

# Potential effects of sea-level rise on energy infrastructure in the Sacramento-San Joaquin Delta

John Radke<sup>1,2,4</sup> & Greg Biging<sup>3</sup>

<sup>1</sup> Landscape Architecture and Environmental Planning

<sup>2</sup> City and Regional Planning

<sup>3</sup> Environmental Science Policy & Management

<sup>4</sup> Center for Catastrophic Risk Management

Howard Foster<sup>4</sup>, Emery Roe<sup>4</sup>, Martine Schmidt-Poolman<sup>4</sup>,  
William Fourt<sup>1</sup>, Wei-Chen Hsu<sup>1</sup>, Uriel Garcia<sup>4</sup> and Ben Wheeler<sup>3</sup>

California Energy Commission

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University of California, Berkeley



# Assessment of Bay Area Gas Pipeline Vulnerability to Climate Change

John Radke<sup>1,2,4</sup> & Greg Biging<sup>3</sup>

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# The Pipelines we are looking at:

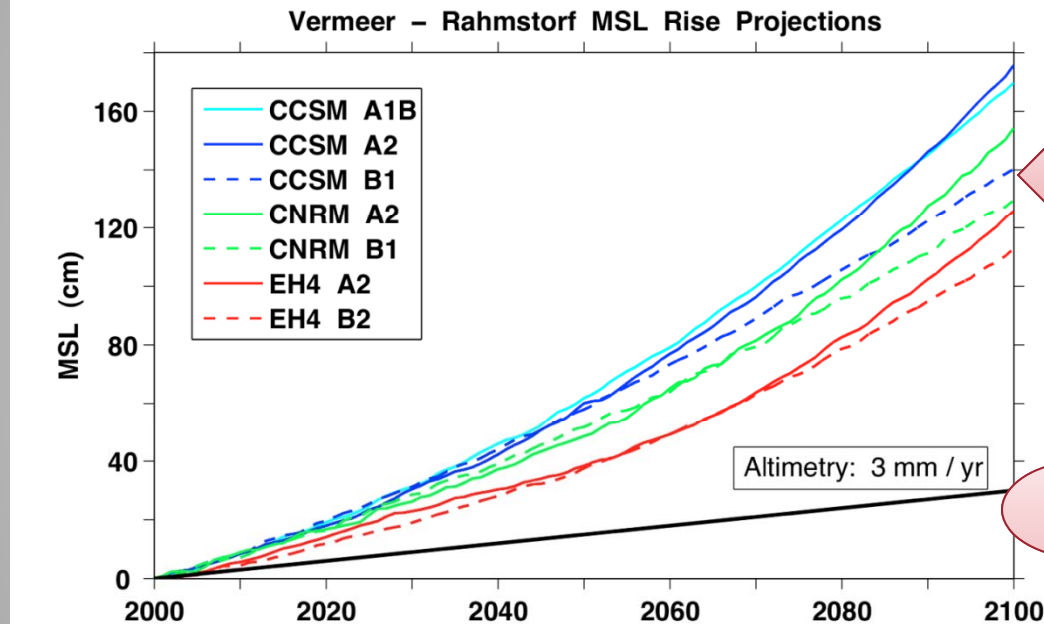


## Transmission Pipelines in the National Pipeline Mapping System (NPMS)

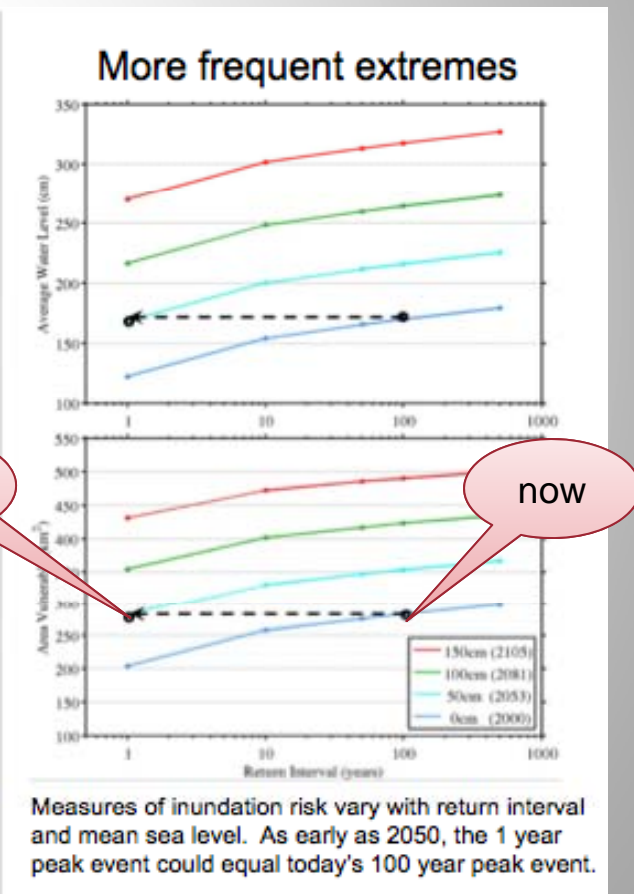
- Natural Gas Pipelines
  - Mainly methane
  - Most of the intra-state pipelines in CA that are regulated by CPUC
- Hazardous Liquid Pipelines
  - Crude oil, petroleum products, anhydrous ammonia etc.
  - In CA (intra-state and inter-state) safety is regulated by Office of the State Fire Marshall.
- Pipelines can be “gathering”, “transmission” or “distribution”
  - Sizes vary
  - Pressure under which product is transported also varies

# Global circulation models: The Crisis

... global change.



(Source) Bromirski, P. D., D. R. Cayan, N. Graham, R. E. Flick and M. Tyree (Scripps Institution of Oceanography). 2012. Coastal Flooding Potential-Projections 2000–2100. California Energy Commission. CEC-500-2012-011





# Data: Surface Model

Lidar → DEM & DSM

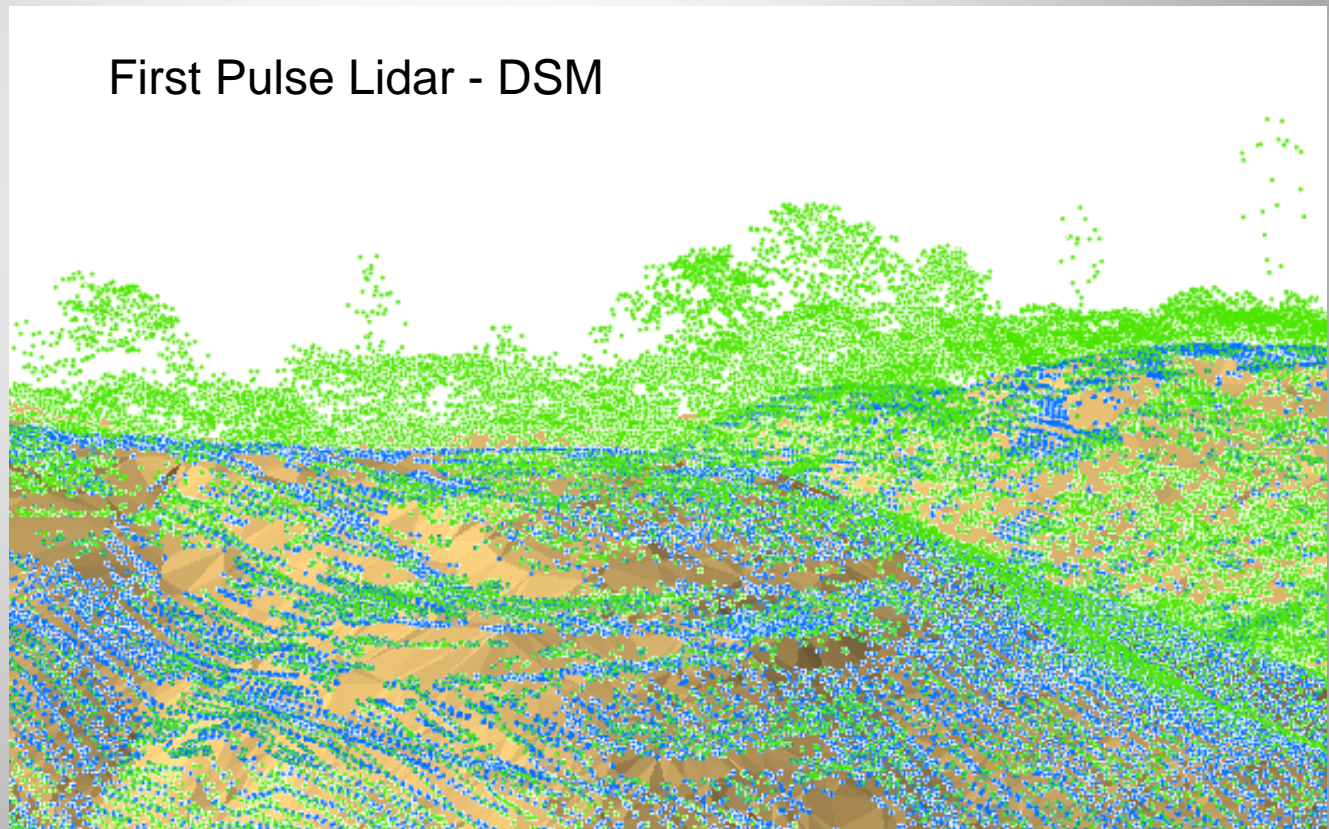
LiDAR data

DEM

DSM



First Pulse Lidar - DSM

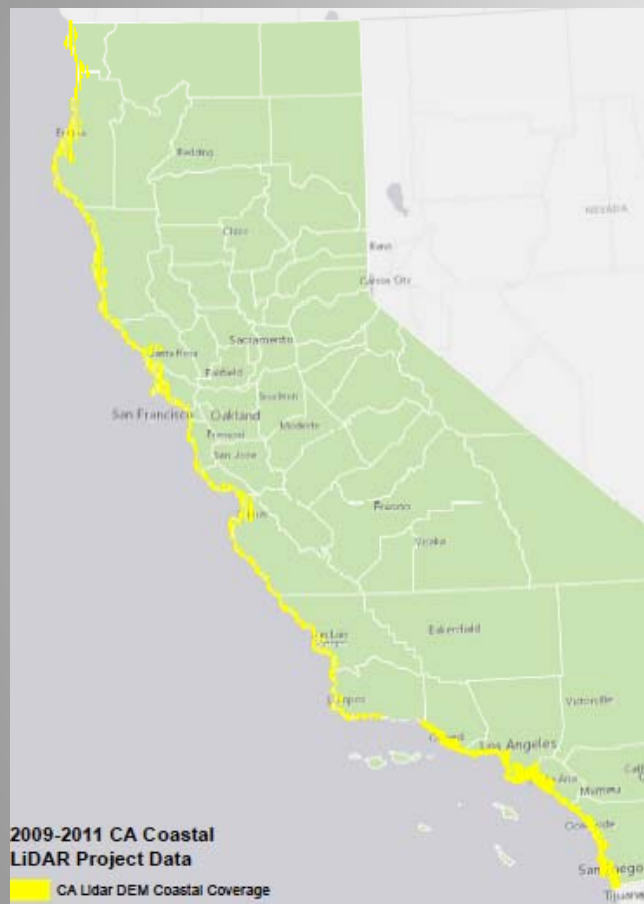


# Lidar Coverage:

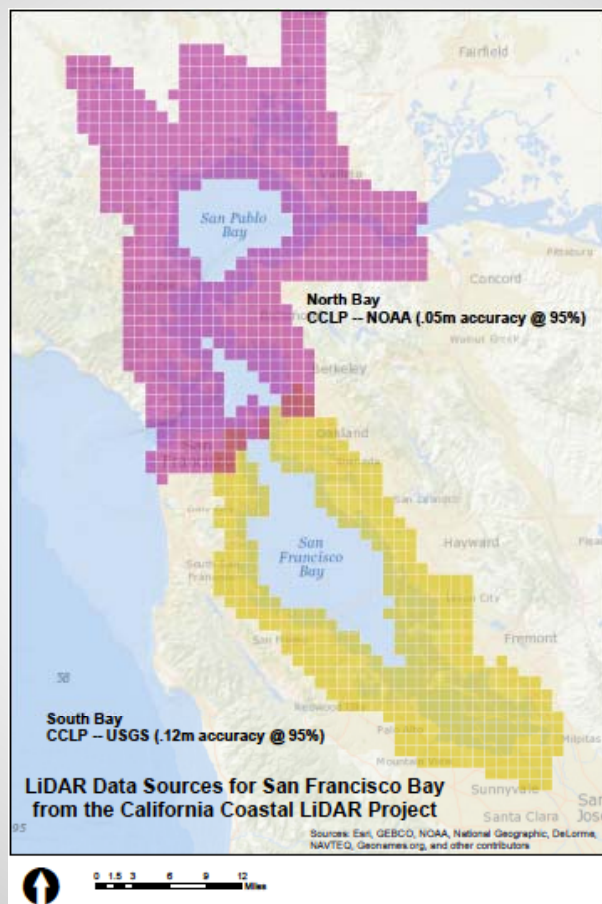
– California Coast

– SF Bay

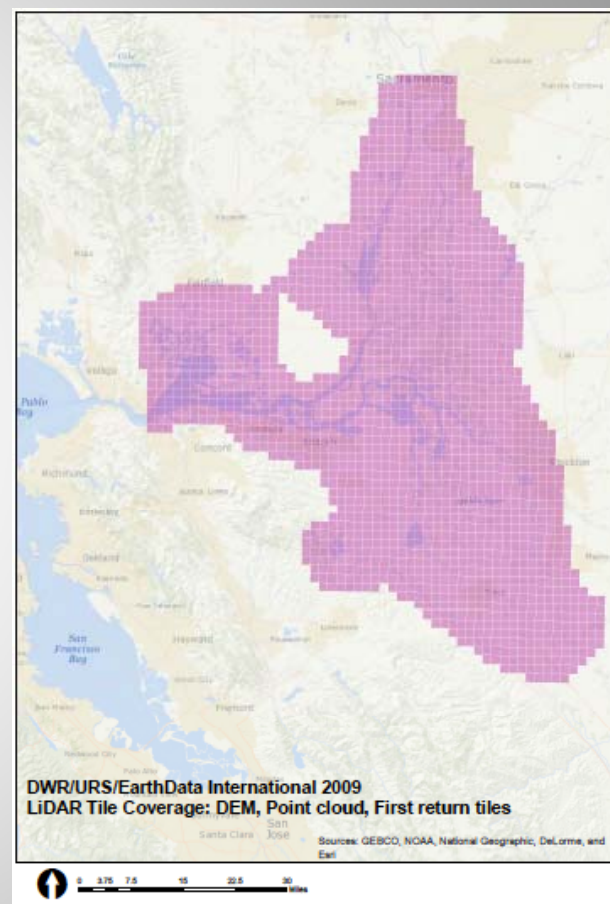
– Sacramento-San Joaquin Delta



NOAA California Coastal LiDAR project



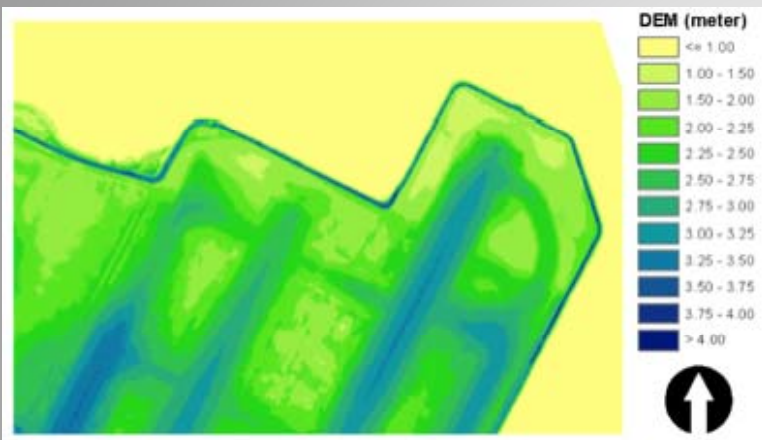
USGS California Coastal LiDAR Project



DWR Delta LiDAR Project



# Lidar → DEM - an illustration of the resolution of our study



a. Source: CEC-500-2012-040

An Example of the DEM: San Francisco International Airport. (a) Detailed view of the DEM for SFO, (b) the overview of the area (Google Earth), and (c) an oblique view (Google Earth) of a retaining structure at SFO pointed to in (b). The elevation data set is referenced to NAVD88 vertical datum.



b. Source: Google Earth



c. Source: Google Earth

# Data: Pipelines



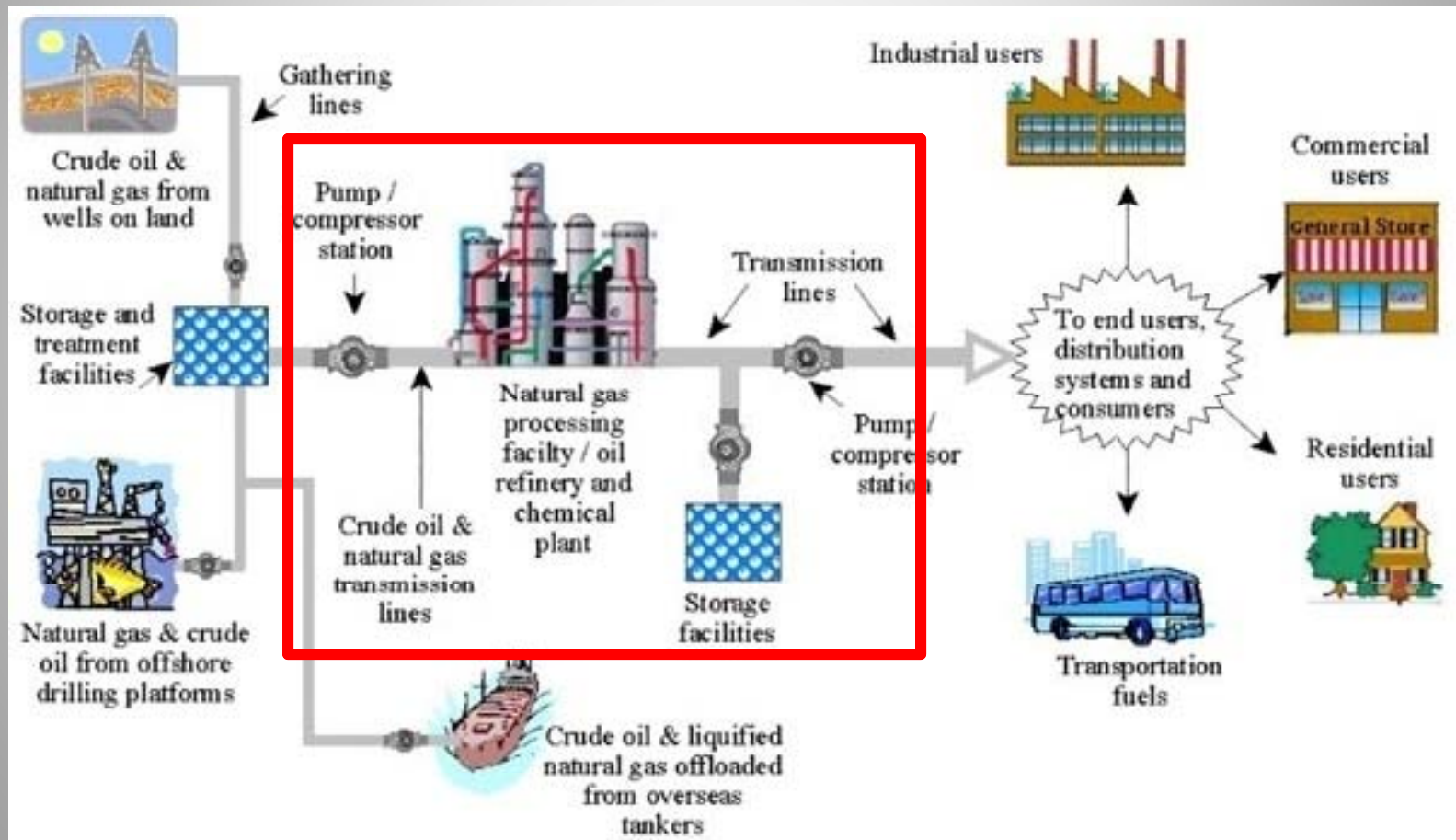
## NPMS: National Pipeline Mapping System

- Pipeline and Hazardous Materials Safety Administration (PHMSA)
- Pipeline operators required annually to review NPMS data (Dec 31)
- Data:
  - Updated in March (by repository staff – Michael Baker Jr. Corp.)
  - Gives data of natural gas and hazardous liquid trunk lines (transmission), does not contain distribution or gathering pipeline information.
  - Part of data is relevant for mapping purposes, part gives detailed information about a specific pipeline.



# In the World of Pipeline Infrastructure ...

The NPMS data base contains only part of the following diagram ...



# California pipelines from NPMS data base



PACIFIC GAS & ELECTRIC CO

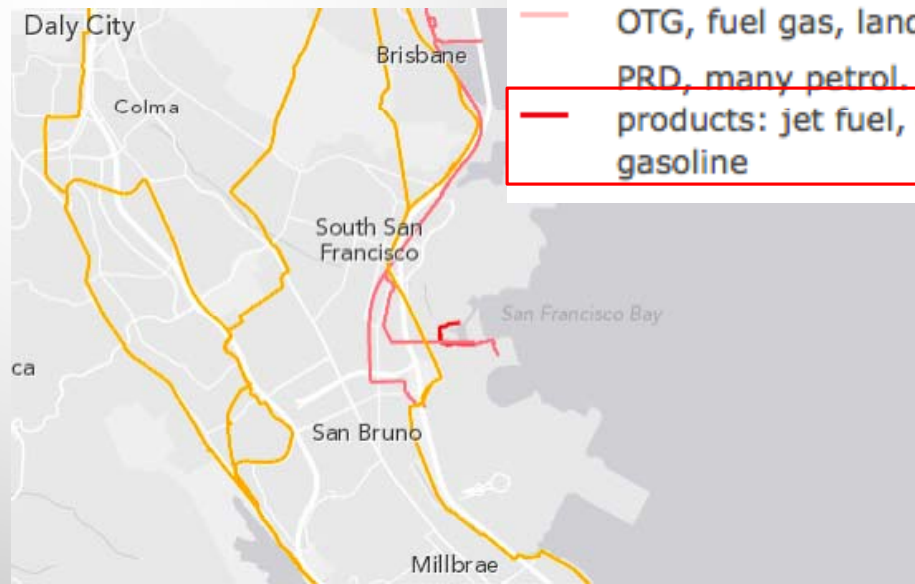
SOUTHERN CALIFORNIA GAS CO



# Pipeline Infrastructure: SF Bay Region



SF Bay Area



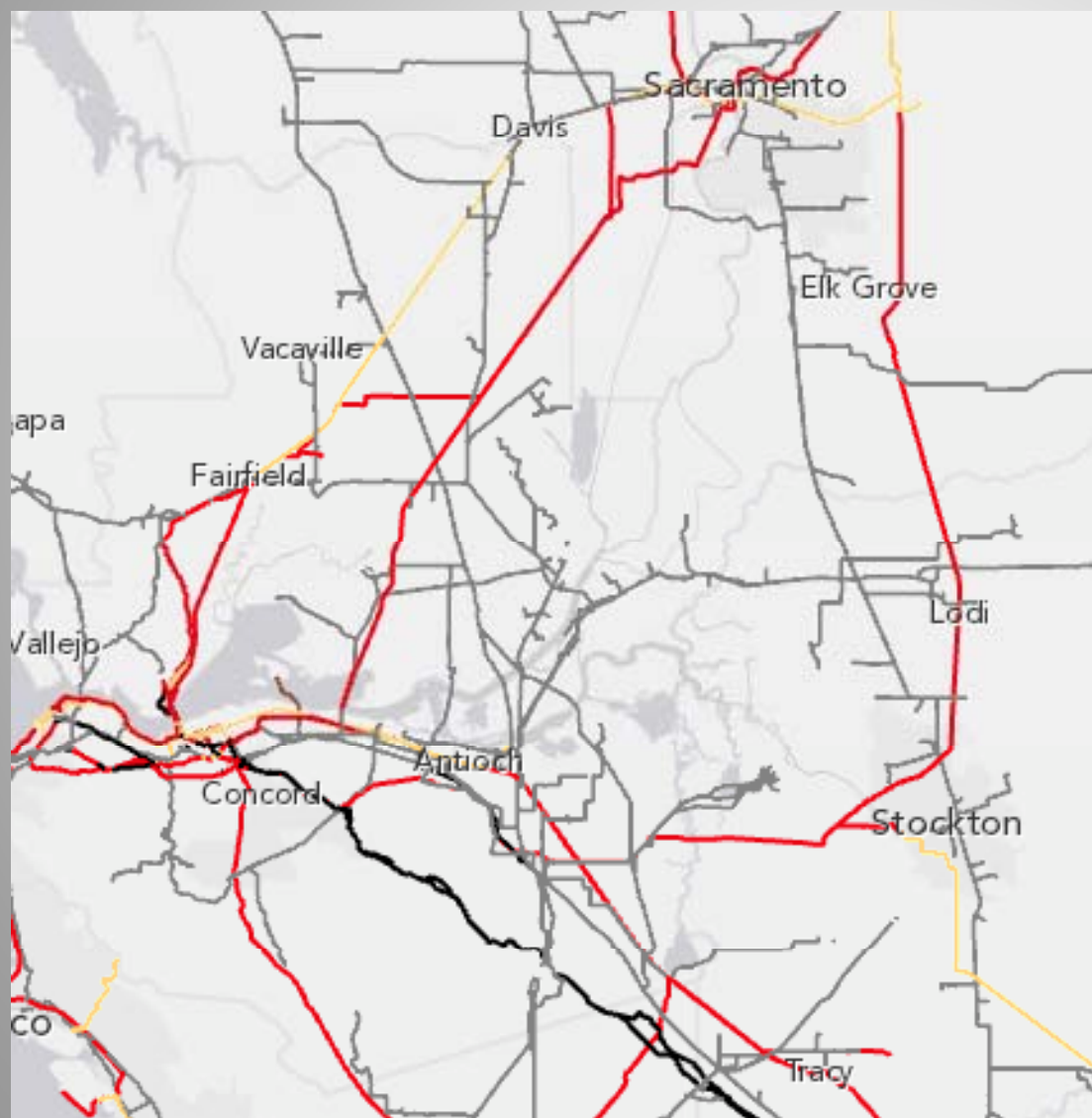
SFO Airport, for example

## NPMS transmission pipelines

- ul style="list-style-type: none; padding-left: 0;">
- CRD, e.g., crude oil
- EPG, empty gas
- EPL, misc. empty liquid
- ETH, ethanol
- HG, hydrogen
- HVL, butane, propane
- LPG, liquid petroleum gas
- NG, natural gas
- NGL, produced liquids
- OHV, propane
- OTG, fuel gas, landfill gas
- PRD, many petrol
- products: jet fuel, diesel, gasoline



# Pipeline Infrastructure in Sacramento-San Joaquin Delta



## NPMS transmission pipelines

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- products: jet fuel, diesel, gasoline

# Pipeline Infrastructure in Sacramento-San Joaquin Delta

— NG, natural gas

Sherman Island



McDonald Island

# Pipelines: a typical record in the NPMS database

## Identify

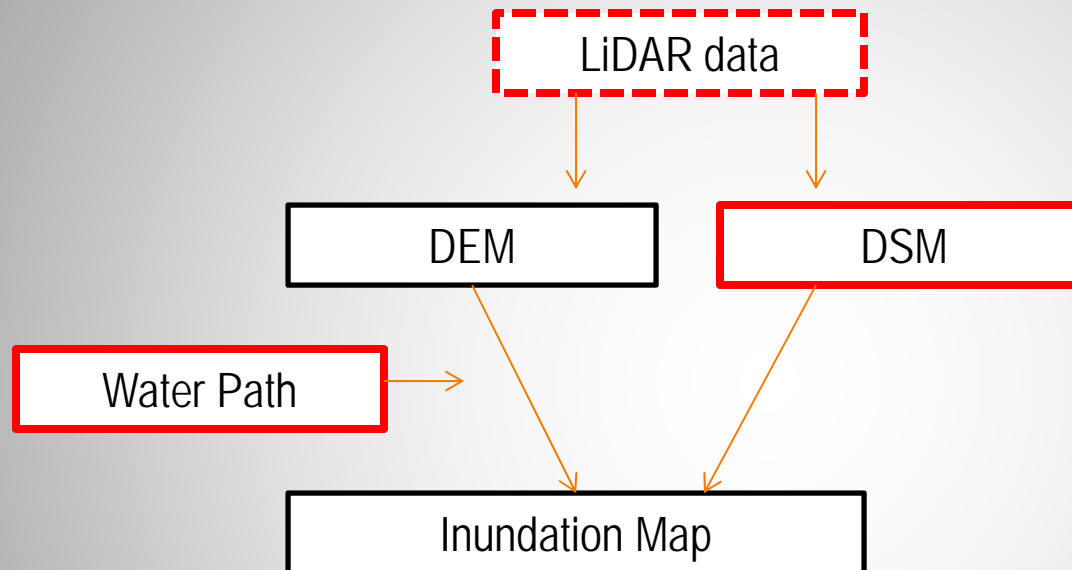
FID: 223  
objectid: 4038  
opid: 18092  
oper\_nm: SFPP, LP  
sys\_nm: SFPP\_NORTH  
subsys\_nm: LS-8; RICHMOND -  
**CONCORD 8"**  
pline\_id: 485008RMCC  
diameter: 8.63  
miles: 22.40301  
commodity: PRD  
cmdty\_dtl1:  
cmdty\_dtl2:  
cmdty\_dtl3:  
cmdty\_desc: MULTI-PRODUCTS  
interstate: Y  
low\_stress: N  
status\_cd: I  
quality\_cd: V  
revis\_cd: B  
sub\_date: 6/14/2012  
revis\_date: 6/14/2012  
submit\_id: 18092-0017  
cnty\_fips: 06013  
cnty\_mixed: Contra Costa  
st\_fips: 06  
st\_mixed: California  
os\_yn: NO  
st\_length\_: 46708.191433

## NPMS Attributes:

- Required by operators to submit:
  - Operator ID
  - System Name (syst\_nm)
  - Pipeline ID (pline\_id)
  - Commodity (PRD here = petroleum product)
  - Interstate designation
  - Status of segment
  - Quality of positional accuracy (quality\_cd)
- Also includes meta data information, examples:
  - Metadata file name
  - Date on which NPMS received data
  - Date on which NPMS received notice of update or change in data



# Inundation Pathway



# Comparison of 2 methods for estimating inundation with a DEM and DSM

Overestimation of inundation with a 2.0 m (water Level) using a bathtub model

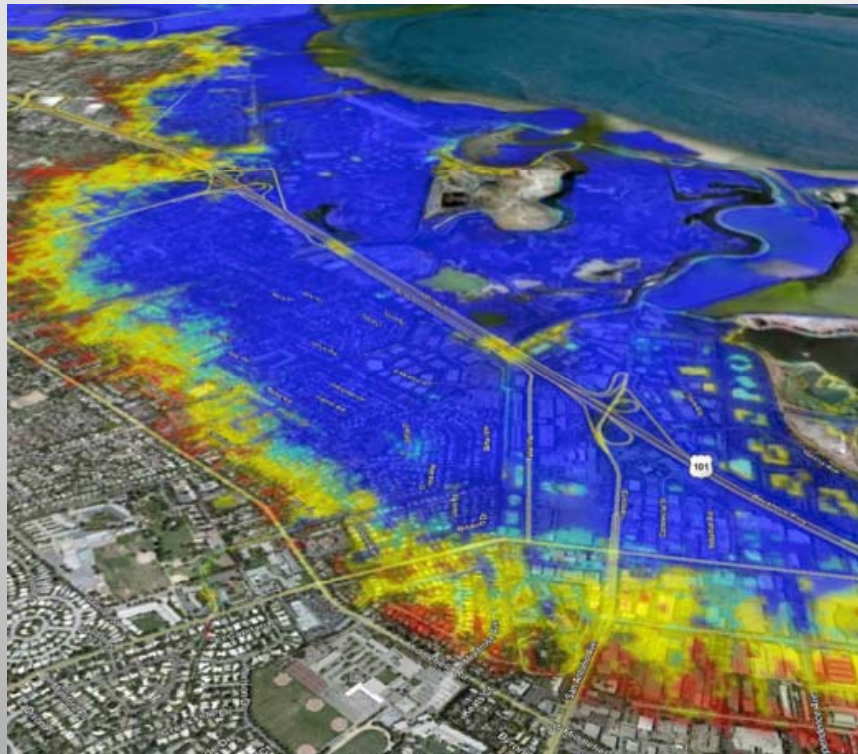


Improvement of inundation estimation with a 2.0 m (water level) with water pathway model



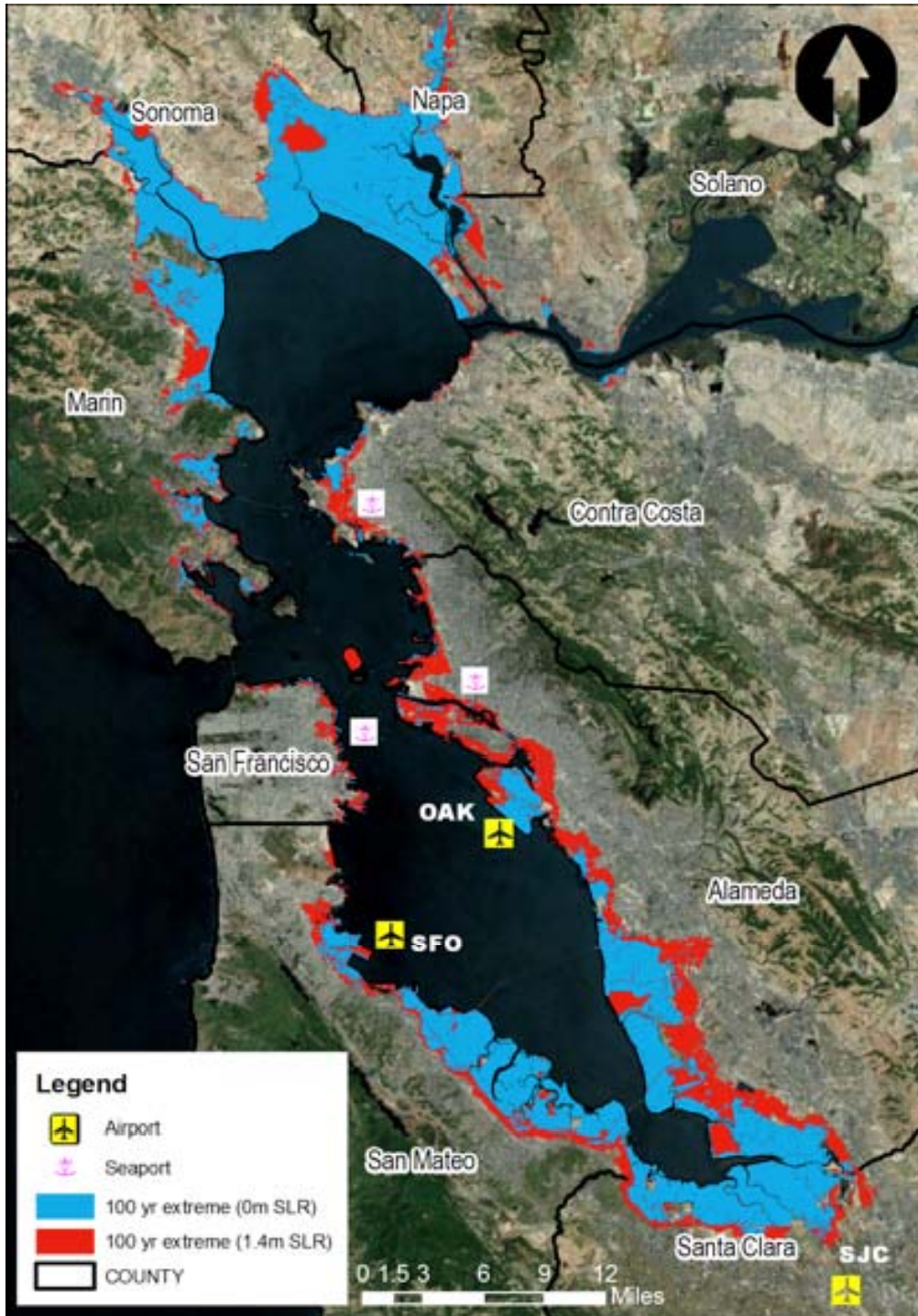
$$PWL_x = SLR_x + ESE_{100}$$

- We model four sea-level rise ( $SLR_x$ ) increments {x: 0 m, 0.5 m, 1.0 m or 1.4 m}
- to which we add the 100-year extreme storm event ( $ESE_{100}$ )
- without sea-level rise and then with sea-level rise





# SF Bay Area Inundation Results



  $SLR_0 + ESE_{100}$

  $SLR_{1.4} + ESE_{100}$

# The Delta Inundation Process → the Dynamics are Different

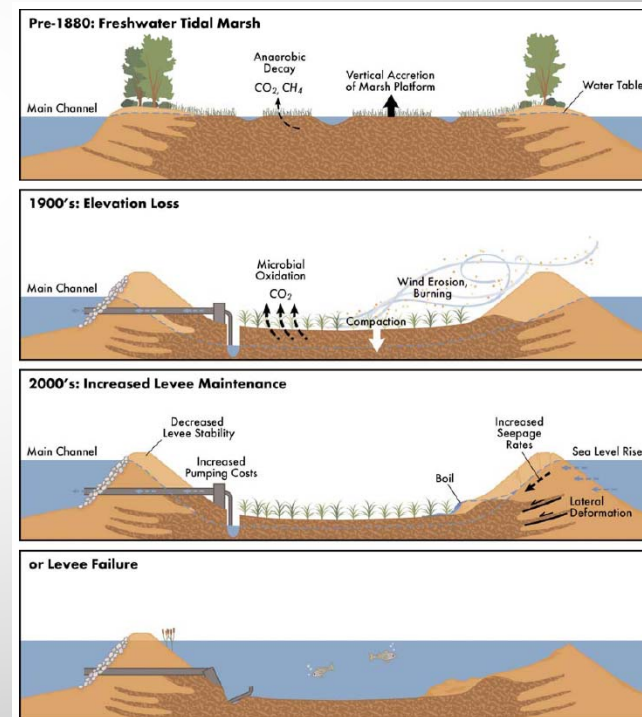
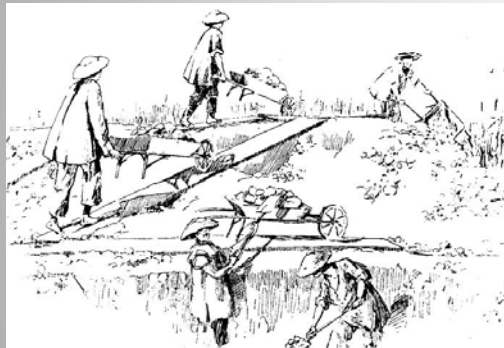


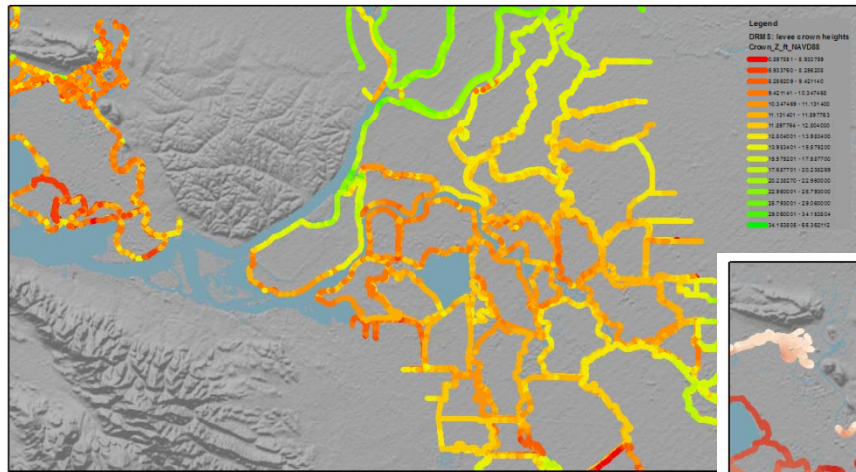
Figure 2. Conceptual diagram illustrating evolution of Delta islands due to levee construction and island subsidence. Modified from Ingebritsen et al. (2000).

(Source) Mount, J.F. and R. Twiss (2005), "Subsidence, sea level rise, seismicity in the Sacramento-San Joaquin Delta," San Francisco Estuary and Watershed Science, v. 3, article 5, 2005.

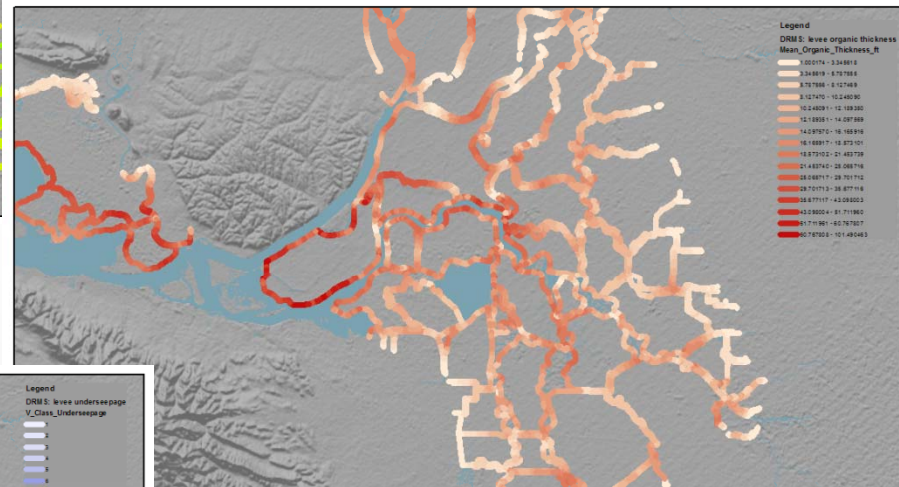


# Levee issues

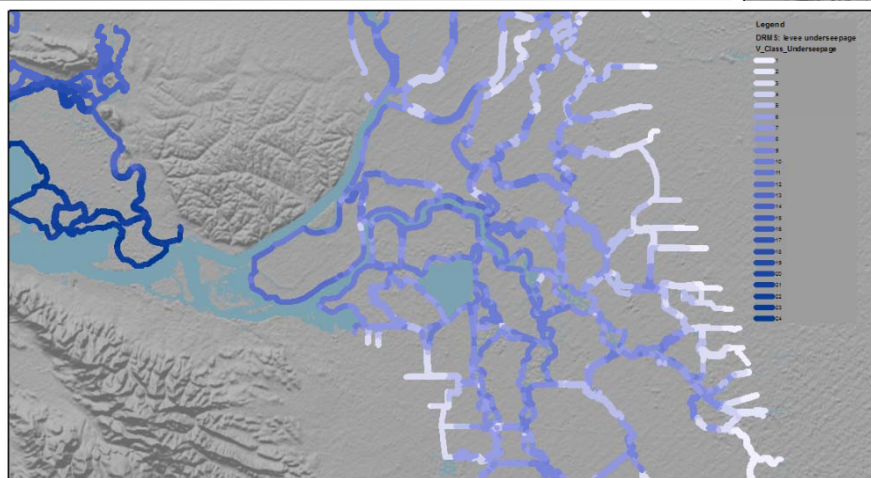
# 1100 miles of levees



## Levee heights (freeboard)



# Organic materials



## Under seepage

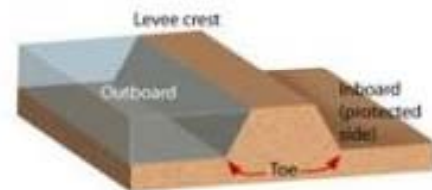


# Island Levee: incremental construction, seepage, subsidence

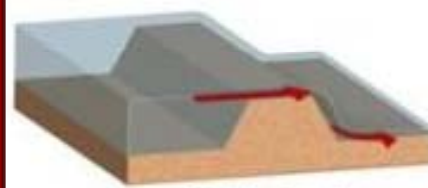


(Source) RESIN Research Group, UC Berkeley

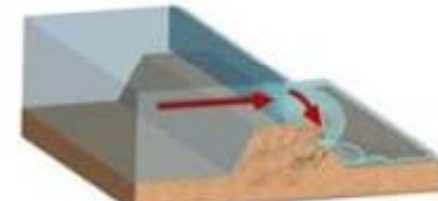
# Levee Failure Modes



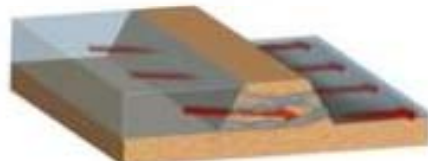
Anatomy of a levee



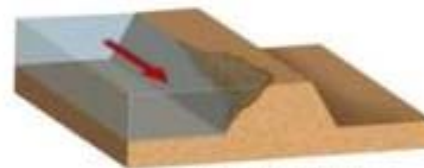
1a. Overtopping



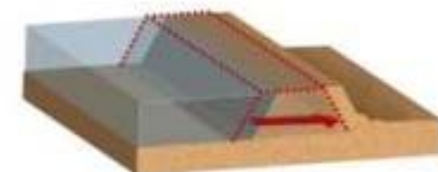
1b. Overtopping/Jetting



2. Internal Erosion/Piping



3. Surface Erosion



4. Sliding



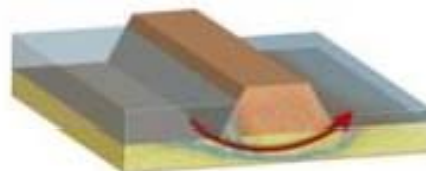
5. Wave Impacts



6. Structural Impacts



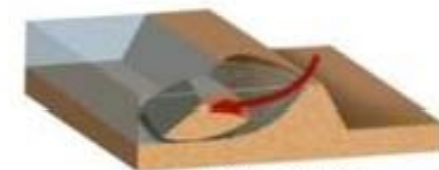
7. Liquefaction



8. Piping of substratum



9. Tree damage



10. Slope failure

(Source) <http://www.cnn.com/2008/US/weather/06/19/levee.explainer/index.html>



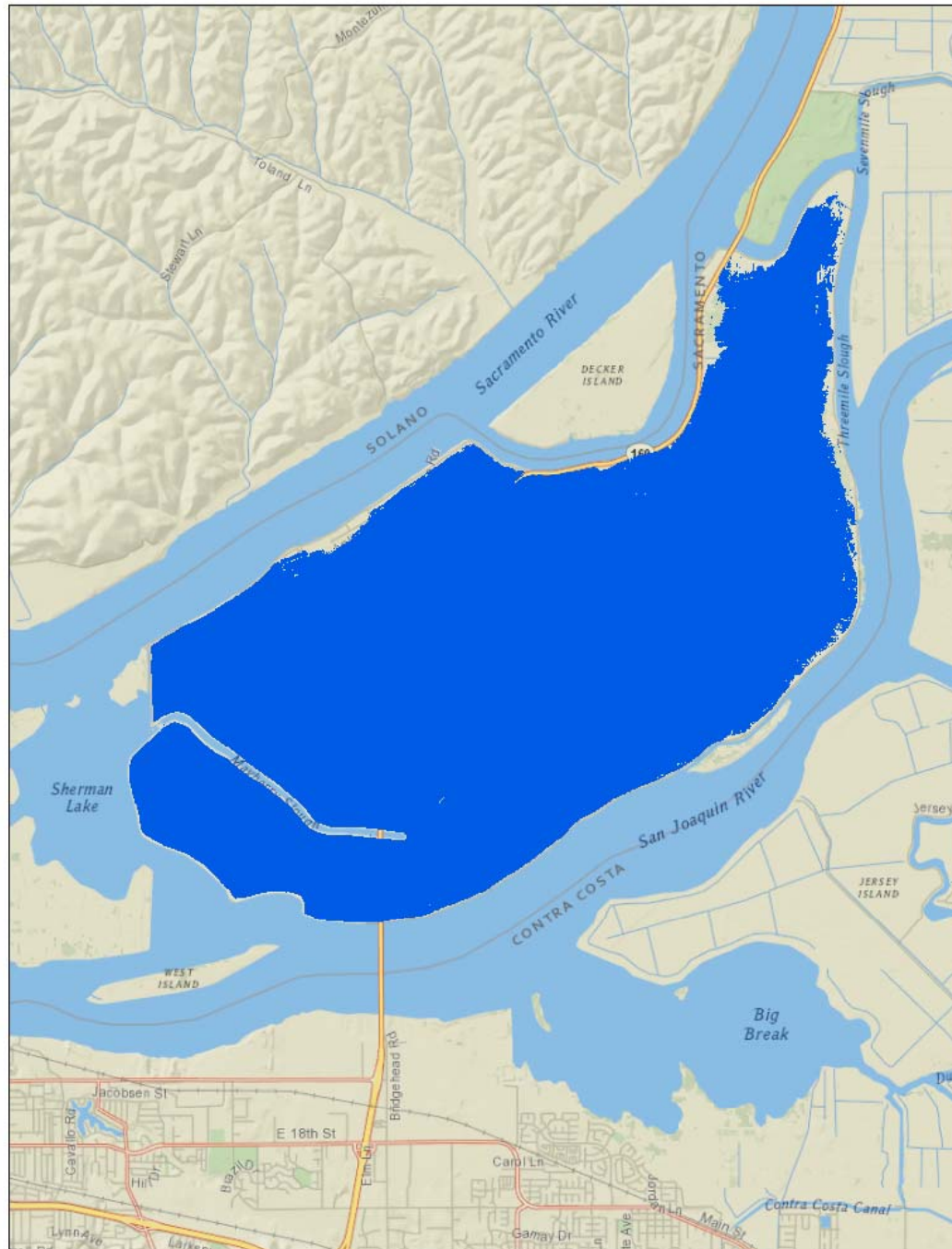
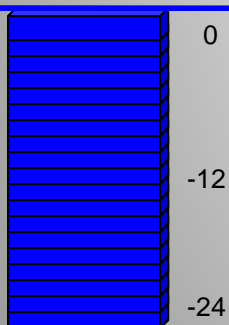
# Problem Amplification



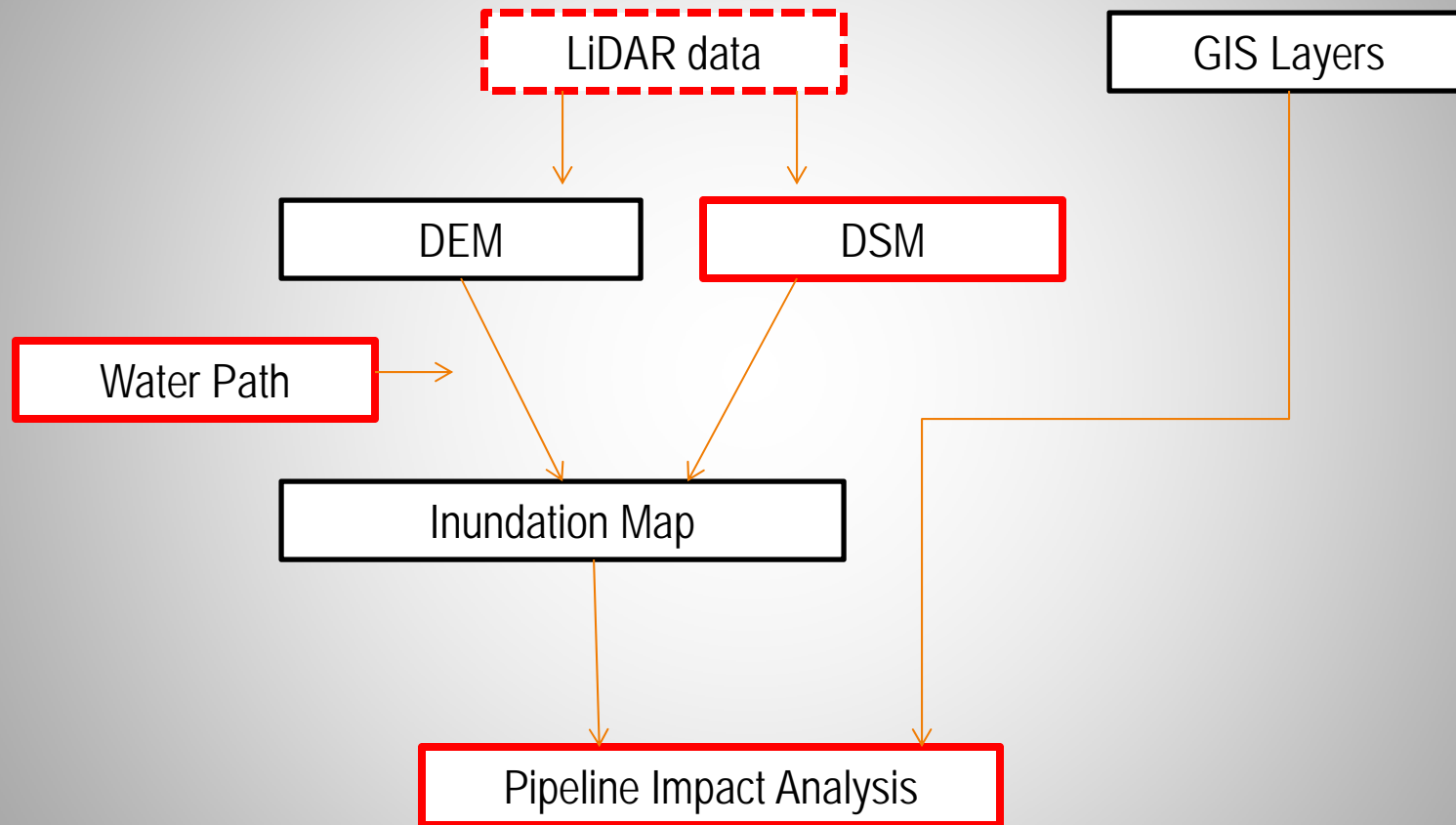


# Inundation Delta Islands

Flooding scenario  
Sherman Island

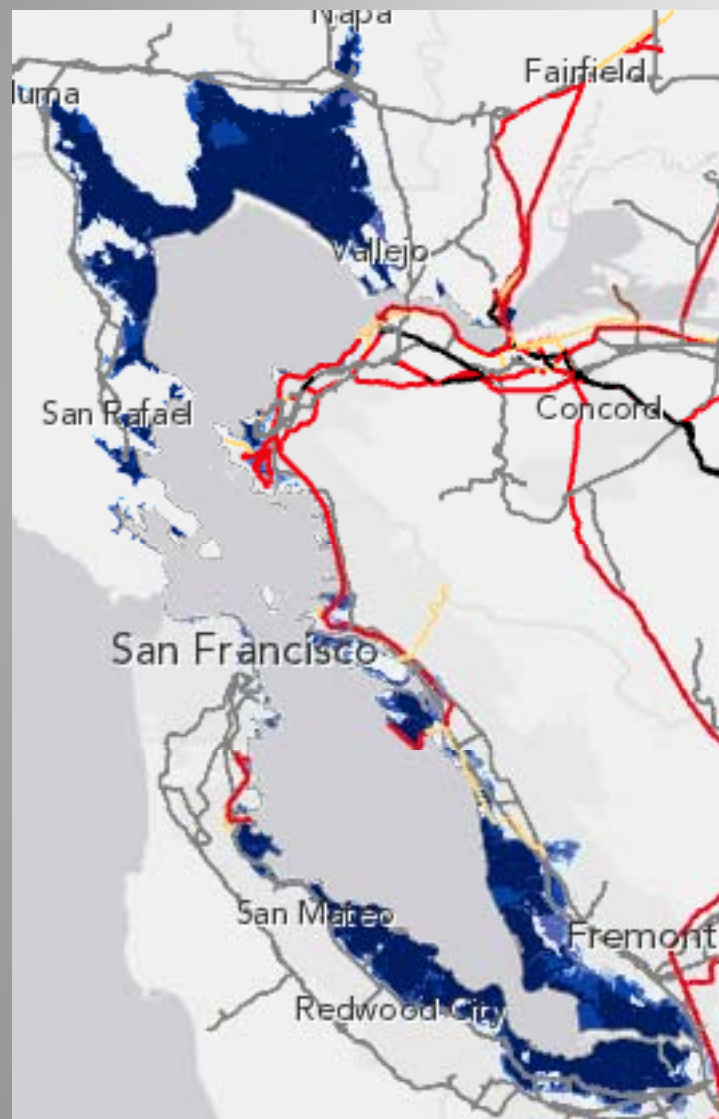


# Analysis pathway



# Results to date:

## Impacted Pipeline in SF Bay Region



### NPMS transmission pipelines

- CRD, e.g., crude oil
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- OTG, fuel gas, landfill gas
- PRD, many petrol.
- products: jet fuel, diesel, gasoline

### Bay Area outline



100-year storm surge only



Surge plus 0.5m SLR



Surge plus 1.0m SLR



Surge plus 1.4m SLR



## Impacted Pipeline in SF Airport Region

San Bruno

San Francisco Bay

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### Bay Area outline



100-year storm surge only



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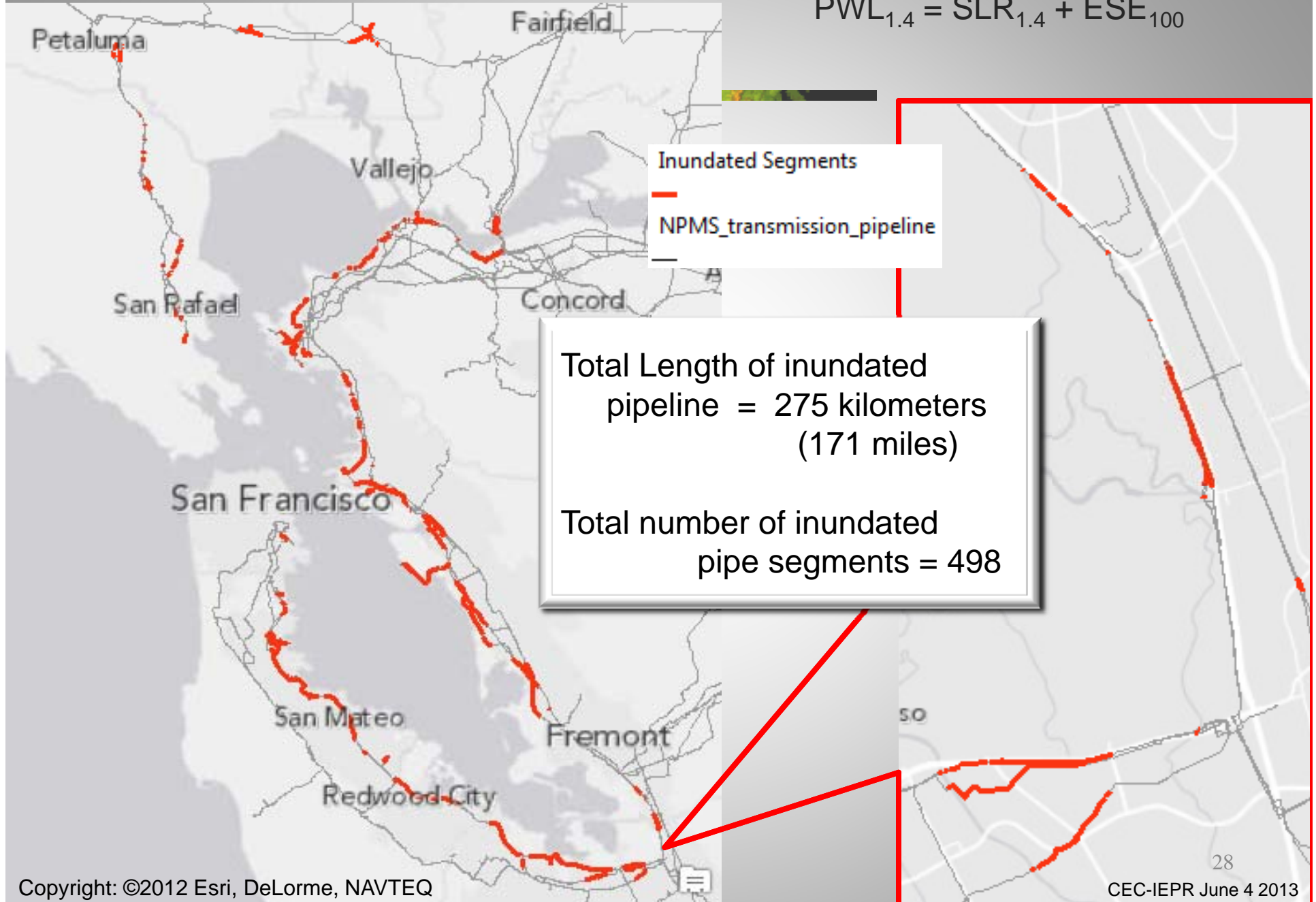
Surge plus 1.0m SLR



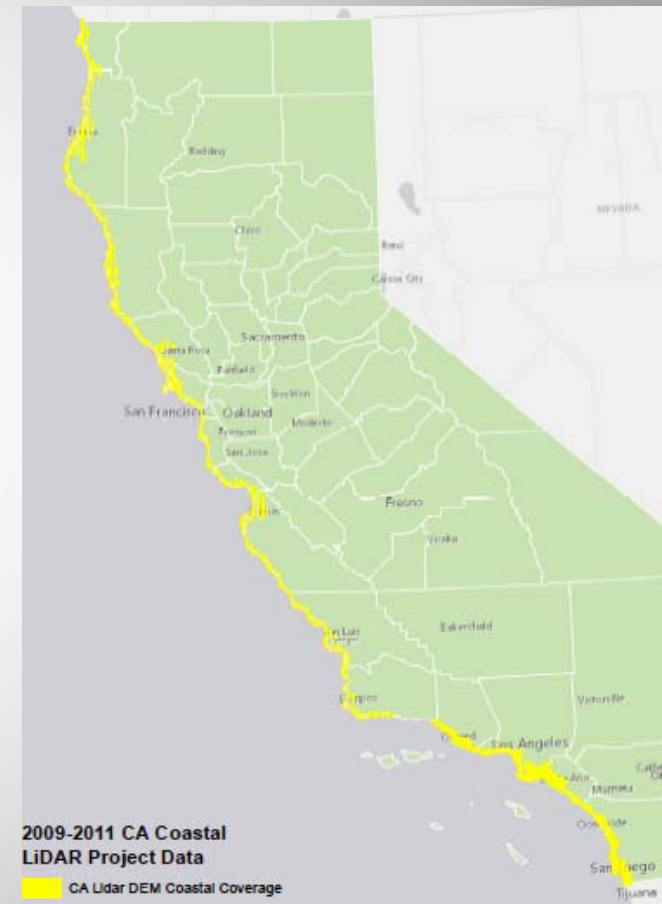
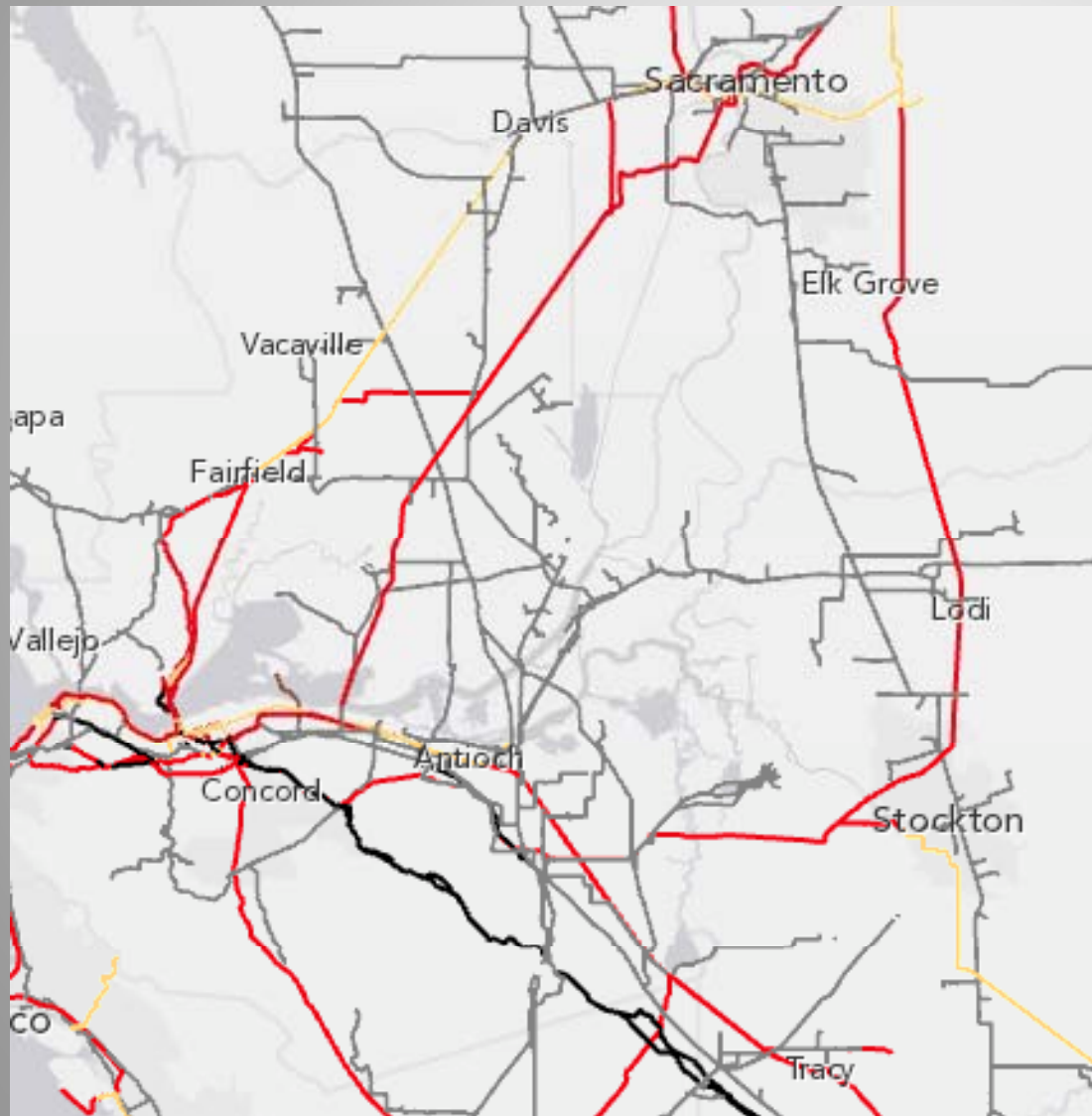
Surge plus 1.4m SLR



# Inundated Pipeline in SF Bay Region



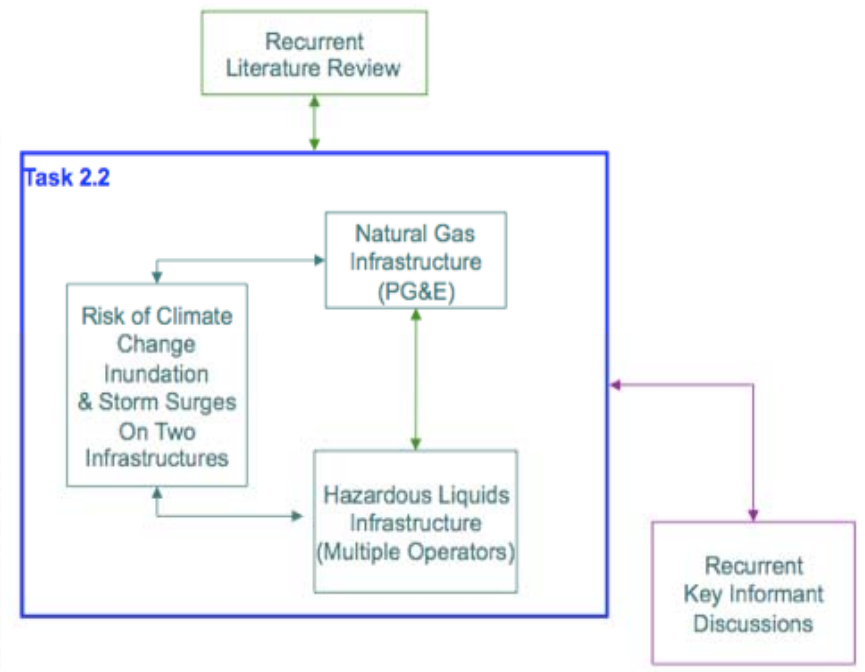
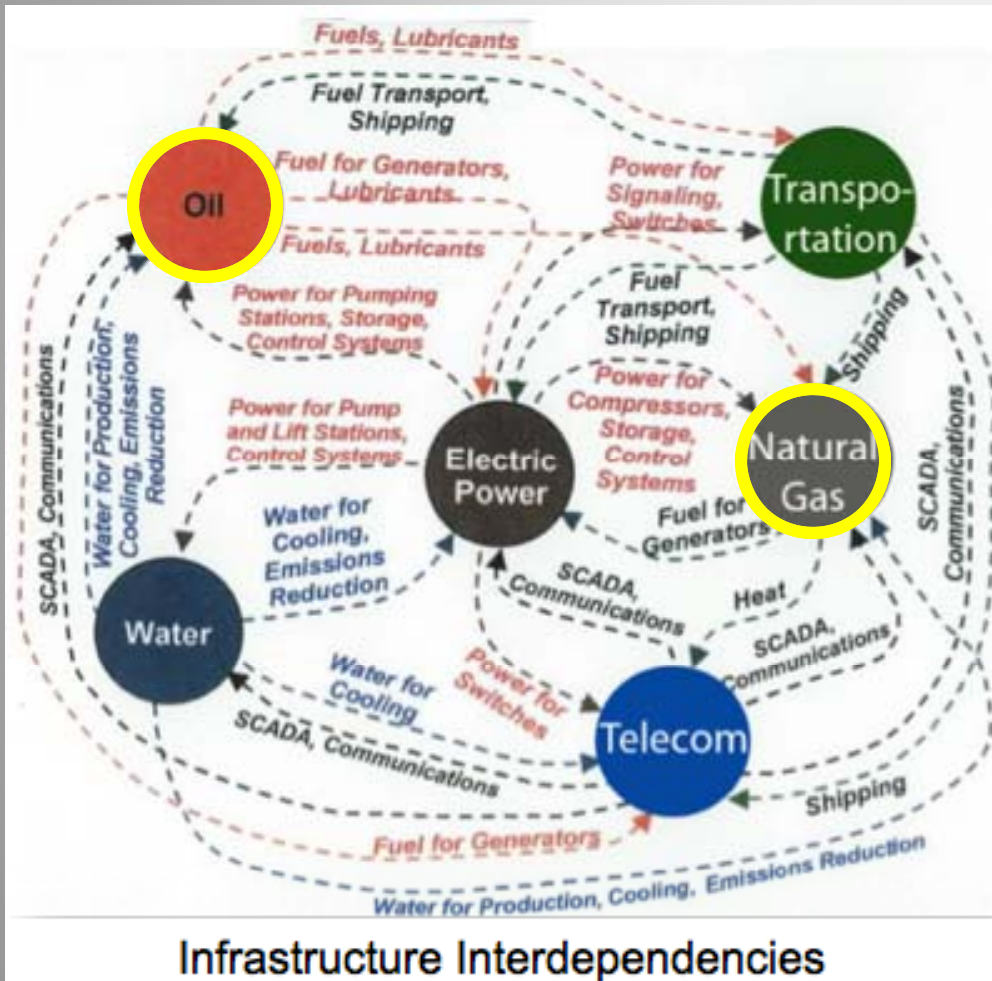
# To Do: Impacted Pipeline in Delta Region & California Coast





# To Do: Assess vulnerability of pipeline network

Employing this process:



Determine where interconnected critical pipeline infrastructures are impacted.