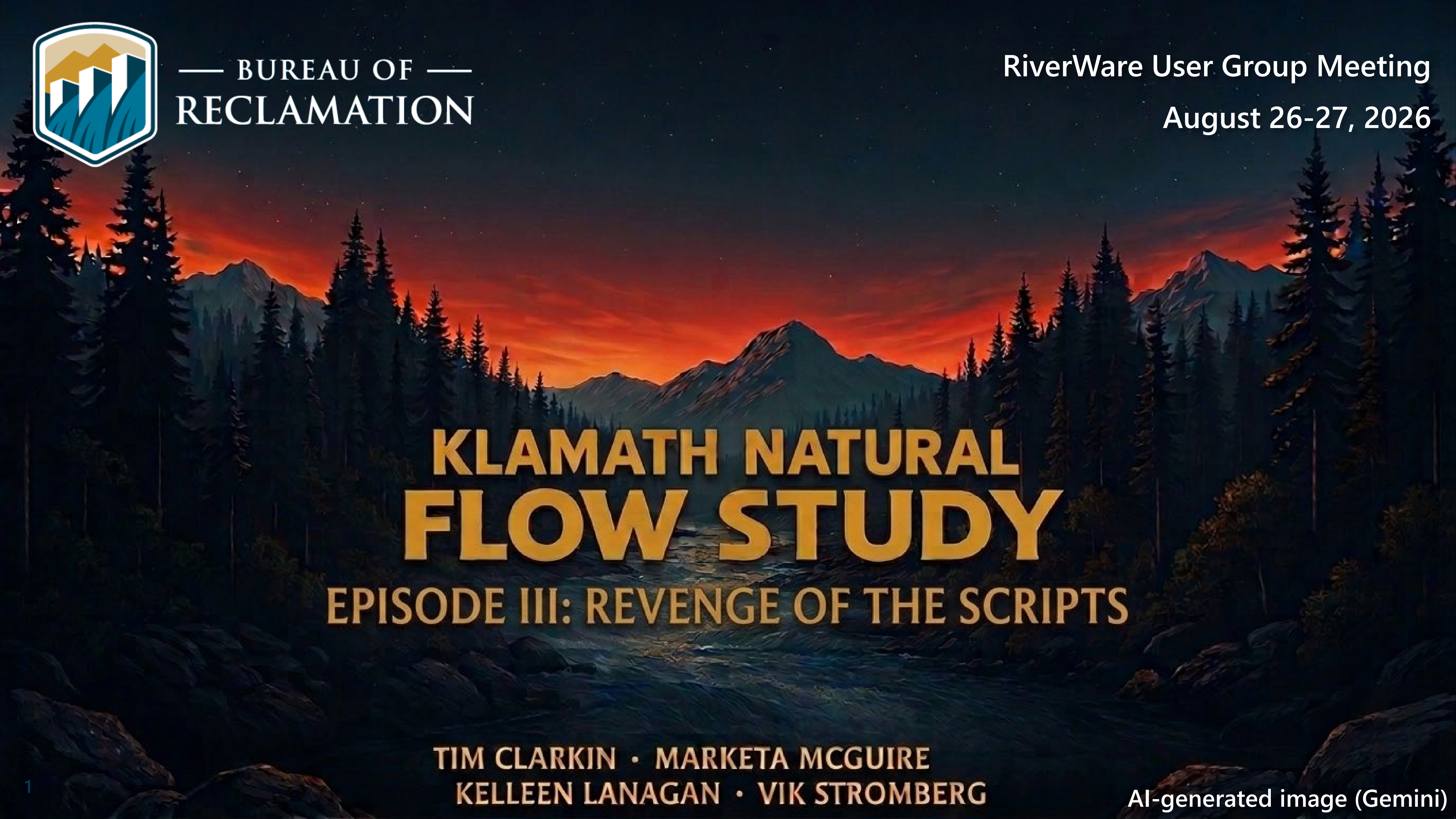
BUREAU OF RECLAMATION

RiverWare User Group Meeting

August 26-27, 2026



AI-generated image (Gemini)

Not so long ago in a river basin quite close by….

In the previous RiverWare User Group Meeting, Reclamation highlighted some roadblocks on the Klamath Natural Flow Study. The current episode recaps the context and modeling approach and focuses on the resolutions to the roadblocks and progress made towards a final solution….

Since this is the third time you're hearing about this project, we figured a new theme would make everything better.

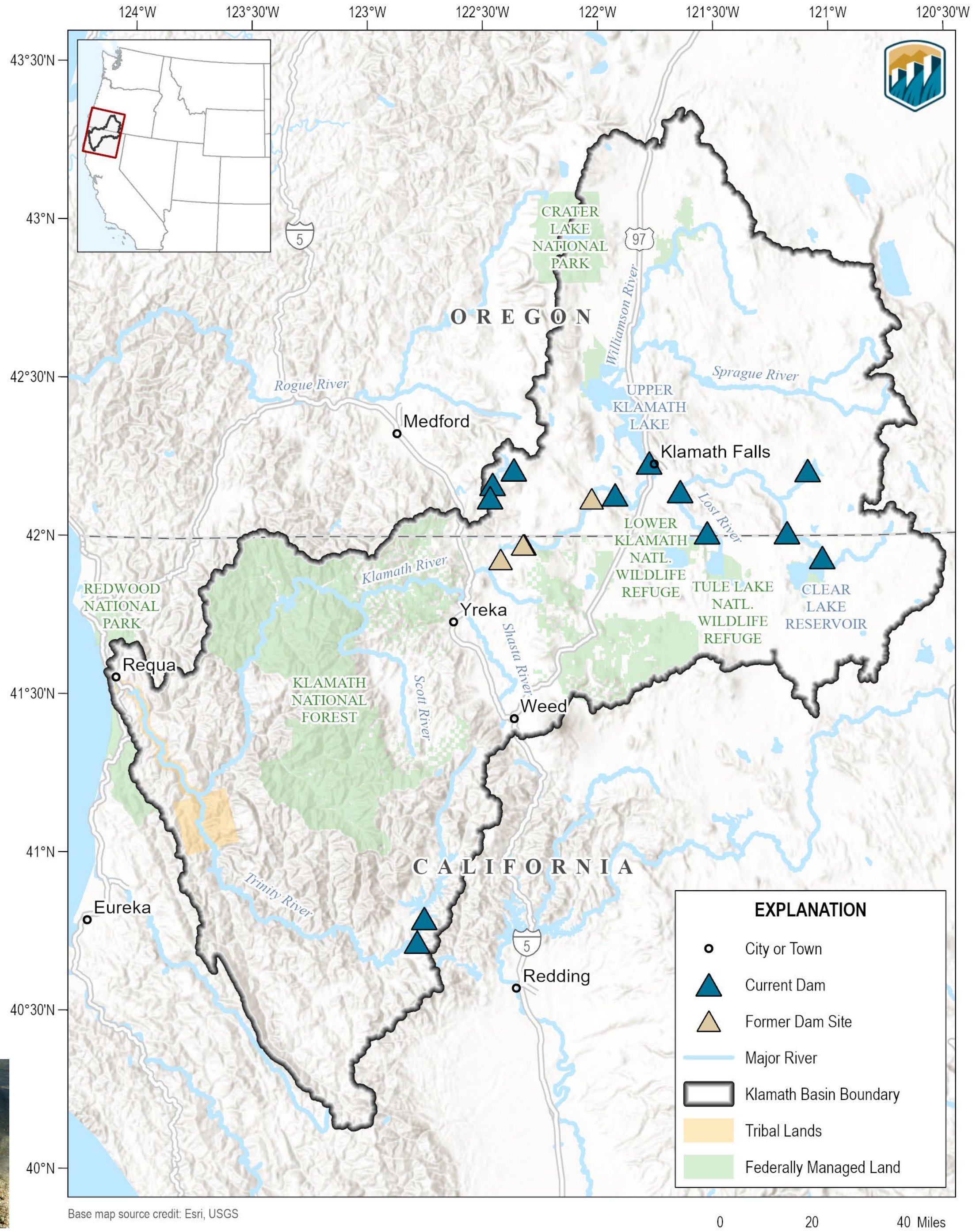
In this presentation, we will:

(1) recap the context and modeling approach and
(2) focus on the resolutions to the roadblocks and progress made towards a final solution

Context

Klamath River

- Often described as an **upside-down** watershed: upper portions are flat and heavily populated; lower portions are mountainous and forested
- Home to **six federally recognized tribes**
- Frequent **Endangered Species Act** (ESA) consultations for Klamath Project
  - 1988 ESA listing of **Lost River Sucker** and **Shortnose Sucker** as endangered
  - 1997 ESA listing of **SONCC Coho Salmon** as threatened species



Context

Klamath River

- Native American tribes led successful effort to **remove four dams** from Klamath River (Copco 2 shown to right)
- Removal of these four dams restores access to approximately **400 sq mi of habitat** for Salmon and other native species
- While not Reclamation dams, Reclamation has been tasked with seeking to understand the **natural flow** regime of the Klamath River prior to major development around 1900

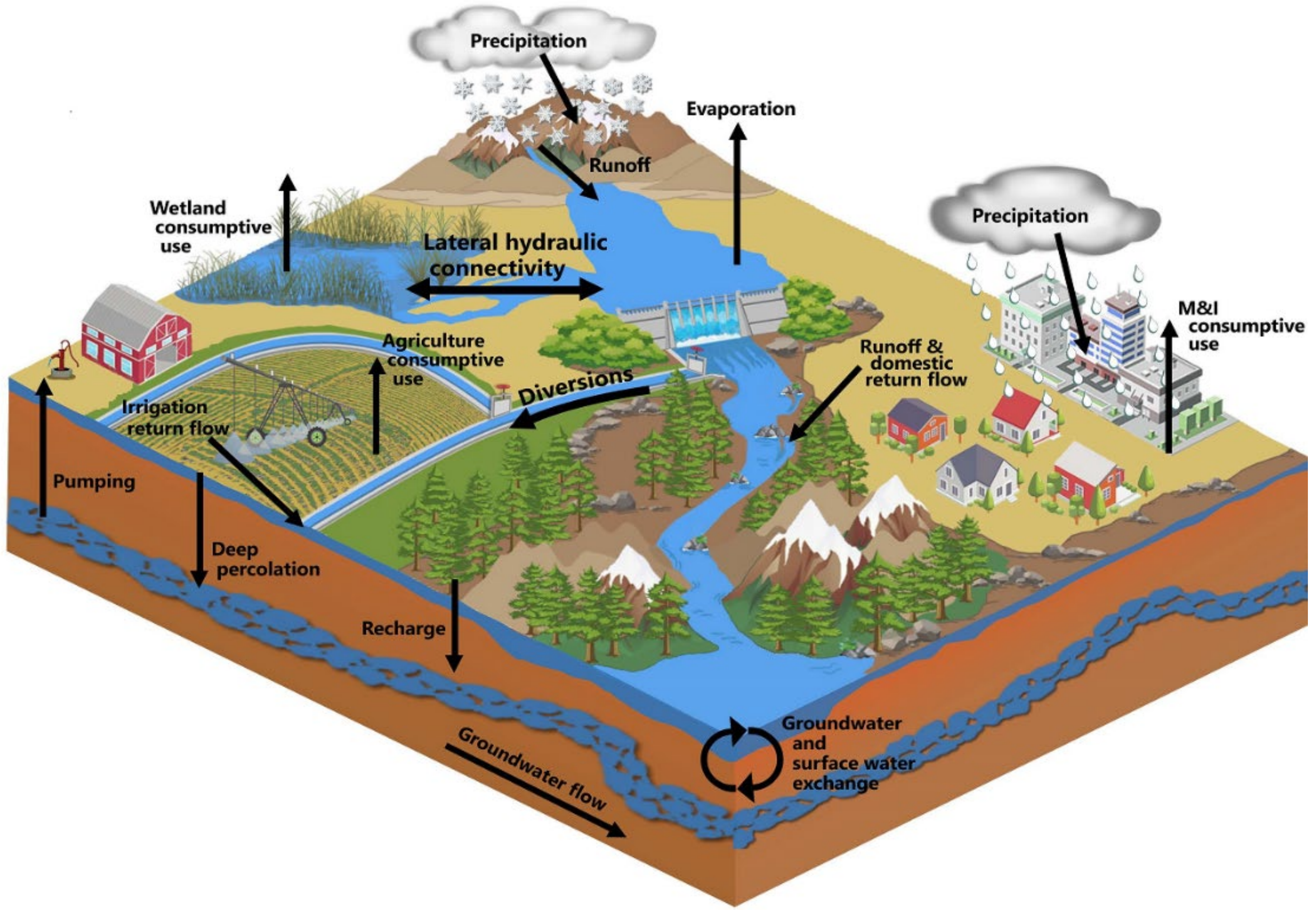
Former Copco Reservoir at Beaver Creek, Feb 2024. (RES)

Former Copco Reservoir at Beaver Creek, May 2024. (RES)

Context

Klamath Revised Natural Flow Study

- Purpose
  - Estimate daily **natural flows** at chosen locations in the Klamath River basin, removing the significant effects of human development
- Use of RiverWare
  - Integrates outputs from **process models** that simulate:
    - **1981-2020** conditions <u>and</u>
    - **pre-development** conditions

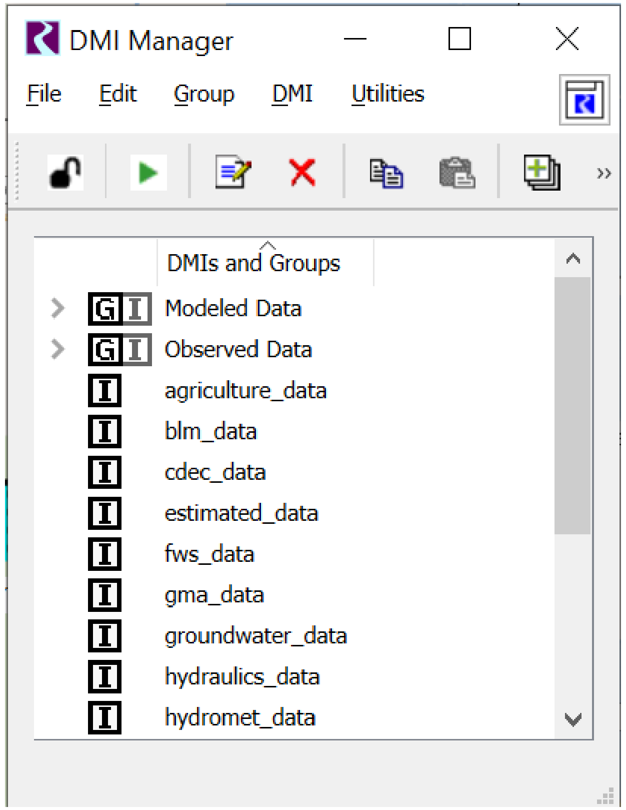


Modeling Approach

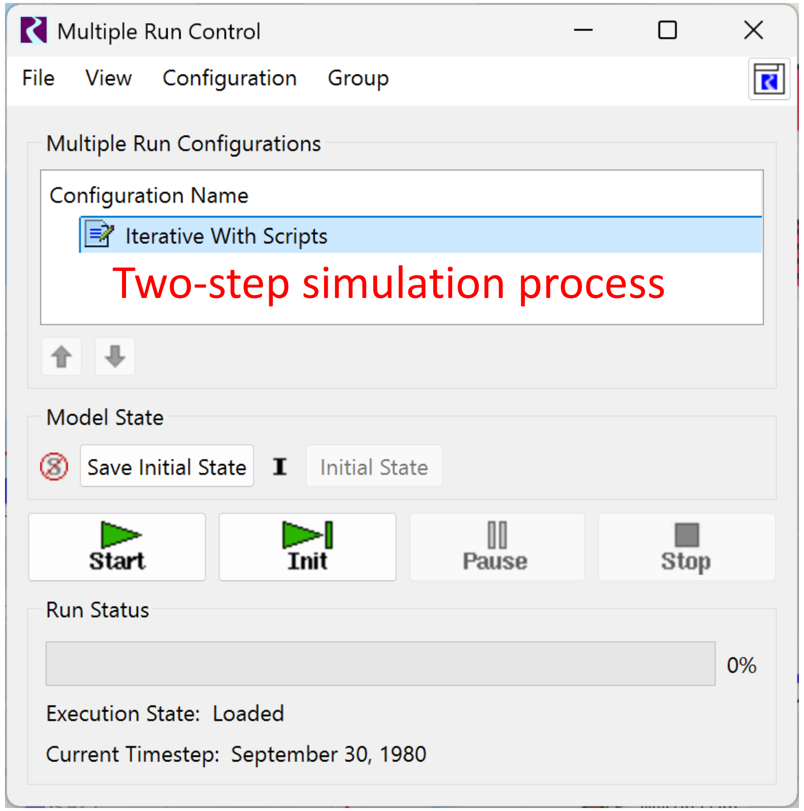
Modeling Pipeline

Python/R Script Pre-Processing

Data Import using Control File DMIs



Run configuration and execution with iterative multiple run management

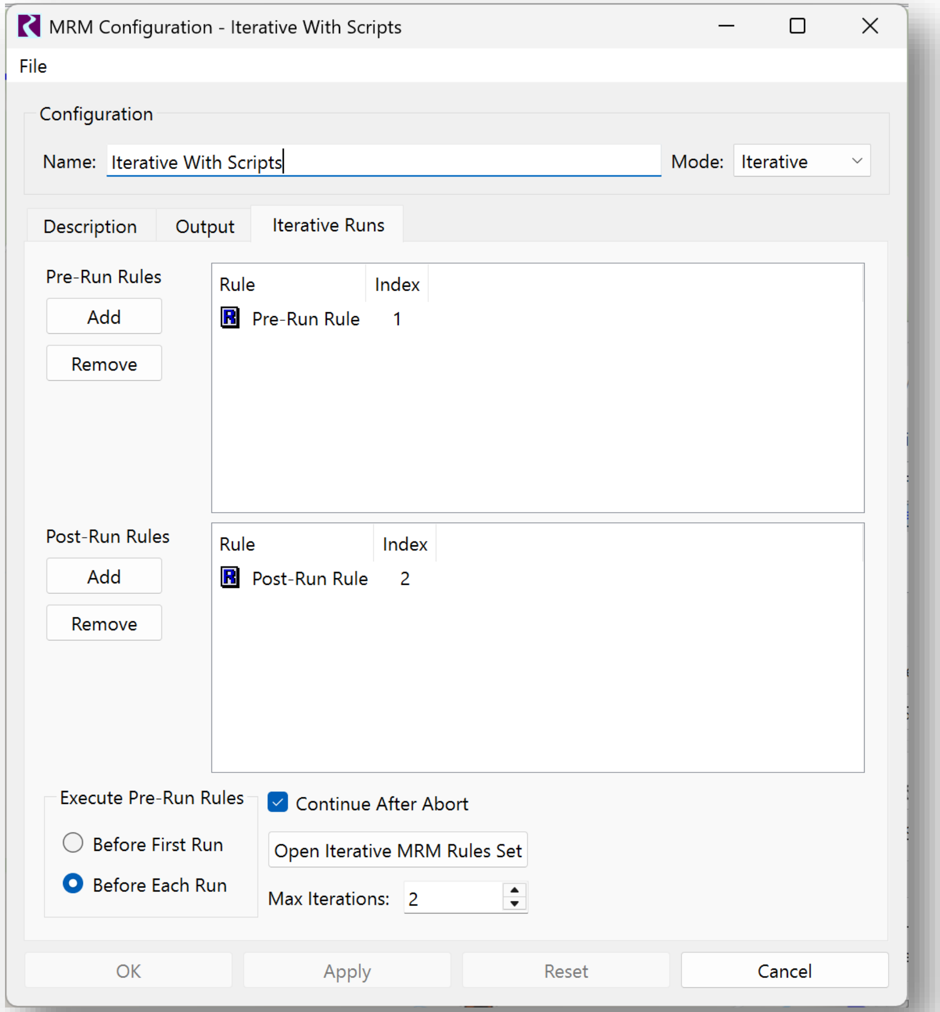


RiverSMART used to handle sensitivity analyses

Modeling Approach

Two-step simulation process

- Iterative MRM with pre-run and post-run rules
- Rules initiate pre-run and post-run scripts depending on run number
  - Run 1: 1981-2020
  - Run 2: Pre-Development

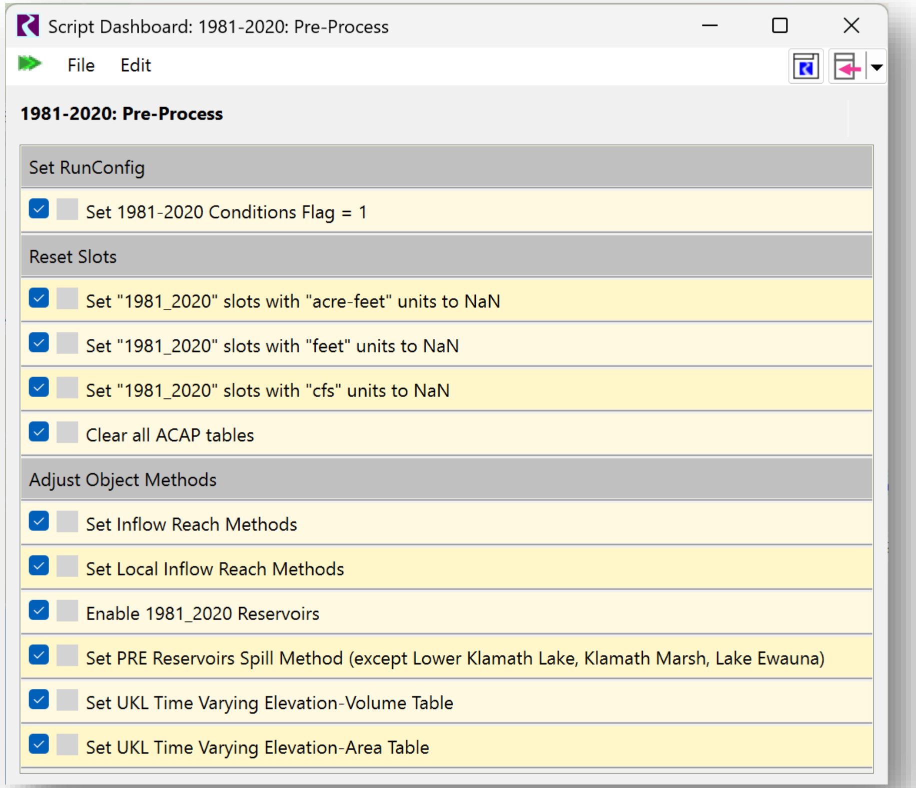


"It may not look like much, but it's got it where it counts, kid." – Han Solo

Modeling Approach

Two-step simulation process

- Run 1: 1981-2020
    - Pre-run rule script configures model



Set flag

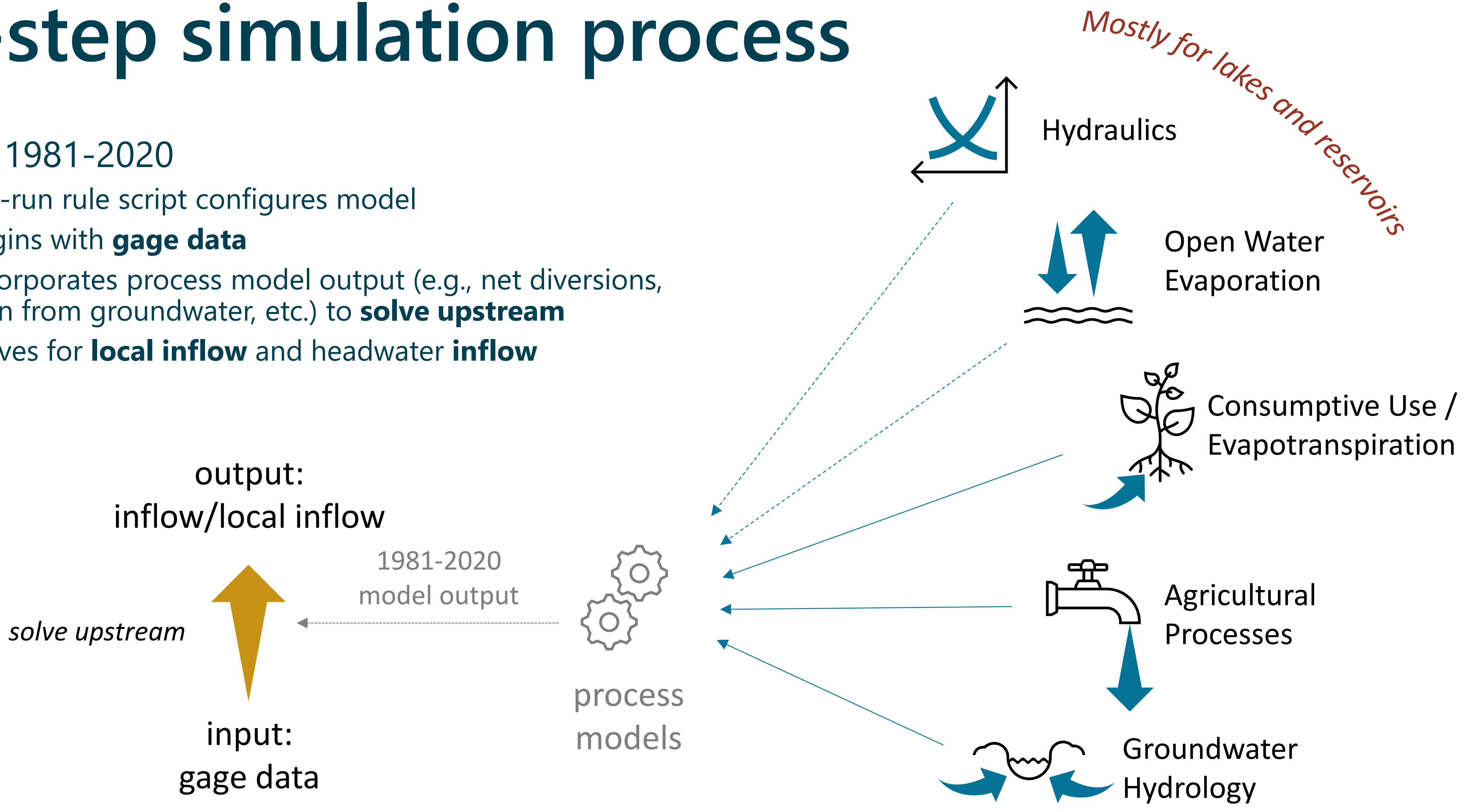
Reset slots

Configures objects for 1981-2020 (e.g., enable reservoirs)

Modeling Approach

Two-step simulation process

- Run 1: 1981-2020
  - Pre-run rule script configures model
  - Begins with **gage data**
  - Incorporates process model output (e.g., net diversions, gain from groundwater, etc.) to **solve upstream**
  - Solves for **local inflow** and headwater **inflow**



Modeling Approach

Two-step simulation process

- Run 1: 1981-2020
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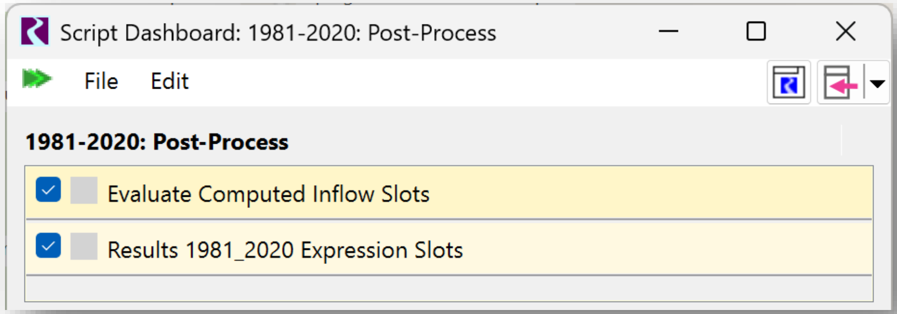
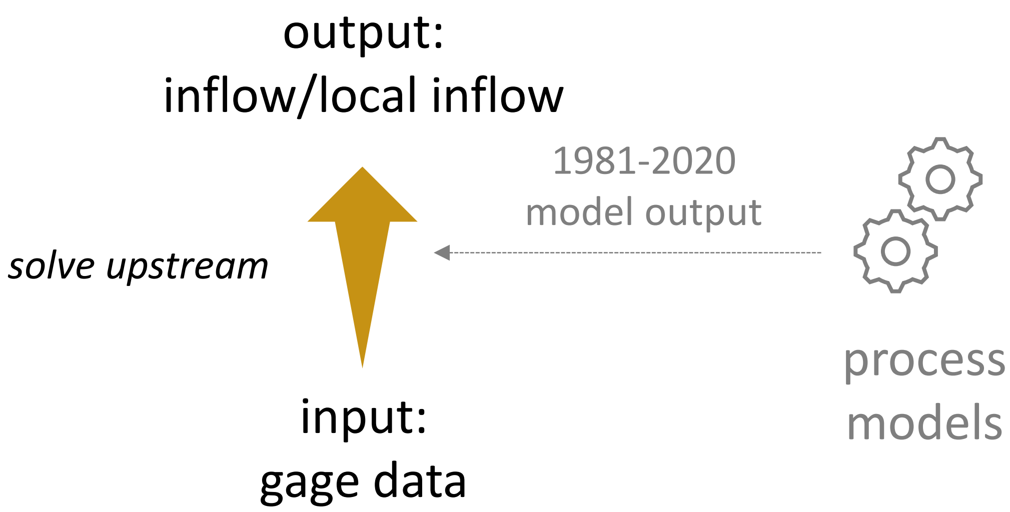
  - Solves for **local inflow** and headwater **inflow**
  - Post-run rule copies timeseries to data for later use





Modeling Approach

Two-step simulation process

- Run 1: 1981-2020
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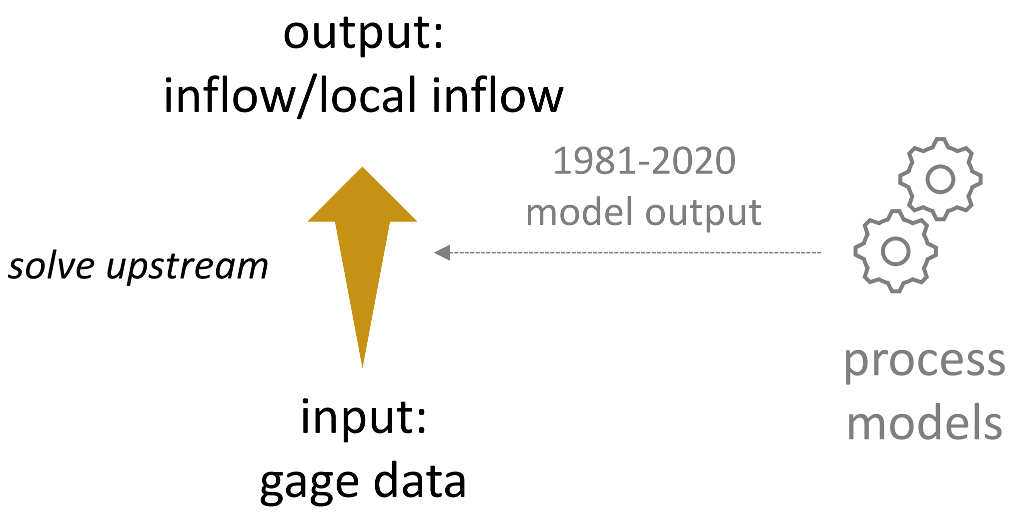
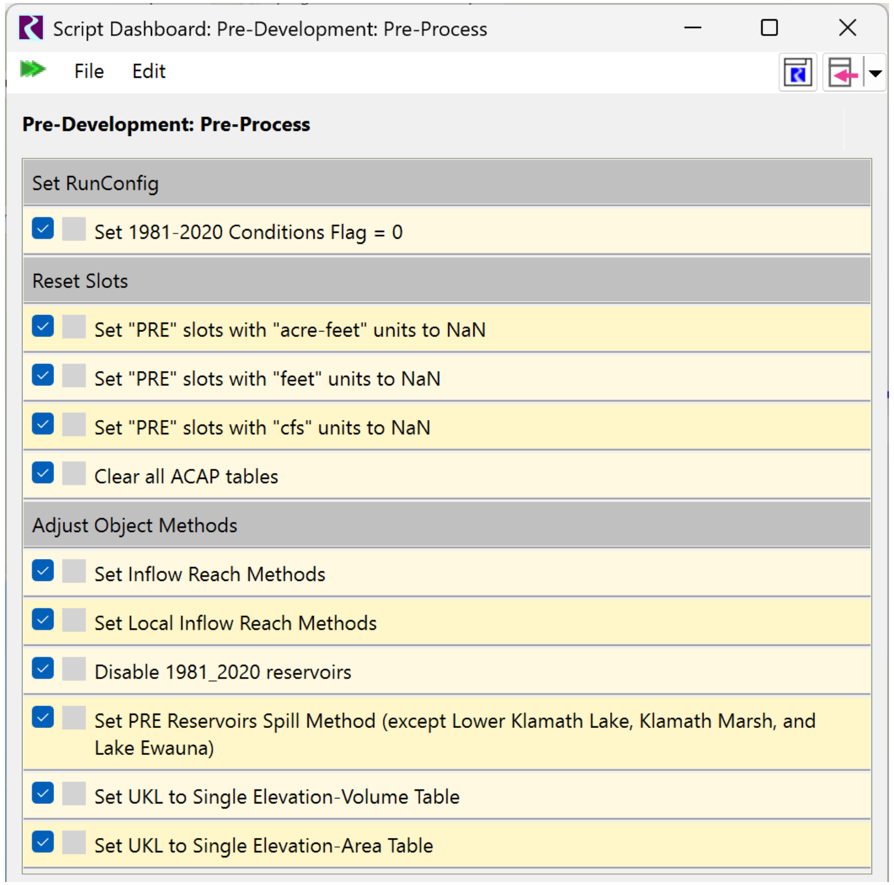


- Run 2: Pre-Development
  - Pre-run rule script configures model



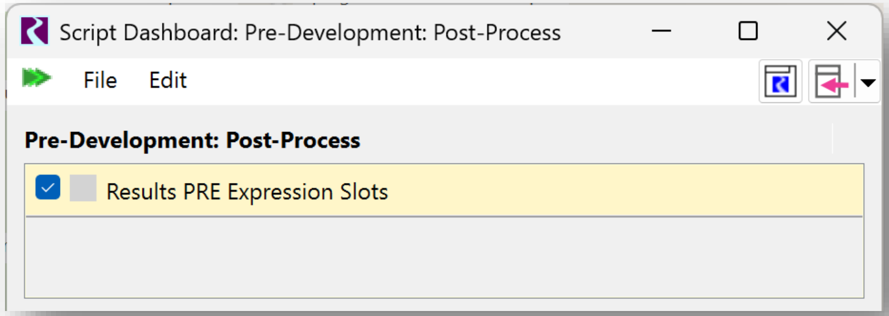
Set flag

Reset slots

Configures objects for pre-development (e.g., disable reservoirs)

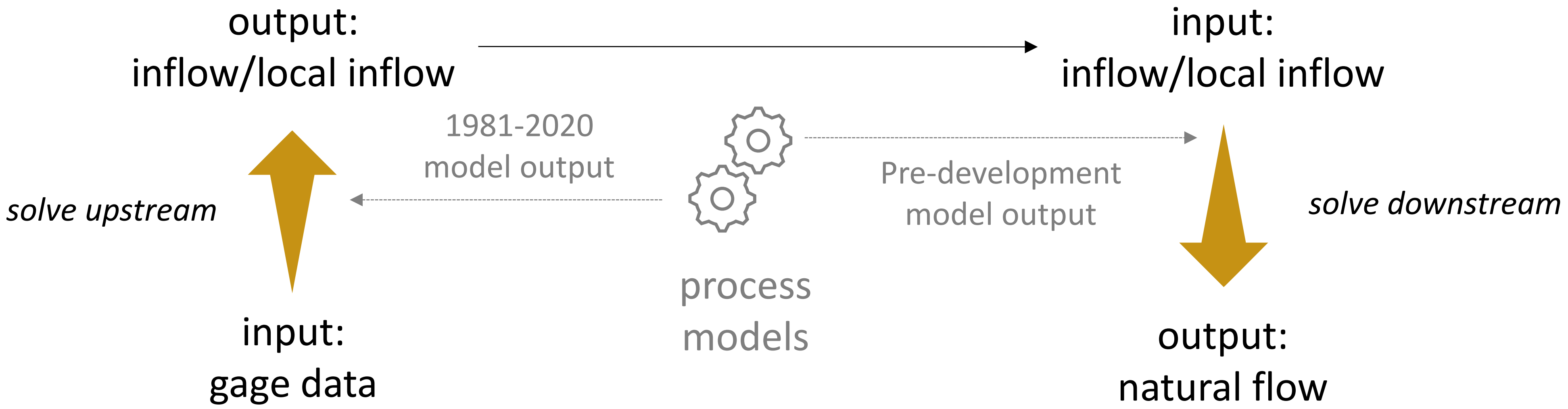
Modeling Approach

Two-step simulation process



- Run 1: 1981-2020
  - Pre-run rule script configures model
  - Begins with **gage data**
  - Incorporates process model output (e.g., net diversions, gain from groundwater, etc.) to **solve upstream**
  - Solves for **local inflow** and headwater **inflow**
  - Post-run rule copies timeseries to data for later use

- Run 2: Pre-Development
  - Pre-run rule script configures model
  - Begins with **local inflow** and headwater **inflow**
  - Incorporates process model output (e.g., wetland ET, gain from groundwater, etc.) to **solve downstream**
  - Estimates **natural flow** throughout model
  - Post-run rule saves natural flow results



2025 Roadblocks & Resolutions

Roadblock	Resolution
• Script-based modeling approach not compatible with RiverSMART	☑ David helped develop iterative MRM "This is the way" – Mandalorian
• Dynamic reservoir characteristics	☑ Existing RiverWare capabilities
• Variable reach routing	☒ No solution "Always with you, it cannot be done." – Yoda
• Klamath Marsh	☑ Remote-sensing and statistics
• Missing gage records	☑ K-fold cross-validation solution
• Process model uncertainty	☑ RiverSMART study solution

2025 Roadblocks & Resolutions

- Script-based modeling approach not compatible with RiverSMART — ☑ David helped develop iterative MRM
  - Iterative MRM with pre-run and post-run scripts (presented)
- Dynamic reservoir characteristics — ☑ Existing RiverWare capabilities
  - Surface Area Modification and Sediment Methods
- Variable reach routing — ☒ No solution
  - Time-Lag is the only method for solving upstream
- Klamath Marsh — ☑ Remote-sensing and statistics
- Missing gage records — ☑ K-fold cross-validation solution
- Process model uncertainty — ☑ RiverSMART study solution

We'll focus on the resolutions to these three roadblocks

Roadblock & Resolutions

Klamath Marsh

"Do. Or do not. There is no try." — Yoda

- Klamath Marsh attenuates and stores water, but is not a typical lake or reservoir. There is limited information to represent it as a Storage Reservoir
- **2025 Expected Solution:** using Google Earth Engine (GEE) to process aerial imagery to reconstruct historical open water area; potentially representing marshes as storage reservoirs

Klamath Marsh "typical" setting (K. Lanagan)

Kirk Reef - Klamath Marsh downstream hydraulic control (T. Clarkin)

Roadblock & Resolutions
Klamath Marsh

- ☑ GEE scripts used to develop Elevation-area and Elevation-storage relationships.
  - ☒ Not enough data to fill missing records.

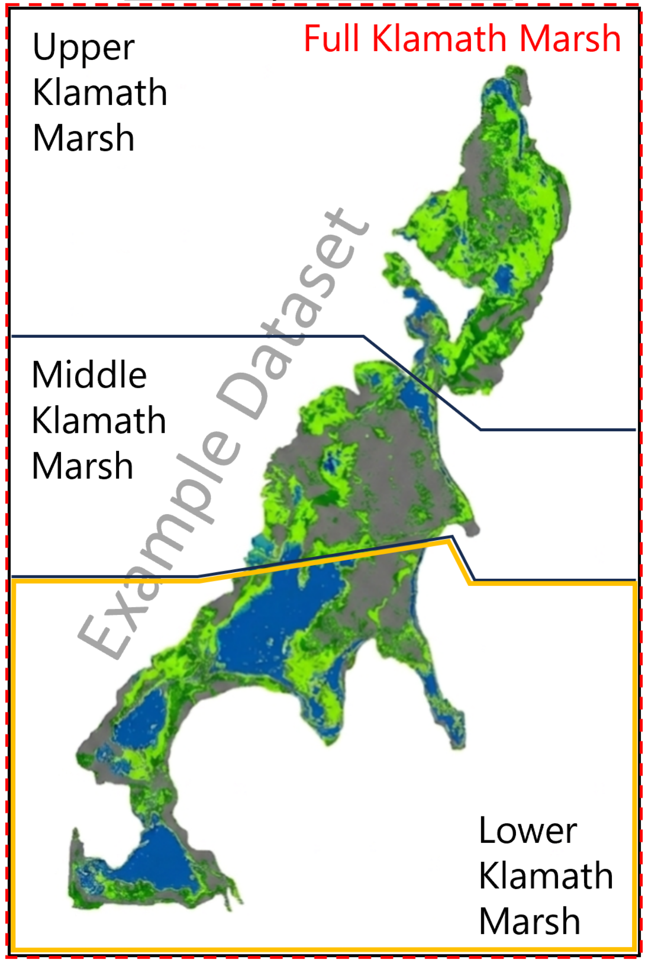
DSWE Area Definitions

DSWE 1				Excluded
DSWE 1+2				Excluded
DSWE 1+2+3				Excluded
DSWE 1+2+3+4				Excluded
Water – high confidence	*Water – moderate confidence*	*Water – partial*	*Water or Wetland – low confidence*	*Not Water*

Area calculations are a combination of the Marsh Spatial Extents and DSWE Area Definition being used. For example:

- Lower Klamath Marsh "DSWE 1+2" would include only water – high confidence (dark blue) and water – moderate confidence (light blue) cells within the Lower Klamath Marsh polygon (gold).
- Full Klamath Marsh "Area 4" would include all four DSWE classifications and exclude the "not water" cells (grey) throughout the full marsh (red dash)

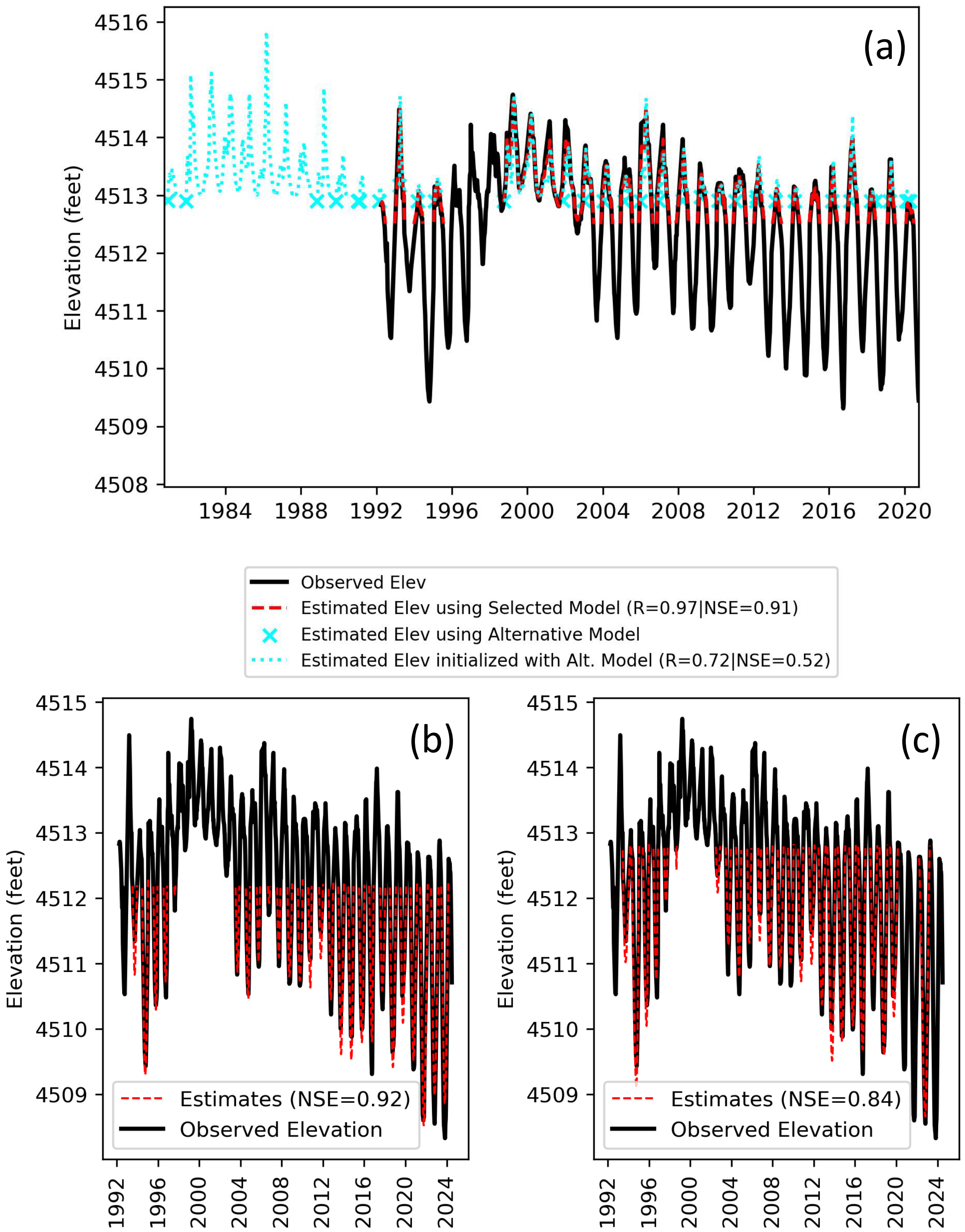
Marsh Spatial Extents



Roadblock & Resolutions

Klamath Marsh

- ☑ GEE scripts used to develop Elevation-Area and Elevation-Storage relationships.
  - ☒ Not enough data to fill missing records.
- ☑ Two regression approaches taken to complete record:
  - (a) Multiple Linear Regression used to estimate marsh elevations from outflow and previous elevation
  - (b & c) Drawdowns estimated using available variables



Roadblocks & Resolutions

Missing Gage Records

- Many gages have short records or have missing records
- **2025 Expected Solution:** use machine learning (ML) techniques to estimate missing records

“I find your lack of flow disturbing”
– Darth Vader

Photo of USGS Gage for Klamath River below J.C. Boyle (K. Lanagan)

Klamath Straits Drain (T. Clarkin)

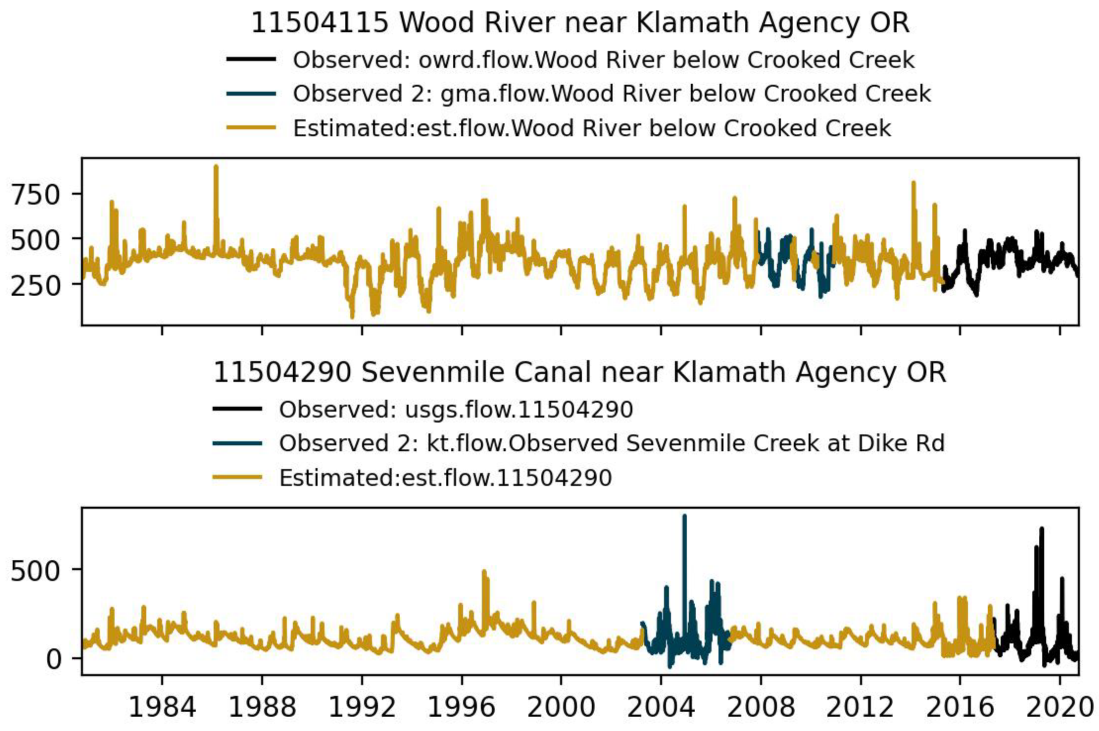
Roadblocks & Resolutions

Missing Gage Records

☒ Training an ML model to predict flow didn't make sense with the ongoing surface water modeling component of the study

☑ A k-fold cross-validation framework for testing multiple regression types was used:

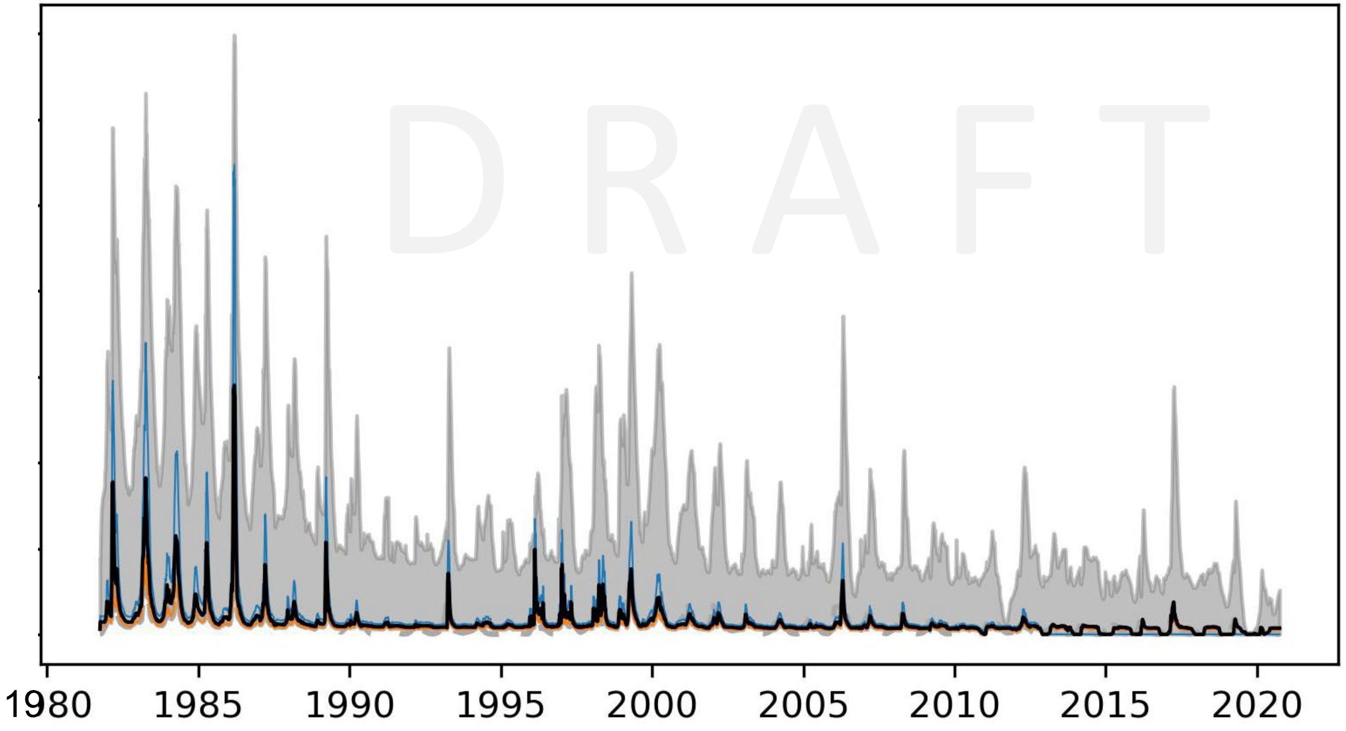
- MOVE.1, first- and second-order polynomials, quantile-quantile mapping
- Surface water modeling estimates also considered in rank selection



Roadblocks & Resolutions

Process Model Uncertainty

- Initial conditions and process models have uncertainty that needs to be carried into the uncertainty of natural flow estimates
- **2025 Expected Solution:** use RiverSMART to run a study that iterates through sensitivity output from process models

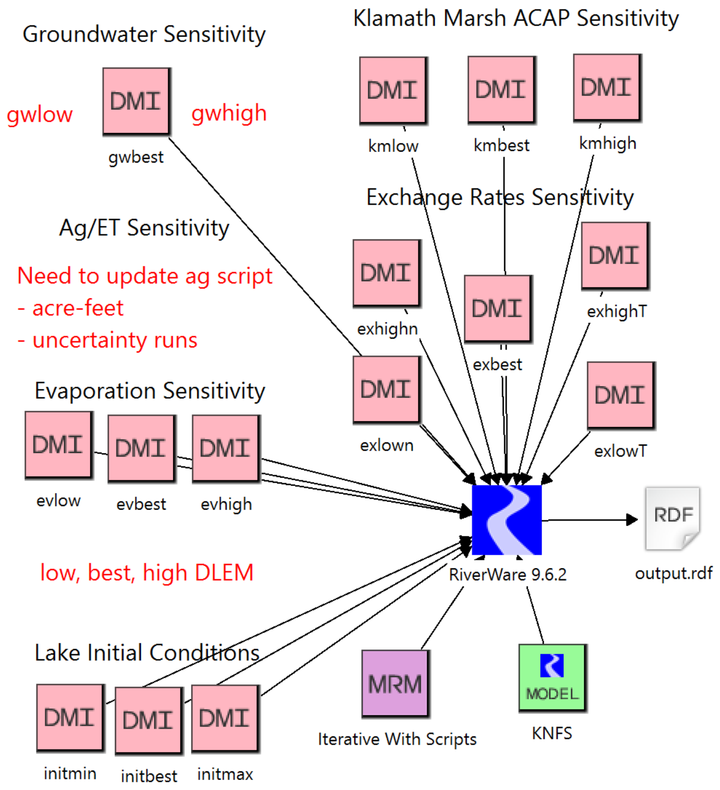


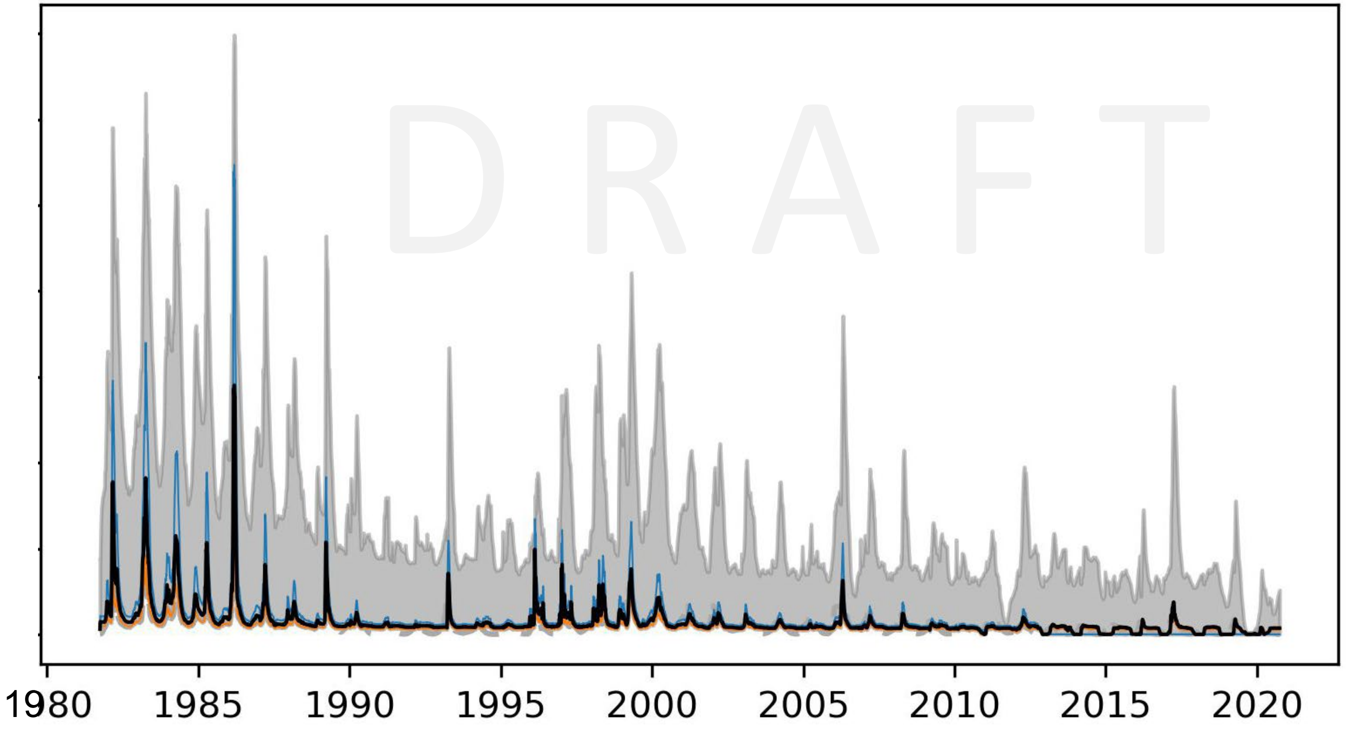
"These aren't the natural flows you're looking for." – Obi-Wan

Roadblocks & Resolutions

Process Model Uncertainty

☑ RiverSMART is designed for this exact purpose!





As we continue to seek to understand the natural flow regime of the Klamath River, next steps are:

- *Finalize documentation of model*
- *Await process model final results*

Your questions, I sense them…

may the flows be with you!

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