COMMERCIAL RAINWATER HARVESTING

10-03.0.0 COMMERCIAL RAINWATER HARVESTING.

10-03.1.0 GENERAL

1.1 INTRODUCTION. Harvesting rainwater is a useful strategy for providing supplemental irrigation water to commercial landscapes, making more efficient use of the desert's most limited resource--water. The City of Tucson Mayor and Council adopted the Commercial Rainwater Harvesting Ordinance on October 14, 2008 to increase the use of harvested rainwater at commercial sites in Tucson and to decrease use of potable and reclaimed water supplies. The ordinance takes effect June 1, 2010.

1.2 PURPOSE. This Development Standard has been prepared to facilitate effective use of available rainwater resources for landscape irrigation in commercial development as a means of reducing dependency on potable and reclaimed water sources. It clarifies requirements for compliance with Ordinance No. 10597, the Commercial Rainwater Harvesting Ordinance (Ordinance), including the key requirement of meeting 50% of landscape water demand using harvested water. This standard provides:

A. Design considerations and technical requirements for passive and active water harvesting systems;

B. Requirements and guidelines for the preparation and implementation of Rainwater Harvesting Plans;

C. Requirements for landscape and irrigation at water harvesting sites;

D. Recommended maintenance steps;

E. Elements required for compliance with the Ordinance;

F. Enforcement provisions;

G. Water budget assumptions and calculations (Exhibit A)

H. Annual reporting form (Exhibit B)

1.3 APPLICABILITY. This standard applies to all commercial development plans submitted after June 1, 2010.

10-03.2.0 DEFINITIONS

Other than as provided below, definitions used in this Standard are found in the Development Standards Glossary or Sec. 6.2.0 of the *LUC*.

2.1 *Active Water Harvesting*. The collection of stormwater into containment systems for storage and later diversion to beneficial uses.

2.2 *Catchment Areas.* Areas of a site where water is harvested, including where rain falls directly on plant canopies and pervious Water Harvesting Infiltration Areas, and where rain falls on impervious rooftops, sidewalks, parking lots, driveways and other surfaces from which stormwater is directed toward Water Harvesting Infiltration Areas.

2.3 *Catchment Ratio.* The ratio of the water harvesting catchment area to the canopy area of the plants that use water harvested from that catchment area.

2.4 *Commercial development.* Any new non-residential development that is intended to be used primarily for commercial activities, and is subject to the requirements of the International Building Code.

2.5 *Containment systems.* Above-ground tanks, below-ground tanks, other types of above- and below-ground water-holding containers, and associated pipes and transmission equipment that enable beneficial use of harvested water.

2.6 *Evapotranspiration.* The transfer of water from land surface to the atmosphere through the combination of evaporation and plant transpiration.

2.7 *Impervious Subwatersheds.* Discrete nonporous subareas of a site--including rooftops, sidewalks, parking lots, driveways and other impervious areas--that capture stormwater and deliver it through gravity flow to discrete containment systems or Water Harvesting Infiltration Areas.

2.8 *Passive Water Harvesting.* The collection of stormwater directly into Water Harvesting Infiltration Areas without the temporary storage of water in a containment system.

2.9 *Plant Canopy Area.* The area covered by plants as indicated on the landscape plans, including understory, midstory and overstory plants.

2.10 *Rainwater.* Liquid precipitation falling from the sky before it lands on a surface.

2.11 *Stormwater.* Rainwater that has landed on a surface.

2.12 *Water harvesting.* The process of intercepting stormwater and putting it to beneficial use.

2.13 *Water Harvesting Infiltration Areas.* Pervious areas of a site where harvested water collects and soaks into the subsurface to support landscape plants. Water Harvesting Infiltration Areas include exposed soil shaped to hold and infiltrate water, permeable soil subgrades

overlain with impervious pavement that receive water via perforated pipes or other conveyance techniques, structured soil overlain with permeable paving, and other strategies that collect water and allow it to soak into the subsurface to support landscape plants.

10-03.3.0 DESIGN CONSIDERATIONS AND TECHNICAL REQUIREMENTS

Two primary strategies for harvesting water are commonly used in the southwest US to support landscape water needs. Passive water harvesting is accomplished by infiltrating stormwater runoff directly into Water Harvesting Infiltration Areas. Active water harvesting stores harvested water in containment systems located above or below ground so the stored water is available for later beneficial use. The commercial facility may determine the strategy or strategies most appropriate for their site. Design considerations and technical requirements for passive and active water harvesting systems are described in the sections below.

3.1 PASSIVE WATER HARVESTING. Passive water harvesting consists of the collection of stormwater directly in Water Harvesting Infiltration Areas without the temporary storage of water in containment systems. Passive water harvesting functions through gravity-flow of stormwater. It requires no tanks, piping, metering, pumps or other infrastructure associated with containment systems. However, in passive water harvesting, infrastructure components may be needed to route overflow water, pass water under roads or parking lots, or for other purposes conducive to the effective functioning of the passive systems.

A. Passive Water Harvesting Design Considerations. An array of techniques and designs are available to accomplish passive water harvesting. Whatever techniques or designs are used, the items listed below should be considered to create safe, efficient and effective passive water harvesting systems.

1. Use Water Harvesting Infiltration Areas, where feasible, to offset the size of a retention/detention basin that may be needed at a site. Consult Appendix C of the City of Tucson Water Harvesting Guidance Manual for information on the allowed offset.

2. The area and depth of Water Harvesting Infiltration Areas should be determined according to the anticipated volume of harvested water that will enter these areas and the infiltration characteristics of the underlying soil.

3. Plants with similar water demands should be placed in the same areas within Water Harvesting Infiltration Areas.

4. Soils within Water Harvesting Infiltration Areas should be modified as needed to counteract the effects of mechanical compaction and/or poor soil infiltration conditions in order to ensure appropriate water infiltration.

5. The edge of Water Harvesting Infiltration Areas should be set back from building foundations or other structures to allow for positive drainage of water. Consult a soils professional where necessary.

6. Planting areas that harvest water should be recessed below the grade of adjacent hardscapes. Hardscape surfaces should be sloped toward adjacent recessed planting areas.

7. Pedestrian circulation should be designed to discourage cutting across recessed planting areas to avoid soil compaction, erosion, and damage to plants and to minimize the risk of injury to pedestrians.

8. Maximum reveal at the edge of public sidewalks and pedestrian circulation paths should be 2 inches or less to minimize the risk of injury to pedestrians. A minimum 12-inch wide shoulder with a maximum two (2) percent cross-slope away from a public sidewalk or pedestrian circulation path should be provided where possible.

9. Water Harvesting Infiltration Areas should be stabilized for dust control purposes. Techniques could include spreading ½-inch or larger rock, hydroseeding with native seed mixes, or using other stabilizing techniques and materials. Fine-grained particles that could block water infiltration by clogging soil pores should be washed from materials prior to placement. Avoid the use of fine-grade decomposed granite within or directly adjacent to Water Harvesting Infiltration Areas due to the potential for shed silts and clays to reduce water infiltration.

10. Organic mulch is appropriate for reducing evaporation, controlling dust and increasing soil quality in Water Harvesting Infiltration Areas in those locations where the vegetation, water collection, erosion conditions, and slope characteristics are amenable to its use.

B. Passive Water Harvesting Technical Requirements. The following technical requirements apply to all passive water harvesting systems.

1. Water Harvesting Infiltration Areas shall be designed so that water infiltrates into soil within twenty-four (24) hours.

2. Water Harvesting Infiltration Areas shall be designed to minimize ponding in areas that may create a nuisance for pedestrians. Ponding is not allowed on or over public sidewalks or required pedestrian circulation paths.

3. Materials for erosion control shall be specified where they are necessary due to erosion potential. The ground surface treatment of spillways and other areas that convey water flows shall be able to withstand scouring.

3.2 ACTIVE WATER HARVESTING. Active water harvesting stores harvested water in containment systems located above or below ground so the stored water is available for later beneficial use. Active water harvesting systems include the tanks, piping, metering, pumps and other infrastructure elements needed to store and transmit water to a beneficial use. Active water harvesting systems might be gravity-flow based or use pumps depending on the size and needs of the site.

A. Active Water Harvesting Design Considerations. An array of techniques and designs are available to accomplish active water harvesting. Whatever techniques or designs are used, the items listed below should be considered to create safe, efficient and effective active water harvesting systems.

1. Tanks may be constructed of metal, plastic, masonry, reinforced concrete, fiberglass, or other suitable DSD-approved material designed to store water.

2. The dimensions of tanks may be determined by the applicant based on site-specific design needs.

3. Above-ground tank construction material or coating should be opaque to prevent sunlight from inducing algae growth. Any portion of a subsurface tank that is exposed to sunlight should be opaque to prevent sunlight from inducing algae growth.

4. A "first flush device" is intended to prevent the dust, grit, leaves and other materials that may accumulate on a roof from being washed into a water harvesting tank. This is accomplished by deflecting the first flush of stormwater from entering the tank inlet line. The installation of first flush devices is strongly recommended.

5. Inlet piping may convey water overhead from a roof to a tank, or in a U-shaped configuration that conveys water to a lower entry point on the tank. The U-shaped configuration should be designed to hold standing water, and must be pressure rated and sealed to prevent leaks.

6. Designs that involve water falling freely through the air before entering a tank may be allowed provided the design minimizes the entry of light and mosquitoes into the tank.

B. Active Water Harvesting Technical Requirements. The following technical requirements apply to all active water harvesting systems.

1. Materials must be installed per manufacturer's specifications.

2. Tanks shall have a base or foundation that meets manufacturer's specifications. If no specifications are provided by the manufacturer, the base shall be designed by an engineer.

3. Locations of containment systems shall be in accordance with applicable codes.

4. Consult the International Building Code for applicable regulations.

5. Sub-surface storage tanks shall be constructed of materials designed for holding water underground. Below-ground tanks must be designed and installed under the guidance of a civil or structural engineer and/or tanks must be installed per manufacturer's specifications regarding bedding, setting the tank, strapping or other anchoring device, load bearing characteristics and backfill requirements.

6. If debris screening is used for inlets to tanks, screening must be configured in such a way that an unmaintained screen cannot block inlet pipes to a tank. Obstructed screens can prevent water harvesting and back water up on the roof creating unsafe weight load conditions on the roof.

7. There must be a structured overflow device installed with the tank to automatically allow excess infill water to exit the tank safely.

8. An overflow mechanism, separate from that provided inside the tank, shall be provided to ensure that water cannot back up on a roof. Roof overflow drains shall not be connected to tanks.

9. Outlets for overflow pipes shall be positioned so as not to compromise the foundations of buildings or other structures.

10. Tanks and covers shall be constructed of materials appropriate for use for storing water.

11. Tanks must have an inspection port of sufficient size to conduct any necessary visual inspection, maintenance, cleaning, repair and other tasks as described in the manufacturer's specifications.

12. If a manhole is provided with the intent of allowing human access into a tank, it must meet any applicable size and safety requirements.

13. A means should be provided to enable particulate materials that accumulate in the bottom of tanks to be cleaned out or flushed out if needed.

14. Containment systems shall be designed, maintained and operated to prevent mosquito harboring and/or breeding.

15. A reduced-pressure backflow-preventer assembly is required when connecting irrigation from an active water harvesting system to a potable water irrigation system in order to protect the public water system and/or building water system.

16. Hose bibs connected to an active water harvesting system shall be keyed and shall be posted "NON-POTABLE, DO NOT DRINK."

10-03.4.0 RAINWATER HARVESTING PLAN

A Rainwater Harvesting Plan shall be submitted with all applications for commercial developments at which landscaping is required. The Rainwater Harvesting Plan shall consist of two elements: a Site Water Budget and a Water Harvesting Implementation Plan. Preparation of the Rainwater Harvesting Plan elements requires coordination between project managers, site engineers and landscape architects from the inception of the project. The two elements of the Rainwater Harvesting Plan shall illustrate how water harvesting will meet 50 percent of annual landscape water demand, as required by the Ordinance.

4.1 SITE WATER BUDGET. The Site Water Budget shall detail the landscape water demand and the harvested water supply needed to meet 50 percent of landscape demand. The Site Water Budget and the Water Harvesting Implementation Plan shall be consistent with one another.

A water budget format is shown in Exhibit A, along with the background data and assumptions used to develop it. This water budget format is available to applicants as an

Excel spreadsheet at <http://www.tucsonaz.gov/dsd/What_s_New/what_s_new.html>. Applicants may use this water budget format to enter site-specific data to develop their Site Water Budget. Alternatively, applicants may develop their own Site Water Budget format. Whichever format is used, the submitted Site Water Budget shall incorporate and provide the information below.

A. Water Demand. Applicants shall use plant water demand categories and data provided in Exhibit A unless alternative assumptions are provided and satisfactorily justified.

B. Water Supply. Applicants shall use the effective monthly rainfall assumptions shown in Exhibit A unless alternative assumptions are provided and satisfactorily justified.

C. Output. Output of the Site Water Budget shall include calculations showing how 50 percent of landscape water demand as an average across the site will be met using harvested rainwater, and shall include assumptions and supporting calculations as necessary to document these outputs. Output of the Site Water Budget shall include total water demand and rainwater supply calculations for each Water Harvesting Infiltration Area at the site.

4.2 WATER HARVESTING IMPLEMENTATION PLAN. The Water Harvesting Implementation Plan (Implementation Plan) shall consist of a separate sheet with a plan view layout of the site. The format and design of the Implementation Plan shall be consistent with the base plan, be it a Development Package (DS 2-01), Plat (DS 2-03), Site Plan (DS 2-04), Development Plan (DS 2-05), or their successor documents, as applicable. The Implementation Plan shall include all details necessary and appropriate to convey the technical concept of the water harvesting system design and to facilitate proper installation and maintenance of the water harvesting system in compliance with the Ordinance and this Standard.

Submittal of the Implementation Plan shall be made concurrently with the Development Plan and Landscape Plan. Revision of the Implementation Plan may be required in conjunction with preparation of the Grading Plan in order to coordinate the construction details and specifications.

A. General Information. The following general information will be provided on the Implementation Plan.

1. The case number located in the lower right corner of the plan.

2. The means by which monthly rainfall data will be obtained and recorded

3. The means by which monthly irrigation data will be obtained and recorded

4. Soil pretreatment techniques, locations and schematics

5. Maintenance notes

6. Monitoring and Annual Reporting Requirements

B. Tabulated Data. The Implementation Plan shall include a table detailing information for each identified Water Harvesting Infiltration Area (WHIA) at the site, and for the site as a whole, as described below.

1. General WHIA information:

   a) WHIA identifier

   b) Spatial size (square feet) of WHIA

   c) Average depth (feet) of WHIA

   d) Capacity (gallons) of WHIA

   e) Type and general location where any sensors that control the irrigation system will be placed

2. Plant canopy information:

   a) Plant canopy area (square feet) that is served by each WHIA, consisting of the sum of understory, midstory and overstory plant canopies at 60 percent of the mature plant sizes

   b) Plant water demand category

   c) Total annual plant water demand (gallons)

3. Information about passive and/or active water harvesting systems serving each WHIA:

   a) For the Subwatershed passively serving each WHIA:

      i. Subwatershed identifier

      ii. Spatial size (square feet) of the subwatershed

      iii. Material the subwatershed is made of or covered with

      iv. Percent of annual plant water demand provided by this subwatershed to the WHIA

   b) For the containment system actively serving each WHIA:

      i. Tank Identifier

      ii. Tank capacity (gallons)

      iii. Tank location

      iv. Percent of annual plant water demand provided by this tank to the WHIA

c) Any additional information needed to document how 50% of irrigation demand will be met using harvested water.

d) Data tabulated for the entire site:

i. Percent of annual landscape water demand met using harvested water

ii. Water harvesting capacity that will offset standard retention/detention basin size, if applicable

e) Additional plan information may be requested or required by the Development Services Department (DSD) Director to evaluate rainwater-harvesting Implementation Plan

C. Mapped Data. The Implementation Plan shall graphically show the following information drawn from tabulated data.

1. For the WHIA:

a) Indicate the boundary of each WHIA and show its identifier

b) Use arrows to show water flow directions within WHIA, including flow direction at inlets and outlets

c) Show location where any sensors that control the irrigation system will be placed

2. Indicate the boundary of the plant canopy area to be served by each WHIA

3. Information about Passive and/or Active Water Harvesting Systems serving each WHIA:

a) Passively supplied water:

i. Indicate the Subwatershed Area serving each WHIA and show its identifier

ii. Use arrows to indicate the flow path water will take from source to WHIA

iii. Indicate spot elevations for the bottoms of water harvesting structures, at spillways, and to define other grades as needed

iv. Indicate the location of all surface or subsurface infiltration structures, pipelines, spillways, French drains, scuppers, curb cuts and other infrastructure elements needed to convey, store or overflow passively supplied water, or to control erosion

b) Actively supplied water:

i. Show tank and show its identifier

ii. Label tank as delivering water by gravity flow or pump

iii. Use arrows to indicate flow path water will take from source to WHIA

iv. Show additional piping, pump and other infrastructure needed to store, overflow, and convey water to WHIA

D. Additional Information. Additional notes shall be provided on the Implementation Plan to ensure current and subsequent site owners and operators are informed of the inspection and maintenance required in Section 6 of this development standard.

10-03.5.0 LANDSCAPE AND IRRIGATION REQUIREMENTS

5.1 LANDSCAPE REQUIREMENTS.

A. Soil pretreatment. Due to construction site compaction, the soils in planting areas might need to be pretreated to ensure adequate infiltration of harvested water. Soil Pretreatment techniques, locations and schematics should be provided on the Implementation Plan.

B. Plant selection and placement. Plants selected for use within discreet Water Harvesting Infiltration Areas should have compatible water needs. Drought tolerant plants native to Tucson are adapted to the seasonal rainfall patterns present in the Sonoran Desert and present an advantage over low-water-use plants from other climates. Plants should be positioned to account for the level of expected inundation. They may be placed on the bottoms or sides of recessed areas or the tops of adjacent soil where their roots can grow toward adjacent moist soil. Other placement considerations should include sun exposure, maintenance requirements, shape, form and aesthetics.

C. Mulch placement. Mulch shall be positioned away from the base of plant trunks to avoid excessive moisture there.

5.2 IRRIGATION REQUIREMENTS.

A. Irrigation control. Irrigation systems shall be fitted with irrigation controllers and shall be capable of monitoring and responding to plant water needs through the use of soil moisture gauges, tensiometers, weather stations and/or evapotranspiration data. The irrigation technology chosen should be capable of preventing the irrigation system from running if sufficient soil moisture is present to support the vegetation. All systems shall include rain shut-off devices. Instruments shall be correctly placed to ensure plants are kept healthy using a combination of harvested and non-harvested water and to ensure the stated water-saving goal of the Ordinance is met.

B. Irrigation timers. Irrigation timers, where used, shall be used in conjunction with other irrigation controls to ensure compliance with the provisions of this development standard.

C. Water-use calculations. Irrigation Plans must include calculations for estimated water use based on assumptions about plant water demand and canopy size used in the Site Water Budget.

D. Drip system efficiency. Drip irrigation systems shall meet and maintain a minimum 80% emission uniformity.

10-03.6.0 MAINTENANCE

6.1 MAINTENANCE REQUIREMENTS. All Passive and Active Water Harvesting System components, Water Harvesting Infiltration Areas, and other site improvements necessary for the water harvesting system to function properly, should be regularly inspected and maintained. The following maintenance requirements should be addressed on the Implementation Plan.

A. All systems. Periodically inspect and clean gutters, leaf screens, and filters. Inspect systems following heavy rains to check for leaks and/or overflow problems. Periodically inspect and maintain Water Harvesting Infiltration Areas to ensure proper infiltration, overflow, and prevention of erosion, if occurring. Repair and correct problems.

B. Passive Systems. In addition to requirements for all systems, to ensure proper functioning of Passive Water Harvesting Systems, periodically inspect and maintain Subwatershed surfaces and infrastructure associated with the system such as French drains, spillways, scuppers and other elements. Repair and correct problems as needed.

C. Active Systems. In addition to requirements for all systems, to ensure proper functioning of Active Water Harvesting Systems periodically inspect tanks, access hatches and associated locks, overflow devices, pipes, pipe joints and connectors, pumps, vents, controllers, and other associated infrastructure. Empty first flush devices as needed after rainfalls to ensure correct operation in the next rainfall. Inspect systems following heavy rains to check for leaks and/or overflow problems. Determine whether sludge should be removed from tanks. Repair and correct problems as needed.

D. Irrigation systems. Irrigation systems and associated controllers, soil moisture sensors, tensiometers, weather stations, and any other associated instruments shall be properly maintained and replaced as needed to ensure the potable and reclaimed water-saving goal of the Ordinance is met.

10-03.7.0 COMPLIANCE

7.1 MONITORING. Monitoring of water use and related information at the site shall be the responsibility of the property owner. Monitoring is required to verify compliance with the approved Water Harvesting Implementation Plan. Monitoring data shall be compiled, along with other necessary information, into an annual report to be submitted to the City by January 30 of each year. The site conditions described below shall be monitored.

A. Monthly water use. Monthly water use for landscape irrigation shall be monitored.

1. Monitoring of monthly potable water use for irrigation of landscape plants is required at sites subject to the Ordinance. Sites shall monitor water use with a Tucson Water Irrigation Service Meter, an equivalent meter from another water provider, or a private sub-meter that meets Accuracy Standards for Private Sub-meters.

2. Monitoring of monthly water use for irrigation of landscape plants is required at sites served by private wells or reclaimed water. Sites shall monitor water use with a private submeter that meets Accuracy Standards for Private Sub-meters.

B. Monthly rainfall. Monthly rainfall shall be monitored using an on-site rain gauge, or a monthly rainfall estimate shall be developed using data from the closest available rain gauge recorded at www.rainlog.org.

7.2 ANNUAL REPORTING. An Annual Report shall be submitted to the Tucson Water Conservation Office by January 30 of each year, on a form provided by that Office (Exhibit B). Each Annual Report shall, at a minimum, contain the following information for the previous calendar year.

A. Name and contact information for site and owner.

B. Name, title and contact information for person who prepares the annual report.

C. Source of rainfall data (on-site gauge or www.rainlog.org).

D. Sources of metered irrigation water other than harvested rainwater used at the site.

E. Monthly and total annual readings of the following: rainfall, projected landscape water demand shown in the approved Rainwater Harvesting Plan, actual metered water use, difference between these amounts.

F. Explanation for any exceedence of annual metered irrigation water use projected in the approved Rainwater Harvesting Plan.

G. Changes to the landscape or irrigation system in the reporting year.

H. Other information as deemed necessary.

10-03.8.0 ENFORCEMENT

The steps described below are required to ensure the site is constructed according to the requirements of the approved Implementation Plan.

8.1 INSPECTIONS.

A. All site-scale grading related to water harvesting Subwatersheds and Water Harvesting Infiltration Areas must be inspected and accepted by DSD prior to application of any surface treatment (e.g concrete, asphalt, rock, etc.) to verify that slopes, recessed areas, overflows and other design elements have been properly graded.

B. All landscape-scale grading in Water Harvesting Infiltration Areas where planting will be conducted must be inspected and accepted by DSD prior to plant installation and application of organic mulch or rock to verify they have been properly graded.

C. DSD will inspect the site for compliance with the provisions of the Rainwater Harvesting Plan prior to issuance of a final certificate of occupancy.

8.2 AUDITS AND REPORTING.

A. Landscape Irrigation Audit. In the event the site fails to meet the percent water harvesting in a reporting year required in the approved Rainwater Harvesting Plan, Tucson Water may request that additional information or documentation be submitted to assist in determining the cause of the violation. A site visit and a landscape irrigation audit may be required to verify the Rainwater Harvesting Plan is being adhered to and all components are properly functioning.

B. Non-compliance. Sites determined to be in non-compliance may be required to submit monitoring reports monthly and may be required to provide Owner's annual certification of continued maintenance and proper operation of water harvesting systems and the irrigation system and associated controls.

8.3 DROUGHT CONTINGENCY. The 50 percent landscape budget provision shall not apply in any calendar year in which the annual precipitation has fallen below nine (9) inches at the site, as reported in the site's annual report.

EXHIBITS

Exhibit A Site Water Budget Assumptions and Calculations

Exhibit B Annual Report Form for Commercial Water Harvesting Sites

EXHIBIT A. SITE WATER BUDGET ASSUMPTIONS AND CALCULATIONS

Designing water harvesting systems at a commercial site requires coordination between site developers, site engineers and landscape architects from the inception of the site design process. The information below is provided to inform site designers and engineers of the assumptions and methods the City recommends for use in designing and engineering water harvesting for a commercial site. This approach can be used both in preparation of the two components of the Rainwater Harvesting Plan: the Site Water Budget and the Water Harvesting Implementation Plan.

Preparing a Site Water Budget that meets the requirements of Commercial Rainwater Harvesting Ordinance and Development Standard 10-03 requires projecting yearly plant water demand for the site landscape then determining how much harvested water supply is needed to meet at least 50% of this demand. Sites may choose to use passive water harvesting (earthworks), active water harvesting (tanks), or a combination of both methods to accomplish this goal. Because most sites will be able to accomplish the 50% goals with passive water harvesting alone, the site design calculations provided at the end of this exhibit focus on data for passive water harvesting sites. An example Site Water Budget is shown in Table A-1. This example is provided to serve as a model for sites undertaking water-harvesting design. An excel spreadsheet of this water budget is available from <http://www.tucsonaz.gov/dsd/What_s_New/what_s_new.html> for use by site designers in preparing their Site Water Budget. This information in turn should be used to prepare the Water Harvesting Implementation Plan. Calculations

1.0 WATER DEMAND ASSUMPTIONS

Multiple techniques can be used to determine how much water is needed to support plants at a site. For purposes of complying with City requirements, the methods and assumptions described below are recommended.

1.1 REFERENCE EVAPOTRANSPIRATION.

To determine how much water plants need, a measurement of how much water plants consume through evapotranspiration is needed. Evapotranspiration is the transfer of water from land surface to the atmosphere through the combination of evaporation and plant transpiration. In the Reference Evapotranspiration Method (ETo Method), water use by plants is estimated for a high-water-use grass cover crop (such as alfalfa) for which evapotranspiration can be directly measured. Monthly Reference ETo values for a high-water-use grass crop in Tucson have been tabulated in Table A-2.

Table A-2. Reference Evapotranspiration (ETo) for Tucson

MONTHLY REFERENCE EVAPOTRANSPIRATION (Inches)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.0	3.72	6.0	8.04	9.96	10.56	9.36	7.92	7.20	5.76	3.60	2.64

Table A-1. Site Water Budget Format

Line	DESCRIPTIONS OF WATER BUDGET COMPONENT	SOURCES FOR EACH WATER HARVESTING INFILTRATION AREAS (WHIAs)	EXAMPLE WHIA
	PLANT WATER DEMAND		
1	Individual WHIA identifier	APPLICANT PROVIDE	WHIA - 1
2	Plant water demand category for this WHIA	APPLICANT PROVIDE USING ADWR PLANT LIST	low
3	Plant canopy area (square feet) for this WHIA. Add the canopies of understory, midstory and overstory plant areas to get total canopy for each WHIA. Assume 60% of mature plant size	APPLICANT PROVIDE. CAN BE BASED ON LANDSCAPE PLAN OR PLANT LIST	1250
4	Plant water demand per year (vertical feet of water per year per square foot of canopy) for this WHIA	APPLICANT USES APPROPRIATE NUMBER BASED ON PLANT WATER DEMAND CATEGORY FOR THIS WHIA	1.7
5	*CALCULATE:* Annual plant water demand for this WHIA based on plant canopy area (gallons)	= line 3 times line 4 times 7.48 gallons/cubic foot of water	15,895
6	**OVERALL WATER HARVESTING SUPPLY**		
7	WHIA area (square feet)	APPLICANT PROVIDE	1000
8	WHIA average depth (feet)	APPLICANT PROVIDE	0.5
9	*CALCULATE:* WHIA capacity (gallons)	line 7 times line 8 times 7.48 gallons/cubic foot of water	3,740
10	**If Passive water harvesting is used:**		
11	Subwatershed identifier	APPLICANT	S-1
12	Ratio of subwatershed area to plant canopy area needed to meet plant water demand in this WHIA in July through March (use March plant water demand as the indicator month) (no units)	APPLICANT USES APPROPRIATE NUMBER BASED ON PLANT WATER DEMAND CATEGORY FOR EACH WHIA	3.85
13	*CALCULATE:* Total catchment area ideally needed to meet plant water demand in March (square feet)	= line 3 x line 12	4,813
14	Actual total catchment area designed for this WHIA including the WHIA area itself (square feet)	APPLICANT PROVIDE	1500
15	*CALCULATE:* Actual catchment ratio for this WHIA	= line 14 divided by line 3	1.20
16	*CALCULATE:* Actual percent of plant water demand that will be met for this WHIA	= 64% times line 15 divided by line 12	20%
17	**If Active water harvesting is used:**		
18	Tank identifier	APPLICANT PROVIDE	T-1
19	above or below ground?	APPLICANT PROVIDE	above
20	tank height (feet)	APPLICANT PROVIDE	8
21	tank diameter (feet)	APPLICANT PROVIDE	6
22	tank capacity (gallons)	APPLICANT PROVIDE	1619
23	tank location	APPLICANT PROVIDE	East corner
24	*CALCULATE:* Percent of plant water demand for this WHIA met by this tank	(Assume tank will be filled and emptied 4 times per year). Total water provided = 4 times line 22 divided by line 5	41%
25	*CALCULATE:* Percent of plant water demand for this WHIA met using harvested rainwater from passive systems and active systems (as applicable)	= line 16 + line 24	61%
26	TOTAL SITE INFORMATION		
27	Percent to total site annual landscape demand met using harvested water	Prorate percent of water harvesting supply based on area of each WHIA	61%
28	Water harvesting capacity offsetting retention basin size capacity	APPLICANT PROVIDE	

1.2 PLANT COEFFICIENTS.

Four categories of plant types are typically used in Tucson. These categories are established based on their water use characteristics (Table A-3). Plant coefficients are an estimate of the water needed by each plant type expressed as a fraction of the water needed for the reference high-water-use grass crop. Plant types and corresponding plant coefficients are shown in Table A-3.

Table A-3. Plant Coefficients for use in Tucson

PLANT TYPE	**PLANT COEFFICIENT**
Very low water use	0.13 times monthly Reference ETo
Low water use	0.26 times monthly Reference ETo
Moderate water use	0.45 times monthly Reference ETo
High water use	0.65 times monthly Reference ETo

1.3 PLANT WATER DEMAND.

Plant water demand is the water needed over a given period of time to support a landscape. The first step in determining plant water demand is to calculate the inches of water needed per year for each square foot of plant canopy (as seen from a bird's eye view). This is calculated by multiplying Tucson's monthly reference ETo by the plant coefficient for each plant type to be used at a site (Table A-4). Add monthly amounts to get the total annual plant demand per square foot of canopy (Table A-4).

Table A-4. Plant water demand per square foot of plant canopy for Tucson

PLANT TYPE	MONTHLY PLANT WATER DEMAND (Inches)												**ANNUAL DEMAND (Inches)**
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	
Very low water use	0.39	0.48	0.78	1.05	1.29	1.37	1.22	1.03	0.94	0.75	0.47	0.34	10.11
Low water use	0.78	0.97	1.56	2.09	2.59	2.75	2.43	2.06	1.87	1.50	0.94	0.69	20.22
Moderate water use	1.35	1.67	2.70	3.62	4.48	4.75	4.21	3.56	3.24	2.59	1.62	1.19	34.99
High water use	1.95	2.42	3.90	5.23	6.47	6.86	6.08	5.15	4.68	3.74	2.34	1.72	50.54

To calculate various plant water demands for large planted areas, the inches of water needed per square foot of one type of plant canopy is multiplied by the total canopy area for that plant type to get plant water demand. Plant Water Demand should be calculated for each individual Water Harvesting Infiltration Areas. These can then be added together to get total plant water demand for the site.

1.4 ALTERNATIVE CALCULATIONS.

Applicants wishing to use alternative values and methods from those described above may do so. Along with the alternative calculations, they should provide justification for deviation from the assumptions and methods recommended above.

2.0 RAINWATER SUPPLY ASSUMPTIONS

2.1 FACTORS AFFECTING RAINFALL.

Rainfall in the Sonoran Desert is highly variable. Between 1993 and 2008, Tucson's annual rainfall ranged from 7.62 inches to 14.99 inches and averaged 12.17 inches per year. Tucson sites experience localized differences in rainfall primarily due to widely spaced summer monsoon storms. Winter rains tend to cover larger areas with more even distribution of rainfall. The amount of water that can be harvested also depends on how much rain falls each time it rains. Very light rains might not create sufficient runoff to reach waterharvesting basins, while runoff from heavy rains might overflow basins.

2.2 EFFECTIVE AVERAGE ANNUAL RAINFALL.

To comply with the City's Commercial Rainwater Harvesting Ordinance, average rainfall for Tucson should be adjusted to a lower effective average rainfall. Two adjustments should be made: reduce average rainfall by 25% to address localized variability and reduce average rainfall by an additional 25% to remove very light and very heavy rainfall events from monthly rainfall. Tucson's average rainfall and the calculation of effective average rainfall are shown in Table A-5 month-by-month and totaled for the year.

Table A-5. Effective average rainfall for Tucson for use in Site Water Budget calculations

RAINFALL ASSUMPTIONS	MONTHLY AVERAGE RAINFALL (Inches)												**ANNUAL TOTAL (inches)**
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	
Average rainfall	0.99	0.88	0.81	0.28	0.24	0.24	2.07	2.3	1.45	1.21	0.67	1.03	12.17
Effective Average Rainfall	0.50	0.44	0.41	0.14	0.12	0.12	1.04	1.15	0.73	0.61	0.34	0.52	6.09

1.3 ALTERNATIVE CALCULATIONS.

Applicants wishing to use alternative values and methods from those described above may do so. Along with the alternative calculations, they should provide justification for deviation from the assumptions and methods recommended above.

3.0 DETERMINING WATER HARVESTING CATCHMENT NEEDS FOR PASSIVE WATER HARVESTING

3.1 DEFINITION OF CATCHMENT AREA AND CATCHMENT RATIO

Because most commercial sites should be able to accomplish the Ordinance's 50 percent water harvesting goal using passive water harvesting strategies alone, the following information focuses on data for passive water harvesting sites.

Passive water harvesting sites typically consist of an array of Water Harvesting Infiltration Areas, each served by a catchment area that provides harvested water to support the plants within it. To meet the City Ordinance requirements, the site needs to be designed so that 50% of annual plant water demand is met with harvested rainwater as an average across the site. If the 50 percent goal cannot be met at some Water Harvesting Infiltration Areas due to site conditions, then other Water Harvesting Infiltration Areas should be designed to exceed the 50 percent goal in order to achieve 50 percent overall.

Catchment areas are locations at a site from which water is harvested for beneficial use. These locations include areas where rain falls directly into earthen basins and infiltrates into the ground (these are known as Water Harvesting Infiltration Areas. Catchment areas also include locations where rain falls on rooftops, sidewalks, parking lots, driveways and other hard surfaces then flows toward Water Harvesting Infiltration Areas where the water infiltrates into the soil. The catchment ratio for any given Water Harvesting Infiltration Area is the ratio between the water harvesting catchment area serving it and the canopy area of the plants located within it. As one example, runoff from 100 square feet of sloped parking lot and soil drains to a Water Harvesting Infiltration Area that is planted with trees that have a canopy area of 20 square feet (as seen from a bird's eye view). The catchment ratio for this example is 100 to 20, which can be simplified as 5 to 1.

3.2 CALCULATION OF CATCHMENT AREAS

In Tucson, different types of plants need different amounts of water each month because rainfall and temperature vary from month-to-month (Table A-4). Table A-6 shows the catchment area needed to provide harvested water for each square foot of plant canopy area for different plant types in different months. The data on Table A-6 was calculated using the following equation for each month and each plant type:

$$\text{Catchment area needed} = \frac{\text{Monthly water demand per square foot of plant type}}{\text{Effective monthly rainfall}}$$

Table A-6 . Catchment area needed to meet monthly plant water demand in Tucson

PLANT TYPE	SQUARE FEET OF CATCHMENT AREA NEEDED TO MEET WATER DEMAND FOR EACH SQUARE FOOT OF CANOPY AREA											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Very low water use	0.8	1.0	1.8	7.1	10.3	10.9	1.1	0.9	1.2	1.2	1.3	0.6
Low water use	1.5	2.1	3.7	14.2	20.6	21.8	2.2	1.7	2.5	2.4	2.7	1.3
Moderate water use	2.6	3.6	6.3	24.6	35.6	37.7	3.9	3.0	4.3	4.1	4.6	2.2
High water use	3.8	5.2	9.2	35.6	51.4	54.5	5.6	4.3	6.1	5.9	6.7	3.2

3.3 CALCULATION OF CATCHMENT RATIOS

In Tucson, plants need around 37 percent of their annual water supply in the hot dry months of April, May and June. The remainder of their annual water supply, about 63 percent, is needed in July through March. Figure A-1 illustrates the relationship between plant water demand and

effective rainfall supply in Tucson. In April, May and June there is a large gap between plant water demand and effective rainfall supply. There is a smaller, but still substantial gap between demand and supply in March. The rest of the year, rainwater supply lags behind demand, but not as much as in March through June.
By designing a site that has catchment areas sized to fully meet March plant water demand, the harvested water supply would typically exceed plant water demand in July through February (Figure A-2). This design strategy provides a cushion in meeting the 50 percent goal for the site and is recommended by the City as a general approach.

Based on Table A-6, a landscape composed of low water use plant types would need a catchment ratio of 3.7 to 1 to meet March water demand. This means that for each square foot of plant canopy area (as seen from a bird's eye view), 3.7 square feet of catchment area is needed to collect rainwater from. This area includes the dirt Water Harvesting Infiltration Area the plants are located in, and any parking lot, roof-top, or other hard surface around the plant that drains to that area.

It is best to locate plants of the same type in a Water Harvesting Infiltration Area, though sites may have different plant types in other Water Harvesting Infiltration Areas. Table A-6 can be used to determine appropriate catchment ratios for the plant types used in Tucson.

Figure A-1. Monthly Low-Water-Use Plant Demand vs Adjusted Rainfall, Tucson, Arizona

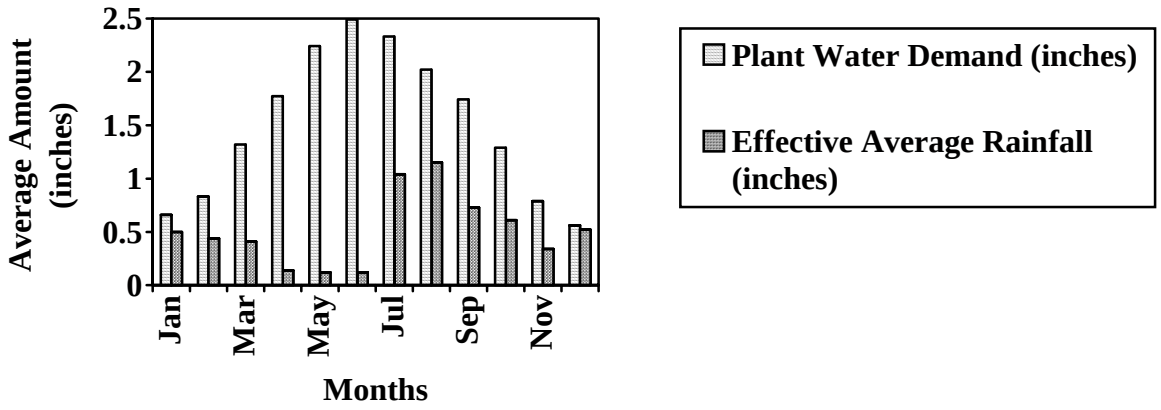
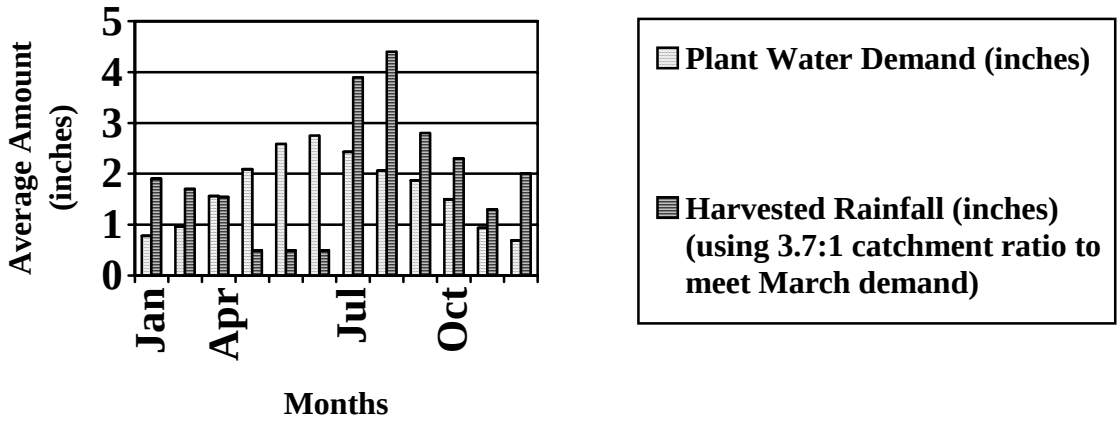


Figure A-2. Monthly Low-Water-Use Plant Demand vs Harvested rainfall, Tucson, Arizona



ATTACHMENT B. ANNUAL REPORT FORM FOR COMMERCIAL WATER HARVESTING SITES

Annual Water Use Report

Reporting period (month/day/year): from _____ to _____

Project Name

Project Address

Owner name

Report Preparer name Preparer title

Preparer address

Preparer email Preparer phone

Source of rain data (check all that apply): ____on site raingage ___ www.rainlog.org station: note the closest cross streets _____

Source of metered irrigation water (check all that apply): ___Tucson Water, acct # _____
____ water from another water utility ____well water ____ reclaimed water

MONTHS	RAINFALL (inches)	IRRIGATION WATER USE		
		Projected landscape water demand shown in the Rainwater Harvesting Plan (gallons)	Actual metered use (gallons)	Difference (gallons)
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
ANNUAL TOTAL				

Explanation for any exceedence of annual irrigation water use projected in the approved Rainwater Harvesting Plan:

Changes to the landscape or irrigation system in the reporting year:

AREA BELOW FOR STAFF USE ONLY

Drought conditions exist at the site:

Compliance with Rainwater Harvesting Plan:

Audit required/date/outcome