Linking Channel-Margin Bed Thickness to Hydrodynamics in the Tidally Influenced Fraser River, British Columbia*

Andrew La Croix[1], Shahin Dashtgard[1], and James MacEachern[1]

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[1]Department of Earth Sciences, Simon Fraser University, Burnaby, BC (alacroix@sfu.ca)

Abstract

Sedimentation across the tidal-fluvial transition of the lower Fraser River is a function of the interplay of fluvial flow and tidal flux, and the degree of saltwater – freshwater mixing. The local hydrodynamic conditions in the channels determine the distribution of sand and mud, with mud concentrated in the turbidity maximum zone. Vibracores were collected from three channel bars in the tidally influenced reaches of the Fraser River, to assess the lateral distribution and thickness of mud layers and link them to the causative hydrodynamic conditions.

In the freshwater tidal reach near Fort Langley, muds are thin (mm to cm) and laterally continuous for meters¬ – tens of meters. They accumulate in the upper intertidal zone and are planar-laminated, reflecting suspension settling during base-flow conditions. Intervals lack cyclic mud deposition, with <5 mud beds/meter in vertical profile. Bioturbation is sparse (BI 0-1), with rare horizontal traces (e.g., *Planolites*) of deposit-feeders. In the brackish-water, tide-influenced reach at Port Mann, muds are thicker (cm to dm) and span tens – hundreds of meters laterally. They are deposited in the uppermost subtidal and intertidal zones, are planar-laminated or show floccule ripples, and are more abundant (~5 beds/meter in vertical profile). Bedding cyclicity is not well expressed, due to the dominance of fluvial processes. Bioturbation is reduced (BI 0-2) and patchily distributed, consisting of vertical-dwelling traces (e.g., *Skolithos, Polykladichnus*) subtending into muds from sand-mud contacts. In the brackish-water, strongly tide-influenced reaches in Canoe Pass, muds are thickest (cm to dm) and extend laterally for hundreds of meters – kilometers. They comprise stacked floccule ripples, with lesser structureless and laminated layers, reflecting dynamic mud deposition. A weak, seasonally induced cyclicity occurs, with muds ranging from 5-10 beds/meter in vertical profile. Bioturbation shows BI 0-2, is patchily distributed, and comprises diminutive deposit-feeding (e.g., *Planolites, Teichichnus*) and dwelling (e.g., *Skolithos, Polykladichnus*) traces. Burrows occur in both sand and mud beds.

This semi-quantitative comparison of hydrodynamics and mud characteristics is of fundamental importance to the production of unconventional hydrocarbons from tidal-fluvial reservoirs (e.g., McMurray Formation). The study shows that these types of mud layers control heterogeneity and, ultimately, reservoir compartmentalization.

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Andrew La Croix, Shahin Dashtgard, and James MacEachern

Department of Earth Sciences

Simon Fraser University

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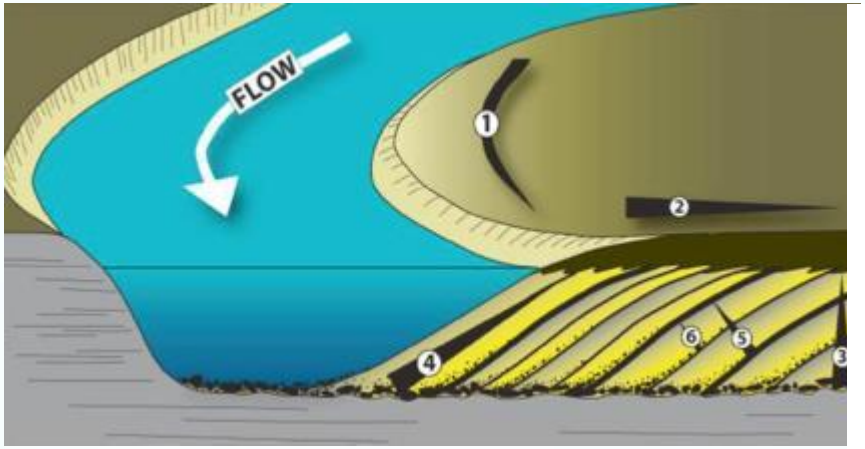
Outline of Presentation

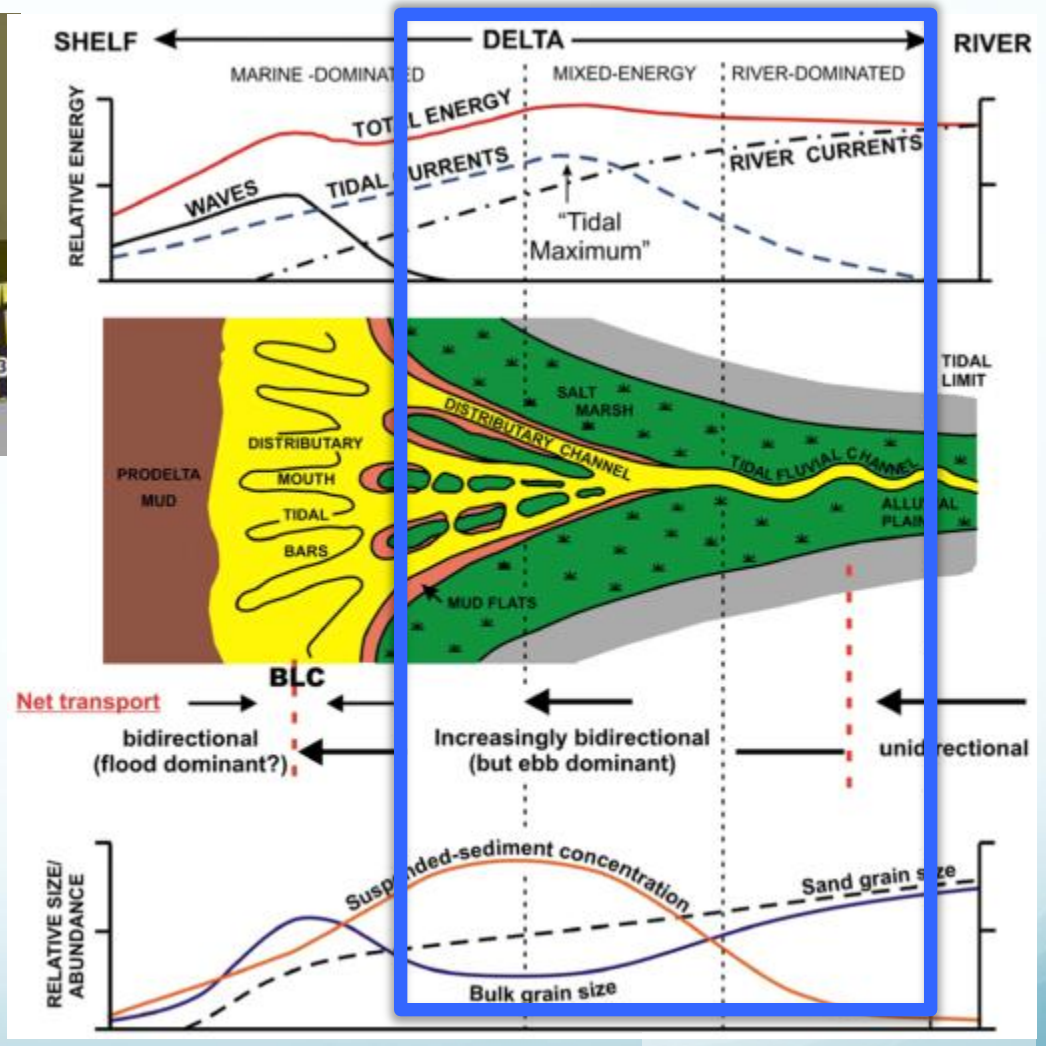
- Tidal-fluvial channel-margin bars
- Fraser River hydrodynamics
- Bed thickness across the transition
- Can we discern cyclicity??
- Predicting position relative to turbidity max
  - Reservoir compartmentalization
- Summary and Conclusions

The Tidal-Fluvial Transition



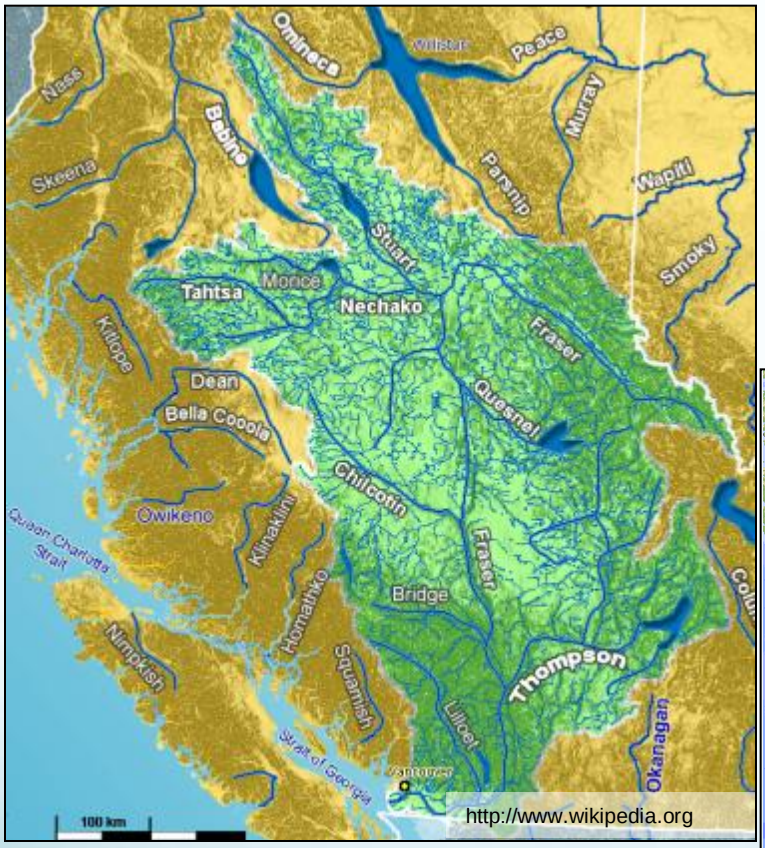
Modified by S. Hubbard, after Thomas et al., 1987

- Channel margins/tops dominated by IHS
- Complex interplay of tidal and river flow determine character
- **Lack of quantitative assessment**

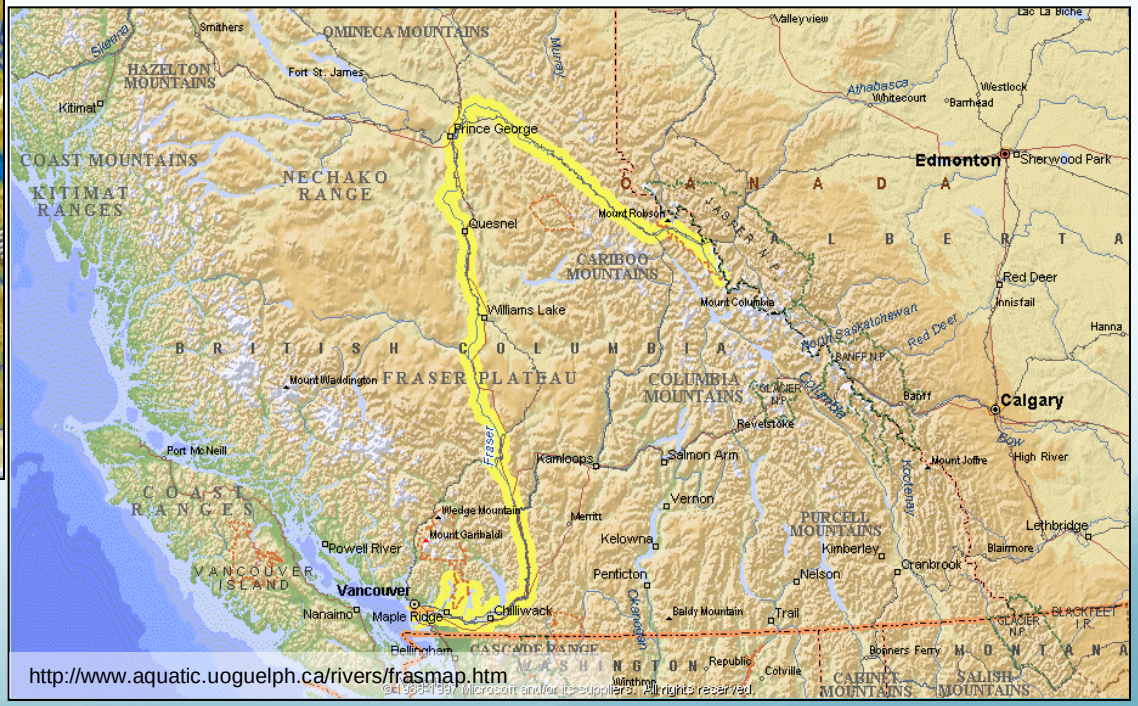


From Dalrymple and Choi, 2007

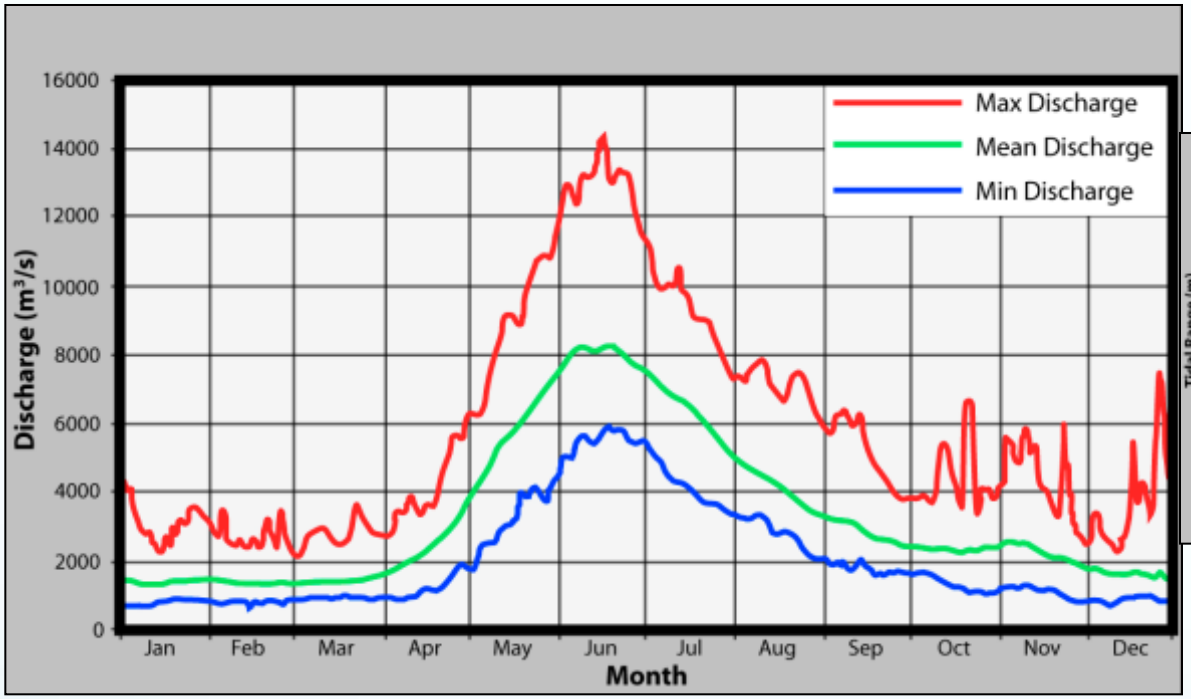
The Fraser River Basin



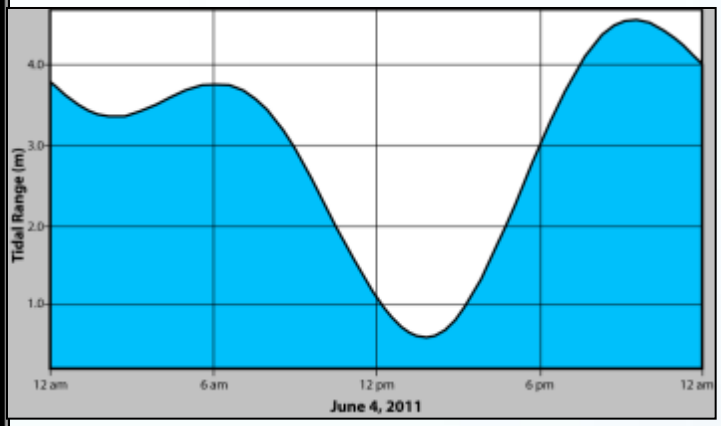
- **Drainage basin 228 000 km^2**
- **Unrestricted river flow for 1200 km**



River Flow and Tides in the Fraser River

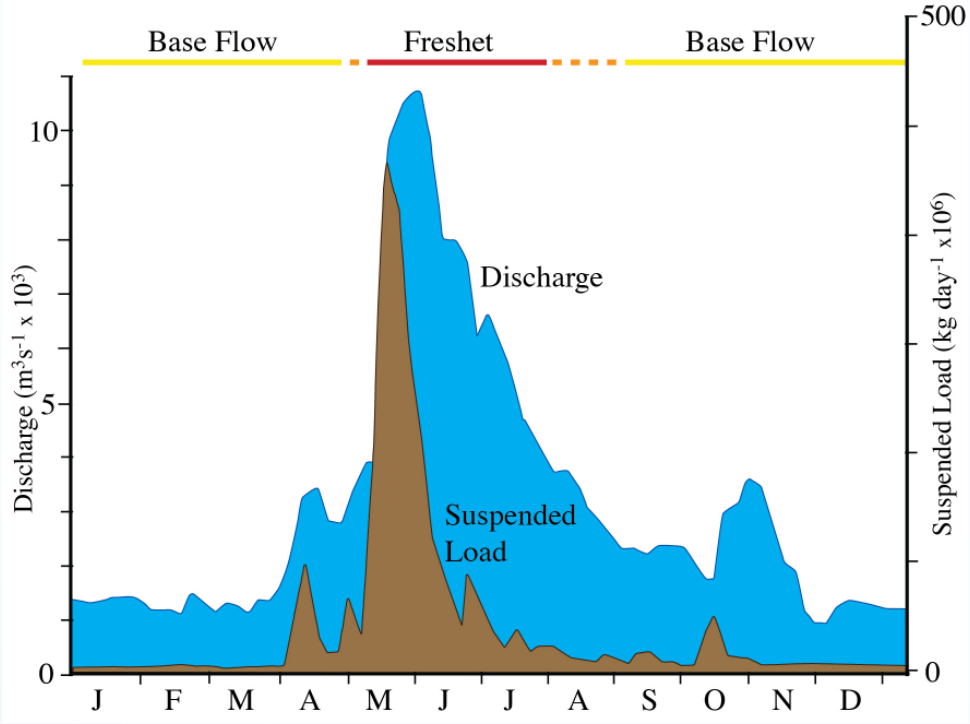


Mixed semi-diurnal tides



- **Base flow: 1000 - 3000 m^3/s**
- **Freshet flow: 6000 - 15000 m^3/s**
- **Tidal range: 3 m average, 5 m (spring tides)**

Sediment Load in the Fraser River



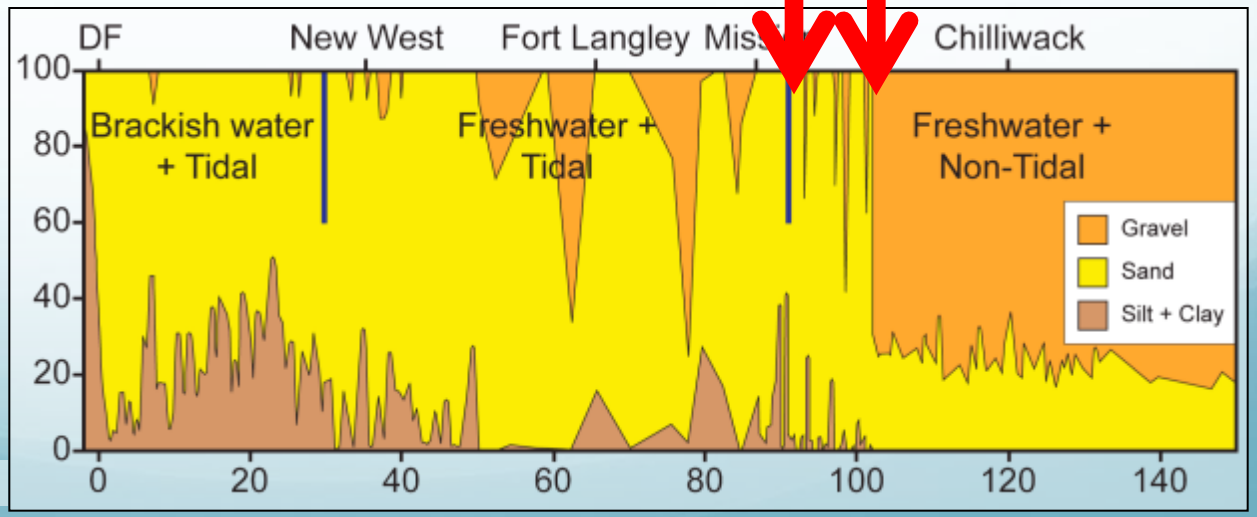
(From Sisulak & Dashtgard, 2012, after Kostaschuk et al. 1998)

- **Channel depth: 11-15 m, max 23 m**
- **17 x 10^6 tonnes annual sediment load**
- **65% mud, 35% sand**

Freshwater, non-tidal:

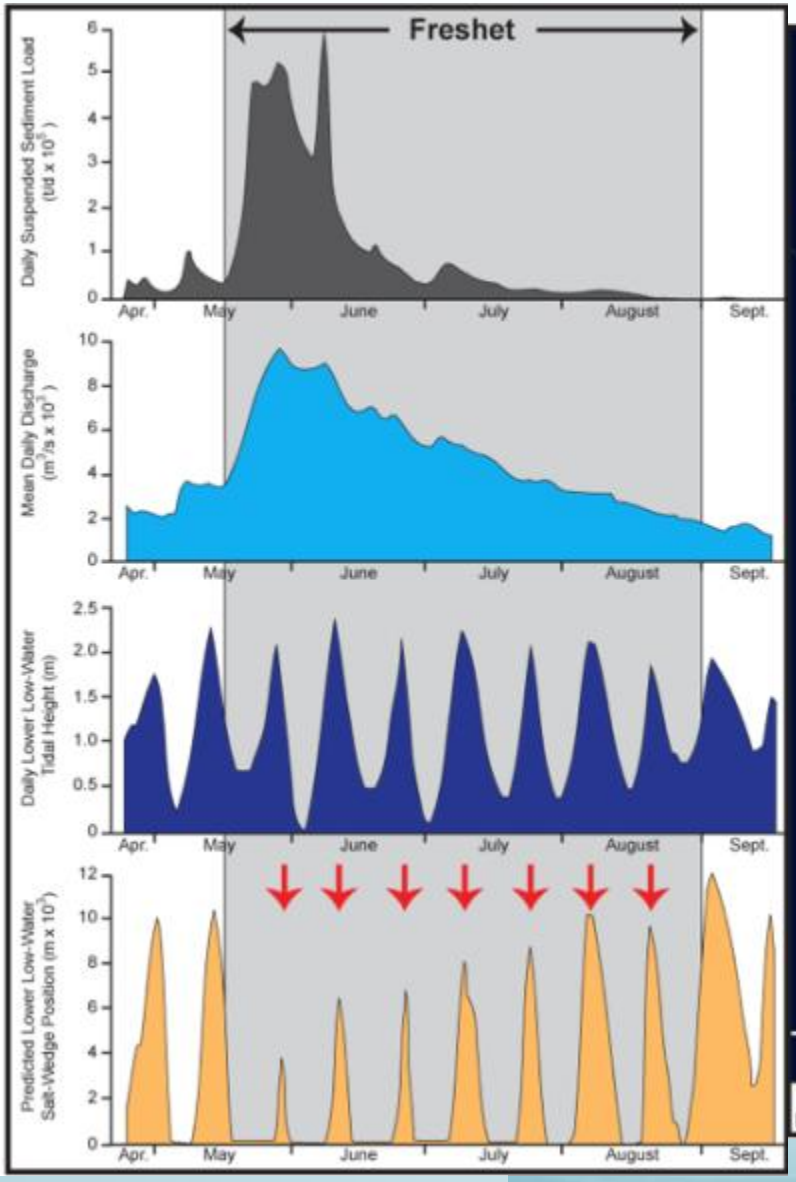
90 km at freshet

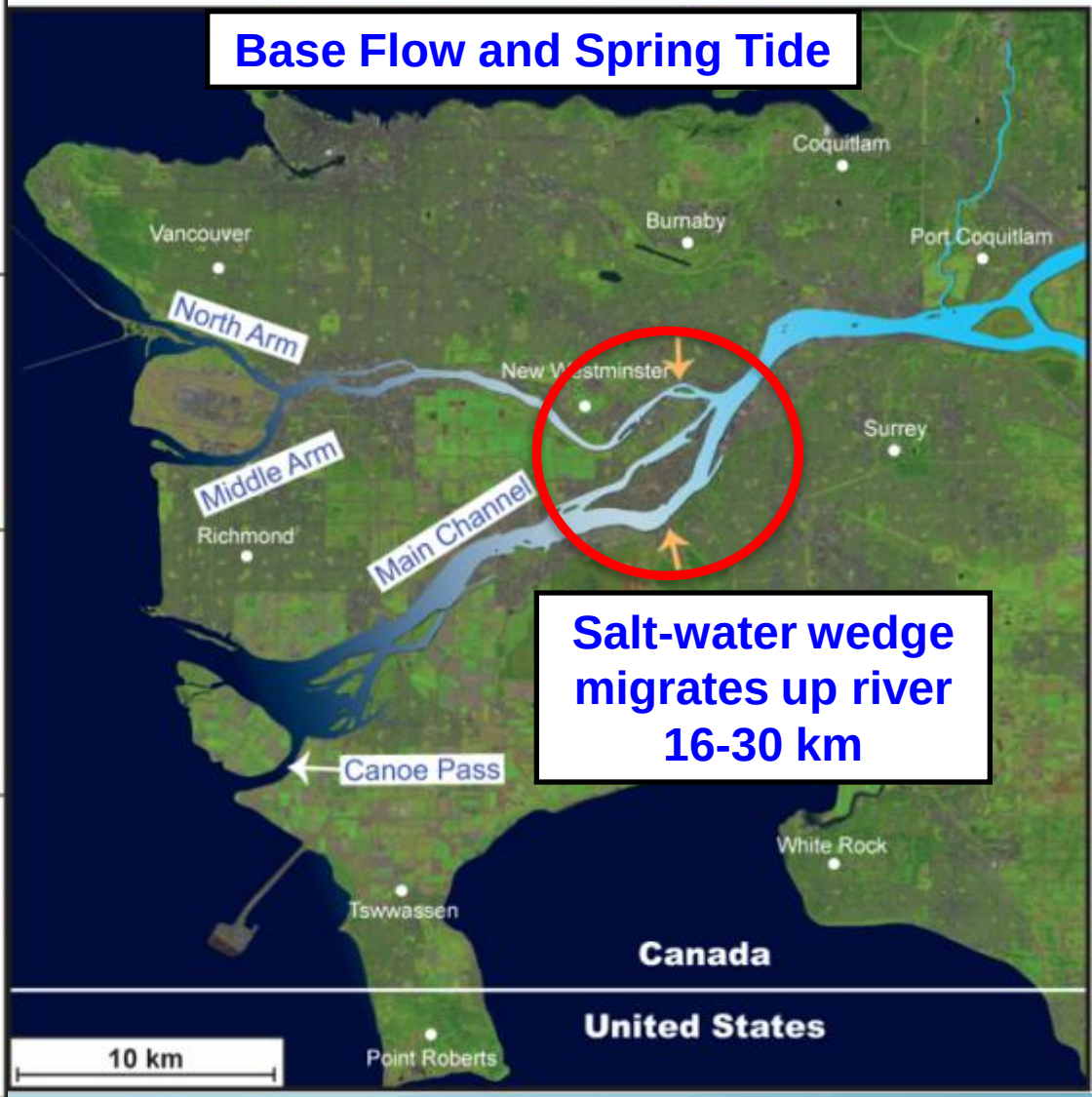
102 km at base flow



(From Venditti et al., 2010)

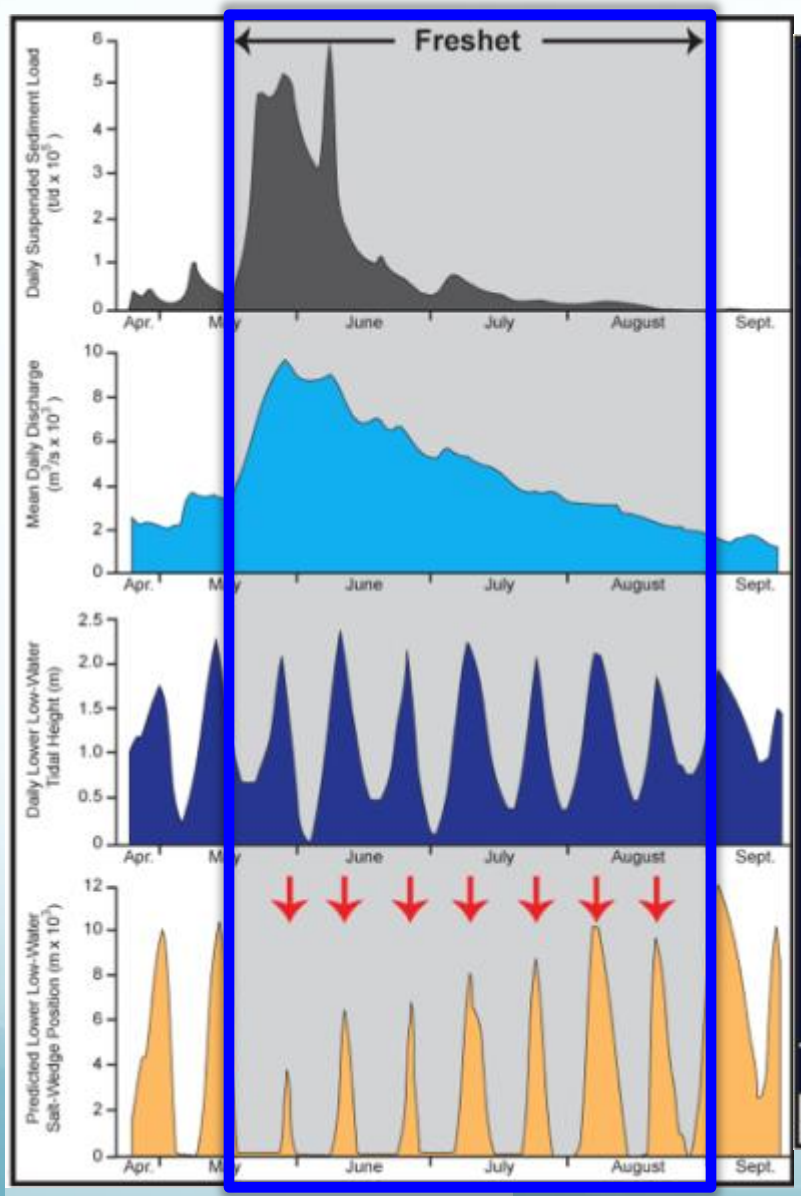
Seasonal Position of the Turbidity Max





Modified from Kostaschuk and Atwood, 1990

Seasonal Position of the Turbidity Max



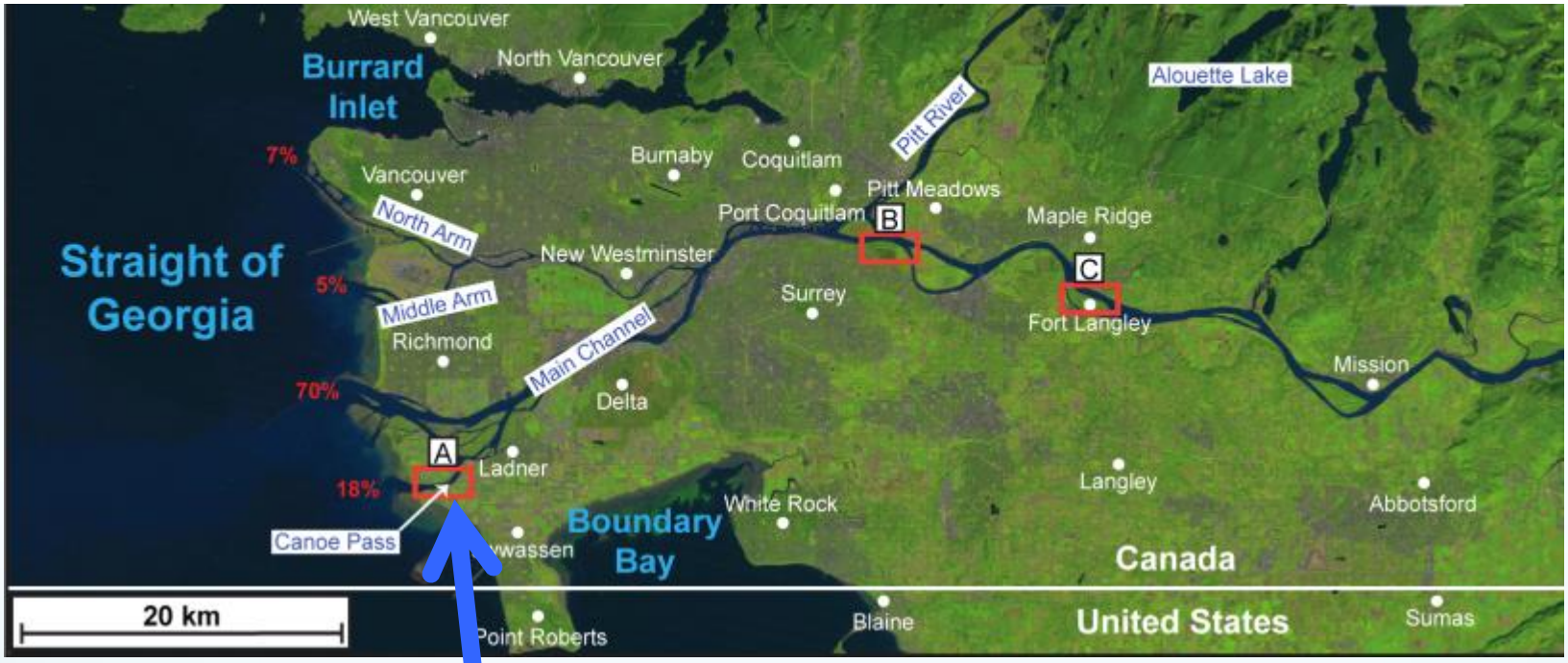
Modified from Kostaschuk and Atwood, 1990

Canoe Pass (Westham Island)

Mixed tidal-fluvial, Brackish water

Tidally-influenced, FW-SW transition

Tidally-influenced, Fresh water



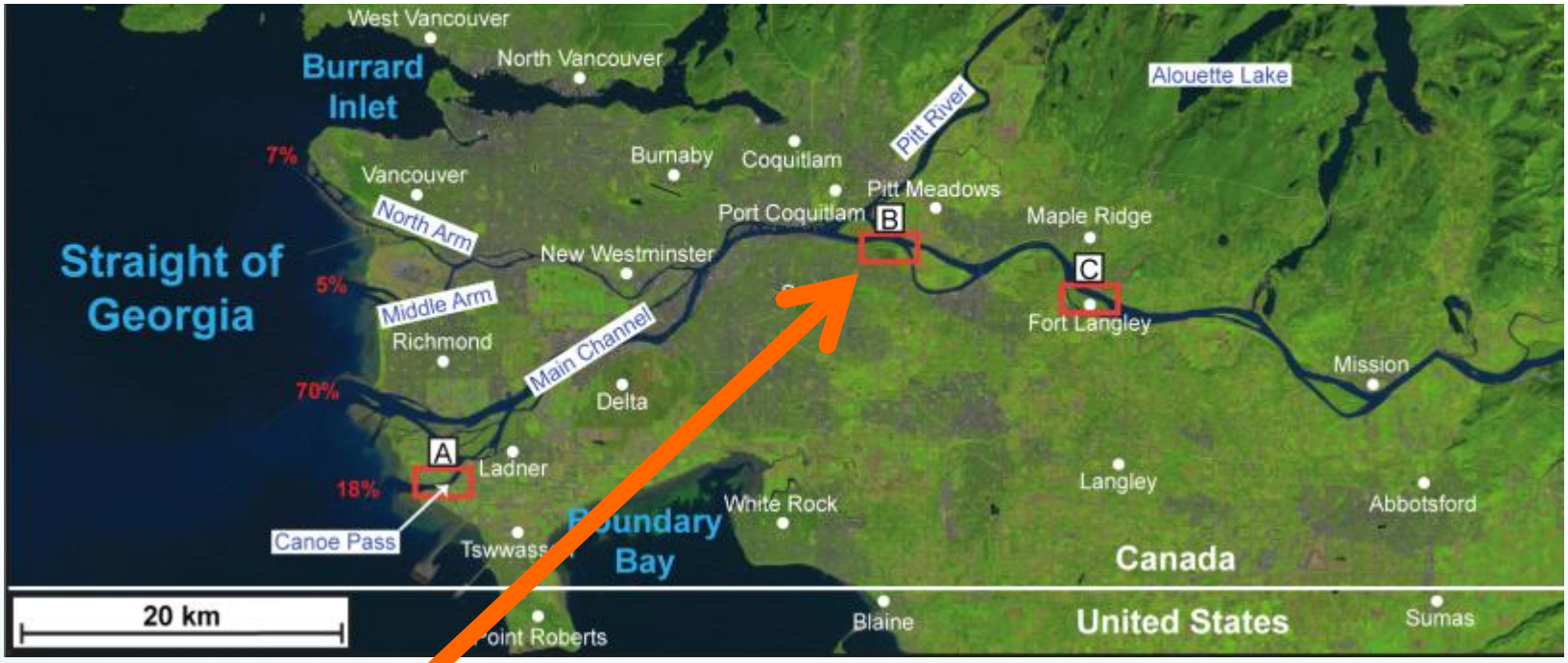
- 18% of river flow (WCHL, 1977)
- **Mixed tidal-fluvial, sustained brackish during base flow**

Fraser Heights

Mixed tidal-fluvial, Brackish water

Tidally-influenced, FW-SW transition

Tidally-influenced, Fresh water



- 100% of river flow (WCHL, 1977)
- **Landward of max. SW wedge (transition)**

Fort Langley (MacMillan Island)

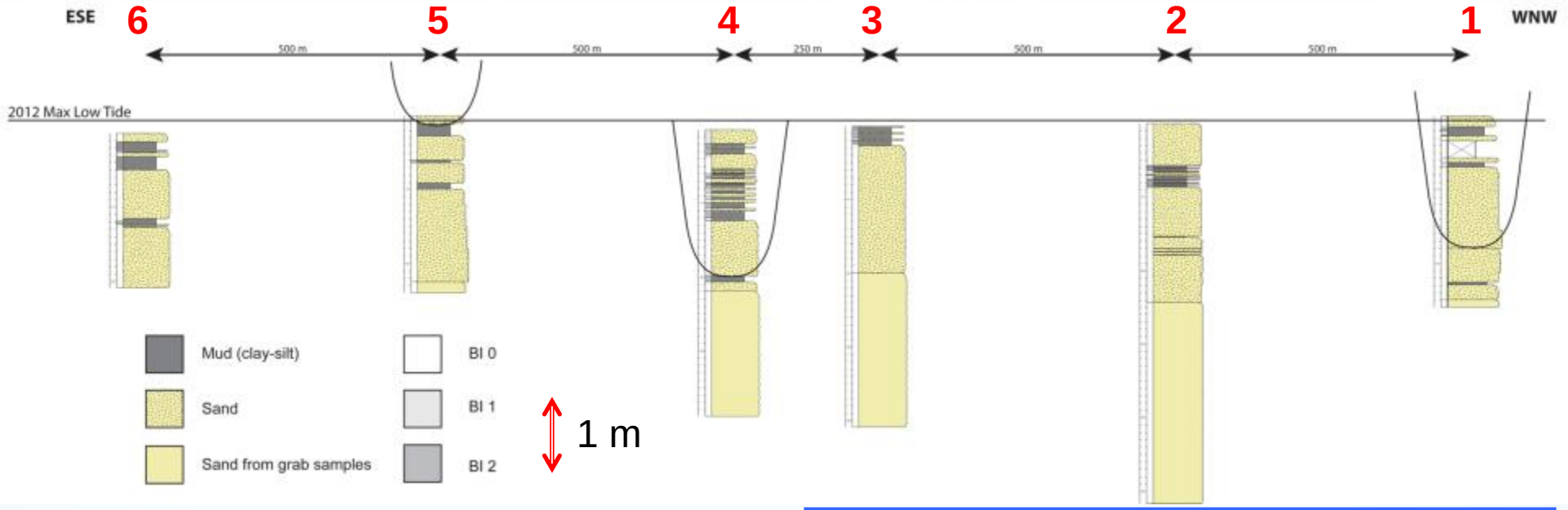
Mixed tidal-fluvial, Brackish water

Tidally-influenced, FW-SW transition

Tidally-influenced, Fresh water

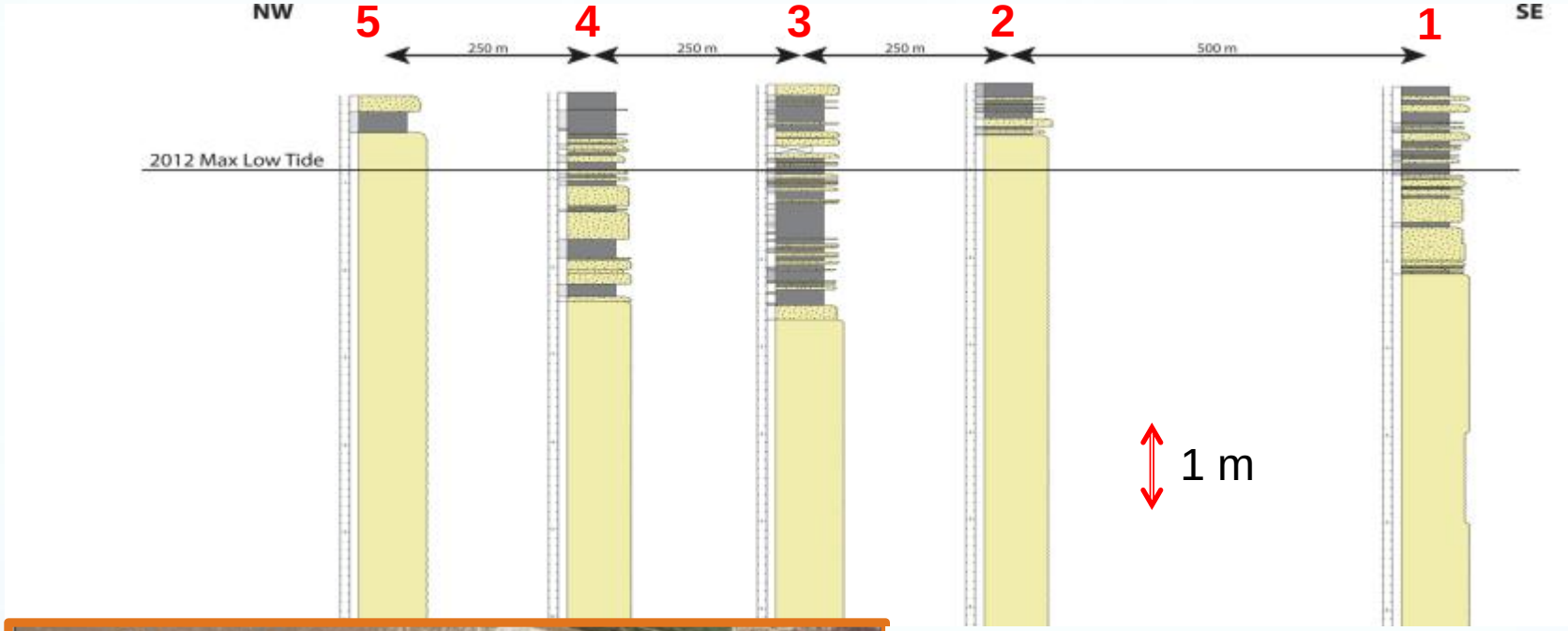
- 100% of river flow (WCHL, 1977)
- **Tidal (1-2 m range)**
- **Sustained fresh water**

Canoe Pass (Brackish Water)



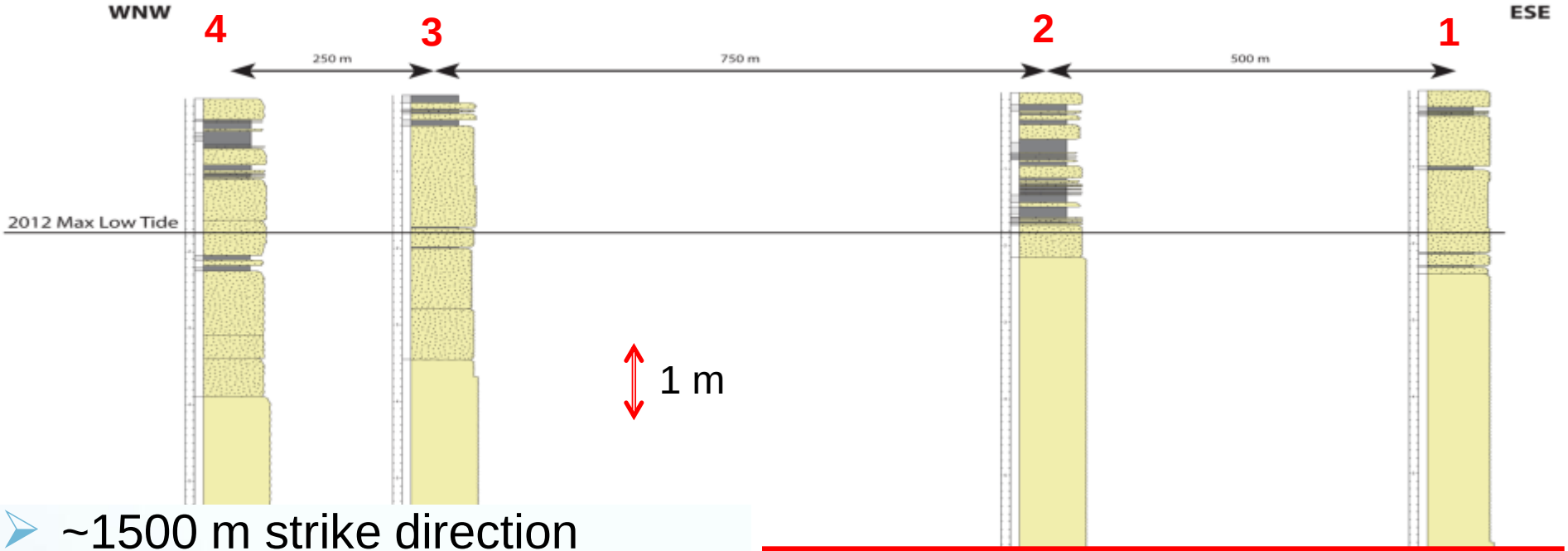
- ~2000 m strike direction
- 6 cores, 3 upstream + 3 downstream
- ~13.5 m of core
- **ALL CORES from upper subtidal and lower intertidal zone**

Fraser Heights (FW-SW Transition)



- ~1500 m strike direction
- 5 cores, 2 upstream + 3 downstream
- ~8.3 m of core
- **ALL CORES from upper subtidal and lower intertidal zone**

Fort Langley (Fresh Water)



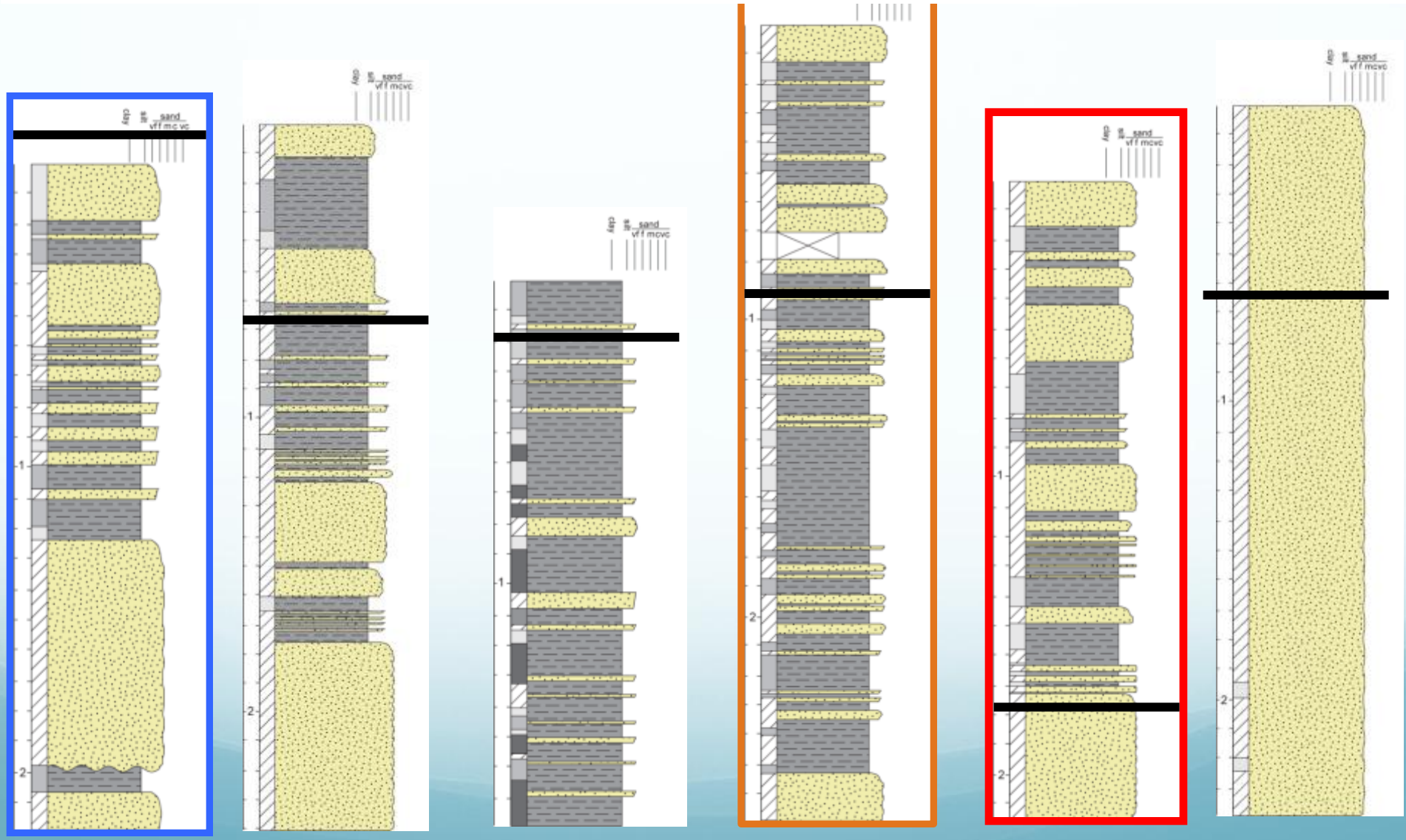
- ~1500 m strike direction
- 4 cores, 2 upstream + 2 downstream
- ~12 m of core
- **ALL CORES from upper subtidal and lower intertidal zone**

Variation Across the Transition

Mixed tidal-fluvial,
Brackish water

Tidally-influenced,
FW-SW transition

Tidally-influenced,
Fresh water

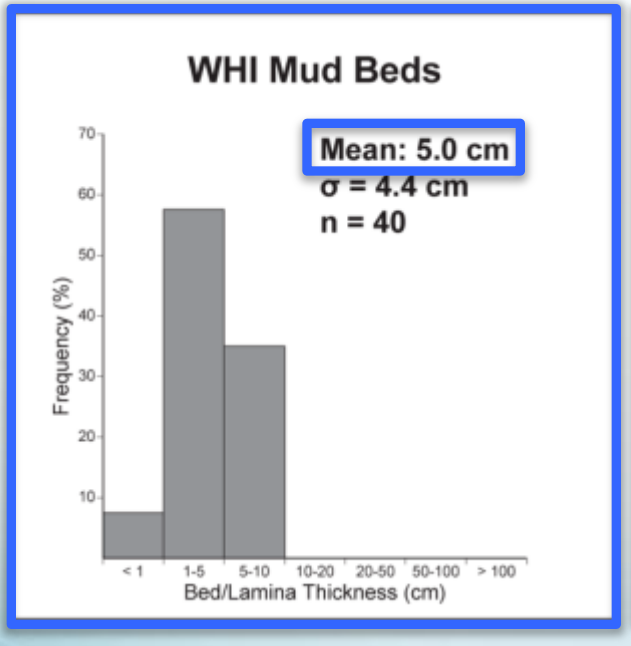


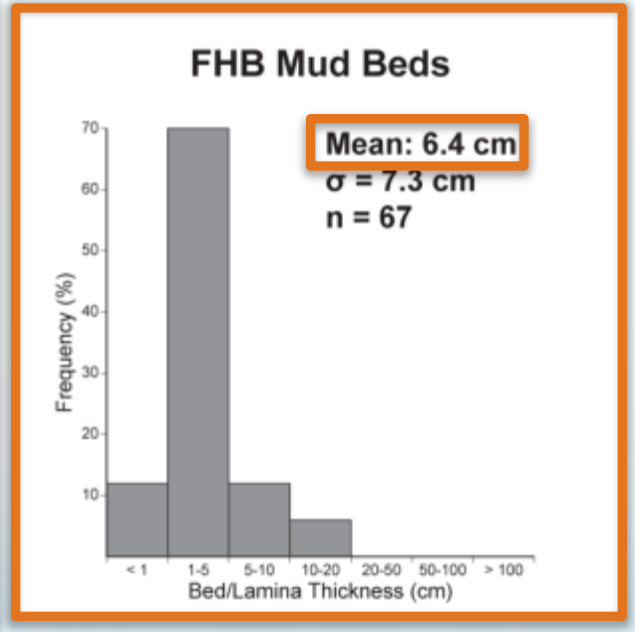
Mud Bed Thickness Distribution

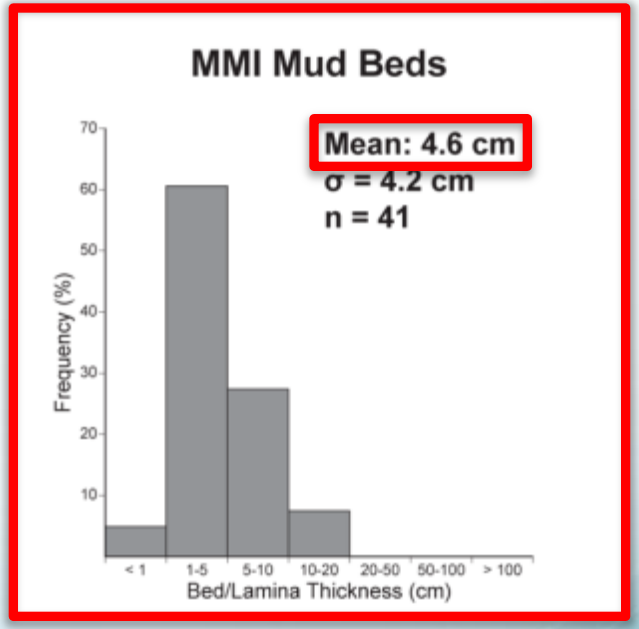
Mixed tidal-fluvial,
Brackish water

Tidally-influenced,
FW-SW transition

Tidally-influenced,
Fresh water







Most muddy beds/bedsets
1- 10 cm thick

Most muddy beds/bedsets
1- 5 cm thick

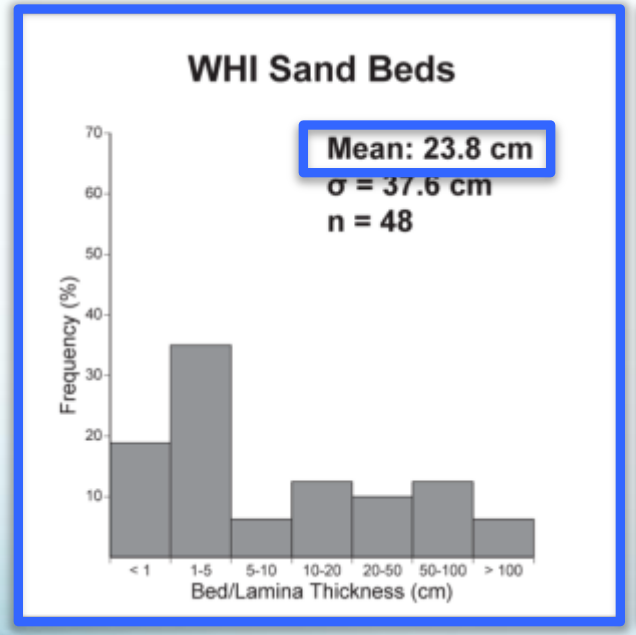
Most muddy beds/bedsets
1 – 10 cm thick

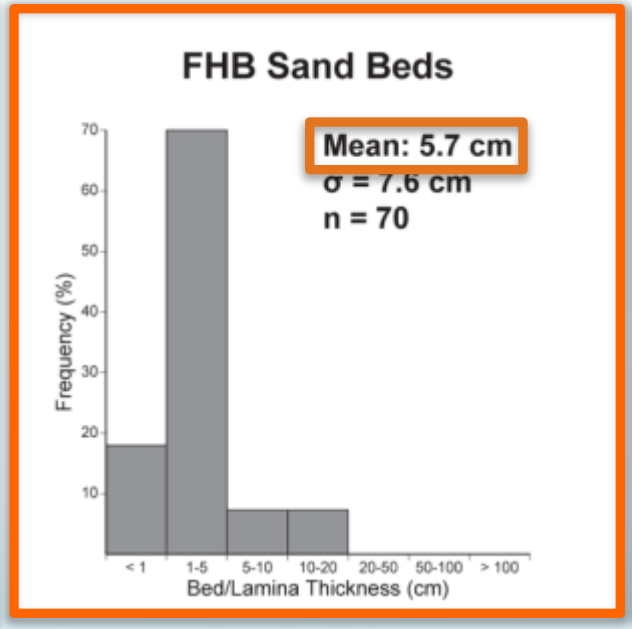
Sand Bed Thickness Distribution

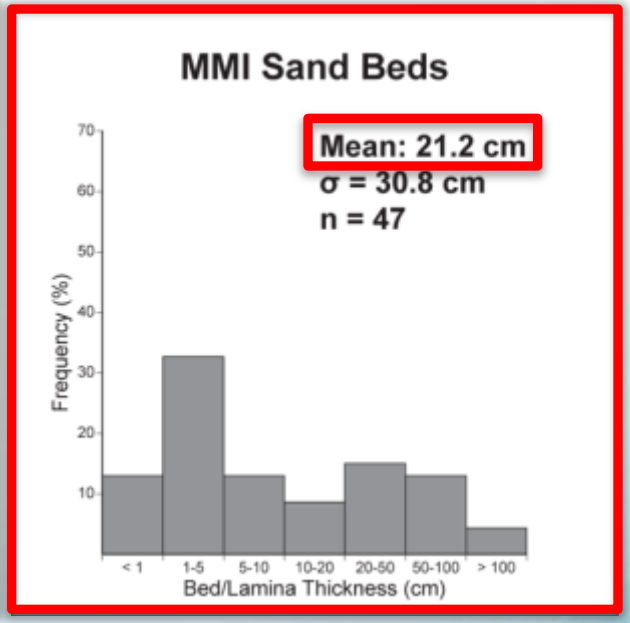
Mixed tidal-fluvial, Brackish water

Tidally-influenced, FW-SW transition

Tidally-influenced, Fresh water





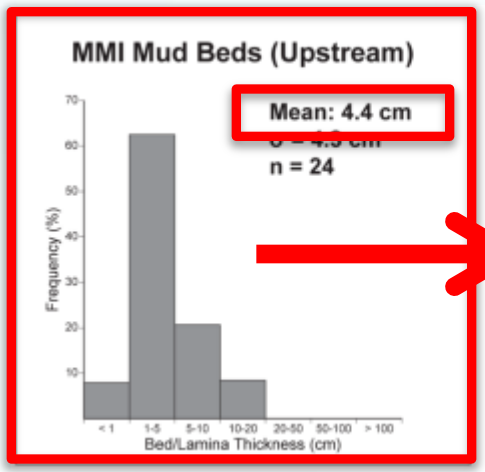


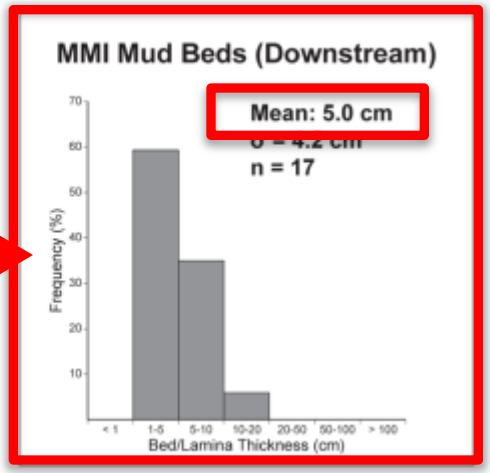
Evenly distributed between **1 cm and 1 m thick**

Most between **1- 5 cm thick**

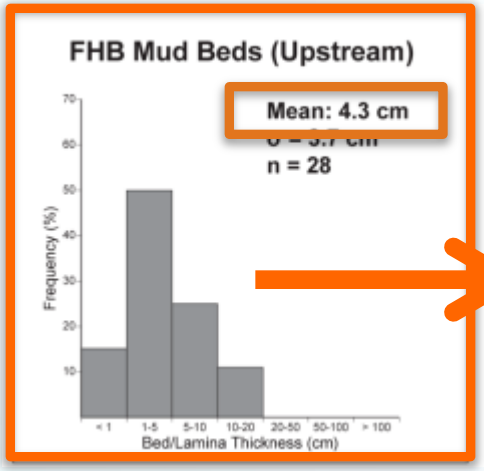
Evenly distributed between **1 cm and 1 m thick**

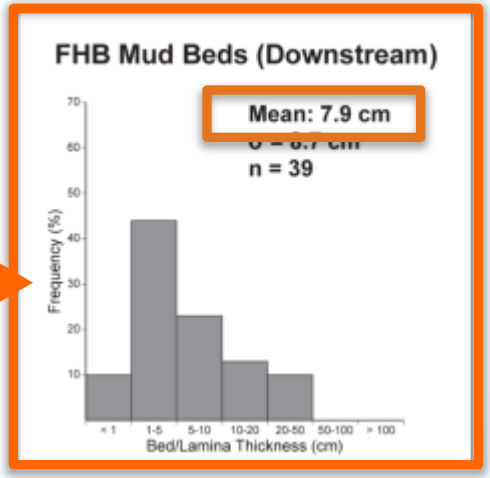
Intra-Bar Mud Trends



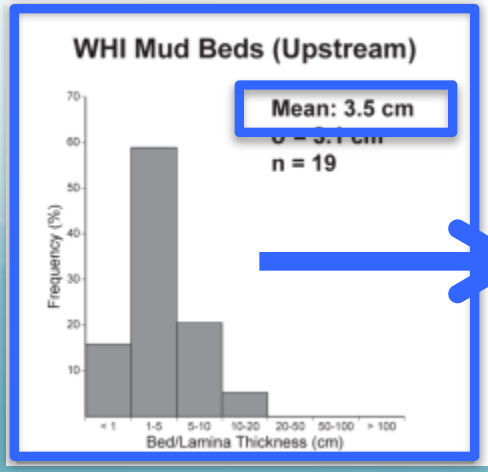


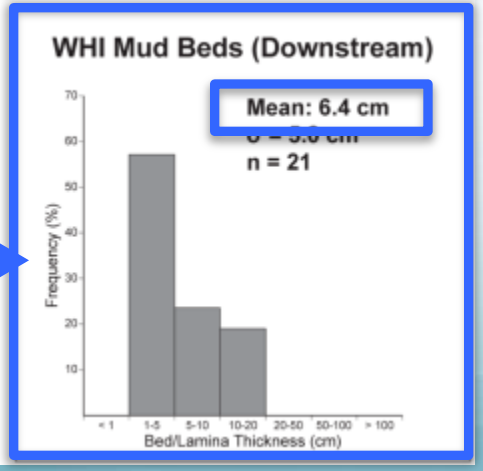
Average thickness upstream ≈ downstream





Average thickness upstream < downstream





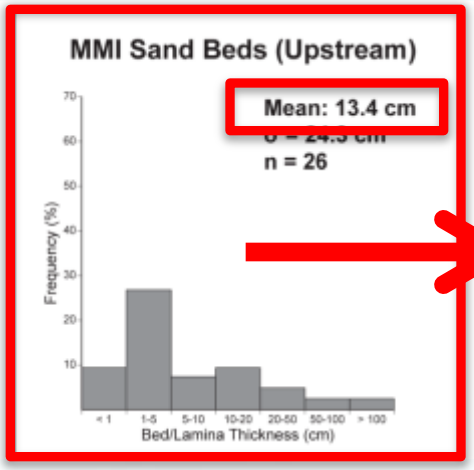
Average thickness upstream < downstream

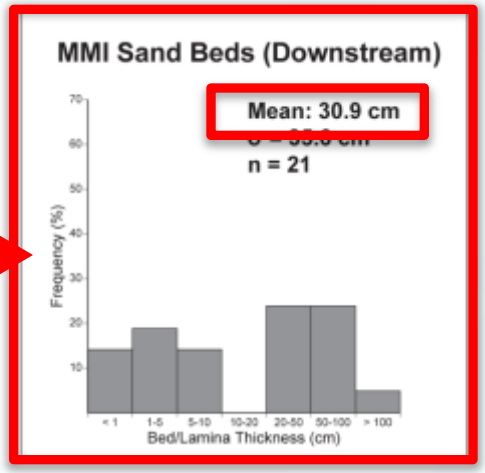
Intra-Bar Sand Trends

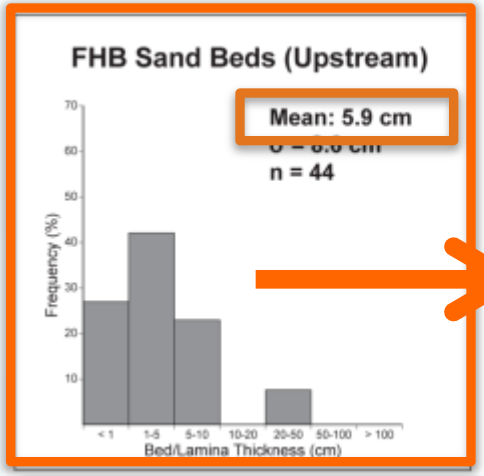
Average thickness upstream < downstream

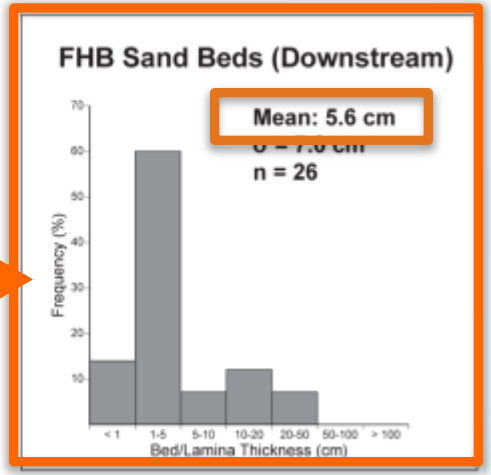
Average thickness upstream ≈ downstream

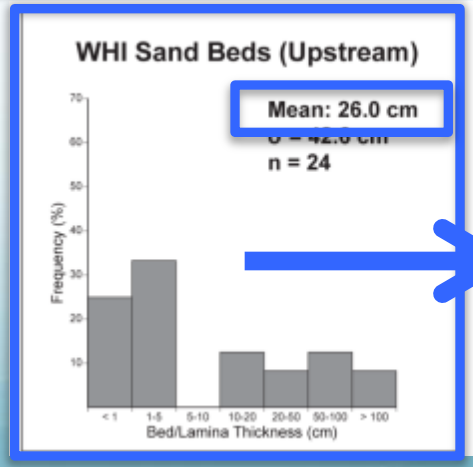
Average thickness upstream > downstream

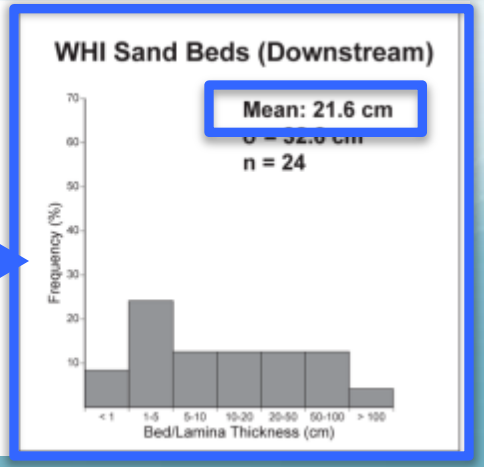




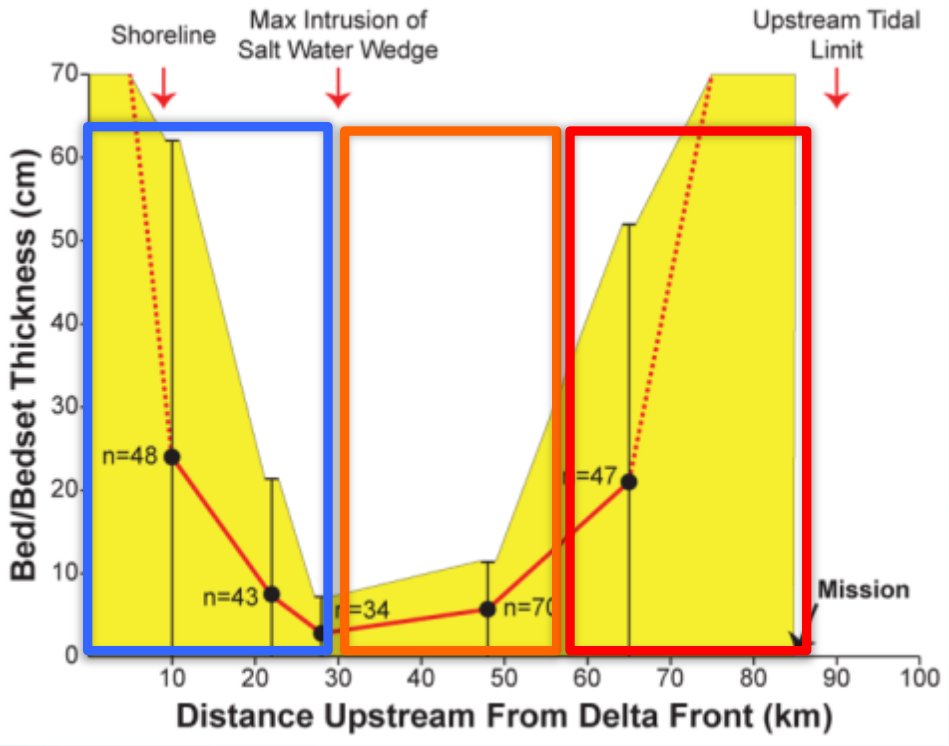


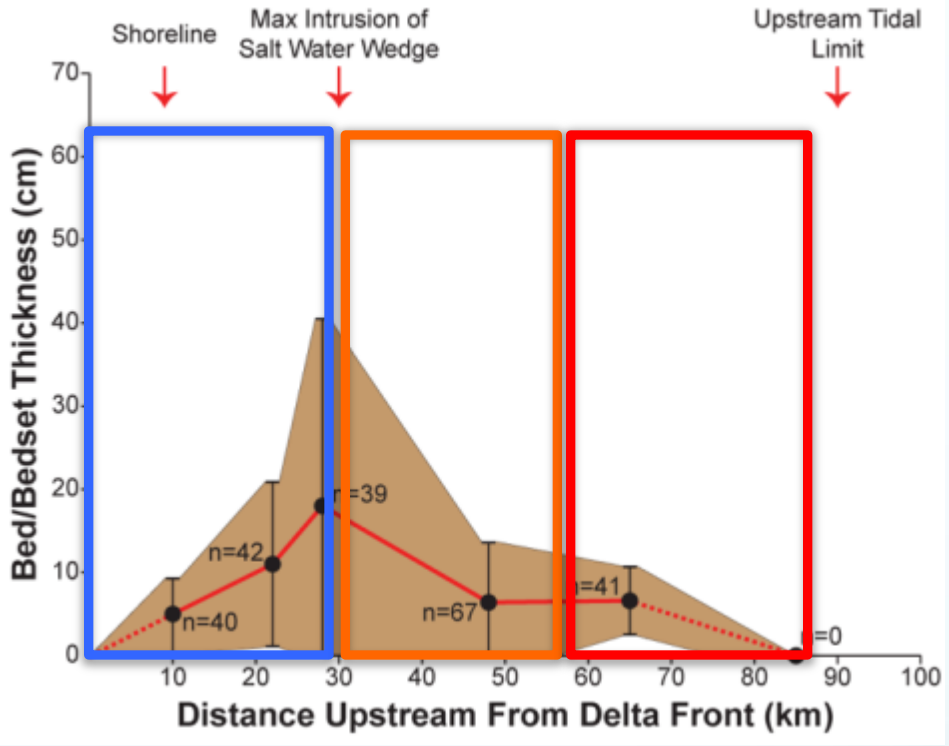






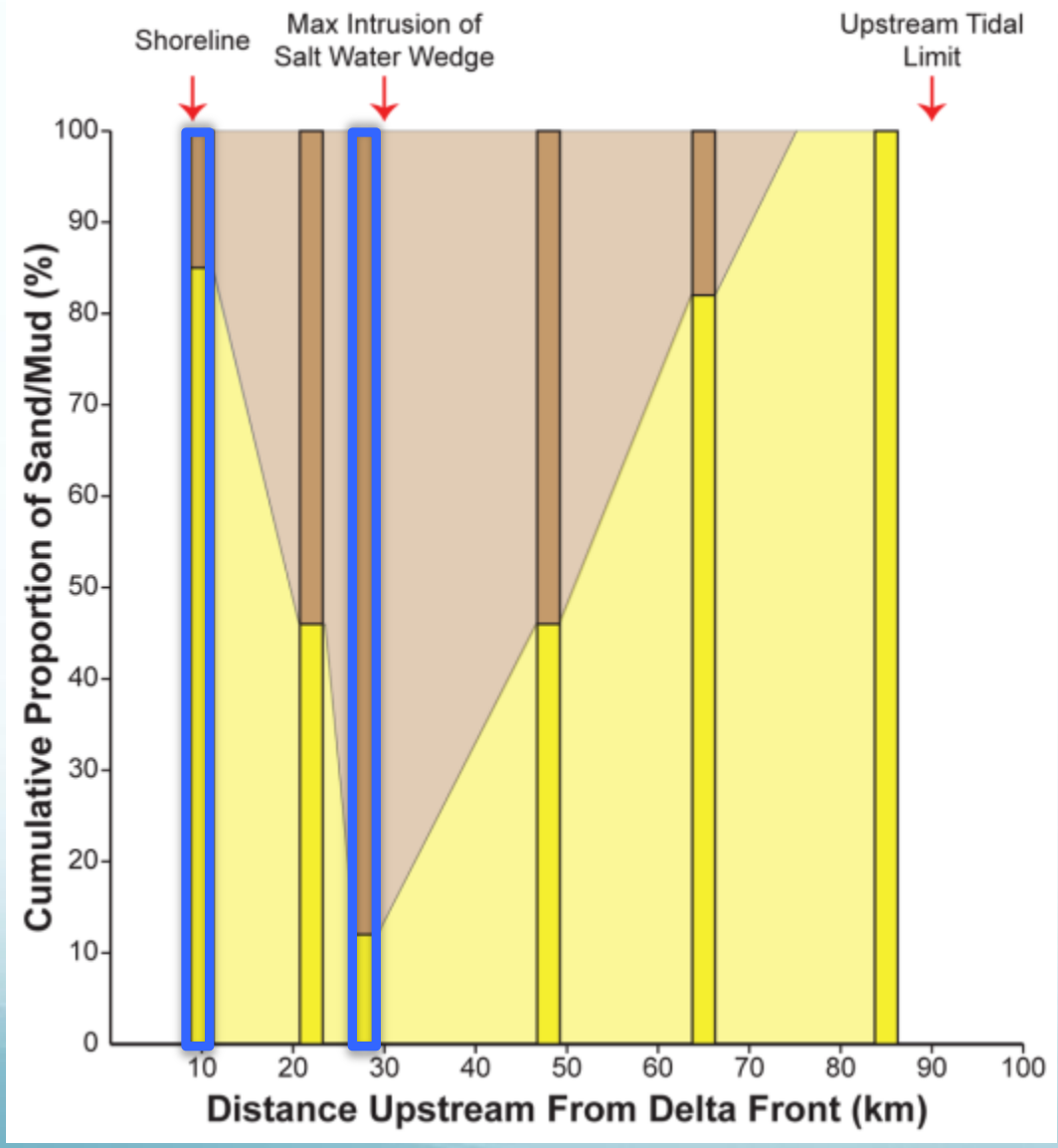
Average Thickness vs. Distance Upstream





- **Fresh Water, tidally-influenced**: sand beds to 50 cm, mud beds to 15 cm
- **SW-FW Transition, tidally-influenced**: sand beds to 8 cm, mud beds to 40 cm
- **Brackish Water, mixed tidal-fluvial**: sand beds to 65 cm, mud beds to 10 cm

Sand-Mud Proportion vs. Distance Upstream

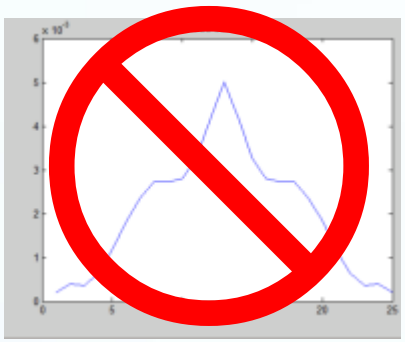


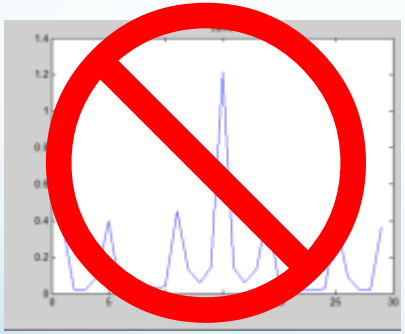
- Fresh-water: sand-dominated
- Transition: mud-dominated
- Brackish: mixed sandy-muddy
- **Small distributaries are muddy**
- **Backwater effect extends landward of turbidity max**

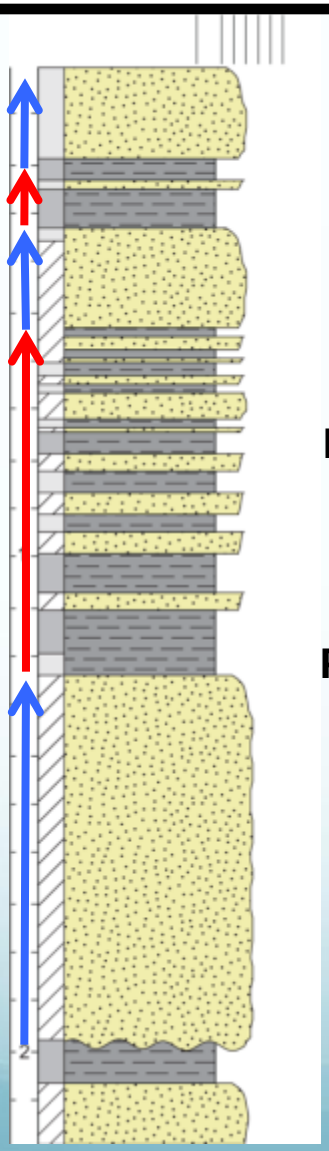
Seasonal Cyclicity in Fraser River IHS

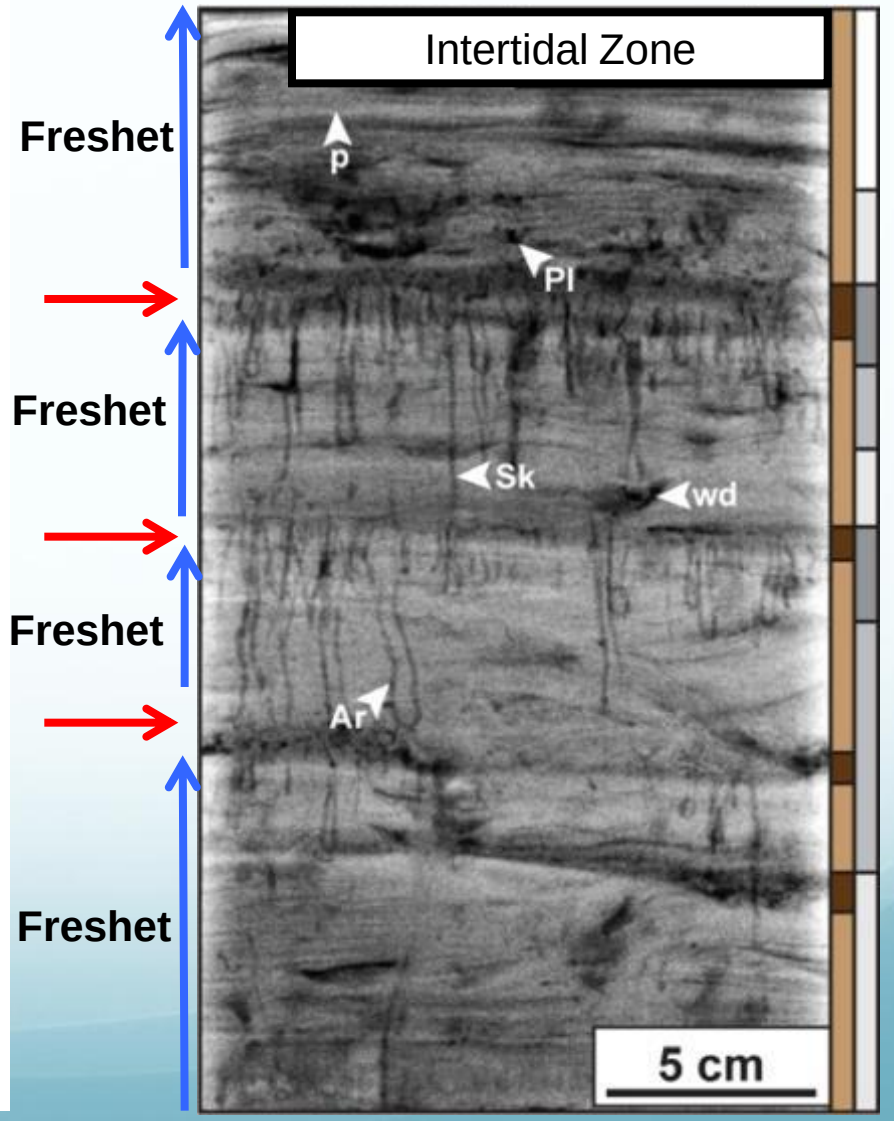
Autocorrelation, Fourier…

Qualitative cyclicity in structure and bioturbation, probably seasonal



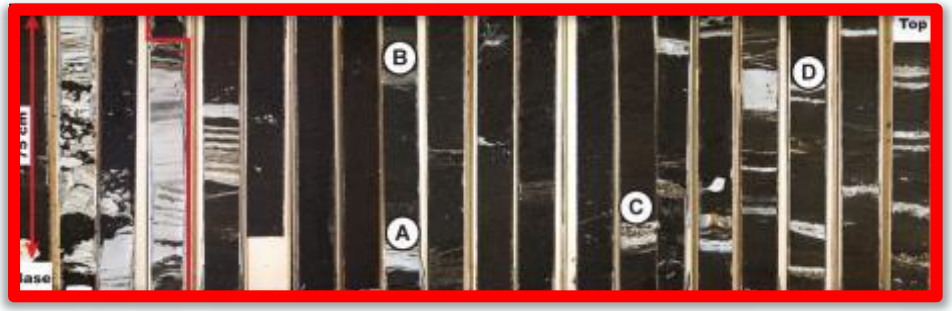


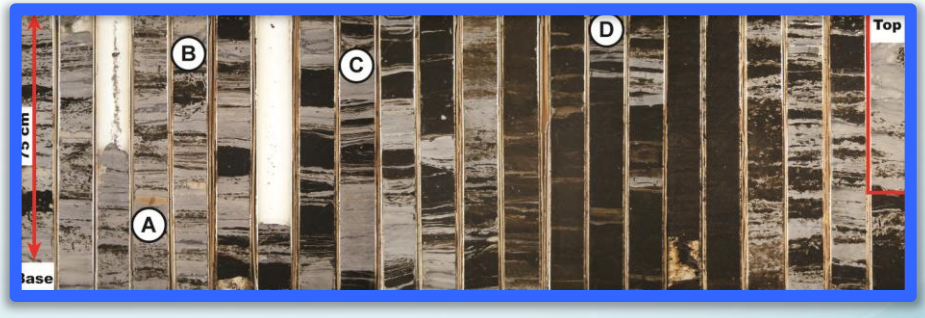


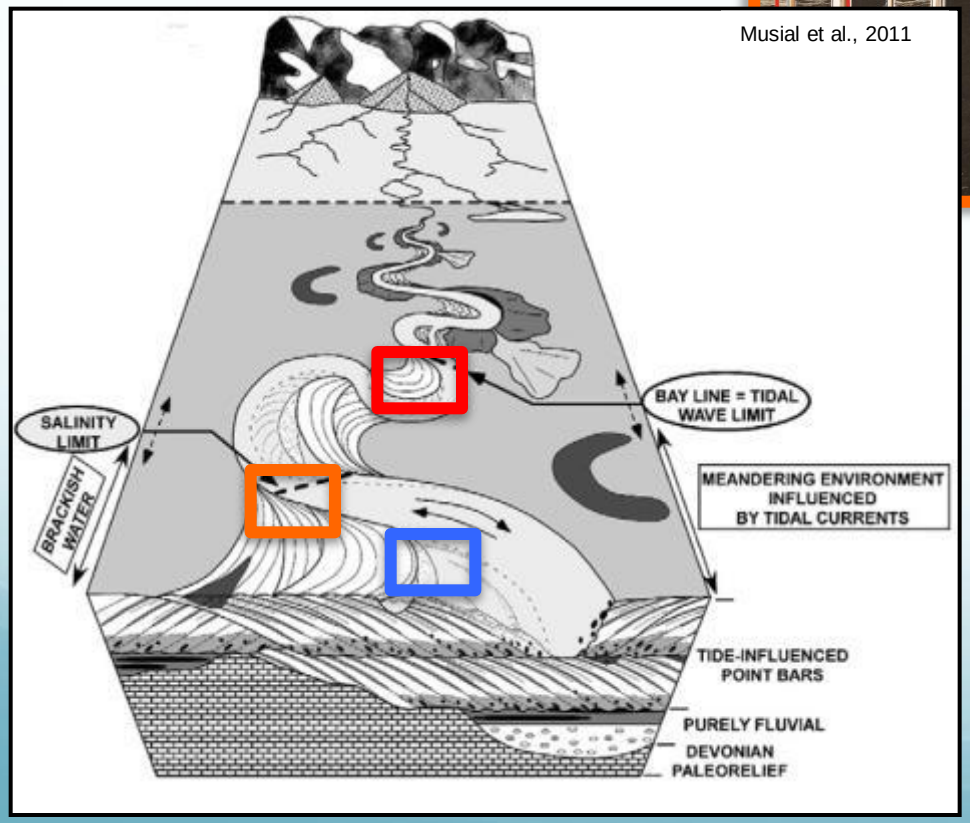


Where is the Turbidity Maximum?

- **Bed thickness distribution!**
- BI and diversity
- Channel size and morphology







Summary

Fresh water + tidal zone: sand beds thick and variable; mud beds are consistently thin

FW-SW transition + tidal: sand beds are thin; mud beds are generally thick

Brackish water + tidal-fluvial: sand beds thick and variable; mud beds are generally thin

Conclusion

1) Upstream to downstream “fining” most pronounced near turbidity maximum

2) Backwater effect beyond salt-water intrusion

3) Thickness distribution + sedimentary structures + **bioturbation** give indication of turbidity max and seasonality

4) **Predicting turbidity maximum zone has important implications for reservoir compartmentalization**

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