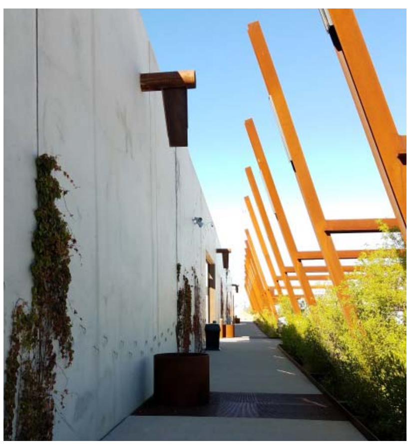
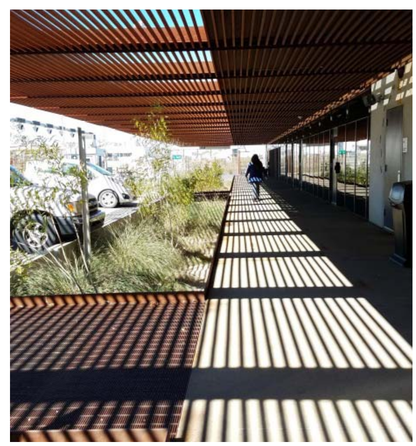




MARIPOSA LAND PORT OF ENTRY

ANALYSIS AND RECOMMENDATIONS FOR SITE SYSTEMS

February 2018

Prepared by:
Conservation Design Forum
Landscape Architecture Foundation

Client:
U.S. General Services Administration

Project Sponsor:
Christian Gabriel, National Design Director-Landscape Architecture
Office of the Chief Architect / Office of Design and Construction

EXECUTIVE SUMMARY

GSA redeveloped the Mariposa Land Port of Entry – one of the U.S.'s busiest land ports of entry – with construction completed in 2014. The 55-acre, $187 million, LEED Gold-certified project included significant use of photovoltaics, a solar domestic hot water system, advanced lighting, and a building automation system with diagnostics, and additional systems for future implementation aimed at assuring continued performance. The landscape includes a mix of drought-tolerant, native species and enhanced plantings in the more public areas. The landscape irrigation system features a 1-million-gallon underground cistern storage system supplied by harvested rainwater from pavement and building roofs. **This system was intended to eliminate the need to use potable water for irrigation.**

To comply with GSA's Total Building Commissioning process and the LEED-NC v2.2 requirements, five building systems were commissioned during the design and construction phases: (1) HVAC, (2) plumbing, (3) lighting, (4) electrical, and (5) fire protection throughout the port of entry. This process included thorough design review followed by system inspection, operational testing, and functional testing. **The site systems, including water harvesting and irrigation, were not commissioned.**

During the period from 2015 to 2018, the Landscape Architecture Foundation and Conservation Design Forum were contracted to study the rainwater harvesting and irrigation system at Mariposa to evaluate its performance in terms of stormwater runoff reduction and water conservation. **A site visit revealed two critical malfunctions of the system:** (1) the cistern water level sensor was malfunctioning, causing the pump to interpret this as an empty cistern; and (2) one of the irrigation controllers was non-functional due to wiring issues. The result of these malfunctions is that municipal potable water rather than harvested rainwater is being used to irrigate the landscapes, and the landscape contractor is reportedly manually operating the irrigation system resulting in higher than intended irrigation rates.

The table below shows irrigation water use for the one-year period from October 2016 through September 2017. **Four times the amount of water needed for the drought-tolerant landscape is being applied.** Further, if the cistern and water harvesting system were providing the required irrigation water, no water should be required from the local water utility. **The combined impact of using the automated irrigation controllers and water harvesting system would save approximately $3,360 per year in water utility bills.** If GSA were paying the standard Nogales commercial rate, the savings would be $27,900 per year.

	Designed	Actual	Difference/ Potential Savings
Annual Water Use for Irrigation (gallons)	1.8 million	7.3 million	5.5 million
Annual Potable Water Use (gallons)	0	7.3 million	7.3 million
Annual Potable Water Cost (GSA rate of $0.46/1,000 gallons)	$0	$3,356	$3,356

While it is unclear exactly when the harvesting system stopped functioning, commissioning the cistern and other site elements would have holistically verified their performance. This report recommends repairing the malfunctioning components, commissioning the system according to the process in the "GSA Site Commissioning White Paper" for the Construction and Post-Construction phases, and following the recommendations in new Long-Term Management phase proposed in the white paper.

This report offers specific recommendations to aid in the operation and monitoring of the rainwater harvesting and irrigation system and to provide necessary diagnostics to identify operations outside design protocols. These recommendations include:

- Acquire maintenance contract with Calsense, the irrigation system vendor
- Train GSA and landscape contractor staff
- Integrate the irrigation and water harvesting systems into Building Automation Systems
- Prepare quarterly reports to document performance

STUDY CONTEXT

Study Purpose

During the period from 2015 to 2018, the Landscape Architecture Foundation and Conservation Design Forum were contracted to study the rainwater harvesting and irrigation system at Mariposa Land Port of Entry in Nogales, Arizona. The intent of the study was to measure the performance of this system in terms of water runoff reduction and water conservation. However, observations about current conditions and performance led to a change in study's scope, modifying it to address where deficiencies occurred and how these might have been corrected or avoided through a site commissioning process.

The U.S. General Services Administration (GSA) was one of the earliest entities to develop and adopt a commissioning program, which today is called Total Building Commissioning. This process and commissioning efforts under the U.S. Green Building Council's LEED program have largely focused on buildings rather than sites. However, GSA's adoption of the SITES rating system in 2016 broadened GSA's attention toward commissioning of the sites on which buildings sit in addition to buildings themselves. The promise of GSA's effort is that the building industry, as a whole, will begin to commission active site systems.

Concurrent with the Mariposa Land Port of Entry water harvesting study, GSA assembled working groups and commissioned a study to examine how a measurement and verification framework could be applied to high-performance sites. This effort culminated in the release of GSA's "Site Commissioning White Paper" in July 2017. This report builds on that study.

Background

The Mariposa Land Port of Entry – one of the U.S.'s busiest land ports of entry – was redeveloped with construction completed in 2014. The 55-acre, $187 million, LEED Gold-certified project involved the demolition of all existing buildings, acquisition of adjacent land, and construction of new facilities and integrated site amenities. Major constructed elements included buildings, inspection booths, loading docks, a hazmat area, vehicular parking, pedestrian gathering spaces, landscape plantings, water features, shade structures, and terraced embankments.

GSA retained Commissioning Concepts, a third-party agent, to perform commissioning during the design and construction phases to meet the LEED-NC v2.2 requirements. The agent commissioned five building systems: (1) HVAC, (2) plumbing, (3) lighting, (4) electrical, and (5) fire protection throughout the port of entry. This process included thorough design review followed by system inspection, operational testing, and functional testing. Design elements that helped achieve the sustainability goals included significant use of photovoltaics, a solar domestic hot water system, advanced lighting, building automation system with diagnostics, and additional systems for future implementation aimed at assuring continued performance. Additionally, the drought-tolerant, native landscape was designed to be irrigated with a non-commissioned, 1-million-gallon underground cistern storage system supplied by harvested rainwater from pavement and building roofs. Commissioning the site systems, including water harvesting and irrigation, would have holistically verified the project performance.

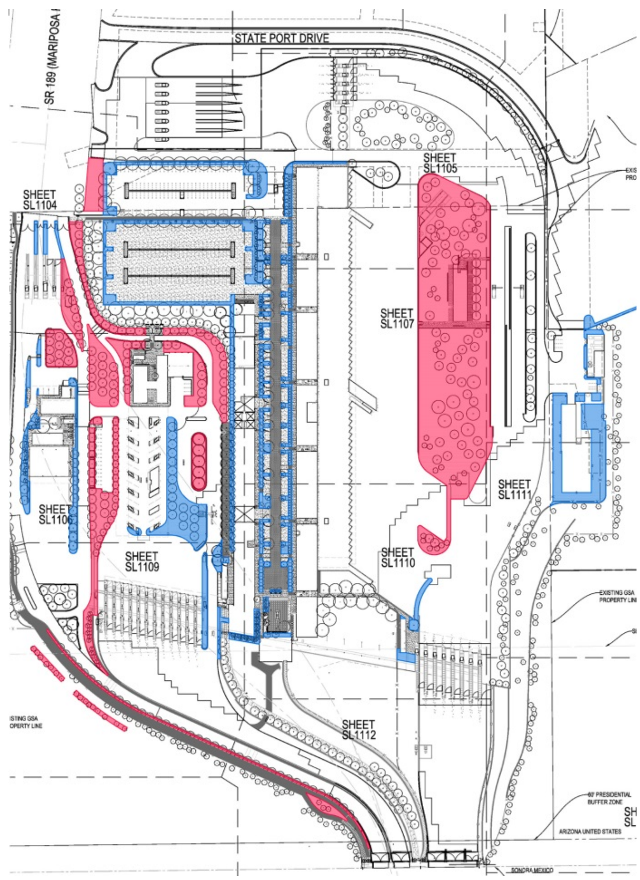
Performance Outcomes (as verified by project commissioning):[1]
35% energy cost reduction compared to ASHRAE 90.1-2004
100% potable water use reduction for irrigation (not verified by commissioning)
38% domestic water use reduction
97% construction waste diversion from the landfill

Site System Design

The study team determined the design intent and configuration of the Mariposa rainwater collection system using drawings and reports provided by project architect, landscape architect, and site engineer as well as conversations with representatives of those firms.

A pallet of indigenous plant species was used to minimize irrigation needs. The landscape zones were subdivided into: (1) drought tolerant zones and (2) enhanced planting zones. The drought tolerant species were selected to require irrigation only during the plant establishment period and during extended dry periods. The enhanced planting zones require irrigation both initially and long-term. Both zones are served by a permanent irrigation system.

The image to the right is a site plan for the Mariposa Land Port of Entry. The drought tolerant zones are shown in red and the enhanced planting zones are shown in blue. The image below shows an example of the plantings found in drought tolerant zones.



[1] *Site Commissioning White Paper*, U.S. General Services Administration, Public Buildings Service, Office of the Chief Architect. July 2017

A highly automated water harvesting and irrigation system was selected to maximize conservation of domestic water supplies. The irrigation system was designed to monitor rainfall and utilize monthly average evaporation rates to optimize the amount of water applied to the landscape, thereby minimizing water usage. The irrigation system was designed to utilize water from the harvesting system when available, with automatic conversion to domestic water when harvested water is not available. When the irrigation system calls for water, harvested rain water is pumped from the cistern storage system, which has a water level sensor that overrides the pump control when no harvested water is available. This is a required element of the system designed to protect the pump from being run dry.

When functional, the system is intended to be a simple and effective method for providing an optimized quantity of irrigation water using a renewable source (harvested rainwater) with little to no intervention required by facilities staff or support contractors.

Rain Water Harvesting and Irrigation System Statistics

Rainfall and design requirements

- The average annual rainfall for Nogales, Arizona is 18.11 inches (USClimateData.com)
- The landscape and rainwater harvesting, irrigation systems were designed to meet the obtain the following LEED-NC v2.2 credits:
  - LEED SS6.1: Stormwater Quantity Control - Schematic estimated stormwater storage requirement to meet was 1.56 acre-feet (508,000 gallons).
  - LEED WE1.2: Water Efficient Landscape - No potable water use for irrigation

Stormwater capture and rainwater harvesting system

- The first 2 inches of runoff from roof areas is retained in the rain gardens to provide passive irrigation.
- A crash plate scupper focuses runoff from 26,000 square feet of canopy roof into a collection basin that drains directly to the rainwater harvesting cistern.
- Runoff from 263,000 square feet of roof area is captured, equivalent to approximately 164,000 gallons per inch of runoff or 2.7M gallons of runoff per year for the average annual rainfall.
- In total, 827,440 square feet are tributary to the rainwater capture cistern, equivalent to 6.5M gallons of runoff per year for the average annual rainfall.
- The rainwater harvesting cistern has a 1M gallon stormwater storage capacity, equivalent to 6.1 inches of runoff over the captured roof area and 1.9 inches of runoff over the total tributary area.

Landscape irrigation areas

- In total 282,000 square feet of land are irrigated
  - 96,300 square feet are the enhanced landscape, designed to receive regular irrigation (design irrigation rate of approximately 1.0 inch per month April through November)
  - 186,000 square feet are drought tolerant native landscape, designed to require irrigation only during plant establishment and supplementally during extended dry periods (assumed average irrigation rate of 0.5 inches per month April through November)

ANALYSIS

Site Observations

Conservation Design Forum, design team members from Jones Studio and Arc Studios, product vendors from Calsense (irrigation controllers) and Munro pumps, GSA Office of the Architect staff, and Border Patrol staff met at the site on February 16, 2017 to assess the rainwater harvesting and irrigation system, review current operations, and identify technical and operational issues.

During the visit, two malfunctions within the system were identified.

1) The west Calsense controller was found to be non-functional due to wiring issues. (The east Calsense controller was found to be functional.)
2) The water level sensor in the water storage facility was malfunctioning. This sensor prevents pump operation when the cistern is empty in order to protect the pump. Because the pump interprets a non-functional sensor as an empty cistern, the pump has not been functioning to deliver harvested water to the irrigation system.

Because the irrigation controllers were not functioning, the landscape contractor has reportedly been overriding the automatic controls and directing the system to function on manual control. Further, because the water cistern facility pump was not operating, domestic potable water has been the water source rather than collected rainwater.

Assessment of Current Performance

Design Conditions

As reported by the project landscape architect, the design irrigation rate for the enhanced landscape is 1.0 inch per month April through November. In drought tolerant zones – where only supplemental irrigation is necessary since these plants are beyond the 2-year establishment period – the assumed irrigation rate was 0.5 inches per month for the same period. Using these rates and the enhanced and supplemental irrigation areas cited in the System Statistics table above, the estimated average annual irrigation requirement is 1.8 million gallons per year. Although an independent assessment was not conducted, a 1 million gallon cistern that receives 6.5 million gallons of runoff per year should be adequate to supply the required 1.8 million gallons of irrigation water with little or no use of domestic water.

Actual Conditions

To determine actual water usage for irrigation, water bills were collected for the period October 2016 through September 2017. The data were analyzed for water meter 71780084, which reportedly measures water used by the irrigation system. The water usage for the period is shown in the table below along with the cost of that water from the utility. Although, the irrigation controller and cistern sensor malfunctions were discovered in February 2017, it is believed that they were non-functional during the entire period of data in the table.

Two rates are included in the table. The utility bills obtained from the City of Nogales indicate an average rate of $0.46 per 1,000 gallons. This is a very low rate and therefore further investigation was conducted. A published report of water rates throughout Arizona indicated a commercial water rate for Nogales of $3.83 per 1,000 gallons for monthly water usage between 50,000 and 100,000 gallons.

Mariposa 2016/2017 Irrigation Water Usage

Month	Start Date	Start Reading	End Date	End Reading	Usage (kgal)	Cost at $0.46/kgal[1]	Cost at $3.83/kgal[2]
October	10/11/16	21204	11/9/16	21204	0	$0.00	$0.00
November	11/9/16	21204	12/9/16	21230	26	$11.96	$99.58
December	12/9/16	21230	1/11/17	21230	0	$0.00	$0.00
January	1/11/17	21230	2/9/17	21242	12	$5.52	$45.96
February	2/9/17	21242	3/9/17	21245	3	$1.38	$11.49
March	3/9/17	21245	4/11/17	21287	42	$19.32	$160.86
April	4/11/17	21287	5/9/17	21296	9	$4.14	$34.47
May	5/9/17	21296	6/9/17	21297	1	$0.46	$3.83
June	6/9/17	21297	7/12/17	23801	2504	$1,151.84	$9,590.32
July	7/12/17	23801	8/9/17	25631	1830	$841.80	$7,008.90
August	8/9/17	25631	9/12/17	27061	1430	$657.80	$5,476.90
September	9/12/17	27061	10/12/17	28499	1438	$661.48	$5,507.54
Total					**7295**	**$3,355.70**	**$27,939.85**

[1]Based on City of Nogales water utility bills, GSA Finance Division Utilities Unit is paying approximately $0.46/1,000 gallons
[2]Based on UNC Environmental Final Center "Water and Wastewater Rates and Rate Structures in Arizona as of July 2017", the standard commercial rate for monthly usages of 50,000-100,000 gallons is approximately $3.83/1,000 gallons

As can be seen from the table, the total usage for the period was 7,295,000 gallons, which represents a cost to GSA of $3,356 for the year at the current unit cost of $0.46 per 1,000 gallons. However, at standard commercial rates, the cost for this usage would be $27,940.

Conclusions

While the design assumed the irrigation period to be from April through November, the Water Usage table above shows that the actual irrigation appears to have only occurred June through September. However, the rate of water application was apparently much greater than the design application rates of 1.0 inch and 0.5 inch per month as evidenced by the approximately 7.3 million gallons used during the year in comparison to the design irrigation amount of only 1.8 million gallons. This difference in usage is likely attributable to manual operation of the irrigation system rather than relying on the automated irrigation controllers and a landscape contractor that may not have a good understanding of the actual irrigation needs of the site landscapes. Further, if the cistern and water harvesting system were providing the required irrigation water, no water should be required from the Nogales water utility. Because of the very low water rate that GSA is paying, the combined impact of using the automated irrigation controllers and water harvesting system would only save approximately $3,400 per year. However, at retail commercial rates, the savings would be $27,900 per year.

CONSIDERATIONS AND RECOMMENDATIONS

Maintenance and Operations

Design Considerations

Planning for maintenance and operations should begin early in the programming and design phase of a project. An understanding of the current and potential maintenance capabilities of the owner (GSA, in the case of this project) is essential to designing a system that will meet the performance goals of the project in both the short term and long term. During exploration of design alternatives, the maintenance and operations implications should be well defined and communicated to the owner and their facilities management team. When current maintenance and operations capabilities are inadequate for a given design alternative, strategies for enhancing capabilities should be explored. Capabilities can be enhanced through training of existing staff, acquisition of staff with the required expertise, or through use of outside support from maintenance contractors and/or from vendors that may provide maintenance contracts.

As an element of the design, system complexity should be considered. In the case of Mariposa, a highly automated water harvesting and irrigation system was selected and designed to maximize conservation of domestic water supplies. When functional, the system provides a simple and effective method for providing an optimized quantity of irrigation water using a renewable source (harvested rainwater) with little to no intervention required by facilities staff or support contractors. However, when a component of the system becomes non-functional, it may not be immediately apparent, depending on the component. If an irrigation controller goes down, irrigation may not occur, which should be apparent due to the lack of water being discharged from emitters. In this event, manual override can be used to provide irrigation water. However, if the water supply pump for the harvesting system or its controllers malfunction, the irrigation system automatically converts to use of domestic water, which will not be evident until the next water utility bill arrives. Depending on utility bill processing procedures, the utility bill may not be seen by facilities managers and therefore no cue given that the system is functioning improperly.

Design and as-built drawing files as well as operational intent reports should be prepared and provided to facilities staff to ease ongoing commissioning and to facilitate adaptive management of the systems and trouble shooting in the event of malfunction.

Maintenance and Operations Recommendations

The format of the maintenance and operations program should be responsive to the design and complexity of the system. The simpler the system the more it can be operated and monitored using existing facilities staff. The more automated and complex the system, the greater the need for expert assistance. Based on discussions with facilities staff, it does not appear that adequate expertise exists in-house.

The following recommendations are intended to aid in the operation and monitoring of the rainwater harvesting and irrigation system and to provide necessary diagnostics to identify operations outside design protocols.

1) **Acquire Maintenance Contract with Calsense**

With the addition of cellular communications, Calsense has the ability to monitor the operation of the system and make programming changes as may be necessary based on landscape health. Since the capability to monitor the irrigation controller does not exist in house, use of Calsense's capabilities may be a cost effective way to ensure proper operation of the irrigation controllers. The communications portion of the system would need to be designed to ensure that no communications with the Mariposa building or other data systems can occur via the cellular communications.

2) **Train GSA and Landscape Contractor Staff**

Training of landscape contractors on the operation of and proper protocols for the irrigation system is a key component of ensuring optimum performance. The landscape contractors will know, first hand, when landscapes are receiving insufficient irrigation water. However, they should be trained not to make manual adjustments and instead to notify GSA facilities staff who can then contact Calsense to determine necessary system program modifications. Any program modifications should be documented.

3) **Integrate into Building Automation Systems**

Automated irrigation and harvesting systems should be integrated into building automation systems to provide real-time information and allow real-time operation of the system. Based on discussions with facilities staff, it does not appear that this integration is present at Mariposa. The system should include information on the following. This should be provided in real-time and allow for reviewing system history for a minimum of 30 days.

- Precipitation: During periods of precipitation, irrigation should not be required and the cistern should be filling.
- Cistern water level: Provides information regarding available water that may be used to make operational decisions. It can also be used to monitor and verify harvesting efficiency (rate of water collection relative to rainfall amount) and irrigation rates.
- Cistern pump status: Indicator of when the cistern pump is operating and providing water to the irrigation system.
- Irrigation system status: Indicator of when the various irrigation zones are operational.
- Irrigation application rates: This requires flow meters for each of the irrigation zones. This is somewhat redundant with cistern water level monitoring but can aid in leak detection when there are significant differences between cistern depletion rate and irrigation rate. It can also be used to verify that the water is being properly applied for each irrigation zone.
- Diagnostics: To verify proper function of the system, a number of diagnostics should be included. Potential diagnostics include:
    - Cistern supply irregularities: Notifications should be provided when significant rainfall is occurring without a coincident increase in cistern water level. This could indicate a problem with the cistern water level sensor or problems with the storm system supplying the cistern.
    - Cistern withdraw irregularities: The water level, cistern pump operation, and irrigation system flow rates should be compared to identify potential problems with the system, including problems with the cistern water level sensor (when the pump is on but the cistern level is not dropping) and problems with the valves

controlling use of harvested water versus utility water (when the irrigation system is running but the cistern pump is not).
    - Irrigation system controller irregularities: The system should notify the user when irrigation irregularities are occurring such as simultaneous irrigation and rainfall.

4) **Quarterly Reporting**
It is recommended that quarterly reports be prepared to document performance of the system. The reporting should also include any irrigation programming changes that occurred during the period. This will not only provide ongoing records but force review of the system to facilitate identification of malfunctions or performance outside expected ranges to ensure timely correction. Standardized reporting forms should be prepared to minimize the overheard burden associated with reporting.

Commissioning

Site Commissioning

GSA published its “Site Commissioning White Paper” in July 2017. The paper highlights both the increasing level of ecosystem services that we are demanding from our landscape systems and the greater complexity of those systems necessitated by that demand. Because of the higher expectations and greater complexity, there is an increasing need to ensure that the systems are functioning in a manner consistent with the design intent. Building commissioning has been part of the delivery process for high performance buildings for quite some time. Commissioning ensures that the building systems are performing in a manner consistent with the design intent, primarily from the perspective of energy use and HVAC systems. However, commissioning for site systems is a relatively new concept. Analogous to building commissioning, site commissioning is intended to ensure that landscape, stormwater, and site water conservation systems are performing as intended. The “Site Commissioning White Paper” articulates the need for and value of site commissioning, discusses the hurdles, and then presents a process for implementing a site commissioning system for GSA projects.

The White Paper recommends four core commissioning areas: (1) soil, (2) water, (3) vegetation, and (4) materials and three supporting commissioning areas: (1) climate, (2) habitat and (3) human health + well-being. For each of the commissioning areas, there are three tier performance levels with Tier 1 being the minimum level of performance and Tier 3 being the highest level of performance.

The White Paper also recommends two phases of post-construction commissioning and monitoring. Site Commissioning would end two years after construction completion at the end of a typical plant establishment period. The Long-Term Management phase includes monitoring / adaptive management and commissioning to formalize a process for identifying, reporting, and remediating site system performance deficiencies. Recommissioning would occur every three to five years to ensure the site is continuing to perform as designed.

Commissioning of the Mariposa Site

The Mariposa site was featured as Case Study 2 in the GSA “Site Commissioning White Paper”. This case study indicates the building was commissioned but the site was not. The case study lists performance levels found as part of the commission of the building, as well as the goal of 100% reduction in potable water use for irrigation, which was not verified because the water harvesting and irrigation systems were not commissioned. (See Performance Outcomes table in the Background section of this report.) However, that performance level is not being achieved due to malfunction of the cistern and irrigation system controls.

Commissioning Recommendations for Mariposa Site

The GSA "Site Commissioning White Paper" includes recommended actions specific to site commissioning that can be inserted into GSA's existing commissioning process. Since the project was fully completed without site commissioning, the opportunity to complete the actions for the Planning/Pre-Design through Post-Construction phases has passed. However, there continues to be an opportunity to apply the monitoring / adaptive management and recommissioning recommendations proposed for the Long-Term Management phase. Specifically, the malfunctioning components of the system should be repaired and the water components of the site commissioned as if they were part of the original commissioning. This work should include the following.

Construction (Repair) and Post-Construction Phases of Commissioning

The existing system should be repaired to a functioning condition and commissioned as if it were a new system.

1) Replace the cistern storage water level sensor and calibrate the sensor to the elevations of the installed storage. Verify proper functioning of the sensor.
2) Review the wiring and controllers of the irrigation system and repair and replace wiring and components as needed.
3) Evaluate and program the irrigation controller.
    - Evaluate the site landscape and determine if modifications to the original irrigation controller programming are warranted.
    - Program the controller per evaluation findings.
4) Verify proper operation of the irrigation controller and cistern pump system.
    - Verify that pump operates when the system calls for irrigation.
    - Verify transfer to utility water when the cistern is empty and transfer back when the cistern again contains runoff.
    - Verify proper communication between the site rain gage and the irrigation controller.
    - Verify that the system is operating per the program.

Long-Term / Recommissioning Phase

In addition to the commissioning recommendations above, the Maintenance and Operations Recommendations detailed in the previous section should be implemented to facilitate continuous monitoring and recommissioning of the water systems and other site components.

1) Integrate the water harvesting and irrigation systems into the building automations systems as outlined previously. Make repairs and adjustments when the system is operating outside design parameters.
2) Evaluate landscape and stormwater components per the recommendations in the "Site Commissioning White Paper".
    - Maintain and repair site components per findings of the evaluations.
    - Modify landscape irrigation regime based on findings of the evaluations.