Great Salt Lake Basin Study: Characterizing Uncertainty Spread of Hydroclimate Scenarios

RiverWare User Group Meeting, August 26 & 27, 2026

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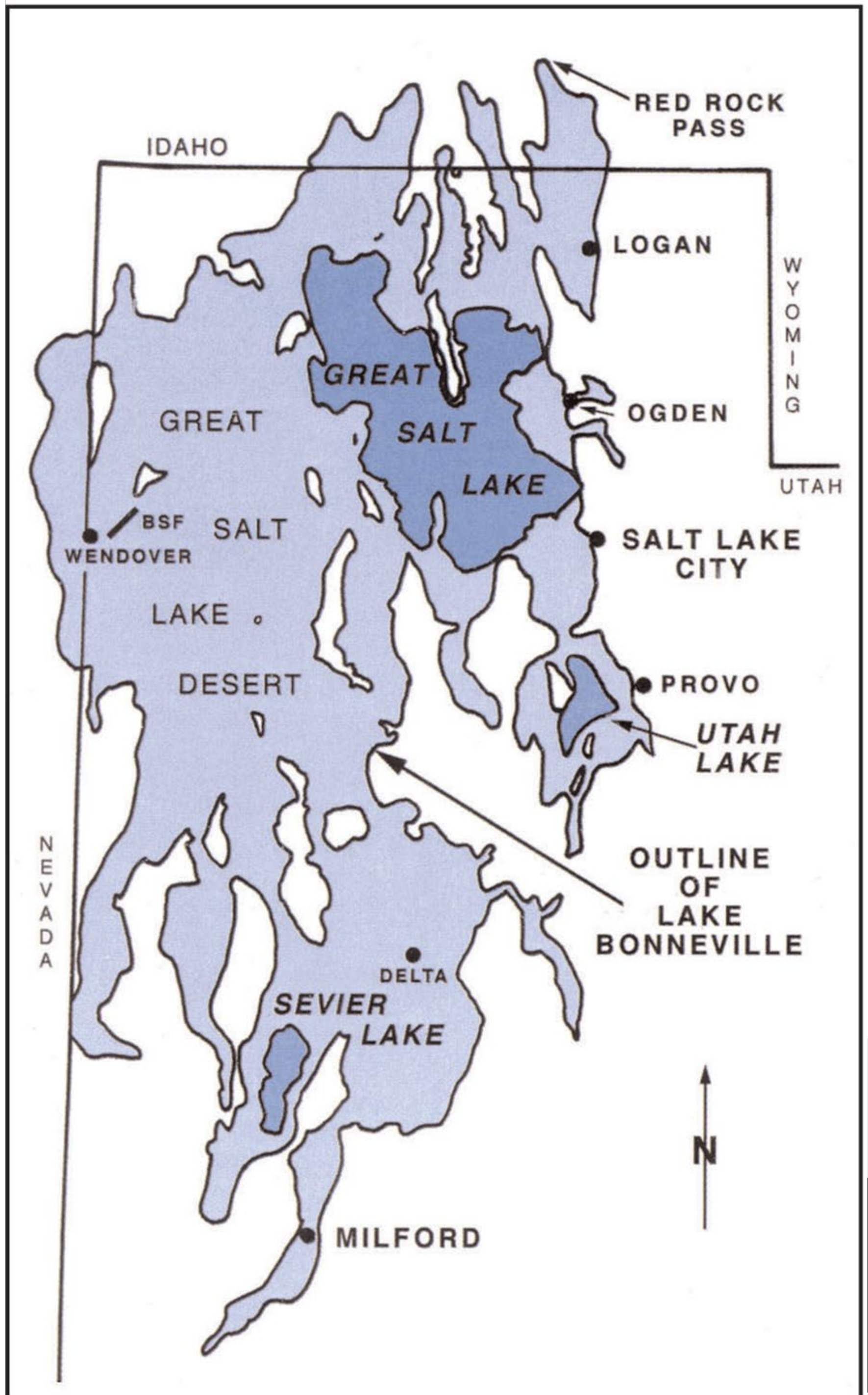
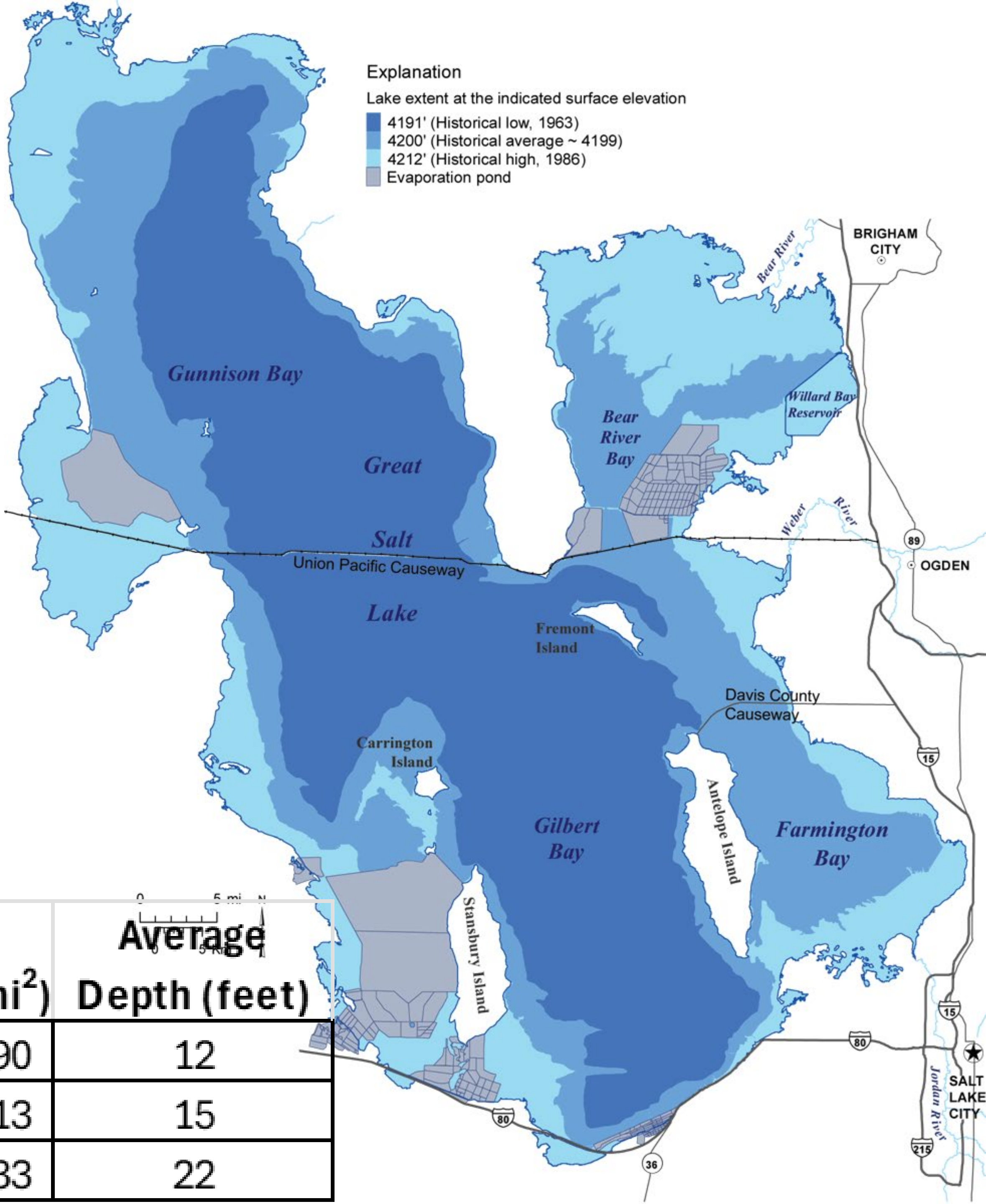
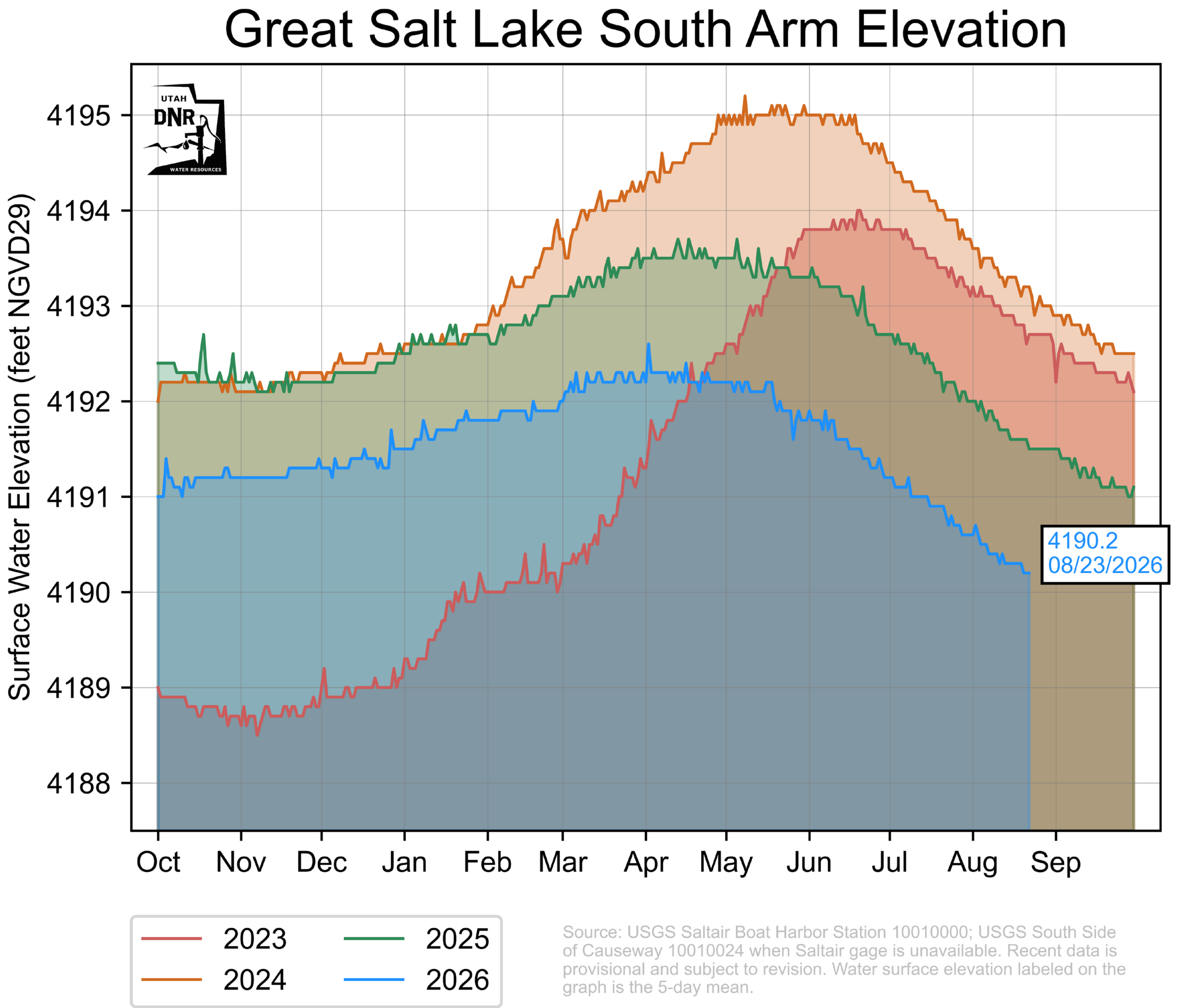
[3]University of Utah

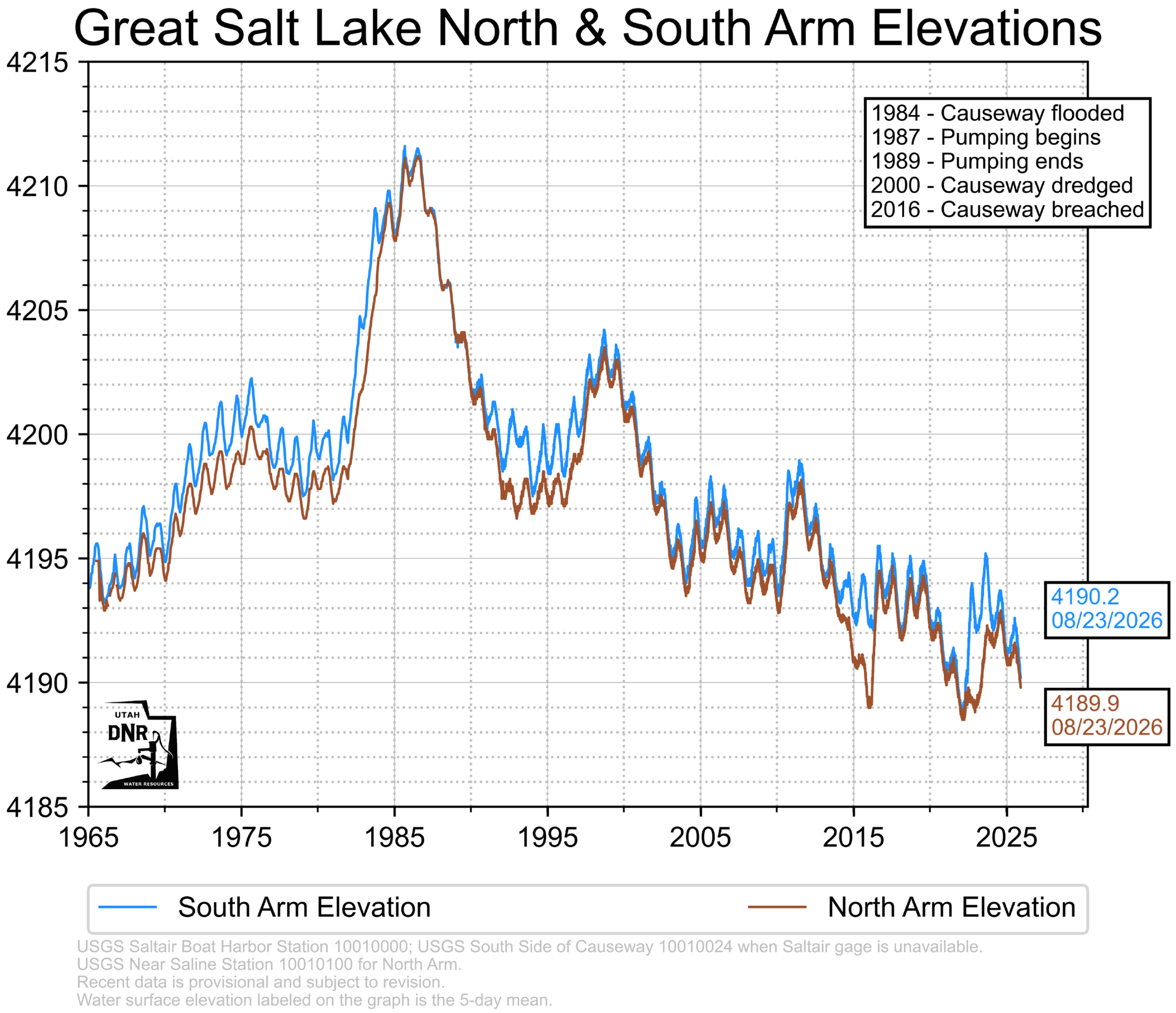
[4]Vanderbilt University





Elevation	Area (mi^2)	Average Depth (feet)
4188.5	890	12
4198	1,413	15
4212	2,233	22


Great Salt Lake South Arm Elevation
UTAH DNR WATER RESOURCES
Surface Water Elevation (feet NGVD29)
4195
4194
4193
4192
4191
4190
4189
4188
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
4190.2
08/23/2026
2023
2024
2025
2026
Source: USGS Saltair Boat Harbor Station 10010000; USGS South Side of Causeway 10010024 when Saltair gage is unavailable. Recent data is provisional and subject to revision. Water surface elevation labeled on the graph is the 5-day mean.



- **High to low: 32 yrs**
- **Low to high: 24 yrs**
- **High to low: 40 yrs**
- **Low to high: 22 yrs**
- **High to low: 36 yrs**
- **Retirement planning**

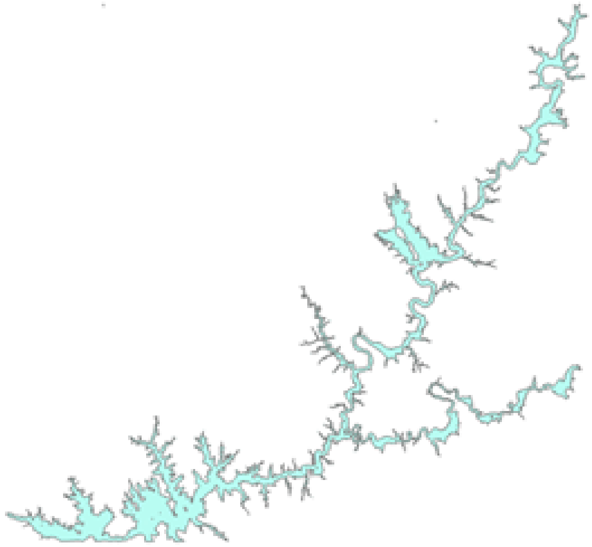
Current Conditions

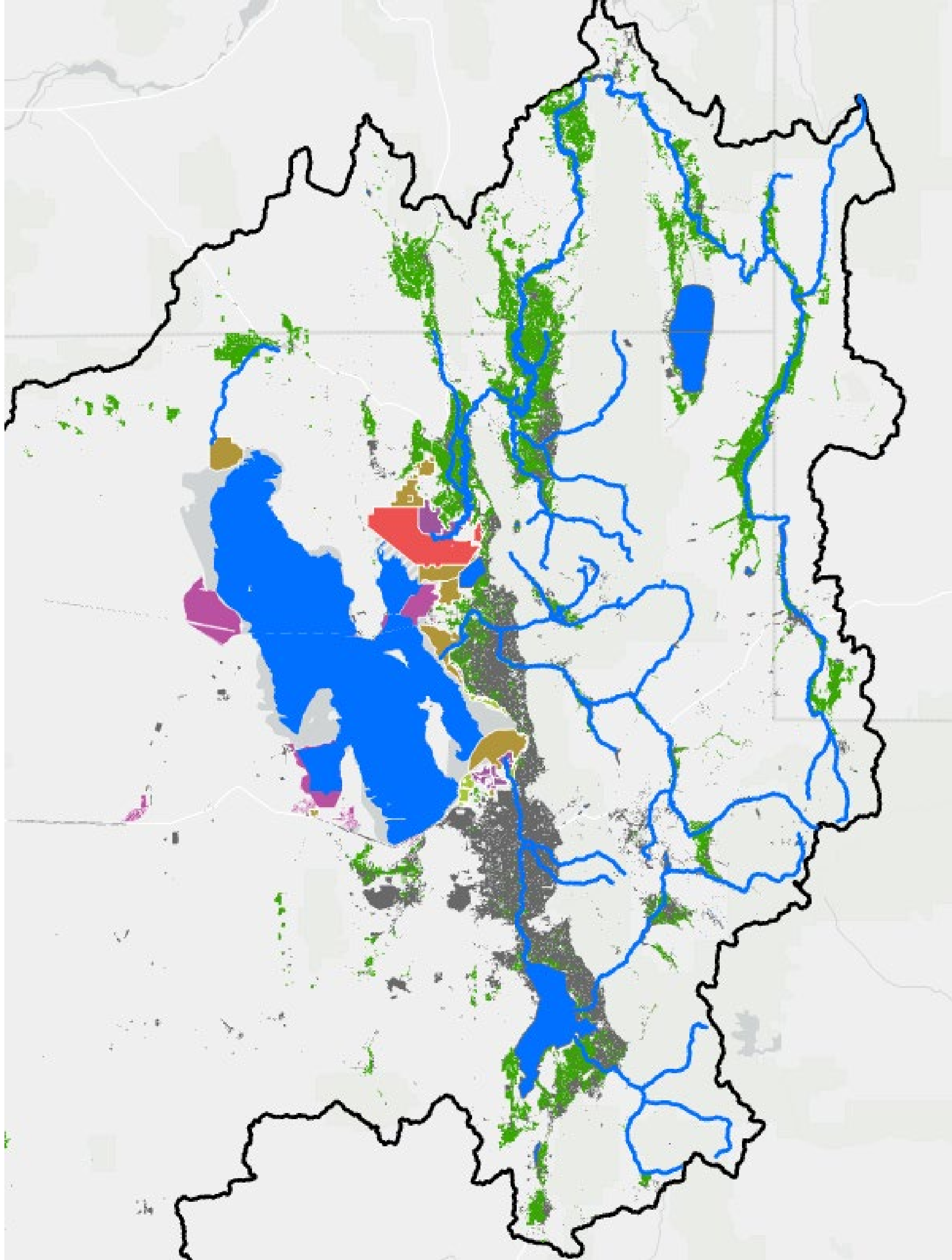
Lake Powell

- 26% full (6.5 of 24 MAF)
- 5-Year average inflow = 10.3 MAF
- 5-Year average evaporation = 0.34 MAF
- Outflow/Inflow Ratio = 0.82

Great Salt Lake

- 36% of historical max (12.2 of 34 MAF)
- 5-Year average inflow = 1.8 MAF
- 5-Year average evaporation = 2.1 MAF
- Outflow/Inflow Ratio = 1.4

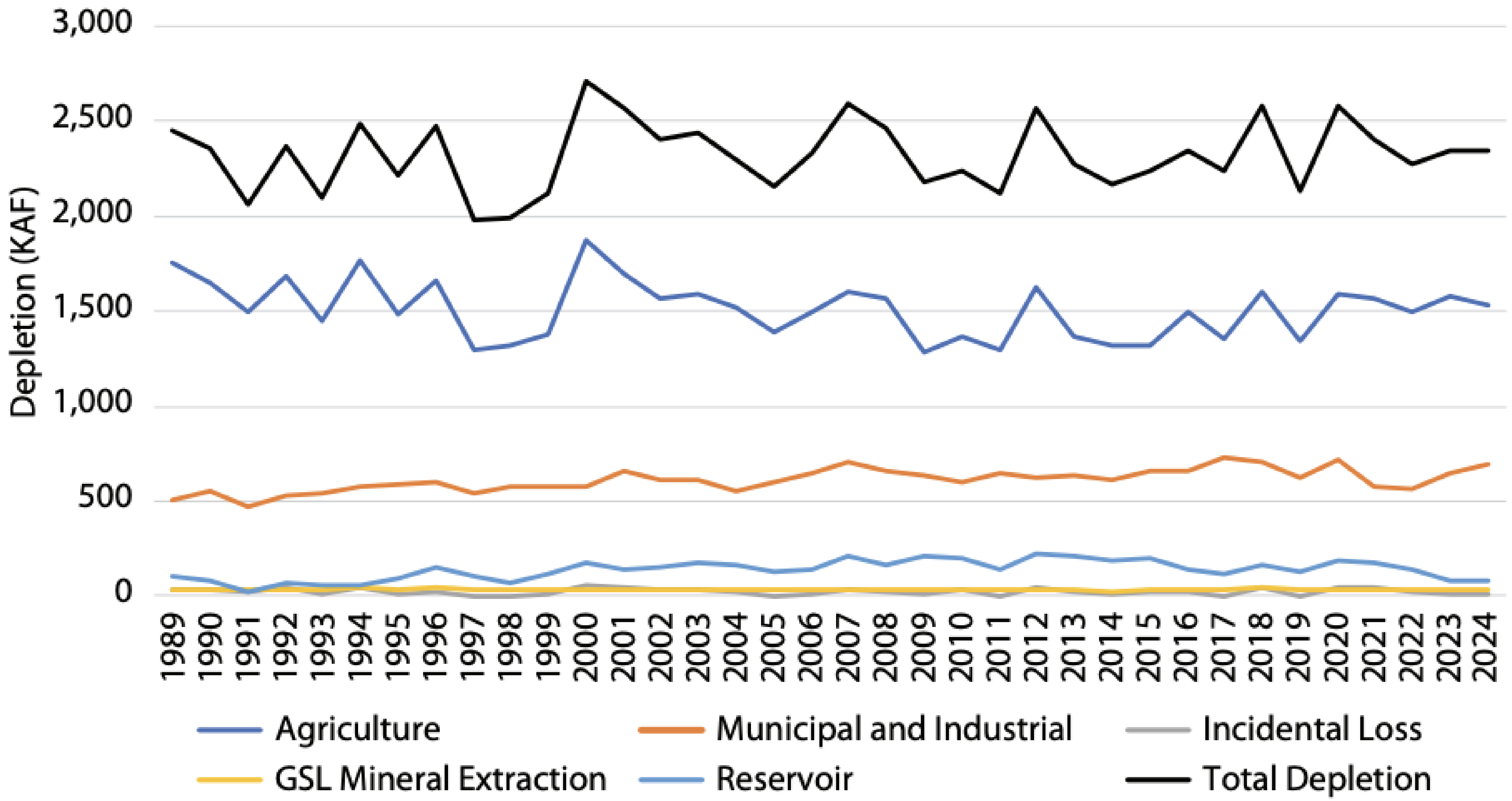




Complexity

- 36,000 mi2
- 4 States
- 18 Counties
- 141 Cities
- 70 Groundwater aquifers
- 1,300 reservoirs
- 150,000 water rights
- 2.6 million humans
- 1.4 million acres of farmland
- 741 thousand urban acres
- 233,000 acres managed wetlands
- Behaviors
- Attitudes
- Values

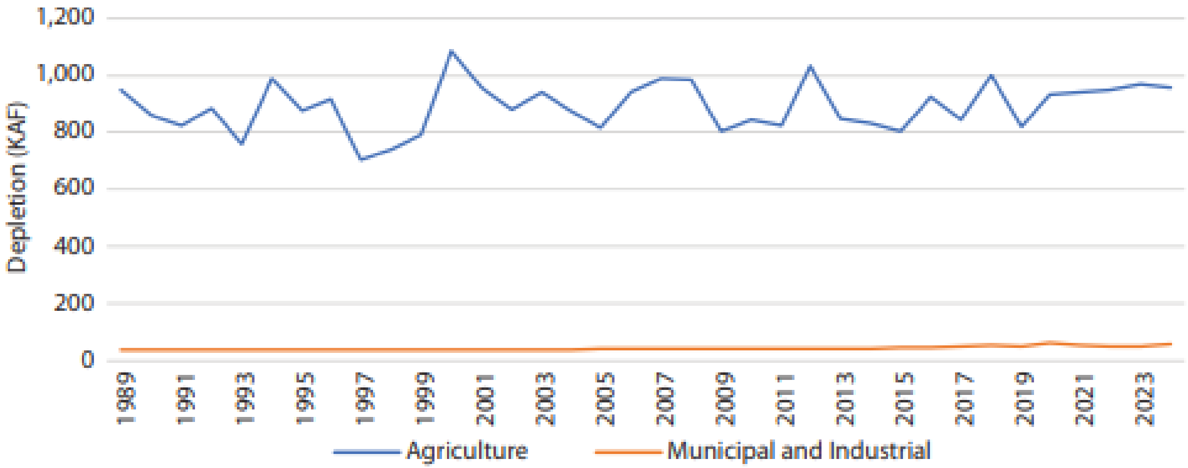
Figure 12: Human Water Depletion by Type, 1989-2024



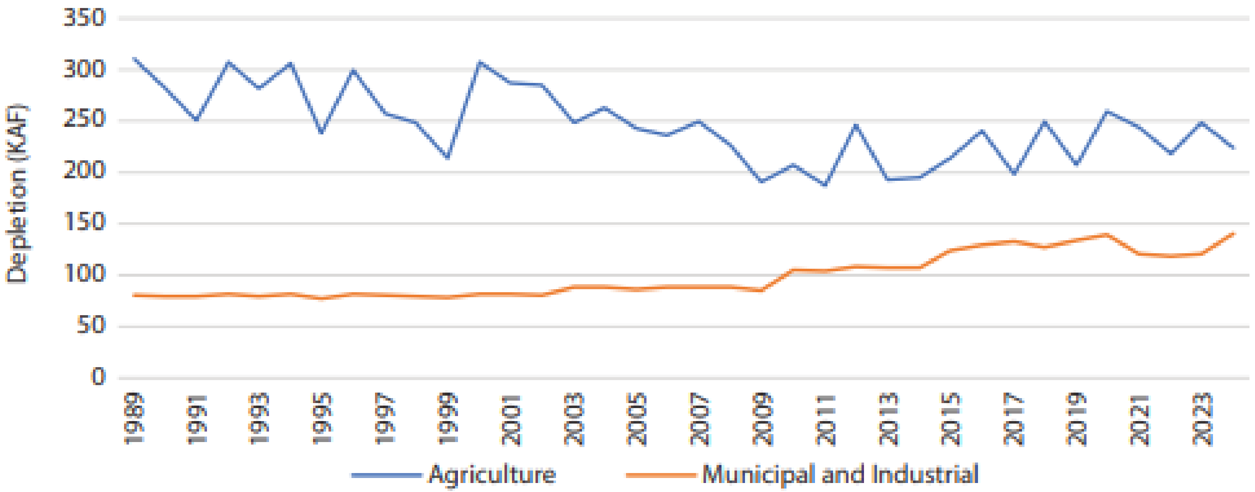
Urban & Agricultural Water Use

Figure 13: Agriculture and M&I Depletion by Basin, 1989-2024

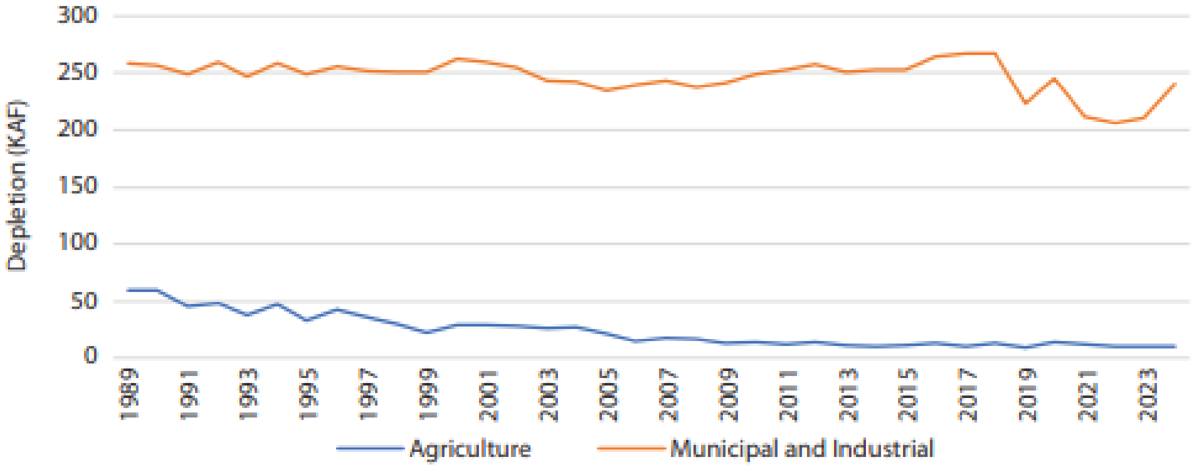
Bear River Basin



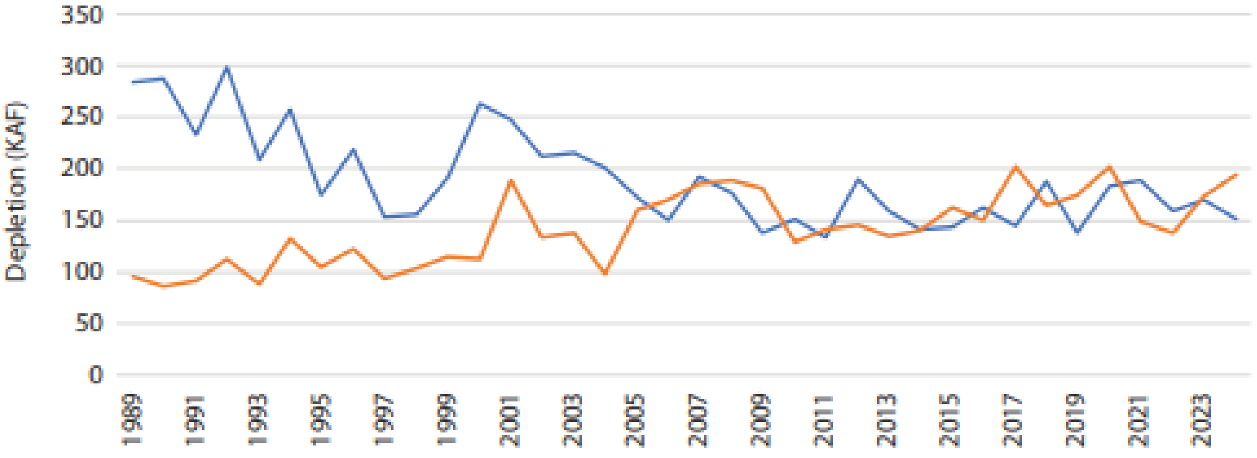
Utah Lake Basin



Jordan River Basin



Weber River Basin



"Across the world, saline lakes are in decline. Utah will be the exception. The Great Salt Lake is our lake, our heritage, and our responsibility."

— Gov. Spencer J. Cox


RALLY TO
SAVE
OUR
GREAT
SALT
LAKE
NOON AT
THE CAPITOL
SATURDAY
JANUARY 31ST


2026 VIGIL
FOR GREAT SALT LAKE
AT THE CAPITOL
WALK THE WAVES
OPENING DAY WALK - JAN 20 8AM
MONDAYS 8AM - JAN 26-MAR 2
CELEBRATE THE SPECIES
FRIDAYS 5PM - JAN 23-MAR 6
MAKING WAVES

Planning and Coordination

Problem

GSL's water level is in long-term decline. Water users face shortages and challenges. Increased temperatures and greater precipitation extremes are stressing water supplies in the basin. 84% of Utah residents think the Government is accountable for resolving issues facing GSL.

Vision

By the end of 2027, major water rights holders - facilitated by DNR, have agreed to a shared vision of water management success and have adopted coordinated actions to achieve it.

— BUREAU OF —
RECLAMATION

Bureau of Reclamation Mission

To manage, develop, and protect
water and related resources
in an environmentally and economically sound manner
in the interest of the American public.

Reclamation Basin Study Program

- **Collaborative, long-range planning** effort
- Part of WaterSMART Program funded under the Secure Water Act
- Established to provide framework to **secure water supplies for future generations**
- Basin studies conducted as **cost-shared partnerships**

Reclamation Basin Study Program

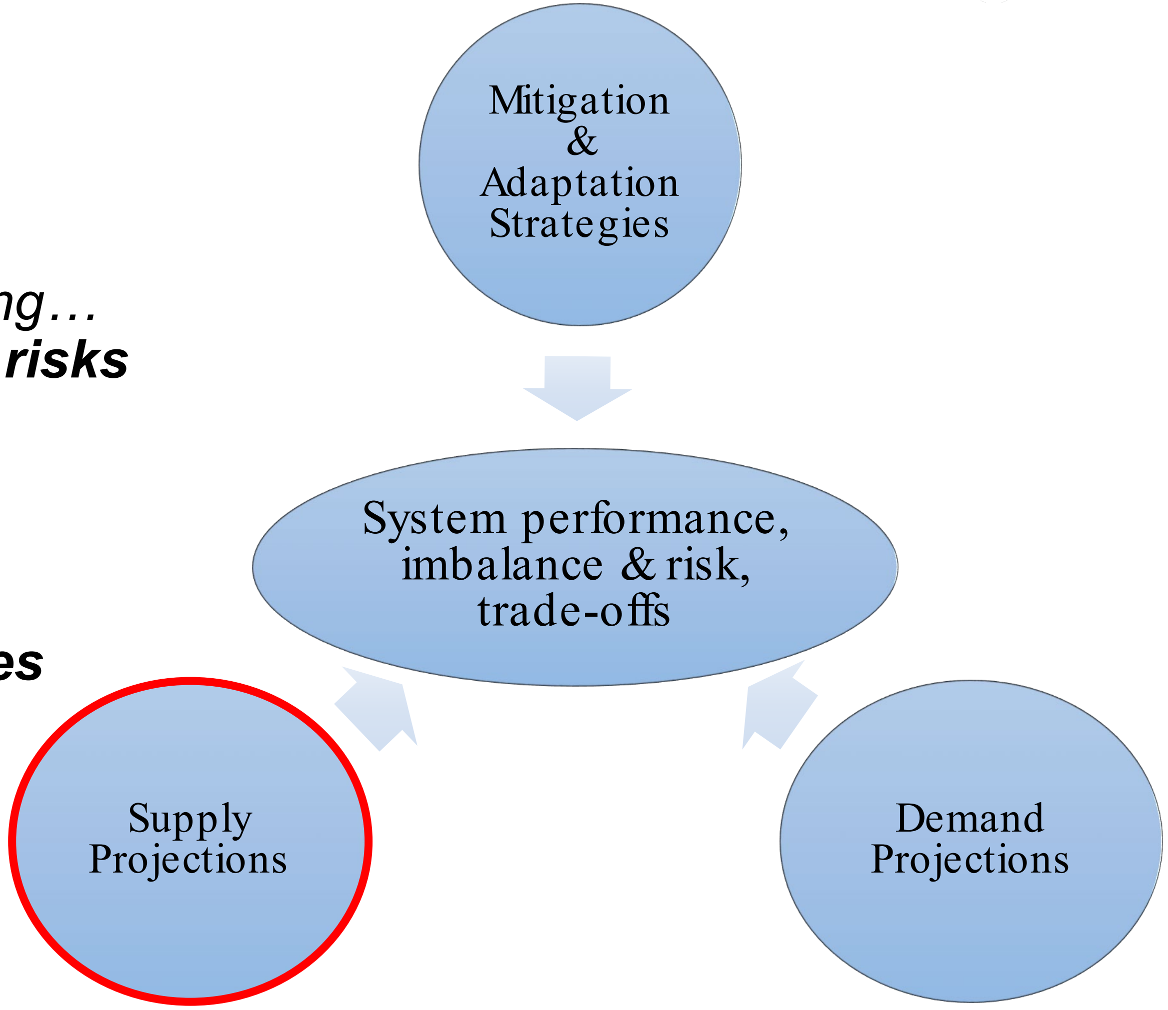
Elements of a Basin Study

1. ***Project water supply*** *and* ***demand*** *considering…*
   impacts from ***climate change*** *and associated* ***risks***

2. ***Analyze performance*** *of water and power* ***infrastructure*** *and* ***operations***

3. ***Develop adaptation*** *and* ***mitigation strategies***

4. ***Conduct*** *a* ***trade-off analysis***



Reclamation Manual, Directives and Standards

GLSB Study Question

How can the **uncertainty** of future hydroclimate projections be characterized in five to six **representative projections** to **assess risk**, **foster public understanding of** projected changes, and stay within the project scope, budget and timeline?

Risk is not caused by an extreme value alone but emerges when characteristics of a hazard interact with the thresholds and needs of an exposed, vulnerable system.

Goals

Fundamental Goals

- Provide **scientifically informed** analyses that are **relevant**, **credible**, **legitimate**, and **bound** so that parties with vested interest in the basin can **respond** to risks associated with hydroclimate non-stationarity
- Analyze **system performance** including **imbalances** between supply and demand; **assess risk** in alignment with Reclamation's mission, and **evaluate trade-offs** of mitigation and adaptation strategizes

Process/Means Goal

- Apply **collaborative modeling** to establish modeling workflow

Collaborative Modeling: Linking Community Priorities to Hydroclimate Scenarios

- UDWRe engaged **community partners** and **water users** to identify important **climate** and **water-supply concerns**
- **UDWRe survey**: 10 questions with 47 respondents representing a range of water users and organizations
- Combined community input with scientific analysis to identify **relevant hydroclimate metrics**

VALUING LOCAL, OPERATIONAL & SCIENTIFIC KNOWLEDGE

UTAH DNR WATER RESOURCES

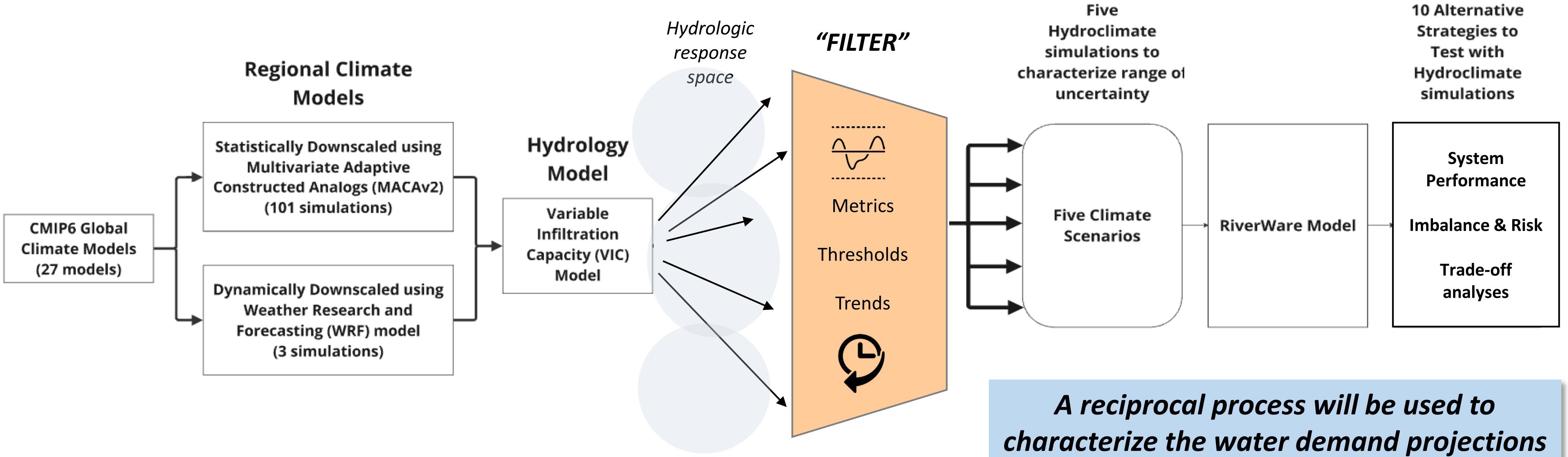
Provo Area Office

& State-Federal Partnerships

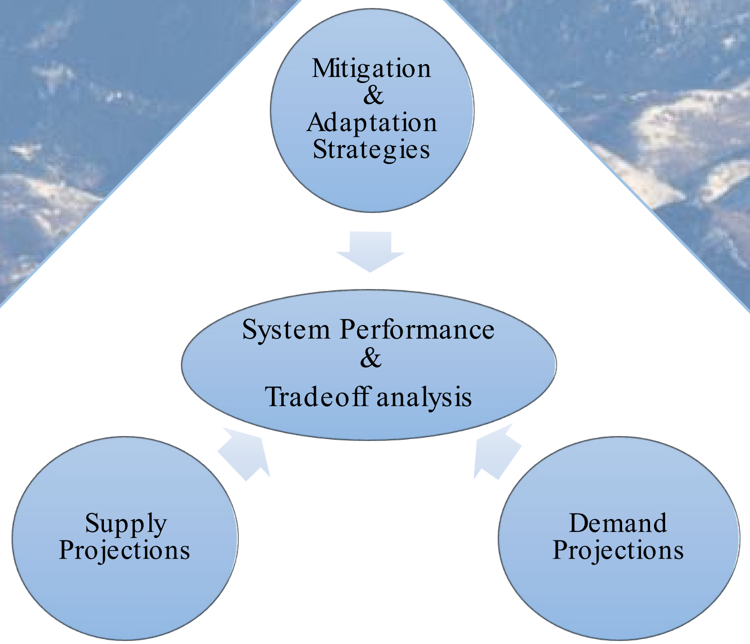
Objectives

- **Characterize historical** and **projected hydroclimate** and water **demand** across the basin using **local**, **operational**, and **scientific knowledge** to inform **trends**, **metrics**, and events capable of pushing the community past **thresholds** that matter
- **Identify five representative hydroclimate projections** that span future projections uncertainty space

Process for characterizing and identifying representative hydroclimate projections



A reciprocal process will be used to characterize the water demand projections



TODAY'S OUTLINE

Coupled Model Framework

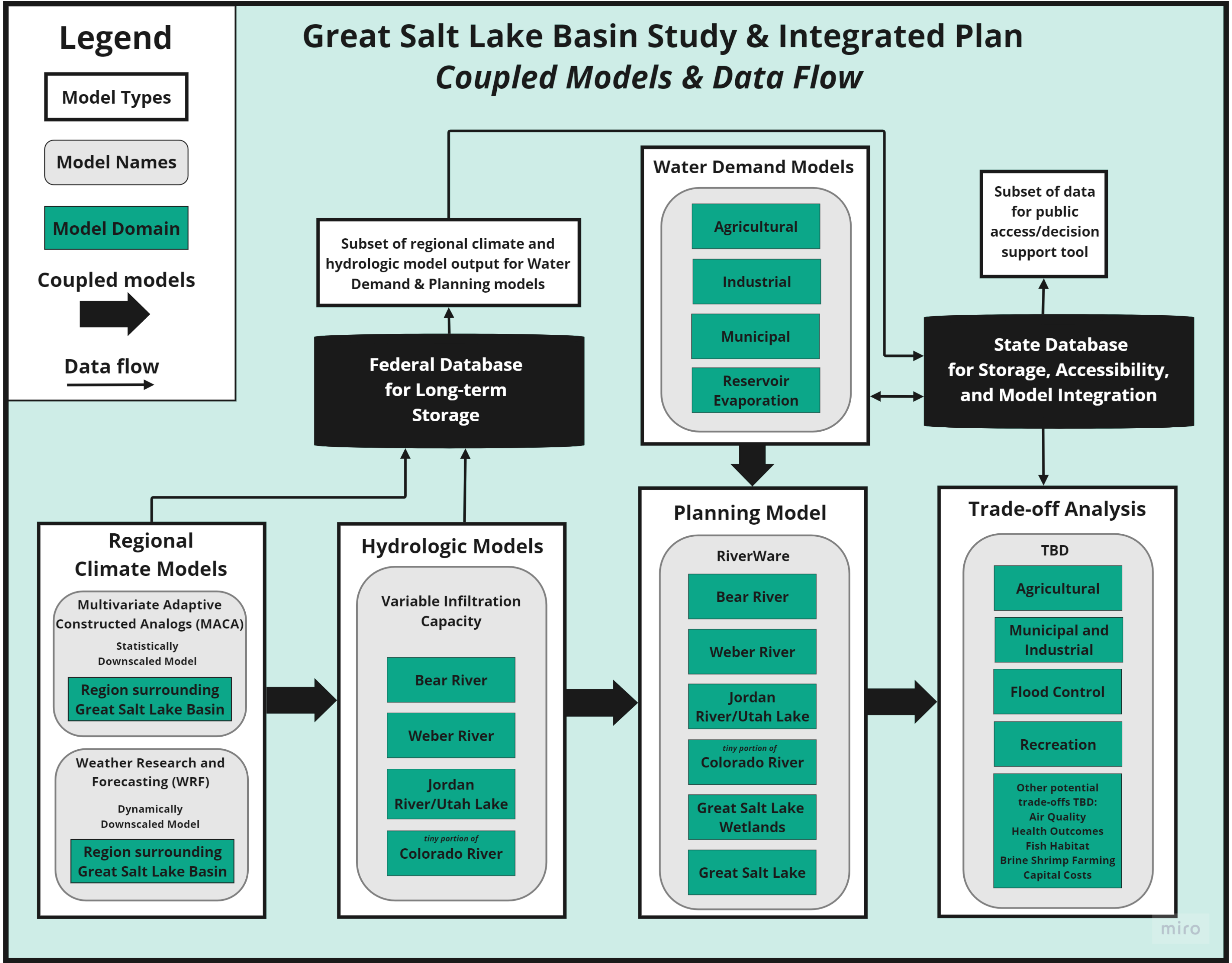
Model Domains

Supply (Hydroclimate) Models & Projections

Hydroclimate-RiverWare Handshake

Water Demand Models

Lessons Learned (So Far)


Legend
Model Types
Model Names
Model Domain
Coupled models
Data flow
Great Salt Lake Basin Study & Integrated Plan
Coupled Models & Data Flow
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Industrial
Municipal
Reservoir Evaporation
Subset of data for public access/decision support tool
State Database for Storage, Accessibility, and Model Integration
Regional Climate Models
Multivariate Adaptive Constructed Analogs (MACA)
Statistically Downscaled Model
Region surrounding Great Salt Lake Basin
Weather Research and Forecasting (WRF)
Dynamically Downscaled Model
Region surrounding Great Salt Lake Basin
Hydrologic Models
Variable Infiltration Capacity
Bear River
Weber River
Jordan River/Utah Lake
tiny portion of
Colorado River
Planning Model
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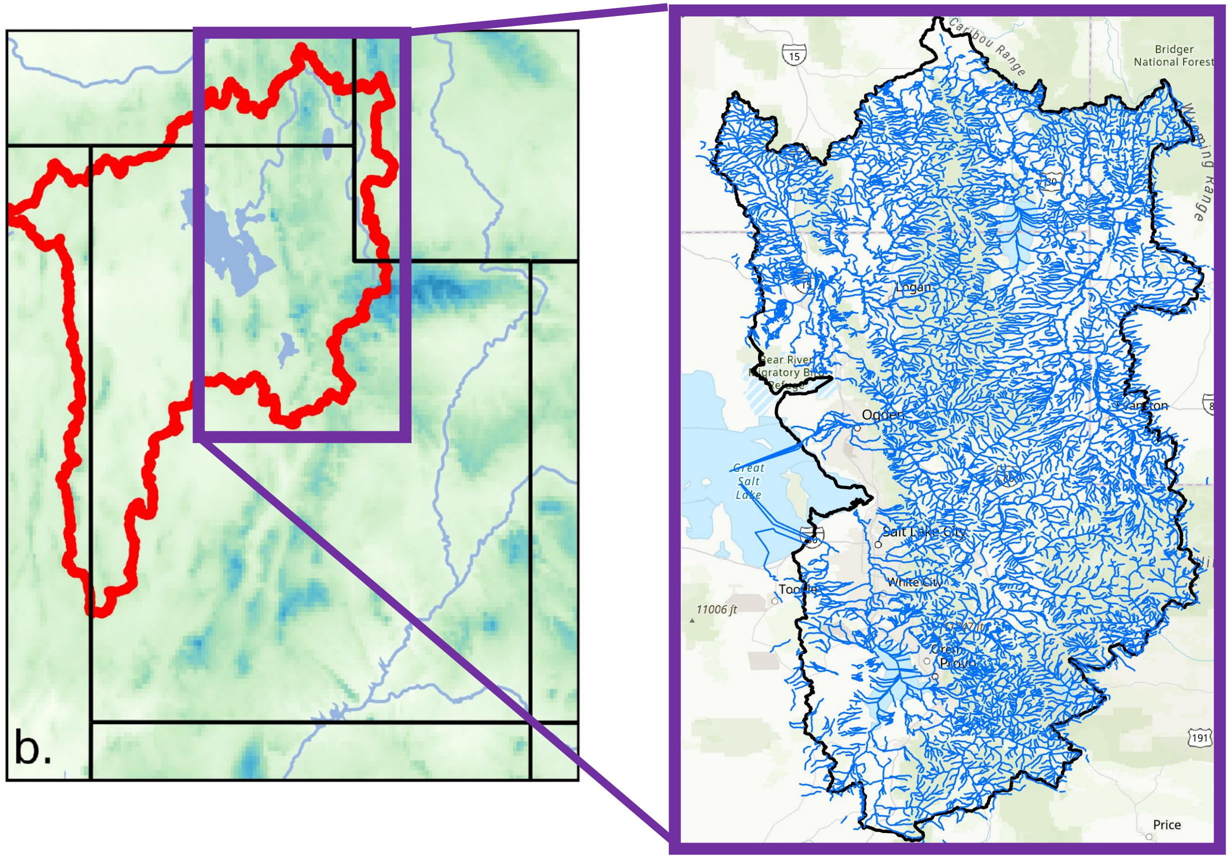
Great Salt Lake Wetlands
Great Salt Lake
Trade-off Analysis
TBD
Agricultural
Municipal and Industrial
Flood Control
Recreation
Other potential trade-offs TBD:
Air Quality
Health Outcomes
Fish Habitat
Brine Shrimp Farming
Capital Costs
miro

Model Domains

Regional Climate Model

Hydrology Model

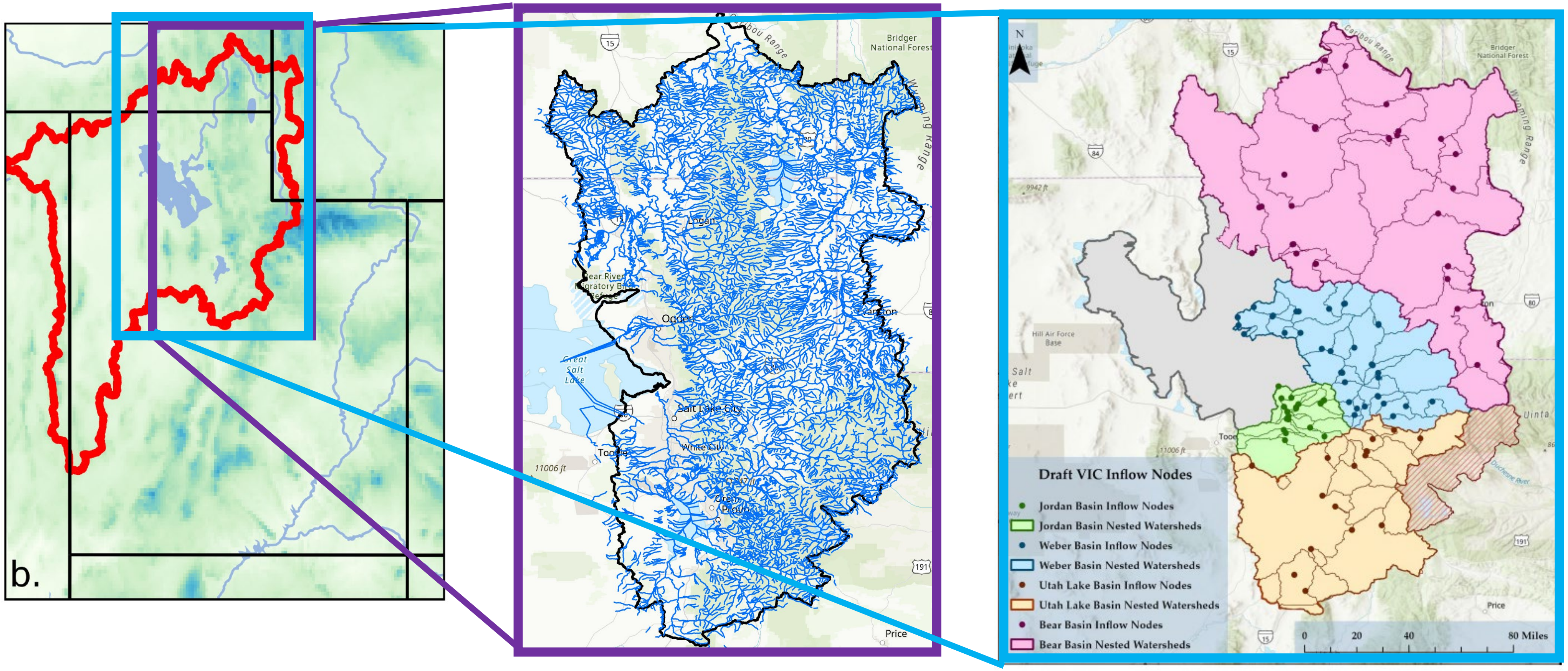


Gridded

Gridded & routed

Model Domains

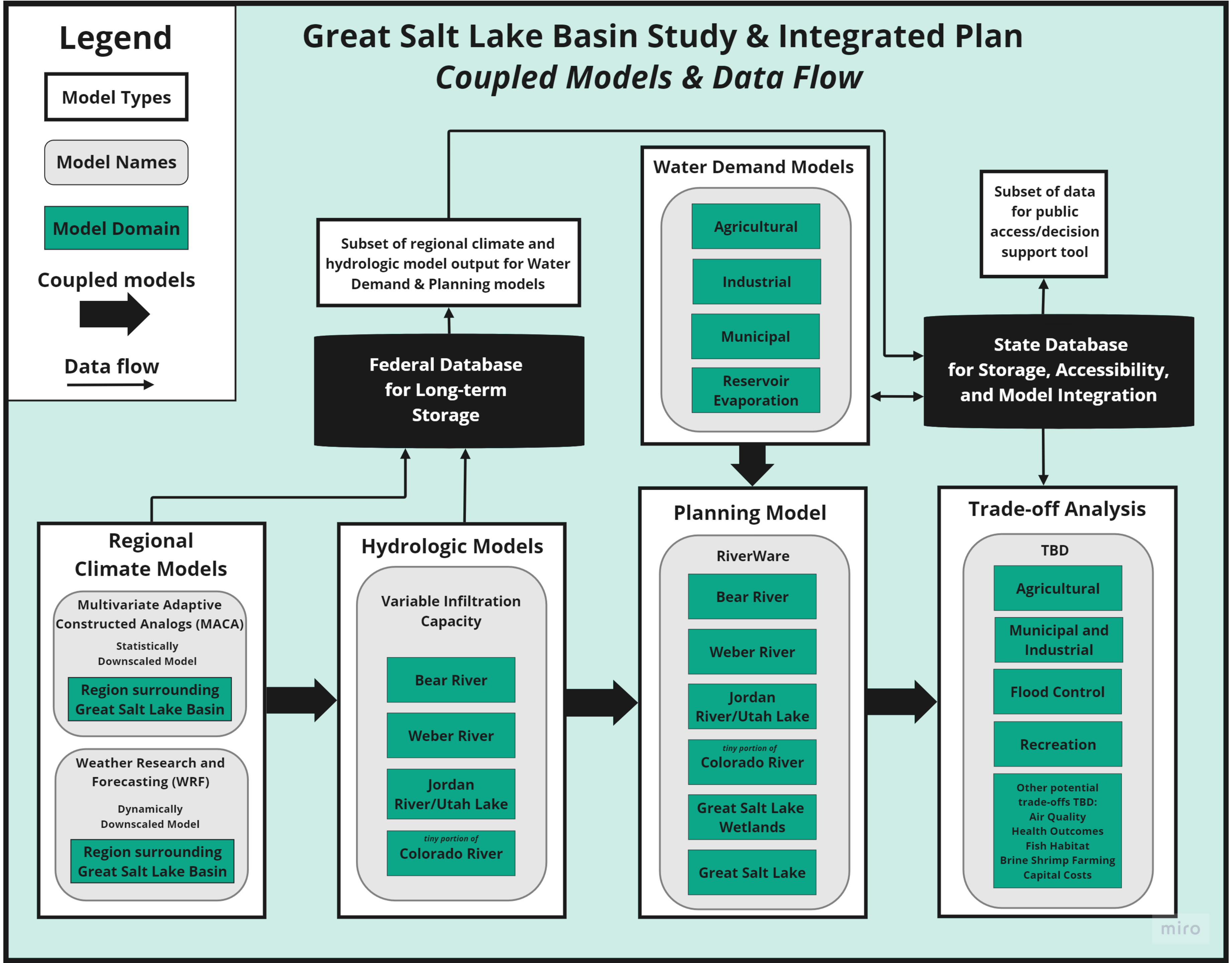
Regional Climate Model | Hydrology Model | River Planning Model



Gridded | Gridded & routed | Network-based, object-oriented

Subwatersheds

- Bear River
- Weber River
- Jordan/Utah Lake
- Upper Strawberry Lake/ Duchesne River Basins
- (Great Salt Lake)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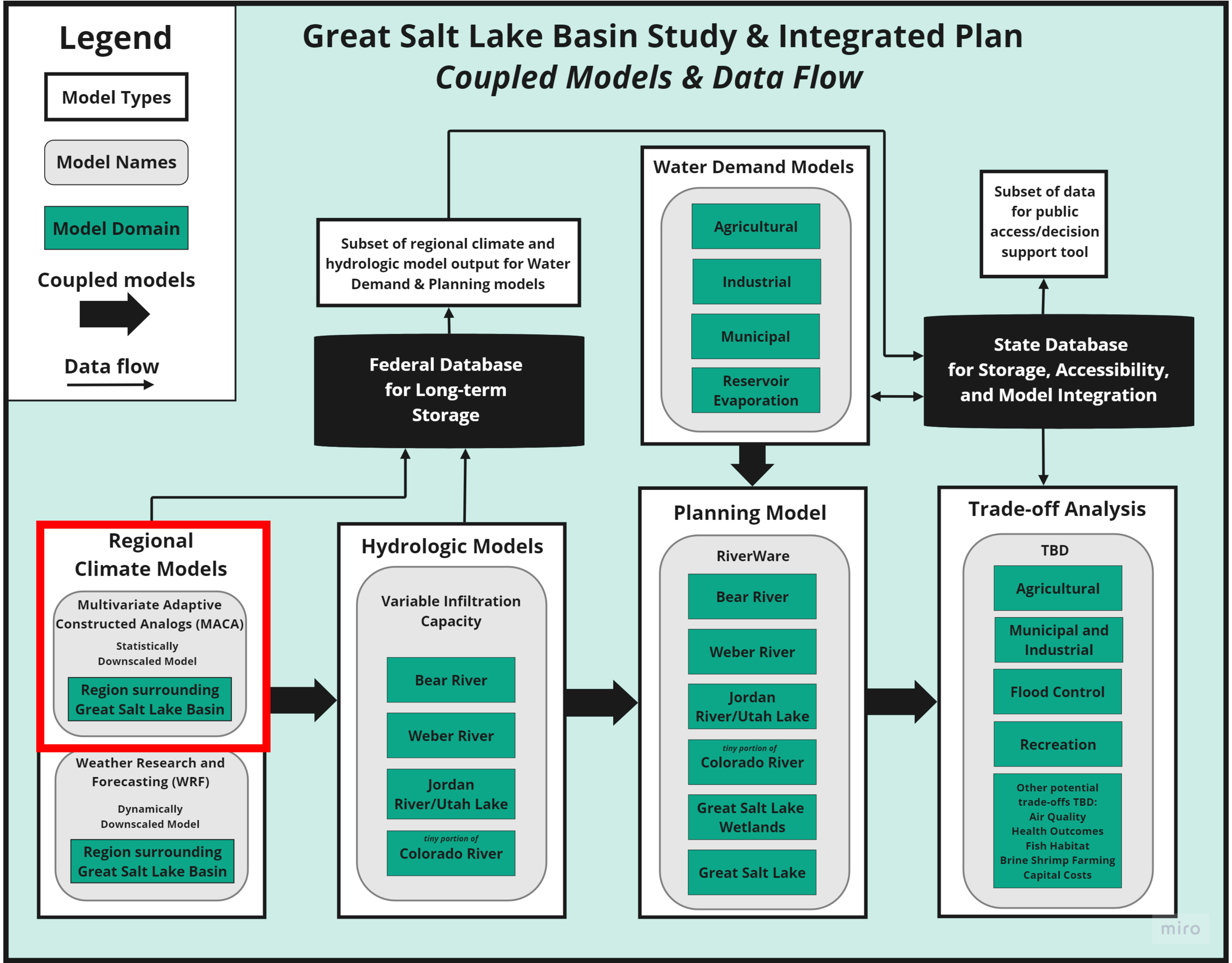
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miro

Climate Model: MACA

Meteorological surface variables

- From Coupled Model Intercomparison Project Phase 6 (**CMIP6**) multi-model ensemble
  - Historical: 27 (# of models)
  - Projected: 101 (Model + Shared Socioeconomic Pathways)
- **Regionally downscaled**
- Method: Multivariable Adaptive Constructed Analog Version 2 (**MACAv2**)[1, 2]
  - Epoch adjustment, quantile mapping, constructed analogs
  - Process based on GridMET, historical high-spatial-resolution (1/24th) data set (1979-present)

Seven Variables

- Precipitation
- Temperature (min and max)
- Relative humidity
- Solar radiation
- Windspeed (u & v)

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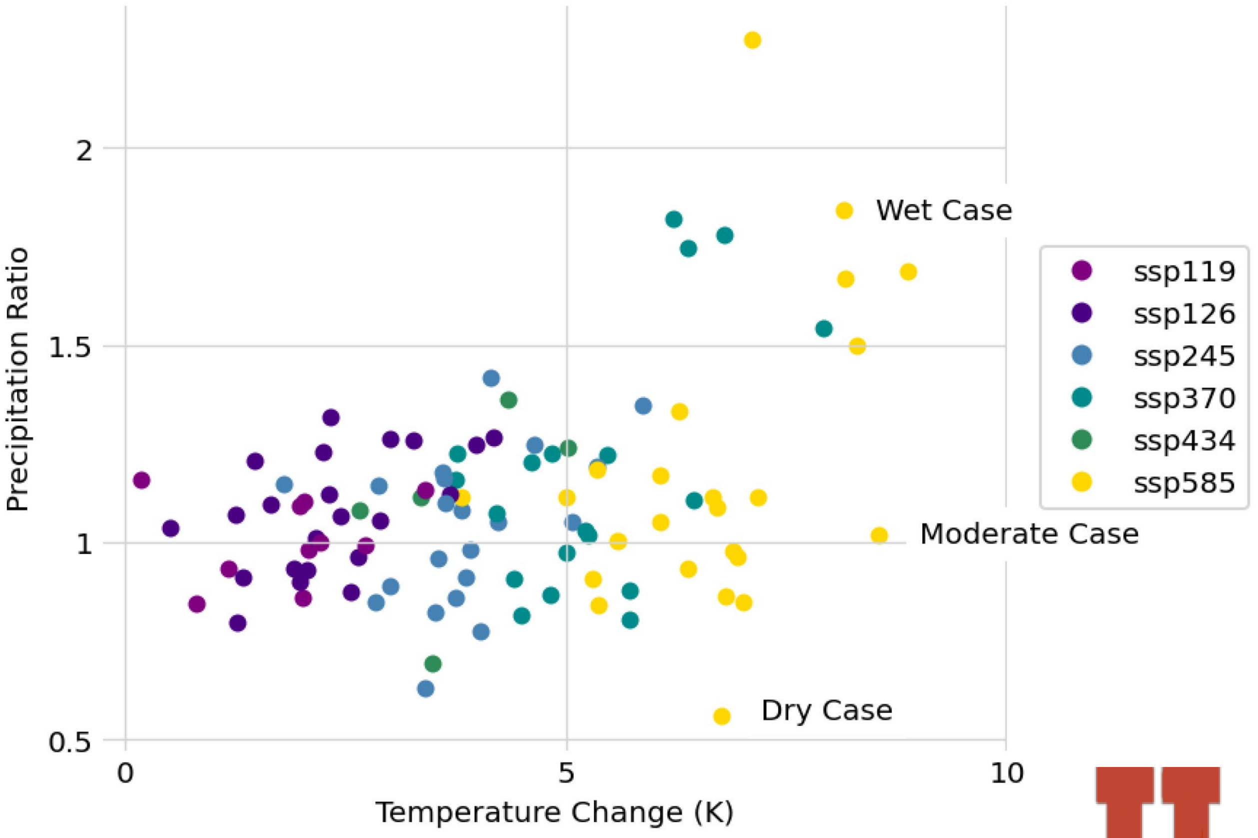
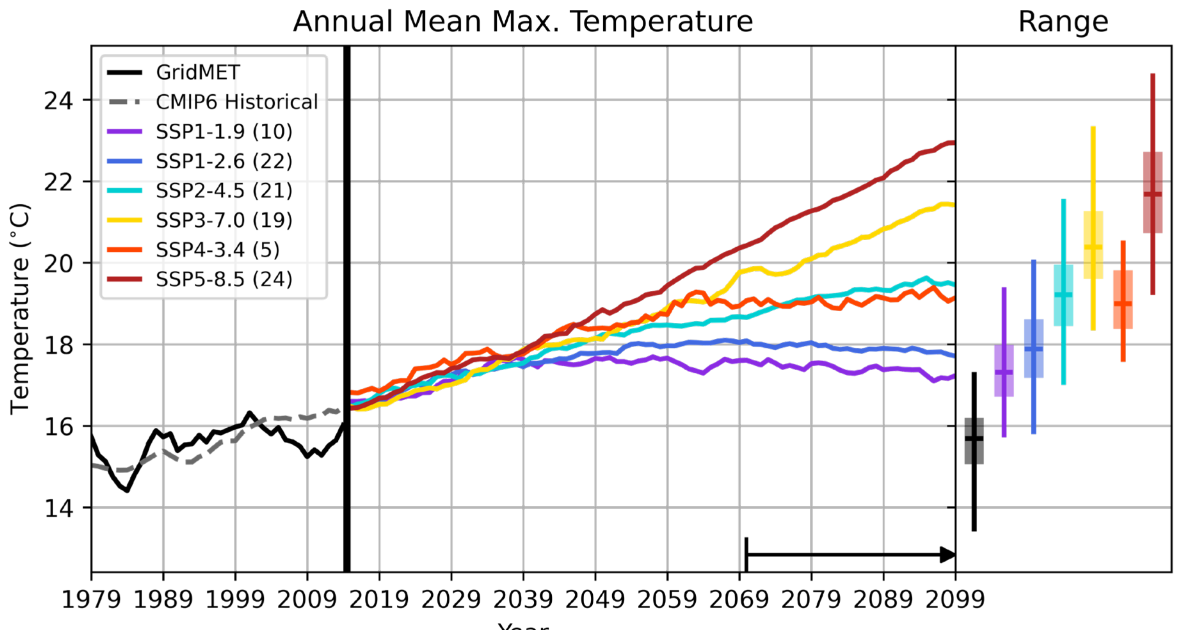
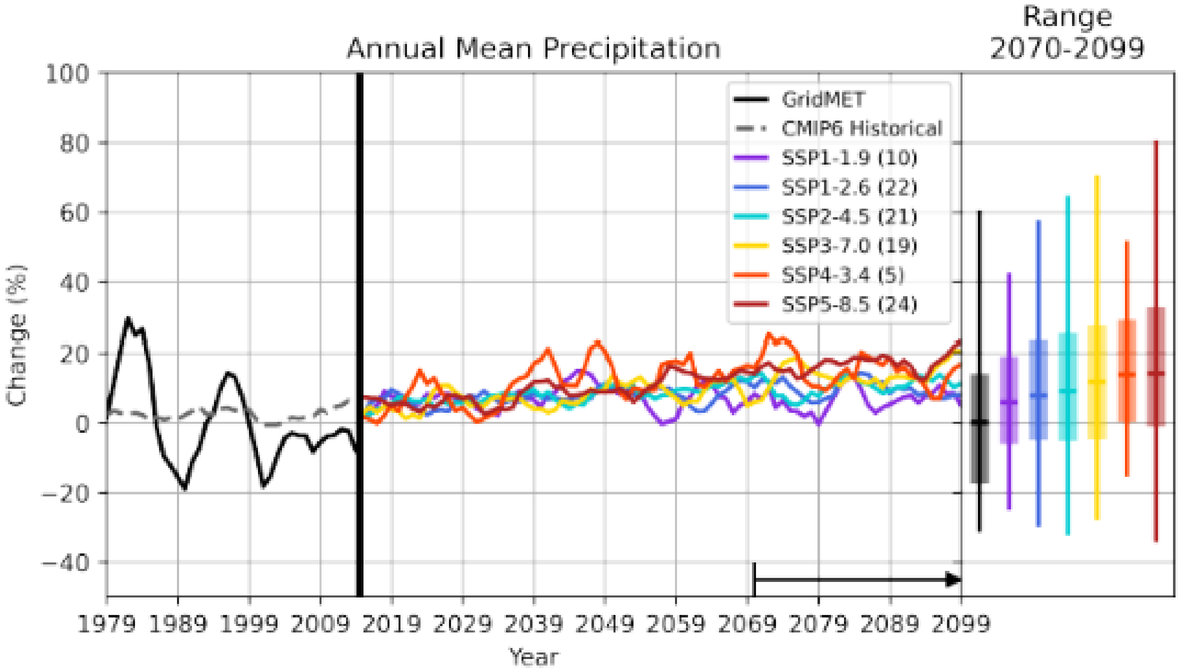
[1]Abatzoglou and Brown (2012); [2]Abatzoglou (2013)

Climate Projections

MACA Results







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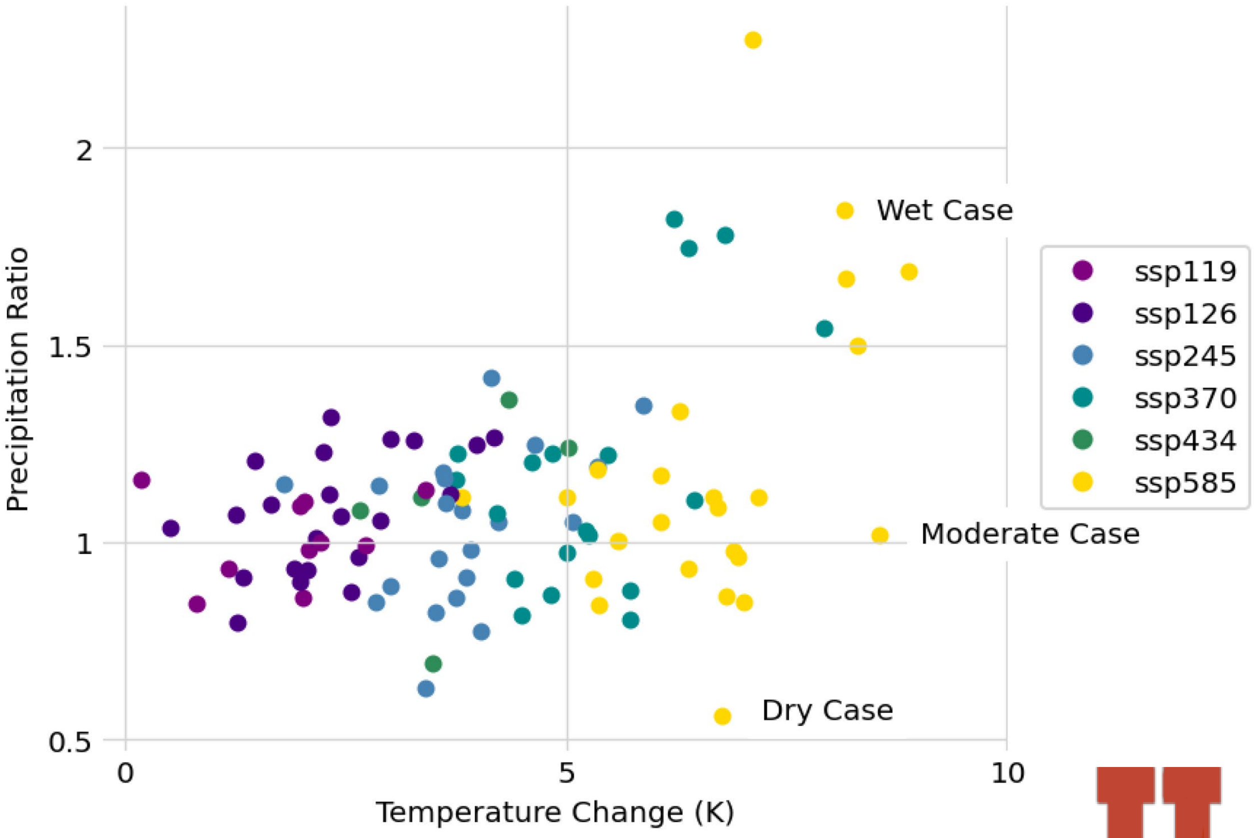
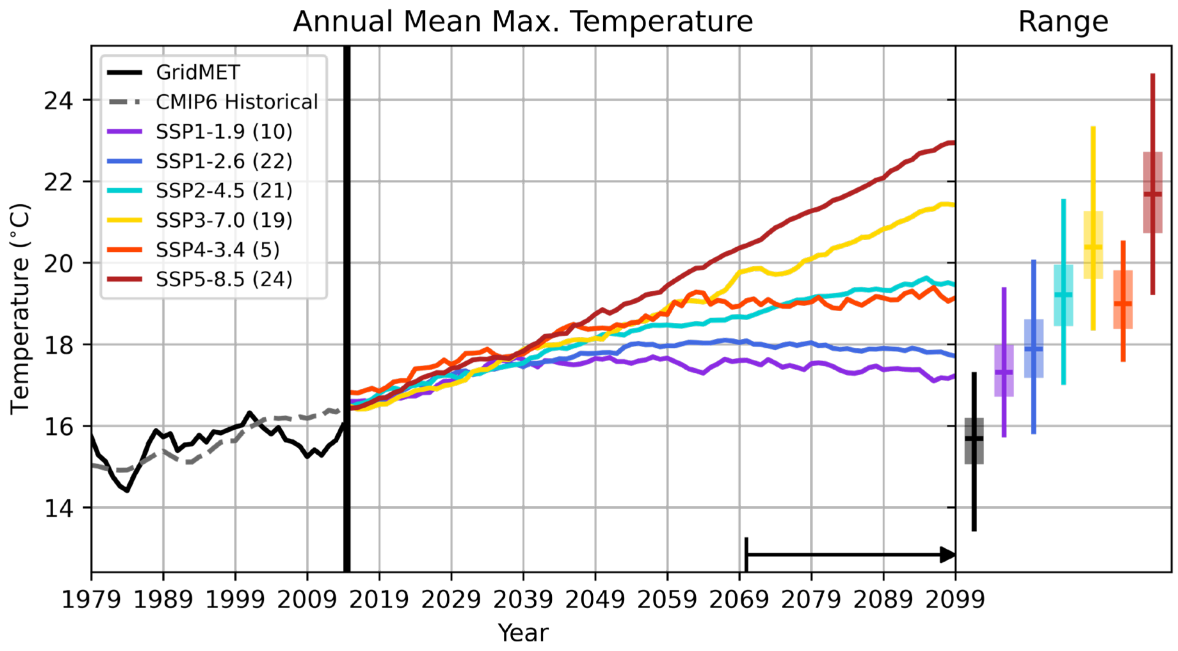
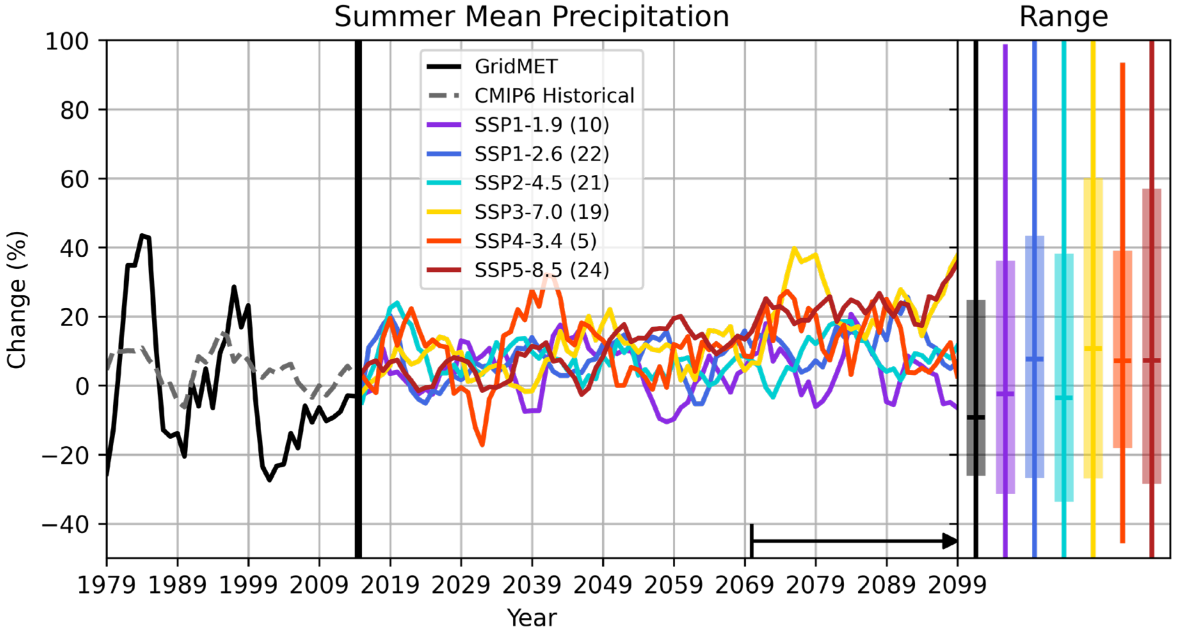
Climate Projections

MACA Results







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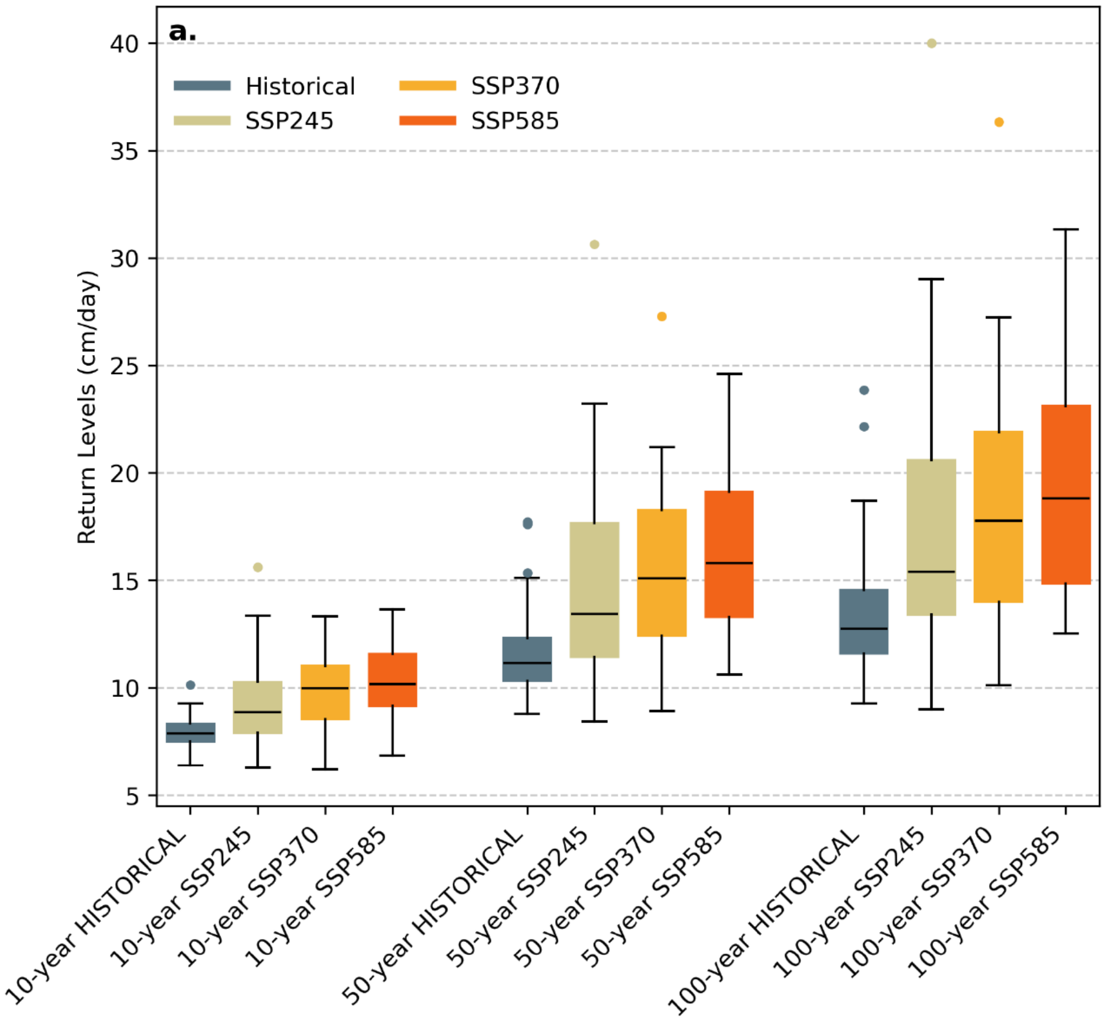
Metrics representing priority characteristics

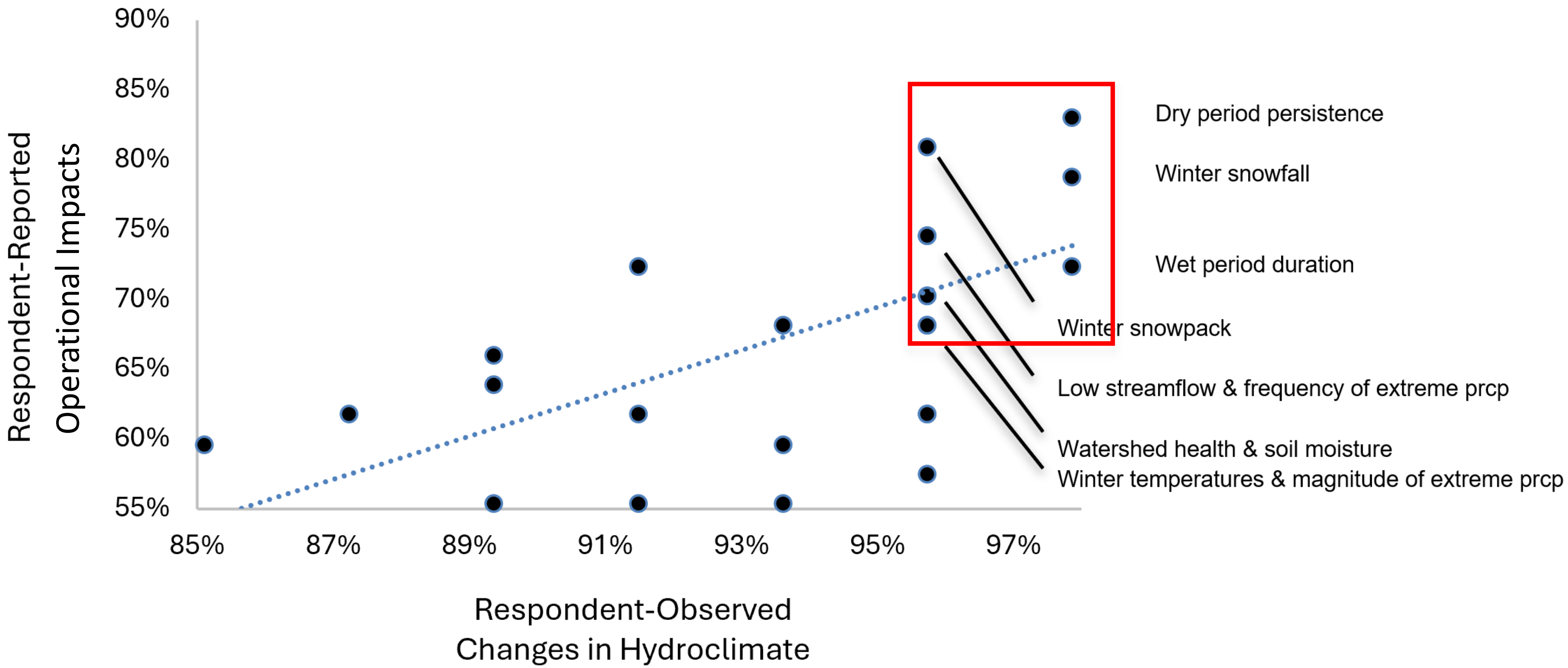


Water supply reliability

Risk mitigation

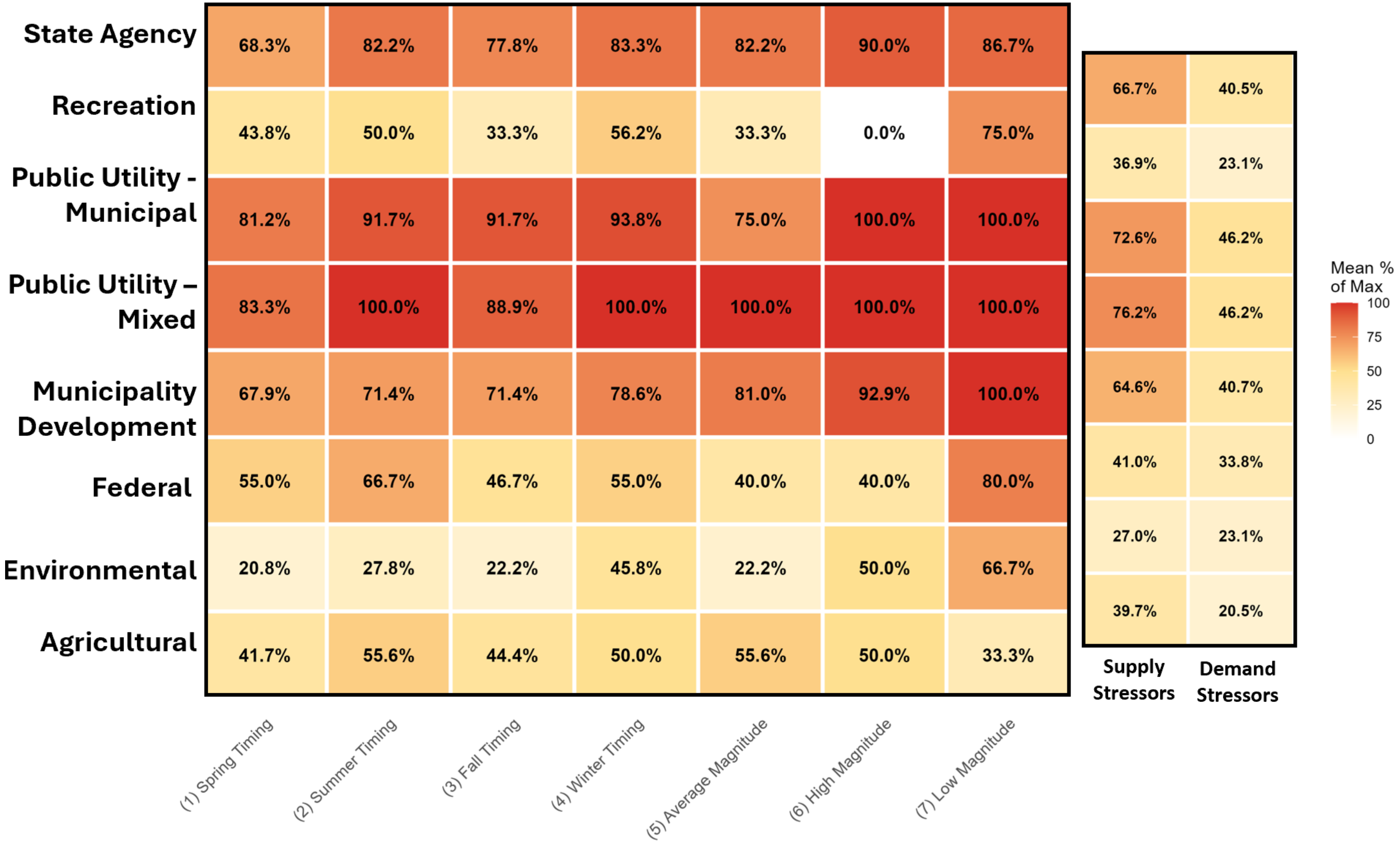
Next steps: trends, thresholds

Survey Results: Observations & operational impacts



Normalized Impact Intensity on Operations by Water User Group and Hydroclimate metrics

Percent of available hazards selected



Identifying priority metrics

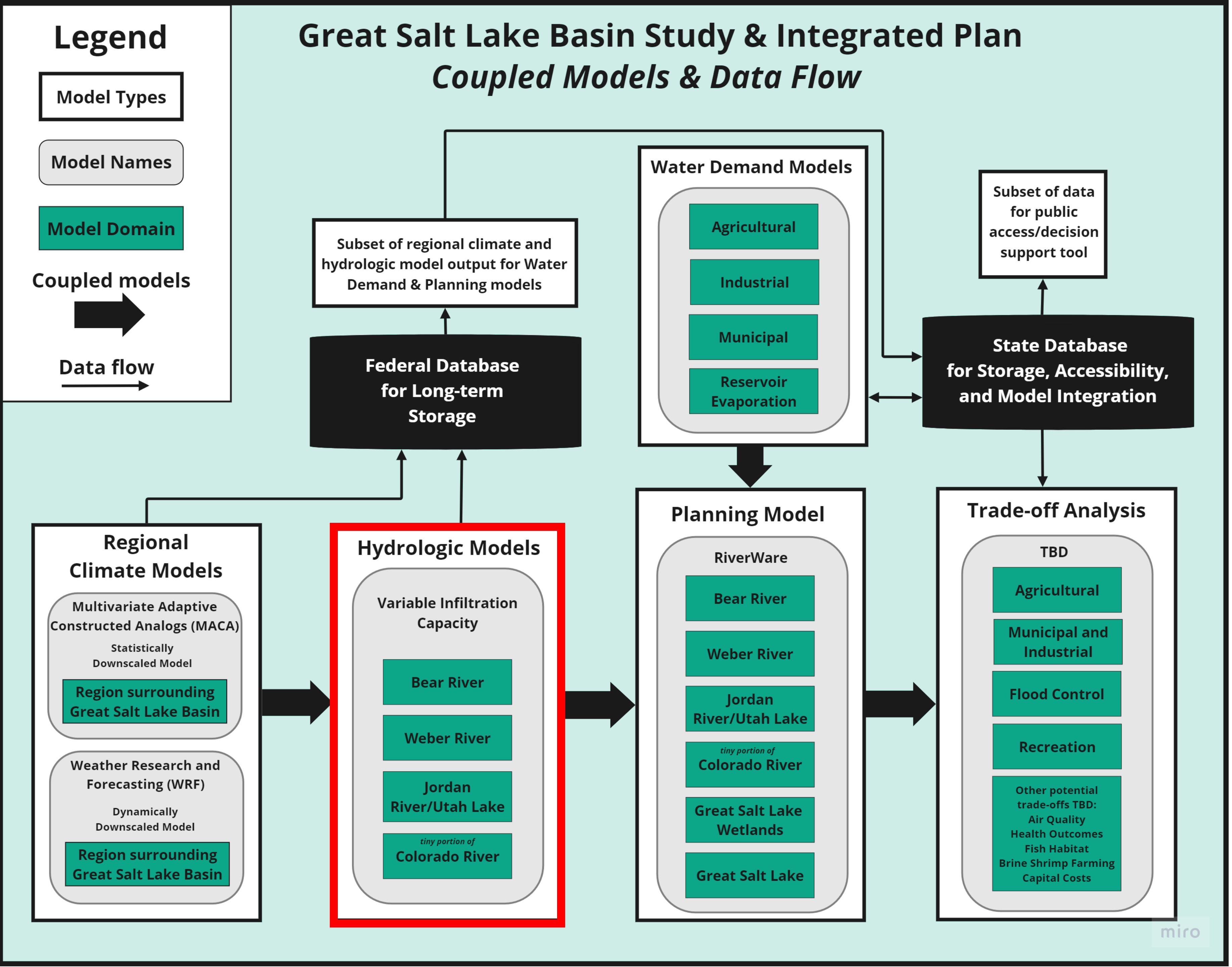
Respondents' perceptions of operational impacts related to hydroclimate metrics

Priority Climate projections & characteristics

1. “Business-as-usual” baseline
2. Hottest case - MIROC6, SSP585 (extreme)
3. Hot with dry summers – MPI-HR, SSP585 (high-stress, low-precipitation future)

Other priorities identified in survey and other analyses:

- Streamflow dynamics (early-season run-off, water stress)
- Snow (larger percentage of precipitation falling as snow)
- High variability scenario
- North American Monsoon (summer extreme but rare events)
- Multi-year droughts (extreme but rare events)
- Rain-on-snow precipitation events



NEXT UP:

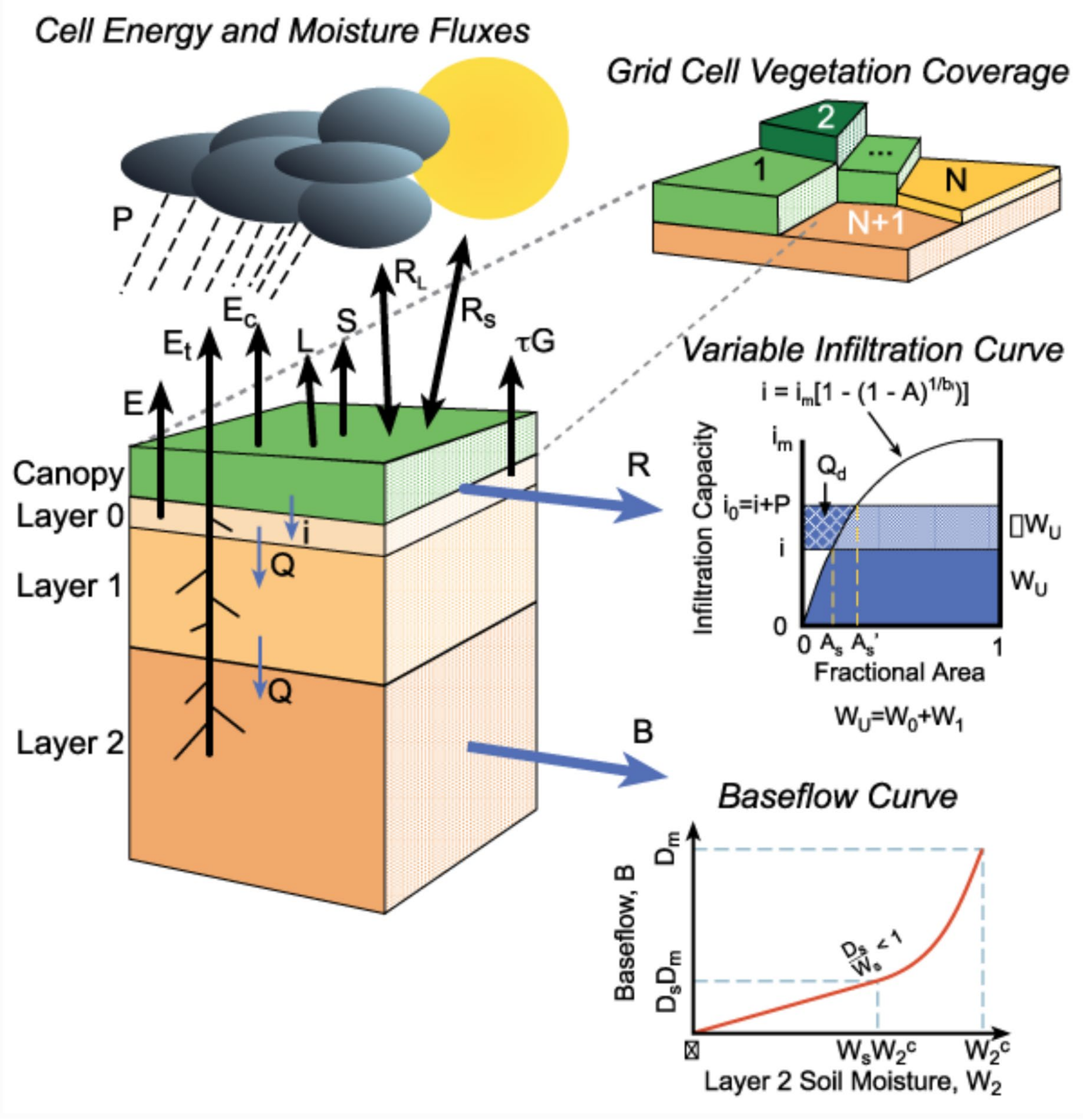
Characterizing the streamflow characteristics of projections

Informing hydroclimate projections by hydrology metrics, trends, and thresholds

Hydrology Model

Variable Infiltration Capacity (VIC)

- Large-scale, semi-distributed hydrologic model
- Naturalized flow model which assumes there are no diversions
- No communication between grid cells
- Inputs are time series of sub-daily meteorological drivers
- Routing of stream flow is performed separately from the land surface simulation



Hydrology Model

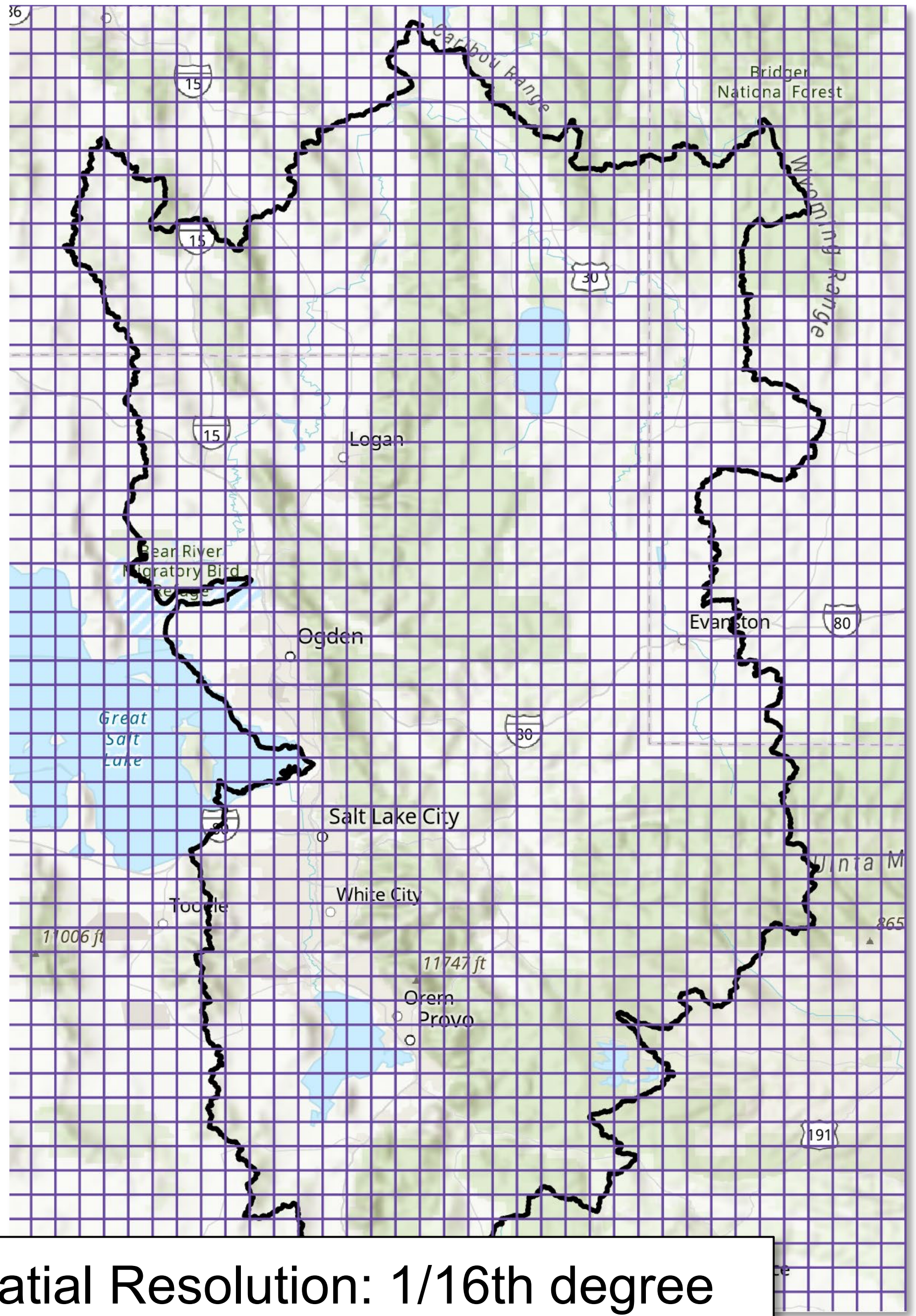
Variable Infiltration Capacity (VIC)

Input

- Historical period: GridMET (1979-2024)
- Projections: MACA downscaled CMIP6 projections (1979-2099)
- Daily temperature (max & min), precipitation, snow water equivalent, wind speed, solar radiation, vapor pressure, and more
- Vegetation input LAI, land surface cover, soil parameters (Bohn and Vivoni, 2019)

Output

- Baseflow, soil moisture, ET, snowfall, rainfall
- Routed streamflow at point locations



Spatial Resolution: 1/16th degree

Hydrology Model

Modeling Process

gridMET/ MACA

Gridded, daily meteorological data

- Precipitation
- Minimum temperature
- Maximum temperature
- Wind speed

MetSim

Disaggregated to 3-hourly data

- Precipitation
- Air temperature
- Shortwave radiation
- Longwave radiation
- Vapor pressure
- Air pressure
- Wind speed

VIC

Input disaggregated data into VIC

- Runoff
- Baseflow
- Soil moisture
- Evaporation
- SWE

mizuRoute[1]

Input gridded baseflow and runoff

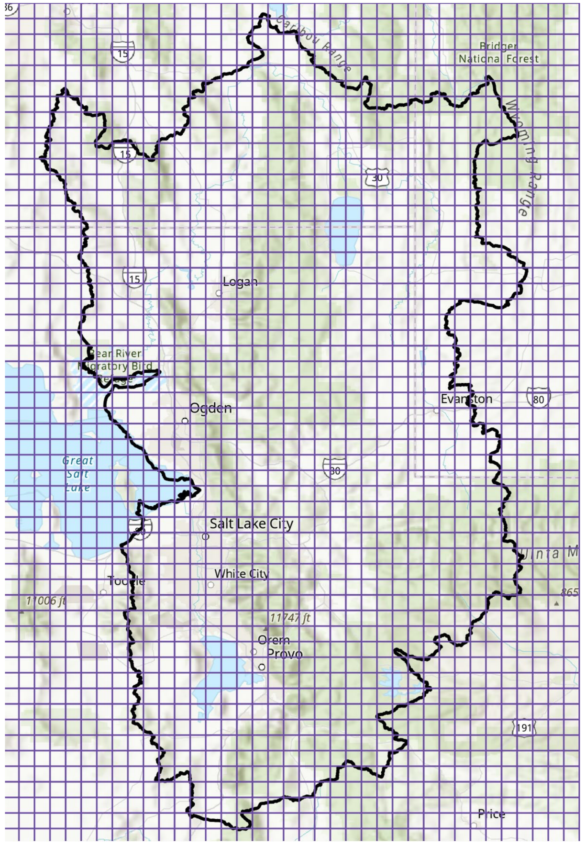
- River network
- Routed streamflow at point locations

[1]*Mizukami, 2016*

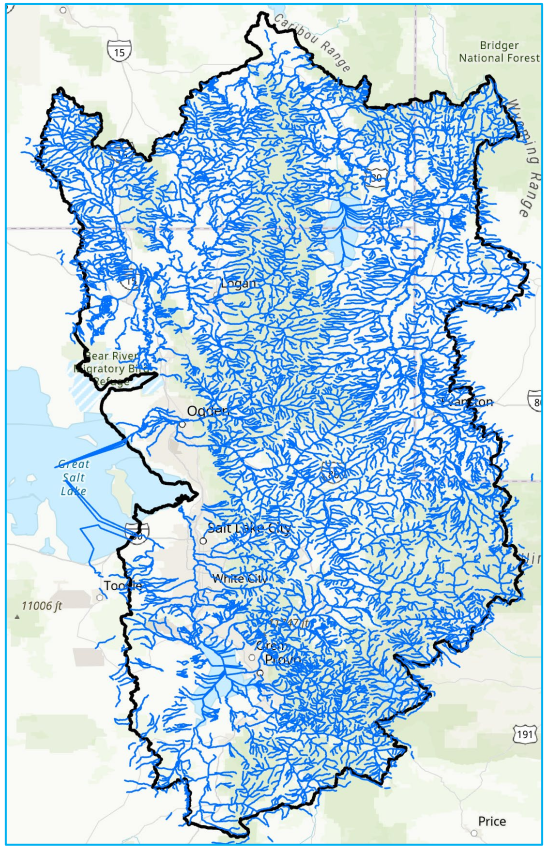
Hydrology Model

Routing Network

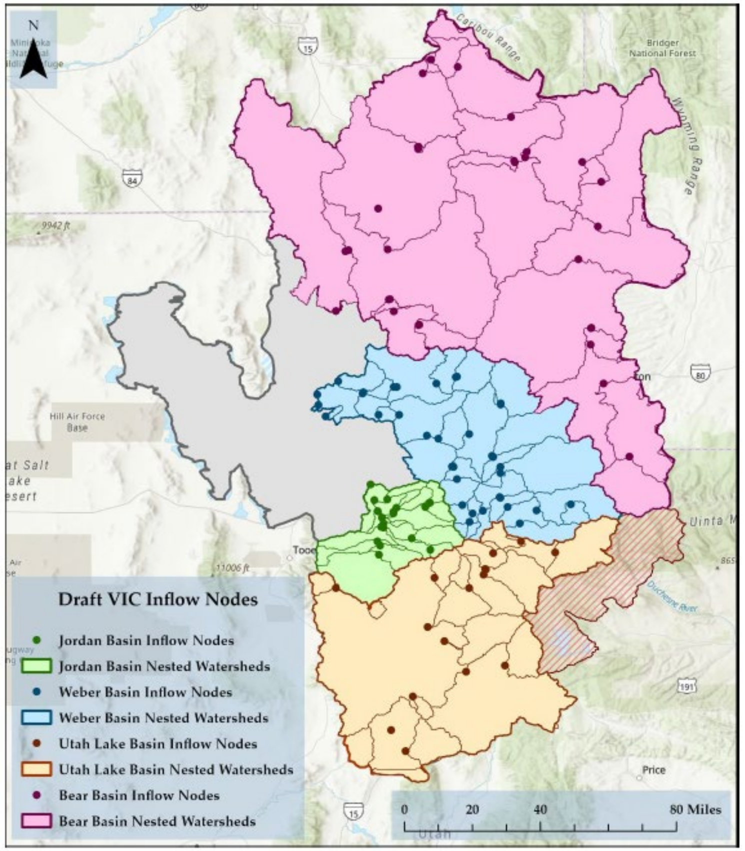
Hydrology Model Grid



Hydrology Model Routing



River Planning Model



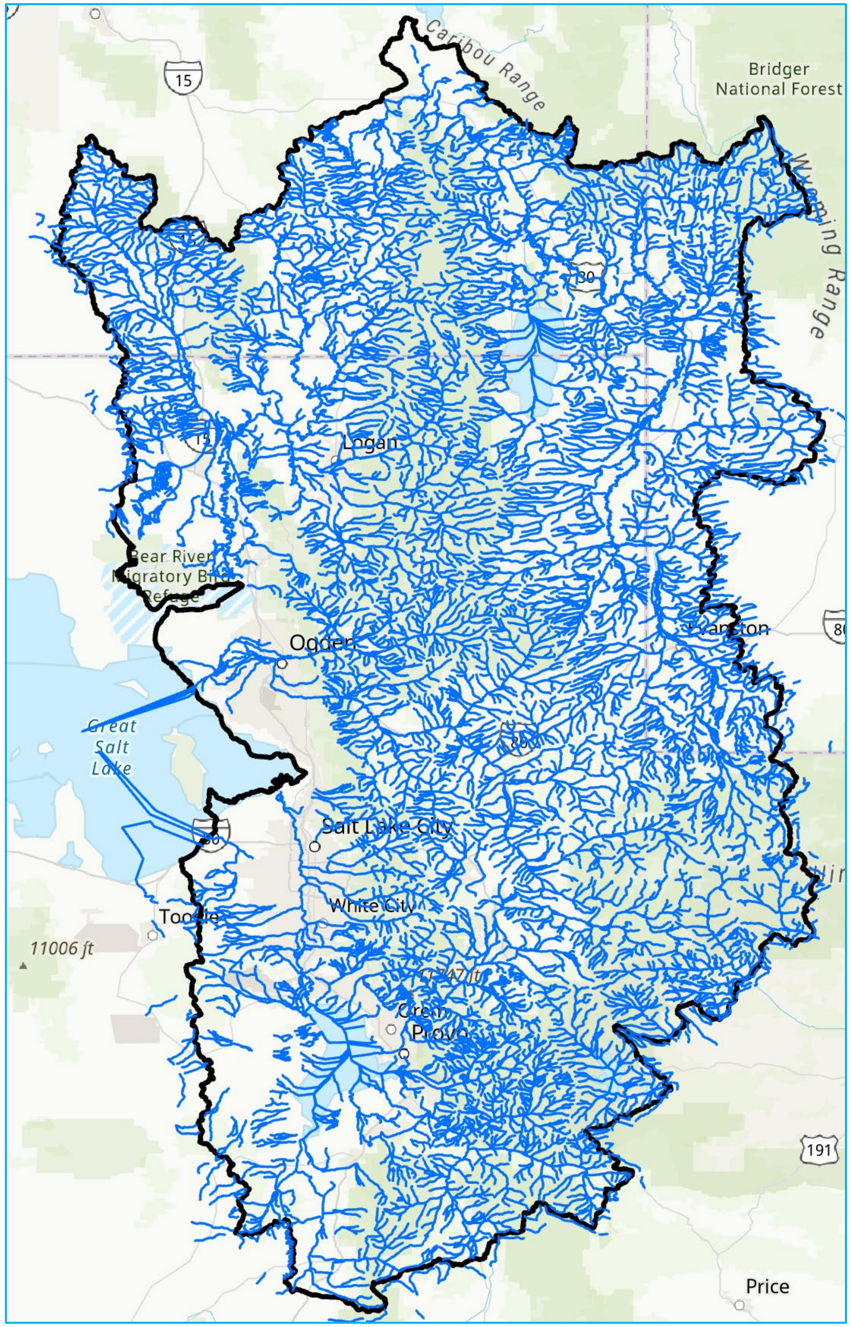
Subwatersheds

- Bear River
- Weber River
- Jordan/Utah Lake
- Upper Strawberry Lake/ Duchesne River Basins
- (Great Salt Lake)

VIC streamflow will be input to RiverWare at specific nodes

MACA-VIC–RiverWare Model Coupling

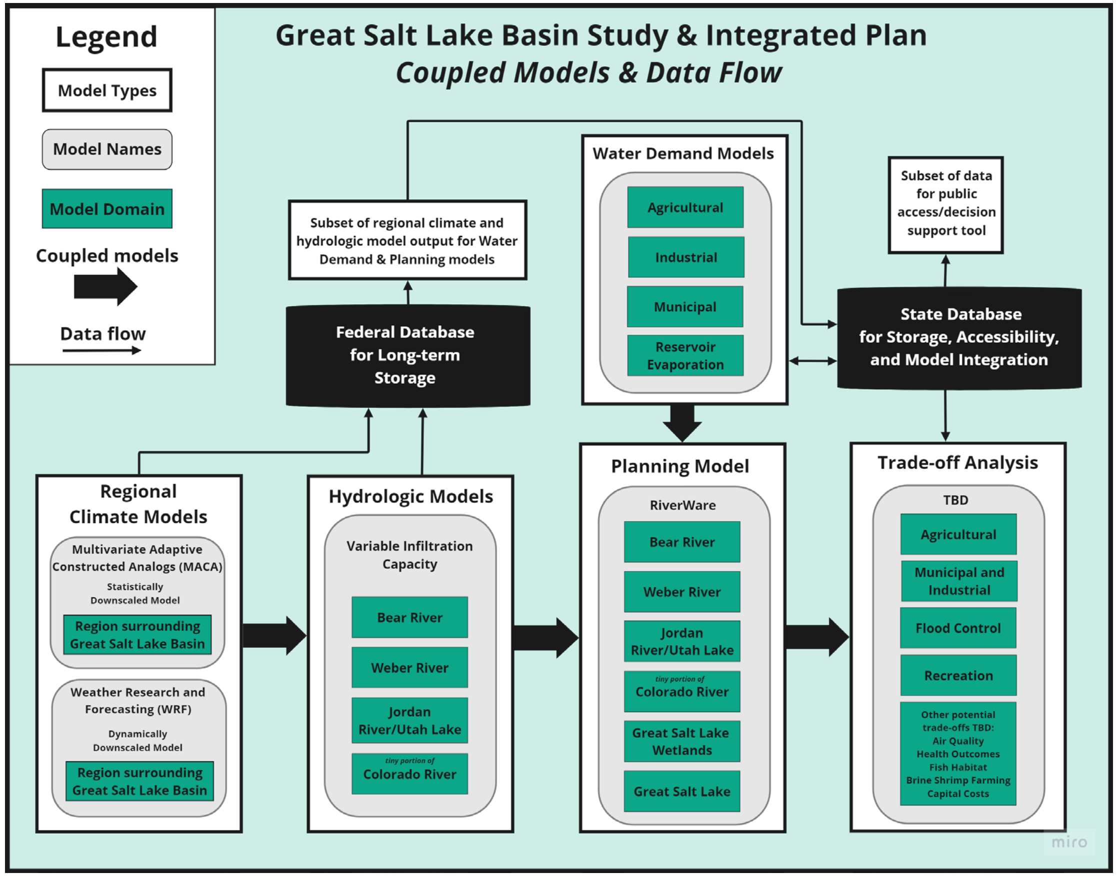
- MACA + VIC **outputs** provide climate and hydrologic **inputs** to the RiverWare planning model
- VIC river network and routing files shared to maintain **consistency** between VIC and RiverWare
- VIC grid and hydrography GIS layers shared to **support spatial alignment** and modeling decisions
- **Nested watershed delineations** and **RiverWare nodes** shared to guide VIC streamflow calibration and avoid double-counting

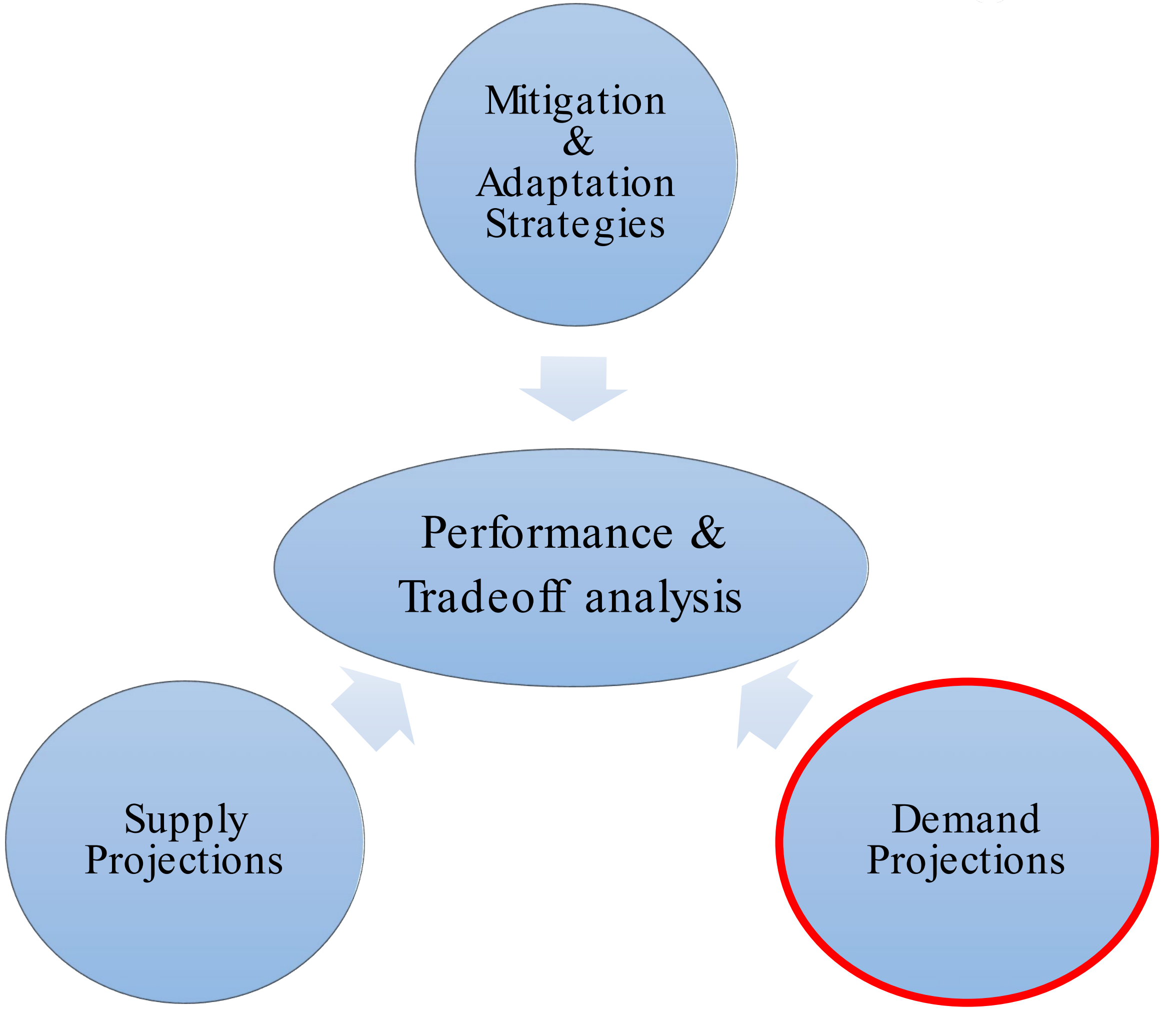


Hydroclimate projections spanning uncertainty space

Scenario Type	Projection	Description
S1: Middle-of-the-road	SSP2, specific projection TBD	Warmer, but not extreme, similar annual precipitation totals
S2: Hot with dry summers	MPI-HR, SSP585	High temperatures year-round, particularly in summer, low precip in summers
S3: Hottest case	MIROC6	Extremely hot future; large percent of precipitation falling as rain; early snowmelt, later summer water stress
S4: North American Monsoon signal	SSP5 or SSP3, specific projection TBD	Summer extreme precipitation events rare, but present; prone to flooding
S5: High P&T variability	TBD	Back-to-back extremes in precipitation; important for reservoir fill and release strategies

Demand Models & Projections





Water Demand Models

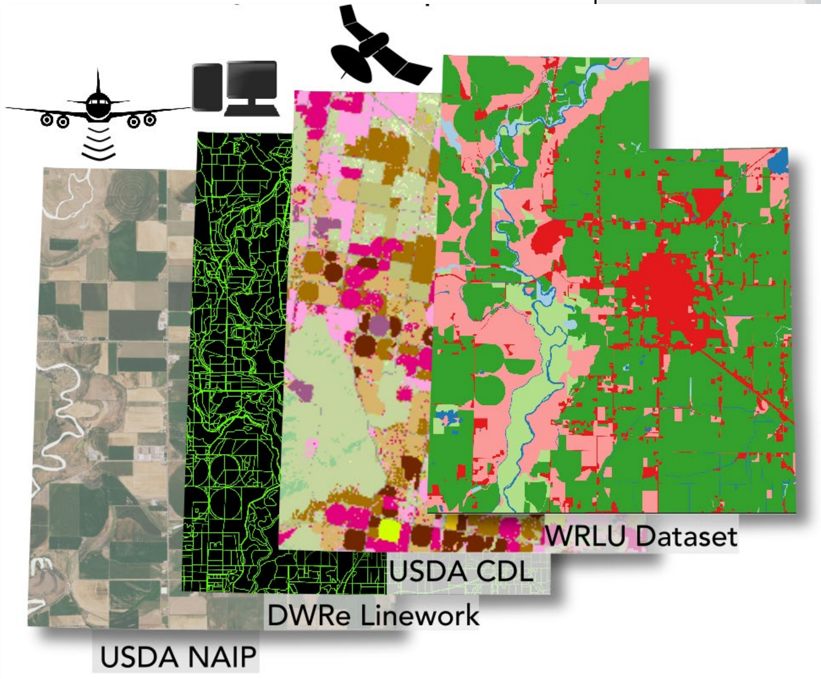
Purpose: *Provide **diversions** and **depletions** for agricultural and municipal water users objects in RiverWare*

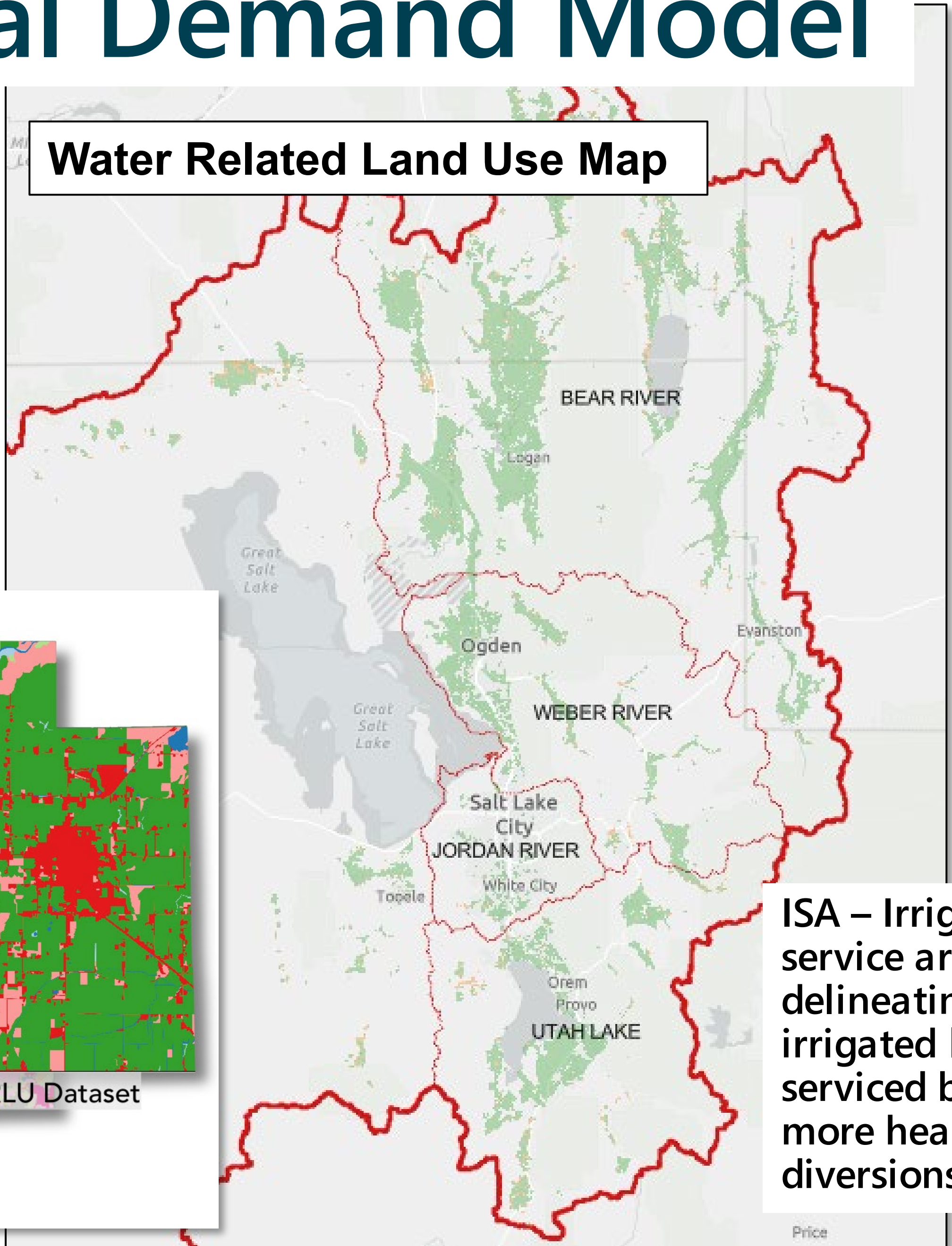
- Agricultural Demand Model
- Municipal and Industrial Model

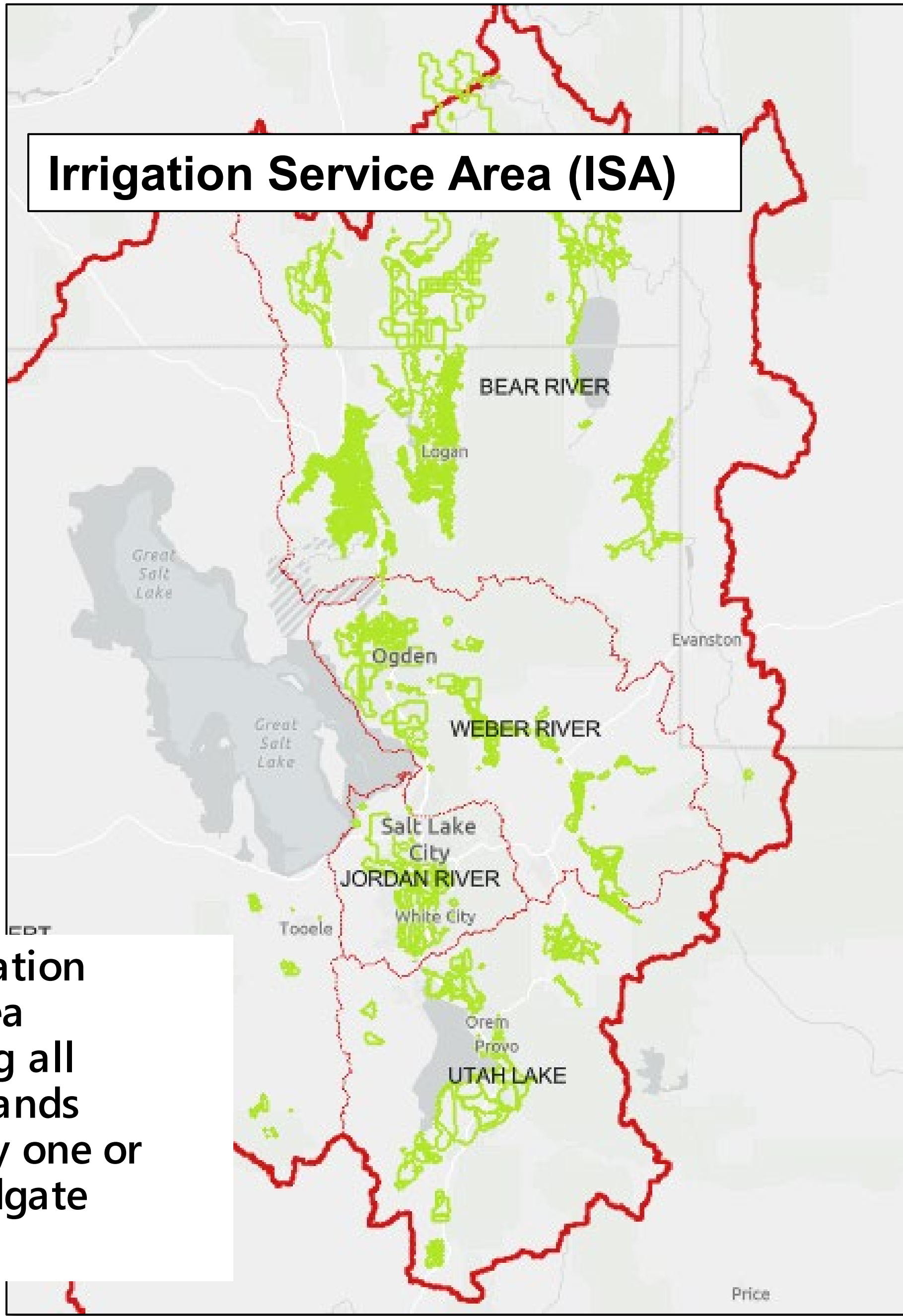
Agricultural Demand Model

$$Diversion_{Ag} = \frac{\sum ET_{crop}}{e_f e_c}$$

*ET_{crop} – ET ref * crop coefficient*
e_f – mean on-farm irrigation efficiency in an ISA
e_c – system conveyance efficiency







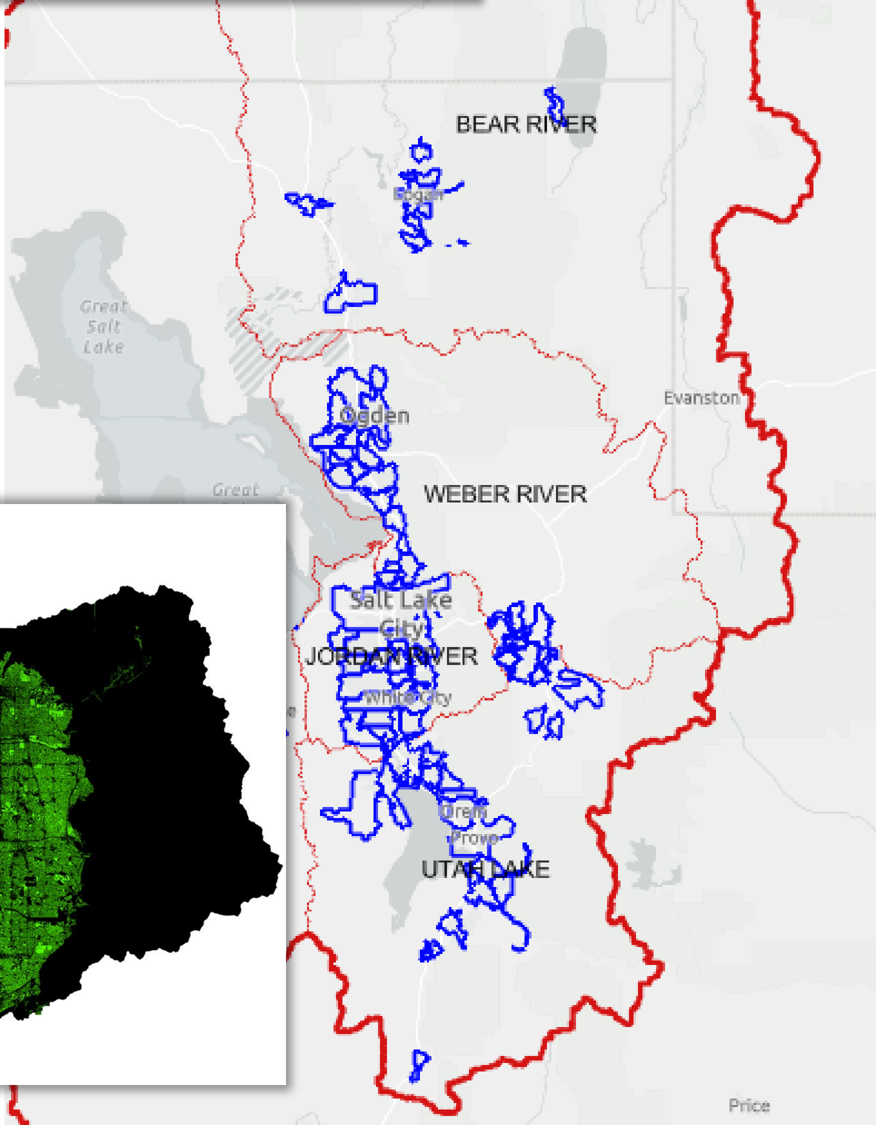
ISA – Irrigation service area delineating all irrigated lands serviced by one or more headgate diversions

Municipal & Industrial (M&I) Demands

- Estimate **indoor** and **outdoor M&I demands** separately using population, indoor water-use rates, and remotely sensed irrigated green space and evapotranspiration.

- **Map** and **validate** outdoor irrigated areas using NAIP imagery and NDVI, summarized by municipal/public water-system service areas.

- **Translate** demands into **diversions** and **depletions** by accounting for irrigation efficiency, system losses, return flows, and available supplies



Next steps

State
- Finalize water demand projections

State + Reclamation
- Ensure structural consistency between demand and supply projections

State + Consultants
- Complete the Demand Model–RiverWare handshake and data transfer framework

Reclamation
- Finish VIC calibration and incorporate streamflow into hydroclimate metrics and trends
- Define risk metrics and thresholds for vulnerability and trade-off analyses
- Conduct trade-off analysis across water users and ecosystems to identify constraints, vulnerabilities, and key trade-offs

Consultants
- Complete RiverWare model development and calibration
- Identify future supply–demand imbalances

All
- Finalize five representative scenarios, integrating VIC streamflow projections with water-demand conditions
- Connect adaptation strategies to scenarios and evaluate exposure and vulnerability across water-use sectors

Summary & Lessons learned

Steps

- Alternative management strategies
- Supply scenarios
- Demand scenarios
- Evaluation of performance, risk and trade-offs

Lessons Learned (so far!)

- Coordination of data and data sharing is critical
- Technical sufficiency review has been helpful for alignment and time-intensive
- Congruent timelines are a challenge and an opportunity
- Ongoing communication is a must

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