GREEN RESERVE

The **American Recovery and Reinvestment Act (ARRA), Green Project Reserve** of 2009, through the State Revolving Fund, provided funding for a wide variety of qualifying projects in the categories of: ***green infrastructure, energy efficiency, water efficiency, and other innovative projects***.

Green Infrastructure in Arid and Semi-Arid Climates

Adapting innovative stormwater management techniques to the water-limited West.

Forward-thinking communities in water-limited regions are increasingly recognizing green infrastructure as a cost-effective approach to stormwater management that conserves water.

In arid and semi-arid regions, many green infrastructure practices may not be "green" at all!

When rain falls on natural landscapes, much of it either soaks into the ground or is returned to the atmosphere by plants or evaporation. Rain that is not absorbed into the soil flows into nearby washes, arroyos, creeks, or streams. By armoring landscapes with parking lots, roads, and rooftops, we dramatically change this water balance. Much less precipitation is absorbed into the soil, and much more flows across the land, gathering oils, pesticides, animal waste, and trash along the way. Gray stormwater infrastructure relies on storm sewers to drain this water and its pollutants to the nearest body of water—increasing flooding, pollutant loads, and erosion, and degrading water quality and habitat.

Green infrastructure refers to a set of practices that mimic natural processes to retain and use stormwater. By promoting infiltration, evapotranspiration, and harvesting throughout the landscape, green infrastructure preserves and restores the natural water balance. Though many green infrastructure practices were first developed and applied in temperate regions, green infrastructure is perhaps even more relevant in arid and semi-arid climates. Communities, researchers, and design professionals in these water-limited regions are increasingly recognizing green infrastructure as a cost-effective approach not only to stormwater management, but to water conservation as well. This guide discusses the drivers, applications, and design of green infrastructure in arid and semi-arid regions.

In the 1920s, approximately 5% of precipitation in the Los Angeles region flowed to the sea. Today, extensive impervious cover and massive stormwater conveyance systems deliver 50% of the rain falling in the region to the sea, even as more than 80% of the city's water demand is met by costly imports from distant locations. [1, 2]

BENEFITS OF GREEN INFRASTRUCTURE

Although this guide views green infrastructure through the lens of stormwater management, green infrastructure can provide many environmental, social, and economic benefits. Green infrastructure not only reduces runoff, but can conserve water, recharge groundwater, conserve energy, and improve air quality. These environmental benefits create more sustainable cities and towns, and translate into significant social and economic gains. This section reviews the multiple benefits of green infrastructure.

ENVIRONMENTAL BENEFITS

- **Reduces flooding:** Increasing infiltration, evapotranspiration, and storage where precipitation falls will reduce runoff and flooding.
- **Improves water quality:** Reducing runoff and allowing runoff to be treated by soils and vegetation will reduce pollutant loads to receiving water bodies.
- **Provides habitat:** Native and drought-adapted plants that thrive on infrequent precipitation can provide habitat for native birds and insects.
- **Reduces the urban heat island effect:** Removing pavement and planting vegetation can cool and shade urban neighborhoods in the hot summer months.
- **Improves air quality:** Urban vegetation removes pollutants from the air and can mitigate smog formation by reducing temperatures.
- **Mitigates global warming:** By sequestering carbon dioxide in soils and plant biomass, urban vegetation can reduce atmospheric CO_2 concentrations and mitigate global warming.
- **Increases groundwater recharge:** In many cities and towns in the arid and semi-arid West, impervious cover and engineered conveyance systems reduce the amount of precipitation that enters the groundwater store. Green infrastructure practices that reduce impervious cover and enhance infiltration can increase the flow of water to the groundwater. The Los Angeles Basin Water Augmentation Study (WAS) for instance, estimates that the installation of green infrastructure practices that infiltrate the first ¾" of rainfall on each parcel could increase groundwater recharge in the Los Angeles region from 16% of annual rainfall to 48%. Despite concerns about the impact of stormwater recharge on groundwater quality, studies have consistently demonstrated that soils are very effective in removing priority pollutants from stormwater.[3, 5] Local conditions will shape the effect of green infrastructure on groundwater recharge in each region, but the impact of extensive implementation can be substantial.

BENEFITS OF GREEN INFRASTRUCTURE CONT.

SOCIAL BENEFITS

- **Improves public health:** Cooler summer temperatures and cleaner air can dramatically improve health, particularly for children and the elderly. More pedestrian-friendly landscapes can also promote physical activity.
- **Beautifies neighborhoods:** Private gardens and public rights-of-way irrigated with passive and active rainwater harvesting can create beautiful landscapes.
- **Calms traffic:** By reducing street widths and introducing curves, green street techniques can slow traffic.
- **Builds communities:** By beautifying neighborhoods and creating a unique sense of place, green infrastructure practices can increase neighborhood interaction. Neighbors may even work together to integrate green infrastructure into their neighborhood.

ECONOMIC BENEFITS

- **Reduces landscape maintenance costs:** Passive rainwater harvesting and drought adapted plants will reduce the cost of irrigation and maintenance.
- **Increases groundwater resources:** In the arid and semi-arid Southwest, groundwater resources comprise ~55% of the water supply. Green infrastructure practices that increase groundwater recharge can provide significant cost savings by averting increased pumping costs or increased water imports. The Los Angeles WAS concluded that infiltration-based practices distributed across the region could increase groundwater recharge by 384,000 acre-feet per year—more than 1.5 times the volume captured by centralized spreading grounds. Based on the cost of the current water supply, the study estimated the corresponding value at approximately $310 million per year.
- **Reduces water imports:** Many cities and towns in the West depend on costly imports of water from great distances to meet their water demand. By reducing landscape irrigation, green infrastructure can reduce water demand and water imports.
- **Reduces energy use:** The energy required to import, treat, and distribute municipal water could be significantly reduced by using precipitation where it falls. The energy and cost savings would not be trivial. The Natural Resources Defense Council (NRDC) estimates that transportation and treatment of water consumes 19% of all electricity in the state of California.[4]

In Los Angeles, enhancing groundwater recharge through green infrastructure practices could supply approximately $310 million worth of water per year.

The green roof installed by EPA Region 8 provides welcome open space in the heart of the city. *Photo courtesy of Greg Davis.*

APPLICATIONS OF GREEN INFRASTRUCTURE

Green infrastructure is a versatile approach to stormwater management that can be applied in a range of climates and at a range of different scales. This section discusses the many practices that can be applied in arid and semi-arid regions, from the scale of a single building to the scale of a neighborhood or watershed.

Active rainwater harvesting in Tucson, AZ.

Passive rainwater harvesting in Tucson, AZ. *Photo courtesy of Watershed Management Group.*

Subsurface infiltration basin in Rancho Mirage, CA. *Photo courtesy of RGA Landscape Architects.*

RAIN GARDENS

Rain gardens (or bioretention cells) are vegetated depressions that retain and treat runoff from rooftops, sidewalks, and streets. Unlike conventional gardens, rain gardens receive most of their water from precipitation. In the arid and semi-arid West, where landscape irrigation accounts for about 40% of municipal water demand, rain gardens can play an important role in both water conservation and stormwater management.

Rain garden design is based on three simple components: a drainage area that collects rainwater, a distribution system that connects the drainage area to the receiving area, and a receiving area that retains and infiltrates the rainwater.

Rain gardens should be sited to treat as much impervious area as possible, and sized to match the volume of soil storage with the extent of the drainage area. Excavation may be required to increase soil storage and accommodate plant roots, and soil amendments may be required to increase soil water retention and maintain healthy plants. In arid and semi-arid regions, rain garden design must be conscious of the limited water supply. The following section discusses techniques for selecting and maintaining vegetation in water-limited regions.

SWALES

Swales are vegetated or mulched earthen channels that retain and treat runoff from rooftops, sidewalks, and streets. Though similar to rain gardens, swales are linear features designed to convey runoff downslope. As runoff flows through the swale, it is slowed by the vegetation or mulch, and may be infiltrated into the soil. Again, techniques for selecting and maintaining vegetation in arid and semi-arid regions are discussed in the following section.

For more information on passive rainwater harvesting with rain gardens, swales, and other landscape features, see the City of Tucson's comprehensive Water Harvesting Guidance Manual, available at http://dot.tucsonaz.gov/stormwater/education/waterharvest.php

POROUS PAVEMENT

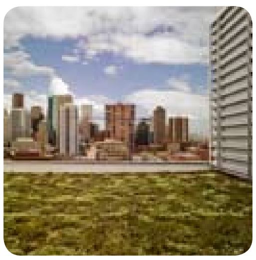
Porous pavement reduces runoff volumes and contaminant loads by allowing more precipitation to infiltrate into the soil. Porous pavement systems generally consist of a permeable surface (often porous asphalt, porous concrete, or interlocking concrete pavers) and several layers of bedding. Water that drains through the surface and layers of bedding infiltrates into the soil below. Studies have shown that porous pavement treats the water that passes through the system by retaining oils and heavy metals. Porous pavement, therefore, provides a direct water quality benefit by removing the contaminants associated with streets and parking lots, as well as an indirect water quality benefit by reducing the volume of runoff. Porous pavement may also reduce irrigation demand by providing water to trees with extensive root systems.

RAIN BARRELS OR CISTERNS

Rain barrels, cisterns, or tanks reduce stormwater runoff and municipal water demand by storing rainwater from rooftops and other impervious areas for later use. The appropriate storage volume will depend on the roof area, rainfall, available space, and other site conditions, as well as the system objectives. Whereas smaller rain barrels can provide modest reductions in runoff volume and irrigation demand, larger rain cisterns or

APPLICATIONS OF GREEN INFRASTRUCTURE
CONT.

tanks can capture most rooftop runoff and supply much of the irrigation demand. A 2007 study prepared for the Colorado Water Conservation Board, for instance, found that a 5,000-gallon cistern paired with water-wise landscaping could provide 50% of the irrigation demand for a 7,000-square-foot lot in Douglas County, CO. The cost of these systems, however, increases significantly with storage volume—particularly for underground storage construction. In sizing rainwater harvesting systems, site owners must balance the multiple benefits of stormwater retention and water conservation against the costs of construction.



Green roof atop the EPA Region 8 office in Denver, CO. *Photo courtesy of Greg Davis.*

GREEN ROOFS

As in temperate regions, green roofs in arid and semi-arid regions reduce and treat stormwater runoff. The green roof installed atop the EPA Region 8 Office in Denver, Colorado, for instance, retains more than 80% of the rainfall it receives.

When designed appropriately, green roofs may offer a water-efficient approach to urban stormwater management in arid and semi-arid regions. Though green roofs in these regions will require irrigation throughout their lifetimes, water efficiency can be significantly increased by adapting green roof designs. Irrigation requirements can be reduced by increasing growing media depth, planting native and drought-adapted species, and applying drip irrigation. Municipal water demand can be further reduced by installing systems that irrigate green roofs with harvested stormwater runoff and/or AC condensate.

Green street in Tucson, AZ. *Photo courtesy of Watershed Management Group.*

When installed in appropriate settings, green roofs may also represent a cost-effective approach to urban stormwater management. The cost-effectiveness of a given green roof installation depends on the benefits offered by the green roof, as well as the value placed upon those benefits. Green roofs not only retain and treat stormwater, but conserve energy, reduce heating and cooling costs, reduce the urban heat island effect, sequester CO2, provide habitat, and extend the lifetime of the roof. While conventional roofs typically require replacement every 10-20 years, green roofs typically require replacement every 40-50 years. In dense, urban settings, green roofs also provide valuable recreational space and can reduce stormwater management costs by reducing or eliminating the need for stormwater vaults or ponds. EPA Region 8's green roof, for instance, reduced the cost of the below-ground stormwater detention vault from about $363,800 to $150,000.

GREEN STREETS

The principles of green infrastructure are most effective when designed as a system and applied across a neighborhood or watershed. Green streets are one example of a neighborhood-scale system. Green streets integrate rain gardens and swales into the street design to retain and treat stormwater while beautifying streets and slowing traffic. Rain gardens can be installed in rights-of-way, medians, traffic circles, and chicanes, and rainwater can be directed into these areas by introducing curb cuts or installing curbs flush with the ground.

RIPARIAN BUFFERS

Riparian buffers are one example of a watershed-scale approach to green infrastructure. Riparian buffers restrict development in the land adjacent to washes, arroyos, creeks, or streams to reduce erosion and preserve channel form and function. When applied throughout a watershed, riparian buffers can provide multiple environmental and social benefits. By preserving an interconnected network of habit, riparian buffers can increase wildlife diversity in urban areas. Many communities designate recreational trails within riparian buffers. These trails can provide access to nature as well as opportunities for physical activity.

SELECTING AND MAINTAINING VEGETATION IN ARID AND SEMI-ARID CLIMATES

To establish green infrastructure in arid and semi-arid climates, particular care must be given to the selection and maintenance of vegetation. Though some planners have expressed skepticism about the viability of vegetated practices in water-limited regions, appropriately designed practices will not only be effective and sustainable, but will conserve water resources as well. The key to selecting and maintaining vegetation in water-limited regions is to follow the principles of xeriscaping.

This section reviews these principles and discusses their application to particular green infrastructure practices.

1. **Create a plan.** The first step in designing landscape features that can remain healthy and attractive with limited irrigation is to create a plan balancing water supply and demand. By preparing a site water budget, designers can choose the plant species and densities that best meet their aesthetic objectives while reducing water demand.

   The numbers required to prepare a site water budget include annual or monthly precipitation, mature plant size, and annual or monthly plant water needs. Annual water budgets will generally be appropriate for landscapes consisting of native plants at native densities, while monthly water budgets will be more effective for landscapes with exotic plants and higher plant densities.

   Comprehensive lists of plant water requirements for Arizona plants are provided by Brad Lancaster's *Rainwater Harvesting for Drylands and Beyond, Volume 1* and the Arizona Municipal Water Users Association's *Landscape Plants for the Arizona Desert*. In other areas, landscape designers may consult the local Cooperative Extension office, local chapter of American Society of Landscape Architects, local association of landscape contractors, native plant societies, or nurseries.

Plant selection for rain gardens:
Bear in mind the potential for occasional inundation. Though standing water should last no more than 72 hours, plants located at the lowest elevations should be able to tolerate inundation.

Rain gardens fed by passive rainwater harvesting border the buildings and parking lots of the TAXI redevelopment project in Denver, CO. The rain gardens beautify the site, reduce the urban heat island effect, and provide habitat, while reducing runoff to the nearby South Platte River. *Photo courtesy of Wenk Associates.*

SELECTING AND MAINTAINING VEGETATION IN ARID AND SEMI-ARID CLIMATES CONT.

2. **Use low water use plants.** Native and drought-tolerant plants can drastically reduce, if not eliminate, the irrigation requirements of green infrastructure practices. Note that low water use plants do not exclude trees. On the contrary, drought-adapted trees thrive on deep, infrequent watering, and are particularly suitable for green infrastructure practices.

Plant selection for green roofs:
Bear in mind the hot, windy environment, the difficulty of accessing most rooftops, and the importance of maintaining the roof structure. Green roof plants should be low growing, self shading, and self-propagating, and should have shallow root systems.

3. **Use efficient irrigation systems.** Irrigation systems will be most efficient when plants are grouped according to their water needs, and when the frequency and depth of irrigation is adjusted according to plant type, plant maturity, and season. Irrigation schedules should be adjusted at least four times per year, and in warm months, irrigation should take place during the night or early morning. Drip or low flow irrigation techniques will minimize evaporation, runoff, and weed growth.

4. **Consider soil amendments.** Healthy soils are essential to retain soil moisture, sustain vegetation, and treat stormwater runoff. Poor site soils can be amended with organic material.

5. **Use mulch.** Organic mulch can increase water retention and pollutant removal while building soil structure and suppressing weeds. Note, however, that many desert trees and shrubs react poorly when their trunks come in contact with mulch.

6. **Maintenance.** All landscapes require maintenance, and xeriscaping is no exception.

When applied to rain gardens, swales, green roofs, and green streets, these principles will produce sustainable green infrastructure practices that require minimal irrigation. Because these practices will often replace very water intensive conventional landscaping, the net effect will be a dramatic decline in water use.

This rainwater cistern installed at a residence in Tucson, Arizona supplies water for citrus trees and a small vegetable garden, as well as native plants. *Photo courtesy of Technicians for Sustainability.*

NAVIGATING WATER RIGHTS LAW IN THE ARID AND SEMI-ARID WEST

Green infrastructure approaches in the arid and semi-arid West must recognize and adapt to the complex legal landscape associated with water rights law. In most western states, water law is based on the doctrine of prior appropriation. According to this doctrine, the diversion and use of state waters requires a water right, and water rights are allocated based on the time of appropriation ("first in time, first in right").

This doctrine does not affect most green infrastructure practices, but the application of this doctrine to rainwater harvesting does raise several questions. Does the state have jurisdiction over precipitation? Does active rainwater harvesting require a water right? Each state offers its own answers, and in many states, these answers continue to evolve. While some states have developed laws and policies that promote rainwater harvesting, others are extremely restrictive, and still others have no formal policy at all.

The table below summarizes the present stance of 11 western states toward rainwater harvesting. The table:

- Identifies the agency responsible for the administration and enforcement of state water law;
- Indicates whether the state has jurisdiction over atmospheric rainwater;
- Indicates whether a permit would be required to harvest and use rainwater; and
- Identifies who may apply for rainwater harvesting permits if they are required.

State	Responsible Agency	Jurisdiction over Atmospheric Water?	Permit Required?	Who May Apply for Permit
Arizona	Arizona Department of Water Resources	No	No	NA
California	California Environmental Protection Agency, Division of Water Rights	No	No	NA
Colorado	Colorado Division of Water Resources	Yes	Yes. Colorado law identifies properties that may apply for a permit	1. Residential properties that are supplied by a well (or could qualify for a well permit) and are not served by a municipality or water district 2. Developers wishing to apply for approval to be one of 10 statewide pilot projects
Idaho	Idaho Department of Water Resources	No	No	NA
Montana	Montana Department of Natural Resources & Conservation, Water Resources Division, Water Rights Bureau	Yes	Yes	No formal policy
Nevada	State of Nevada, Department of Conservation & Natural Resources, Division of Water Resources	Yes	Technically, yes	Applications not accepted
New Mexico	New Mexico Office of the State Engineer	No	No	NA
Oregon	Water Resources Department	Yes	No. Oregon law exempts "the collection of precipitation water from an artificial impervious surface" from permit requirements	NA
Utah	Utah State Engineer	Possibly	Yes	No formal policy
Washington	Washington Department of Ecology	Possibly	No	NA
Wyoming	Wyoming State Engineer and Board of Control	Yes	Technically, yes, but residential rainwater harvesting is regarded as de minimus	No formal policy

NAVIGATING WATER RIGHTS LAW IN THE ARID AND SEMI-ARID WEST

CONT.

Many states and municipalities recognize the vast gains in water efficiency that rainwater harvesting can provide, and are playing an active role in promoting this practice. The table below reviews innovative policies and incentives that western states and municipalities have developed to expand rooftop rainwater harvesting.

State	State/Municipal Policies and Incentives
Arizona	A state tax credit is available for plumbing stub outs and water conservation systems (including rainwater harvesting) through 2011. The city of Tucson mandates that commercial developments meet 50% of their landscaping water requirements with harvested rainwater. A Bernalillo County ordinance requires builders to employ certain water conservation measures. Two of the measures builders may select are active and passive rainwater harvesting.
California	A draft Los Angeles ordinance would require builders to employ rainwater storage tanks, permeable pavement, infiltration swales, or curb bumpouts to manage 100% of the runoff from a 3/4" storm, or pay a mitigation fee.
New Mexico	The New Mexico State Engineer issued a Rainwater Harvesting Policy encouraging "the harvesting, collection, and use of rainwater from residential and commercial roof surface for on-site landscape irrigation and other on-site domestic uses." Santa Fe County's Water Harvesting Ordinance mandates the use of rain barrels, cisterns, or catchments for small residences, and the use of buried or partially buried cisterns for large residences and commercial buildings. The Albuquerque Bernalillo County Water Utility Authority offers rebates for rainwater harvesting systems based on the amount of water that can be stored.
Oregon	Building Code OPSC 08-01 allows rainwater harvesting systems for residential potable uses as a statewide alternative method.
Washington	The Washington Department of Ecology issued an Interpretive Policy Statement clarifying that a water right is not required for rooftop harvested rainwater used on site. Washington law states that commercial buildings that utilize active rainwater harvesting systems must receive a 10% reduction in any municipal stormwater management fees. Kitsap County offers a 50% reduction in stormwater management fees to new or remodeled commercial buildings that utilize rainwater harvesting.

The policies above represent a few of the actions that local and state governments can take to remove barriers to green infrastructure and provide incentives for its adoption. As communities across the West struggle to allocate limited water resources among growing populations, green infrastructure can play an important role in preserving water quality while conserving water supply.

Green infrastructure offers a versatile, simple, and cost-effective solution to several of the arid and semi-arid West's most pressing environmental concerns.

Additional green infrastructure resources are available at www.epa.gov/greeninfrastructure and www.epa.gov/smartgrowth.

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