FORWARD MODELING OF WELL PUMPAGE FROM THE POWDER MOUNTAIN CARBONATE AQUIFER, NORTHERN UTAH

by Paul Inkenbrandt

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UTAH GEOLOGICAL SURVEY
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Cover photo: Ridge of the Powder Mountain area. Photo by Stefan Kirby.

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by Paul Inkenbrandt

EXECUTIVE SUMMARY

The objective of this study is to satisfy the requirement of the Utah State Engineer to evaluate the influence of pumping a groundwater well near the Cache-Weber county line in the Powder Mountain area, east of James Peak. The purpose of this objective is to determine the mitigation required for each county impacted by pumping of the proposed well. The potential drawdown from the proposed well in the Powder Mountain carbonate aquifer system was modeled using aquifer properties derived from air-lift tests to determine the shape and size of a cone of depression around the proposed well. Based on the proposed well site location, assuming homogenous aquifer properties and typical municipal well use, 35 to 40% of the water pumped by the well would be derived from the Cache County side of the carbonate aquifer system.

INTRODUCTION

This study was conducted to determine the relative contribution of groundwater from the lower carbonate aquifer system of Cache and Weber Counties to a proposed well in the Powder Mountain area of northern Utah. The relative volume of water from each county was determined based on a technique that uses forward modeling of the pumping from the proposed well (Inkenbrandt, 2016). The impetus of this project is to satisfy the Reissued Order of the State Engineer (8/19/2015):

> *"A separate, similar evaluation to that already conducted for the Hidden Lake Well to determine any necessary mitigation to be provided to Bear River water right holders must be completed by the applicant when each well is drilled. The mitigation amount and plan for each individual well must be approved by the State Engineer."*

To determine the relative volume of water captured from Cache and Weber Counties, I conducted a forward model of a proposed well in the lower carbonate aquifer system, based on aquifer properties estimated from pumping tests.

Location

The study area consists of the Powder Mountain area (figure 1), including adjacent streams and springs. The Powder Mountain area straddles the Cache-Weber county line, which follows the natural surface water divide between the Little Bear and Ogden Rivers, within hydrologic unit codes 160102030102 and 160201020304. The proposed well, henceforth referred to as the Bloomington Well, is located at North 1487 ft and East 1548 ft from the south-center of section 6, T. 7 N., R. 2 E., Salt Lake Base Line and Meridian. UTM coordinates based on this public land survey description are approximately 436144m E and 4580000m N (NAD 83 UTM Zone 12). The proposed Bloomington well site is approximately 50 feet north of the existing Hidden Lake Well tapping the Nounan Formation, but will be drilled deeper into the carbonate aquifer below the Calls Fort Member of the Bloomington Formation (figure 2). The ground elevation of the proposed well site is approximately 8915 feet above sea level.

Hydrogeology

The regional carbonate aquifer consists of upper and lower carbonate units. The shale-rich Calls Fort Member of the Bloomington Formation separates the two carbonate units. The units are likely hydraulically connected on a regional scale by secondary permeability (fractures and karst) (Inkenbrandt and others, 2016). However, differences in groundwater elevations (downward gradient), as well as springs near formation boundaries and the presence of significant thicknesses of shale in the well logs, all support localized separation of the two units (appendix A). Recharge to the lower carbonate aquifer by leakage from the overlying aquifer is likely.

The upper carbonate aquifer is unconfined and locally perched, and has a transmissivity of 228 ft^2/day and a storativity of 0.006 (Inkenbrandt and others, 2016). Unconsolidated sediments and the Tertiary Wasatch Formation overlie the upper carbonate aquifer. Lefty's Spring issues from the Nounan Formation, which is part of the upper carbonates south of the Hidden Lake Well. Lefty's spring is currently equipped with continuous monitoring equipment.

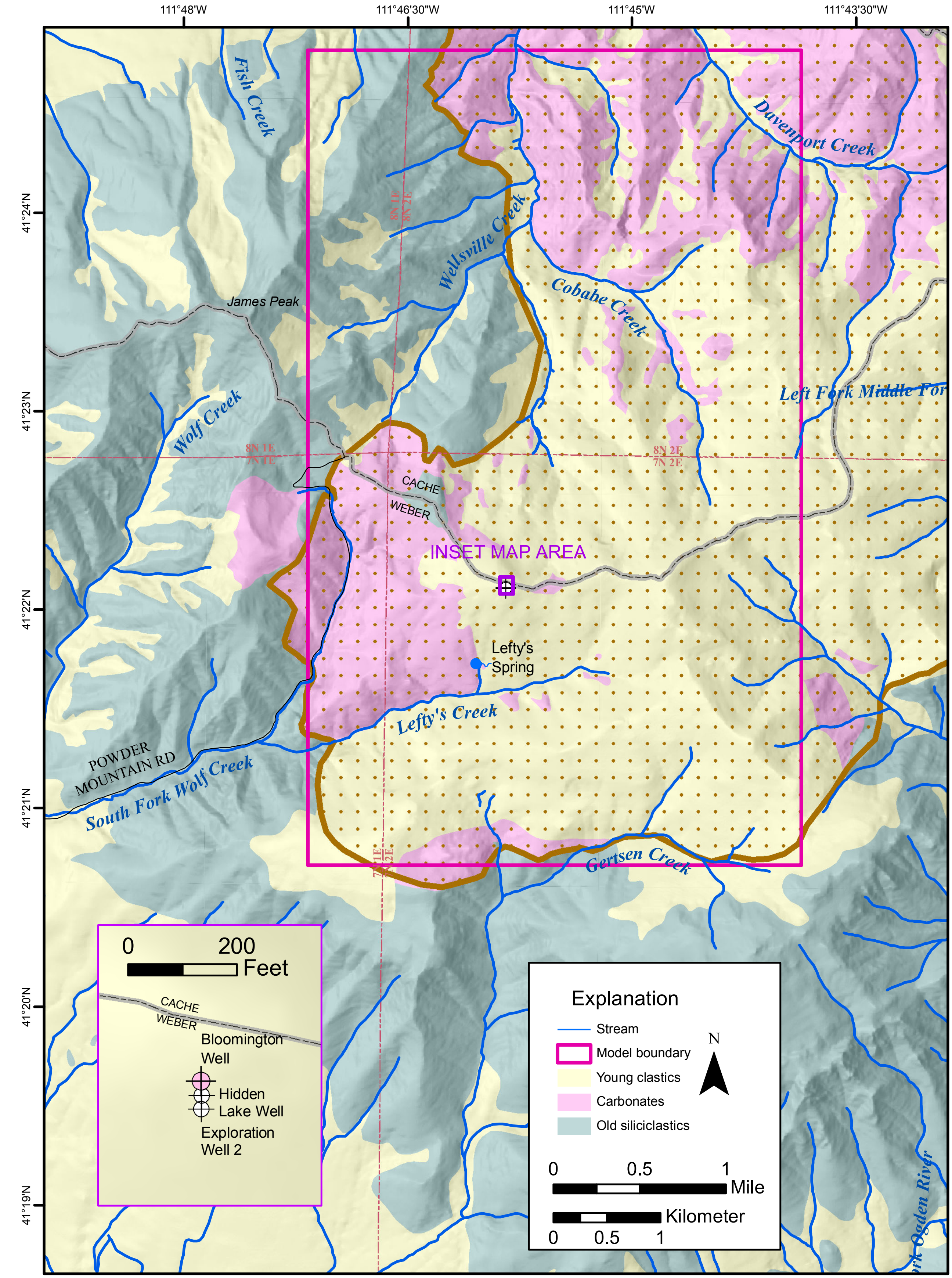

Figure 1. The area of study is Powder Mountain, with a focus on the extent of the carbonate aquifer (dotted area). The inset shows the relative position of the wells examined for this study.

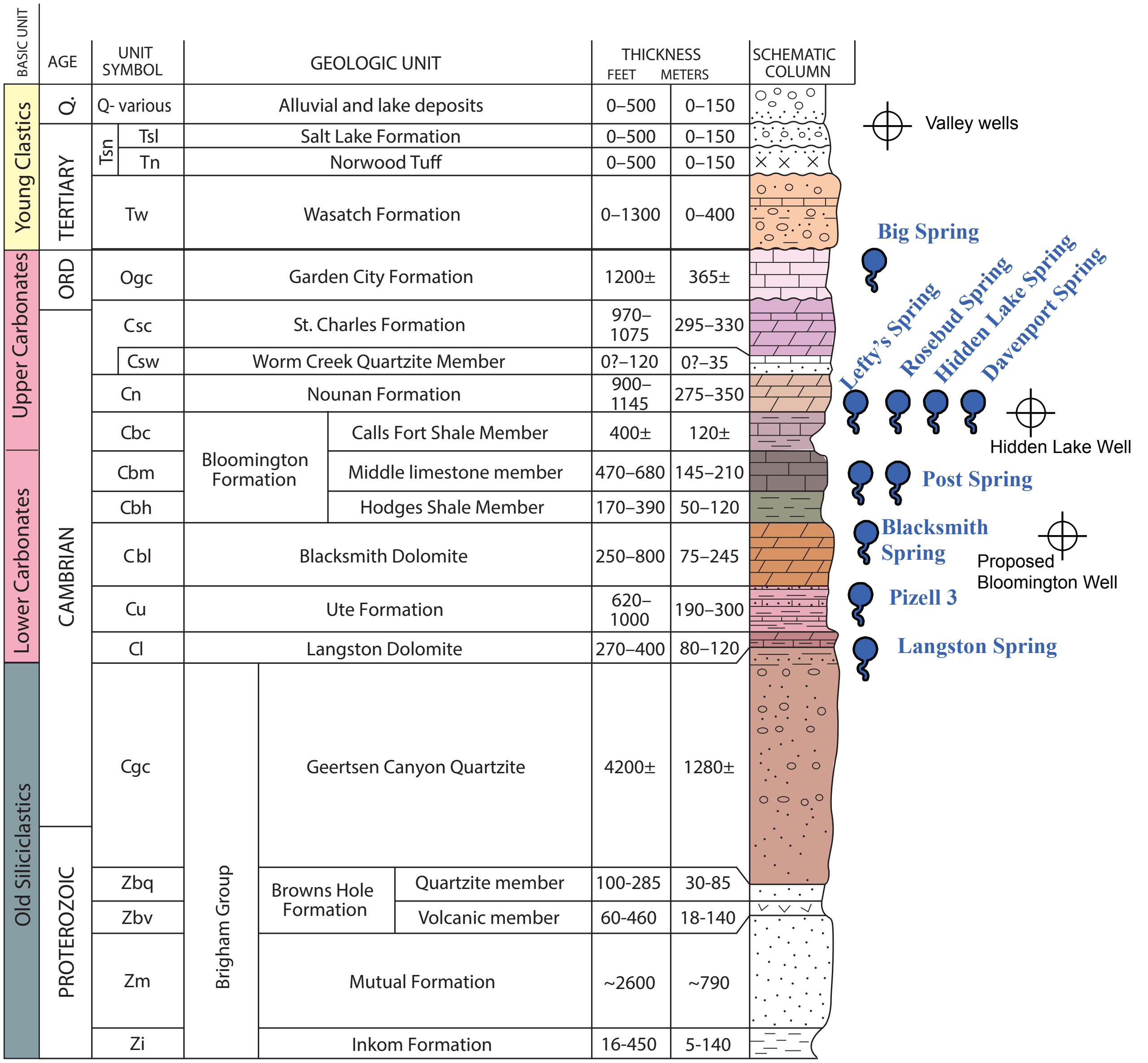

Figure 2. *Hydrostratigraphy for the Powder Mountain area (modified from Coogan and King, 2016). The approximate stratigraphic position of important springs and wells is shown on the right.*

The only information available for the lower carbonate aquifer is from spring measurements and data provided by Loughlin Water Associates, LLC. The Loughlin Water Associates, LLC data are derived from a 2480-foot-deep observation borehole known as Exploration Well 2 adjacent to the Hidden Lake Well (figure 1). Analyses of groundwater level changes from a 24-hour airlift test indicate that the transmissivity of the lower carbonate aquifer is approximately 130 ft^2/day (appendix A). Inkenbrandt and others (2016) measured springs issuing from the lower carbonate unit and noted that flow contribution from the lower carbonate unit makes up about half of the flow of Wolf Creek (figure 1), the major drainage on the Weber County (Ogden River) side of the Powder Mountain area.

METHODS

This project applied methods described in Inkenbrandt and others (2016). This approach uses properties derived from aquifer tests to determine the shape of the cone of depression created by pumping. The distribution of the cone of depression across the county line then determines the relative volume extracted from each county. To model the cone of depression I used AQTESOLV (Duffield, 2007) and an ArcGIS toolbox; each program created a modeled cone of depression.

The models applied in both the ArcGIS toolbox and AQTESOLV are two-dimensional models that assume the aquifer is isotropic and homogeneous. However, the aquifer is likely anisotropic and primary permeability may result from heterogeneous fracturing. Heterogeneity exists in the aquifer in the form of karst and stratigraphic discontinuities in the carbonate units are likely (Inkenbrandt and others, 2016). The modeling approach assumes that the modeled cones of depression would not intersect or tap karst conduits or significant solution-enhanced fractures. Both ArcGIS and AQTESOLV are limited to conditions with no recharge, and therefore do not account for distribution of recharge across county boundaries.

The conceptual model used for the AQTESOLV (Duffield, 2007) analysis was of a bounded, leaky confined aquifer. To conduct the forward model, I applied the Neuman-Witherspoon (1969) solution to the aquifer test data. The Neuman-Witherspoon (1969) solution allows for two-dimensional analysis of a two-aquifer system separated by a leaky confining layer. This model allows the user to account for water derived from overlying layers. The model uses a constant 100 gpm pump rate and aquifer parameters calculated from recovery of an air-lift test (appendix A). Aquifer storativity was assumed to be comparable to that of the upper carbonate unit. The setup of the AQTESOLV model (Duffield, 2007) is provided in appendix B. The same analysis was conducted using a pumping rate of 200 gpm to determine the model's sensitivity to pumping rate.

The expected drawdown from the ArcGIS model was also plotted using a higher pumping rate and the assumption of a confined aquifer to determine the sensitivity to the conceptual model. For the conceptual model of the confined aquifer, I used the Theis (1935) solution for a confined aquifer.

Forward model results were plotted as grids of drawdown for time intervals of one week, two months, four months, and one year of pumping. Each grid was then cut along the county boundary, and an average drawdown was calculated using ArcGIS statistics to yield the relative percentage of drawdown by county.

RESULTS

As average areal drawdown in the lower carbonate aquifer increases, the relative volume of water taken from Cache County increases (figure 3A; appendix C), eventually flattening out around 40% of the total volume of water extracted. Forward modeling of the aquifer test shows that 24 to 44% of the water extracted from the aquifer comes from Cache County for time intervals between 2 and 240 days (figure 3A; appendix C). More than 240 days without recharge while pumping at 100 gpm is an unlikely condition. To reproduce these conditions, large amounts of pumping or very little precipitation would have to occur for an extended

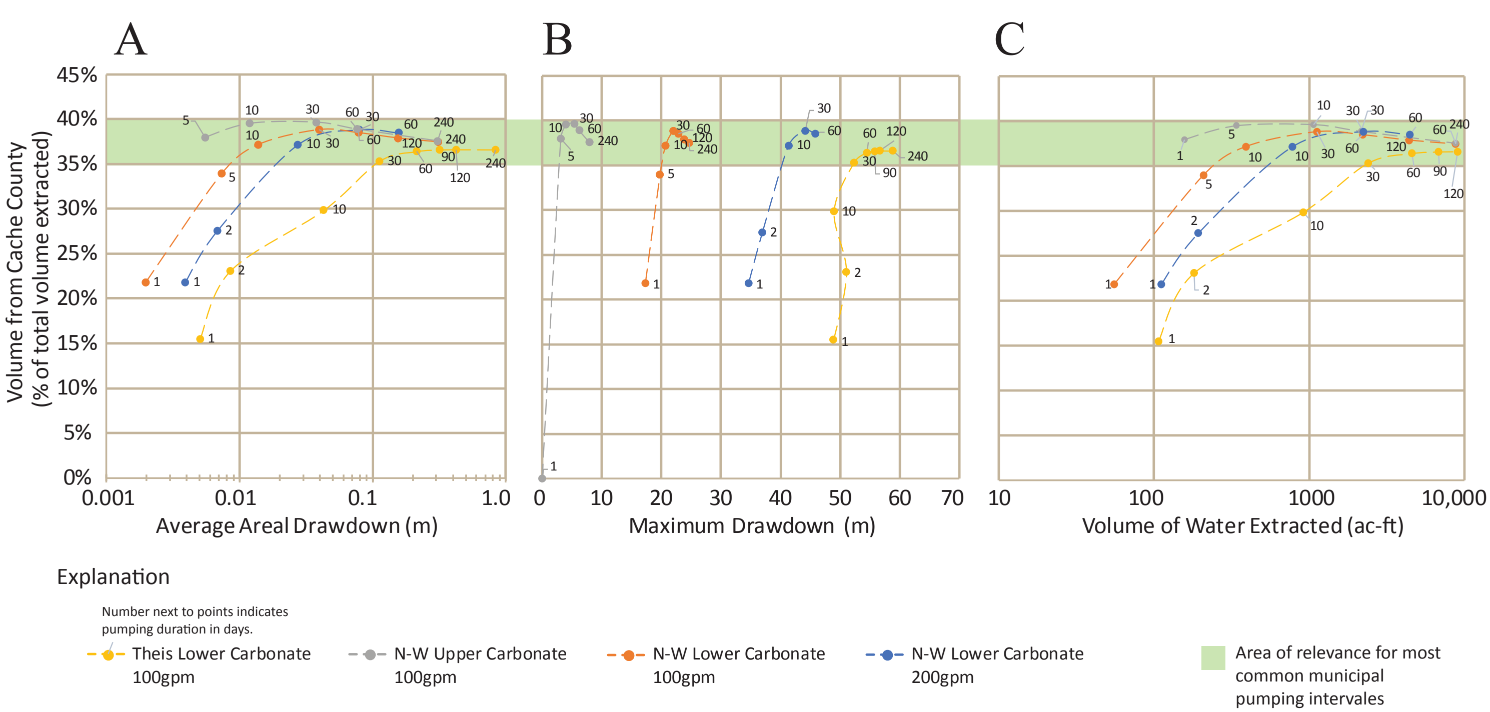

Figure 3. *Percent of water from Cache County as a function of (A) areal drawdown, (B) maximum (pumping well) drawdown, and (C) volume of water extracted.*

duration. A long-term imbalance between groundwater recharge and pumping could result in the conditions like those produced by the long-term cases of the forward model.

To illustrate maximum potential drawdown due to long-term pumping, a plot of forward-model drawdown for a pumping period of 240 days is shown in figure 3B. Based on this model, the cone of depression does not extend to the assumed aquifer boundaries. This period of pumping is greater than the typical 6-month recession, or no recharge period, shown by long-term water-level trends and could be assumed to represent maximum possible drawdown related to pumping of the Hidden Lake Well over an extended drought period. The relative amount of forward model drawdown encountered in Cache or Weber County varies depending on the time span of pumping and the volume extracted (figure 3C).

DISCUSSION

Based on the above methods, relative volume extracted from the aquifer on each side of the county line is a function of the shape, size and placement of the well's cone of depression. The proposed Bloomington Well would be closer to the county line than the Hidden Lake Well, shifting the cone of depression 50 feet north. Because this well would likely have a relatively low transmissivity, the bulk of the volume of groundwater extracted would be focused near the well.

Based on observed drawdown and use of the existing Hidden Lake Well, pumping will most likely reproduce areal drawdown and maximum drawdowns greater than those produced for the one- to five-day simulations, meaning that the expected extracted volume taken from Cache County will likely be 35 to 40% (figure 3; appendix C). If the wellbore is not completely vertical, and deviates significantly to the north or south of the proposed location, it will influence the percent volume extracted from each county. The size of the cone of depression would increase with pumping from the existing well, and total drawdown caused by both wells would be the sum of each individual well's cone of depression.

Neither model was highly sensitive to the conceptual model or the pumping rate. Water levels in the confined Theis (1935) conceptual model declined more rapidly than the Neuman-Witherspoon (1969) model.

The aquifer system of the Powder Mountain area is particularly challenging to model because it is fractured and karstic, on an assumed groundwater divide, and layered. Analytic element modeling could be applied to a layered system, but applying it to a groundwater divide is challenging, as it is usually assumed that there is one dominant hydrologic gradient. For this area, three-dimensional modeling, specifically MODFLOW (Harbaugh, 2005), would be most appropriate because it could account for spatial variations in recharge and aquifer orientation, but it would still fall short in reproducing the karst flow paths in the aquifer system.

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APPENDICES

APPENDIX A

ABRIDGED CONSULTANT'S REPORT FOR EXPLORATION WELL 2

LOUGHLIN WATER ASSOCIATES LLC

July 26, 2013

Summit Mountain Holding Group
c/o Watts Enterprises, Inc.
Attn: Russ Watts
5200 Highland Drive, Suite 101
Holladay, Utah 84117-7065

Subject: Report of Exploration Well 2 at Powder Mountain
Weber County, Utah
For Summit Mountain Holding Group, LLC

Dear Russ:

INTRODUCTION

We prepared this letter report to summarize our findings from the drilling and testing of Exploration Well 2 at Powder Mountain. The purpose of the exploration well program was to assess the presence, character, and potential yield of the aquifer and provide information that can be used in the final design and permitting of a public water system (PWS) production well.

We summarized our findings from Exploration Well 1 in a separate letter report.

WELL DRILLING, LOGGING, AND PIEZOMETER CONSTRUCTION

DRILLING AND WELL CONSTRUCTION

Figure 1 shows the location of Powder Mountain. As shown on Figure 2, the approximate location of Exploration Well 2 is north 1402 feet, east 1544 feet from the south corner of Section 6, Township 7 North, Range 2 East, Salt Lake Base & Meridian (SLB&M).

National EWP, Utah-licensed Water Well Driller No. 805, drilled and tested the borehole and completed the well by constructing a standpipe piezometer. National EWP:

- Drilled a 19-inch diameter borehole using conventional mud rotary methods to a depth of 130 feet;
- Installed 14-inch diameter steel casing to a depth of 125 feet and grouted the casing in place;

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Loughlin Water Associates LLC

- Drilled a 12-inch diameter borehole using conventional mud rotary methods to a depth of 430 feet;
- Installed 7-inch diameter threaded and coupled steel casing to a depth of 420 feet and grouted the casing in place;
- Drilled a 6-inch diameter borehole using dual-wall, reverse-circulation air rotary methods to a depth of 2480 feet;
- Performed short-term air-lift yield tests about every 20 feet at depths below 945 feet;
- Performed two one-hour long air-lift yield tests and two half-hour-long air-lift tests;
- Performed two 24-hour long air-lift yield test and measured recovery;
- Arranged for geophysical logging of the borehole; and
- Plugged the lower part of the borehole and installed a standpipe piezometer in the upper part (upper aquifer) of the borehole.

A copy of the Well Driller's Report for the well is presented in Attachment A.

Loughlin Water Associates, LLC ("Loughlin Water") observed well drilling, described drill cuttings, performed field water quality test (specific conductance, temperature and pH), collected three water samples for water quality analyses by Chemtech-Ford Laboratories ("Chemtech") of Salt Lake City, a Utah-certified analytical laboratory, summarized air-lift test data and recovery measurements, and interpreted the geophysical logs.

LITHOLOGIC LOG

As the well was drilled, National EWP personnel collected drill cutting samples about every 5 feet to total depth (2480 feet) by compositing portions of the material returning up the borehole. Loughlin Water staff described the samples and prepared the lithologic (geologic) log that is summarized in Table 1. Our detailed lithologic log was incorporated into the Well Driller's Report that is presented in Attachment A. We based our log on (1) our descriptions of samples, (2) the geophysical logs, and (3) geologic interpretations.

We used the 2009 Munsell geological rock-color chart for our color descriptions. We described the samples in a wet condition.

Two aquifers occur at Exploration Well 2: an upper aquifer in the Nounan Formation and a lower aquifer in the Middle Member of the Bloomington Formation. Shale of the Calls Fort Member of the Bloomington Formation separates the aquifers.

GEOPHYSICAL LOGS

After National EWP drilled the borehole to 2440 feet in depth, Century Wireline Services ("Century") ran the following geophysical logs:

- Natural gamma log, which measures the total gamma radiation emitted by subsurface materials, and
- Borehole deviation, which measures the borehole for plumbness, vertical alignment and location in the subsurface.

We initially planned to have additional geophysical logs run but potentially unstable borehole conditions precluded Century from running open-hole logs. Century ran the geophysical logs from within the drill pipe to a depth of 2408 feet.

Loughlin Water used the gamma log to help interpret lithologies and formation contacts. The deviation log can be used to help select the location of future production wells with respect to the exploration well to avoid having the wells intersect. Attachment B presents the geophysical logs.

AIR-LIFT TESTS

END-OF-ROD AIR LIFT MEASUREMENTS

During the drilling program, National EWP measured air lift rate upon finishing each drill rod (about every 20 feet in depth). These were short-term tests, conducted after cuttings were flushed from the borehole. National EWP estimated the discharge rate by measuring the time to fill a small container (5 to 20 gallons capacity) or by directing the discharge from the borehole to an 8000-gallon tank and recording the time to fill the tank in 0.1-foot (138-gallon) increments. During drilling of the upper aquifer, end-of-rod air-lift rates generally increased with depth and submergence of the drill rods. In the lower aquifer, air-lift rates did not indicate an overall increase. Figure 3A presents a plot of the end-of-rod air lift rates versus drilled depth during drilling of Exploration Well 2.

After adding a drill rod to continue drilling, National EWP recorded the peak air pressure that caused water discharge to begin ("unloading pressure"). This pressure is related to the pressure exerted by the water column in the borehole, so the depth to water in the borehole can be estimated. Figure 3B shows a plot of the estimated water level depth versus depth of the borehole. Note that National EWP placed and used a set of lifters in the drill string when the borehole was at a depth of 1900 feet. The lifters are openings in the drill pipe between the inner tube and the outer part of the dual tube drill pipe that carries the compressed air. The lifters help start the air-lift discharge process and reduce time to re-pressurize ("air-up") and start drilling. However, because the compressed air is released at two different depths when lifters are used, interpretation of the water level depth in the borehole is less accurate. As shown on Figure 3B, when the lifters were in use, actual water level depths were higher than that estimated, probably on the order of 100 feet higher.

National EWP also recorded the system air pressure upon finishing each rod. This pressure is an indication of the pressure required to lift water, cuttings and air through the inner drill rods to the discharge tank; this pressure is related in part to the drawdown in the aquifer created by air lifting the water from the aquifer.

SHORT-TERM AIR-LIFT TESTS

National EWP performed two one-hour-long air-lift tests and two half-hour-long air-lift tests in Exploration Well 2. National EWP conducted the tests by directing the discharge from the borehole to an 8000-gallon tank and recording the time to fill the tank in 0.1-foot (138-gallon) increments. Results of these tests are summarized below.

Date	Exploration Well	Aquifer	Test Duration	Borehole Depth (feet)	Bottom of Drill Rods (feet)	Average Discharge Rate (gpm)	
6/14/2013	2	Upper	1 hour	1560	1500	84	*
6/16/2013	2	Upper and Lower	0.5 hour	1900	1540	79	
6/16/2013	2	Upper	0.4 hour	1320 (bridge**)	1315	62	
6/22/2013	2	Lower	1 hour	2480	1900	89	

* Water sample taken for laboratory analysis.

** Lower part of borehole isolated by formation material that fell into hole below this depth.

24-HOUR AIR-LIFT TESTS

National EWP performed two 24-hour-long air-lift tests: (1) a test in the lower part of the Exploration Well 2 (the Middle Member of the Bloomington Formation or lower aquifer), and (2) a test in the upper part of Exploration Well 2 (the Nounan Formation or upper aquifer). National EWP conducted the tests by directing the discharge from the borehole to an 8000-gallon tank and recording the time to fill the tank in 0.1-foot (138-gallon) increments. Results of the 24-hour air-lift tests are summarized in the following.

Date Started	Exploration Well	Aquifer	Test Duration	Borehole Depth (feet)	Bottom of Drill Rods (feet)	Average Discharge Rate (gpm)	
6/22/2013	2	Lower	24 hours	2480	2200	92	*
6/24/2013	2	Upper	24 hours	1510**	1480	84	*

* Water sample collected for laboratory analysis.

** Borehole was filled and sealed below this depth.

24-Hour Air-lift Test of the Lower Aquifer

The air-lift rate decreased slowly during the 24-hour test of the lower aquifer. During the first hour of the test, the average air-lift discharge rate was 94 gpm. The average air-lift rate for test was 92 gpm. Average rate for last four hours was 89 gpm.

Drawdown during air-lifting testing cannot be measured directly because water is being blown up the borehole. A rough estimate of the water level while drilling might be made based on the air-pressure required to lift and push the water (and air and rock cuttings, if any) through the drill pipe to the surface. However, this water level estimation method is not accurate because of friction losses and other factors that are difficult to quantify. Back pressure readings indicated only minor drawdown when air-lifting. Analysis of groundwater recovery data (water levels measured inside the drill pipe following cessation of air-lifting) indicate that drawdown during the air-lift test was on the order of 200 feet. This estimate is based on the calculated transmissivity discussed below and other assumptions.

Water level measurements made with an electric sounder lowered inside the drill rods after air-lifting provide data upon which to estimate the un-pumped ("static") water level, drawdown and recovery. Because of (1) the time required to release the air pressure in the system and open the drill rods, (2) the rather large depth to water, and (3) the tendency for the sounder line to stick to the inside of the drill pipe, obtaining the first sounder reading generally took a rather long time; during this test it took 48 minutes.

Figure 4A presents a plot of measured depth to water in the well versus time since air-lifting stopped. The depth to water was 1054 feet 48 minutes after air-lifting ceased. The depth to water was 1038 feet, 339 minutes after air-lifting ceased.

Figure 4B presents a plot of measured depth to water in the well versus the ratio of time since air-lifting started /time since air-lifting ceased (t/t'). Projecting the trend on Figure 4B to a ratio of 1.0 indicates that the depth to the "static" groundwater level would be about 1020 feet.

We estimated an aquifer transmissivity from the plot on Figure 4B using the constant discharge method developed by Cooper and Jacob (1946) and described in Lohman (1972). Transmissivity of the lower aquifer estimated from Figure 4B is about 130 feet squared per day (ft^2/d), which indicates an aquifer of small transmissivity but greater than the transmissivity in the lower aquifer at Exploration Well 1. Due to the nature of air-lift tests, we do not put much reliance on this exact value, but it does indicate an aquifer with small production capability, 100 gpm or less, at this location.

24-Hour Air-lift Test of the Upper Aquifer

The air-lift rate was relatively steady during the 24-hour test of the upper aquifer. During the first hour of the test, the average air-lift discharge rate was 84 gpm. The average air-lift rate for test was 84 gpm. Average rate for last four hours was 85 gpm.

Drawdown during air-lifting testing cannot be measured directly because water is being blown up the borehole. Back pressure readings, which we consider to be not very accurate, indicated only minor drawdown when air-lifting. Analysis of groundwater recovery data (water levels following cessation of air-lifting) indicate that drawdown during the air-lift test was on the order of 80 feet.

Figure 5A presents a plot of measured depth to water in the well versus time since air-lifting stopped. Water levels measured with an electric sounder lowered inside the drill rods after air-lifting took about 15 minutes to obtain the first reading. The depth to water was 772 feet, 15 minutes after air-lifting ceased. The depth to water was 761.6 feet, 255 minutes after air-lifting ceased.

Figure 5B presents a plot of measured depth to water in the well versus the ratio of time since air-lifting started /time since air-lifting ceased (t/t'). Projecting the trend on Figure 4B to a ratio of 1.0 indicates that the depth to the "static" groundwater level would be about 754 feet. Following completion of the standpipe piezometer (June 29, 2013) that was completed in the upper aquifer, National EWP measured a water level of 763 feet below the top of the PVC pipe.

We estimated an aquifer transmissivity from the plot on Figure 5B using the constant discharge method developed by Cooper and Jacob (1946) and described in Lohman (1972). Evaluation of the data in Figure 4B indicates a transmissivity of about 330 ft^2/d. Due to the nature of air-lift tests, we do not put much reliance on this exact value, but it does indicate a production capability of around 200 gpm in the upper aquifer at this location.

WATER QUALITY

Field Analyses of End-of-Rod Water Samples

During the drilling process, we measured specific conductance, pH, and temperature of grab samples of groundwater collected after rock cuttings had been blown from the borehole upon finishing each drill rod. End-of-rod air-lift rates and field water quality results are summarized as follows:

Exploration Well	Aquifer	Range of Rates (gpm)	Average Specific Conductance (μS)	Average pH (units)	Water Temperature
2	Upper	10 –110	353	8.4	44 °F
2	Lower	80 – 150	421	8.5	42 °F

Field Analysis of Samples from 24-Hour Air-Lift Tests

During the 24-hour air-lift tests, water samples were collected every 10 minutes during the first hour and every two hours thereafter for analysis of field parameters (specific conductance, pH, and temperature). Overall, conductivity and pH were generally steady during air-lifting. Overall results are summarized in the following:

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Exploration Well	Aquifer	Average Specific Conductance (µS)	Average pH (units)	Water Temperature
2	Lower	362	8.4	42 °F
2	Upper	368	8.5	42 °F

Discharge from Exploration Well 2 during the 24-hour tests started turbid and light brown in color. After two hours water cleared considerably and was colorless. Turbidity at the end of the test of the lower aquifer was 6.4 NTU. Turbidity at the end of the test of the upper aquifer was 8.8 NTU.

Laboratory Analysis of Water Quality Samples

Loughlin Water staff collected a water quality sample on June 14, 2013, after air-lifting the borehole for one hour and when the borehole was at a depth of 1560 feet (upper aquifer). Chemtech analyzed the sample for major ions concentrations, iron, manganese, total dissolved solids (TDS), pH and conductivity. Results are summarized in Table 2. The sample was cloudy due to incomplete development of the borehole.

Loughlin Water staff collected a water quality sample on June 23, 2013, when the borehole was at a depth of 2480 feet and at the end of the 24-hour air-lift test of the lower aquifer. Chemtech analyzed the water samples for primary, secondary and additional constituents required for a new drinking water source under UAC R309-515-4(5). Analyses were not performed for organic chemicals (herbicides, pesticides, volatile organics, PCBs, etc.) and radiologic chemicals because of the analysis time needed, expense and unlikely presence of these constituents. Samples for metals analyses (placed in bottle with nitric acid preservative) were field-filtered with a 0.45 micron filter. Samples for all other analyses were unfiltered. Table 2 summarizes analytical results. Copies of the laboratory reports and chain-of-custody forms are provided in Attachment C.

Loughlin Water staff collected a water quality sample on June 26, 2013, when the borehole was sealed below a depth of 1510 feet and at the end of the 24-hour air-lift test of the upper aquifer. Chemtech analyzed the water samples for primary, secondary and additional constituents required for a new drinking water source under UAC R309-515-4(5). Analyses were not performed for organic chemicals (herbicides, pesticides, volatile organics, PCBs, etc.) and radiologic chemicals because of the analysis time needed, expense and unlikely presence of these constituents. Note that Loughlin Water staff collected samples for both dissolved and total metals analyses so that dissolved and total concentrations could be compared. Loughlin Water staff field-filtered the sample for dissolved metals analyses with a 0.45 micron filter (sample was placed in bottle with nitric acid preservative). Samples for all other analyses were unfiltered. Table 2 summarizes analytical results. Copies of the laboratory reports and chain-of-custody forms are provided in Attachment C.

The water sample results indicate that waters of the upper and lower aquifers are relatively similar. TDS ranged from 208 to 244 milligrams per liter (mg/L), which are within the primary and secondary drinking water standards. Iron and manganese exceeded secondary drinking water standards. No other analyte exceeded primary or secondary drinking water standards.

The dominant ions were calcium, magnesium and bicarbonate. pH was measured at 8.2 to 8.3 units. Total hardness was reported to be 203 mg/L as $CaCO_3$, which is considered very hard. The Langlier Index of 0.8 indicates the water will tend to be incrusting.

STANDPIPE PIEZOMETER CONSTRUCTION

After completion of the 24-hour test of the lower aquifer, National EWP installed gravel in the lower part of the borehole (from 2480 to 1750 feet in depth) and unhydrated bentonite adjacent to the Calls Fort Member (1750 to 1510 feet in depth). National EWP disinfected the gravel as it was being placed in the well in accordance with UAC R655-9.6.5, *Well Disinfection and Chlorination of Water*. National EWP placed gravel in the lower part of the borehole instead of cement grout to preclude cement from sealing the lower aquifer in the event that a production well is constructed nearby in the future.

After sealing the lower part of the borehole, National EWP conducted the 24-hour air-lift test of the upper aquifer. After completing the 24-hour air-lift test of the upper aquifer, National EWP constructed a standpipe piezometer in the upper part of the borehole. National EWP disinfected the gravel as it was being placed in the well. The standpipe piezometer consists of 2-inch diameter Schedule 80 un-slotted ("blank") pipe and slotted PVC pipe. Blank PVC pipe extends from 2 feet above ground level to 1450 feet below ground level. Slotted PVC pipe (0.020-inch slots) extends from 1450 to 1470 feet in depth and blank pipe with a bottom cap extends from 1470 to 1480 feet in depth. The PVC standpipe is enclosed within the 14-inch diameter steel conductor casing and a steel plate welded to the top of the casing. Figure 3 is a schematic diagram of the completion of Exploration Well 2.

Following completion of the standpipe piezometer (June 29, 2013), National EWP measured a water level of 763 feet below the top of the PVC pipe.

SUMMARY AND CONCLUSIONS

Two aquifers occur at Exploration Well 1: an upper aquifer in the Nounan Formation and a lower aquifer in the Middle Member of the Bloomington Formation. Shale of the Calls Fort Member of the Bloomington Formation separates the aquifers.

We estimate that the depth to groundwater in the upper aquifer at the site under non-pumping conditions is about 750 feet. The depth to groundwater in the lower aquifer at the site under non-pumping conditions is about 1020 feet.

Water sample results indicate that waters of the upper and lower aquifers are relatively similar. TDS ranged from 208 to 244 milligrams per liter (mg/L), which are within the primary and secondary drinking water standards. Iron and manganese exceeded secondary drinking water standards. No other analyte exceeded primary or

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secondary drinking water standards. The dominant ions were calcium, magnesium and bicarbonate. pH was measured at 8.2 to 8.3 units. Total hardness was reported to be 203 mg/L as $CaCO_3$, which is considered very hard. The Langlier Index of 0.8 indicates the water will tend to be incrusting.

Evaluation of the 24-hour air-lift test data of the upper aquifer indicates a production capability of about 200 gpm from the upper aquifer at the location of Exploration Well 2. Evaluation of the 24-hour air-lift test data of the lower aquifer indicates a production capability of about 100 gpm from the lower aquifer at the location of Exploration Well 2.

Because of the difference in groundwater levels in the two aquifers, wells should not be open to both aquifers. Therefore, separate wells are required at this location if both aquifers are to be tapped.

We believe that the location of Exploration Well 2 (Hidden Lake parking area) is more favorable than the area of Exploration Well 1.

If you have any questions or need more information, please do not hesitate to call us at (435) 649-4005 (office) or George at (435) 659-1753 (mobile).

Very truly yours,

Loughlin Water Associates, LLC

REGISTERED PROFESSIONAL ENGINEER
7-26-13
NO. 4922
GEORGE W. CONDRAT
State of Utah

George W. Condrat, P.G., P.E.
Senior Engineer

LICENSED PROFESSIONAL GEOLOGIST
WILLIAM D. LOUGHLIN
5205683-2250
7.26.2013
STATE OF UTAH

William D. Loughlin, P.G.
Manager, Principal Hydrogeologist

Attachments:

- Table 1 – Simplified Lithology
- Table 2 –Water Quality Data and Utah Drinking Water Standards
- Figure 1 – Location Map
- Figure 2 – Vicinity Map

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Figure 3 – Plots of Air-Lift Yield and Groundwater Level versus Borehole Depth
From End-of-Rod Data
Figure 4 – Schematic Well Diagram
Attachment A – Well Driller's Report
Attachment B – Geophysical Logs
Attachment C – Laboratory Certificates of Analysis

Table 1 - Simplified Lithology
Exploration Well 2 at Powder Mountain

Depth		Thickness (ft)		Formation and Predominant Lithology
From	To			
0	15	15	15	Fill - gravel, boulders, clay and silt with some sand. Mostly moderate reddish brown. Unconsolidated.
15	205	350	190	Wasatch Formation - Gravel and boulders with clay, silt and some sand. Mostly moderate reddish brown. Mostly unconsolidated.
205	260		55	Wasatch Formation - Clay with silt, gravel and cobbles. Mostly moderate reddish brown.
260	285		25	Wasatch Formation - Fine-grained sandstone with siltstone and mudstone, some clay and limestone /dolomite. Mostly consolidated.
285	305		20	Wasatch Formation - Lacustrine - Limestone/dolomite with sandy dolomite, trace mudstone and clay.
305	365		60	Wasatch Formation - Fine-grained sandstone, siltstone and mudstone.
365	695	330	330	St. Charles Formation - Dolomite with sandstone, siltstone, limestone and clay. Mostly light gray to grayish black; clay, mudstone and sandstone tend to orange-yellow.
695	840	145	145	Worm Creek Quartzite Member - Quartzite, siltstone, shale, clay and dolomite. Light to dark gray and pale to dark orange.
840	1315	655	475	Nounan Formation - Dolomite. Light gray to dark gray.
1315	1415		100	Nounan Formation - Dolomite. Light gray to dark gray with trace red clay.
1415	1495		80	Nounan Formation - Dolomite. Light gray to dark gray.
1495	1530		35	Nounan Formation - Dolomite, mudstone and shale; pyrite noted; medium to dark gray and light olive gray.
1530	1580		50	Nounan Formation - Dolomite and limestone with oolites and some shale. Dark gray and light olive gray. With white calcite streaks and spots.
1580	1640	215	60	Calls Fort Shale Member - Dark gray shale with some limestone.
1640	1722		82	Calls Fort Shale Member - Shale, slightly calcareous. Dark gray, dark greenish gray, and moderate olive gray.
1722	1795		73	Calls Fort Shale Member - Shale and limestone with some dolomite, dark gray to grayish black.
1795	1845	685	50	Middle Limestone Member - Dolomite with a little limestone, occasional pyrite noted, grayish black, dark gray and black. Minor siltstone.
1845	1900		55	Middle Limestone Member - Limestone and dolomite with some siltstone. Medium to dark gray.
1900	2020		120	Middle Limestone Member - Dolomite with a little limestone, occasional pyrite noted, grayish black, dark gray and black. Minor siltstone.
2020	2210		190	Middle Limestone Member - Dolomite with a little limestone and calcareous sand, grayish black to light gray and white. Some reddish-orange staining.
2210	2235		25	Middle Limestone Member - Alteration Zone - Light brown sandstone with dolomite inclusion and calcite veins.
2235	2315		80	Middle Limestone Member - Dolomite, dark gray and white with some reddish and brown colored alteration/staining.
2315	2480		165	Middle Limestone Member - Limestone and dolomite with some oolites, shaley limestone and shale argillite, dark to light gray in color, trace pyrite.

For detailed descriptions, see Borehole Lithologic Log

Table 2 - Water Quality Data and Utah Drinking Water Standards
Exploration Well 2 at Powder Mountain

Sample Date:	6/14/2013 [f]	6/23/2013 [g]	6/26/2013 [g]		
Borehole Depth (feet):	1560	2480	1510		
Metals - Dissolved [h]				MCL [a]	Units
Aluminum	NA	0.05	ND / ND [h]	0.05 to 0.2	mg/L
Antimony	NA	ND	ND / ND [h]	0.006	mg/L
Arsenic	NA	ND	ND / ND [h]	0.01	mg/L
Boron	NA	ND	ND / ND [h]	NS	mg/L
Barium	NA	0.023	0.022 / 0.024 [h]	2	mg/L
Beryllium	NA	ND	ND / ND [h]	0.004	mg/L
Calcium	67.9	48.7	48.2 / 48.4 [h]	NS	mg/L
Cadmium	NA	ND	ND / ND [h]	0.005	mg/L
Chromium	NA	ND	0.0017 / ND[h]	0.1	mg/L
Copper	NA	0.001	0.0011 / 0.0015 [h]	1.3 [b, e]	mg/L
Cyanide (free)	NA	ND	ND	0.2	mg/L
Fluoride	NA	ND	ND	4 [b]	mg/L
Iron	7.44	0.06	0.03 / 0.40 [h]	0.3	mg/L
Lead	NA	ND	ND / 0.0034 [h]	0.015 [e]	mg/L
Mercury	NA	ND	ND / ND [h]	0.002	mg/L
Magnesium	30.1	19.7	19.1 / 19.9 [h]	NS	mg/L
Manganese	0.323	0.008	0.006 / 0.010 [h]	0.05	mg/L
Nickel	NA	ND	ND / ND [h]	0.1	mg/L
Potassium	NA	0.5	ND / 0.7 [h]	NS	mg/L
Selenium	NA	ND	ND / ND [h]	0.05	mg/L
Silver	NA	ND	ND / 0.001 [h]	0.1	mg/L
Silica (as SiO2)	NA	5.9	6.3 / 7.3 [h]	NS	mg/L
Sodium	10.7	2.4	2.7 / 3.6 [h]	NS	mg/L
Thallium	NA	ND	ND / ND [h]	0.002	mg/L
Zinc	NA	ND	ND / ND [n]	5	mg/L
Inorganic Parameters					
Alkalinity - Bicarbonate (HCO3)	282	246	240	NS	mg/L
Alkalinity - Carbonate (CO3)	1	5	3	NS	mg/L
Alkalinity - CO2	205	185	1	NS	mg/L
Alkalinity - Hydroxide (OH)	ND	ND	ND	NS	mg/L
Alkalinity - Total (as CaCO3)	233	211	201	NS	mg/L
Chloride	3	2	2	250	mg/L
Sulfate	8	4	4	500/1000 [b, c]	mg/L
Nitrate as N	0.5	0.6	0.7	10	mg/L
Nitrite as N	ND	ND	ND	1	mg/L
Ammonia as N	NA	ND	ND	NS	mg/L
Phosphate, ortho as P	NA	ND	ND	NS	mg/L
Fluoride	NA	ND	ND	4	mg/L
MBAS Surfactants	NA	0.13	ND	0.5	mg/L
Physical Parameters					
pH	8.3	8.2	8.2	6.5 to 8.5	pH Units
Conductivity	340	347	356	NS	umho/cm
Total Dissolved Solids (as CaCO3)	244	228	208	1000/2000 [b, d]	mg/L
Turbidity	NA	6.4	8.8	5	NTU
Color	NA	7	ND	15	Color Units
Odor	NA	ND	ND	3	0 to 5
Hardness, Total as CaCO3	NA	203	203	NS	mg/L
Langlier Index	NA	0.85	0.83	NS	None

MCL means Maximum Contaminant Level.

NA means laboratory analysis not performed.

ND means not detected.

NS means no standard.

NTU means Nephelometric Turbidity Unit

[a] As per UAC R309-200.

[b] Secondary MCL is 2 mg/L for fluoride, 250 mg/L for sulfate, 500 mg/L for TDS, and 1 for copper.

[c] If Sulfate is greater than 500 mg/L, then supplier must demonstrate that (1) no better water is available and (2) the water will not be available for human commercial establishments.

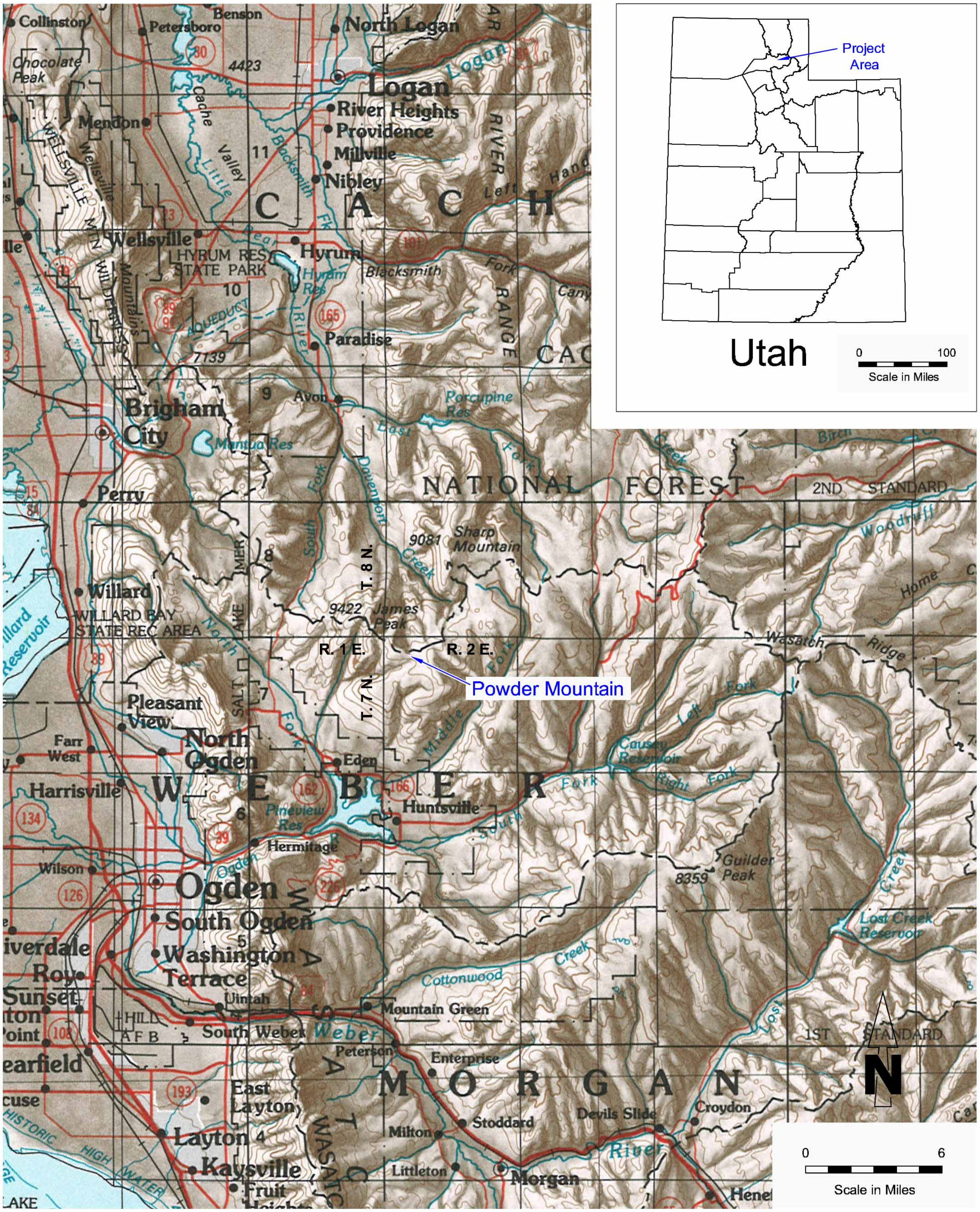
[d] If TDS is greater than 1,000 mg/L, then supplier must demonstrate that no better water is available.

[e] Standard is applicable at the consumer's tap based on statistical sampling.

[f] Sample collected after borehole was air-lift tested for 1 hour.

[g] Sample collected after borehole was air-lift tested for 24 hours.

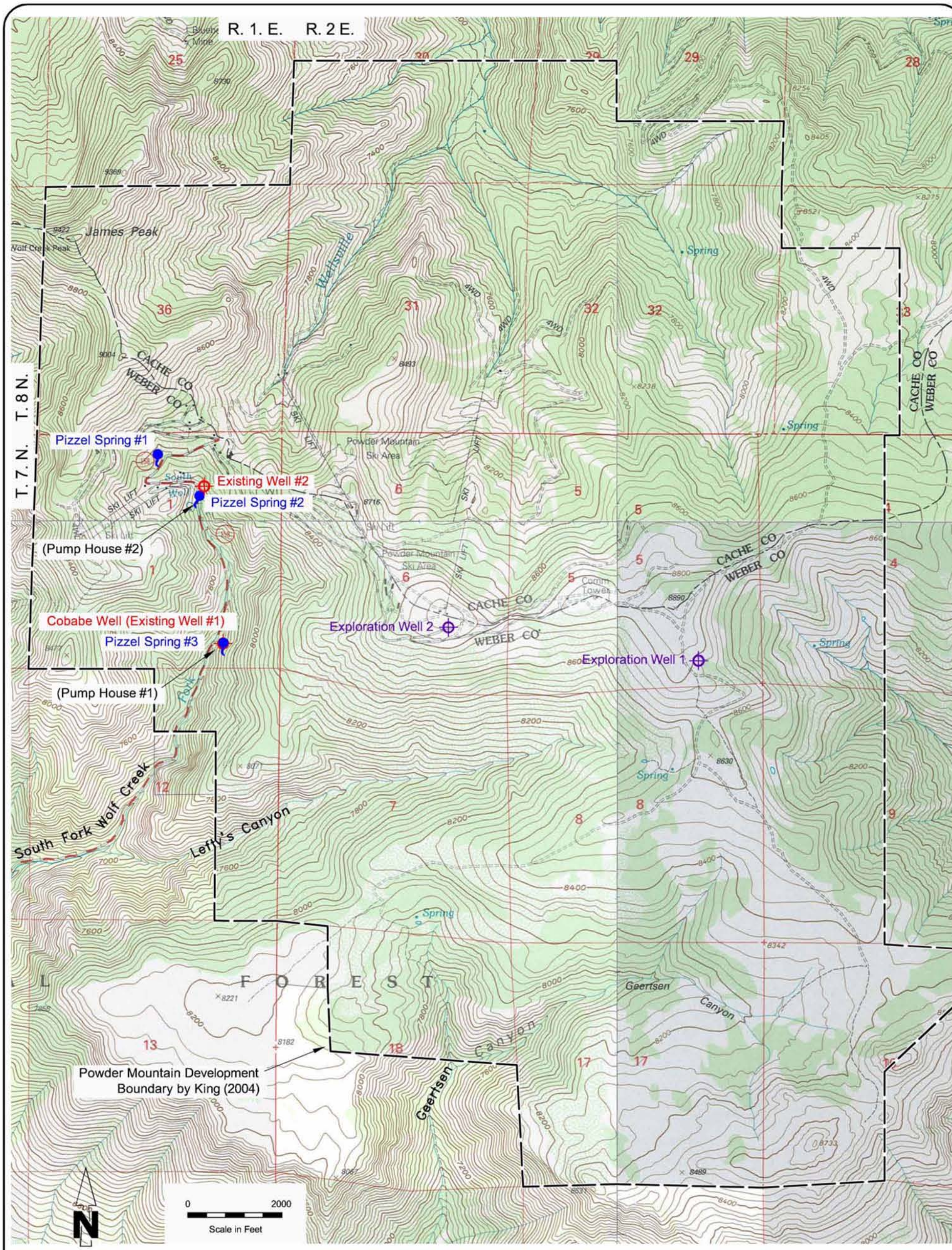
[h] Metals analyses are dissolved except for sample of 6/26/2013 in which both dissolved and total metals analyses were performed. For sample of 6/26/2013, first value in row is dissolved, second value is total.



Base map: "State of Utah Shaded Relief Map":
U.S. Geological Survey (1988).
Contour interval 500 feet.

LOUGHLIN WATER ASSOCIATES LLC

Summit Group
Powder Mountain
Location Map
Figure 1



Base maps: USGS Quadrangle maps (1998): James Peak, UT", "Sharp Mountain, UT", Huntsville, UT", and Browns Hole UT"

Note: Pizzel Spring #1 and #2 designations have been reversed in some documents. Number designations shown are those in current use by PMWSID.

LOUGHLIN WATER ASSOCIATES LLC

Summit Group
Powder Mountain
Vicinity Map
Figure 2

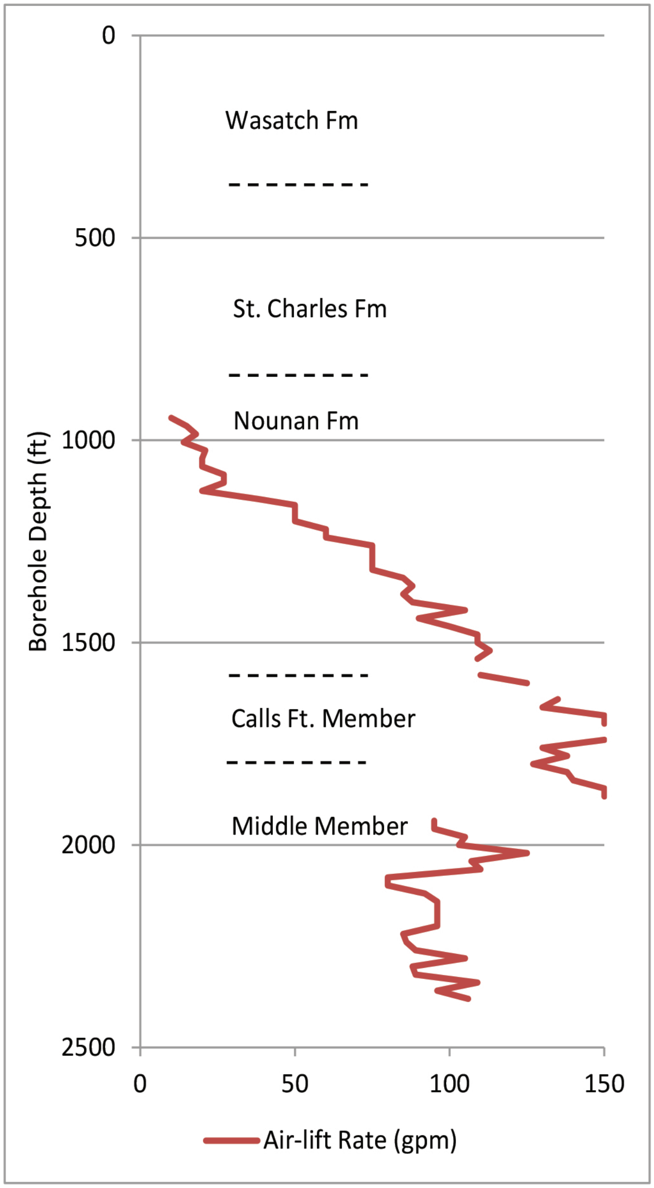


Figure 3A. Plot of air-lift yield rate versus borehole depth

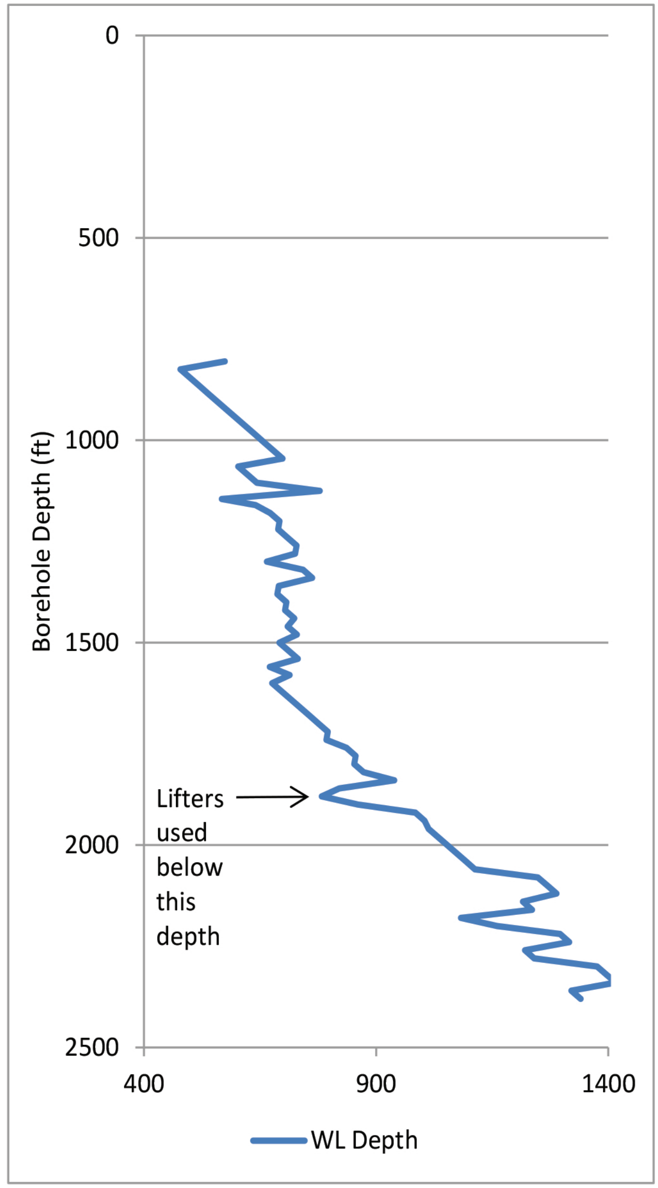


Figure 3B. Plot of groundwater level versus borehole depth

Exploration Well 2 Plots of Air-Lift Yield and Groundwater Level versus Borehole Depth From End-of Rod Data

Loughlin Water Associates LLC

Figure 3

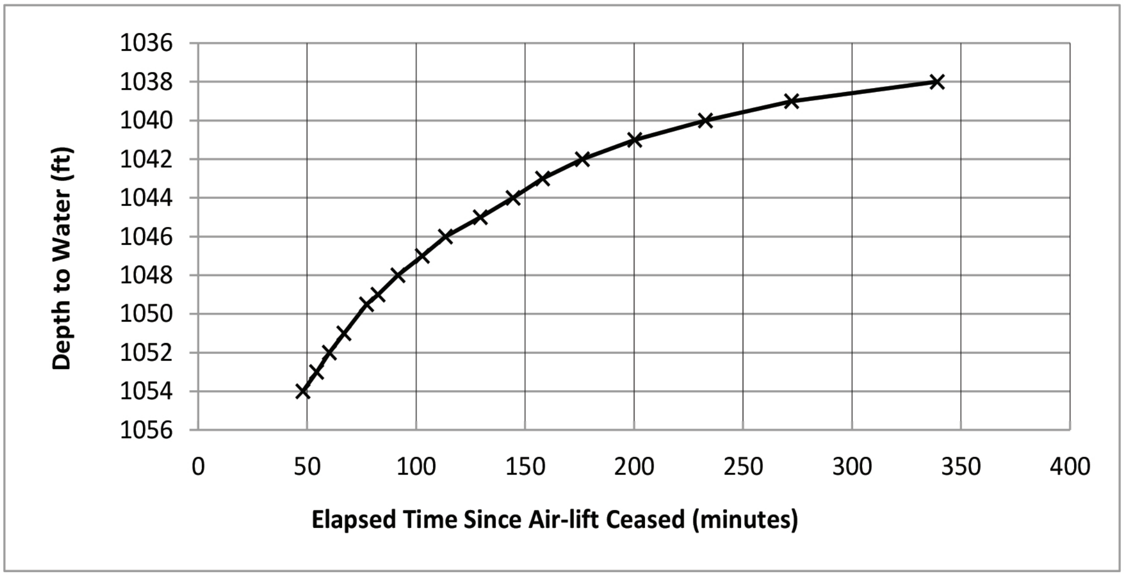


Figure 4A. Groundwater level following 24-hour air-lift test (water level vs. time)

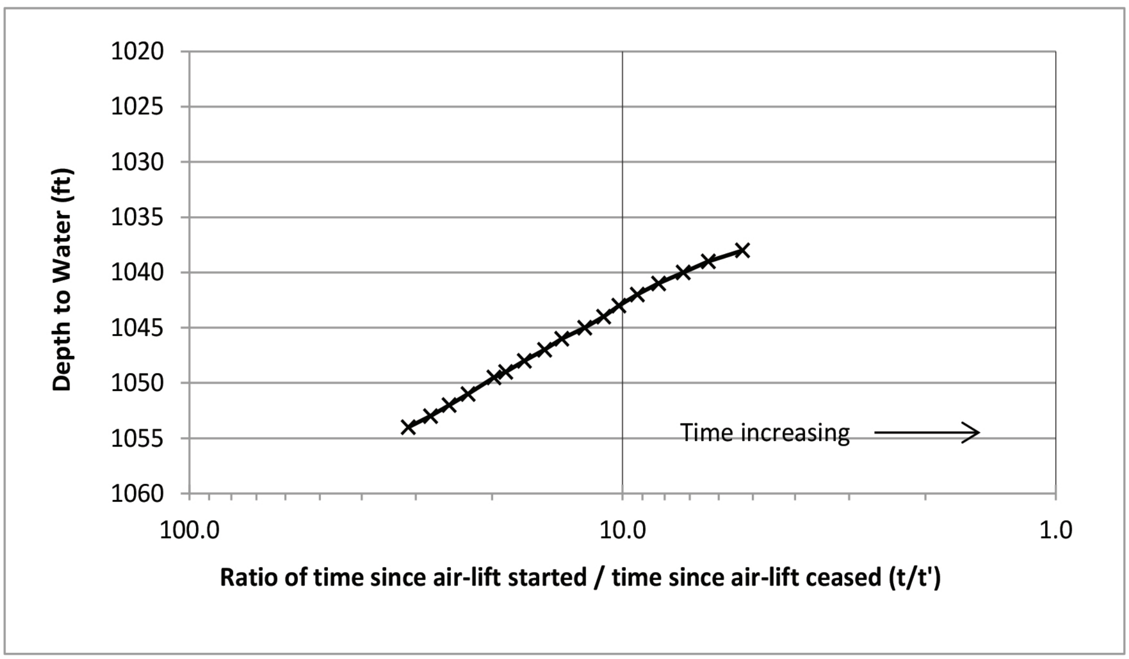


Figure 4B. Groundwater level following 24-hour air-lift test (water level vs. t/t')

Exploration Well 2 - Lower Aquifer
Plots of Residual Groundwater Level
24-hour Air-Lift Test

Loughlin Water Associates LLC **Figure 4**

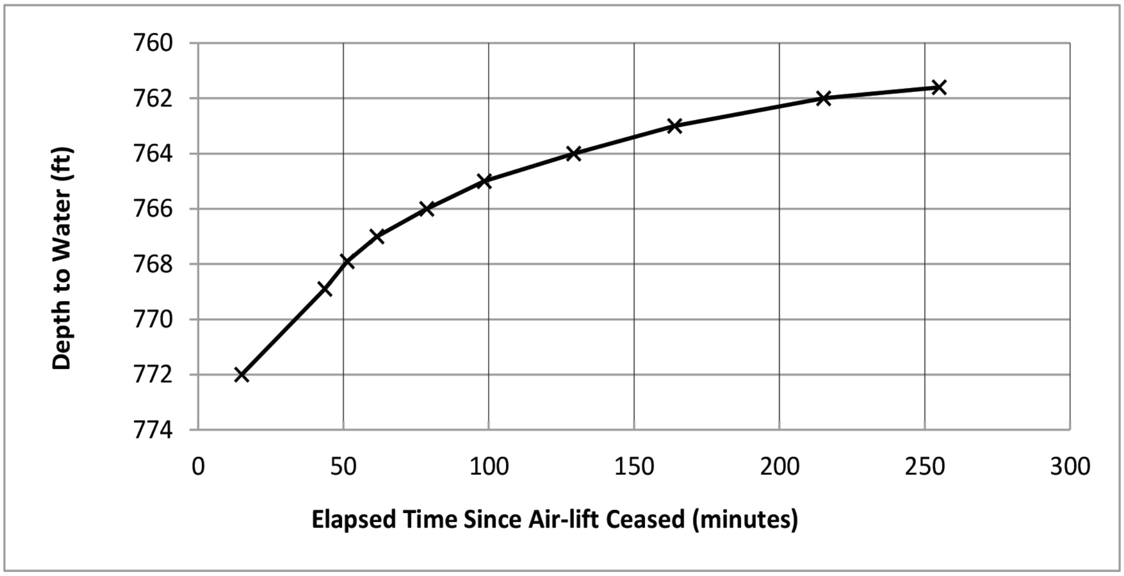


Figure 5A. Groundwater level following 24-hour air-lift test (water level vs. time)

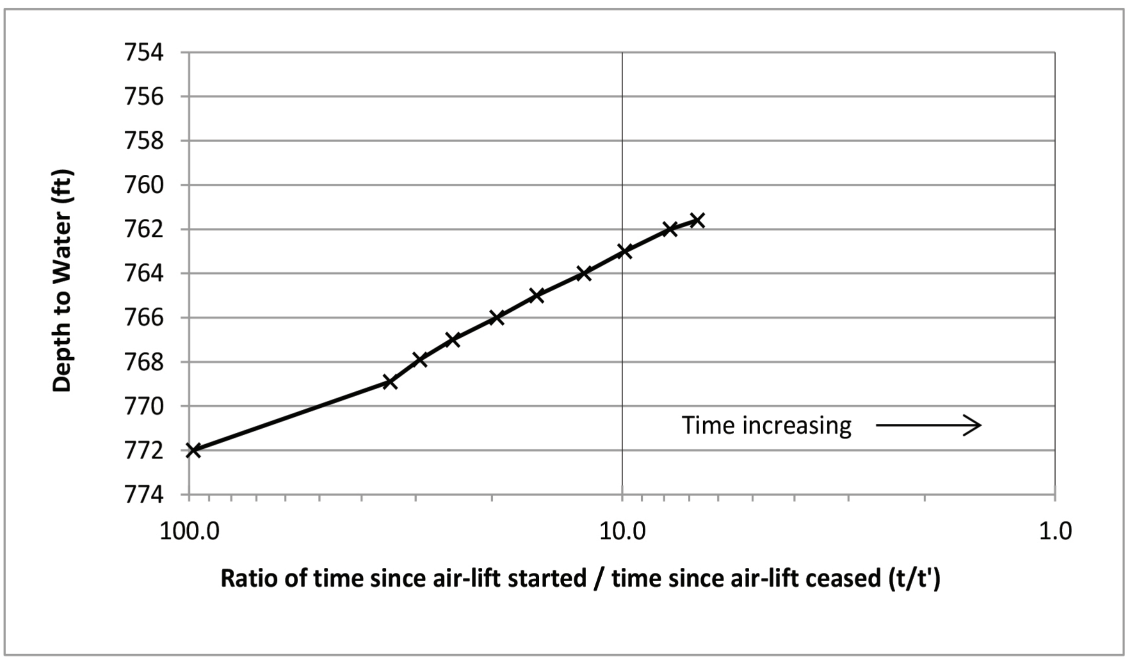
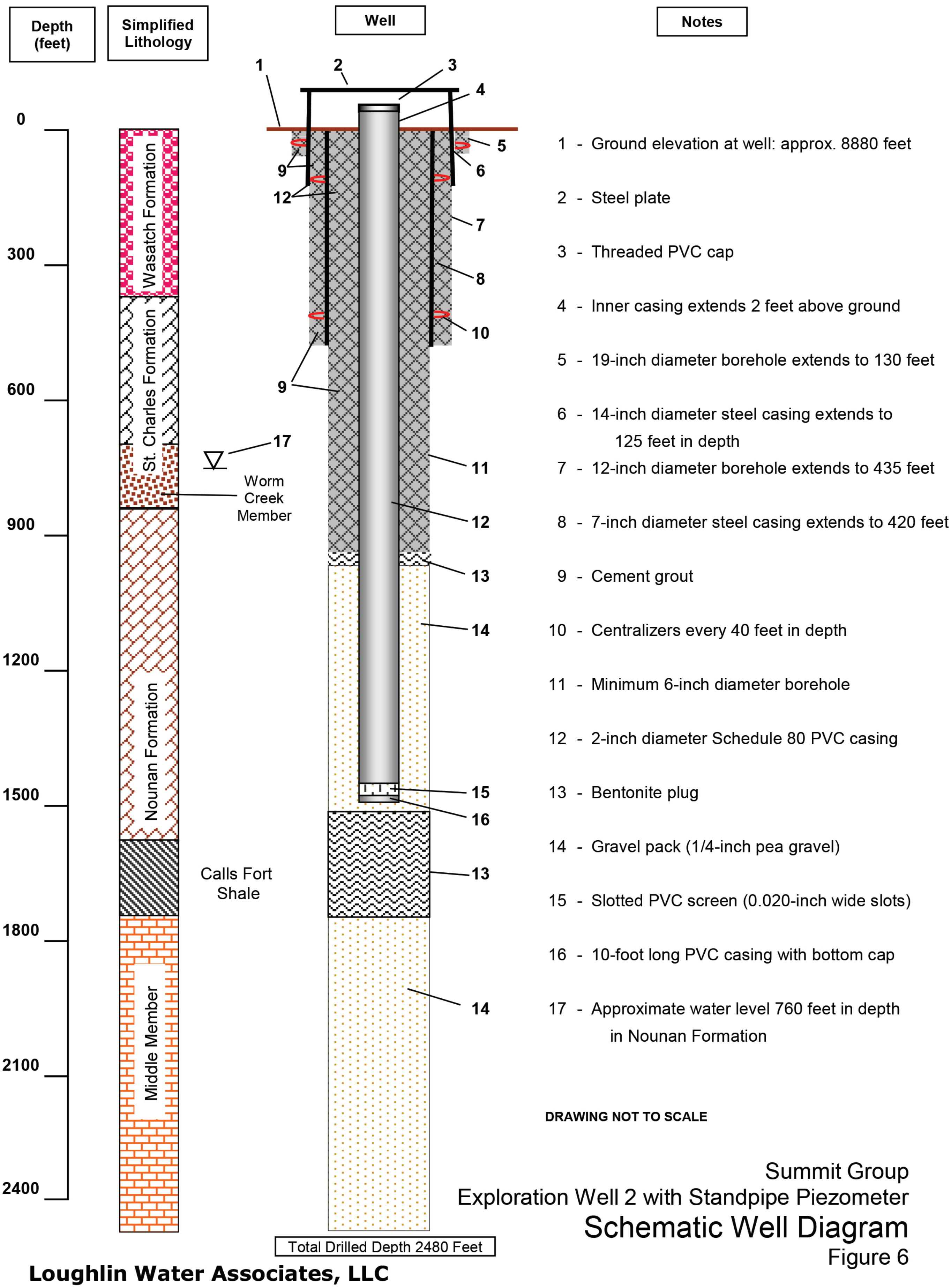


Figure 5B. Groundwater level following 24-hour air-lift test (water level vs. t/t')

Exploration Well 2 - Upper Aquifer
Plots of Residual Groundwater Level
24-hour Air-Lift Test

Loughlin Water Associates LLC **Figure 5**


Depth (feet)
Simplified Lithology
Well
Notes
0
300
600
900
1200
1500
1800
2100
2400
Wasatch Formation
St. Charles Formation
Worm Creek Member
Nounan Formation
Calls Fort Shale
Middle Member
1 - Ground elevation at well: approx. 8880 feet
2 - Steel plate
3 - Threaded PVC cap
4 - Inner casing extends 2 feet above ground
5 - 19-inch diameter borehole extends to 130 feet
6 - 14-inch diameter steel casing extends to 125 feet in depth
7 - 12-inch diameter borehole extends to 435 feet
8 - 7-inch diameter steel casing extends to 420 feet
9 - Cement grout
10 - Centralizers every 40 feet in depth
11 - Minimum 6-inch diameter borehole
12 - 2-inch diameter Schedule 80 PVC casing
13 - Bentonite plug
14 - Gravel pack (1/4-inch pea gravel)
15 - Slotted PVC screen (0.020-inch wide slots)
16 - 10-foot long PVC casing with bottom cap
17 - Approximate water level 760 feet in depth in Nounan Formation
DRAWING NOT TO SCALE
Total Drilled Depth 2480 Feet
Summit Group
Exploration Well 2 with Standpipe Piezometer
Schematic Well Diagram
Figure 6
Loughlin Water Associates, LLC

ATTACHMENT A

WELL DRILLER'S REPORT

WELL DRILLER'S REPORT
State of Utah
Division of Water Rights

For additional space, use "Additional Well Data Form" and attach

Well Identification

Non-Production Well: 1335007M00 WIN: 436850

Owner *Note any changes*

Summit Mountain Holding Group LLC
c/o Watts Enterprises
5200 Highland Drive, Ste 101
Holladay, UT 84117-7065

Contact Person/Engineer: ______

Well Location *Note any changes*

N 1530 E 1173 from the S4 corner of section 06, Township 7N, Range 2E, SL B&M

Location Description: (address, proximity to buildings, landmarks, ground elevation,local well #)

Drillers Activity Start Date: 6-4-13 Completion Date: 6-29-13

Check all that apply: [X] New [ ] Repair [ ] Deepen [ ] Clean [ ] Replace [ ] Public Nature of Use: ______

If a replacement well, provide location of new well. ______ feet north/south and ______ feet east/west of the existing well.

DEPTH (feet) FROM	TO	BOREHOLE DIAMETER (in)	DRILLING METHOD	DRILLING FLUID
0	125	19"	mud rotary	bentonite
125	420	12.25	mud rotary	bentonite
420	2480	6.5	air rotary	

Well Log

DEPTH (feet) FROM	TO	WATER	PERMEABLE High	PERMEABLE Low	UNCONSOLIDATED CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDER	OTHER	CONSOLIDATED ROCK TYPE	COLOR	DESCRIPTION AND REMARKS (e.g., relative %, grain size, sorting, angularity, bedding, grain composition density, plasticity, shape, cementation, consistancy, water bearing, odor, fracturing, minerology, texture,degree of weathering, hardness, water quality, etc.)

Static Water Level

Date 6-28-13 Water Level 763 feet Flowing? [ ] Yes [X] No

Method of Water Level Measurement Static tape If Flowing, Capped Pressure ______ PSI

Point to Which Water Level Measurement was Referenced Rig table Elevation ______

Height of Water Level reference point above ground surface 4' feet Temperature Cool degrees [ ] C [ ] F

WELL DRILLER'S REPORT ADDTIONAL DATA FORM
State of Utah
Division of Water Rights

Page ____ of ____

Well Identification

Non-Production Well: 1335007M00

Owner *Note any changes*

Summit Mountain Holding Group LLC
c/o Watts Enterprises
5200 Highland Drive, Ste 101
Holladay, UT 84117-7065

Contact Person/Engineer: ____________________

Well Location *Note any changes*

N 1530 E 1173 from the S4 corner of section 06, Township 7N, Range 2E, SL B&M

Location Description: (address, proximity to buildings, landmarks, ground elevation,local well #)

Well Log

DEPTH (feet)		WATER	PERMEABLE		UNCONSOLIDATED							CONSOLIDATED		DESCRIPTION AND REMARKS (e.g., relative %, grain size, sorting, angularity, bedding, grain composition density, plasticity, shape, cementation, consistancy, water bearing, odor, fracturing, minerology, texture,degree of weathering, hardness, water quality, etc.)
FROM	TO		High	Low	CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDER	OTHER	ROCK TYPE	COLOR	

Construction Information (con't)

DEPTH (feet) FROM	TO	CASING: CASING TYPE AND MATERIAL/GRADE	WALL THICK (in)	NOMINAL DIAM. (in)	DEPTH (feet) FROM	TO	☒SCREEN ☐PERFORATIONS ☐OPEN BOTTOM: SCREEN SLOT SIZE OR PERF SIZE (in)	SCREEN DIAM. OR PERF LENGTH (in)	SCREEN TYPE OR NUMBER PERF (per round/interval)
+3	120	Steel	.375	14	1450	1470	.020	2.375	
0	420	Steel	.301	7.625					
+2	1480	Sch 80 pvc	.154	2.375					

DEPTH (feet) FROM	TO	SURFACE SEAL / INTERVAL SEAL / FILTER PACK / PACKER INFORMATION: SEAL MATERIAL, FILTER PACK and PACKER TYPE and DESCRIPTION	Quantity of Material Used (if applicable)	GROUT DENSITY (lbs./gal., # bag mix, gal./sack etc.)
0	983	neat cement		
983	1004	3/8 hole plug		
1004	1510	1/4 gravel		
1510	1750	3/8 hole plug		
1750	2480	1/4 gravel		

Comments (con't)

Well Driller Statement This well was drilled and constructed under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge and belief.

Name NATIONAL EWP (Person, Firm, or Corporation - Print or Type) License No. 8

Signature Date

Construction Information

DEPTH (feet)		CASING			DEPTH (feet)		☐SCREEN ☐PERFORATIONS ☐OPEN BOTTOM		
FROM	TO	CASING TYPE AND MATERIAL/GRADE	WALL THICK (in)	NOMINAL DIAM. (in)	FROM	TO	SCREEN SLOT SIZE OR PERF SIZE (in)	SCREEN DIAM. OR PERF LENGTH (in)	SCREEN TYPE OR NUMBER PERF (per round/interval)

Well Head Configuration:______ Access Port Provided? ☑Yes ☐No

Casing Joint Type:______ Perforator Used:______

Was a Surface Seal Installed? ☑Yes ☐No Depth of Surface Seal: 983 feet Drive Shoe? ☐Yes ☑No

Surface Seal Material Placement Method pumped

Was a temporary surface casing used? ☐Yes ☑No If yes, depth of casing:______ feet diameter:______ inches

DEPTH (feet)		SURFACE SEAL / INTERVAL SEAL / FILTER PACK / PACKER INFORMATION		
FROM	TO	SEAL MATERIAL, FILTER PACK and PACKER TYPE and DESCRIPTION	Quantity of Material Used (if applicable)	GROUT DENSITY (lbs./gal., # bag mix, gal./sack etc.)

Well Development and Well Yield Test Information

DATE	METHOD	YIELD	Units Check One		DRAWDOWN (ft)	TIME PUMPED (hrs & min)
			GPM	CFS		
6-24-13	air lift	84	/		16	24 HRS

Pump (Permanent)

Pump Description:______ Horsepower:______ Pump Intake Depth:______ feet

Approximate Maximum Pumping Rate:______ Well Disinfected upon Completion? ☐Yes ☐No

Comments Description of construction activity, additional materials used, problems encountered, extraordinary Circumstances, abandonment procedures. *Use additional well data form for more space.*

Well Driller Statement This well was drilled and constructed under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge and belief.

Name NATIONAL EWP (Print or Type) License No. 805

Signature (Driller) Date

Simplified Lithology
Exploration Well 2 at Powder Mountain

Depth From	Depth To	Thickness (ft)		Formation and Predominant Lithology
0	15	15	15	Fill - gravel, boulders, clay and silt with some sand. Mostly moderate reddish brown. Unconsolidated.
15	205	350	190	Wasatch Formation - Gravel and boulders with clay, silt and some sand. Mostly moderate reddish brown. Mostly unconsolidated.
205	260		55	Wasatch Formation - Clay with silt, gravel and cobbles. Mostly moderate reddish brown.
260	285		25	Wasatch Formation - Fine-grained sandstone with siltstone and mudstone, some clay and limestone /dolomite. Mostly consolidated.
285	305		20	Wasatch Formation - Lacustrine - Limestone/dolomite with sandy dolomite, trace mudstone and clay.
305	365		60	Wasatch Formation - Fine-grained sandstone, siltstone and mudstone.
365	695	330	330	St. Charles Formation - Dolomite with sandstone, siltstone, limestone and clay. Mostly light gray to grayish black; clay, mudstone and sandstone tend to orange-yellow.
695	840	145	145	Worm Creek Quartzite Member - Quartzite, siltstone, shale, clay and dolomite. Light to dark gray and pale to dark orange.
840	1315	655	475	Nounan Formation - Dolomite. Light gray to dark gray.
1315	1415		100	Nounan Formation - Dolomite. Light gray to dark gray with trace red clay.
1415	1495		80	Nounan Formation - Dolomite. Light gray to dark gray.
1495	1530		35	Nounan Formation - Dolomite, mudstone and shale; pyrite noted; medium to dark gray and light olive gray.
1530	1580		50	Nounan Formation - Dolomite and limestone with oolites and some shale. Dark gray and light olive gray. With white calcite streaks and spots.
1580	1640	215	60	Calls Fort Shale Member - Dark gray shale with some limestone.
1640	1722		82	Calls Fort Shale Member - Shale, slightly calcareous. Dark gray, dark greenish gray, and moderate olive gray.
1722	1795		73	Calls Fort Shale Member - Shale and limestone with some dolomite, dark gray to grayish black.
1795	1845	685	50	Middle Limestone Member - Dolomite with a little limestone, occasional pyrite noted, grayish black, dark gray and black. Minor siltstone.
1845	1900		55	Middle Limestone Member - Limestone and dolomite with some siltstone. Medium to dark gray.
1900	2020		120	Middle Limestone Member - Dolomite with a little limestone, occasional pyrite noted, grayish black, dark gray and black. Minor siltstone.
2020	2210		190	Middle Limestone Member - Dolomite with a little limestone and calcareous sand, grayish black to light gray and white. Some reddish-orange staining.
2210	2235		25	Middle Limestone Member - Alteration Zone - Light brown sandstone with dolomite inclusion and calcite veins.
2235	2315		80	Middle Limestone Member - Dolomite, dark gray and white with some reddish and brown colored alteration/staining.
2315	2480		165	Middle Limestone Member - Limestone and dolomite with some oolites, shaley limestone and shale argillite, dark to light gray in color, trace pyrite.

For detailed descriptions, see Borehole Lithologic Log

Loughlin Water Associates LLC Page 1 of 1 Printed: 7/15/2013

APPENDIX B

PARAMETERS OF THE AQTESOLV MODEL

Appendix B. Parameters of the AQTESOLV model.

AQTESOLV for Windows

Data Set: E:\Google Drive\WORK\Powder Mountain Aquifer Extension\For Distribution\Long_Term_Aquifer_Test_U
Date: 05/18/17
Time: 14:44:20

PROJECT INFORMATION

Company: UGS
Client: DWR
Project: 1
Location: Powder Mountain
Test Date: 11/2/2014
Test Well: Hidden Lake

AQUIFER DATA

Saturated Thickness: 819. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b'): 65.5 m
Aquitard Thickness (b"): 1280. m

PUMPING WELL DATA

No. of pumping wells: 1

Pumping Well No. 1: Developed Exp2

X Location: 436144. m
Y Location: 4580000. m

Casing Radius: 0.18 m
Well Radius: 0.18 m

Fully Penetrating Well

No. of pumping periods: 1

Pumping Period Data

Time (min)	Rate (gal/min)
0.	100.

OBSERVATION WELL DATA

No. of observation wells: 1

Observation Well No. 1: Developed Exp2

X Location: 436144. m
Y Location: 4580000. m

Radial distance from Developed Exp2: 0. m

Fully Penetrating Well

No. of Observations: 0

SOLUTION

Pumping Test
Aquifer Model: Leaky
Solution Method: Neuman-Witherspoon

VISUAL ESTIMATION RESULTS

Estimated Parameters

Parameter	Estimate	
T	130.	ft^2/day

Appendix B. Parameters of the AQTESOLV model.

AQTESOLV for Windows

S	0.006	
r/B	0.08	
ß	1.	
T2	228.	ft^2/day
S2	0.006	

K = T/b = 0.04838 ft/day (1.707E-5 cm/sec)
Ss = S/b = 7.326E-6 1/m
K'/b' = 0.001657 min^{-1}
K' = 512.7 ft/day

APPENDIX C

OUTPUT OF THE FORWARD MODELS

Appendix C. Output of the forward models.

County	Cell Count	AREA (m^2)	Drawdown Max (m)	Drawdown Areal Mean (m)	Drawdown Sum (m)	Pumping Duration (days)	Pump Rate (gpm)	Solution[1]	Aquifer	Volume Removed (ac-ft)	Contribution
Cache	207474	20837901	8.1	0.0014	298	1	200	N-W	Bottom	24	22%
Weber	140907	14152164	34.6	0.0076	1070	1	200	N-W	Bottom	87	78%
Total	348381	34990065	34.6	0.0039	1368	1	200	N-W	Bottom	111	100%
Cache	207474	20837901	10.2	0.0032	654	2	200	N-W	Bottom	53	28%
Weber	140907	14152164	36.9	0.0122	1723	2	200	N-W	Bottom	140	72%
Total	348381	34990065	36.9	0.0068	2378	2	200	N-W	Bottom	194	100%
Cache	207474	20837901	14.5	0.0172	3563	10	200	N-W	Bottom	290	37%
Weber	140907	14152164	41.3	0.0428	6027	10	200	N-W	Bottom	491	63%
Total	348381	34990065	41.3	0.0274	9590	10	200	N-W	Bottom	781	100%
Cache	207474	20837901	17.3	0.0515	10691	30	200	N-W	Bottom	871	39%
Weber	140907	14152164	44.1	0.1195	16844	30	200	N-W	Bottom	1372	61%
Total	348381	34990065	44.1	0.0788	27535	30	200	N-W	Bottom	2242	100%
Cache	207474	20837901	19.0	0.1010	20957	60	200	N-W	Bottom	1706	38%
Weber	140907	14152164	45.8	0.2378	33501	60	200	N-W	Bottom	2728	62%
Total	348381	34990065	45.8	0.1558	54458	60	200	N-W	Bottom	4434	100%
Cache	207474	20837901	4.0	0.0007	149	1	100	N-W	Bottom	12	22%
Weber	140907	14152164	17.3	0.0038	535	1	100	N-W	Bottom	44	78%
Total	348381	34990065	17.3	0.0020	684	1	100	N-W	Bottom	56	100%
Cache	207474	20837901	6.4	0.0042	869	5	100	N-W	Bottom	71	34%
Weber	140907	14152164	19.8	0.0120	1690	5	100	N-W	Bottom	138	66%
Total	348381	34990065	19.8	0.0073	2559	5	100	N-W	Bottom	208	100%
Cache	207474	20837901	7.3	0.0086	1782	10	100	N-W	Bottom	145	37%
Weber	140907	14152164	20.7	0.0214	3013	10	100	N-W	Bottom	245	63%
Total	348381	34990065	20.7	0.0137	4795	10	100	N-W	Bottom	390	100%
Cache	207474	20837901	8.6	0.0258	5345	30	100	N-W	Bottom	435	39%
Weber	140907	14152164	22.1	0.0598	8422	30	100	N-W	Bottom	686	61%
Total	348381	34990065	22.1	0.0394	13768	30	100	N-W	Bottom	1121	100%
Cache	207474	20837901	9.5	0.0505	10478	60	100	N-W	Bottom	853	38%
Weber	140907	14152164	22.9	0.1189	16751	60	100	N-W	Bottom	1364	62%
Total	348381	34990065	22.9	0.0779	27229	60	100	N-W	Bottom	2217	100%
Cache	207474	20837901	10.4	0.0989	20522	120	100	N-W	Bottom	1671	38%
Weber	140907	14152164	23.8	0.2387	33637	120	100	N-W	Bottom	2739	62%
Total	348381	34990065	23.8	0.1549	54159	120	100	N-W	Bottom	4410	100%
Cache	207474	20837901	11.2	0.1951	40472	240	100	N-W	Bottom	3295	37%
Weber	140907	14152164	24.6	0.4795	67562	240	100	N-W	Bottom	5501	63%
Total	348381	34990065	24.6	0.3091	108034	240	100	N-W	Bottom	8797	100%
Cache	207474	20837901	0.0	0.0000	0	1	100	N-W	Top	0	0%
Weber	140907	14152164	0.1	0.0000	0	1	100	N-W	Top	0	0%
Total	348381	34990065	0.1	0.0000	0	1	100	N-W	Top	0	0%
Cache	207474	20837901	2.7	0.0035	732	5	100	N-W	Top	60	38%
Weber	140907	14152164	3.2	0.0085	1195	5	100	N-W	Top	97	62%
Total	348381	34990065	3.2	0.0055	1927	5	100	N-W	Top	157	100%
Cache	207474	20837901	3.5	0.0079	1647	10	100	N-W	Top	134	40%
Weber	140907	14152164	4.0	0.0179	2522	10	100	N-W	Top	205	60%
Total	348381	34990065	4.0	0.0119	4169	10	100	N-W	Top	339	100%
Cache	207474	20837901	4.9	0.0251	5208	30	100	N-W	Top	424	40%
Weber	140907	14152164	5.4	0.0563	7933	30	100	N-W	Top	646	60%
Total	348381	34990065	5.4	0.0376	13142	30	100	N-W	Top	1070	100%
Cache	207474	20837901	5.7	0.0498	10340	60	100	N-W	Top	842	39%

Appendix C. Output of the forward models.

County	Cell Count	AREA (m^2)	Drawdown Max (m)	Drawdown Areal Mean (m)	Drawdown Sum (m)	Pumping Duration (days)	Pump Rate (gpm)	Solution[1]	Aquifer	Volume Removed (ac-ft)	Contribution
Weber	140907	14152164	6.2	0.1154	16263	60	100	N-W	Top	1324	61%
Total	348381	34990065	6.2	0.0761	26603	60	100	N-W	Top	2166	100%
Cache	207474	20837901	7.5	0.1944	40333	240	100	N-W	Top	3284	38%
Weber	140907	14152164	8.0	0.4760	67076	240	100	N-W	Top	5462	62%
Total	348381	34990065	8.0	0.3073	107409	240	100	N-W	Top	8746	100%
Cache	13747	12372300	4	0.002	23	1	100	Theis	Bottom	17	16%
Weber	15629	14066100	49	0.008	125	1	100	Theis	Bottom	91	84%
Total	29376	26438400	49	0.005	148	1	100	Theis	Bottom	108	100%
Cache	13747	12372300	6	0.004	57	2	100	Theis	Bottom	42	23%
Weber	15629	14066100	51	0.012	191	2	100	Theis	Bottom	140	77%
Total	29376	26438400	51	0.008	249	2	100	Theis	Bottom	181	100%
Cache	13747	12372300	13	0.027	376	10	100	Theis	Bottom	274	30%
Weber	15629	14066100	49	0.057	883	10	100	Theis	Bottom	645	70%
Total	29376	26438400	49	0.043	1259	10	100	Theis	Bottom	919	100%
Cache	13747	12372300	16	0.084	1158	30	100	Theis	Bottom	845	35%
Weber	15629	14066100	52	0.136	2121	30	100	Theis	Bottom	1548	65%
Total	29376	26438400	52	0.112	3279	30	100	Theis	Bottom	2392	100%
Cache	13747	12372300	18	0.167	2296	60	100	Theis	Bottom	1675	36%
Weber	15629	14066100	54	0.257	4011	60	100	Theis	Bottom	2927	64%
Total	29376	26438400	55	0.215	6307	60	100	Theis	Bottom	4602	100%
Cache	13747	12372300	19	0.248	3415	90	100	Theis	Bottom	2492	37%
Weber	15629	14066100	56	0.379	5920	90	100	Theis	Bottom	4320	63%
Total	29376	26438400	56	0.318	9335	90	100	Theis	Bottom	6811	100%
Cache	13747	12372300	20	0.329	4526	120	100	Theis	Bottom	3303	37%
Weber	15629	14066100	57	0.501	7837	120	100	Theis	Bottom	5718	63%
Total	29376	26438400	57	0.421	12363	120	100	Theis	Bottom	9021	100%
Cache	13747	12372300	22	0.651	8953	240	100	Theis	Bottom	6533	37%
Weber	15629	14066100	59	0.992	15511	240	100	Theis	Bottom	11317	63%
Total	29376	26438400	59	0.833	24464	240	100	Theis	Bottom	17850	100%

1 "Theis" is the Theis (1935) solution and "N-W" is the Neuman Witherspoon (1969) solution.