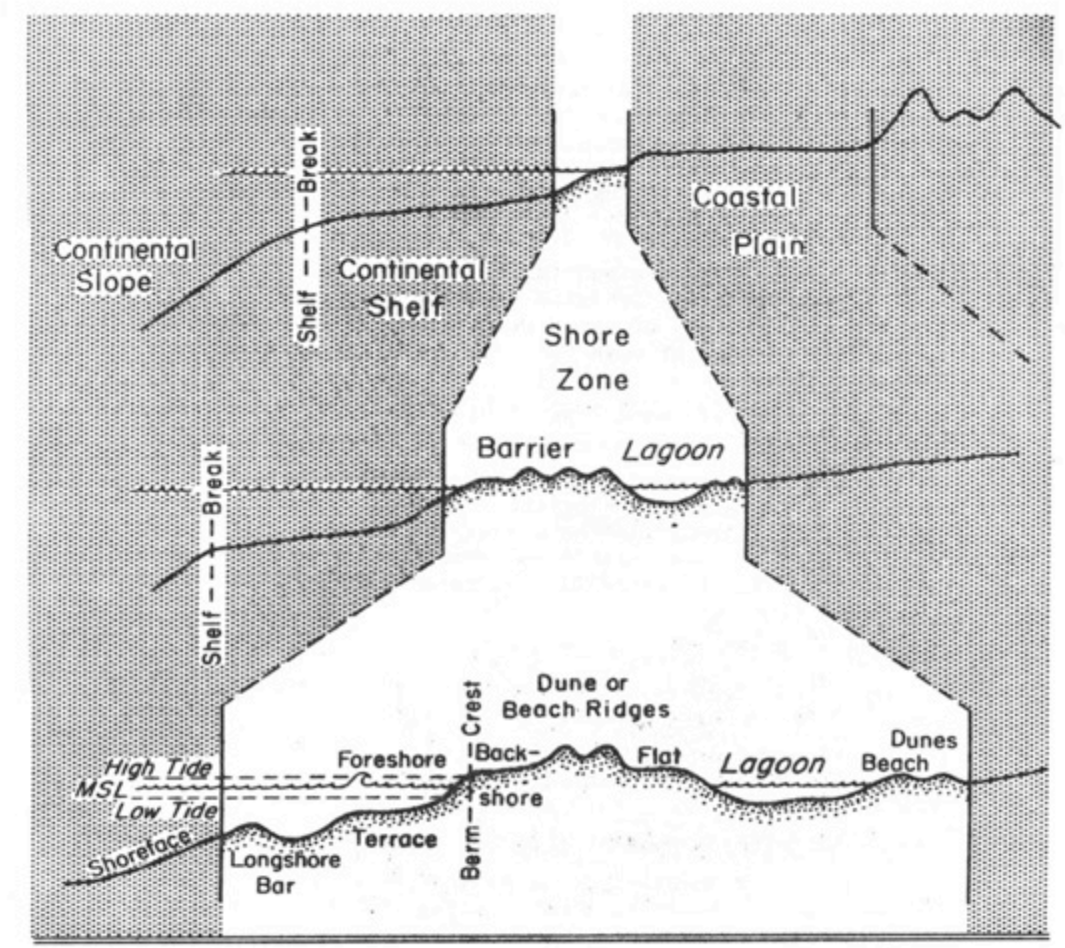
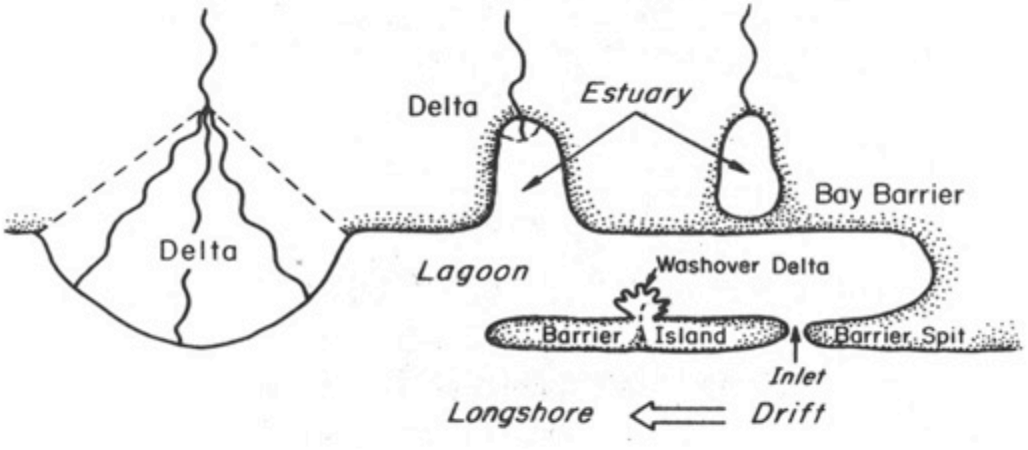
BEACH PROCESSES AND COASTAL ENVIRONMENTS

COASTAL FEATURES

Cross section



Map view



TOPICS:

Terminology
Waves
Beach Morphology
Barriers
Coastal Migration
Tides
Tidal Flats and Marshes
Sediment Budgets

Human Structures

Beach Reading Material

"Inshore oceanography",
Anikouchine and Sternberg
The World Ocean, Prentice-Hall

Terminology for Coastal Environment

Beach – extending from MLLW to dunes/cliff
Shoreline – where land and ocean meet
Spit – linear extension of shoreline, due to accumulation of sediment
Barrier – spit or island seaward of land, usually ~parallel to trend of land
Bars and troughs – seabed features in surf zone
Berm – relatively flat region of beach, behind shoreline
Foreshore – seaward sloping surface, located seaward of berm
Backshore – berm and dunes
Inlet/washover – means to transport beach sediment landward, due to tides and storms (respectively)
Longshore (littoral) drift or transport – water and sediment movement parallel to beach

COASTAL FEATURES

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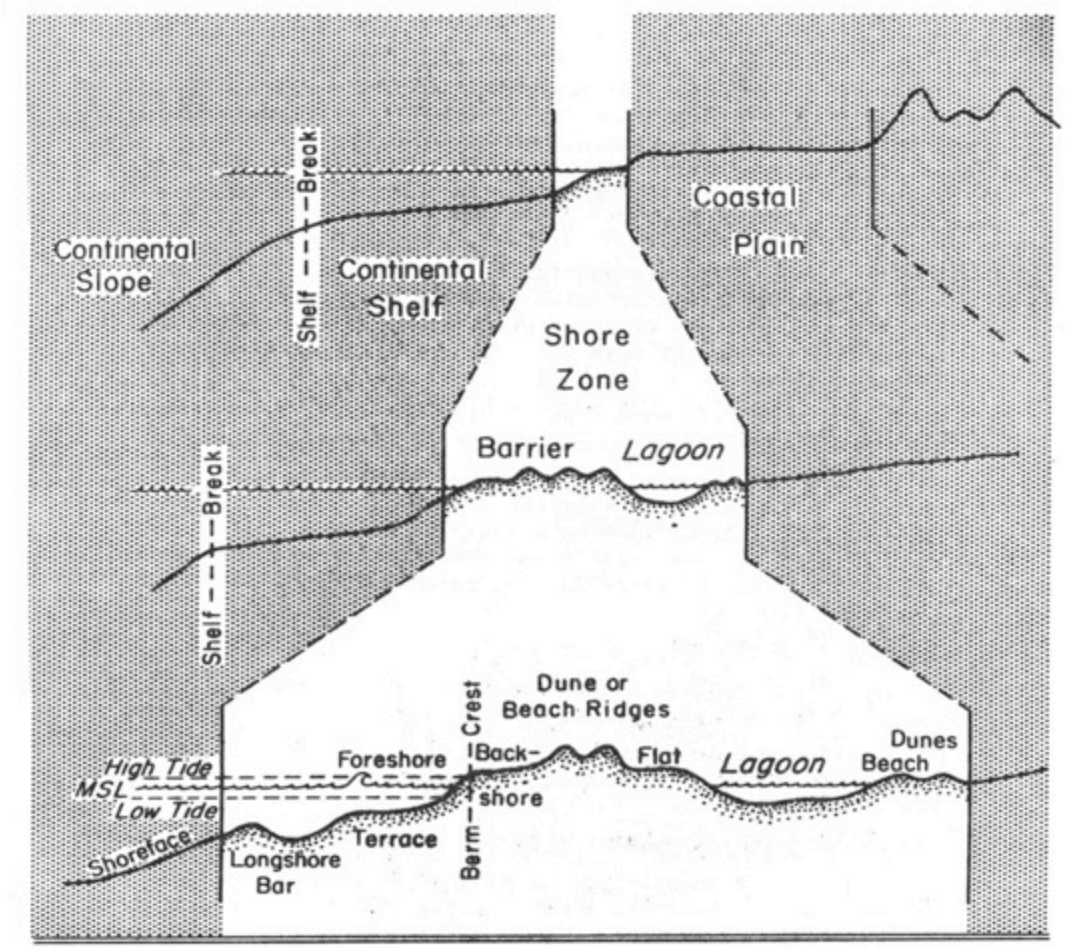

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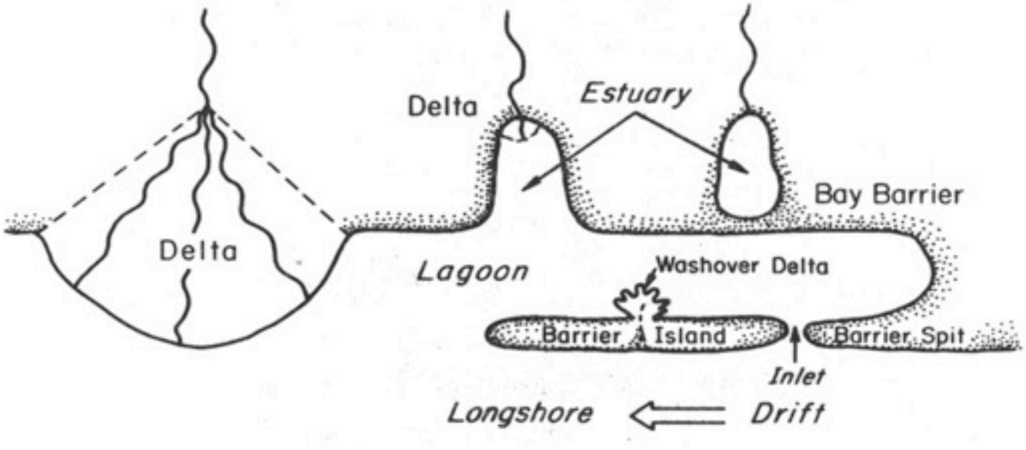

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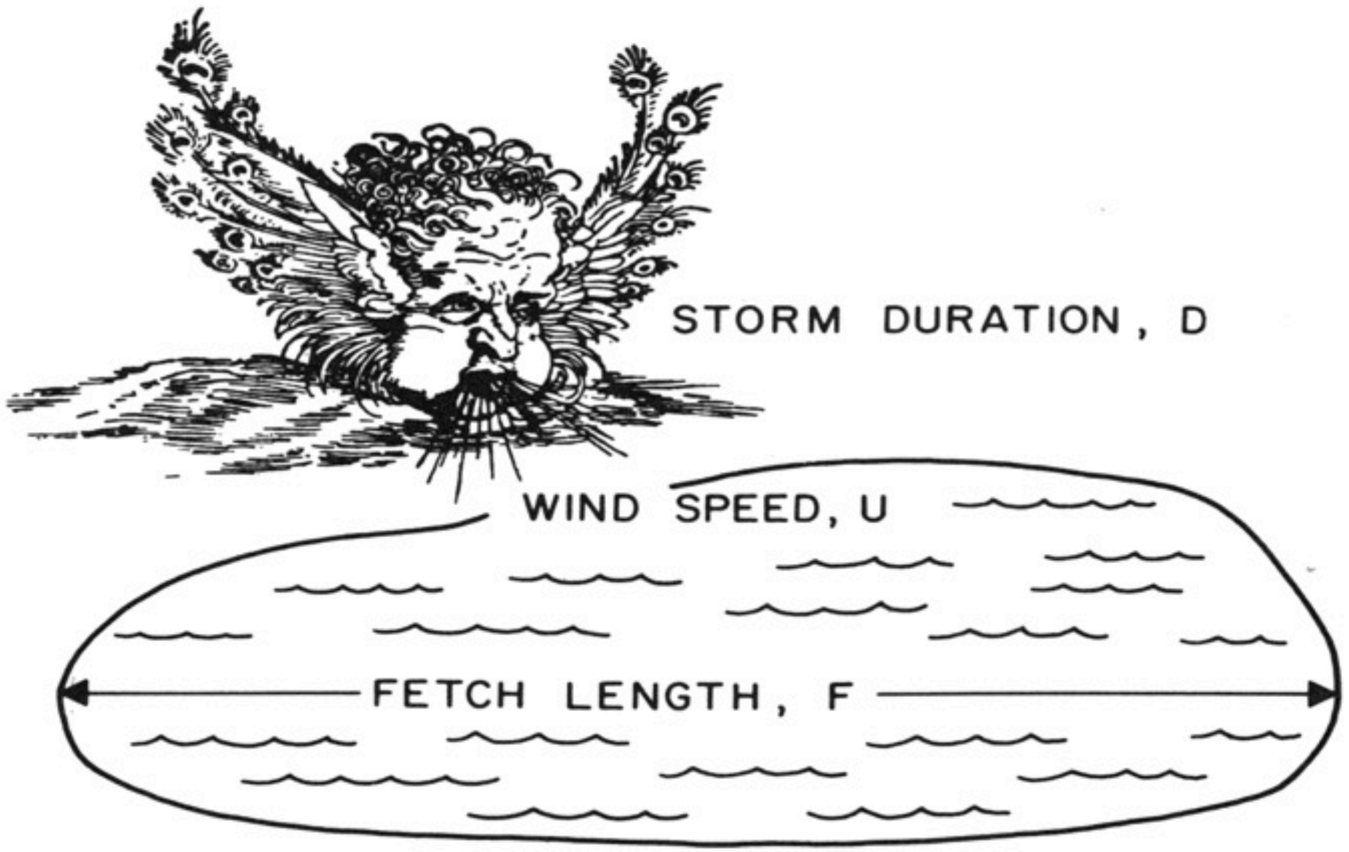
SURFACE WAVES

Factors affecting formation of wind waves

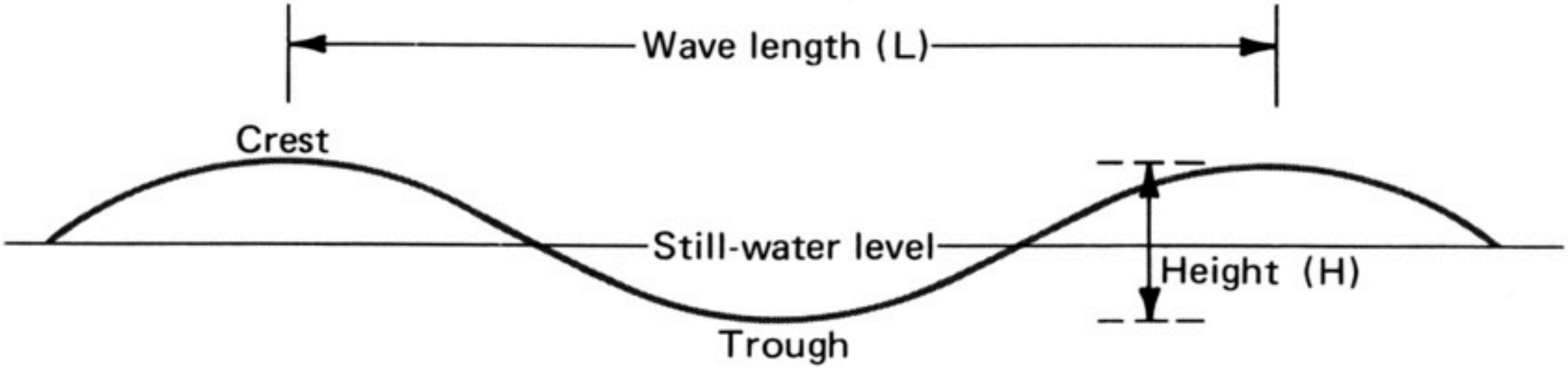


Duration wind blows

Wind speed

Distance over which wind blows (fetch)

Terminology for Describing Waves



T = wave period = time between two wave crests passing a point

generally proportional to wavelength

In deep water, wave speed increases with wavelength

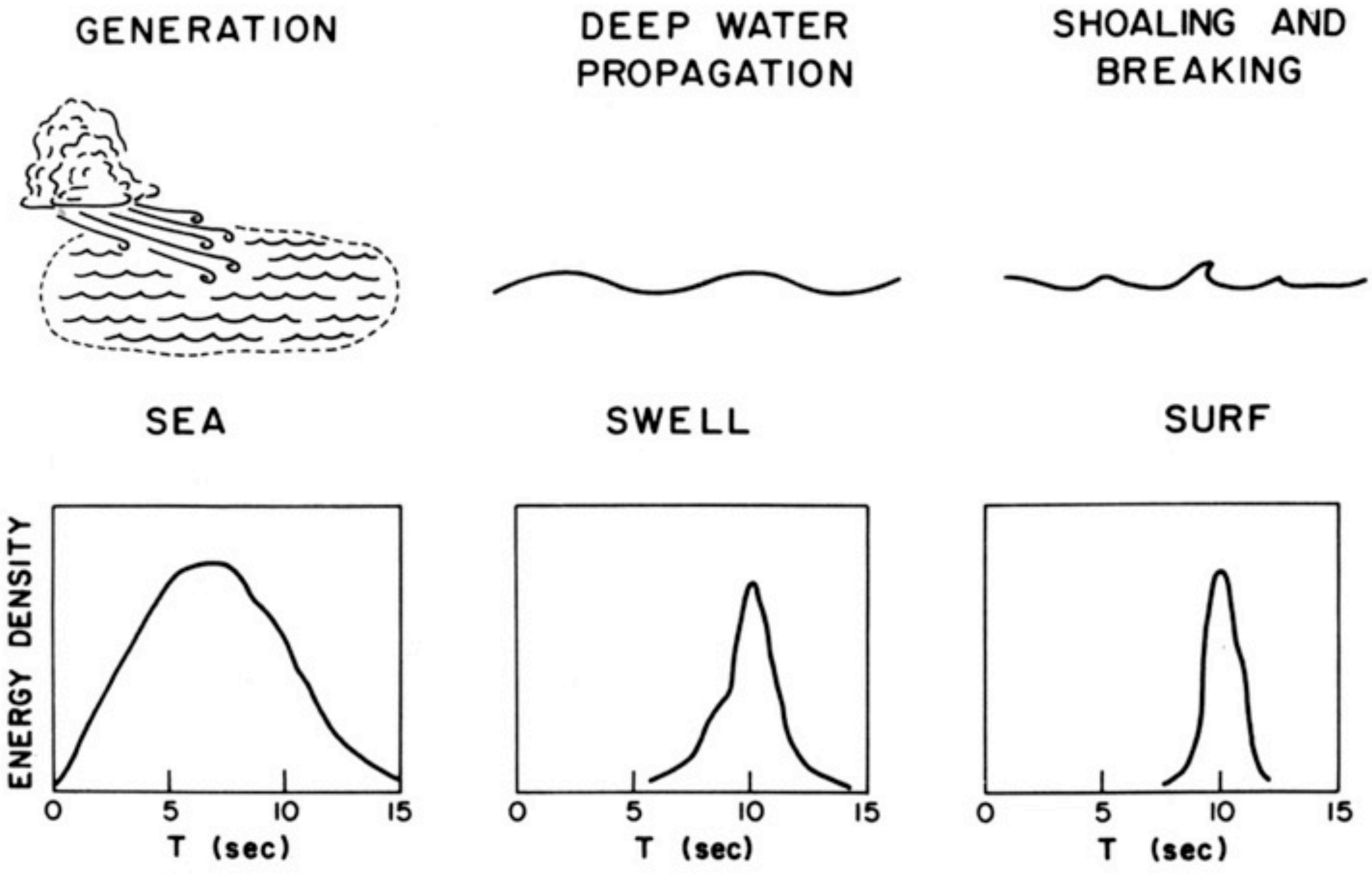
Therefore, waves sort themselves as they travel from source area;

waves with large wavelength reach beach first = swell

Changing Wave Character from Source to Surf

Wave shape

Wave characteristics change with long travel distance, because waves sort themselves

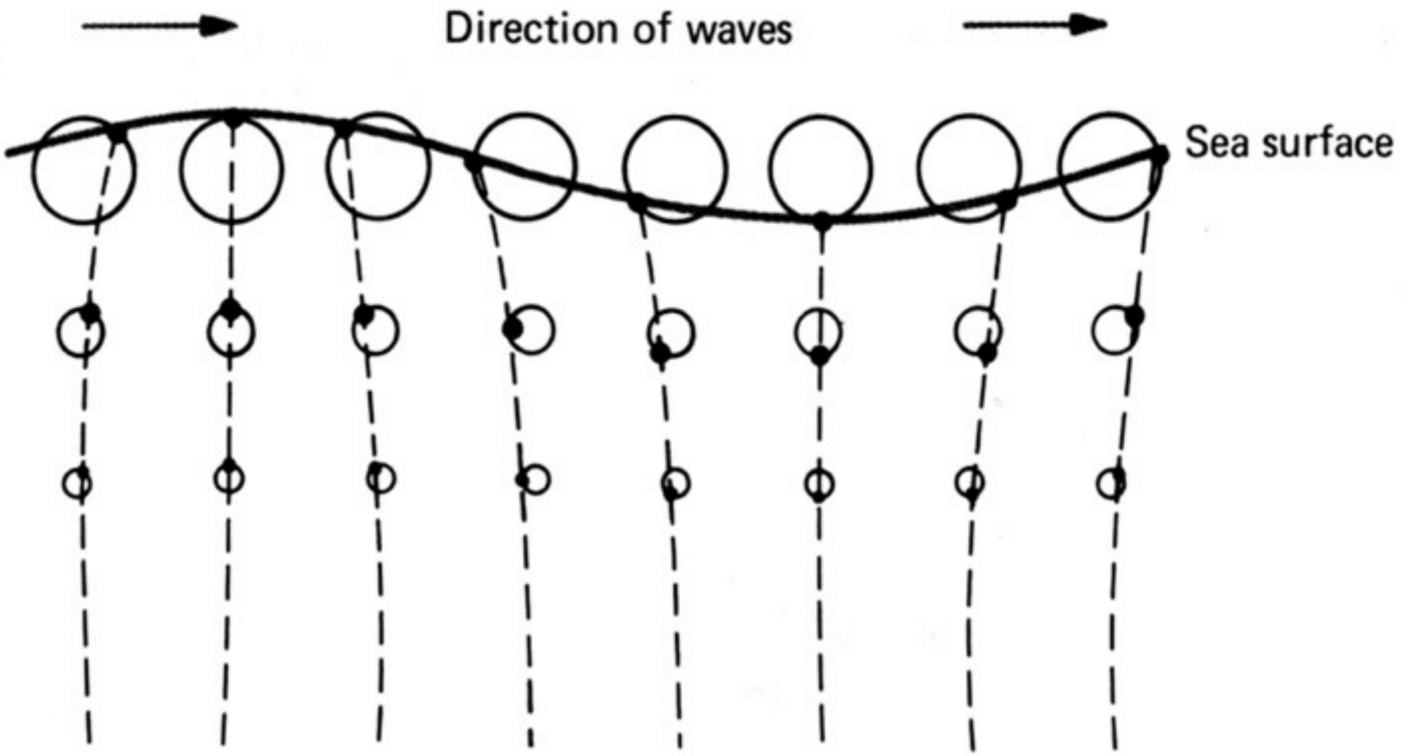


confused sea

single wave shape

pointed wave crest

Waves in deep water



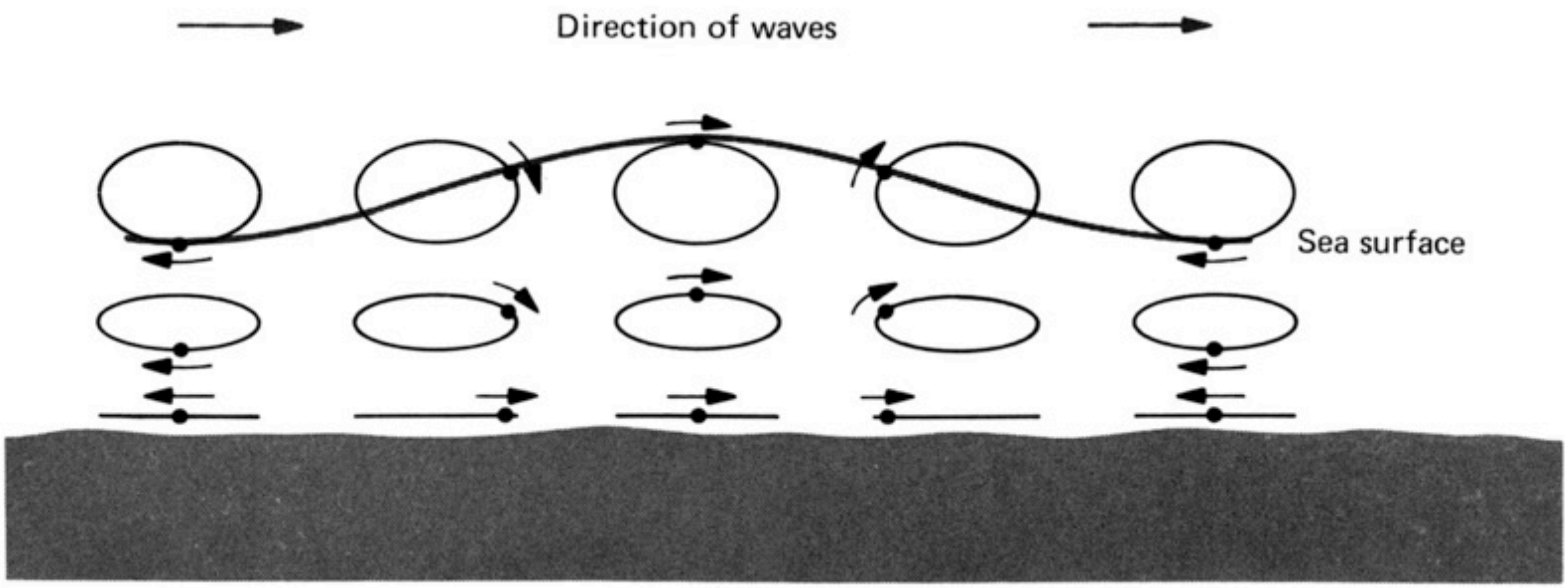
Water molecules move in closed circular orbits

Diameter of orbit decreases with depth below water surface

No motion at a water depth >1/2 wavelength of wave = wave base

Waves in shallow water

(water depth <1/2 wavelength)

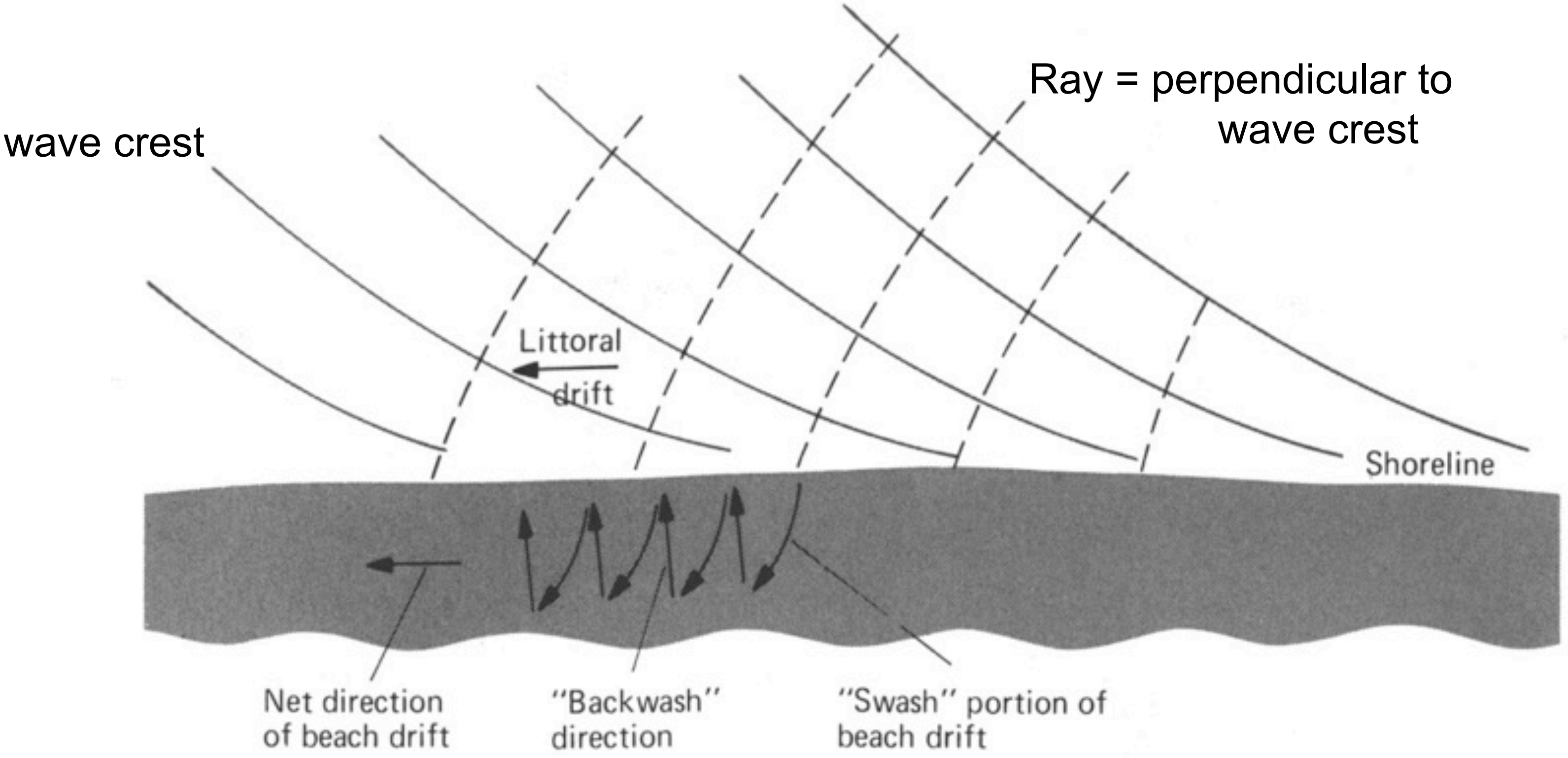


Water molecules move in elliptical orbits

At seabed, water (and sediment) moves back and forth

There is an asymmetry with more transport under crest than trough, causing net movement in the direction of the waves – i.e., toward shore

Waves approaching a straight shoreline

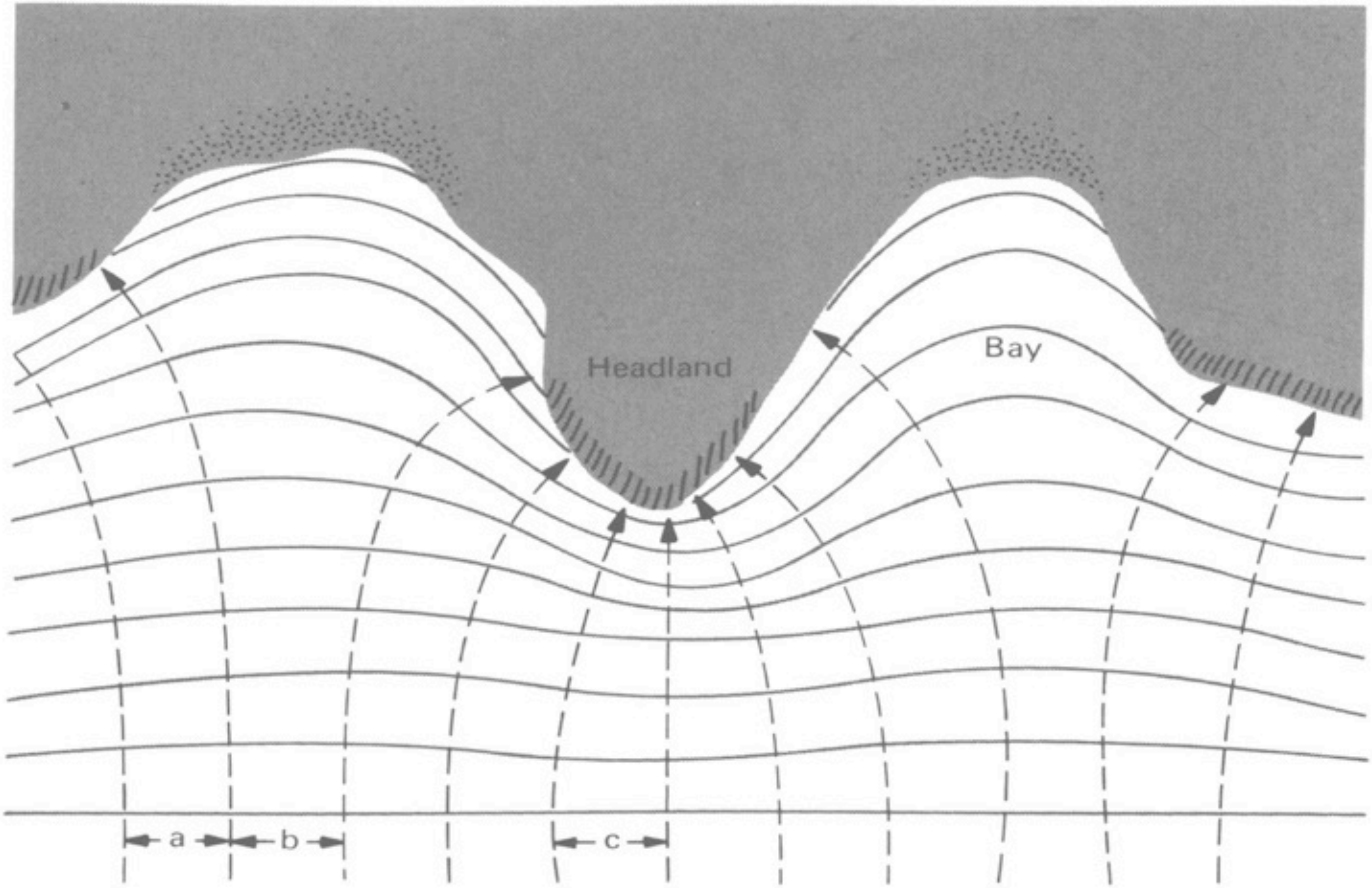


In shallow water, wave speed decreases as water depth decreases

waves travel progressively slower as depth decreases,

therefore crests bend = wave refraction

Waves Approaching an Irregular Shoreline



wave rays = perpendicular to wave crests

paths of rays indicate that waves:
focus energy on headland, eroding it
and defocus energy in embayments, allowing sediment deposition

Transitions as waves approach shoreline

1) Waves feel bottom at wave base (1/2 wavelength), ~10-50 meters depth

2) Seabed is eroded, mud moves seaward in suspension, sand moves as bedload back-and-forth with net drift toward shore

3) Wave speed decreases as water depth decreases (wave refraction)

4) Wave height increases, wavelength decreases

5) Crest becomes progressively steeper – ratio of wave height to wave length (H/L) becomes large

6) At H/L ratio > 1/7, wave becomes unstable and breaks = surf

7) Water moves up foreshore as swash, and back down as backwash

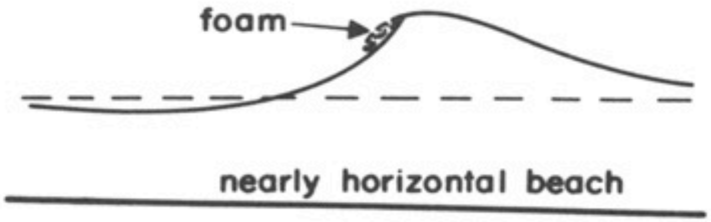
Types of Breaking Waves

Largely dependent on steepness of seabed, which is related to grain size

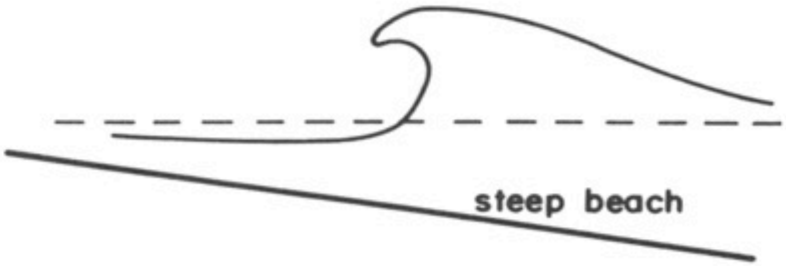
spilling breakers are found on fine sand beaches (e.g., southern Washington coast beaches)

plunging and surging breakers are found on coarse sand and gravel beaches (e.g., northern Washington coast and Puget Sound beaches)

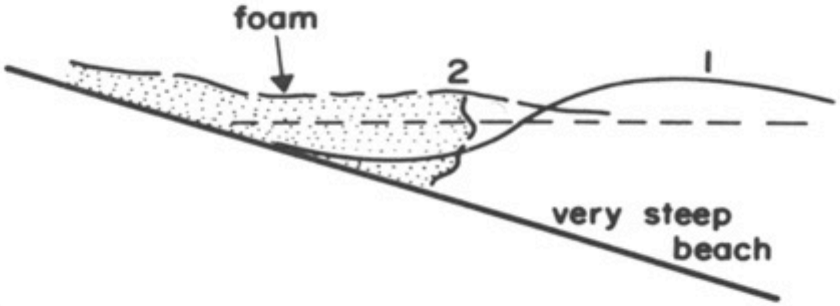
SPILLING BREAKERS



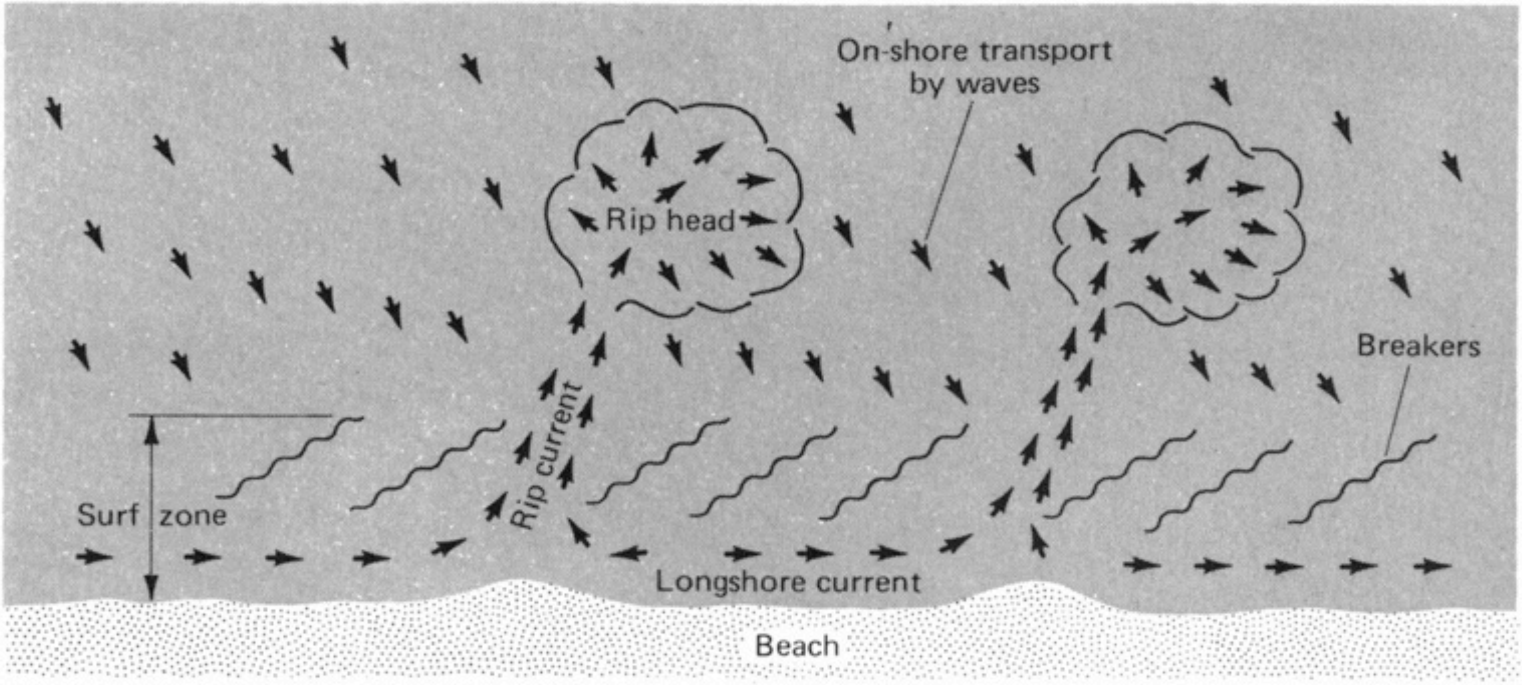
PLUNGING BREAKERS



SURGING BREAKERS



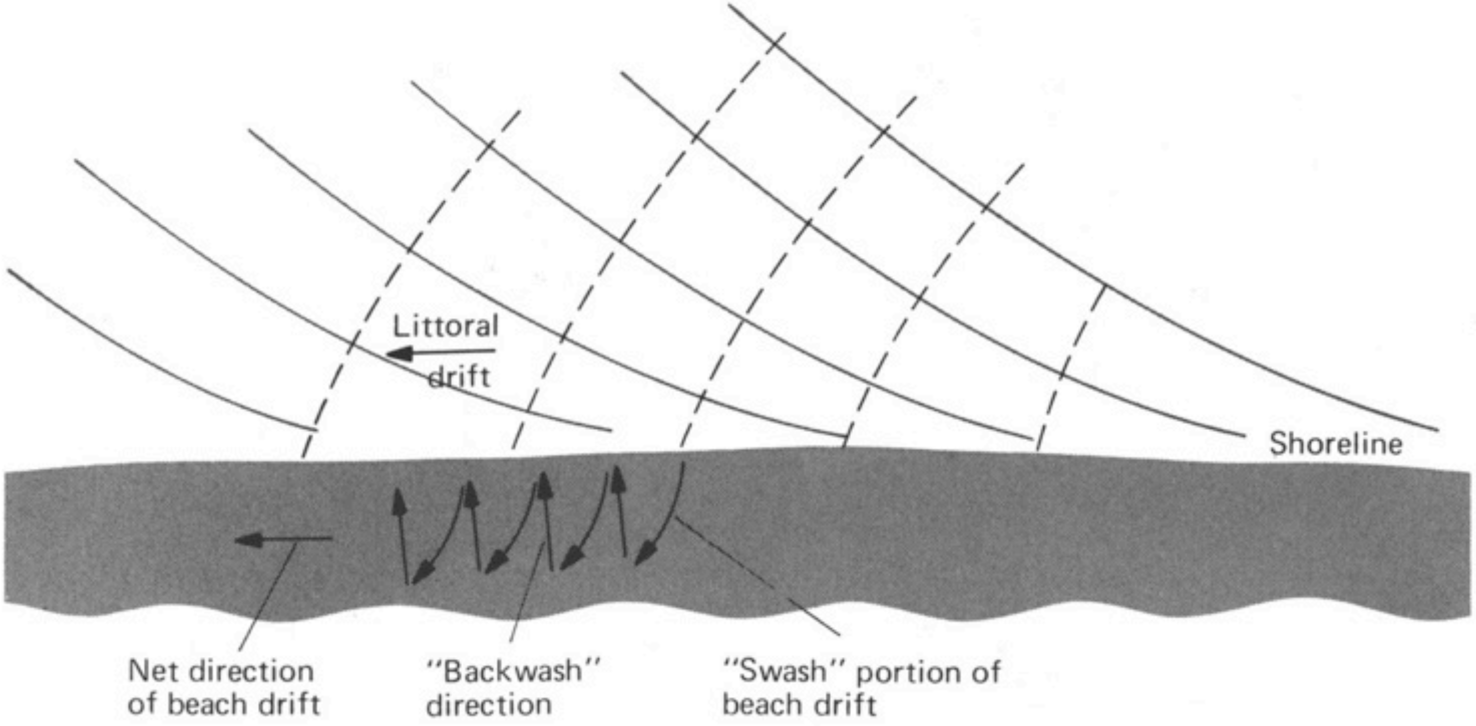
Rip Currents



Rip currents are the primary mechanism for returning water through surf zone, and are the most dangerous for swimmers

Also broad, weak flow near seabed = undertow

Longshore or Littoral Drift

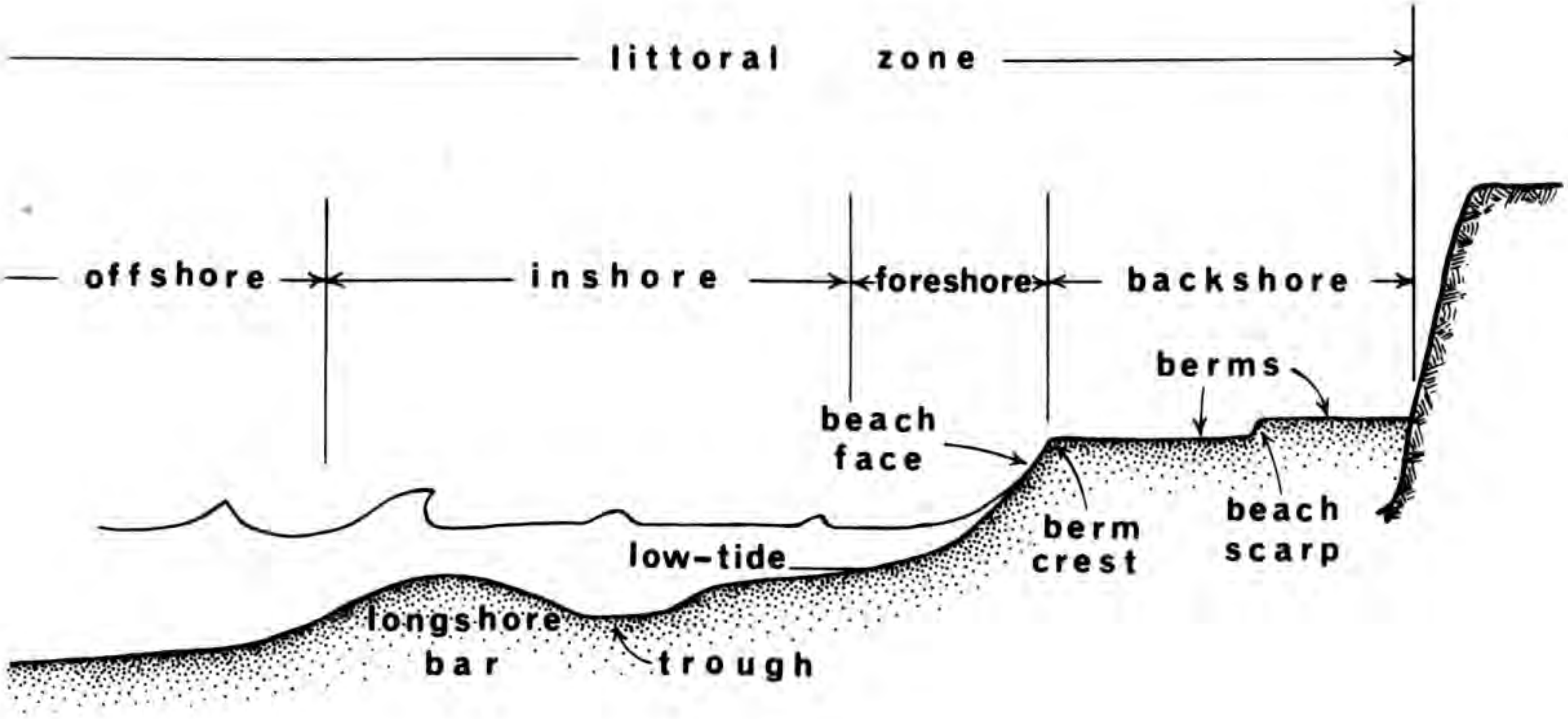


Waves break at angle to shore, which causes swash at angle to shore

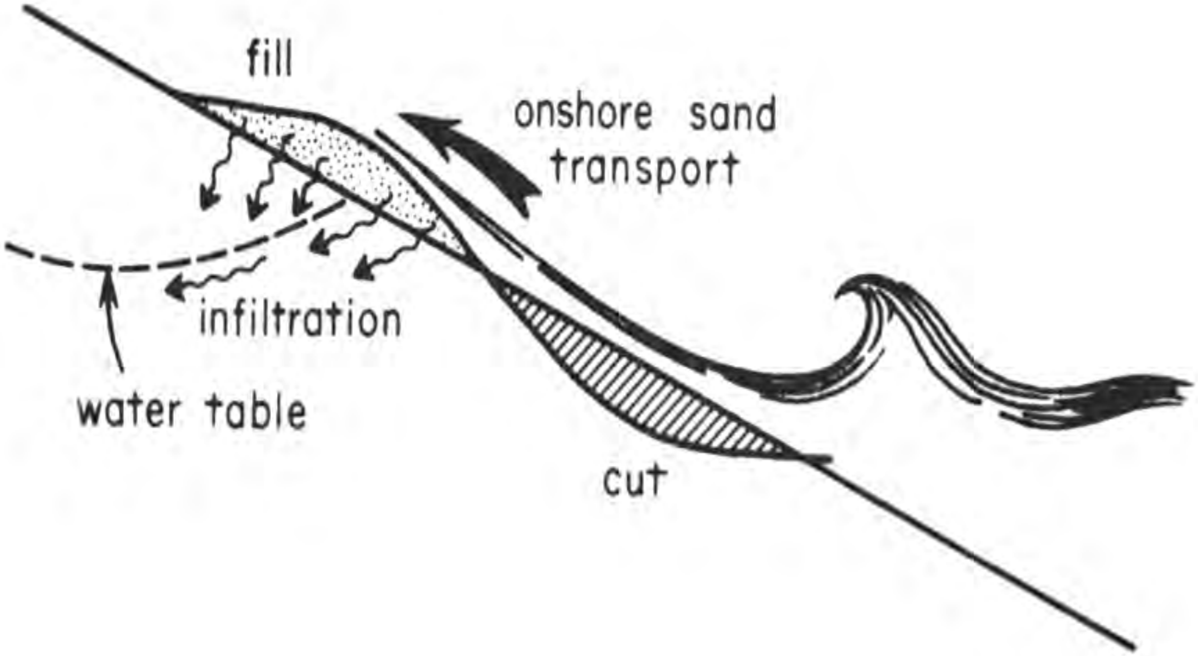
Backwash follows gravity down foreshore

Net effect is water and sediment transport along shore

Beach Morphology



Beach growth during swash and backwash

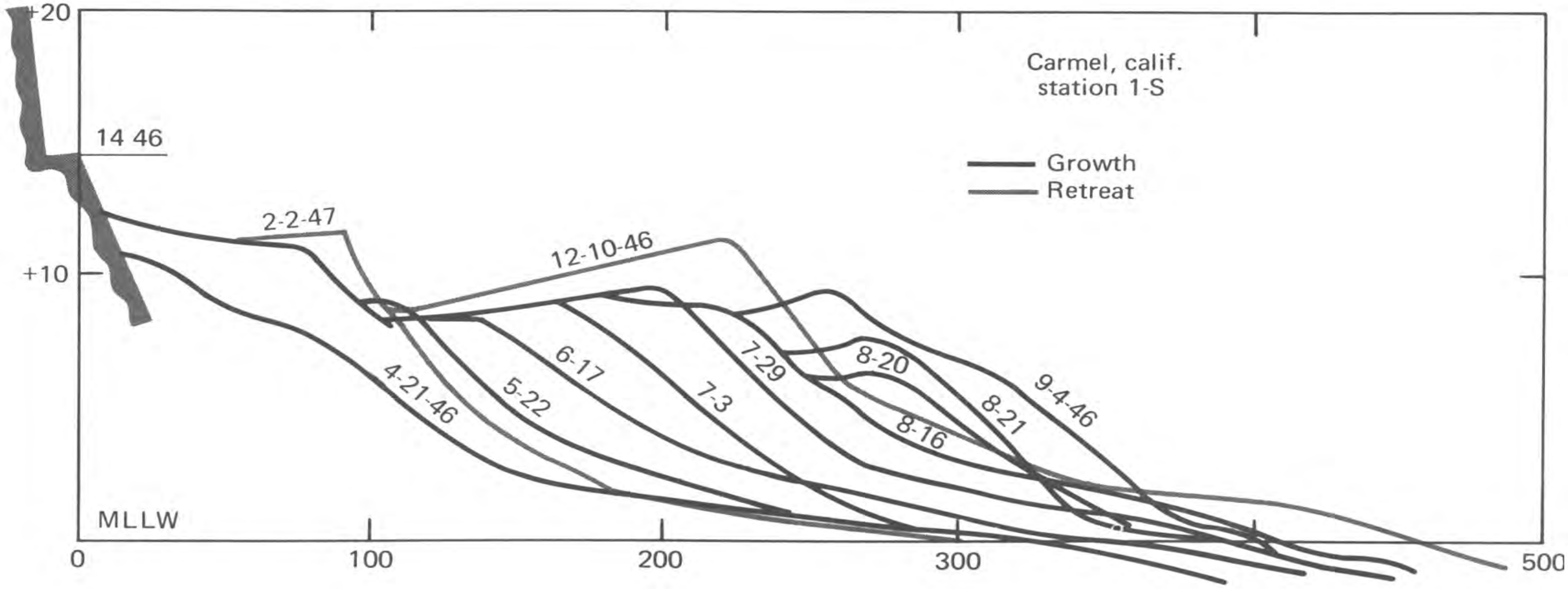


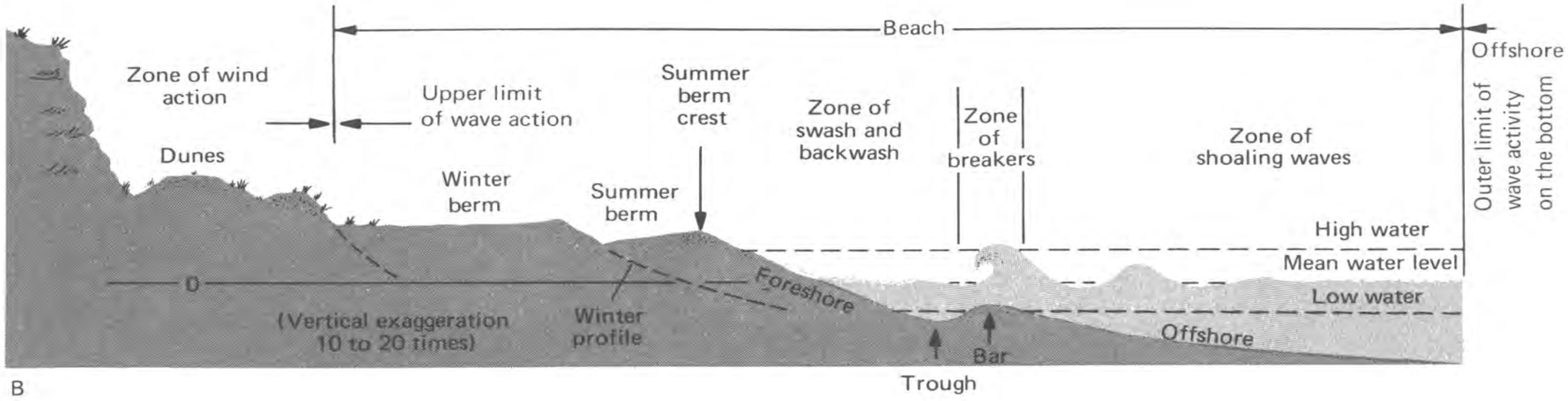
Swash – flow up foreshore after wave breaks
transport all water and much sediment,
but water percolates into permeable beach sand

Backwash - less water and sediment flow with backwash

Therefore, beach builds up to uniform level, creating the berm

Summer Beach Growth





Impacts of winter storms

Storms bring strong winds and larger waves

Strong winds push ocean water against coast = storm surge

Larger waves erode beach sediment (i.e., erode fairweather berm)

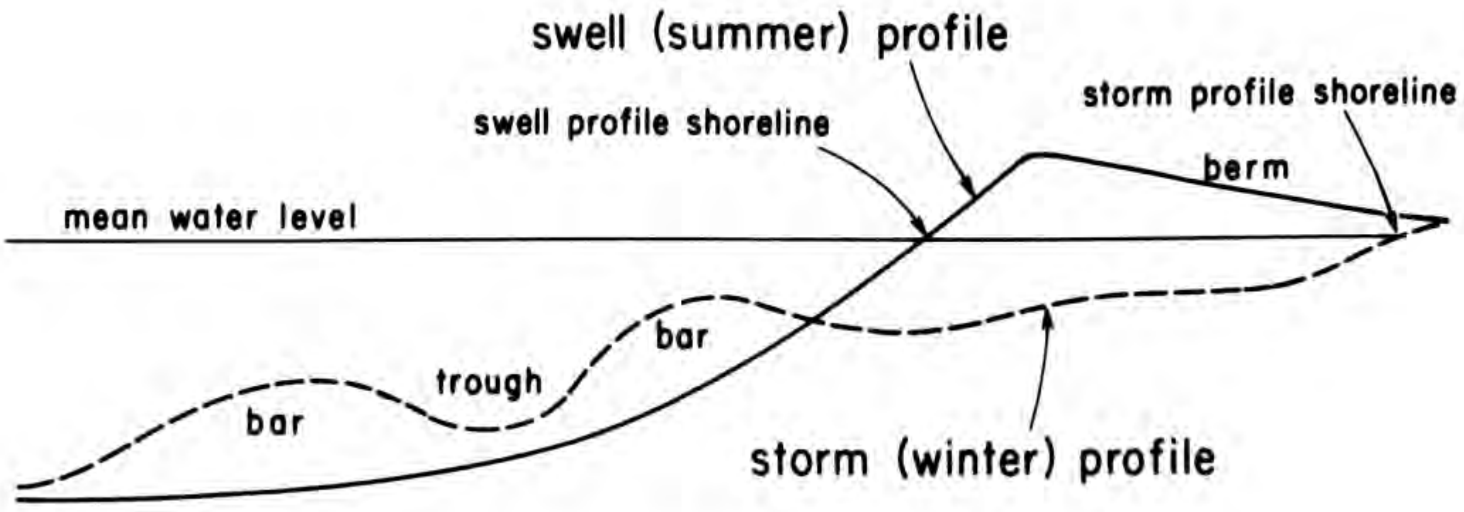
Sediment goes to:

- build bars offshore
- build higher berm (storm berm)
- washes through dunes forming washover deposits

Sediment stored in offshore bars is transported back slowly by waves during fairweather (due to wave crest/trough asymmetry and net drift shoreward)

Processes create cycle of summer/winter beach profiles

Summer/Winter Beach Profiles



Summer: wider berm

not much sediment in bars

Winter: summer berm gone; higher berm possible

much sediment in bars

Coastal Barriers

Spits and barrier islands

Common for trailing-edge margins
- gentle gradients
- little tectonic uplift/subsidence

Stretch along most of US Atlantic and Gulf coasts

southern Washington coast
- (protecting Willapa Bay and Grays Harbor)

Landward migration is common today
- due to sea-level rise

Seaward growth can occur near fluvial sediment sources

Formation of spit

Longshore transport is dominant mechanism

Tidal flux in/out of embayment creates inlet

Barrier Islands

Tidal inlets at both ends

Elevation depends on sand supply and winds forming dunes – typically <10 m

Low barrier islands can experience washover during storms

Length of island depends on amount of water that must enter/ leave lagoon with tides (= tidal prism)

Formation of Barrier Islands

Spit elongation – Extension of spit becomes too long to allow inlet to transport all water between tides, and a new inlet forms, changing a spit into an island

Bar submergence – Old dune or topographic high is surrounded by water as sea level rises.

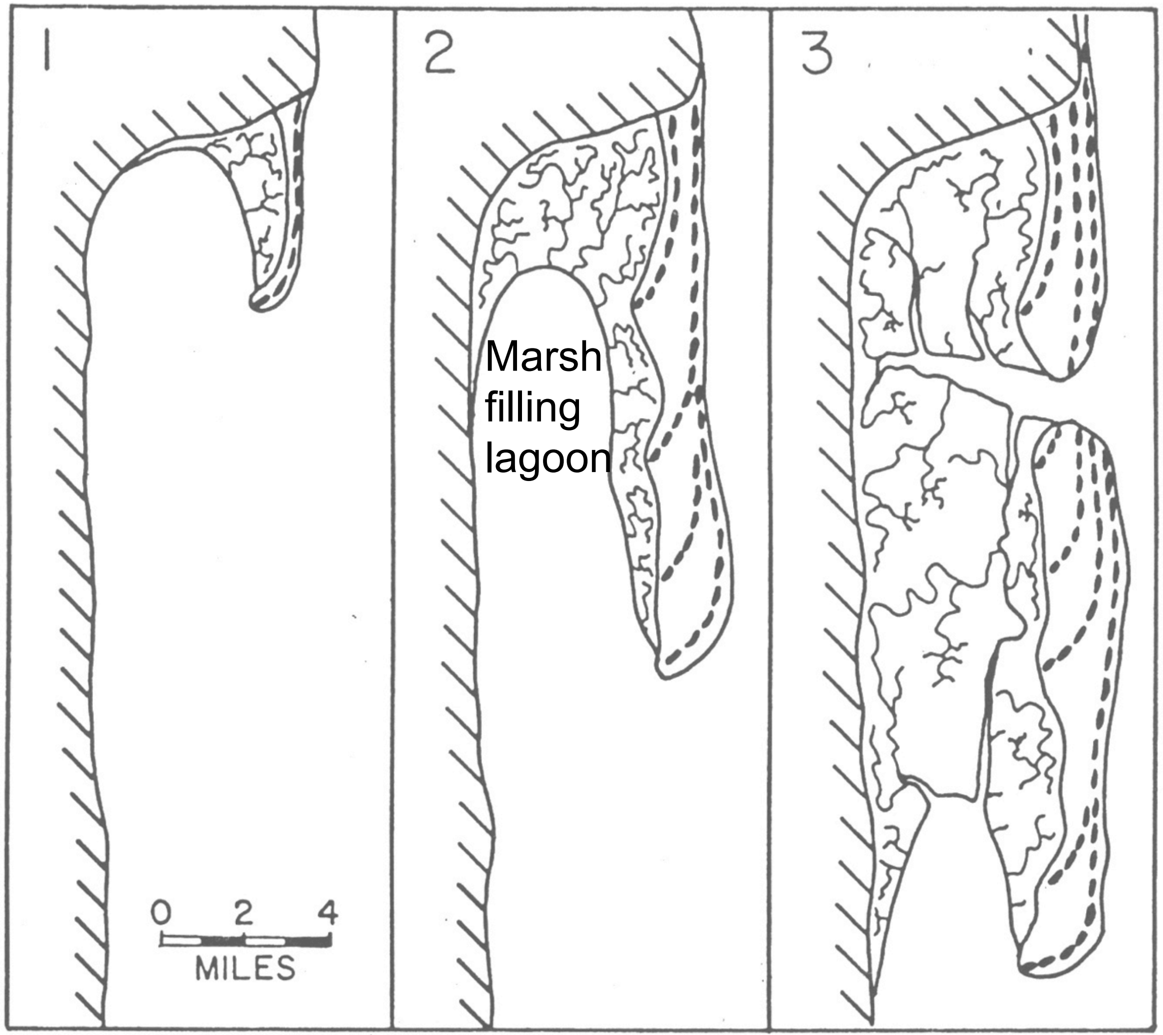
Bar emergence – During strong storm, waves create a large bar offshore, which becomes island when storm surge subsides

Spit Elongation

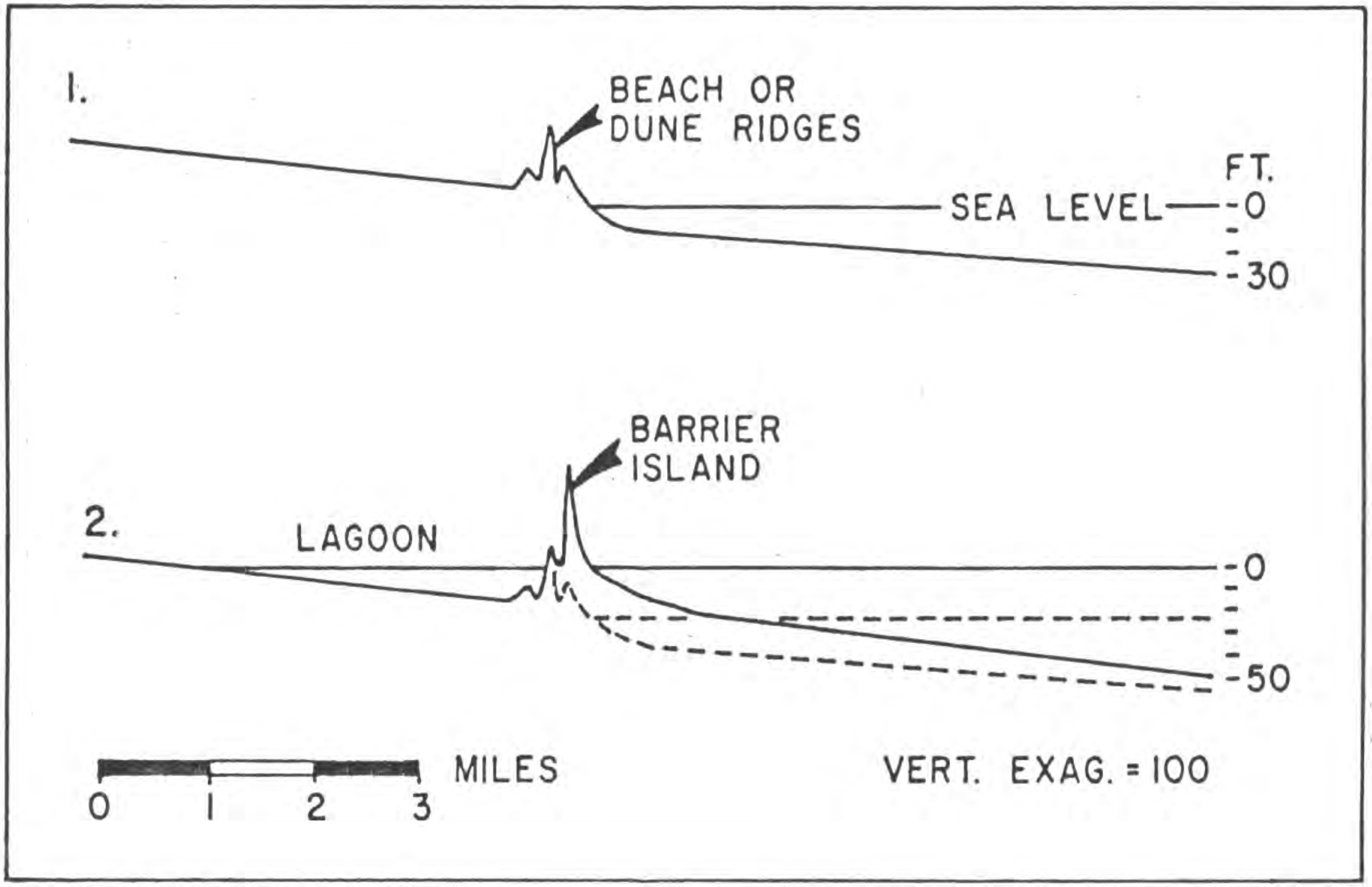
Longshore transport causes spit extension

Flow in and out of lagoon cannot occur entirely with changing tides.

Different water levels on the two sides of spit cause a new inlet to form – usually occurs during storms due to washover disruption and storm surge



Bar submergence



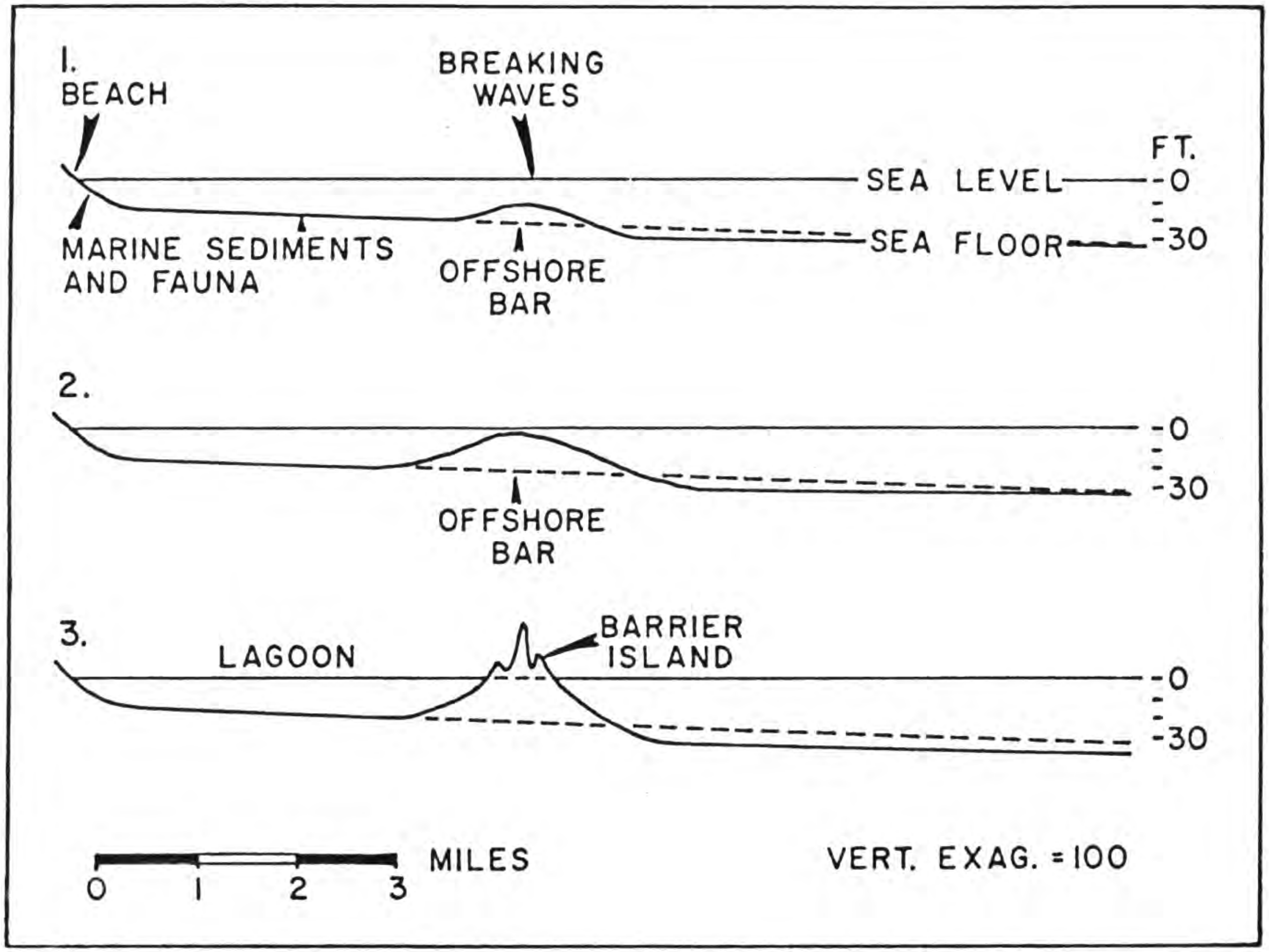
A dune or other topographic high is surrounded by water as sea level rises.

Bar emergence

Large bar forms offshore during storm

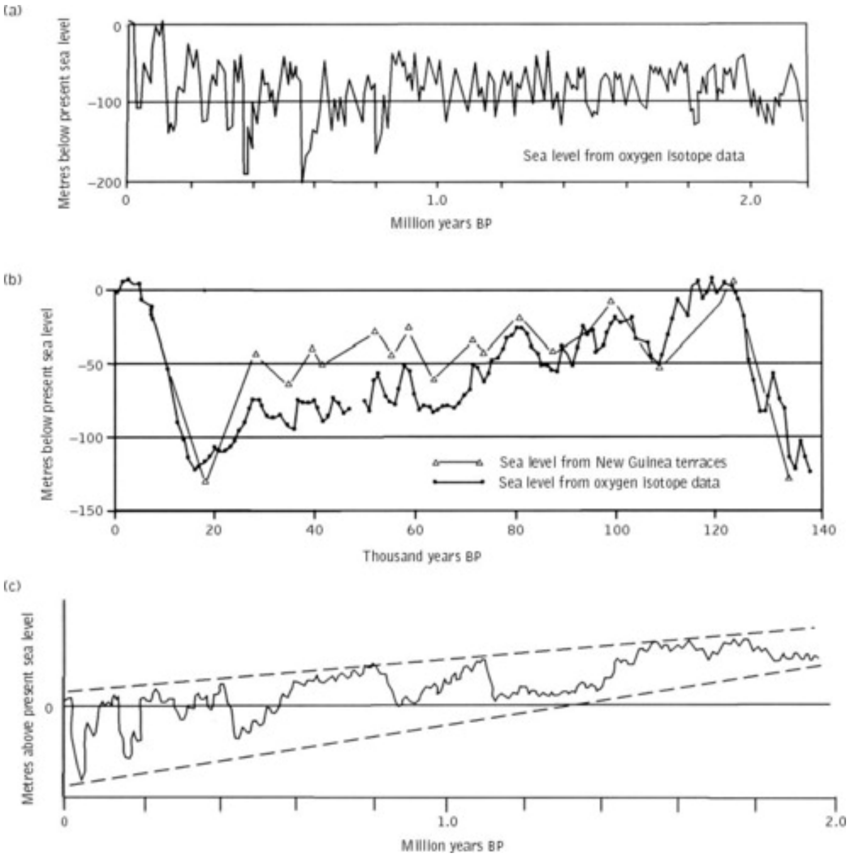
When storm surge subsides, bar is left at or above sea level

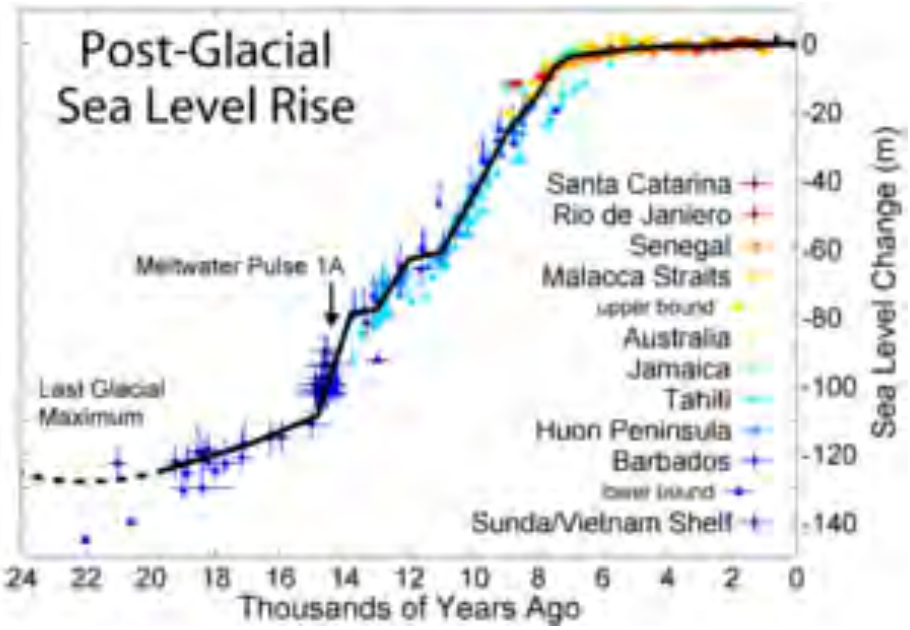
Winds create dunes that raise bar above sea level



Coastal Migration

Sea-Level changes cause beaches to migrate





Sea-level rise and migration of barriers

Shorelines migrate in response to:

- sea-level rise
- sediment supply (usually small for barriers,
  no coastal mountains on trailing-edge margin)
- shoreline erosion (waves, tidal currents, storms)
- tectonic motions (not important for most barriers,
  on trailing-edge margins tectonics are weak)
- consolidation (not important for most barriers,
  dominated by sand)

Landward migration found for most barriers

Seaward migration occurs where much sediment supplied
(e.g., near rivers)

Mechanisms for landward migration

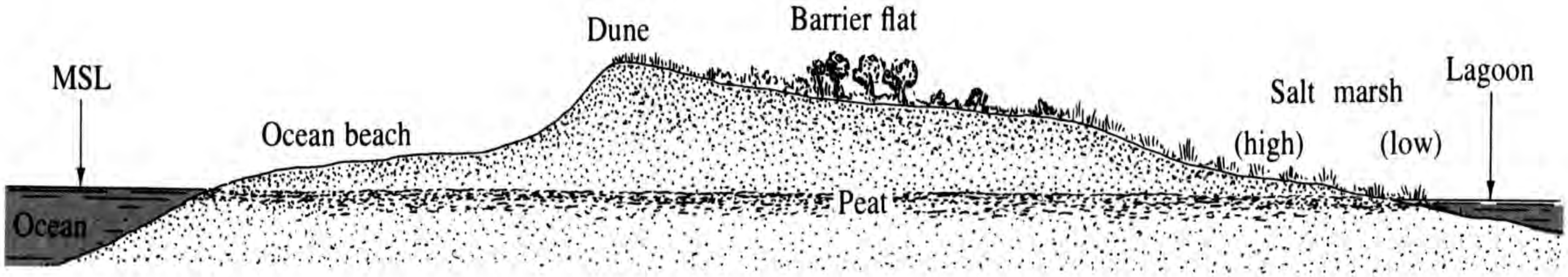
Must move beach sediment landward:

Wind transport to and through dunes

Washover during large storms

Tidal transport through inlets

Barrier cross section

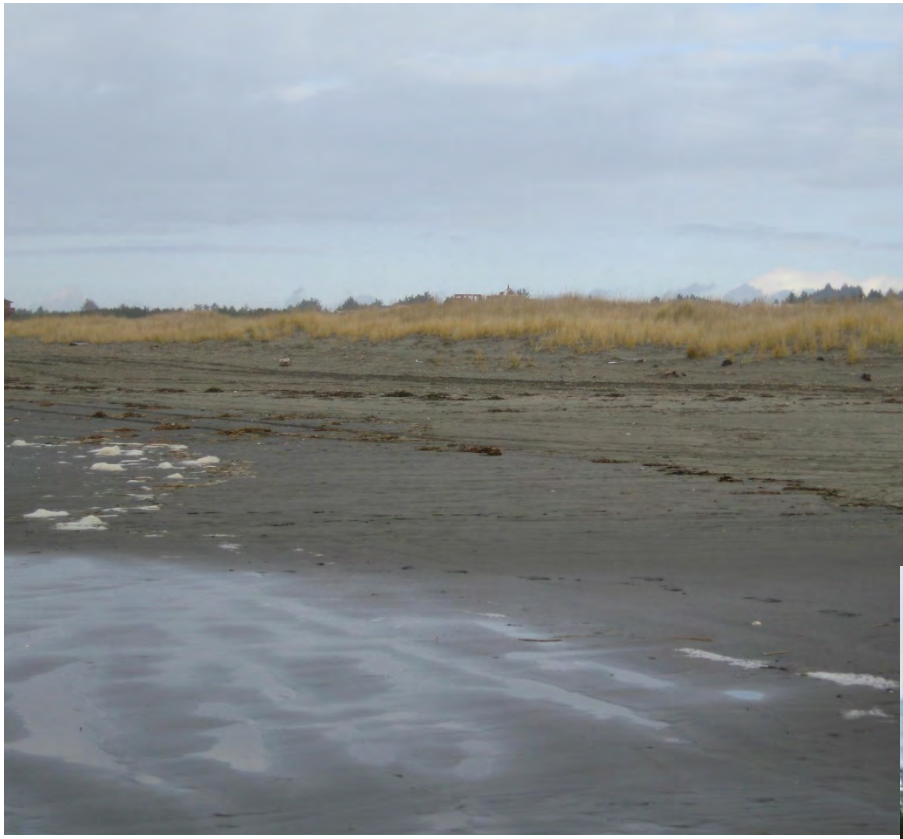


Natural dunes are not continuous, they have breaks that allow washover sediment to nourish some parts of the barrier flat

Other parts of the flats are protected and develop maritime forests

Tidal flats, salt marshes (temperate) and mangrove forests (tropical) are found near sea level on the lagoon side – contain mud and peat

As barrier migrates landward, mud and peat are buried, and then exhumed on beach



Grayland dunes

healing dunes with snow fences

New Jersey overwash
from Hurricane Sandy

Flood-tide delta

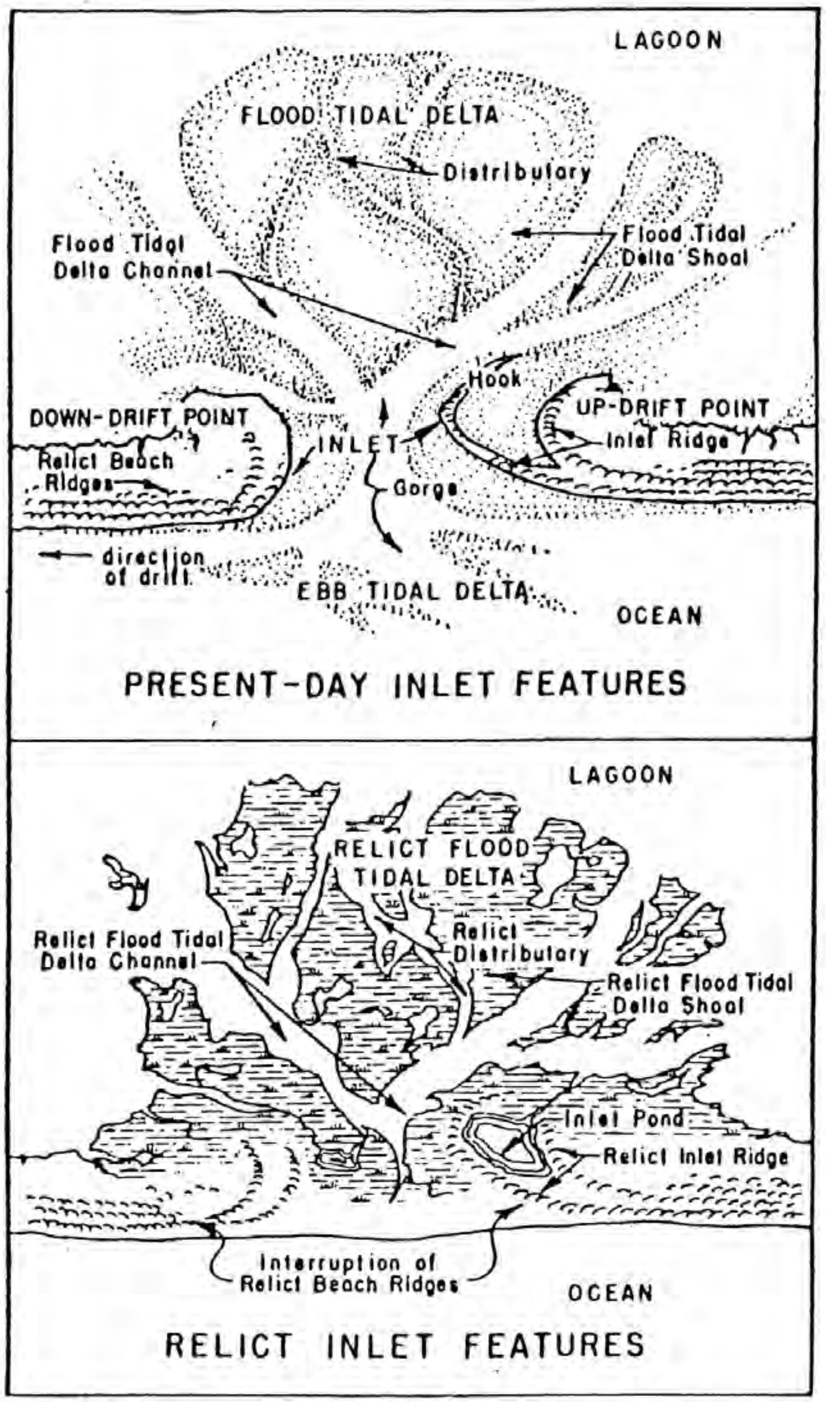
Beach sand carried by longshore transport reaches inlet

If tide is flooding (rising), sand carried into lagoon – where waves are weak

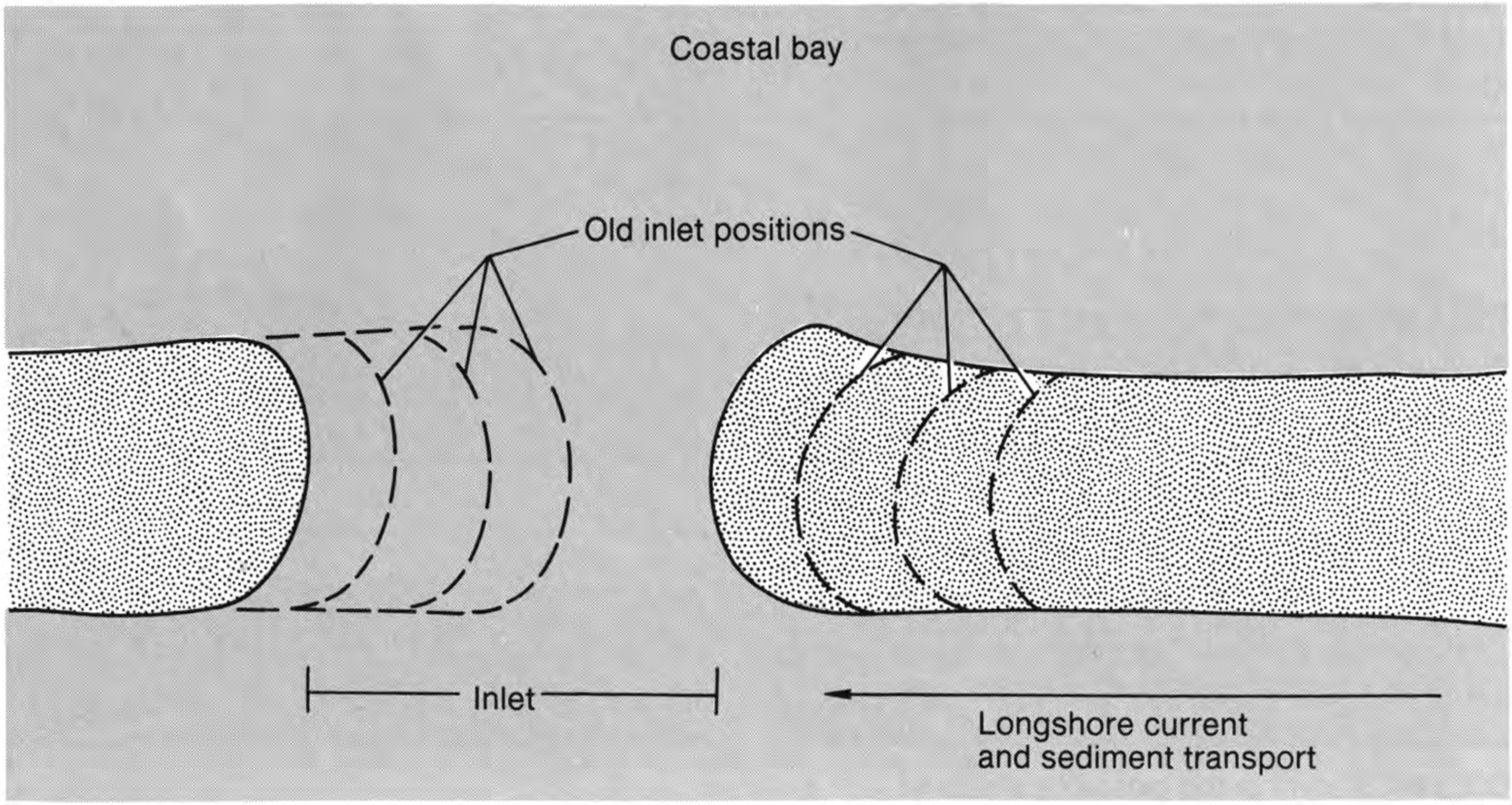
Sand stops moving and forms flood-tide delta, with distributary channels

Some sand reaches inlet during ebb (falling) tide and some sand is transported out of lagoon by ebbing currents. This sediment forms an ebb-tide delta

Ebb-tide deltas are small, due to continued reworking by ocean waves



Inlet Migration



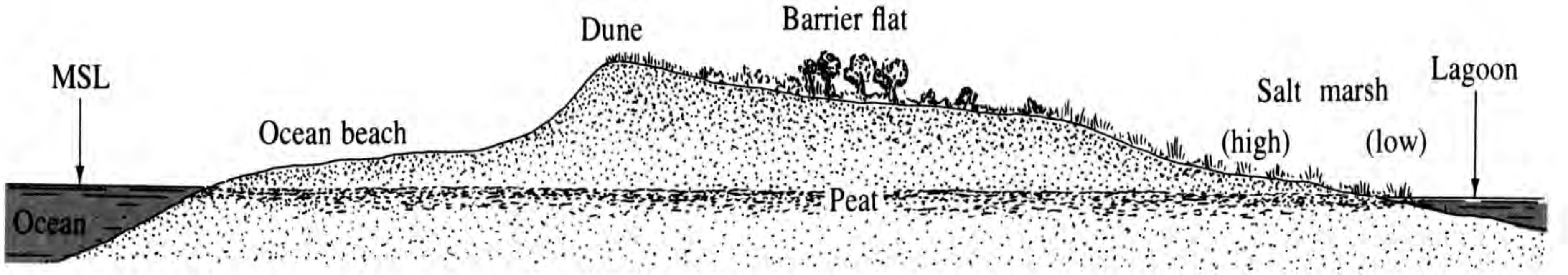
Sand is removed from longshore transport by:

- accumulation on upstream side
- entrapment in the flood-tide delta

Removal of sand starves the longshore transport system, and causes erosion of the downstream side…

causing the inlet to migrate in direction of longshore transport

Barrier cross section



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Tides

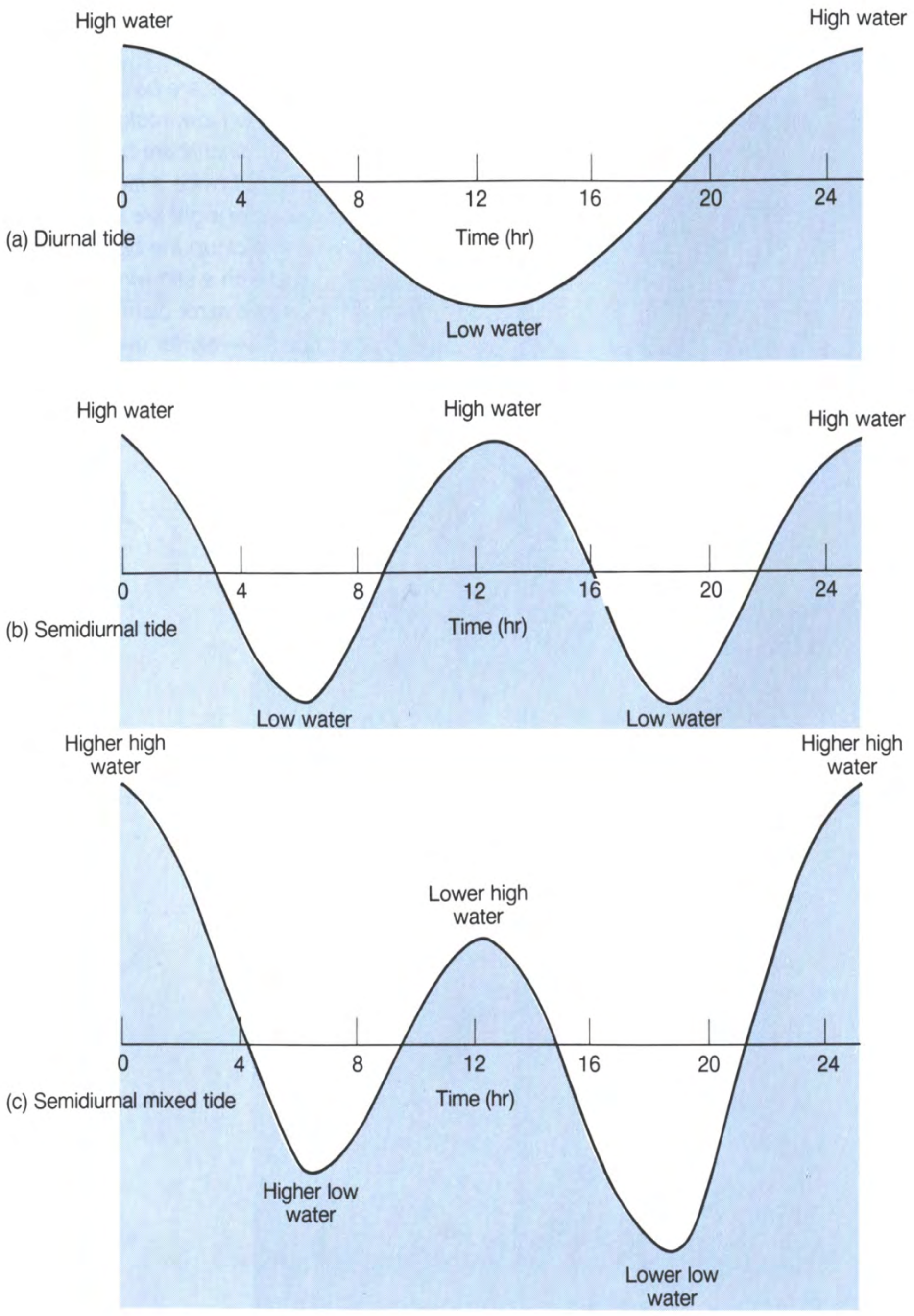
Daily tidal fluctuations

(actually a little more than 24 hours)

Some areas have diurnal fluctuations, with one high and one low each day

Most areas have semidiurnal fluctuations, with two nearly equal high and low tides each day

Other areas have mixed semidiurnal fluctuations, with two highs and two lows of unequal elevation

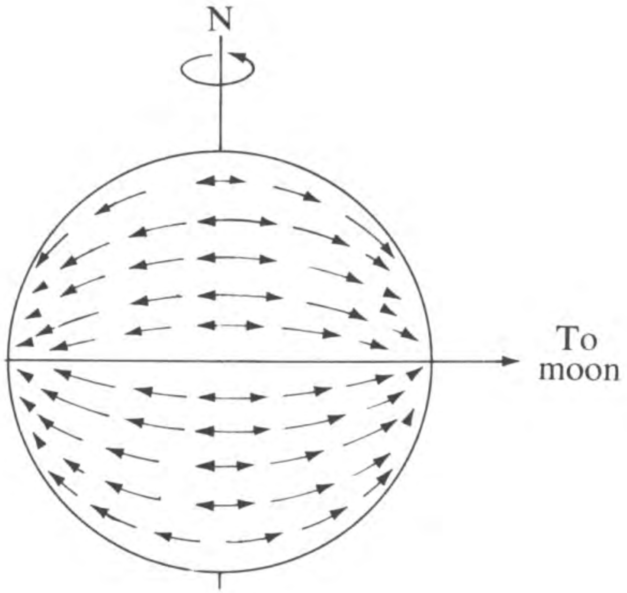


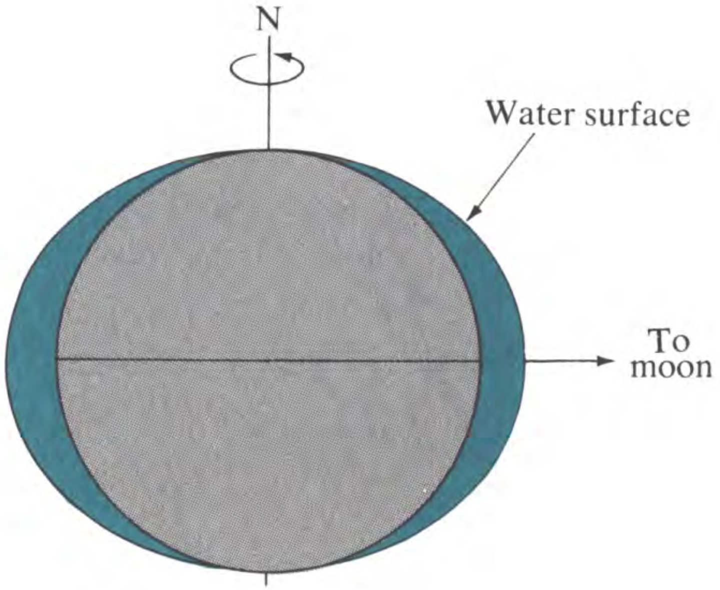
Cause of Tides

Gravitational attraction of moon/sun creates bulge of ocean water

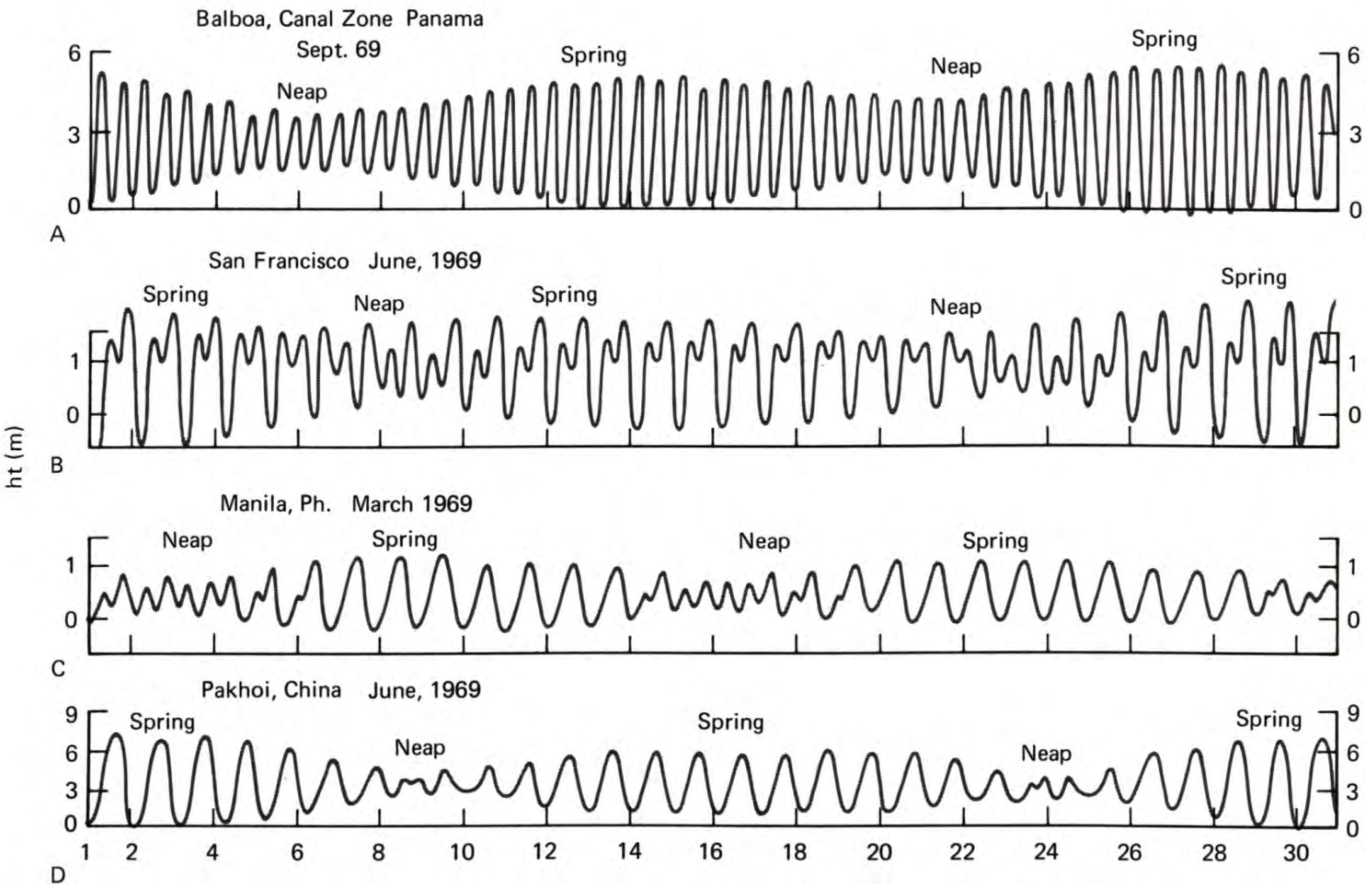
Centrifugal force creates second bulge

Earth rotates through both bulges in ~24 hours, causing two high and two low tides each day





Monthly fluctuations in tides



Over ~28 days, orientation of moon and sun changes with respect to Earth

This causes two periods of large tidal range (spring tides) and two periods of small tidal range (neap tides) each month

Why we have monthly changes in tides

Gravitational attraction from moon and sun pull water toward them

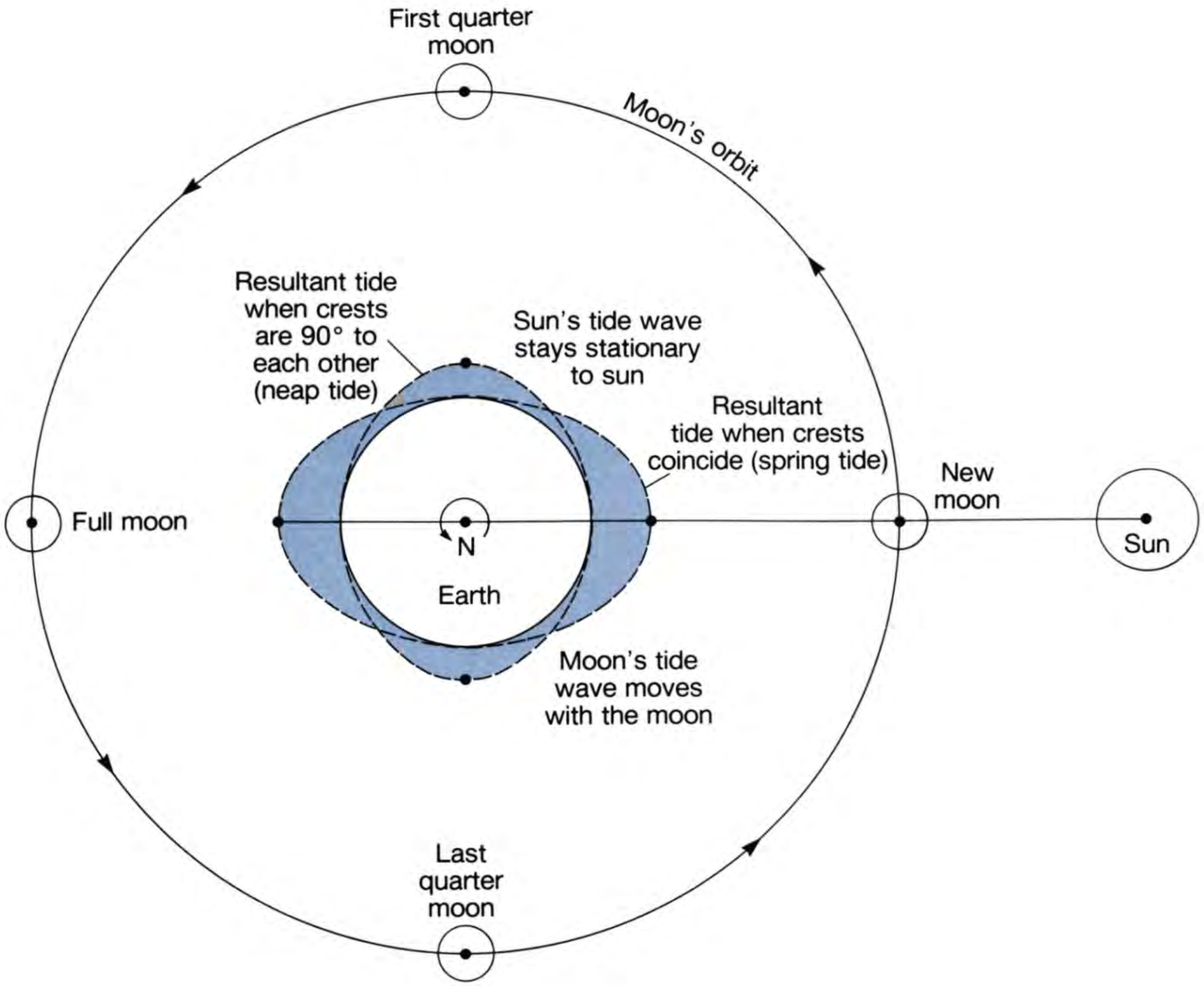
This creates two bulges

As the Earth rotates through these bulges each day, locations experience changing sea level

Over a ~28-day period, the orientation of the moon and sun change, creating different tidal ranges through month

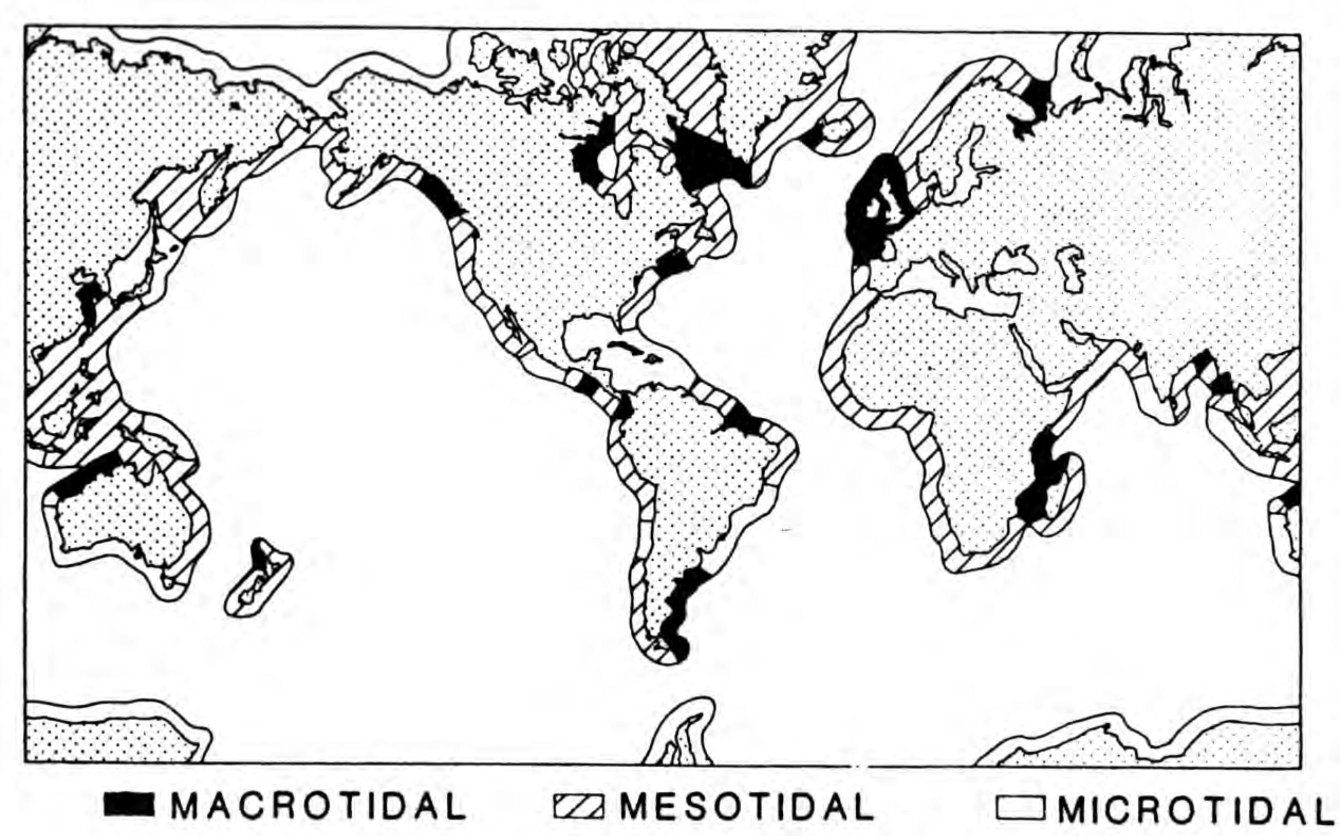
Spring tide = large differences

Neap tide = small differences



Tidal range

(vertical difference between high and low tide)



Macro > 4 m

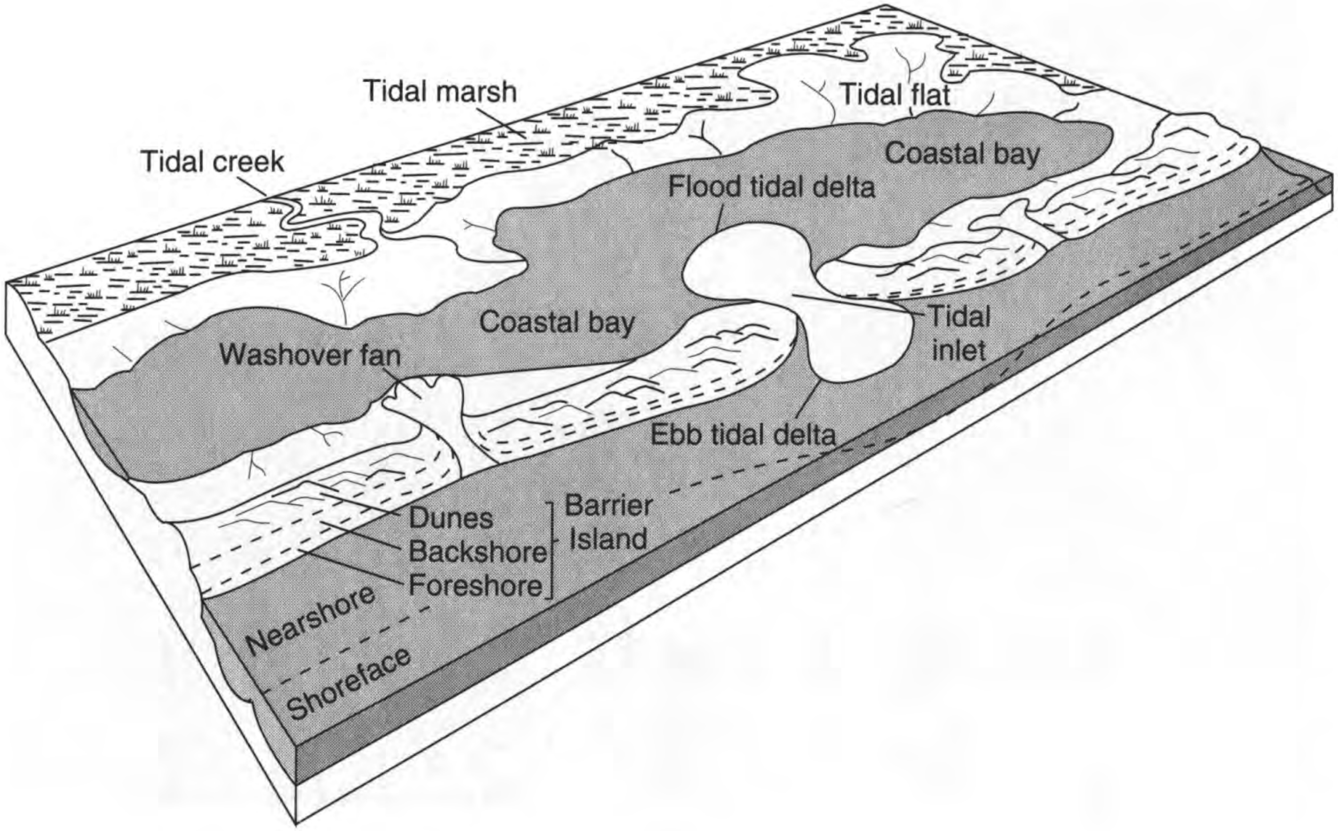
Meso = 2-4 m

Micro <2 m

Local differences in geometry of seabed can increase or decrease tidal range

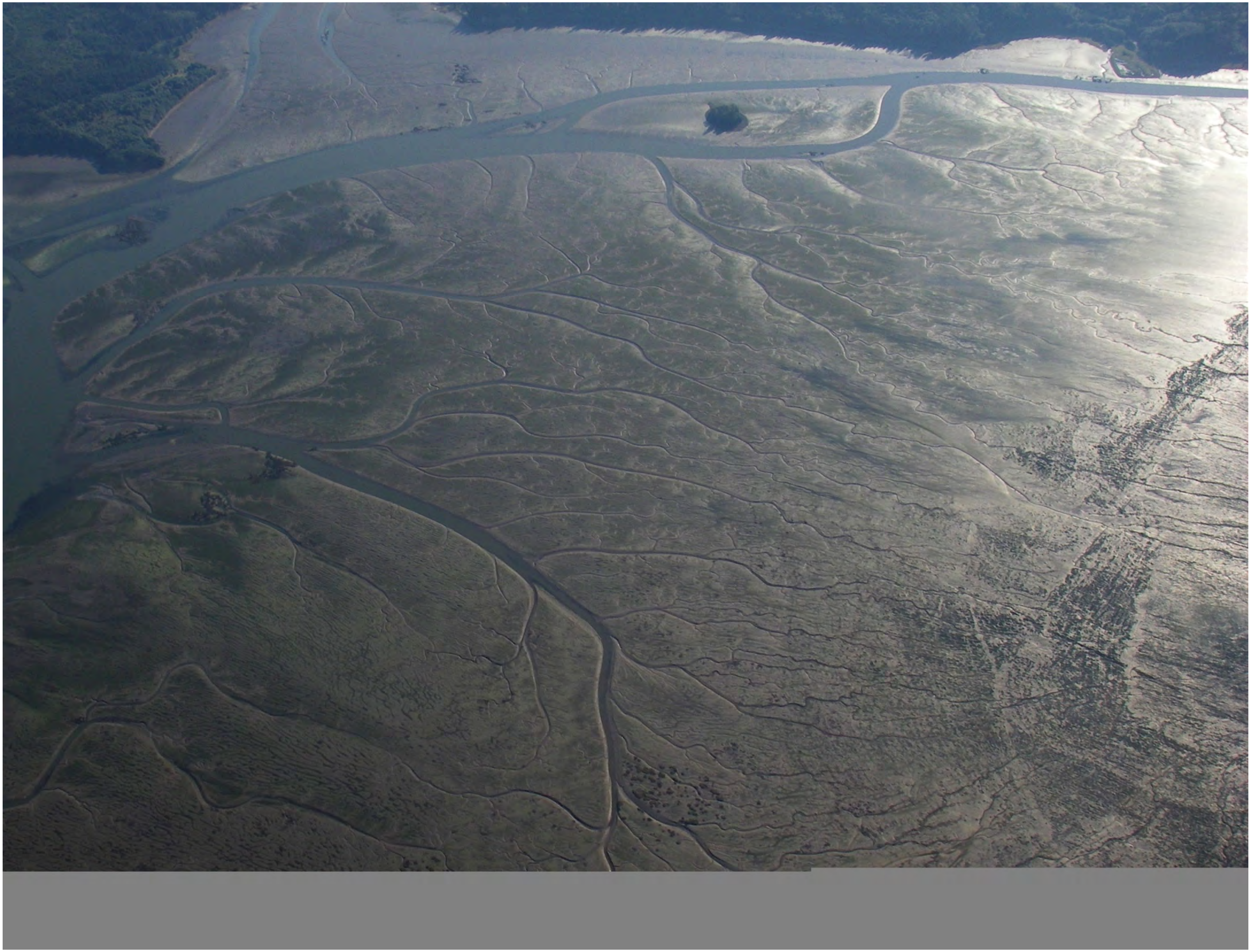
Tidal Flats and Marshes

Lagoonal environments

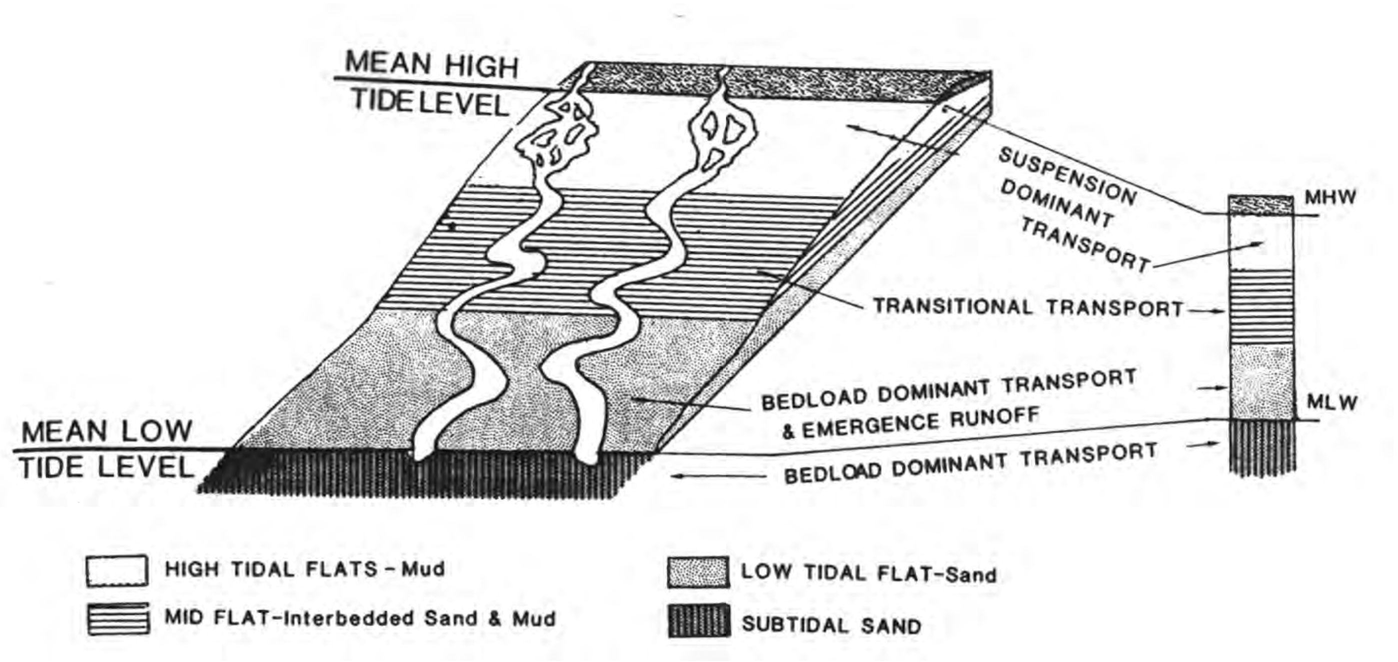


Intertidal environments (between high and low tide) surround lagoon

They trap and accumulate sediment, filling lagoon



Tidal-flat sedimentation

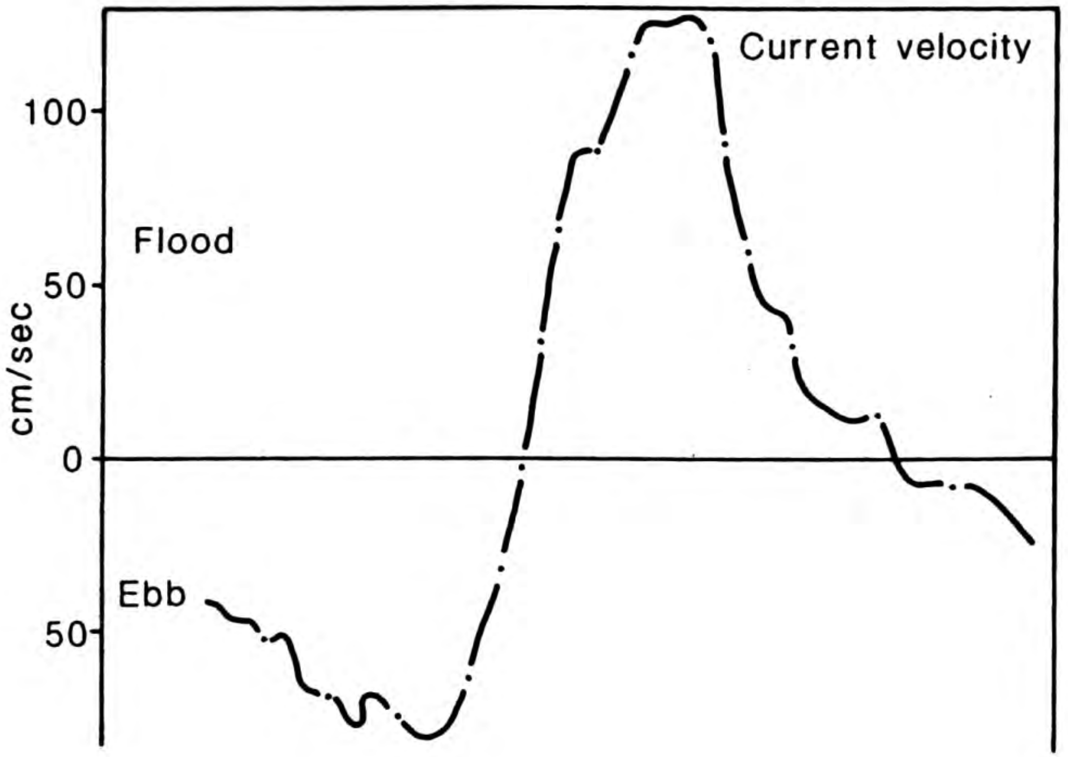


Mud transported as suspended load accumulates on high flat

Sand transported as bedload accumulates on low flat

Upward growth ultimately controlled by rate of sea-level rise

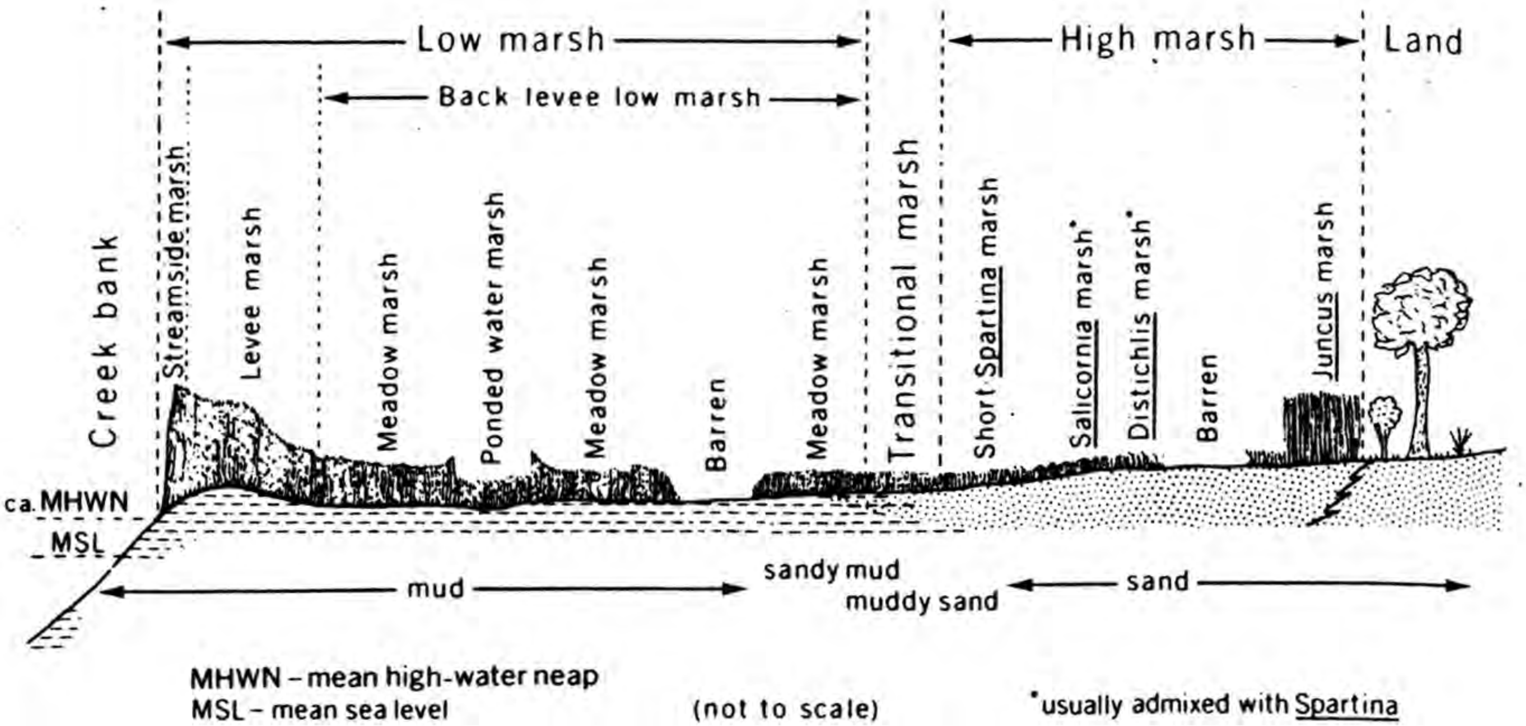
Asymmetry between flood and ebb currents



Frictional interaction with seabed commonly causes flood current to be stronger

This results in more sediment being transported into the lagoon and onto the tidal flats, enhancing accumulation

Marsh vegetation

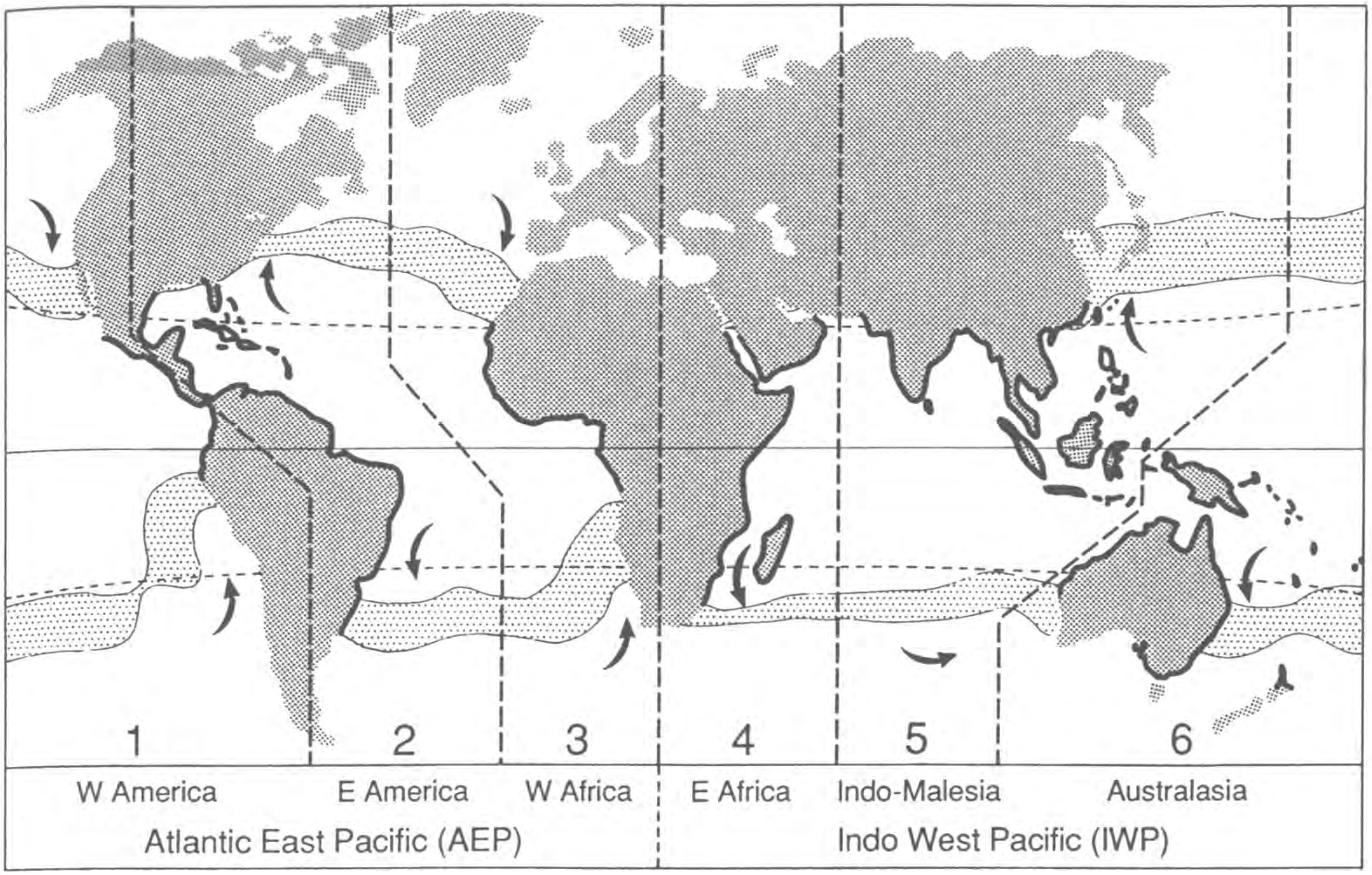


Many niches develop, depending on many variables, e.g.,: salt and soaking tolerance, and current velocity

Vegetation helps to baffle flow, reduce tidal current velocity, and enhance sediment accumulation

Mangrove vegetation

Mangrove distribution



Found in warm, tropical settings

Ocean circulation extends latitudinal distribution on west sides of ocean basins, and reduces distribution on east sides

Sediment Budgets for Beaches and Coasts

Sediment Sources:

Longshore drift (local source)

Cliff erosion

Rivers

Biogenic shells

Continental shelf

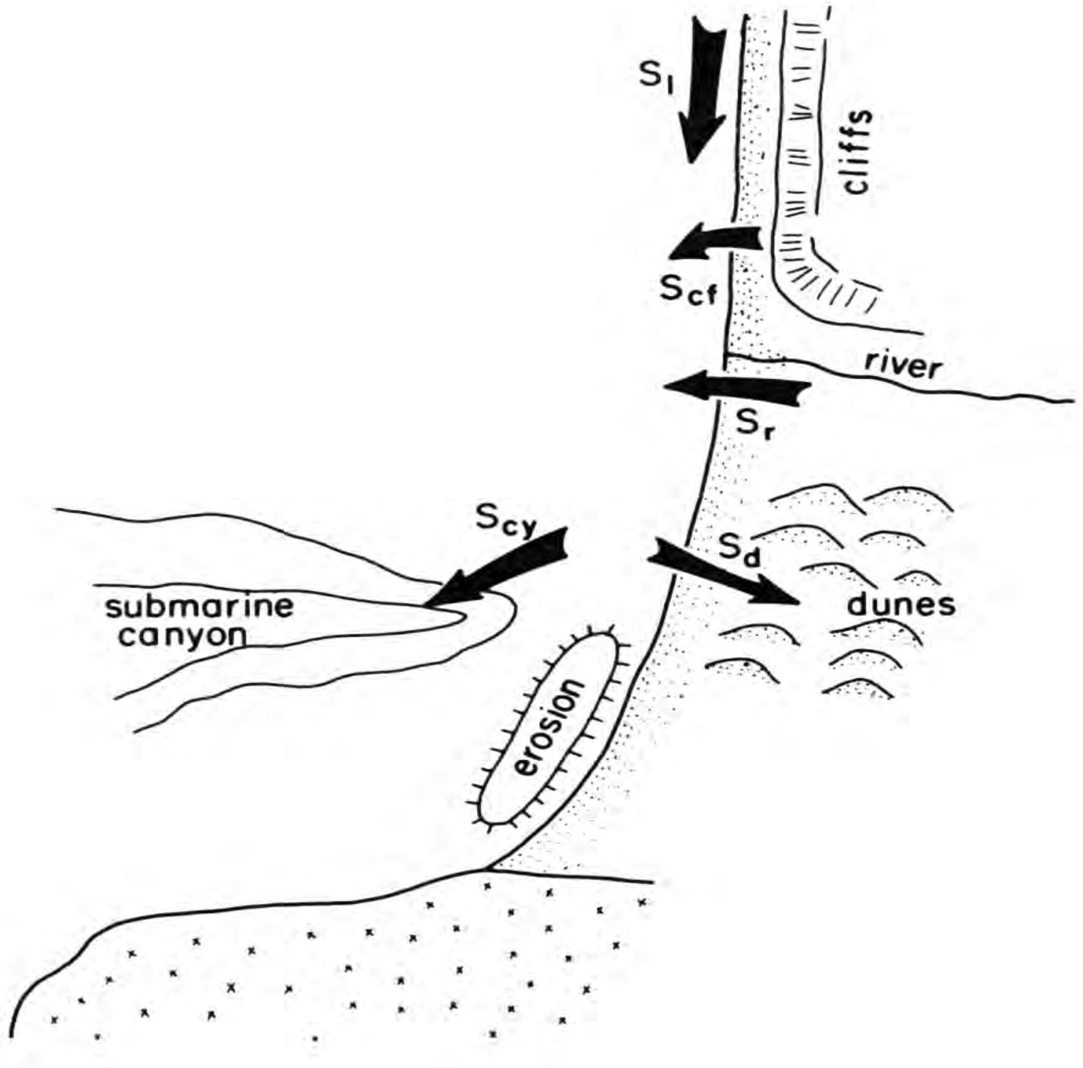
Sediment Losses:

Dunes

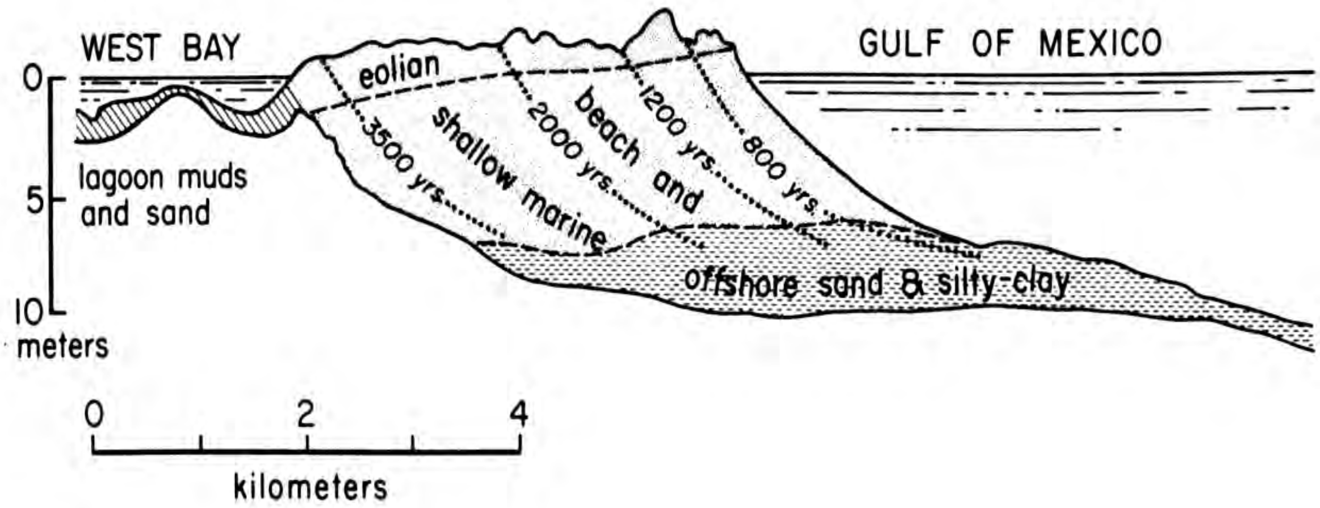
Lagoon (washover, tidal inlets)

Submarine canyons (unusual)

Longshore drift (local sink)



Prograding shoreline, building seaward



Requires sediment supply to exceed processes leading toward landward movement of shoreline.

Rivers are most common supply mechanism

(example from east Texas coastline, downstream of Mississippi supply)

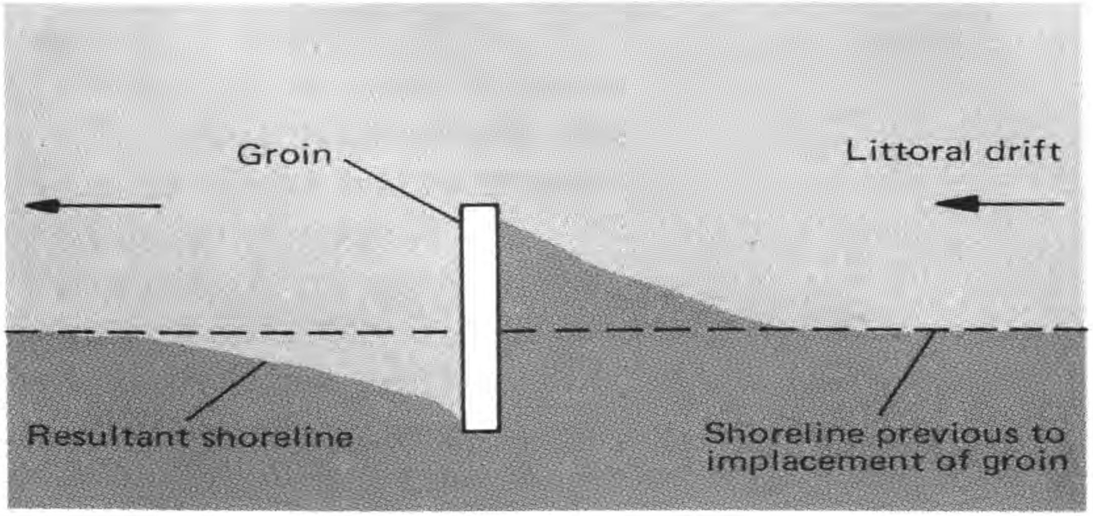
Prograding beach ridges

Human Structures

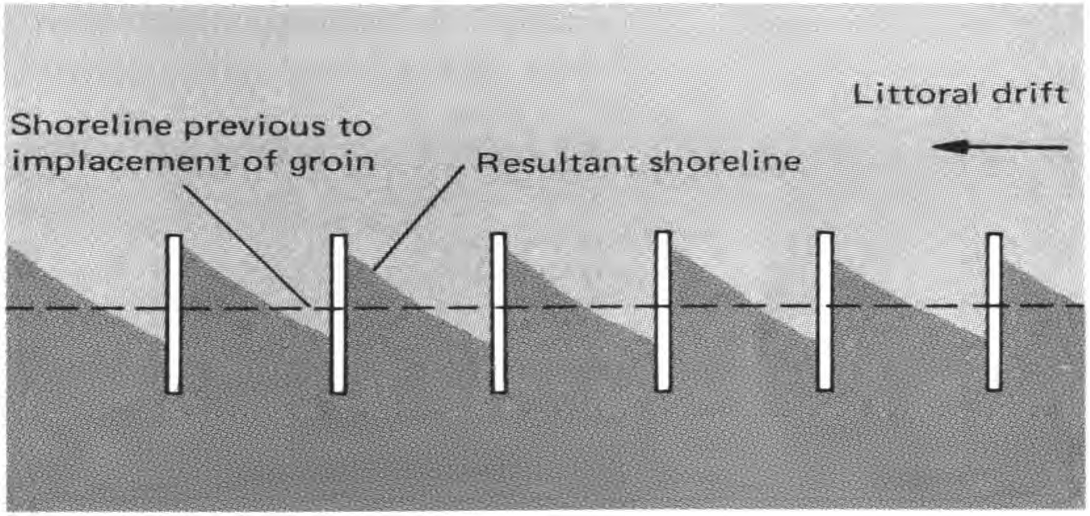

10

Impact of Groins to Shoreline

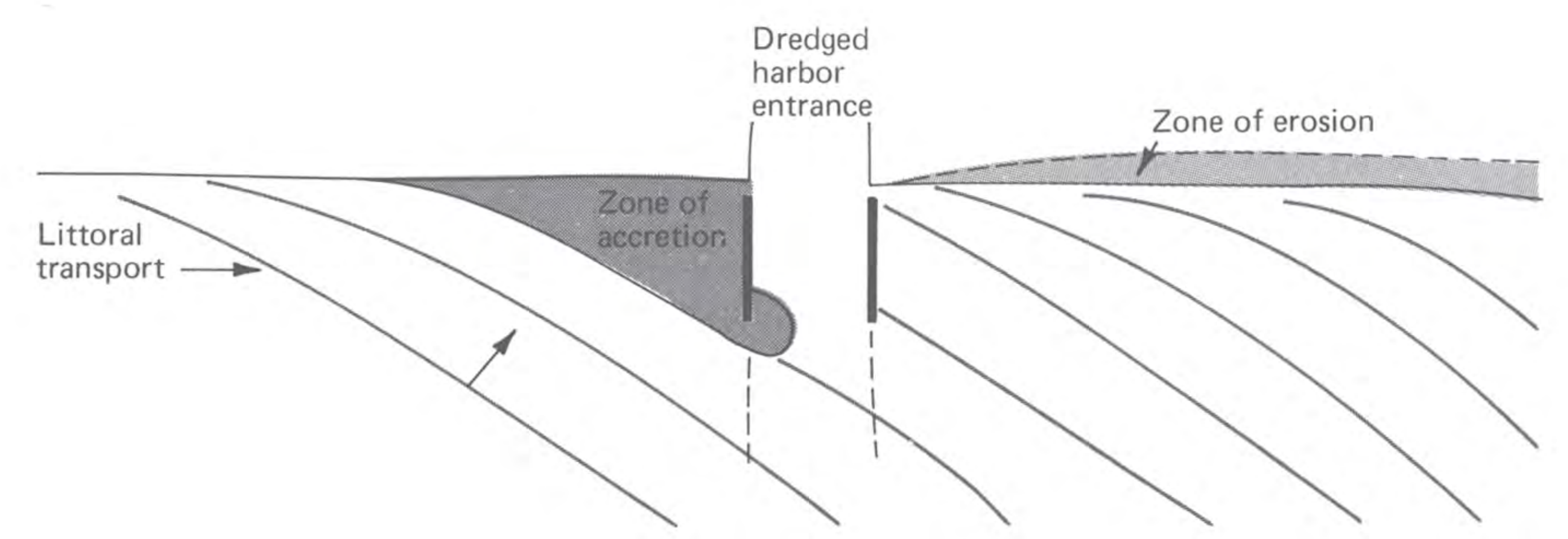
Deposit sediment on upcurrent side, erode beach on downcurrent side



Deflects longshore transport farther offshore



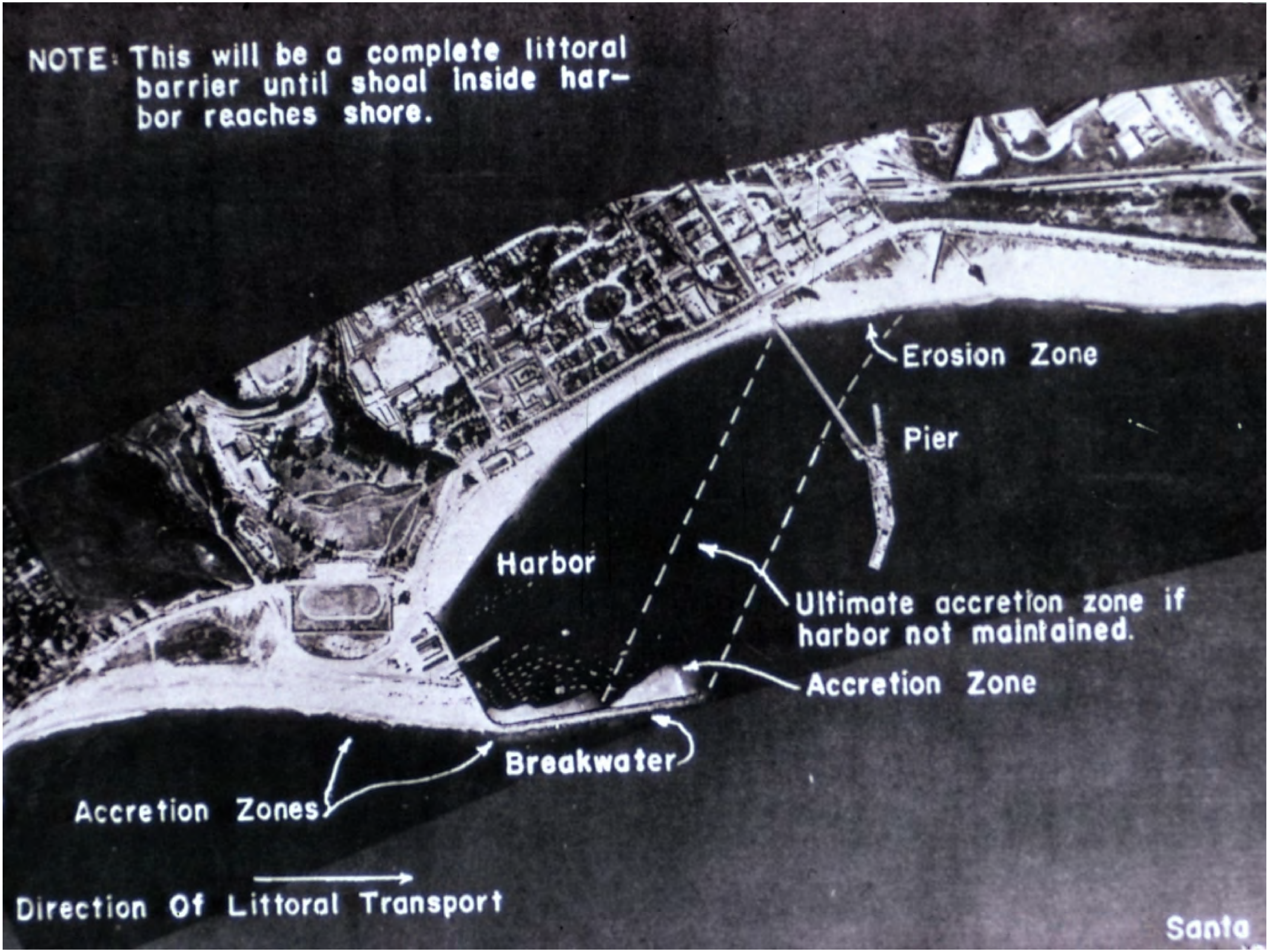
Jetty entrapment of sediment

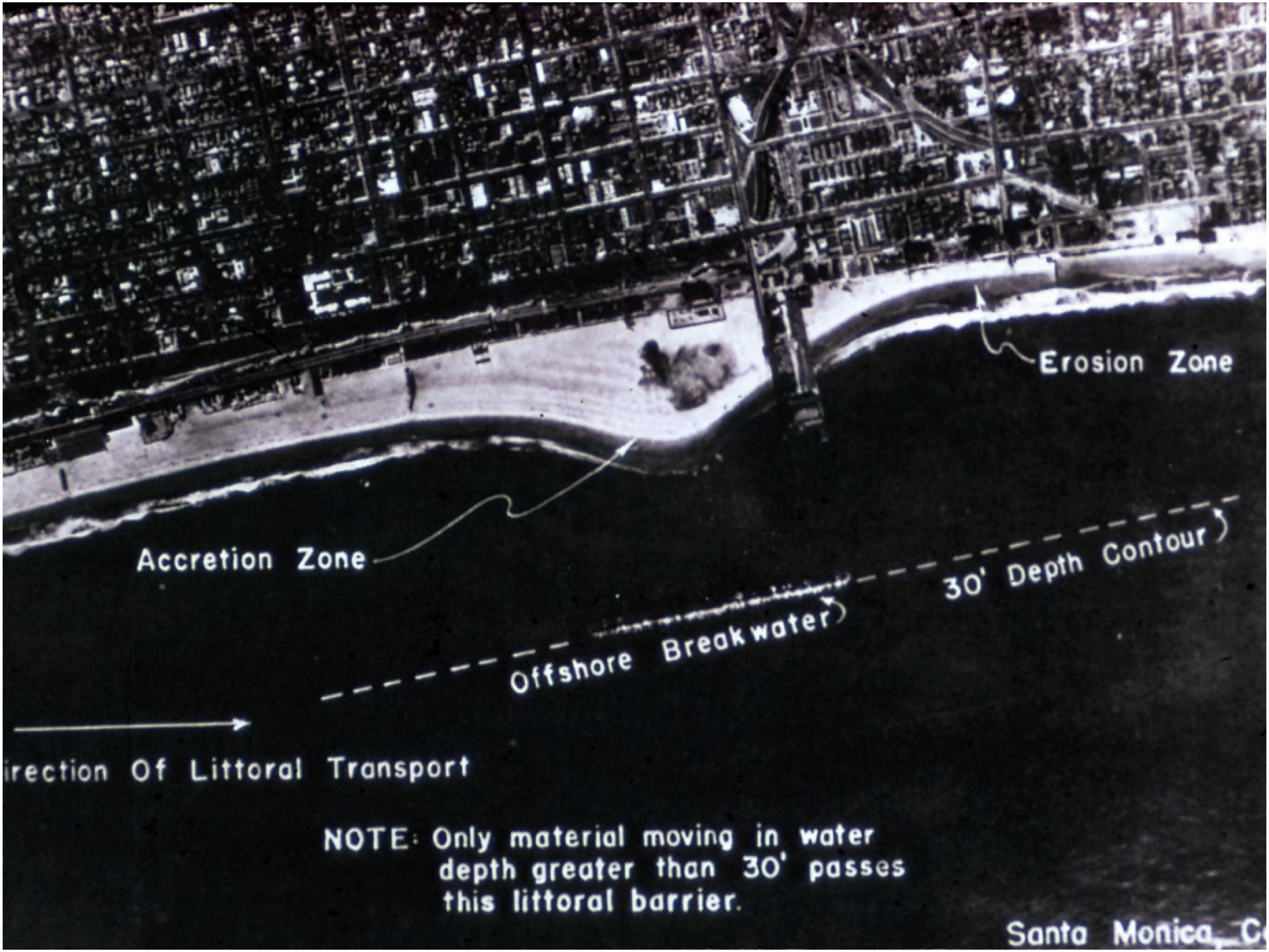


Sediment trapped on upstream side, due to longshore transport

Loss of sediment causes erosion on downstream side, to resupply longshore transport system

Similar to entrapment associated with groins, but on larger scale


NOTE: This will be a complete littoral barrier until shoal inside harbor reaches shore.
Erosion Zone
Pier
Harbor
Ultimate accretion zone if harbor not maintained.
Accretion Zone
Breakwater
Accretion Zones
Direction Of Littoral Transport
Santa



NOTE: Only material moving in water depth greater than 30' passes this littoral barrier.

Santa Monica, C

Human Beach Structures