COASTAL STORM RISK MANAGEMENT PLANNING OVERVIEW IN A RISK INFORMED CONTEXT

Prepared by Coastal PCX
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CSRM PLANNING OVERVIEW (OBJECTIVES OF TODAY'S WEBINAR)

Highlight required components, processes and analyses of Coastal Storm Risk Management Planning with an emphasis on iterative plan formulation to address study, decision, and implementation risk.

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CSRM PLANNING TOPICS

- Background, Authorities and History of CSRM
- Scoping: (characterizing the problems and opportunities)
- Plan Formulation: (Types of solutions)
- Deciding: (Evaluating and comparing alternatives)
- Implementing: Policies unique to Corps Coastal Program

KEY TAKEAWAYS - OVERALL

1. CSRM planning is similar to FRM, but with additional damage mechanisms (flooding, plus erosion and waves)

2. In CSRM Lifecycle consideration is very important.

3. In CSRM, Formulation is heavily dependent on setting. Atlantic Ocean, Pacific Ocean, Great Lakes, Tidal Estuaries - all require different considerations.

4. There are many policies unique to CSRM
   - Continuing Construction over 50 years (up to 65 yrs now)
   - Recreation is NED, but incidental to CSRM
   - Requirements for public access, which affects cost-sharing

HOW IS "COASTAL" DEFINED?

Geographic Applicability

- Ocean and Gulf (of Mexico) shorelines and connected estuaries and bays
- Great Lakes shorelines
- Inland Extent – Where the dominant causes of flood, erosion, and wave damage are tidal action (or Great Lakes motion).

Atlantic Ocean

Great Lakes

Pacific Ocean

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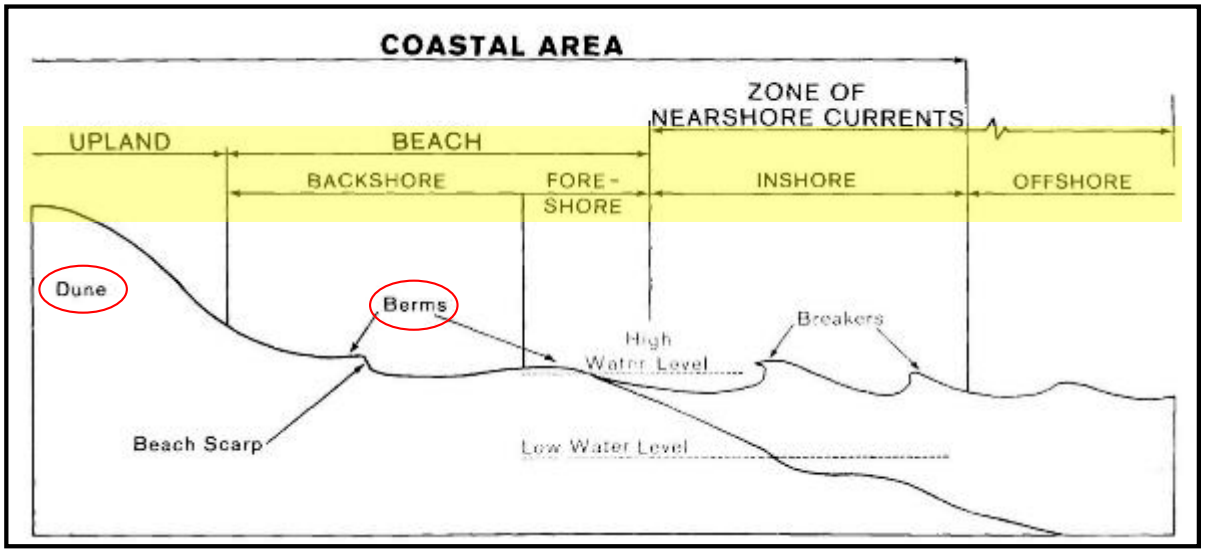
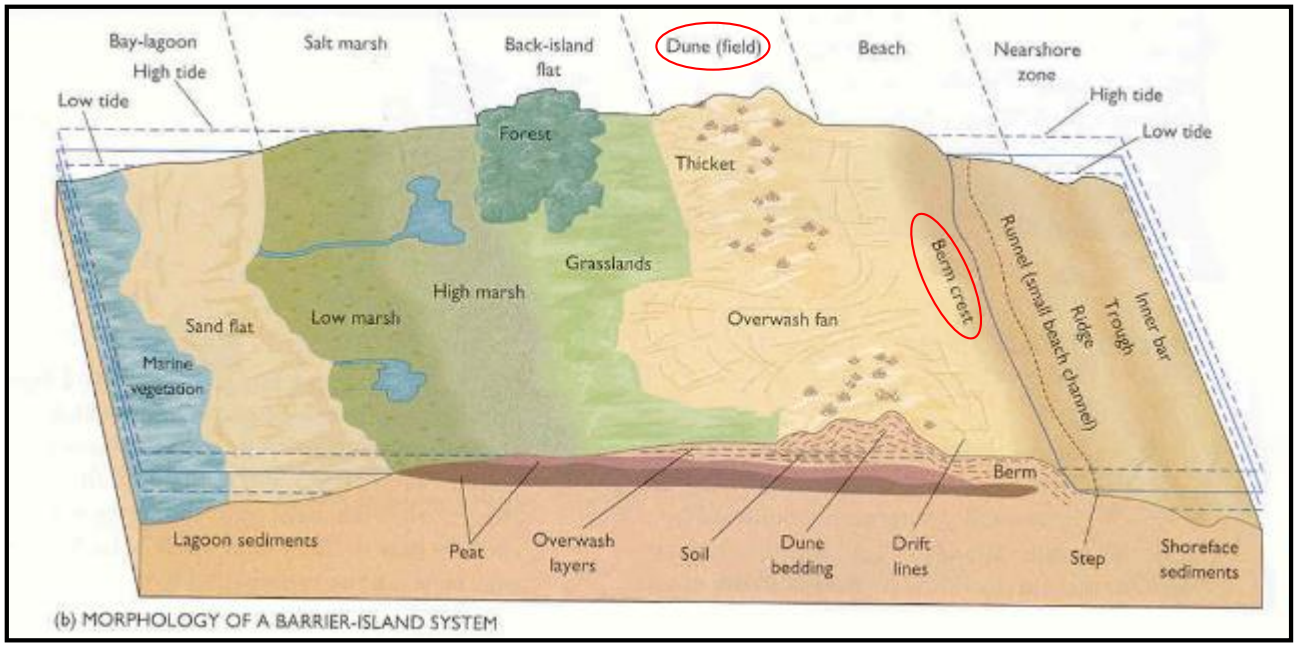
COASTAL FEATURES DEFINED





Idealized depiction of undeveloped barrier island

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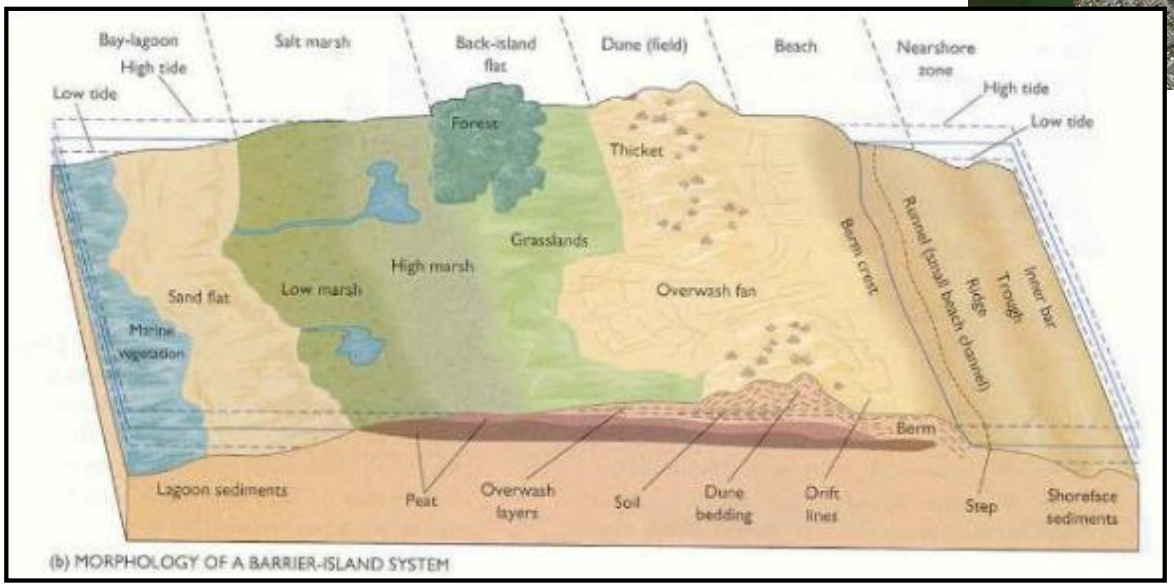
COASTAL FEATURES DEFINED

Contrast with modern Absecon Island, NJ



Idealized depiction of undeveloped barrier island

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COASTAL STORM RISK MANAGEMENT POLICY

CSRM Mission has evolved over time, from two specific objectives, into one purpose:

1930: Corps Authorized to undertake “Shore Erosion Control Studies”

1955: Corps Authorized to undertake “Hurricane and Abnormal Tidal Flood Protection”

1986: Two Mission Areas combined into Coastal Storm Damage Reduction (Now Coastal Storm Risk Management)

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PLANNING TASKS

Scoping: problems and opportunities

Plan Formulation

Deciding: evaluation and comparison

Implementation

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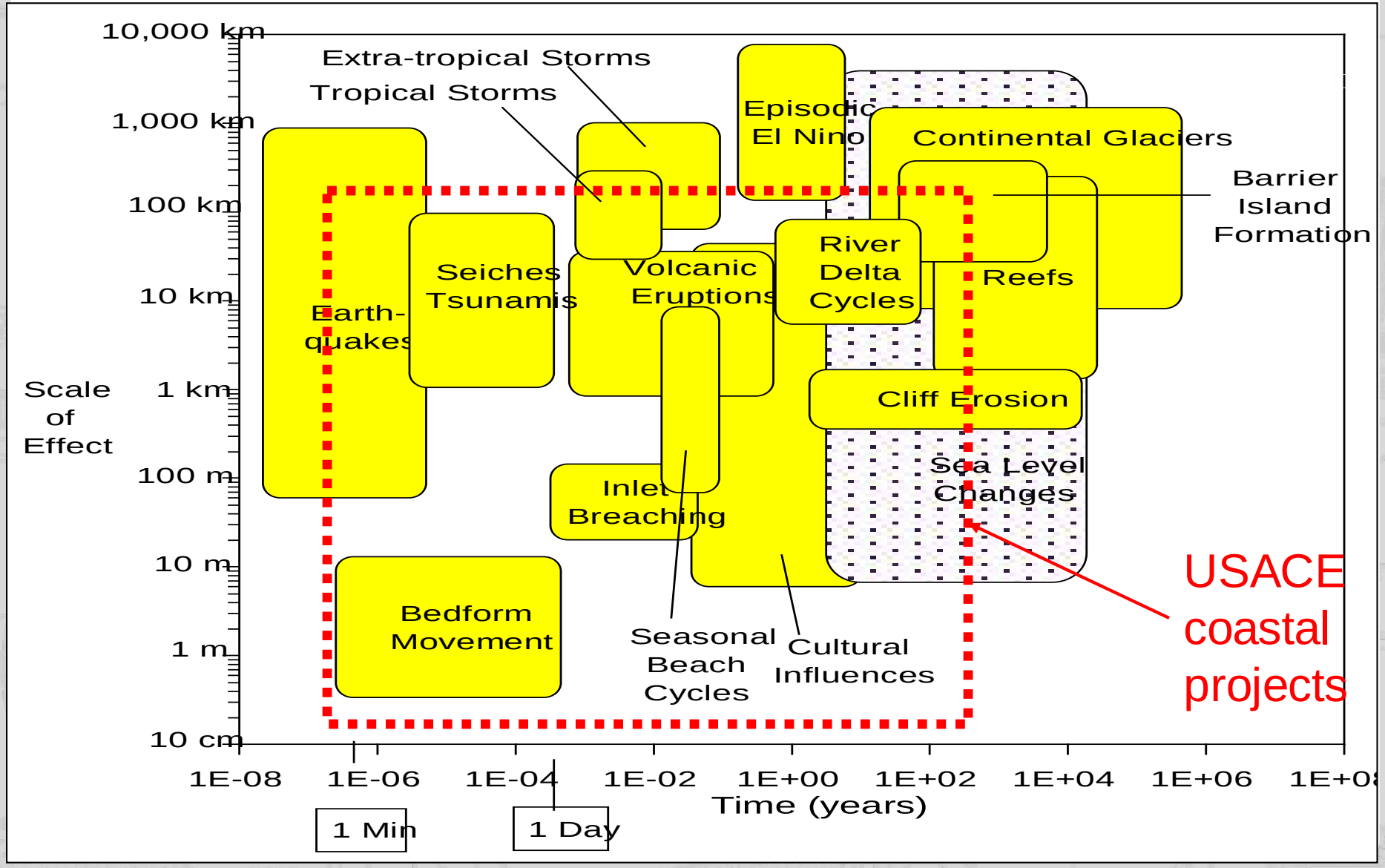
SCOPING: PROBLEMS AND OPPORTUNITIES

- Short-Term and Long-Term Processes
- Extratropical and Tropical Storms
- Storm Characteristics & Damage Mechanisms
- Geologic Considerations
  - Atlantic Coast & Gulf Coast
  - Pacific Coast
  - Great Lakes
  - Tidal Estuaries

TIME AND DISTANCE SCALE



STORMS
TROPICAL VS. EXTRATROPICAL

Both originate as low pressure systems – CCW wind in northern hemisphere

Tropical cyclones

- Rotating, organized system of clouds and thunderstorms
- Originate over tropical or subtropical (i.e., warm) water – Atlantic hurricanes typically originate off west coast of Africa
- Grade from "Depression" (wind speed < 39 MPH through "Major hurricane (wind speed > 110 MPH)

Extra-tropical cyclones

- Form along fronts in higher latitudes, commonly over land, no warm water core
- Nor'easters and winter storms are extra-tropical cyclones
- "Typically" larger area, less intense wind speed, longer duration over any one area compared to tropical cyclones (but "exceptions are the rule")

PROBLEM AND OPPORTUNITIES
DAMAGE MECHANISMS

Storm Effects:

- Inundation
- Erosion
- Waves
- Wind – we do not/cannot reduce wind risk (that's the job of building codes)

Important Long-Term Trends

- Long-Term Erosion / Accretion (Sediment Imbalances)
- Sea Level Change

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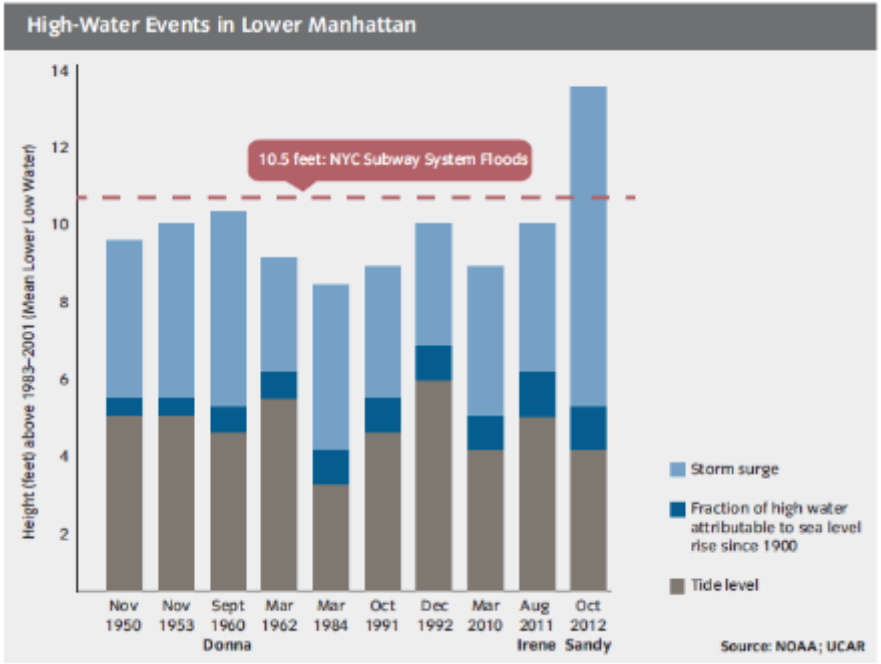
INUNDATION

- Storm Surge
- Wave Runup
- Precipitation
- Astronomical/King Tides
- Sea Level Rise

Sandy (2012) vs. Florence (2018)
Storm surge inundation in both events. But Sandy's damage was primarily from storm surge. In some locations inundation from Florence was primarily the result of extreme precipitation. Storm surge was also a major contributor.



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INUNDATION DAMAGES

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EROSION

- Erosion is the wearing down of land by wind, water, and other geological agents.

- Erosion is unique since it is both a damage mechanism produced by storms and an ongoing coastal process.

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WAVE ATTACK

The direct impact of waves impacting a building or structure. A 3 foot wave breaking directly on a structure can completely damage a building.

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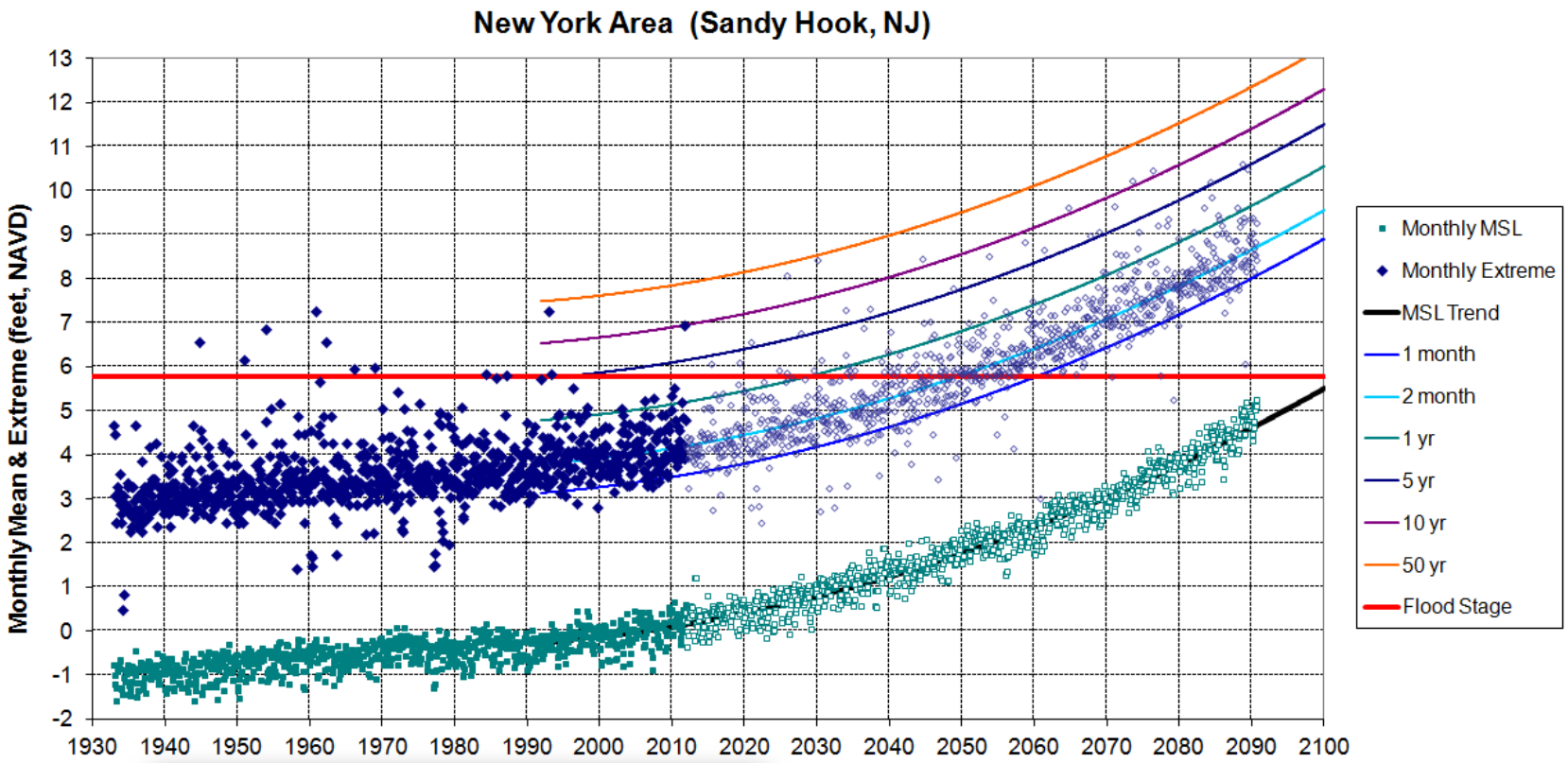
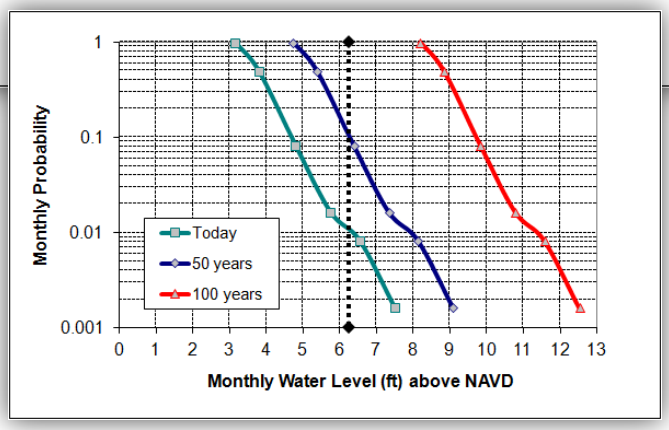
Combined Storm Effects

- The combined effects of tides, surge, waves, and erosion can result in overtopping.
- Overtopping that is severe enough can result in overwash or breaching.

Mantoloking, NJ (Hurricane Sandy)

COASTAL FLOOD FREQUENCY AND SEA LEVEL





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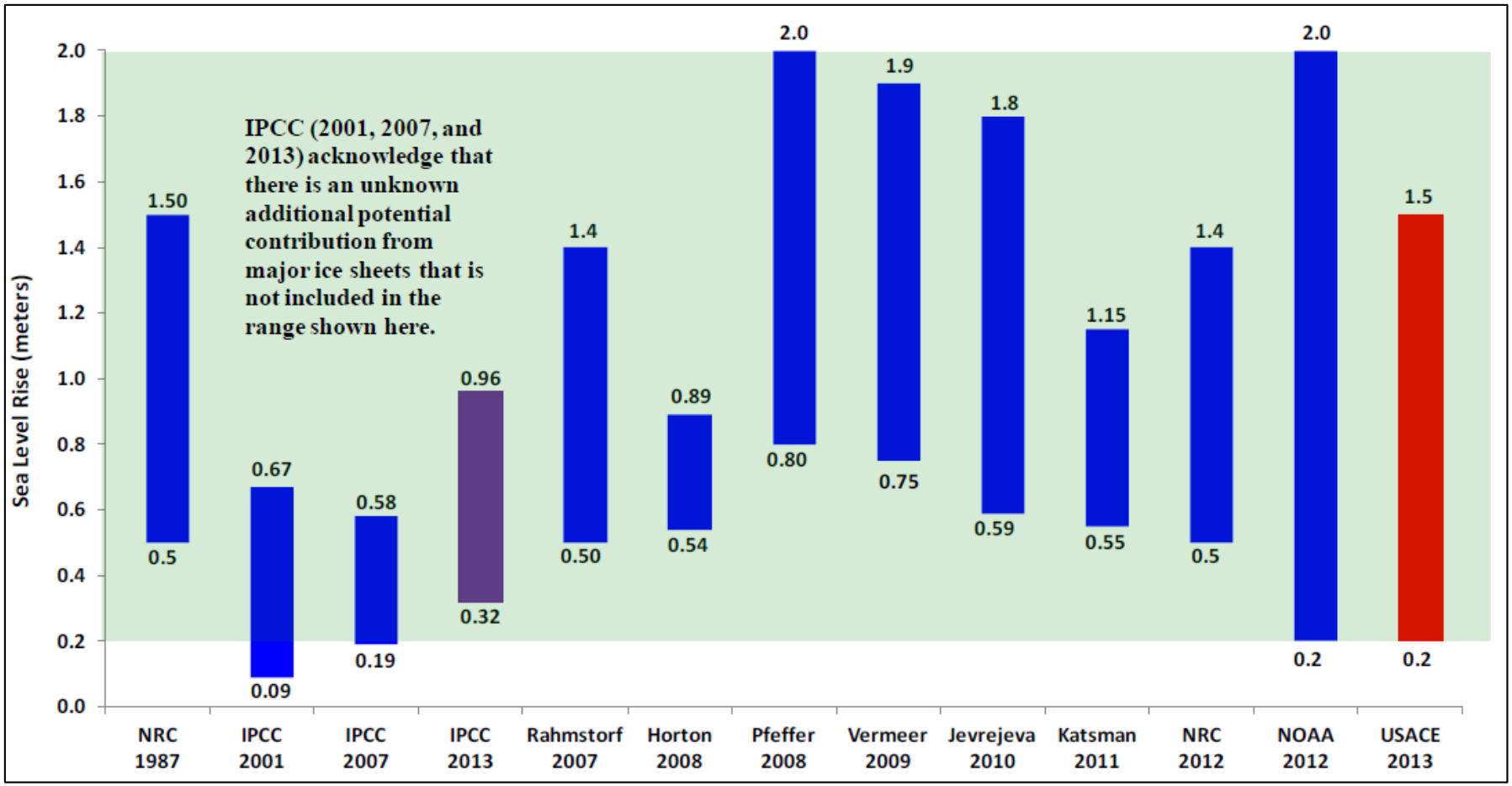
ESTIMATES OF FUTURE SEA LEVEL CHANGE



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SEA LEVEL CHANGE AND DATUMS

Sea Level Change

- ER 1100-2-8162, INCORPORATING SEA LEVEL CHANGE IN CIVIL WORKS PROGRAMS
- ETL 1110-2-1, PROCEDURES TO EVALUATE SEA LEVEL CHANGE: IMPACTS, RESPONSES, AND ADAPTATION

Sea-Level Change Curve Calculator (Version 2017.55)

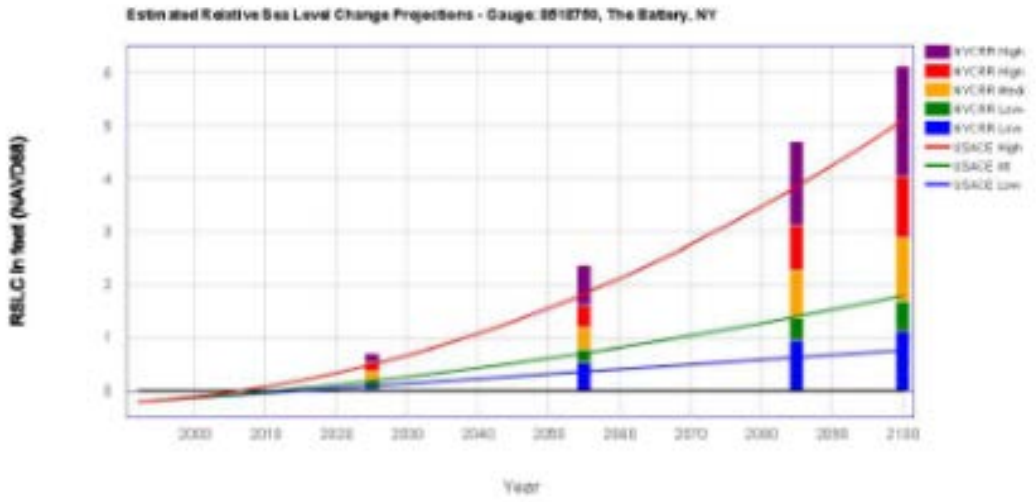
http://corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html

Datums

- ER 1110-2-8160, POLICIES FOR REFERENCING PROJECT ELEVATION GRADES TO NATIONWIDE VERTICAL DATUMS

Sea Level Tracker

https://maps.crrel.usace.army.mil/projects/rcc/portal.html



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TIDAL INLETS
WHAT A PLANNER NEEDS TO KNOW

- Inlets and shorelines interact - they are parts of a system
- Hydraulically complex, rarely “stable”
- Inlets convey tidewater between ocean and back bays – 24 hrs/day
- Tidal circulation “flushes” the bays – water quality (GOOD)
- During storms, inlets convey storm surge that floods back bays (BAD)
- Inlets can trap significant quantities of sand
- CG (shore protection) vs O&M (navigation) – one system, two checkbooks
- Small nav projects – no funding for dredging (low budgetary priority)

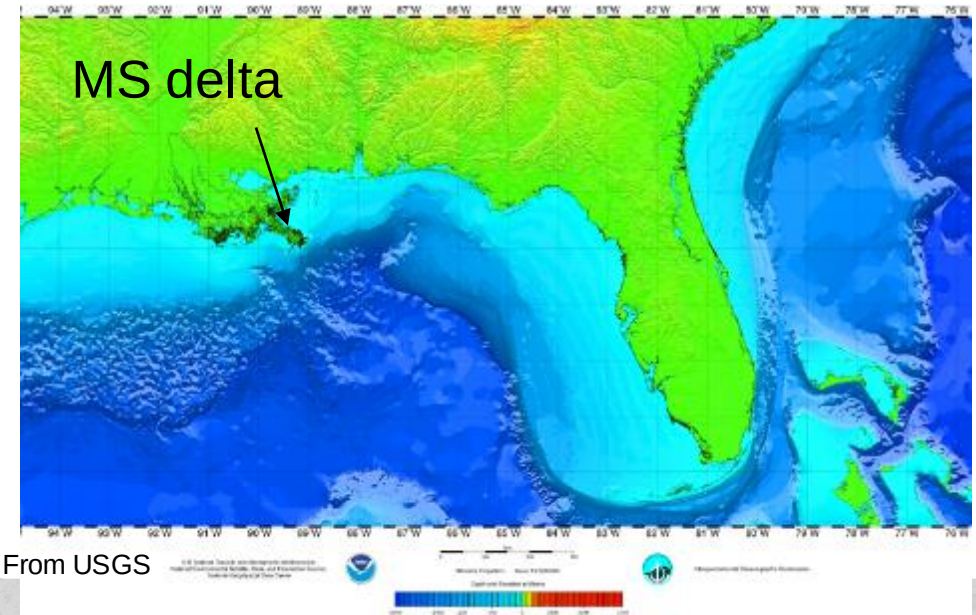
"The improvement of an inlet on a sandy coast is one of the most difficult problems in harbor engineering, and its cost and uncertainty are so great that it should only be attempted when necessary to improve the approach to some great port of commerce.”

Major C. W. Raymond
Report to the Chief of Engineers, August 1892
(Examination of Barnegat Inlet, Entrance and Harbor, New Jersey)

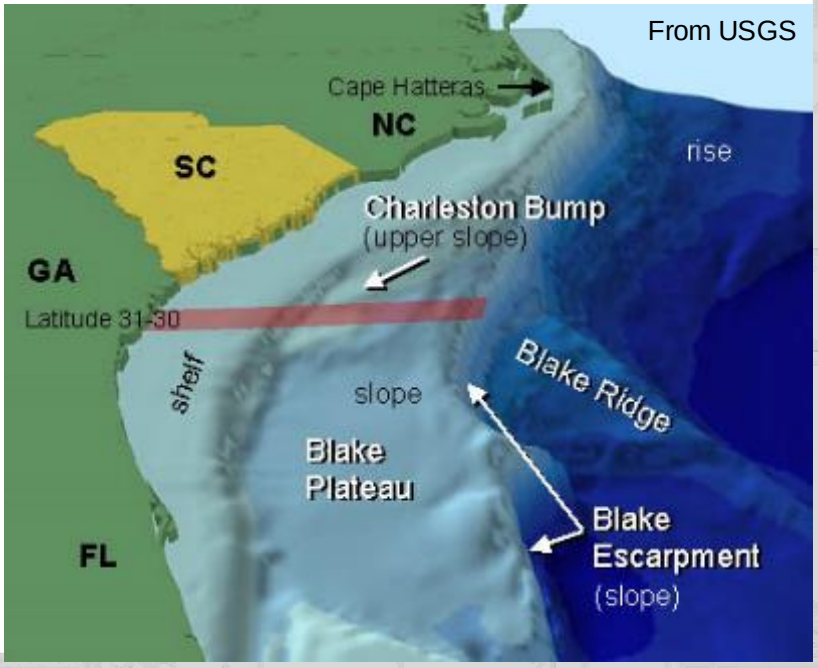
GEOGRAPHIC / GEOLOGIC DIFFERENCES

ATLANTIC & GULF TECTONIC FRAMEWORK

- *Trailing edge* coast (moving away from mid-ocean spreading center)
- Broad continental shelf and platform with low slopes → room for sediment accumulation and storage
- Sed. not compartmentalized → longshore movement 100s or 1000s km
- Sed. is ancient, recycled shelf and coastal deposits, minimal new sand from Appalachians
- Storm surges more likely than on steep coast



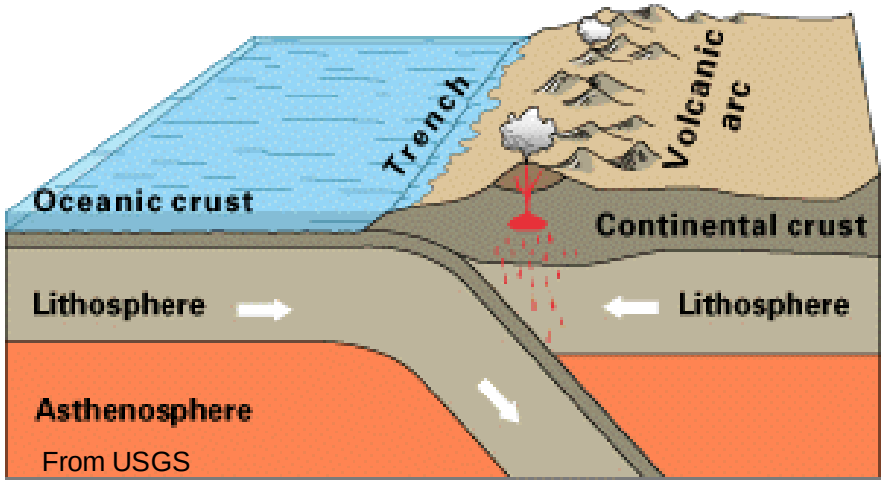
From USGS



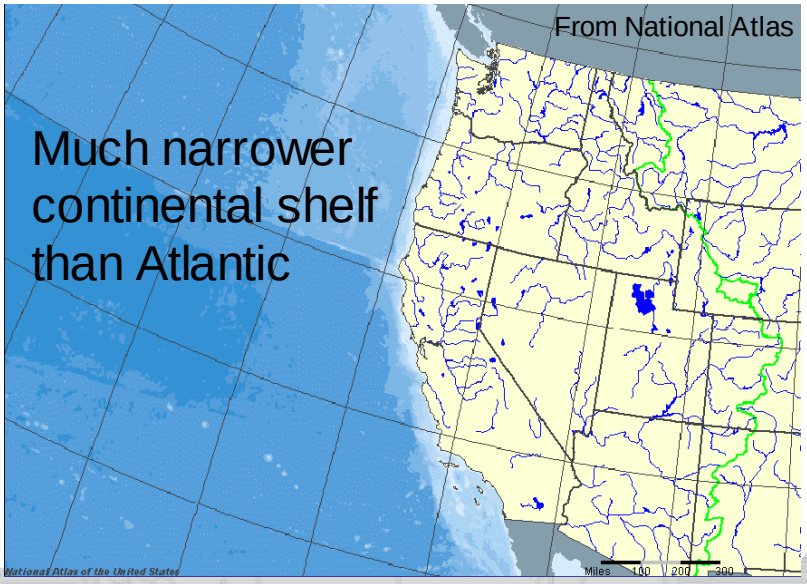
From USGS

PACIFIC TECTONIC FRAMEWORK

- *Leading edge* coast (faces trench)
- Usually steep, narrow continental shelf and limited platform for sed. accumulation
- Sediment compartmentalized, limited lateral movement (except Columbia R.)
- Sediment young, only centuries?
  - (Comes from mountain, temporary residence in coastal zone, then moves off the shelf)
- Volcanism, earthquakes



Oceanic-continental convergence



TECTONIC FRAMEWORK, GREAT LAKES

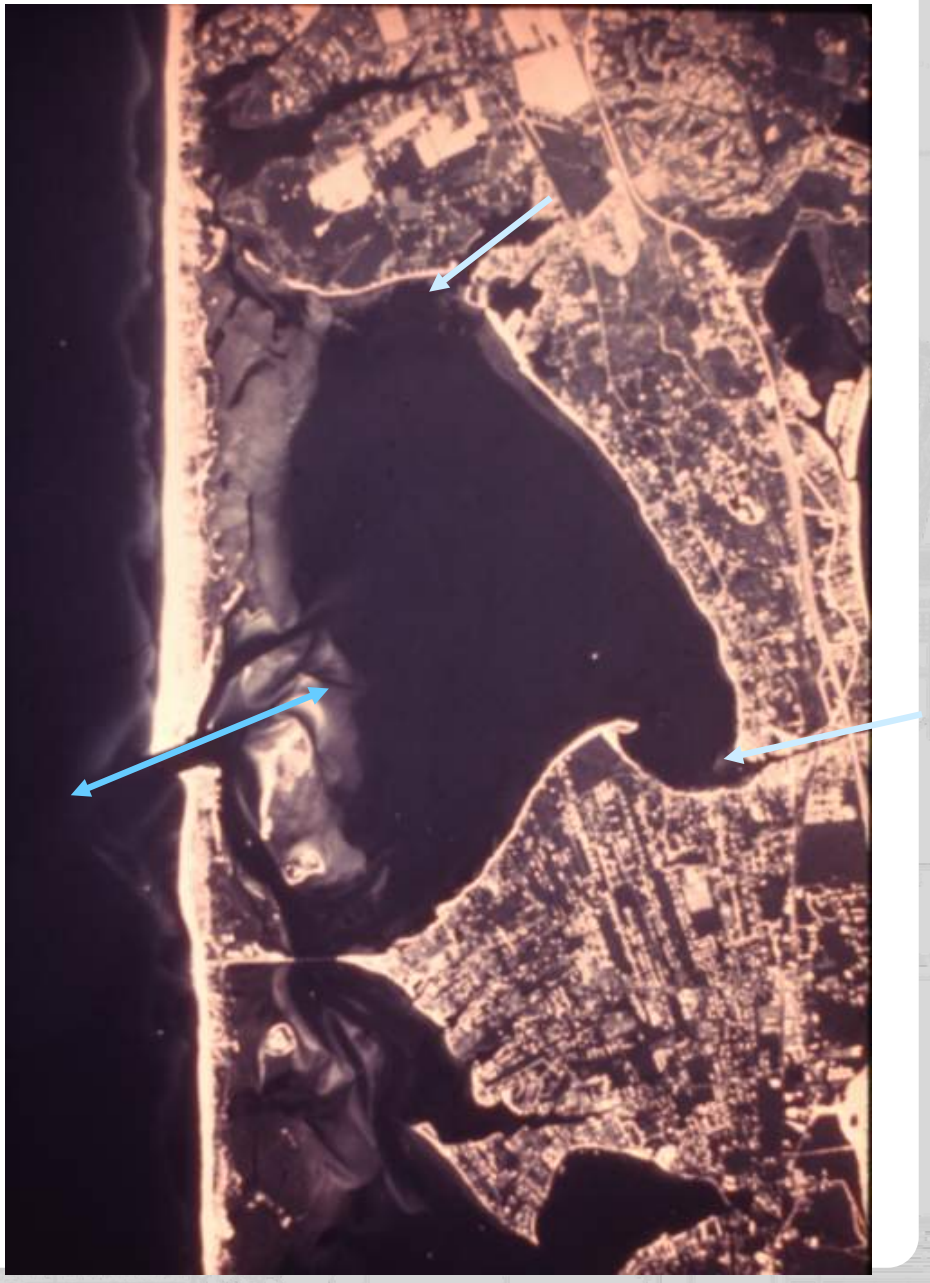
- Glacially-eroded ancient continental platform → minimal new sed. from inland
- Bedrock outcrops (Canadian Shield)
- Cohesive glacial till, highly erodible, variety of grain size (boulder to clay)
- No tides, ice, fresh water → different biology than ocean coasts
- Typically limited fetch, no swell → beaches do not recover as well after storms

Estuarine Morphology and Processes

Estuary: semi-enclosed body of water having a opening to the open ocean within which sea water is measurably diluted with fresh water from river input

River forces vs.

- Tidal Forces with
  - o Waves
  - o Wind
- Geologic setting



QUESTIONS?

PLANNING TASKS

Scoping: problems and opportunities

Plan Formulation

Deciding: evaluation and comparison

Implementation

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PLAN FORMULATION

On the open coast, the solution is easily identified in the first iteration, tried and true focused array, but as recognition of vulnerability broadens, solving problems becomes more complex.

In tidal estuaries (“back bays”) the solution may not be as easily recognizable in the first iteration.

ALTERNATIVES / MEASURES

Alternative Overview:

- Nonstructural Measures
- “Soft” Structural Measures (Sand is an NNBF)
- “Hard” Structural (steel, concrete, stone, etc.)
- Innovative Methods
  - Natural and Nature Based Features
  - Policy and Programmatic Measures

Nonstructural Measures

- Moving what gets damaged, rather than moving the water

3 Categories of Nonstructural

- Land Management
- Acquisition and Relocation
- Building Retrofits (Elevating and Flood-proofing)

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CSRM TWISTS ON NONSTRUCTURAL

- Few instances of nonstructural plans implemented by Corps along US coasts, compared to number of sand ("berm and dune") or structural CSRM projects
- Generally building retrofits are most common types of Corps nonstructural Plans
- Building retrofits are not applicable in highly erosive areas (elevation doesn't meet objectives if land is eroded).
- Acquisition (buyouts) very rarely supported. In many coastal settings, very high cost of land compared to structure value.

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SOFT STRUCTURAL SOLUTION

Includes:

- Beach Fill
- Beach and Dune Fill
- Sand bypassing

Beach Fill Measures

- Soft Solution
- Mimics Nature (“NNBF”)
- Reversible
- Must Be Replaced

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PERIODIC NOURISHMENT

- Formulated as least cost over a specific period of time (Trade-off: Volume vs. Frequency of Nourishment)

- Volume
- Interval
- Suitable Material

Monmouth Beach, New Jersey (background) and Sea Bright (foreground)

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BORROW SOURCES

- How much sand needed?
- Initial Fill, 50 yr periodic nourishment, storm repair/restore
- How far away is the Borrow Area (distance=$$$$)
- Quality of the Sand: Grain Size, Color
- Compatibility Analyses (native sand vs borrow material)

Borrow Areas

- Offshore (larger projects >100,000 cys)
- Inlets/Navigation Channels
- Backpassing/Bypassing from adjacent beaches
- Upland – truckfill from pits & quarries

REPLACING SAND OVER PROJECT LIFE CYCLE

Renourishment (Cost-Shared)

- Fill placed at intervals to replace material eroded from the design beach

Maintenance (Non-Federal Responsibility)

- Local monitoring, and sand recontouring between nourishment cycles (defined in OMRR&R Manual)

Bypassing & Backpassing (Varies)

- Plants generally considered as O&M (non-Fed)
- Can be cost-shared if shown to be more economical than periodic renourishment

Emergency Repairs (Federal)

- Projects are eligible for repairs under PL 84-99 / FCCE if impacted by an “extraordinary storm”

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ALTERNATIVE PROTECTIVE MEASURES

3 Categories of Hard Structures

- Coastal Armoring structures
  - Reduce risk of loss of upland
- Beach Stabilization structures
  - Reduce erosion rates, periodic nourishment qty.
- Navigation structures
  - Stabilize navigation channels

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STRUCTURAL MEASURES

Armoring

- Seawalls
- Revetments
- Buried seawalls
- Bulkheads
- Levees
- Floodwalls

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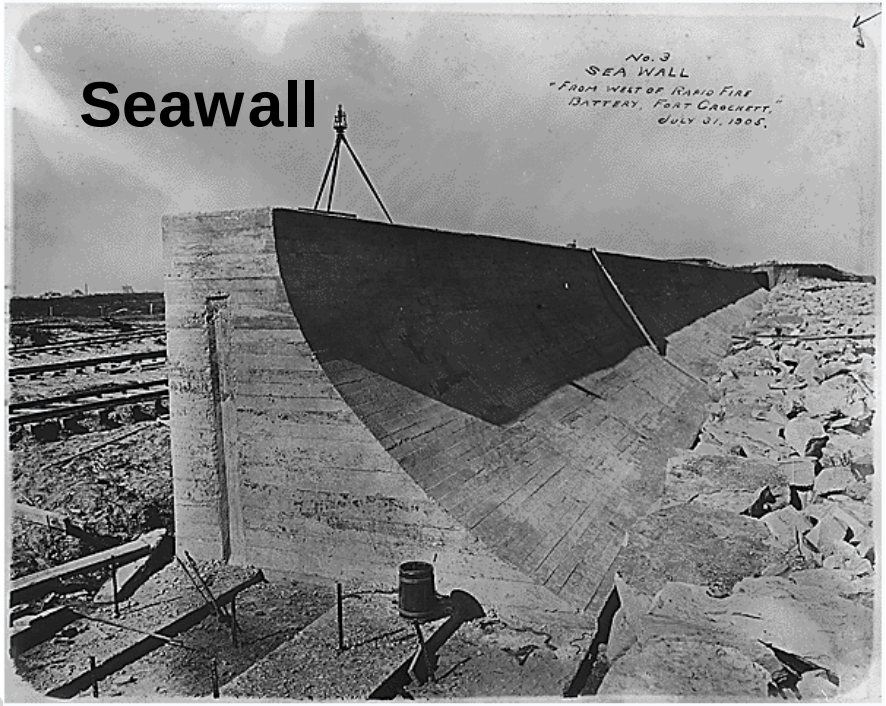
Revetment

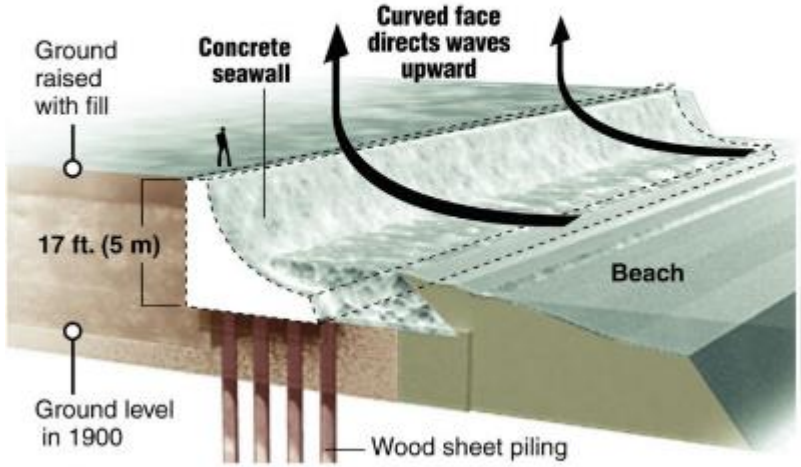
Bulkhead

Seawall



Galveston's seawall

Four years after the catastrophic 1900 hurricane, a seawall was built along the Gulf shore to protect Galveston from storm surges.

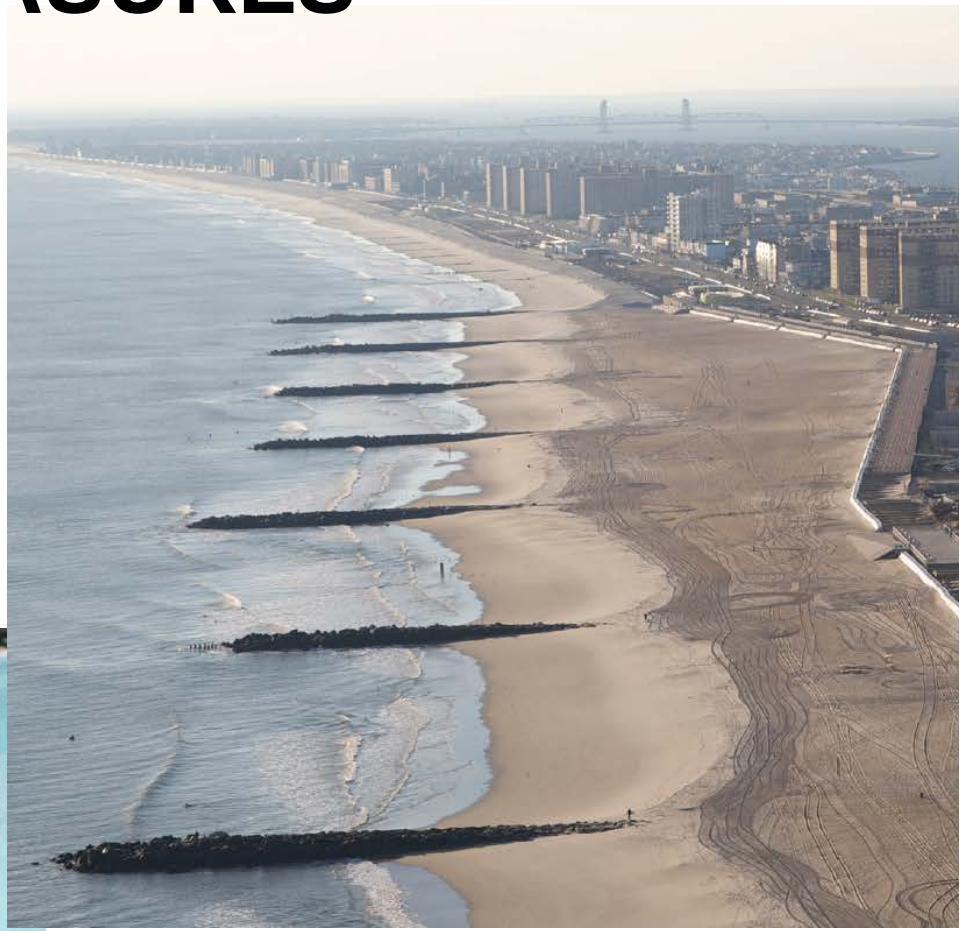


Source: U.S. Army Corps of Engineers Graphic: Fort Worth Star-Telegram

STRUCTURAL MEASURES

Shoreline Stabilization

- Breakwaters
- Groins
- T-Groins



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NAVIGATION STRUCTURES

Jetties

Breakwater

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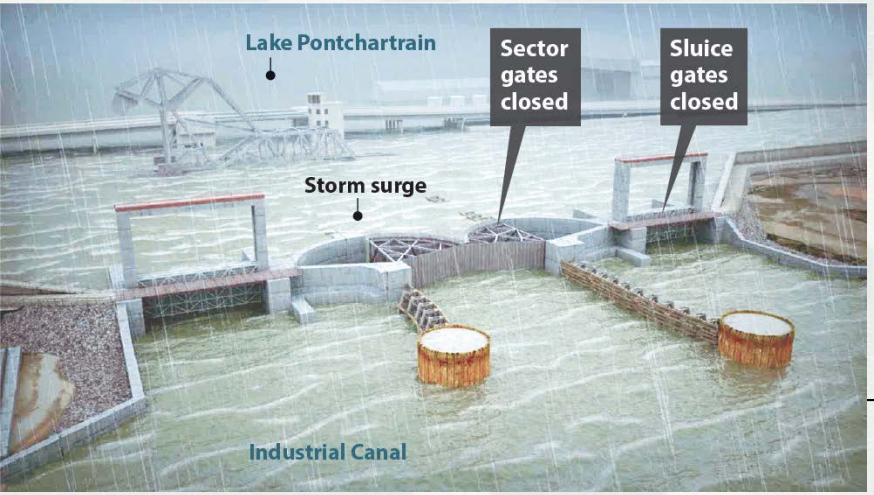
MOVEABLE STORM SURGE BARRIERS

Gate Design Options

Floating Sector Gate

Sector and Sluice Gates



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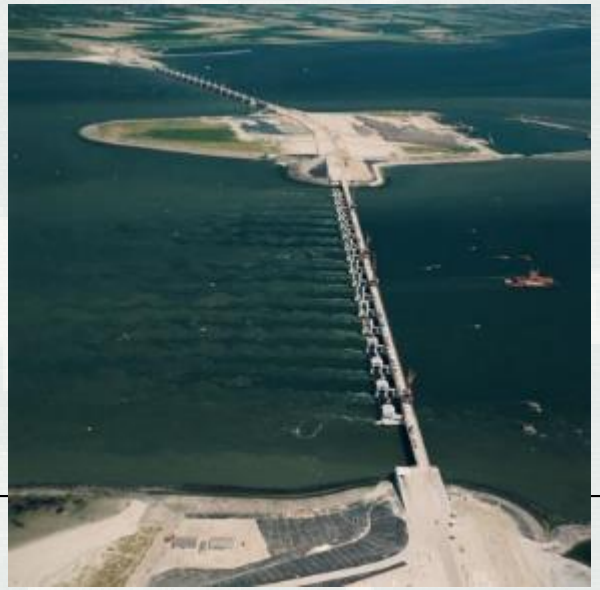

Tainter Gates

QUESTIONS?

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PLANNING TASKS

- **Scoping:** problems and opportunities
- **Plan Formulation**
- **Deciding:** evaluation and comparison
- **Implementation**

DECIDING: EVALUATION AND COMPARISON

- Evaluation of CSRM is typically NED, and selected based upon plans that reasonably maximize net benefits
- Evaluation of NER, RED, OSE can be done, but is less common in studies
- Economic and engineering analyses must be risk based, addressing RISK and uncertainty in input parameters and incorporating life cycle considerations.
- Many categories of benefits, typically include:
  - Reduced damages to buildings and contents
  - Emergency costs avoided
  - Loss of Land
  - Recreation (which is an NED benefit)
- Evaluating costs and benefits can be modeling intensive for both engineering and economics

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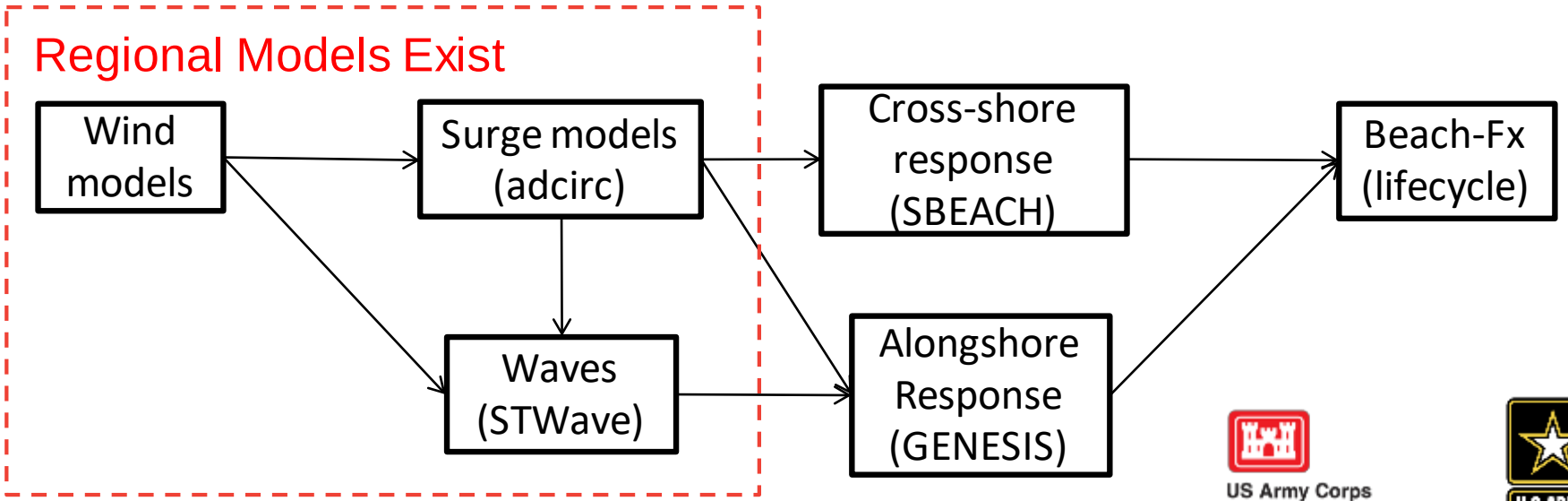
ENGINEERING MODELS

Modelling to represent:

- Water Elevations
- Waves
- Beach response to storms
- Currents and Inlet Processes
- Long-shore Sediment Transport (Shoreline Change)
- Sediment Budget



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PLANNING MODELS

- There is presently 1 approved model for CSRM: Beach-fx
- HEC – FDA is an approved model for FRM that can be applied for CSRM studies, primarily where inundation is the dominant damage mechanism (but model requires manipulation)
- G2CRM is a model under development by USACE. Similar to HEC-FDA, but incorporating life-cycle analysis

Beach-fx, G2CRM, HEC-FDA require:

- Structure Inventory
- Damage Functions (distinguish between different functions)
- Engineering inputs (extensive for Beach-fx)
- Assumptions about FWOP and FWP, rebuilds, renourishment

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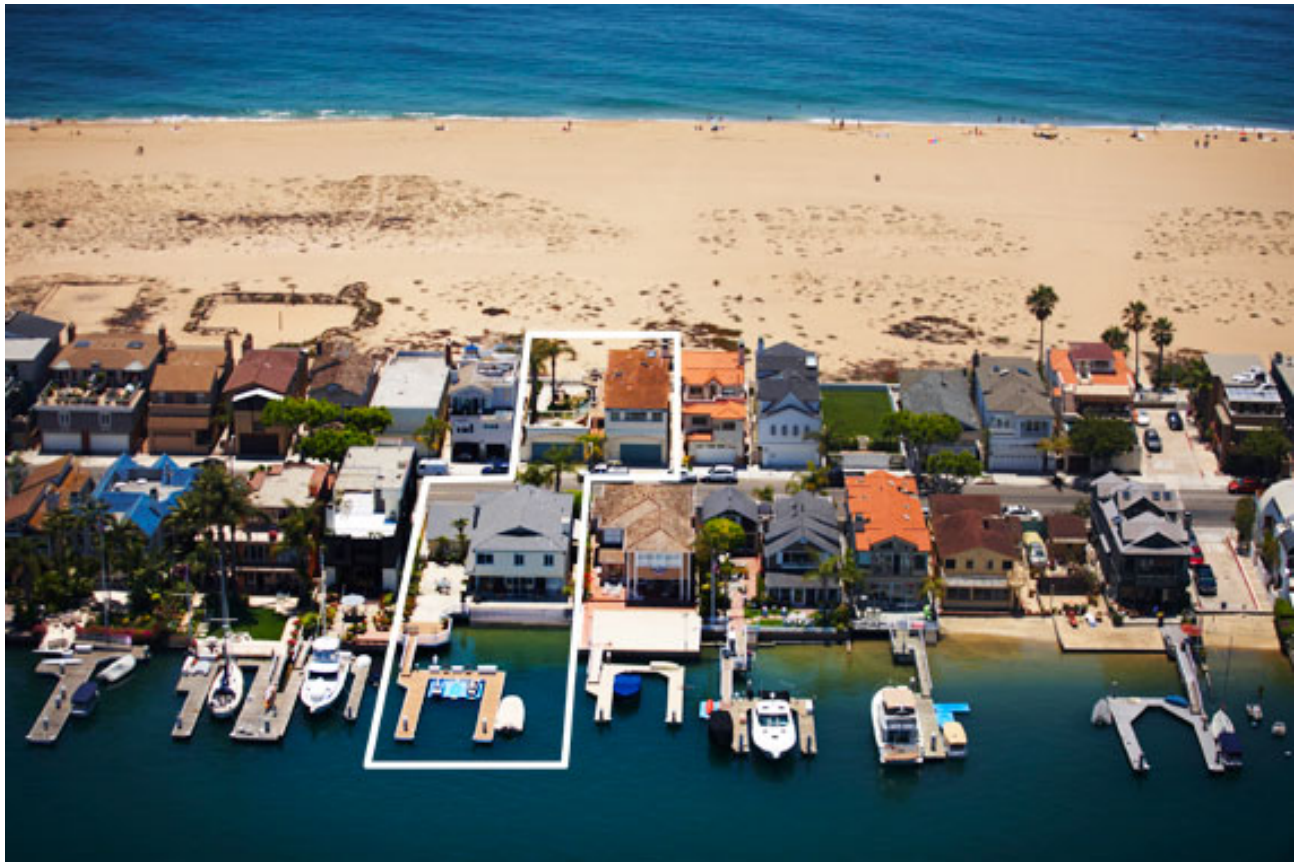
WHICH ECONOMIC MODEL DO WE USE?



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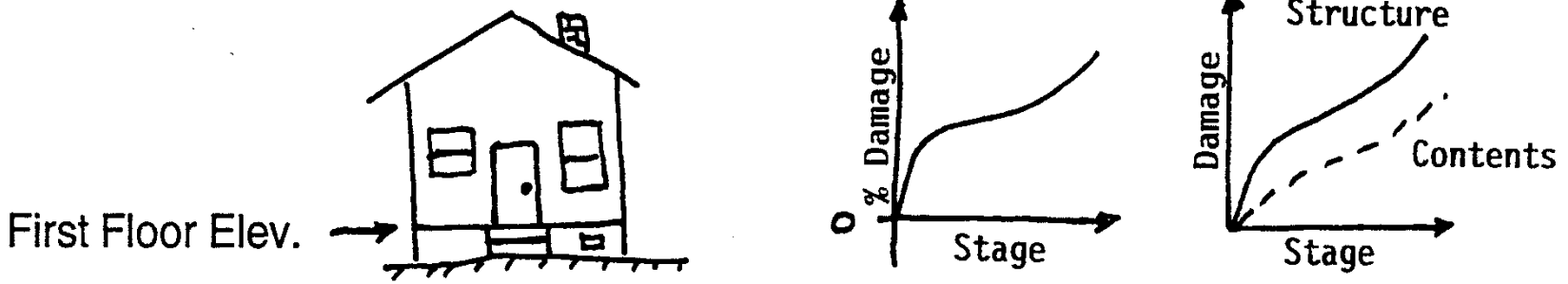
ECONOMIC STUDIES



Structure Inventory Data

- Structure ID
- Location/Address
- Structure Value
- Content Ratio
- Damage Category
- Depth-Damage Function
- First Floor Stage
- Ground Stage
- Coordinates
- Stream Station

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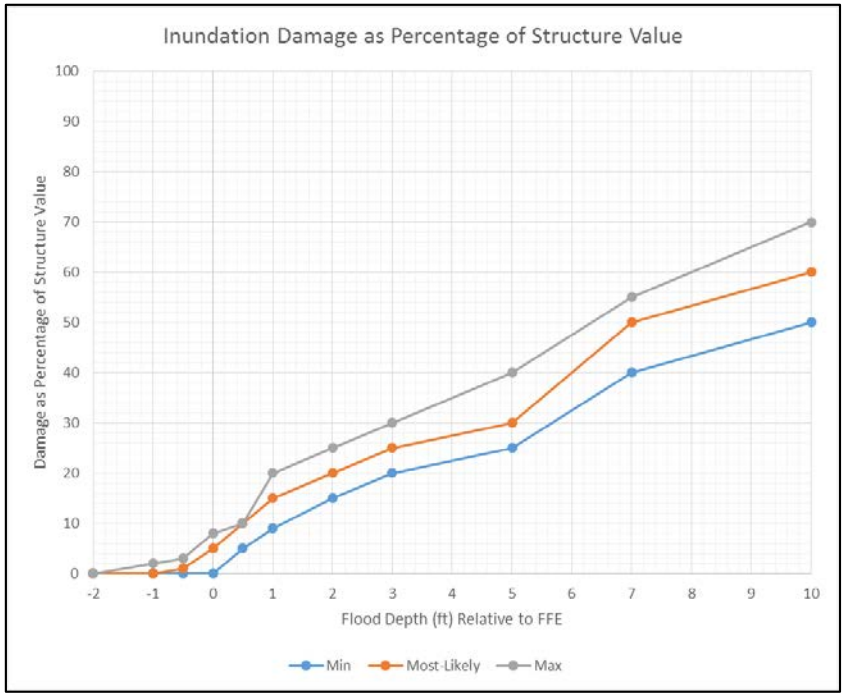
STRUCTURE DAMAGE

Damage as a percentage of structure value



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ECONOMIC MODELING FRAMEWORK

Riverine studies:

- Develop a frequency discharge relationship
- Develop a stage discharge relation
- Derive a stage frequency relationship
- Derive relationship for:
  - Water level and damages
- Model for Damages

Coastal studies:

- Develop storm input parameters
- Develop relationships for:
  - water level and damages
  - Erosion response and damages
  - wave height and damages
- Consider lifecycle response
  - Cumulative effects of storms & recovery
  - Emergency response after storms
  - Sea level change
  - Rebuilding

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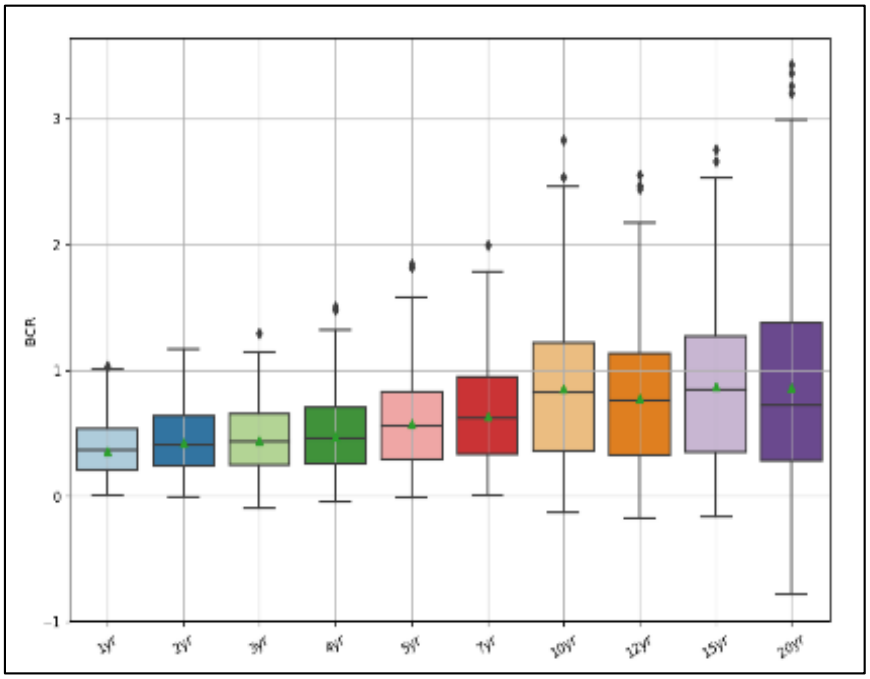
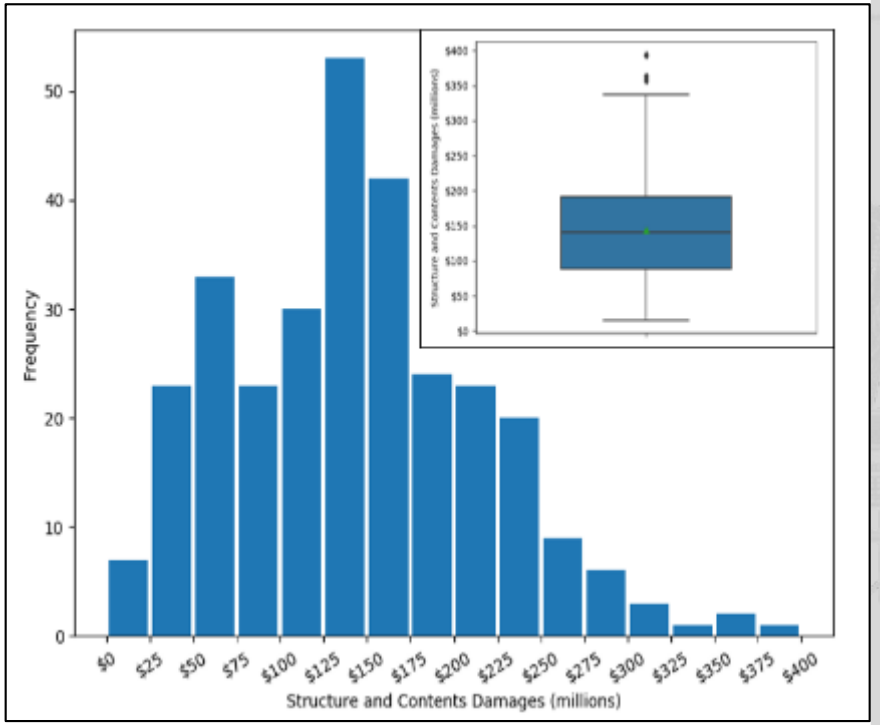
BEACH-FX ECONOMIC OUTPUTS

Box and Whisker Plot of BCRs at Varying Nourishment Intervals





FWOP Damages

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UNCERTAINTIES IN ECONOMICS

- **Sea level change**
  - Timing of the water surface increase

- **Future with and without project**
  - Rebuilds, nourishment

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ITERATIONS

ALL STUDIES ARE DIFFERENT
INCORPORATE STEPWISE PLANNING AS YOU ELIMINATE CRITICAL UNCERTAINTIES

1st iteration – Planning with knowledge in the room (within 30 days)

Helps the PDT understand what they don't know

2nd iteration – Planning with knowledge from others (within 90 days)

Focuses on reducing the most significant uncertainties

3rd iteration – Planning with analysis based on risk and uncertainty to select the tentatively selected plan (TSP) (within 1 year)

Relies on detailed analysis undertaken as part of the evidence gathering and uncertainty reduction process

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COASTAL TEXAS - ITERATIONS

1st iteration – Planning with knowledge in the room

Individual measures were qualitatively screened for their capability to meet objectives while avoiding or minimizing the study constraints. Developed Focused Array for AMM

2nd iteration – Planning with knowledge from others

Applied metrics to compare differences among alternatives

- Performance – Compare the Without Project Condition
- Cost – First cost estimate
- Impacts – Direct and Indirect estimates

3rd iteration – Analysis based on risk & uncertainty to select the TSP

Eliminated meaningful uncertainty

- HEC FDA with project benefit estimates
- Refined Cost estimates to address uncertainties in key features
- Environmental impacts refined with AdH modeling of gate feature

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1ST ITERATION: CSRM ALTERNATIVES

Features	Bolivar Roads (Alt. A)	Texas City Gate (Alt. B)	Mid-bay (Alt. C)	Upper HSC (Alt. D1)	Upper HSC (Alt. D1)
Galveston Sea Wall	x	x	x	x	x
Galveston Ring levee	x	x	x	x	x
Gates, navigation and environmental	x	x	x	x	x
Clear Lake and Dickinson Bayou	x	x		x	x
Dickinson Bay	x	x			x
GIWW near High Island	x				
Non-structural Improvements					
Galveston Island	x				
West side of upper Galveston Bay	x	x		x	
Levees/Flood Walls					
Galveston Island (Sea Wall to San Luis Pass)	x				
Bolivar Peninsula to High Island to near Winnie	x	x			
West side of Upper Galveston Bay levee/flood wall				x	x
Texas City Hurricane Flood Protection extension inland to west		x	x	x	x
Texas City					
Dike improvements		x			
Texas City Hurricane Flood Protection improvements along shore		x	x	x	x

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2nd ITERATION: SAMPLE ALTERNATIVE

Coastal Texas Protection and Restoration Study

Alternative C

- Texas City Hurricane Flood Protection Levee Improvements
- Navigation and Environmental Gates
- Levee/Floodwall
- Galveston Seawall Improvements
- Galveston Levee/Floodwall

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COASTAL TEXAS - ITERATIONS

2nd iteration – Planning with knowledge from others

Applied metrics to compare differences among alternatives

- Performance – Compare the Without Project Condition
- Cost – First cost estimate
- Impacts – Direct and Indirect estimates

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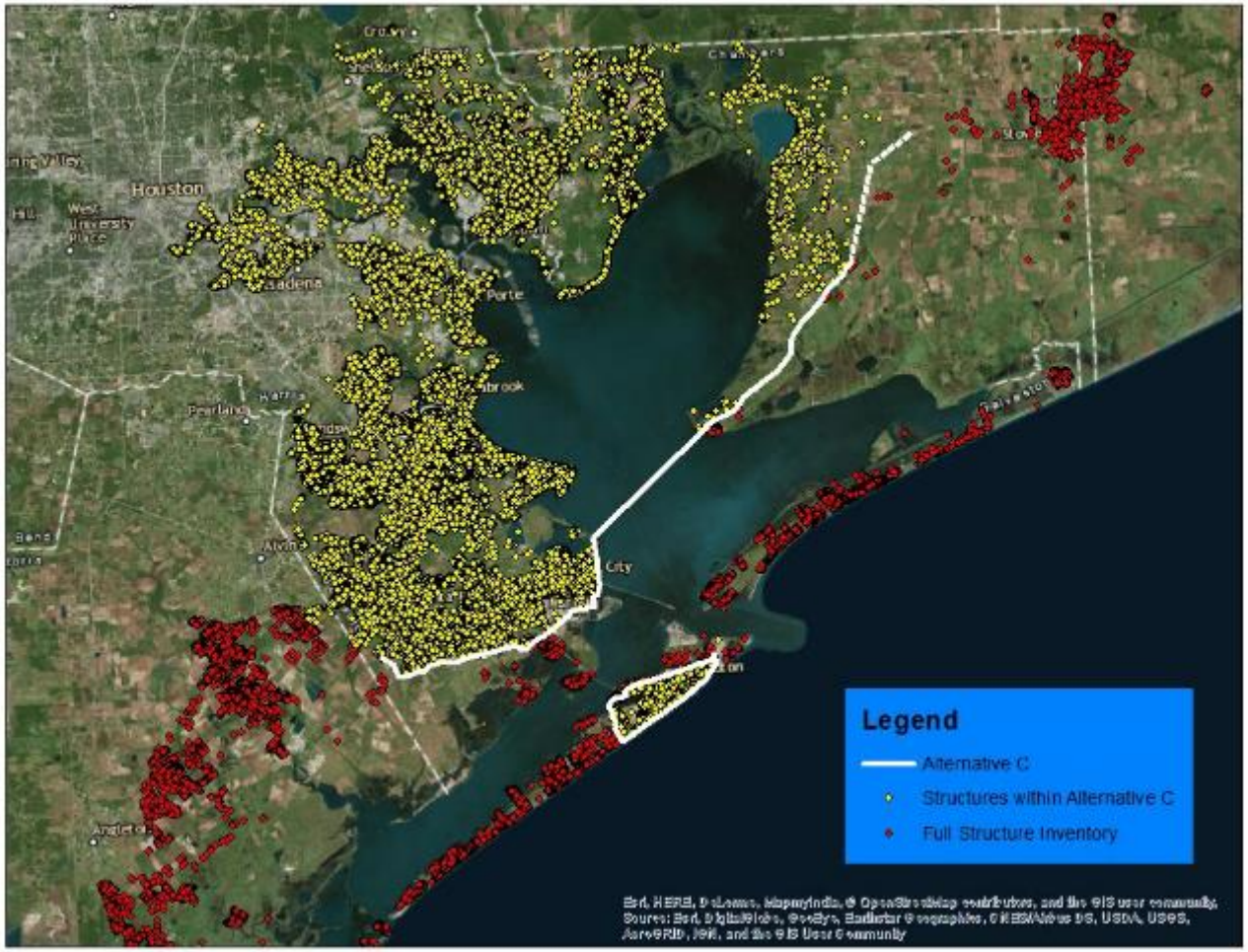
2nd ITERATION: ECONOMIC ANALYSIS
STRUCTURES IN AND OUT OF THE WITH PROJECT AREA



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3RD ITERATION – REFINE ANALYSIS TO CHOOSE TSP

Alt A (TSP)

- Region wide CSRM system focusing on all benefit categories, Measured and Unmeasurable
- Provides risk reduction to the regions critical navigation features
- Potential Induced Damages focused in areas where structures are already raised.
- Maintains the regions critical landscape features
- Provides risk reduction the regions evaluation routes
- System can easily be adapted to address extreme events due the bay's storage capacity.
- The Galveston Ring levee is only needed to address wind driven surges from the north.
- As the regions population expands westward and eastward the system provides some level of risk reduction.

Alt D2

- Region wide CSRM system focusing on dense industrial and commercial benefit area
- Leaves the regions critical navigation features outside of the system
- Potential Induced Damages focused in areas where surge can flank the system.
- System could be closed off to address nuisance flooding if RSLR becomes an issue.
- As the regions population expands westward and eastward the system leaves the population out of the system and increases risk of induced damage
- The Galveston Ring levee potential has to be built to a higher elevation/standard due to the fact it is trying to address induced stages risk and wind driven surges from the north.
- Under extreme events when the system is overtopped the area is immediately inundated increasing the life safety risk

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COASTAL TEXAS - ITERATIONS

3rd iteration – Analysis based on risk & uncertainty to select the TSP

Eliminated meaningful uncertainty

- HEC FDA with project benefit estimates
- Refined Cost estimates to address uncertainties in key features
- Environmental impacts refined with AdH modeling of gate feature

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QUESTIONS?

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PLANNING TASKS

- **Scoping:** problems and opportunities
- **Plan Formulation**
- **Deciding:** evaluation and comparison
- **Implementation**

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POLICY ISSUES SPECIFIC TO CSRM

- Cost Sharing
- Public access
- Recreation
- Environmental considerations

COST SHARING

Costs Allocated to Category of Benefiting Property

- Borrow area not part of project area
- Insignificant Benefits to Private Shores Outside Project Limits Not Subject to Cost Sharing

Categories based on Ownership and Use
Type of Benefit also influences cost-sharing

- Private Developed Shores, where use is limited to private interest
- Private Developed Shores, where use is open to the public
- Federal Shores
- Non-Federal Public Shores (Park and Conservation Areas)
- Undeveloped Private Shores

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COST SHARING

All costs assigned to protection of:

- Private Shores, with Public Use: Cost-shared 65% Federal
- Private Shores, with Private Use: All costs are non-Federal
- Federal Shores: All costs are Federal agency cost
- Non-Federal Public Shores: Cost-Shared 50% Federal
- (Assumption is primary benefit is loss of recreation outputs)
- Undeveloped Private Lands: All Costs are non-Federal
- (Regardless of Use)
- (Assumption is benefits derived from land loss)

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PUBLIC ACCESS IS REQUIRED FOR COST-SHARING

Public Access, consistent with recreational use of the area

- Access Points must be no more than ½ mile apart
- Open to all visitors
- Adequate parking, or alternative to parking

Non-Fed Sponsor prepares public access plan

If access requirements are not met, feature is considered privately owned and constructed at full non-federal expense

RECREATION

Formulation is based on Storm Damage Reduction Benefits

- Recreation is an **NED benefit**
- Recreation benefits are incidental in the formulation process, and not the primary purpose

- **Recreation can be used in combination with damage reduction benefits for project justification**

- Incidental = No separable construction costs are required to achieve recreation benefits
- Recreation cannot be more than 50% of benefits required for justification

- Total recreation benefits used once the plan is selected.

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ENVIRONMENTAL CONSIDERATIONS
CSRM PROJECTS

CSRM requires the typical NEPA and permitting, with some unique requirements.

- Coastal Zone Management Act
- Coastal Barrier Resource Act (CBRA)
- Magnuson-Stevens Act - Essential Fish Habitats

- Fish and Wildlife Coordination Act
- Clean Air Act
- National Historic Preservation Act
- Endangered Species Act
- Migratory Bird Conservation Act

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MULTI-PURPOSE CSRM AND ER PROJECT

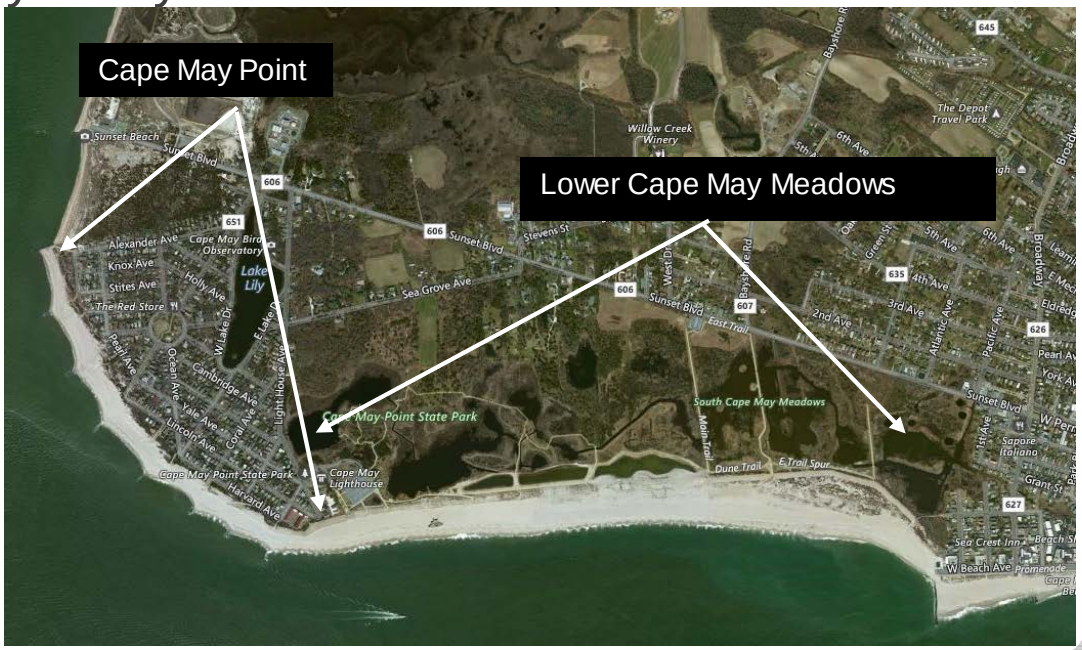
Lower Cape May Meadows – Cape May Point

Problems

- Erosion/salt water flooding of freshwater wetlands (the “Meadows”), managed by TNC and NJ State Parks
- CSRM in adjacent developed Cape May Point

Solution

- Berm and dune beachfill in 2004-2005
- Periodic nourishment on 4-year cycle
- Phragmites eradication
- Interior hydrologic improvements & water management
- Piping plover habitat mods
- Improved rare plant habitat



SOME RIDM CHALLENGES

- Analysis to support a TSP can be data intensive.
  - Required Modeling can have a long-lead time
  - Know what models exist, and what model input is available
- Ranges of output can be pesky
  - Beach-fx provides the ability to report ranges of costs and benefits
  - Sea level rise analysis results in ranges of costs and benefits
- Consideration of Sea Level Rise in Alternative Selection
  - Guidance provides flexibility in selection of TSP (use it)
  - Complexity is added when considering multiple scenarios
- Evaluation of System vs. Increments
  - Incremental justification is required
  - Coastal areas often work as a system

KEY TAKEAWAYS

1. This Presentation only hits upon the key concepts, and is not an in-depth tutorial on CSRM planning.

2. CSRM formulation is similar to FRM, but with additional damage mechanisms (flooding, plus erosion and waves)

3. In CSRM, Formulation is heavily dependent on setting. Atlantic Ocean, Pacific Ocean, Great Lakes, Tidal Estuaries - all require different considerations.

4. There are many policies unique to CSRM
   - Only highlighted some of the most common policy concerns

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WHERE TO GO FOR MORE INFORMATION?

- ER 1165-2-130 (Corps guidance on CSRM)
- https://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1165-2-130.pdf

- IWR Primer on CSRM economics
- https://www.iwr.usace.army.mil/portals/70/docs/iwrreports/2011-r-09.pdf

- NACCS
- http://www.nad.usace.army.mil/Portals/40/docs/NACCS/NACCS_main_report.pdf

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Questions?

Type questions in the chat box.
We will answer as many
as time allows.

This webinar will be posted to the
Planning Community Toolbox:
http://www.corpsplanning.us

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