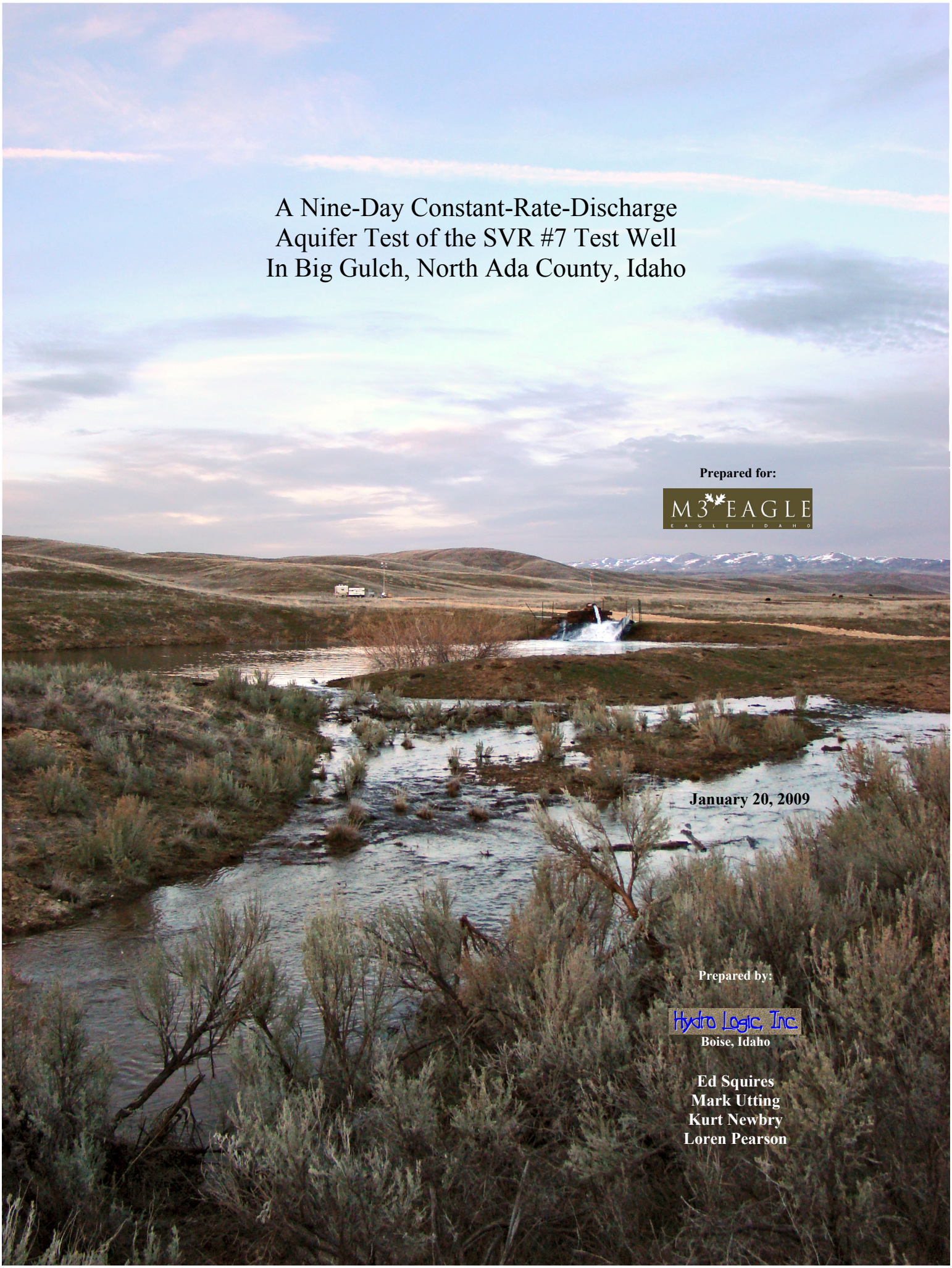


A Nine-Day Constant-Rate-Discharge Aquifer Test of the SVR #7 Test Well In Big Gulch, North Ada County, Idaho

Prepared for:

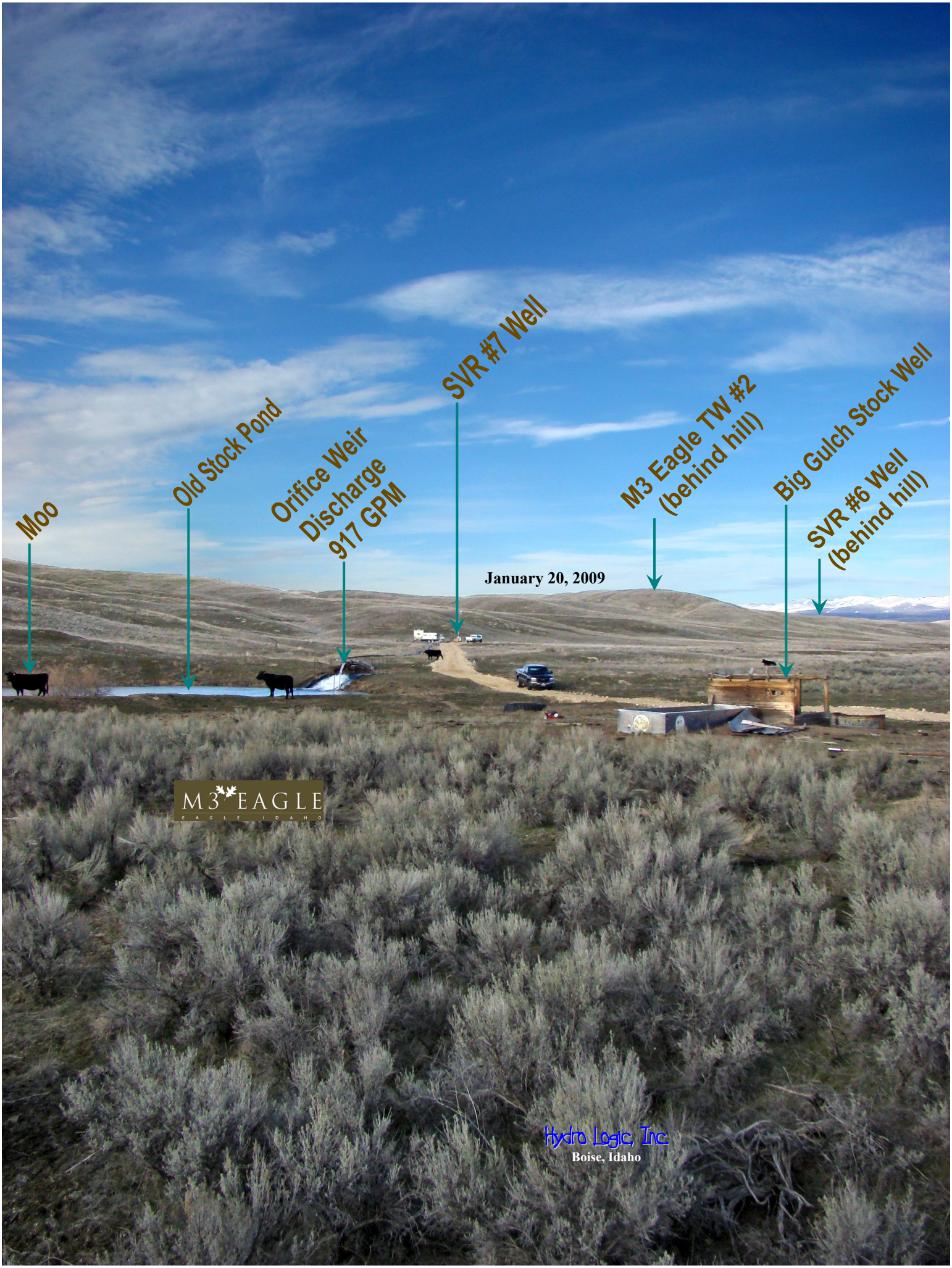
M3 EAGLE
EAGLE IDAHO

January 20, 2009

Prepared by:

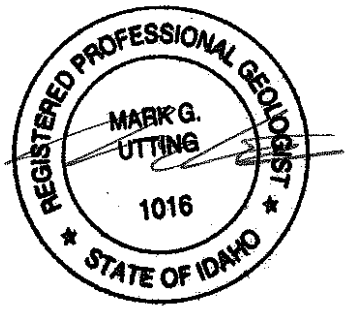
Hydro Logic, Inc.
Boise, Idaho

Ed Squires
Mark Utting
Kurt Newbry
Loren Pearson


Moo
Old Stock Pond
Orifice Weir
Discharge
917 GPM
SVR #7 Well
M3 Eagle TW #2
(behind hill)
Big Gulch Stock Well
SVR #6 Well
(behind hill)
January 20, 2009
M3 EAGLE
EAGLE IDAHO
Hydro Logic, Inc.
Boise, Idaho

A Nine-Day Constant Rate Discharge Aquifer Test of the SVR #7 Test Well in Big Gulch, North Ada County, Idaho

Prepared for:
M3 Eagle, LLC



January 20, 2009

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OVERVIEW

A nine-day, 917 gallons per minute (gpm) constant-rate aquifer test was conducted by Hydro Logic, Inc. for M3 Eagle, LLC in the Big Gulch vicinity of North Ada County during the Spring of 2008. Water levels were measured in 22 on-site and 2 off-site wells for two-to-five days before and two weeks after the nine-day, pumping portion of the test.

HLI designed and orchestrated the nine-day discharge test over the period March 1-31, 2008 after directing a comprehensive well development program of high-pressure water jetting, surge block swabbing, and isolation packer-pumping of the screened interval of the SVR #7 well (the pumping well for the aquifer test). A total of 26 wells were monitored during the test. Most of these wells were inspected with down-hole video cameras, swabbed, bailed, and/or tested to ensure viability as monitoring wells. Those wells equipped with pumping plants had the equipment removed prior to development and designated monitoring tubes installed when the pumps were replaced in the wells; only the pumping well was produced during the month-long test period.

The SVR#7 well was pumped at a constant and continuous pumping rate of 917 gpm (± 0.5 percent) for 12,970 minutes (9-days). The discharge, to a stock pond ~800 feet from the pumping well and, ultimately, spilling over into the dry bed of intermittent Big Gulch Creek, was measured with both, a transducer-equipped circular orifice weir and a propeller-type, totalizing in-line flow-meter. Approximately 12 million gallons of water were pumped during the draw down portion of the test.

Drawdown in the pumped well (SVR #7) at the end of the test was measured at 193.78 feet below the pre-test, non-pumping level of 165.21 ft bgl (below ground level) for an end-of-test drawdown of 28.57 ft, and a calculated nine-day specific-capacity of 32.1 gpm/ft. Most of the drawdown observed in the pumping well was the result of low well-efficiency (calculated at 15 percent) caused by frictional flow through a louvered well screen, torch-cut perforated pipe, and a crushed-gravel "hole-filler" used to envelop the completion interval of the well during its original construction. Water level measurements in the pumping well, as with all of the observation wells for this test, were obtained with steel-tape-calibrated electric sounders and programmed pressure-transducer/data-loggers over the entire month-long test (pre-test, drawdown, recovery).

Water level responses in observation wells during the test were measurable but small, ranging from 1.71 to 0.09 feet in observation wells located 845 feet to more than two miles from the pumping well, respectively. The relatively small drawdown observed in the pumping well, and the shallow regional drawdown "cone of depression" generated in the Pierce Gulch Sand Aquifer during the test, indicate that sustainable pumping yields in excess of 2,000 gpm are possible from properly designed and constructed water supply wells beneath the western and central portions of the M3 property.

The maximum drawdown in the nearest observation well ("Big Gulch Stock Well") located 845 ft from SVR #7, was1.71 ft. The furthest responding observation well (SVR #9, at 11,660 ft from SVR #7, indicated a drawdown of 0.09 ft. Several of the observation wells located from 8,173 to 22,302 feet from SVR #7 indicated no measurable drawdown response during the test.

Analysis of the test data by HLI demonstrates that the Pierce Gulch Sand Aquifer beneath the foothills areas north of the City of Eagle is more transmissive than previously believed with a mean aquifer transmissivity of 410,000 gallons per day per foot (gpd/ft). The data were analyzed using Aqtesolv® after preprocessing with MS Excel spreadsheet software to quantify and remove barometric effects and back ground regional aquifer water level trends. The results of the HLI analyses indicate that the Pierce Gulch Sand Aquifer (pumped by SVR #7 and monitored by most of the 22 observation wells) has a transmissivity ranging from 450,000 to 580,000 gpd/ft and a storativity averaging $2x10^{-3}$ (unitless) beneath the western and central portions of the M3 property. The calculated transmissivity values are lower, and the storativity values higher, beneath the eastern and central portions of the property where the Pierce Gulch Sand Aquifer rises to the surface, has a smaller saturated thickness, and is mostly unconfined. In these areas the transmissivity ranges from 180,000 to 300,000 gpd/ft with storativities (specific yields) on the order of 0.1 to 0.2; still large values for both coefficients. Theis (1935) analyses of drawdown data proved most effective because most observation wells were too far from the pumping well to use the Cooper-Jacob (1946) method. Barometric Efficiency is quite high, ranging from 33% to 99% in wells on the M3 property, supporting HLI's conclusion (HLI, 2007) that the Pierce Gulch Sand Aquifer is somewhat-to-highly cemented.

The results of our aquifer test analyses indicate that the Pierce Gulch Sand Aquifer beneath the M3 site has similar characteristics to the Pierce Gulch Sand Aquifer beneath the greater Eagle-Star vicinity. The Pierce Gulch Sand Aquifer is highly transmissive beneath both upland and valley regions. The analyses reported from this test are comparable to the high-transmissivity results reported in the reanalyses of 16 other North Ada County aquifer tests reported in HLI (2008b).

Our interpretation of borehole geophysical logs, high-quality lithologic logs (from both on-site and from several wells to the south in the greater Eagle and Star vicinity), and previously conducted aquifer tests, has resulted in an improved understanding of the 3-dimensional geometry and hydrogeologic framework of the Pierce Gulch Sand Aquifer, and the overlying shallow alluvial sub-aquifers, present beneath parts of the M3 site and beneath areas to the south. This refined understanding helped to guide the test design and was essential to our analysis of the data from the SVR #7 aquifer test.

The SVR #7 nine-day aquifer test satisfies our previous recommendation (HLI, 2008b) to conduct a major aquifer test in the North Ada County foothills. This prolonged hydraulic testing at 917 gpm, a rate comparable to a many other municipal water supply wells in the area, allowed the pumping well cone of depression to be monitored at distances of over 2 miles. The results of this test help to further refine and support the previous

analyses of the Pierce Gulch Sand Aquifer as *the* major regional water supply aquifer in the greater M3-Eagle-Star vicinity. The aquifer test is meaningful and useful because:

a) The testing period was sufficiently long and the pumping rate sufficiently high to adequately characterize true aquifer response,

b) The three-dimensional hydrogeologic framework of the aquifer system is now better understood because of careful analysis of borehole geophysical logs and careful lithologic analysis,

c) The effects of atmospheric pressure changes and pre-test water level trends were removed as part of the data analysis,

d) Only one well (SVR #7) was pumping during the test,

e) Water level measurements were made at one-minute intervals using electronic data loggers carefully calibrated to hand-measured levels,

f) Rigorous state-of-the-art, computer-based analytical techniques were used to assess whether the chosen methods were applicable over the time-period of analysis and to the specific hydrogeologic setting. None of the previous tests conducted within the greater Eagle-Star-M3 vicinity have met all six of these criteria,

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SECTION I: INTRODUCTION

A nine-day, constant-rate aquifer test with pumping occurring from March 10 through 19, 2008, followed by water level recovery through March 31, 2008, demonstrates that large yields of greater than 2,000 gallons per minute (gpm) are possible from individual wells completed in the highly transmissive Pierce Gulch Sand Aquifer beneath portions of the M3 Eagle property. During the test, well SVR #7 was pumped continuously at 917 gpm (± 0.5 percent) with water levels measured in a total of 23 wells completed at 13 locations. The analysis of data collected from wells completed at distances of 845 feet to 22,300 feet from the pumping well indicates an average aquifer transmissivity of 410,000 gallons per day per foot (gpd/ft) and an average storativity of $5x10^{-3}$ (unitless). Changes in water levels ("drawdowns") caused by the pumping of SVR #7 ranged from 1.71 feet in the nearest observation well to about 0.09 feet in SVR #9, located 11,660 ft from the pumping well. The drawdown in the 8-in diameter pumping well at the end of the test was 28.57 ft feet, resulting in a 9-day specific capacity of 32.1 gpm/ft of drawdown.

The test was designed and conducted after Hydro Logic, Inc (HLI) reanalyzed the data from a 22-hour pumping test of the test well (previously conducted by others) and concluded that the aquifer was highly transmissive and appeared potentially capable of large, municipal well yields. The previous test, however, was inconclusive for accurate quantification of aquifer transmissivity and storativity (HLI, 2008), parameters needed to accurately predict the long-term performance of a supply well and to predict the impacts on wells completed in Pierce Gulch Sand Aquifer within the greater Eagle-Star vicinity. To ensure the best possible test data, HLI designed and supervised a comprehensive well-development program (the well had not been previously developed and produced sand).

The constant-rate-discharge test was conducted under the direction of Hydro Logic, Inc. Denis Owsley from the Idaho Department of Water Resources (IDWR) assisted during the early part of the test. Water levels were measured using both electronic data loggers, and calibrated electrical water level sounders (hand-collected data). The use of hand-collected data allowed for verification and calibration of the data logger data and backup measurements in the event of data logger failure (which did not occur).

The pumping rate of the SVR #7 well was measured using a standard and precisely set-up circular orifice weir and a propeller-type totalizing flow-meter. Discharge from the orifice weir, considered the most accurate means of measurement, was recorded from visual height measurements and with an electronic data logger on the piezometer tube. Water was discharged via an 800-foot long, eight-inch diameter pipeline to a stock watering pond which, in turn, overflowed into the channel of the dry stream bed of Big Gulch Creek. Regular observations of the wetting front of the water in the stream channel indicated that water flowed about 6,800 feet from the pond during the test and did not reach newly planted agricultural fields located just up-stream from the Farmers Union Ditch. As would be predicted from the underlying stratigraphy and deep water table,

there was no indication in the hydraulic test data from the pumping or observation wells that the discharged water returned to the aquifer.

The locations of the pumped well (SVR #7), the observation wells monitored before, during, and after the test, the discharge pond, and Farmers Union Ditch, are shown in Figures 1 and 2 (pages 71 and 72).

This report has ten sections.

- SECTION I: INTRODUCTION AND OVERVIEW,
- SECTION II: HYDROGEOLOGIC OVERVIEW
- SECTION III: PUMPING TEST PROCEDURE AND DATA COLLECTION
- SECTION IV: PREPROCESSING OF THE WATER-LEVEL DATA
- SECTION V: ANALYTICAL METHODS
- SECTION VI: TEST RESULTS
- SECTION VII: WELL EFFICIENCY AND WELL LOSS
- SECTION VIII: INHERENT DIFFICULTIES AND CONSTRAINTS - SHORTCOMINGS OF THE TEST
- SECTION IX: SUMMARY OF MAJOR FINDINGS AND RECOMMENDATIONS
- SECTION X: ACKNOWLEGEMENTS

Each section should be consulted for details relevant to each of these section topics. Four Appendices are also included at the back of the report to support the analyses and discussion presented in the seven sections. The Appendices are:

- Appendix A – Well Driller's Reports for Wells without Additional Information
- Appendix B – Barometric Efficiency Analyses
- Appendix C – Actual and BE-Corrected Water Levels
- Appendix D – Additional Information on the Analytical Methods Used in this Report

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SECTION II: HYDROGEOLOGIC OVERVIEW

The hydrogeology of, both, the greater project area and that specific to the M3 Eagle property are presented in this section. The Pierce Gulch Sand Aquifer is the regional aquifer that currently supplies water to major supply wells in the greater Eagle-Star

vicinity. This aquifer varies in depth beneath the M3-Eagle-Star vicinity at depths of 100 feet to 350 feet (top to bottom) at Lexington Hills Well #1 to 200[1] to 720 feet (top to bottom) at the UWID State and Linder Test Well #1, below the Boise River Valley and from land surface to 350 feet beneath the upland M3 Eagle property. The Pierce Gulch Sand Aquifer conveys ground water beneath the Boise River Valley to the northwest to aquifers beneath the Payette River Valley. An unnamed, alluvial aquifer (or layered series of sub-aquifers, tapped by numerous domestic and irrigation wells in the greater Eagle area) overlies the Pierce Gulch Sand Aquifer. The unnamed alluvial aquifer is present beneath the southwestern and south-central portion of the M3 Eagle property but the sands that comprise the aquifer are dry beneath most of the upland areas. The Willow Creek Aquifer lies to the northeast of the Pierce Gulch Sand Aquifer. These two aquifers are separated by low-permeability mudstone of the Terteling Springs Formation.

The hydrogeology of the greater north Ada County vicinity has been the subject of an extensive characterization program commissioned by M3 Eagle, LLC and conducted by HLI, underway since May 2006. A one-year update of the test-well drilling and construction, water level measurement program, geophysical analyses, and pumping tests, was presented in HLI (2007). This report indicated that the Pierce Gulch Sand Aquifer, which underlies the greater Eagle-Star vicinity, also underlies the M3 property. The Pierce Gulch Sand Aquifer allows groundwater to flow from beneath the Boise River Valley to aquifers beneath the Payette River Valley. The initial conclusions on the characteristics of the Pierce Gulch Sand Aquifer are strengthened by the additional hydrogeologic information supplied in a 2007 water level study (HLI, 2008a) a reanalysis of 16 pumping tests (HLI, 2008b), a numerical modeling report (HLI, 2008c), and an evaluation of inorganic geochemistry (Glanzman and Squires, 2009). In addition, detailed analyses of borehole geophysical records presented in a series of geologic cross sections of the sub-surface (HLI, in preparation) provide even more conclusive documentation of the extent and geometry of the Pierce Gulch Sand Aquifer. The hydrogeologic overview presented below was extracted from that series of reports, which should be consulted for additional details.

The regional ground water flow-system of north Ada County (and beyond) consists of the Pierce Gulch Sand Aquifer which lies beneath Eagle, Star, Meridian, and the southern, western and central portions of the M3 Eagle site. Ground water in the highly transmissive Pierce Gulch Sand Aquifer flows generally from the southeast beneath the Boise River Valley, toward the northwest to the correlative sediments beneath the lower Payette River Valley. The Pierce Gulch Sand Aquifer is bounded on the northeast by low-permeability sediments of the Terteling Springs mudstone that hydraulically separate it from the Willow Creek Aquifer (the saturated sands of the sand-facies of the Terteling Springs Formation), which lies beneath the northeastern portions of the M3 Eagle property (Figures 3 and 4, pages 75 and 76) A shallower, unnamed fluvial sand aquifer (or series of sub-aquifer units) overlies the Pierce Gulch Sand Aquifer beneath a small portion of the southwest portion of the M3 Eagle site and other parts of the Boise Valley

[1] The depth of the top of the Pierce Gulch Sand Aquifer is uncertain at this location. Suspected normal faulting may have caused coupling to other non-Pierce Gulch Sand Aquifer sand units.

(Figures 3 and 4). These undifferentiated sand units are either not present or unsaturated ("dry") beneath other parts of the M3 site.

A total of 19 of the 23 wells monitored during the constant-rate test are completed in the Pierce Gulch Sand Aquifer. Two wells are completed in the shallower, unnamed fluvial aquifer while one observation well is completed in the Willow Creek Aquifer. Details on each of the three aquifers, as well as the Terteling Springs mudstone aquitard are presented below. Figures 1 and 2 show well locations, the approximate boundary between the Pierce Gulch Sand Aquifer and the Willow Creek Aquifer, and the approximate boundary of the M3 Eagle property. Specific details of each of the major and minor hydrostratigraphic units are presented below.

Significant Hydrostratigraphic Units

The Pierce Gulch Sand Aquifer consists of a sheet of lake-margin sediments ranging from about 275-to-360-feet thick (and locally more) that directly, and conformably, overlies the mudstone facies of the Terteling Springs Formation of the Idaho Group of formations (discussed below). These sand sediments are named the Pierce Gulch Sand after the type-locality exposure in the north-western Boise Foothills at Pierce Gulch (Wood, 2004). At the type locality, the Pierce Gulch Sand rests conformably on mudstone facies of the Terteling Springs Formation. At higher elevations, and nearer the contact of sediments with the granitic rocks, the Pierce Gulch Sand rests upon the sand facies of the Terteling Springs Formation, as a paraconformity or disconformity contact (, Figure 5, page 79, reproduced from Wood and Clemens, 2002). Southwest of the Boise Foothills, and under much of the Boise Valley, this contact is gradational-upward from mudstone to sand showing the characteristic pro-delta signature on geophysical logs (Figure 6, page 80, reproduced from Squires and Wood, 2004).

The sequence of sand over mudstone is a regional feature related to the slow draining of Pliocene Lake Idaho. Draining was caused by the slow down-cutting of the outlet in upper Hells Canyon (Wood and Clemens, 2002). As lake levels lowered, the delta sands and lake shoreline prograded into the basin, thereby spreading sand over the former muddy bottom of the deeper lake. The muddy lake bottom probably had a basin-ward slope of 1 to 4 degrees (100 to 350 feet per mile) (Figure 7, page 81, reproduced from Wood, 1994).

This spreading of sediments along the gently sloping lake bottom, left a continuous layer of sand with some interbedded clay and silt dipping to the southwest beneath the project area, at a slope of about 100 feet per mile. The slope (dip) of the deposits becomes slightly steeper beneath the M3 project site where the sand units that lie in the depth interval, 250 to 500 feet beneath the Valley floor in the Eagle-Star area, rise and subcrop just below the surficial soils in the upper northwestern part of the M3 site. This increase in slope is interpreted to be a feature of the basin margin and lakeshore, but may have some small component of tectonic dip also.

The Pierce Gulch Sand is saturated beneath the Boise Valley and much of the foothills area containing the M3 project site. This saturated sand unit is now recognized as the regional Pierce Gulch Sand Aquifer. Borehole-geophysical logs from more than a dozen deep wells in the area exhibit a distinct and recognizable character that is traceable across the region (Figure 6, page 80, reproduced from Wood and Clemens, 2002). The basal sand of the Pierce Gulch Sand Aquifer, as shown by geophysical logging[2] lies beneath the foothills of the greater M3-project area and beneath the Boise Valley in Eagle, Star and Meridian areas. Indeed, the identified characteristic "geophysical signature" of the base of the Pierce Gulch Sand Aquifer (HLI, 2007) appears to be present in deep petroleum exploration bores beneath the cities of Meridian, Caldwell, and Payette, Idaho (S.H. Wood, personal communication, 2009) suggesting that the Pierce Gulch Sand Aquifer is extensive to not only the Payette River Valley but also to the Snake River Valley. *All* the major municipal supply wells and many irrigation wells in the greater Eagle-Star-M3 area are believed to derive their water from the Pierce Gulch Sand Aquifer. M3 Eagle plans to complete an estimated additional three to eleven supply wells in the Pierce Gulch Sand Aquifer beneath its property.

In this report, and in previous analyses of the Pierce Gulch Sand Aquifer, we have treated the entire thickness of the Pierce Gulch Sand as *one* heterogeneous aquifer; an interpretation we believe to be valid, based on the existing data. Thin zones of low permeability within the Pierce Gulch Sand are present as indicated by geophysical logging of 13 boreholes in the greater M3-Eagle-Star vicinity (HLI, 2007). The composite diagrams for seven wells with geophysical logs included in this report (Figures 9 through 16, pages 83 -97) show that the low-permeability intervals are 1) less that a few feet thick, 2) discontinuous between wells, and 3) are neither dominated by clay nor do they extend or connect to greater thicknesses of low-permeability sediments. We believe that it would be unreasonable (at the current level of understanding and data availability) and unrealistic to subdivide the Pierce Gulch Sand Aquifer into a series of poorly-connected aquifers and aquitards for purposes of understanding and /or analysis. Most naturally stratified depositional units are not uniform and homogeneous, and the Pierce Gulch Sand Aquifer is no exception. We consider the aquifer to be hydraulically connected throughout its thickness in the study area. Therefore, our interpretation and analytical treatment of the Pierce Gulch Sand Aquifer is that of a single aquifer, varying in hydraulic properties at various locations, both horizontally and vertically.

From our recent detailed studies of the Pierce Gulch Sand Aquifer, we have been able to confirm our emerging concept of the Pierce Gulch Sand Aquifer as being somewhat-to-highly cemented. Cemented sand is a significant characteristic of the aquifer that is not generally recognized owing to the preponderance of wells drilled by the air- method. Air-rotary drilling (as opposed to mud-rotary and reverse-circulation mud-rotary drilling) all but destroys the true representative nature of cuttings from cemented sands. Only when the driller encounters highly indurated rock will the entry on the lithologic log actually state "sandstone" or "shale".

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[2] Logs for all the wells monitored in this report that have been geophysically logged are included in Figures x through x, discussed later in this section of the report.

Our characterizing the Pierce Gulch Sand Aquifer as cemented (with fracture flow as well as porous-media flow) is based on the following considerations:

1) Consolidated sandstone and siltstone cuttings are commonly returned in direct mud-rotary and reverse –circulation drilling projects,

2) High barometric efficiencies are typical of wells completed in the Pierce Gulch Sand Aquifer; even in portions that are unconfined. The high barometric efficiencies (discussed in Section IV of this report, page 12) are attributed to low-permeability sediments overlying a rigid aquifer framework that does not compress significantly under the loading of atmospheric pressure. We attribute the rigidity of the aquifer to cementation of the sand grains comprising the aquifer,

3) Most boreholes stand open during drilling (even with air-rotary drilling),

4) Borehole caliper logs of open holes show smooth bores with limited caved zones,

5) Conscientious and trained drilling contractors recognize the harder (slower drilling), and enter that information on logs or inform supervising hydrogeologists.

6) Down-hole video surveys of open-hole wells show fractures and jointing,

7) Loss of drilling fluid (lost circulation) and loss of grout slurries during well drilling/construction. On more than one occasion, grout placed at the bottom of a borehole, within a portion of the aquifer identified as sand to sandstone, flowed out of the borehole overnight during the well construction process, apparently through fractures within the indurated aquifer/aquitard,

8) The cemented nature of the aquifer along with relatively large transmissivities calculated from numerous aquifer tests (HLI, 2008b) supports the possibility of fracture flow in addition to porous media flow. This type of flow would allow for higher transmissivities in a somewhat cemented sand or sandstone aquifer, than would porous-media flow by itself. We do not postulate that the entire Pierce Gulch Sand Aquifer is cemented because there are many instances of sand production in wells and borehole collapse to suggest otherwise. As a general rule, cementation appears to increase with proximity to the basin margin and in the vicinity of known structural faulting.

The <u>Willow Creek Aquifer</u> is a highly-permeable aquifer of limited lateral extent consisting of a sand facies of the Terteling Springs Formation that lies beneath the northeastern portion of the M3 Eagle site and areas to the north and northeast. This aquifer was informally called the "Willow Creek Aquifer" by SPF Water Engineering (2004). The facies relationship to the mudstone facies is shown in Figure 6 (reproduced from Squires and Wood (2004). The sand and occasional gravels of the Willow Creek Aquifer were deposited as deltas at the margins of Lake Idaho while the finer-grained muds were being deposited further offshore to the southwest in the slacker waters of the

deeper lake. These relationships indicate that the Willow Creek Aquifer is time-correlative to the upper-most mudstone underlying the Pierce Gulch Sand Aquifer. This facies change occurs to the west of M3 TW-#2 well in Big Gulch beneath the M3 Eagle property. Conceptually, the Terteling Springs Formation is a transgressive unit associated with rising water levels of Pliocene Lake Idaho. As a consequence, sand was only deposited along the margins of the lake (Wood and Clemens, 2002). In other words, while the finer-grained sediments (muds) were being deposited offshore in the deeper waters of Lake Idaho, the coarser-grained sediments (sands and gravels) were being deposited in deltas along the near-shore margins of the lake.

A few irrigation and domestic wells tap the Willow Creek Aquifer to the north of the M3 Eagle property. These include the Lynn family wells along Willow Creek, Spring Valley Ranch test wells SVR #6, and SVR #10 (SPF Water Engineering, 2004). The Well Driller's Reports for these wells indicate coarse-grained sand essentially from top to bottom. The contact at the base of this sand, in this area, is yet to be drilled but probably rests unconformably on volcanic rocks of the Boise Volcanic Assemblage and/or granitic rocks of the Idaho Batholith.

Unnamed Alluvial Sand Aquifer: An as-yet-unnamed group of sand units overlie the Pierce Gulch Sand Aquifer. These sand units consist of alluvium deposited by the streams flowing across the flood plain of the valley formerly occupied by Lake Idaho. Where saturated (as it is beneath the southwestern and parts of the central portion of the M3 site and all of the valley lowlands around the City of Eagle), these sands form relatively thin, local, and shallow aquifer units. These sands are present beneath other portions of the M3 site but are unsaturated and, therefore, not designated as an aquifer. Beneath the southern portions of the M3 Eagle property, the shallow aquifer is separated from the underlying Pierce Gulch Sand Aquifer by a sequence of lower-permeability sediments consisting mostly of clay and silt.

Terteling Springs Aquitard: Lithologic logs prepared by hydrogeologists and borehole geophysical logs of four on-site test wells drilled under the direction of HLI, show a thick sequence of clay and claystone (mudstone facies) of the Terteling Springs Formation. At the locations of test wells M3-TW#1 through M3-TW#4 in Big Gulch, the top of the Terteling Springs mudstone lies at depths of 380 to more than 500+ feet below ground surface. A layer (or layers) of this facies is/(are)believed to be present in the subsurface, just below the surficial soils in a band running southeast to northwest through the middle of the M3 site, north of the "green line" in Figures 1 and 2, pages 71 and 73. (The green line represents the estimated position of where the base of the Pierce Gulch Sand Aquifer projects to land surface). Unfortunately, borehole geophysical logs are not available for the few wells that have pierced this unit to show compelling evidence for mud units within or overlying the Terteling Springs Formation sands. Such mud units would evidence rapid transgressions of the lake(s) and should exist as "tongues" extending toward the granitic highlands of the lake margin (as shown in Figure 5, reproduced from Wood and Clemens, 2004). Outcrop evidence for this occurrence is present in Stewart Gulch Creek (S.H. Wood, personal communication, 2009a). In the Boise Valley and beneath the southern, western and central parts of the M3 site, the Terteling Springs

- SVR #6 - Figure 15
- SVR #7 (the pumped well) - Figure 9
- SVR #9 - Figure 14

As part of the characterization of the M3 Eagle project site, HLI reviewed the geologic and geophysical data from each of these three wells. We also interviewed the driller's of these wells to obtain a better understanding of their construction and subsurface conditions. HLI also conducted additional geophysical logging and video surveys inside these cased wells. We then interpreted the subsurface geology based upon that data and our understandings developed from collecting and interpreting the data from the five wells listed above. We then produced composite diagrams (following the format used for HLI designed-and-installed wells) for these three wells.

Five other existing older wells were monitored during the test that were originally designed and constructed for stock or irrigation purposes. These are:

- Big Gulch Stock Well
- Little Gulch Stock Well
- Flack Corral 6-inch well
- Flack Corral 4-inch well
- Kling irrigation well

None of these wells were designed, sampled or logged geophysically or geologically by HLI or HLI personnel (or for that matter, any hydrogeologic professional). The information about subsurface conditions from these wells is more limited and less credible as the main information available is from IDWR Well Driller's Reports (Appendix A), which were not available for all five of these wells. Geologic and subsurface information presented on these reports was interpreted and documented by the well driller who installed the well. In our experience, well driller's interpretation of sub-surface geology is uneven in quality, often poor and generally unreliable for use in aquifer studies. But, because these wells were relatively close to the pumping well, water level data were collected from these wells, for the sake of completeness.

Prior to using these five wells as observation wells, HLI inspected of all of these wells (with the exception of the Flack Corral 4-in stock well) with down hole video surveys), cleaned, and directed some limited well re-development including scraping, brushing, swab-surging of the completion intervals, and bailing of infill to ensure that the wells would produce reasonably reliable results. In some instances, the installed pumping plants had to be removed and replaced for the rehabilitation/evaluation. In the case of the Kling irrigation well, the well was partially reconstructed and pump tested prior to the aquifer test. In the wells equipped with submersible pumping plants, designated monitoring tubes were installed with the pumps to ensure safe use of pressure transducers and water level sounders for the aquifer test.

A summary of the well construction details and aquifer positions for these thirteen wells monitored during the nine-day test is presented in Table 1 (page 40).

mudstones comprise an aquitard that defines the bottom of the potable, cold-ground-water system. Beneath the central parts of the site where they rise up to near the surface, the mudstones act as a hydraulic barrier between the Pierce Gulch Sand Aquifer and the Willow Creek Aquifer (Figure 3). Most compelling for this concept are that the well cuttings and water levels in wells, and the recharge sources and aquifer geochemistries are very different in the two aquifers as is described in Glanzman and Squires (2009). The influence of structural basin-margin faulting, which is known to exist in the general vicinity, is not addressed here.

Hydrogeology and Details of Well-Construction for the Pumping and Observation Wells

Figures 9 through 16 show the details of well construction and the subsurface hydrogeology for eight of the main observation wells and well nests monitored during the SVR #7 aquifer test. These composite diagrams include geologist's lithologic logs, borehole geophysical logs, and well construction details as a cross-section on a side-by-side basis, at the same vertical scale. Figure 17 (page 99) shows a photo of the typical configuration of the wellhead shelter with individual small-diameter wells within a single borehole. Development of the individual small-diameter wells is also shown in Figure 17.

Five of the eight main observation wells are well nests designed, inspected during construction, and sampled by HLI or individuals that are now employed at HLI. These well nests are:

- M3-TW #1 (5 individual small-diameter wells within the one borehole)-Figure 10
- M3-TW #2 (2 individual small-diameter wells within the one borehole)-Figure 11
- M3-TW #3 (4 individual small-diameter wells within the one borehole)-Figure 12
- M3-TW #4 (4 individual small-diameter wells within the one borehole)-Figure 13
- UWID State and Linder TW #1 (2 individual small-diameter wells within the one borehole) - Figure 16

All five well nests were drilled using the direct mud-rotary method and all were logged geophysically by HLI or HLI personnel using the same set of geophysical tools and equipment, allowing for a consistent interpretation of subsurface conditions. HLI or individuals who are now employed by HLI also examined and described the drill cuttings from each of the five boreholes to interpret the subsurface geology and develop correlations between drill cuttings and borehole geophysical traces. All of these boreholes were completed with more than one small-diameter tube well to allow for collection of water level data and geochemical samples from various depth intervals of the saturated geologic section. We believe that these well nests provide the best available interpretation of the subsurface geology of the greater M3 Eagle project area.

Three of the eight observation well locations were overseen by other consultants but are part of the HLI monitoring network. These three wells have significantly lower-quality geologic and geophysical logs available.

These figures and Table 1 (page 63) indicate that wells specifically constructed for long-term monitoring and the careful collection of subsurface geologic information (M3-TW #1 through 4, UWID State and Linder Test Well) have provided a significant amount of information that includes detailed lithologic descriptions of the subsurface geology, borehole geophysical logs, water levels, and geochemistry across the geologic section. Wells constructed with limited hydrogeologic oversight (SVR #6, #7 and #9) have contributed some helpful data, while stock and irrigation wells constructed with no hydrogeologic oversight (Kling, Flack-Corral 4-in and 6-in, Big Gulch and Little Gulch wells) are even less useful.

The interpretations of the subsurface geology, based on the detailed analyses of the geophysical and geological data from seven key wells, were used to produce two hydrogeologic cross-sections indicating the subsurface geology of the project area (Figures 3 and 4). The surface traces of the sub-surface cross-sections are shown on Figure 1. The southwest-northeast cross-section (Figure 3) shows the dip of the Pierce Gulch Sand Aquifer toward the southwest and its rise to the near surface toward the northwest. The figure shows the wide-spread extent of the Pierce Gulch Sand Aquifer. The north-south oriented cross section in Figure 4 also shows the areal extensiveness of the Pierce Gulch Sand Aquifer.

The two figures also show several shallow, unnamed aquifers overlying the Pierce Gulch Sand Aquifer. Wells M3-TW #4 Zone 4 and M3-TW-1 Zone 5 are completed in these relatively thin and shallow aquifer zones. Figure 3 also shows a relatively thin but aerially extensive water bearing sand and sandstone zone *below* the Pierce Gulch Sand Aquifer rising upward toward the northeast more steeply than the Pierce Gulch Sand Aquifer. This zone (in which well M3-TW #4 Zone 1 is completed) is enveloped in the thick mudstone facies of the Terteling Springs Formation appears to merge with the sand facies of the Terteling Springs Formation (Willow Creek Aquifer) beneath upper Big Gulch (Figure 3). We believe this aquifer unit to represent the transgressing sand facies of the migrating shoreline as the level rose in Lake Idaho.

SECTION III: PUMPING TEST PROCEDURES, PERSONNEL, AND DATA COLLECTION

This section of the report describes the procedures, personnel and data collection for the constant-rate-discharge conducted from March 10 16:00 hrs through March 19 16:00 hrs, 2008. The test had three phases: pre-test water level collection, pumping, and recovery. Pre-test water levels were measured for two to five days prior to pumping, during early March to establish barometric efficiency and antecedent water level trends. The pumping phase consisted of measuring water levels in 23 wells while SVR #7 was pumped at a constant and continuous 917 gpm (± 0.5 percent) for nine days (12,970 minutes). The recovery phase consisted of measuring water levels during the 12 days after pumping ceased in SVR #7 to evaluate the aquifer recovery and post-test water level

trends. Water levels were measured with electronic data loggers and hand measurements. Flow measurements were recorded from visual observations of a circular orifice weir and a totalizing propeller-type flow meter. The orifice weir piezometer tube was equipped with a continuously-recording, low-pressure-range, digital pressure-transducer/ data logger. All electronic measurements were obtained and recorded at one-minute intervals. The details of the test are discussed in this section of the report.

Development

HLI's analysis of data collected during a 24-hour test of SVR #7 (conduced in 2004 by others) indicated that the well continued to develop during testing and would therefore require development/rehabilitation prior to long-term testing (HLI, 2008), in order to produce meaningful results. Prior to pump testing, SVR #7 was inspected with an HLI down-hole camera. Based on the video survey, HLI designed a well development program for the well. SVR #7 was then developed through a process of scraping, swabbing, jetting and pumping by McLeran Well Drilling LLC during late May 2007. During the development of the well, significant fine-grained aquifer materials and residual drilling muds were removed from the near-screen portion of the aquifer, allowing increased flow to the well. However, because the well was completed with crushed-rock as a filter pack material (as opposed to a properly graded and rounded, silica-sand filter envelope), and a combination of louvered openings and torch-cut perforations (as opposed to efficient wire-wound screen openings) a thorough and complete development of the well is probably not possible.

Pumping, Flow Measurement and Discharge Routing

For purposes of the aquifer test, the SVR #7 well was equipped with a specially designed, slim-hole pumping plant. The pump, a Goulds Pumps Model # 8-DHLO, was a nominal 8-inch diameter (7.52-inch), 6-stage submersible vertical turbine with a full (5.062") impeller trim driven by a 5.62-inch diameter, 2,200-volt, 133 HP Centrilift (Baker-Hughes) submersible motor suspended on 5-inch diameter Schedule 40 column pipe Figure 18, page 100). The pump was installed by Wood Group, ESP Inc., and powered by a "MQ Power" brand 180 kVA "prime[3]", diesel-fueled electrical power generation unit, which was not shut down during the entire 9-day test. The generator was operated, maintained, and re-fueled by McLeran Well Drilling on site 24-hours a day for the pumping portion of the test.

Water from the wellhead was routed through an 8-inch propeller-type (McCrometer) flow meter indicating instantaneous and total flow, placed 40 ft from the well head to minimize measurement errors associated with turbulence. The discharge from the propeller meter was routed via an 8-in high-pressure HDPE plastic pipe approximately 800 ft long to the discharge pond. Water was discharged through a circular orifice weir consisting of an eight-inch pipe fitted with a six-inch diameter plate opening and two methods for measuring pressure at the orifice weir (Figure 19, page 101). Pressure was

[3] "Prime" indicates a high-quality generator capable of continuous-duty and, during extended periods of operation, not needing maintenance that requires shut down of the unit.

visually observed and recorded regularly from a transparent vertical piezometer tube (method 1) and electronically at one-minute intervals via a low-range data logger (method 2). Pressure measured using method 2 was converted to discharge rates via a logarithmic equation fitted to an empirical orifice weir chart and "look-up table" (Driscoll, 1986). The equation was developed using MS Excel software.

Comparison of the electronic and manual orifice/piezometer data from the constant-rate test shows the two methods generated almost identical results (mean discharge rate of 916 gpm and 918 gpm, respectively, equivalent to a difference of 0.2 percent). Our calculated mean flow during the test was 917 gpm, based on an average of these two methods. Comparison of the orifice with the totalizer meter shows that the propeller meter indicated a total flow that was 95.4 percent of the total indicated by the orifice. We believe the orifice is more accurate than the propeller meter and have used the data from it in our analyses.

Water was discharged into a pre-existing stock watering pond adjacent to the Big Gulch Stock Well (Figure 19). Once the pond was filled, overflowing water discharged to the dry stream channel of intermittent Big Gulch Creek. Flow continued down the channel for the duration of the test with its progress down the normally dry channel monitored from time to time. At the end of the test, the wetting front of the stream was located approximately 2,000 ft downstream from M3-TW #4. The clay layers lying within the upper 200 feet below ground surface (as shown in the geologic logs of SVR #7 and TW #4, Figures 9 and 13) kept the water from reaching the Pierce Gulch Sand Aquifer during the test, a conclusion that was supported by the shallowest well at M3-TW #4 (screened between 61 and 71 ft bgl) remaining dry throughout the test and the complete absence of a positive "recharge" hydraulic boundary showing up in the test data.

Water Level Measurement

Water levels were measured in 23 wells using electronic data loggers calibrated and backed up by a combination of manual measurements with electric well sounders and steel tapes (hand-collected data). The use of hand-collected data allowed for verification and calibration of the data logger data and backup measurements in the event of data logger failure (which did not occur). The electronic data loggers consisted of un-vented, Solinst Leveloggers® (accurate to 0.05%-to-0.1% full scale) and therefore requiring air pressure readings from a Solinst Barologger® to convert the pressure readings to feet of water above the transducer opening. A few of the observation wells were doubly-equipped with vented Global® data loggers which directly record water level above the transducer opening and therefore require no barometric compensation. All data loggers were set to measure and record water level data at one-minute intervals for the entire test period that included two to five days prior to the initiation of pumping and the twelve days after pumping ceased. Water levels were also measured in many of these wells prior to the March 2008 test as part of the ongoing monitoring program. These wells are measured at 30 or 60 minute intervals with some in place since November 2006. The electronic data from all of the wells for the entire test period are included on a compact disk inside the back cover of the report.

Personnel

HLI staff manually measured water levels and discharge rates continuously during the constant-rate test. Initially, HLI employees Kurt Newbry, and Loren Pearson, were on site to commence the test and to record frequent measurements during the early portions of the test (first day). In addition, Dennis Owsley of the Idaho Department of Water Resources assisted during the initial startup period of the test. Ed Squires and Mark Utting of HLI made periodic site visits for measurements throughout the test but Kurt Newbry almost single-handedly maintained the monitoring program in a continuous loop program visiting all monitoring wells several times a day for the final eight days of the drawdown portion of the test and including daily visits during the recovery period. Personnel from McLeran Well Drilling remained on-site, 24-hours per day, to maintain the pump/generator system and re-fueling operation during the entire pumping period. Manual water level measurements during the recovery period were measured by HLI personnel.

SECTION IV: PREPROCESSING OF THE WATER-LEVEL DATA

This section of the report describes how data from the digital data loggers were preprocessed to generate sets of drawdowns for each well, suitable for analysis using Aqtesolv®. Pressure data from the data loggers were initially converted to depth-to-water using hand measured water levels collected frequently during the test. Depths to water were then corrected using barometric efficiency (BE) corrections derived for each well. Water level trends were then used to generate two sets of drawdown data: one based on estimated seasonal water level trends and one set that assumed no trend (i.e., the level in the well just before pumping began represented the non-pumping level in the aquifer throughout the test). In some cases, the seasonal trend appeared to reverse during the test (water levels not associated with pumping rose during the beginning of the test but then started to fall during the later part of the test) At the end of the preprocessing, two sets of drawdown data bracketing the effects of potential aquifer-wide water level trends were generated for each observation well. The bracketed data sets allowed for a range of analyses that represented the uncertainty of our estimate of water level trends.

Overview

HLI analyzed the water level data from 24 separate wells monitored during the nine day pumping tests. Water-level data[4] were also collected during the two-to-five days before the test and the twelve days after pumping at SVR #7 stopped. The pretest data were collected for two purposes: 1) to calculate the barometric efficiency of the well and 2) to help establish aquifer water-level trends that might affect the calculated drawdowns

[4] Many of the wells monitored during the test are part of the on-going M3 monitoring program in which water levels are electronically measured every 30 minutes. For the purposes of this test, data were obtained at one-minute intervals for a more detailed record of well response.

during the test. For some of the wells, the data were inadequate for one or both of these purposes. Where barometric efficiencies could not be calculated from the data collected during the week before the test, barometric efficiency was calculated using data from an earlier period when nearby pumping was insignificant and atmospheric changes were relatively large (as is discussed below). The post-test data were collected to measure water level recovery and to help estimate aquifer-wide water level trends. In some cases, longer-term monitoring data collected at 30 minute intervals (after (March 31, 2007) were used to estimate seasonal water level trends.

The general procedure for the analysis of the data from each well was as follows: Data from electronic data loggers were downloaded after the test and entered into Excel spreadsheets. Non-vented transducer data from the Solinst data loggers were then corrected to water levels above the data logger transducer by subtracting the pressure recorded by a Solinst Barologger. Water levels above the transducer were then converted to depth to water below the measuring point (typically the top of the steel well shelter) by comparison to hand measured water levels using Powers® well sounders calibrated to chalked steel tapes. Calculated barometric efficiencies were then used to remove the effects of atmospheric pressure changes on well water levels. Data plots from the pre-pumping and end-of-recovery periods were then visually assessed to estimate the approximate trends in aquifer water level changes not associated with either atmospheric changes or the pumping test itself. The differences in water levels between the initial, pretest level and the levels caused by pumping (drawdown) were then calculated in two ways. The details of the preprocessing are discussed below.

Raw Depth to Water

The first step in our data preprocessing was to convert the pressures recorded by the non-vented data loggers to *height of water standing above the logger.* To do so, we subtracted the simultaneously-recorded barometric pressure from the logger data. The second step was to convert the *height of water standing above the logger* to a *depth to water below the measuring point* by subtracting the *height of water standing above the logger* from the calculated depth of the logger below the measuring point (typically the top of the well casing). The depth of the logger below the measuring point was calculated by adding the *height of water standing above the logger* to a hand-measured *depth to water level below the measurement point* obtained at the same time. The third step was to convert the *depth to water below the measuring point* to *depth to water below ground level* by subtracting the measured height of the casing above ground surface (casing "stick up") from the *depth to water below the measuring point*. The end result was a set *of depth-to-water below ground level* measurements at one minute intervals.

Barometric Efficiency

The next step was to remove the effects of changing atmospheric pressure on the water level data[5]. The ratio of the change in water level and change in atmospheric pressure is referred to as the "barometric efficiency" (BE). In a well with 100-percent barometric efficiency, an atmospheric pressure change equivalent to the weight of 1.0 foot of water[6] would cause the water level in the well to change by 1.0 foot. In a well with a BE of 50-percent, the change would only be 0.50 feet.

Barometrically induced changes in water level in a well only occur because the well is open to the atmosphere. In a well open to the atmosphere (typical of most wells), the atmosphere directly pushes on the standing water in the well but cannot push with equal force on the ground water in the aquifer; a combination of overlying low-permeability layers and the rigidity of the aquifer framework do not allow the atmosphere to push directly on the water contained within the pore space of the aquifer. The differences between the direct force of atmospheric pressure on the water in the well and the reduced force of atmospheric pressure on the water in the aquifer cause the water level in the well to fluctuate with changes in atmospheric pressure as water moves into and out of the well. The change only occurs because the well is open to the atmosphere. A well sealed from the atmosphere would not show barometric effects nor need BE corrections.

Changes in water level associated with changes in atmospheric pressure do not actually occur in the aquifer. Because the changes in atmospheric pressure load equally over the entire aquifer, water levels (or more correctly, water pressures or "head") are not significantly affected by changes in atmospheric pressure.

We calculated barometric efficiency using water-level data collected when the only significant changes in water level would likely have been from changes in atmospheric pressure, following the method outline in the Ground Water Manual (US Department of the Interior, 1981). The pretest measurement period (2 to 5 days long) was used for our BE calculations for most of the monitored wells. No significant pumping occurred near the wells (except for well development pumping in SVR #7 – see discussion below) and changing atmospheric pressure caused by passing weather systems provided the data for comparison of atmospheric pressure changes with changes in water levels. The BE for each well was calculated by plotting atmospheric pressure on the X-axis (horizontal) against the corresponding water level measured at the same time on the Y-axis (vertical). The points generated a "scatter" plot. A "best-fit" straight line was then calculated (using MS Excel) with the slope of the line indicating the BE and the "R^2" indicating the statistical correlation of the best-fit line.

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[5] Long-term monitoring by HLI of wells in the North Ada County foothills using continuously recorded water level and barometric data loggers has shown that water levels closely mimic the changes in atmospheric pressure as recorded by the barometer.

[6] Atmospheric pressure can be measured in any unit of pressure. Typical units are millibars and inches of mercury but feet of water can also be used. The use of feet of water (which is directly recorded by the Barologger) simplifies data logger corrections and corrections for barometric efficiency (BE).

Pre-test, development pumping at SVR #7 and stock-water pumping at the Little Gulch Stock Well affected the water levels during the pretest period making calculation of BE for these wells impossible using data from early March 2008. Instead, we used long-term monitoring data from January of 2007 (SVR #7) and from January 2008 (Little Gulch) to calculate the BE for these wells.

Barometric-Efficiency-Corrected Water Levels

After the BE was calculated for each well, the water level data were corrected for BE effects. This correction was accomplished by multiplying the change in atmospheric pressure by the BE and subtracting the result from the water level data for each minute of data collection after pumping began. The corrections were applied using the initiation of pumping ("t = 0") as the reference point in order to calculate the difference in pumping and post-pumping water levels (drawdown and residual drawdown, respectively) from the non-pumping level. Subtraction was used to compensate for this inverse relationship because the water level goes down in elevation when the atmospheric pressure goes up and vice versa. The end result was a water level plot where changes in water levels caused by changes in atmospheric pressure, were much reduced. Because the barometric efficiencies of the wells completed on the M3 Eagle property are relatively high and the distances between the pumping well and the observation wells are relatively large, barometric effects during the test were similar in magnitude to the drawdown effects in most of the observation wells. Calculation of drawdowns and aquifer properties would not have been possible without correcting the water level data for barometric efficiency.

The following equation, based on the method outlined in the Ground Water Manual (US Department of the Interior, 1981), was used to correct for barometric efficiency:

$BE_{correction} = (P_0 - P_{(t)}) * BE$ Where:

$BE_{correction}$ = the correction added to the raw calculated drawdown, in ft
P_0 = atmospheric pressure at the start of the test, in ft (of water)
$P_{(t)}$ = atmospheric pressure at the time of each measurement, in ft (of water)
BE = scaling factor for Barometric Efficiency (dimensionless, from 0 to 1.0)

Theses corrections greatly improve the usability of the data but do not completely remove all variations ("noise") from the data for several reasons. The first is that atmospheric pressure effects are not instantaneous as is assumed in the method. Time lag in atmospheric effects on ground water within the pore space of the aquifer can introduce small errors. The second is that variations in well water levels not caused by changes in atmospheric pressure (such as seasonal aquifer water level trends or unrecognized pumping effects) introduce small errors in the analysis. A third reason is that apparent changes in water level caused by analog-to-digital conversion in the data logger (digital "flutter") can introduce an error in the calculation of BE. Lastly, the rhythmic effects of "earth tides" added a small amount of "noise" to the data on the order of a few hundredths of a foot. These four potential sources of error allow residual noise (fluctuations) to remain in the BE corrected data.

In cases where the BE effect could not be completely removed using the BE calculated from the pretest data, we conducted a number of analyses using BE's slightly larger than those calculated. We then selected the BE coefficient that best removed the barometric changes from the data. We attribute the need for a slightly large BE scaling factor to one or more of the potential errors discussed above.

We note, that the remaining fluctuations (after the BE corrections) are indeed small, generally on the order of a few hundredths of a foot. Were the data to be plotted on a vertical scale that was coarser (say, a 20 foot vertical range on the "Y" axis, instead of 2 feet, as plotted), the remaining fluctuations would, for all practical purposes, disappear. We have chosen to analyze the data using a fine scale in order to be more complete.

Water Level Trend Corrections

The effects of water level trends unrelated to either pumping at SVR #7 or changes in atmospheric pressure were then estimated visually. The BE-corrected water levels for each well were plotted and a line was projected through the initial pretest period and the end of the post-pumping recovery period. The equation of the trend line associated with each well was then generated using MS Excel software. The water level trend visually identifiable at TW #2 and TW #4 appeared as a declining level over the course of the entire test (including the week before the test began). The peak (highest elevation) of the 2008 water levels in the aquifer near these wells appeared to occur just prior to March. Beneath the eastern portion of the M3 property, however, the water levels appeared to be rising before the start of the test and declining at the end. Based on linear projections of the pre-test and post-test trends observed in SVR #7, Flack Corral 6-inch stock, Flack Corral 4-in stock and the Little Gulch Stock Wells, the 2008 peak in water levels in this area appeared to occur sometime during the period March 17 to 19. Because of the peak occurring during the test, two separate equations were generated for the estimated water level trend at each well: one for the rising-level period and one for the declining-level period.

Trends could not be estimated for aquifer near the pumping well (SVR #7) and the nearby Big Gulch Stock Well using the pretest data because pre-test pumping caused water levels to fluctuate, obscuring any visually discernable trends. Instead, we used the data collected during the two months following the completion of the test. These data indicated a declining trend (as indicated by all the other analyzed wells for the period beginning about mid-March). The use of the trend calculated using April and May monitoring data helped to calculate water level recovery, after pumping started.

Regional water level trends were not estimated at wells that did not experience significant drawdowns during the aquifer test. These wells *may* have had a drawdown on the order of a few hundredths of a foot, but such small drawdowns could not be reliably separated from the many fluctuations caused by un-removed barometric effects, un-removed trends and un-removed earth-tide effects. The absence of drawdowns that could be justifiably calculated from the corrected data made quantitative analysis for aquifer parameters of

questionable value. Aquifer water-level trends were not calculated for the Kling Irrigation well, TW #1, TW #3, SVR #6, and UWID State and Linder TW #1).

BE-and-Trend-Corrected Drawdowns

Drawdowns were calculated following two methods after a preliminary evaluation of the data indicated that the drawdowns at some of the more-distal observation wells were small, and in many cases, smaller than the non-pumping-related trend in water levels within the aquifer. Two methods were used to bracket the range of, and therefore give a better representation of, our understanding of the aquifer parameter values calculated in our analysis. The two methods differed in how aquifer water level trends were included in the analyses, as explained below.

The first method (Method 1) to calculate drawdown was to subtract the depth to water just before pumping started ("t=0") from the depth to water at the time of observation. These drawdowns are equivalent to the assumption that the water level at the start of the test best represents the non-pumping water level within the aquifer and that there was no pre-test trend in water level changes, an assumption we believe to be incorrect. The method does *not*, however, introduce a change in water level that could potentially be misinterpreted as drawdown. By not using any trend corrections, the resulting drawdowns *are* affected by the water level trend, but by an unknown amount. We refer to the product of this method as the "no-water-level-trend correction data."

The second method (Method 2) to calculate drawdown included the estimated water level trend. These "water-level-trend corrected drawdown data" were calculated by subtracting the projected trend-based water level (at the time of observation) from the depth to water at the time of observation. The advantage of this method is that our best estimate of water level trends are incorporated into our analyses. The disadvantage is that any errors in our trend would potentially result in errors in our analyses for aquifer parameter values.

Using these two methods, we generated two sets of drawdown data for each well and then subsequently used these two data sets to bracket our analytical results. The two data sets allowed us to present what we believe to be a more-realistic understanding of the aquifer parameters of transmissivity and storativity and the uncertainty of the pre-test and post-test water level trends on the analytical results.

SECTION V: Methods of Analysis

This section of the report describes the methods used to analyze the processed drawdown data to calculate aquifer parameters of transmissivity and storativity. Our first step was to examine the drawdown plots for wellbore storage effects using the method outlined in HydroSOLVE, Inc. (2007). Next, we reviewed "straight-line" (semi-log time versus arithmetic drawdown) and "curved-line" (log-time versus log-drawdown) plots of the data along with geologic and well-construction data to select the appropriate method of

analysis. The following analytical methods were used: Theis (1935), Cooper-Jacob (1946), Theis recovery (1935), and Neuman-Witherspoon (1972). These analyses were conducted using drawdowns calculated both without water-level trend corrections ("Method 1" – described above) and with water-level trend corrections ("Method 2" – also described above). Each drawdown analysis also was accompanied by a "derivative analysis" (Bourdet et al, 1989) to assess the applicability of the method to the data used. The various methods used in this report are described below. Additional information on each method is included in Appendix D.

Analytical Methods

Well-Bore Storage (HydroSOLVE, Inc., 2007): A log-log, radial flow plot of the data collected for every well was examined prior to conducting any aquifer-property analysis. A slope of 1:1 on the log-log plot of the drawdown vs. time data during early-time pumping indicates that the effects of well-bore storage dominate the drawdown response, and the appropriate method of aquifer analysis would then be selected. Based on this method, none of the wells exhibited significant well-bore storage effects. However, the pumping well (SVR #7) did indicate small wellbore storage effects (on the order of 1 to 4 feet of reduced drawdown) in the data collected during the first 10 minutes of pumping.

Derivative (Bourdet et al, 1989): A derivative analysis was conducted to verify the validity of the chosen method of drawdown analysis. In a derivative analysis, the slope of the drawdown plot ("derivative") is calculated for each data point and compared with the derivative type curve appropriate to the chosen method of drawdown analysis. A general match of the data-point derivatives to the derivative type curve indicates that the test data are valid for the selected method of analysis. For example: Cooper-Jacob (1946) analyses are only valid where the derivatives fall on a horizontal line (i.e., the drawdowns plot on a line with constant slope), while a Theis (1935) analysis requires derivatives that plot on a curve that rises with a decreasing slope that eventually approaches a constant value. When the derivative plot data does not match the type curve, it indicates that the method of analysis is likely invalid and the results erroneous. In most of our analyses, we used a "differentiation interval" (the range over which the average slope of the drawdown curve was calculated for each point) of 0.3 log cycles to help "smooth" the derivative curves. Occasionally we used a higher value of 0.4 log cycles when the value of 0.3 generated too much scatter in the derivative plot to be useful. Each drawdown analysis includes a derivative plot to help indicate the relative validity of the method.

Theis (1935): In this method a type-curve is matched to the data on a log-log plot for drawdown and recovery and the appropriate aquifer parameter values associated with that type curve are indicated. When unconfined aquifers were analyzed, the correction developed by Jacob (1944) was used to correct the data to make the analysis applicable. In some cases, a semi-log Theis plot was used to better match the data where drawdowns were relatively small and water level trends (caused by other factors beyond the pumping SVR #7) were relatively large. Because Aqtesolv® can generate a type curve for any system of axes, the semi-log plot for some wells allowed for better curve matching and better assessment of the effects of our quantification of non-pumping-related water level

trend. The Theis method requires matching the data generated when the drawdown levels begin to change most rapidly. This rapid rise occurs as the "cone of depression" moves outward from the pumping well, reaches the observation well and continues to move outward. Butler (1990) indicates that this method generally indicates the average properties of the aquifer over an area defined by the distance between the pumped well and observation well being analyzed (in other words, the average properties of the region between the pumping well and the observation well).

Cooper-Jacob (1946): In this method a straight-line is best-fit to the drawdown data on a semi-log graph (linear drawdown versus log of time). This is a variation of the method of Theis that becomes valid after a sufficiently long time into the test such that most of the terms in the Theis equation become insignificant and the data plot on a straight line on a semi-log plot. The straight line plot occurs when the "u" terms in the Theis equation (See Appendix D) become sufficiently small after a critical time (t_c).When "u" is sufficiently small, the non-linear terms of the Theis equation become insignificant resulting in a logarithmic curve that becomes a straight line on a semi-log plot. We have used a "u" equal to or less than 0.05 as our criteria for validity (the so-called "u assumption") as indicated by Driscoll (1986). Many of the observation wells monitored during the SVR #7 test were sufficiently far from the pumping well such that the "u assumption" was not valid, indicating that the results of the Cooper-Jacob analysis were not valid for these wells.

When a Cooper-Jacob analysis is valid, however, it provides an insight into the aquifer that is different from that provided by a valid Theis analysis. Butler (1990) indicates the results of the Cooper-Jacob analysis generally indicate the average properties of the aquifer over an area much larger than that defined by the distance between the observation well and the pumping well. Because the cone of depression caused by the pumping well must move outward for a sufficiently long time for the Cooper-Jacob method to be valid, the leading edge of the cone of depression caused by the pumping well must pass the observation well and expand outward by a relatively large distance before the "u assumption" is met. By the time the "u assumption" is met, the leading edge of the cone of depression is well beyond the observation well. It is the portion of the aquifer within the circle described by the leading edge of the cone of depression that controls the response in the observation well. This response represents an average of the properties of the entire aquifer region within the circle defined by the cone of depression.

Theis–Recovery (1935): In this method, the water-level recovery data plot as a straight-line on a semi-log plot with time plotted as the ratio of time since pumping started divided by time since pumping stopped. This method helps to remove the effects of well loss and small pumping variations that affect the analysis of pumping data. It also indicates whether hydraulic boundaries and /or recharge affected recovery ("S/S' analysis"). A ratio of S/S' greater than 1.0 indicates "late" recovery and the effects of a "no-flow" boundary to the system, while a ratio of S/S' less than 1.0 indicates "early" recovery and recharge or the effects of a "recharge" boundary. When water level trends unrelated to the pumping of the test well are not accounted for or incompletely accounted for, the usefulness of the S/S' analysis is reduced.

Neuman-Witherspoon (1972): In this method, the data are plotted on a log-log graph and then matched to a type-curve generated for a "leaky," confined-aquifer system (aquifer/leaky-aquitard/aquifer). The parameters of the two aquifers and the aquitard are indicated by the selected type curve. The Neuman-Witherspoon method is based on the concept that pumping from one aquifer causes ground water to flow through a leaky aquitard from an adjacent un-pumped aquifer. This type of two-aquifer behavior is often indicated by a test data plot that flattens out after a time and remains "stabilized" (no increase in drawdown with time). The Neuman-Witherspoon method requires an understanding of the geometry of the unpumped aquifer and the separating aquitard in addition to the geometry of the pumped aquifer.

Composite Plot **(Theis)**: In this method, drawdown data from more than one well are plotted on the same graph with the distance of the observation well from the pumping well normalized as time/distance^2. In an ideal aquifer all the data points will plot on the same type curve. Similarly derivative data points for all wells would plot on the ideal derivative curve.

Distance-Drawdown Plot **(Theis)**: In this method, drawdowns occurring at the same time, from more than one well are plotted on the same graph. It the selected time is sufficiently large such that the "u-assumption" is met for all the plotted wells, a Cooper-Jacob-method, straight-line, semi-log, plot can be used to calculate the transmissivity of the aquifer. This was not the case, however, in this aquifer test and the Theis log-log curve-match method was used. In an ideal aquifer all the data points will plot on the same type curve.

Issues Affecting the Pumping Well Analyses

Selecting the appropriate method of analysis for pumping wells is often problematic. Some workers consider the use of the Theis log-log method of analysis invalid for the pumping well because the selection of an effective well radius affects the analytical results. In addition, well loss (drawdown in the well caused by frictional head loss through the well screen and near-screen materials) also affects the calculations for transmissivity. The Theis method, however, is able to accommodate anisotropy of the aquifer (different vertical and horizontal permeabilities) and partial penetration (well screens only a portion of the vertical thickness of the aquifer), through the use of Hantush (1961a and b) corrections. The Cooper-Jacob semi-log method does not need input of effective well radius or well loss as it relies solely on the slope of the straight-line plot to indicate transmissivity of the aquifer. It does, however, not include the effects of anisotropy or partial penetration of the aquifer.

In cases where the pumping well is open to all or most of the aquifer thickness and the aquifer is isotropic (same permeability in all directions of flow), the Cooper-Jacob method is generally more accurate than the Theis method for pumping well analyses. This was not the case with SVR #7, however, which was completed in only about one-fifth of the thickness of the anisotropic Pierce Gulch Sand Aquifer. Therefore the issues

of partial penetration, well loss, and effective well radius were addressed, as discussed below.

Partial Penetration

When the pumping well only is open to only a relatively small portion of the entire aquifer thickness, the effects of "partial penetration" can result in errors (Freeze and Cherry, 1979), especially when the aquifer is anisotropic. Hantush (1961a and b) developed a method for correcting for the effects of partial penetration and anisotropy that applies to the Theis method. The Hantush corrections, however, do not apply to the semi-log Cooper-Jacob method.

The Pierce Gulch Sand Aquifer contains relatively thin, discontinuous layers of clay, silt and silty sands within the overall sand section that defines the aquifer. These discontinuous clay and silt layers result in an aquifer that has a bulk anisotropy that directs the initial effects of pumping primarily in a lateral direction with slower effects directed vertically. The discontinuous layering of clay and variations in permeability with depth within the Pierce Gulch Sand Aquifer system are also problematic for application of the Hantush corrections to the Theis method. The effects of the layering can only be approximated, as the ratio between the relative vertical and horizontal hydraulic conductivity of the aquifer must be estimated as input to the method. This ratio is never measured directly in a pumping test. In lieu of direct measurement we have assumed that the thin discontinuous low-permeability layers result in an overall preference for flow in the horizontal direction, in other words we have estimated that the ratio of the bulk vertical to bulk horizontal permeability of the aquifer is about 0.1, on average.

Effective Radius

To better quantify the potential errors inherent in applying the Theis method to pumping well data, we conducted sensitivity analyses on the effective well radius, which can never be known exactly. When a well is developed, the permeability of the aquifer materials just outside the well screen and filter pack is increased. This increase causes the well to behave as if it had a larger radius than the drilled borehole. The actual size of this effective well radius is typically a few inches larger than the actual radius of the borehole, but is not directly measurable. Our analyses indicated that doubling the effective well radius from the actual bore-hole radius to twice that value, resulted in differences in analytical results of only about five percent. (i.e., using actual well-bore radius resulted in transmissivity calculations that were five percent larger than those using an effective radius twice that of well bore diameter.) The true effective radius is very likely to be much less than twice that of the actual well bore inherent in a well test. We therefore used an effective well radius equal to the well borehole radius and acknowledge a potential error of up to 5 percent.

Well Loss

Well loss is the increased drawdown in the pumped well caused by frictional head loss as water flows through the well screen, filter pack, the under-developed aquifer directly adjacent to the pumped well, and/or near-well, vertical flow caused by partial penetration. Well loss includes both linear terms associated with laminar flow (well loss increases in

direct proportion to pumping rate) and exponential terms associated with turbulent flow (increases exponentially to the pumping rate, often assumed to be the square of the pumping rate). In the case of SVR #7, well loss was estimated thorough a comparison of measured versus back-calculated theoretical-drawdown based on a nearby observation well. Details of this method are presented in Section VII of the report, below.

HLI Approach to Analyses for the Pumping Well

Our approach to dealing with these potential pumping-well issues was to conduct three analyses. The first was a Cooper-Jacob analysis using the raw data. This analysis did not take into account partial penetration or aquifer anisotropy. Well loss and effective radius were not factors affecting the results. The second analysis followed the Theis method (with Hantush corrections) using data corrected by removing estimated well loss. Well loss was estimated as described in Section VII. The Theis analysis with Hantush corrections incorporated the effects of partial penetration, anisotropy and well loss. Effective well radius errors were assumed to be less than five percent. The third analysis was based on the Theis recovery method using raw data. Similarly to the Cooper-Jacob drawdown analysis, partial penetration and aquifer anisotropy were not taken into account, and well loss and effective well radius are not factors affecting the results. All three analyses were then compared and the representative transmissivity calculated.

Issues Affecting the Method of Analysis for Observation Wells

Analysis of observation well data has issues that are different from those affecting pumping well data. The Cooper-Jacob method requires that pumping occurs for a sufficiently long period such that the "u assumption" is met and the data plot as a straight line on a semi-log graph. The length of time ("critical time" or "t_c") required to meet the "u assumption" becomes larger as the distance between the observation well and the pumping well increases. Most of the observation wells monitored during the test were sufficiently far from the pumping well such that the calculated critical time was too large before the "u assumption" was met to allow the Cooper-Jacob method to generate accurate results. In these cases, we used the Theis method to analyze the data. Aqtesolv® incorporates the partial penetration and anisotropy corrections developed by Hantush when using the Theis method; however, all of the monitored observation wells (except for possibly the Big Gulch Stock Well) were too far from the pumping well to be significantly affected by partial penetration.

No-Flow Boundaries

All of the wells analyzed during the test were considered to be potentially affected by the hydraulic (boundary) effects of the edge of aquifer, as represented by the green line on Figures 1 and 2. To address these effects, the analytical methods that used curve matching (Theis and Neuman-Witherspoon) included the use of image well techniques, as described by Ferris et al (1962). Image wells are imaginary wells that pump at the same rate(s) and timing as the well undergoing the analysis. In the case of a no-flow boundary, the well is incorporated into the analysis by assuming it lies on the opposite side of the boundary, at a distance equal to the distance between the pumped well and the

boundary. An image well in this position produces the same hydraulic effects on a well in an infinite aquifer (as is assumed in the Theis and Neuman-Witherspoon methods) comparable to the theoretical effects caused by a no-flow (or "edge-of-aquifer") boundary (Ferris et al, 1962). Through the principal of "superposition," the type curves used in the data matching for the log-log analyses were generated by Aqtesolv® to model the type curve that would result from pumping a well in the bounded system.

Curve Matching

In all cases, we reviewed the computer-generated match and then manually adjusted the curve match to best fit the data, when needed. Computer-generated matches often were less accurate, especially when evaluating later-time data where errors in water-level trend estimation or barometric efficiency were large relative to changes in residual drawdown. The computer match would consider these late-time data to be as significant as early-time data falling on the theoretical curve. Through manual matching, we were able to apply "best professional judgment" in deciding which data were representative and which data were likely to be less representative. Alternatively we could have applied weighting factors to the late-time data causing Aqtesolv® to place less emphasis on the late-time data, but that, too, would have required "best professional judgment' and be no more accurate than the visual-match method.

Non-Pierce Gulch Sand Aquifers

Most of the wells monitored during the SVR #7 test were competed in the Pierce Gulch Sand Aquifer, as shown in Table 1.These wells were analyzed using standard single-aquifer methods.

A few wells, however, appear to be completed in aquifers other than the Pierce Gulch Sand Aquifer. Well SVR #6 is known to be completed in the Willow Creek Aquifer (sand facies of the Terteling Springs Formation) and as such, showed no drawdown response during the test. Two wells completed at the M3-TW #4 site (the Zone 1 and Zone 3 small-diameter wells within the TW #4 borehole) indicated a drawdown response to pumping at SVR #7. The composite diagram for these wells (Figure 13, page 91) suggests they could be completed in zones above and below the Pierce Gulch Sand Aquifer. Well M3-TW #4 Zone 1 appears to be a small water-bearing zone lying below the Pierce Gulch Sand Aquifer that, based on test result discussed below, is in hydraulic connection with the Pierce Gulch Sand Aquifer. Well TW #4 Zone 3 appears to be completed in a shallower, un-named alluvial aquifer overlying the Pierce Gulch Sand Aquifer. As such, we explored the response of these two wells using the Neuman-Witherspoon (1972) analytical method which is designed for analyzing data from aquifer systems comprising pumped and unpumped aquifers separated by a leaky aquitard. We also analyzed the data from these two wells as if they were completed in the zones that are a part of the Pierce Gulch Sand Aquifer. We then compared the results to examine whether the analyses supported a single aquifer system or a system comprising close-by small aquifers separated by a leaky aquitard.

SECTION VI: RESULTS OF THE CONSTANT-RATE-DISCHARGE TEST

This section of the report presents the calculated drawdowns and the results of the Aqtesolv® analyses based on these drawdowns. Drawdown in the pumped well (SVR #7) at the end of the test was measured at 193.78 feet below the pre-test, non-pumping level of 165.21 ft bgl for an end-of-test drawdown of 28.57 ft, and a nine-day specific-capacity of 32.1 gpm/ft. The maximum drawdown in the nearest observation well ("Big Gulch Stock Well") was 1.71 ft while the furthest responding observation well (SVR #9) indicated a drawdown of 0.09 ft. The Pierce Gulch Sand Aquifer beneath the property is more transmissive then previously believed with a mean transmissivity of 410,000 gallons gpd/ft. The transmissivity beneath the western and central portions of the M3 property ranges from 450,000 to 580,000 gpd/ft with a storativity averaging $2x10^{-3}$ (unitless). The transmissivity is smaller beneath the eastern portions of the property ranges from 180,000 to 300,000 gpd/ft with storativities averaging 0.04 ($4x10^{-2}$) and estimated specific yields on the order of 0.1 to 0.2.

Drawdowns and Specific Capacity

Pumping at a rate of 917 gpm for the SVR #7 aquifer test began at 16:00 hrs on March 10, 2008 and concluded at 16:00 hrs on March 19, 2008 for a total pumping time of 12,960 minutes (nine days). Recovery water-level data were collected through March 31, 2008 (a 12-day period) at one-minute intervals and thereafter at the background-monitoring rate of 30-minute intervals. The collected data have been archived and are included on a CD attached to printed copies of this report. Drawdowns in the various wells are summarized in Table 2.

Starting at an initial, non-pumping water level of 165.21 ft bgl, the final water level in SVR #7 after nine days of pumping was 193.78 ft bgl, equivalent to a drawdown of 28.57 ft, indicating a nine-day specific capacity of 32.1 gpm/ft of drawdown. As is shown in Section VII, much of this drawdown is related to well loss. A properly designed and constructed well completed over the full thickness of the aquifer, would have an even higher specific capacity. We estimate that such a well would have a likely yield of 2,000 gpm or more.

Measurable drawdowns in the observation wells at the end of the pumping phase of the test ranged from a maximum of 1.71 ft in the closest observation well (Big Gulch – 842 ft from SVR #7) to a minimum of 0.05 to 0.17 ft in TW #2 Zone 2 (3,636 ft from SVR #7). SVR #9 was the furthest observation well (11,660 ft from SVR #7) to indicate a measureable drawdown (0.09 to 0.15 ft). Many wells located to the west and south of SVR #7 indicated no measureable response. Well SVR #6 completed in the Willow Creek Aquifer also indicated no measureable drawdown during the test.

Barometric Efficiency

The calculated Barometric Efficiencies (BE) for the monitored wells are included in Table 1. These BE values were used to correct the raw depth to water data and were derived from plots on the figures presented in Appendix B. The plots show the atmospheric pressure versus water level plots, the best-fit lines applied to the data, the calculated BE and the degree of correlation (R^2). Most of the wells exhibit very high BE's (greater than 80-percent efficient). Only the lower zones of M3-TW #1 and #4, the Kling Irrigation well and the UWID State and Linder test well had efficiencies of less than 50 percent. The high BE's (as much as 99 percent) strongly suggest that the Pierce Gulch Sand Aquifer is cemented. This high degree of cementation and high barometric efficiencies indicate a rigid aquifer framework and overlying low-permeability materials effectively sealing the aquifer from the effects of atmospheric pressure changes.

Water Levels

Linear plots of the actual water-levels and BE-corrected water-levels reported in all the wells monitored before, during, and after pumping (at WRE #7), along with the atmospheric pressure recorded by two on-site Barologgers are included in Appendix C. The hydrographs for the pumped well SVR #7 (Appendix Figure C-1) and the nearby Big Gulch Stock Well (Appendix Figure C-3) clearly show the "classic" response of a rapidly dropping water level shortly after pumping started with the drawdown curve flattening over time after the initial steep drop. After pumping ceased, a similar but inverted residual-drawdown curve is shown where water levels "recovered." The barometric pressure (plotted at a different scale on the right of the hydrographs) shows numerous rises and falls during the test. Because the drawdown at and near the pumping well are much greater than the changes in water level caused by barometric effects, the barometric fluctuations are effectively "masked" and are too small to be readily observed in the water-level plots for SVR #7 or the Big Gulch well at the presented scale.

The pumping well shows a wide variation in water levels while it was being pumped. These fluctuations are on the order of 3 feet and appear to be the result of surging in the pumping well. The surges may have been caused by a combination of the high rate of pumping (917 gpm) with a pump-and-motor assembly that was only ½ inch in diameter smaller than the well screen and well casing. The rapid flow within the well along with the tight constriction of the pump-and-motor assembly may have caused the surging which was observed in both the electronic and hand-measured water levels. A long discharge line may also have contributed to the surging. The discharge orifice was approximately 10 to 15 feet lower than the well head. The lower discharge point could have induced a partial vacuum in the rigid discharge line, causing the surging observed in the water level data. Figure C-1 shows that a running average (mean) of the data taken over intervals of 10 minutes before and 10 minutes after the time of observation significantly reduces the fluctuations and produces a much smother, less "noisy" data plot.

Smaller, but still distinct, drawdowns and recoveries are observable in the water level plots for the following wells: M3-TW #2, M3-TW #4, Flack Corral 6-in, Flack Corral 4-

in, Little Gulch Stock Well, and SVR #9 (all hydrographs in Appendix C). No easily discernable drawdowns are observable in the water level plots for the following wells: M3-TW #1, M3-TW #3, SVR #6, Kling Irrigation and UWID State and Linder TW #1. Small drawdowns on the order of a few hundredths of a foot may have occurred in these wells but could not be discerned in the corrected water level plots. Small drawdowns may have been obscured by the "noise" in the data, as discussed above.

Data from back-up wells did not need to be used as all the primary observation wells performed as planned. Data from these wells were neither plotted nor analyzed. These back-up wells had both: a) data loggers with high ranges (and therefore less precision and accuracy where small changes in water levels are concerned), and b) were duplicated by wells in adjacent depth intervals that that had low-range data loggers and had shown similar aquifer response between the zones during previous analyses. These unanalyzed back-up wells included: M3-TW #1 Zone 1 (duplicated by Zone 2) and Zone 3 (duplicated by Zone 4) and M3-TW #3 Zone 4 (duplicated by Zone 3) and Zone 2 (duplicated by Zone 1).

The Flack Corral 4-inch well was analyzed but may be of limited value in that several assumptions on well construction and aquifer position had to made because no well construction information beyond well diameter (measurable at the surface) was known; its depth and length of screen (if any) are unknown. (A depth was tagged at 252-feet bgl but we do not know if the tagged depth represents the bottom of the well, infill, and/or an obstruction.) No Driller's Report was available for this well. We also do not know which parts of the Pierce Gulch Sand Aquifer (if any) are tapped by this well. Based on projections of the position of the Pierce Gulch Sand Aquifer from other locations, we estimated the depths to both the top and the bottom of the aquifer. Because we had to make these assumptions, we believe that the calculated aquifer parameter results should be considered with these assumptions in mind.

Analyses for Aquifer Parameter Values

In this sub section of the report, the drawdown data generated using the preprocessing methods discussed above are analyzed using Aqtesolv®. Individual well analyses are discussed first, followed by an analysis of a composite plot. The results are summarized in Table 2 (page 43).

SVR #7 Analyses

The pumping well, SVR #7, had 28.57 ft of drawdown at the end of the test. The Aqtesolv® analyses indicated a mean transmissivity of 470,000 gpd/ft.

Four different analyses of the drawdown data collected from SVR #7 indicate a transmissivity ranging from 400,000 to 520,000 gpd/ft. These results are based upon 1) a Cooper-Jacob analysis using raw data, 2) a Theis analysis using data with 23 ft of well loss removed from the raw data, 3) a Theis-recovery analysis using raw data, and 4) a Theis-recovery analysis using data corrected for estimated seasonal aquifer water level trend. Water level trends were not included (nor are they important) in the drawdown

analyses for the pumping portion of the test. The pre-test pumping precluded the collection of non-pumping water level data to establish a trend for the pumping portion of the test. Since drawdowns in the well (28.57 ft at the end of the nine-day pumping period) were much larger than the aquifer water-level trends observed in other on site wells (about 0.1 ft change over the pumping portion of the test), aquifer water-level trends during the pumping portion of the test were deemed insignificant. The Theis-recovery analysis were considered both without and with water-level trend corrections based on monitoring data collected during April and May of 2007, as is discussed, below.

The Cooper-Jacob analysis shown in Figure 20 (page 102) indicates a transmissivity of 400,000 gpd/ft. The straight line plot through the data plot is only an approximation because surging in the pump column caused water levels to fluctuate throughout the pumping period. The derivative analysis indicates that the method is valid after about 10 minutes of pumping. The data from before this period appear to be slightly affected by wellbore storage effects. After 10 minutes, however, the relatively good match of the derivative plots to the type curve support the method.

The Theis analysis shown in Figure 21 (page 103) indicates a transmissivity of 450,000 gpd/ft. The data plot shown in the lower portion of the figure presents a drawdown corrected by removing 23 feet of well loss from the raw data (calculation described in Section VII, below). In other words the well-loss-corrected drawdowns are 23 feet less than the raw-data drawdowns (plotted in the upper portion of the figure). As with the Cooper-Jacob plot, the type curve fitted through the data points is only an approximation because surging in the pump column caused water levels to fluctuate throughout the pumping period. The derivative analysis indicates that the method is valid after about 10 minutes of pumping. The data from 0 to 10 minutes appear to be slightly affected by wellbore storage effects. After 10 minutes, however, the relatively good match of the derivative plots to the type curve support the method.

The Theis recovery analysis using data uncorrected for seasonal aquifer water-level trend presented in Figure 22 (page 104), indicate a transmissivity of 520,000 gpd/ft. The data from the period t/t' 3 to 300 (equivalent to about 40 minutes through about one and one-half day of recovery) fall on a straight line, as required by the method. Recovery after this period (t/t' less than 3) shows the effects of incomplete barometric corrections and the lack of trend corrections.

Using data corrected for seasonal aquifer water-level trend (based on monitoring over the period April 1 through May 31 as shown in Appendix C Figure C-2) in the Theis recovery analysis presented in Figure 23 (page 105) indicate a transmissivity of 490,000 gpd/ft. The data plot on a straight line from the period t/t' 3 to 300, similarly to the uncorrected analysis.

The S/S' ratio of less than 1 (as indicated by both of these Theis recovery analyses) often indicates that a no-flow aquifer boundary influenced water-level recovery. Because the aquifer is bounded to the north east of the SVR #7 site by unsaturated and low-permeability sediments (green line in Figure 2), the apparent incomplete recovery could

be explained by this aquifer boundary. However, the boundary is under water-table conditions and could, therefore, also act as an apparent recharge source. We believe the apparent incomplete recovery is more likely the result of small errors in estimating the rate of seasonal water-level decline in the Pierce Gulch Sand Aquifer that occurred during the end of the test.

In summary, our analyses of the pumping well data indicate a transmissivity ranging from 400,000 to 550,000 gpd/ft, with a mean of 470,000 gpd/ft. We believe that this mean is a good, representative value for the transmissivity of the Pierce Gulch Sand Aquifer in this area.

As with all pumping well analyses, storativity cannot be accurately calculated.

Big Gulch Stock Well Analyses

The Big Gulch Stock Well located 845 ft from the pumping well had 1.71 ft of drawdown at the end of the test. The Aqtesolv® analyses indicated a mean transmissivity of 470,000 gpd/ft and a mean storativity of $1.5x10^{-3}$.

Drawdown data collected from the Big Gulch Stock Well (located 845 ft from SVR #7) indicate a transmissivity ranging of 450,000 to 500,000 gpd/ft. Four methods of analysis were applied: Cooper-Jacob, Theis, Theis recovery (using raw data) and Theis recovery (using data corrected for water level trends). As with the pumping well, water level trends were calculated using water level data obtained during April and May of 2007, after the test was completed (shown in Appendix C Figure C-4). Pumping (drawdown) analyses did not include trend corrections because pre-test pumping at SVR #7 precluded the collection of non-pumping water level data to quantify a trend. However, because the aquifer-wide trend over the pumping period of nine days is on the order of 0.1 ft, a trend correction error is not highly significant in comparison to the 1.7 ft of drawdown observed by the end of the pumping period.

The Cooper-Jacob analysis shown in Figure 24 (page 106) indicates a transmissivity of 500,000 gpd/ft and a storativity of $1.2x10^{-3}$. The data begin to plot along a straight line after about 80 minutes into the test, with a critical time ("u-assumption" analysis) of 95 minutes. The straight line and critical time are supported by a derivative analysis which indicates that the method is applicable from 100 to 6,000 minutes. After this time, the drawdown and derivative curve both rise. Had the increase in drawdown been caused by an aquifer boundary, the derivative would have leveled off at a value approximately twice that of the earlier period. Because the derivative values continued to rise and did not level off, it is more likely that the increase in drawdown was caused by the seasonal decline in aquifer water levels and not an aquifer no-flow ("negative hydraulic") boundary.

The Theis analysis shown in Figure 25 (page 107) indicates a transmissivity of 450,000 gpd/ft and a storativity of $1.8x10^{-3}$. The derivative analysis suggests that the method is valid from the beginning of the first indication of drawdown (5 minutes after pumping at SVR #7 started) through about 5,000 minutes. As with the Cooper-Jacob analysis,

seasonal aquifer-wide water level trends affected the apparent drawdown during the end of the test.

The Theis recovery analysis presented in Figure 26 (page 108) using data uncorrected for seasonal water-level trend indicates a transmissivity of 450,000 gpd/ft and a S/S' of 0.6. The data from the period t/t' 20 to 200 (equivalent to about 1 through 10 hours of recovery) fall on a straight line, as required by the method. Recovery after this period (t/t' less than 20) show the effects of incomplete barometric corrections and the lack of trend corrections. The S/S' ratio of less than 1.0 is likely the result of the seasonal decline in regional water levels, as discussed above for SVR #7.

The Theis recovery analysis presented in Figure 27 (page 109) using data corrected for seasonal water-level trend indicates a transmissivity of 480,000 gpd/ft and a S/S' of 0.4. The data from the period t/t' 20 to 500 (equivalent to about on-half hour through 10 hours of recovery) fall on a straight line, as required by the method. The analysis using the corrected data still shows the effects of incomplete trend corrections in that the recovery line does not project through residual drawdown = 0 at t/t' = 1.

In summary, the analyses for the Big Gulch Stock Well indicate a transmissivity ranging from 450,000 to 500,000 gpd/ft, with a mean of 470,000 gpd/ft. This mean result is identical to that indicated by the pumping well analyses.

Even though the Big Gulch Stock Well is completed within a shallower portion of the Pierce Gulch Sand Aquifer and is not fully penetrating, the distance between the pumping well and this observation well (~845 feet) is large enough, such that partial penetration effects are not significant. Hantush (1961a and b) indicated that wells located at a distance two or more times the thickness of the aquifer do not need corrections for partial penetration. Since the Pierce Gulch Sand Aquifer is about 340 feet thick at this location, the Big Gulch Stock Well lies at a distance that is more than twice the aquifer thickness.

We calculated a mean storativity of 1.5×10^{-3} from the two analyses of the Big Gulch Stock Well data. This value indicates a confined to semi-confined aquifer and is comparable to other values calculated from other aquifer tests of the Pierce Gulch Sand Aquifer (HLI, 2008).

Potential Issue of Concern for the Big Gulch Stock Well

One potential issue with the interpretation of the analysis of the data from the Big Gulch Stock Well is that it may be completed about 100 feet above the top of the Pierce Gulch Sand Aquifer. Our interpretation of the geophysical logs from SVR #7 indicate that the top of the Pierce Gulch Sand Aquifer lies approximately 240 feet below ground level while the limited information we have available for the Big Gulch Stock Well suggest it is completed (and open to an aquifer) 180 feet below ground level. Although this apparent discrepancy might be considered a complication, we believe it neither invalidates the analysis of the data from this well nor our interpretation of aquifer properties, for the following four reasons.

The first is that the documentation of the details of construction for the SVR #7 well is somewhat limited with respect to the annular seal. Additionally, only one geophysical log is available from the open hole; an uncalibrated single-point resistance log run by the well driller with no training in geophysics and reconstituted from a pen-and-ink strip chart. The geophysical and lithologic logs suggest a sand-dominated sequence of coarse sand, sand, silt and clay throughout the depth corresponding to the bottom of SVR #7 and the depth of the Big Gulch Stock Well indicating a hydraulically connected water bearing zone, as shown in Figure 9. In short, the reported lithology does not make good sense to us in comparison to relatively good data from nearby wells although a sand-dominated section is typical of geologic materials becoming coarser toward the margin of the basin. In addition, the poor understanding of the construction details of the Big Gulch Stock Well may also play a role. We have assumed the bottom depth of this well based on a video camera survey. We do not know if the well extends deeper (as open hole) because we have no Well Driller's Report for this well. The Big Gulch Stock Well may, in fact, extend to the depth of SVR #7, but we do not know. Based on the incomplete understanding of well construction and the lack of direct knowledge of the specific geology at the Big Gulch Stock Well, the differing well depths do not appear to be an issue.

The second reason is the similarity in the calculated transmissivities using the Big Gulch Stock Well, SVR #7 and the TW #4 Zone 2 well. The drawdown data from all three of these wells, as well as the trend-corrected recovery data from the Big Gulch Stock Well and SVR #7, all indicate transmissivities in the range of 400,000 gpd/ft to 550,000 gpd/ft. Were the Big Gulch Stock Well to be completed in a separate aquifer, the calculated transmissivity from the Big Gulch Stock Well data would have been very different. Our interpretation of the properties of the Pierce Gulch Sand Aquifer does not rely upon the analyses of the Big Gulch Stock Well data. Rather, the calculated values are consistent with, and support, the analyses from the other responding wells completed in the confined portions of the Pierce Gulch Sand Aquifer. For these reasons the differing well depths do not appear to be an issue.

The third reason supporting the validity of the data from the Big Gulch Stock Well, is the timing of the initial response to pumping at SVR #7. Water levels in the Big Gulch Stock Well began to drop between 4 and 5 minutes after pumping began at SVR #7. This timing is consistent with responses typical of a well completed 845 feet from a pumping well under semi-confined conditions. It is *not* consistent with responses typical of a well completed in an unpumped aquifer separated from the pumped aquifer by an aquitard 100 feet thick. Neuman and Witherspoon (1969) in his, now, famous research on the layered-aquifer system in Oxnard, California, had an initial response time of almost two days, from an observation well only 72 feet from the pumping well. This observation well was completed in an overlying unpumped aquifer separated by a well-defined leaky aquitard of a thickness comparable to the separation between the bottom of the Big Gulch Stock Well and the top of the intake in SVR #7. The difference in response time (less than 5 minutes versus almost two days), indicates that the Big Gulch Stock Well is not likely to be completed in an unpumped aquifer, separated by a leaky aquitard. Clearly the 100-foot thickness of material between the apparent bottom of the Big Gulch Stock Well and the

top of the intake (louvered well "screen") of SVR #7 does not act as a typical "leaky aquitard." The hydraulic response is transmitted far too quickly for this material to be considered an aquitard. This material behaves more like the coarse sand that is the dominant material indicated on the lithologic log for this well (shown in Figure 9).

The fourth reason why the different depths do not appear to present a problem is the role of fracture flow. The Pierce Gulch Sand Aquifer and adjacent materials beneath the M3 property (and in fact the greater M3-Eagle-Star vicinity), is partially cemented and possibly even fractured to some extent. We believe that ground water flows through these fractures as well as through the open pore-spaces of the sandy geologic materials. Fractures present in the 100-foot thick material between the bottom of the Big Gulch Stock Well and the top of the intake of SVR #7, if present, could allow the exchange of ground water, unlike an unfractured aquitard.

In summary, the 100 feet of geologic materials separating the indicated bottom of the Big Gulch Stock Well and the top of the intake for SVR #7 does not appear to invalidate our analysis of the data from the Big Gulch Stock Well as a well completed in the pumped Pierce Gulch Sand Aquifer. By itself, the 100-foot difference could appear to indicate a separate aquifer. However, the similarity of analyses of the data from different wells, the rapid initial response in the Big Gulch Stock Well, the uncertainty in both well-construction details and specific geologic interpretation, and the presence of fractures throughout the subsurface materials all support our assessment that the data from the Big Gulch Stock Well are representative of the Pierce Gulch Sand Aquifer. Any of these four factors alone would not be enough to draw this conclusion, but the four factors together support our interpretation.

TW #2 Analyses

Test well TW#2 located 3,636 ft from the pumping well had 0.05 to 0.17 ft of drawdown at the end of the test. The Aqtesolv® analyses indicated a mean transmissivity of 300,000 gpd/ft and a mean storativity of 0.085 (8.5x10^{-2}).

Four analyses of the drawdown data collected from well TW #2 (the second closest observation well to SVR #7, at 3,636 ft away) indicate a transmissivity ranging from 230,000 to 370,000 gpd/ft. These results are based on Theis analyses from two Zones (1 and 2) within the Pierce Gulch Sand Aquifer using both raw data and data adjusted for estimated water level trend. A Zone 3 small-diameter well completed in the unsaturated, upper portion of the Pierce Gulch Sand at this location is dry indicating the saturated portions of the Pierce Gulch Sand are unconfined at the TW #2 location. The analyses of the data collected from two saturated portions of the Pierce Gulch Sand (Zones 1 and 2) also indicate that the aquifer is unconfined with calculated storativities ranging from 0.027 (2.7x10$^{-2)}$ to 0.16 (1.6x10^{-1}). The analyses are discussed below.

The Theis analysis for TW #2 Zone 2 (middle of the Pierce Gulch Sand Aquifer) shown in Figure 28 (page 110), based on data *not* corrected for estimated water level trend indicates a transmissivity of 240,000 gpd/ft and a storativity of 9.0x10^{-2}. The data match

the type curve through about 9,000 minutes with a derivative analysis that suggests that the method is valid from the beginning of the first indication of drawdown (about 3,000 minutes after pumping at SVR #7 started) through about 6,000 minutes. After this time the derivatives do not match the type curve. This falling off of the derivatives is likely related to the relatively large interval of differentiation of 0.4 log cycles that includes no drawdown data after pumping stopped at 12,960 minutes. In short, the derivative analysis supports the method of analysis.

The Theis analysis for TW #2 Zone 2 shown in Figure 29 (page 111), based on data corrected for estimated water level trend indicates a larger transmissivity of 370,000 gpd/ft and a smaller storativity of 2.7×10^{-2}. The data match the type curve through about 9,000 minutes with a derivative analysis that suggests that the method is valid from the beginning of the first indication of drawdown (about 6,500 minutes after pumping at SVR #7 started) through about 9,000 minutes. After this time the derivatives do not match the type curve. As with the analysis for the uncorrected data, this falling off of the derivatives is likely related to the relatively large interval of differentiation. The derivative analysis supports the method of analysis.

The Theis analysis for TW #2 Zone 1 (bottom of the Pierce Gulch Sand Aquifer) shown in Figure 30 (page 112) , based on data *not* corrected for estimated water level trend indicates a transmissivity of 350,000 gpd/ft and a storativity of 6.2×10^{-2}. The data match the type curve through the entire test (12,960 minutes) with a derivative analysis that suggests that the method is valid from about 2,000 minutes after pumping at SVR #7 started through about 7,000 minutes. After this time the derivatives do not match the type curve. As with the Zone 2 analyses, this falling off of the derivatives is likely related to the relatively large interval of differentiation. In short, the derivative analysis supports the method of analysis.

The Theis analysis for TW #2 Zone 1 shown in Figure 31 (page 113), based on data corrected for estimated water level trend indicates a transmissivity of 230,000 gpd/ft and a storativity of 0.16 (1.6×10^{-1}). The data match the type curve through about 10,000 minutes with a derivative analysis that suggests that the method is valid from the beginning of the first indication of drawdown (about 5,500 minutes after pumping at SVR #7 started) through about 8,000 minutes. After this time the derivatives do not match the type curve. This falling off of the derivatives is likely related to the relatively large interval of differentiation. The derivative analysis supports the method of analysis. The trend correction appears to delay the initial drawdown response and the overall magnitude of drawdown.

In summary, the analyses indicate a transmissivity ranging from 230,000 to 370,000 gpd/ft, with a mean of about 300,000 gpd/ft. These results are somewhat smaller than those indicated by wells further to the west where the aquifer is thicker. The smaller values are likely the result of the thinner saturated thickness of the Pierce Gulch Sand Aquifer toward the eastern parts of the M3 property. In a similar manner the storativities indicated by the four analyses range from 0.027 (2.7×10^{-2})to 0.16 (1.6×10^{-1}) with a mean

of 0.085 ($8.5x10^{-2}$). All of these values indicate an unconfined aquifer (at this location) as does the composite diagram of TW #2 (Figure 11, page 87).

The range of the values presented in these analyses is in part the result of analyzing data both with and without a water level trend correction and the averaging effect of a cone of depression spreading outward from SVR #7 (where the aquifer is confined) into both areas with a thinner unconfined aquifer (such as TW #2) and into areas where the saturated thickness is greater and the aquifer is confined (such as TW #4, discussed below). Since a trend is apparent but can only be estimated, and because of the averaging effect of the expanding cone of depression, we believe that most representative values for the aquifer near TW #2 are best indicated by the mean of the four analyses, listed above.

The Cooper-Jacob and Theis recovery methods did not generate reliable analytical results when applied to the data collected from the two TW #2 wells. TW #2 is too far from the pumping well for the Cooper-Jacob method to be applied (as indicated by a critical time analysis using the values generated using the Theis method). The Theis recovery analysis could not be applied because the regional water-level decline (unrelated to pumping at SVR #7) that occurred during the 12 days of recovery was larger (0.10 to 0.20 ft) than the drawdown recovery (0.05 to 0.17 ft), effectively masking it and making it impossible to accurately measure and analyze. This water level trend and recovery are shown in Appendix C.

TW #4 Analyses

Test well TW #4 located 4,489 ft from the pumping well had 0.60 to 0.67 ft of drawdown at the end of the test, in the small-diameter well (Zone 2) fully completed within the Pierce Gulch Sand Aquifer. The Aqtesolv® analyses for this zone indicated a mean transmissivity of 580,000 gpd/ft and a mean storativity of $3.0x10^{-3}$. A deeper aquifer unit (or sub-aquifer) (Zone 1) either separate from the Pierce Gulch Sand Aquifer or a part of the Pierce Gulch Sand Aquifer indicated a drawdown of 0.58 to 0.59 ft at the end of the test. The Aqtesolv® analyses for Zone 1 as an aquifer separate from the Pierce Gulch Sand Aquifer indicated a mean transmissivity of 80,000 gpd/ft and a mean storativity of $3.5x10^{-4}$. A shallow aquifer (Zone 3) overlying the Pierce Gulch Sand Aquifer indicated a drawdown of 0.08 to 0.15 ft at the end of the test but did not generate drawdown data that could be reliably analyzed.

<u>M3 TW #4 Zone 2</u>

Two analyses of the drawdown data collected from well TW #4 Zone 2 (located 4,489 ft from SVR #7 - the third closest observation well) indicate a transmissivity ranging from 570,000 to 580,000 gpd/ft and a storativity of $3.0x10^{-3}$ (indicating a confined to semi-confined aquifer). These results are based on two Theis analyses (raw data and data adjusted for estimated water level trend) from the Zone 2 well which almost fully penetrates the Pierce Gulch Sand Aquifer at this location. The details of these analyses are discussed below.

The Theis analysis for TW #4 Zone 2 (fully penetrating the Pierce Gulch Sand Aquifer) shown in Figure 32 (page 114), based on data *not* corrected for estimated water level trend, indicates a transmissivity of 570,000 gpd/ft and a storativity of 3.0×10^{-3}. The data generally match the type curve through about 3,000 minutes into the test with a derivative analysis that suggests that the method is valid from the beginning of the first indication of drawdown (about 120 minutes after pumping at SVR #7 started) through about 1,000 minutes. After this time the derivatives do not match the type curve because of deviation in the drawdown levels whereby fluctuations could not be completely removed from the raw data. However, visually, the drawdown data and the Theis drawdown type curve generally match through 3,000 minutes. The cause of the large decrease in drawdown of about 0.10 to 0.20 ft between 3,000 and about 10,000 minutes is unknown. After 10,000 minutes the drawdown data return to levels close to the type curve.

The Theis analysis for TW #4 Zone 2, based on data corrected for estimated water level trend, indicates a transmissivity of 580,000 gpd/ft and a storativity of 3.0×10^{-3} (Figure 33, page 115). The data generally match the type curve through about 3,000 minutes into the test with a derivative analysis that suggests that the method is valid from the beginning of the first indication of drawdown (about 120 minutes after pumping at SVR #7 started) through about 1,000 minutes. As with the analysis based on data uncorrected for regional water level trend, the derivatives do not match the type curve after this time because of barometric fluctuations that could not be completely removed from the raw data. The drawdown data and the Theis drawdown type curve generally match through 3,000 minute, however, with the cause of the large decrease in drawdown between 3,000 and about 10,000 minutes, unknown.

M3 TW #4 Zone 1

Data from the deepest aquifer zone (Zone 1) beneath the Pierce Gulch Sand Aquifer were analyzed in four different ways. Two of the analyses were based on the assumption that the thin (40 ft thick) permeable sand unit 30 ft below the bottom of the Pierce Gulch Sand Aquifer is a small (unpumped) aquifer unit within the Terteling Springs Formation separated by a thin "leaky" aquitard. These analyses were based on the method of Neuman and Witherspoon (1972) using data both with and without corrections for regional water level trends. A second set of analyses used the Theis method and assumed that Zone 1 was a part of the Pierce Gulch Sand Aquifer, and therefore, directly pumped by SVR #7.

The Neuman-Witherspoon analyses without water level trend corrections (Figure 34, page 116) and with water level trend corrections (Figure 35, page 117) indicate similar results. Both analyses indicate a transmissivity of 80,000 gpd/ft and a storativity of 1.0×10^{-3} for the Zone 1 aquifer. Both analyses were set up with the assumption that pumping occurred only in the Pierce Gulch Sand Aquifer and that this aquifer has properties generally indicated by the fully penetrating Zone 2 analyses with the transmissivity slightly reduced to 500,000 gpd/ft and storativity kept at 3.0×10^{-3}. The Neuman-Witherspoon analysis was then adjusted through a combination of the manual curve fitting process and manual adjustment of leakage factors (which cannot be

measured directly). The similarity of the results using data uncorrected and data corrected for regional water level trends appears to be the result of low sensitivity of the method because six parameters can be adjusted in the analysis. Unique and reliable results are not readily obtained when six parameters are not known (transmissivity and storativity of the pumped Pierce Gulch Sand Aquifer and the Zone 1 aquifer, and the two leakage factors associated with the aquitard) and many combinations of these can generate the same general curve match. In addition, the derivatives and derivative type curve do not match well, suggesting that the analysis may not be valid.

In spite of the non-uniqueness and the poor match of the derivative curves, the calculated results of these analyses are consistent with the Zone 2 analyses in that the sum of the transmissivities from the Newman-Witherspoon analyses (500,000 gpd/ft for the Pierce Gulch Sand Aquifer and 80,000 gpd/ft for Zone 1) equals the results of the Zone 2 Theis analysis (575,000 for the average results of the two analyses).

The Theis analysis for TW #4 Zone 1 that assumes that the Zone 1 is part of the Pierce Gulch Sand Aquifer and was directly pumped by SVR #7, is not much better than the Newman-Witherspoon analyses that assumes that the Zone 1 is separate from the Pierce Gulch Sand Aquifer and was not directly pumped by SVR #7. In addition, the results of these Theis analyses appear to us to be unrealistic. The drawdown analyses without (Figure 36, page 118) and with (Figure 37, page 119) water level trend corrections indicate transmissivities that appear unrealistically large for a 40 ft thick aquifer (170,000 gpd/ft and 160,000 gpd/ft, respectively). The derivative analyses generate a match for the initial portions of the drawdown curves and then deviate later in the test. The recovery analyses (not shown) generated transmissivities that were even higher: 690,000 and 790,000 gpd/ft, respectively, analyses we consider to be invalid.

Neither the analyses based on the assumption of Zone 1 as a separate aquifer nor the analyses based on the assumption that it was part of the Pierce Gulch Sand Aquifer offer conclusive affirmation of which assumption is more likely to be correct. Zone 1 is observable in the composite diagrams of all the TW series wells (Figures 10-13) and the UWID State and Linder well (Figure 16). Analysis of the presence of Zone 1 shows that it dips at a steeper angle than the overlying Pierce Gulch Sand Aquifer. The steeper dip means that it rises toward the northeast where it likely merges with the Pierce Gulch Sand (a conceptual fit to HLI's model for the basin). Because of a potential hydraulic interconnection, neither of the two models assumed in the two sets of analyses strictly applies. We believe that neither of the methods is likely to yield accurate analytical results, only approximations. The smaller transmissivity indicated by the Newman-Witherspoon method appears to be the more realistic for the 40-ft-thick zone. Perhaps of greater importance, though, is that there is a hydraulic interconnection between the two aquifer units. Based on thorough on-site supervision and measurement during the entire piezometer nest construction and, in particular, emplacement of grout seals during construction of TW #4 leave us with the strong conviction that the observed hydraulic connection is not via the well bore. However, given the thinning aquitard between the two units, and the stated arguments for cemented section (and potential fracture flow), there is more than enough uncertainty concerning leakage and/or fractured flow between

these two closely spaced units. Of course, if the two units do converge shortly up gradient of TW #4, that hydraulic connection could also explain the observed drawdown.

M3 TW #4 Zone 3

A shallow aquifer (Zone 3) overlying the Pierce Gulch Sand Aquifer indicated a drawdown of 0.08 to 0.15 ft at the end of the test but did not generate drawdown data that could be reliably analyzed for the reasons cited previously in this report. The water level plot is included in Appendix C.

Little Gulch Stock Well Analyses

The Little Gulch Stock Well located 9,740 ft from the pumping well had 0.08 to 0.14 ft of drawdown at the end of the test. The Aqtesolv® analyses indicated a mean transmissivity of 230,000 gpd/ft and a mean storativity of 0.012 (1.23x10^{-2}). The results should be considered with some skepticism in that the details of well construction are not well known and a description of the aquifer materials pierced by this well are also not available.

Two analyses of the drawdown data collected from the Little Gulch Stock Well (located 9,749 ft from SVR #7) indicate a transmissivity ranging from 180,000 to 270,000 gpd/ft and a storativity of 0.011 (1.1x10^{-2}) to 0.013 1.3x10^{-2}, indicating an unconfined aquifer. These results are based on two Theis analyses: one using data not adjusted for estimated water level trend and one Theis analysis using water level trend corrections. The Little Gulch Stock Well appears to be completed where the Pierce Gulch Sand Aquifer is relatively thin (only partially saturated), as interpreted from projections of the aquifer from other locations to the Little Gulch well site. (There is not a Well Driller's Report available for this well, therefore, aquifer position could only be estimated.) Comparisons of the projected bottom elevation of the Pierce Gulch Sand Aquifer and the measured depth to water in the Little Gulch Stock Well suggest the upper portions of the Pierce Gulch Sand are dry (unsaturated) at this location. The details of our analyses are discussed below.

The Theis analysis for data without water-level trend corrections (Figure 38, page 120) indicates a transmissivity of 180,000 gpd/ft and a storativity of 0.013 (1.3x10^{-2}). The data generally match the type curve through almost all of the test with a derivative analysis that suggests that the method is valid from the beginning of the first indication of drawdown (about 4,200 minutes after pumping at SVR #7 started) through about 8,000 minutes. After 8,000 minutes, the derivative curve flattens off. This flattening of the derivative curve is likely related to the relatively large interval of differentiation of 0.4 log cycles that includes no drawdown data after pumping stopped at 12,960 minutes. In short, the derivative analysis supports the method of analysis.

The Theis analysis for data with water-level trend corrections (Figure 39, page 121) indicates a transmissivity of 270,000 gpd/ft and a storativity of 1.3x10^{-2}. The data generally match the type curve through about 7,000 minutes with a derivative analysis that suggests that the method is valid through about 5,000 minutes of the test. After this

time the derivatives do not match the type curve for the same reasons discussed above. Generally, the derivative analysis supports the use of the Theis method for these data.

The analyses for the Little Gulch Stock Well indicate a range for transmissivity because of the effects of the declining regional water level trend (0.0125 ft per day). It is only possible to estimate but not accurately quantify this trend. Based on the range of results we estimate a representative transmissivity on the order of 200,000 gpd/ft. The storativity results with and without tend consideration were almost identical. The mean storativity indicated by these two methods is 1.2×10^{-2}.

Recovery analyses could not be realistically assessed. Because the overall water level trend was so much greater than the amount of drawdown recovery that occurred over the 12-day recovery period, true recovery was effectively masked, rendering meaningful analysis, impossible.

SVR #9 Analyses

Well SVR #9, located 11,660 ft from the pumping well, had 0.09 to 0.18 ft of drawdown at the end of the test. The Aqtesolv® analyses indicated a mean transmissivity of 290,000 gpd/ft and a mean storativity of 7.9×10^{-3}.

Two analyses of the drawdown data collected from well SVR #9 (located 11,660 ft from SVR #7) indicate a transmissivity ranging from 250,000 to 320,000 gpd/ft and a storativity of ranging from 7.1×10^{-3} to 8.7×10^{-3}(a semi-confined aquifer). These results are based on two separate Theis analyses one using data adjusted for estimated water-level trend and the other using unadjusted data. Well SVR #9 is completed where the aquifer is relatively thin because the upper portions of the Pierce Gulch Sand at this location are dry (unsaturated) and therefore, not considered part of the aquifer, as shown in the composite diagram (Figure 14, page 93). The details of these analyses are discussed below.

The Theis analysis for data without water-level trend corrections (Figure 40, page 122) indicates a transmissivity of 250,000 gpd/ft and a storativity of 0.087 (8.7×10^{-2}). The data generally match the type curve through about 8,000 minutes of the test with a derivative analysis that suggests that the method is valid from the beginning of the first indication of drawdown (about 4,100 minutes after pumping at SVR #7 started) through about 6,000 minutes. After this time the derivatives do not match the type curve because the period of differentiation is relatively large (0.4 log cycles) such that the derivative curve includes time periods where recover and drawdown data are used to calculate the derivative. Generally, the derivative analysis supports the use of the Theis method for these data.

The Theis analysis for data with water-level trend corrections (Figure 41, page 123) indicates a transmissivity of 320,000 gpd/ft and a storativity of 7.1×10^{-3}. The data generally match the type curve through about 8,000 minutes with a derivative analysis that suggests that the method is valid through about 6,000 minutes of the test. After this

time the derivatives do not match the type curve for the same reasons discussed above. Generally, the derivative analysis supports the use of the Theis method for these data.

The analyses for SVR #9 indicate a range for transmissivity because of the effects of the declining regional water level trend can only be estimated at about 0.01 ft per day. The mean of the two calculated transmissivity values is 290,000 gpd/ft. Based on the potential error introduced in the estimates of water level trends, we believe that a transmissivity on the order of 300,000 gpd/ft better indicates the precision of the analysis. The storativity results with and without water-level tend corrections were very close to each other indicating that the effects of the seasonally declining water levels had only minimal effect on the calculation of storativity. The mean storativity indicated by these two methods is about 7.9×10^{-3}.

Recovery analyses did not yield meaningful results. No meaningful recovery curve could be generated from the recovery data because the overall water level trend (about 0.13 ft) was similar to the amount of drawdown recovery (0.09 to 0.18 ft) that occurred over recovery period. True recovery was effectively masked, rendering meaningful analysis, impossible.

Flack Corral 4-in Well Analyses

The Flack Corral well located 5,974 ft from the pumping well had 0.14 to 0.20 ft of drawdown at the end of the test. The Aqtesolv® analyses indicated a mean transmissivity of 240,000 gpd/ft and a mean storativity of 0.022 (2.2×10^{-2}). The results should be considered approximate in that no details are known about this well or the aquifer materials near this well.

Two analyses of the drawdown data collected from the Flack Corral 4-in well (located 5,974 ft from SVR #7) indicate a transmissivity ranging from 200,000 to 270,000 gpd/ft and a storativity of 2.1×10^{-2} to 2.3×10^{-2}, indicating an unconfined aquifer. These results are based on two separate Theis analyses: one using data not adjusted for estimated water level trend and one Theis analysis using data adjusted using a correction for water level trend. The Flack Corral 4-in well appears to be completed where the Pierce Gulch Sand Aquifer is relatively thin, as interpreted from projections of the aquifer from other locations to the Little Gulch well site. (The position of the aquifer had to be estimated because no Well Driller's Reports are available for this well.) Comparisons of the projected bottom elevation of the Pierce Gulch Sand Aquifer and the measured depth to water in this well suggest the upper portions of the Pierce Gulch Sand are dry (unsaturated) at this location, meaning the aquifer is under unconfined conditions. The details of our analyses are discussed below.

The Theis analysis for data without water-level trend corrections (Figure 42, page 124) indicates a transmissivity of 200,000 gpd/ft and a storativity of 2.3×10^{-2}. The data generally match the type curve through almost all of the test with a derivative analysis that suggests that the method is valid from the beginning of the first indication of drawdown (about 4,000 minutes after pumping at SVR #7 started) through about 7,000 minutes. After 7,000 minutes, the derivative curve falls off with decreasing derivative

values. This falling off of the derivative curve is likely the result of the declining aquifer-wide water level trend that caused the apparent drawdown to decrease from what likely would have occurred were there no aquifer-wide seasonal water level trend. We believe the derivative analysis supports the method of analysis.

The Theis analysis for data with water-level trend corrections (Figure 43, page 125) indicates a transmissivity of 270,000 gpd/ft and a storativity of 0.021 (2.1×10^{-2}). The data generally match the type curve through about 7,000 minutes with a derivative analysis that suggests that the method is valid through at least 6,000 minutes of the test. After this time the derivatives do not match the type curve for the same reasons discussed above. Generally, the derivative analysis supports the use of the Theis method for these data.

The analyses for the Flack Corral 4-in well indicate a range for transmissivity because of the effects of the declining regional water level trend (0.01 ft per day). It is only possible to estimate but not accurately quantify this trend. Based on the range of results we estimate a representative transmissivity on the order of 240,000 gpd/ft. The storativity results with and without tend consideration were almost identical. The mean storativity indicated by these two methods is 0.022 (2.2×10^{-2}).

Recovery analyses could be realistically assessed. Because the overall water level trend was similar to the amount of drawdown recovery that occurred over the 12-day recovery period, true recovery was effectively masked, rendering meaningful analysis, impossible.

Composite Well Analysis

A composite Theis (1935) analysis using data from the pumping well, the Big Gulch Stock Well, TW #4, TW #2, and SVR #9 (Figure 44, page 126) indicates a transmissivity of 430,000 gpd/ft and a storativity of 2.1×10^{-3}. This analysis plots the drawdowns from the five wells on the same time scale by "normalizing" time by dividing the time by the square of the distance of each well from the pumping well. The normalization allows all the wells to plot on the same drawdown type curve, *if* (and only if) the aquifer is homogenous and isotropic (in other words it has the same values for transmissivity, storativity, thickness, etc., at all points and directions of flow within the aquifer). If the properties of the aquifer vary at different locations, the drawdown data will not plot on the same general curve.

The composite plot shows that drawdown data from the SRV #7 (with a correction of 23 feet of well loss removed, as explained below), the Big Gulch Stock Well and TW #4 Zone 2 generally plot on the type curve while data from TW #2 Zone 2 and SVR #9 plot away from the type curve. SVR #7, Big Gulch Stock Well and TW #4 plot on the curve because the aquifer beneath the central and western portion of the M3 Eagle property has approximately the same transmissivity and storativity. Further to the east where TW #2 and SVR #9 are located, the Pierce Gulch Sand Aquifer rises toward land surface. The aquifer is thinner and unconfined beneath the eastern portions of the M3 Eagle property. Because the aquifer has less thickness, it has a correspondingly lower transmissivity.

Where it is unconfined, the specific yield (the "unconfined storativity") which is much larger than the confined storativity, dominates aquifer response. With a smaller transmissivity and a larger storativity the aquifer does not behave in a homogeneous manner. The drawdown is somewhat delayed and attenuated.

Distance-Drawdown Analysis

A Theis (1935) distance-drawdown analysis using data from the same five wells, SVR #7, the Big Gulch Stock Well, TW #4, TW #2, and SVR #9, (Figure 45, page 127) indicates a transmissivity of 380,000 gpd/ft and a storativity of 7.0×10^{-3}. This analysis plots the drawdowns from the five wells at 5,000 minutes into the test. The plot shows that the three central and western wells (SVR #7, the Big Gulch Stock Well, TW #4) plot on the same general type curve while the eastern wells (TW #2 and SVR #9) plot off the curve. Similarly to the composite plot, the difference in the plots is the result of the eastern portion of the Pierce Gulch Sand Aquifer thinner and unconfined (water table) while the western portions are generally thicker and confined. In a homogeneous and isotropic aquifer (identical transmissivity, storativity, thickness, and degree of confinement in all parts of the aquifer and for all directions of flow), all five wells would plot on the same Theis type curve.

Invalid Well Analyses

Some of the analyses we conducted appear to be invalid. These include all the recovery analyses except for those of SVR #7 and the Big Gulch Stock Well. These two wells had drawdowns recoveries that were much larger than the seasonal water level trend. These recoveries could be realistically separated from the water level trends (beginning of the springtime regional decline in aquifer-wide water levels) with relatively good precision. Theis recovery analyses were meaningful using the data from these wells, as demonstrated by analytical results fro the recovery data that agreed with the analyses of the drawdown data.

All other wells that indicated measurable drawdowns, showed water level recoveries that were small in comparison to the seasonal water level decline that occurred over the recovery period. None of the recovery data from these wells could be meaningfully analyzed in our opinion. None of the data exhibited meaningful straight-lines when plotted as semi-log t/t' vs. linear residual drawdown, as required by the method. The water-level decline occurring during the recovery period, (even with corrections using our best estimate of water level decline) caused the data plots to diverge from a straight line, making our analyses at best, only a very rough approximation and at worst, wrong. It is probable that our estimate of a linear decline in water levels was not entirely correct. We were not able, however, to calculate a meaningful equation for water level decline beyond the projection of a straight line from time periods were the effects of pumping SVR #9 were insignificant (either before or after the pumping portion of the test). The analytical results from these wells are listed in Table 2 as either "invalid" or are shown within quotation marks and include a question mark. These invalid recovery analyses include: TW #2 – Zones 1 and 2; TW #4 – Zones 1, 2, and 3; both Flack Corral wells; Little Gulch Stock Well, and SVR #9. Fortunately, during the drawdown portion of the

aquifer test, the discharge was kept consistently constant and thus, negating, at least part of the need for a recovery analysis.

In a similar manner, two wells indicated that pumping at SVR #7 caused drawdowns to occur, but generated data that could not be accurately analyzed. Meaningful drawdown data could not be separated from the water level data from these wells that included the effects of both pumping drawdown, and seasonal water level trends. Meaningful drawdown data were apparently masked by the seasonal trend. These included TW #4 Zone 3 (overlying the Pierce Gulch Sand Aquifer) and the Flack Corral 6-in well.

Non-Responding (?) Wells

A number of wells did not appear to have measurable drawdowns during the test. Very small drawdowns may have occurred in the wells that are completed in the Pierce Gulch Sand Aquifer, but at such a small scale they were not detectible. These wells included: TW #1 – Zones 1-4, TW #3 – Zones 1-4, Kling Irrigation well, and State and Linder TW #1 Zone 1. Any drawdown that might have occurred was likely less than 0.05 ft and, therefore, likely obscured and masked by un-removed barometric fluctuations and/or seasonal water level trends.

Variations in subsurface geology may have resulted in drawdowns in these wells that were too small to measure. Geophysical evidence (Wood, 2007) suggests that a structural fault may be present between TW #4 and the monitored wells lying to the west (TW #1, TW #3 and Kling Irrigation well. Such a fault, if present, could have attenuated and/or delayed the response in the portions of the Pierce Gulch Sand Aquifer lying to the west of the fault, caused by pumping the Pierce Gulch Sand Aquifer at a location east of the fault. Variations in aquifer transmissivity may have also played a role. The results of the two-day aquifer test using the Kling Irrigation well (HLI, 2008b), indicate transmissivities only one tenth of the values indicted by the SVR #7 13-day test. The lower transmissivities in this portion of the Pierce Gulch Sand Aquifer may help to explain why drawdowns were not measurable in the western well. In a manner similar to the SVR #7 test, pumping from the Kling Irrigation well (located west of the possible fault) caused no measureable drawdowns in wells lying to the east of the fault, supporting the concept of a structural fault.

Drawdown did not appear to be measurable in the State and Linder Test Well #1 Zone 2. The water level in this well, however, did decline about 0.10 feet from the projected trend-corrected water level, starting at about the same time that SVR #7 started pumping. This decline *may* represent drawdown from pumping SVR #7 but because the apparent drawdown began to decline 5 to 6 days into the test (behavior not explained by hydraulic theory as a response to pumping), we cannot definitively ascribe this drawdown to the pumping of SVR #7. Similarly, Well TW #4 Zone 2 which definitely responded with a measureable drawdown, also showed a somewhat delayed "dip" in the drawdown curve (Figure 32, page 114), supporting the concept that the response at the State and Linder Test Well may have been drawdown from pumping SVR#7. Because the State and Linder test well lies 22,302 feet from SVR #7, the great distance from the pumping well (SVR #7) may be another reason why drawdown could not be measured in this well. In other

words, the drawdown response may have been too minute to measure or the pumping cone of depression did not actually reach this well during the test period.

Shared drawdown and recovery responses observed in long-term monitoring data from Valley and M3 wells, support the concept that the small declines in water levels in the State and Linder Test Well #1 Zone 2 and Well TW #4 Zone 2 during the SVR#7 aquifer test may have been small drawdowns caused by SVR #7 pumping. The long-term monitoring data indicate that the valley and upland portions of the Piece Gulch Sand Aquifer are directly connected hydraulically. In any case, the monitoring data (collected over the past two years) show contemporaneous changes in water levels, that appear to be caused by various well pumping events affecting wells in both areas of the aquifer. It appears that the responses may have been too small in comparison to the other changes in water levels occurring during the test to have been measureable.

Figure 46 (page 128) shows barometric-efficiency-corrected water levels measured over the past two years from the western portions of the M3 property (TW #1, Kling domestic well, and TW #3) the central portions of the M3 property (TW #4 and SVR #7), the eastern portions of the M3 property (TW #3 and SVR #9) and the valley (UWID State and Linder TW #1). The water levels shown in these plots have been shifted vertically to allow the wells to be compared on the same plot. The amount of shift is shown for each well as a constant amount added to each water level measurement (to produce the shift). The actual water level can be calculated by subtracting the listed amount from the values plotted on the figure. The relative vertical scale for the water level plot for each well is identical (about 3-½ ft of water level change per inch on the graph).

At least three hydraulic events (pumping?) are apparent in the water level plots for UWID State and Linder TW #1, TW #1 and the Kling domestic well. These events, marked as dashed-blue vertical lines show similar rises and/or declines in each well. We attribute the rises and declines to pumping in the Pierce Gulch Sand Aquifer and not the result of variations in atmospheric pressure. Because barometric efficiency corrections have been applied to the data, the effects of variations in atmospheric pressure have been mostly removed. The response at SVR #7 is not as clear, however, possibly because of the scale used of the plot (one that allows the larger annual variations in water levels in some wells to fit on the plot).

We have correlated one such shared fluctuation that occurred during first two weeks of June, 2008, to the hydraulic testing of the City of Eagle's Eaglefield and Legacy wells. The Eaglefield well was pumped for 30 hours at 2,450 gpm on June 4-5, 2008 and the Legacy well was pumped for 24 hours at 1600 on June 10, 2008. Before the test began, water levels at the State and Linder test well were rising, beginning from the middle of May (Figure 48, page 129). The pumping tests caused 48.9 feet of drawdown in the Eaglefield well and 61.83 feet of drawdown in the Legacy well. During this period, we observed 8.20 feet of drawdown in the UWID State and Linder Test Well #1 Zone 2.After the test, water levels generally trended downward throughout the summer until early September. As seen in Figure 47 (page 129), a similar rise in water levels followed by a large drop also occurred in TW #1 Zone 2. A similar pattern is not as clearly

defined, but also observable in SVR #7. While drawdowns cannot be quantified using the data from these two M3 wells, a hydraulic connection between these wells and pumping in the vicinity of the Eaglefield and Legacy wells does seem to be apparent.

Figure 47 shows that similar common hydraulic responses appears to occur within wells completed in the Pierce Gulch Sand Aquifer beneath the central and western portions of the M3 property. Since common responses appear between the valley and the southwestern portion of the M3 site and common responses appear to occur within wells completed in the southwestern and central portions of the M3 property, it is likely that water level changes in one part of the system affect water levels in other parts of the system. Figure 47 shows water level plots for TW #1, TW #3 and SVR #7 with two different and much-finer vertical scales. TW #1 and SVR #7 are plotted at about 0.4 ft of water level change per inch of plot while TW #1 is plotted at 4 ft of water level change per inch on the graph. Three hydraulic events appear to be common to all three wells, as shown by the dashed-blue vertical line. Although the response at TW #1 is about ten times greater than the response at SVR #7, the hydrographs are similar suggesting a common hydraulic event and supporting the concept that the small water level changes observed in some of the wells during the test, may have been drawdowns from the pumping at SVR #7.

These conclusions are, of course, only preliminary and additional monitoring (currently on-going) will help to clarify and test our understandings of interconnectivity. Other projects completed by HLI also support the conclusion of a common hydraulic connection between the Pierce Gulch Sand Aquifer beneath the M3 property and the valley. A geochemistry study (Glanzman and Squires, 2009) and a computer modeling study (HLI, 2008c) should be consulted for additional details on the common hydraulic connection.

Drawdowns were not measurable in wells not completed in the Pierce Gulch Sand Aquifer. These included TW #1 Zone 5 (completed in the overlying, unnamed alluvial aquifer) and SVR #6 (completed in the Willow Creek Aquifer). Drawdowns did not (of course) occur in dry wells TW #3 Zone 5 and TW #4 Zone 4. These wells were monitored during the test to verify that the pumped discharge water did not return to the ground-water system during the test. These wells remained dry during the entire month-long test.

Summary of Results and Comparison with the Previous SVR #7 and Other Regional Aquifer Tests

The results of the pumping test analyses indicate that the Pierce Gulch Sand Aquifer in the vicinity of SVR #7 has a transmissivity on the order of 420,000 gpd/ft and a storativity on the order of $3x10^{-3}$. Portions of the Pierce Gulch Sand Aquifer beneath the western portions of the M3 Eagle property have larger transmissivities than the portions toward the east where the aquifer thins and becomes unconfined. Beneath the eastern portions of the property the transmissivity of the aquifer is estimated to be on the order of

200,000 to 300,000 gpd/ft, depending on the proximity of the saturated edge of the aquifer (approximated by the dashed green line in Figure 2). Transmissivities further to the west, near TW #4, are on the order of 400,000 to 500,000 gpd/ft. The smaller transmissivities beneath the eastern portions of the property appear to be the result of the decreasing aquifer thickness. Because transmissivity is equal to the product of hydraulic conductivity times aquifer thickness, transmissivities are approximately half the value where the aquifer thickness is reduced by half; a point that would suggest that the hydraulic conductivity of the Pierce Gulch Sand Aquifer does not vary significantly between the eastern wells and as far west as TW #4.

Beneath the eastern portions of the M3 Eagle property where the Pierce Gulch Sand Aquifer is unconfined, the effective storativity (specific yield) has not been directly calculated but is likely to be on the order of 0.1 to 0.2 or more (values typical of unconfined sand aquifers). The specific yield cannot be directly calculated because the storativity values indicated by the wells in the eastern part of the property represent an average of the properties between the pumping well and the observation well. As such, the average values include both confined storage coefficient values (storativity) where the aquifer is confined (SVR #7, TW #4) and unconfined storage coefficient values (specific yield) where the shallower aquifer is unconfined (TW #2, Flack Corral wells, Little Gulch Stock Well and SVR #9). Neither can be directly calculated using the data from the observation wells completed in the Pierce Gulch Sand Aquifer beneath the eastern portions of the M3 Eagle property.

A previous test of SVR #7 was conducted by SPF Water Engineering (2004). HLI's reanalysis of this test (HLI, 2008b) indicated transmissivity values that ranged from 180,000 to 300,000 and a storativity of 0.01 ($1x10^{-2}$). The previous 22-hour test of SVR #7 was deemed not useful for deriving aquifer coefficients of T and S. The pumped well appeared to develop during the test and the observation well water levels were not measured until after the test was underway making the drawdown data from both wells questionable for meaningful analysis. The transmissivity of the Pierce Gulch Sand Aquifer was estimated solely from the recovery responses in SVR #7 and the Big Gulch Stock Well while the calculated storativity could not be accurately calculated such that a representative value from other parts of the aquifer was deemed more likely to represent the aquifer beneath the M3 Eagle property. In summary, the previous short-term test was of limited usefulness because development of the well during the test resulted in water levels that actually rose throughout the later parts of the test in the pumping well (making curve matching impossible) and because water levels were not measured in Big Gulch Stock Well (the only observation well used during the test) until after pumping began, making true drawdowns, and the time of initial response, impossible to accurately quantify. Thus, the results of the 2008 nine-day M3 test are considered far more accurate and representative of actual aquifer conditions than the 2004 22-hour test.

The results of the 2008 nine-day SVR #7 test are consistent with recalculated results from tests conducted in other parts of the Pierce Gulch Sand Aquifer in the greater M3-Eagle-Star vicinity. Several tests analyzed and reported in HLI (2008b) indicate transmissivities ranging from about 200,000 gpd/ft to 500,000 gpd/ft, values similar to those discussed

above for the 2008 nine-day SVR #7 test. Similar values for storativity are also indicated in HLI (2008b), especially in areas affected by the portions of the aquifer that are approaching unconfined conditions, resulting in semi-confined storativity values. The mean value of $2x10^{-3}$ calculated for the 2008 SVR #7 test is comparable to the values reported in HLI (2008b) for the two long-term tests (Lexington Hills 30-day test - $3x10^{-3}$ and Eaglefield seven-day test - $2x10^{-3}$) of the Pierce Gulch Sand Aquifer.

The SVR #7 nine-day aquifer test results are, however, quite different from the results of the 2006 two-day test of the Kling Irrigation well (HLI, 2008b) which indicated much lower transmissivity (39,000 gpd/ft) and no response in any observation wells except for the closest (TW #1 Zones 1 thorough 4). We concluded that the Kling Irrigation well aquifer test was not representative of the large expanse of the Pierce Gulch Sand Aquifer because of: a) improper well construction and/or b) local (and unrecognized) faulting of the aquifer and/or c) the well being completed within an anomalous zone of the aquifer. The 2008 SVR #7 test indicates that the properties of the Pierce Gulch Sand Aquifer beneath the M3 Eagle property are similar to those beneath the Boise River Valley. The results of the Kling Irrigation well aquifer test do not represent the major portion of Pierce Gulch Sand Aquifer beneath the M3 Eagle property. Testing with a properly designed and completed production well near TW #1 would be needed to better assess the Pierce Gulch Sand Aquifer in this area.

SECTION VII: WELL EFFICIENCY AND WELL LOSS

The pumping of an eight-inch-diameter well, SVR #7, at the rate of 917 gpm resulted in well losses that were relatively large and well efficiencies that were relatively low, as would be expected from a well completed with a combination of louvered well "screen," torch-cut slots and angular-crushed rock "filter pack." Calculations based on comparisons of actual (measured) drawdown in the SVR #7 with theoretical drawdowns generated using the aquifer parameters calculated from the test data indicate a well loss drawdown on the order of 23 feet and a well efficiency on the order of 15 percent. An efficient supply well at this location would easily produce 2,000 gpm or more, based on the high yield possible from SVR #7, in spite of its low efficiency and large well loss.

Well Loss

Well loss and well efficiency for SVR #7 were calculated based on the differences between the actual drawdowns measured in SVR #7 during the first four hours of pumping and the theoretical drawdown calculated using the transmissivity and storativity derived from the analysis of data from the closest observation well (Big Gulch Stock Well). The theoretical drawdown was calculated with the test-derived transmissivity and storativity calculated using the Big Gulch Stock Well data (mean transmissivity of 470,000 gpd/ft and mean storativity of $1.5x10^{-3}$), using the method of Theis (1935). The theoretical and actual drawdowns are included in Table 3.

A well loss drawdown in SVR #7 of 23 ft was calculated by subtracting the theoretical drawdowns from the drawdowns actually measured in SVR #7 for eight time intervals during the first four hours of the pumping test. These differences ("well loss") represent the drawdown caused by frictional head loss in the well screen, filter pack and geologic materials near the well screen. This well loss occurred in addition to the drawdown caused within the aquifer ("formation loss"). Based on the data collected during the first 4 hours of the test, the mean drawdown due to well loss was 22.92 feet (Table 3). This compares favorably with the almost immediate measured drawdown in the pumping well at the onset of pumping (22.62 ft) as an indication of well loss. Considering that the actual pumping water levels in the pumping well fluctuated by about 3 feet during the test, we report the well loss to 2 significant figures, or 23 feet.

The calculated well loss of 23 feet was used in the various Theis analyses for the pumping well, presented in Section VI of the report. The well loss of 23 feet was subtracted from each measured drawdown to obtain a drawdown representative of that which would have likely occurred in a 100-percent efficient well, as required by the Theis method which assumes no well loss. The analysis of pumping well total drawdown (well loss plus formation loss) causes a Theis analysis to yield incorrect values for transmissivity because well loss causes each data point to be shifted, requiring a match to a type curve that does not represent actual aquifer conditions. Subtracting the theoretical well loss from the raw data leads to a more accurate Theis analysis and helps to attenuate the objection that some workers have with using the Theis method with pumping well data.

Well Efficiency

The efficiency of SVR #7 pumping at 917 gpm was estimated to be about 15 percent. This efficiency was calculated as the ratio of theoretical drawdown (formation loss only with no well loss included) divided by the actual measured drawdown (formation loss plus well loss). Over the first four hours this ratio varied from 13 to 15 percent. Because water levels fluctuated so much in SVR #7 while pumping, we have rounded this range of efficiencies to 15 percent.

The efficiency of SVR #7 actually increases with increased pumping time because the formation loss (drawdown in the aquifer) increases with increased time of pumping while well loss remains constant with time of pumping and is only a function of pumping rate. Therefore, well efficiency (the ratio of formation loss divided by formation loss *plus* well loss) grows closer to 100-percent as drawdown in the pumping well increases and formation loss represents a larger percentage of the total drawdown in the well.

Supply Well Yield

A properly designed and constructed supply well with minimized well losses and relatively high well efficiency, completed near SVR #7 (and many other locations of the M3 Eagle property) would be capable of yields of 2,000 gpm and probably more. Because 85 percent of the drawdown in SVR #7 was caused by well loss (23 ft), only 15 percent of the drawdown (about 5.6 ft, at the end of the test) was inducing the 917 gpm to flow into the well. A supply well with efficiency that was three or four times greater would be capable of yields that would be three or four times greater under the same drawdown. A properly-

designed and efficiently-developed supply well that fully penetrated the aquifer, and was completed with a wire-wrap well screen and a properly graded sand filter envelope (unlike SVR #7 which has none of these characteristics) would be highly likely to have efficiencies of 60 percent or greater such that yields of 2,000 gpm or more are considered likely.

Sustainable Yield

The well yields discussed above appear to be sustainable over the foreseeable future. This sustainability is supported by a number of factors. The **first** is the projection of the recovery data from SVR #7 toward full recovery using the recovery data corrected for aquifer water-level trend (Figure 23, page 105). Although the various methods of analysis employed by Aqtesolv® are all based on the concept of an aquifer with no recharge, the projection toward full recovery supports long term sustainability. **Secondly**, ground water geochemistry studies recently completed (Glanzman and Squires, 2009) indicate that the water sampled from the Pierce Gulch Sand Aquifer at all locations is very similar, supporting the concept of regional, and relatively swift, flow through the Pierce Gulch Sand Aquifer at relatively high rates and large volumes. The similarity of the composition of the ground water at the sampled locations, separated by as much as 13 miles, is likely a result of a chemically stable aquifer matrix and a high transmissivity which, in turn, allows relatively rapid flow and low residence time for a large ground water flux. **Additionally**, a modeling study presented in HLI (2008c) also supports the sustainability of long-term yields. The study which included quantification of recharge sources (and even an assessment of the impacts that might occur were recharge to be diminished), showed that long term pumping of 4,500 gpm on a continuous basis was sustainable over the 50 years of simulation. Both of these studies should be consulted for additional details that support the long-term sustainability of ground-water-pumping from beneath the M3 site.

Water level data collected over the past 10 years, and longer, also support the sustainability of the Pierce Gulch Sand Aquifer ground-water flow system. Data collected from UWID TW #1 and TW #2 at State and Linder show that water levels within the Pierce Gulch Sand Aquifer have not declined since monitoring began in 1998. Figure 48 shows water levels collected by a variety of entities for this well using both hand measured methods and electronic methods (backed by hand measurements). The plot for Zone 2 in TW #1 (the same zone monitored and analyzed in this report) shows that artesian water levels over the course of a year generally range between 10 and 15 feet above ground level. Water levels in the other three zones (not measured as frequently as TW #1 Zone 2) also show no net decline in water level. This stability has occurred, even though the population of the greater Eagle-Star vicinity has grown during the same time period as has the demand for ground water. The State and Linder test well is considered a reliable well for the collection of long term data because it is well sealed, protected for long-term use, it already has a length of monitoring record, and was constructed solely for monitoring purposes. Other properly constructed well and well nests in the area show a similar sustained water level. The monitoring program at M3 includes four such well nests.

SECTION VIII: INHERENT DIFFICULTIES AND CONSTRAINTS - SHORTCOMINGS OF THE TEST

No aquifer test is perfect under the best of circumstances and the SVR#7 nine-day test is no exception. Although we took every possible precaution to avert difficulties, some problems still surfaced. We believe that through the best efforts of the all those involved with the test and M3 Eagle's commitment to funding the project so that it could be completed successfully without "cutting corners," we were able to largely overcome the difficulties that surfaced during the test.

The first problem that presented itself was the time of year. We wanted the test to be conducted before irrigation and regional well pumping began in earnest. Experience has shown that significant pumping centers (wells) pumping from the Pierce Gulch Sand Aquifer, even if done from the lowland areas near Eagle and Star, had the potential to affect the data collected during the test, thereby complicating the test results and reducing its ability to be interpreted correctly. Time constraints were such that any small delay would have pushed the test to the following year. Set up of the test including well development, pump placement, data logger set ups and more, had to be completed during winter even though the site was basically impassible during winter, except during periods of prolonged freezing temperatures.

Pre-test work during winter required the building of an all-weather road to allow access when wet conditions make the existing dirt roads slick and impassible. Approximately two miles of gravel road was laid down to allow access for heavy for drill rigs, support trucks, pump and generator delivery trucks, fuel deliveries, and pump installation rigs. During the test, the road and culvert allowing drainage of the discharge pond required emergency repairs when the water level in the pond rose to the point where a washout appeared to be imminent. Quick response on the part of the road-building contractor avoided a washout of the main road to SVR #7. Had a washout occurred, the test would likely have been curtailed as access to the well to re-supply the generator with fuel without the road would have been prevented.

Security and general access were also difficulties that had to be addressed. The M3 Eagle property, in spite of locked gates, is treated by some as a public outdoor recreation area with activities that include firearm target practice. All wells had to be competed with bullet-proof protection. Judging by the numerous .45 caliber and magnum casings found near several of the wells, and numerous lead smears on the well-head security-enclosures themselves, this security measure was warranted.

A third difficulty was the relatively small diameter of the pumping well and the lack of nearby electrical power. It was important to pump the well at a rate that would adequately stress the aquifer. An eight-inch diameter test well typically limits the size of the pump to about 500 to 550 gpm when non-pumping depth-to-water levels are 165 ft. We overcame this difficultly by using a special-design slim-hole pump motor using much higher than normal voltages and a small diameter (5.62-inch) 133 HP motor that allowed the 917 gpm

rate non-stop throughout the nine-day test. A diesel-powered 250 KVA "Prime" generator was brought in to supply the electrical power for the test.

A fourth complication was the rapidly fluctuating water level (on the order of 3 feet) in the pumping well. It is not clear whether this surging in water levels was caused by turbulent flow where water was constricted by the pump bowls being set beneath the upper well screens or whether the surging was cause by a partial vacuum that formed in the discharge line between the well head and the downhill discharge orifice. We partially corrected for this problem by using a running ±10-minute average to smooth the water level data from SVR #7. We also relied on observation well data which had no such surging.

Lubrication oil used in the test pump motor caused some difficulties in obtaining accurate hand water level measurements with the electric well sounders. When the test pump was installed, the pump motor was apparently topped off, if not overfilled, with mineral oil. After the motor was installed in the well casing, it warmed up causing the oil to expand and flow out of the motor assembly to accumulate on top of the water column in the well. Even though we had installed a designated flush-joint monitoring tube for measurements, this tube could not be extended past the pump bowls (owing to the tight clearances) and the leaking motor oil moved upwards into the open bottom of the measuring tube thus interfering with the electrical sounding tapes. We overcame this difficulty by making multiple measurements, inside and outside the monitoring tube, until we were had a reasonably high degree of confidence in the measurements.

The routing of almost 12 million gallons of discharge water was a potential issue of concern at the outset of the test.. Our geologic characterization of the site near SVR #7 indicated the possibility of discharge water returning to the Pierce Gulch Sand Aquifer and affecting drawdown results by acting as a recharge (positive) aquifer boundary (or at least entering a degree of uncertainty to any data that might indicating a positive hydraulic boundary was encountered; a situation we envisioned as possible given the relatively close proximity of the unconfined edge of the Pierce Gulch Aquifer. To overcome this potential problem, water was pumped via an 800-ft long sealed line where it discharged to a clay-lined pond that subsequently allowed for overflow to the dry streambed of Big Gulch Creek. Our geologic characterization indicated that the area near the pond was generally underlain mostly by clay, which would inhibit surface water from moving downward. Lower reaches of the stream, however, are believed to be underlain by sub-cropping sand strata. HLI pre-designed two shallow monitoring wells to be completed in dry sand units near the site, and downstream of the aquifer test discharge area, as a means to verify whether the discharge water could return to the Pierce Gulch Sand Aquifer and "short-circuit" the test. The data collected during the test indicate that the discharged water ultimately caused no problems to the test or landscape.

A fifth difficulty presented itself unexpectedly, a day prior to the commencement of the drawdown portion of the test, when the Spring Valley Ranch turned 60 range cows onto the M3 Eagle property in Little Gulch. Because the cows tend to use the well head casings and capping security shelters as "rubbing posts", and because we intended to leave well sounding tapes extending down into the monitoring wells during the test, it became

immediately necessary to fence around each monitoring well, the orifice weir discharge to the stock pond, and the pumping well site. As soon as the pump discharge began filling the pond, cows that would typically be spread out over the entire property migrated to the discharge pond and the nearby Big Gulch Stock Well used for monitoring. The temporary barbed-wire barricades did serve to prevent cows from damaging the monitoring equipment.

The propeller-type mechanical flow meter installed in the SVR #7 discharge piping malfunctioned during the test, giving inaccurate readings; most likely attributable to the down hill discharge "sucking a vacuum" in the discharge even though adequate pressure was maintained to create back-pressure behind the orifice plate at the weir. Fortunately, the circular orifice weir, with continuous measurements recorded with a data logger and backed up with hand measurements of water levels in the orifice manometer, gave reliable results. We believe that discharge rates are accurately known for the entire test.

Cable stretch in the new Powers Electric™ well sounders was a problem that at first caused confusion in the hand measurements of water levels. Many new water-level sounders were used owing to the shear number of monitoring stations and our desire to not remove and re-insert a tape in each well measured; a time consuming task. Fortunately we used sounders that were individually numbered, with each one dedicated to a specific well. We were able to back calculate cable stretch errors to our calibration measurements using chalked-steel tapes to compare (and correct) these errors. Also, because the digital pressure-transducers/data-loggers worked so well, the steel-tape calibrations of the digital instruments provided a second check that confirmed accurate measurements were obtained.

Barometric effects were a potential problem that was anticipated and dealt with accordingly. As described above in Section V of this report, we used water level data and on-site contemporaneously-recorded atmospheric pressure from periods of little-to-no nearby well pumping to calculate barometric efficiency of each well. We used these calculated barometric efficiencies to correct for the changes in water level caused by variations in atmospheric pressure. Unfortunately, the corrections were not perfect as the effects of time lag and other factors made our corrections good, but not perfect. As a result, some atmospheric interference effects remain in our processed data; but not enough to prevent good analysis of the test data as a whole.

Water level trends were also a potential problem that was anticipated. By calculating the change in water levels unassociated with pumping or atmospheric effects, before the test began, we had hoped to be able to apply a correction that would remove the effects of pre-existing rising or falling regional/seasonal trends. We did not anticipate, however, a reversing trend that occurred in some wells but not others. Unfortunately, the seasonal change (trend reversal) occurred at slightly different times at different locations of the Pierce Gulch Sand Aquifer. The seasonal change to declining water levels occurred in some wells just before the test began (a declining trend throughout both the pumping and recovery period) while the seasonal change occurred at other parts of the aquifer *during* the pumping portion of the test (rising water levels during the first part of the test and

declining water levels over the second part of the test). To overcome this problem were estimated water level trends by projecting water levels (with barometric effects removed) from the pre-pumping portion of the test and the end-of-recovery portion of the test. As discussed in Section V, the corrections were good, but not perfect. Because the calculated seasonal changes were all on the order of 0.01 ft per day and the recoveries during the end of the recovery period were similar to and in some cases, smaller than 0.01 ft per day, even a small error on the order of a one or two thousandths of a foot per day in our estimated water-level trend, caused a small error in our residual recovery data. For this reason, drawdown data were more reliable than the recovery data.

The final difficulty we encountered in the SVR #7 nine-day test was the great depth to water in Willow Creek Aquifer well SVR #6. The depth to water in this well is more than 450 feet below ground level. Just getting an accurate water level reading with an electric well sounder or a steel tape in this well requires patience and skill. An electric sounder rubbing against the condensation along the steel well-casing can trigger false readings. In a similar manner, a chalked-steel tape lowered to this depth can have the chalk removed as it contacts the wetted casing requiring many attempt to get an accurate reading. Fortunately, field staff persisted to obtain reliable readings that were later correlated to, and verified by, the data logger readings that were used in our analysis.

SECTION IX: SUMMARY CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following summarizes our conclusions from the analysis of the SVR #7 aquifer test:

1. The analysis of the data collected from 24 wells over nine days of continuous pumping of SVR #7 at 917 gpm indicates that the Pierce Gulch Sand Aquifer is highly productive beneath the M3 Eagle property with transmissivities ranging from 450,000 to 550,000 gpd/ft beneath the central and western parts of the property, and 250,000 to 300,000 gpd/ft beneath the eastern parts of the property where the aquifer thins but becomes unconfined.

2. Analysis of test data from wells completed in the Pierce Gulch Sand Aquifer beneath much of the M3 Eagle property indicates a mean storativity of $2x10^{-3}$. This value indicates a semi-confined aquifer overall, with the western and central portions of the M3 Eagle property being confined and the eastern portions unconfined. The unconfined portion of the Pierce Gulch Sand Aquifer occurs where the rise of the aquifer toward the east results in water levels that are below the top of the Pierce Gulch Sand. Further to the west (central and western portion of the M3 Eagle property) water levels are slightly-to-moderately higher than the top of the aquifer. The overlying clay layers cause the aquifer to be confined in

these areas (as it is under most of the valley regions near Eagle and Star where aquifer heads can exceed ground level by 20 feet.)

3. The transmissivity values calculated from the test data are consistent with several analyses of aquifer test data from wells completed in the lowland regions in the greater Eagle-Star vicinity, and reanalyzed in HLI (2008b). The test supports the previous conclusion that the Pierce Gulch Sand Aquifer beneath much of the M3 Eagle property has similar properties to the Pierce Gulch Sand Aquifer beneath the Boise River Valley.

4. The test shows hydraulic connection between most of the wells on the M3 Eagle site. Wells along the far western portion of the site (TW #1, TW #3 and the Kling Irrigation well) did not show measurable drawdown. A small drawdown response may have occurred in these wells, but if present, may have been masked by incompletely removed barometric effects and/or seasonal water-level trend effects. It is also possible that differences in geology such as a structural fault between TW #4 (to the east of the fault) and TW #1 and TW #3 (to the west of the fault) attenuated the drawdown response beneath the western part of the site. Surficial geophysical analyses by Wood (2007) do suggest the presence of such a fault. The lack of measurable drawdown near TW #1 and the Kling irrigation well may also be the result of the apparent lower transmissivity in this region as indicated by testing conducted at the Kling irrigation well in 2006 (HLI, 2008b).

5. High capacity supply wells (with sustainable, long-term yields of 2,000 gpm or more) are possible from the Pierce Gulch Sand Aquifer beneath much of the western and central portions of the M3 Eagle property. Slightly lower yields are likely from much of the eastern portions of the property.

6. SVR #7 pumping at 917 gpm had 23 ft of calculated well loss, resulting in a well efficiency of only 15 percent. In spite of this low efficiency, the well was capable of yields of 917 gpm.

7. Starting at an initial, non-pumping water level measured at 165.21 ft bgl, well SVR #7 was pumped continuously at 917 gpm for nine days with a final pumping water level of 193.78 ft bgl, for a calculated drawdown of 28.57 ft. The nine-day specific capacity was 32.1 gpm/ft of drawdown, a value quite high for a well with such inefficient well construction.

8. Confirmed drawdowns were measurable in observation wells at distances of up to 11,660 ft from the pumping well. Observation well drawdowns ranged from 1.71 ft in the closest observation well (Big Gulch Stock Well – 845 ft from SVR #7) to 0.09 ft at SVR #9 – 11,660 ft away from SVR #7.

9. Barometric efficiencies of the wells completed beneath the M3 Eagle property are high. Calculation of barometric efficiency was necessary to remove the effects of water level changes caused by variations in atmospheric pressure associated with

passing weather systems. Calculated barometric efficiencies range from a low of 20 percent (State and Linder TW #1) to as high as 99 percent (SVR #9). These values are similar to those calculated for wells completed in the Pierce Gulch Sand Aquifer. The high barometric efficiency suggests that the aquifer is partially-to-moderately cemented.

10. Perceptible drawdowns were not measured at State and Linder TW #1 Zone 2, completed in the Pierce Gulch Sand Aquifer, probably because it lies so far (22,302 feet) from the pumping well.

11. Well SVR #6, completed in the Willow Creek Aquifer, did not indicate a measurable or detectible drawdown. The lack of response in this well is likely due to the separation of the Willow Creek Aquifer from the Pierce Gulch Sand Aquifer by low-permeability Terteling Springs mudstone. SVR #6 is located at a considerable distance (8,189 ft) from the pumping well and, so, the hydraulic separation posed above is not conclusive.

12. The SVR #7 nine-day test demonstrates that a successful long-term, multiple-well aquifer-test of the Pierce Gulch Sand Aquifer in the greater M3-Eagle-Star vicinity can be completed with careful coordination and selection of the best time of year to minimize interference effects from the pumping of major supply wells and the pumping and application of irrigation water.

13. The large transmissivities calculated from the SVR #7 test data support the previous conclusions that pumping from the Pierce Gulch Sand Aquifer from beneath the M3 Eagle property will produce "cones of depression" (water level interference drawdowns) that are shallow and areally extensive.

14. Our earlier recommendation for the need to conducting a major, regional scale aquifer test of the Pierce Gulch Sand Aquifer beneath the north Eagle foothills has been met by the SVR #7 test.

15. The data obtained from the SVR #7 nine-day test has been used to calibrate and update the existing M3 Modflow numerical ground-water model.

Recommendations

The following summarizes our recommendations based on the analysis of the SVR #7 aquifer test:

1. M3 Eagle should continue to monitor water levels beneath the M3 site to allow for proper management and administration of the ground water resources of the region. Although the SVR#7 Aquifer Test serves as a good benchmark regional scale pumping test, only long-term (years to decades) high quality water level

monitoring will be able to document the stresses to the Pierce Gulch Sand Aquifer from increased withdrawals from wells. It is important that monitoring well locations be secured and the wells designated only to that purpose be used so that the same wells remain available over time to preserve the length of record and to avoid uncertainty and complexity in correlation of data from a series of changing wells over time.

2. Additional testing to evaluate specific yield of all new future water supply wells is recommended with water levels observed in the pumped well and in nearby observation wells in a continuing effort to improve the conceptual and numerical models for the Aquifer. The time, effort, and cost of a second regional aquifer test in the M3 Eagle area is deemed unnecessary. Rather, efforts should be devoted to coordination of a high-rate regional scale aquifer test in the north Eagle area using an existing, or future, large capacity well during the winter months with the cooperation of all major water users.

SECTION X: ACKNOWLEDGMENTS

The SVR #7 nine-day aquifer test could not have been completed so successfully without the help and support of many people; past and present. Specifically we would like to acknowledge and thank the following.

Bill Brownlee and Gerry Robbins of M3 Eagle, LLC, encouraged us to make this test complete and scientifically sound: they put the financial resources of M3 Eagle toward this goal. They understand that the purpose of the work being conducted by HLI is to understand the ground-water resources of the region such that the M3 Master Planned Community has the water it needs for successful completion 20-to-30 years from now, and successful operation of water supply wells over the decades well beyond. We have appreciated the perspective and approach taken by M3 Eagle, LLC to devote efforts to understanding the resource rather than striving solely for entitlements (water rights). The comprehensive research-based approach commissioned by M3 Eagle is also aimed at supporting the IDWR's North Ada County Comprehensive Aquifer Management Plan objectives in this area.

We gratefully acknowledge IDWR Director David Tuthill for his understanding of the need to carry out this testing and in swiftly exercising his powers under IC 42-1805 (3) to conduct such investigations relating to availability of unappropriated water when time was of the essence. We now know that a delay of a week or two would have introduced complications and data uncertainties from local pumping wells and/or caused postponement of the test for a year; until the following winter (non-pumping) season.

We appreciate the involvement of Sean Vincent and Dennis Owsley of the IDWR Hydrology Section. Sean's insight from testing of similar environments was helpful and Dennis' direct participation in the early drawdown portion of the test is appreciated. The

hours spent on several field trips to the project site, and the professional collaboration that resulted contributed to a successful project.

McLeran Well Drilling, LLC and Treasure Valley Well Drilling and Pump, Inc. assisted in timely well development and piezometer well construction, respectively. We value the contributions of conscientious contractors when it is important to obtain high quality data. Shortcuts by contractors often lead to compromised data, a situation that did not occur. We are indebted to Dave McLeran particularly for his efforts to maintain the pumping plant, generator re-fueling operations, and 24-hour surveillance to ensure that there were no interruptions to the constant-rate test. Gregg Barney Excavation provided a quality all-weather road, well site gravel pads, and water culvert diversions for the test.

We would also like to thank Hydrogeologist Roger Dittus, Engineer Dan Brown, and Vice President and General Manager Greg Wyatt of United Water Idaho, Inc. (UWID) for allowing us access to their test well at State and Linder Streets, in Eagle, and for their generous provision to well data in general. The excellent foresight of UWID, in its previous execution of many hydrogeologic investigations in this area, including aquifer testing, geophysical surveys, hydrogeologic characterization of the drilled geologic section, water level monitoring, and ground water analytical results, serves as the foundation for understanding of the ground water resource going forward. For these commitments and actions, UWID has contributed greatly to the entire community and is recognized, here, as a leader in these endeavors.

We laud the concerted efforts of Dr. S.H. Wood and his graduate students over the years. Dr. Wood's devoted mapping of the geologic and hydrogeologic relationships, including the recognition and mapping of major stratigraphic units and structural features that ultimately control the occurrence and movement of ground water in the subsurface environment, provides the essence of the current understanding of the aquifer system beneath the Treasure Valley. It is important to recognize that the majority of Dr. Wood's earlier work has not only served as the basis for all recent geologic studies, but that the findings of recently published research has not contradicted in any significant way, his earlier research; some of which dates back more than 20 years. Thank you, Spence.

Jerry Thompson, ranch manager for Spring Valley Ranch, was instrumental in allowing access to the property, preventing pumping of on-site stock wells that could have caused interference during the test and other aspects of site management critical to the successful completion of the test.

Last but not least, we recognize the able assistance of Hydro Logic, Inc.'s own Kurt Newbry for his tenacious efforts to, almost single-handedly, execute the data acquisition for the 30-day test period of the aquifer test with the exception of the first day of the draw down portion of the test. Kurt's 24-hour availability and stamina during the 9-day pumping test is impressive and punctuated by the fact that no data was lost, no interruptions to the test occurred, and the recovered data is stellar. Kurt, you are our hero.

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TABLES

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Table 1. Summary of Well and Aquifer Details

	WATER LEVELS			WELL INFORMATION									AQUIFER DESCRIPTION					
		Start-of-Test Level																
Well	Measur-able Test Draw-down?	DTW btc	Elev.	Well Elev.	Distance from	Screen Top/Bottom		Radius	Length	Distance between top of Aquifer	Percent of Aquifer	Borehole Radius	Top/Bottom		BE*	Nature of	Thickness	Aquifer
		ft	ft amsl	ft amsl	SVR #7	Depth feet	Elev	inches/ feet	feet	and top of Screen	Screened	inches/ feet	Depth	Elev	%	Aquifer	feet	
SVR #7 (Pumping Well)	yes	165.21	2544.63	2709.84	0	280	2430	4	70	100	21%	6.00	180	2530	95%	Confined	340	Pierce Gulch Sand Aquifer
						350	2360	0.33				0.50	520	2190				
Big Gulch Stock Well	yes	152.13	2546.09	2698.22	845	180	2518	2	0	0	<1%	3?	180	2518	96%	Confined	340	Pierce Gulch Sand Aquifer
						180	2518	0.17				0.25?	520	2178				
M3-TW#2 Zone 3	dry	dry	dry	2766.01	3636	180	2586	1	10	120	3%	4.00	60	2706	dry	dry	300	Pierce Gulch Sand (dry)
						190	2576	0.08				0.33	360	2406				
M3-TW#2 Zone 2	yes	218.96	2547.05	2766.01	3636	230	2536	1	20	170	7%	4.00	60	2706	99%	Unconfined?	300	Pierce Gulch Sand Aquifer
						250	2516	0.08				0.33	360	2406				
M3-TW#2 Zone 1	yes	218.62	2547.39	2766.01	3636	270	2496	1	50	210	17%	4.00	60	2706	99%	Unconfined?	300	Pierce Gulch Sand Aquifer
						320	2446	0.08				0.33	360	2406				
M3-TW#4 Zone 4	no	dry	dry	2673	4489	61	2612	1	10	na	na	4.00	180	2493	na	na	20	dry sand
						71	2602	0.08				0.33	200	2473				
M3-TW#4 Zone 3	yes	134.96	2538	2673	4489	181	2492	1	20	1	100%	4.00	180	2493	85%	Confined	20	**unnamed alluvial sand aquifer**
						201	2472	0.08				0.33	200	2473				
M3-TW#4 Zone 2	yes	130.94	2542	2673	4489	325	2348	1	231	25	89%	4.00	300	2373	39%	Confined	260	Pierce Gulch Sand Aquifer
						556	2117	0.08				0.33	560	2113				
M3-TW#4 Zone 1	yes	130.23	2543	2673	4489	625	2048	1	21	325	53%	4.00	300	2373	33%	Confined	40	**may be part of PGSA**
						646	2027	0.08				0.33	560	2113				
Flack Corral 4-in	yes	208.25	2551.98	2760.23	5974	252?	2508	2	0?	38?	<1%?	3?	210	2550	99%	Unconfined?	120	Pierce Gulch Sand Aquifer
						252?	2508	0.17				0.25?	330	2430				
Flack Corral 6-in	yes	215.01	2555.24	2770.25	6749	74	2696	3	312	0	100%	3?	220	2550	95%	Unconfined?	120	Pierce Gulch Sand Aquifer
						386	2384	0.25				0.25?	340.25	2430				
M3-TW#3 Zone 5	no	dry	dry	2786.63	8173	238	2549	1	20	na	na	4.25	265	2522	na	na	235	Pierce Gulch Sand (dry)
						258	2529	0.08				0.35	500	2287				
M3-TW#3 Zone 4	no	264.36	2522.27	2786.63	8173	334	2453	1	20	69	9%	4.25	265	2522	na	Unconfined?	235	Pierce Gulch Sand Aquifer
						354	2433	0.08				0.35	500	2287				
M3-TW#3 Zone 3	no	264.25	2522.38	2786.63	8173	369	2418	1	10	104	4%	4.25	265	2522	82%	Unconfined?	235	Pierce Gulch Sand Aquifer
						379	2408	0.08				0.35	500	2287				
M3-TW#3 Zone 2	no	264.09	2522.54	2786.63	8173	399	2388	1	20	134	9%	4.25	265	2522	na	Unconfined?	235	Pierce Gulch Sand Aquifer
						419	2368	0.08				0.35	500	2287				
M3-TW#3 Zone 1	no	263.98	2522.65	2786.63	8173	432	2355	1	10	167	4%	4.25	265	2522	81%	Unconfined?	235	Pierce Gulch Sand Aquifer
						442	2345	0.08				0.35	500	2287				
SVR #6	no	456.75	2358.88	2815.63	8189	560	2244	4	170	103	<37%	4.00	457	2359	84%	Unconfined?	>283	**Willow Creek Aquifer**
						730	2084	0.33				0.33	>740	<2064				
Little Gulch Stock Well	yes	176.02	2552.77	2728.79	9740	220	2509	2	3	44	3%	3?	176	2553	99%	Unconfined?	112.79	Pierce Gulch Sand Aquifer
						223	2506	0.17				0.25?	288.79	2440				
Kling-Irrigation well	no	96.66	2516.94	2613.60	9908	198	2416	8	210	0	76%	11?	300	2314	45%	Confined	275	Pierce Gulch Sand Aquifer
						408	2206	0.67				0.92?	575	2039				
M3-TW#1 Zone 5	no	92.03	2514.36	2606.39	10916	97	2260	1	40	12	73%	4.00	85	2521	93%	Confined?	55	**unnamed alluvial sand aquifer**
						137	2056	0.08				0.33	140	2466				
M3-TW#1 Zone 4	no	94.54	2511.85	2606.39	10916	353	2260	1	30	0	13%	4.00	353	2253	33%	Confined	237	Pierce Gulch Sand Aquifer
						383	2056	0.08				0.33	590	2016				
M3-TW#1 Zone 3	no	93.97	2512.42	2606.39	10916	395	2260	1	30	42	13%	4.00	353	2253	na	Confined	237	Pierce Gulch Sand Aquifer
						425	2056	0.08				0.33	590	2016				
M3-TW#1 Zone 2	no	91.57	2521.77	2606.39	10916	467	2260	1	40	114	17%	4.00	353	2253	27%	Confined	237	Pierce Gulch Sand Aquifer
						507	2056	0.08				0.33	590	2016				
M3-TW#1 Zone 1	no	91.54	2521.77	2606.39	10916	514	2260	1	42	161	18%	4.00	353	2253	na	Confined	237	Pierce Gulch Sand Aquifer
						556	2056	0.08				0.33	590	2016				
SVR #9	yes	197.22	2555.84	2753.06	11660	235	2518	3	28	38	38%	6.00	197	2556	99%	Unconfined?	73	Pierce Gulch Sand Aquifer
						263	2490	0.25				0.50	270	2483				
UWID State and Linder TW#1 Zone 2	no	-14.67	2533.63	2518.96	22302	280	2239	1	90	70	17%	4.00	210	2309	20%	Confined	525	Pierce Gulch Sand Aquifer
("UWID State and Linder #1A" in HLI, 2007)		(above ground)				370	2149	0.08				0.33	735	1784				

NOTES: All wellheads surveyed by Idaho Survey Group during Aug 2007 except M3-TW #4 which has well elevation estimated based on TOPO. " BE" = Barometric Efficiency. "na" = Not Analyzed. Confined nature of aquifer based on comparisons of water levels with geology (interpreted from geophysical and geologic logs).

ver: January 20, 2009

Table 2. Results of SVR #7Aquifer Test Analyses

Well	Distance from SVR #7	Maximum Measured Drawdown		Calculated Transmissivity	Calculated Storativity	Theis	Cooper-Jacob	Recovery (Theis)	Neuman-Witherspoon	No WL Trend Correction	With WL Trend Correction	Well Loss Removed	Valid Analysis Possible?
	ft	No Trend* Adjustment ft	With Trend* Adjustment ft	T (gpd/ft)	S (unitless)								
Composite for SVR #7, Big Gulch stock, TW #2 Zone 2, TW #4 Zone 2 and SVR #9	varies	-	-	430,000	2.1E-03	x				x			
Distance-Drawdown for SVR #7, Big Gulch stock, TW #2 Zone 2, TW #4 Zone 2 and SVR #9	varies	-	-	380,000	7.0E-03	x				x			
SVR #7 (Analysis of drawdown data from pumping period conducted with well loss removed)	0	29.79	7.51	450,000	Invalid	x				x		x	
		(as measured)	(w/ well loss removed)	400,000	Invalid		x			x			
				520,000	Invalid			x		x			
				490,000	Invalid			x			x		
Big Gulch stock	842	1.71	1.79	450,000	1.8E-03	x				x			
				500,000	1.2E-03		x			x			
				450,000	na			x		x			
				480,000	na			x			x		
M3-TW#2 Zone 2	3,636	0.17	0.05	240,000	0.091	x				x			
				370,000	0.027	x					x		
				Invalid	Invalid		x			x	x		No
				Invalid	-			x		x	x		No
M3-TW#2 Zone 1	3,636	0.17	0.08	350,000	0.06	x				x			
				230,000	0.16	x					x		
				Invalid	na			x		x	x		No
M3-TW#4 Zone 3 (as upper part of PGSA)	4,489	0.15	0.08	Invalid	Invalid	x	x	x		x	x		No
M3-TW#4 Zone 3 (as overlying, unnamed aquifer)		0.15	0.08	Invalid	Invalid				x				No
M3-TW#4 Zone 2	4,489	0.67	0.60	570,000	3.0E-03	x				x			
				580,000	3.0E-03	x					x		
				"700,000?"	na			x		x			?
				"840,000?"	na			x			x		?
M3-TW#4 Zone 1 (as lower part of PGSA)	4,489	0.58	0.59	170,000	2.4E-03	x				x			
				160,000	2.2E-03	x					x		
				"690,000?"	na			x		x			?
				"790,000?"	na			x			x		?
M3-TW#4 Zone 1 (as underlying aquifer)				80,000	3.5E-04				x	x			
				80,000	3.5E-04				x		x		
Flack Corral 4-in	5,974	0.14	0.20	200,000	0.023	x				x			
				270,000	0.021	x					x		
				Invalid	Invalid		x	x		x	x		No
Flack Corral 6-in	6,749	0.13	0.34	"50,000"	"0.014"	x				x			?
				Invalid	Invalid	x					x		No
				Invalid	Invalid		x	x		x	x		No
M3-TW#3 Zones 1-4	8,173	none	none	-	-								No
SVR #6 (Willow Creek Aquifer)	8,189	none	none	-	-								No
Little Gulch stock	9,740	0.08	0.14	180,000	0.013	x				x			
				270,000	0.011	x					x		
				Invalid	na			x		x			No
				"670,000?"	na			x			x		?
Kling Irrigation	9,908	none	none	-	-								No
M3-TW#1 Zones 1-5	10,916	none	none	-	-								No
SVR #9	11,660	0.09	0.18	250,000	8.7E-03	x				x			
				320,000	7.1E-03	x					x		
				Invalid	na			x		x			No
				"780,000?"	na			x			x		?
UWID State & Linder TW#1 Zone 2	22,302	none	none	-	-								No

*Note: For pumping well, drawdown correction is for well loss, only. No trend correction because changes in water level caused by aquifer trend is insignificant compared with drawdowns caused by pumping, especially during time period of curve matching.

ver: January 19, 2009

Table 3. Well Loss and Well Efficiency Comparison

	Theoretical	Actual	Well Loss -Efficiency		Means	
Pumping Time	DD	DD	(difference)	(ratio)	Well Loss	Efficiency
min	ft	ft	ft	%	22.92	14%
12	3.34	25.83	22.49	13%		
18	3.43	26.07	22.64	13%		
28	3.53	26.49	22.96	13%		
43	3.63	26.57	22.94	14%		
66	3.72	27.14	23.42	14%		
101	3.82	27.70	23.88	14%		
156	3.92	26.83	22.91	15%		
240	4.02	26.13	22.11	15%		

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FIGURES

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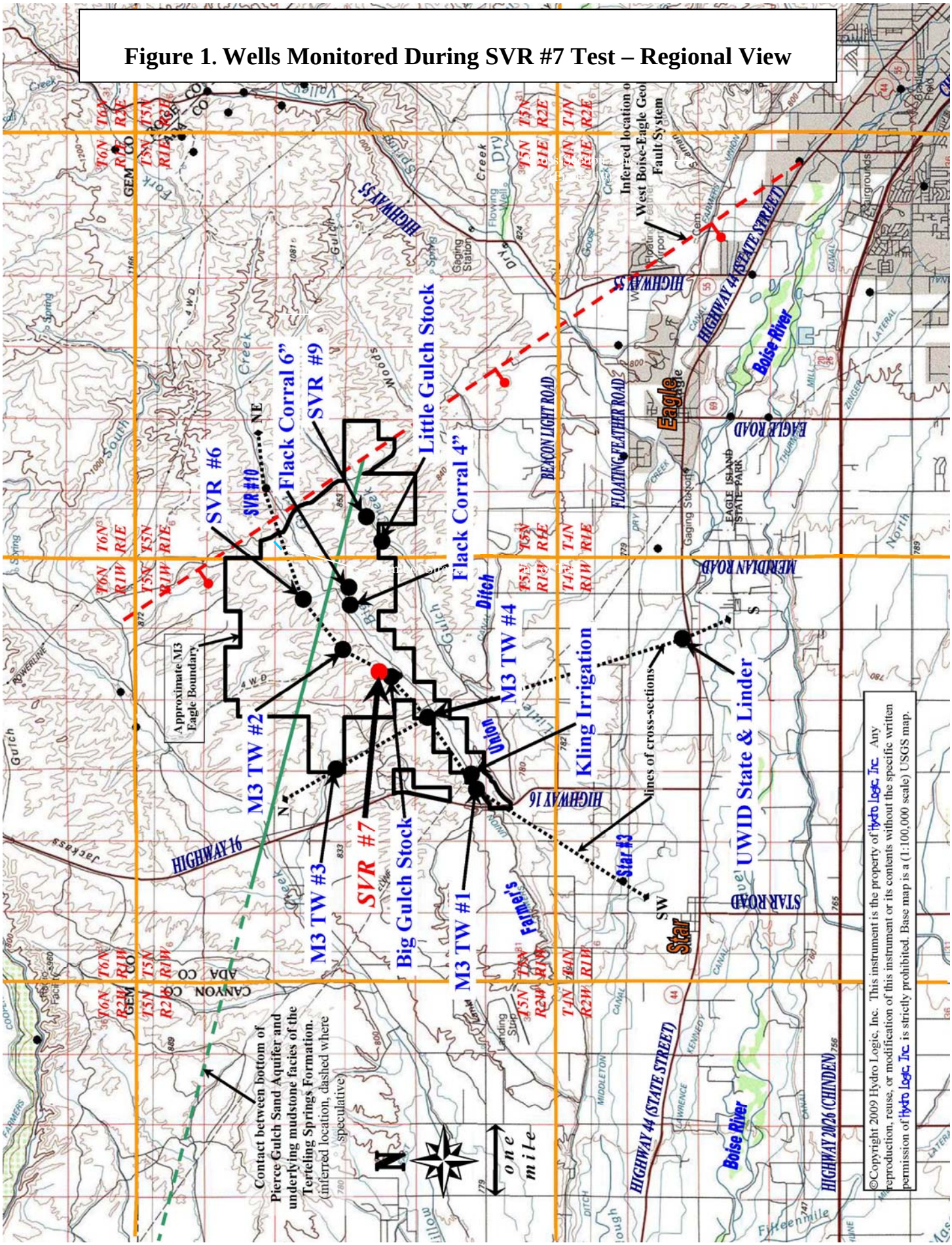
Figure 1. Wells Monitored During SVR #7 Test – Regional View



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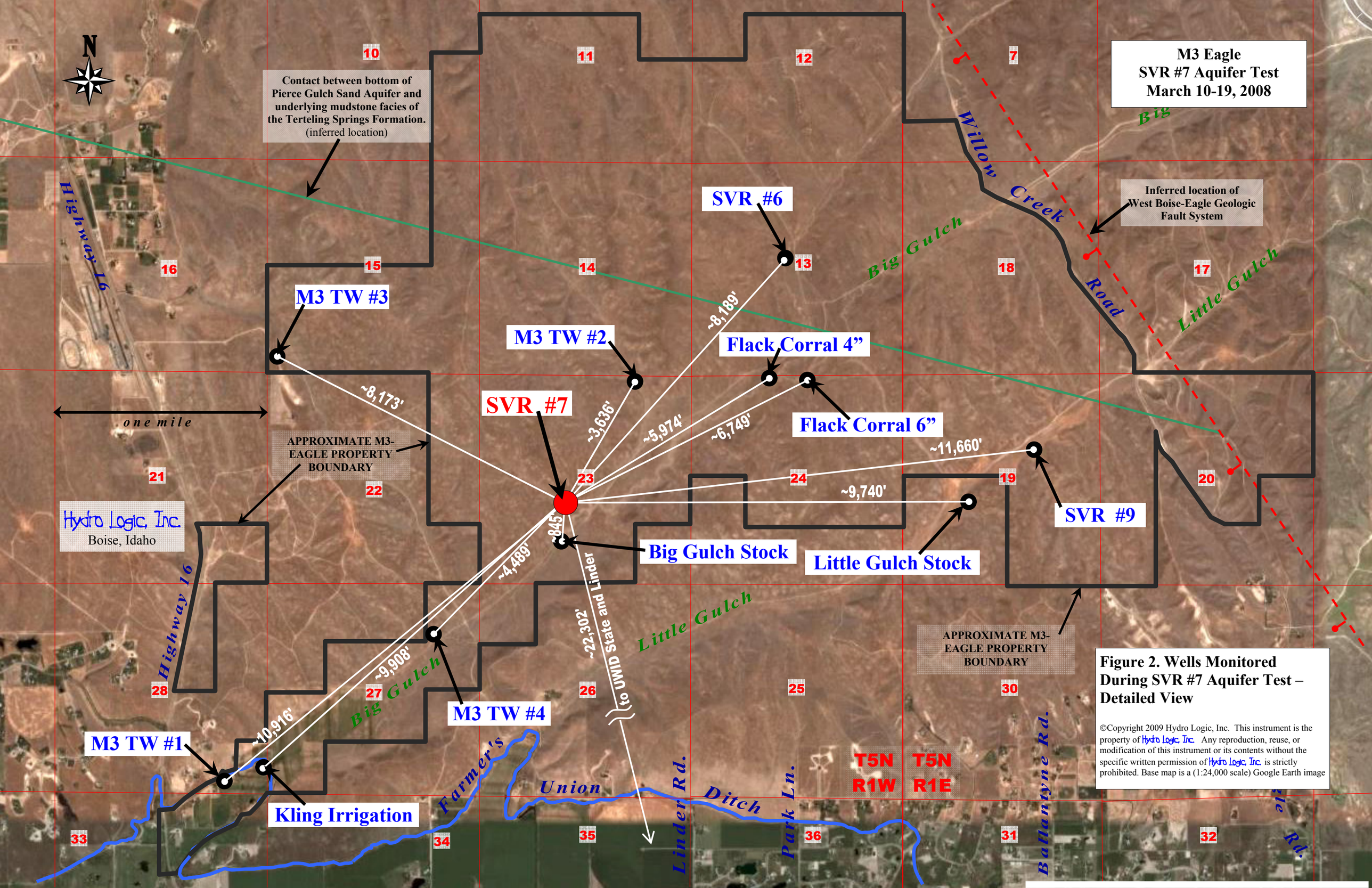

Figure 2. Wells Monitored During SVR #7 Aquifer Test – Detailed View

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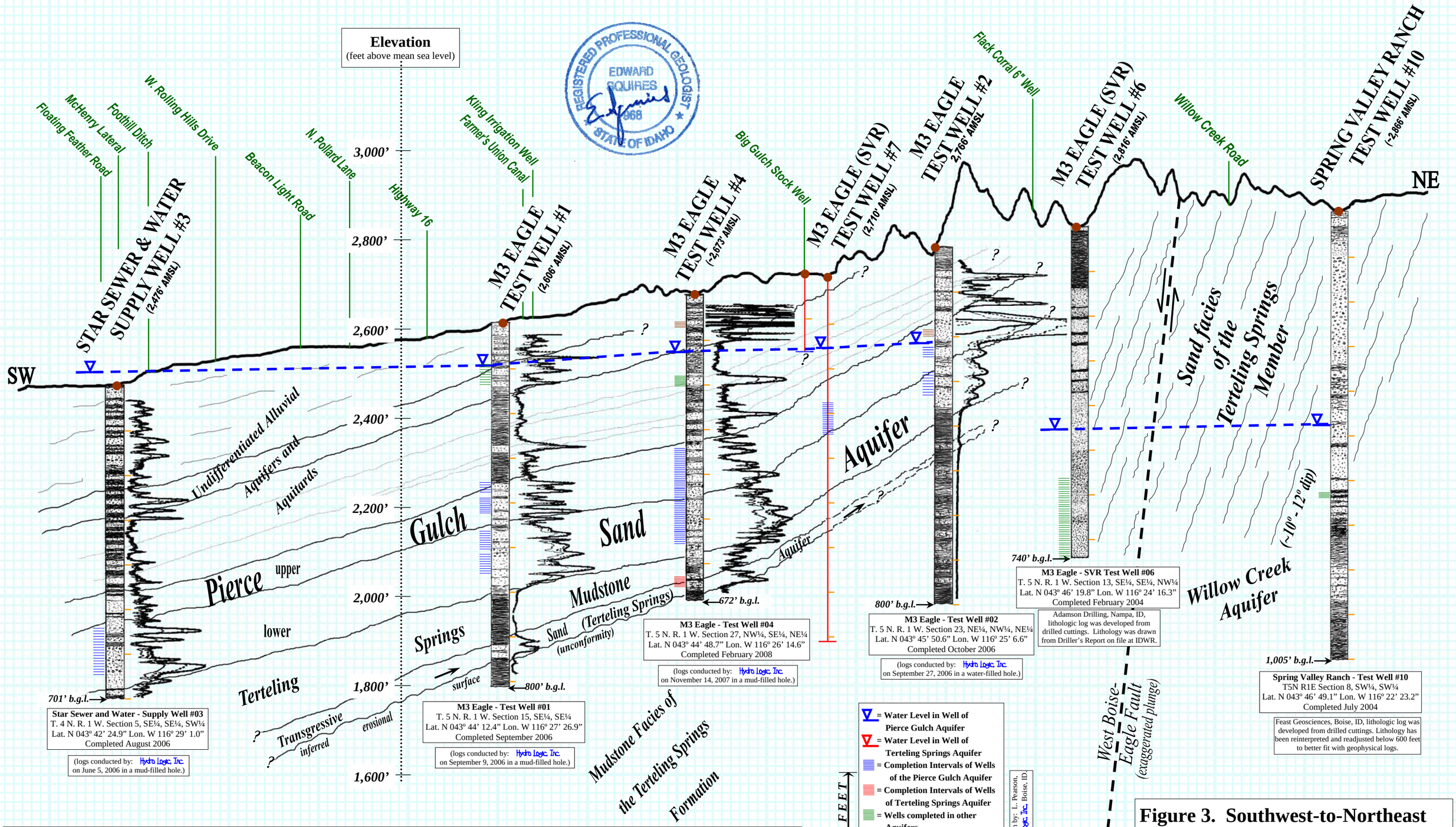
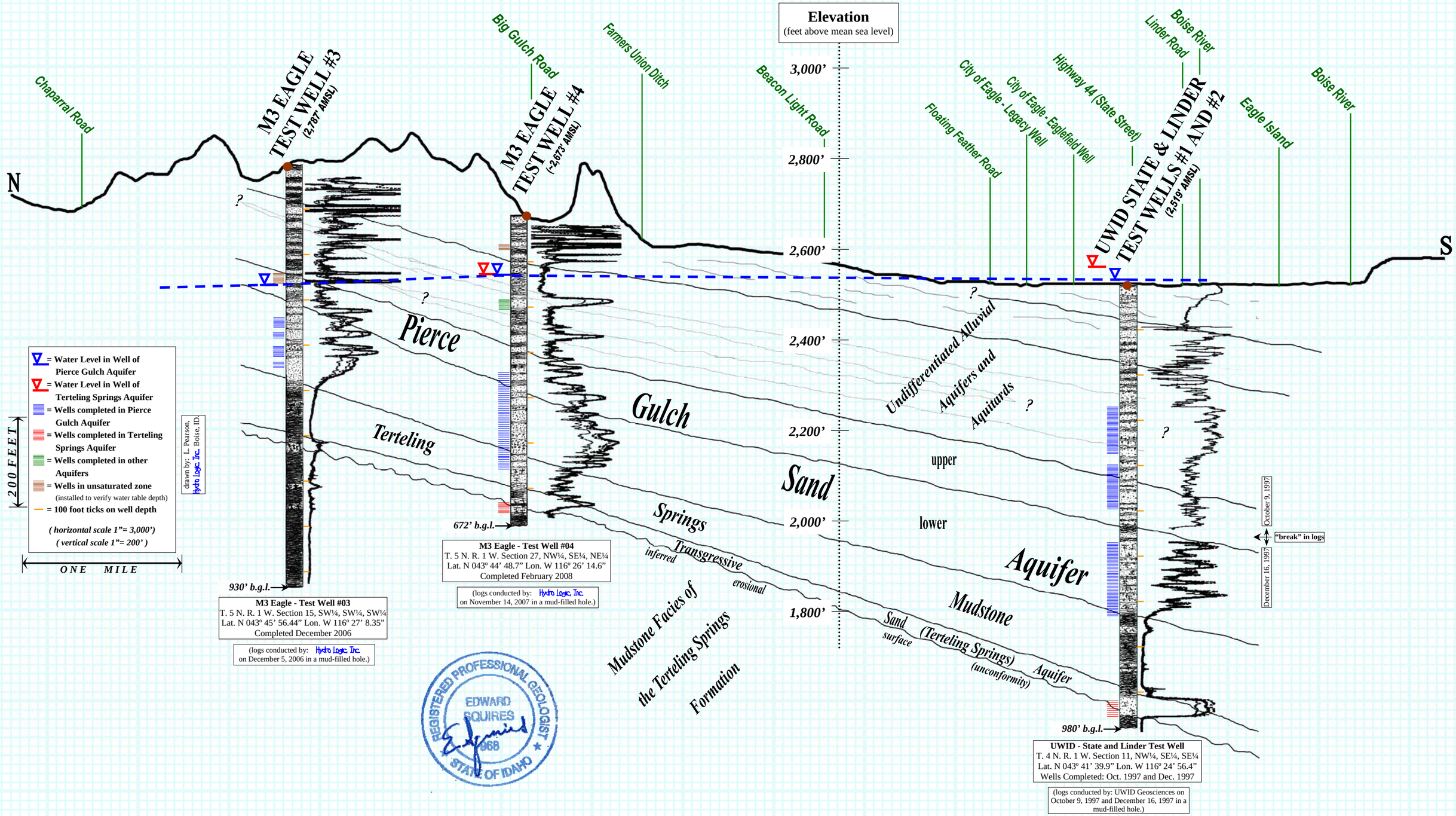


SW-to-NE Cross-Sectional Sketch of Major Hydro-Stratigraphic Units Beneath Big Gulch. Sub-surface cross-sectional diagram depicting the major hydro-stratigraphic units underlying the Big Gulch-to-Star area in North Ada County, Idaho (refer to Figure 1 for line of section). The aquifer stratigraphy is interpreted from lithologic logs and borehole geophysical logs of some of the supply and test wells evaluated and relied upon for this study. ©2009 Hydro Logic, Inc. This instrument is the property of Hydro Logic, Inc. Any reproduction, reuse, or modification of this instrument or its contents without the specific written permission of Hydro Logic, Inc. is strictly prohibited.

Figure 3. Southwest-to-Northeast Cross-Sectional Sketch of Major Hydro-Stratigraphic Units Underlying Big Gulch



N-to-S Cross-Sectional Sketch of Major Hydro-Stratigraphic Units Beneath SW Portion of Big Gulch. Sub-surface cross-sectional diagram depicting the major hydro-stratigraphic units underlying the southwestern portion of Big Gulch in North Ada County, Idaho (refer to Figure 1 for line of section). The aquifer stratigraphy is interpreted from lithologic logs and borehole geophysical logs of some of the supply and test wells evaluated and relied upon for this study. ©2009 Hydro Logic, Inc. This instrument is the property of Hydro Logic, Inc. Any reproduction, reuse, or modification of this instrument or its contents without the specific written permission of Hydro Logic, Inc. is strictly prohibited.

Figure 4. North-to-South Cross-Sectional Sketch of Major Hydro-Stratigraphic Units Underlying the Southwest portion of Big Gulch

Figure 5. Schematic Cross-Section from Wood and Clemens

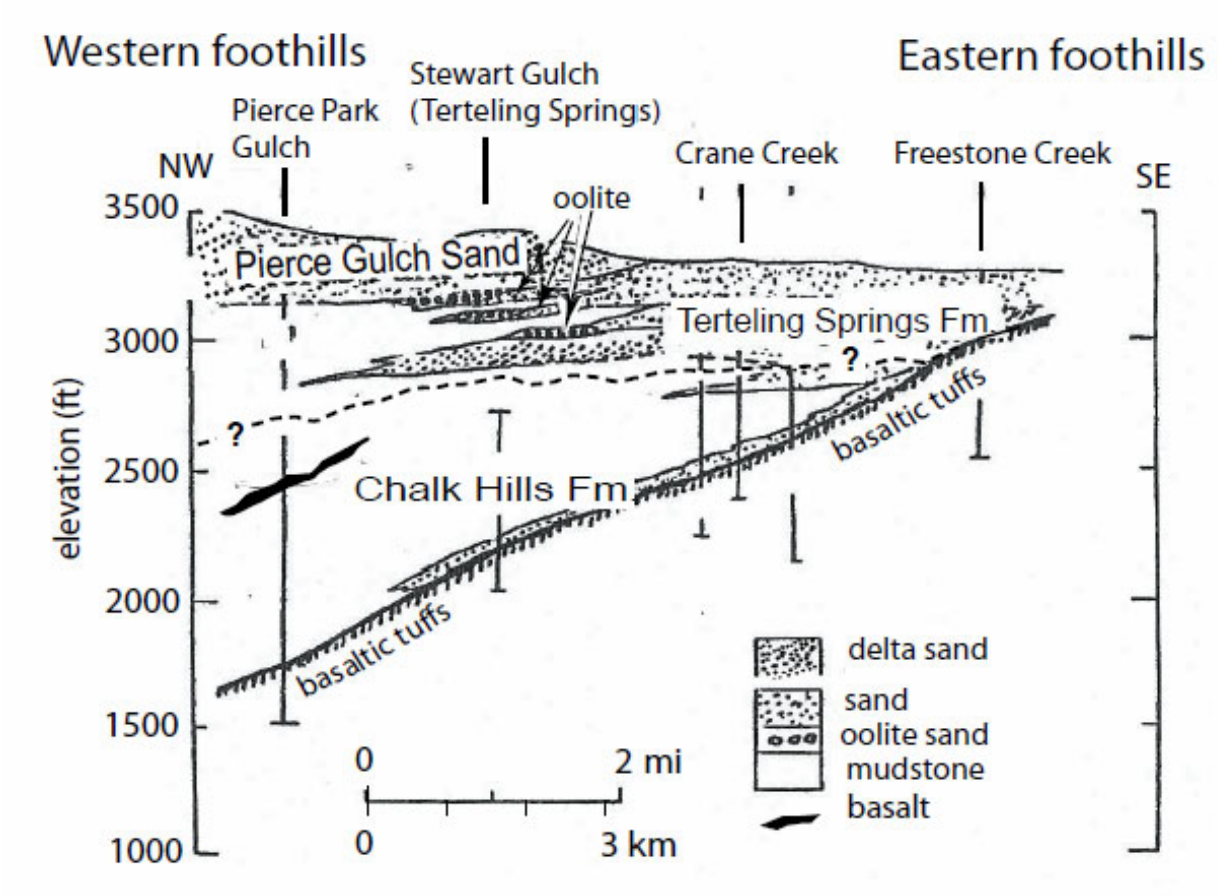


Figure 23. Stratigraphic diagram showing relation of the Chalk Hills Formation with the overlying Terteling Springs Formation and the Pierce Gulch Sand (from Wood and Clemens, 2002).

Figure 6. Stratigraphic Cross-Section from Squires and Wood

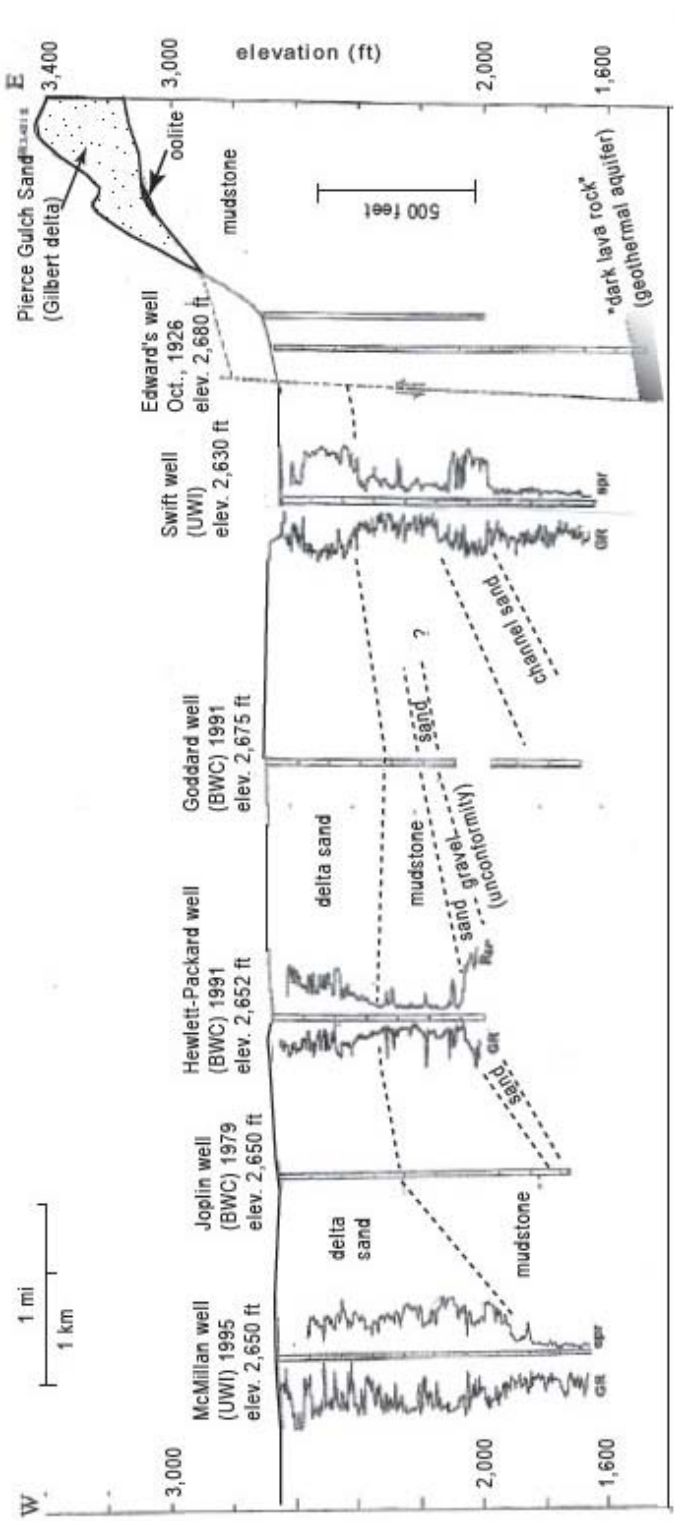


Figure 24. Stratigraphic section and well logs from Polecat Gulch in the foothills to west Boise, showing the Pierce Gulch Sand and equivalent delta facies in the subsurface. Well locations shown in figure 18. GR, natural gamma log; spr, single-point resistance log; and R_{64}, 64-inch normal-resistivity log. Well logs courtesy of United Water Idaho, Inc. (UWI), and its predecessor, Boise Water Company (BWC).

Reproduced from Squires and Wood (2001)

Figure 7. Delta Profiles from Wood

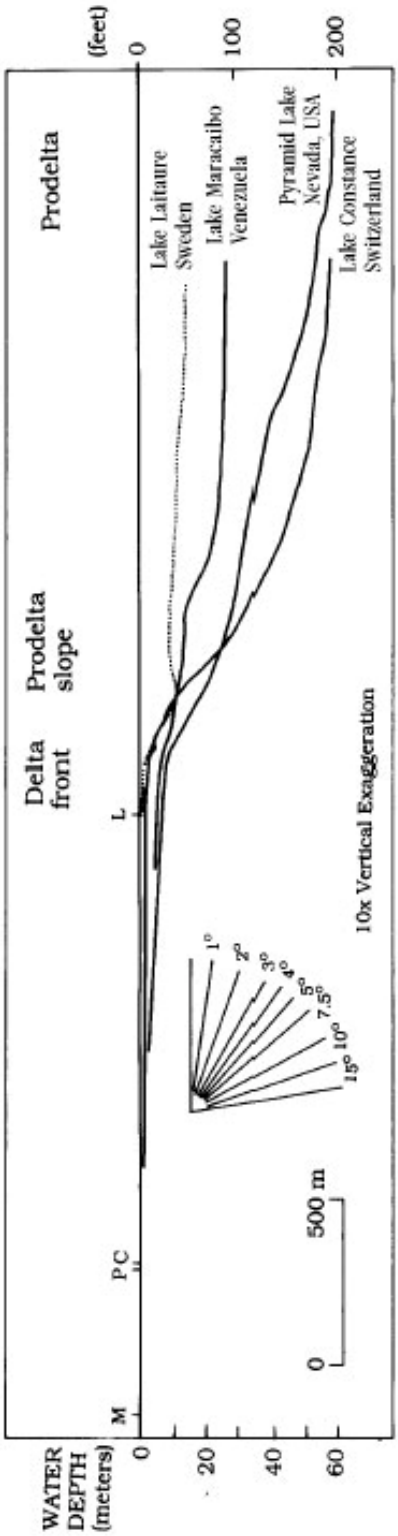


Figure 9—Profiles of modern lacustrine deltas showing the delta front and the prodelta slope. Data sources are Lake Constance (Müller, 1966); Lake Laitaure (Axelsson, 1967); Lake Maracaibo (Hyne et al., 1979); and Pyramid Lake (Born, 1972; Russell, 1885).

Figure reproduced from Wood, 1994

Figure 8. Seismic-Reflection Cross-Section from Wood and Clemens

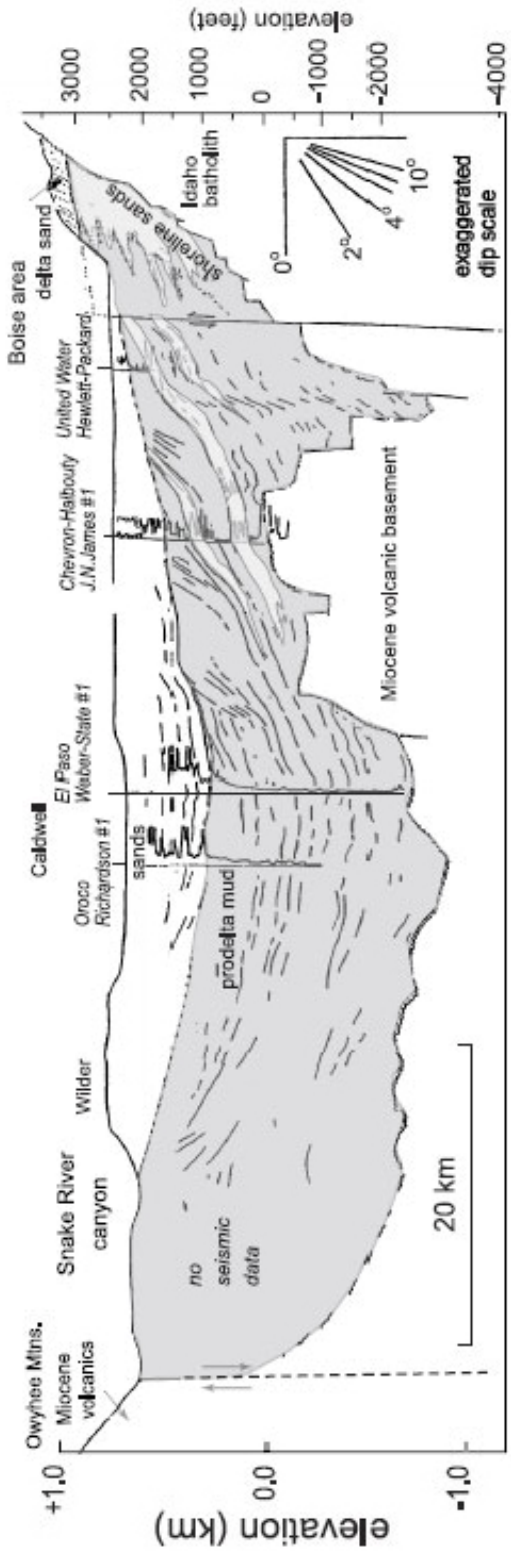


Figure 16. Tracing from seismic reflection section across the western Snake River Plain showing the upper sequence of fluvial-deltaic sediments and character of resistivity logs in wells. Resistivity-log excursions to the right are fresh-water aquifer sands, and the monotonous, near zero, resistivity values are indicative of mudstones. Notice the abrupt change upward from pro-delta muds to the sandy section of the delta systems, delta plain, and fluvial sands in the Caldwell area. Deposition may have been continuous in the center of the plain, but beds appear truncated by erosion to the east, and this surface to the east may be the unconformity at the top of the Chalk Hills Formation. The deltaic deposits in the Richardson well are discussed by Wood (1994). Line of section extends from Terteling Springs in Stewart Gulch shown in Figure 10 westward through the J.N. James well to the Caldwell area shown on Figure 2.

Reproduced from Wood and Clemens, 2002

M3 Eagle - S.V.R Well #7

T5N R1W Section 23, NE¼, SW¼

Latitude 43º 45' 18.9" Longitude 116º 25' 29.7"

Completed April 2004

Geophysical Log

(March 2004)
by Stevens and Sons Drilling
in a mud-filled borehole.

Geophysical Logs

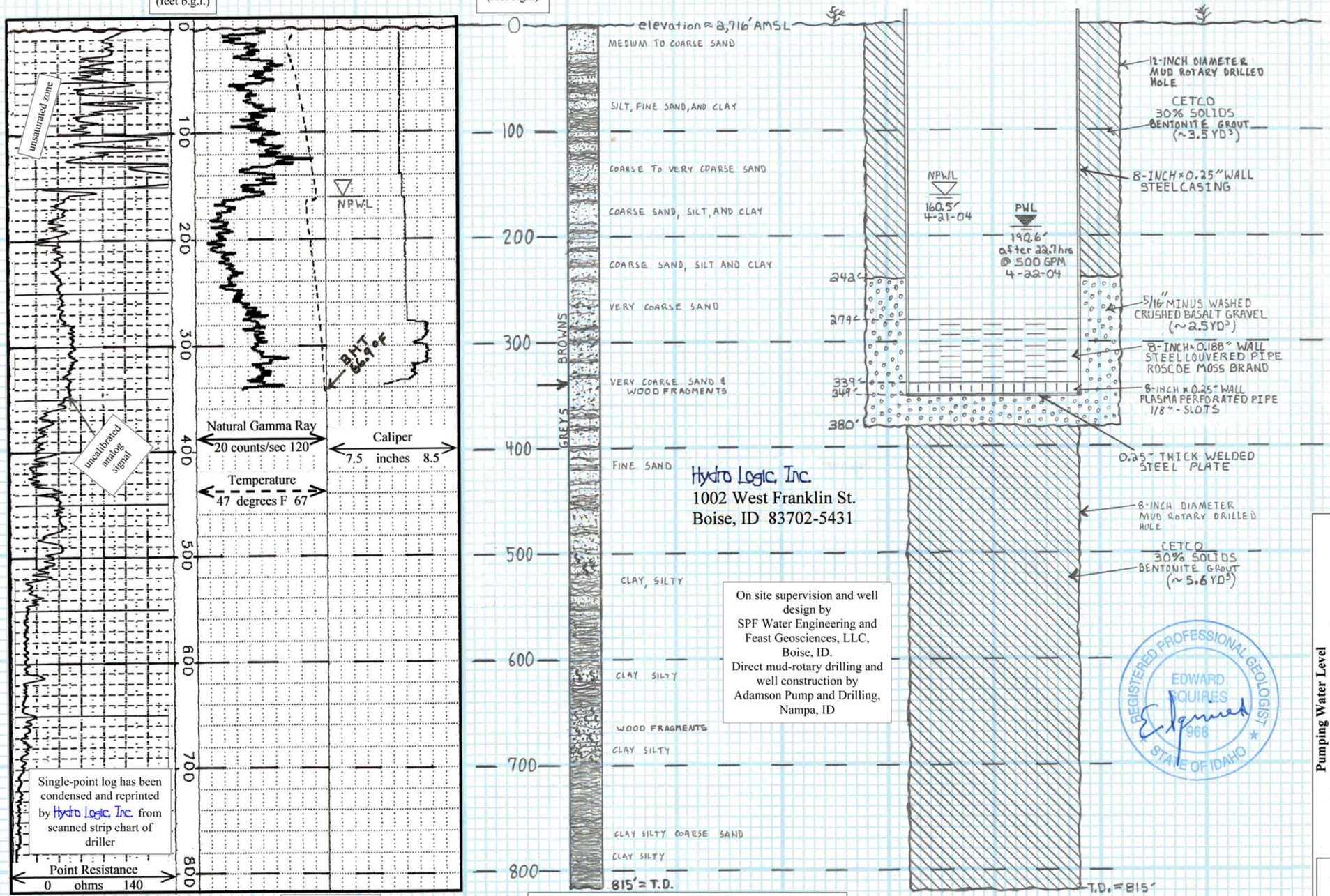
(April 27, 2007)
by Hydro Logic, Inc.
in a steel cased well.

Lithology

Feast Geosciences lithologic log was developed from drilled cuttings. Lithology has been reinterpreted and readjusted to better fit with geophysical logs by Hydro Logic, Inc.

As-Built Well Construction

(from IDWR Driller's Report and Hydro Logic, Inc. downhole camera survey conducted on August 28, 2007)
(horizontal scale 0.1"=0.5")
(vertical scale 1"=100')



Hydro Logic, Inc.
1002 West Franklin St.
Boise, ID 83702-5431

On site supervision and well design by SPF Water Engineering and Feast Geosciences, LLC, Boise, ID.
Direct mud-rotary drilling and well construction by Adamson Pump and Drilling, Nampa, ID

REGISTERED PROFESSIONAL GEOLOGIST EDWARD AQUIRES 968 STATE OF IDAHO

Drafted 02-15-08
by Loren Pearson,
Hydro Logic, Inc.

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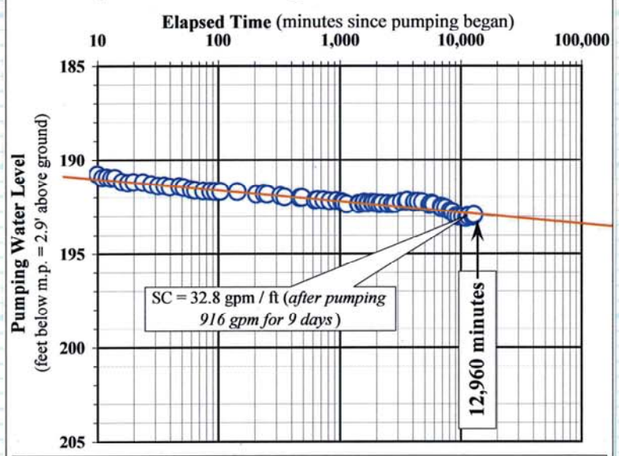
Ground Water Chemistry

Lab Analyses	SPF Water Engineering **Results** (in mg/L unless noted)	Hydro Logic, Inc. **Results** (in mg/L unless noted)
	SCREENED *(279 - 349 feet bgl)*	SCREENED *(279 - 349 feet bgl)*
Alkalinity		120.0
Ammonia as N	<0.04	0.02
Arsenic	<0.005	0.0037
Calcium as $CaCO_3$	29.1	77.8
Chloride	5	4.42
Conductivity (uS)		305.0
Corrosivity		-0.35
Fluoride	0.44	0.43
Hardness	110	115.0
Iron (dissolved)		0.11
Iron (total)	0.11	0.11
Magnesium	8.19	8.91
Manganese	<0.05	0.02
Nitrate as N	0.31	0.34
Nitrite as N	<0.01	<0.01
Odor		<1
pH		7.63
Potassium	2.0	2.60
Silica		38.9
Sodium	22.9	23.2
Sulfate	24	23.5
Sulfide	<0.05	<0.05
Total Dissolved Solids	212	235.0
Total Kjeldahl Nitrogen		<0.10
Total Organic Carbon		3.36
Field Analyses		
Field Conductivity (µS)	300	382
Field Dissolved Oxygen		+1.37
Field Odor (describe)		minor H_2S
Field O.R.P. (mV)		+55
Field pH (S.U.)	7.00	7.40
Field Temperature (°F)	68.1	67.0
Field Visible Gas (yes or no)		yes

HLI samples collected on March 14, 2008 by Hydro Logic, Inc.
Analyses by Alchem Laboratories, Boise, ID
SPF samples collected on April 21, 2004 by Feast Geosciences.
Analyses by Analytical Laboratories, Boise, ID

Hydraulic Testing - (March 10-19, 2008)



Non-Pumping Water Level = 165.00 feet below m.p. (16:00 hrs on 03/10/2008)
Testing conducted by Hydro Logic, Inc. and McLeran Well Drilling, LLC.
(no barometric or antecedent trend corrections applied to this plot.)

Figure 9.

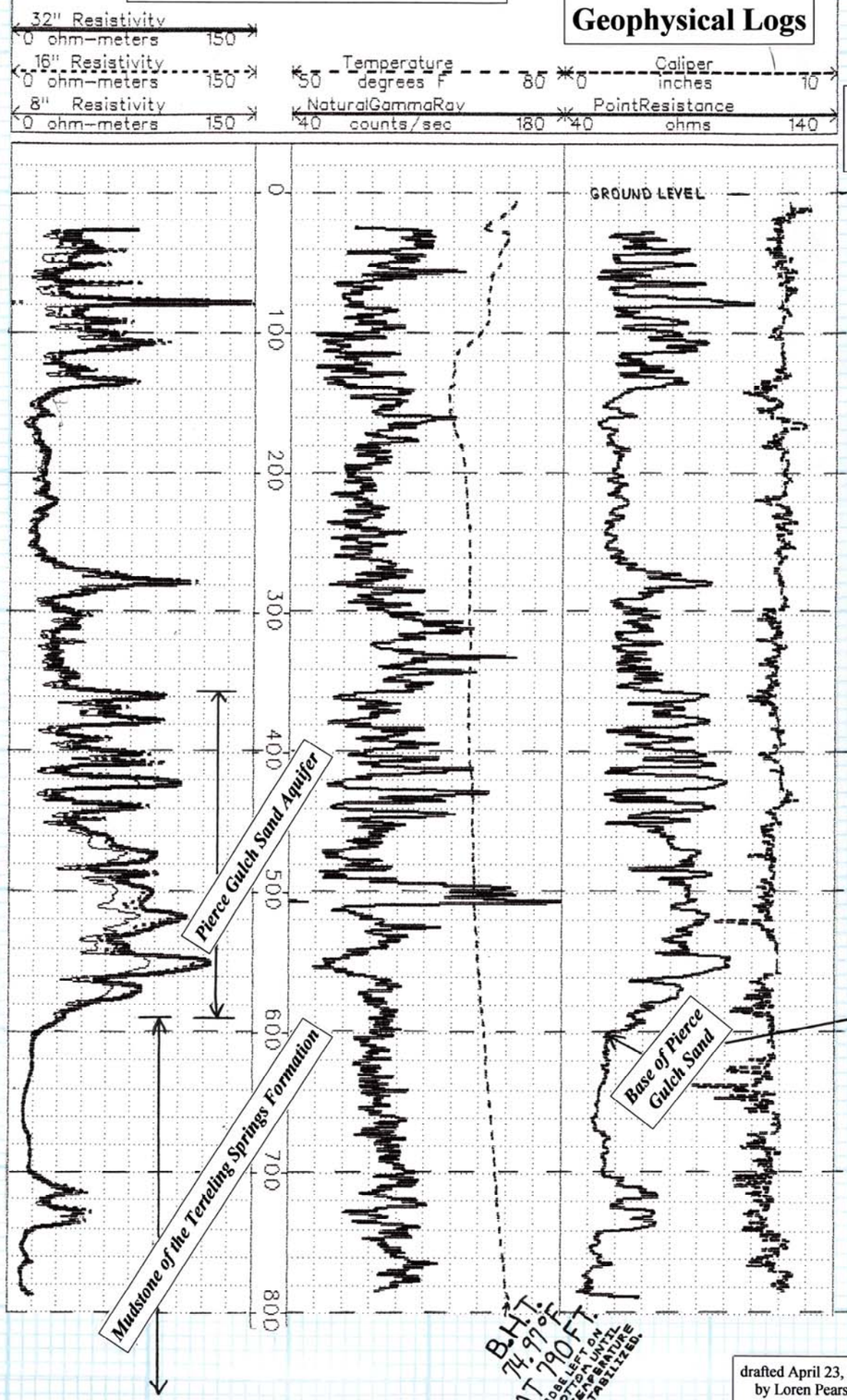
M3 Eagle - Test Well #1

T. 5 N., R. 1 W., Section 28, SE¼, SE¼
Latitude 43° 44' 12.37" Longitude 116° 27' 26.86"
Well completed September 2006

Figure 10.

Geophysics conducted by: Hydro Logic, Inc. on September 9, 2006 immediately after removal of drill steel

Geophysical Logs



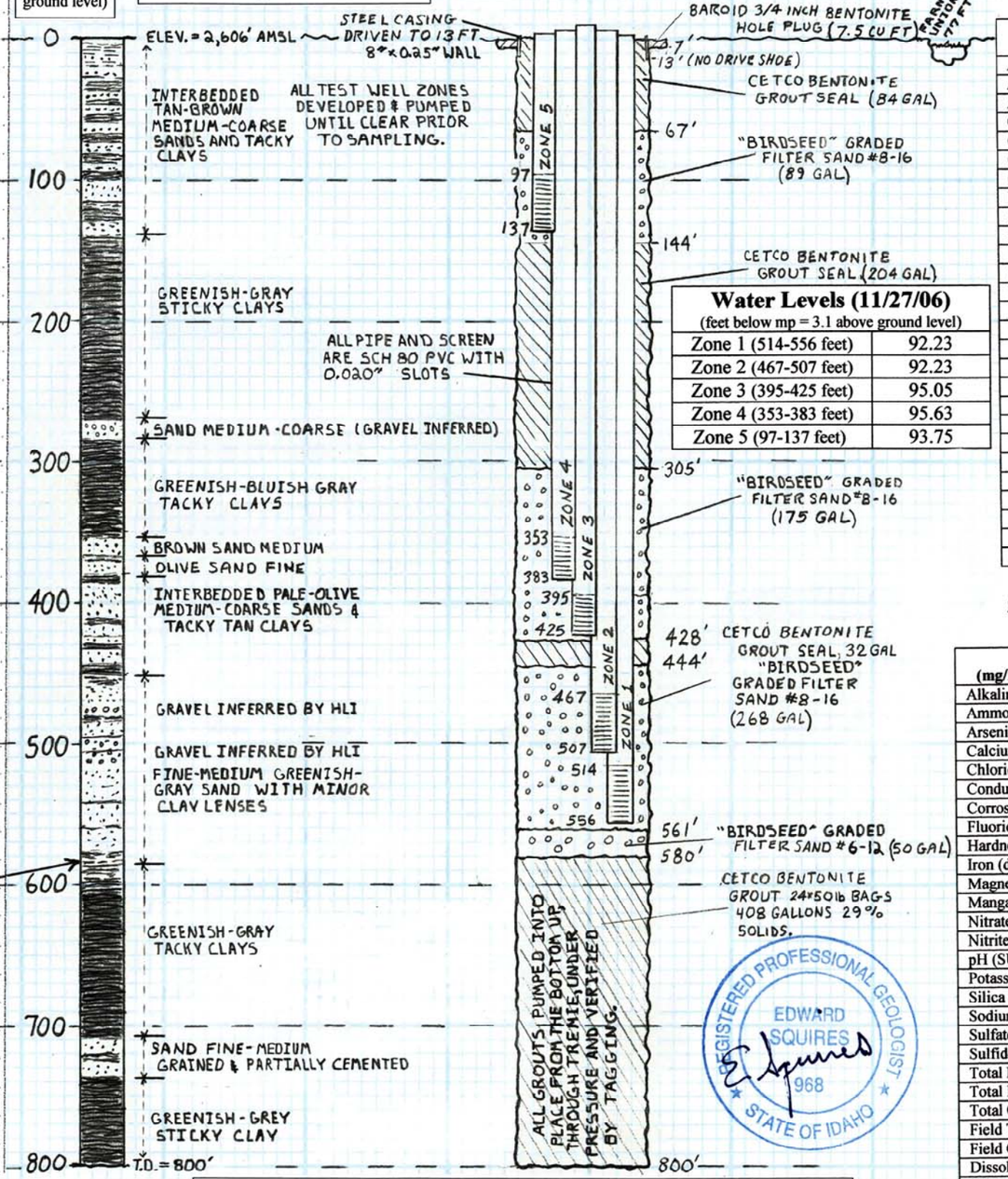
Depth
(feet below ground level)

Lithology

Hydro Logic, Inc. lithologic log is interpreted and drawn from geophysical logs and drilled cuttings from the borehole.

As-Built Well Construction

(horizontal scale 0.1"=1.0")
(vertical scale 1"=100')



Water Levels (11/27/06)

(feet below mp = 3.1 above ground level)

Zone 1 (514-556 feet)	92.23
Zone 2 (467-507 feet)	92.23
Zone 3 (395-425 feet)	95.05
Zone 4 (353-383 feet)	95.63
Zone 5 (97-137 feet)	93.75

Water Chemistry

Analyte (mg/L unless noted)	Zone 1 514-556 feet	Zone 2 467-507 feet
Alkalinity	133.0	125.0
Ammonia as N	0.37	0.06
Arsenic	<0.003	<0.003
Calcium as CaCO3	84.4	85.5
Chloride	3.42	3.22
Conductivity (uS/cm)	302	297.0
Corrosivity	-0.40	-0.44
Fluoride	0.69	0.60
Hardness	111.0	109.0
Iron (dissolved/filtered)	0.23	<0.01
Magnesium	6.50	5.73
Manganese (dissolved)	0.10	0.02
Nitrate as N	<0.10	<0.10
Nitrite as N	<0.01	<0.01
pH (SU)	7.47	7.48
Potassium	2.26	2.21
Silica	31.8	30.7
Sodium	22.1	21.7
Sulfate	17.2	20.7
Sulfide	<0.05	<0.05
Total Dissolved Solids	173 .0	188.0
Total Kjeldahl Nitrogen	0.39	0.13
Total Organic Carbon	<1.0	<1.0
Field Temperature (°F)	67.1	66.0
Field Conductivity (uS)	305	295
Dissolved Oxygen	+1.7	+2.6
Field pH (S.U.)	7.19	7.19

Analyses by Alchem Laboratories, Boise, Idaho.
Zones 1 to 3 sampled 10/09/06. Zones 4 & 5 sampled 10/9/06.
Field measured parameters by Hydro Logic, Inc.

Analyte (mg/L unless noted)	Zone 3 395-425 feet	Zone 4 352-382 feet	Zone 5 98-138 feet
Alkalinity	119.0	114.0	119.0
Ammonia as N	0.04	<0.01	<0.01
Arsenic	<0.003	0.0049	0.0081
Calcium as CaCO3	77.7	81.3	85.9
Chloride	3.57	3.54	4.36
Conductivity (uS/cm)	282.0	285.0	281.0
Corrosivity	-0.50	-0.61	-1.16
Fluoride	0.60	0.50	0.24
Hardness	102.0	105.0	111.0
Iron (dissolved/filtered)	0.01	<0.01	<0.01
Magnesium	5.83	5.85	6.22
Manganese (dissolved)	<0.01	<0.01	<0.01
Nitrate as N	0.30	0.33	2.30
Nitrite as N	<0.01	<0.01	<0.01
pH (SU)	7.84	7.40	6.91
Potassium	2.07	2.10	2.74
Silica	29.5	28.7	38.0
Sodium	21.1	17.9	13.6
Sulfate	21.4	22.3	12.0
Sulfide	<0.05	<0.05	<0.05
Total Dissolved Solids	185.0	203.0	208.0
Total Kjeldahl N	<0.10	<0.10	<0.10
Total Organic Carbon	<1.0	<1.0	<1.0
Field Temperature (°F)	64.7	63.8	57.4
Field Conductivity (uS)	274	268	265
Dissolved Oxygen	+4.9	+2.63	+9.51
Field pH (S.U.)	7.27	7.07	6.72

REGISTERED PROFESSIONAL GEOLOGIST
EDWARD SQUIRES
968
STATE OF IDAHO

drafted April 23, 2008
by Loren Pearson

On site supervision, well design and water quality sampling by Hydro Logic, Inc., Boise, ID.
Direct mud-rotary drilling and well construction by
Treasure Valley Drilling and Pump, Inc., Weiser, ID
Wells developed by McLeran Well Drilling, LLC, New Plymouth, ID.

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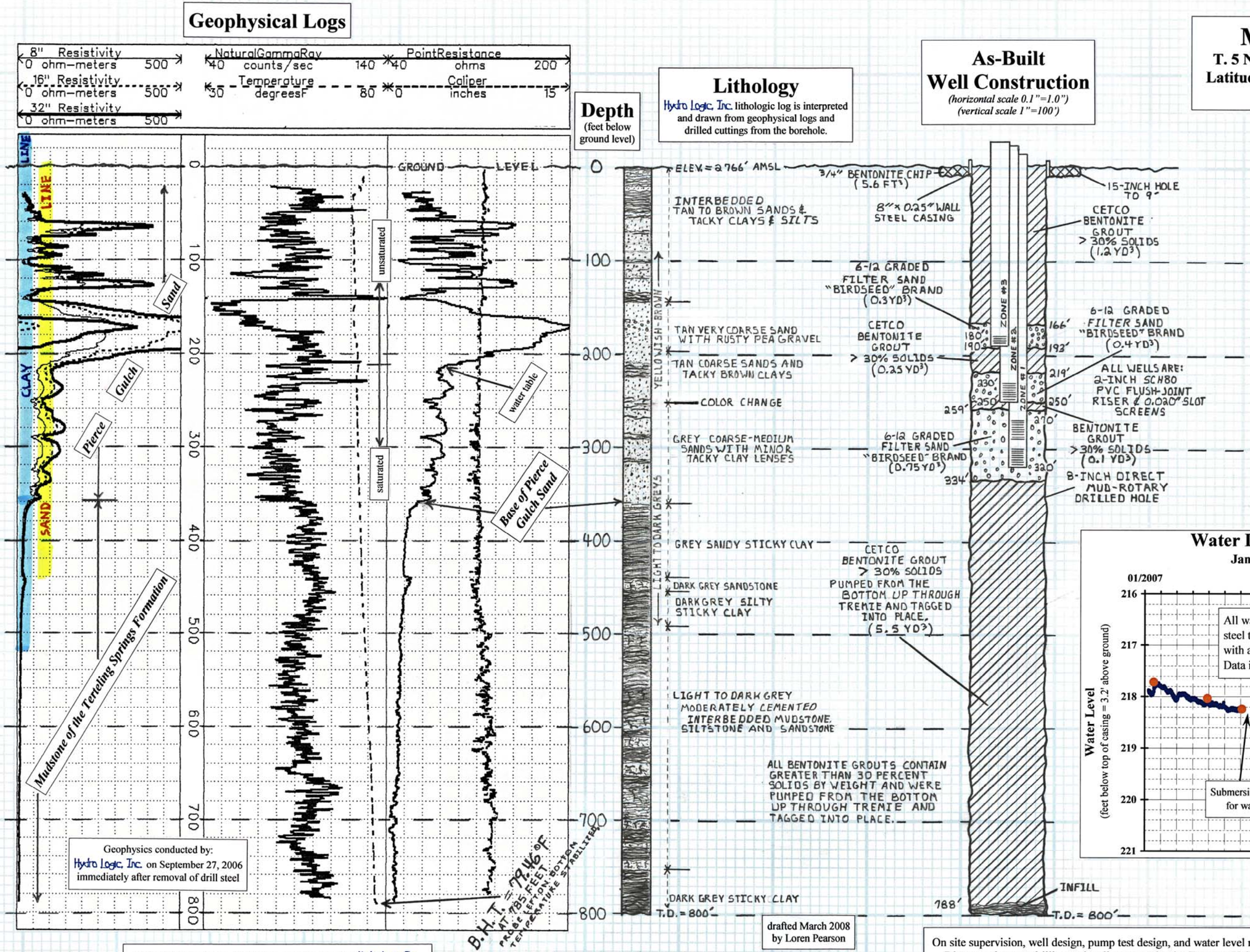
M3 Eagle - Test Well #2

T. 5 N., R. 1 W., Section 23, NE¼, NW¼, NE¼
Latitude 43° 45' 50.63" Longitude 116° 25' 6.58"
Well completed October 2006



Geophysics conducted by:
Hydro Logic, Inc. on September 27, 2006
immediately after removal of drill steel

drafted March 2008
by Loren Pearson

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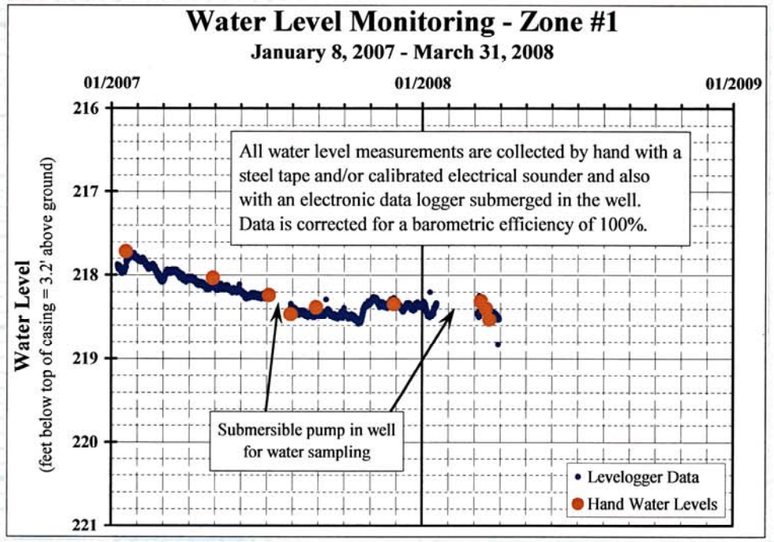
Water Levels

(feet below measure point = 3.0 feet above ground)

Date / Time (24-hr clock)	ZONE #1 (320 - 270 feet bgl)	ZONE #2 (250 - 230 feet bgl)	ZONE #3 (190 - 180 feet bgl)
10/10/06 13:05	216.87	-	unsaturated zone (installed to confirm water table depth)
11/07/06 12:00	217.23	217.36	
1/18/07 14:27	217.19	217.37	
4/30/07 15:25	216.97	215.76	
6/01/07 12:00	216.17	216.75	
7/24/07 12:30	-	217.11	
7/31/07 13:00	217.58	217.91	
8/30/07 12:20	217.60	217.93	
9/19/07 16:30	215.93	216.26	

Water levels recorded by Hydro Logic, Inc.



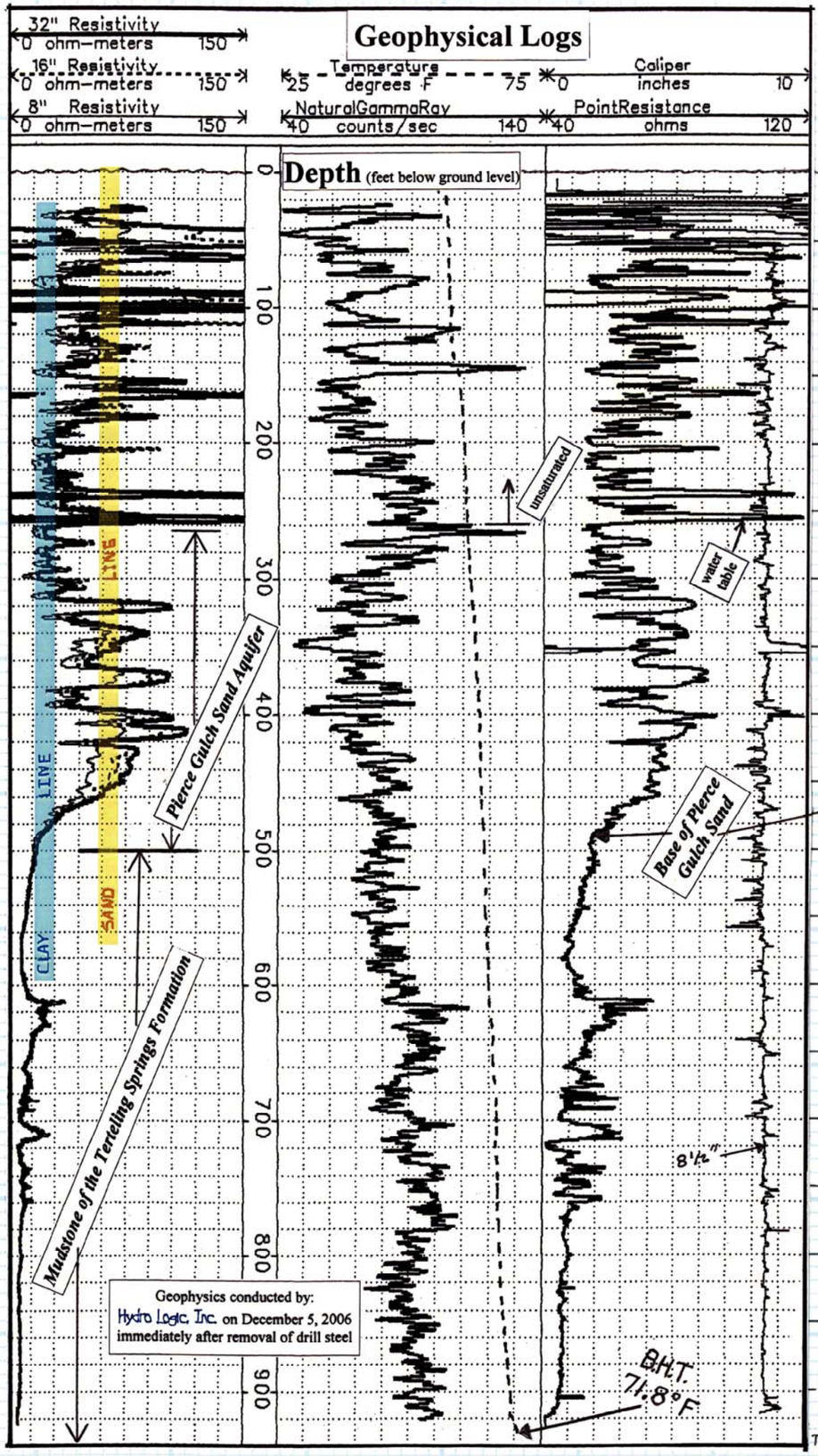
On site supervision, well design, pump test design, and water level monitoring by Hydro Logic, Inc., Boise, ID.
Direct mud-rotary drilling and well construction by Treasure Valley Drilling and Pump, Inc., Weiser, ID
Wells developed by McLeran Well Drilling, LLC, New Plymouth, ID.

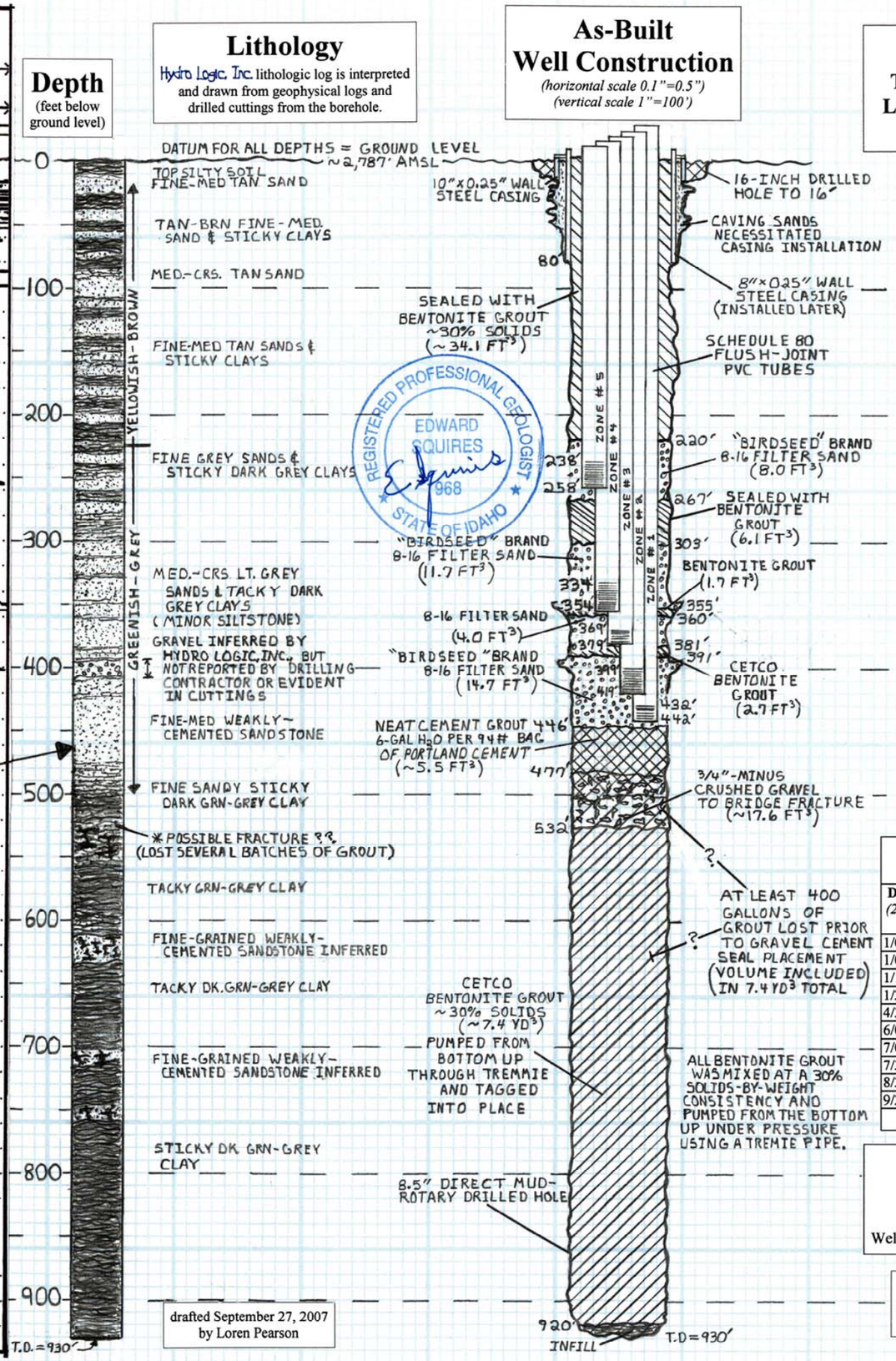
Figure 11.

M3 Eagle - Test Well #3

T. 5 N., R. 1 W., Section 15, SW¼, SW¼, SW¼
Latitude 43° 45' 56.44" Longitude 116° 27' 8.35"
Well completed December, 2006

Figure 12.





Ground Water Chemistry

Analysis (in mg/L unless noted)	ZONE #1 (442 - 432 feet bgl)	ZONE #2 (419 - 399 feet bgl)	ZONE #3 (379 - 369 feet bgl)
Alkalinity	136.0	123.0	117.0
Ammonia as N	0.28	0.14	0.05
Arsenic	0.008	0.005	0.009
Calcium as $CaCO_3$	69.8	74.8	86.5
Chloride	5.39	5.31	7.02
Conductivity *(µS)*	316.0	305.0	321.0
Corrosivity	-0.14	-0.46	-0.30
Fluoride	0.51	0.52	0.52
Hardness	98.4	106.0	118.0
Iron *(dissolved)*	0.16	0.09	0.03
Magnesium	6.94	7.48	7.47
Manganese *(dissolved)*	0.07	0.09	0.05
Nitrate as N	0.13	0.13	0.12
Nitrite as N	<0.01	<0.01	<0.01
Orthophosphate	0.477	0.270	0.276
pH - Lab *(S.U.)*	7.90	7.59	7.72
Potassium	2.90	2.54	2.53
Silica	43.5	41.2	35.8
Sodium	30.4	24.3	26.2
Sulfate	22.7	23.9	32.3
Sulfide	< 0.05	< 0.05	< 0.05
Total Dissolved Solids	253	235.0	238.0
Total Kjeldahl Nitrogen	0.35	0.23	0.18
Total Organic Carbon	1.34	< 1.0	< 1.0
Field Conductivity (µS)	*310*	*307*	*321*
Field Dissolved Oxygen	*6.64*	*4.89*	*4.87*
Field O.R.P. (mV)	*+106*	*+6*	*+110*
Field pH (S.U.)	*7.62*	*7.22*	*7.46*
Field Temperature (°F)	*64.2*	*63.2*	*62.2*

Analyses by Alchem Laboratories, Boise, ID
Samples collected on January 30, 2007 by Hydro Logic, Inc.

Water Levels

(feet below measure point = 3.5 feet above ground)

Date / Time (24-hr clock)	ZONE #1 (442 - 432 feet bgl)	ZONE #2 (419 - 399 feet bgl)	ZONE #3 (379 - 369 feet bgl)	ZONE #4 (354 - 334 feet bgl)	ZONE #5 (258 - 238 feet bgl)
1/05/07 13:05	261.42	261.48	261.68	261.79	unsaturated zone (installed to prove water table depth)
1/08/07 17:34	262.28	262.34	262.43	262.62	
1/18/07 10:07	263.30	263.34	263.42	263.60	
1/29/07 09:26	262.22	262.30	262.35	262.54	
4/30/07 11:39	262.62	262.63	262.71	262.90	
6/01/07 09:45	261.85	261.84	261.90	262.09	
7/03/07 09:54	262.34	263.74	263.81	263.99	
7/31/07 10:58	263.85	263.82	263.92	264.07	
8/30/07 10:01	263.93	263.95	263.96	264.18	
9/20/07 16:06	262.15	262.10	262.17	262.35	

Water levels recorded by Hydro Logic, Inc.

On site supervision, well design, pump test design, and water quality sampling by Hydro Logic, Inc., Boise, ID.
Direct mud-rotary drilling and well construction by Treasure Valley Drilling and Pump, Inc., Weiser, ID
Well development by McLeran Well Drilling, LLC, New Plymouth, ID.

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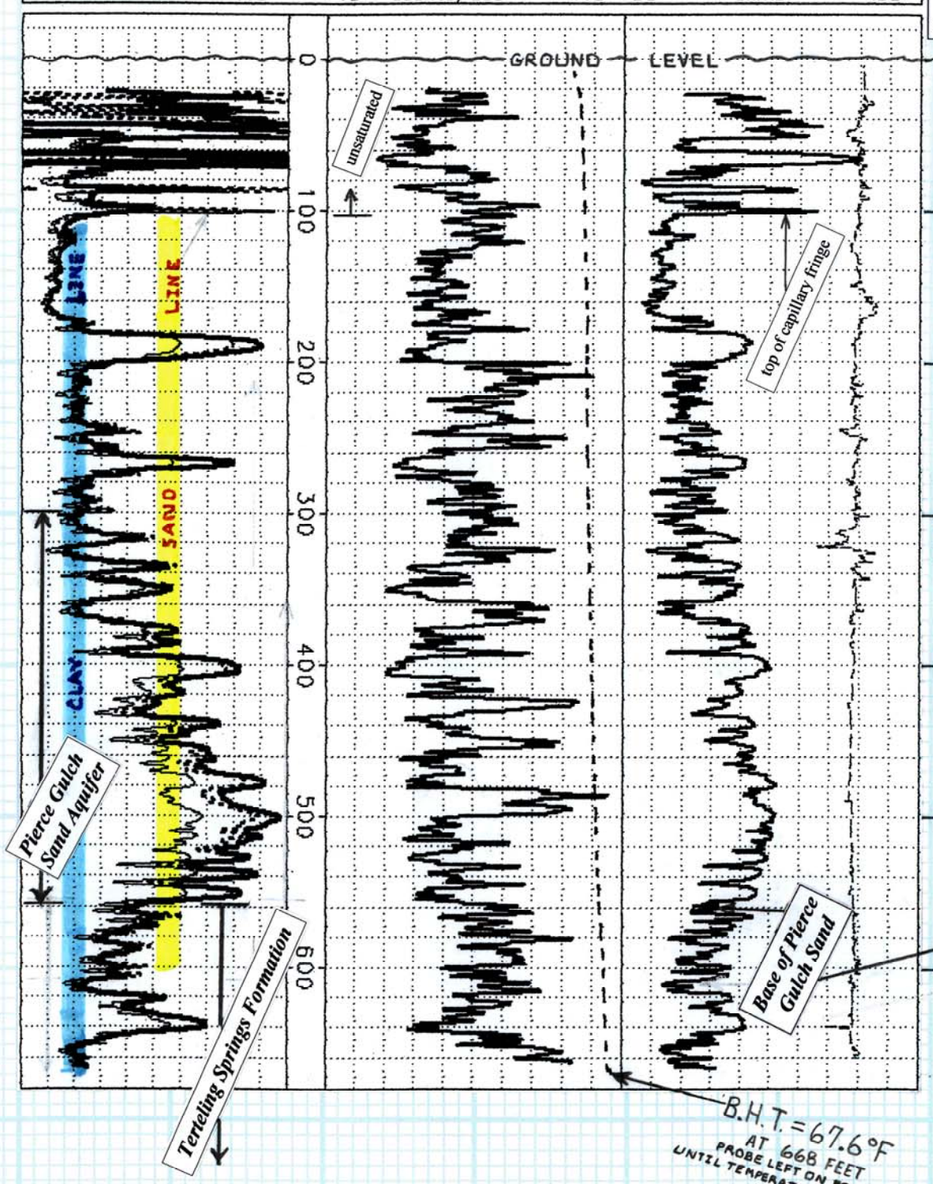
M3 Eagle - Test Well #4

T. 5 N., R. 1 W., Section 27, NW¼, SE¼, NE¼
Latitude 43° 44' 48.7" Longitude 116° 26' 14.6"
Well completed February 2008

Figure 13.

Geophysical Logs

Geophysics conducted by: Hydro Logic, Inc. on September 27, 2006 immediately after removal of drill steel

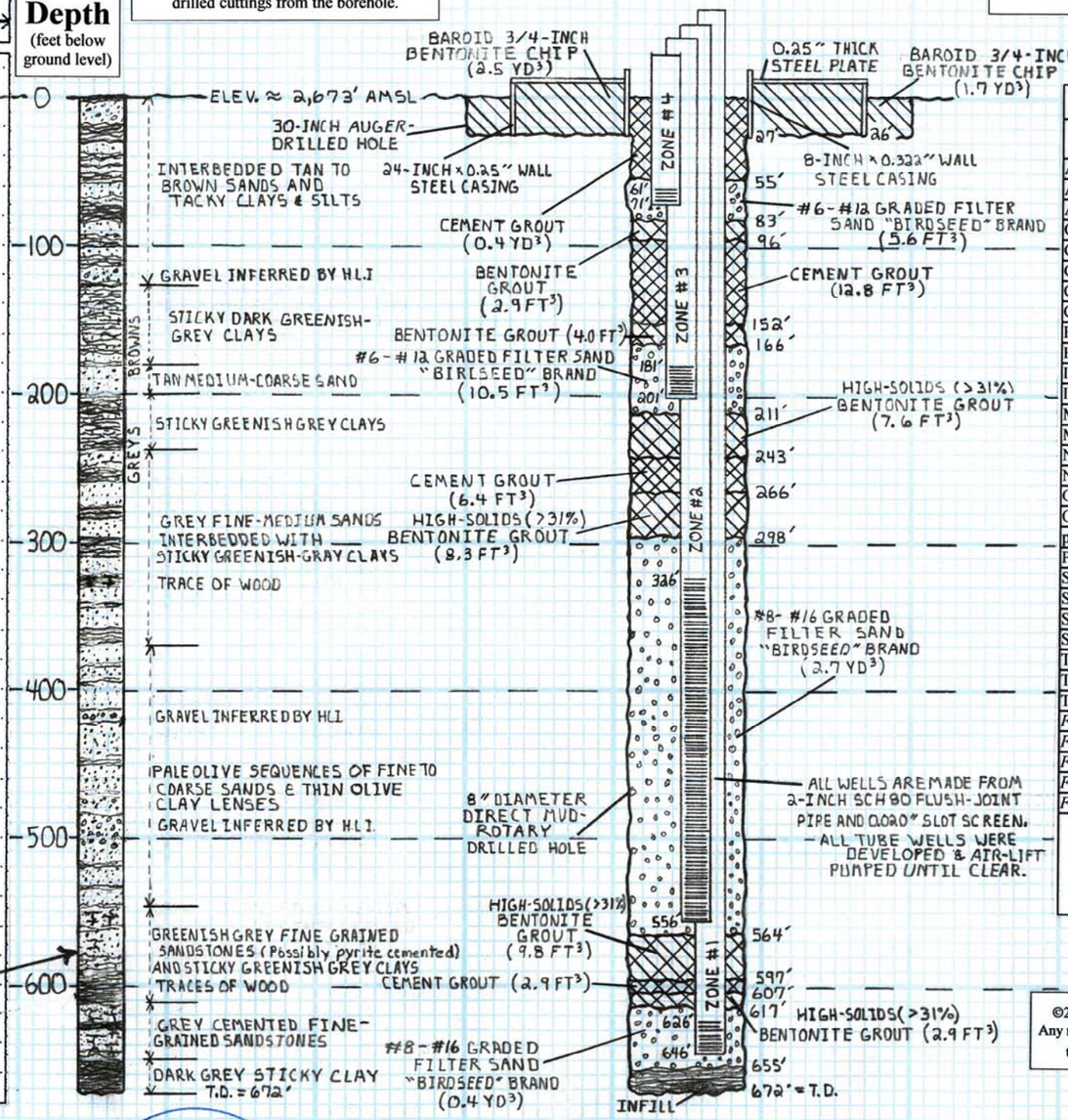


Lithology

Hydro Logic, Inc. lithologic log is interpreted and drawn from geophysical logs and drilled cuttings from the borehole.

As-Built Well Construction

(horizontal scale 0.1"=1.0")
(vertical scale 1"=100')



Ground Water Chemistry

Analysis (in mg/L unless noted)	ZONE #1 (646 - 626 ft bgl)	ZONE #2 (556 - 326 ft bgl)
Alkalinity	128.0	122.0
Ammonia as N	0.11	<0.01
Arsenic	0.0029	0.0066
Calcium as $CaCO_3$	83.9	81.0
Chloride	4.13	4.57
Color (apparent)	<1	<1
Conductivity (µS)	307.0	300.0
Corrosivity	-0.45	-0.46
Fluoride	0.48	0.43
Hardness	118.0	109.0
Iron (total)	0.31	0.02
Iron (dissolved)	0.27	0.01
Magnesium	8.33	6.81
Manganese (dissolved)	0.07	0.01
Nitrate as N	<0.10	0.39
Nitrite as N	<0.01	<0.01
Odor	<1	<1
Orthophosphate	0.104	0.133
pH - Lab (S.U.)	7.45	7.52
Potassium	2.52	2.28
Silica	37.2	32.5
Sodium	24.0	25.8
Sulfate	21.2	23.0
Sulfide	<0.05	<0.05
Total Dissolved Solids	225.0	223.0
Total Kjeldahl Nitrogen	0.11	<0.10
Total Organic Carbon	<1.0	1.00
Field Conductivity (µS)	*316 to 333*	*303 to 334*
Field Dissolved Oxygen	*0.09*	*2.26*
Field O.R.P. (mV)	*-122 to -105*	*+99 to +116*
Field pH (S.U.)	*7.48 to 7.64*	*7.53 to 7.70*
Field Temperature (°F)	*68.9*	*64.6*

Water samples and field parameters collected on April 3, 2008 by Hydro Logic, Inc.
Each field parameter (except DO) was acquired with two separate calibrated meters to validate measurements.
Analyses by Alchem Laboratories, Inc., Boise, ID

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On site supervision, well design, pump test design, and water quality sampling by Hydro Logic, Inc., Boise, ID.
Direct mud-rotary drilling and well construction by Treasure Valley Drilling and Pump, Inc., Weiser, ID
Well development by McLeran Well Drilling, LLC, Fruitland, ID

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NOTES: ALL GROUTS PUMPED FROM THE BOTTOM UP THROUGH TREMIE AND TAGGED INTO PLACE.
ALL BENTONITE GROUTS CONTAIN GREATER THAN 31% SOLIDS BY WEIGHT.
ALL CEMENT GROUTS WERE MADE WITH 6 GALLONS OF WATER MIXED WITH 94 POUNDS OF PORTLAND CEMENT.

drafted March 2008
by Loren Pearson

Water Levels

(feet below measure point = 3.5 feet above ground)

Date / Time (24-hr clock)	ZONE #1 (646 - 626 ft bgl)	ZONE #2 (556 - 326 ft bgl)	ZONE #3 (201 - 181 ft bgl)	ZONE #4 (61 - 71 ft bgl)
3/07/08 18:31	130.25	130.72	134.76	unsaturated zone (installed to confirm vadose zone)
3/14/08 17:12	130.25	130.73	134.20	
3/20/08 12:27	130.32	130.79	134.49	
3/22/08 18:12	130.43	130.92	134.74	
3/31/08 14:51	130.11	130.60	134.56	

Water levels recorded by Hydro Logic, Inc.

M3 Eagle - S.V.R. Well #9

T.5.N R.1E. Section 19, SW¼, NE¼

Latitude N43° 45' 33.3" Longitude W116° 22' 52.1"

Completed June 2004

Figure 14.

Geophysical Log

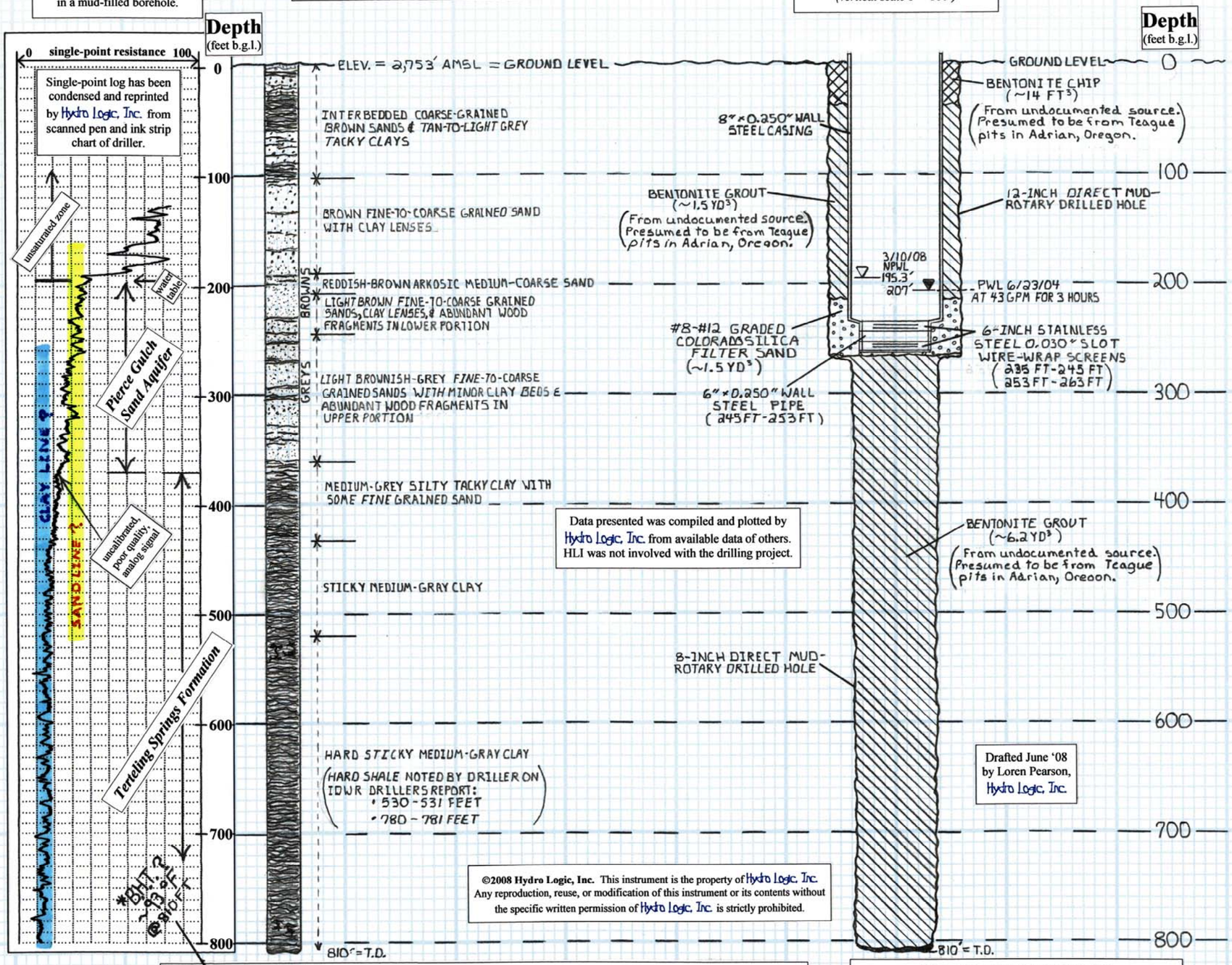
(June 2004)
by Stevens and Sons Drilling
in a mud-filled borehole.

Lithology

Feast Geosciences lithologic log was developed from drilled cuttings. Lithology has been reinterpreted and readjusted below 120 feet to better fit with HLI's interpretation of the geology and the geophysical log.

As-Built Well Construction

(horizontal scale 0.1"=1.0")
(vertical scale 1"=100')



Data presented was compiled and plotted by Hydro Logic, Inc. from available data of others. HLI was not involved with the drilling project.

Drafted June '08 by Loren Pearson, Hydro Logic, Inc.

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* SPF report of 10-13-2004 states:
"The driller measured the bottom-hole temperature (at 810 feet below ground surface) by running a bit to the bottom of the borehole, then pulling up and measuring the temperature of a chunk of clay attached to the bit. He recorded a temperature of 93°F in the clay. The actual temperature of the clay is probably higher (but cooled as the bit was retracted to ground surface)."

On site supervision and well design by:
SPF Water Engineering and Feast Geosciences, LLC, Boise, ID.
Direct mud-rotary drilling and well construction by:
Stevens and Son Drilling Co., Nampa, ID

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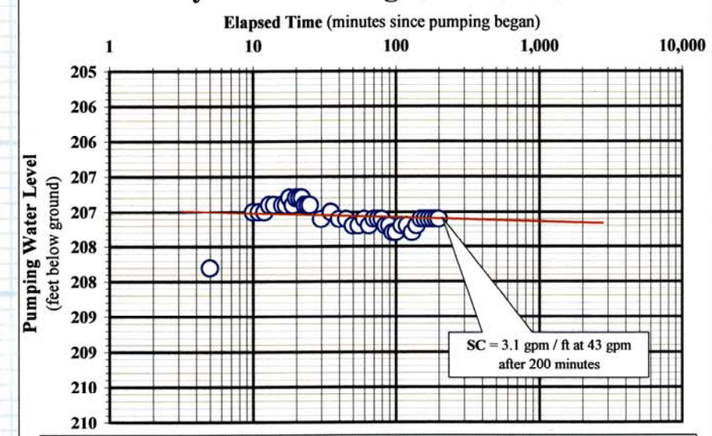
Ground Water Chemistry

Lab Analyses (note: all samples with 0.45µm filter prior to analysis except sulfide)	SPF Water Engineering Results (in mg/L unless noted) SCREENED (235 - 263 feet bgl)
Ammonia as N	0.10
Antimony	<0.005
Arsenic	<0.005
Barium	0.10
Beryllium	<0.0005
Bicarbonate	107
Cadmium	<0.0005
Calcium as $CaCO_3$	24.9
Chloride	10
Chromium	<0.002
Conductivity (µS)	336
Fluoride	0.45
Hardness	102
Iron (dissolved)	0.60
Magnesium	10.4
Manganese	0.12
Mercury	<0.0002
Nickel	<0.02
Nitrate as N	<0.2
Nitrite as N	<0.01
pH (S.U.)	2.5
Potassium	2.0
Selenium	<0.005
Sodium	26.9
Sulfate	44
Sulfide (*unfiltered*)	<0.05
Thallium	<0.002
Total Dissolved Solids	216
Field Analyses	
Field Temperature (°F)	68

SPF samples collected on June 23, 2004 by Feast Geosciences. Analyses by Analytical Laboratories, Boise, ID

Hydraulic Testing - (June 23, 2004)



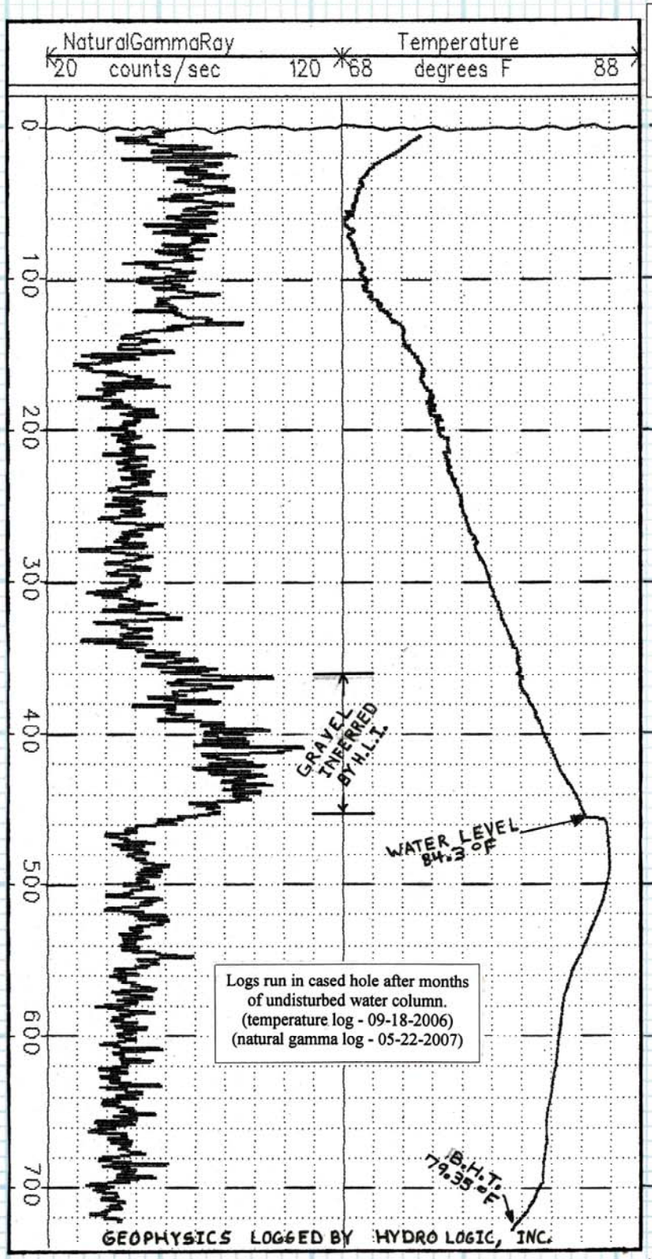
Non-Pumping Water Level = 193.3 feet below ground (09:10 hrs on 06/23/04)
Test conducted by Feast Geosciences and Stevens and Son Drilling Co.
Well was developed by pumping and surging according to SPF report.
Plotted by Hydro Logic, Inc.

M3 Eagle - S.V.R. Well #6

T5N R1W Section 13, SE¼, SE¼, NW¼
Latitude 43° 46' 19.8" Longitude 116° 24' 16.3"
Completed February 2004

Figure 15.

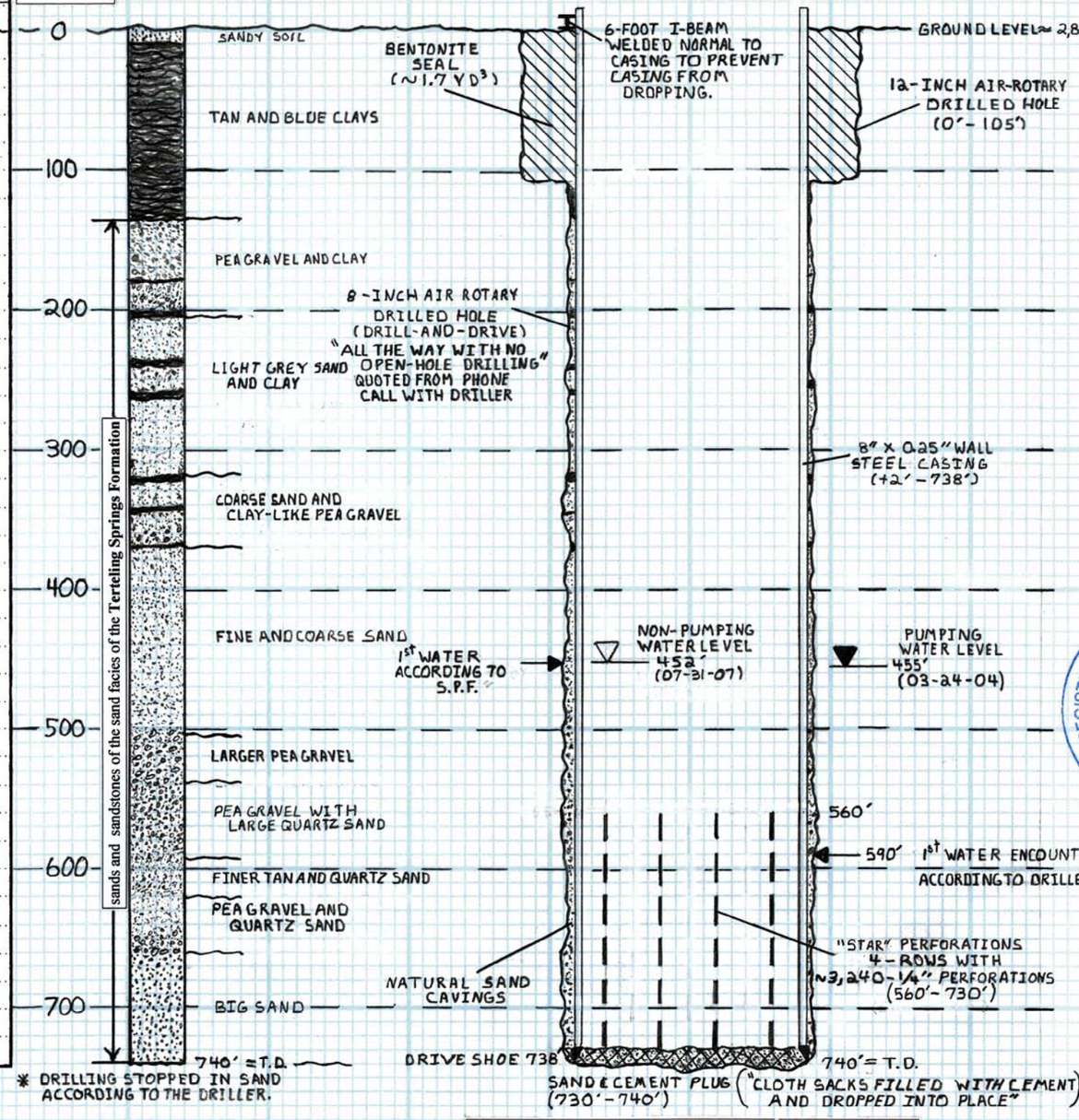
Geophysical Logs



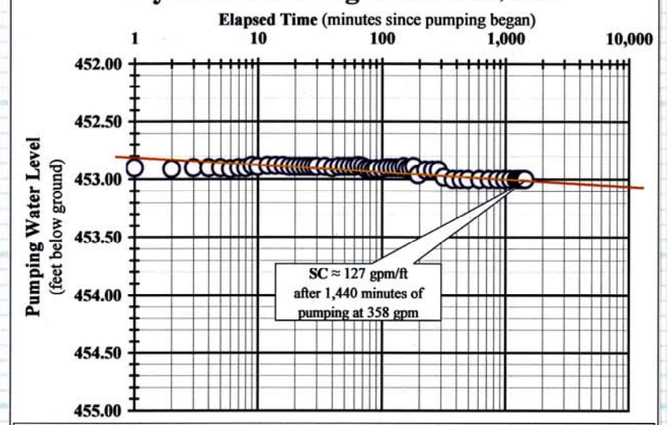
Depth
(feet below ground level)

Driller's Lithology
(from IDWR well log)

As-Built Well Construction
(horizontal scale 0.1"=0.5")
(vertical scale 1"=100')



Hydraulic Testing - March 23-24, 2004



Non-Pumping Water Level = 450.18 feet below ground (11:45 hrs on 03/23/04)
Test conducted by SPF Water Engineering, LLC and Adamson Pump & Drilling Co.
According to the driller, the well was not developed prior to pumping and is believed (HLI) to have been developing during the short-term test, imparting some uncertainty into the results.

Ground Water Chemistry

Lab Analyses	SPF Water Engineering Results (in mg/L unless noted)
	SCREENED (560 -730 feet bgl)
Alkalinity	58.8
Ammonia as N	0.13
Arsenic	0.067
Calcium as $CaCO_3$	9.71
Chloride	5
Conductivity (uS)	
Corrosivity	
Fluoride	0.95
Hardness	<5.0
Iron (total)	0.09
Magnesium	0.69
Manganese	<0.05
Nitrate as N	1.09
Nitrite as N	0.02
pH	
Potassium	1.5
Sodium	27.8
Sulfate	13
Sulfide	<0.05
Total Dissolved Solids	98
Field Analyses	
Field Conductivity (µS)	189.9
Field pH (S.U.)	7.67
Field Temperature (°F)	81.1

Water samples and field parameters collected on March 16, 2004 by SPF Water Engineering. Analyses by Analytical Laboratories, Boise, ID.

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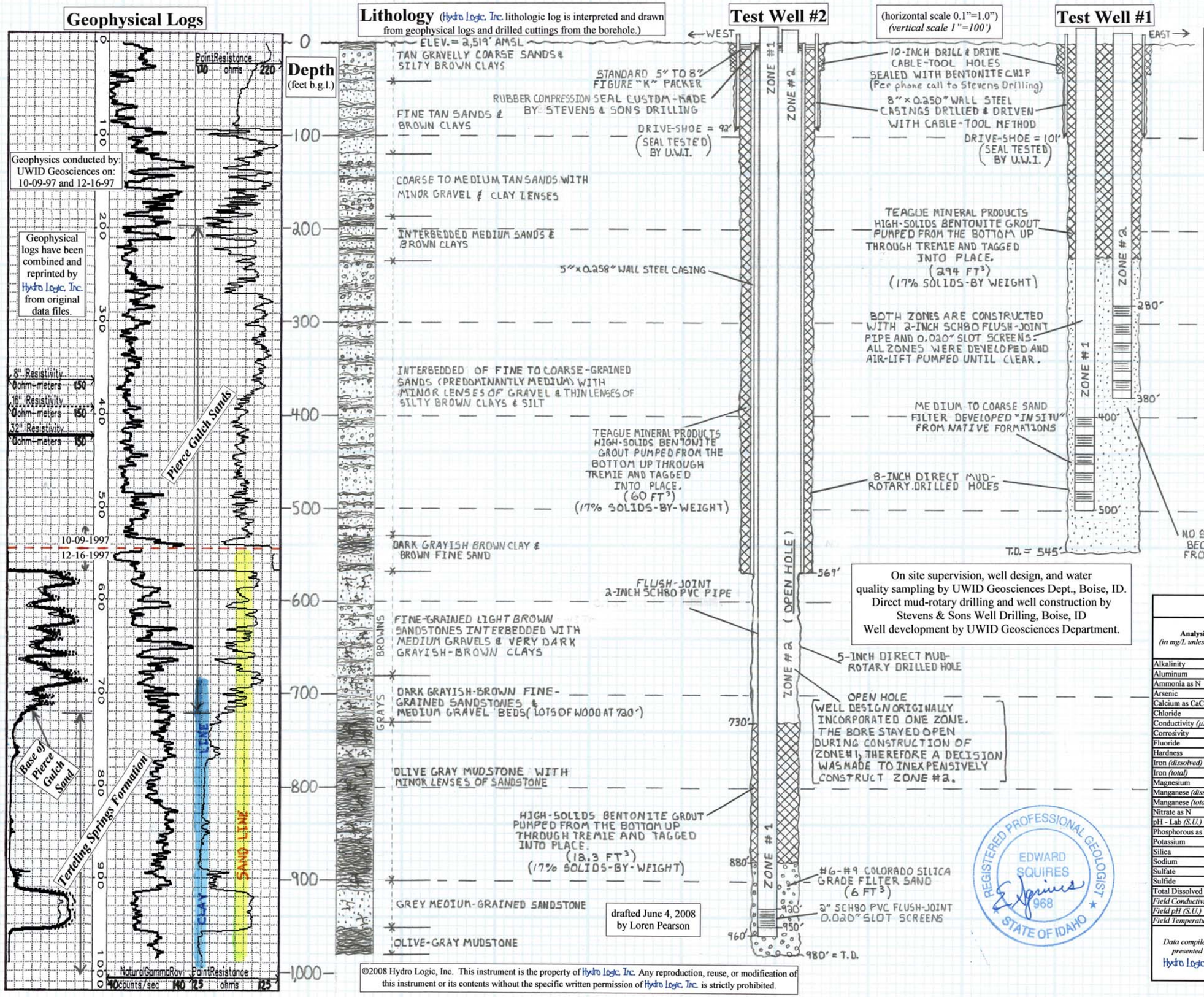
drafted August 15, 2007
by Loren Pearson,
Hydro Logic, Inc.

Well design, pump test design, and water quality sampling by SPF Water Engineering, LLC, Boise, ID
Air-rotary drilling, well construction, and pump testing by Adamson Pump & Drilling Co., Nampa, ID

Data compiled and plotted by Hydro Logic, Inc. from available data of others with the exception of the geophysical logs and a video inspection run in the completed well. HLI was not involved with the drilling project.



UWID State and Linder Test Wells #1 and #2

T. 5 N., R. 1 W., Section 15, NE¼, SE¼, SE¼
Latitude 43° 41' 39.9" Longitude 116° 24' 56.4"
Wells completed: Oct. 1997 and Dec. 1997

Figure 16.

On site supervision, well design, and water quality sampling by UWID Geosciences Dept., Boise, ID. Direct mud-rotary drilling and well construction by Stevens & Sons Well Drilling, Boise, ID. Well development by UWID Geosciences Department.

drafted June 4, 2008 by Loren Pearson

Water Levels

(feet above ground level)

Date / Time (24-hr clock)	Test Well #1 ZONE #1 (490 - 400 feet bgl)	Test Well #1 ZONE #2 (370 - 280 feet bgl)	Test Well #2 ZONE #1 (950 - 920 feet bgl)	Test Well #2 ZONE #2 (730 - 569 feet bgl)
03/06/2007 14:54	14.07	13.96	39.67	13.84
04/30/2007 10:48	12.69	12.92	38.06	13.26
06/01/2007 08:45	11.53	11.76	36.90	12.22
07/03/2007 08:53	11.55	11.55	36.50	11.55
07/31/2007 09:46	10.40	10.40	36.50	11.55
08/30/2007 09:10	12.94	12.94	37.89	12.94
09/20/2007 17:23	12.00	12.00	37.42	12.00
11/28/2007 11:48	14.32	14.32	40.19	14.32
01/24/2008 11:42	14.09	13.86	39.73	14.78
03/04/2008 17:17	14.78	14.78	39.50	15.02
03/31/2008 11:55	14.32	14.32	38.81	14.32
05/09/2008 10:07	12.01	12.01	36.96	12.47

Water levels recorded by: Hydro Logic, Inc.

Ground Water Chemistry

Analysis (in mg/L unless noted)	Test Well #1 ZONE #1 (490 - 400 feet bgl) Alchem	Test Well #1 ZONE #1 Analytical	Test Well #1 ZONE #2 (370 - 280 feet bgl) Alchem	Test Well #1 ZONE #2 Analytical	Test Well #2 ZONE #1 (950 - 920 feet bgl) Alchem	Test Well #2 ZONE #1 Analytical	Test Well #2 ZONE #2 (730 - 569 feet bgl) Alchem	Test Well #2 ZONE #2 Analytical
Alkalinity	97.5	99.7	89.7	93.3	100.0	105	179.0	191.0
Aluminum						0.54		0.18
Ammonia as N		<0.04		<0.04		7.02		6.05
Arsenic		0.003		<0.003		0.005		0.004
Calcium as $CaCO_3$	27.3	28.3	25.2	25.6	24.7	24.5	24.0	23.6
Chloride	2.52	4	3.13	3	2.47	3	5.73	6
Conductivity (µS)	231.0	234	213.0	214	231.0	220	365.0	343
Corrosivity		-1.2		-1.2	-0.84	-1.5	-0.25	-0.4
Fluoride	0.34	0.52	0.38	0.52	0.48	0.48	0.29	0.31
Hardness	89.2	86.9	81.8	78.9	82.2	83.5	79.7	78.5
Iron *(dissolved)*	<0.01	<0.05	<0.01	<0.05	0.38	0.32	0.17	0.14
Iron *(total)*	<0.01	<0.05	<0.01	<0.05	2.04	0.86 (0.23)	0.18	0.14 (28.6)
Magnesium	5.10	4.97	4.60	4.32	4.99	5.20	4.82	4.79
Manganese *(dissolved)*	<0.01	<0.05	<0.01	<0.05	0.02	<0.05	0.11	0.10
Manganese *(total)*	<0.01	<0.05	<0.01	<0.05	0.05	<0.05 (0.10)	0.11	0.10 (0.26)
Nitrate as N	0.12	0.18	<0.10	0.12	<0.10	0.11	<0.10	<0.10
pH - Lab *(S.U.)*	7.00	6.9	7.05	7.0	7.35	7.6	7.60	8.0
Phosphorous as P (total)	0.05	0.07	0.04	<0.05	0.14	0.05	0.13	0.14
Potassium	1.74	1.67	1.47	1.56	1.70	1.67	4.83	4.06
Silica	42.2	14.7	42.6	14.4	33.4	30.9	67.8	59.5
Sodium	15.0	16.6	13.6	15.0	15.5	15.8	38.8	35.5
Sulfate	16.6	17	14.9	14	15.1	16	<0.50	<1
Sulfide	<0.05		<0.05		<0.05		<0.05	
Total Dissolved Solids	98.0	94	128.0	82	148.0	144	235.0	204
Field Conductivity (µS)	*255*		*224*		*345*		*242*	
Field pH (S.U.)	*6.80*		*6.92*		*7.60*		*6.7*	
Field Temperature (°F)	*60.0*		*59.5*		*72.4*		*62.0*	
Data compiled and presented by: Hydro Logic, Inc.	Water samples and field parameters collected on 10-27-97 and 08-28-00 by UWID Geosciences Department. Analyses by Alchem Laboratories, Boise, ID				Water samples and field parameters collected on 02-16-98 and 08-28-00 by UWID Geosciences Department. Analyses by Alchem Laboratories, Boise, ID *Note: entries that show x.xx (x.xx) are retests of the same analyte in Aug. 2000.*			

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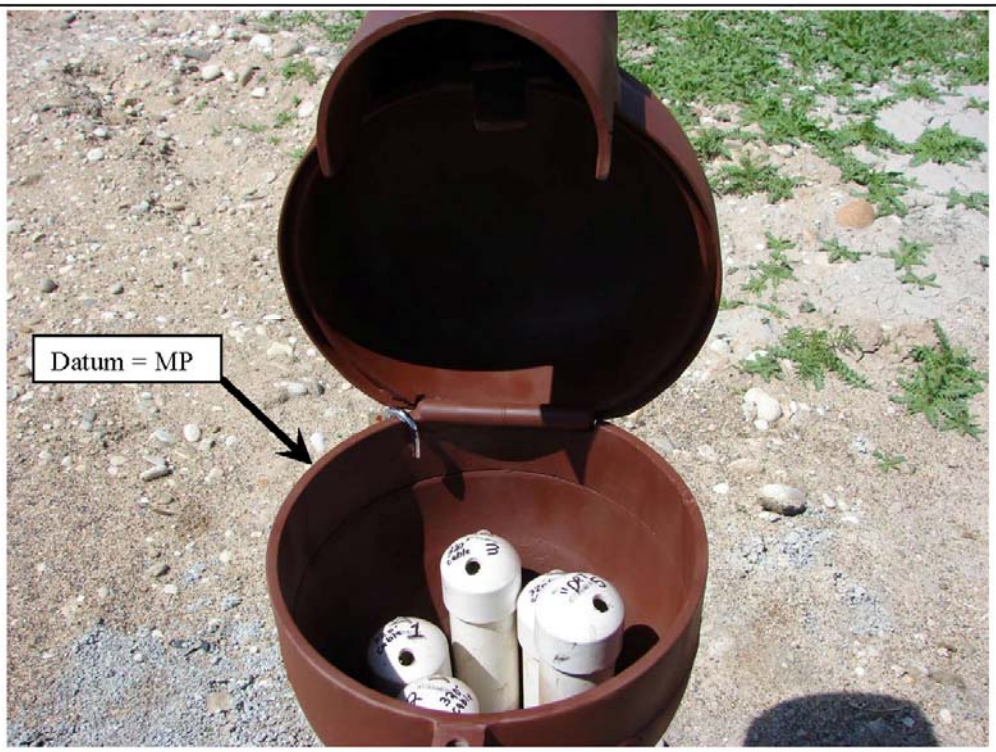
Figure 17. Well Development, Wellhead Shelter, and Small-Diameter Wells within a Single Borehole

May, 2007 site photograph of McLeran Well Drilling conducting well development of five 2-inch tube wells of the M3 Eagle Test Well #1 prior to sampling and water level monitoring. Air-lift pumping, in concert with swab-surge development with mud-dispersant is employed until pumped water is clear, sand-free, and field-measured geochemistry parameters are stabilized. All tubes equipped with digital pressure-transducer/data-loggers for aquifer test.



Open lockable well head security shelter and piezometer tubes extending to five separate depths of the aquifer system. M3 Eagle Test Well #1. Drilled holes accommodate well tape.

Figure 18. Pump and Motor Assembly used in the SVR #7 Test

"Shoehorning" a set of 8-inch diameter pump bowls into the 8-inch diameter steel cased SVR#7 Test Well with 133 HP motor, power cable and two 1-inch PVC monitoring tubes on 5-inch drop pipe for SVR#7 aquifer test.

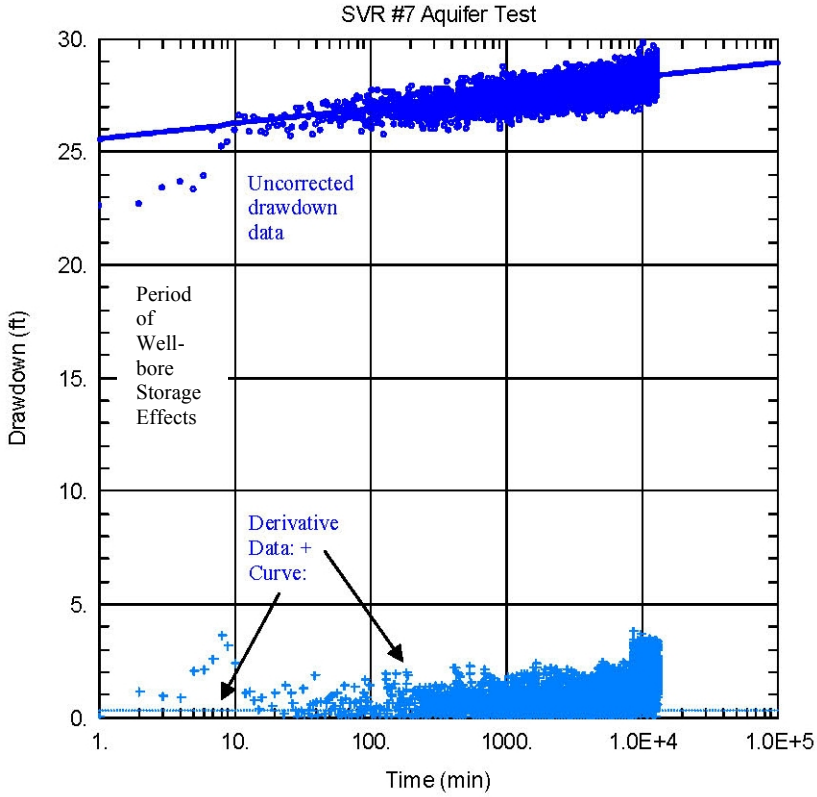
Discharge head of the SVR#7 Test Well in March of 2008 showing well head configuration with two 1-inch PVC monitoring tubes and the submersible power cable protruding from well before start of aquifer

Figure 19. SVR #7 Test - Discharge Pond and Orifice Weir

March 2008 site photograph showing 8-inch diameter discharge piping of the SVR#7 Test Well with propeller-type flow-meter and control valve. Site fencing in progress to deter range cows from well head, generator-set, & measurement equipment during the 9-day aquifer test.

March 2008 site photograph of the circular orifice weir discharge for the SVR#7 nine-day constant-rate aquifer test. 8-inch pipe/6-inch plate weir discharging 917 gpm to stock pond.

Figure 20. Cooper-Jacob Analysis for Well SVR #7



Screen = 279-349 ft bgl
T=400,000 gpd/ft
S = Invalid
Kv/Kh=0.1
b = 340 ft
t_c < 1 min
r = 0.5ft
Q = 917gpm

Derivative analysis indicates method is valid for data after 20 min. Wide scatter of drawdown and derivative points the results of surging water levels well casing.

Partial penetration correction corrections not applied. Analysis likely underestimates transmissivity value without PP correction.

$T = 264Q/\Delta s$ Where:

T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid, is less than 1 minute.

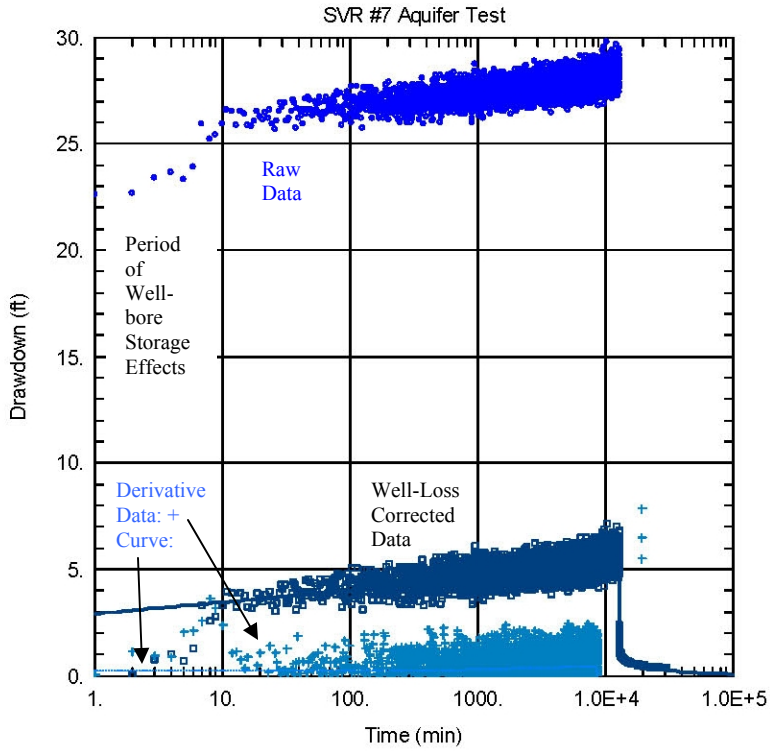
$u = 1.87r^2S/Tt$

t = time in days
r = effective radius of pumping well (ft)

b = aquifer thickness in feet (ft), calculated from geophysical log of well.

Based on the analytical method of Cooper and Jacob (1946).
No partial penetration corrections.

Figure 21. Theis Analysis for Well SVR #7



Screen = 279-349 ft bgl
T=450,000 gpd/ft
S = Invalid
Kv/Kh=0.1
b = 340 ft
r = 0.5ft
Q = 917gpm

Derivative analysis indicates method is valid for data after 20 min. Wide scatter of drawdown and derivative points the results of surging water levels in well casing.

Well-loss correction of 23 feet applied derived from back-calculated theoretical-drawdown based on observation well analysis. See text for details.

Linear vertical scale (drawdown) used to allow better curve fit to data and less-exaggerated derivative data plot.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

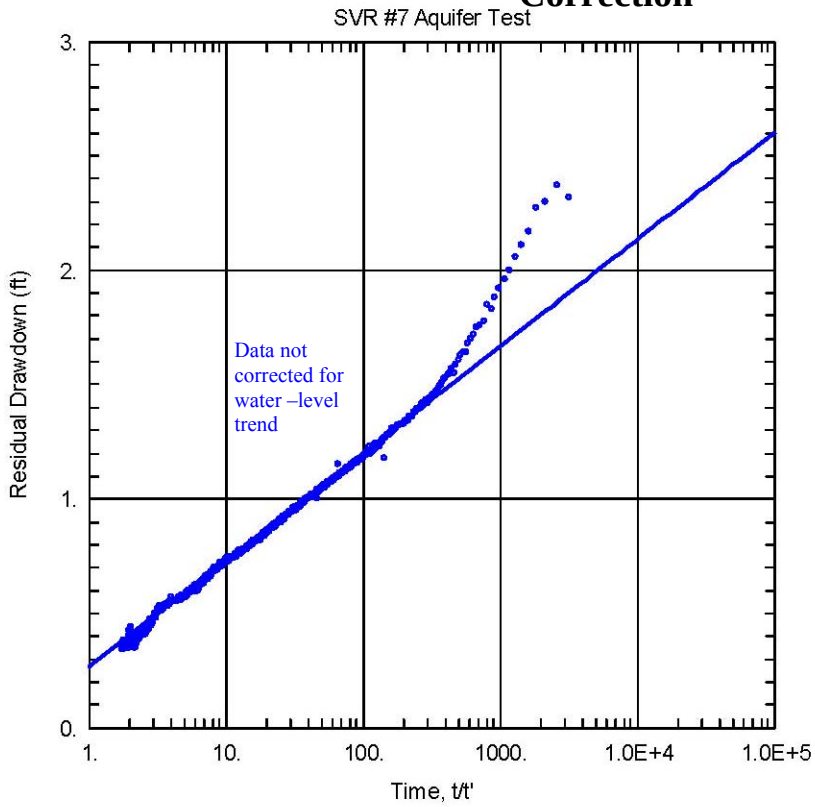
$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = effective radius of pumping well (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs, Well Driller's Reports and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown. Variations from "smooth," semi-log curve the result of Aqtesolv® generating type curve based on variations in reported pumping rate.

Based on the analytical method of Theis (1935) with partial penetration corrections of Hantush (1961a and b).

Figure 22. Theis Recovery Analysis for Well SVR #7 without Trend Correction



Screen = 279-349 ft bgl
T=520,000 gpd/ft
S/S' =0.3
Kv/Kh=0.1
b = 340 ft
r = 0.5 ft
Q = 917gpm

S/S' less than 1 suggests "late" or "incomplete" recovery, often indicative of an aquifer no-flow boundary, as is present beneath the M3 site (see green line in Figure 1). However, seasonal (declining), regional, water- level trend over 12 days of recovery is the likely cause of the apparent incomplete recovery, as demonstrated in Figure 16.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

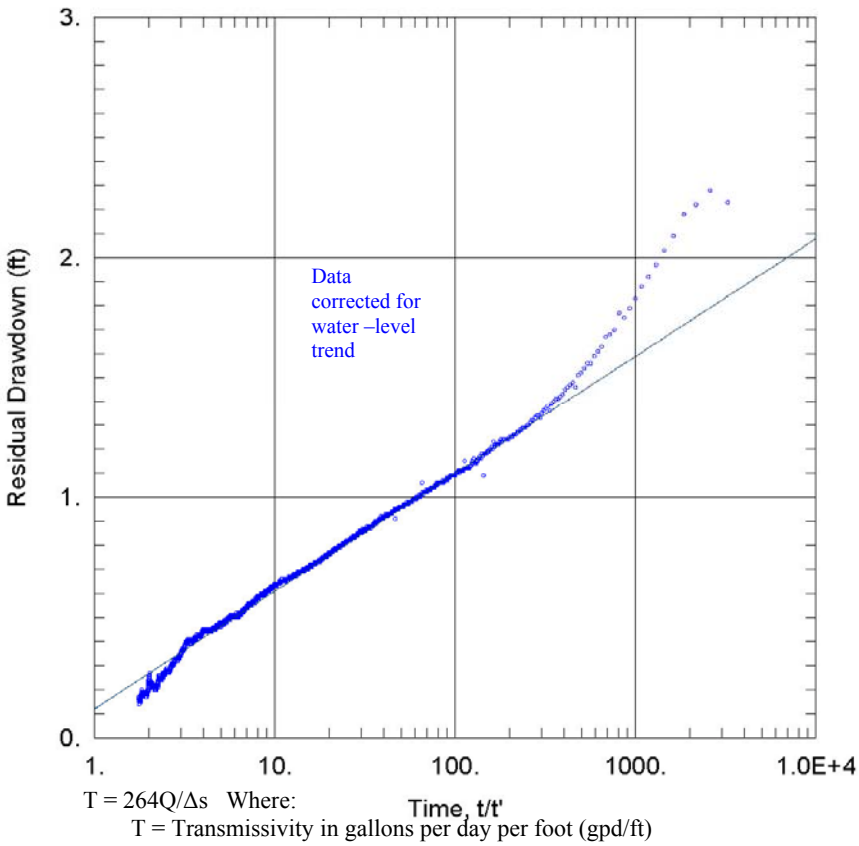
t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs, Well Driller's Reports and well logs in the area
r = effective radius of pumping well (ft)

Based on the analytical method of Theis (1935).

Figure 23. Theis Recovery Analysis for Well SVR #7 with Trend Correction



Screen = 279-349 ft bgl
T=490,000 gpd/ft
S/S' =0.6
Kv/Kh=0.1
b = 340 ft
r = 0.5 ft
Q = 917gpm

S/S' slightly less than 1 suggests "late" or "incomplete" recovery, however, projection of end of recovery data would likely intersect residual recovery = 0 at t/t' = 1, indicative of complete recovery. Data corrected for seasonal, regional, water-level trend of 0.009426 ft/day (declining) trend over period Feb 23-May 25, 2008. This correction allows recovery to project to near 0 at t/t' = 0

T = 264Q/Δs Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

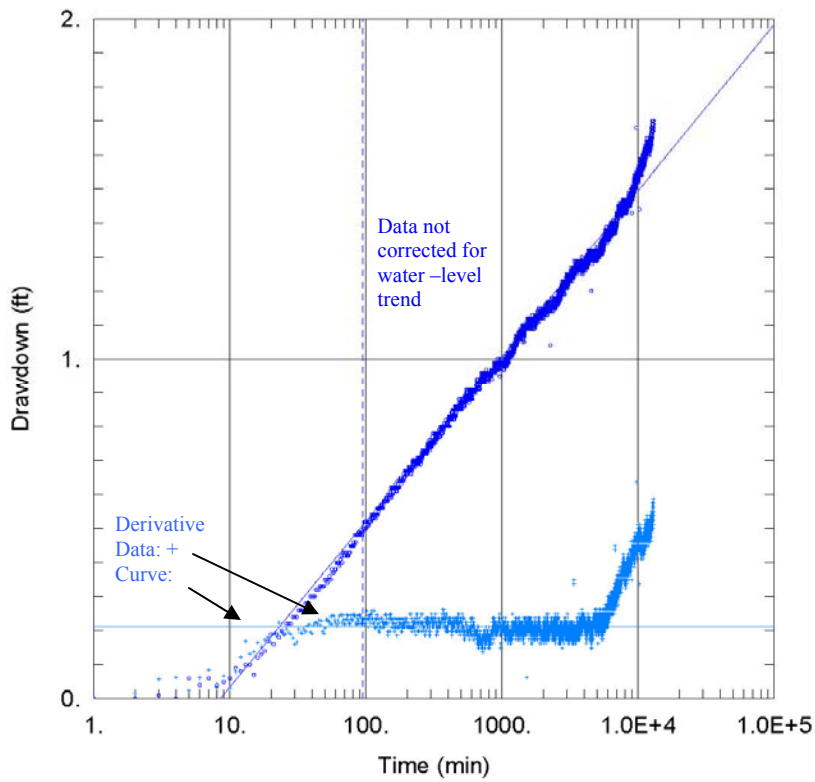
t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs, Well Driller's Reports and well logs in the area
r = effective radius of pumping well (ft)

Based on the analytical method of Theis (1935).

Figure 24. Cooper-Jacob Analysis for the Big Gulch Stock Well



Screen = 180 ft bgl (open hole)
T=500,000 gpd/ft
S = 1.2x 10^{-3}
Kv/Kh=0.1
b = 340 ft
t_c = 95 min
r = 845 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates method is valid for data between 100 and 6,000 min. Rise in apparent drawdown and derivatives after 6,000 minutes caused by declining regional aquifer water level trend. Data are uncorrected for this trend.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

t_c = critical time where "u assumption" is met (where u = 0.05) such that method may be valid, is 95 minutes as shown by dashed vertical line.

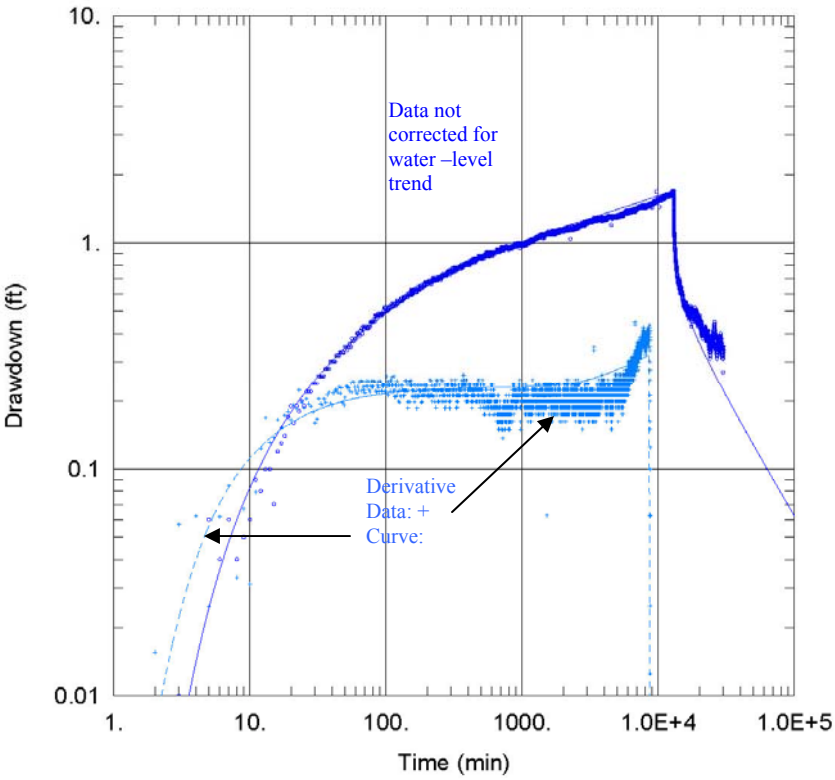
$u = 1.87r^2S/Tt$
t = time in days
r = distance to pumping well (ft)

b = aquifer thickness in feet (ft), estimated from geophysical log of well SVR #7.

Based on the analytical method of Cooper and Jacob (1946).

No partial penetration corrections needed because well is more than 2x aquifer thickness from pumping well.

Figure 25. Theis Analysis for the Big Gulch Stock Well



Screen = 180 ft bgl (open hole)
T=450,000 gpd/ft
S = 1.8x 10^{-3}
Kv/Kh=0.1
b = 340 ft
r = 845 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates method is valid for data between 100 and 5,000 min. Rise in apparent drawdown and derivatives after 6,000 minutes caused by declining regional aquifer water level trend. Data are not corrected for this trend.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

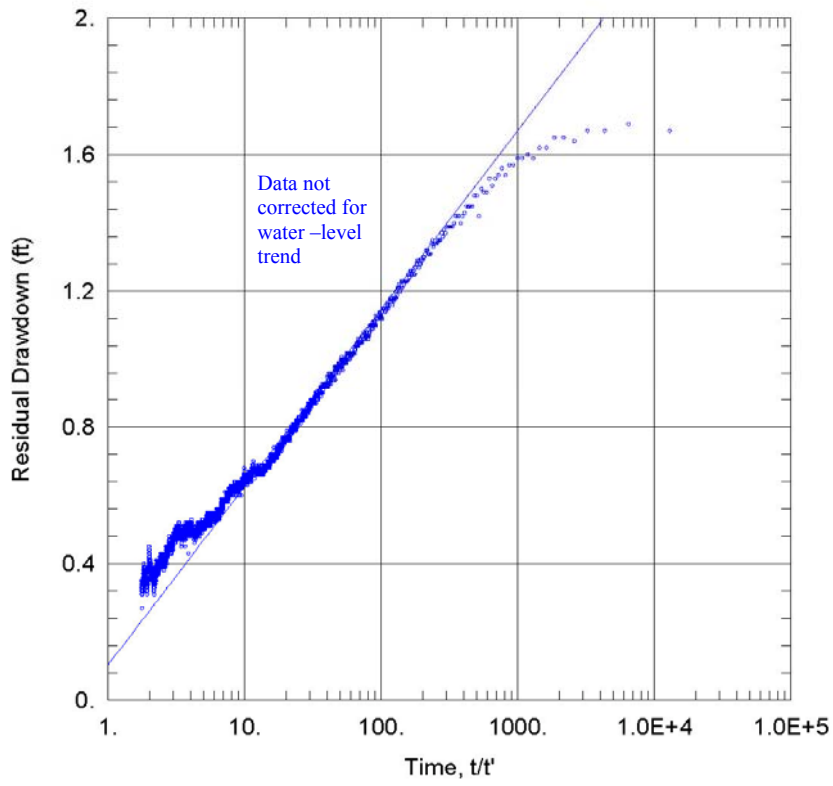
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical logs, Well Driller's Reports and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 26. Theis Recovery Analysis for the Big Gulch Stock Well with no Water-Level Trend Correction



Screen = 180 ft bgl (open hole)
T=450,000 gpd/ft
S/S' =0.6
Kv/Kh=0.1
b = 340 ft
r = 845 ft
Q = 917gpm (at SVR #7)

S/S' less than 1 suggests "late" or "incomplete" recovery. However, seasonal (declining), regional, water- level trend over 12 days of recovery is most probable cause of apparent incomplete recovery.

Partial penetration corrections neither needed nor applied.

$T = 264Q/\Delta s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

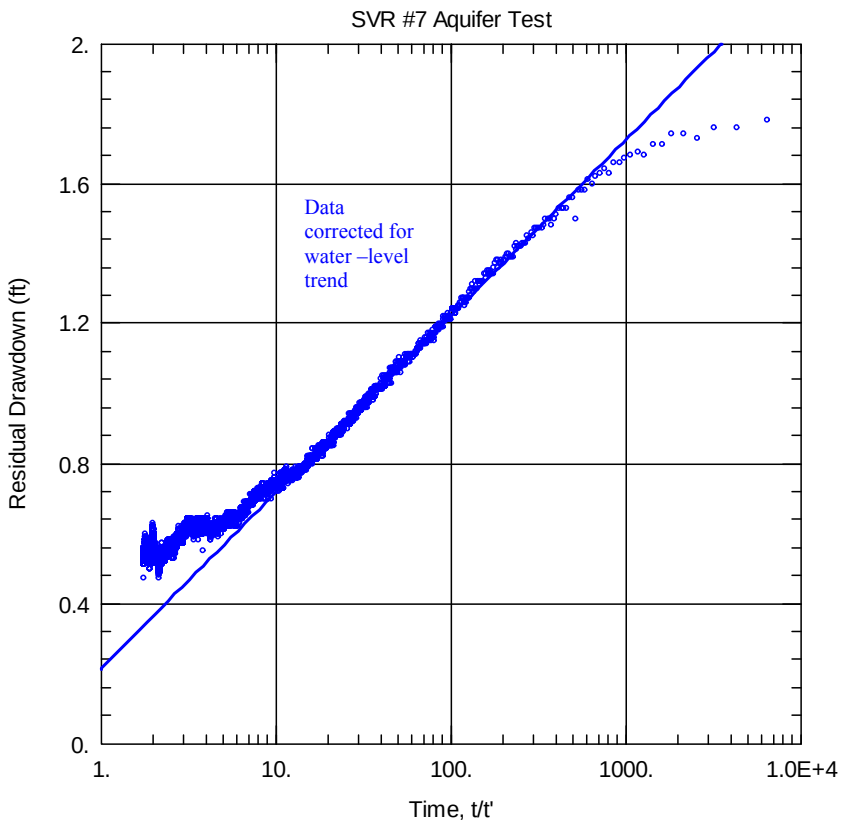
t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs, Well Driller's Reports and well logs in the area
r = distance to pumping well (ft)

Based on the analytical method of Theis (1935).

Figure 27. Theis Recovery Analysis for the Big Gulch Stock Well with Water-Level Trend Corrections



Screen = 180 ft bgl (open hole)
T=480,000 gpd/ft
S/S' =0.4
Kv/Kh=0.1
b = 340 ft
r = 845 ft
Q = 917gpm (at SVR #7)

S/S' less than 1 suggests "late" or "incomplete" recovery. However, incomplete correction for seasonal (declining), regional, water- level trend over 12 days of recovery is most probable cause of apparent incomplete recovery.

Partial penetration corrections neither needed nor applied.

T = 264Q/Δs Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
Δs = Change in drawdown of water level over one log cycle of time, in feet (ft)

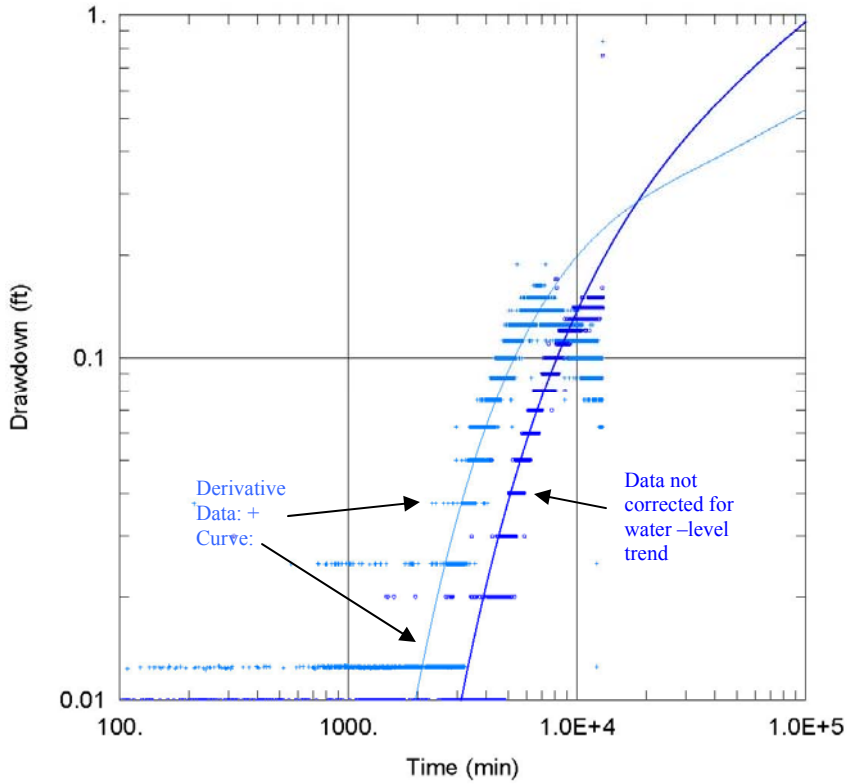
t = time since pumping started (minutes)
t' = time since pumping stopped (minutes)

S/S' = storativity ratio (unitless) where:
S/S' < 1 indicates no-flow boundary ("late" recovery)
S/S' = 1indicates no recharge or discharge boundaries ("normal" recovery)
S/S' >1 indicates recharge boundary ("early" recovery)

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), estimated from geophysical logs, Well Driller's Reports and well logs in the area
r = distance to pumping well (ft)

Based on the analytical method of Theis (1935).

Figure 28. Theis Analysis for the M3-TW #2 Zone 2 – No Trend Correction



Screen = 230-250 ft bgl
T=240,000 gpd/ft
S = 9.0x 10^{-2}
Kv/Kh=0.1
b = 300 ft
r = 3,636 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates method is valid for data between 2,000 and 7,000 min. Fall in apparent drawdown and derivatives after 6,000 minutes caused by end of rising regional aquifer water level trend. Data are uncorrected for this trend.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

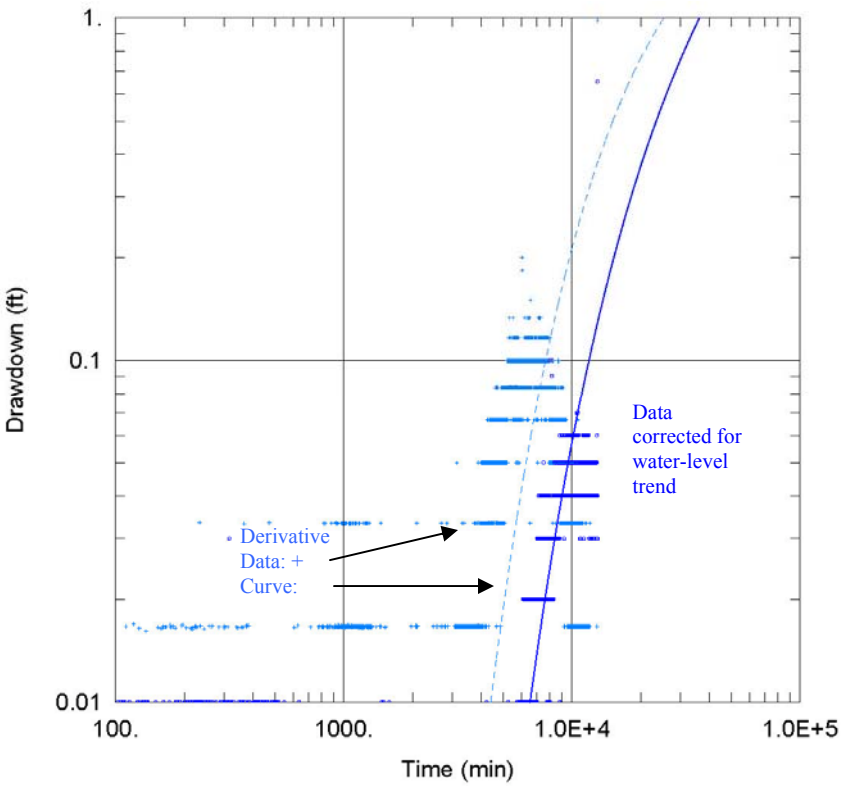
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), calculated from geophysical log of well.

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 29. Theis Analysis for the M3-TW #2 Zone 2 – With Trend Correction



Screen = 230-250 ft bgl
T=370,000 gpd/ft
S = 2.7x 10^{-2}
Kv/Kh=0.1
b = 300 ft
r = 3,636 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates method is valid for data between 2,000 and 5,000 min. Fall in apparent derivatives after 6,000 minutes may be caused in part by relatively large range for calculating derivative (0.4 log cycles) that extends beyond data collection period.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

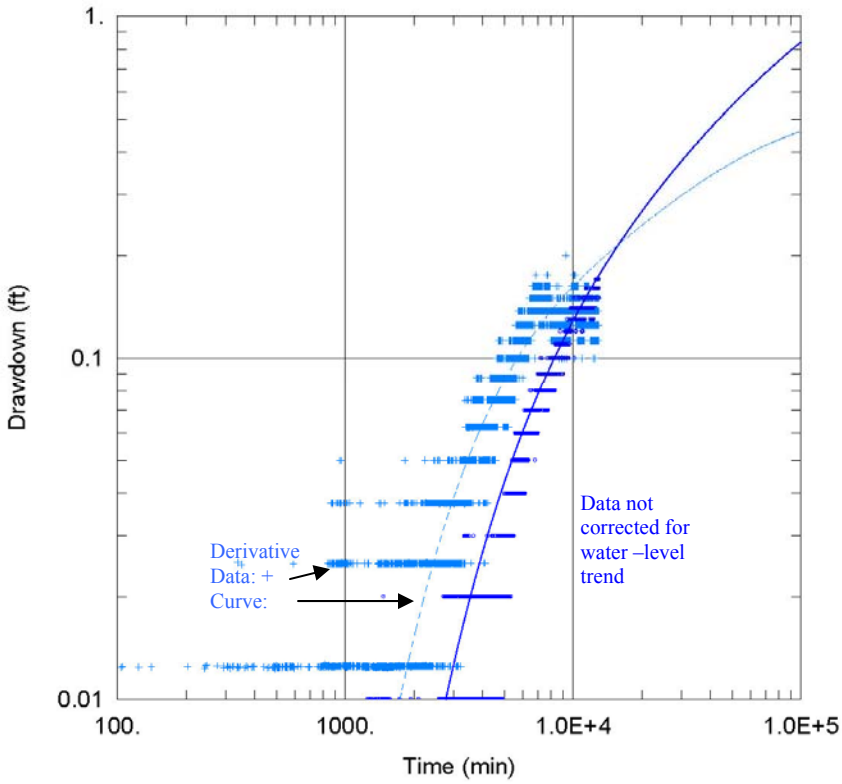
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), calculated from geophysical log of well.

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 30. Theis Analysis for the M3-TW #2 Zone 1 – No Trend Correction



Screen = 270-320 ft bgl
T=350,000 gpd/ft
S = 6.2x 10^{-2}
Kv/Kh=0.1
b = 300 ft
r = 3,636 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates method is valid for data between 2,000 and 7,000 min. Flattening in apparent drawdown and derivatives after 7,000 minutes caused by end of rising regional aquifer water level trend. Data are uncorrected for this trend.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

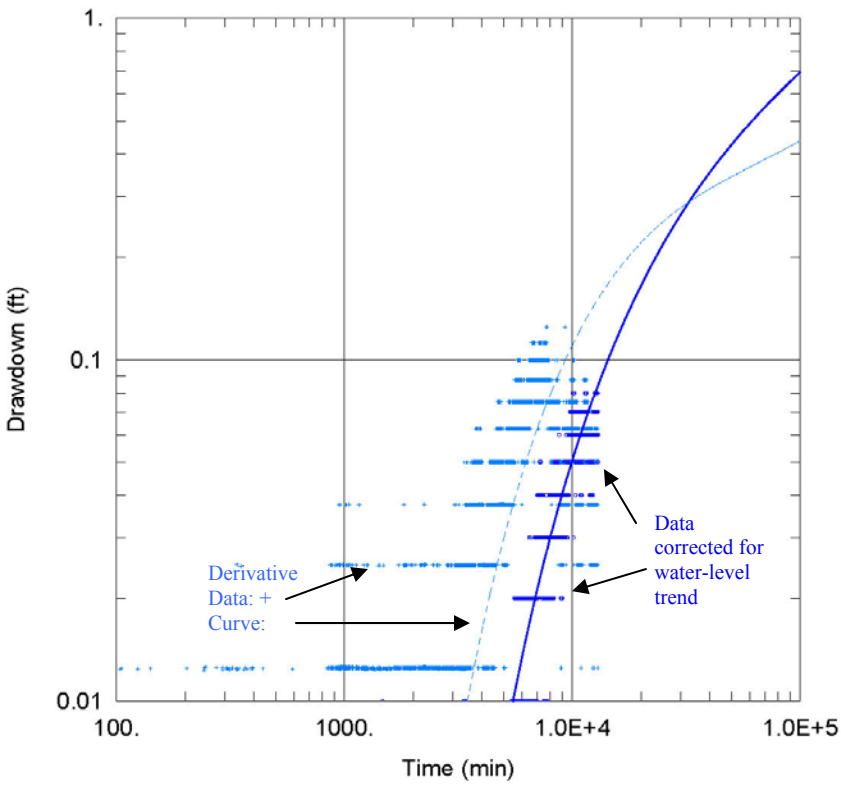
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), calculated from geophysical log of well.

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 31. Theis Analysis for the M3-TW #2 Zone 1 – With Trend Correction



Screen = 270-320 ft bgl
T=230,000 gpd/ft
S = 1.6x 10^{-1}
Kv/Kh=0.1
b = 300 ft
r = 3,636 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates method is valid for data for entire test. Data are corrected for seasonal aquifer water-level trend.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

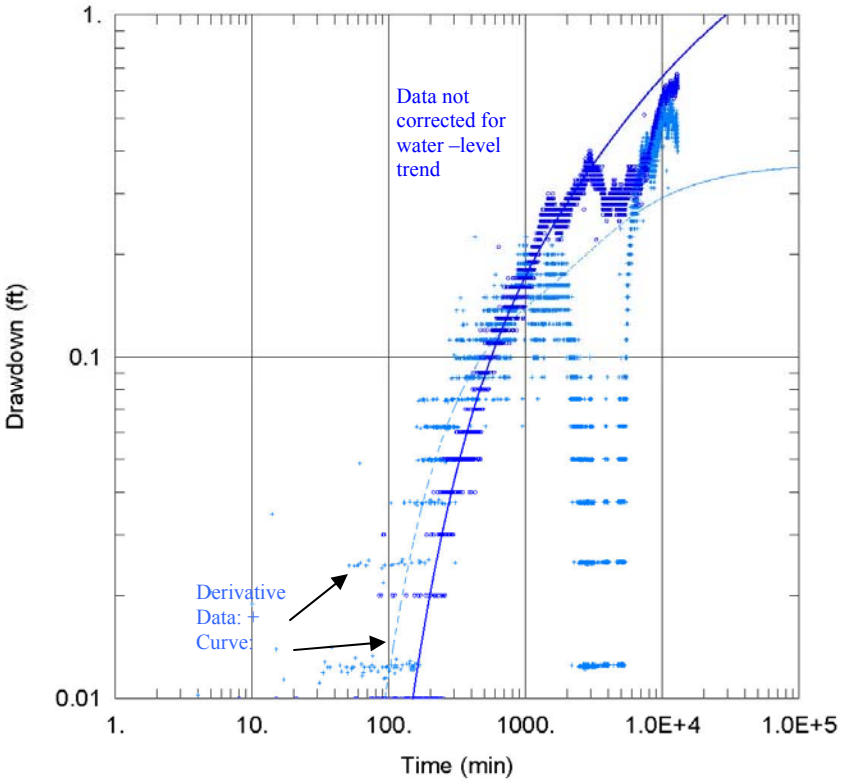
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), calculated from geophysical log of well.

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 32. Theis Analysis for the M3-TW #4 Zone 2 – No Trend Correction



Screen = 325-556 ft bgl
T=570,000 gpd/ft
S = 3.0x 10^{-3}
Kv/Kh=0.1
b = 260 ft
r = 4,489 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates method is valid for data from first 1,000 minutes of test. Afterward, incomplete barometric corrections and lack of water level trend corrections make analysis only approximate. Data are uncorrected for seasonal aquifer water-level trend.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

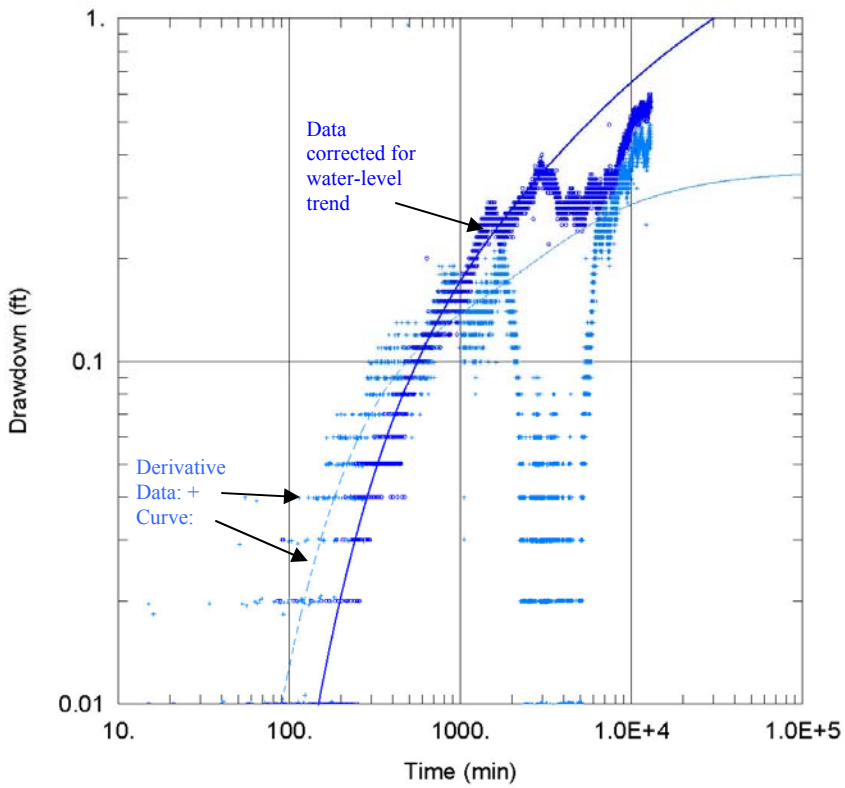
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), calculated from geophysical log of well.

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 33. Theis Analysis for the M3-TW #4 Zone 2 – With Trend Correction



Screen = 325-556 ft bgl
T=580,000 gpd/ft
S = 3.0x 10^{-3}
Kv/Kh=0.1
b = 260 ft
r = 4,489 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates method is valid for data from first 1,000 minutes of test. Afterward, incomplete barometric corrections and incomplete water level trend corrections make analysis only approximate. Data are corrected for seasonal aquifer water-level trend.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

W(u) = $1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

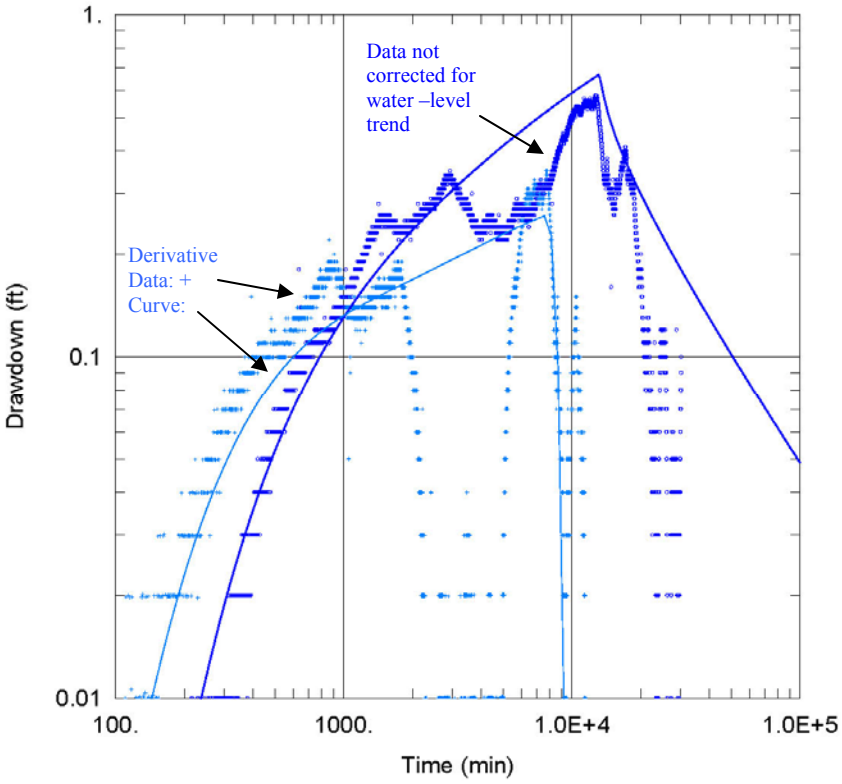
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), calculated from geophysical log of well.

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 34. Neuman-Witherspoon Analysis for the M3-TW #4 Zone 1 – as an Aquifer Separate from the PGSA, No Trend Correction

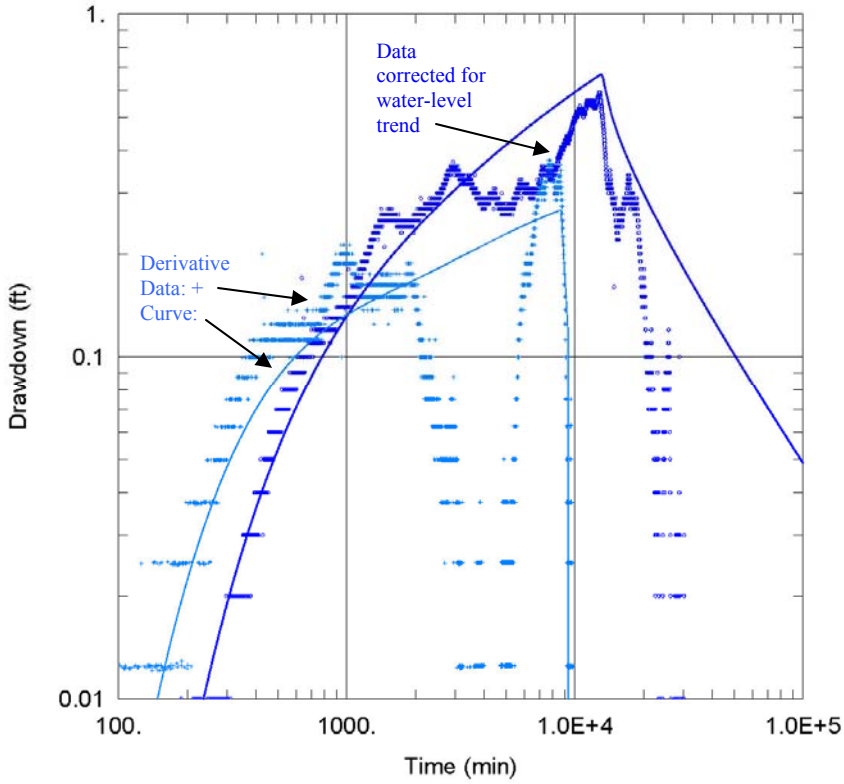


Screen = 625-646 ft bgl
T_{PGSA}= 500,000 gpd/ft
S_{PGSA} = 2.3x 10^{-3}
Kv/Kh=0.1
b_{PGSA} = 260 ft
$T_{zone\ 1}$= 80,000 gpd/ft
$S_{zone\ 1}$ = 1 x 10^{-3}
$b_{zone\ 1}$ = 30 ft
$b_{aquitard}$ = 30 ft
r = 4,489 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates only fair match for method. After 200 minutes, incomplete barometric corrections and incomplete water level trend corrections make analysis only approximate. Data are not corrected for seasonal aquifer water-level trend.

Based on the analytical method of Neuman and Witherspoon (1972) derived from the original method of Theis (1935). Based on assumption of flow to the pumped aquifer, through a leaky aquitard, from a second aquifer. Flow through the aquitard is assumed to be vertical. See Appendix D for equations and illustrations.

Figure 35. Neuman-Witherspoon Analysis for the M3-TW #4 Zone 1 – As Aquifer Separate From PGSA, With Trend Correction

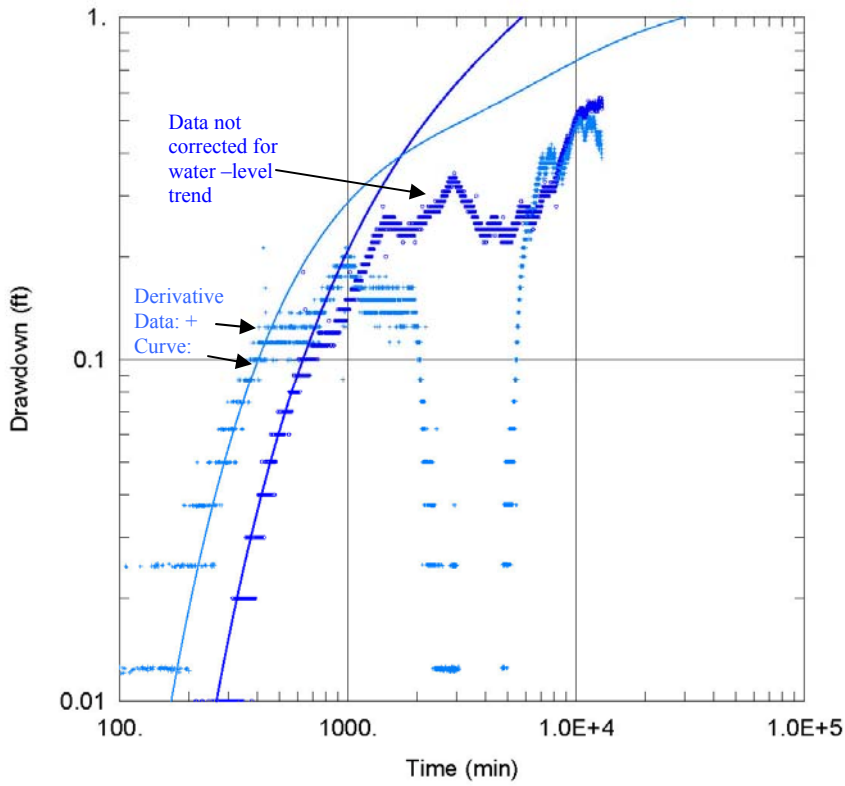


Screen = 625-646 ft bgl
T_{PGSA}= 500,000 gpd/ft
S_{PGSA} = 2.3x 10^{-3}
Kv/Kh=0.1
b_{PGSA} = 260 ft
$T_{zone\ 1}$= 80,000 gpd/ft
$S_{zone\ 1}$ = 1 x 10^{-3}
$b_{zone\ 1}$ = 30 ft
$b_{aquitard}$ = 30 ft
r = 4,489 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates only fair match for method. After 300 minutes, incomplete barometric corrections and incomplete water level trend corrections make analysis only approximate. Data are not corrected for seasonal aquifer water-level trend.

Based on the analytical method of Neuman and Witherspoon (1972) derived from the original method of Theis (1935). Based on assumption of flow to the pumped aquifer, through a leaky aquitard, from a second aquifer. Flow through the aquitard is assumed to be vertical. See Appendix D for equations and illustrations.

Figure 36. Theis Analysis for the M3-TW #4 Zone 1 – As a part of the PGSA, No Trend Correction



Screen = 625-646 ft bgl
T= 170,000 gpd/ft
S = 2.4x 10^{-1}
Kv/Kh=0.1
b = 260 ft
r = 4,489 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates method is valid for data from first 500 minutes of test. Afterward, incomplete barometric corrections and incomplete water level trend corrections make analysis only approximate. Data are not corrected for seasonal aquifer water-level trend.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

W(u) = $1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

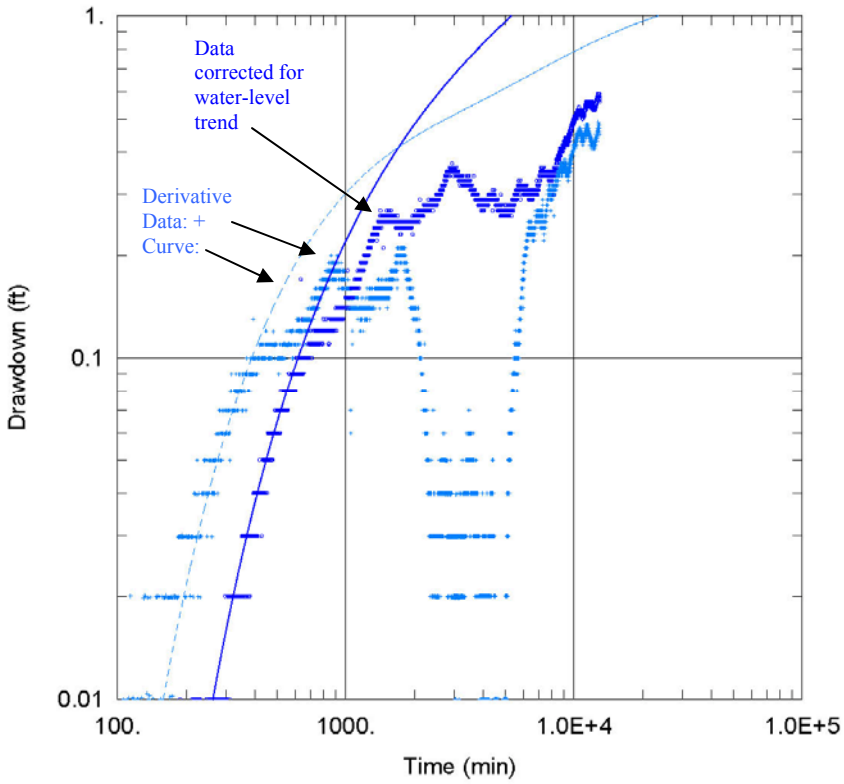
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), calculated from geophysical log of well.

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 37. Theis Analysis for the M3-TW #4 Zone 1 – As a part of the PGSA, With Trend Correction



Screen = 625-646 ft bgl
T= 160,000 gpd/ft
S = 2.4x 10^{-1}
Kv/Kh=0.1
b = 260 ft
r = 4,489 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates method is valid for data from first 500 minutes of test. Afterward, incomplete barometric corrections and incomplete water level trend corrections make analysis only approximate. Data are corrected for seasonal aquifer water-level trend.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

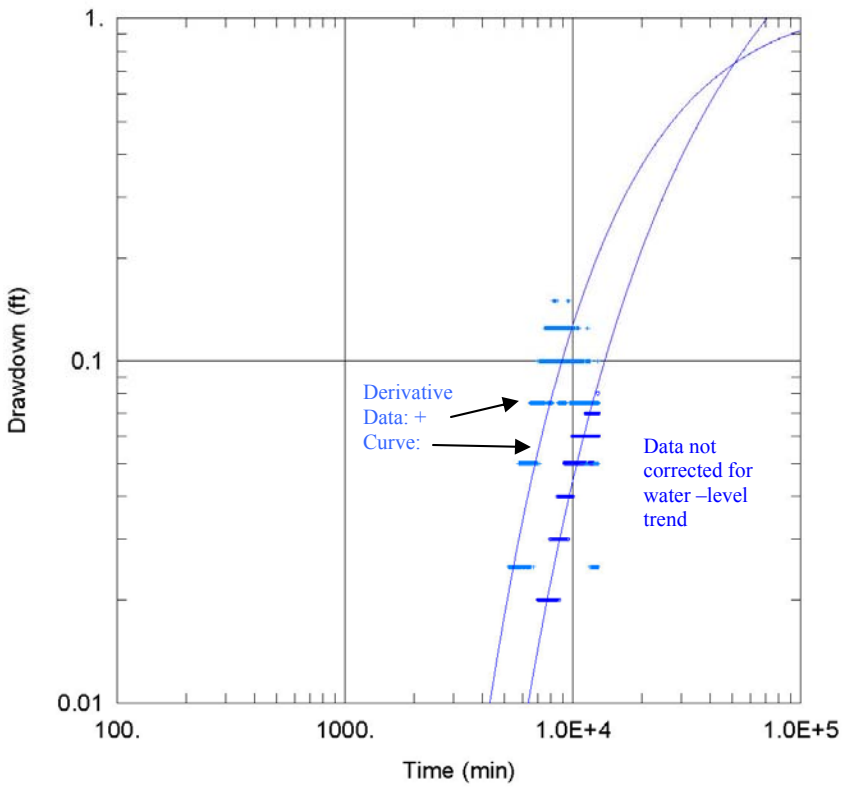
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), calculated from geophysical log of well.

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 38. Theis Analysis for the Little Gulch Stock Well – No Trend Correction



Screen = 220-223 ft bgl
T=180,000 gpd/ft
S = 1.3x 10^{-2}
Kv/Kh=0.1
b = 176 ft
r = 9,740 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates method is generally valid for data from first 8,000 minutes of test. However, small drawdown response and need to filter barometric effect make analysis only approximate. Data are not corrected for seasonal aquifer water-level trend.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

W(u) = $1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

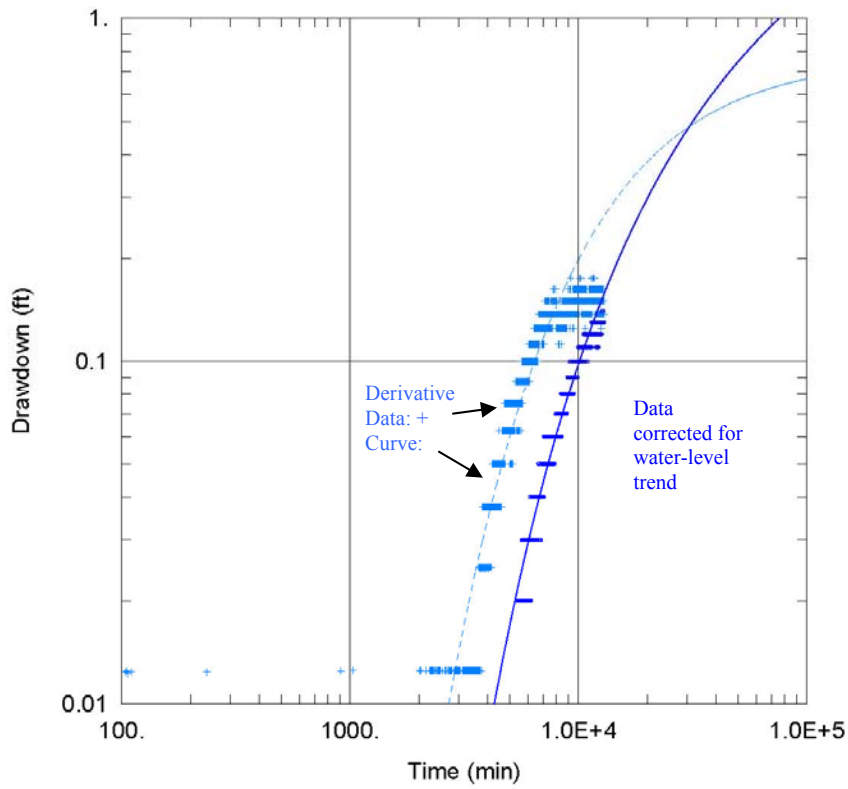
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), calculated from geophysical log of well.

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 39. Theis Analysis for the Little Gulch Stock Well – With Trend Correction



Screen = 220-223 ft bgl
T=270,000 gpd/ft
S = 1.1x 10^{-2}
Kv/Kh=0.1
b = 176 ft
r = 9,740 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates method is generally valid for data from first 8,000 minutes of test. Fit is better than analysis without trend correction. However, small drawdown response and need to filter barometric effect make analysis only approximate. Data are corrected for seasonal aquifer water-level trend.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

W(u) = $1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

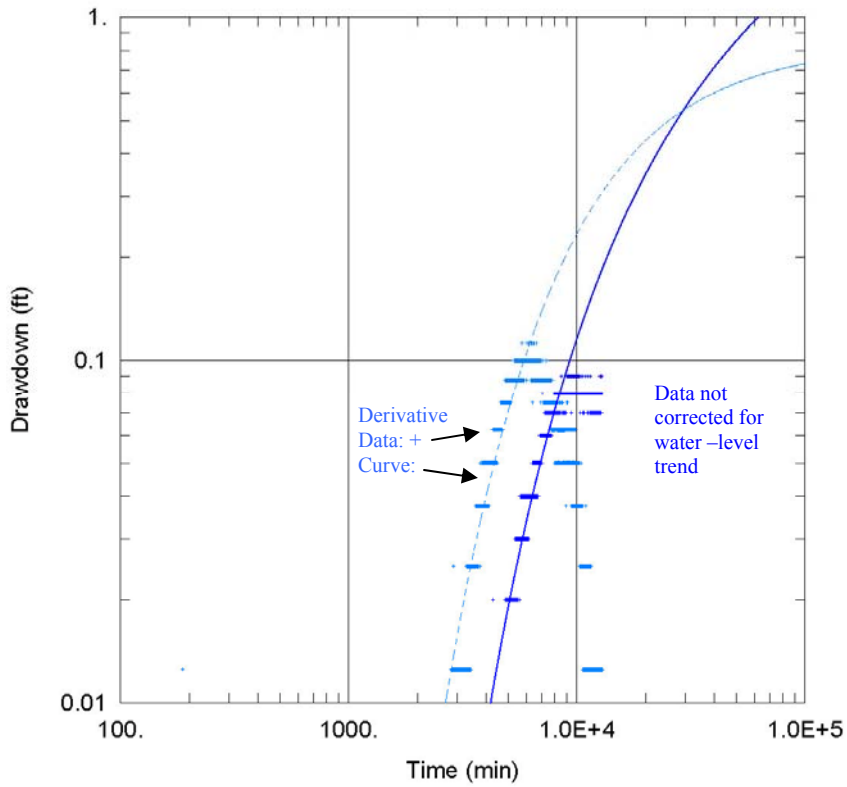
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical logs, Well Driller's Reports and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 40. Theis Analysis for Well SVR #9– No Trend Correction



Screen = 235-263 ft bgl
T = 250,000 gpd/ft
S = 8.7x 10^{-3}
Kv/Kh=0.1
b = 73 ft
r = 11,660 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates method is generally valid for data from first 6,000 minutes of test. However, small drawdown response and need to filter barometric effect make analysis only approximate. Data are not corrected for seasonal aquifer water-level trend.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

W(u) = $1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

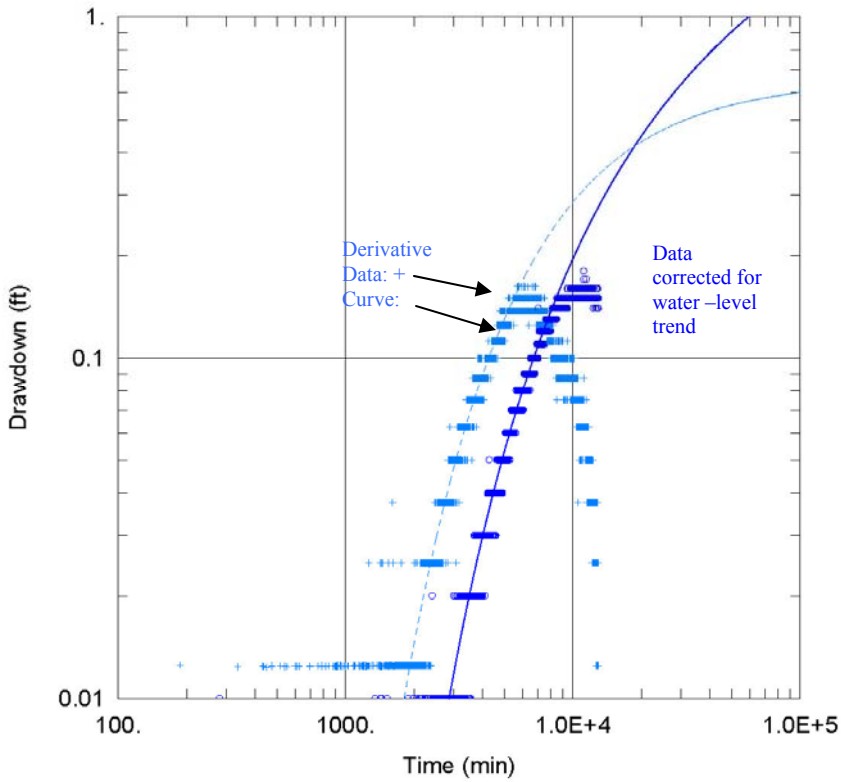
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), calculated from geophysical log of well.

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 41. Theis Analysis for Well SVR #9 – With Trend Correction



Screen = 235-263 ft bgl
T = 320,000 gpd/ft
S = 7.1x 10^{-3}
Kv/Kh=0.1
b = 73 ft
r = 11,660 ft
Q = 917gpm (at SVR #7)

Derivative analysis indicates method is generally valid for data from first 6,000 minutes of test. Fit is better than analysis without trend correction. However, small drawdown response and need to filter barometric effect make analysis only approximate. Data are corrected for seasonal aquifer water-level trend.

T = 114.6 Q W(u)/s Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

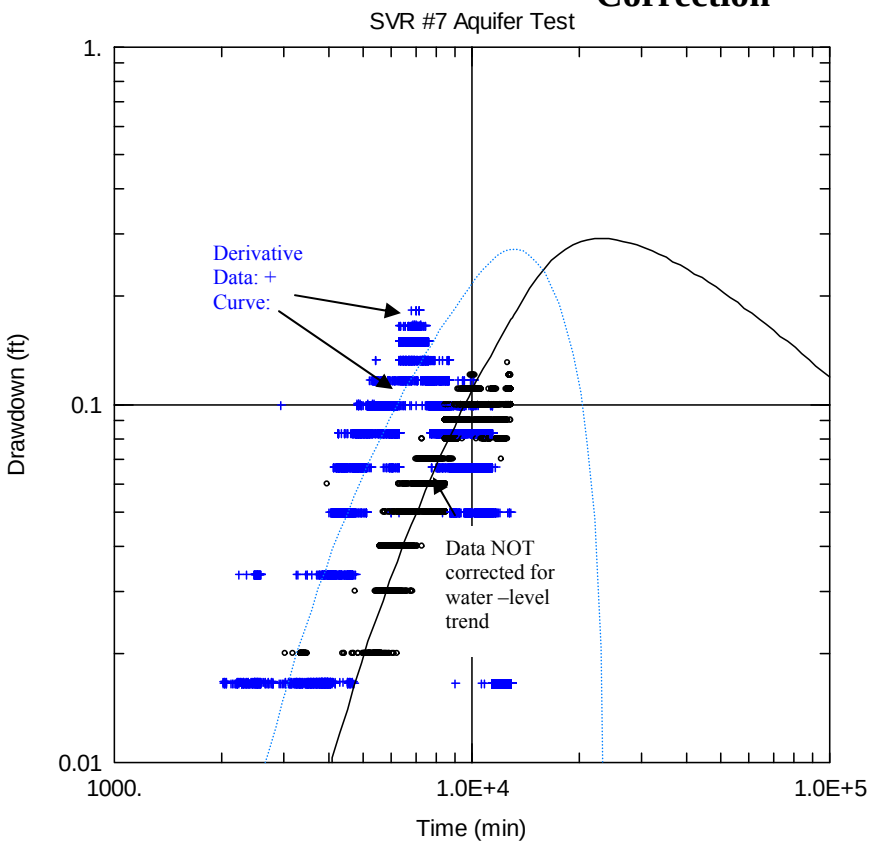
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), calculated from geophysical log of well.

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 42. Theis Analysis for Flack Corral 4-In Well without Trend Correction



Screen = ? ft bgl
T=200,000 gpd/ft
S =0.023
Kv/Kh=0.1
b = 300 ft
r = 5974 ft
Q = 917gpm

Derivative analysis indicates method is generally valid for data from first 6,000 minutes of test. Fit is better than analysis without trend correction. However, small drawdown response and need to filter barometric effect make analysis only approximate. Data are not corrected for seasonal aquifer water-level trend.

$T = 114.6\ Q\ W(u)/s$ Where:

T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:

S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

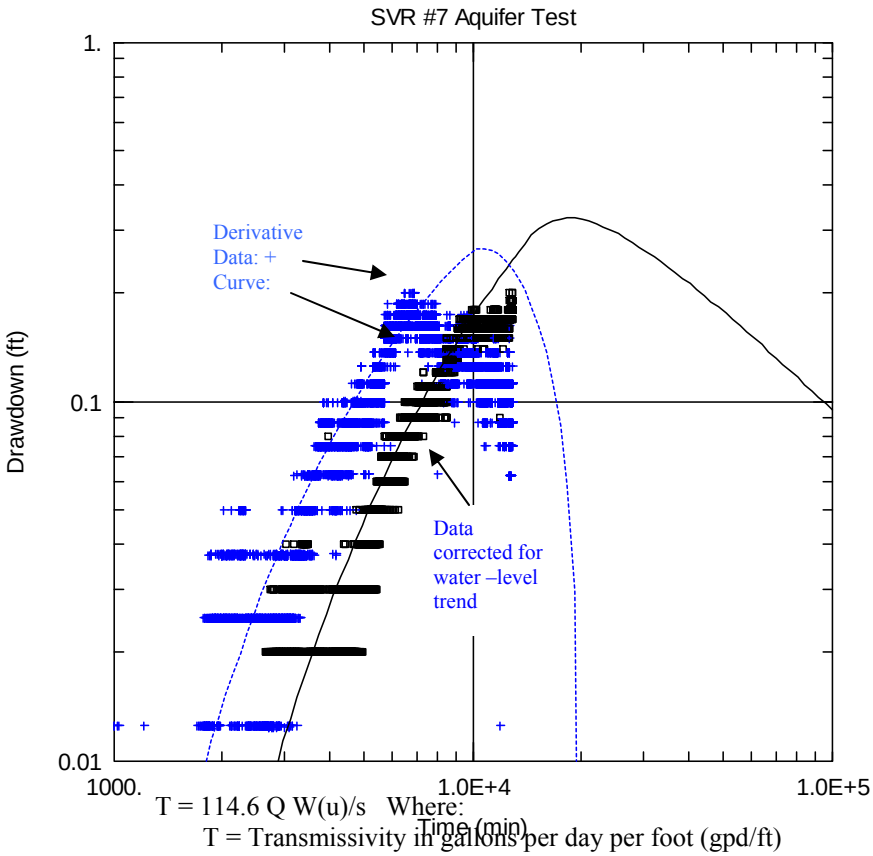
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical logs, Well Driller's Reports and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 43. Theis Analysis for Flack Corral 4-In Well with Trend Correction



Screen = ? ft bgl
T=270,000 gpd/ft
S =0.02
Kv/Kh=0.1
b = 300 ft
r = 5974 ft
Q = 917gpm

Derivative analysis indicates method is generally valid for data from first 6,000 minutes of test. Fit is better than analysis without trend correction. However, small drawdown response and need to filter barometric effect make analysis only approximate. Data are corrected for seasonal aquifer water-level trend.

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

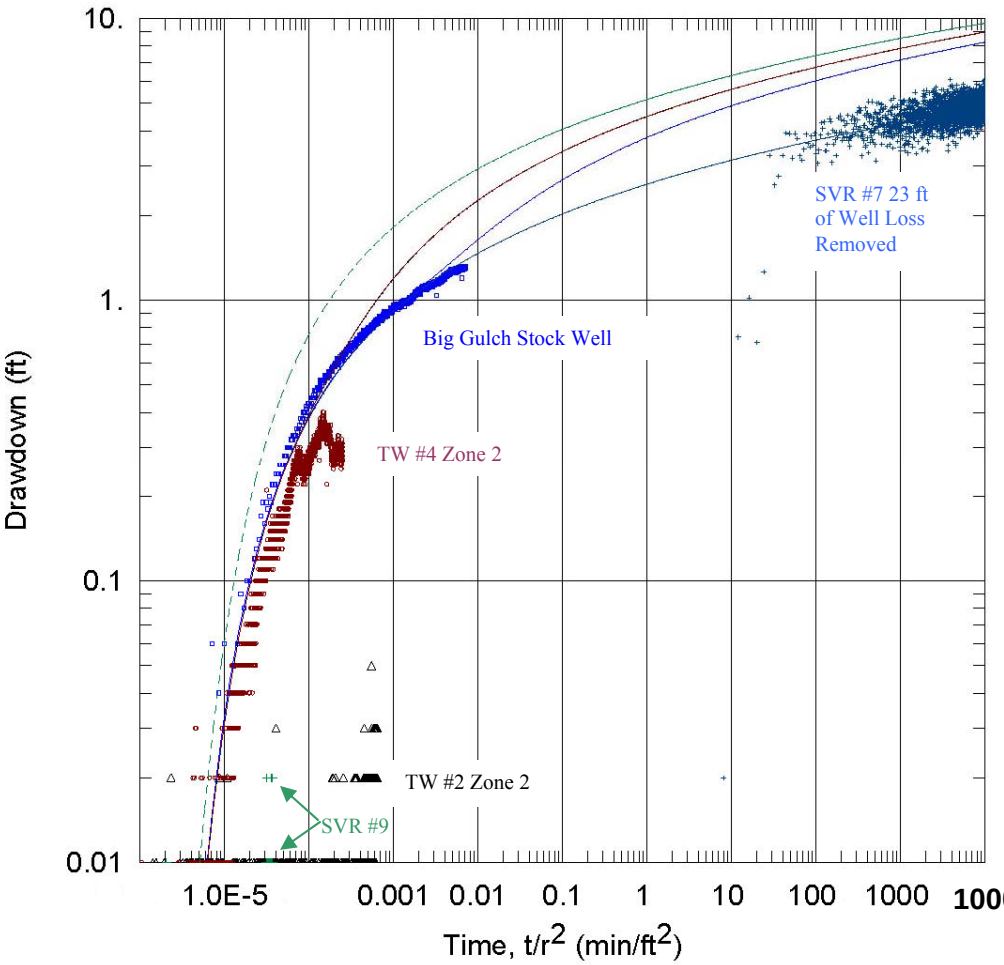
Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details

b = aquifer thickness in feet (ft), estimated from geophysical logs, Well Driller's Reports and well logs in the area

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 44. Composite Theis Analysis for Five Observation Wells



$T_{composite}$ = 430,000 gpd/ft
$S_{composite}$ = 2.1x 10^{-3}
Kv/Kh=0.1
Q = 917gpm (at SVR #7)

SVR #7
b = 340 ft, r = 0.5 ft

Big Gulch Stock Well
b = 340 ft, r = 845 ft

TW #2 Zone 2
b = 300 ft, r = 3,636 ft

TW #4 Zone 2
b = 260 to 360 ft, r = 4,489 ft

SVR #9
b = 73 f, r = 11,660 ft

Data normalized by dividing time by radius squared. Pumping well data corrected by subtracting 23 feet of well loss (as calculated based on comparison of actual drawdown and theoretical drawdown calculated using data derived from analysis of Big Gulch well.)

Composite plot for five wells with time normalized by distance such that data would plot on similar curves in a uniform, homogeneous aquifer. The pumping well (SVR #7), nearest observation well ("Big Gulch") and observation well to west (TW #4) plot on curve. Wells to the east of the pumping well (TW #2 and SVR #9) where the Pierce Gulch Sand Aquifer becomes unconfined, show a delayed response caused by thinner aquifer (lower transmissivity) and unconfined conditions (larger storativity).

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

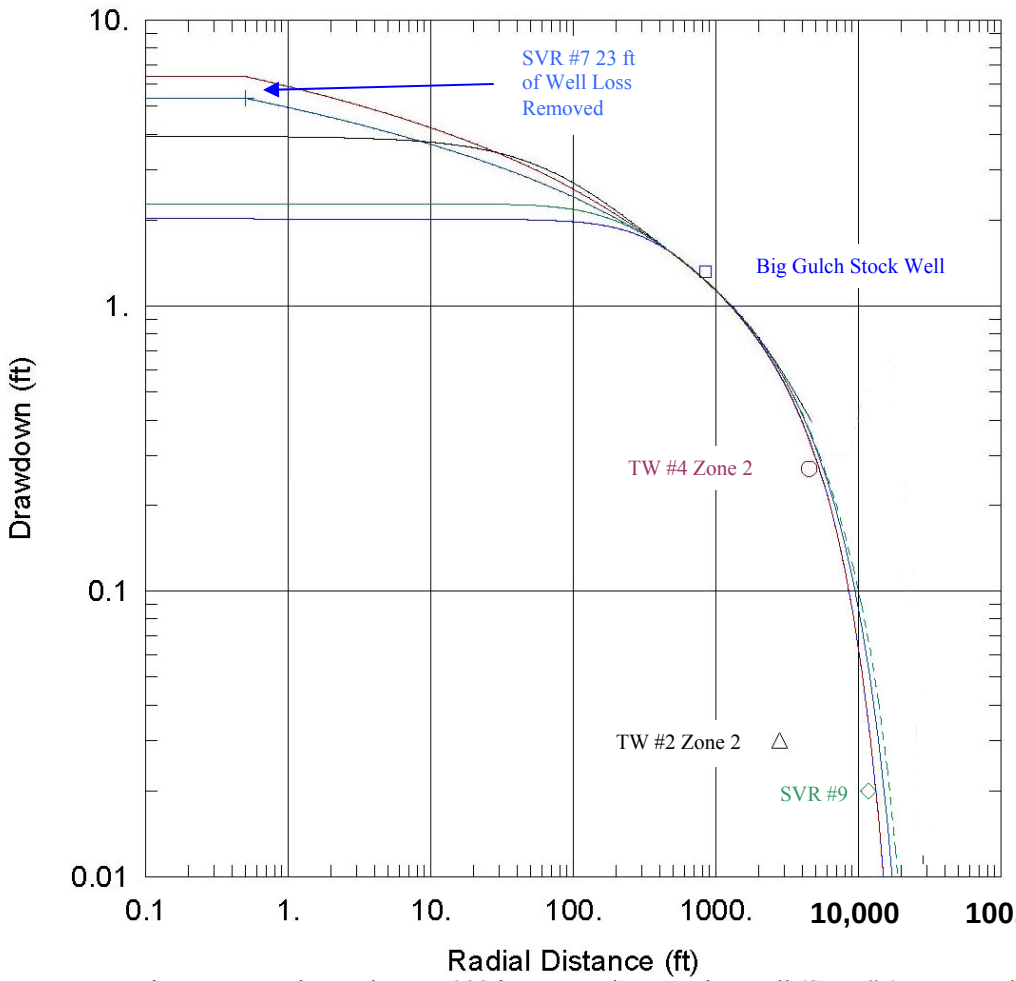
$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), calculated from geophysical log of well.

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 45. Theis Distance Drawdown Analysis



$T_{Dist\text{-}Drawdwon}$ = 380,000 gpd/ft
$S_{Cist.\text{-}Drawdwon}$ = 7.0x 10^{-3}
Kv/Kh=0.1
t = 5,000 min
Q = 917gpm (at SVR #7)

SVR #7
b = 340 ft, r = 0.5 ft

Big Gulch Stock Well
b = 340 ft, r = 845 ft

TW #2 Zone 2
b = 300 ft, r = 3,636 ft

TW #4 Zone 2
b = 260 to 360 ft, r = 4,489 ft

SVR #9
b = 73 f, r = 11,660 ft

Pumping well data corrected by subtracting 23 feet of well loss (as calculated based on comparison of actual drawdown and theoretical drawdown calculated using data derived from analysis of Big Gulch well.)

Distance Drawdown plot at 5,000 into test. The pumping well (SVR #7), nearest observation well ("Big Gulch") and observation well to west (TW #4) plot on curve. Wells to the east of the pumping well (TW #2 and SVR #9) where the Pierce Gulch Sand Aquifer becomes unconfined, show a different response caused by thinner aquifer (lower transmissivity) and unconfined conditions (larger storativity).

$T = 114.6\ Q\ W(u)/s$ Where:
T = Transmissivity in gallons per day per foot (gpd/ft)
Q = Pumping rate in gallons per minute (gpm) and
W(u) = "well function" (defined below)

$W(u) = 1.87r^2S/Tt$ Where:
S = storativity (unitless)
r = distance to pumping well (ft)
t = time in days

Kv/Kh = Bulk vertical to horizontal ratio of hydraulic conductivity (unitless), see text for details
b = aquifer thickness in feet (ft), calculated from geophysical log of well.

Solid Line represents "type curve" where T and S best match observed drawdown.

Based on the analytical method of Theis (1935) with aquifer anisotropy and partial penetration corrections of Hantush (1961a and b).

Figure 46. Comparison of Pierce Gulch Sand Aquifer Water Levels in M3 On-Site and State and Linder Wells

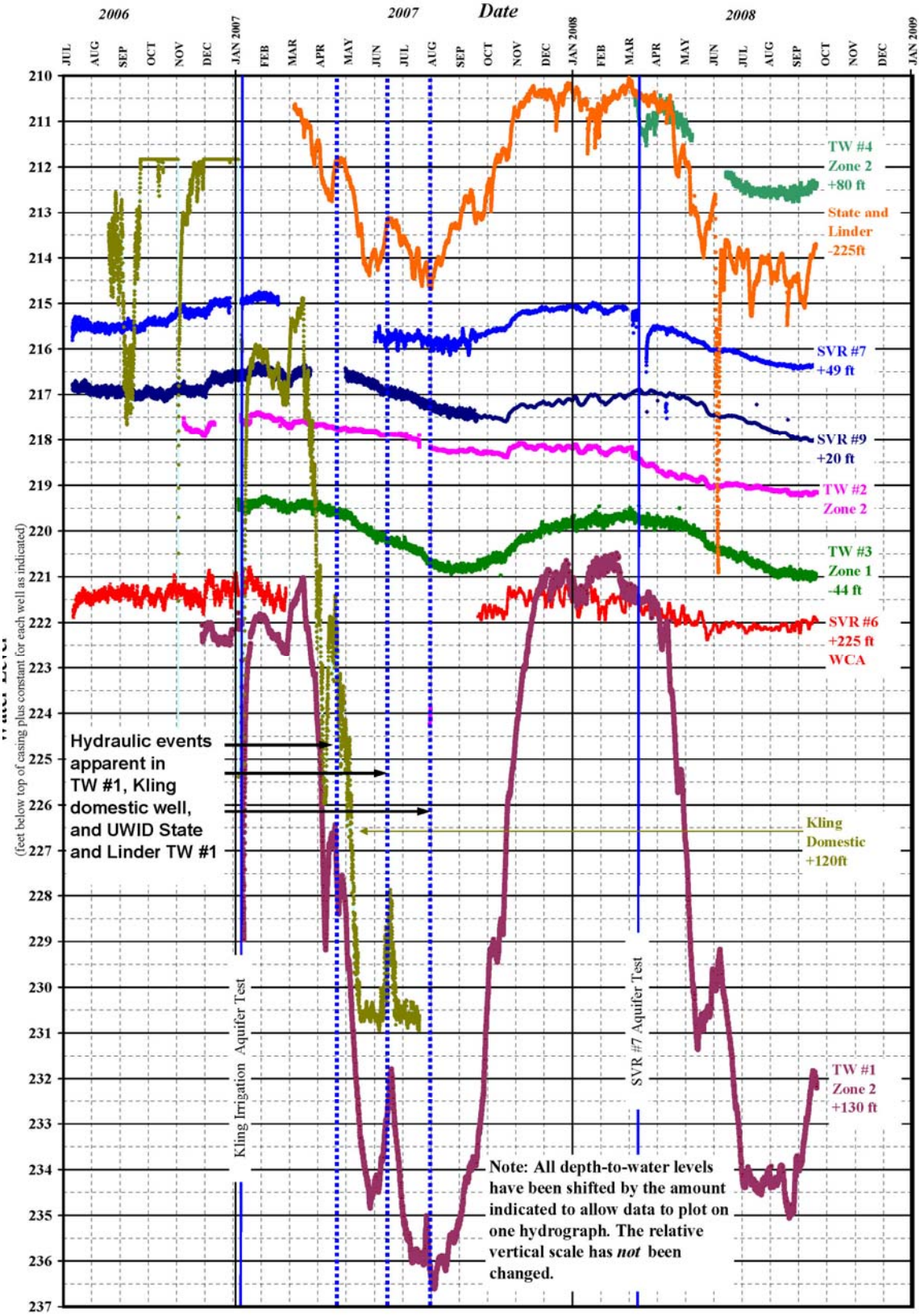


Figure 47. Comparison of Pierce Gulch Sand Aquifer Water Levels in Wells Completed on Western and Central M3 Property

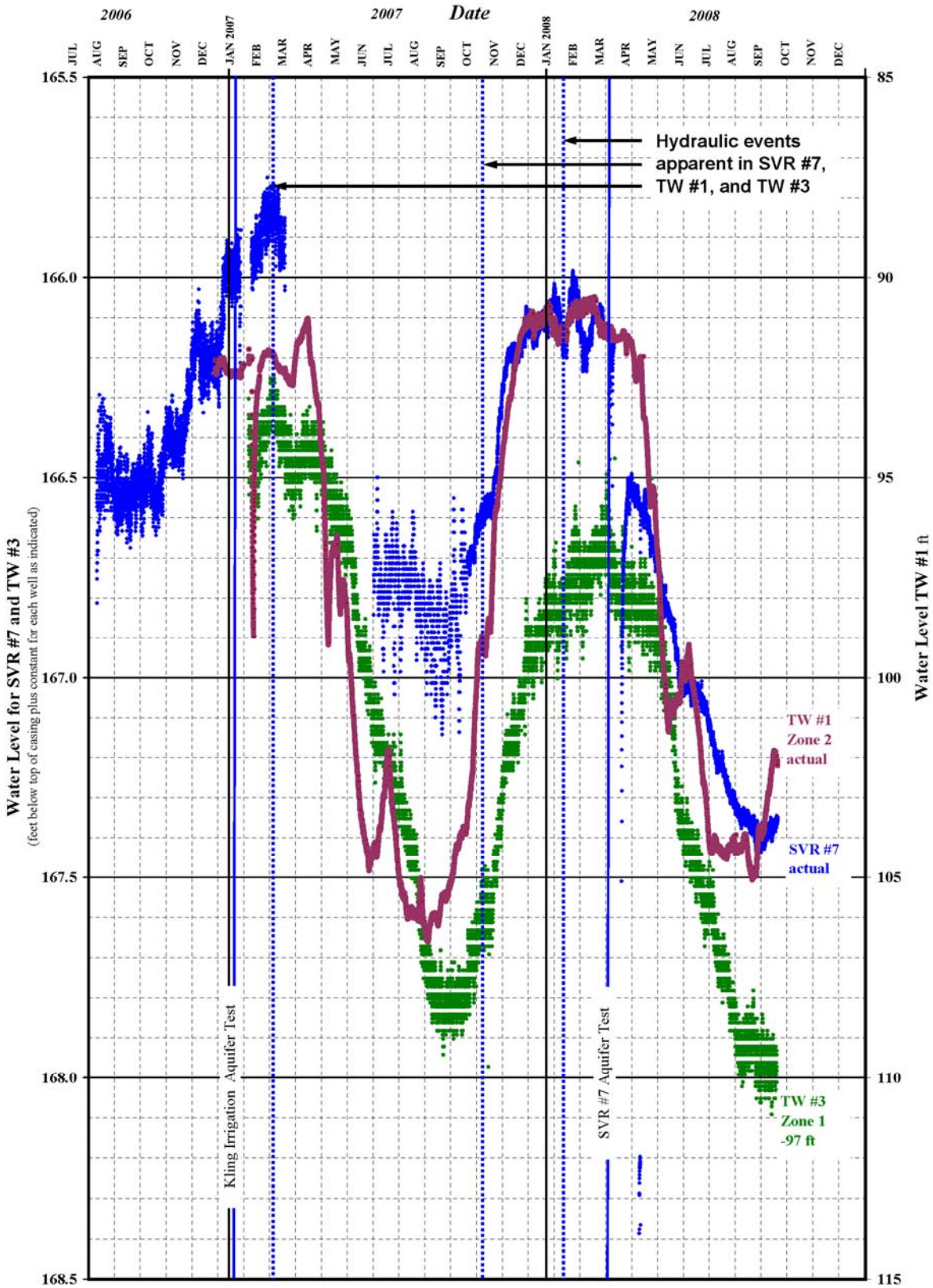
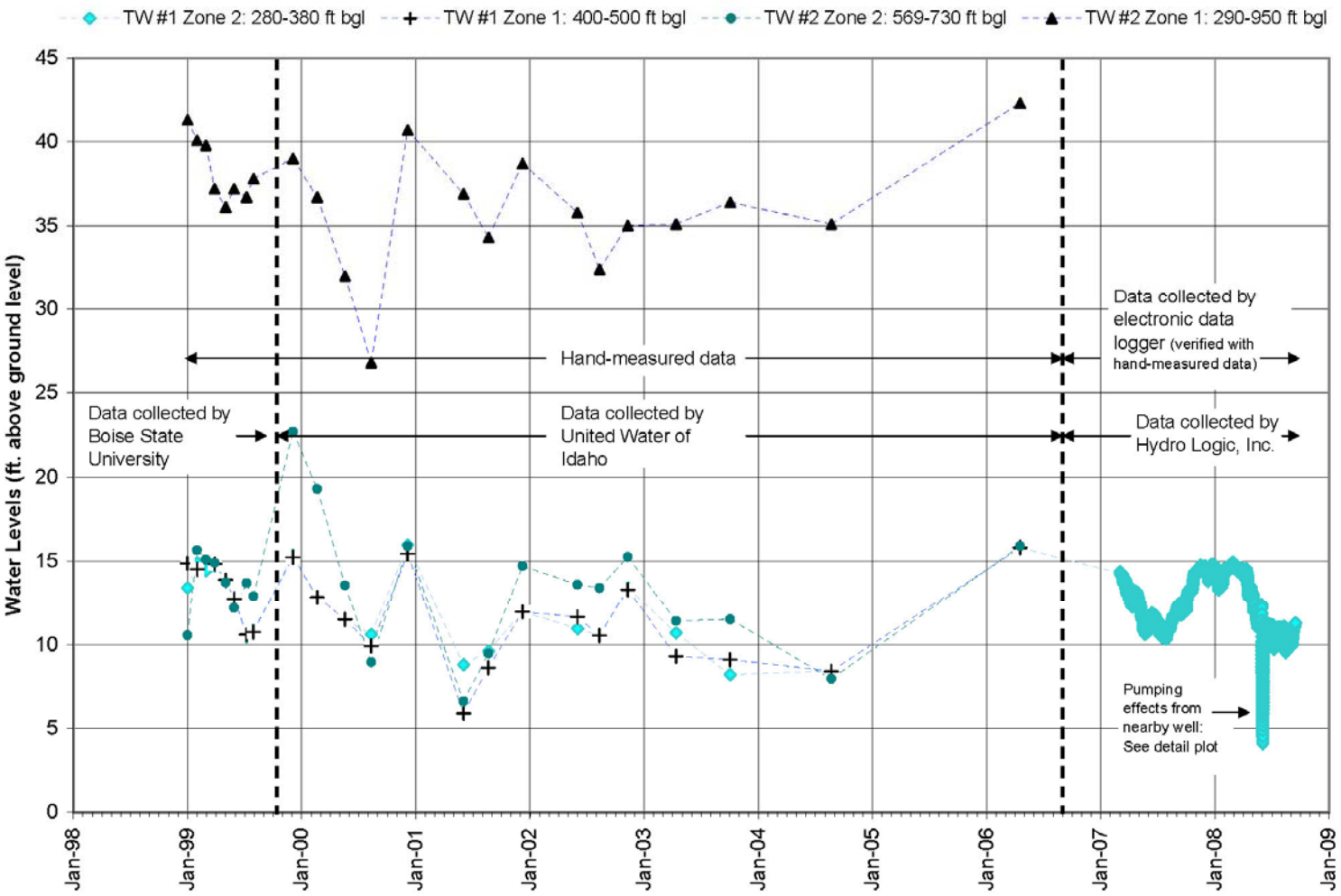


Figure 48. Water Levels in UWID State and Linder TW #1 Showing No Net Decline Over 10-Year Period



Almost ten years of data show that TW #1 Zone 2 shows no net decline with water levels remaining generally between about 10 and 15 feet above ground level, in spite of increase in population of greater Eagle-Star vicinity and subsequent net increase in regional well pumping. Measured data from the other three monitored zones show a similar pattern of no net decline. Sharp drop followed by sharp rise in levels during May of 2008 appears to be the result of pumping from a nearby well.

APPENDICES

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Appendix A - Well Driller's Reports for Wells without Additional Information

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Well Driller's Report for Flack Corral 6-in Stock Well

3/95

WELL DRILLER'S REPORT

Use Typewriter or Ballpoint Pen

094025

Inspected by _____
Twp ____ Rge ____ Sec ____
____ 1/4 ____ 1/4 ____ 1/4
Lat: : : Long: : :

1. DRILLING PERMIT NO. 63-96-W-0184-000
Other IDWR No. _____

2. OWNER:
Name Bill Flack
Address 4035 Hartley Rd.
City Eagle State Id. Zip 83616

3. LOCATION OF WELL by legal description:
Sketch map location must agree with written location.

N / W / E / S — X

Twp. 5 North ☒ or South ☐
Rge. 1 East ☐ or West ☒
Sec. 24, NW 1/4 (10 acres) NE 1/4 (40 acres) ____ 1/4 (160 acres)
Gov't Lot ____ County Ada
Lat: : : Long: : :
Address of Well Site _____
Eagle Rd. Meridian City Eagle
(Give at least name of road + Distance to Road or Landmark)
Lt. ____ Blk. ____ Sub. Name _____

4. USE:
☒ Domestic ☐ Municipal ☐ Monitor ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other _____

5. TYPE OF WORK check all that apply (Replacement etc.)
☒ New Well ☐ Modify ☐ Abandonment ☐ Other _____

6. DRILL METHOD
☒ Air Rotary ☒ Cable ☐ Mud Rotary ☐ Other _____

7. SEALING PROCEDURES

SEAL/FILTER PACK Material	From	To	AMOUNT Sacks or Pounds	METHOD
Bentonite	0	20	300	Pour.

Was drive shoe used? ☒ Y ☐ N Shoe Depth(s) 253
Was drive shoe seal tested? ☐ Y ☒ N How? _____

8. CASING/LINER:

Diameter	From	To	Gauge	Material	Casing	Liner	Welded	Threaded
6	+1	253	.250	Steel	☐	☐	☒	☐
					☐	☐	☐	☐
					☐	☐	☐	☐

Length of Headpipe _____ Length of Tailpipe _____

9. PERFORATIONS/SCREENS
☒ Perforations Method NW
☐ Screens Screen Type _____

From	To	Slot Size	Number	Diameter	Material	Casing	Liner
240	400	1/8	340	4½	PVC	☐	☐
						☐	☐
						☐	☐

10. STATIC WATER LEVEL OR ARTESIAN PRESSURE:
____ ft. below ground Artesian pressure ____ lb.
Depth flow encountered ____ ft. Describe access port or control devices: welded metal plate.

11. WELL TESTS:
☒ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal./min.	Drawdown	Pumping Level	Time
20			10

Water Temp. _____ Bottom hole temp. _____
Water Quality test or comments: _____
Depth first Water Encountered _____

12. LITHOLOGIC LOG: (Describe repairs or abandonment)

Bore Dia.	From	To	Remarks: Lithology, Water Quality & Temperature	Water Y	Water N
6	0	2	Top Soil		X
	2	12	Sandy Blue clay		X
	12	27	Blue clay		X
	27	110	Brn. Sand		X
	110	165	Reddish Brn. Sand		X
	165	229	Sandy Brn Clay		X
	229	239	Blue Clay		X
	239	289	Blue Sandy Clay w/ Brn. Streaks	X	
	289	292	Brown Sand	X	
	292	340	Sandy Blue clay	X	
	340	400	Sandy Blue clay SAND	X	

RECEIVED
JUL 16 1996
Department of Water Resources

RECEIVED
JUN 24 1996
WATER RESOURCES
WESTERN REGION

SEP 11 1996

Completed Depth 400 (Measurable)
Date: Started 4-9-96 Completed 5-4-96

13. DRILLER'S CERTIFICATION
I/We certify that all minimum well construction standards were complied with at the time the rig was removed.

Firm Name Dennis Phipps Firm No. 332
Firm Official [signature] Date 5-6-96
and
Supervisor or Operator Mark Phipps Date 5-6-96
(Sign once if Firm Official & Operator)

FORWARD WHITE COPY TO WATER RESOURCES

There are no Well Driller's Reports on file with IDWR for the:

Flack Corral 4-in well,
Little Gulch stock well, or
Big Gulch stock well.

The construction information we have available for the Big Gulch stock well and the Little Gulch stock well comes from down-hole video survey. The camera survey indicated well depth, diameter, well opening type and length, and general condition of the well. This information is included on Table 1 of the report.

A camera survey was not conducted on the Flack Corral 4-in well. The apparent bottom of this well was measured using a weighted tag line. It is not known whether the indicated bottom was the actual well bottom or the depth of materials standing in the bottom of the well or well bore collapse in an open hole. The casing diameter of the Flack Corral 4-in well was assumed to be equal to the casing diameter at ground surface. Well opening to the aquifer (size, type, materials, etc.) for this well is unknown. The assumed well depth and diameter are included on Table 1 of the report.

Appendix B – Barometric Efficiency Analyses

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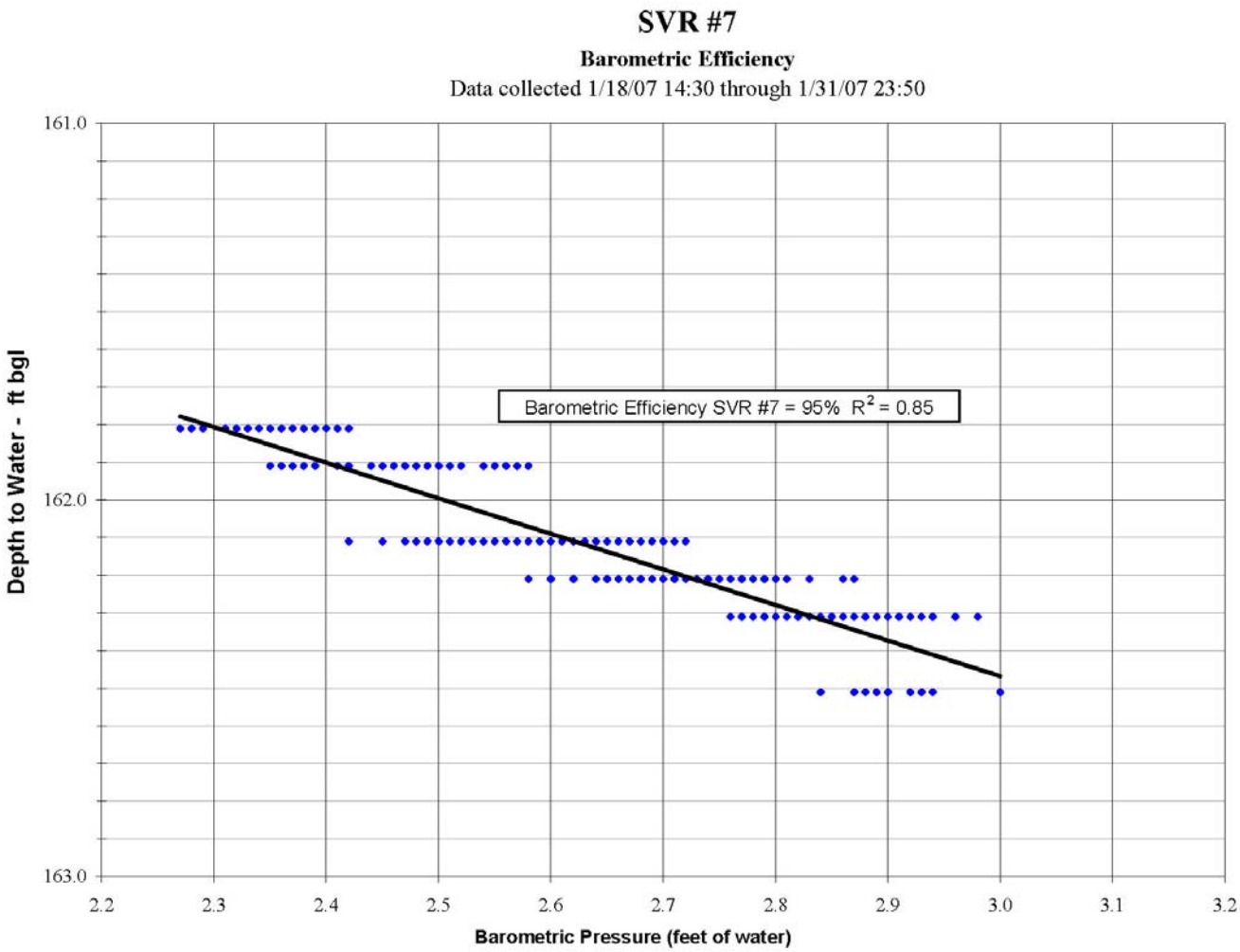
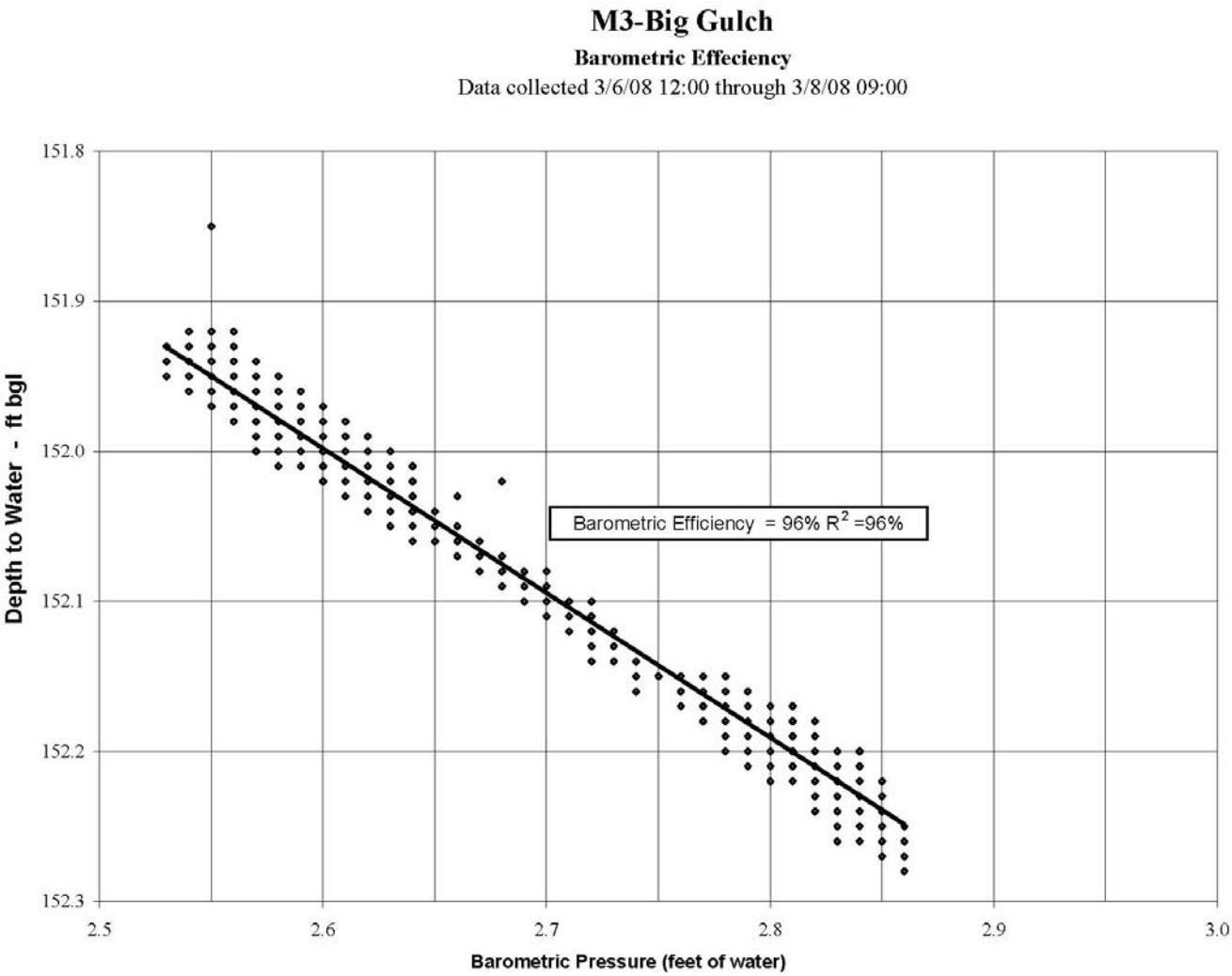
Figure B-1. Barometric Efficiency Plot for SVR #7



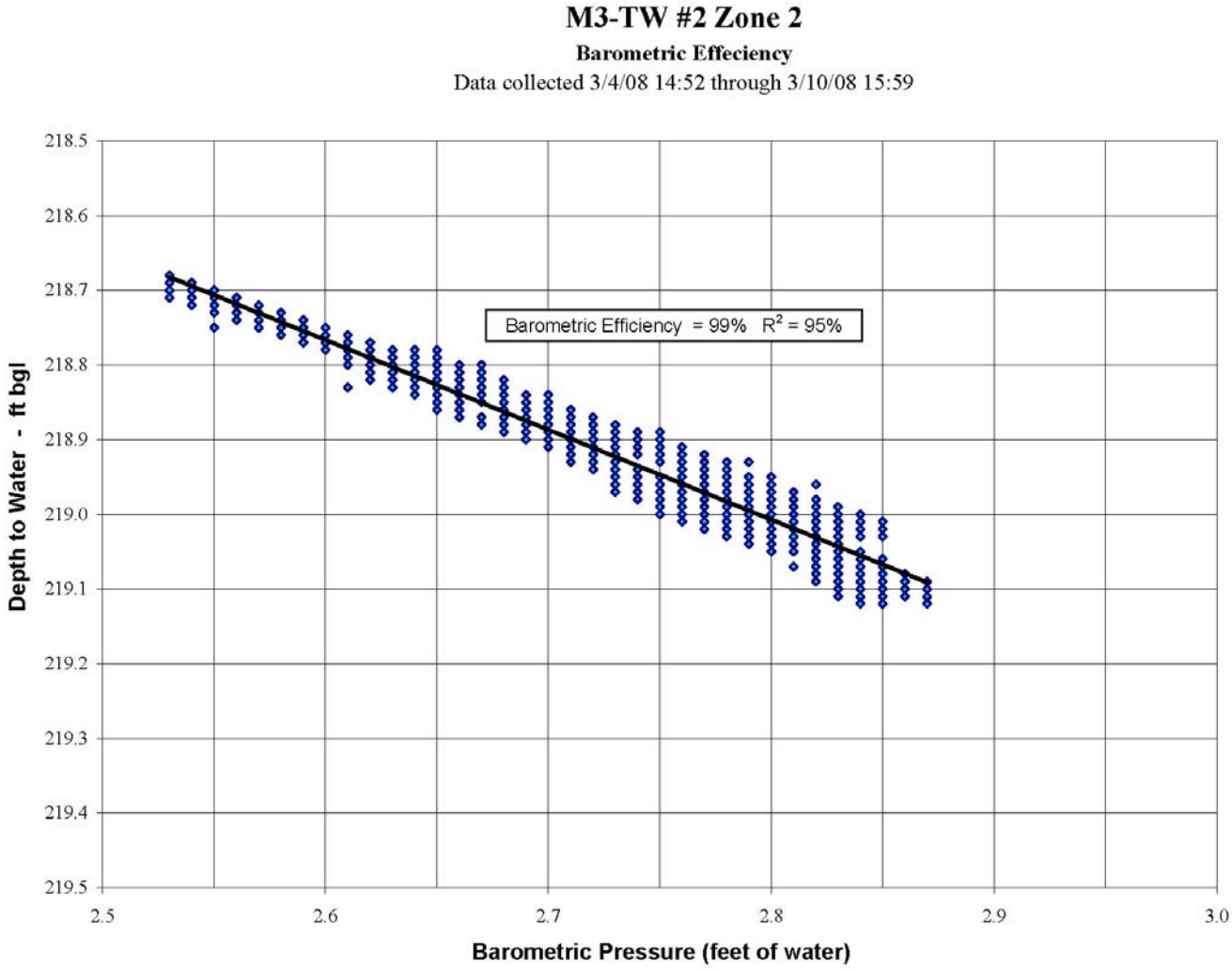
Distance from Pumping Well SVR #7 = 0 ft
Screen Depth = 280 to 350 ft

Figure B-2. Barometric Efficiency Plot for Big Gulch Stock Well



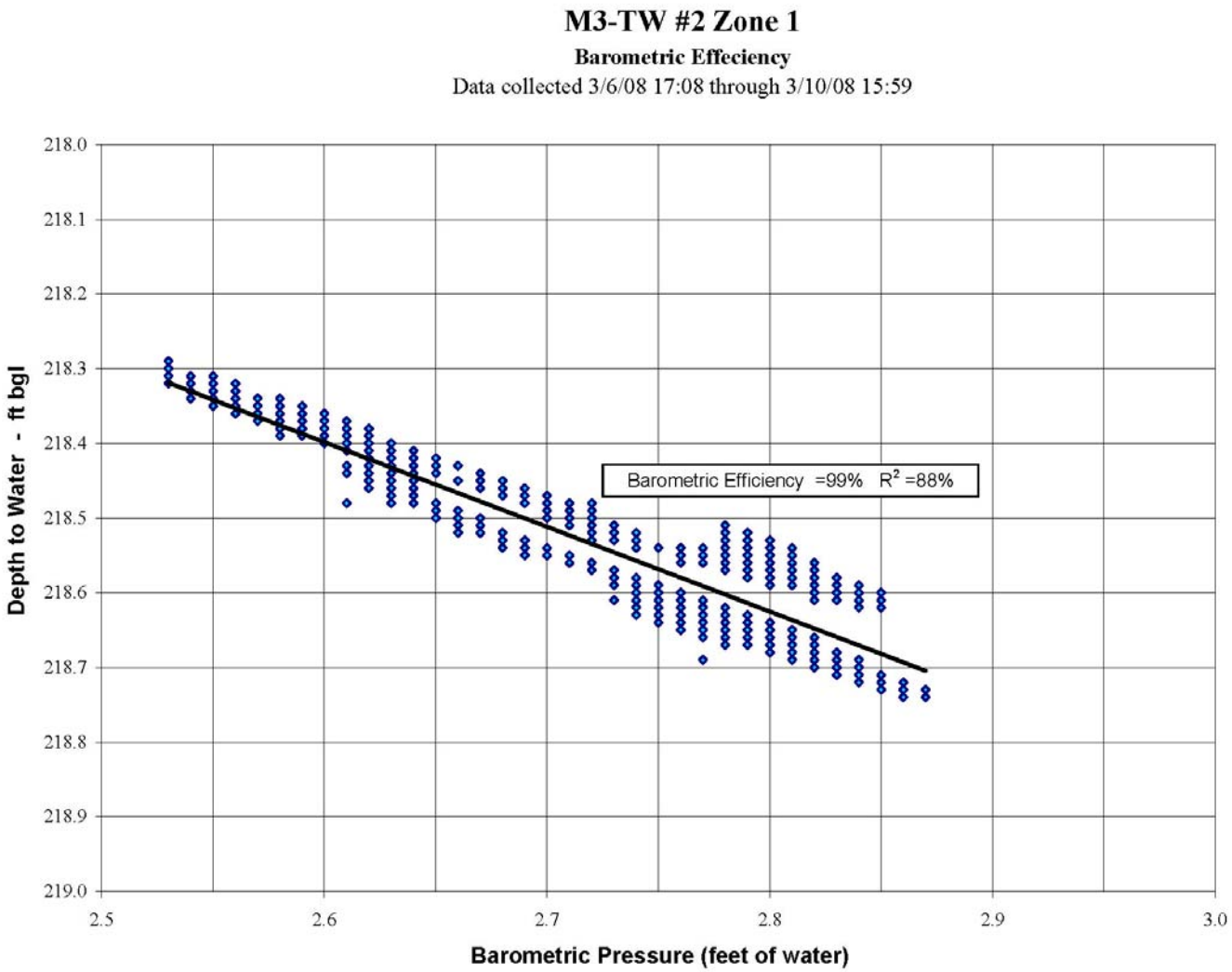
Distance from Pumping Well SVR #7 = 845 ft
Screen Depth = 180 to 180 ft ("open hole," no well screen)

Figure B-3. Barometric Efficiency Plot for TW #2 Zone 2



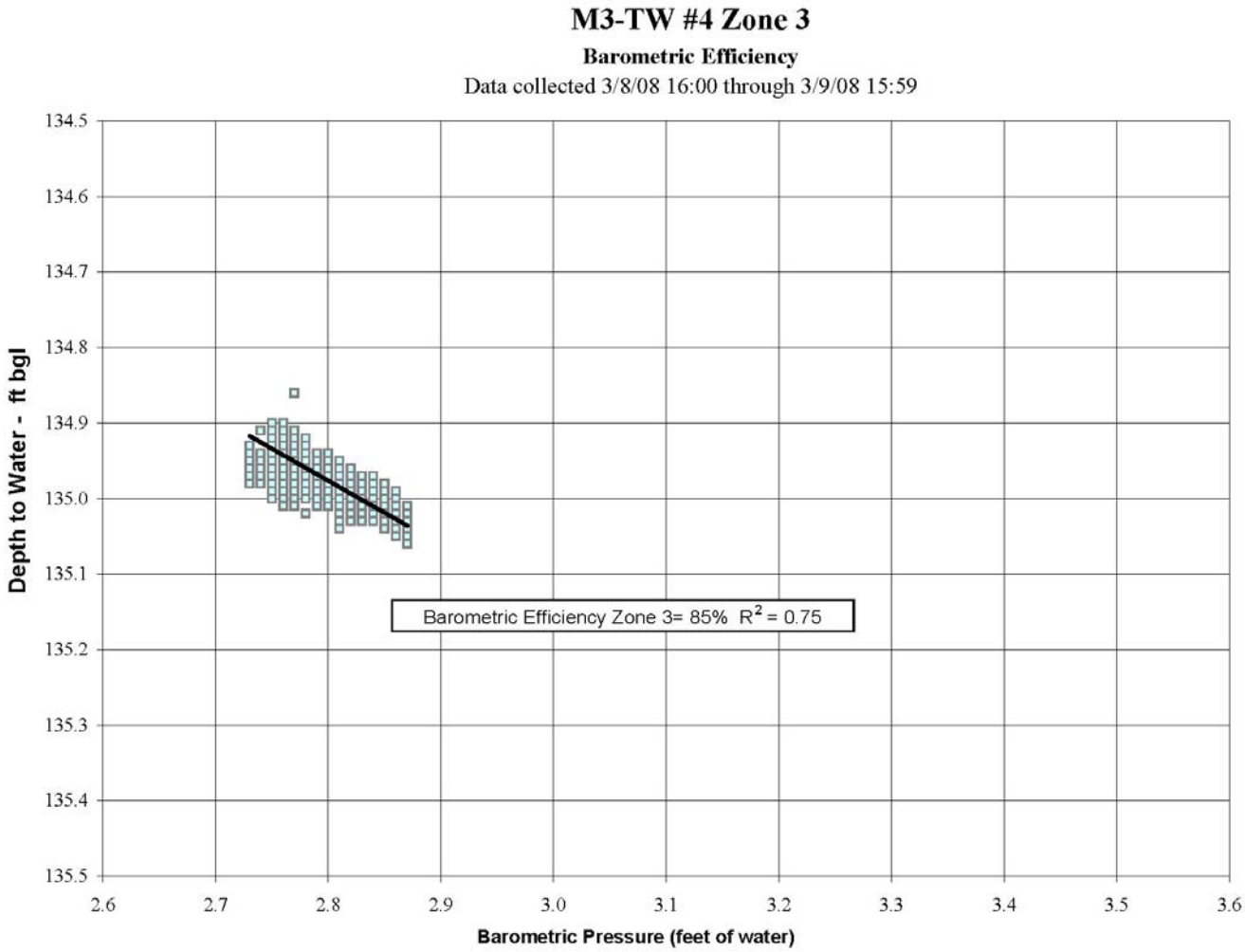
Distance from Pumping Well SVR #7 = 3,636 ft
Screen Depth = 230 to 250 ft

Figure B-4. Barometric Efficiency Plot for TW #2 Zone 1



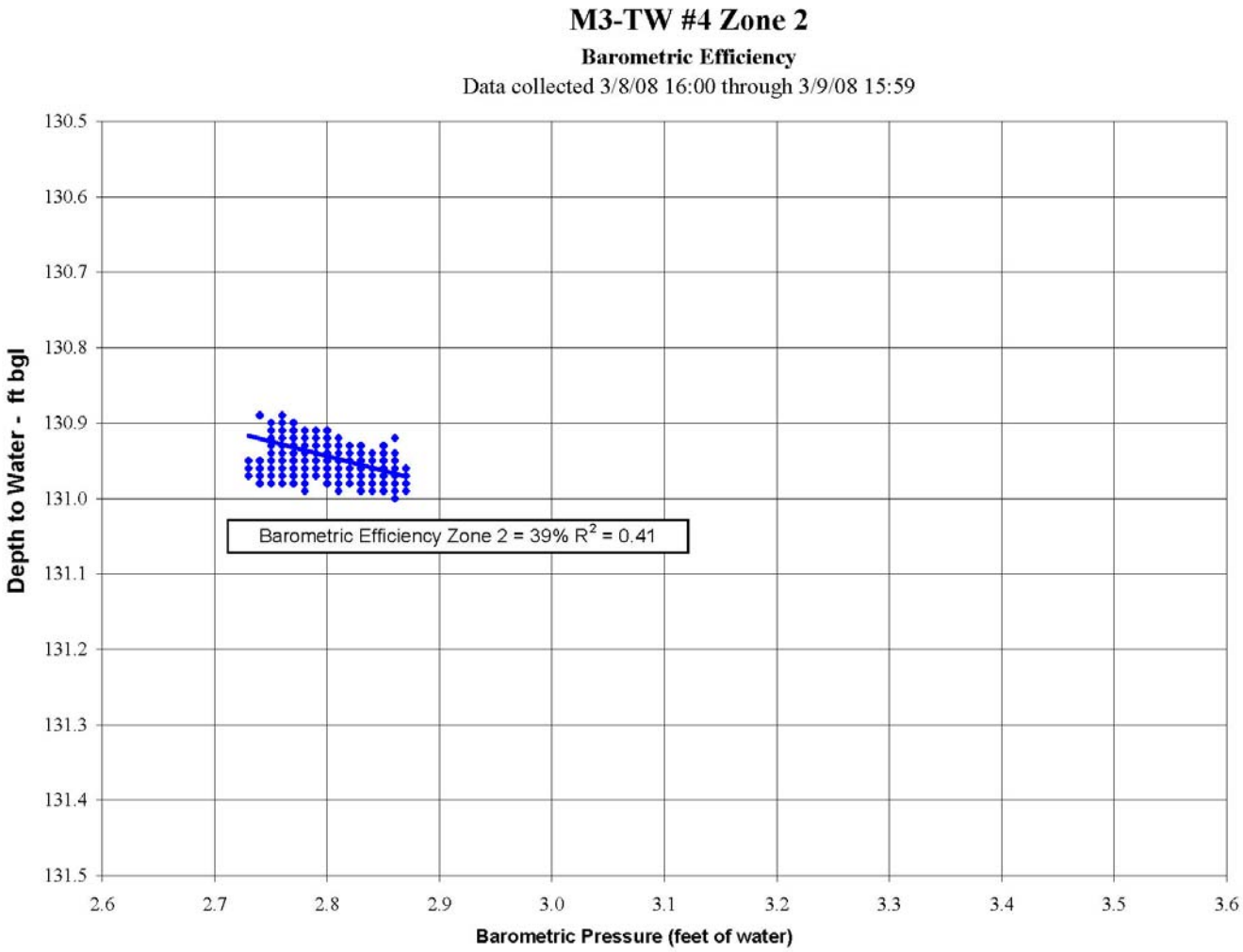
Distance from Pumping Well SVR #7 = 3,636 ft
Screen Depth = 270 to 320 ft

Figure B-5. Barometric Efficiency Plot for TW #4 Zone 3



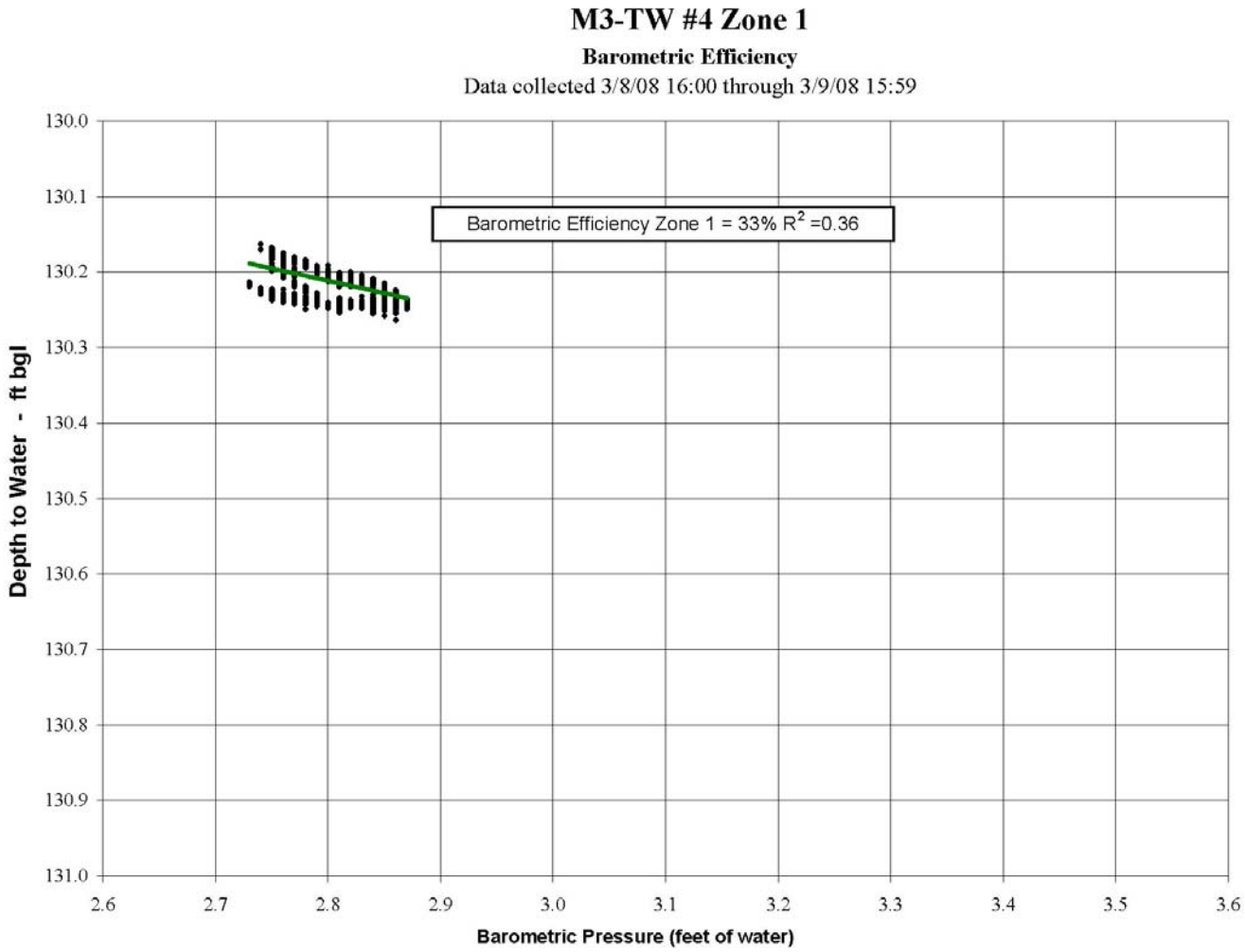
Distance from Pumping Well SVR #7 = 4,489 ft
Screen Depth = 181 to 201 ft

Figure B-6. Barometric Efficiency Plot for TW #4 Zone 2



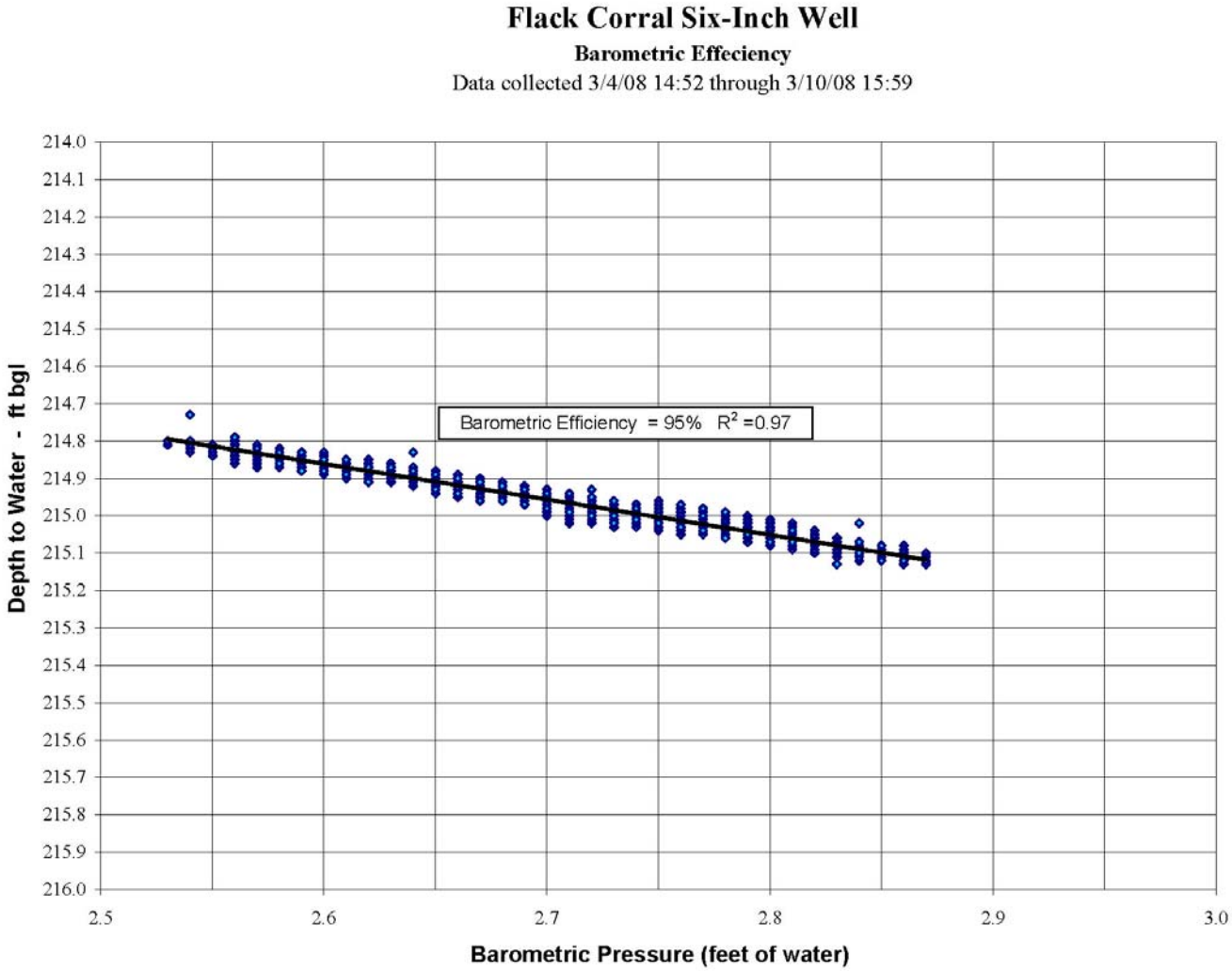
Distance from Pumping Well SVR #7 = 4,489 ft
Screen Depth = 325 to 556 ft

Figure B-7. Barometric Efficiency Plot for TW #4 Zone 1



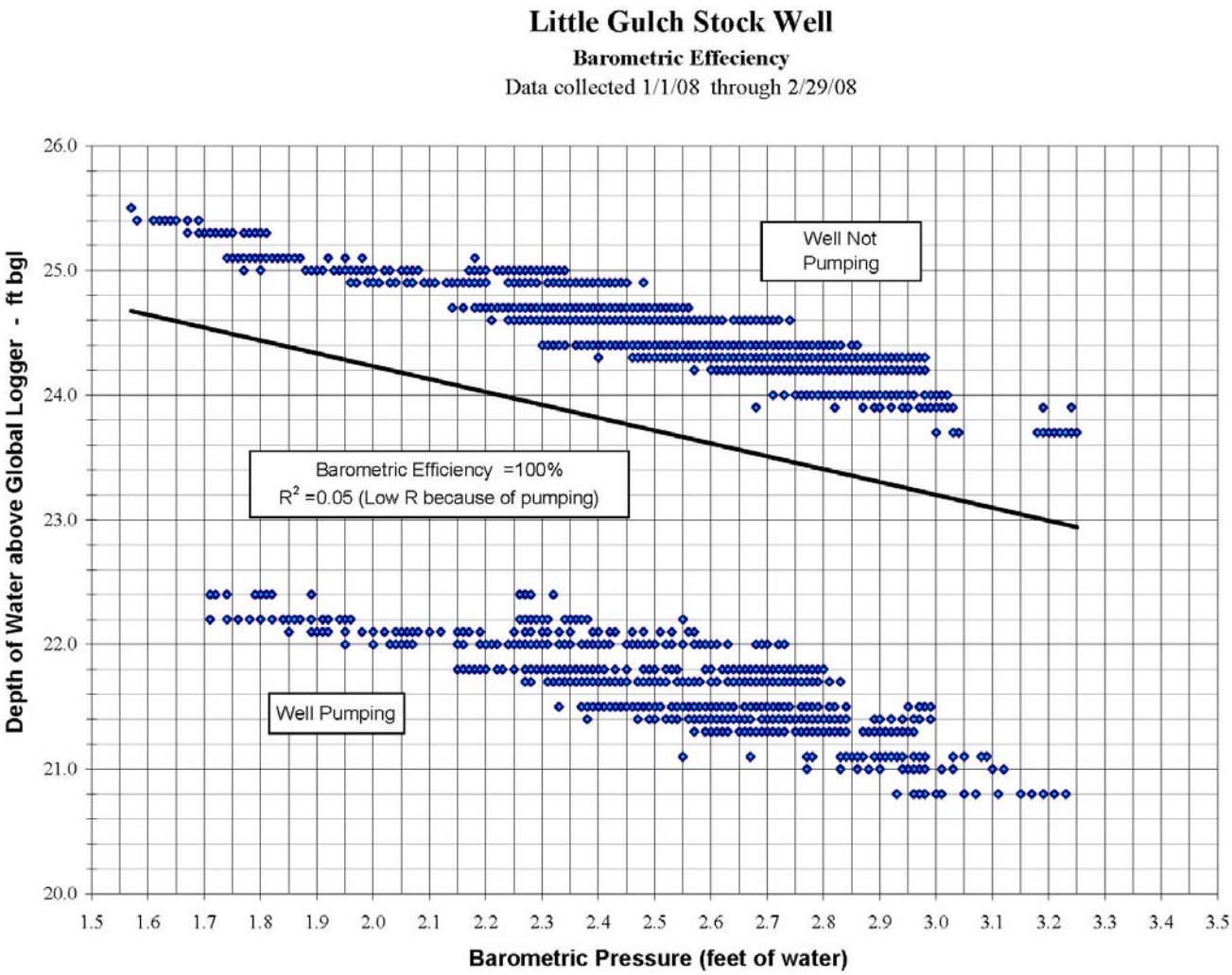
Distance from Pumping Well SVR #7 = 4,489 ft
Screen Depth = 625 to 646 ft

Figure B-8. Barometric Efficiency Plot for Flack Corral 6-Inch Well



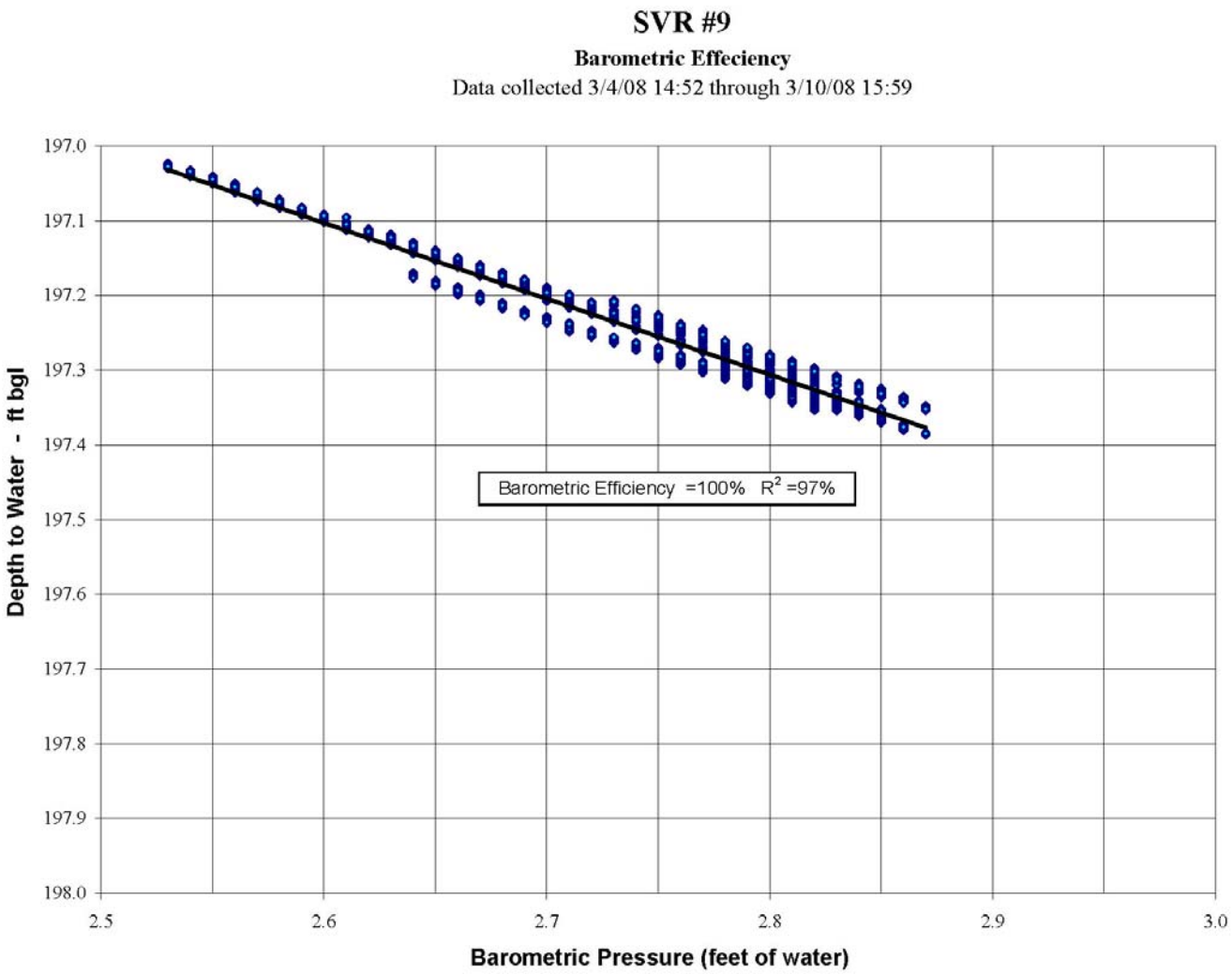
Distance from Pumping Well SVR #7 = 6,749 ft
Screen Depth = 74 to 386 ft

Figure B-9. Barometric Efficiency Plot for Little Gulch Stock Well



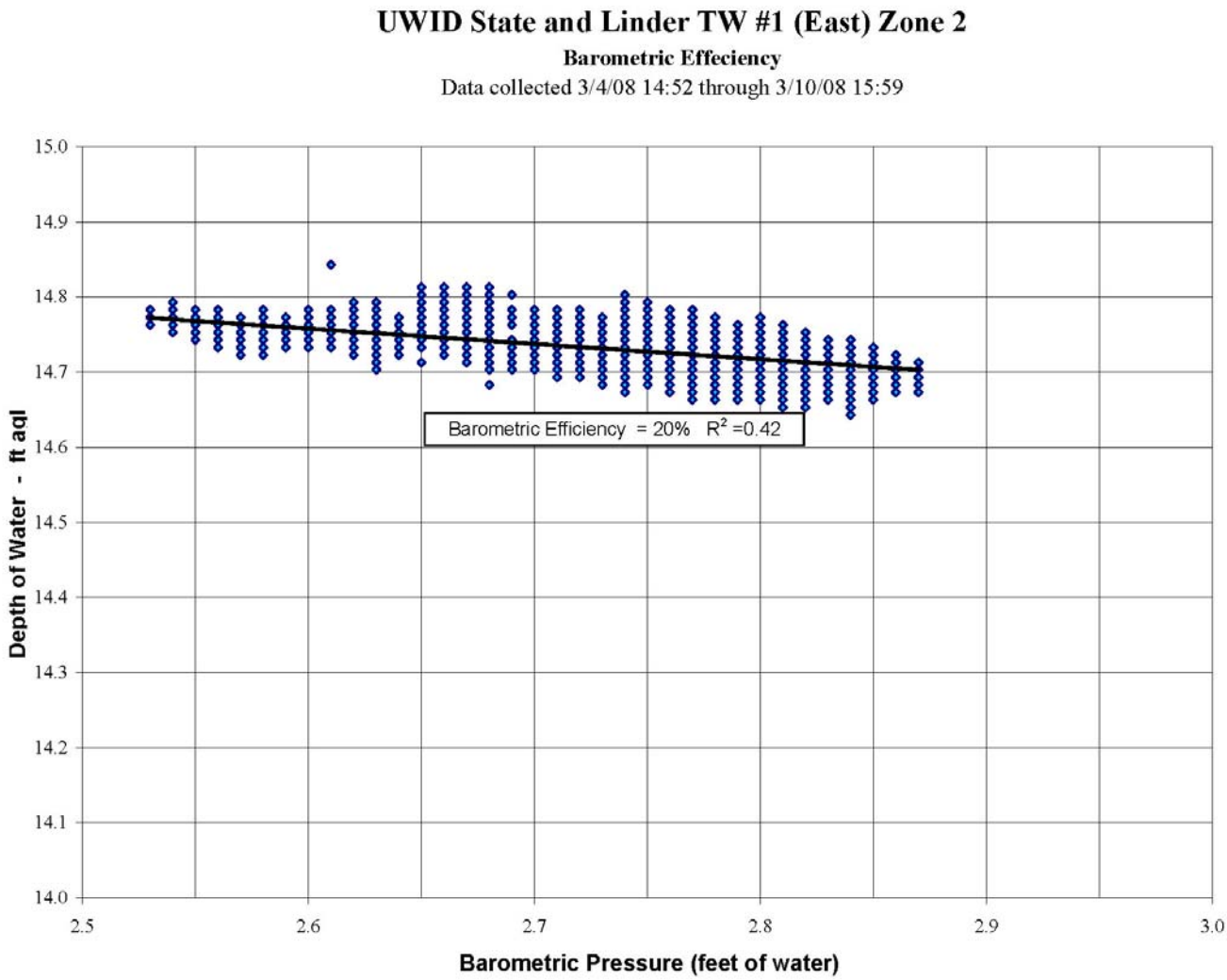
Distance from Pumping Well SVR #7 = 9,740 ft
Screen Depth = 220 to 223 ft

Figure B-10. Barometric Efficiency Plot for SVR #9



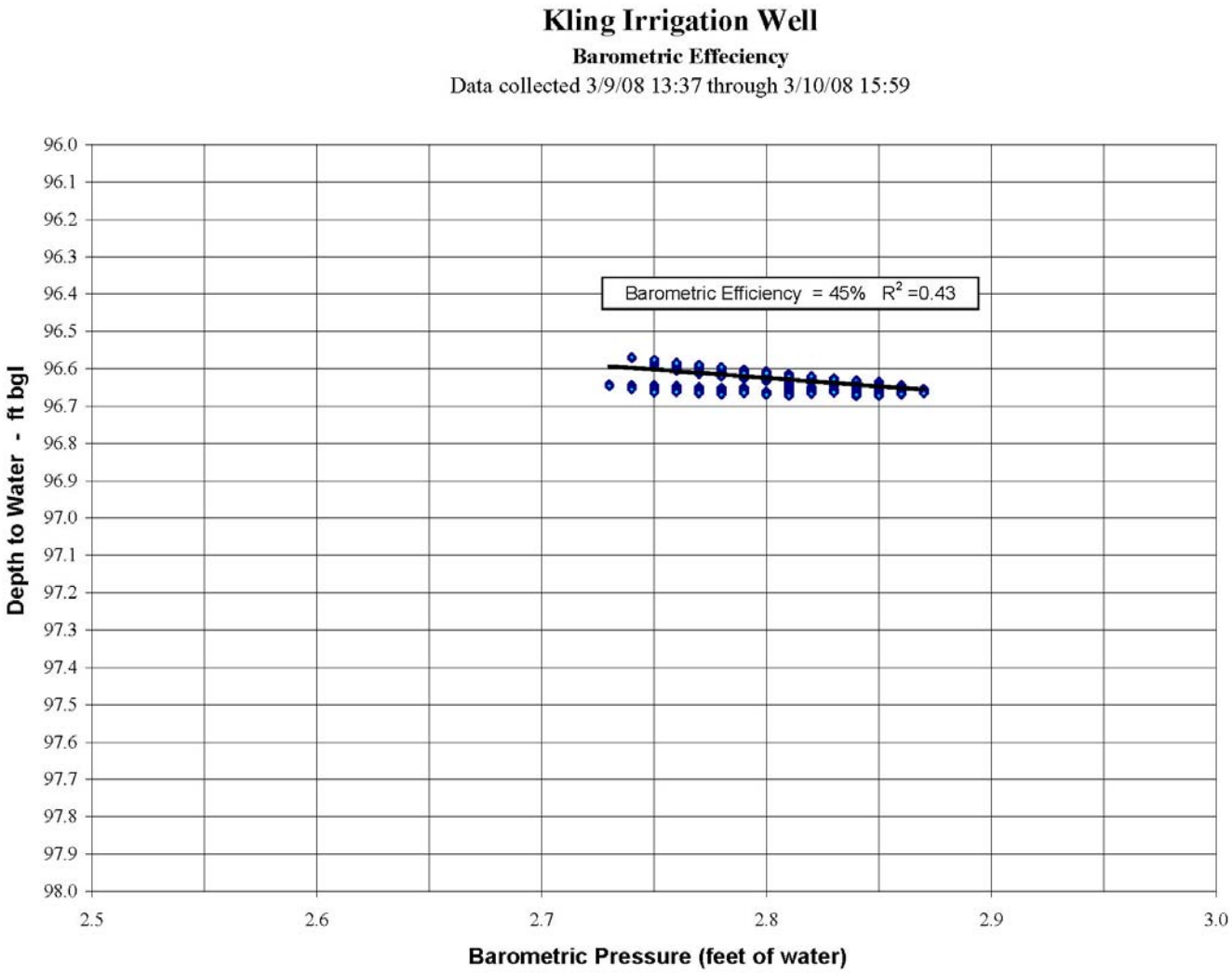
Distance from Pumping Well SVR #7 = 11.660 ft
Screen Depth = 235 to 263 ft

Figure B-11. Barometric Efficiency Plot for State and Linder TW #1 (east) Zone 2



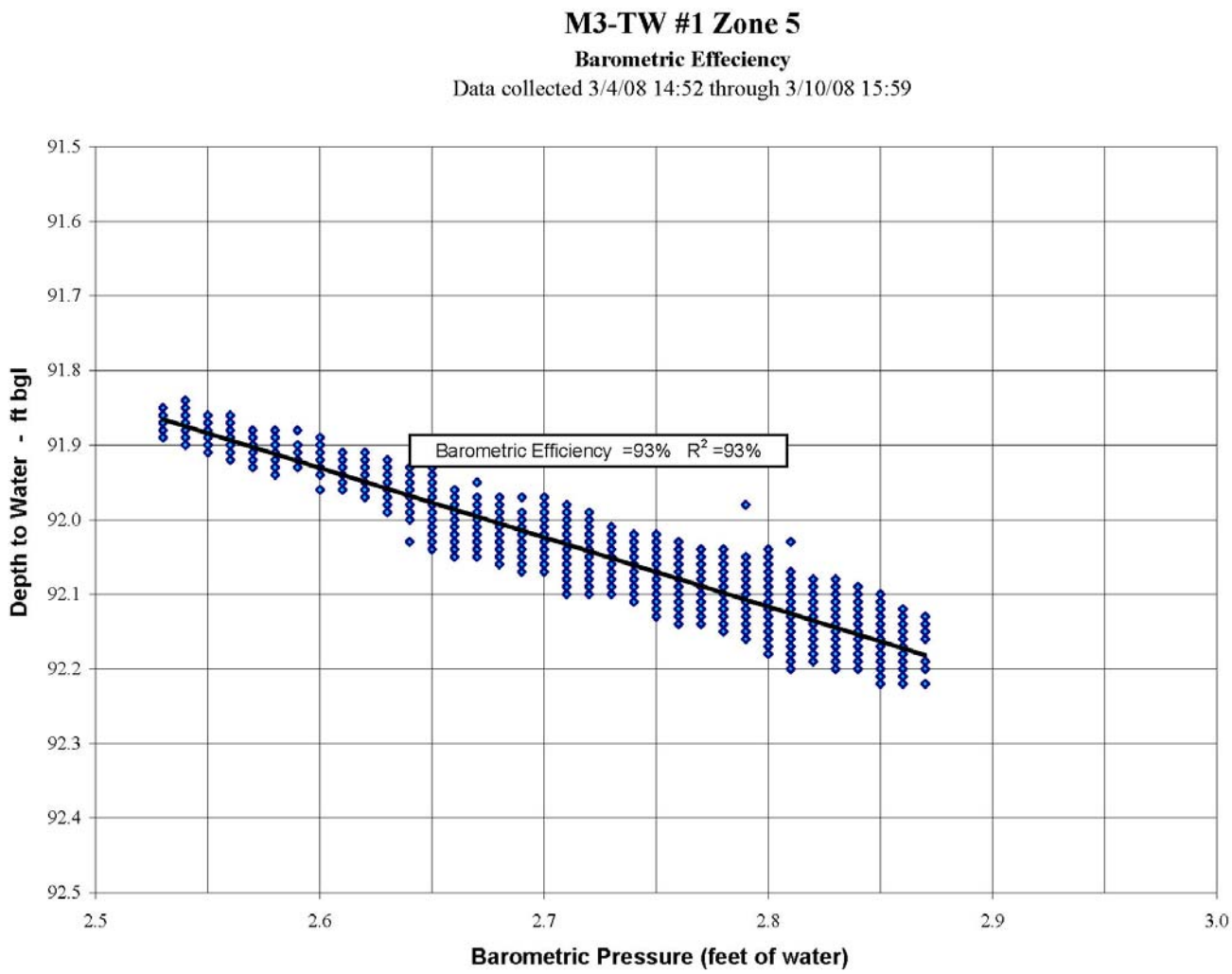
Distance from Pumping Well SVR #7 = 22,302 ft
Screen Depth = 280 to 370 ft

Figure B-12. Barometric Efficiency Plot for the Kling Irrigation Well



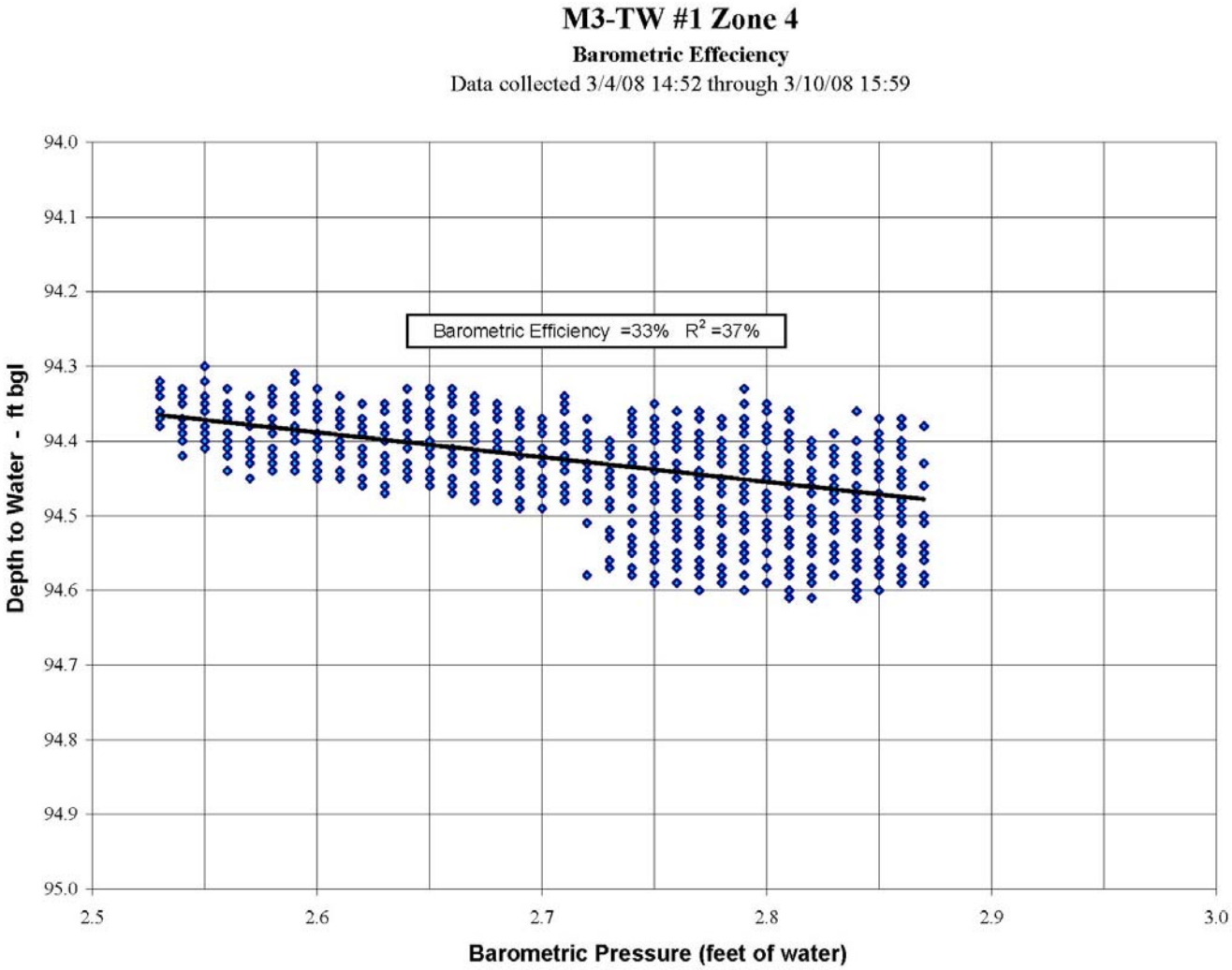
Distance from Pumping Well SVR #7 = 9,908 ft
Screen Depth = 198 to 408 ft

Figure B-13. Barometric Efficiency Plot for TW #1 Zone 5



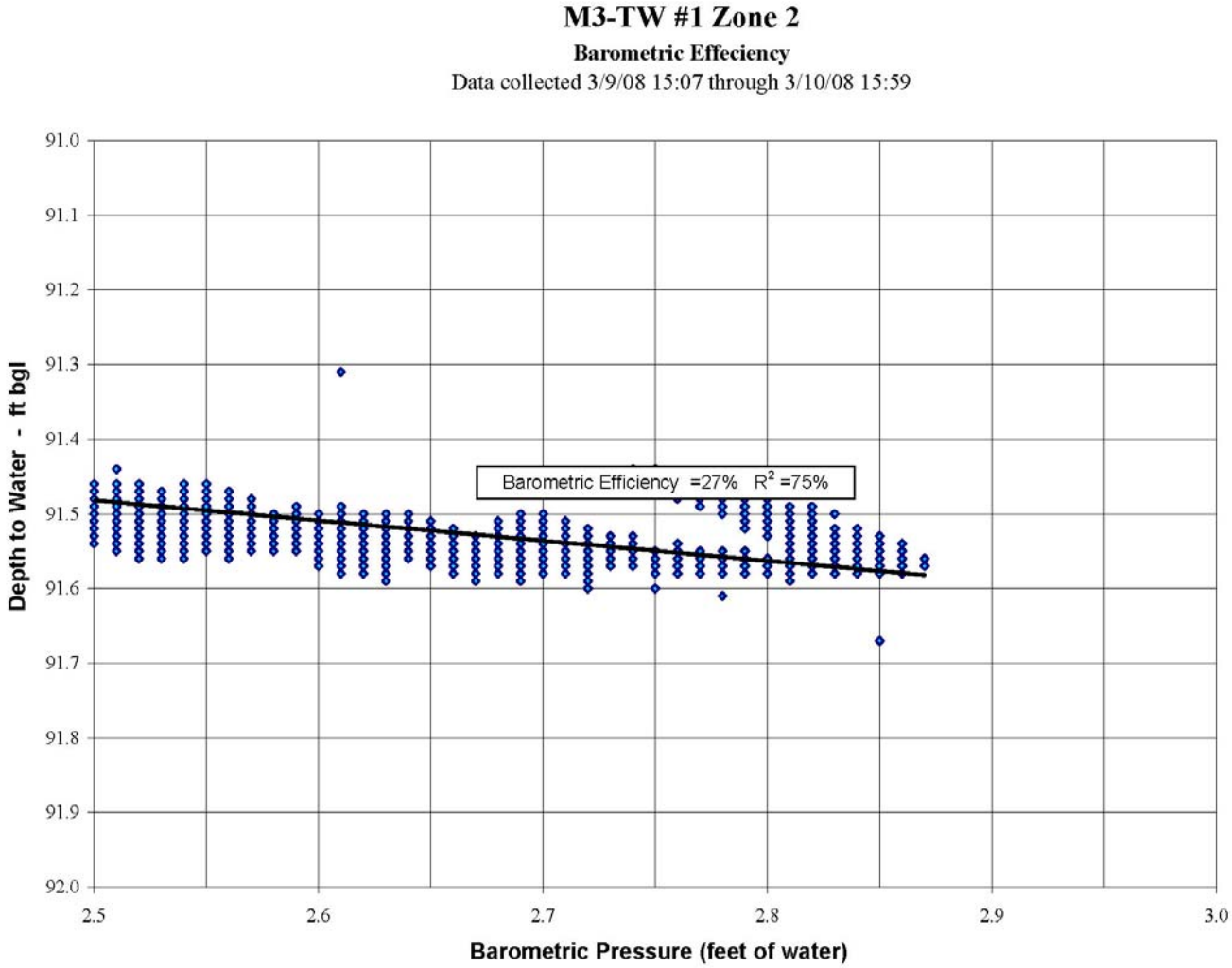
Distance from Pumping Well SVR #7 = 10,916 ft
Screen Depth = 97 to 137 ft

Figure B-14. Barometric Efficiency Plot for TW #1 Zone 4



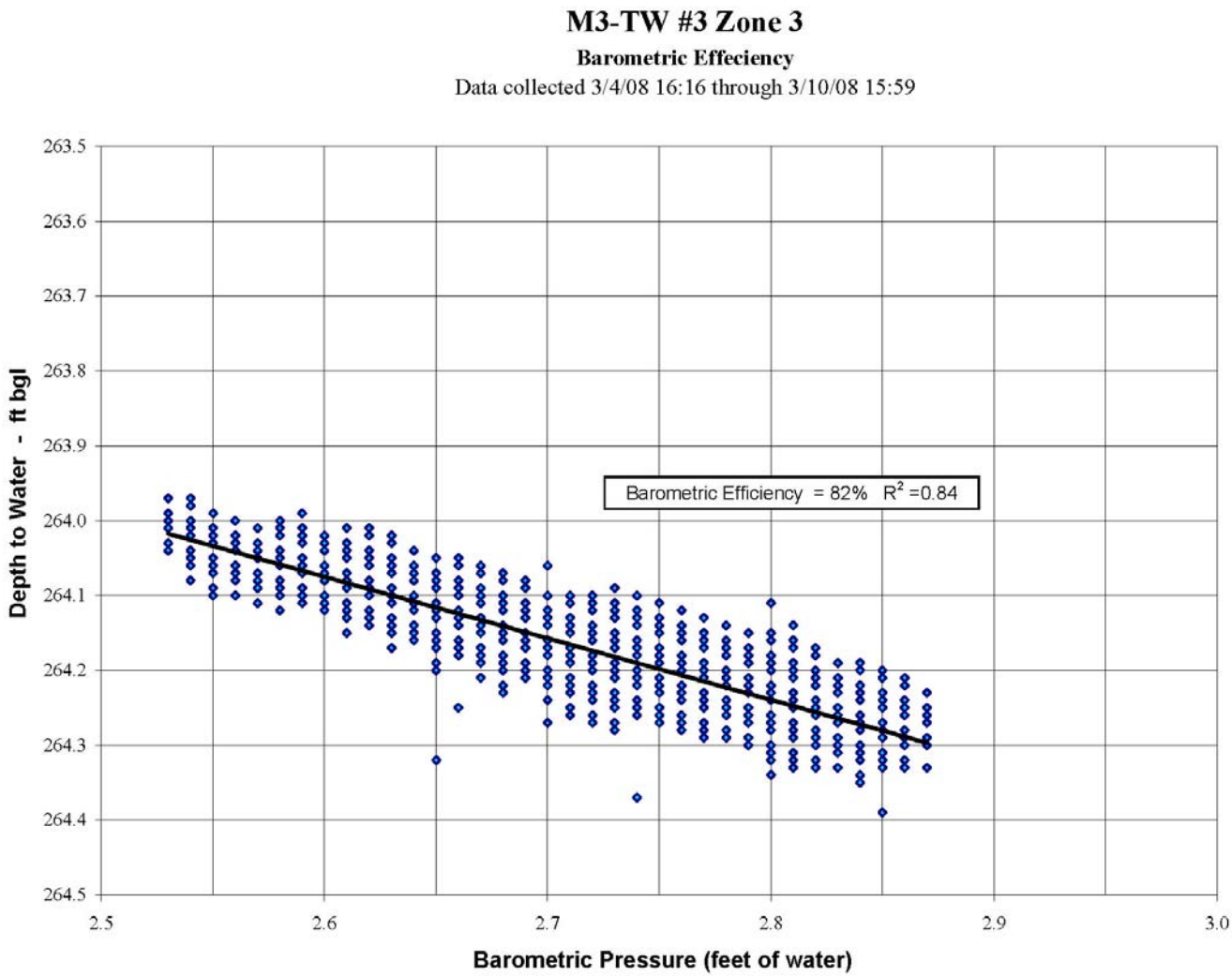
Distance from Pumping Well SVR #7 = 10,916 ft
Screen Depth = 253 to 383 ft

Figure B-15. Barometric Efficiency Plot for TW #1 Zone 2



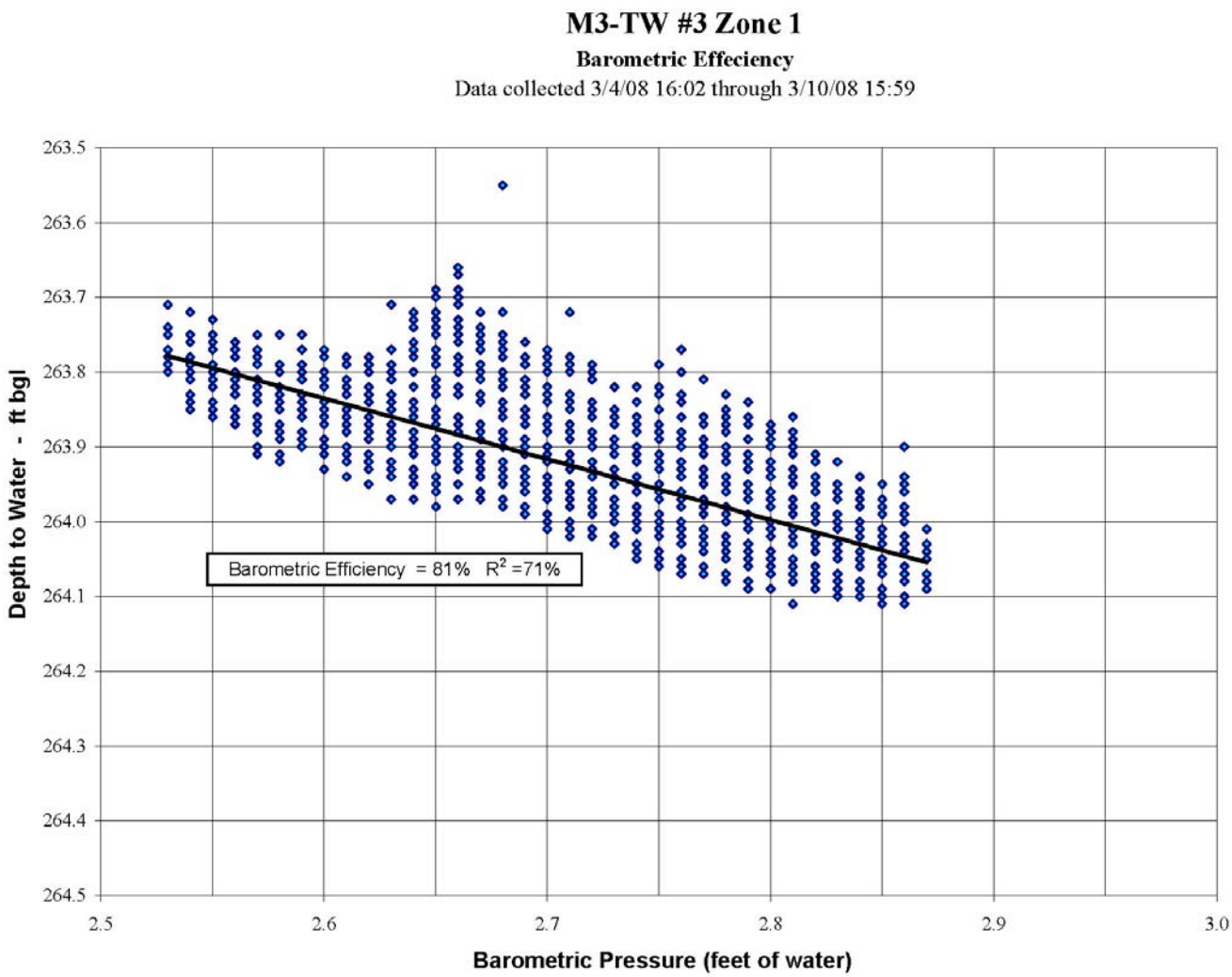
Distance from Pumping Well SVR #7 = 10,916 ft
Screen Depth = 467 to 507 ft

Figure B-16. Barometric Efficiency Plot for TW #3 Zone 3



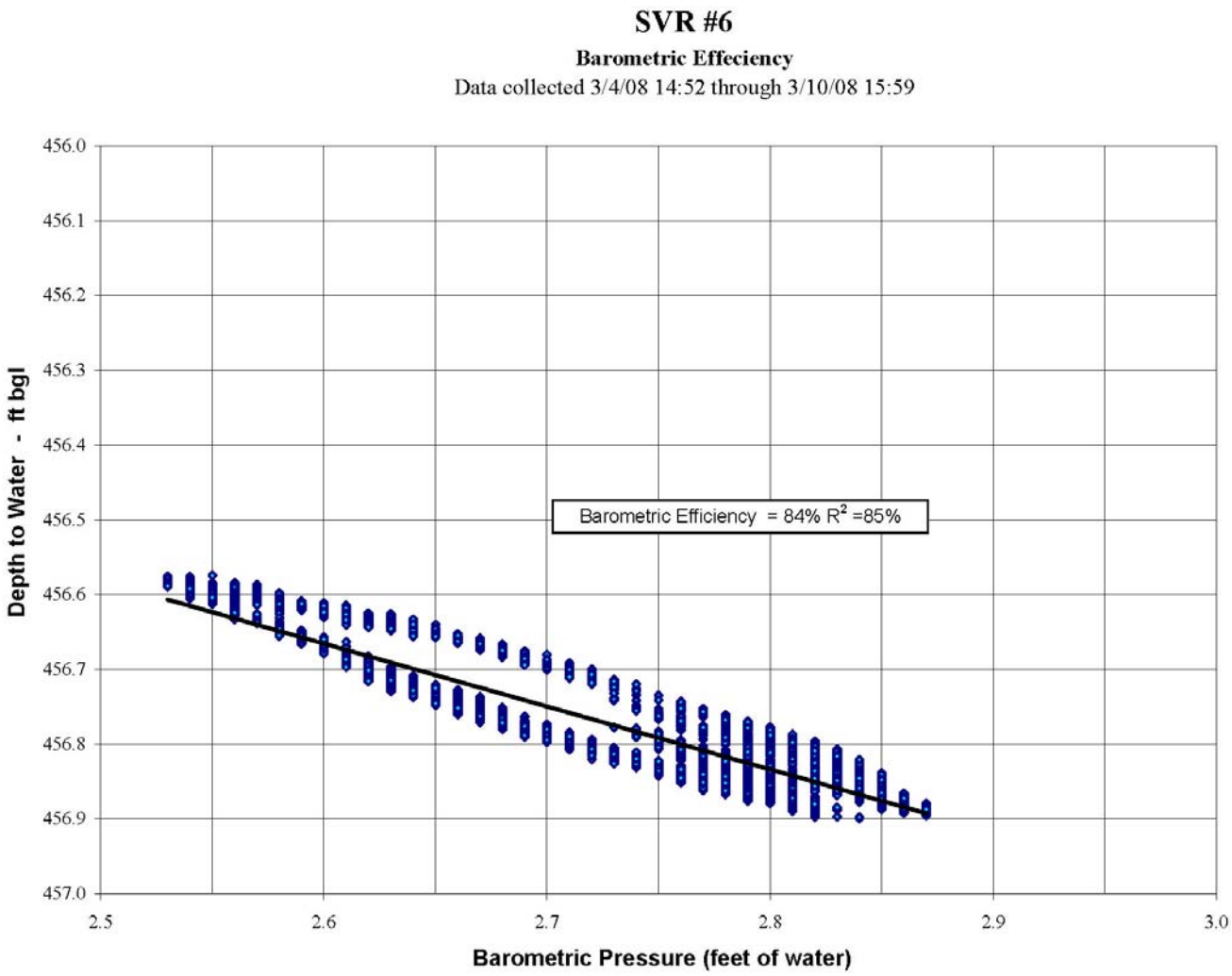
Distance from Pumping Well SVR #7 = 8,173 ft
Screen Depth = 369 to 379 ft

Figure B-17. Barometric Efficiency Plot for TW #3 Zone 1



Distance from Pumping Well SVR #7 = 8,173 ft
Screen Depth = 432 to 442 ft

Figure B-18. Barometric Efficiency Plot for SVR #6



In Willow Creek Aquifer - NOT in Pierce Gulch Sand Aquifer
Distance from Pumping Well SVR #7 = 8,189 ft
Screen Depth = 560 to 730 ft

Appendix C – Actual and BE-Corrected Water Levels

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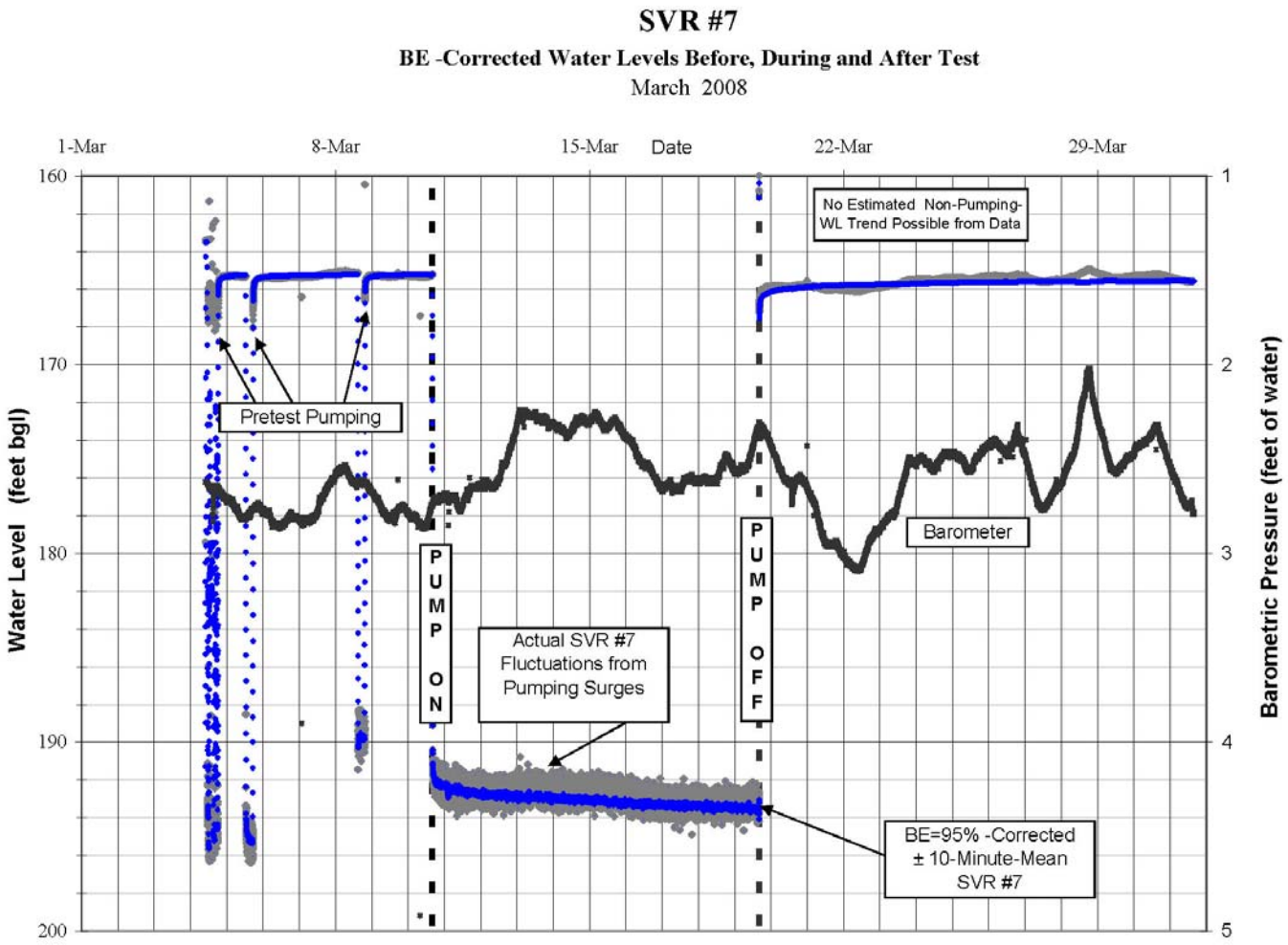
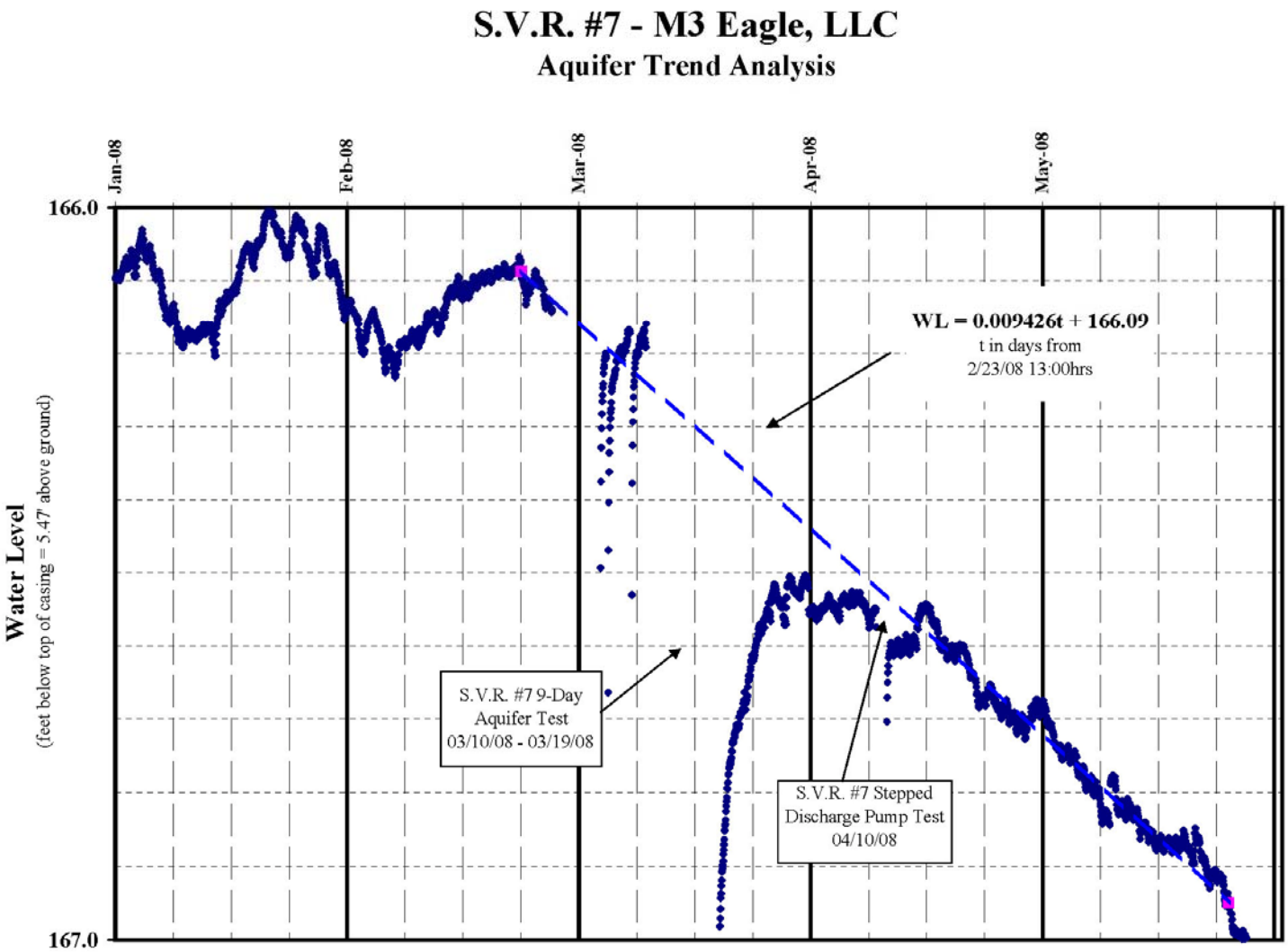
Figure C-1. Actual and BE-Corrected Water Levels for SVR #7



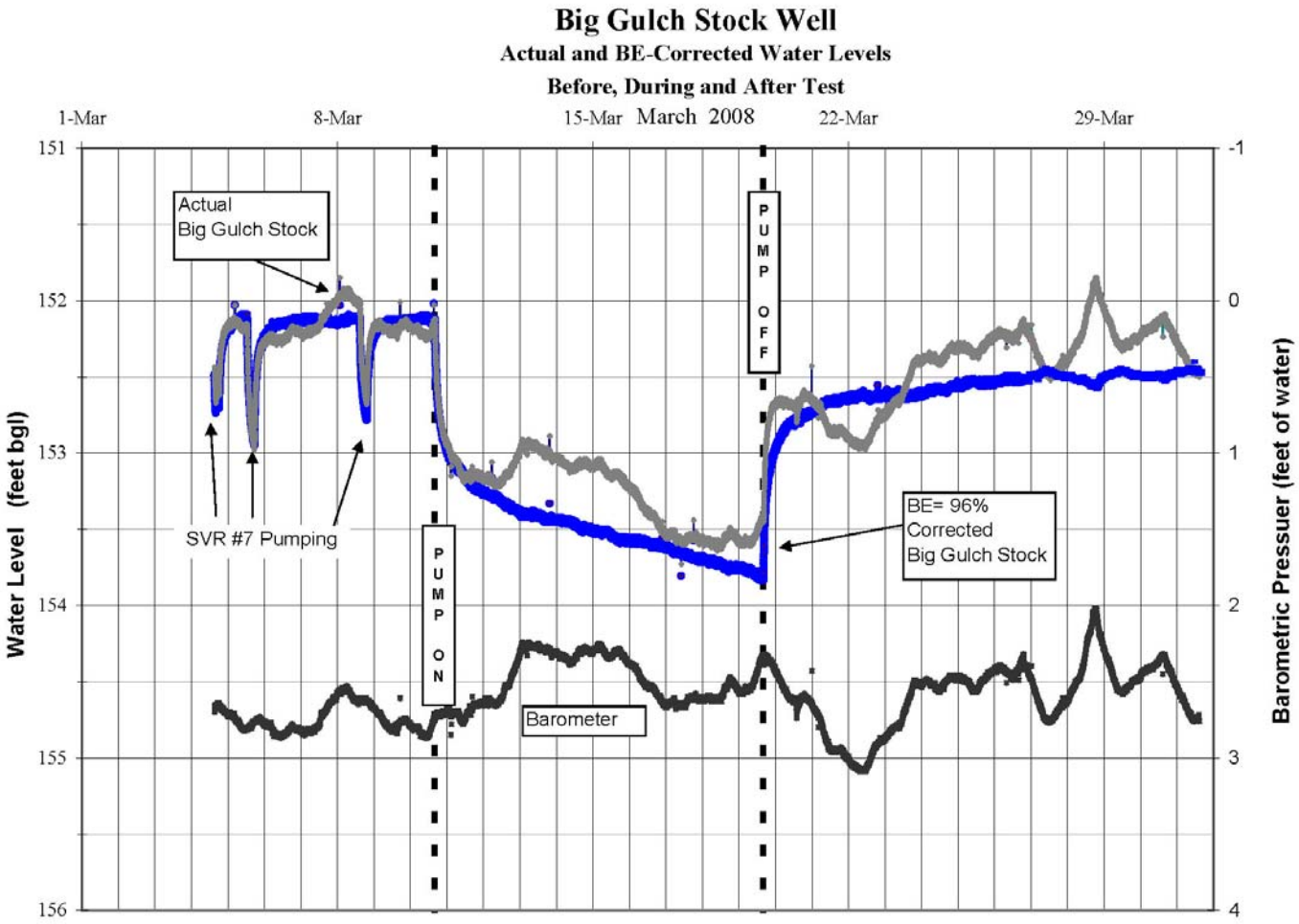
Distance from Pumping Well SVR #7 = 0 ft
Screen Depth = 280 to 350 ft

Figure C-2. Post-Test Water-Level Trend Analysis for SVR #7



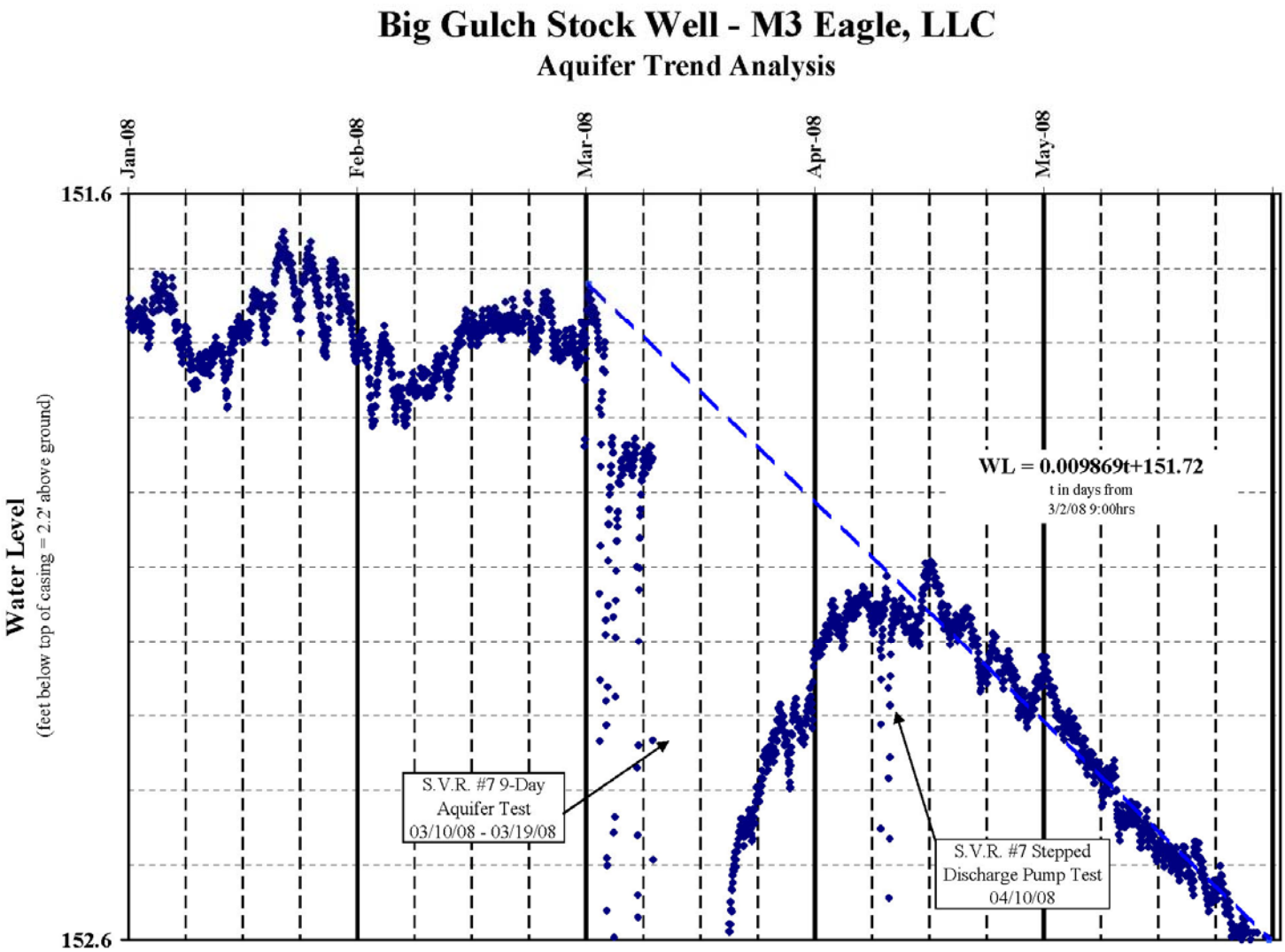
Plotted water levels shown above on hydrograph have been corrected for barometric fluctuations.

Figure C-3. Actual and BE-Corrected Water Levels for Big Gulch Stock Well



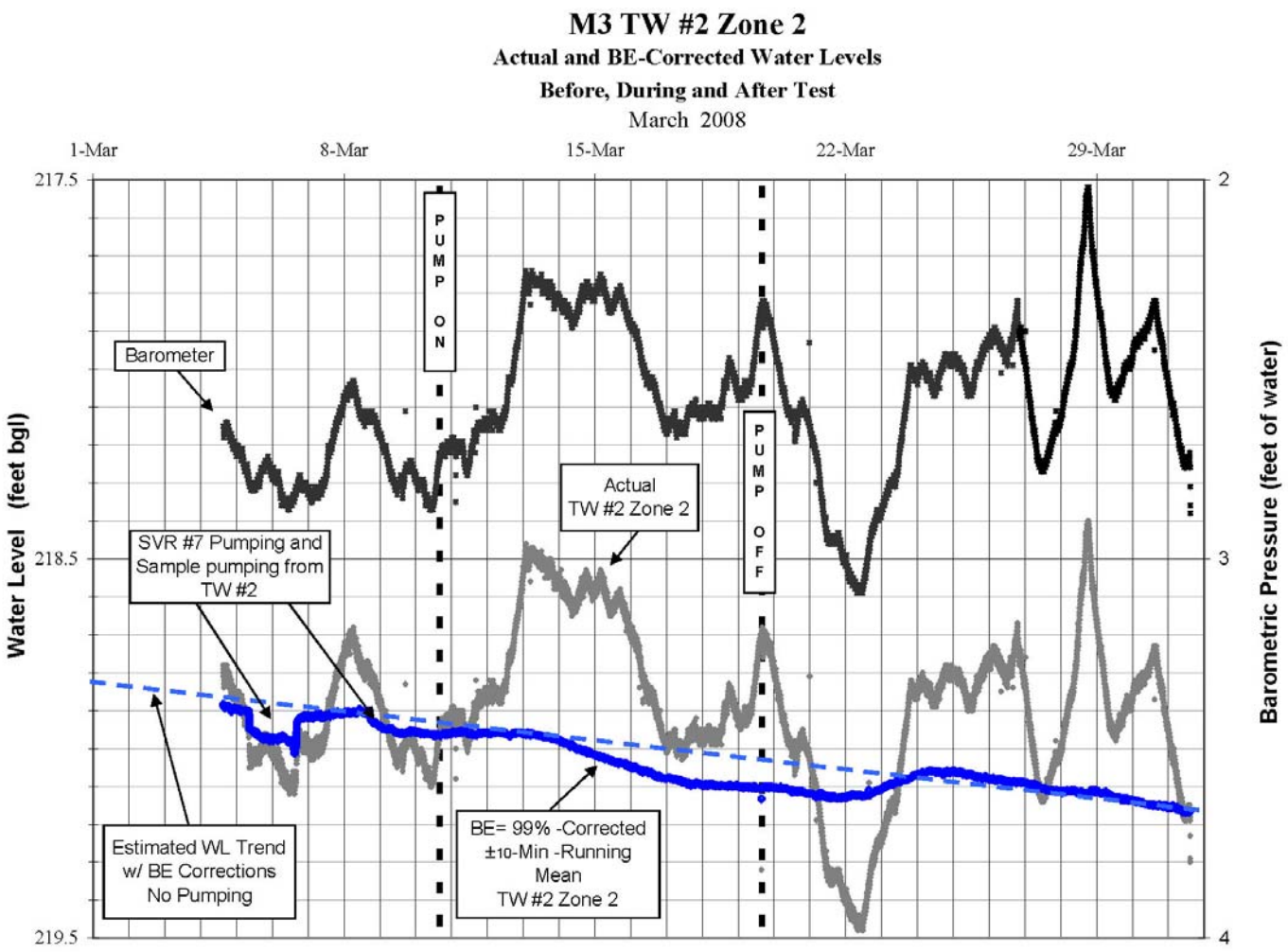
Distance from Pumping Well SVR #7 = 845 ft
Screen Depth = 180 to 180 ft ("open hole," no well screen)

Figure C-4. Post-Test Water-Level Trend Analysis for Big Gulch Stock Well



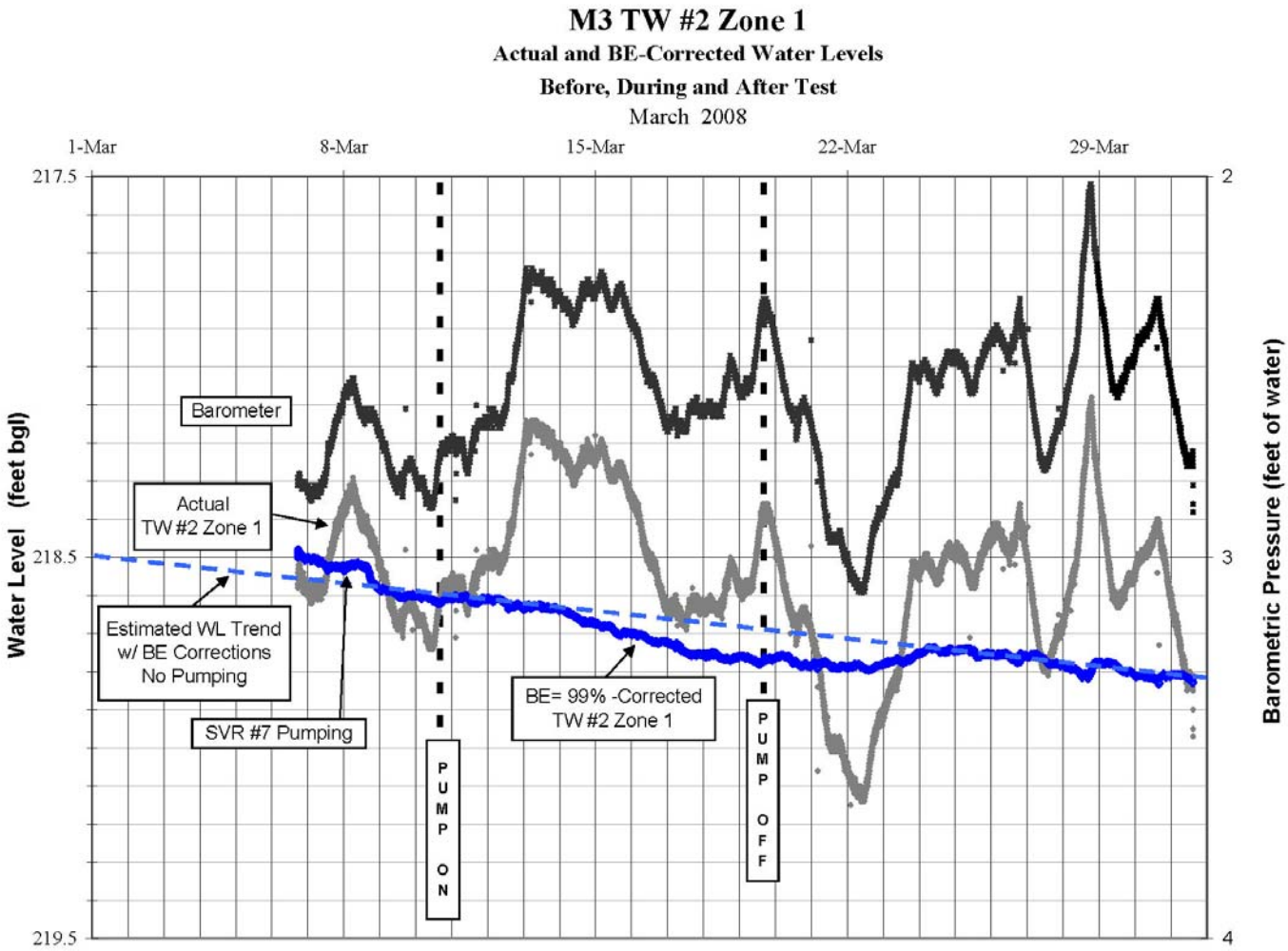
Plotted water levels shown above on hydrograph have been corrected for barometric fluctuations.

Figure C-5. Actual and BE-Corrected Water Levels for TW #2 Zone 2



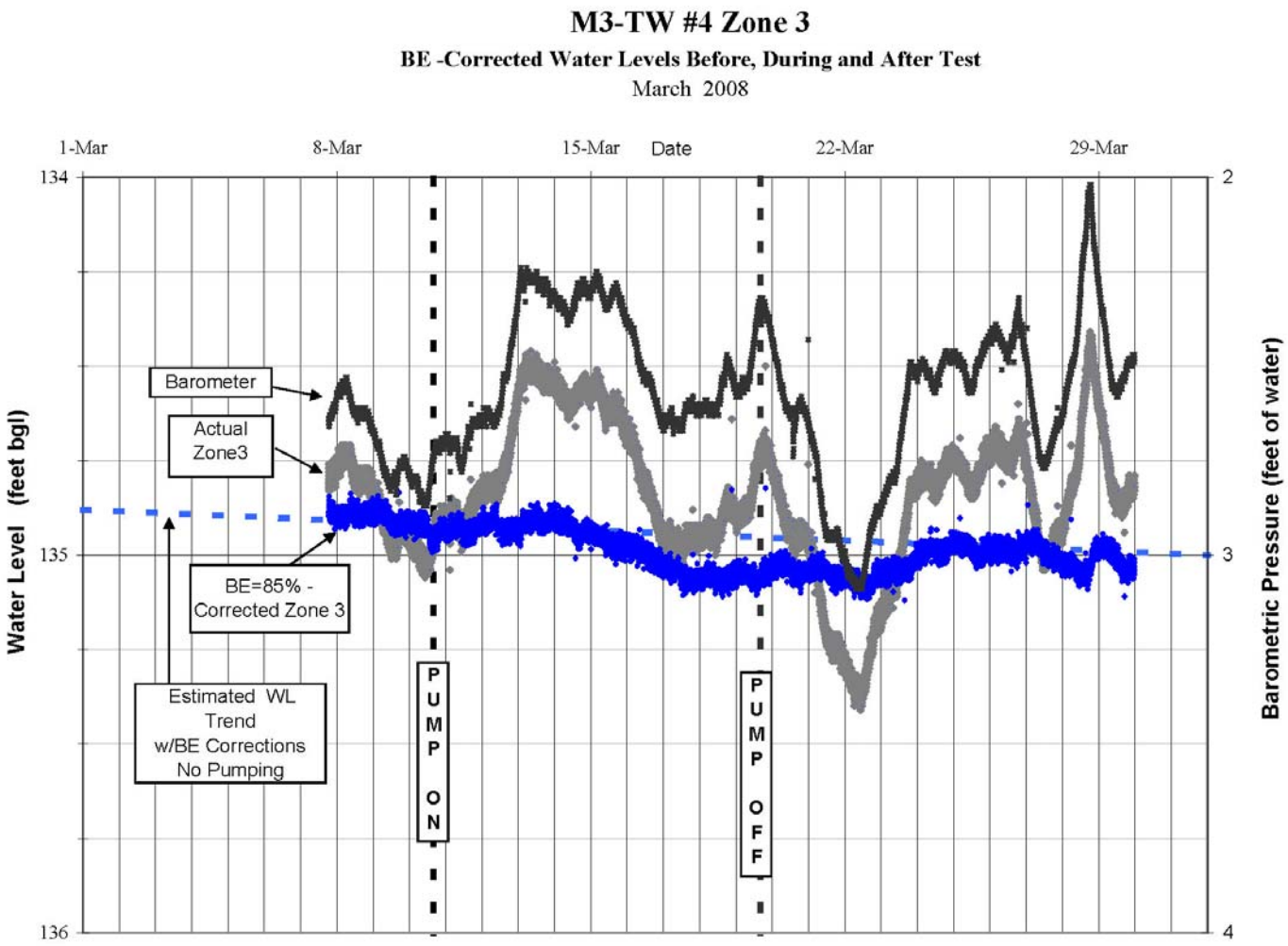
Distance from Pumping Well SVR #7 = 3,636 ft
Screen Depth = 230 to 250 ft

Figure C-6. Actual and BE-Corrected Water Levels for TW #2 Zone 1



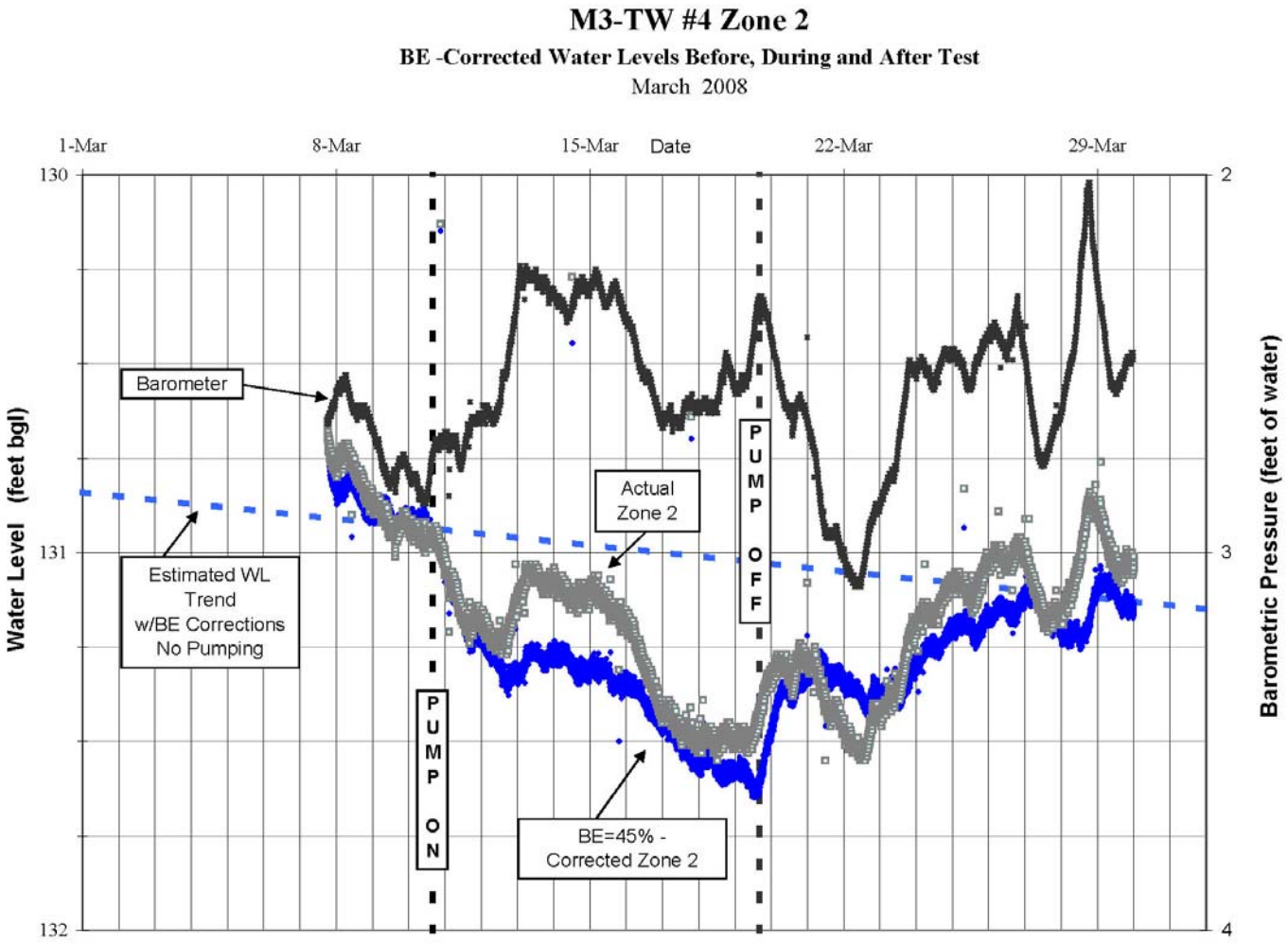
Distance from Pumping Well SVR #7 = 3,636 ft
Screen Depth = 270 to 320 ft

Figure C-7. Actual and BE-Corrected Water Levels for TW #4 Zone 3



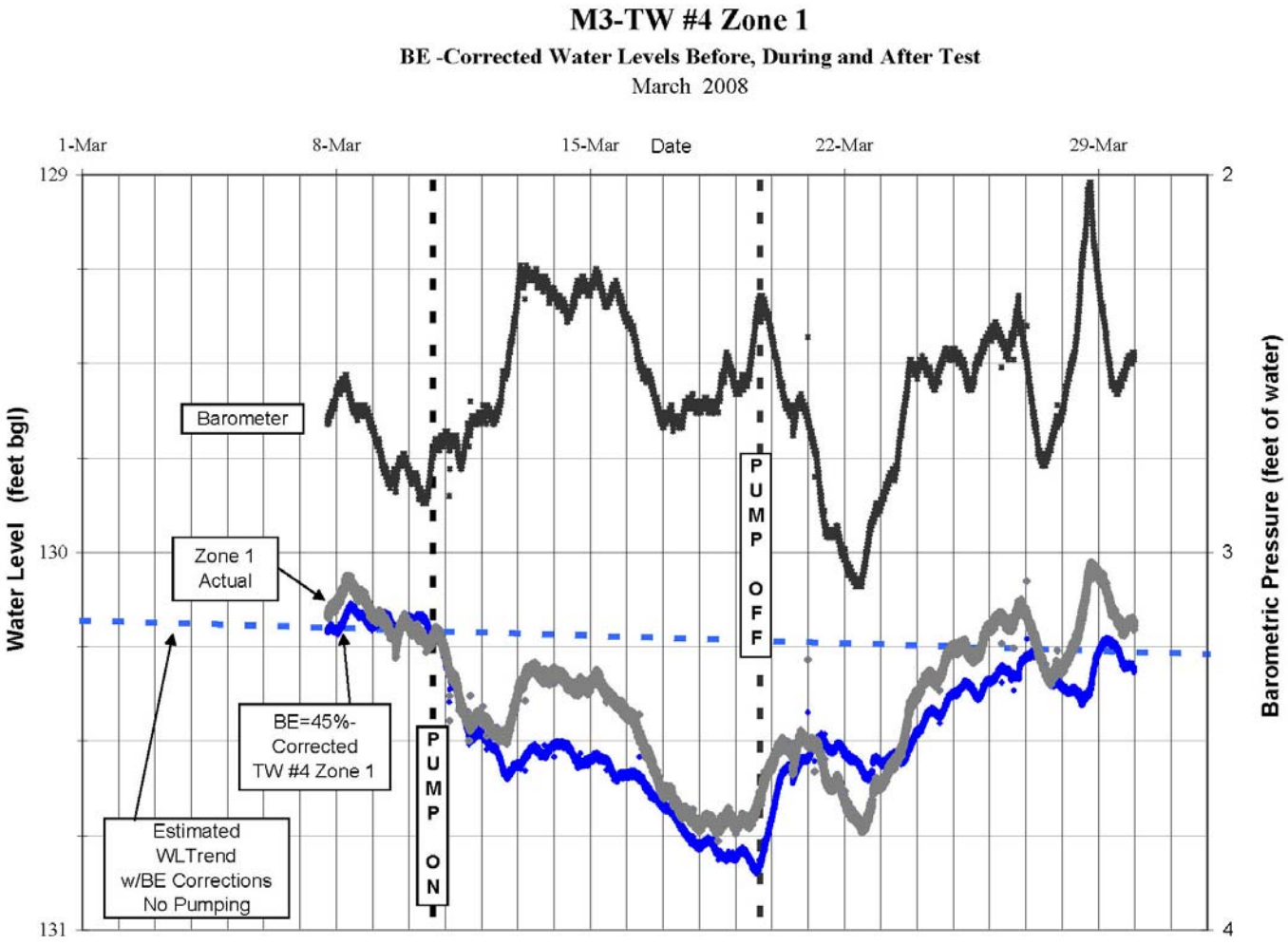
Distance from Pumping Well SVR #7 = 4,489 ft
Screen Depth = 181 to 201 ft

Figure C-8. Actual and BE-Corrected Water Levels for TW #4 Zone 2



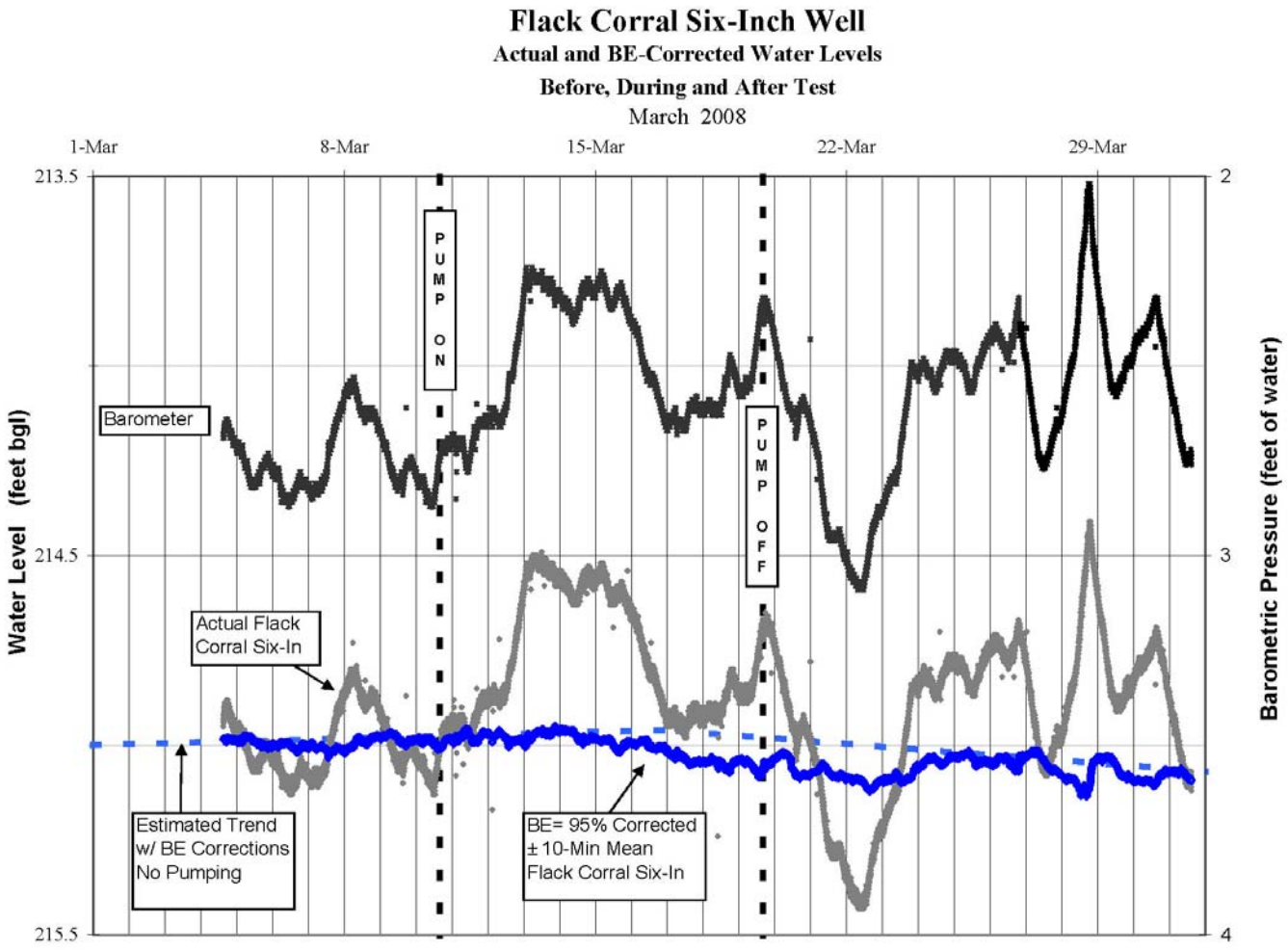
Distance from Pumping Well SVR #7 = 4,489 ft
Screen Depth = 325 to 556 ft

Figure C-9. Actual and BE-Corrected Water Levels for TW #4 Zone 1



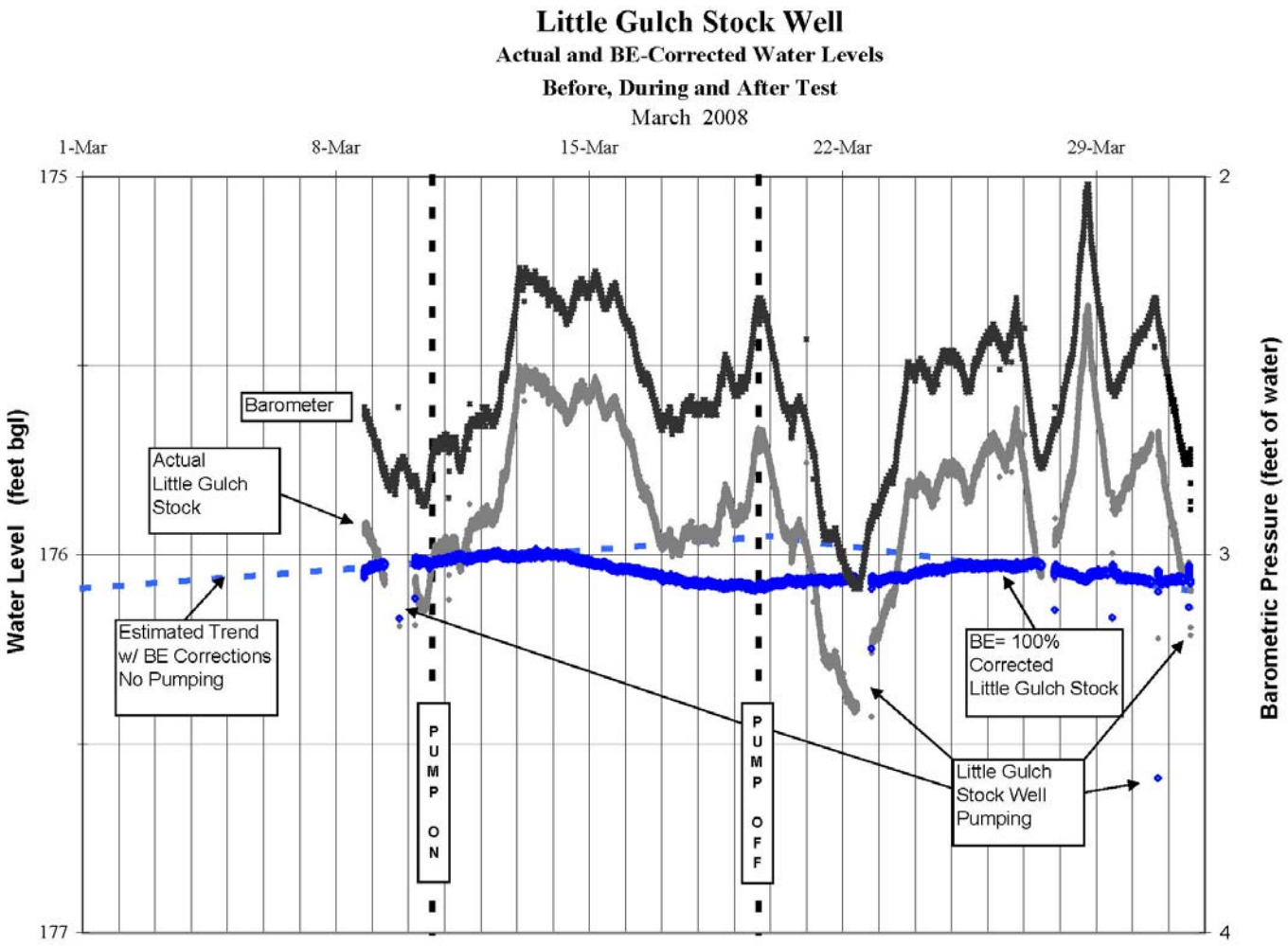
Distance from Pumping Well SVR #7 = 4,489 ft
Screen Depth = 625 to 646 ft

Figure C-10. Actual and BE-Corrected Water Levels for Flack Corral 6-Inch Well



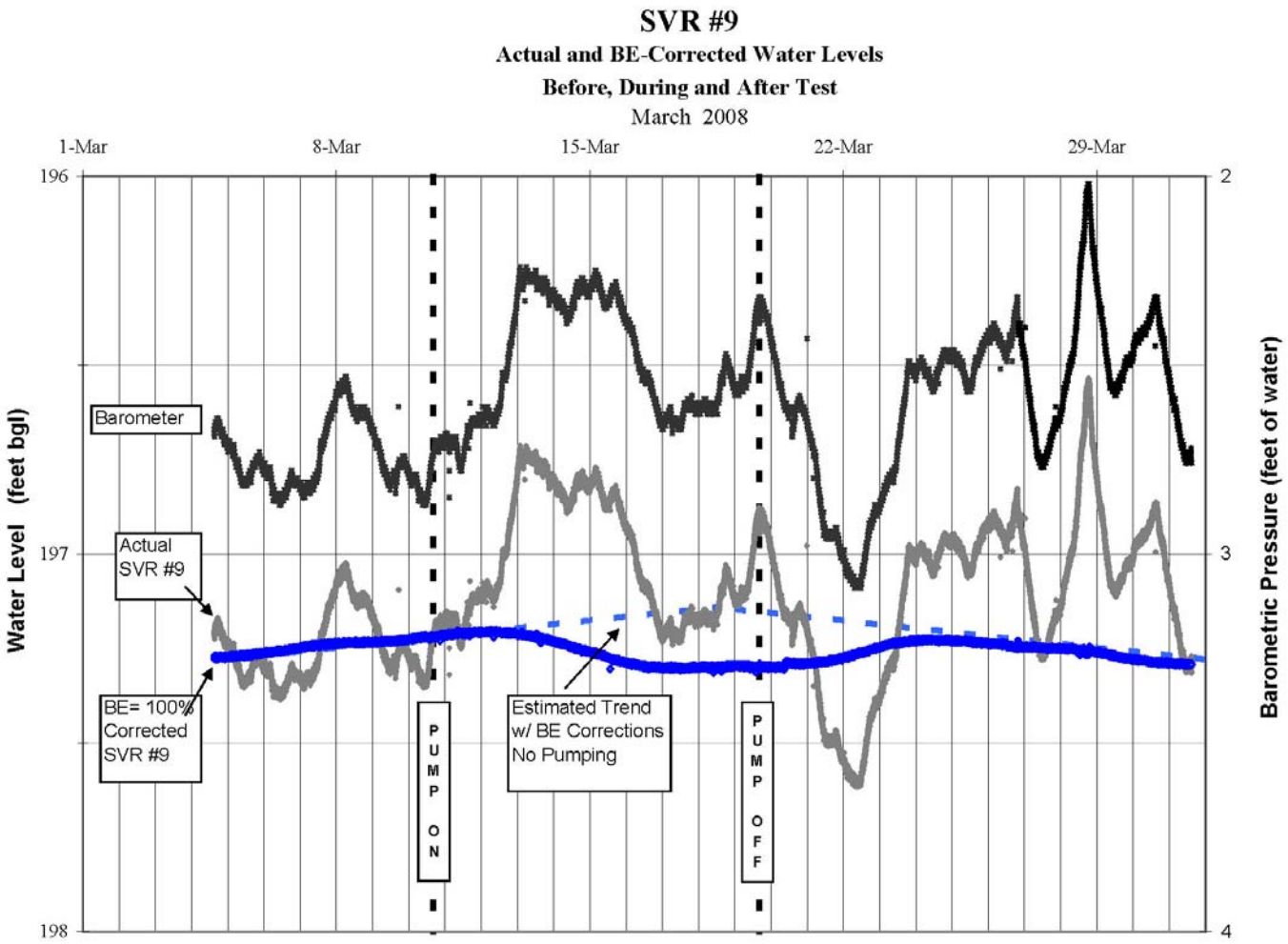
Distance from Pumping Well SVR #7 = 6,749 ft
Screen Depth = 74 to 386 ft

Figure C-11. Actual and BE-Corrected Water Levels for Little Gulch Stock Well



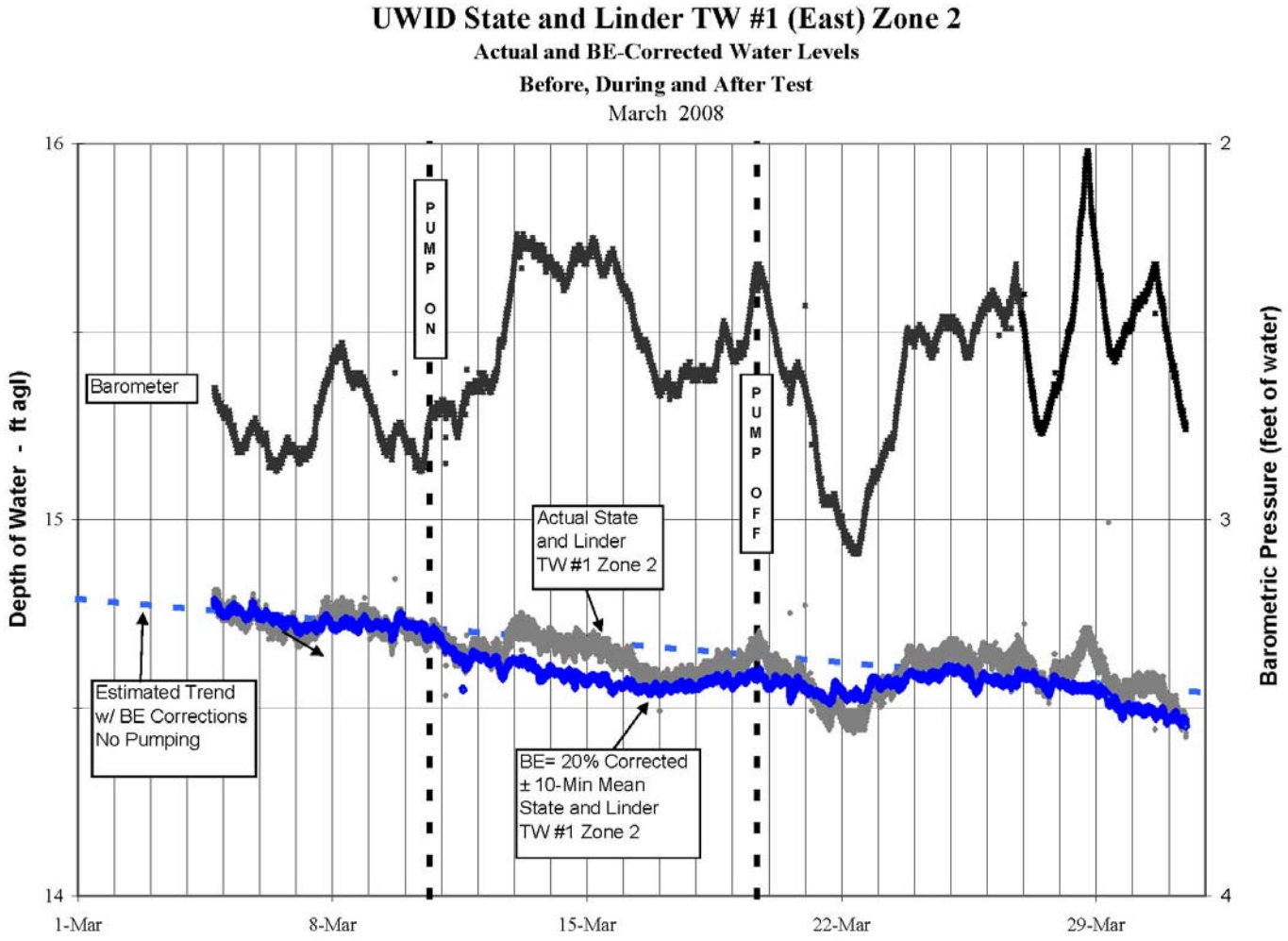
Distance from Pumping Well SVR #7 = 9,740 ft
Screen Depth = 220 to 223 ft

Figure C-12. Actual and BE-Corrected Water Levels for SVR #9



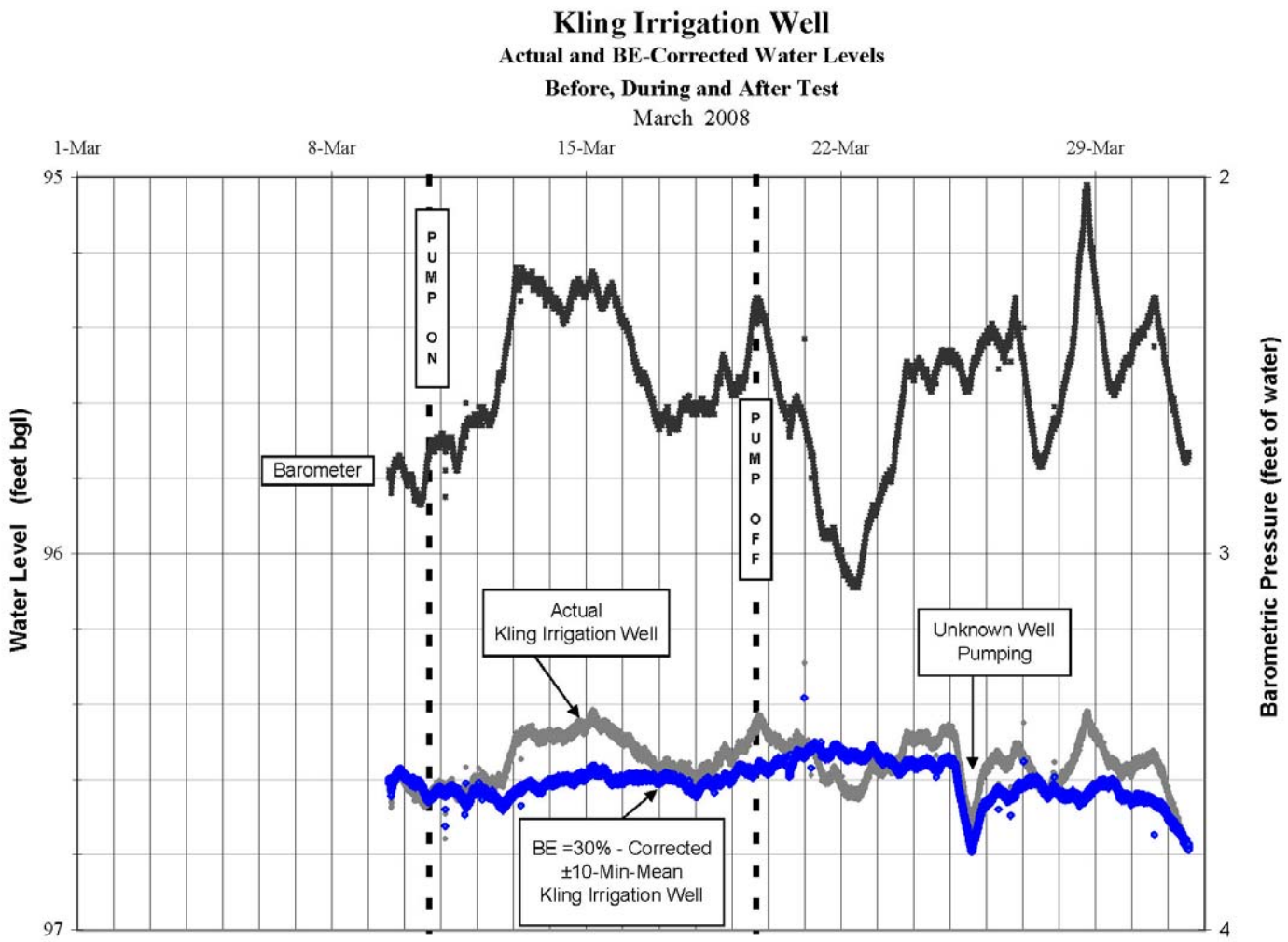
Distance from Pumping Well SVR #7 = 11,660 ft
Screen Depth = 235 to 263 ft

Figure C-13. Actual and BE-Corrected Water Levels for UWID State and Linder TW #1 Zone 2



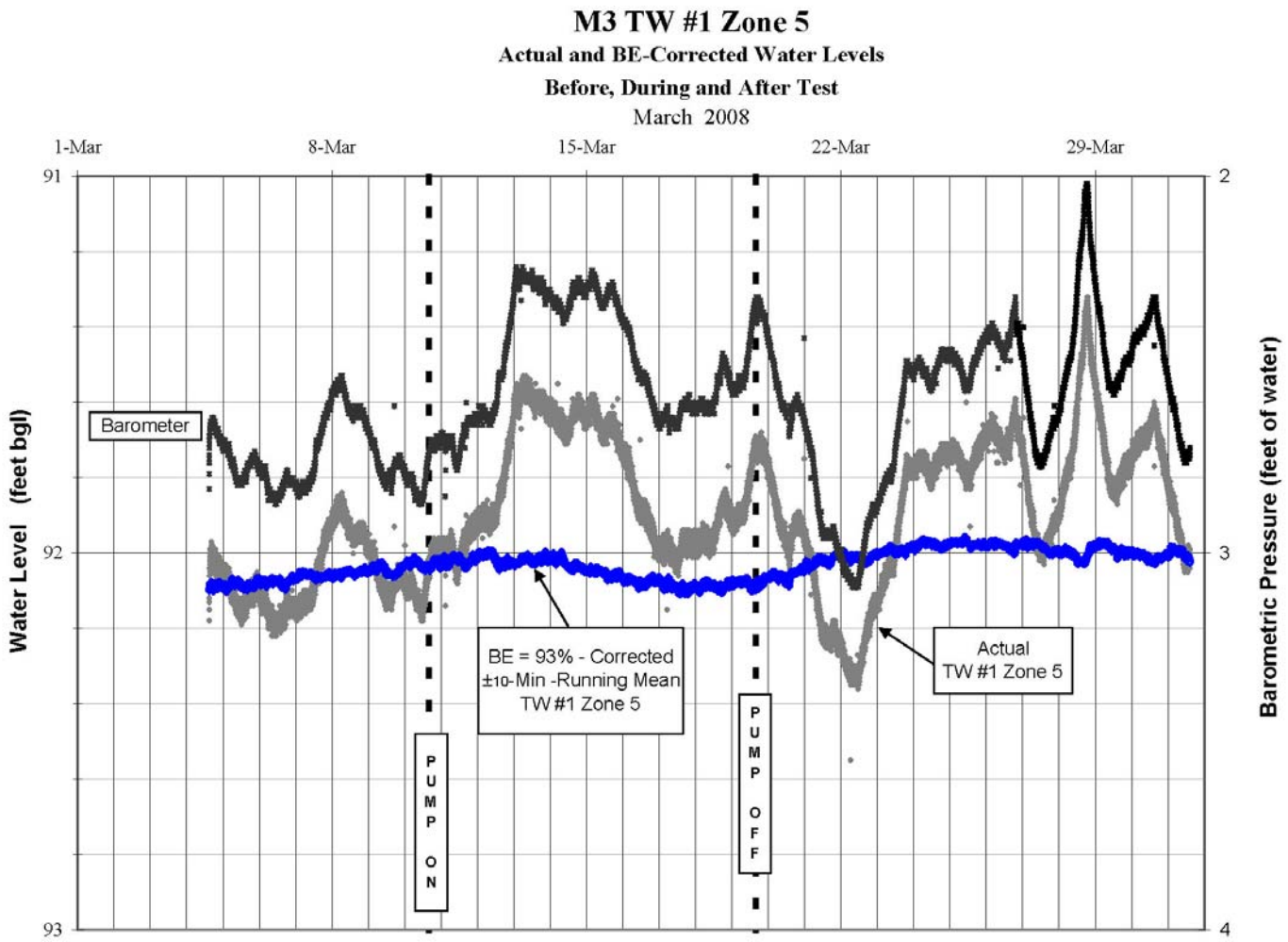
Distance from Pumping Well SVR #7 = 22,302 ft
Screen Depth = 280 to 370 ft

Figure C-14. Actual and BE-Corrected Water Levels for the Kling Irrigation Well



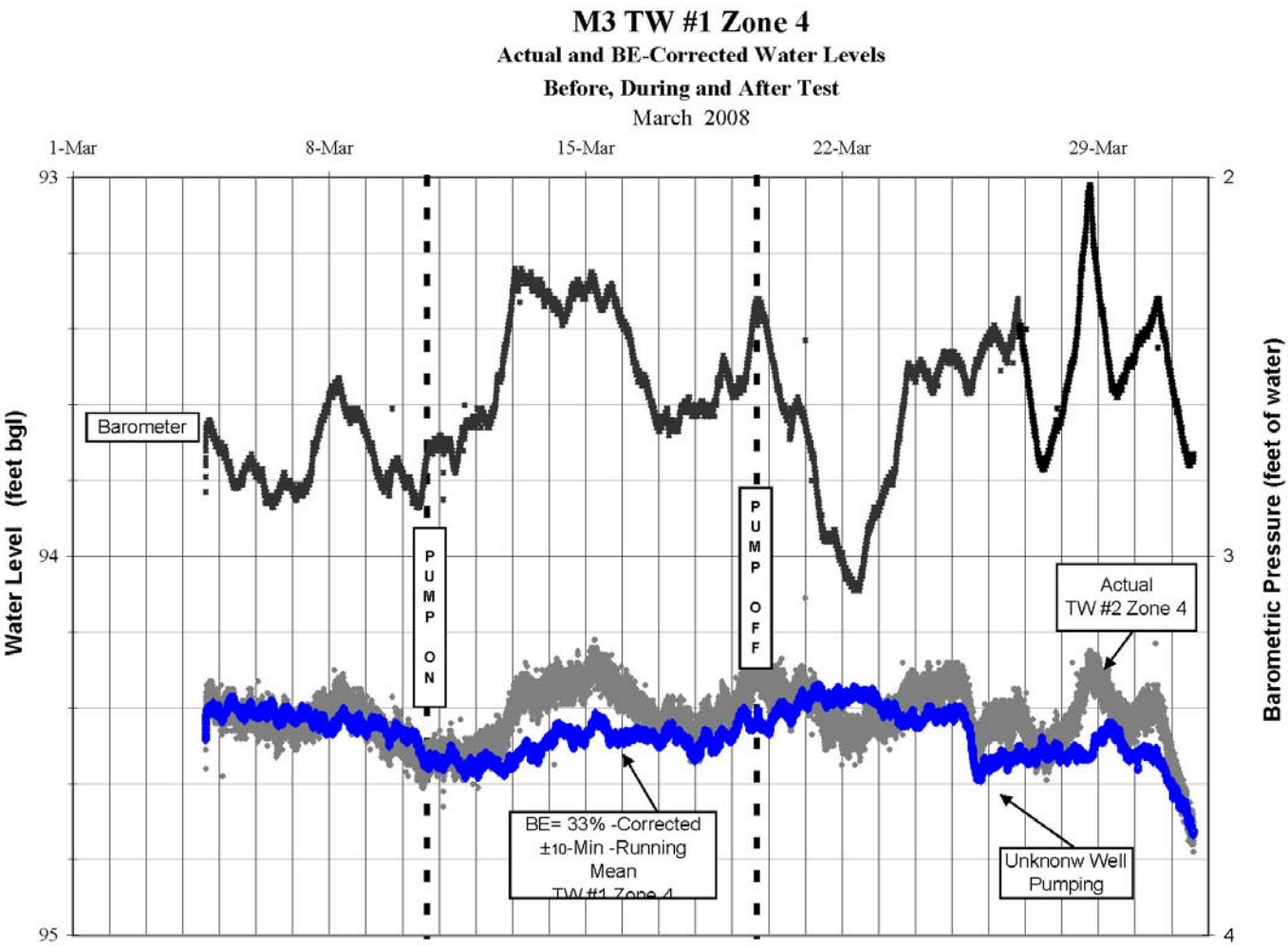
Distance from Pumping Well SVR #7 = 9,908 ft
Screen Depth = 198 to 408 ft

Figure C-15. Actual and BE-Corrected Water Levels for TW #1 Zone 5



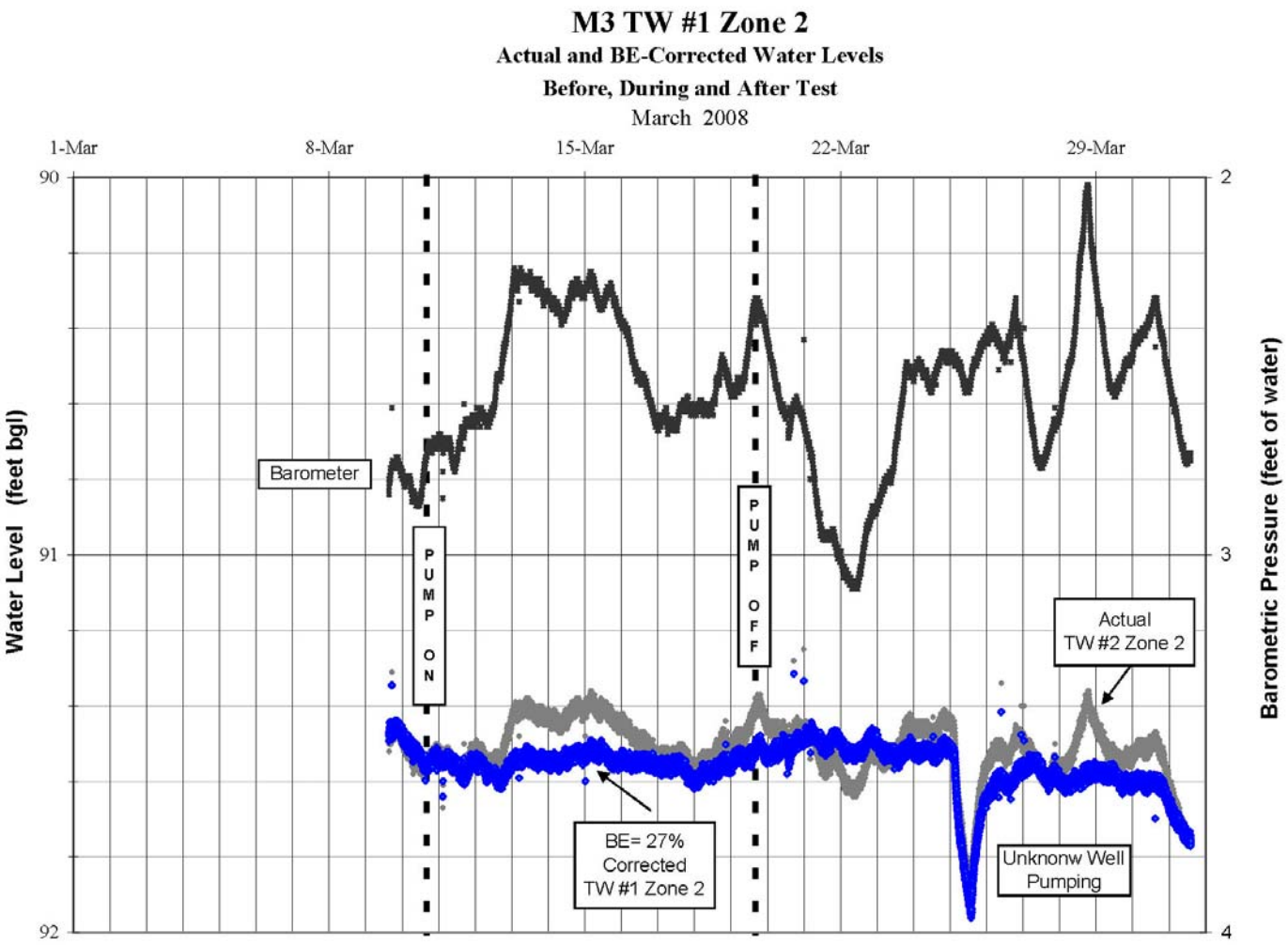
Distance from Pumping Well SVR #7 = 10,916 ft
Screen Depth = 97 to 137 ft

Figure C-16. Actual and BE-Corrected Water Levels for TW #1 Zone 4



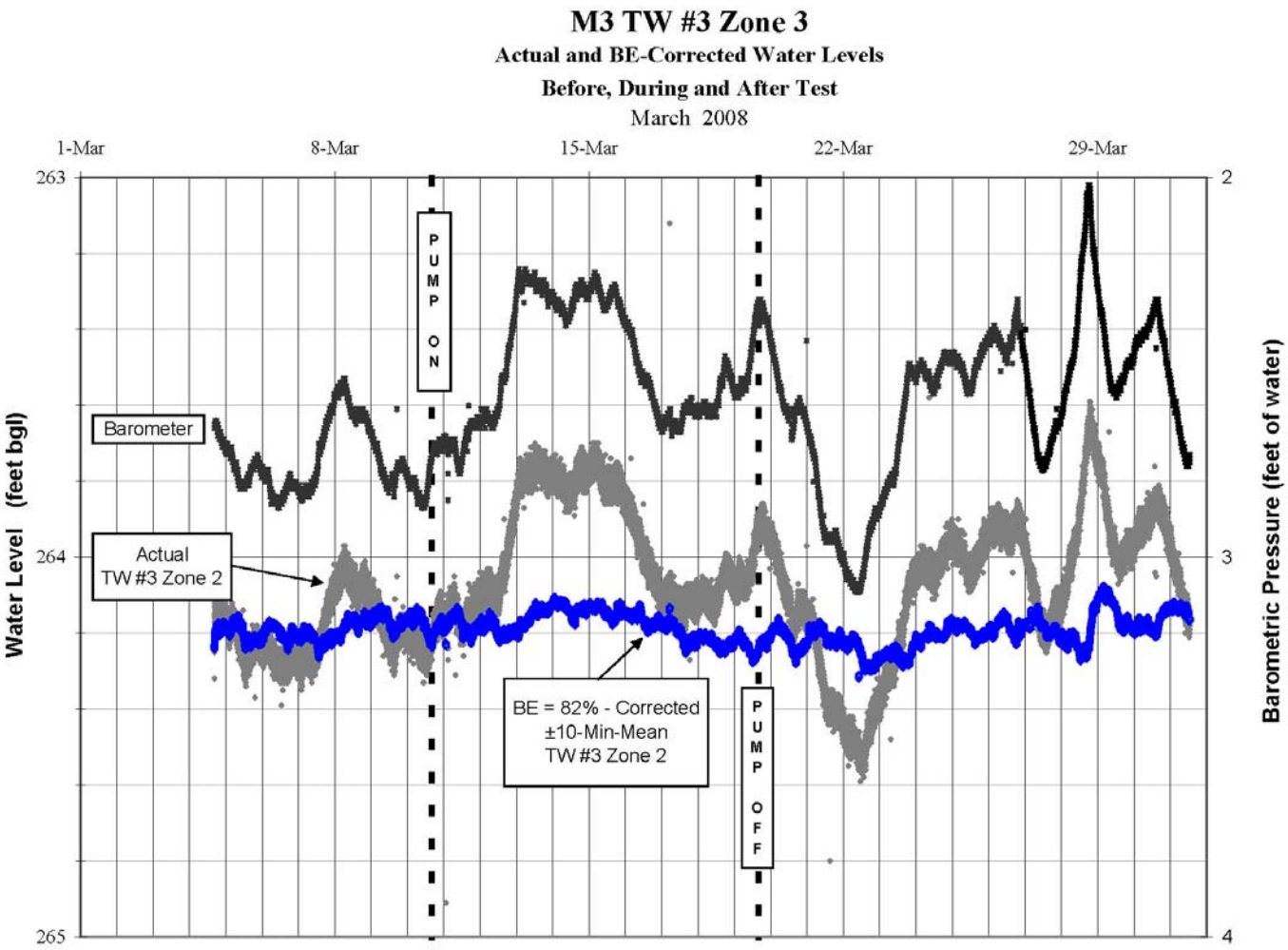
Distance from Pumping Well SVR #7 = 10,916 ft
Screen Depth = 253 to 383 ft

Figure C-17. Actual and BE-Corrected Water Levels for TW #1 Zone 2



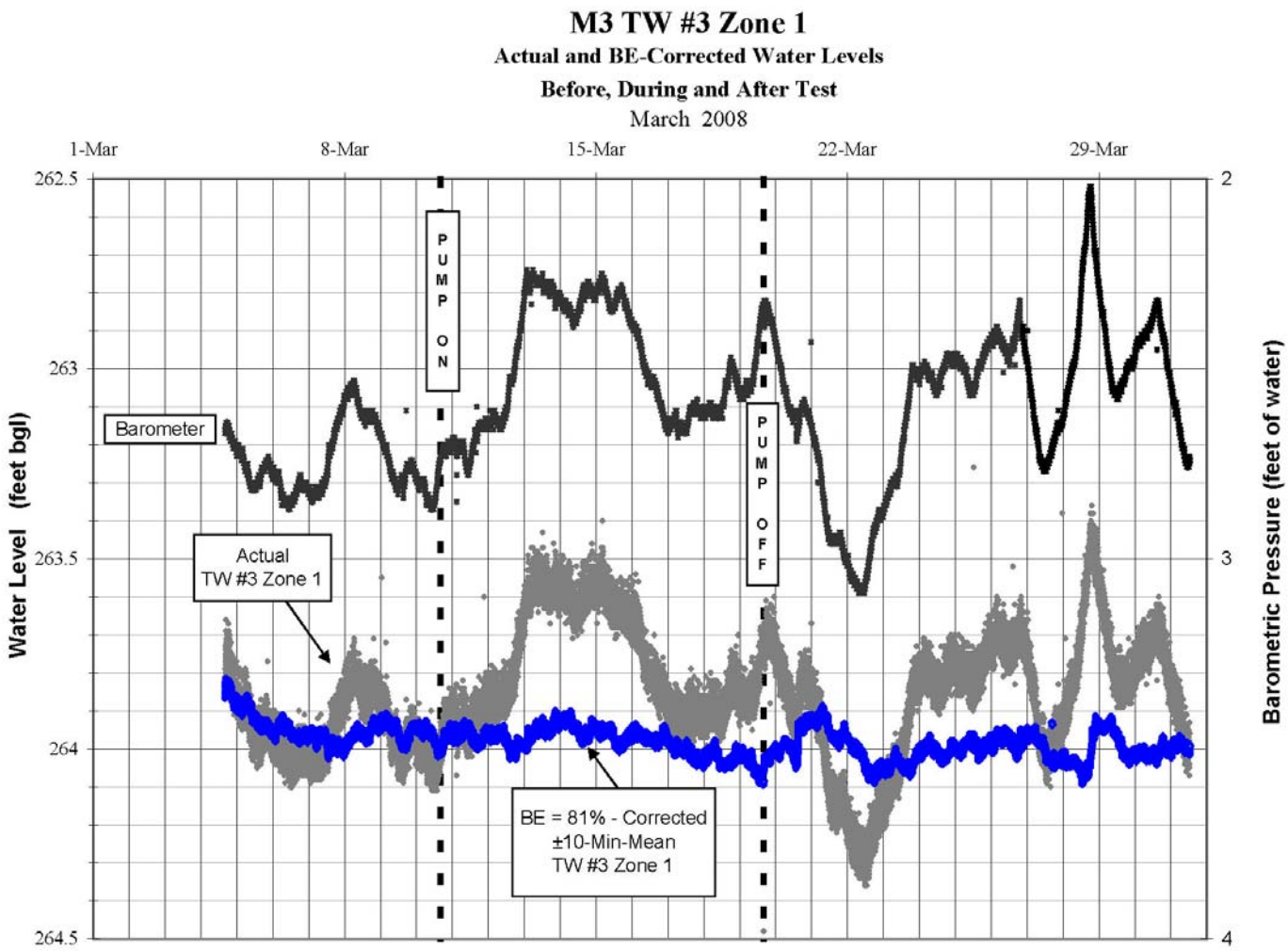
Distance from Pumping Well SVR #7 = 10,916 ft
Screen Depth = 467 to 507 ft

Figure C-18. Actual and BE-Corrected Water Levels for TW #3 Zone 3



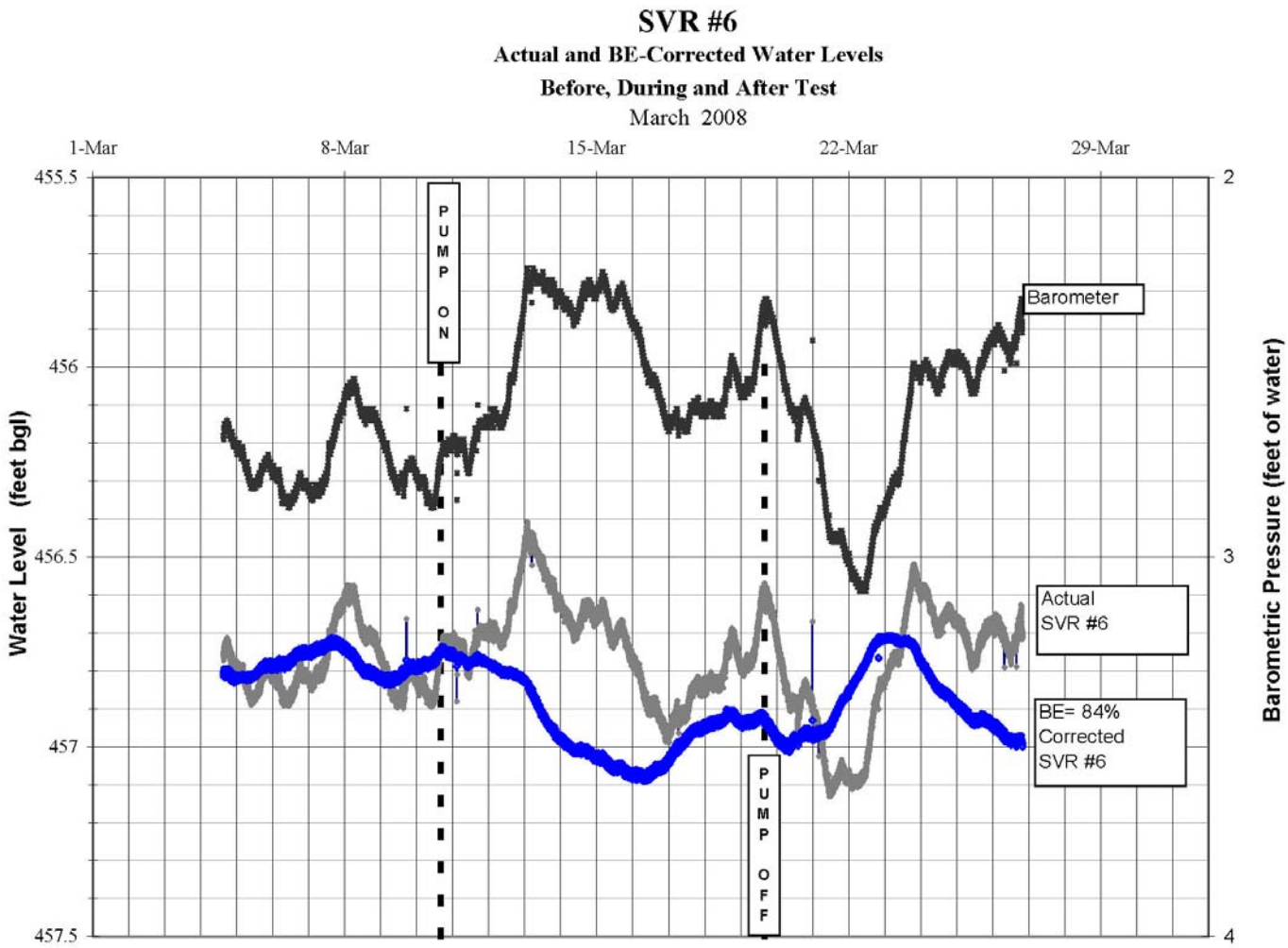
Distance from Pumping Well SVR #7 = 8,173 ft
Screen Depth = 369 to 379 ft

Figure C-19. Actual and BE-Corrected Water Levels for TW #3 Zone 1



Distance from Pumping Well SVR #7 = 8,173 ft
Screen Depth = 432 to 442 ft

Figure C-20. Actual and BE-Corrected Water Levels for SVR #6



In Willow Creek Aquifer - NOT in Pierce Gulch Sand Aquifer
Distance from Pumping Well SVR #7 = 8,189 ft
Screen Depth = 560 to 730 ft

Appendix D – Additional Information on the Analytical Methods Used in this Report

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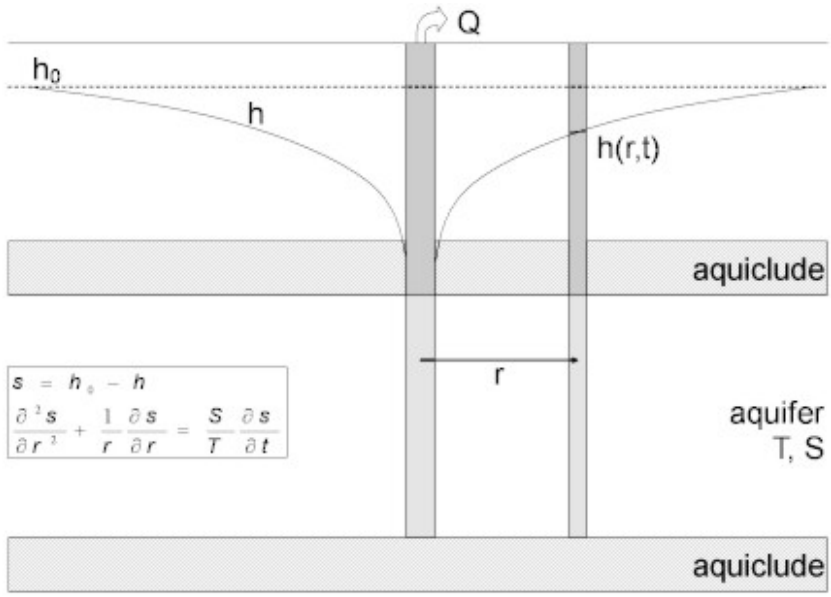
Details on the Method of Cooper, H.H. and C.E. Jacob, 1946. (From Aqtesolv®)
Schematic Diagram:



Assumptions:

- aquifer has infinite areal extent
- aquifer is homogeneous, isotropic and of uniform thickness
- pumping well is fully penetrating
- flow to pumping well is horizontal
- aquifer is confined
- flow is unsteady
- water is released instantaneously from storage with decline of hydraulic
- diameter of pumping well is very small so that storage in the well can be
- values of u are small (i.e., r is small and t is large)

Equations:

For large values of time, Cooper and Jacob (1946) proposed the following equation for displacement in a confined aquifer in response to pumping:

$$s = \frac{2.303Q}{4\pi T}\log\left(\frac{2.25Tt}{r^2S}\right)$$

$$s_D = \frac{4\pi T}{Q}s$$

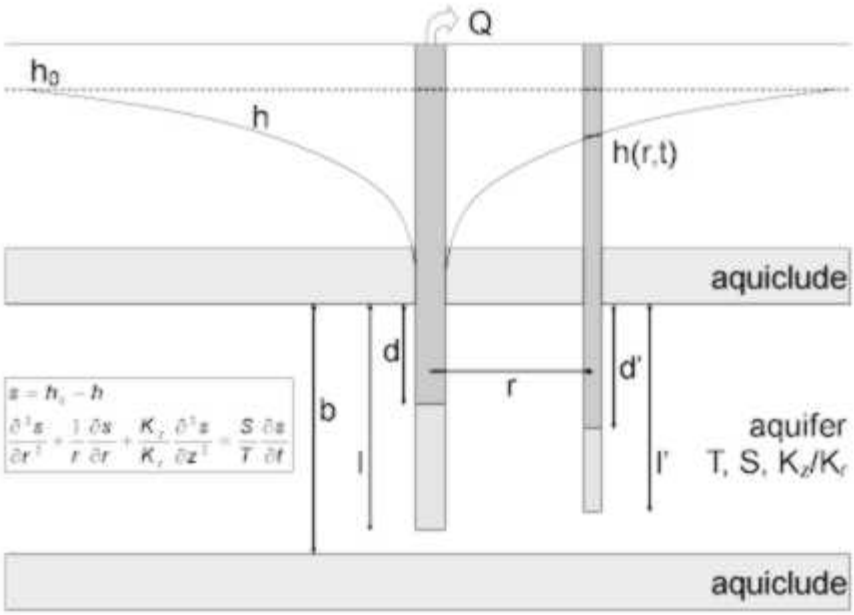
$$t_D = \frac{Tt}{r^2S}$$

where

- Q is pumping rate [L^3/T]
- r is radial distance [L]
- t is time [T]
- s is drawdown [L]
- S is storativity [dimensionless]
- T is transmissivity [L^2/T]

Details on the Method of Hantush, M.S. 1961a and b (From Aqtesolv®)

Schematic Diagram:



Assumptions:

- aquifer has infinite areal extent
- aquifer is homogeneous and of uniform thickness
- pumping well is fully or partially penetrating
- flow to pumping well is horizontal when pumping well is fully penetrating
- aquifer is confined
- flow is unsteady
- water is released instantaneously from storage with decline of hydraulic head
- diameter of pumping well is very small so that storage in the well can be neglected

Equations:

Hantush (1961a, b) derived equations for the effects of partial penetration in a confined aquifer. For a piezometer, the partial penetration correction is as follows:

$$s = \frac{Q}{4\pi T}\left(w(u) + \frac{2b}{\pi(l-d)} \sum_{n=1}^{\infty} \frac{1}{n} [\sin(\frac{n\pi l}{b}) - \sin(\frac{n\pi d}{b})] \cdot \cos(\frac{n\pi z}{b}) \cdot w(u, \sqrt{\frac{K_z}{K_r}} \frac{n\pi r}{b}) \right)$$

For an observation well, the following partial penetration correction applies:

$$s = \frac{Q}{4\pi T}\left(w(u) + \frac{2b^2}{\pi^2(l-d)(l'-d')} \sum_{n=1}^{\infty} \frac{1}{n^2} [\sin(\frac{n\pi l}{b}) - \sin(\frac{n\pi d}{b})] \cdot [\sin(\frac{n\pi l'}{b}) - \sin(\frac{n\pi d'}{b})] \cdot w(u, \sqrt{\frac{K_z}{K_r}} \frac{n\pi r}{b}) \right)$$

where

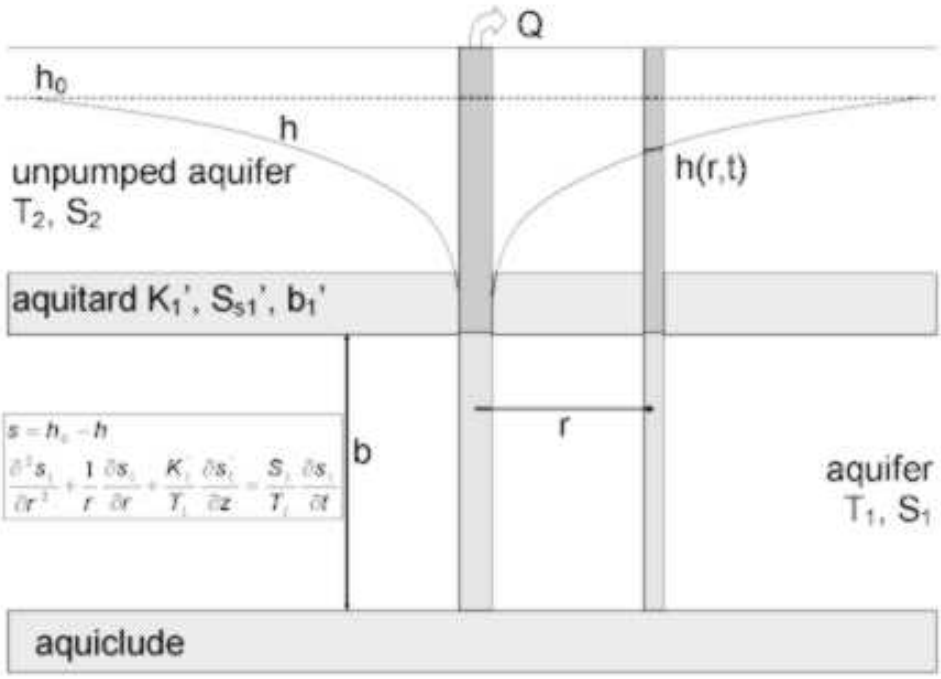
- b is aquifer thickness [L]
- d is depth to top of pumping well screen [L]
- d' is depth to top of observation well screen [L]
- l is depth to bottom of pumping well screen [L]
- l' is depth to bottom of observation well screen [L]
- K_z/K_r is vertical to horizontal hydraulic conductivity anisotropy [dimensionless]
- $w(u,\beta)$ is the Hantush-Jacob well function for leaky confined aquifers
- z is depth to piezometer opening [L]

At large distances, the effect of partial penetration becomes negligible when

$$r > 1.5b / \sqrt{K_z / K_r}$$

Details on the Method of Neuman, S.P., and Witherspoon, P. 1972. (From Aqtesolv®)

Schematic Diagram:



Assumptions:

- aquifer has infinite areal extent
- aquifer is homogeneous, isotropic and of uniform thickness
- pumping well is fully penetrating
- flow to pumping well is horizontal
- aquifer is leaky confined
- flow is unsteady
- water is released instantaneously from storage with decline of hydraulic head
- diameter of pumping well is very small so that storage in the well can be neglected
- confining bed(s) has infinite areal extent, uniform vertical hydraulic conductivity, storage coefficient and thickness
- flow is vertical in the aquitard(s)l

Equations:

$$s_1 = \frac{Q}{4\pi T}\int_0^\infty (1-e^{-y^2 t_D})([1+G(y)]J_0(\varpi_1(y))+[1-G(y)]J_0(\varpi_2(y)))\frac{dy}{y}$$

$$s_1' = \frac{Q}{4\pi T}\frac{2}{\pi}\sum_0^\infty \frac{1}{n}\sin\frac{n\pi z}{b_1'}\int_0^\infty [1-e^{-n^2\pi^2 t_D}+\frac{e^{-n^2\pi^2 t_D}-e^{-y^2 t_D}}{1-y^2/(n^2\pi^2)}]([\frac{2(r/B_{21})^2(-1)^n y}{F(y)\sin y}-G(y)-1]J_0(\varpi_1(y))$$

$$-[\frac{2(r/B_{21})^2(-1)}{F(y)\sin y}-G(y)+1]J_0(\varpi_2(y)))\frac{dy}{y}$$

$$s_2 = \frac{Q}{4\pi T}\int_0^\infty (1-e^{-y^2 t_D})\frac{2(r/B_{21})^2}{F(y)}[J_0(\varpi_1(y))-J_0(\varpi_2(y))]\frac{dy}{\sin y}$$

$$t_{D1} = \frac{T_1 t}{r^2 S_1}$$

$$\bar{t}_{D1} = t_{D1}(r/B_{11})^4/(4\beta_{11})^2$$

$$r/B_{ij} = r\sqrt{K_i'/T_i b_j'}$$

$$\beta_j = \frac{r}{4b_i}\sqrt{\frac{K_j' S_{sj}'}{K_i S_{si}}}$$

$$G(y) = M(y)/F(y)$$

$$\varpi_1^2(y) = \frac{1}{2}[N(y)+F(y)]$$

$$\varpi_2^2(y) = \frac{1}{2}[N(y)-F(y)]$$

$$F^2(y) = M^2(y)+\left[\frac{2(r/B_{11})(r/B_{21})y}{\sin y}\right]^2$$

$$M(y) = \left[\frac{(r/B_{11})^4}{(4\beta_{11})^2}-\frac{(r/B_{21})^4}{(4\beta_{21})^2}\right]y^2-\left[(r/B_{11})^2-(r/B_{21})^2\right]y\cot y$$

$$N(y) = \left[\frac{(r/B_{11})^4}{(4\beta_{11})^2}+\frac{(r/B_{21})^4}{(4\beta_{21})^2}\right]y^2-\left[(r/B_{11})^2+(r/B_{21})^2\right]y\cot y$$

$$s_D = \frac{4\pi T}{Q}s$$

$$t_D = \frac{Tt}{r^2 S}$$

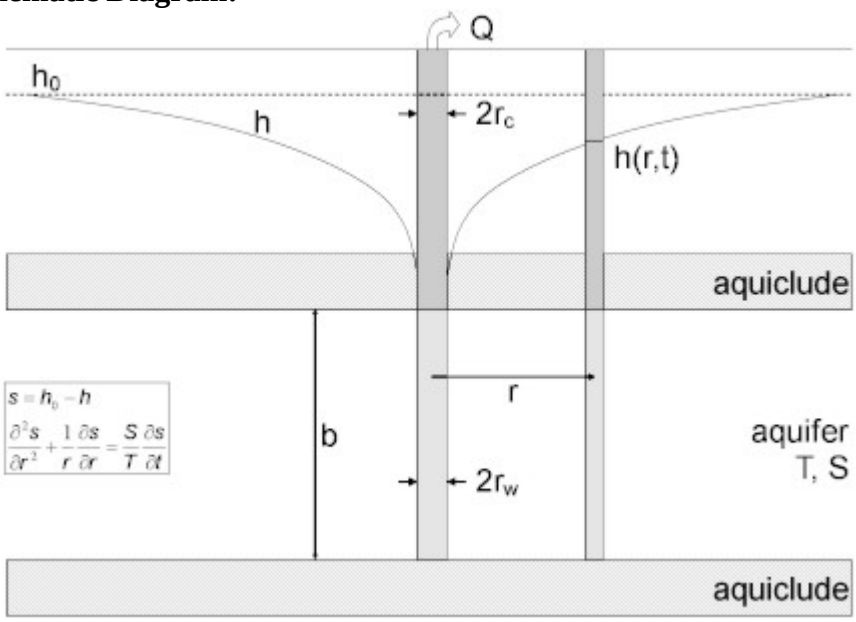
where

- b_i is thickness of aquifer i [L]
- b_j' is thickness of aquitard j [L]
- J_0 is Bessel function of first kind, zero order
- K_i is horizontal hydraulic conductivity in aquifer i [L/T]
- K_j' is vertical hydraulic conductivity in aquitard j [L/T]
- Q is pumping rate [L^3/T]
- r is radial distance [L]
- s_1 is drawdown in the pumped aquifer [L]

- s'_1 is drawdown in the aquit: ard [L]
- s_2 is drawdown in the unpun ıped aquifer [L]
- S, S_1 is storativity in the pu mped aquifer [dimensionless]
- t is time [T]
- T, T_1 is transmissivity in the pumped aquifer [L^2/T]

Details on the Method of Papadopulos, I.S. and H.H. Cooper, 1967. (From Aqtesolv®)

Schematic Diagram:



Assumptions:

- aquifer has infinite areal extent
- aquifer is homogeneous, isotropic and of uniform thickness
- pumping well is fully penetrating
- flow to pumping well is horizontal
- aquifer is confined
- flow is unsteady
- water is released instantaneously from storage with decline of hydraulic head

Equations:

Papadopulos and Cooper (1967) derived a solution for a finite-diameter pumping well with wellbore storage in a confined aquifer as follows:

$$s = \frac{Q}{4\pi T} F(u, \alpha, r_D)$$

$$F = \frac{8\alpha}{\pi} \int_0^\infty \frac{(1 - e^{-\beta^2 r_D^2/4u})[J_0(\beta r_D)A(\beta) - Y_0(\beta r_D)B(\beta)]}{([A(\beta)]^2 - [B(\beta)]^2)\beta^2} d\beta$$

$$A(\beta) = \beta Y_0(\beta) - 2\alpha Y_1(\beta)$$

$$B(\beta) = \beta J_0(\beta) - 2\alpha J_1(\beta)$$

$$u = \frac{r^2 S}{4Tt}$$

$$\alpha = \frac{r_w^2 S}{r_c^2}$$

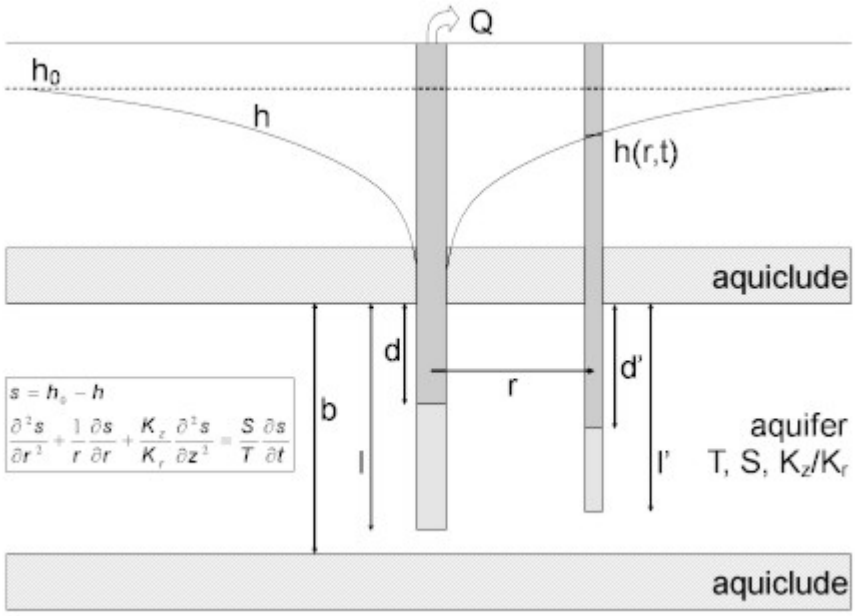
$$r_D = \frac{r}{r_w}$$

where

- J_i is Bessel function of first kind, order i
- Q is pumping rate [L^3/T]
- r is radial distance [L]
- r_c is casing radius [L]
- r_w is well radius [L]
- s is drawdown [L]
- S is storativity [dimensionless]
- t is time [T]
- T is transmissivity [L^2/T]
- Y_i is Bessel function of second kind, order i

Details on the Method of Theis, C.V., 1935. (Pumping) (From Aqtesolv®)

Schematic Diagram:



Assumptions:

- aquifer has infinite areal extent
- aquifer is homogeneous and of uniform thickness
- pumping well is fully or partially penetrating
- flow to pumping well is horizontal when pumping well is fully penetrating
- aquifer is confined
- flow is unsteady
- water is released instantaneously from storage with decline of hydraulic head
- diameter of pumping well is very small so that storage in the well can be neglected

Equations:

$$s = \frac{Q}{4\pi T}\int_u^\infty \frac{e^{-y}}{y}dy$$

$$u = \frac{r^2 S}{4Tt}$$

where

- Q is pumping rate [L^3/T]
- r is radial distance [L]
- s is drawdown [L]
- S is storativity [dimensionless]
- t is time [T]
- T is transmissivity [L^2/T]

Hydrogeologists commonly refer to the exponential integral in the drawdown equation as the Theis well function, abbreviated as w(u). Therefore, we can write the Theis drawdown equation in compact notation as follows:

$$s = \frac{Q}{4\pi T}w(u)$$

Hantush (1961a, b) derived equations for the effects of partial penetration in a confined aquifer. For a piezometer, the partial penetration correction is as follows:

$$s = \frac{Q}{4\pi T}\left(w(u) + \frac{2b}{\pi(l-d)}\sum_{n=1}^{\infty}\frac{1}{n}[\sin(\frac{n\pi l}{b}) - \sin(\frac{n\pi d}{b})]\cdot\cos(\frac{n\pi z}{b})\cdot w(u, \sqrt{\frac{K_z}{K_r}}\frac{n\pi r}{b})\right)$$

For an observation well, the following partial penetration correction applies:

$$s = \frac{Q}{4\pi T}\left(w(u) + \frac{2b^2}{\pi^2(l-d)(l'-d')}\sum_{n=1}^{\infty}\frac{1}{n^2}[\sin(\frac{n\pi l}{b}) - \sin(\frac{n\pi d}{b})]\cdot[\sin(\frac{n\pi l'}{b}) - \sin(\frac{n\pi d'}{b})]\cdot w(u, \sqrt{\frac{K_z}{K_r}}\frac{n\pi r}{b})\right)$$

where

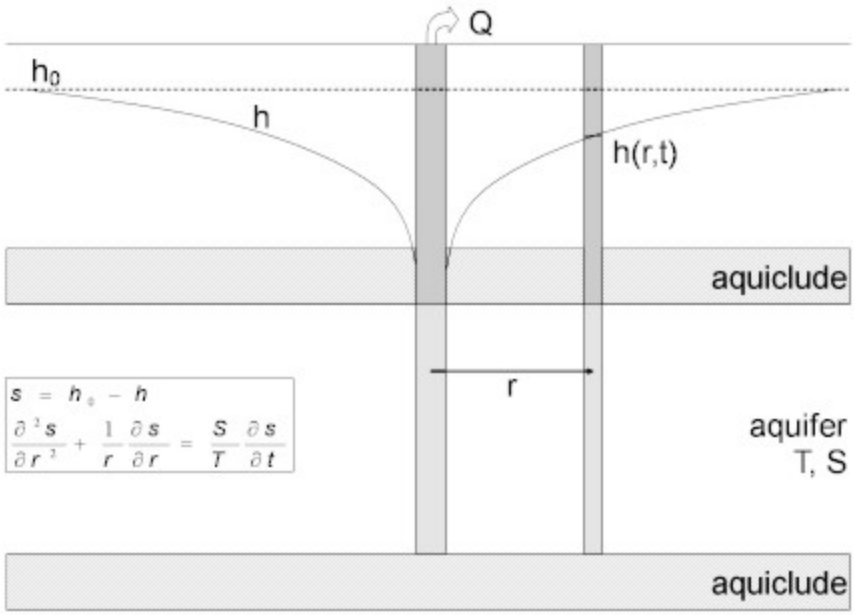
- b is aquifer thickness [L]
- d is depth to top of pumping well screen [L]
- d' is depth to top of observation well screen [L]
- l is depth to bottom of pumping well screen [L]
- l' is depth to bottom of observation well screen [L]
- K_z/K_r is vertical to horizontal hydraulic conductivity anisotropy [dimensionless]
- w(u,β) is the Hantush-Jacob well function for leaky confined aquifers
- z is depth to piezometer opening [L]

At large distances, the effect of partial penetration becomes negligible when

$$r > 1.5b/\sqrt{K_z/K_r}$$

Details on the Method of Theis, C.V., 1935. (Straight-Line Recovery) (From Aqtesolv®)

Schematic Diagram:



Assumptions:

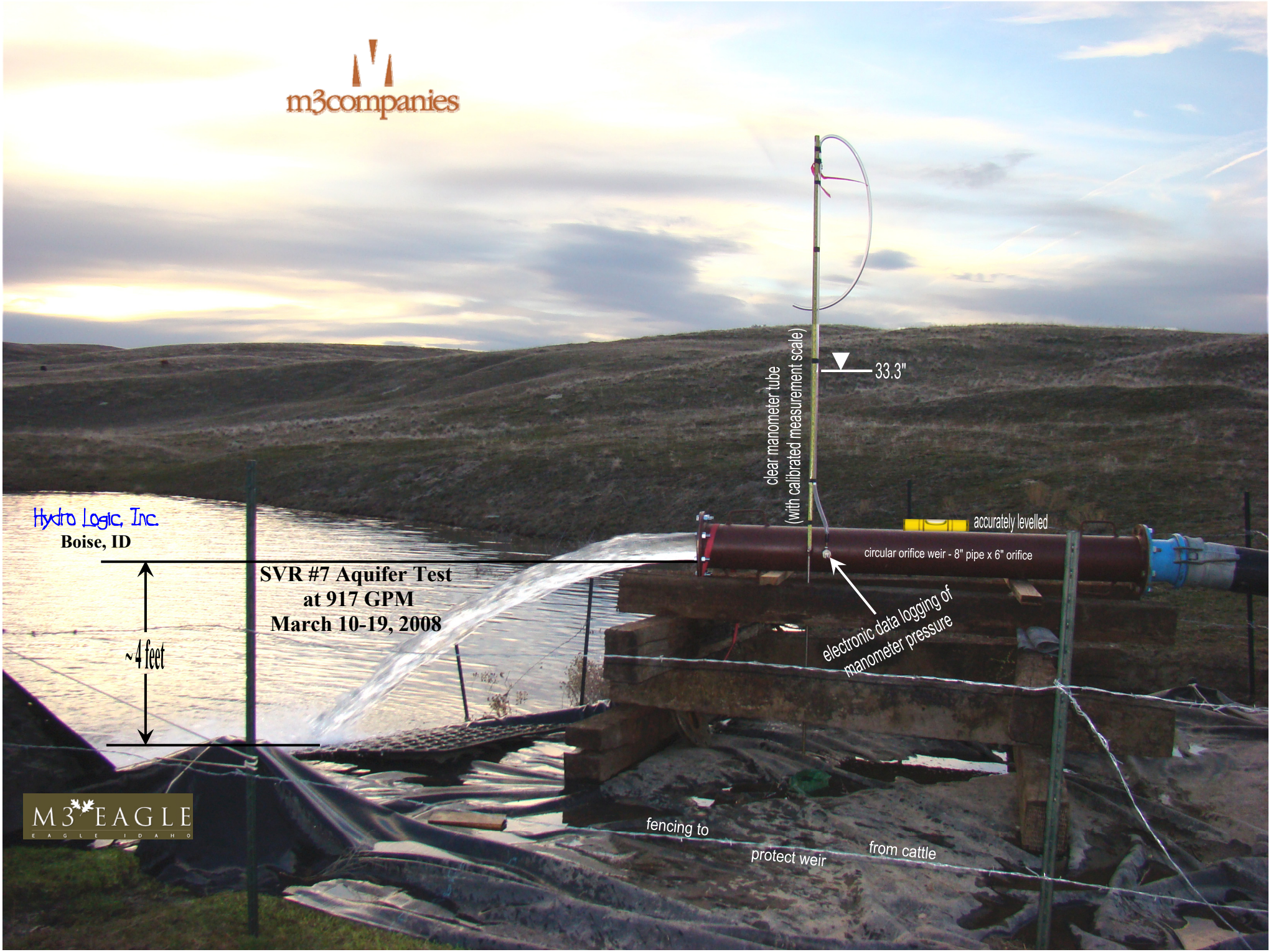
- aquifer has infinite areal extent
- aquifer is homogeneous, isotropic and of uniform thickness
- pumping well is fully penetrating
- flow to pumping well is horizontal
- aquifer is confined
- flow is unsteady
- water is released instantaneously from storage with decline of hydraulic head
- diameter of pumping well is very small so that storage in the well can be neglected
- values of u are small (i.e., r is small and t is large)

Equations:

$$s' = \frac{Q}{4\pi T}\left[\ln(t/t') - \ln(S/S')\right]$$

where

- Q is pumping rate [L^3/T]
- s' is residual drawdown [L]
- S is storativity during pumping [dimensionless]
- S' is storativity during recovery [dimensionless]
- t is time since pumping began [T]
- t' is time since pumping stopped [T]
- T is transmissivity[L^2/T]


m3companies
Hydro Logic, Inc.
Boise, ID
SVR #7 Aquifer Test
at 917 GPM
March 10-19, 2008
~4 feet
clear manometer tube
(with calibrated measurement scale)
33.3"
accurately levelled
circular orifice weir - 8" pipe x 6" orifice
electronic data logging of
manometer pressure
fencing to
protect weir
from cattle
M3 EAGLE
EAGLE IDAHO