California Coastal Analysis and Mapping Project

Two Companion Large-Scale Efforts:
- Open Pacific Coast (OPC) Study
- San Francisco Bay Area Coastal (BAC) Study

Re-study flood risk along the open coast and inland bays of all California coastal counties

Re-map the elevation and inland extent of wave-induced coastal flooding

www.r9coastal.org
## Overall OPC Study Schedule

The chart above represents the schedule for fiscal years 2011 to 2018 for the OPC Study Phase 2, which includes Southern California Counties. Each county is represented in the chart with specific dates indicating when the various phases of the study were scheduled to occur. The chart also highlights the typical workflow phases, such as Coastal Analysis, Floodplain Mapping, Preliminary Map Production, and Post-Preliminary Process.

**OPC Study Phase 2 includes Southern California Counties**
# Santa Barbara / Ventura Schedule

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Completion Date</th>
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<tbody>
<tr>
<td><strong>Santa Barbara</strong></td>
<td></td>
</tr>
<tr>
<td>Kick-Off Meeting</td>
<td>December-11</td>
</tr>
<tr>
<td>Present Work Maps</td>
<td>March-16</td>
</tr>
<tr>
<td><em>Work Map Comment Period</em></td>
<td>May-16</td>
</tr>
<tr>
<td>Resilience Meeting</td>
<td>July-16</td>
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<tr>
<td>Issue Preliminary FIRM Panels</td>
<td>January-17</td>
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<tr>
<td>FIRM Panel Effective date</td>
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<tr>
<td><strong>Ventura</strong></td>
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<tr>
<td>Kick-Off Meeting</td>
<td>December-11</td>
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<tr>
<td>Present Work Maps</td>
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<tr>
<td><em>Work Map Comment Period</em></td>
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<td>Resilience Meeting</td>
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<tr>
<td>Issue Preliminary FIRM Panels</td>
<td>May-16</td>
</tr>
<tr>
<td>FIRM Panel Effective date</td>
<td>September-17</td>
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Coastal Study Process

1-D Transect-based Analysis
Data Acquisition & Processing

Offshore Water Levels

- 50-year (1960-2009) hourly stillwater level (SWL) time series
  - Rely on long-term observed tide station records where available
  - Use predicted tide data and adjacent station data to fill gaps
- Extreme tide frequency analysis for stillwater elevations (SWEL)
  - Based on observed annual maxima tide data
  - 50-, 20-, 10-, 4-, 2-, 1-, and 0.2-percent annual chance SWELs
Data Acquisition & Processing

Deepwater Wave Hindcast (OWI) – Oceanweather Inc.

- Global Reanalysis of Ocean Waves (GROW) Model
- 50-year hourly hindcast of waves (1960-2009)
- COASTAL model provides wave spectra at 124 grid point locations
- Extensive validation with buoy data

Model output points
Data Acquisition & Processing

Nearshore Wave Transformation – Scripps Institution of Oceanography

- SIO SHELF linear spectral refraction and shoaling model from deepwater to surf zone (15m water depth in San Mateo at 200 m spacing)
- 50-year hourly hindcast of nearshore waves (1960-2009)
- Model validation with buoy data

Wave height and peak direction
1-D Coastal Hazard Analyses

- Transect-based analysis
- 59 analysis transects
- Transect locations and density based on:
  - Shoreline characteristics
  - Shoreline orientation
  - Nearshore bathymetry
  - Wave climate
  - Land use and development
Total Water Level

Components of the total water level (TWL)

- Astronomical tide (predicted tide): 5-7 ft
- Surge components: atmospheric pressure, wind setup, El Niño sea level effects: 1-3 ft
- Wave components: wave setup + runup: 10-20 ft

\[
\text{SWL} = \text{Tide} + \text{surge (no wave effects)}
\]
\[
\text{TWL} = \text{SWL} + \text{setup} + \text{runup}
\]

No overland wave propagation analysis in San Mateo OPC Study area
Analyzing Wave Setup, Runup, and Overtopping

Setup and Runup Methods
- Stockdon (2006): sandy beaches and dunes with slope < 1:9
- DIM (Pacific Guidelines): rocky beaches with slope > 1:9
- DIM + TAW (van der Meer): steep barriers (bluff, seawalls, and revetments)

Overtopping Method
- Cox-Machemehl (inland extend of high velocity zone beyond crest)

Dune Erosion Method
- MK & A geometric dune erosion model
- Kriebel and Dean time dependence adjustment

Extreme Value Statistical Analysis
- Primary: Peaks-over-threshold (POT) with Generalized Pareto Distribution (GPD)
- Secondary: Annual maxima (AM) with Generalized Extreme Value Distribution (GEV)
Estimating Extreme TWLs

- TWL time series is computed for 50-year hindcast period
- Peak TWLs values are extracted for extreme value statistical analysis
- EVA to determine: 50-, 20-, 10-, 4-, 2-, 1-, and 0.2-percent annual chance TWLs
Coastal Structures

- Wide variety of coastal structures present along CA coast
- BakerAECOM reviewed: LiDAR, as-builds from community, aerial photos, site visit notes, USACE drawings and surveys, and Coastal Commission GIS layers to identify and represent structures in profile
Coastal Structures

- BakerAECOM developed global treatments to guide decisions at each site based on FEMA’s Pacific Guidelines and USACE guidance.

- Consider historical performance, structure condition, as-built drawings, maintenance history, certification, permits, and engineering judgment.

- Will structure withstand base flood event?
  - Yes → Conduct Intact analysis only
  - No or uncertain → Conduct Intact and Failed Analysis

- Failed Analysis = partial failure or removal, depending on site conditions.

- Map the most hazardous Base Flood Elevation only.
Flood Hazard Mapping

Special Flood Hazard Area (SFHA) Mapping

- **Zone VE**: Inundated by 1-percent annual chance flood with additional wave-induced hazards (wave runup, wave overtopping splash, high velocity, or overland wave propagation); detailed Base Flood Elevation (BFE)
- **Zone AE**: Inundated by 1-percent annual chance flood; detailed BFE
- Both high hazard zones carry mandatory flood insurance purchase requirements
- **Zone X (shaded)**: Inundated by 0.2-percent annual chance flood (or inundated by <1 ft for 1-percent flood)

Coastal High Hazard Areas
Primary Frontal Dune V Zone Mapping

Primary Frontal Dune (PFD) V Zone Mapping

- **Definition:** “a continuous or nearly continuous mound or ridge of sand with relatively steep seaward and landward slopes immediately landward and adjacent to the beach and subject to erosion and overtopping from high tides and waves during major coastal storms…”

- **Landward extent:** “a point where there is a distinct chance from a relatively steep slope to a relatively mild slope” (i.e., the *dune heel*)

- **Implications:** The PFD represents the landward extension of the VE Zone

- **Purpose:** Floodplain management tool to protect dunes and regulate coastal construction practices and building standards

- **Delineation of the PFD is mandated by FEMA regulations**

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![Diagram of Primary Frontal Dune](PFD_diagram.jpg)

**PFD at Pacifica State Beach**
FEMA Regulatory Flood Insurance Rate Map
Coastal Non-Regulatory Products

- Changes Since Last FIRM
- Flood Depth Grids
- Flood Risk Analysis Grids
  - 50-, 20-, 10-, 4-, 2-, 1-, and 0.2-percent annual chance
- Primary Frontal Dune Location
- Increased Flooding Scenarios (BFE + 1 ft, BFE + 2 ft, BFE + 3 ft)
Coastal Non-Regulatory Products

Figure 2: Example of the Increased Flooding Scenarios Dataset
FEMA West Coast Sea Level Rise Pilot Study

City and County of San Francisco
SLR Pilot Study and FEMA Pacific Guidelines

**Linear Superposition**

- **Offshore Zone**
  - Offshore Waves
  - Wave Transformations
  - Nearshore Waves

- **Shoaling Zone**
  - Wave Transformations
  - Water Levels

- **Surf Zone and Backshore**
  - Erosion
  - Coastal Structures
  - Wave Setup
  - Wave Runup
  - Overtopping
  - Overland Wave Propagation (if necessary)

- **TWL + SLR**
  - Flood Hazard Mapping

**Direct Analysis**

- **Offshore Zone**
  - Offshore Waves
  - Wave Transformations
  - Nearshore Waves

- **Nearshore Waves**
  - Erosion
  - Coastal Structures
  - Wave Setup
  - Wave Runup
  - Overtopping
  - Overland Wave Propagation (if necessary)

- **TWL + SLR**
  - Flood Hazard Mapping

- **SLR**
  - Shoreline Change & Profile Adjustment

**Equations**

- \( \text{TWL}_{\text{SLR}} = \text{TWL} + \text{SLR} \)
- \( \text{TWL}_{\text{SLR}} > \text{TWL} + \text{SLR} \)
Pilot Study SLR Scenarios *

- Mid-range values for 2050 and 2100
  - +12” and + 36”
- High end of range for 2050 and 2100
  - +24” and +66”

San Francisco County

San Francisco County Shoreline

China Beach
(Narrow beach + seawall + rocky bluffs)

Ocean Beach
(Wide beach + seawall)

Ocean Beach
(Narrow beach + eroding bluff)
Current Condition Mapping
Sloat Blvd – Armored Low Bluff

- 1% Runup (TWL) = 26 ft NAVD
- 0.2% Runup (TWL) = 27 ft NAVD
- No overtopping

Bluff Crest at 30-31 ft NAVD
Linear Superposition vs. Direct Analysis
Sloat Blvd – Armored Low Bluff

- BFE increase exceeds the SLR increase by a factor of ~2
- Overtopping occurs at much lower SLR under direct analysis vs. linear superposition method

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<th>ΔBFE (ft)</th>
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<td>9.6</td>
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<tr>
<td>5.5</td>
<td>12.9</td>
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Current Condition Mapping
Cliff House – Natural High Bluff

- 1% Runup (TWL) = 25 ft NAVD
- 0.2% Runup (TWL) = 26 ft NAVD
- No overtopping

Bluff Crest at 60 ft
Linear Superposition vs. Direct Analysis
Cliff House – Natural High Bluff

- BFE increase exceeds the SLR increase by a factor of ~3

<table>
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<tr>
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<tr>
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Armored Shoreline – Potential Shoreline Retreat

2050 Potential Shoreline Retreat

2100 Potential Shoreline Retreat
Stay Informed Throughout the Study

- Meetings
- Materials
- Study Updates

Website: www.r9coastal.org
FEMA Resources

- Follow FEMA R9 via Twitter @femaregion9
- Sign up for the CCAMP E-newsletter at www.r9map.org/SiteAssets/signUPNewsletter.html

- **Flood Map Center**: https://msc.fema.gov/portal - Print a FREE flood map
Questions & Answers