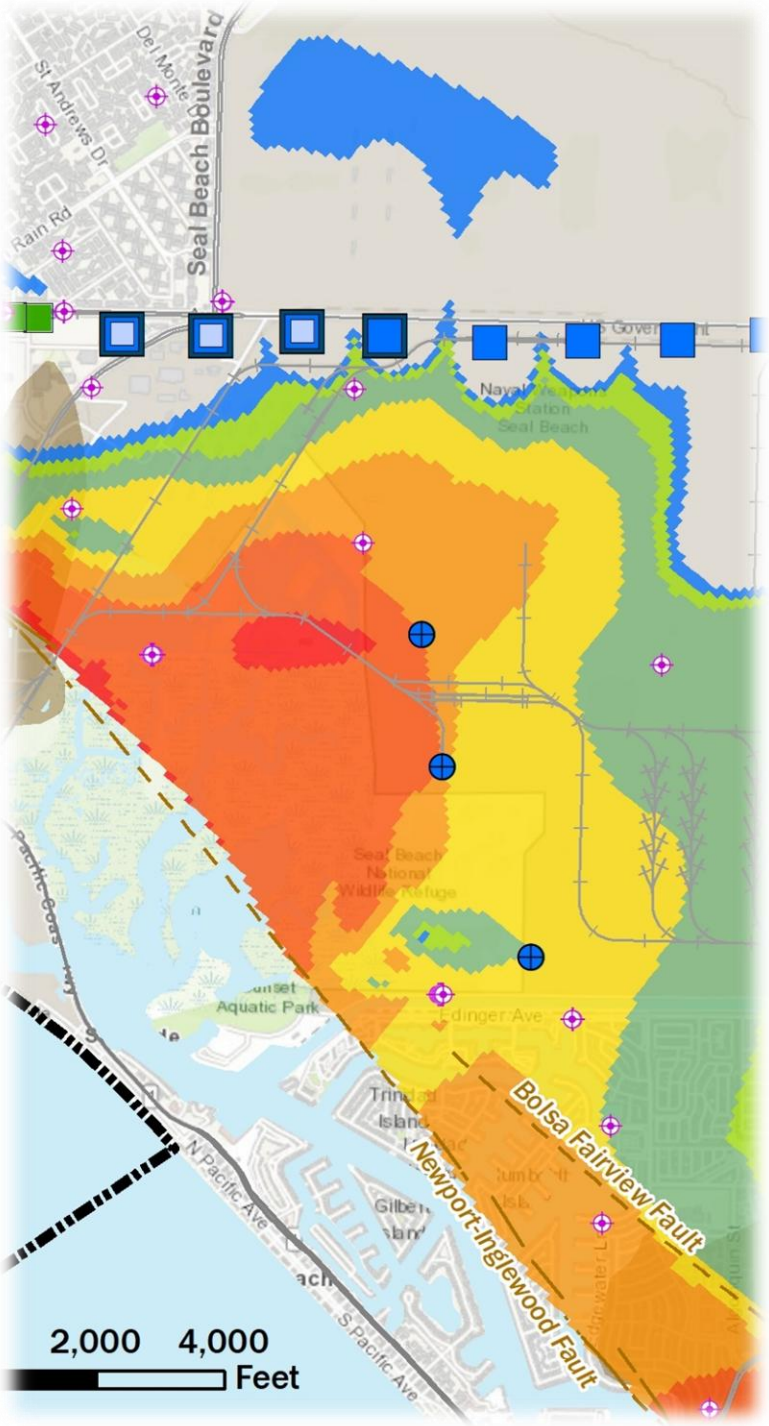


Seawater Intrusion Barrier Modeling

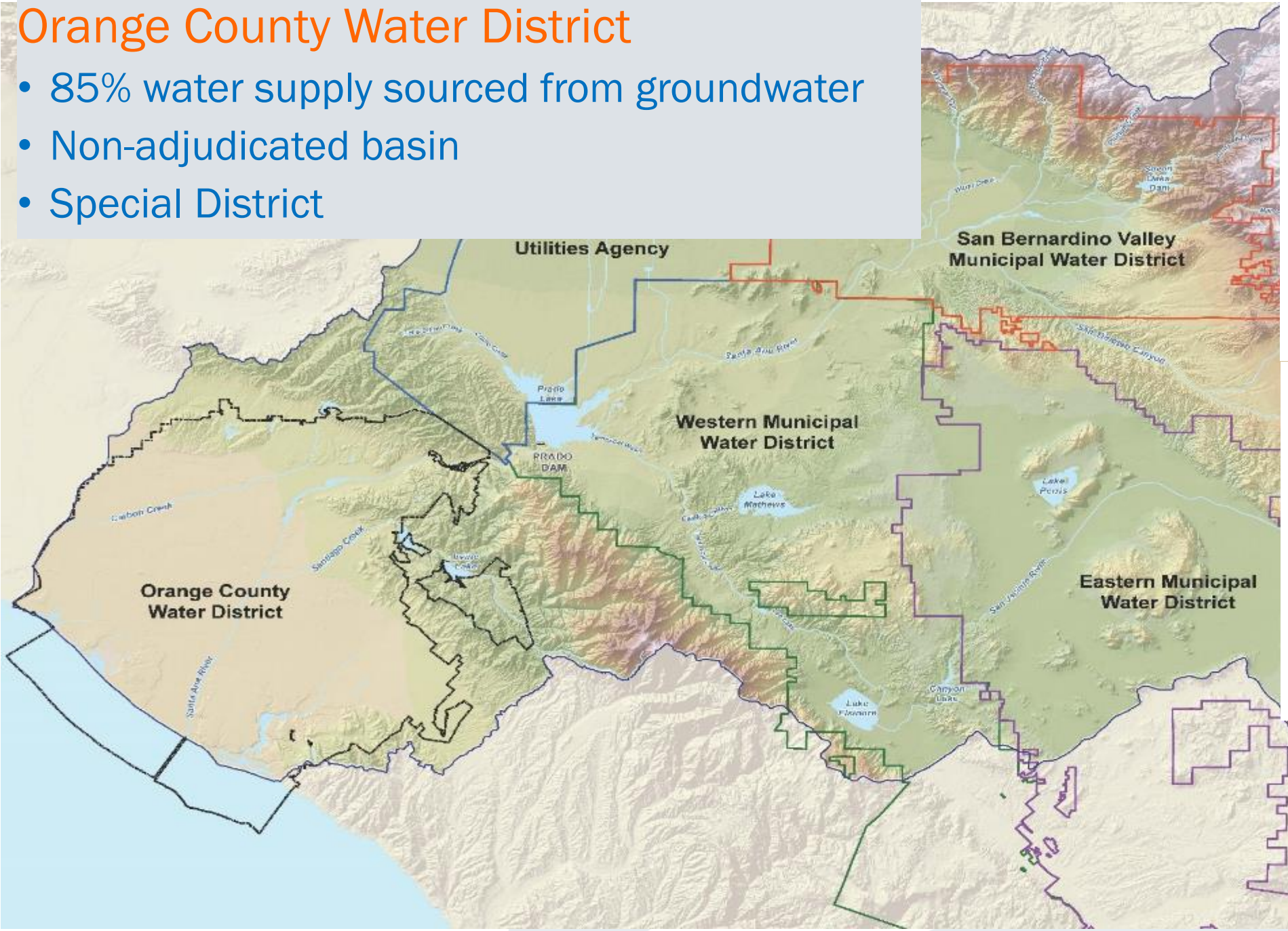
Agenda

- Hydrogeologic Setting
- Model Design
- Assessment of Alternatives

INTERA

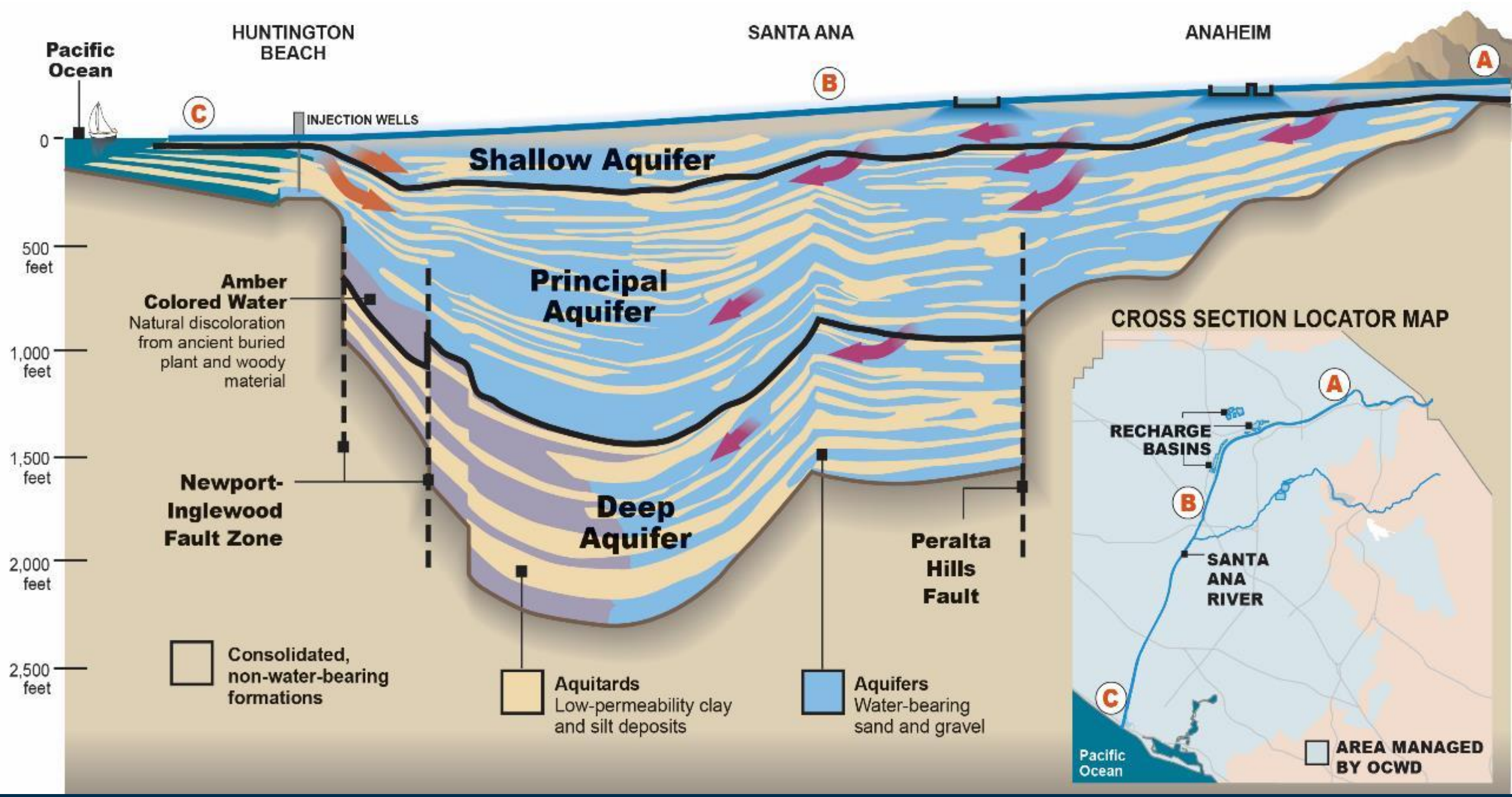
Orange County Water District

- 85% water supply sourced from groundwater
- Non-adjudicated basin
- Special District



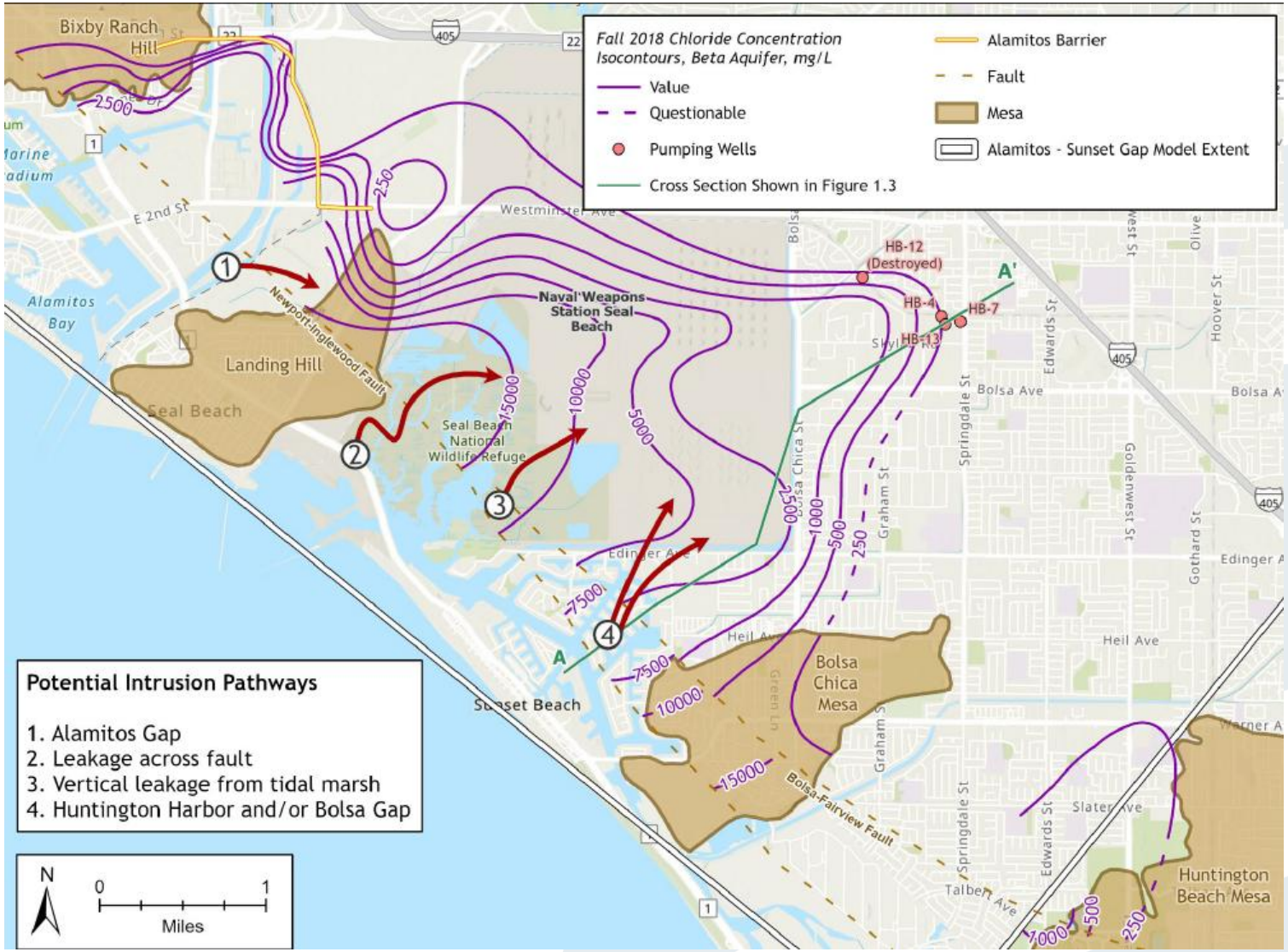
2.5 million people served

OCWD Recharge System



OC Groundwater Basin

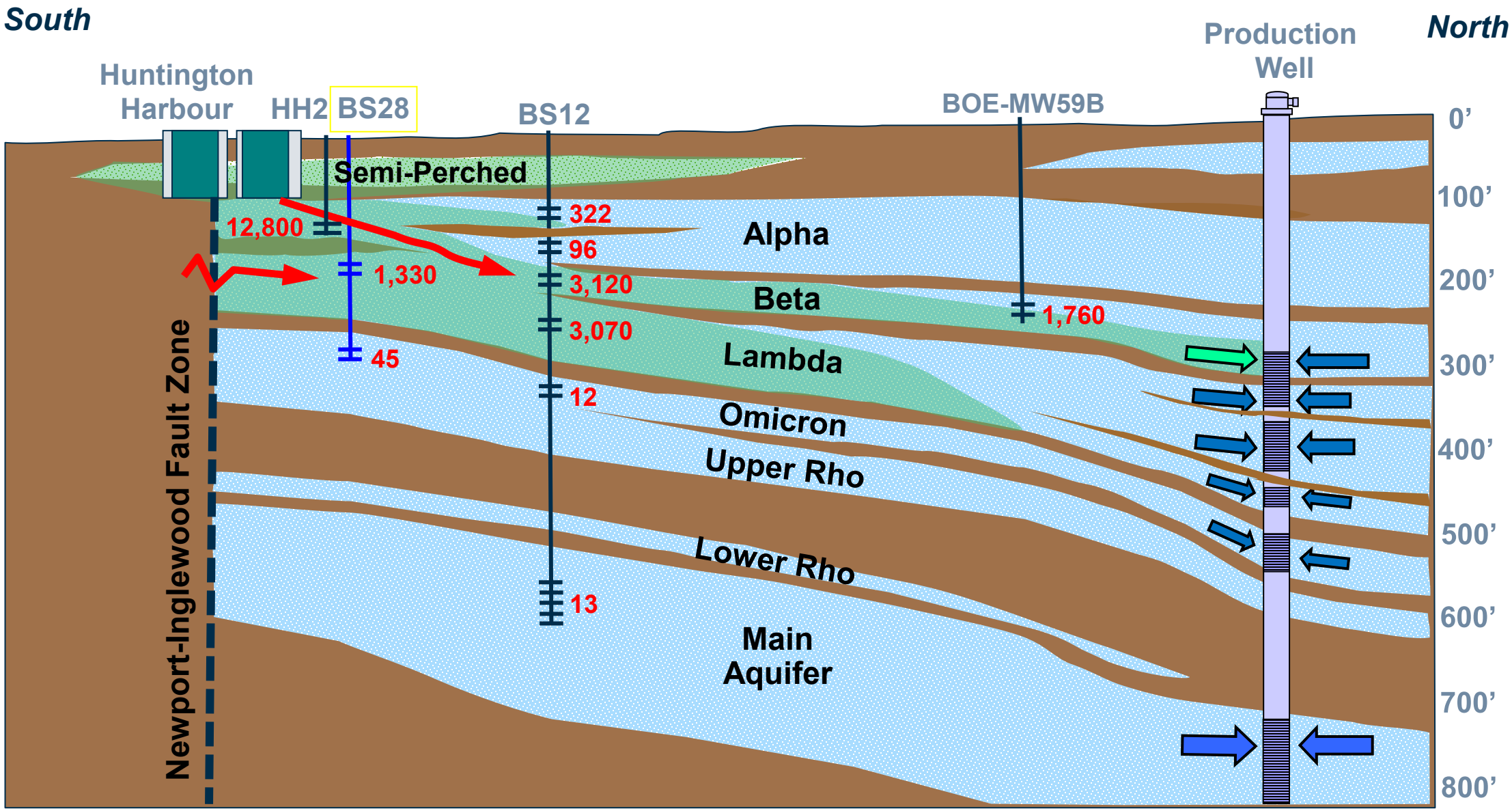
Problem



- Unknown source(s) of <u>seawater intrusion</u>
- One well already destroyed due to brackish water
- Significant pumping continues to draw seawater further inland, threatening more wells & water supply

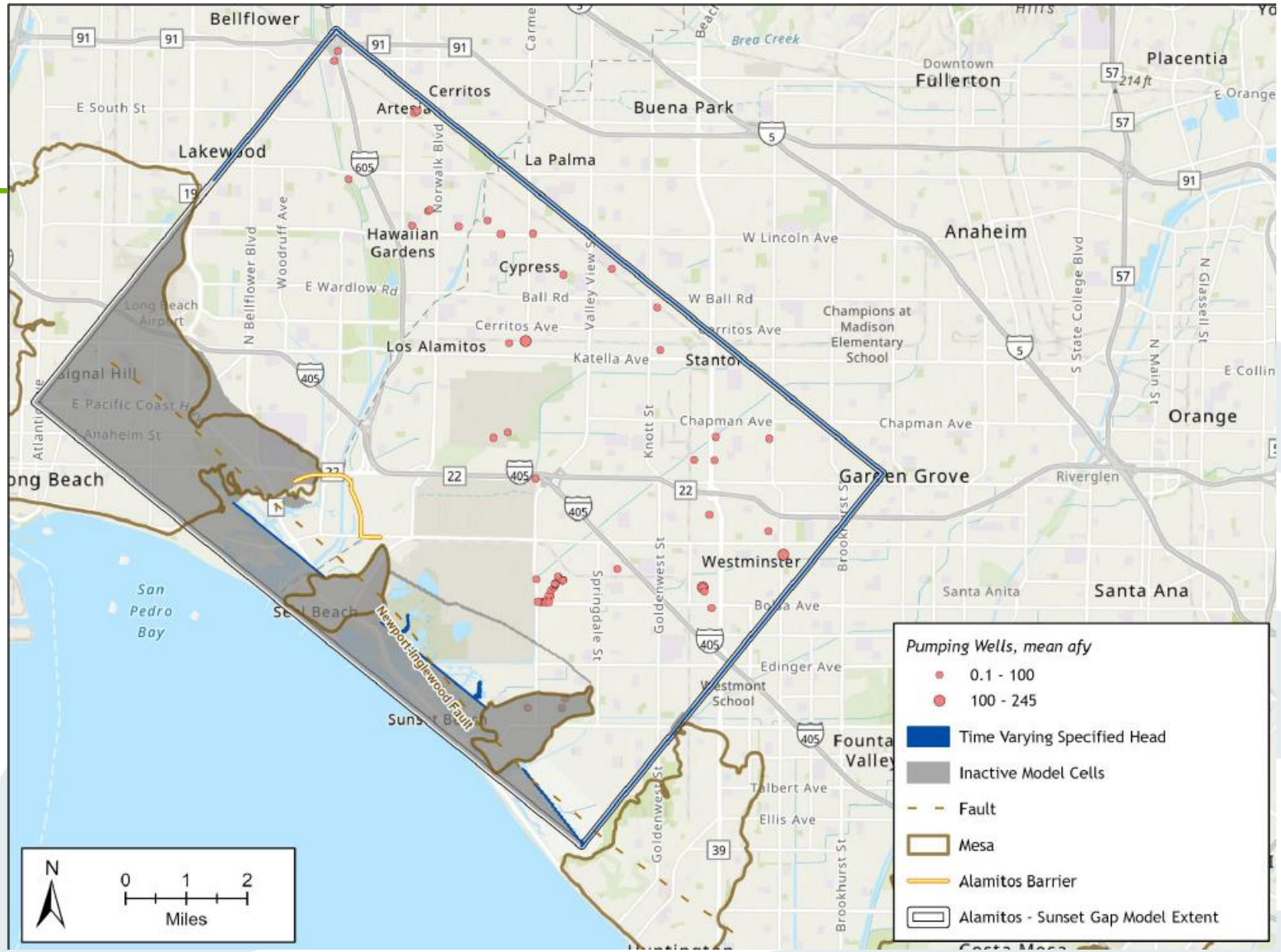
INTERA

Seawater is intruding inland towards Huntington Beach production wells primarily in the Beta Aquifer.



Model Design

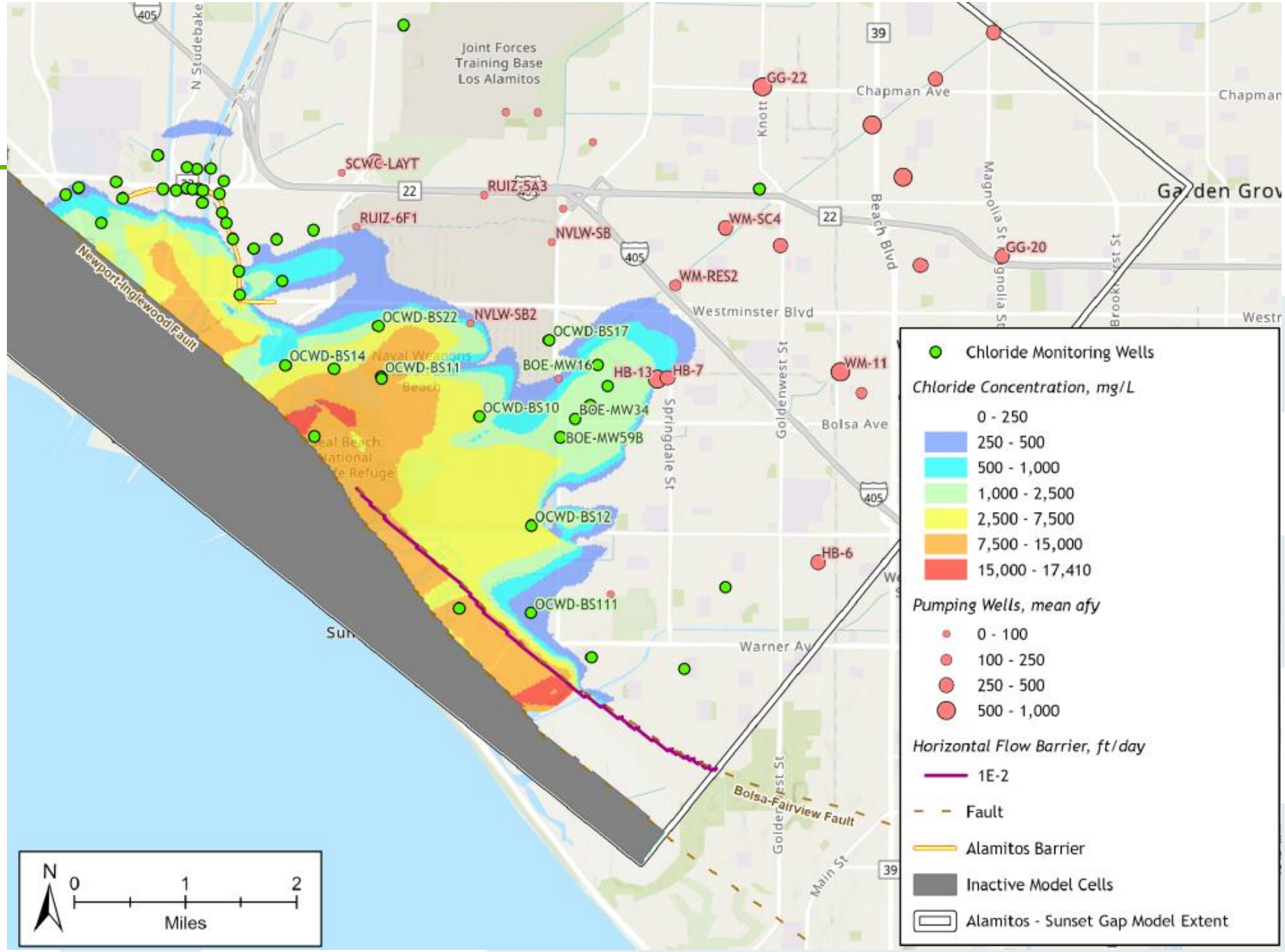
- 15 layers
  - 8 aquifers, 7 intervening aquitards
- 100-ft x 100-ft grid discretization
- “Cut-out Model”
  - Inland boundary based on interpolated water levels between monitoring wells
  - Coastal boundary at ocean boundary
- Monthly stress periods from July 2006-June 2020



Transport Model

- MT3DMS
- Simulate transport of chlorides to represent seawater intrusion

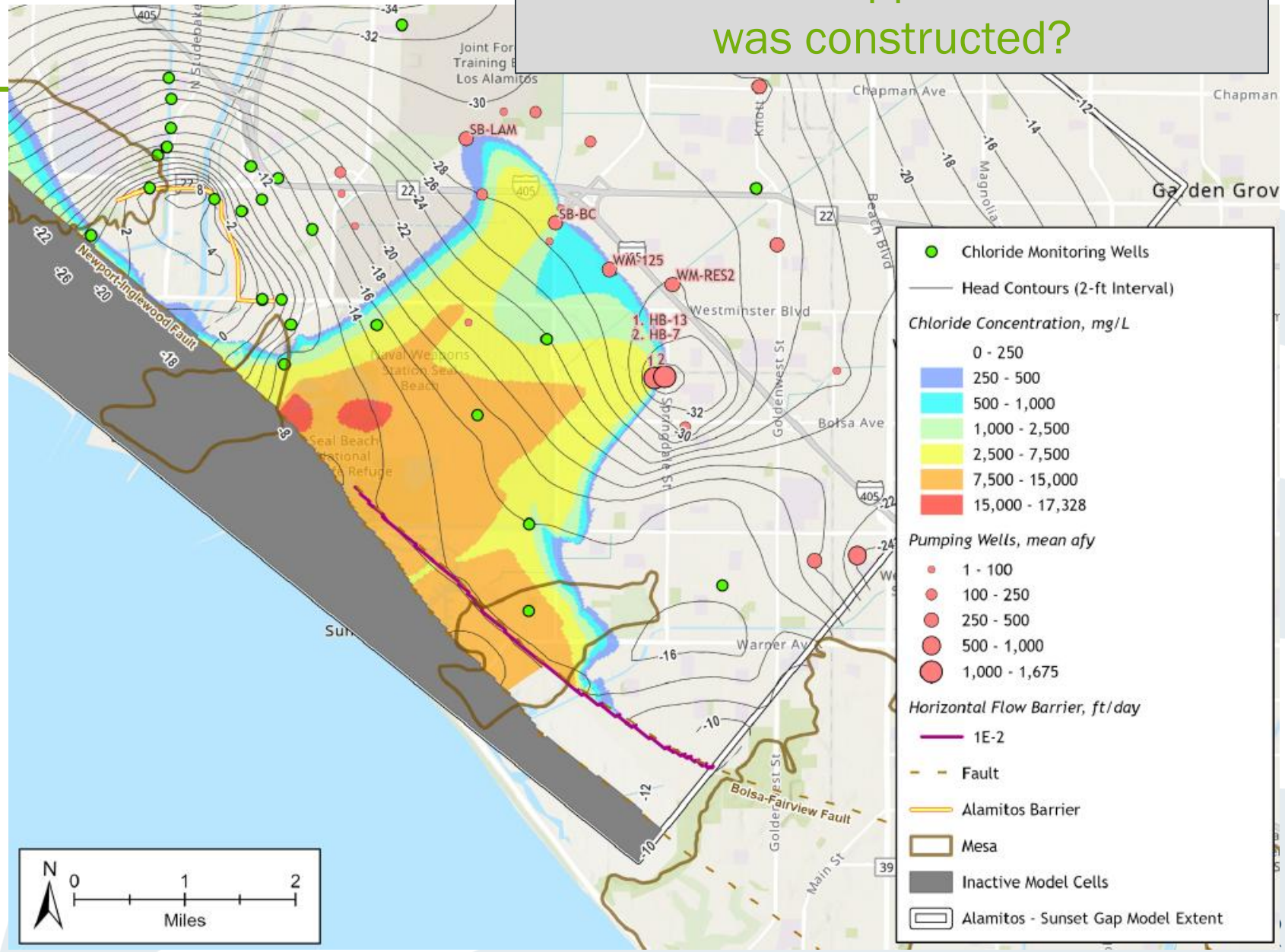
- Model initialized in 2012 (data availability)
- Informed model calibration



60-Year Projected Simulations

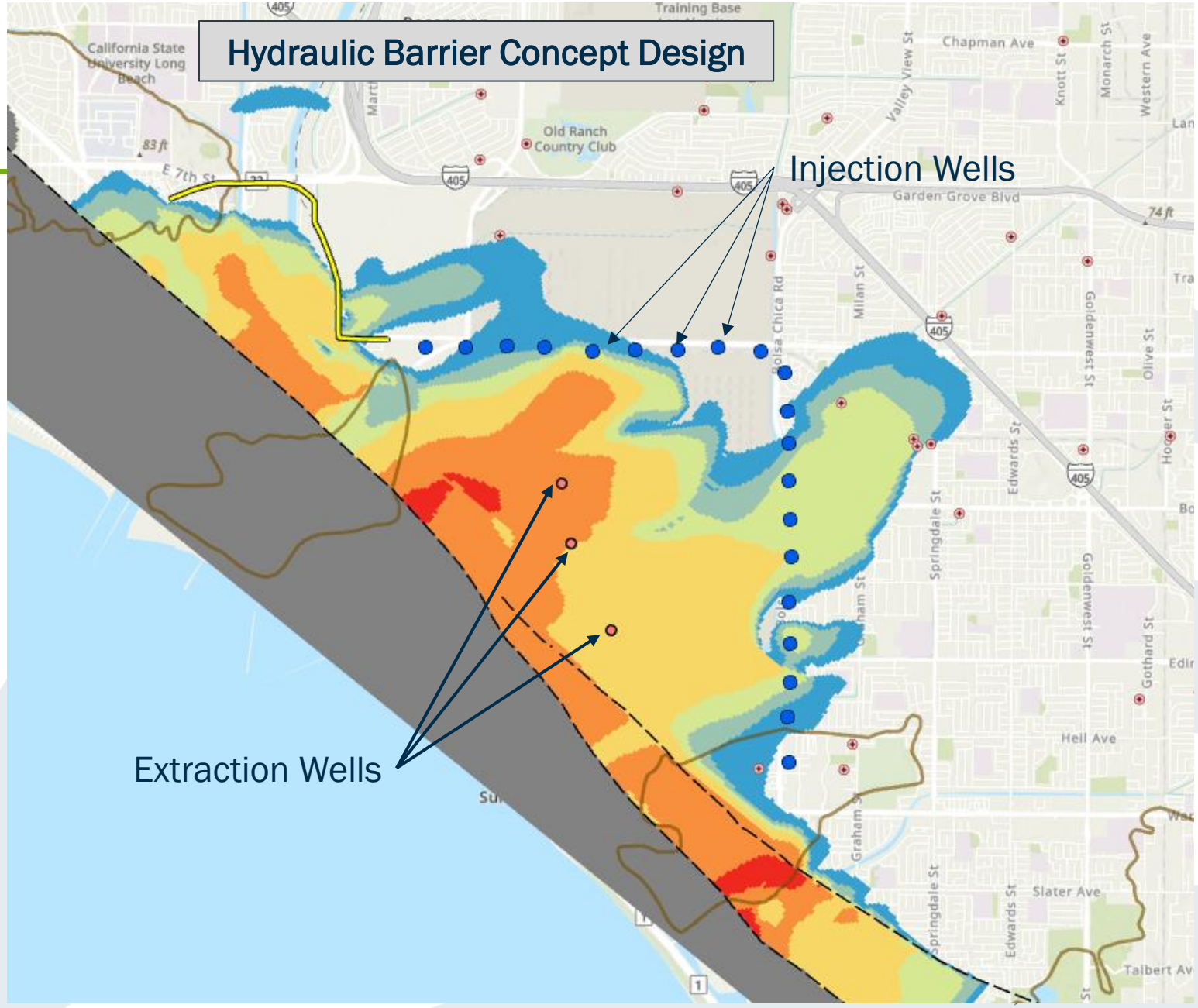
- Unimpeded intrusion
- Production wells serve as terminus
- 4 new wells at risk

What would happen if no barrier was constructed?



Possible Solution

- Hydraulic Barrier
  - Combined Injection-Extraction System

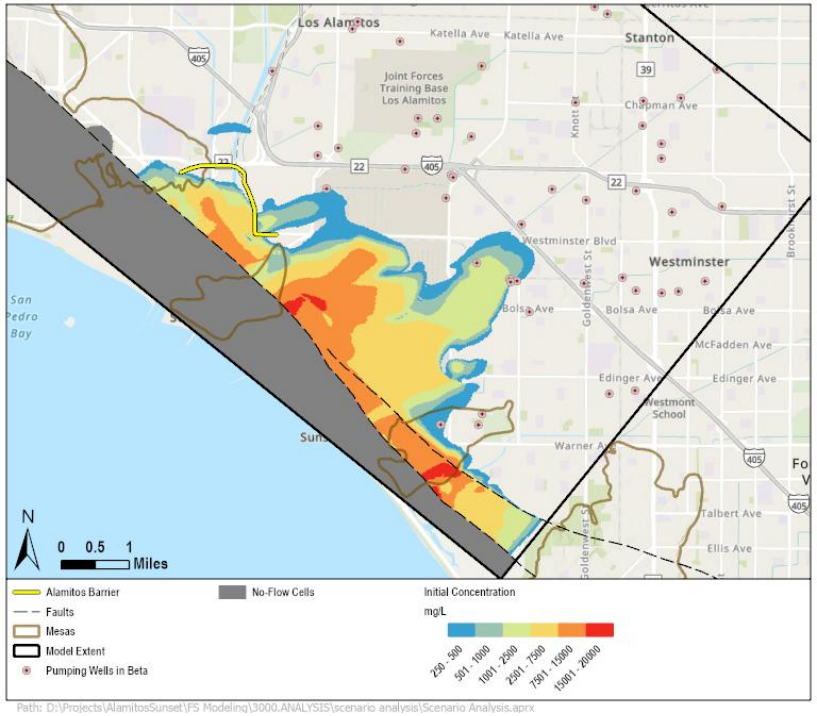


INTERA

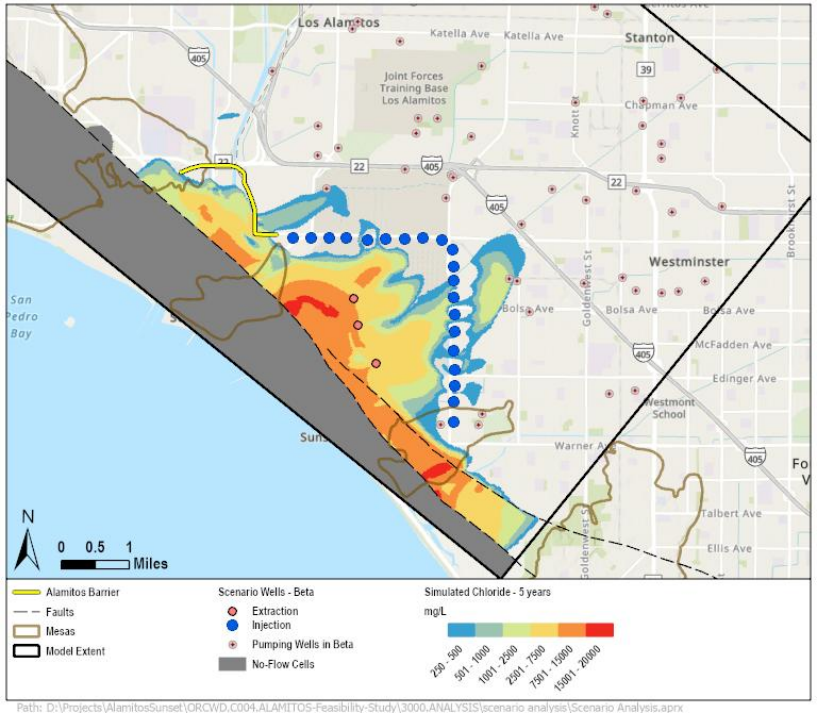
Constant-Rate Scenario Modeling Results

Run IE4D1*: Injection = 6.8 MGD and Extraction = 6 MGD

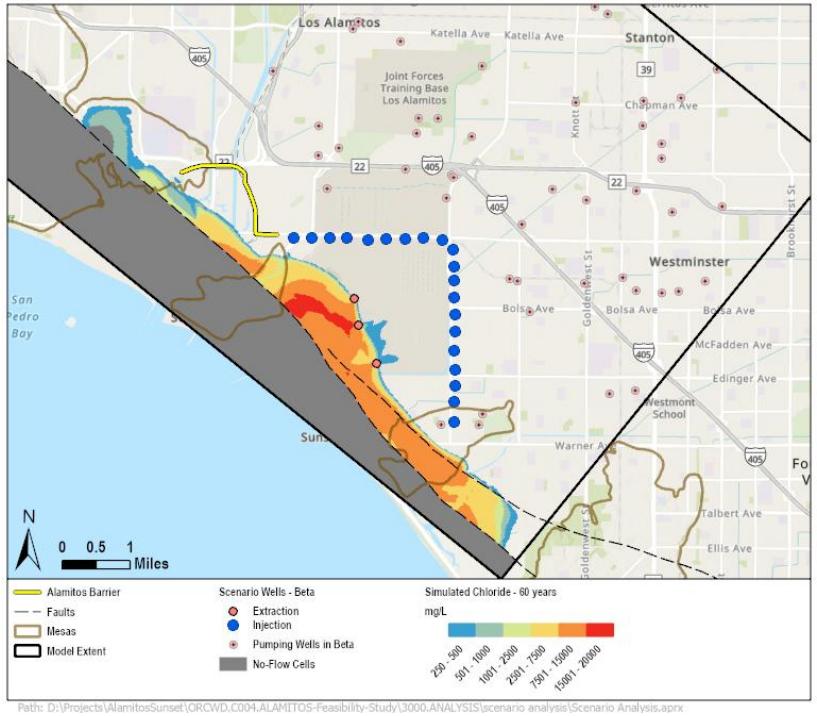
Initial (end of 2020)



5 years



60 years



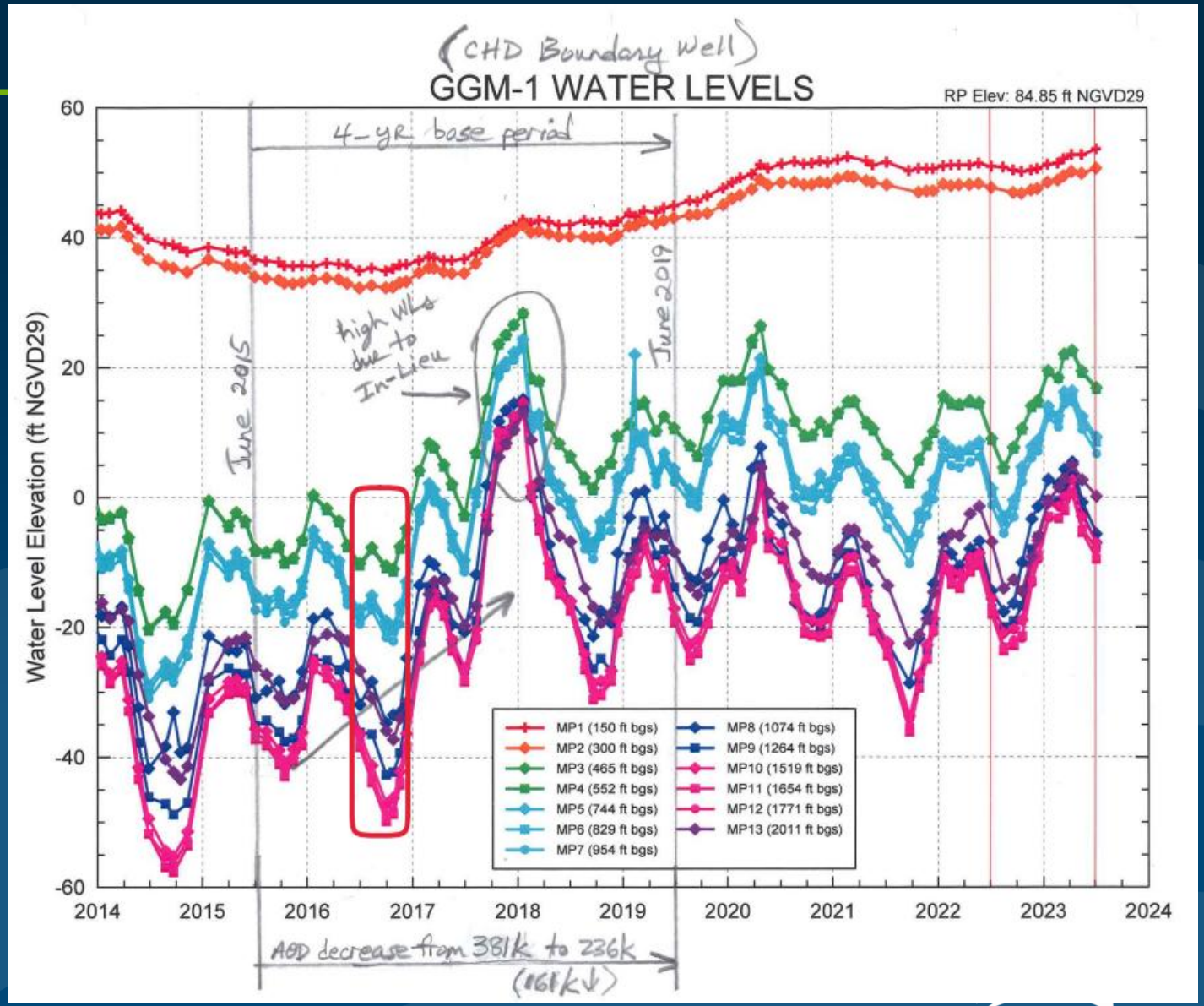
Good capture of chloride in all scenarios.

However,

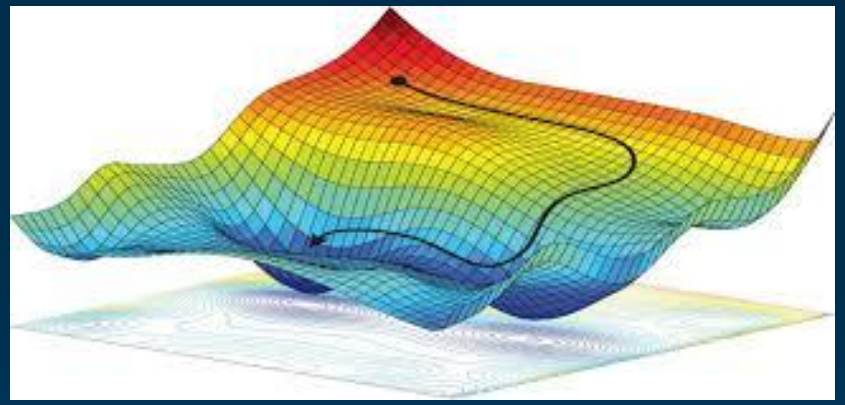
Can we use fewer wells and less water at the barrier?

Barrier Optimization

- Need to know:
  1. Maximum rate for water supply pipeline capacity
  2. Average rate for assessing long-term water supply options
     - Recycled water?
     - Deep production?
  3. How many wells may be necessary to prevent intrusion
     - Where are the optimal locations?

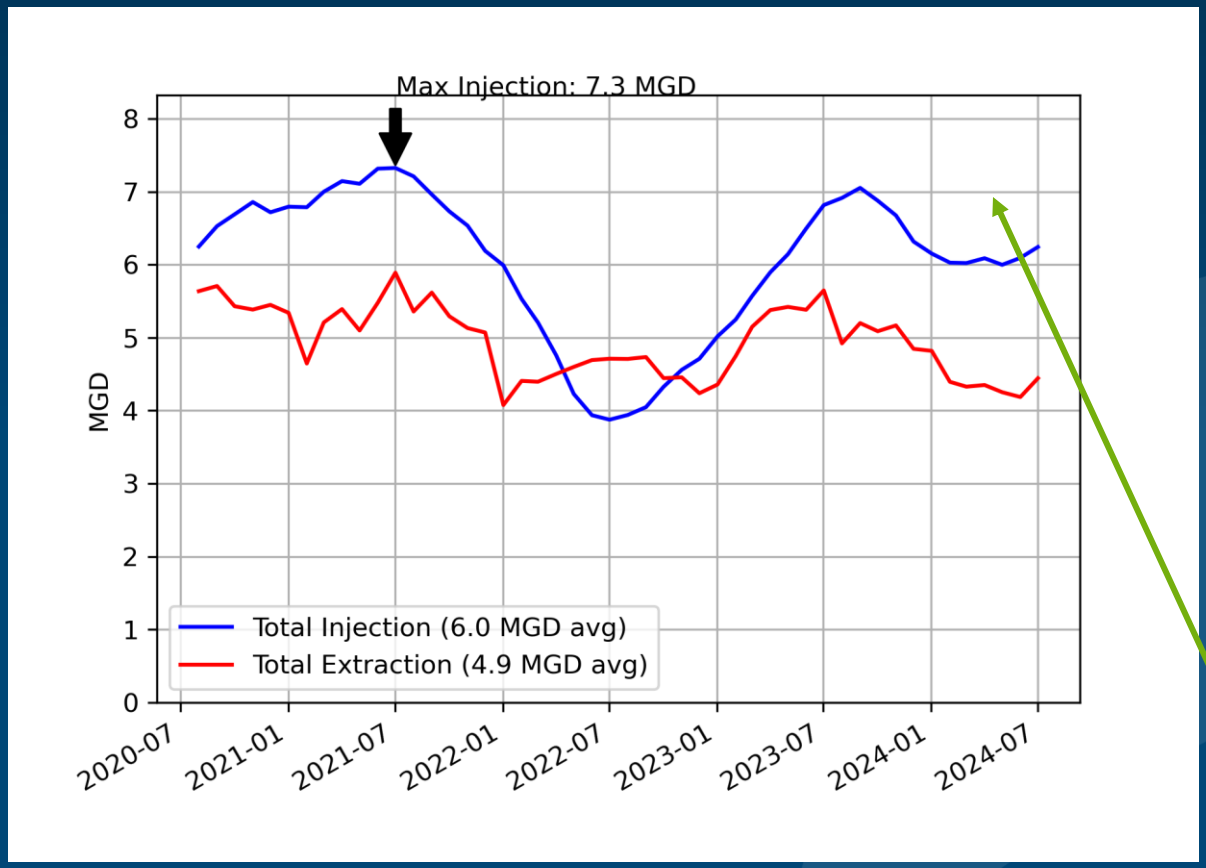


INTERA



Barrier Optimization Approach

- Software:
  - PESTPP-IES (MOU)
- Constraints:
  - High water level (land surface)
    - Flooding, liquefaction
  - Low water level (historical low)
    - Subsidence
  - Cannot allow seawater intrusion
    - Surrogate (because transport is expensive and much more nonlinear):
      - Head gradient must be seaward
      - Particles must not travel past barrier

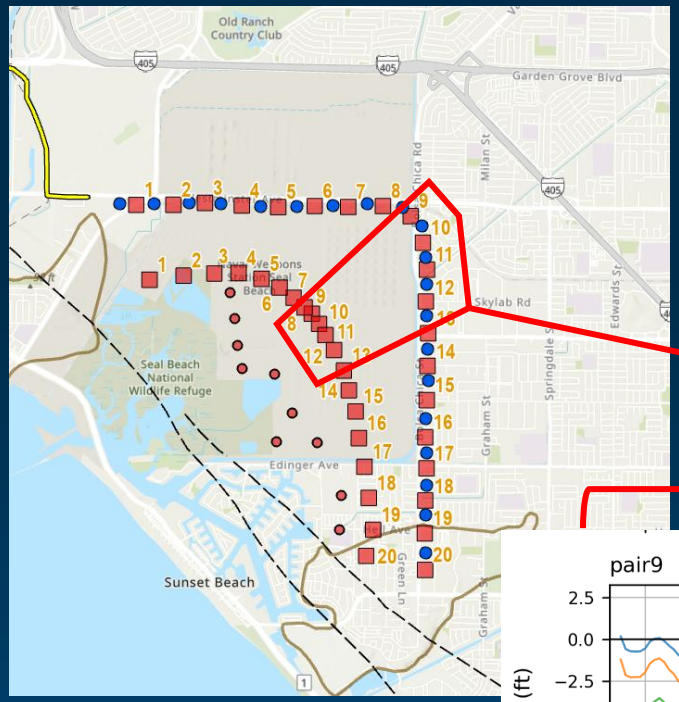


Reduced average injection and extraction each by ~1 MGD, at the cost of a slightly higher maximum rate…

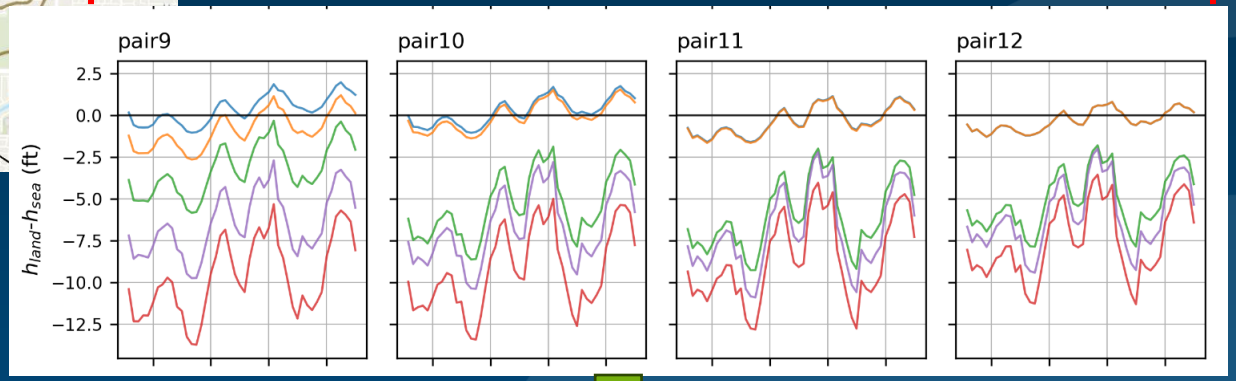
INTERA

Seawater Intrusion Surrogate

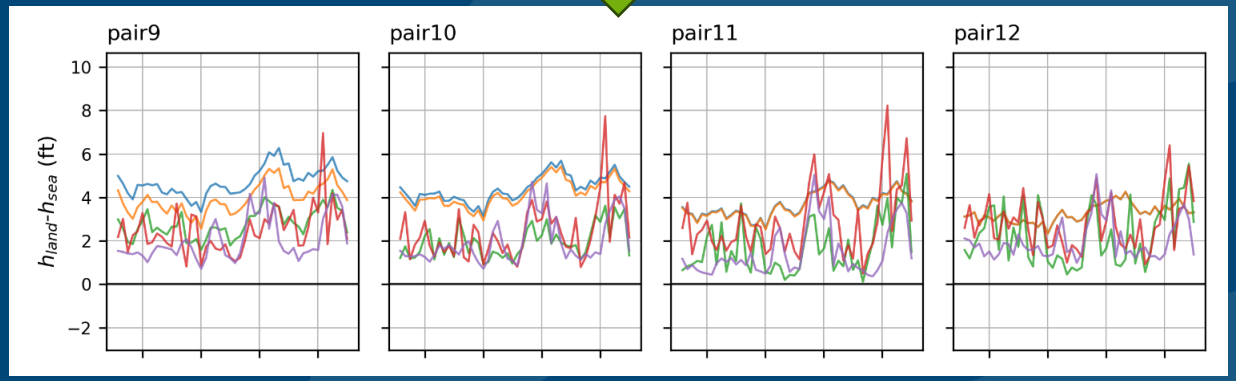
- **Head Difference**
  - Need to maintain seaward gradient
  - H(land) – H(sea) > 0 + buffer



No Project



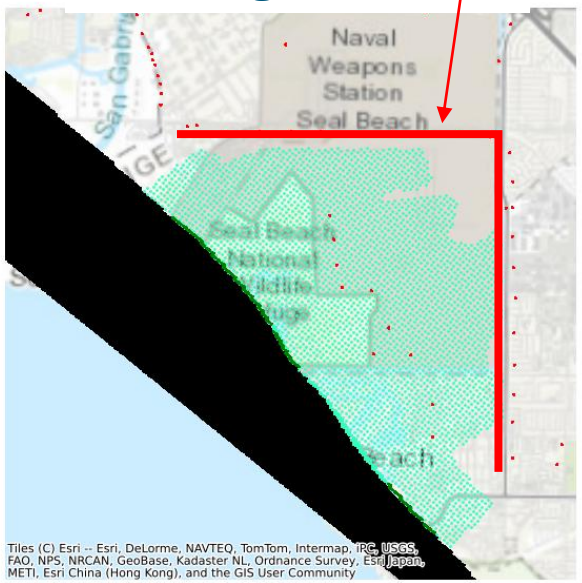
Optimal Solution



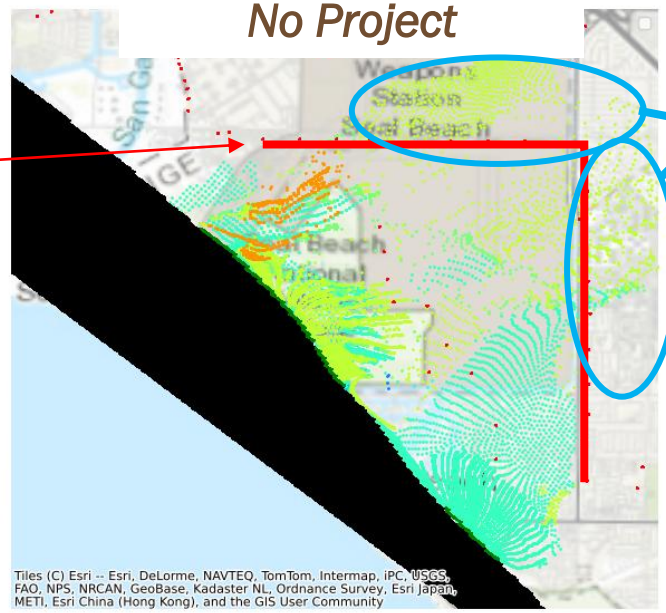
INTERA

Barrier

Starting Locations

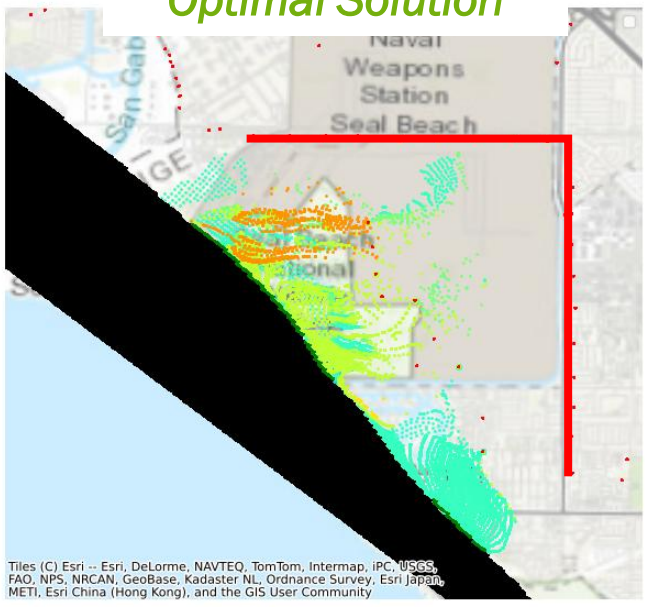


No Project



Particles that have gotten past the barrier

Optimal Solution



- **Particle Tracking**
  - Limit particles movement to stay seaward of barrier
  - Important to note: particle release locations must be representative of initial chloride concentrations.

Particles are all contained

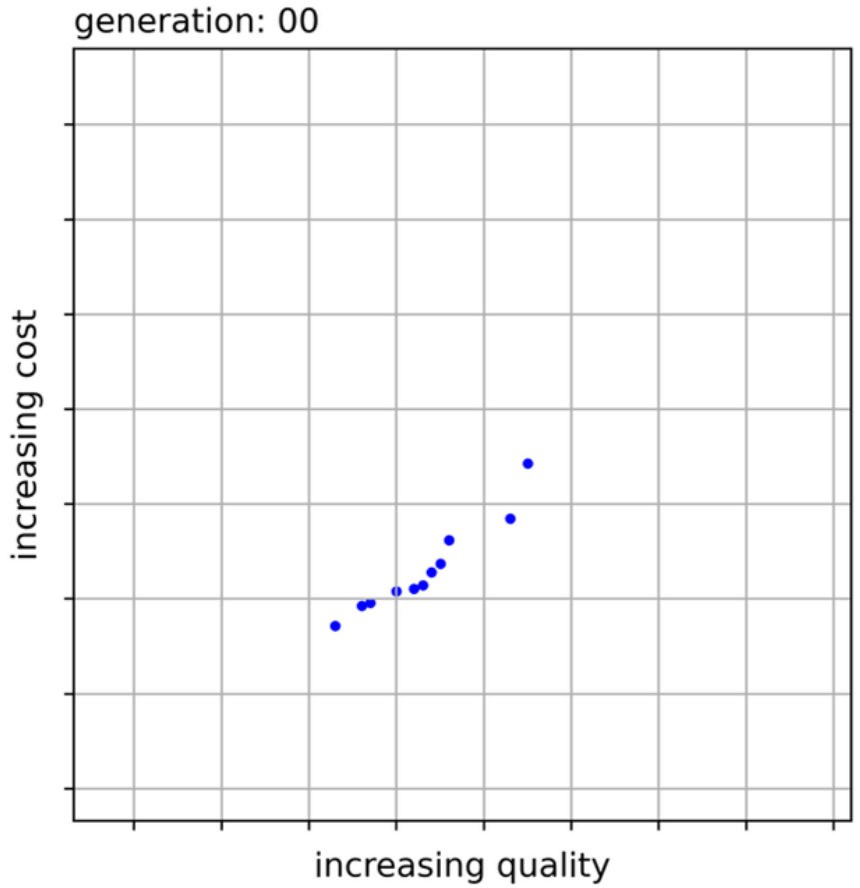
INTERA

Multi-Objective Optimization

- Directly Evaluate Trade-Offs

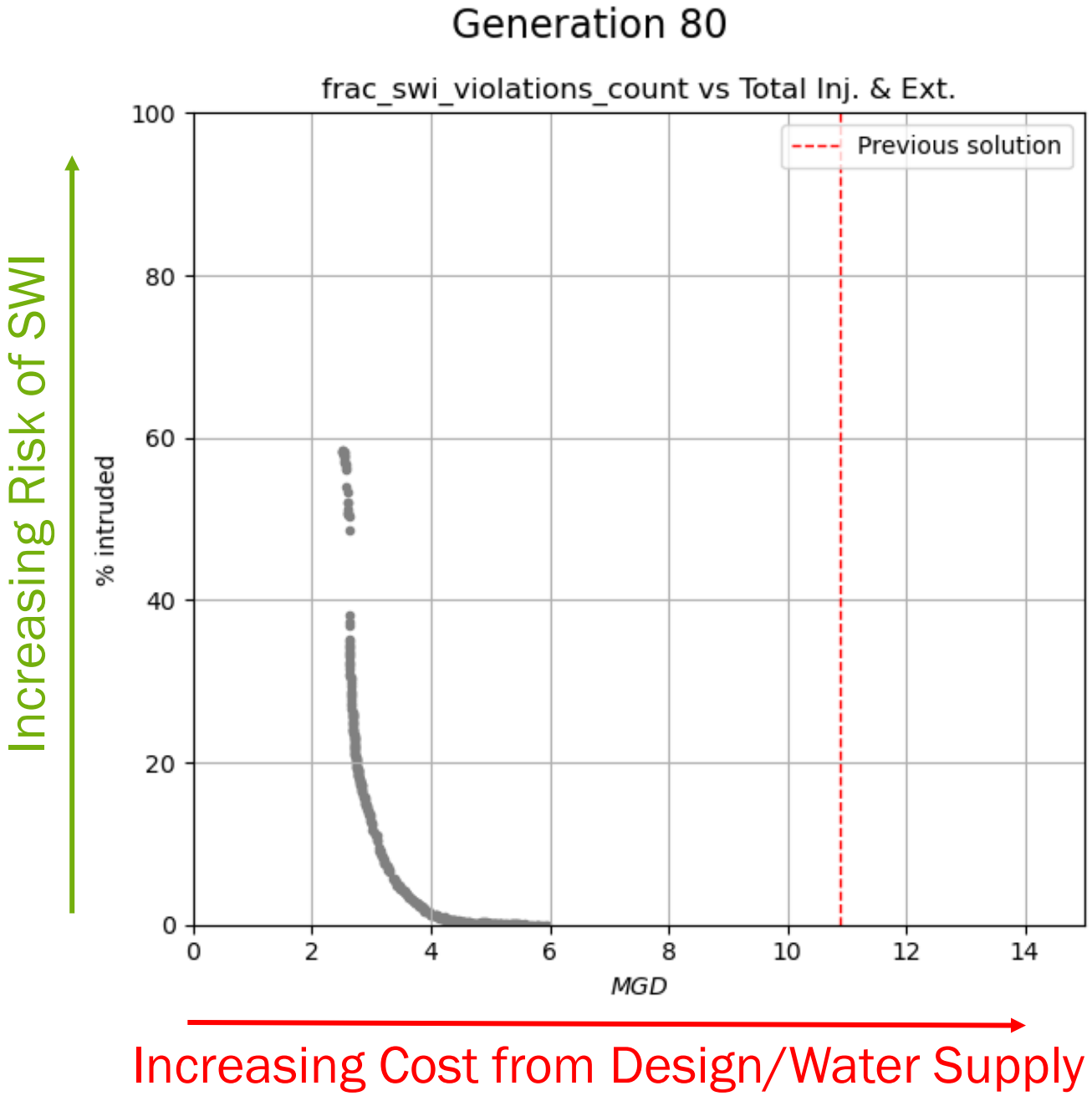
- Objectives:
  - Minimize total rates (summing injection & extraction)
  - Minimize low water level violations
  - Minimize particles moving past the barrier

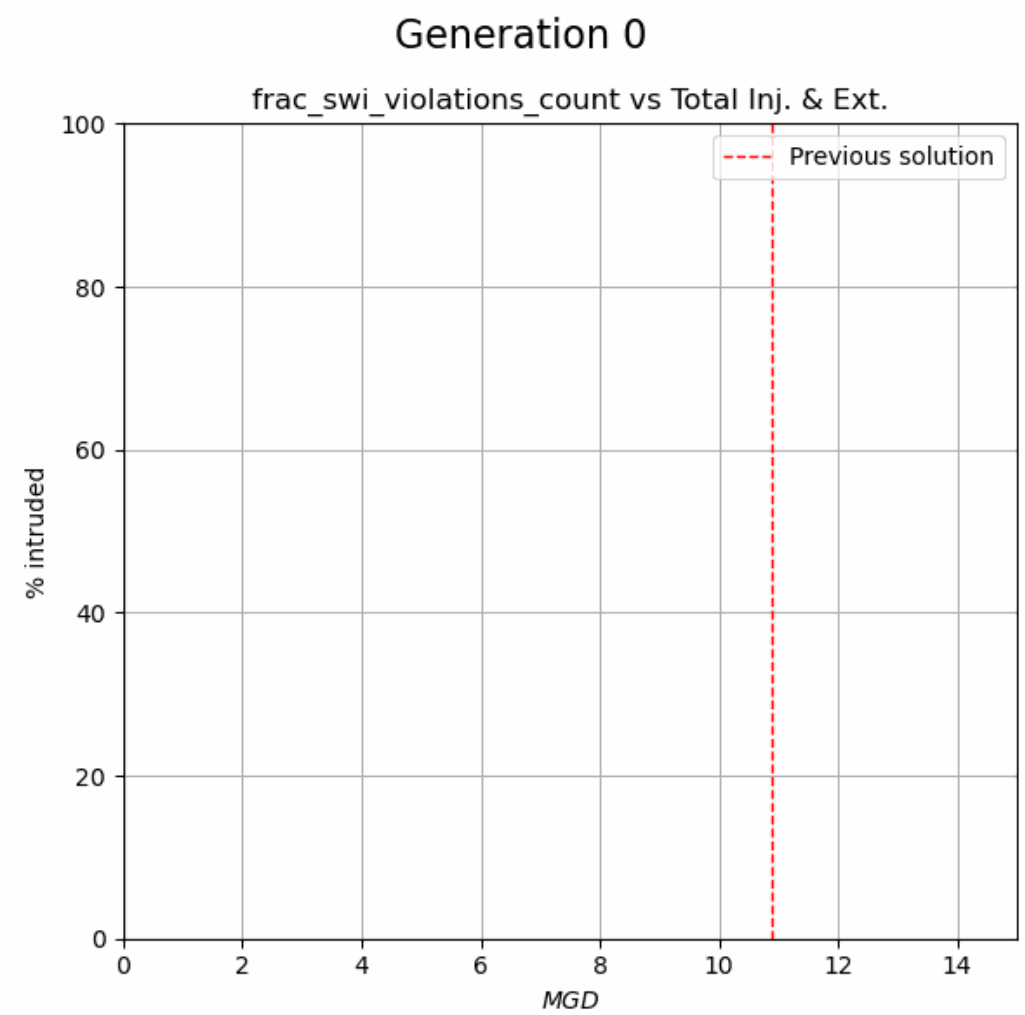
- Problem Simplification:
  - Focus on one (steady) stress period at a time:
    - Faster run times & easier interpretation
  - Test for one worst-case and best-case stress period to bookend results



INTERA

SWI Results


Generation 80
frac_swi_violations_count vs Total Inj. & Ext.
Previous solution
% intruded
MGD
0
20
40
60
80
100
0
2
4
6
8
10
12
14
Increasing Risk of SWI
Increasing Cost from Design/Water Supply


Generation 0
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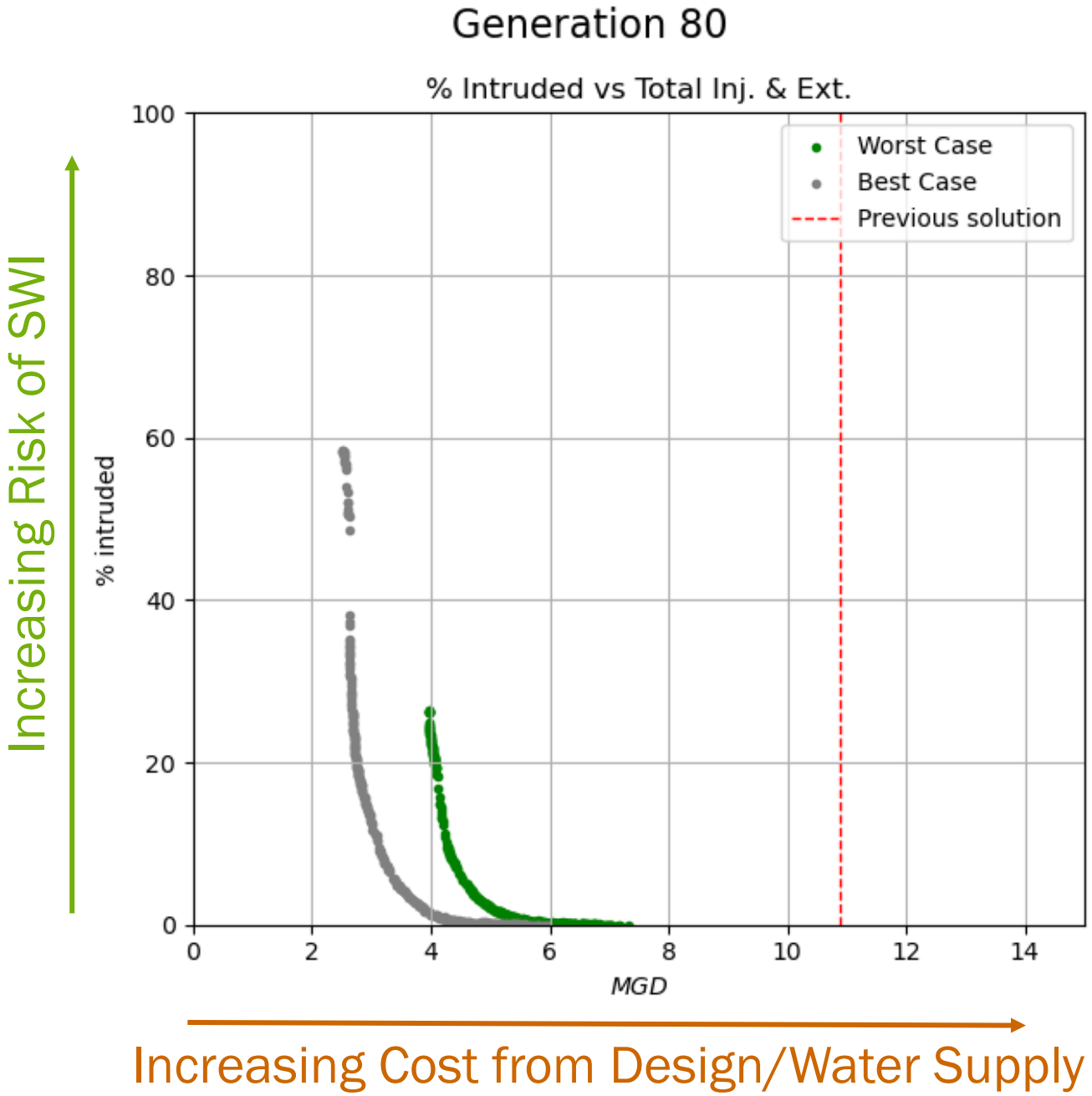
Previous solution
% intruded
MGD
0
20
40
60
80
100
0
2
4
6
8
10
12
14

Bookends


Generation 80
% Intruded vs Total Inj. & Ext.
Worst Case
Best Case
Previous solution
% intruded
MGD
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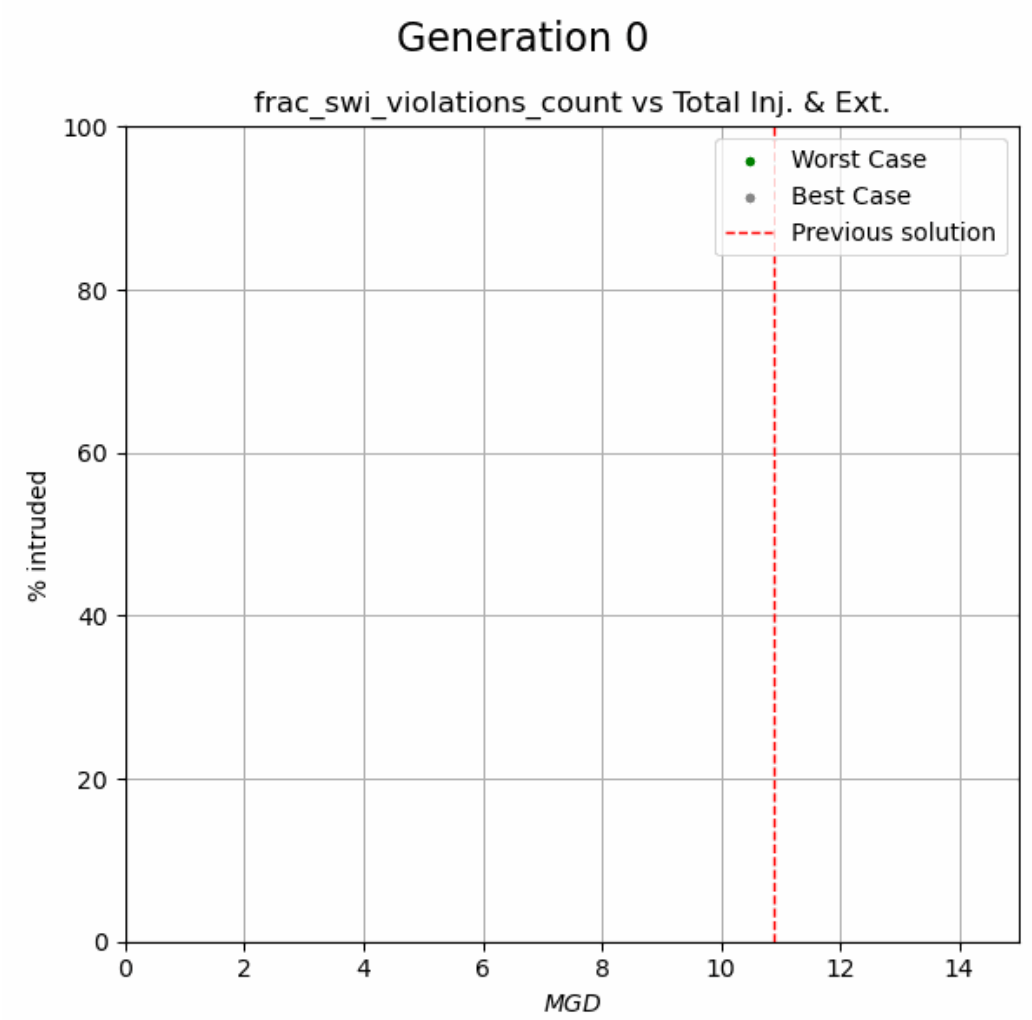
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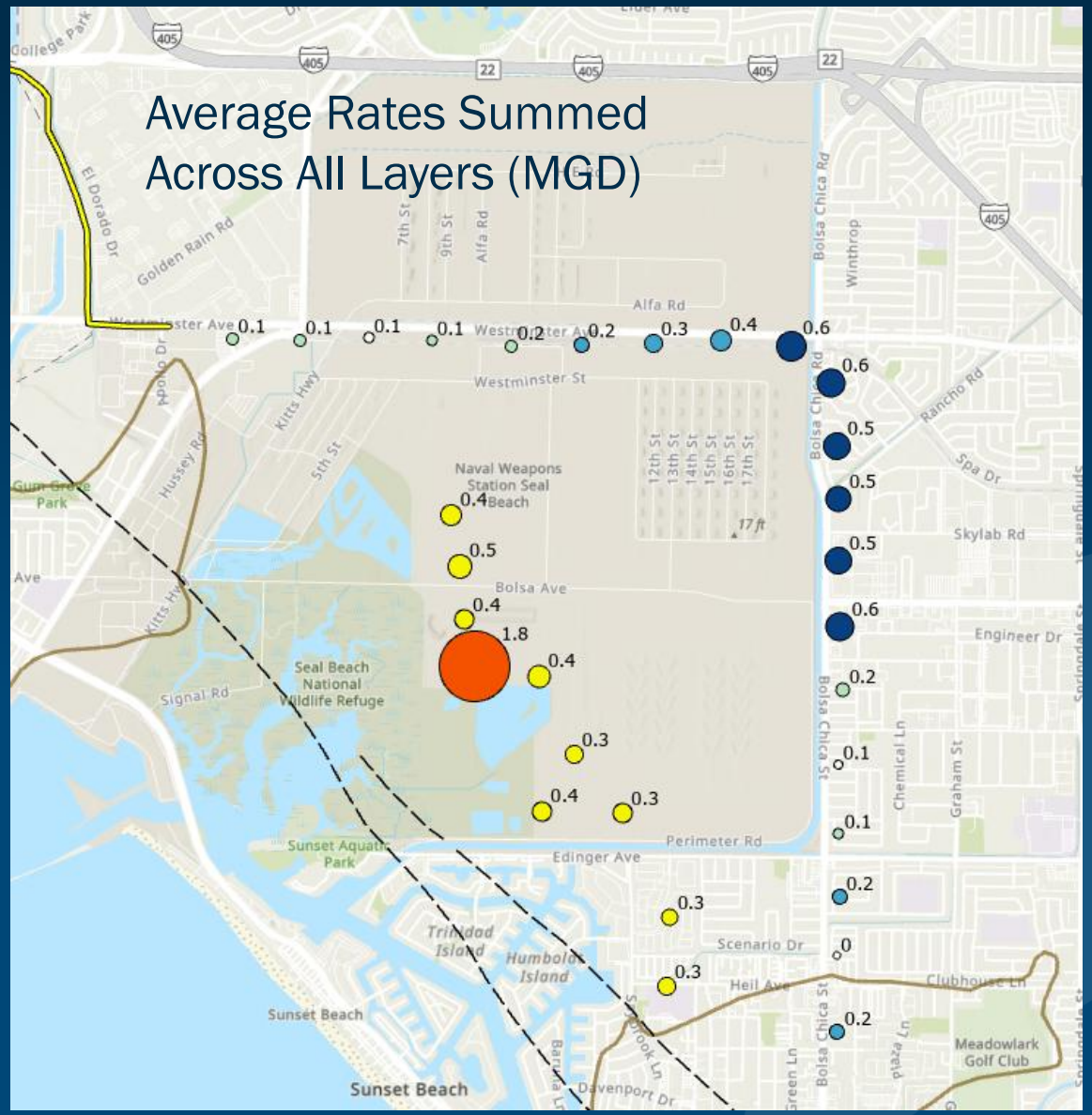
Key Takeaways



- Trade-offs abound: No Free Lunch
- Location of Mergence Zones is Critical
- Proactive barrier operation can lessen the need for a high max capacity
  - If you have a decent sense of when and how long low water level periods may occur…
- Simplify your problem into true decision variables and key outputs

INTERA

Questions?

Feel free to reach out to me:
nhatch@intera.com

Thanks for listening!