July 1, 2012

Ms. Veva Deheza
Colorado Water Conservation Board
1313 Sherman Street, Suite 721
Denver, CO 80203

Mr. Kevin Rein
Division of Water Resources
1313 Sherman Street, Suite 818
Denver, CO 80203

RE: 2012 Sterling Ranch Precipitation Harvesting Pilot Study Annual Report

Dear Veva and Kevin,

This is the second annual report addressing the Precipitation Harvesting Pilot Study to be submitted by Leonard Rice Engineers, Inc. on behalf of Sterling Ranch Development.

Introduction

The proponents of the Sterling Ranch Development continue to work passionately towards a vision for the land that is in harmony with the area, the community, and the State, and that meets a significant need for housing and infrastructure in Douglas County. Sterling Ranch's participation in the Colorado Water Conservation Board's (CWCB) Rainwater Harvesting Pilot Project Program (Program) is a reflection of their goals for establishing sustainable, defensible, non-potable water supplies for their development, as well as to be a positive example of conservation and efficient resource management.

Generally, the Sterling Ranch Precipitation Harvesting Pilot Study (Pilot Project) has proceeded on schedule. However, there have been some delays in the installation of monitoring equipment. The variances to the Pilot Project, including the proposed schedule, are described herein.

Summary of Pilot Project Progress

The following tasks were accomplished during the 2011-2012 monitoring season:

- Climate data collection from the Sterling Ranch Climate Station
- Surface water station installation and data collection
- Trail camera installation and data collection
- Installation and data collection from two ground water monitoring wells, and one shallow (datum) well

- A rainwater collection and irrigation system has been installed at the Residential Experimental Site (Demonstration Site):
    - Rainwater collection tank installed
    - Irrigation system installed
    - Water efficient landscape planted

These tasks, associated costs, and variances to the overall Pilot Project are further discussed in this Annual Report.

CWCB Program and Reporting Requirements

On March 1, 2010 Sterling Ranch provided an application for the "Sterling Ranch Precipitation Harvesting Pilot Study Application" (Application) based on the criteria and guidelines outlined by the CWCB established under House Bill 09-1129. The aim of the Program is to use field verification to evaluate precipitation harvesting in Colorado as a water conservation enhancement when paired with advanced outdoor water demand management and as a legally obtainable water supply.

The Application described the conceptual Sterling Ranch planning policies and requirements, including their current water conservation plan, and the Pilot Project strategies to be implemented to assist in the overall precipitation harvesting design.

The Pilot Project is split into three phases; 1) Natural Conditions, 2) Experimental Precipitation Harvest Designs, and 3) New Precipitation Harvest Designs.

Annual Reporting Requirements

One of the requirements of the Pilot Project Program is to submit an annual progress report (Report) by July 1st of every year that the Pilot Project is in operation. In accordance with Section 37-60-115(6)(a), C.R.S., the Report summarizes each component of the Pilot Project and indicates how the data and findings address Program goals. The CWCB Annual Report Requirements serve as an outline for this report and are included in **Attachment A**. The information required includes:

1. A **description of variances** from the Application including information on any data quality issues that may magnify if results are extrapolated to a larger scale project.

2. **Precipitation harvesting performance metrics**.

3. Pilot Project **implementation plan and estimated water conservation** achieved through pairing precipitation harvesting with advanced outdoor water management.

4. A **description of the climate and hydrologic data collected** to characterize the pre-existing, natural vegetation conditions.

Sterling Ranch Precipitation Harvesting Pilot Project - Progress and Variances

Four objectives were established in the Application that are designed to meet the guidelines and criteria provided by CWCB. They are:

1. Evaluate natural conditions (climate, hydrology, and ET) to quantify the amount of precipitation physically and legally available as a water supply.
2. Evaluate a variety of precipitation collection designs.
3. Evaluate precipitation harvesting paired with advanced outdoor water demand management as a water conservation practice.
4. Create a baseline set of data to support;
    a) An engineering report for a water court application for an augmentation plan to use harvested precipitation, and define a defensible water supply.
    b) Develop sound, transferable, and scalable methodologies for use at other locations in the State of Colorado.

In 2010, the Pilot Project began with the installation of the measuring devices for the natural conditions, collecting associated data, and implementing a demonstration site. These efforts are further discussed in the sections below.

Phase 1: Natural Conditions

Two study basins were proposed to evaluate natural conditions of Sterling Ranch as part of a comprehensive monitoring plan. The integrated monitoring plan includes measuring climate, precipitation, surface runoff, native ET, and deep percolation to ground water to provide the foundation for defining physical yield characteristics and return flow obligations.

Figure 1 shows the location of the two watersheds and the location of the implemented and proposed monitoring stations within the Sterling Ranch boundary. The study basins are being used to quantify the site-specific amount of precipitation that, under pre-existing natural vegetation conditions, accrues to the natural stream system via surface and ground water return flows. The sections below summarize the progress, variation, and data collected to date for each of the monitoring programs that were designed to characterize the return flows.

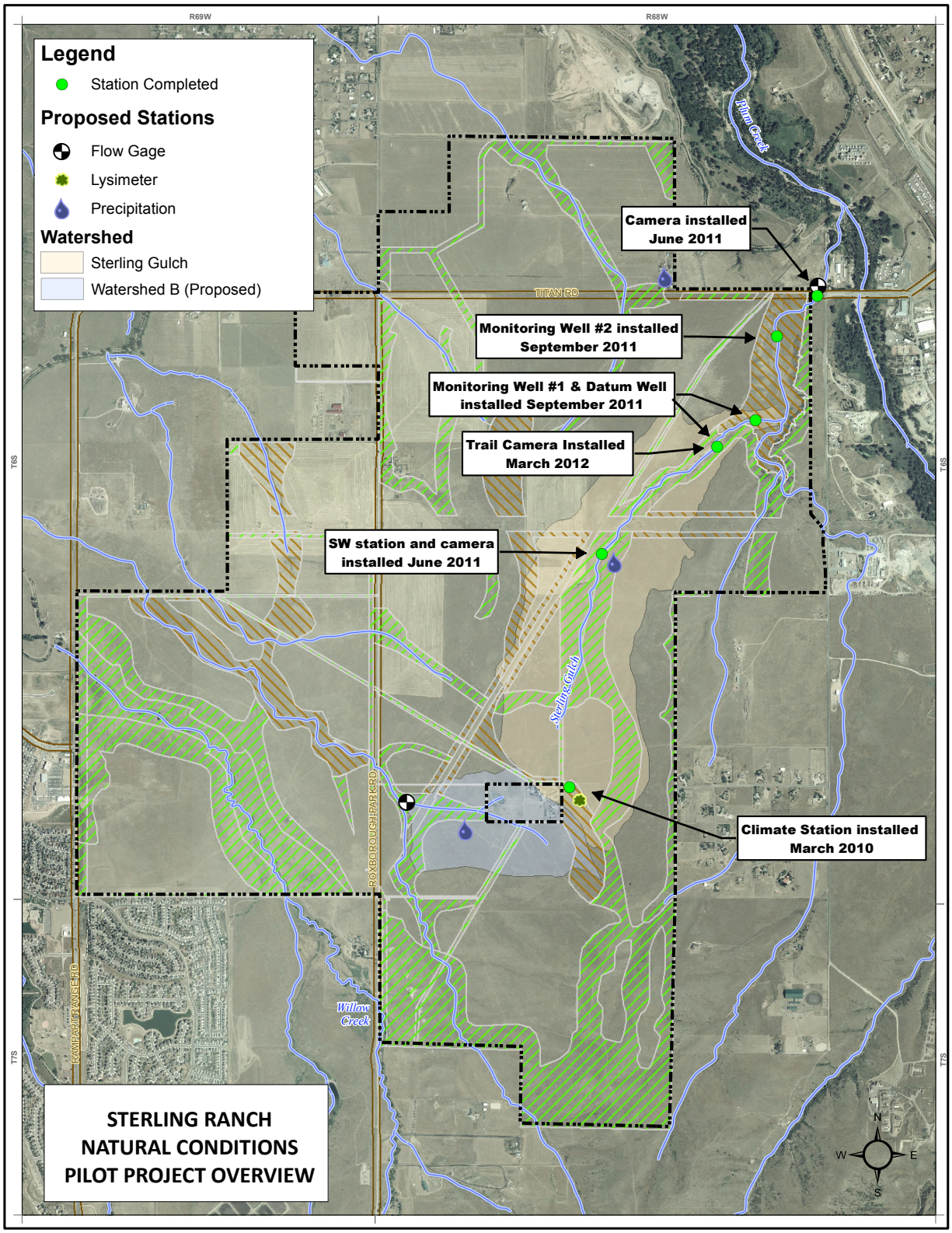

Figure 1- Proposed Study Basin Map

Climate Monitoring Program

2011-2012 Variance from Application: None

The Sterling Ranch Climate Station was installed on March 29, 2010. The station continues to collect data used to characterize local weather patterns, and will be used for the future estimates of native ET. The data collected at the Sterling Ranch site includes net solar radiation, air temperature, wind velocity and direction, relative humidity, barometric pressure, and soil temperature at varying depths. Most data is recorded in 15-minute intervals, transmitted to the Sterling Ranch website, and archived in a centralized database.

Figure 2 - Sterling Ranch Climate Station

Table 1 is a monthly summary of the data collected to date from the Sterling Ranch Climate Station.

Table 1 –Sterling Ranch Climate Station Monthly Summary

Year	2011							2012				
Month	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Temperature (F)												
Average Temperature	68.25	73.68	74.61	63.34	52.51	41.79	29.1	36.73	29.94	49.54	53.52	59.63
Max Temperature	95	96	95	93	84	69	61	69	57	81	83	90
Min Temperature	47	56	57	41	19	15	-4	2	6	16	28	37
Temp Range	48	40	48	52	65	54	66	67	51	65	55	53
Soil Temp (5 cm) (F)												
Average Temperature	73.23	77.63	78.26	67.78	53.20	38.06	32.63	32.41	32.79	47.23	56.64	64.19
Max Temperature	99	103	102	96	86	51	39	42	41	73	82	89
Min Temperature	55	62	62	51	35	32	30	31	32	31	40	46
Temp Range	43	40	40	45	51	19	9	11	9	42	42	42
Soil Temp (15 cm) (F)												
Average Temperature	70.89	75.78	76.86	67.77	54.64	39.25	33.95	33.28	33.47	45.92	55.61	62.69
Max Temperature	82	85	85	82	72	46	40	36	36	62	68	74
Min Temperature	60	67	68	57	39	35	32	32	33	33	44	52
Temp Range	22	18	17	25	33	11	8	4	3	29	24	22
Wind (mph)												
Average Velocity	6.20	5.95	6.07	5.29	6.34	7.03	6.74	6.85	6.84	7.90	7.40	6.58
Max Velocity	34.00	31.32	36.06	22.38	40.27	38.42	48.81	34.57	50.85	43.71	45.44	40.51
Average Direction (Deg N	175.62	182.06	182.34	181.25	175.41	193.40	191.74	189.70	191.97	181.58	181.41	175.70
Solar Radiation (MJ/m2 h)												
Average Radiation	1.05	1.02	0.90	0.76	0.62	0.45	0.38	0.39	0.56	0.79	0.92	1.00
Max Radiation	4.25	4.42	4.38	3.90	3.11	2.95	2.13	2.48	3.09	3.55	4.29	4.45
Barometric Pressure (mbar)												
Average BP	820.23	824.03	824.27	826.25	822.39	819.58	822.29	820.39	819.10	817.78	819.36	820.75
Max BP	829.19	829.23	829.78	835.41	831.87	834.77	834.09	837.34	832.25	834.66	829.74	830.55
Min BP	808.97	818.41	817.37	818.86	804.57	798.39	808.99	799.57	803.40	801.11	803.54	807.12
Humidity (%)												
Average Humidity	39.44	48.90	39.65	42.42	42.01	39.24	57.66	44.38	59.04	29.32	44.29	41.13
Max Humidity	95.74	95.62	90.32	94.40	99.75	99.24	98.86	98.80	99.20	98.12	99.37	98.04
Min Humidity	6.47	9.23	8.53	8.91	5.63	6.62	11.87	11.32	11.62	5.10	5.06	6.03

Precipitation Monitoring Program

2011-2012 Variance from Application: None

Figure 3 – OTT Pluvio[2]

The OTT Pluvio[2] weighing precipitation gage was installed on the site and began collecting data on March 29, 2010 (see **Figure 3**). The precipitation gage is located at the same site as the Sterling Ranch Climate Station and reports data in 15-minute intervals. The data collected at the site includes total accumulation and maximum rainfall intensity. This is the first of many proposed precipitation stations for the Pilot Project (see **Figure 1**). The physical measurement of precipitation is important in characterizing the native water supply, native water demand, and other hydrologic processes. **Table 2** is a summary of the data collected from the Sterling Ranch precipitation station. During the 2011-2012 monitoring season there was a total of 19.18 inches of precipitation accumulated.

Table 2 - Sterling Ranch Precipitation Station Summary

Year	2011							2012				
Month	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Precipitation (in)												
Monthly Total	2.25	3.82	2.17	1.39	1.47	0.45	0.76	0.39	1.22	0.12	2.87	2.27
Max Intensity (in/hr)	1.69	3.70	3.03	0.74	1.16	1.78	0.26	1.87	0.43	0.27	3.10	2.45

*Maximum intensity using precipitation measured over 15-minute intervals

Surface Water Monitoring Program

2011-2012 Variance from Application: None

- *To document surface water events in real-time, trail cameras have been added to the plan at the surface monitoring sites within the Sterling Gulch basin.*

A surface water monitoring program was initiated during the 2011-2012 monitoring season to quantify the site-specific stream flow that accrues to the natural stream system through surface water flows. One of the three proposed surface water measurement stations has been installed (see **Figure 1**).

The surface water station located on upper Sterling Gulch was completed in June 2011. This station includes a 9-inch Parshall Flume, shaft encoder level sensor, data logger, and a time-lapse camera for visual checks during precipitation events. Additional trail cameras were installed at the culverts at Titan Rd, and near the Datum well. Each of the cameras take a photo every 15 minutes documenting hydrologic events in real-time.

Recorded Surface Water Events

The 2011-2012 monitoring season was fairly dry with the only major rainfall events occurring in July 2011. In total there were 3 days with measurable surface water events recorded at the Upper Sterling Gulch flume. Most of the events were less than 1.0 cfs with the maximum event occurring on July 19th, 2011 at a flow rate of 1.01 cfs. **Figure 4** through **Figure 6** show the pictures of the three events at the Upper Sterling Gulch flume. Although these events were measured at the Upper Sterling Gulch flume there was no surface water shown leaving Sterling Gulch at Titan Road trail camera. Note that photos times may not directly correspond with measured peak discharge.

Figure 4 – July 13th 2011, 0.17 cfs

Figure 5 – July 14th 2011, 0.96 cfs

Figure 6 – July 19th 2011, 1.01 cfs

During the 2011-2012 monitoring season, there were two changes made to the data logger at the flume to correctly and more accurately capture surface water events.

- After the initial installation of the flume, the data logger was set to record changes in stage every hour. In August of 2011 the data logger settings were changed to record changes in stage every 15 minutes.
- During the data post-processing, we confirmed data inconsistencies with the recorded stage at the Upper Sterling Gulch flume for the month of May 2012, and was corrected on June 12, 2012.

Native Vegetation (ET) Monitoring Program

2011-2012 Variance from Application: None

Lysimeters are proposed specifically to collect data regarding two important aspects of the pilot study; the actual native vegetation ET and the amount of precipitation that percolates through the soil root zone to the ground water table known as ground water recharge or deep percolation. The lysimeters may also provide some insight on site-specific soil moisture storage and surface runoff.

This monitoring program is still in the proposal/planning phase and has not yet been implemented.

Ground Water Monitoring Program

2011-2012 Variance from Application: Originally, monitoring wells were proposed to install near the Upper Sterling Gulch flume site. Based on detailed site investigation it was determined that Lower Sterling Gulch was more suitable based on the depth of the alluvium.

Understanding pre-existing ground water interactions on Sterling Ranch is another important component of the water budget. Quantifying the amount, timing, and location of ground water return flows that accrue to the local alluvial aquifer from precipitation events is important when defining augmentation requirements to local streams. The installation of two monitoring wells and one shallow (datum) well located within Sterling Gulch was completed in September 2011 (see **Figure 1**). **Table 3** below summarizes the ground water level data collected at each of the monitoring wells.

Table 3 – Sterling Gulch Monitoring Well Recorded Depth to Ground Water

Year	2011				2012		
Date	Depth (ft)	9/2/2011 (Installed)	11/14/2011	12/16/2011	3/8/2012	4/24/2012	6/8/2012
Recorded Depth of Ground Water (ft)							
Datum Well	6.25	Dry	Dry	Dry	Dry	Dry	Dry
MW-1	15.30	Dry	Dry	Dry	Dry	Dry	Dry
MW-2	17.96	Dry	Dry	Dry	Dry	Dry	Dry

During the 2011-2012 ground water monitoring season shown above there was no alluvial ground water table recorded in Sterling Gulch.

Monitoring Program Maintenance Plan

The design of the monitoring plan is modular, and the maintenance requirement of each monitoring program element is different. Once installed, routine physical inspections of all instrumentation were conducted. Real-time sensors were remotely monitored to verify that they are operating correctly. The data-logging sensors were checked and maintained every time that the data was retrieved.

OneRain is the contractor responsible for maintaining the Sterling Ranch climate station and reporting any issues. OneRain has made two maintenance visits to the climate station over the last year, in November and April. The goal of the maintenance visits is to detect failure before it occurs. When servicing a climate station, the inspections are broken down into the following areas: power, telemetry, data logger, and sensors.

Beginning in July 2011, Leonard Rice Engineers, Inc. has been responsible for the data collection and maintenance of the Upper Sterling Gulch flume, trail cameras, and monitoring wells. The site has been visited a total of seven times over the 2011-2012 monitoring season with maintenance and data collection occurring each time. Each trail camera requires all photos to be downloaded and cleared from the memory card, a fresh set of batteries, and review of settings to make sure the time-lapse mode is operating correctly. At each of the monitoring wells water level data is collected manually using an M-scope.

Natural Consumptive Use, Return Flows to the River, Water Budgets, and Models

There is nothing to report on these sections for the 2011-2012 project year.

Phase 2: Experimental Precipitation Harvest Designs

The purpose of Phase 2 is to collect information about different types of precipitation harvesting designs, equipment, and materials from existing sites and structures so that Sterling Ranch can immediately begin collecting data that can be used to refine harvesting designs implemented on new structures.

Residential Experimental Sites

2011-2012 Variance from Application:

- *The Residential experimental sites have been reduced to one site – the Allis Ranch Demonstration Garden. This site is referred to herein as the Demonstration Site.*
- *The Colorado Rush Site has not been developed.*
- *Through a partnership with the Denver Botanic Gardens DBG, the Demonstration Site has been expanded to further demonstrate water conservation landscaping that could be implemented throughout Sterling Ranch.*

Per Phase 2 of the Application, an existing residential site, Allis Ranch, has been developed with rainwater capture systems and water conserving landscapes and irrigation systems. This site provides an opportunity to analyze collection efficiencies, review different collection equipment, and document and demonstrate various water-saving landscapes and irrigation systems.

In 2011, a rainwater capture and irrigation system was installed that includes runoff capture, piping, a cistern, and irrigation to water-saving plantings. A metering system has yet to be installed to quantitatively evaluate water capture efficiency and use. With the help of a partnership with the DBG, the Demonstration Site qualitatively illustrates the use of various water conserving irrigation products from several manufacturers, water saving landscapes that may be typical at Sterling Ranch, and the use of various rainwater harvesting equipment.

Commercial Experimental Monitoring Site and the Regional Observation Site

Sterling Ranch is currently in the proposal phase for the commercial experimental monitoring site, and regional observation site. There is no data to report on these sections for the 2011-2012 project year.

Phase 3: New Precipitation Harvest Designs

The new precipitation harvesting designs were not expected to begin in 2011-2012.

Overall Pilot Project Schedule

2011-2012 Variance from Application:

- The first surface water monitoring site was installed in June 2011 and is collecting data. *Ahead of schedule = 6 months*
- Ground water monitoring started in September 2011. *Ahead of schedule = 1 year*
- Lysimeters for measuring ET and deep percolation of return flows are still in the proposal/planning phase. *Delay = approx. 1.5 years*
- Residential Experimental Site (Demonstration Site) is nearly complete except for a metering system. *On schedule*
- Commercial experimental monitoring site is currently in the proposal phase. *Delay = approx. 1 year*
- Regional observation site is currently in the proposal phase. *Delay = approx. 6 months*
- All New Precipitation Harvesting Designs are planned to begin next year. *Delay = approx. 1 year*
- The proposed Administration plan originally included a preliminary administration reporting developed for the Demonstration Site as a test for the development of the new sites. Planning and development of Administration is not planned to begin until next year. *Delay = approx. 2 years*

Figure 7 shows the timeline proposed with the adjustments made due to the extended schedule as described above. As shown, the climate and precipitation monitoring programs were implemented and began monitoring in 2010. In 2011, both the ground water and surface water monitoring began. Sterling Ranch is currently in the proposal phase for the commercial monitoring site and regional observation site.

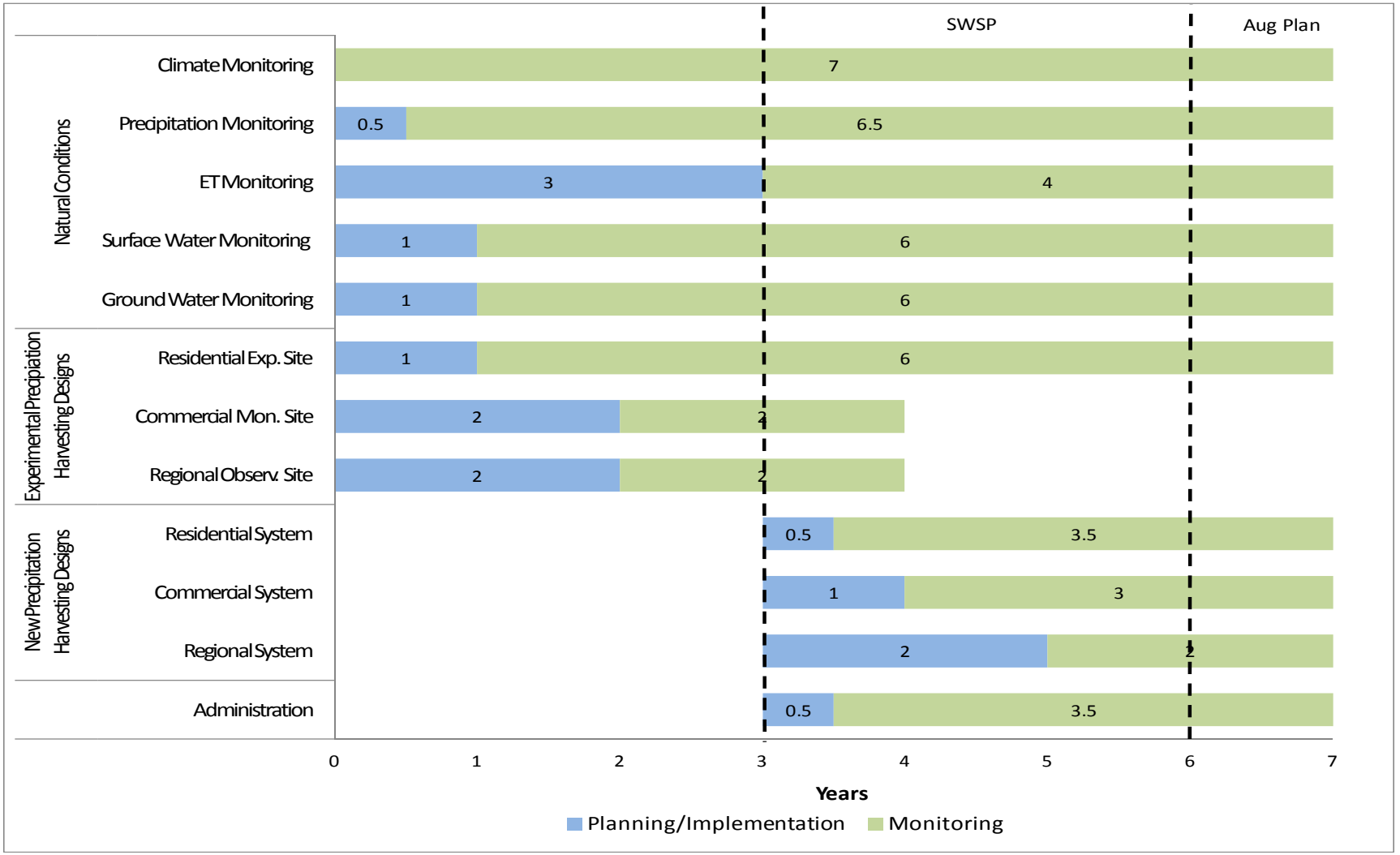

Figure 7 - Pilot Project Schedule

Augmentation Requirements

The Augmentation Requirements that will be met under an approved Substitute Water Supply Plan are expected to begin with Phase 3, and therefore were not expected to begin in 2011-2012. An example SWSP may be developed for the Demonstration Site to provide guidance for the new sites that will be implemented in Phase 3 of the Pilot Project.

Implementation

Collection and irrigation system design have not currently been finalized or implemented, therefore, no data is yet available for describing operation and maintenance or for estimating collection efficiencies.

Supplemental Water Supply

A permit for Demonstration Site was obtained from the Colorado Division of Water Resource to collect precipitation under S.B. 09-80 as a supplemental water supply to the existing well on site.

No other supplemental water supply will be needed until rainwater harvesting systems are implemented on new construction in Phase 3.

Estimated Water Savings, Landscape Plans, Metered Water Use, Consumptive Use and Estimated Water Conservation, Estimated Unit Cost for Rainwater

Currently there is no new information to provide on the estimated water savings, landscape plans, metered water use, consumptive use, estimated water conservation, and estimate unit cost for rainwater capture and use.

Costs to date

Costs for the Pilot Project have occurred primarily in the efforts for the monitoring of natural conditions and for the Demonstration Site. These are summarized below:

Natural Conditions

In 2011-2012; station maintenance, data collection, data management and reporting were the primary costs. These costs were:

- Data Management/Analysis/Reporting - $14,900
- Maintenance and Labor - $24,000

Demonstration Site

In 2011 -2012 a single cistern and pump were installed at the Demonstration Site. The associated costs were:

- Tank/Installation/Labor - $20,400

Partnerships and the Sharing of Information

Educational efforts continue to be made during this phase of the Pilot Project to help people understand the concept of what Sterling Ranch is doing in terms of water conservation and rainwater harvesting. While a formal education program has not yet been developed, the current form of education is in a website, media articles, and interviews. The Sterling Ranch website, located at http://sterlingranchcolorado.com/, goes into a significant amount of detail about the project overview that includes a description of the lifestyle, housing, and conservation that will be built into the development. The website includes articles that have been published about Sterling Ranch that is kept current by Sterling Ranch staff. Other pages include conservation, community, and frequently asked questions.

The partnership with Denver Botanic Gardens (DBG) was imperative to the development of the Allis Ranch Demonstration site. DBG has provided guidance for the landscape designs, and plantings at the site. The demonstration gardens themselves serve as an educational tool. Here is a quote from the DBG website (http://www.botanicgardensblog.com/2011/09/23/sterling-ranch-a-sustainable-partnership/#more-8813).

"As the community starts to build-out over the next 20 years, these demonstration gardens will serve as a teaching tool educating the public on how to create attractive living spaces while conserving one of our most precious natural resources – water"

DBG continues to provide support and has been a great resource for education and a partner in the water conservation community.

Additionally, a list is being kept of manufacturers that are interested in having their products used at Sterling Ranch. These opportunities and others will continue to be pursued throughout the next year.

Closing

This letter report describes the second year of the Sterling Ranch Precipitation Harvesting Pilot Study. If you have any questions, please feel free to call at 303-455-9589.

Sincerely,

LEONARD RICE ENGINEERS, INC.

Mark Mitisek, H.I.T.
Staff Hydrologist

Greg Roush, P.E.
Chief Operating Officer

Sterling Ranch, Attachment A - CWCB Requirements for Annual Report

1. A description of variances from the Pilot Project application including information on any data quality issues that may magnify if results are extrapolated to a larger scale project.

2. Precipitation harvesting performance metrics, including:
    a) Description of final collection system design with plans and specifications of all system components.
    b) Operation and maintenance plans and any issues encountered.
    c) Meter data of water flowing into the precipitation collection device and estimated capture efficiency.

3. Pilot project implementation plan and estimated water conservation achieved through pairing precipitation harvesting with advanced outdoor water management, including:
    a) A description of the applied method used to capture precipitation and any potable water supply with plans and specifications for all system components including any technology utilized (system programmers, ET controllers, etc.).
    b) Landscaping plans including measured irrigated acres, plan descriptions, theoretical irrigation water requirement methods, results, and water budgets reflecting application efficiencies.
    c) Metered water use from precipitation collection system. Water use will be categorized by use if application varies.
    d) Metered water use from other potable water supplies if the precipitation collection is supplemented. Water use will be categorized by use if application varies.
    e) Comparison of actual consumptive use by category of use to estimated water budgets. Estimate amount of water conserved as a result of the precipitation harvesting.
    f) A landscape maintenance assessment of quality of the landscapes, maintenance issues encountered, and any necessary replacement of plantings. The results of the irrigation system audit and corresponding actions.
    g) Cost to date including design, infrastructure, operations, and maintenance costs. Estimated costs to implement precipitation harvesting system per acre-foot of water saved; and comparison of original projected and actual costs from implementing the precipitation harvesting systems. The cost comparison will include institutional, legal, technical/design, infrastructure, and augmentation water supplies.

4. A description of the climate and hydrologic data collected to characterize the preexisting, natural vegetation conditions including:
    a) A description of the methodology and analysis results toward providing information about the technical ability to reasonably quantify the site-specific amount of precipitation that, under preexisting natural conditions, accrues to the natural stream system via surface and ground water return flows.
    b) A description of the baseline set of data and sound, transferrable methodologies used for measuring local weather and precipitation patterns that account for variations in hydrology and precipitation event intensity, frequency, and duration.
    c) Descriptions of the methodology and analysis results quantifying preexisting natural vegetation consumption; measuring precipitation return flow amounts; identifying surface versus ground water return flow splits; and identifying delayed ground water return flow timing to receiving streams.

d) Quantification of the amount of precipitation that must be augmented to prevent injury to decreed water rights.
e) Description of the location and methods used to collect climate data measurements, with a summary of data including, at a minimum, temperature and precipitation.