Reliability, Robustness and Resilience: Geospatial considerations

by Xavier Irias
Director of Engineering
EBMUD, Oakland CA
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Reliability

Reliability **is the ability to maintain full or partial level of service over a period of time, possibly when subjected to shocks.**

Example reliability measures:

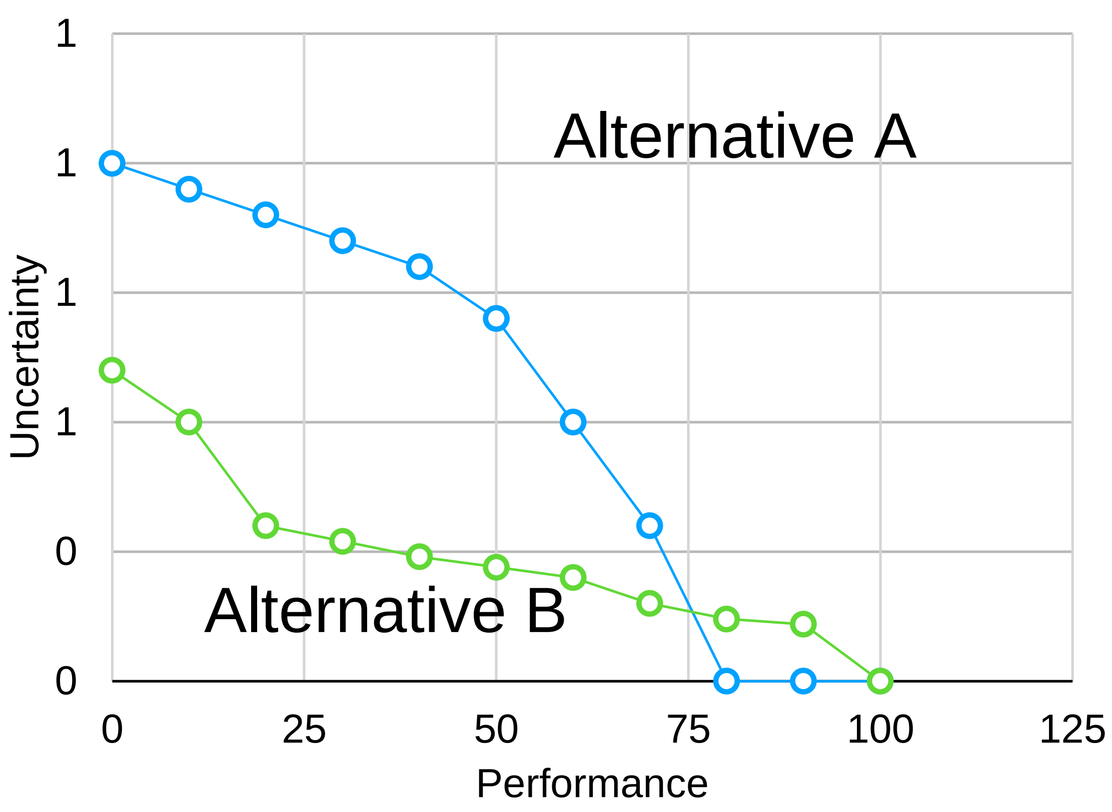
- Probability of component failure P_f on a sunny day
- Probability of component failure P_f given hazard H
- Probability of maintaining ***system*** capacity Q given hazard H
- Probability that at least k of n components survive hazard H
- Total count of qualifying failures over a period of interest
- Total downtime over a period of interest

Robustness

***Robustness* is the ability to perform "good enough even if we're wrong", i.e., perform reasonably well over a range of uncertainty [even if not optimally for the predicted conditions].**

Alternative B is preferred to A unless uncertainty is considered.

If uncertainty is considered, rational preference depends on the level of uncertainty.



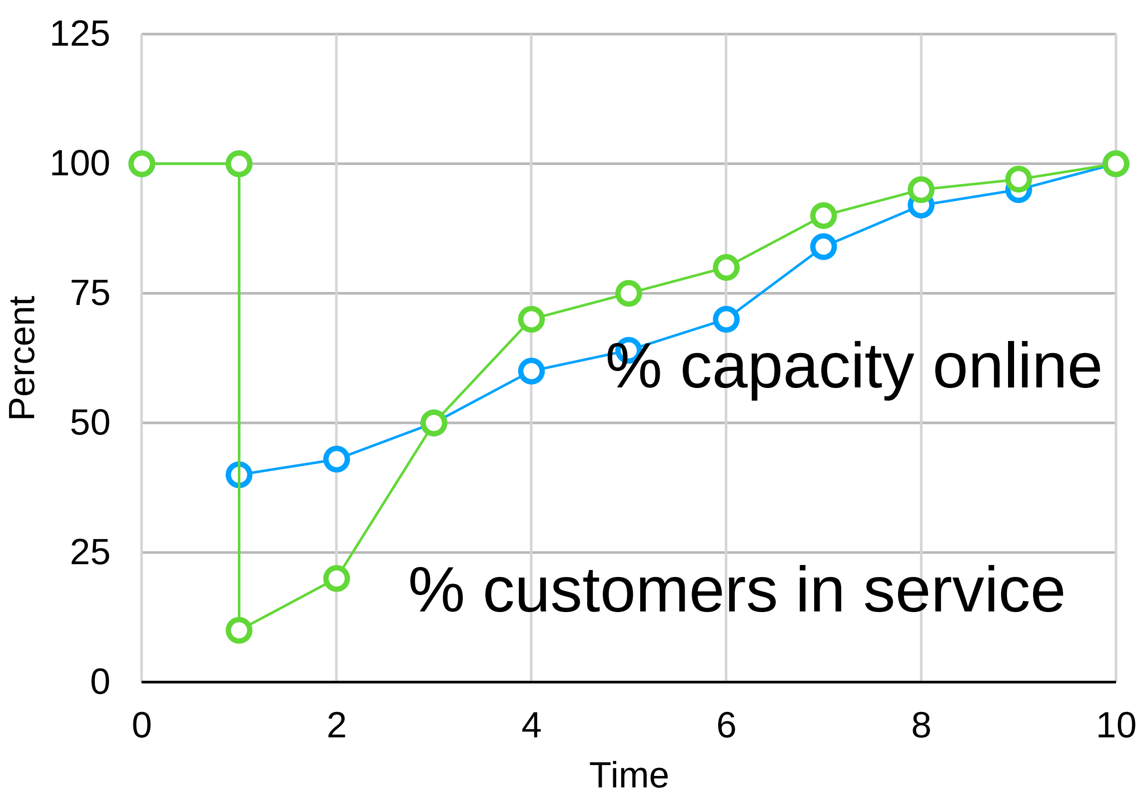
Resilience

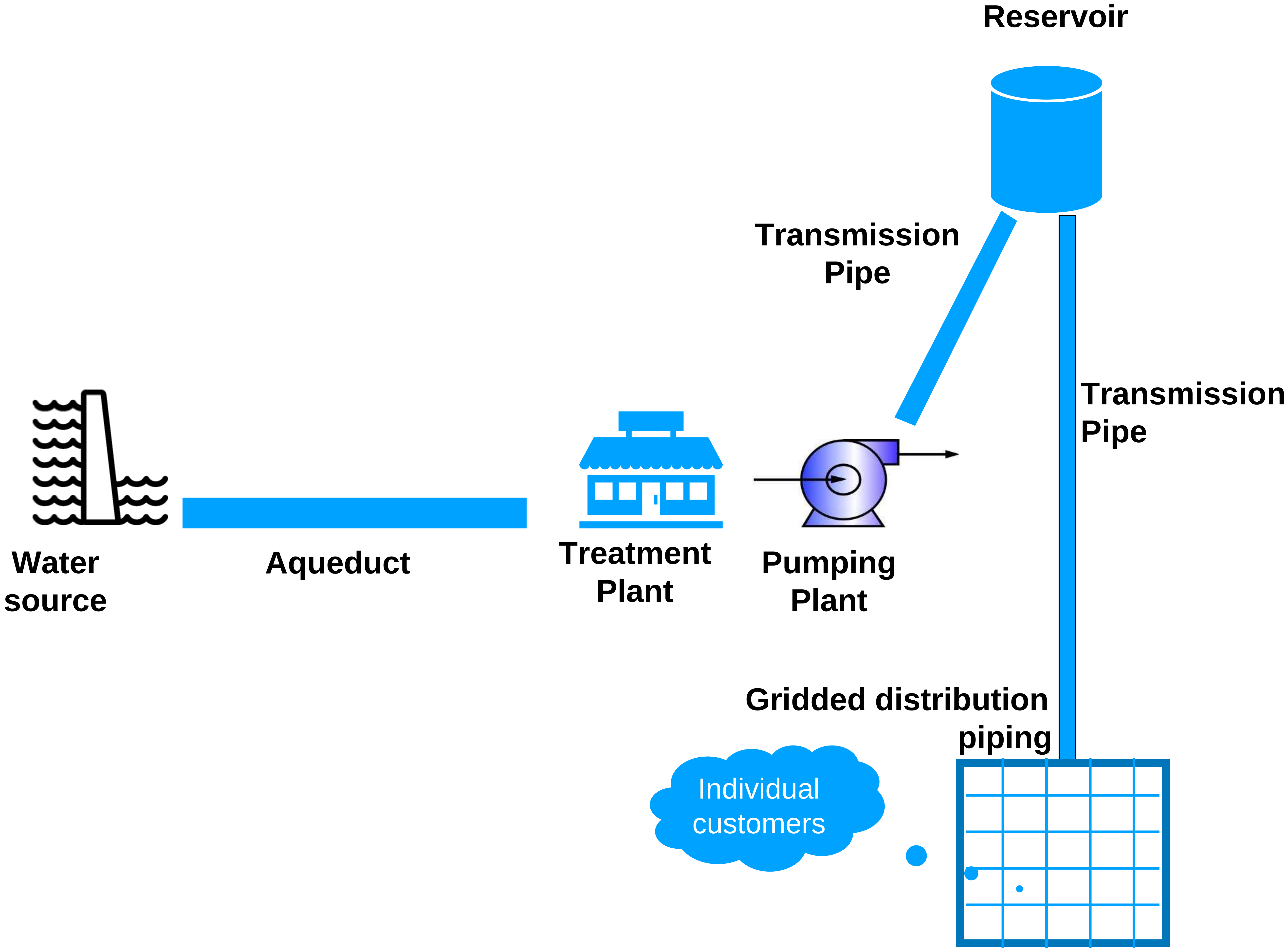
***Resilience* is the ability to function to a degree even when damaged, and to be repaired in a reasonably short time.**

Resilience can be measured different ways, leading to different “scores” being assigned to a given scenario by different stakeholders.

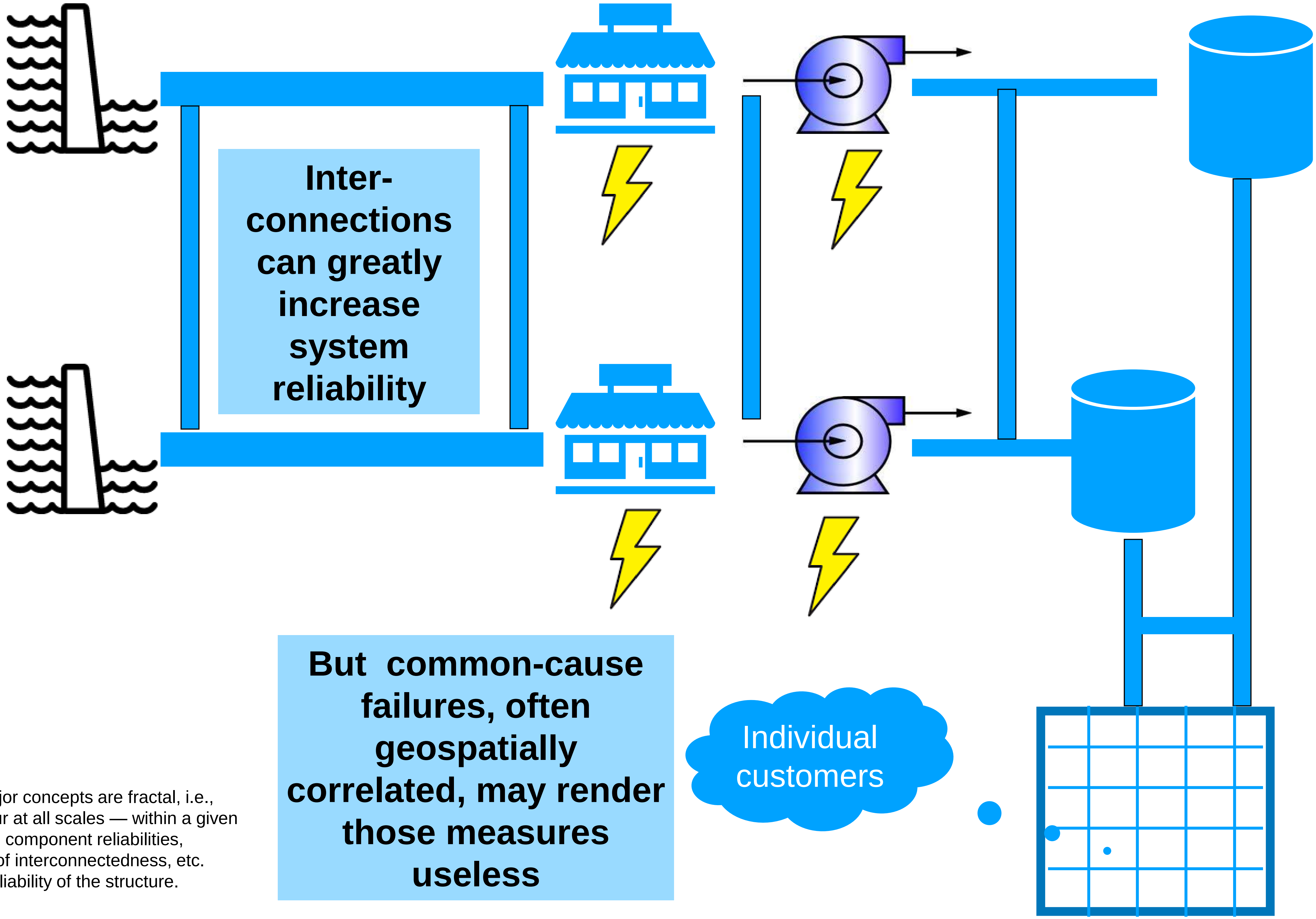
Overall resilience is a composite of resilience across a set of scenarios.

The likelihood and importance of each scenario is often not known or agreed upon.



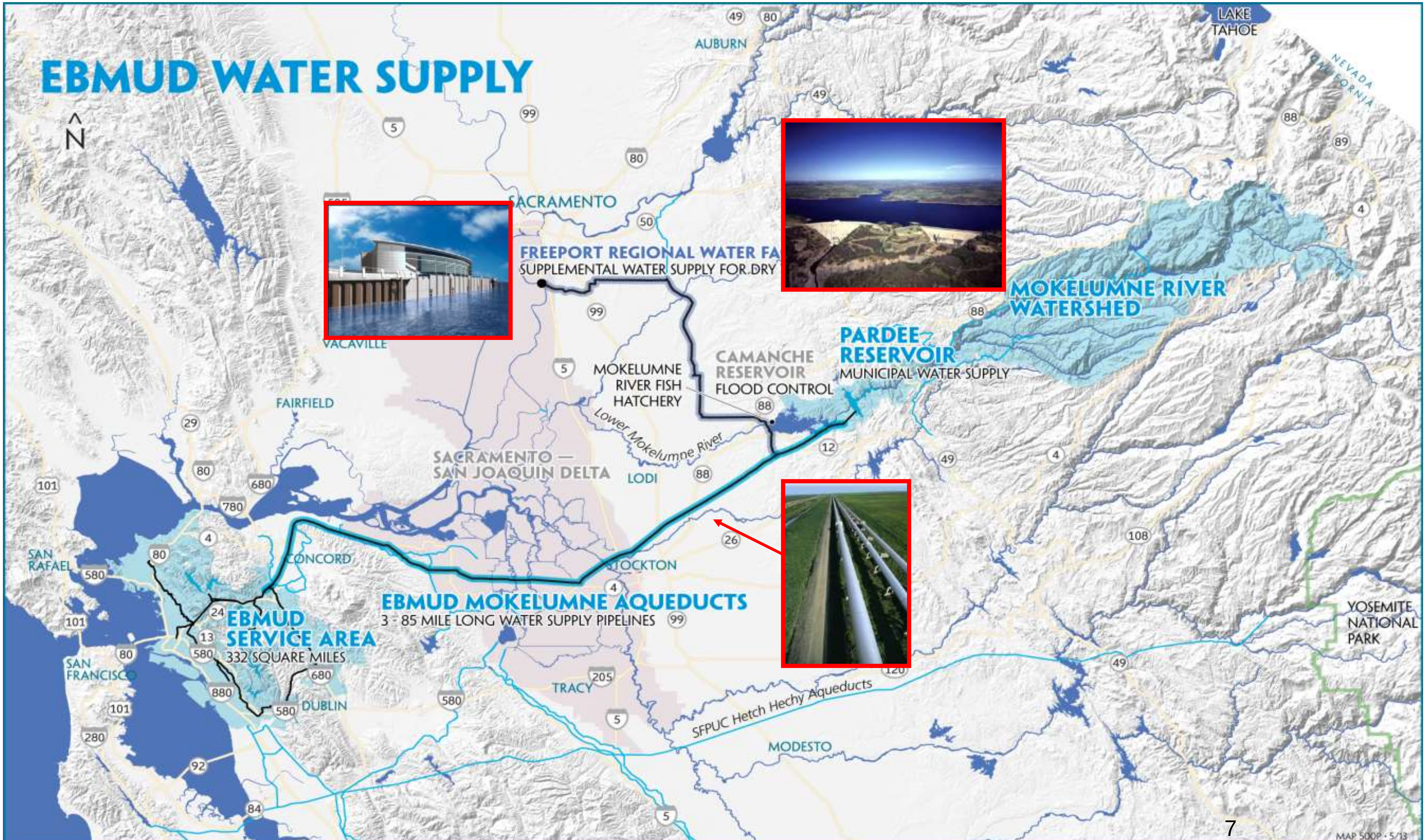

Reservoir
Transmission Pipe
Transmission Pipe
Water source
Aqueduct
Treatment Plant
Pumping Plant
Gridded distribution piping
Individual customers

Redundancy → Reliability?

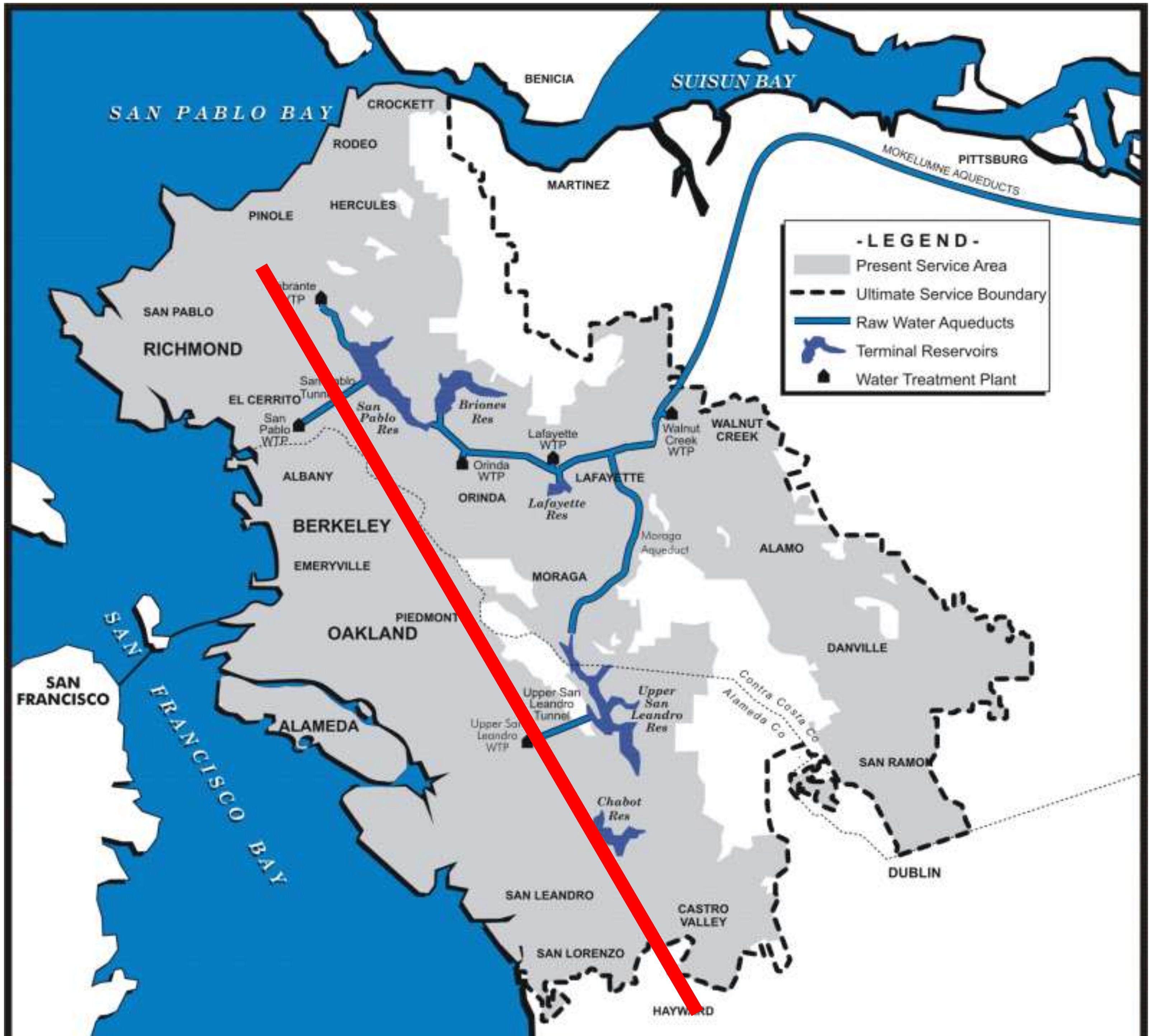


Note: Major concepts are fractal, i.e., they occur at all scales — within a given structure, component reliabilities, degrees of interconnectedness, etc. dictate reliability of the structure.

EBMUD System



EBMUD's Water System

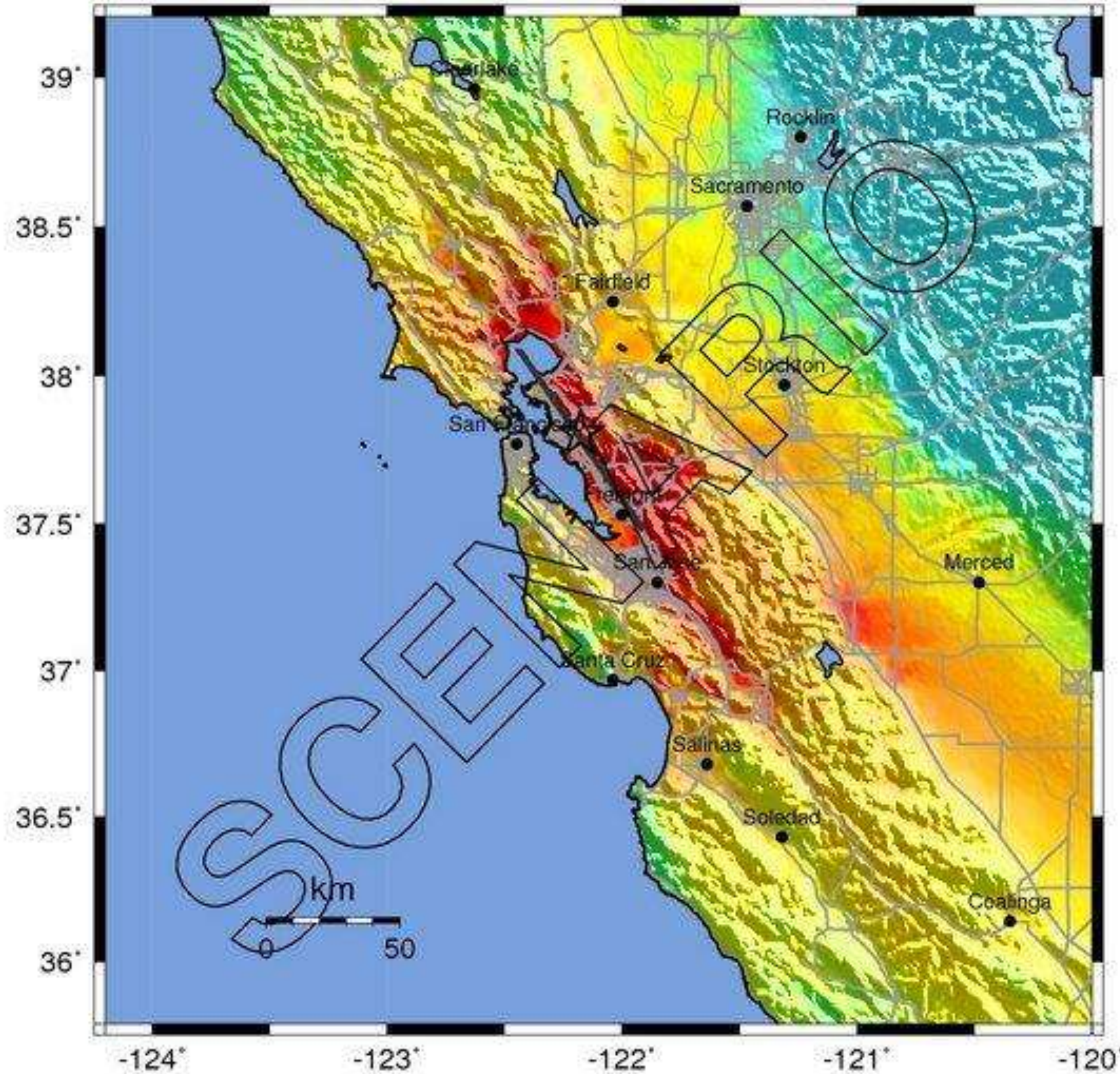


- 1,400,000 retail customers
- 400,000 services
- 6,600 km pipe
- 25 dams
- 5 treatment plants
- 126 pumping plants
- 165 reservoirs/tanks
- 122 pressure zones
- Elevation: MSL-442 m

-- Earthquake Planning Scenario --

ShakeMap for haywiredm7.05 Scenario

Scenario Date: Apr 9, 2014 00:00:00 UTC M 7.0 N37.80 W122.18 Depth: 8.0km

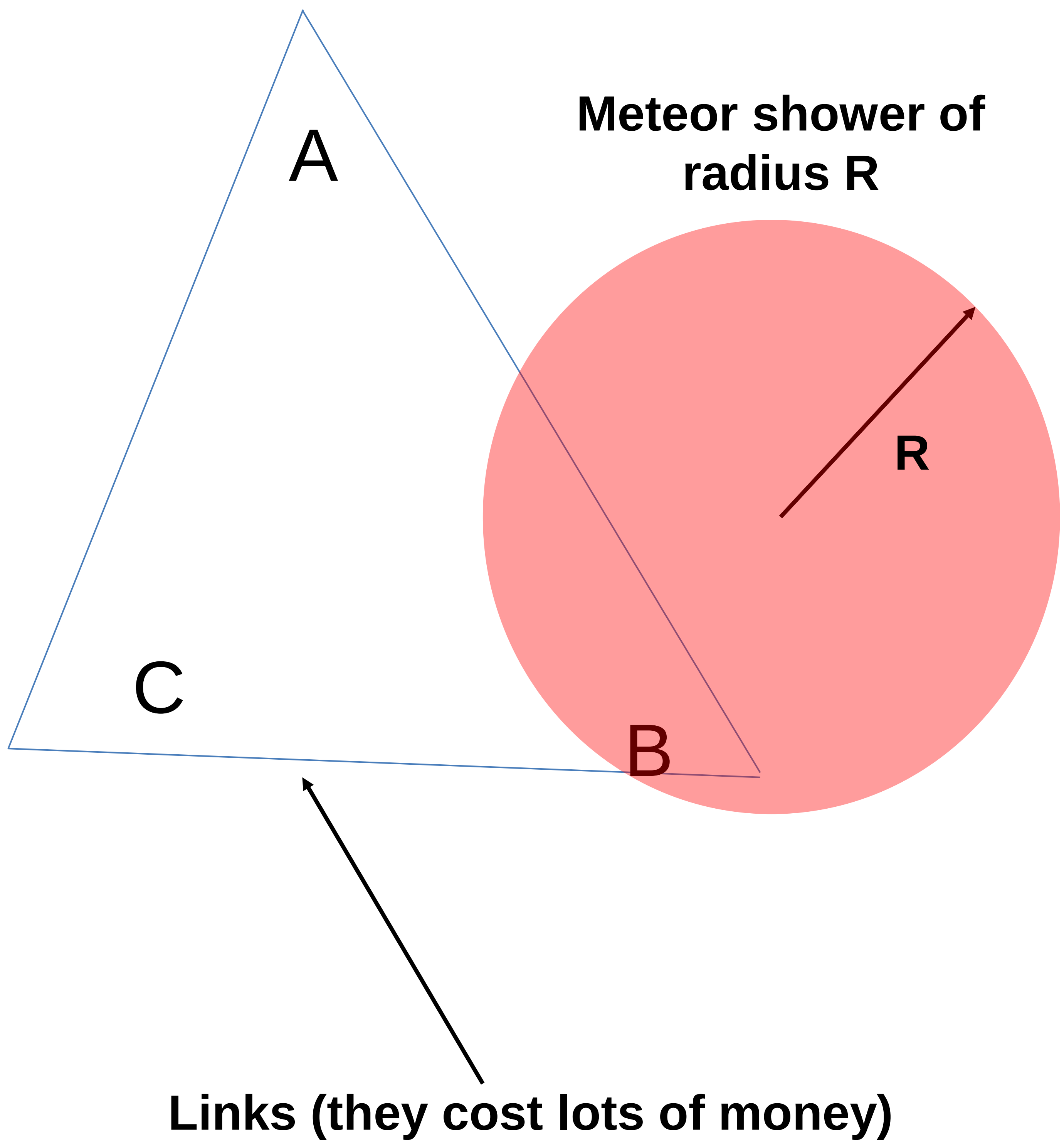


PLANNING SCENARIO ONLY -- Map Version 28 Processed 2015-05-13 22:46:39 UTC

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	*<0.02*	*0.1*	*1.4*	*4.7*	*9.6*	*20*	*41*	*86*	*>178*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2012)

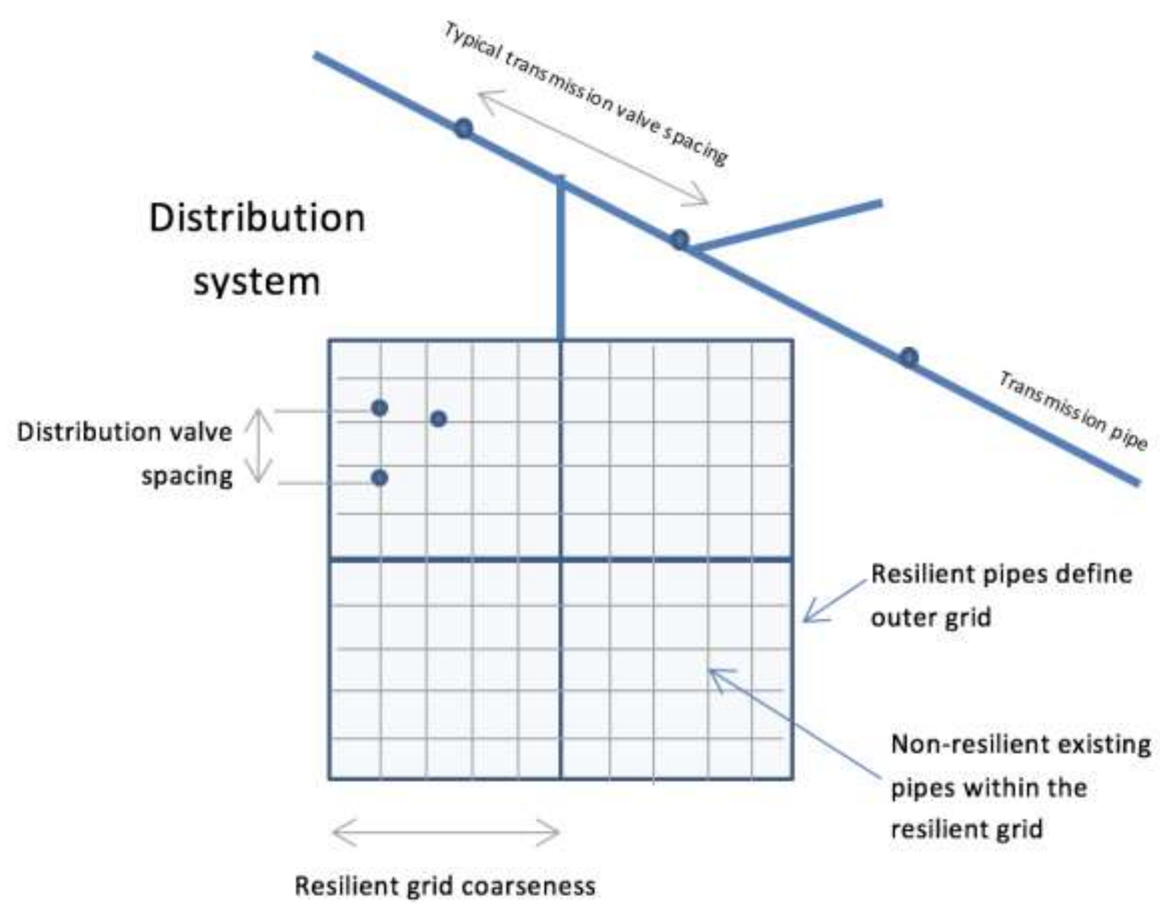
Idealized network



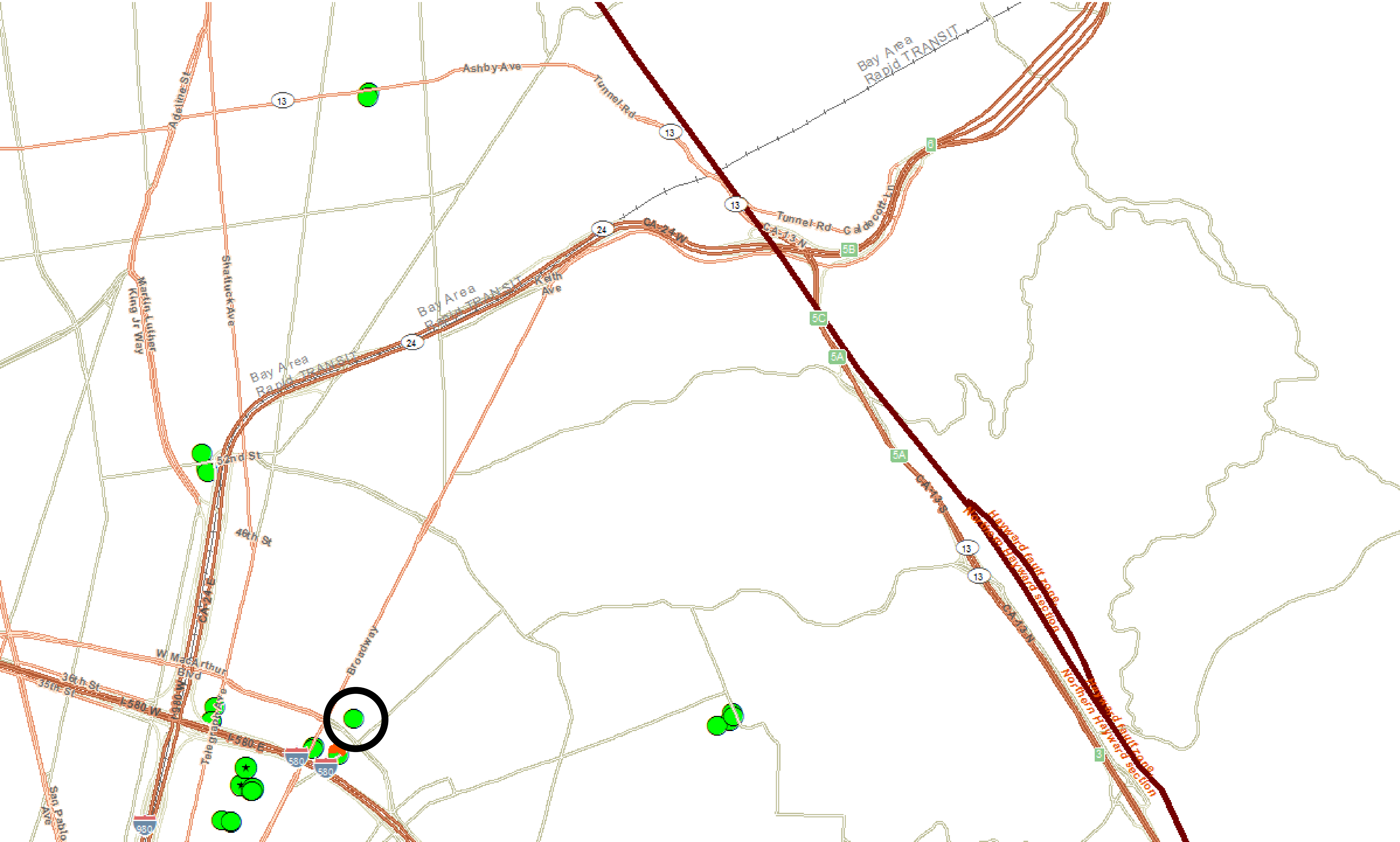
- Assume that service goals are met if A, B or C are in service
- The primary risk is a meteor shower
- Meteor shower's likely radius has been estimated
- Options include:
  1. Harden A,B or C to reduce chance of failure when meteors hit
  2. Separate A,B and C to make it unlikely or impossible for a single meteor strike to knock out all three
  3. Combination of 1 and 2
- Optimal choice depends on:
  - Extent of geographic hazard (e.g. size of meteor shower)
  - Cost of hardening A, B or C
  - Cost of links per mile
  - Needed levels of service

Real-life Tools to Enhance Resilience & Reliability

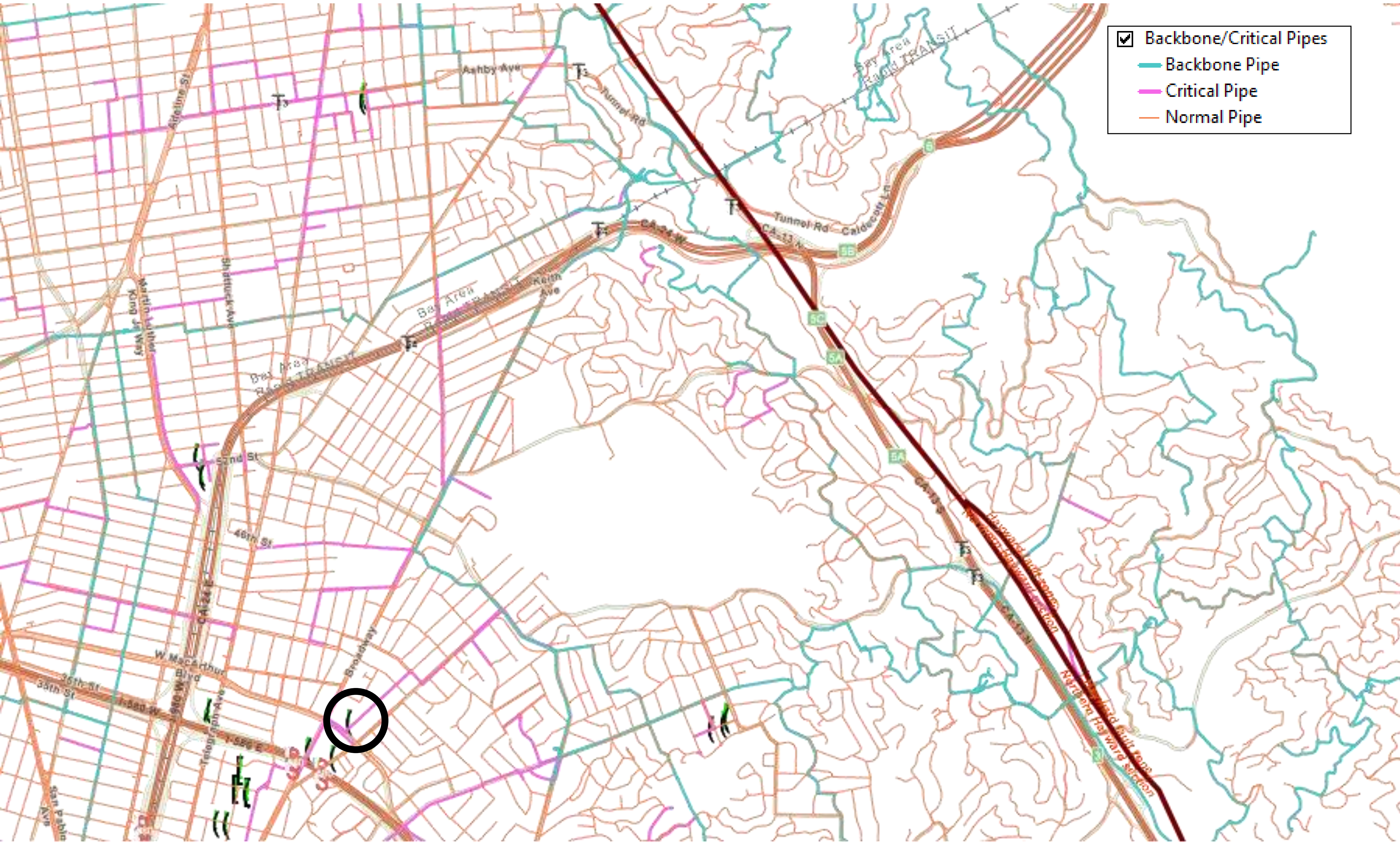
1. **Redundancy of Transmission Mains**
2. **Valve Spacing in Transmission Mains**
3. **Valve Spacing in Distribution Mains**
4. **Resilient Distribution Grid - Coarseness**



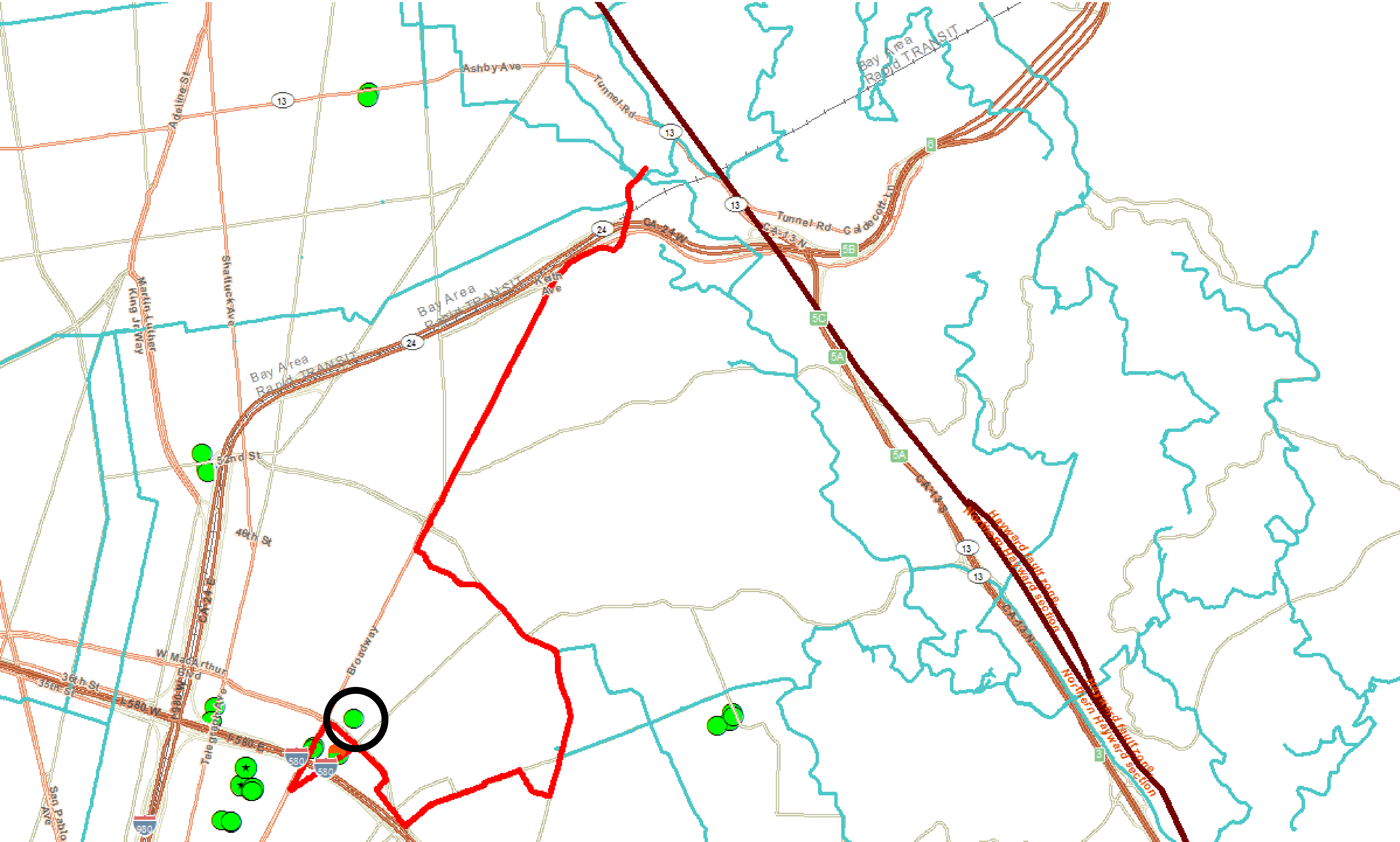
Example Kaiser Oakland



Existing Critical and Backbone Pipe Network



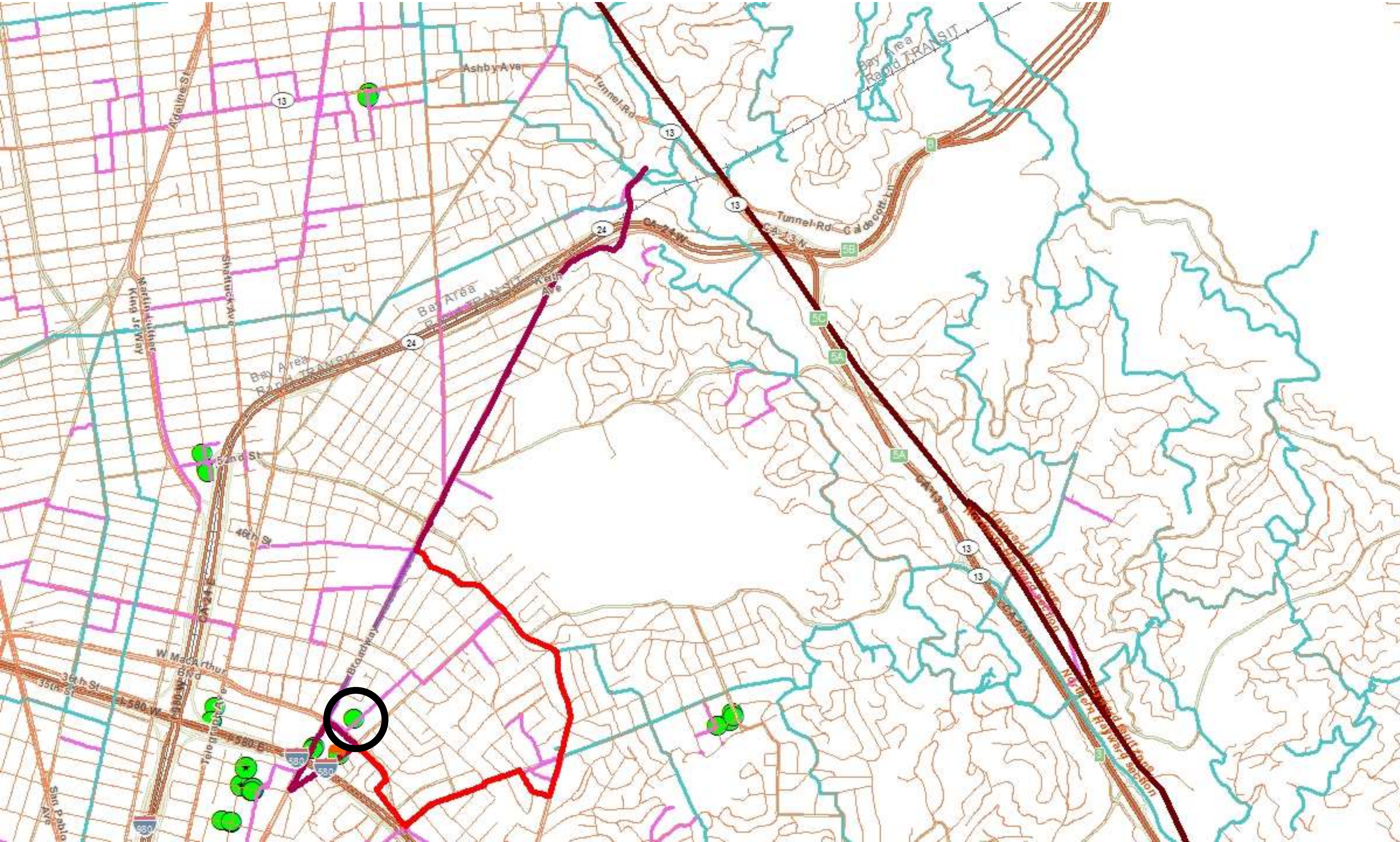
Critical Pipe May Be Largest Pipeline



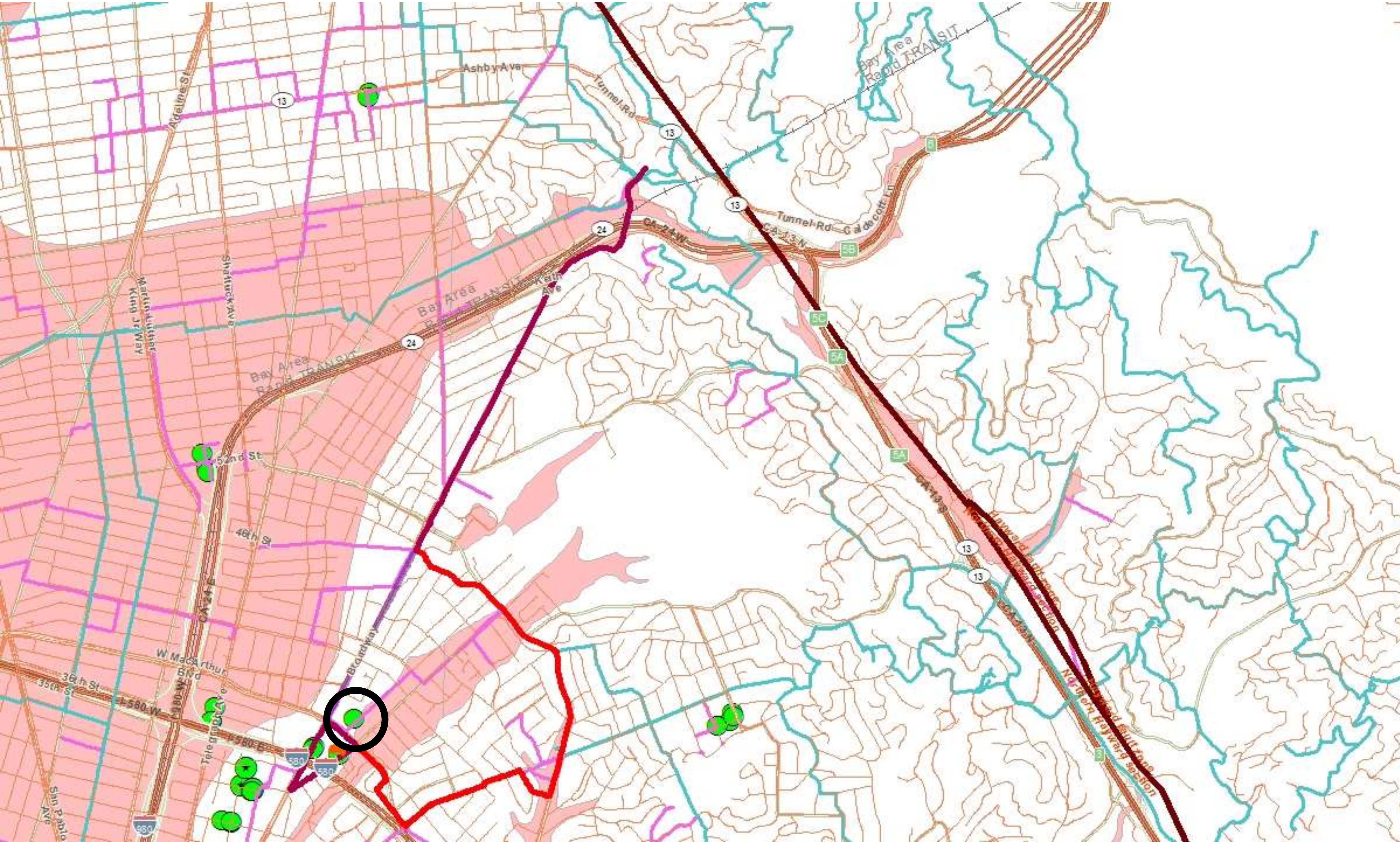
Critical Pipe May Be Most Direct Pipeline

Two Alternative Routes

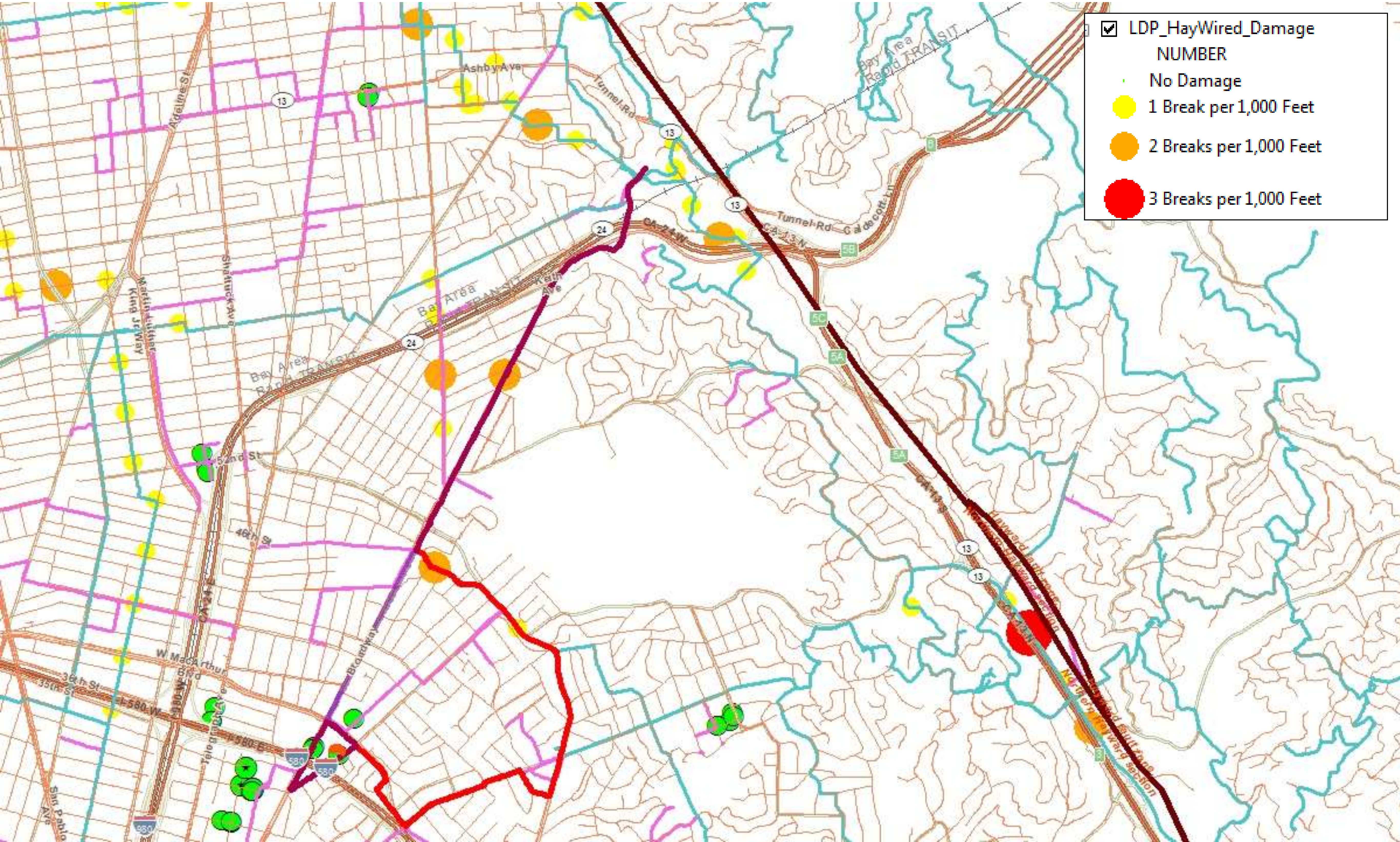
Three Alternative Routes



Hayward Fault and Mapped Liquefaction Areas



HayWired Damage Predictions



Large and Small Diameter Risk Model Scores

Large and Small Diameter Risk Model Scores

Summary

- Achieving reliability, robustness and resilience involves many tradeoffs and uncertainties
- Many hazards may be geospatially correlated such as:
  - Natural disasters
  - Power outages
  - Acts of malice
- Geospatial analysis is fundamental to estimation of hazard and probability, and thus to estimation of risk, and thus to development of solutions