Flood and Sea Level Rise

Mapping Updates

Petaluma City Council Meeting
January 8, 2024

Informational Workshop

Today: Understanding Flood Hazard Areas

- Today we are talking about flood hazards

  - From rain

  - From the Bay

- Flood risk planning will impact land use decisions and policy making

- Today we are focusing on how we understand hazard areas for the General Plan (mapping)

- Next meeting we will look at impacts

Flood and Sea Level Rise Modeling and Map

FLOODPLAIN MANAGEMENT

Coordinate w/ FEMA

Prepare for the Future

KEEPING PETALUMA SAFE

Improve Flow River & Creeks

Update Flood Models / Maps
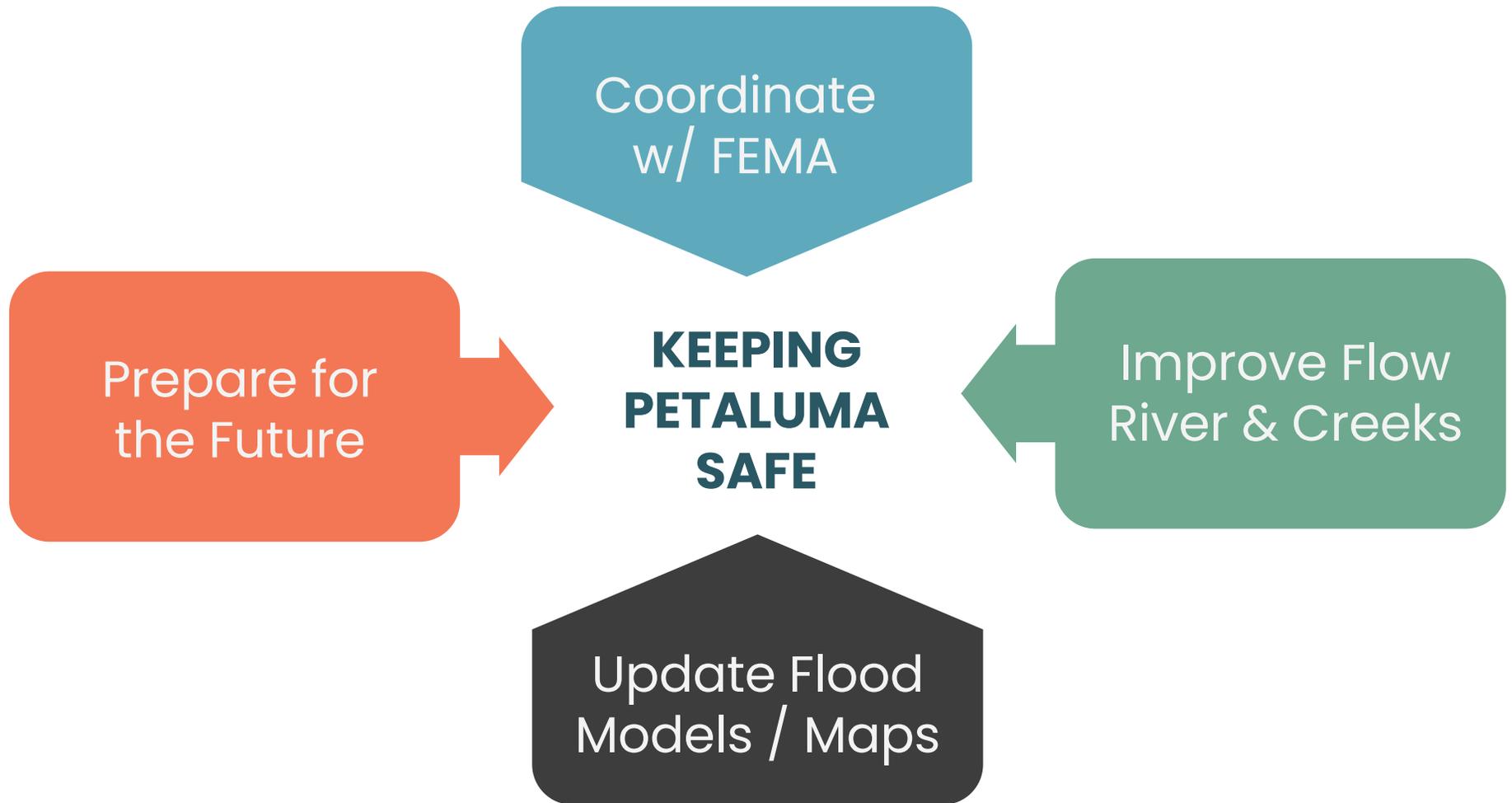
FLOOD MAPPING UPDATE PROCESS

FOLLOWS BEST GUIDANCE

- FEMA
- NOAA
- CA OPC

COMPLEX AND LOCALLY FOCUSED

01

02

03

04

UPDATED RAINFALL

PREDICTIVE SEA LEVEL RISE DATA

WEST CONSULTANTS
WATER | ENVIRONMENTAL | SEDIMENTATION | TECHNOLOGY
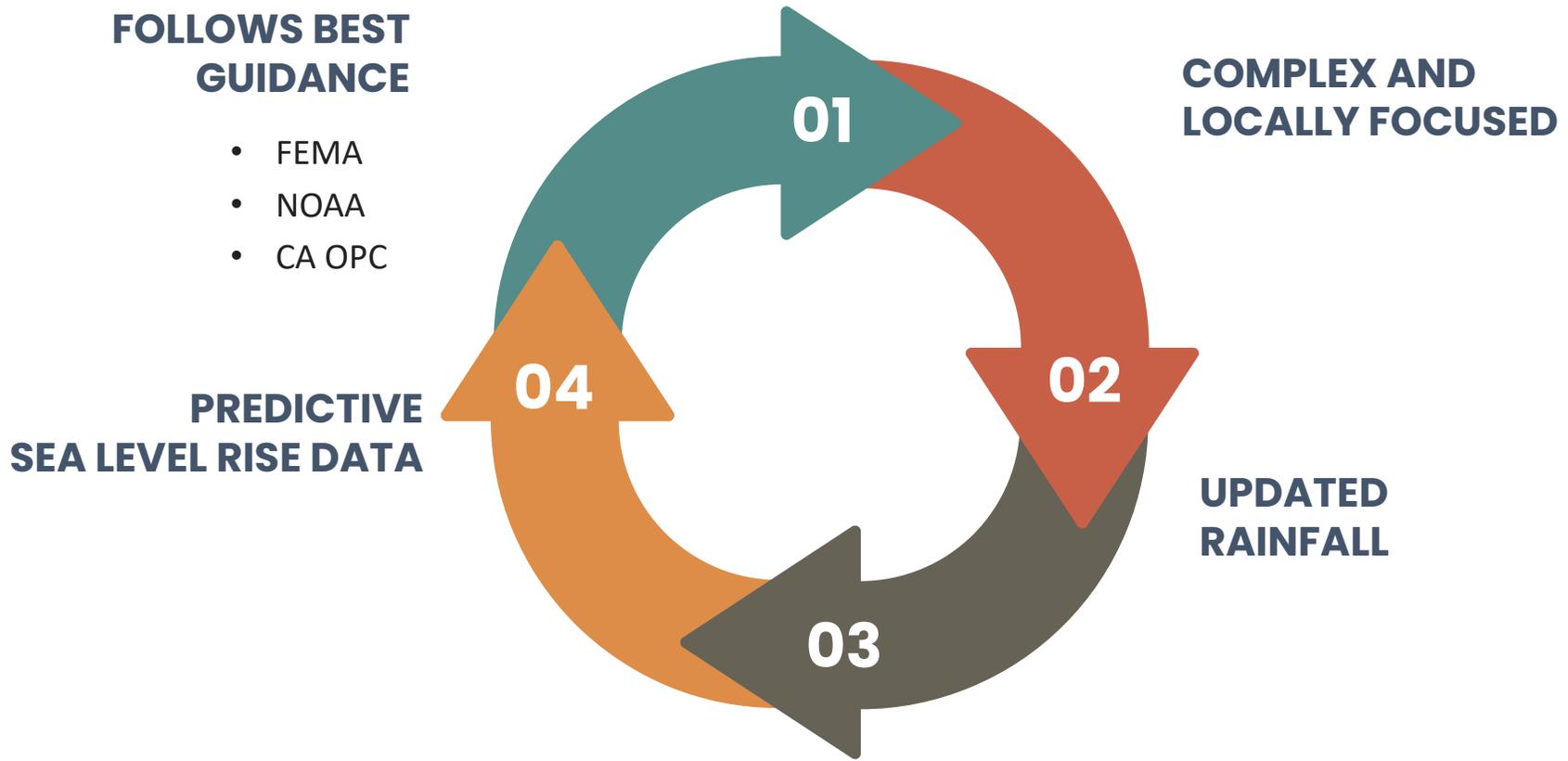
EXPERIENCED TECHNICAL PROFESSIONALS

- 60 w/ advanced degrees in water resources engineering
- 14 w/ a PhD

LEADERS AND TEACHERS

- We teach nationwide - American Society of Civil of Engineers & Floodplain Managers

MANAGER - DAVE SMITH

- P.E., CFM, D.WRE – 20 Years experience performing / managing hydrologic and hydraulic modeling in Petaluma since 2005

CIVIL ENGINEERING FIRM

- International, regional, Petaluma
- 110 + Staff

HYDROLOGY MODELING, STORM WATER MANAGEMENT, WATERSHED RESTORATION, INFRASTRUCTURE PLANNING

- Recent SLR projects include multiple Bay Area Jurisdictions

PROJECT MANAGER - SEBASTIAN BERTSCH

Where does flood water come from?

Water comes down the land, creeks and river from rain

Water also comes up the River from the Bay

Flooding comes from many places

1 Relative Sea Level Rise
Local sea level changes over time because of a combination of global, regional, and local forces that affect the height of the water (e.g., global sea level rise, regional changes in ocean circulation patterns) and the height of the land (e.g., regional earth deformation from melting ice sheets, local land subsidence).

2 Tides
Tides reflect the regular rise and fall of the sea surface at the shore in response to forces exerted by the moon and sun. Our model uses an astronomical "spring" tide fluctuation that occurs during a full or new moon, and results in the highest tides of the month.

3 Storm Surge
During a storm, seawater can rise significantly above normal levels as a storm's low-atmospheric pressure causes sea level to rise, and winds push water onshore. Storm surge is measured as the height of the water above the normal predicted tide.

Mean High Water

Swash Uprush
How far up the water briefly reaches after the break

Wave Setup
Increase in water level due to breaking waves

4 Seasonal Effects
Water levels can vary greatly during seasonal events such as El Niño, where thermal expansion (warmer water increasing in volume) and changes to ocean circulation cause coastal water levels to rise.

5 River Discharge
Freshwater outflow from a river creates a bulge of water (backflow) where the river and ocean meet, increasing local water levels.

6 Wave Runup
Wave runup is the total rise in coastal water levels as waves break and rush up the beach. It consists of **wave setup** (increases in water levels from breaking waves) and **swash uprush** (how far up the water briefly reaches after the break).

Source: Science and Modeling – Our Coast, Our Future (ourcoastourfuture.org)

3 Flood Types to Consider

- King Tide
  - The highest tides of the year
  - Happen every year
  - Tide gauges tell us this water level

- Rainfall
  - Rain falling on the city and watershed, trying to move down river
  - 1% chance of happening every year
  - Flood models tell us what floods

- Storm Surge
  - Extreme high water in the river due to atmospheric events, separate from rain
  - 1% chance of happening every year
  - Tide gauges/the US Army Corp of Engineers tells us this water level

What is a flood model?

- A software flood model considers 4 main factors

    1: The shape of the land and creeks

    2: Rainfall amount and location

    3: Amount and speed of run off

    4: Height of the River/Bay

- 1% Annual Flood Risk = 1% chance every year = 100 year flood

    - Common standard for Flood Planning

elevation model

flow

time

hydrograph
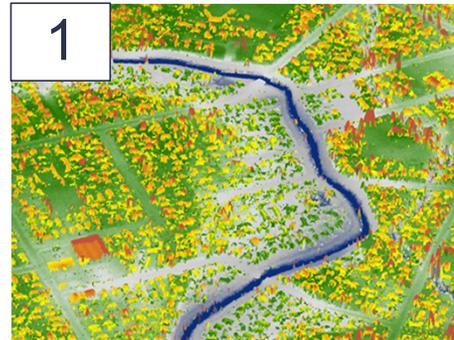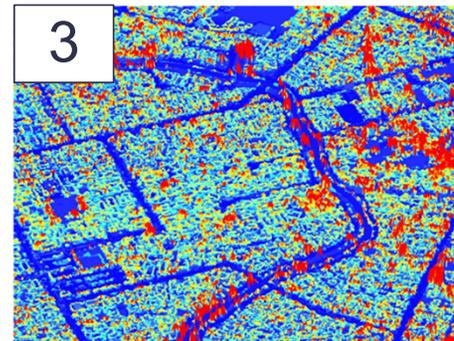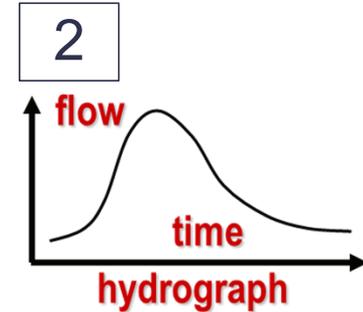
surface roughness model

Niwa.co.nz
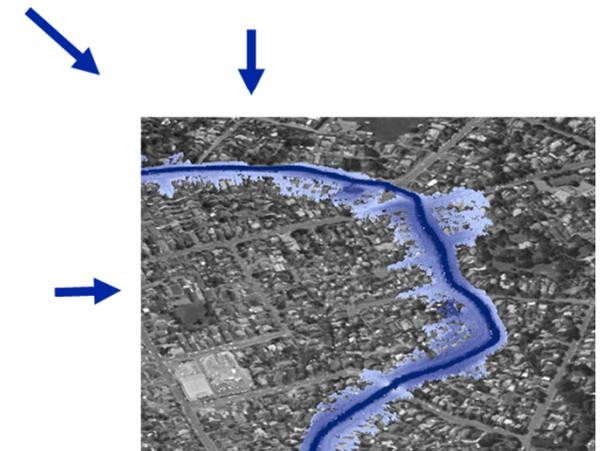
flood depths & extent

WE USED THE BEST MODEL

MODEL FEATURES	HEC–HMS and HEC–RAS 2D	XPSTORM
Great for out of bank flows	✔	✖
Most up to date	✔	✖
Can model outside Petaluma	✔	✖
Used regionally	✔	✔
Economical	✔	✖
Developed by Army Corps	✔	✖

MODEL PROCESS WAS PRECISE, PETALUMA FOCUSED

USED BEST MODEL
HEC-HMS and HEC-RAS 2D

USED BEST, PETALUMA DATA
Rainfall data, terrain data (ground surface), structure data

01

02

03

04

RAN MODEL, COMPARED TO DATA, DOUBLE CHECKED

Calibrated to the three largest events of record, checked model results carefully for reasonableness stream by stream, reach by reach

GOT AS GRANULAR AS POSSIBLE
We walked the streams to determine roughness values, hundreds of culverts/bridges

Model Background

What is hydrology?

What is hydraulics?
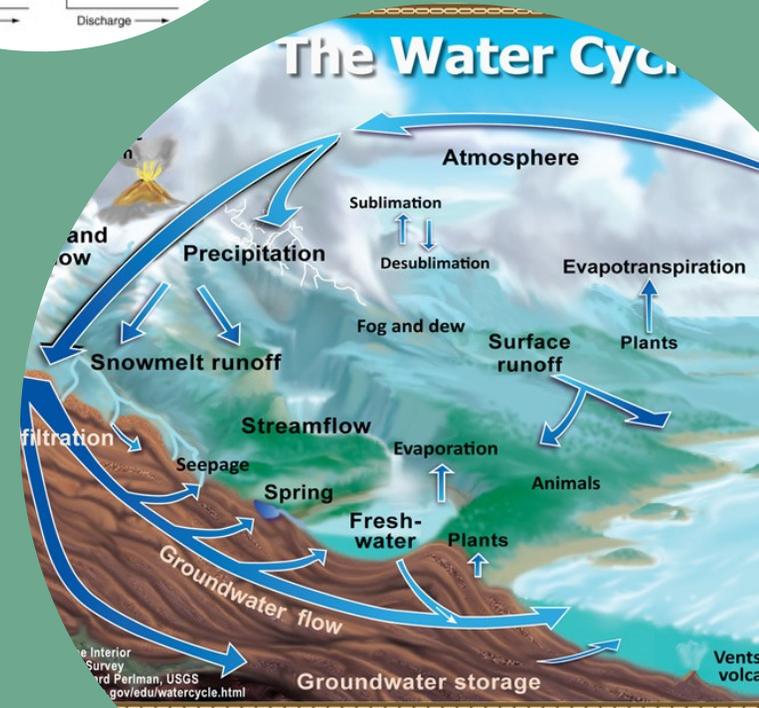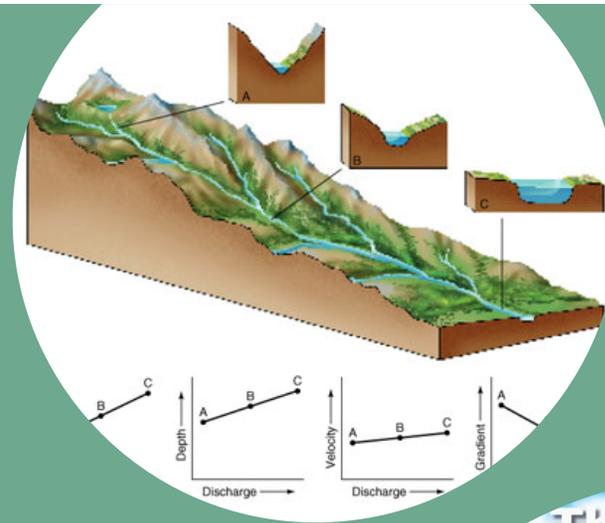
PETALUMA FLOOD MODELING

Includes Climate Change Impacts, Uses Petaluma Specific Data

SEA LEVEL RISE

Based on current science

MEAN HIGHER HIGH TIDE

The average of the highest tides each year as provided by NOAA.

FLOOD MODEL

HYDROLOGY and HYDRAULICS

Ground Surface Terrain, Field Surveys, Land Uses, Vegetation levels

RAIN

Custom rain study specific to Petaluma in 2023. Considered how much rain is reasonable, where it falls in the watershed heaviest, and how quickly it falls.

Hydrology (HEC-HMS)

- This is the Petaluma River watershed

- Flow estimated in each drainage area

- 154 subbasins
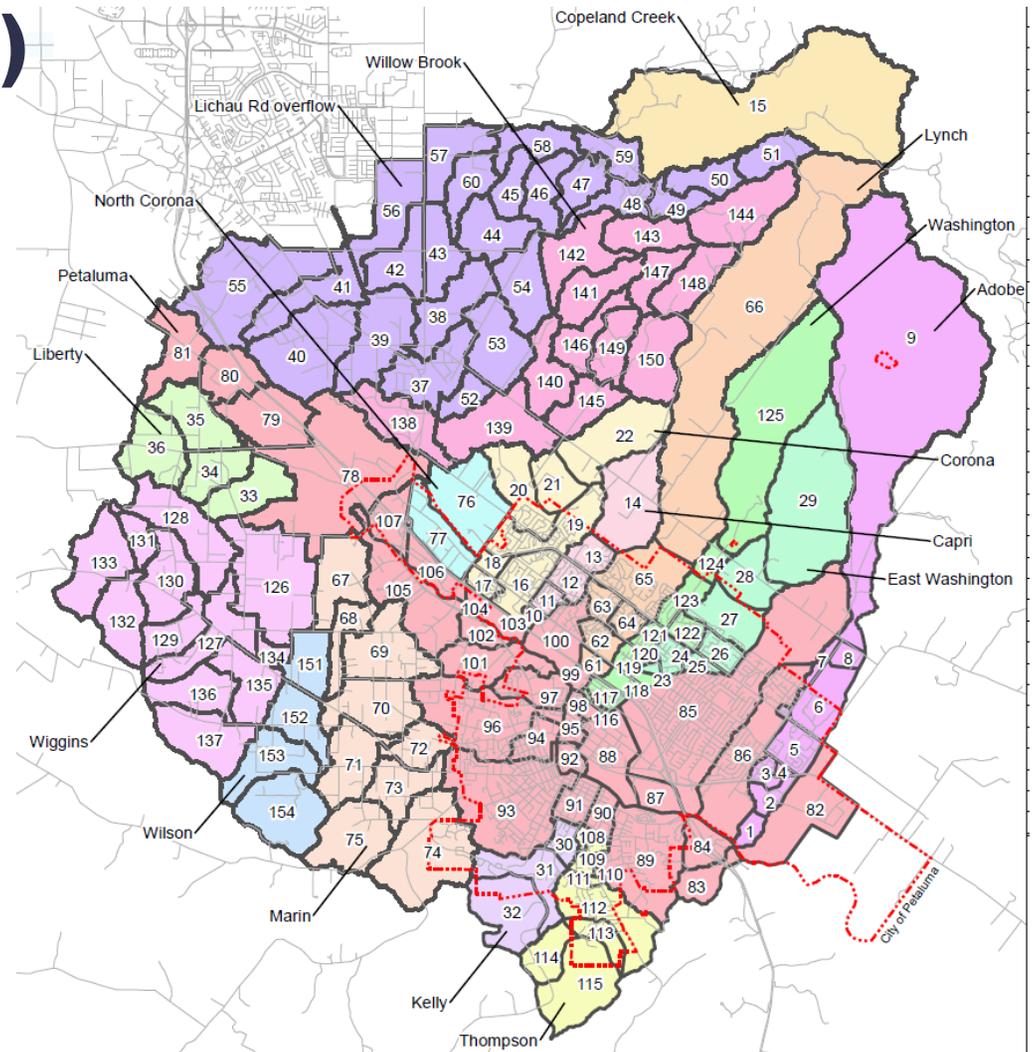
Hydraulics (HEC-RAS 2D)

- Ground elevation data

- Structures

- Roughness (streets vs. vegetation)

City of Petaluma Flood and Sea Level Rise Mapping Updates | 19
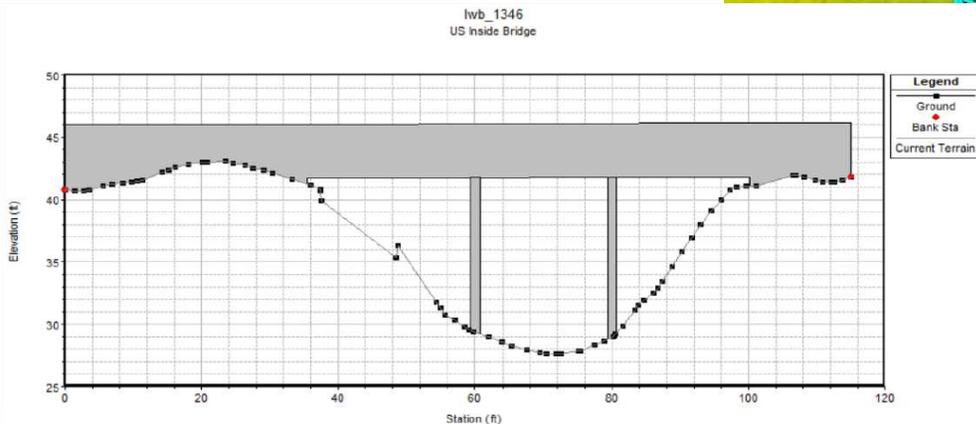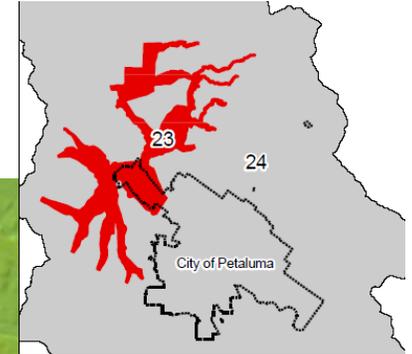
Predicting the Future

- Data will guide General Plan with predictions of potential future floods

  - Many variables were considered: Precipitation, Bigger Surge, Urban Cover

  - Sea Level Rise (SLR) will also have a significant impact, as it impacts River drainage

Source for SLR Predictions

- California Ocean Protection Council Guidance (OPC2018)
  - Used by numerous state and local agencies and counties/cities
  - Provides ranges of SLR, and how likely they are to happen in future decades
  - Recommends which predictions are appropriate for different planning efforts
  - Recommends assuming continued High Emissions (RCP)

(b) Relative sea level in San Francisco, California
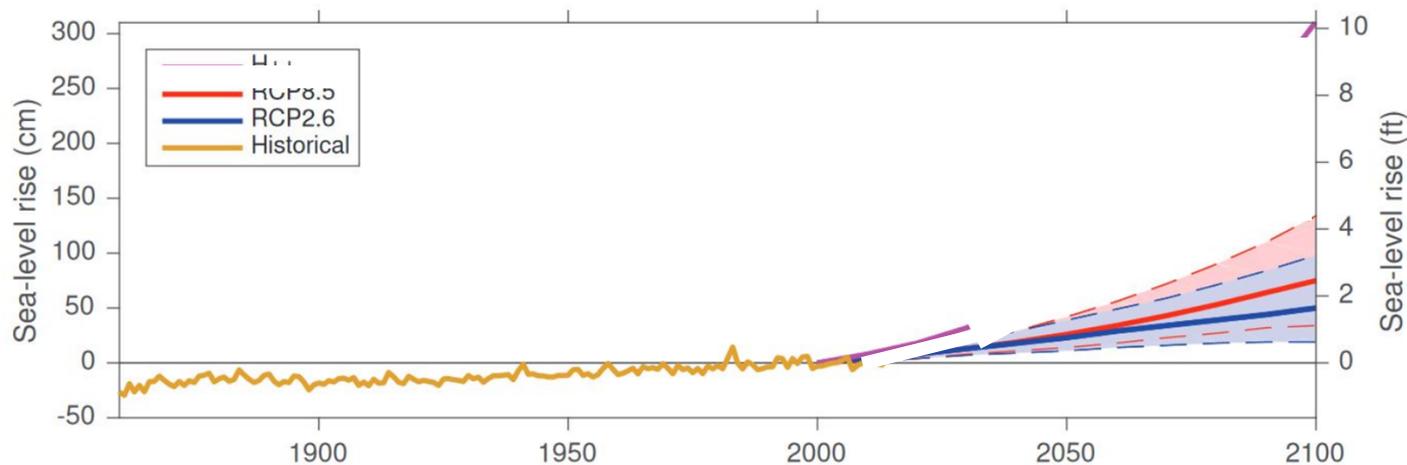
Source for SLR Predictions

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  - Recommends which predictions are appropriate for different planning efforts

Sea Level Rise (SLR) Selections

- Mid-Century
  - Roughly 2050
  - Very low probability SLR
  - 0.5% chance
  - **1.9 feet**

  - Short planning horizon, so the worst case was selected

Mid Century SLR		
Likelihood	Elevation	PETGP Definition
0.5%	1.9'	Very Low Probability
5%	1.4'	
17%	1.1'	Low Probability
50%	0.9'	
83%	0.6'	

Likely Range

Sea Level Rise (SLR) Selections

- End-of-Century
  - Roughly 2100
  - Low probability SLR
  - 17% chance
  - **3.4 feet**

  - Longer planning horizon gives us more time to prepare
  - Appropriate for most planning efforts

End of Century SLR		
Likelihood	Elevation	PETGP Definition
0.5%	6.9'	Very Low Probability
5%	4.4'	
17%	3.4' →	Low Probability
50%	2.5'	
83%	1.6'	
96%	1.0'	

Likely Range

Sea Level Rise (SLR) Selections

- End-of-Century
  - Roughly 2100
  - Very Low probability SLR
  - 0.5% chance
  - **6.9 feet**

- Longer planning horizon gives us more time to prepare
- Appropriate for isolated critical or high risk infrastructure and uses

	End of Century SLR		
Likelihood	**Elevation**	**PETGP Definition**	
0.5%	6.9'	Very Low Probability	
5%	4.4'		
17%	3.4'	Low Probability	
50%	2.5'		
83%	1.6'		
96%	1.0'		

Likely Range

Using SLR in flood maps

- The maps most relevant for long term planning are 1.9' of SLR in Mid-Century and 3.4' in the End-of-Century

    - It is straightforward to explore how SLR affects King Tide and Storm Surge flooding

    - Considering how SLR affects Rainfall flooding requires our new model

King Tide and Storm Surge

- Current King Tide and Storm Surge patterns are layered on top of Sea Level Rise to predict what will flood in the future

SLR +1.9'	Future Flood Level
	Current Flood Level
Current Annual King Tide	

SLR +1.9'	Future Flood Level
	Current Flood Level
Current 100 year Storm Surge	
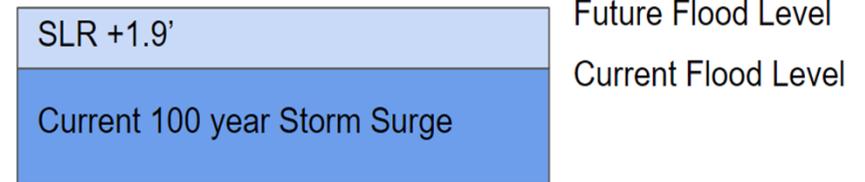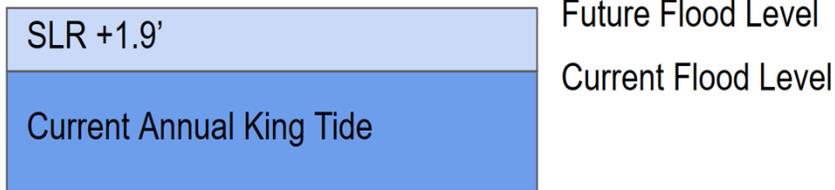
SLR effects on Rainfall flooding

- Considering how SLR impacts rainfall flooding requires updated rain model

  - Model Method

    - 1: Add SLR amount to current MHHW tide level

    - 2: Run the rain flood model, now with rainfall needing to "fight" the higher river elevation

    - 3: Model results may show extra flooded areas
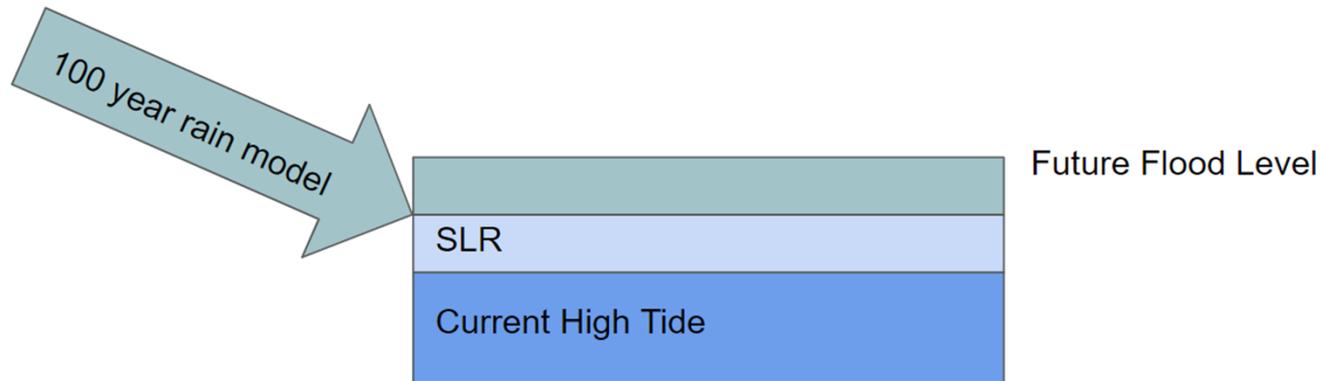
What did we model?

- What are flood risks at mid-century (around 2050), if we look at
  - Rain and storm surge (Map 1)
  - King tides (Map 2)

- What are flood risks at the end of the century (around 2100), if we look at
  - Rain and storm surge (Map 3)
  - King tides (Map 4)

- What could the very low probability flood risks at the end of the century
  - Rain and storm surge (Map 5)
  - King tides (Map 6)

- Maps are next! First, questions?

Clarifying Questions

Current FEMA 100 Yr (1% Chance) Floodplain
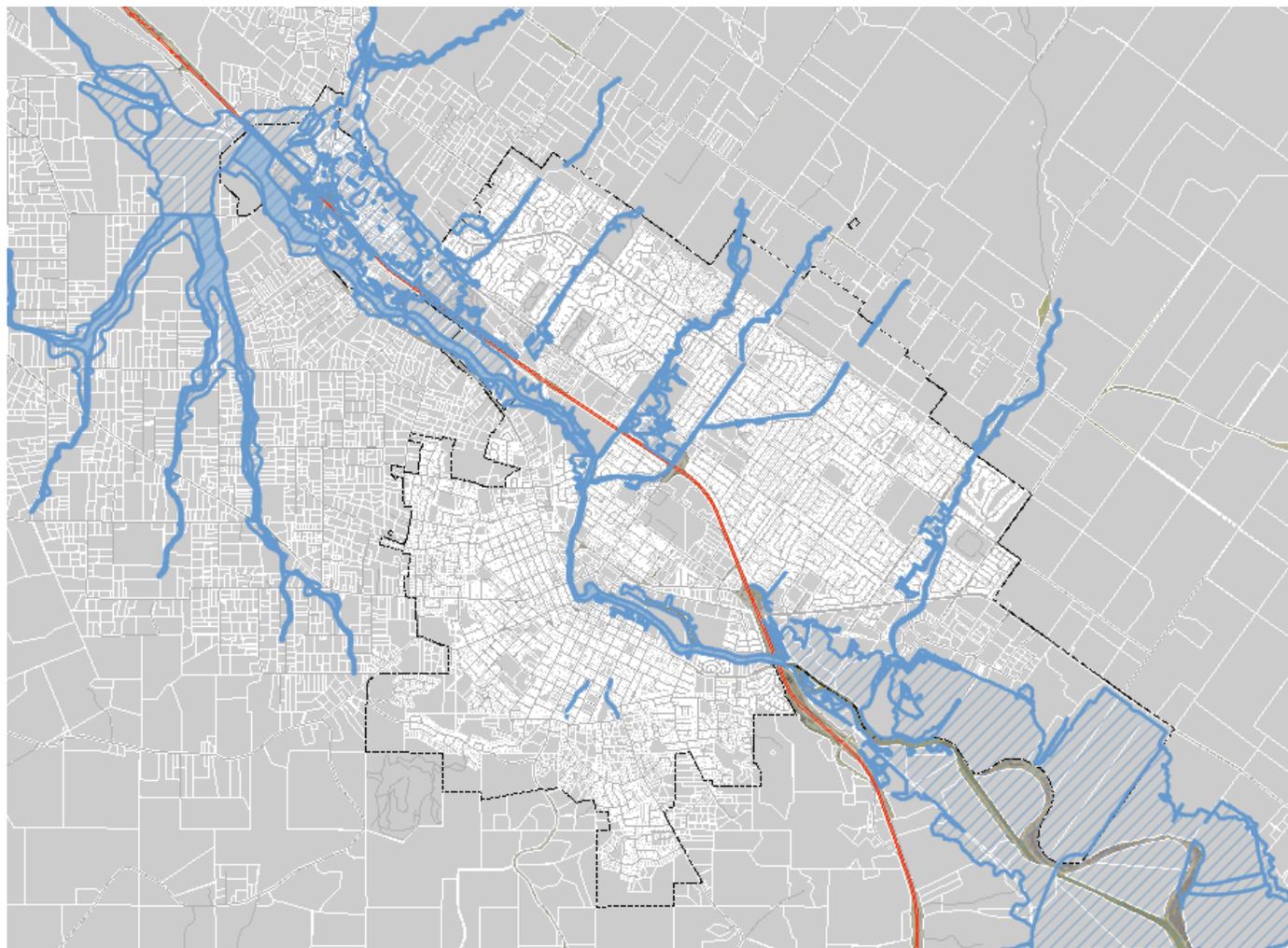
Mid-Century SLR (1.9 feet), Rain and Storm Surge
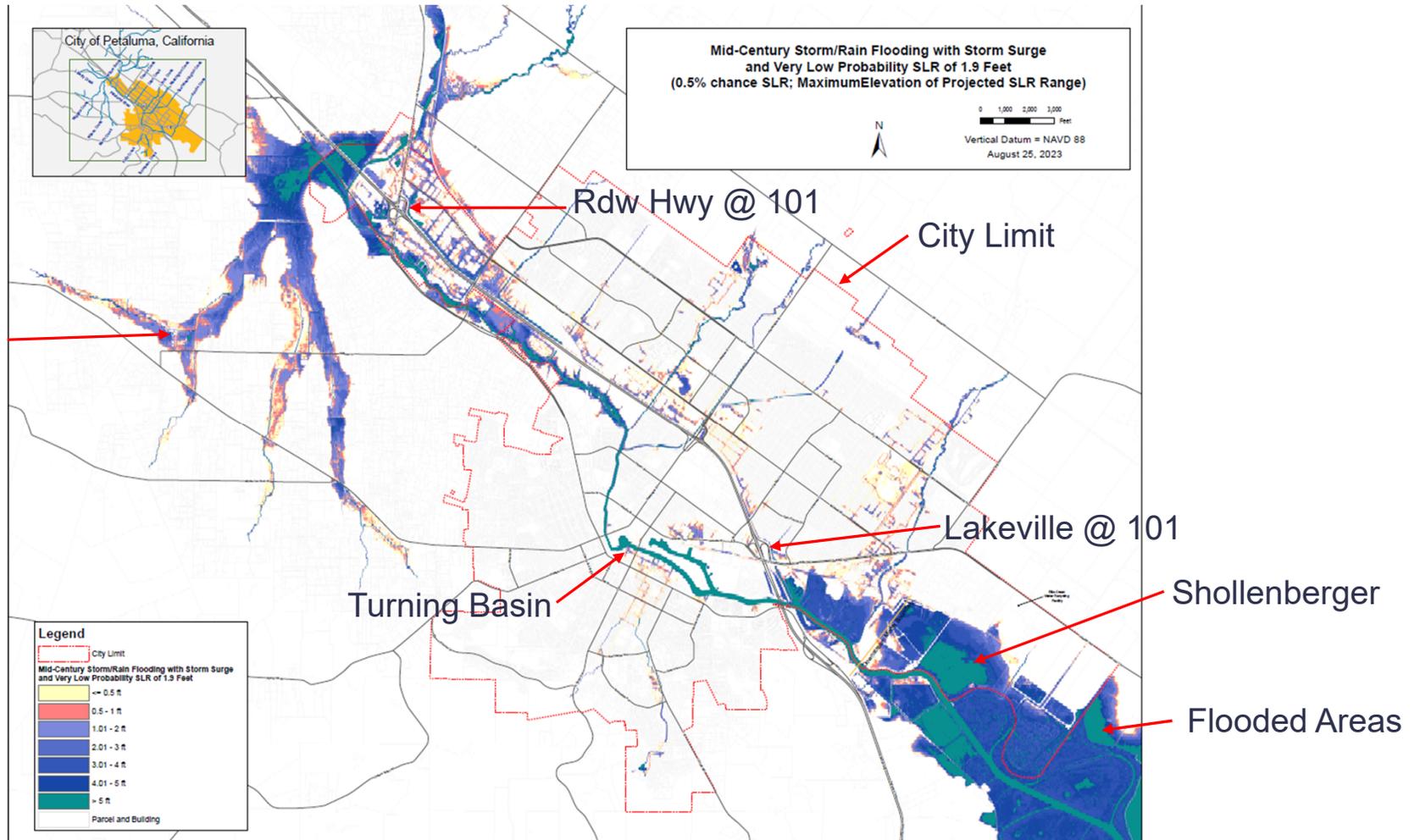
Mid-Century SLR (1.9 feet), King Tide
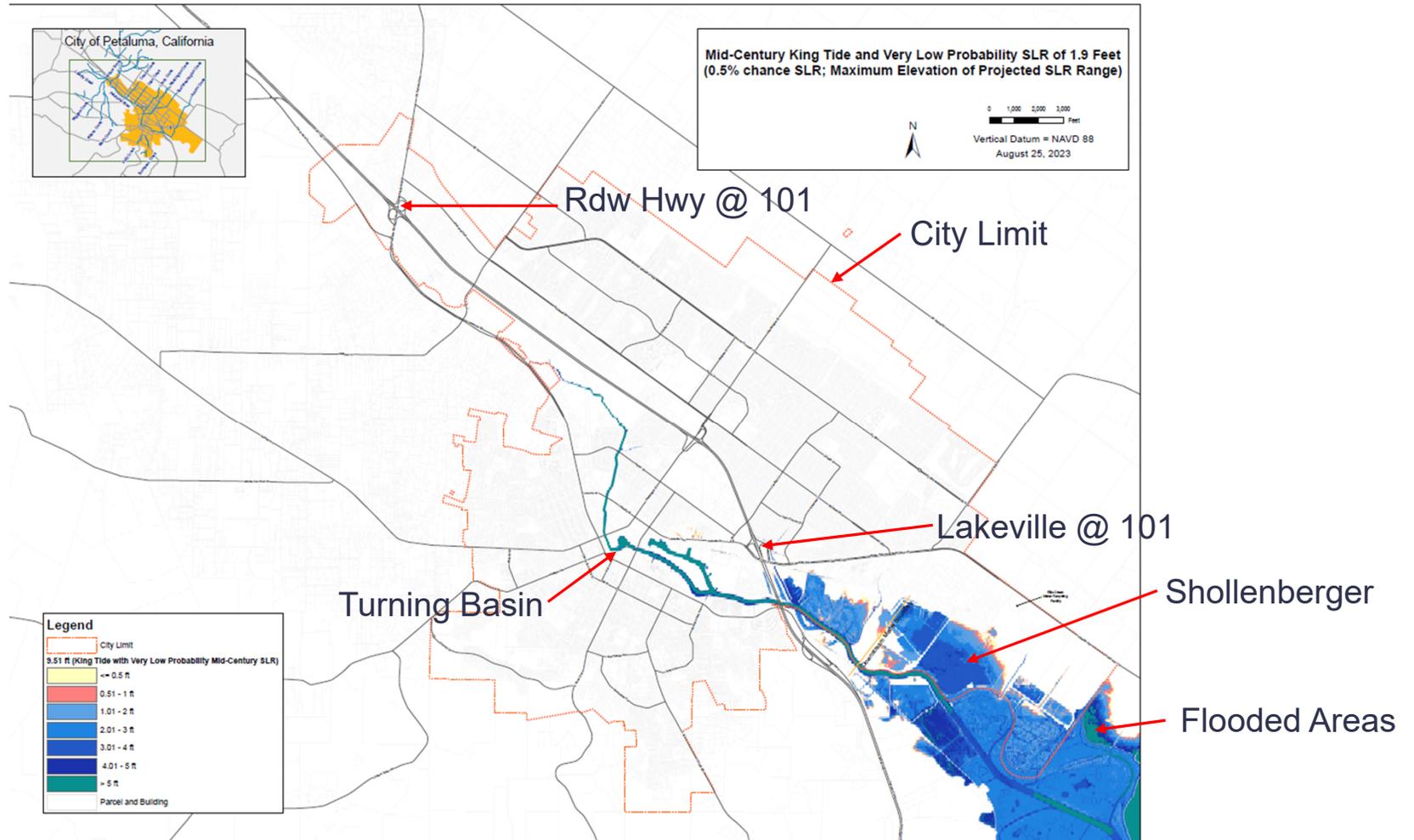
End-of-Century SLR (3.4 feet), Rain and Storm Surge
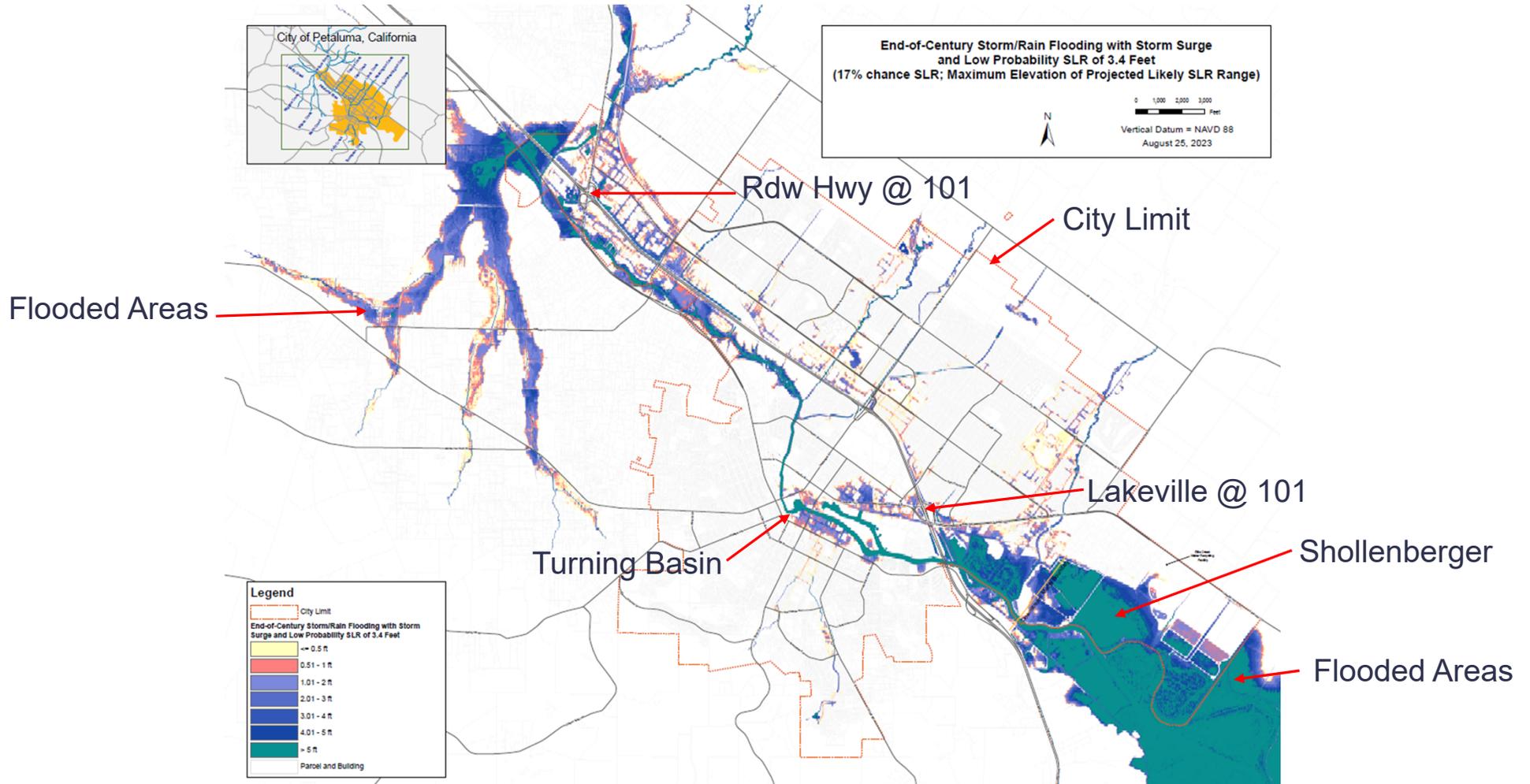
End-of-Century SLR (3.4 feet), King Tide
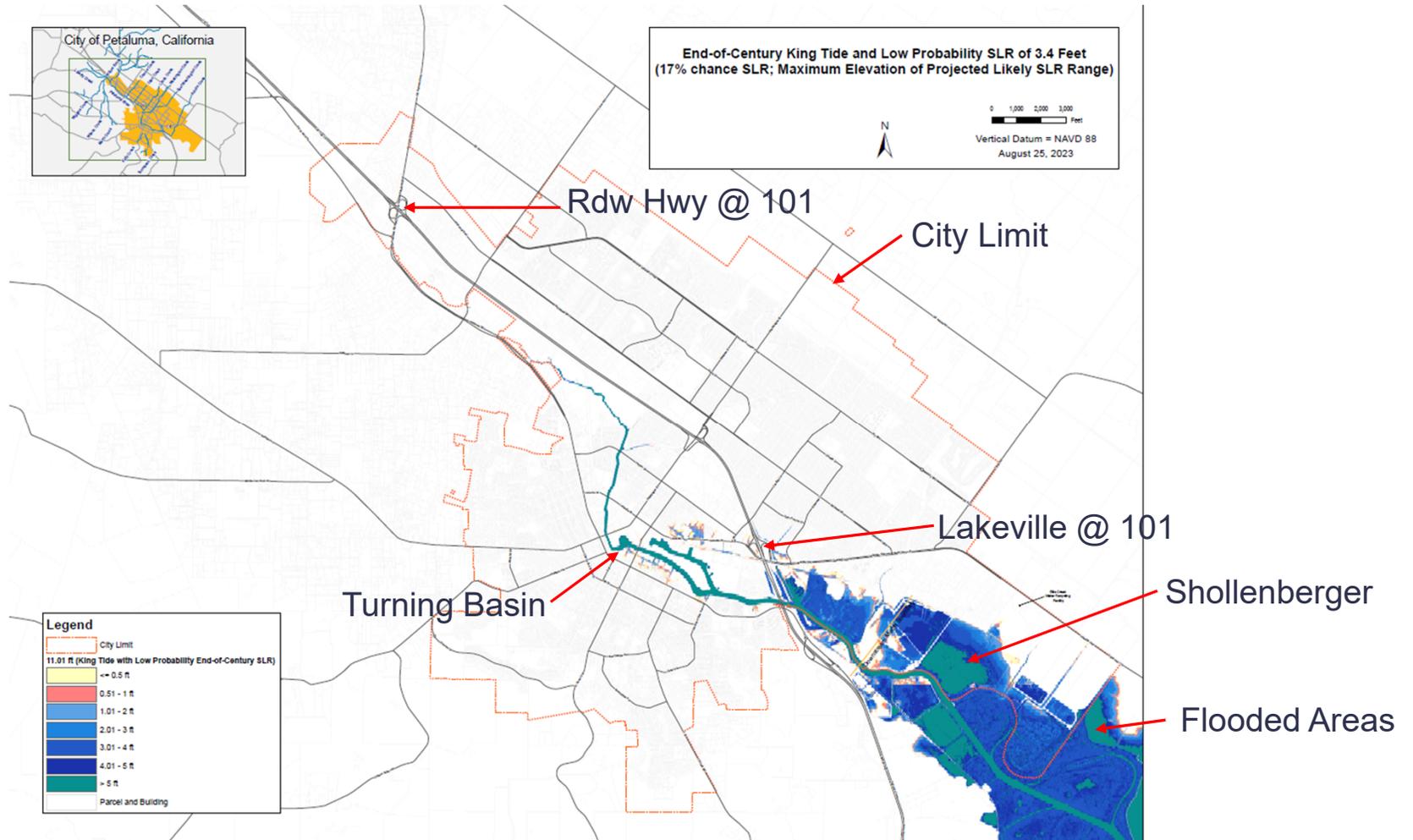
End-of-Century SLR (6.9 feet), Rain and Storm Surge
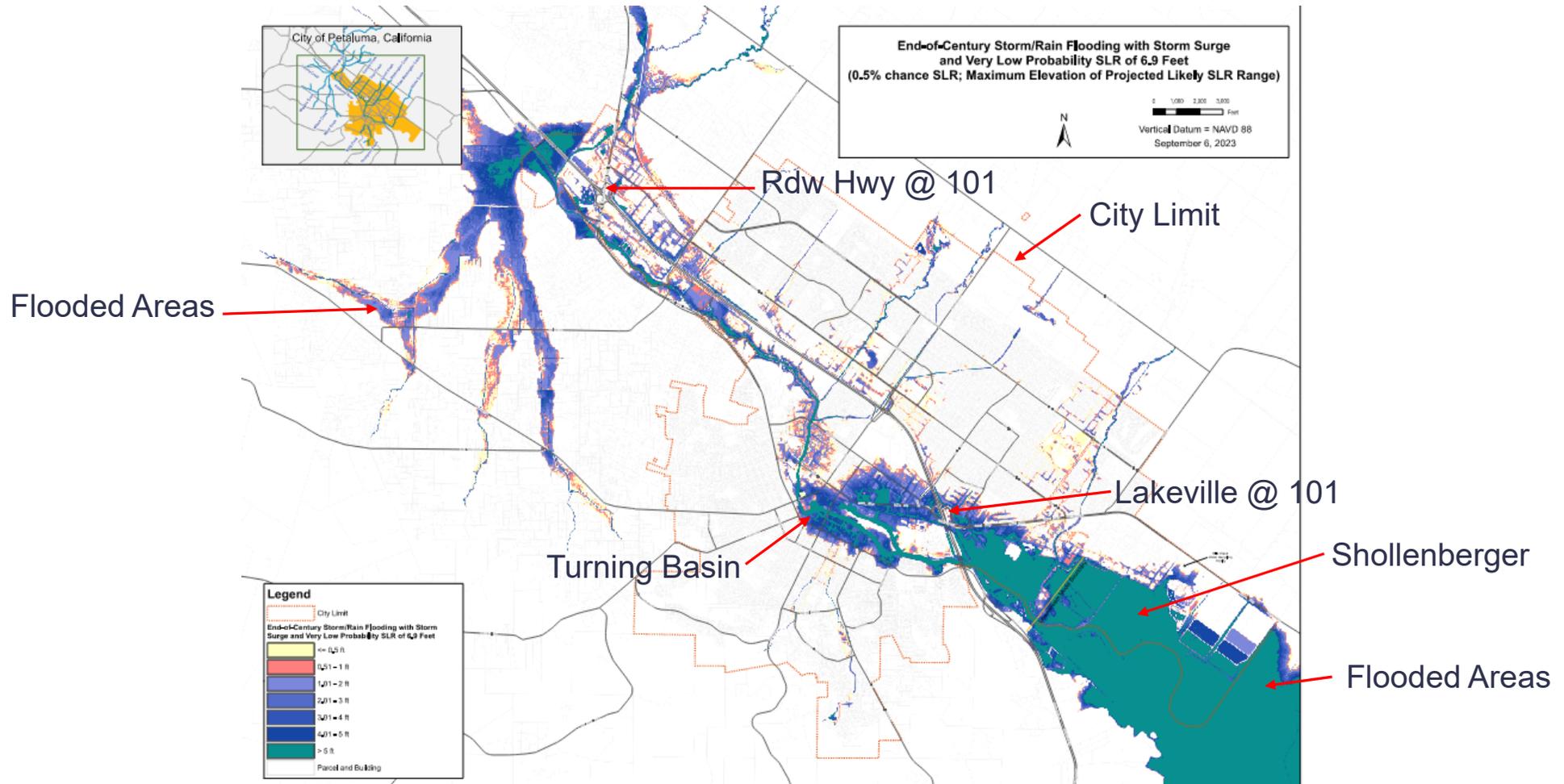
End-of-Century SLR (6.9 feet), King Tide

Where can SLR affect the City in the Future

• Let's zoom in to the same maps

Mid-Century SLR (1.9 ft), Rain + Storm Surge

Zoom to main areas affected by SLR

Lakeville @ 101

City Limit

Ellis Creek Water
Recycling Facility

D Street Bridge

Flooded Areas

Downstream Model Boundary

Shollenberger

Legend

Mid-Century Storm/Rain Flooding with Storm Surge
and Very Low Probability SLR of 1.9 Feet

	<= 0.5 ft
	0.5 - 1 ft
	1.01 - 2 ft
	2.01 - 3 ft
	3.01 - 4 ft
	4.01 - 5 ft
	> 5 ft
	City Limit
	Parcel and Building

Mid-Century SLR (1.9 feet), King Tide

Zoom to main areas affected by SLR

Flooded Areas

Lakeville @ 101

City Limit

D Street Bridge

Shollenberger

Downstream Model Boundary

Ellis Creek
Water Recycling
Facility

Legend

9.51 ft (King Tide with Very Low Probability Mid-Century SLR)

	<= 0.5 ft
	0.51 - 1 ft
	1.01 - 2 ft
	2.01 - 3 ft
	3.01 - 4 ft
	4.01 - 5 ft
	> 5 ft
	City Limit
	Parcel and Building

End-of-Century SLR (3.4 ft), Rain + Storm Surge

Zoom to main areas affected by SLR

Lakeville @ 101

Flooded Areas

City Limit

Ellis Creek Water Recycling Facility

Flooded Areas

D Street Bridge

Downstream Model Boundary

Shollenberger

Legend

End-of-Century Storm/Rain Flooding with Storm Surge and Low Probability SLR of 3.4 Feet

- <= 0.5 ft
- 0.51 - 1 ft
- 1.01 - 2 ft
- 2.01 - 3 ft
- 3.01 - 4 ft
- 4.01 - 5 ft
- > 5 ft
- City Limit
- Parcel and Building

End-of-Century SLR (3.4 feet), King Tide

Zoom to main areas affected by SLR

Lakeville @ 101

City Limit

Ellis Creek
Water Recycling
Facility

Downstream Model Boundary

Shollenberger

D Street Bridge

Flooded Areas

Legend

11.01 ft (King Tide with Low Probability End-of-Century SLR)

	<= 0.5 ft
	0.51 - 1 ft
	1.01 - 2 ft
	2.01 - 3 ft
	3.01 - 4 ft
	4.01 - 5 ft
	> 5 ft
	City Limit
	Parcel and Building

Very Low Probability, End of Century SLR, Storm Surge

End-of-Century Storm/Rain Flooding with Storm Surge and Very Low Probability SLR of 6.9 Feet

- <= 0.5 ft
- 0.51 - 1 ft
- 1.01 - 2 ft
- 2.01 - 3 ft
- 3.01 - 4 ft
- 4.01 - 5 ft
- > 5 ft

D Street Bridge

Flooded Areas

City Limit

Downstream Model Boundary

Very Low Probability, End-of-Century SLR, King Tide

14.51 ft (King Tide with Very Low Probability End-of-Century SLR)

- <= 0.5 ft
- 0.51 - 1 ft
- 1.01 - 2 ft
- 2.01 - 3 ft
- 3.01 - 4 ft
- 4.01 - 5 ft
- > 5 ft

D Street Bridge

Flooded Areas

City Limit

Downstream Model Boundary
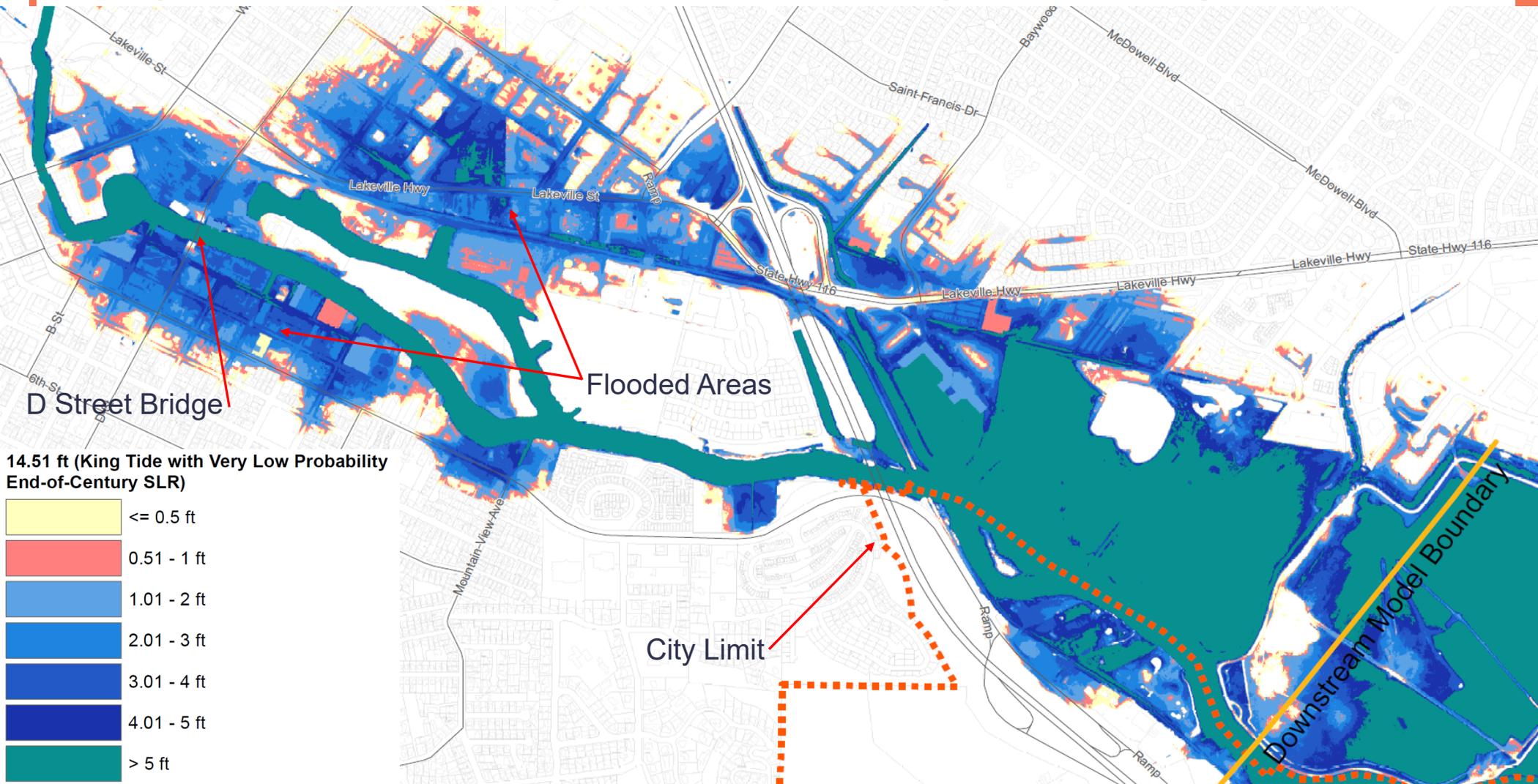
Flood Mapping in the General Plan Update

General Plan Update Roadmap

Project Initiation — 1

Discovery — 2

Visioning — 3

Policy Development — 4

Alternatives — 5

Plan Development — 6

Plan Review + Adoption — 7

2021   2022   2023   2024   2025

GPAC Meetings

GPAC meetings are the 3rd Thursday of the month @ 6:00 pm

✓ Introduction of Updated Flood & Sea Level Rise Modeling & Maps - September 21, 2023

✓ Discussion of Flood Resilience Planning - October 19, 2023

✓ Discussion of Land Use Alternatives I - November 16, 2023

❑ **Discussion of Land Use Alternatives II – January 18, 2023.**

WHERE WE ARE NOW

- Administrative Draft Flood Resilience Policy Framework

- Discussion and Development of Land Use Alternatives
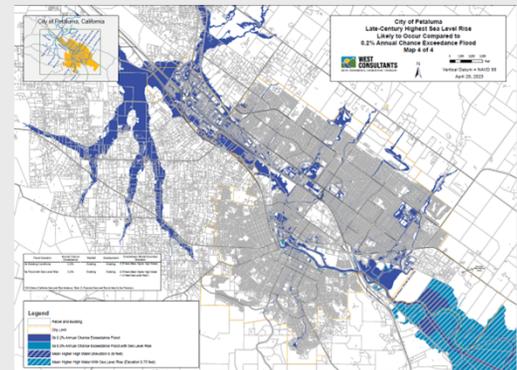
NEXT STEPS

MORE PUBLIC ENGAGEMENT

2024

- Complete and Release Public Draft Policy Frameworks for GPAC and Public Review

- Public Review of Land Use Alternatives and selection of the Preferred Alternative
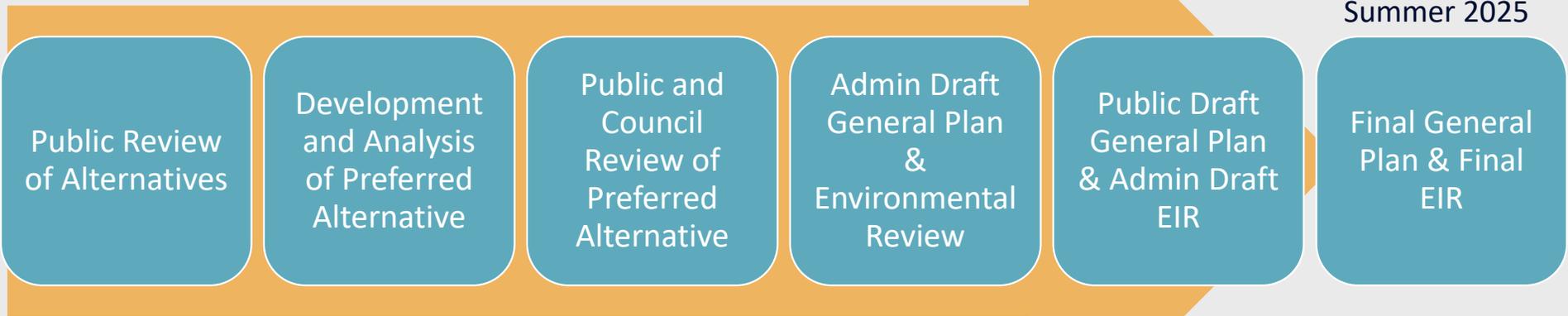
FEMA Map Update Process

- The City will soon begin the process to update our flood maps with FEMA

- Led by Public Works

- Including:

    - Technical review with FEMA

    - Community Engagement

- 1-2 year timeline to completion

Floodplain Management in Petaluma

- Floods can happen anywhere and wreak havoc quickly

- Keep our community safe by minimizing flood risk and damage

- Community Rating System (CRS)

- Projects to manage the flow of water through our river and creeks.

  - Payran Reach Flood Walls,
  - Denman Reach Detention Ponds/Terracing
  - Capri Creek improvements

- **Floodplain Maps & Sea Level Rise Maps**

- Updated models will help inform General Plan policies as well as provide critical information to inform upcoming flood management projects.

Clarifying Questions

Appendix

Model Background

- City's current model updated in 2012 for General Plan

- "XP Storm"
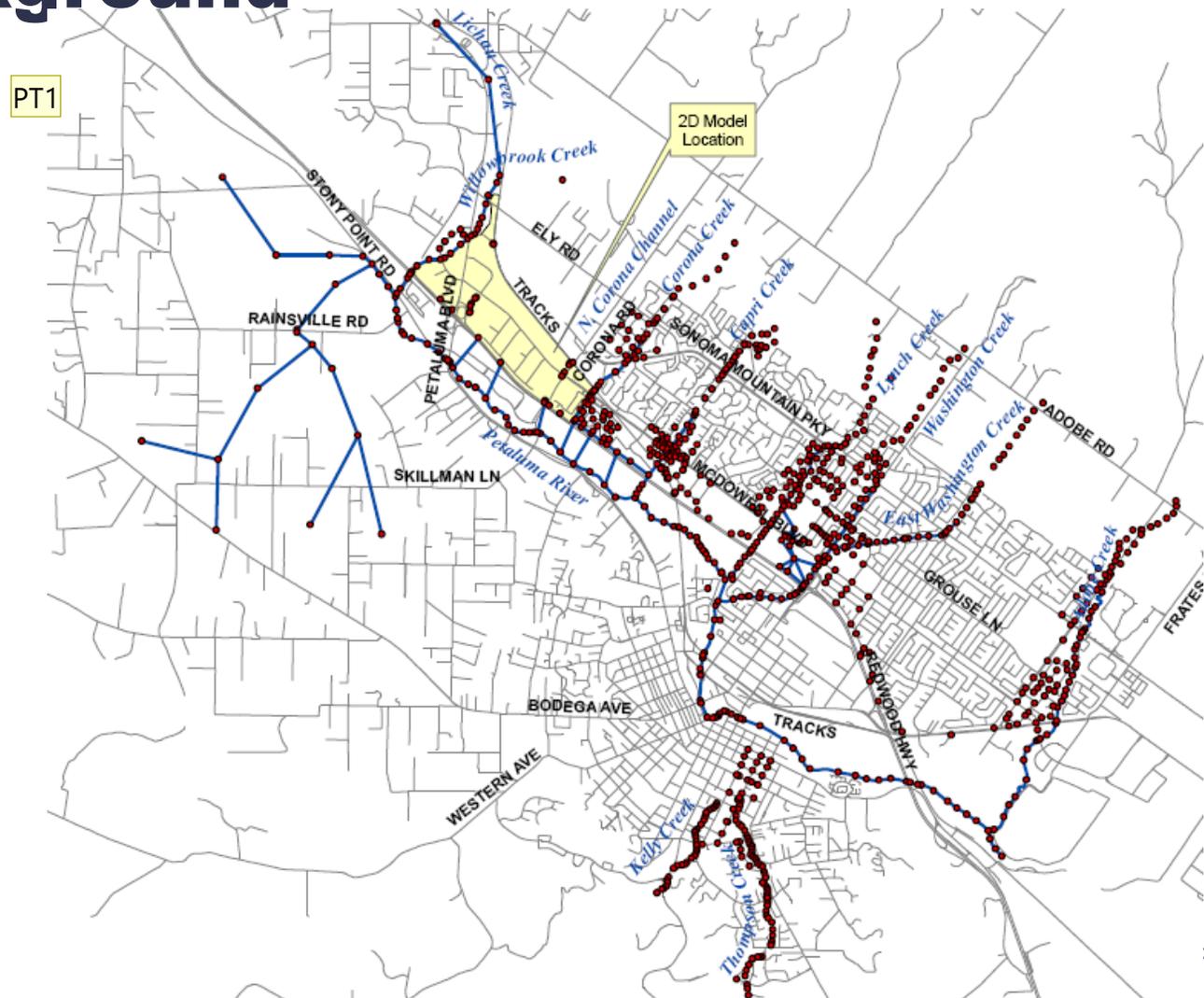
Model Background
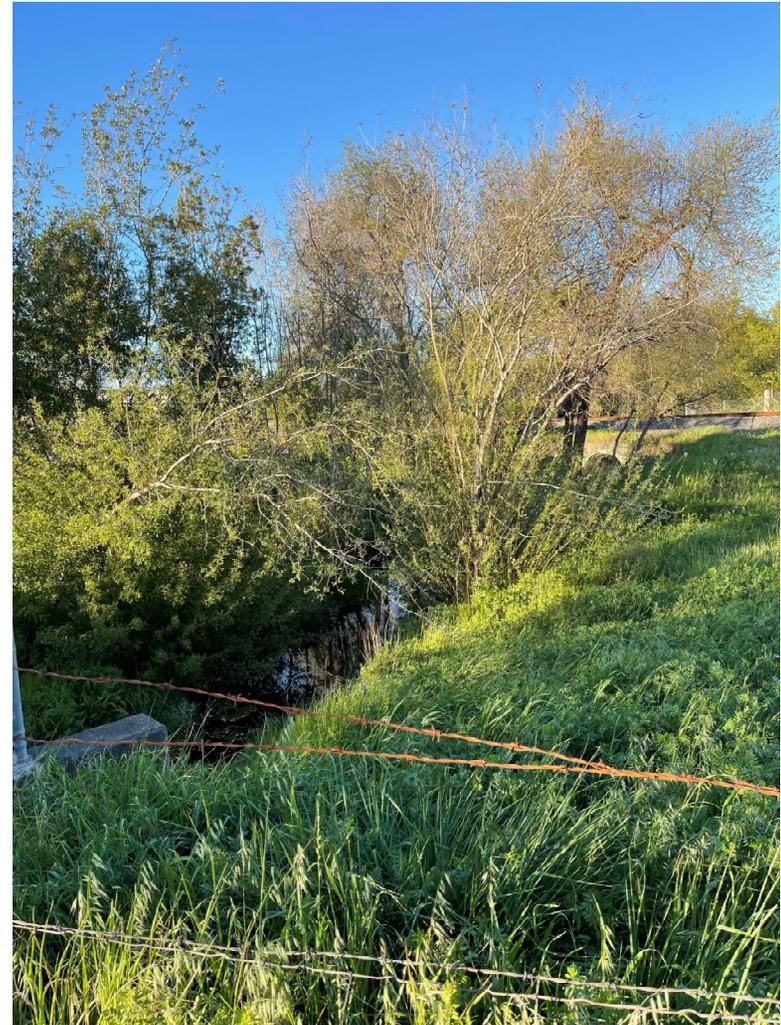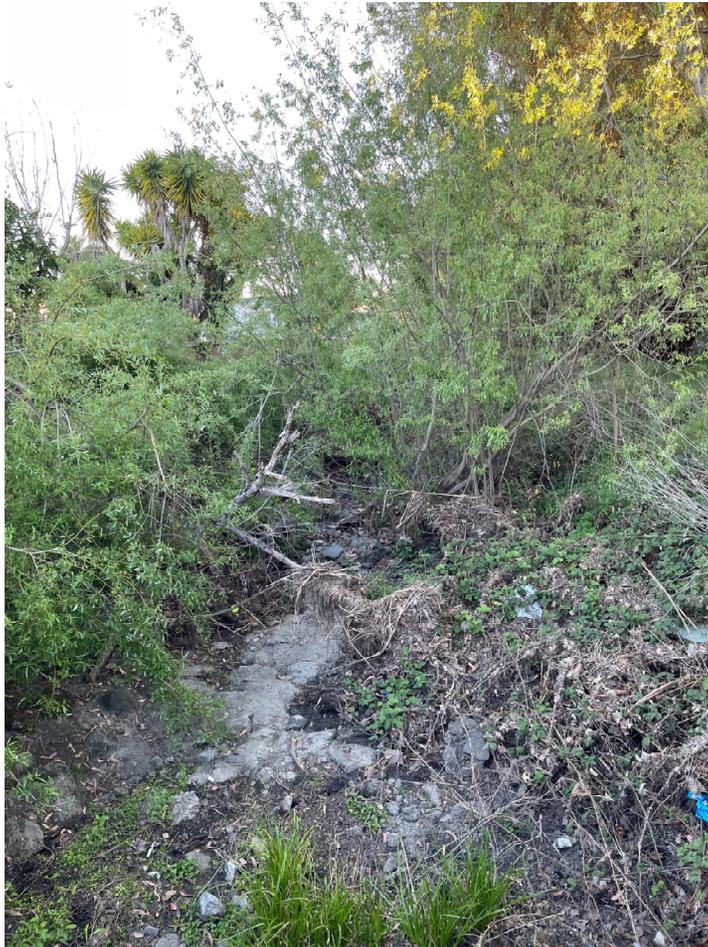
Model Background

- New Model: HEC-RAS (River Analysis System) 2D for hydraulics and HEC-HMS (Hydrologic Modeling System) for hydrology.

Model Background

- What is hydrology?

- Hydrology analyses how rainfall turns into runoff. How much of the rain sinks in and how much runs off?
  - HEC-HMS inputs include:
    - Rainfall depth for a given storm (how deep), rainfall spatial distribution (where is it falling), and rainfall temporal pattern (how quickly it falls).
    - Loss rates (rate that water sinks into the ground)
    - Watershed/subbasin geometry (are the basins long and skinny for example, or more rounded). The basin response forms the shape of the discharge/flow hydrograph (flow vs. time).
  - HEC-HMS outputs include:
   - Flow hydrographs for each subbasin

Model Background

- What is hydraulics?

- Hydraulics tells us how high the water gets in channels and overbanks.
  - HEC-RAS inputs include:
    - Flow hydrographs from HEC-HMS at each subbasin outlet.
    - Downstream boundary conditions (tide levels assumed)
    - Channel roughness (vegetation, roads/parking lots—not just where but how rough/smooth)
    - Topography (ground surface data excluding buildings/structures—"bare earth")
    - 2D grid limits
    - Structure data (bridges, culverts, floodwalls, weirs)
  - HEC-RAS outputs include:
    - Depth, velocity, and water surface elevations...everywhere within the 2D grid limits.

Hydrology (HEC-HMS)

Legend:
- Watershed Boundary
- Rainfall sites
- Gage area of influence

100-year, 24-hour rainfall (inches)
Band 1 (Gray)
10
2

SB0
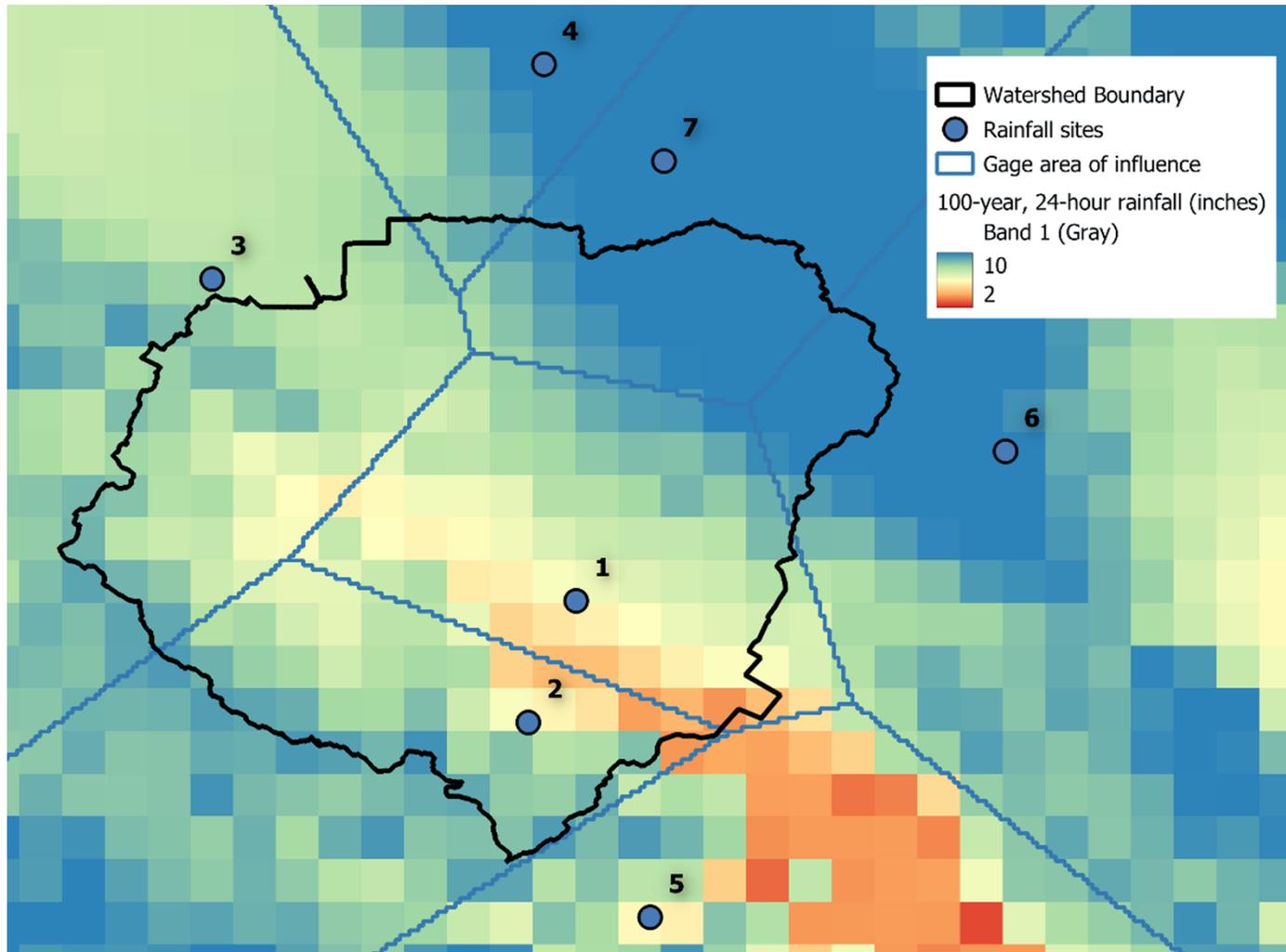
Rain falls unevenly on the Petaluma Watershed

- Every storm is different

- Recent data provided averages

Hydrology (HEC-HMS)

Instead of modeling the rainfall pattern of specific historical storms an "average" 100-year storm is modeled
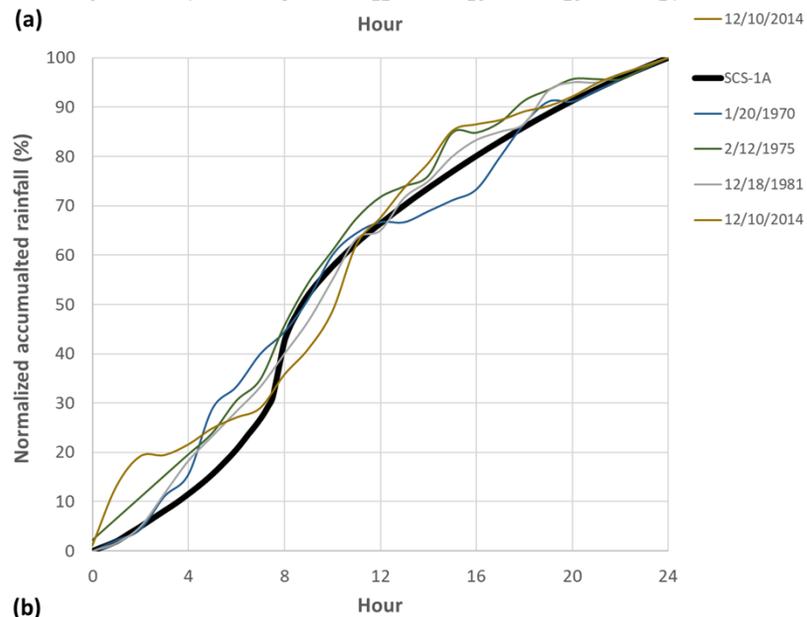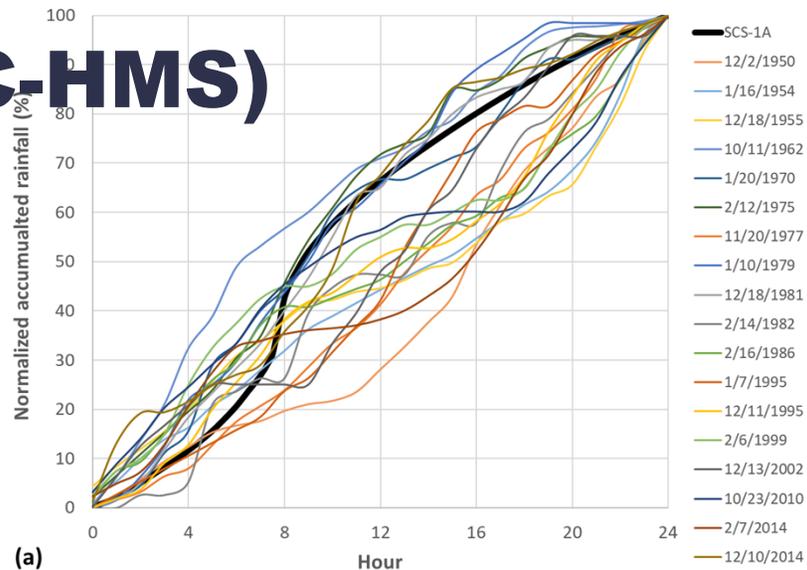
Hydraulics (HEC-RAS 2D)

- Calibration—what is it? SB0

- We can compare the model to past storms

- Precipitation gages and stream gages

Hydraulics (HEC-RAS 2D)

- Model calibration was performed for the largest rain events of record:
  - December 2005 (the "New Year's Flood")
  - January 2017
  - February 2019

Legend

Gages
- 🔵 Precipitation
- ✕ Stream
- ⊗ Stream and Precipitation
- 🟠 County Precipitation
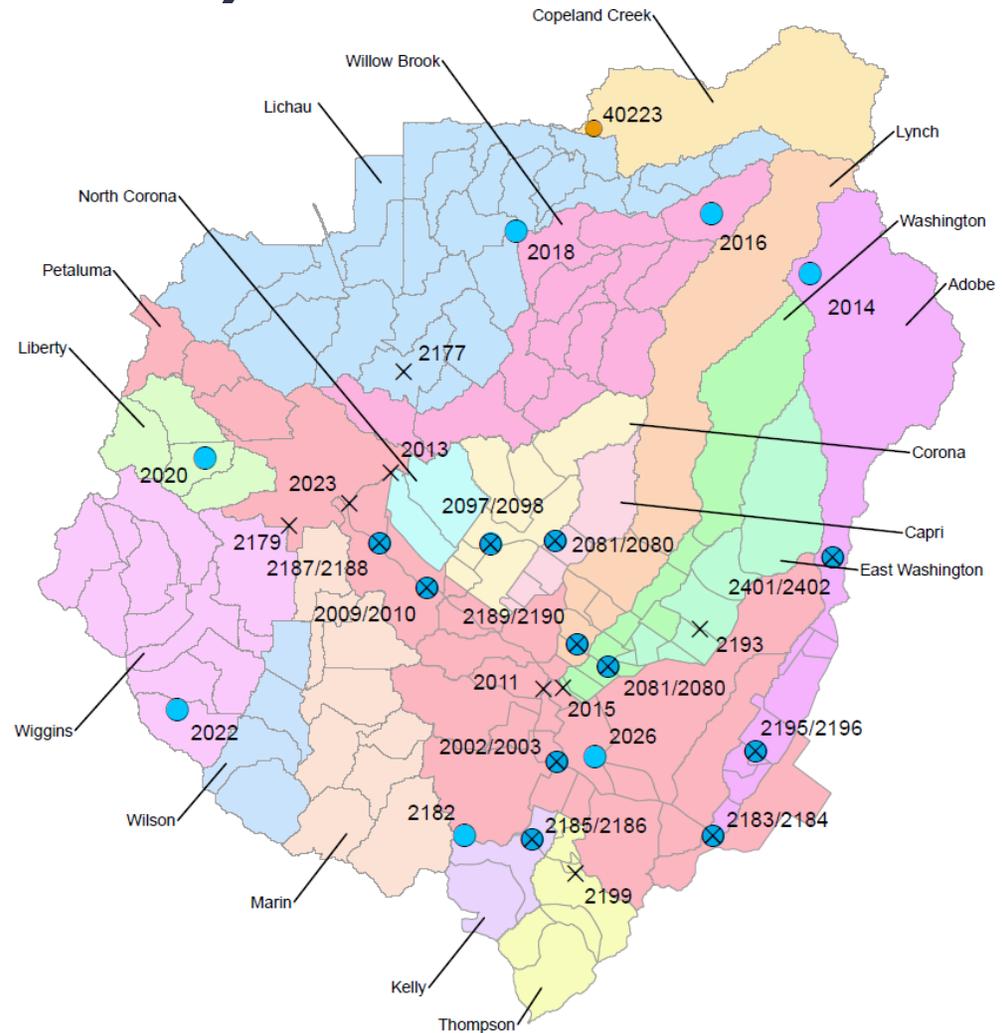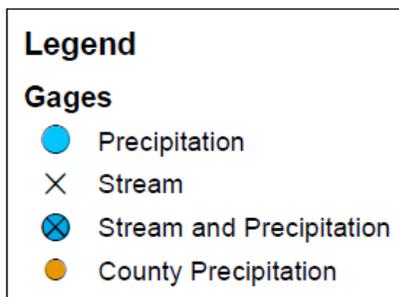
Hydraulics (HEC-RAS 2D)

- Calibration results at Payran:
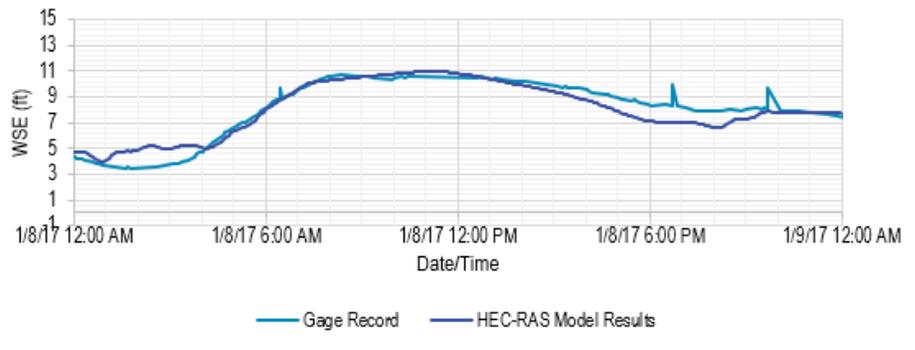
Figure·4-14.·2017·Stream·Gage·Data·Comparison:·Petaluma·R·@·Payran·St·(ID:2011)¶
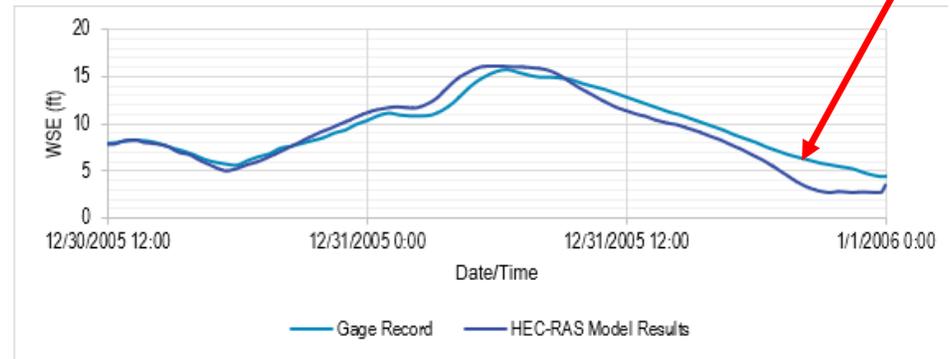
Figure·4-7.·2005·Stream·Gage·Data·Comparison:·Petaluma·R·@·Payran·St·(ID:2011)¶
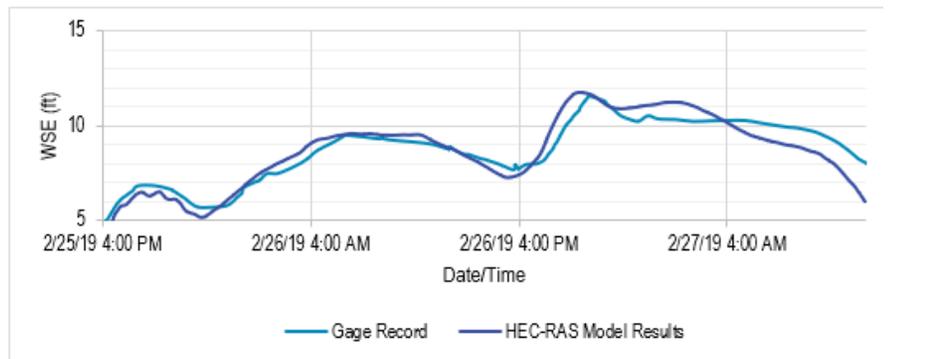
Figure·4-23.·2019·Stream·Gage·Data·Comparison:·Petaluma·R·@·Payran·(ID:2011)¶

- Model predicts floods very similar to historical storms

The Bay level impacts how much water can flow down the River

How high is the river during a rain event?

- The model must make an assumption about the height of the River near the railroad drawbridge (near 101 bridge) during a storm

  - The river elevation is assumed to be the Mean Higher High Water (MHHW), as in previous models


Datums for 9415584, Petaluma River, Upper Drawbridge, CA
All figures in feet relative to NAVD88
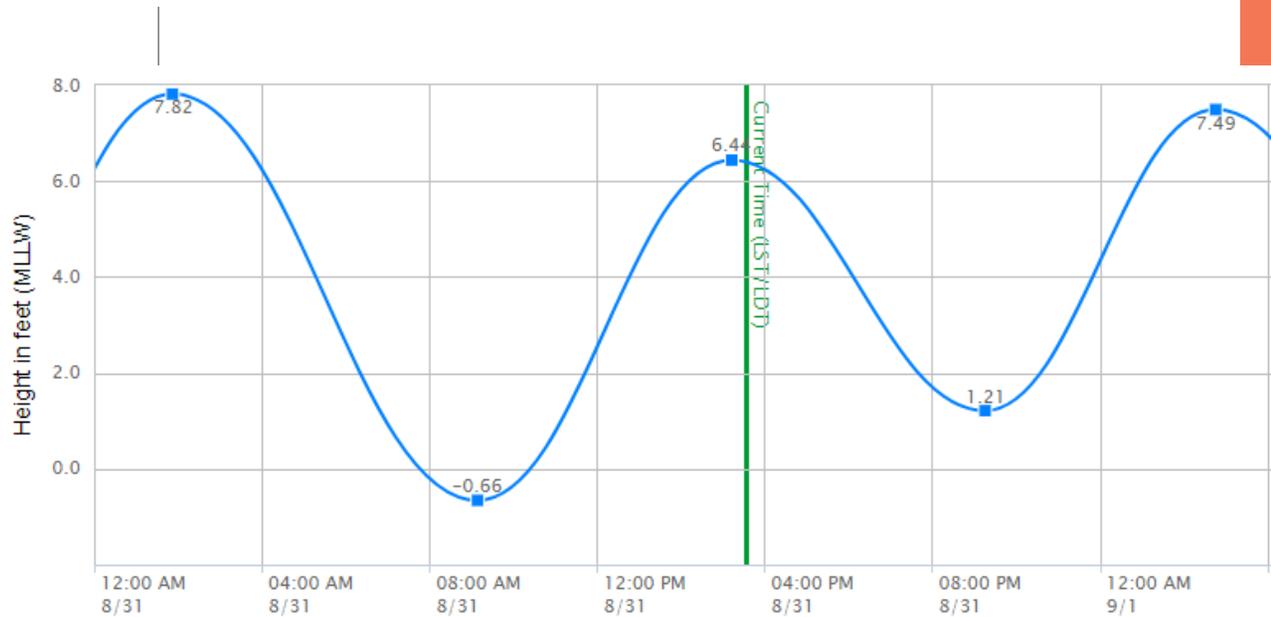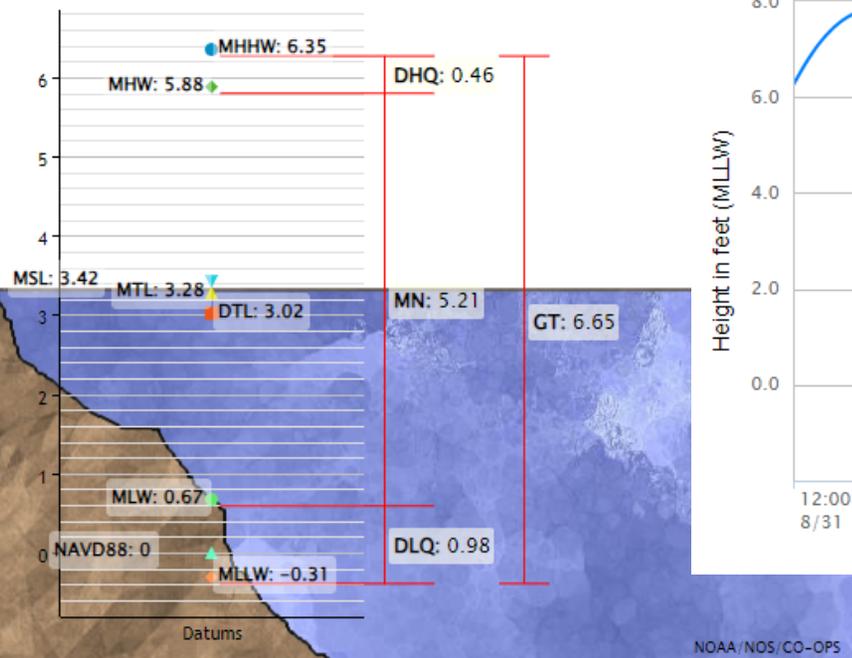
What about King Tides?

- Why not assume the river is at King tide during the rain event?

  - King tide is an exceptionally high tide (typically during new or full moon around the Equinox)

  - It is very unlikely for 1%ACE Rain to happen during King Tide

  - Using "Mean Higher High Water" (MHHW) is sufficiently conservative
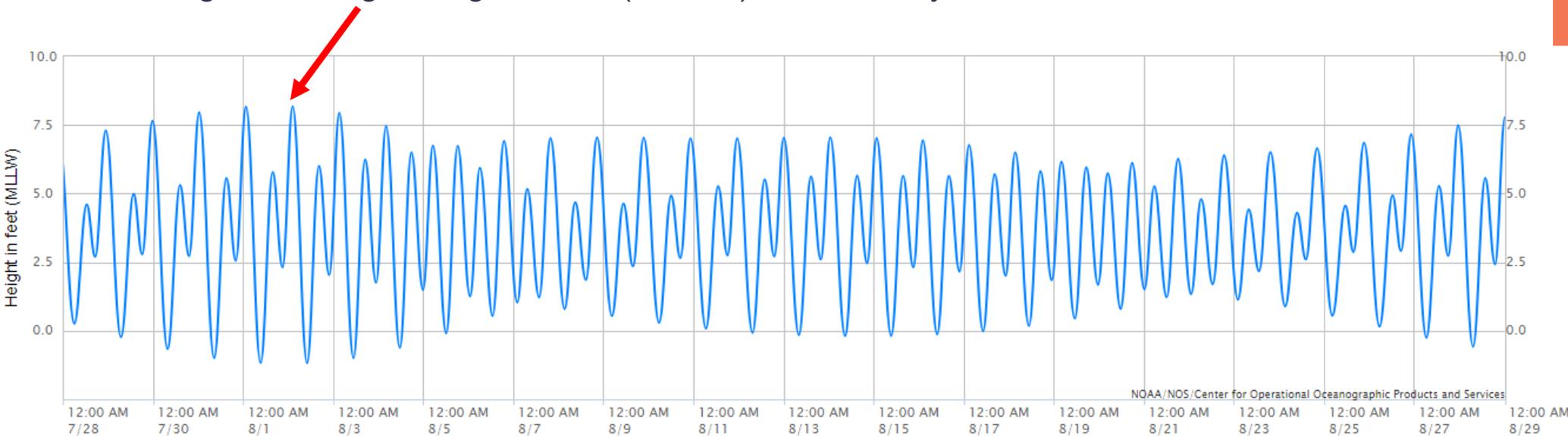
# Downstream Boundary Assumptions/Definitions

- The model doesn't assume a storm surge (ocean water moving upriver) happens at the same time as rainfall (rain moving down river)

- US Army Corps standards were followed.
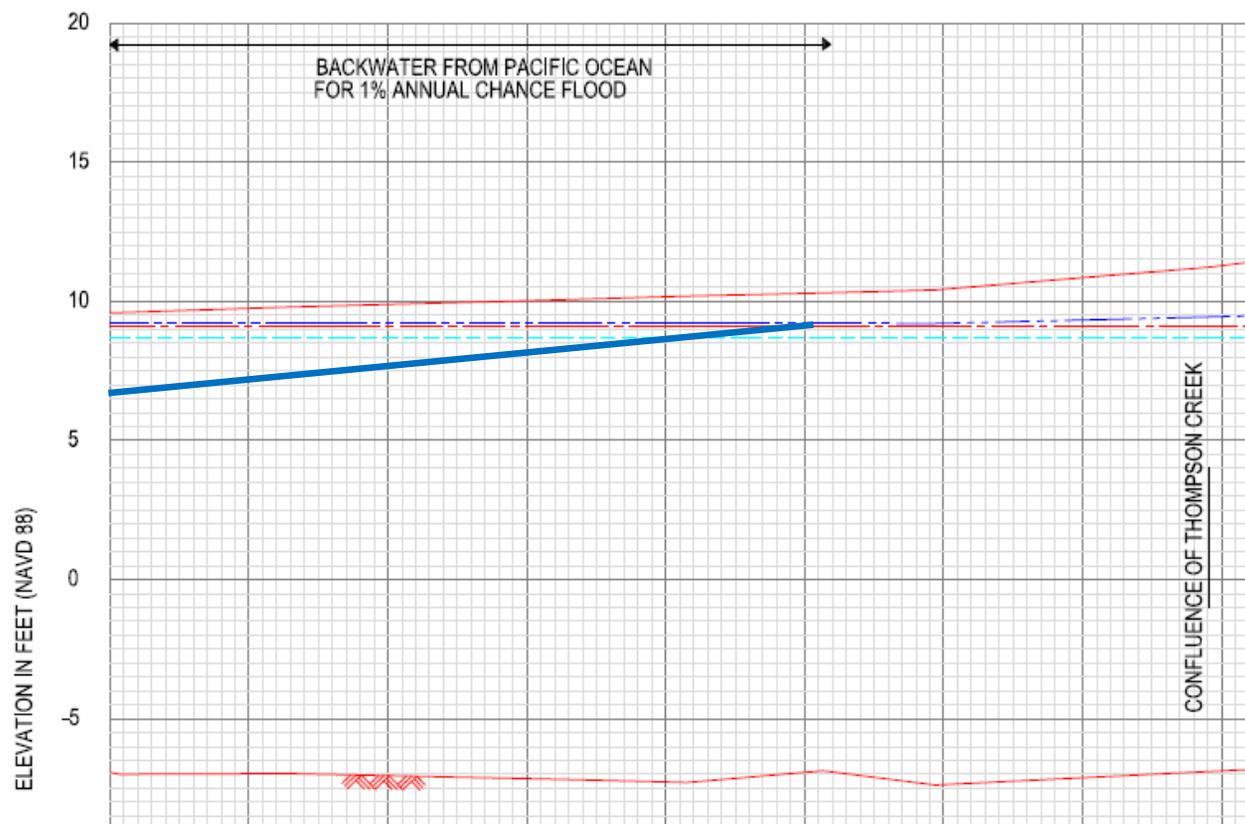
Possible Changes to Precipitation and Storms

- Limited state guidance or local precedence to factor in changes

- Rain is expected to get more intense, and storms surge to get higher

- Available data in 2022 wasn't sufficient to include in model

- Draft policy to incorporate estimates in future flood model

Figure A-6. Projected Changes in Mean Annual Precipitation for the Sonoma County Region based on CMIP3 and CMIP5 Projections
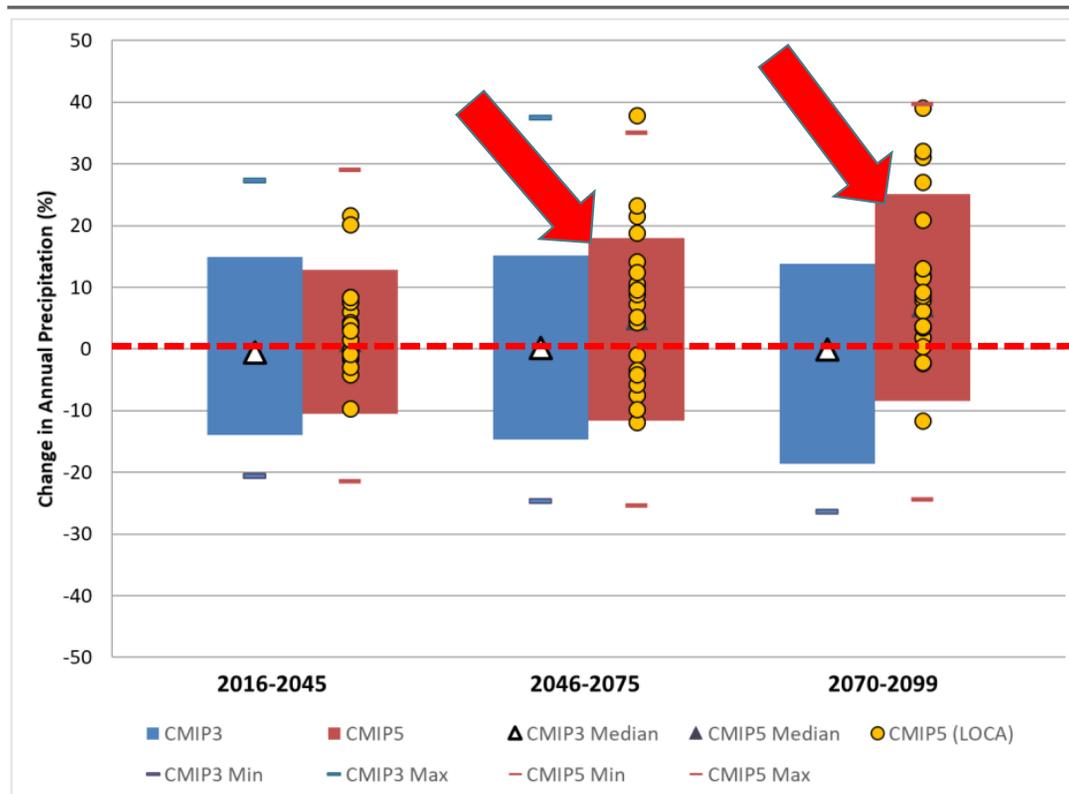
Sonoma Water: Climate Resilience Efforts Appendix A

Changes to Urban Cover

- Impervious surfaces = added pavement & buildings which cause more runoff
  - Issues include pollution, groundwater depletion, erosion, urban heat island, etc
  - Cause more flooding in small rain events
  - Model was stress tested
    - Not sensitive to higher impervious cover in city
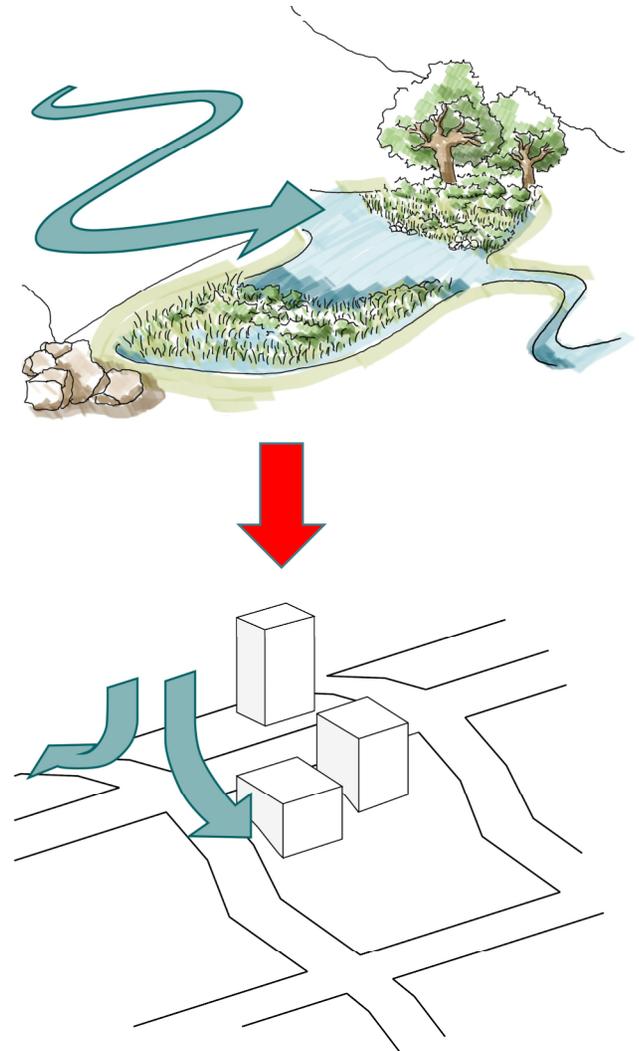
Sherwood Design Engineers

Hazard + Likelihood + Impact = Risk

RISK EXPOSURE MATRIX		IMPACT				
		Insignificant	Minor	Moderate	Major	Catastrophic
LIKELIHOOD	Almost Certain	Low	Medium	High	Critical	Critical
	Likely	Low	Medium	High	Critical	Critical
	Possible	Insignificant	Low	Medium	High	High
	Unlikely	Insignificant	Low	Low	Medium	Medium
	Rare	Insignificant	Insignificant	Insignificant	Low	Low