TECHNICAL MEMORANDUM – INSTALLATION OF AND INVESTIGATIONS AT WELL RID-111R

JUNE
2013

WEST VAN BUREN WQARF REGISTRY SITE
PHOENIX, ARIZONA

Prepared for: **Arizona Department of Environmental Quality**

Prepared by: **Synergy Environmental, LLC**

On Behalf of: **Roosevelt Irrigation District**

SYNERGY ENVIRONMENTAL, LLC

2013
ADEQ WPD
RPS

REGISTERED GEOLOGIST
CERTIFICATE
26393
DENNIS H.
SHIRLEY
Date Signed 6/21/13
ARIZONA, U.S.A.
Expires 09/30/15

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LIST OF ABBREVIATIONS

ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
bls	below land surface
COC	Contaminant of Concern
EPA	Environmental Protection Agency
ERA	Early Response Action
gpd/ft	gallons per day per foot
gpm	gallons per minute
LAU	Lower Alluvial Unit
MAU	Middle Alluvial Unit
µg/L	micrograms per liter
PVC	polyvinyl chloride
RID	Roosevelt Irrigation District
SCADA	Supervisory Control and Data Acquisition
SWE	Southwest Exploration Service, LLC
TCE	Trichloroethene
TM	Technical memorandum
UAU	Upper Alluvial Unit
VOC	Volatile Organic Compound
WQARF	Water Quality Assurance Revolving Fund
WVBA	West Van Buren Area

June 18, 2013

INSTALLATION AND INVESTIGATIONS AT WELL RID-111R

ROOSEVELT IRRIGATION DISTRICT
EARLY RESPONSE ACTION
WEST VAN BUREN AREA WQARF SITE

1.0 INTRODUCTION

Synergy Environmental LLC (Synergy) prepared this Technical Memorandum (TM) to document the drilling and installation of a replacement water supply well at the RID-111 well site and subsequent well investigations conducted at the well, designated as RID-111R. As shown in **Figure 1**, RID-111R is located on the south side of Van Buren Street, about one-third mile west of 35th Avenue in Phoenix, Arizona. RID has operated a well at this location since at least 1943 when the existing RID-111 well (Arizona Department of Water Resources [ADWR] registration number 55-607200) was installed or deepened. According to the well log shown in **Attachment A**, the well that was completed in 1943 was 454 feet deep and constructed with 24-inch diameter casing installed from land surface to a depth of 206 feet below land surface (bls) and 16-inch diameter casing from 198 to 454 feet bls. The well casing was perforated from 55 to 192 and 206 to 442 feet bls. RID records do not indicate how long the well was in service prior to partial collapse of well casing which rendered the well inoperable. Recent video logging of the original well indicates the well was plugged with debris at a depth of 75 feet bls, which prevented any further logging of the well.

The replacement well was drilled at this site in 2011. RID authorized and installed the new well in response to requirements imposed by the Arizona Department of Environmental Quality (ADEQ) in a letter dated June 24, 2010, that approved implementation of the *RID Early Response Action Work Plan* (Montgomery & Associates, 2010a) within the West Van Buren Area (WVBA) Water Quality Assurance Revolving Fund (WQARF) Registry Site. ADEQ approved the Early Response Action (ERA) with conditions, including a requirement for RID to conduct investigation of RID wells to be used for remediation so as to insure that changes in pumping will not adversely affect groundwater quality and levels within the WVBA beyond what would be expected with the current pumping conditions. RID submitted a *Well Investigation Work Plan* on August 9, 2010 prepared by Montgomery & Associates (2010b), that was subsequently revised and resubmitted on November 24, 2010 (Montgomery & Associates, 2010c). The revised Work Plan, referred to as the *Phase 1 Well Investigation Work Plan*, summarized the proposed scope of well testing to be conducted at three (3) RID production wells, including RID-92, RID-95, and RID-114.

In order to conduct this work, RID advised[1] ADEQ that the well investigation task must be undertaken in a manner that would not damage or pose unnecessary risk to RID wells, impede RID's ability to provide critical water supply, or unnecessarily delay implementation of the ERA. To enable RID's timely performance of the work and minimize the potential impact to RID's operations from the well investigation tasks required by the ADEQ approval letter, the RID Board of Directors authorized drilling and installation of RID-111R. RID notified ADEQ of the decision to install the RID-111R well in a letter[2] dated November 15, 2010 and indicated drilling would commence in the spring of 2011. ADEQ approved the Phase 1 Work Plan, conditioned on comments provided in a letter[3] dated December 16, 2010, that was reissued with clarification on February 9, 2011. ADEQ also agreed[4] to RID's suggestion to conduct well testing at newly constructed RID-111R in lieu of RID-114 in a letter dated July 7, 2011.

Drilling and installation of the RID-111R replacement well was conducted from March through June 2011, and development of the well occurred in October 2011. The well testing program was initiated in November 2011 and was preceded by test pumping of the well consisting of a step test and 24-hour constant rate test. Well testing was discontinued, however, when it was found that the well casing was filled with sediment at a depth of 260 feet bls. The test pump was removed and additional well development was conducted to remove the fill and limit subsequent infilling. Following development, a video log confirmed the well casing was intact and sediment fill was removed from the well casing. The well testing program was resumed in February 2012 with test pumping followed by borehole logging and depth sampling under pumping conditions. In April 2012, the borehole logging and depth sampling were repeated under non-pumping conditions.

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[1] Letter from David Kimball of Gallagher & Kennedy to Henry Darwin of ADEQ dated October 28, 2010.
[2] Letter from David Kimball of Gallagher & Kennedy to Henry Darwin of ADEQ.
[3] Letter from Julie Riemenschneider of ADEQ to Dennis Shirley of Synergy Environmental.
[4] Letter from Julie Riemenschneider of ADEQ to Dennis Shirley of Synergy Environmental.

This TM presents a summary of the well drilling and installation, well testing methodology, a description of field activities for the well investigation tasks, analysis and interpretation of well investigation results, and conclusions in the following sections. Synergy prepared this TM in collaboration with Montgomery & Associates.

2.0 WELL DRILLING AND INSTALLATION

RID-111R is a replacement well drilled at the same site as the original RID-111 well. In accordance with ADWR requirements, RID submitted a *Notice of Intent (NOI) to Replace an Existing Non-Exempt Well at Approximately the Same Location* to ADWR on January 5, 2011. The NOI was approved by ADWR on February 10, 2011, and RID contracted with Weber Water Resources (Weber) of Chandler, Arizona to install the well utilizing a Cable Tool rig. Based on comments from ADWR, RID planned for the replacement well to be completed in and produce groundwater from the Upper Alluvial Unit (UAU) only.

The new well is located 27 feet southeast of the existing well, which places it in the center of the southeast quadrant of the well site. Synergy provided a copy of the *Health and Safety Plan, Roosevelt Irrigation District Well Investigations*[5] to Weber as guidance for addressing potential hazards from possible chemical exposure and risks of injury during drilling and well testing activities. Synergy provided a briefing of the *Health and Safety Plan* (HASP) for the Weber drilling crew and all personnel working at the site were asked to read and acknowledge their understanding of the HASP. Synergy also monitored the breathing zone around the work area periodically during the well testing activities using a Photoionization Detector (PID) for the presence of organic vapors. No organic vapors were detected at the well site or in storage bins used to contain groundwater pumped from the well during the drilling and well testing program. Representative samples of drill cuttings obtained during the drilling program and sediments produced during well development were analyzed for VOCs by EPA Method 8260B, polynuclear aromatic hydrocarbons by EPA Method 8310, and metals following extraction by the Toxicity Characteristics Leaching Procedure (TCLP). There were no detectable concentrations of organics or leachable metals reported. Weber disposed of the sediments as non-hazardous solid waste.

Drilling of the replacement well commenced on March 9, 2011 with installation of a 30-inch diameter steel conductor casing that was cemented in place to a depth of 20 feet bls. Weber drilled the borehole by cable tool percussion and advanced 20-inch diameter high-strength low alloy (HSLA) steel casing using the drill rig and casing jacks. The HSLA casing had a wall thickness of 0.3125 inches (5/16-inch thick). Drilling was terminated on June 14, 2011 at 428 feet bls, following identification of sticky clay in sediments penetrated at a depth of 425 feet bls. The well casing was perforated in the interval from 100 to 420

[5] A copy of the *Health and Safety Plan* was submitted to ADEQ on January 8, 2011.

feet bls using a Mills Knife Perforator with 10 cuts per round, one foot apart. The perforations were 3/8-inch wide and 3-inches long. A schematic diagram of the well completion is provided as **Figure 2.**

A copy of the Weber driller's log is included in **Attachment B** and indicates unconsolidated to semi-consolidated sediments consisting of layered clay, silt, sand, and gravels were encountered during drilling. The driller reported caving of the borehole in coarse gravels and boulders coinciding with depth intervals of 139-145, 215-220, 235-245, 270-290, 332-335, and 355-360 feet bls. The driller was requested to obtain samples for lithologic logging at 5-foot intervals, however no samples were obtained from the depths of 0-25, 65-100, 230-300, and 420-425 feet bls. Lithologic descriptions of the samples obtained are included in **Attachment C**.

The driller's log and lithologic log indicate the subsurface geology consists of alluvial sediments that are characteristic of the UAU. According to geologic interpretation provided in the *Remedial Investigation Report* (Terranext, 2012) for the WVBA WQARF Registry Site, the UAU is divided into two sub-layers consisting of an upper interval (termed UAU1) that is primarily inter-fingering sand and gravel lenses and a lower interval (termed UAU2) where clay lenses increase and dominate the lithologic horizons. The transition between the UAU and Middle Alluvial Unit (MAU) is characterized by a sequence of at least 40 feet of material often referred to as hard brown clay or sticky brown clay. MAU sediments are notably finer-grained than the overlying UAU deposits.

In vicinity of RID-111R, the UAU1 interval is present from ground surface to at least a depth of 290 feet bls. Below this depth, the occurrence and size of gravels generally decreases and the sediments become increasingly fine-grained. Although only limited clay-sized sediments were encountered in the interval from 290 to 420 feet bls, this interval likely correlates to the UAU2 horizon. The contact with the underlying MAU is inferred to coincide with the reported occurrence by the driller of sticky clay at a depth of 425 feet bls. In accordance with ADWR request, drilling was terminated upon encountering MAU sediments, and the well was completed as a UAU-only production well.

3.0 WELL TESTING METHODOLOGY

Fluid-movement investigations were used to assess the vertical distribution of flow and water quality in well RID-111R conducted in association with wellhead and depth-specific water sampling operations. Fluid-movement investigations comprised: geophysical logging to assess the physical and chemical characteristics of the groundwater, and spinner logging to measure the groundwater flow rate at all depths within the well casing. When evaluated in conjunction with laboratory analysis of depth-specific groundwater samples, these data allow determination of differences in water quality and flow rate associated with specific zones of inflow or outflow.

When a well is not used continuously, there is a potential for the well to provide a conduit for vertical movement of groundwater if a vertical hydraulic gradient exists in the portion of the aquifer penetrated or screened by the well. Although this issue is considered of little significance for a UAU only well such as RID-111R, nevertheless, fluid movement investigations were conducted during both non-pumping and pumping conditions as requested by ADEQ.

Weber conducted all pump work and the principal video surveys at well RID-111R. Southwest Exploration Services, LLC (SWE) of Gilbert, Arizona, conducted all depth-specific sampling and borehole geophysical logging, and calculated flow rate in the well using the spinner logging results. Synergy supervised aquifer testing, coordinated geophysical logging, and, in conjunction with Montgomery & Associates (M&A), selected depths for groundwater sampling, and conducted analysis of flow data and water quality results from the well investigations. Synergy informed ADEQ of the schedule of major field program activities and Terranext, ADEQ's technical support services contractor, was on-site during the borehole logging and sampling events. TestAmerica, Inc., of Phoenix, Arizona conducted all laboratory chemical analyses.

Geophysical logging and groundwater sampling tasks were conducted in the following sequential order to permit consideration of all information in the selection of sampling depths:

1) Borehole Geophysical Logging – A combination probe provided continuous measurements for fluid temperature and conductivity. A three-arm caliper tool measured the diameter of the well casing. These data were used to calculate

volumetric flow rates based on linear flow velocities measured with the spinner flow meter tool. A caliper log was obtained under pumping conditions.

2) Borehole Spinner Flow Meter Logging – A spinner flow meter measured flow rates in the well. For non-pumping conditions, the spinner flow meter was used in the following modes: 1) during downward travel at three separate constant speeds; and 2) during upward travel at three separate constant speeds. For pumping conditions, the spinner flow meter was used in the following modes: 1) during downward travel at three separate constant speeds; and 2) in a stationary position at selected depths.

3) Depth-Specific Water Sampling – Depths for sampling were selected in the field based on results of geophysical logging; ADEQ and/or Terranext were informed of the proposed depths prior to sample collection. Depth-specific groundwater samples were obtained using sampling tools lowered into the well via the geophysical contractor's wire line. Groundwater samples were analyzed for VOCs and the following general chemistry constituents and parameters: total dissolved solids content; electrical conductivity; and pH. Analyses for general chemistry were conducted to evaluate changes in general groundwater chemistry between aquifer zones. In addition, field measurements for pH, electrical conductivity, and temperature were recorded for the groundwater samples obtained when recovered sample volumes were sufficient.

Aquifer testing was conducted during the purging and pumping operations for the fluid-movement investigation.

To the extent practicable, the field activities, sampling methods, laboratory analyses, and quality assurance procedures were conducted in accordance with protocols developed for ADEQ in the *WVBA Field Sampling and Analysis Plan, Quality Assurance Project Plan, and Site-Specific Health and Safety Plan* (BE&K/Terranext, 2000a, b, and c). Wellhead and depth-specific water quality samples submitted to the laboratory were analyzed using the following methods: 1) VOCs using U.S. Environmental Protection Agency Method 8260B; 2) total dissolved solids content using Standard Method 2540 C; 3) electrical conductivity using Standard Method 2510 B; and 4) pH using Standard Method 4500-H+. Groundwater pumped from well RID-111R during development and testing operations was piped to a storage tank to settle any solids and conveyed from the tank by transfer pump to the existing below-ground conveyance of the RID Salt Canal.

4.0 WELL INVESTIGATIONS

This section describes operations conducted at well RID-111R to provide data used for interpretation of well conditions. These operations include aquifer testing, well geophysical logging, and depth-specific sampling. Interpretation of the results of these operations is given in a subsequent section of the report.

4.1 TEST PUMP INSTALLATION AND AQUIFER TESTING

Weber mobilized to the RID-111R well site in August 2011 to develop the well by bailing and swabbing initially and then pumping and surging using a test pump. Based on observed sand production that gradually lessened, RID-111R was pumped and surged a total of 61 hours from October 11 through November 4, 2011. The pumping rate during development operations ranged from 700 gpm to more than 3,500 gpm.

The test pump utilized was operated with a variable speed diesel driver to allow the flow rate to be adjusted to ramp up production during development and testing operations. The well was equipped with a two-stage, 12-inch diameter test pump set at a depth of 209 feet bls. Two access tubes were installed: a 1½-inch diameter steel pipe for sounder and transducer access was installed to a depth of 165 feet bls; and a perforated 3-inch diameter polyvinyl chloride (PVC) tube for logging tool access was installed to a depth of 212 feet bls. All equipment installed in the well or used for testing operations, including the column and access pipes, was cleaned using hot water and a high-pressure sprayer at an off-site location prior to mobilization to the site.

Prior to well development a pressure transducer was installed in RID-111R and 4 nearby monitoring wells (AVB-117-01, AVB 120-02, AVB 120-03, AVB 128-01). The transducers collected water level data every five minutes. A barometer was also installed above water level in well AVB 120-02. Well AVB-117-01 is located approximately 1,800 feet north of RID-111R, wells AVB 120-02 and AVB 120-03 are located about 3,800 feet southwest from RID-111R, and well AVB 128-01 is located about 1,600 feet southwest from RID-111R, respectively. Additionally, a pressure transducer was installed at RID-95, which is located approximately 4,300 feet southeast of RID-111R. RID executed an Environmental Access Agreement with ADEQ and a Right-of-Way Permit with the City of Phoenix to gain access to the ADEQ-owned monitoring wells.

RID conducted the pumping tests in two stages with the first being a 10-hour step test followed by a 24-hour constant rate test. The step test was initiated at 10:40 on November 8, 2011 and consisted of operating the pump at 5 separate pumping rates ranging from 1,361 to 3,313 gpm for 2 hours each until 20:45. **Figure 3** shows the results of the step test. Following a recovery period, the 24-hour constant rate pump test was started at 12:10 on November 10, 2011 and stopped at 12:10 the following day. The flow rate was monitored and adjusted as needed to maintain a constant rate for 24 hours. The average flow rate for the test was 3,121 gpm, the pre-pumping water level was 123.4 feet bls and the maximum depth to water during pumping was 149.4 feet bls.

Data from the test pumping show a maximum of about 27 feet of drawdown while pumping in excess of 3,000 gpm, indicating RID-111R is an excellent production well. Water level drawdown and recovery data obtained during the constant rate test are provided in **Figure 4**. Water level responses obtained from pressure transducers at the four equipped ADEQ monitor wells and RID-95 are shown in **Figure 5**.

4.2 FLUID-MOVEMENT INVESTIGATIONS: PUMPING CONDITIONS

SWE mobilized to the RID-111R site the morning of November 11, 2011 to conduct borehole logging and depth sampling. The borehole monitoring activities were intended to coincide with the last 4 hours of pumping conducted for the constant rate test. However, during the initial temperature and fluid resistivity log, SWE was unable to run their tool beyond a depth of 260 feet bls. The logging and sampling activity was suspended pending further investigation. Following completion of the constant rate test, pumping was discontinued. A video log of the well was run on November 18, 2011 and confirmed that the well casing was open and unobstructed to a depth of 260 feet bls, at which point the casing was filled with sediment. Weber pulled the test pump and mobilized a development rig to bail and remove the fill material and continue well development. Following development, Weber videoed the well and confirmed the well casing was intact and all fill material was removed.

Subsequent logging and sampling of RID-111R took place in February 2012. Based on information gained from previous testing, the test pump was installed at a shallower depth and operated at a lower pumping rate. The base of the pump was set at 151 feet bls with the 3-inch diameter perforated access tube extending below the pump to a depth of 155 feet bls. Pumping to purge the well was initiated on February 1, but the diesel engine stopped after 12 hours of run time and restarted at 20:30 on February 5. Spinner logging operations and depth-specific sampling were conducted under pumping conditions from approximately 9:00 to 13:30 on February 7. The test pump generally operated at 2,500 gpm to purge the well prior to the well testing. Pre-pumping water level was 117.9 feet bls with the pumping water level approximately 132 feet bls.

Caliper, temperature, fluid resistivity, and spinner flow meter logs were obtained; these logs are provided in **Attachment D**. SWE measured the depth to the bottom of the well at 380 feet bls, indicating some infilling had occurred following the previous well development work. A fluid conductivity log was produced from the fluid resistivity data and was compensated to 25 degrees Celsius. Spinner logs comprised three downward traverses at approximately constant line speeds of 60, 80, and 100 feet per minute (fpm). Synergy staff observed logging operations, interpreted preliminary field results, and, in conjunction with M&A staff, selected the following depths for groundwater samples: 140, 160, 225, 250, and 320 feet bls. These depths correspond to significant inflection points noted on the temperature, resistivity, and/or spinner logs and sample points above and below the pump intake. A wellhead sample was obtained after completion of depth-specific sampling operations. ADEQ's oversight contractor, Terranext, observed the logging operations and was consulted in selection and justification of sample depths.

Synergy obtained depth-specific samples using the SWE sampling tool and submitted samples to TestAmerica for VOC and total dissolved solid (TDS) analyses. Results of laboratory chemical analyses for the depth-specific samples are given in **Attachment E** and summarized in **Table 1**. Because it is large, **Attachment E** is included only in the electronic version of this report, which is included in a sleeve at the end of the report.

4.3 FLUID-MOVEMENT INVESTIGATIONS: NON-PUMPING CONDITIONS

Logging under non-pumping conditions was conducted by SWE from approximately 12:00 to 14:30 on April 24, 2012. The suite of logs obtained was the same as for testing conducted under pumping conditions, except spinner logging comprised three upward and three downward traverses at approximately constant line speeds of 60, 80, and 100 fpm. These logs[6] are provided in **Attachment F**.

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[6] Results for the 60 fpm traverse were of very poor quality and were not reported by SWE.

Synergy staff observed logging operations, interpreted preliminary field results, and, in conjunction with M&A staff, selected the following depths for groundwater samples: 140 and 250 feet bls. The sample depths generally corresponded to minor inflection points noted on the temperature, resistivity, and/or spinner logs. Sample collection began immediately following logging operations. ADEQ's oversight contractor, Terranext, observed the logging operations and was consulted in selection and justification of sample depths.

The samples were delivered to TestAmerica for VOC and TDS analyses. Results of laboratory chemical analyses are given in **Attachment G** and are summarized in **Table 3**. Because it is large, **Attachment G** is included only in the electronic version of this report, which is included in a sleeve at the end of the report.

4.4 PERMANENT PUMPING EQUIPMENT

Following well testing operations, Weber installed permanent pumping equipment in well RID-111R. Permanent equipment included: a new 12-inch diameter vertical line-shaft turbine pump and 200-horsepower motor capable of yielding 3,000 gpm; two-stage bowl assembly, 12-inch diameter column pipe; and a 1-inch sounder access pipe installed to the top of the bowls at a depth of 202 feet bls. RID returned the well to normal service during May 2012. The operating production rate of the well on June 20, 2012 was reported by RID at approximately 2,700 gpm, and just over 3 months later the production rate increased to 3,100 gpm. RID measured a pumping water level of 165 feet bls on September 27, 2012, and a static water level of 124 feet bls in January, 2013. Well RID-111R was shut down in November, 2012 by RID due to its annual canal maintenance (and the well remained shut down because of seasonal decrease in water supply demand).

5.0 ANALYSIS AND INTERPRETATION OF RESULTS

This section describes interpretations and analyses of the data obtained from RID-111R aquifer testing, geophysical logging, and depth-specific sampling. Results of depth-specific sampling and fluid-movement investigations often contain some contradictory information. Each phase of investigation provides unique information that was synthesized and combined together with data from other phases to arrive at a complete interpretation of well and aquifer conditions.

5.1 AQUIFER TEST

Groundwater level data collected from well RID-111R during the 24-hour aquifer test were processed and analyzed to determine aquifer transmissivity. Transmissivity is a measure of the ability of an aquifer to transmit groundwater; it is defined as the rate of groundwater movement under a 1:1 hydraulic gradient through a vertical section of an aquifer 1 foot wide and extending the full saturated thickness of the aquifer (Theis, 1935). Units for transmissivity in this report are gallons per day per foot width of aquifer (gpd/ft). Transmissivity was calculated from the drawdown data using the Cooper-Jacob semi-logarithmic graphical procedure (Cooper and Jacob, 1946). To account for unconfined aquifer conditions, the drawdown data were corrected for water table conditions prior to application of the Cooper-Jacob analysis (Jacob, 1944; Kruseman and De Ridder, 1990). Transmissivity was calculated from the residual drawdown data obtained during the recovery period using the Theis (1935) semi-logarithmic graphical procedure. Results of the analyses are shown on **Figure 4**.

The drawdown data for well RID-111R exhibited two distinct slopes on a semi-log plot (**Figure 4**), rather than one constant slope as expected for a porous medium. This type of water level response is not common and implies that either the aquifer is not homogeneous and laterally extensive or that conditions in the well/aquifer were not constant during the test. The slope of the drawdown curve noticeably increased starting at about 50 minutes after pumping began, and the transition to the steeper slope ended at about 500 minutes after pumping began. The Cooper-Jacob (1946) analysis of the drawdown indicated that the transmissivity was about 260,000 gpd/ft for the early part of the curve and 109,000 gpd/ft for the late part of the curve. Transmissivity calculated from the recovery data using the Theis (1935) method was about 168,000 gpd/ft. Although other interpretations are possible, the simplest interpretation for the increase in the rate of drawdown during the test is that the well was filling with sand/sediment during the test. The stabilization of the slope after about 500 minutes may represent the point at which the sand reached its highest level in the well (i.e., 260 feet bls).

Water level data obtained in two of the four monitor wells equipped with transducers showed a response to pumping well RID-111R during the 24-hour test: wells AVB 128-01 and AVB 120-03. Water level at well RID-95 did not show a response to pumping at well RID-111R. **Figure 6** is a semi-log plot of the change in depth to water level from the start of the 24-hour test at well RID-111R for the four monitor wells and well RID-95. The maximum change in water level was about 3 feet at well AVB 128-01 and about 0.7 feet at well AVB 120-03.

5.2 FLUID-MOVEMENT INVESTIGATIONS

Groundwater pumped from the wellhead represents a flow-weighted average of all of the intervals of the aquifer yielding groundwater to the well. Similarly, groundwater quality parameters measured at specific depths in the well represent the average quality of all groundwater entering the wellbore and traveling past the depth sampled, and do not represent chemical quality of groundwater in the aquifer at the depth sampled. Thus, in cases where hydrogeologic conditions and aquifer water quality may vary with depth, results of depth-specific samples can be analyzed in conjunction with flow data from spinner logging operations to calculate values for groundwater quality parameters that are representative for intervals between depth-specific sample locations.

Results of spinner logging operations under pumping and non-pumping conditions are given in **Attachments D and F,** respectively. Results of laboratory chemical analyses for the depth specific samples obtained during pumping and non-pumping conditions are summarized in **Table 1.** Depth-specific water quality data collected under pumping and non-pumping conditions do not show significant variability; thus, mass-flux from different zones were not warranted or conducted.

5.2.1 Pumping Conditions

Spinner logging and depth-specific sampling under pumping conditions at well RID-111R was conducted on February 7, 2012 following removal of the fill material. The test pump was installed to a depth of 151 feet bls, which is below the top of perforations at 100 feet bls.

The pumping water level was reported to be about 132 feet bls. Therefore, flow in the well may have been moving both downward and upward toward the pump intake. However, flow above the pump could not be detected by the spinner flow meter because the access tube was installed to a depth of 155 feet bls. Below the pump intake, the magnitude of the spinner flow meter response under pumping conditions generally increased upward from the bottom of the well, indicating upward flow. At some depths, the magnitude of the spinner flow meter response decreased with decreasing depth. This effect was likely a result of turbulence due to horizontal flow into the well and did not impact the overall interpretation of upward flow in the well.

A summary plot of the driller's log, calculated flow, interpreted flow, and depth-specific concentrations of TCE is provided in **Figure 7**. Calibration curves developed by SWE were used to calculate the volumetric flow rate in the well using the 60 fpm data. The principal results of the pumping spinner profiles are summarized as follows:

- No flow was detected at the bottom of the well.
- About 350 gpm entered the well in the depth interval from 350 feet bls to about 320 feet bls.
- About 100 gpm enters the well in the depth interval from about 320 to 253 feet bls.
- About 1,500 gpm enters the well in the depth interval from about 253 to 223 feet bls.
- About 300 gpm enters the well in the depth interval from about 223 to 151 feet bls (assumes uniform flow above 161 feet bls, which is the first point where the spinner flow meter was capable of measuring flow as the tool exited the access tube).
- The remaining 250 gpm (the discharge rate of 2,500 gpm at the wellhead minus cumulative 2,250 gpm flow that is moving up the well casing to pump intake) is inferred to enter the well above the pump and move downward to the pump intake.

The flow interpretation summarized above was used to select depths corresponding to changes in flow rate within the well; values for flow were assigned to these depths and interval flow rates were calculated to graphically illustrate where flow enters the well (**Figure 7**). Depth specific samples were obtained at 140, 160, 225, 250, and 320 feet bls.

The results shown in **Table 1** indicate that only two VOCs, tetrachloroethene (PCE) and chloroform, are present in depth-specific samples obtained under pumping conditions. Although the data suggest a trend of increasing VOC concentrations with depth, the concentrations are small and fall within a limited range. For example, PCE is observed at concentrations from 0.52 to 1.2 µg/L and chloroform from 2.7 to 4.8 µg/L in the depth-specific samples and wellhead sample. The reported TDS concentrations are nearly identical in all samples.

Based on the fact that groundwater quality parameters observed in RID-111R depth-specific samples exhibit limited variability, the data do not provide a basis for quantitative analysis of vertical VOC mass flux.

5.2.2 Non-Pumping Conditions

Under non-pumping conditions, no net flow occurs in the well. However, vertical flow may occur as groundwater enters the well (inflow) from one or more screened intervals, while an equivalent volume of groundwater exits the well (outflow) through other screened intervals. The spinner, temperature, and fluid resistivity logs are given in **Attachment F**. SWE conducted the downward and upward traverses of the spinner flow meter at the same line speeds; thus, because the meter response varies with traverse direction, the downward traverse profiles were adjusted to roughly match the upward profiles at zones of no flow (**Attachment F**). Depths where the downward and upward profiles deviate from one another indicate zones of inflow or outflow. Where the downward profile deviates to the right of the upward profile, flow is upward; and conversely, where the upward profile deviates to the right of the downward profile, flow is downward.

Spinner logging of well RID-111R under non-pumping conditions was conducted on February 24, 2012. The spinner flow meter data obtained under non-pumping conditions were of poorer quality than the data obtained under pumping conditions. The spinner data are not interpretable because the two sets of traverses at 80 fpm and 100 fpm provided different results. Although the 80 fpm spinner curves suggest upward flow starting at a depth of about 270 feet bls, there is no depth apparent where the apparent upward flow exists in the well. The temperature curve indicates that a zone of relatively low temperature water is present at a depth of 315 to 330 feet bls, which suggests a possible zone of inflow to the well. However, direction of flow, if present, cannot be determined.

Depth-specific samples were not obtained under non-pumping conditions on February 24, 2012, because of the presence of an oil film on the surface of the water in the well. Following removal of the oil, depth-specific samples were collected on April 20, 2012 at 140 and 250 feet bls. These depths were selected to represent the base and upper interval of the major inflow zone observed in the well under pumping conditions. As indicated in **Table 1**, chloroform was the only VOC observed in depth-specific samples obtained under non-pumping conditions. However, the data show no variation aside from that related to lab accuracy. The reported TDS concentration is 1,200 milligrams per liter in both depth-specific samples. Thus, mass flux calculations were not warranted or conducted for well RID-111R under non-pumping conditions.

6.0 CONCLUSIONS

The RID-111R well investigation was conducted in accordance with the Phase 1 Well Investigation Work Plan prepared by Montgomery & Associates (2010b), dated November 24, 2010. The Work Plan was prepared pursuant to the ADEQ approval of the RID ERA Work Plan for the WVBA Site (ADEQ, 2010). The objectives outlined in the Phase 1 Well Investigation Work Plan were to:

- Demonstrate that well investigations can be conducted at minimal risk to RID and provide meaningful information for the ERA; and,
- Document existing construction and structural integrity of the wells.

As a newly-constructed replacement well completed solely in the UAU, the well testing program at RID-111R provides meaningful data for characterization of groundwater conditions and aquifer parameters, as presented below:

- RID-111R is capable of producing large quantities of water with relatively limited drawdown. The specific capacity observed during a step-rate pumping test ranged from 227 to 142 gpm per foot of drawdown. The final stage of 10-hour step rate pumping test was conducted at average 3,313 gpm pumping rate that resulted in 23.3 feet of drawdown. Data from the test pumping show a maximum of about 27 feet of drawdown while pumping at an average rate of 3,121 gpm during a 24-hour constant rate pump test.

- The estimated transmissivity of the UAU is large with values ranging from 109,000 gpd/ft to about 260,000 gpd/ft, based on drawdown data obtained during the 24-hour constant-rate pumping test. The wide range of estimated transmissivity is attributed to different drawdown rates observed during test pumping that may be attributed to sediment infilling of the well while pumping. An estimated UAU transmissivity of 168,000 gpd/ft was derived from recovery data. These reported transmissivities are generally consistent with values determined by aquifer tests at other RID wells, which ranged from 110,000 to 127,000 gpd/ft at RID-92 (Synergy, 2013) and from 54,000 to 189,000 gpd/ft at RID-95 (Montgomery & Associates, 2012).

- Aquifer conditions within the UAU are highly heterogeneous. For example, spinner logging data indicate approximately 1,500 gpm of the total extraction rate of 2,500 gpm occurred in a 30-foot interval from 253 to 223 feet bgs. This highly prolific zone contributes 60 percent of the well yield, while the remaining 40 percent of the groundwater entering the well was irregularly spread over the remaining interval from 350 feet bls to the pumping water level of 132 feet bls. There was no observed water entering the well below a depth of 350 feet bls.

- There are no remarkable trends in vertical water quality distribution. Only limited and low-level concentrations of WVBA contaminants of concern were reported in groundwater samples obtained in depth-specific intervals from RID-111R. The observed concentrations of PCE and chloroform exhibit little, if any, vertical variability. The reported TDS concentrations in depth samples are nearly identical.

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