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Impacts of Shoreline Armoring on Sediment Dynamics: State of (my) knowledge

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Hypothesis

Shoreline armoring activities represent one of the most dramatic sources of nearshore morphodynamic and marine habitat modification in Puget Sound.

Photo: Hugh Shipman

However

It has not yet been (conclusively) confirmed in the field or the laboratory whether currents and sediment transport rates will increase or decrease in front of a hardened shoreline, as compared to a non-armored section of beach!!

Photo: Gary Griggs

Seawalls have been implicated in the following:

- Formation of scour troughs
- Beach lowering
- End scour
- Up-coast accretion
- Down-coast erosion
- Far down-coast shoals
- Reflection bars
- Delayed post-storm recovery
- Grain size modification
- Etc…

POSSIBLE EFFECTS OF SEAWALLS ON ADJACENT SHORELINES AND BEACHES

No.	Possible Effect	Sketch
1	Causes local scour (a) Toe of seawall (b) Endwall effects	(a) seawall, MSL, toe scour, section; (b) seawall, shoreline, endwall scour, waves, plan
2	Causes beach fronting seawall to diminish in width	(a) Barrier Island Retreat: year 2, year 1, retreat rate, moves, plan; (b) Seawall: year 2, year 1, retreat rate, fixed wall, plan
3	Causes acceleration of beach erosion rate	(a) natural: year 2, year 1, MLW, erosion rate, fixed dune, plan; (b) seawall: year 2, year 1, MLW, fixed wall, increased erosion rate
4	Causes downdrift erosion	updrift accretion, downdrift erosion, normal shoreline position, protruding seawall, waves, plan
5	Causes delay in post-storm beach recovery	normal (land recovered) profile, WS, storm profile, section
6	Causes beach profile to steepen	WS, normal beach profile, steeper, section
7	Serves no purpose if located well back on stable beach	berm, beach face, WS, section
8	Causes increase in longshore sediment transport rate	natural dune, seawall, natural dune, Q_1, $Q_2 > Q_1$, Q_1, waves, plan
9	Causes sand transport substantial distance offshore	WS, storm profile, normal profile, section
10	Other	

Dean, 1986

Affected processes include:

- Sediment impoundment (groin effect)
- Removal of upland sand from the sediment budget
- Wave reflection
- Acceleration of longshore currents
- Increased sediment mobilization
- So on…

Photo: Gary Griggs

Suggested controls on how these processes affect beach

- Long-term coastal change (passive erosion)
- Storm events (active erosion)
  - Position of seawall relative to surf zone
  - Width of surf zone
  - Sediment supply
  - Wave characteristics
  - Seawall design characteristics

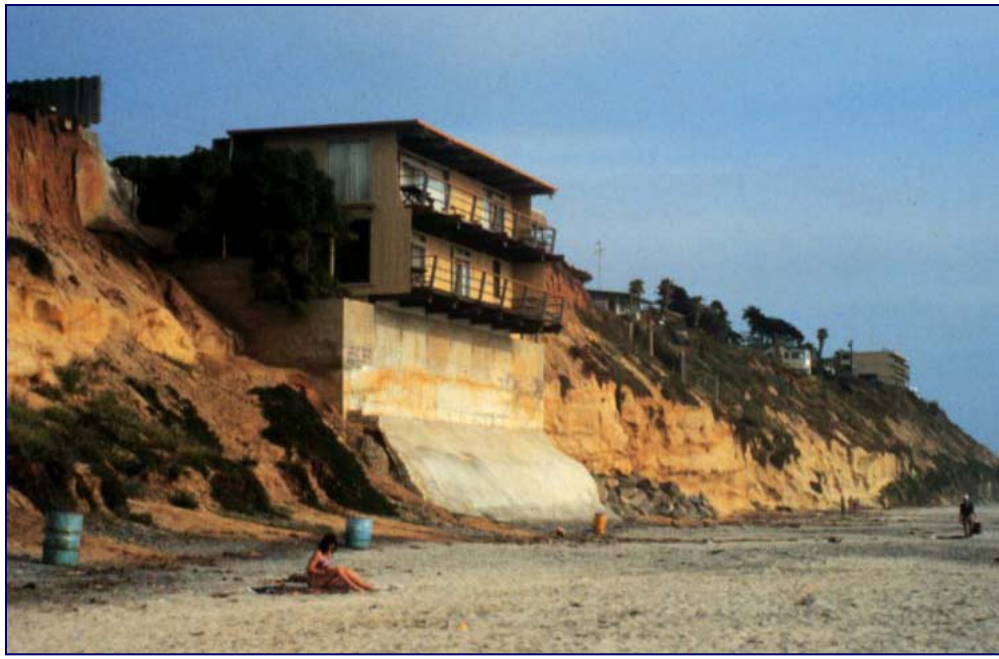


Photo: Gary Griggs

Passive erosion: Loss of beach due to fixed barrier but the seawall is not necessarily culpable for the erosion.

Fletcher et al., 1997. Seawalls have ‘caused the narrowing of 17.3+- 1.5 km and loss of 10.4 +- 0.9 km of sandy beach’ over a 50 -70 yr period. ~24% of the original sandy shoreline of Oahu.

Kraus, N., 1987, 1988. The effects of seawalls on the beach: A literature review, Proceedings of Coastal Sediments, Journal of Coastal Research

Critical review of laboratory, field, and theoretical studies (over 100 citations):

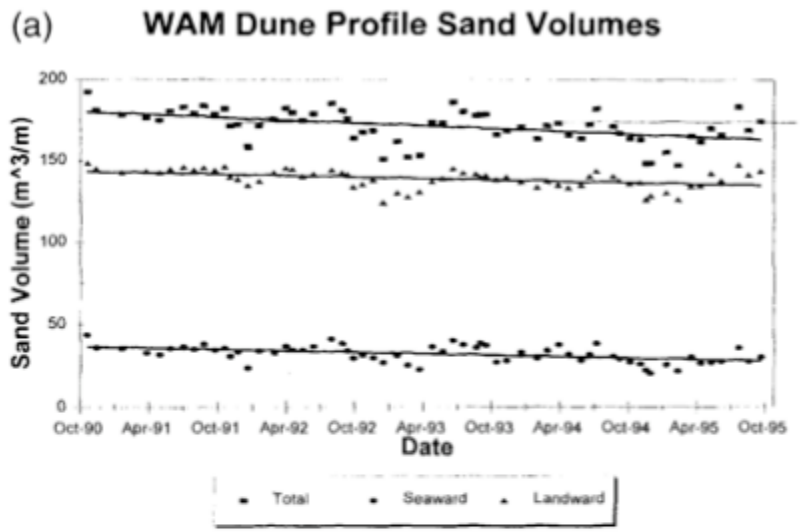
Little quantitative information is available on the effects of seawall on the beach!!!

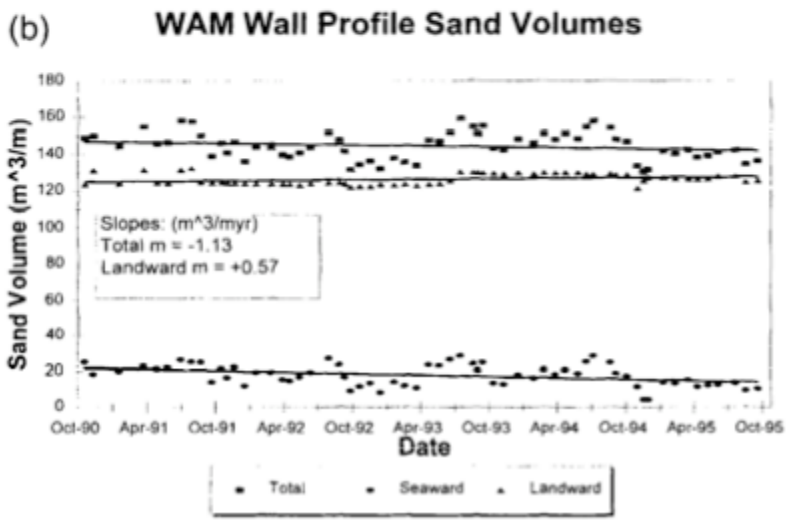
Recommendation: Initiate comprehensive monitoring programs

California (1986-1994) : **'A comparison of summer and winter beach profiles on beaches with seawalls and on adjacent control beaches show no significant long term effects or impacts of seawalls during this seven year period.' (Griggs and co-workers early 90's)**

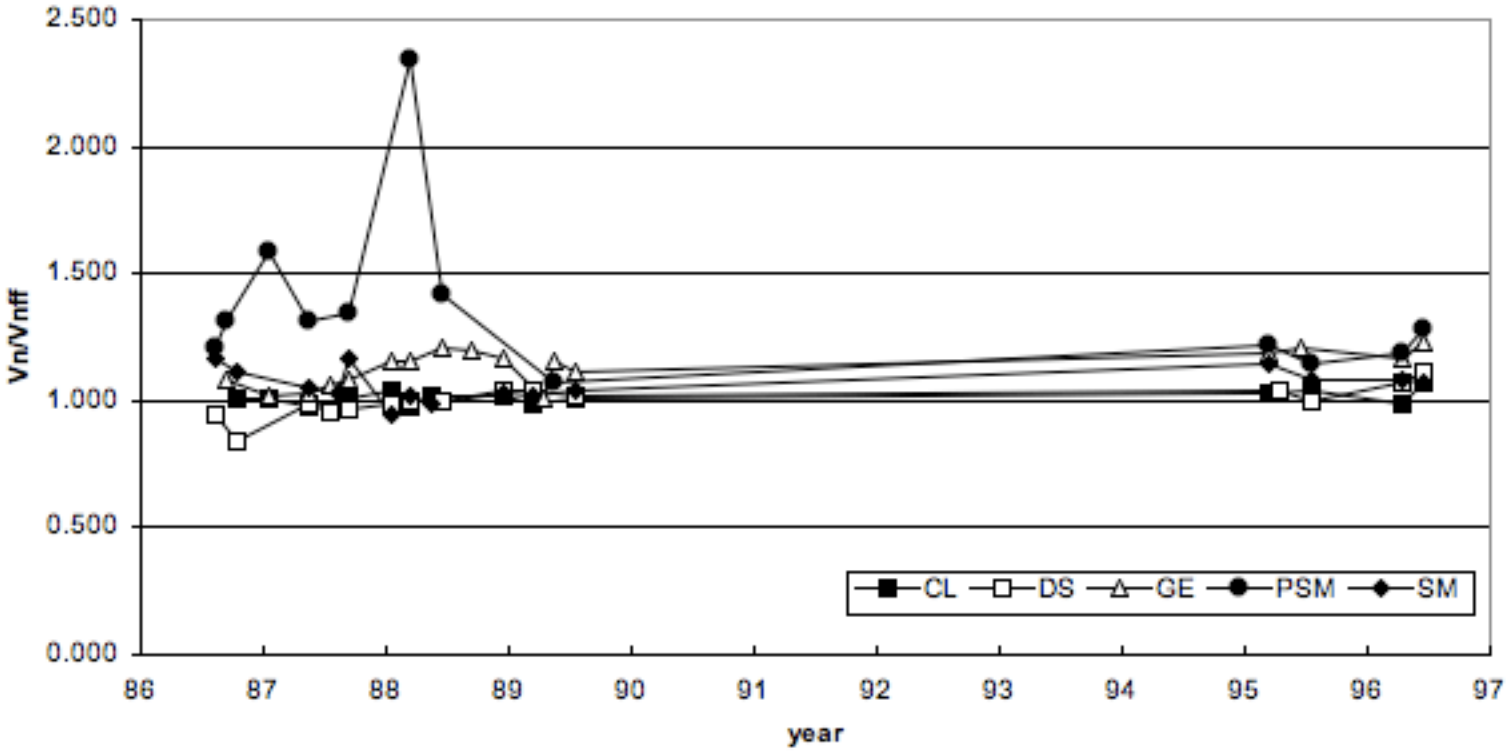
Virginia (1980-1992): 'The results at three time scales (storm seasonal and interannual) and from the three analysis methods all supported the same conclusion, namely: the volume erosion rates are *not higher* in front of seawalls.' (Basco and co-workers mid 90's)

Oregon (1986-1998): 'Ten years of monitoring has revealed that the structures at these seven sites are having no adverse impacts on the surrounding beach or adjacent properties.' (Hearon and McDougal, 1996)





Basco et al., 1997. Walled and unwalled sections are not Statistically different along Sandbrige, VA



Hearon and McDougal, 1996. Near field volume/far field Volume for 5 Oregon sites.

Weggel's (1988) Seawall Classifications

Type	Location of Seawall
I	Landward of maximum storm runup
II	Above SWL of max storm surge and below the level of the max runup
III	Above MHW and below SWL of storm surge
IV	Within the normal tide range; base is submerged at high water
V	Seaward of MLLW; base is always submerged; subjected to breaking or broken waves
VI	So far seaward that incident waves do not break on or seward

Kraus, N. and McDougal, W.G. 1996, The effects of seawalls on the beach: An updated literature review, Journal of Coastal Research.

Reflection is not a significant contributor to (2D) beach profile change and scour during a storm event.

Recommendation: Investigate alongshore processes

Video Carl Schoch

Rakha and Kampuis, 1997. A morphology model for an eroding beach backed by a seawall, Coastal Engineering, 30, 53-75.

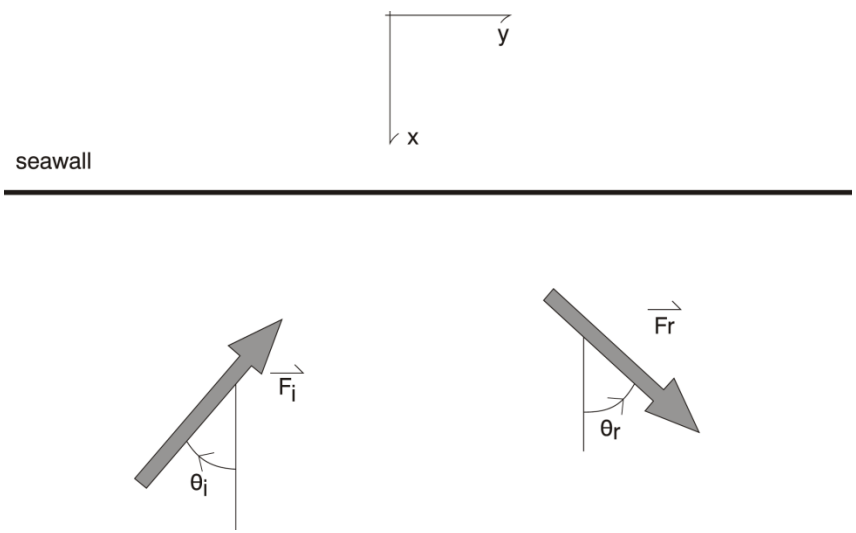
- Reflected waves reduce the undertow, and have a small effect on the longshore current.
- Reflected waves have a small effect on beach profile evolution.
- Reflected waves reduce erosion close to the seawall.

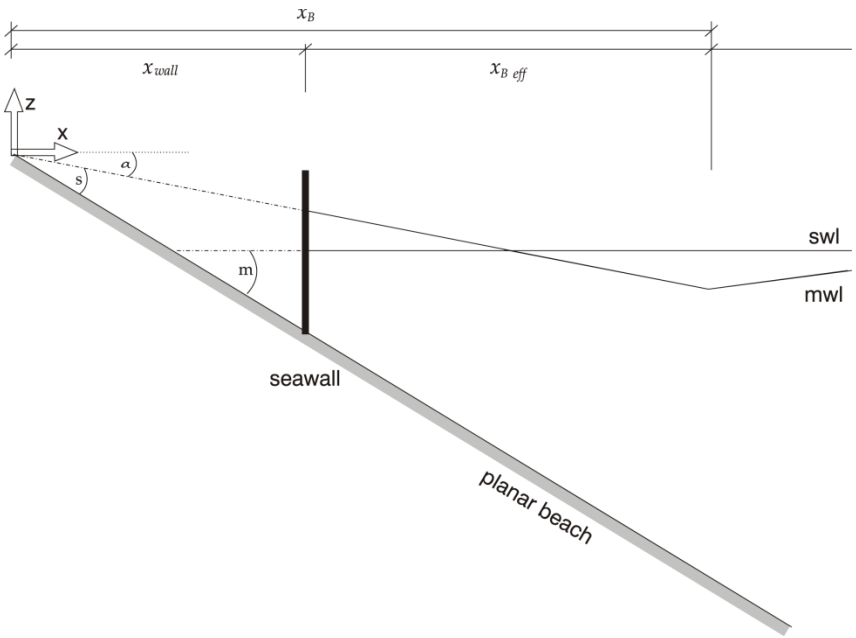
Miles et al., 2001. Field measurements of sediment dynamics in front of a seawall, Journal of Coastal Research, 17(1), 195-206.

- Mean suspended sediment concentrations were found to be up to 3 times larger in front of the wall than on the natural beach.
- The longshore current in front of the wall was stronger than that observed on the natural beach.
- This combination resulted in a longshore sediment transport rate which was an order of magnitude greater in front of the wall.

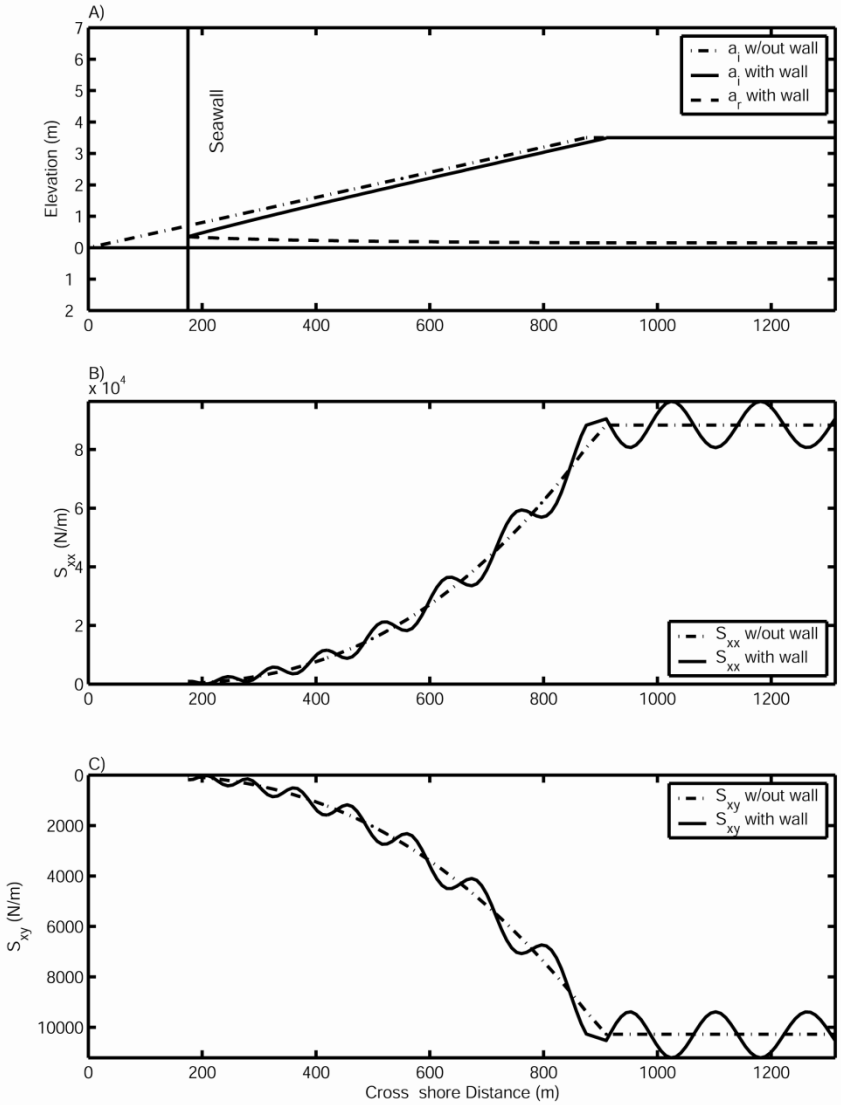
Ruggiero, P. and McDougal, W.G. 2001, An analytic model for the prediction of wave setup, longshore currents, and sediment transport on beaches with seawalls, Coastal Engineering, (43), 161-182.

Longshore currents and sediment transport on beaches backed by walls can be MORE OR LESS than that for a natural beach!



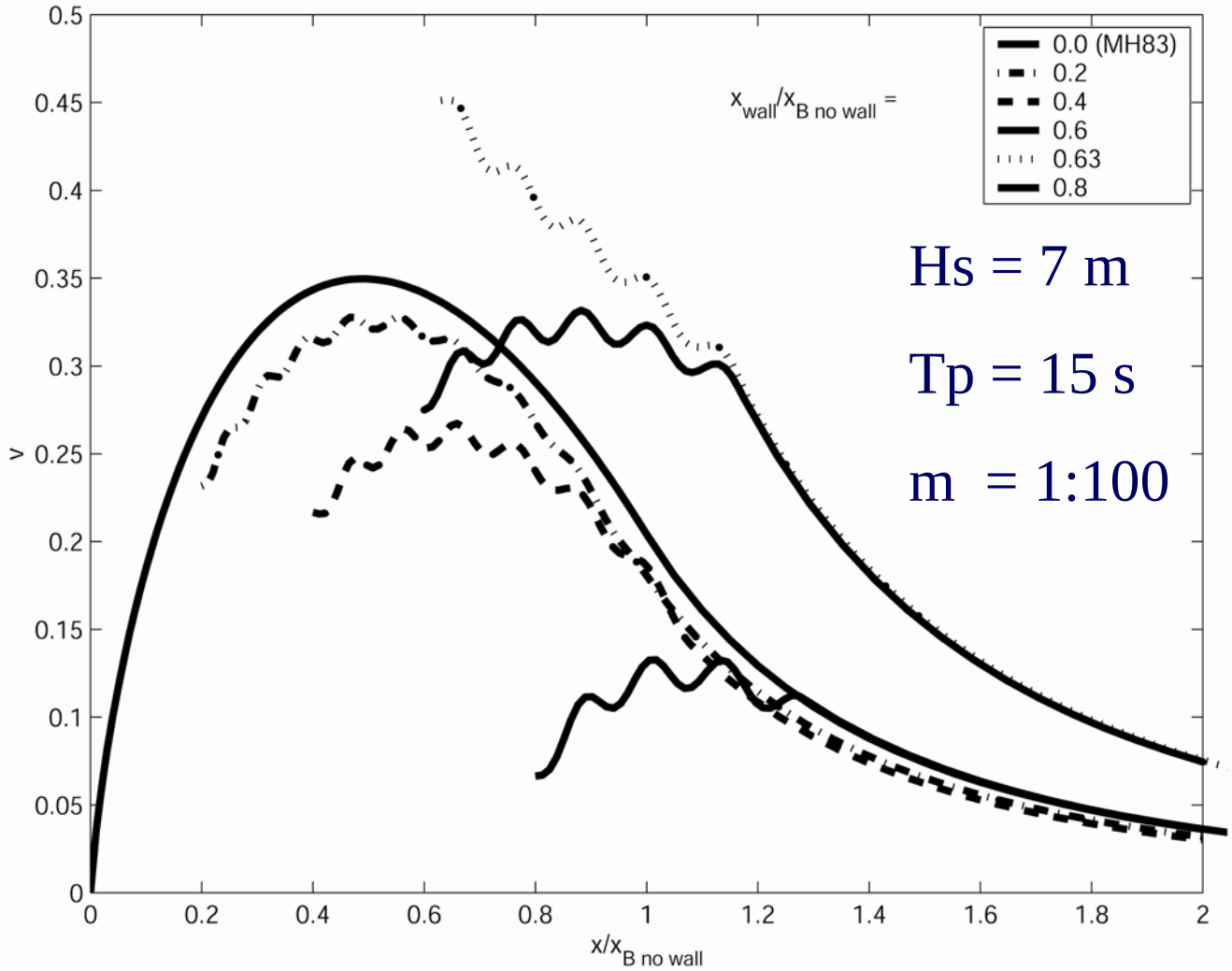


Effect of Seawall on Nearshore Processes

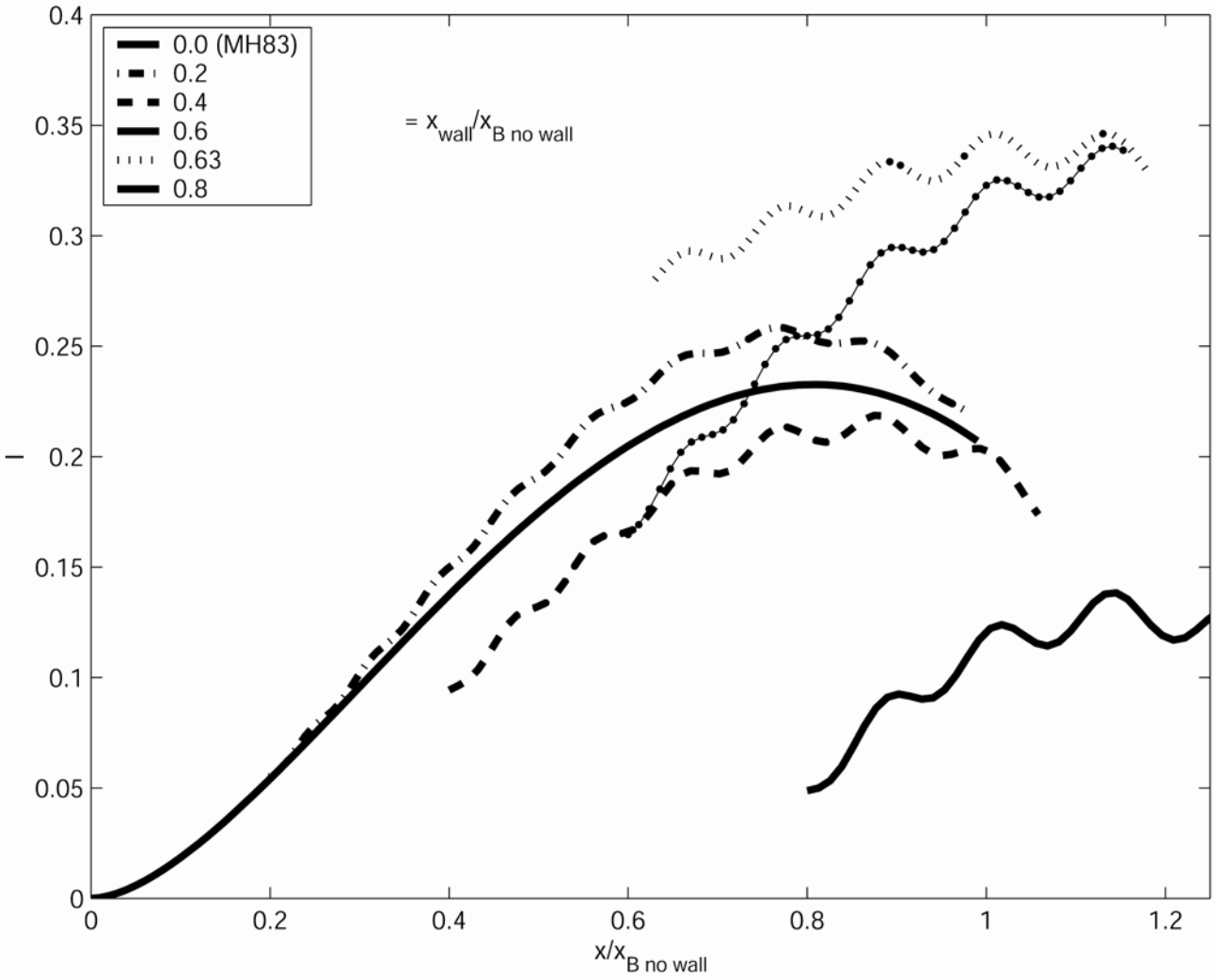


1. Breaking position moves seaward
2. Effective surf zone width is reduced
3. Cross-shore distribution of radiation stresses, wave setup, and bottom stress are modulated by a partial standing wave
4. Ratio of wavelength to beach slope determines number of oscillations in surf zone

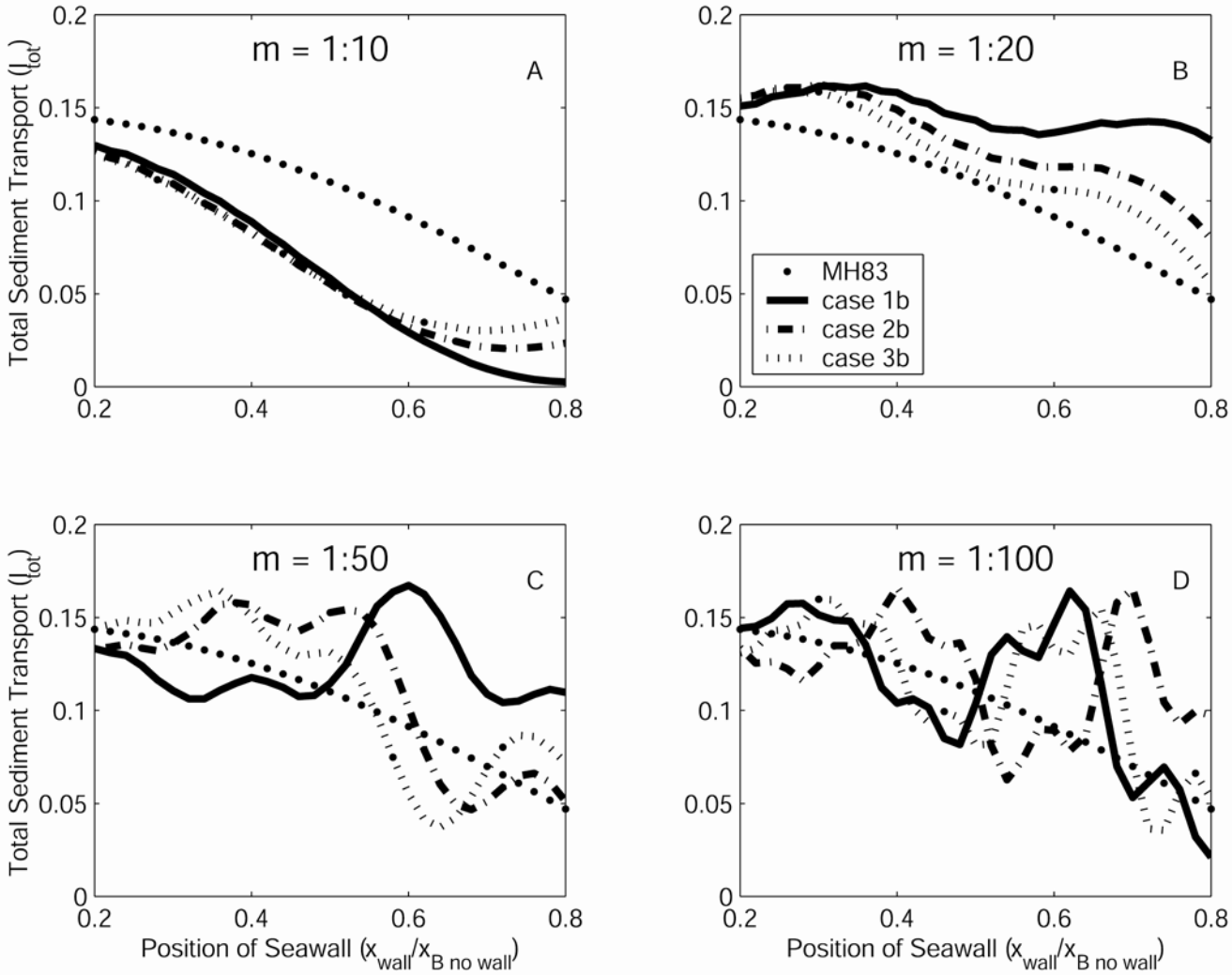
Effect of Seawall on Longshore Current Velocity



Effect of Seawall on Longshore Sediment Transport

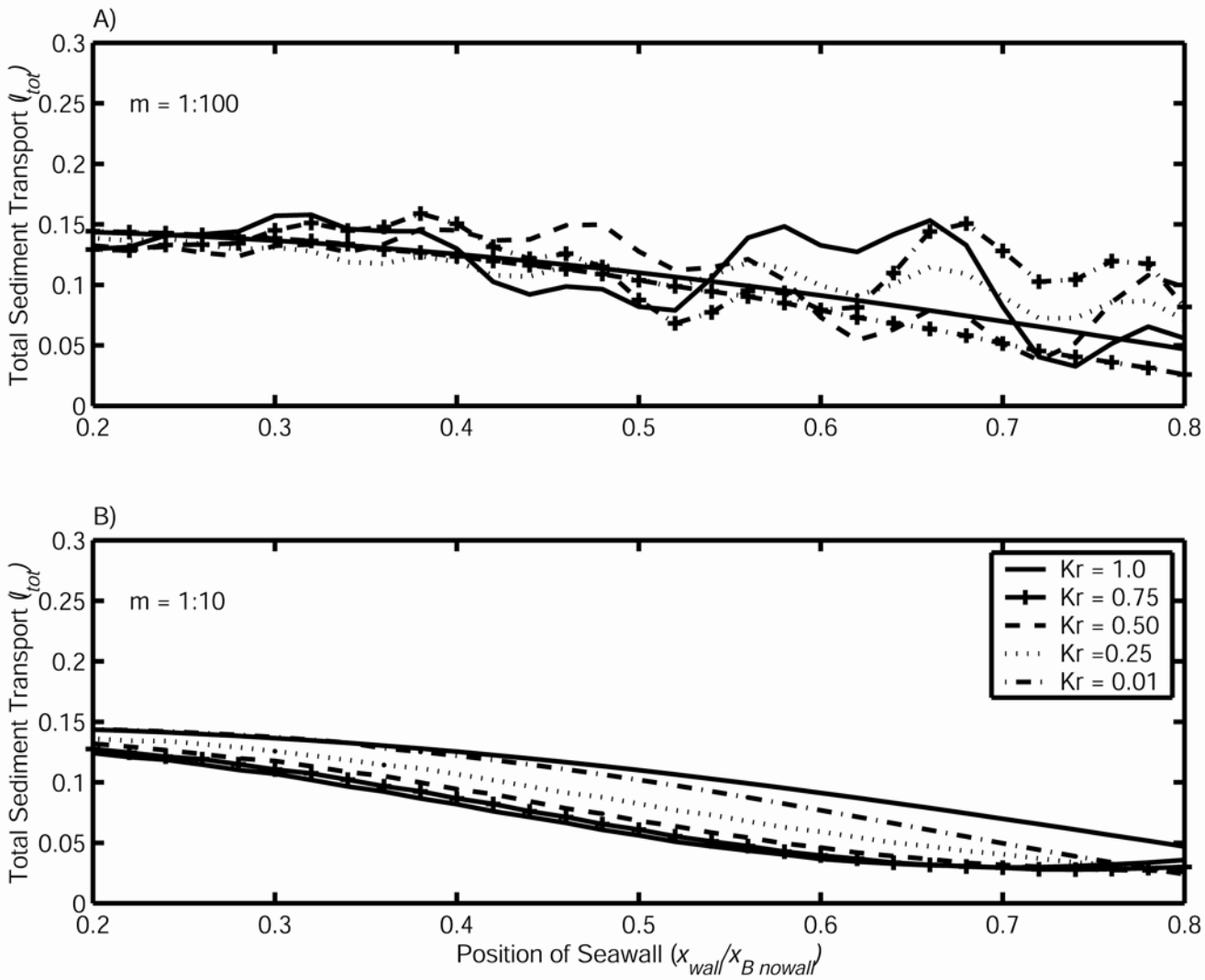


Effect of Seawall on Total Longshore Sediment Transport



1. Hs=1.0 m, T=6 s
2. Hs=3.0 m, T=10 s
3. Hs=7.0 m, T=15 s

Effect of Reflection Coefficient on Longshore Sediment Transport



Summary

- **The debate about the influence of seawalls on beaches has not been resolved!**

- **A simple analytical model sheds light on the confusion found in the literature; but there is much more to do.**

- **The effect of seawalls on beaches appears to be most sensitive to the position of the seawall in the surf zone, the beach slope, and the reflection coefficient.**

Suggested Future PS Research

- **Synthesize existing inventories of armoring trends; identify field sites for field experiments and modelling efforts; quantify % of PS shoreline suffering from passive erosion?**

- **Investigate the interactions between seawalls and active nearshore processes via examination of the following: Random high frequency waves, complicated beach morphology and mixed sediment environment, variable water levels changing position of seawall relative to surf zone.**

- **Quantify rates (volume) of sediment source reduction due to shoreline armoring.**

- **Investigate the linkages between shoreline armoring and biological impacts.**

Suggested Approach

- **Investigate seawall impacts via beach monitoring, field experiments, and modeling efforts.**
  - **Nearshore morphology monitoring: both walled/no-walled sections of coast. Separate short-term morphodynamic variability (active) from interannual or longer-term shoreline change trends (passive).**
  - **Field experiments: examine the cross-shore and alongshore hydrodynamics and sediment transport characteristics on walled/no-walled sections of coast.**
  - **Numerical models: examine the cross-shore and alongshore hydrodynamics and sediment transport characteristics on beaches backed by seawalls.**