Presented at Puget Sound Shorelines and the Impacts of Armoring Workshop,
May 12-14 2009.
This presentation not peer reviewed.

Puget Sound Shorelines and the Impacts of Armoring May 11-4, 2009

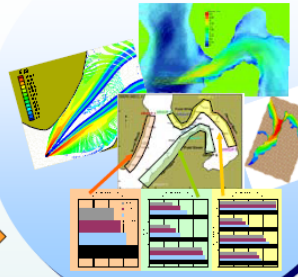
Observations of gravel transport and morphological response on a supply-limited beach backed by bulkheads and exposed to waves, wakes, and tidal currents, Point White, Bainbridge Island

Passenger Only Fast Ferry Study

Travel Time (38 Knots), min	
Everett-Seattle	55
Mukilteo-Seattle	50
Edmonds-Seattle	31
Kingston-Seattle	29
Bremerton-Everett	66
Bremerton-Seattle	26
Southworth-Seattle	21
Vashon-Seattle	18
Tacoma-Seattle	63
Des Moines-Seattle	34

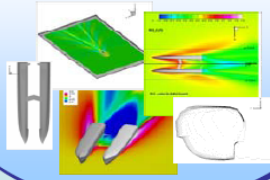
Field Data Collection

Integrated Modeling & Analysis



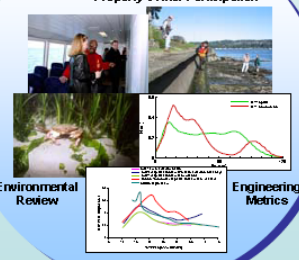
Vessel Design & Optimization Study

CFD Modeling Automated System-Based Design

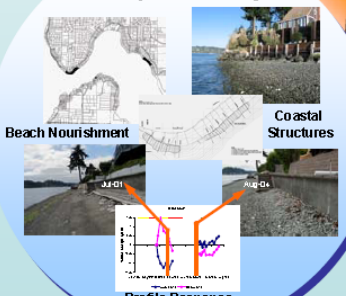


Performance Criteria

Property Owner Participation



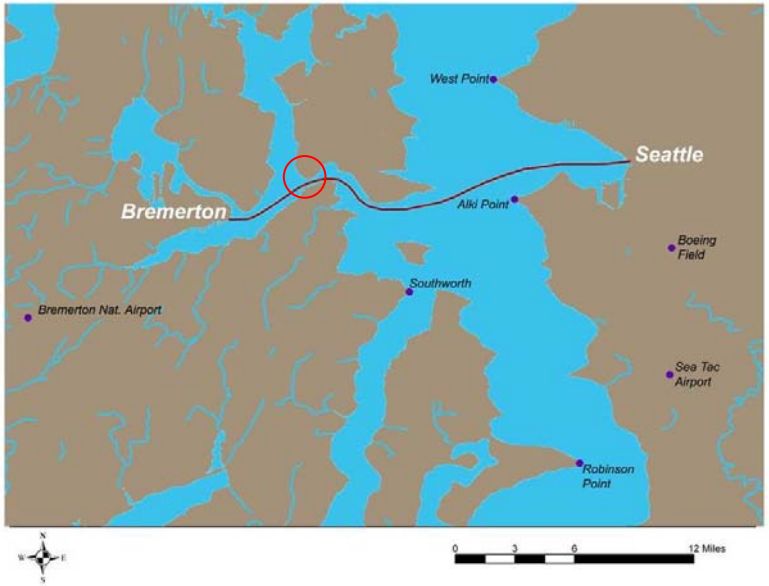
Beach Response Study



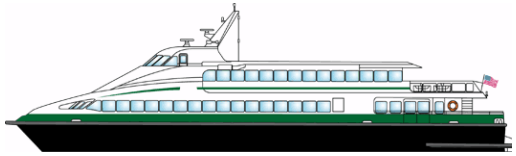
New Rich Passage Research Vessel

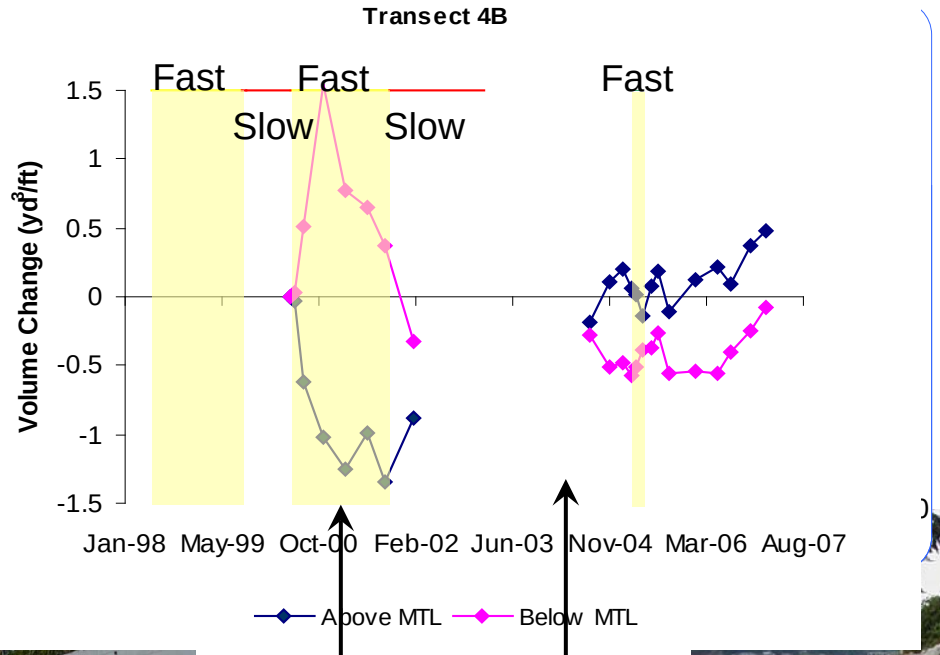
Kitsap Transit

PACIFIC INTERNATIONAL ENGINEERING



- Resolve seasonal patterns of sediment transport and morphology change on MSG beach
- Quantify relative importance of waves, wakes, tidal currents
- Validate integrated wake impact modeling system

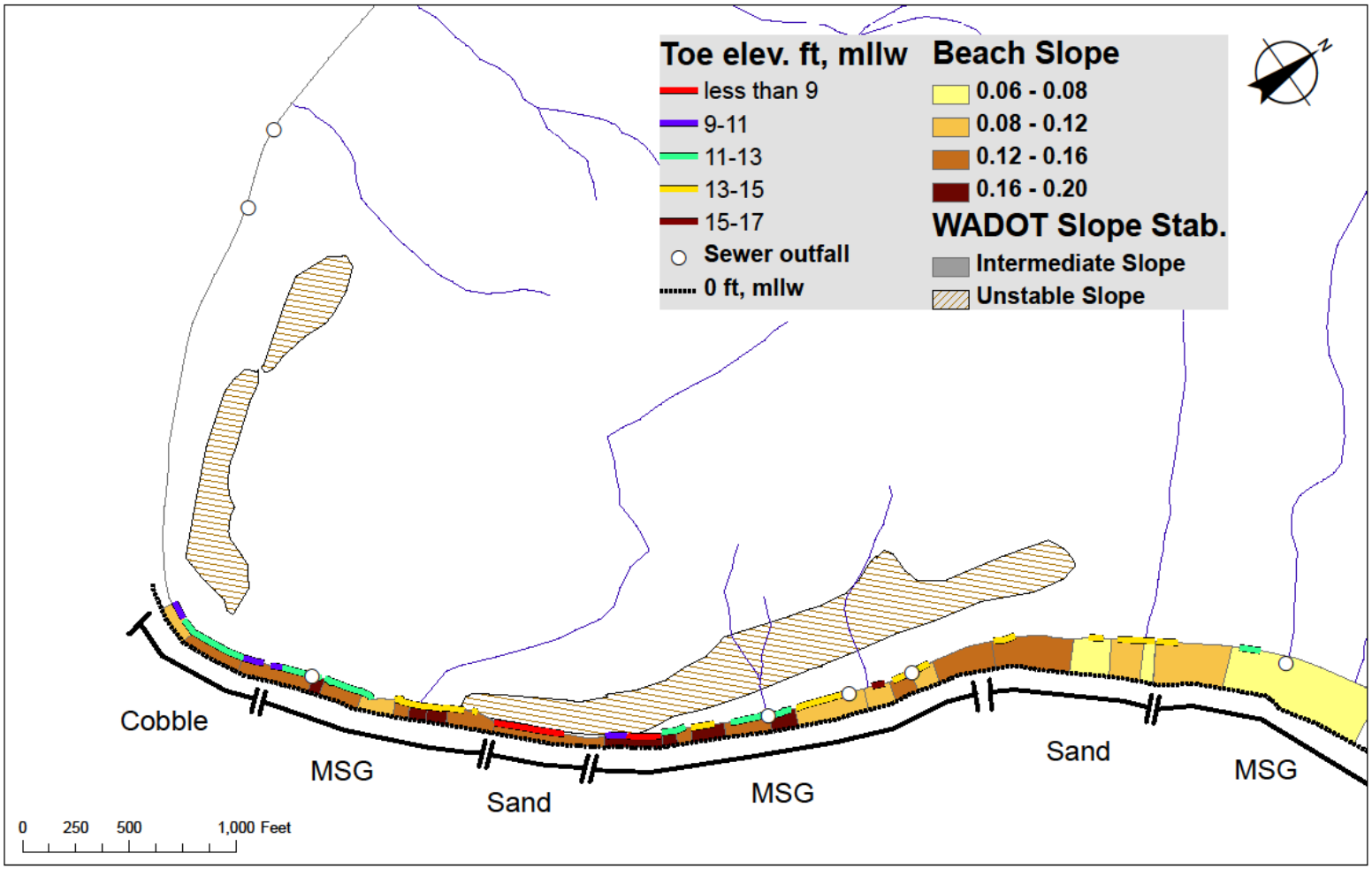


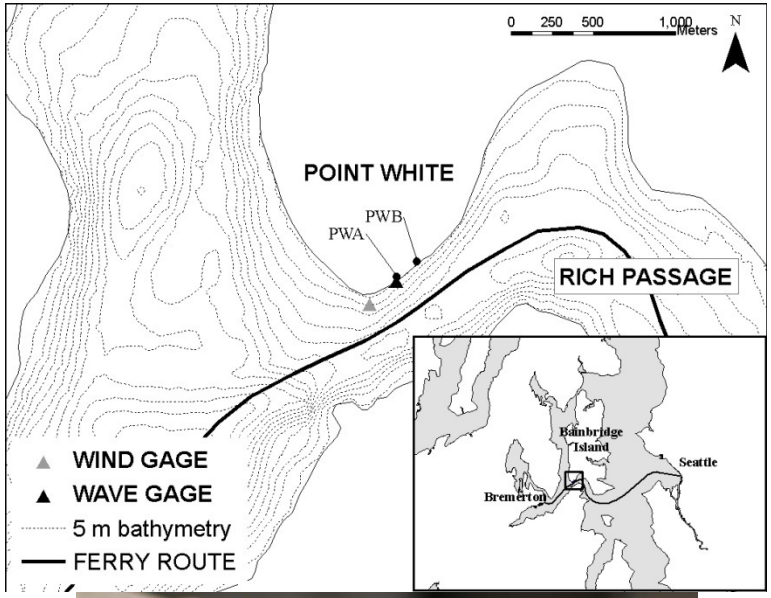


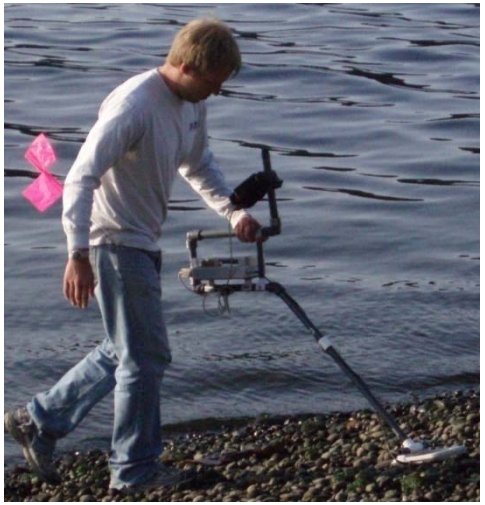
JUL 2001

AUG 2004

- Beach supply limited by structures
- Morphology shaped by large infrequent storms and long term exposure to wakes
  - Limited or gradual post-storm recovery
- Vessel wakes → significant
- Requires long term, high resolution monitoring to capture morphologic response

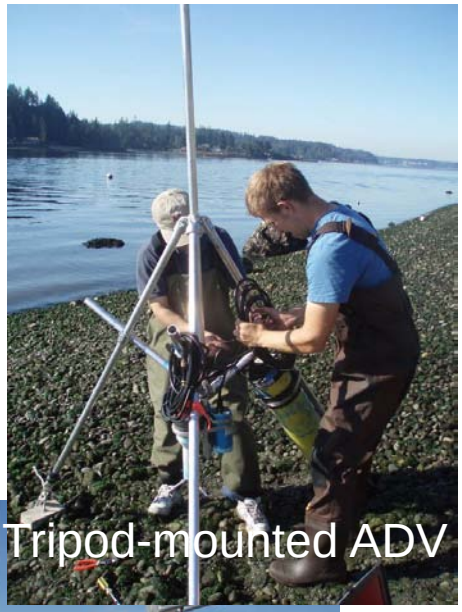

Toe elev. ft, mllw
less than 9
9-11
11-13
13-15
15-17
Sewer outfall
0 ft, mllw
Beach Slope
0.06 - 0.08
0.08 - 0.12
0.12 - 0.16
0.16 - 0.20
WADOT Slope Stab.
Intermediate Slope
Unstable Slope
N
Cobble
MSG
Sand
MSG
Sand
MSG
0
250
500
1,000 Feet

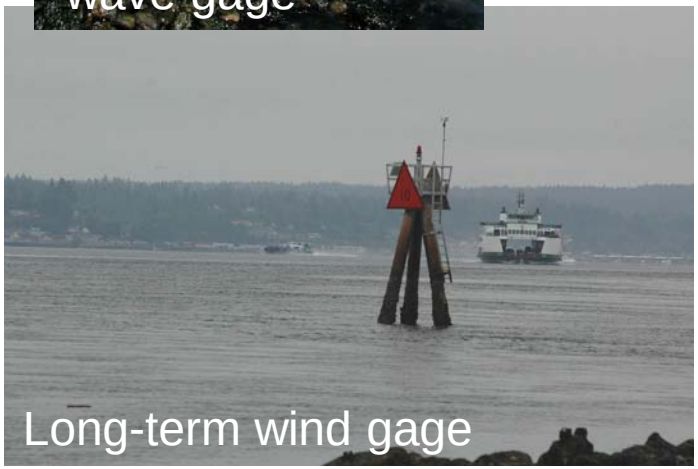

0 250 500 1,000 Meters
N
POINT WHITE
PWB
PWA
RICH PASSAGE
Bainbridge Island
Seattle
Bremerton
WIND GAGE
WAVE GAGE
5 m bathymetry
FERRY ROUTE

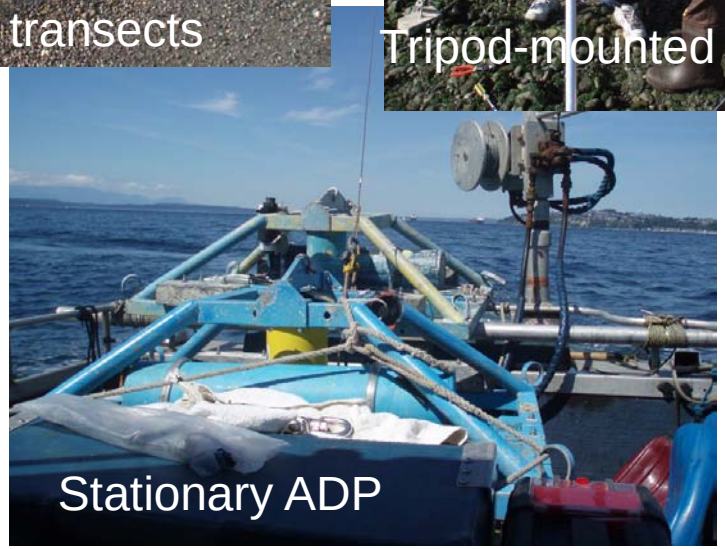


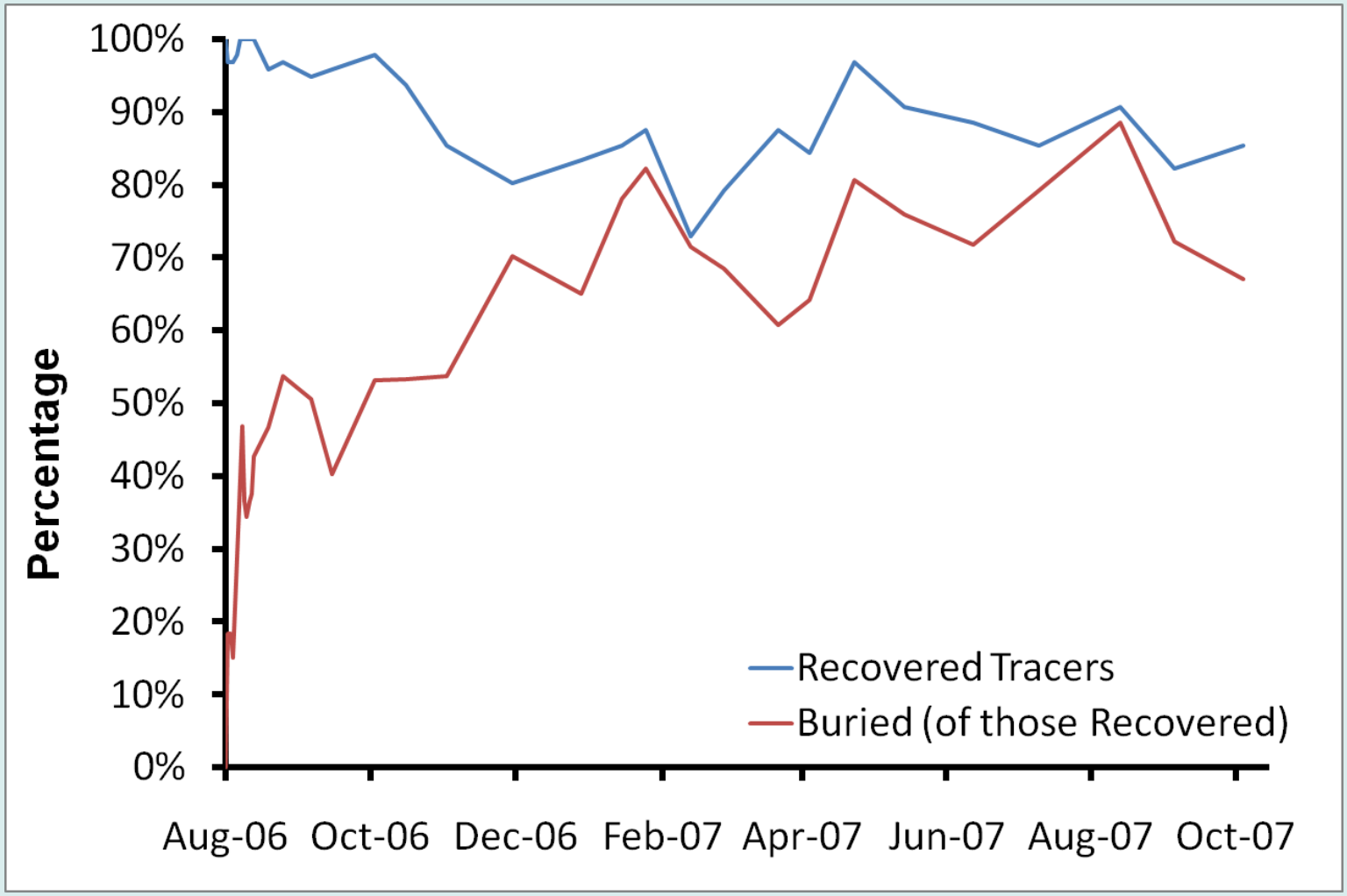
Long-term wave gage

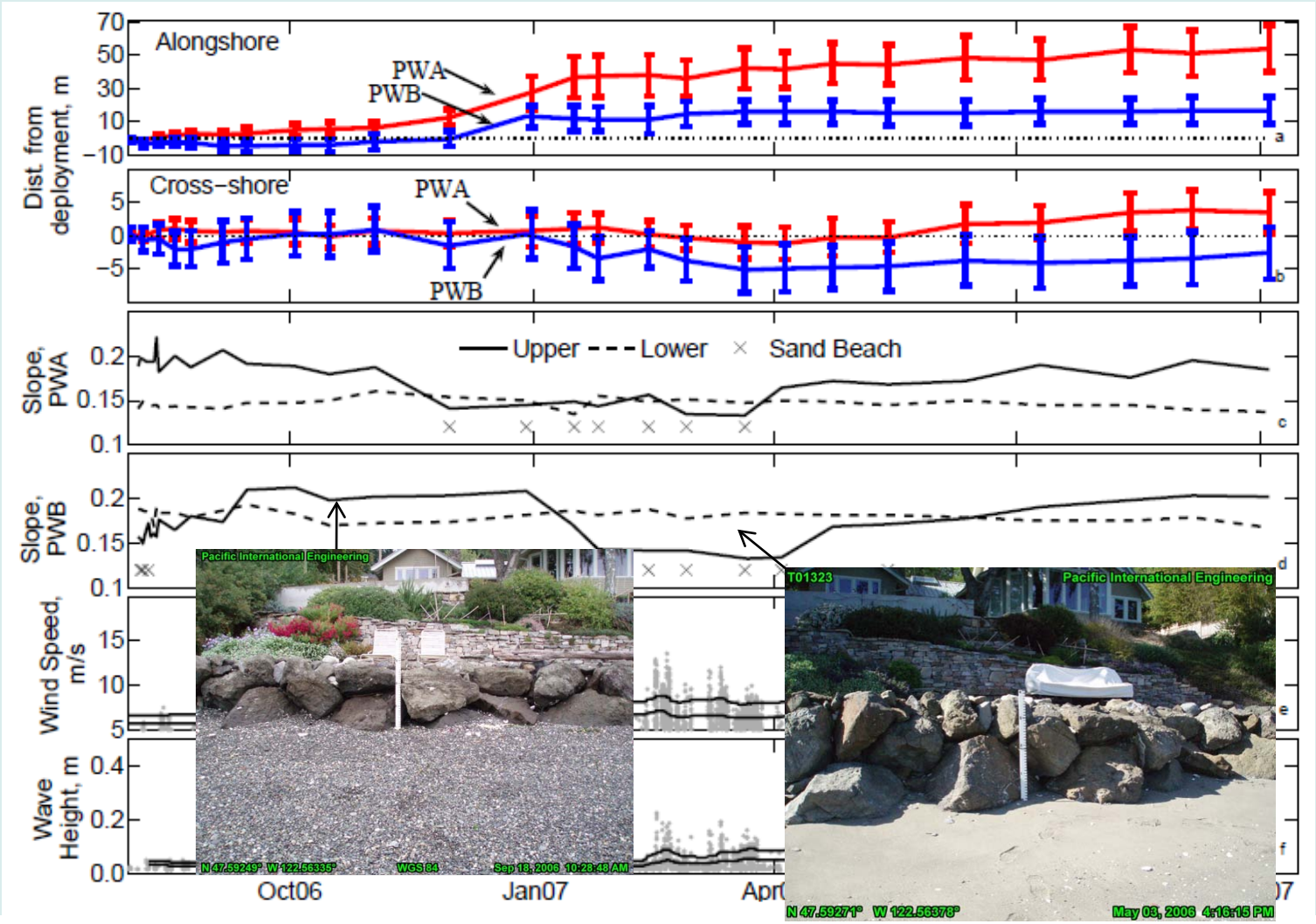
Kayak-based ADP transects

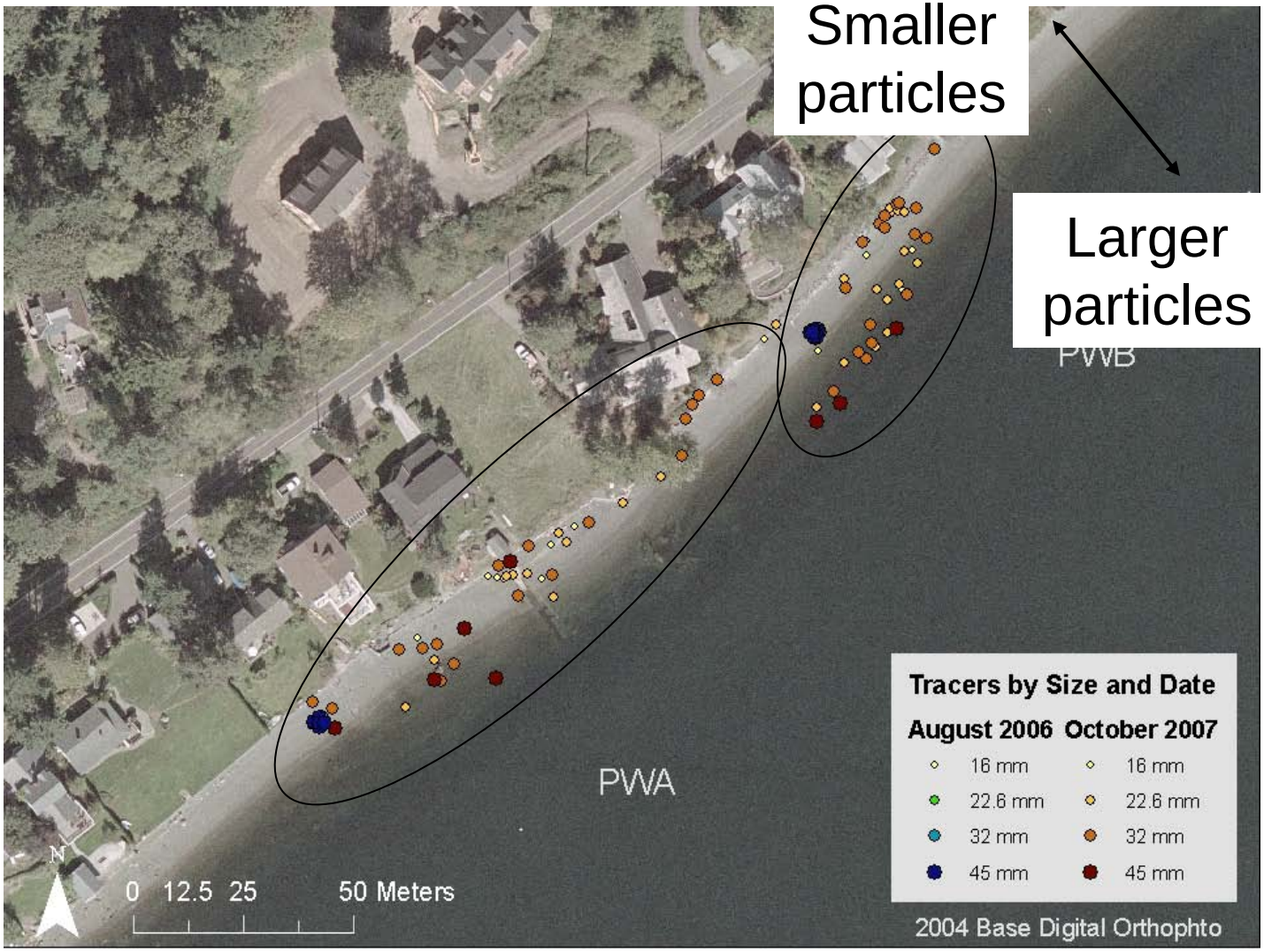

Tripod-mounted ADV


Long-term wind gage

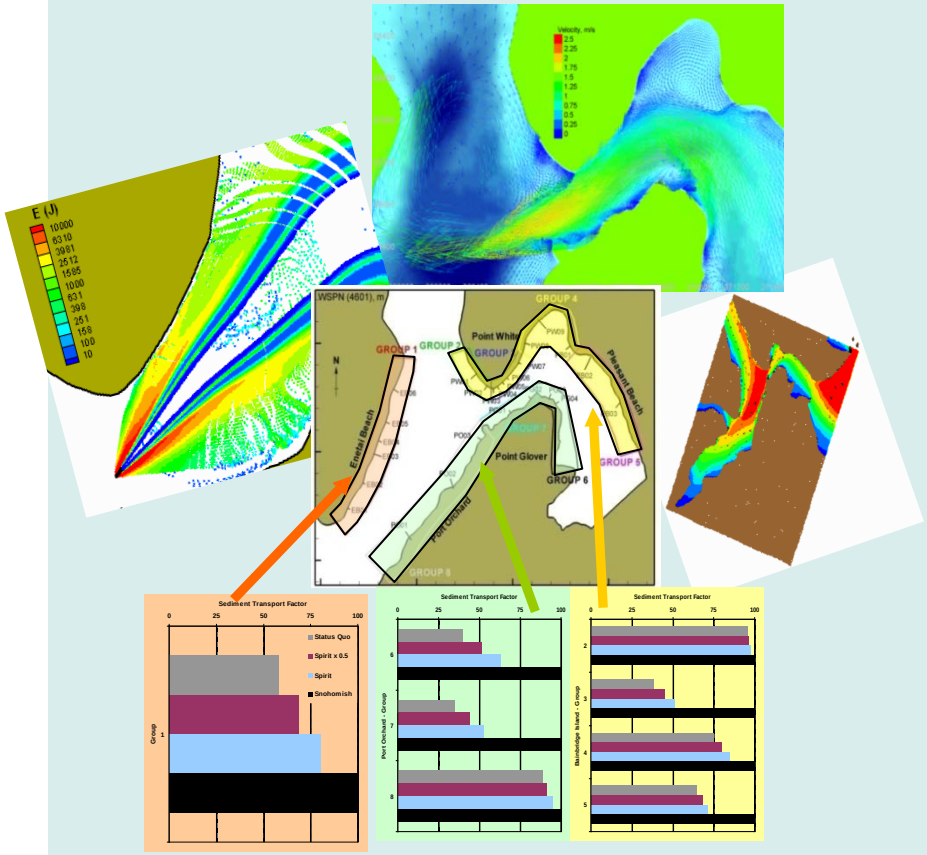

Stationary ADP


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage
Aug-06
Oct-06
Dec-06
Feb-07
Apr-07
Jun-07
Aug-07
Oct-07
Recovered Tracers
Buried (of those Recovered)

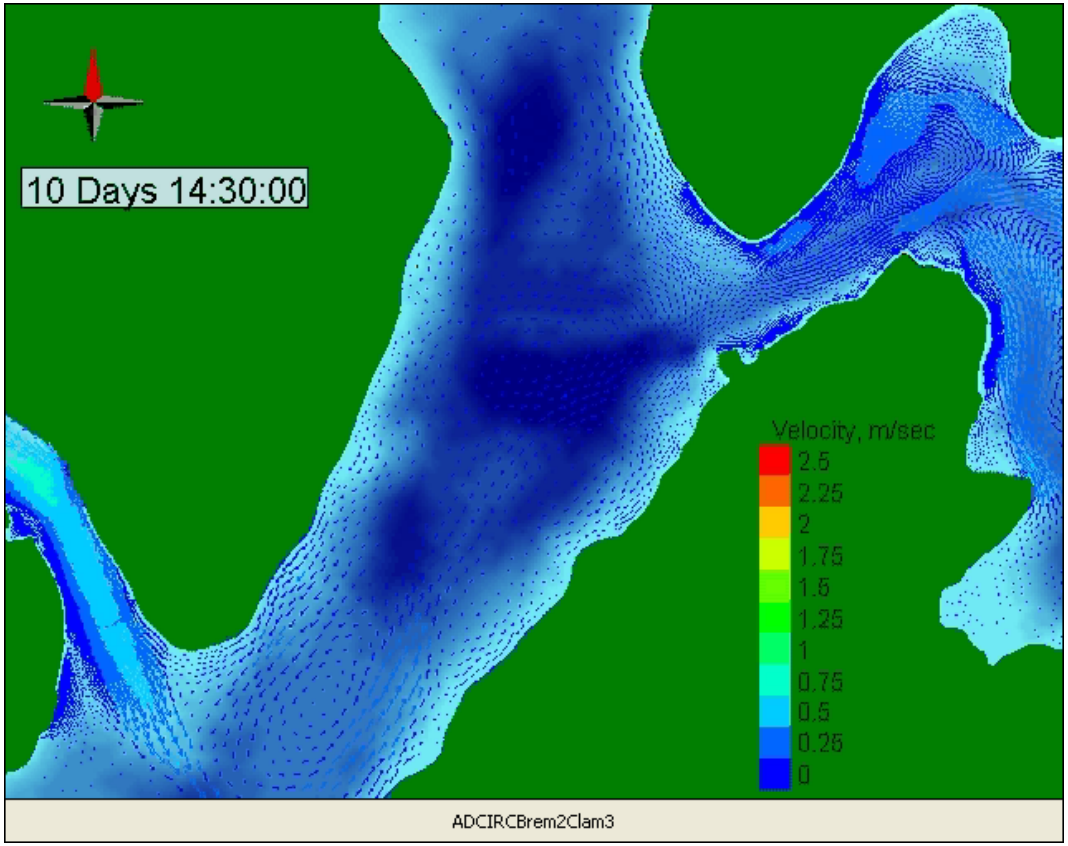

Alongshore
PWA
PWB
Dist. from deployment, m
70
50
30
10
−10
a
Cross−shore
PWA
PWB
5
0
−5
b
Slope, PWA
0.2
0.15
0.1
Upper
Lower
Sand Beach
c
Slope, PWB
0.2
0.15
0.1
d
Wind Speed, m/s
15
10
5
e
Wave Height, m
0.4
0.2
0.0
f
Oct06
Jan07
Apr
07
Pacific International Engineering
N 47.59249° W 122.56335°
WGS 84
Sep 18, 2006 10:28:48 AM
T01323
Pacific International Engineering
N 47.59271° W 122.56378°
May 08, 2006 4:16:15 PM


Smaller particles
Larger particles
PWB
PWA
Tracers by Size and Date
August 2006
October 2007
16 mm
16 mm
22.6 mm
22.6 mm
32 mm
32 mm
45 mm
45 mm
N
0 12.5 25 50 Meters
2004 Base Digital Orthophto

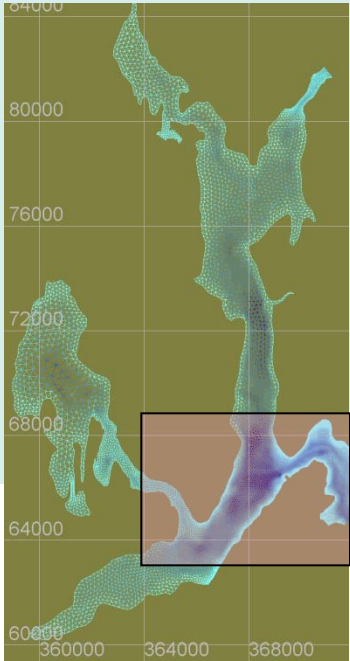
04Oct07
31Dec06
30Nov06
01Aug06
04Oct07
31Dec06
30Nov06
01Aug06
PWB
PWA
N
0 12.5 25 50
Meters
2004 Base Digital Orthophoto

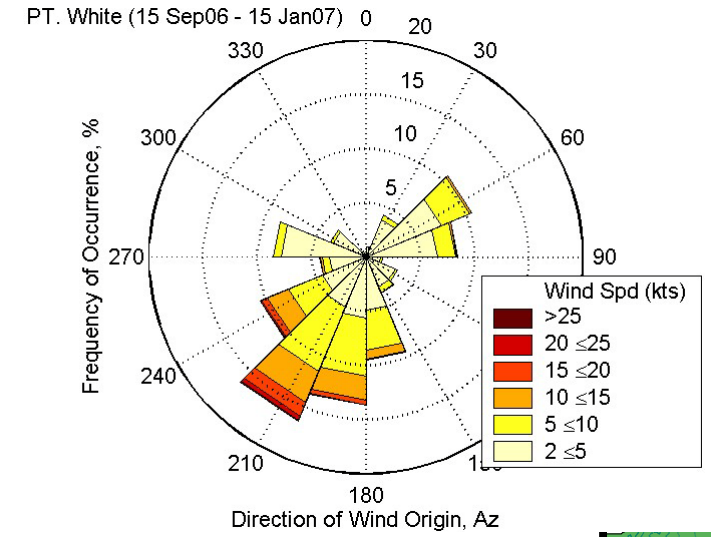


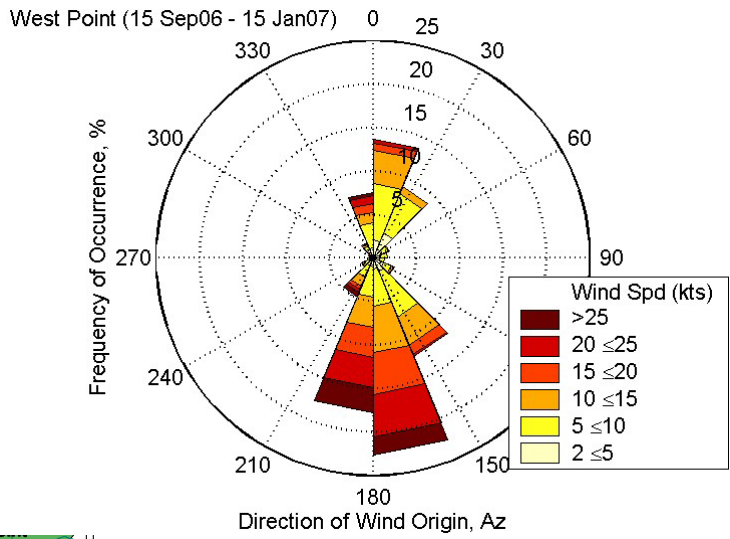
- Tidal Circulation Model
- Wind Wave Model
- Lagrangian Super Critical Vessel Model
- Profile Analysis Model

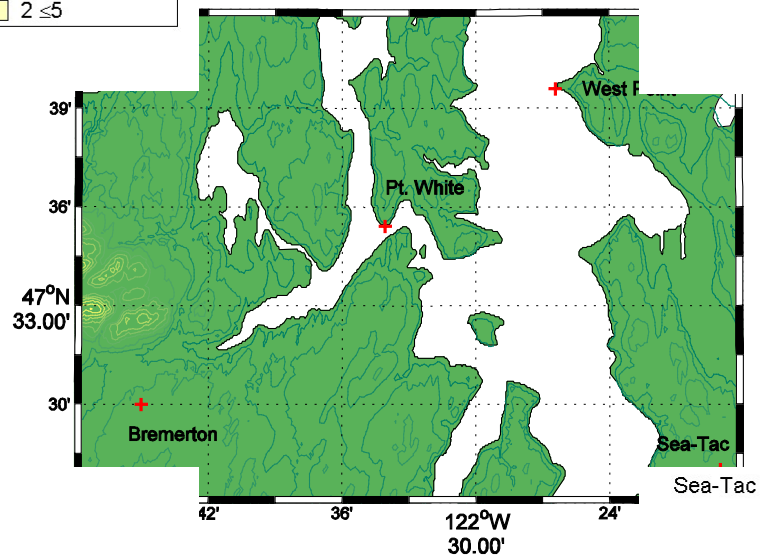


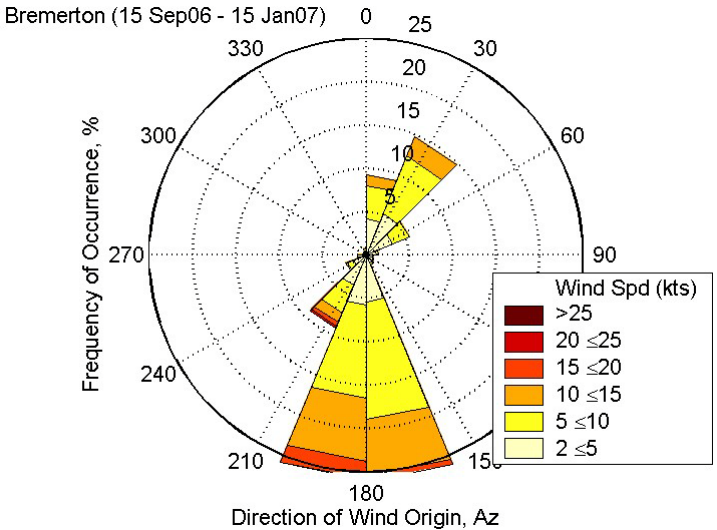
- Extensive available current, wave, sediment transport, and ship traffic data
- Fully validated high res 2D models

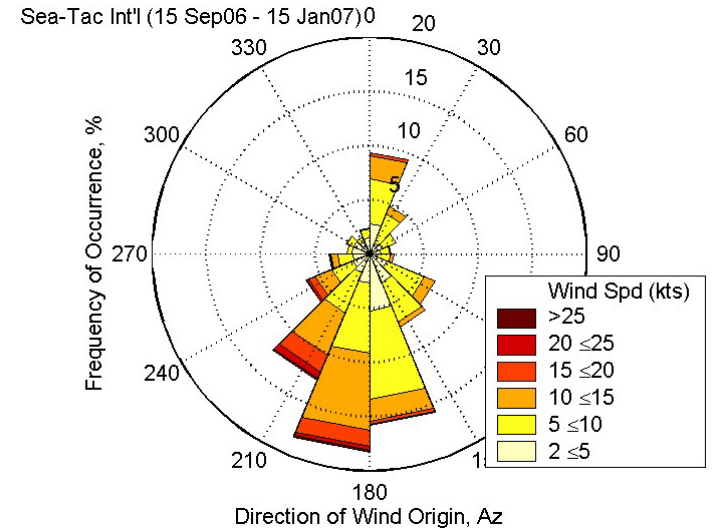


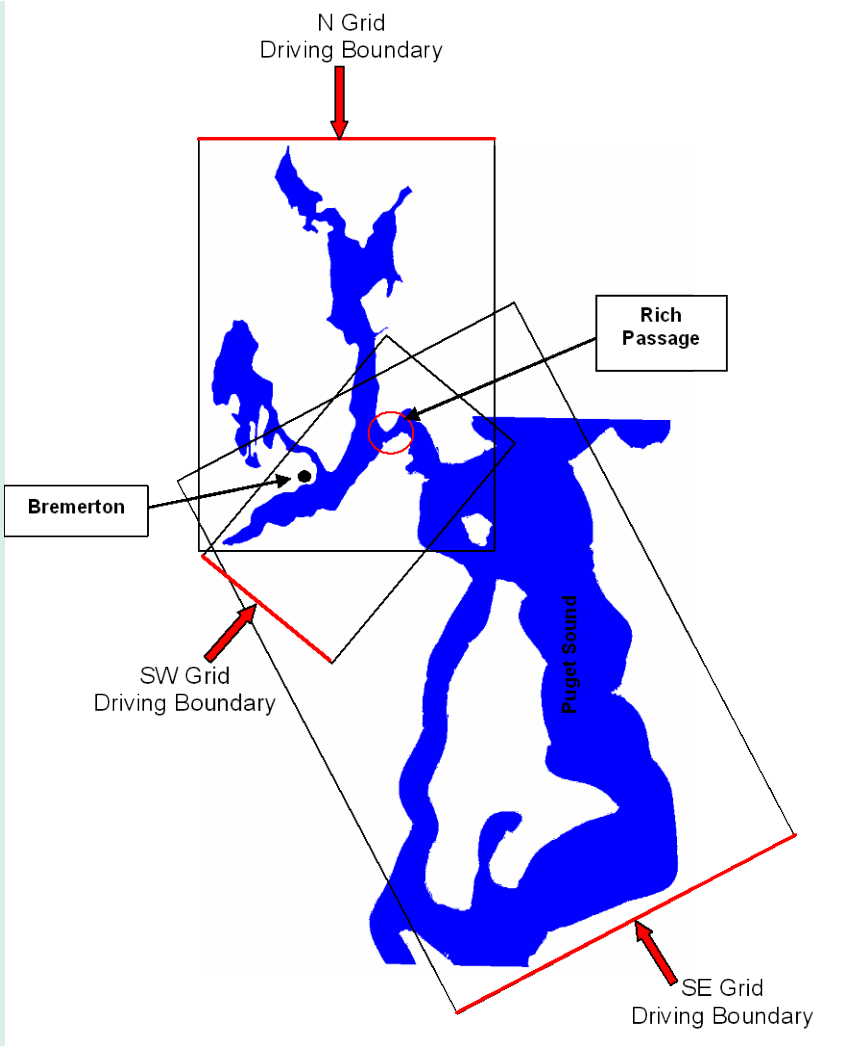

PT. White (15 Sep06 - 15 Jan07)
Frequency of Occurrence, %
Direction of Wind Origin, Az
Wind Spd (kts)
>25
20 ≤25
15 ≤20
10 ≤15
5 ≤10
2 ≤5


West Point (15 Sep06 - 15 Jan07)
Frequency of Occurrence, %
Direction of Wind Origin, Az
Wind Spd (kts)
>25
20 ≤25
15 ≤20
10 ≤15
5 ≤10
2 ≤5

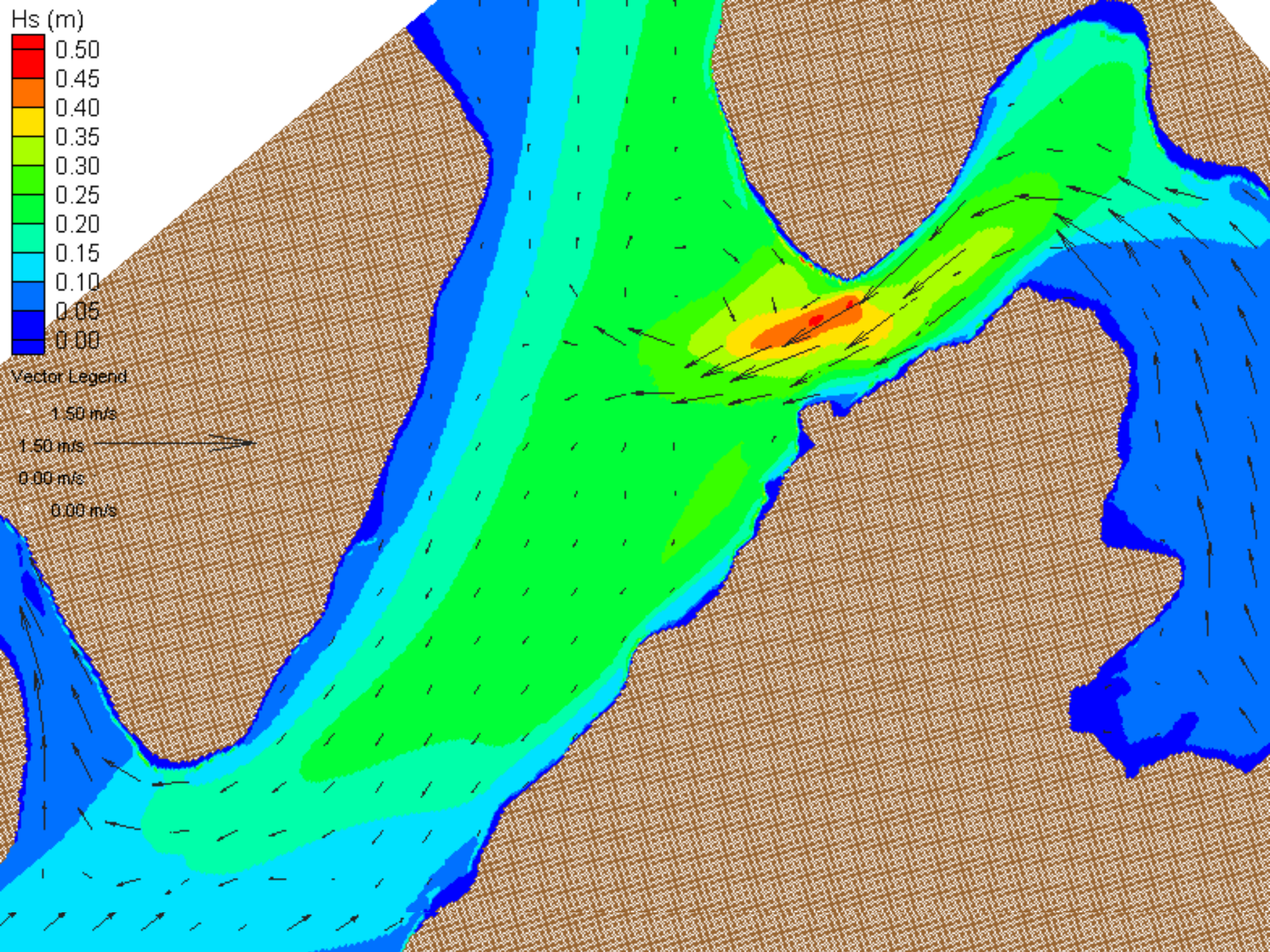

Pt. White
Bremerton
Sea-Tac
47°N
33.00'
122°W
30.00'


Bremerton (15 Sep06 - 15 Jan07)
Frequency of Occurrence, %
Direction of Wind Origin, Az
Wind Spd (kts)
>25
20 ≤25
15 ≤20
10 ≤15
5 ≤10
2 ≤5


Sea-Tac Int'l (15 Sep06 - 15 Jan07)
Frequency of Occurrence, %
Direction of Wind Origin, Az
Wind Spd (kts)
>25
20 ≤25
15 ≤20
10 ≤15
5 ≤10
2 ≤5



- Fully validated with local wind and wave measurements throughout study area
- Long term simulations of full seasonal climatology


Hs (m)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Vector Legend
1.50 m/s
1.50 m/s
0.00 m/s
0.00 m/s

- Governing equations:

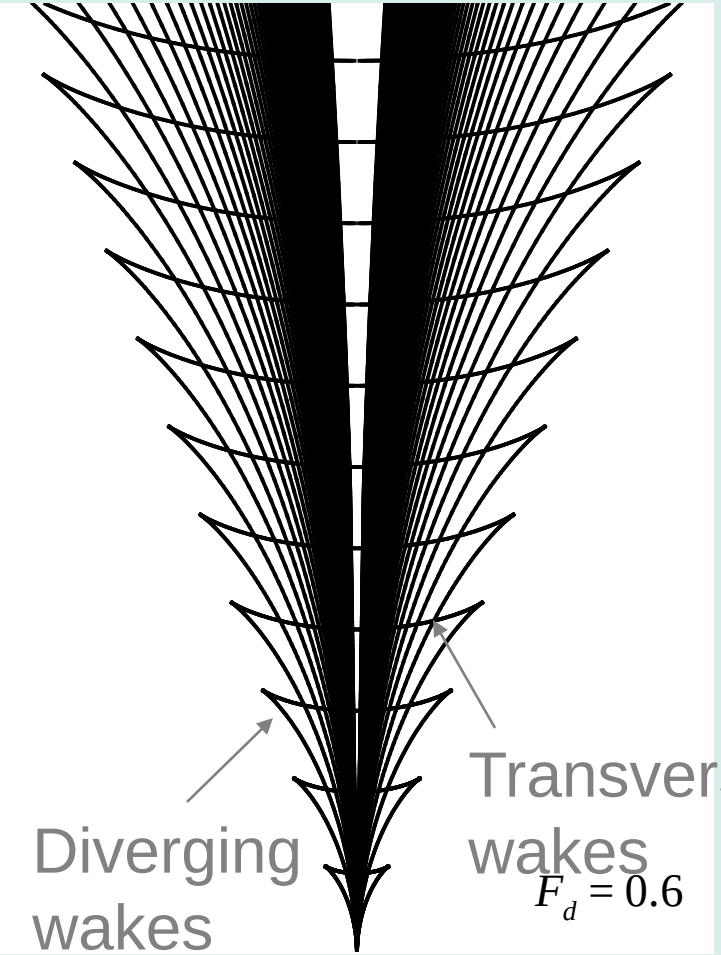
$$\int_{t_0}^{t_1}\left[\frac{dE}{dt}+E\left(\frac{\partial U}{\partial x}+\frac{\partial V}{\partial y}\right)+E\left(\frac{\partial Pc_g}{\partial x}+\frac{\partial Qc_g}{\partial y}\right)\right]dt=D$$

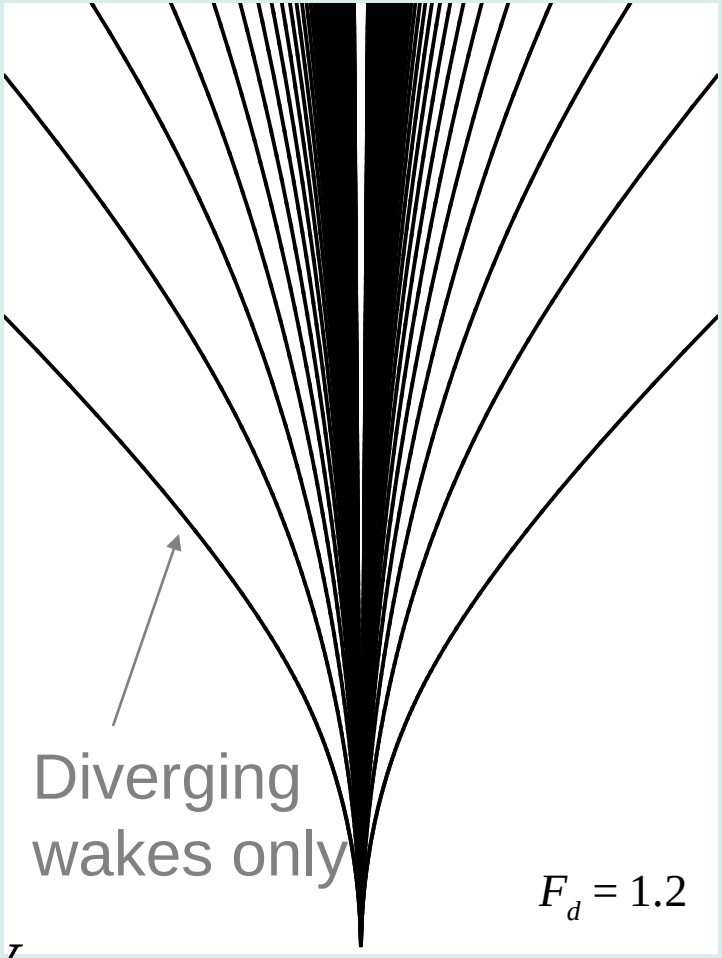
$$\int_{t_0}^{t_1}\left[\frac{dP}{dt}+\frac{\sigma\ \ k}{\sinh 2kd}\frac{\partial d}{\partial x}+P\frac{\partial U}{\partial x}+Q\frac{\partial V}{\partial x}\right]dt=0$$

$$\int_{t_0}^{t_1}\left[\frac{dQ}{dt}+\frac{\sigma\ \ k}{\sinh 2kd}\frac{\partial d}{\partial y}+P\frac{\partial U}{\partial y}+Q\frac{\partial V}{\partial y}\right]dt=0$$

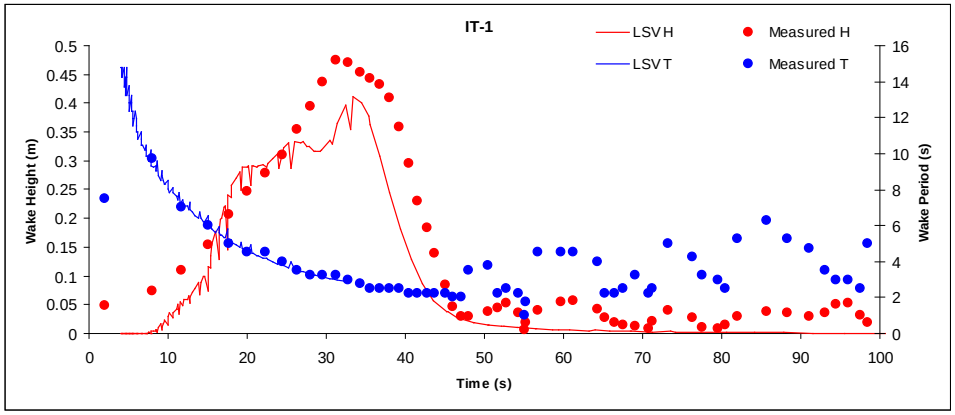
$$\frac{dx}{dt}-c_g\frac{P}{k}-U=0 \qquad \frac{dy}{dt}-c_g\frac{Q}{k}-V=0$$

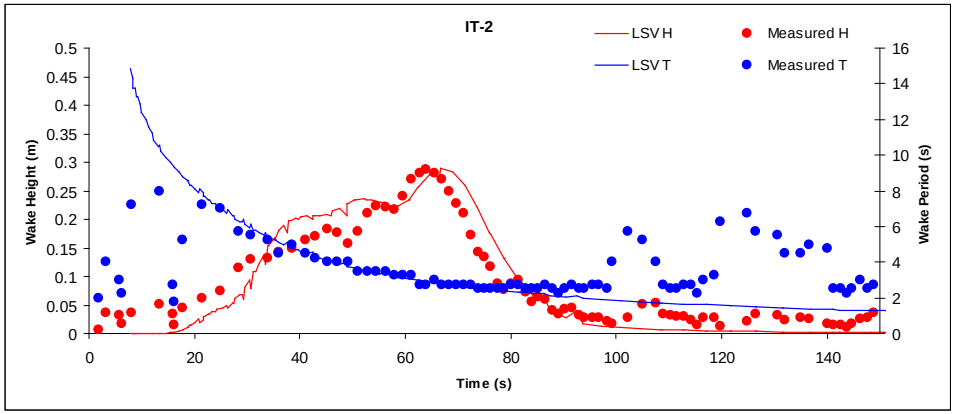
- Need boundary conditions…

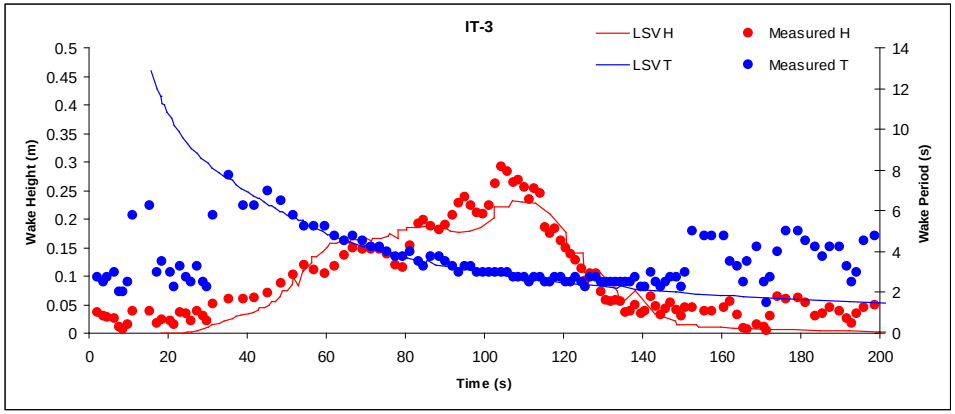


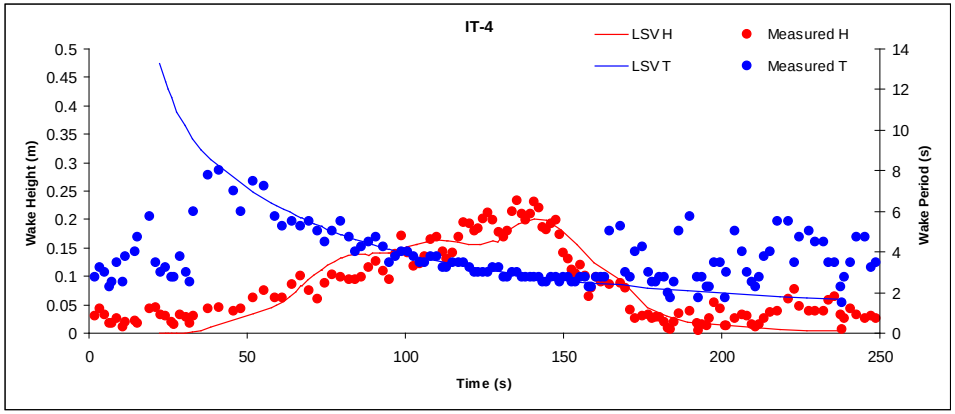


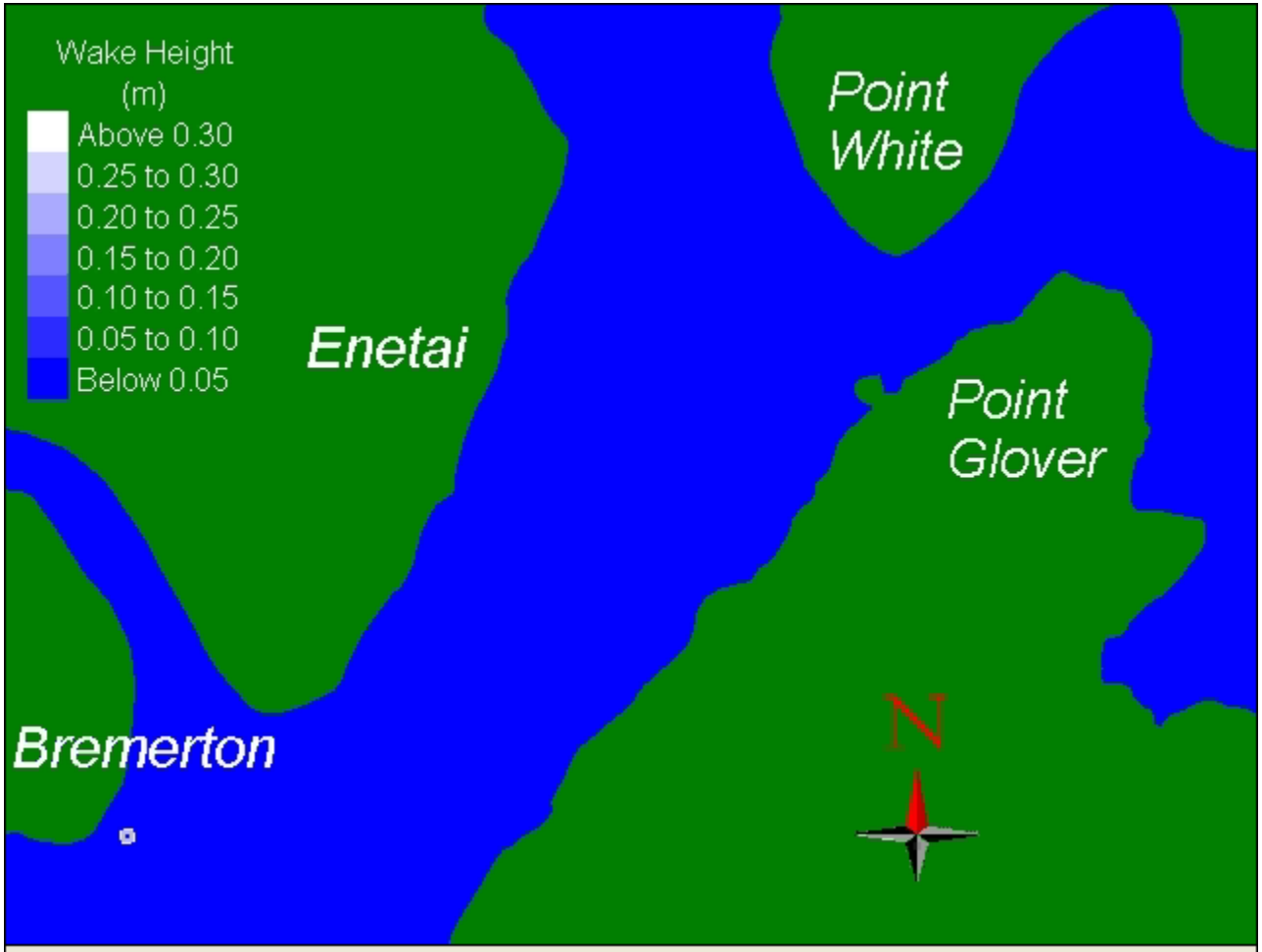
Sub-critical $F_d = \frac{V}{\sqrt{gd}}$ Super-critical


IT-1
LSV H
LSV T
Measured H
Measured T
Wake Height (m)
Wake Period (s)
Time (s)


IT-2
LSV H
LSV T
Measured H
Measured T
Wake Height (m)
Wake Period (s)
Time (s)


IT-3
LSV H
LSV T
Measured H
Measured T
Wake Height (m)
Wake Period (s)
Time (s)


IT-4
LSV H
LSV T
Measured H
Measured T
Wake Height (m)
Wake Period (s)
Time (s)



Bremerton-Seattle-7

Sunday

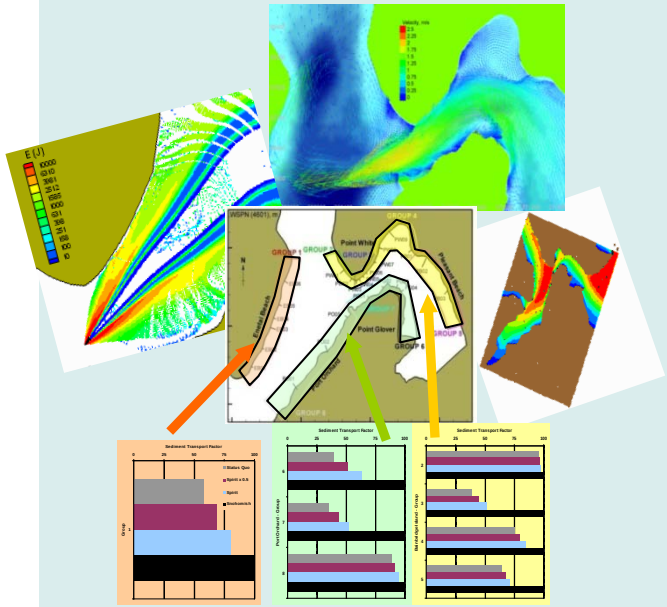
Monday, Tuesday, Wednesday

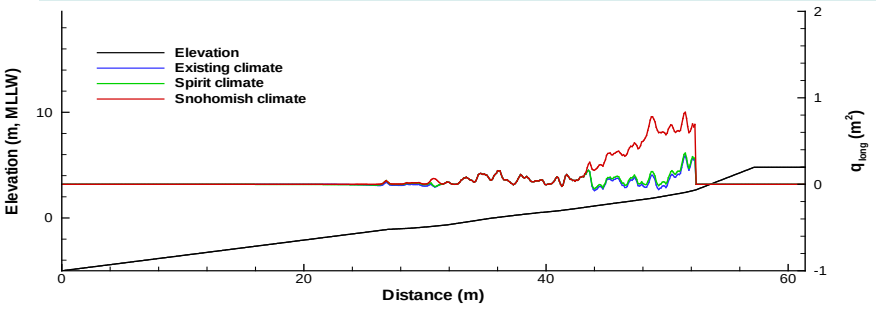
Thursday

Friday

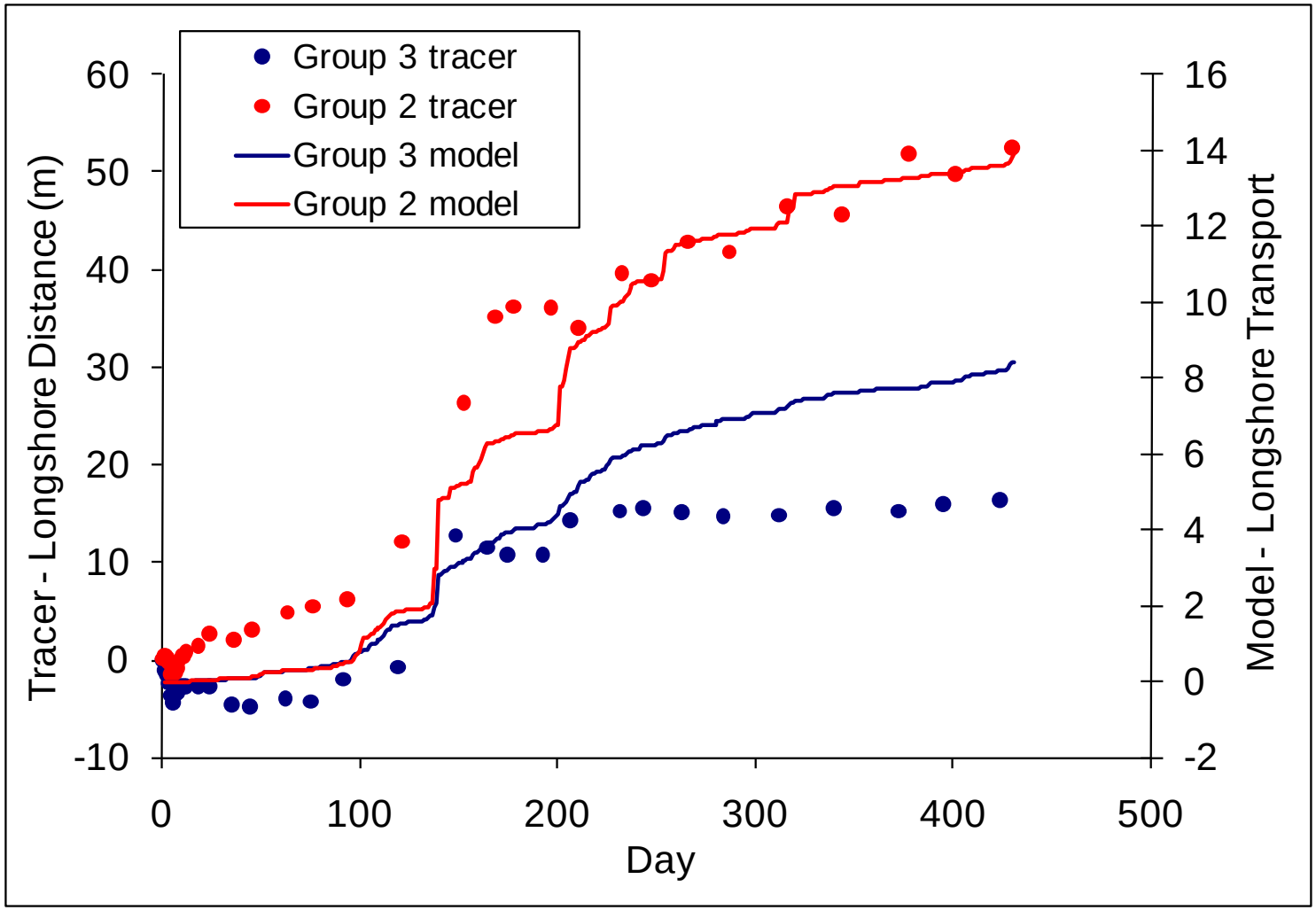
Saturday

- Time series of wind speeds, directions → wind wave climate
- Daily vessel schedules:
  - WSF + Other
  - POFF + WSF + Other





- Time series of wind speed, direction
  - 3 CMSWave models – storm waves: H, T, α
- Time series of vessel traffic and modeled wake time series for representative vessels: H, T, α
- ADCIRC – tidal currents, u,v
- Soulsby-Damgaard (2005) bedload transport under asymmetric waves with current
- Δt =1 sec
- Transform waves/wakes across profile
- Calculate q at each step & integrate across profile


Group 3 tracer
Group 2 tracer
Group 3 model
Group 2 model
Tracer - Longshore Distance (m)
Model - Longshore Transport
Day
60
50
40
30
20
10
0
-10
16
14
12
10
8
6
4
2
0
-2
0
100
200
300
400
500

November to April

- Alongshore transport 6 to 90 times non-storm transport
- Offshore transport of coarse sediment
- Sand, flat upper beach slope
- Dominated by wind waves, site specific exposure

May to October

- Minimal alongshore transport
- Onshore transport
- Gravel berm formation in upper beach, steepening
- Contributions from vessel wakes and tidal currents

Dominant

Subordinate

- Wind waves
  - Site specific alongshore transport
  - Offshore transport & flattening
- Super-critical wakes (fast POFs)
  - Offshore transport & flattening
- Sub-critical wakes (car ferries)
  - Onshore transport (post-storm recovery & steepening)
  - Site specific alongshore
- Tidal currents
  - Cannot mobilize tracer-sized particles
  - Enhance alongshore transport in combination with ferry wakes

- MSG Transport Prediction on Puget Sound Beaches requires careful attention to
  - Site specific validation of multiple models/components
  - Spatial/temporal sediment size distributions and differential transport of sizes and sediment supply
  - Spatial (alongshore) and temporal variability in forcing mechanisms
    - 1D model domain not shifting with tracers
- Integrated modeling approach provides efficient tool(s) for system wide impact indicators
  - Relative importance of key processes
  - Sediment mobility
  - Sediment transport potential
  - Scour depth at toe of seawall
  - Pre-assessment and optimization of candidate vessel operations