Scoping Plan for the Water Resources Planning Tool

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Utah Division of Water Resources
Great Salt Lake Basin Integrated Plan
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Jacobs Engineering Inc.

6440 S. Millrock Drive
Suite 300
Holladay, UT 84121
United States

T +1385.474.8500
F +1.916.920.8463
www.jacobs.com

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Acronyms and Abbreviations

DWR	Division of Wildlife Resources
GSL	Great Salt Lake
GSLBIP	Great Salt Lake Basin Integrated Plan
GSLIM	Great Salt Lake Integrated Model
H.B.	House Bill
JBRPM	Joint Bear River Planning Model
M&I	municipal and industrial
RAPID	Routing Application for Parallel Computation of Discharge
Reclamation	U.S. Bureau of Reclamation
USGS	United States Geological Survey
VIC	variable infiltration capacity
WBM	Utah Division of Water Resources Water Budget Model
WeberSim	Weber River Simulation Model
WRe	Utah Division of Water Resources

1. Introduction

The Great Salt Lake (GSL) is the largest saline lake in the Western Hemisphere. The continued decline of its water levels is threatening billions of dollars in economic activity, a globally important ecosystem, local public health, air quality, and other critical values that the lake supports, including the lake's essential contribution to the Wasatch Mountains' regional water cycle through lake effect precipitation. The local, regional, and hemispherical importance of the lake requires a Great Salt Lake Basin Integrated Plan (GSLBIP) to build and promote an improved understanding of the changing watershed conditions through a platform of knowledge that enables buy-in from stakeholders at the watershed scale down to the individual water user.

The development of a revised GSL water budget is included in the GSLBIP, which will assess current and future water supplies and demands, and evaluate actions to provide a reliable water supply for human, agricultural, and ecological needs while sustaining GSL levels. The water budget is a scenario planning tool (hereafter referred to as the GSLBIP Water Resources Planning Tool, to differentiate from existing Utah Division of Water Resources [WRe]'s Water Budget Model [WBM]) which will strive to incorporate the past work of the GSL watershed stakeholders and include the latest available data and science to build a trusted screening tool that supports the ongoing decision-making process for a sustainable GSL.

This Scoping Plan summarizes the development process of the GSLBIP Water Resources Planning Tool and its application in the GSLBIP. This document also includes details regarding the development steps completed to date and steps yet to be completed. The development steps that are yet to be completed serve as a roadmap to inform next steps in 2024 and beyond.

2. Background

House Bill (H.B.) 429 from the 2022 Legislative General Session (Legislature 2022) laid out the initial requirements for development of a work plan and implementing an integrated water assessment. The GSLBIP was initiated to combine the collective efforts and requirements of parallel programs, including the integrated assessment under H.B. 429, the Basin Study funded under a WaterSMART grant awarded by the U.S. Bureau of Reclamation (Reclamation 2023), the United States Geological Survey (USGS) and Utah Geological Survey's ongoing work on the Great Salt Lake Regional Flow Model, and the Great Salt Lake Recovery Act, a program carried out by the U.S. Army Corps of Engineers.

The GSLBIP will be completed through collaboration between the WRe and Reclamation, under the oversight of the Great Salt Lake Commissioner, and in partnership with numerous federal and non-federal partners, a GSLBIP advisory committee, a GSLBIP steering committee, and five river basin watershed councils.

3. Water Resources Planning Tool Development Process

The GSLBIP Water Resources Planning Tool development process meets the requirements of H.B. 429 and Reclamation's Basin Plan, supports rapid development of an initial tool that provides scenario planning capability (near-term), allows for the tool to evolve with time, incorporating model components as they are developed throughout the GSLBIP project timeframe (midterm), and supports development of a comprehensive model that is not limited by time constraints to best inform water supply and demand performance (long-term). This development process includes the following steps:

- **Completed Development Steps**

1. Identify practical modeling approaches given the tools currently available and GSLBIP requirements.
2. Formulate modeling approach selection criteria.
3. Evaluate practical modeling approaches against selection criteria.
4. Select near-, mid-, and long-term modeling approaches based on evaluation results.

- **Development Steps To Be Completed**

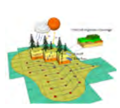
5. Develop scenarios to support answering the key questions required by H.B. 429 and Basin Study.
6. Select components that support the modeling approach, which may be existing or require development, and may include supporting models, creation of a central database of input datasets, and supporting computation modules required for the projections of water supply and demand and system performance evaluation. This selection will use a secondary evaluation of criteria as needed to complete component selection.
7. Update or develop Water Resources Planning Tool components to support simulation of scenarios.
8. Develop scenarios performance criteria and post-processing approach.
9. Conduct scenario simulations and results analysis.
10. Develop adaptation and mitigation strategies.
11. Perform trade-off analysis.
12. Conduct technical sufficiency review.

4. Water Resources Planning Tool Development – Work Completed to Date

4.1 Identification of Modeling Approaches

Identification of modeling approaches to be evaluated against GSLBIP Water Resources Planning Tool requirements was performed through a series of workshops, attended by members of the WRe staff and Jacobs project team, during which a compilation of existing models and algorithms informed the process of identifying relevant models. Each modeling approach presented herein is a combination (or a standalone) of the components listed in Table 4-1.

Table 4-1. Descriptions of Model Components

Model Component	Description
 	▪ **Watershed Water Balance—**The GSLIM is WRe's water balance integrated model of the GSL watershed developed in the general system dynamics modeling platform GoldSim.[a] GoldSim is a Monte Carlo simulation software used to dynamically model complex systems. The GSLIM model allows for modeling of future scenarios, including changes in climate, operations, and water demand. It is divided into the following three different modules to facilitate integrating existing data, which can be used as standalone modules: - **GSLIM River Basins Module—**Each river basin (Bear, Weber, and Jordan Rivers) is represented by a separate river basin module. Inflow from each river basin has been filtered through a second module representing the wetland complexes that exist at the interface between each river and GSL. - **GSLIM Wetland Module—**This module incorporates the unique characteristics for the wetlands at the mouth of each river basin. - **GSLIM Lake Module—**This module represents the lake itself and characterizes each of the four main bays: Gilbert (South Arm), Farmington, Bear River, and Gunnison (North Arm).
	▪ **WBM**[b]**—**WRe's water budget model is used for planning purposes at the state, basin, and county level. The WBM tracks or estimates historical surface and groundwater diversion, return flow, consumptive use, yield, and natural system use for agricultural and M&I water uses. This historical information is used to formulate plans for conservation, demand reduction, repurposing of water use, interbasin transfers, and other planning activities.
	▪ **Basin Snowpack and Streamflow Models—**WRe is currently developing VIC[c] and RAPID[d] models that are loosely coupled to simulate climate change impacts on GSL watersheds. The primary goal of this ongoing modeling effort is to analyze the impact of changing temperatures and precipitation on future snowpack, streamflow, and water availability in the watersheds.
	▪ **River Basin Models—**Several river basin models have been developed for different purposes using a variety of modeling platforms or software: - **RiverWare**[e] is a river system modeling tool, a platform for operational decision-making, responsive forecasting, operational policy evaluation, system optimization, water accounting, water rights administration and long-term resource planning. There are models for the Weber River (WeberSim), Bear River (JBRPM), and Utah Lake Basin (Utah Lake/Jordanelle Exchange Model) that were developed independently and for different purposes (that is, reservoir operations rules, water exchange assessment). - **GoldSim**[f] is currently used to model the Jordan River (Jordan River GoldSim Model).
	▪ **Groundwater Models—**Several groundwater models have been developed with MODFLOW[g] in the Bear, Weber, and Jordan Rivers, but they cover only the corresponding groundwater basin. USGS is currently developing the Great Salt Lake Regional Flow Model to quantitatively model groundwater inflow to GSL on a transient basis.

Model Component	Description
	▪ **Central Database—**This component would need to be developed and include the input data required for all models that integrate the centralized database. These data may include measured or estimated historical and estimated projected input data such as: climate data (precipitation, temperature), groundwater and streamflow measurements, reservoir storage information, land use cover by type, M&I water use (including population and gallon per capita per day), agriculture water use (conveyance and on-farm efficiencies, evapotranspiration), and riparian water use. Current databases exist that could provide datasets to a central database such as WRe's Utah's Open Water Data[h] input database and the WRi's database;[i] additional data would need to be integrated as well.
	▪ **Water Management Algorithms—**This component would need to be developed if GSLIM River Basin Model is not included in the modeling approach. This component could include the assumptions and algorithms to estimate water demand, water supply usage priorities, and other criteria not included in the RiverWare models to allow for setting up variations of water demand and water supply.
	▪ **River Basin Outflow Algorithms—**This component includes river basin outflow data that can be processed through the GSLIM Wetland and Lake Modules. The outflow data include correlations between river basin outflows and variables such as land use and population to project future river basin outflows to GSL wetlands. Correlations are developed using historical supply and demand data.

[a] More information is at https://www.goldsim.com/Web/Applications/ExampleApplications/EnvironmentalExamples/GSLIM/
[b] More information is at Water Budget - Home | Utah Open Water Data (arcgis.com).
[c] Sources: Liang et al. 1994; Liang et al. 1996.
[d] Source: David et al. 2011.
[e] More information is at RiverWare--A River and Reservoir Modeling Tool.
[f] More information is at GoldSim - A dynamic Monte Carlo Simulation Software.
[g] More information is at MODFLOW and Related Programs | U.S. Geological Survey (usgs.gov).
[h] More information is at https://dwre-utahdnr.opendata.arcgis.com/.
[i] More information is at https://maps.waterrights.utah.gov/asp/wrplatGE.asp.

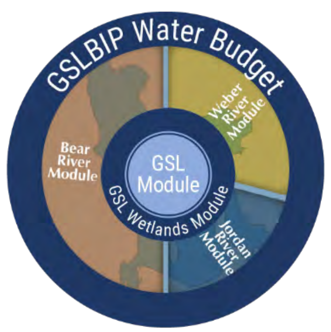
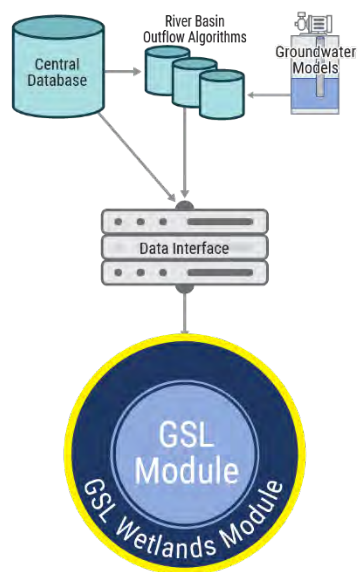
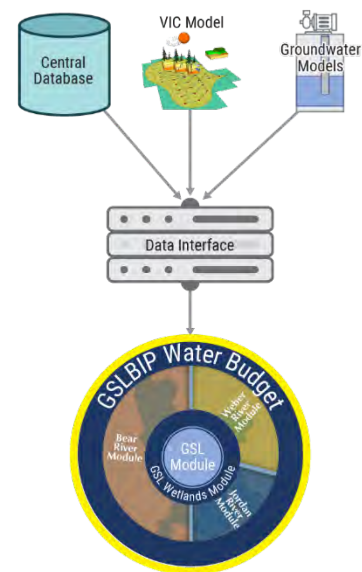
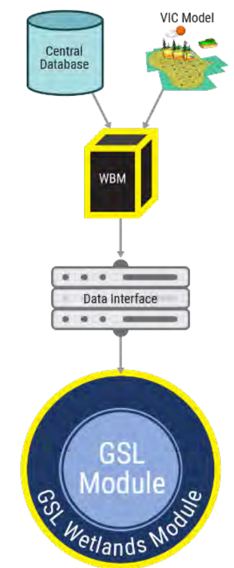
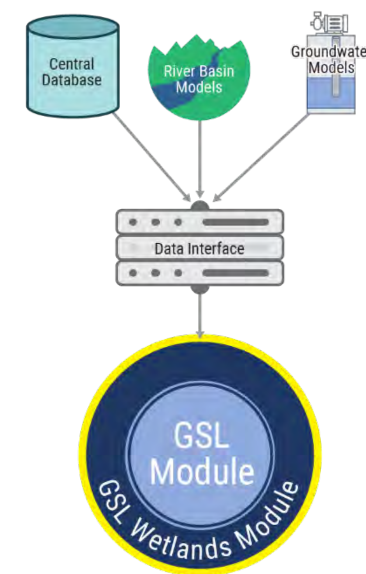
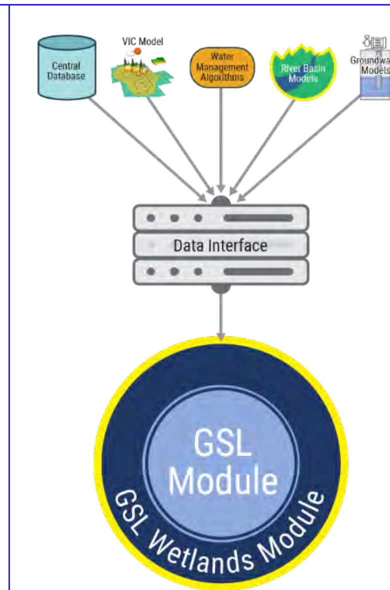
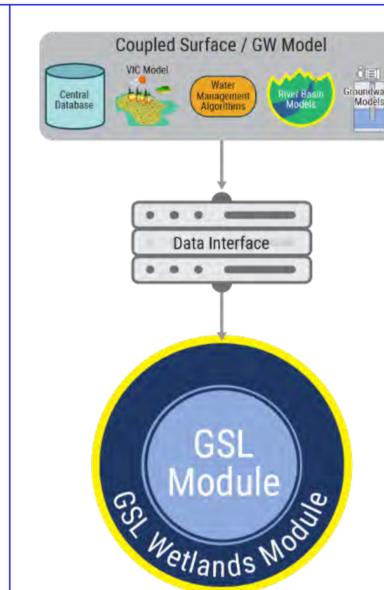
Notes:

GSL = Great Salt Lake
GSLIM = Great Salt Lake Integrated Model
JBRPM = Joint Bear River Planning Model
M&I = municipal and industrial
RAPID = Routing Application for Parallel Computation of Discharge
USGS = United States Geological Survey
VIC = Variable Infiltration Capacity
WBM = Water Budget Model
WeberSim = Weber River Simulation Model
WRe = Utah Division of Water Resources
WRi = Utah Division of Water Rights

These model components may be combined with additional model components as modeling approaches are refined through the development process (refer to Section 3, Development Step 6). Models such as those simulating water quality exist in various frameworks such as Hydrologic Simulation Program – FORTRAN, QUAL2Kw, and Distributed Hydrology Soil Vegetation Model, which may be integrated into the recommended modeling approaches to support the GSLBIP. Appendix A includes preliminary summaries of the existing models. As part of the selection of components that support the recommended modeling approaches, this summary will be updated and reviewed to include a precise knowledge of model status, input data requirements, and output data characteristics. This updated information will be used as the basis of the modeling approach component selection.

The modeling approach workshops, and subsequent reviews led to seven modeling approaches evaluated against a list of selection criteria. These modeling approaches all use models and tools previously developed by GSL watershed stakeholders with a goal of reducing the need for new tool development and promoting improved stakeholder confidence in the resulting GSLBIP Water Resources Planning Tool. Table 4-2 summarizes the seven modeling approaches.

Table 4-2. Summary of Model Approaches

#1 GSLIM	#2 Supply and Demand Database + Outflow Algorithms -> GSLIM Wetland and Lake Modules	#3 Updated GSLIM	#4 WBM -> GSLIM Wetland and Lake Modules	#5 Existing River Basin Models -> GSLIM Wetland and Lake Modules	#6 Updated River Basin Models -> GSLIM Wetland and Lake Modules	#7 Coupled Surface and Groundwater Model -> GSLIM Wetland and Lake Modules
Schematic						
						
Description						
GSLIM to be used as is. No updates to existing River, Wetland, or Lake Modules are needed.	Historical supply and demand data (central database) will be used to develop correlations between river basin outflows and variables (for example, land use, population) to project future river basin outflows to GSL wetlands. Groundwater models would need to be integrated to the river basin outflow algorithms. These projected outflow data (river inflows to wetlands) will be processed through updated GSLIM Wetland and Lake Modules. The central database also will provide input data (for example, land use, population) to support river basin outflow algorithms and Wetland and Lake Module computations.	This is an updated GSLIM model (River Basin, Wetland and Lake Modules), and it incorporates VIC model results, updated input data from the central database, and additional enhancements to GSLIM listed in the *Modeling Approach Development Needs* row.	This is an updated state-level WBM processed through GSLIM Wetland and Lake Modules. Updated state-level WBM includes input data from the central database, VIC model results, future demand projections, and other updates provided in the *Modeling Approach Development Needs* row.	Existing river basin models and groundwater models processed through GSLIM Wetland and Lake Modules.	Updated river basin models are processed through GSLIM Wetland and Lake Modules.	Coupled surface and groundwater model has with system demands and water distribution network (with full administrative capabilities) processed through GSLIM Wetland and Lake Modules.

#1 GSLIM	#2 Supply and Demand Database + Outflow Algorithms -> GSLIM Wetland and Lake Modules	#3 Updated GSLIM	#4 WBM -> GSLIM Wetland and Lake Modules	#5 Existing River Basin Models -> GSLIM Wetland and Lake Modules	#6 Updated River Basin Models -> GSLIM Wetland and Lake Modules	#7 Coupled Surface and Groundwater Model -> GSLIM Wetland and Lake Modules
Summary of Incorporated Elements						
▪ GSLIM River Module ▪ GSLIM Wetland Module ▪ GSLIM Lake Module	▪ Central database ▪ River Basin Outflow Algorithms ▪ Groundwater models (where available) ▪ GSLIM Wetland Module ▪ GSLIM Lake Module	▪ Central database ▪ VIC model ▪ Groundwater models (where available) ▪ GSLIM River Module ▪ GSLIM Wetland Module ▪ GSLIM Lake Module	▪ Central database ▪ VIC model ▪ State WBM ▪ GSLIM Wetland Module ▪ GSLIM Lake Module	▪ Central database ▪ River Basin Models: - JBRPM - WeberSim - Utah Lake/Jordanelle Exchange Model - Jordan River GoldSim Model ▪ Groundwater models (where available) ▪ GSLIM Wetland Module ▪ GSLIM Lake Module	▪ Central database ▪ VIC model ▪ Water management algorithms (for example, assumptions and algorithms to estimate water demand, water supply usage priorities, and other criteria setting up variations of water demand and water supply), similar to existing GSLIM River Basin user-define algorithms and user-define assumptions ▪ River Basin Models: - JBRPM - WeberSim - Utah Lake/Jordanelle Exchange Model - Jordan River GoldSim Model ▪ Groundwater models (where available) ▪ GSLIM Wetland Module ▪ GSLIM Lake Module	▪ Central database ▪ VIC model ▪ Water management algorithms (for example, assumptions and algorithms to estimate water demand, water supply usage priorities and other criteria setting up variations of water demand and water supply), similar to existing GSLIM River Basin user-define algorithms and user-define assumptions ▪ River Basin Models: - JBRPM - WeberSim - Utah Lake/Jordanelle Exchange Model - Jordan River GoldSim Model ▪ Great Salt Lake Regional Flow Model (groundwater) ▪ Other groundwater models (where available) ▪ GSLIM Wetland Module ▪ GSLIM Lake Module

#1 GSLIM	#2 Supply and Demand Database + Outflow Algorithms -> GSLIM Wetland and Lake Modules	#3 Updated GSLIM	#4 WBM -> GSLIM Wetland and Lake Modules	#5 Existing River Basin Models -> GSLIM Wetland and Lake Modules	#6 Updated River Basin Models -> GSLIM Wetland and Lake Modules	#7 Coupled Surface and Groundwater Model -> GSLIM Wetland and Lake Modules
Modeling Approach Development Needs						
Not applicable	▪ Develop central database. ▪ Develop River Basin outflow algorithms. ▪ Update GSLIM Wetland Module based on scenario development process and improvements identified as part of previous model development process (CH2M 2018). ▪ Update GSLIM Lake Module based on scenario development process and improvements identified as part of previous model development process (Jacobs 2021).	▪ Develop central database using WBM and other available historical data sources. ▪ Complete VIC model along with post-process results. ▪ Update GSLIM (Jacobs 2021). ▪ Expand reservoir operations modeling capabilities using existing RiverWare models. ▪ Expand integration of groundwater, including safe yield where existing groundwater data are available. ▪ Incorporate water import and export rules and enable dynamic implementation. ▪ Add scenarios related to watershed management such as practices which improve snowpack retention, increase soil moisture, sustain river flows during low-flow seasons, mitigate wildfire risk, and improve water quality. ▪ Include scenarios that incorporate results of functional flow studies conducted by DWR. ▪ Update Wetland Module based on scenario development process and improvements identified as part of previous model development process. ▪ Update Lake Module based on scenario development process and improvements identified as part of previous model development process.	▪ Develop central database. ▪ Complete VIC model and post-process results. ▪ Update state WBM codes as follows: - Incorporate VIC model results. - Incorporate data from central database. - Support future demand and supply projections. ▪ Update GSLIM Wetland Module based on scenario development process and improvements identified as part of previous model development process (Jacobs 2021). ▪ Updates GSLIM Lake Module based on scenario development process and improvements identified as part of previous model development process (Jacobs 2021).	▪ Develop central database. ▪ Run parameters of the existing river basin models need to be updated to achieve consistent run periods and validate with existing groundwater models. ▪ Update GSLIM Wetland Module based on scenario development process and improvements identified as part of previous model development process (Jacobs 2021). ▪ Update GSLIM Lake Module based on scenario development process and improvements identified as part of previous model development process (Jacobs 2021).	▪ Develop central database. ▪ Complete VIC model. ▪ River basin models may require the following various updates based on their current status: - Addition of future scenario capabilities - Incorporation of import/export (trans-basin diversions) rules - Reservoir operating rules - Groundwater safe yield rules - Incorporate watershed management impacts - Incorporate results of functional flow studies conducted by DWR ▪ Water management algorithms need to be developed. ▪ Update GSLIM Wetland Module based on scenario development process and improvements identified as part of previous model development process. ▪ Update GSLIM Lake Module based on scenario development process and improvements identified as part of previous model development process.	▪ Develop central database. ▪ Complete VIC model. ▪ Develop required coupled surface and groundwater model, including identification of update needs from contributing model components. ▪ Update GSLIM Wetland Module based on scenario development process and improvements identified as part of previous model development process. ▪ Update GSLIM Lake Module based on scenario development process and improvements identified as part of previous model development process.
Compliance with GSLBIP Requirements (H.B. 429, Basin Study)						
See Selection Matrix						

#1 GSLIM	#2 Supply and Demand Database + Outflow Algorithms -> GSLIM Wetland and Lake Modules	#3 Updated GSLIM	#4 WBM -> GSLIM Wetland and Lake Modules	#5 Existing River Basin Models -> GSLIM Wetland and Lake Modules	#6 Updated River Basin Models -> GSLIM Wetland and Lake Modules	#7 Coupled Surface and Groundwater Model -> GSLIM Wetland and Lake Modules
Strengths						
▪ Is quickly deployable. ▪ Eliminates the need for development of new models. ▪ Supports continuous modeling of future planning horizon. ▪ Simulates impact of drivers of water supply and demand. ▪ Provides stochastic results.	▪ Uses available observed and modeled data, and requires no hydrologic code processing.	▪ Provides a readily available existing GSLIM model, allows improvements to be prioritized, and is sequenced to ensure GSLBIP timeline met. ▪ Supports continuous modeling of future planning horizon. ▪ Simulates impact of drivers of water supply and demand. ▪ Provides stochastic results.	▪ Has fewer modeling components to be updated.	▪ Most direct path to incorporate existing river basin models owned by GSLBIP stakeholders. ▪ Involves stakeholders in modeling process, promotes buy-in.	▪ Involves stakeholders in the modeling process, promotes buy-in. ▪ Supports modeling of policy, management, and infrastructure which control water allocation. ▪ Includes operating rules (including reservoir operations) native to existing river basin models. ▪ Supports evaluation of individual river basin system performance and imbalances.	▪ Allows complete integration of surface and groundwater interaction. ▪ Involves stakeholders in the modeling process, promotes buy-in. ▪ Supports modeling of policy, management, and infrastructure which control water allocation. ▪ Includes operating rules (including reservoir operations) native to existing river basin models. ▪ Supports evaluation of individual river basin system performance and imbalances. ▪ Models water quality.
Limitations						
▪ Lacks system logic determining how and when water is delivered within the subarea. ▪ Does not include groundwater model. ▪ Does not simulate water quality in the watershed, only at the lake level. ▪ Requires stakeholder education to inform them on model details.	▪ Provides input data and data preprocessing steps to support data driven model approach need to be identified and developed. ▪ Lacks physical processes and their associated understanding. ▪ Requires preprocessing of assessment of water supply and demand drivers. ▪ Requires stakeholder education to inform them on model details. ▪ Lacks groundwater supply data across GSL watershed.	▪ Lacks system logic determining how and when water is delivered within the subarea. ▪ Lacks individual river basin validation. ▪ Does not provide fully integrated groundwater modeling; incorporates available safe yields where existing data are available. Does not provide groundwater supply data across the GSL watershed. ▪ Does not simulate water quality in the watershed, only at the lake level. ▪ Requires stakeholder education about model details.	▪ Lacks system logic determining how and when water is delivered within the subarea. ▪ Does not model groundwater. ▪ Does not model water quality. ▪ Needs demand and supply projection algorithms to be developed. ▪ Requires stakeholder education about model details. ▪ Lacks continuous modeling over a future planning horizon.	▪ Does not model groundwater. ▪ Does not model water quality. ▪ Does not include future projections in all existing river basin models. ▪ Requires some stakeholder education to inform them on model details (GSLIM components). ▪ Lacks continuous modeling over a future planning horizon.	▪ Provides limited groundwater modeling. ▪ Does not model water quality. ▪ Requires some stakeholder education to inform about model details (GSLIM components).	▪ Requires some stakeholder education to inform about model details. ▪ Lacks some readily available computation resources. ▪ Does not provide development time that aligns with GSLBIP timeline.

Sources: Liang et al. 1994; Liang et al. 1996.

Notes:

An icon outlined in yellow indicates the base model(s) have been updated.

DWR = Utah Division of Wildlife Resources
GSL = Great Salt Lake
GSLBIP = Great Salt Lake Basin Integrated Plan
GSLIM =Great Salt Lake Integrated Model
JBRPM = Joint Bear River Planning Model
WBM =Water Budget Model
WeberSim = Weber River Simulation Model
VIC =variable infiltration capacity

4.2 Formulation of Modeling Approach Selection Criteria

Modeling approach selection criteria were developed to evaluate GSLBIP Water Resources Planning Tool requirements to select the near-, mid-, and long-term modeling approaches. These modeling approaches will inform recommended actions to provide for a sustainable GSL system as part of the GSLBIP and beyond. The modeling approach selection criteria were developed through a series of workshops, attended by members of the WRe staff and Jacobs's project team. During these collaborative meetings, a mapping process was conducted to link H.B. 429 (Legislature 2022) and Basin Study (Reclamation 2023) requirements to GSLBIP Water Resources Planning Tool requirements, and ultimately to criteria needed to support meeting the Water Resources Planning Tool requirements. This mapping process is illustrated on Figure 4-1.

Figure 4-1. Selection Criteria Development Process

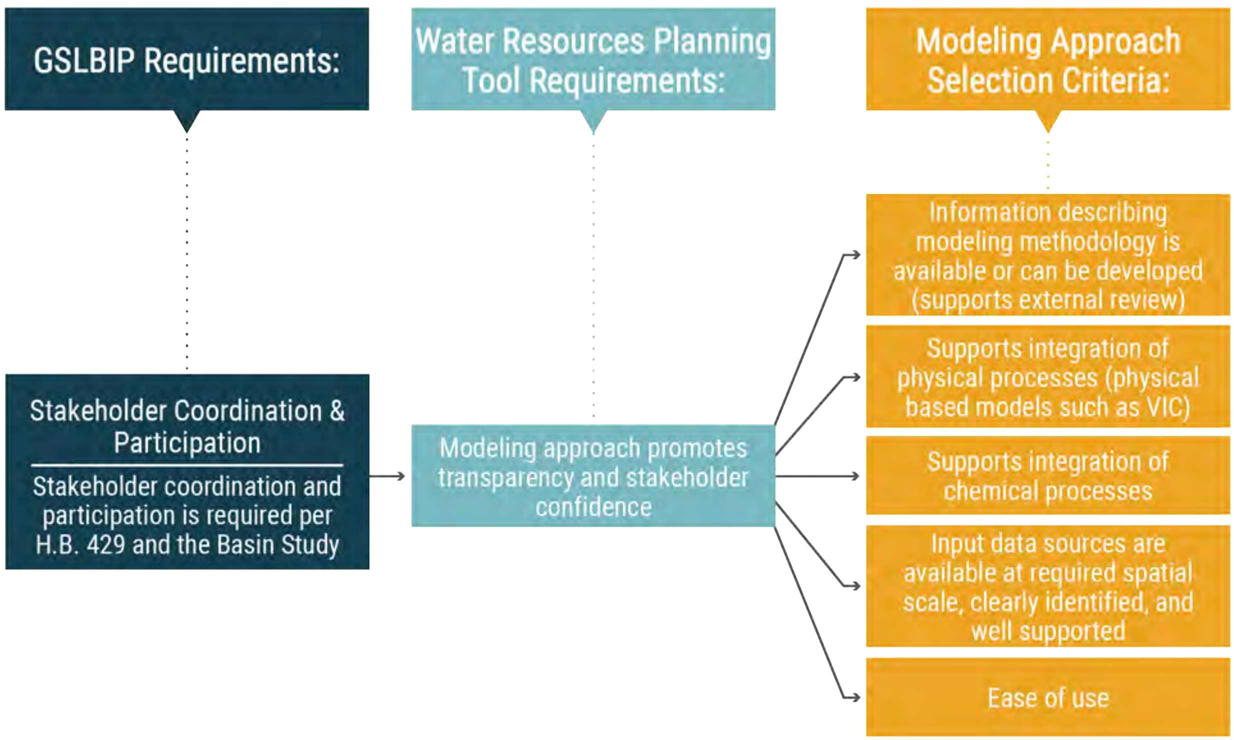


Figure 4-1 illustrates the mapping process for the *Promotes Transparency* and *Stakeholder Confidence* requirement, which resulted in five supporting selection criteria. This same process was completed for the complete list of the Water Resources Planning Tool requirements identified as part of the mapping process:

- **Promotes transparency and stakeholder confidence—**Water Resources Planning Tool transparency and building stakeholder confidence are key components to the successful implementation of GSL watershed best management practices. Coordination across state, local, regional, and federal governmental entities, water users, and other stakeholders is required per H.B. 429.
- **Includes water supplies (surface and groundwater) and water demands—**To effectively evaluate GSL system performance, water supplies and demands must be included in the Water Resources Planning Tool.
- **Can simulate future scenarios, including adaptation and mitigations Strategies—**The Water Resources Planning Tool must support the forecast of plausible futures to assess future risks, enabling development of adaptation and mitigation strategies.

- **Supports GSLBIP completion timeline—**To meet H.B. 429 and Basin Study requirements, the GSLBIP must be completed by November 30th, 2026.
- **Simulates key water and energy infrastructure and system operations—**Simulation of key water and energy infrastructure and system operations are required parts of a basin study.
- **Effectively models system performance—**The Water Resources Planning Tool must model system performance to support identification and evaluation of adaptation and mitigation strategies and to perform a subsequent trade-off analysis.

The criteria mapping process resulted in 20 selection criteria. Table 4-3 provides the complete list of selection criteria. The Water Resources Planning Tool requirements are identified in blue-filled rows with the applicable selection criteria that support meeting the requirement immediately following. Some criteria support more than one of the requirements but are listed only under one requirement.

Table 4-3. Summary of Modeling Approach Selection Criteria

Modeling approach promotes transparency and stakeholder confidence
▪ Information describing modeling methodology is available or can be developed (supports external review) ▪ Supports integration of physical processes (physical based models), specifically considers VIC model results[a] ▪ Supports integration of chemical processes (physical based models) ▪ Input data sources are available at required spatial scale, clearly identified, and well supported ▪ Supports interface with central database of input data ▪ Ease of use
Modeling approach includes water supplies (surface and groundwater) and water demands
▪ Supports modeling of key components of water supply ▪ Supply components include surface and groundwater hydrology, surface water, groundwater, and other alternative supplies such as reused water (direct and indirect) and stormwater capture ▪ Supports modeling of key components of water demand ▪ Demand components include M&I, agricultural, environmental demands, and ecological needs
Modeling approach includes ability to simulate future scenarios, including adaptation and mitigation strategies
▪ Supports modeling of key drivers of water supply ▪ Supply drivers include climate change, cloud seeding, forest management, infrastructure changes, importation projects, stormwater capture, reused water, and land use change ▪ Supports modeling of key drivers of water demand ▪ Demand drivers include population growth, land use change, conservation, and climate change ▪ Supports continuous modeling (simulation over a planning horizon period) ▪ Modeling supports computation of seasonal to decadal results
Modeling approach supports meeting GSLBIP completion timeline
▪ Supports beginning scenario evaluation at start of 2025 ▪ Integrates existing, accessible models; minimizes need for new model development ▪ Computation resources (hardware, software) are available to meet the timeline given estimated simulation time ▪ Computation time aligns with completion timeline
Modeling approach simulates key water and energy infrastructure and system operations
▪ Supports modeling of reservoirs and related operations ▪ Supports modeling of policy, management, and infrastructure, which control water allocation
Modeling approach effectively models system performance
▪ Resolution of GSL, GSL watershed, and river basin results inform decision-making process ▪ Ability to analyze the uncertainty of scenario results

[a] VIC model, which is a physically-based hydrologic model (Liang et al. 1994; Liang et al. 1996), is currently in development for the GSL watershed by the WRe.

4.3 Evaluation of Modeling Approaches Against Selection Criteria

Evaluation of modeling approaches against the selection criteria identified in Table 4-3 was accomplished through a series of workshops, attended by members of the WRe staff and Jacobs project team. The selection criteria evaluation included an initial quantitative assessment of each modeling approach. The quantitative assessment included the following steps:

1. Scoring of each criteria on a scale from 0 to 5, with 5 being most favorable and 0 being least favorable.
2. Scoring each modeling approach's ability to meet the Water Resources Planning Tool requirements (the Water Resources Planning Tool requirement score) by averaging the scores of the selection criteria that support each requirement.
3. Summing the Water Resources Planning Tool requirement scores to generate a modeling approach total score.
4. Modeling approach total scores were then averaged across all workshop participants to generate final scores and modeling approach rankings.

Table 4-4 provides the resulting modeling approach rankings (a score of 1 indicates the highest rank).

Table 4-4. Results of Quantitative Evaluation of Modeling Approaches

Modeling Approach	Modeling Approach Ranking
#1—GSLIM	5
#2—Supply and Demand Database -> GSLIM Wetland and Lake Modules	7
#3—Updated GSLIM	3
#4—WBM -> GSLIM Wetland and Lake Modules	6
#5—Existing River Basin Models -> GSLIM Wetland and Lake Modules	4
#6—Updated River Basin Models -> GSLIM Wetland and Lake Modules	1
#7—Coupled Surface and Groundwater Model -> GSLIM Wetland and Lake Modules	2

The results of the quantitative evaluation of modeling approaches against the selection criteria indicate that the three modeling approaches that most effectively meet the Water Resources Planning Tool requirements are Approach #6: Updated River Basin Models processed through the GSLIM Wetland & Lake Modules, Approach #7: Coupled Surface and Groundwater Model processed through the GSLIM Wetland and Lake Modules, and Approach #3: Updated GSLIM. Appendix B provides the complete set of evaluation results. These quantitative results were subsequently used to inform the selection of near-, mid-, and long-term modeling approaches, discussed in the following section.

4.4 Selection of Near-, Mid-, Long-Term Modeling Approaches

Although the results of the quantitative analysis provided a means to evaluate each modeling approach against the established Water Resources Planning Tool requirements, the rankings themselves could not be used to directly select recommended approaches for near-, mid-, and long-term Water Resources Planning Tool development. Thus, a subsequent, qualitative analysis step was required where the highest ranked modeling approaches were considered for their ability to:

1. Allow rapid development of a Water Resources Planning Tool, which could be ready to evaluate scenarios at the start of 2025 (near-term need)

2. Most effectively meet the requirements of H.B. 429 and the Basin Study by the end of 2026 (midterm need)

3. Provide the most comprehensive tool in evaluating current and future GSL system performance and deployment of adaptation and mitigation strategies without any development time constraints (long-term need)

This qualitative analysis step was conducted through workshop discussions attended by members of the WRe staff and Jacobs project team and resulted in the following recommendations:

1. **Near-term Water Resources Planning Tool development recommendation**: Approach #3 was determined to provide the best opportunity to rapidly develop a water budget that could begin evaluating scenarios in 2025 and inform mitigation and adaptation strategy development.

2. **Midterm Water Resources Planning Tool development recommendation**: Approach #6 was determined to most effectively meet H.B. 429 and Basin Study requirements. River basin models included in Approach #6 are anticipated to be updated and developed in parallel to development of Approach #3. When sufficiently developed, the river basin models may replace the GSLIM River Basin Module. Approach #6 is expected to improve upon Approach #3 by providing enhanced Water Resources Planning Tool capabilities and increased stakeholder confidence.

3. **Long-term Water Resources Planning Tool development recommendation**: Approach #7 was determined to provide the most comprehensive tool to evaluate current and future GSL system performance and deployment of adaptation and mitigation strategies, but is not expected to be completed by the end of 2026. Thus, its development is recommended to occur in parallel to the GSLBIP Water Resources Planning Tool to support future planning efforts.

5. Water Resources Planning Tool Development - Work to be Completed

The following subsections build upon the work completed to date and inform the work to be completed. These development steps sequentially follow the development process steps previously provided in the Water Resources Planning Tool Development section.

5.1 Scenario Development

Water resource management decisions must consider the future amount of water available and the progression of demand for water in the GSL watershed over at least the next 50 years (planning horizon will be determined based on the availability of supporting information and ability to meet the GSLBIP schedule). These are highly uncertain, dependent upon a complex interplay between natural and human systems, and driven by climatic, demographic, economic, social, institutional, political, and technological factors. Given the broad uncertainty and the vast range of future possibilities, a scenario planning process is recommended to consider and portray the broad range of plausible futures in a manageable number of supply and demand scenarios. Scenarios are alternative views of how the future might unfold. Scenarios are not predictions or forecasts of the future. Rather, a set of well-constructed scenarios represents a range of plausible futures that assists in the assessment of future risks and impacts and the development of mitigation and adaptation options and strategies. Figure 5-1 provides the general steps involved in the scenario planning process.

Figure 5-1. Scenario Planning Process

Source: Reclamation, 2012.

Notes:

H.B. = House Bill

VIC = variable infiltration capacity

It is envisioned that the scenario planning process for the GSLBIP Water Resources Planning Tool will be conducted through a series of workshops and follow this process. The scenarios that result are expected to be supported by all three recommended Water Resources Planning Tool approaches, that is, have the ability to simulate those future scenarios. Variables which are expected to be considered include:

- **Climate –** historical and future climate projections
- **Land use –** changes in proportions of urban and irrigated acreages
- **Forest management and watershed restoration –** benefits of these activities on water supply and quality
- **Population –** various future growth pathways

- **Water use –** including future agricultural and residential water use, and agriculture to residential water use conversions
- **Water management –** changes to culinary and secondary supply percentages, water reuse, new storage/diversion infrastructure, and low-impact development stormwater infrastructure
- **Wetlands –** changes in area and type of wetland communities
- **Minerals management –** changes to extent, location, and management of mineral extraction
- **Lake barriers –** changes to structures that influence hydraulics between bays

5.2 Selection of Model Components That Support Modeling Approach

Following identification of the appropriate scenarios, specific model components needed to support the near-, mid-, and long-term modeling approaches will be selected. The selection process will include a review of the preliminary summaries of the existing models in Appendix A and other available sources. The selected model components may be currently existing or need to be developed, and may include supporting models, development of a central database of input datasets, and supporting computation modules required for the projections of water supply and demand and system performance evaluation. Selection of these model components may be straightforward, as in selection of GSLIM to support Approach #3, or may need to be evaluated through secondary criteria to best select the appropriate model component. Table 5-1 provides an example secondary criteria matrix that would serve to evaluate model components against one another, and additionally identify the development needs for each model component. This model component evaluation will also identify the updates that might be required in the selected modeling approach.

5.3 Update or Development of Water Resources Planning Tool Components

Following selection of the model components that support each modeling approach (Approach #3 [near-term], Approach #6 [midterm], Approach #7 [long-term]), update of existing components or development of new components is expected to be needed. Identification of update or development needs will be a key step in this process and necessary at the start of the GSLBIP development step. It is expected this will be performed through a workshop process similar to the modeling approach selection and evaluation workshops conducted, and may include a criteria evaluation matrix similar to the example presented in Table 5-1.

Metrics for performance evaluation of the scenarios will be developed through a collaborative process involving GSL stakeholders. The development approach for performance metrics is recommended to follow a multi-step process that has been used in other basin studies (Reclamation 2012), in which each metric will be defined by applying the following process steps:

1. **Resource categories—**These correspond to the areas of interest that need to be assessed. For example: water deliveries, water quality, ecological resources.
2. **Attribute of interest—**An attribute is a specific property or trait that can be associated with a resource category. Several attributes will be identified in each resource category that are informative when evaluating system performance for that category. For instance, for water deliveries, the attributes may be consumptive uses and shortages; for water quality, the attributes may be GSL level, salinity.
3. **Location of interest—**Specific locations need to be selected where a metric would be evaluated. Some metrics could be evaluated at GSL, others at the river basin or reservoirs.

4. **Metric types (quantitative or qualitative)—** Metrics will be evaluated in either a quantitative or qualitative fashion. A metric could be evaluated quantitatively if: (1) direct evaluation was possible using output from GSLBIP Water Resources Planning Tool or results from post-processing of GSLBIP Water Resources Planning Tool output data or (2) an indicator of the attribute of interest at the specified location could be developed, based on output from GSLBIP Water Resources Planning Tool or post-processing of GSLBIP Water Resources Planning Tool output data. If a particular attribute of interest could not be represented either directly in GSLBIP Water Resources Planning Tool or through the development of an indicator, the potential performance of an attribute under various future scenarios will be discussed qualitatively. Qualitative metrics bypass Steps 5 and 6 and are documented in Step 7.

Table 5-1. Example Criteria to Support Selection of Model Components Supporting Modeling Approach

Approach			Criteria						
			Model	Ease of Use	Accessibility	Flexibility	Scalability	Resources/ Development Time	Scenario[a]
Integrated Approach									
Future Drivers of Change	Climate Change	Seasonal							
		Long-term							
		Extreme Events							
	Population Growth								
	Urbanization (Land Use and Land Cover Change)								
	Water Policy								
	Economic Growth								
Water Supply	Surface Water (Rainfall Runoff)								
	Groundwater								
	Reservoir								
	Stormwater								
Water Demand	Agriculture								
	M&I								
	Environment								
Lake	Lake Level (Water Balance, Salinity)								
	Wetland (Water Balance, Water Quality)								
Network	Infrastructure								
	Policy								
	Management								
Option Evaluation	Scenarios, Strategy								

[a] Scenarios will include the following: (1) land use and land cover change, (2) climate change, (3) conservation, (4) infrastructure, (5) water rights, and (6) management practices..

5. **Methods for quantifying metrics—**If a metric is identified as quantitative, then a specific method for quantifying that metric is selected. Two methods for quantifying metrics are identified as options: Reference Value Method and Relative Comparison Method.

6. **Identify reference value (if appropriate) —**If the reference value method is selected in Step 5, then an appropriate reference value is selected. Reference values could be based on physical constraints in the GSL Basin, prescribed conditions, estimated resource needs, or historical or simulated conditions.

7. **Documentation—**Metric definitions developed by applying Steps 1 through 6 are documented in tabular fashion.

System performance metrics are measures that indicate the ability of the GSL system to meet basin resource needs under multiple future conditions. These metrics will be used to measure the potential impacts to GSL from future supply and demand imbalances and to measure the effectiveness of adaptation and mitigation strategies to address those imbalances.

The post-processing approach will be developed and clearly identify the spatial and temporal scale required for each model component that will provide input to another model component or components. Also, post-processing will be required to align modeling outputs to the previously mentioned performance metrics. Visualization tools will be considering for the performance metrics to facilitate the results analysis. Some of these tools include Tableau,[1] Microsoft Power BI,[2] and tailor made web-based dashboards.

5.4 Conduct Scenario Simulations and Results Analysis

Following identification of the scenarios to be evaluated, completion of the update or development of Water Resources Planning Tool components, and development of performance criteria and post-processing approach, the Water Resources Planning Tool's integrated models will be used to simulate the suite of hydrologic and climate scenarios. The results of these simulations will quantify system performance under various future conditions using the selected metrics (Figure 5-2), and support prediction of future water supply and demand imbalances and resulting impacts on GSL water surface elevation. An understanding of these imbalances will support development of adaptation and mitigation strategies. This is a likely time in the development process where updated river basin models replace the GSLIM River Basin Module to transition from the near- to midterm modeling approach.

5.5 Develop Adaptation and Mitigation Strategies

Based on scenario simulation results and understanding of GSL system imbalances, including risks and vulnerabilities in the GSL Basin, adaptation and mitigation strategies will be formulated and may include:

- Modification of reservoir operating guidelines
- Development of new water management, operating, or habitat restoration plans
- Development of water conservation and demand reduction strategies or projects
- Development of new water infrastructure
- Development of new water importation projects such as trans-basin diversions
- Development or expansion of water reclamation and reuse projects

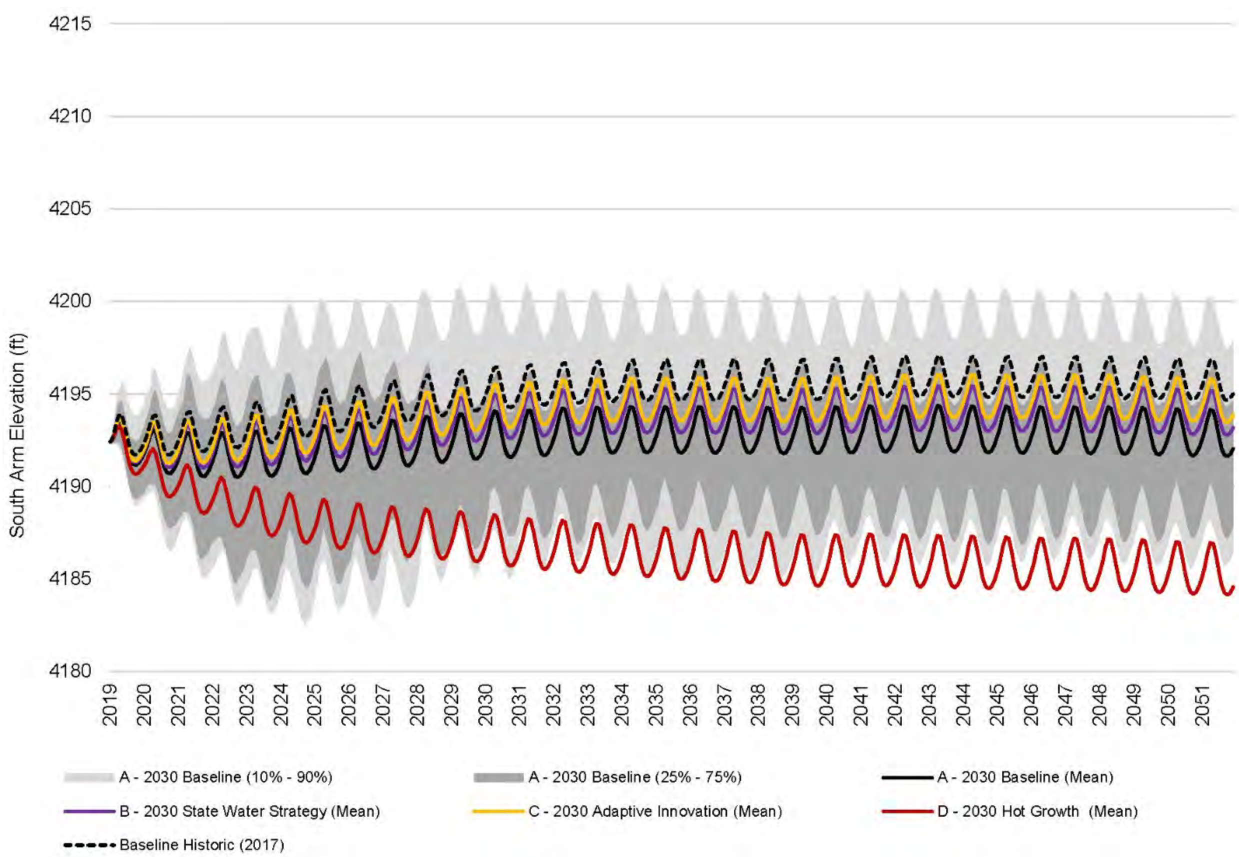
These adaptation and mitigation strategies are not intended to be comprehensive or constrain the possibilities that may present themselves as part of this analysis, but rather to serve as a set of examples for consideration. The development process of adaptation and mitigation strategies is expected to involve

[1] More information about Tableau can be found at https://www.tableau.com/.

[2] More information about Power BI can be found at https://powerbi.microsoft.com/en-us/.

GSL watershed stakeholders to provide for a well-rounded list of strategies that incorporates the view and values of various stakeholder groups.

Figure 5-2. 2030 Scenarios Results: Future Baseline Probabilistic Results and Scenarios Mean Results



Source: Jacobs, 2019.

Notes:

% = percent
ft = feet

5.6 Perform Trade-Off Analysis

Following development of the adaptation and mitigation strategies, additional simulations will be performed as needed to determine the effectiveness, efficiency, and acceptability of the adaptation and mitigation alternatives. The trade-off analysis will include all identifiable benefits, costs, and risks. The trade-off analysis will consider results, such as those from a GSLIM sensitivity analysis presented on Figure 5-3, that will allow GSL watershed stakeholders to conceptualize and visualize results between mitigation and adaptation strategies and to aid in future decision-making. The performance metrics will be used to quantify the benefits. Additional system performance metrics may be considered.

5.7 Conduct Technical Sufficiency Review

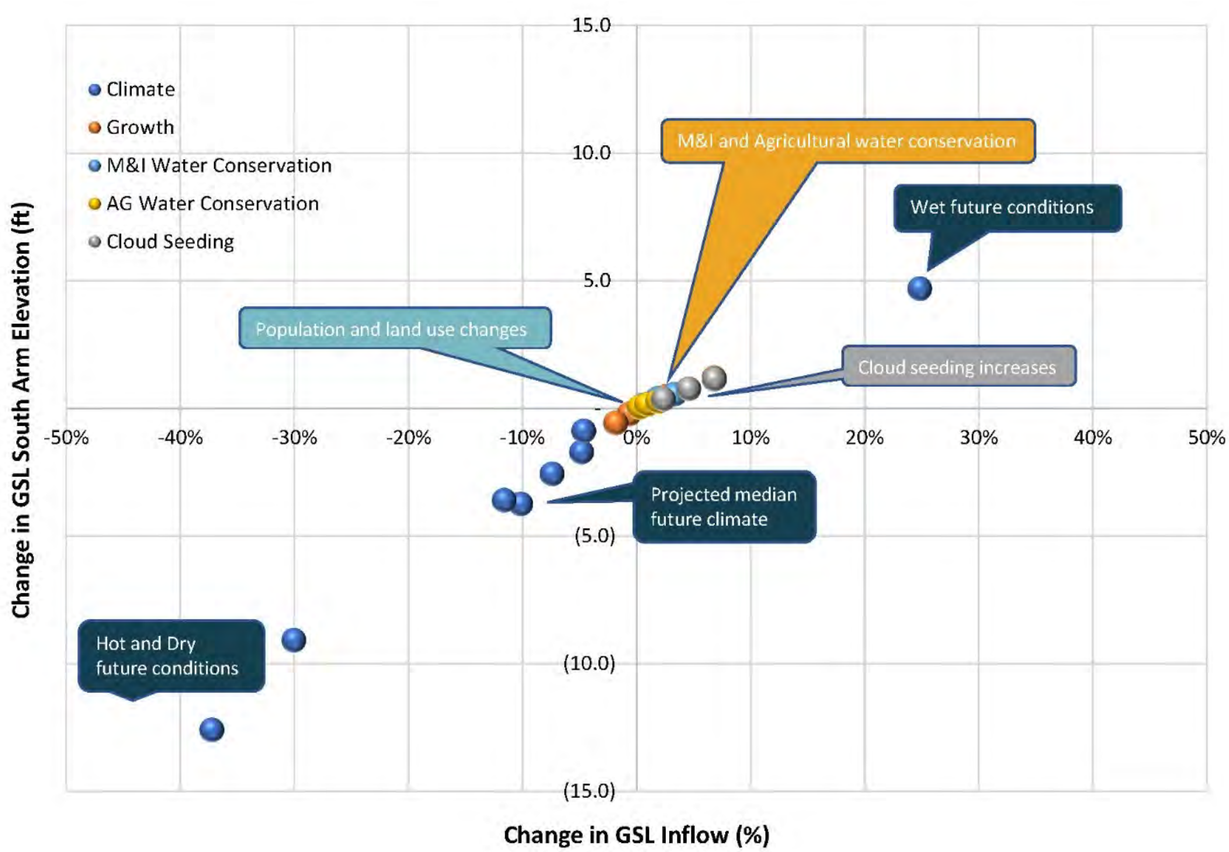
A technical sufficiency review is a stated requirement of Reclamation Basin Studies. This technical review of the GSLBIP Water Resources Planning Tool analysis and findings will be performed by Reclamation subject matter experts in accordance with Appendix K, Technical Sufficiency Review Plan, of the GSLBIP Work Plan (Jacobs 2023 in progress), which includes the following elements:

- The timing of the review

- What aspects of the Basin Study will be reviewed (the scope of the review)
- How the review will be conducted
- The anticipated number of reviewers
- A plan for selecting reviewers

The technical sufficiency review is intended to validate that the study was conducted in accordance with Reclamation requirements and that the study objectives were met.

Figure 5-3. Great Salt Lake Inflow and South Arm ElevationSensitivity to Potential Future Changes



Source: Jacobs, 2019

Notes:

% = percent
AG = agriculture
ft = feet
M&I = municipal and industrial

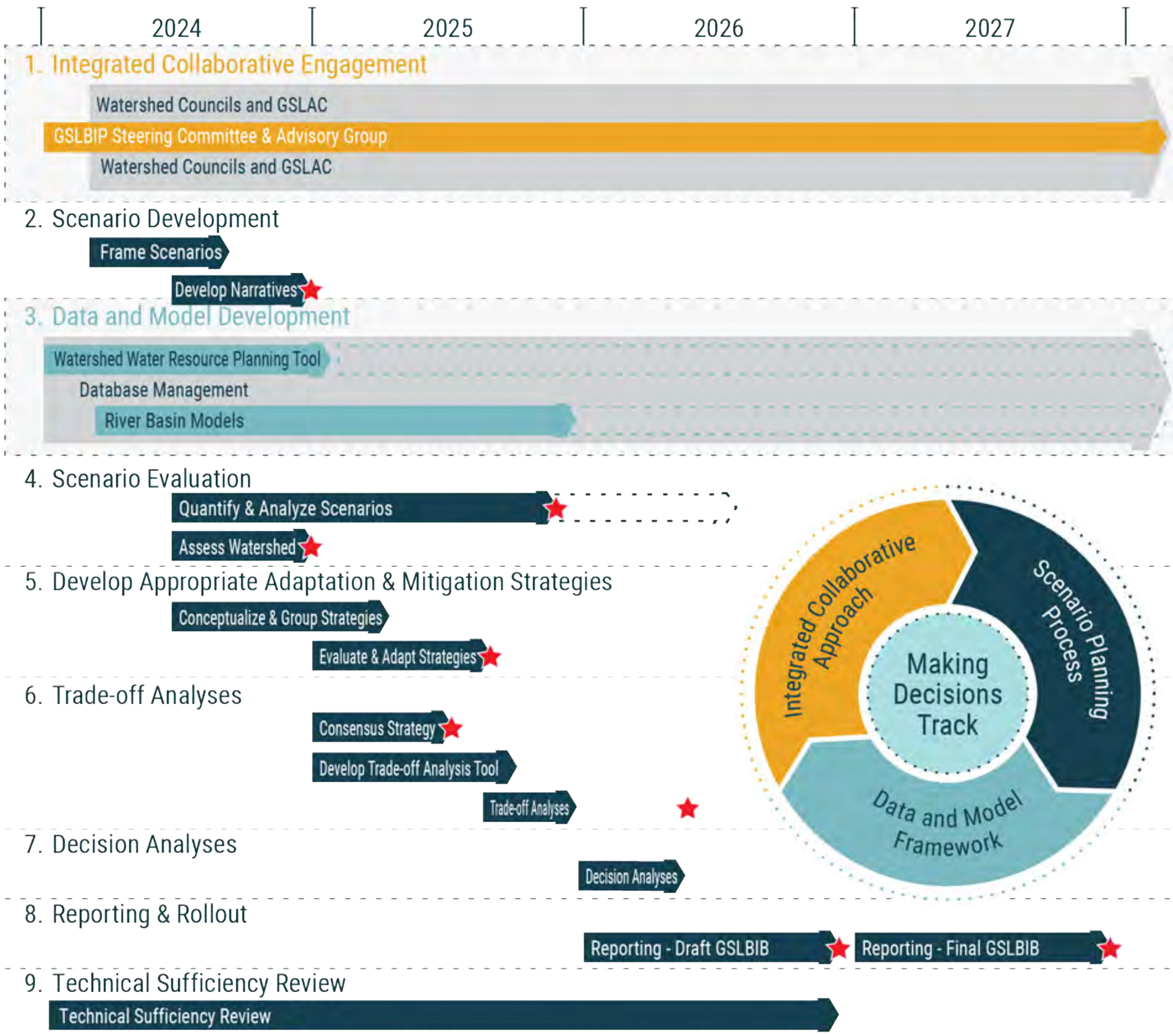
6. Water Resources Planning Tool Development Schedule

Per H.B. 429 and Reclamation's Basin Study requirements,[3] the GSLBIP needs to be completed by November 30th, 2026. As part of the modeling approach selection criteria development process, this completion requirement was incorporated as a GSLBIP Water Resources Planning Tool requirement. Supporting criteria such as "Supports beginning scenario evaluation at start of 2025" was additionally included in the modeling approach evaluation process. Figure 6-1 provides an overall GSLBIP timeline. The mapping of Water Resources Planning Tool development process steps to this overall timeline is provided in the following list:

1. Identify practical modeling approaches given the tools currently available and GSLBIP requirements. **(Completed)**
2. Formulate modeling approach selection criteria. **(Completed)**
3. Evaluate practical modeling approaches against selection criteria. **(Completed)**
4. Select near-, mid-, and long-term modeling approaches based on evaluation results. **(Completed)**
5. Develop scenarios which support answering the key questions required by H.B. 429 and Basin Study – aligns with Task 2 on Figure 6-1.
6. Selection of components which support modeling approach. These may exist or need to be developed, and may include supporting models, development of a central database of input datasets, and supporting computation modules required for the projections of water supply and demand and system performance evaluation. This selection will use a secondary evaluation of criteria as needed to complete component selection – aligns with Task 3 on Figure 6-1.
7. Update or develop Water Resources Planning Tool components to support simulation of scenarios – aligns with Task 3 on Figure 6-1.
8. Develop performance criteria and post-processing approach – aligns with Task 4 on Figure 6-1.
9. Conduct scenario simulations and results analysis – aligns with Task 4 on Figure 6-1.
10. Develop adaptation and mitigation strategies – aligns with Task 5 on Figure 6-1.
11. Perform trade-off analysis – aligns with Task 6 on Figure 6-1.
12. Conduct a technical sufficiency review – aligns with Task 9 on Figure 6-1.

[3] These requirements are pending execution of the Basin Study Memorandum of Agreement between Reclamation and WRe by November 30, 2023.

Figure 6-1. GSLBIP Program Schedule



7. References

Bureau of Reclamation (Reclamation). 2012. *Colorado River Basin Water Supply and Demand Study, Technical Report A- Scenario Development.* U.S. Department of the Interior, Bureau of Reclamation, Lower Colorado Region. December. https://www.usbr.gov/lc/region/programs/crbstudy/finalreport/.

CH2M HILL Engineers, Inc. (CH2M, now a wholly owned subsidiary of Jacobs Engineering Group Inc.). 2018. *Great Salt Lake Integrated Model, v1.10, An Integrated Water Resource Management Tool for the Great Salt Lake Watershed*. Prepared for State of Utah; Great Salt Lake Advisory Council; Utah Department of Natural Resources, Divisions of Forestry, Fire & State Lands, Water Resources, Water Rights, and Wildlife Resources; Utah Department of Environmental Quality, Division of Water Quality; and Utah Department of Technology Services. January.

David, Cédric H., David R. Maidment, Guo-Yue Niu, Zong-Liang Yang, Florence Habets, and Victor Eijkhout. 2011. "River network routing on the NHDPlus dataset." *Journal of Hydrometeorology* 12(5), 913-934. DOI: 10.1175/2011JHM1345.1.

Hansen Allen & Luce, Inc. (HAL) and Bowen Collins & Associates (BCA). 2019. *Utah's Regional M&I Water Conservation Goals*. Prepared for State of Utah, Department of Natural Resources, Division of Water Resources. Accessed August 25, 2023. https://conservewater.utah.gov/wp-content/uploads/2021/05/Regional-Water-Conservation-Goals-Report-Final.pdf.

Jacobs Engineering Group Inc. (Jacobs). 2019. *Great Salt Lake Integrated Model. An Integrated Water Resource Management Tool for the Great Salt Lake. Phase II – GSLIM Evaluation Report*. Prepared for State of Utah, Department of Natural Resources, Division of Water Resources. September.

Jacobs Engineering Group Inc. (Jacobs). 2021. *Great Salt Lake Integrated Model, v.1.15. An Integrated Water Resource Management Tool for the Great Salt Lake Watershed*. Prepared for State of Utah, Department of Natural Resources, Division of Water Resources.

Jacobs Engineering Group Inc. (Jacobs). 2023 in progress. *Technical Sufficiency Review Plan.* Appendix K of the *Work Plan for the Great Salt Lake Basin Integrated Plan*. Draft. Prepared for State of Utah, Department of Natural Resources, Division of Water Resources, Great Salt Lake Watershed Integrated Water Assessment. October.

Liang, X., D.P. Lettenmaier, E.F. Wood, and S.J. Burges. 1994. "A Simple Hydrologically Based Model of Land Surface Water and Energy Fluxes for General Circulation Models." *Journal of Geophysical Research* 99: 14415–14428. https://doi.org/10.1029/94JD00483.

Liang, X., D.P. Lettenmaier, and E.F. Wood. 1996. "Surface Soil Moisture Parameterization of the VIC-2L Model: Evaluation and Modification." *Global and Planetary Change* 13 (1-4): 195-206. https://doi.org/10.1016/0921-8181(95)00046-1.

U.S. Bureau of Reclamation (Reclamation). 2023. *Program Requirements*. WaterSMART Basin Study Program. Accessed October 16, 2023. https://www.usbr.gov/watersmart/bsp/require.html.

Utah State Legislature (Legislature). 2022. House Bill 429: Great Salt Lake Amendments. 2022 Utah Legislative Session. https://le.utah.gov/~2022/bills/static/HB0429.html

Appendix A
Matrix of Existing Models

Appendix A Matrix of Existing Models

Table A-1. Development Details of Existing Models

Model	Model Development Objective	Model Owner	Model Status	Model Access or Link	Model Development Year/Period	Model Platform or Software	Model Domain
BEARSIM (superseded by Joint Bear River Planning Model)	Historically used by WRe to evaluate the river system and its water allocation among Utah users. Converted from monthly to daily time step in 2009; currently being used to evaluate options for Bear River Development Project	WRe	Completed; application ongoing	N/A	1983 to present	FORTRAN	Bear River Basin
JBRPM	Water supply planning and operational assessment model that replaces BEARSIM and is focused on the Bear River mainstem; does not model tributaries	WRe	Completed; updates ongoing	N/A	2018 to present	RiverWare	Bear River Basin
Bear River Basin Model	Originally developed from WRe model as educational tool. Graduate and undergraduate students have been working to refine and add model details; numerous system components, demand service areas, dam operations, and conservation scenarios have been added	USU	Completed; updates ongoing	N/A	2007 to present	WEAP	Bear River Basin
Cache Valley	USGS expanded groundwater model in the Bear River watershed	USGS, WRi	Completed; not updated	WRi groundwater models: https://www.waterrights.utah.gov/groundwater/gwmodelsview.asp#Cache	2006	MODFLOW	Bear River Basin/Cache Valley Utah and Idaho
Malad-Lower Bear	USGS expanded groundwater model in the Bear River watershed	USGS, WRi	Completed	WRi groundwater models: https://www.waterrights.utah.gov/groundwater/gwmodelsview.asp#Malad	2017	MODFLOW	Bear River Basin
Weber River Streamflow Model	Historical water allocation simulation in the Weber River Basin to evaluate reservoir storage, originally for Willard Bay Reservoir	WRe	Completed; replaced	N/A	N/A	FORTRAN	Weber Basin
Weber Sim	Model water resulting water storage from various water supply scenarios to inform rules for water restrictions to reach reservoir storage targets. This model supersedes the FORTRAN model	WRe	Completed	Available from WRe: https://www.coloradomesa.edu/water-center/documents/cortlambson_ucrf_wsvs_11-01-17.pdf	2018	RiverWare	Weber River
Weber River Basin Model	Recreate WRe model in WEAP to evaluate reservoir storage carryover policies and impacts from increases in demand and water conservation. Author notes that "protected storage" not simulated well within WEAP model	USU	N/A	Tesfatsion 2011: https://digitalcommons.usu.edu/cee_facpub/860/	2011	WEAP	Weber Basin
East Shore (Weber Delta)	USGS groundwater model in the Weber River watershed	USGS, WRi	Completed; not updated	WRi groundwater models: https://www.waterrights.utah.gov/groundwater/gwmodelsview.asp#Weber	1990	MODFLOW	Weber Basin/ East Shore
Ogden Valley	USGS groundwater model in the Weber River watershed	USGS, WRi	Unavailable	Unavailable	1994	MODFLOW	Weber Basin/ Ogden Valley
Weber Delta ASR	USGS groundwater model in the Weber River watershed	Weber State	Completed	WRi groundwater models: https://www.waterrights.utah.gov/groundwater/gwmodelsview.asp#WeberASR	2011	MODFLOW	Weber Basin/ Weber County
Bountiful Area	USGS groundwater model in the Weber River watershed	USGS, WRi	Completed; not updated	WRi groundwater models: https://www.waterrights.utah.gov/groundwater/gwmodelsview.asp#Bountiful	1991	MODFLOW	Weber Basin/ Bountiful Area
Kamas Valley	USGS groundwater model in the Weber River watershed	USGS, WRi	Completed; not updated	WRi groundwater models: https://www.waterrights.utah.gov/groundwater/gwmodelsview.asp#Kamas	2003	MODFLOW	Weber Basin/ Kamas Valley
Morgan Valley	USGS groundwater model in the Weber River watershed	USGS, WRi	Unavailable	Unavailable	1984	MODFLOW	Weber Basin/ Morgan Valley
Jordan River Return Flow Study	Evaluates the effects of future reuse projects on Jordan River flows downstream of Turner Dam	Jacobs	Superseded by Jordan River GoldSim Model	CH2M HILL. 2005. Jordan River Return Flow Study. Final report: prepared for the Recycled Water Coalition.	2005	VOYAGE	Jordan River

Model	Model Development Objective	Model Owner	Model Status	Model Access or Link	Model Development Year/Period	Model Platform or Software	Model Domain
Jordan River GoldSim Model	Converted 2005 VOYAGE model into GoldSim platform and daily time step to allow water management in Farmington Bay wetlands to be evaluated	GoldSim	Completed	CH2M (2012).	2012	GoldSim	Jordan River
Farmington Bay Water Budget Model	Creates a daily water balance for Farmington Bay, demonstrates model with example management application, and identifies data needs and next steps to advance the model	UU	Confirmation needed, may have been incorporated into Jordan River GoldSim Model.	Burian et al. (2014).	2014	GoldSim	Jordan River
BRMBR GAMS Model	Water optimization for wetland management	USU	Completed	Assumed available upon request to the authors: https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1002/2015WR018105	2016	GAMS	BRMBR
Jordan River Bridge Model	Explores the impacts that bioretention, rainwater harvesting, and climate change individually and combined may have on downstream stakeholders and receiving water systems in SLC	UU	Confirmation needed, may have been incorporated into Jordan River GoldSim model	Need to confirm if this was included in Jordan River GoldSim model	2014	GoldSim	Jordan River
SLC Integrated Water Resources Management Models	See also: Wasatch Front Water System and Farmington Bay Water Budget Models	SLC Department of Public Utilities	Confirmation needed, may have been incorporated into Jordan River GoldSim model	N/A	N/A	GoldSim	Jordan River
WASH Optimization Model	Determines when, where, and how much to allocate scarce water, financial resources, and revegetation efforts to improve aquatic, floodplain, and wetland habitat areas and quality	Utah Water Research Laboratory, USU	All source code, input data, post-processing file, and documentation available from Alafifi (2019); WASH is applied to Lower Bear River, Utah for 1 year (2003) on an open-access web map at https://www.WASHmap.usu.edu; source code available on GitHub: https://github.com/ayman510/WASH	All WASH model input data, code, and post-processing files are 399 available at WASH GitHub repository: https://github.com/ayman510/WASH Full PDF: https://www.sciencedirect.com/science/article/am/pii/S1364815218305309	2017 to 2020	GAMS with nonlinear global solver (such as Branch-And-Reduce Optimization Navigator, Microsoft Excel, web browser)	Lower Bear River
WaMDaM	Addresses the fragmentation issue that water modelers face, where systems models are developed in independent, study area-specific tools that makes comparisons difficult both within and across study areas; connects tools for data storage, web visualization, and data repository in an open-source software, allowing water conservation simulations and optimization between two distinct study areas in the U.S. and Mexico (Bear River and Monterrey, respectively) to be compared	Adel M. Abdallah	GitHub	Full PDF: https://www.sciencedirect.com/science/article/am/pii/S1364815222000779 GitHub: https://github.com/WamdamProject/WaMDaM_JupyterNotebooks/blob/master/3_VisualizePubli 56 sh/00_WaMDaM_Directions_and_Use_Cases.ipynb	2020	WaMDam Wizard, Hydra Platform, Open Agua, HydraShare	Bear River (U.S.) and Monterrey (Mexico)
WaMDaM Wizard using WEAP Models of Bear and Weber Rivers	Presents an architecture and three software tools to enable researchers to more readily and consistently prepare and reuse data to develop, compare, and synthesize results from multiple models in a study area	Adel M. Abdallah	Completed	Available on GitHub (free): https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=8938&context=etd	2019	WaMDaM Wizard, Hydra Platform, Open Agua, HydraShare	Bear River/U.S. and Monterrey/ Mexico)
Weber Basin GAMS Model	Prioritizes stream barrier removal to maximize connected aquatic habitat and minimize water scarcity	USU	Data openly shared at hydroshare.com (Kraft et al. 2019); model publicly available on GitHub: https://github.com/MaggiK/Optimizing-Stream-Barrier-3Removal	Available on GitHub (free): https://www.researchgate.net/profile/Sarah-Null/publication/330328730_Prioritizing_Stream_Barrier_Removal_to_Maximize_Connected_Aquatic_Habitat_and_Minimize_Water_Scarcity/links/605e06d9a6fdccbfea0b2796/Prioritizing-Stream-Barrier-Removal-to-Maximize-Connected-Aquatic-Habitat-and-Minimize-Water-Scarcity.pdf	2019	GAMS	Weber River

Model	Model Development Objective	Model Owner	Model Status	Model Access or Link	Model Development Year/Period	Model Platform or Software	Model Domain
BMP Optimization for Echo Creek Watershed	Identifies cost-effective BMPs to reduce phosphorus loading to Echo Creek Reservoir; optimization program tests feasibility of proposed TMDL allocations based on potential BMP options and provides information regarding the spatial redistribution of loads among subwatersheds	USU	Completed	Assumed to be available by request: https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1773&context=cee_facpub	2012	Microsoft Excel or other linear program software packages	Echo Creek Watershed
Weber Basin Drought Vulnerability Model	Identifies where WBWCD is vulnerable to climate changes and population growth	USU	Completed as part of a graduate degree	Assumed to be available by request: https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=2500&context=gradreports	2020	RiverWare (developer modified WRe-created RiverWare model)	Weber Basin
Jordan River Management Plan	N/A	Wri	Available and working	Available on Wri website: https://waterrights.utah.gov/wcat/Default.asp?id=154#/last	N/A	Wri format	Jordan River
Central Utah Project Simulation Model	Models drought planning using inputs to develop an overall reliability of the CUWCD system; model likely to be used as an input for planning model	CUWCD	Complete	Assumed to be available by request	Existing	RiverWare	Jordan River
Utah Lake Jordanelle Exchange Model	Evaluate Utah Lake Jordanelle Exchange	CUWCD	Completed	Assumed to be available by request	Existing	RiverWare	Jordan River
LakeSim	Models unmeasured flows into Utah Lake	CUWCD	No longer supported	No longer supported	Existing	N/A	N/A
SLCo County HSPF Model	Intended for TMDL purposes, predicts flow at a number of USGS and other stream flow gages throughout the Salt Lake valley; performs climate change analysis and TDML scoping	DWQ	Completed; updates ongoing	Original model simulates water years 1994 through 2005. Model currently being updated by Tetra Tech to water years =2006 through 2022 and expanded to all of Jordan River/State Canal watershed below Utah Lake. Estimated completion by end of 2023. https://documents.deq.utah.gov/water-quality/watershed-protection/total-maximum-daily-loads/DWQ-2011-011501.pdf	N/A	HSPF	Jordan River
Spanish Fork Forecaster (HAL)	Optimizes Spanish Fork City use of various water sources and rights	HAL	Available and working	Available, working	2010's	Microsoft Excel (spreadsheet)	Jordan River
Provo Forecaster (HAL)	Predicts distribution of water rights and wet water based on snowpack runoff to supply Provo City with adequate drinking water over the course of a water year	HAL	Available and working	Available, working	2023	Microsoft Excel (spreadsheet)	Jordan River
Jordan River WASP Model	Models dissolved oxygen TMDL allocations	DWQ	N/A	Model developed by UU and UDWQ. Currently available but requires additional calibration to improve model performance: https://documents.deq.utah.gov/water-quality/watershed-protection/DWQ-2019-021341.pdf	2019	WASP	Jordan River
Utah Lake Carbon, Nitrogen, and Phosphorus Budgets Study	Models mass balance of external carbon, nitrogen, and phosphorus inputs/outputs Utah Lake	DWQ	Unclear	Unclear	2022	Mass Balance	Jordan River
Utah Lake Hydrodynamic (EFDC) and Water Quality (WASP) Model	Models Utah Lake water quality management	DWQ	Under development	Not yet available; under development by Tetra Tech. Previous version developed by UU and DWQ is available.	2020	EFDC, WASP	Jordan River
Utah Lake Watershed Model	Develops and calibrates a watershed model to be used as scientifically defensible, decision support tool for evaluating existing nutrient loads delivered to Utah Lake from diverse sources; applies watershed model to evaluate nutrient load reduction scenarios aimed at achieving numeric nutrient targets in Utah Lake; evaluates load contributions from point and nonpoint sources in drainage area and supports load scenarios in conjunction with Utah Lake EFDC-WASP model; scenarios may include simulating alternative strategies to achieve lake nutrient targets and/or evaluate outcomes under future landscape or climate conditions	DWQ	Under development	N/A	In development (draft available summer 2023)	HSPF	Jordan River

Model	Model Development Objective	Model Owner	Model Status	Model Access or Link	Model Development Year/Period	Model Platform or Software	Model Domain
Jordan River QUAL2Kw	Originally modeled Jordan River dissolved oxygen TMDL, which transitioned to dynamic WASP model; currently, supports wasteload allocations for Jordan River publicly owned treatment works UPDES permitting	▪ Nick von Stakelberg/ DWQ	Completed and updated	QUAL2Kw theory and documentation (version 5.1) (Chapra and Pelletier 2008). A modeling framework for simulating river and stream water quality. Environmental Assessment Program, Washington State University, Olympia, WA. https://apps.ecology.wa.gov/publications/documents/0503044.pdf	N/A	QUAL2Kw	Jordan River
Utah Lake/Jordan River SWMM	Supports EPA STAR grant	UU	Available but poorly documented	N/A	2020	SWMM	Jordan River
Multiple linear regression model	Predicts monthly streamflow values that extend back in time many centuries from tree ring chronologies and other paleo climate data; all other methods rely on resampling the historical record	Jim Stagge	Completed; unclear whether the model has been used in real world applications apart from drafting the publication	Assumed to be available upon request from the authors: https://www.sciencedirect.com/science/article/am/pii/S0022169417308855	2017	N/A	Logan and Bear Rivers
Utah Lake/Jordan River GoldSim	Supports EPA STAR grant	UU	Available but poorly documented	N/A	2020	GoldSim	Jordan River
Utah Lake/Jordan River DHSVM	Supports EPA STAR grant	UU	Available but poorly documented	The DHSVM is a spatially distributed, physics-based hydrology model developed in the early 1990s (Wigmosta et al. 1994) by PNNL and the University of Washington https://www.pnnl.gov/projects/distributed-hydrology-soil-vegetation-model	2020	DHSVM	Jordan River
Salt Lake Valley	USGS groundwater model in the Jordan River watershed	USGS, Wri	Completed; not updated	Wri groundwater models: https://www.waterrights.utah.gov/groundwater/gwmodelsview.asp#Weber	1990	MODFLOW	Jordan River/ Salt Lake Valley
North Utah Valley	USGS groundwater model in the Jordan River watershed	USGS, Wri	Completed; updates ongoing	Wri groundwater models: https://water.usgs.gov/GIS/metadata/usgswrd/XML/sir2021-5010.xml	2021	MODFLOW	Jordan River/ Utah County
South Utah and Goshen Valley	USGS groundwater model in the Jordan River watershed	USGS, Wri	Completed; updates ongoing	Wri groundwater models: https://www.waterrights.utah.gov/groundwater/gwmodelsview.asp#SoUtah	2013	MODFLOW	Jordan River/ Utah County
Heber and Round Valley	USGS groundwater model in the Jordan River watershed	USGS, Wri	Completed	Wri groundwater models: https://www.waterrights.utah.gov/groundwater/gwmodelsview.asp#Heber	1991	MODFLOW	Jordan River/ Heber City
Juab Valley	USGS groundwater model in the Jordan River watershed	USGS, Wri	Completed	Wri groundwater models: https://www.waterrights.utah.gov/groundwater/gwmodelsview.asp#Juab	1996	MODFLOW	Jordan River/ Juab Valley
Cedar Valley MODFLOW Groundwater Model	USGS groundwater model in the Jordan River watershed	USGS, Wri	Completed	Wri groundwater models: https://www.waterrights.utah.gov/groundwater/gwmodelsview.asp#Cedar	2012	MODFLOW	Jordan River/ Utah County
Water Budget Model	Performs as water budget model for state-, basin-, and county-level water planning	Wre	Currently available	Currently available: https://dwre-utahdnr.opendata.arcgis.com/pages/water-budget	1989	FORTRAN, VB.net	State of Utah
GSL Integrated Model: River Basin Module, Lake Module, Wetland Module	Evaluates GSL scenarios to understand sensitivity of GSL's water levels and salinity to potential changes in its watershed	Wre	Currently available	Currently available	2017, update in 2019; more updates by Wre in 2022	GoldSim	GSL watershed
GridET	N/A	Wre	N/A	N/A	2021	N/A	N/A
Water Demand Model	Models future water demand scenarios	Wre	Currently available	Currently available	N/A	VB.net	N/A
GBCAAS versions 1.0, 2.0, 3.0	Understands groundwater availability in light of rapid populations growth, high per capita water use, arid climate, and groundwater dependence and depletion	USGS	Completed; updates ongoing	Available from USGS	2011 to 2017	MODFLOW	Great Basin

Model	Model Development Objective	Model Owner	Model Status	Model Access or Link	Model Development Year/Period	Model Platform or Software	Model Domain
GSL Regional Flow Model	Quantitatively models groundwater inflow to GSL on a transient basis	USGS	Under development	Under development; supersedes GBCAAS	Approximately 2026	MODFLOW 6	Great Basin
VIC and RAPID Models		Wre	Under development	Under development	Under development	VIC and RAPID	Tooele Valley
Ranking Automation for Networks Tool	Identifies and ranks stability, topological significance, and redundancies in water resource networks	Leah Meeks	Complete	Assumed to be available upon request from the authors: https://ascelibrary.org/doi/10.1061/%28ASCE%29WR.1943-5452.0000755	2017	WEAP	Lower Bear River
Strawberry Collection System Model	N/A	CUWCD	N/A	N/A	Under development	RiverWare	N/A
Tooele Valley	USGS groundwater model in the GSL watershed	USGS, Wri	Completed	https://www.waterrights.utah.gov/groundwater/gwmodelsview.asp#Tooele	1996	MODFLOW	Tooele Valley
Wri Distribution Models	Supports distribution of water per water rights	Wri	Currently available	Currently available	Various	Varied	Distribution area
SLCo-wide Watershed Model	1. Performs as ongoing drainage and water quality planning and management tool, including future updates to the Water Quality Stewardship Plan. 2. Serves as decision-support tool for potential implementation strategies for the Jordan River TMDL water quality study and may estimate pollutant loads, allocate waste loads, and implement strategy evaluation for future TMDL water quality studies in SLCo. 3. Serves as a tool for SLCo drainage, flood control, and water quality permitting purposes. 4. May assess water quality impacts for subbasin-scale proposed actions. 5. May assess Water Quality Stewardship Plan strategic objectives, such as instream flow analyses and the effect of Utah Lake on Jordan River and tributaries; effects of Utah Lake could be modeled by observing downstream water quality effects of altering the Utah Lake boundary conditions in the model	Developed for SLCo Flood Control by Stantec	Unclear	Unclear	2011	HSPF	SLCo
NOAA Colorado Basin River Forecast Center Operational Hydrologic Models	N/A	NOAA	N/A	N/A	N/A	N/A	Colorado River Basin

Sources:
Alafifi, A.H. and D.E. Rosenberg. 2019. "Systems Modeling to Improve River, Riparian, and Wetland Habitat Quality and Area. *Environmental Modeling and Software* vol. 126, April 2020.
Burian, S., E. Goharian, C. York, J.K. Panthail, Y. Feng, Z. Zahmatkesh, and H. Tavakol-Davani. 2014. *Farmington Bay Water Budget Model*. Final Report Submitted to Jordan River/Farmington Bay Water Quality Council. June 20.
CH2M HILL, Inc. (CH2M). 2005. *Jordan River Return Flow Study*. Final Report. Prepared for the Recycled Water Coalition.
CH2M HILL, Inc. (CH2M). 2012. *A Review: Farmington Bay Hydrology and Water Management*. Final Report. Prepared for the Utah Department of Natural Resources, Division of Forestry, Fire, and State Lands. January.
Chapra, S. and G. Pelletier. 2008. QUAL2Kw theory and documentation (version 5.1).
Kraft, M., S.E. Null, and D.E. Rosenberg. 2019. "Prioritizing Stream Barrier Removal to Maximize Connected Aquatic Habitat and Minimize Water Scarcity." *Journal of the American Water Resources Association* 55 (2): 382-400. https://doi.org/10.1111/1752-1688.12718.
Tesfatsion, B.K. 2011. "Managing Water Shortages in the Weber Basin Using the water Evaluation and Planning (WEAP) System." MS Thesis. Utah State University. Paper 1087.
Wigmosta M.S., B. Nijssen, and P. Storck. 1994. *The Distributed Hydrology Soil Vegetation Model*.

Notes:
ASR = aquifer storage and recovery
BMP = best management practice
BRMBR = Bear River Migratory Bird Refuge
CUWCD = Central Utah Water Conservancy District
DHSVM = Distributed Hydrology Soil Vegetation Model
DWQ = Utah Division of Water Quality
EFDC = Environmental Fluid Dynamics Code
EPA = U.S. Environmental Protection Agency
GAMS = General Algebraic Modeling System
GBCAAS = Great Basin carbonate and alluvial aquifer system
GSL = Great Salt Lake
HAL = Hansen Allen & Luce, Inc.
HSPF = Hydrological Simulation Program – FORTRAN
MODFLOW = Modular Three-Dimensional Finite-Difference Groundwater Flow Model
N/A = not available
NOAA = National Oceanic and Atmospheric Association
RAPID = Routing Application for Parallel Computation of Discharge
SLC = Salt Lake City
SLCo = Salt Lake County
STAR = Science to Achieve Results
SWMM = stormwater management model
TMDL = total maximum daily load
U.S.= United States
UPDES = Utah Pollutant Discharge Elimination System
USGS = U.S. Geological Survey
USU = Utah State University
UU = University of Utah
VIC = variable infiltration capacity
WaMDaM = Water Management Data Model
WASH = Watershed Area of Suitable Habitat
WASP = Water Quality Assessment Simulation Program
WBWCD = Weber Basin Water Conservancy District
WEAP = Water Evaluation and Planning
WRe = Utah Division of Water Resources
WRi = Utah Division of Water Rights

Table A-2. Existing Models Specifications and Functions

Model	Spatial Scale	Temporal Scale	Time Step	Key Model Inputs	Key Model Outputs	Simulation Period	Water Demands	Water Supply	Climate Scenarios	Scenario Management
BEARSIM (superseded by Joint Bear River Planning Model)	N/A	N/A	Daily	Streamflow records from USGS, Bear River Commissioner, WRe Weber River model	Daily surface evaporation from reservoirs, return flows, hydropower production, optimized allocations among service areas per specified shortages	Current daily model uses streamflow records from 1966 to 2006	Allocations defined at various model nodes, and monthly demand patterns for M&I and agriculture; demands calculated within the model (no external model); Bear River canals have the senior water right priority followed by BRMBR; BRMBR demand pattern defined by State Engineer	Determined from streamflow records; begins at the Oneida stream gage in Idaho	None currently included; a factor can be used to reduce available water supply	Does not address potential future changes in things like demand, climate
Joint Bear River Planning Model	N/A	N/A	Daily	Reach gain hydrographs, historical mainstem diversions, inflow forecasts	Bear Lake elevations, irrigation storage allocation, streamflows	1980 to 2020	Historical mainstem diversions	Reach gains computed using observed streamflow measurements and diversion records	None; model based on historical data	Operations of Bear Lake and influence of water supply forecast
Bear River Basin Model	N/A	N/A	Monthly	Streamflow records from USGS, Bear River Commissioner, and WRe Weber River model	Daily surface evaporation from reservoirs, return flows, hydropower production, optimized allocations among service areas per specified shortages	N/A	Service areas and details added within existing service areas but requires additional work to accurately characterize demands; details currently being added to Cache Valley and Box Elder County areas	Determined from streamflow records; begins at the Oneida stream gage in Idaho	Limited work completed	Various operations, conservation, development, and infrastructure scenarios evaluated
Cache Valley	Grids: 0.375 to 0.5 mile per cell side to 1 mile per cell side	Annual	Yearly	Hydrological studies, precipitation, streamflow records	Groundwater head, groundwater discharges to rivers/reservoirs	1982 to 1990, steady state	ET, well, other discharges	Recharge from precipitation records	Can be factored in through altering recharge via precipitation	Can add wells and changes in recharge caused by climate change
Malad-Lower Bear	Grid: Malad-Lower Bear River area, approximately 0.2 mile per cell side	N/A	N/A	Hydrological studies, precipitation, streamflow records	Groundwater head, groundwater discharges to rivers/reservoirs	steady state	ET, eell, other discharges	Recharge from precipitation records	Can be factored in through altering recharge via precipitation	Can add wells and changes in recharge caused by climate change
Weber River Streamflow Model	N/A	N/A	Monthly	Streamflow records, reservoir operations	River flows, reservoir water storage, level and evaporation, flow in the Willard Diversion, spills to GSL, unmet demands	1950 to 2006	Twenty service areas (that is, canal groupings): two have zero demand and remaining have individual aggregated demand on monthly basis; no information on how demands were aggregated or areal coverage of each service area; 100-percent consumption assumed for each service area; actual return flows are incorporated as reach gains	Determined from streamflow records	None	Used to evaluate reservoir management
WeberSim	River routing model (not a gridded model)	Matched time step; computational and reporting timesteps are same	Monthly	Upstream gaged (extended record) streamflow, reach gain hydrographs, WBWCD reservoirs, available stream gages for water supply input	Reservoir storage volumes	1400s to present	Historical or rule based	Paleohydrologic record calibrated with historic measured data	CMIP5	Impacts of different water supply scenarios on storage; rules developed for demand restrictions to maintain storage at target levels

Model	Spatial Scale	Temporal Scale	Time Step	Key Model Inputs	Key Model Outputs	Simulation Period	Water Demands	Water Supply	Climate Scenarios	Scenario Management
Weber River Basin Model	Subarea	N/A	Monthly	Same as WRe monthly model	Same as WRe monthly model	Same as WRe monthly model	Same as WRe monthly model; demand scenarios created by increasing service area demands by various factors (per WRe, doubling); conservation scenarios developed by decreasing demands by various factors (25 percent)	Developed annual flows based upon randomized historical record	N/A	Looked at storage carryover for various demand and conservation scenarios
East Shore (Weber Delta)	Gridded: approximately about 0.5 to 0.7 mile per cell side	Annual	Yearly	Hydrological studies, precipitation, streamflow records	Groundwater head, groundwater discharges to rivers/reservoirs	1955 to 1984, steady state	ET, well, other discharges	Recharge from precipitation records	Can be factored in through altering recharge via precipitation	Can add wells and changes in recharge caused by climate change
Ogden Valley	Gridded: approximately 0.25 0.31 mile per cell side	Monthly	Yearly	Hydrological studies, precipitation, streamflow records	Groundwater head, groundwater discharges to rivers/reservoirs	1985 to 1986, steady state	ET, well, other discharges	Recharge from precipitation records	Can be factored in through altering recharge via precipitation	Can add wells and changes in recharge caused by climate change
Weber Delta ASR	Gridded: 250 to 1,000 feet per cell side	1956 to 2006, annual	Yearly	Hydrological studies, precipitation, streamflow records	Groundwater head, groundwater discharges to rivers/reservoirs	1956 to 2006	ET, Well, other discharges	Recharge from precipitation records	Can be factored in through altering recharge via precipitation	ASR added; can add wells and changes in recharge caused by climate change
Bountiful Area	Gridded: approximately 0.25 mile per cell side	Annual	Yearly	Hydrological studies, precipitation, streamflow records	Groundwater head, groundwater discharges to rivers/reservoirs	1947 to 1986, steady state	ET, Well, other discharges	Recharge from precipitation records	Can be factored in through altering recharge via precipitation	Can add wells and changes in recharge caused by climate change
Kamas Valley	Gridded: approximately 15 to 55 acres per cell	Twice annually	2 seasons per year: Winter and summer	Hydrological studies, precipitation, streamflow records	Groundwater head, groundwater discharges to rivers/reservoirs	Steady state	ET, Well, other discharges	Recharge from precipitation records	Can be factored in through altering recharge via precipitation	Can add wells and changes in recharge caused by climate change
Morgan Valley	Gridded: approximately 0.13 mile per cell side	Annual	Yearly	Hydrological studies, precipitation, streamflow records	Groundwater head, groundwater discharges to rivers/reservoirs	Steady state	ET, Well, other discharges	Recharge from precipitation records	Can be factored in through altering recharge via precipitation	Can add wells and changes in recharge caused by climate change
Jordan River Return Flow Study	N/A	N/A	Monthly	Utah Lake releases based upon defined flow rates, Jordan River and tributary stream gauge data, approximated stormwater input, imported flows, groundwater withdrawals and returns, M&I demands and agricultural return flows, inflow an infiltration and wastewater flows, reuse options, agricultural land/crop demands	Stream flow along Jordan River	Three scenarios: historical, current, and future (with and without future reuse) for dry, average, and wet hydrology	M&I demands: 22 separate water demand entities accounted for indoor/outdoor demands by entity and population, residential-industrial ratio, conservation, demand trends, and outdoor water use patterns. Agricultural demands: based upon area, crop and coefficients, and delivery capacity	Water supplies for each water agency based upon assumed wet, average, dry year deliveries and system capacities	None	Many model variables can be adjusted depending upon user need
Jordan River GoldSim Model	N/A	N/A	Daily	Same as 2005 Jordan River Return Flow Study	Stream flow along Jordan River, inflow at points to Farmington Bay	Same as 2005 Jordan River Return Flow Study	Same as 2005 Jordan River Return Flow Study, Wetland demands were approximated	Same as 2005 Jordan River Return Flow Study	Same as 2005 Jordan River Return Flow Study	Same as 2005 Jordan River Return Flow Study

Model	Spatial Scale	Temporal Scale	Time Step	Key Model Inputs	Key Model Outputs	Simulation Period	Water Demands	Water Supply	Climate Scenarios	Scenario Management
Farmington Bay Water Budget Model	N/A	N/A	Daily	Precipitation, climate data for ET/evaporation modeling, stream flow data, wastewater effluent flow rates, duck club and waterfowl management area water allocations, Farmington Bay causeway outflow measurements	Farmington Bay water volume, surface area, inflow	2004 to 2009	Used Jordan River flows as input, detailed demand parameters for SLC	Detailed parameters for the SLC water supply	One climate change scenario run for three 30-year periods	Looked at climate change, flow reduction, water reuse, combined scenarios
BRMBR GAMS Model	BRMBR	2008	Monthly	Inflow data for bird refuge, habitat suitability indices for 20 birds, wetland unit water levels, evaporation rates, water requirements	Reports, time series, and maps showing model-recommended water levels and vegetation control actions in WUs and how actions affect overall WU metric and WU in individual WUs	2008	Used water requirements as indicated by bird refuge staff	Inflow data from USGS	No	Yes
Jordan River Bridge Model	N/A	N/A	N/A	Streamflow, surface runoff, precipitation, effluent from wastewater treatment facilities, return flows from irrigation, net groundwater flow		2003 to 2010	M&I (indoor and outdoor)	Boundary stream gages plus model inputs provided in key model inputs cell	Yes	Climate change scenarios assigned to be 20-percent reduction in precipitation and natural streamflow
SLC Integrated Water Resources Management Models	N/A	N/A	Daily	N/A	N/A	N/A	N/A	N/A	N/A	N/A
WASH Optimization Model	Lower Bear River Watershed	2003	Monthly	Hydrological (National Hydrography Dataset reach lengths and U.S Fish and Wildlife Service water depth ecological suitability curves); floodplain habitat, wetland habitat, physical constraints (reservoir storage and diversions), natural constraints (headwater and local inflows, water level, evaporative losses, plant growth), management constraints, and model formulation.	Recommended flows, reservoir releases, storage volumes, planted area, vegetation cover, temporal/spatial variations of suitable aquatic, floodplain, and impounded wetland habitat area	2003	Model inputs are urban and agricultural water demands and consumptive flow use; these water demands are as modeled by Adams et al. (1992)	Water supply inputs taken from WRe water budget model	Yes	Wet- and dry-year scenarios modeled by changing headflows
WaMDaM	Bear River (U.S.) and Monterrey (Mexico)	Based on input models	User defined simple time steps (day, month, year)	Variable, depending on source models	Variable, depending on source models	Variable, depending on source models	Connects modeling tools in software ecosystem to allows modelers to compare simulation and optimization models for same and different modeling domains; water supply and demand from multiple source models can be compared in standardized outputs	N/A	No	Yes
WaMDaM Wizard using WEAP Models of Bear and Weber Rivers	Bear River (U.S.) and Monterrey (Mexico)	Based on input models	User-defined simple time steps (day, month, year)	Variable, depending on source models	Variable, depending on source models	Variable, depending on source models	Connects modeling tools in a software ecosystem to allows modelers to compare simulation and optimization models for same and different modeling domains; water and water demand from multiple source models can be compared in standardized outputs	N/A	No	Yes

Model	Spatial Scale	Temporal Scale	Time Step	Key Model Inputs	Key Model Outputs	Simulation Period	Water Demands	Water Supply	Climate Scenarios	Scenario Management
Weber Basin GAMS Model	Weber Basin	2005-2015	monthly and weekly	Water scarcity costs, barrier passage, habitat suitability, barrier removal costs	Barrier removal prioritization and optimization to maximize connected habitat and minimize water scarcity	2005 to 2015	No	No	No	Yes
BMP Optimization for Echo Creek Watershed	Echo Creek Watershed	2012	N/A	BMP costs, efficiencies, existing loads, reduction targets, available land and stream bank lengths to implement BMPs	BMP placement optimization	2012	No	No	No	Yes
Weber Basin Drought Vulnerability Model	Weber Basin	2030-2060	monthly	Inflows, demands, reservoir capacity, reservoir evaporation	Reservoir storage for each reservoir, water deliveries to each service area, shortages (difference between service area delivery request and actual delivery)	2030 to 2060	Yes	Yes	Yes	Yes
Jordan River Management Plan	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Central Utah Project Simulation Model	Utah Lake Watershed	N/A	Monthly	N/A	N/A	N/A	High-level characterization of d delivery point demands	Historical, current, and projected scenarios	N/A	N/A
Utah Lake Jordanelle Exchange Model	Provo River	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LakeSim	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SLC HSPF Model	Jordan River Watershed (excluding Utah Lake)	Dynamic	Hourly	Meteorological and solar radiation; hydrologic response units; diversions and return flow; irrigation; WWTP, septic, groundwater inflow	Water temperature, TSS, BOD, nitrogen and species	1994 to 2022	Yes; irrigation for crops and lawns	Yes; diversion records obtained by WRi	Yes; UU/Court Strong dynamically downscaled	Stormwater BMPs to be implemented in TMDL scenarios
Spanish Fork Forecaster (HAL)	Spanish Fork River (as it applies to Spanish Fork City)	Monthly	Monthly	NRCS streamflow forecast, previous year's Strawberry water in Spanish Fork River, water rights info (built in)	Predicted future flows on Spanish Fork River at Castilla; water rights and credits available for DW and PI sources	Upcoming year	Average based on city records, water rights, and credit allowable from River Commissioner for water sources	Spanish Fork River flow and Strawberry water in river, DW sources (for example, Crab Creek, Cold Springs Upper Meter, Malcomb Spring), and PI sources (for example, Darger Springs, Golf Course Delivery)	None; some conditions can be incorporated by adjusting forecasted streamflow or demand curve	Can hypothetically address several future scenarios (that is, different river flows or distributions from Strawberry Reservoir, estimate power losses, water rights and credits for DW/PI sources)
Provo Forecaster (HAL)	Provo River (below Deer Creek Dam as it applies to Provo City)	Weekly	Weekly	NRCS streamflow forecast, projected water demand curve, control settings for Provo-specific operations, water rights info (built in)	Weekly distribution of wet water and water right use, reservoir levels, well usage and timing, managed aquifer recharge usage	Any future year	Usually projected as demand of the prior year from city record	Natural flow of the Provo River multiplied by forecasted streamflow	None; some conditions can be incorporated by adjusting forecasted streamflow or demand curve	Can hypothetically address several future scenarios (for example, loss of springs, loss of one or more wells, drought years, wet years)
Jordan River Water Quality Assessment Simulation Program (WASP) Model	Jordan River main stem, State Canal	Dynamic	Hourly	Meteorological and solar radiation, shading, inflows/outflow quantity, inflow quality, groundwater Inflow quantity and quality	Dissolved nitrogen and phosphorus species, oxygen, ultimate cBOD, phytoplankton, macro and benthic algae, particulate organic matter, water temperature, TSS, pH, alkalinity	Water years 2006 to 2019	No	No	Yes	Scenarios run for TMDL allocations

Model	Spatial Scale	Temporal Scale	Time Step	Key Model Inputs	Key Model Outputs	Simulation Period	Water Demands	Water Supply	Climate Scenarios	Scenario Management
Utah Lake Carbon, Nitrogen, and Phosphorus Budgets Study	N/A	2015-2020	N/A	Hydrologic inputs/outputs and carbon, nitrogen, and phosphorus inputs/outputs	Hydrologic inputs/ outputs and carbon, nitrogen, and phosphorus inputs/outputs	N/A	N/A	N/A	No	N/A
Utah Lake Hydrodynamic (EFDC) and Water Quality (WASP)	Utah Lake and embayments	Dynamic	Hourly	Lake physical characteristics: inflow/outflow, inflow quality, solar radiation, sediment transport, phytoplankton speciation, atmospheric deposition, wave characteristics	Water volume, velocity, and temperature; TSS; organic matter; BOD; nitrogen and phosphorus species; chlorophyll	2006 to 2021	No	No	Yes	Scenarios run to support developing numeric nutrient criteria and implementation
Utah Lake Watershed Model	Utah Lake Watershed	Dynamic	Hourly	Meteorological and solar radiation; hydrologic response units; diversions and return flow; irrigation; WWTP, septic, groundwater, inflow	Water temperature, TSS, BOD, and nitrogen and phosphorus species	2005 to 2021	Yes - irrigation for crops and lawns.	Yes - diversion records obtained from WRi	Yes	Scenarios run to support developing numeric nutrient criteria and implementation
Jordan River QUAL2Kw	Jordan River main stem, State Canal	Steady State	Hourly	Meteorological and solar radiation, shading, inflows/ outflow quantity, inflow quality, groundwater Inflow quantity and quality	Dissolved nitrogen and phosphorus species, oxygen, ultimate cBOD, phytoplankton, macro and benthic algae, particulate organic matter, water temperature, TSS, pH, alkalinity	Seasonal 7Q10 and synoptic surveys conducted between 2007 and 2015	No	No	No	Includes 7Q10 seasonal scenarios; 7Q10 flows based on HAL study completed in 2020
Utah Lake/Jordan River SWMM	Utah Lake/Jordan River urbanized watershed	Dynamic	Daily	Precipitation, hydrologic response units	Flow, BOD, nutrients	2005 to 2015	No	No	Yes	Future climate scenarios using dynamically and statistically downscaled climate models
Multiple linear regression model	Logan and Bear Rivers	paleo/historic	Monthly	Tree rings and other paleo climate data	Monthly stream flow	Paleo and historical	No	No	No	No
Utah Lake/Jordan River GoldSim	Utah Lake/Jordan River	Dynamic	Daily	N/A	Flow, BOD, nutrients	2005 to 2015	Yes	Yes	Yes	Future climate scenarios using dynamically and statistically downscaled climate models
Utah Lake/Jordan River DHSVM	Utah Lake/Jordan River mountainous area	Dynamic	3-hour	Precipitation, hydrologic response units	Flow	2005 to 2015	No	No	Yes	Future climate scenarios using dynamically and statistically downscaled climate models
Salt Lake Valley	Gridded: 0.35 mile per cell side	Annual	Yearly	Hydrological studies, precipitation, streamflow records	Groundwater and discharges to rivers/reservoirs	1969 to 1991 steady state	ET, well, other discharges	Recharge from precipitation records	Can be factored in through altering recharge via precipitation	Can add wells and changes in recharge caused by climate change
North Utah Valley	Gridded: 0.3 to 0.6 mile per cell side	Annual	Yearly	Hydrological studies, precipitation, streamflow records	Groundwater head, groundwater discharges to rivers/reservoirs	1947-2016, 2017-2066, steady state	ET, well, other discharges	Recharge from precipitation records	Can be factored in through altering recharge via precipitation	Future ASR scenarios and groundwater withdrawal projections; can add wells and changes in recharge caused by climate change
South Utah and Goshen Valley	Gridded: 0.13 to 0.3 mile per cell side	Annual	Yearly	Hydrological studies, precipitation, streamflow records	Groundwater head, groundwater discharges to rivers/reservoirs	1949-2011, steady state	ET, well, other discharges	Recharge from precipitation records	Can be factored in through altering recharge via precipitation	Future managed aquifer recharge scenarios and groundwater withdrawal projections. Can be added by addition of wells, changes in recharge caused by climate change
Heber and Round Valley	Gridded: 0.25 mile per cell side	Monthly	Monthly	Hydrological studies, precipitation, streamflow records	Groundwater head, groundwater discharges to rivers/reservoirs	1949-1950, steady state	ET, well, other discharges	Recharge from precipitation records	Can be factored in through altering recharge via precipitation	Can add wells and changes in recharge caused by climate change

Model	Spatial Scale	Temporal Scale	Time Step	Key Model Inputs	Key Model Outputs	Simulation Period	Water Demands	Water Supply	Climate Scenarios	Scenario Management
Juab Valley	Gridded: 0.25 mile per cell side	Monthly (1992 to 1994), annually (1949 to 1992)	Monthly, annually	Hydrological studies, precipitation, streamflow records	Groundwater head, groundwater discharges to rivers/reservoirs	1949 to 1950, steady state	ET, well, other discharges	Recharge from precipitation records	Can be factored in through altering recharge via precipitation	1993-2042 with additional withdrawals. More can be added by addition of wells, changes in recharge caused by climate change
Cedar Valley MODFLOW Groundwater Model	Gridded: 1,000 feet per cell side	Annual	Yearly	Hydrological studies, precipitation, streamflow records	Groundwater head, groundwater discharges to rivers/reservoirs	Steady state, 1970 to 2007	ET, well, other discharges	Recharge from precipitation records	Can be factored in through altering recharge via precipitation	30 year projections to model increase in well discharge or decrease in recharge from climate change; more wells and changes in recharge caused by climate change can be added
Water Budget Model	Subarea	Annual Outputs	Monthly	Precipitation, groundwater and streamflow measurements, reservoir storage, ET estimates, crops, land use, M&I and riparian water use	Agriculture diversion and depletion, irrigated acreage, M&I diversion and depletion, riparian depletion, reservoir storage and reservoir evaporation, groundwater use, total precipitation, tributary inflow, river inflow, basin yield	1989 to present (usually 1 or 2 years behind)	N/A	Basin yield	No	No
GSL Integrated Model: River Basin Module, Lake Module, Wetland Module	12-square-kilometer grid	N/A	Daily (computation), monthly (reporting)	Climate, population, residential and agricultural water use; land use and future conversions; cloud seeding and lake inflows; precipitation	GSL surface elevation and salinity	2019 to 2060	N/A	N/A	For future scenarios, climate input data developed based on monthly scaling factors by subarea computed using CMIP5 bias corrected statistical downscaled ensemble climate model projections centered at 2030 and 2060, representing three RCPs (RCPs 4.5, 6.0, and 8.5)	Yes
GridET	N/A	N/A	Daily	Climate data from an hourly gridded weather forcing dataset (North American Land Data Assimilation System), daily precipitation (DAYMET), digital elevation model (National Elevation Dataset), crop specific data	Residential outdoor demands, agricultural demands (potential ET)	1980-2021	Residential outdoor and agricultural demands (potential ET)	N/A	N/A	N/A
Water Demand Model	N/A	N/A	10-year projections	Population projections, lot size, people per household, percent green space, percent single-family home, ET, efficiency	Gallon per capita per day per acre foot projections on a decadal scale	2020-2070	M&I demand	N/A	Climate conservation factor (percent)	Yes

Model	Spatial Scale	Temporal Scale	Time Step	Key Model Inputs	Key Model Outputs	Simulation Period	Water Demands	Water Supply	Climate Scenarios	Scenario Management
Great Basin Carbonate and Alluvial Aquifer System versions 1.0, 2.0, 3.0	v1.0: Eastern Nevada and Western Utah; Las Vegas to Cache Valley; very high scale and not to be used for detail in subregions; 1-square mile grid. v2.0: v1.0 with local grid refinement in the Lower Bear and Malad Rivers area. v3.0: v2.0 with local grid refinement in the Pine and Wah Wah Valleys	v1.0 and 2.0: steady state v3.0: 1950 through 2013 in multiyear stress periods	Steady state	Hydrological studies, precipitation, streamflow records	Groundwater head and contours, groundwater discharges to rivers/reservoirs, aquifer properties	1940 to 2006 (v3.0)	ET, well, other discharges	Precipitation	None considered; input data could be altered to mimic scenarios	v2.0 considered whether additional pumping caused an recharge increase or decrease from Malad River; v3.0 considered effects of newly approved withdrawals in Pine and Wah Wah Valleys and determined pumping reduction to stabilize groundwater levels
GSL Regional Flow Model	0.25-square-mile grid	Quarterly stress periods, potentially for predevelopment conditions (30s to 40s)	Quarterly stress periods	N/A	Groundwater discharge to GSL, including direct and indirect discharges	1940 to present	Discharge to drains, rivers, GSL, ET, springs	Recharge from precipitation (usually 10 to 20 percent)	N/A	Yes
VIC and RAPID Models	N/A	N/A	Daily and spatial resolutions of 1/16 degree	Land use, land cover, soil data, albedo, leaf area index, meteorological inputs minimum of minimum and maximum daily temperatures, precipitation, wind speed, and time series data of streamflows and SWE for the model calibration	Mainly snowpack and streamflow but also other results such as ET (based on the Penman-Monteith Equation) and soil moisture; total evaporation from reservoirs is optional (best results for natural reservoirs and lakes)	Historical simulations between 1980 and 2020; future simulations until end the century	N/A	Mainly water supply; flows are natural flows; incorporating diversion and calibrating model are possible but computationally heavy	Ten future global climate models, CMIP5 database, and twos RCPs 4.5 and 8.5 to be simulated and data downscaled using Localized Constructed Analogues Method	Model scope (set about 2 years earlier when no funding available) was to simulate climate change impacts; therefore, climate change scenario has been planned and requires a more effort if land use and cover are simulated
Ranking Automation for Networks Tool	Lower Bear River Watershed	N/A	N/A	Source model nodes	Nodes prioritization	Unclear	No	No	No	Yes (indirectly)
Strawberry Collection System Model	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tooele Valley	Tooele Valley: 0.3 to 0.4 mile per cell side	Annually	Annually	Hydrological studies, precipitation, streamflow records	Groundwater and discharges to rivers/reservoirs	1969 to 2003, steady state	ET, well, other discharges	Recharge from precipitation records	Can be factored in by altering recharge via precipitation	1993 to 2042 with additional withdrawals; more well and changes in recharge caused by climate change can be added
WRi Distribution Models	Distribution area	N/A	Daily	Streamflow, diversions (measured manually or automatically), reservoir storage	Natural flow, storage and other accounts per water right	Mostly irrigation season	N/A	N/A	N/A	No
SLCo-wide Watershed Model	SLCo	1994 to 2006	N/A	N/A	Temperature, TSS, TDS, nitrogen (organic, ammonia, nitrate), phosphorus (organic, orthophophate), BOD, dissolved oxygen	N/A	N/A	N/A	N/A	N/A
NOAA Colorado Basin River Forecast Center Operational Hydrologic Models	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Model	Spatial Scale	Temporal Scale	Time Step	Key Model Inputs	Key Model Outputs	Simulation Period	Water Demands	Water Supply	Climate Scenarios	Scenario Management

Source: Adams, T.D., D.B. Cole, C.W. Miller, and N.E. Stauffer. 1992. "GENRES: A Computer Program System for 625 Reservoir Operation with Hydropower." In: *Resources*, U.D.o.W. (Ed.). In-stream flow requirements (as indicated by stakeholders).

Notes:

7Q10 = lowest 7-day average flow that occurs on average once every 10 years
ASR = aquifer storage and recovery
BMP = best management practice
BOD = biochemical oxygen demand
BRMBR = Bear River Migratory Bird Refuge
cBOD = carbonaceous biochemical oxygen demand
CMIP5 = Coupled Model Intercomparison Project Phase 5
DHSVM = Distributed Hydrology Soil Vegetation Model
DW = drinking water
EFDC = Environmental Fluid Dynamics Code
ET = evapotranspiration
GAMS = General Algebraic Modeling System
GSL = Great Salt Lake
HAL = Hansen Allen & Luce, Inc.
HSPF = Hydrological Simulation Program – FORTRAN
M&I = municipal and industrial
MODFLOW = Modular Three-Dimensional Finite-Difference Groundwater Flow Model
N/A = not available
NOAA = National Oceanic and Atmospheric Association
NRCS = Natural Resources Conservation Service
PI = pressurized irrigation
RAPID = Routing Application for Parallel Computation of Discharge
RCP = representative concentration pathway
SLC = Salt Lake City
SLCo = Salt Lake County
SWE = snow water equivalent
SWMM = stormwater management model
TDS = total dissolved solids
TMDL = total maximum daily load
TSS = total suspended solids
U.S.= United States
USGS = U.S. Geological Survey
VIC = variable infiltration capacity
WaMDaM = Water Management Data Model
WASH = Watershed Area of Suitable Habitat
WASP = Water Quality Assessment Simulation Program
WBWCD = Watershed Area of Suitable Habitat
WEAP = Water Evaluation and Planning
WRe = Utah Division of Water Resources
WRi = Utah Division of Water Rights
WU = watershed unit
WWTP = wastewater treatment plant

Appendix B
Modeling Approach Selection Criteria Evaluation Results

Table B-1. Participant #1 Modeling Approach Evaluation Results

Model Selection Criteria	Approach #1	Approach #2	Approach #3	Approach #4	Approach #5	Approach #6	Approach #7
Modeling approach promotes transparency and stakeholder confidence	3.0	2.0	2.7	2.7	2.7	2.7	2.8
▪ Information describing modeling methodology is available or can be developed (supports external review)	4	3	3	3	3	3	4
▪ Supports integration of physical processes (physical based models). Specifically consider VIC	3	1	4	4	4	4	4
▪ Supports integration of chemical processes (physical based models)	0	0	0	0	0	0	1
▪ Input data sources are available at required spatial scale, clearly identified, and well supported	4	3	4	4	4	4	4
▪ Supports interface with central database of input data	3	3	3	3	3	3	3
▪ Ease of use	4	2	2	2	2	2	1
Modeling approach includes water supplies (surface and groundwater) and water demands	2	2	3.5	3.5	3	3.5	4
▪ Supports modeling of key components of water supply	2	2	3	3	2	3	4
- Supply components include surface and groundwater hydrology, surface water, groundwater, and other alternative supplies such as reused water (direct and indirect) and stormwater capture							
▪ Supports modeling of key components of water demand	2	2	4	4	4	4	4
- Demand components include M&I, agriculture, environmental demands, and ecological needs							
Modeling approach includes ability to simulate future scenarios including mitigation and adaptation strategies	2.5	2.5	3.5	3.5	3	3.5	4
▪ Supports modeling of key drivers of water supply	1	1	3	3	1	3	4
- Supply drivers include climate change, cloud seeding, forest management, infrastructure changes, importation projects, stormwater capture, reused water, and land use change							
▪ Supports modeling of key drivers of water demand	1	1	3	3	3	3	4
- Demand drivers Include: population growth, land use change, conservation, climate change							
▪ Supports continuous modeling (simulation over a planning horizon period)	4	4	4	4	4	4	4
▪ Modeling supports computation of seasonal to decadal results	4	4	4	4	4	4	4
Modeling approach supports meeting GSLBIP completion timeline	4.75	4.5	3.5	3.5	3	2.75	1.25
▪ Supports beginning scenario evaluation at start of 2025	5	5	3	3	2	2	0
▪ Integrates existing, accessible models; minimizes need for new model development	4	4	4	4	3	3	1
▪ Computation resources (hardware, software) are available to meet the timeline given estimated simulation time	5	4	3	3	4	3	1
▪ Computation time aligns with completion timeline	5	5	4	4	3	3	3
Modeling approach simulates key water and energy infrastructure and system operations	1	1	2	1.5	3.5	3.5	3.5
▪ Supports modeling of reservoirs and related operations	1	1	2	2	3	3	3
▪ Supports modeling of policy, management, and infrastructure which control water allocation	1	1	2	1	4	4	4
Modeling approach effectively models system performance	3	3	3	3	3	3	3
▪ Resolution of GSL, GSL watershed, and river basin results inform decision-making process	4	4	4	4	4	4	4
▪ Ability to analyze the uncertainty of scenario results	2	2	2	2	2	2	2
SUM	**16.3**	**15.0**	**18.2**	**17.7**	**18.2**	**18.9**	**18.6**

Notes:

GSL = Great Salt Lake
GSLBIP = Great Salt Lake Basin Integrated Plan
VIC = Variable Infiltration Capacity

Table B-2. Participant #2 Modeling Approach Evaluation Results

Model Selection Criteria	Approach #1	Approach #2	Approach #3	Approach #4	Approach #5	Approach #6	Approach #7
Modeling approach promotes transparency and stakeholder confidence	3.2	2.3	2.7	2.7	2.8	2.7	3.7
▪ Information describing modeling methodology is available or can be developed (supports external review)	4	2	4	3	3	3	5
▪ Supports integration of physical processes (physical based models). Specifically consider VIC	4	1	4	4	2	4	5
▪ Supports integration of chemical processes (physical based models)	1	1	0	0	0	0	4
▪ Input data sources are available at required spatial scale, clearly identified, and well supported	3	3	3	4	4	4	4
▪ Supports interface with central database of input data	3	4	2	3	4	3	2
▪ Ease of use	4	3	3	2	4	2	2
Modeling approach includes water supplies (surface and groundwater) and water demands	3	2	3	3.5	2	4	4.5
▪ Supports modeling of key components of water supply	3	2	3	3	2	4	5
- Supply components include surface and groundwater hydrology, surface water, groundwater, and other alternative supplies such as reused water (direct and indirect) and stormwater capture							
▪ Supports modeling of key components of water demand	3	2	3	4	2	4	4
- Demand components include M&I, agriculture, environmental demands, and ecological needs							
Modeling approach includes ability to simulate future scenarios including mitigation and adaptation strategies	3.75	2.75	4	3.5	2.75	3.75	3.75
▪ Supports modeling of key drivers of water supply	2	1	3	3	2	3	3
- Supply drivers include climate change, cloud seeding, forest management, infrastructure changes, importation projects, stormwater capture, reused water, and land use change							
▪ Supports modeling of key drivers of water demand	3	2	3	3	2	4	4
- Demand drivers Include: population growth, land use change, conservation, climate change							
▪ Supports continuous modeling (simulation over a planning horizon period)	5	4	5	4	4	4	4
▪ Modeling supports computation of seasonal to decadal results	5	4	5	4	3	4	4
Modeling approach supports meeting GSLBIP completion timeline	4.75	3.5	2.75	3.5	4	3.25	2
▪ Supports beginning scenario evaluation at start of 2025	4	3	3	3	4	4	2
▪ Integrates existing, accessible models; minimizes need for new model development	5	4	2	4	4	3	2
▪ Computation resources (hardware, software) are available to meet the timeline given estimated simulation time	5	4	3	3	4	3	2
▪ Computation time aligns with completion timeline	5	3	3	4	4	3	2
Modeling approach simulates key water and energy infrastructure and system operations	0	1	2.5	1.5	3	3	3.5
▪ Supports modeling of reservoirs and related operations	0	1	2	2	3	3	3
▪ Supports modeling of policy, management, and infrastructure which control water allocation	0	1	3	1	3	3	4
Modeling approach effectively models system performance	3	1.5	3.5	3	1.5	2	4
▪ Resolution of GSL, GSL watershed, and river basin results inform decision-making process	2	1	3	4	1	2	4
▪ Ability to analyze the uncertainty of scenario results	4	2	4	2	2	2	4
SUM	**17.7**	**13.1**	**18.4**	**17.7**	**16.1**	**18.7**	**21.4**

Notes:

GSL = Great Salt Lake
GSLBIP = Great Salt Lake Basin Integrated Plan
VIC = Variable Infiltration Capacity

Table B-3. Participant #3 Modeling Approach Evaluation Results

Model Selection Criteria	Approach #1	Approach #2	Approach #3	Approach #4	Approach #5	Approach #6	Approach #7
Modeling approach promotes transparency and stakeholder confidence	2.7	2.3	2.8	2.8	2.5	3.0	2.8
▪ Information describing modeling methodology is available or can be developed (supports external review)	4	3	3	3	3	3	2
▪ Supports integration of physical processes (physical based models). Specifically consider VIC	2	1	3	3	2	4	5
▪ Supports integration of chemical processes (physical based models)	1	2	1	1	1	1	1
▪ Input data sources are available at required spatial scale, clearly identified, and well supported	3	2	4	4	3	4	4
▪ Supports interface with central database of input data	2	2	3	3	3	3	3
▪ Ease of use	4	4	3	3	3	3	2
Modeling approach includes water supplies (surface and groundwater) and water demands	1.5	2.5	3	4	3	4	4.5
▪ Supports modeling of key components of water supply	1	2	3	4	2	4	5
- Supply components include surface and groundwater hydrology, surface water, groundwater, and other alternative supplies such as reused water (direct and indirect) and stormwater capture							
▪ Supports modeling of key components of water demand	2	3	3	4	4	4	4
- Demand components include M&I, agriculture, environmental demands, and ecological needs							
Modeling approach includes ability to simulate future scenarios including mitigation and adaptation strategies	2.75	2.75	3	3.25	3	3.5	4
▪ Supports modeling of key drivers of water supply	1	2	3	3	3	3	4
- Supply drivers include climate change, cloud seeding, forest management, infrastructure changes, importation projects, stormwater capture, reused water, and land use change							
▪ Supports modeling of key drivers of water demand	3	3	3	4	3	4	4
- Demand drivers Include: population growth, land use change, conservation, climate change							
▪ Supports continuous modeling (simulation over a planning horizon period)	3	3	3	3	3	3	4
▪ Modeling supports computation of seasonal to decadal results	4	3	3	3	3	4	4
Modeling approach supports meeting GSLBIP completion timeline	4	3.75	3	3.25	3.25	2.5	2
▪ Supports beginning scenario evaluation at start of 2025	4	4	3	3	3	2	1
▪ Integrates existing, accessible models; minimizes need for new model development	4	3	3	4	4	3	3
▪ Computation resources (hardware, software) are available to meet the timeline given estimated simulation time	4	4	3	3	3	2	1
▪ Computation time aligns with completion timeline	4	4	3	3	3	3	3
Modeling approach simulates key water and energy infrastructure and system operations	1.5	2	2	1.5	3	3.5	3.5
▪ Supports modeling of reservoirs and related operations	1	2	2	2	4	4	4
▪ Supports modeling of policy, management, and infrastructure which control water allocation	2	2	2	1	2	3	3
Modeling approach effectively models system performance	3	2.5	3	3	2.5	3	3
▪ Resolution of GSL, GSL watershed, and river basin results inform decision-making process	3	2	4	4	3	4	4
▪ Abilility to analyze the uncertainty of scenario results	3	3	2	2	2	2	2
SUM	**15.4**	**15.8**	**16.8**	**17.8**	**17.3**	**19.5**	**19.8**

Notes:

GSL = Great Salt Lake
GSLBIP = Great Salt Lake Basin Integrated Plan
VIC = Variable Infiltration Capacity

Table B-4. Participant #4 Modeling Approach Evaluation Results

Model Selection Criteria	Approach #1	Approach #2	Approach #3	Approach #4	Approach #5	Approach #6	Approach #7
Modeling approach promotes transparency and stakeholder confidence	2.0	2.8	2.5	2.2	3.0	3.2	3.0
▪ Information describing modeling methodology is available or can be developed (supports external review)	4	3	4	2	3	4	3
▪ Supports integration of physical processes (physical based models). Specifically consider VIC	3	0	3	2	4	4	5
▪ Supports integration of chemical processes (physical based models)	0	0	0	0	0	0	0
▪ Input data sources are available at required spatial scale, clearly identified, and well supported	3	5	3	2	4	4	3
▪ Supports interface with central database of input data	0	5	3	5	4	4	4
▪ Ease of use	2	4	2	2	3	3	3
Modeling approach includes water supplies (surface and groundwater) and water demands	3.5	2.5	3.5	2	3	3	4
▪ Supports modeling of key components of water supply	3	1	3	2	3	3	4
- Supply components include surface and groundwater hydrology, surface water, groundwater, and other alternative supplies such as reused water (direct and indirect) and stormwater capture							
▪ Supports modeling of key components of water demand	4	4	4	2	3	3	4
- Demand components include M&I, agriculture, environmental demands, and ecological needs							
Modeling approach includes ability to simulate future scenarios including mitigation and adaptation strategies	4.25	3.5	4.5	3.75	4.5	4.5	4.75
▪ Supports modeling of key drivers of water supply	3	1	4	3	4	4	5
- Supply drivers include climate change, cloud seeding, forest management, infrastructure changes, importation projects, stormwater capture, reused water, and land use change							
▪ Supports modeling of key drivers of water demand	4	3	4	2	4	4	4
- Demand drivers Include: population growth, land use change, conservation, climate change							
▪ Supports continuous modeling (simulation over a planning horizon period)	5	5	5	5	5	5	5
▪ Modeling supports computation of seasonal to decadal results	5	5	5	5	5	5	5
Modeling approach supports meeting GSLBIP completion timeline	5	4	4.5	3.75	4.5	3.25	2.5
▪ Supports beginning scenario evaluation at start of 2025	5	5	4	3	4	3	2
▪ Integrates existing, accessible models; minimizes need for new model development	5	1	4	3	4	1	1
▪ Computation resources (hardware, software) are available to meet the timeline given estimated simulation time	5	5	5	5	5	4	3
▪ Computation time aligns with completion timeline	5	5	5	4	5	5	4
Modeling approach simulates key water and energy infrastructure and system operations	0	1.5	2	1.5	4.5	4.5	4
▪ Supports modeling of reservoirs and related operations	0	2	3	1	5	5	4
▪ Supports modeling of policy, management, and infrastructure which control water allocation	0	1	1	2	4	4	4
Modeling approach effectively models system performance	2	2.5	2.5	1.5	4	4.5	4.5
▪ Resolution of GSL, GSL watershed, and river basin results inform decision-making process	2	1	3	2	4	5	5
▪ Abililty to analyze the uncertainty of scenario results	2	4	2	1	4	4	4
SUM	**16.8**	**16.8**	**19.5**	**14.7**	**23.5**	**22.9**	**22.8**

Notes:
GSL = Great Salt Lake
GSLBIP = Great Salt Lake Basin Integrated Plan
VIC = Variable Infiltration Capacity

Table B-5. Participant #5 Modeling Approach Evaluation Results

Model Selection Criteria	Approach #1	Approach #2	Approach #3	Approach #4	Approach #5	Approach #6	Approach #7
Modeling approach promotes transparency and stakeholder confidence	2.7	2.2	2.3	2.7	2.8	3.0	3.0
▪ Information describing modeling methodology is available or can be developed (supports external review)	4	2	3	3	4	4	4
▪ Supports integration of physical processes (physical based models). Specifically consider VIC	3	2	4	4	2	4	5
▪ Supports integration of chemical processes (physical based models)	0	0	0	0	0	0	2
▪ Input data sources are available at required spatial scale, clearly identified, and well supported	3	3	3	4	5	4	3
▪ Supports interface with central database of input data	3	4	2	3	3	3	3
▪ Ease of use	3	2	2	2	3	3	1
Modeling approach includes water supplies (surface and groundwater) and water demands	3.5	1	2.5	3.5	3	4	4
▪ Supports modeling of key components of water supply	3	1	2	3	2	4	5
- Supply components include surface and groundwater hydrology, surface water, groundwater, and other alternative supplies such as reused water (direct and indirect) and stormwater capture							
▪ Supports modeling of key components of water demand	4	1	3	4	4	4	3
- Demand components include M&I, agriculture, environmental demands, and ecological needs							
Modeling approach includes ability to simulate future scenarios including mitigation and adaptation strategies	2.25	1	3.5	3.5	2.5	4.25	4.25
▪ Supports modeling of key drivers of water supply	2	0	3	3	1	4	5
- Supply drivers include climate change, cloud seeding, forest management, infrastructure changes, importation projects, stormwater capture, reused water, and land use change							
▪ Supports modeling of key drivers of water demand	3	0	3	3	3	4	3
- Demand drivers Include: population growth, land use change, conservation, climate change							
▪ Supports continuous modeling (simulation over a planning horizon period)	1	1	4	4	3	5	5
▪ Modeling supports computation of seasonal to decadal results	3	3	4	4	3	4	4
Modeling approach supports meeting GSLBIP completion timeline	3.5	3.5	3	3.5	2.5	3.5	0
▪ Supports beginning scenario evaluation at start of 2025	5	3	3	3	3	3	0
▪ Integrates existing, accessible models; minimizes need for new model development	0	3	2	4	1	4	0
▪ Computation resources (hardware, software) are available to meet the timeline given estimated simulation time	5	4	3	3	3	3	0
▪ Computation time aligns with completion timeline	4	4	4	4	3	4	0
Modeling approach simulates key water and energy infrastructure and system operations	0.5	0	1.5	1.5	3	4.5	2
▪ Supports modeling of reservoirs and related operations	1	0	2	2	3	5	3
▪ Supports modeling of policy, management, and infrastructure which control water allocation	0	0	1	1	3	4	1
Modeling approach effectively models system performance	2	2	3.5	3	2.5	3.5	3.5
▪ Resolution of GSL, GSL watershed, and river basin results inform decision-making process	3	3	3	4	2	4	4
▪ Abililty to analyze the uncertainty of scenario results	1	1	4	2	3	3	3
SUM	**14.4**	**9.7**	**16.3**	**17.7**	**16.3**	**22.8**	**16.8**

Notes:
GSL = Great Salt Lake
GSLBIP = Great Salt Lake Basin Integrated Plan
VIC = Variable Infiltration Capacity

Table B-6. Participant #6 Modeling Approach Evaluation Results

Model Selection Criteria	Approach #1	Approach #2	Approach #3	Approach #4	Approach #5	Approach #6	Approach #7
Modeling approach promotes transparency and stakeholder confidence	3.7	2.0	4.0	3.0	2.3	3.7	3.5
▪ Information describing modeling methodology is available or can be developed (supports external review)	4	2	4	3	3	3	3
▪ Supports integration of physical processes (physical based models). Specifically consider VIC	4	1	4	4	3	4	5
▪ Supports integration of chemical processes (physical based models)	2	2	4	2	2	4	4
▪ Input data sources are available at required spatial scale, clearly identified, and well supported	4	2	4	4	2	4	4
▪ Supports interface with central database of input data	4	3	4	3	2	4	4
▪ Ease of use	4	2	4	2	2	3	1
Modeling approach includes water supplies (surface and groundwater) and water demands	3.5	2.5	4	3.5	2	3.5	5
▪ Supports modeling of key components of water supply	3	2	4	3	2	3	5
- Supply components include surface and groundwater hydrology, surface water, groundwater, and other alternative supplies such as reused water (direct and indirect) and stormwater capture							
▪ Supports modeling of key components of water demand	4	3	4	4	2	4	5
- Demand components include M&I, agriculture, environmental demands, and ecological needs							
Modeling approach includes ability to simulate future scenarios including mitigation and adaptation strategies	4.5	2	4.5	3.5	2.5	4	5
▪ Supports modeling of key drivers of water supply	4	2	4	3	1	4	5
- Supply drivers include climate change, cloud seeding, forest management, infrastructure changes, importation projects, stormwater capture, reused water, and land use change							
▪ Supports modeling of key drivers of water demand	4	2	4	3	1	4	5
- Demand drivers Include: population growth, land use change, conservation, climate change							
▪ Supports continuous modeling (simulation over a planning horizon period)	5	2	5	4	4	4	5
▪ Modeling supports computation of seasonal to decadal results	5	2	5	4	4	4	5
Modeling approach supports meeting GSLBIP completion timeline	5	3.75	4.5	3.5	4	3.5	0
▪ Supports beginning scenario evaluation at start of 2025	5	3	4	3	2	0	0
▪ Integrates existing, accessible models; minimizes need for new model development	5	2	4	4	4	4	0
▪ Computation resources (hardware, software) are available to meet the timeline given estimated simulation time	5	5	5	3	5	5	0
▪ Computation time aligns with completion timeline	5	5	5	4	5	5	0
Modeling approach simulates key water and energy infrastructure and system operations	2	1	3	1.5	4.5	5	5
▪ Supports modeling of reservoirs and related operations	2	1	3	2	5	5	5
▪ Supports modeling of policy, management, and infrastructure which control water allocation	2	1	3	1	4	5	5
Modeling approach effectively models system performance	3	2.5	3.5	3	3	4.5	4
▪ Resolution of GSL, GSL watershed, and river basin results inform decision-making process	2	3	3	4	4	5	5
▪ Abililty to analyze the uncertainty of scenario results	4	2	4	2	2	4	3
SUM	**21.7**	**13.8**	**23.5**	**18.0**	**18.3**	**24.2**	**22.5**

Notes:

GSL = Great Salt Lake
GSLBIP = Great Salt Lake Basin Integrated Plan
VIC = Variable Infiltration Capacity

Table B-7. Participant #7 Modeling Approach Evaluation Results

Model Selection Criteria	Approach #1	Approach #2	Approach #3	Approach #4	Approach #5	Approach #6	Approach #7
Modeling approach promotes transparency and stakeholder confidence	3.2	2.7	3.7	3.3	3.0	3.5	4.0
▪ Information describing modeling methodology is available or can be developed (supports external review)	5	2	3	3	3	3	3
▪ Supports integration of physical processes (physical based models). Specifically consider VIC	3	3	4	4	3	4	4
▪ Supports integration of chemical processes (physical based models)	2	2	2	4	2	4	4
▪ Input data sources are available at required spatial scale, clearly identified, and well supported	3	4	4	4	4	4	4
▪ Supports interface with central database of input data	3	3	4	3	2	3	5
▪ Ease of use	3	2	5	2	4	3	4
Modeling approach includes water supplies (surface and groundwater) and water demands	3.0	2.0	4.0	4.0	3.0	4.0	4.0
▪ Supports modeling of key components of water supply	3	2	4	4	3	4	4
- Supply components include surface and groundwater hydrology, surface water, groundwater, and other alternative supplies such as reused water (direct and indirect) and stormwater capture							
▪ Supports modeling of key components of water demand	3	2	4	4	3	4	4
- Demand components include M&I, agriculture, environmental demands, and ecological needs							
Modeling approach includes ability to simulate future scenarios including mitigation and adaptation strategies	3.5	3.0	4.0	3.5	3.5	3.8	3.8
▪ Supports modeling of key drivers of water supply	3	2	4	3	3	4	4
- Supply drivers include climate change, cloud seeding, forest management, infrastructure changes, importation projects, stormwater capture, reused water, and land use change							
▪ Supports modeling of key drivers of water demand	3	2	4	3	3	3	3
- Demand drivers Include: population growth, land use change, conservation, climate change							
▪ Supports continuous modeling (simulation over a planning horizon period)	4	4	4	4	4	4	4
▪ Modeling supports computation of seasonal to decadal results	4	4	4	4	4	4	4
Modeling approach supports meeting GSLBIP completion timeline	4.5	3.8	3.8	3.5	3.3	2.3	1.5
▪ Supports beginning scenario evaluation at start of 2025	5	3	4	3	2	0	0
▪ Integrates existing, accessible models; minimizes need for new model development	5	4	4	4	4	3	2
▪ Computation resources (hardware, software) are available to meet the timeline given estimated simulation time	4	5	3	3	4	3	2
▪ Computation time aligns with completion timeline	4	3	4	4	3	3	2
Modeling approach simulates key water and energy infrastructure and system operations	3.5	1.5	3.5	1.5	4.5	4.5	3.5
▪ Supports modeling of reservoirs and related operations	4	2	4	2	5	5	3
▪ Supports modeling of policy, management, and infrastructure which control water allocation	3	1	3	1	4	4	4
Modeling approach effectively models system performance	4.0	4.0	4.5	4.0	4.0	4.0	4.0
▪ Resolution of GSL, GSL watershed, and river basin results inform decision-making process	3	4	4	4	4	4	4
▪ Abililty to analyze the uncertainty of scenario results	5	4	5	4	4	4	4
SUM	**21.7**	**16.9**	**23.4**	**19.8**	**21.3**	**22.0**	**20.8**

Notes:
GSL = Great Salt Lake
GSLBIP = Great Salt Lake Basin Integrated Plan
VIC = Variable Infiltration Capacity

Table B-8. Compiled Modeling Approach Selection Results

Attendee	Approach #1	Approach #2	Approach #3	Approach #4	Approach #5	Approach #6	Approach #7
Attendee #1	16.3	15.0	18.2	17.7	18.2	18.9	18.6
Attendee #2	17.7	13.1	18.4	17.7	16.1	18.7	21.4
Attendee #3	15.4	15.8	16.8	17.8	17.3	19.5	19.8
Attendee #4	16.8	16.8	19.5	14.7	23.5	22.9	22.8
Attendee #5	14.4	9.7	16.3	17.7	16.3	22.8	16.8
Attendee #6	21.7	13.8	23.5	18.0	18.3	24.2	22.5
Attendee #7	21.7	16.9	23.4	19.8	21.3	22.0	20.8
Average of Attendee Scores	17.7	14.4	19.5	17.6	18.7	21.3	20.4