Design of Coastal Hazard Mitigation Structures Under Uncertainty of Future Sea Level Rise

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Coastal Hazards and Concerns

Coastal Hazard

- **Elevated** Water Levels (Flooding)
- **High** Waves
- **Erosion** of shoreline
- **Loss** of Tidal Wetlands

Coastal Concern

- **Property** (private, business, government)
- **Infrastructure** (utilities, etc.)
- **Transportation** Systems
- **Ecology**

Alternatives for Coastal Hazard Mitigation (Flooding, Waves, Erosion, Wetlands)

Structural

- Seawalls, Floodwalls
- Dikes, Revetments
- Breakwaters, Groins
- Movable Gate Structures
- Beach/Dune Nourishment
- Wetlands Restoration

Non- Structural

- Elevated Structures
- Raise Grade
- Zoning (setbacks, land use, purchase of lands).
- Retreat

and Combinations

Civil/Coastal Engineering **Definitions**

MITIGATION

- to **REDUCE** (**Mitigate**) the damage caused by coastal storms and increased SLR using **both** structural and non-structural alternatives

ADAPTATION

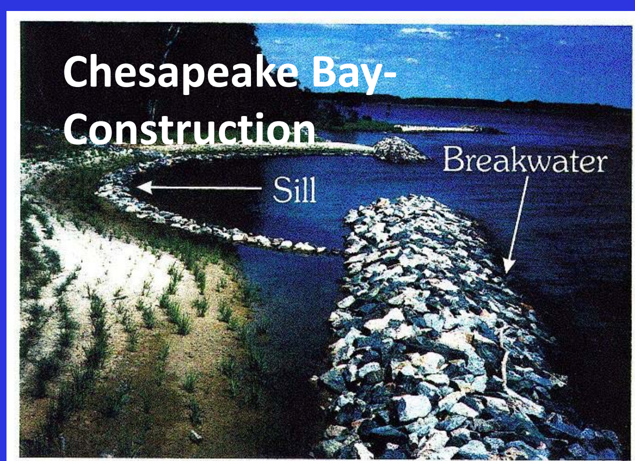
- to **CHANGE** (**Adapt**) our present alternative methods (structural, non-structural) and **decision making methods** as caused by the **predicted levels and uncertainty in SLR**

Non-structural mitigation is NOT adaptation

Design Considerations

- **Structural Integrity** (Strength to resist damage under design conditions)
- **Functional Performance** (Ability to reduce flood levels, lower wave heights, decrease erosion rates, and provide ecosystem habitat)

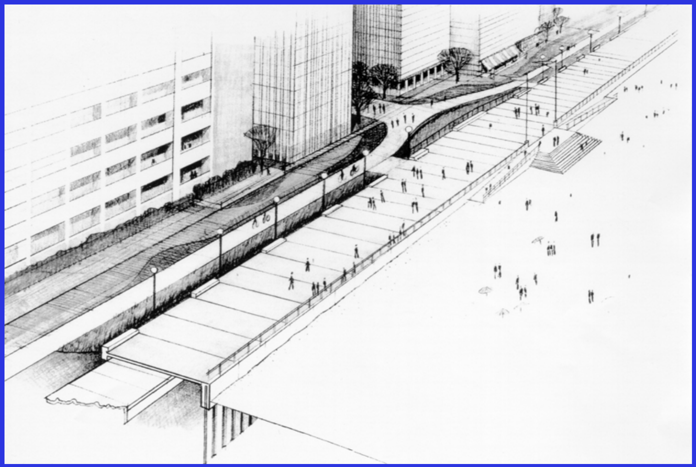
Near shore **Breakwaters** and Living Shoreline Systems – **Chesapeake Bay**



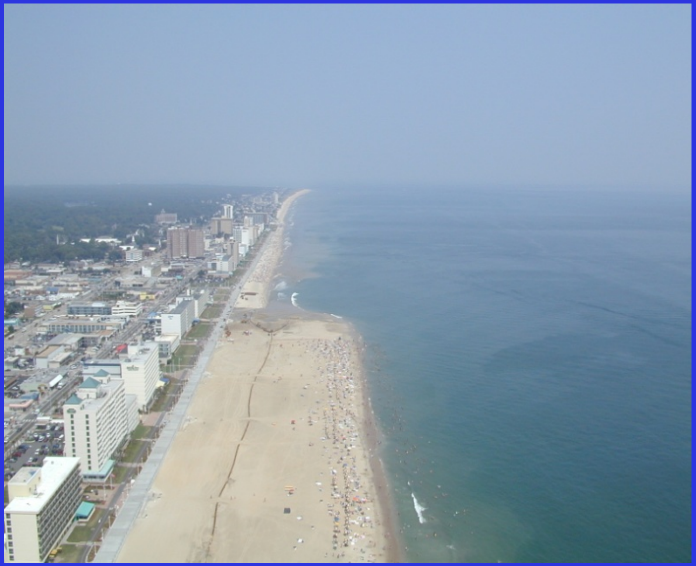
Wave height reduction, less shoreline erosion permits marsh grass restoration

Virginia Beach Hurricane Damage Mitigation Project –Open Ocean

(Combined **Seawall** and **Beach Nourishment**)

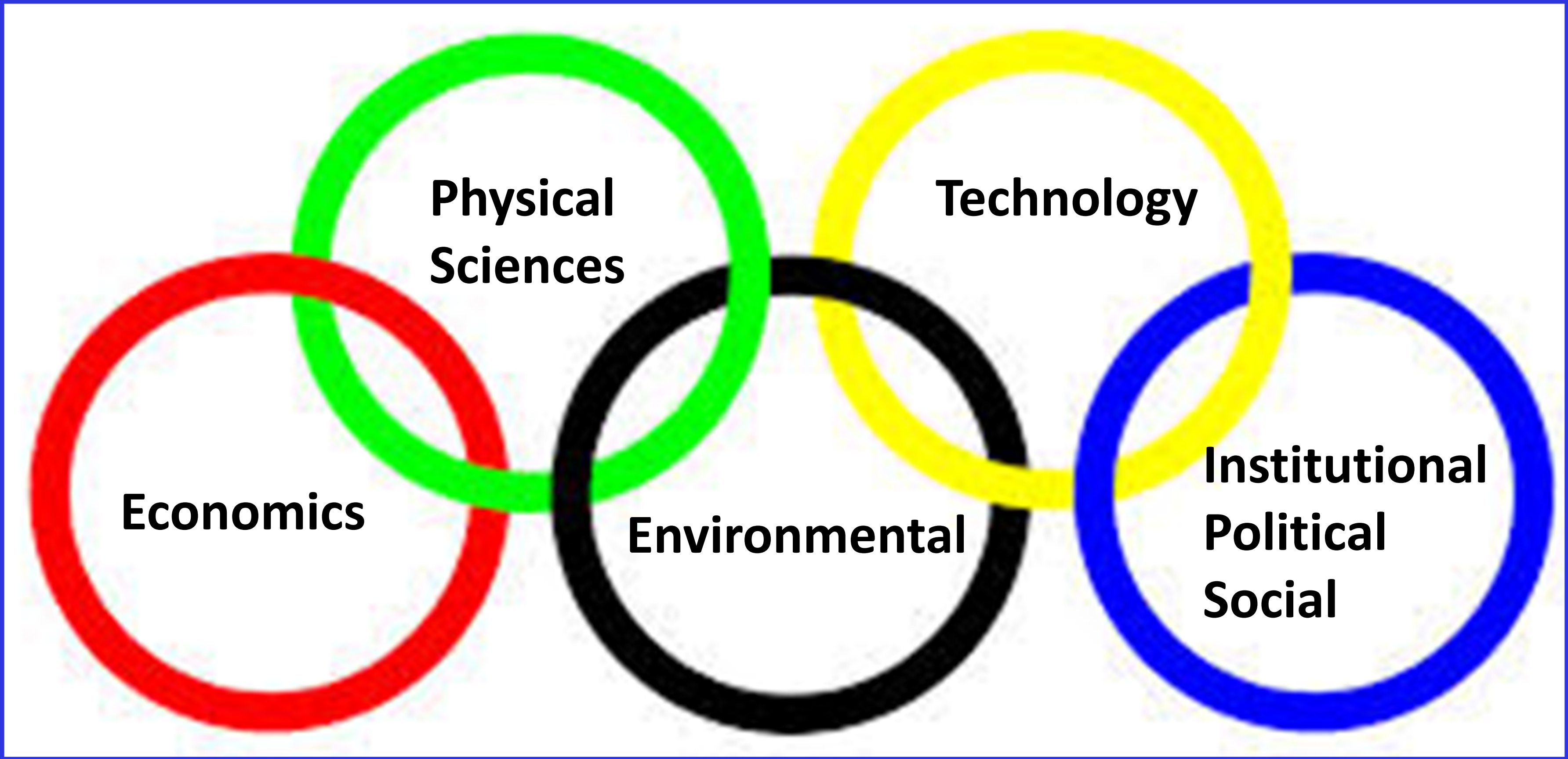


Storm surge flooding and coastal erosion



CONSTRAINTS in Coastal Engineering **Design**

Knowledge of



Quantification of Risk, R

$$R = \sum_{1}^{n} (p_f \, . \, p_d) \, C_i$$

where

p_f *= exceedance probability for water elevation at level, j*

p_d **=** *water level damage at exceedance probability, j*

j = 1-jj for intervals of water elevation and damage level

and C_i *= the consequences (costs of damage repair, functional impairment, loss of life, etc.) for n = 1 to n consequences.*

Life-Cycle Cost Constraint -- Example for **Current Method** for Probabilistic Design of Rubble-mound Breakwater

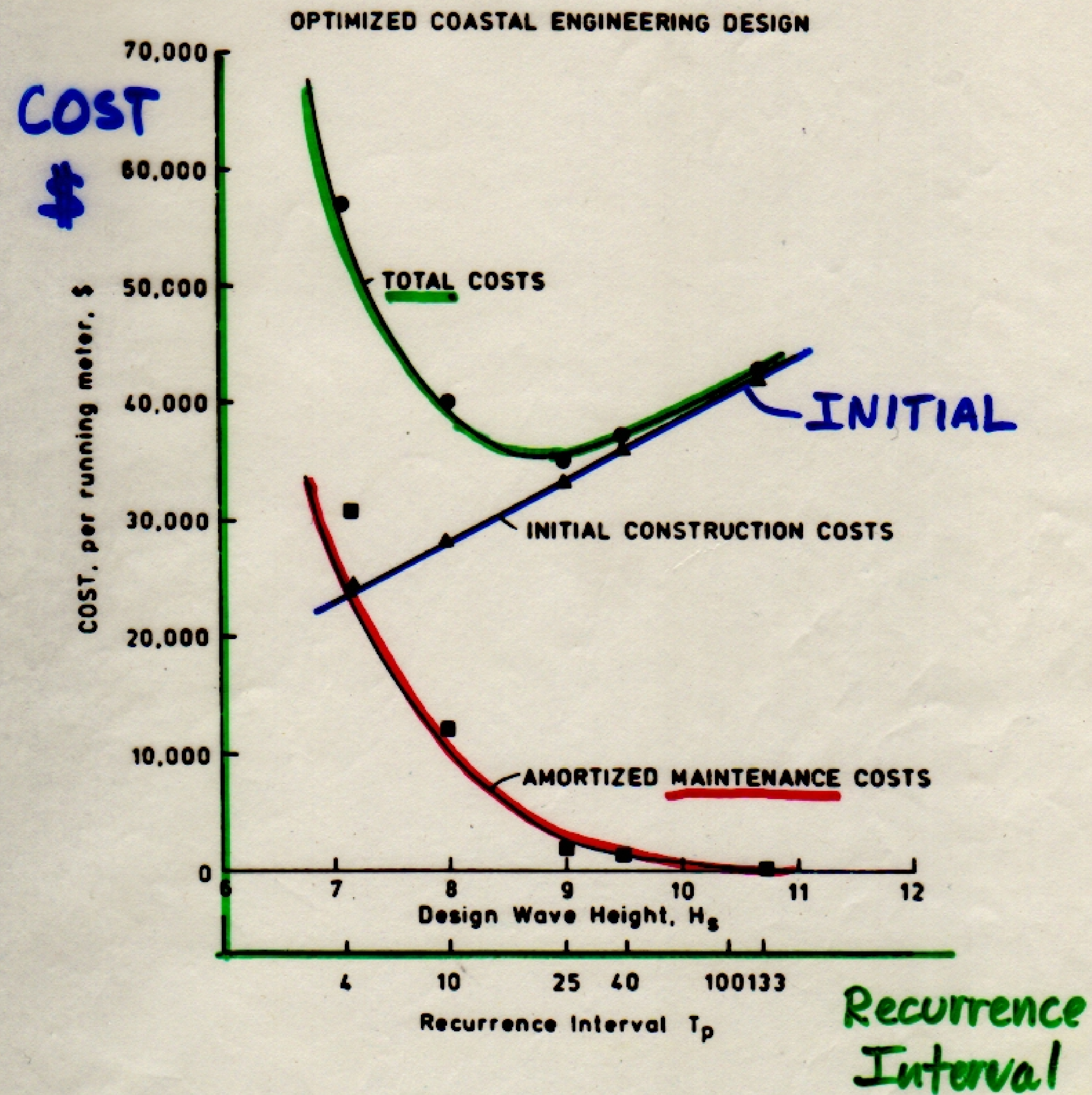
1. **Initial Costs Increase** With Wave Height (Higher waves require larger, stronger breakwater)
2. **Maintenance Costs Decrease** With Wave Ht (Stronger breakwater has less damage in bigger, less frequent storms

Total, Life-Cycle Costs (classic U-shaped cost curve)

Annual Costs (i = interest rate, N= design life.

pwf = present worth factor)

OPTIMIZED DESIGN

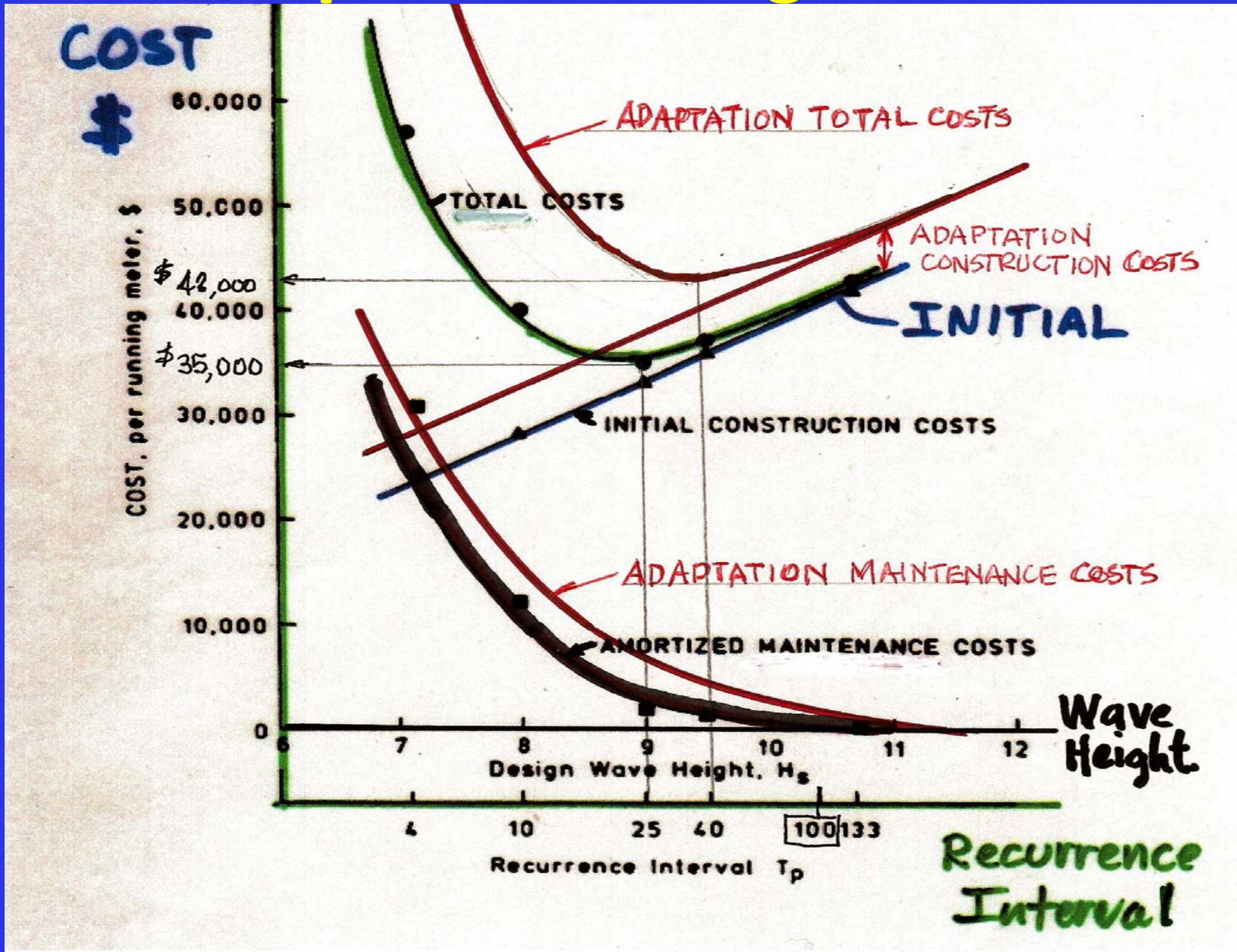


Life-Cycle Cost Constraint -- Example for **Adaptation Method** for Probabilistic Design of Rubble-mound Breakwater

1. **Initial Costs Increase With Wave Height** (Higher waves require larger, stronger breaker)
2. **Initial Maintenance Costs Decrease With Wave Height** (Stronger breakwater has less damage in bigger, less frequent storms
3. **SLR Adaptation Costs Increase** (SLR requires increased crest elevation to maintain function and stronger structure for larger waves)

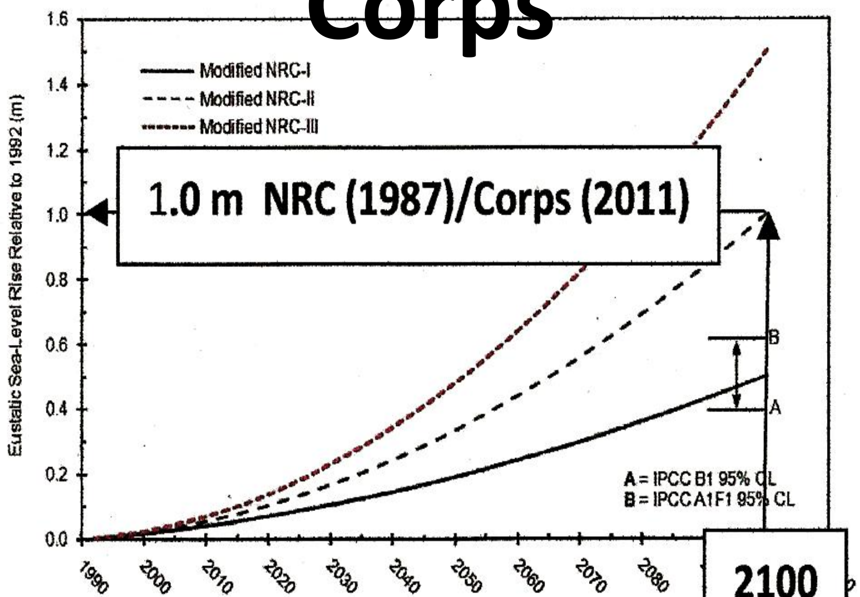
Total, Life-Cycle Costs INCREASE

Adaptation Design Costs

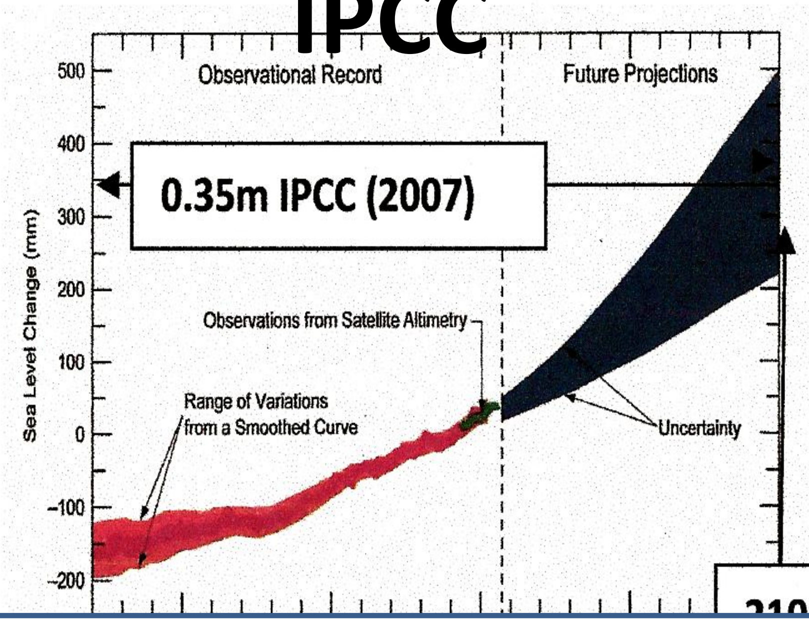


Science Constraint- SLR Projections

Corps



IPCC



What to use for Coastal Engineering Design for year 2100 at Intermediate Projection Level ?

Corps (2011) 1.0 m
Corps (2014) ???

IPCC (2007) 0.18-0.59 (0.35)m
IPCC (2013) 0.28-0.98 (0.63)m

Adaptation Strategies for Uncertainty in SLR Projections

- Consider **shorter design-life** for economic analysis of alternatives.
- **Add third cost component** for SLR adaptation costs in life-cycle cost analysis
- **Design for Intermediate Level** of SLR projections for year 2100 (use time curves)
- **Always consider Consequences of Failure** (both strength and function of design) for Highest Level of SLR projections for year 2100.
- **Consider Redundancy measures** for when failure occurs in Coastal Structures Design

Summary- Predicted Levels and Uncertainty in SLR

- **will require adaptation of present methods of economic analysis;**
- **will give preference to alternatives that can be most economically adapted;**
- **will require that the consequences of failure and redundancy be considered**; and
- **will require adaptation** of present **Environmental** and **(Institutional, Political, and Social) constraints.**

Seminar Series - Spring 2014
Mitigation and Adaptation Strategies of Civil/Coastal Engineers for Future Sea Level Rise

- **March 7, 2014:** **Corps of Engineers Role in SLR – Post Superstorm SANDY**
- 1:00 – 2:00 PM Dr. Charlie Chesnutt, Chiefs Office, Washington, DC
- **April 4, 2014:** **Adaptive Management Strategies for SLR: Ports, Beaches,**
- 2:00 – 3:00 PM **Coastal Structures and Marsh Restoration Projects**
- John Headland, Moffatt & Nichol Engineers, New York City
- **April 25, 2014** **European Union Perspective on Adaptation and**
- 2:00 – 3:00 PM **Mitigating SLR Impacts**
- Professor Marcel Stive, Coastal Engineering,
- Delft Technical University, The Netherlands