Littoral Hydrodynamics and Sediment Transport around a Semi-Permeable Breakwater

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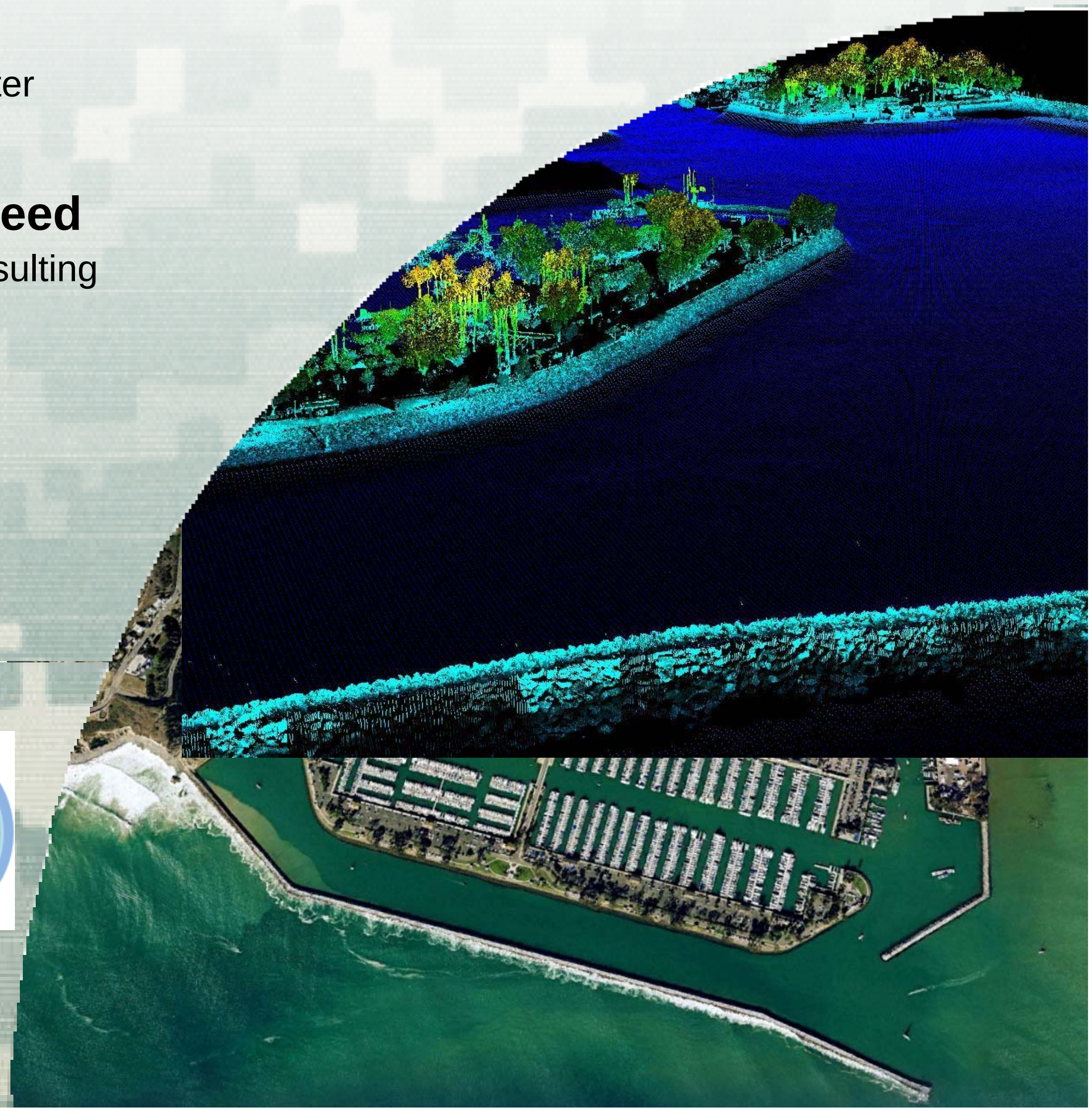

Coasts and Ports 2015
Auckland, New Zealand
September 18, 2015

US Army Corps of Engineers
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Outline

- Introduction
- Data
- Method
- Results
- Summary

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Dana Point Harbor and Present Issues

- Sediment seepage increase through the permeable West Breakwater

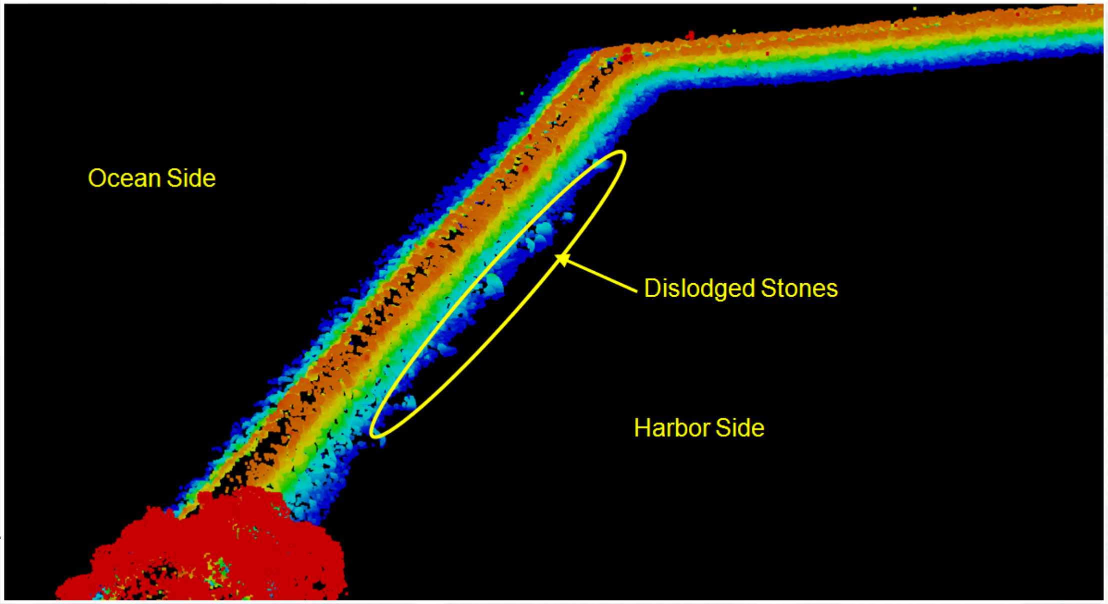
- Sediment built up inside the breakwater ~ 3,800 to 4,600 m^3/year

- Dredge required in last two decades (1989, 1999, 2009)

- Needs for circulation and water quality improvement at Harbor

Bathymetry Survey

- Conducted during October 20–24, 2009
- Side-scan sonar: data below the water surface
- LiDAR: data above the water surface
- East and west breakwater extending out approximately 46 m offshore on the ocean side
- Main navigation and primary access channels on the harbor side within the marina basins



ADCP Measurements

Two ADCPs deployed by Noble Consultants

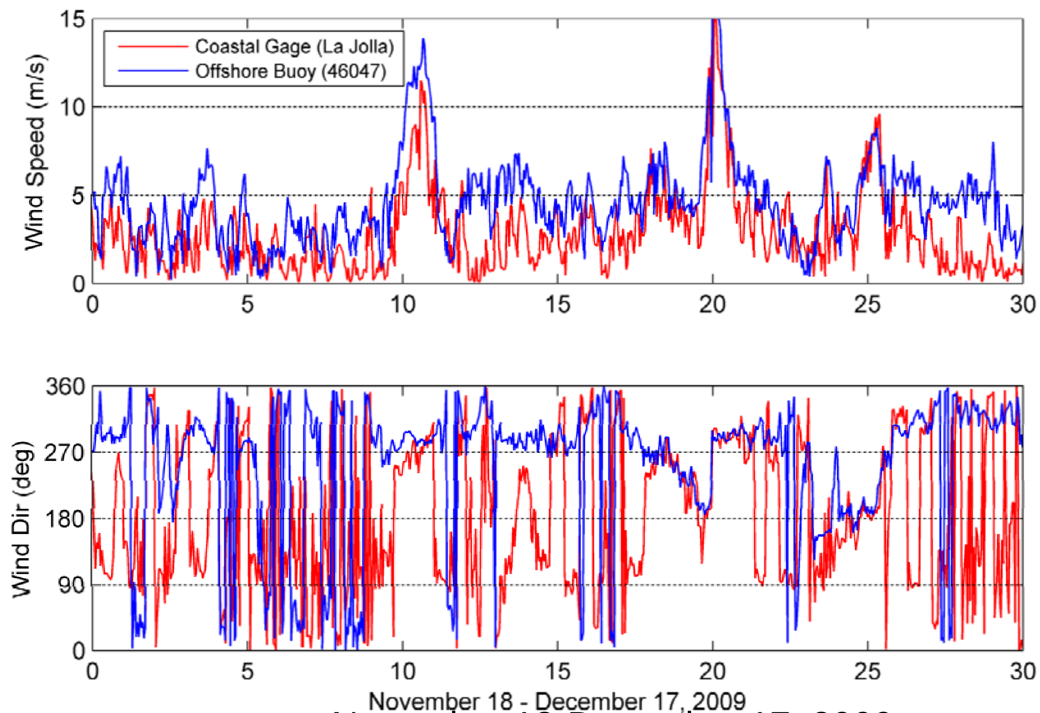
Inside and outside the harbor

Current, water level and directional waves measured

Inside: Depth 7.8 m
11/20/2009-01/15/2010

Outside: Depth 8.4 m
11/20/2009-11/26/2009

CMS-Flow Wind Forcing



November 18-December 17, 2009

Wind at NOAA's La Jolla Gage, 9410230, and an offshore buoy, 46047

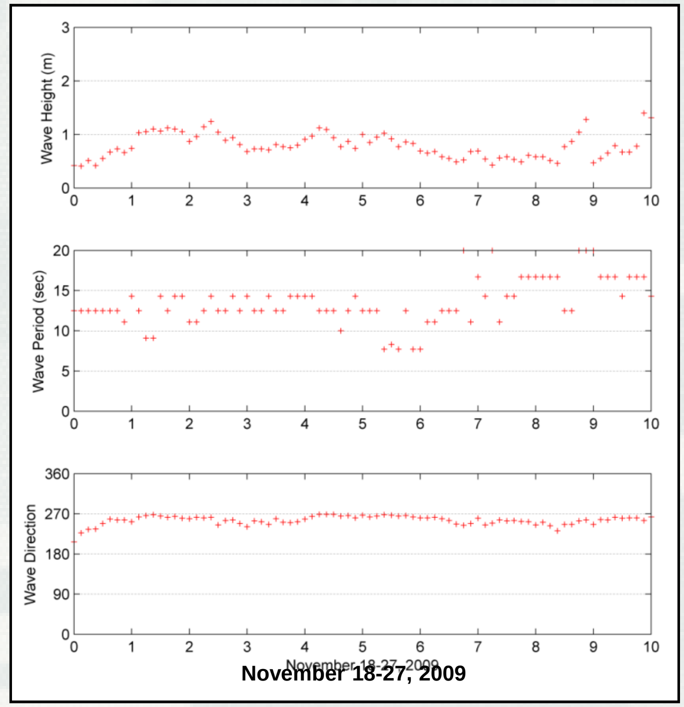
Surface boundary forcing for CMS-Flow

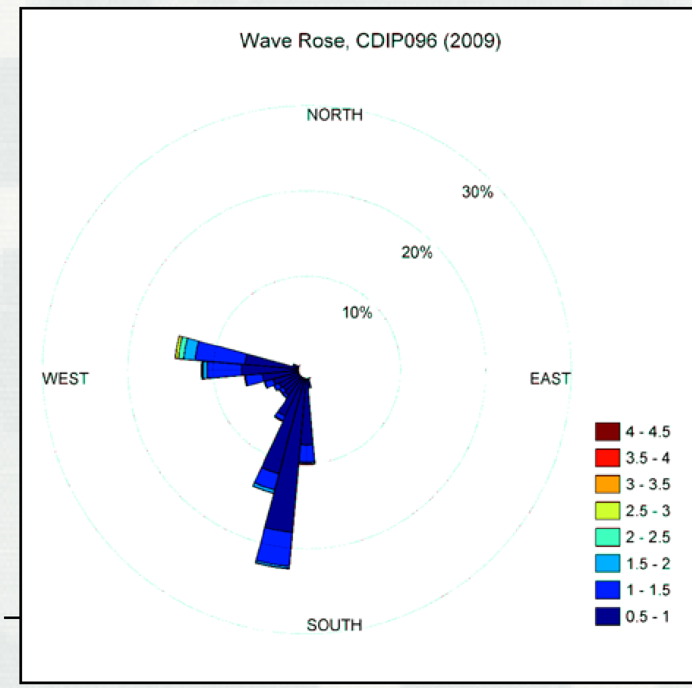
Sea breeze signal

Wind direction: **0° North, 90° East, etc. from which wind blowing**

CMS Wave Forcing

Wave Parameters (CDIP096)





Mean Significant Wave Height: 0.78 m

Mean Wave Period: 13.5 sec

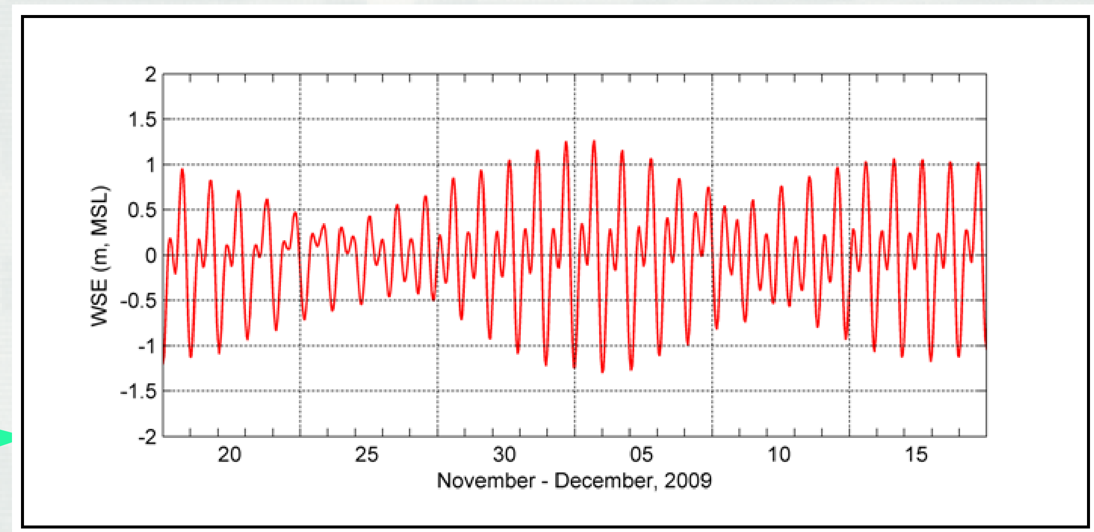
Mean Wave Direction: 255.2°

CMS-Flow Water Level Forcing

Data: Water surface elevation (WSE) at NOAA's Los Angeles Gage, 9410660

Method: Apply WSE along the open boundary

Tide (Los Angeles)

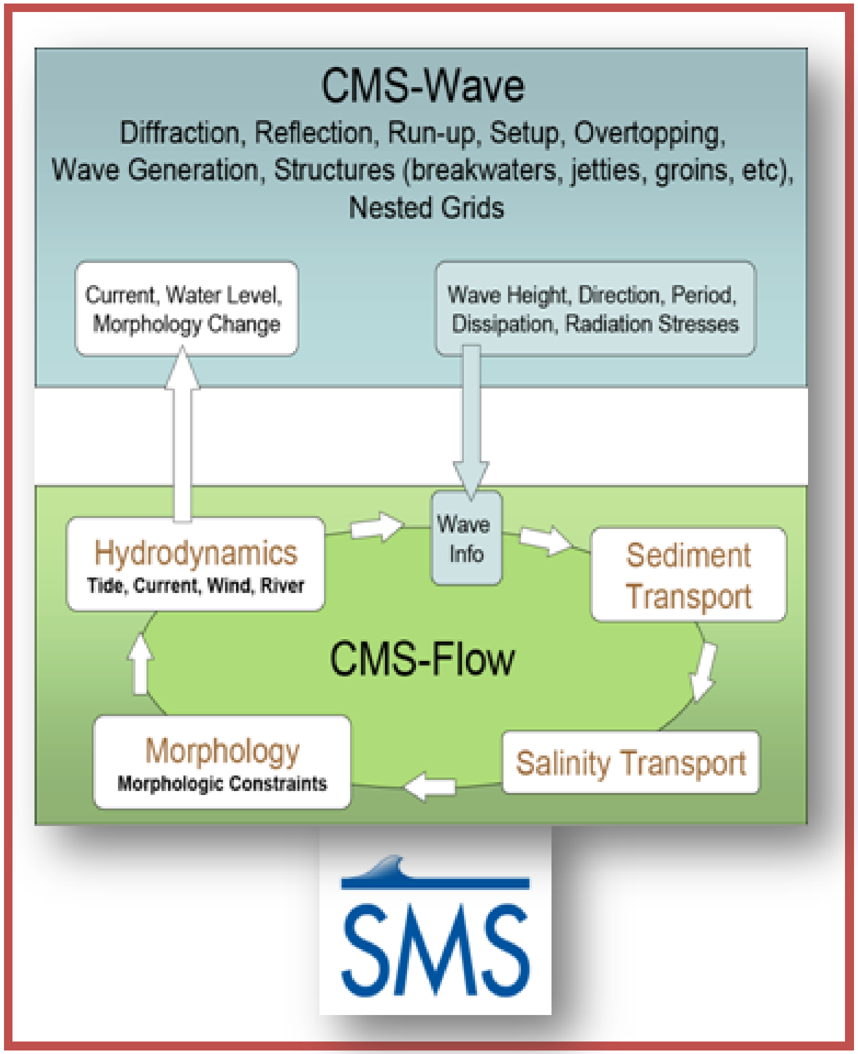


Mixed, predominately semi-diurnal tide

Mean tide range (MHW – MLW): 1.2 m

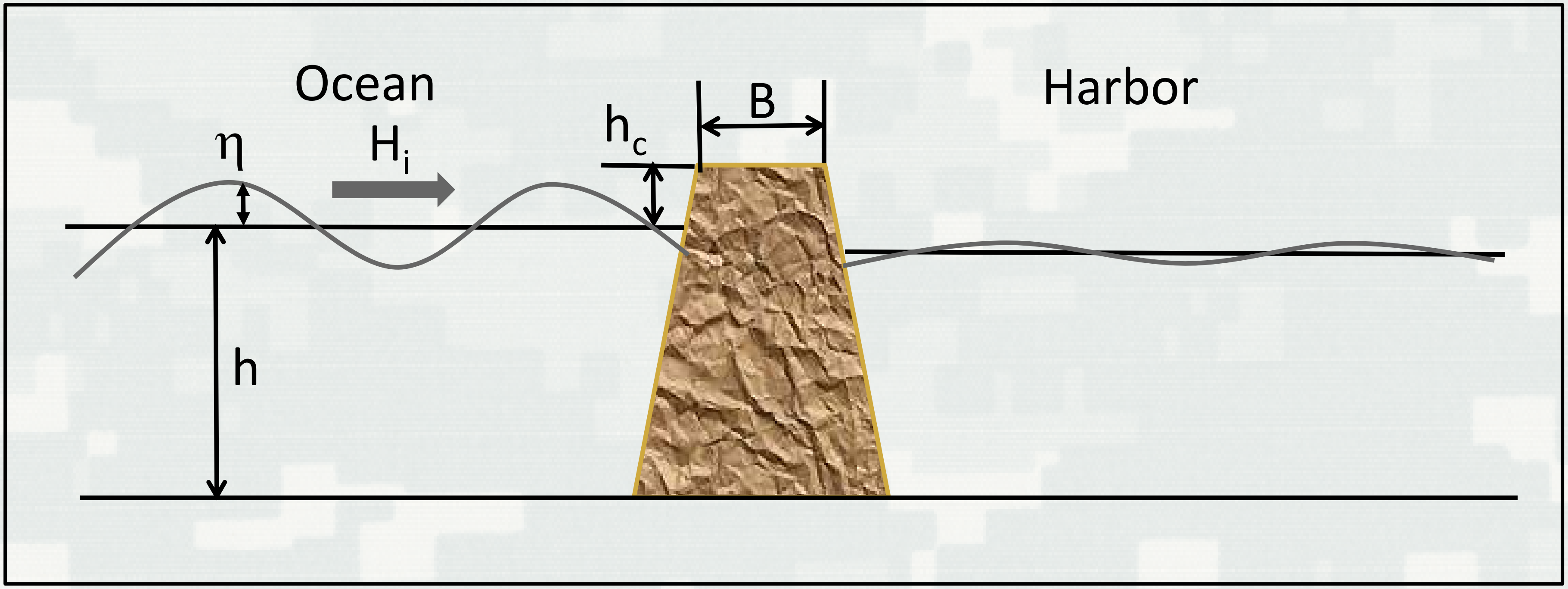
Calibration period: 18 Nov – 17 Dec 2009

Coastal Modeling System (CMS)



- Developed since 1997 by the Coastal Inlets Research Program (CIRP), U.S. Army Corps of Engineers
- An integrated suite of numerical models for simulating water surface elevation, current, waves, sediment transport, and morphology change for coastal applications
- Consists of a hydrodynamic model, CMS-Flow, and a spectral wave model, CMS-Wave
- Coupled and operated within the Surface-water Modeling System (SMS), a GUI.

Implementation of Breakwater Permeability



CMS-Flow:

Hydraulic Conductivity
Void Factor (Porosity)
Crest Elevation

CMS-Wave:

Porous Breakwater Wave Transmission (Porous Section below MWL)

CMS-Wave Permeable Breakwater

Wave Transmission Calculation
(D'Angremond et al. 1996):

$$K_t = 0.64\left(\frac{B}{H_i}\right)^{-0.31}\left[1-\exp\left(-\frac{\xi}{2}\right)\right] - 0.4\frac{h_c}{H_i}, \quad \text{for} \quad B < 10\ H_i$$

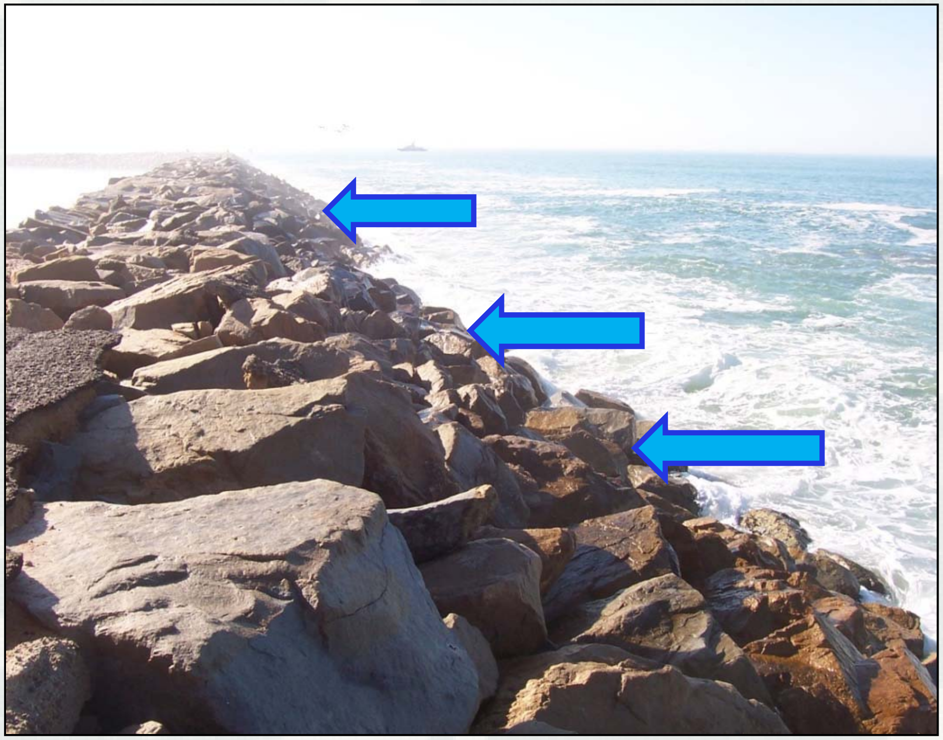
ξ: the Iribarren Parameter – the fore-slope of the breakwater divided by the square-root of the incident wave steepness

CMS-Flow Permeable Breakwater

Equation for laminar and turbulent resistance in porous media (Forchheimer, 1901):

$$I = au + bu^2$$

I : Hydraulic Gradient
u: Flow Speed
a, b: Resistance Coefficients

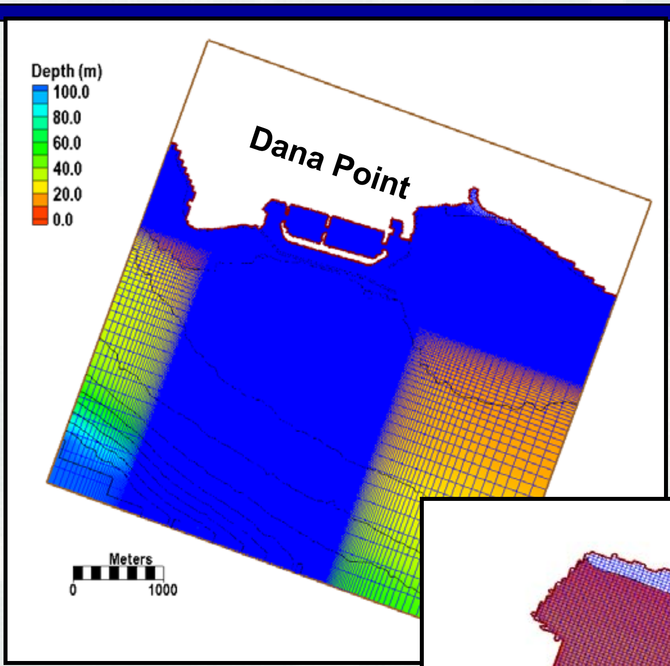


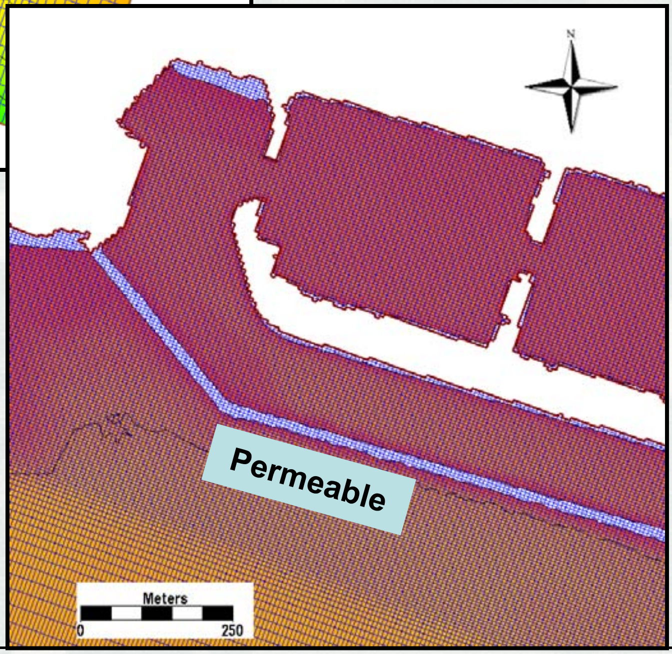
Sidiropoulou et al. (2007)

$$a = 0.003333\, D^{-1.500403}\, n^{0.060350}$$
$$b = 0.194325\, D^{-1.265175}\, n^{-1.141417}$$

D: Rock Diameter
n: Void Factor

CMS Grid and Settings





Current, Waves and Sediment Transport Simulation

CMS Domain:

5 x 5 km

Cell Size:

5 to 70 m

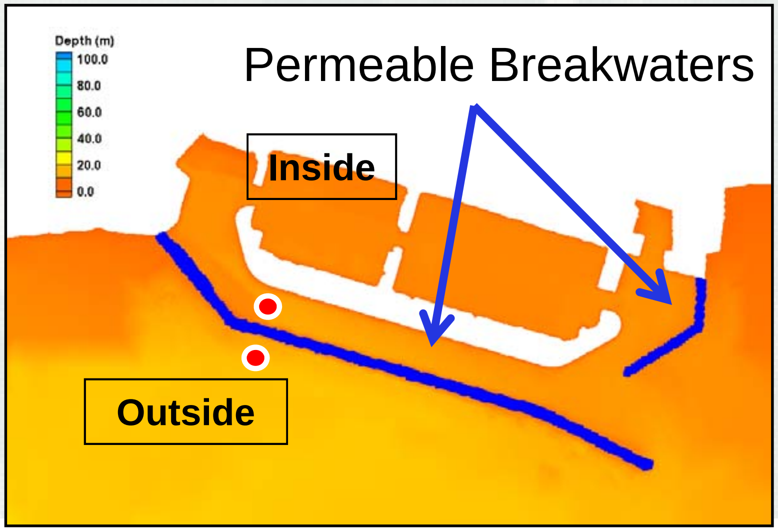
Water Depth:

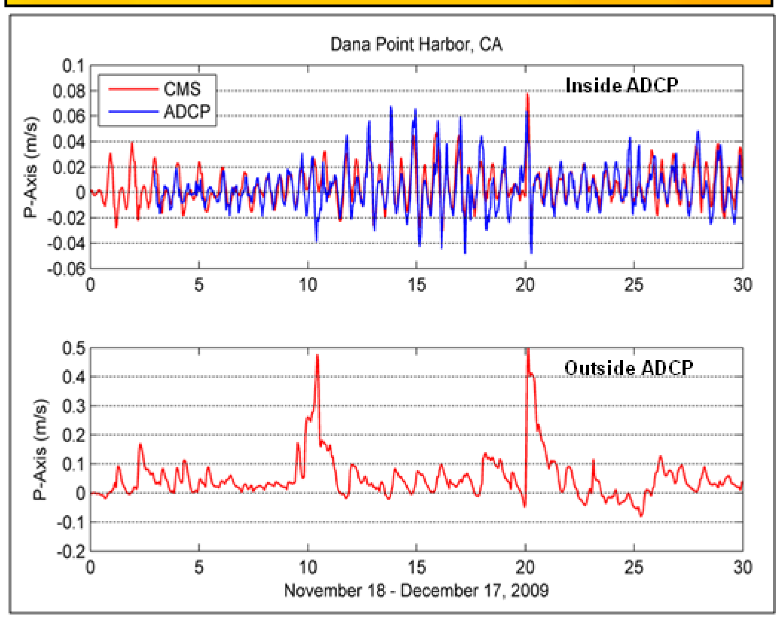
0 to 300 m

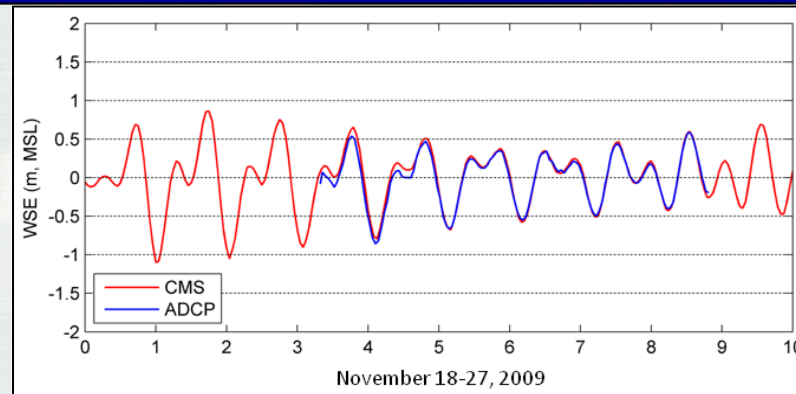
Structure:

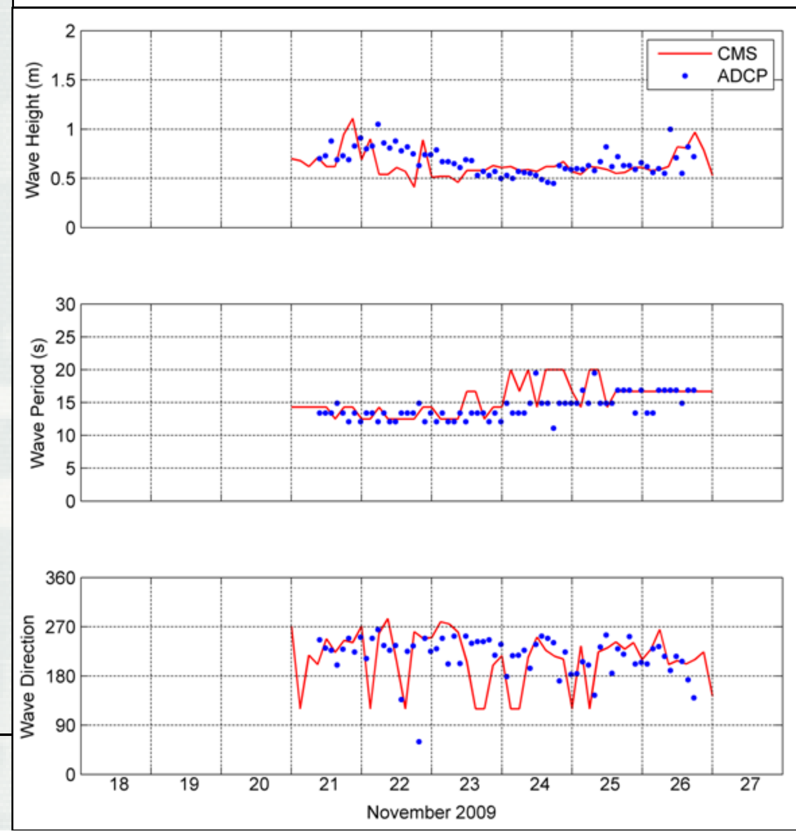
permeable breakwaters

Calculation and Validation





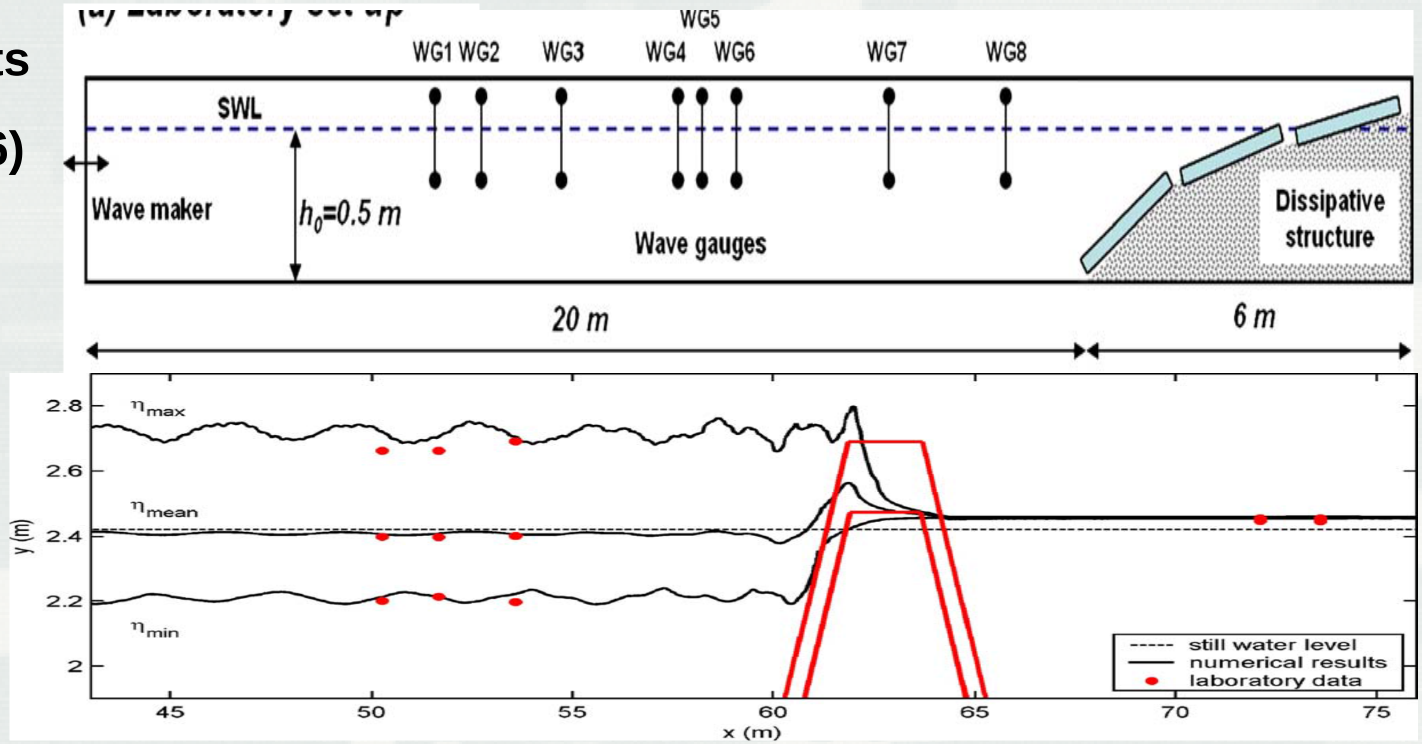




Calculation and Validation

Lab experiments

(Lara et al. 2006)



Experiment	Wave height (m)	Foreslope	Crest width (m)	Crest freeboard (m)
R1F1C2	0.30	1V:2H	1.825	0.07
R1F2C2	0.30	1V:2H	1.825	0.27

Calculation and Validation

Wave height comparison

Experiment	Scenario	Wave Height (m)				
		WG 3	WG 4	WG 5	WG 6	WG 7
R1F1C2	Lab	0.45	0.46	0.51	0.10	0.10
	CMS	0.51	0.51	0.51	0.09	0.09
R1F2C2	Lab	0.47	0.46	0.51	0.01	0.01
	CMS	0.46	0.46	0.46	0.01	0.01

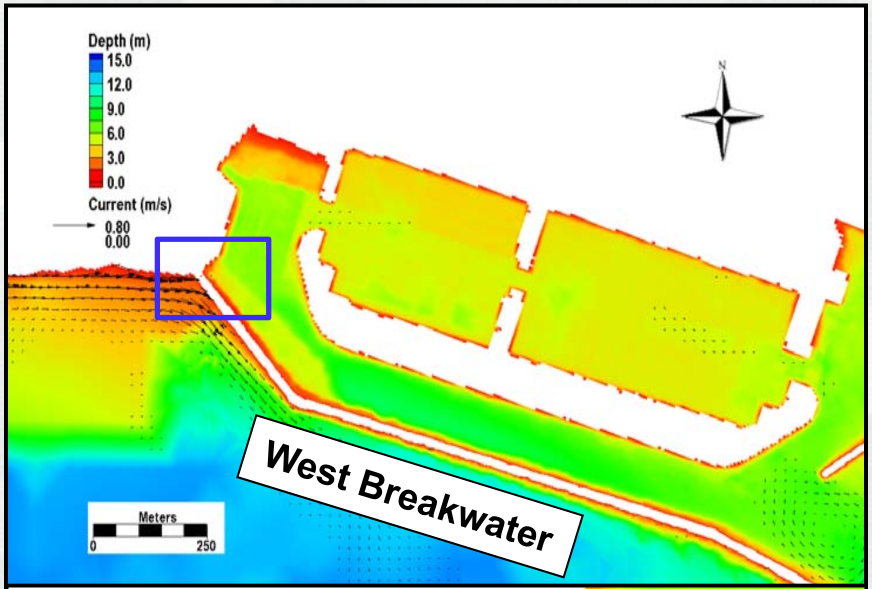
Calculated Current and Waves

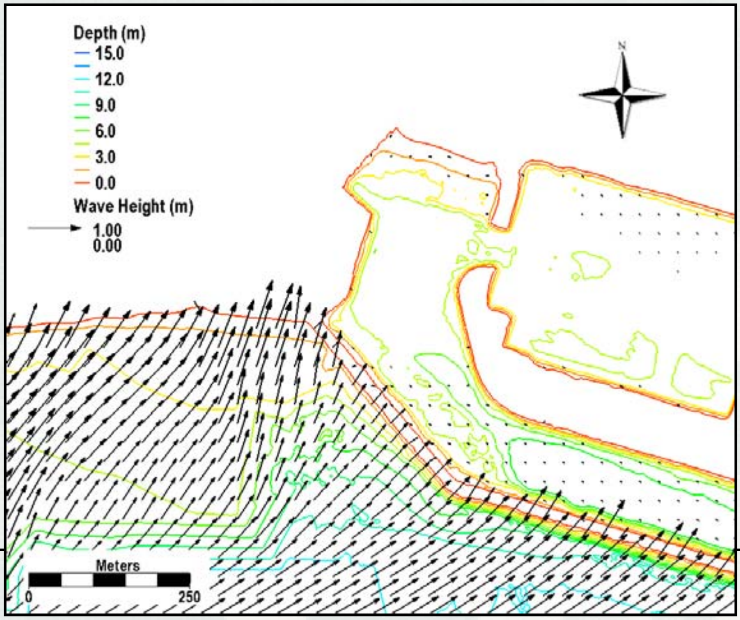
Depth-averaged current:

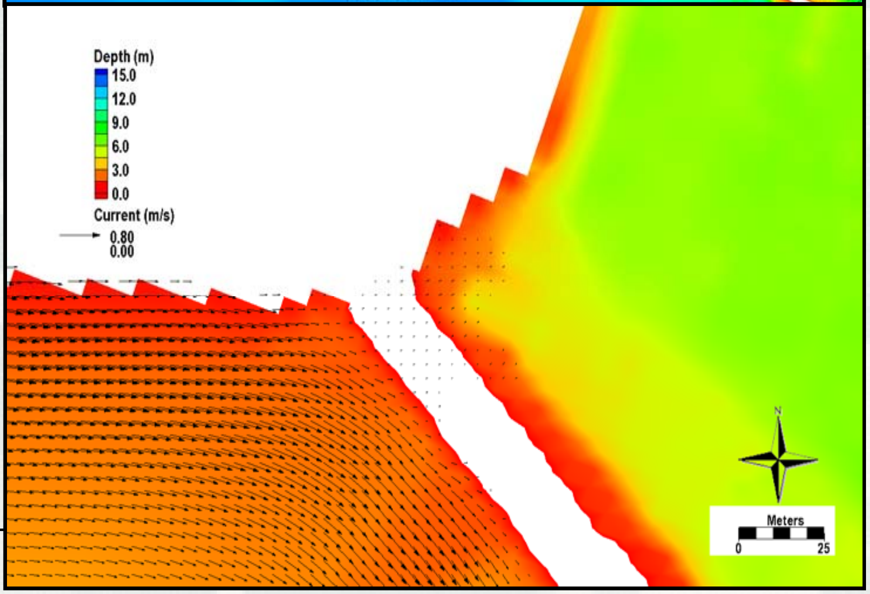
maximum current speed
50–70 cm/s on the ocean side
3–4 cm/s on the harbor side

Waves:

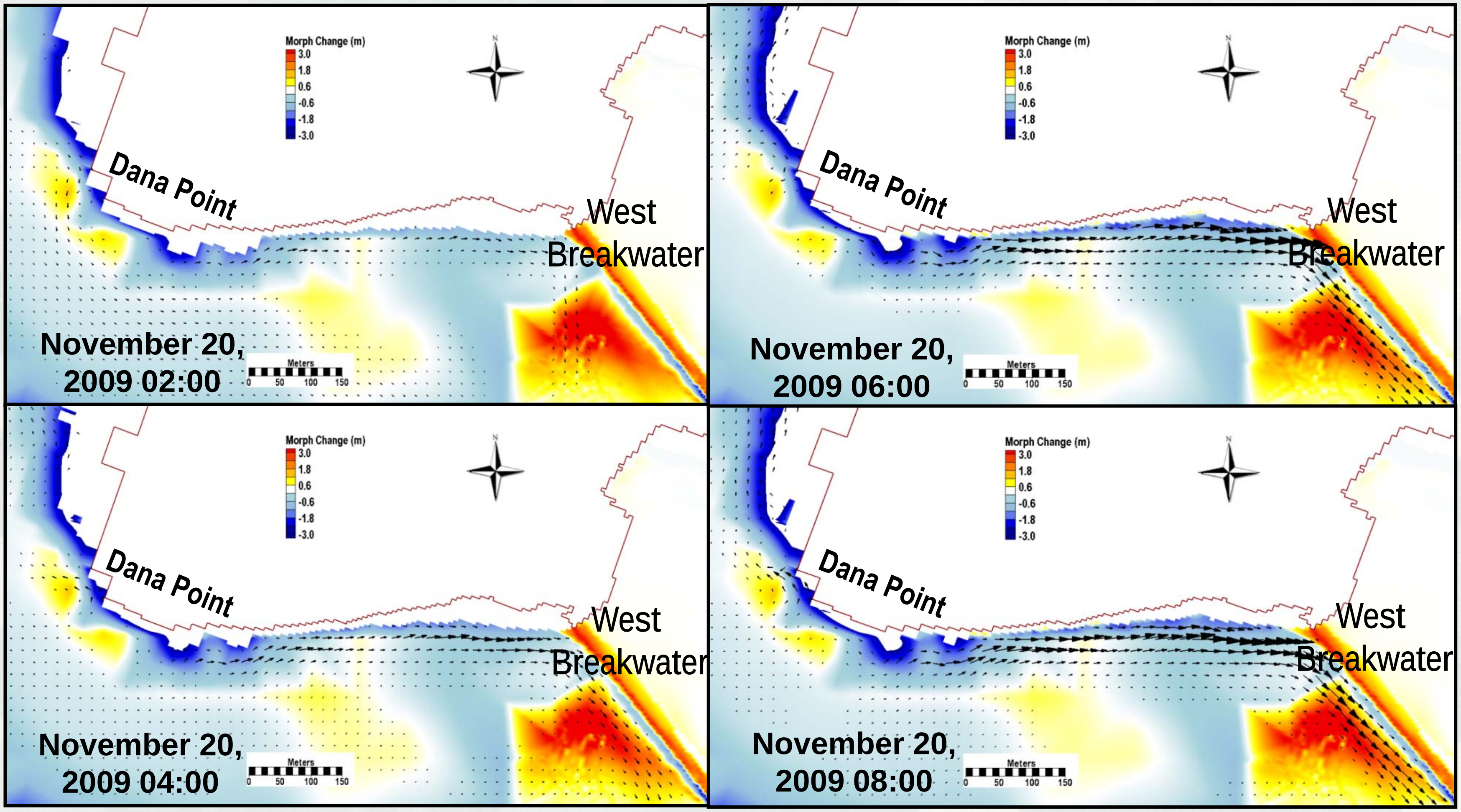
significant height of 0.6–0.7 m.
reduce to 0.05–0.07 m on the harbor side







Calculated Sediment Transport



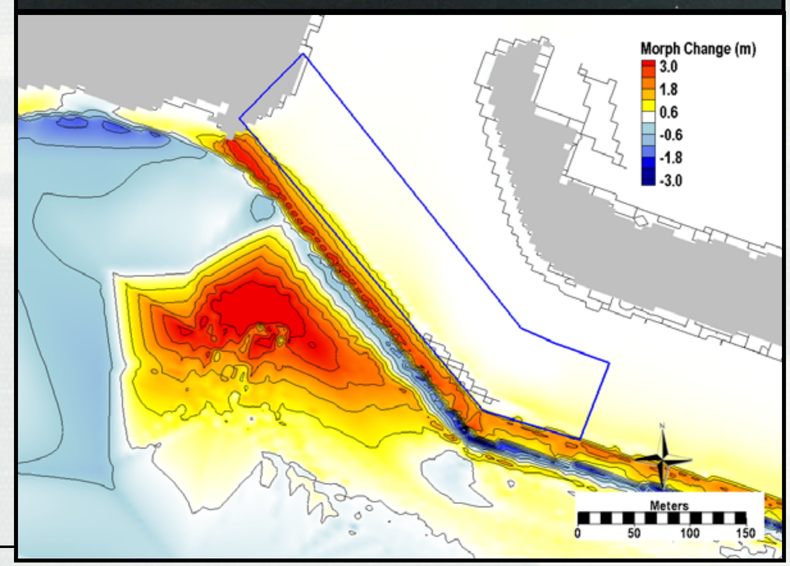
Calculated Sediment Transport

Sediment Transport Through the Structure:

2,600 m^3/year

Based on dredged volumes, average sediment accumulation rate on the harbor side:

3,800-4,600 m^3/year



Summary

- Incorporate calculations of flow and sediment seepage, and wave transmission through a porous structure into CMS to investigate wave, hydrodynamic conditions, and sediment transport.
- The system is tide- and wind-dominated on the harbor side and wave-dominated on the ocean side.
- The calibrated and validated model shows that 4-8% of currents flow and about 10% of wave heights transmits through the structure.
- The annual sediment transport rate obtained from the CMS simulations is reasonably comparable to the sand accumulation rate obtained from the dredging records.

Thank You!

Questions?

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