Machine Learning-Based Tools for Ion Constituent Simulation in the Delta

Machine Learning in Water and Environmental Modeling Workshop
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Module #4

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CALIFORNIA DEPARTMENT OF
WATER RESOURCES

Outline

1. Problem Definition
2. Study Phases
   - **Phase 1**: Pilot study (South Delta)
   - **Phase 2:** Interior Delta
   - **Phase 3:** Water intake locations
   - **Phase 4:** Hybrid model
3. Dashboard Tools
4. Key Messages

Problem Definition

Why ion levels matter in the Delta?

- Water quality management
- Regulatory compliance
- Decision-making and forecasting

Photo credit: California Department of Water Resources (https://pixel-ca-dwr.photoshelter.com)

Problem Definition

Why use a conversion method (Electrical Conductivity (EC) → Ion constituents)?

Sampling limitations:

- time-consuming: collection, laboratory analysis
- costly
- limited spatial and temporal coverage

Source of Photos: https://pixel-ca-dwr.photoshelter.com)

Hydrodynamic modelling

EC

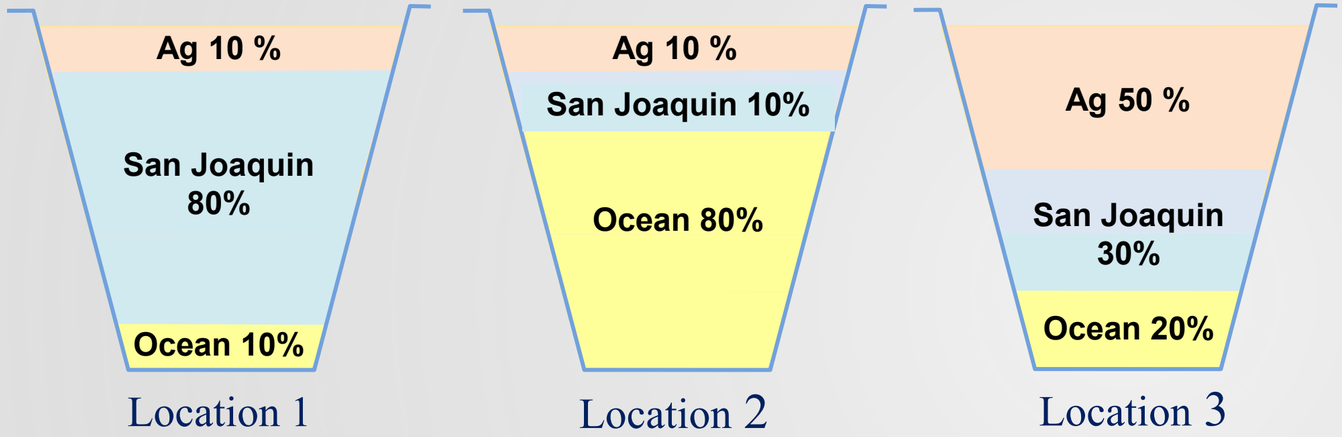
Conversion Model

Ion

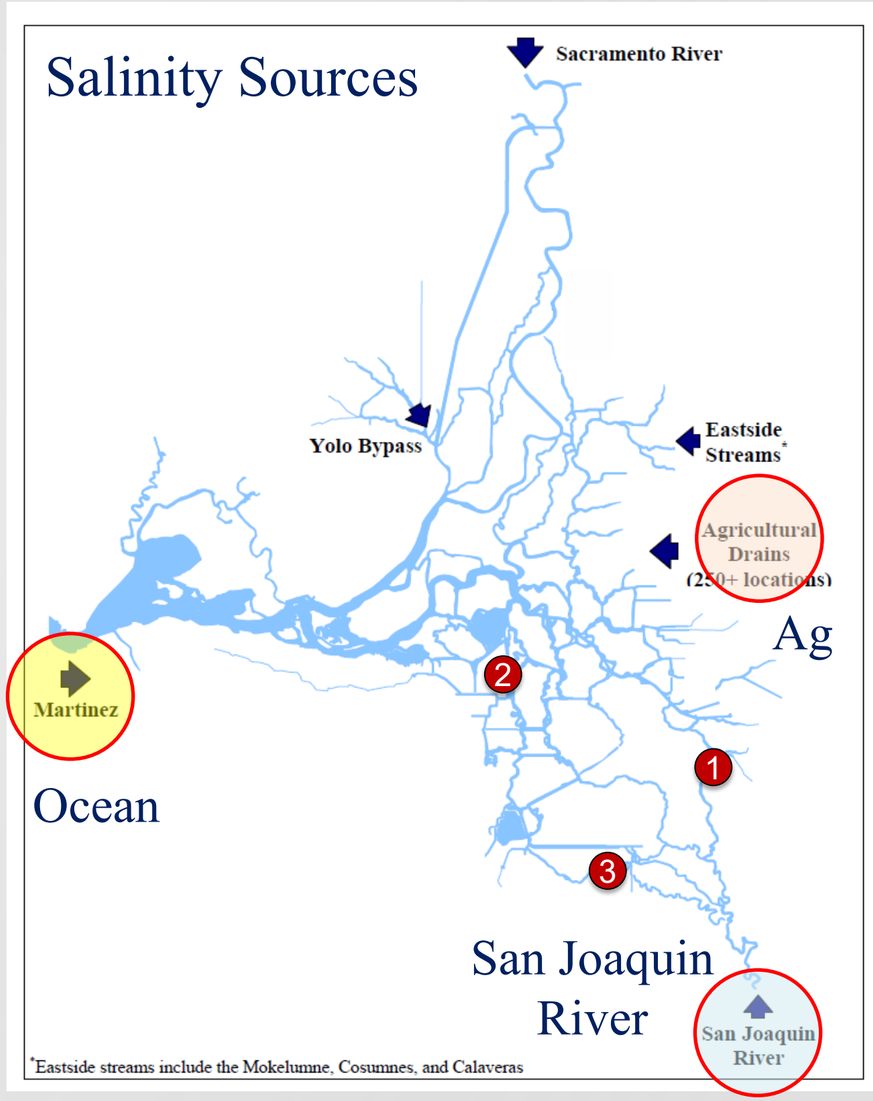
Problem Definition

EC ⟶ **Ion**

Contribution from each source (demonstration purposes only)



- Even with **similar EC levels, the ion constituent levels can vary** as the **sources of salinity are different.**
  - **Ocean sources** → higher levels of **Chloride/Bromide**.
  - **Agricultural drainage** → more **Sulfate**.
- Understanding the **source of salinity** is crucial for accurately assessing ion constituents.



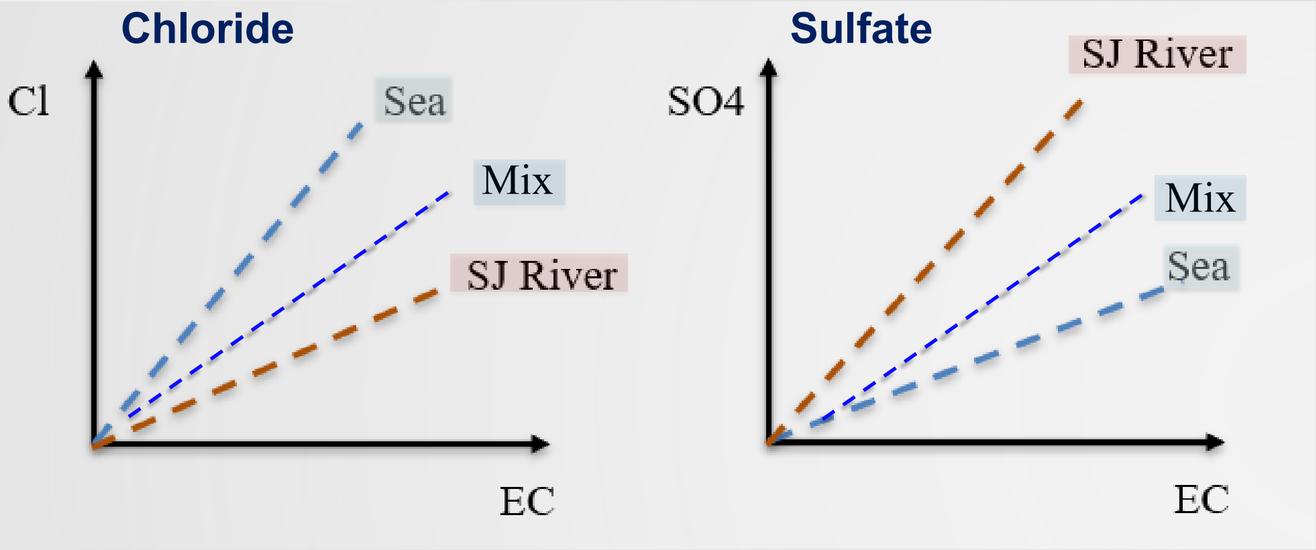
Problem Definition

Traditional method:

$$\text{Similarity} \begin{cases} Ion = \boldsymbol{A} \times EC + \boldsymbol{B} \\ Ion = \boldsymbol{A} \times EC^2 + \boldsymbol{B} \times EC + \boldsymbol{C} \end{cases} \longrightarrow \begin{cases} \text{If Region} = \text{R1 \& X2*} < 81\text{ km \& Month} = \text{June \& WYT*} = \text{Wet} \longrightarrow A_1, B_1, C_1 \\ \text{If Region} = \text{R2 \& X2} < 81\text{ km \& Month} = \text{June \& WYT} = \text{Dry} \longrightarrow A_2, B_2, C_2 \\ \text{If Region} = \text{R3 \& X2} > 81\text{ km \& Month} = \text{April \& WYT} = \text{Critical} \longrightarrow A_3, B_3, C_3 \\ \vdots \qquad\qquad \vdots \end{cases}$$

Water Year Type and Season Matrix #2

	J	F	M	A	M	J	J	A	S	O	N	D
	Jan				Old-Middle River Export Corridor Subregion							Dec
W	SEA	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SEA	SEA	SEA	SEA
AN	SEA	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SEA	SEA	SEA	SEA
BN	SEA	SEA	SEA	SEA	SEA	SEA	SEA	SEA	SEA	SEA	SEA	SEA
D	SEA	SEA	SEA	SEA	SEA	SEA	SEA	SEA	SEA	SEA	SEA	SEA
C	SEA	SEA	SEA	SEA	SEA	SEA	SEA	SEA	SEA	SEA	SEA	SEA
					San Joaquin River Corridor Subregion							
W	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR
AN	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR
BN	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR
D	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR
C	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR
					South Delta Subregion							
W	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR
AN	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR	SJR
BN	IND	IND	SJR	SJR	SJR	SJR	SJR	IND	IND	IND	IND	IND
D	IND	IND	SJR	SJR	SJR	SJR	SJR	IND	IND	IND	IND	IND
C	IND	IND	SJR	SJR	SJR	IND	IND	IND	IND	IND	IND	IND



Wet (W), Above-Normal (AN), Below-Normal (BN), Dry (D), Critical (C),
SEA (Sea boundary is dominant), SJR (San Joaquin boundary is dominant), IND (indeterminate or Mix)

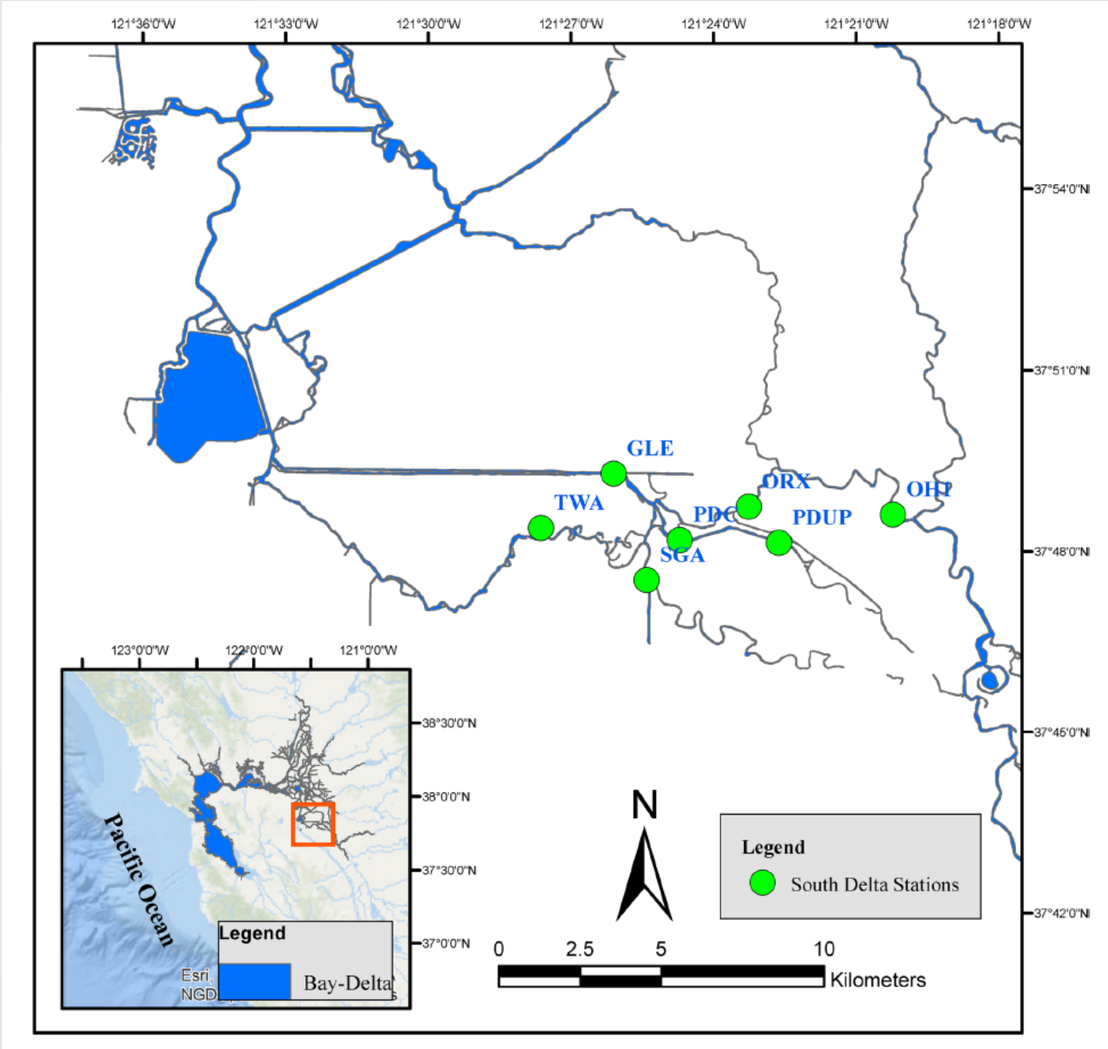
Data Preparation: Phase 1

South Delta:

- 11 ion constituents
- ~180 samples (2018 to 2020)

1- EC
2- Sacramento X2
3- Month
4- Water Year Type
5- Location

1- Bromide
2- Chloride
3- Sulfate
4-Total Dissolved Solids
5- Alkalinity
6- Sodium
7- Calcium
8- Magnesium
9- Potassium
10- Nitrate
11- Boron



Data Preparation: Phase 2

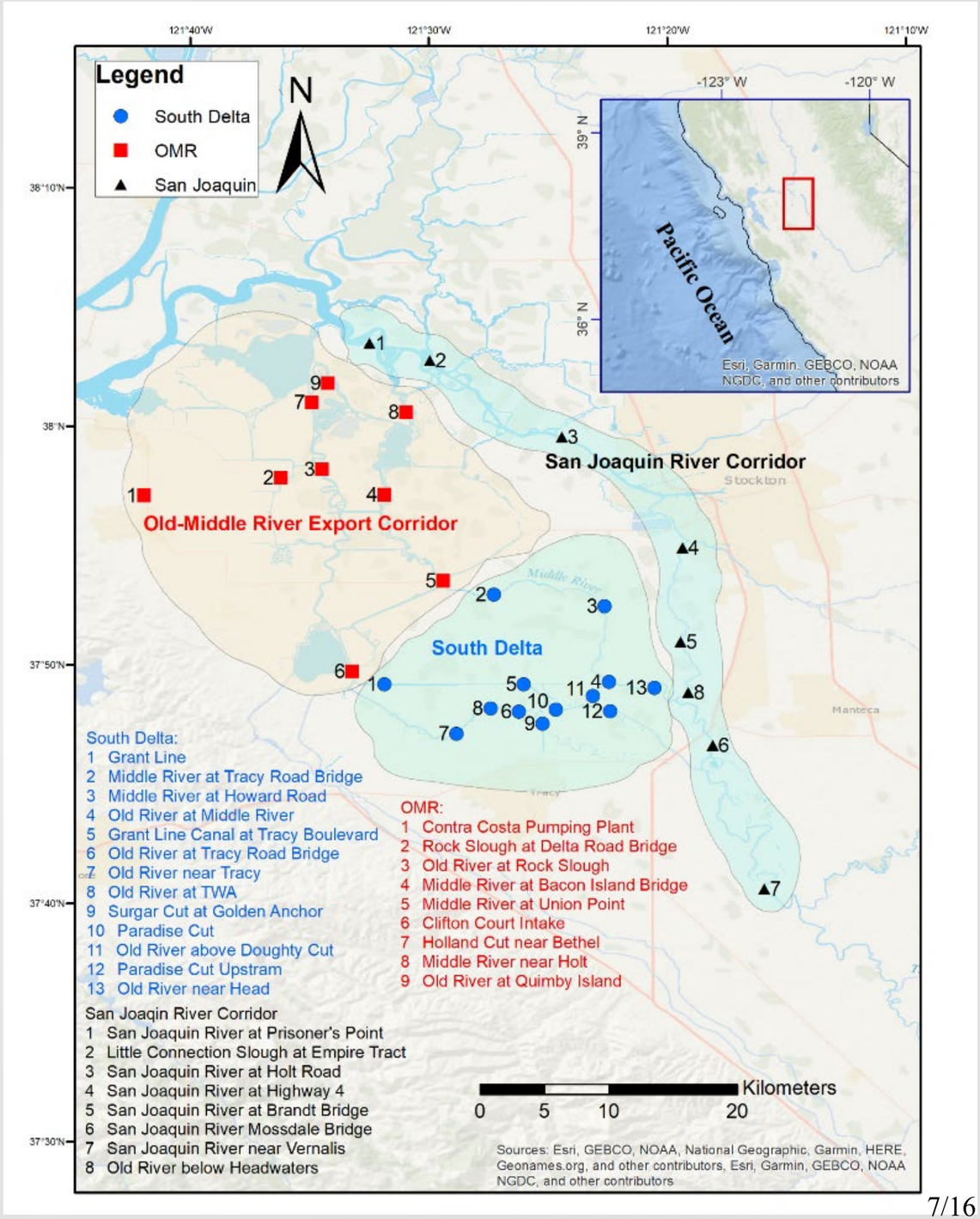
Interior Delta

9 ion constituents; 1000 ~ 2000 samples (1959-2022)

- Old-Middle River Export Corridor (OMR)
- San Joaquin River Corridor
- South Delta

x:
1- EC
2- Sacramento X2
3- Month
4- Water Year Type
5- Location

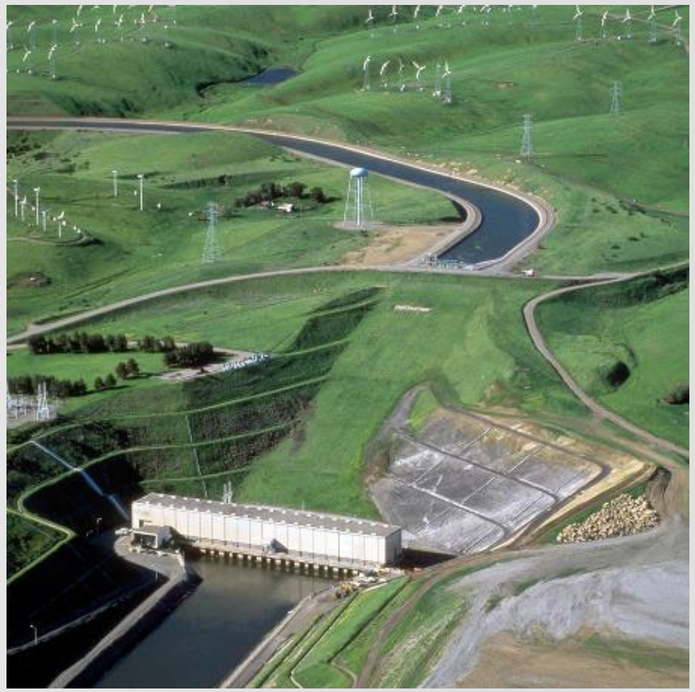
y:
1- Bromide
2- Chloride
3- Sulfate
4-Total Dissolved Solids
5- Alkalinity
6- Sodium
7- Calcium
8- Magnesium
9- Potassium

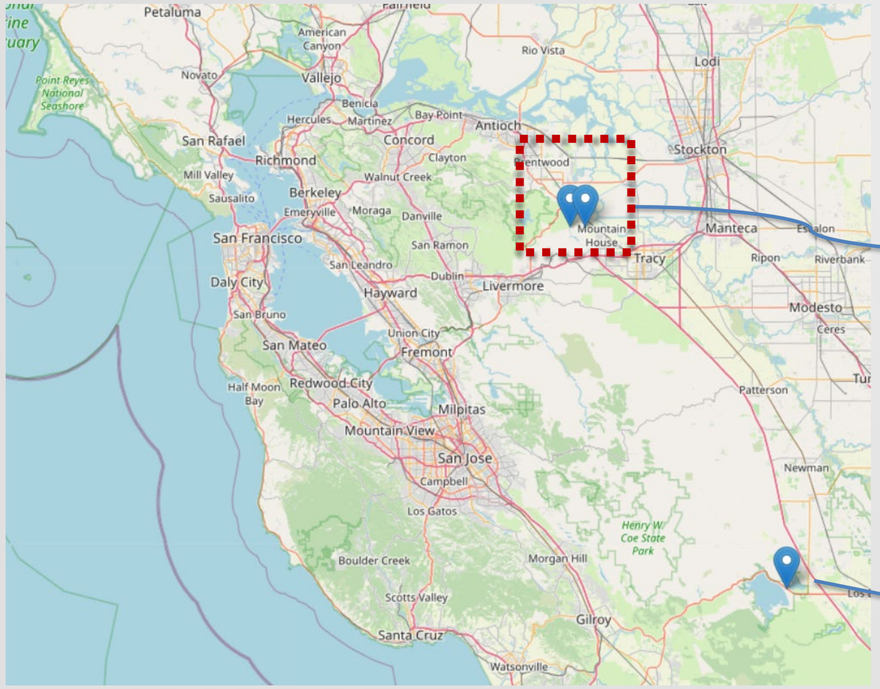


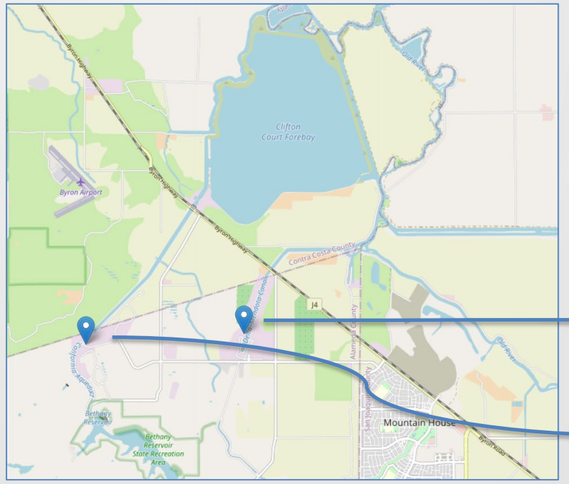
Data Preparation: Phase 3

Key Intake Locations

- 3 ion constituents (Bromide, Chloride, Sulfate)
- ~5000 samples
- HRO and TRP (2019-2023), ONG (2012-2023)





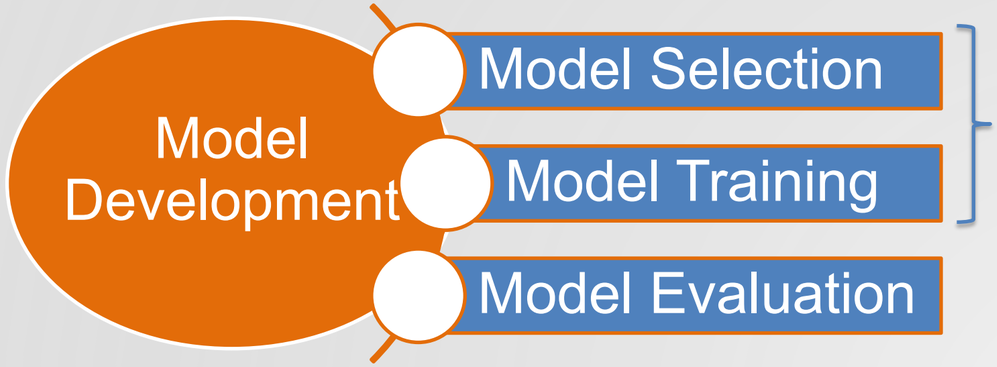


Tracy Pumping Plant (TRP)

Banks Pumping Plant (HRO)

'Neill Forebay at Gianelli Pumping Plant (ONG)

Model Development: Phrases 1-3



Details to be covered in the hands-on portion

K-fold cross validation; Sensitivity analysis

% improvement over traditional method (Phase 2): **R^2** & Mean Absolute Error (**MAE**)

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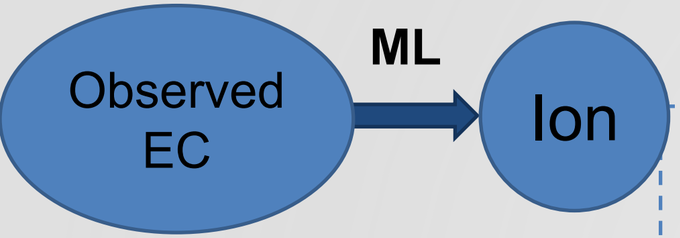
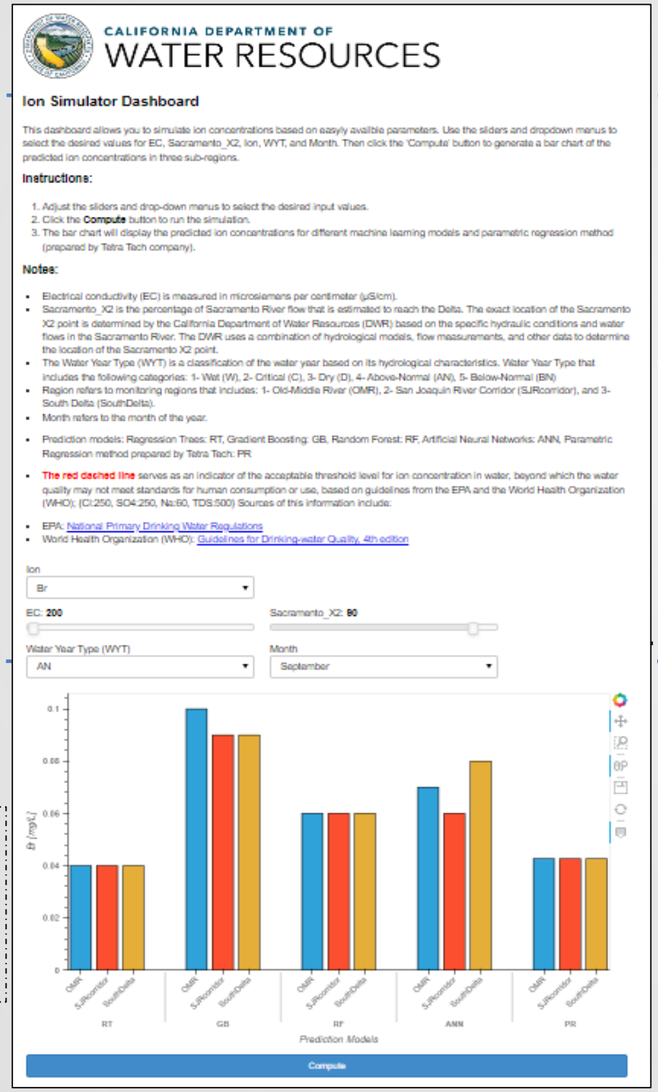
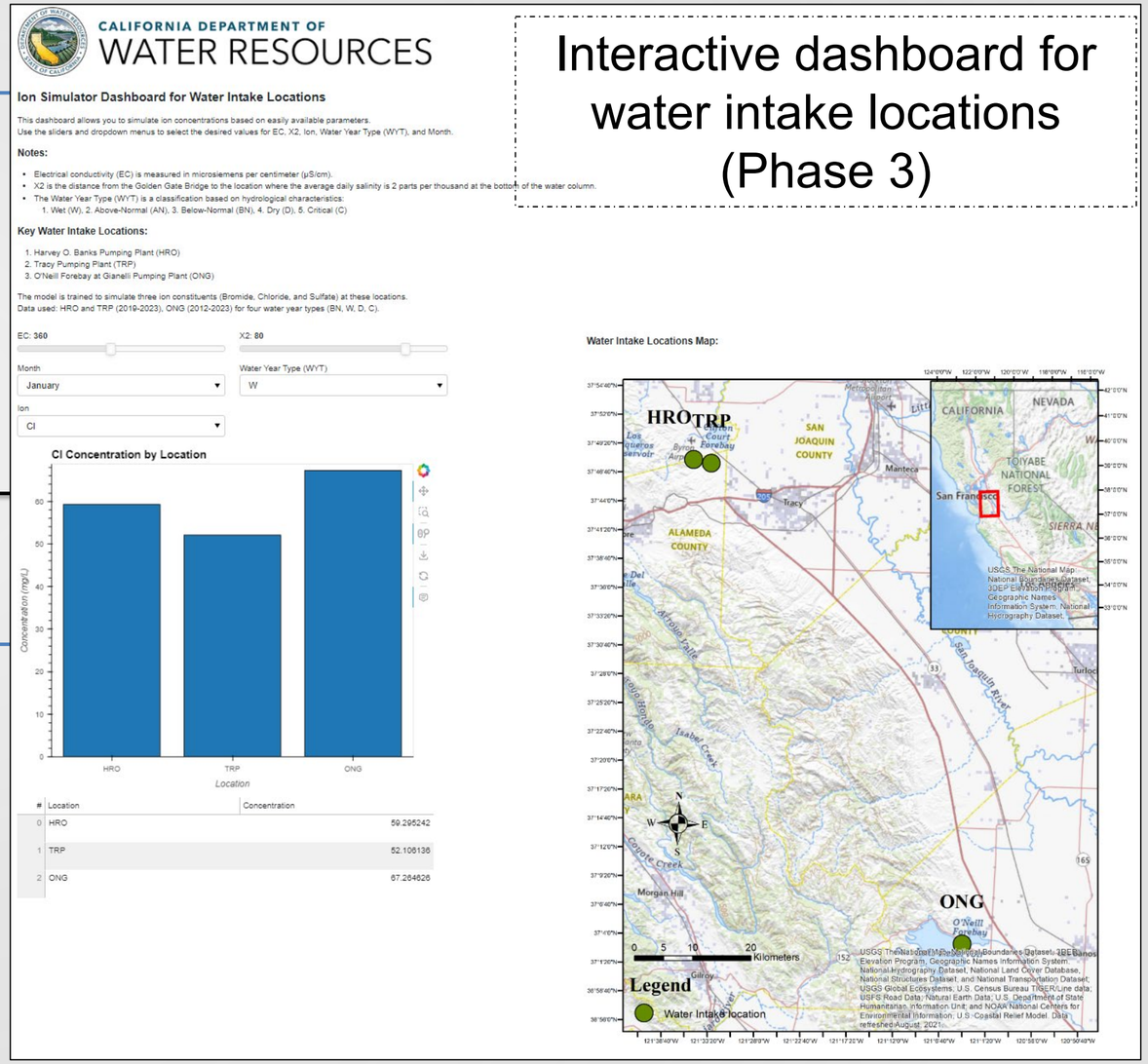
Model Deployment: Dashboards



Interactive dashboard for interior Delta (Phase 2)





Interactive dashboard for water intake locations (Phase 3)

Model Deployment: Dashboards

https://dwrdashion.azurewebsites.net/Dashboard (Interior Delta)

https://dwrdashionintake.azurewebsites.net/Intake_dashboard (Intake Locations)

https://dwrdashionsensitivity.azurewebsites.net/Sensitivity_IonStudy (Intake Locations: Sensitivity)

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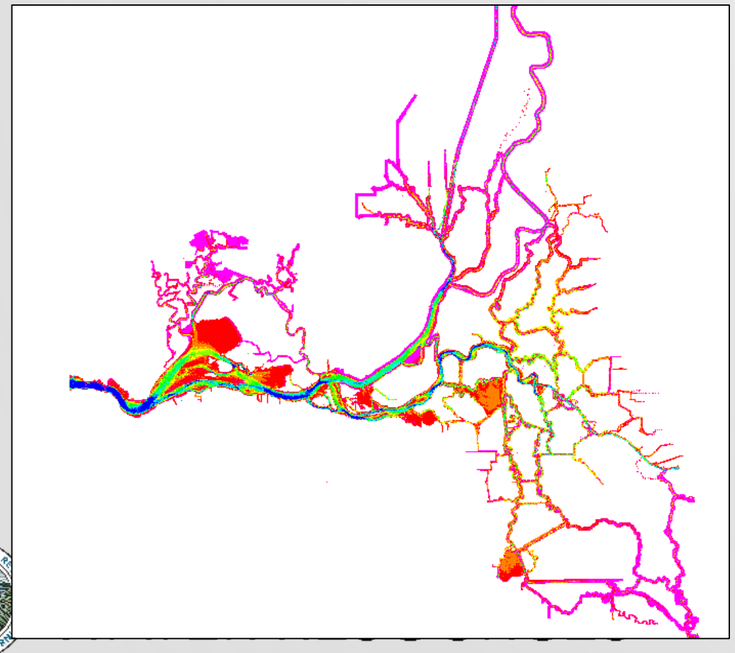
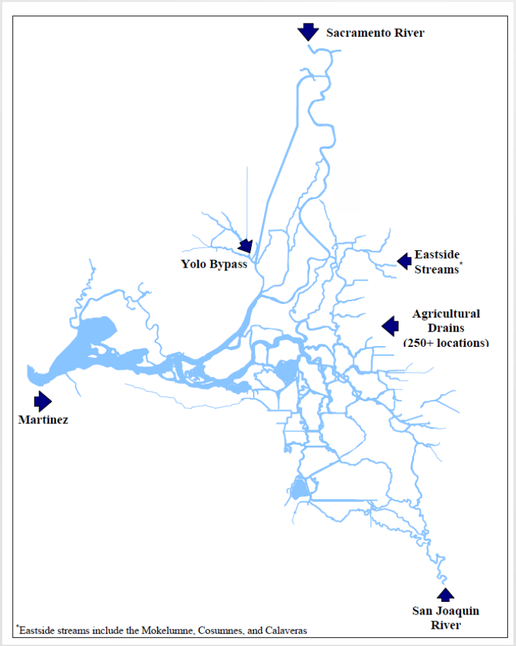
Note: No dashboard developed for Phase I pilot study on South Delta

Limitations: Phrases 1-3

- Limited temporal and spatial coverage
- No source contribution analysis
- Inability to simulate potential planning scenarios

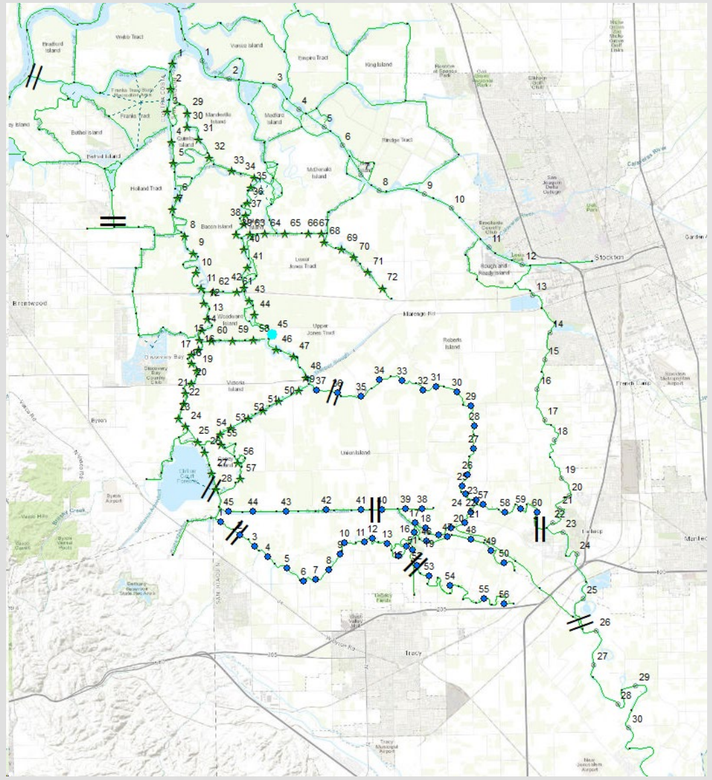


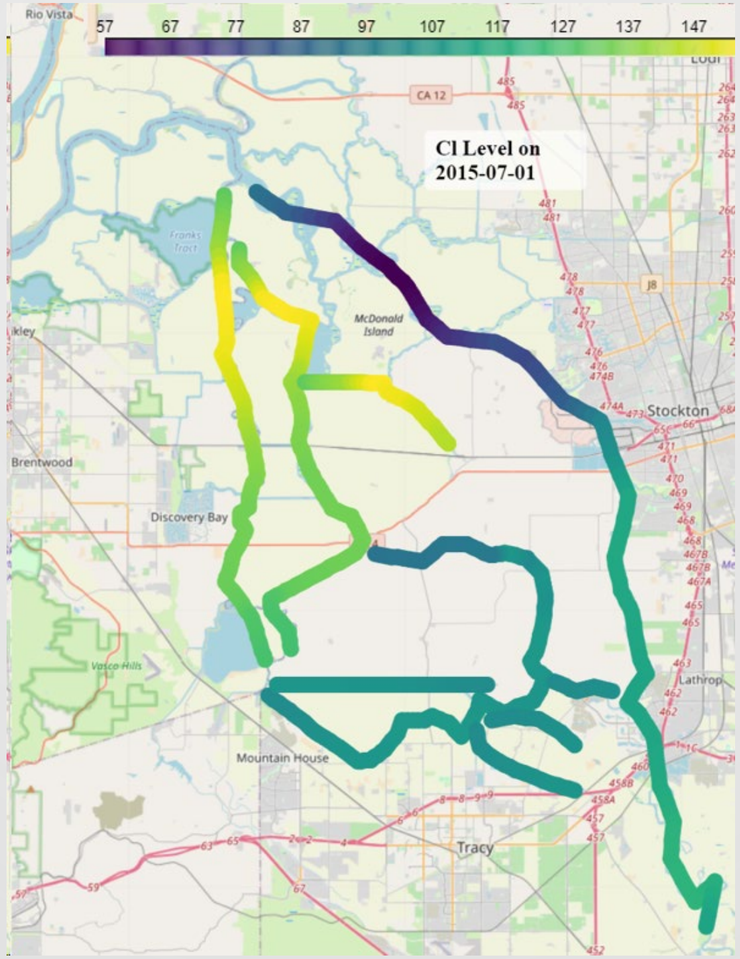


Phrase 4: Hybrid Model

DELTA SIMULATION MODEL DSM2

EC → Machine Learning → Ion

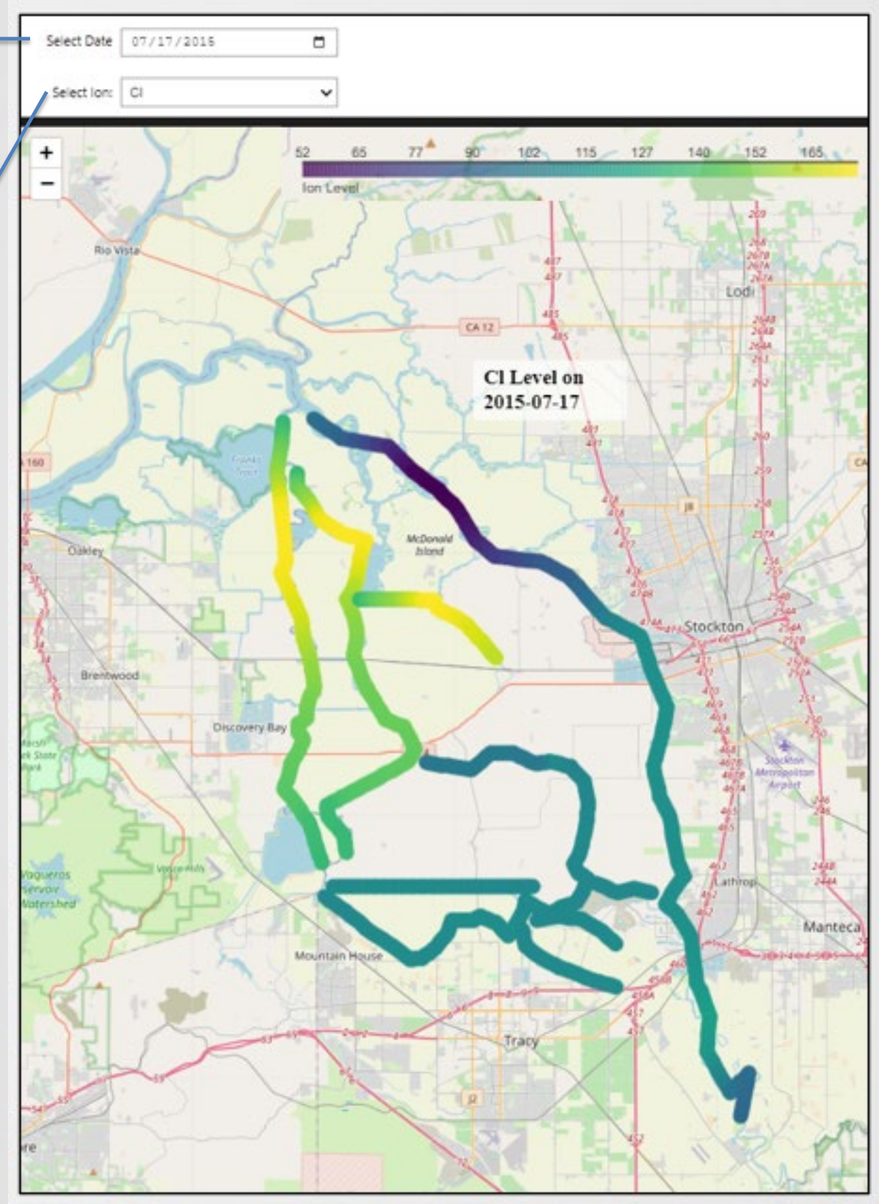




Phrase 4: Dashboard

2000 – 2022

1- Total Dissolved Solids
2- Bromide
3- Chloride
4- Sulfate
5- Alkalinity
6- Sodium
7- Calcium
8- Magnesium
9- Potassium



Documentation: Peer-Reviewed Articles

- **Phase 1** : Pilot study (South Delta)
- **Phase 2:** Interior Delta
- **Phase 3:** Water intake locations
- **Phase 4:** Hybrid model

Phase 1

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

RESEARCH ARTICLE

Check for updates

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

Peyman Namadi[1] · Minxue He[1] · Prabhjot Sandhu[1]

Received: 15 February 2022 / Accepted: 25 May 2022

Phase 2

Journal of Hydroinformatics

Check for updates

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

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Phases 3 and 4 Under review

water

Article

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

Peyman Namadi [1*], Minxue He[2], and Prabhjot Sandhu[3].

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Key Messages

- **Machine learning (ML) models:**
  - run fast
  - perform better

- **User-friendly dashboards:**
  - **Interior Delta Ion Simulation Dashboard**
    - 9 ion constituents
  - **Water Intake Locations Ion Dashboard**
    - 3 ion concentrations
  - **Sensitivity Analysis Dashboard**
    - Sensitivity of ML models
  - **Hybrid Hydrodynamic & Machine Learning Dashboard**
    - Higher spatial and temporal distribution
  - Suitable for users with or without coding or ML expertise

Questions?

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