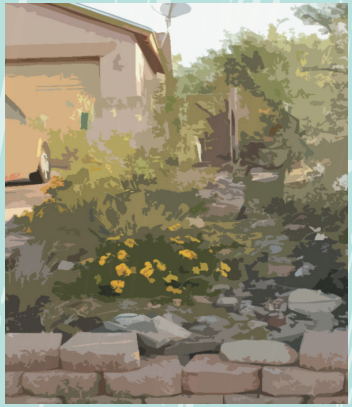
Santa Cruz County
WATER HARVESTING GUIDANCE MANUAL



August 2012

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WATER HARVESTING GUIDANCE MANUAL

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Santa Cruz County Board of Supervisors

Modified from City of Tucson Water Harvesting Guidance Manual for Santa Cruz County by
Sonoran Institute

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Santa Cruz County Flood Control District

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www.co.santa-cruz.az.us/com_development/index.html
www.co.santa-cruz.az.us/public_works/flood/public-info.html

COVER: images from left to right include a water harvesting microbasin at the Guy Tobin Memorial Anza Trailhead, a local residential rain garden, and a rain garden at the Santa Cruz County Administration Complex.

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Sonoran Permaculture Guild

Glossary

Note: The following definitions have been developed specifically for use within this manual and are not intended to be generalized to other uses.

Capillary rise. The tendency of water in soil to rise due to the strong attraction of water molecules to each other and to small pore spaces between soil particles.

Cistern. A water tank used to store harvested stormwater.

Contour line. A topographic contour line which is a line of equal elevation on a land surface.

Detention/retention basin. A structure that decreases flow from the site by temporarily holding stormwater runoff on the site.

Downslope. The portion of a slope that is downhill from a reference location.

Filter fabric. A nonwoven geo-textile material placed under riprap to prevent the movement of fine soils by water running through the riprap.

French drain. A gravel-filled trench that allows stormwater to quickly seep below land surface and ultimately into adjacent soil.

Gabions. A semipermeable barrier of rock or other material, which is usually encased in wire mesh. Gabions carefully placed in a small drainage slow, but do not stop, the flow of stormwater.

Infiltration. Movement of water from the surface to below ground through soil pore spaces.

Integrated design. A highly efficient site design that matches site needs with site products, and takes into account stormwater drainage, solar orientation, winds, and many other factors. An integrated design saves resources while improving the function and sustainability of the site.

Building code. A set of specifications for construction adopted by Santa Cruz County.

Microbasin. A small, relatively shallow basin used to capture, store and utilize stormwater.

Microclimate. Local conditions of moisture, sun, wind, and other characteristics.

Overflow device. Component of a water harvesting structure that allows excess stormwater to flow out of the structure without damaging the structure.

Rainwater. Liquid precipitation falling from the sky before it has hit a solid surface.

Rock riprap. A rock layer that protects earthen surfaces from erosion.

Stormwater. Rainwater becomes stormwater once it has landed on a surface.

Stormwater Quality Storm (SQS). Commonly known as the "First Flush Storm," the SQS is the rainfall depth that results in runoff that transports the majority of pollutants during a storm event.

Swale. A curvilinear depression in the land surface that collects stormwater. Generally has a mounded berm on the downslope side that assists in retaining stormwater.

Upslope. The portion of a slope that is uphill from a reference location.

Water harvesting. The process of intercepting stormwater from a surface such as a roof, parking area, or land surface, and putting it to beneficial use.

Watershed. A term commonly used to describe a catchment area within which all stormwater drains toward a common collection point. Used in this manual to describe those drainage areas affecting a particular site, which might include upslope areas draining toward the site or downslope areas receiving drainage from the site.

Xeriscape. Landscaping that saves water by using water conserving designs, drought tolerant plants, water harvesting techniques, reduced turf area, appropriate irrigation methods, soil improvements and mulching, and proper maintenance practices.

Introduction

What is water harvesting?

Water harvesting is the process of intercepting stormwater runoff from a surface (e.g. roof, parking area, land surface), and putting it to beneficial use. Intercepted stormwater can be collected, slowed down, and retained or routed through the site landscape using microbasins, swales and other water harvesting structures. Water harvesting reduces dependence on limited groundwater reserves. Capturing and using stormwater runoff also reduces site discharge and erosion, and the potential transport of stormwater pollutants.

How will water harvesting benefit my site?

Developed sites typically have a high ratio of impervious area (buildings and pavement) to pervious area (vegetated and bare soil areas). By harvesting and using stormwater you can:

- Increase water availability for on-site vegetation,
- Reduce on-site flooding and erosion,
- Reduce water bills and groundwater pumping, and
- Extend the life of landscaping (rainwater is usually low in salt content and relatively high in nitrogen).

In addition, you may be able to save money and increase usable land area by using stormwater harvesting techniques to reduce the Santa Cruz County retention/detention requirements for a site. Developments in Santa Cruz County are accountable for the quality of the stormwater leaving their sites. Harvesting stormwater and vegetating stormwater collection areas can help improve stormwater quality by reducing particulates and pollutants in stormwater.

Who should read this manual?

The Water Harvesting Guidance Manual was prepared for Santa Cruz County to provide basic information and design ideas to developers, engineers, designers and contractors of commercial sites, public buildings, subdivisions and public rights-of-way. The manual will also be useful for those interested in water harvesting on their existing or future home sites. See Appendix G for other water harvesting references and contacts.

Is water harvesting going to cost me more?

Site development costs typically include design, grading, and landscaping. Long-term maintenance adds to these initial costs. Incorporating water harvesting into site development can save money by:

- Reducing the size of code-required detention/retention facilities,
- Saving the costs of structural stormwater quality controls,
- Combining detention/retention, landscape buffers and visual screens into single features,
- Reducing landscaping water bills, and
- Lowering energy requirements by shading buildings with vegetation watered with harvested stormwater.

Incorporating water harvesting concepts early into an integrated design for the site is key to reducing costs and maximizing long-term benefits.

What is a site watershed?

The term watershed is commonly used to describe an area within which all stormwater drains toward a common collection point. The term watershed is used in this manual to describe drainage areas affecting your site, which might include upslope areas draining toward your site, drainage areas on your site, or downslope areas receiving drainage from your site.

How to use this manual

This manual describes a process for evaluating site characteristics and developing integrated designs in which water harvesting enhances site efficiency, sustainability, and aesthetics. Water harvesting principles and techniques are described, followed by example designs for a subdivision, commercial site, public building and for public rights-of-way. This manual is intended to provide general guidance; implementation will require site-specific modification, sizing, and engineering. Illustrations indicate relative size and order of magnitude, not specific scale. **Note: Every site is unique; adapt the information in this manual to specific conditions at your site. Prior to installation, obtain all permits and have the site Blue Staked (1-800-782-5348) to locate underground utilities.** Appendices have been included to address Santa Cruz County code requirements (Appendix A), engineering considerations (Appendix B), water harvesting calculations (Appendix C), landscaping considerations (Appendix D), mosquito considerations (Appendix E), example water harvesting sites (Appendix F), and related resources and contact information (Appendix G).

Water Harvesting Principles

Start managing water at the top of the watershed

- Determine the site watershed, including off-site watersheds that contribute stormwater runoff to, or receive stormwater runoff from, your site.
- By managing small volumes of water at the top and throughout the watershed, the need to manage a large volume of stormwater at the bottom of the watershed is decreased.
- Encourage upslope neighbors to conduct water harvesting on their sites, and/or capture and use this stormwater runoff as it enters your site.

Create multiple small watersheds

- Evaluate existing topography using a detailed site contour map and site visits.
- Divide the site into small watersheds based on existing topography, or based on grading and reshaping as necessary, to maximize stormwater harvesting.

Collect, slow and infiltrate the water

- Slow and spread stormwater flow to reduce its erosive nature, allow sediments to drop out, and allow more water to infiltrate into soils.
- Expose stormwater to as much soil surface area as possible within the confines of the water harvesting structure to increase infiltration into the soil; the least expensive place to store water is in the soil.
- Stormwater should be stored in the soil at locations where it can support plant growth but not damage facility foundations. Building foundations should be separated from ponding water or infiltration areas by a minimum of 10 feet, or as required by the building code. Consultation with a soil professional is recommended when planning water harvesting near a building.
- As more stormwater infiltrates into the soil, less stormwater has to be managed as surface runoff.

Prepare for overflow

- Water harvesting structures need to allow excess stormwater to overflow safely to other locations, ideally where it will be used beneficially.
- Overflow devices (tank overflow pipes, spillways, etc.) should be sized to safely handle large rainfall events. Convey overflow discharge to safe locations to avoid contributing to erosion.
- Overflow devices should be checked and maintained regularly.

Mulch to reduce evaporation

- Mulching soil by adding a thick layer of organic or inorganic material reduces evaporation of water from, and retains moisture in, the soil to support plants. Mulch to an appropriate thickness (3 to 4 inches is usually sufficient) for the vegetation types present. Avoid mulching against tree trunks.
- Organic mulches include bark, leaves, straw, and other plant materials that decompose over time to create healthier, more porous soils. Organic mulches can float on water, so water harvesting basins should be large enough to contain floating mulch. Vegetation will help immobilize mulch.
- Inorganic mulches include rock, gravel, decorative rock (not decomposed granite because of clogging fine particles), and other materials that do not inhibit infiltration into the soil.

Put harvested water to beneficial use

- Think about all the ways you use water at your site, and consider how harvested stormwater can be used to meet these needs.
- Harvested stormwater can be better for plants than groundwater, as it is much lower in salts and higher in nitrogen.
- Stormwater stored in well-mulched soil supports plants during and after the rainy season. Stormwater stored in tanks is typically available beyond the rainy season as well.

Adjust and maintain your systems as needed

- Inspect water harvesting systems periodically, especially after big rainstorms, and adjust as needed to address basin or overflow sizing, erosion, or mosquito breeding issues.
- Water harvesting basins might need to be expanded as plants mature.
- Some systems will need more ongoing maintenance than others; all systems should be carefully designed to be as low-maintenance as possible.

Water Harvesting Design Process: Integrated Site Design

Introduction

Integrated site design matches the needs of a site (e.g. water, energy, aesthetics) with the products of a site (e.g. stormwater runoff, shade from buildings, vegetation) to create an efficient design that saves resources (e.g. energy, water) while improving the function and sustainability of the site. An integrated design is based on detailed site analysis.

Step 1:

Adopt an integrated design process

- An integrated design process must be based on a multidisciplinary approach. Members of the design team can include the developer, architect, engineer/hydrologist, landscape architect, contractor, land use planner, and others.
- Hold a predesign meeting with the entire team to address water harvesting potential.
- Throughout the design process, it is important to keep focused on integrating various technical perspectives and to pursue opportunities to achieve multiple benefits.

Step 2:

Analyze site characteristics and conditions

- Inventory site characteristics including topography, geology, native plants, soils, views, site history, pollution history, etc.
- Obtain a detailed contour map of the site.
- Map the site's watersheds (stormwater drainage pattern) on the contour map and determine stormwater flow rates.
- On the contour map, plot other conditions that affect the site including warm and cool microclimates, seasonal winds, noise, light pollution, traffic patterns, wildlife corridors, human pathways, etc.
- Evaluate adjacent land uses for their impact on the site, and evaluate the site's impact on them.

Step 3:

Identify the potential to use harvested water and other site resources

- Determine how harvested stormwater and other resources can improve efficiency, comfort, open-space buffering and aesthetics of the site.
- Determine how harvested stormwater and other resources can reduce water consumption, energy requirements, landscape maintenance, and other needs.
- Determine how each site element can serve multiple functions (e.g. above-ground water tanks could provide stored water, shade, and noise abatement).

Step 4:

Develop an integrated design for the site

- Evaluate maps and potential uses prepared in Step 2 and Step 3 to determine which characteristics are useful (e.g. stormwater) and which are not useful (e.g. noise).
- Design water harvesting, landscapes, buildings, roads, parking lots, and sidewalks to use desirable elements (e.g. stormwater, winter sun, views) and deflect unwanted elements (e.g. harsh winds, noise, summer sun).
- Design water harvesting approaches to supplement landscape irrigation, reduce stormwater discharge, and downsize detention/retention facilities.
- Design landscapes to use harvested water, to cool buildings, shade parking lots, provide visual screens, and improve aesthetics.
- Develop an integrated design for the site that incorporates these considerations and incorporates the multidisciplinary approach.

Step 5:

Prepare detailed designs

- Use the final integrated design as the basis for preparing detailed plans for site layout, grading, drainage, architecture and landscaping.
- Check detailed plans for consistency with the integrated design.

Water Harvesting Techniques: Microbasins

Goal
Collect stormwater in localized basins served by small watersheds.

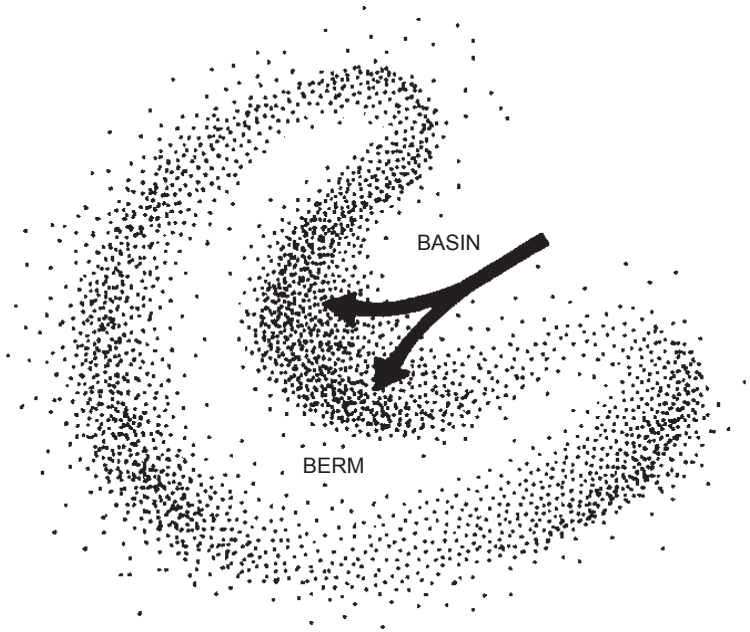
Appropriate siting, water volume and slope
Microbasins are appropriate for use on gently sloped or nearly flat land with low volumes of runoff water such as along sidewalks, in landscaped areas, in parking lot planters, etc. Microbasins can be used in areas with more concentrated runoff if they are arrayed in a series with spillways in between. **Microbasins are generally not suitable in washes or other locations with heavy stormwater flow. Every site is unique; the appropriate scale of any water harvesting technique needs to be determined based on site-specific conditions. Consult a professional when in doubt.**

Construction
Dig out a shallow basin, putting the extra dirt downhill and on the sides of the basin to create a thick, crescent-shaped, gently-sloped berm. Compact the berm to keep it from eroding. Berms can be covered with riprap or ground cover vegetation to protect them from the impact of rain and overflow erosion. The upslope side of microbasins should be open to intercept water. The bottom of the basin can be flat to spread the water evenly, or gently concave to focus water where desired. It may be necessary to construct depressed, rock-lined spillways on some microbasins to manage overflow. **Do not** compact the bottom of the basin since this would inhibit water infiltration. Microbasins should be vegetated and mulched to encourage rapid infiltration of stormwater.

Vegetation
Plants will prefer the sides or bottoms of microbasins depending on their tolerance for temporary inundation. Plant seedlings rather than seeds in microbasins since temporary inundation can drown sprouting seeds. Basins are also useful for retaining supplemental irrigation water. Mulch the basins to reduce evaporation losses. Avoid mulching against tree trunks.

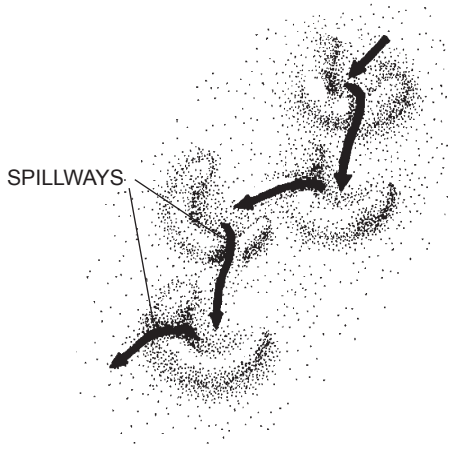
Maintenance
After heavy rainfall, check microbasins for evidence of overflow. If needed, build a shallow spillway on the berm to control the outlet of future large flows from the microbasin. A well-mulched and planted microbasin receiving water from a small localized watershed generally does not overflow. Microbasins **must** be designed and maintained to infiltrate stormwater completely within 12 hours to avoid mosquito problems (Appendix E).

Variations
Several variations of microbasins are shown on the following page. Microbasins can be constructed in a range of sizes to support single or multiple plants with different water needs. All variations **must** be designed and maintained to infiltrate stormwater completely within 12 hours to avoid mosquito problems.

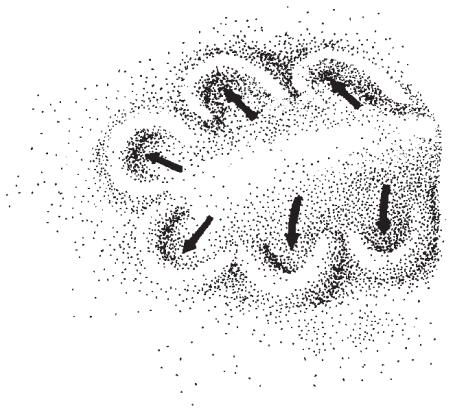


Water Harvesting Techniques: Microbasins

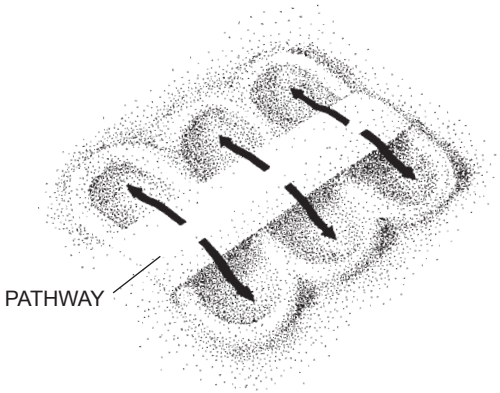
A. Microbasins in a series.
Offset the spillways on microbasins to create a longer water flow path to encourage more infiltration into the soil. These are appropriate for moderate flows. May need more erosion control measures for overflow areas.



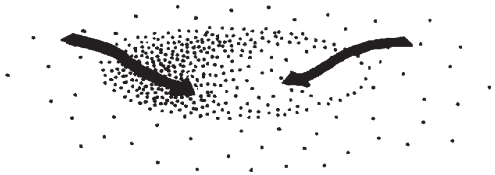
B. Microbasins on-contour.
Arrange microbasins to intercept water running off a ridge. Microbasins will follow the shape of the contour line around a ridge with the upslope ends of basins at the same elevation.



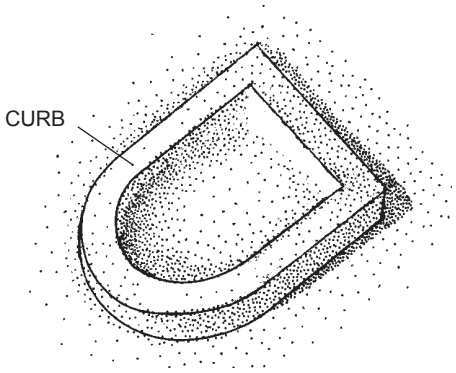
C. Build microbasins in association with pathways, driveways, etc.
Raise pathways and other hard surfaces relative to microbasins so the surfaces drain toward basins and water does not pool where people walk or drive. Avoid a steep drop off at the pathway edge.



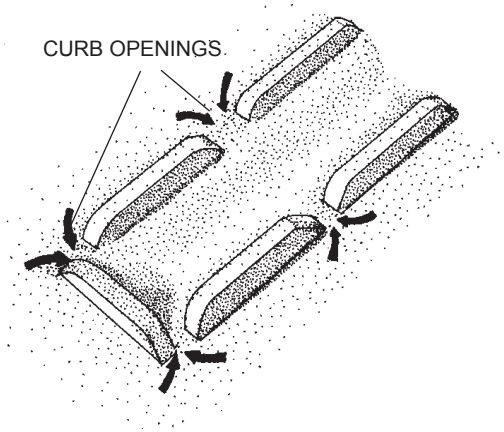
D. Localized depressions.
Construct gentle localized depressions without constructing associated berms.



E. Lower soil level inside curbed areas.
Use a concrete header as the berm for a microbasin and lower the soil level inside the header. This allows retention of all the rainwater that falls into the basin, though it *does not intercept additional stormwater flowing in the area unless a curb opening is provided*. This is a good way to retrofit existing parking lot planting areas. If multiple plants are present, multiple internal basins can be shaped to further focus the water.



F. Direct parking lot runoff toward microbasins.
Slope parking lot surfaces to direct stormwater runoff toward depressed microbasins positioned so that trees planted in them will shade cars and people. Use curb-stop sections or formed curb with openings to allow water to flow into the microbasin planting areas, while stopping car tires.



Water Harvesting Techniques: Swales On-Contour

Goal
Intercept small to moderate volumes of shallow, slow-moving stormwater (sheet flow) with swales and associated berms constructed on-contour.

Appropriate siting, water volume and slope
On-contour swales can be used in small- to moderate-sized watershed areas with gentle slopes such as parks, large landscaped areas, open spaces, etc. On-contour swales should not be constructed within a drainage channel, and should be at least 10 feet from any building foundation, or as required by the building code. Position swales carefully since water will pond in the swale to a line approximately level with the top of the spillway. **Every site is unique; appropriate scale of any water harvesting technique is determined based on site-specific conditions. Consult a professional when in doubt.**

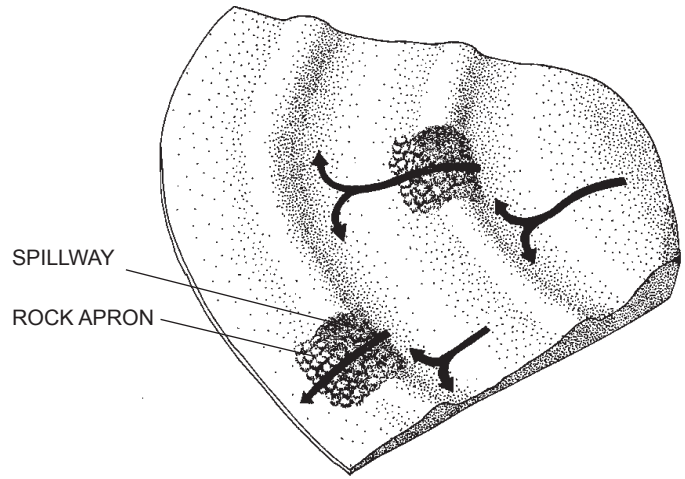
Construction
Determine the overall storage volume needed for the water harvesting swale based on the watershed area above the swale and the slope at the swale location. Dig a curvilinear swale (depression) parallel with the land contour (any line of equal elevation), and place excavated dirt on the downhill side to create a berm. Smooth the swale and berm and compact the berm only. The berm should be wide and strong and can be covered with riprap or ground cover vegetation to reduce erosion. The top of the berm should generally be level, with the exception of a depressed spillway area. The spillway will be the low point in the berm, and should be lined with rock to reduce erosion. The bottom of the swale is lower than the berm and spillway so stormwater is stored within the swale. Multiple swales catching stormwater runoff at multiple locations in the watershed are preferable to a single large swale.

Carefully design and construct spillways to handle large flows without damaging the structure. Large spillways should be depressed in the center to avoid the tendency of water to scour around the outside edges of the spillway. Extend the rock downslope of the spillway to create an apron or splash pad to absorb the impact of overflow water. The bottom of swales can be uneven (but lower than the spillway) to allow existing plants to be left in place. Swales should be planted and mulched to assist rapid infiltration of water and minimize evaporation. Swales **must** be designed to infiltrate stormwater completely within 12 hours to avoid mosquito problems (Appendix E).

Vegetation
Native drought-tolerant plant species are appropriate for planting in or near these water harvesting structures. Extensive roots will help stabilize the structure, as will the self-mulching tendency of dense vegetation (leaf drop accumulation creating a mulch layer). Position plants to take advantage of water but avoid placing plants where they block spillways or would be damaged by large flows. Smaller plants with shallow roots should be planted in the bottom or sides of the swale close to higher soil moisture areas. Trees can be planted in the swale, on the berm, or immediately downslope of the berm, since tree roots will seek moist soils. Mulch the plantings. Supplemental irrigation might be needed to establish vegetation. Once established, low water use plants typically do not need irrigation, except during extended dry periods.

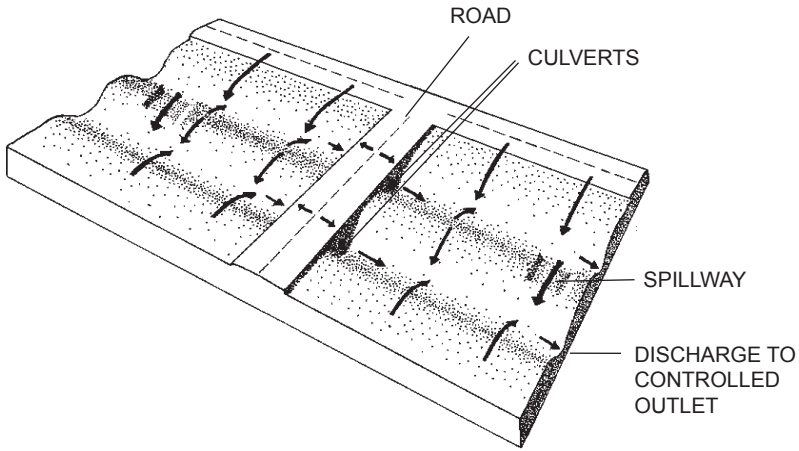
Maintenance
Check swales and spillways after heavy rainfall for overflow of the berm, erosion of the spillway, and to see if water remains in the swale for more than 12 hours. Adjust spillway or swale configuration accordingly. Sediment can accumulate in the bottom of swales reducing storage volume and infiltration rate. Break up the bottom of the swale, add mulch or increase plantings to aid infiltration rate. If needed, remove built-up sediment to re-establish storage volume and infiltration rate.

Variations
Variations of on-contour swales are shown on the following page. All variations **must** be designed and maintained to infiltrate stormwater completely within 12 hours to avoid mosquito problems (Appendix E).

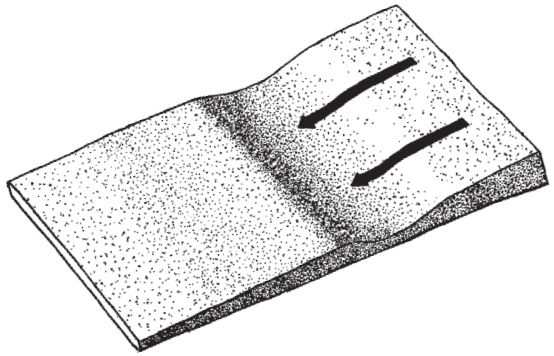


Water Harvesting Techniques: Swales On-Contour

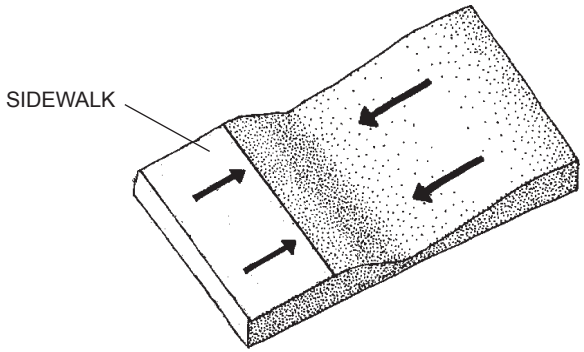
A. Large-scale parallel on-contour swales.
Install parallel on-contour swales to act as a retention/detention feature. The first swale intercepts the water and retains it for use. The second swale intercepts overflow stormwater from the first swale, and can be built to transmit excess stormwater off-site if necessary. Plant both swales with vegetation to utilize the stored water and act as landscape buffers. Roads, sidewalks, and paths can be built in conjunction with these structures.



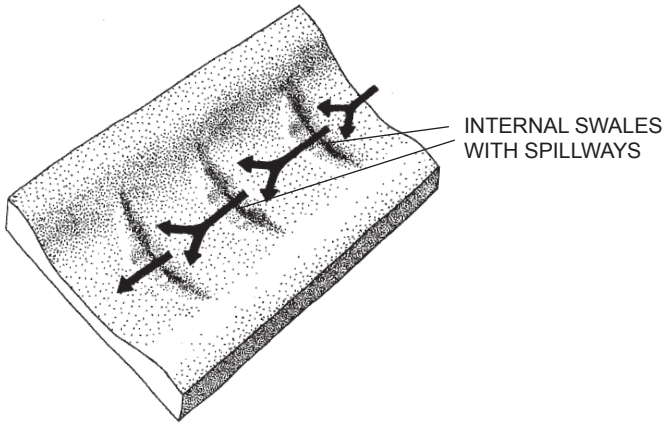
B. Swales without associated berms.
Create wide, gentle linear depressions on-contour to collect stormwater without constructing associated downslope berms. This results in less volume of storage, but is a less noticeable structure.



C. Use roads, sidewalks, and paths as berms for adjacent swales.
Raised roads, sidewalks and paths constructed on-contour can act as berms to retain water in upslope swales. Direct a portion of the paved surface runoff toward the upslope swale. Earth along the edge of paved surface is vulnerable to erosion and might need erosion controls. Use caution where infiltration into the subsurface could saturate a compacted road base. Provide a gentle slope between a sidewalk and adjacent basin to avoid creating a tripping hazard.



D. Swales as microbasins.
Build swales and berms along contour lines within the confines of a gently-sloped drainageway. Include overflow spillways to allow excess stormwater to flow downslope.



Water Harvesting Techniques: Swales Off-Contour

Goal
An off-contour swale is constructed at a slight angle from the contour line. As shown in the illustration, the swales and berms are aligned slightly off parallel with the contour lines. Off-contour swales convey stormwater **slowly** downslope in a controlled manner to maximize infiltration, support vegetation, control erosion, reduce stormwater flow velocity, and eventually discharge any excess stormwater to a safe location.

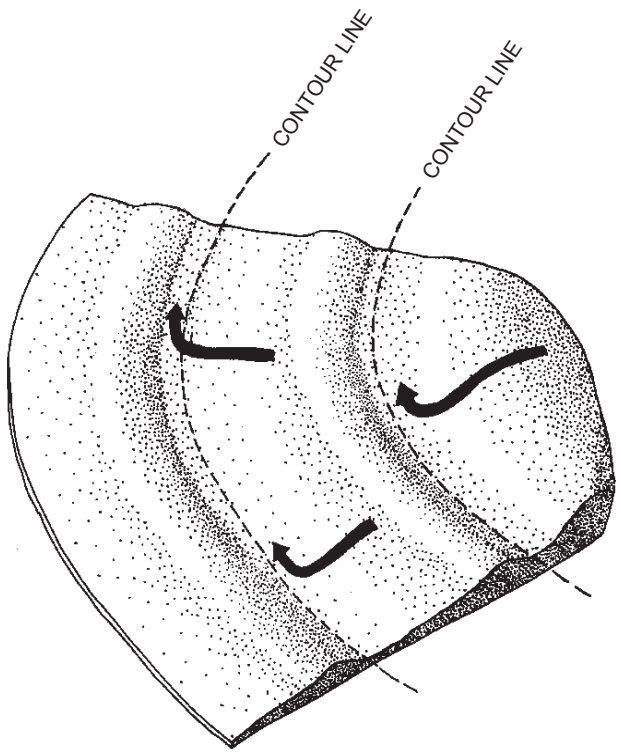
Appropriate siting, water volume and slope
Off-contour swales and berms can be used in moderate-sized watersheds in areas with gentle slopes such as parks, large landscaped areas, open spaces, etc. They are not designed for use within a drainage channel. Large off-contour swales should be at least 10 feet from any building foundation, or as required by the building code. **Every site is unique; the appropriate scale of any water harvesting technique should be determined based on site-specific conditions. Consult a professional when in doubt.**

Construction
Off-contour swale construction methods are similar to those for on-contour swales, as detailed on page 6. Very slight drops in the slope of the off-contour swale will convey water **slowly** downslope without causing erosion. Additional basins can be constructed inside larger swales to further reduce flow rate and retain more water in the soils. The final destination of the water should be a multipurpose detention basin area or other area where the stormwater can be put to beneficial use and/or discharged safely. Minimize erosion by using rock riprap on any steep banks. Spillways might be needed if the swales serve relatively large watershed areas.

Vegetation
Drought-tolerant native trees and shrubs and other drought tolerant species are appropriate for planting in or near these structures. The root systems will help stabilize the structure, as will the self-mulching tendency of dense vegetation. Arrange plants to take advantage of water availability and avoid planting near spillways where plants might be damaged by large flows.

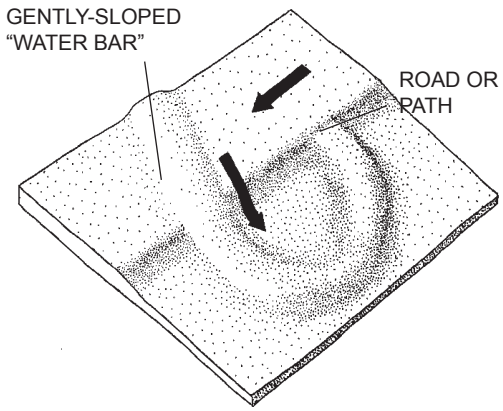
Maintenance
Inspect the structure after large rainfall events for erosion, inadequate sizing of spillways, and other deficiencies. Correct any deficiencies and continue to inspect and maintain the swale following major events. Swales **must** be designed and maintained to infiltrate stormwater completely within 12 hours to avoid mosquito problems (Appendix E).

Variations
Several variations of off-contour swales are shown on the next page. An additional variation is to create a wide, gently sloped drainage swale perpendicular to the land contour to move water gently downslope. Use appropriate plantings to stabilize soil in the gentle drainage swale. Swales can also be arranged to direct stormwater slowly downslope in a switchback pattern. All variations **must** be designed and maintained to infiltrate stormwater completely within 12 hours to avoid mosquito problems.

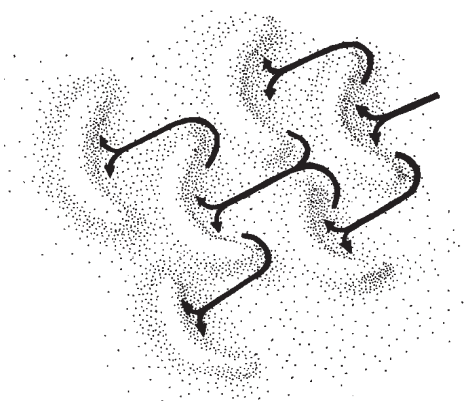


Water Harvesting Techniques: Swales Off-Contour

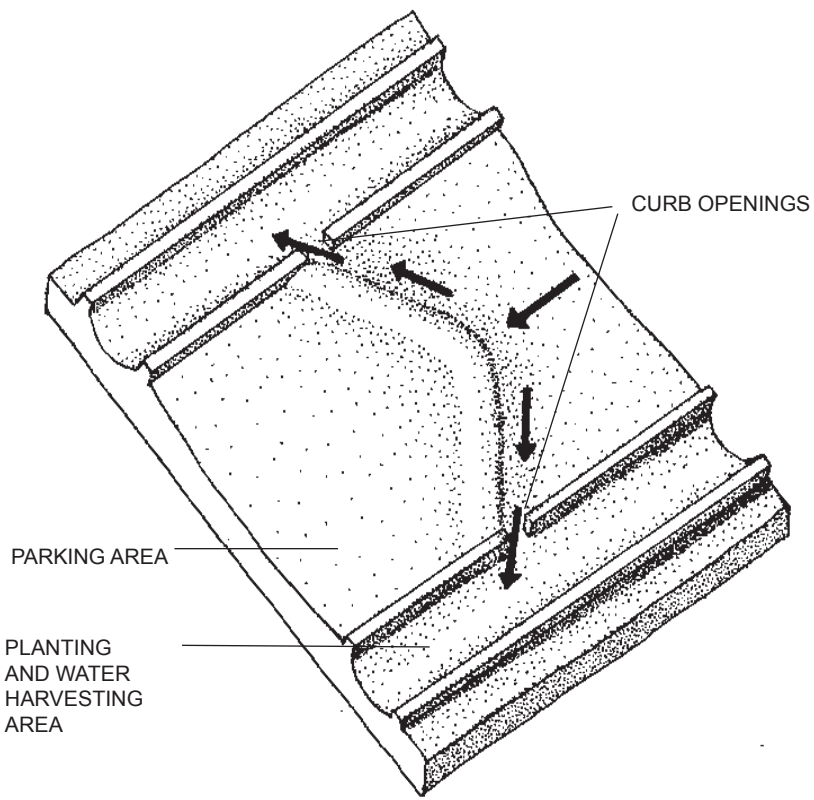
A. Pocket swales.
Where roads and paths slope downhill, install a "water bar" (a gently sloped berm) across the travel surface to intercept stormwater that might cause erosion. The water bar should be constructed slightly off-contour to direct water toward an adjacent depression. Extend the water bar to create a hook-shaped berm enclosing a basin next to the path. If the watershed area is relatively large, an overflow spillway can be constructed in the hooked portion of the berm to route excess water away from the path. Make sure the water bar is gently rounded to avoid creating a tripping hazard on pathways. Avoid a steep drop off at the pathway edge.



B. Boomerang swales.
Endpoints of these arc-shaped swales point uphill, and are the low points of the berm. After a swale fills, overflow occurs at one or both end points. Protect end points from erosion using rip rap or other erosion-control approach. Boomerang swales can be installed individually or in a series.



C. Parking lot berms.
Parking lots are typically sloped to funnel stormwater runoff down the middle of the travel lane. Instead, gently crown the parking lot to direct stormwater toward adjacent depressed planting/water harvesting areas. To retrofit an existing parking lot, construct asphalt berms (speed humps) in the parking lot to intercept water and direct it into adjacent depressed planting areas (see figure below). Add appropriately sized curb openings to allow runoff water to enter the planting areas.



Water Harvesting Techniques: French Drains

Goal
French drains are rock-filled trenches that are designed to encourage rapid stormwater infiltration through the sides, ends and bottom of the trench where soil and water meet.

Appropriate siting, water volume and slope
Because they are filled with rock, French drains hold only about one-third of the water that an open trench would hold. French drains can intercept low to moderate flows depending on their size. French drains are typically used on flat to moderate slopes. French drains should receive runoff water only from watershed areas that are relatively free of sediment like parking lots, rooftops, sidewalks, or areas stabilized with vegetation. French drains should not be built in a watercourse, where silt could quickly clog the pore spaces. French drains are useful for intercepting water in areas where a level surface is needed. French drains could be used on steeper slopes where water harvesting basins would have only small storage volumes.

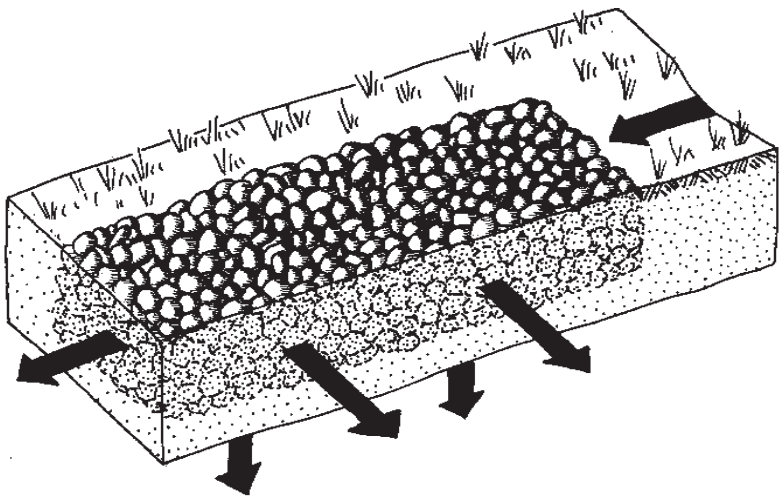
The use of French drains in required vehicular use areas is not recommended and would need approval by a County official. French drains are not typically designed to stand up to the weight of vehicular traffic. As with other water harvesting structures, French drains should be placed at least 10 feet away from building foundations, or as required by the building code. **Be sure water harvesting efforts do not generate unstable slopes. Consult a soils engineer when designing water harvesting structures for any slopes that may not be completely stable. Every site is unique; the appropriate scale of any water harvesting technique should be determined based on site-specific conditions. Consult a professional when in doubt.**

Construction
Dig a trench and fill it with gravel or cobbles to a level even with the land surface. Rounded rock provides larger pore space between rocks resulting in more storage volume than angular rock. French drains can be built on-contour to intercept water, or across contour to intercept and transmit water slowly downslope without erosion. *To reduce clogging of gravel pore spaces in areas where the runoff carries sediment, place filter fabric around and on top of the French drain, or construct a shallow basin upslope of the French drain to intercept stormwater and allow sediment to settle out before stormwater enters the French drain.* Ground cover plants can stabilize soils in upslope locations to reduce sediment transport to the French drain.

Vegetation
Shrubs and trees can be planted along the sides or at the terminus of the French drain. Avoid potential clogging of the French drain from accumulated leaf litter by using good maintenance practices.

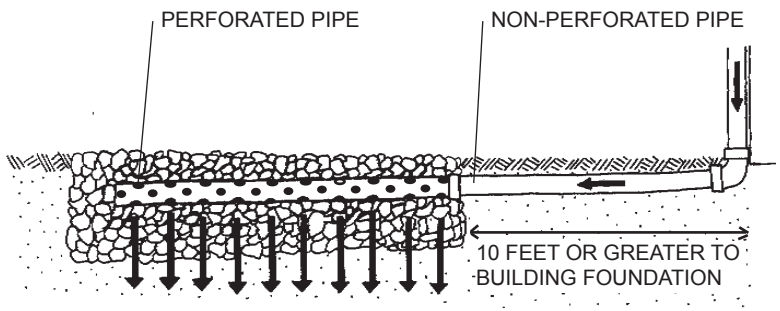
Maintenance
Keep French drains free of surface debris and sediment buildup to keep pore spaces open. French drains **must** be designed and maintained to infiltrate stormwater completely below the top surface of the French drain within 12 hours to avoid mosquito problems (Appendix E).

Variations
Several variations of French drains are shown on the next page. An additional variation is to create a large expanse of "porous" pavement to allow water to infiltrate directly into parking areas and pathways. The use of "porous" pavement may require approval by a County official and is recommended only in areas with light traffic. All variations **must** be designed and maintained to infiltrate stormwater completely below the ground level surface of the French drain within 12 hours to avoid mosquito problems.

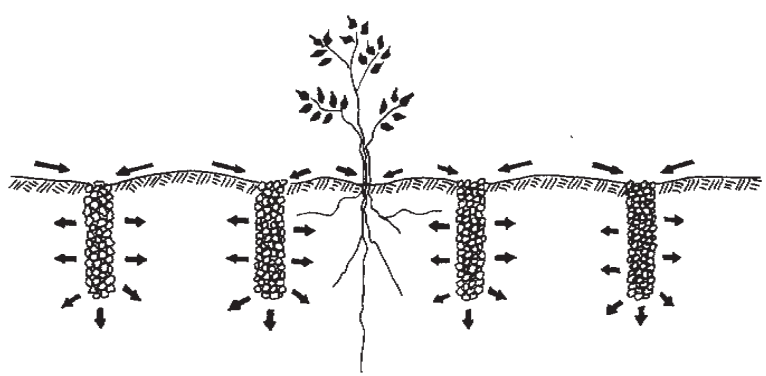


Water Harvesting Techniques: French Drains

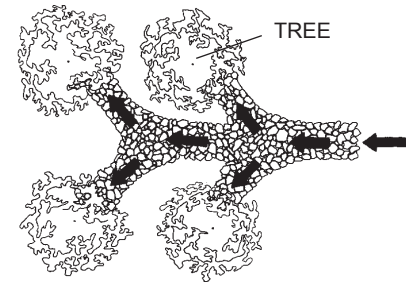
A. Direct stormwater to a French drain using subsurface pipe.
Install non-perforated pipe from the point of origin of water to the edge of the French drain. Switch to perforated pipe within the French drain to allow water to enter the drain and infiltrate into the soil. When pipe is used inside the drain, the pipe will not usually withstand heavy loading. French drains should be placed at least 10 feet away from building foundations.



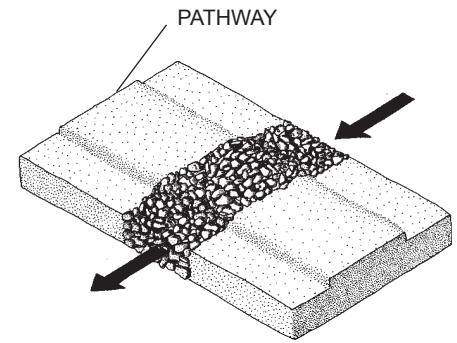
B. Construct vertical gravel columns or "curtains."
Stormwater can be directed quickly into the ground around tree roots by excavating columns or "curtains" around the perimeter of the tree and backfilling these with gravel. Over time the tree roots will find the water provided by the wider-spaced curtains. These structures will fill with silt over time, but will continue to provide better infiltration than without the drain. If this style of French drain is constructed around an existing tree, locate the columns outside the perimeter of the drip line of the tree to avoid damaging growing roots and to encourage their spread.



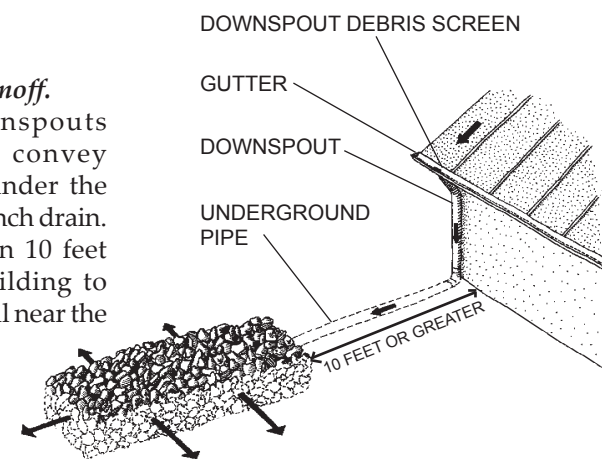
C. Branch the French drain.
The bottom of the French drain trench can be sloped to direct water toward a specific point, and can have multiple branches to direct water to different planting areas.



D. French drains and pathways.
Build French drains in association with paths to keep the walking surface relatively level while safely moving stormwater toward nearby vegetation. The surface must be stable in the pathway area to avoid tripping hazards. Use of French drains in association with paths should be reviewed by the County Flood Control District.



E. Intercept rooftop runoff.
Extend gutter downspouts by using a pipe to convey stormwater over or under the ground to a nearby French drain. Keep the French drain 10 feet or more from the building to avoid saturating the soil near the building foundation.



Water Harvesting Techniques: Gabions

Goal
Construct a semipermeable barrier or grade control structure to slow, but not stop, the flow of stormwater in a small watercourse to help prevent or repair upstream erosion, trap rich detritus, and allow stormwater to infiltrate into the channel sediments and adjacent soils.

Appropriate siting, water volume and slope
Gabions are appropriate for use in small watercourses. Gabions should be located within a straight reach of the watercourse, *not* on a curve nor immediately after a curve. Do not build a gabion taller than 3 feet; instead, work upstream to construct more frequent, smaller gabions. Gabions should be located along washes with firm or rocky banks and shallow to moderate slopes. Sandy banks generally are not structurally strong enough to anchor gabions. A poorly designed or poorly constructed gabion can do more harm than good by diverting water towards the bank, or failing in a large flow, so proceed carefully with this technique and **consult a qualified professional. Every site is unique; the appropriate scale of any water harvesting technique should be determined based on site-specific conditions. Consult a professional when in doubt.**

Note: For purposes of constructing a gabion, a small watercourse has a watershed of less than 4 acres in size, and/or has a 100-year flow rate of less than 20 cubic feet per second (cfs). Construction in a wash involves complex factors that can become a liability, therefore a qualified design professional should be consulted. For development in areas where 100-year flow rates are 50 cubic feet second (cfs) or more, a Floodplain Use Permit and a design by a registered Professional Engineer are required. ***Obtain all necessary permits prior to the start of construction. Consult the U.S. Army Corps of Engineers to determine if a Clean Water Act Section 404 permit is needed. Consult the Arizona Department of Water Resources to determine if existing surface water rights would preclude gabion use on your site.***

Construction
Construct gabions perpendicular to a watercourse channel so stormwater flows straight into the gabion rather than at an angle. Excavate a trench perpendicular to the channel and "key" it 12 to 18 inches or more into both banks and 12 to 18 inches deep into the streambed to hold the gabion firmly in place. Place the excavated dirt upstream (do not dam the wash) so it will begin the process of filling in the gabion. In the bottom of the trench place a length of wire mesh that has enough length to fold over the top and completely enclose the rock that will fill the gabion. Two- by four-inch galvanized steel fencing with wrapped joints serves as a good wire mesh. Fencing made with welded joints might not hold up to the stresses over time. Carefully place 6- to 12-inch angular rocks into the wire mesh framework to create a stable rock structure. Angular rock locks together creating a more stable structure than rounded rock. Wrap the wire mesh over the top of the rock structure and secure the wire mesh snugly to completely enclose the structure.

The top surface of a gabion should be sloped so it is higher at the wash banks and lower at the center of the wash. The lowered center portion focuses overflow water in the center of the channel. Construct a rock apron on the downstream side of the gabion. The apron thickness should be twice the diameter of the rock used to fill it. Construct the apron across the entire width of the gabion to absorb the energy of overflow water. The apron should extend downstream of the gabion a distance of at least two or three times the height of the gabion. Completely enclose the rock apron with wire mesh. Attach the apron to the gabion. Tie the upper and lower wire mesh layers of the apron together in several places to keep the rocks from shifting. Prefabricated gabion baskets are available. A gabion-like structure can be built with tightly placed rocks without a wire framework. However, these must be carefully designed to not be damaged by flowing water forces.

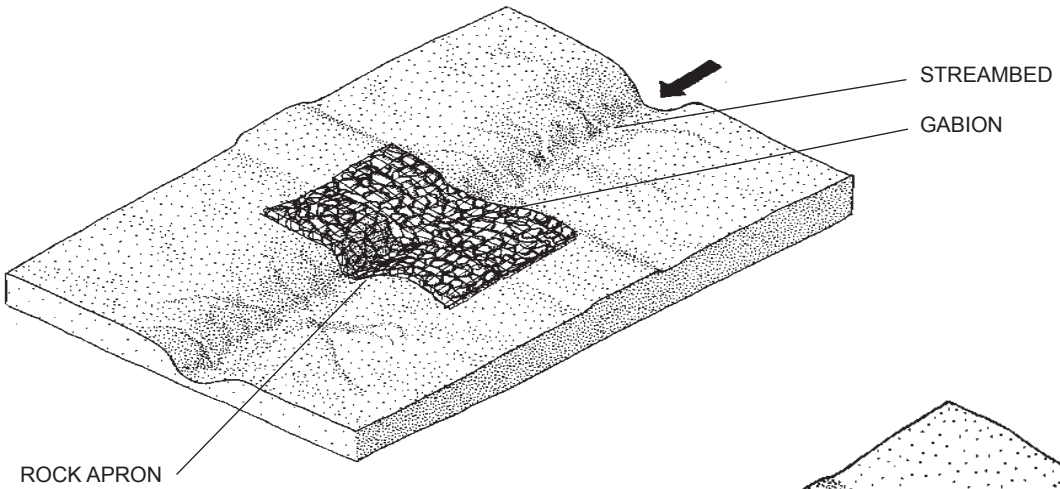
Vegetation
Silt and organic material are trapped upstream of the gabion. Water slowed by the gabion will infiltrate into the stream bed and banks creating a moist, fertile microclimate for existing and newly planted vegetation.

Maintenance
Inspect gabions following major runoff events. Adjust apron size, gabion width, and gabion height as needed based on its performance. Watch for stormwater flowing under or around the structure, and correct as needed. Gabions **must** be designed and maintained to infiltrate stormwater completely within 12 hours to avoid mosquito problems (Appendix E).

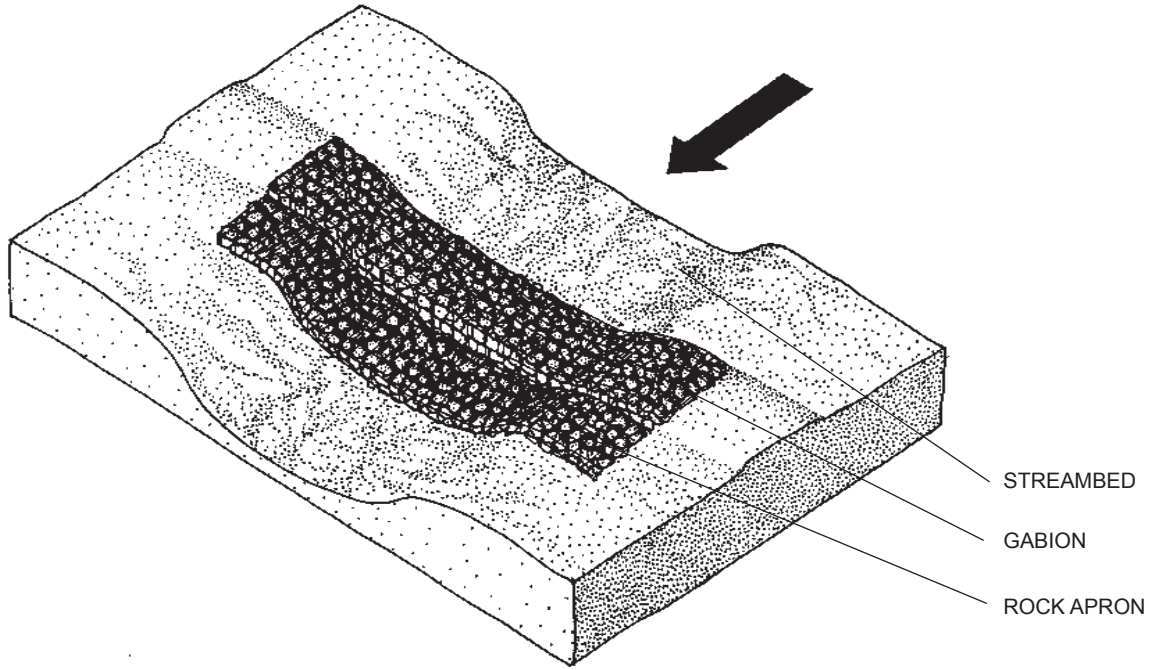
Variations
Gabions vary in size and location. If the top of a gabion serves as a crossing point over a wash, additional surfacing materials might be needed for safe pedestrian or equestrian uses. Consult County officials and design professionals to ensure gabions meet safety and construction standards.

Water Harvesting Techniques: Gabions

GABION IN NARROW STREAMBED



GABION IN WIDE STREAMBED



Water Harvesting Techniques: Water Tanks

Goal
Store rooftop runoff for use at a later time.

Appropriate siting, water volume and slope
Water tanks (sometimes called cisterns) come in all shapes, materials and sizes. Determine appropriate tank volume based on roof area, rainfall, downspout location, available space, water uses, and site-specific conditions. Tanks need to be placed on level pads in areas not vulnerable to settling, erosion or slope failure. Tanks should be located at least 10 feet from a building to avoid foundation damage in case the tank leaks. In addition to storing water, tanks can serve multiple functions such as shading, providing visual screens, and moderating hot and cold temperature extremes. The higher on the site above-ground tanks are located, the more gravity-feed pressure will be available. Water can be distributed by gravity flow or by a booster pump via hoses, irrigation systems, channels, or perforated pipes.

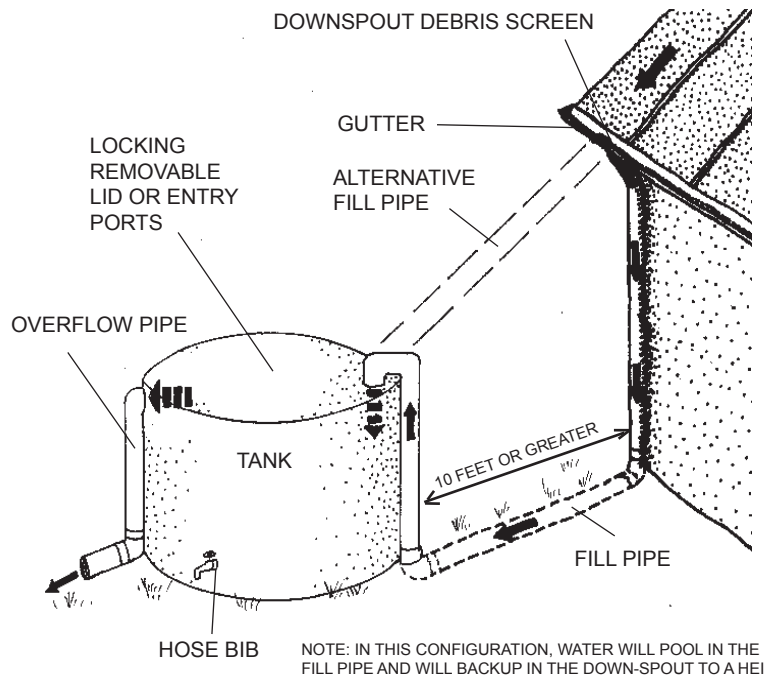
Construction
Prefabricated tanks of plastic, metal, or concrete can be purchased and installed professionally. Securely cap tanks with opaque material to prevent evaporation, mosquito breeding, and algae growth. Lock all caps and entry ports for safety. The interior of tanks should be accessible for periodic inspection and maintenance. Downspouts, inlets and outlets **must** be screened to keep mosquitoes (Appendix E), animals and debris out of the tank. Gutters must be cleaned regularly. Position outlet pipes several inches above the bottom of the tank to allow sediment to settle in the bottom. All tanks need an overflow pipe of equal or greater capacity than the fill pipe.

Overflow pipes should be able to operate passively (i.e. not dependent on a pump). Route overflow water into a water harvesting basin, adjacent tank, French drain, or other useful location away from buildings. Water in above-ground tanks can be delivered by gravity flow alone to low-pressure uses nearby. Below-ground tanks save land area, but require substantially more construction. A booster pump can be added to hook tanks into an irrigation system. Tank water should be filtered as it enters irrigation lines to keep debris from plugging the irrigation system. Calculations for sizing tanks are shown in Appendix C and discussed in some references listed in Appendix G.

Vegetation
Areas around above-ground tanks can provide beneficial microclimates for heat- and cold-sensitive plants. Avoid placing plants with intrusive roots around below-ground tanks. Vegetation can be used to visually screen above-ground tanks to improve site aesthetics.

Maintenance
Periodically inspect all screens, gutters and tanks to remove accumulated debris. Check tanks following major rainfall events to verify that overflow system is working correctly. Periodically inspect and maintain the interior of tanks.

Variations
Tanks can be constructed individually or in a series with the overflow from one tank filling the adjoining tank, or connected at the bottom to maintain the same water level in all tanks.



NOTE: IN THIS CONFIGURATION, WATER WILL POOL IN THE U-SHAPED FILL PIPE AND WILL BACKUP IN THE DOWN-SPOUT TO A HEIGHT EQUAL TO THE HEIGHT OF WATER IN THE TANK. INSTALL WATER-TIGHT SEALS TO PREVENT LEAKS.

Water Harvesting Technique: Mulch

Goal
Optimize water harvesting by reducing evaporation from soils.

Appropriate siting, water volume and slope
Rainfall in Santa Cruz County averages around 17 inches per year (range 15-19 inches). Solar energy quickly evaporates soil water brought to the surface by capillary rise. Placing mulch over bare soils in water harvesting depressions will reduce moisture loss from the soil, leaving soil moisture available for use by plants. Use organic mulches in relatively low flow areas where mulch will not be washed away. Use inorganic mulches in areas where higher velocity flow might occur.

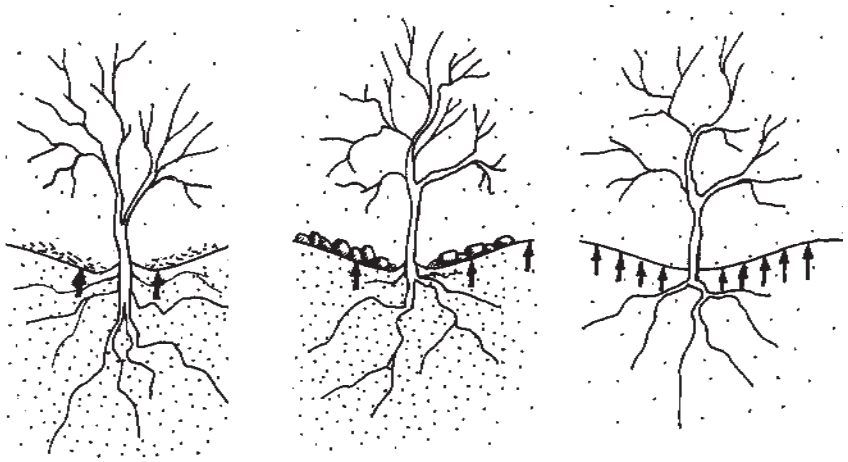
Construction
All water harvesting swales and basins should be mulched to substantially reduce water loss through evaporation. Organic mulches include composted bark, wood chips, leaves, twigs, straw, and grass clippings. Living understory and ground cover plants also have a mulching effect. Chipped, composted vegetation cleared during construction is a good source of mulch. Organic mulch should be applied in a layer from 3 to 4 inches deep. Organic mulch has a tendency to float, so make sure basins are deep enough to retain mulch during heavy rainfall events.

Inorganic mulches include rock, gravel, cobbles, decorative rock (not decomposed granite) and other hard materials. Do not use mulches that contain fine-grained particles that can clog soil pore spaces and seriously inhibit infiltration. Use a sufficient depth of inorganic mulch (2 - 3 inches or more) to reduce evaporation and help prevent erosion from berms and steeper slopes. Supplement cobble-size mulches with smaller diameter gravel or small-grained organic mulch to fill in crevices and prevent erosion between the cobbles. The top layer of inorganic mulch will become hot in summer and might damage heat sensitive plants. A canopy of established plants can provide shade to reduce inorganic mulch temperature during the hot summer days.

When placing organic or inorganic mulch, leave several inches of open space between the mulch edge and the base of plants. A small earthen mound at the base of plants will protect plants from contact with mulch. **In addition, the lowest point of water collection should be away from the trunk and outside of the dripline to encourage tree roots to spread.**

Vegetation
Plant seedlings in water harvesting basins since seeds usually will not germinate under deep mulch. Allow seeds, leaves, and twigs that drop off plants to accumulate to supplement the mulch layer.

Maintenance
Organic mulch breaks down with time forming rich soil, and should be replenished as needed. With time, seeds, leaves, and twigs dropping from plants in the basins will create a renewable mulch layer (self mulching). Additional mulch can be added if the level of self-mulching is not sufficient. Both inorganic and organic mulch should be periodically maintained to keep soils covered.



ORGANIC MULCH
LOW EVAPORATION
HIGH SOIL MOISTURE

INORGANIC MULCH
LOW EVAPORATION
HIGH SOIL MOISTURE

NO MULCH
HIGH EVAPORATION
LOW SOIL MOISTURE

Water Harvesting Techniques Information Sheet

Goals for Techniques	Appropriate Locations	Variations	General Notes	Maintenance and Inspection Notes	Construction Techniques
MICROBASINS					
Captures surface water from very small catchment areas and infiltrates it into the soil.	Gentle to nearly flat sloped land. Very small to small catchment areas (10s to 100s of square feet).	- in a series	1, 2, 3, 4, 6	7, 8, 10	13 and/or 14
		- on-contour	1, 2, 3, 4, 6	7, 8, 10	13 and/or 14
		- w/pathway/driveway	1, 2, 3, 4, 6	7, 8, 10	13, 14 and/or 19
		- local depression	1, 2, 3, 4, 6	7, 8, 10	13 and/or 14
		- inside curbed areas	1, 2, 3, 4, 6	7, 8, 10	13, 14, 16 and/or 17
		- in a parking lot	1, 2, 3, 4, 6	7, 8, 10	14, 15, 16 and/or 17
SWALES ON-CONTOUR					
Captures surface water from small to moderate catchment areas and infiltrates it into the soil.	Small to moderate sized catchment areas with gentle slopes. Large scale use should be based on engineered designs.	- large scale	1, 2, 3, 4, 6	7, 8, 10	13, 14, 15, 16, 17, and/or 19
		- without berms	1, 2, 3, 4, 6	7, 8, 10	13, 14, 15, 17, and/or 19
		- adjacent to paths	1, 2, 3, 4, 6	7, 8, 10	13, 14, 15, and/or 19
		- internal microbasins	1, 2, 3, 4, 6	7, 8, 10	13, 14, 15, and/or 19
SWALES OFF-CONTOUR					
Captures surface water from small to moderate catchment areas and slowly conveys it downgradient while it infiltrates into the soil.	Small to moderate sized catchment areas with gentle slopes. Large scale use should be based on engineered designs.	- pocket swales	1, 2, 3, 4, 6	7, 8, 10	13, 14 and/or 19
		- boomerang swales	1, 2, 3, 4, 6	7, 8, 10	13, 14, 15, 16, and/or 19
		- parking lot berms	1, 2, 3, 4, 6	7, 8, 10	14, 15, 16, 17, and/or 19
FRENCH DRAINS					
Captures surface water and rapidly conveys it underground in a subsurface trench. Maximizes infiltration while minimizing evaporation.	Very small to small catchment areas. Flat to moderately sloped land. Avoid use in areas where sediment will clog pores in the French drain.	- subsurface pipe	1, 2, 3, 4, 6	7, 9, 10	13, 14, and/or 16
		- as "curtains"	1, 2, 3, 4, 6	7, 9, 10	13, 14, and/or 16
		- branched	1, 2, 3, 4, 6	7, 9, 10	13, 14, and/or 16
		- across pathways	1, 2, 3, 4, 6	7, 9, 10	13, 14, 16 and/or 19
		- for roof drainage	1, 2, 3, 4, 6	7, 9, 10	13, 14, and/or 16
		- general surface flow	1, 2, 3, 4, 6	7, 9, 10	13, 14, and/or 16
GABIONS					
Slow surface water flow in very small drainages, capture detritus and sediment from water to fill in erosion cuts upstream of the gabion.	Very small drainages with stable banks. Put in straight reaches of the drainage, not on curves.	- Wire basket wrapped around rocks	1, 2, 3, 4, 5, 6	7, 8	13, 14, 15, 16, 17, 18 and/or 19
		- Loose rock gabions	1, 2, 3, 4, 5, 6	7, 8	13, 14, 15, 16, 18 and/or 19
WATER TANKS/CISTERNS					
Stores harvested water for later use.	Above-ground tanks placed high in the landscape afford more pressure for gravity feed. Water stored in above- and below-ground tanks can be accessed via small pumps.	- Above-ground tanks	1, 2, 3, 6	7, 12	13, 14, 16, 17, 18, and/or 19
		- Below-ground tanks	1, 2, 3, 6	7, 12	13, 14, 15, 16, 17, 18, and/or 19
MULCH					
Aids water infiltration into soils, retards evaporation, enriches soil nutrients, suppresses weed growth, and helps reduce pollutants. Keeps soil temperature lower in summer and warmer in winter.	Basins, swales and other water harvesting depressions. Place mulch 3 - 4 inches deep. Replenish as needed.	- organic	--	7, 11	13 and/or 14
		- inorganic	--	7, 11	13 and/or 14

Water Harvesting Techniques Information Sheet

General Notes
1. All of the water harvesting techniques are scalable from home site designs to large scale applications. Larger projects will involve more complex designs and construction. If you are unsure how to proceed, hiring a professional is strongly advised. Hiring a professional for large applications may be required.
2. Always design for overflow. Create overflow spillways as needed to focus overflow in preselected locations. Protect water harvesting structures from overflow erosion, and direct overflow to locations that will not be damaged by and will benefit from additional water, such as other water harvesting areas.
3. Design standing/ponding water at least 10 feet from structure foundations or as required by the building code. A soils professional should be consulted for poor soil conditions or for ponding closer than 10 feet.
4. When placing berms, depressions, and gabions, be sure to configure them to eliminate/minimize tripping hazards. Trees should be placed 15 to 20 feet from structures to allow for full growth.
5. Use caution in designing, placing and constructing gabions. Do not obstruct or divert stream flows. An engineered design might be needed. Development in a wash may require a Floodplain Use Permit and/or a Clean Water Act Section 404 permit from the US Army Corps of Engineers. Check with a County official for County requirements. Check with the Arizona Department of Water Resources to determine if there are any surface water right issues in the stream.
6. For larger projects, check with County officials regarding grading permits (50 cubic yards of fill from any source) and/or stormwater pollution prevention plan requirements (1-acre or more of disturbance). Both permits will require a registered professional to design and seal the plans.

Maintenance and Inspection Notes
7. Proper monitoring and maintenance is important for any system to work appropriately and efficiently. Each configuration will perform differently. After the system has stabilized, inspection and maintenance might be needed several times a year and/or after heavy rainfall events.
8. Ponding should not last more than 12 hours to avoid mosquito breeding (Appendix E). Long-term standing water can damage vegetation. Soil types percolate at different rates. Soils in Santa Cruz County generally percolate about 1/2 to 1 inch of water per hour. Test soil and modify design as needed.
9. French drains are most effective when they are kept free of sediment. Filter fabrics and/or sediment traps might be needed to keep sediment out of the drain. The rocks in French drains might settle over time. Refill and relevel as needed.
10. Water harvesting structures placed on steeper, soil covered slopes tend to fill with sediment and overflow more frequently then swales on flatter slopes. More frequent inspection/maintenance might be needed.
11. Mulches are important to keeping harvested water in the soil due to the high evaporation rate in Santa Cruz County. Choose organic or inorganic mulch based on location, need for soil enrichment, and availability of materials. Do not place mulch against trunks of shrubs and trees. Wash fine sediments off decomposed granite if it is to be used for mulch. Organic mulches are light weight and can float away in heavy water flows. Organic mulches decompose and might need to be replenished.
12. Inspect water tanks periodically to insure proper functioning. Screen inlet and outlet pipes to keep the system closed to mosquitoes (Appendix E). Cap and lock tanks for safety. Caps should have access ports for interior inspection and maintenance. Clean gutters, inflow and outflow pipes as needed.

Construction Techniques
13. Hand tools, light earthwork
14. Small machine earthwork
15. Heavy machine earthwork
16. Construction materials needed
17. Plans by a registered professional may be required
18. Prefabricated materials available
19. Check with a County official

Design Examples: Subdivision

Background For Subdivision Example

A subdivision is planned as an infill development within the community. Water harvesting will be practiced at the subdivision level and will be encouraged at the household level. Santa Cruz County Flood Control District requires retention and/or detention of stormwater runoff for all subdivisions with residential densities of 3 or more units per acre.

Step 1. Assemble the site team

- Team members include the developer, civil engineer, building architect, landscape architect, construction foreman, and one volunteer future resident (if available).
- The member chosen as team leader should have knowledge of subdivision-wide drainage and lot design to accomplish water harvesting.

Step 2: Map resource flows & physical elements

- The site contour map indicates that drainage flows from east to west on moderate slopes. Drainage is generally in the form of sheet flow, with no significant off-site contribution to drainage.
- Site conditions: The site is somewhat rocky and covered with sparse vegetation. Geology and soils are suitable for building.
- Flows and elements: The moderate west-facing slope increases summer heating. Harsh prevailing winds come from the southwest. Water pools at low points on the west side. There is noise from an arterial street along the south side of the site.

Step 3: Identify potential for resource use

- Stormwater harvested from roads and lots and infiltrated into soils will reduce stormwater runoff and support vegetation on-site.
- Vegetation removed during construction will be chipped and composted on-site for use as mulch in water harvesting structures.
- New native, drought-tolerant vegetation will provide shade for passive cooling, comfort, aesthetics, visual screening, child play areas, and wildlife habitat.
- On-site rocks and cobbles will be collected during construction and used to build gabions, to armor spillways, and as inorganic mulch.
- Water harvesting at residences will help support vegetation used to provide shade and windbreaks. Tanks could be built at private residences and the community building to store additional runoff water.
- Existing vegetation will be preserved in place whenever possible.

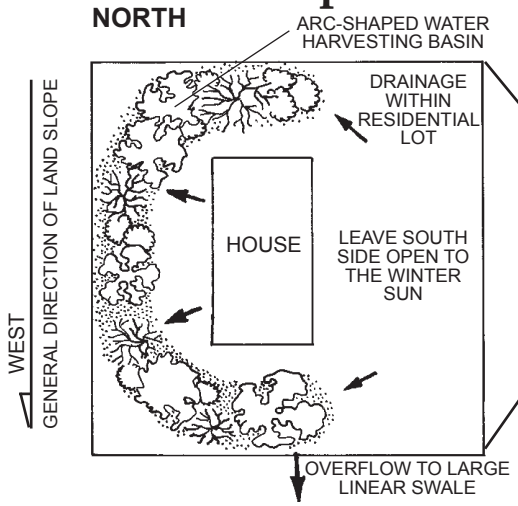
Step 4: Develop an integrated site concept design

- Construct large linear on-contour and off-contour swales around the site and between rows of houses to intercept stormwater runoff. Construct path systems in association with the swales. These swales will slow stormwater, support plantings that screen noise, provide recreational areas, and create wildlife habitat.
- Use on-site rock to build gabions, and line the sides and spillways of water harvesting features to reduce erosion and reduce evaporation.
- Crown roadways, construct curb cuts, and scupper and grade the parkway to direct runoff water towards the large swales.
- Grade individual lots to create arc-shaped basins along the west, north, and east sides of the lots. These will collect runoff water to support trees that provide windbreaks, shade, and other benefits. Orient the longest axis of the house toward the south to intercept warm winter sun. Install window overhangs to provide shade in summer.
- Provide the installation of gutters, downspouts, and covered household tanks as options on model/house plans. Specify roof surfaces such as tile and metal that are long lasting and shed relatively pollutant-free stormwater.
- Prepare information for home owners on the purpose, potential uses, and maintenance of pre-graded, yard-scale water harvesting basins. Customize a water harvesting layout for each model unit. Write covenants, conditions, and restrictions to encourage water harvesting. Install separate water meters to track outdoor water use at each home (dual metering) to provide data on the benefits of water harvesting.
- Demonstrate water harvesting techniques in the common areas by placing water tanks adjacent to the community building, using the detention areas for recreation, and installing low water use landscaping (xeriscape) that could ultimately be entirely sustained by water harvesting. If an irrigation system is used, install soil moisture sensors to prevent overwatering.
- Mulch all basins and vegetated areas in the subdivision.

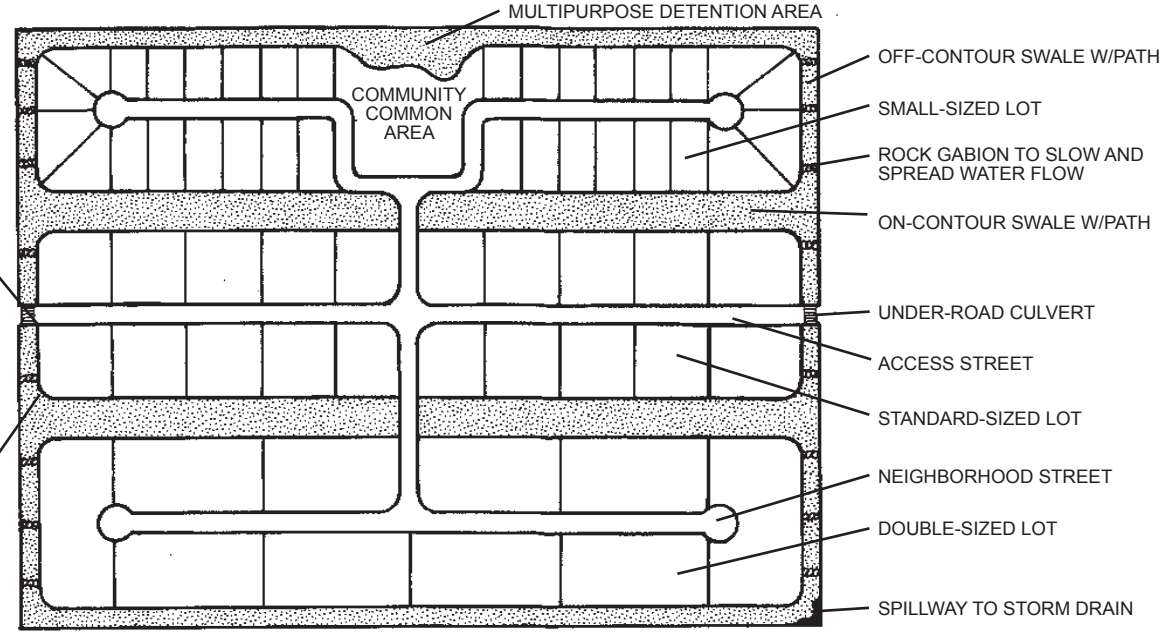
Step 5: Review and finalize the concept design

- All team members review and comment on the draft concept plan.
- Prepare the final concept design. Use the final concept design as the basis for detailed site plans including lot layout, grading, drainage, building layout, architecture and landscaping plans.
- Check detailed site plans for consistency with the concept plan.

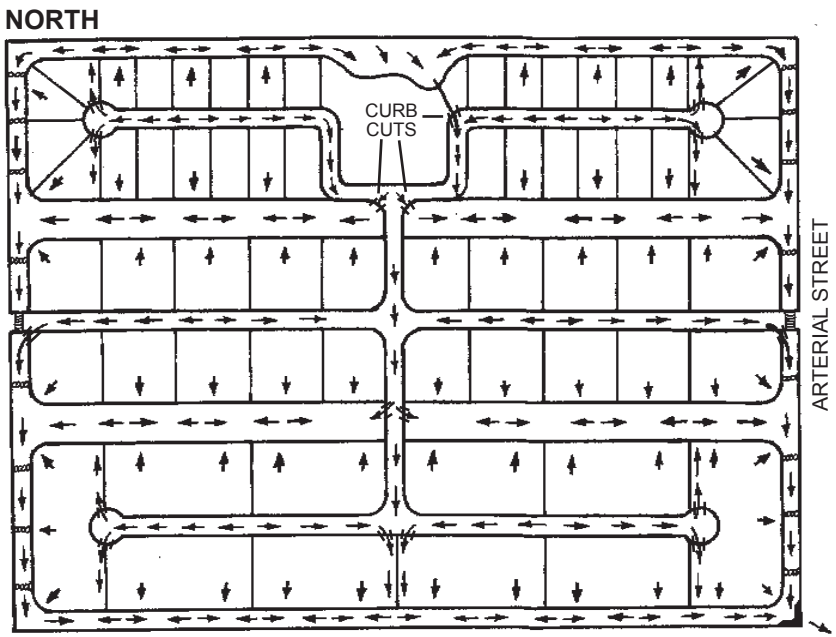
Subdivision Example



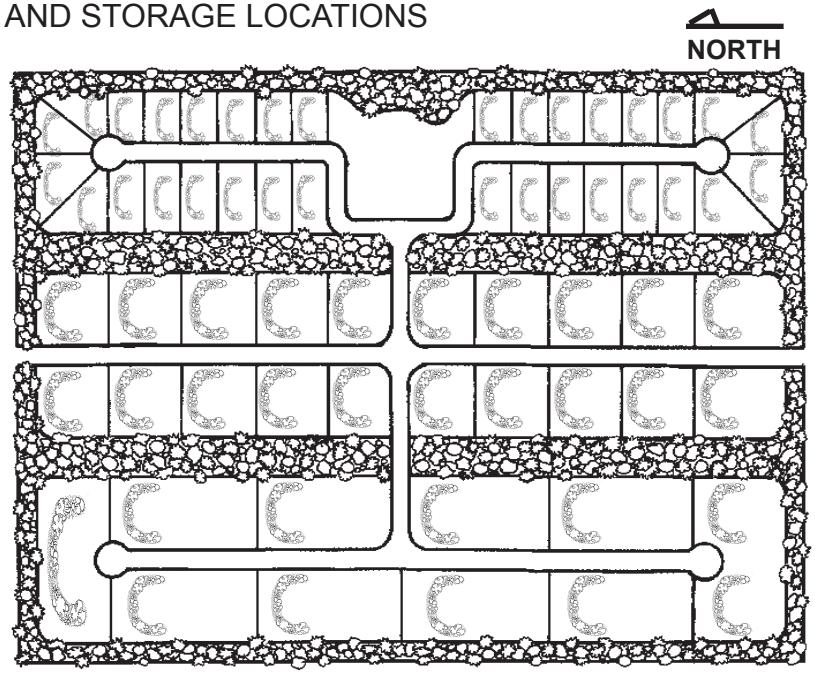
EXAMPLE RESIDENTIAL LOT



WATER COLLECTION AND STORAGE LOCATIONS



DIRECTION OF WATER FLOW



PLANTS RECEIVING HARVESTED WATER

Design Examples: Commercial Site

Background For Commercial Site Example

A retail store that needs a large parking lot will be constructed. A small cooling tower will serve the air conditioning unit. Stormwater will be harvested throughout the site. Santa Cruz County Flood Control District requires retention and/or detention of stormwater runoff on commercial and industrial sites greater than 1 acre in size or with more than 66% impervious area. Note: Duplexes and multi-family housing are considered commercial projects by Santa Cruz County Flood Control District.

Step 1. Assemble the site team

- Team members include the developer, civil engineer, building architect, landscape architect, and construction foreman.
- The member chosen to be the team leader should have a good working knowledge of site drainage issues.

Step 2: Map resource flows & physical elements

- The contour map shows the drainage flows from east to west, with off-site flow entering the site from the east.
- Site conditions: There are no geological issues. There is existing native vegetation on the east side. There is a good view to the northeast.
- Flows and elements: A slight west-facing slope increases summer heat. There are harsh prevailing winds from the southwest. Water tends to pool at low points on the west side. There is significant traffic along the north side on an arterial street.

Step 3: Identify potential for resource use

- Rooftop stormwater runoff will be stored to serve the cooling tower and the site irrigation system. Water harvesting systems in the landscape will store water in the soil to support vegetation and cleanse and reduce the volume of stormwater runoff, allowing a reduction in the size of required detention/retention facilities.
- Existing vegetation will be left in place, transplanted, or chipped and composted for later use on-site as mulch. New and existing vegetation will provide shade and summer cooling, aesthetics, and screening.
- The building will provide shade, a windbreak, and rooftop runoff for harvesting. The longest wall of the building will face south allowing maximum winter sun to enter south-facing windows. Adequate roof overhangs will provide needed shade on the south side in summer.

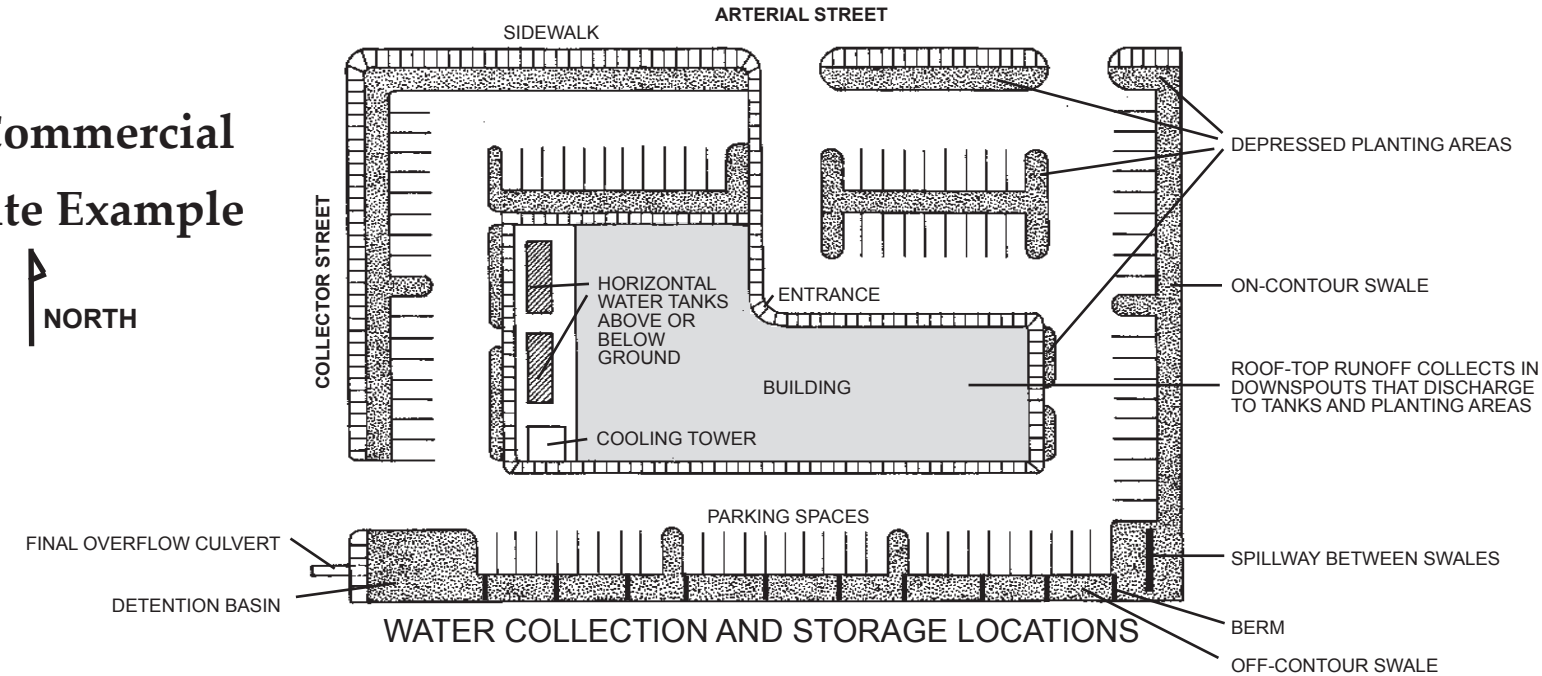
Step 4: Develop an integrated site concept design

- Two water harvesting tanks will be used to capture rooftop runoff, and can be constructed above or below ground. Locate the water tanks next to the cooling tower and irrigation controls to provide rainwater to serve both. The remaining rooftop runoff and tank overflow will support vegetation located near the building including trees that help shade the water tanks and the building itself.
- Slope the parking lot to drain towards adjacent planting areas. Direct sidewalk drainage toward adjacent water harvesting features.
- Existing vegetation will be retained whenever possible. The remainder of the vegetation will be transplanted or chipped and composted for use as mulch to reduce evaporation and improve soils in water harvesting areas.
- Trees and shrubs will be planted in or near the water harvesting structures to provide shade, cleanse and reduce stormwater runoff, generate mulch, reduce erosion, increase infiltration into the soil, provide visual screens, and create wildlife habitat. The building will be passively cooled and shaded with trees sustained by rooftop runoff. Use high profile plantings on the west side of the building to increase shade on the building in the summer. The soils report prepared for the site indicates that small, low volume depressed planting basins may be located within 10 feet of the building.
- Align the longest wall of the building to face south to utilize the warmth of the sun in winter. Overhangs on the south side reduce the sunlight entering during other times of the year. Align the narrow walls of the building to face east and west toward the rising and setting sun to reduce the amount of direct sun hitting the building in summer. The building will shade the parking lot at different times of the day, and will shield the front entrance from harsh prevailing southwest winds.

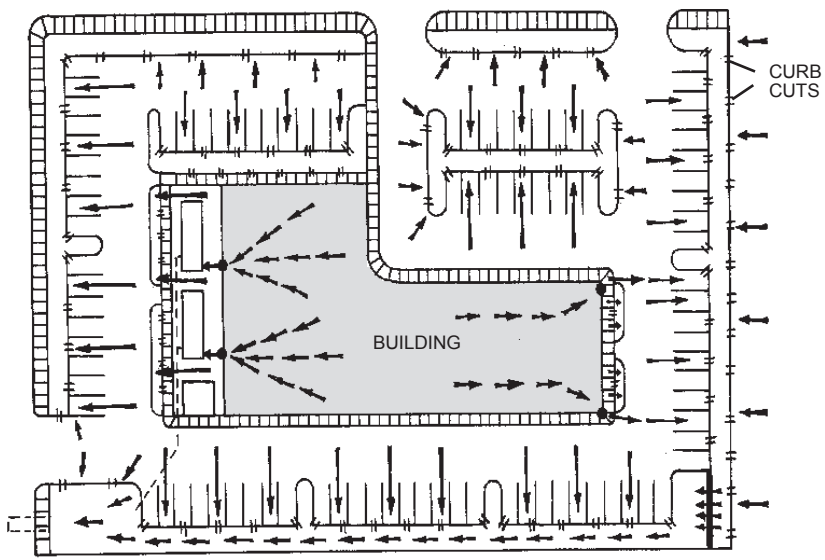
Step 5: Review and finalize the concept design

- Have all team members review and comment on the draft plan.
- Prepare the final concept design. Use the final concept plan as the basis for detailed site plans including building layout, grading, drainage, architecture, and landscaping.
- Check the detailed site plans for consistency with the concept plan.

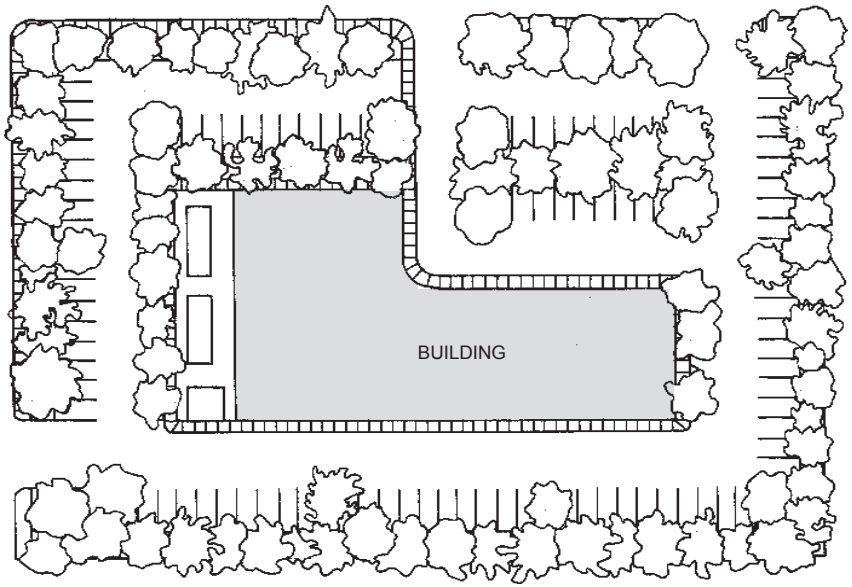
Commercial Site Example



WATER COLLECTION AND STORAGE LOCATIONS



DIRECTION OF WATER FLOW



PLANTS RECEIVING HARVESTED WATER

Design Examples: Public Building

Background For Public Building Example

A public library will be built in a neighborhood on a nearly flat lot. The local community wants the library grounds to be a water harvesting demonstration site. Neighbors have requested that an outdoor community gathering space be included in the library plan.

Step 1. Assemble the site team

- Team members include a County official, civil engineer, building architect, construction foreman, and neighborhood representative.
- The member chosen to be the team leader should have an understanding of design for water harvesting demonstration sites and outdoor gathering spaces.

Step 2: Map resource flows & physical elements

- The site contour map shows a slight slope from north to south, with no significant off-site contributions to drainage. The site will be regraded to facilitate water harvesting.
- Site conditions: The site is nearly flat and bare with type B soils (see Appendix C).
- Flows and elements: Water flows as sheet flow from north to south. There is arterial street noise on the north side, and collector street noise on the east side. Prevailing winds are from the southwest.

Step 3: Identify potential for resource use

- Water stored in tanks will support landscaping around the building and in the outdoor gathering space. Storing water in soils at the site will cleanse and reduce the volume of stormwater runoff, demonstrate water harvesting techniques for the public, and support vegetation to shade the building, outdoor gathering space, paths, and cars. This vegetation will act as a visual screen and improve site appearance.
- The library building will provide shade and rooftop runoff for vegetation and shield the outdoor gathering space from street noise.
- The library grounds will serve the community by providing a gathering place and illustrating how people can incorporate water harvesting concepts into their own sites.

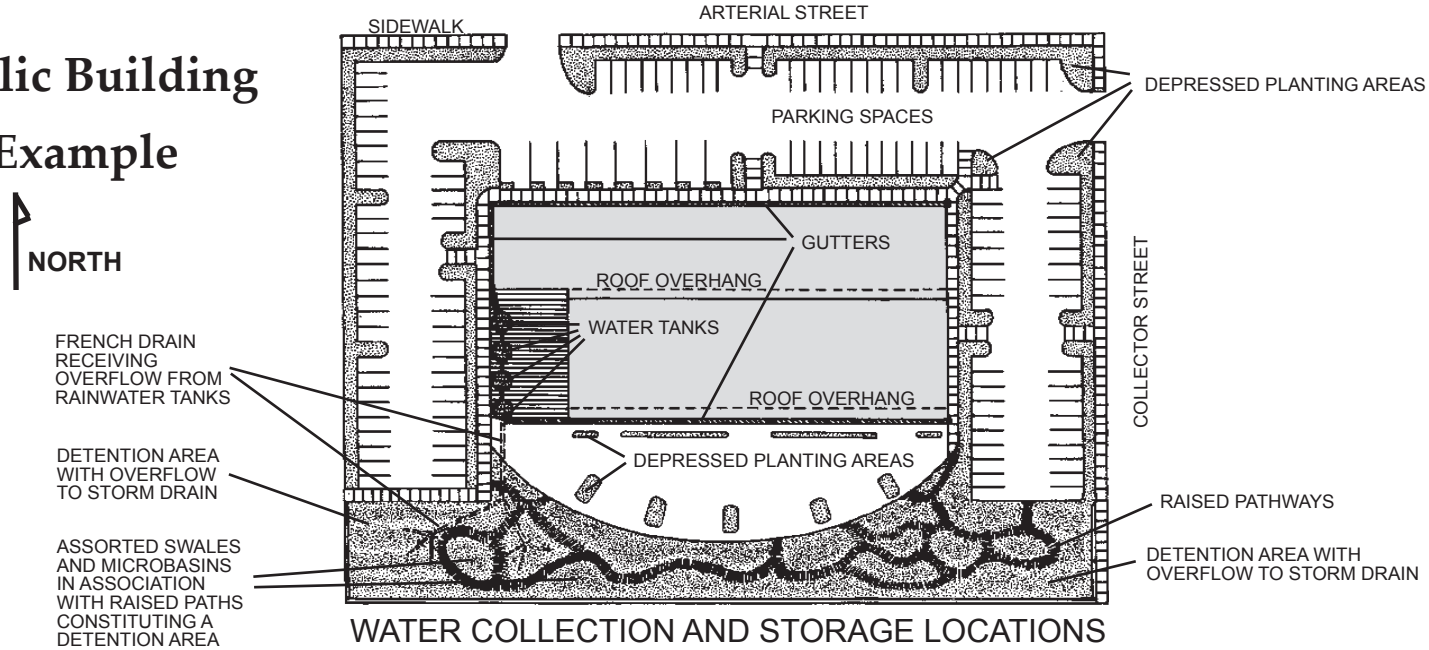
Step 4: Develop an integrated site concept design

- Install gutters, downspouts, and covered water collection tanks on the west side of the building. As part of the water harvesting demonstration, cover the roof with a material that sheds relatively pollutant-free water, such as metal or tile. Tanks on the west side of the building will shade and cool the western wall and create a temperature-moderated microclimate. Locate the tanks near the outdoor gathering space to provide supplemental irrigation. The tanks could be custom painted with neighborhood-themed art.
- Slope the parking lot and sidewalks toward adjacent planting areas. Trees will shade people and cars and buffer traffic noise. Route excess parking lot water toward the small, vegetated detention areas on the southwest and southeast corners of site. Plant trees in water harvesting structures on the southwest and west to create a windbreak, and on the east, west and north to provide shade from summer sun.
- Trees and shrubs will be planted throughout the site to provide shade, cleanse and reduce stormwater runoff, generate mulch, reduce erosion, increase infiltration into the soil, provide visual screens, and create wildlife habitat.
- Supply 2 to 4 years of supplemental irrigation to native drought-tolerant plants by first using water from water tanks. Use tap water only as necessary. Add a rain sensor control that shuts the irrigation system down when soil is wet from rain or previous irrigation.
- Align the shortest length walls of the library building to face east and west toward the rising and setting sun to reduce the amount of direct sun hitting the building. The longest south-facing wall will have large windows facing south so the winter sun will warm people inside. Install clerestory windows to warm the north half of the building as well. Roof overhangs allow direct sunlight to enter the building only during winter months.
- Provide a brochure and map of the water harvesting components so visitors can take a self-guided tour of the site. Place signs on the water harvesting components and associated plantings.

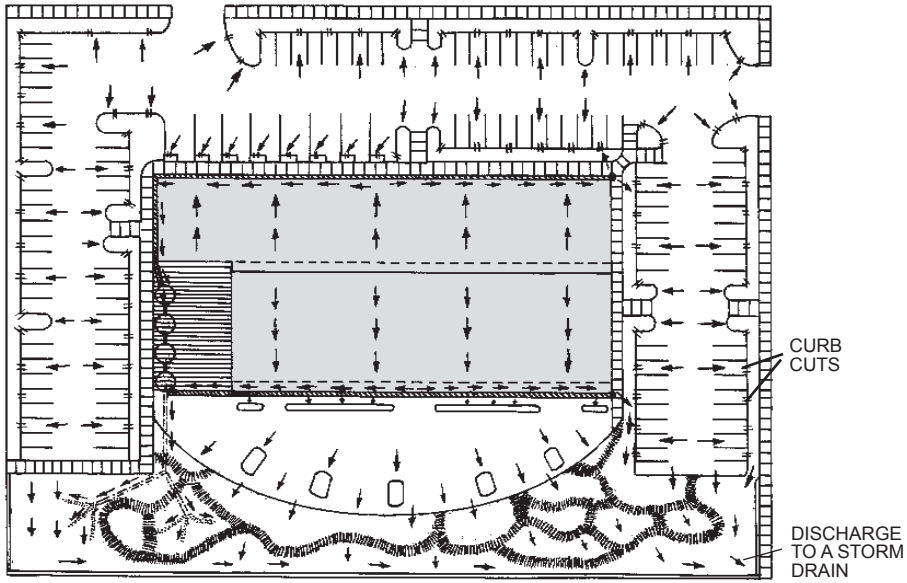
Step 5: Review and finalize the concept design

- Have all team members review and comment on the draft concept plan.
- Prepare the final concept design and use it as the basis for detailed plans for building layout, grading, drainage, architecture and landscaping.
- Check the detailed site plans for consistency with the concept plan.
- Develop inspection criteria and maintenance plan for the site.

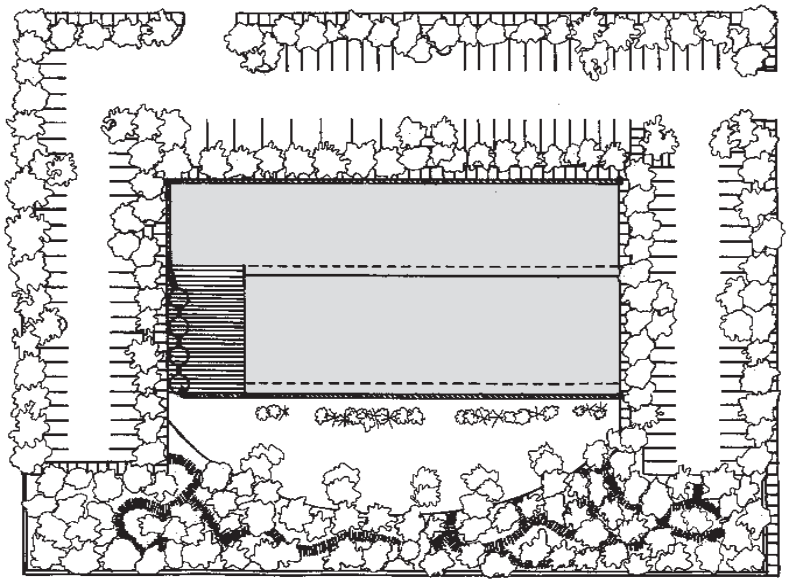
Public Building Example



WATER COLLECTION AND STORAGE LOCATIONS



DIRECTION OF WATER FLOW



PLANTS RECEIVING HARVESTED WATER

Design Examples: Public Rights-of-Way

Background For Public Rights-of-Way Example

Landscaping will be installed as part of a roadway capital improvement project, an improvement district project, or a neighborhood improvement project along the public rights-of-way. The roadways involved are an arterial with a median island, a collector street, and a local street.

Step 1. Assemble the site team

- Team members include the County engineer, landscape architect, project design engineer and if possible, the construction foreman.
- The project manager should facilitate coordination between the design engineer and landscape architect to maximize water harvesting on all three roadway landscaping projects.

Step 2: Map resource flows & physical elements

- The contour maps indicate all three roadways are gently crowned.
- Standard street cross sections will be modified to accommodate and maximize water harvesting in associated landscaping features.

Step 3: Identify potential for resource use

- Stormwater stored in soils adjacent to the roads will cleanse and reduce the volume of stormwater entering the roadway and storm drains.
- Vegetation supported by runoff water will shade the roadways and sidewalks, and in the case of medians, will shield cars from the headlights of oncoming traffic. Both areas will provide green relief for both pedestrians and vehicle drivers creating a more pleasant and attractive environment.
- Drainage from the roads will initially be routed to the median and/or the shoulder. Excess drainage will be routed to storm drains.
- Drainage intercepted within curbed areas will be collected in water harvesting areas to supplement irrigation of the landscaping and reduce or eliminate flows across the sidewalk.

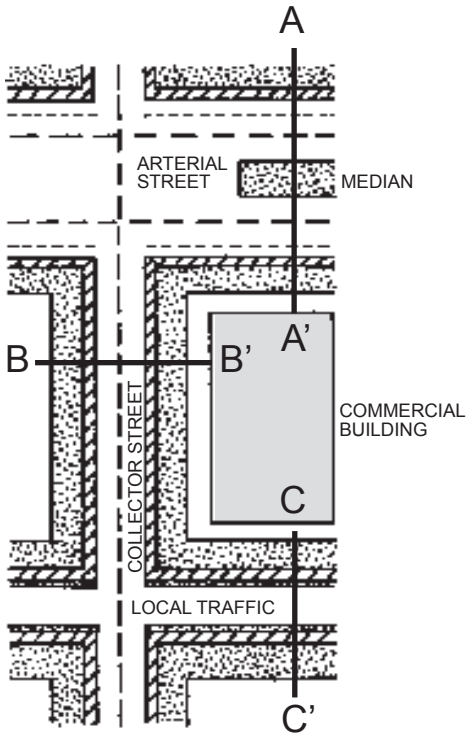
Step 4: Develop an integrated site concept design

- Gently slope roads and sidewalks toward the median and/or shoulder planting areas where possible. Depress planting areas in medians and shoulders to allow stormwater to collect and infiltrate into the soil. Separate deeper water harvesting structures from sidewalks by constructing a gently sloped 2-foot wide strip of soil and vegetation between the sidewalk and water harvesting area. Shallow basins (6-inches deep or less) may be placed immediately next to sidewalks as long as no tripping hazard is created.
- Construct inlets and outlets from medians and shoulders using curb openings and scuppers to drain stormwater from the street to the water harvesting area. Cover inlets, outlets, and intermediate spillways with filter cloth and/or cobbles to minimize erosion.
- Choose native drought tolerant plants that need minimal supplemental watering to become established. Irrigate the plantings periodically until the plants are fully established. Hook up the irrigation system to a rain sensor so the irrigation system shuts down when the soil has enough moisture to support the plants.
- Plant small plants at the top of the basins, plant shrubs and trees in the sides and bottoms depending on their tolerance for short-term inundation.
- Heavily mulch all planting areas. Either organic mulch, rock mulch, or decorative rock (not decomposed granite) will reduce evaporation, prevent erosion, and allow infiltration. Organic mulch soaks up water and builds soil. Allow plant litter to remain where it falls to replenish this mulch layer.

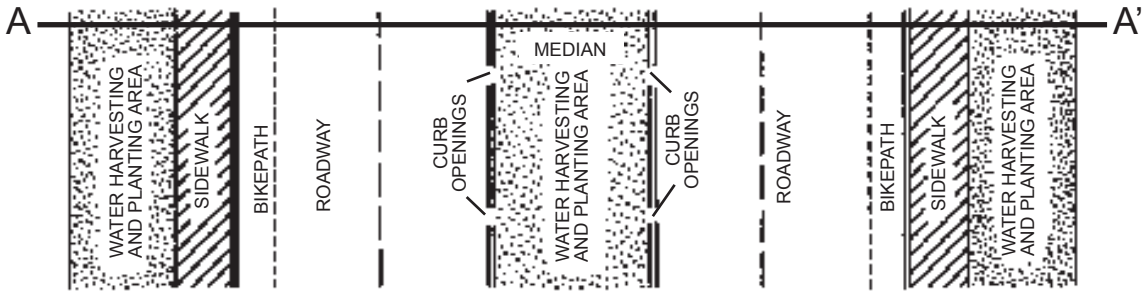
Step 5: Review and finalize the concept design

- Have all team members review and comment on the draft concept plan.
- Prepare the final concept design. Use the final concept plan as the basis for detailed site plans including grading, drainage, construction, and landscaping plans.
- Check detailed plans for consistency with the final concept plan.
- Develop inspection criteria and a maintenance plan for the landscaping and water harvesting areas.

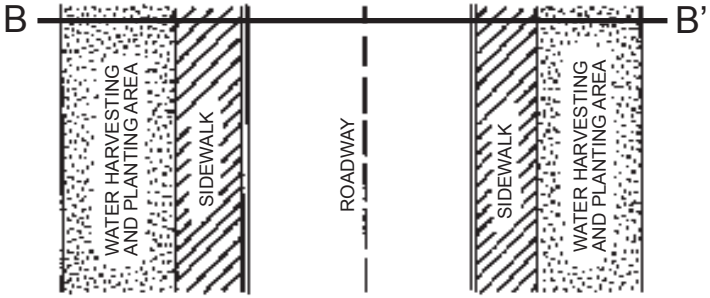
Public Rights-of-Way Example



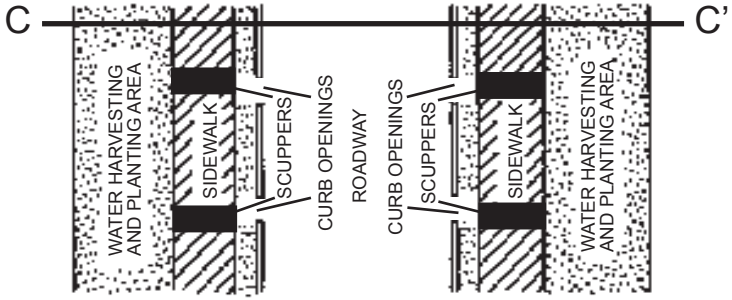
CROSS SECTION LOCATIONS



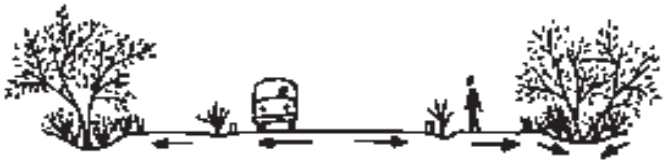
CROSS SECTION A-A'



CROSS SECTION B-B'



CROSS SECTION C-C'



Appendix A. Santa Cruz County Code Requirements

The Santa Cruz County Floodplain and Erosion Hazard Management Ordinance (No. 2001-03), Section 5.5 J, Runoff detention and retention systems states: "All proposed residential densities of three or more units per acre and all proposed commercial and industrial developments greater than one acre in size or more than 66 percent impervious area (including structure, concrete work, and paving) shall provide some method of peak or volumetric runoff reduction. The amount of reduction shall, at a minimum, reduce the peak or volumetric runoff of the base flood event to the undeveloped conditions, based on a study prepared by an Arizona Registered Professional Civil Engineer."

For lots less than one acre in size, rain gardens are offered as an alternative. Santa Cruz County Flood Control District and Floodplain Administration Public Information Series: Water Harvesting and Rain Gardens defines a rain garden as "a constructed depressed area used as a landscape tool to improve water quality and reduce site runoff. A Rain Garden is equal in size to 15% of the impervious area (building, paving, and concrete) constructed on the lot....The area is depressed 6 inches below the surrounding grade, with runoff from the building, sidewalk, and driveway directed to the garden, and planted with a variety of plants, including trees, shrubs, and grasses".

Water harvesting will aid in meeting code requirements for the Floodplain and Erosion Hazard Management Ordinance. Water harvesting also benefits County residents by reducing the volume of stormwater flowing in streets or onto adjacent properties and by helping keep potential stormwater pollutants out of our watercourses and groundwater. Water harvesting reduces the amount of potable water used for irrigation, saving development costs and reducing the demands placed on the region's potable delivery system and limited water table.

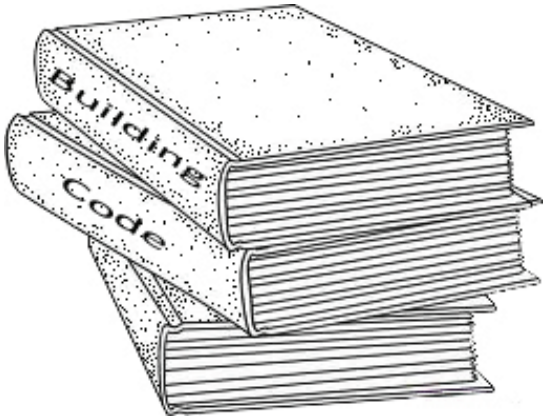
The State Standard for Stormwater Detention/Retention (State Standard 8-99) recommends using detention/retention tools in order to mitigate the "effects of urbanization on flood peak discharges and runoff volume". Where possible, stormwater retention/detention should be implemented on a regional basis -- "Such a watershed wide assessment should include an evaluation of the cumulative effects of urbanization such that the implementation of the stormwater detention/retention program addresses both localized increases in runoff and regional effects to the extent possible". If regional analysis is not attainable, the state standard recommends that the site's post-development peak discharges are no greater than the site's pre-development discharge rates for the 2-, 10- and 100-year flood events for small subdivisions <160 acres and large subdivisions or planned communities >160acres.

References:

Santa Cruz County Floodplain and Erosion Hazard Management Ordinance (No. 2001-03). Floodplain Regulations For The Unincorporated Area of Santa Cruz County, Arizona, 2001. Available online at: www.co.santa-cruz.az.us/public_works/flood/ordinance.html

Santa Cruz County Flood Control District and Floodplain Administration Public Information Series: Water Harvesting and Rain Gardens. Available online at: www.co.santa-cruz.az.us/public_works/flood/public-info.html

State Standard for Stormwater Detention/Retention (SS8-99). Arizona Department of Water Resources, 1999. Available online at: www.azwater.gov/azdwr/surfacewater/floodmanagement/StateStandards.htm



Appendix B. Engineering Considerations for Water Harvesting

General considerations

- Capturing water in small increments beginning at the top of the site watershed will reduce the volume concentrating at the bottom.
- Existing topography will influence storage locations, site layout, water harvesting design and layout, and types of water harvesting features.
- Design water harvesting systems to add value to the project.
- Capture as much runoff as possible without depriving adjacent or downstream vegetation of water, and without violating downstream water rights (see note 5, page 17). If all runoff cannot be permanently captured, then slow the flow of the remaining volume to increase percolation.
- Design for overflow from large rainfall events with erosion controls and overflow conveyance to useful and safe discharge locations.
- Design water harvesting areas to avoid ponding or soil saturation within 10 feet of building foundations or as required by the building code.
- For simple systems, the technique on page 30 may be used to determine how much of the water harvesting area may be considered off line and deducted from retention/detention requirements calculations.
- Multiple small harvesting techniques distributed throughout a site will harvest and utilize water more effectively than a few large techniques.

Above-ground landscape storage

- Landscaping basins should be configured with generally flat uncompacted bottoms to maximize the water storage volume.
- Use erosion-protected spillways between basins.
- A 10-foot wide, 6-inch deep water harvesting basin (level pool) with 3:1 side slopes provides 4.25 cubic feet of storage per linear foot. Deeper harvesting basins will provide more storage volume per linear foot.
- The 10-foot wide, 6-inch deep water harvesting basin described above will contain the 100-year rainfall event volume that lands within the basin. The area of landscaping basins configured to contain the 100-year rainfall is considered to be noncontributing to site runoff and may be subtracted from site area for drainage facility design. At the same time, the landscaping storage volume may be used to offset threshold retention volume requirements, provided enough site drainage is routed to the landscaping storage areas to meet stormwater volume requirements for the rainfall event.
- Construct and manage above-ground basins to infiltrate stormwater within 12 hours to avoid mosquito problems (Appendix E).
- Above-ground storage may occur in small basins or linear features.
- Take into account the displacement volume of riprap and mulches when calculating water storage capacity in depressions.

Below-ground landscape storage

- Water can be quickly infiltrated and stored under land surfaces using French drains (rock-filled trenches), which are effective in providing storage on flat to moderate slopes. Be sure water harvesting efforts do not destabilize slopes. Consult a soils engineer when designing water harvesting structures for any slopes that are not completely stable.
- Over-excavation of basins and backfilling with 3/4-inch screened gravel or rock provides additional storage volume of approximately one-third of the gravel-filled volume.
- Perforated underground pipes can provide additional storage volume.

Above- and below-ground tank storage

- Storage of rooftop runoff water in tanks reduces the volume of runoff draining to stormwater detention/retention basins.
- Design tanks and piping so stored water will not be accessible to mosquitoes (Appendix E), insects, sunlight, or animals.
- Above-ground tanks maintain head pressure to allow some gravity flow. Below-ground tanks take less space but usually require pumps.
- For all tanks, install a tank overflow and route it to a safe location, ideally where it will be put to beneficial use; overflow capacity of pipes must be equal to or greater than the inflow capacity.
- Plumb the site irrigation system to accept both potable water and tank water, supply hose bib piping for the tank.
- Screen inflow from roof to tank to keep debris out. Screen tank outflow before it enters the irrigation system to prevent clogging.
- Evaluate the potential to use tank water in site cooling towers or for wash water uses; design location and piping accordingly.
- Select roofing surface based on planned uses of tank water (metal or tile roofing provide high quality runoff water).
- Plan roof slopes to direct water to downspouts based on tank capacity.
- Consider installing a bypass to allow direct drainage of rooftop runoff when tanks are full. Route bypass water to a beneficial use area.

Appendix C.
Water Harvesting Calculations

Runoff volume for small watersheds

The following technique works best for watershed areas of 2 acres or less that are not extremely flat. Using this technique for a larger watershed area will result in over estimation of volume. Contact a County official for larger watersheds.

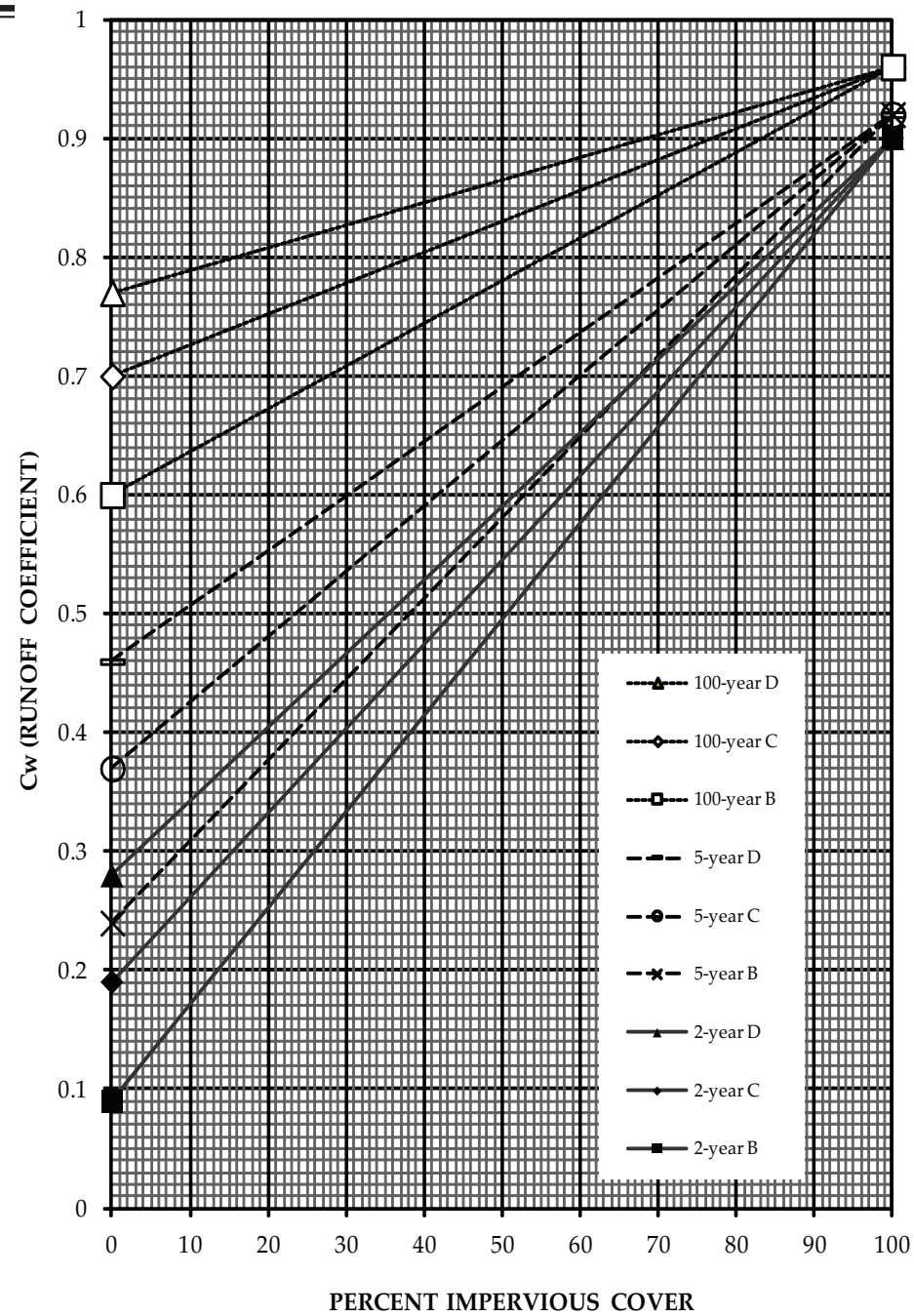
1. Determine the area of the watershed.
2. Determine the hydrologic soil type for the watershed (see page 29).
3. Determine the percent impervious cover (rooftops, pavement, sidewalk, driveways, etc.).
4. Determine which storm event (2-, 5-, 100-year) is to be used.
5. Use the chart at right and equation below as follows:
   a. Locate the percent impervious cover on the x-axis (bottom of the chart).
   b. Project vertically to intersect the line for the soil type and storm event of interest (n^{th}-year is the event; B, C, and D are hydrologic soil types).
   c. Project horizontally to the y-axis (left side of the chart) to determine the runoff coefficient Cw_n for the watershed (read to the $1/100^{th}$ unit).
   d. Substitute the value for Cw_n into the equation below.

Runoff Volume (V) = $Cw_n * A * P_n/12$, where
Cw_n = runoff coefficient for the nth storm event (2-, 5-, 100-year)
A = watershed area in ft^2
P_n = rainfall in inches for the nth storm event (see page 29)

The equation converts rainfall depth, P_n, from inches to feet by dividing by 12 in/ft. This allows the use of watershed area, A, in ft^2 yielding a runoff volume in ft^3.

Example:
Watershed = 20,000ft^2, hydrologic soil type = B, impervious cover = 40%
Cw_{100} = 0.74, V = 0.74*20,000*3.06/12 = 3,774ft^3
Cw_5 = 0.51, V = 0.51*20,000*1.76/12 = 1,496ft^3
Cw_2 = 0.41, V = 0.41*20,000*1.36/12 = 929.3ft^3
To convert ft^3 to gallons, multiply ft^3 by 7.48 gallons/ft^3.

RUNOFF COEFFICIENT CALCULATOR



Appendix C. Water Harvesting Calculations (continued)

Variables used in this appendix

A = watershed area in square feet
Cw_n = runoff coefficient for the nth year event
P_n = rainfall depth (in) for the nth year event
Q_n = n^{th} year peak discharge rate in cfs
V = runoff volume in cubic feet

For the Nogales/Rio Rico area, rainfall depths for a 60 minute duration are as follows (to determine rainfall depths in other parts of the county see reference below):

n^{th} year event	P_n
2-yr storm	1.36 inches
5-yr storm	1.76 inches
10-yr storm	2.06 inches
100-yr storm	3.06 inches

Units used in this appendix

cfs = cubic feet per second
ft = feet
ft^2 = square feet
ft^3 = cubic feet
gal = gallons
hr = hour
in = inches
sec = seconds

Further references

Soil Survey of Santa Cruz County and Parts of Cochise and Pima Counties, Arizona. Natural Resource Conservation Service, 1979.

Point Precipitation Frequency Estimates (depth of rainfall estimates) can be obtained online at: http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=az

Runoff Flow Rate estimates

The table below estimates Q_n, discharge or flow rate (ft^3/sec), for locations within Santa Cruz County given watershed size and type of storm. Contact a County official for larger watersheds.

Drainage Area		Rainfall Event Discharge in Cubic Feet per Second					
Square Feet	Acres	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
0	0.00	0.0	0.0	0.0	0.0	0.0	0.0
10,890	0.25	0.5	0.6	0.6	0.6	0.4	0.3
21,780	0.50	1.0	1.3	1.4	1.4	1.2	1.0
32,670	0.75	1.4	2.0	2.2	2.4	2.2	1.9
43,560	1.00	1.8	2.7	3.0	3.5	3.2	2.9
54,450	1.25	2.2	3.4	3.9	4.5	4.3	4.1
65,340	1.50	2.6	4.1	4.7	5.6	5.4	5.2
76,230	1.75	3.0	4.8	5.6	6.7	6.6	6.5
87,120	2.00	3.3	5.4	6.4	7.8	7.7	7.7
98,010	2.25	3.7	6.1	7.3	9.0	9.0	9.0
108,900	2.50	4.0	6.7	8.1	10.1	10.2	10.4
119,790	2.75	4.3	7.3	9.0	11.2	11.4	11.7
130,680	3.00	4.6	8.0	9.8	12.3	12.7	13.1
141,570	3.25	4.9	8.6	10.6	13.5	13.9	14.5
152,460	3.50	5.3	9.2	11.4	14.6	15.2	16.0
163,350	3.75	5.6	9.8	12.2	15.7	16.4	17.4
174,240	4.00	5.8	10.4	13.1	16.8	17.7	18.8
185,130	4.25	6.1	11.0	13.9	17.9	19.0	20.3
196,020	4.50	6.4	11.6	14.7	19.1	20.2	21.7
206,910	4.75	6.7	12.1	15.4	20.2	21.5	23.2
217,800	5.00	7.0	12.7	16.2	21.3	22.8	24.7

Drainage Area		Rainfall Event Discharge in Cubic Feet per Second					
Square Feet	Acres	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
228,690	5.25	7.3	13.3	17.0	22.4	24.0	26.2
239,580	5.50	7.5	13.8	17.8	23.5	25.3	27.6
250,470	5.75	7.8	14.4	18.6	24.6	26.6	29.1
261,360	6.00	8.1	15.0	19.3	25.7	27.9	30.6
272,250	6.25	8.3	15.5	20.1	26.8	29.1	32.1
283,140	6.50	8.6	16.1	20.9	27.9	30.4	33.6
294,030	6.75	8.8	16.6	21.6	28.9	31.7	35.1
304,920	7.00	9.1	17.1	22.4	30.0	33.0	36.6
315,810	7.25	9.4	17.7	23.1	31.1	34.2	38.1
326,700	7.50	9.6	18.2	23.9	32.2	35.5	39.6
337,590	7.75	9.8	18.7	24.6	33.2	36.8	41.1
348,480	8.00	10.1	19.2	25.4	34.3	38.0	42.6
359,370	8.25	10.3	19.8	26.1	35.4	39.3	44.1
370,260	8.50	10.6	20.3	26.8	36.4	40.5	45.6
381,150	8.75	10.8	20.8	27.5	37.5	41.8	47.2
392,040	9.00	11.0	21.3	28.3	38.5	43.1	48.7
402,930	9.25	11.3	21.8	29.0	39.6	44.3	50.2
413,820	9.50	11.5	22.3	29.7	40.6	45.6	51.7
424,710	9.75	11.7	22.8	30.4	41.7	46.8	53.2
435,600	10.00	12.0	23.3	31.1	42.7	48.1	54.7

Hydrologic soil types - Soil maps

The Natural Resource Conservation Service (NRCS), previously known as the Soil Conservation Service, has conducted soil surveys of Santa Cruz County. Soil Survey of Santa Cruz County and Parts of Cochise and Pima Counties, Arizona 1979, 111pp.
Available online at http://soils.usda.gov/survey/online_surveys/arizona/#santa1979
Contact a County official to view hard copies of the soil maps for Santa Cruz County.

Mixed hydrologic soil types

Most smaller sites will have one hydrologic soil type. If mixed hydrologic soil types are present, simply use a weighted average of the runoff coefficients (Cw_n) reflecting the percentages of the soil types and the percentage of impervious cover:
Example calculation: 30% B soils, 70% D soils; 40% impervious cover, 100-year event.
B soils, Cw_{100} = 0.74, determined by using the runoff coefficient calculator on the opposite page
D soils, Cw_{100} = 0.85, determined by using the runoff coefficient calculator on the opposite page
The site 100-year Cw for the mixed soils is calculated as follows:
$Cw_{100} = (0.3*0.74)+(0.7*0.85) = 0.222 + 0.595 = 0.82$

Appendix C. Water Harvesting Calculations (continued)

Detention/Retention impacts

Assume the commercial site shown on page 21 measures 200 ft by 400 ft, or 80,000 ft2 (1.84 acres), lies within a balanced watershed, and fronts on both an arterial (a major transportation route) and a collector street (a street that funnels traffic into an arterial street). The site was originally undisturbed desert with dispersed flow over hydrologic type B soils. The site will be developed as a commercial use with 90% impervious cover. Using the equation and chart on page 29, the site would result in the following:

Original site: B type soils	1.84 acres (80,000ft^2)	V_{100}	= 12,240 ft^3
	0% impervious cover	V_5	= 2,816 ft^3
Developed site:	1.84 acres (80,000ft^2) B type soils	V_{100}	= 18,870 ft^3
	90% impervious cover	V_5	= 9,973 ft^3

Since the site will be a commercial use over 1 acre in size and in a balanced basin, both detention (temporarily hold stormwater on-site to match the pre-developed 2-, 10-, and 100-year event discharge rates) and 5-year threshold retention (permanently hold the difference between the pre- and post-development stormwater volume for the 2- or 5-year event) are required.

The 100-year estimated detention volume is estimated by subtracting the original site condition from the developed condition, resulting in 6,630ft^3. The required 5-year threshold retention volume is estimated in the same manner, resulting in 7,157ft^3. Note, the 5 year threshold is larger in this case because of the nature of B type soils. If the area is dominated by C or D type soils, the volume required for the 100 year event will always be larger.

To harvest stormwater in the required 10ft landscaping borders along the arterial and collector streets, use stormwater harvesting basins 6 inches deep or more with 3:1 side slopes. Six-inch deep basins designed as level pools, will provide 4.25ft^3 per linear foot of water harvesting basin volume, resulting in the following retention volumes:

Arterial Street: 400ft of frontage less two 24-foot driveways (25ft wide with curb) and one 4ft wide sidewalk:
400ft - 54ft = 346ft ∗ 4.25ft^3/ft = 1,470ft^3

Collector Street: 200ft of frontage less 10ft (arterial landscape border), one 24ft driveway (25ft wide with curb), one 4ft wide sidewalk,
200ft - 39ft = 161ft ∗ 4.25ft^3/ft = 684ft^3

Arterial Street + Collector Street: 1,470ft^3 + 684ft^3 = 2,154ft^3
The resultant 2,154ft^3 of retention volume equals 30.1% of the required retention volume for the site.

The level pool configured water harvesting areas no longer contribute runoff to the site. Therefore, the area of the water harvesting basins may be deducted from the site area to recalculate detention and retention volume requirements.

(346ft ∗ 10ft) + (161ft ∗ 10ft) = 5,070ft^2
80,000ft^2 - 5,070ft^2 = 74,930ft^2 or 1.72 acres.

The resultant 100-year detention volume estimate is reduced to 6,210ft^3 and the required 5-year threshold retention volume is reduced to 6,704ft^3.

The retention volume provided in the water harvesting areas may be deducted from the new 5-year threshold retention required volume, reducing the required 5-year threshold retention volume to 4,550ft^3. *This is a 36.4% reduction in required retention volume from the conventional calculation method simply as a result of maximizing stormwater harvesting within the Land Use Code- required 10 ft landscaping border.* More water harvesting area is available. However, there must be enough site area draining to the water harvesting area to provide the 5-year storm volume to the water harvesting area (easily back-calculated by solving for area). Less frequent, larger rainfall events will overflow the water harvesting areas and flow should be directed to the detention basin and/or to a safe discharge location. The estimated detention basin volume requirement has been reduced by 6.5%.

Results

By configuring the required landscape borders to maximize water harvesting in 6-inch deep retention basins with little or no impact to site layout, the required retention volume is reduced by 36.4% and the estimated detention volume is reduced by 30%. Larger reductions can be achieved if water harvesting is incorporated into the remaining available landscape areas, by using deeper basin, and/or by the use of alternative materials such as porous pavement, French drains, and/or cisterns. Further reduction can also result by performing an engineering route analysis of the stormwater through the system.

Further considerations

With additional water harvesting/retention in interior landscaping areas, between parking areas, and with the use of water tanks to further supplement landscaping irrigation or a cooling system, the detention and retention volume requirements in the previous example can be reduced further. Sites with less impervious cover or other soil types can realize even larger reductions of required stormwater storage volumes. Site elevation change and length of street frontage will affect the percentage of benefit for each site.

Example 1

On page 28, runoff volume was calculated for a 20,000ft^2 watershed area. Assume that the 20,000ft^2 watershed area represents the northern quarter of the 80,000ft^2 commercial site on page 30, and that the 20,000ft^2 drains to the landscape border water harvesting area along the arterial street. The runoff volume calculation shown on page 28 indicated the areas would generate approximately 929.3ft^3 in the 2-year event, 1,496ft^3 in the 5-year event, and 3,774ft^3 in the 100-year event. The area would also generate an approximate 100-year flow rate of 1 cfs (see table on page 29).

The water harvesting area along the arterial street has 1,470ft^3 of retention/storage volume so the 2-year is entirely contained in the water harvesting area. The 5-year event (though nearly contained) and the 100-year event will overflow the water harvesting area. Erosion protection and conveyance for the full 100-year flow rate is required and may be as simple as 4-inch diameter riprap over filter fabric on spillways between water harvesting areas, with final discharge to a detention basin. The entire 100-year storm event volume of 3,774 ft^3 could be contained along the arterial landscape border in level pool water harvesting basins only 1.6 feet deep with 3:1 side slopes (3,875 ft^3), as long as the stormwater percolates into the soils in 12 hours or less. French drains can provide additional storage volume.

Example 2

The developer/owner of a commercial site in Rio Rico decides to incorporate water tanks to store stormwater for both landscaping irrigation and supplemental, low-salt content water for evaporative cooler use. The roof watershed area totals 11,350ft^2 with half of the roof draining to one tank and half to another tank. The total stormwater volume from the roof will vary with rainfall depth. A rare 100-year storm event yields a 3.06in rainfall depth, and the average annual total rainfall depth for Santa Cruz County is 17in. The following results may be considered for sizing the water tanks.

Volume can be calculated using the equation Volume = $Cw_n * A * P_n/12$. Use rooftop runoff coefficients (Cw_n) for 100% impervious cover for respective event/rainfall depths. For the 17in total annual rainfall depth, a Cw of 0.88 is reasonable since the 17in total rainfall depth is a summation of many smaller rainfall depths.

2-year, 1.36in rainfall depth yields = 0.90∗11,350∗1.36/12 = 1,158ft^3 or 8,662gal or 0.76gal/ft^2
5-year, 1.76in rainfall depth yields = 0.92∗11,350∗1.76/12 = 1,531ft^3 or 11,453gal or 1gal/ft^2
100-year, 3.06in rainfall depth yields = 0.96∗11,350∗3.06/12 = 2,778ft^3 or 20,780gal or 1.8gal/ft^2
17in average total annual rain depth = 0.88∗11,350∗17/12 = 14,150ft^3 or 105,849gal/year or 9.3gal/ft^2

Now all that remains to be decided is how big to make the water tanks and how to direct the overflow so it can be used by the vegetation. (See information on water tanks on pages 14 and 27 and in references in Appendix G). Tanks could conceivably be filled and emptied twice during each rainy season (monsoon season and winter rainy season). If a facility installed sufficient tank capacity to store 25% of annual rooftop runoff, this would theoretically allow the facility to pass up to 100% of annual available rooftop runoff through the tank system. For any given facility, the determination of how much tank capacity to install should be based on the volume of rooftop runoff available, the position of existing gutters and downspouts and the costs to add new ones, availability of space for above- or below-ground tanks, costs of tanks and associated pipes and pump, and the potential uses of the stored water. If the tanks have the capacity to contain all the runoff for the 2, 5, 10, and/or 100-year events (whichever is applicable based on tank capacity) the roof area may be deductible from the site area for detention/retention calculations. Consult with a County official to determine applicability.

Appendix D. Xeriscape Landscaping for Water Harvesting

Planting locations

- Always strive to achieve multiple functions in the placement of plants such as providing shade, habitat, passive cooling, screening, etc.
- Trees placed on the west, north, and east side of buildings reduce heat load in the summer and benefit from water provided from rooftop runoff. Use deciduous trees or low shrubs on the south side to allow sunlight to enter the building in the winter.
- In Santa Cruz County, hot prevailing winds are typically from the west and southwest. Plant trees on the west and southwest sides of buildings and outdoor spaces to provide a shield from drying winds.
- Tree-shaded parking areas greatly improve customer and employee comfort by creating pleasant microclimates.
- Trees and understory plants act as visual barriers to surrounding sites.
- Combine landscape buffers with detention/retention basins to achieve multiple benefits from one feature.
- When placing plants in the landscape, consider the volume and frequency of stormwater they will receive from water harvesting structures, the plant's tolerance for sun and cold, whether the plant has thorns (needs to be pruned along pathways), what the plant's maintenance needs are, and other site-specific considerations.
- Trees should be 15 to 20 feet from buildings to allow full development.
- Integrate the irrigation system into the water harvesting structure until plants are well established. After establishment, native drought-tolerant plants typically do not need supplemental irrigation except during extended dry periods.

Mulching

- Heavily mulch all planting areas to reduce evaporation and maintain soil moisture. Avoid mulching against shrub and tree trunks.
- Organic mulch (composted bark, wood chips, leaves, twigs, straw, grass clippings, etc.) improves soil. Periodically renew mulch if plants do not generate enough mulch from normal leaf drop (self mulching). Organic mulch tends to float; design basin depth accordingly.
- Inorganic mulches such as cobbles, gravel, decorative rock (not decomposed granite) help stabilize berms and spillways, reduce erosion over broad areas, and are very effective at reducing evaporation.
- Mulching in water harvesting areas helps increase the speed at which standing water is absorbed or infiltrated.

Plant selection

- Use native drought-tolerant plants (Xeriscape techniques), that adjust well to seasonal rainfall patterns, and look good during the dry season with minimal supplemental irrigation. Native and drought-tolerant plants in the Santa Cruz Active Management Area have been compiled by the Arizona Department of Water Resources (800-352-8488, or online: www.azwater.gov/azdwr/WaterManagement/AMAs/documents/SCAMA_PLANTLIST2009_000.pdf). Santa Cruz County Planning and Zoning Code, Article 29, lists native and low water use plants (520-375-7930, or online: www.co.santa-cruz.az.us/com_development/pdf/Zoning_and_Development_Code_2012.pdf)
- Use plants tolerant of inundation in areas where ponding will occur.
- Combine understory, midstory, and overstory plants to encourage beneficial relationships and self-mulching, and to minimize maintenance.
- Choose planting themes including pollinator-attracting gardens, native edible plants, fragrance gardens, bird/butterfly gardens, plants used by early inhabitants, or other themes. These plantings in association with water harvesting structures improve aesthetics and provide educational opportunities.

Water harvesting structures

- Include landscape planning in the integrated design process to coordinate with site drainage, road layout, building locations, etc.
- Fine-tune the designs of water harvesting features to make their configuration suitable for selected plants.
- Fine-tune the designs of erosion control features and spillways to make them functional and aesthetically pleasing.
- Plants can be placed in the upper edges of water harvesting areas to avoid prolonged inundation and encourage deeper root growth.

Irrigation

- Establish plants in water harvesting basins using several years of supplemental watering, then gradually wean plants off extra watering.
- Connect water tanks (may need filtration) to irrigation systems to use stormwater instead of potable water when tank water supply is sufficient.
- Install soil moisture and rainfall-detecting devices in association with irrigation systems to prevent unneeded use of both potable and harvested water for irrigation.

Appendix D. Xeriscape Landscaping for Water Harvesting

Maintenance

- Maintenance of water harvesting systems is essential for effective operation. Plan for on-going maintenance to ensure a successful project.
- Inspect water harvesting structures after major rains and on a periodic basis to monitor infiltration capacity, remove obstructions, maintain berms, treat erosion problems, and adjust the systems as necessary.
- Allow plant litter to accumulate. Chip and reuse plant clippings on-site as mulch.
- As climate allows, reduce and try to eliminate supplemental irrigation to native drought tolerant plants once they are well established.

Appendix E. Mosquito Considerations for Water Harvesting

Mosquitoes are an increasing problem in southeastern Arizona due to lush, heavily watered landscapes and many small shallow pockets of standing water (plant trays, bird baths, old tires, etc.). This is a concern because some mosquitoes harbor disease-causing organisms that can be passed to people through mosquito bites. By carefully planning, sizing, and maintaining water harvesting systems, the inadvertent creation of mosquito habitat can and should be avoided.

To control mosquitoes in water harvesting systems, avoid conditions that allow the mosquito to complete the cycle from egg to larvae to adult. It is important that water harvesting structures be designed and built to rapidly infiltrate water below the land surface, and that water does not pool at land surface for more than 12 hours. While mosquitoes are found all over during the monsoon season, you can avoid contributing to the situation by taking the following precautions in water harvesting systems:

- Do not compact the bottom of water harvesting structures such as swales, microbasins and French drains; loose soil will facilitate infiltration.
- Mulch the bottoms of basins and swales with 3 to 4 inches of mulch.
- Establish plants in water harvesting structures. Roots break up the subsurface and improve infiltration.
- Size structures appropriately for the amount of runoff received; construct overflow spillways to release excess water and prevent erosion.
- If soil is clayey (hydrologic type D soils, etc.), mix sand, gypsum and gravel into the first 2 feet under basins to increase pore space and infiltration capacity, and/or use French drains to convey water underground quickly.
- If using inorganic mulch, make sure rock has been screened to remove fine-grained material that can clog soil pores. Do not use decomposed granite unless the fine particles have been removed.
- Observe your system after initial and heavy rainfalls. If water stands for more than 12 hours in a structure, it might be necessary to loosen the bottom of the basin, add more mulch, lower the spillway, and/or construct smaller, more frequent structures upslope.
- Securely cover all tanks, and put fine-mesh screens on all inlet and outlet pipes to keep mosquitoes from entering tanks. Tank overflow water can be routed through a French drain to keep it underground.
- Microbasins positioned along the flow path of a large detention feature should be appropriately sized, planted, and mulched to allow rapid infiltration. Maximize infiltration upslope of the final detention area.
- Do not plant high water use landscape plants that must be watered frequently. Use drought tolerant plants.
- Keep all bowl-shaped structures (plant trays, wheel barrows, tires, etc.) emptied of any standing water. Avoid standing water features such as fountains and birdbaths. If these features are desirable, use *Bacillus thuringiensis israelensis* (BTI), a larvae-killing bacteria that inhibits completion of the mosquito life cycle but will not harm the environment of bird baths and fish ponds. It is sold under the name "Mosquito Dunk."
- Periodically inspect your system to see if mosquitoes are breeding. If so, adjust water harvesting areas accordingly and/or put BTI in the basins.
- Install a bat house in your yard. Bats eat large amounts of insects and can help reduce mosquito problems. http://www.batcon.org/

Appendix F. Water Harvesting Sites in/near Santa Cruz County

SANTA CRUZ COUNTY

Guy Tobin Memorial Anza Trailhead, Rio Rico
Rio Rico Drive just east of I-19
- Large-scale water harvesting earthworks direct and infiltrate stormwater throughout this two-acre site, and erosion control structures help stabilize the site for large flows. These features filter pollutants, reduce erosion, beautify the site, and conserve water used for landscape irrigation.

Rio Rico Fire Station
822 Pendleton Dr, Rio Rico
- Rooftop water is harvested and stored in three large steel culvert cisterns. Water is used for landscape irrigation and washing of fire trucks.

Santa Cruz County Administration Complex
2150 North Congress Drive, Nogales
- A rain garden in the front of the building complex directs rainwater to basins planted with native vegetation.

Out of the Way Galleria
29 Tubac Plaza, Tubac, (520) 398-9409, www.outofthewaygalleria.org
- Rooftop water is harvested and stored in six 18-inch culvert pipes that are aesthetically integrated as columns along the front of the building.
- Harvested water is used to irrigate plants that are part of living architecture of the galleria and nearby plaza.

Avalon Organic Gardens & EcoVillage
38 Santa Gertrudis Lane, Tumacácori, (520) 603-9932,Tours booked through Spirt Steps Tours, (520) 398-2655, www.avalongardens.org
- 165 acre EcoVillage demonstrating sustainable community living
- Water harvested from 8,500 ft^2 of rooftop is stored in large cisterns for irrigation of vegetables and emergency fire suppression. A rain garden harvests runoff from a 5,000 ft^2 rooftop. Collectively, 7,000 gallons of water are harvested with 1 inch of rain.
- Laundry and bath facilities create graywater that is distributed via underground infiltration chambers buried 8-10 inches below the surface and perforated pipes buried in shallow trenches lined with gravel. Harvested graywater helps maintain shade trees and other vegetation. Soaps used biodegrade into plant food.

NOGALES, SONORA

Instituto Tecnológico de Nogales
Ave. Instituto Tecnológico # 911 CP. 84065
- Rooftop water is harvested and stored in a large cistern. Berms and basins capture stormwater, filter pollutants, and reduce erosion.
- A 100-year storm or 2.75 inches of rain can be captured.

Hogar de Esperanza y Paz (HEPAC - Home of Hope and Peace)
Located in Colonia Bella Vista, Nogales, Sonora
- Roof top water is harvested and stored in a large plastic cistern and used to water fruit trees and a vegetable garden.

PIMA COUNTY

City of Tucson Ward I City Council Office
940 W. Alameda St., Tucson (520) 791-4040
- Rooftop water is harvested and stored in a cistern.
- Berms and basins capture stormwater and irrigate native plants.

Dunbar/Spring Neighborhood and Community Garden
11th Ave. and University Blvd., Tucson, www.dunbarspring.org/
- Raised pathways shed runoff to sunken garden beds.
- Curbcuts, chicanes, and traffic circles harvest stormwater and irrigate native trees and vegetation in the neighborhood. Chicanes, or bumpouts, calm traffic by narrowing streets in targeted locations, reduce impervious surfaces, and are often planted with shade producing vegetation.

The Nature Conservancy
1510 E. Ft. Lowell, Tucson (520) 622-3861
- 30,000 square foot parking lot with porous surface designed to infiltrate rainfall from a 100-year rainfall event; no detention basin required.
- Rooftop water is captured in two cisterns (one above-ground and one below the parking lot) with a combined capacity of 50,000 gallons.

Milagro Cohousing
3057 N. Gaia Place, Tucson (520) 622-6918, http://milagrocohousing.org
- Minimal disturbance subdivision with water harvesting features, graywater use, gabions, 13 cisterns, and permeable surface paving.

Appendix G. Water Harvesting-Related Resources and Contacts

PUBLICATIONS ADDRESSING WATER HARVESTING

HARVESTING RAINWATER FOR LANDSCAPE USE, University of Arizona Pima County Cooperative Extension and Arizona Department of Water Resources, Tucson Active Management Area, 2004, 2006.
Online at: http://ag.arizona.edu/pubs/water/az1052/

RAINWATER HARVESTING FOR DRYLANDS, Vol. 1&2, by Brad Lancaster, 2006, 2007. "A how-to book about welcoming rainwater into your life, landscape, and soil." Excellent for homeowners wanting to harvest rainwater. www.harvestingrainwater.com/

SECOND NATURE, ADAPTING LA'S LANDSCAPE FOR SUSTAINABLE LIVING edited by Patrick Condon and Stacy Moriarty. Metropolitan Water District of Southern California, 1999. Concepts such as passive rainwater harvesting and multi-use landscaping for sustainability are presented. TREEPEOPLE, 12601 Mulholland Drive, Beverly Hills, CA 90210,
Online at: www.treepeople.org/second-nature-adapting-LAs-landscape-sustainable-living

THE TEXAS MANUAL ON RAINWATER HARVESTING, 3rd Ed., Texas Water Development Board, 2005.
Online at: www.twdb.state.tx.us/publications/reports/Rainwater-HarvestingManual_3rdedition.pdf

RAINWATER HARVESTING FOR THE MECHANICALLY CHALLENGED by Suzy Banks & Richard Heinichen, 2006. www.rainwatercollection.com/

ROOFTOP HARVESTING, A HANDBOOK FOR PROFESSIONALS by T.H. Thomas and D.B. Martinson, 2007. The Netherlands, IRC International Water and Sanitation Centre. (Technical Paper Series; no. 49). 160 p.
Online at www.irc.nl/page/37471

STORMWATER AS A RESOURCE "HOW TO HARVEST AND PROTECT A DRYLAND TREASURE" by David Morgan and Sandy Trevathan. A brief, clear, and concise guide for harvesting rain and snow on your property.
Online at: www.nmenv.state.nm.us/swqb/Storm_Water_as_a_Resource.pdf

WATER HARVESTING CLASSES

American Rainwater Catchment Systems Association, offering professional educational programs around the country. www.arcsa-usa.org/content.asp?pl=4&contentid=4

Sonoran Permaculture Guild, Water Harvesting Teachers and Consultants, Tucson www.sonoranpermaculture.org

Pima County Cooperative Extension classes, 4210 N. Campbell Avenue Tucson, AZ 85719, free, reservations required: 520-626-5161, http://cals.arizona.edu/pima/smartscape/workshop_water.html

Watershed Management Group, Trainings, workshops, educational materials, and consulting, Tucson http://watershedmg.org/tech-trainings

WEB SITES

Santa Cruz County Flood Control District, information on flood hazard avoidance, regulation, and management. www.co.santa-cruz.az.us/public_works/flood/

American Rainwater Catchment Systems Association, many resources, publications and links. www.arcsa-usa.org/content.asp?pl=6&contentid=6

HarvestH20.com The Online Rainwater Harvesting Community. Many links, resouces, and information on rainwater harvesting. www.harvesth2o.com/

Water Conservation Alliance of Southern Arizona (Water CASA) - publications and links to water harvesting and gray water use. www.watercasa.org/publications/

GRAYWATER

THE NEW CREATE AN OASIS WITH GREYWATER, Your Complete Guide to Choosing, Building and Using Greywater Systems - Includes Branched Drains 5th Ed. Art Ludwig, published by Oasis Design, 2006. www.oasisdesign.net

HOME USE OF GRAYWATER, RAINWATER CONSERVES WATER AND MAY SAVE MONEY, by Joe Gelt University of Arizona. http://wrrc.arizona.edu/publications/arroyo-newsletter/home-use-graywater-rainwater-conserves-water-and-may-save-money

RELATED RESOURCES

Arizona Native Plant Society, Box 41206, Sun Station, Tucson, AZ 85717 www.aznps.com

Bowers, Janice Emily. SHRUBS AND TREES OF THE SOUTHWEST DESERTS. Tucson: Southwest Parks and Monuments Association, 1993.

Laney, Nancy R. DESERT WATERS - FROM ANCIENT AQUIFERS TO MODERN DEMANDS. Arizona-Sonora Desert Museum, 1998. A good short and concise publication on our water situation in the southwest with tips on how to reduce our water use. www.desertmuseum.org/books/book_detail.php?press_id=32

A LANDSCAPER'S GUIDE TO MULCH by StopWaste.org the Alameda County Waste Management Authority and the Alameda County Source Reduction and Recycling Board.
Online at: www.stopwaste.org//docs/mulch_guide_2011.pdf

Mielke, Judy. NATIVE PLANTS FOR SOUTHWESTERN LANDSCAPES, Austin: University of Texas Press, 1993

Nabhan, Gary Paul. GATHERING THE DESERT, Tucson: University of Arizona Press, 1985

Native Seeds/SEARCH. 3061 N. Campbell Ave., Tucson, AZ 85719, 520-622-5561, open-pollinated, native edibles, both domesticated and wild. www.nativeseeds.org

Tucson Audubon Society, 300 E. University Blvd., Ste 120, Tucson AZ 85705. Information on avian and riparian habitat restoration using water harvesting. 520-629-0510. www.tucsonaudubon.org

Wildlands Restoration, 2944 N. Castro, Tucson, AZ 85705, tel: 520-882-0969: Drought tolerant native seed source. Habitat restoration mixes, native grass mixes, wildflowers, butterfly mix and others.

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