

Best Practice Criteria for Marine Dredging to Minimize Impacts on Coastal Erosion

by
Emre Otay

Bogazici University

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Outline

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 BEACH PROFILES, SHORELINE, WAVES & CURRENTS
- THEORY
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 STATISTICAL ESTIMATION OF THE CLOSURE DEPTH
- INDIRECT EFFECTS – Longshore Sediment Transport
 WAVE TRANSFORMATION – Refraction, Diffraction, etc.
 PERTURBATIONS IN LONGSHORE CURRENT FIELD
 SHORELINE CHANGE
- CONCLUSIONS TOWARDS RATIONAL DREDGING
 CRITERIA

Alternative: Coastal Sand Mining



NW Coast of Istanbul, 1999

Introduction

Findings are based on experimental and numerical studies by Demir (2002 and 2004) and Samancı (2005) at Boğaziçi Univ.

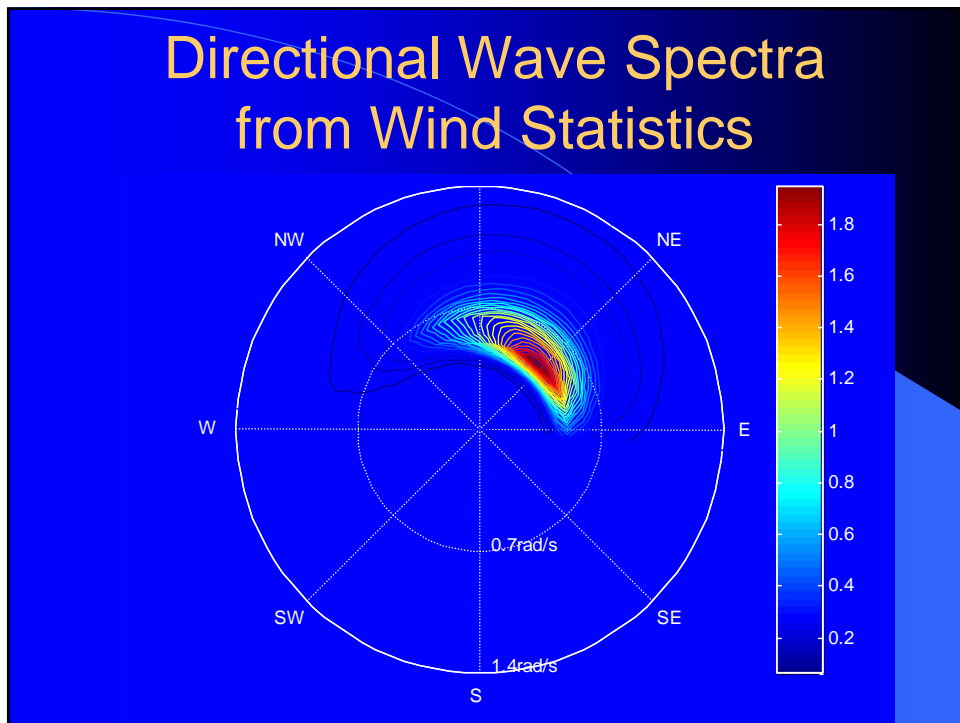
- Starting Point: Reinforced concrete is the primary construction material in Turkey.
- Approx. 30% of concrete mix is sand.
- Sand demand in Istanbul is 10 million m³ per year.
- Approx. 10% of this amount is dredged from offshore.

Dredging Sites in Istanbul

- Before scientific studies, dredging in the Black Sea was only allowed 3 nm offshore and beyond (corresponds to approx. 70 m and deeper).
- Dredging at these depths are not feasible
- Dredging in Istanbul Region continues at few licensed earlier sites West of Bosphorus, 1 nm offshore at 20-25 meters water depths.

Dredging Operation with Clam Shell

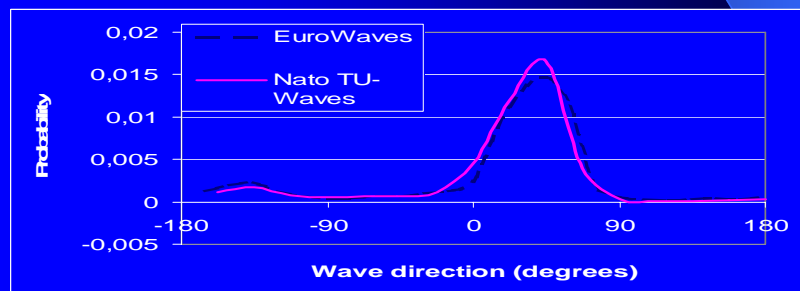
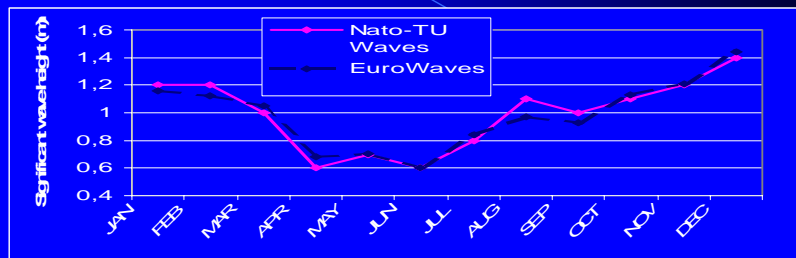




Wave Climate in the Black Sea

- **Nato-TU Waves** (Özhan and Abdalla, 1999).
directional distribution of wave heights.
- **Eurowaves:** (Cavaleri et al, 1999).
JPD of wave height and period.
- Both data sets rely on numerically generated waves from measured weather data.
- Both predict similar wave conditions for Kilyos:
 $H_s=1.0$ m., $T_m=5.15$ s.

Wave Statistics in the SW Black Sea



Aerial Photo of the Project Site



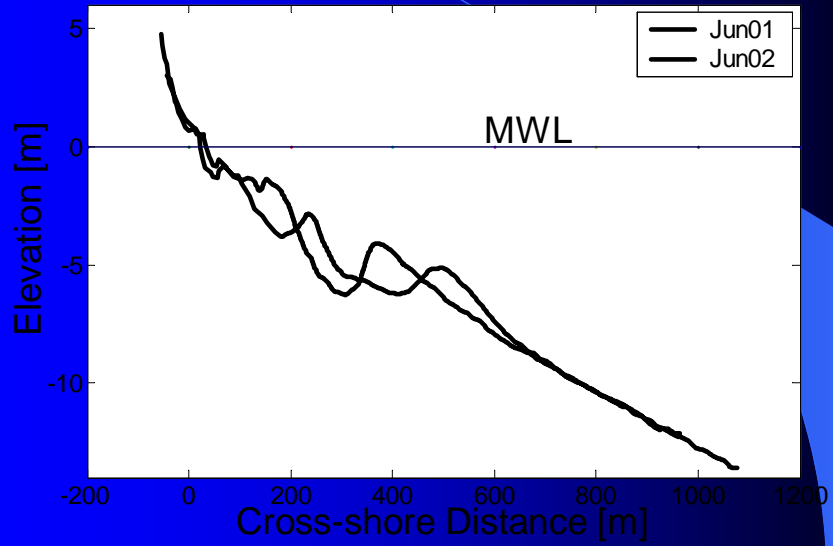
Field Measurements

- Profile measurements
- Shoreline measurements
- Bathymetry measurements
- Sediment sampling
- Wave and current measurements

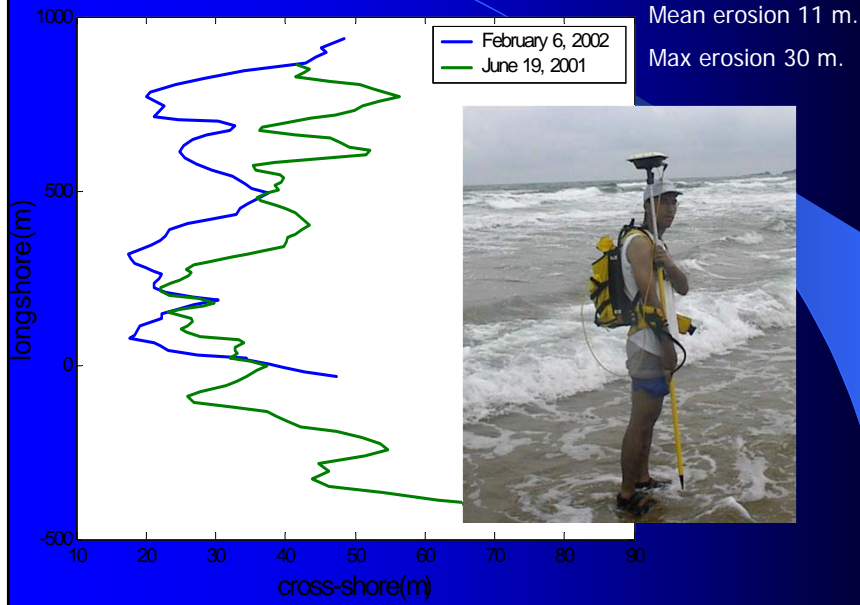
Profile Measurements



Ambient Profile Change

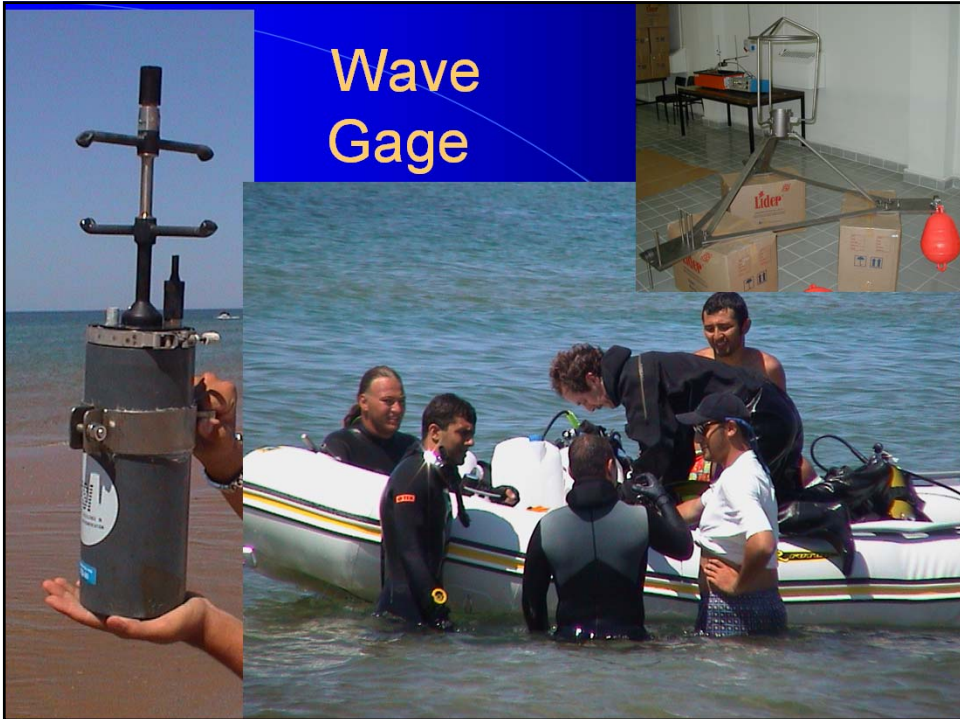
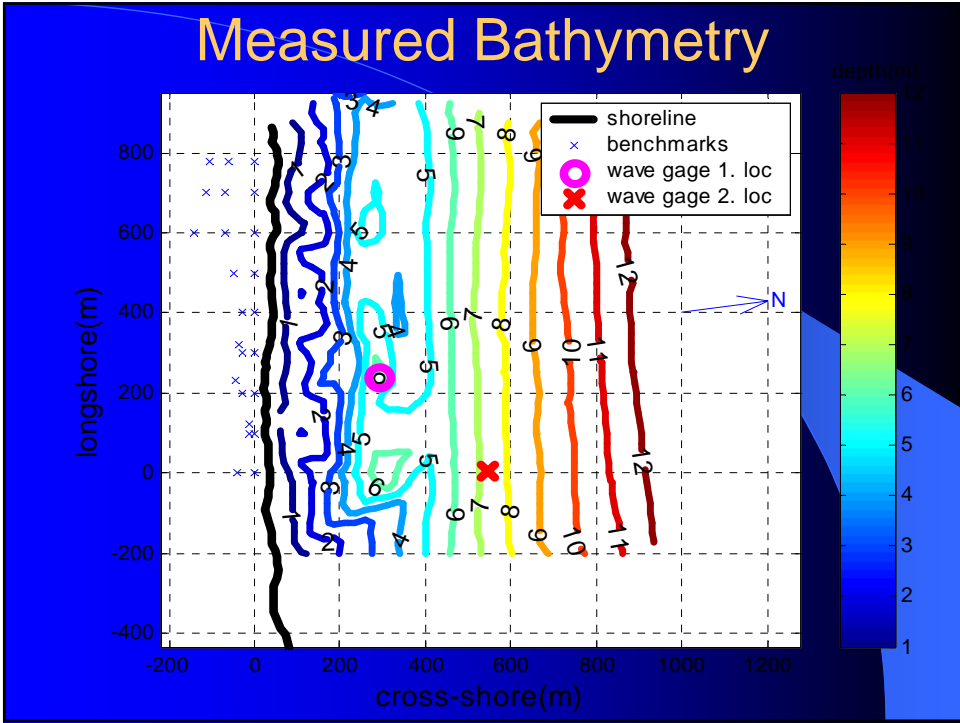


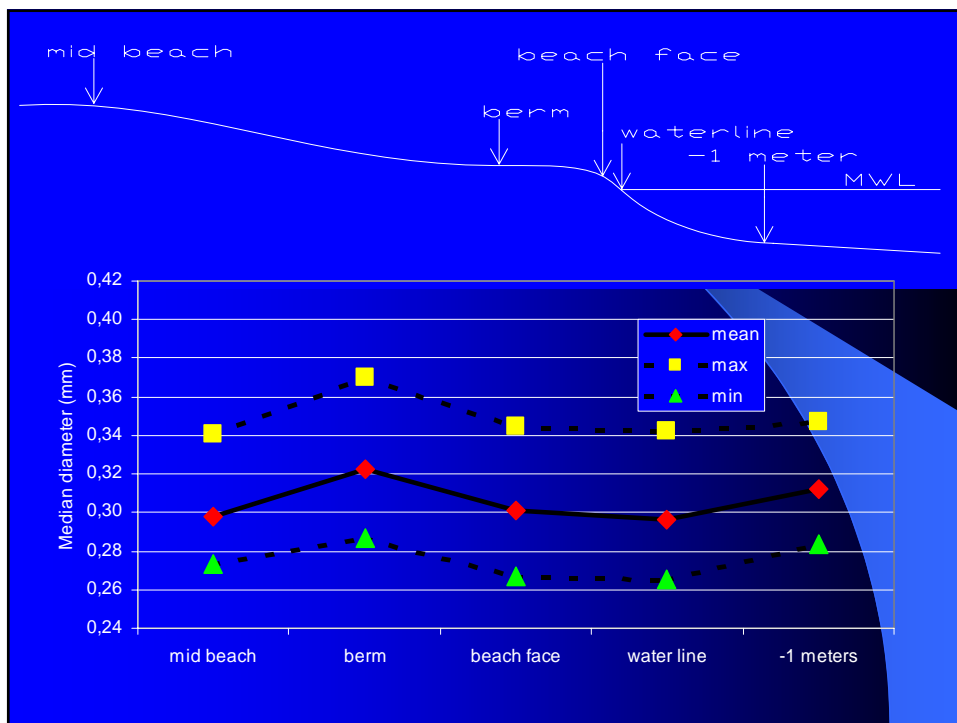
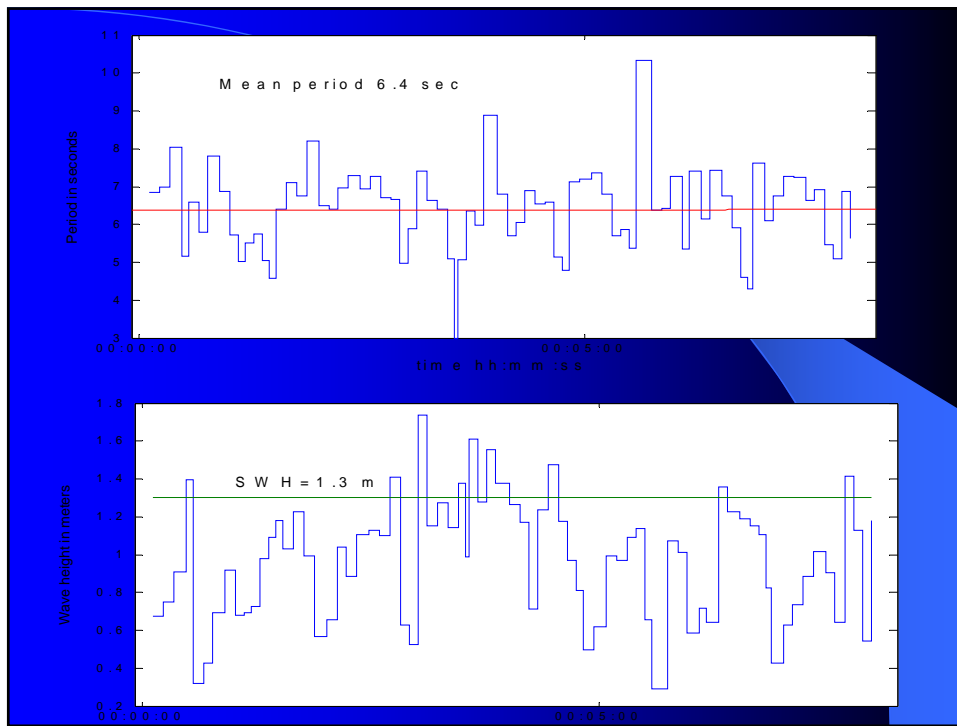
Profile Measurements



Bathymetry Measurements



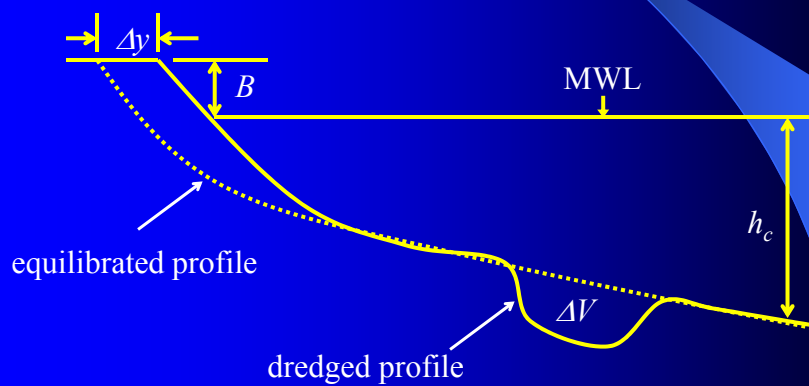




Theory

- DIRECT EFFECTS OF DREDGE HOLES
 - CROSS-SHORE PROFILE EQUILIBRATION
 - CROSS-SHORE SEDIMENT TRANSPORT FILLS THE HOLE
 - NET LOSS OF BEACH
- INDIRECT EFFECTS OF DREDGE HOLES
 - WAVE TRANSFORMATION ACROSS THE PIT
 - PERTURBATIONS IN LONGSHORE CURRENT FIELD
 - LONGSHORE SEDIMENT TRANSPORT
 - DEFORMATION IN SHORELINE SHAPE

Direct Effects (Profile Equilibration)



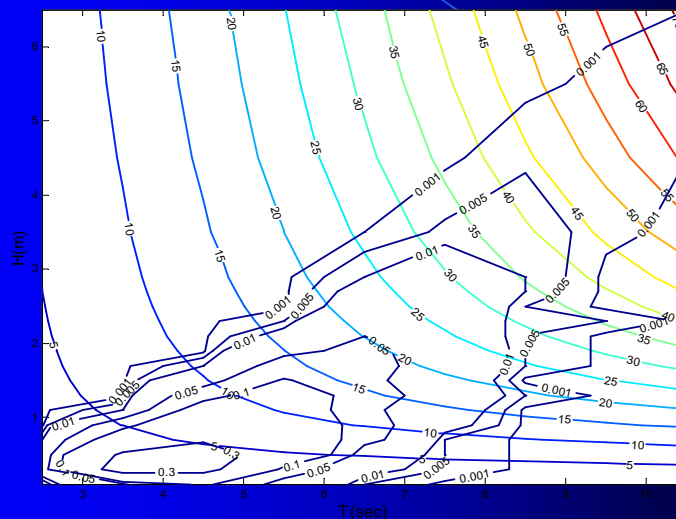
Closure Depth Concept

- Sediment movement decreases with increasing water depth
- Hallermeier (1980): sand motion initiation for turbulent boundary flow

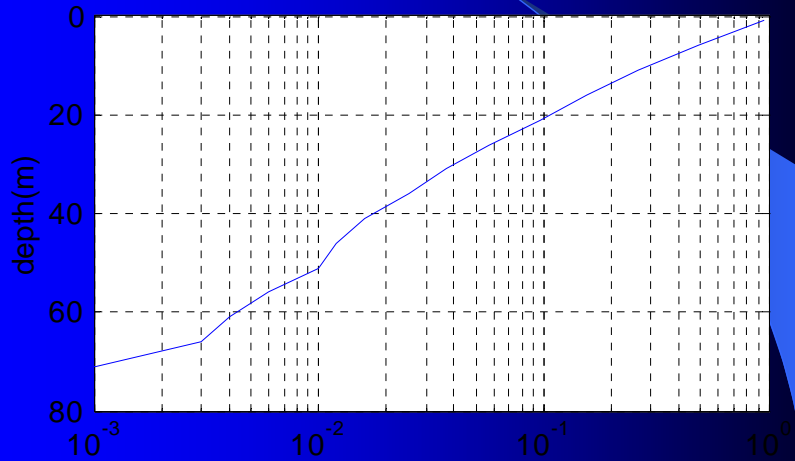
$$U_b = (8(s-1)gD)^{0.5}$$

U_b = Maximum Horizontal Fluid Velocity at the Sea Bed
 s = Specific Gravity
 D = Sediment Grain Diameter

JPDF of Wave Height and Period with Associated Closure Depths



Probability of Sand Motion at a Specified Depth



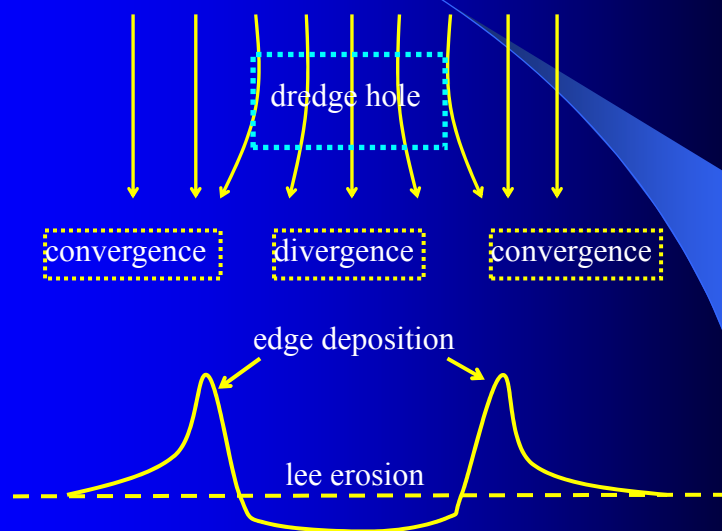
Indirect Effects - State of the Art

- Motyka and Willis (1974) and Horikawa et al. (1977). Refraction effects, 1-line model with 1st transport term only. Shoreline shape opposite.
- Basco and Lonza (1997), Maa and Hobbs (1998), Maa and Hobbs (2001). Various wave transformation models, real bathymetry, change in sediment transport.
- Bender (2001) using Williams (1990) diffraction model. 1-line model, effects of 2nd transport term.

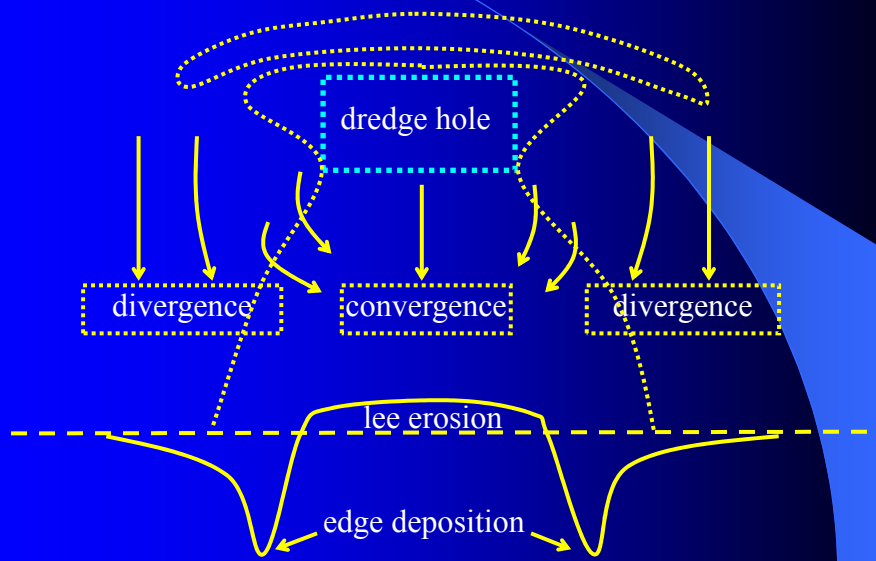
Salient Formation Adjacent to Borrow Area (Combe and Soileau, 1987)



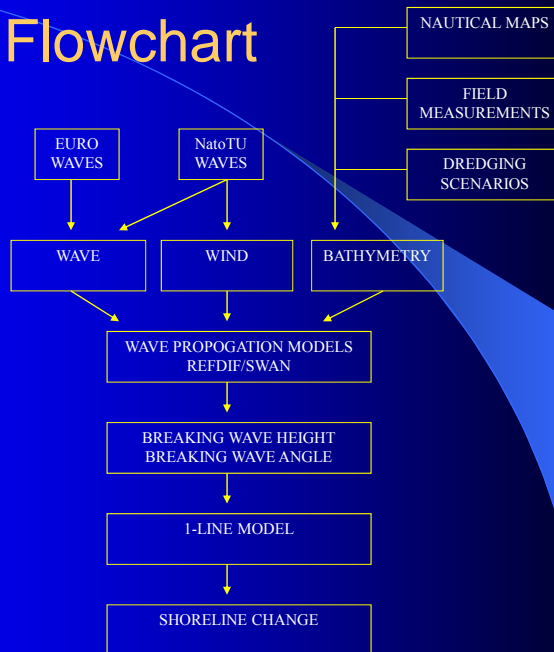
Shoreline Response to Wave Refraction



Shoreline Response to Wave Diffraction



Model Flowchart

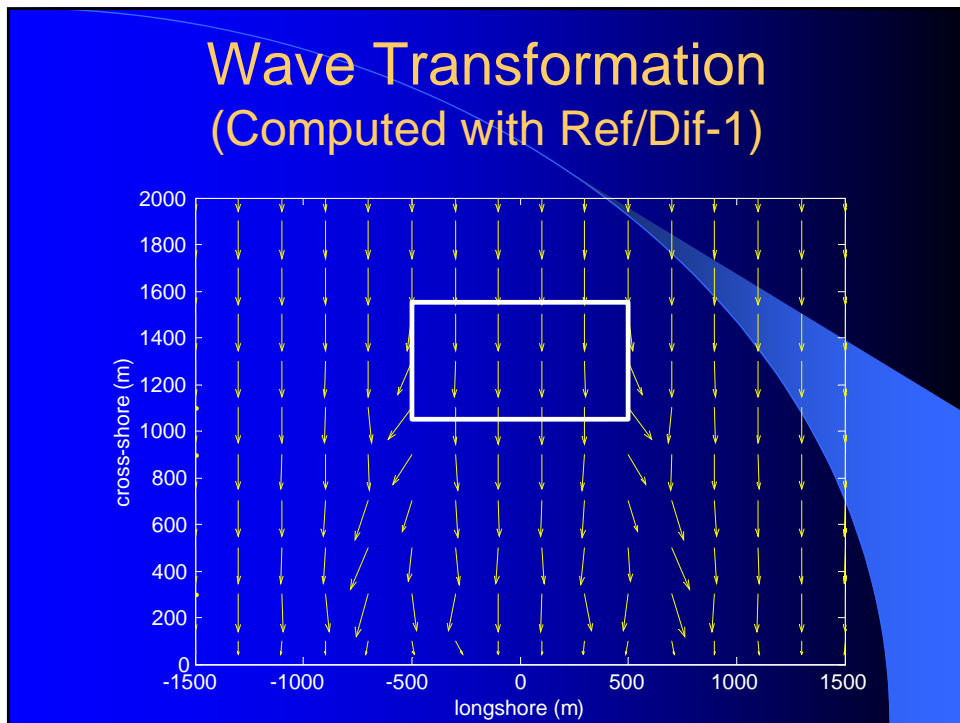
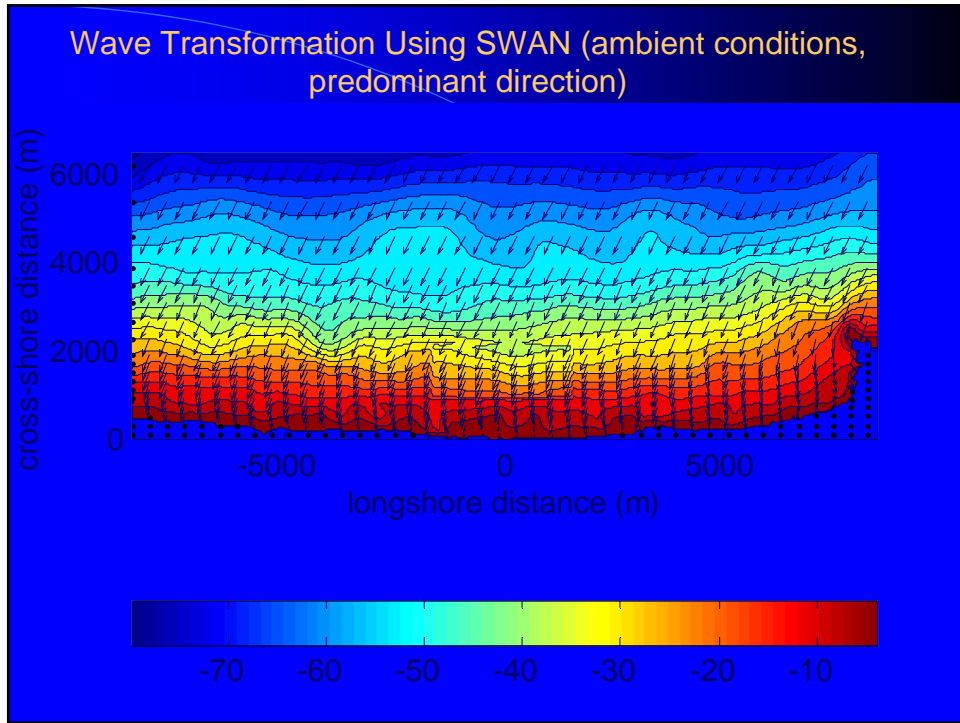


Ref/Dif-1 (Kirby and Dalrymple, 1983)

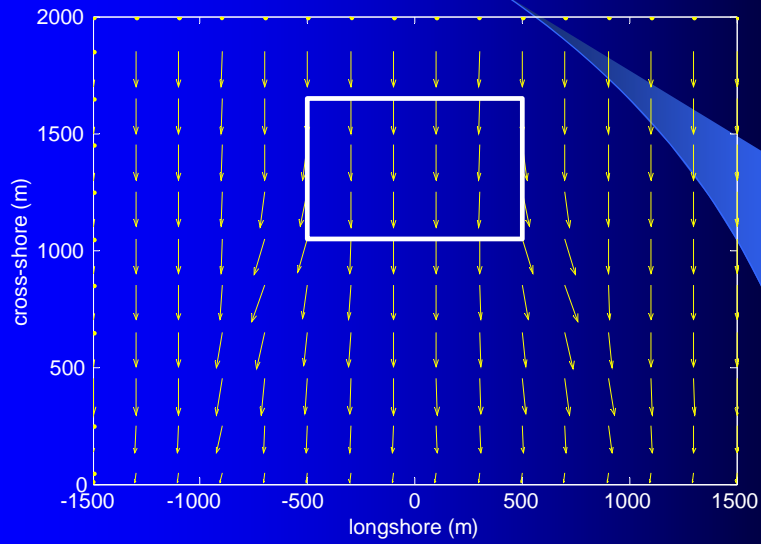
- Weakly nonlinear combined refraction and diffraction model for monochromatic waves.
- Solves the mild slope equation (Berkhoff, 1973) with parabolic approximation.

SWAN (Booij Et Al, 1999)

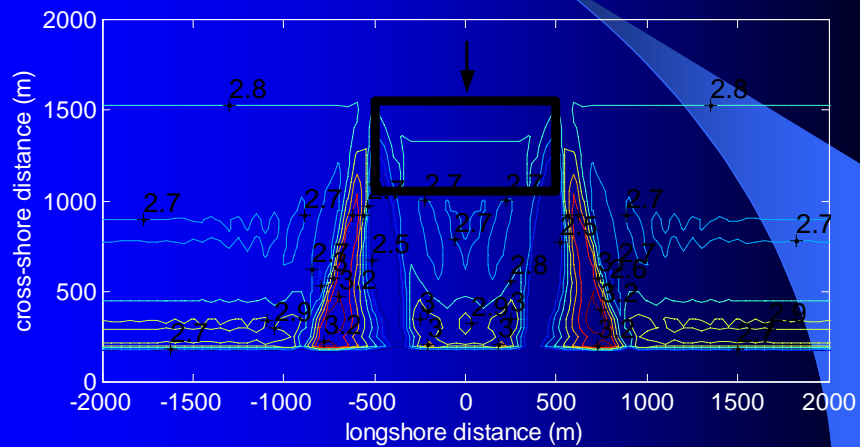
- Third generation model on energy transfer equation.
- Can simulate refraction, generation by wind, whitecapping and wave-wave interactions.
- Based on spectral balance of action density.



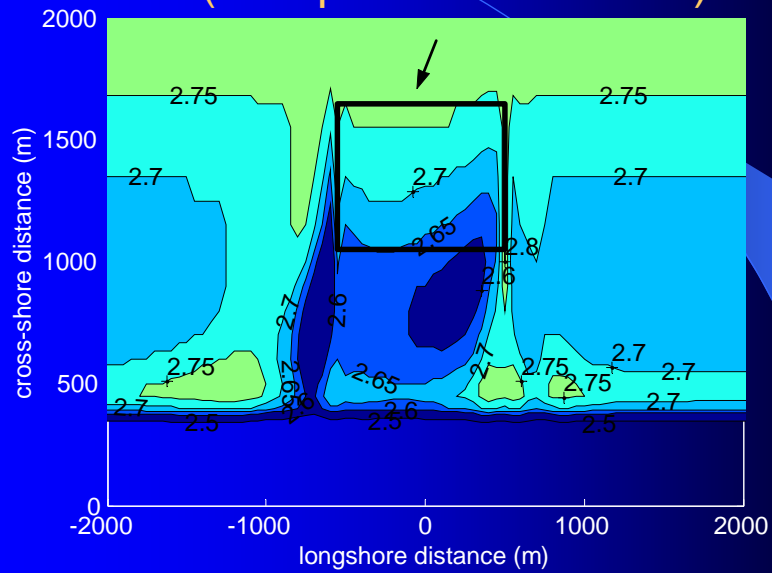
Wave Transformation (Computed with SWAN)



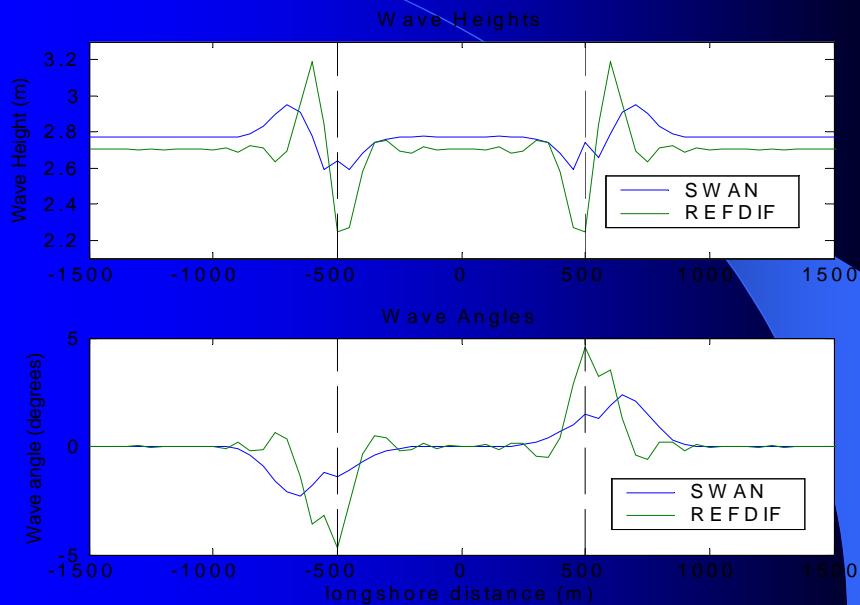
Distribution of Wave Heights (Computed with Ref/Dif-1)

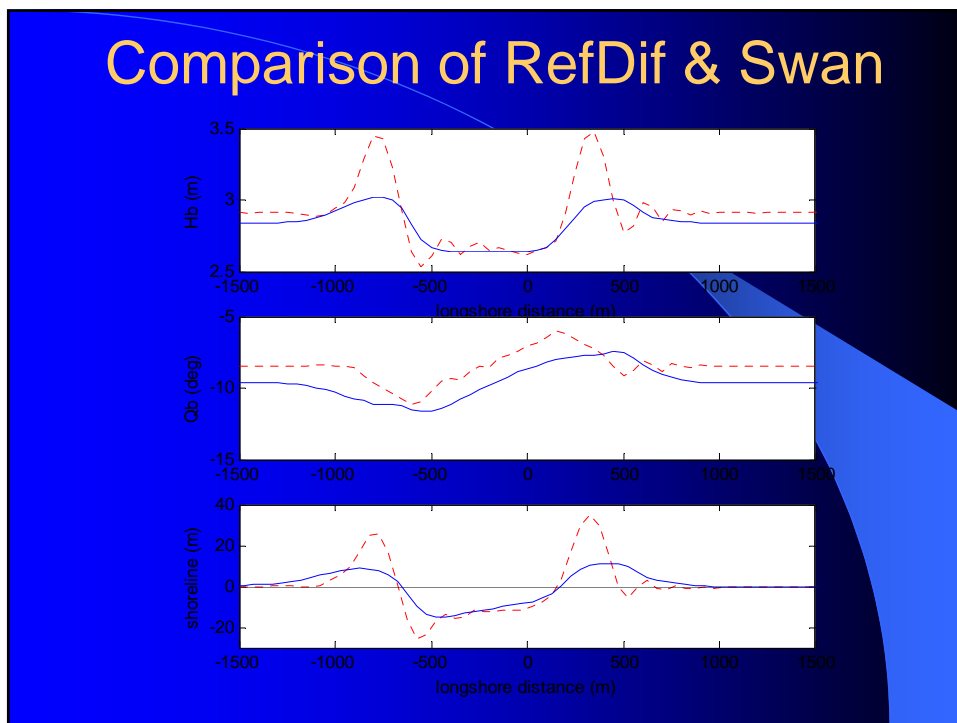
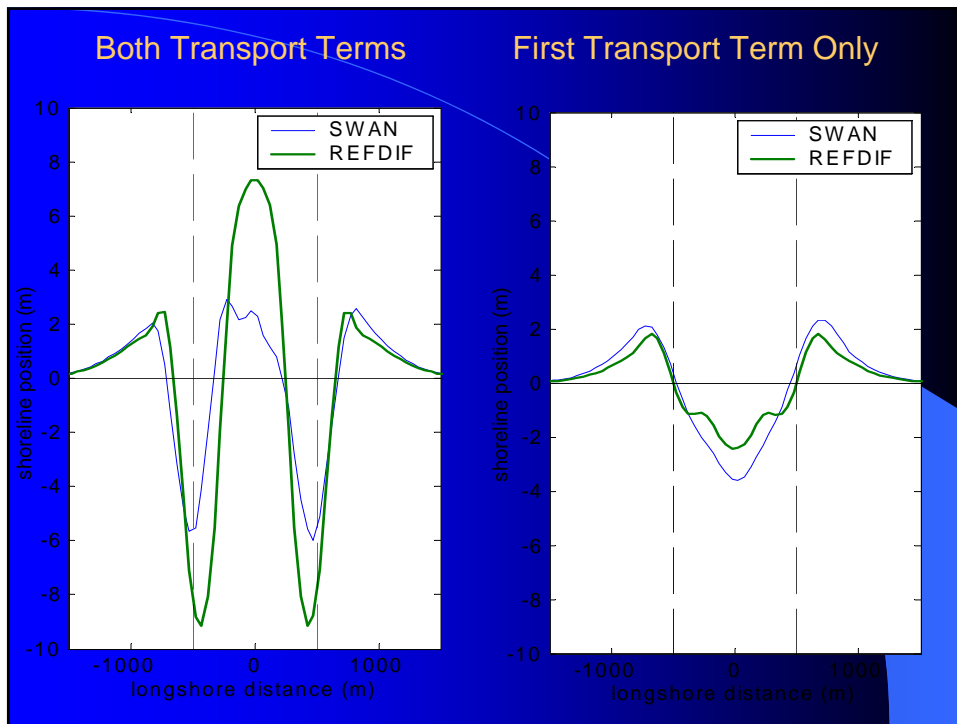


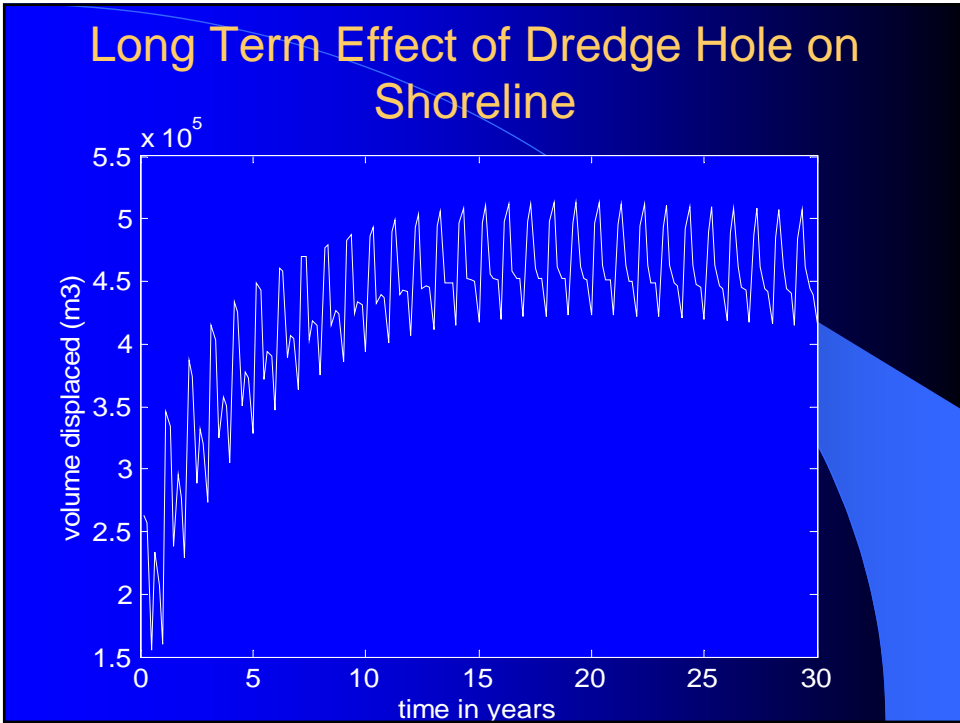
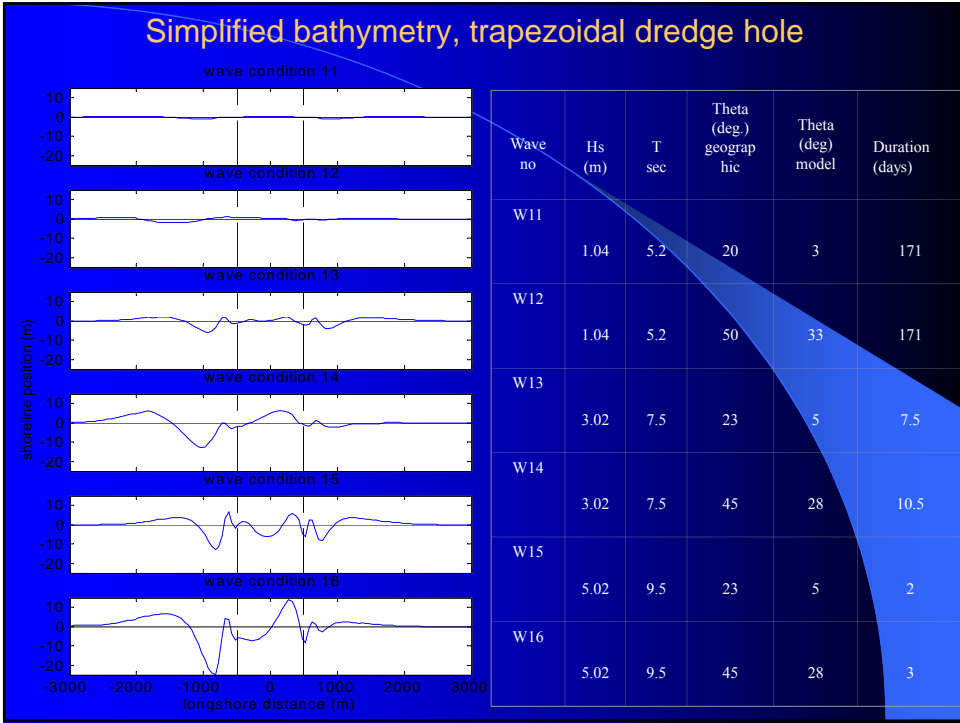
Distribution of Wave Heights (Computed with SWAN)



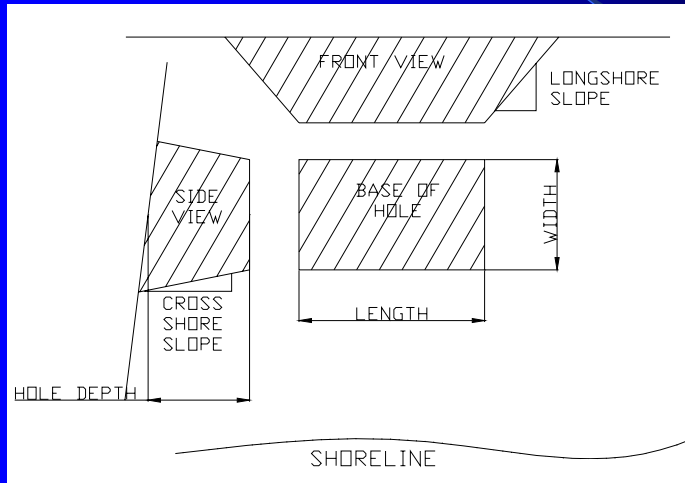
Wave Transformation due to Dredge Hole





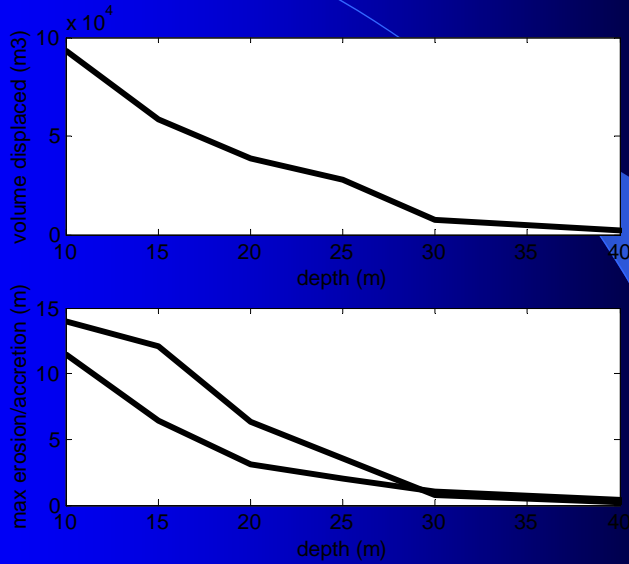


Dredge Hole Geometry

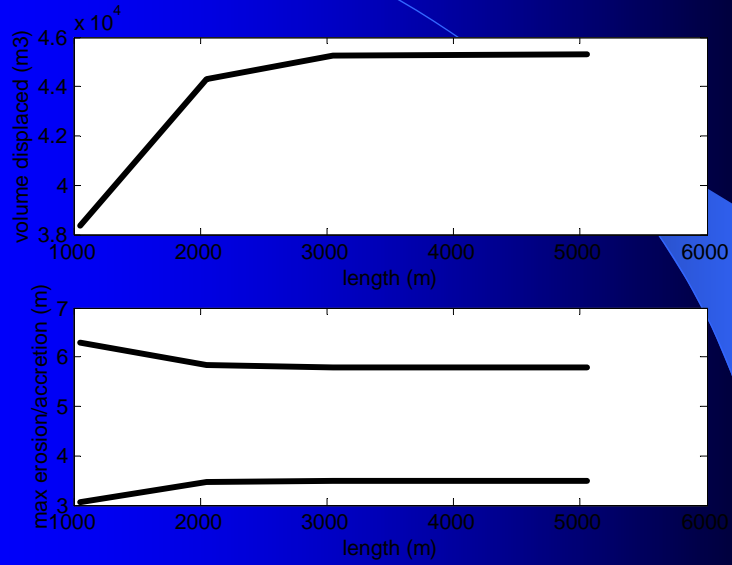


Geometric Property	Reference pit
Length	1000 m
Width	500 m
Hole Depth	3 m
Water Depth	20 m
Longshore Slope	3/50
Cross-shore slope	3/50

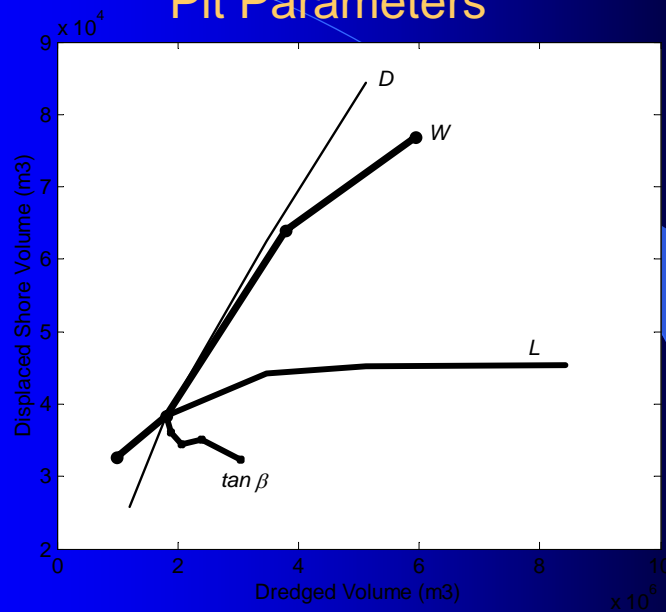
Effect of Dredging Depth



Effect of Pit Length



Dredging Efficiency as a Function of Pit Parameters



CONCLUSION

- Two mechanisms are identified through which offshore dredging may effect the shoreline.
- Direct effects cause net beach loss while indirect effects change the shape of the shoreline.
- Both of these effects are related to water depth and not to distance. Regulations should be based on water depth rather than distance offshore.
- At 20 m water depth, sediment activity at the seabed is less than 10%.

Best Practice Criteria for Dredge Pits

Rules of Thumb to minimize erosional impact of dredge pits on adjacent shorelines.

- Dredge offshore of the *closure depth*.
- Dredge in *narrow and long trenches parallel to shore*.
- Avoid *sharp slopes* at longshore ends of the pit.
- One *large pit* is better than many smaller pits.

Note:

After this study, the Turkish legislation has changed the criteria for dredging in the Black Sea from minimum distance offshore (3nm) to minimum depth of water (20m) .

Acknowledgements

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