Navy/DoD Recognition of Need to Plan for Climate Change

- **2010 Quadrennial Defense Review:** Complete a comprehensive assessment of all installations to assess the potential impacts of climate change on its missions and adapt as required.
- **Navy Task Force Climate Change** - Climate Change Roadmap signed by VCNO in May 2010: Action Item 3.1 Initiate a Navy Climate Change Adaptation Capabilities Based Assessment (CBA).
  - The impact of changing precipitation and weather patterns on installations, including environmental stewardship efforts, land use, and water management
  - Current and required capability of infrastructure to adapt to climate change, with particular emphasis on sea level rise and impacts on installations' natural and cultural resources
- **2011 Naval Studies Board** - National Security Implications of Climate Change for U.S. Naval Forces: Address naval coastal installation vulnerabilities due to anticipated sea level rise and storm surges.

Navy Task Force Climate Change

Establishment

Chief of Naval Operations
Executive Board on May 15, 2009

Composition

Navy, NOAA, USCG in core group with
Joint, interagency, international support

Charter

Global climate change impacts

NAVY
Task Force
Climate Change

Rear Admiral Dave Titley
Director, Task Force Climate Change /
Oceanographer of the Navy

Navy Task Force Climate Change

Near-term

- Increasing Arctic maritime activity
- Partnership opportunities
- Energy security initiatives

Mid-Term

- Sea level rise impact on installations
- Water/resource challenges
- Potential increase in HA/DR

Wild-cards

- Ocean acidification
- Abrupt climate change
- Geoengineering

Recent/Ongoing Research and Studies

- DoD Strategic Environmental Research Development Program (SERDP):
  - Naval Station Norfolk, Virginia
  - Eglin Air Force Base, Florida
  - Marine Corps Base Camp Lejeune, North Carolina
  - Marine Corps Base Camp Pendleton and Naval Base Coronado, California
- NAVFAC Engineering Service Center: 2009 inundation study in support of the QDR
- DoD Strategic Sustainability Performance Plan (SSPP): 2010 North Carolina Study
- Center for Naval Analyses: DoD Climate Change Adaptation Planning
- Noblis: 2010 Climate Change Planning for Military Installations

Strategic Environmental Research and Development Program

- 2009 SERDP Statement of Need: Assessment Of The Impact Of Sea Level Rise On Military Infrastructure
  - Develop analysis methods to assess the impacts of local mean sea level rise of 0.5, 1.0, 1.5 and 2.0 meters on U.S. military infrastructure
  - Include an assessment of the potential impacts caused by an increase in the frequency and intensity of storms.
  - The physical effects of sea level rise to be examined include, but are not limited to:
    - inundation of land,
    - increased storm and flood damage,
    - loss of wetlands,
    - changes in erosion patterns and rates,
    - salt water intrusion in surface and ground waters,
    - rising water tables, and
    - changes in tidal flows and currents.

A Methodology for Assessing the Impact of Sea Level Rise on Representative Military Installations in the Southwestern US

Dr. Bart Chadwick, PI - SPAWAR Systems Center Pacific

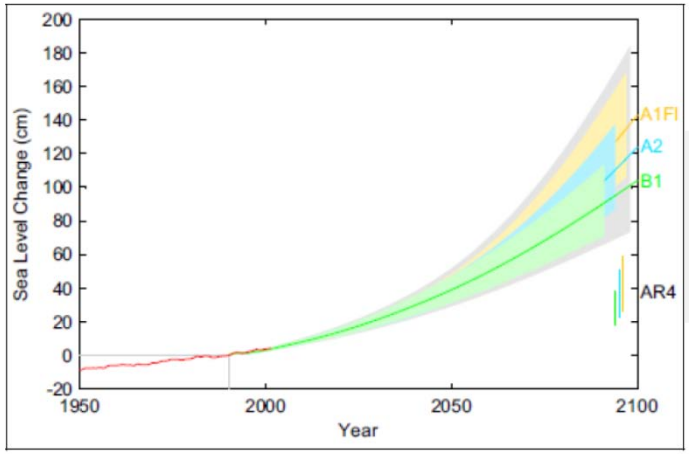
Dr. Reinhard Flick – Scripps Institution of Oceanography

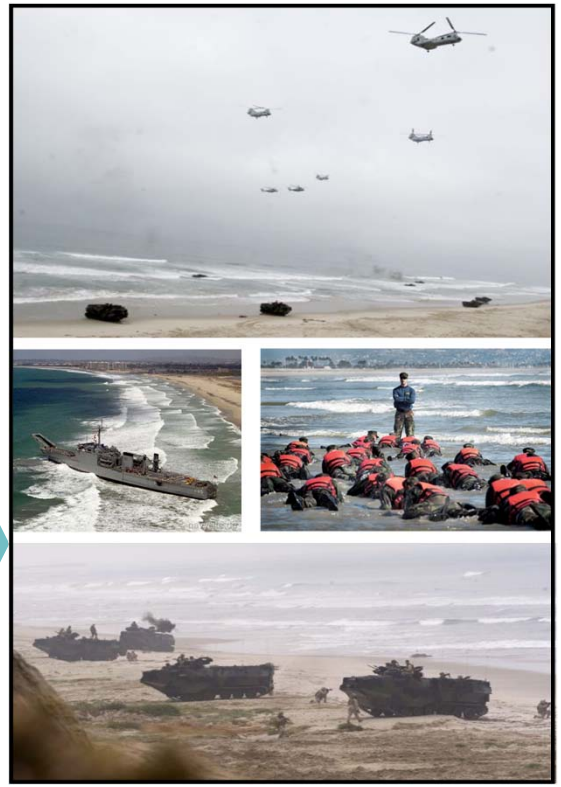
Dr. John Helly – UCSD: San Diego Supercomputer Center

Dr. Walter Oechel – SDSU: Global Change Research Group

Dr. Tracy Nishikawa – US Geological Survey

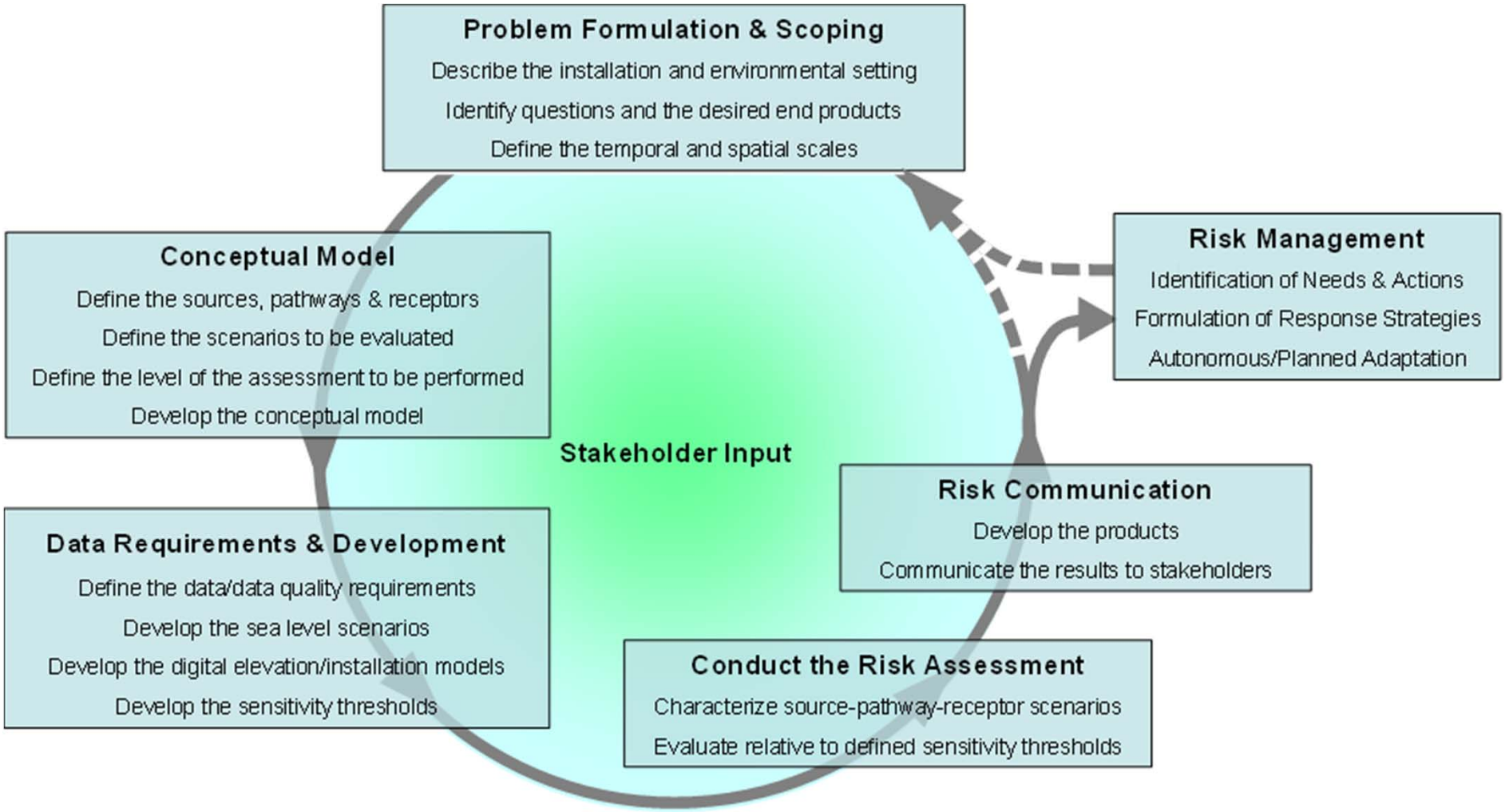
Mr. Issac Canner – Moffatt/Nichol Blaylock





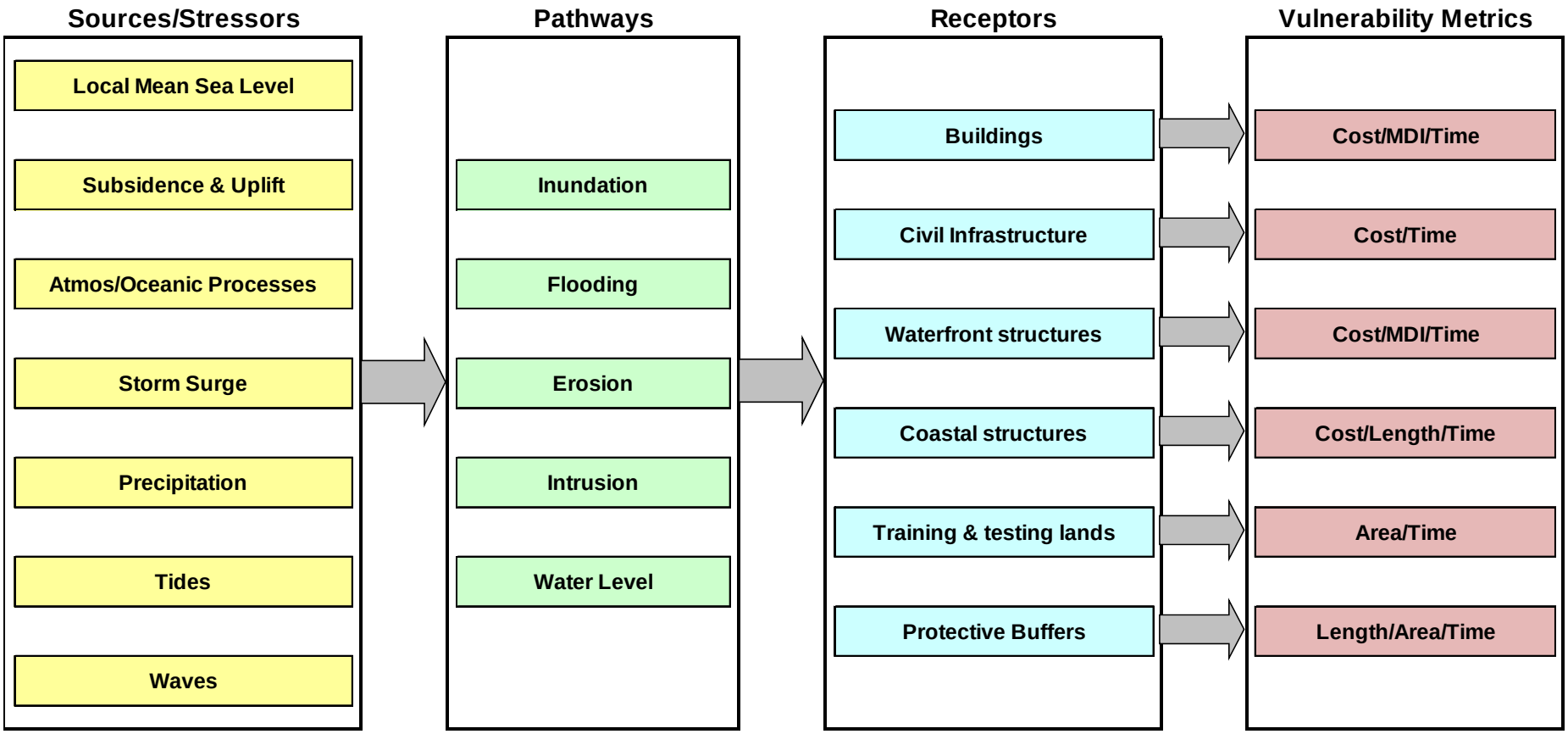
Vulnerability Framework

- Improved specificity and refinement of framework



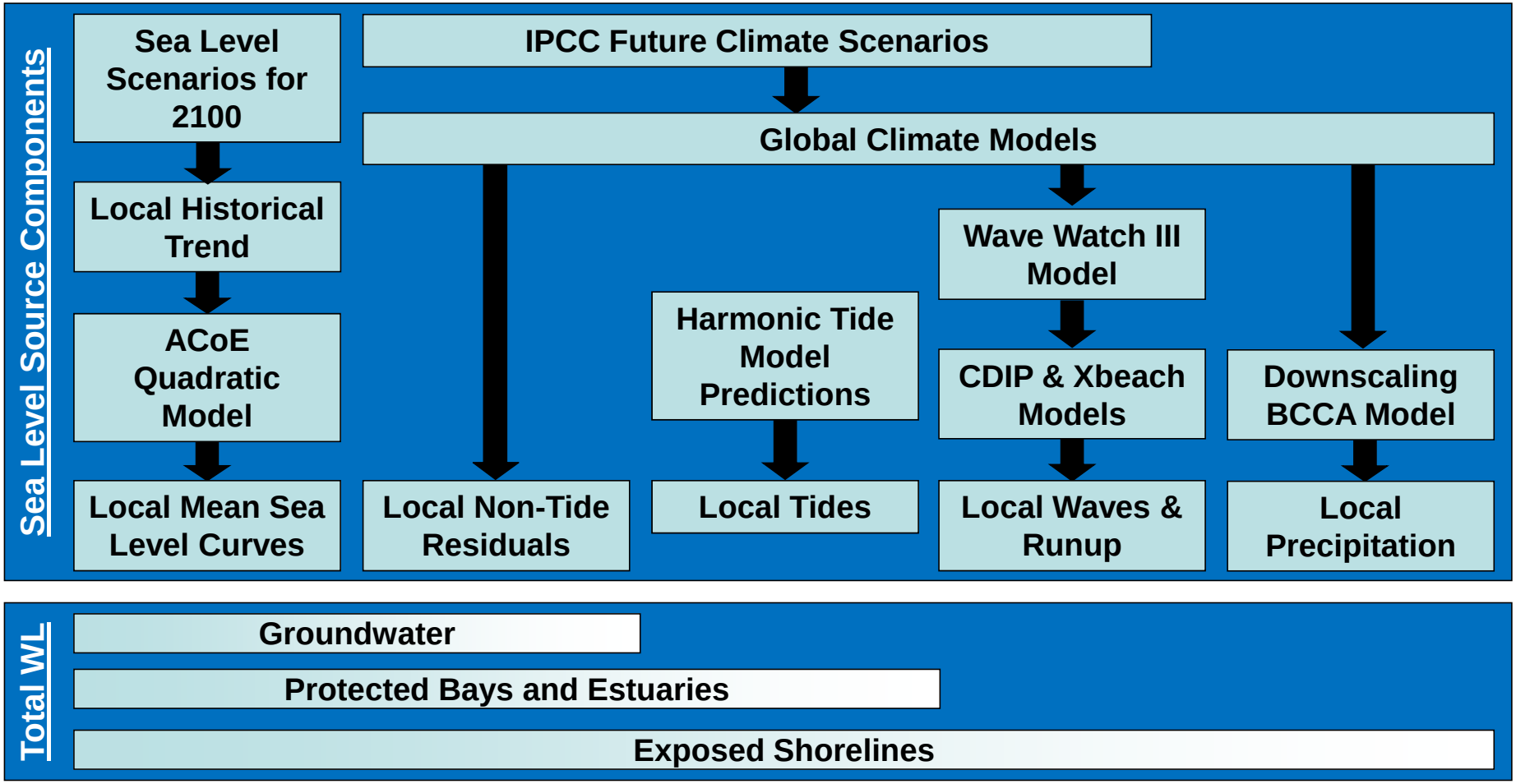
Vulnerability Framework – Conceptual Model

- Refined conceptual model with metrics



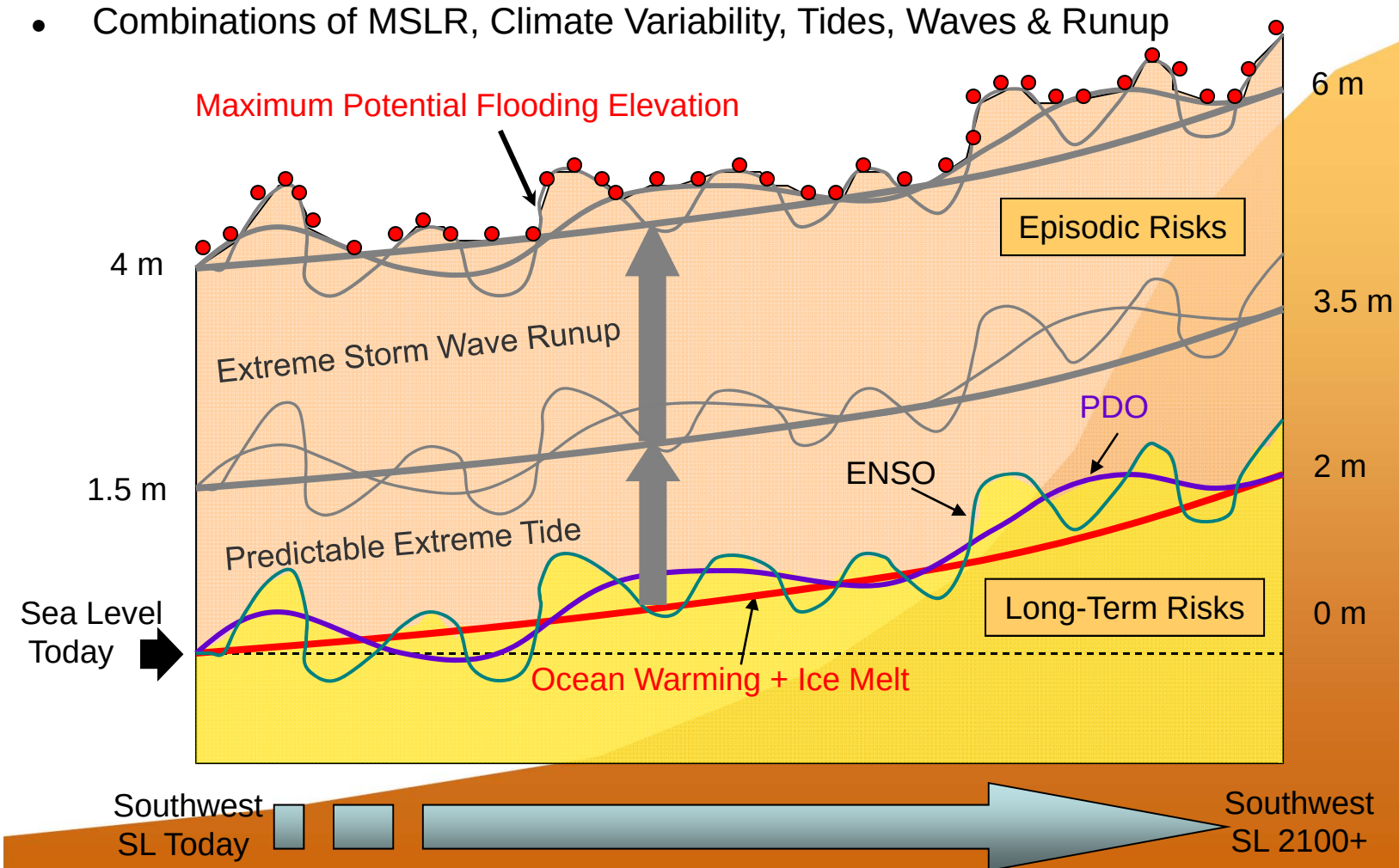
Regional Sea Level Rise Scenarios

- Prescribed scenarios, historical trends, & modeled projections
- Develop regional scenarios for the range of coastal regimes
- Conduct joint probability analysis of forcing factors

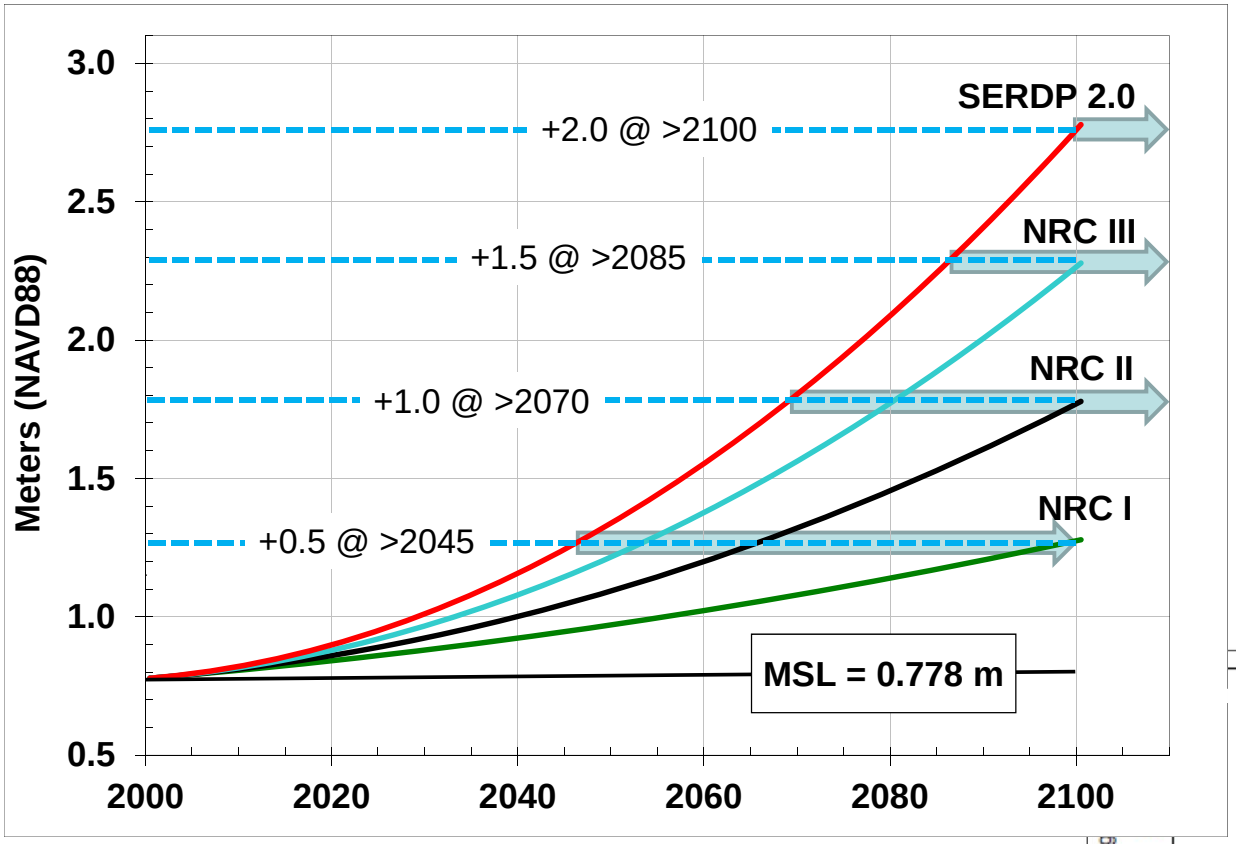


Regional Sea Level Rise Scenarios

- Represent the source term for the assessment
- Prescribed scenarios, historical trends, & modeled projections
- Combinations of MSLR, Climate Variability, Tides, Waves & Runup

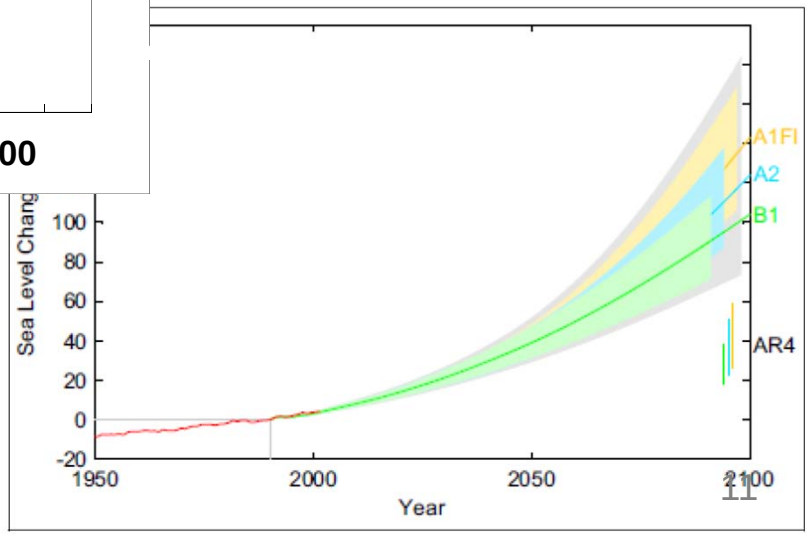


Sea Level Scenarios – Mean Sea Level



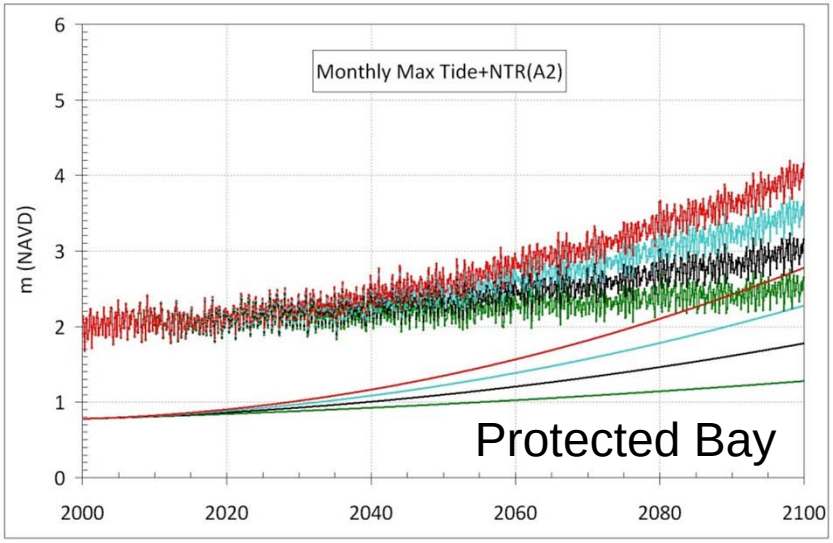
- MSL curves from ACOE model
- Linear trend + acceleration
- Start at 2000 centered epoch
- Encompass range of most MSLR estimates
- Create range of planning horizons

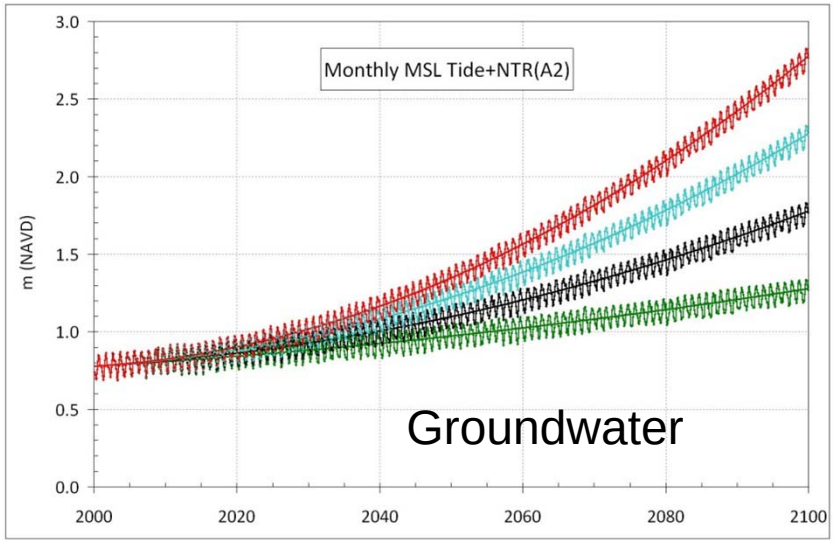
Scenario	*2100 Sea Level (m)*		*a*	*b*
Designation	*NAVD88*	*MSLR from 2000*	*(m/yr)*	*(m^2/yr)*
NRC I	1.27	0.5	2.80×10^{-3}	2.20×10^{-5}
NRC II	1.77	1	2.80×10^{-3}	7.20×10^{-5}
NRC III	2.27	1.5	2.80×10^{-3}	1.22×10^{-4}
SERDP 2.0	2.77	2	2.80×10^{-3}	1.72×10^{-4}

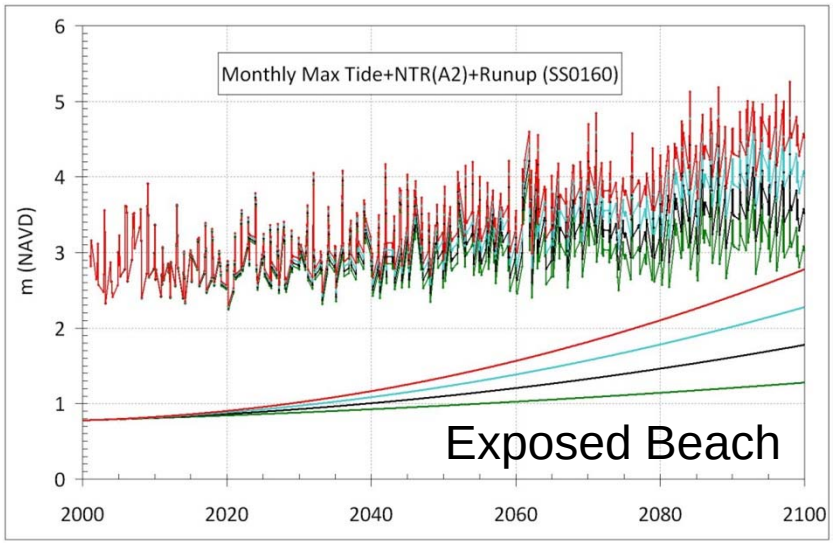


Sea Level Scenarios - Combined

- Combine prescribed future MSL scenarios with SL variability
- Construct time series 2000-2100
- Include range of exposures







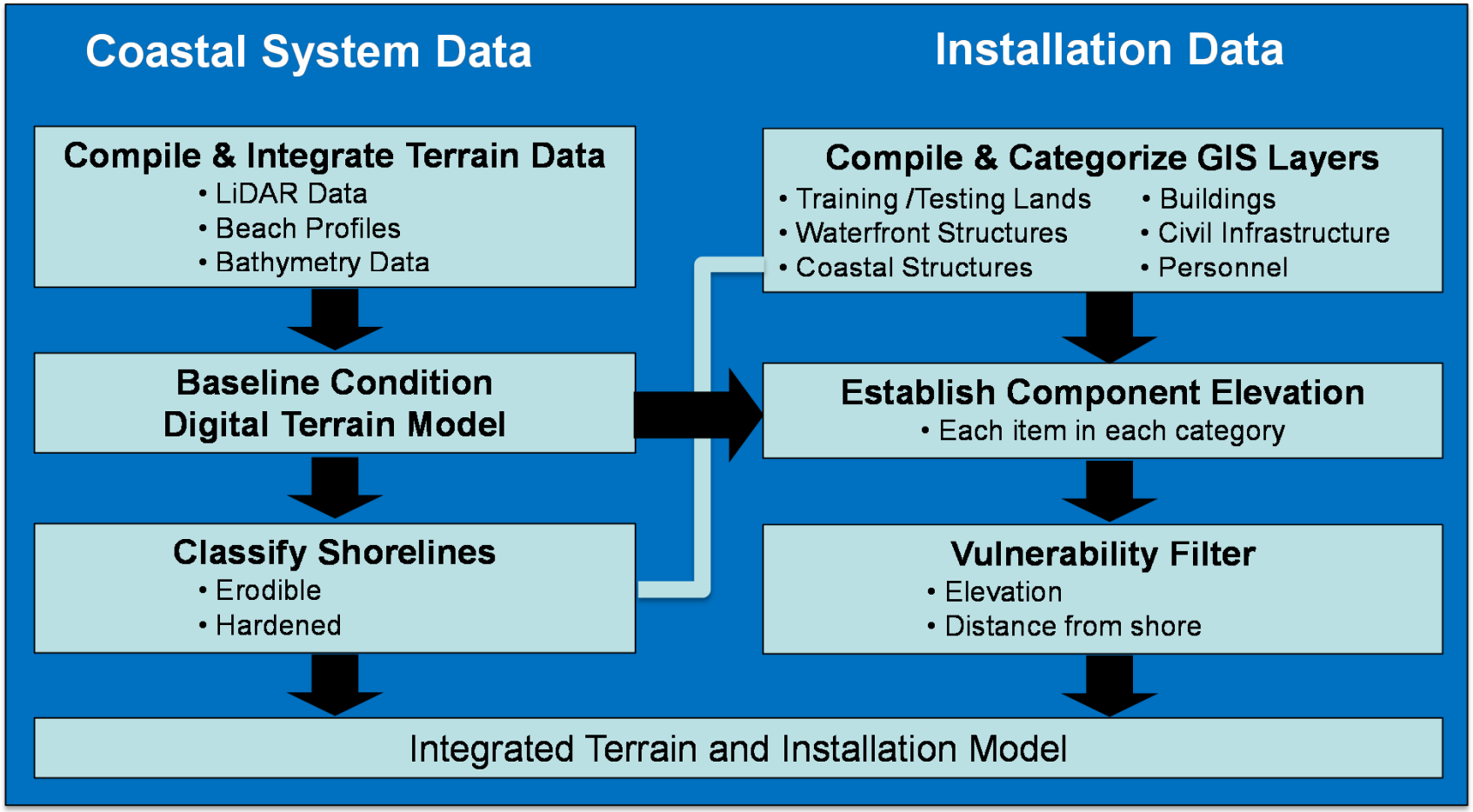
Sea Level Scenarios – Scenario Matrix

- Define the scenario matrix for the vulnerability assessment
- Combine prescribed MSL conditions with the return period events
- Illustrates the progression of rare events toward common events

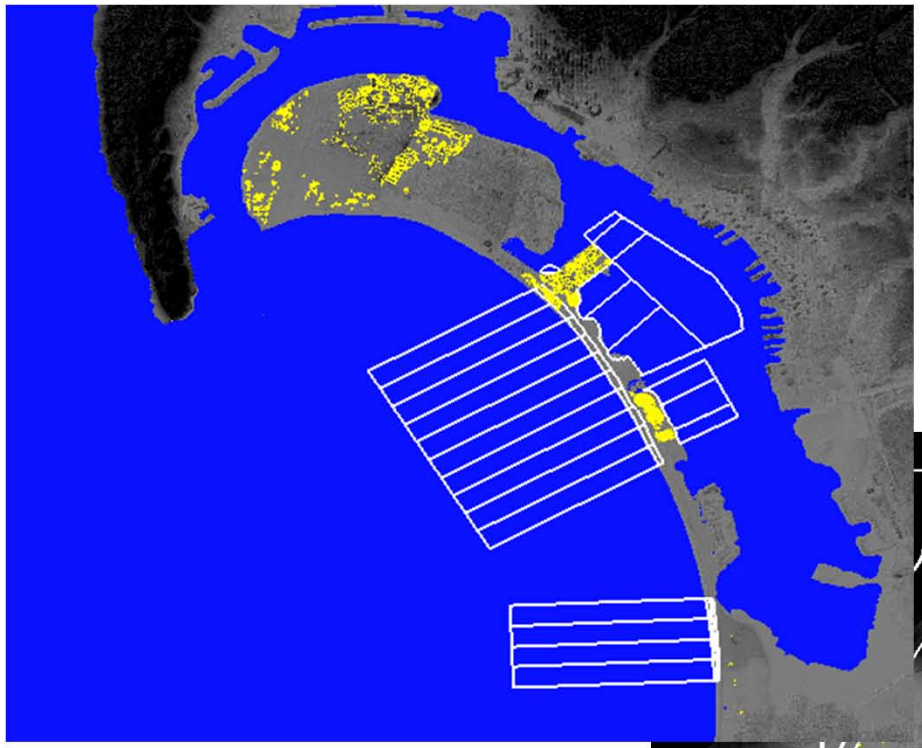
Location/ Condition	Rerurn Period	Baseline (m NAVD)	Future MSLR (m)			
			0.5 >2045	1.0 >2070	1.5 >2085	2.0 >2100
MCBCP PN1110 Tide + Runup	Week	2.17	2.67	3.17	3.67	4.17
	Month	2.60	3.10	3.60	4.10	4.60
	Year	3.22	3.72	4.22	4.72	5.22
	Decade	3.67	4.17	4.67	5.17	5.67
	Century	4.04	4.54	5.04	5.54	6.04
NBC SS0160 Tide + Runup	Week	2.31	2.81	3.31	3.81	4.31
	Month	2.73	3.23	3.73	4.23	4.73
	Year	3.31	3.81	4.31	4.81	5.31
	Decade	3.74	4.24	4.74	5.24	5.74
	Century	4.07	4.57	5.07	5.57	6.07

Delineation of the Coastal System

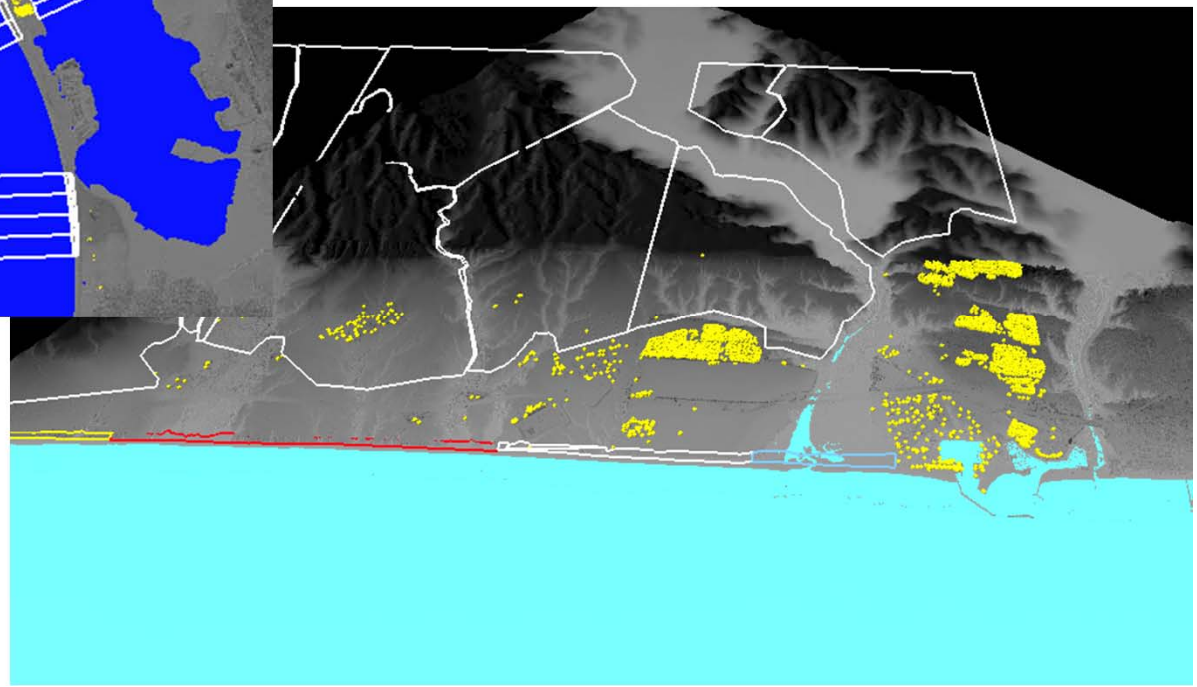
- Compile relevant coast and installation data
- Develop terrain and installation models
- Filter and integrate into common GIS analysis framework



Coastal System – Terrain & Installation Models

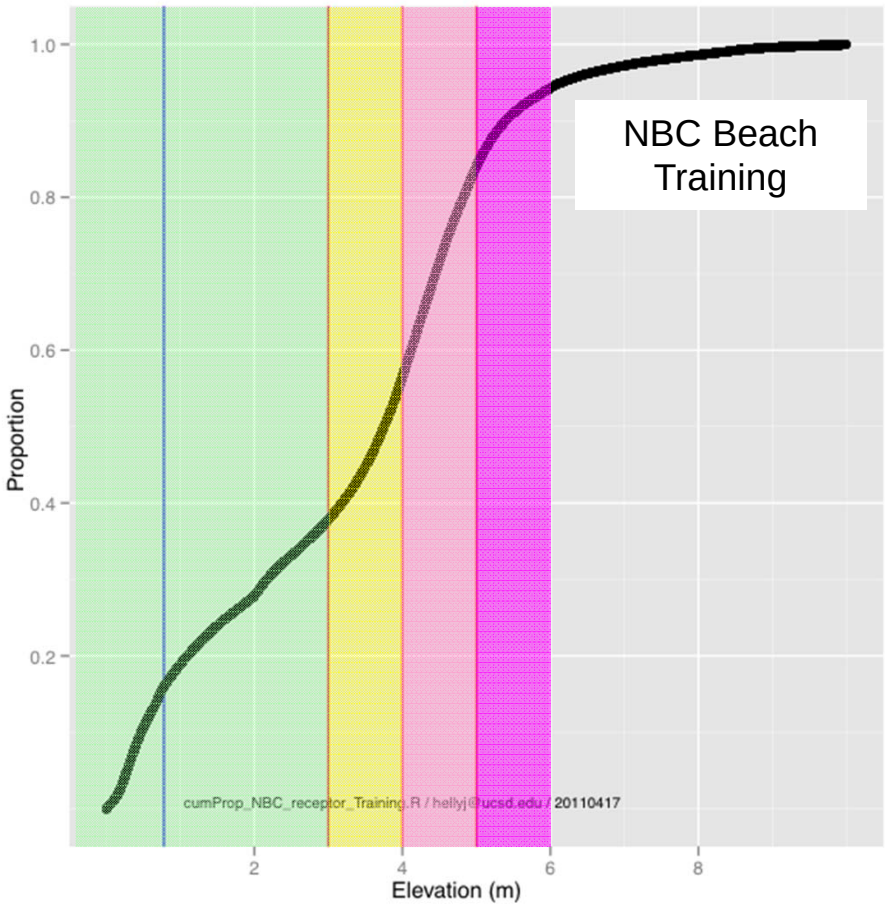


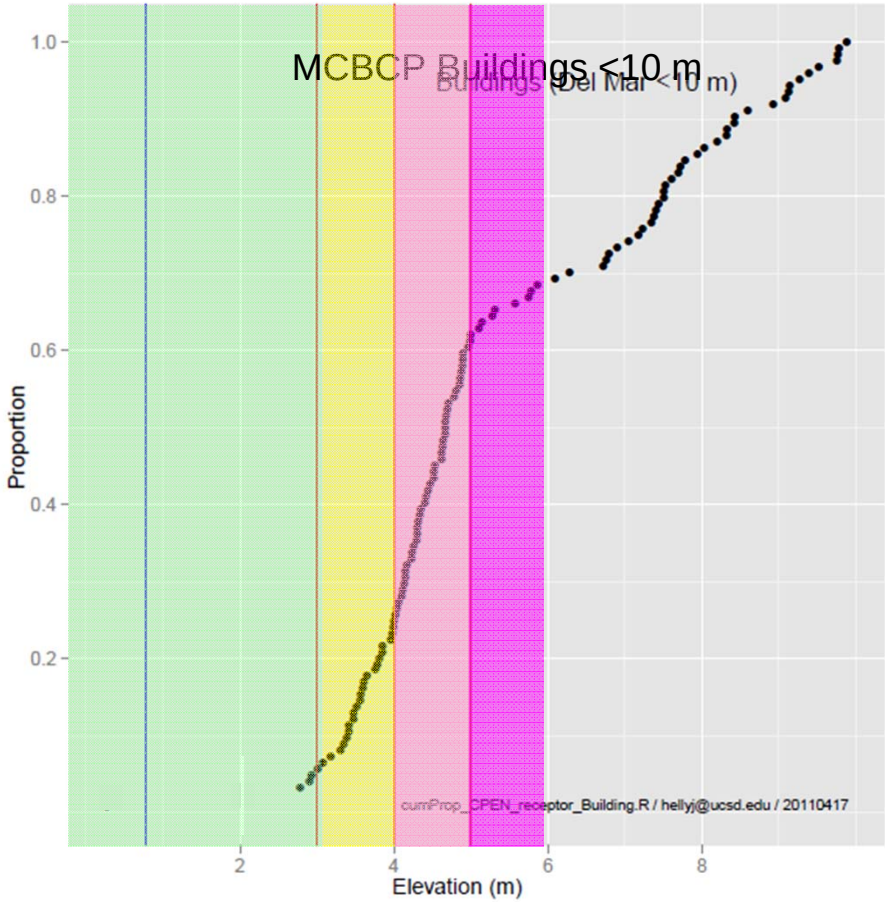
- Integrate upland, shoreline, and offshore data into a common elevation model
- Form baseline condition for shoreline change models



Coastal System – Sensitivity Curves

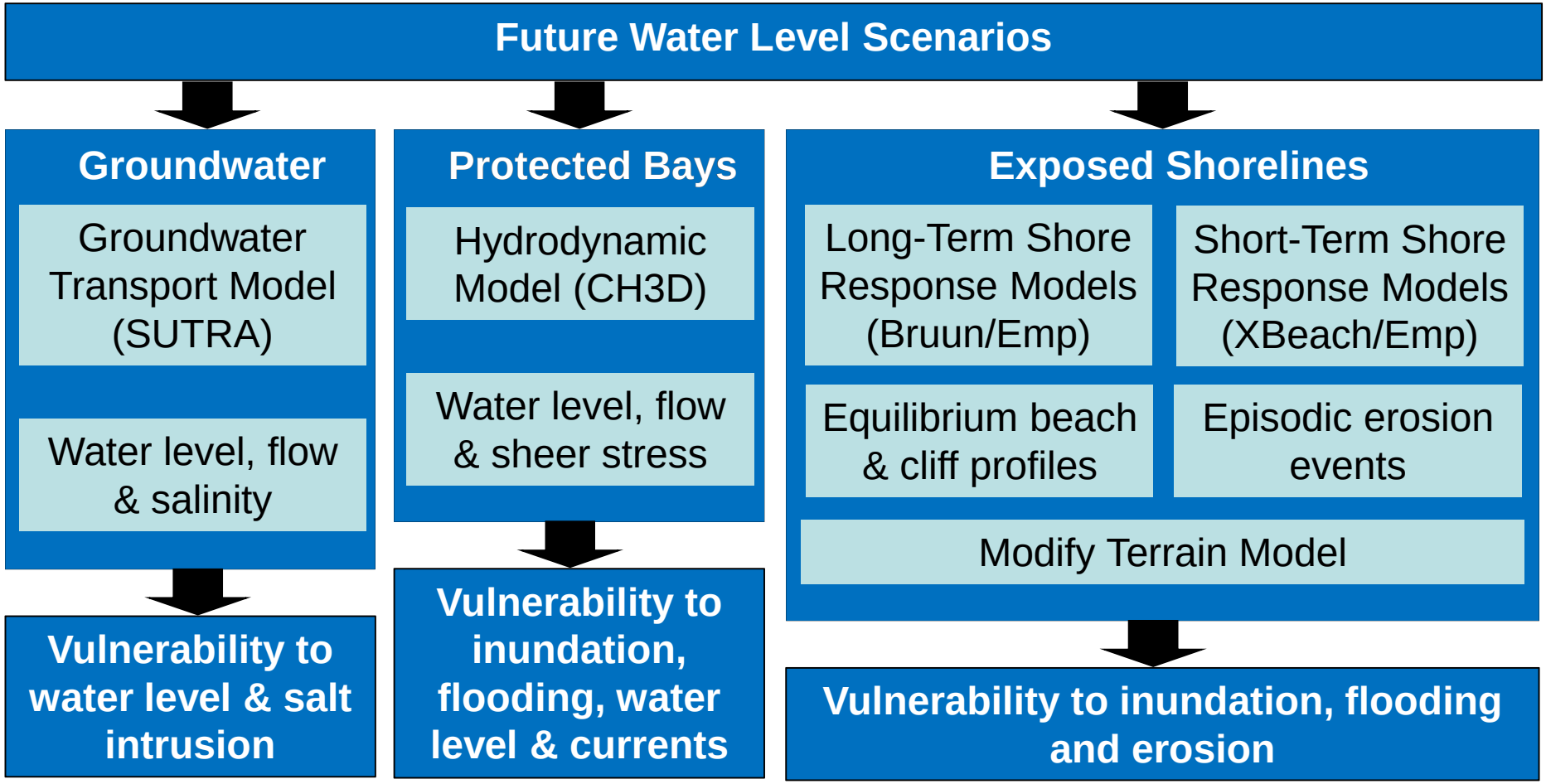
- From integrated terrain and installation model, generate installation sensitivity curves
- Identify sensitivity thresholds





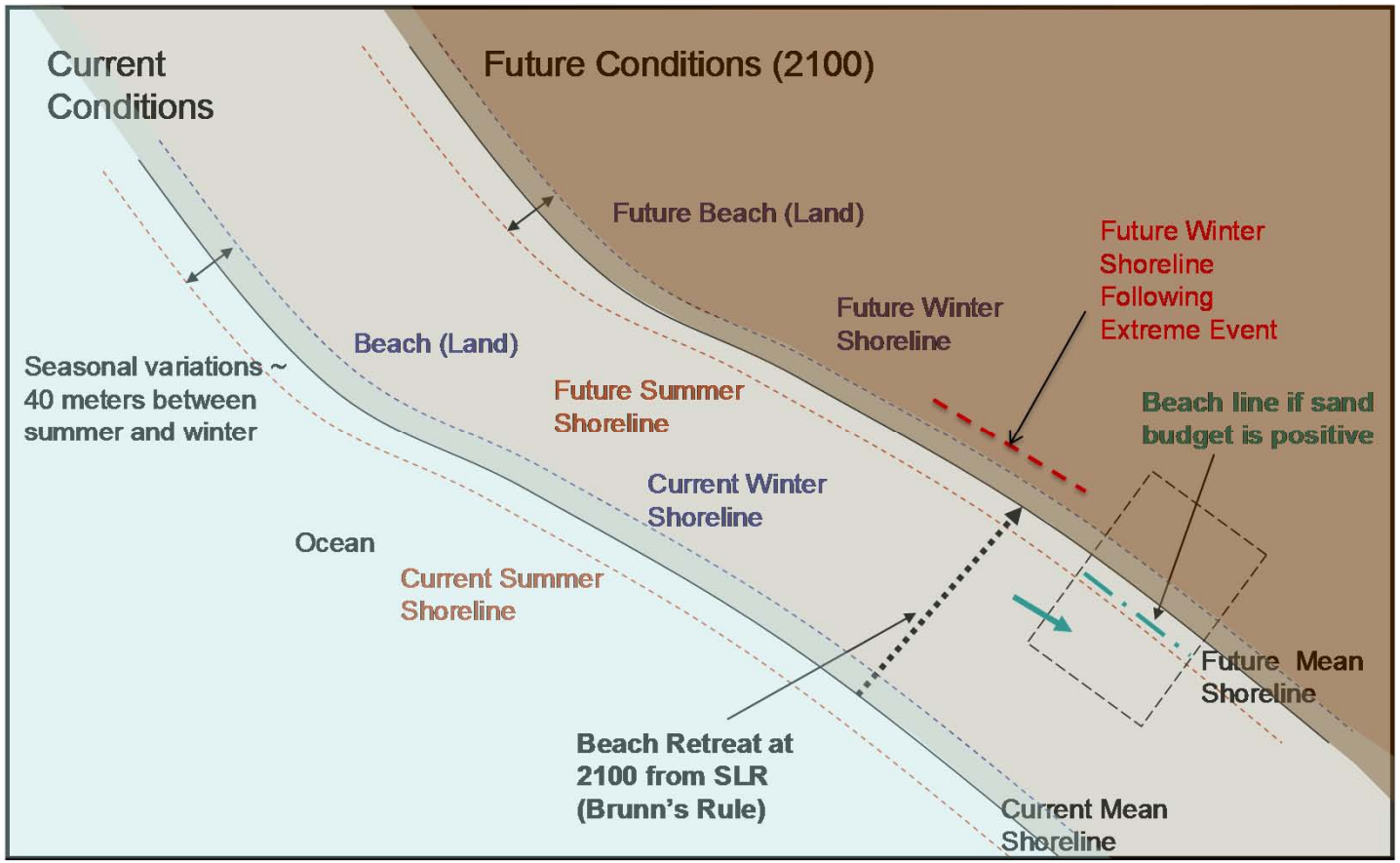
Assessment of Physical Effects

- Assess response pathways for sea level rise
- Integrate results with terrain model
- Apply to assess vulnerability

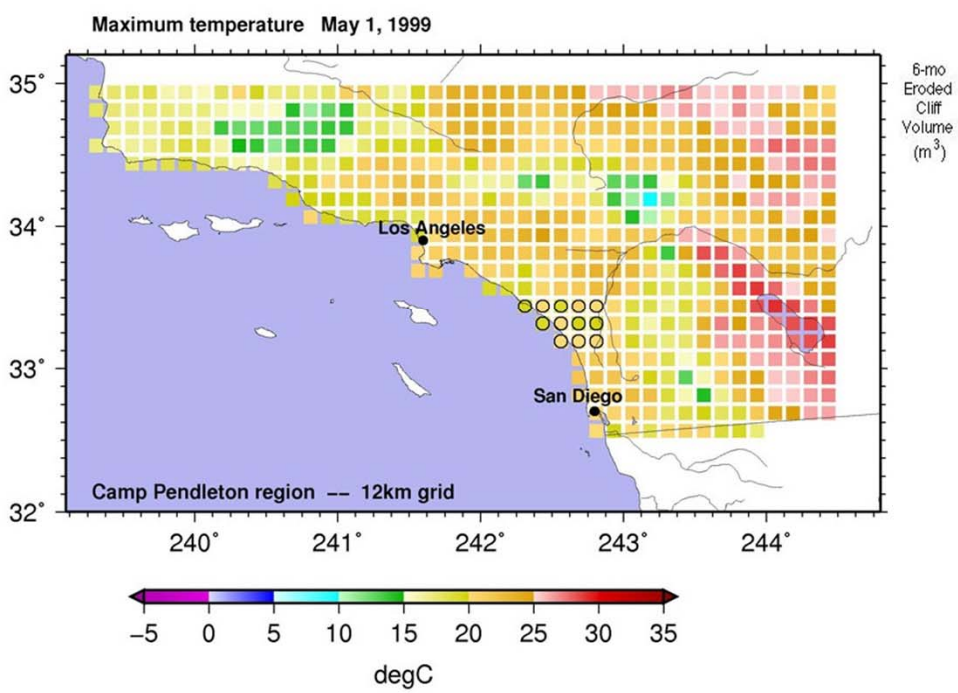


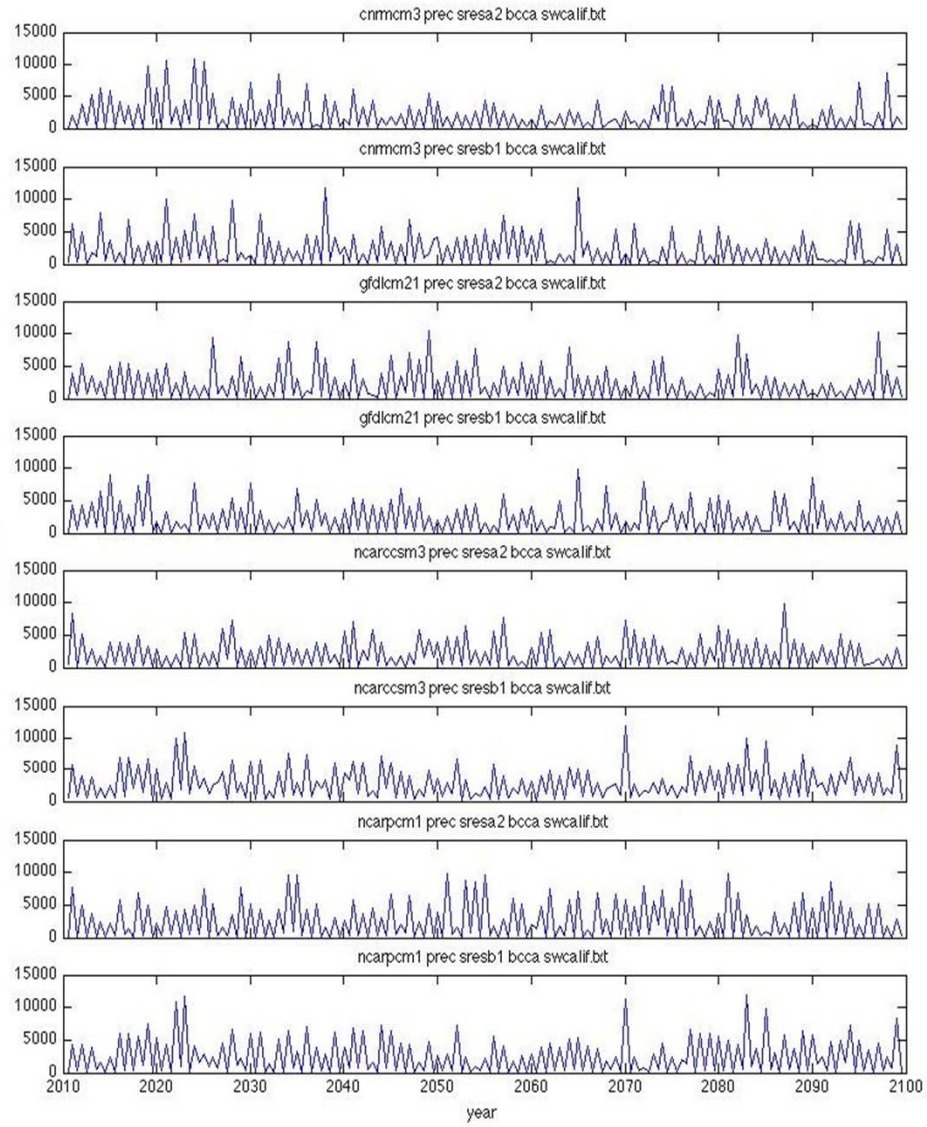
Physical Effects - Exposed Shorelines

- Long-term shoreline profile influenced by:
  - Sea Level
  - Sand Budget
  - Wave climate (extreme events, seasonal cycles and long term trends)



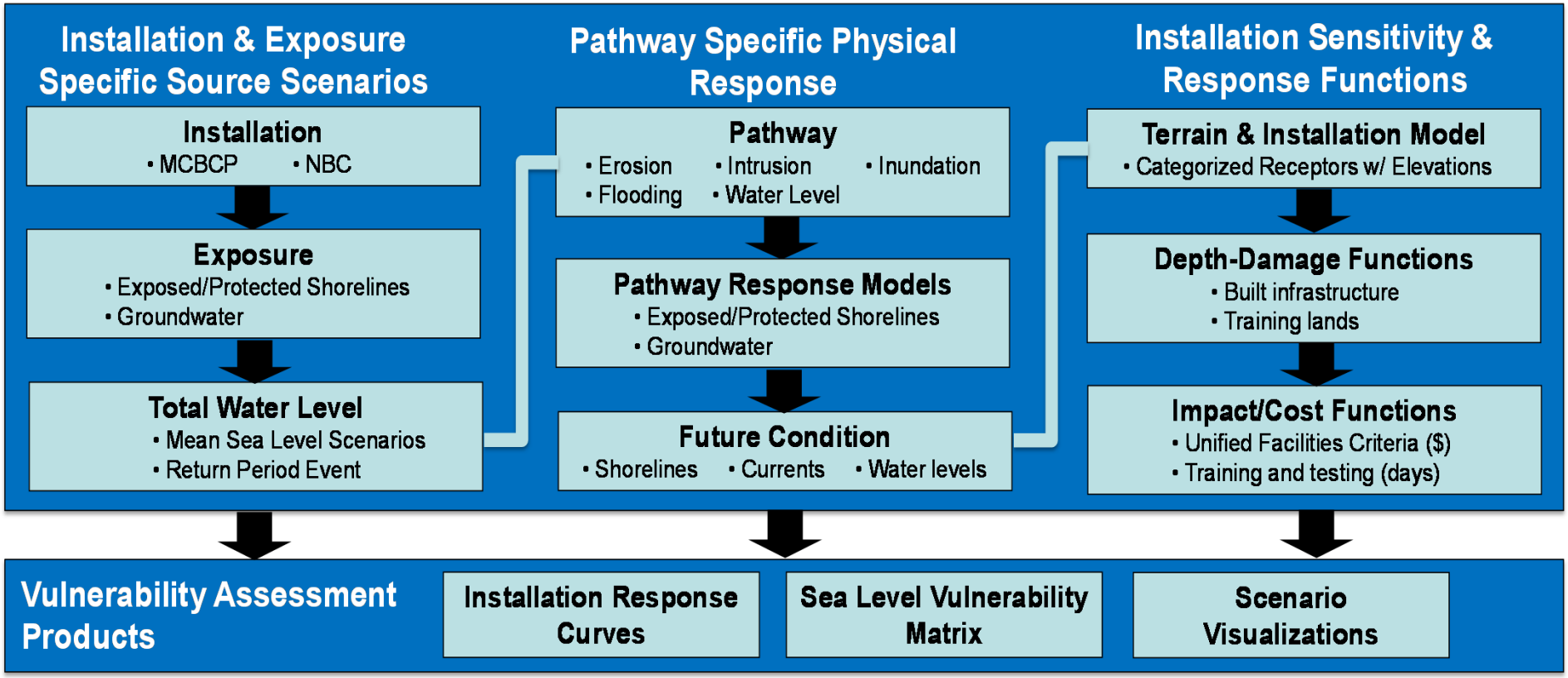
- Also developing response model fo bluff erosion (MCBCP)
- Based on empirical relationship between LiDAR-based erosion rates and precipitation
- Utilize 2000-2100 downscaled precipitation data from Cayan and Tyree





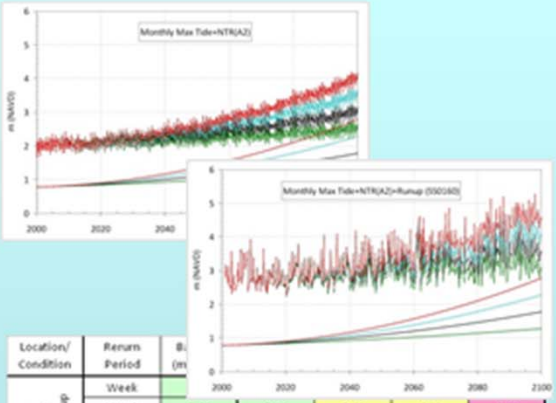
Assessment of Vulnerability

- Integrate installation scenarios with responses
- Assess vulnerability for the range of scenarios, return periods and time windows



Assessment of Vulnerability

Installation & Exposure Specific Source Scenarios



Location/ Condition	Return Period	B (m)				
MCBCP PN1110 Tide + Runup	Week					
	Month	2.60	3.10	3.60	4.10	4.60
	Year	3.22	3.72	4.22	4.72	5.22
	Decade	3.67	4.17	4.67	5.17	5.67
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NBC SS0160 Tide + Runup	Week	2.31	2.81	3.31	3.81	4.31
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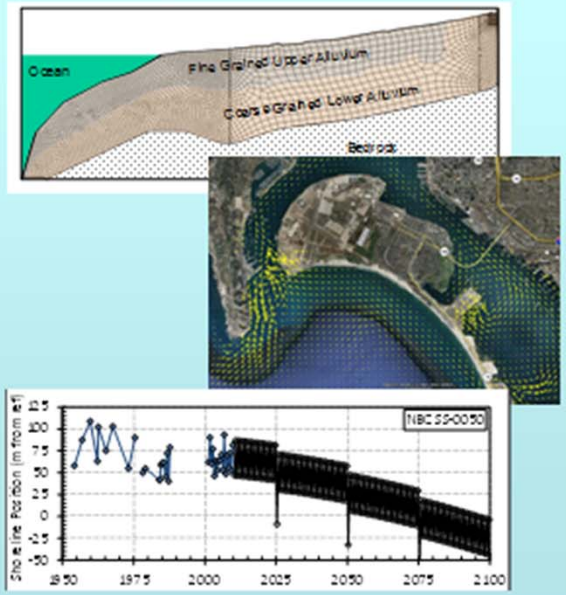
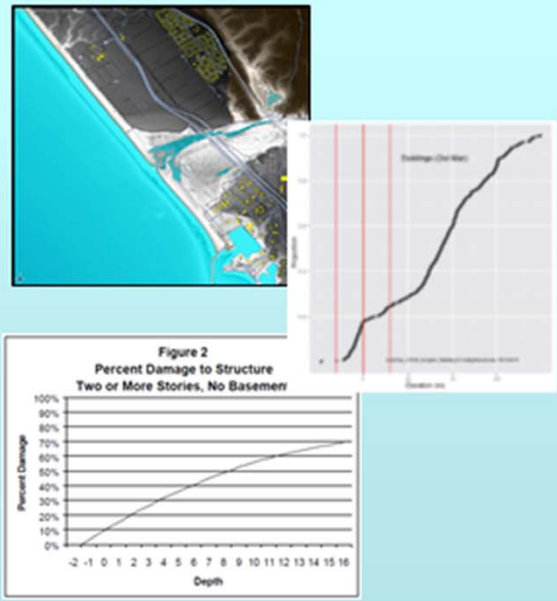
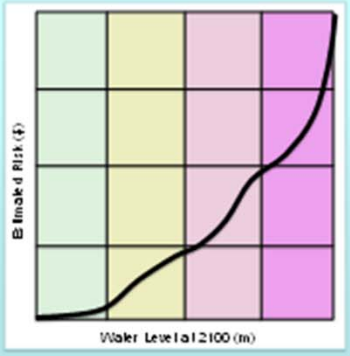
Pathway Specific Physical Response



Installation Sensitivity & Response Functions

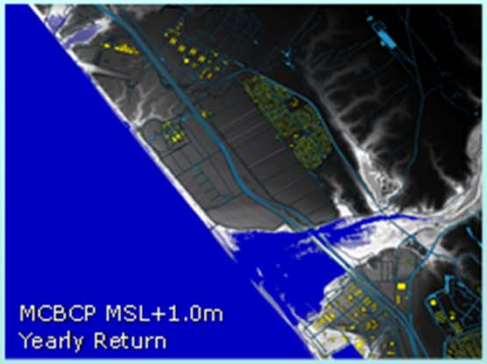


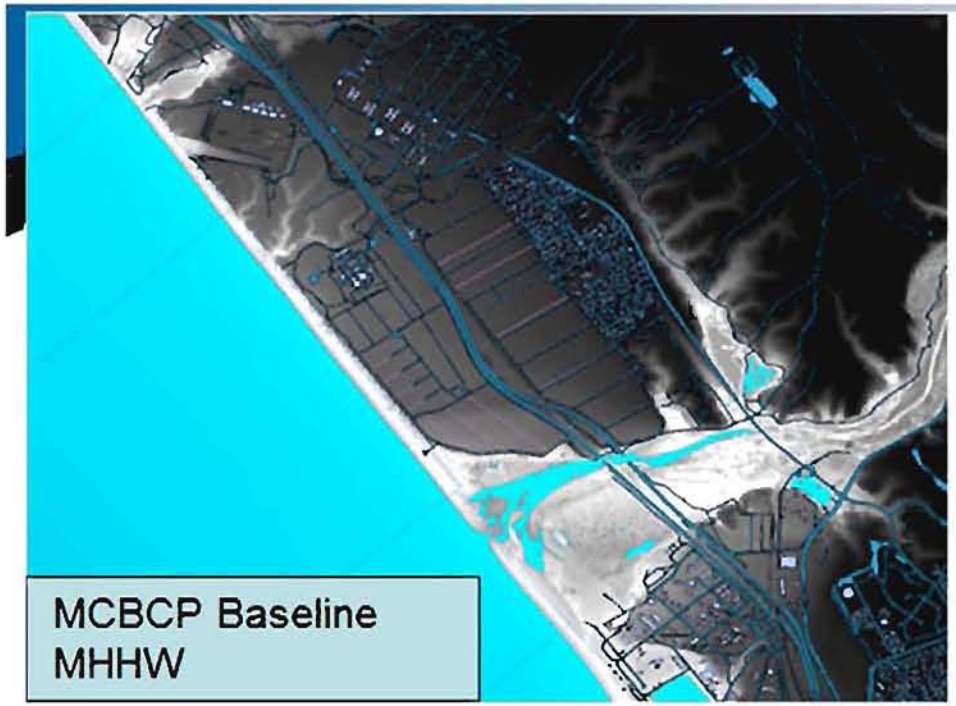
Vulnerability Assessment Products

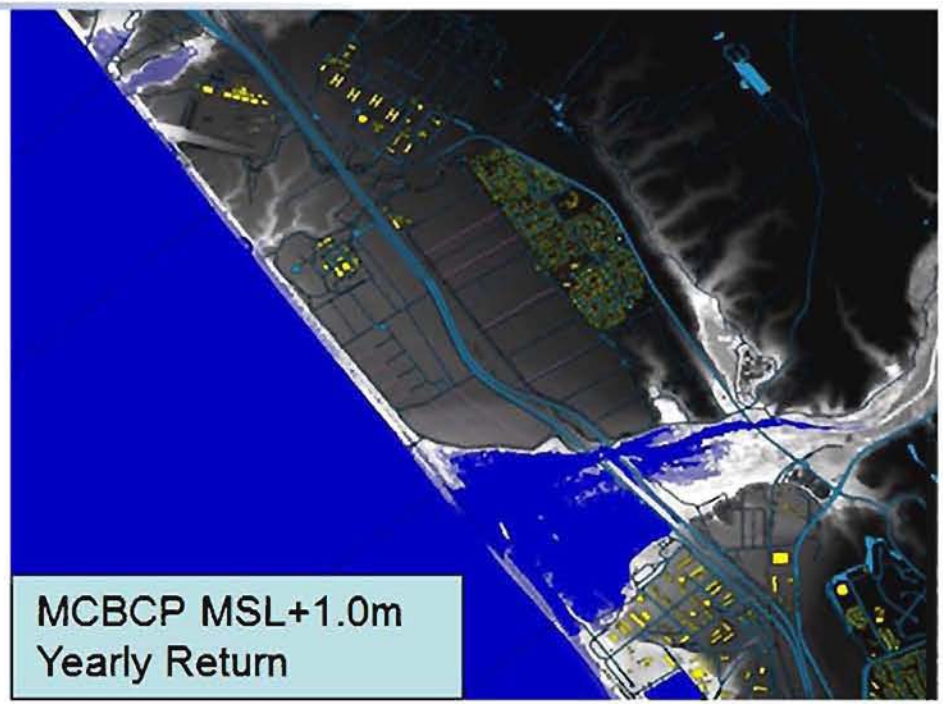


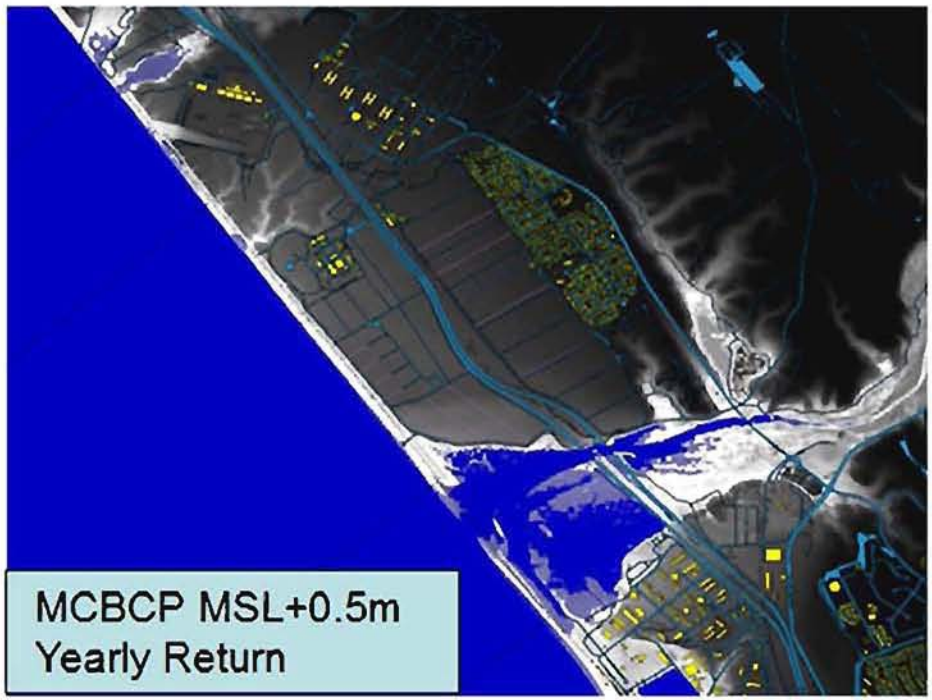
Long Term Scenario	Short Term Scenario	Receptor	Training and testing lands	Buildings	Civil infrastructure	Waterfront structures	Coastal structures	Protective Buffers
Mean SLR	Return Period	Metric	Days/Area	Cost	Cost	Days/Cost	Cost	Length
0.5 m	1 day	Estimated Risk						
	1 month							
	1 year							
	10 year							
	100 year							
1.0 m	1 day							
	1 month							
	1 year							
	10 year							
	100 year							
1.5 m	1 day							
	1 month							
	1 year							
	10 year							
	100 year							
2.0 m	1 day							
	1 month							
	1 year							
	10 year							
	100 year							

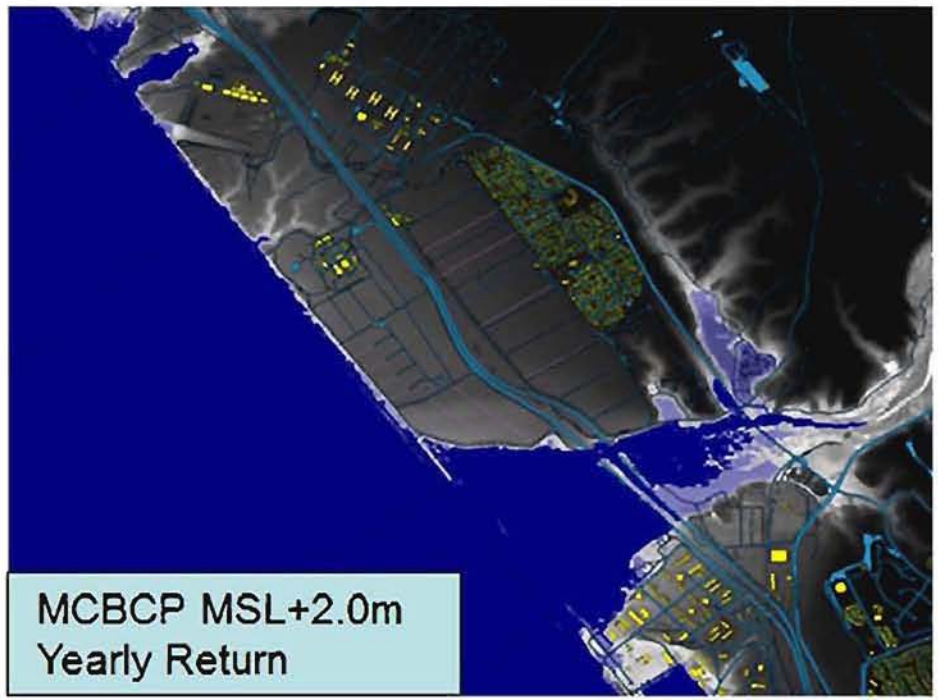
$$Risk_s = probability_s \sum vulnerabilities$$



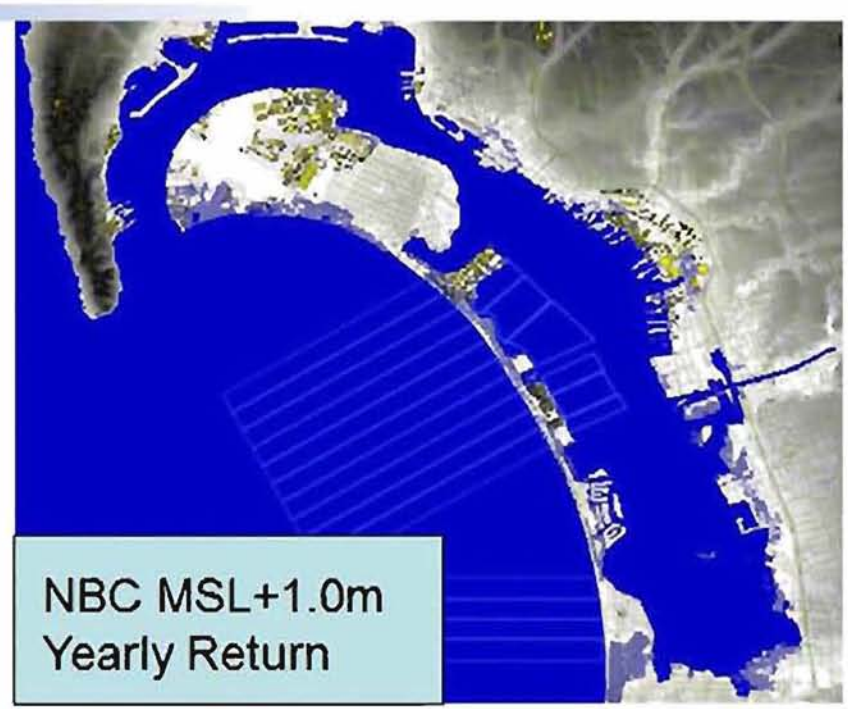

MCBCP Baseline
MHHW

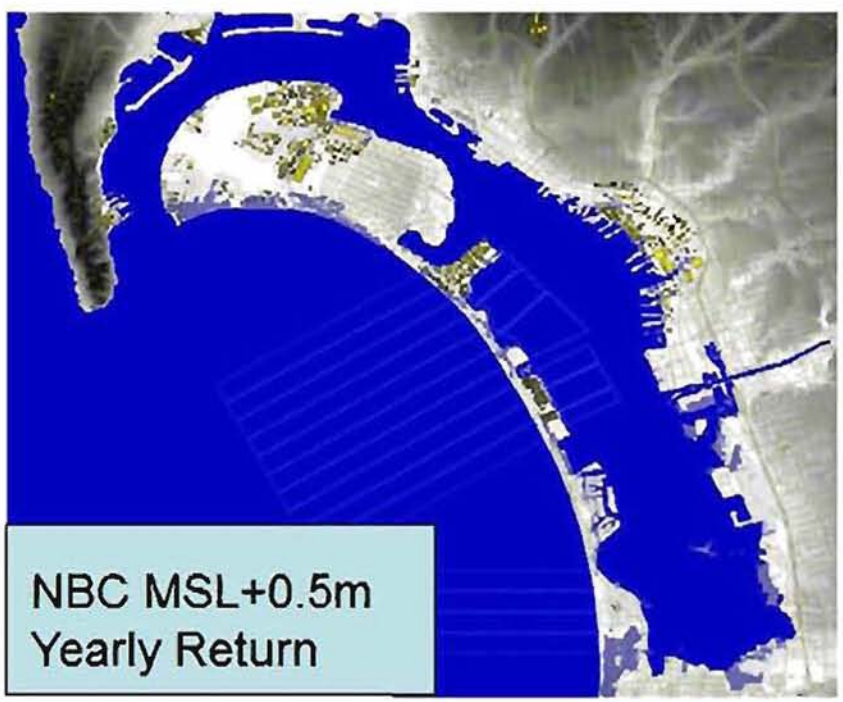

MCBCP MSL+1.0m
Yearly Return

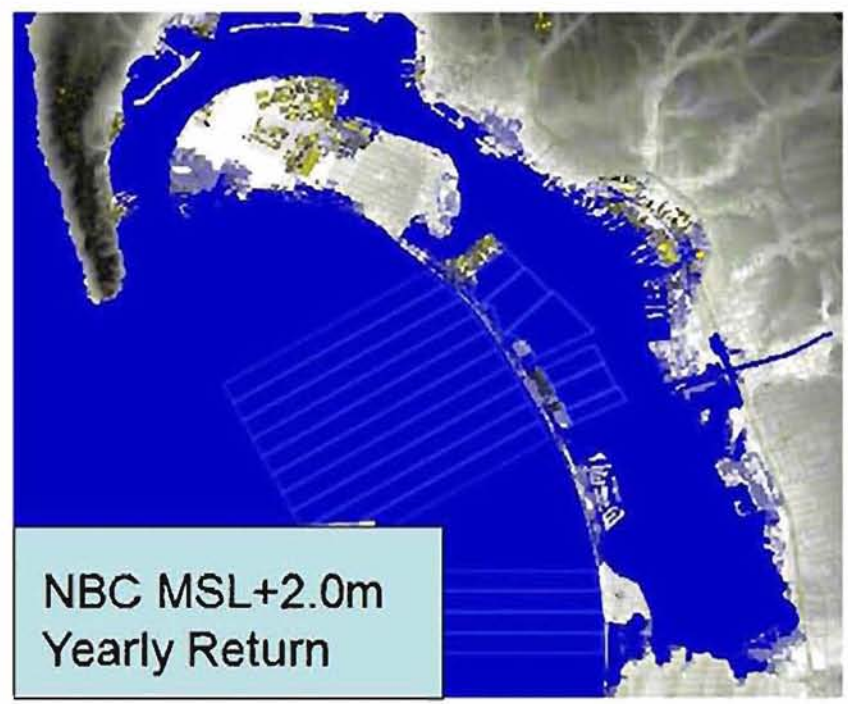

MCBCP MSL+0.5m
Yearly Return


MCBCP MSL+2.0m
Yearly Return

NBC Baseline
MHHW


NBC MSL+1.0m
Yearly Return


NBC MSL+0.5m
Yearly Return


NBC MSL+2.0m
Yearly Return

Assessment of Vulnerability

- Quantify the vulnerability based on stakeholder defined metrics
- Estimate scenario-specific risk based on the probability of occurrence combined with the associated vulnerability

Long Term Scenario	Short Term Scenario	Receptor	Traning and testing lands	Buildings	Civil infrastructure	Waterfront structures	Coastal structures	Protective Buffers
Mean SLR	Return Period	Metric	Days/Area	Cost	Cost	Days/Cost	Cost	Length
0.5 m	1 day	Estimated Risk						
	1 month							
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1.0 m	1 day							
	1 month							
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	10 year							
	100 year							
1.5 m	1 day							
	1 month							
	1 year							
	10 year							
	100 year							
2.0 m	1 day							
	1 month							
	1 year							
	10 year							
	100 year							

$$Risk_s = probability_s \sum vulnerabilities$$