APPLICATION OF A 3D MODEL OF MIRAMAR RESERVOIR FOR INDIRECT POTABLE REUSE

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NALMS 2023 10/23/2023

Water Quality Solutions

The City of SAN DIEGO

Pure Water San Diego

Model Setup, Calibration, and Validation

Approach to Demonstrating Dilution

Factors Affecting Dilution

Lessons Learned

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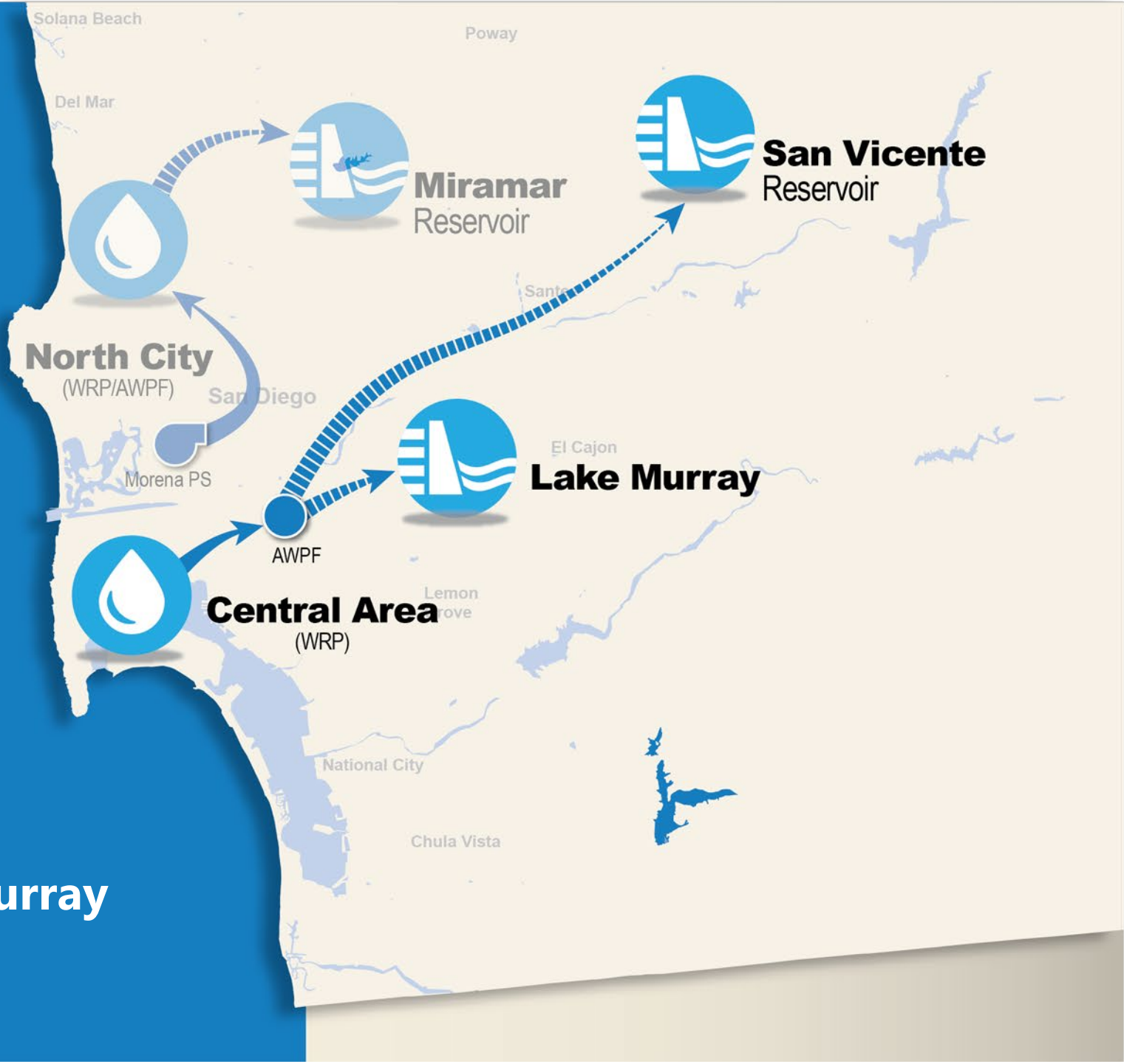
Pure Water
will produce

1/2
of San Diego's water
locally

Phase 2
Central Area Project

- **2035 Completion**
- **53 mgd**
- **Central Area PWF to San Vicente or Lake Murray**

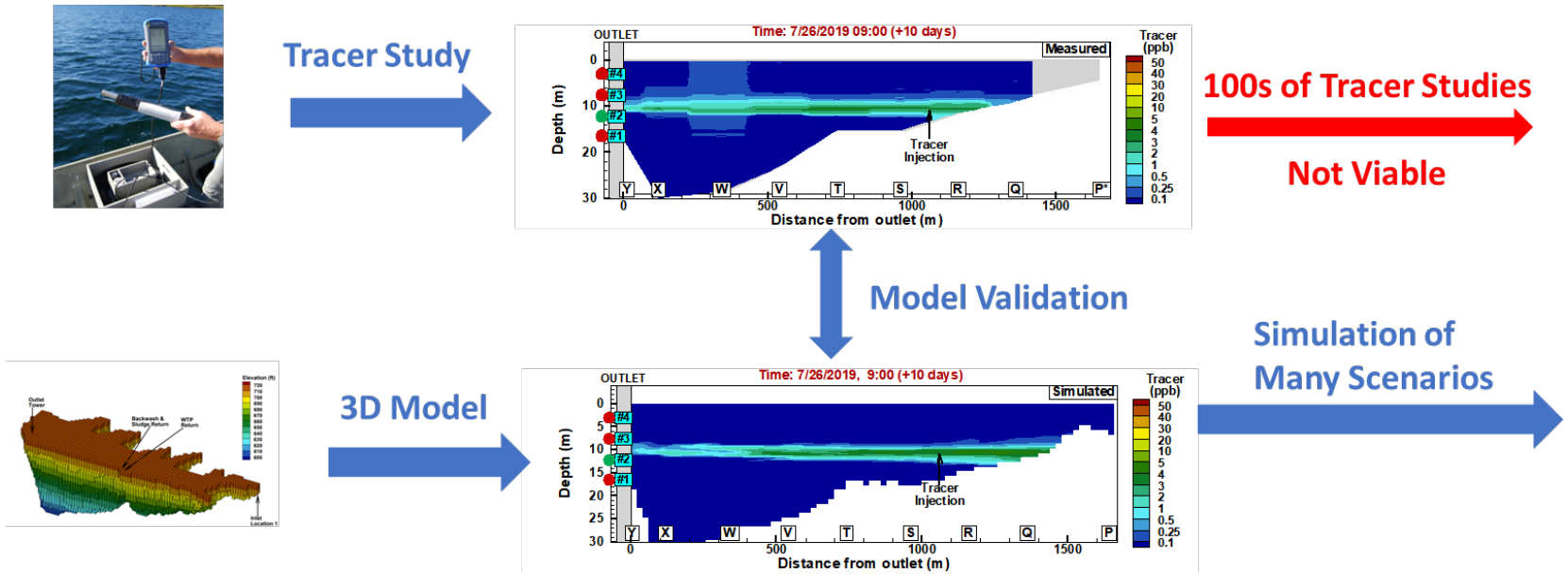


Miramar Reservoir Storage

- 6,700 acre-feet max storage (2200 MG)
- 650 acre catchment area

IPR Dilution Criteria

- >10:1 dilution of all 24-hour purified water inflows
- Tracer study and modeling to demonstrate compliance



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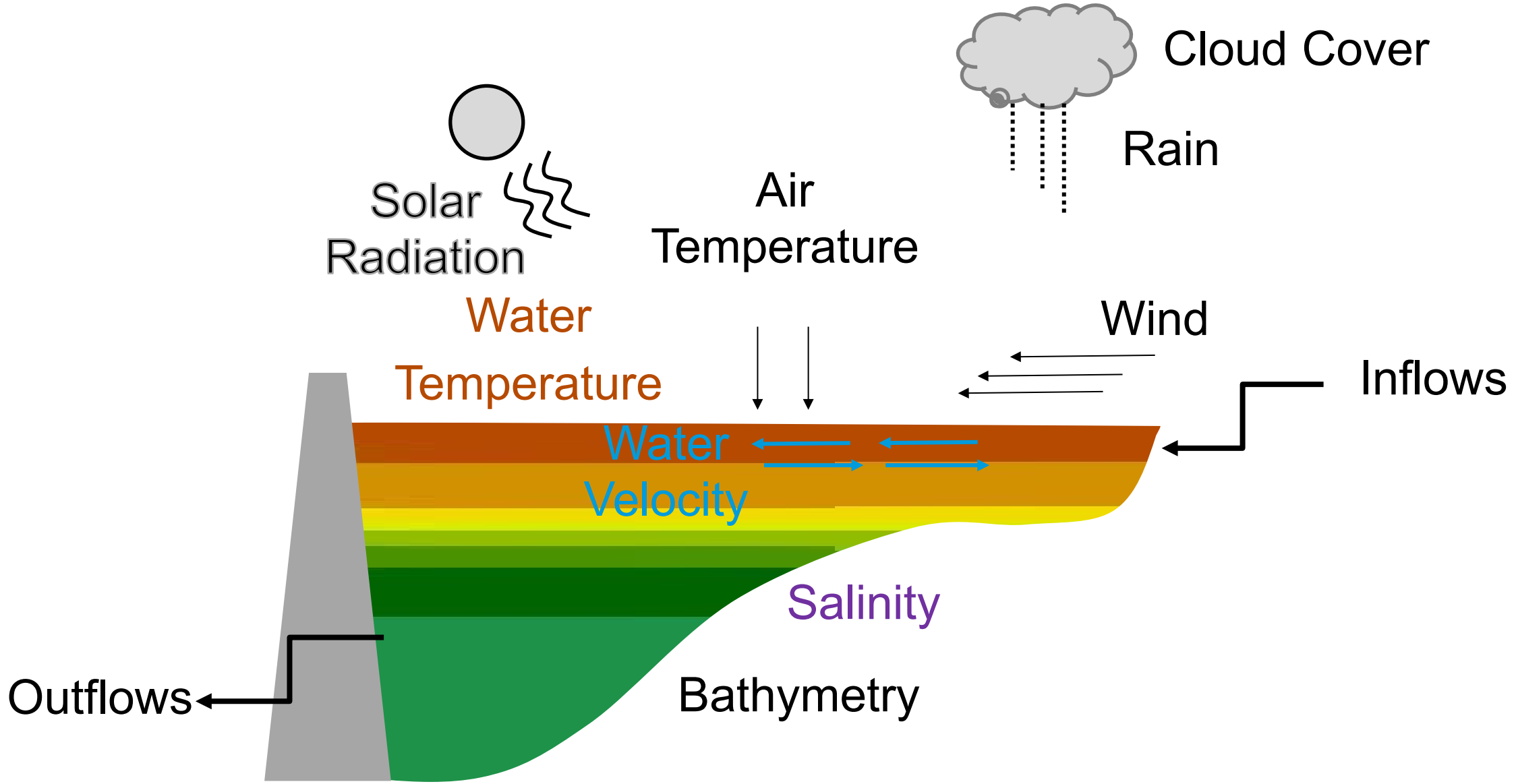
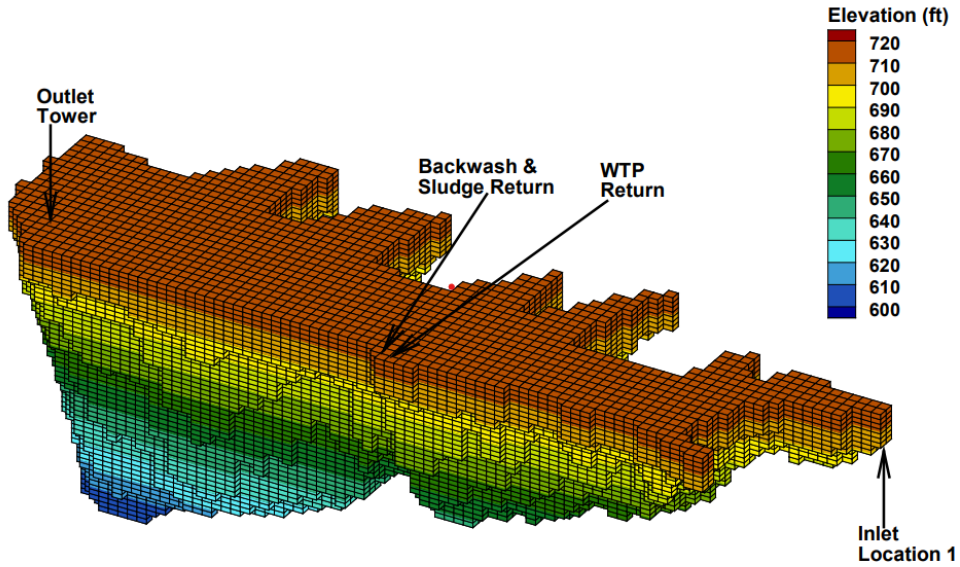
AEM3D Hydrodynamics



Model Setup

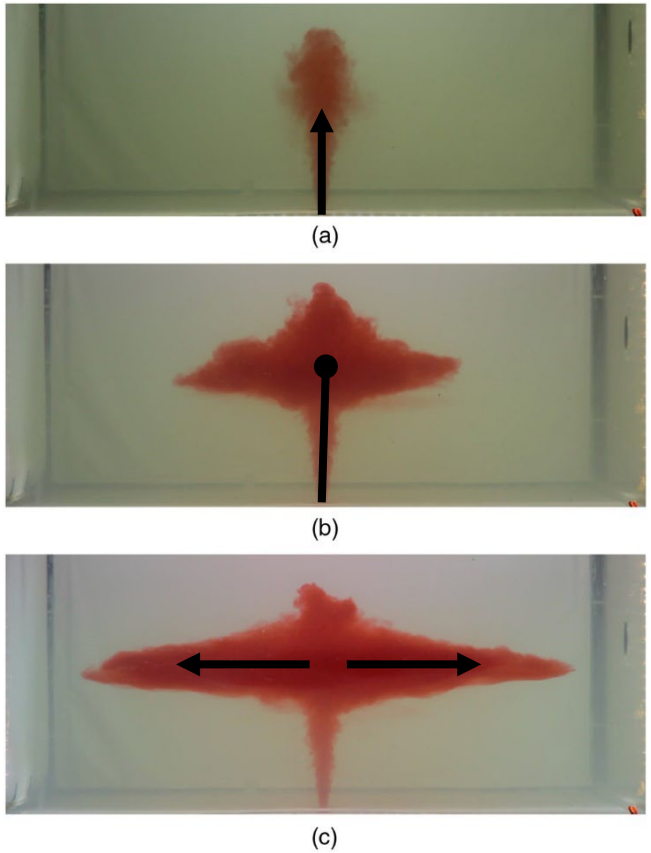
- AEM3D simulates reservoir hydrodynamics
  - *Grid generated*
  - *Meteorological data obtained nearby*
    - Wind measured at dam
  - *Numerous model enhancements made*
    - Fine Grid
    - Coupled EPA Plumes near-field model



20 m x 20 m x 0.2 m grid

USEPA Plumes Sub-Model

- USEPA Plumes model conducts mixing zone analysis and computes the insertion level of jets/plumes and the initial dilution at the insertion level due to entrainment
- When a buoyant jet enters a strongly stratified water body, the final insertion level of the jet flow depends on
  - Initial momentum of jet flow
  - Temperature of jet flow
  - Ambient stratification
  - Jet orientation

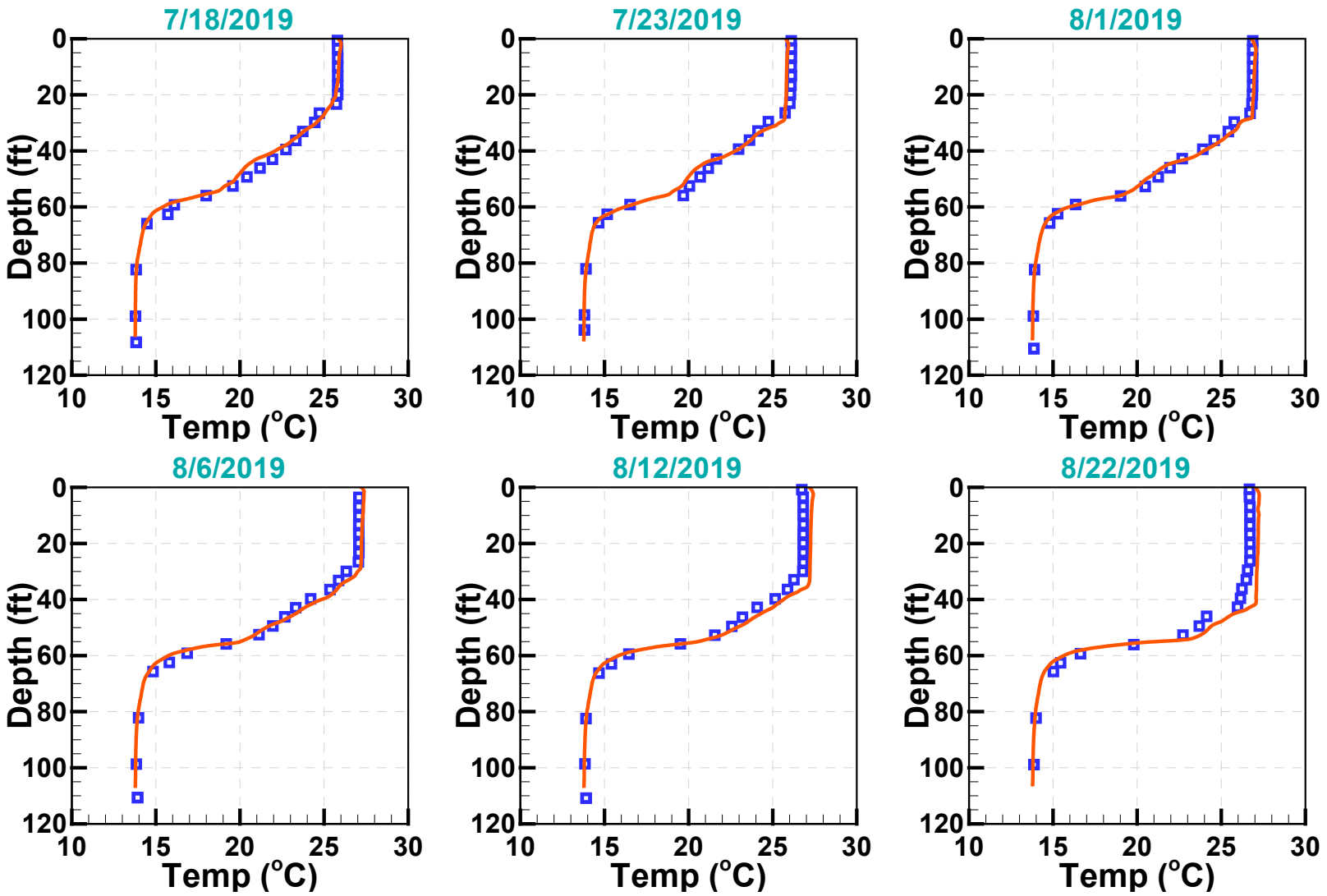


Initial rise

Maximum rise

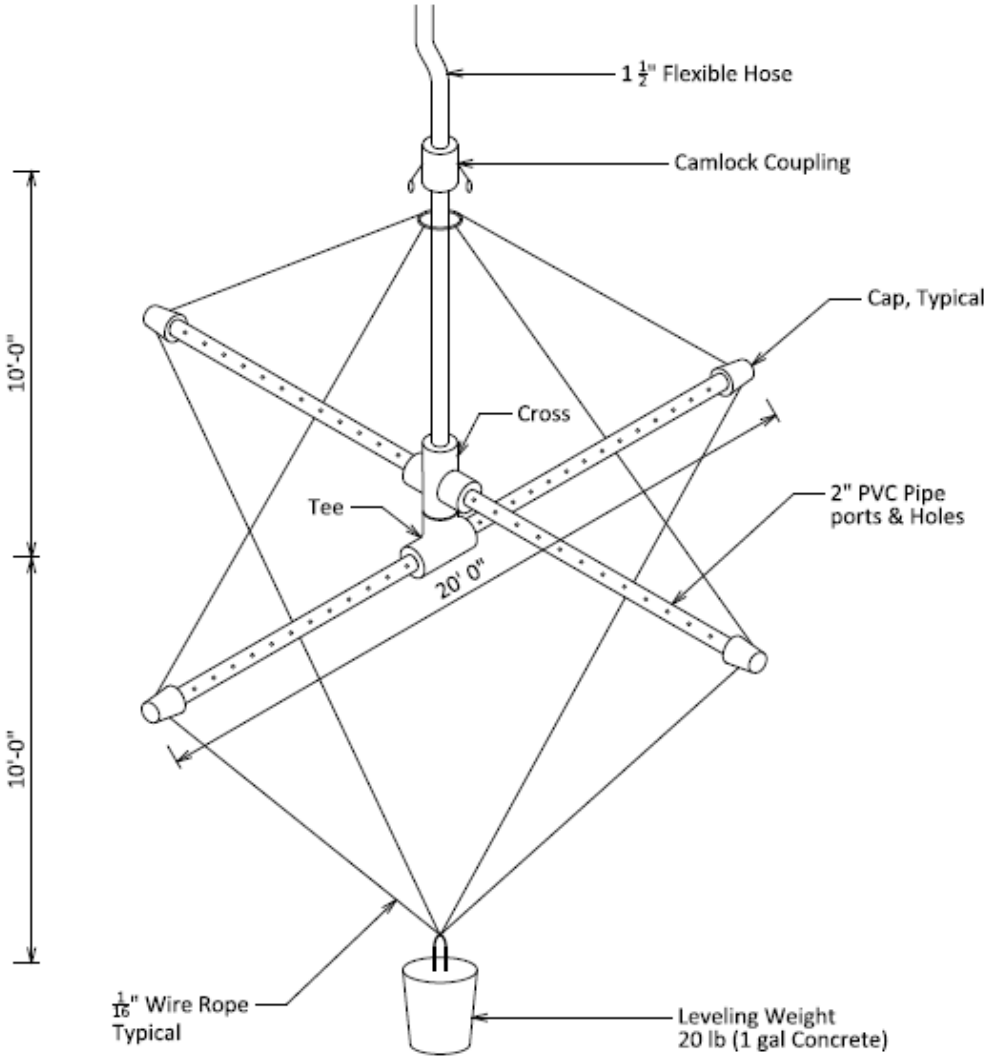
Horizontal spreading

Model Calibration: Temperature Profiles

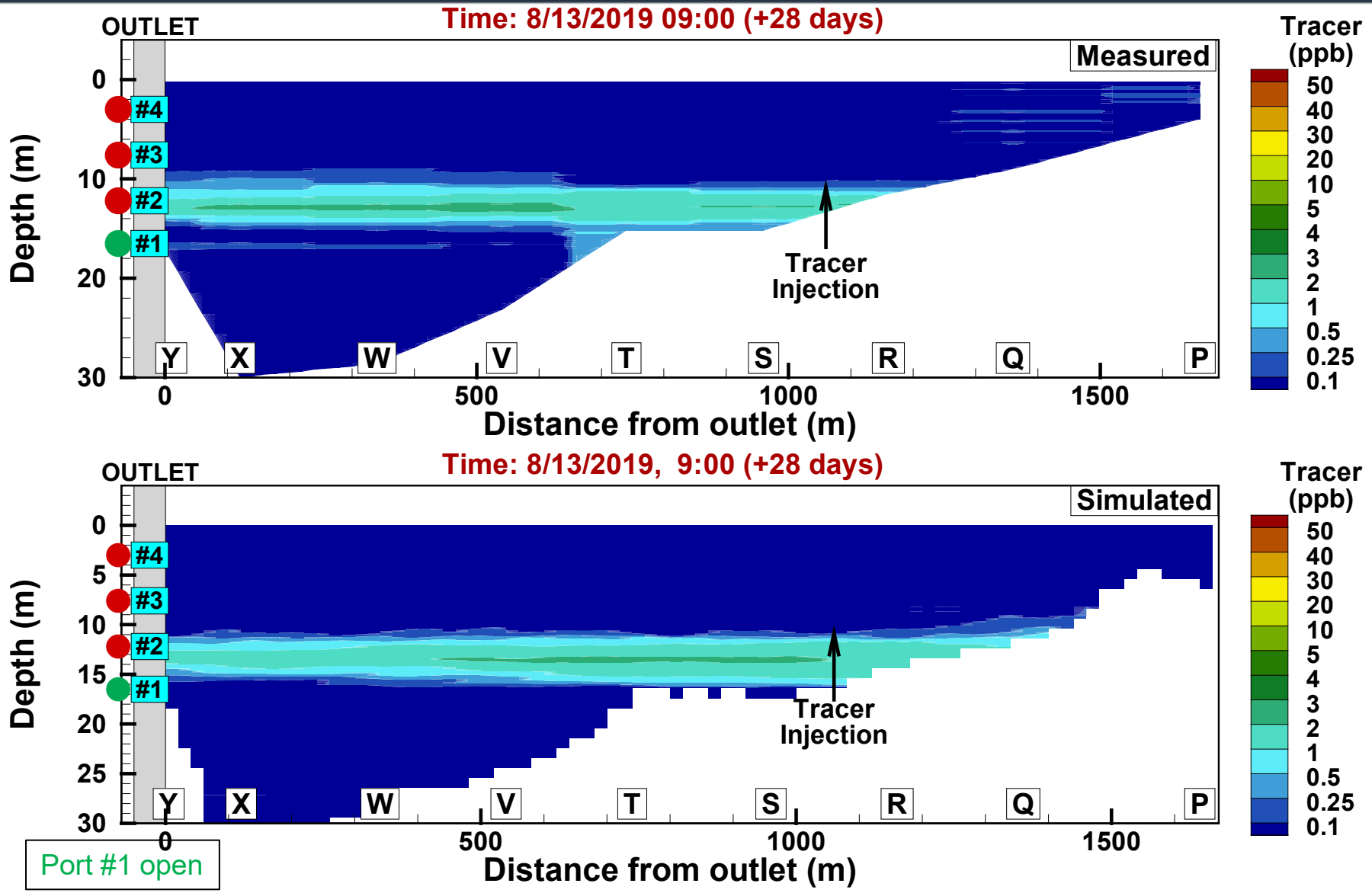


Tracer Study

- Tracer Study in July-Oct 2019
- Rhodamine WT tracer
  - *Injected through small diffuser*



Comparison of Tracer Contours



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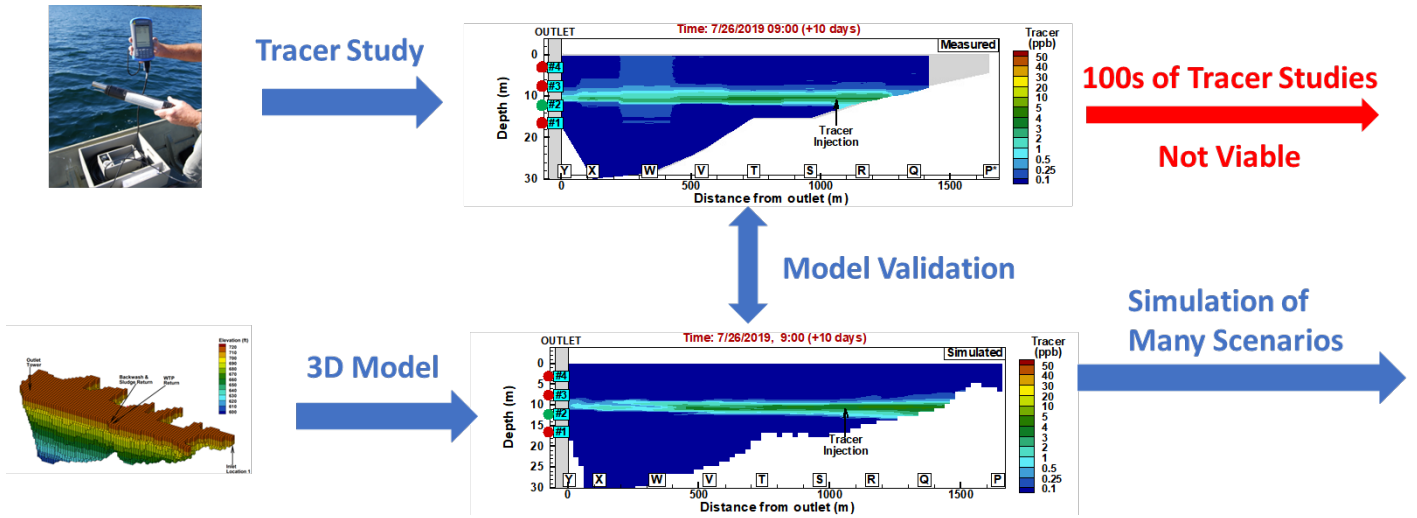
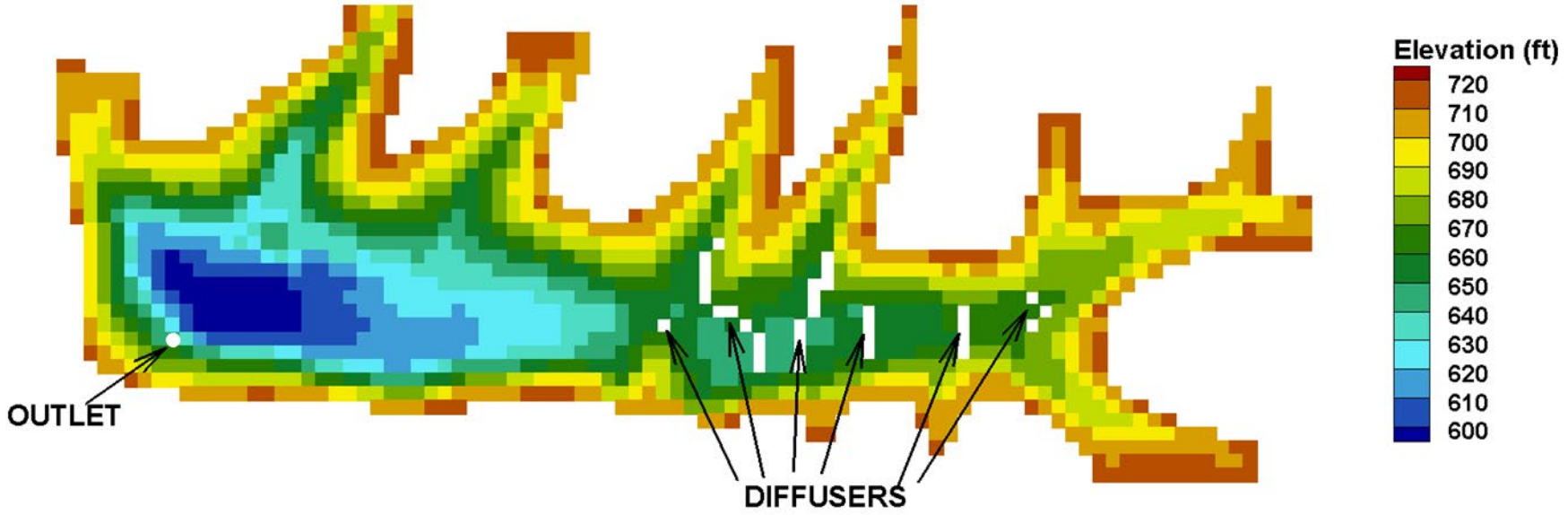
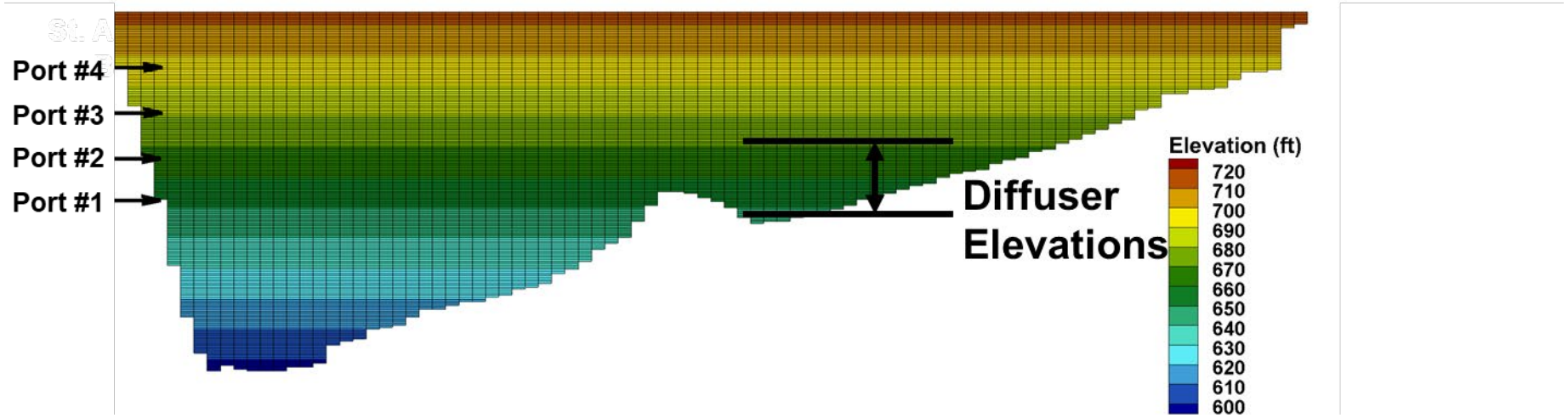
Modeling Approach

- Model 1000s of virtual tracer injections for each operational scenario
  - *Scenarios differ by open outlet port and reservoir level*
  - *Determine minimum dilution for each tracer*

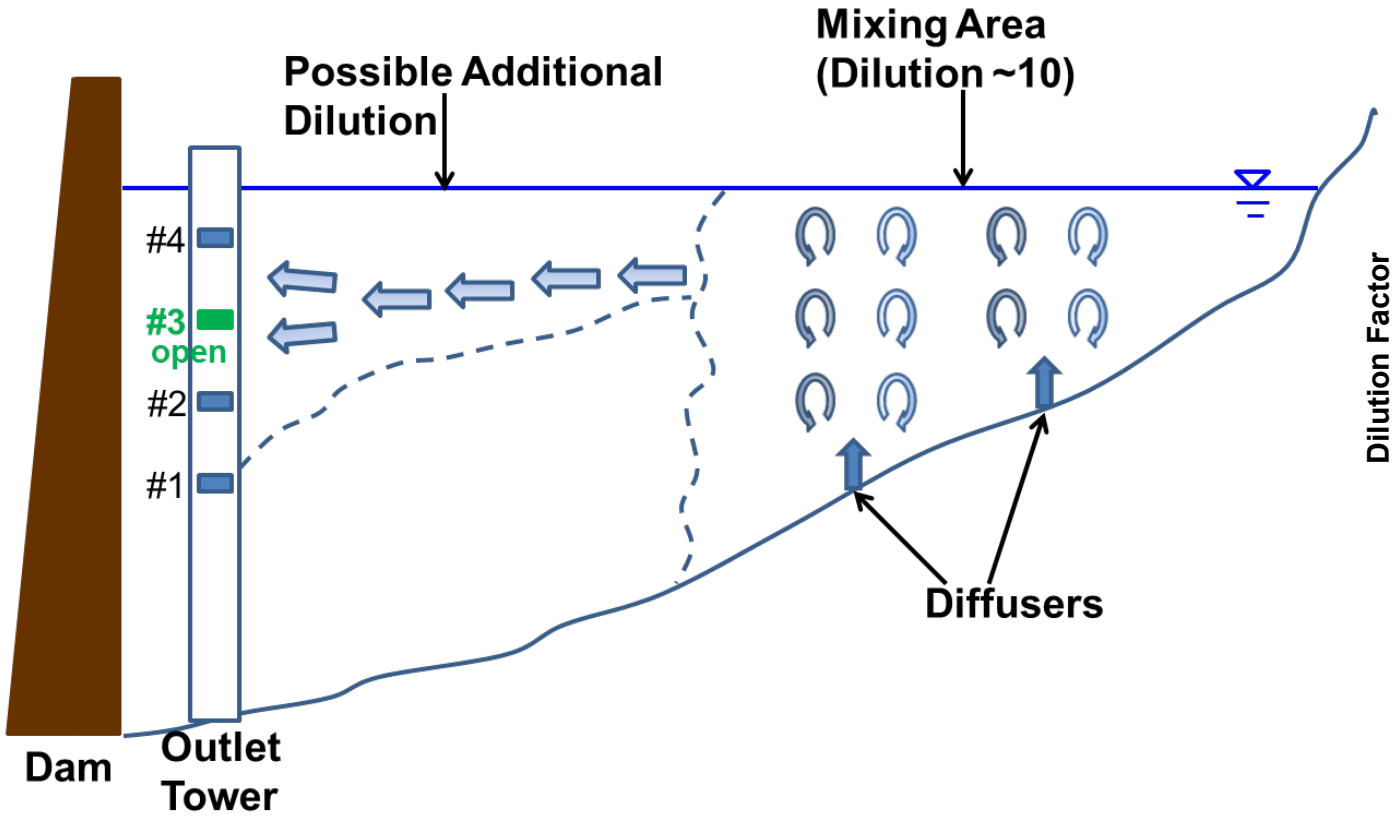


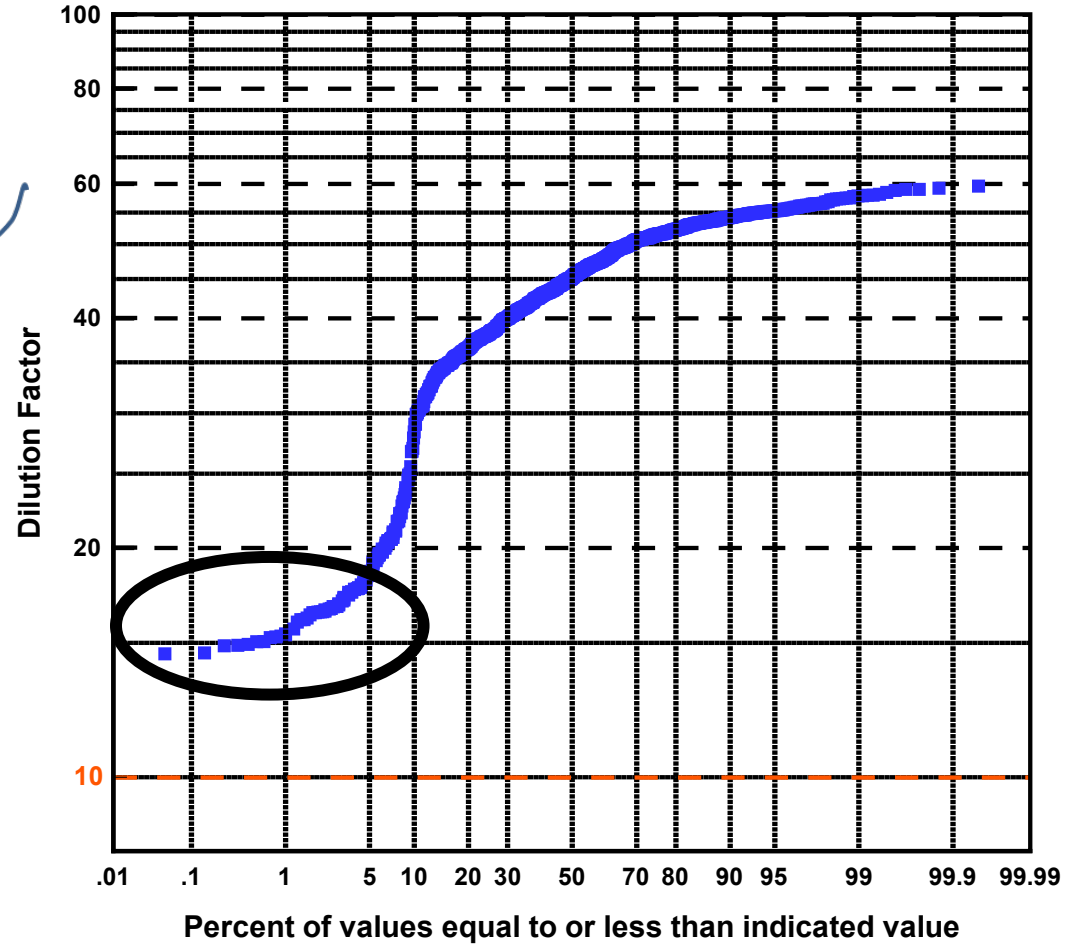
Subaqueous Diffuser and Outlet Tower





Initial Dilution





Initial dilution increases with insertion height

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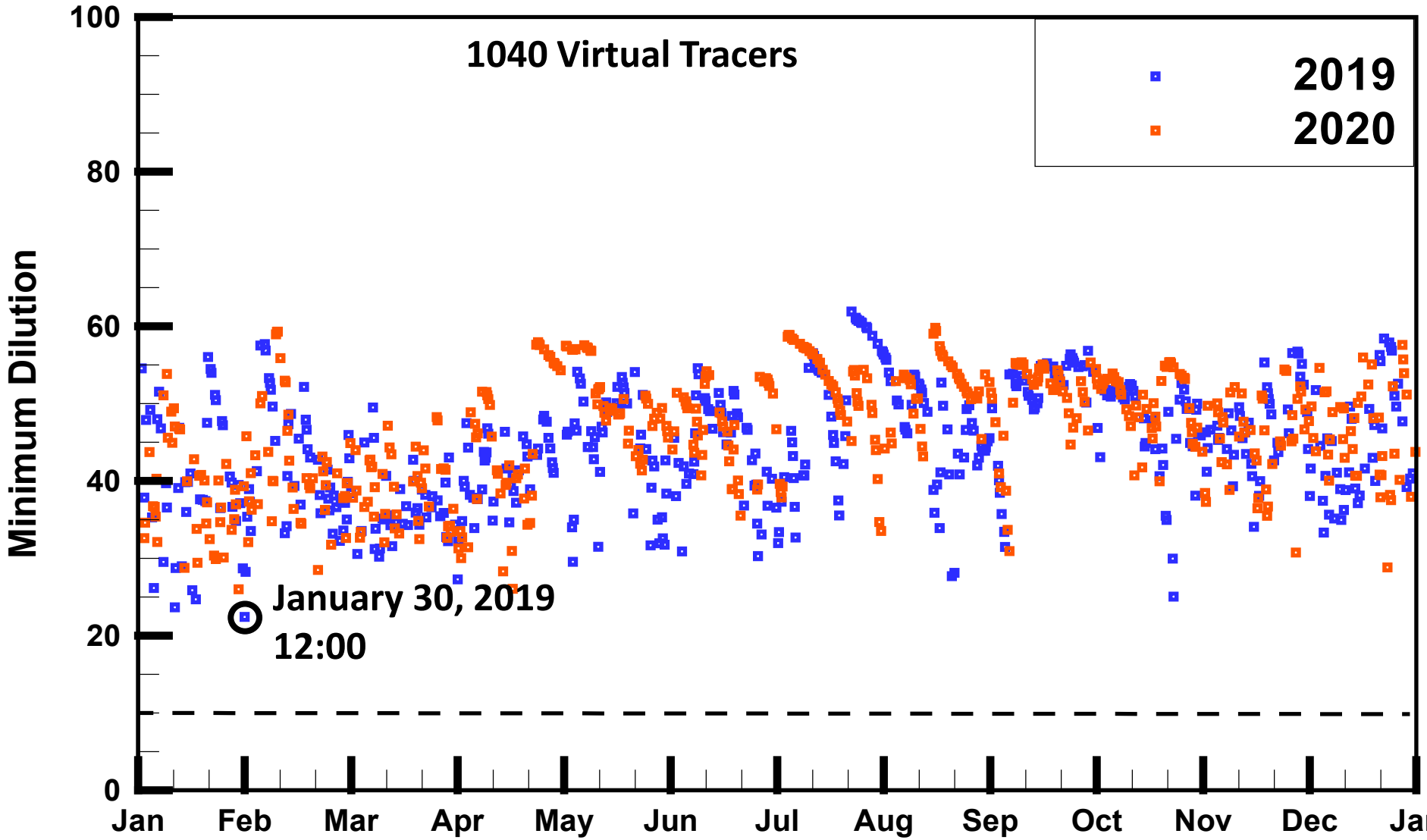
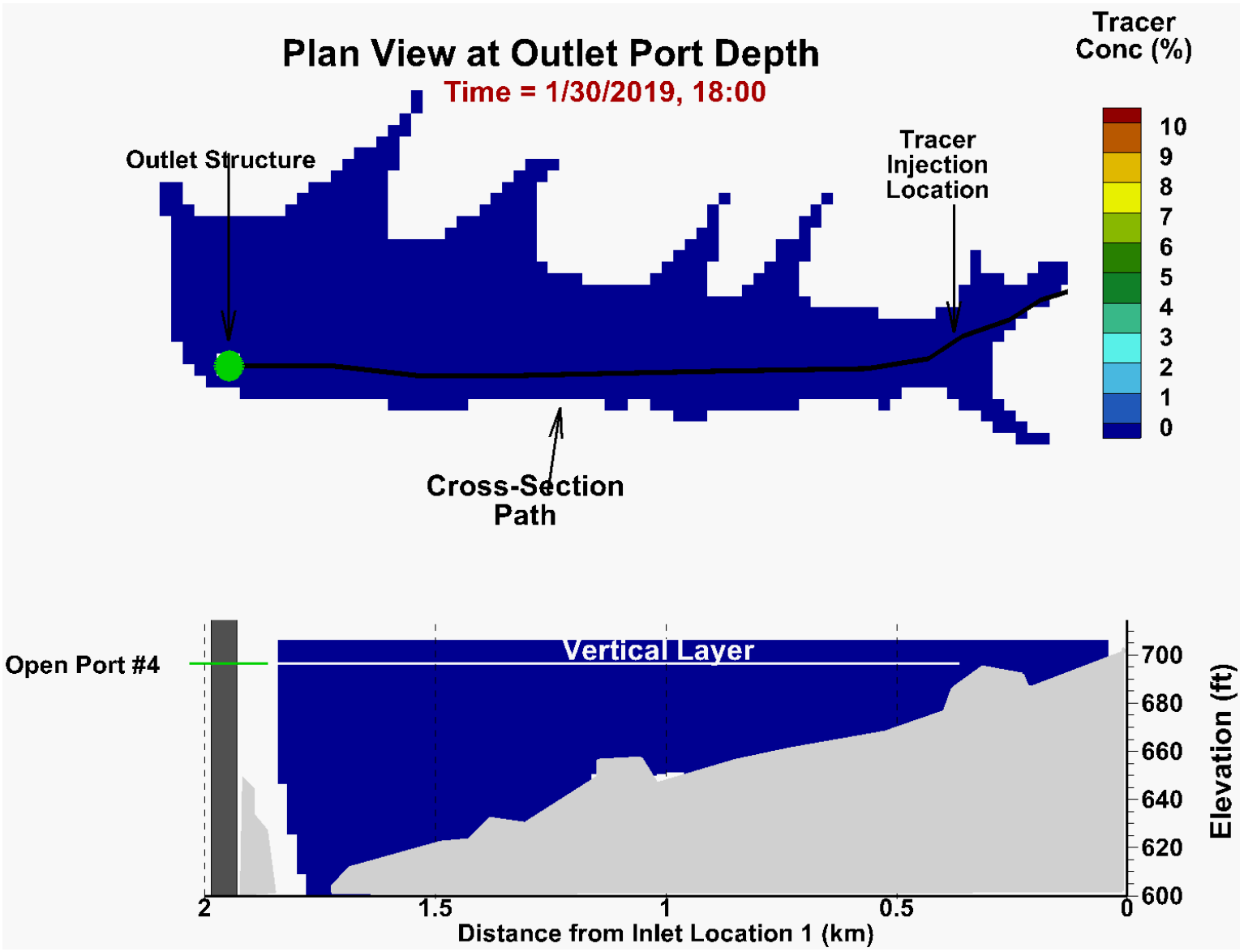
Preliminary Dilutions (Port #4 Open)



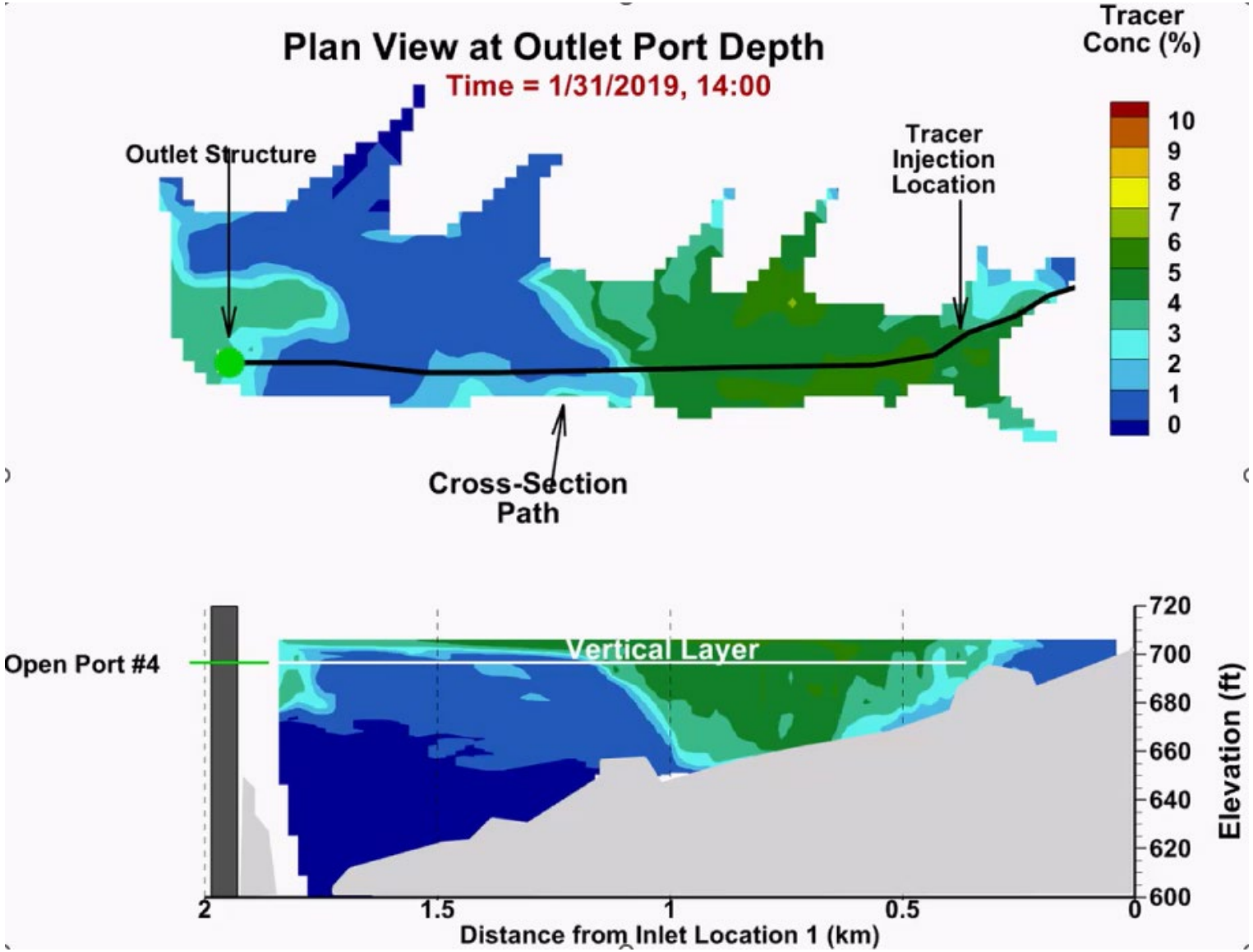
Most dilutions >>10:1, reduced dilutions of interest

*Dilutions shown in this presentation are not based on final modeling assumptions

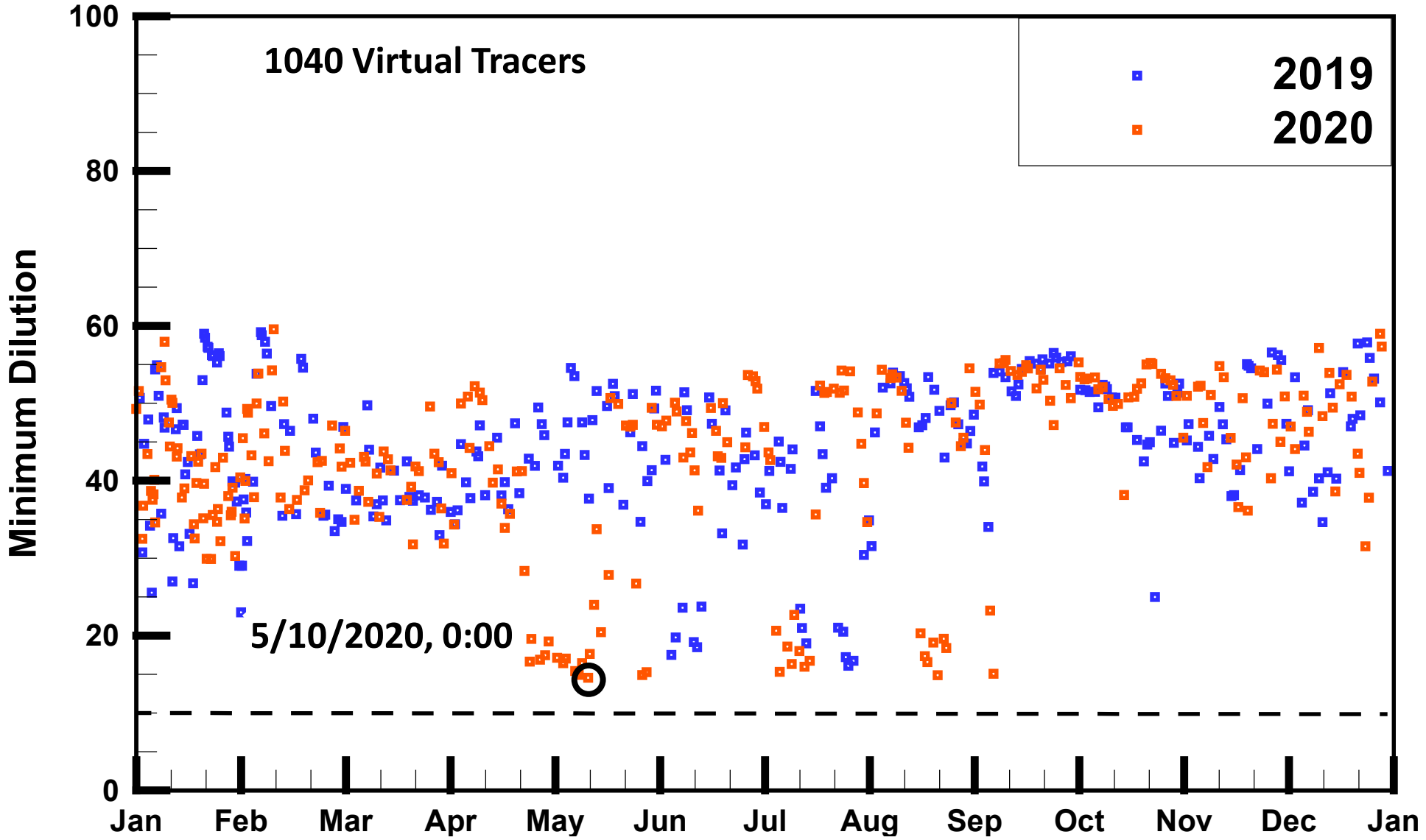
Unstratified Reduced Dilution



Unstratified Reduced Dilution



Port #3 Open Reduced Dilution



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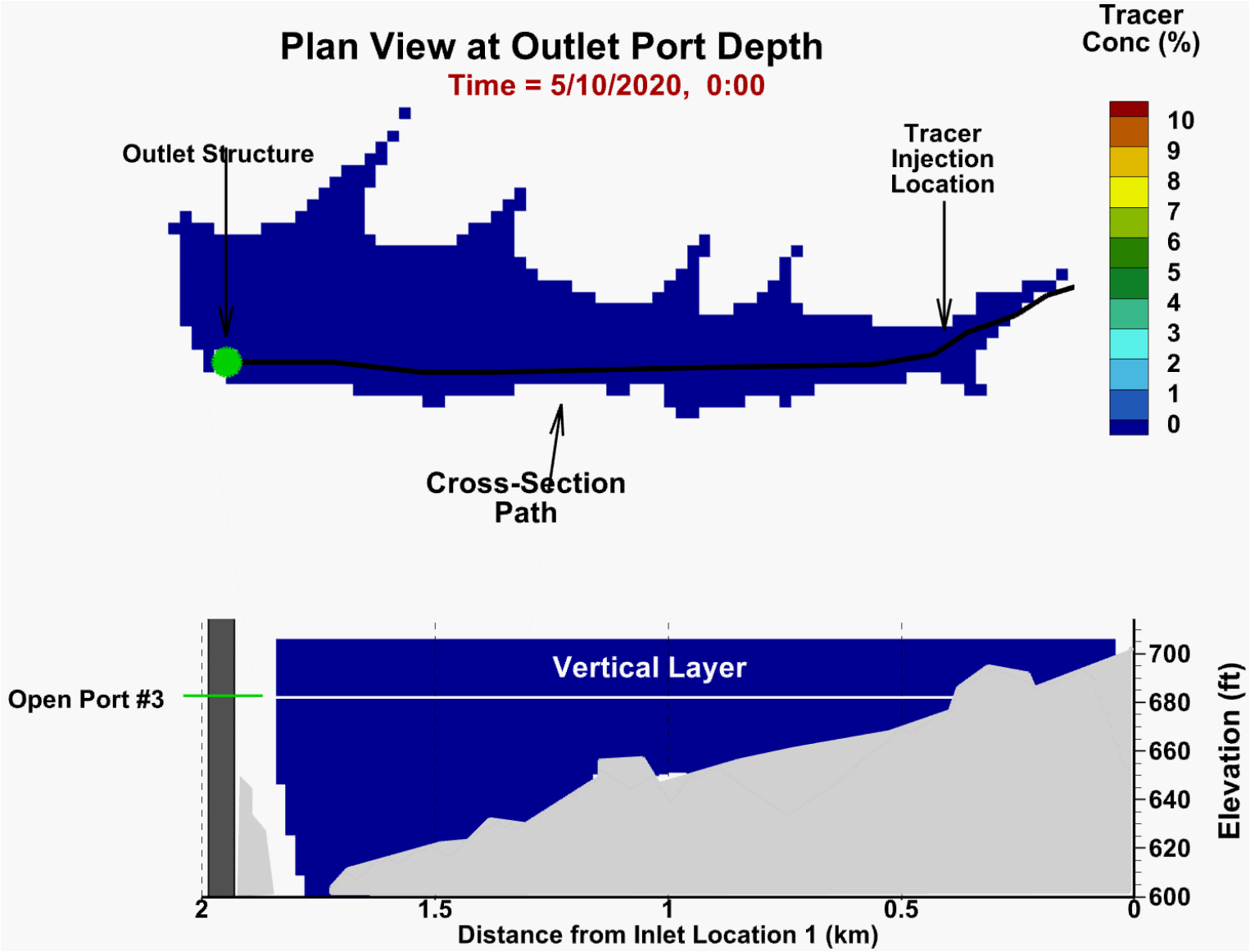
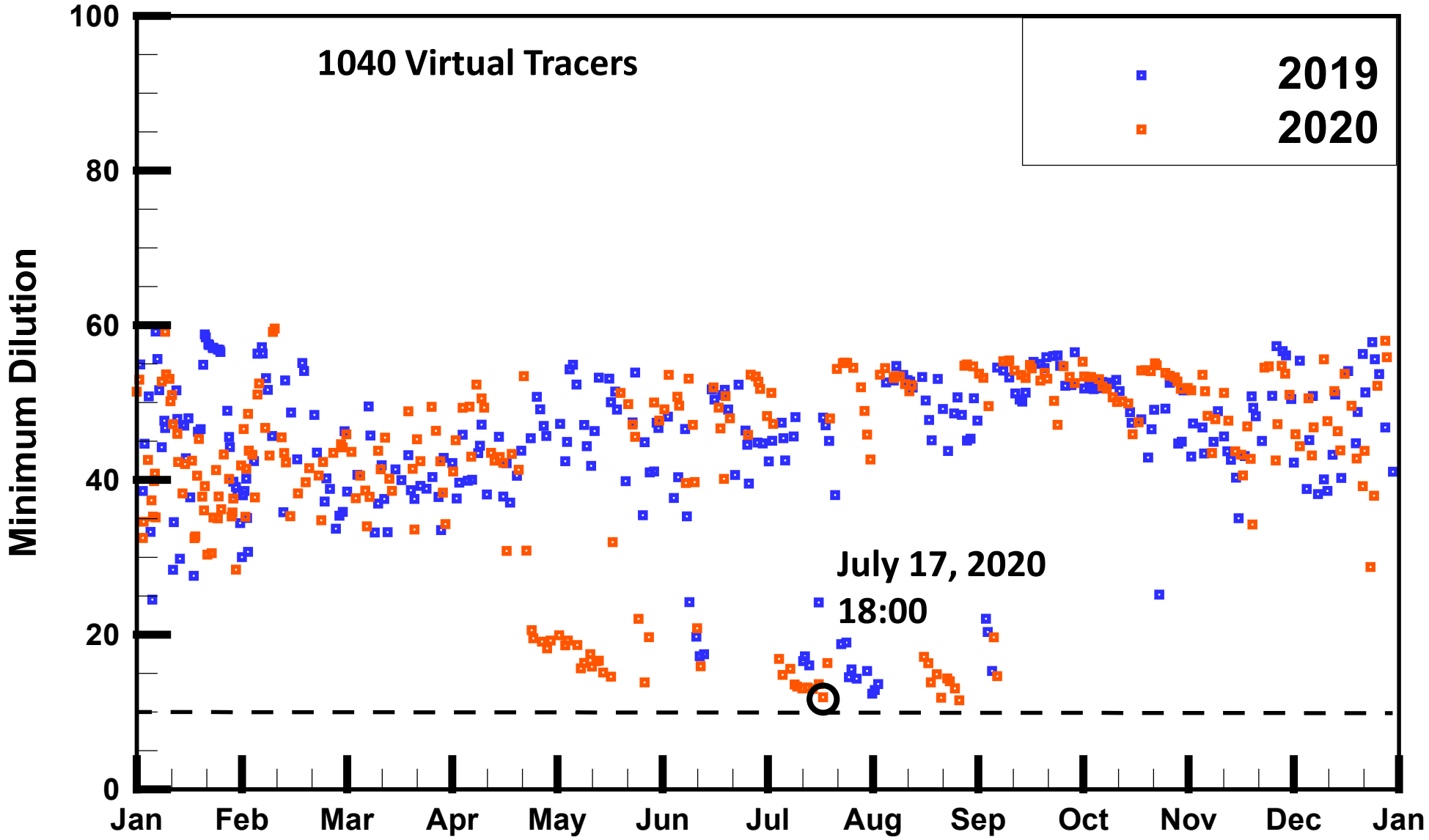
Reduced Dilution (Port #3)

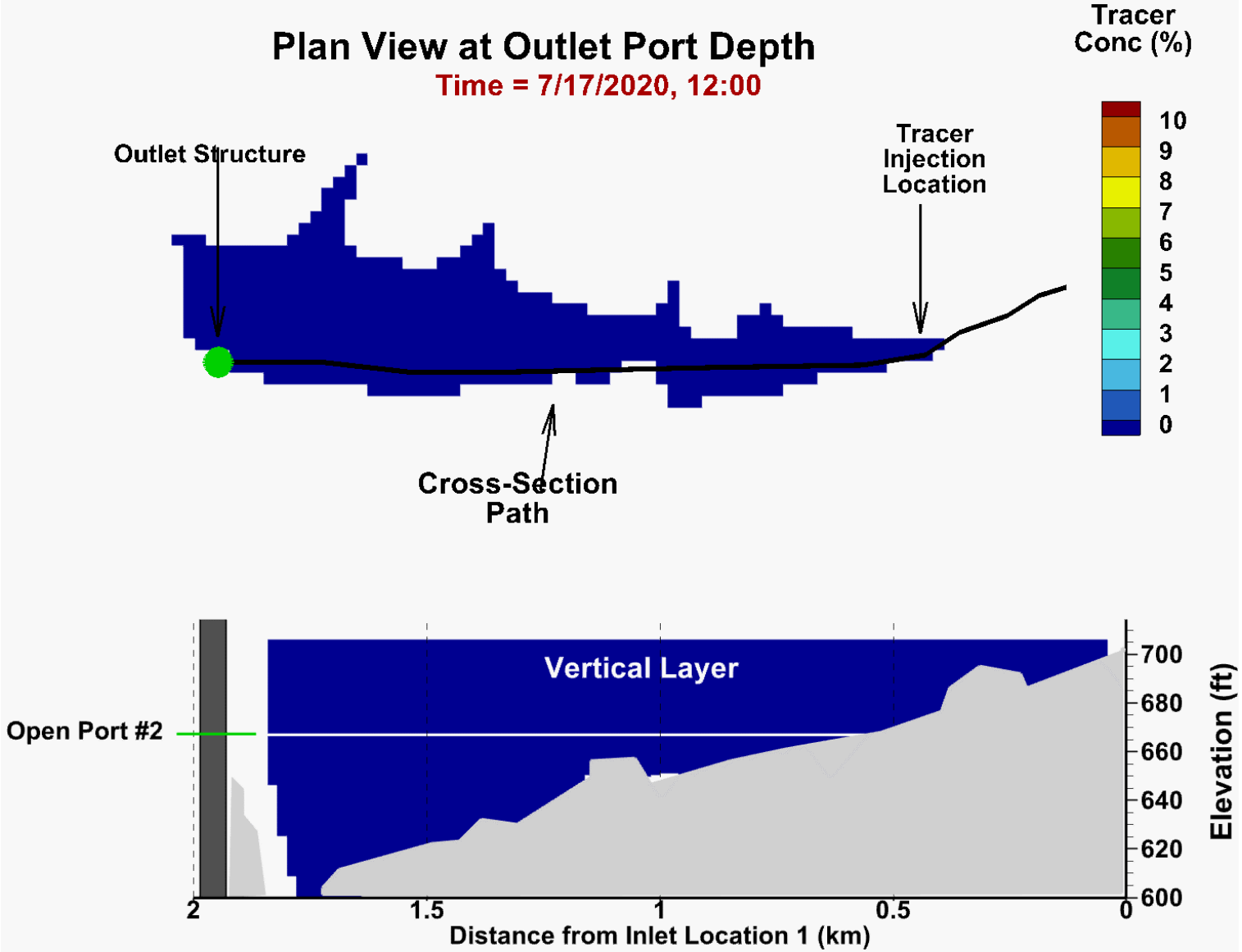


Port #2 Reduced Dilution

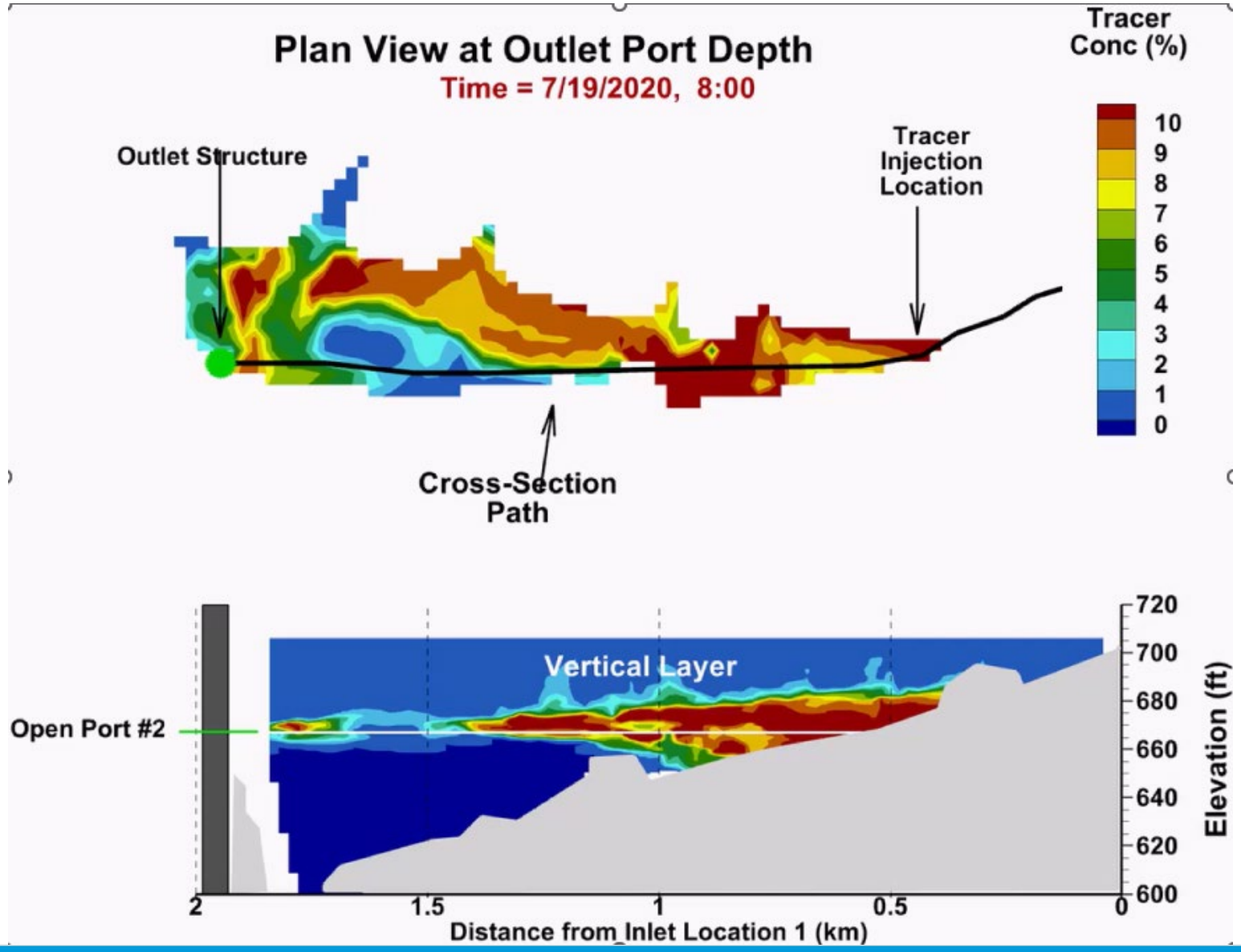


*Dilutions shown in this presentation are not based on final modeling assumptions

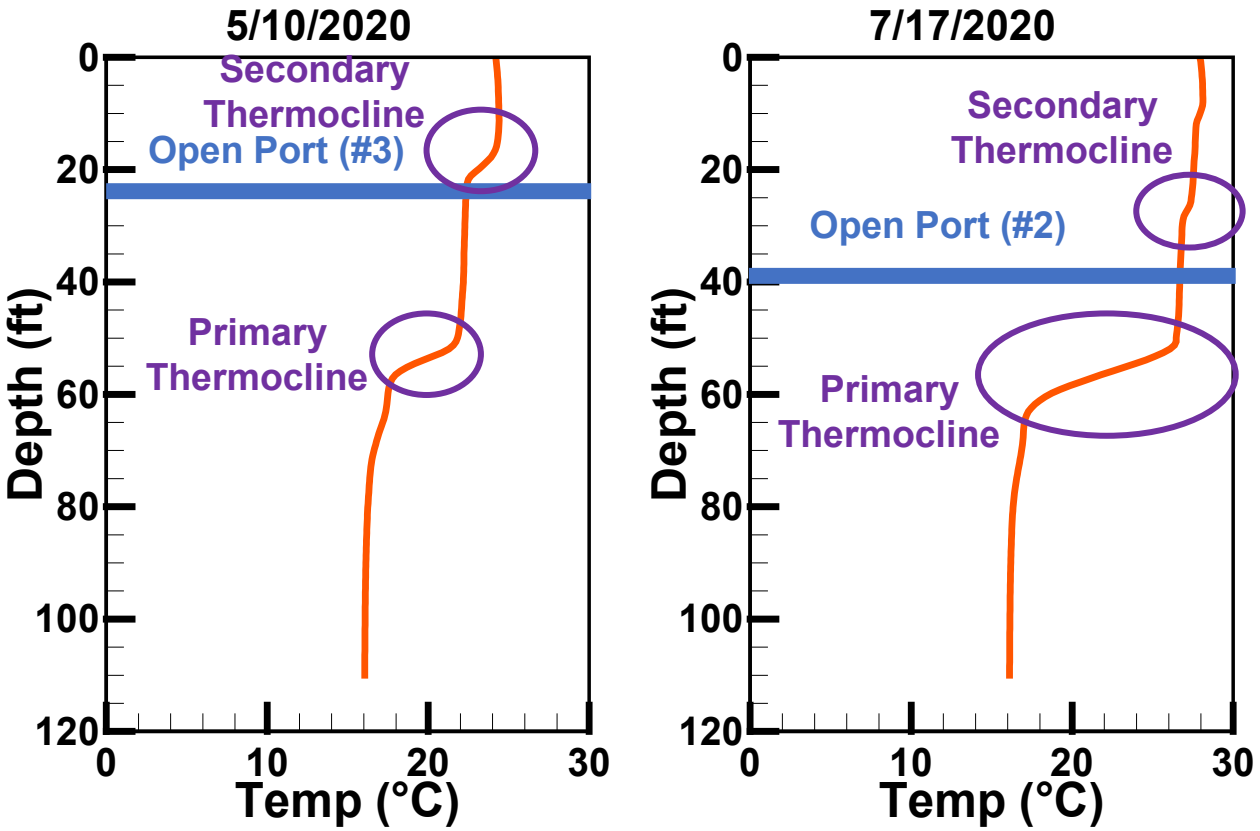
Reduced Dilution (Port #2)



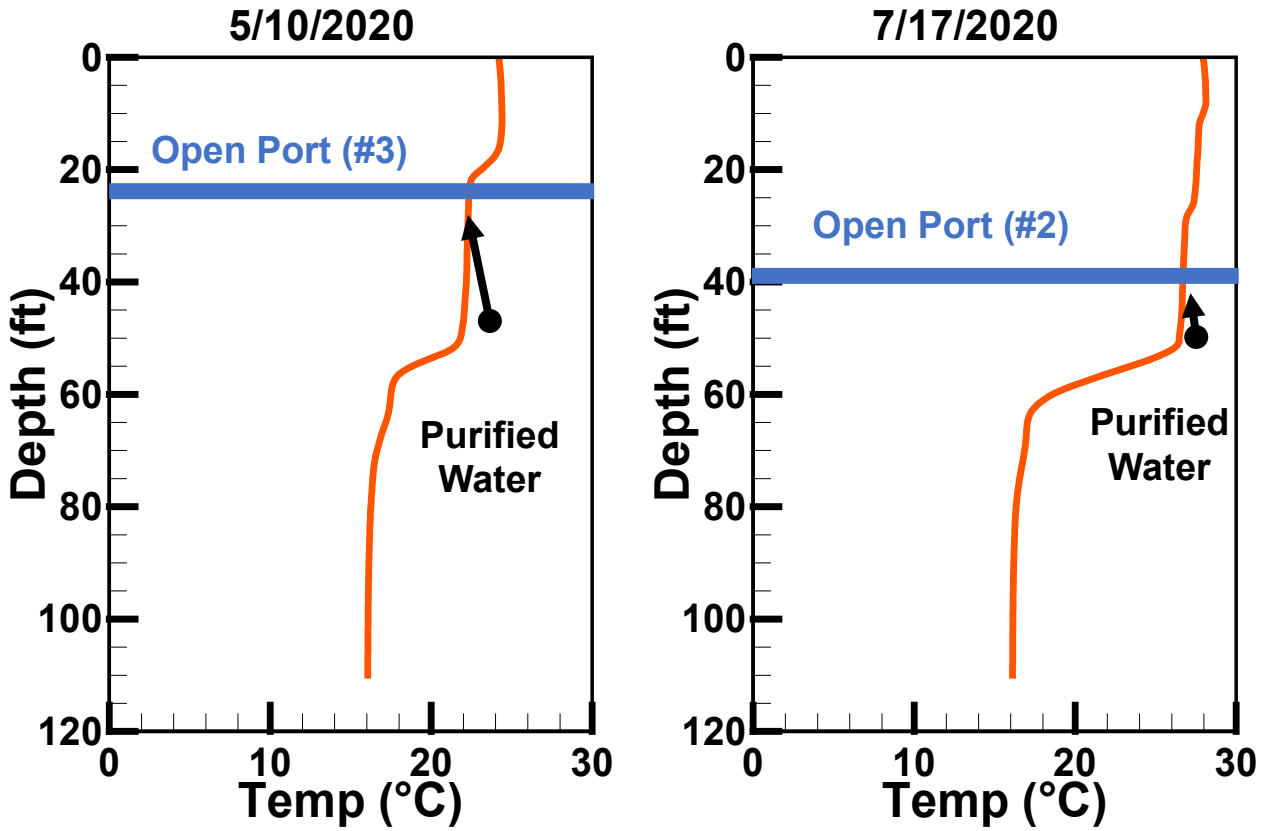
Reduced Dilution (Port #2)



Conditions Leading to Reduced Dilution



Conditions Leading to Reduced Dilution



Primary Thermocline < Purified Water Insertion Level ≈ Open Port Level < Secondary Thermocline

⇒ Reduced Dilution

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Summary and Lessons Learned

- 3D model setup and calibrated
  - *Operational Rules Model Runs underway*
- Reduced dilutions occur when virtual tracer trapped in layer near outlet port
  - *Initial dilution gives "floor" for minimum mixing*
  - *Secondary thermocline forms trapping layer*
- Modeling identified conditions for reduced dilution
  - *Results can inform WTP operations*

City Will Use Model Results to Inform Operations Plan

Questions?

Dr. Kareem Hannoun

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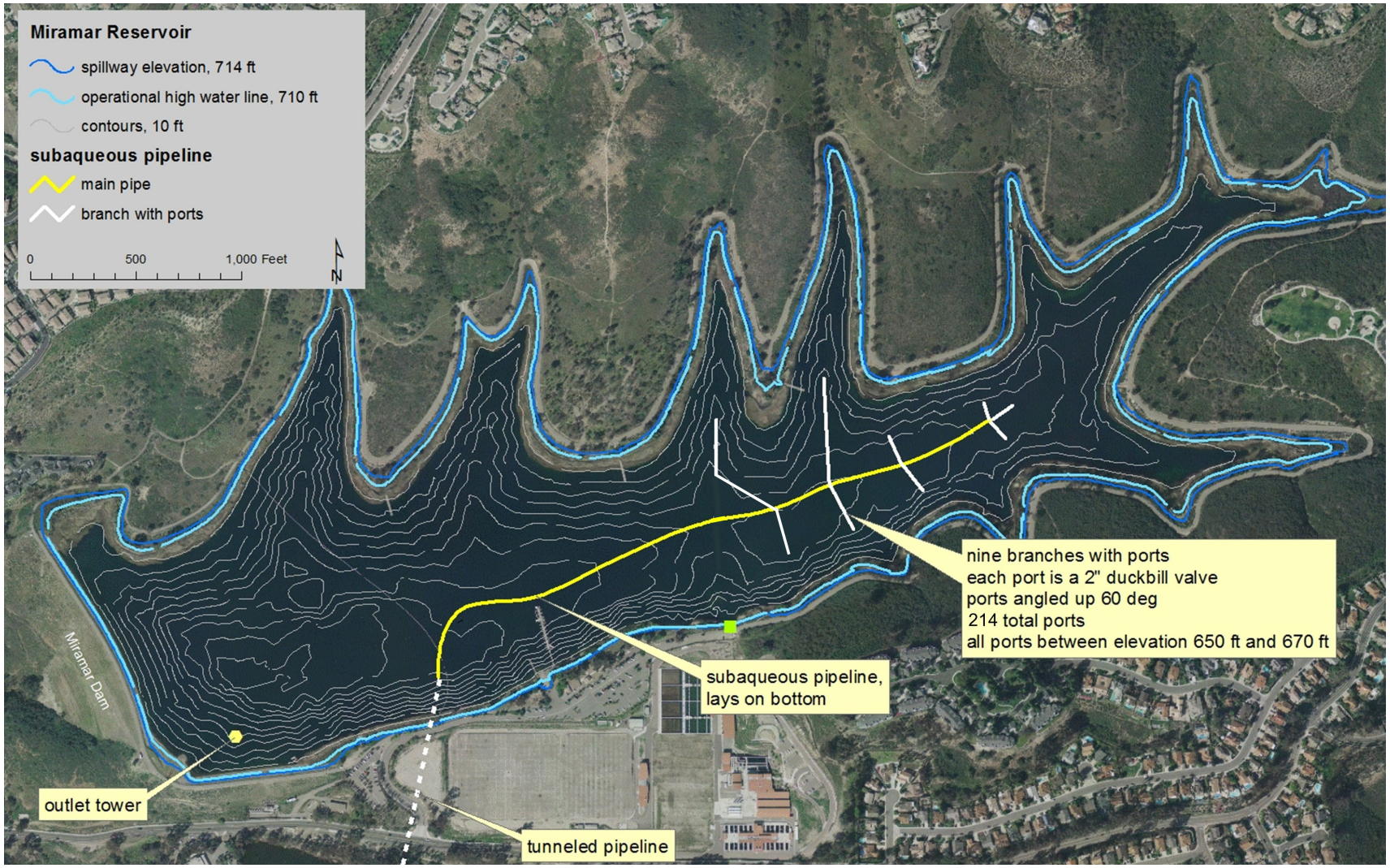
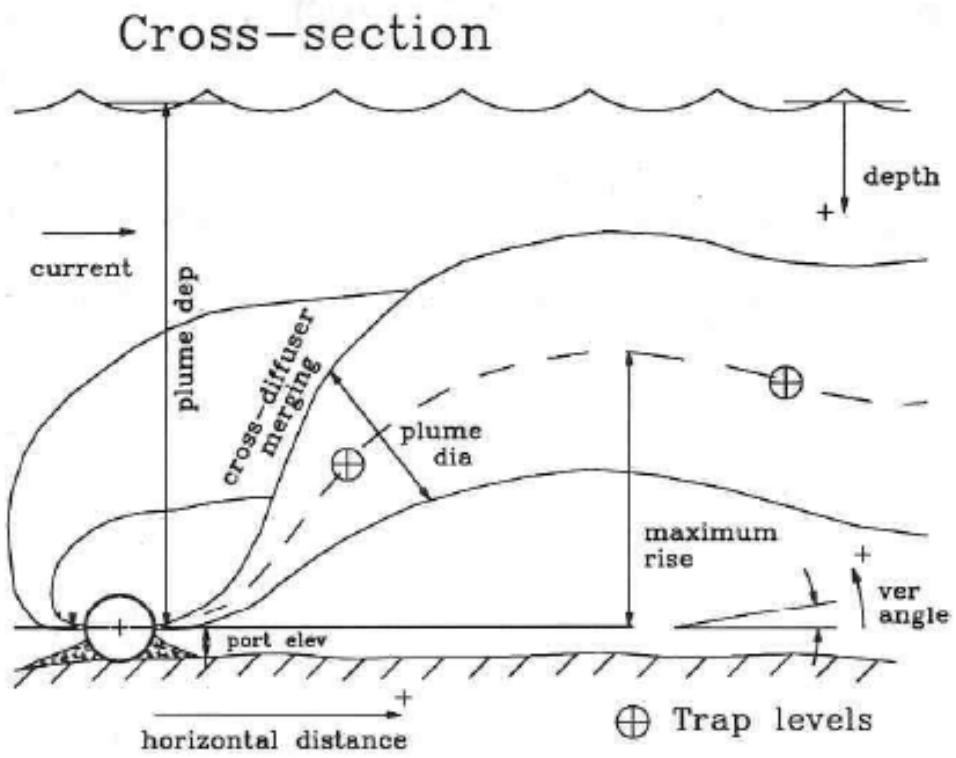
Backup Slides

Purified Water Diffuser



Modeling Initial Dilution



UM3 model (three-dimensional Updated Merge model) of the EPA PLUMES is embedded in the diffuser code;

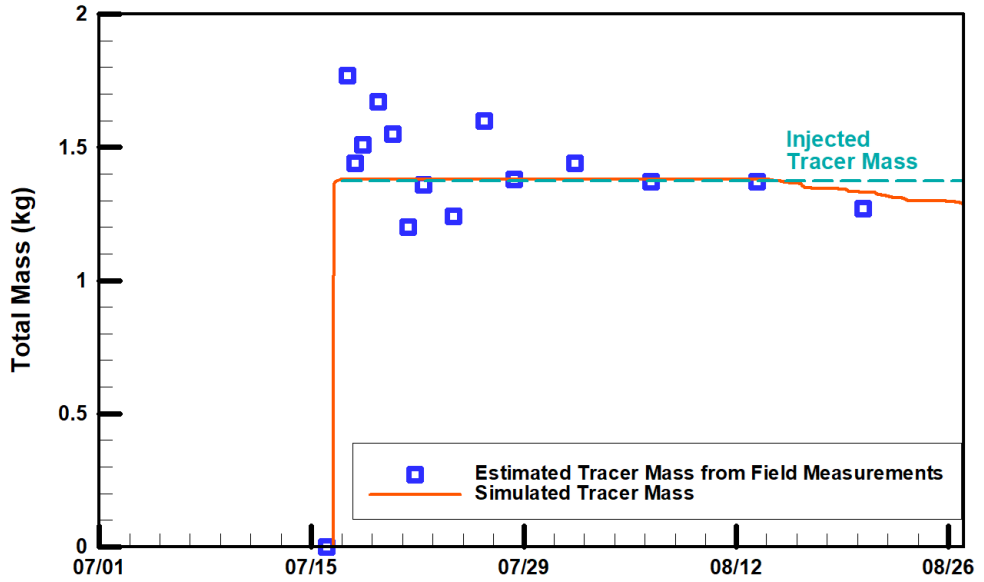
UM3 model, originally coded in Delphi Pascal, simulates single and multi-port submerged discharges;

Dilution (and entrainment) at different depths and the final insertion level are calculated by the UM3 model, then returned to the AEM3D program.

Source: Dilution Models for Effluent Discharges, EPA (1994)

Tracer Study: Measured Tracer

- **Simulation Period:** 7/2/2019 – 8/26/2019
- **Total Tracer Mass:** Simulation matched with the field measurements



*Note that this plot includes only those dates when at least 10 of 11 stations were sampled. Dates when fewer than ten stations were sampled are not included because it is not possible to calculate the mass of tracer in the reservoir when some data is absent. The sampling dates not included are 7/16 (14:00, 16:00, 20:00), 7/17 (3:00), 7/30, and 8/4.

Statistics

Metrics	Definition	
Mean Error	$Mean\ Error = \frac{\sum_{i=1}^{N}(C_{simulated} - C_{measured})}{N}$	
Root Mean Squared Error (RMSE)	$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(C_{simulated} - C_{measured})^2}{N}}$	
Relative RMSE	(1) Based on the range of measured data	$Relative\ RMSE = \frac{RMSE}{\lvert C_{meansured,max} - C_{measured,min} \rvert}$
	(2) Based on the range of ($C_{95} - C_5$)	$Relative\ RMSE = \frac{RMSE}{\lvert C_{meansured,95\%} - C_{measured,5\%} \rvert}$
Relative Absolute Error (RAE)	$RAE = \frac{\sqrt{\sum_{i=1}^{N}(C_{simulated} - C_{measured})^2}}{\sqrt{\sum_{i=1}^{N} C_{measured}{}^2}}$	

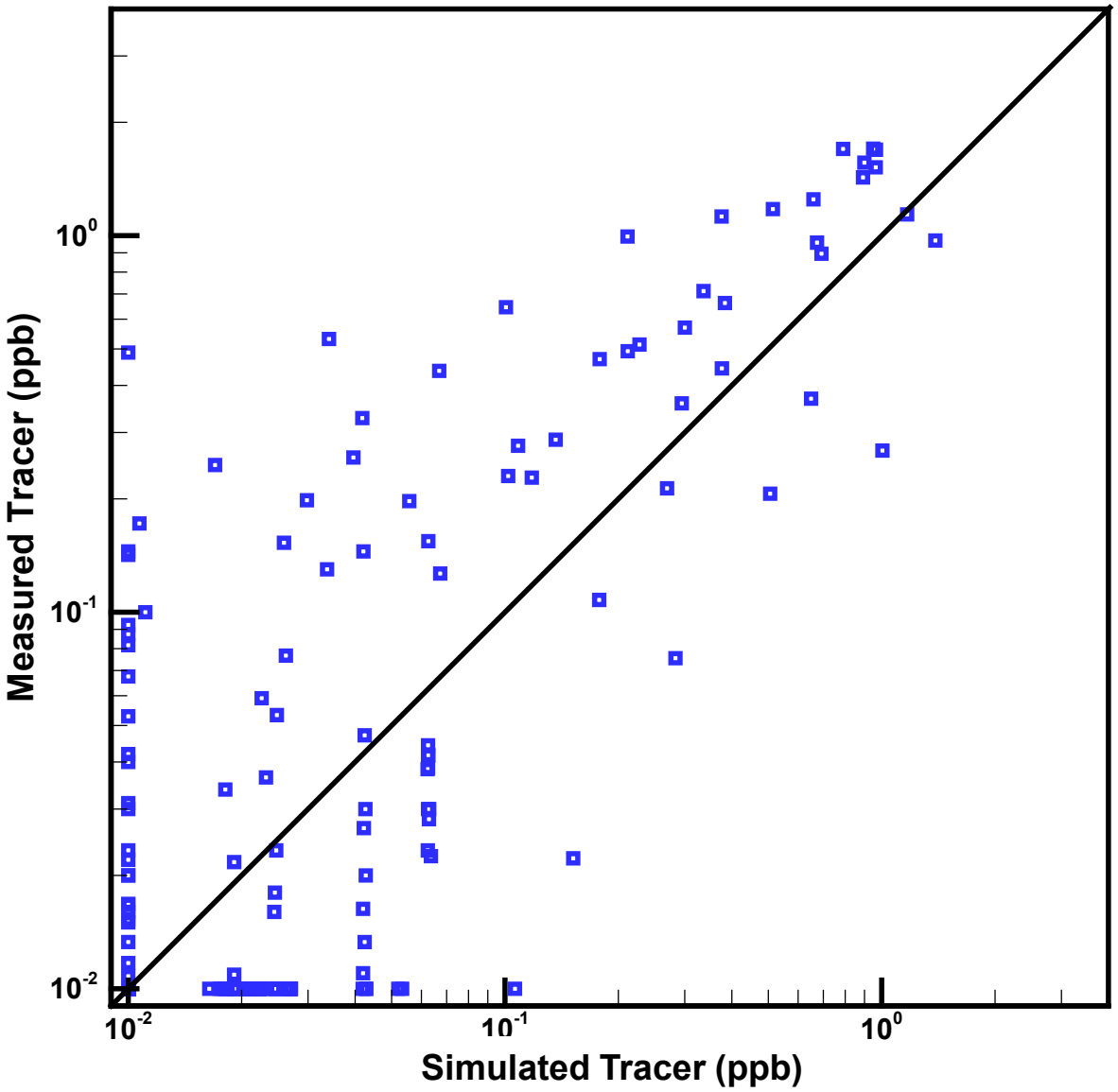
C = Concentration
N = the number of paired predictions-observations.
*RAE and the two types of relative RMSE only differ in the denominator in the definitions.

Statistics

$$r = \frac{1}{n-1} \Sigma \left(\frac{x - \overline{x}}{s_x} \right) \left(\frac{y - \overline{y}}{s_y} \right)$$

$$R^2 = 1 - \frac{SS_{RES}}{SS_{TOT}} = 1 - \frac{\sum_i (y_i - \hat{y}_i)^2}{\sum_i (y_i - \overline{y})^2}$$

Statistics at Outlet



Tracer measured at outlet matches well with simulated concentrations

	Total Number of Data Points	r	R^2	Relative RMSE
Sampling at outlet	284	0.86	0.69	9.8%

Limited literature for statistics on similar studies