

CALIFORNIA DEPARTMENT OF WATER RESOURCES

Real-Time Multi-Ion Prediction in the Delta via Machine Learning

32nd CWEMF Annual Meeting, April 22, 2026

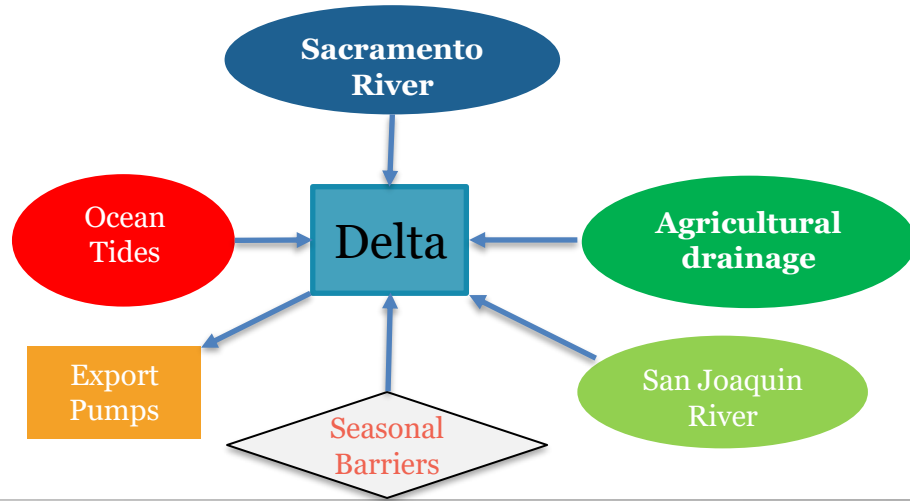


CALIFORNIA DEPARTMENT OF
WATER RESOURCES

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DWR Modeling Support Office

The Delta & Ion Monitoring

A Complex System



Why Ion Monitoring Matters



Agriculture



Drinking Water



Ecosystem



Economy

7 ions tracked:

Cl, SO₄, Ca, Mg, Na, Alkalinity, Br

Predict → Protect water quality in Delta

The Monitoring Gap

Grab Sample
Collected



Lab Analysis
(Days)



Results
Available



Problems:

- A- By the time lab results arrive, water quality conditions may have changed.
- B- Grab sampling spatially and temporally limited.

The Evolution: From Regression to Real-Time ML

Classical Regression (PR) *Prior Work*

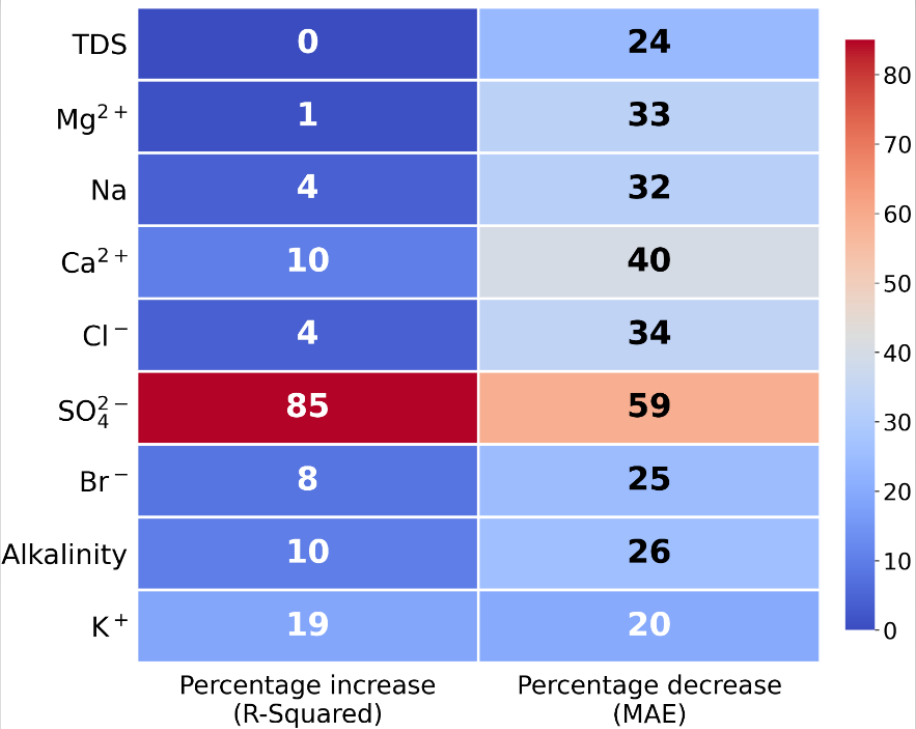
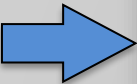
- $EC^* \rightarrow$ Ion equations
- $a \cdot EC^2 + b \cdot EC + c$
- Separate per ion

Limited

Phase 1 & 2 ML Models *Published*

- X2, WYT, Month, EC
- $ML^* \gg$ Regression
- Azure dashboards

Improved



Namadi et al. (2023)

Earth Science Informatics
<https://doi.org/10.1007/s12145-022-00828-1>

RESEARCH ARTICLE



Salinity-constituent conversion in South Sacramento-San Joaquin Delta of California via machine learning

Peyman Namadi¹ · Minxue He¹ · Prabhjot Sandhu¹

Namadi et al. (2023)

Journal of
Hydroinformatics



International Association
for Hydro-Environment
Engineering and Research



Check for updates

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Journal of Hydroinformatics Vol 25 No 6, 2541 doi: 10.2166/hydro.2023.158

Modeling ion constituents in the Sacramento-San Joaquin Delta using multiple machine learning approaches

Peyman Namadi , Minxue He and Prabhjot Sandhu

Namadi et al. (2025)



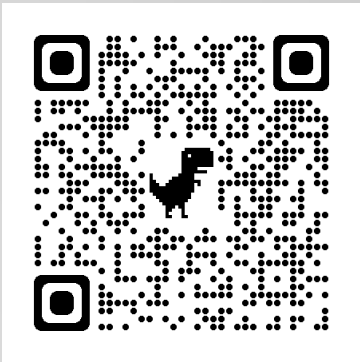
Article

Advancing Ion Constituent Simulations in California's Sacramento–San Joaquin Delta Using Machine Learning Tools

Peyman Namadi, Minxue He and Prabhjot Sandhu

Phase 1 & 2: Operational Dashboards

Interactive dashboard for interior Delta



<https://dwrdashboard.azurewebsites.net/Dashboard>

Ion Simulator Dashboard

This dashboard allows you to simulate ion concentrations based on easily available parameters. Use the sliders and dropdown menus to select the desired values for EC, Sacramento_X2, Ion, WYT, and Month. Then click the 'Compute' button to generate a bar chart of the predicted ion concentrations in three sub-regions.

Instructions:

1. Adjust the sliders and drop-down menus to select the desired input values.
2. Click the **Compute** button to run the simulation.
3. The bar chart will display the predicted ion concentrations for different machine learning models and parametric regression method (prepared by Tetra Tech company).

Notes:

- Electrical conductivity (EC) is measured in microsiemens per centimeter ($\mu\text{S/cm}$).
- Sacramento_X2 is the percentage of Sacramento River flow that is estimated to reach the Delta. The exact location of the Sacramento X2 point is determined by the California Department of Water Resources (DWR) based on the specific hydraulic conditions and water flows in the Sacramento River. The DWR uses a combination of hydrological models, flow measurements, and other data to determine the location of the Sacramento X2 point.
- The Water Year Type (WYT) is a classification of the water year based on its hydrological characteristics. Water Year Type that includes the following categories: 1- Wet (W), 2- Critical (C), 3- Dry (D), 4- Above-Normal (AN), 5- Below-Normal (BN)
- Region refers to monitoring regions that includes: 1- Old-Middle River (OMR), 2- San Joaquin River Corridor (SJRcorridor), and 3- South Delta (SouthDelta).
- Month refers to the month of the year.
- Prediction models: Regression Trees: RT, Gradient Boosting: GB, Random Forest: RF, Artificial Neural Networks: ANN, Parametric Regression method prepared by Tetra Tech: PR
- **The red dashed line** serves as an indicator of the acceptable threshold level for ion concentration in water, beyond which the water quality may not meet standards for human consumption or use, based on guidelines from the EPA and the World Health Organization (WHO); (Cl:250, SO4:250, Na:60, TDS:500) Sources of this information include:
- EPA: [National Primary Drinking Water Regulations](#)
- World Health Organization (WHO): [Guidelines for Drinking-water Quality, 4th edition](#)

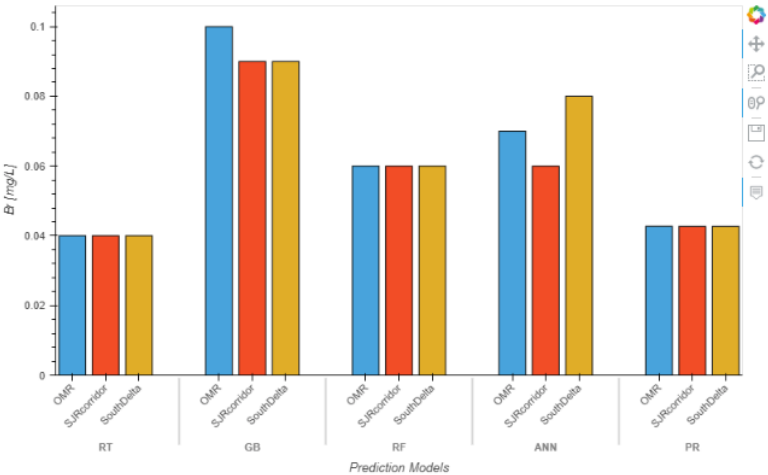
Ion

EC: 200

Water Year Type (WYT)

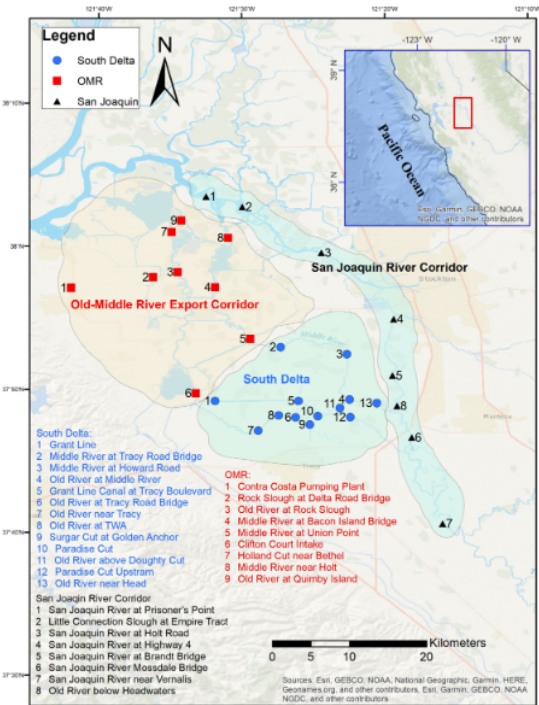
Sacramento_X2: 90

Month



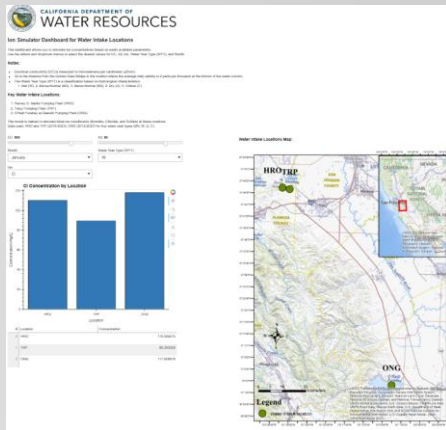
Compute

Study Area

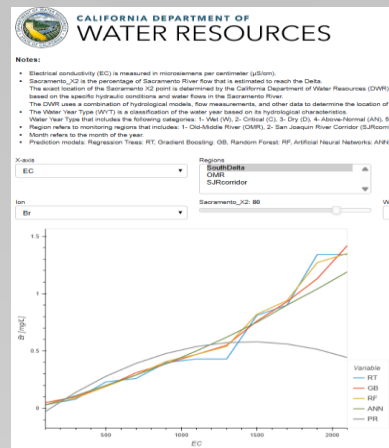


Phase 1 & 2: Operational Dashboards

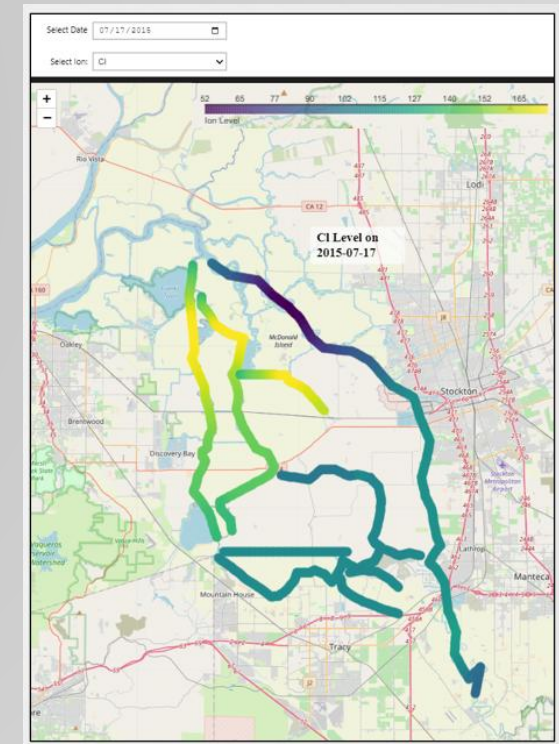
Interactive
dashboard for
**water intake
locations**



Interactive
dashboard for
**Model
Interpretability**



Hybrid DSM2-ML
Water Quality
Dashboard



The Remaining Gap After Phase 2

✓ What Phase 2 Achieved

- ✓ ML outperformed regression equations
- ✓ Unified framework for 7 ions
- ✓ Azure dashboards deployed
- ✓ Peer-reviewed publications

✗ What Was Still Missing

- ⚠ **Lumped predictors (X2, WYT, Month)**
- ⚠ **EC of grab sample required**
→ *Still need lab sample to predict*
- ⚠ **Nowcast only**
→ *No forecasting capability*
- ⚠ **Manual operation of dashboard**
→ *No live data / automation*

Phase 3 Goal: Replace lumped predictors with hydrodynamic variables + enable forecasting + automated warning system

Phase3: Study Area: South Delta

Study Period

June 2018 – Aug 2023

Grab Samples

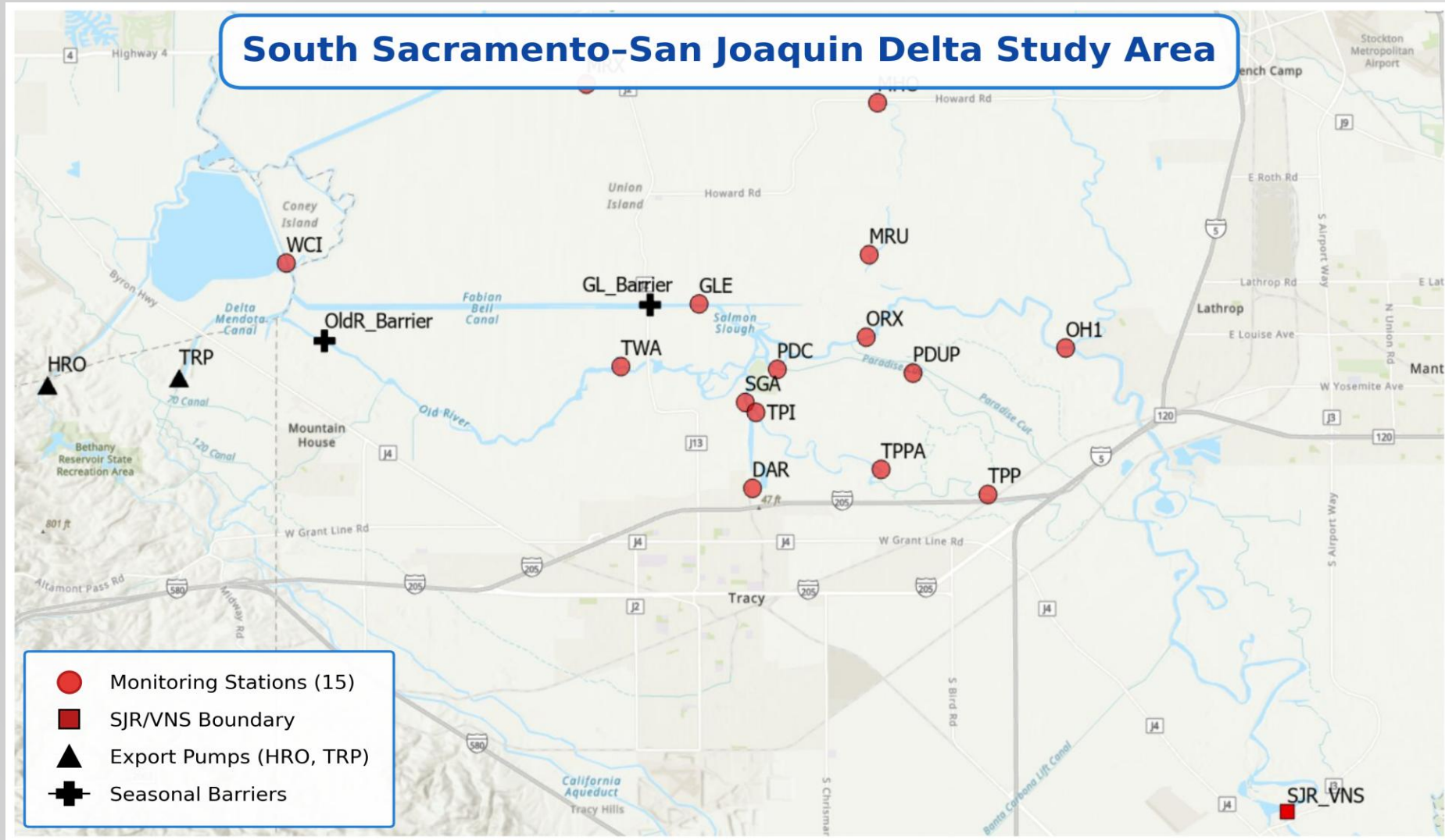
413 samples, 15
stations

Target Ions (7)

**Cl, SO₄, Ca, Mg, Na,
Alk, Br**

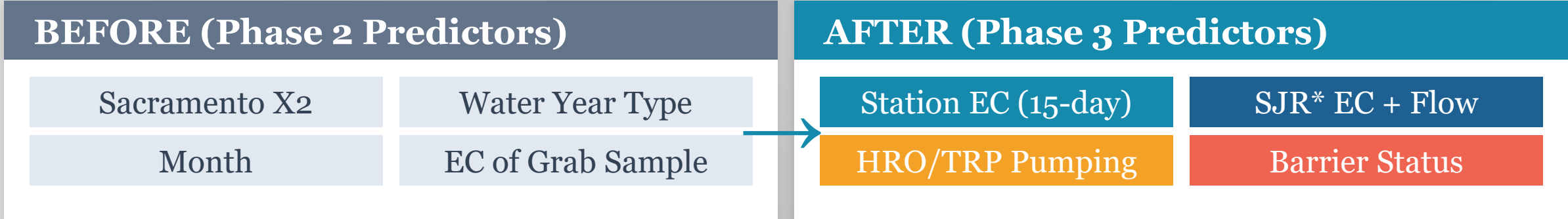
Predictors (Phase 3)

- **Station EC** (15-day lag)
- **SJR EC & Flow**
- **Export Pumping**
- **Barrier Status**



Phase 3: Predictors

What Changed?



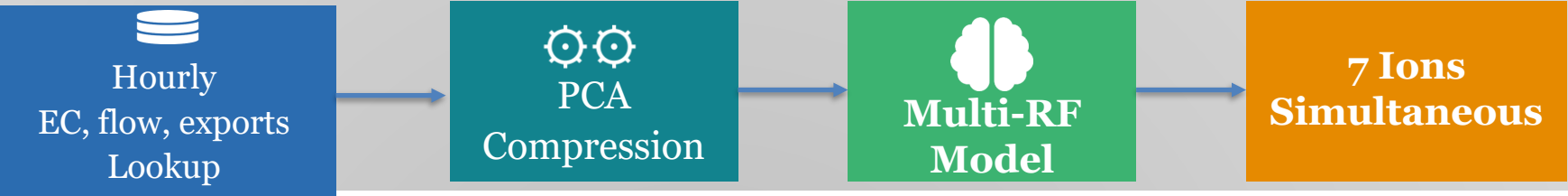
Feature Engineering:

Feature Group	Source	Raw	After PCA*
Station EC (lags 0–14d)	Station continuous	15	2 PCs
SJR* EC (lags 0–14d)	SJR boundary	15	2 PCs
SJR Flow (lags 0–14d)	SJR boundary	15	2 PCs
Grab sample EC	Lab measurement	1	1 (scaled)
HRO Export Pumping	Banks SWP	1	1 (scaled)
TRP Export Pumping	Tracy CVP	1	1 (scaled)
Barrier Status	DWR operations	1	1 (binary)
TOTAL		49	10

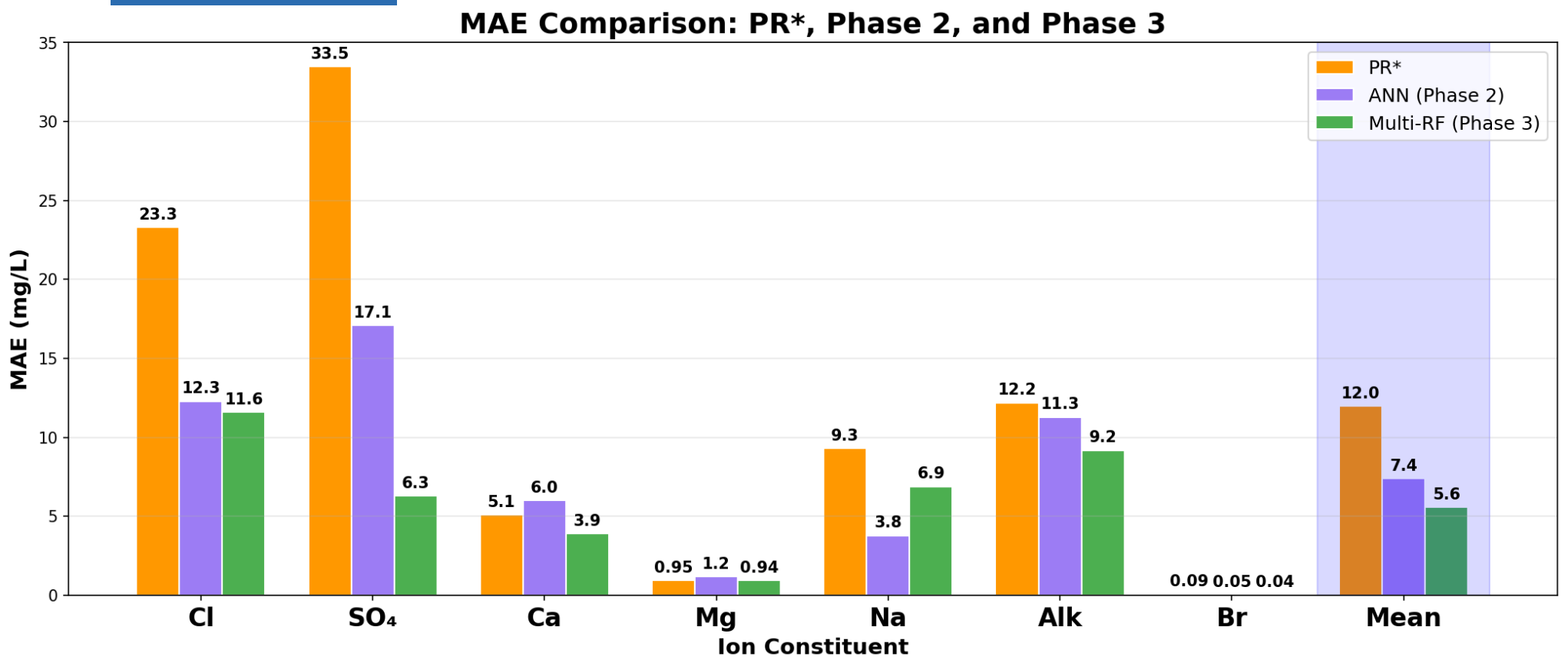
PCA*: Principal Component Analysis
SJR*: San Joaquin River

Phase 3: Structure

Model Structure:



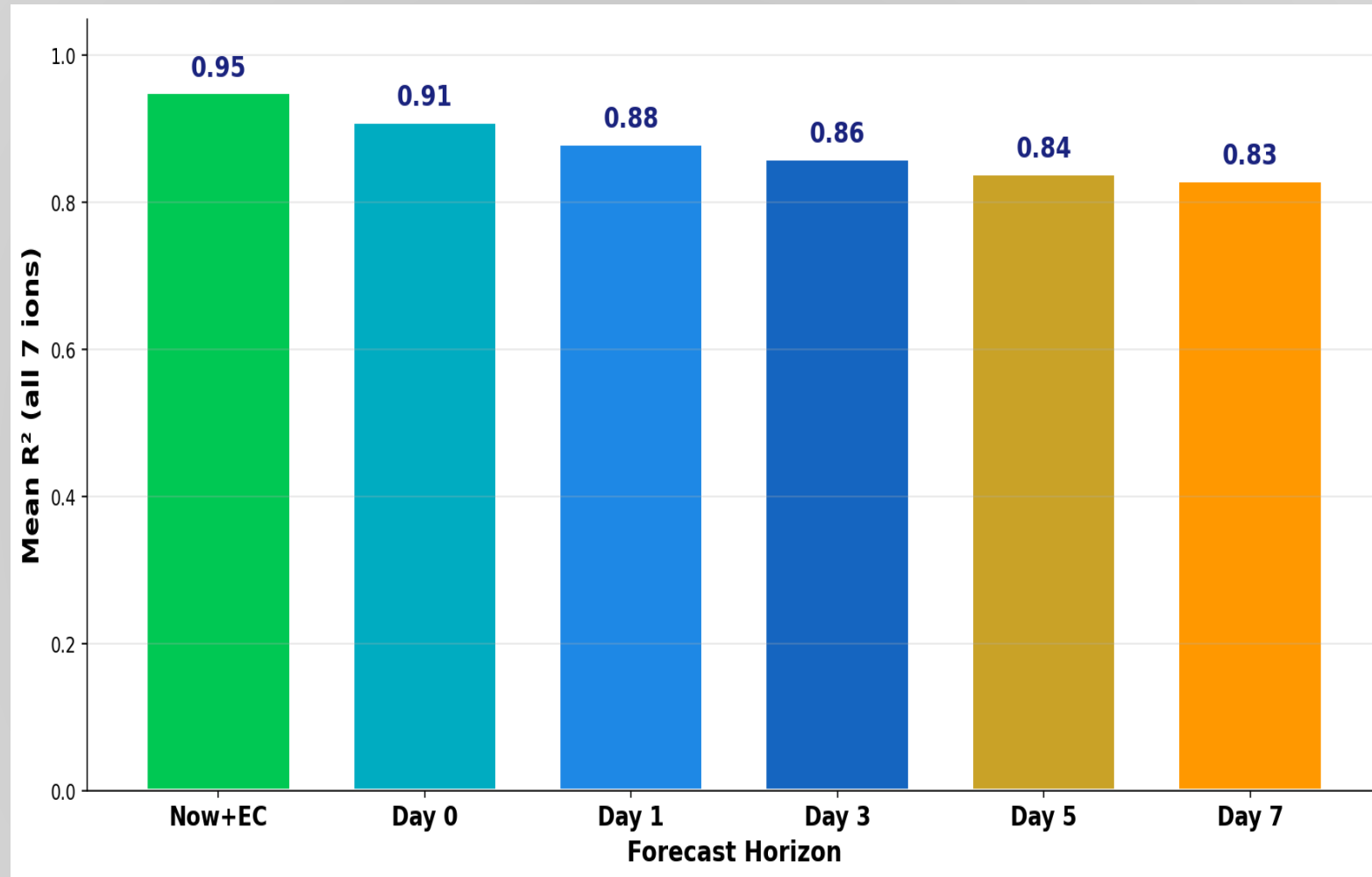
Performance Comparison



PR*: Parametric Regression Method

Nowcast $R^2 = 0.95$ | 7-Day Forecast $R^2 = 0.83$ | Outperforms ANN (0.93) and PR (0.62)

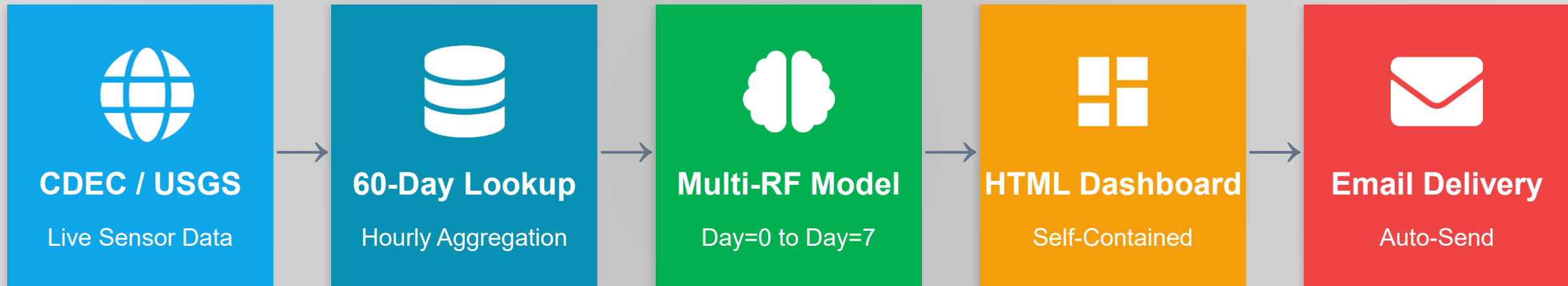
Phase 3: Adding Forecasting Capability



Key Findings:

- ✓ Real-time EC from stations alone achieves $R^2 = 0.91$ (no grab-sampling needed)
- ✓ Accuracy declines gradually with forecast horizon — consistent with meteorological forecasting behavior
- ✓ 7-day forecast still operationally useful ($R^2 = 0.83$)

Automated Daily Pipeline



Runs automatically at scheduled times



No manual intervention required



Self-contained HTML (no server)

Task Scheduler executes daily → Forecasts delivered to your inbox every day

Early Warning System

How It Works

- 1 Forecast values compared against operational thresholds
- 2 If ANY station × ion × horizon exceeds safe limits → Alert
- 3 Warning email sent immediately to designated recipients
- 4 Dashboard attached with complete diagnostic details



 **ALERT: Ion Threshold Exceeded**

To: `operations@dwr.ca.gov`

Subject: `Delta Ion Forecast Warning`

Station: `GLE`

Ion: `Chloride (Cl-)`

Forecast: `258 mg/L @ h=3`

Threshold: `250 mg/L`



`dashboard_20260413.html`

Operational System: Live Forecasting

p.hosseinzadeh.n@gmail.com

To: HosseinzadehNamadi, Peyman@DWR; +2 others

Tue 4/21/2026 5:01 PM

Retention: Enforced: Inbox 90 day (3 months) Expires: Mon 7/20/2026 5:01 PM

dashboard_20260421_1701.html
108 KB

dashboard_20260408_1113.html

SOUTH DELTA ION FORECAST — 2026-04-21 17:00
Prediction hour: 17:00
Barrier status: OPEN

NOWCAST (Day 0 - Today)

Station	Cl	SO4	Ca	Mg	Na	Alkalinity	Br
OH1	32.9	25.6	16.4	7.8	27.9	59.6	0.1
ORX	32.9	25.6	16.4	7.8	27.9	59.6	0.1
TWA	65.6	47.1	24.6	12.8	52.2	77.4	0.2
SGA	66.1	48.5	25.0	13.0	52.3	77.8	0.2
PDC	67.2	48.5	25.1	13.0	53.4	78.5	0.2
WCI	32.5	25.4	16.3	7.7	27.6	59.4	0.1
DAR	143.3	117.3	48.3	26.5	117.4	140.8	0.4
TPI	65.9	46.2	24.4	12.7	52.4	76.8	0.2
TPP	382.5	243.2	124.9	60.1	229.3	212.9	1.2
MHO	64.5	46.6	24.3	12.7	51.6	76.5	0.2
MRU	33.1	25.7	16.5	7.8	28.0	59.6	0.1
MRX	33.1	25.6	16.4	7.8	27.9	59.3	0.1

13/14

Conclusions

Key Achievements

- ↗ Hydrodynamic predictors outperform lumped indicators
- 🧠 Multi-RF predicts 7 ions simultaneously
- 📈 Nowcast $R^2 = 0.95$ • 7-day $R^2 = 0.83$
- 🚀 First **live** multi-ion forecast for South Delta with **warning system**

Questions?

Peyman Namadi

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Acknowledgements

- ❑ Kevin He, Nicky Sandhu, Paul Hutton, Shaun Philippart, Jared Frantzich and David Colvin (DWR)
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- ❑ Leslie Palencia (MWQI)
- ❑ Funded by MWQI