

Strategy Code	Management Strategy by Landscape Type	Key Opportunity	Major Constraints/Limiting factors? Unintended Consequences?
A	Urban Areas		
A1	Design flood control facilities (e.g., basins, floodways) to maximize recharge either within the facilities or on adjacent lands	Flood control basins/facilities may provide multiple benefits (including habitat enhancement) if location and design is based on hydrogeology and habitat potential as well as potential for managing flooding	Differences in local hydrogeology can make a big difference in recharge rates; incentives for flood control managers to engage in recharge activities may be lacking in some areas
A2	Coordinate with Flood Control District staff to use data collected by Counties across the State to better understand stormwater/surface water supplies to maximize recharge opportunities in the context of flood control	Existing laws (Arizona Revised Statutes) allow for integration of recharge objectives into existing flood control efforts	
A3	Develop regional stormwater plans that incorporate aquifer properties to optimize location of flood control/stormwater detention facilities for multiple benefits (recharge). Consider methods for stormwater conveyance and recharge as part of regional/urban planning including roadway alignment and the ultimate design of urban landscapes.	Water recharge objectives can easily be integrated into stormwater management plans if considered early in the design/planning process.	Regional plans will commonly need to cross jurisdictional boundaries
A4	Use localized, dispersed stormwater collection and conveyance (sewer-like) systems to deliver stormwater to favorable recharge locations	Localized systems can be most effectively incorporated into drainage plans for developing areas	It may be costly/infeasible to retrofit these systems into existing communities
A5	Increase ponding time in detention basins in places that are suitable for recharge	Ponding significantly increases deep infiltration and the potential for recharge to the aquifer	Need to manage potential pests, e.g. mosquitos; may not be useful immediately adjacent to residences
A6	Use dry wells in urban locations capable of recharge to reduce evaporative losses and increase infiltration rates/recharge	Dry wells can provide stormwater recharge benefits in urban areas with limited space	Dry wells may infiltrate runoff, but not result in significant recharge, depending on hydrogeology. Water quality concerns need to be addressed, since urban runoff may contain pollutants.
A7	Install infiltration trenches in areas with large magnitude, short duration runoff events in order to minimize evaporation and increase infiltration rates in areas with fine textured surface soils.	Infiltration trenches are relatively inexpensive to construct, and given their relatively large surface area for intake can capture more water in flashy flood environments as compared to dry wells, but still require appropriate hydrogeology	Requires more space than dry wells, not suitable for high sediment loads(clogging)
A8	Install permeable pavement in urban areas (rather than asphalt or concrete)	Given the extent of paved and impermeable surfaces in metro areas, this has the potential for widespread application	Likely to increase infiltration rates, but unlikely to result in recharge, except in areas with high groundwater levels and/or very high permeability, not recommended for locations with much sediment due to clogging
A9	Place scuppers (installed along curbs to convey water to small detention basins for landscaping) and/or use ditches to collect and convey runoff to recharge locations via floodways	Can result in both increased groundwater storage and improved water quality of urban runoff through infiltration or recharge	Initial engineering and design of roadways and parking lots needs to consider stormwater conveyance-harder to redesign after constructed
A10	Capture rooftop rainwater from individual units, multifamily homes or neighborhoods and convey to high permeability basins	Relatively inexpensive to install, requires limited maintenance/operation	Hydrogeology/depth to vadose must be favorable if recharge will occur, otherwise may enhance infiltration without reaching the groundwater table
A11	Install subsurface storage under large paved areas, tennis courts, to direct water to landscaping or recharge facilities	Little conveyance required-stores water for reuse near point of collection from impervious surface, reduces flood hazards	May require considerable maintenance given oils, other pollutants found in parking lot runoff; can offset groundwater use and/or be a "landscape rescue supply" during drought. Unless this water is subsequently directed to a recharge area, this is capture and use, not recharge.

A12	Use hydrodynamic separators to remove garbage, sediments, and grime prior to conveying floodwaters to recharge zone (Example: Los Cerritos Channel Sub Basin 4 Stormwater Capture Project, LA County)	Addresses both water quantity and quality in a highly urbanized landscape	Cost for construction and O&M is considerable
A13	Increase infiltration and recharge of urban enhanced runoff (UER= runoff that is increased in volume due to impervious surfaces) in ephemeral washes by slowing storm discharge via detention basin(s) and/or low head dams	Nature -based solution that utilizes typically high infiltration and recharge rates of ephemeral channels	Need to quantify the amount of UER, vs pre-development flood flows, to avoid surface water rights issues if there are downstream water rights or claims
A14	Collect and convey sheetflow (movement of stormwater across land surface) in areas of low infiltration-to viable recharge locations to limit evaporation losses	Sheetflow can be generated in many suburban/rural settings: man-made impervious surfaces (roadways, roofs, etc), compacted soils typical of developed rural residential areas, and clayey surface soils all generate sheetflow	Evaporation rate of sheetflow is exceptionally high, and collection and conveyance must rapidly transport sheetflow to collection areas to avoid evaporative losses
A15	Collect and convey sheetflow generated from paved roads to viable recharge locations	Some paved roads generate significant runoff. Collecting and conveying this water to viable recharge locations where infiltration can occur could increase recharge. This may be easier in rural areas but can be part of land use planning/design. Most existing roads already have culverts and other means of diverting flows but may not include recharge as an objective	It may be costly to retrofit these systems into existing communities
A16	Detain stormwater runoff that would otherwise cross or flood roads on the upslope side of roads, in basins designed to increase infiltration and runoff and improve public safety	Flooded road crossings at ephemeral channels are a major issue across Arizona and these sites could instead be beneficial recharge locations. These flows could be significantly reduced through upstream detention and infiltration of stormwater, while also increasing recharge.	Right of ways along roadways need to be of adequate size for construction of detention basins. Statewide flood suitability map may be useful to locate best areas. Hydrogeologic conditions at project sites must be favorable for both infiltration and recharge to occur.
A17	Design areas for deposit of plowed snow in high elevation urban areas (e.g. Flagstaff) to maximize infiltration/recharge	Plowed snow can become an asset instead of a nuisance	May be water quality issues
A18	Limit erosion damage from urban stormwater runoff, and/or poor watershed conditions, by establishing native vegetation in detention/retention areas	Enhance habitat values within open space and natural areas using capture and recharge of accelerated runoff from development	Increasing vegetation generally increases use of water through ET, so this tradeoff needs to be evaluated
A19	Integrate stormwater collection, conveyance, and storage systems into the planning of subdivisions/commercial areas to substitute groundwater use with stormwater runoff	Subdivisions/commercial areas generate runoff from impervious surfaces that may provide a new source of water, to replace groundwater use and/or reverse groundwater depletion, if they are thoughtfully designed to maximize the benefits of this resource	Need to manage flood potential and possibility of water quality issues in urban runoff
A20	Consider storm drains that convey to combination sewers and wastewater treatment to expand available effluent supplies for subsequent recharge in situations where water quality issues are not a concern	This approach could dramatically increase volumes of municipal effluent available for recharge	Variability of AZ precip makes sizing/capacity of effluent treatment facilities difficult; there are capacity and water quality considerations associated with combined storm/sewer systems

B Rural and Developing Areas			
B1	Work with ADOT to map the potential locations for road-related capture and recharge strategies throughout the State	Over the long-term these drainage/recharge improvements could increase public safety and save public infrastructure from flood damage, as well as increase recharge	These improvements may require additional maintenance to function properly over the long term
B2	Work with Forest Service on opportunities to integrate recharge with forest road construction and improvements, thinning strategies, pre-and post fire management strategies	There are significant water capture and storage opportunities that can be inexpensively integrated into forest management efforts	
B2	Prevent/minimize future development in recharge areas, floodplains, or sensitive karst systems. Areas with high recharge potential need to be identified in the early stages of development, e.g. in Comprehensive Plans, to incorporate groundwater recharge considerations	These natural recharge zones are especially important for infiltration and recharge of floodflows and stormwater that supply water for local communities and natural systems	These areas are often located in high priority development zones, so protection may be costly
B3	Protect floodplains and channels in ephemeral, intermittent and perennial systems from development (grading, cut/fill), where the potential for high infiltration rates and recharge exists. Retain and utilize areas for open space where vadose zones are shallow and there is high recharge potential. Allow sufficient areas for floodplains to migrate naturally over time	Floodplains of streams often have high infiltration rates and are important for natural groundwater recharge processes during storm events. Groundwater-surface water connectivity within floodplains plays an important role in groundwater storage and recharge; floodflows can increase adjacent groundwater levels for extended periods of time	There may be objections from landowners regarding limits to development. Protection will require incorporation of recharge considerations into comprehensive land use plans.
B4	Protect natural wetlands, riparian, aquatic and spring systems from groundwater and/or surfacewater depletion; increase public awareness about their hydrologic function and ecosystem services	Groundwater availability for wetlands, riparian, aquatic, and spring systems plays an essential role in sustaining their health- groundwater storage and recharge processes are pivotal to support these natural systems	Continued drought in Arizona in combination with increased human water demands can dewater natural systems without careful consideration and management of both groundwater and surfacewater supplies.
B5	Incorporate recharge objectives into mining and sand & gravel facility design and operations (mine dewatering activities, etc.). Require recharge as part of mine dewatering operations if water quality and hydrogeologic considerations allow	Substantial water is often removed from mining pits and shafts, this may significantly affect local and downstream hydrology	Water quality problems could arise with dewatering; there may be permitting and pollution issues
C Agricultural landscapes			
C1	Diversion of floodflows to fallowed agricultural lands for recharge (Examples: Bryant et al., 2020 ; Tule Basin Land & Water Conservation Trust, Central Valley Groundwater Recharge Incentives and Strategies, 2023)	This technique has received a lot of attention in CA as a way to manage major floods and recharge local aquifers	This may be problematic in terms of surface water laws, water quality, and impacts on riparian and aquatic ecosystems. Site specific assessment will be required. Large scale flooding can damage irrigation systems
C2	Use lined ponds to store captured sheetflow and reduce groundwater demands for irrigation and/or livestock watering	If ponds are losing water to evaporation and infiltration it may be helpful to capture more sheetflow	If it offsets groundwater use, this might stabilize local groundwater levels.
C3	Use unlined irrigation canals in areas with favorable recharge ("planned" incidental recharge)	Canals could be "multi-purpose" if designed correctly for both purposes (irrigation and recharge); could include floodflows in specific circumstances	Irrigators may not have incentives for doing this, could lead to annual reporting issues in AMAs? This approach is only worth pursuing in special circumstances to avoid evaporative losses and/or enhance groundwater supplies in particular areas
C4	Shade or cover basins and/or water delivery canals that deliver to recharge facilities to reduce evaporative losses	GRIC has recently built solar panels over CAP canals to reduce evaporation and produce energy	Need to avoid potential for increased ghg emissions from shaded canals; these facilities are costly to construct and maintain
C5	For grazing applications, see Grasslands section (F)		

D Sloped/Mountainous areas			
D1	Use perforated pipe, french drains, infiltration trenches in mountainfront locations to increase infiltration and recharge of sheetflow in these areas that receive runoff from higher elevations to capture water that would otherwise evaporate	Mountainfront recharge is a critical component of aquifer recharge across Arizona	If mountainfronts are already effective areas for natural recharge processes, are we confident that we can significantly improve them? Would these measures significantly reduce evaporation losses?
D2	Amunas (lateral ditches) have been traditionally used to divert flows from high and mid-elevation mountain streams during wet seasons. They convey water across slopes to enhance infiltration into the groundwater aquifer, at higher elevations, to later emerge as springs at lower elevations during the dry season. This approach is best suited to porous, rocky slopes where infiltration on the higher slopes reduces evaporation, as the water moves down slope, and is stored as groundwater	Amunas may help to manage the more intense, but less frequent, precipitation events anticipated in the future. They may also benefit forest health and reduce drought stress in hillside forests by increasing soil moisture and the moisture of forest fuels while water moves through the soil profile, ultimately reducing the potential for catastrophic forest fires	The impacts of flow diversion to downstream wetland, riparian and aquatic systems should be carefully considered. This approach may impact the timing, duration and/or magnitude of downstream flows, with either beneficial or detrimental effects. Historically, amunas were intended to supply surfacewater at lower elevations for consumptive uses during dry periods
D3	Qanats are underground tunnels that use gravity to channel (more rapidly) groundwater at higher elevations, such as mountain aquifers, to lower altitude locations for subsequent uses. They typically include a "mother well" a gently sloping tunnel (or pipeline) and regularly spaced vertical shafts for construction, ventilation and maintenance. This ancient technology minimizes evaporation and ensures a relatively reliable water source for arid regions	Groundwater recharge is typically greater at higher elevations where precipitation rates are greater, and this system enables the relatively rapid transportation of that water to lower elevations for subsequent use or storage without using any energy. Evaporative losses are very low	The ecological impacts to wetland, riparian, aquatic and spring systems down gradient from the source of water for qanats may need evaluation. Amunas have historically been intended to supply surface water at lower elevations for consumptive uses during dry periods. Tunnels of significant length may be impossible to construct given current land ownership and development patterns in the modern landscape
E Forests			
E1	Fuels reduction, forest thinning and/or prescribed fire can be designed to maximize recharge of water that would otherwise be lost to evaporation e.g. in vicinity of karst, certain forest types, or site types for largest gains in infiltration and recharge interventions	If capture of water otherwise lost to evaporation results in infiltration or surface runoff that leads to recharge there may be benefits in terms of downstream water flows as well as enhanced soil moisture to support forest productivity. ATUR's forest thinning suitability mapping focuses on these issues	Local characteristics including elevation, slope, aspect, canopy cover and forest type, hydrogeology, floodplain connectivity and other factors may limit utility of this approach
E2	Capture of stormwater runoff along hillslope roads through collection in ditches or swales that are up slope of roadways may increase the infiltration of water, benefiting forest health in downslope areas, while reducing erosion and evaporative losses	This strategy may also reduce the risk of catastrophic fires due to increased fuel moisture, and contribute to aquifer recharge if the infiltrated water can reach the water table. In addition, it would likely reduce sediment transport and erosion leading to reduced road repairs and maintenance	Based on soil type and depth, unless infiltrated water can move downslope or vertically to the water table, groundwater recharge will not occur; water will instead only be available for transpiration or evaporation
E3	Various erosion control methods can slow accelerated runoff, especially areas with insufficient vegetative cover, and reduce the potential for sediment transport and debris flows, as well as increase infiltration in areas that may be suitable for recharge. These include berms, swales, contour furrows, rip rap, silt fences and other mechanisms to capture overland flows, sheet flows, and debris before they reach floodplains and streams	Erosion control measures provide multiple benefits to forests in areas with accelerated runoff, given the steep slopes and higher gradients that are typical of these ecosystems. They can also provide hydrologic benefits to both surfacewater and groundwater supplies if carefully considered	Watershed and site specific conditions both need to be evaluated, e.g., slope, amount of runoff, stability and depth of soils, amount of debris, condition of remaining vegetation, etc.

E4	The prompt revegetation of burned areas after wildfires with herbaceous groundcover can stabilize forest soils, reduce the velocity of overland flows, and increase infiltration of runoff. Without stabilization efforts, excessive post-fire runoff can downcut stream channels and eventually lower water tables, reducing groundwater storage. The use of native species for revegetation will increase the longterm viability of restoration efforts and maximize habitat values	Revegetation and restoration efforts post-fire will be most effective when promptly conducted after the burn occurs, before subsequent large precipitation events	Revegetation efforts need to be consistent with long-term forest management plans and strategies given climate change and the rapid changes in the environment
F Grasslands/Shrublands and Deserts			
F1	Capture runoff within grasslands via ditches, trenches, swales, or qanats/pipelines, and convey sheetflow to suitable recharge locations and/or habitat enhancements	Suitable recharge locations (in terms of soils, hydrogeology) should be identified before the design of capture and conveyance systems, to ensure that recharge can effectively occur. This approach will ensure that runoff in grassland settings is conveyed to places where it has the best chances of recharging the aquifer and reducing evaporation	Suitable areas for recharge may be limited. In addition, very few data are available regarding depth to water table/vadose zone and subsurface soil characteristics in grasslands. This strategy may not be very cost effective.
F2	Utilize "Natural Infrastructure", such as wood and rock dams in ephemeral/small tributary channels to slow flood flow velocities, and allow more time for infiltration into the channel bed and banks	Natural Infrastructure materials are commonly readily available, and a cost effective approach, especially for remote areas	How much actual aquifer recharge will result from this strategy, as opposed to increased infiltration, soil moisture, and vegetation, is uncertain, very site-specific, and difficult to quantify
F3	Identify old stock ponds that are overgrown or silted in, in areas with a shallow vadose zone, and retrofit them for capture and recharge	There are likely several thousand stock ponds across Arizona, easily identified via air photo, already located in areas where water likely accumulates	There may be a need to ensure that current stock watering and habitat values are enhanced/protected as a co-benefit to new recharge improvements. Determination of the hydrogeology and depth of the vadose zone in these remote areas may be difficult. There may be water rights associated with historic stockponds, which requires verification.
F4	Maintain overall watershed condition with adequate plant cover to slow overland flow and flood peaks, extending the duration of flows and allowing more time for floodplain recharge.	Healthy watersheds minimize erosion, increase infiltration, and enhance the productivity of grasslands	Grassland cover may increase infiltration, without increasing groundwater recharge, due to subsurface soils and hydrogeology

G Floodplains / Riparian Systems			
G1	Protect, maintain, and/or restore flows in perennial/ephemeral streams to provide habitat enhancement and replenish alluvial aquifers	Natural floodplain recharge is the least expensive way of getting water into the ground and floodplains typically have very high infiltration rates	The presence of riparian vegetation within floodplains reduces erosion, slows the velocity of floodwaters, and helps to increase infiltration rates, but it also uses water for evapotranspiration
G2	Remove invasive exotic riparian species, such as saltcedar, russian olive, and arundo	In some circumstances, removal of these invasive species will reduce evapotranspiration, at least for some period of time, until/unless other vegetation replaces them, resulting in increased surface flows and/or groundwater storage	This strategy could enhance the duration and/or magnitude of baseflows and recharge rates, but it is a very context specific management measure. The potential evapotranspiration savings are hard to quantify, studies have shown these species are rapidly replaced by others that use a similar amount of water
G3	Maintain the integrity of natural channel processes by minimizing channel stabilization (rip rap, cement lining) or the alteration of natural vegetation, especially in larger order stream channels to maintain sinuosity and floodplain connectivity to the active stream channel	The active stream channel, stream banks, and the lower terraces of floodplains all infiltrate flood waters during larger events, and can help to raise groundwater levels rapidly if they remain in a natural, vegetated condition. Reductions in the sinuosity of stream channels increases their gradient and flow velocity; removal of vegetation can also result in increased velocities during flood flows. Reduced flood velocities typically increase the available time for natural recharge processes to occur.	Vegetation in channels may negatively affect flood control through reduction of channel conveyance capacity
G5	Allow large woody debris to remain within active stream channels and floodplains to reduce excessive velocities of runoff, and allow for more near stream recharge, especially in steep gradient stream systems	Large woody debris provides a natural mechanism for trapping sediment, and reducing the gradient and velocity of flows, helping to stabilize stream channels after large flood events have occurred	Debris in channels can divert water out of the active channel into the broader floodplain and cause damage to adjacent properties if floodplains are altered or developed
G6	(Re)introduction of beaver, especially in stream systems where they historically occurred, is an inexpensive approach to reducing stream velocities and increasing near stream infiltration and/or recharge	Beaver dams (or beaver dam analogues) provide a natural mechanism for trapping sediment, and reducing the gradient and velocity of flows, helping to stabilize stream channels especially after large flood events have occurred. They require no (human) maintenance	Many streams have lost the majority of their baseflows within the State and may no longer have adequate water availability for beaver to persist. Beaver dams may also increase local overbank flooding, and may damage any development within the floodplain

H			
Water Bodies (e.g. lakes, playas, reservoirs, etc.)			
H1	Lakes, playas and reservoirs can provide transitional storage prior to groundwater recharge, but open water loses up to 6 feet of water to evaporation annually. Finding ways to minimize surface area of lakes, reservoirs and playas while maximizing nearby or downstream recharge will reduce those losses	Maximizing the benefit of flood control, power generation and water supply outcomes is a significant scientific and policy challenge. One example of a possible water supply benefit is reducing the surface area of the water in the Salt River system reservoirs by releasing more water downstream to recharge facilities. Long term storage in aquifers is much more efficient due to reduced evaporative losses.	Development of regional aquifer recharge facilities is dependent on favorable hydrogeology and would require significant investment to develop, as well as being more expensive to operate. There are regulatory limitations on generating recharge credits from surface water that would otherwise have naturally recharged.
H2	Capture, intercept, or beneficially use water in closed basins with terminal lakes and playas before it is lost to evaporation, or enhance recharge in suitable parts of the basin. In these watersheds with no outlet (endorheic basins), reductions in evaporation or nearby groundwater pumping can directly benefit local water balance. Strategies may include upstream capture in alluvial settings, diversion to recharge facilities, or direct use that offsets groundwater withdrawals	Playas are topographic low points in closed basins that periodically store large volumes of runoff that would otherwise evaporate (McKenna & Sala, 2018). Although long assumed to have negligible recharge due to clay, some recharge can occur and may exceed surrounding uplands. The greatest recharge potential may occur by intercepting runoff before it reaches the playa, particularly in mountain-front or alluvial environments	Clay layers, caliche, salinity, and high suspended sediment loads can limit infiltration, clog engineered features, and reduce water quality. Much infiltrated water may remain shallow and be subject to evaporation rather than deep recharge, making effectiveness highly site-specific. Playas are also important wetland habitat for migratory birds, so hydrologic alterations higher in the watershed or the basin itself may degrade ecological function and create environmental or stakeholder conflicts
J			
Recharge Options Not Limited to Specific Landscape Types: Constructed Recharge Facilities			
J1	Large volume, constructed recharge basins are commonly used to facilitate recharge of imported surface water, treated municipal effluent, or stormwater. They typically result in more reliable groundwater supplies by enhancing groundwater storage that in turn may benefit the water needs of either/both human communities and/or natural systems	In the alluvial basins of southern Arizona there is substantial capacity to store additional water, especially in areas where the aquifer has been dewatered due to prior pumping. The major advantage over surface reservoirs is reduced evaporative losses	These facilities require high infiltration rates at or near the surface and the absence of impermeable layers below the surface, as well as significant depth to groundwater to avoid mounding that can cause water quality concerns. Ongoing maintenance of the basin surface is required to maintain infiltration rates, and these facilities require significant investments and land surface area to construct. Regulations related to recharge basins are included in the Arizona Revised Statutes and administered by the Arizona Department of Water Resources and Arizona Department of Environmental Quality. Permits are required for these facilities
J2	Injection wells involve inserting water under pressure into specific layers of the aquifer, which is useful particularly in urban areas or when managing water quality concerns	Injection wells are most useful where there is limited land area and/or there are impeding soil layers at the surface or in the vadose zone and/or when managing water quality challenges	The primary limitation of injection wells is cost of construction, though they require ongoing maintenance and involve pumping energy costs. Depending on the design of the well field there may be limits on how much water can be recharged this way. As with recharge basins, this method is regulated by ADWR and ADEQ