# Portland Harbor Remedial Investigation

Presentation to the
CSTAG/NRRB
November 18, 2015

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# Portland Harbor

## Site Background

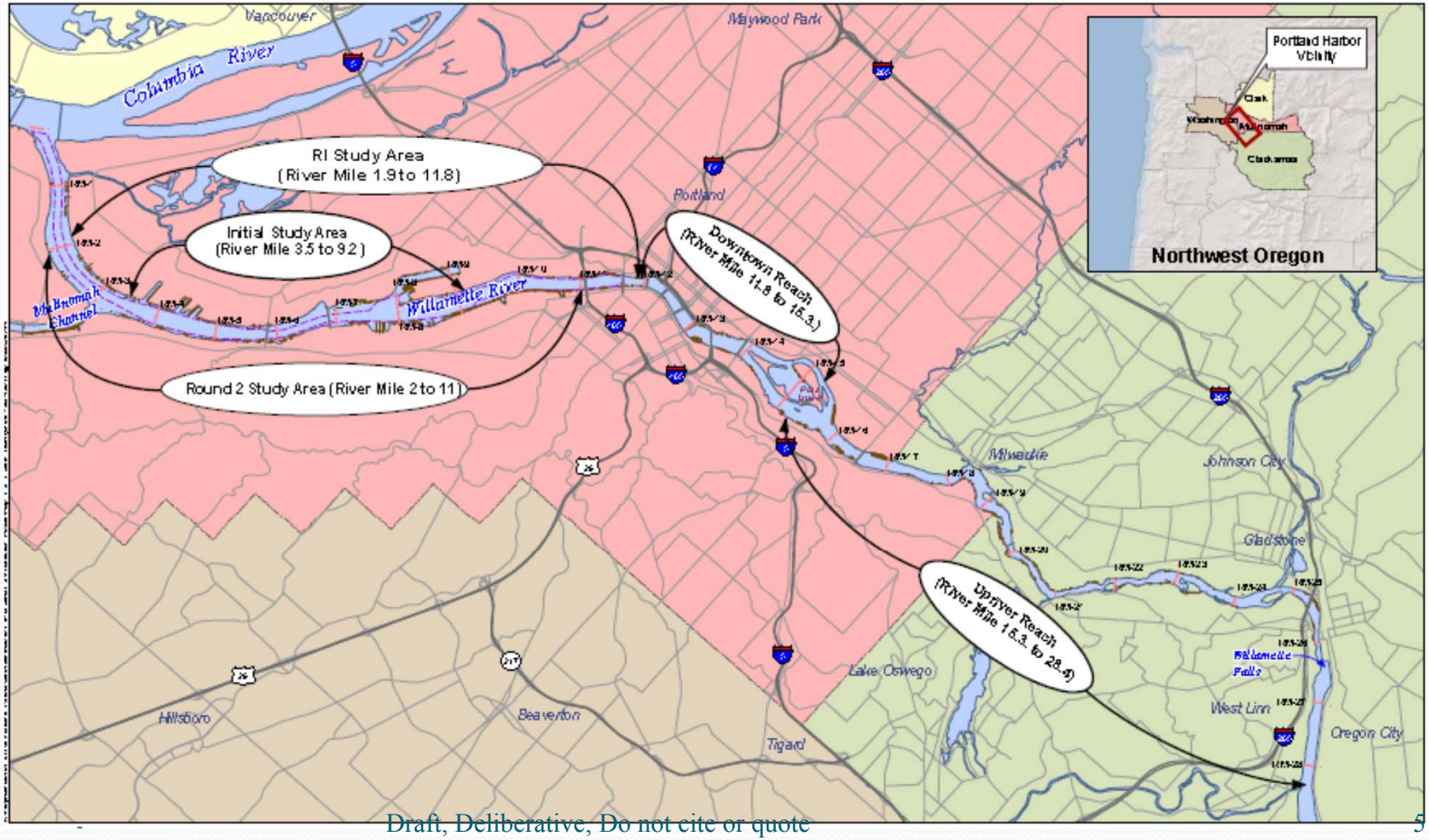
# Site Background

- Listed December 2000
- AOC
  - October 2001
  - LWG performing party (10 entities)
- MOU
  - February 2001
  - 6 Tribes
  - 2 Federal agencies
  - 2 State agencies

# Site Setting

- Willamette River
  - Cascade Mountain Range to Columbia River
  - 187 Miles long
  - Drainage Area 11,478 $mi^2$
  - Discharge 8,200 (Aug) – 79,000 (Dec) $ft^3/s$
  - 19th largest river
  - 1 of 14 American Heritage Rivers
  - Lower Reach RM 0 to RM 26.4

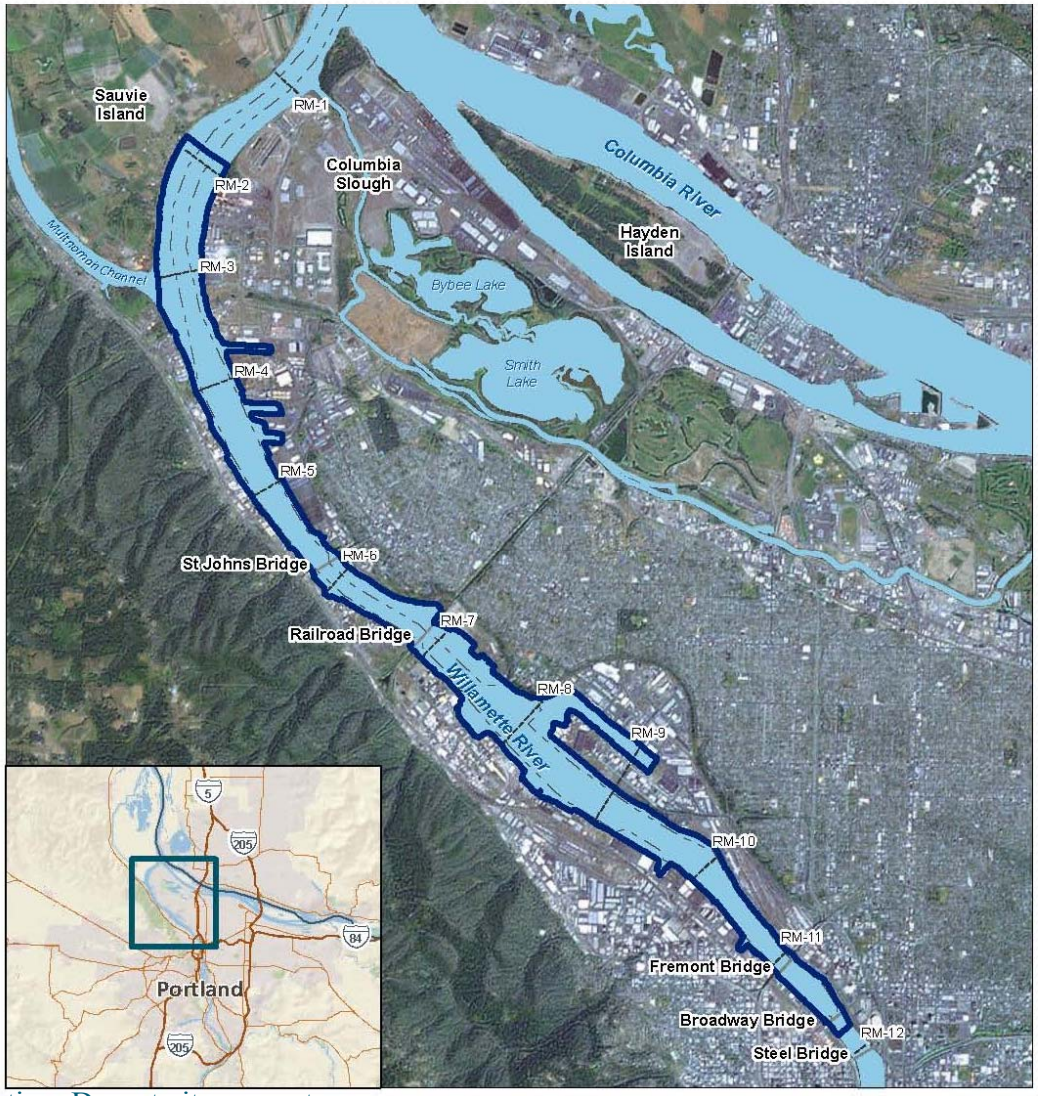
# Lower Willamette River



# Study Area

- Approx. 10 Mile site
- 40-foot deep navigation channel
- Width varies 600-1,900 ft.
- Armoring ~1/2 shoreline
- Dams moderate flow
- City of Bridges – 5 bridges in study Area

# Study Area


Sauvie Island
RM-1
Columbia Slough
RM-2
Columbia River
Hayden Island
Multnomah Channel
RM-3
Bybee Lake
Smith Lake
RM-4
RM-5
St Johns Bridge
RM-6
Railroad Bridge
RM-7
Willamette River
RM-8
RM-9
RM-10
RM-11
Fremont Bridge
Broadway Bridge
RM-12
Steel Bridge
5
205
84
Portland
205

# Prior Investigations

- Since 1920s
- Most 1970s to 1980s
- Nearly 700 data sets
  - Large Scale – Federal & State
  - Small Scale – Private
  - Only data collected under the AOC was used for risk assessments

# Portland Harbor

## Study Area Investigation

# Study Area Investigation

- Multi-year study
  - Four rounds
  - 2001 through 2008
  - Timed around
    - varying river stages, river flows, and storm events
  - Four consultants

# Preliminary (2001-2002)

- Multibeam Bathymetric Survey
- Juvenile Salmonid Residence Time Survey
- Sediment Trend Analysis Survey
- Sediment Profile Image Survey
- Acoustic Doppler Current Profiler Survey

# Round 1 (2002 – 2004)

- Juvenile Salmonid Mark/Recapture Pilot Study
- Collection of Fish Tissue for Chemical Analysis
- Hard-bottom Benthos Sampling Using Multiplates
- Aquatic Plant and Amphibian/Reptile Reconnaissance Survey
- Adult Lamprey Harvest Reconnaissance Survey
- Nearshore Sediment Stakes

# Round 1 (cont.)

- 4 Multibeam Acoustic Bathymetry Survey
- Seep Reconnaissance Survey
- Juvenile Lamprey and Benthic Infaunal Biomass Reconnaissance Surveys
- Composite Beach Sediment and Co-located Surface Sediment Sampling
- Soft-bottom Benthos Reconnaissance Survey
- Acoustic Doppler Current Profiler Survey

# Round 2 (2004 – 2006)

- Shorebird Area and Beach Sediment Sampling
- Surface Sediment Sampling
- Subsurface Sediment Sampling
- Surface Water Sampling
- Benthic Sediment Toxicity (Bioassays)
- Physical System Information
- Natural Attenuation (radioisotope cores)
- Groundwater Pilot Study – Mapping Tools and Sampling Methods

# Round 2 (cont.)

- Groundwater Pathway Assessment
- Subyearling Chinook Salmon Tissue
- Multiplate Epibenthic Invertebrate Tissue
- Reconnaissance for Benthic Invertebrates and Clam Tissue
- Mussel and Lamprey Ammocoete Tissue
- Cultural Resources Analysis

# Round 3 (2006 – 2008)

- Surface Water
- Groundwater -Gunderson Site
- Storm Water
- Lamprey Ammocoete Tissue
- Sturgeon Tissue
- Fish and Invertebrate Tissue with Co-located Surface Sediment
- Sediment (Willamette Cove)

# Round 3 (cont.)

- Sediment and Sediment Toxicity Bioassay Testing
- Sediment Trap
- Upstream/Downstream Surface and Subsurface Sediment Samples
- Natural Attenuation (Radioisotope Subsurface Sediment Cores)
- Sediment Chemical Mobility Testing

# Portland Harbor

## Environmental Setting

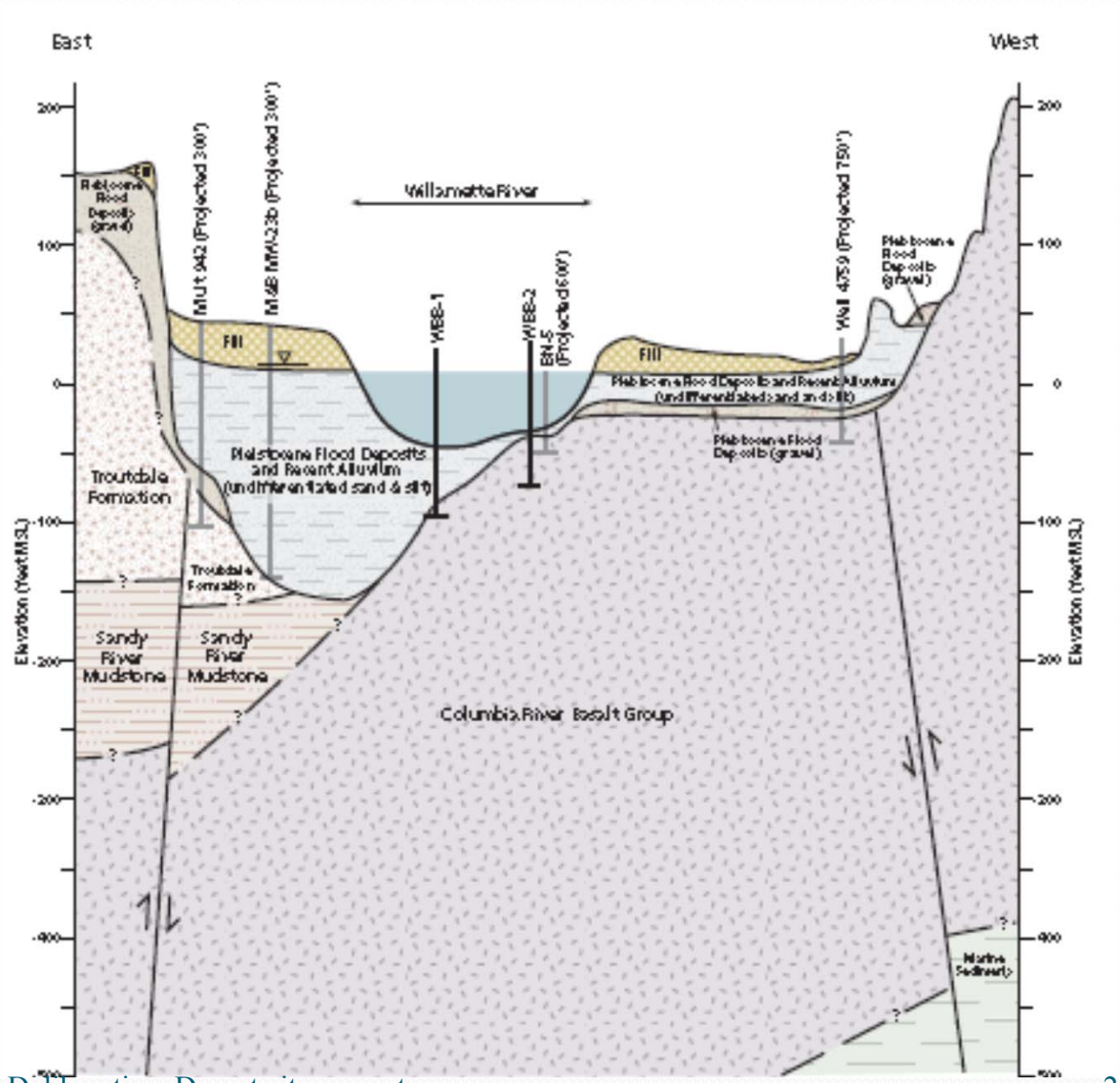
# Physical Environment

- 65 miles inland from the Pacific Ocean
- 20 ft above sea level
- Precipitation primarily rain
  - 90% mid-October to mid-May
  - ~42 inches per year
  - Snow rarely >2 in.

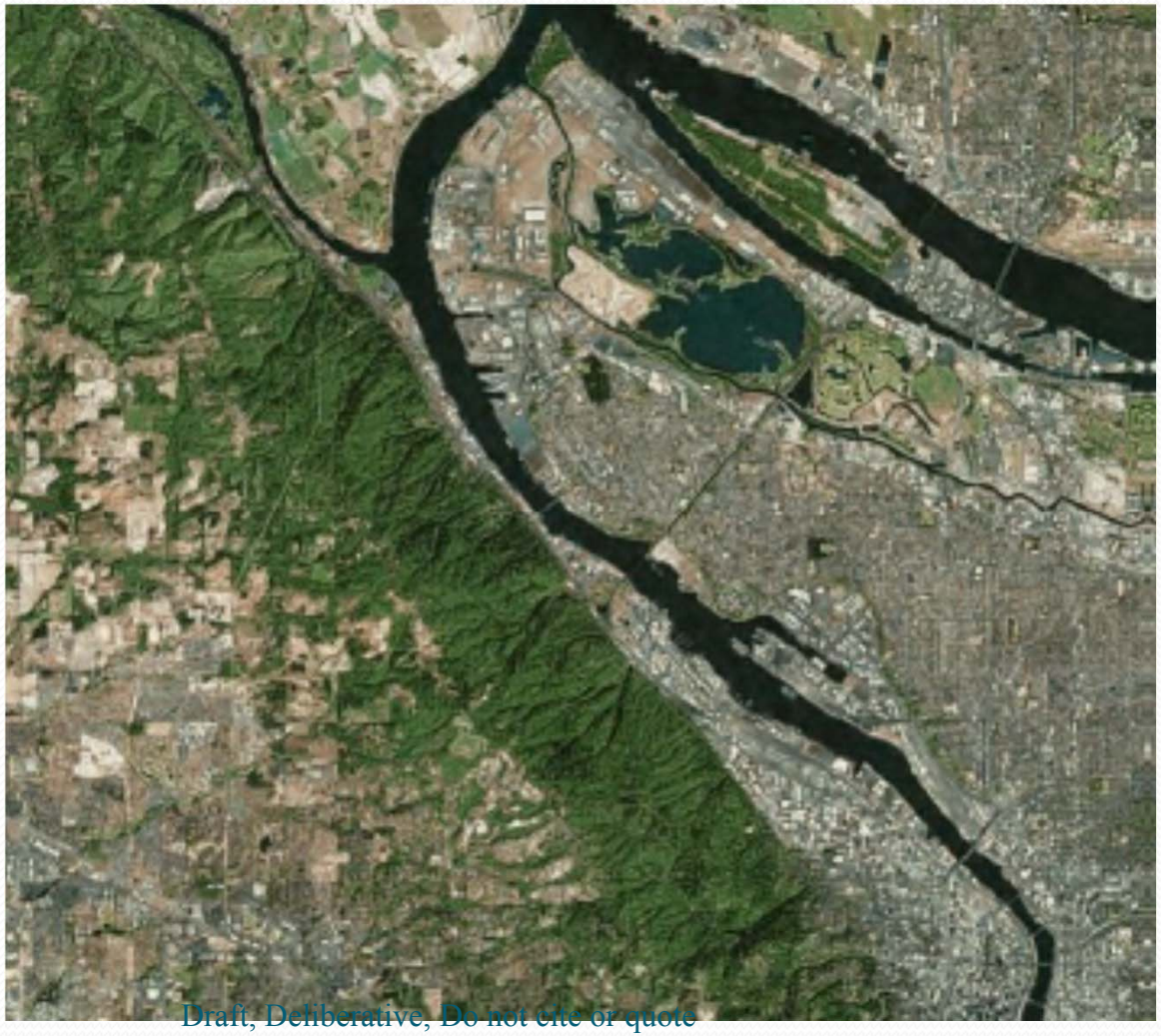
# Geology

- Portland Basin
- Tualatin Mountains (Portland West Hills)
- 3 Tectonic Fault Mechanisms

# Geology


East
West
Willamette River
Fill
Fill
Pleistocene Flood Deposits and Recent Alluvium (undifferentiated sand & silt)
Troutdale Formation
Sandy River Mudstone
Sandy River Mudstone
Columbia River Basalt Group
Elevation (feet MSL)
200
100
0
-100
-200
-400

# Groundwater Flow



# Groundwater Flow

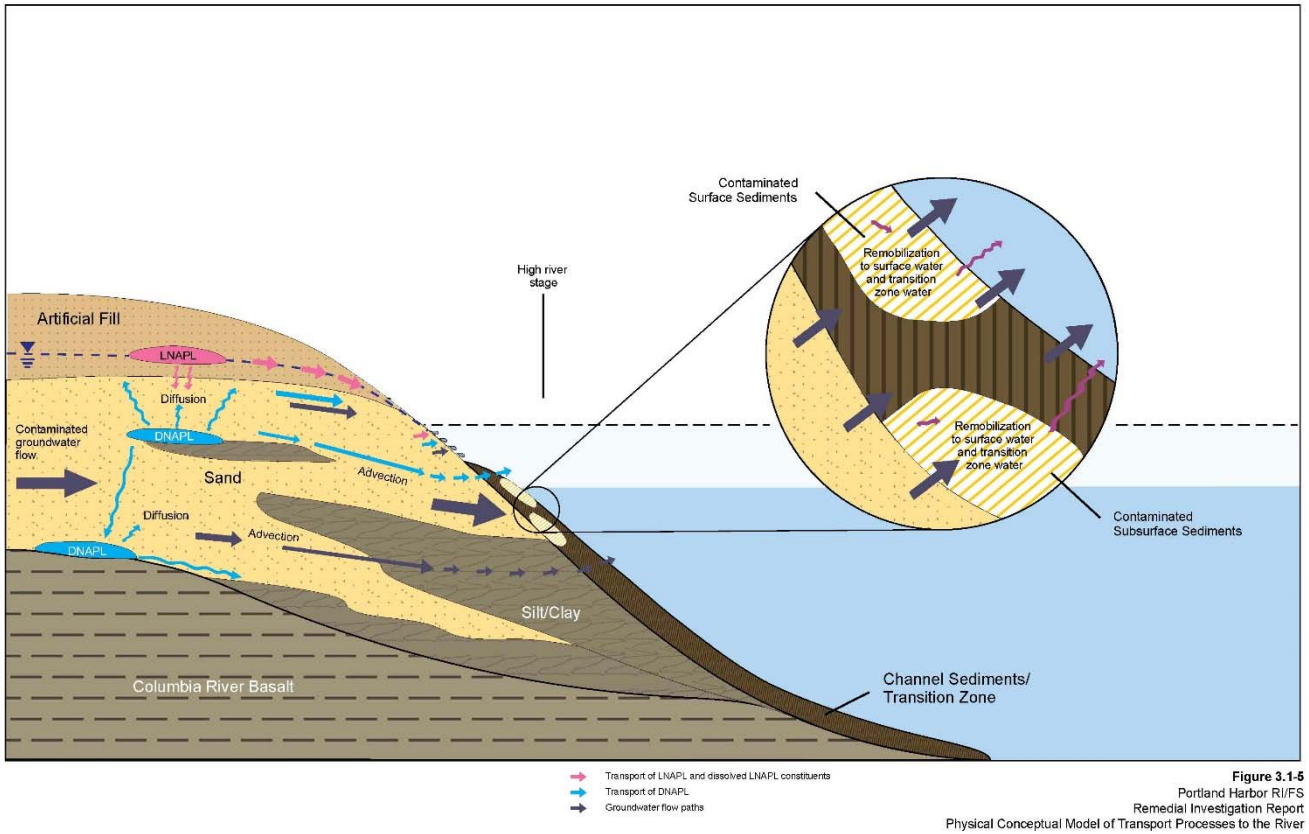
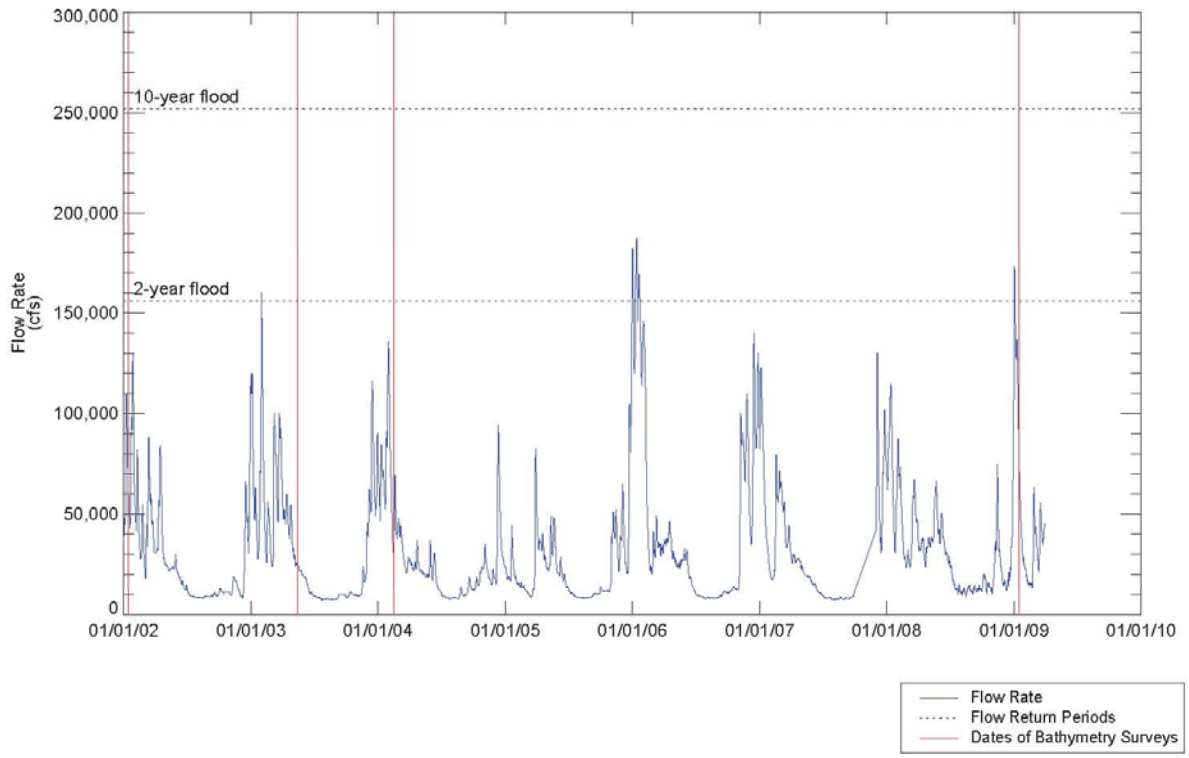



**Figure 3.1-5**
Portland Harbor RI/FS
Remedial Investigation Report
Physical Conceptual Model of Transport Processes to the River

# Regional Hydrology

- Average daily mean discharge
  - Willamette River 33,000 cfs
  - Columbia River 177,000 cfs
- Peak Flows
  - Willamette River 420,000 cfs
  - Columbia River 675,000 cfs
- Columbia River & Multnomah Channel
  - Low flow Columbia & Willamette
  - Low flow Columbia/High flow Willamette
  - High flow Columbia/Low flow Willamette**
- Tidal action
- Dams
- Velocities

# Hydrograph

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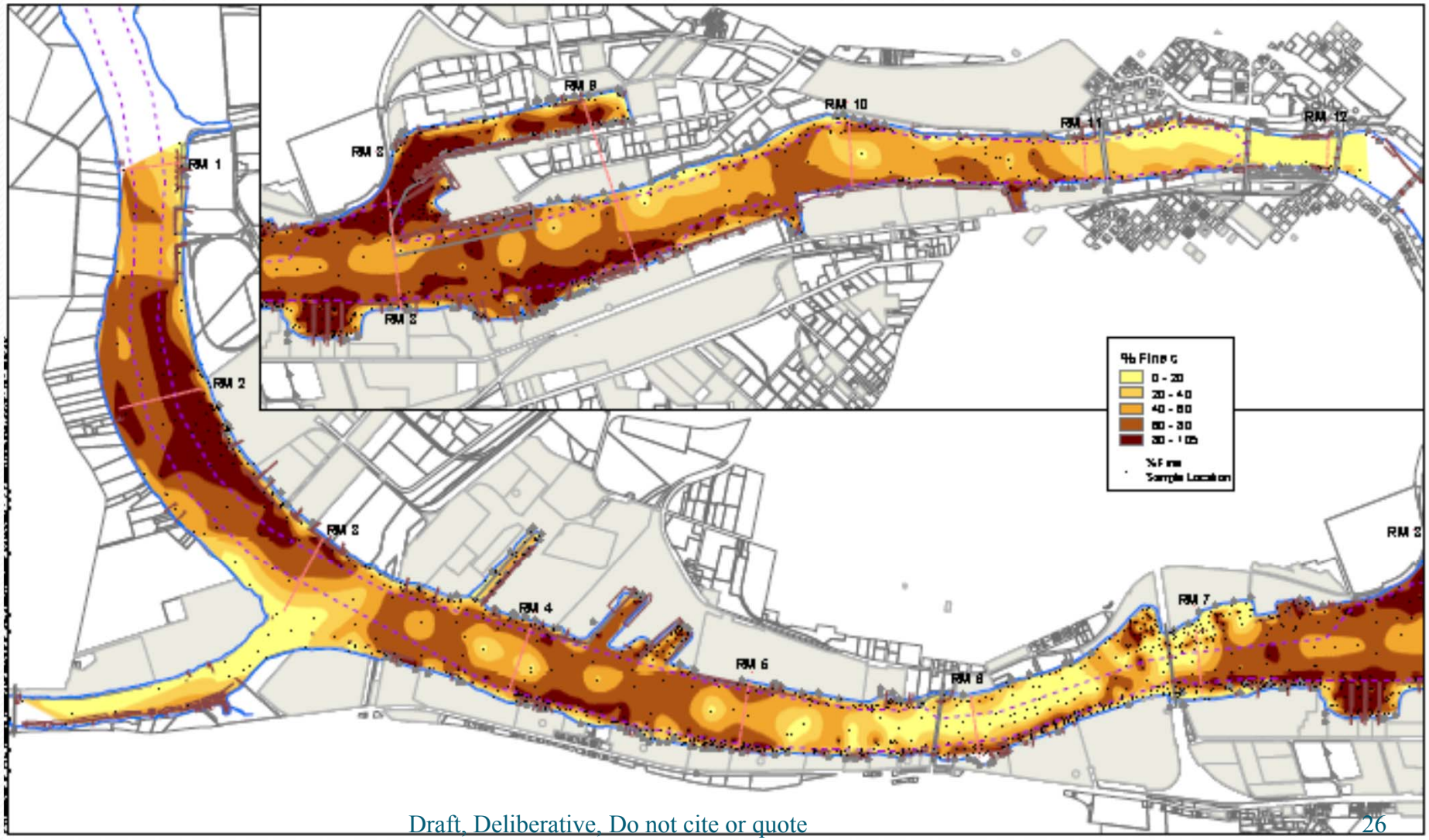
DO NOT QUOTE OR CITE
This document is currently under review by US EPA and its federal, state, and tribal partners, and is subject to change in whole or in part

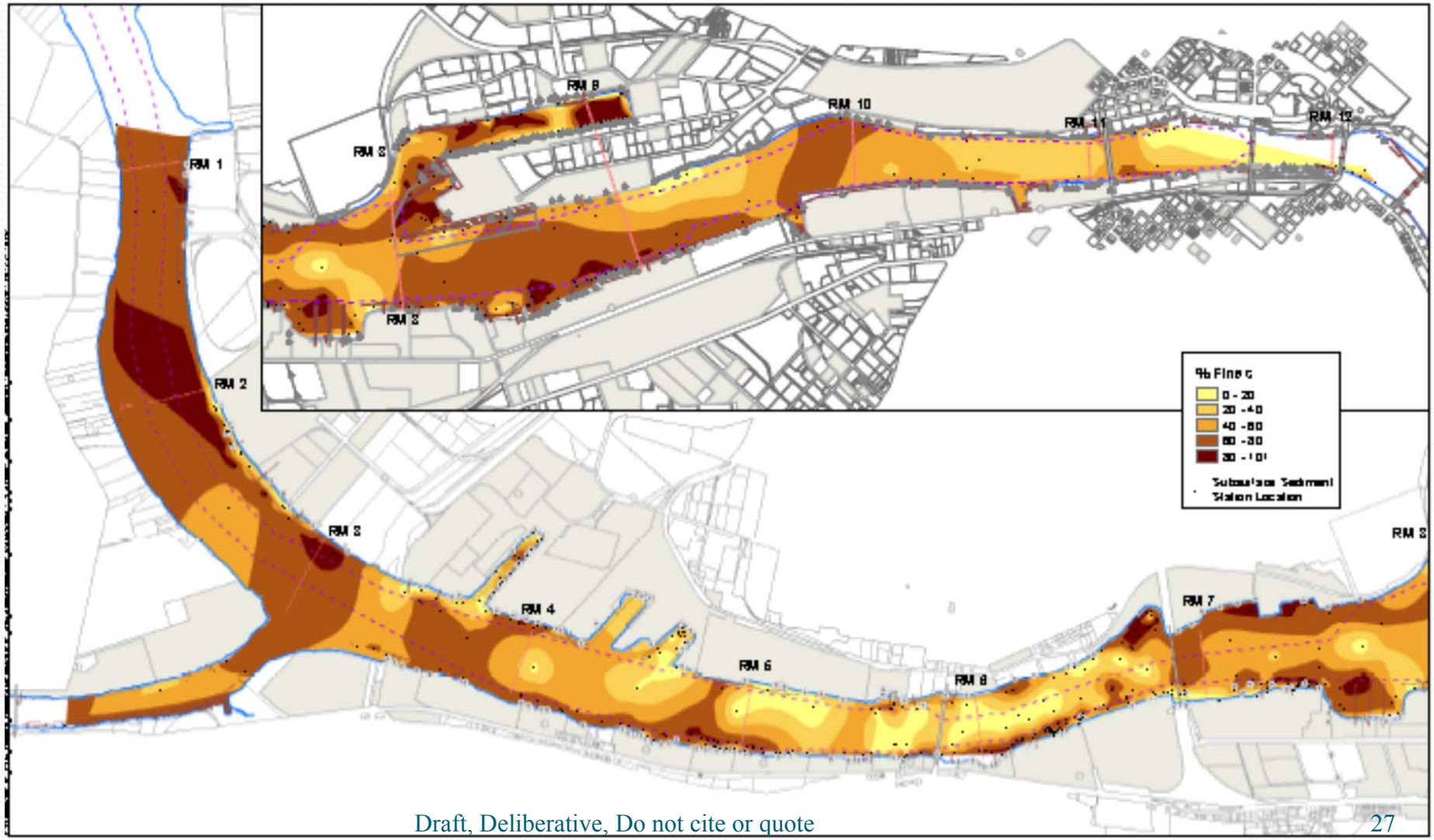
LWG LOWER WILLAMETTE GROUP

Figure 2-66
**Portland Harbor RI/FS**
Draft Feasibility Study
Flow Rate in Lower Willamette River
*Flow rate measured at USGS Gage # 14211720 (Willamette River at Portland, OR).*

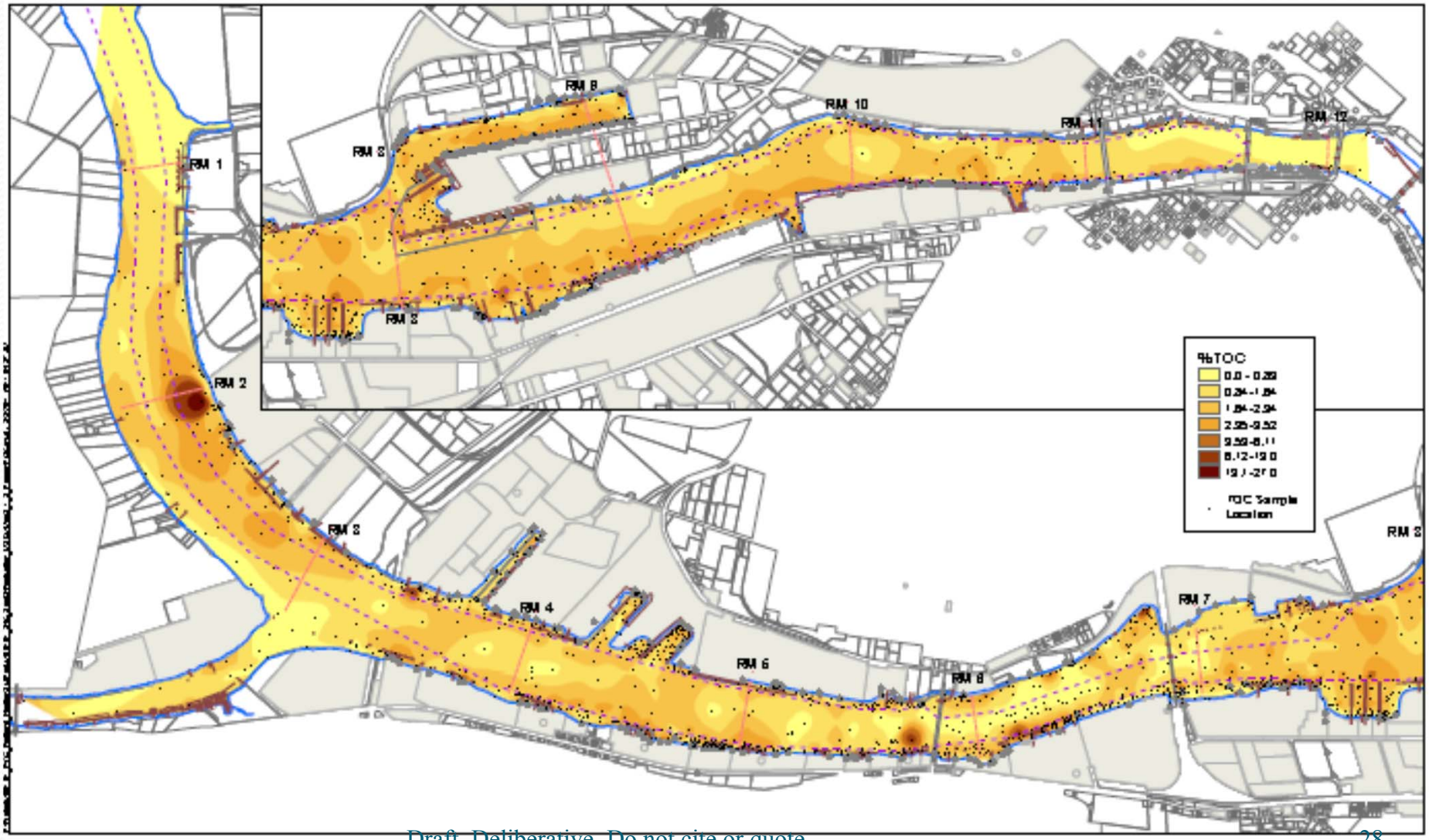
# Percent Fines – Surface Sediment



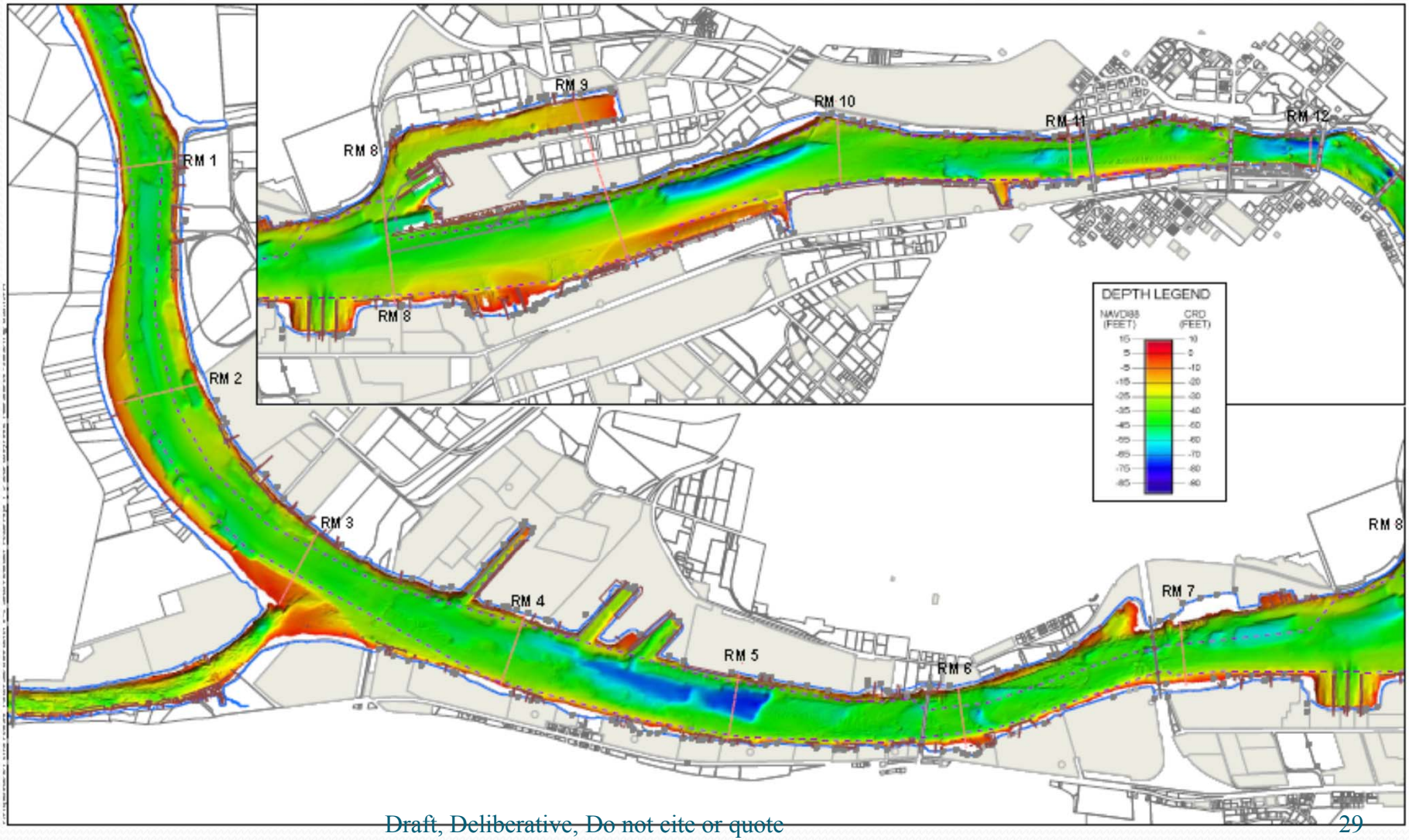
# Percent Fines – Subsurface Sediment



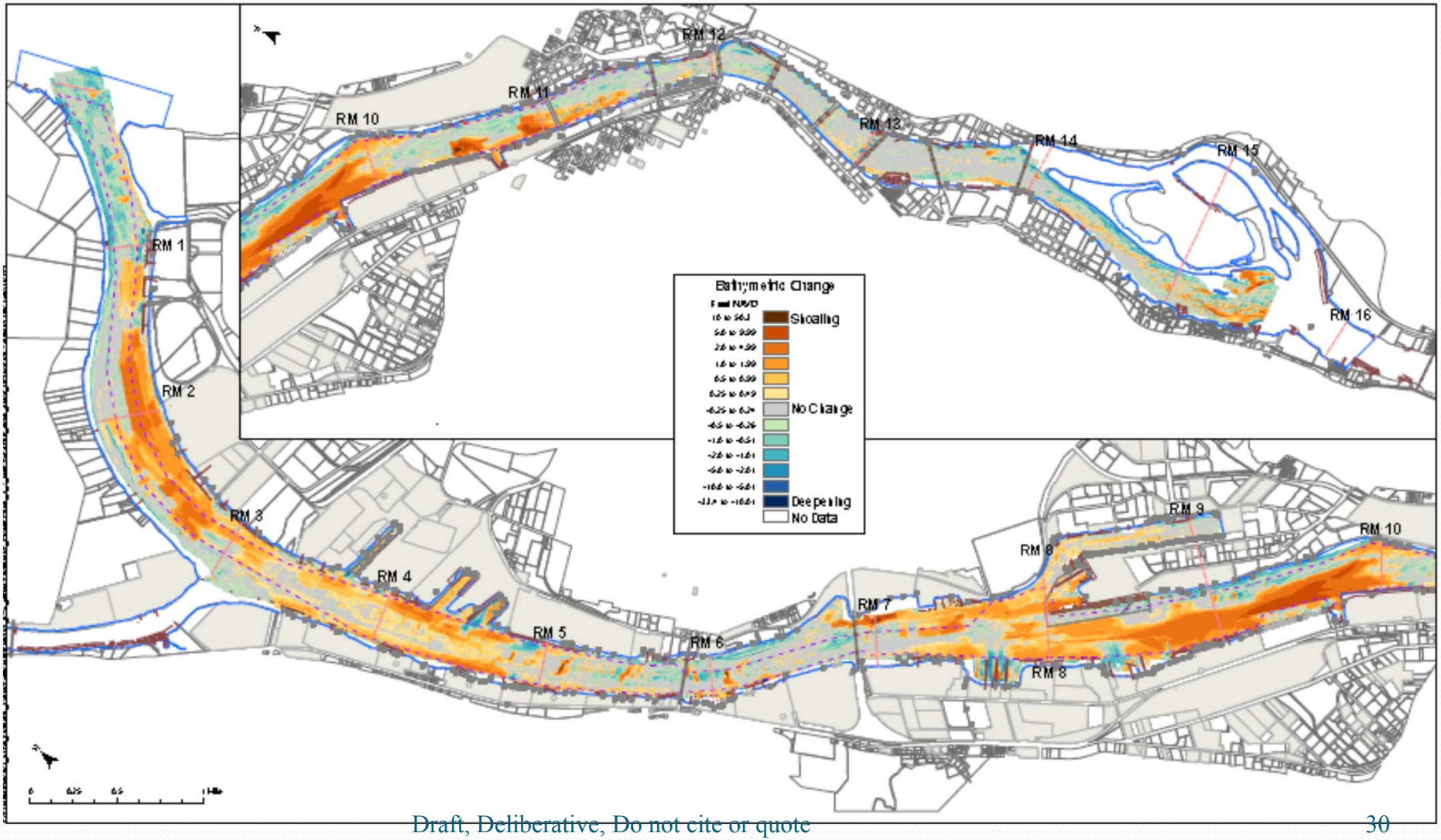
# Percent TOC – Surface Sediment



# Bathymetry


RM 1
RM 2
RM 3
RM 4
RM 5
RM 6
RM 7
RM 8
RM 8
RM 8
RM 9
RM 10
RM 11
RM 12
DEPTH LEGEND
NAVD88 (FEET)
CRD (FEET)

# Bathymetric Change (2002 – 2009)



# Sheer Stress

- Sedflume System
- 17 sediment cores – 25 cm
- Range of sheer: 0.1 - 10 $N/m^2$
- Measured every 5 cm

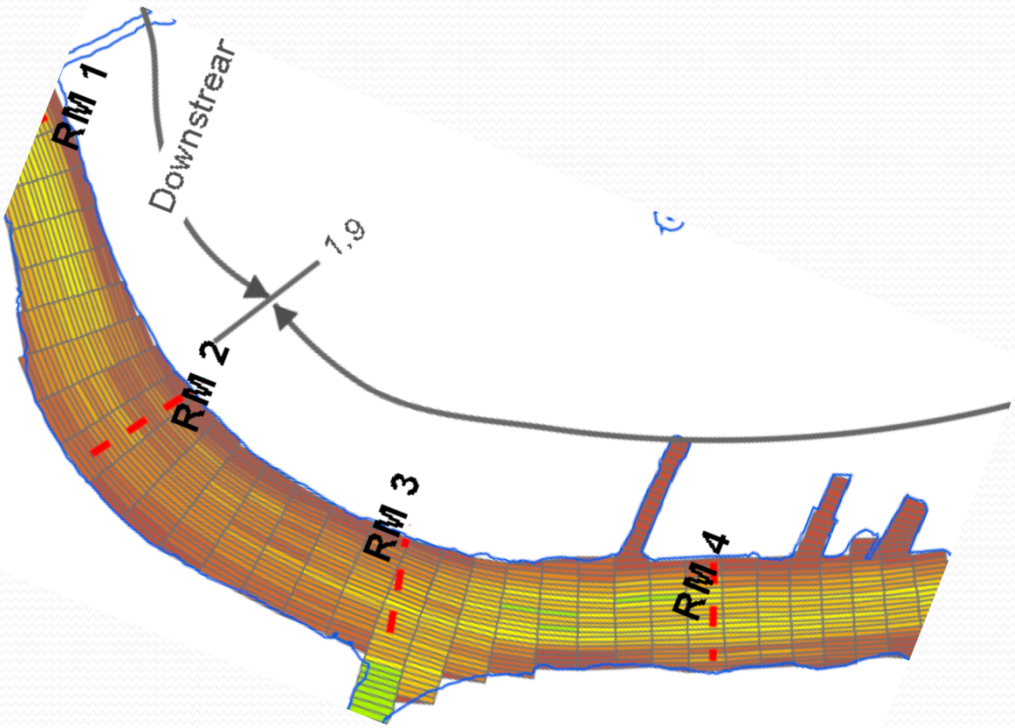
# Sheer Stress and Erosion

| Shear Stress | Measurements | Erosion Rate (cm/s) | |
|---|---|---|---|
| ($N/m^2$) | Count | Min | Max |
| 0.1 | 16 | 0 | 0.0003 |
| 0.2 | 23 | 0 | 0.0003 |
| 0.4 | 55 | 0 | 0.001 |
| 0.8 | 74 | 0 | 0.04 |
| 1.6 | 76 | 0.0002 | 0.1 |
| 3.2 | 76 | 0.0003 | 0.3 |
| 6.4 | 60 | 0.007 | 0.4 |
| 10 | 2 | 0.02 | 0.04 |

# Sheer Stress and Grain Size

| Sample Depth Category | d50 (μm) | | | $T_{cr}$ (N/m²) | |
|---|---|---|---|---|---|
| | Min | Max | | Min | Max |
| 0–5 cm | 9.7 | 401 | | 0.06 | 0.64 |
| 5–10 cm | 12 | 367 | | 0.32 | 1.28 |
| 10–15 cm | 10 | 378 | | 0.22 | 1.28 |
| 15–20 cm | 7.8 | 384 | | 0.26 | 1.28 |
| 20–25 cm | 10.9 | 357 | | 0.24 | 1.28 |

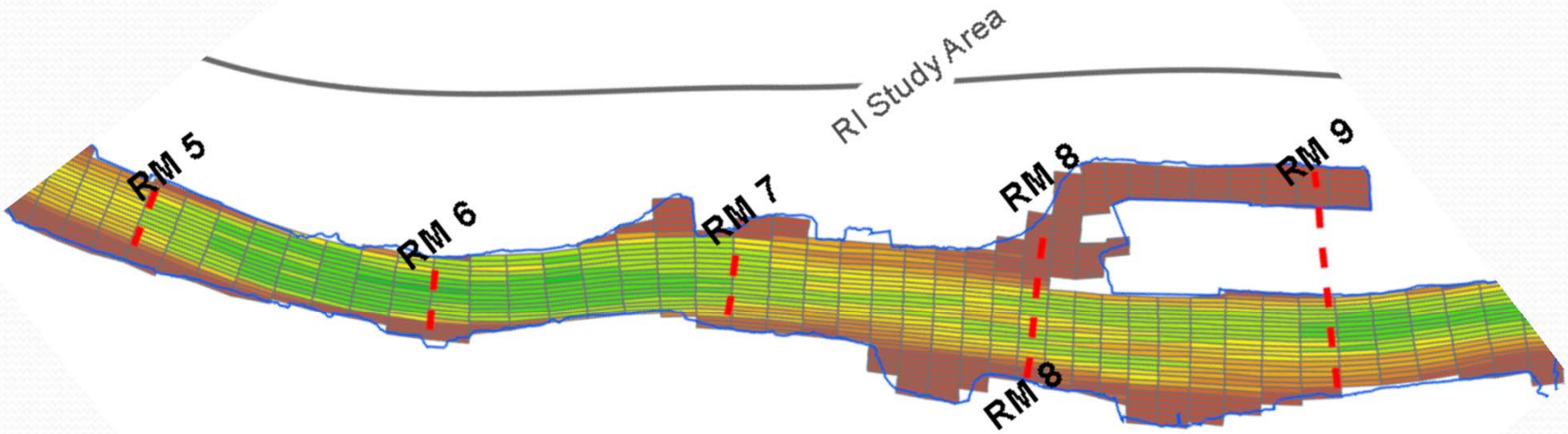
# Hydrodynamic and Sediment Transport (HST) Model



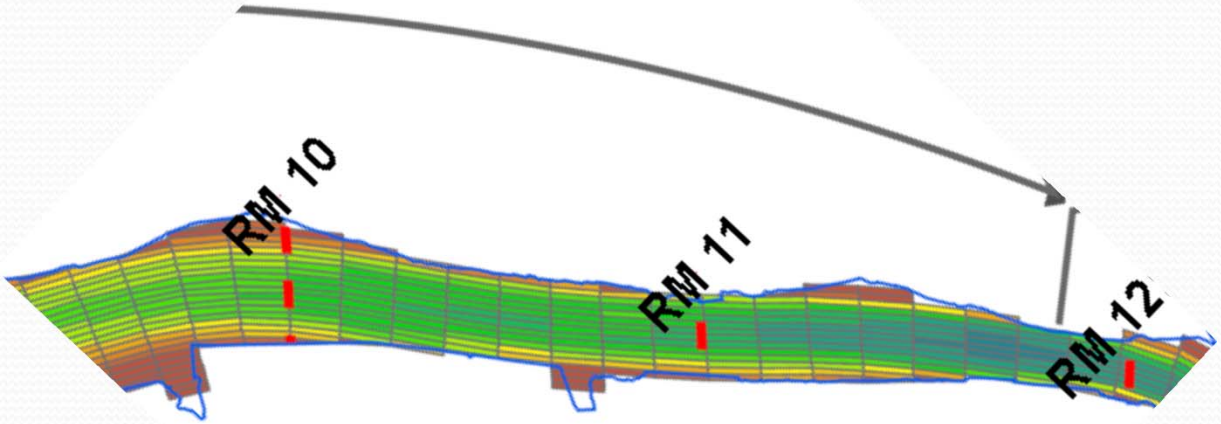

**Bed Shear at 160,000 cfs ($N/m^2$)**

- 0.00 - 0.10
- 0.11 - 0.40
- 0.41 - 0.70
- 0.71 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
- 2.01 - 3.00
- 3.01 - 4.00
- 4.01 - 5.00
- 5.01 - 6.00
- 6.01 - 8.00
- 8.01 - 20.00
- 20.01 - 40.00
- 40.01 - 64.63

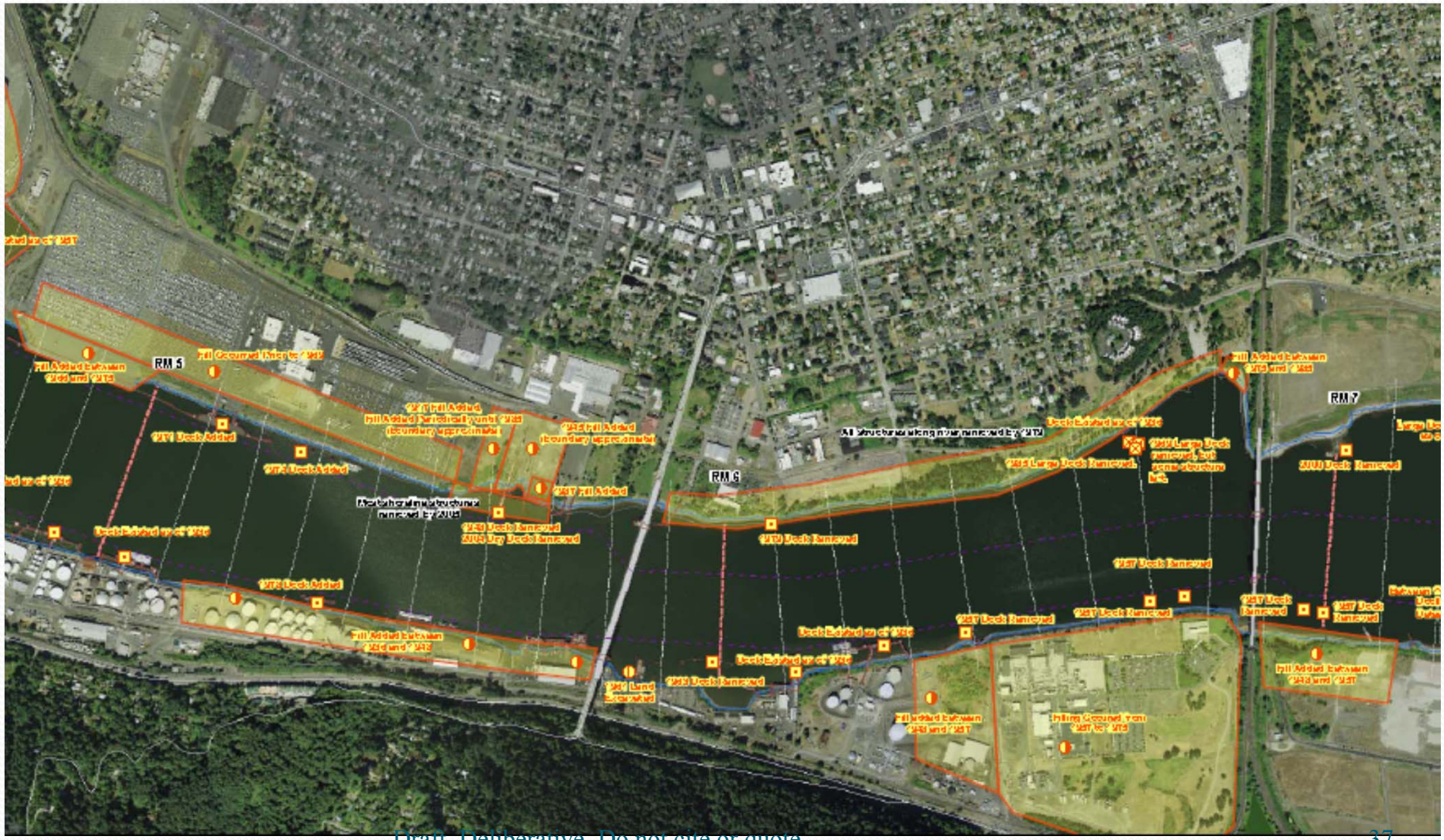
# HST Model (cont.)



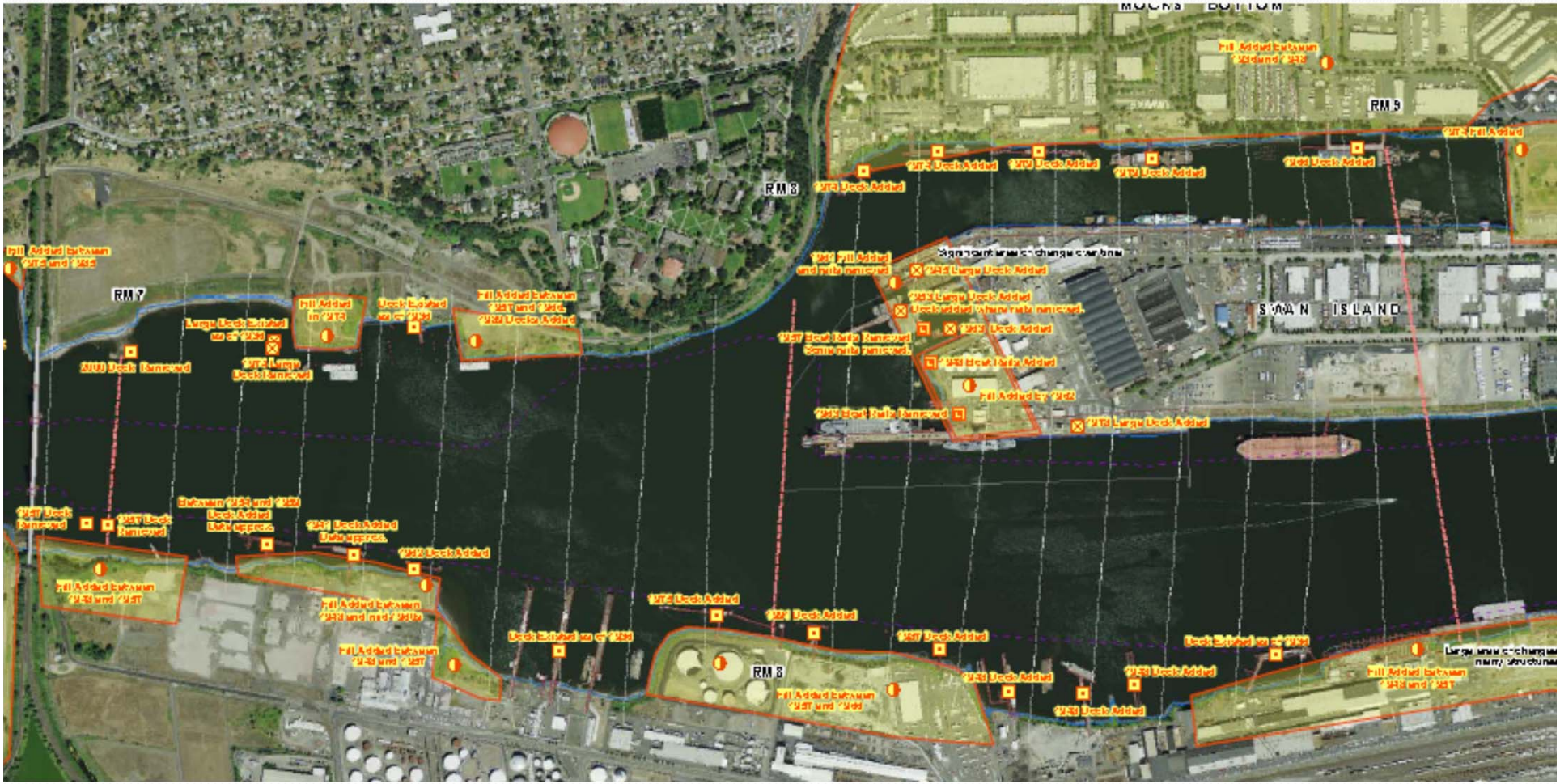
# HST Model (cont.)



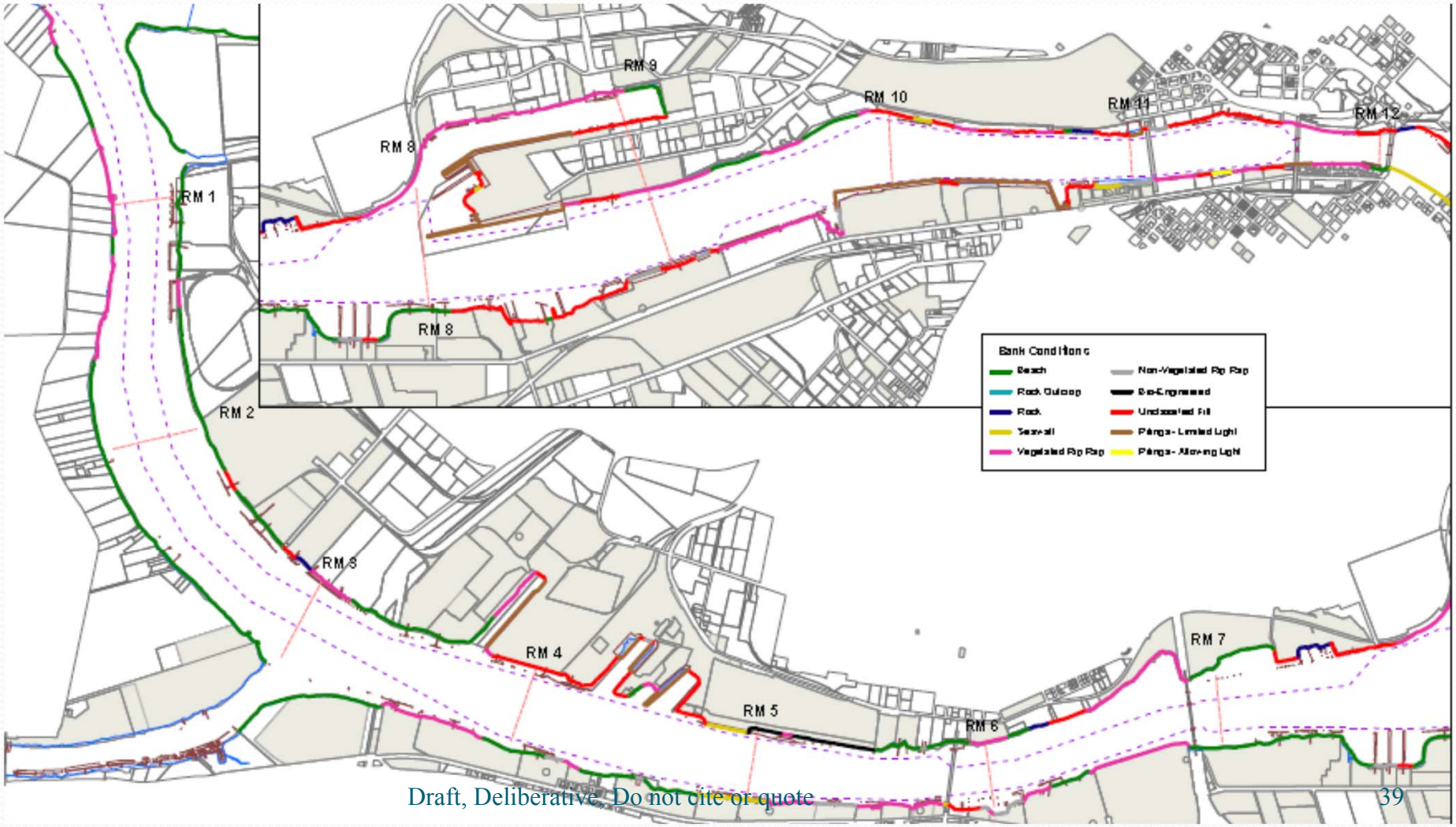
# In-Water Structures (RM 5 – 7)



# In-Water Structures (RM 7 – 9)



# River Banks


RM 1
RM 2
RM 3
RM 4
RM 5
RM 6
RM 7
RM 8
RM 8
RM 9
RM 10
RM 11
RM 12
Bank Conditions
Beach
Rock Outcrop
Rock
Seawall
Vegetated Rip Rap
Non-Vegetated Rip Rap
Bio-Engineered
Undocumented Fill
Pilings - Limited Light
Pilings - Allowing Light

# Land Use

- Marine terminals
- Manufacturing
- Commercial operations
- Public facilities
- Parks
- Open spaces

# Site Use

- Industry
- Recreation (boating, swimming, camping)
- Fishing
- Navigation
- Ceremonial practices
- Ecological habitat
- Tribal treaty rights to fish and ceremonial practices
- Migratory corridor for ESA listed species (salmon)

# Portland Harbor

## Nature and Extent

# Industrial Sources

- Ship building, dismantling & repair
- Wood products & wood treating
- Chemical manufacturing and distribution
- Metal recycling, production & fabrication
- Manufactured gas production
- Electrical production & distribution
- Bulk fuel distribution & storage
- Asphalt manufacturing
- Steel mills, smelters & foundries
- Commodities shipping terminals
- Rail yards

# Contaminant Pathways

- Storm water & CSO discharges
- Industrial waste discharges
- Ground water transport
- Soil & bank erosion
- Air deposition
- Overwater releases
- Upriver sources

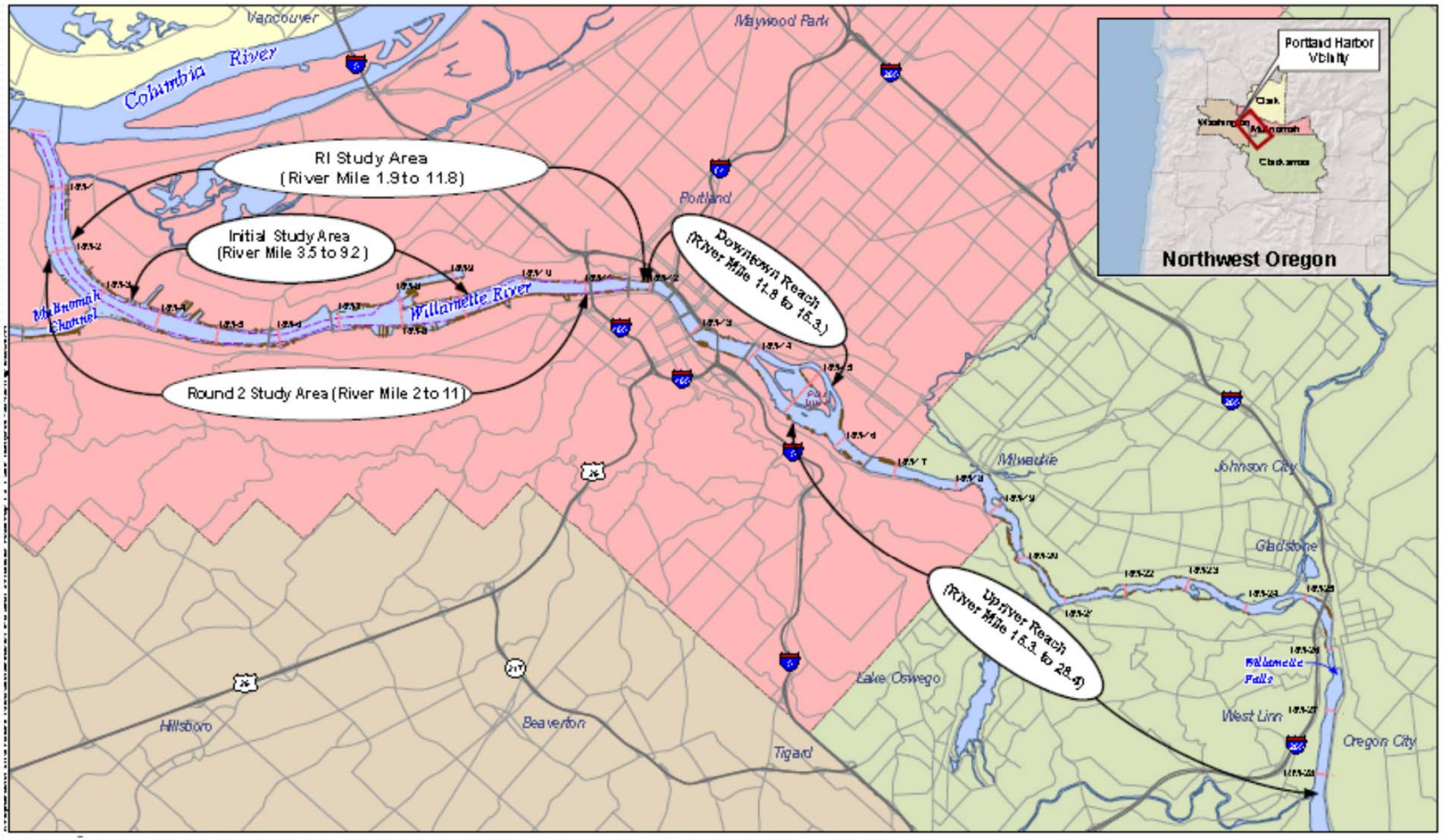
# Contaminants

- 185 detected
- 12 indicator contaminants
  - Frequency of detection
  - Cross-media detection
  - Wide-spread sources
  - Risk exceedance
- 21 others – Appendices
- Example with 4 COCs

# 12 Indicator Contaminants

- Aldrin/Dieldrin
- Arsenic
- BEHP
- Chlordanes
- Chromium
- Copper
- Dioxins/Furans
- DDT & metabolites
- PAHs
- PCBs
- TBT
- Zinc

# River Segments



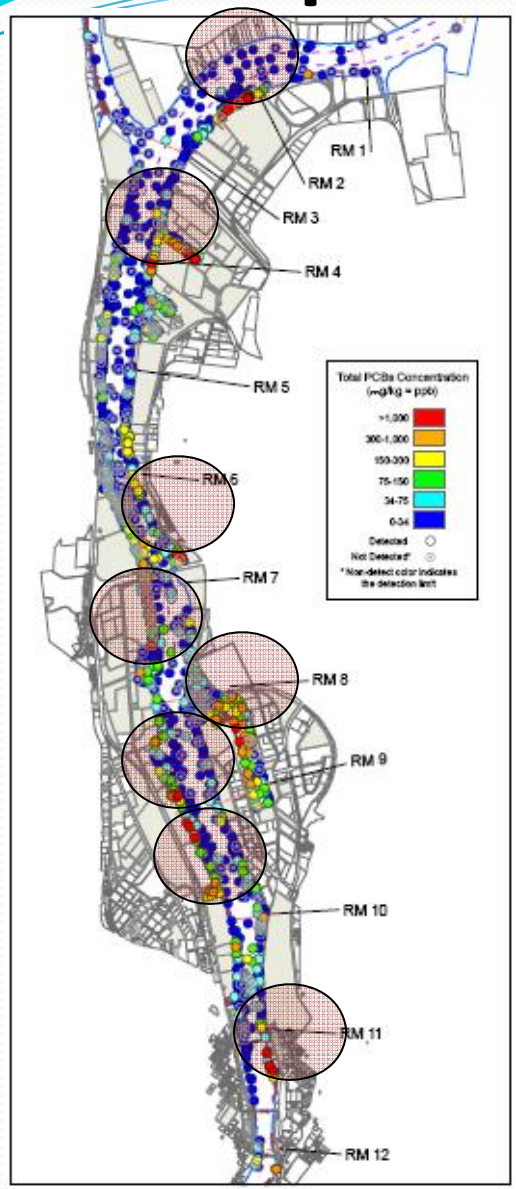
# PCBs – Media

- ✓ Sediment
- ✓ Sediment traps
- ✓ Surface water
- ✗ Pore water
- ✓ Biota

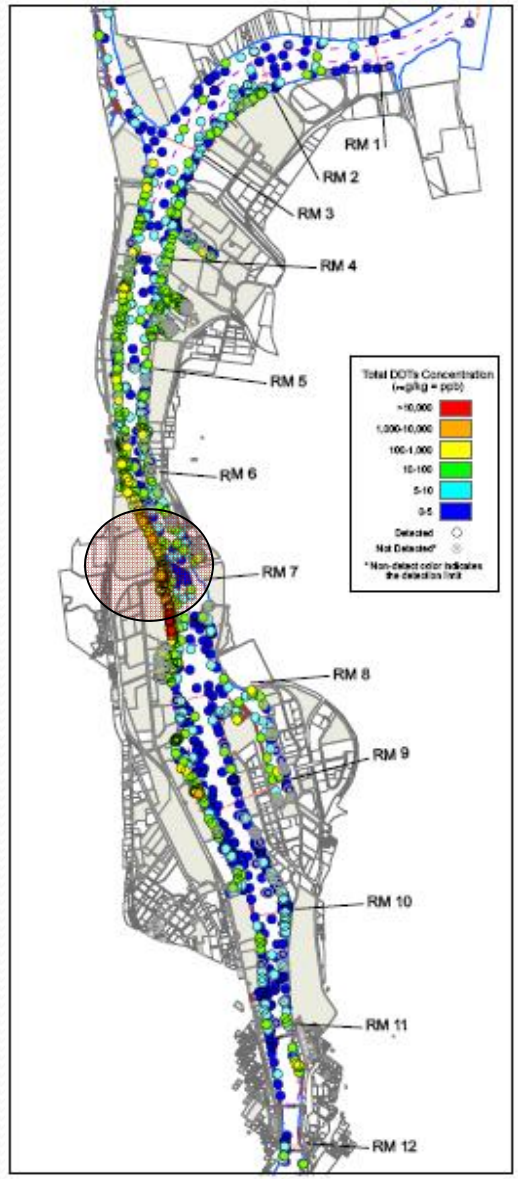
# PCB Summary

| | Sediment | Sediment Traps | Surface Water | Biota |
|---|---|---|---|---|
| RM 2E | X | | X | X |
| International Slip (RM 4E) | X | NA | X | X |
| Willamette Cove (RM 7E) | X | X | X | X |
| Swan Island Lagoon (RM 8E) | X | X | X | X |
| RM 11E | X | X | X | X |
| RM 9W | X | X | X | X |

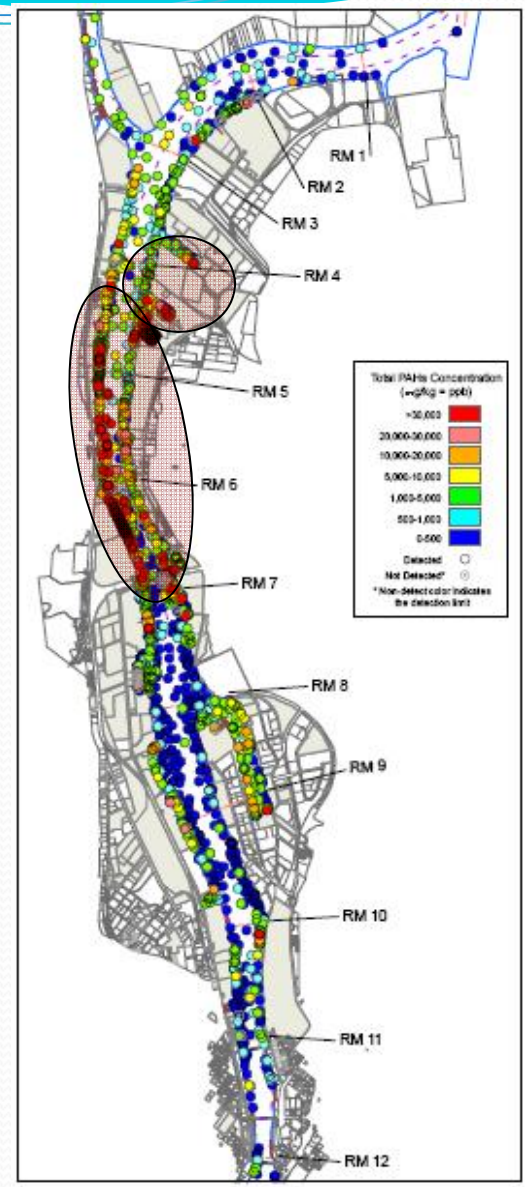
# Examples of Contaminant Distribution




Total PCBs




Total DDx




Total PAHs

# Dioxin/Furan – Media

- ✓ Sediment
- ✓ Sediment traps
- ✓ Surface water
- ✓ Pore water
- ✓ Biota

# Dioxin/Furan Summary

| | Sediment | Sediment Traps | Surface Water | Pore Water | Biota |
|---|---|---|---|---|---|
| International Slip (RM 4E) | X | X | X | NA | X |
| Willamette Cove (RM 7E) | X | | X | NA | X |
| Swan Island Lagoon (RM 8E) | X | X | X | NA | X |
| RM 7W | X | X | X | X | X |
| RM 9W | X | X | X | NA | X |

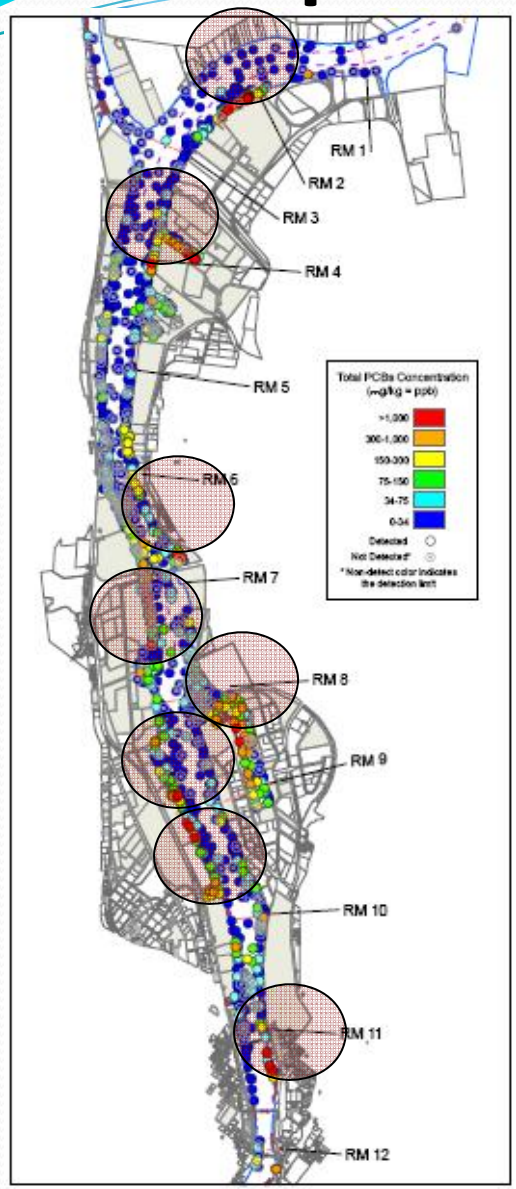
# DDx – Media

- ✓ Sediment
- ✓ Sediment traps
- ✓ Surface water
- ✓ Pore water
- ✓ Biota

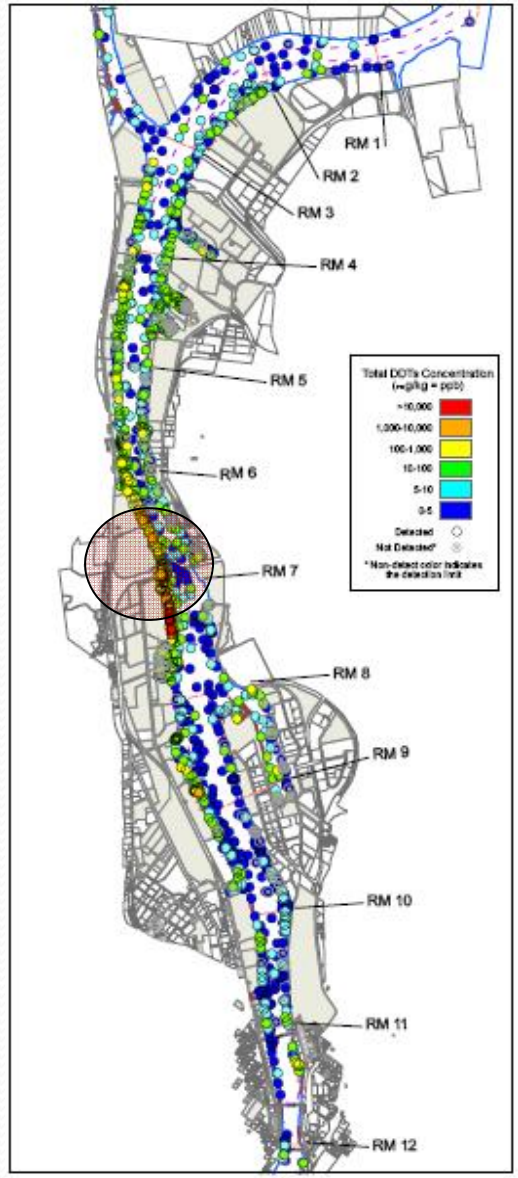
# DDx Summary

| | Sediment | Sediment Traps | Surface Water | Pore Water | Biota |
|---|---|---|---|---|---|
| RM 11E | X | X | | NA | |
| RM 7W | X | X | X | X | X |
| RM 9W | X | X | X | NA | X |

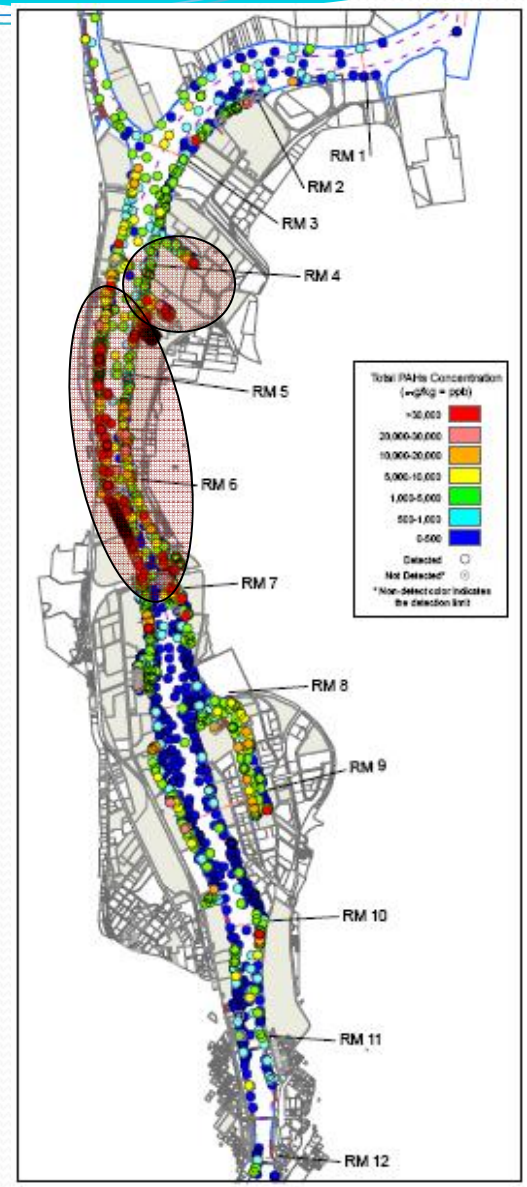
# Examples of Contaminant Distribution




Total PCBs




Total DDx




Total PAHs

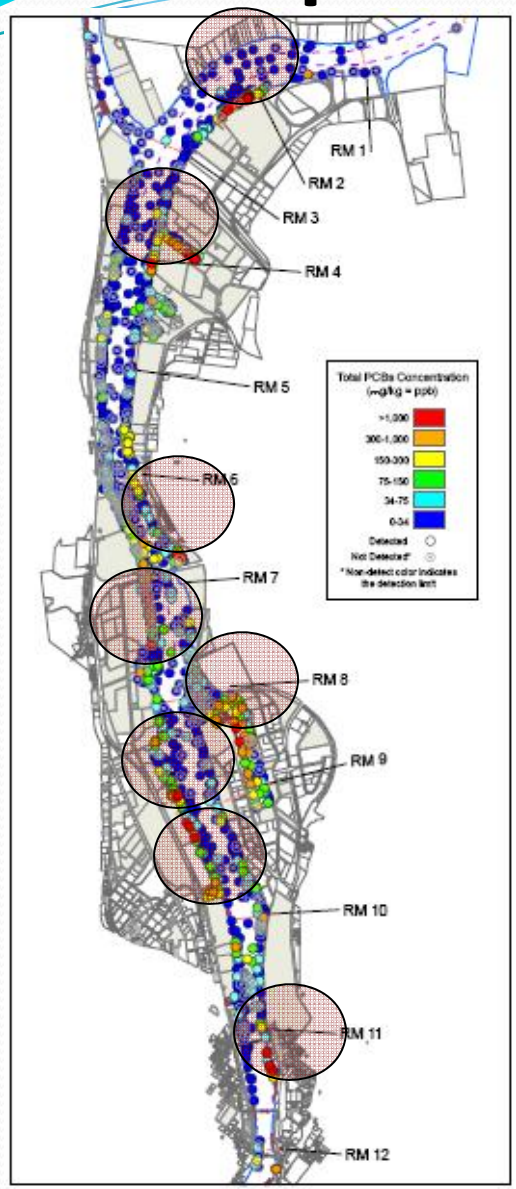
# PAHs – Media

- ✓ Sediment
- ✓ Sediment traps
- ✓ Surface water
- ✓ Pore water
- ✓ Biota

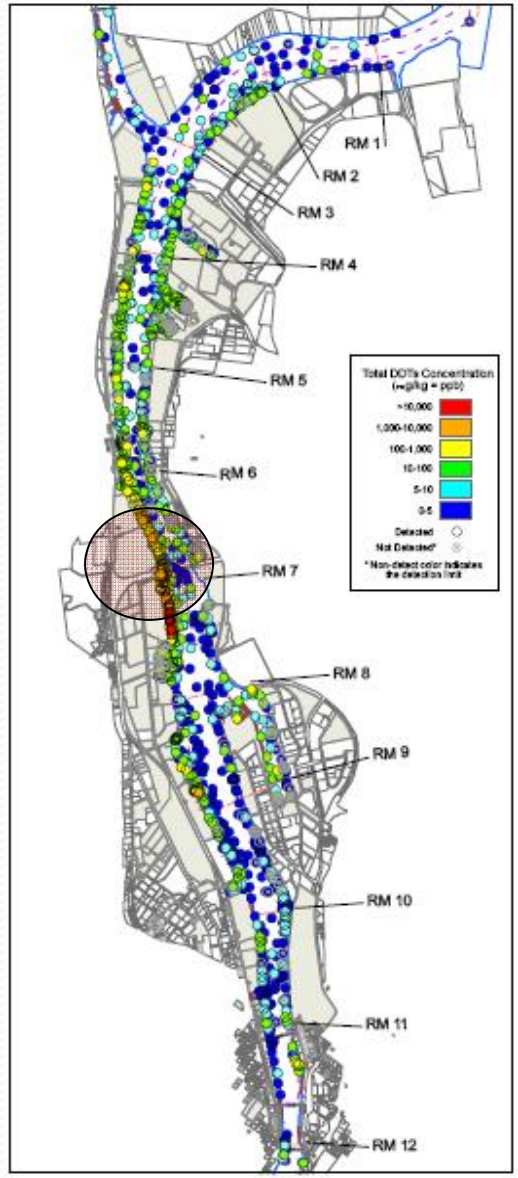
# PAH Summary

| | Sediment | Sediment Traps | Surface Water | Pore Water | Biota |
|---|---|---|---|---|---|
| International Slip (RM 4E) | X | X | | NA | X |
| Swan Island Lagoon (RM 8E) | X | X | X | NA | NA |
| RM 3W-6W | X | | | X | X |
| RM 6W | X | X | X | X | X |
| RM 9W | X | | X | NA | X |

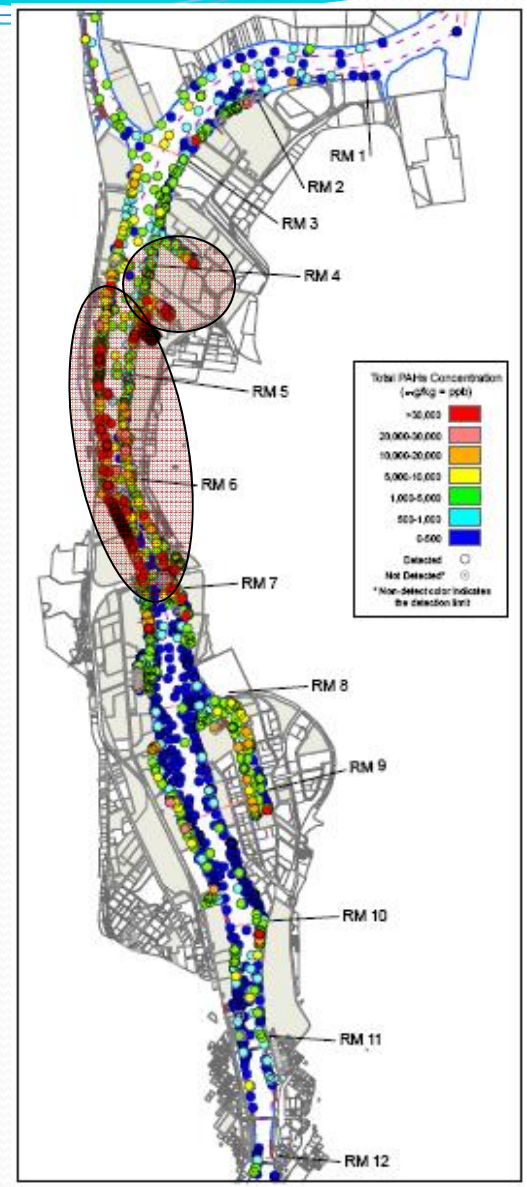
# Examples of Contaminant Distribution




Total PCBs




Total DDx




Total PAHs

# Portland Harbor

## Fate & Transport

# Loading, Fate, and Transport

- External Loading – Mass loading to the site from external sources
- Internal Loading – Movement within the site from one medium to another

# External Loading Pathways

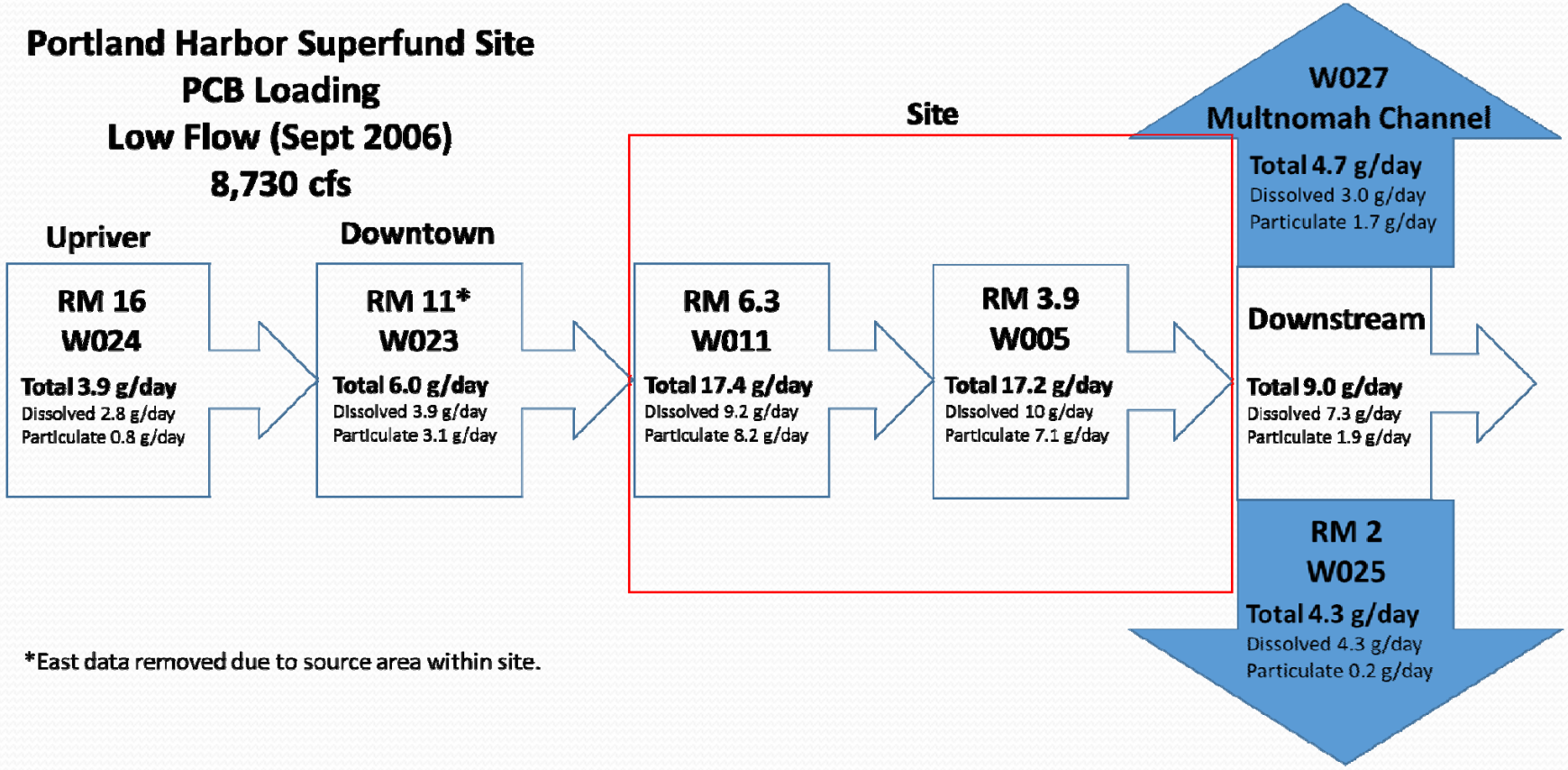
- Upstream loading via surface water, including suspended sediment load and sediment bedload*
- Stormwater runoff
- Permitted non-stormwater point source discharges
- Upland groundwater plume transport to the river
- Atmospheric deposition to the river surface
- Upland riverbank erosion*
- Groundwater advection through sediments
- Overwater releases*

*qualitative evaluation only

# Sediment Bedload Transport

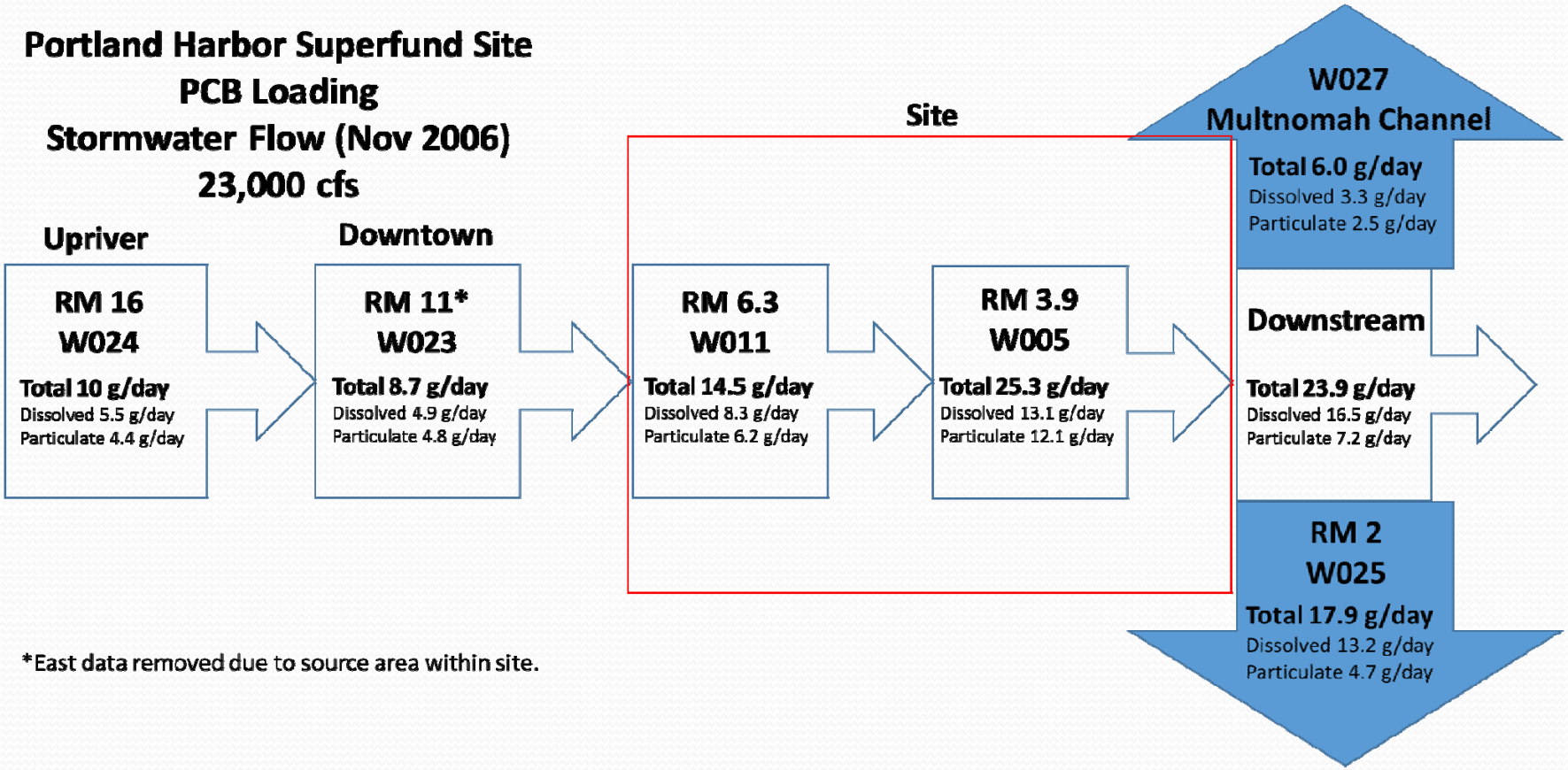
"Quantification of sediment bedload into the Study Area and associated contaminant transport was deemed unnecessary because the sediment bed of the lower Willamette River is mainly cohesive … bedload transport processes are not significant components of upstream loading."

# Example Loads in Low Flow



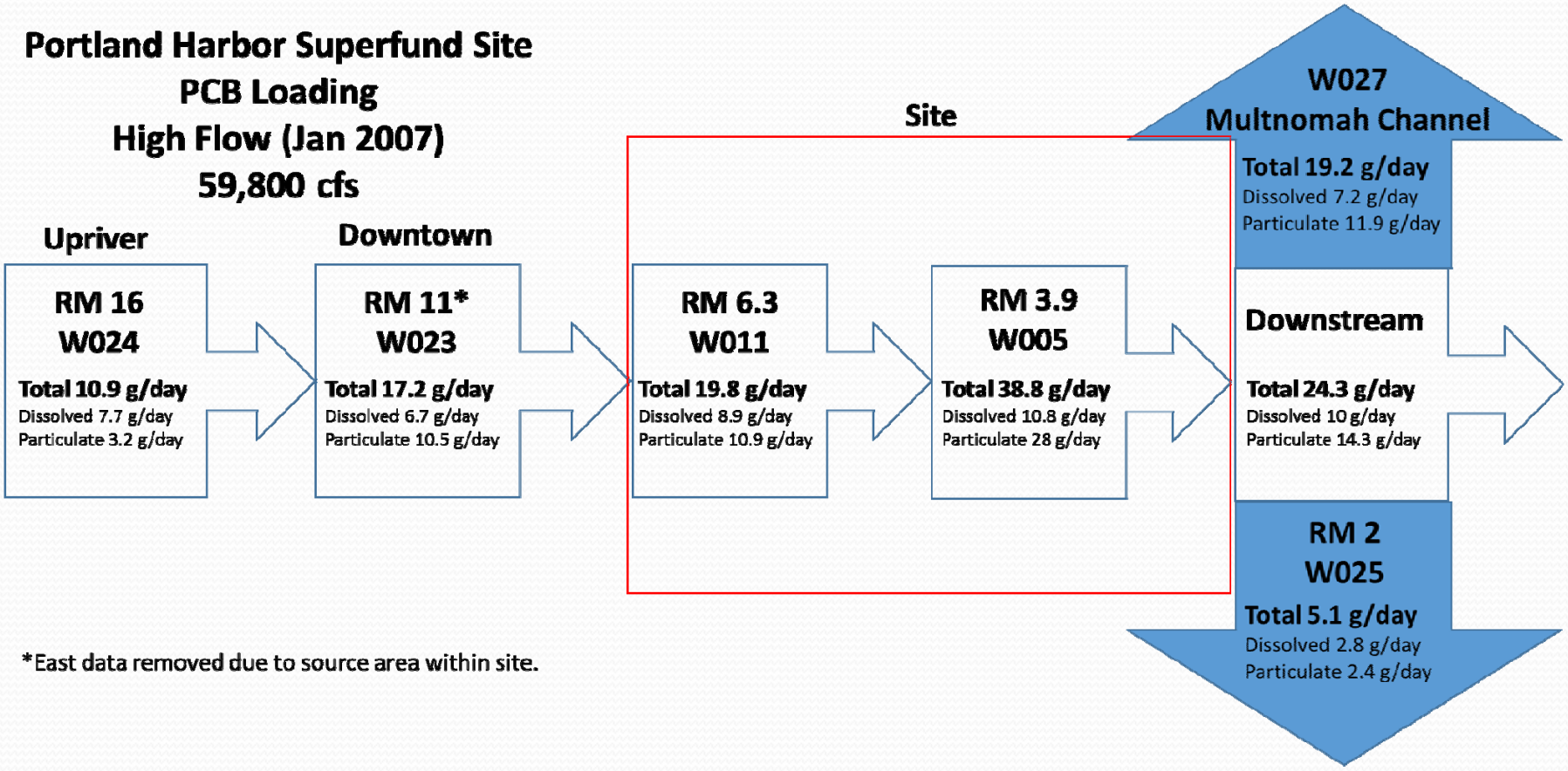

*East data removed due to source area within site.

# Example Loads in Stormwater Flow




*East data removed due to source area within site.

# Example Loads in High Flow




*East data removed due to source area within site.

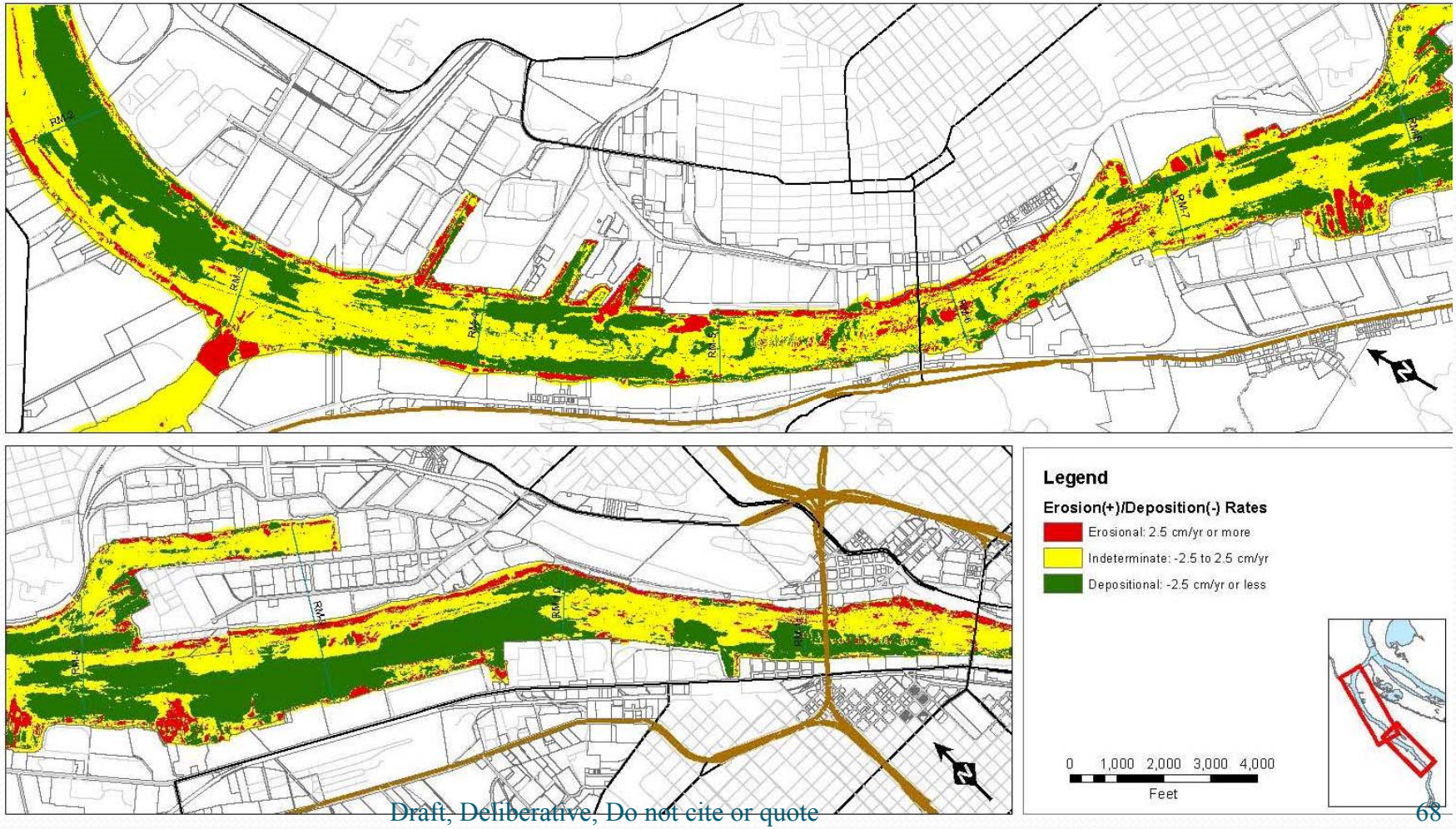
# Internal Fate and Transport Processes

- Sediment re-suspension/transport/ deposition
- Solid/aqueous-phase portioning
- Abiotic/biotic transformation and degradation
- Biological uptake
- Groundwater advection through surface sediments

# Modeling Results

- 82 percent passes through site
- 18 percent retained
  - 277 million kg/year

# Sediment Deposition Rates



# Portland Harbor

## Background

# Sediment Background

**OC-corrected BTV and CT Background Concentrations**

| Contaminant | Units | BTV (95% UPL) | CT (95% UCL) |
|---|---|---|---|
| Arsenic | mg/kg | 4 | 3 |
| BEHP | µg/kg | 155 | 60 |
| Chlordanes | µg/kg | 1.1 | 0.6 |
| Chromium | mg/kg | 32.2 | 23.8 |
| Copper | mg/kg | 37.4 | 25.8 |
| DDx | µg/kg | 5 | 3 |
| Mercury | mg/kg | 0.052 | 0.034 |
| PAHs | µg/kg | 222 | 110 |
| PCB, total Aroclor | µg/kg | 23 | 9 |
| PCB, total congener | µg/kg | 12 | 6 |
| PCDD/F, total | µg/kg | 0.29 | 0.12 |
| Zinc | mg/kg | 104 | 77 |

# Portland Harbor

## Baseline Risk Assessment

# Baseline Human Health Risk Assessment

Approach developed with input from:

- LWG
- ODEQ
- OHA
- Six Tribes
  - Yakama
  - Nez Perce
  - Grande Ronde
  - Umatilla
  - Warm Springs
  - Siletz

# Receptors Evaluated

- Dockside workers
- “In-water” workers
- Recreational
- Transients
- Recreational & subsistence fishers
- Tribal fishers
- Divers
- Domestic water use
- Infants via consumption of breast milk

# Exposures Evaluated

| | Dockside workers | In-water workers | Recreational | Transients | Recreational/ Subsistence/ Tribal Fishers | Divers | Domestic Water Use |
|---|---|---|---|---|---|---|---|
| **Beach Sediment** | ● | | ● | ● | ● | | |
| **River Sediment** | | ● | | | ● | ● | |
| **Surface Water** | | | ● | ● | | ● | ● |
| **Groundwater Seeps** | | | ● | ● | | | |
| **Fish/Shellfish Tissue** | | | | | ● | | |

# Fish Consumption Rates

175 g/day – Tribal Fishers

- Based on CRITFC Study

142 g/day – Subsistence Fishers RME

- Based on national consumption data

49 g/day – Recreational Fishers RME

- Based on Columbia Slough Creel Survey

17.5 g/day – Recreational Fishers CT

- Based on national consumption data

# Fish Consumption Practices

- Tribal Fishers – Combined diet of migratory and resident fish, whole body consumption
- Subsistence and Recreational Fishers – Resident fish only, fillet only consumption.
- Site-wide – mixed diet, four species
- River mile – SMB only as surrogate for mixed species diet

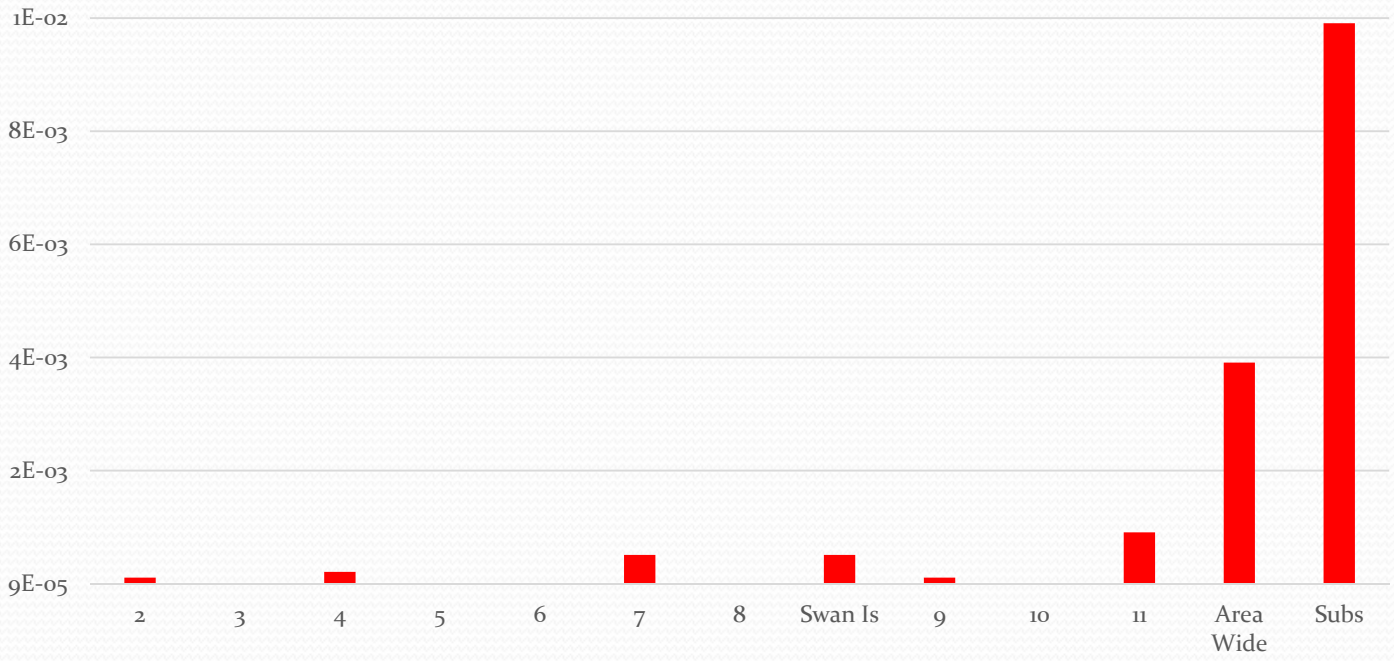
# Infant Exposures to POPs

- Children of nursing mothers exposed via pathways evaluated in the risk assessment
- Inclusion of this pathway a collaborative effort between Region 10, ODEQ, and OHA
- Evaluated for PCBs, dioxins/furans, DDx, and PDBEs
- ODEQ incorporated the methodology into its risk assessment guidance

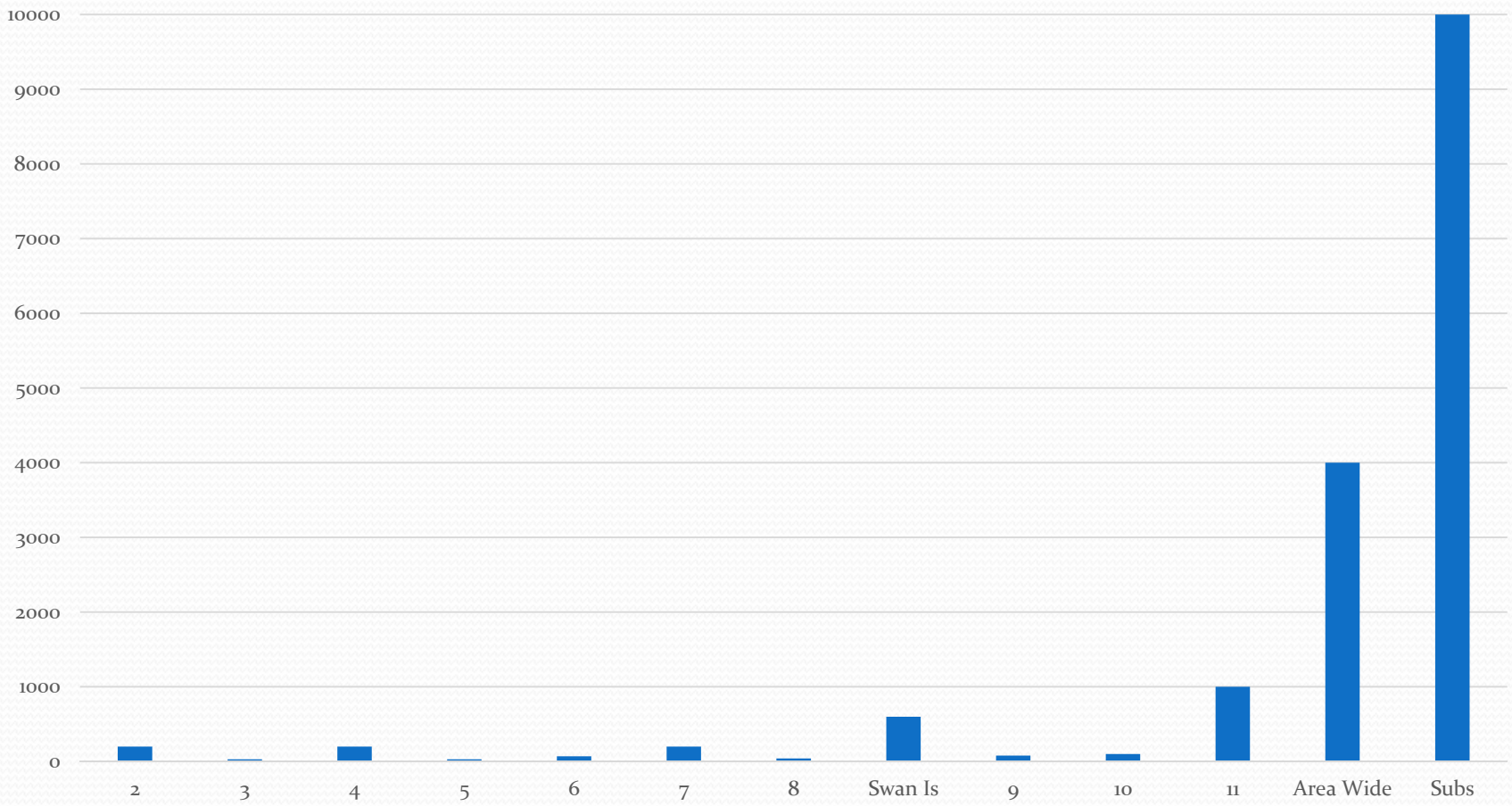
# Major Conclusions

- Direct contact >$10^{-4}$ at RM6W and RM7W
- Drinking surface water no significant risks
- Fish consumption risk orders of magnitude higher
  - PCBs primary contributor
  - Dioxins/furans secondary contributors
  - DDx and PAHs on localized scale
- Infants
  - PCBs primary contributors

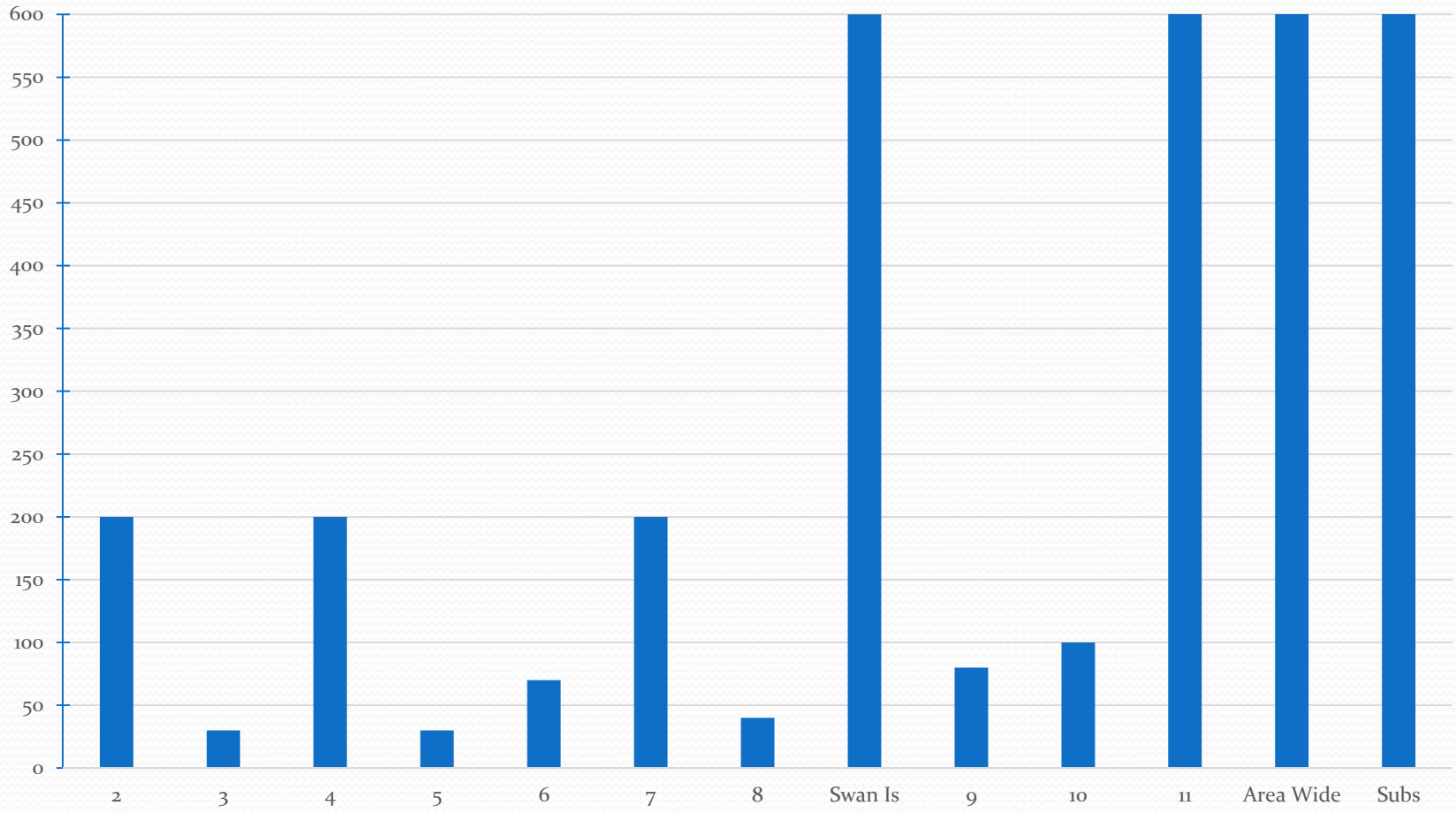
# Estimated Cancer Risk by RM



# Estimated Hazard Index by RM



# Estimated Hazard Index by RM



# Baseline Ecological Risk Assessment

- Baseline risk assessment problem formulation
- Study design and Data Quality Objectives
- Field verification of sampling design
- Site investigation and analysis of exposure & effects
- Risk characterization

# Contaminants Evaluated in BERA

| Number of COPCs Evaluated in the BERA | | |
|---|---|---|
| Medium or Diet | No. of COPCs | No. of Chemicals without Screening-Level TRVs |
| Sediment | 67 | 106 |
| Invertebrate tissue | 18 | 23 |
| Fish tissue | 16 | 8 |
| Fish dietary dose | 9 | 11 |
| Bird dietary dose | 23 | 19 |
| Mammal dietary dose | 12 | 11 |
| Bird egg tissue | 5 | 0 |
| Surface water | 14 | 19 |
| TZW | 58 | 14 |

# Evaluated 13 Assessment Endpoints

Survival, growth, and reproduction of:

- Aquatic plants
- Benthic macroinvertebrates
- Bivalves
- Decapods
- Invertivorous fish
- Omnivorous fish
- Piscivorous fish
- Amphibians
- Invertivorous birds
- Omnivorous birds
- Piscivorous birds
- Aquatic dependent mammals
- Survival & growth – detrivorous fish (Pacific Lamprey)

# Exposure Routes Evaluated

**Aquatic plants** – Root uptake; direct contact with sediment, surface water, and TZW

**Benthic invertebrates** – Direct contact with sediment, surface water, and TZW; ingestion of sediment and food

**Fish** – Direct contact with sediment, surface water, and TZW; ingestion of sediment and food

**Birds and mammals** – Ingestion of soil, sediment, and food

**Amphibians** – Direct contact with surface water and TZW; ingestion of sediment and food

# Ecological Effects Assessment

- Compare contaminant concentrations in with TRVs or site-specific SQVs.
- Benthic risks used sediment bioassays and 2 models to develop sediment SQVs

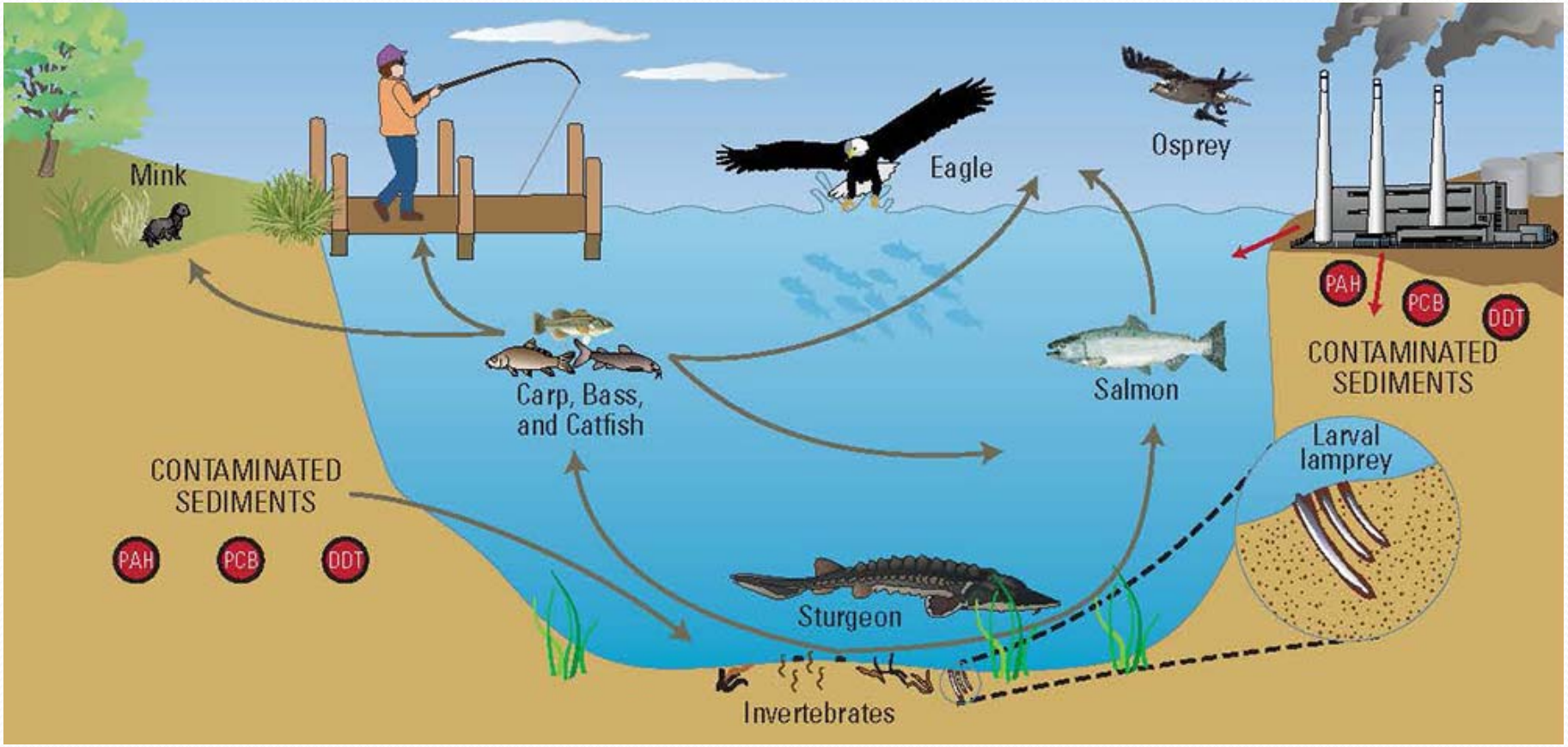
# Determination of Ecological Significance

- Relatively high HQs in one or more environmental media
- Unacceptable ecological risks over extensive areas
- Spatial extent of unacceptable risk not generally encompassed by other contaminants
- Unacceptable risks to multiple ecological receptors
- Multiple LOEs indicated unacceptable risks
- Known or has potential to biomagnify in food webs

# Contaminants Posing Ecologically Significant Risk

| | |
|---|---|
| PCBs | Dioxins/furans |
| PAHs | DDT and metabolites |
| Total chlordanes | Mercury |
| Lead | Cadmium |
| Copper | Bis(2-ethylhexyl)phthalate |
| Zinc | Dieldrin |
| Lindane (γ-HCH) | Cyanide |
| Tributyltin | Ethylbenzene |
| Perchlorate | $C_{10}$ – $C_{12}$ TPH |
| Manganese | Vanadium |

# Baseline Risk Assessment



# COCs in Sediment

- PCBs
- Dioxins/Furans
- Total cPAH
- Total PAH
- Aldrin
- Dieldrin
- Total DDE
- DDx
- Lindane
- Total Chlordanes
- Arsenic
- Cadmium
- Chromium
- Copper
- Lead
- Mercury
- Zinc
- BEHP
- Tributyltin
- Hexachlorobenzene
- PBDE