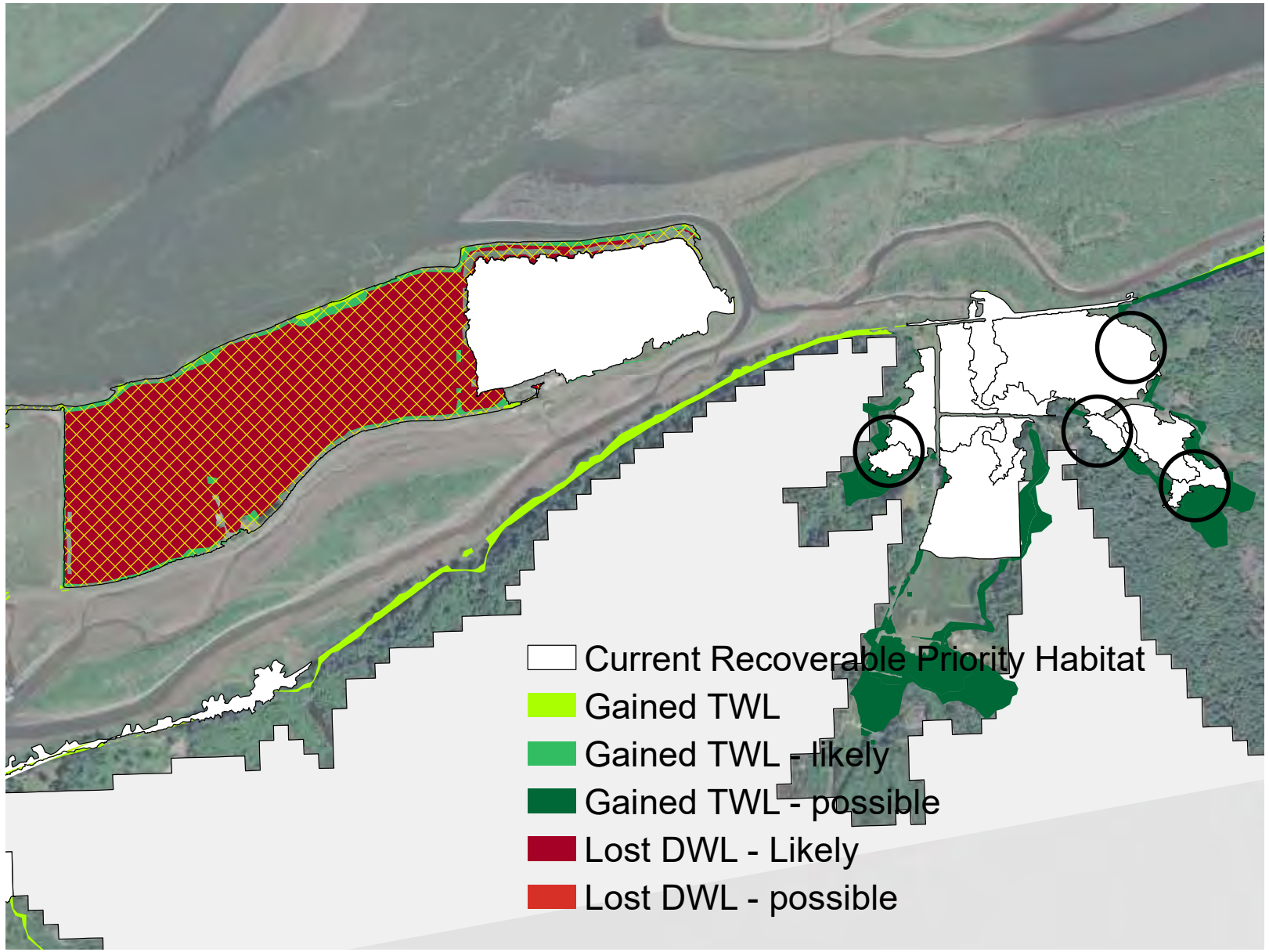
Recoverable Habitat Example



Current Recoverable
Priority Habitat: 154 acres

1.5 m SLR scenario

Likely PRH loss: 97 acres
Possible PRH loss: 44 acres

Non-contributing gains inside PRH zone:
Possible: 3 acres
Likely: 4 acres

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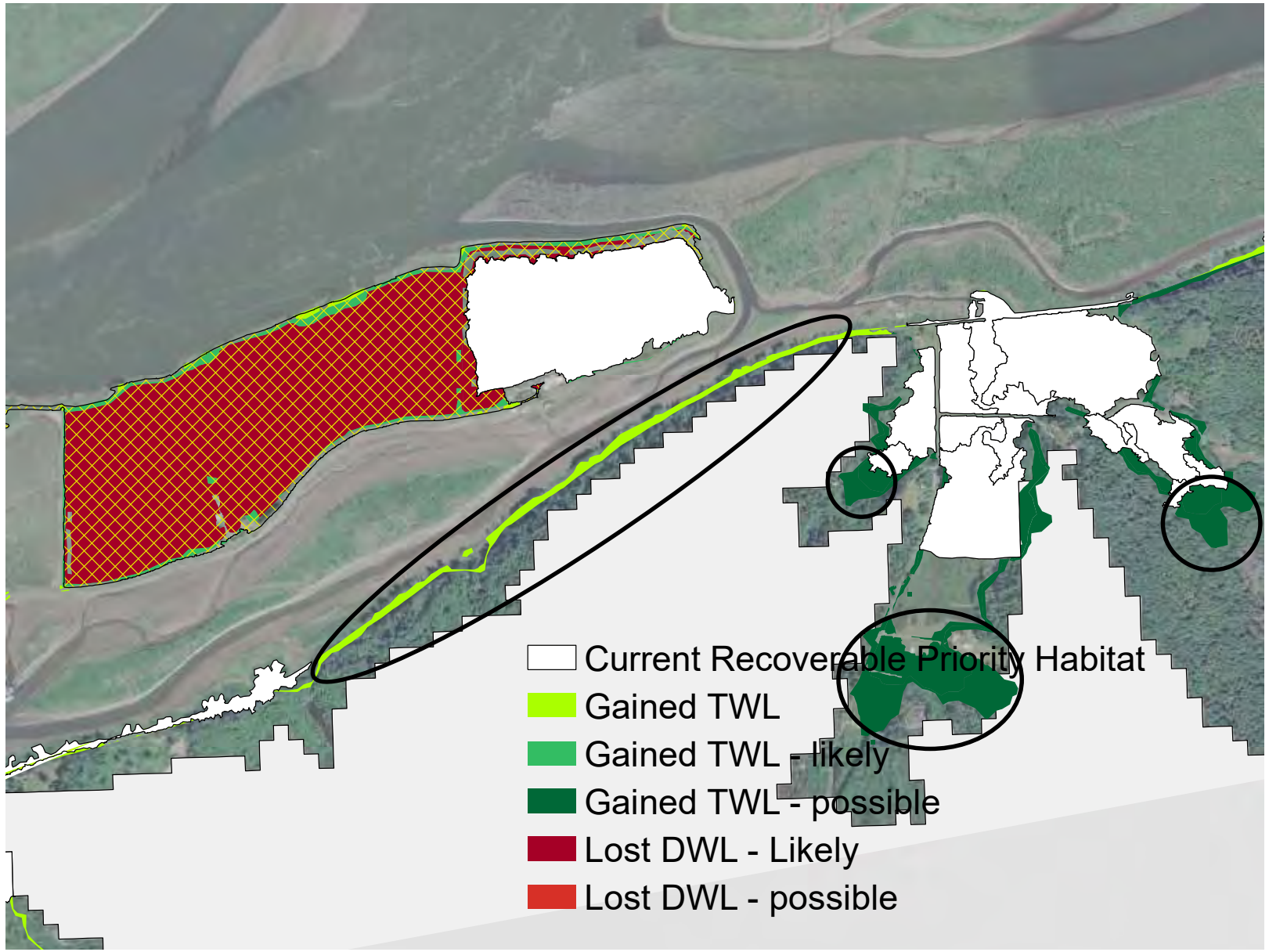
Recoverable Habitat Example



Current Recoverable
Priority Habitat: 154 acres

1.5 m SLR scenario

Likely PRH loss: 97 acres
Possible PRH loss: 44 acres

Non-contributing gains inside PRH zone:
Possible: 3 acres
Likely: 4 acres

Gained habitat outside PRH zone could offset losses: Possible: 23
Likely: 7

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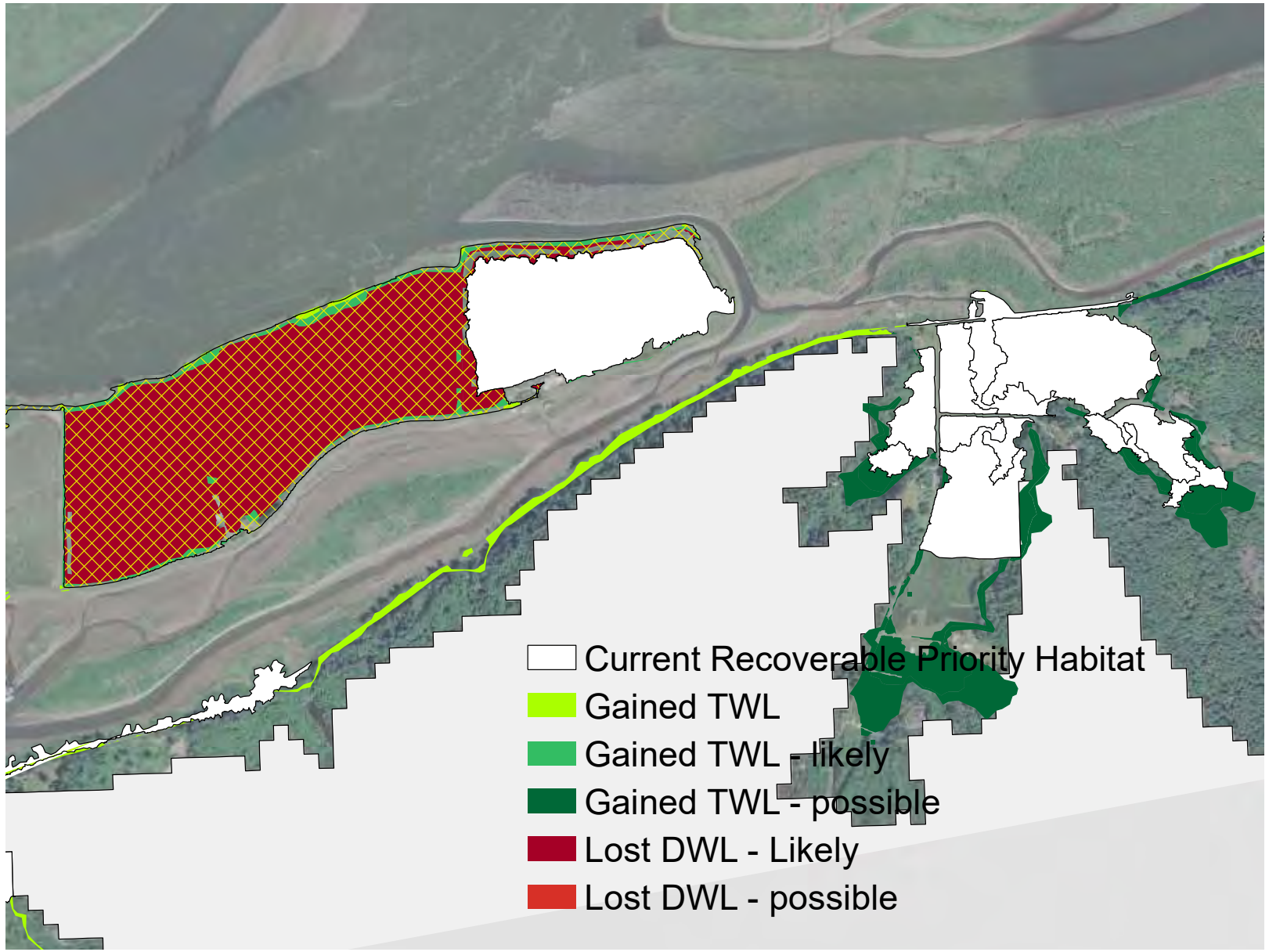
Recoverable Habitat Example



Current Recoverable
Priority Habitat: 154 acres

1.5 m SLR scenario

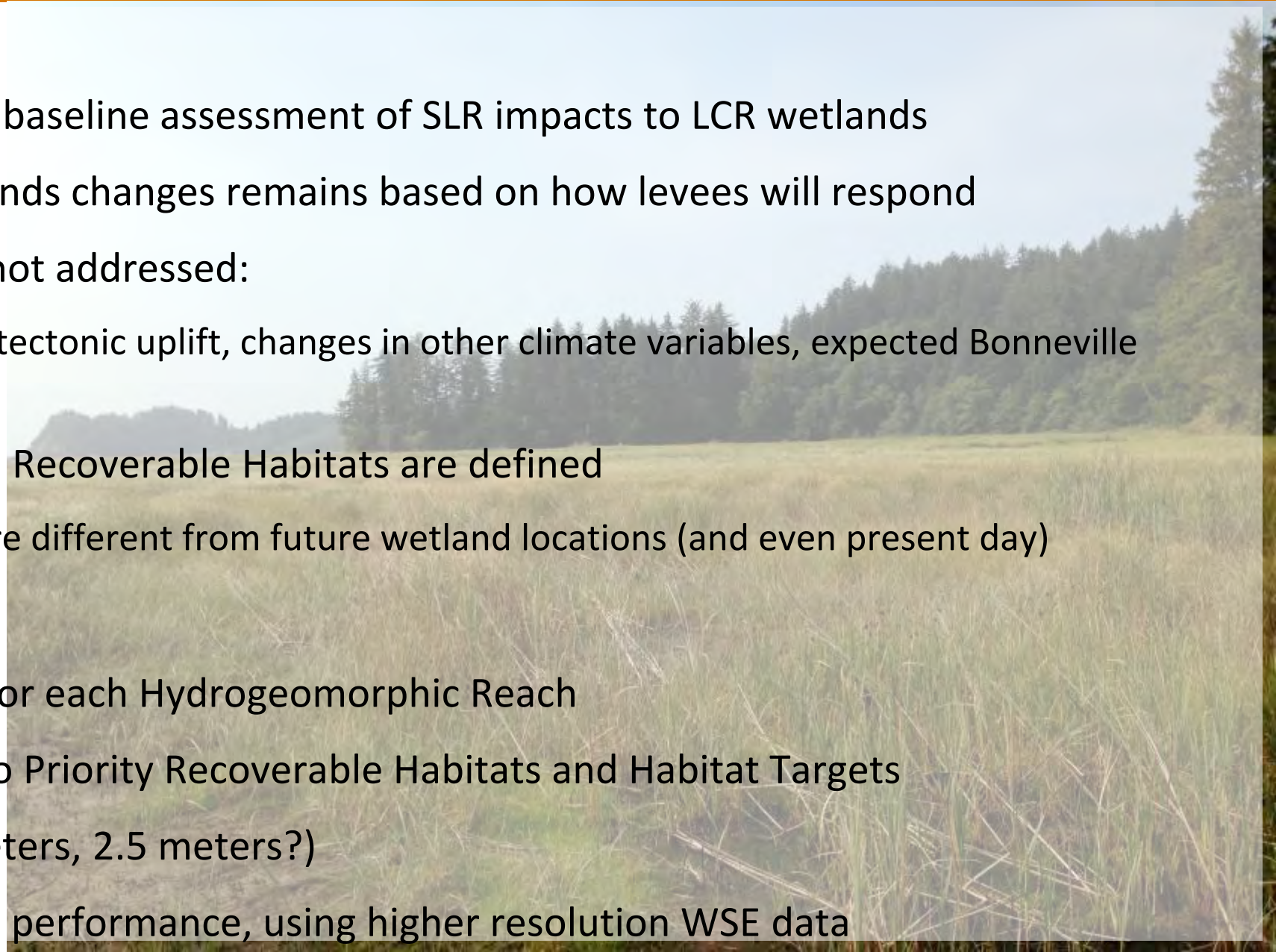
Likely PRH loss: 97 acres
Possible PRH loss: 44 acres

Non-contributing gains inside PRH zone:
Possible: 3 acres
Likely: 4 acres

Gained habitat outside PRH zone could offset losses: Possible: 23
Likely: 7

Net change in PRH:
Possible: -21 acres - (44 – 23)
Likely: -90 acres - (97 – 0)

Conclusions and Next Steps



Conclusions:

- Available data provides a good baseline assessment of SLR impacts to LCR wetlands
- Significant uncertainty in wetlands changes remains based on how levees will respond
- Additional uncertainties were not addressed:
  - Sediment accretion, localized tectonic uplift, changes in other climate variables, expected Bonneville discharge
- Must re-consider how 'Priority' Recoverable Habitats are defined
  - Historical wetland locations are different from future wetland locations (and even present day)

Next Steps:

- Tabulate Phase 2 SLR impacts for each Hydrogeomorphic Reach
- Complete analysis of impacts to Priority Recoverable Habitats and Habitat Targets
- Run higher SLR scenarios (2 meters, 2.5 meters?)
- More detailed analysis of levee performance, using higher resolution WSE data


Thank you! Questions?