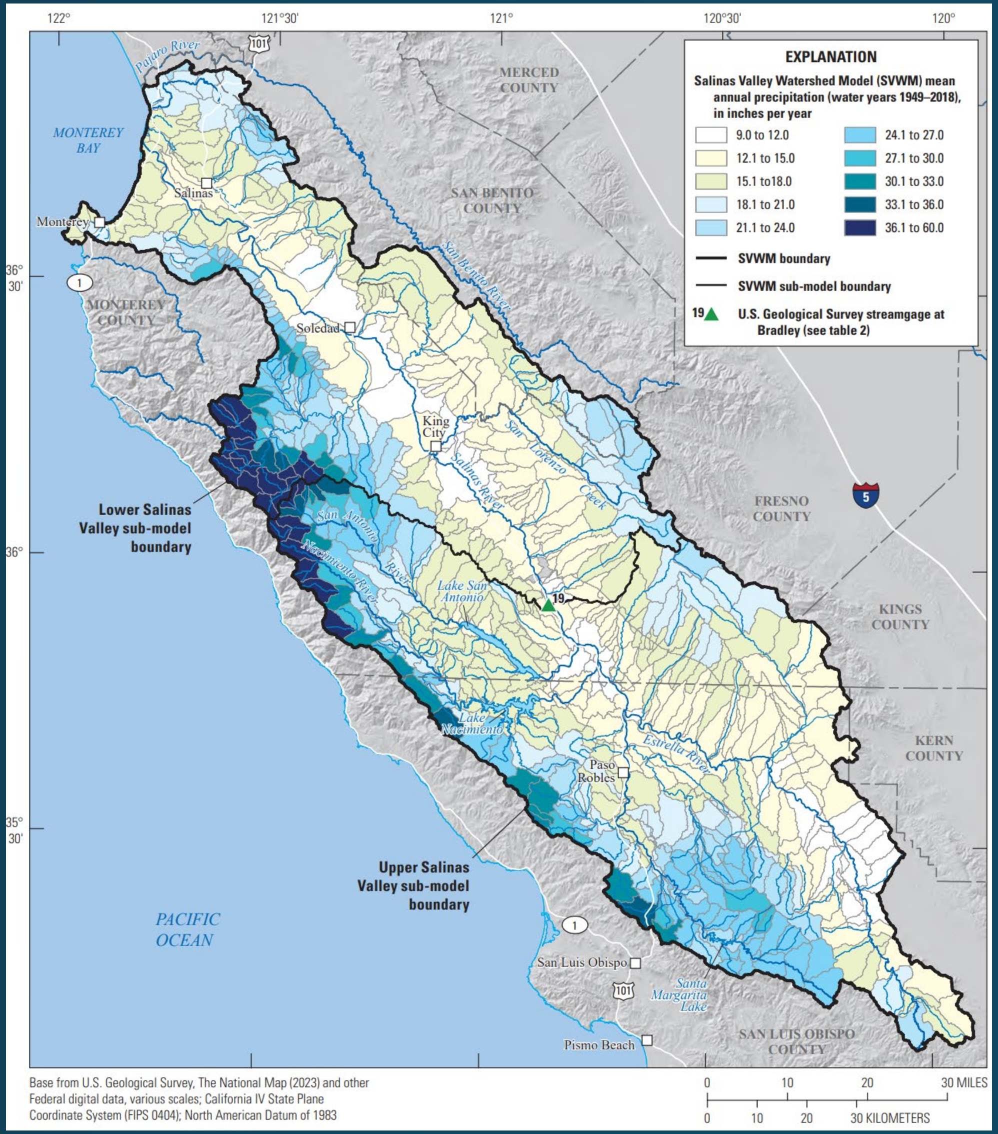
# MODELING TOOLS

What they do, what they don’t do, and future needs

Jason Demers and Amy Woodrow



# What are models?

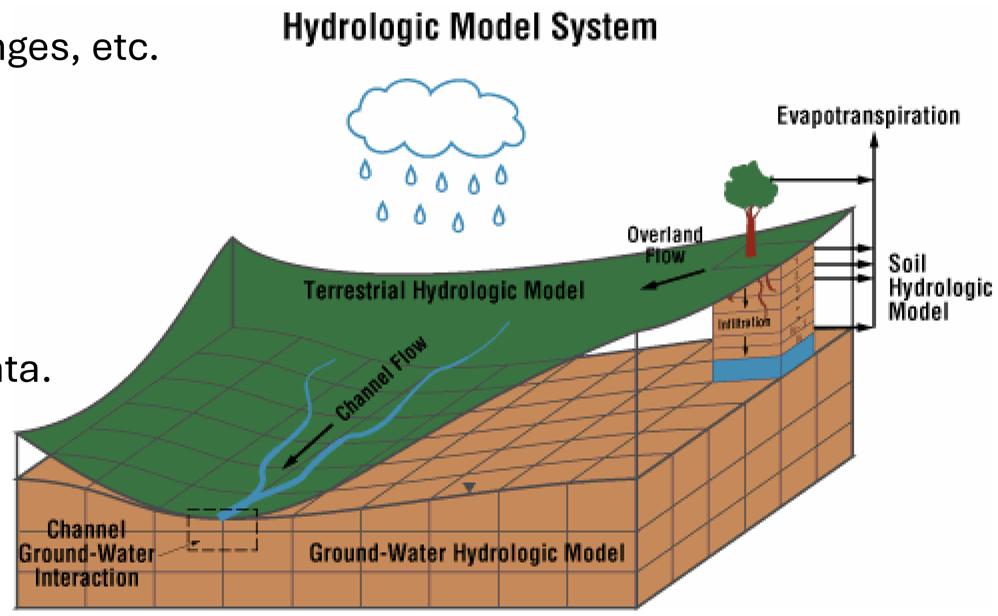
- Models are a simplified numerical representation of a complex natural system.
- Simulate how water moves and interacts with the environment.
- They are tools to help us make decisions.

**Capabilities:**

- Represent multiple hydrologic processes simultaneously (e.g., precipitation, streamflow, infiltration, groundwater flow).
- Run alternative scenarios such as future climates, land-use changes, etc.
- Provide consistent, reproducible results.
- Allow interpolation where there are data gaps.

**Limitations:**

- They are only approximations to reality.
- Results are dependent on the quality and quantity of available data.
- Uncertainty is always present.




*Source: Earth System Science Center, Penn State University*

# Why are models used?

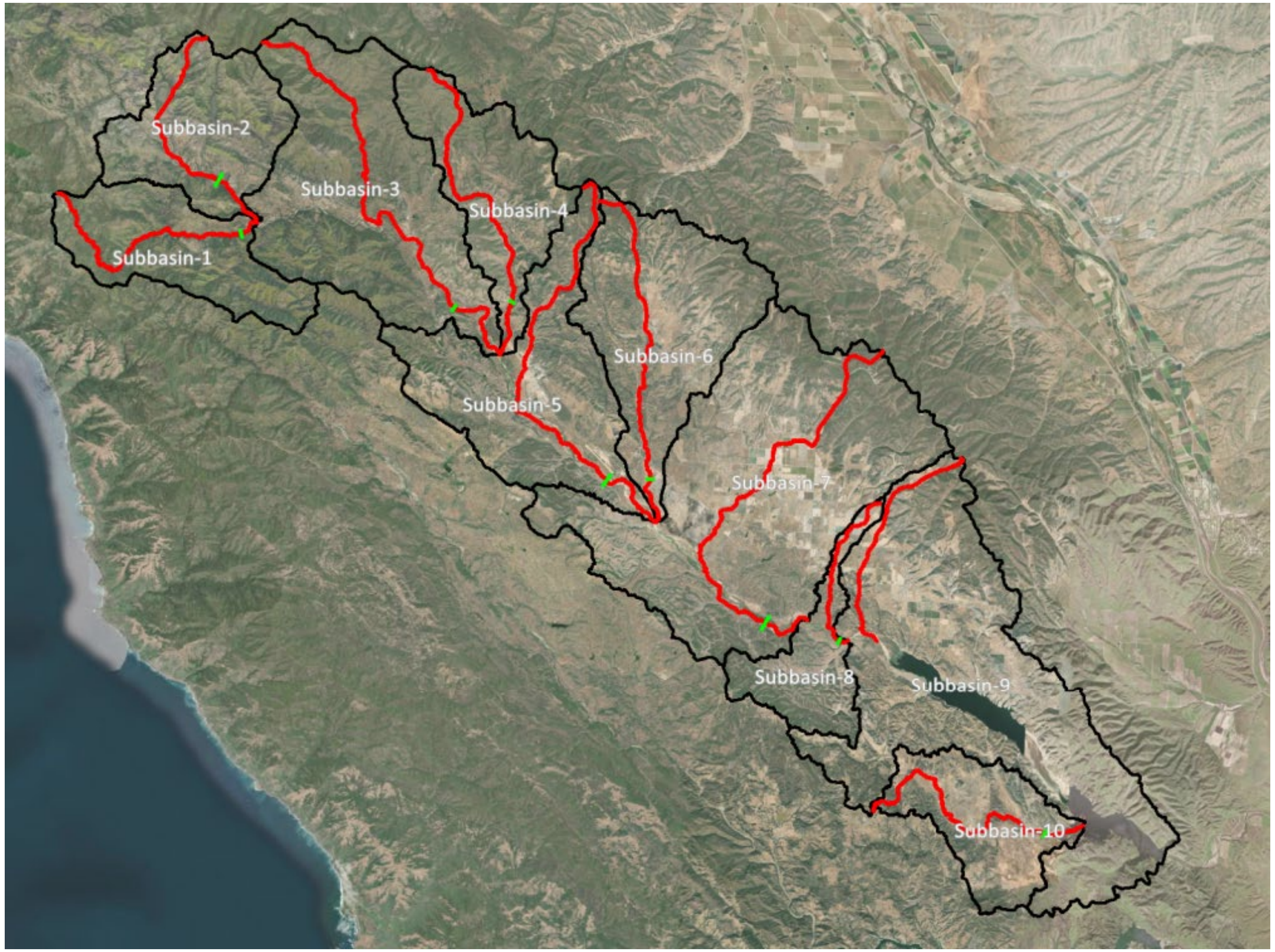
- Models provide a means for exploring solutions to complex problems.
- Not all parts of what needs to be managed can be easily observed.
- Estimate parameters that cannot be directly measured.
- Scientifically interpolate between data points.
- Provide tools to explore and understand potential scenarios (future climate, new projects, etc.)

# How are they used?

- **Planning:** long-term basin sustainability, drought management, project viability.
- **Operations:** reservoir releases.
- **Risk assessment:** probability of hydrologic events, flood magnitude, flood timing, and inundation area.
- **Decision making:** providing data to inform direction on policies, programs, and projects.

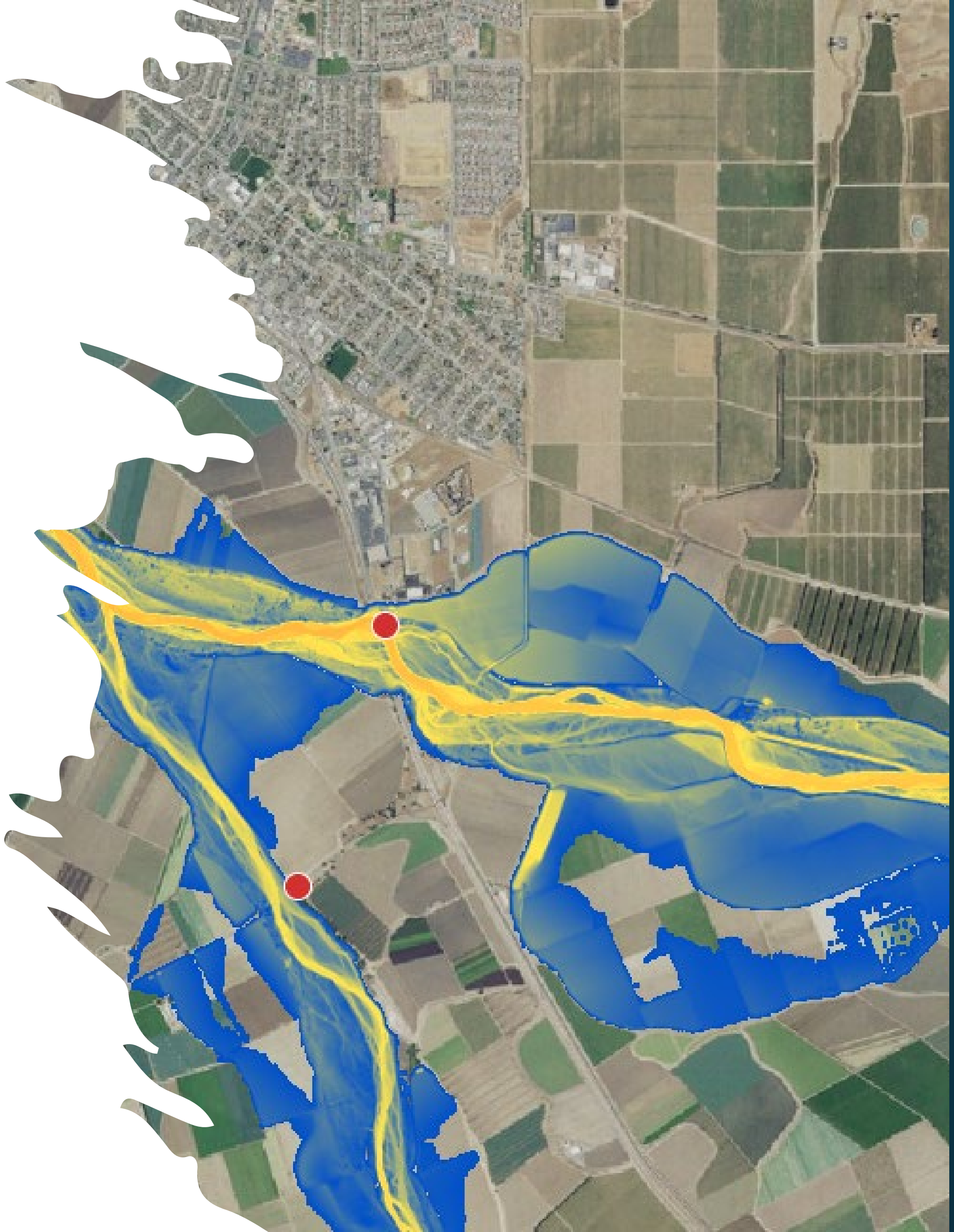
# Why are models important for basin management?

- Used for planning, operations, evaluating new infrastructure, assessing flood risks and more.
- They provide a scientific basis for policy and operational decisions.



# Types of models

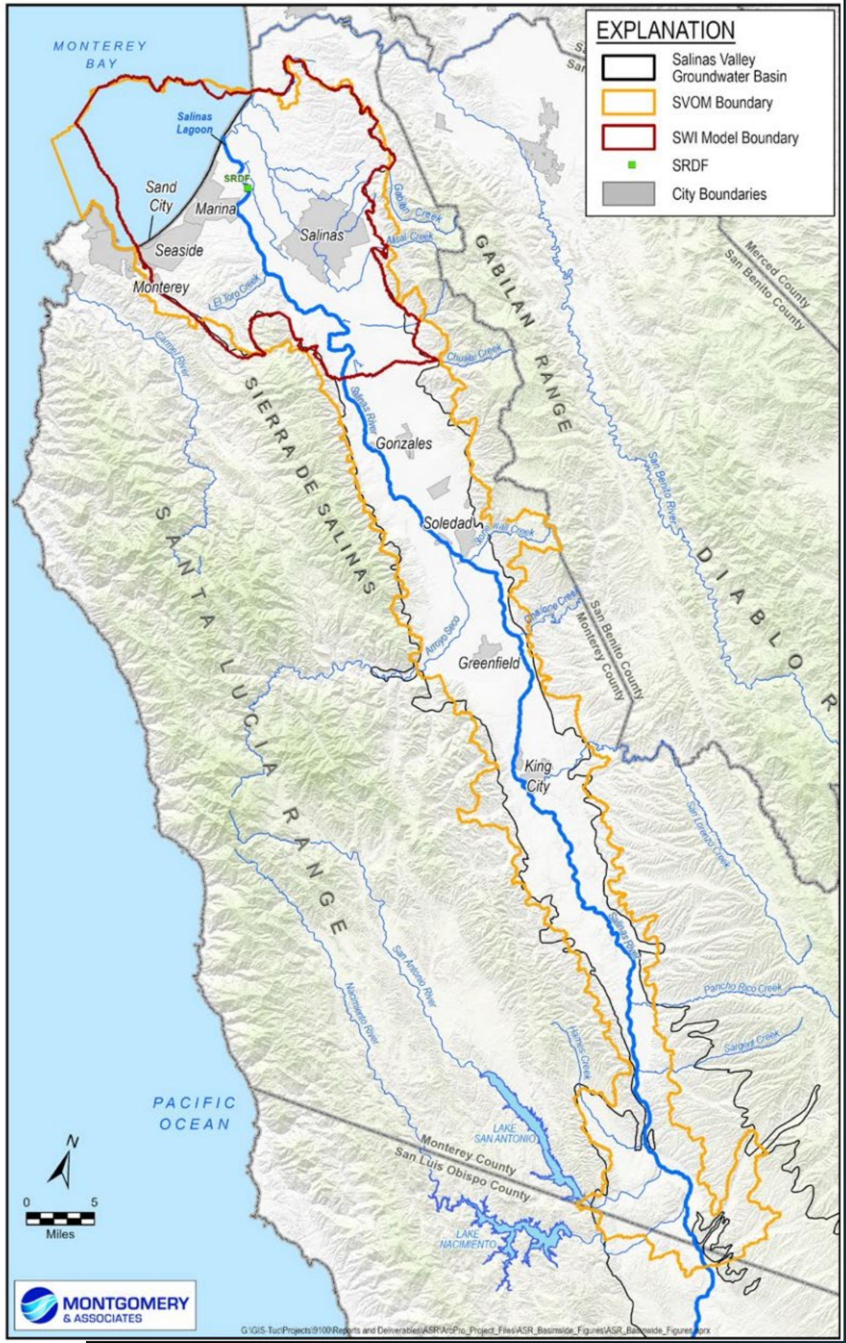
- MCWRA and our partner agencies use a wide variety of hydrologic modeling tools to help meet our regional water management goals
- These models assist with the evaluation of new projects as well as the day-to-day operation of existing projects and facilities
- These tools include:
  - Large basin-wide models that take significant time and computing power to run
  - Spreadsheet based modeling tools developed by staff
  - Conceptual models that help with our shared understanding of our watersheds



# Large Scale Models

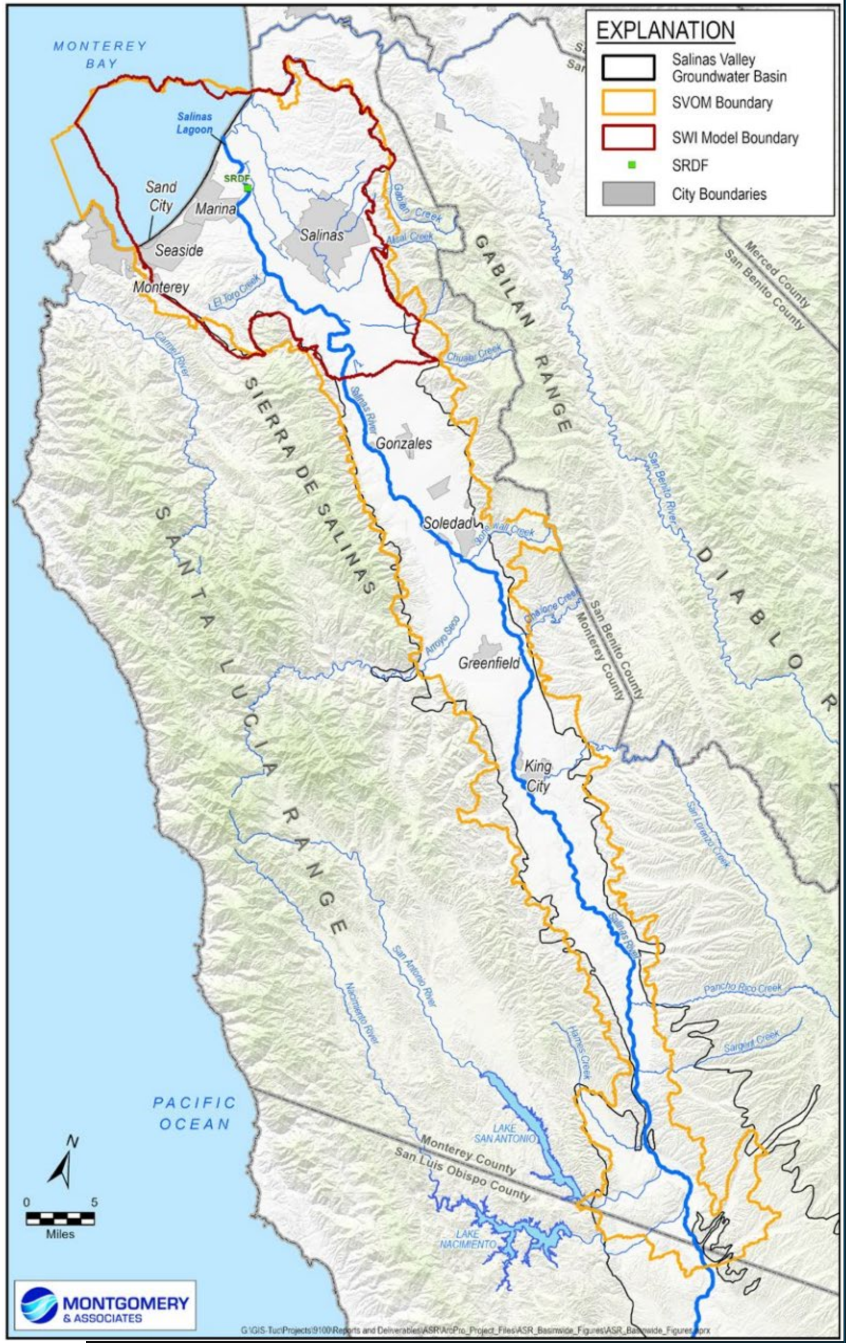
## Larger, more complex models that have a regional scope, include a large geographic area, or address complex interactions with many variables

- Salinas Valley Integrated Hydrologic Model (SVIHM)
- Salinas Valley Operational Model (SVOM)
- Seawater Intrusion Model (SWIM)
- Salinas River HEC-RAS Model
- Forecast Informed Reservoir Operations (FIRO)



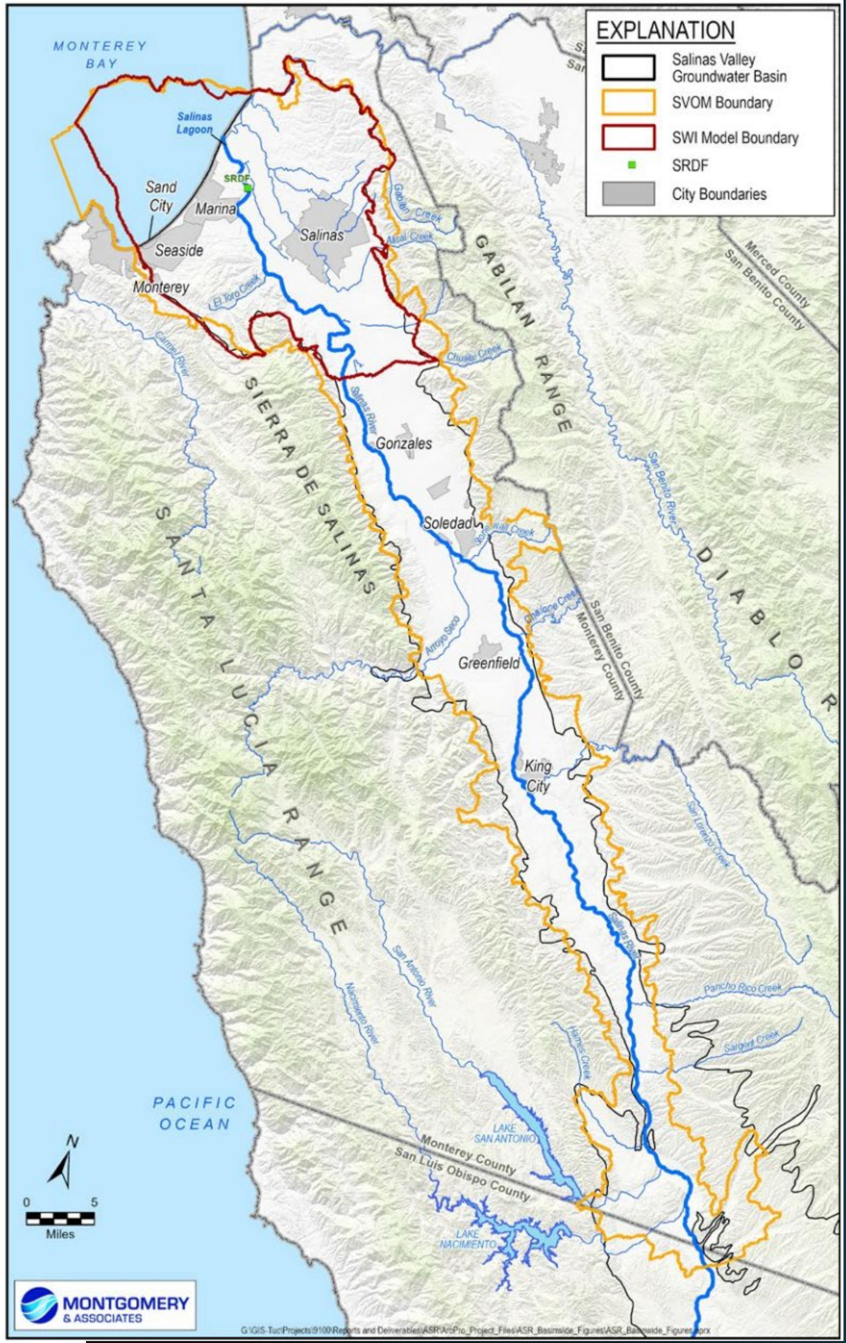
# Salinas Valley Integrated Hydrologic Model (SVIHM)

- An "historical" model
- Active model domain extends from just below the reservoirs to Monterey Bay.
- Covers Zone 2C and aligns with DWR Bulletin 118 subbasin boundaries.
- Uses historical data on climate, land use, and reservoir releases to simulate water demands and surface water diversions.
- Simulates Water Years 1968-2022.



# Salinas Valley Operational Model (SVOM)

- An "operational" model
- Same geographic extent and time frame as the SVIHM.
- Built on the SVIHM structure and calibration, with the addition of an embedded reservoir operations framework.
- Allows specified operational rules for the reservoirs.
- Can be used to simulate changed operations, future climate conditions, or new projects.



# SVOM Data Components

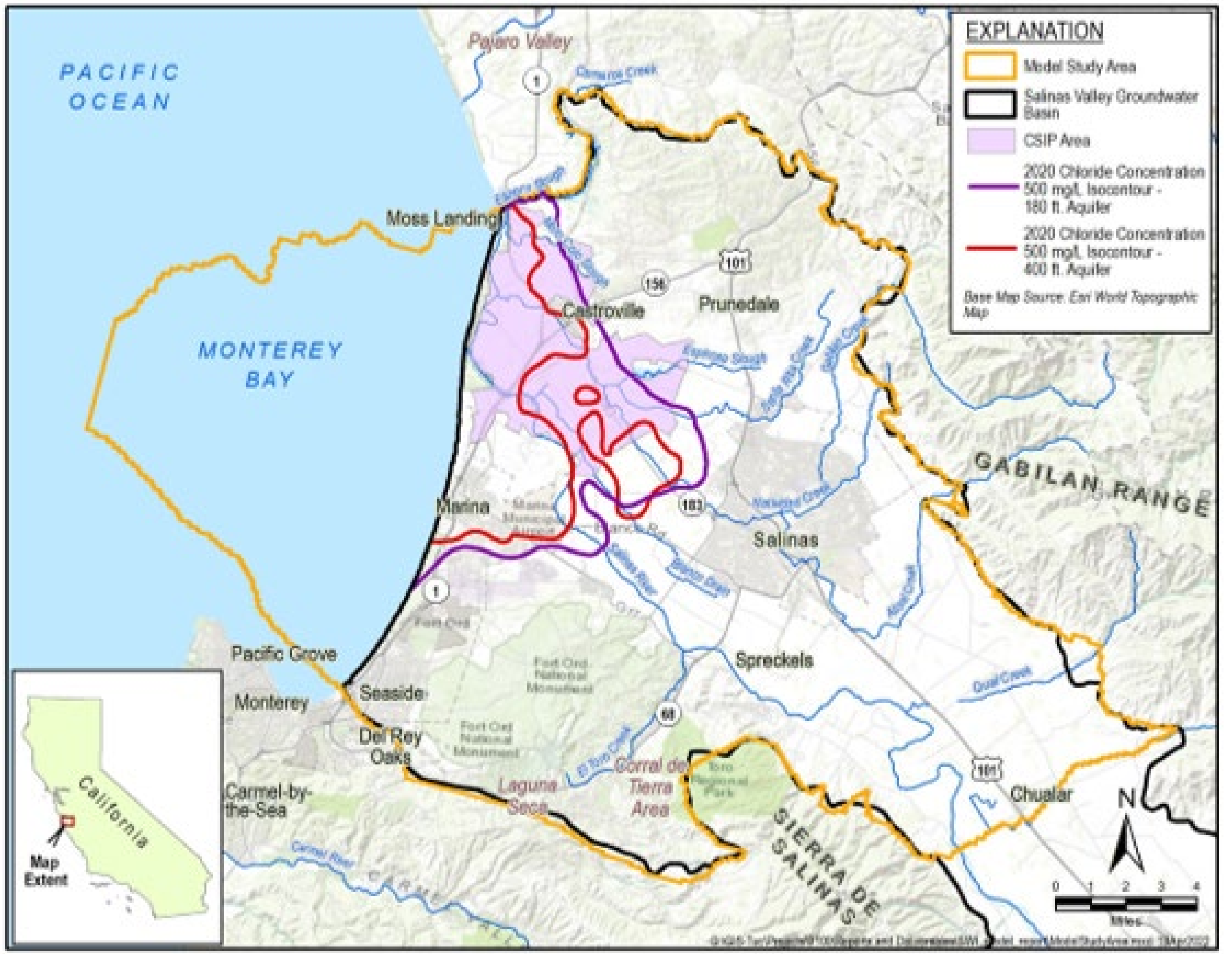
The SVOM is constructed using a series of sub-models, each with a more focused data set and purpose.

This broad scope makes for a robust analytical tool, but one that is also computationally intensive.

- Climate Model
- Watershed Model
- Geologic Framework Model
- Surface Water Operations Module

# Seawater Intrusion Model (SWIM)

- The SWIM is a "flow and transport" model that can simulate the movement of seawater intrusion. It accounts for the density differences between fresh water, brackish water, and seawater.
- Model area covers the full extent of existing seawater intrusion within the Salinas Valley.
- Builds on the SVIHM, Monterey Subbasin Groundwater Flow Model, North Marina Groundwater Model, and Seaside Basin Model.
- The SWIM was calibrated to:
  - Groundwater levels
  - Chloride concentrations
  - Streamflow measurements
  - Geophysical data




More information at svbgsa.org/resources/groundwater-models/

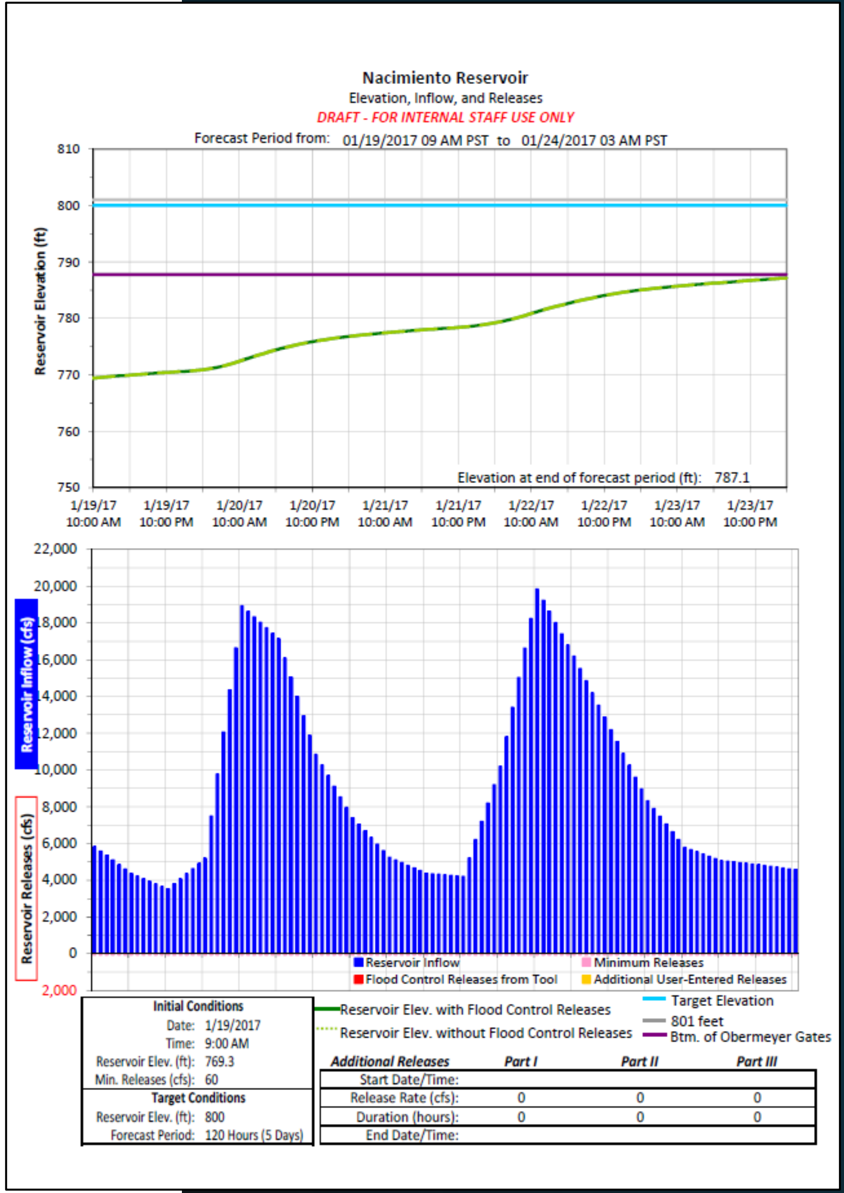
# HEC-RAS model of Salinas River – flood inundation

- Flood inundation mapping tool being developed by FlowWest for the Agency.
- Will be used by Agency staff to produce maps of modeled flood conditions.
- These maps will support reservoir and flood warning operations.

# Smaller Scale Models

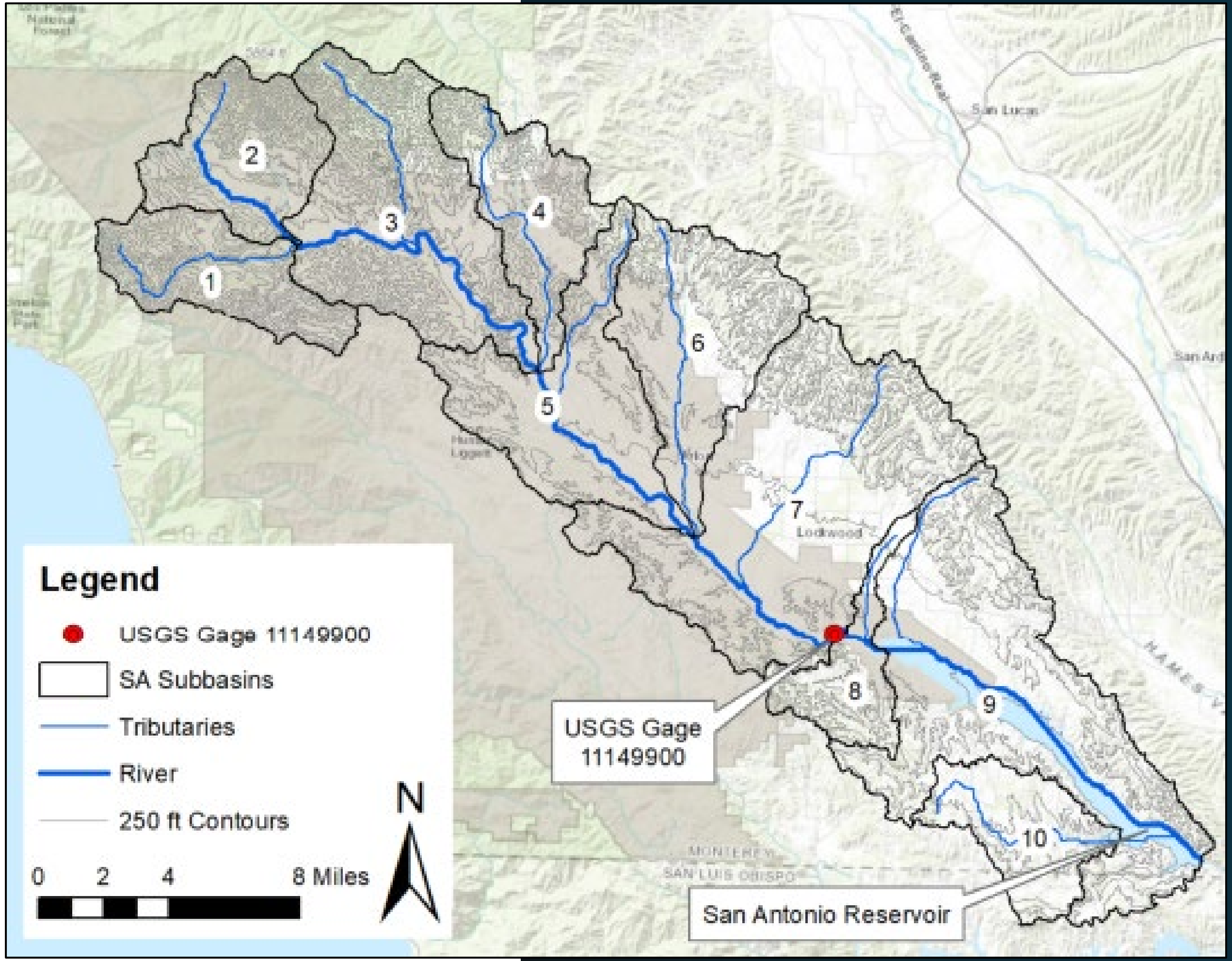
**Smaller, less complex models that include a single location or smaller geographic area such as a smaller portion of a watershed or address less complex interactions**

- San Antonio Dam Probable Maximum Flood (PMF)
- Critical Riffle Analysis
- Agency's Reservoir Release Schedule
- Agency's Reservoir Inflow/Outflow Spreadsheet model



# San Antonio Probably Maximum Flood (PMF) Model

- HEC-HMS based inflow hydrograph for San Antonio Reservoir
- Calibrated to the three largest flow events on record
  - March 1995
  - February 1998
  - January 2023
- Pending DSOD approval
- Will be basis for San Antonio Spillway redesign



# Agency Reservoir Inflow/Outflow Spreadsheet Model

- Pulls data from CNRFC
  - River forecasts for reservoir inflow
- Starting conditions are hand entered
  - Water surface elevation
  - Hypothetical flood control releases
- Output is a graph of projected reservoir elevation

**Initial Conditions**

| Reservoir Elevation (ft) | Corresponding Storage (af) | Percent Storage | Flood Storage Capacity (af) | Percent Capacity | Minimum Daily Releases (cfs): |
|---|---|---|---|---|---|
| 781.55 | 280,395 | 74% | 97,505 | 26% | 60 |

**Target Conditions**

| | | | | | | |
|---|---|---|---|---|---|---|
| 800 | 377,900 | 100% | 0 | 0% | Select Time Period for the Forecast: | 12 |

**Distribution of Flood Control Releases**

| Release rates using the tool's distribution: | | Distribution of Releases Recommended by the Analytical Tool | | | | |
|---|---|---|---|---|---|---|
| Maximum (cfs) | Average (cfs) | Starting Date | Starting Time | Duration (hours) | Ending Date | Ending Time |
| 0 | | | | | | |

| Release Rate (cfs) | Duration (hours) | End Date & Time |
|---|---|---|
| | | Sat 11/18 12:00 PM |
| | | Sat 11/18 12:00 PM |
| | | Sat 11/18 12:00 PM |

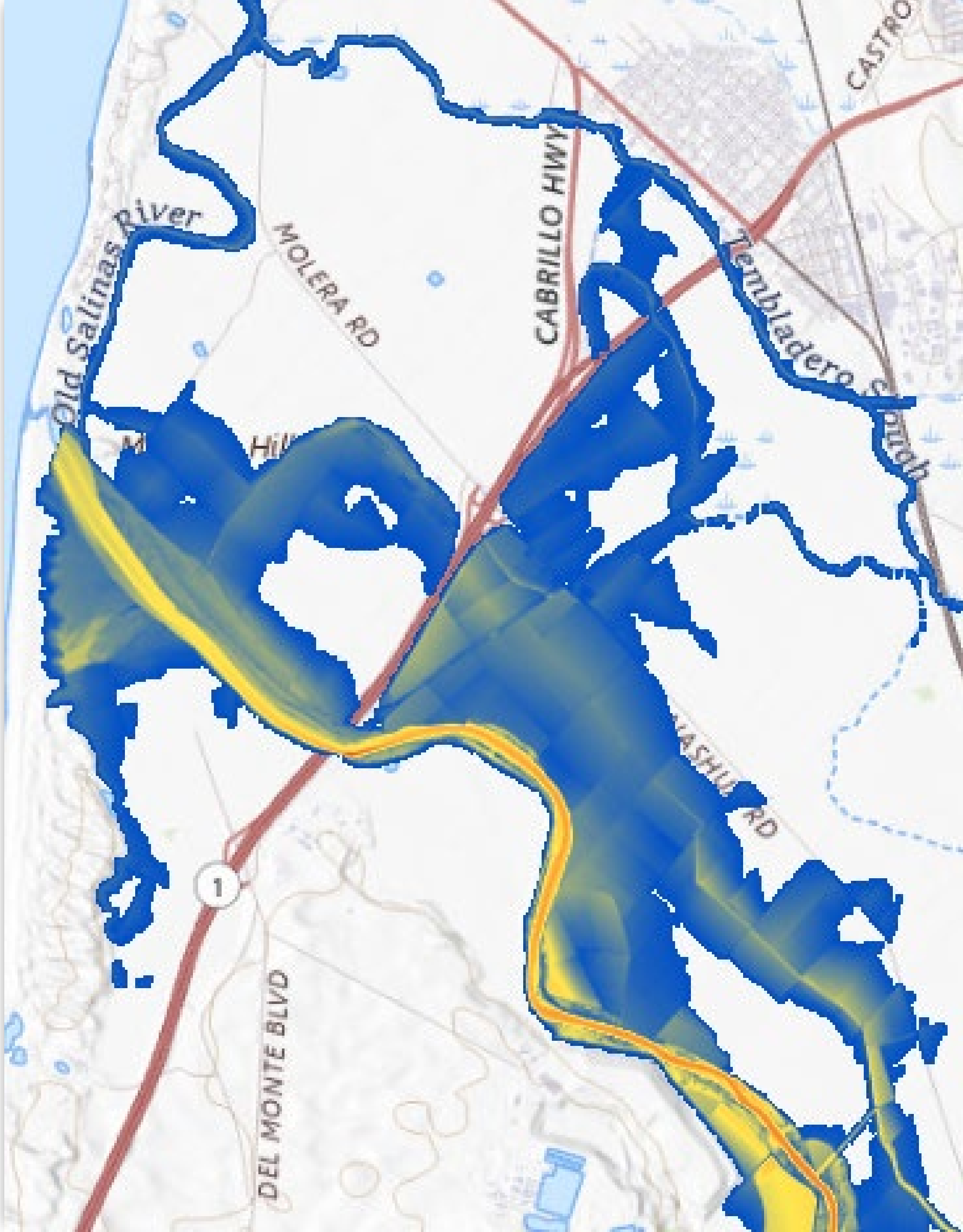
*NOTE* - The Release Rate being set to the left is a TOTAL release amount during the selected time period, **not the amount that will be added to the minimum releases**. For example, entering a Release Rate of 1,000 cfs to the left when there is a Minimum Daily Releases value of 400 cfs will result in a release *increase* of 600 cfs to the tool's input parameters.

**Projected Conditions**

| Reservoir Elevation (ft) | Corresponding Storage (af) | Percent Storage | Flood Storage Capacity (af) | Percent Capacity | Required FC Releases to Reach Target (af/hr) | Required FC Releases to Reach Target (cfs) |
|---|---|---|---|---|---|---|
| 781.60 | 280,658 | 74% | 97,242 | 26% | 0 | 0 |
| 781.65 | 280,965 | 74% | 96,935 | 26% | 0 | 0 |
| 781.70 | 281,319 | 74% | 96,581 | 26% | 0 | 0 |

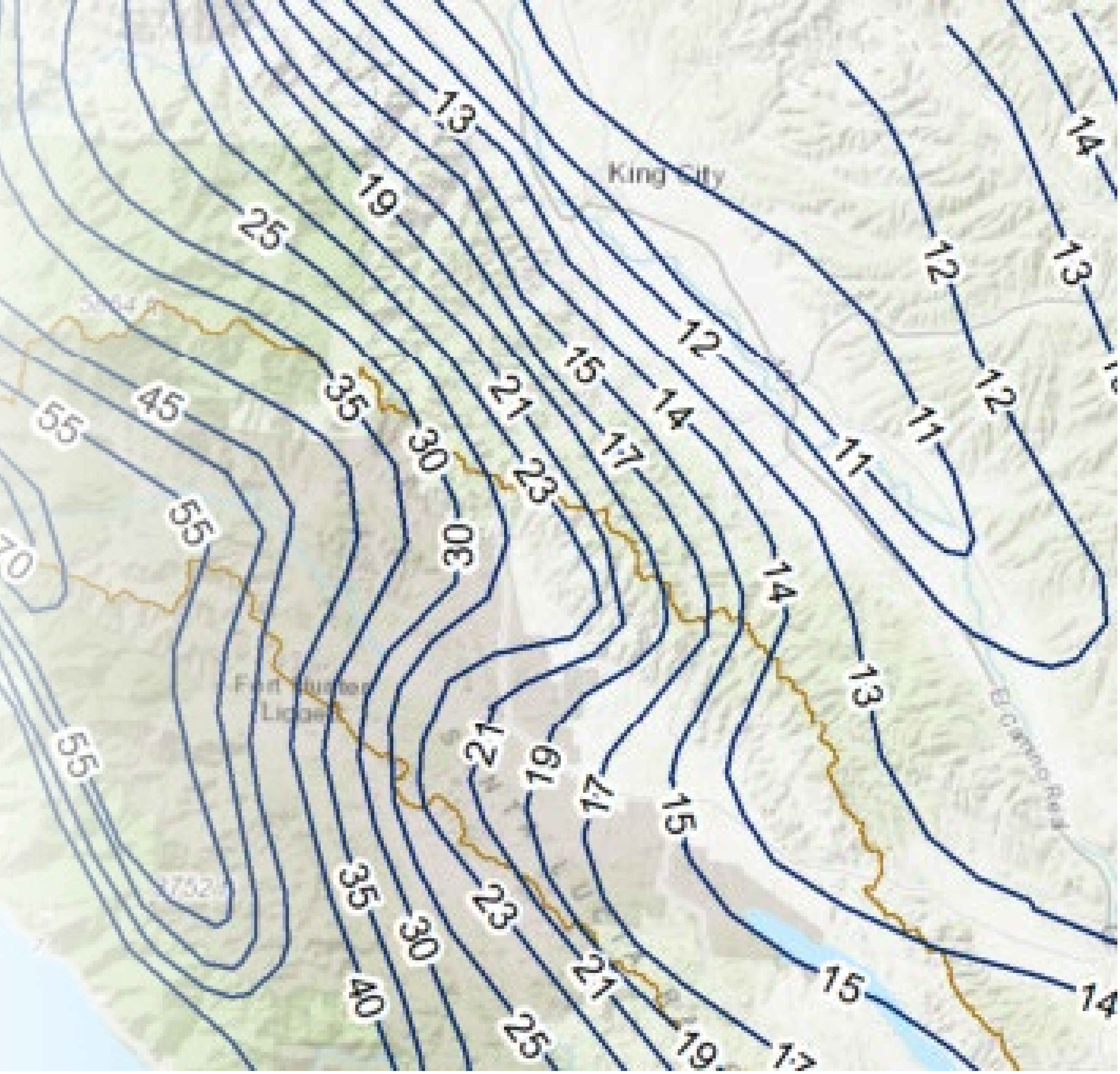
# Why we need to update models in the future

- Models have inaccuracies but within established and accepted bounds. Refining and updating the data that inform models help to reduce uncertainties.
- Watersheds experience physical changes over time
  - Land use
  - Vegetation growth
  - Erosion/deposition
  - River movement within the floodplain
- Accurate topography is essential for models that predict surface flows or inundation areas.
- Reflecting a full range of historical hydrologic conditions and capturing current geologic understanding is essential.
- Updating model assumptions and including recent data helps keep the tools accurate, relevant, and reliable.



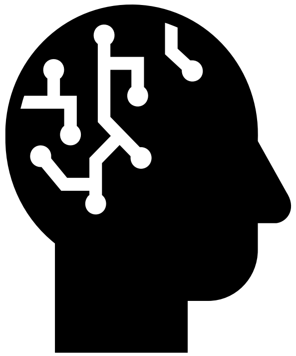
# Importance of Agency’s data collection

- Data collected by the Agency are used to calibrate the models we use, as well as other external models.
- Examples:
  - Rain data feed to CNRFC
  - Groundwater level, extraction, and quality data, and reservoir operations data are incorporated in SVIHM and SVOM, and SWIM
  - Well location data



# Joint Technical Advisory Committee

- The SVBGSA established an ad hoc Groundwater Technical Advisory Committee (GTAC) to provide technical input on groundwater-related topics.
  - GTAC members are third-party experts with expertise in hydrology, hydrogeology, hydrological modeling, civil engineering or a related field.
- The Agency and SVBGSA are collaborating to expand the scope of the ad hoc group, so it is not limited to groundwater topics. With this change, there will be a renaming to the **Joint Technical Advisory Committee** (JTAC).
- The JTAC will:
  - ✓ Provide technical guidance and peer review on items such as integrated surface water-groundwater model development or updates, data gaps or data collection needs, or feasibility studies.
  - ✓ Convene at the request of Agency or SVBGSA staff on an as-needed basis.
  - ✓ Eliminate duplication of effort between agencies.
  - ✓ Minimize time required of JTAC subject matter experts.
  - ✓ Provide a more efficient and unified process for considering model applications and updates.



# Artificial Intelligence (AI)

- AI has become more integrated in many aspects of modern life
  - Internet search results
  - Virtual assistants
  - Customer service
  - IOT and smart home devices
  - Medical diagnosis
  - Weather forecasting

- What is the difference between numerical hydrologic modeling and AI based modeling or forecasting?

- How are the two approached being used?

- Let's ask AI…
  - The next 4 slides are populated with content generated by Microsoft Copilot

# 🔬 Numerical Hydrologic Modeling

- **Foundation:** Built on physical laws (e.g., conservation of mass, energy, and momentum).
- **Inputs:** Rainfall, soil type, land use, topography, evaporation, infiltration, and channel hydraulics.
- **Approach:** Uses differential equations to simulate processes like runoff, streamflow, and groundwater recharge.
- **Strengths:**
  - Physically interpretable and explainable.
  - Can be applied to ungauged basins if physical parameters are known.
  - Useful for scenario testing (e.g., land-use change, climate change impacts).
- **Limitations:**
  - Requires extensive calibration and high-quality input data.
  - Computationally intensive, especially for large basins.
  - Struggles with uncertainty in complex or poorly understood processes

# AI-Based Forecasting

- **Foundation:** Data-driven, using machine learning (ML) and deep learning (DL) algorithms such as **Artificial Neural Networks (ANNs), Long Short-Term Memory (LSTM), and Random Forests**.
- **Inputs:** Historical hydrologic data (rainfall, streamflow, temperature, soil moisture), often combined with satellite observations.
- **Approach:** Learns statistical relationships between inputs and outputs without explicitly modeling physics.
- **Strengths:**
  - Handles nonlinear and complex relationships better than traditional models.
  - Requires less domain-specific knowledge of physical processes.
  - Faster computation once trained, enabling real-time flood/drought forecasting.
  - Can integrate diverse data sources (remote sensing, climate models, IoT sensors).
- **Limitations:**
  - Often considered a “black box” with limited interpretability.
  - Performance depends heavily on the quality and quantity of training data.
  - May fail in extrapolation (e.g., predicting extreme events outside historical records)

# Key Differences Between Numerical Hydrologic Models and AI-Based Forecasting

| Aspect | Numerical Hydrologic Models | AI-Based Forecasting |
|---|---|---|
| Basis | Physics & equations | Data-driven learning |
| Interpretability | High (process-based) | Low (black-box) |
| Data Needs | Physical parameters + climate inputs | Large historical datasets |
| Flexibility | Limited to modeled processes | Can adapt to diverse datasets |
| Computation | Often intensive | Fast once trained |
| Extrapolation ability | Strong (if physics known) | Weak (outside training range) |
| Use cases | Scenario analysis, climate change impacts | Real-time flood/drought forecasting |

# Can the approaches be integrated?

## 🌍 Integration Trend

- Modern hydrology increasingly uses **hybrid approaches** that combine numerical models with AI. For example:
- AI can **calibrate parameters** in physics-based models.
- Numerical models provide **physical constraints** to improve AI interpretability.
- Together, they enhance **accuracy, robustness, and trustworthiness** in hydrologic predictions