Apr 27th, 9:45 AM - 11:15 AM

Climate Impacts to Groundwater Ponding and Salinity – Stillaguamish and Snohomish

Daniel Elefant, PE

Ag Resiliency Studies
Climate Impacts to Groundwater

Stillaguamish River
and Snohomish River

Presentation to SSEC
2022

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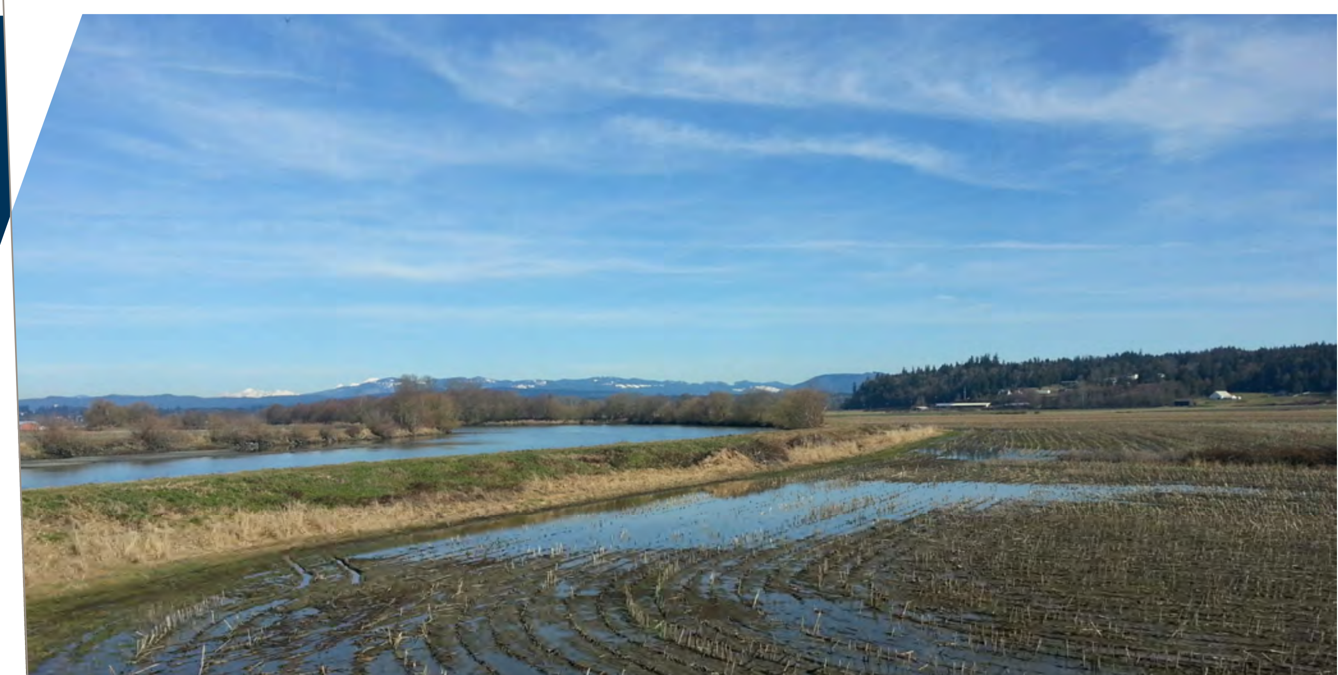

Late winter view from south side of Stillaguamish mouth looking east

Stillaguamish Flood Control District

SNOHOMISH CONSERVATION DISTRICT

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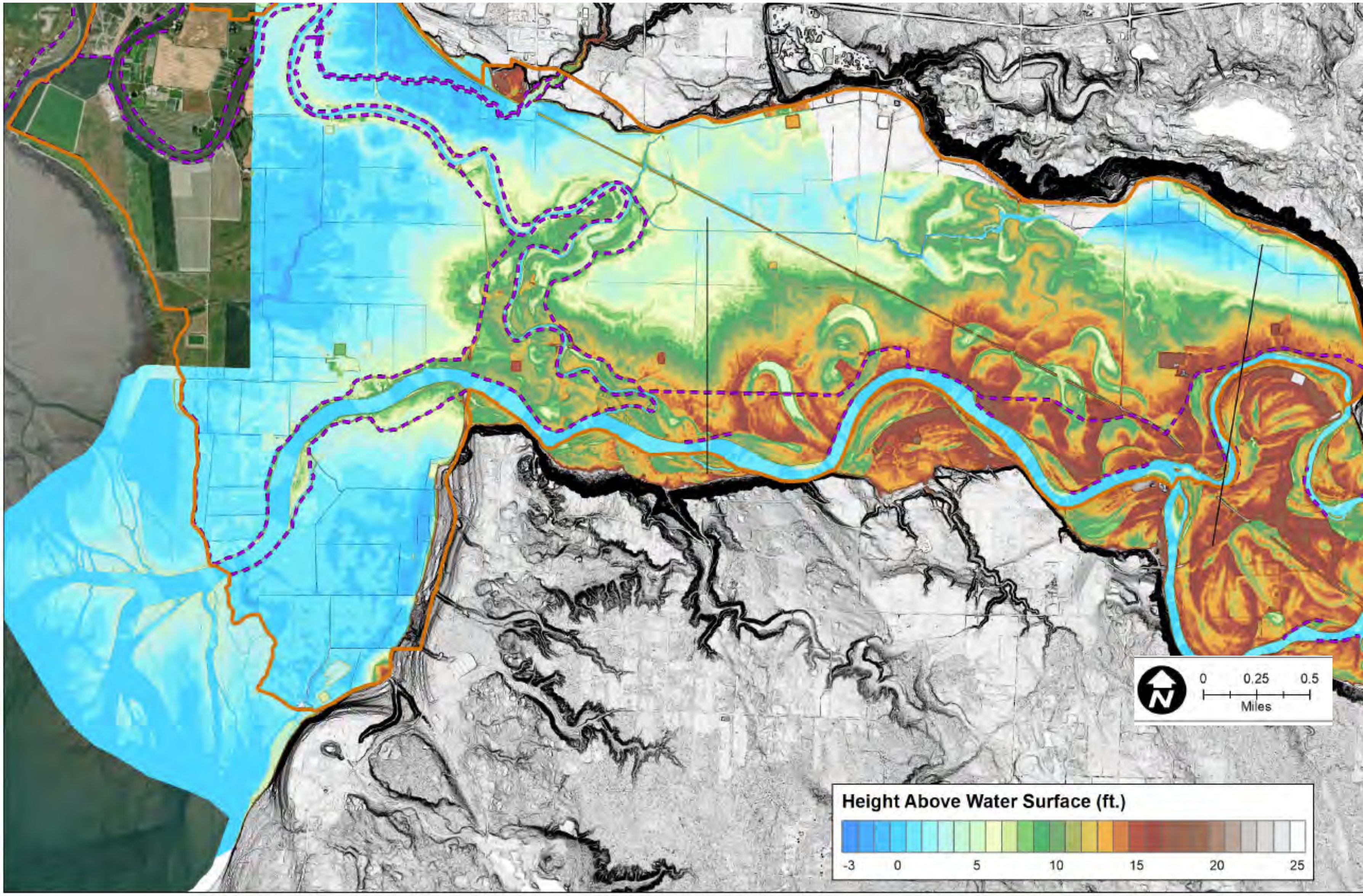
Presentation Overview

1. Focus on Groundwater but this type of an analysis can't operate in a "vacuum"
2. Salmon, Farms, & Flood Resiliency
3. Geomorphic Setting
4. Groundwater and SLR
    a. Spring Cropping Delay
    b. Salinity Intrusion



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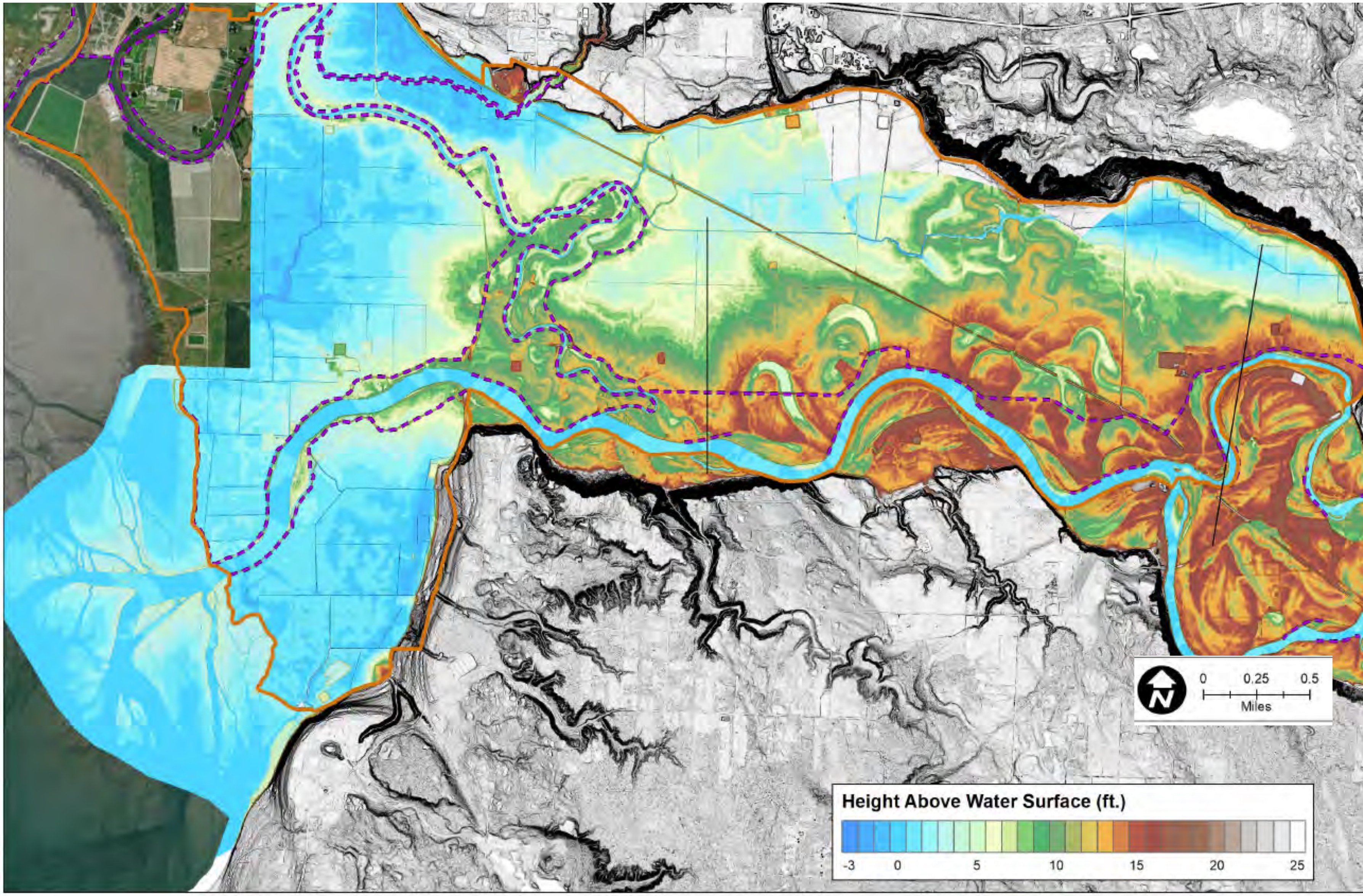
Geomorphic Setting – Holocene Process and Modern Levees

- Lower Stillaguamish similar to other alluvial rivers, world-wide: “Natural Levees”
  - higher adjacent to river - river is the primary source of sediment, which drops out as flows move out across the floodplain.

1. Modern levee construction - reduced floodplain deposition & amplifies topo relief.
2. Upstream of the 1911-avulsion node, constructed levees are built on the flanks of the natural levee
3. Natural levee might increase the hazard associated with flooding: any overtopping of levees caused by even small peak flow increases could presumably cause large flood problems



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Groundwater and Sea Level Rise (SLR)

1. Increased Groundwater Ponding will cause **Spring Cropping Delays**
   1. Methods
   2. Delay Maps
2. **Salinity Intrusion** at Florence Island will reduce crop yields
   1. Thresholds: 3 mS/cm specific conductivity
   2. Intrusion Maps

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Well data and strategic interpolation!

Spring GW Table recedes at 1 foot per month AND we assume similar aquifer properties into the future.

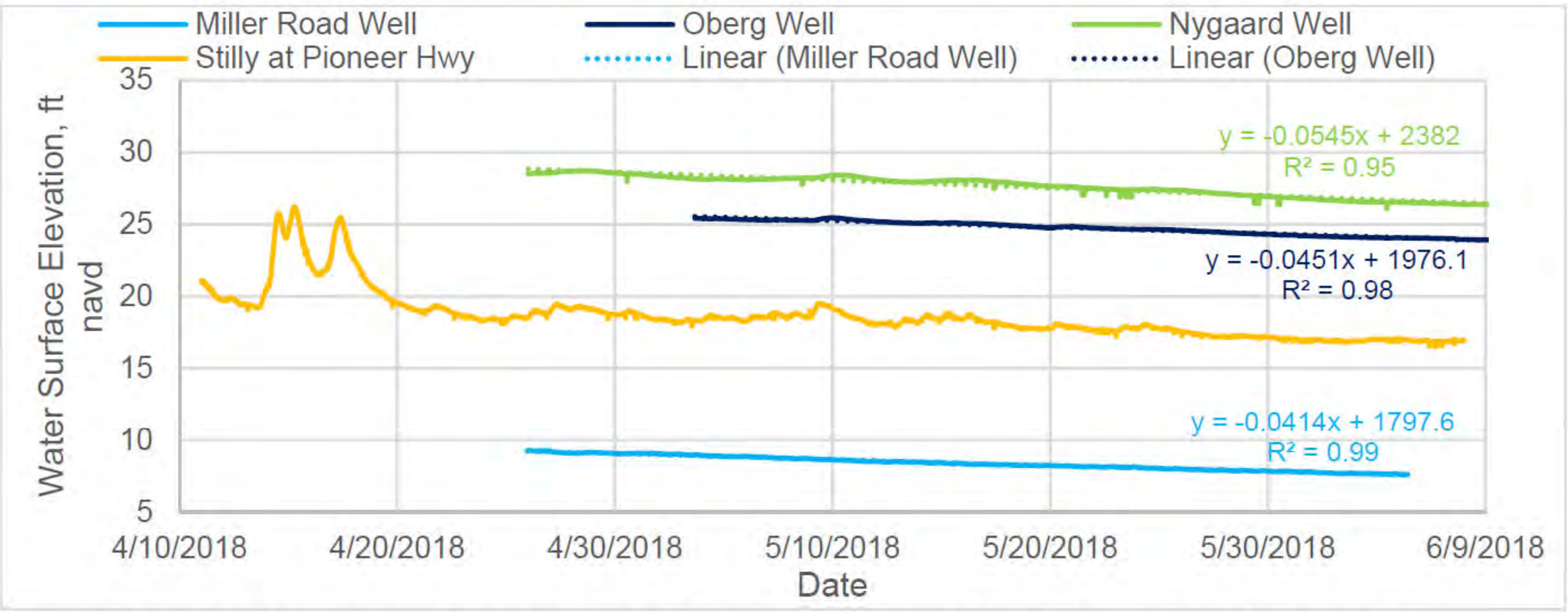

Figure 6-4 Selected groundwater data relative to WSEL of the Stillaguamish River at Pioneer Highway Bridge. Linear trend lines were fit to the groundwater datasets after the last significant detectable response to pulses in river flow resulting from spring floods. Slope of the trend line is the groundwater table rate of decline. Generally, the three wells recorded water-table lowering at an average rate that slightly exceeds 1 foot per month.

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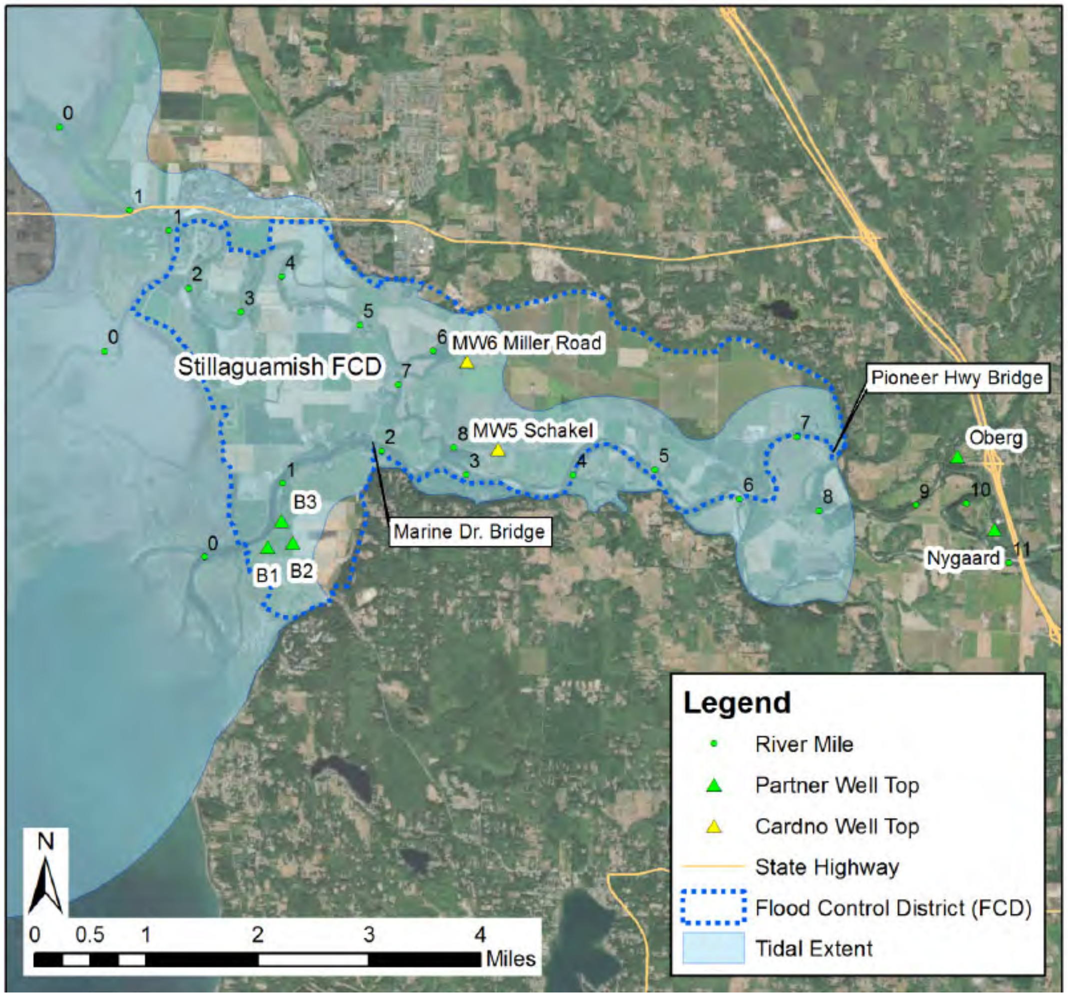
Relative SLR (RSLR)

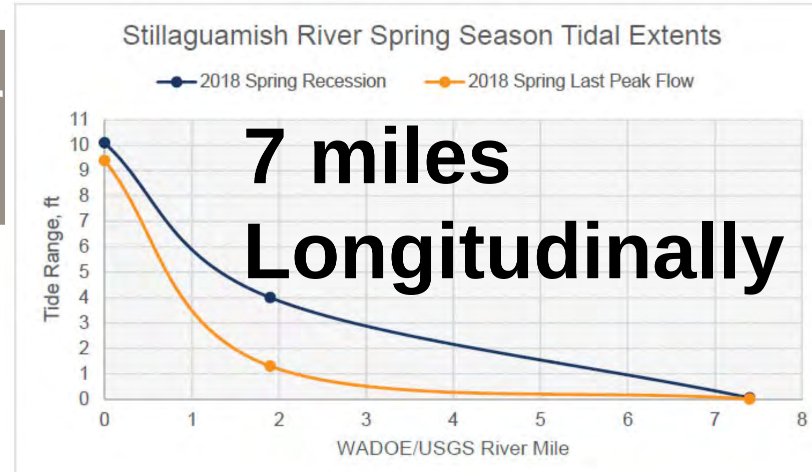
Table 2-1 **RSLR Projections with a 50% Likelihood for Exceedance for the Snohomish River and Stillaguamish Rivers under Greenhouse Gas Scenarios RCP 4.5 (low) and RCP 8.5 (high)**

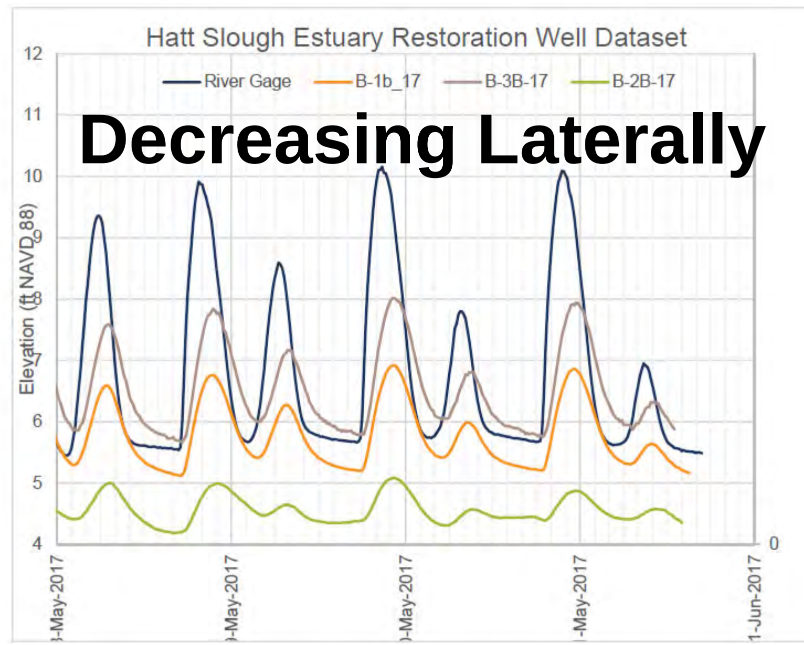
	Year 2050	Year 2080	Year 2100
Snohomish River Mouth:			
RSLR 50% for RCP 8.5 (feet)	0.8	1.5	2.2
RSLR 50% for RCP 4.5 (feet)	0.7	1.3	1.7
Stillaguamish River Mouth:			
RSLR 50% for RCP 8.5 (feet)	0.7	1.5	2.2
RSLR 50% for RCP 4.5 (feet)	0.7	1.3	1.7

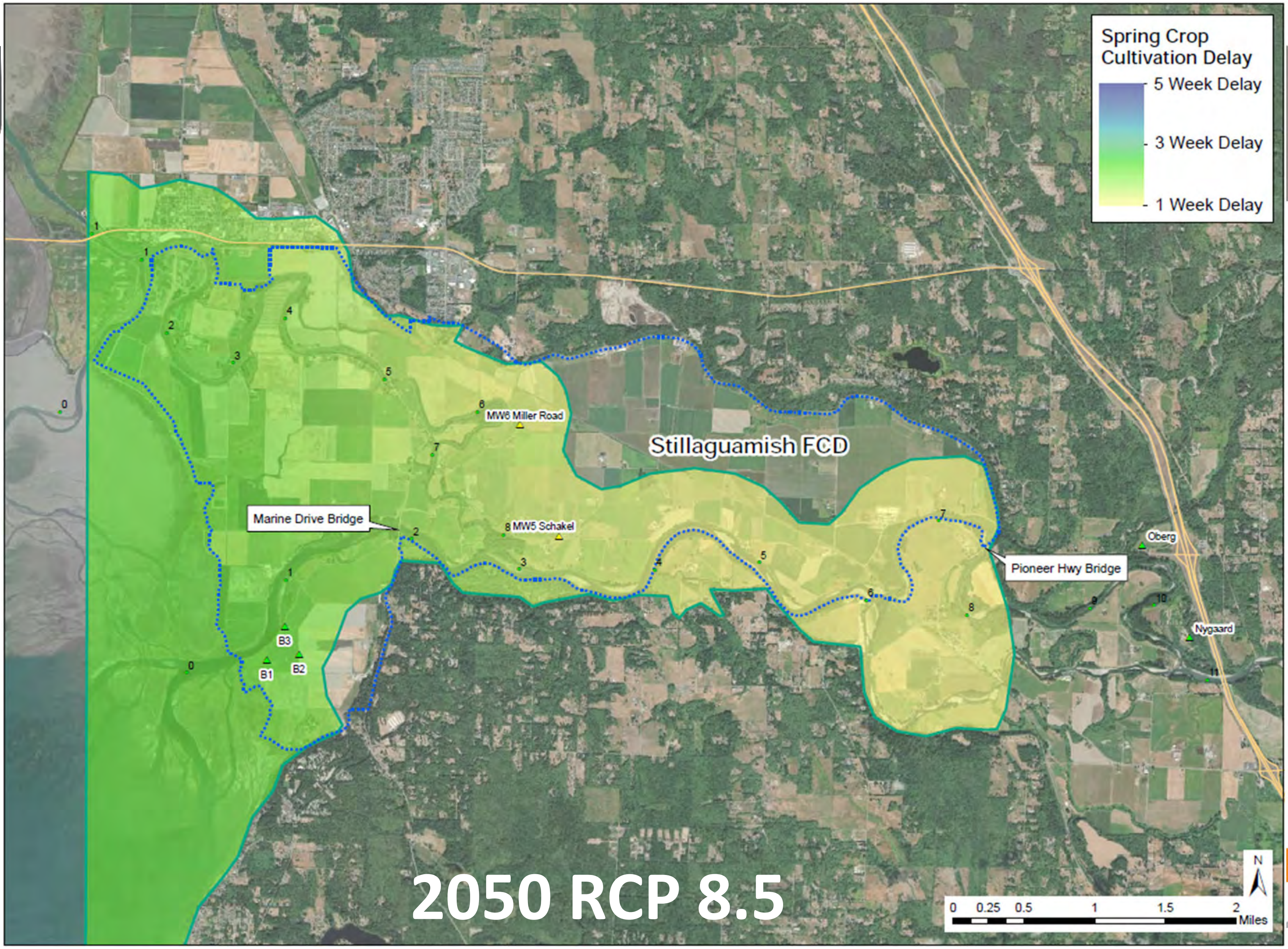
Source: Washington Coastal Resilience Project (WCRP) 2018

Extent of tide in groundwater









2050 RCP 8.5

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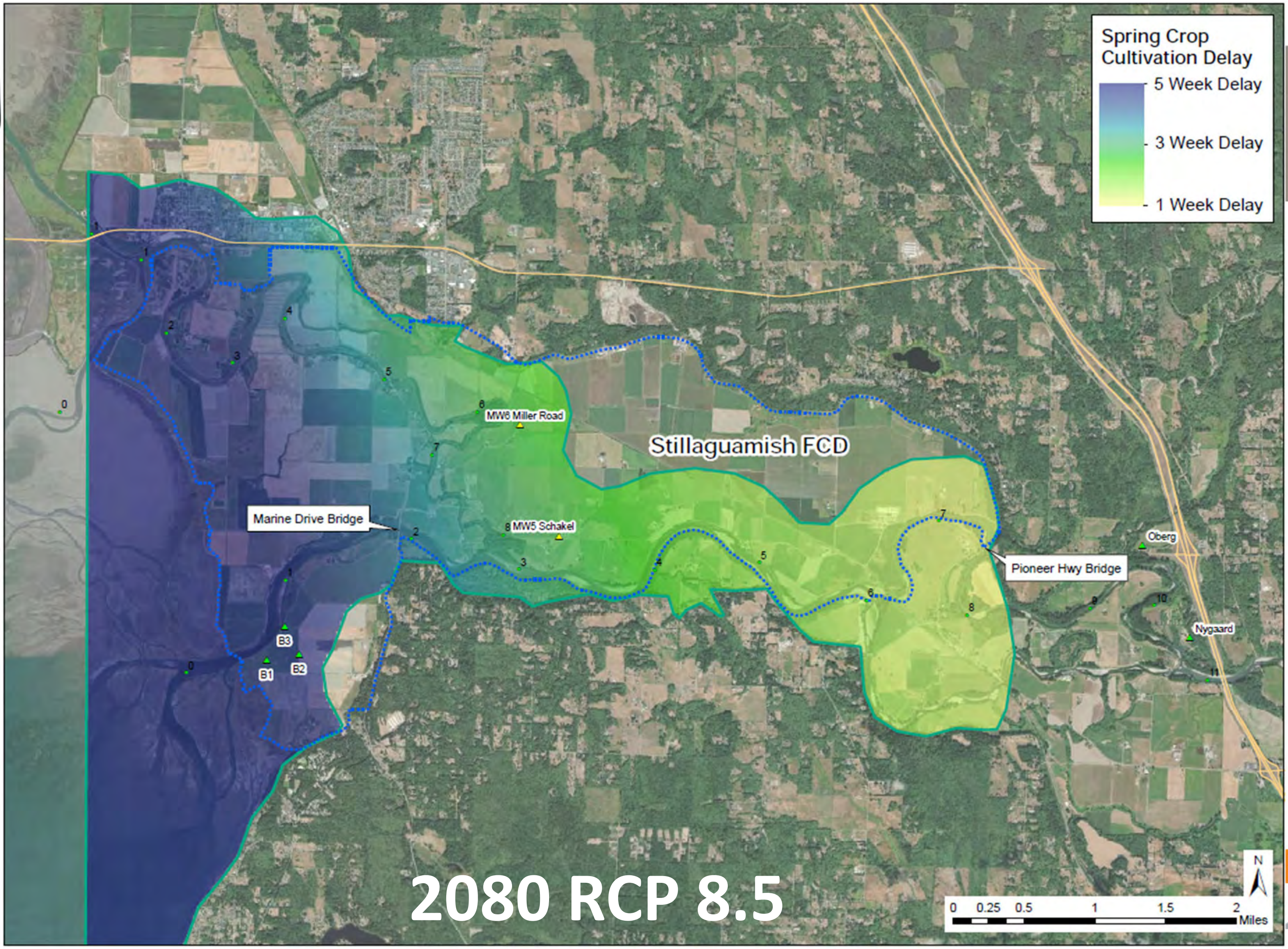
Spring Crop Cultivation Delay
5 Week Delay
3 Week Delay
1 Week Delay
Stillaguamish FCD
MW6 Miller Road
MW5 Schakel
Marine Drive Bridge
Pioneer Hwy Bridge
Oberg
Nygaard
B1
B2
B3
N
0 0.25 0.5 1 1.5 2
Miles
2080 RCP 8.5

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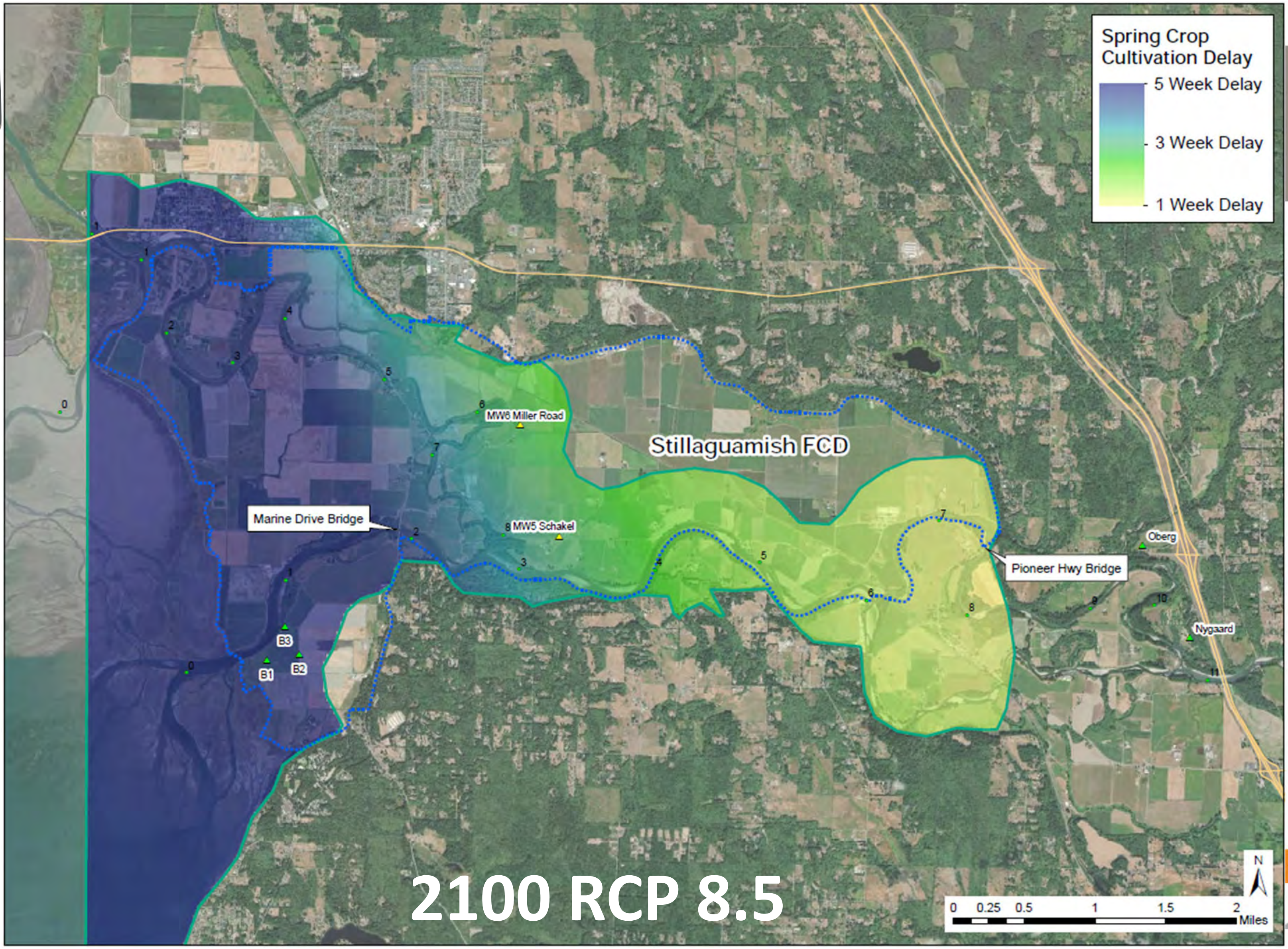

2100 RCP 8.5

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Salinity is complex … conductivity was chosen as a proxy for salinity since it was measured directly *in situ* in our wells

Table 8-1 **Cowardin Classification of Estuarine Habitats Compared to Agricultural Salinity Rating and Electrical Conductivity Value**

Coastal Modifiers[a]	Inland Modifiers[b]	Salinity (parts per thousand)	Approximate specific conductance (mS/cm)
Hyperhaline	Hypersaline	>40	>60
Euhaline	Eusaline	30.0–40	45–60
Mixohaline (Brackish)	Mixosaline[c]	0.5–30	0.8–45
Polyhaline	Polysaline	18.0–30	30–45
Mesohaline	Mesosaline	5.0–18	8–30
Oligohaline	Oligosaline	0.5–5	0.8–8
Fresh	Fresh	<0.5	0.8

Source: Cowardin 1979 and Agdex 2001

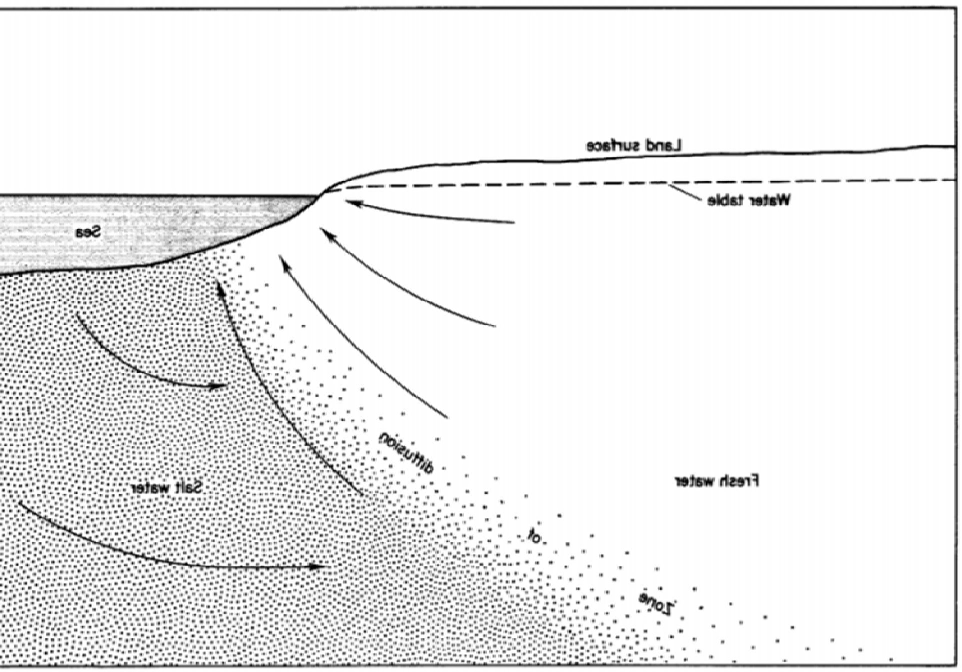
Notes:

[a] Coastal modifiers are used in marine and estuarine systems.
[b] Inland modifiers are used in riverine, lacustrine, and palustrine systems.
[c] The term brackish should not be used for inland wetlands or deepwater habitats.

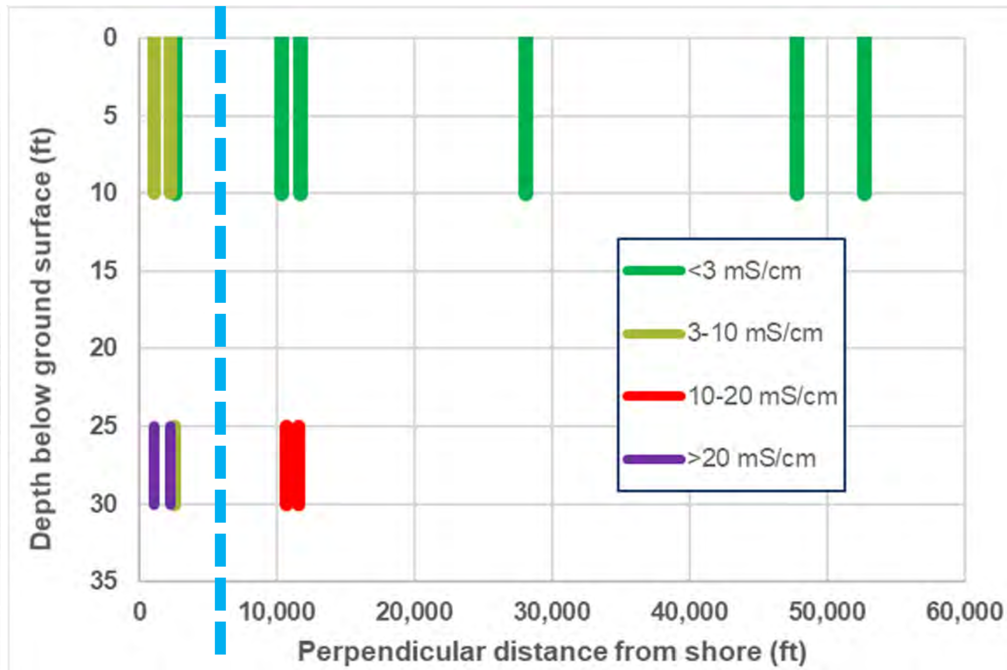
3mS/cm Threshold – "sensitive crops may have restricted growth"

Vertical (Z) Saltwater Zone of Diffusion

Theoretical (Source: Cooper et al.



Empirical Data from this study (root zone upper 5 to 10 ft) :



Crop root zone effects to ~ 5000 feet from shore

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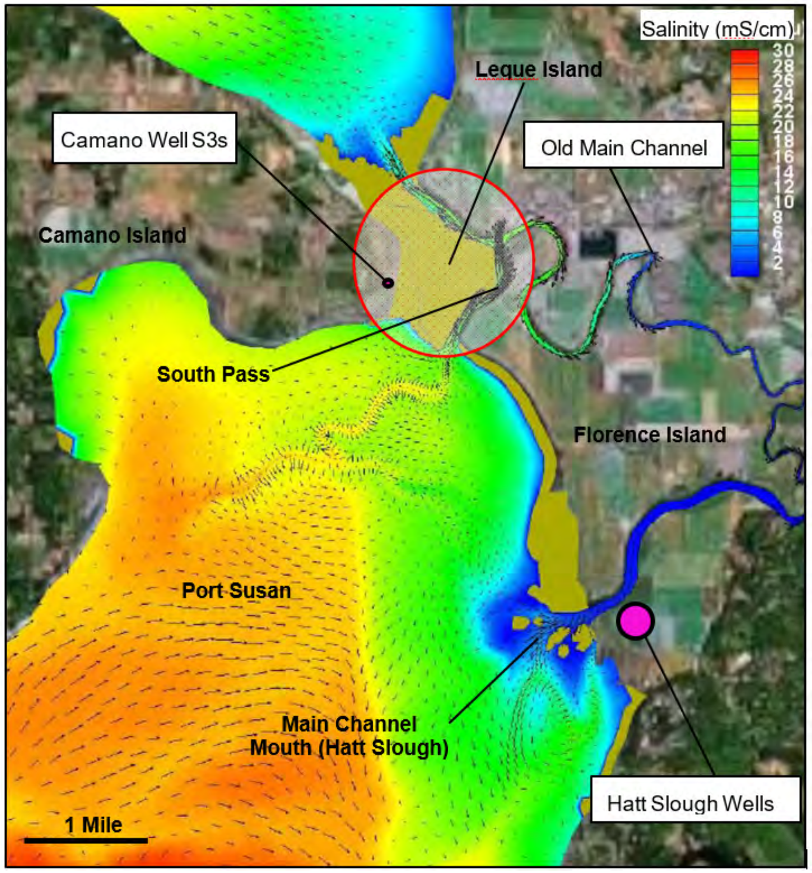
Spatial (XY) complexity of surface hydrodynamics effect GW salinity patterns



Predicted surface salinities for existing conditions in northern Port Susan during high tide and low Stillaguamish River flows (~1,250 cfs).

1. Freshwater outflows in the Main Channel (**BLUE**)

2. Tidal driven flows in the "OLD" Main Channel (**YELLOW/GREEN**)

Source: Yang 2008

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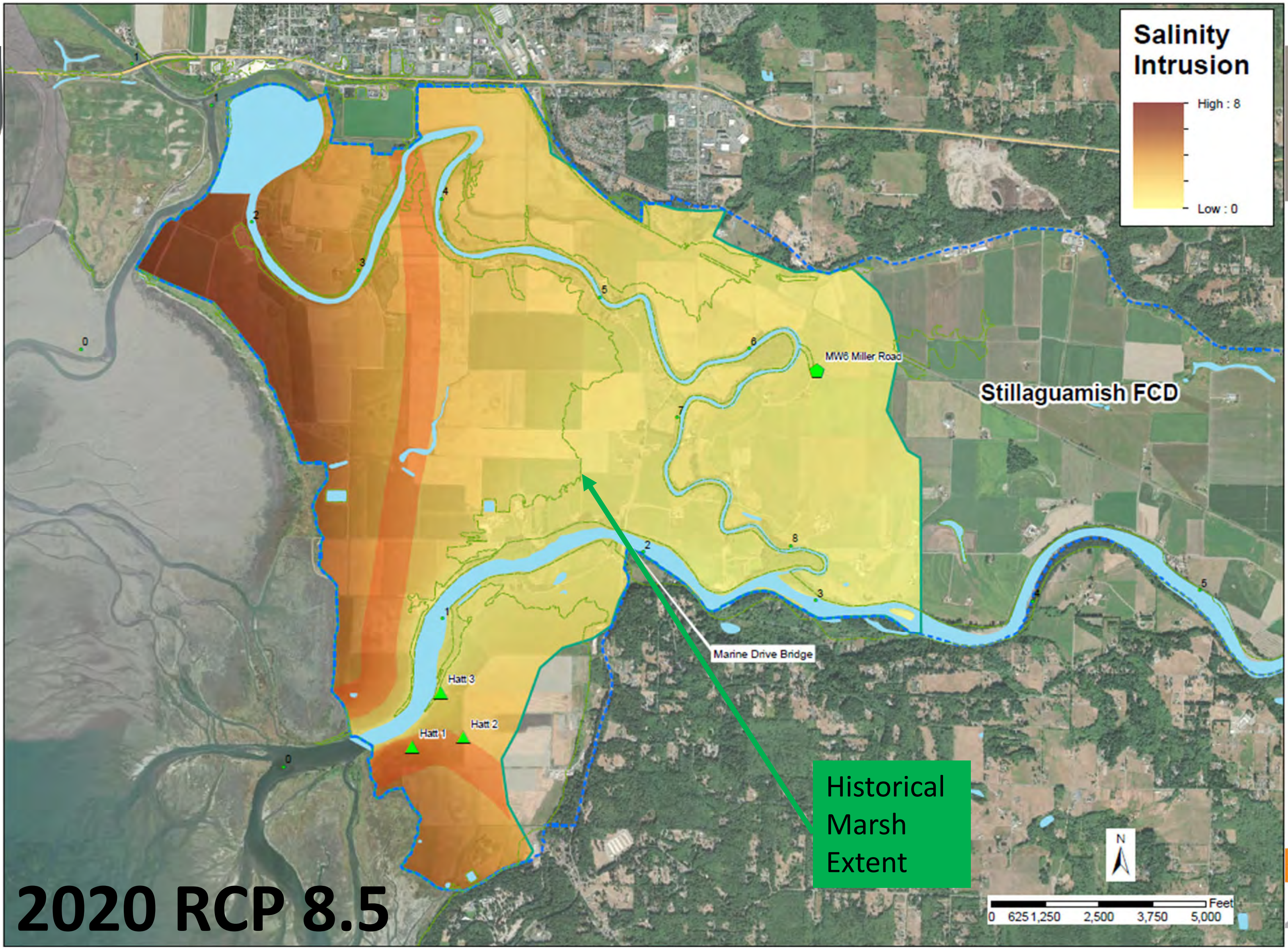

Salinity Intrusion
High : 8
Low : 0
MW6 Miller Road
Stillaguamish FCD
Marine Drive Bridge
Hatt 3
Hatt 2
Hatt 1
Historical Marsh Extent
N
0 625 1,250 2,500 3,750 5,000 Feet
2020 RCP 8.5

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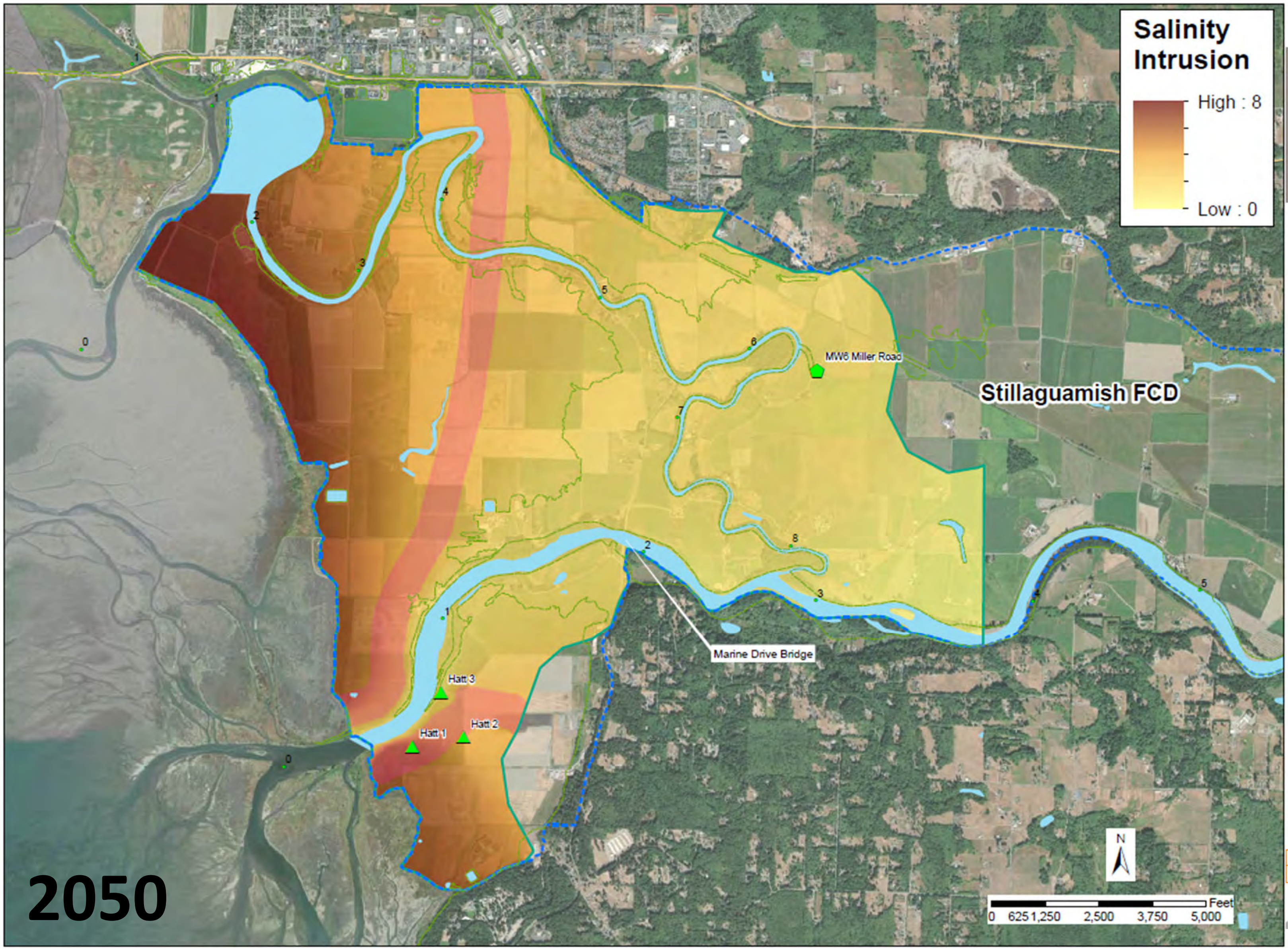
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Feet
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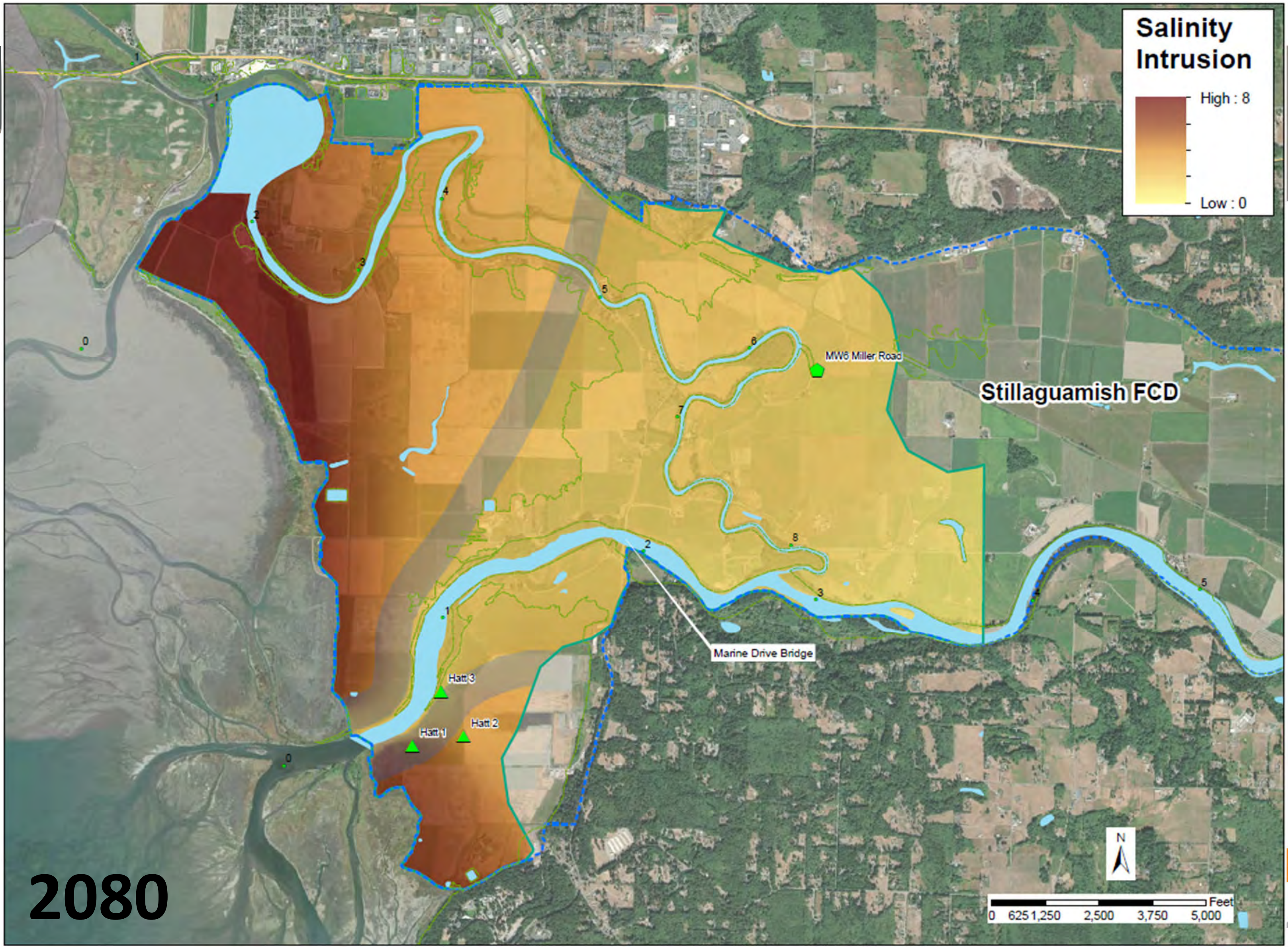
2050



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Feet
2080

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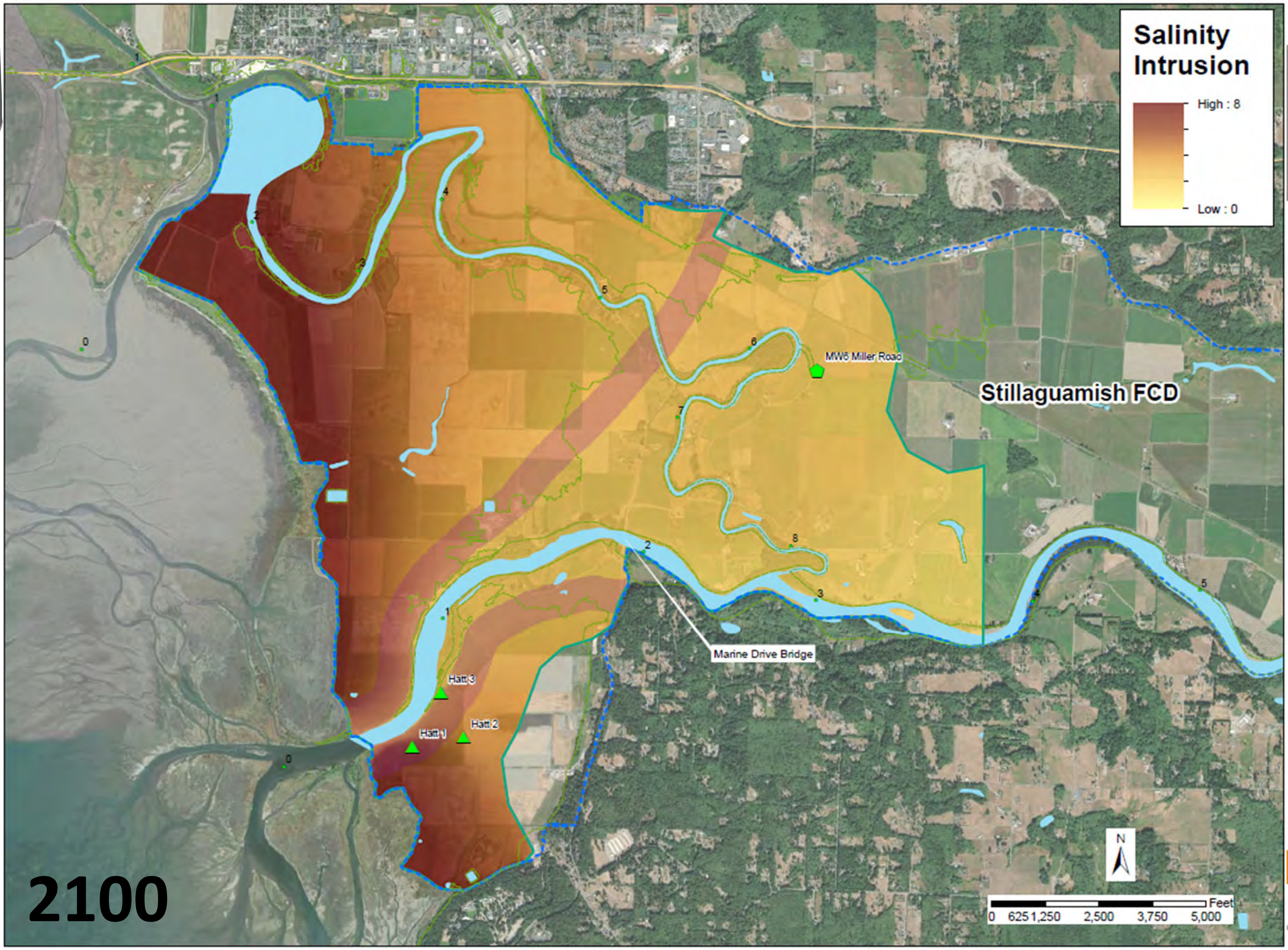

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Feet
2100

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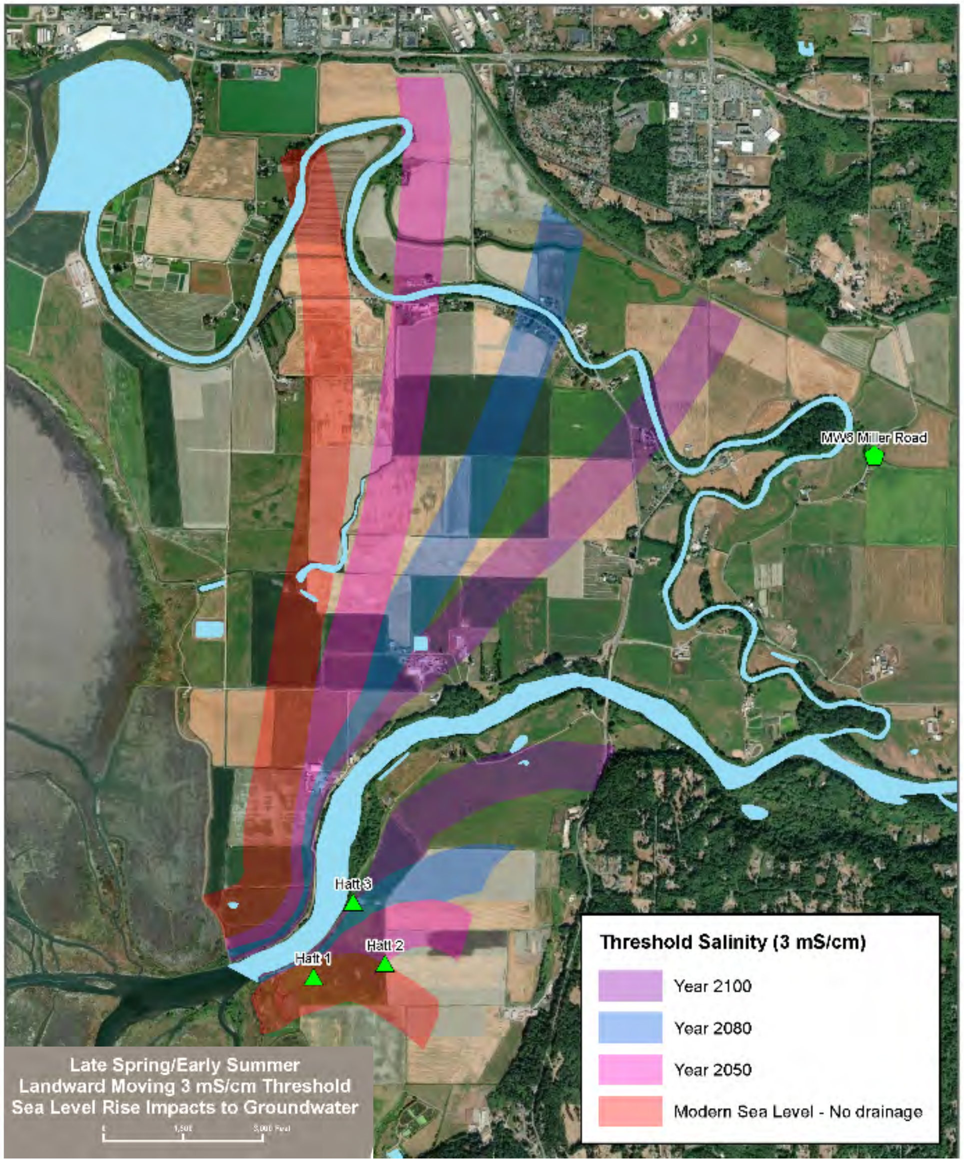

Thanks… any questions?

It's all online:

https://snohomishcd.org/impact-assessment-take-aways

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Snohomish Example at Ebey Island if Time Allows …

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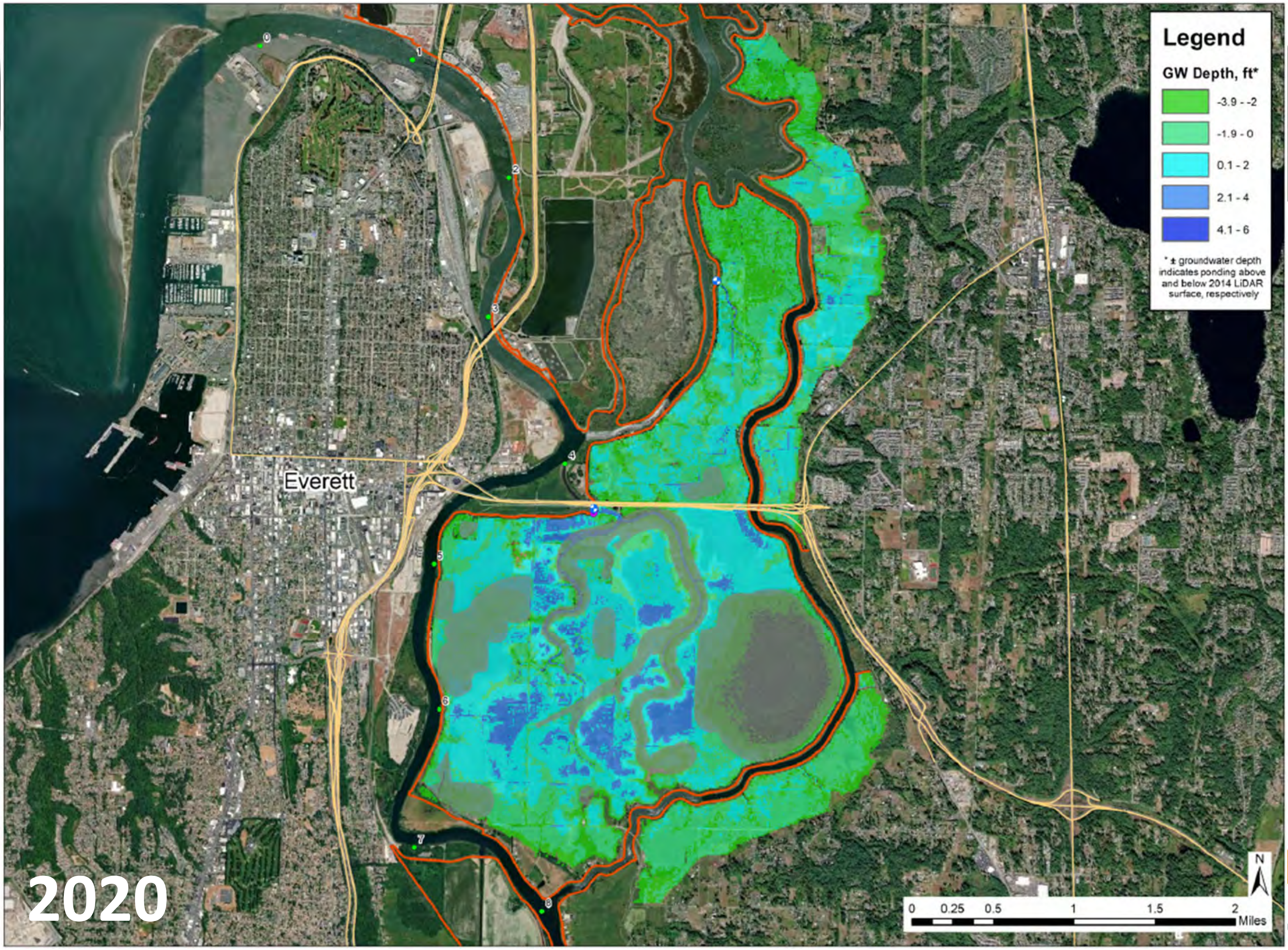
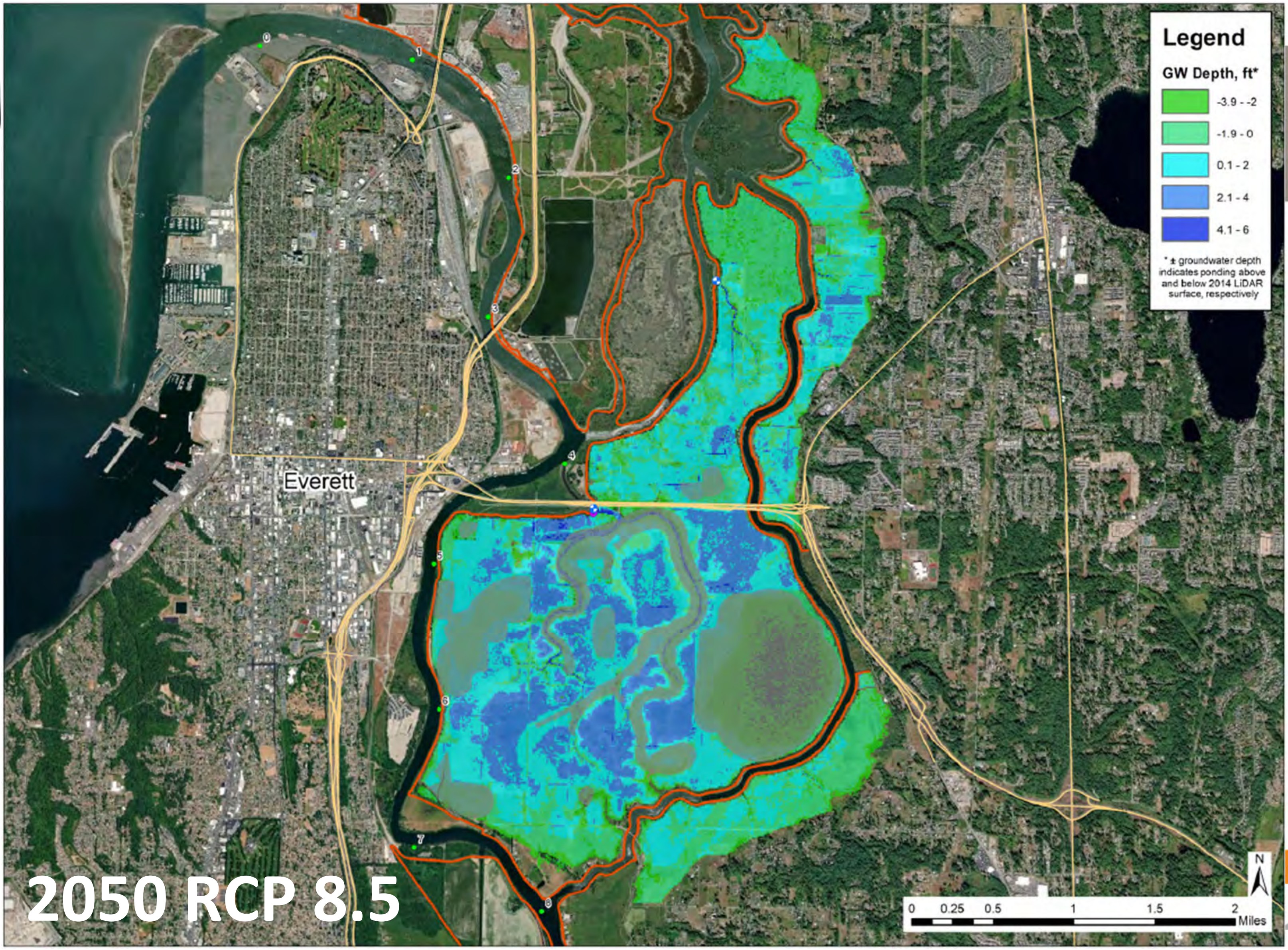


Legend
GW Depth, ft*
-3.9 - -2
-1.9 - 0
0.1 - 2
2.1 - 4
4.1 - 6
* ± groundwater depth indicates ponding above and below 2014 LiDAR surface, respectively
Everett
0 0.25 0.5 1 1.5 2 Miles
N
2020

ESA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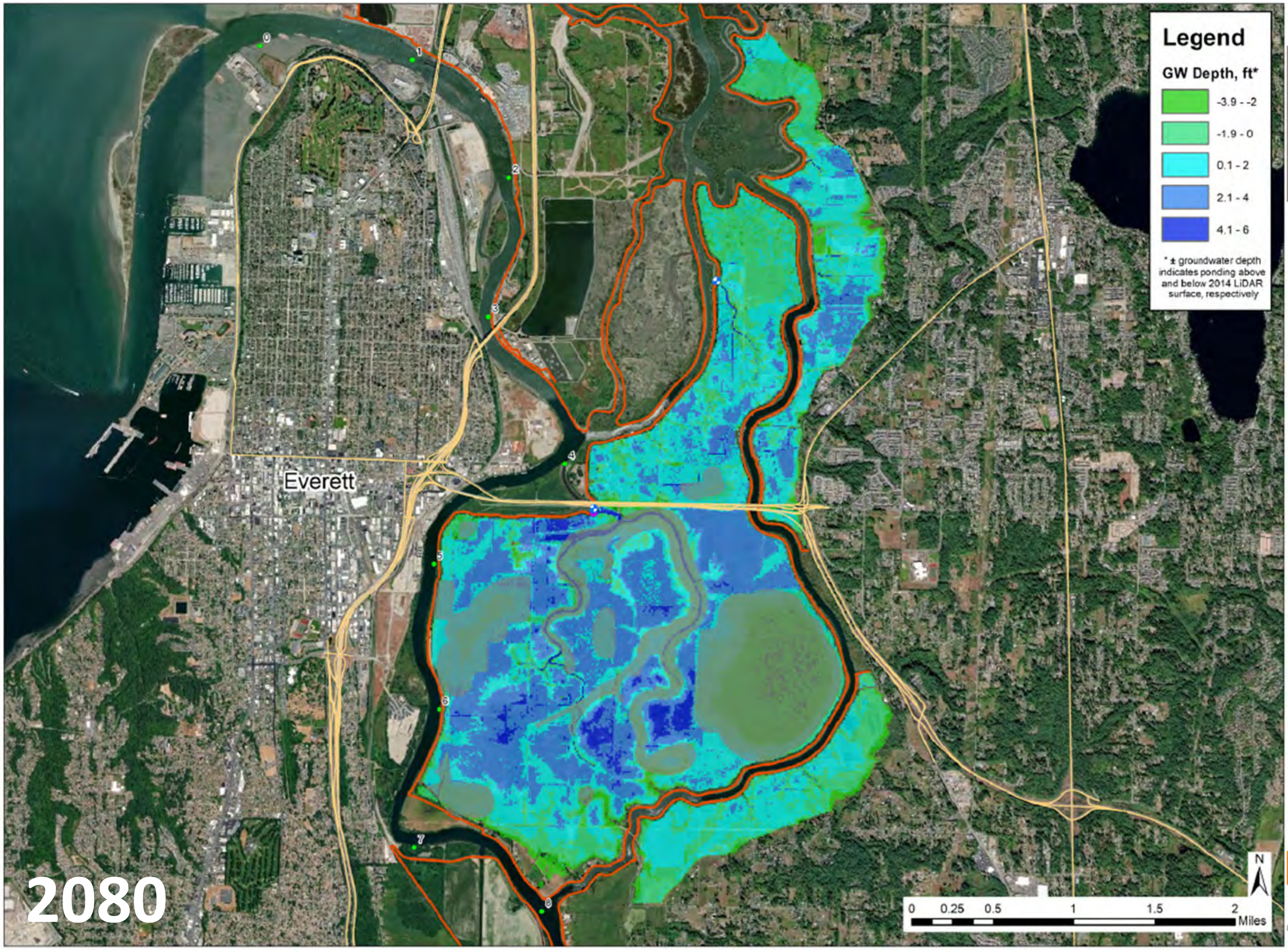
Everett
0 0.25 0.5 1 1.5 2 Miles
N
2050 RCP 8.5

ESA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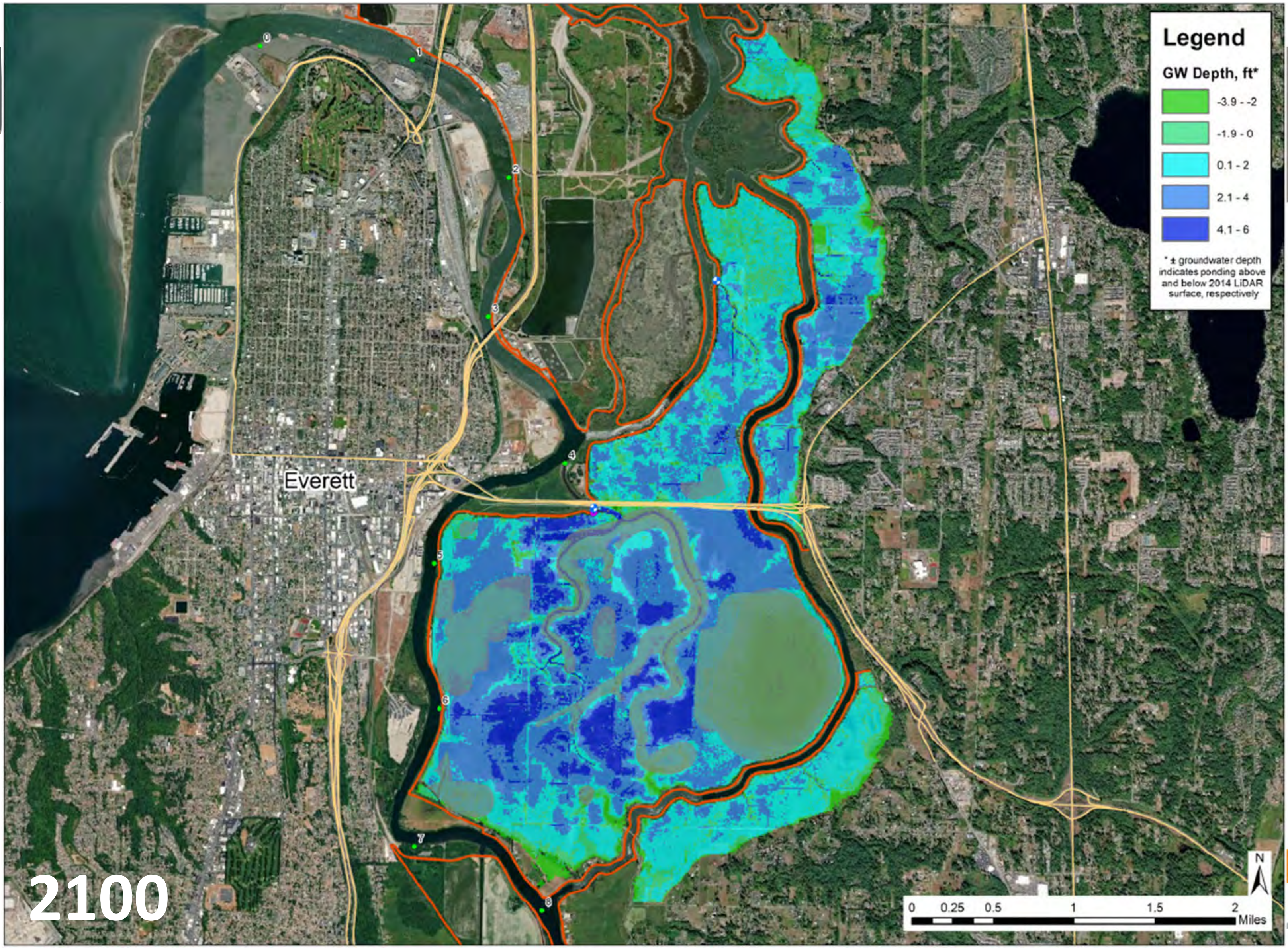
GW Depth, ft*
-3.9 - -2
-1.9 - 0
0.1 - 2
2.1 - 4
4.1 - 6
* ± groundwater depth indicates ponding above and below 2014 LiDAR surface, respectively
Everett
0
1
2
3
4
5
6
7
8
0 0.25 0.5 1 1.5 2 Miles
N
2080

ESA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Everett
0 0.25 0.5 1 1.5 2 Miles
N
2100