MONTGOMERY & ASSOCIATES
Water Resource Consultants

Report

August 5, 2015

Prepared for:

CAP CENTRAL ARIZONA PROJECT

Recovery Plan Update for Tonopah Desert Recharge Project

Maricopa County, Arizona

www.elmontgomery.com 520-881-4912 1550 East Prince Road, Tucson AZ 85719

MONTGOMERY
& ASSOCIATES
Water Resource Consultants

August 5, 2015
Report

Recovery Plan Update for Tonopah Desert Recharge Project

Maricopa County, Arizona

Contents

Contents – continued

Tables

Illustrations

Contents – continued

Appendix

1 EXECUTIVE SUMMARY

Montgomery & Associates (M&A), in conjunction with WestLand Resources, completed this update of the Tonopah Desert Recharge Project (TDRP) direct recovery plan for the Central Arizona Project (CAP). In 2009, M&A completed a Phase 1 direct recovery plan based on recovering 100,000 acre-feet per year (AF/yr) for 20 years. To date, over 800,000 AF of CAP water has been stored at TDRP and no additional storage is expected. CAP now anticipates much less water will need to be recovered on an annual basis than was assumed for the 2009 study. This report reflects reduced recovery volumes and includes costs to construct and operate facilities to recover and treat water to drinking water standards.

Updated Recovery Plan. The current projected volume and timing of recovery for the purposes of this study are shown in the table below.

Phases and Assumed Recovery Volumes for TDRP Recovery Plan Update

Recovery Phase	Dates	Annual Recovery Volume, in AF	Cumulative Total Recovery Volume, in AF
Phase I	2020-2029 (10 years)	10,000	100,000
Phase II	2030-2039 (10 years)	20,000	300,000
Phase III	2040-2045 (6 years)	30,000	480,000

Information provided by CAP

Water Quality. The quality of recovered water will be influenced by the relative proportions of native groundwater and CAP water. Therefore, water quality will change as recovery operations progress. Pre-recharge groundwater sampling indicates that arsenic and fluoride exceed drinking water standards, and it is assumed that recovered water will need to be treated to comply with drinking water standards. Actual concentrations could vary significantly from those determined from on-site monitor wells as water quality data are not yet available from deeper zones of the aquifer below the depths penetrated by the monitor wells.

Wellfield Layout. The conceptual wellfield was designed to minimize costs for construction and operation of the wellfield and water treatment plant, with the assumption that recovery and treatment facilities would be within the boundaries of the TDRP property. A numerical groundwater flow model was used to project water level drawdown and pumping lifts. Three potential layouts were considered, each with a different objective. These are: (1) minimize lengths of pipeline to the treatment plant, (2) maximize the proportion of CAP water in the recovered water to minimize treatment costs, and (3) minimize drawdown and pumping lift costs. Due to the high cost of water treatment relative to pipeline and pumping costs, scenario 2 (maximize proportion of CAP water) was the most cost-effective and therefore was selected for the final conceptual wellfield layout.

Recovery Wells. The conceptual wellfield design consists of a total of 9 recovery wells (3 constructed during each phase), each with capacity to pump 2,750 gallons per minute (gpm). Projected pumping lifts at the end of the 26-year recovery period range from 700 to 740 feet. Proposed recovery wells are 20-inch diameter in order to accommodate 14-inch diameter pump bowls, and are designed to be completed to a depth of 1,500 feet. Wellfield collection pipelines will be installed below ground.

Water Treatment Facilities. The objective of water treatment is to remove arsenic and fluoride from recovered water as needed so that water discharged to the CAP aqueduct meets the applicable drinking water standard of 0.010 milligrams per liter (mg/L) for arsenic and 4 mg/L for fluoride. Two options were evaluated as the most applicable for the TDRP site: (1) coagulation-assisted microfiltration, and (2) iron-based sorbent media filter for arsenic removal followed by activated alumina media filter for fluoride removal. If pilot testing shows Option 1 is technically feasible, then this method or a closely related method is preferred due to the lower costs.

Estimated Costs. Total estimated capital and O&M cost for construction and operation of recovery wells over the 26-year recovery period, without water treatment, is $67,462,000 (in 2015 dollars). Total estimated cost for recovery and water treatment over the 26-year recovery period (in 2015 dollars) ranges from $143 million to $213 million, depending on the water treatment option. These costs include the estimated cost of $4.2 million to bring power to the site.

2 INTRODUCTION

The TDRP stores Colorado River water supplies underground on behalf of CAP customers. During times of shortage when deliveries of CAP and Colorado River water are curtailed, the stored water will be recovered, conveyed to the CAP canal, and delivered to CAP customers. TDRP is located in the Phoenix Active Management Area (AMA) in western Maricopa County. The facility location is shown on **Figure 1** and a site map is shown on **Figure 2**.

2.1 Recharge Operations

M&A conducted several investigations that led to the siting, design, and permitting of TDRP (M&A, 2001; 2003a; 2003b, 2006; 2007). In 2005, TDRP was permitted as an Underground Storage Facility (USF) by the Arizona Department of Water Resources (ADWR) to recharge up to 150,000 AF per year of CAP water, with a maximum permitted storage volume of 2,000,000 AF over a 20-year period. Since TDRP recharge operations commenced in 2006, approximately 806,000 AF of Arizona's Colorado River water has been stored at TDRP by the end of 2014. Total annual delivery and recharge volumes are shown in the table below. Monthly recharge volumes and observed groundwater levels from 2006 through 2014 are shown on **Figure 3**.

Delivery and Recharge Volumes at TDRP

Year	Annual Delivery Volume, in AF	Annual Recharge Volume, in AF
2006	130,667	129,991
2007	144,060	143,199
2008	74,978	74,543
2009	150,535	149,703
2010	150,789	149,893
2011	70,873	70,349
2012	49,707	49,480
2013	12,900	12,847
2014	25,794	25,664
Total	810,303	805,669

Information provided by CAP. The difference between delivery and recharge volumes is due to evaporative losses.

The amount of water recharged at TDRP has declined in recent years due to declining availability of CAP for water banking purposes and the increased availability of recharge capacity in other parts of the Phoenix AMA. Therefore, as of 2015 CAP has discontinued recharge operations at TDRP for the foreseeable future.

2.2 Recovery Planning

In 2009, under contract with CAP, M&A completed a Phase 1 direct recovery plan, for recovery of 100,000 AF/yr for a period of 20 years (M&A, 2009a). The 2009 recovery plan identified the most cost-effective wellfield design, including both the fixed cost of installing the recovery infrastructure, and the variable costs of wellfield operations and maintenance. In 2009, M&A also prepared a work plan for Phase 2 field investigations designed to provide hydrogeologic data for the deeper part of the aquifer, as needed to verify feasibility for large-scale recovery, assess chemical quality of recovered water, and refine design of the wellfield and estimates of capital and operating costs (M&A, 2009b). The Phase 2 investigations were not implemented.

In 2014, Arizona Water Banking Authority (AWBA), CAP, and ADWR jointly released the Recovery Plan for AWBA water in storage (CAP and ADWR, 2014). This plan provided likely scenarios on the timing, magnitude, and duration of a Colorado River shortage. The shortage and recovery modeling indicates approximately 20,000 to 30,000 AF/yr of direct recovery capacity may be needed in the Phoenix AMA. As a result, CAP has revised its estimate of the rate and duration of needed recovery from TDRP from the original 2009 plan. The current projected volume and timing of recovery for the purposes of this study are shown in the table below.

Phases and Assumed Recovery Volumes for TDRP Recovery Plan Update

Recovery Phase	Dates	Annual Recovery Volume, in AF	Cumulative Total Recovery Volume, in AF
Phase I	2020-2029 (10 years)	10,000	100,000
Phase II	2030-2039 (10 years)	20,000	300,000
Phase III	2040-2045 (6 years)	30,000	480,000

Information provided by CAP

An additional change from the 2009 plan is that CAP anticipates that recovered water will need to adhere to U.S. Environmental Protection Agency (EPA) drinking water quality standards in order to be “wheeled” through the CAP canal. Therefore, the cost of water treatment is also included in this study.

2.3 Recovery Plan Update Objectives

The objectives of the TDRP Recovery Plan Update are to refine the 2009 direct recovery plan and estimated costs based on new information on recharge volumes, timing and volumes of recovery, and requirements for chemical quality of recovered water. This recovery plan update includes updating the TDRP groundwater flow model based on additional data available for model calibration. The results of the recovery plan update will be used by CAP to assess the option of recovering stored CAP water using a series of large-capacity recovery wells at the TDRP site, and to compare this option to other options involving recovery using existing wells at other locations in the Phoenix AMA, or involving credit exchanges.

The work was overseen by M&A. Hydrologic modeling, assessment of water quality, and conceptual wellfield layout, design, and cost estimates were completed by M&A. Engineering, including conceptual water treatment design and cost estimates, was completed by WestLand Resources under subcontract to M&A.

3 HYDROGEOLOGIC CONDITIONS AND GROUNDWATER QUALITY

3.1 Hydrogeologic Conditions

The TDRP site is located in the northwest part of the Lower Hassayampa Basin in western Maricopa County (**Figure 1**). This groundwater basin is part of the Basin and Range physiographic province of the western United States, which is characterized by fault-bounded basins that are filled with alluvial sediments eroded from surrounding mountains. This basin-fill alluvium consists of interbedded strata of poorly sorted gravel, sand, silt, and clay, and comprises the primary water-bearing units in the region. Detailed descriptions and references for stratigraphy, hydrogeologic conditions, and groundwater resources for the Lower Hassayampa Basin and the TDRP site are provided in previous reports (M&A, 2001, 2003a, 2003b, 2006, 2007, 2009).

Information for characterization of aquifer hydraulic parameters in the vicinity of the TDRP site is limited to two short-term pumping tests conducted at monitor wells at the TDRP site (M&A, 2006) and aquifer parameters determined from calibration of the TDRP groundwater flow model. The groundwater flow model was developed to project water level response to recharge and recovery operations and transport of nitrate in the aquifer(M&A, 2003b, 2007, 2009a), and was further calibrated for the current study based on water level data through 2014, as described in a subsequent section of this report.

3.2 Groundwater Quality

Groundwater quality at or near the TDRP site has been characterized based on laboratory analyses of samples obtained from TDRP monitor wells MW-1 and MW-2 from 2005 through 2014, and from exploration borehole TD-B in 2001. Monitor well and borehole locations are shown on **Figure 2**. Monitor wells MW-1 and MW-2 are completed to depths of 518 and 545 feet, respectively, approximately 70 feet below groundwater level at the time of construction. Borehole TD-B was drilled to a depth of 780 feet, about 286 feet below groundwater level at the time of drilling. No water quality data are available for deeper parts of the aquifer.

Due to the differences in water chemistry between native groundwater and CAP water, concentrations of inorganic constituents in groundwater changed substantially as a result of recharge operations from 2006 through 2014. Concentrations of major cations and anions, and total dissolved solids are higher in CAP water than in native groundwater. Concentrations of fluoride, nitrate, and trace metals are higher in groundwater than in CAP water. Concentrations of inorganic constituents in CAP water and groundwater before start of recharge in 2006 ("Pre-Recharge") and in late 2014 ("Post-Recharge") are summarized in **Table 1**. Groundwater quality for total dissolved solids, pH, arsenic, and fluoride from late 2005 through 2014 are shown on **Figure 4**. Based on these results, arsenic and fluoride are identified as constituents of concern that are likely to exceed EPA maximum concentration levels (MCLs) in recovered water.

Before start of recharge in 2006, measured concentrations of arsenic in native groundwater at or near the TDRP site were in the range of 0.018 to 0.21 mg/L, approximately 2 to 20 times higher than the EPA MCL of 0.010 mg/L (**Figure 4**). Concentrations of fluoride were in the range of 5.1 to 6.1 mg/L, slightly above the MCL of 4 mg/L.

3.2.1 Arsenic

As summarized in **Table 1**, concentrations of arsenic in native groundwater (pre-recharge) ranged from 0.018 mg/L for borehole TD-B to 0.21 mg/L for samples from monitor well MW-1 (arithmetic mean of four pre-recharge samples). The concentration for monitor well MW-2 was 0.023 mg/L (arithmetic mean of four pre-recharge samples). A geometric mean of these values of 0.04 mg/L was used as an estimate of representative average concentration of arsenic in native groundwater. The geometric mean is calculated as the n^{th} root of the product of n values, and is often used instead of the arithmetic mean when the data contain one or more anomalously large or small values (such as the large concentration of arsenic at well MW-1) that would skew the arithmetic mean. For large data sets in which the geometric mean is considered applicable, the distribution of the values is asymmetrical, but the distribution of the logarithm of the values shows symmetry (Yevjevich, 1972).

The reason for the relatively high concentrations of arsenic in native groundwater at the TDRP site, and the differences in concentration in samples from borehole TD-B, and monitor wells MW-1 and MW-2 is not well understood, but there are several possibilities, as described below.

Geothermal Water. High concentrations of arsenic can occur in association with geothermal water. Temperature of water from the sampled borehole and monitor wells were 90.3 degrees Fahrenheit at monitor well MW-1, 90.1 degrees at monitor well MW-2, and 92.3 degrees at borehole TD-B. The higher temperature for borehole TD-B is likely due to the larger drilled depth of 780 feet compared to less than 550 feet for monitor wells MW-1 and MW-2, and the natural geothermal gradient in which temperatures normally increase with depth. Temperatures at the two monitor wells, as well as borehole TD-B, are somewhat higher than typically observed in groundwater in the upper part of basin-fill aquifers in Arizona. The slightly higher temperatures of groundwater at the TDRP site may indicate an influence from geothermal sources. In addition, mobility of arsenic increases as temperature increases.

High pH. Mobility of arsenic is also influenced by pH of the groundwater. When pH is above 8.0, arsenic tends to be desorbed from solids in an aquifer. The measured pH of samples from the TDRP site were 8.15 for borehole TD-B, 9.38 for monitor well MW-1, and 8.69 for monitor well MW-2. These results indicate alkaline conditions, which would tend to favor desorption of arsenic and release into solution in groundwater.

Reducing Conditions. Oxidation-reduction potential (ORP) of the groundwater affects the species of arsenic, which affects mobility. Oxidizing conditions favor arsenate which is more strongly adsorbed to iron oxides (positive ORP). Reducing conditions favor arsenite, which is not as strongly adsorbed to iron oxides (negative ORP). Oxidizing conditions are more common than reducing conditions in Arizona basin-fill aquifers. If oxidizing conditions occur in the aquifer at the TDRP site, mobility of arsenic (as arsenate) would be limited due to adsorption to iron oxides. However, the ORP for groundwater at the TDRP site is not known and should be determined.

Lithology. It is possible that differences in arsenic between monitor wells MW-1 and MW-2 are related to lithology of basin-fill sediments at these wells. Drill cuttings from monitor well MW-2 indicate larger amounts of silt and clay than at monitor well MW-1 (M&A, 2006). Clay minerals provide adsorption sites for arsenic, and may result in smaller concentrations of arsenic in groundwater at monitor well MW-2 compared to MW-1.

Post-recharge concentration of arsenic was 0.016 mg/L in samples obtained in late 2014 from both monitor wells MW-1 and MW-2 (**Table 1**). A simple geochemical mixing model indicates that this value is larger than would be expected based on blending of CAP water and native groundwater. The mixing model, based on relative concentrations of chloride and sulfate in CAP and native groundwater, indicates that the percentage of CAP water in these post-recharge samples was more than 80 percent. With 80 percent CAP water and 20 percent groundwater, the concentration of arsenic in MW-2 would be 0.0067 mg/L, whereas the measured concentration is 0.016, more than twice the value predicted by simple mixing. This suggests that there was release of arsenic from the aquifer matrix via geochemical reactions.

A similar calculation for MW-1 predicts an arsenic concentration of 0.044 mg/L. The measured concentration of 0.016 mg/L is less than half as large as would be expected, suggesting that the relatively high concentration of 0.21 mg/L for native groundwater may be localized, and not representative for areas surrounding well MW-1. However, for the purpose of estimating representative maximum concentration of arsenic in recovered water, arsenic concentrations in native groundwater for MW-1 were considered along with results for MW-2 and TD-B because other localized areas with anomalously large concentrations of arsenic may occur in other areas, including the deeper part of the aquifer below the depths sampled by monitor wells MW-1 and MW-2.

3.2.2 Fluoride

Concentrations of fluoride in native groundwater (pre-recharge) ranged from 5.1 mg/L for borehole TD-B to 6.1 mg/L for samples from monitor well MW-1 (arithmetic mean of four pre-recharge samples) (**Table 1**). The concentration for monitor well MW-2 was 5.7 mg/L (arithmetic mean of four pre-recharge samples). A geometric mean of these values of 5.6 mg/L was used as an estimate of representative average concentration of fluoride in native groundwater. The geometric mean rather than arithmetic mean was used to determine a representative average for fluoride to be consistent with the approach used for arsenic, as described above.

Post-recharge concentrations of fluoride in samples obtained in late 2014 from monitor wells MW-1 and MW-2 were 1.7 and 3.0 mg/L, respectively. These values are larger than would be expected based on blending of CAP water and native groundwater. Assuming 80 percent of the post-recharge water is CAP water, the projected concentration of fluoride in samples based on simple mixing from monitor well MW-2 would be 1.5 mg/L. The measured concentration of 1.7 mg/L is similar, suggesting minimal to no geochemical reactions involving fluoride. However, the concentration of fluoride in samples from monitor well MW-2 is projected to be 1.4 mg/L, compared to a measured concentration of 3.0 mg/L. This value is approximately twice as large as it would be from simple non-reactive mixing, suggesting there may be release of fluoride from the aquifer matrix via geochemical reactions in this area. Similar to the approach used for arsenic, measured concentrations in native groundwater for all three sampling points was used to estimate maximum concentration of fluoride in recovered water.

4 UPDATE OF GROUNDWATER FLOW MODEL

A numerical groundwater flow model was originally prepared for the TDRP USF permit application (M&A, 2003b). In 2007, the model was updated to project nitrate solute transport due to TDRP recharge operations for the USF permit application (M&A, 2007). For the 2009 recovery plan, the groundwater model was modified to project groundwater level changes resulting from recharge of 2 MAF followed by recovery of 2 MAF (M&A, 2009a). The model is designed to simulate only the groundwater level changes caused by recharge and recovery operations at the TDRP site, and does not include other pumping from the regional aquifer. The nearest substantial pumping occurs in the Tonopah Irrigation District, located 4.5 to 5 miles east-southeast from the TDRP site. A detailed description of the TDRP groundwater flow model is given in previous reports (M&A, 2003b, 2007, and 2009a).

4.1 Background Groundwater Level Trends

Because the groundwater flow model simulates only groundwater level changes caused by TDRP recharge and recovery, background trends must be evaluated separately from the model. Any significant background trends would need to be superimposed on the water level changes projected using the model. Monitor wells MW-1 and MW-2 were installed only a few months prior to start of TDRP recharge in January 2006, and do not have a sufficiently long record to determine background water level trends. However, long-term records were available for other wells in the northwest part of Hassayampa basin. The locations of the wells are shown on **Figure 5** and the hydrographs for the wells are shown on **Figure 6**. The observations are summarized below:

- The hydrograph for well (B-02-07)05bbc, located less than 1 mile west from the TDRP site, indicates that water level was declining through 1995, and then stabilized with very little change in water level from 1995 through 2003. No data were available for this well after 2003.

- The hydrograph for well (B-02-07)12cbb, located approximately 2.8 miles east-southeast from the TDRP site, indicates that water level was declining at a rate of about 1.7 ft/yr from 2003 through early 2006, and then rose dramatically due to the effects of recharge.

Assuming a declining trend of 1.7 ft/yr as a background trend, this would correspond to a total change of 15 feet during the 9-year model calibration period (2006 through

2014), which is about 4 percent of the measured water level change at monitor wells MW-1 and MW-2. Due to the small magnitude of the background trend relative to the increase in groundwater levels due to recharge, and the uncertainty regarding the continuation of this trend through the model calibration and projection periods, the background trend was neglected for the purposes of model calibration and projections of future water level changes.

4.2 Recharge Volumes and Groundwater Levels

As part of the current study, the TDRP model was updated with monthly recharge volumes through the end of 2014 (**Figure 3**). Water level hydrographs were prepared for the TDRP monitor wells with data provided by CAP through the end of 2014. Hydrographs for nearby offsite wells were prepared using publicly available data.

4.3 Aquifer Hydraulic Parameters

The model was run through 2014 in order to compare measured to simulated water level changes and evaluate the need for adjustments to aquifer hydraulic parameters in the model. The wells used to evaluate adjustments to the model were TDRP monitoring wells MW-1 and MW-2, and offsite wells (B-02-06)05daa, (B-02-07) 12cbb, and (B-02-07)27aab (**Figure 5**). Based on comparison of simulated and measured water level change at these wells, the following modifications were made to calibrate the model:

- Horizontal hydraulic conductivity was increased from 16 to 24 feet/day in model layers 1 and 2 (to depth of 1,000 feet)
- Horizontal hydraulic conductivity was increased from 2 to 3 feet/day in model layers 3 and 4 (from 1,000 to 2,000 feet)
- The ratio of horizontal to vertical hydraulic conductivity was not changed (10:1)
- Specific yield was reduced from 15 percent to 7.5 percent in model layers 1, 2, and 3 (not applicable to layer 4)

Figures 7 and 8 show simulated and measured water level change in TDRP monitor wells MW-1 and MW-2. The simulated water level change is lower than measured at both wells during the initial recharge period (2006 to 2009). However, simulated water level change matches the measured change over the more recent period (2010 to 2014) in both wells.

Figure 9 shows a comparison of simulated and measured water level change for offsite wells. Results indicate that simulated water change is lower than measured change for well (B-02-07)12cbb, higher than measured change for well (B-02-06) 05daa, and similar to measured change for well (B-02-07)27aab. For well (B-02-07) 12cbb, the initial measured water level rise in 2007 is substantially larger than simulated, which may be due to local effects such as reduction in nearby pumping; however, the trends of simulated and measured change are very similar from 2008 through 2014.

The correspondence between simulated and measured water levels is reasonably good overall, and the TDRP model is considered sufficiently well calibrated to project future water level response to recovery pumping.

5 CONCEPTUAL DESIGN OF RECOVERY FACILITIES

5.1 Wellfield Design Considerations

5.1.1 Design Factors Affecting Wellfield Capital and Operating Costs

The 2009 recovery plan (M&A, 2009a) concluded that the optimal wellfield design with respect to minimizing capital and operating costs minimizes the number of recovery wells, subject to drawdown constraints which are controlled by hydraulic properties of the aquifer. Although minimizing the number of recovery wells results in larger drawdown and pumping lifts, the resulting increased power costs would be small compared to the reduced capital costs relative to wellfield designs with a larger number of recovery wells.

Another factor affecting capital costs is total length of collector pipelines, which can be reduced by locating the recovery wells as close as possible to the CAP aqueduct (discharge location), while maintaining sufficient distance between wells to avoid excessive drawdown interference effects between the wells.

5.1.2 Design Factors Affecting Water Treatment Costs

Capital and operating costs for water treatment depend directly on concentrations of arsenic and fluoride in recovered water. These constituents have been measured at levels exceeding MCLs in native groundwater at the site; however, concentrations are expected to vary with time, and potentially with location of recovery wells. As described below, treatment costs may be potentially decreased by locating recovery wells in order to maximize capture of CAP water as it moves to the south-southeast, in the regional direction of groundwater movement.

Chemical quality of groundwater at the TDRP site has evolved substantially due to the effects of adding CAP water to the aquifer during recharge operations. Concentrations of total dissolved solids have increased, and concentrations of arsenic and fluoride have decreased from late 2005, before start of recharge, through 2014, as shown on **Figure 4**.

After cessation of recharge operations in 2014, chemical quality of groundwater at the TDRP site is expected to evolve gradually due to the influence of the natural groundwater hydraulic gradient and the effects of recovery operations. Under natural pre-recharge conditions, groundwater at the TDRP site was moving south-southeast under a natural hydraulic gradient of approximately 15 feet per mile (**Figure 5,** M&A, 2007). Due to the effects of groundwater mounding from recharge, CAP water has moved downward and outward in all directions from the TDRP site, displacing and mixing with native groundwater. However, following cessation of recharge in 2014, groundwater mounding will dissipate and groundwater levels will evolve gradually toward natural conditions, with the principal direction of groundwater movement returning to the south-southeast. As a result, stored CAP water will gradually move to the south-southeast, and will be gradually replaced with native groundwater. Without additional recharge, chemical quality of groundwater at the TDRP site is expected to evolve gradually back toward natural conditions, similar to conditions prior to start of recharge.

Groundwater pumped from recovery wells will comprise a blend of CAP water and native groundwater, with relative proportions of the two water types changing with time. The chemical quality of recovered water cannot be predicted accurately based on existing data; however, it is reasonable to assume that chemical quality of recovered water will reflect primarily CAP water initially, and evolve with time toward the chemistry of native groundwater due to the south-southeasterly regional direction of groundwater movement. It is also reasonable to assume groundwater produced from recovery wells located in the south and east parts of the site would reflect larger proportions of CAP water than recovery wells located in the north and west parts of the TDRP site.

5.2 Wellfield Design

5.2.1 Alternative Recovery Wellfield Layouts

Three conceptual recovery wellfield layouts, each with eight recovery wells, were initially considered:

- Scenario 1: Minimize Pipeline Length
- Scenario 2: Maximize CAP Water Recovery
- Scenario 3: Minimize Pumping Lifts

Each scenario included eight recovery wells; conceptual layouts are shown on **Figures 10 through 12**. Wells are numbered in order of construction (R1 through R8) to maximize capture of CAP water.

For scenario 1, all eight recovery wells are located in the north half of the TDRP site (**Figure 10**), in order to reduce total length of collector pipelines.

For scenario 2, the eight recovery wells are located along the east and south boundaries of the TDRP site (**Figure 11**), in order to maximize recovery of CAP water that is moving down hydraulic gradient to the south-southeast.

For scenario 3, the eight recovery wells are located around the perimeter of the TDRP site (**Figure 12**), in order to maximize distance between wells, and minimize drawdown interference effects between wells.

For each of the three conceptual wellfield layouts, the TDRP groundwater flow model was used to project drawdown and pumping lifts for the recovery wells, and changes in relative proportions of CAP water in the recovered water. Results are summarized in the table below.

Pumping Lifts, Power Costs, and Relative Chemical Quality of Recovered Water for Conceptual Wellfield Scenarios

Scenario	Max. Drawdown (feet)	Max. Pumping Lift (feet)	Cumulative Power Costs	Percent CAP Water in Recovered Water
1 – Minimize Pipeline Lengths	449	755	$20,178,000	65
2 – Maximize CAP Water Recovery	428	737	$19,834,000	74
3 – Minimize Pumping Lifts	424	730	$19,751,000	72

For the purpose of comparing alternatives, cumulative power costs were projected based on an energy charge of $0.03576 per kilowatt-hour (kWh) or $35.76 per megawatt-hour (mWh), which corresponds to a weighted average of energy charges for on-peak and off-peak periods, as determined by WestLand Resources (**Appendix A**). Because demand charges (calculated based on maximum power draw) would be similar for the three conceptual wellfield scenarios, demand charges were neglected for the purpose of comparing cumulative power costs among the three scenarios. Compared to scenario 3 (minimize pumping lifts), cumulative power cost is only $83,000 larger for scenario 2 and $427,000 larger for scenario 1 – a relatively small difference compared to the total cost.

Total pipeline lengths for the three scenarios are on the order of 2.5 miles for scenario 1, 2.9 miles for scenario 2, and 3.3 miles for scenario 3. For the purpose of comparing alternatives, pipeline construction cost was assumed to be approximately $1.2 million per mile. Pipeline costs for scenarios 1, 2, and 3 would be approximately $3.0 million, $3.5 million, and $4.0 million, respectively. Compared to scenario 1 (minimize pipeline lengths), pipeline costs would be about $0.5 million higher for scenario 2 and $1.0 million higher for scenario 3. The differences in pipeline costs for the three scenarios are substantially larger than differences in cumulative power costs.

The proportion of CAP water recovered for the three scenarios was projected to be 65 percent for scenario 1, 74 percent for scenario 2, and 72 percent for scenario 3, corresponding to average concentrations of arsenic in recovered water of 0.0157 mg/L, 0.0123 mg/L, and 0.0131 mg/L based on concentrations of arsenic in native groundwater and CAP water. Compared to scenario 2 (maximize CAP water recovery), concentrations of arsenic in recovered water would be 27.6 percent higher for scenario 1 and 6.5 percent higher for scenario 3. For each 1 percent increase in arsenic concentration, treatment costs would increase by more than 1 percent. This is because increases in concentration result not only in proportionately larger amounts of arsenic to be removed per volume of water, but also results larger volumes of water that need to be treated (decrease volumes that bypass the plant) in order to treat to the 10 mg/L level. Water treatment costs are projected to be more than $50 million; therefore, treatment costs would be more than $13.8 million (27.6 percent) higher for scenario 1 and more than $3.2 million (6.5 percent) higher for scenario 3 compared to scenario 2. The differences in treatment costs for the three scenarios are substantially larger than differences in pipeline costs or cumulative power costs.

Due to the large costs for water treatment, the conceptual design that has the potential to maximize the proportion of CAP water in recovered water may minimize water treatment costs. Therefore, scenario 2 is considered to be the most cost-effective, and was selected for the final conceptual wellfield layout.

5.2.2 Final Conceptual Wellfield Layout

The scenario 2 wellfield layout was refined based on drawdown constraints and staging of construction for the recovery wells and pipeline. In order to meet the drawdown constraint of 30 percent of saturated thickness, it was necessary to add a ninth well. In addition, it was assumed that construction of the wells and pipeline would proceed with north to south, so that the pipeline could be constructed in phases along with the wells, with three wells constructed in each phase. The final conceptual wellfield layout is shown on **Figure 13**.

5.2.3 Projected Drawdown and Pumping Lifts

The TDRP groundwater flow model was used to project drawdown and pumping lifts for the purpose of estimating power consumption costs. Projected pumping lifts for the 26-year recovery period are shown on **Figures 14 and 15**. The actual pumping rate of the recovery wells was assumed to be 2,750 gpm when pumping, with a 75 percent capacity factor (pumping 75 percent of the time). The model was set up with 2 periods of recovery pumping per year: a 7-month period of April through October and a 5-month period of November through March. For the 7-month periods, the simulated wells pump 13.7 hours per day. For the 5-month periods, pumping occurs 24 hours per day. Recovery pumping was staged as follows:

- April 2020 - March 2030 (10,000 AF/yr from 3 wells, wells R1 - R3)
- April 2030 - March 2040 (20,000 AF/yr from 6 wells, wells R1 - R6)
- April 2040 - March 2045 (30,000 AF/yr from 9 wells, wells R1- R9)

Since the wells will pump only a portion of each day over the 7-month period, an equivalent continuous rate must be provided that results in the same volume removed. Therefore, pumping for the time period April through October was specified at a daily average rate of 1,570 gpm to represent the 13.7 hours/day of operation. Pumping for the time period November through March, when the wells pump 24 hours a day, was specified in the model as a pumping rate of 2,750 gpm.

Projected pumping lifts were calculated based on simulated drawdown in following manner:

- Drawdown at an individual well was corrected (increased) to account for the larger amount of drawdown that would occur in a well compared to the amount that occurs in a much larger-diameter model grid cell. The correction factor is dependent on cell size, well diameter, aquifer transmissivity, and pumping rate.

- A well efficiency of 80 percent was then applied to the drawdown.

- Lift was then calculated by adding the corrected drawdown to the initial lift. The initial lift is the depth to water at the beginning of recovery. Initial lifts for the selected scenario range from 283 to 335 feet.

- Pumping lifts for the wellfield were determined at the end of each year.

Projected pumping lifts for the wellfield at the end of year 2046 range from 700 to 740 feet (**Figure 15**).

5.2.4 Recovery Well Pumping Equipment

Requirements for pumping equipment were determined based on required discharge rate and total dynamic head (TDH). TDH includes:

- Pumping lift from groundwater level to land surface
- Additional lift from recovery well to treatment plant reservoir high water level
- Frictional head losses in pump column pipe, collector pipelines, valves, and bends

Calculated TDH for the recovery wells at the end of the 26-year recovery period ranges from 824 to 899 feet. Based on these values and a discharge rate of 2,750 gpm, and assuming an overall pump and motor efficiency of 75 percent, calculated pump horsepower ranges from 763 to 829 horsepower. After adding 25 horsepower to overcome mechanical shaft losses for the line shaft turbines, final estimated motor horsepower ranges from 788 to 857 horsepower, which was rounded up to 900 horsepower (**Appendix A**).

For pumping at a rate of 2,750 gpm with a TDH of almost 900 feet, the wells would need to be equipped with line-shaft turbines pumps with 14-inch diameter bowls. Pump manifolds would include a check valve, well service air release valve, flow meter, isolation valve, and a pressure relief valve. A single hydropneumatic tank would be installed during each phase to protect against pressure surges (**Appendix A**).

5.2.5 Recovery Well Design

In order to accommodate 14-inch diameter pump bowls, recovery wells are designed with 20-inch diameter casing. A schematic diagram of construction for proposed recovery wells is shown on **Figure 16**. The wells are designed with surface casing installed to a depth of approximately 40 feet, 20-inch diameter blank steel casing to a depth of approximately 130 feet below pre-pumping water level, and 20-inch diameter louvered casing to near total depth of approximately 1,500 feet below land surface.

5.3 Wellfield Collection Pipelines

The conceptual layout of wellfield collection pipelines is shown on Figure 1 of the WestLand Resources design memorandum (**Appendix A**), and includes approximately 11,400 feet of pipeline. The pipelines would be constructed of high-density polyethylene (HDPE) and installed below ground at a minimum depth of 3 feet. Pipeline sizes range from 16-inch diameter between wells R-9 and R-8 to 42-inch diameter north of well R-1, as required to maintain flow velocities between 5 and 10 feet per second to avoid excessive frictional head losses.

6 CONCEPTUAL DESIGN OF WATER TREATMENT FACILITIES

6.1 Water Treatment Design Considerations

The objective of water treatment is to remove arsenic and fluoride from recovered water as needed so that water discharged to the CAP aqueduct meets the applicable MCLs of 0.010 mg/L for arsenic and 4 mg/L for fluoride. Concentrations of arsenic and fluoride in recovered water cannot be predicted with certainty because: (1) groundwater chemistry is currently known only for the uppermost part of the aquifer at two locations at the TDRP site, and (2) groundwater chemistry will change with time as CAP water moves down hydraulic gradient, and the blend of recovered water evolves increasingly toward the chemistry of native groundwater. Therefore, for the purpose of designing water treatment facilities and estimating capital and operating costs, the following assumptions were made:

- Concentrations of arsenic and fluoride in the deeper parts of the aquifer are assumed to be similar to concentrations indicated by monitor wells MW-1, MW-2, and borehole TD-B, from the upper part of the aquifer.
- Concentrations in year 2020 at the start of recovery operations are assumed to be similar to current concentrations measured in late 2014 from monitor wells MW-1 and MW-2.
- Concentrations in year 2045 are assumed to be similar to ambient, pre-recharge concentrations in native groundwater, determined as the geometric mean of concentrations in samples obtained in late 2005-early 2006 at three locations at or adjacent to TDRP site (monitor wells MW-1 and MW-2 at the site, and exploration borehole TD-B adjacent to northwest corner of the site). With the exception of iron, for which data are not available for borehole TD-B, geometric mean concentrations were determined using data from all three locations.
- Concentrations of arsenic and fluoride in recovered water are assumed to change linearly with time from 2020 through 2045.

Based on these assumptions, projected concentrations at the beginning and end of the 26-year recovery period are summarized as follows:

Projected Concentrations of Arsenic and Fluoride in Recovered Water (mg/L)

Constituent	Projected Concentration in 2020	Projected Concentration in 2045	Average Concentration in CAP Water	EPA MCL
Arsenic	0.016	0.041	0.0026	0.010
Fluoride	2.3	5.6	0.32	4.0

6.2 Pumping and Storage Facilities

Pumping facilities include three booster pump stations to deliver water to three respective treatment trains, each to be constructed at the beginning of one of the three project phases (**Appendix A**). The three booster stations will share a common suction manifold. A hydropneumatic tank will be provided at the discharge of each booster pump station to protect the system from pressure surges during startup and shutdowns, including unplanned shutdowns.

A single 3-million gallon reservoir is proposed to provide storage and equalization between well flows and treatment flows, and would be located upstream of the proposed booster stations. The reservoir is assumed to be welded steel, with a single inlet from the well pumps and single outlet with a manifold for all 3 phases of treatment. The reservoir will be installed on a concrete ring wall.

6.3 Water Treatment Plant

Various methods for arsenic and fluoride treatment were initially considered (**Appendix A**), including:

- Reverse Osmosis
- Ion Exchange (arsenic only)
- Activated alumina
- Iron-based sorbents (arenic only)
- Enhanced lime softening
- Coagulation with settling or filtration

After consideration of these methods, two options were identified as the most applicable for the TDRP site, and were further evaluated (**Appendix A**):

- Option 1: Coagulation-assisted microfiltration

- Option 2: Iron-based sorbent media filter for arsenic removal followed by activated alumina media filter for fluoride removal

6.3.1 Option 1: Coagulation-Assisted Microfiltration

Coagulation-assisted microfiltration would remove arsenic and fluoride in one step. The system includes pre-oxidation to convert arsenic (III) to arsenic (IV), addition of coagulant, mixing, flocculation, settling, filtration, and sludge dewatering. Wastewater from sludge dewatering would be discharged to on-site evaporation ponds (repurposed recharge basin), and sludge would be shipped to an appropriate landfill.

Pilot testing will be necessary to verify this technology will work for the chemistry of the water to be treated, to improve understanding of chemical use and waste stream generation, and refine estimates of both capital and O&M costs. If pilot testing shows Option 1 would be technically feasible, then this method or a closely related method is preferred.

6.3.2 Option 2: Iron-Based Sorbent and Activated Alumina

Option 2 is a two-step process involving: (1) removal of arsenic using an iron-based sorbent, and (2) removal of fluoride using activated alumina. The system includes:

- pre-oxidation to convert arsenic III to arsenic IV
- multiple tanks of iron-based sorbent for arsenic removal
- backwash settling basin and dewatering facilities
- multiple tanks of activated alumina, pH adjustment prior to activated alumina, pH adjustment following activated alumina, and activated alumina regeneration system
- evaporation ponds for waste from regeneration system.

The activated alumina produces a waste stream that results in significant costs. Therefore, this system is not recommended unless Option 1 cannot be used.

7 ESTIMATED RECOVERY AND TREATMENT COSTS

Costs for recovery of stored water at the TDRP site have been estimated for construction and operation of wells, pumping equipment, and water treatment facilities. Recovery and treatment facilities would be installed in phases corresponding to Phases I through III of recovery pumping. Estimated capital and Operation & Maintenance (O&M) costs in 2015 dollars are summarized in **Table 2**, and are described in more detail below and in **Appendix A**. Total estimated capital and O&M cost (2015 dollars) ranges from $143 million to $213 million, depending on the water treatment option that is selected. Present value of estimated costs are shown in **Table 3** for a range of discount rates.

Capital costs include:

- Recovery wells R-1 through R-9 and associated pumping equipment
- Wellfield collection pipelines
- Site electrical equipment
- Electrical and control building
- 3.0 MG reservoir and associated appurtenances
- Booster pumps to deliver water from the reservoir to the treatment systems
- Water treatment facilities (two options)
- Extension of medium voltage power supply to TDRP site (estimated by CAP)
- Detailed engineering design
- Construction management
- Legal, permitting, and administration
- Contingency costs to account for uncertainties and unforeseeable elements involving increased costs associated with the normal execution of a project

Estimated capital costs do not include a new discharge line from the treatment system into the CAP canal; it was assumed that the existing inlet can be re-purposed as an outlet.

O&M costs include electrical power costs for wellfield pumping and treatment-related pumping, and other O&M costs associated with wells, pumping equipment, electrical equipment, and the water treatment plant.

7.1 Recovery Wellfield Costs

Capital and O&M costs were estimated for the recovery wellfield.

7.1.1 Recovery Wells

The table below summarizes the capital and O&M estimated costs for constructing and maintaining recovery wells. Three wells will be constructed during each phase. Capital costs were estimated for installation of nine recovery wells (three recovery wells per phase) and associated pumping equipment and collection pipelines.

Estimated Capital and O&M Costs for Recovery Wells

	Capital Costs			
Phase	Well drilling contractor	Consultant costs + contingency (15 percent)	O&M Costs	Total (Capital and O&M costs)
I	$ 3,847,000	$ 577,050	$ 300,000	$ 4,724,050
II	$ 3,847,000	$ 577,050	$ 600,000	$ 5,024,050
III	$ 3,847,000	$ 577,050	$ 540,000	$ 4,964,050
Total	**$11,541,000**	**$ 1,731,150**	**$ 1,440,000**	**$14,712,150**

O&M costs are the total costs for the phase.

Cost for drilling contractor services to drill, construct, develop, and test nine wells was estimated to be $11,541,000, or $3,847,000 for each of 3 phases of construction (three wells per phase). The total estimated capital cost of $13,272,000 (**Table 2**) includes the following additional costs estimated as a percent of contractor cost:

- Consultant services for preparation of technical specifications and bid documents, assistance with contractor procurement, field monitoring of contractor activities and data acquisition, conduct of pumping test, preparation of recommendations for pumping equipment, and preparation of well construction report for each phase of construction (5 percent)
- Contingencies (10 percent)

O&M costs for the wells are based on the need for wells to be occasionally serviced or re-developed to remove buildup of scale or encrustation on casing perforations or in the gravel pack in order to maintain hydraulic efficiency of the wells. Re-development may be conducted using methods such as wire-brushing, bailing, and swabbing, and may include addition of chemicals to facilitate re-development. For the purpose of estimating costs for well maintenance, the following assumptions were made:

- Cost for pump removal, well re-development, and pump re-installation would be $30,000 per well.
- The number of wells requiring re-development was assumed to be one well per year during Phase I, two wells per year during Phase II, and three wells per year during Phase III

Based on these assumptions, annual well maintenance costs would be $30,000 during Phase I, $60,000 during Phase II, and $90,000 during Phase III.

7.1.2 Pumping Equipment & Pipelines

Costs for contractor services to provide and install well pumping equipment and associated electrical and control equipment was estimated by WestLand Resources to be $11,059,000 for the 3 phases, as described in **Appendix A**. The total estimated cost of $15,040,000 (**Table 2**) includes the following additional costs estimated as a percent of construction contractor costs:

- Construction contractor mobilization and demobilization (3 percent)
- Engineering and permitting (10 percent)
- Construction management (8 percent)
- Contingencies (15 percent)

O&M costs for the recovery wellfield include electrical power costs for pumping of the recovery wells, and costs for maintenance and periodic replacement of pump line shafts and motors, and maintenance of electrical equipment. Estimated annual O&M costs for these items for Phases I, II, and III are given in **Appendix A**. Power costs were estimated based on projected pumping lifts (**Section 5.2.3**) and estimated power consumption, and APS's published off-peak and on-peak power rates, as described in the appendix to the WestLand Resources design memorandum (**Appendix A**).

Present value of wellfield capital costs was calculated based on the assumption that the recovery wells and collection pipelines would be constructed in 3 phases, with three wells per phase, and that construction would proceed from north to south. Capital costs were assumed to be incurred in 2019 for Phase I, 2029 for Phase II, and 2039 for Phase III. Present value of wellfield costs are summarized in **Table 3**.

7.2 Water Treatment Capital and O&M Costs

Capital and O&M costs were estimated for treatment-related pumping and for water treatment.

7.2.1 Treatment-Related Pumping Costs

Capital costs were estimated for installation of the 3 MG reservoir, three booster stations (one per phase) and associated controls and electrical equipment. Cost for contractor services was estimated to be $4,126,000 for the 3 phases (**Appendix A**). The total estimated cost of $5,612,000 (**Table 2**) includes the following additional costs estimated as a percent of contractor costs:

- Construction contractor mobilization and demobilization (3 percent)
- Engineering and permitting (10 percent)
- Construction management (8 percent)
- Contingencies (15 percent)

O&M costs for treatment-related pumping include electrical power costs, and costs for periodic maintenance and replacement of pumps and motors. Power costs were estimated using estimated power consumption and APS's published off-peak and on-peak power rates, as described in the appendix to the WestLand Resources design memorandum (**Appendix A**).

Present value of treatment-related pumping was calculated based on the assumption that pumping equipment would be constructed in 3 phases corresponding to the 3 phases of recovery well construction. Capital costs were assumed to be incurred in 2019 for Phase 1, 2029 for Phase 2, and 2039 for Phase 3. Present value of treatment-related pumping costs are summarized in **Table 3**.

7.2.2 Water Treatment Facilities

Limited data are available for characterizing chemical quality of recovered water, and associated unknowns regarding the optimal treatment method; therefore, capital and O&M costs were evaluated for two treatment options:

- Option 1: Coagulation-assisted microfiltration
- Option 2: Iron-based sorbent media filter for arsenic removal followed by activated alumina media filter for fluoride removal

Assumptions for estimating costs for both alternatives are summarized as follows:

- Capital costs include pilot testing to determine feasibility of treatment method for chemistry of water at TDRP site
- O&M costs are based on the quantity of water treated and on the concentrations of influent arsenic and fluoride.
- Power cost is $0.0342/kWH – based on 1,520 on-peak hours per year at $0.04076/kWH and 5,110 off-peak hours per year at $0.03219/kWH.
- Capital and O&M costs are in 2015 dollars
- Arsenic is treated to 0.010 mg/L.
- Fluoride is treated to 4 mg/L.
- When sizing bypass versus treatment flows, all treatment units are considered 95 percent efficient.
- Both arsenic treatment options require pre-oxidation to oxidize arsenic III to arsenic V
- Chlorine system with dose of 1.5 mg/L treated water.
- Both options require dewatering of a waste stream.
- Removal of waste solids is $65/ton, which includes hauling and landfill fees.

  Costs include electronic control system, and concrete pads and structures.

Estimated capital and O&M costs for Options 1 and 2 are shown in **Table 2.** Total capital costs are $50,850,000 for Option 1 and $44,715,000 for Option 2. For both options, the capital cost includes the following additional costs estimated as a percent of contractor costs:

- Engineering (10 percent)
- Contingencies (25 percent)

Total O&M costs $16,796,000 for Option 1 and $92,199,000 for Option 2.

Present value for Options 1 and 2 was calculated based on the assumption that treatment facilities would be constructed in 3 phases corresponding to the 3 phases of recovery well construction. Capital costs were assumed to be incurred in 2019 for Phase I, 2029 for Phase II, and 2039 for Phase III. Present values of water treatment costs for Options 1 and 2 are summarized in **Table 3**.

Option 1 has a much lower O&M cost and a lower overall life-cycle cost. In addition, capital and O&M costs for Option 1 are less sensitive to changes in arsenic and fluoride concentrations. Pilot testing is required to determine if Option 1 will work as expected, and also to refine the estimated capital and O&M costs.

7.3 Capital Costs for Extending Power Supply to TDRP Site

Capital costs for extending a 3-phase power supply from the nearest substation to the TDRP site were estimated to be approximately $4.2 million by CAP in consultation with Arizona Public Service. Capital costs include rebuilding the existing substation and constructing a new distribution line to the site. Additional costs for possible upgrades to the transmission line that feeds the substation, and costs for a cable network to distribute power to transformers at the site, are not included in the estimate of $4.2 million.

7.4 Total Estimated Cost

Total estimated cost in 2015 dollars for recovery of stored water, without treatment, is $67,462,000. Based on real discount rates in the range of 1 percent to 4 percent, present value of cost for recovery without treatment ranges from about $57 million to $36 million.

Total estimated cost in 2015 dollars for recovery and treatment of stored water ranges from about $143 million for treatment Option 1 to $213 million for treatment Option 2 (**Table 2**). Based on real discount rates in the range of 1 percent to 4 percent, present value of total estimated cost ranges from about $122 million to $79 million for Option 1 and from about $175 million to $102 million for Option 2 (**Table 3**).

8 REFERENCES CITED

CAP and ADWR, 2014, **Recovery of Water Stored by the Arizona Water Banking Authority:** Prepared by Central Arizona Project and Arizona Department of Water Resources on behalf of the Arizona Water Banking Authority, April 14, 2014.

Montgomery & Associates, 2001, **Results of Stage 1 – Preliminary Investigations, Phase B Feasibility Investigations, Western Arizona Recharge Project:** Prepared for Central Arizona Water Conservation District, September 7, 2001.

_______, 2003a, **Summary Report for Phase B Feasibility Investigations for Tonopah Desert Private Lands, Vicksburg Farms, and Bouse Hills Sites, Western Arizona Recharge Project:** Prepared for Central Arizona Water Conservation District, July 1, 2003.

_______, 2003b, **Application for Underground Storage Facility Permit and Water Storage Permit for Tonopah Desert Recharge Project:** Prepared by Montgomery & Associates, in cooperation with Central Arizona Water Conservation District and Carollo Engineers, May 5, 2003.

_______, 2006, **Installation of Groundwater Monitor Wells and Vadose Zone Piezometer Nests, Tonopah Desert Recharge Project, Central Arizona Water Conservation District, Maricopa County, Arizona:** Prepared for Central Arizona Project, March 3, 2006.

_______, 2007, **Projection of Nitrate Movement in Groundwater Resulting from Tonopah Desert Recharge Project Operations, Maricopa County, Arizona:** Prepared for Central Arizona Water Conservation District, May 15, 2007.

_______, 2009a, **Direct Recovery Plan - Phase 1, Tonopah Desert Recharge Project, Maricopa County, Arizona:** Prepared for Central Arizona Water Conservation District, May 11, 2009.

_______, 2009b, **Phase 2 Work Plan, Direct Recovery Plan, Tonopah Desert Recharge Project, Maricopa County, Arizona:** Prepared for Central Arizona Water Conservation District, October 8, 2009.

Yevjevich, Vujica, 1972, **Probability and Statistics in Hydrology:** Published by Water Resources Publications, Fort Collins, Colorado.

TABLE 1. SUMMARY OF INORGANIC CONSTITUENTS IN CAP WATER AND GROUNDWATER AT TDRP SITE

Constituents	Units	CAP Source Water	Pre-Recharge				Post-Recharge		
			TD-B	MW-1	MW-2	Combined	MW-1	MW-2	Combined
		Arithmetic mean (2005-2014)	Sampled 6/25/2001	Arithmetic mean 10/12/2005-2/2/2006	Arithmetic mean 11/9/2005-2/2/2006	Geometric mean TD-B, MW-1, and MW-2	Sampled 10/22/2014	Sampled 12/29/2014	Arithmetic mean MW-1 and MW-2
Field Parameters									
pH	s.u.	8.12	8.15	9.38	8.69	8.73	8.02	8.03	8.03
Specific Conductance	umhos/cm	996	665	363	427	469	991	1026	1009
Temperature	degrees F	69.2	92.3	90.3	90.1	90.9	70.8	74.7	72.8
Common Constituents									
Akalinity	mg/L	128	9	79	138	46	110	110	110
Calcium	mg/L	74	11	1.7	3.5	4.0	22	35	29
Chloride	mg/L	89.6	76	22	19.8	32	79	90	85
Fluoride	mg/L	0.32	5.1	6.1	5.7	5.6	1.7	3.0	2.4
Nitrate (as N)	mg/L	0.26	0.73	1.9	1.4	1.2	0.46	0.45	0.46
Potassium	mg/L	4.86	1.6	ND	2.3	1.9	1.4	5.6	3.5
Sodium	mg/L	97	140	74	89.8	98	200	170	185
*Silica	mg/L	7.9	NA	NA	NA	NA	NA	NA	NA
Sulfate	mg/L	249	110	34	27	47	220	240	230
Total Dissolved Solids	mg/L	642	420	222	274	295	620	640	630
*Orthophosphate as PO4	mg/L	<0.01	NA	NA	NA	NA	NA	NA	NA
Trace Metals									
Antimony	mg/L	0.0002	<0.0040	ND	ND	ND	ND	ND	ND
Arsenic	mg/L	0.0026	0.018	0.21	0.023	0.04	0.016	0.016	0.016
Barium	mg/L	0.133	<0.010	0.01	0.011	0.01	0.0021	0.0047	0.0034
Beryllium	mg/L	ND	<0.00050	ND	ND	ND	ND	ND	ND
Cadmium	mg/L	ND	<0.00050	ND	ND	ND	ND	ND	ND
Copper	mg/L	0.01	<0.0040	ND	0.002	ND	ND	ND	ND
Chromium	mg/L	0.0004	<0.0040	0.02	0.035	0.03	ND	ND	ND
Iron	mg/L	0.098	NA	0.94	1.85	1.32	0.74	1.7	1.2
Lead	mg/L	0.00028	<0.0020	0.0007	0.003	0.001	0.00067	0.00074	0.00071
Magnesium	mg/L	27.8	1.5	0.16	0.53	0.5	2.4	13	7.7
*Manganese	mg/L	0.0023	NA	NA	NA	NA	NA	NA	NA
Mercury	mg/L	ND	<0.00020	ND	NA	ND	ND	ND	ND
Nickel	mg/L	ND	NA	ND	ND	ND	ND	ND	ND
Selenium	mg/L	ND	<0.0040	ND	ND	ND	ND	ND	ND
Thallium		ND	<0.0020	ND	ND	ND	ND	ND	ND
Microbiological									
†Total Coliform		present	NA	present	absent		absent	absent	

*CAP results for manganese; silica, and orthophosphate (as PO4) obtained from CAP website for the Little Harquahala pumping station. Data are for 3-10-15.

s.u. = standard units

umhos/cm = micromhos per centimeter

mg/L = milligrams per liter

† Total Coliform sporadically present

ND = Not detected

NA = Not available

MONTGOMERY & ASSOCIATES

TABLE 2. SUMMARY OF CAPITAL AND O&M COSTS
TDRP RECOVERY PLAN UPDATE

	ESTIMATED COSTS[1]		
	Capital	**O&M[2]**	**Total**
WELLFIELD			
Recovery Wells	$13,272,000	$1,440,000	$14,712,000
Wellfield Pumping Equipment & Pipelines	$15,040,000	$33,510,000	$48,550,000
Subtotal Recovery Wellfield	$28,312,000	$34,950,000	$63,262,000
WATER TREATMENT			
Treatment-Related Pumping	$5,612,000	$2,688,000	$8,300,000
Treatment Option 1	$50,850,000	$16,796,000	$67,646,000
Treatment Option 2	$44,715,000	$92,199,000	$136,914,000
Subtotal Treatment, Option 1	$56,462,000	$19,484,000	$75,946,000
Subtotal Treatment, Option 2	$50,327,000	$94,887,000	$145,214,000
POWER SUPPLY			
Extending power to site[3]	$4,200,000	---	$4,200,000
GRAND TOTAL			
with Treatment Option 1	$88,974,000	$54,434,000	$143,408,000
with Treatment Option 2	$82,839,000	$129,837,000	$212,676,000

Notes

[1]All costs are in 2015 dollars

[2]Total estimated O&M costs for 26-year recovery period

[3]Cost to extend power to TDRP site provided by CAP. Additional costs for possible upgrades to the transmission line that feeds the nearest substation, and costs for a cable network to distribute power to transformers at the site, are not included.

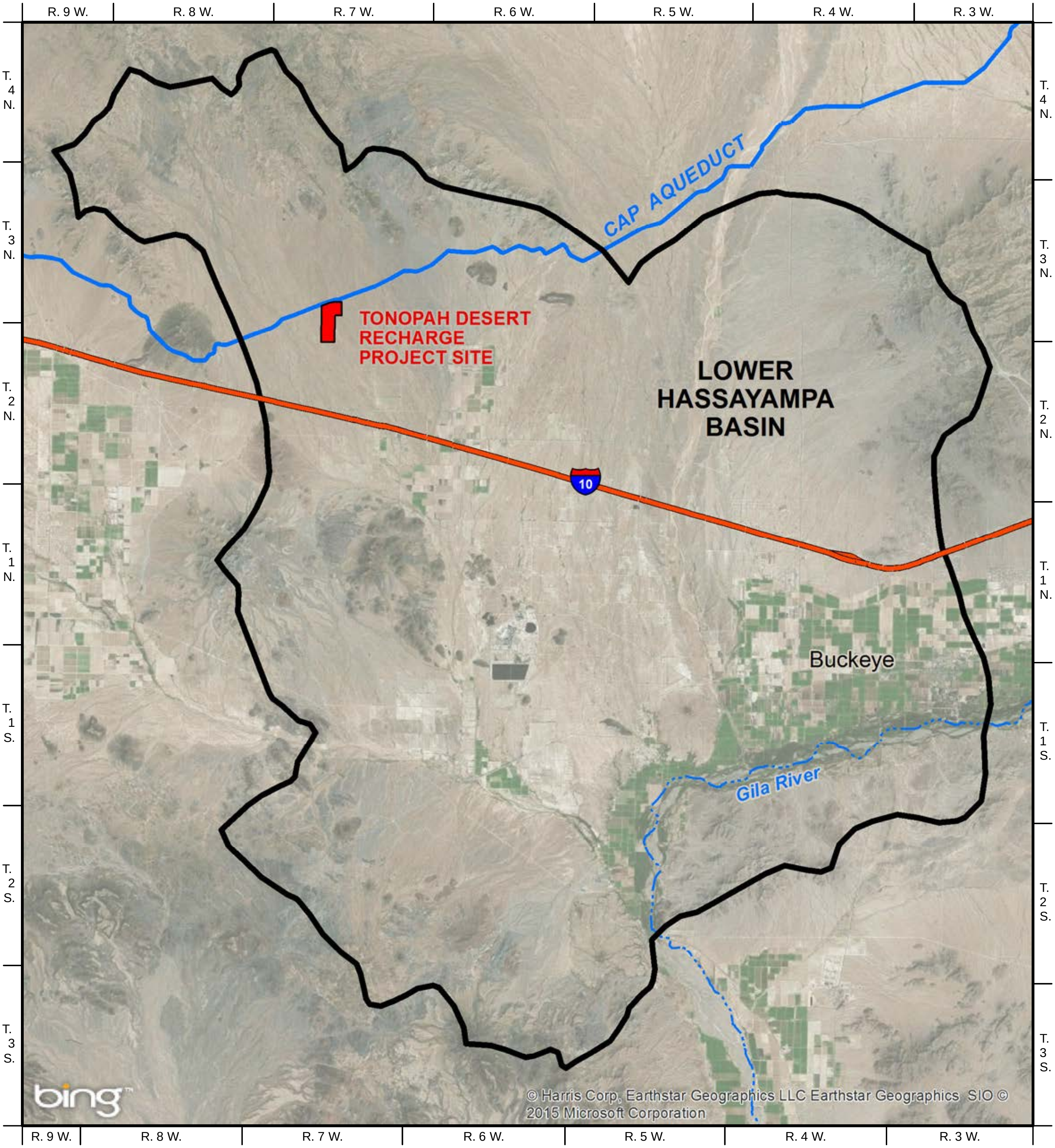
--- = Not applicable

TABLE 3. PRESENT VALUE OF ESTIMATED CAPITAL AND O&M COSTS
TDRP RECOVERY PLAN UPDATE

	PRESENT VALUE AT REAL DISCOUNT RATES OF 0% TO 4%				
	0%	**1%**	**2%**	**3%**	**4%**
WELLFIELD					
Recovery Wells	$14,712,000	$12,774,000	$11,181,000	$9,862,000	$8,762,000
Wellfield Pumping Equipment & Pipelines	$48,550,000	$40,144,000	$33,480,000	$28,160,000	$23,885,000
Subtotal Recovery Wellfield	$63,262,000	$52,918,000	$44,661,000	$38,022,000	$32,647,000
WATER TREATMENT					
Treatment-Related Pumping	$8,300,000	$7,266,000	$6,420,000	$5,720,000	$5,137,000
Treatment Option 1	$67,646,000	$57,650,000	$49,560,000	$42,965,000	$37,549,000
Treatment Option 2	$136,914,000	$110,378,000	$89,672,000	$73,421,000	$60,588,000
Subtotal Treatment, Option 1	$75,946,000	$64,916,000	$55,980,000	$48,685,000	$42,686,000
Subtotal Treatment, Option 2	$145,214,000	$117,644,000	$96,092,000	$79,141,000	$65,725,000
POWER SUPPLY					
Extending power to site[1]	$4,200,000	$4,036,000	$3,880,000	$3,732,000	$3,590,000
GRAND TOTAL					
with Treatment Option 1	$143,408,000	$121,870,000	$104,521,000	$90,439,000	$78,923,000
with Treatment Option 2	$212,676,000	$174,598,000	$144,633,000	$120,895,000	$101,962,000

Notes

[1]Cost to extend power to TDRP site provided by CAP. Additional costs for possible upgrades to the transmission line that feeds the nearest substation, and costs for a cable network to distribute power to transformers at the site, are not included.



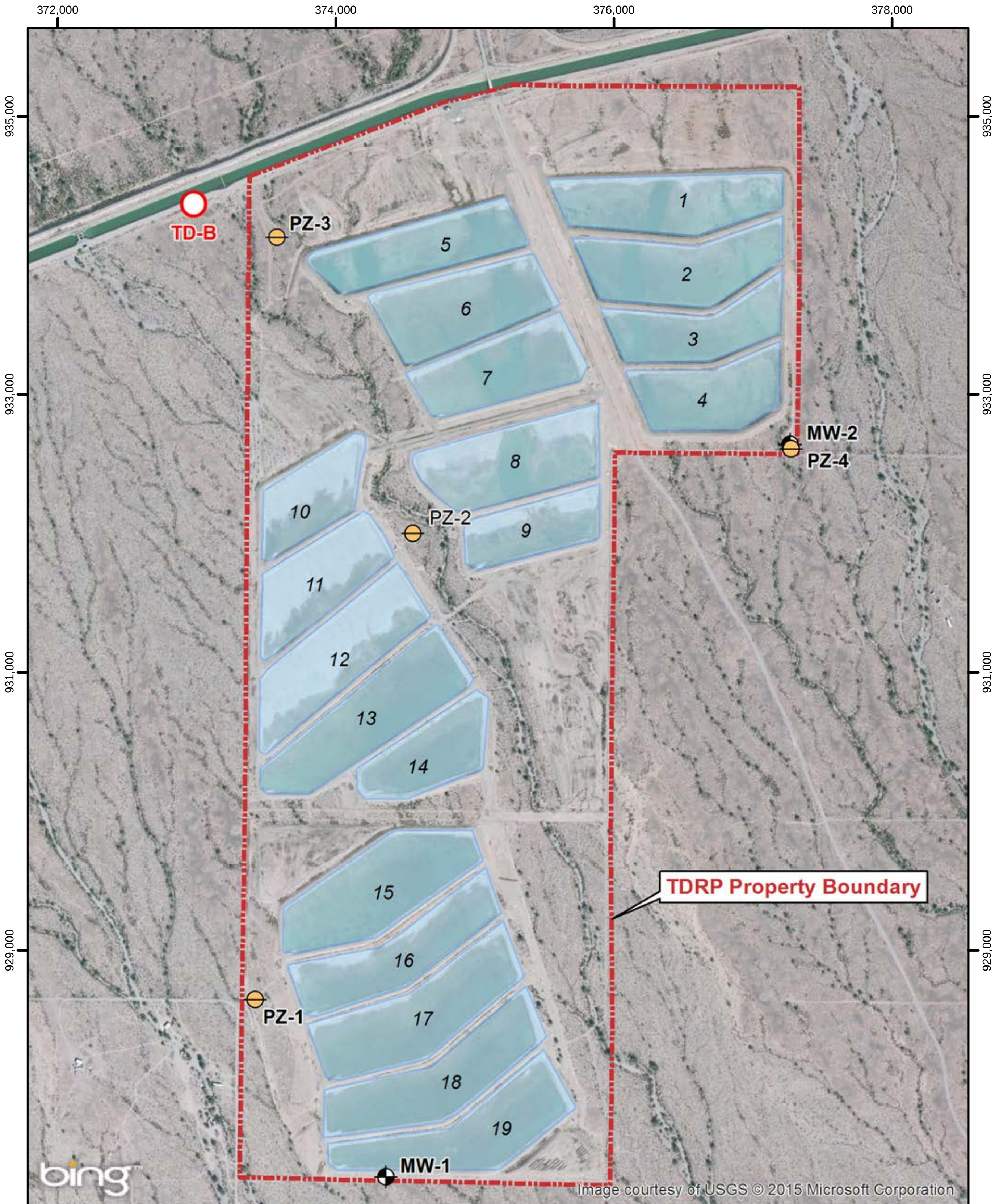
EXPLANATION

Boundary of Groundwater Basin

FIGURE 1. LOCATION OF TONOPAH DESERT RECHARGE PROJECT LOWER HASSAYAMPA BASIN

MONTGOMERY & ASSOCIATES

GIS-Tuc\1447.0103\Hassayampa_LocMap\05Aug2015



EXPLANATION

MW-1 Location and Identifier of Monitor Well

PZ-1 Location and Identifier of Piezometer

TD-B Location and Identifier of Exploration Borehole

8 Recharge Basin and Identifier

N

0 500 1,000
Feet

FIGURE 2. SITE MAP OF TONOPAH DESERT RECHARGE PROJECT

MONTGOMERY & ASSOCIATES

GIS-Tuc\1447.0103\TDRP_SiteMap\05Aug2015 State Plane NAD83 Feet

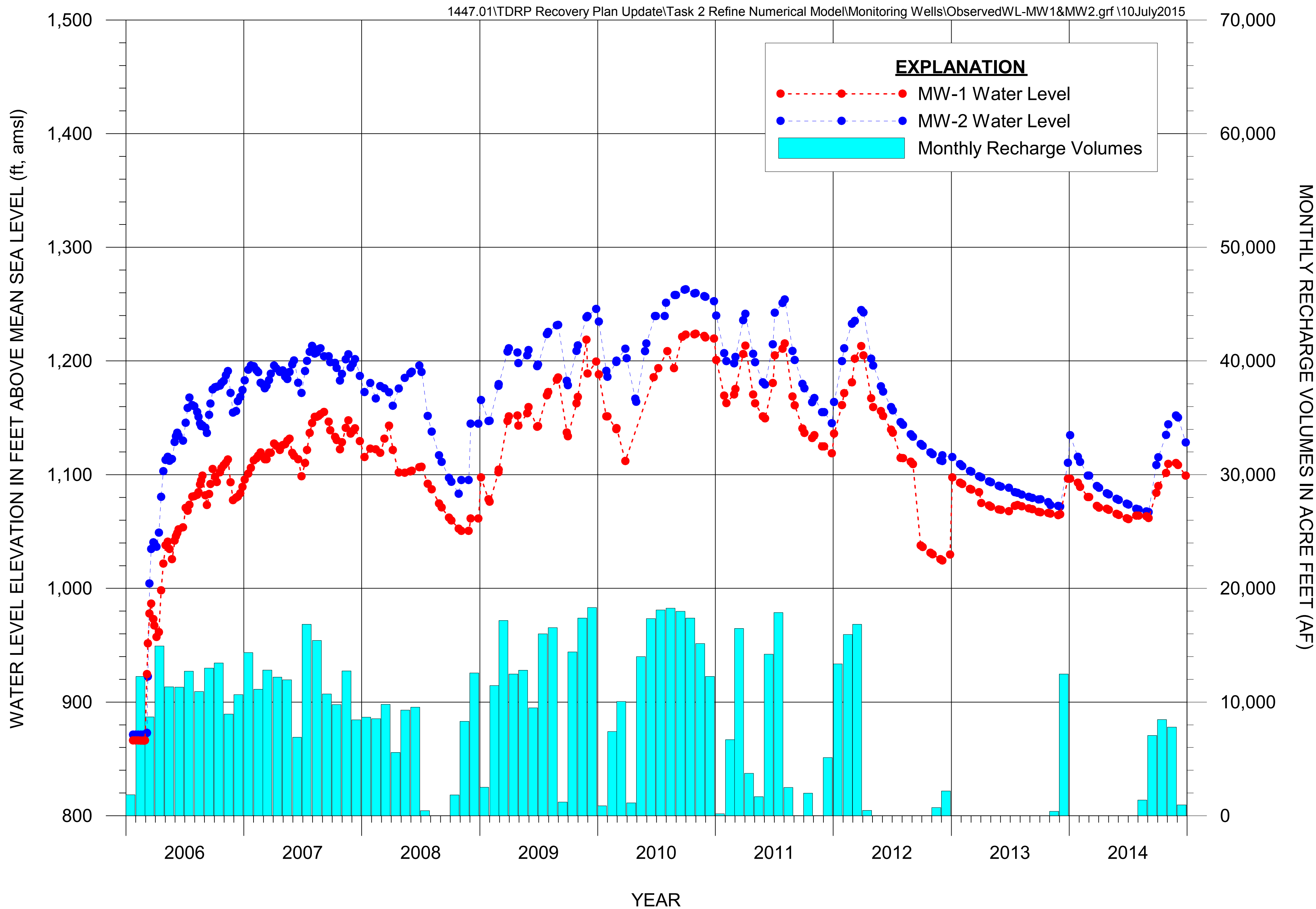


FIGURE 3. HYDROGRAPH OF MONTHLY RECHARGE VOLUMES AND GROUNDWATER LEVELS AT TONOPAH DESERT RECHARGE PROJECT SITE

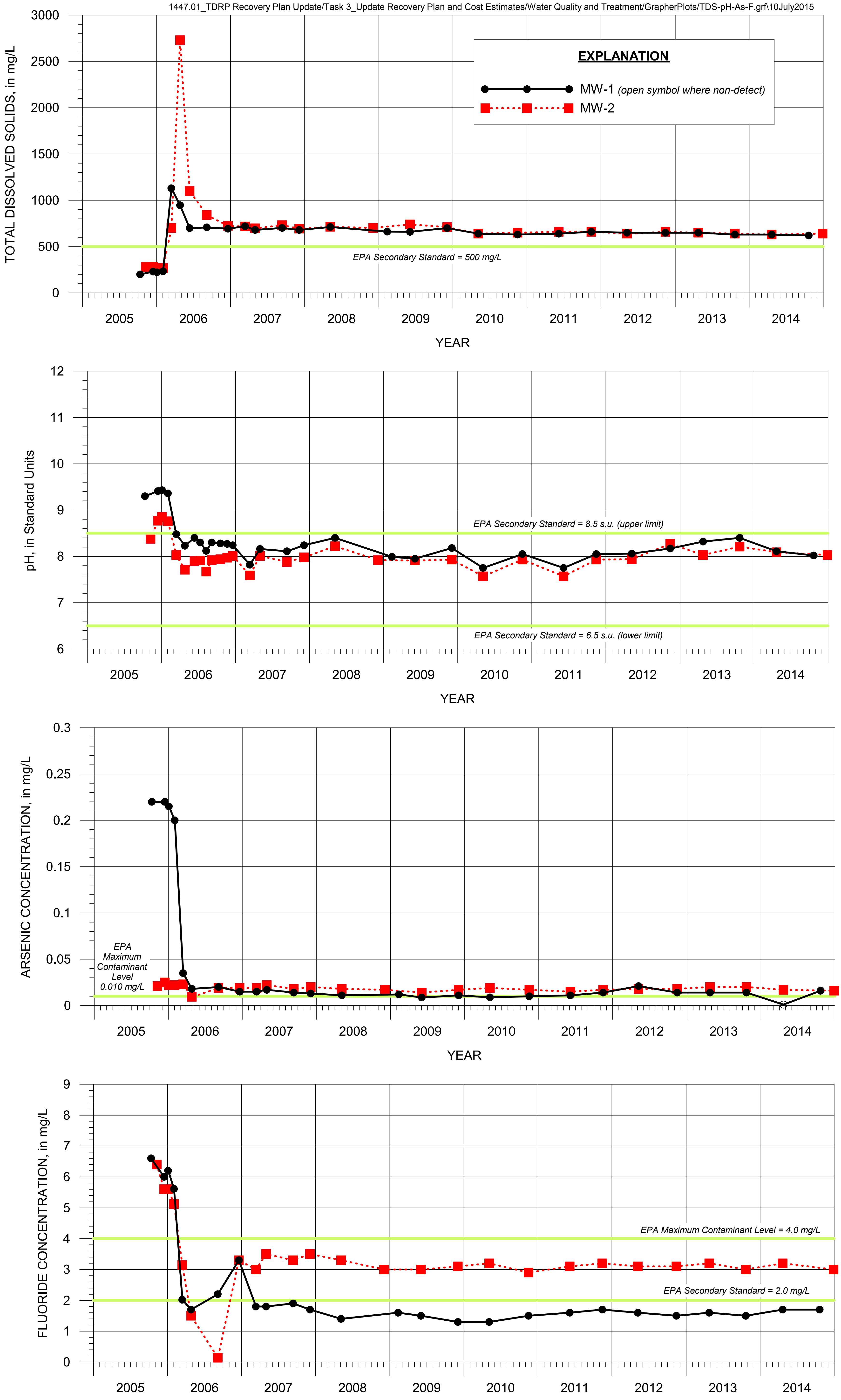


FIGURE 4. CONCENTRATIONS OF TOTAL DISSOLVED SOLIDS, pH, ARSENIC, AND FLUORIDE IN GROUNDWATER SAMPLES FROM MONITOR WELLS MW-1 AND MW-2, 2005 THROUGH 2014

MONTGOMERY & ASSOCIATES

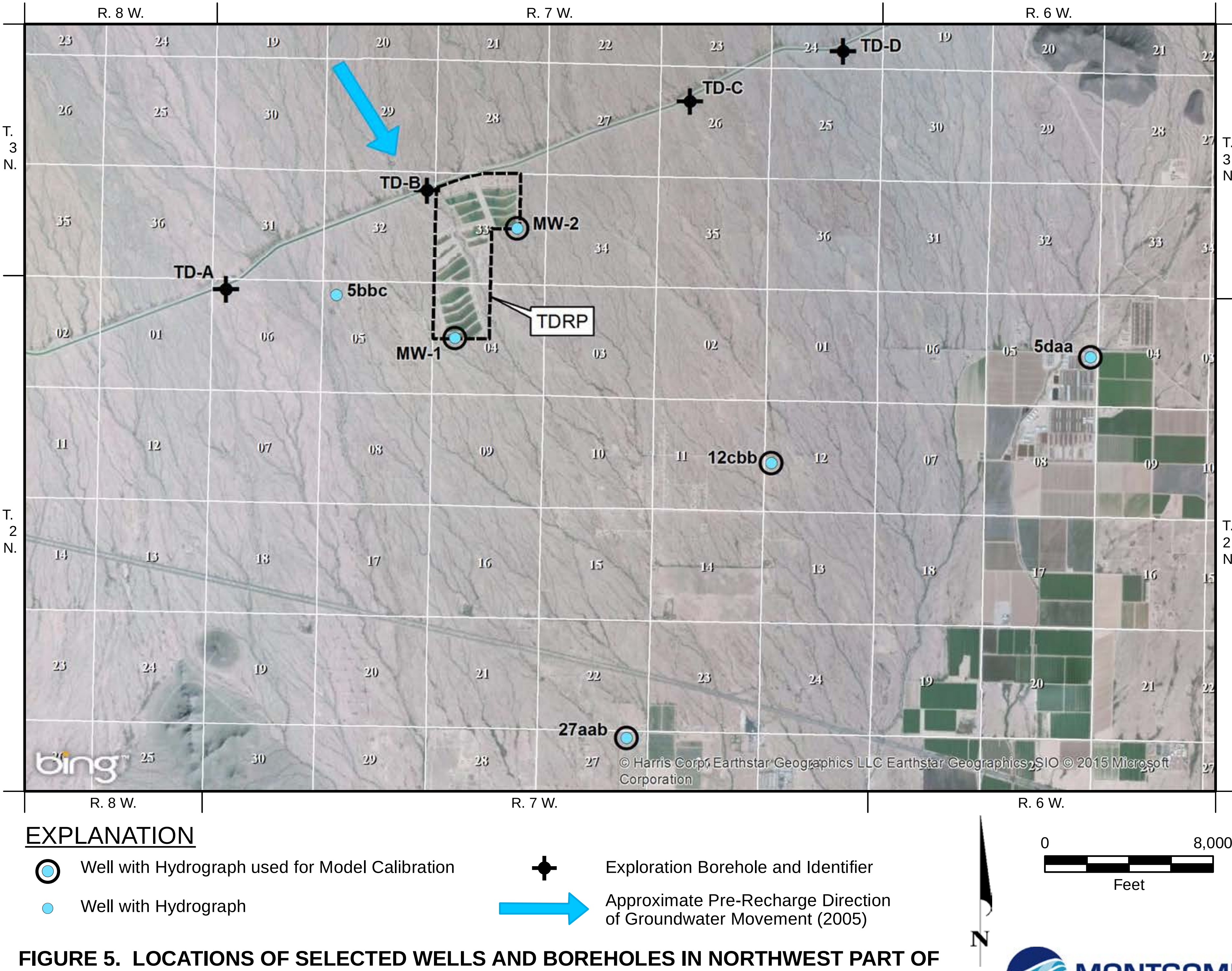


FIGURE 5. LOCATIONS OF SELECTED WELLS AND BOREHOLES IN NORTHWEST PART OF LOWER HASSAYAMPA BASIN

GIS-Tuc\1447.0104\SelectedWellocMap_hydrograph\05Aug2015

MONTGOMERY & ASSOCIATES

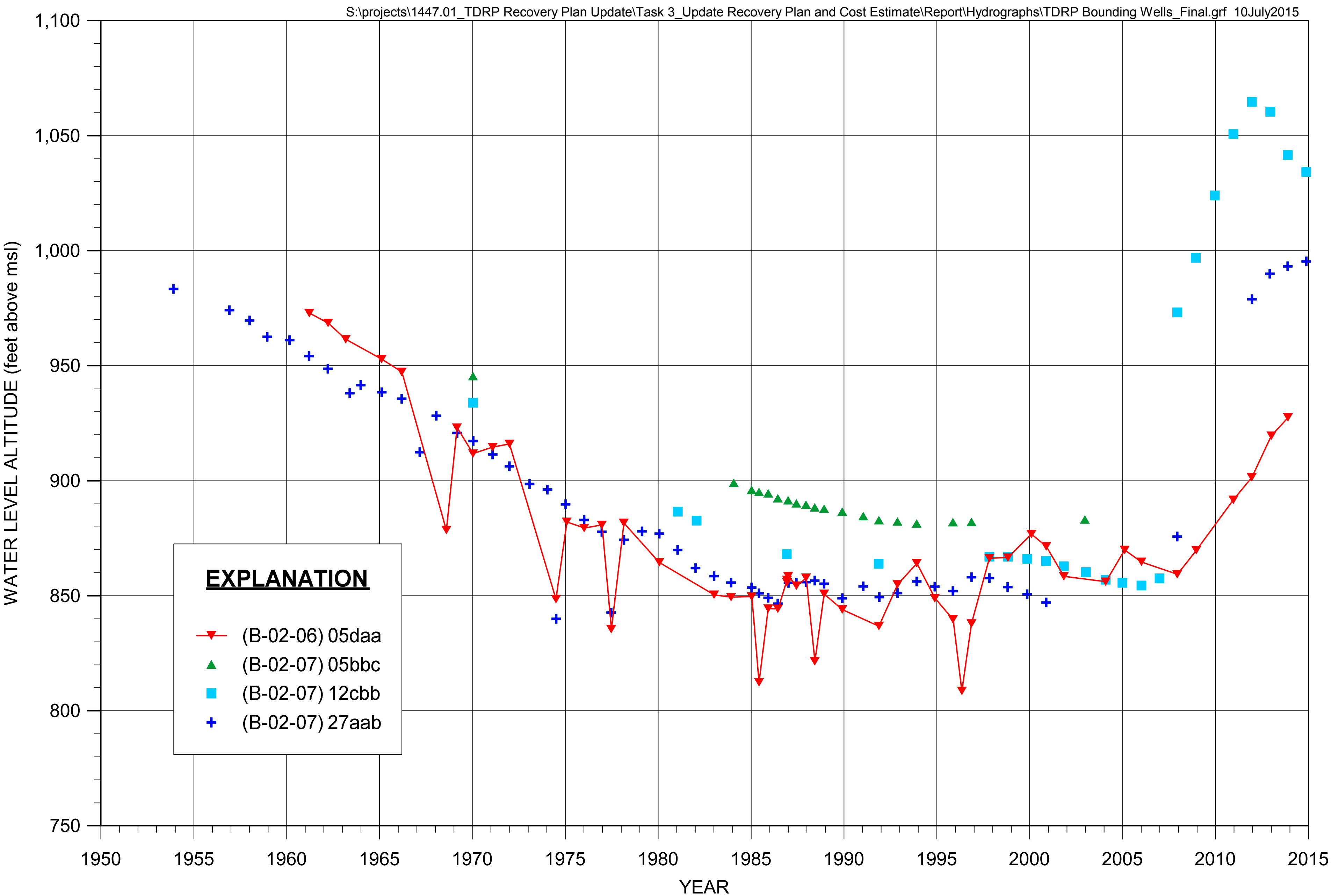


FIGURE 6. HYDROGRAPHS FOR WELLS IN NORTHWEST PART OF LOWER HASSAYAMPA BASIN

MONTGOMERY & ASSOCIATES

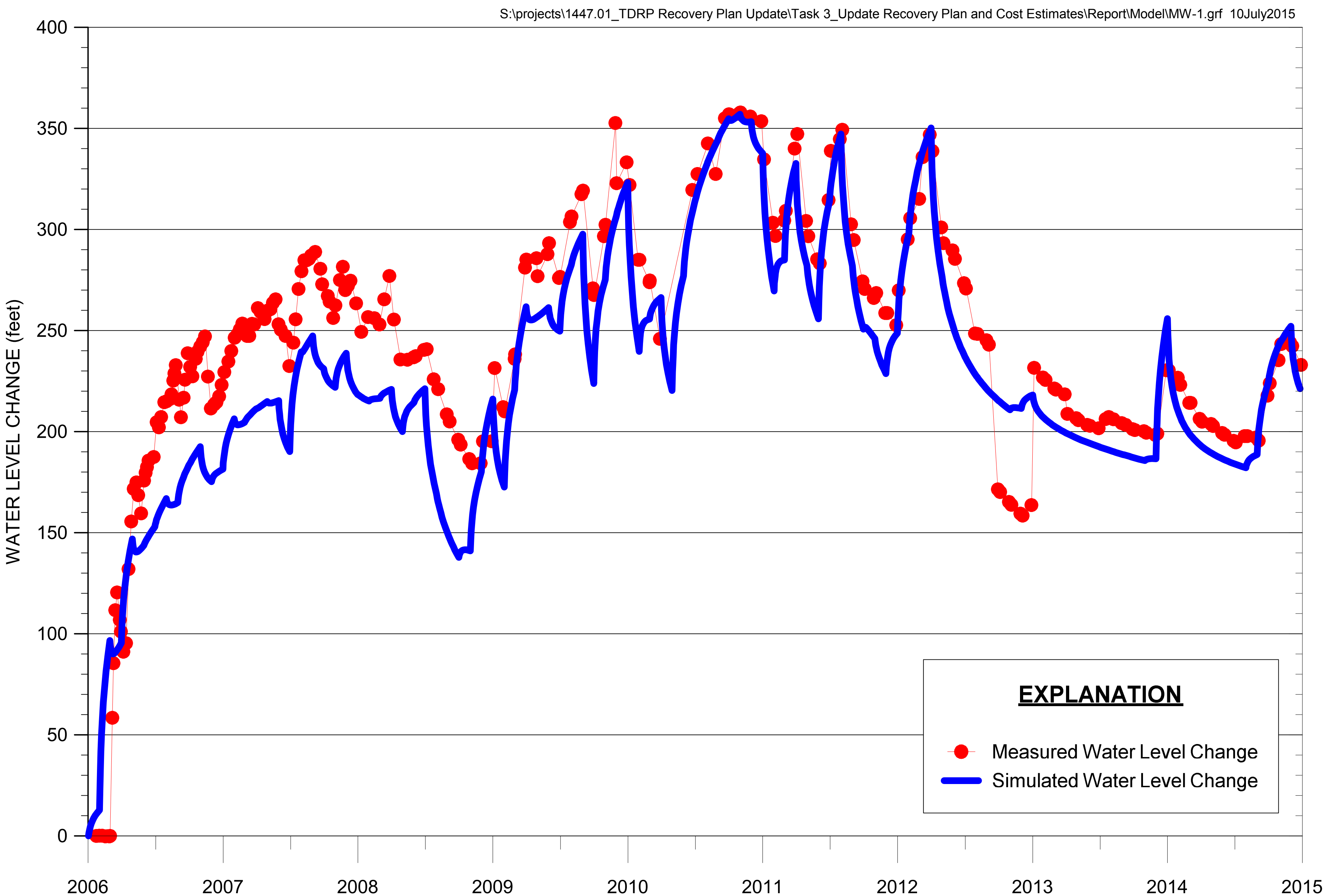


FIGURE 7. SIMULATED AND MEASURED WATER LEVEL CHANGE IN TDRP MONITOR WELL MW-1

MONTGOMERY & ASSOCIATES

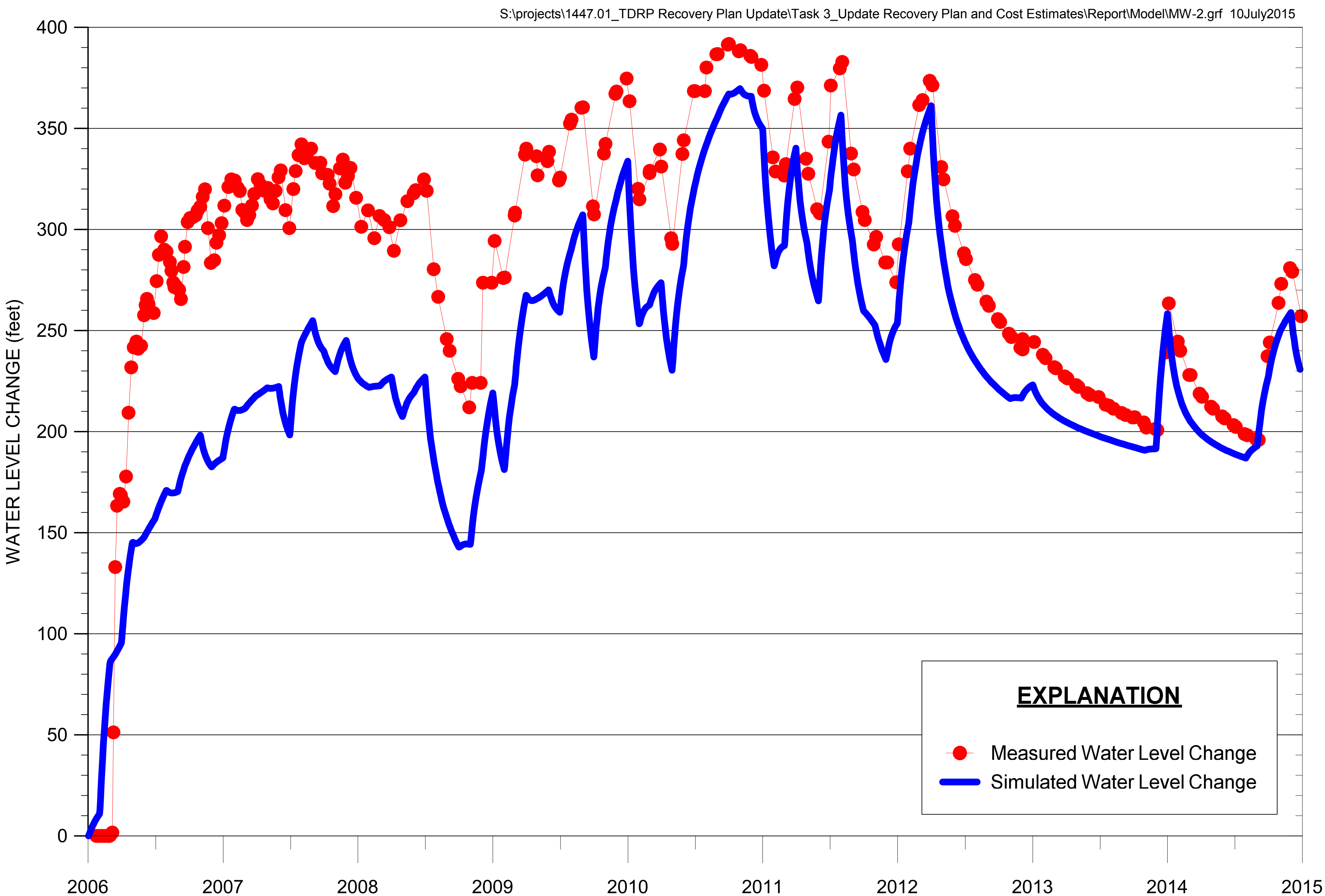


FIGURE 8. SIMULATED AND MEASURED WATER LEVEL CHANGE IN TDRP MONITOR WELL MW-2

MONTGOMERY & ASSOCIATES

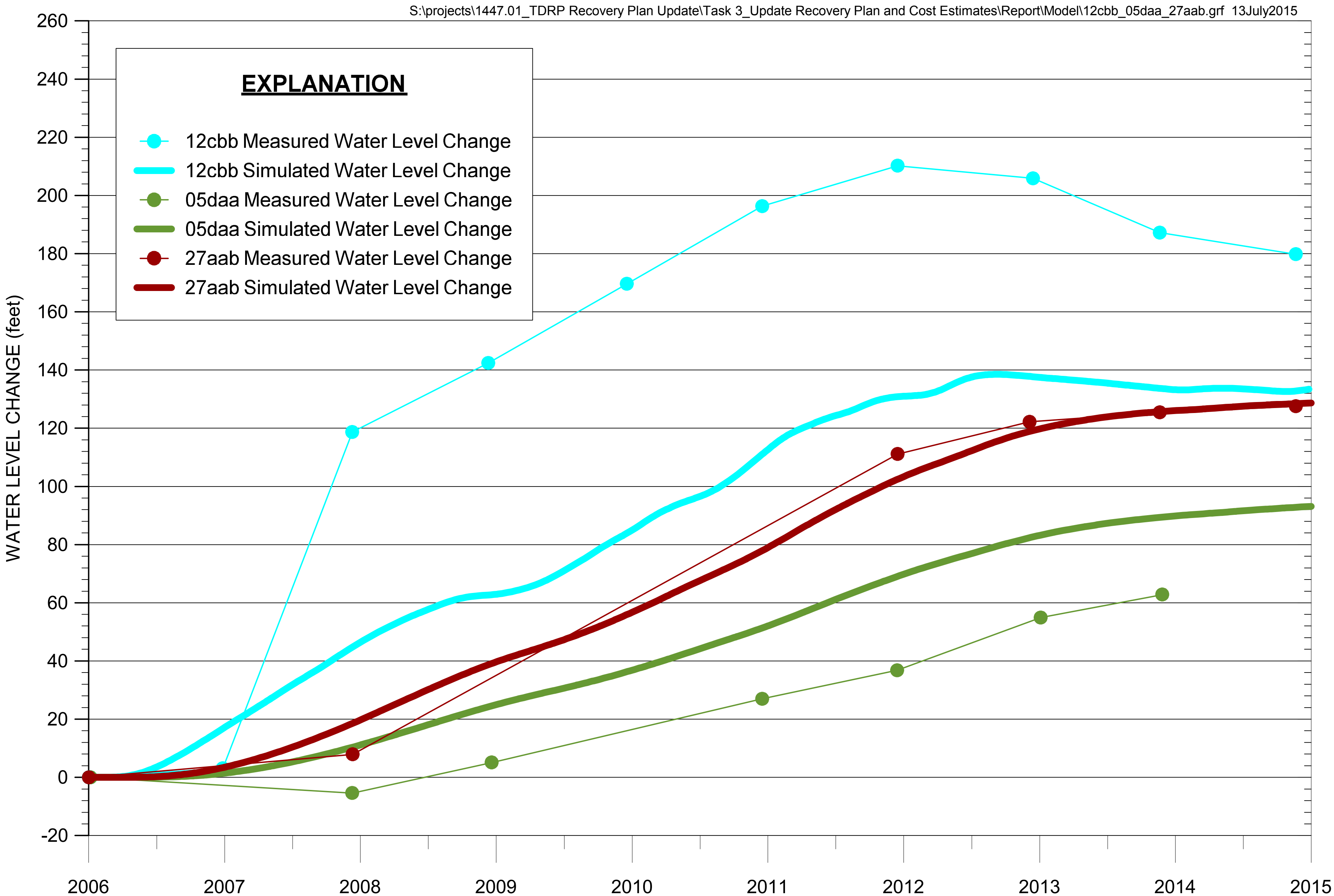
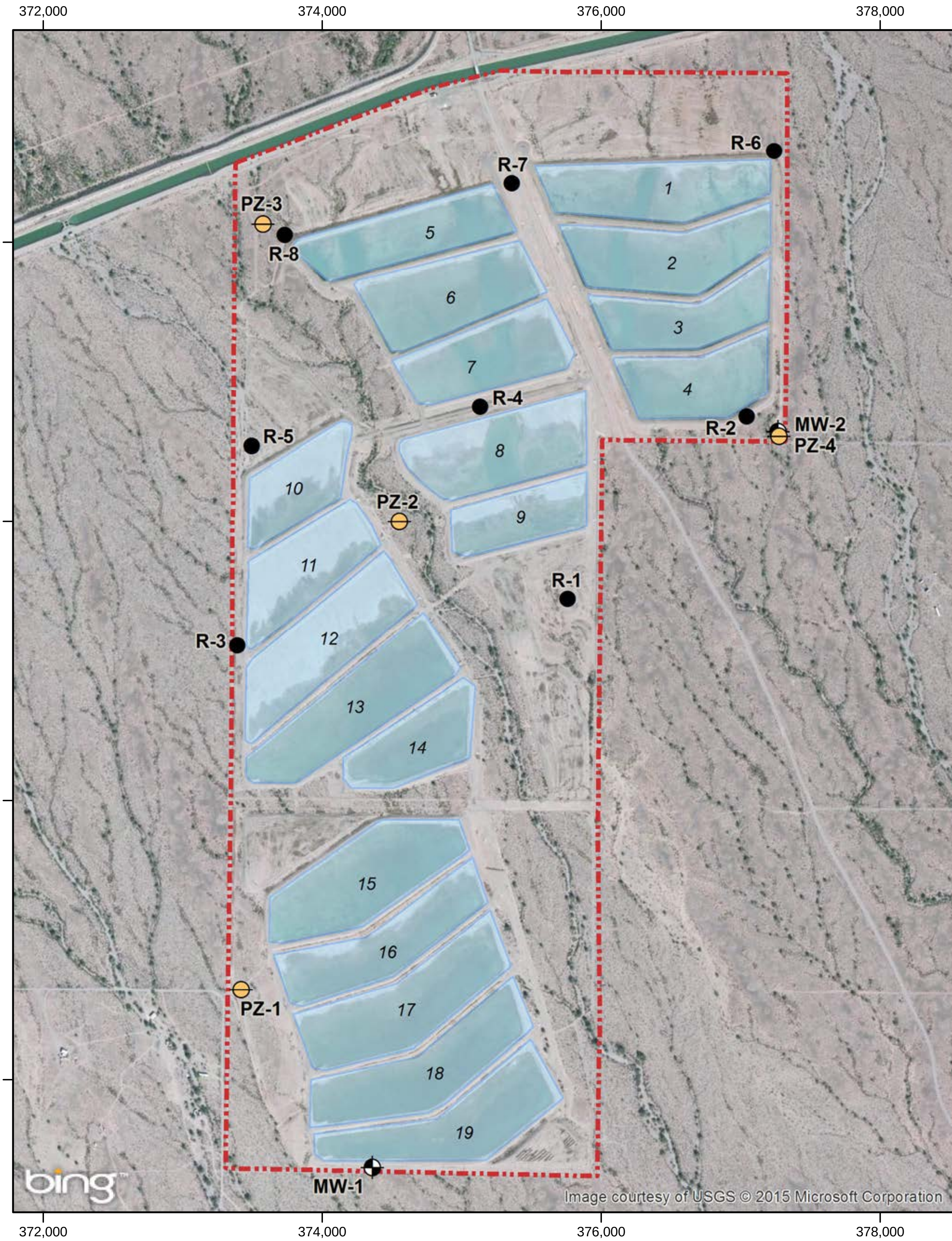


FIGURE 9. SIMULATED AND MEASURED WATER LEVEL CHANGE IN WELLS (B-02-06)05daa, (B-02-07)12cbb, and (B-02-07)27aab

MONTGOMERY & ASSOCIATES



EXPLANATION

- MW-1 Monitor Well Location and Identifier
- PZ-1 Piezometer Location and Identifier
- R-1 Recovery Well Location and Identifier
- 8 Recharge Basin and Identifier
- TDRP Property

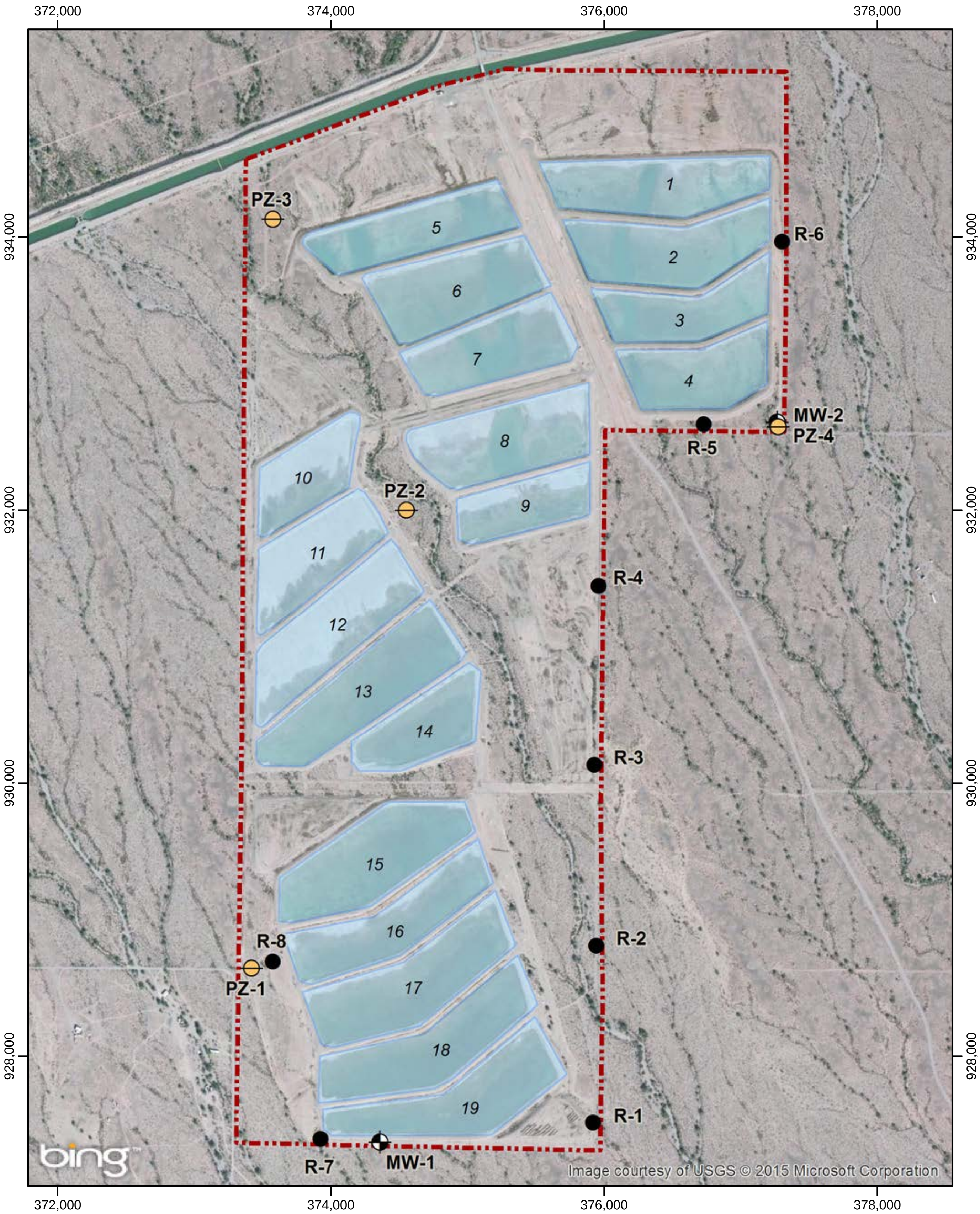
N

0 500 1,000
Feet

FIGURE 10. CONCEPTUAL RECOVERY WELLFIELD SCENARIO 1 (MINIMIZE PIPELINE LENGTHS)

MONTGOMERY & ASSOCIATES

GIS-Tuc\1447.0103\Scenario1_ConceptualRecoveryWellfield\05Aug2015 SP_ NAD83 Feet



EXPLANATION

- MW-1 Monitor Well Location and Identifier
- PZ-1 Piezometer Location and Identifier
- R-1 Recovery Well Location and Identifier
- 8 Recharge Basin and Identifier
- TDRP Property

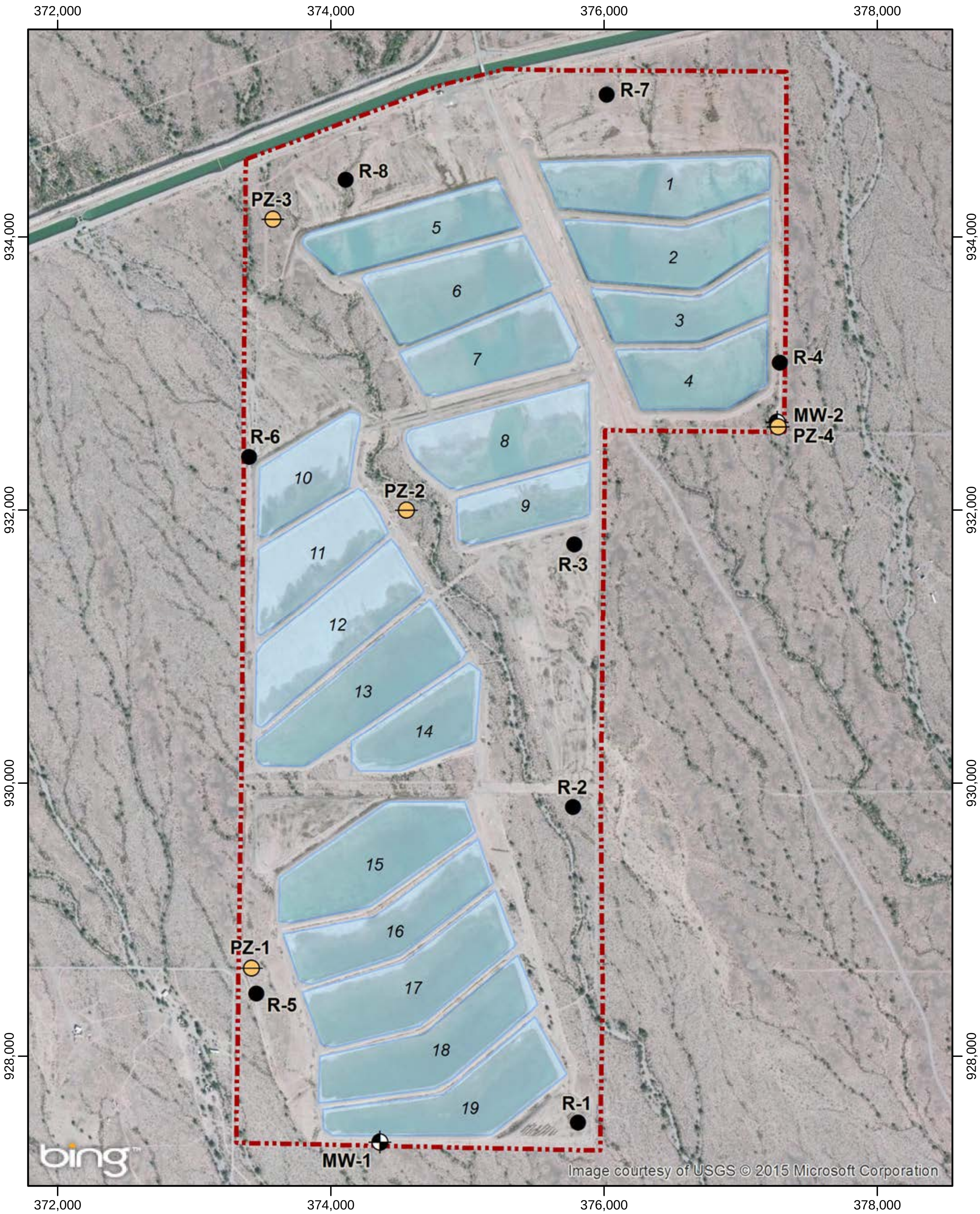
N

0 500 1,000
Feet

FIGURE 11. CONCEPTUAL RECOVERY WELLFIELD SCENARIO 2 (MAXIMIZE CAP WATER RECOVERY)

MONTGOMERY & ASSOCIATES

GIS-Tuc\1447.0103\Scenario2_ConceptualRecoveryWellfield\05Aug2015 SP_ NAD83 Feet



EXPLANATION

MW-1 Monitor Well Location and Identifier

PZ-1 Piezometer Location and Identifier

R-1 Recovery Well Location and Identifier

8 Recharge Basin and Identifier

TDRP Property

N

0 500 1,000
Feet

FIGURE 12. CONCEPTUAL RECOVERY WELLFIELD SCENARIO 3 (MINIMIZE PUMPING LIFTS)

MONTGOMERY & ASSOCIATES

GIS-Tuc\1447.0103\Scenario3_ConceptualRecoveryWellfield\05Aug2015 SP_ NAD83 Feet

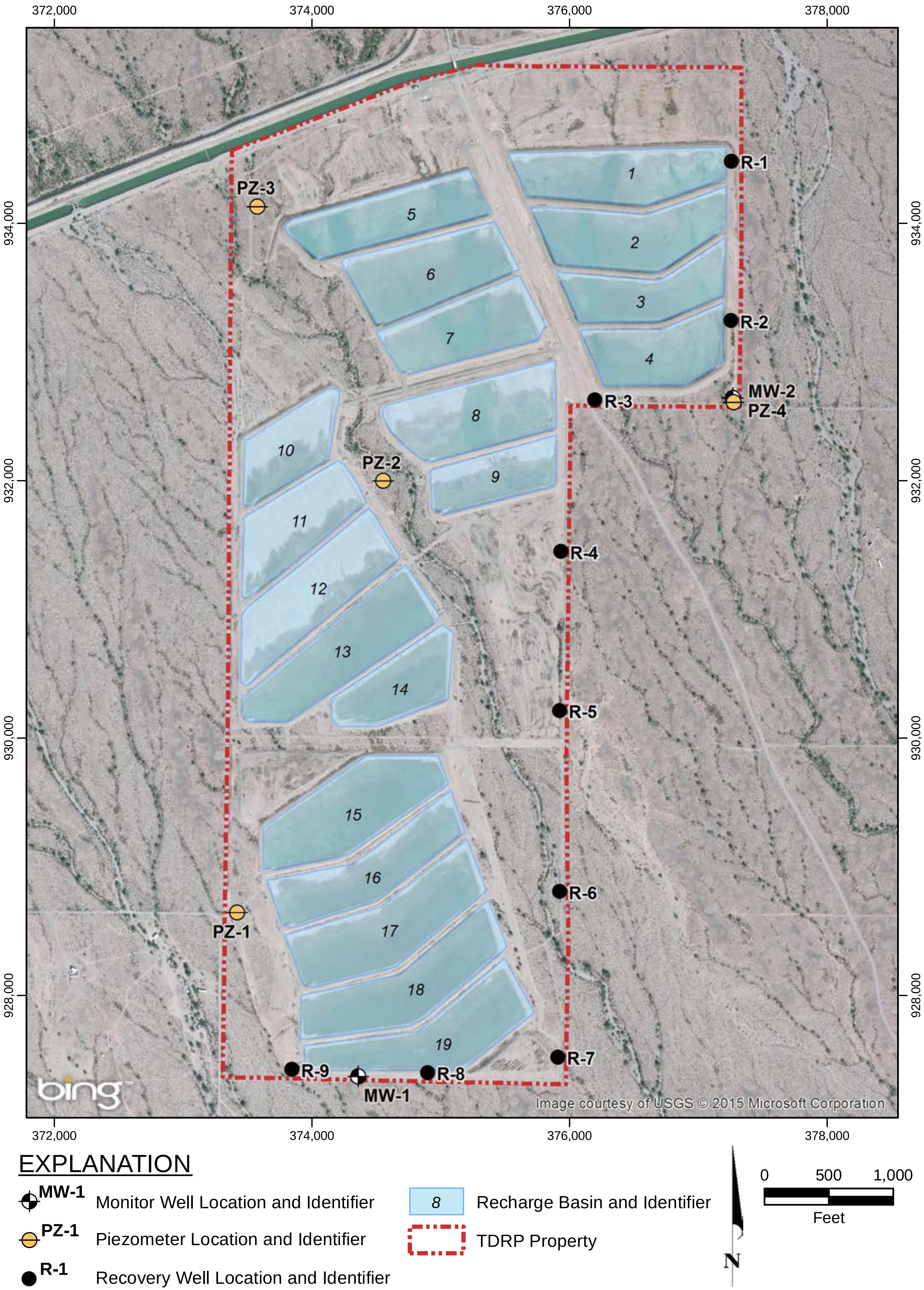


FIGURE 13. FINAL CONCEPTUAL WELLFIELD FOR ANALYSIS

GIS-TUC\1447.01\Scenario2_NineWellRecoveryWellfield\05Aug2015

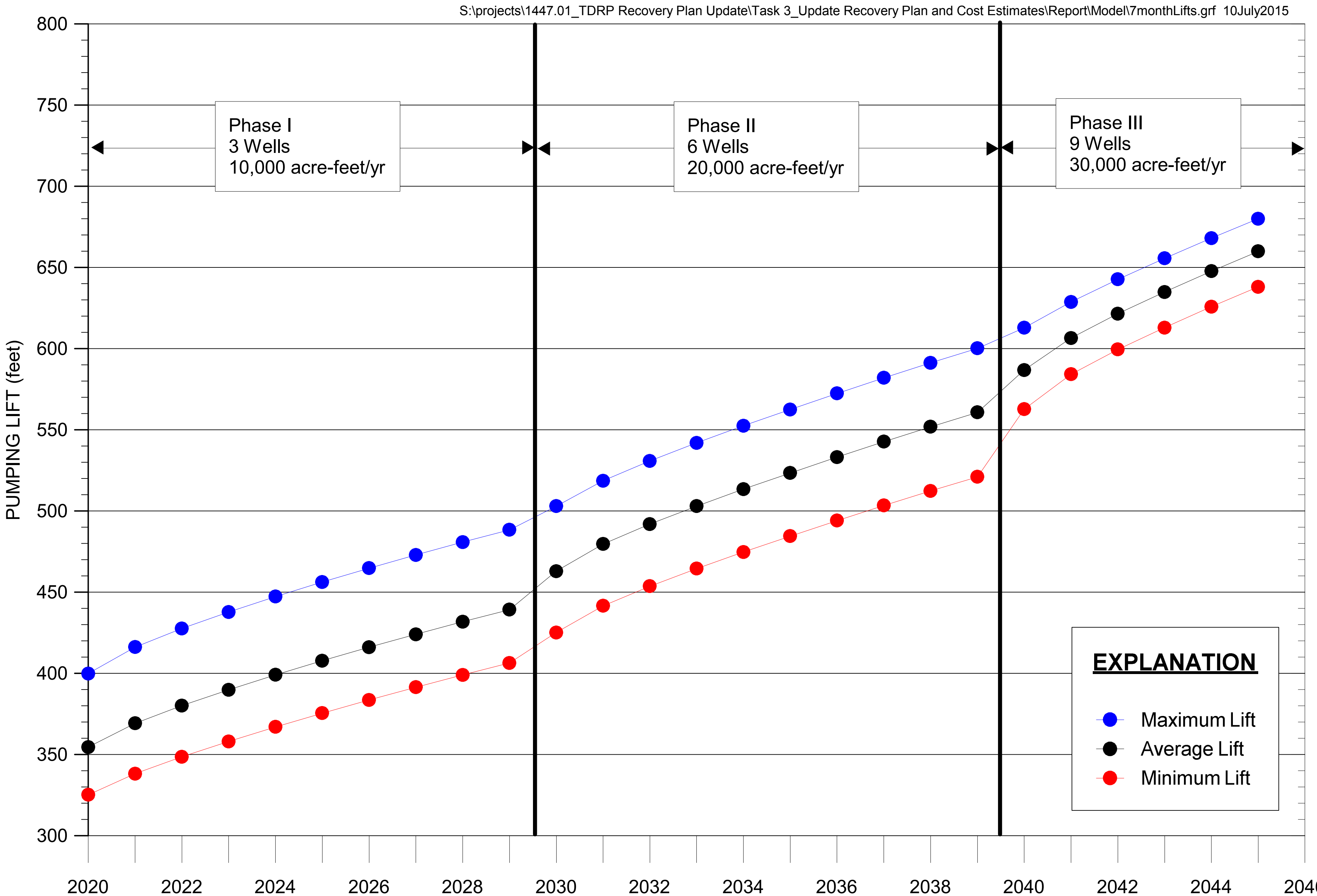


FIGURE 14. PROJECTED PUMPING LIFTS FOR RECOVERY WELLFIELD AT END OF APRIL - OCTOBER PERIODS OF CYCLICAL PUMPING

MONTGOMERY & ASSOCIATES

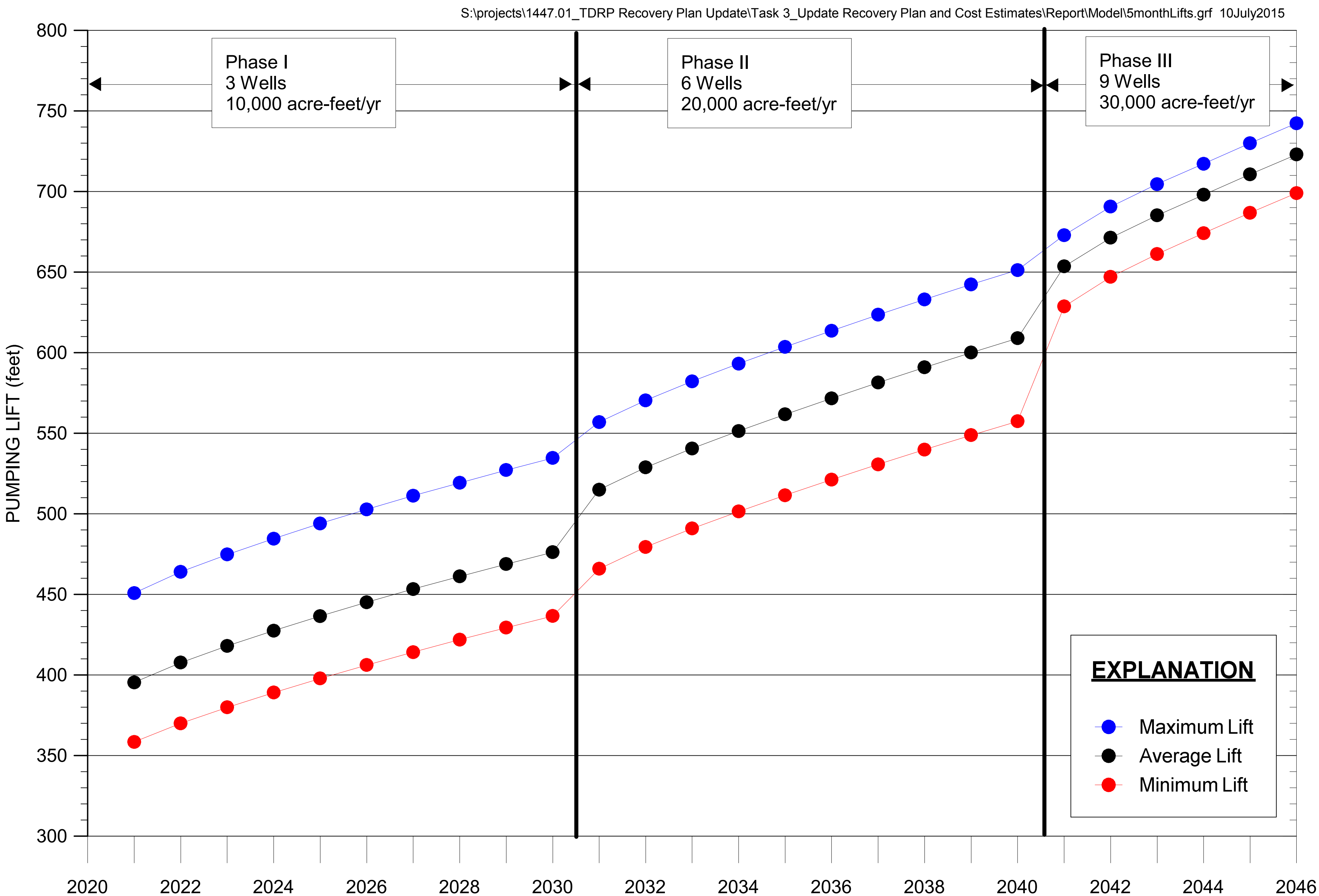
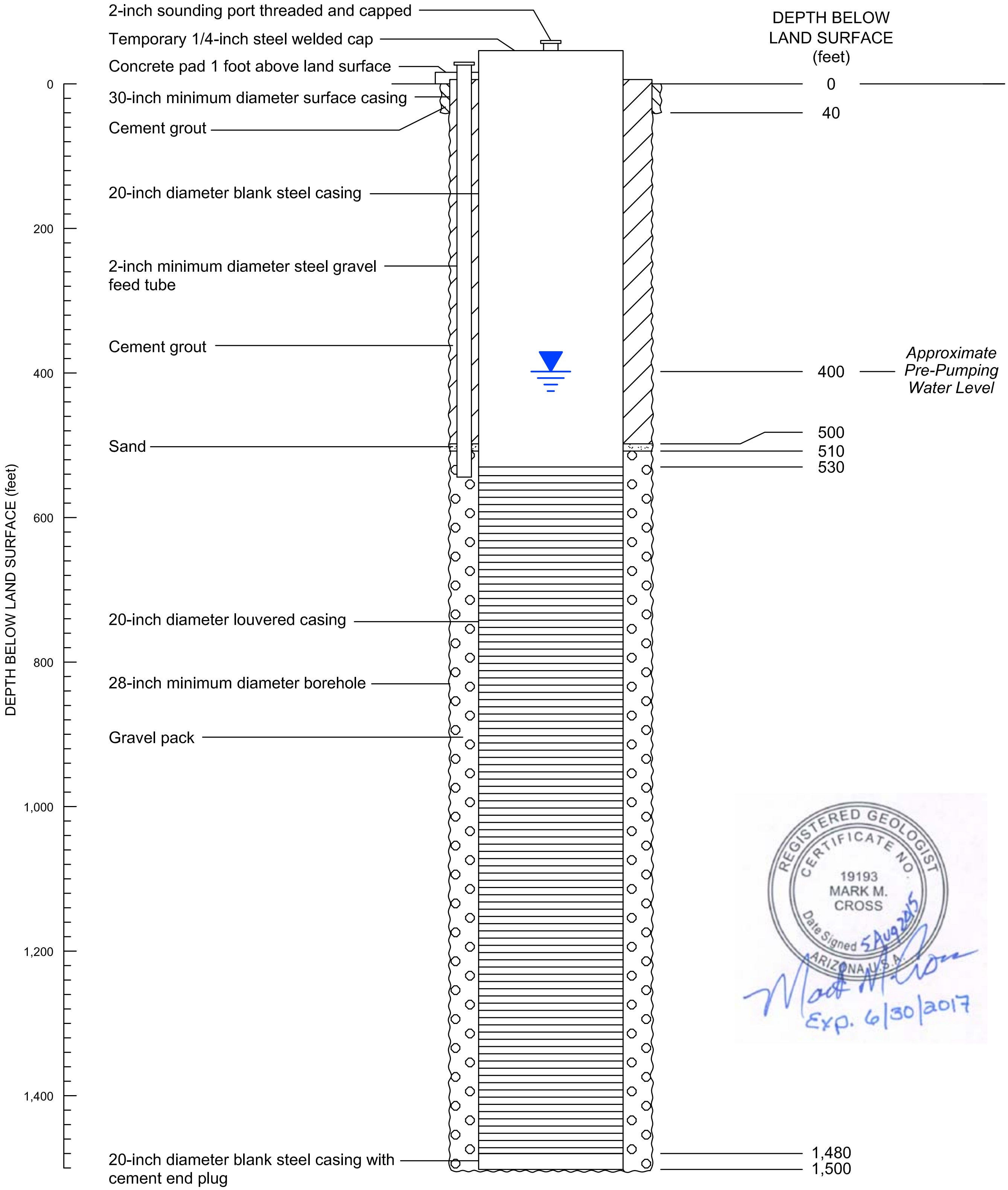


FIGURE 15. PROJECTED PUMPING LIFTS FOR RECOVERY WELLFIELD AT END OF NOVEMBER - MARCH PERIODS OF CONTINUOUS PUMPING

MONTGOMERY & ASSOCIATES



Central Arizona Project

Tonopah Desert Recharge Project

SCHEMATIC DIAGRAM OF CONSTRUCTION FOR PROPOSED RECOVERY WELLS

MONTGOMERY & ASSOCIATES

FIGURE 16

1447.0103\PropRecoveryWell_ws_final\05Aug2015

APPENDIX A

Design Memo and Budgetary Cost Estimate for Recovery Wellfield Equipping, Pumping, and Water Treatment (Prepared by WestLand Resources, Inc.)

EXPIRES: 6/30/2017

MEMORANDUM

Prepared for: Mark M. Cross, P.G., Montgomery & Associates

Prepared by: Erik D. Christenson, P.E., WestLand Resources, Inc.

Date: August 5, 2015

CC: Juliet McKenna, P.G., Montgomery & Associates
Mark F. Taylor P.E., WestLand Resources, Inc.
Robert Archer, P.E., WestLand Resources, Inc.
Patrick Mette, E.I.T., WestLand Resources, Inc.

Project No.: **DESIGN MEMO AND BUDGETARY COST ESTIMATE FOR RECOVERY WELLFIELD EQUIPPING, PUMPING, AND WATER TREATMENT WESTLAND PROJECT NO. 1916.01**

EXECUTIVE SUMMARY

WestLand Resources Inc. (WestLand) was tasked by Montgomery & Associates (M&A) to provide feasibility-level estimates for Capital and Operations and Maintenance (O&M) expenses associated with the well equipping, pipeline installation, and treatment plant construction and operation for the Tonapah Desert Recharge Project's (TDRP) recovery wellfield. The Central Arizona Project (CAP) has been recharging Colorado River water into the basins located at TDRP since 2006. The purpose of this project is to determine the costs associated with the recovery and treatment of this banked water.

The water contained in the TDRP aquifer contains background levels of arsenic and fluoride, which exceed the Environmental Protection Agency (EPA) Maximum Contaminant Levels (MCLs) for potable water. This Memorandum provides preliminary cost estimates for retrieving the banked water from the aquifer, and treating this water to meet the EPA MCLs. This Memorandum assumes that blending with CAP water in the CAP canal will not count towards treatment.

WestLand understands that the project has been grouped into three phases as follows:

- Years 1-10 require recovery of 10,000 acre-feet per year (af/yr)
- Years 11-20 require recovery of 20,000 af/yr
- Years 21-26 require recovery of 30,000 af/yr

As the project progresses through phases, water levels in the aquifer are projected to decline and background contaminant levels are expected to increase. As such, energy requirements for pumping water will increase throughout the life of the project, and the required level of treatment for contaminant removal will also increase.

WestLand's cost estimates for the well field and treatment related pumping costs are shown in ***Table ES-1.***

Table ES-1. Well Field and Treatment Pumping Cost Opinions by Phase

Phase	Duration Years	Well-Field Related Pumping Costs		Treatment-Related Pumping Costs	
		Capital[1]	O&M[1] (annual average)	Capital[1]	O&M[1] (annual average)
I	10	$5,686,000	$627,000	$3,694,000	$56,000
II	10	$5,055,000	$1,374,000	$959,000	$112,000
III	6	$4,299,000	$2,250,000	$959,000	$168,000
Total	**26**	**$15,040,000[2]**	**$33,510,000[3]**	**$5,612,000[2]**	**$2,688,000[3]**

[1]All costs in 2015 dollars with no present value adjustments.
[2]Total Capital costs are the sum of the phases with no present value adjustments.
[3]Total O&M costs are the sum of annual O&M costs with no present value adjustments.

In addition to wells and related facilities, WestLand also prepared cost opinions for a water treatment system to remove arsenic to 10 parts per billion (ppb) and fluoride to 4 parts per million (ppm). Influent concentrations are assumed to increase linearly each year. Because limited water quality data are available at this time, two treatment options were evaluated to provide a range of possible treatment costs. Option 1 is coagulation-assisted microfiltration, and Option 2 is an iron-based sorbent media filter for arsenic removal followed by an activated alumina media filter for fluoride removal. Construction of the treatment facilities were phased to coincide with the three phases of well construction. ***Table ES-2*** shows the Capital cost opinions by phase, and the average of the annual O&M cost opinions by phase.

Table ES-2. Treatment System Cost Opinions by Phase

Phase	Duration Years	Option 1 Coagulation-assisted Microfiltration		Option 2 Media Filters	
		Capital[1]	O&M[1] (annual average)	Capital[1]	O&M[1] (annual average)
Pilot Testing (2016)		$337,500		$337,500	
I	10	$17,737,650	$321,000	$9,131,400	$761,000
II	10	$16,387,650	$701,000	$17,622,900	$3,461,000
III	6	$16,387,650	$1,096,000	$17,622,900	$8,331,000
Total	**26**	**$50,850,450[2]**	**$16,796,000[3]**	**$44,714,700[2]**	**$92,200,000[3]**

[1]All costs in 2015 dollars with no adjustment for inflation.
[2]Total Capital costs are the sum of the phases with no present value adjustments.
[3]Total O&M costs are the sum of annual O&M costs with no present value adjustments.

Although Option 2 (media filters) has a lower Capital cost, Option 1 (Coagulation-assisted microfiltration) has much lower O&M costs, and a lower overall life-cycle cost. In addition, Capital and O&M costs for Option 1 are less sensitive to changes in arsenic and fluoride concentrations. Pilot testing is required to determine if Option 1 will work as expected, and also to refine the Capital and O&M cost opinions.

1. PROJECT LOCATION

The TDRP site is located in portions of Section 33 of Township 3 North and Range 7 West and Section 4 of Township 2 North and Range 7 West, and is approximately 25 miles northwest of Buckeye in Maricopa County, Arizona. The site is at an elevation of 1,350 feet above mean sea level (amsl).

2. WELL EQUIPPING

2.1. WELL FIELD OVERVIEW

The proposed well field will be constructed in three phases and is based upon the recovery volume needs provided by Montgomery & Associates (M&A). Each phase is anticipated to consist of three wells with approximately 2,750 gallons per minute (gpm) each. The final buildout is anticipated to consist of nine wells, with a total recovery volume of 30,000 af/yr at a 75 percent (75%) capacity factor. ***Table 1*** provides a summary of the phasing as provided by M&A.

Table 1. Summary of Phasing

Phase	Years	Annual Recovery Volume	Flow Rates at 75% Capacity Factor (gpm)	Active Wells
I	1-10	10,000 AF	8,267	3
II	11-20	20,000 AF	16,533	6
III	21-26	30,000 AF	24,800	9

2.2. WELL EQUIPPING DESIGN

The new wells will be equipped with vertical turbine line shaft pumps. Typical site manifolds will include a check valve, well service air release valve, flow meter, isolation valve, and a pressure relief valve. Wells were assumed to operate at 1,800 revolutions per minute (rpm).

A single hydropneumatic tank is anticipated during each phase to protect the line from pressure surges.

2.2.1. Column Pipe Selection

WestLand's cost estimate assumes that the well pumps are constructed with carbon steel column pipe, ductile iron bowls with bronze impellers, and a 416 stainless steel line shaft.

The depths of the wells were assumed to be 1,500 feet (ft) below land surface (bls) as determined by M&A. Wells will be designed by M&A, and well capital costs are not considered as a part of this cost estimate. The column pipe length was assumed to be approximately 100 ft below the dynamic pumping water level, which varies between 700 and 750 ft bls at the end of Phase III.

Well column pipe was designed to maintain a velocity between 3 and 10 feet per second (fps). This velocity is sufficient to prevent sand in the water column from settling out and clogging the pump bowls, but slow enough to prevent excessive head loss due to friction in the column pipe.

Table 2 lists the anticipated size of the well pump components.

Table 2. Well Column Pipe Sizing

Flow (gpm)	Column Size (in.)	Column Velocity (fps.)	Nominal Bowl Size (in.)
2,750	12	8.16	14

The total dynamic head (TDH) is the total equivalent height that the groundwater is to be pumped, and is a measurement of the pressure head acting against the pump. Well TDH is the sum of the static head, drawdown, and the friction losses; the units are in feet. The static head is the difference in elevation between the groundwater level, and the treatment forebay reservoir high water elevation. The drawdown is the difference in the water level between static conditions and pumping conditions. The friction losses are the loss of energy due to friction of the water against the pipe, column pipe, valves, and bends.

Estimated pumping water levels for initial and future conditions were provided by M&A. ***Table 3*** shows the final dynamic pumping depths for each phase, which is a portion of the static head plus the drawdown. The remainder of the static head is the difference in elevation between the well discharge (ranging from 1,304 to 1,366 ft amsl) and the 3 million gallon (MG) treatment plant reservoir high water elevation (1,400 ft amsl).

Pipeline friction losses were calculated using the Hazen-Williams method. ***Section 3*** contains more information regarding the calculation of friction losses. Preliminary well pump and motor sizes were selected using the calculated discharge pressures at the specified flow rate. Column and manifold losses were estimated to be 50 ft.

The estimated TDH for all nine wells is shown in ***Table 3.*** Dynamic pumping water levels were provided by M&A.

Table 3. Well Pumping Level and TDH by Phase

Well	Wellhead Elevation (ft amsl)	Column Loss (ft)	PHASE I		PHASE II		PHASE III	
			Pumping Level (ft bls)	TDH (ft)	Pumping Level (ft bls)	TDH (ft)	Pumping Level (ft bls)	TDH (ft)
R-9	1310	50					699	895
R-8	1305	50					707	899
R-7	1304	50					708	895
R-6	1313	50			599	746	717	888
R-5	1325	50			621	754	728	879
R-4	1337	50			635	755	734	867
R-3	1345	50	519	626	649	760	742	861
R-2	1352	50	524	623	647	749	736	842
R-1	1366	50	535	619	651	737	736	824

2.2.2. Horsepower Calculation

The new well field will be equipped for initial conditions with some provisions for future projected conditions. The nominal motor sizes in horsepower (hp) for each well are shown in ***Table 4.*** Motor horsepower is determined by the following equation, with an assumed pump efficiency (η_{pump}) of 80 percent (80%) and shaft losses assumed to be 25 hp. Calculated horsepower is rounded up to determine the nominal horsepower. This calculation is used to size the motor for wells and is different from the calculations shown in ***Attachment A.*** The calculations in ***Attachment A*** are used to determine the actual energy consumption of each well motor, and take into account inefficiencies in the ability of the motor to convert electrical energy into mechanical energy. A nominal motor size of 900 hp was chosen for each well to be conservative, based on horsepower requirements of the highest TDH well. It is understood that all wells will need to undergo detailed design after well drilling, and well testing has been performed.

Equation 2.2.2

$$Power\ (hp) = \frac{(Final\ TDH)\times(Flow)}{(3960)(\eta_{pump})} + \text{shaft losses}$$

Well TDH values tabulated in ***Table 4*** and horsepower's calculated using those TDH's are subject to change pending the new information including well pump tests, which will be done after the wells are drilled. All values shown are per the best available information known to date.

Table 4. Well Horsepower

Well ID	Flow (gpm)	Final TDH (ft)	Calculated hp	With Mechanical Shaft Losses	Nominal Motor hp
R-1	2750	824	715	740	900
R-2	2750	842	731	756	900
R-3	2750	861	747	772	900
R-4	2750	867	753	778	900
R-5	2750	879	763	788	900
R-6	2750	888	771	796	900
R-7	2750	895	777	802	900
R-8	2750	899	780	805	900
R-9	2750	895	777	802	900

Attachment A provides more information on the TDH values tabulated in ***Table 4.***

3. PIPING

3.1. PIPELINE SIZING

The well field collection pipelines are arranged as shown in ***Figure 1*** (attached). Pipe size varies from 16-inch to 42-inch based on maintaining velocities between 5 to 10 fps during Phase III in order to avoid excessive head loss and to balance Capital costs. ***Table 5*** provides the lengths of pipe and associated estimated head losses during each phase.

Table 5. Pipe sizing and Head Loss by Phase

Pipe	Well	Length (ft)	Nominal Diameter (in)	PHASE I		PHASE II		PHASE III		
				Flow (gpm)	Head Loss (ft)	Flow (gpm)	Head Loss (ft)	Flow (gpm)	Head Loss (ft)	Velocity (fps)
1	R-9	1,080	16					2,756	8.8	6.19
2	R-8	950	22					5,511	5.9	6.55
3	R-7	1,290	26					8,267	7.6	7.03
4	R-6	1,420	30			2,756	0.5	11,022	7.1	7.04
5	R-5	1,220	32			5,511	1.2	13,778	6.7	7.74
6	R-4	1,510	36			8,267	1.8	16,533	6.5	7.33
7	R-3	1,630	42	2756	0.1	11,022	1.6	19,289	4.4	6.29
8	R-2	1,230	42	5511	0.3	13,778	1.8	22,044	4.3	7.18
9	R-1	1,030	42	8267	0.6	16,533	2.1	24,800	4.5	8.08
Totals		**11,360**			**1**		**9**		**56**	

3.2. PIPELINE MATERIAL

Pipe material for all well transmission pipelines will be DR 13.5 high density polyethylene (HDPE) 4710. DR 13.5 pipe has a thick wall which allows the pipe to be more self-supporting and durable. Additionally, the pipe has a pressure rating of 161 pound per square inch (psi).

3.3. PIPELINE INSTALLATION METHODS

New pipeline will be installed below ground in all locations. All belowground pipe will be installed at a 3-ft minimum depth with tracer wire and magnetic tape. The pipeline is assumed to be installed in an open trench with screened and compacted native backfill. At locations where the pipe crosses existing utilities, new utilities, or conduits larger than 3-inch in diameter, the backfill will be aggregate base course on both sides of the intersecting pipe.

4. TREATMENT RELATED PUMPING FACILITIES

4.1. BOOSTER STATION OVERVIEW

Three booster stations are needed to deliver water to three respective treatment trains. Each booster station and treatment train is sized to treat the flow volume associated with one phase of the project and will be constructed at the beginning of its respective phase. It is anticipated that these booster stations will share a common suction manifold and concrete pad.

Each booster station will consist of one horizontal split case pump, pressure gauges, a suction and inlet isolation valve, and a discharge check valve. A hydropneumatic tank will be provided at the discharge of each booster pump station to protect the system from pressure surges during startup and shutdowns, including unplanned shutdowns.

4.2. FOREBAY RESERVOIR OVERVIEW

WestLand recommends that a single reservoir be located upstream of the proposed booster stations to provide storage and equalization between well flows and treatment flows. The reservoir is sized at 3 MG to provide one hour of storage for the Phase III treatment plant, and assumes that 30 percent (30%) of the reservoir's total volume is "dead" storage for maintenance of pump suction head.

The reservoir is assumed to be welded steel, with a single inlet from the well pumps, and single outlet with a manifold for all three phases of treatment. The reservoir will be installed on a concrete ring wall.

4.3. BOOSTER STATION DESIGN CRITERIA

Each booster station will have a flow capacity of 9,000 gpm and operate based on the level in the reservoir, turning on when the water level is high, and turning off when the water level is low.

Piping from the forebay reservoir to each booster station, and from each station to its respective treatment train, will be 30-inch steel piping. This size is based upon maintaining flow velocities lower than 5 fps, to maintain the available net positive suction head at the pump inlet.

Head loss through each treatment train is expected to be less than 50 ft for all alternatives considered; therefore, pump motors are expected to be sized at 200 hp.

5. CONTROLS & ELECTRICAL DESIGNS

5.1. DESIGN CRITERIA – 4,160 VOLT WELL POWER SYSTEM

Each well will be served by 4,160-volt, 3-phase, 4-wire power from a dedicated pad-mounted transformer near each well site. The source of power will be from a 15 kilovolt (kV) distribution system provided by others and not considered as a part of this report. The 4,160 volt service will be fed underground directly to a fused main disconnect switch.

Electrical power equipment will be mounted in a motor control center consisting of NEMA-rated cabinets. Control equipment will be mounted on a steel equipment rack, which will incorporate sheathing on the rear and on a top structure to provide shade.

A high capacity surge protection unit will be connected to the incoming 4,160 volt system to provide surge protection for electrical equipment. A single phase, 480-120/240-volt, mini-power distribution center will be provided at each well to supply 120/240-volt power to miscellaneous loads including lighting, receptacles and control equipment.

An electronic soft start control panel with fused power disconnect switch and bypass contactor will be provided for well pump control. Air conditioning will not be provided for the panel as minimal heat will be generated due to the use of the bypass contactor. Detailed well control features are described elsewhere in this report.

Each well will be provided with power factor correction capacitors to address poor power factor conditions. These capacitors will prevent penalties from being charged by the utility company by reducing the capacity of the facilities the utility company would have to provide to serve a poor power factor load. The capacitors will be installed on the line side of the electronic soft start controllers as placing them on the load side, where they would only be connected when the well runs, is not recommended due to the soft start electronics. A contactor will be provided that will connect the capacitors only when the well pump is running.

All electrical panels will be lockable. Electrical equipment will be rated NEMA 3R where located outdoors.

5.2. DESIGN CRITERIA – WELL CONTROL SYSTEM

Well pumps will use electronic soft start controllers with bypass contactors. Well controls will be interfaced with a Programmable Logic Controller (PLC) control panel. A hands-off remote switch on the front of the well control panel will allow for either local manual control of the well or fully automated control via the PLC system. A green "Run" pilot light, red "High Pressure Cutoff" alarm pilot light, high pressure cutoff reset pushbutton, and an elapsed run-time meter will also be provided on the front of the well control panel behind a lockable door.

Each well will have a high discharge pressure switch located on the discharge piping to shut the well pump off on high pressure conditions. This switch will be connected to a time delay relay in the well control panel which will latch on when a high pressure condition is monitored for the set time. Normally the time setting will be zero to provide instant shutdown of the well on high pressure. However, if high pressure surges are present on starting of the well, a small time delay can be set to allow such disturbances to pass. If this high pressure shutdown function trips the well pump off, the operator will need to press the reset pushbutton on the front of the control panel before the well pump can be restarted.

The PLC panel will provide 3-wire control of the well pump when operating in the "Remote" control mode. In this configuration, the PLC panel provides two relay contact outputs to the well control panel. A normally open contact will pulse closed to start the well pump, and the well controls will latch on via a normally closed contact from the PLC panel. The well pump is stopped by pulsing the normally closed contact open.

The well pumps will not be provided with anti-reverse ratchets. The relay, described below, will prevent rapid restarting of a pump upon stopping so that the pump cannot restart while it is spinning backwards due to the falling water column in the well. No provisions will be made for automatic control of well pump lineshaft lubrication. The operator will need to manually control and monitor the flow of lubricant.

The well pumps' controls will incorporate a power monitoring relay that provides several safety features including low and high voltage, loss of phase, over and undercurrent, and restart time delay to prevent starting during pump backspin after stopping. The PLC panel will monitor well pump motor parameters such as voltage and amperage to the relay.

A magnetic flow meter will be installed on the discharge of each well. The PLC panel will monitor the flow meter and will shut down the well pump if a flow rate that is too low is detected to provide failure-to-pump protection, and will shut down the well pump if a flow rate that is too high is detected to provide discharge line break protection. Reverse flow detection from the flow meter will provide a well discharge check valve failure alarm. A totalizer pulse will also be sent to the PLC panel to provide a total flow value.

Each well will be provided with a well water level transmitter to allow monitoring of well level via the PLC/telemetry system

5.3. 480 Volt Booster Pumping Station Power System

Each booster pumping station will be served 480-volt, 3-phase, 4-wire power from a single shared dedicated pad mounted transformer. The source of power will be from a 15 kV distribution system provided by others and not considered as a part of this report. Electrical and control equipment will be mounted in a dedicated electrical control building. Power from the main disconnect switch will feed to each piece of equipment using 480 volt power. This building will be air-conditioned to protect the equipment from heat damage. WestLand anticipates that the electrical control building will be constructed with room for expansion to accommodate Phases II and III.

A high capacity surge protection unit will be connected to the incoming 480-volt system to provide surge protection for electrical equipment. A single phase, 480-120/240-volt, mini-power distribution center will be provided at to supply 120/240-volt power to miscellaneous loads including lighting, receptacles and control equipment.

An electronic soft start control panel with fused power disconnect switch and bypass contactor will be provided for booster pump control.

Each booster pump will be provided with power factor correction capacitors to address poor power factor conditions. These capacitors will prevent penalties from being charged by the utility company by reducing the capacity of the facilities the utility company would have to provide to serve a poor power factor load. The capacitors will be installed on the line side of the electronic soft start controllers as placing them on the load side, where they would only be connected when the well runs, is not recommended due to the soft start electronics. A Contactor will be provided that will connect the capacitors only when the well pump is running.

All electrical panels will be lockable.

5.4. BOOSTER STATION PLC AND INSTRUMENTATION EQUIPMENT

A new PLC panel will be installed at the booster pumping station to provide control and monitoring functions. The PLC panel will also incorporate an operator interface display panel to allow an operator to monitor system operation and provide manual control input at the panel. The PLC will be provided to allow for expansion during Phases II and III.

The PLC panel will be provided with an APC uninterruptable power supply. The operator interface display panel will be located on a swing out door behind the exterior door to prevent exposure of the operator to energized components when the exterior door is open.

Each booster pump will have a high discharge pressure switch located on the discharge piping to shut the pump off on high pressure conditions. This switch will be connected to a time delay relay in the pump control panel which will latch on when a high pressure condition is monitored for the set time. Normally the time setting will be zero to provide instant shutdown of the pump on high pressure; however, if high pressure surges are present during starting of the pump or during other conditions, a small time delay can be set to allow such disturbances to pass without tripping the pump off. If this high pressure shutdown function trips the pump off, the operator will need to press the reset pushbutton on the front of the control panel before the pump can be restarted.

A pressure transmitter will be installed on the common discharge line of the booster pumps. This pressure signal will provide for general monitoring of the pumping system operation, and can be used to provide backup high and low pressure alarms.

A magnetic flow meter will be installed on the common discharge line of the booster pumps to measure the combined flow of all booster pumps. This flow rate will be monitored by the PLC. The flow rate signal will be used to shut down the booster pump if a pump is started and an appropriate increase in flow rate is not detected within a set time to provide failure-to-pump protection. It will also be used to shut down all pumps if an excessive flow rate is detected for a given number of pumps operating. Reverse flow detection from the flow meter will provide a pump discharge check valve failure alarm. A totalizer pulse will also be sent to the PLC panel to provide a total flow value.

Reservoir level will be monitored by a pressure sensing level transmitter located on a port low on the side of the reservoir. This level signal will provide for general monitoring of the reservoir operation, will provide control of the booster pumps (as described elsewhere in this report), and will provide high and low level alarms. Two float type level switches will be suspended in the reservoir to provide High-High and Low-Low level backup alarms. A Low-Low level alarm will cause shutdown of all booster pumps to prevent running pumps without water. A High-High alarm can be used to turn off wells supplying the reservoir to prevent overflowing the reservoir.

Level in the hydropneumatic tank on the discharge of the booster pumps will be monitored by analog float type level sensor. This unit will also have level displays that are visible from a large distance for operator convenience. The level signal will provide for general monitoring of the tank operation, will provide start/stop control of an air compressor to maintain a desired level in the tank, and will provide high and low level alarms. Pressure switches on the tanks will be used to prevent the air compressor from over-pressuring the tanks.

6. TREATMENT PLANT

The purpose of this section is to present the assumptions and methods used to estimate the Capital and O&M costs for a treatment system to reduce the concentrations of both arsenic and fluoride in recovered water. Because the water quality is defined by a limited number of tests, plus the complexity of treating for both arsenic and fluoride, it is difficult to estimate Capital and O&M costs without pilot testing appropriate systems.

For this reason, we have estimated costs for two systems:

- Option 1 is coagulation/microfiltration system. If pilot testing shows that this method would work, then this method or a closely related method would be preferred. Coagulation/Micro-filtration would remove arsenic and fluoride in one step. The system requires highly skilled operators, and produces a waste stream that needs to be dewatered and shipped to an appropriate landfill.
- Option 2 is a two-step process: the first step removes arsenic using an iron-based sorbent, and the second step removes fluoride using activated alumina. The activated alumina produces a waste stream that results in a significant part of the cost of the system. This system is not recommended unless other technologies cannot be used.

Because of the high cost of these systems in both Capital and O&M, it is imperative that pilot testing be performed to 1) make sure that the technology will work, and 2) to have a better understanding of chemical use and waste stream generation. These factors will affect both capital and O&M costs.

At this time, and with the data in hand, we recommend pilot testing coagulation/filtration processes. If these processes do not work, there are several other options, but they will be more expensive.

6.1. INFLUENT WATER QUALITY

Table 6 shows the anticipated water quality for the years 2020 and for 2045.

Table 6. Anticipated Water Quality for Years 2020 and 2045

Constituent	Units	Year	
		2020	2045
pH	s.u.	8.03	8.69
Specific Conductance	umhos/cm	1009	427
Temperature	degree F	72.8	90.1
Akalinity	mg/L	110	138
Calcium	mg/L	29	3.48
Chloride	mg/L	85	19.8
Flouride	mg/L	2.4	5.68
Nitrate (as N)	mg/L	0.46	1.38
Potassium	mg/L	3.5	2.27
Sodium	mg/L	185	89.8
Sulfate	mg/L	230	27
Total Dissolved Solids (TDS)	mg/L	630	274
Antimony	mg/L	ND	ND
Arsenic	mg/L	0.016	0.023
Barium	mg/L	0.0034	0.011
Beryllium	mg/L	ND	ND
Cadmium	mg/L	ND	ND
Copper	mg/L	ND	0.002
Chromium	mg/L	ND	0.035
Iron	mg/L	1.2	1.85
Lead	mg/L	0.00071	0.003
Magnesium	mg/L	7.7	0.53
Mercury	mg/L	ND	NA
Nickel	mg/L	ND	ND
Selenium	mg/L	ND	ND

In addition to the results in ***Table 6***, CAP water contains silica (7.9 milligrams per liter (mg/L)) and manganese (0.0023 mg/L). For the purposes of estimating O&M costs, we assumed that the concentration of each element varies linearly over the 26 year pumping period. ***Figure 2*** shows the values assumed for arsenic and fluoride from 2020 through 2045.

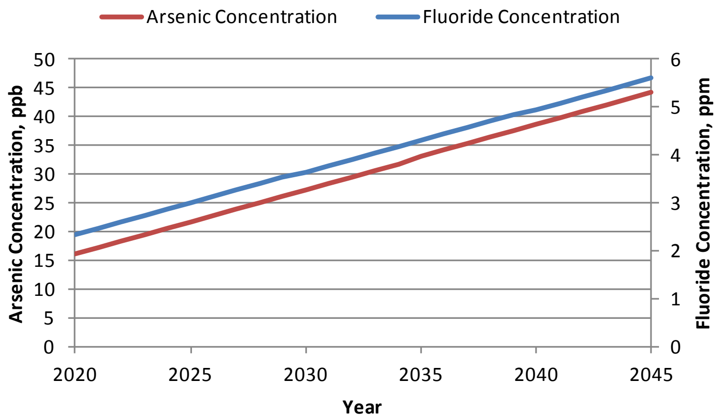


Figure 2. Assumed Arsenic and Fluoride Concentrations from 2020 through 2045

6.2. Treatment Alternatives

This section contains descriptions of the most commonly used processes used to remove arsenic and fluoride from water. Some methods may remove both, but their success depends on several water quality parameters.

6.2.1. Arsenic Treatment Alternatives

Some of the possible arsenic treatment alternatives are:

- Reverse Osmosis (RO) – not considered for TDRP because water loss is usually over 15 percent, RO requires high pressures and consume a lot of energy, and the large waste stream of brine contaminated with arsenic and fluoride needs to be treated or evaporated. This method would remove both arsenic and fluoride.
- Ion Exchange – not considered for TDRP because the influent sulfate level would make the process very inefficient with high O&M costs.
- Activated Alumina – not considered for arsenic treatment because of the large contaminated waste stream.
- Iron-based Sorbents – This is considered in Option 2. The iron-based sorbent attaches to arsenic, and the spent media is not hazardous. There is a backwash stream, but it is not hazardous and with the solids removed, the waste stream can be returned to the head of the treatment plant.
- Enhanced Lime Softening – might work for both arsenic and fluoride, but produces a large contaminated waste stream. The waste stream is dewatered and can be disposed of in a special waste capable landfill. Not considered for this project because of large waste stream, which would result in high O&M costs.
- Coagulation – There are several methods under this category. In all of the methods, a coagulant such as ferric chloride is used to join molecules together where they either settle in a

sedimentation tank or are filtered. The coagulation/microfiltration version is used to develop costs for Option 1. Produces a contaminated waste stream, but the waste stream is much smaller than enhanced lime softening.

6.2.2. Fluoride Treatment Alternatives

Some of the most common treatments for fluoride are

- RO – not considered for TDRP because water loss is usually over 15 percent (15%), RO requires high pressures and consume a lot of energy, and the large waste stream of brine contaminated with arsenic and fluoride needs to be treated or evaporated. This method would remove both arsenic and fluoride.
- Activated Alumina – this was not used for arsenic because of the large contaminated waste stream, but is evaluated in Option 2 for fluoride removal. Based on the levels of arsenic and fluoride to be treated, the waste stream, while still large, is much smaller than for arsenic removal.
- Enhanced Lime Softening – might work for both arsenic and fluoride, but produces a large contaminated waste stream. The waste stream is dewatered and can be disposed of in a special waste capable landfill. Not considered for this project because of large waste stream, which would result in high O&M costs.
- Coagulation – There are several methods under this category. In all of the methods, a coagulant such as ferric chloride is used to join molecules together where they either settle in a sedimentation tank or are filtered. The coagulation/microfiltration version is used to develop costs for Option 1. Produces a contaminated waste stream, but the waste stream is much smaller than enhanced lime softening.

6.3. ALTERNATIVES EVALUATED

Of the options listed in ***Sections 6.2.1*** and ***6.2.2***, two were considered in the Capital and O&M cost analysis:

- Option 1 – coagulation assisted microfiltration. System includes pre-oxidation to convert arsenic (III) to arsenic (IV), addition of coagulant, mixing, flocculation, settling, filtration, and sludge dewatering.
- Option 2 – iron-based sorbent for arsenic removal and activated alumina is used for fluoride removal. System includes pre-oxidation to convert arsenic (III) to arsenic (IV), multiple tanks of iron-based sorbent for arsenic removal, backwash settling basin, dewatering facilities, multiple tanks of activated alumina, pH adjustment prior to activated alumina, pH adjustment following activated alumina, activated alumina regeneration system, and evaporation ponds for regeneration waste.

It is assumed that construction will occur in three phases concurrent with the well construction phasing. ***Table 7*** shows the phasing for the two options.

Table 7. Construction Phasing for Two Arsenic/Fluoride Treatment Options

Phase	Flow (af/yr)	Construction	
		Option 1	Option 2
1	10,000	1. One-third of coagulation/filtration facilities 2. Dewatering facilities	1. One-third of iron-based media facilities. 2. Dewatering facilities
2	20,000	1. One-third of coagulation/filtration facilities	1. One-third of iron-based media facilities 2. One-half of activated alumina facilities 3. One-half of evaporation pond area
3	30,000	1. One-third of coagulation/filtration facilities	1. One-third of iron-based media facilities 2. One-half of activated alumina facilities 3. One-half of evaporation pond area

Constituent concentrations are expected to increase linearly from samples taken post-recharge, representing predominantly CAP influenced water, to samples taken prior to recharge, representing groundwater influenced samples and concentrations expected in year 26. ***Table 8*** presents a qualitative examination of the sensitivity of treatment system Capital and O&M costs to changes in the maximum arsenic and fluoride levels.

Table 8. Treatment System Costs Sensitivity to Arsenic and Fluoride Concentrations

Event	Option 1 Coagulation/microfiltration	Option 2 Media Filters
Increased Fluoride	Capital costs not sensitive; O&M costs slightly sensitive to increased fluoride at end of project.	Capital and O&M costs close to proportional to increased fluoride concentration at end of project;.
Decreased Fluoride	O&M costs slightly sensitive to decreased fluoride at end of project.	O&M costs close to proportional to fluoride concentration.
Increased Arsenic	Capital and O&M costs slightly sensitive to increased arsenic at end of project.	Capital and O&M costs close to proportional to increases in arsenic concentration.
Decreased Arsenic	O&M costs slightly sensitive to decreases in arsenic concentrations.	O&M costs proportional to decreases in arsenic concentrations.

The result of ***Table 8*** is that the Capital and O&M cost for Option 1 are less sensitive to changes in the concentrations of arsenic and fluoride than Option 2, and Option 2 Capital and O&M costs could increase significantly if concentrations of fluoride, and to a lesser extent, arsenic are greater than the values predicted by groundwater sampling and the assumptions associated with intermediate values.

6.4. ASSUMPTIONS COMMON TO BOTH ALTERNATIVES

This section contains assumptions that were the same for Options 1 and 2.

- O&M costs are based on the quantity of water treated and on the concentrations of influent arsenic and fluoride.

- Loaded labor rate is $75/hour.
- Power is $0.0342/kWH – based on 1,520 on-peak hours per year at $0.04076/kWH and 5,110 off-peak hours per year at $0.03219/kWH.
- Engineering is 10 percent (10%) of Capital cost.
- Contingency is 25 percent (25%) of Capital cost.
- Capital and O&M costs are in 2015 dollars. For construction, if source was from an earlier year, the RSMeans Index was used to convert to 2015 dollars. For O&M, if source was from an earlier year, the Bureau of Labor Statistics Consumer Price Index was used to convert to 2015 dollars.
- Arsenic is treated to 10 ppb.
- Fluoride is treated to 4 ppm.
- Treatment is designed for arsenic and fluoride removal, and not to meet other drinking water standards. (There is one exception: for Phases 2 and 3 of Option 2, pH adjustment will be required so that treated water will meet the secondary drinking water standard for pH).
- When sizing bypass versus treatment flows, all treatment units are considered 95 percent (95%) efficient.
- Both arsenic treatment options require pre-oxidation to oxidize arsenic(III) to arsenic(V).
  - Capital and O&M costs are based on methods in EPA (2000).
  - Chlorine system with dose of 1.5 mg/L treated water.
- Both options require dewatering of a waste stream.
- Removal of waste solids is $65/ton, which includes hauling and landfill fees.
- Costs include electronic control system.
- Costs include concrete pads and structures.

6.5. ASSUMPTIONS FOR OPTION 1: COAGULATION/MICROFILTRATION

Option 1 is a single-stage coagulation assisted microfiltration treatment plant. The coagulant changes surface charge properties allowing agglomeration or enmeshment of particles that will settle out of solution by gravity. The treatment system will be built in three equal size phases. Each phase will be sized for one-third of the maximum treated flow, which should occur in 2045.

Except where specifically noted, Capital and O&M costs are based on methods in EPA (2000). Other assumptions used to estimate Capital and O&M costs for Option 1 are

- Capital cost is based on highest mass flow rate of arsenic, which occurs in 2045.
- Coagulant is ferric chloride at a dose of 25 mg/L.
- Rapid mix tank sized for 1 minute hydraulic retention time at maximum flow rate.
- Flocculation tank sized for 20 minutes at maximum flow rate.
- Rectangular sedimentation tank sized for 1,000 gpd/SF surface area at maximum flow rate.
- Standard microfilter.
- The waste stream will be thickened, dewatered, and dried before being hauled to an appropriate landfill.

This method of treatment will produce a waste stream from the sedimentation tank and from cleaning the microfilters. The waste stream will be thickened, dewatered, and dried before being hauled to a special materials landfill.

6.6. ASSUMPTIONS FOR OPTION 2: MEDIA FILTERS

Option 2 is a two-stage system with iron-based sorbent media filters for iron removal followed by activated alumina for fluoride removal. The arsenic treatment plant will be phased in three equal sizes coincident with the increases in flow, but since fluoride is not expected to exceed 4 mg/L until year 14 (2024), the fluoride treatment system is built in two equal size phases, with the first phase being built at the same time as the second arsenic phase.

Activated alumina can either be replaced or regenerated when it wears out. In this case, replacing the activated alumina is more expensive than regeneration. This estimate is based on evaporating the regeneration waste stream in large evaporation beds (66 acres total), and at the end of the project hauling the contaminants to an appropriate landfill. It is assumed that the evaporation beds will be double lined with a leak detection system between liners. The cost of the contaminated solids at the end of the project is included as part of the O&M cost in the year 2046.

Except where specifically noted, Capital and O&M costs are based on methods in EPA (1998), EPA (2000), and Westerhoff et al. (2006). Other assumptions used to estimate Capital and O&M costs for Option 2 are:

- Capital costs for arsenic treatment are based on the highest mass flow rates of arsenic and fluoride, which occurs in 2045.
- Arsenic treatment will be by an iron-based sorbent sized to provide 6.7 minutes of Empty Bed Contact Time (EBCT).
- Media cost and replacement frequency are based on Bayoxide E33 media.
- The arsenic treatment plant will be built in three equal phases and sized to handle the maximum treatment flow.
- The arsenic treatment media will be replaced when breakthrough occurs. Arsenic media is not hazardous and can be disposed of in an appropriate landfill.
- The arsenic filters will be backwashed occasionally, and the backwash water will be processed so that most of the water can be sent back through the system; the solids will be thickened, dewatered, and sent to a landfill. The backwash is not hazardous.
- Fluoride treatment will be by activated alumina sized to provide 7.5 minutes EBCT.
- The fluoride treatment plant will be built in two equal phases and sized to handle maximum treatment flow. Construction of the first phase of fluoride treatment facilities is concurrent with construction of the second phase of arsenic treatment facilities.
- It was assumed that 10 percent of the activated alumina media would be replaced each year to make up for losses during the backwash and regeneration cycles.
- The activated alumina filters will be regenerated when breakthrough occurs.

- A base will be added after fluoride treatment to raise the pH to a minimum of 6.5 to meet secondary drinking water standards.
- There are not significant concentrations of competing ions for either the iron-based sorbent or activated alumina. The presence of competing ions would increase both Capital and O&M costs.
- Waste from the regeneration of the activated alumina filters will be sent to evaporation ponds.
- The evaporation ponds will be built in two 33-acre phases.
- It is assumed that little earthwork will be required to construct the evaporation ponds, and that the construction cost for the evaporation ponds is $3.25/ft^2.
- The evaporation pond costs are based on a two-liner system with leak detection.
- When the project is complete, solids from the evaporation ponds will be hauled to a landfill.
- Removal of the liner is not included in the Option 2 cost estimate.

7. COST ESTIMATES

This section includes Capital and O&M cost options for the well field, treatment related pumping, and treatment. The final section provides present value costs for the two treatment options combined with the well field and treatment related pumping.

7.1. CAPITAL COST OVERVIEW

Capital Costs included in this Memorandum are those expenditures required to construct the civil, mechanical, and electrical components of the following:

- Pumping equipment for Wells R-1 through R-9;
- The well-field pipelines;
- Site electrical equipment involved in control and operation;
- An electrical and control building located near the booster pumps;
- The 3.0 MG reservoir and associated appurtenances;
- Booster pumps to deliver water from the reservoir to the treatment systems;
- Two alternative treatment options and associated items;
- Contingency costs to account for uncertainties and unforeseeable elements involving increased costs associated with the normal execution of a project;
- Contractor profit;
- Detailed engineering design;
- Construction management; and
- Legal, permitting, and administration.

The Capital costs in this Memorandum do not include:

- Well drilling and construction (estimated by M&A);
- The 15 kV transmission lines supplying electrical power;

- A new discharge from the treatment system into the CAP canal. This proposal assumes that the existing inlet can be re-purposed as an outlet.

7.2. WELL FIELD RELATED PUMPING CAPITAL COSTS

Table 9 shows the Capital cost by phasing related to equipping of wells and construction of pipelines.

Table 9. Well Field Related Pumping Capital Costs

	Capital Cost			
	Phase I	**Phase II**	**Phase III**	**Total**
Civil/Mechanical	$1,680,000	$1,620,000	$1,620,000	$4,920,000
Electrical and Controls	$1,176,000	$1,176,000	$1,176,000	$3,528,000
Pipelines	$1,325,000	$921,000	$365,000	$2,611,000
Subtotal	**$4,181,000**	**$3,717,000**	**$3,161,000**	**$11,059,000**
3% Mobilization/ demobilization	$125,000	$112,000	$95,000	$332,000
10% Engineering and Permitting	$418,000	$372,000	$316,000	$1,106,000
8% Construction Management	$334,000	$297,000	$253,000	$885,000
15% Contingency	$627,000	$558,000	$474,000	$1,659,000
Total	**$5,686,000**	**$5,055,000**	**$4,299,000**	**$15,040,000**

7.3. TREATMENT RELATED PUMPING CAPITAL COSTS

Table 10 shows the Capital costs associated with the treatment pump station.

Table 10. Pump Station Related Capital Costs

	Capital Cost			
	Phase I	**Phase II**	**Phase III**	**Total**
Reservoir	$1,600,000			$1,600,000
Booster Station Manifolds	$550,000	$550,000	$550,000	$1,650,000
Controls and Electrical Design	$566,000	$155,000	$155,000	$876,000
Subtotal	**$2,716,000**	**$705,000**	**$705,000**	**$4,126,000**
3% Mobilization/ demobilization	$81,500	$21,000	$21,000	$123,500
10% Engineering and Permitting	$271,500	$70,500	$70,500	$412,500
8% Construction Management	$217,500	$56,500	$56,500	$330,500
15% Contingency	$407,500	$106,000	$106,000	$619,500
Total	**$3,694,000**	**$959,000**	**$959,000**	**$5,612,000**

7.4. TREATMENT PLANT CAPITAL COSTS

This Section contains Opinions of O&M Costs for the two treatment options. ***Section 7.9*** provides a comparison of the two options. All costs are in 2015 dollars.

7.4.1. Option 1: Coagulation/Microfiltration

Table 11 shows the cost opinion for each phase of Option 1. Option 1 comprises pre-oxidation, coagulation-assisted microfiltration, dewatering facilities, and an assumed $250,000 cost for pilot testing in 2016. The dewatering facilities for all phases are built in the first phase.

Table 11. Capital Cost Opinion for Option 1: Coagulation Assisted Microfiltration

	Capital Cost			
	Phase I	**Phase II**	**Phase III**	**Total**
Pilot Test (2016)	$250,000			$250,000
Pre-Oxidation	$127,000	$127,000	$127,000	$381,000
Coagulation/Microfiltration	$12,012,000	$12,012,000	$12,012,000	$36,036,000
Dewatering/Sludge Handling	$1,000,000			$1,000,000
Subtotal	**$13,389,000**	**$12,139,000**	**$12,139,000**	**$37,667,000**
10% Engineering	$1,338,900	$1,213,900	$1,213,900	$3,766,700
25% Contingency	$3,347,250	$3,034,750	$3,034,750	$9,416,750
Total	**$18,075,150**	**$16,387,650**	**$16,387,650**	**$50,850,450**

7.4.2. Option 2: Media Filters

Table 12 shows the cost opinion for each phase of Option 2. Option 2 comprises pre-oxidation and iron sorbent media filters to remove arsenic, activated alumina media filters for fluoride removal, dewatering facilities, evaporation ponds for activated alumina regeneration waste, and an assumed $250,000 cost for pilot testing in 2016.

Table 12. Capital Cost Opinion for Option 2: Iron-Based Sorbent and Activated Alumina.

	Capital Cost			
	Phase I	**Phase II**	**Phase III**	**Total**
Pilot Test (2016)	$250,000			$250,000
Pre-oxidation	$127,000	$127,000	$127,000	$381,000
Arsenic Treatment (Iron Media)	$5,637,000	$5,637,000	$5,637,000	$16,911,000
Dewatering/Sludge Handling	$1,000,000			$1,000,000
Fluoride Treatment (Activated Alumina)		$1,917,000	$1,917,000	$3,834,000
Evaporation Ponds (66 acres total)		$5,373,000	$5,373,000	$10,746,000
Subtotal	**$7,014,000**	**$13,054,000**	**$13,054,000**	**$33,122,000**
10% Engineering	$701,400	$1,305,400	$1,305,400	$3,312,200
25% Contingency	$1,753,500	$3,263,500	$3,263,500	$8,280,500
Total	**$9,468,900**	**$17,622,900**	**$17,622,900**	**$44,714,700**

7.5. OPERATIONS AND MAINTENANCE COST OVERVIEW

Annual O&M costs will include electrical costs associated with pumping, maintenance costs associated with maintaining and replacing well equipment, and maintenance costs associated with maintaining and replacing electrical equipment. Other O&M costs include those associated with the treatment plant. Those costs have been presented previously in ***Section 7.8***.

7.6. WELL FIELD RELATED PUMPING OPERATIONS AND MAINTENANCE COSTS

Table 13 shows the O&M costs associated with pumping of recovery wells.

Table 13. Well Field Related O&M Costs

Phase	Years	Annual Operations and Maintenance			
		Electricity	Well Pumps	Electrical Equipment	Total
I	1-10	$520,000	$80,000	$27,000	**$627,000**
II	11-20	$1,160,000	$160,000	$54,000	**$1,374,000**
III	21-26	$1,930,000	$239,000	$81,000	**$2,250,000**

Attachment A provides details on how the cost of electricity was calculated using APS's published rate schedule (***Attachment B***) and the amount of pumping required. O&M costs for well pumps include the normalized cost of periodic maintenance and replacement of pump lineshafts and motors. O&M costs for electrical equipment includes the normalized cost of periodic replacement of that equipment.

7.7. TREATMENT RELATED PUMPING OPERATIONS AND MAINTENANCE COSTS

Table 14 shows the O&M costs related to the reservoir and treatment system pump station.

Table 14. Treatment Related Pumping O&M Costs

Phase	Years	Annual Operations and Maintenance			
		Electricity	Pumps	Electrical Equipment	Total
I	1-10	$40,000	$7,000	$9,000	**$56,000**
II	11-20	$80,000	$14,000	$18,000	**$112,000**
III	21-26	$120,000	$21,000	$27,000	**$168,000**

The cost of electricity was calculated in the same manner as described in ***Attachment A,*** using APS's published rate schedule (***Attachment B***) and the amount of pumping required. O&M costs for booster pumps include the normalized cost of periodic maintenance and replacement of the pumps and their motors. O&M costs for electrical equipment includes the normalized cost of periodic replacement of that equipment.

7.8. Treatment Operations and Maintenance Costs

This section contains opinions of O&M costs for the two treatment options. ***Section 7.9*** contains a comparison of the two options. All costs are in 2015 dollars.

7.8.1. Option 1: Coagulation/Microfiltration

Table 15 is the O&M cost opinion for Option 1 by year. O&M costs include labor, power, chemicals, and solids disposal. The total O&M cost for Option 1 is $16,796,000.

Table 15. O&M Cost Opinion Option 1: Coagulation Assisted Microfiltration

Year	O&M Cost	Year	O&M Cost
2020	$260,000	2033	$689,000
2021	$278,000	2034	$699,000
2022	$294,000	2035	$708,000
2023	$308,000	2036	$717,000
2024	$321,000	2037	$725,000
2025	$332,000	2038	$733,000
2026	$342,000	2039	$740,000
2027	$351,000	2040	$1,073,000
2028	$360,000	2041	$1,083,000
2029	$367,000	2042	$1,092,000
2030	$653,000	2043	$1,101,000
2031	$666,000	2044	$1,109,000
2032	$678,000	2045	$1,117,000

7.8.2. Option 2: Media Filters

Table 16 is the O&M cost opinion for Option 2 by year. O&M costs include labor, power, chemicals, media, and disposal of spent media and backwash solids. The O&M expense in the year 2046 is for the disposal of the solid waste from the evaporation ponds. The total O&M cost for Option 2 is $92,199,000.

Table 16. O&M Cost Opinion for Option 2: Iron-Based Sorbent and Activated Alumina

Year	O&M Cost	Year	O&M Cost
2020	$394,000	2034	$3,297,000
2021	$468,000	2035	$3,576,000
2022	$546,000	2036	$3,852,000
2023	$627,000	2037	$4,123,000
2024	$710,000	2038	$4,391,000
2025	$795,000	2039	$4,655,000
2026	$882,000	2040	$7,296,000
2027	$971,000	2041	$7,684,000
2028	$1,061,000	2042	$8,067,000
2029	$1,152,000	2043	$8,447,000
2030	$2,380,000	2044	$8,824,000
2031	$2,566,000	2045	$9,197,000
2032	$2,753,000	2046	$472,000
2033	$3,013,000		

7.9. PRESENT VALUE ANALYSIS

This section presents the results of four present value analyses:

- The well field pumping Capital and O&M,
- Treatment related pumping Capital and O&M,
- The two treatment options Capital and O&M, and
- The treatment options combined with costs associated with the well field and treatment related pumping.

The real discount rate (as opposed to nominal discount rate) is used for the calculation of the present value. The present value was calculated for 5 discount rates: 0, 1, 2, 3, and 4 percent. The present value is based on the Capital and O&M costs presented in this memorandum unless otherwise noted. It was assumed that the equipment had no value at the end of the project, and that all of the equipment remained in place.

7.9.1. Present Value of Well Field Pumping

Table 17 shows the present value of the well field pumping Capital and O&M. It was assumed that Capital costs would occur in 2019, 2029, and 2039.

Table 17. Present Value (2015) of Well Field Pumping Capital and O&M.

Real Discount Rate	Present Value
0%	$48,550,000
1%	$40,144,000
2%	$33,480,000
3%	$28,160,000
4%	$23,885,000

7.9.2 Present Value of Treatment Related Pumping

Table 18 shows the present value for the pumping facilities and forebay reservoir associated with treatment. Present values are based on the Capital and O&M values in ***Tables 10*** and ***14***. It was assumed that Capital costs would occur in 2019, 2029, and 2039.

Table 18. Present Value (2015) of Treatment Related Pumping Capital and O&M

Real Discount Rate	Present Value
0%	$8,300,000
1%	$7,266,000
2%	$6,420,000
3%	$5,720,000
4%	$5,137,000

7.9.2. Present Value of Treatment Options

This section contains the present value of the Capital and O&M costs for the two treatment options. The present value is based on an assumed $250,000 cost for pilot testing in 2016, Phase I Capital costs in 2019, Phase II Capital costs in 2029, and Phase III Capital costs in 2039. For Option 2, the Capital costs for Fluoride treatment occur in two phases: 2029 and 2039. The actual cost of pilot testing will depend on the options tested, and for how long. O&M costs are according to ***Tables 15*** and ***16***. ***Table 19*** contains the present value costs for Options 1 and 2.

Table 19. Present Value (2015) for Treatment Options 1 and 2

Real Discount Rate	Treatment Option 1	Treatment Option 2
0%	$67,646,000	$136,914,000
1%	$57,650,000	$110,378,000
2%	$49,560,000	$89,672,000
3%	$42,965,000	$73,421,000
4%	$37,549,000	$60,588,000

7.9.3. Combined Present Values

Table 20 shows the present value as a function of the real discount rate for the two treatment options (***Table 19***) combined with the well field pumping costs (***Table 17***) and the pump station and reservoir associated with treatment (***Table 18***). For comparison, ***Table 20*** also includes the present value cost without treatment, which is the same as ***Table 17***: present value of the well field pumping O&M.

Table 20. Present Value (2015) for Treatment Options 1 and 2 combined with Well Field and Treatment Related Pumping

Real Discount Rate	Treatment Option 1 plus All Pumping	Treatment Option 2 plus All Pumping	Well Field Pumping without Treatment
0%	$124,496,000	$193,764,000	$48,550,000
1%	$105,060,000	$157,788,000	$40,144,000
2%	$89,460,000	$129,572,000	$33,480,000
3%	$76,845,000	$107,301,000	$28,160,000
4%	$66,571,000	$89,610,000	$23,885,000

The purpose of showing two treatment options (***Tables 19*** and ***20***) is to provide a range of treatment costs as opposed to providing a decision tool. The appropriate treatment system is the one that can meet the project goals with the lowest life cycle cost. Pilot testing is required to choose a system that will meet project goals, and to refine the Capital and O&M costs.

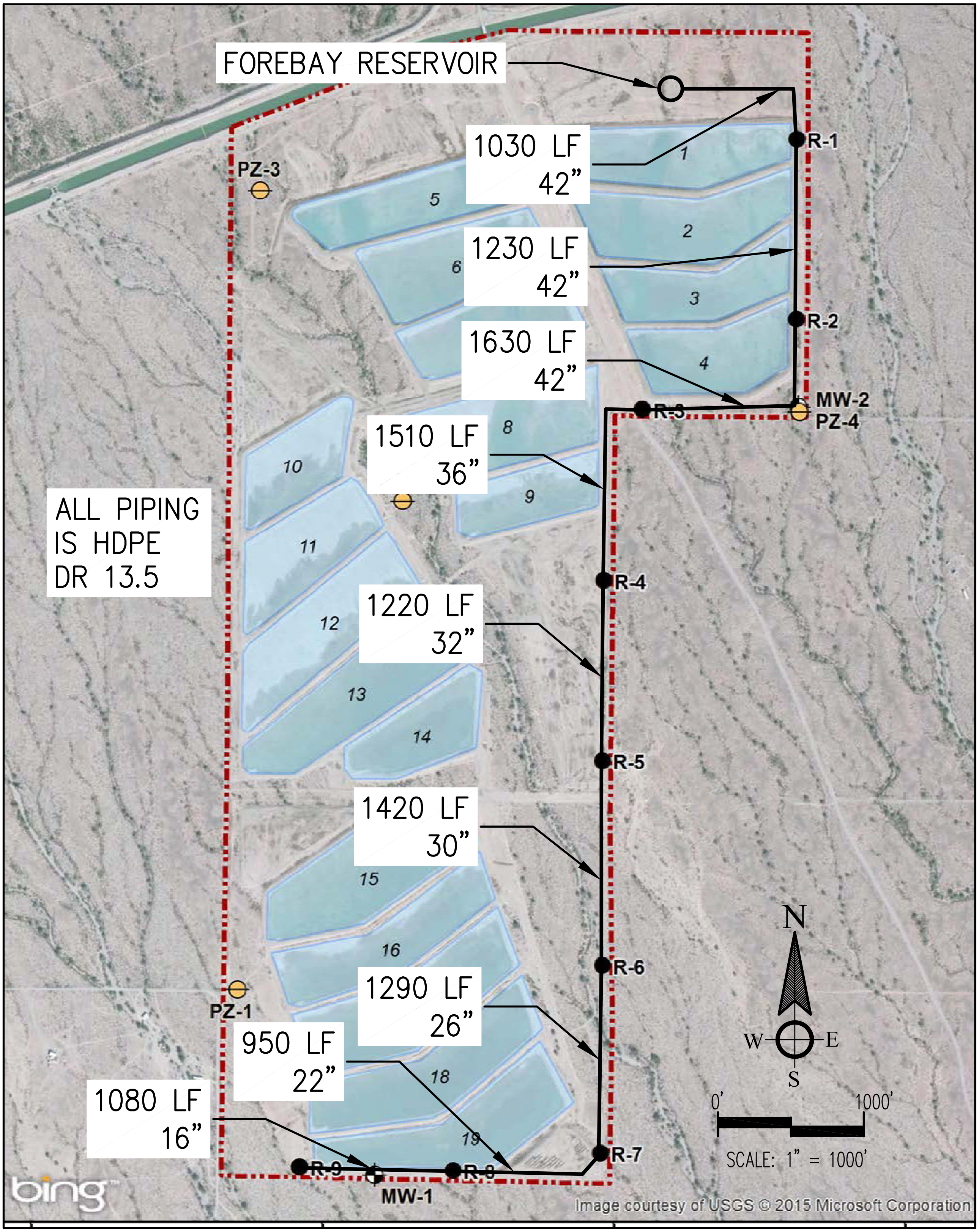
8. REFERENCES

U.S. Environmental Protection Agency (EPA). 1984. Design Manual: Removal of Fluoride from Drinking Water Supplies by Activated Alumina.

U.S. Environmental Protection Agency (EPA). 2000. Technologies and Costs for Removal of Arsenic from Drinking Water. Office of Water 4606.

Westerhoff, Paul, Mechelle De Haan, Alan Martindale, and Mohammad Badruzzaman. 2006. Arsenic Adsorptive Media Technology Selection Strategies. *Water Qual. Res. J.* Canada, 2006. Volume 41, pp 171-184.

FIGURE



TONOPAH DESERT RECHARGE PROJECT

RECOVERY WELLFIELD AND TREATEMENT PLANT

FIGURE 1 — PIPELINES

WestLand Resources, Inc.
Tucson • Phoenix • Flagstaff
4001 E. Paradise Falls Drive
Tucson, Arizona 85712 (520) 206-9585

MONTGOMERY & ASSOCIATES

JUNE 16, 2015

W:\Jobs\1900's\1916.01\ENG\Memorandum\Figure 1.dwg Jun 16, 2015 – 3:53pm patrickm

ATTACHMENT A

WELL FIELD AND TDH

ATTACHMENT A

Electrical Costs, TDH Calculations, and Horsepower Calculations

The cost of electricity is based on APS's "Rate Schedule E-35; Extra Large General Service; Time of Use." This rate schedule consists of 3 primary "charges", a "basic service charge", a "demand charge", and an "energy charge." The costs associated with each "charge" is as follows:

"Basic Service Charge:"

For Service at Primary Voltage:	$3.881	per day

"Demand Charge:"

Primary Service:	$15.792	Per On-Peak kW, plus
	$2.966	Per Off-Peak kW

"Energy Charge:"

	$0.04076	Per kWh during On-Peak hours, plus
	$0.03219	Per kWh during Off-Peak hours

Based on the above charges, it is advantageous for CAP to operate its recovery wellfield during Off-Peak hours as much as possible. It has been recommended that the wellfield be operated 7 months out of the year, running only during the off-peak hours (14 hours per day). The remaining 5 months of the year would need to be run 24 hours per day, during both off-peak and on-peak times. It should be noted, that the 5 months of 24 hour operation should not occur during the 6 summer billing months of May to October. Operating during on-peak hours during these 6 months would result in CAP being charged a Demand Charge based on "80% of the highest On-Peak kW measured during the 6 summer billing months of the 12 months ending with the current month" (see APS Rate Schedule E-35, page 3, "Determination of KW"). This charge is understood to then apply for all billing months of the year. If CAP operates the wellfield primarily in the winter, then the "Demand Charge" would be calculated differently and would instead be calculated as the average kW supplied during the 15-minute period of maximum power use during the off-peak and on-peak hours. The calculation of the 3 primary "charges" are shown in more detail below.

Basic Service Charge

The "Basic Service Charge" is calculated as:

$$Basic\ Service\ Charge\ \left(\frac{\$}{month}\right) = \frac{\$118.05}{month} = \frac{\$3.881}{day} \times \frac{365\ days}{Year} \times \frac{1\ Year}{12\ months}$$

Demand Charge

The "Demand Charge" is calculated based on the maximum power draw. WestLand has calculated the maximum power draw as the sum of all of the well motors' maximum horsepower, converted into kW, as shown in ***Table 1.***

$$Highest\ Power\ Draw\ (kW) = Number\ of\ Motors \times Motor\ Size\ (hp) \times \frac{746\ watts}{hp} \times \frac{1\ kW}{1000\ watts}$$

Table 1 – Wells, Motors, and Peak Power Draw per Phase

Phase	Number of Wells and Corresponding Motors	Motor Size (HP)	Highest Power Draw (kW)
I	3	900	2014
II	6	900	4028
III	9	900	6043

This calculation assumes that all wells will be equipped with 900 HP motors from the very first phase of the project.

The On Peak and Off Peak "Demand Charges" are calculated as follows:

$$On\ Peak\ Demand\ Charge\ \left(\frac{\$}{month}\right) = \frac{\$31{,}808.25}{month} = \frac{\$15.792}{On\ Peak\ kW} \times 2014\ kW$$

$$Off\ Peak\ Demand\ Charge\ \left(\frac{\$}{month}\right) = \frac{\$5{,}974.12}{month} = \frac{\$2.966}{On\ Peak\ kW} \times 2014\ kW$$

Table 2 summarizes the monthly "Demand Charge" for each phase below:

Table 2 – On Peak and Off Peak "Demand Charge" by Phase

Phase	Highest Power Draw (kW)	Off-Peak Demand Charge ($/month)	On-Peak Demand Charge ($/month)
I	2014	$5,974.12	$31,808.25
II	4028	$11,948.23	$63,616.49
III	6043	$17,922.35	$95,424.74

The motor size is determined as shown in section 2.2.2 of the report.

Energy Charge

The "Energy Charge" is based off of how much energy (in kWh) is actually consumed by each well. To determine this energy usage, the actual power draw by each well's motor must be calculated. This was calculated using the following equation:

$$Motor\ Power\ Output\ (hp) = \frac{\frac{(TDH) \times (Flow)}{(3960)} + Lineshaft\ and\ Bearing\ Loss}{(\eta_{wire\ to\ water})}$$

Where TDH is total dynamic head in the units of feet of water, $\eta_{wire\ to\ water}$ is the overall efficiency of the pump and motor (assumed to be 0.75), flow is in gpm (2756 gpm per well), and the $Lineshaft\ and\ Bearing\ Loss$ was estimated to be ~25 hp for each well based off of Simflo's vertical turbine catalogue. The motor power required for each well during years 26, 21, 20, 11, 10, and 1 are provided at the end of this section in ***Table 4.***

After knowing the Motor Power Output for each well/motor, energy use per month can be calculated as follows:

$$Energy\ \left(\frac{kWh}{month}\right) = \sum Motor\ Power\ Outputs\ (hp) \times 0.746\ \frac{kW}{hp} \times \frac{hours\ of\ operation}{month}$$

Based off of APS's "Rate Schedule E-35", page 3, "Time Periods", on-peak hours are the 10 hours occurring from 11 AM – 9 PM, and off-peak hours are the 14 remaining hours. From this the On-Peak and Off-Peak "Energy Charges" are calculated as:

$$On - Peak\ Energy\ Charge\ \left(\frac{\$}{month}\right) = Energy\ \left(\frac{kWh}{month}\right) \times On - Peak\ Energy\ Cost\ \left(\frac{\$\ 0.04076}{kWh}\right)$$

$$Off - Peak\ Energy\ Charge\ \left(\frac{\$}{month}\right) = Energy\ \left(\frac{kWh}{month}\right) \times Off - Peak\ Energy\ Cost\ \left(\frac{\$\ 0.03219}{kWh}\right)$$

Table 3 summarizes the energy and energy costs for years 26, 21, 20, 11, 10, and 1.

Table 3 – Energy and Energy Cost by Year

Year	Off-Peak Energy (kWh)	On-Peak Energy (kWh)	Off-Peak Energy Charge ($/month)	On-Peak Energy Charge ($/month)
1	507931	362808	$16,350.31	$14,788.06
10	581810	415579	$18,728.47	$16,938.99
11	1220796	871997	$39,297.43	$35,542.61
20	1389090	992207	$44,714.79	$40,442.35
21	2223208	1588006	$71,565.06	$64,727.11
26	2407454	1719610	$77,495.94	$70,091.30

Table 4 shows the Motor Power Outputs described earlier in this section and used to calculate the "Energy Charge."

Table 4 – Motor Power, Nominal Motor Size, and TDH by Well and Year

Well	TDH (ft)	Motor Power Output (hp)	Nominal Motor Size (hp)
Year 26			
R-9	895	863	900
R-8	899	867	900
R-7	895	863	900
R-6	888	857	900
R-5	879	849	900
R-4	867	837	900
R-3	861	831	900
R-2	842	814	900
R-1	824	797	900
Year 21			
R-9	825	798	900
R-8	828	801	900
R-7	825	798	900
R-6	818	791	900
R-5	809	784	900
R-4	797	773	900
R-3	791	767	900
R-2	774	751	900
R-1	758	736	900
Year 20			
R-9			
R-8			
R-7			
R-6	746	725	900
R-5	754	733	900
R-4	755	734	900
R-3	760	738	900
R-2	749	727	900
R-1	737	717	900
Year 11			
R-9			
R-8			
R-7			
R-6	652	638	900
R-5	659	644	900
R-4	659	645	900
R-3	663	648	900
R-2	653	639	900
R-1	643	629	900
Year 10			
R-9			
R-8			
R-7			
R-6			
R-5			
R-4			
R-3	626	613	900
R-2	623	611	900
R-1	619	607	900

Year 1			
Well	**TDH (ft)**	**Motor Power Output (hp)**	**Nominal Motor Size (hp)**
R-9			
R-8			
R-7			
R-6			
R-5			
R-4			
R-3	542	536	900
R-2	540	534	900
R-1	535	530	900

Summary of Basic Service Charge, Demand Charge, and Energy Charge

All components of APS's rate structure have been discussed ("Basic Service Charge", "Demand Charge", and "Energy Charge"). WestLand recommends that the wellfield be operated in such a way that on-peak charges be avoided as much as possible. For 7 months out of the year, the monthly electric bill can be calculated as follows:

$$Monthly\ Bill\ for\ Off\ Peak\ Operation\ \left(\frac{\$}{month}\right) = Basic\ Service\ Charge + Off\ Peak\ Demand\ Charge + Off\ Peak\ Energy\ Charge$$

For 5 months out of the year, the monthly electric bill can be calculated as follows:

$$Monthly\ Bill\ for\ all\ day\ Operation\ \left(\frac{\$}{month}\right) = Basic\ Service\ Charge + Off\ Peak\ Demand\ Charge + On\ Peak\ Demand\ Charge + Off\ Peak\ Energy\ Charge + On\ Peak\ Energy\ Charge$$

Table 5, below, summarizes the monthly subtotals for all of the charges for and provides the annual cost for the years 1, 10, 11, 20, 21, and 26. Please note that the electricity costs provided in the report in section 7.6 are reported by Phase I, Phase II, and Phase III. Phase I values are the average of year 1 and 10 costs (as reported here), Phase II values are the average of year 11 and 20, and Phase III values are the average of year 21 and 26.

Table 5 – Summary of Electrical Costs by Year

Year 1	***ALT 1 - 75 % Capacity Well Field - Time of Use Electric Rates***	
	7 Months per year, Off-Peak use, 14 hr per day	**5 Months per year, Off-Peak and On-Peak, 24 hr per day**
Basic Service Charge		
Service at primary voltage	$3.881	$3.881
Days per month	30.42	30.42
Basic service charge	$118.05	$118.05
Demand Charge		
Cost for primary service on-peak	$15.792	$15.792
Cost for primary service off-peak	$2.966	$2.966
Project total power (kW)	2014.2	2014.2
Demand Charge	$5,974.12	$37,782.36
Energy Charge		
Energy cost during on-Peak	$0.04076	$0.04076
Energy cost during off-peak	$0.03219	$0.03219
On-peak energy use (kWh)	0	362808
Off-peak energy use (kWh)	507931	507931
Energy charge	$16,350.31	$31,138.37
Monthly Subtotal	**$22,442.48**	**$69,038.78**
Annual Total		**$502,291.24**

Year 10	***ALT 1 - 75 % Capacity Well Field - Time of Use Electric Rates***	
	7 Months per year, Off-Peak use, 14 hr per day	**5 Months per year, Off-Peak and On-Peak, 24 hr per day**
Basic Service Charge		
Service at primary voltage	$3.881	$3.881
Days per month	30.42	30.42
Basic service charge	$118.05	$118.05
Demand Charge		
Cost for primary service on-peak	$15.792	$15.792
Cost for primary service off-peak	$2.966	$2.966
Project total power (kW)	2014.2	2014.2
Demand Charge	$5,974.12	$37,782.36
Energy Charge		
Energy cost during on-Peak	$0.04076	$0.04076
Energy cost during off-peak	$0.03219	$0.03219
On-peak energy use (kWh)	0	415579
Off-peak energy use (kWh)	581810	581810
Energy charge	$18,728.47	$35,667.47
Monthly Subtotal	**$24,820.64**	**$73,567.88**
Annual Total		**$541,583.85**

Year 11	*ALT 1 - 75 % Capacity Well Field - Time of Use Electric Rates*	
	7 Months per year, Off-Peak use, 14 hr per day	**5 Months per year, Off-Peak and On-Peak, 24 hr per day**
Basic Service Charge		
Service at primary voltage	$3.881	$3.881
Days per month	30.42	30.42
Basic service charge	$118.05	$118.05
Demand Charge		
Cost for primary service on-peak	$15.792	$15.792
Cost for primary service off-peak	$2.966	$2.966
Project total power (kW)	4028.4	4028.4
Demand Charge	$11,948.23	$75,564.73
Energy Charge		
Energy cost during on-Peak	$0.04076	$0.04076
Energy cost during off-peak	$0.03219	$0.03219
On-peak energy use (kWh)	0	871997
Off-peak energy use (kWh)	1220796	1220796
Energy charge	$39,297.43	$74,840.03
Monthly Subtotal	**$51,363.71**	**$150,522.81**
Annual Total		**$1,112,159.97**

Year 20	*ALT 1 - 75 % Capacity Well Field - Time of Use Electric Rates*	
	7 Months per year, Off-Peak use, 14 hr per day	**5 Months per year, Off-Peak and On-Peak, 24 hr per day**
Basic Service Charge		
Service at primary voltage	$3.881	$3.881
Days per month	30.42	30.42
Basic service charge	$118.05	$118.05
Demand Charge		
Cost for primary service on-peak	$15.792	$15.792
Cost for primary service off-peak	$2.966	$2.966
Project total power (kW)	4028.4	4028.4
Demand Charge	$11,948.23	$75,564.73
Energy Charge		
Energy cost during on-Peak	$0.04076	$0.04076
Energy cost during off-peak	$0.03219	$0.03219
On-peak energy use (kWh)	0	992207
Off-peak energy use (kWh)	1389090	1389090
Energy charge	$44,714.79	$85,157.14
Monthly Subtotal	**$56,781.07**	**$160,839.92**
Annual Total		**$1,201,667.11**

Year 21	*ALT 1 - 75 % Capacity Well Field - Time of Use Electric Rates*	
	7 Months per year, Off-Peak use, 14 hr per day	**5 Months per year, Off-Peak and On-Peak, 24 hr per day**
Basic Service Charge		
Service at primary voltage	$3.881	$3.881
Days per month	30.42	30.42
Basic service charge	$118.05	$118.05
Demand Charge		
Cost for primary service on-peak	$15.792	$15.792
Cost for primary service off-peak	$2.966	$2.966
Project total power (kW)	6042.6	6042.6
Demand Charge	$17,922.35	$113,347.09
Energy Charge		
Energy cost during on-Peak	$0.04076	$0.04076
Energy cost during off-peak	$0.03219	$0.03219
On-peak energy use (kWh)	0	1588006
Off-peak energy use (kWh)	2223208	2223208
Energy charge	$71,565.06	$136,292.17
Monthly Subtotal	**$89,605.46**	**$249,757.31**
Annual Total		**$1,876,024.74**

Year 26	*ALT 1 - 75 % Capacity Well Field - Time of Use Electric Rates*	
	7 Months per year, Off-Peak use, 14 hr per day	**5 Months per year, Off-Peak and On-Peak, 24 hr per day**
Basic Service Charge		
Service at primary voltage	$3.881	$3.881
Days per month	30.42	30.42
Basic service charge	$118.05	$118.05
Demand Charge		
Cost for primary service on-peak	$15.792	$15.792
Cost for primary service off-peak	$2.966	$2.966
Project total power (kW)	6042.6	6042.6
Demand Charge	$17,922.35	$113,347.09
Energy Charge		
Energy cost during on-Peak	$0.04076	$0.04076
Energy cost during off-peak	$0.03219	$0.03219
On-peak energy use (kWh)	0	1719610
Off-peak energy use (kWh)	2407454	2407454
Energy charge	$77,495.94	$147,587.24
Monthly Subtotal	**$95,536.34**	**$261,052.38**
Annual Total		**$1,974,016.24**

Total Dynamic Head

The TDH for each well was calculated as follows:

$$TDH\ (ft) = Elevation\ Head\ (ft) + Lift\ (ft\ blgs) + Column\ Loss\ (ft) + Pipe\ Loss\ (ft)$$

Where:
Elevation Head is the difference in elevation from the high water point of the forebay reservoir to the ground surface elevation of each well.

Lift is synonymous with dynamic pumping level and is equal to the static water level in the well + drawdown under pumping conditions. These values were provided by Montgomery and Associates.

Column Loss is the head loss associated with water flowing through the well column and was estimated using product data from Simflo's pump catalogue.

Pipe Loss is the head loss associated with water flowing through the HDPE transmission mains from the well to the forebay reservoir. This value was calculated using the hazen-williams equation.

Table 6 shows the TDHs, elevation heads, lifts, column losses, and pipe losses calculated for each well for years 26, 21, 20, 11, 10, and 1.

Table 6 – Column Loss, Elevation Head, Pipe Loss, Lift, and TDH by Well and Year

Year 26					
Well	**Column Loss (ft)**	**Elevation Head (ft)**	**Pipe Loss (ft)**	**Lift (ft blgs)**	**TDH (ft)**
R-9	50	90	56	699	895
R-8	50	95	47	707	899
R-7	50	96	41	708	895
R-6	50	87	33	717	888
R-5	50	75	26	728	879
R-4	50	63	20	734	867
R-3	50	55	13	742	861
R-2	50	48	9	736	842
R-1	50	34	4	736	824
Year 21					
Well	**Column Loss (ft)**	**Elevation Head (ft)**	**Pipe Loss (ft)**	**Lift (ft blgs)**	**TDH (ft)**
R-9	50	90	56	629	825
R-8	50	95	47	636	828
R-7	50	96	41	638	825
R-6	50	87	33	647	818
R-5	50	75	26	658	809
R-4	50	63	20	665	797
R-3	50	55	13	673	791
R-2	50	48	9	668	774
R-1	50	34	4	669	758
Year 20					
Well	**Column Loss (ft)**	**Elevation Head (ft)**	**Pipe Loss (ft)**	**Lift (ft blgs)**	**TDH (ft)**
R-9					
R-8					
R-7					
R-6	50	87	9	599	746
R-5	50	75	9	621	754
R-4	50	63	7	635	755
R-3	50	55	5	649	760
R-2	50	48	4	647	749
R-1	50	34	2	651	737

Year 11					
Well	**Column Loss (ft)**	**Elevation Head (ft)**	**Pipe Loss (ft)**	**Lift (ft blgs)**	**TDH (ft)**
R-9					
R-8					
R-7					
R-6	50	87	9	506	652
R-5	50	75	9	526	659
R-4	50	63	7	539	659
R-3	50	55	5	553	663
R-2	50	48	4	551	653
R-1	50	34	2	557	643
Year 10					
Well	**Column Loss (ft)**	**Elevation Head (ft)**	**Pipe Loss (ft)**	**Lift (ft blgs)**	**TDH (ft)**
R-9					
R-8					
R-7					
R-6					
R-5					
R-4					
R-3	50	55	1	519	626
R-2	50	48	<1	524	623
R-1	50	34	<1	535	619
Year 1					
Well	**Column Loss (ft)**	**Elevation Head (ft)**	**Pipe Loss (ft)**	**Lift (ft blgs)**	**TDH (ft)**
R-9					
R-8					
R-7					
R-6					
R-5					
R-4					
R-3	50	55	1	436	542
R-2	50	48	<1	441	540
R-1	50	34	<1	451	535

ATTACHMENT B

APS RATE SCHEDULE E-35

RATE SCHEDULE E-35
EXTRA LARGE GENERAL SERVICE
TIME OF USE

AVAILABILITY

This rate schedule is available in all territory served by the Company at all points where facilities of adequate capacity and the required phase and suitable voltage are adjacent to the sites served.

APPLICATION

This rate schedule is applicable to all Standard Offer and Direct Access customers whose monthly maximum demand registers 3,000 kW or more for three (3) consecutive months in any continuous twelve (12) month period ending with the current month. Service must be supplied at one point of delivery and measured through one meter unless otherwise specified by an individual customer contract.

This schedule is not applicable to breakdown, standby, supplemental, residential or resale service.

TYPE OF SERVICE

The type of service provided under this schedule will be three phase, 60 Hertz, at the Company's standard voltages that are available within the vicinity of the customer site.

Service under this schedule is generally provided at secondary voltage, primary voltage when the customer owns the distribution transformer(s), or transmission voltage.

RATES

The bill shall be computed at the following rates or the minimum rates, whichever is greater, plus any adjustments incorporated in this rate schedule:

Bundled Standard Offer Service

Basic Service Charge:

For service through Self-Contained Meters:	$ 1.183	per day, or
For service through Instrument-Rated Meters:	$ 1.795	per day, or
For service at Primary Voltage:	$ 3.881	per day, or
For service at Transmission Voltage:	$ 26.574	per day

Demand Charge:

Secondary Service:	$ 16.768	per On-Peak kW, plus
	$ 3.064	per Off-Peak kW, or
Primary Service:	$ 15.792	per On-Peak kW, plus
	$ 2.966	per Off-Peak kW, or
Transmission Service:	$ 10.755	per On-Peak kW, plus
	$ 2.462	per Off-Peak kW

The Demand Charge for military base customers taking primary service and served from dedicated distribution feeder(s) shall be reduced to $ 12.108 per On-Peak kW and $ 2.597 per Off-Peak kW.

RATES (cont)

Energy Charge:	$ 0.04076	per kWh during On-Peak hours, plus
	$ 0.03219	per kWh during Off-Peak hours

Bundled Standard Offer Service consists of the following Unbundled Components:

Unbundled Standard Offer Service

Customer Accounts Charge:	$ 0.601	per day
Revenue Cycle Service Charges:		
Metering:		
Self-Contained Meters:	$ 0.440	per day, or
Instrument-Rated Meters:	$ 1.052	per day, or
Primary:	$ 3.138	per day, or
Transmission:	$ 25.831	per day

These daily metering charges apply to typical installations. Customers requiring specialized facilities are subject to additional metering charges that reflect the additional cost of the installation, (for example, a customer taking service at 230 kV). Adjustments to unbundled metering components will result in an adjustment to the bundled Basic Service Charge.

Meter Reading:	$ 0.068	per day
Billing:	$ 0.074	per day
System Benefits Charge:	$ 0.00297	per kWh
Transmission Charge:	$ 1.776	per On-Peak kW
Delivery Charge:		
Secondary Service:	$ 6.461	per On-Peak kW, plus
	$ 0.646	per kW Off-Peak, or
Primary Service:	$ 5.485	per On-Peak kW, plus
	$ 0.548	per Off-Peak kW, or
Transmission Service:	$ 0.448	per On-Peak kW, plus
	$ 0.044	per Off-Peak kW

In addition, the Delivery Charge for military base customers taking primary service and served directly from a Company substation shall be reduced to $ 1.801 per On-Peak kW and $ 0.179 per Off-Peak kW.

Generation Charge:	$ 8.531	per On-Peak kW, plus
	$ 2.418	per Off-Peak kW, plus
	$ 0.03779	per kWh during On-Peak hours, plus
	$ 0.02922	per kWh during Off-Peak hours

DIRECT ACCESS

The bill for Direct Access customers will consist of the applicable Unbundled Components Customer Accounts Charge, the System Benefits Charge, and the Delivery Charge, plus any applicable adjustments incorporated in this schedule. Direct Access customers must acquire and pay for generation, transmission, and revenue cycle services from a competitive third party supplier. If any revenue cycle services are not available from a third party supplier and must be obtained from the Company, the applicable Unbundled Components Revenue Cycle Service Charges will be applied to the customer's bill.

POWER FACTOR

The customer deviation from phase balance shall not be greater than ten percent (10%) at any time. Customers receiving service at voltage levels below 69 kV shall maintain a power factor of 90% lagging but in no event leading unless agreed to by Company. Service voltage levels at 69 kV or above shall maintain a power factor of ± 95% at all times. In situations where Company suspects that a customer's load has a non-confirming power factor, Company may install at its cost, the appropriate metering to monitor such loads. If the customer's power factor is found to be non-conforming, the customer will be required to pay the cost of installation and removal of VAR metering and recording equipment.

Customers found to have a non-conforming power factor, or other detrimental conditions shall be required to remedy problems, or pay for facilities/equipment that Company must install on its system to correct for problems caused by the customer's load. Until such time as the customer remedies the problem to Company satisfaction, kVA may be substituted for kW in determining the applicable charge for billing purposes for each month in which such failure occurs.

MINIMUM

The bill for service under this rate schedule shall not be less than the applicable Bundled Standard Offer Service Basic Service Charge plus the applicable Bundled Standard Offer Service Demand Charge for the minimum kW specified in the agreement for service or individual customer contract.

DETERMINATION OF KW

For billing purposes, the On-Peak kW used in this rate schedule shall be the greater of the following:

1. The average On-Peak kW supplied during the 15-minute period (or other period as specified by an individual customer contract) of maximum use during the On-Peak hours of the month, as determined from readings of the Company's meter.

2. 80% of the highest On-Peak kW measured during the six (6) summer billing months (May-October) of the twelve (12) months ending with the current month.

The Off-Peak kW used in this rate schedule shall be the average kW supplied during the 15-minute period (or other period as specified by individual customer contract) of maximum use during the Off-Peak hours of the month as determined from readings of the Company's meter.

TIME PERIODS

Time periods applicable to usage under this rate schedule are as follows:

On-Peak hours:	11:00 am – 9:00 pm Monday through Friday
Off-Peak hours:	All remaining hours

TIME PERIODS (Cont)

Mountain Standard Time shall be used in the application of this rate schedule.

ADJUSTMENTS

1. The bill is subject to the Renewable Energy Standard as set forth in the Company's Adjustment Schedule REAC-1 pursuant to Arizona Corporation Commission Decision No. 70313.

2. The bill is subject to the Power Supply Adjustment factor as set forth in the Company's Adjustment Schedule PSA-1 pursuant to Arizona Corporation Commission Decision No. 67744, Arizona Corporation Commission Decision No. 69663, Arizona Corporation Commission Decision No. 71448 and 73183.

3. The bill is subject to the Transmission Cost Adjustment factor as set forth in the Company's Adjustment Schedule TCA-1 pursuant to Arizona Corporation Commission Decision No. 67744.

4. The bill is subject to the Environmental Improvement Surcharge as set forth in the Company's Adjustment Schedule EIS pursuant to Arizona Corporation Commission Decision No. 69663 and Arizona Corporation Commission Decision No. 73183.

5. Direct Access customers returning to Standard Offer service may be subject to a Returning Customer Direct Access Charge as set forth in the Company's Adjustment Schedule RCDAC-1 pursuant to Arizona Corporation Commission Decision No. 67744.

6. The bill is subject to the Demand Side Management Adjustment charge as set forth in the Company's Adjustment Schedule DSMAC-1 pursuant to Arizona Corporation Commission Decision No. 67744 and Arizona Corporation Commission Decision No. 71448.

7. The bill is subject to the applicable proportionate part of any taxes or governmental impositions which are or may in the future be assessed on the basis of gross revenues of APS and/or the price or revenue from the electric energy or service sold and/or the volume of energy generated or purchased for sale and/or sold hereunder.

CONTRACT PERIOD

The contract period for customers served under this rate schedule will be three (3) years, at the Company's option. If the Company determines that the customer service location is such that unusual or substantial distribution construction is required to serve the site, the Company may require a contract of ten (10) years or longer with a standard seven (7) year termination provision.

TERMS AND CONDITIONS

Service under this rate schedule is subject to the Company's Schedule 1, Terms and Conditions for Standard Offer and Direct Access Services and the Company's Schedule 10, Terms and Conditions for Direct Access. These schedules have provisions that may affect the customer's bill. In addition, service may be subject to special terms and conditions as provided for in a customer contract or service agreement.