Overview of Seawater Intrusion, Seawater Intrusion in the Los Angeles Basin, Sea Level Rise, and Modeling Seawater Intrusion

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Overview

- What is seawater intrusion?
- Seawater intrusion in LA.
- Climate change and sea level rise.
- Seawater intrusion modeling.
  - Santa Barbara
  - Los Angeles

What is Seawater Intrusion?

- Movement of saline water into freshwater aquifers.
- Driven by lowering of aquifer freshwater levels.
- 3 primary mechanisms
  - Subsurface seawater movement (lateral, large-scale movement).
  - Seepage from tidal canals and streams.
  - Connate upward movement from deeper formations.
- Regional, long-term changes more important than seasonal.

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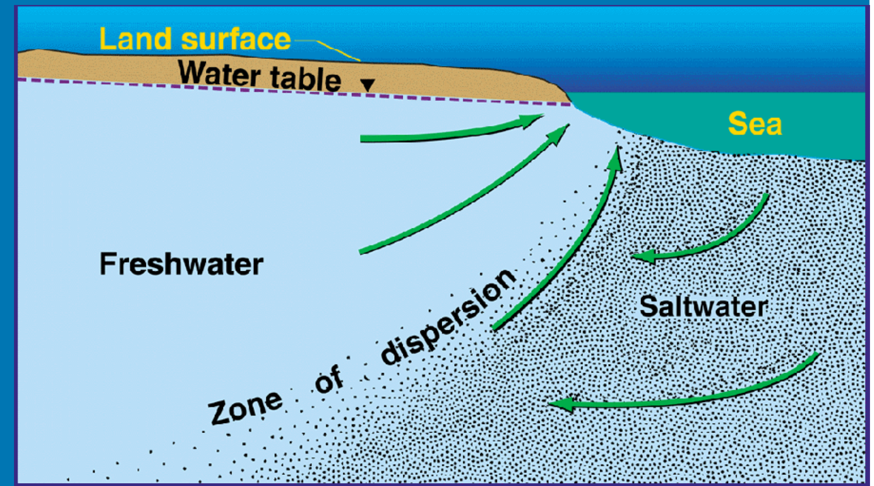
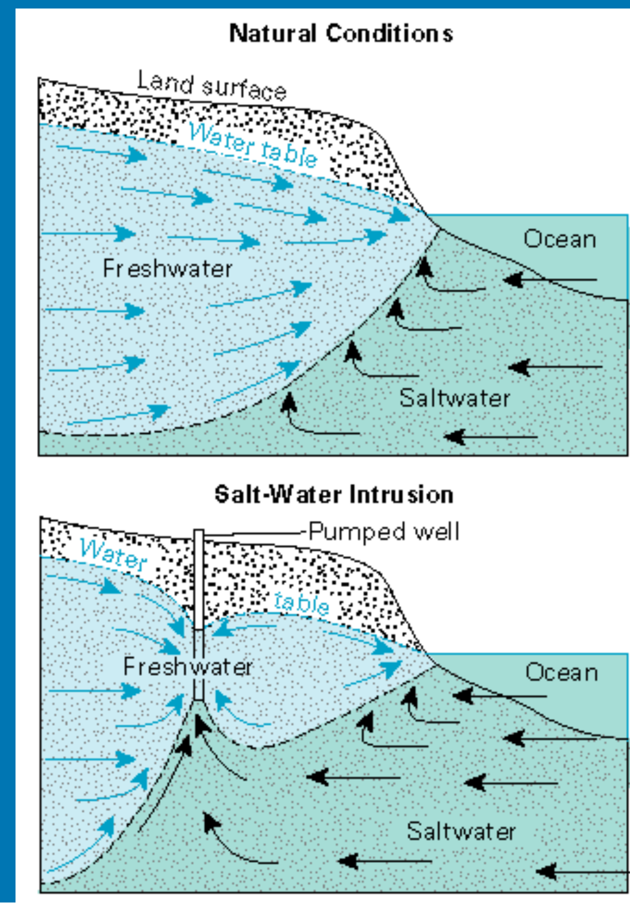
Some Theory

- Seawater is denser than freshwater and creates a wedge that moves underneath the freshwater.
- The transition between fresh and salt water is a dispersion zone (NOT a sharp interface).
- Some places are more prone to seawater intrusion due to topography, channels, geology, and permeability.
- Seawater intrusion is a 3D problem.
- Called a density-dependent groundwater-flow and solute-transport problem.





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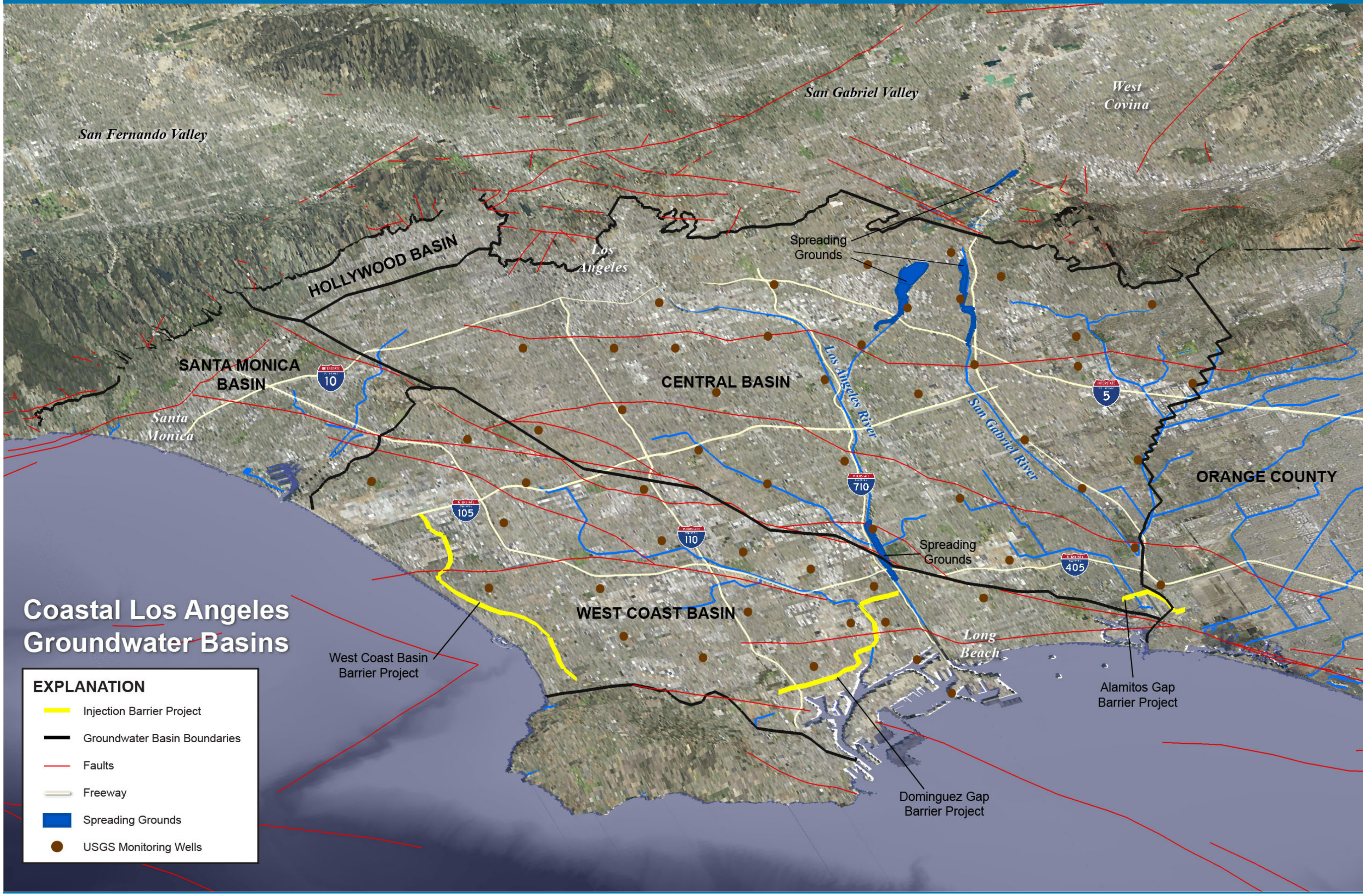
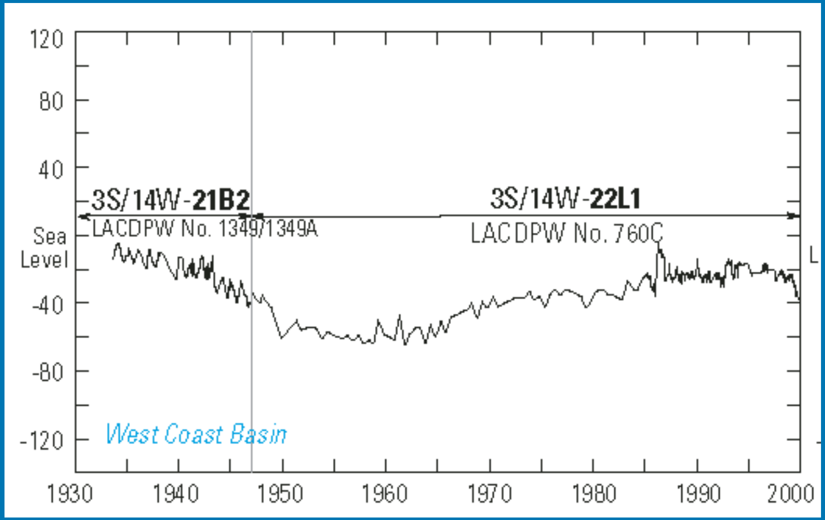
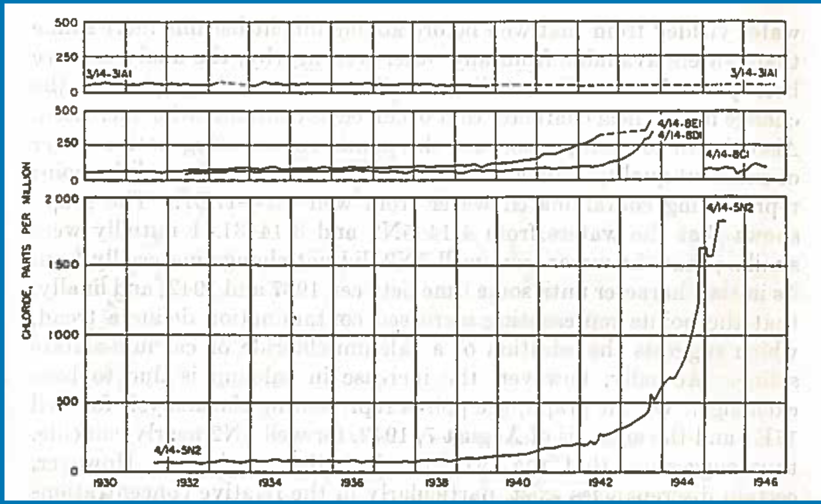
Los Angeles Basin



Brief History of Seawater Intrusion in LA

- Groundwater pumped since the mid-1800’s
- Groundwater overdraft 1900’s to 1950’s resulted in falling water levels.
- Seawater intrusion detected as early as 1912 in Redondo Beach.





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3 Responses to Seawater Intrusion

- Mid-1950s to mid-1960s
- Construction of freshwater injection wells
  - West Coast barrier project
  - Dominguez Gap barrier project
  - Los Alamitos barrier project
- Adjudicated basins to control pumping
- Created Water Replenishment District of So Cal for artificial recharge.

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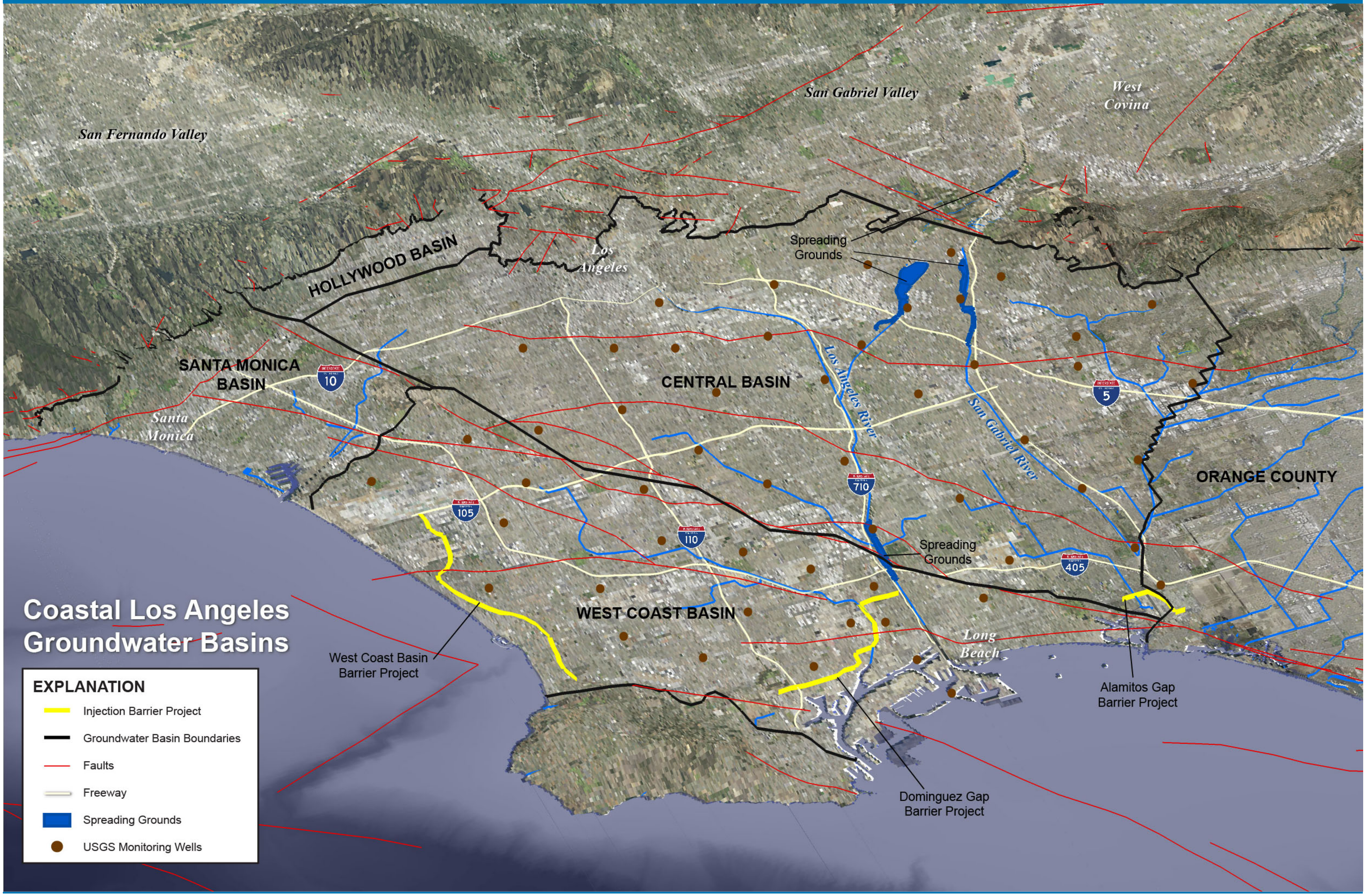
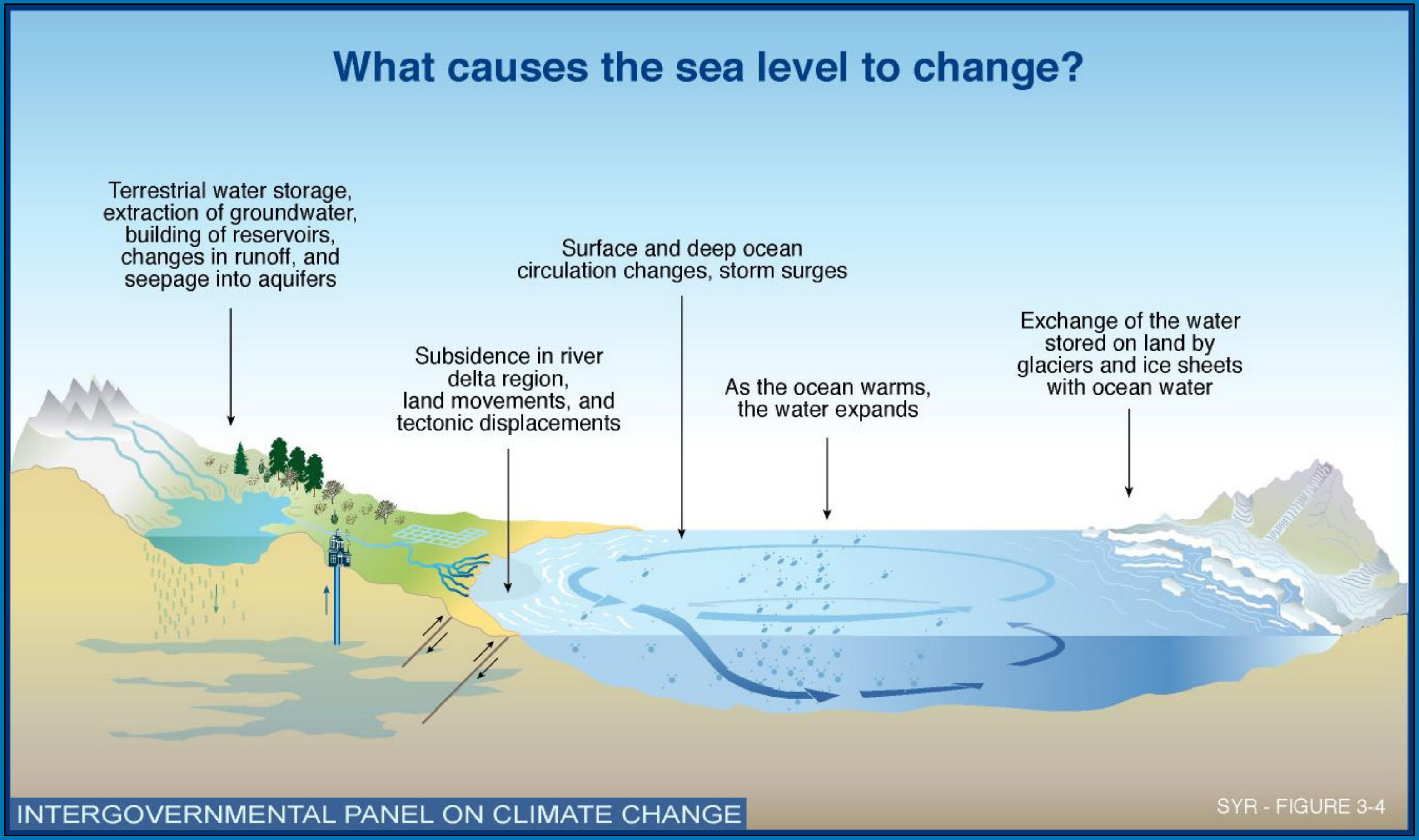
Los Angeles Basin Barrier Projects



Sea Level Rise 101



Other factors

- Ocean basin configuration (geologic time scales)
- Wind patterns (hours to decades)
- Tidal (hours to decades)
- **Storms (hours to days)**

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*Global SLR is accelerating
- 20th century = 2 mm/yr
- 1993-present = 3 mm/yr

Patrick Barnard USGS Pacific Coastal and Marine Science Ctr.

http://walrus.wr.usgs.gov/coastal_processes/cosmos/socal3.0/index.html

Sea Level Rise Components

Table 2 | Global sea-level budget from IPCC AR5[4] compared with the estimate of this study for the land water storage over the two different time intervals (1971–2010 and 1993–2010).

Component	Comparison	1971–2010 (mm yr^{-1})	1993–2010 (mm yr^{-1})
Observed SLR		2.0 (±0.3)	3.2 (±0.4)
Observed			
Thermal expansion		0.8 (±0.3)	1.1 (±0.3)
Glaciers except in Greenland and Antarctica		0.62 (±0.37)	0.76 (±0.37)
Glaciers in Greenland		0.06 (±0.03)	0.10 (±0.03)
Greenland ice sheet			0.33 (±0.08)
Antarctica ice sheet			0.27 (±0.12)
Modelled			
Thermal expansion		0.96 (±0.45)	1.49 (±0.53)
Glaciers except in Greenland and Antarctica		0.62 (±0.22)	0.78 (±0.35)
Glaciers in Greenland		0.10 (±0.05)	0.14 (±0.09)
Land water storage	IPCC AR5	0.12 (±0.09)	0.38 (±0.12)
	This study	−0.10 (±0.03)	0.12 (±0.04)
Total including land water storage	IPCC AR5	1.8 (±0.5)	2.8 (±0.7)
	This study	1.58 (±0.4)	2.53 (±0.6)
Residual	IPCC AR5	0.2 (±0.6)	0.4 (±0.8)
	This study	0.42 (±0.6)	0.67 (±0.8)

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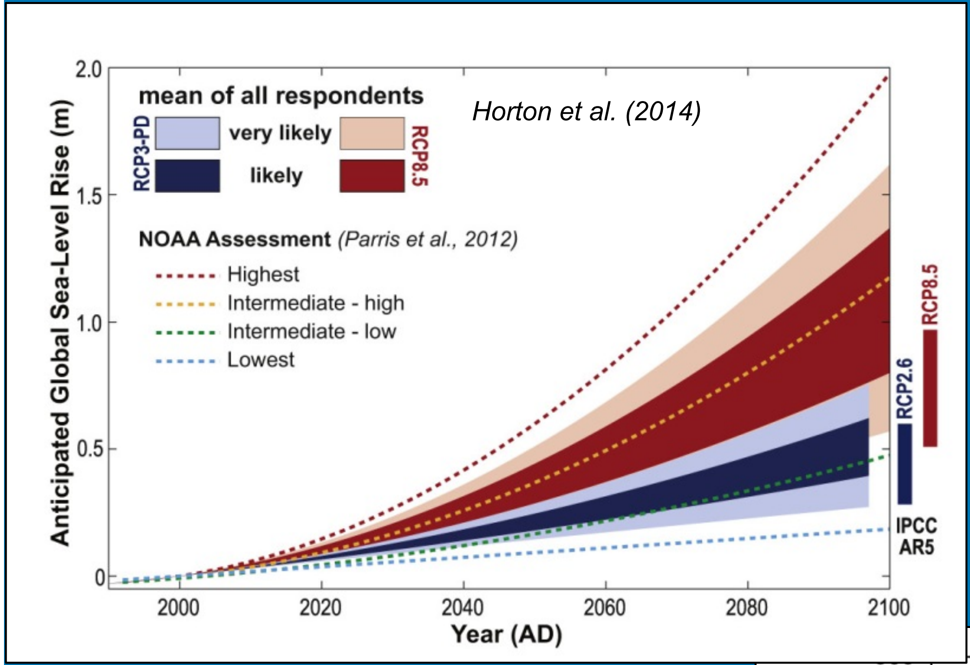
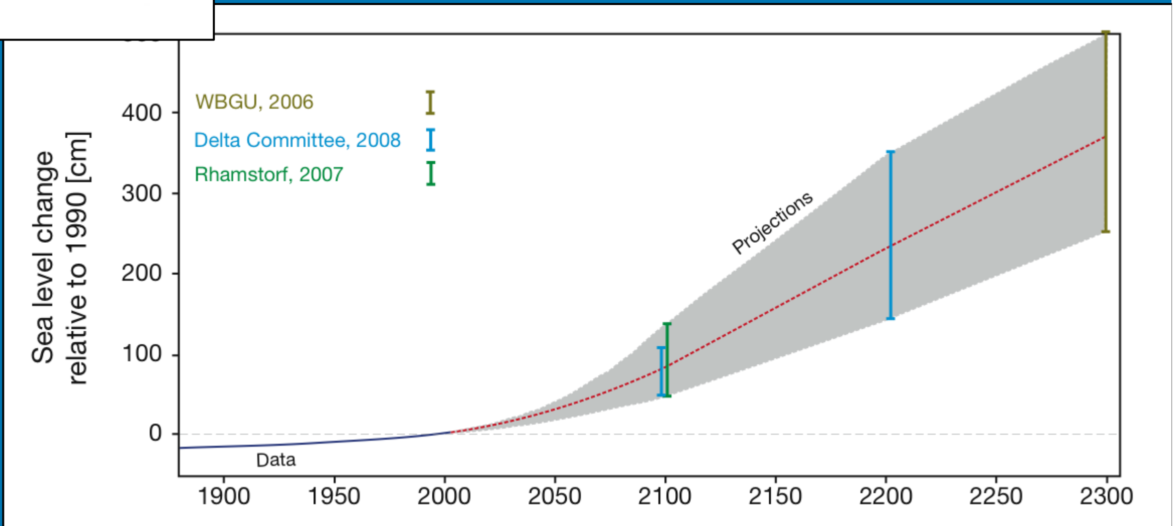
From: Wada et al., 2016, DOI: 10.1038/NCLIMATE3001

Sea Level Rise to 2100 and Beyond





The Copenhagen Diagnosis, 2009

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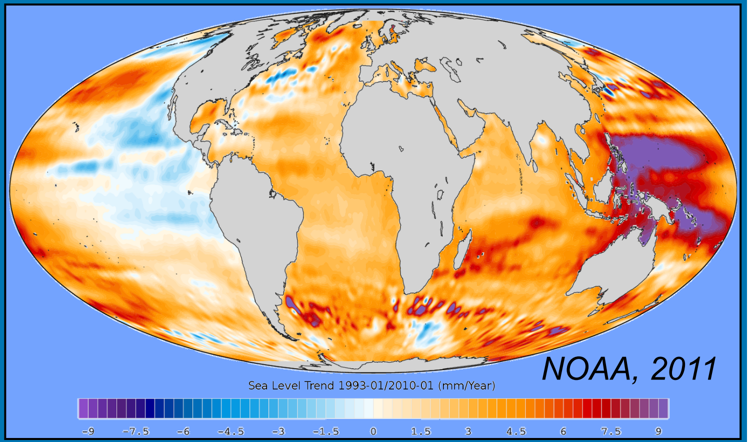
http://walrus.wr.usgs.gov/coastal_processes/cosmos/socal3.0/index.html

21st Century Projections for Southern California

SLR for Los Angeles (National Research Council)

-28 cm of sea level rise by 2050 (range 13-61 cm)

-93 cm of sea level rise by 2100 (range 44-167 cm)
-includes global and regional effects



NOAA, 2011

Waves

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

El Niño

-More frequent extreme events
-Wave energy increase by 30%
-Water level increase by 20-30 cm
-Doubling of winter erosion

Santa Monica Pier, January 1983 (Paul Silhavy)

Net effect

-Today's 100-year coastal flooding event is projected to occur every 1-5 years by 2050 for much of California
-Greatest impacts on low-lying coastal areas (e.g., Oxnard Plain, Venice)

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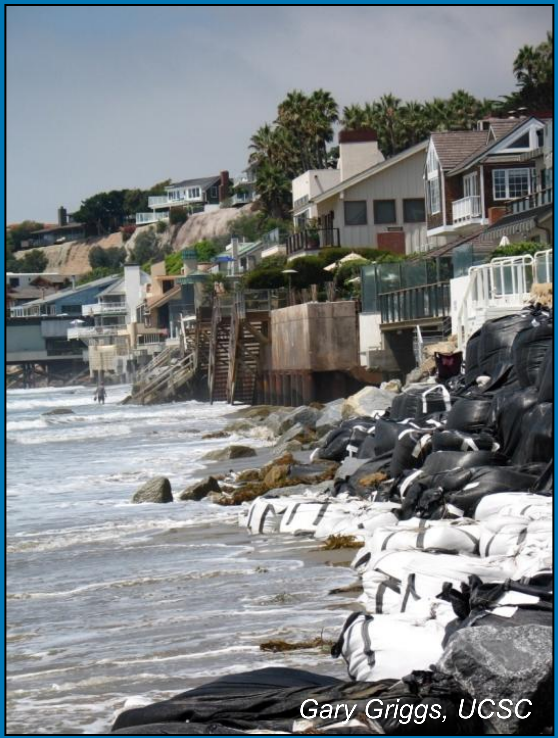
http://walrus.wr.usgs.gov/coastal_processes/cosmos/socal3.0/index.html

CoSMoS: A Tool for Coastal Resilience

- **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**
- **Emphasis on directly supporting federal and state-supported climate change guidance (e.g., Coastal Commission) and vulnerability assessments (e.g., LCP updates, OPC/Coastal Conservancy grants)**


Gary Griggs, UCSC

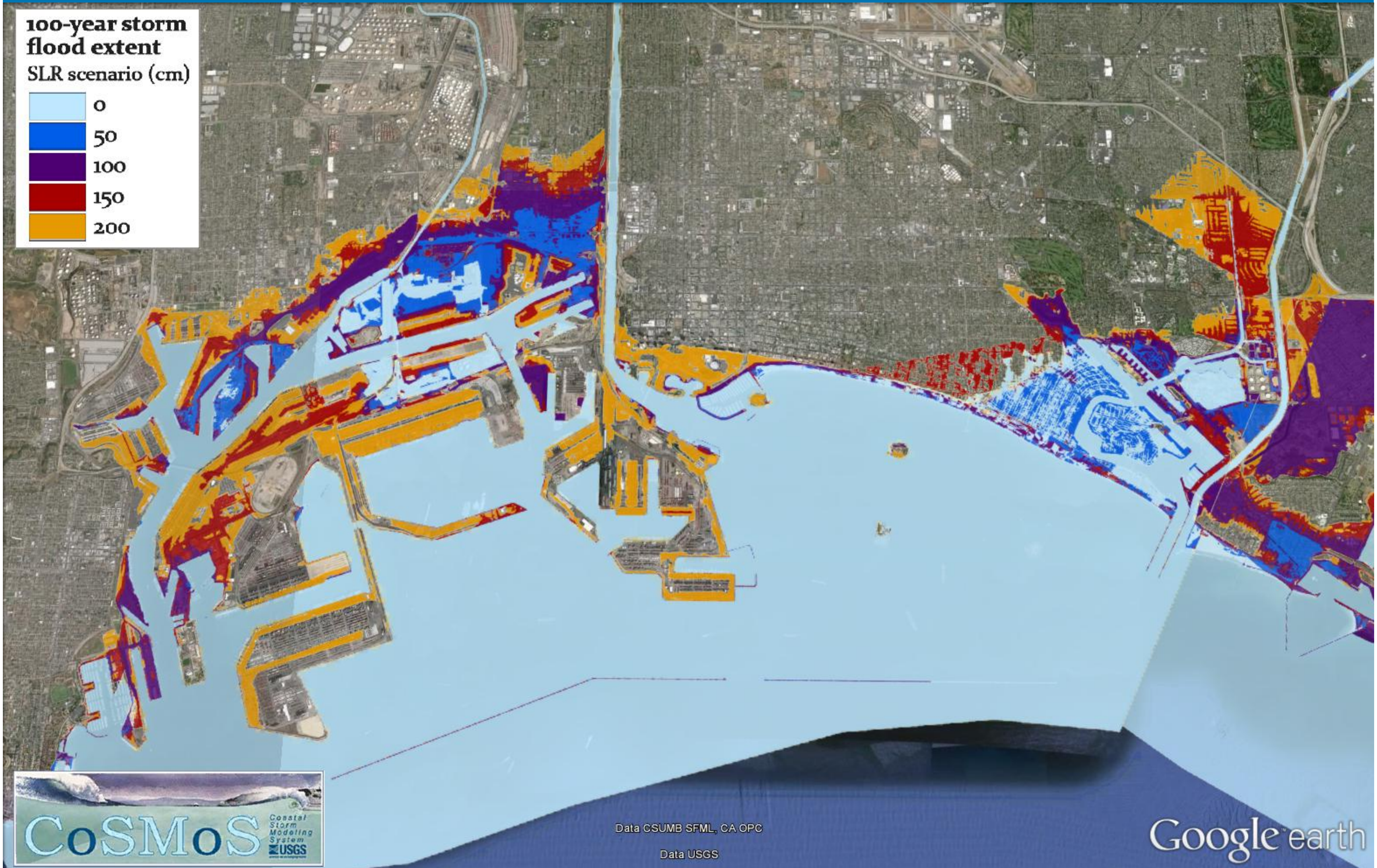
Brad Graverson, January 2010

http://walrus.wr.usgs.gov/coastal_processes/cosmos/socal3.0/index.html

Flooding – Venice

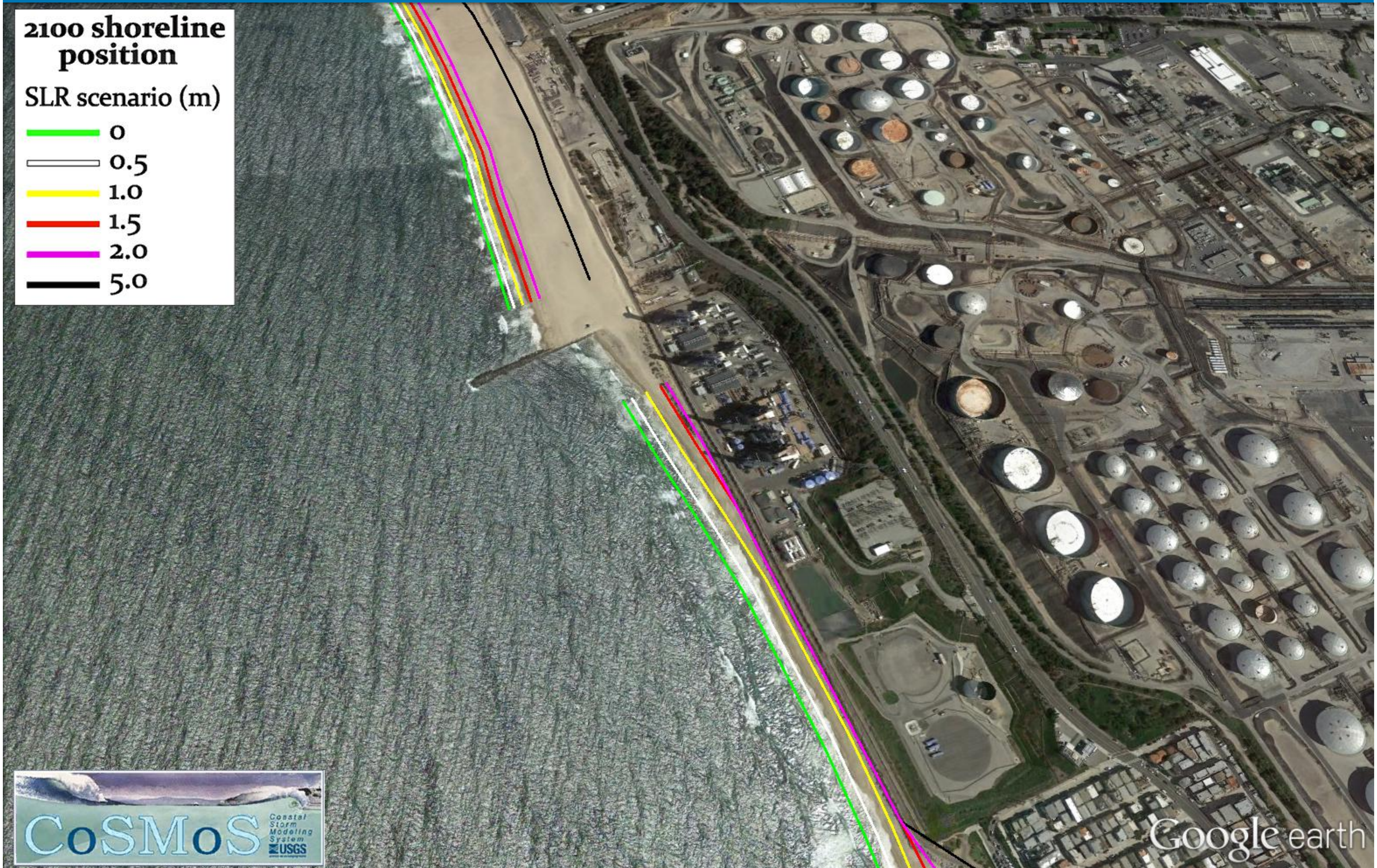
http://walrus.wr.usgs.gov/coastal_processes/cosmos/socal3.0/index.html

Flooding – Port of L.A.



http://walrus.wr.usgs.gov/coastal_processes/cosmos/socal3.0/index.html

Shoreline Projections- El Segundo



http://walrus.wr.usgs.gov/coastal_processes/cosmos/socal3.0/index.html

Modeling Seawater Intrusion

- Density-dependent groundwater-flow and solute-transport problem
- USGS models
  - SEAWAT (http://water.usgs.gov/ogw/seawat/)
  - SUTRA (http://water.usgs.gov/nrp/gwsoftware/sutra/sutra.html)
  - SHARP
  - SWI
  - HST3D

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SEAWAT

- Couples MODFLOW-2000 w/ MT3D
- 3-D finite difference
- Applied to Santa Barbara groundwater basin
- Report in review

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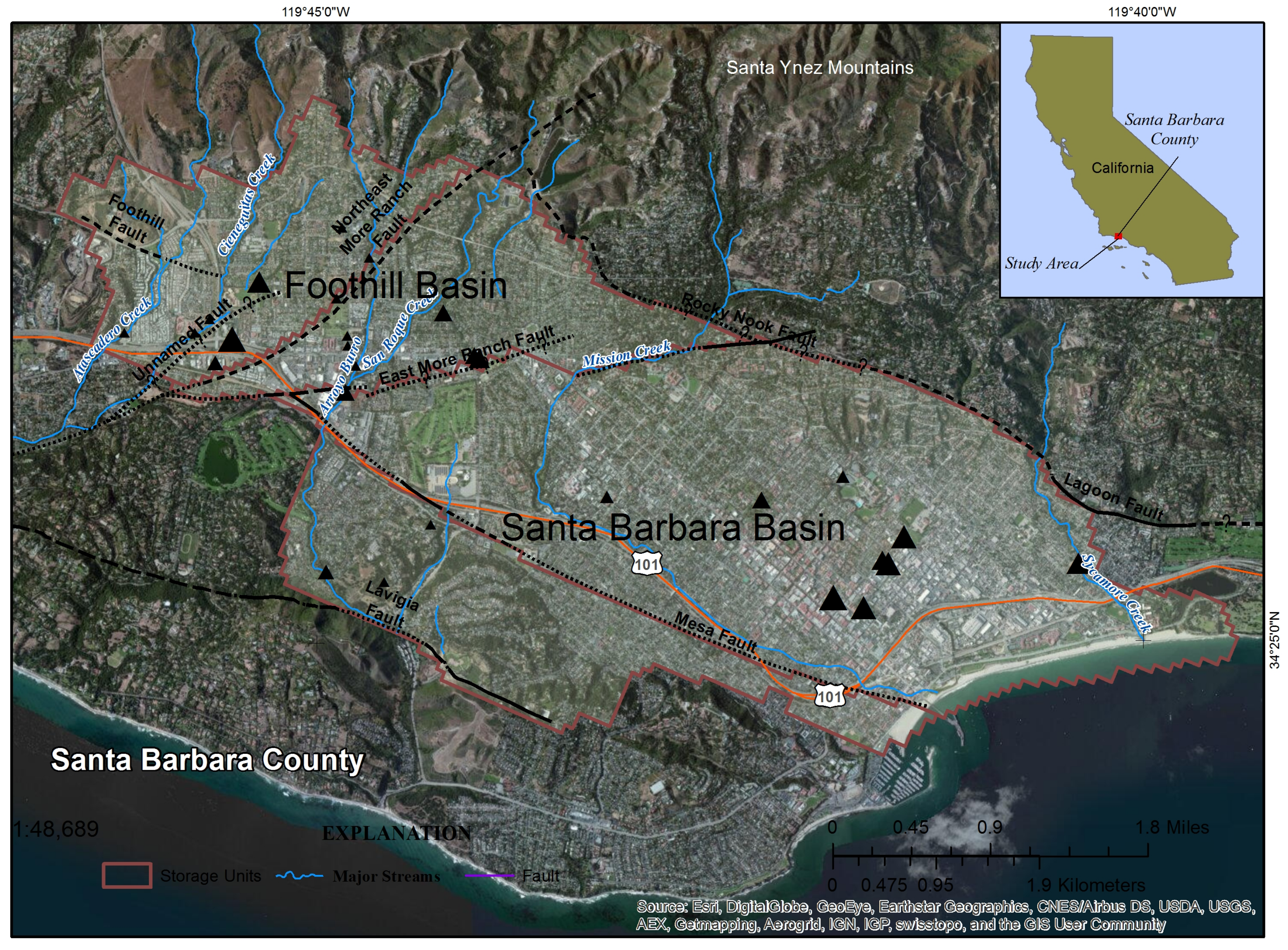
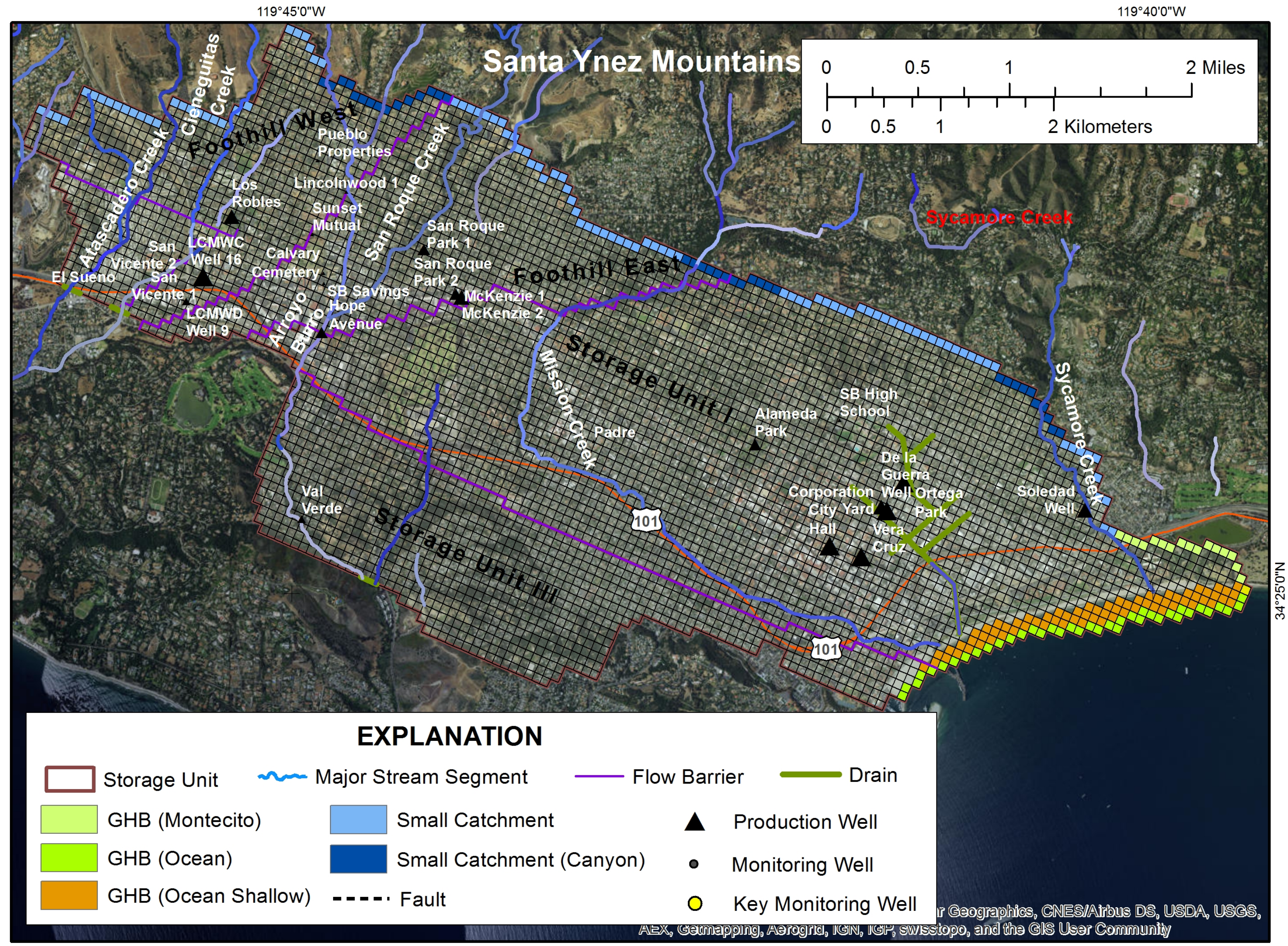
Santa Barbara Model

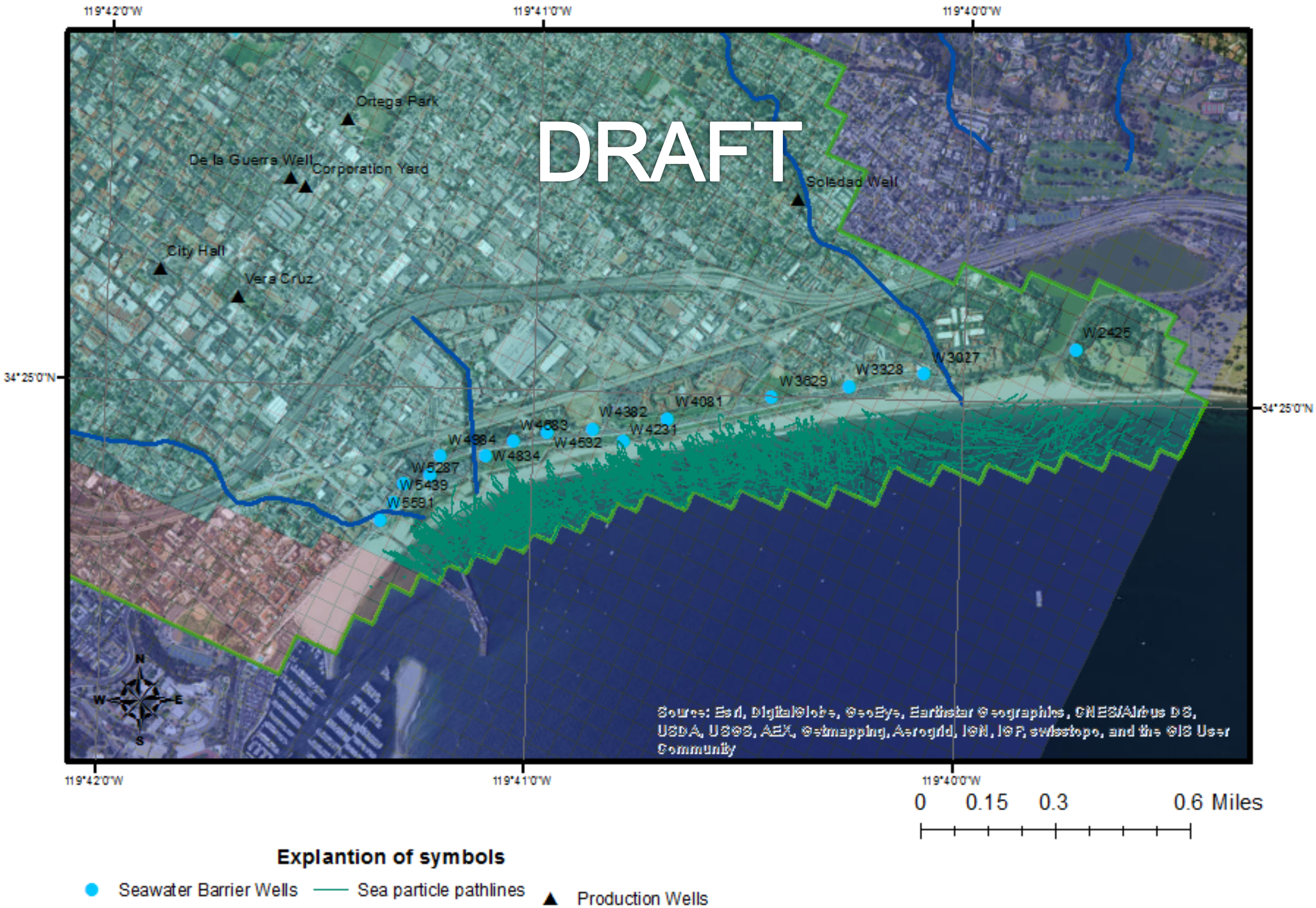


Model Grid

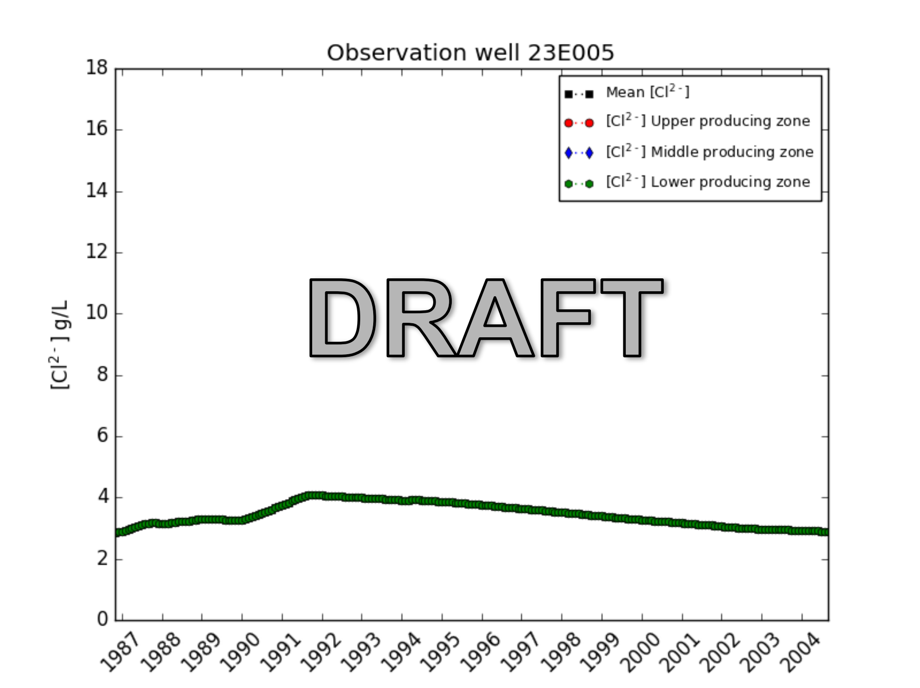


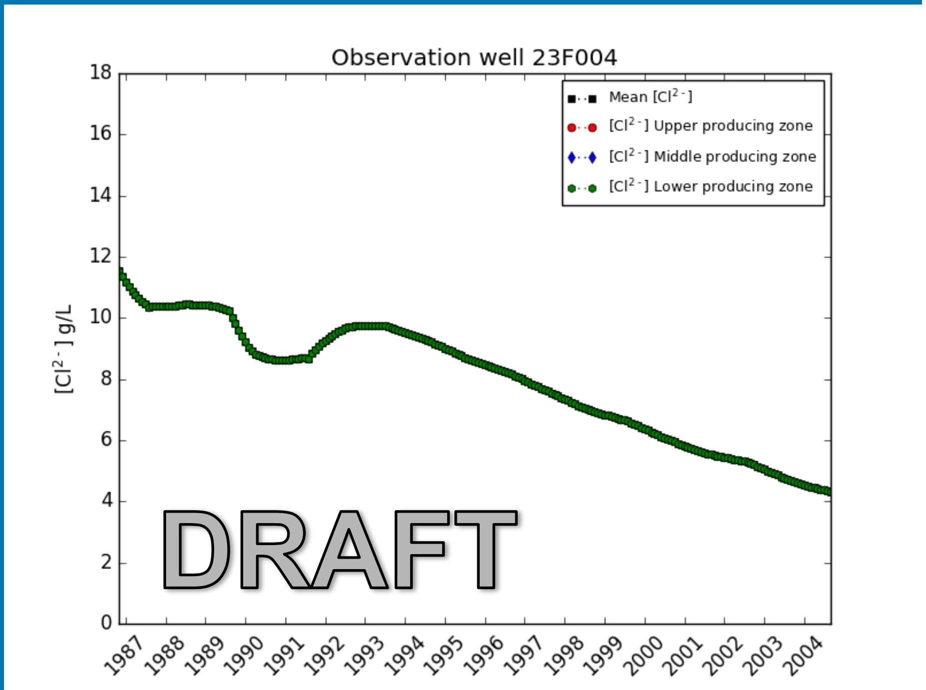
119°45'0"W
119°40'0"W
34°25'0"N
Santa Ynez Mountains
0 0.5 1 2 Miles
0 0.5 1 2 Kilometers
Sycamore Creek
Foothill West
Foothill East
Storage Unit I
Storage Unit III
Cieneguitas Creek
Atascadero Creek
San Roque Creek
Arroyo Burro
Mission Creek
Sycamore Creek
Pueblo Properties
Lincolnwood 1
Los Robles
Sunset Mutual
San Roque Park 1
San Roque Park 2
LCMWC Well 16
San Vicente 2
San Vicente 1
El Sueno
Calvary Cemetery
SB Savings
Hope Avenue
LCMWD Well 9
McKenzie 1
McKenzie 2
Padre
Alameda Park
SB High School
De la Guerra
Well Ortega Park
Corporation City Yard
City Hall
Vera Cruz
Soledad Well
Val Verde
101
EXPLANATION
Storage Unit
Major Stream Segment
Flow Barrier
Drain
GHB (Montecito)
Small Catchment
Production Well
GHB (Ocean)
Small Catchment (Canyon)
Monitoring Well
GHB (Ocean Shallow)
Fault
Key Monitoring Well
r Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Seawater Barrier Scenario



Simulated Breakthrough Curves





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SUTRA

- Simulates groundwater flow coupled with either density-dependent heat or solute transport
- 2D or 3D finite element
- Applied in 2D cross section to Long Beach area

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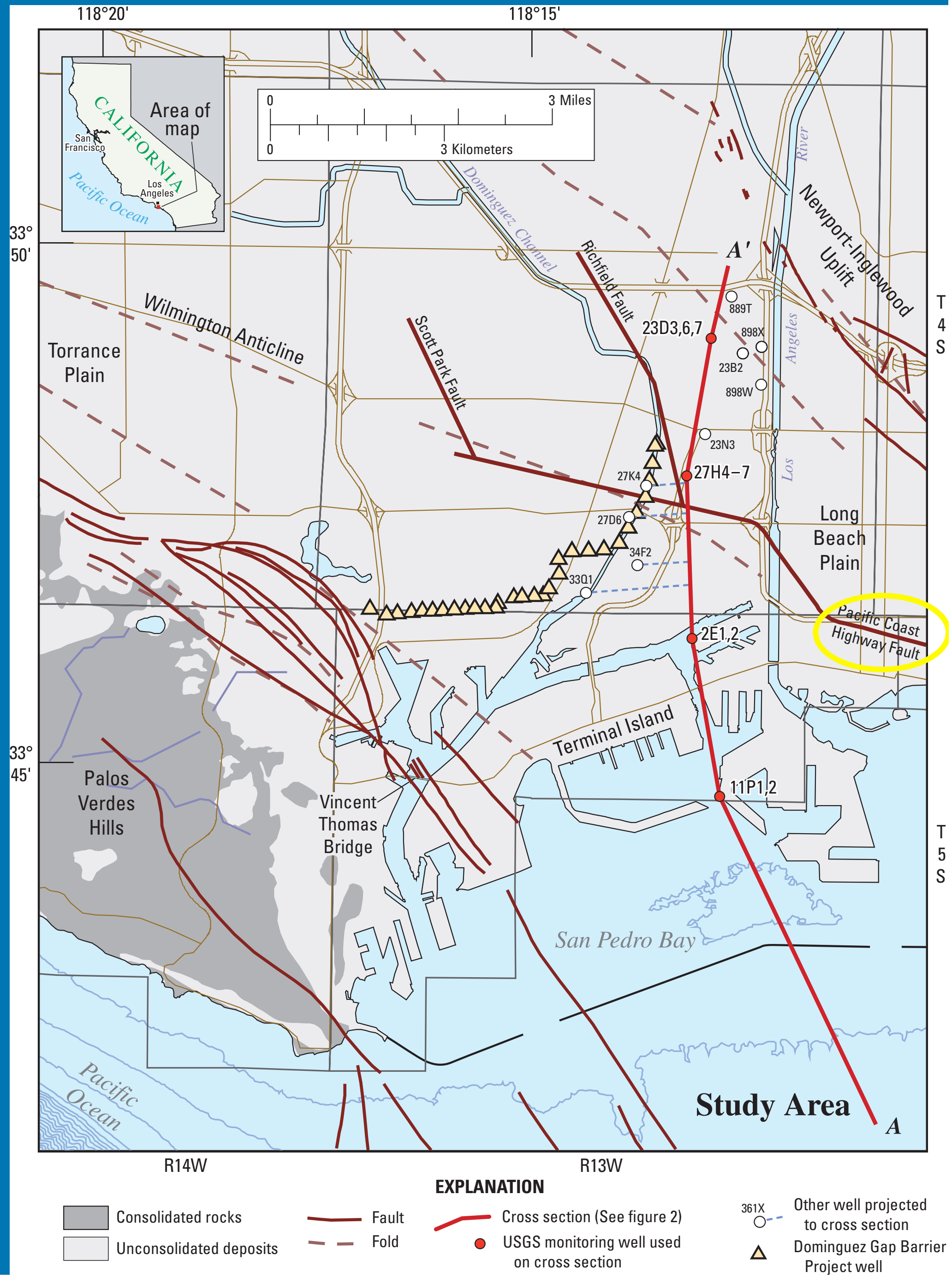
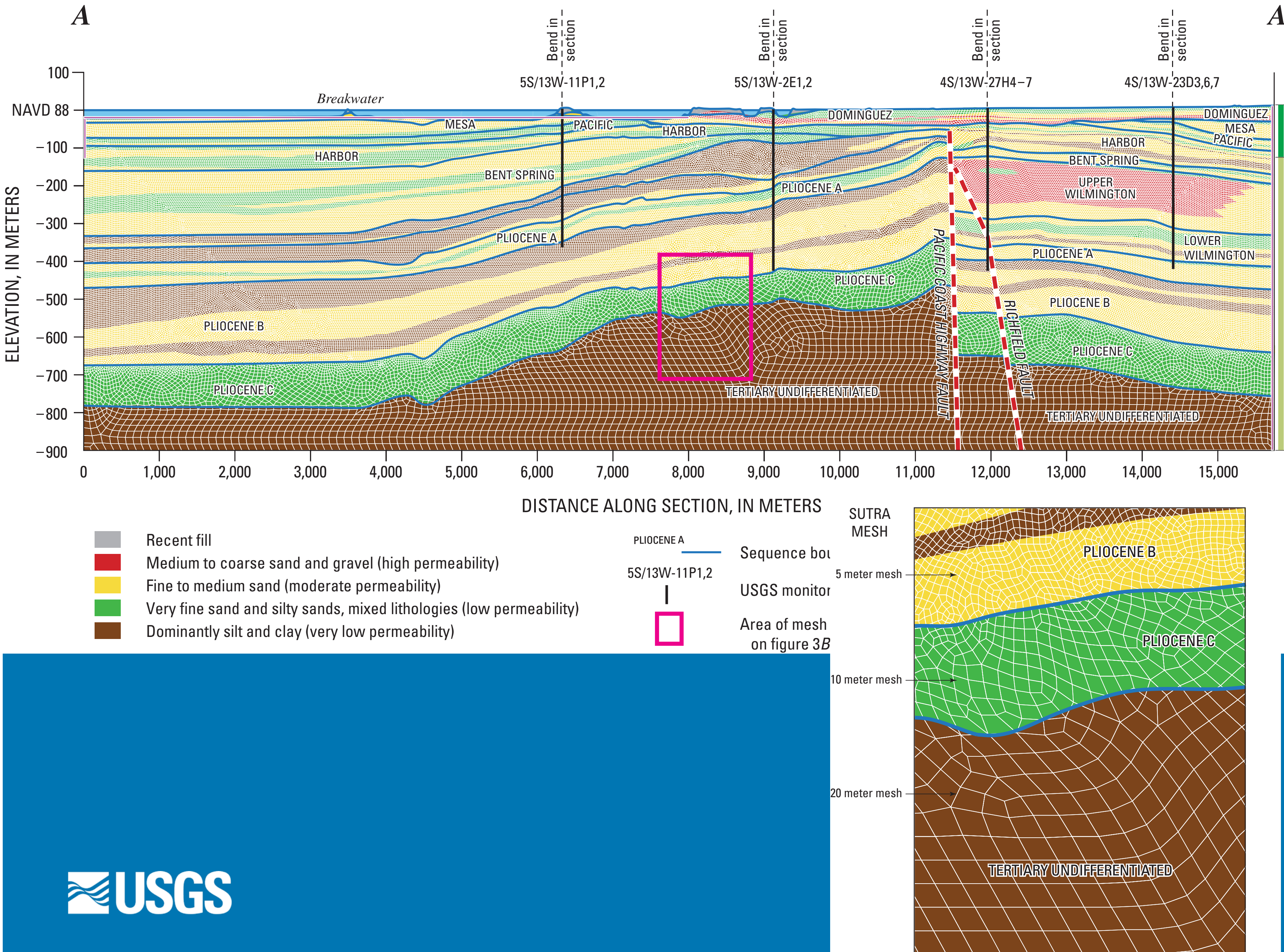
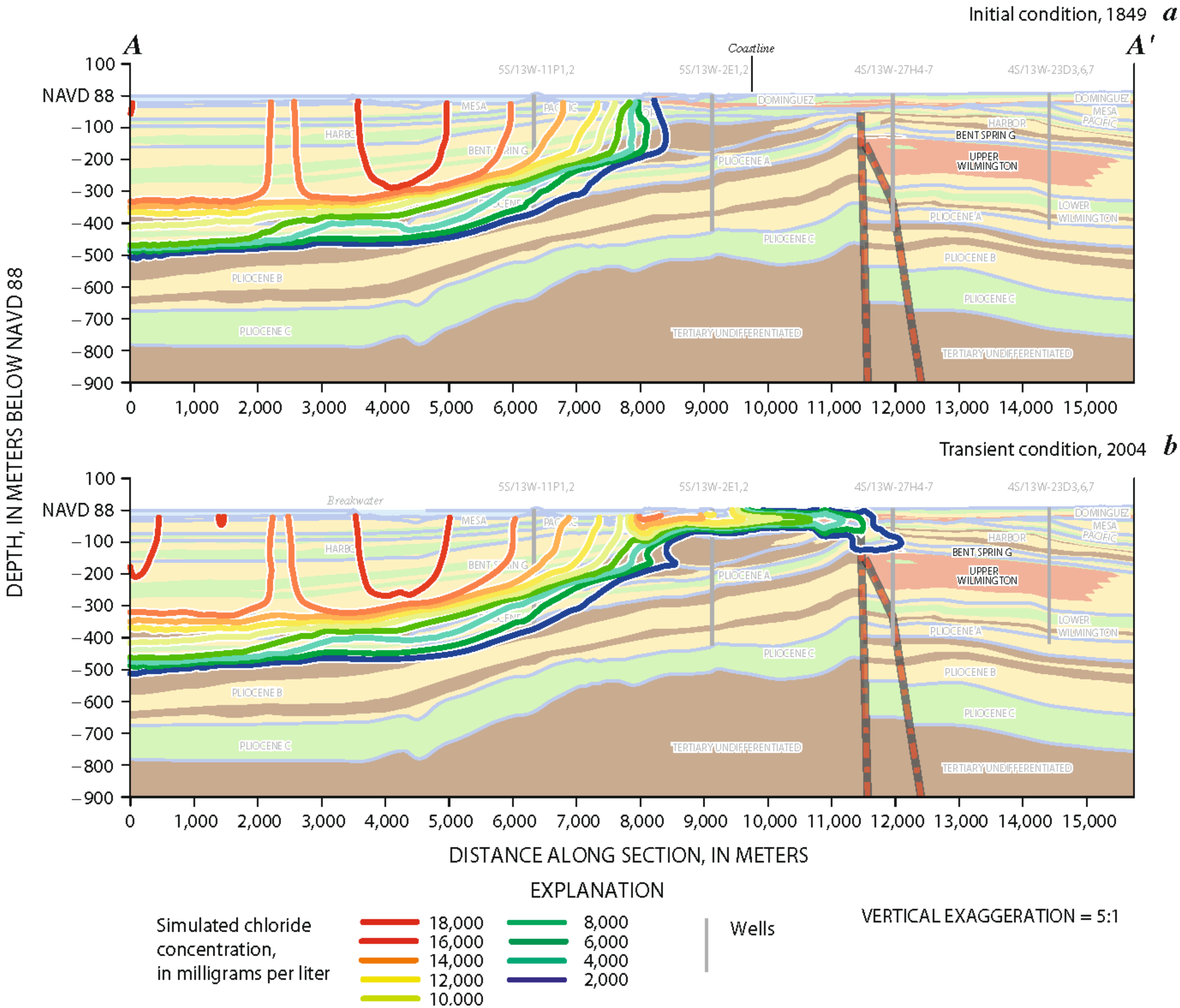
L.A. SUTRA Model



Nishikawa et al., 2009, DOI 10.1007/s10040-009-0481-8



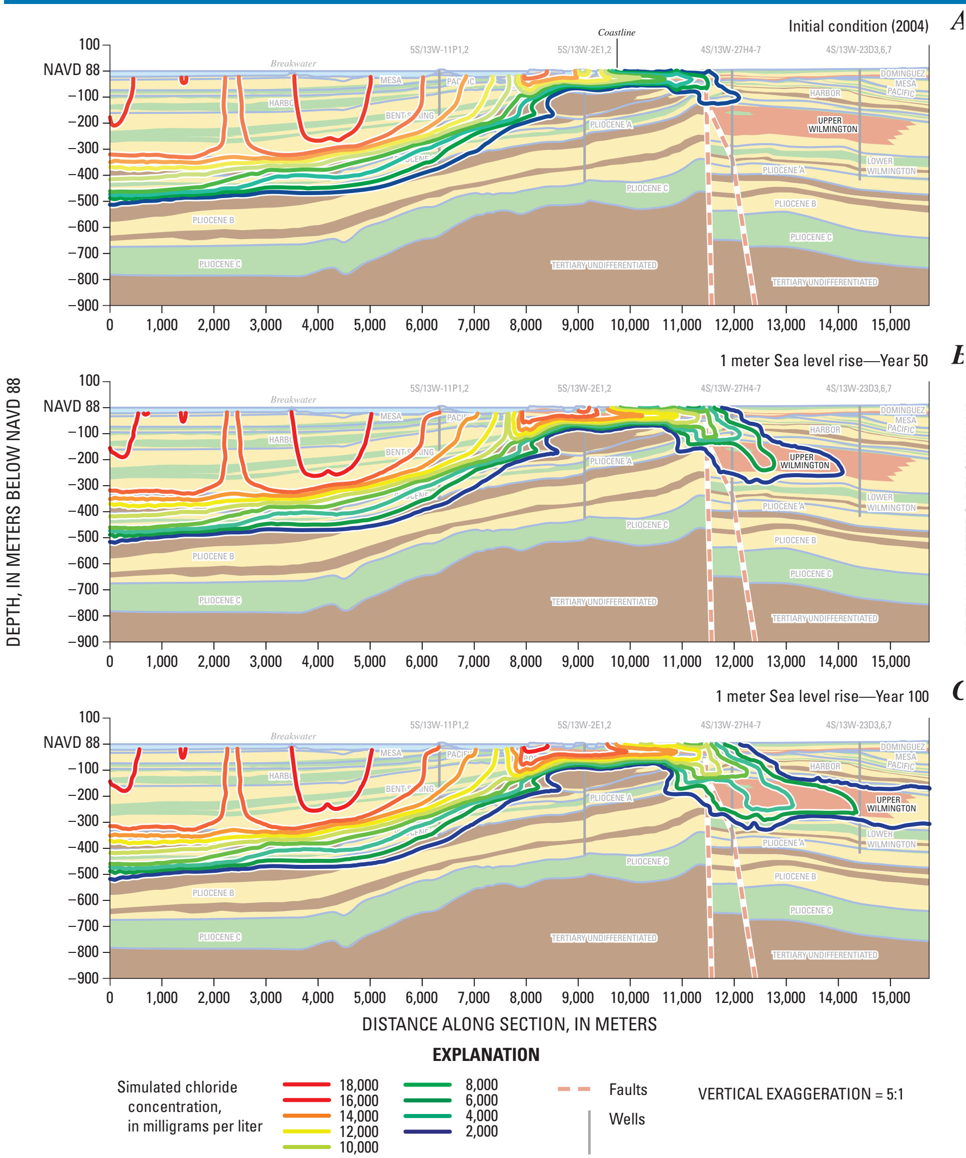
A
A′
Bend in section
5S/13W-11P1,2
5S/13W-2E1,2
4S/13W-27H4–7
4S/13W-23D3,6,7
Breakwater
NAVD 88
ELEVATION, IN METERS
100
−100
−200
−300
−400
−500
−600
−700
−800
−900
MESA
PACIFIC
HARBOR
DOMINGUEZ
BENT SPRING
PLIOCENE A
PLIOCENE B
PLIOCENE C
UPPER WILMINGTON
LOWER WILMINGTON
TERTIARY UNDIFFERENTIATED
PACIFIC COAST HIGHWAY FAULT
RICHFIELD FAULT
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
DISTANCE ALONG SECTION, IN METERS
Recent fill
Medium to coarse sand and gravel (high permeability)
Fine to medium sand (moderate permeability)
Very fine sand and silty sands, mixed lithologies (low permeability)
Dominantly silt and clay (very low permeability)
PLIOCENE A
Sequence bou
5S/13W-11P1,2
USGS monitor
Area of mesh on figure 3B
SUTRA MESH
5 meter mesh
10 meter mesh
20 meter mesh
PLIOCENE B
PLIOCENE C
TERTIARY UNDIFFERENTIATED

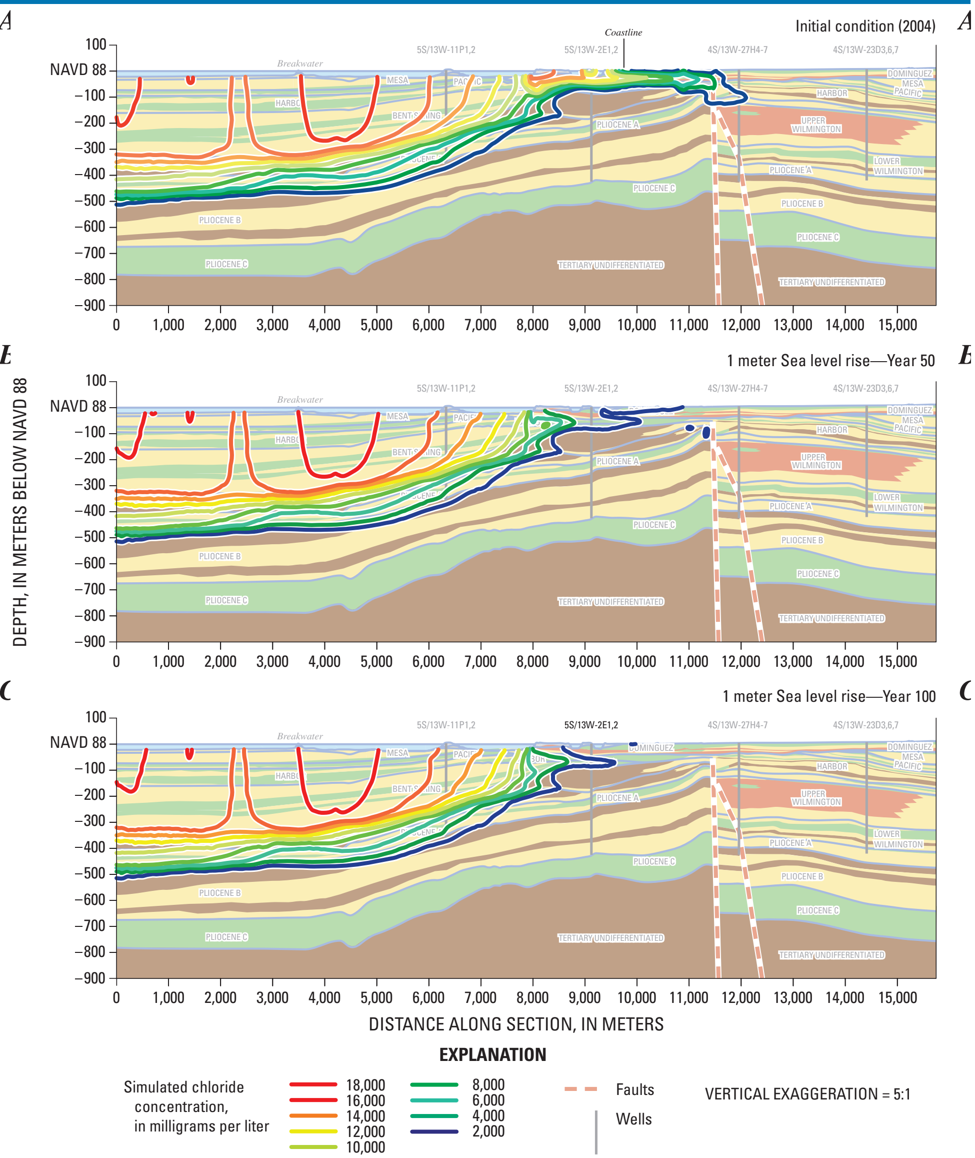


Initial condition, 1849
a
A
A′
Coastline
5S/13W-11P1,2
5S/13W-2E1,2
4S/13W-27H4-7
4S/13W-23D3,6,7
100
NAVD 88
−100
−200
−300
−400
−500
−600
−700
−800
−900
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
DOMINGUEZ
MESA
PACIFIC
HARBOR
BENT SPRING
UPPER WILMINGTON
LOWER WILMINGTON
PLIOCENE A
PLIOCENE B
PLIOCENE C
TERTIARY UNDIFFERENTIATED
Transient condition, 2004
b
Breakwater
DEPTH, IN METERS BELOW NAVD 88
DISTANCE ALONG SECTION, IN METERS
EXPLANATION
Simulated chloride concentration, in milligrams per liter
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
Wells
VERTICAL EXAGGERATION = 5:1

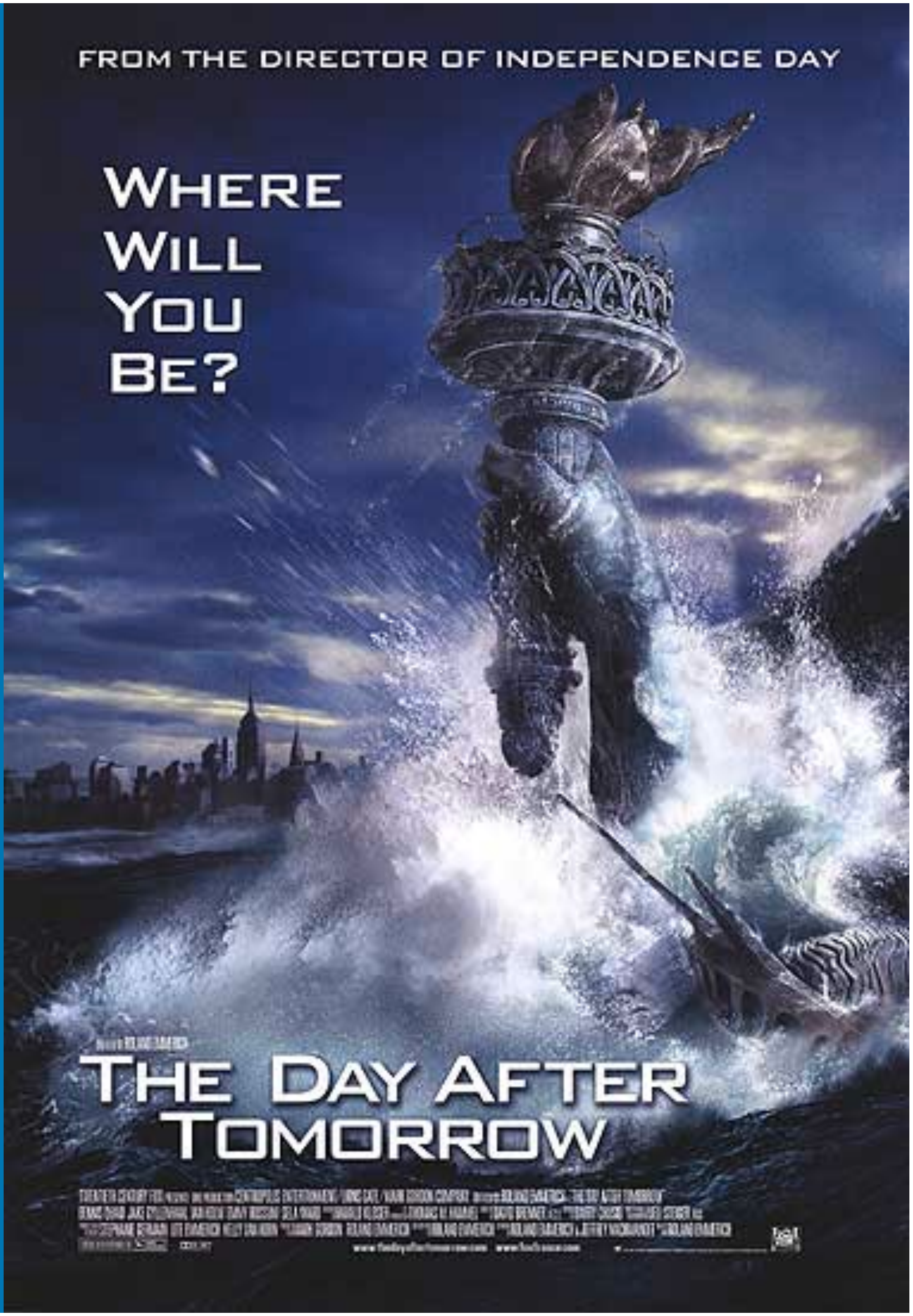
1-m SLR

1-m SLR+8-m inland head





Questions?



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