Improving Stream Crossing Design Guidelines in Tidal Environments

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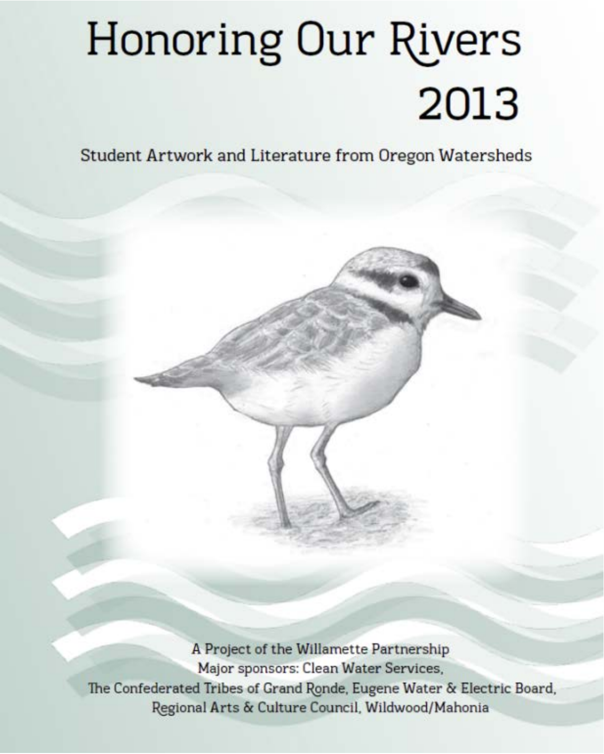
Lower Columbia River
Estuary Workshop
Astoria, Oregon
May 29, 2014

Lower Columbia Estuary Partnership

I Am the River

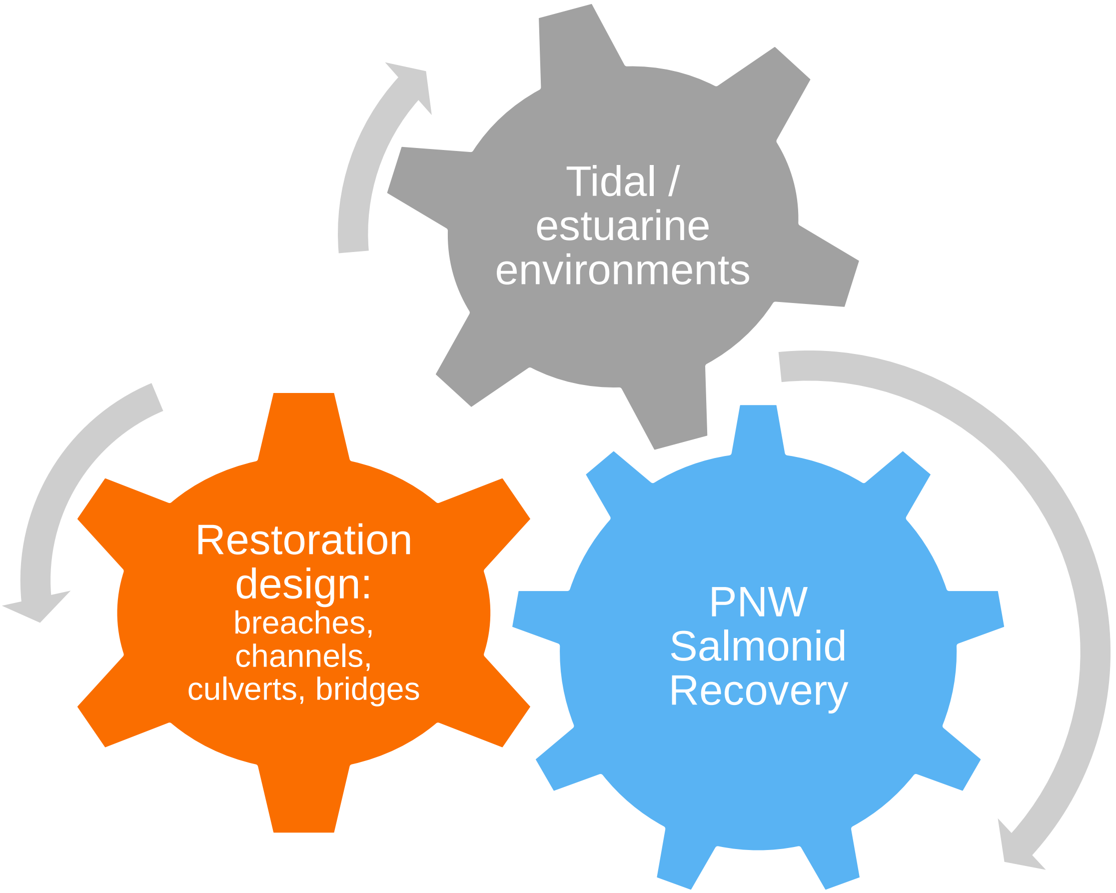
I am the river, swiftly moving by.
I am the river, swaying side to side.
I am the river, going down the mountain side.
I am the river, speeding quickly by.
I am the river, crashing and thrashing by.
I am the river, now softly moving.
Now I've met the ocean.

Abbi Marzolf, Grade 2, Forest Ridge Elementary

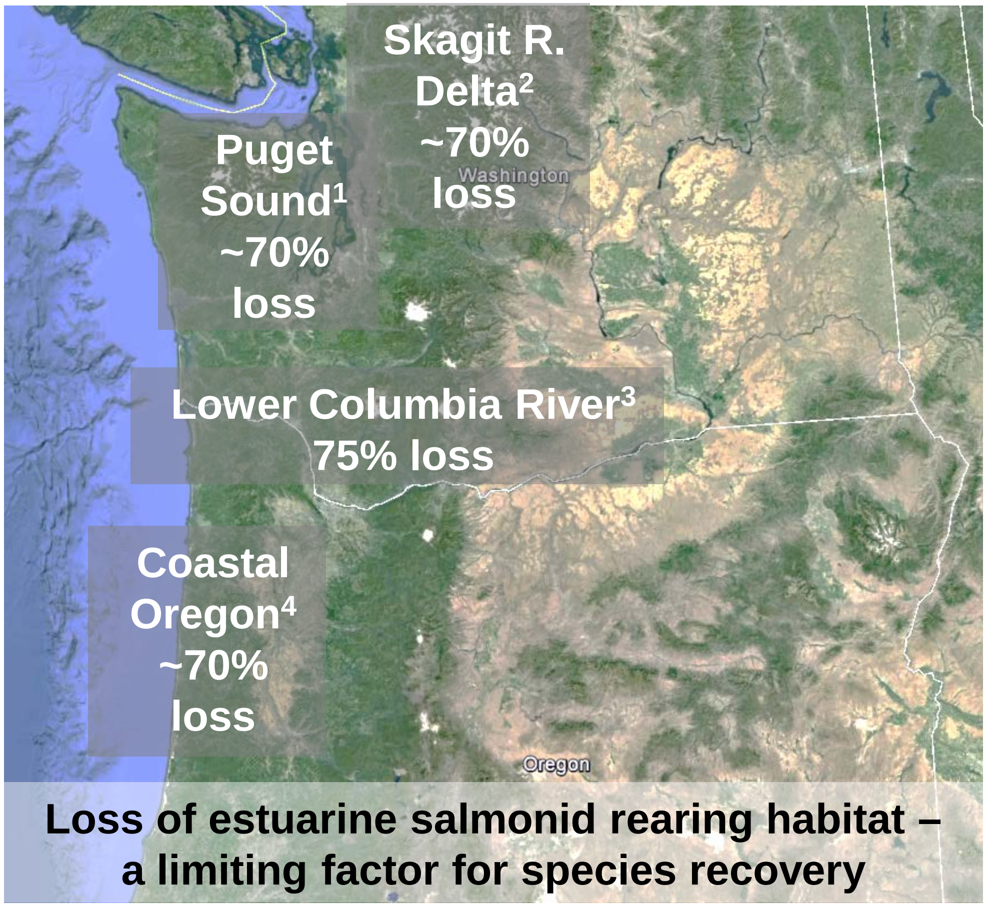


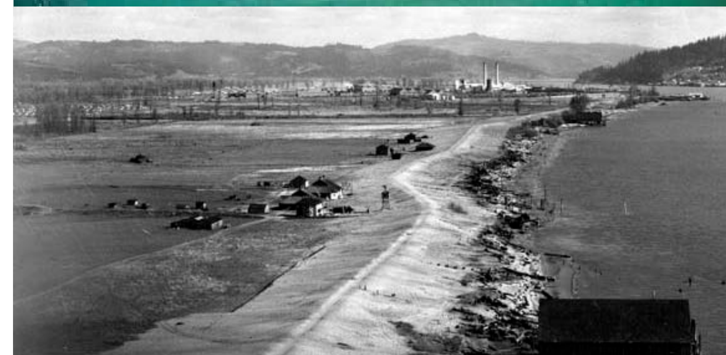
Background

Salmonid recovery driving the need for advancements in restoration design



Estuary habitat focus

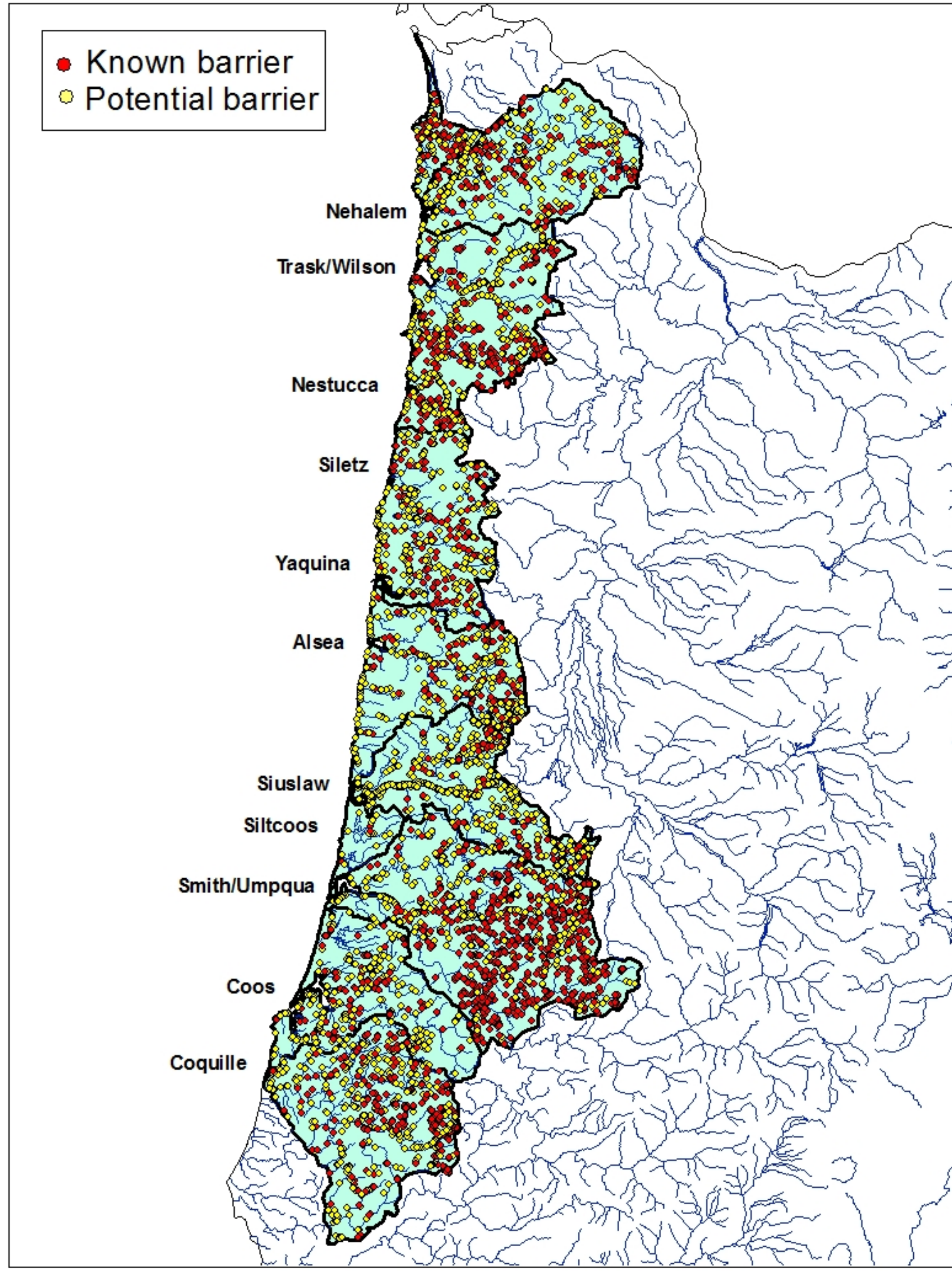




[1]Restore America's Estuaries; [2]Dean et al. 2001; [3]Bottom et al. 2005; [4]Oregon SOER 2000

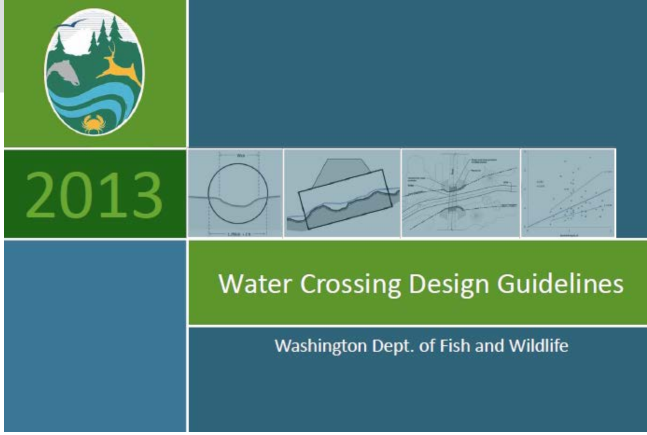
Barriers in Coastal Watersheds

- Over 4,000 known or potential barriers
- Large subset (several hundred??) are likely tidal crossings



Source: ODFW Fish Passage Barrier Std. Dataset

State of Washington Guidance



WDFW 2013 Stream Crossing Structure Guidelines, p. 110:

passage design flow. Continuous-flow simulation models and calibrated regional models most likely provide the best estimate of future conditions. Structural design of the culvert will depend on an accurate analysis of flows higher than the high fish-passage design flow.

LOW FISH-PASSAGE DESIGN FLOW

The low design flow is calculated to determine the minimum water depth within the culvert. One way of determining low design flow is to use the two-year, seven-day, low flow as described in WAC 220-110-070. A simpler option is to use the zero-flow condition as described below.

The WAC 220-110-070 low flow requirement applies only to culverts without sediment inside. Culvert backwatering and baffles are the techniques recommended in this chapter that do not require sediment to be present. In these cases the minimum depth is maintained by rigid control structures in the no flow condition. The remaining technique, roughened channel, uses bed material to create roughness and is therefore exempt from this requirement.

CULVERTS IN TIDAL AREAS

The hydrology of culverts in tidal areas is a special case. The hydraulic conditions in and downstream of the culvert change as the tide elevation changes. A complete discussion of this topic can be found in ***Appendix D***.

VELOCITY AND DEPTH

To keep the average cross-section velocity inside the culvert at or below the velocity criteria, select the appropriate combination of culvert size, roughness and slope. Several types of hydraulic

Oregon tidal passage guidance

- OAR 635-412-0035 (4) & (5)
- Meet riverine criteria, upstream & downstream passage
- Emphasis on hydraulic design rather than geomorphology
  - Greater than 51% of tides
  - Natural passage conditions

- Acknowledges limitations in guidance

Need

Estuarine habitat loss + fish passage barriers

Challenge

Sparse guidance

Approach

Culvert / bridge design guidelines –

new application of common methodology

South Tongue Point Tidal Wetland, Astoria Oregon (CREST)

How are tidal systems different?

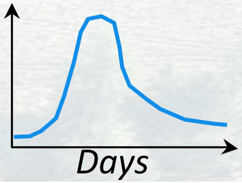
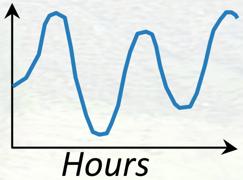
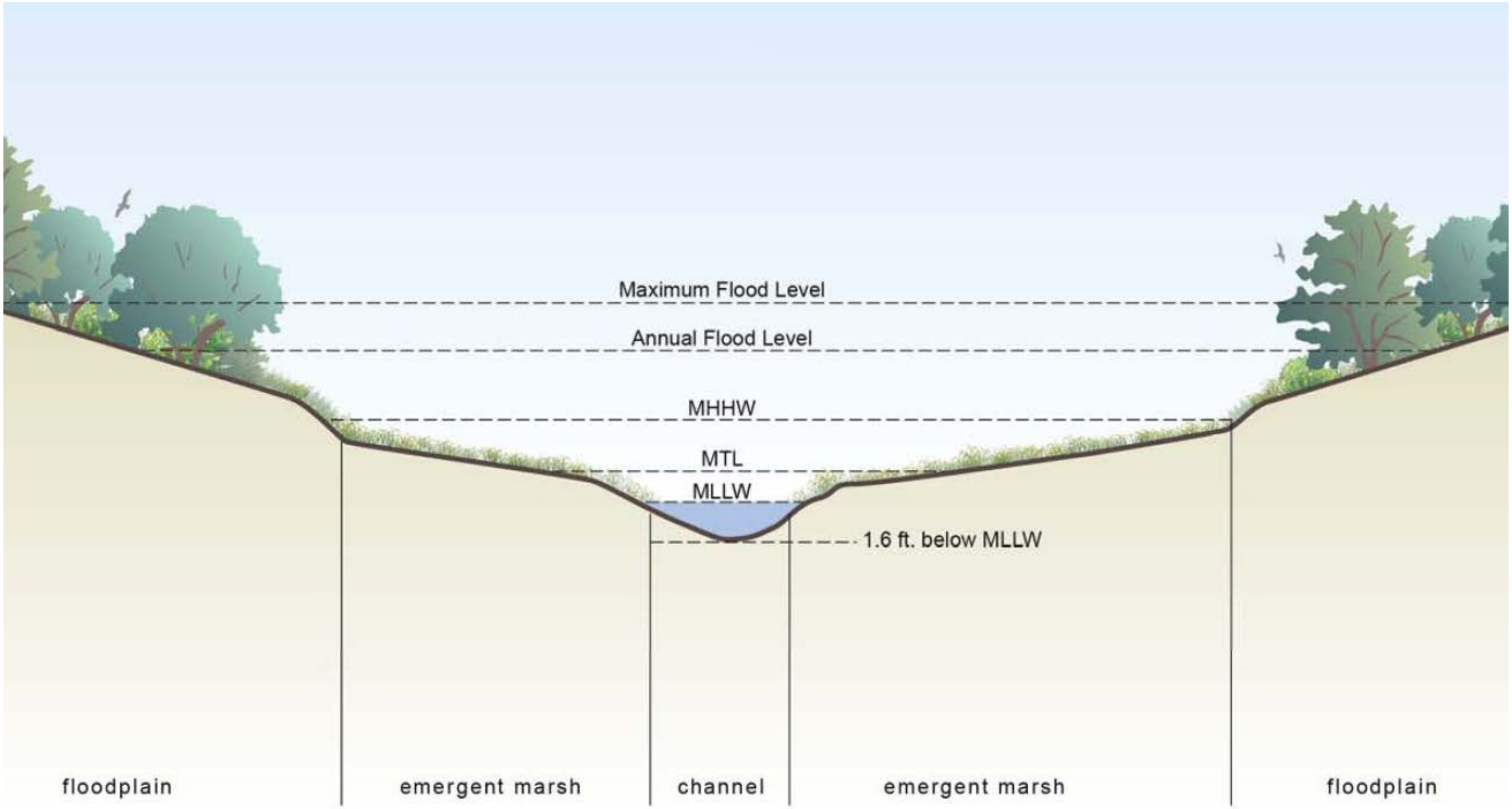
Characteristic	Fluvial	Tidal
Watershed position	High – intermediate	Low
Energy regime	High – intermediate	Low
Characteristic hydrologic variability		
Occurrence of channel forming processes	Years	Weeks
Stream substrate	Coarse	Fine

Photo courtesy of NPS, Fort Clatsop, OR

Representative tidal channel zones



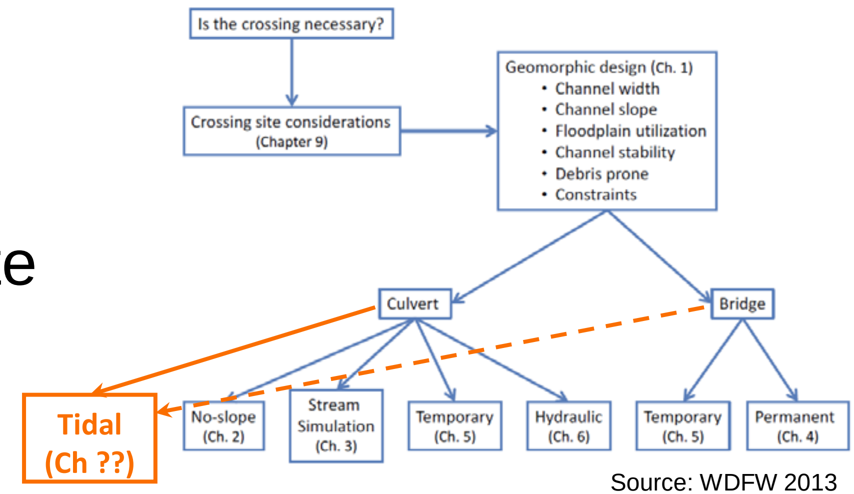
(PWA 2011)

Approach

1 - PHYSICAL

- Applied geomorphology
- Tidal hydraulic geometry
- Level of detail commensurate with that for fluvial crossings

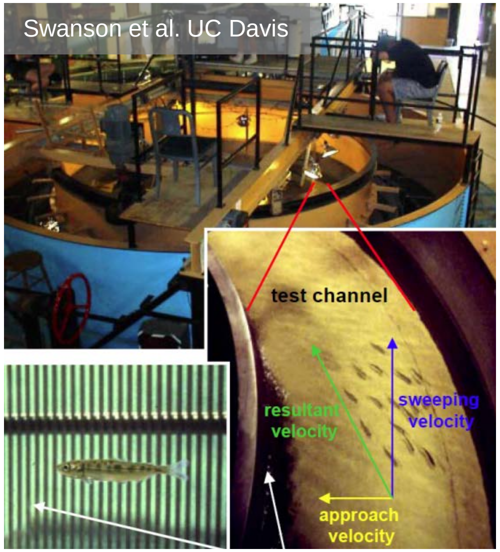
WDFW Design Guidelines Flow Chart



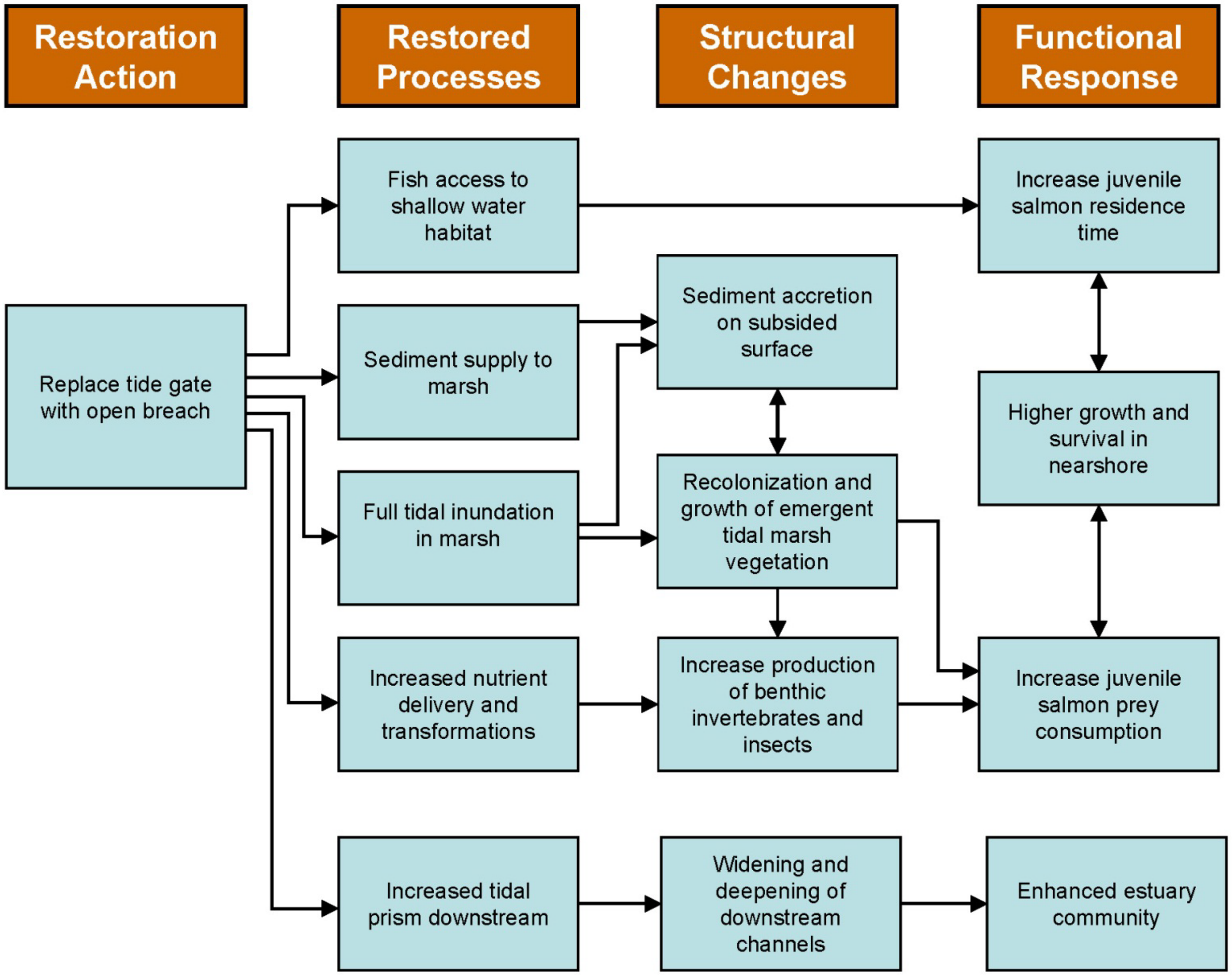
Source: WDFW 2013

2- BIOLOGICAL

- Develop biological design criteria applicable to fish ingress / egress or utilization in tidal areas at patch or site scale



Tidal reconnection conceptual model



Clancy et al. PSNERP Technical 2009-01 Management Measures for Protecting and Restoring the Puget Sound Nearshore.

Part 1
Applied geomorphology approach

- Like stream simulation for rivers
- But very important procedural differences…

…difficult to find applicable reference conditions!



Applied geomorphology approach

- Empirical regressions relating hydraulic geometry (width, depth, area) to drainage area / tidal prism
- Power function form

$$w = cA^n$$

w	*Width of channel*
A	*Wetland area*
c, n	*coefficient, exponent*

- Analogous to fluvial relationships between bankfull width and watershed area / precipitation (WDFW 2013)

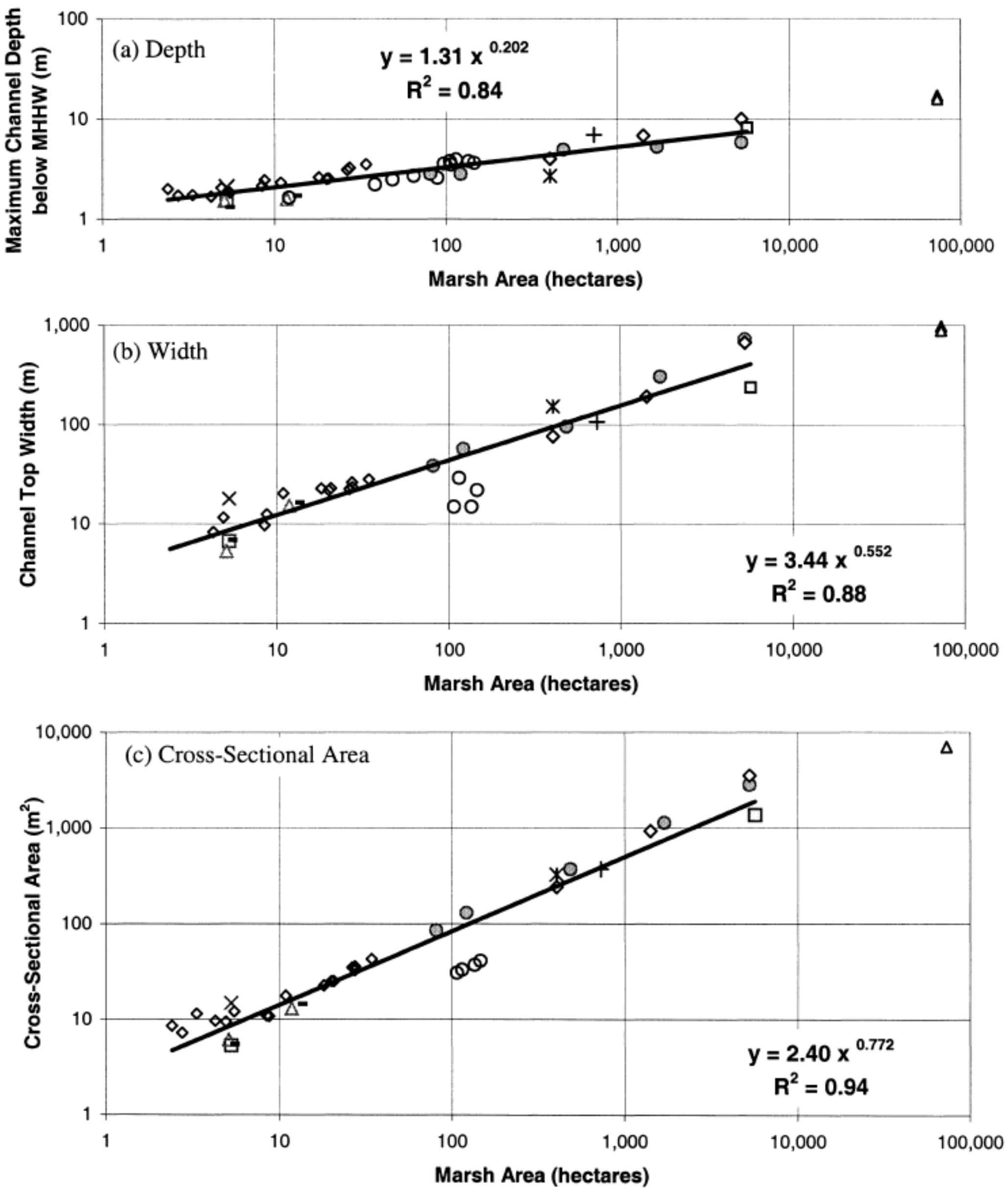
Applied geomorphology approach

- Relationships represent equilibrium conditions
- System specific
- Currently developed for
  - Lower Columbia R., Reaches C, D, E (RM 38 – 85, PWA 2011)
  - LCRE Grays Bay, Reach B (Diefenderfer et al. 2008)
  - Puget Sound (PSNERP 2011)
  - Chehalis R. Estuary (Hood 2002)
  - Skagit R. Delta (Hood 2007)
  - San Francisco Bay (PWA, 1995; Williams et al, 2002)

Applied geomorphology approach

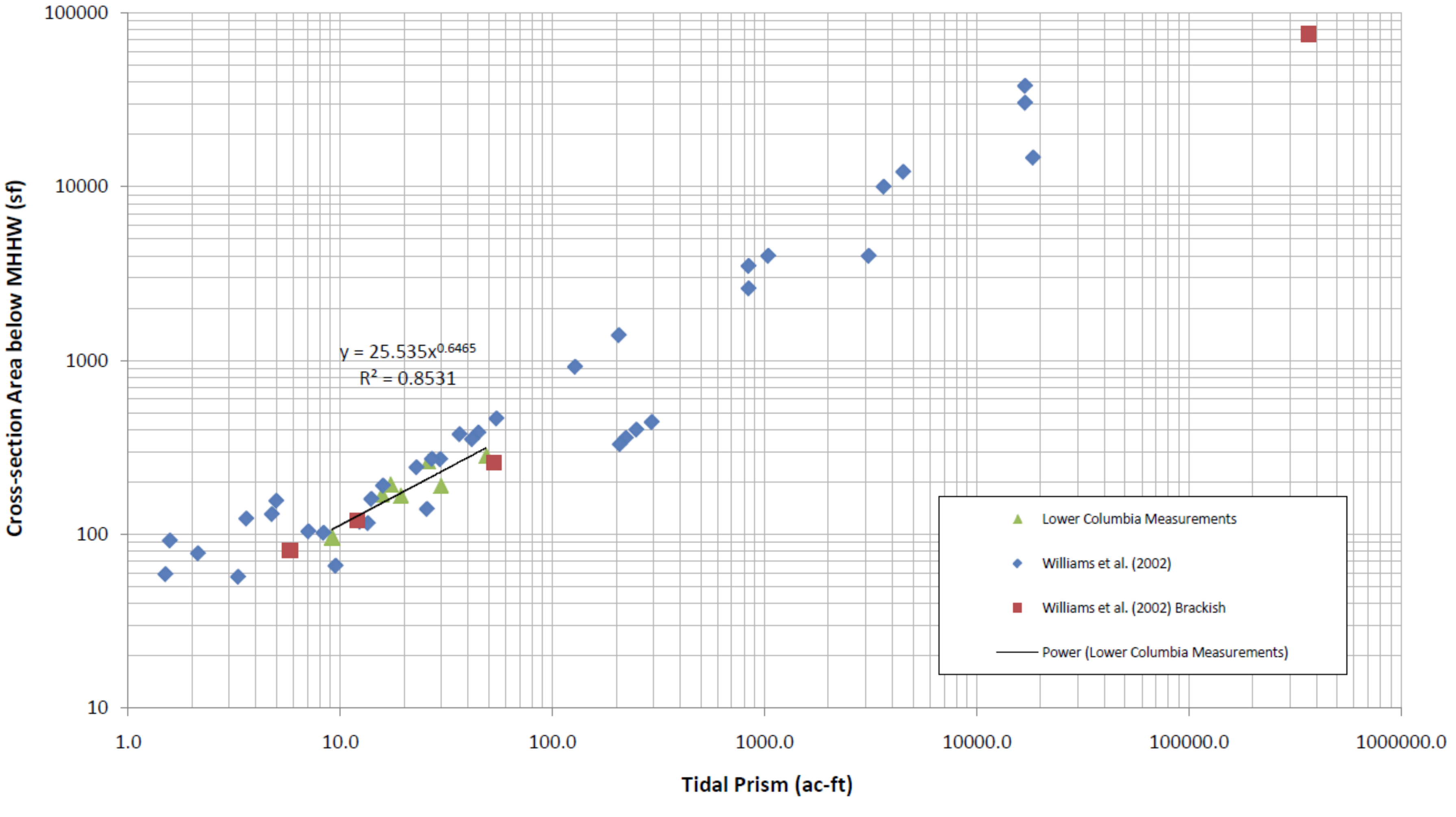
- Relationships will vary by
  - Tide range (MLLW to MHHW)
  - Dominant sediment type
  - Salinity regime & vegetation
- Within similar environment, variations can be
  - Size of site
  - Elevation (level of subsidence)
  - Tidal prism (related to both of the above)

Marsh area regressions – SF Bay



(PWA 2002)

Tidal prism regression – Lower Columbia



(PWA 2011)

Steps of application -1

- Relevant hydraulic geometry curves?
  - Yes → use them
  - No → use others nearby & adjust
- Measure drainage area → calculate channel depth
- Measure tidal prism → calculate channel area
  - Adjust prism for fluvial discharge if necessary

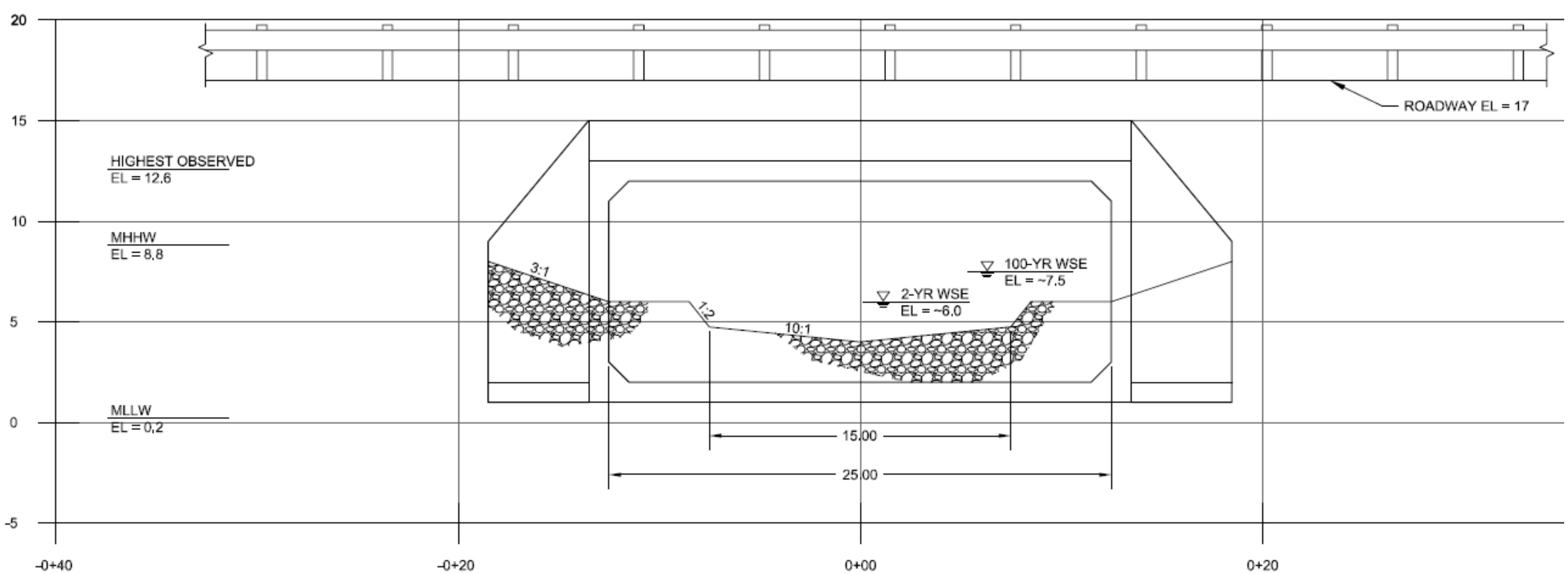
Steps of application - 2

- Calculate channel top width (bankfull)
  - Top width ~ area / depth
  - Assume steep trapezoidal cross section
- Back-check in multiple ways
  - Historic maps
  - Nearby reference locations
  - Hydrodynamic modeling of channel hydraulics
  - Spreadsheet estimates

Steps of application - 3

- Consider other effects
  - Wind-waves, sedimentation, vegetation, CCA / SLR
- Calculate structure type / size
  - Recognize uncertainty
  - Structure span / length

$$Width_{min.\ structure} = \mathbf{1.2}\ W_{bankful} + \boldsymbol{x}\ feet$$



Approach

1 - PHYSICAL

- Applied geomorphology
- New tidal design category
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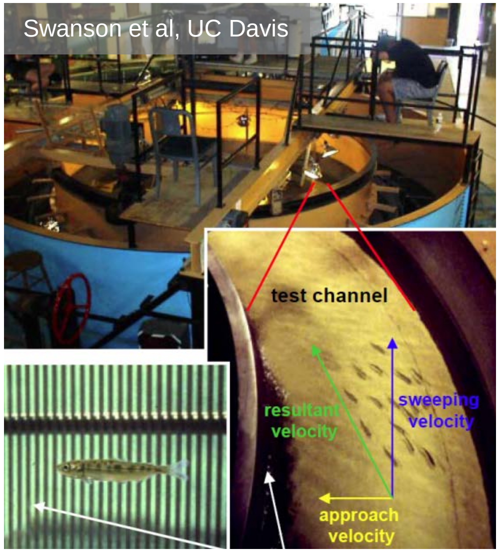
Source: WDFW 2013

2- BIOLOGICAL

- Develop biological design criteria applicable to fish ingress / egress or utilization in tidal areas at patch or site scale



Part 2
Biological design criteria

- Research characterizes seasonal presence/ migration at large-scales & main channels[1,2,3,4]
  - Movement corresponds with tidal cycles which affect egress rates, migration speeds, etc.
  - Migration can be rapid, function of flow, species/run, location, diel period, date, and fish size
  - Correlations between presence and habitat types
- But how do they access off-channel habitats?
- When does tidal velocity/depth become a barrier?
- Or, do fish just go with the flow?

[1]Carter et al. 2009; [2]Cech et al. 2002; [3]Sobocinski et al. 2008; [4]Beamer et al. 2005;

Summary

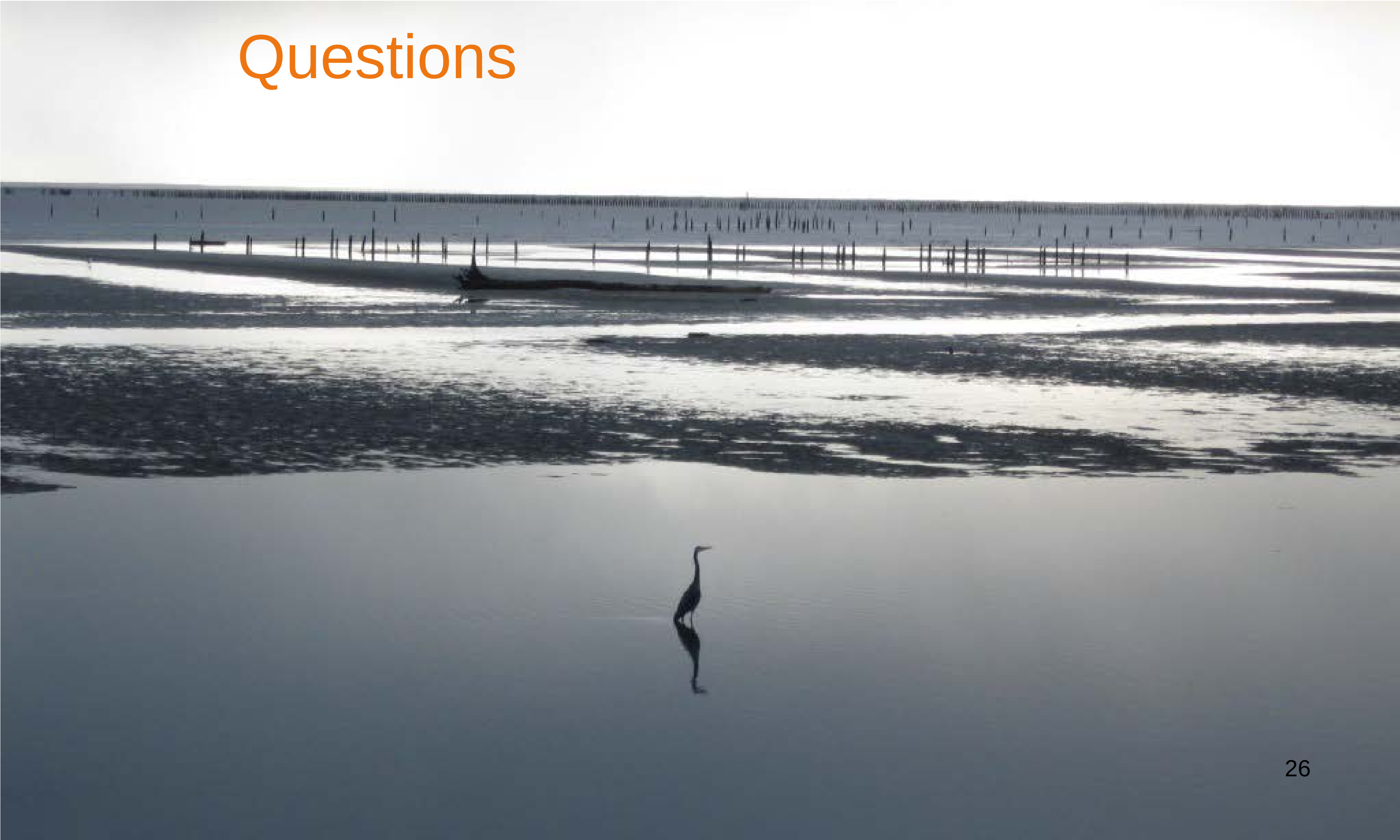


- Approach
  - Analysis: tidal hydrology ≠ fluvial hydrology
  - Design: applied tidal geomorphology
  - Structure size based on physical equilibrium conditions
  - *Biological criteria research (stay tuned…)*
- Implications
  - Consistent, thorough basis of design
  - Efficient regulatory reviews
  - Not only barrier removal, but restored processes & improved habitat functionality

Concluding thoughts

- Pause… listen to the "softly moving waters"
- Is there better way?
- Further our understanding
- Improve our approaches

Questions



Special thanks

- Bob Barnard, WDFW, LaConnor, WA
- Ryan McCormick, Ken Loffink, Greg Apke, ODFW, Salem, OR
- Matt Van Ess, Sam Giese, Tom Josephson, Columbia River Estuary Study Taskforce (CREST), Astoria, OR
- Catherine Corbett, Marshall Johnson, Lower Columbia Estuary Partnership (EP), Portland, OR
- Bob Battalio, Louis White, Jeremy Lowe, Marjorie Wolfe, ESA PWA

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