



ARIZONA TRI-UNIVERSITY
RECHARGE AND WATER
RELIABILITY PROJECT REPORT

APPENDIX E:
DECISION
SUPPORT
FRAMEWORK

INTRODUCTION

Findings from the Arizona Tri-University Recharge and Water Reliability Project (ATUR) have been integrated into a 10-step decision support framework (DSF) to guide Arizona’s natural resource managers in enhancing capture and recharge of rain, snow, and urban runoff to support their water management objectives. It is a screening-level tool for navigating *how* and *where* to enhance natural groundwater recharge in Arizona given landscape-scale considerations. Detailed assessments of recharge suitability are left to site-specific analyses conducted by the user. Decisions for enhancing groundwater recharge should be made by natural resource managers based on their priorities and in consultation with legal advisors.

The DSF consists of a high-level flow chart and guide (also available as an [interactive StoryMap](#)) designed for use by any land or water manager as they consider options for enhancing capture and recharge in their jurisdiction. This framework incorporates consideration of groundwater management objectives, scale and location of the proposed solution, available water sources, recharge threshold criteria, capture and recharge opportunities, and potential costs, benefits, and constraints of possible options.

HOW TO USE THIS FRAMEWORK

The framework is divided into 10 steps:









- 1 Water Management Objective
- 2 Location and Scale of Solution
- 3 Water Sources Inventory
- 4 Source Characterization
- 5 High-Level Threshold Criteria
- 6 Capture and Recharge Opportunities
- 7 Suitability Analyses
- 8 Priority Options
- 9 Cost/Benefit Analysis
- 10 Implementation

The DSF is intended to serve as a tool to help land and water managers navigate to the ATUR products and scientific information that are most relevant to their needs. It is recommended that the user explore the products and information linked in the narrative as they consider each step of the framework.

The icons introduced in Steps 1 and 3 are used to help managers track opportunities for specific groundwater management objectives and potential water sources throughout the flow chart.

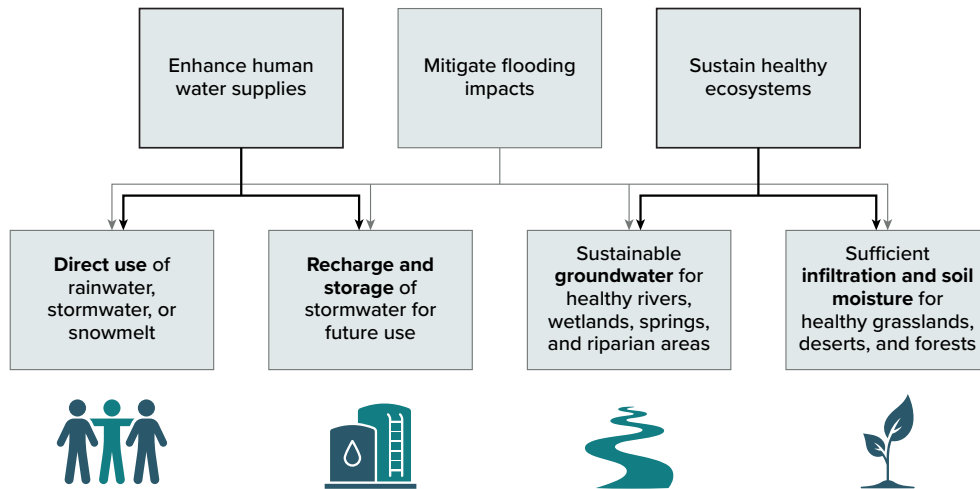
Groundwater management objectives:

Water loss mechanisms from rainwater, stormwater, or snowmelt:

							
Direct Use	Recharge and storage	Sustainable groundwater for healthy rivers	Sufficient soil moisture for healthy ecosystems	Evaporation from water bodies	Evaporation of runoff	Sublimation of snow	Water used by plants

1. Water Management Objective

What is your water management objective?



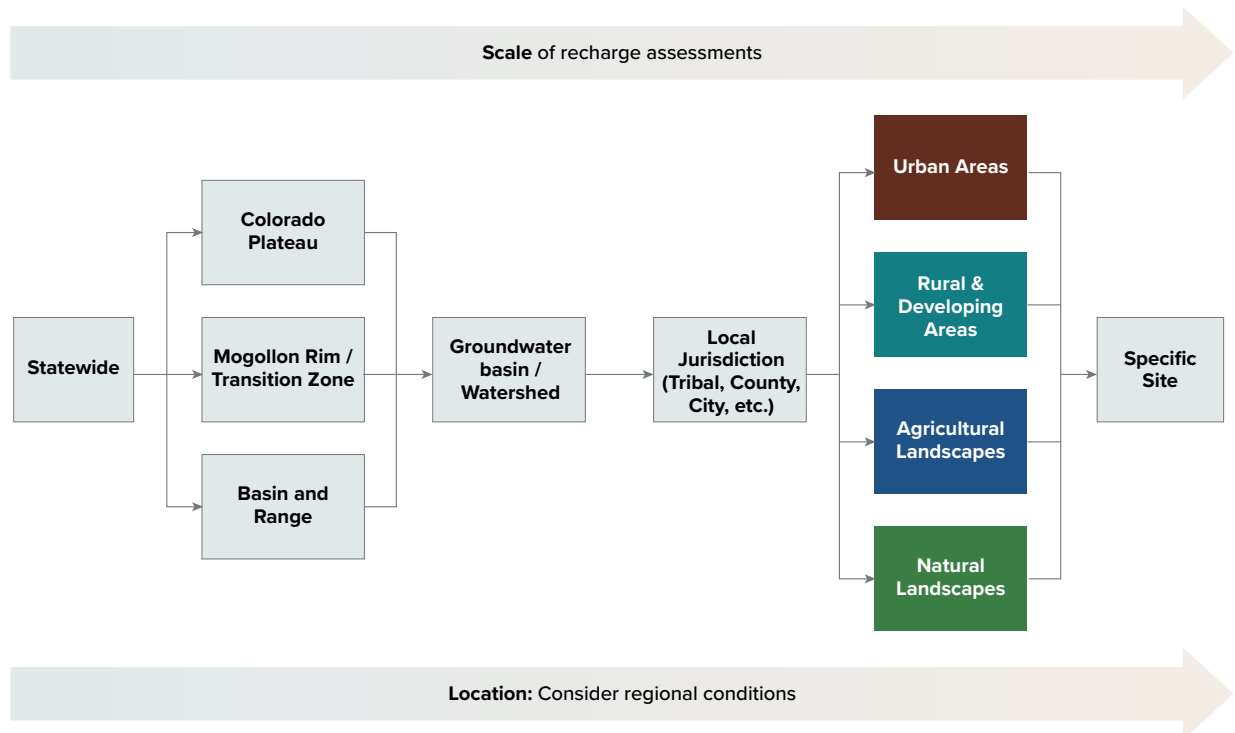
The first step of the framework is to identify the water management objective. Are you exploring opportunities for enhancing water supplies for community use? Would you like to incorporate recharge into your flood control objectives, minimizing flooding impacts while also enhancing recharge? Are you considering how you can sustain healthy ecosystems in your jurisdiction? These objectives are not mutually exclusive, but may be used as a starting point for consideration.

If the identified objective is *enhance human water supplies*, the natural resource manager can consider *direct use* of rainwater/stormwater (indicated by the people icon), or *recharge and storage* of that water for future use (indicated by the storage tanks icon). If the main water management objectives consider *sustaining healthy ecosystems*, focus could be placed on enhancing groundwater supplies for healthy rivers, springs, wetlands and riparian areas (indicated by the river icon). Alternatively, particularly for areas with deep water tables, a manager may wish to improve infiltration and soil moisture for healthy grasslands, deserts and forests (indicated by the plant icon). If mitigating flooding impacts is the primary objective, floodwaters can contribute to any of the four focal points listed (*direct use, recharge and storage, sustainable groundwater, and sufficient infiltration and soil moisture*). These objectives may align, or they may be conflicting depending on the chosen solutions.



2. Location and Scale of Solution

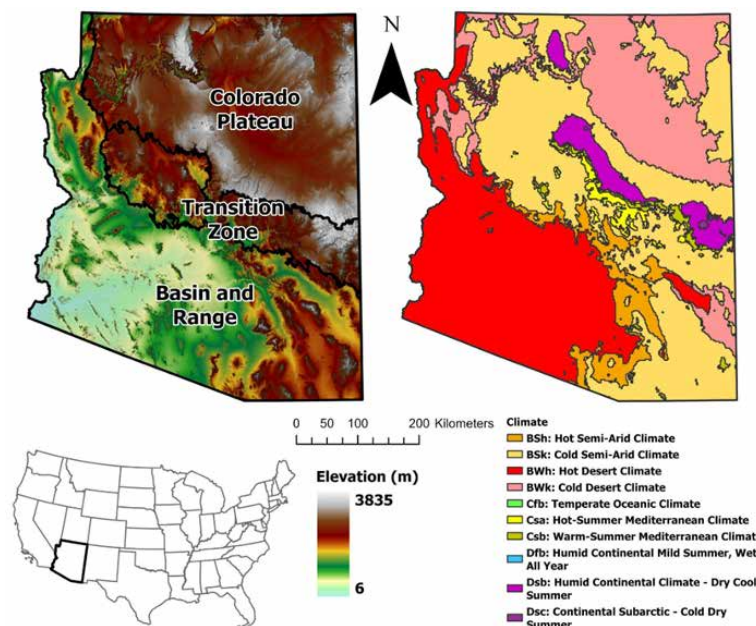
Where do you intend to recharge?



Arizona’s land and water managers are diverse in their objectives and in the scales and locations of their management areas. Scale of management may vary from statewide (i.e. ADWR) to a specific groundwater basin or watershed (i.e. environmental groups), a local jurisdiction (i.e. local flood control districts), and ultimately, a specific site. While the ATUR project has focused on providing a scientific foundation at a statewide scale and recognizing that site-specific analyses are required for project design and implementation, many of ATUR’s findings can guide land and water managers in prioritizing areas for potential capture and recharge interventions in their management area(s).

It is worth considering the location of the intended solution within Arizona’s physiographic provinces—the Colorado Plateau, Mogollon Rim/Transition Zone, and Basin and Range—as each offers diverse opportunities due to their differences in climate, vegetation, and hydrogeology.

2. Location and Scale of Solution



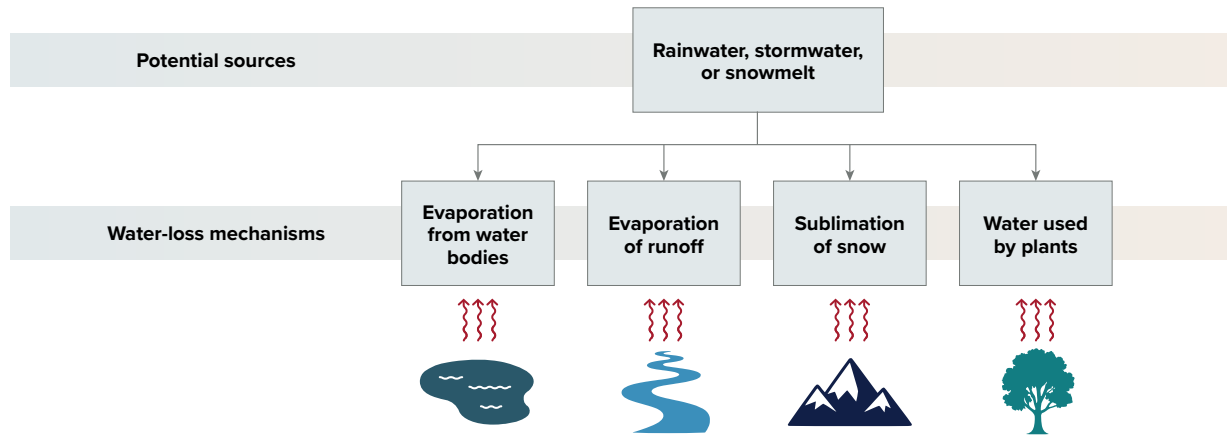
Map of physiographic and climatic diversity in Arizona. Arizona has three major physiographic provinces, with over 3,800 meters (12,467 feet) of relief and 10 different climate zones (Gupta et al., 2026).

The Colorado Plateau receives more than half of its annual precipitation in the cool season (Dec.–March) and contains karst and fractured geology. Winter snowpack supports much of Arizona’s high elevation forests in the Colorado Plateau and Mogollon Rim provinces and provides base flow to most of the state’s perennial and intermittent streams. The Mogollon Rim represents the transition between the Colorado Plateau and Basin and Range provinces and receives the greatest total annual precipitation in the state. The high amounts of precipitation and high incidence of faults and fractures in this province provide many capture and recharge opportunities. The Basin and Range province, and southeast Arizona in particular, are strongly dominated by warm-season precipitation, which helps support perennial streams in this region. While large-scale artificial recharge projects have largely been focused on suitable alluvial basins in the Basin and Range province, enhanced recharge opportunities exist across all three provinces.

Opportunities for capture and recharge also vary across urban areas, rural and developing areas, agricultural landscapes, and natural landscapes within each province. In urban areas, the implementation of retention/detention basins, dry wells, or other strategies may help mitigate flooding impacts while also enhancing recharge potential. In rural and developing areas, protection of floodplains and other areas with high infiltration rates from development can support natural recharge in these regions. Options for direct use of stormwater for agriculture, such as irrigation and livestock watering needs, may be applicable strategies for offsetting groundwater pumping in agricultural landscapes. In natural landscapes, such as sloped/mountainous areas, forests, grasslands, shrublands, and deserts, floodplains/riparian areas, and water bodies, different land management strategies can enhance recharge and increase base flows to the state’s rivers, while enhanced infiltration can increase soil moisture for healthy ecosystems.

3. Water Sources Inventory

What sources of water are available that would have otherwise evaporated, transpired, or sublimated?



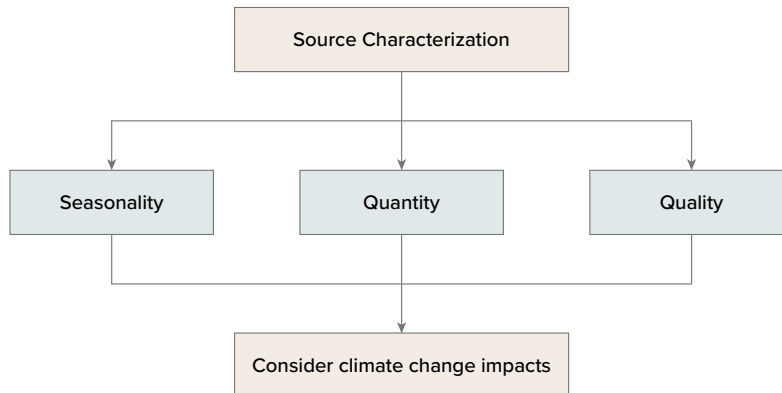
The ATUR project is specifically focused on capturing and recharging water that would have otherwise been subject to evaporative losses. This water lost from rainwater, stormwater, or snowmelt can be broken down into four (4) categories:

- Evaporation from water bodies:
 - Reservoirs, lakes, ponds, playas, etc.
- Evaporation of runoff:
 - New runoff as a result of urban development and post-fire flooding
 - Existing stormwater in urban, rural, and wildland areas
- Sublimation of snow:
 - Occurring mostly in the Colorado Plateau and Mogollon Rim and at high elevations of the Sky Islands
 - Interception of snow by trees can contribute to sublimation of snow that may have otherwise accumulated and infiltrated into the subsurface
- Water used by plants:
 - Plants may use water from the unsaturated (vadose) zone or from the aquifer if the water table is near the surface

These water sources can serve both community and ecosystem needs. Certain water sources may be more relevant to specific regions or land management applications (e.g. sublimation in high elevation areas, evaporation of water bodies in the state's lakes or playas, etc.).

4. Source Characterization

How do the source's characteristics impact its suitability to meet your water management objective?



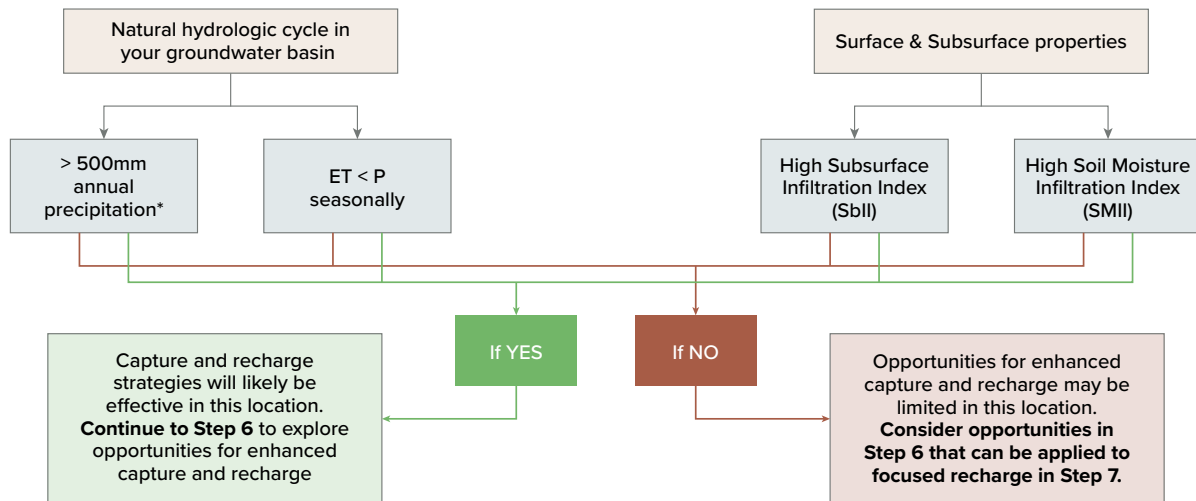
Availability of water sources can vary seasonally, annually, and over longer time spans due to climate change. Considering how seasonal variation can affect the quantity and quality of the identified source water will allow the manager to determine when and how to most effectively capture that water for recharge. For example, a water manager concerned with mitigating flooding impacts due to high intensity precipitation events during the summer should consider the frequency of the storms and the precipitation intensity, the volume, rate, and water quality of stormwater runoff, and the expected evaporative losses. A land manager whose jurisdiction is more influenced by cool-season precipitation will also consider these factors, and a unique solution set will emerge, such as managing canopy cover, shade, and sublimation. Understanding the quality and quantity of the source water allows the manager to consider which opportunities might be most suitable given their water management objective.

Land and water managers can explore the seasonality and quantity of water available for capture in their groundwater basin using the [ATUR Groundwater Basin Profiles](#). They feature hydrologic modeling results for the natural hydrologic cycle (i.e. precipitation, evapotranspiration, recharge, and runoff) for the period of 1980-2020 at statewide, individual basin, and 4-km gridded scales, as well as climate change projections that compare the projected hydrologic cycle at the end of the century (2060-2099) to the historical period for the 51 ADWR groundwater basins in the state. These projections can be used by land and water managers in their longer-term water resources planning efforts.



5. High-Level Threshold Criteria

How effective will capture and recharge be given climatic and site properties?



*Areas with < 500mm annual precipitation may achieve effective recharge on an event basis through conveyance of runoff from high-intensity precipitation events to areas of high infiltration potential.

High-level effective recharge threshold criteria have emerged from ATUR research. If the proposed location meets these statewide thresholds, capture and recharge strategies are likely to be effective. If the location does not meet the statewide thresholds, options for capture and recharge may be limited, but site-specific solutions may still exist. In this case, it is recommended that the user consider options in Step 6 that can be applied to focused recharge opportunities in Step 7.

Hydroclimate criteria such as annual precipitation thresholds or ratios of evapotranspiration (ET) and precipitation (P) allow managers to consider the availability of water for capture in their specific groundwater basin. For areas with less than 500 mm (~20 inches) of annual precipitation or where ET is consistently greater than P on a seasonal basis, there may be limited water available for capture, and opportunities for enhanced recharge may be limited. In these arid regions of the state, effective recharge may be achieved on an event basis through conveyance of runoff from high-intensity precipitation events to areas of high infiltration potential. Land managers can explore the natural hydrologic cycle in their groundwater basin developed through ATUR's National Water Model and Noah-MP land surface modeling efforts (see the ATUR Groundwater Basin Profiles and Step 5 of the [DSF StoryMap](#)).

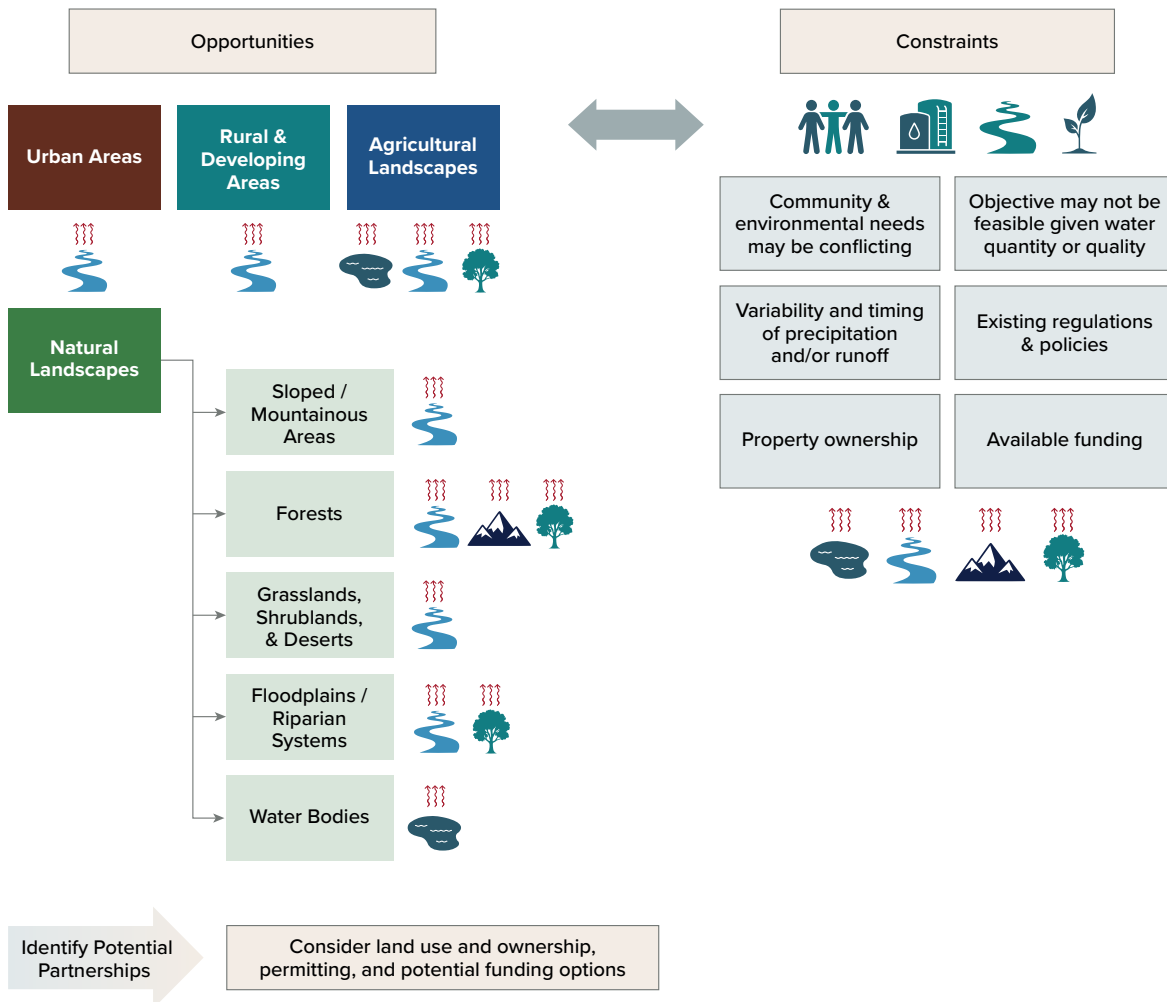
5. High-Level Threshold Criteria

In addition to hydroclimate characteristics, surface and subsurface properties suitable for recharge have also been investigated. ATUR researchers have developed a Subsurface Infiltration Index (SbII) to estimate the infiltration potential of water into the subsurface across Arizona. This index considers permeability, porosity, lineament (faults/fractures) density, and the presence of karst topography to provide a relative measure of infiltration capacity on a scale of 1-10, where a higher SbII indicates higher suitability for infiltration. The Soil Moisture Infiltration Index (SMII) is another index created to determine where on the landscape water is likely to infiltrate into the soil, considering soil hydraulic conductivity as well as surface properties such as aspect, slope, and geomorphology. The SMII is also provided on a scale of 1–10, with higher values indicating a higher likelihood of water infiltrating into the soil. Maps of SbII and SMII across Arizona are available for use by land and water managers (see Step 5 of the [DSF StoryMap](#)). While the SbII and SMII are useful as high-level screening tools, they are GIS-based analyses; field validation would reduce the uncertainties associated with these approaches and is necessary for project design.



6. Capture and Recharge Opportunities

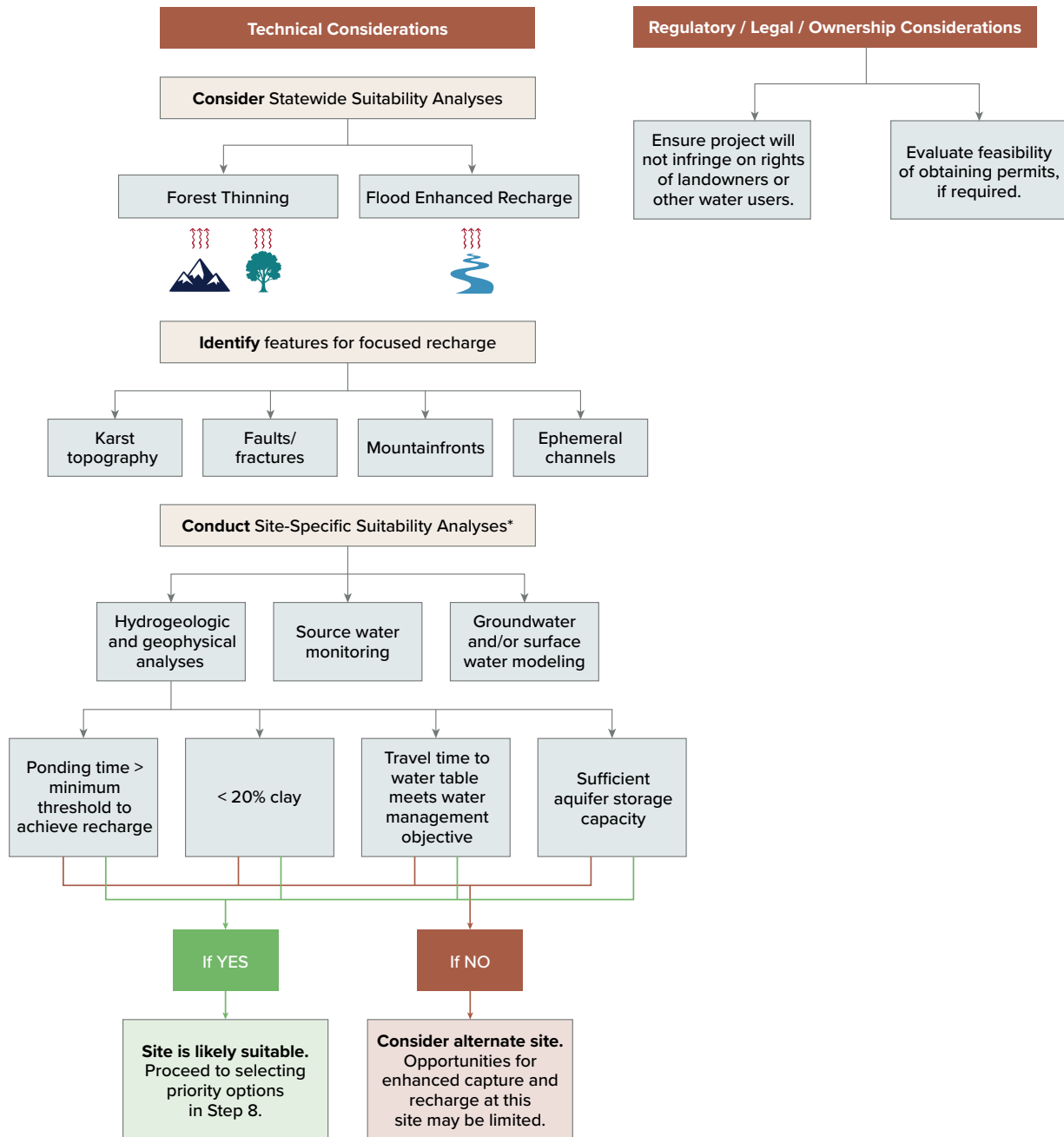
What opportunities exist for enhanced capture and recharge?



The ATUR project has compiled sets of capture and recharge opportunities that include both traditional and novel approaches for urban, rural, agricultural, and natural landscape applications. The natural landscape applications are divided into sloped/mountainous areas, forests, grasslands, shrublands, and deserts, floodplains/riparian systems, and water bodies. Each of these land cover categories is adorned with an icon indicating the most relevant water loss mechanisms based on the identified opportunities in that ecosystem. Managers can access their solution set of interest via the [ATUR Recharge Opportunities Matrix](#). Each set of opportunities also includes constraints that should be considered iteratively for each option within a particular solution set (urban, rural, agricultural, natural landscapes, etc.). Some constraints include existing regulations and policies, property ownership, water quantity and quality, among others. Potential partnerships that can facilitate land use and ownership considerations, permitting, and potential funding options should also be explored at this stage.

7. Suitability Analyses

How suitable are the identified opportunities?



*Site-Specific Suitability Analyses are recommended before moving on to the next steps of the framework unless your goal is to identify opportunities at a statewide level.



7. Suitability Analyses

When determining the technical suitability of the various opportunities for capture and recharge, managers might consider the statewide suitability analyses developed by ATUR researchers, including ponderosa pine forest thinning and flood enhanced recharge (FER), which provide statewide analyses of recharge suitability for these different land management strategies. The icons below each suitability analysis indicate the water loss mechanisms most applicable to that land management strategy. See Step 7 of the [DSF StoryMap](#) to explore these statewide analyses.

Identifying and implementing capture and recharge opportunities near features for focused recharge—karst topography, faults/fractures, mountain fronts, and ephemeral channels—may allow for faster travel times to the water table and increase opportunities for recoverable recharge. Identifying these focused recharge options is especially important in areas where opportunities for recharge may be limited due to limited water available for capture (<500 mm of annual precipitation). A [statewide map of lineament density](#) (faults/fractures) is available for resource managers' use.

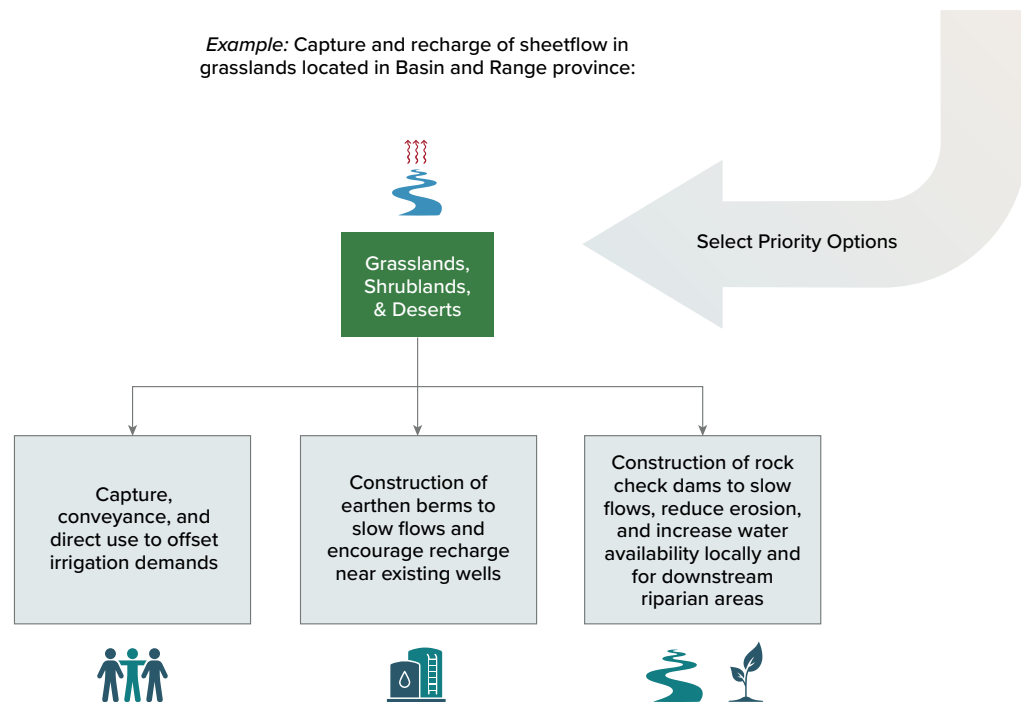
Conducting site-specific analyses—hydrogeologic and geophysical analyses, groundwater and/or surface water modeling, collection of source water monitoring data, etc.—is important to determining if the chosen site is suitable for an enhanced recharge project. These analyses are recommended before moving on to the next steps of the framework unless the management goal is to identify enhanced recharge opportunities at a statewide level. Modeling of the unsaturated (vadose) zone by the ATUR team has shown that the amount of water that reaches the water table is influenced by a range of conditions, including soil properties, vegetation type, and ponding duration. Recharge opportunities are limited in soils with greater than 20% clay content. Site-specific hydrogeologic analyses should include modeling that determines the minimum surface ponding duration threshold required to achieve recharge for the site's soil profile and vegetation type. The time it takes for infiltrated water to travel to the aquifer can vary widely (days to hundreds of years) depending on these surface and subsurface conditions; therefore, hydrogeologic analysis should also include an analysis of travel time to the water table to ensure the specified groundwater management objective can be met (i.e. if the manager would like to recover the water within 10 years, but the travel time to the aquifer is 20 years, an alternate site should be considered). Aquifer storage capacity can be especially critical when considering enhanced recharge in riparian areas with shallow depths to water.

When conducting site-specific analyses, legal considerations such as ensuring the project will not infringe on rights of landowners or other water users and evaluating the feasibility of obtaining required permits are also recommended.



8. Priority Options

What are your priority options based on objectives, available water, and suitability?



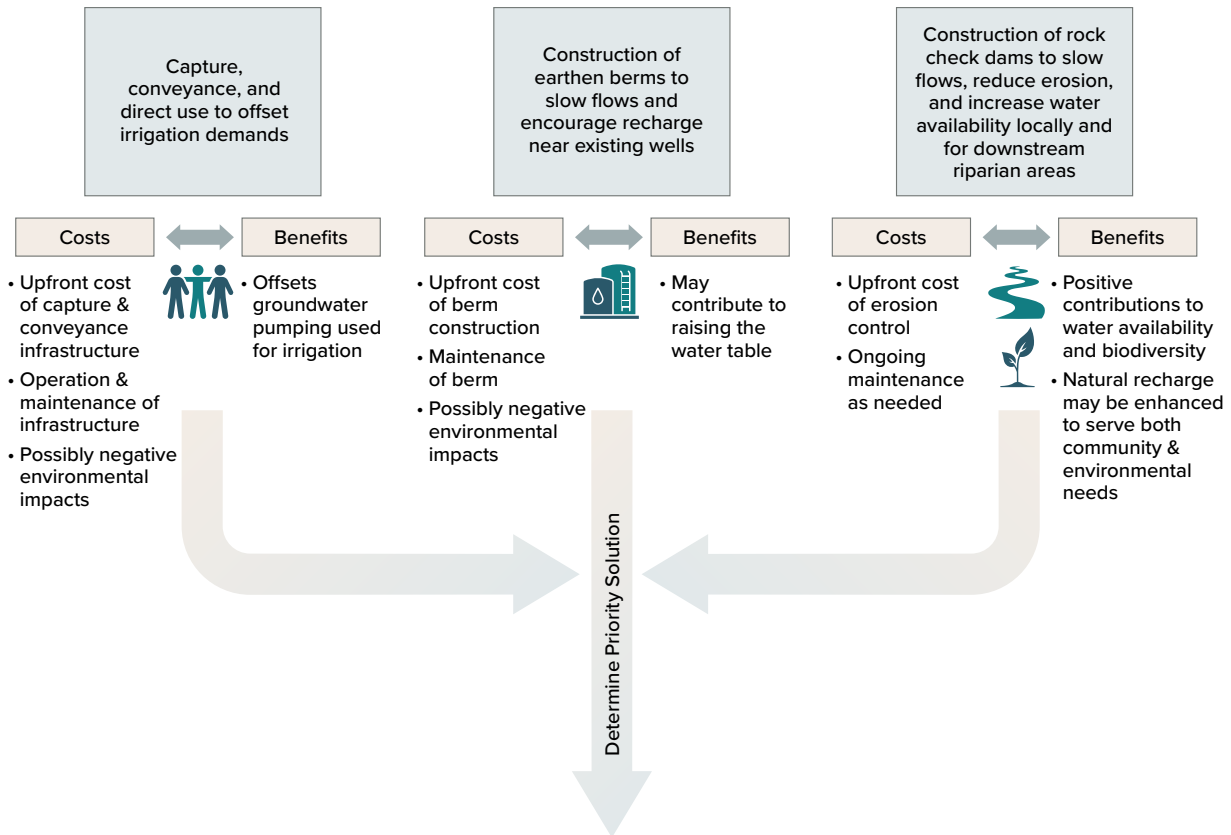
Priority options from Step 6 should be selected for further evaluation given the manager's groundwater management objective, available water sources, and site suitability. An example is provided in this step for consideration. If a land manager whose jurisdiction falls within the Basin and Range province is interested in reducing evaporative losses and improving capture and recharge of overland sheet flow (indicated by the evaporation of runoff icon) in a given grassland area, they may consider different options depending on their objective(s):

- For direct use (indicated by the people icon), the manager may consider capture, conveyance, and direct use of sheet flow to offset local irrigation demands.
- For groundwater storage (indicated by the water storage tanks), construction of earthen berms to slow flows and encourage recharge near existing wells may be an option.
- For improving groundwater supplies in a nearby riparian area (indicated by the river icon) and enhancing infiltration and soil moisture for healthy grasses (indicated by the plant icon), the manager may consider construction of rock check dams to slow flows, reduce erosion, reestablish overbank flows in channelized streams, and increase water availability locally and potentially for downstream riparian areas.

9. Cost/Benefit Analysis

What are the costs and benefits of your priority options over time?

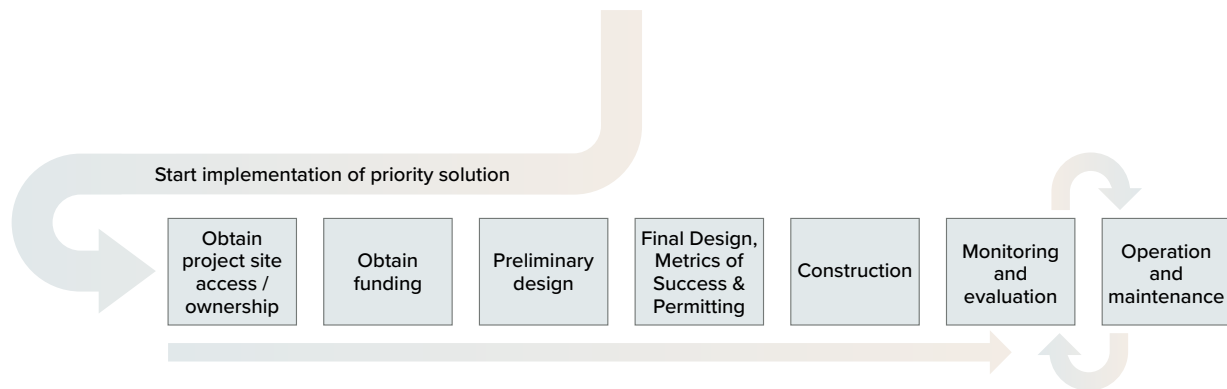
Continued example from Step 8 :



Once the priority options are selected, managers should consider the costs and benefits of those options over time. This should include an evaluation of ecosystem services and non-market values as well as market-based capital and operation and maintenance costs. Examples of non-market values include cultural services (support of water, plants, animals, recreation, etc. that may have cultural significance) and regulating services (such as maintaining the natural hydrologic cycle of an area), among others. The example from Step 8 is carried into this step for consideration. For the direct use (people icon) option, upfront capital costs include capture and conveyance infrastructure, operation and maintenance of that infrastructure over time, and possibly negative environmental impacts from conveying some water that may have eventually infiltrated and contributed to improved soil moisture locally. The main benefit associated with this option is that much of the water that was captured may have been otherwise lost to evaporation, and will instead offset groundwater pumping used for irrigation, protecting the local aquifer. Examples of cost and benefits for each of the other objectives discussed in Step 8 are included in the flow chart. From this cost and benefit analysis, the manager should determine their priority solution for implementation.

10. Implementation

What steps are needed to implement your priority solution?



While specific implementation steps will vary depending on the land or water management application, generic example steps are provided for consideration. Obtaining project site access or ownership is a critical first step and may require time and effort building cross-sector partnerships if the proposed land cannot be simply bought or sold. Project funding will need to be secured, and the preliminary and final designs, including any required permitting, will need to be completed. Depending on the solution chosen for implementation, this may require designs by licensed professional engineers and/or registered or professional geologists. Metrics to assess and monitor success should also be developed at this stage. With the metrics established and final design complete, the project can move into the construction phase. The timeline of the construction phase may vary considerably depending on the specific solution. Finally, enhanced recharge projects will require monitoring and evaluation of success metrics that will inform the specific operation and maintenance activities needed to ensure the solution continues to achieve the intended water management goal(s) into the future.