USGS
science for a changing world

Projected Climate Impacts along the Central California Coast

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United States Geological Survey

Pacific Coastal and Marine Science Center

Santa Cruz, CA

CoSMoS Coastal Storm Modeling System USGS

Collaborators and funders:

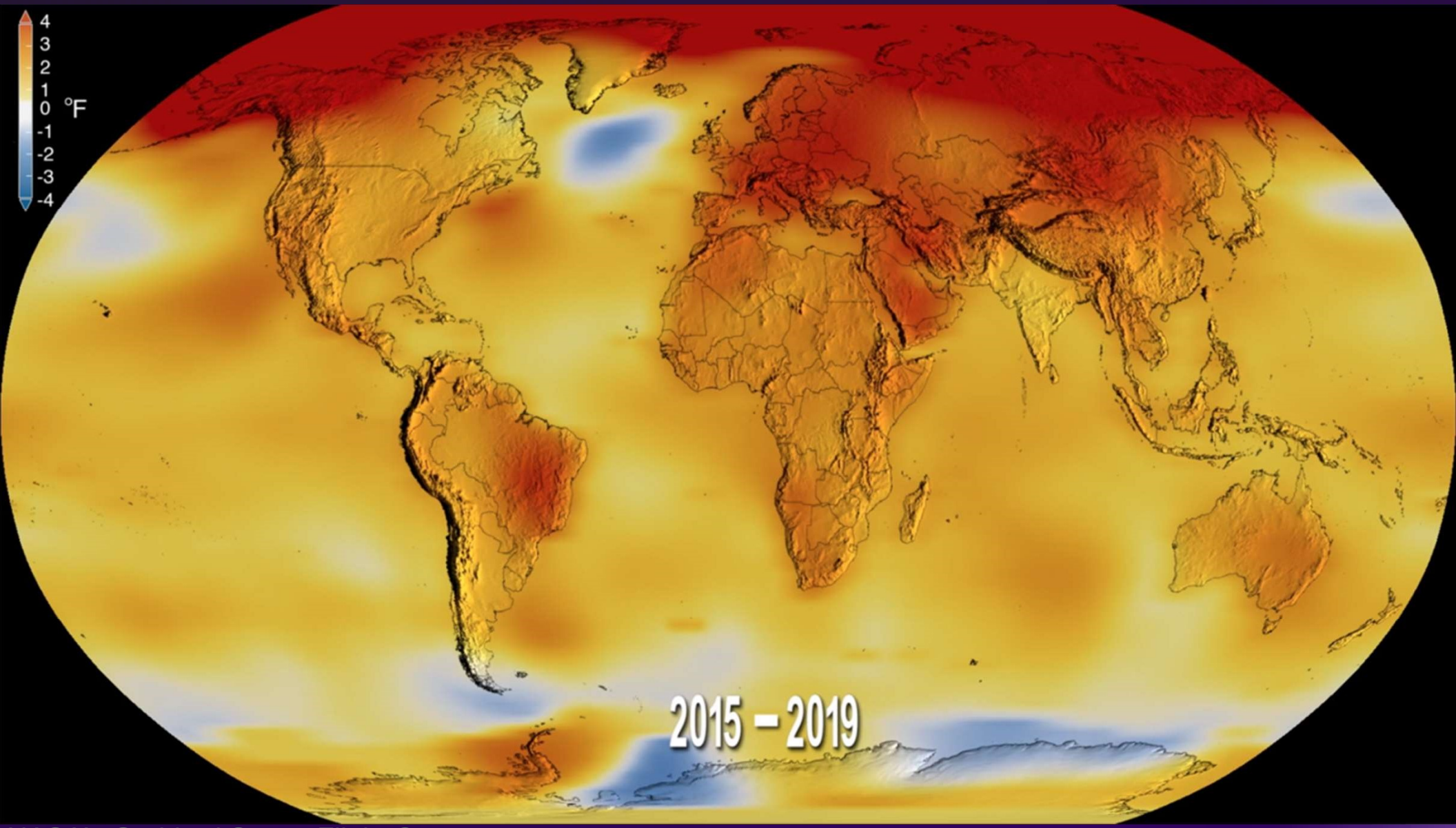
California's Fourth Climate Change Assessment

Point Blue

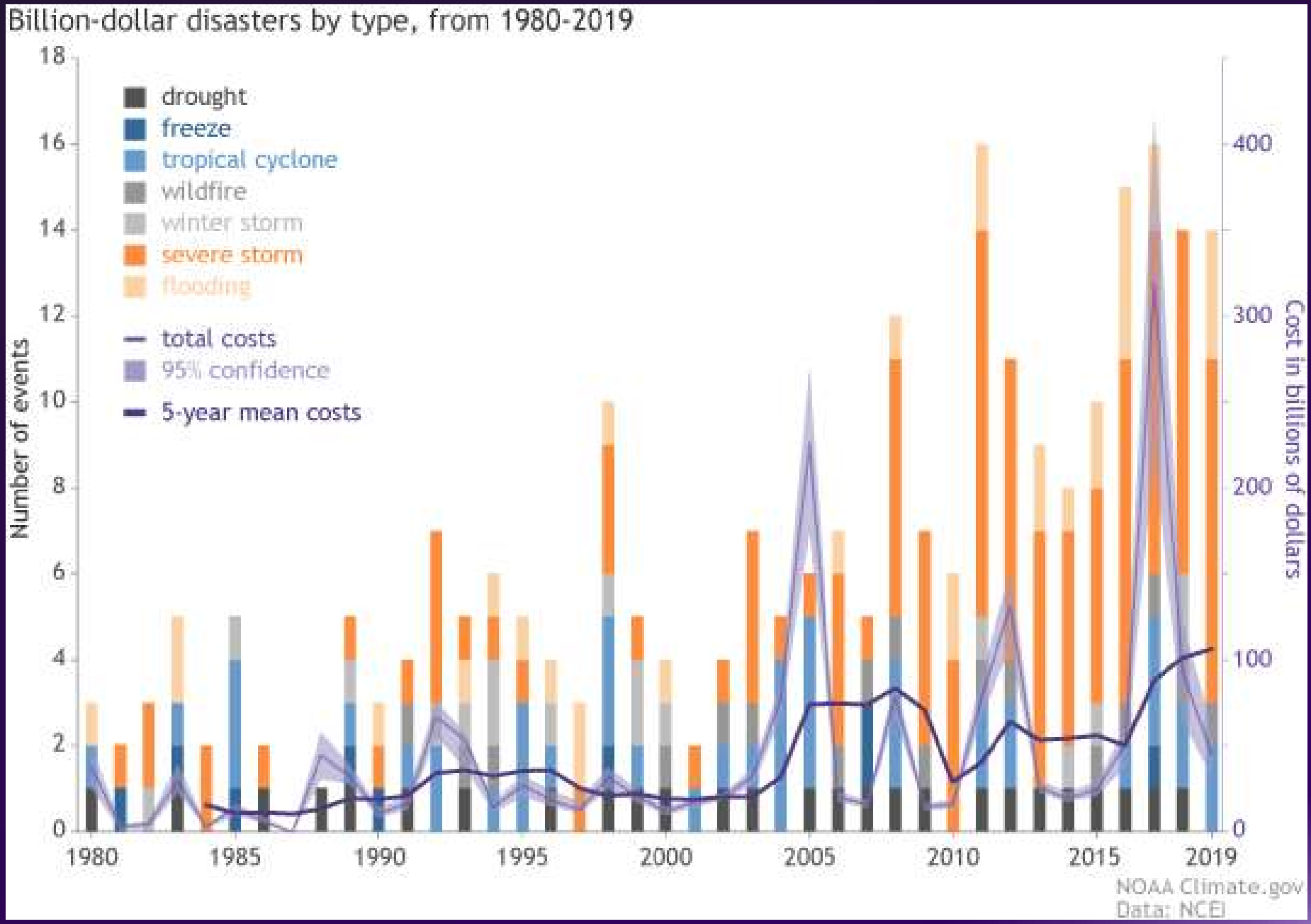
OSU Oregon State University

California natural resources agency

Scripps Institution of Oceanography UCSD



NASA's Goddard Space Flight Center


Billion-dollar disasters by type, from 1980-2019
drought
freeze
tropical cyclone
wildfire
winter storm
severe storm
flooding
total costs
95% confidence
5-year mean costs
Number of events
Cost in billions of dollars
0
2
4
6
8
10
12
14
16
18
0
100
200
300
400
1980
1985
1990
1995
2000
2005
2010
2015
2019
NOAA Climate.gov
Data: NCEI

THE COLORADO SUN

Despite recent snowstorms, Colorado's drought conditions continue in "anomalous" direction

There were only seven other weeks in the past 20 years that have been as intensely dry as the state's current status

Scenes of Castle Rock, CO, October 30, 2020. (Kevin Mohatt, Special to The Colorado Sun)

(AP Photo/Matt Hartman)

ENVIRONMENT

California's Ancient Redwoods Face New Challenge From Wildfires And Warming Climate

npr

December 8, 2020 · 5:01 AM ET

Another day of record-breaking heat in Phoenix as heatwave persists

FOX10 PHOENIX

By FOX 10 Staff | **Published** August 15 | **Updated** August 19 | Weather | Associated Press

Aug. 19, 2020. *AP*

So how does this affect our coast….

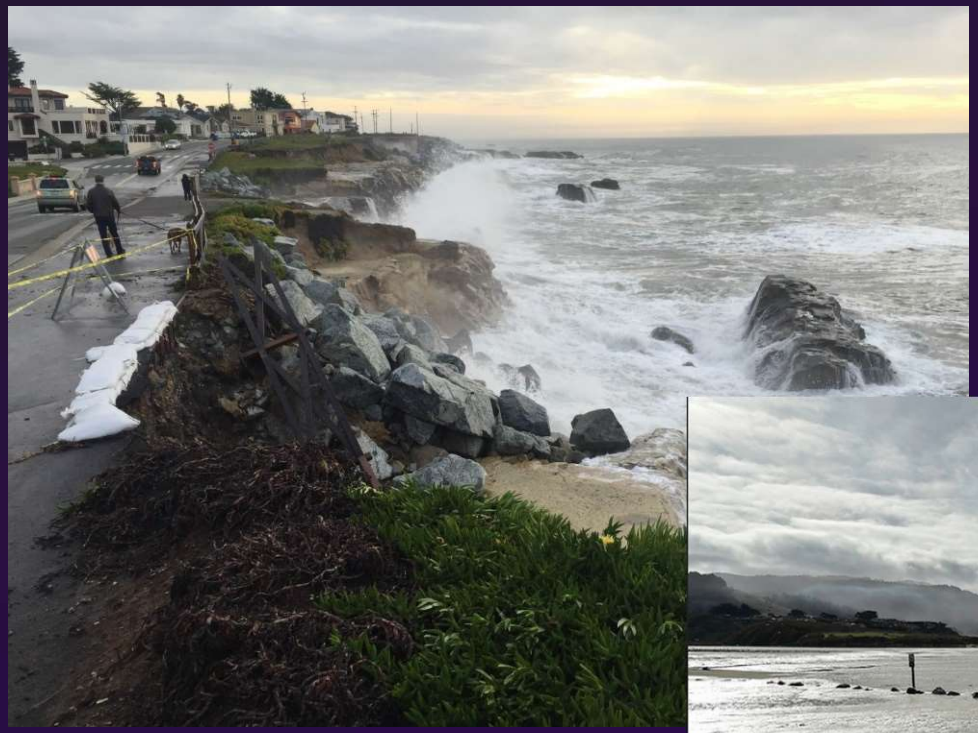
- Warming temperatures reduce ice sheets and glaciers
  → increase ocean volume
  → affect vertical motion of land
- Shifts in atmospheric circulation
  → change storm tracks, winds, and waves
- Increasing ocean temperature and changes in global wind patterns
  → affect changes in sea surface

Photograph Collection, Boulder, Colorado USA: National Snow and Ice Data Center/World Data Center for Glaciology. **Large images:** 1917 | 2005

(Pic: XL Catlin Seaview Survey)

→ many global changes contribute to how sea level affects us locally

So how does this affect our coast….



So how big is the problem?

- **Over 1 billion people are expected to live in the coastal zone by the middle of the 21st century**
- **27 million presently live in CA coastal counties**
- **Over 600,000 people in CA at risk of flooding by the end of the century, in addition to over ~$150 billion in property, ~6% of CA GDP**
- **Initial estimates of 30,000 residents and $5.5 billion in property at risk in Santa Cruz and Monterey Counties by 2100**

USGS

21st Century projections in California

State SLR Guidance for 2100

-Likely range of 30-110 cm
-3.05 m upper bound

Waves

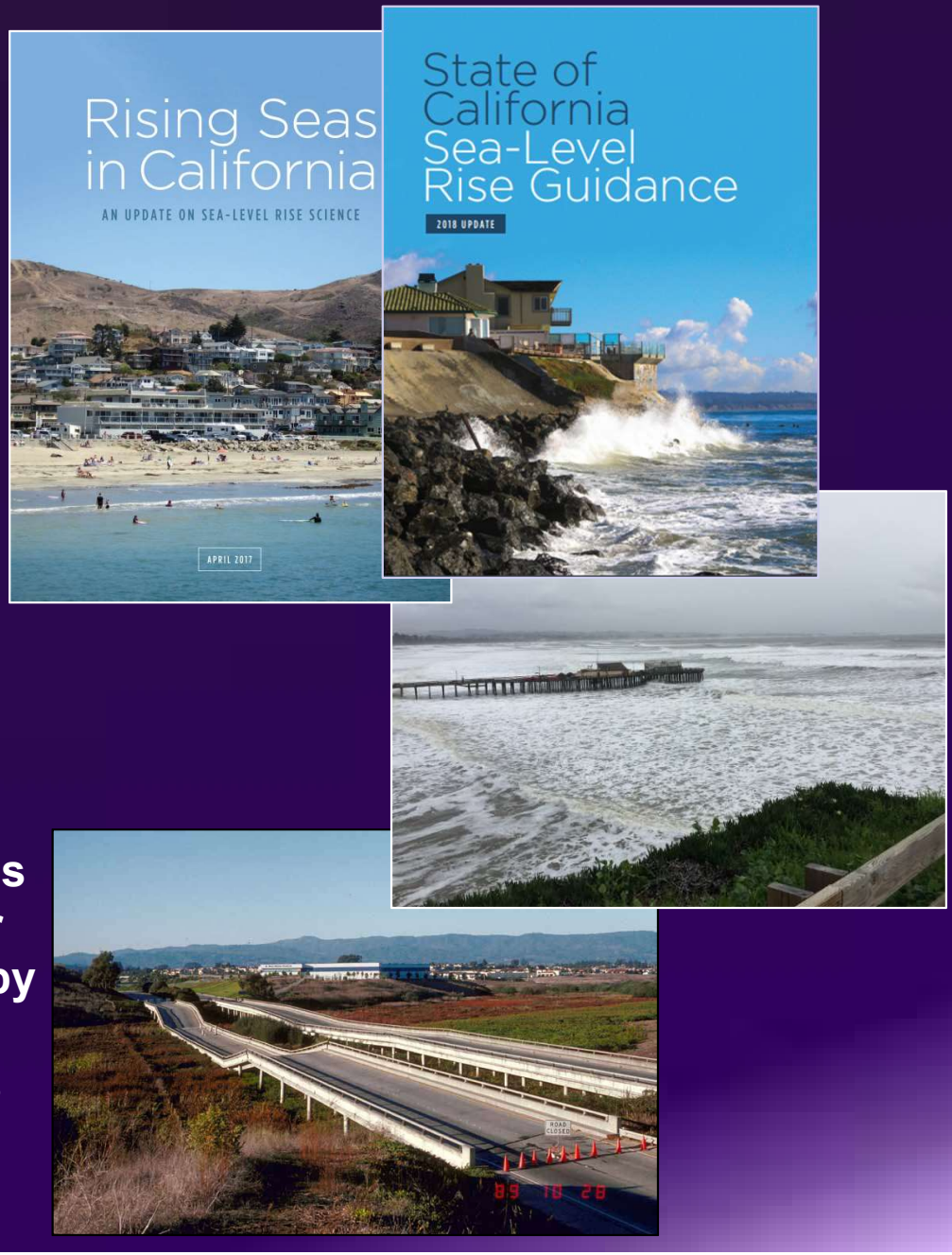
-No significant changes in wave height
-More southerly wave directions

El Niño

-More frequent extreme events
-Doubling of winter erosion
-Wave energy increase by 30%

Net effect

-Today's 100-year coastal water level event is projected to occur every 1-5 years by 2050 for much of California AND every daily high tide by 2100
-Greatest impacts on low-lying coastal areas



USGS

Coastal Vulnerability Approaches

Static

- Passive model, hydrological connectivity
- Tides only
- '1st order screening tool'

"Bathtub" models under predict flooding hazards

USGS

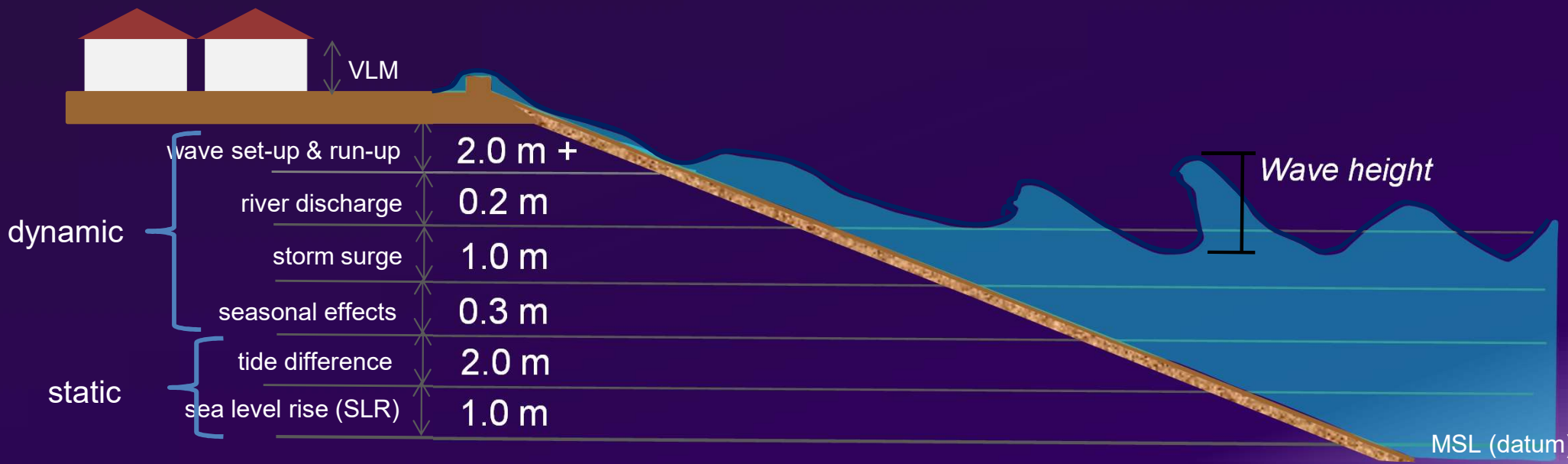
Coastal Vulnerability Approaches

Static

- Passive model, hydrological connectivity
- Tides only
- '1st order screening tool'

Dynamic: USGS-CoSMoS

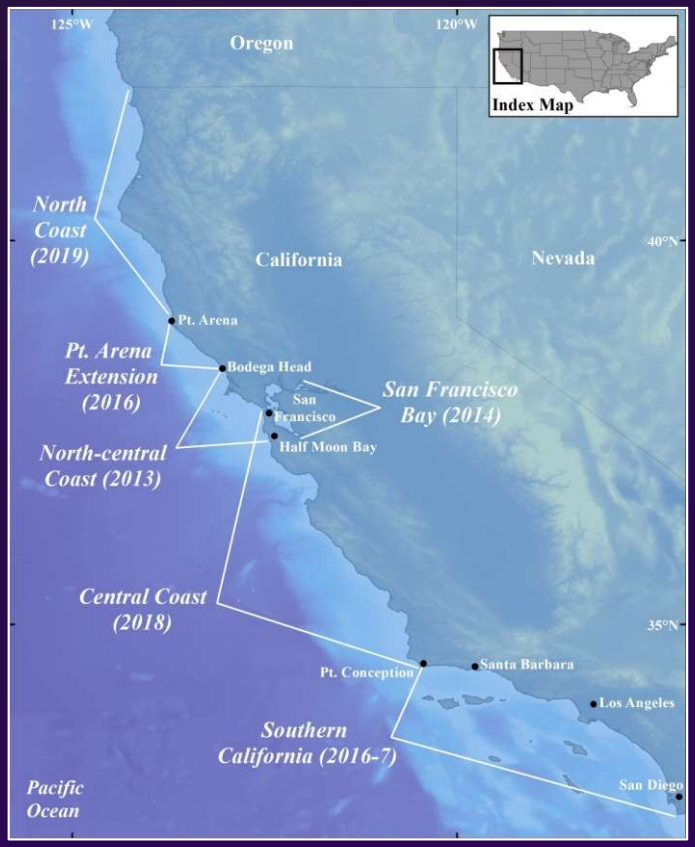
- All physics modeled
- Forced by Global Climate Models
- Includes wind, waves, atmospheric pressure, shoreline change
- Range of SLR and storm scenarios



USGS

Coastal Storm Modeling System (CoSMoS)

- **Physics-based numerical modeling system for assessing coastal hazards due to climate change**
- **Predicts coastal hazards for the full range of sea level rise (0-2, 5 m) and storm possibilities (up to 100 yr storm) using sophisticated global climate and ocean modeling tools**
- **Developing coastal vulnerability tools in collaboration with federal, state, and city governments to meet their planning and adaptation needs**

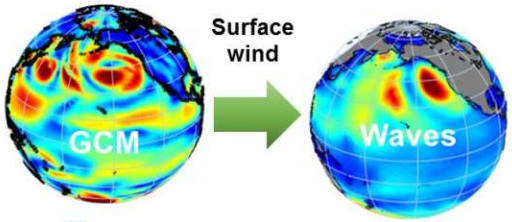


USGS

CoSMoS Framework

Global Scale

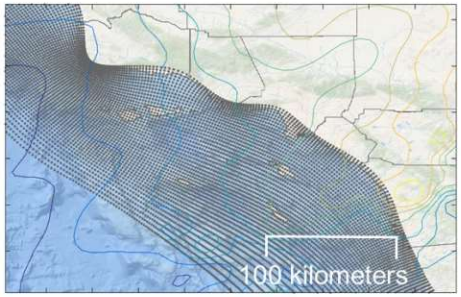
Deep water wave generation and propagation using climate change influenced future winds.



Downscaled winds and atmospheric pressures

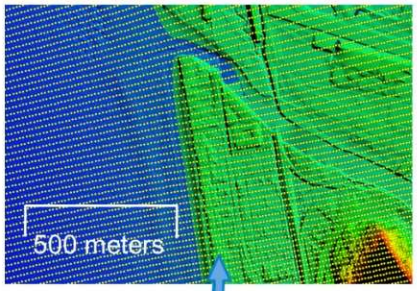
Regional Scale

Swell propagation, wave generation, storm surge, and astronomic tides.



Local Scale

High-resolution hydrodynamics: nearshore waves, wave setup and runup, storm surge, tides, overland flow, fluvial discharge.



Long-term cliff recession and shoreline change

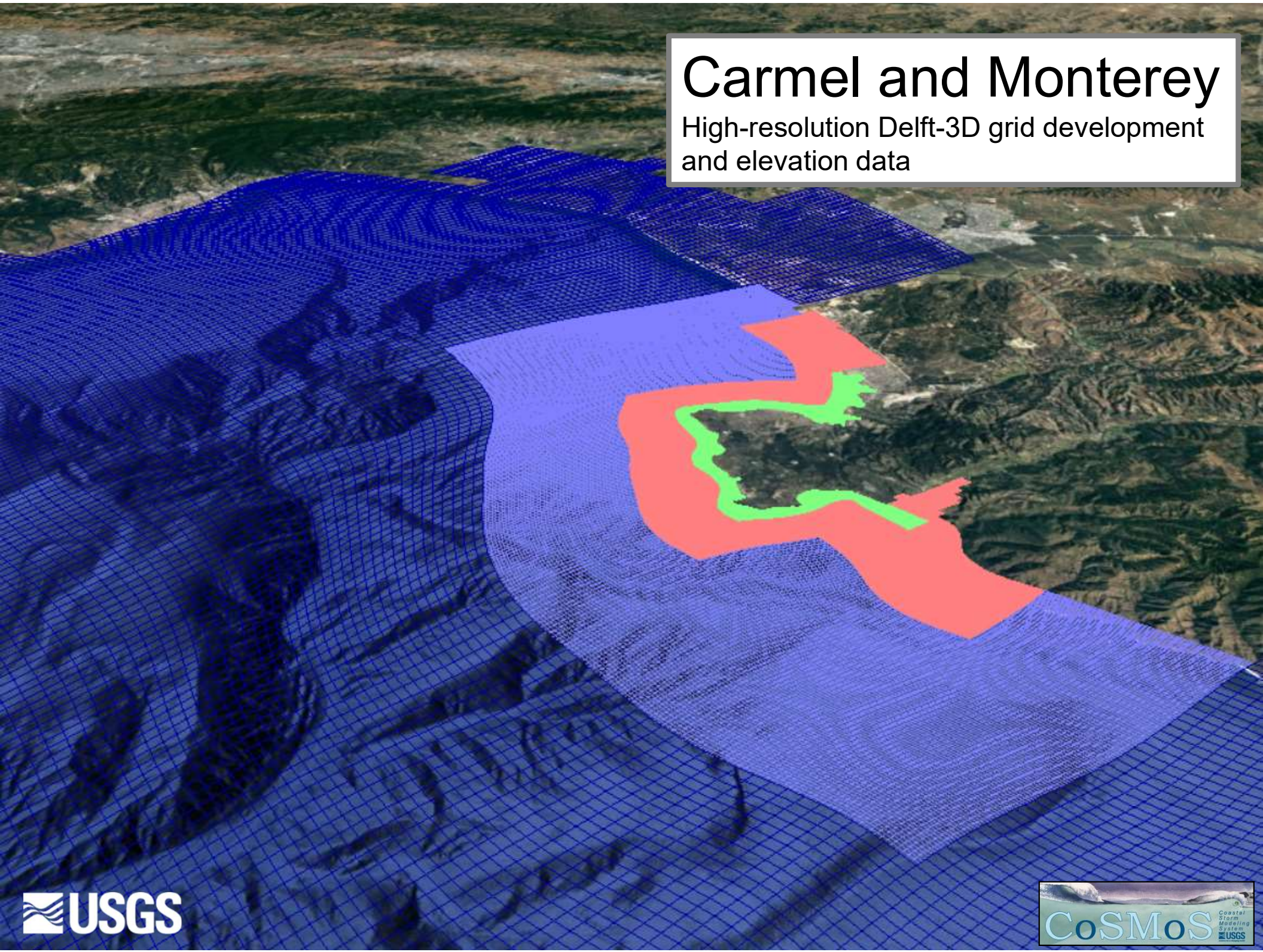
Web-based tools for data visualization and analysis

Flood maps

Socioeconomic impacts

USGS

CoSMoS Coastal Storm Modeling System


Carmel and Monterey
High-resolution Delft-3D grid development
and elevation data
USGS
CoSMoS
Coastal Storm Modeling System
USGS

Back-ground

1-year storm

SLR =
0 to 2 m at 0.25 m
increments, and 5 m

100-year storm

20-year storm

= 40 scenarios

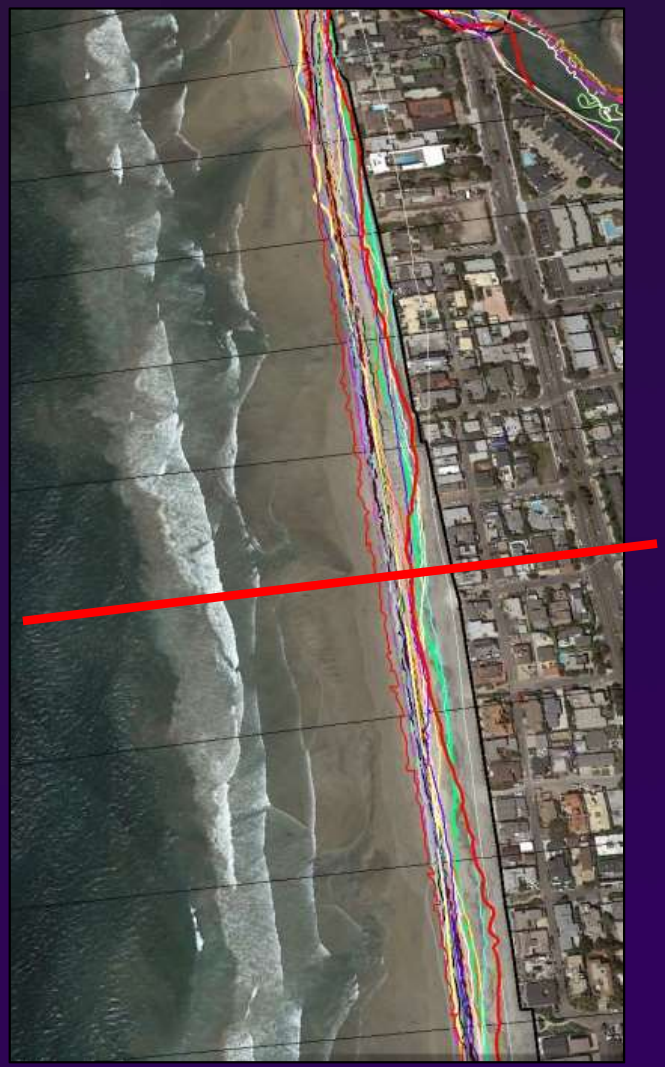
USGS

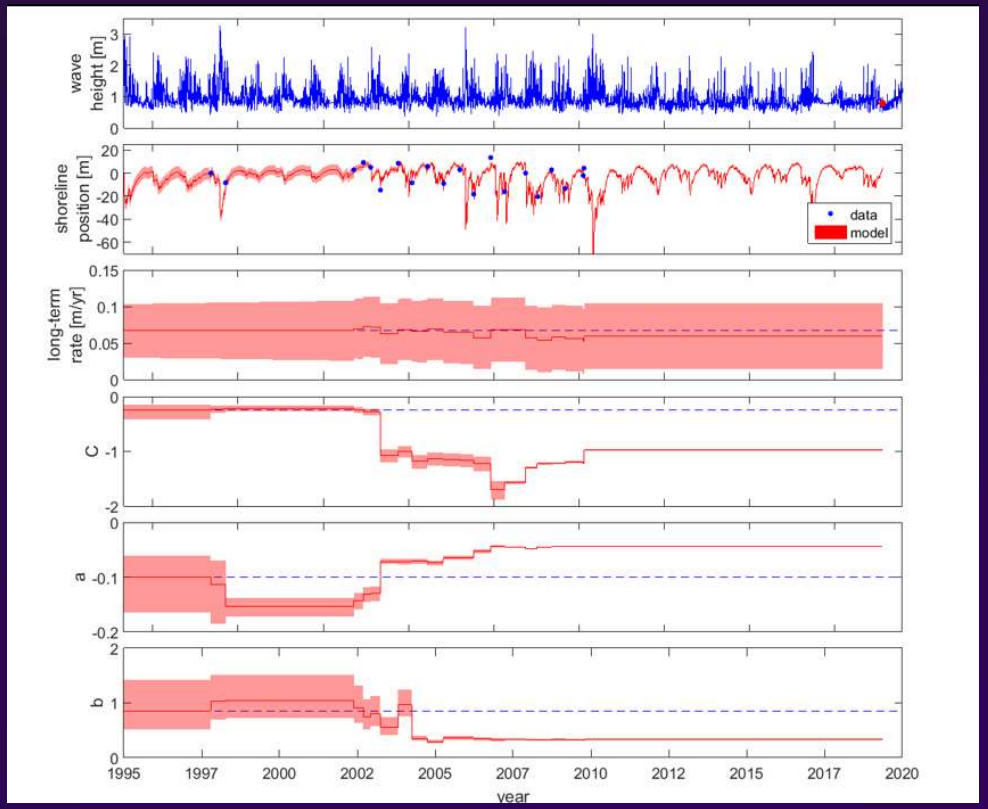
CoSMoS Coastal Storm Modeling System USGS

Shoreline change: CoSMoS-COAST

- A (hybrid) numerical model to simulate long-term shoreline evolution
- Modeled processes include:
  - Longshore and Cross-shore transport
  - Effects of sea-level rise
  - Sediment supply by natural & anthropogenic sources

CoSMoS-COAST:
Coastal
One-line
Assimilated
Simulation
Tool





Vitousek, S., Barnard, P.L., Limber, P., Erikson, L.H. and Cole, B., 2017. A model integrating longshore and cross-shore processes for predicting long-term shoreline response to climate change. *Journal of Geophysical Research-Earth Surface*, http://dx.doi.org/10.1002/2016JF004065

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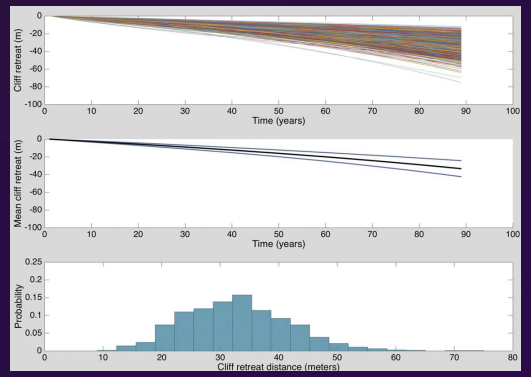
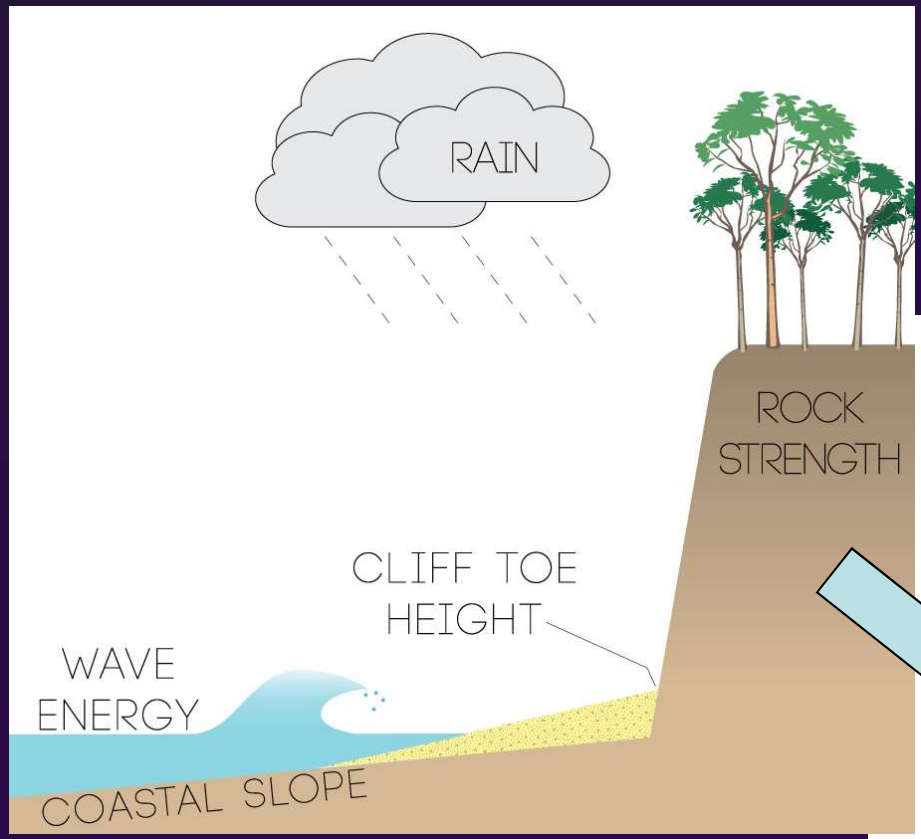
CoSMoS Coastal Storm Modeling System USGS

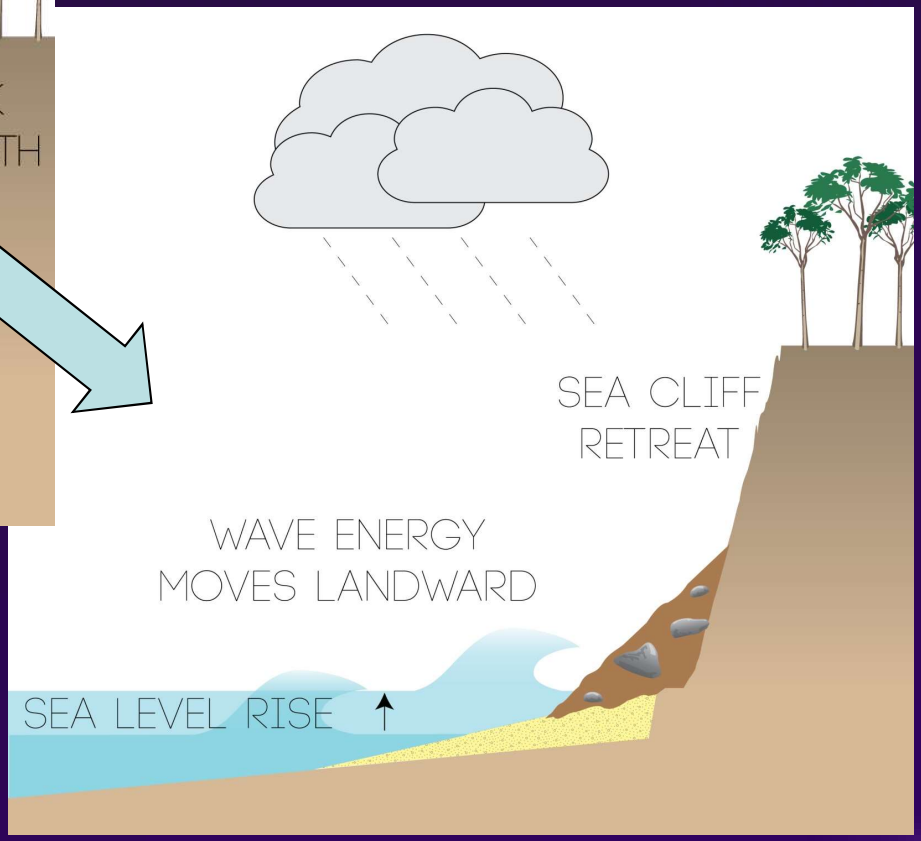
Cliff retreat



Ensemble of 5 different models to relate

- **Wave impacts**
- **SLR**
- **Historical cliff behavior**



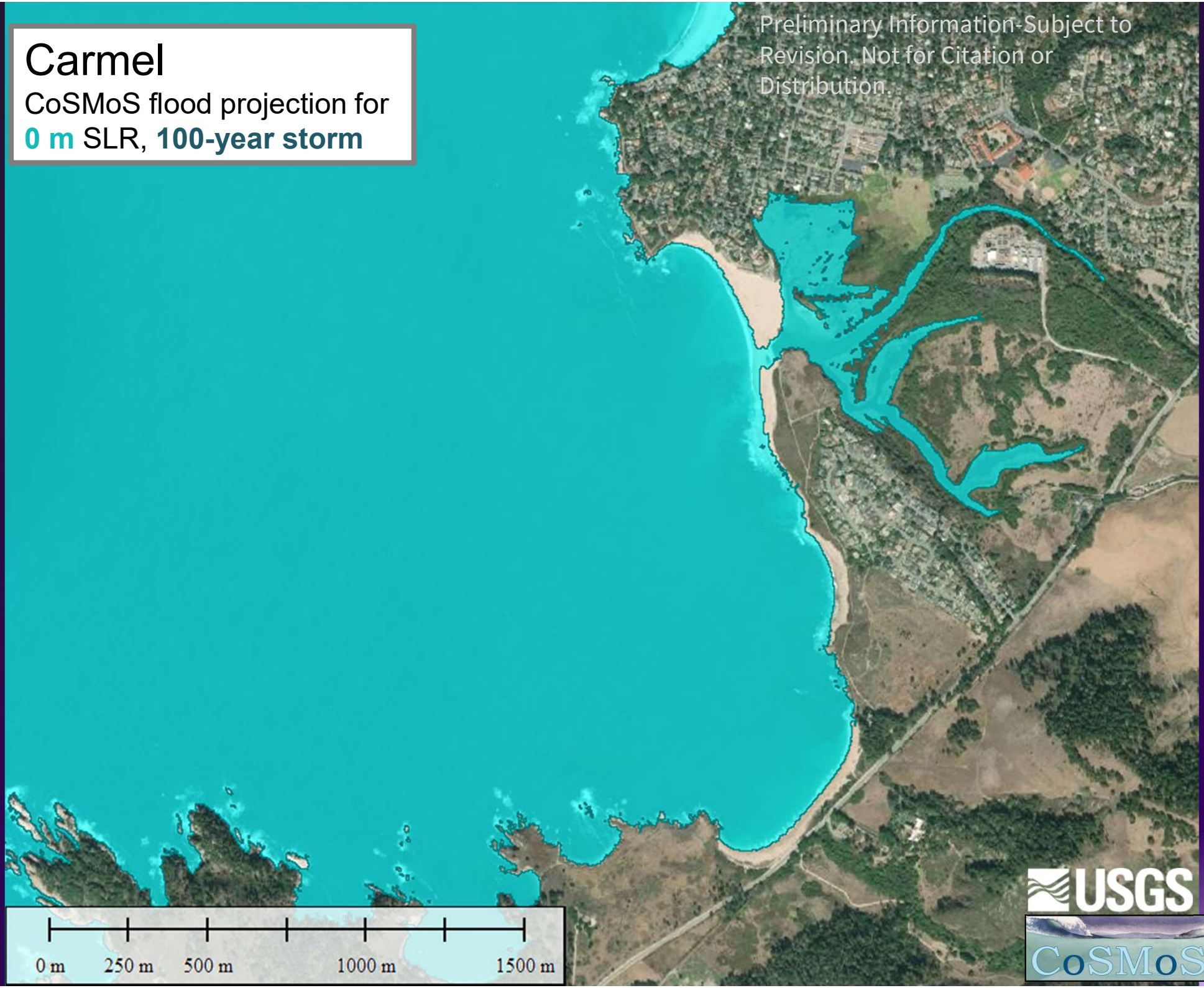


Limber, P. W., Barnard, P. L., Vitousek, S., & Erikson, L. H. (2018). A model ensemble for projecting multidecadal coastal cliff retreat during the 21st century. *Journal of Geophysical Research: Earth Surface*, 123, 1566– 1589. https://doi.org/10.1029/2017JF004401

Carmel

CoSMoS flood projection for
0 m SLR, **100-year storm**

Preliminary Information-Subject to Revision. Not for Citation or Distribution.



USGS

CoSMoS Coastal Storm Modeling System

Carmel

CoSMoS flood projection for
1.0 m SLR, **no storm**

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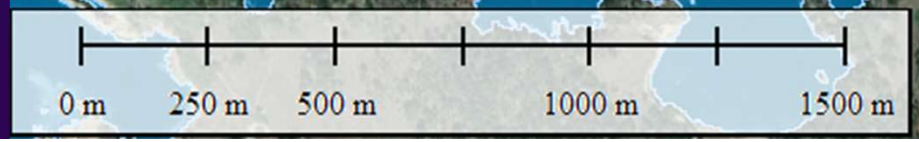

USGS

CoSMoS Coastal Storm Modeling System

Carmel

CoSMoS flood projection for **1.0 m** SLR, **100-year storm**

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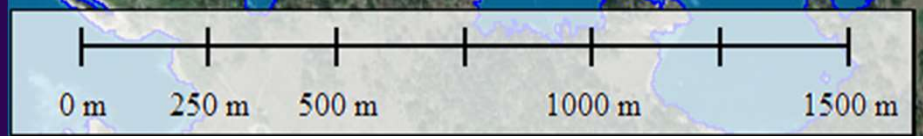

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CoSMoS Coastal Storm Modeling System

Carmel

CoSMoS flood projection for **2.0 m** SLR, **no storm**

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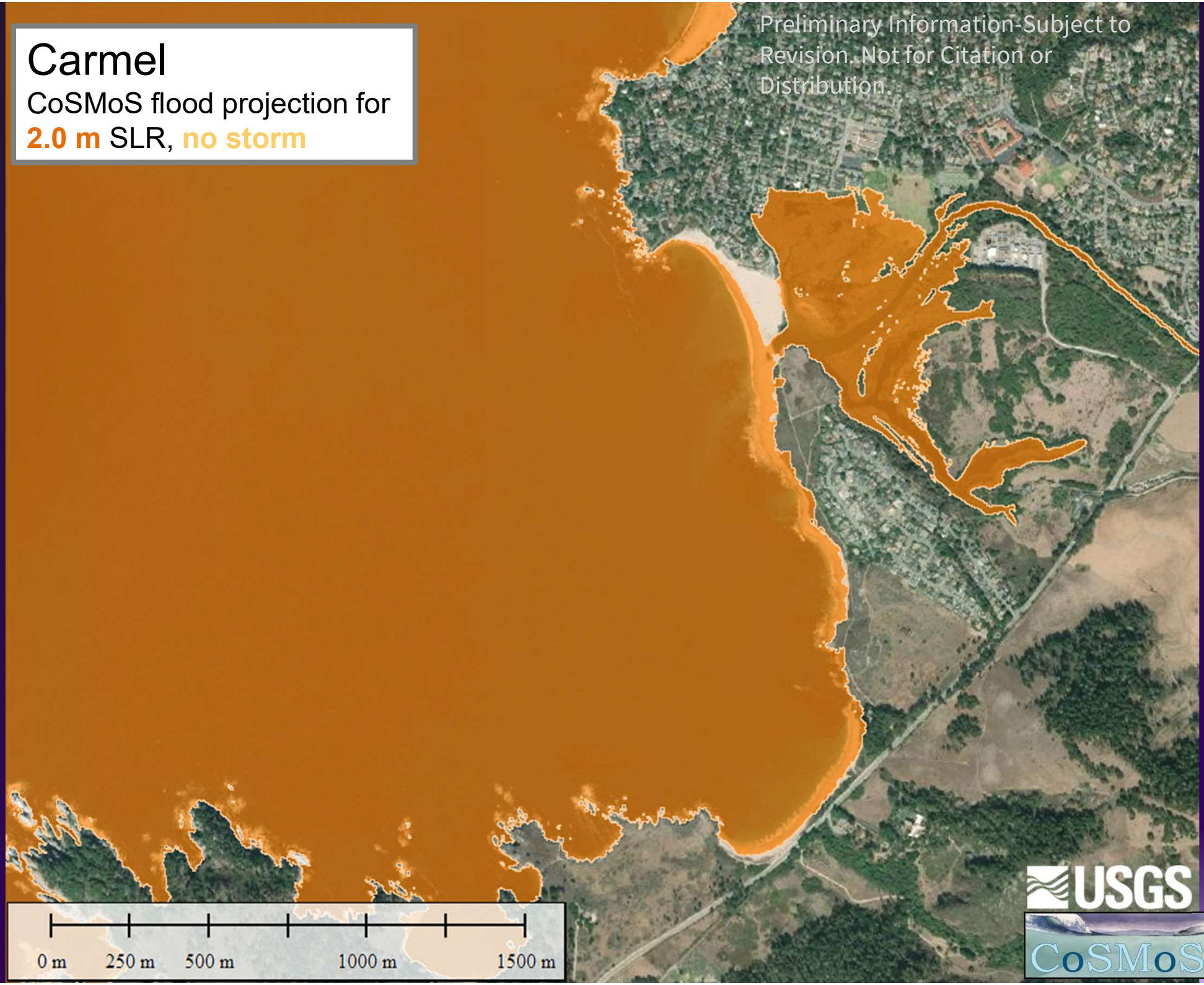

Carmel

CoSMoS flood projection for
2.0 m SLR, **100-year storm**

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

CoSMoS Coastal Storm Modeling System

Carmel

CoSMoS flood projection for
0 m SLR, **100-year storm**

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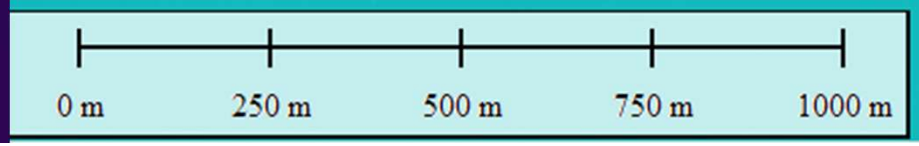

USGS

CoSMoS Coastal Storm Modeling System USGS

Carmel

CoSMoS flood projection for
1.0 m SLR, **no storm**

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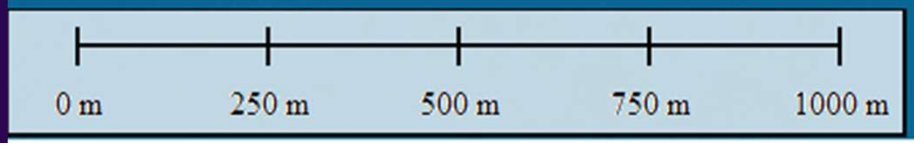

USGS

CoSMoS Coastal Storm Modeling System USGS

Carmel

CoSMoS flood projection for **1.0 m** SLR, **100-year storm**

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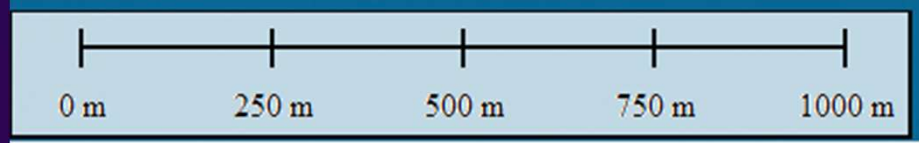

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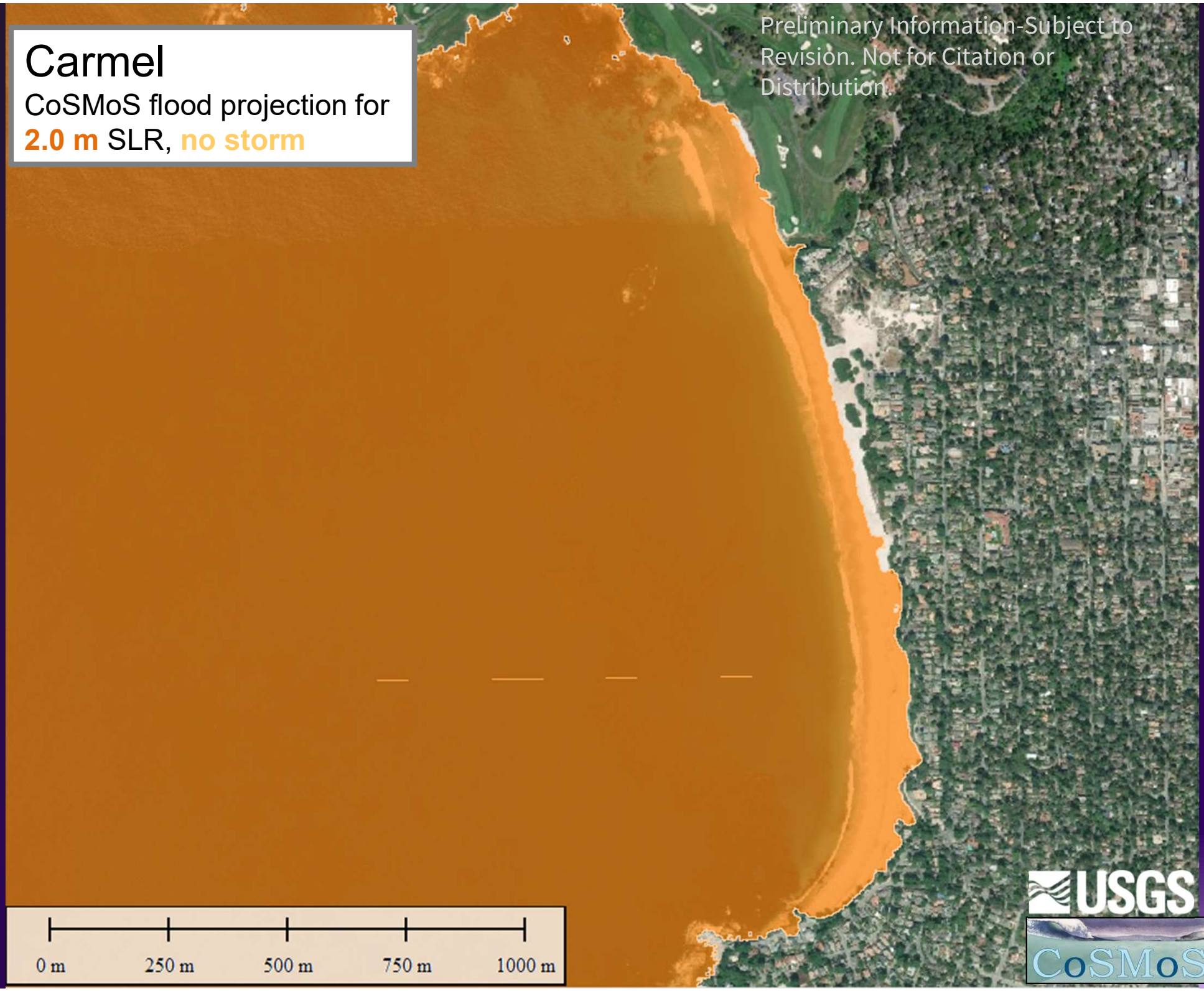
CoSMoS Coastal Storm Modeling System


Carmel
CoSMoS flood projection for
2.0 m SLR, no storm
Preliminary Information-Subject to Revision. Not for Citation or Distribution.
0 m
250 m
500 m
750 m
1000 m
USGS
CoSMoS

Carmel

CoSMoS flood projection for
2.0 m SLR, **100-year storm**

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

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CoSMoS Coastal Storm Modeling System USGS

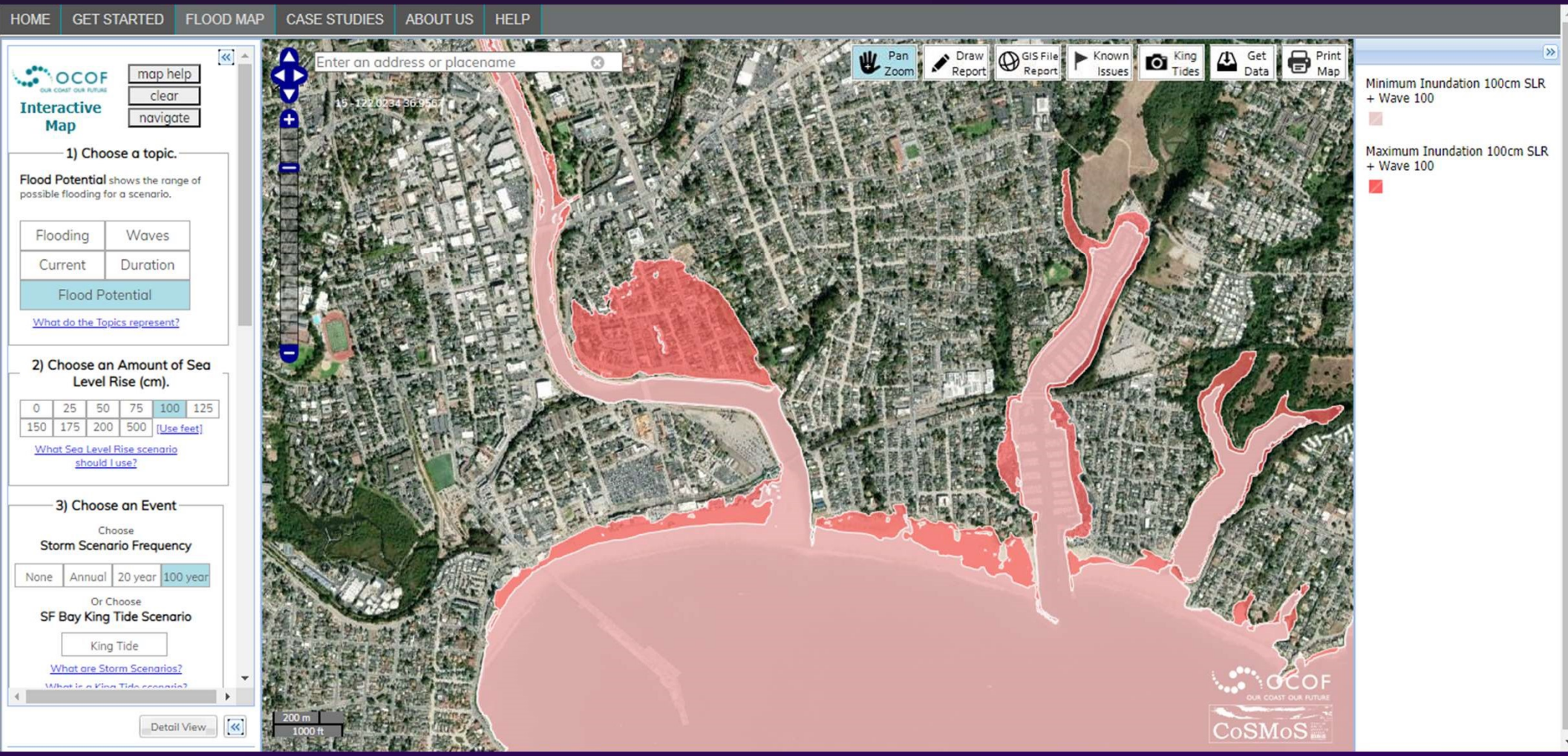
Web tool - Flooding

Our Coast, Our Future tool: *www.ourcoastourfuture.org*

USGS

CoSMoS Coastal Storm Modeling System USGS

Web tool – Flood potential

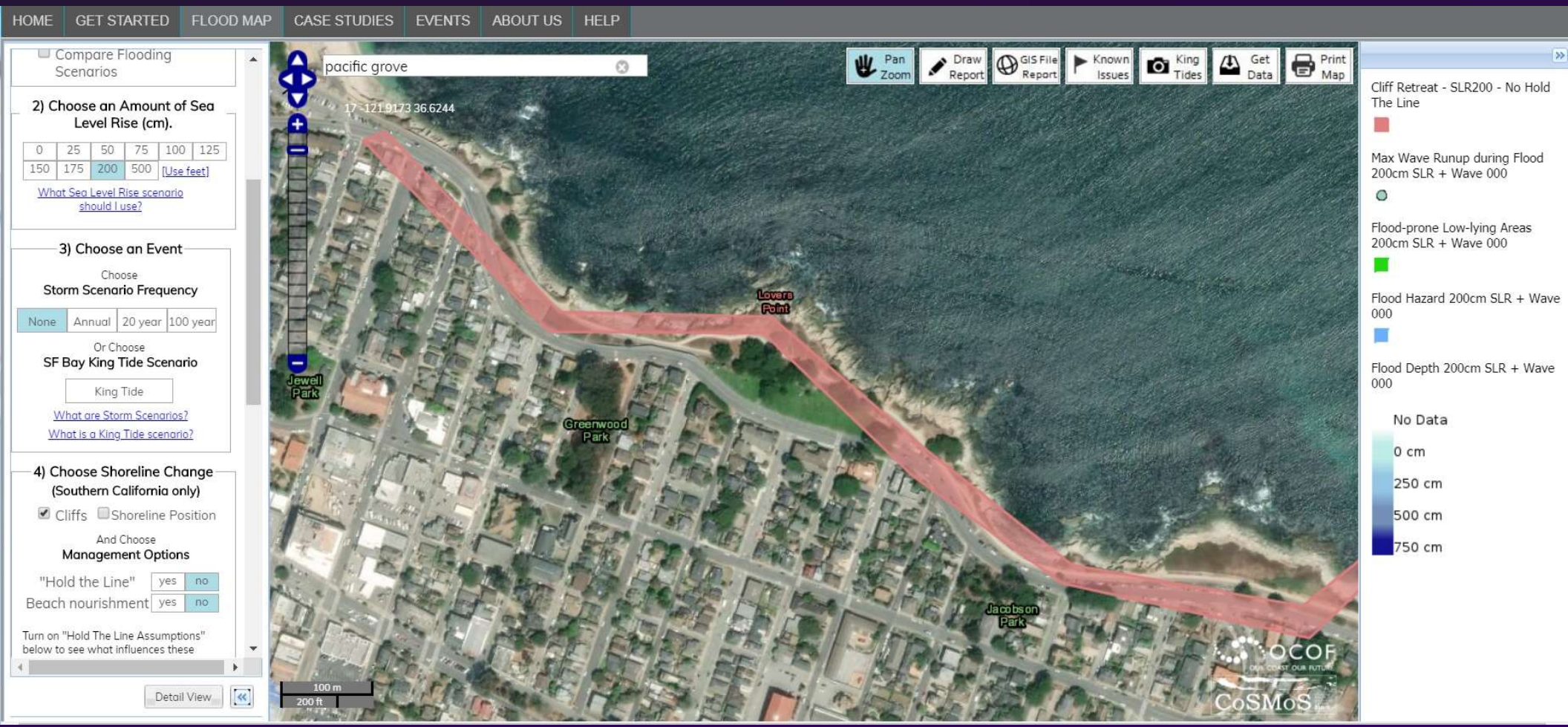


Our Coast, Our Future tool: *www.ourcoastourfuture.org*

USGS

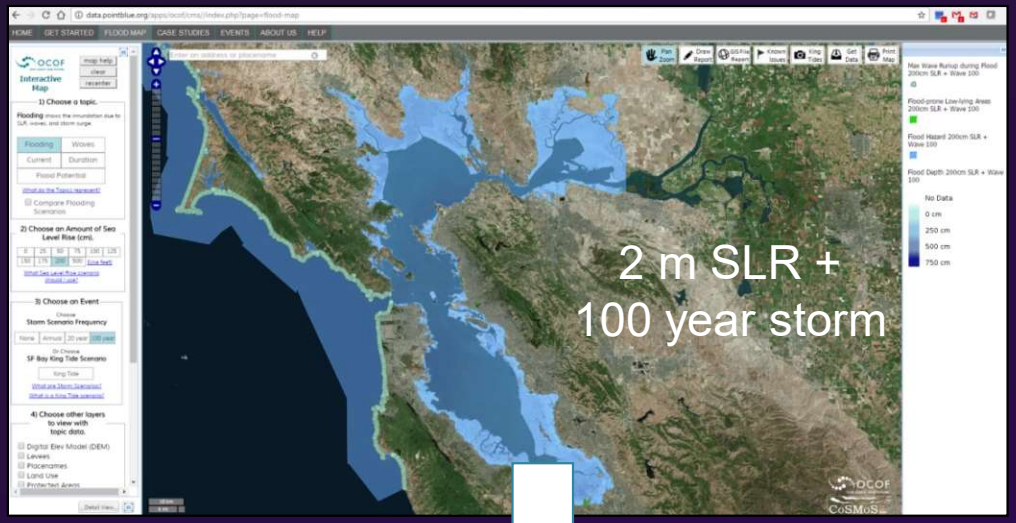
CoSMoS Coastal Storm Modeling System

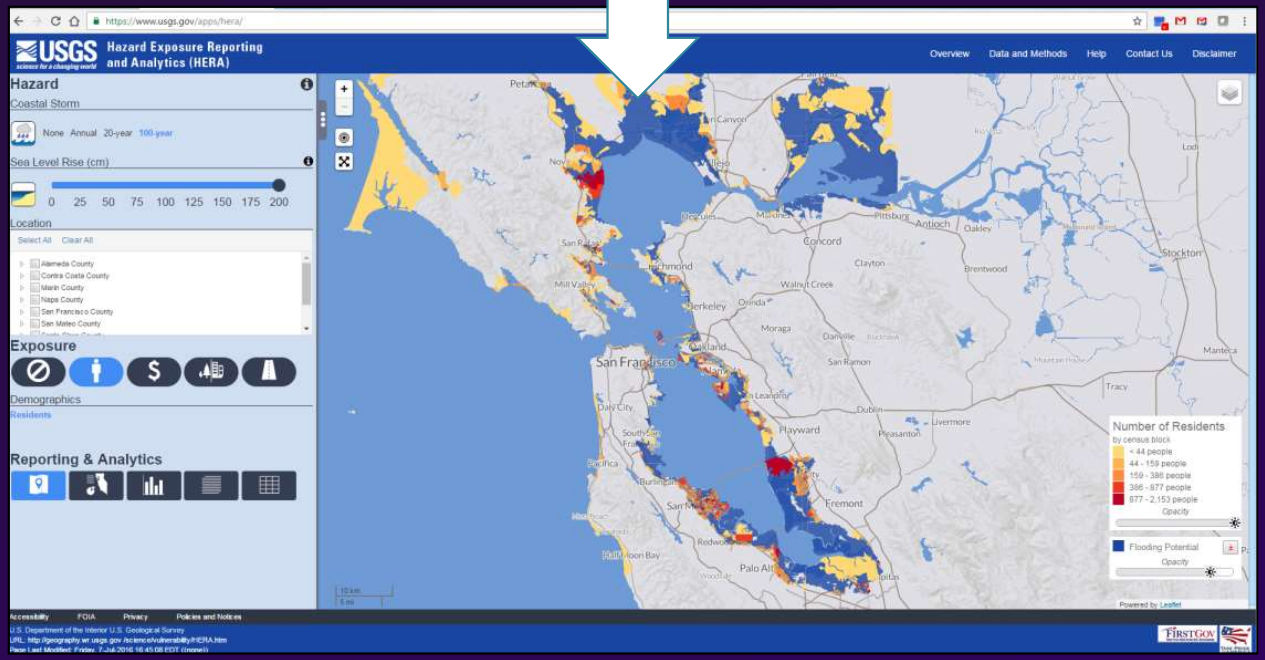
Cliff retreat + Shoreline Position



- **Cliff: 2 coastal management scenarios**
  - **No erosion beyond existing structures ('hold the line'), or not**
- **Shoreline: 4 coastal management scenarios**
  - **No erosion beyond urban infrastructure ('hold the line'), or not**
  - **Incorporate historical rates of change in future projections (e.g. nourishment), or not**

Coastal Climate Impacts by 2100





California

- **600,000+ residents**
- **$150 billion in property**
- **4,700 km of roads**
- **350 critical facilities (e.g., schools, police stations, hospitals)**

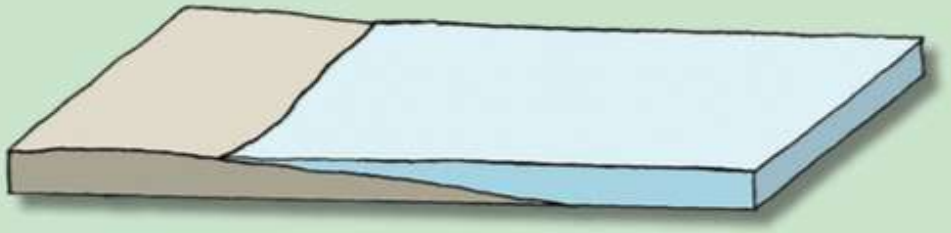
USGS

Hazards Exposure Reporting and Analytics (HERA)
www.usgs.gov/apps/hera

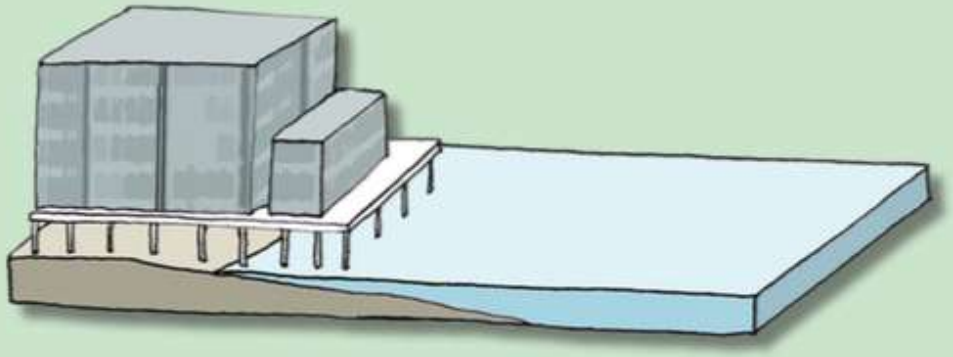
CoSMoS Coastal Storm Modeling System

Common SLR mitigation strategies:

Retreat!

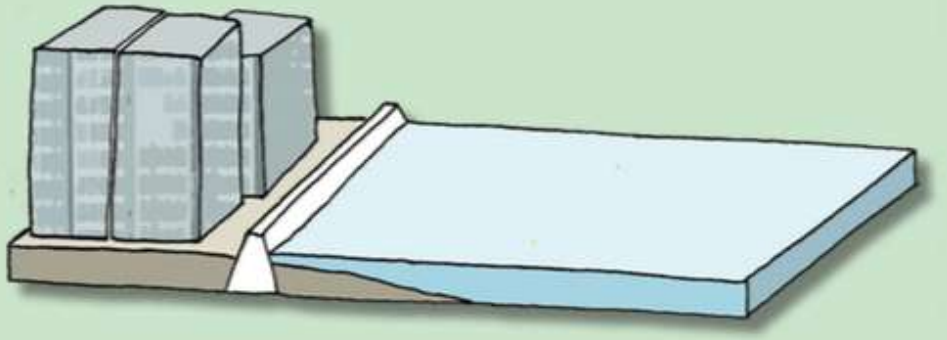


Elevate

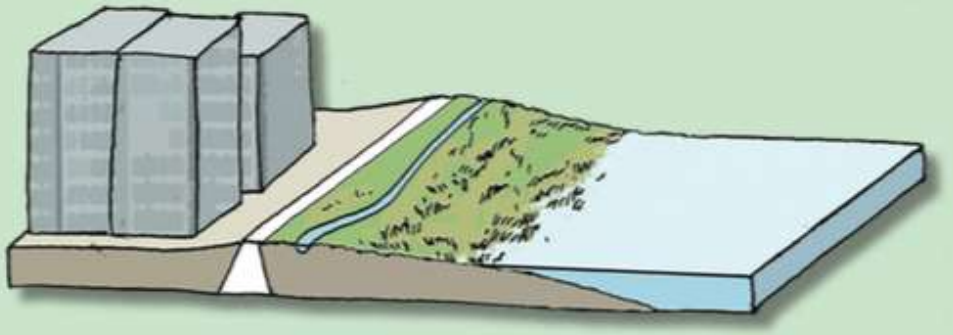


What about groundwater?

Block

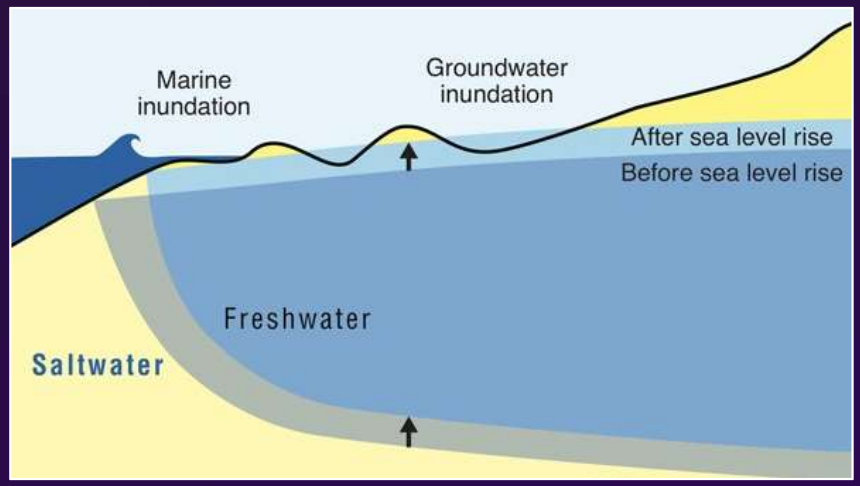


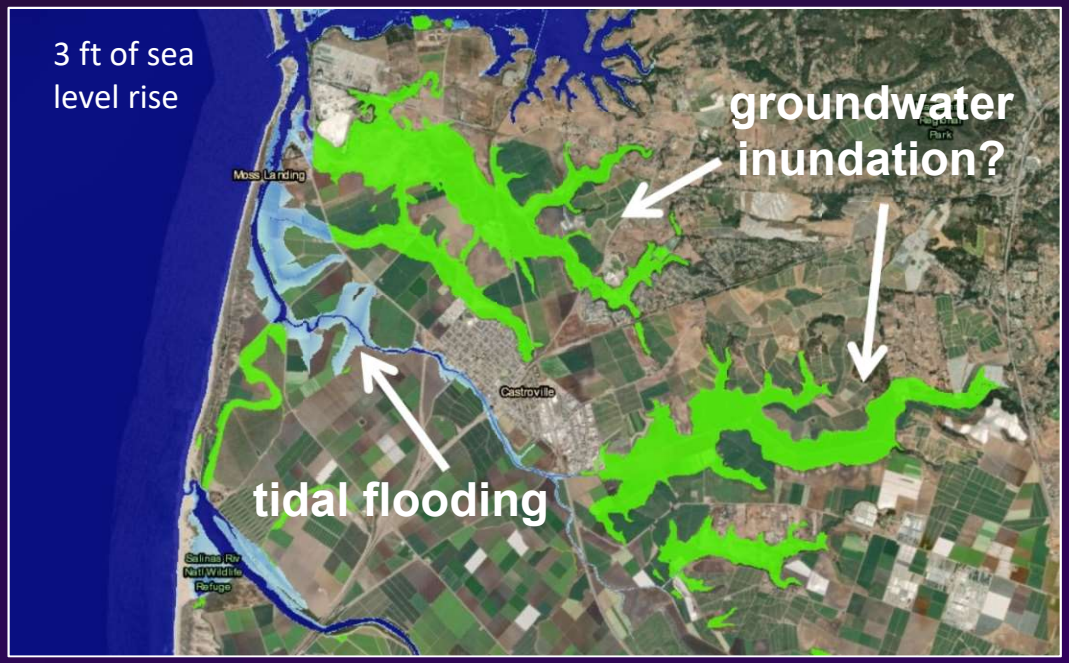
Restore+



Coastal Groundwater response to SLR

- **Major issues**
  - **Emergence/Inundation**
  - **Shallower coastal groundwater**
  - **Saltwater intrusion, major hazard for agriculture**



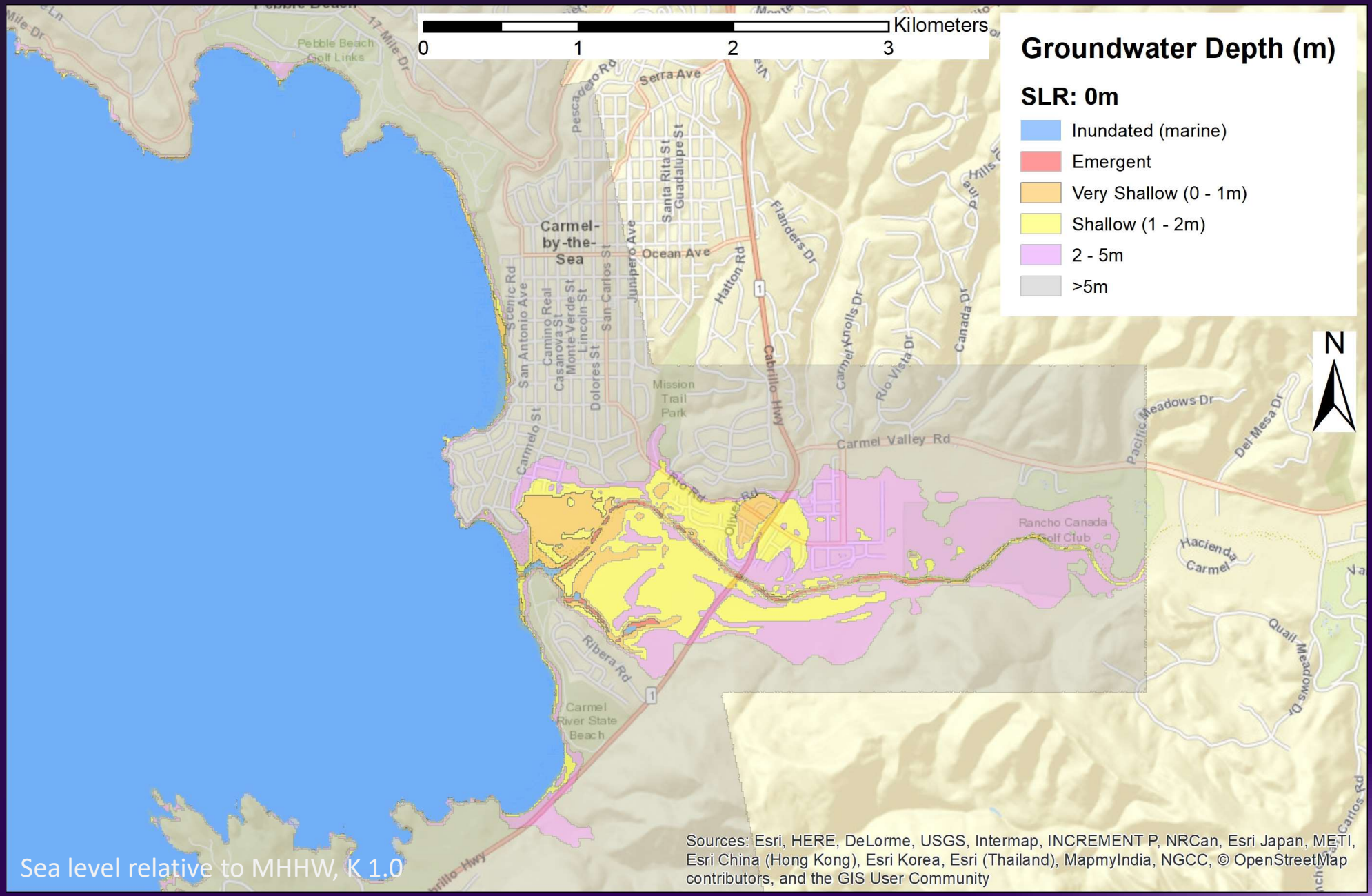


- **Inundation may exceed overland flooding and happen much sooner**
- **May impact infrastructure with no warning**
- **Low-lying areas most vulnerable**

USGS

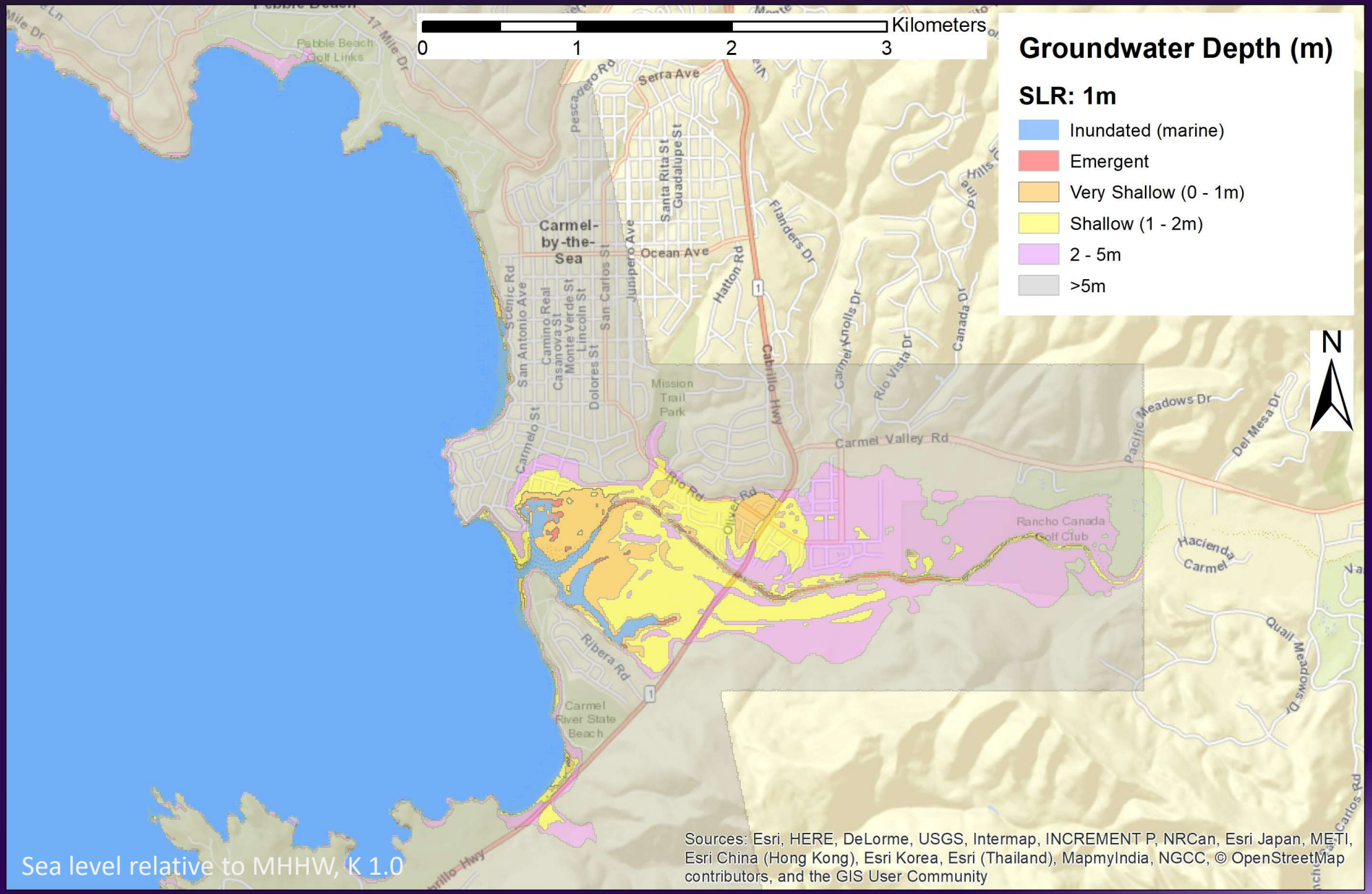
Befus, K.M., Barnard, P.L., Hoover, D.J., Finzi Hart, J.A. and Voss, C.I., 2020. Increasing threat of coastal groundwater hazards from sea-level rise in California. *Nature Climate Change*, 16 pp., https://doi.org/10.1038/s41558-020-0874-1

Groundwater - Carmel



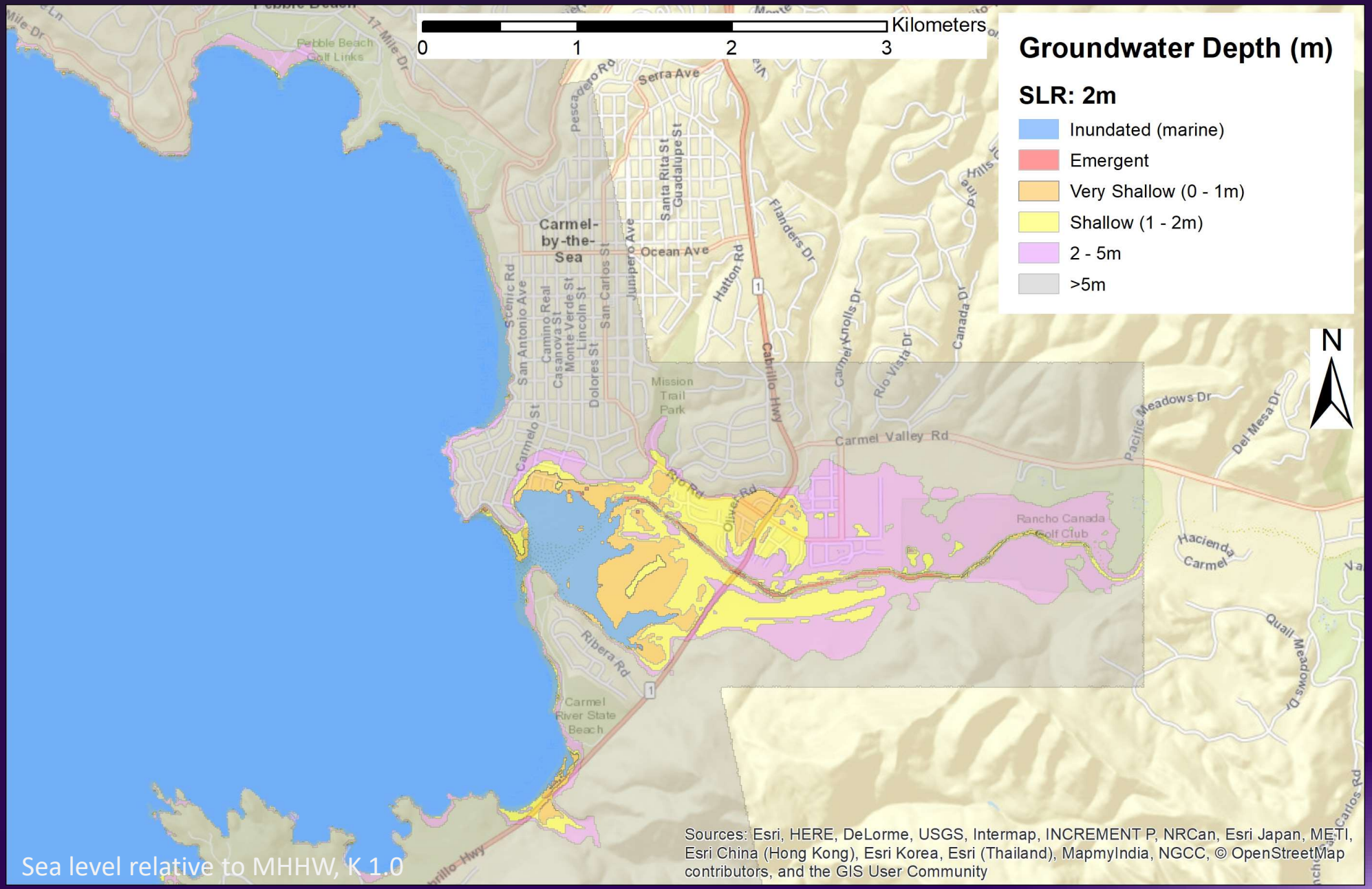
Sea level relative to MHHW, K 1.0

Groundwater - Carmel

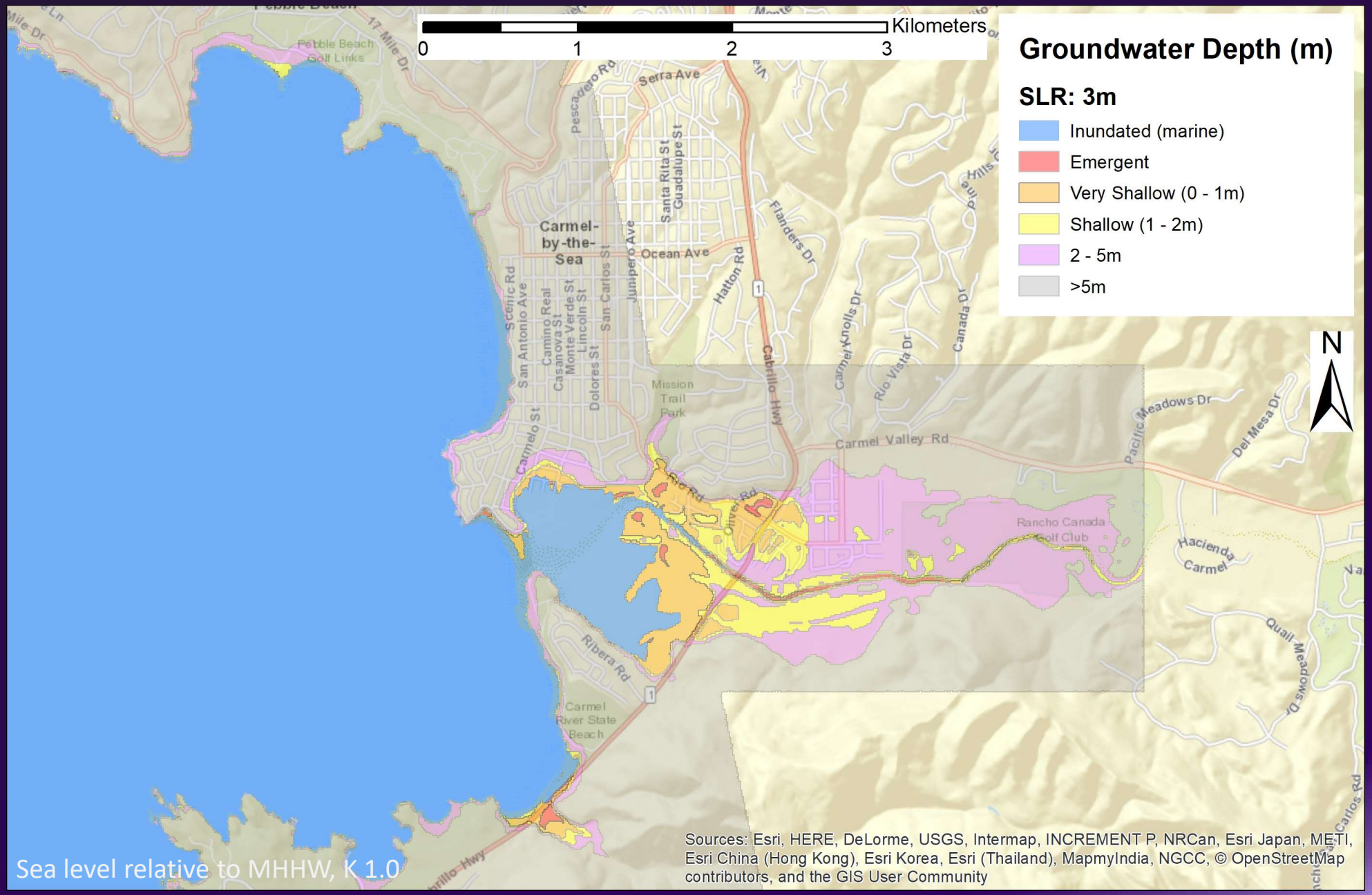


Sea level relative to MHHW, K 1.0

Groundwater - Carmel



Groundwater - Carmel



What makes CoSMoS unique?

- Explicit, high-resolution, dynamic modeling of waves, currents, storm surge, flooding, and beach change
- Considers the future evolution of storm patterns based on the latest Global Climate Models
- Uses state-of-the-art projections of (dynamically-downscaled) winds and waves to calculate surge and seas
- Extensively tested, calibrated, and validated with local, historic data on waves, water levels and coastal change
- Flood projections are based on dynamic wave set-up, i.e., any area that is wet for at least 2 minutes during a storm scenario
- Flooding is determined by the dynamic interaction of the evolving profile and ocean conditions during the storm event, including dune erosion and overtopping, and also the preceding long-term evolution of the coast
- Coastal change projections are based on a series of strenuously tested, peer-reviewed models, and calibrated by the local behavior of the coast
- Predicts the horizontal and vertical evolution of the entire beach profile through time

USGS

CoSMoS Coastal Storm Modeling System USGS

Central Coast CoSMoS

- **Coastal change and flooding projections complete (Monterey online soon)**
- **Flooding projections available with Our Coast, Our Future and HERA web tools**
- **Groundwater projections for all coastal CA available online**

USGS CoSMoS website: *https://walrus.wr.usgs.gov/coastal_processes/cosmos/index.html*

Our Coast, Our Future tool: *www.ourcoastourfuture.org*

HERA Tool: *www.usgs.gov/apps/hera*

*For more information on CoSMoS, contact Patrick Barnard: pbarnard@usgs.gov

or contact Dan Hoover for groundwater projections: dhoover@usgs.gov