CHARACTERIZATION OF GRANDE RONDE AQUIFERS IN THE PALOUSE BASIN USING LARGE SCALE AQUIFER TESTS

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AUTHORIZATION TO SUBMIT THESIS

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ABSTRACT

The study area lies within Palouse region, which is located in southeastern Washington and north-central Idaho. This region relies on groundwater as the sole source of potable water. Majority of the groundwater is derived from the Miocene basalts of the Columbia River Basalt Group (CRBG). The Wanapum Formation and the Grande Ronde Formation form the upper and lower aquifers, respectively. The municipal water supplies are primarily derived from the Grande Ronde Formation, which supplies nearly 95% of the municipal water supply. The municipal wells completed into the Grande Ronde aquifer system have been continuously declining over the past 30 years. These declining water levels have inspired a considerable amount of research over the past 30 years, yet a good understanding of this aquifer system is still unknown.

An east-west hydrogeologic cross-section across the basin was created based on the well logs from the municipal wells completed into the Grande Ronde aquifer system. From this cross-section, four large scale (several miles) aquifer tests were completed to provide a better understanding of the Grande Ronde aquifer system. Data from these aquifer tests allowed hydraulic connections, aquifer coefficients, and hydraulic boundary effects to be estimated.

At least three hydraulically separate Grande Ronde aquifers were identified and mapped based on the constructed cross-section and aquifer test results. Aquifer properties and spatial extent of the separate aquifers were estimated based on trend corrected drawdown data.

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TABLE OF CONTENTS

CHAPTER 1 -- INTRODUCTION

CHAPTER 2 -- HYDROGEOLOGY OF THE MOSCOW-PULLMAN BASIN

CHAPTER 3 -- AQUIFER TEST ANALYSIS

CHAPTER 4 -- CONCLUSIONS

LIST OF FIGURES

Chapter 1 -- INTRODUCTION

Overview

Four large-scale aquifer tests were conducted in the Palouse basin to provide a better understanding of the aquifer systems that exist within the Grande Ronde Formation within the region. The data for these aquifer tests provide information on aquifer properties such as transmissivity and storativity, effects of local impermeable boundaries, and hydraulic connections between selected wells. The data for these tests provide information that is critical with respect to evaluation of the potential groundwater resource systems within the Grande Ronde Formation.

The aquifer tests conducted for this study are named the WSU #7 test, U of I #4 test, Moscow #9 test, and Moscow #8 test. These aquifer tests were each designed with a specific goal in mind. Each aquifer test was conducted and analyzed separately, defining the test, the objectives of the test, and the methods of analysis. Data tables for all of the aquifer tests are presented in Appendices A through E. Well logs are presented in Appendix F.

Statement of the Problem

The study area lies within the Palouse region of north-central Idaho and southeastern Washington (Figure 1). The cities of Moscow, Idaho, Palouse, Washington, and Pullman, Washington, are located within the study area. The

University of Idaho and Washington State University are located in Moscow and Pullman, respectively. This region depends on groundwater as the sole source of water for municipal supplies.   Water levels in these municipal wells have been declining one to 1.5 feet per year over the past 30 years. These declining water levels throughout the Palouse region have water resource managers concerned about future water supplies.

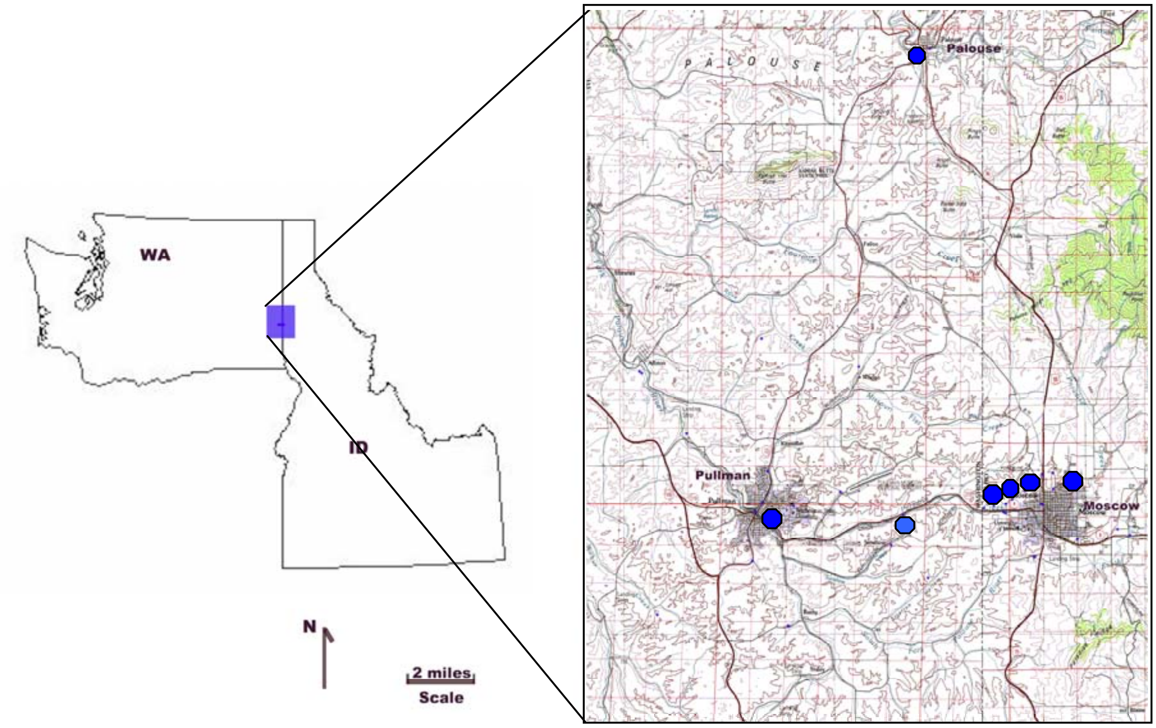

Figure 1. Location of the Palouse region and the locations of the wells used in the aquifer tests.

The general objective of this investigation is to develop a better understanding of the Grande Ronde aquifer system through the analysis of four large-scale aquifer tests.

The specific objectives of this investigation include:

1. Construct a detailed, east-west hydrogeologic cross-section and delineate specific aquifers in the study region.
2. Conduct large-scale aquifer tests using existing wells completed in the Grande Ronde Formation.
3. Analyze aquifer test data to identify hydraulic connections and provide estimates of aquifer properties.
4. Identify specific aquifers in the Grande Ronde Formation through geologic and aquifer test data.

Previous Research

The groundwater systems in the Moscow-Pullman basin have been a topic of research for the past 100 years, beginning with Russell, (1897) who conducted a general groundwater evaluation of the basin. In this study, the original wells drilled in the region were investigated and found to have declining water levels. Foxworthy and Washburn (1963) completed an extensive investigation on the groundwater resources of the basin, and concluded that pumpage would soon exceed the available resources. Sokol (1966), evaluated interconnections and discontinuities within the Moscow city wells based on short-term water level fluctuations. Ross (1965) and Jones and Ross (1972) investigated the general hydrogeology of the basin.

Several groundwater, modeling studies of the basin were conducted beginning in the early 1970’s. Jones and Ross (1972) presented the first mathematical model for predicting water resources of the basin. Barker (1979), created the first numerical groundwater flow model of the basin. Follow-up studies by Smoot and Ralston (1987), Lum et. al, (1990), Brown (1991), and Johnson (1994) reevaluated the model, incorporating additional hydrogeologic factors. These modeling studies grossly oversimplified the geology of the region as they simulated the entire Grande Ronde system as one interconnected aquifer. Widely used and accepted misconceptions of the Palouse Basin hydrogeology have created an unclear understanding of the Grande Ronde aquifer system.

Current studies have shifted away from the modeling studies and are focusing more on the physical factors that control ground water flow through the system. Recharge studies (McDaniel, 2001; Obrien, 1996; Larson et. al, 2000; Nelson, 2003), recently have been conducted to evaluate and quantify the recharge into this aquifer system through isotopic, geochemical, and soil studies. Recent geologic investigations (Teasdale, 2001; Pierce, 1998; Provant, 1995) focused on geologic controls of groundwater occurrence in the region.

Geography

The “Palouse” is an area of about 60,000 ha in southeastern Washington and northern Idaho consisting of rolling, dune shaped, hills composed of wind-blown silt deposits (Figure 1). This region is known for the rich agriculture setting, more distinctively, the Palouse Loess that forms the rolling hills of the area. These rolling hills are used for dry-land agricultural practices that are supported by the area’s climate.

The climate for this region is considered semi-arid. Average precipitation in the area ranges from 19 inches per year in Colfax, Washington to 26 inches in Moscow, Idaho based on 46 years and 55 years of record, respectively. ([U.S.] National Oceanic and Atmospheric Administration, 1987). The surrounding highlands that form the borders of the drainage basin receive up to 40 inches per year, most in forms of seasonal precipitation, falling from November to April (Lum, et al., 1990).

The surrounding highlands also form the boundaries for the groundwater basin in this study (Figure 2). These bedrock ridges form the only major topographic features of the study area, as the rolling hills in the basin have relatively little topographic relief. The ridges form a horse-shoe shaped topographic feature that encloses the groundwater basin completely to the east and south, and portions to the north and west. Gaps within these topographic features exist between Angle Butte and Kamiak Butte, and possibly to the southwest; however, no topographic ridges are exposed above the flood basalts except in the Snake River canyon.

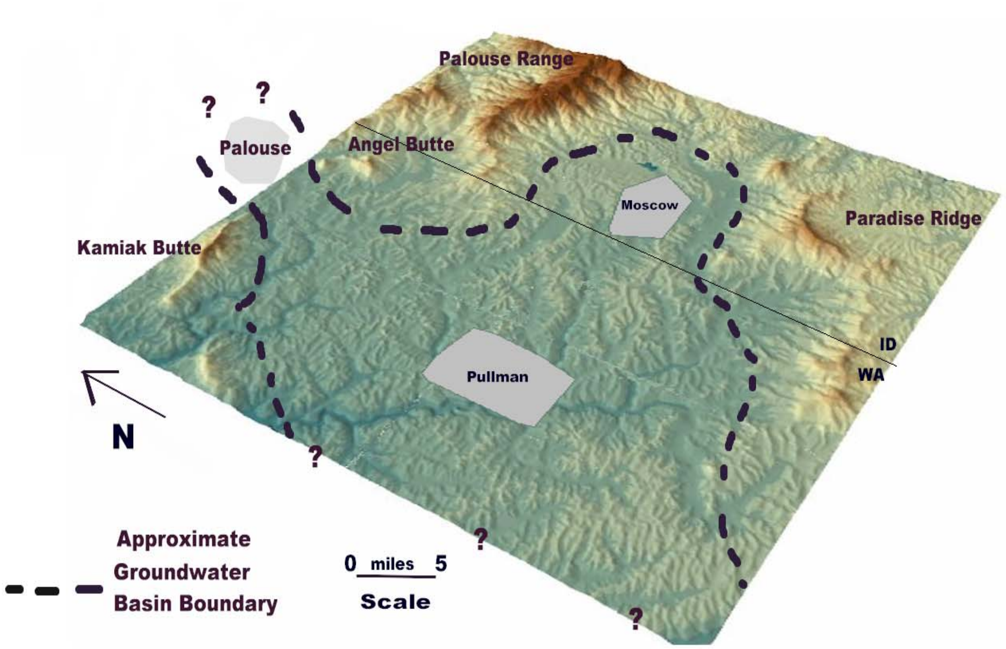

Figure 2. Topographic expression and delineation of groundwater basin of the study area.

Methodology

A schematic geologic cross-section was constructed between Moscow and Pullman based on the well logs for city, university, and private Grande Ronde wells. The purpose of this cross section was to provide a detailed interpretation of the local geology, while focusing on water bearing formations identified in the well logs.

Based on the cross-section, four large-scale aquifer tests were designed and conducted in 2002-2003 to help identify hydraulic connections between various wells of the region. Potential production zones were identified based on the cross-section, and appropriate pumping wells and observation wells were selected.

The data for these aquifer tests were collected and analyzed to evaluate hydraulic connections between wells, and to estimate aquifer properties such as transmissivity and storativity. The data were analyzed based on measured responses, pre-test water level trends, and potential hydraulic boundaries.

Chapter 2 -- HYDROGEOLOGY OF THE MOSCOW-PULLMAN BASIN

Geologic Setting

The Palouse lies on the eastern border of the Columbia River Plateau. The Columbia River Plateau was formed by the emplacement of the Columbia River Basalt Group (CRBG). These basalt flows are part of a regional sequence of flows that are continuous from this basin westward to the Pacific Ocean (Figure 3). As these Miocene basalts flowed into the Palouse from the west and south, they filled in the pre-existing topography (Figure 4). The pre-basalt topography was formed by the antecedent drainage patterns of the basement rock complex. These basement crystalline rock complexes are the formations that form the topographic highlands of the study area. A thick deposit of the Pleistocene Palouse Formation covers most of the basalt flows.

Palouse Formation

The Palouse Formation is an eolian, silt-clay loam that has been deposited over the past 2 million years (Williams and Allman, 1969). These loess deposits range in thickness from zero to 250 feet (Foxworthy and Washburn, 1963). The loess is thickest in the western portion of the study area and gradually becomes thinner to the east. These eolian deposits are the “rock flour” deposited as the glaciers of the Pleistocene era retreated (Williams and Allman, 1969). These glaciers covered an extensive area to the northwest of the study area, but never actually advanced into the basin. Over the past 2 million years, the prevailing winds of the region have carried these deposits into the study area, forming the extensive rolling hills typical of the Palouse region.

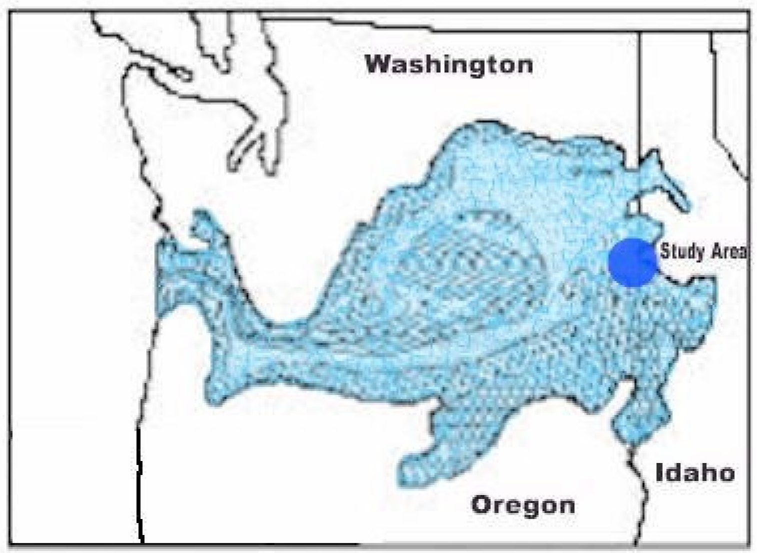

Figure 3. Generalized distribution of the Columbia River Basalt Group (modified from Provant, 1995).

Columbia River Basalt Group

The Columbia River Basalt Group (CRBG) and associated sediments lie directly beneath the Palouse Formation. The CRBG can be divided into four formations from base upward they are the Imnaha, Grande Ronde, Wanapum, and Saddle Mountains. All four of these formations exist in the study area. However, the majority of the research focuses on the Grande Ronde Formation.

The Saddle Mountains and Imnaha formations are present in the study area only in isolated areas. The Imnaha Formation is known to exist at an elevation of 350 feet above mean sea level, near the bottom of the region’s deepest well, the WSU well #7. Flows of the Saddle Mountains Formation do not cover the entire basin, but they do crop out just to the west of the study area and have been encountered in the subsurface of McClure Hall on the University of Idaho campus.

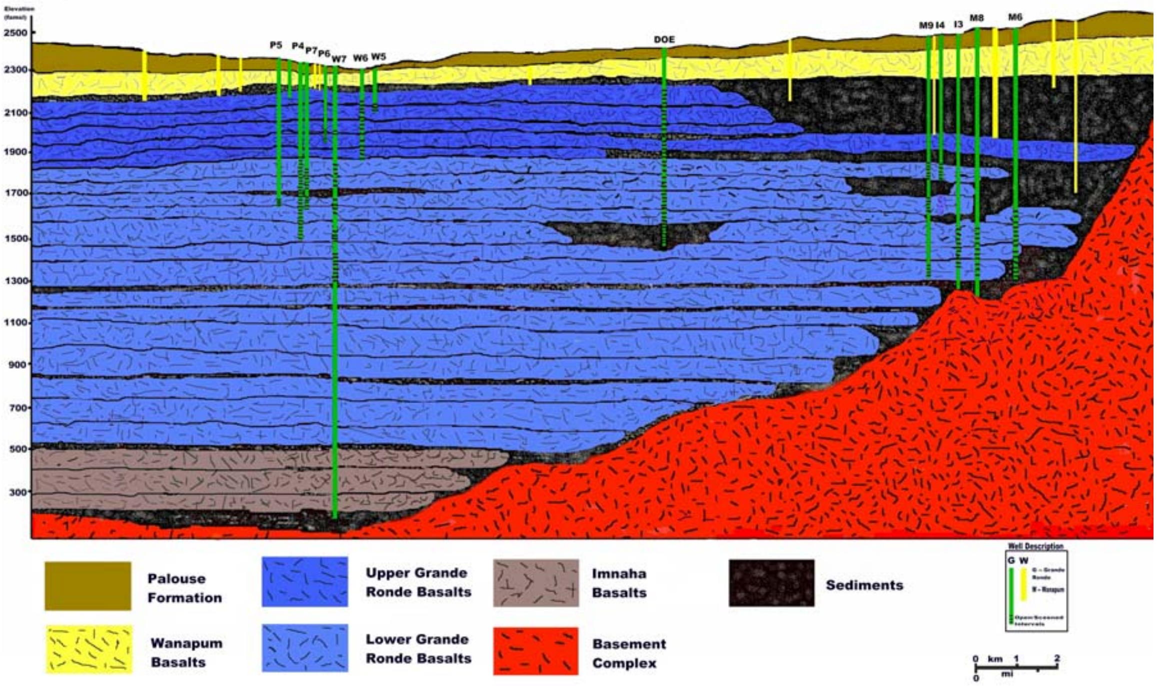

Figure 4. Schematic east west cross section of study area. See Appendix G for a larger version.

The Wanapum Formation is considered the top of the CRBG over most of the Palouse. The Wanapum Formation is generally spatially extensive, with exposures seen throughout the basin. Individual basalt flows range from 50 to 200 feet in thickness. Some flows are thicker in the eastern portion of the basin (Tolan and others, 1989). Wanapum Basalt makes up about 6% of the total volume of the entire CRBG (Teasdale, 2001).

The basalt flows of the Grande Ronde Formation and interbedded sediments of the Latah Formation occur directly below the Wanapum Formation. The Grande Ronde Formation was emplaced between 15.6 and 17.0 Ma, and makes up nearly 90% of the total CRBG volume in the Columbia River Plateau (Silar, 1969). The total thickness of these flows ranges from several hundred feet along the edges of the basin, to almost 2000 feet directly below the city of Pullman. Individual flows range in thickness from a few feet to upwards of 200 feet (Foxworthy, 1963). Seventeen individual flows have been identified in the Columbia River Plateau using paleomagnetic, geochemical, and stratigraphic correlations (Provant, 1995).

The flows of the Grande Ronde Formation are heterogeneous due to a varying degree of fracturing, discontinuous sediment interbeds, and the variable thickness of individual flows. These geologic controls have a significant impact on groundwater flow in the basin.

Sedimentary Units

Sediment deposits of the Latah Formation are associated with the emplacement of successive basalt flows. The Latah Formation sediments exist in the form of interbeds between various individual basalt flows and as sediment deposits adjacent to basalt flows (Figure 4). The interbeds were deposited primarily as river and lake-bed sediments, as successive basalt flows dammed drainages emanating from the crystalline highlands. The interbeds consist primarily of clay, sand, and silt.

The extent and continuity of these deposits vary greatly, forming isolated lenses to laterally extensive units throughout the study area. The eastern portion of the basin contains more of these deposits because the basalts flowed into the basin from the west (Figure 4).

The most notable sedimentary unit is the Vantage Member. The Vanatage is an interbed that separates the Grande Ronde Formation from the Wanapum Formation and exists throughout most of the region. Thickness ranges from 50 feet thick in the western portion of the basin to more than 300 feet in the eastern portion. This unit is composed of clays, silts, shales, and sands. The extensiveness and significant thickness of this unit not only make it a unique marker unit separating the two main formations of the region, but it also impacts the groundwater flow between these two formations.

Basement Complex

The basement complex is composed of granitoids and metasedimentary rocks. The granitoids associated with the Cretaceous rocks of the Idaho batholith form the Palouse Range (Figure 2). The metasedimentary quartzites, associated with Precambrian aged units, form isolated ridges throughout the region. These ridges form the basin divides between different basins.

Groundwater Occurrence

Though groundwater is present in all of the geologic formations of the study area, the CRBG forms the main aquifers the region. The other geologic formations, the Palouse Formation and the basement complex, contain relatively small amounts of potable water; however, they do impact the deep groundwater flow systems in the region significantly.

Seasonal perched aquifers that are not a significant source of potable groundwater are common in the Palouse Formation. However, they do play an important role in the amount of recharge the basalt aquifers receive (Hopster, 2003).

The granitoids and metasedimentary rocks that form the pre-basalt units contain very small amounts of water. These rocks have low hydraulic conductivities, restricting the flow of groundwater. For these reasons, the basement complex is considered to form the basal boundary of the groundwater basin.

Two primary aquifer systems exist in the CRBG in this study area, the Wanapum and Grande Ronde Formations. The Wanapum Formation is considered the upper, shallow aquifer for the region that supplies domestic wells producing 150 to 1500 gallons per minute (gpm) (Smoot and Ralston, 1987). The Grande Ronde Formation supplies most of the municipal water for the region with wells producing up to 3000 gpm (Smoot and Ralston, 1987).

Groundwater occurs within the Grande Ronde basalts in two ways. The water within these basalts is stored under pressure within fractures and vesicles, and within the various sedimentary interbeds. The majority of the water is derived from fracture zones that exist along the interface between separate basalt flows (i.e, interflow zones). In the eastern part of the basin, sedimentary interbeds can supply significant quantities of water. For example, city of Moscow wells #6 and #8 are screened through such intervals (Figure 4).

The four aquifer tests conducted for this study identified hydraulic connections through various wells. These connections were then correlated with the geologic cross section (Figure 4) to identify potential aquifer boundaries. Figures 5, 6, and 7 suggest that the Moscow-Pullman basin has at least three separate Grande Ronde aquifers that, hydraulically, are poorly connected. In this thesis, these aquifers are named Moscow Grande Ronde 1 (MGR1), Moscow Grande Ronde 2 (MGR2), and Pullman Grande Ronde 1 (PGR1).

Aquifer MGR1 is a highly fractured basalt zone that ranges from 100 to 150 feet thick. The elevation of this aquifer ranges from 1750 to 1920 feet above mean sea level in the Moscow vicinity. Figure 5 shows that this aquifer extends to the west to at least the WDOE test well, but not much further. A hydraulic boundary is suspected to exist between the WDOE test well and the Pullman pumping center. U of I well #4 and the city of Moscow well #9 are completed in this aquifer.

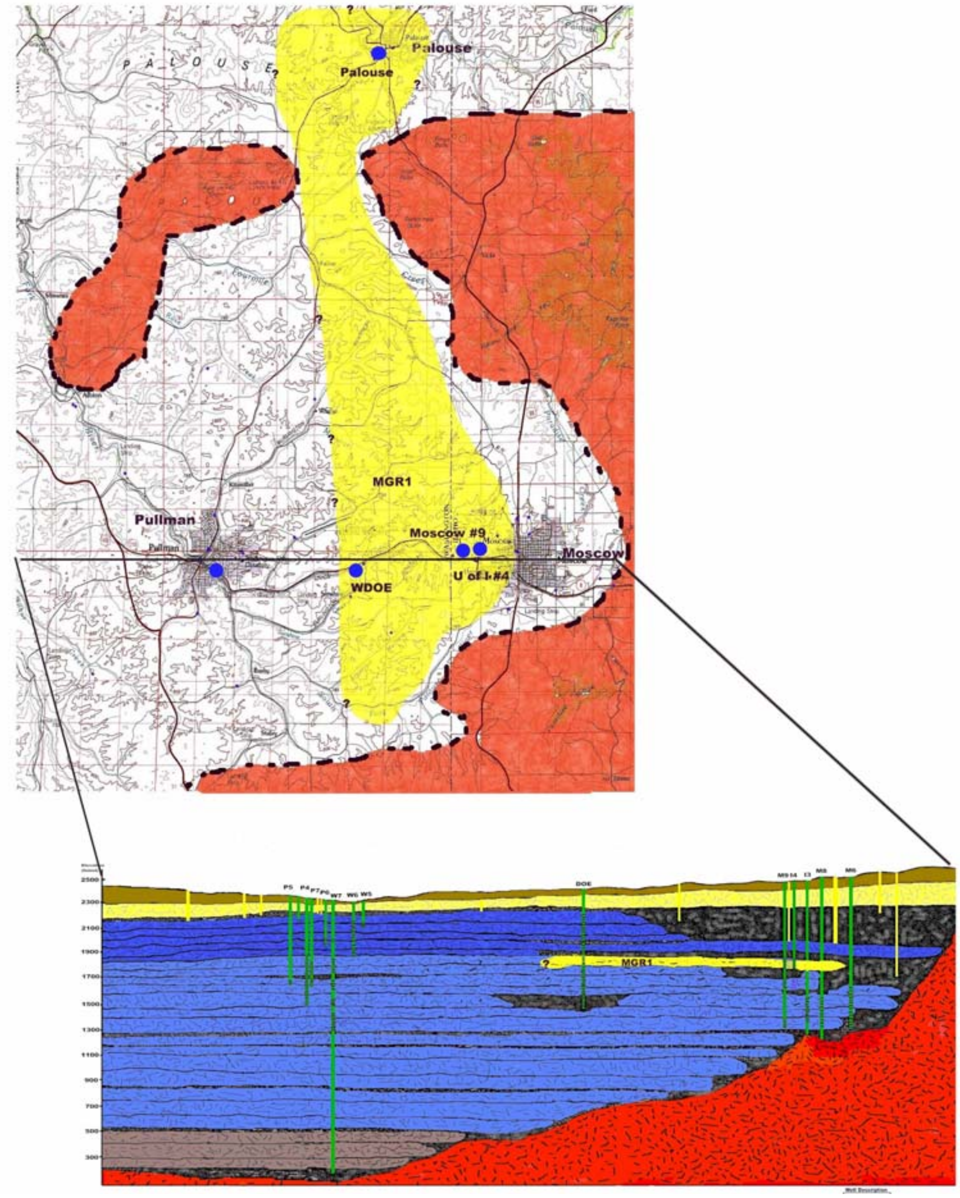

Figure 5. Map and cross-section showing approximate extent and location of MGR1. See Figure 4 for geologic details.

Aquifer MGR2 consists of 300 feet of interbedded basalt flows and sediments. This aquifer is the bottommost aquifer of the region, located between 1350 and 1650 feet above mean sea level. This aquifer is composed of 250 feet of basalt flows and 50 feet of sediments. This aquifer extends westward to at least the WDOE test well; however, a lack of data precludes further extrapolation.

The basement complex forms boundaries for this aquifer to the east, south and north (Figure 6). The city of Moscow wells #8 and #6 are completed in this aquifer.

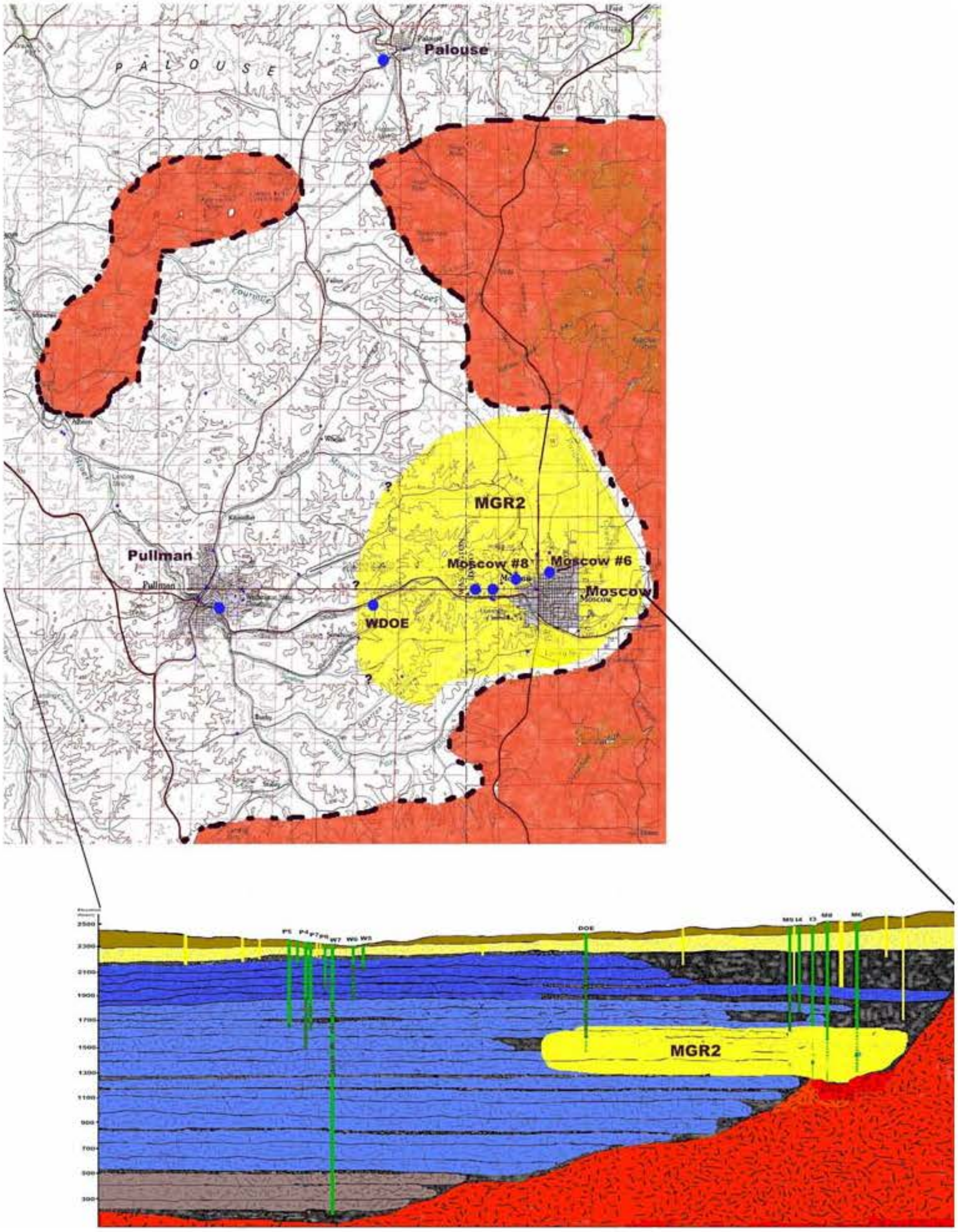

Figure 6. Map and cross-section showing approximate location and extent of MGR2. See Figure 4 for geologic details.

Aquifer PGR1 is the only aquifer delineated in the Pullman pumping center. This aquifer is composed entirely of 200 feet of basalt flows. This aquifer is located between 1700 to 1900 feet above mean sea level in the Moscow region. This aquifer extends northward to the city of Palouse through the gap between Angel Butte and Kamiak Butte. Both MGR1 and PGR1 appear to extend through the gap; however, it is not suspected that MGR1 and PGR1 have a strong hydraulic connection. The western and southern boundaries of PGR1 are still undefined (Figure 7).

An aquifer test conducted by Golder Associates, Inc. (2001) was conducted in Feb, 2001, during which the city of Pullman well #7 was pumped at a rate of 2500 gpm for 48 hours. Surrounding Washington State University wells and the city of Pullman municipal wells were monitored. City of Pullman well #2 was the only well to respond to the pumping of the city of Pullman well #7.

Surrounding wells, including WSU #7, city of Pullman well #5 and well #6 are all located near the pumping well vicinity and completed through similar elevations. The lack of response in these wells suggests that some type of hydraulic discontinuity exists between the wells completed in the Pullman pumping center.

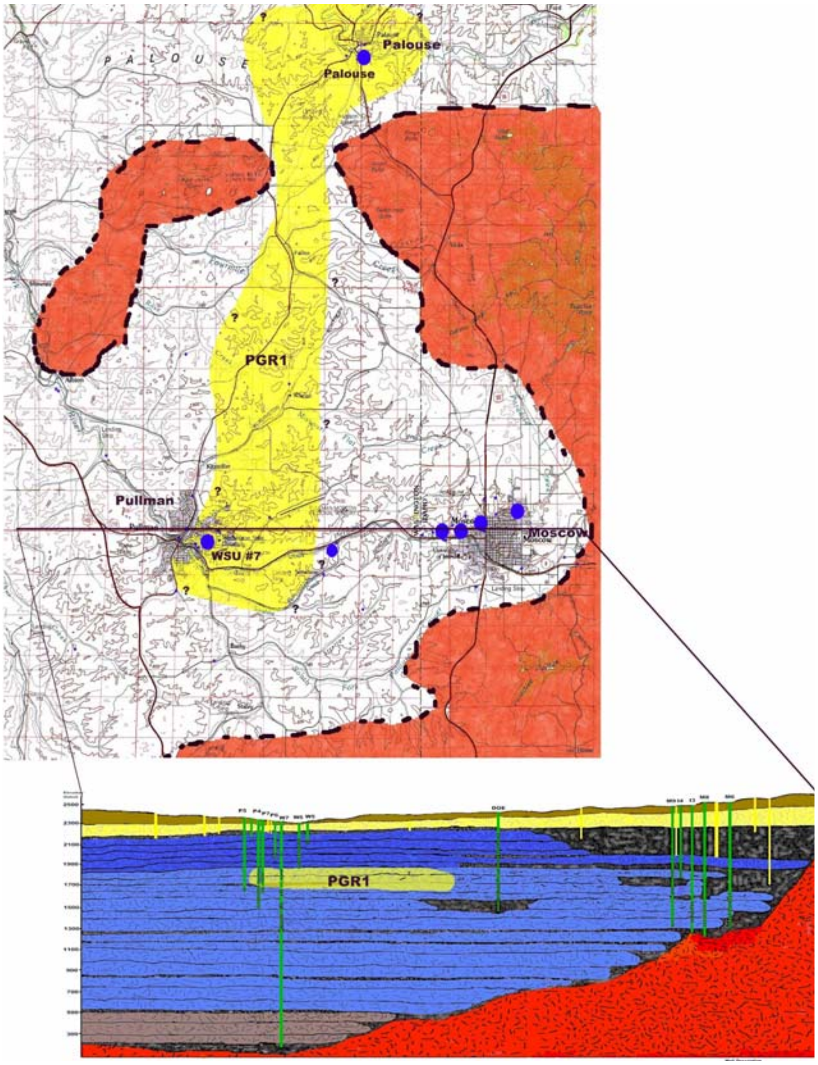

Figure 7. Map showing approximate location and extent of PGR1. See Figure 4 for geologic details.

The WDOE test well was also monitored. No drawdown was measured in this well in response to the pumping of city of Pullman well #7. These wells are open through similar elevations, and drawdown was expected for a pumping stress of this magnitude. The lack of response supports the idea that a hydraulic barrier exists between the Pullman pumping center and the WDOE test well.

An aquifer test was conducted by Beck (2001). During this test, several Pullman city wells and the WSU wells were pumped concurrently with a total discharge of about 5000 gpm. The WDOE test well, city of Palouse well #1, city of Palouse well #2, the city of Colfax Fairview well, city of Pullman wells, and the WSU test well were monitored throughout the duration of the test; however, the only well to respond predictably during the test was the WSU test well. This result supports the hypothesis that a hydraulic barrier exists between the Pullman pumping center and the WDOE test well.

Recharge

Groundwater levels in Grande Ronde wells historically have been declining over the past 40 years. Through mass-balance water budget estimates, the amount of water pumped from the aquifer exceeds the amount of precipitation available to recharge (Smoot and Ralston, 1987). Interest in these declining water levels has initiated geochemical, isotopic, and soil moisture studies to evaluate the timing and extent of the recharge to the basalt aquifers.

An isotopic study was conducted to examine relative ages of the water based on ^{18}O and ^{2}H concentrations in the groundwater in the Moscow-Pullman basin (Larson et al., 1996). This study found that the Wanapum and loess aquifers are receiving measurable recharge. However, the Grande Ronde water was found to be highly depleted in ^{18}O, indicating that the water was recharged during a different time period. It was suggested that the water present in the Grande Ronde aquifers was recharged during the Pleistocene when the climate was much cooler and wetter than the present (Larson et al, 2000).

Recent soil studies have been conducted to evaluate the hydraulic characteristics of the Palouse Formation and the controls they impose on the groundwater recharge. These studies suggested that clay rich horizons (fragipan) located within the soils can restrict up to 88% of the water available from infiltrating precipitation (Brooks et al., 2000). Saturated vertical hydraulic conductivities as low as .06 cm/day were measured, suggesting it is unlikely that significant recharge occurs through these fragipans on an annual basis (McDaniel et al., 2001).

Chapter 3 – AQUIFER TEST ANALYSIS

Overview

Four large-scale (several miles) aquifer tests were conducted for this study using existing municipal and university Grande Ronde wells. Limitations on monitoring, pumping controls, and access, were imposed by the individual pumping entities; therefore, data collection periods were limited and the collection of certain data (e.g., pretest water levels) was precluded in some cases. All of the pumping wells used required city/university personal to manually setup and operate the pumps. Physical access to these municipal wells was limited at the well heads by turbine pump housings. Therefore, monitoring devices built into the wellhead were used to monitor water levels in the city and university wells when available.

Other municipal constraints imposed on the aquifer tests were the pumping duration and magnitude. The pumping wells used were all pumped at rates determined and specified by the well operators. The duration of the pumping depended on the storage facilities available for that particular well. All water withdrawn during the tests was pumped into the individual distribution system(s). No water was discharged to storm drains or streams. The length of non-pumping recovery periods both prior to the tests and after the tests were controlled by the amount of water available to meet critical water needs (e.g. fire protection).

Four large-scale aquifer tests were conducted between June 2002 and March 2003. These tests were designed for several purposes. The first and primary purpose of these tests was to evaluate potential hydraulic connections between selected portions of the basin. In this thesis, hydraulic connection is defined as a measurable response to pumping (i.e. drawdown) in a distant non-pumping observation well. This concept implies that the cone of depression caused by the pumping of one well reached the observation well. If a separate cone of depression from a different pumping well also reached the observation well, then all three wells can be said to be hydraulically connected via the overlapping cones of depression. Likewise, if an observation well did not respond to the pumping of another well, then those two wells are considered hydraulically disconnected. Knowledge of hydraulic connections is crucial for aquifer delineation and analysis of well interference effects.

The aquifer tests were also designed to estimate aquifer properties based on analytical methods of aquifer test analysis. Pre-test measurements and drawdown measurements were taken in all observation wells for these aquifer tests. The pre-test data were used to help identify and “remove” existing pre-test trends according to methods outlined by Stallman (1971). The Theis (1935) analytical solution was used to estimate the aquifer coefficients of transmissivity and storativity after the trends were filtered from the drawdown data.

Another purpose for these tests was to help delineate hydraulic boundaries of the region. Impermeable basement rocks form complex boundary controls on this system and their effects on drawdown were investigated.

The wells used for the aquifer tests were all municipal or university production wells, except for the WDOE test well. Figure 8 shows the well locations. Pumping durations and rates were controlled by the operating official for the particular pumping well.

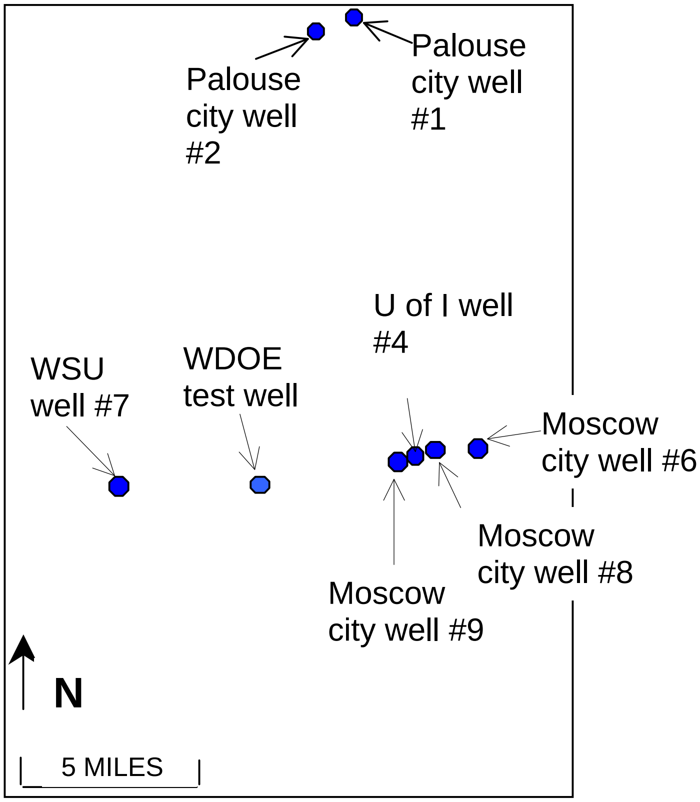

Figure 8. Well locations for wells used during the aquifer tests. Well logs for these wells are presented in Appendix F.

The tests were named according to a critical monitoring point or the pumping well used. The four tests that were conducted are listed in chronological order as follows: WSU #7 test, U of I #4 test, Moscow #9 test, and Moscow #8 test.

Analysis of large-scale aquifer tests conducted in a hydraulically connected urban environment often is fraught with uncertainty. This uncertainty arises because of complicated long-term and short-term water level trends that often develop due to well interference effects between pumping centers. These interferences typically must be evaluated during aquifer test analyses because it generally is not possible to eliminate all extraneous pumping within the zone of influence of specific aquifer tests. Also, limited access to the wells used in these aquifer tests limits the data and durations of data available to monitor.

The trends used to analyze the data were assumed to be linear. This is a very significant assumption, as water levels generally do not rise in a linear fashion. This linear trend was used based on the amounts of pre-test data available to fit a trend to. With limited amounts of data ($t<100$ minutes), linear trends were the most adequate trend procedure to use to show changes in water levels. Also, these trends were developed based on significantly limited amounts of data. According to Stallman (1971), pre-test data should exceed two times the total duration of the pumping periods. With these wells being located in an urban development, idle periods of this duration are difficult to achieve.

The WSU #7 Test

The first aquifer test, WSU #7, was conducted on June 30, 2002. WSU well #7 was pumped at a constant rate of 2500 gpm for 12 hours. During the test, the U of I well #4 began pumping at a rate of 2450 gpm due to critical water supply demands at 620 minutes into the test. Observation wells for this test included the WDOE test well, Moscow city wells #6, #8, and #9, and the Palouse city well #2. The purpose of this test was to pump the deepest well in Pullman and monitor the WDOE test well and the deep wells in Moscow and Palouse.

The screened intervals in WSU well #7 and the observation wells are similar in elevation (Figure 4).

Pumping began at 8:00 am (t=0 min) and ended at 8:00 pm (t=720 min). The Moscow city wells were shut down eight hours prior to the test, and the Palouse city well #2 was shut down 12 hours (t=-720 min to t=0 min) prior to the test, to allow water levels to stabilize.

Palouse City Well #2

The water levels in the Palouse city well #2 were measured for 50 minutes prior to the beginning of the test every five minutes. Drawdown also was measured on five minute intervals for the duration of the test. All measurements were made with an electronic water level sounder. Water level recovery measurements after pumping ceased were not recorded.

The water levels in the Palouse city well #2 were rising prior to the beginning of the test. A trend correction was applied to the data to evaluate the drawdown response to the pumping well. Details of the trend correction are presented in Appendix A. The corrected water levels were subtracted from the measured water levels to derive the adjusted drawdown data.

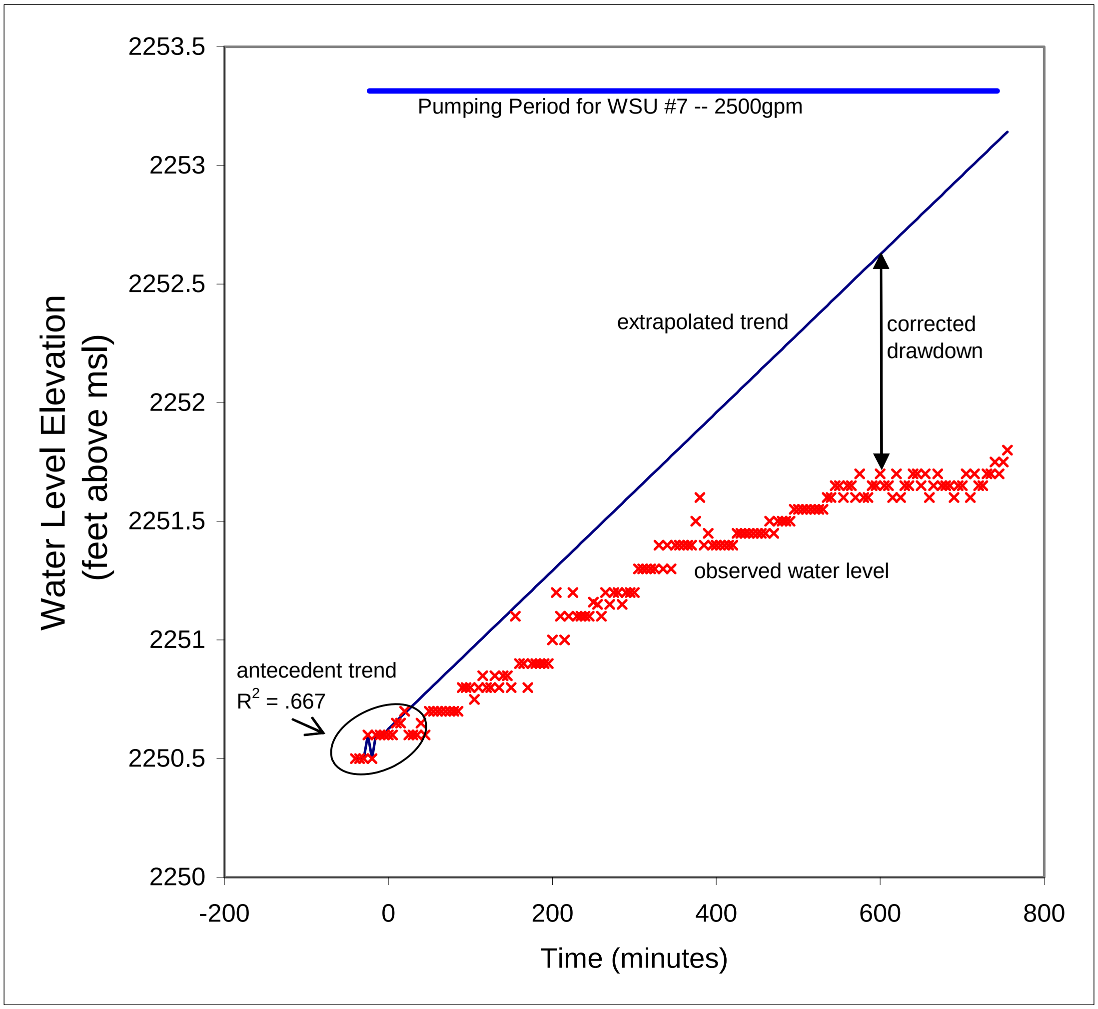

Figure 9. Arithmetic plot of water levels for Palouse city well #2 during the WSU #7 aquifer test.

Figure 9 shows the observed water levels and the extrapolated trend used to estimate the corrected drawdown. This trend is based on the one hour of pre-test measurements taken. Based on this trend, the response to pumping in the Palouse city well #2 appears suddenly, within minutes of the beginning of pumping WSU well #7. The drawdown continues throughout the duration of the test with over 1.2 feet of drawdown occurring by the end of the pumping period. This response indicates a strong hydraulic connection between the wells.

Figure 10 shows a logarithmic plot of corrected drawdown versus time, and identifies effects of a negative barrier on the late time drawdown data. The drawdown data were matched to the Theis type curve even though the aquifer is known to be heterogeneous and possibly anisotropic. The late time departure from the Theis type curve suggests the existence of multiple hydraulic boundaries. The straight line departure of drawdown from the theoretical Theis type curve is believed to reflect basalt/crystalline rock contacts along the Moscow Mountain front and in the gap between Angel Butte and Kamiak Butte (Figure 2).

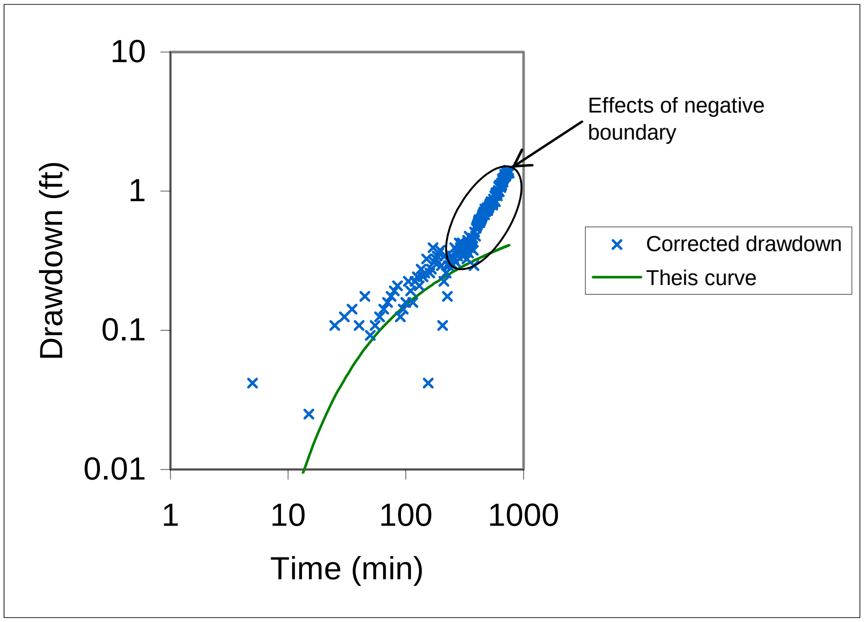

Figure 10. Logarithmic plot of corrected drawdown versus time for the Palouse city well #2 during the WSU #7 aquifer test.

WDOE Test Well

Water levels were measured in the WDOE test well over a pre-test period of 3 days and through the entire aquifer test on five minute intervals using a submersible, Solinst™ pressure transducer, data logger. However, a definable trend did not develop until 95 minutes prior to the start of the test. Water levels for the pumping period were analyzed and corrected for pre-test trends. The water level elevations plotted in Figure 11, suggest the WDOE test well did not respond to the pumping of WSU #7. Though no drawdown due to the pumping of WSU #7 was measured, a measurable response was noticed at 620 minutes into the test. This response corresponds very well to the unexpected pumping of the U of I well #4 that was forced to turn on at t=620 minutes during the test. U of I #4 pumped at a rate of 2300 gpm from t=620 minutes through the end of the test. Though no measurable drawdown was measured that corresponded to the pumping of WSU #7, a increase above the trend line at early time suggest the potential of Noordbergum effects, similar to data described by Andreason, 1963.

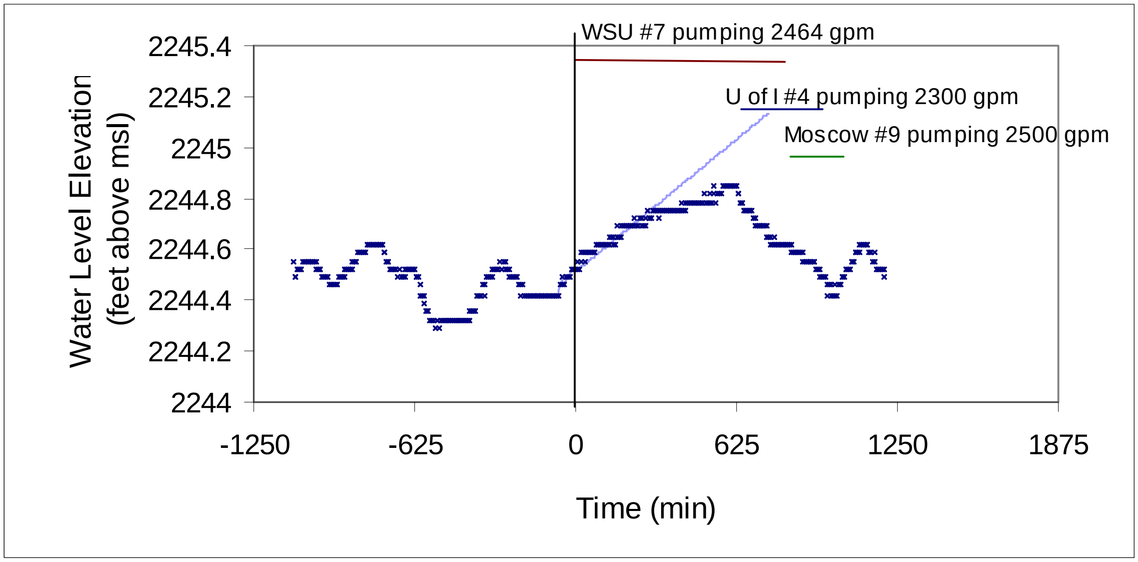

Figure 11. Arithmetic plot of water levels in the WDOE test well for the WSU #7 aquifer test.

The unique responses seen in the WDOE test well suggest the potential for a hydraulic barrier separating this well from the Pullman pumping center. The pumping well, WSU well #7, is completed to similar depths as the WDOE test well and the U of I well #4 (Appendix F). The WDOE test well is located approximately half way between the WSU well #7 and Moscow well #9 (Figure 8). With similar completion zones and pumping rates, the existence of a hydraulic barrier isolating the Pullman pumping center from the eastern portion of the basin is suggested.

The nature and exact location of this hydraulic barrier is still unknown. Figure 11 suggests a strong hydraulic connection between the WDOE test well and U of I #4. With WSU #7 pumping at similar rates as U of I #4, a measurable drawdown would be expected in the WDOE test well from pumping WSU #7 as was measured by pumping U of I #4. The fact that the WDOE test well did not respond to the pumping of the WSU #7 well hydraulically isolates these two particular wells. The separation of these wells could be created by several possibilities. First, a hydraulic barrier imposed on the system by the cones of depression of the two pumping centers converging could create such a barrier. Next, physical barriers such as large scale faulting or folding could also be possible explanations of the barrier. All of these explanations could potentially form barriers that could restrict groundwater flow. With the results from the previous aquifer tests (Golder Associates, Inc., 2001, Beck, 2001), and the WSU #7 test, the existence of the barrier needs to be further identified and mapped.

City of Moscow wells

Water levels were monitored by city personnel in Moscow city wells #6, #8, and #9 during the test with in-line measuring devices (i.e., separate air line in each well). These air lines were checked for accuracy with an electric sounding water level meter and found to be accurate to +/- 0.05 feet. As Figure 12 shows, the water levels rose continuously while WSU well #7 was pumping but began to decline within 5 minutes after pumping started in U of I well #4 at a rate of 2450 gpm. The effects of U of I well #4 pumping reversed the rising water level trends in city of Moscow wells #8 and #9. The rising water level trend in city of Moscow well #6 appears to have been perturbed somewhat as the pressure wave moved through the system; however, the rising trend was not reversed. The lack of response in the city of Moscow wells #6 and #8 indicate the hydraulic connection between these wells and the U of I well #4 and city of Moscow well #9 is weak (Figure 12).

Pre-test measurements were limited to only two measurements prior to the start of the test, so a pre-test trend for the city of Moscow wells is not available. This lack of a pre-test trend for these wells limits the analysis of the drawdown data.

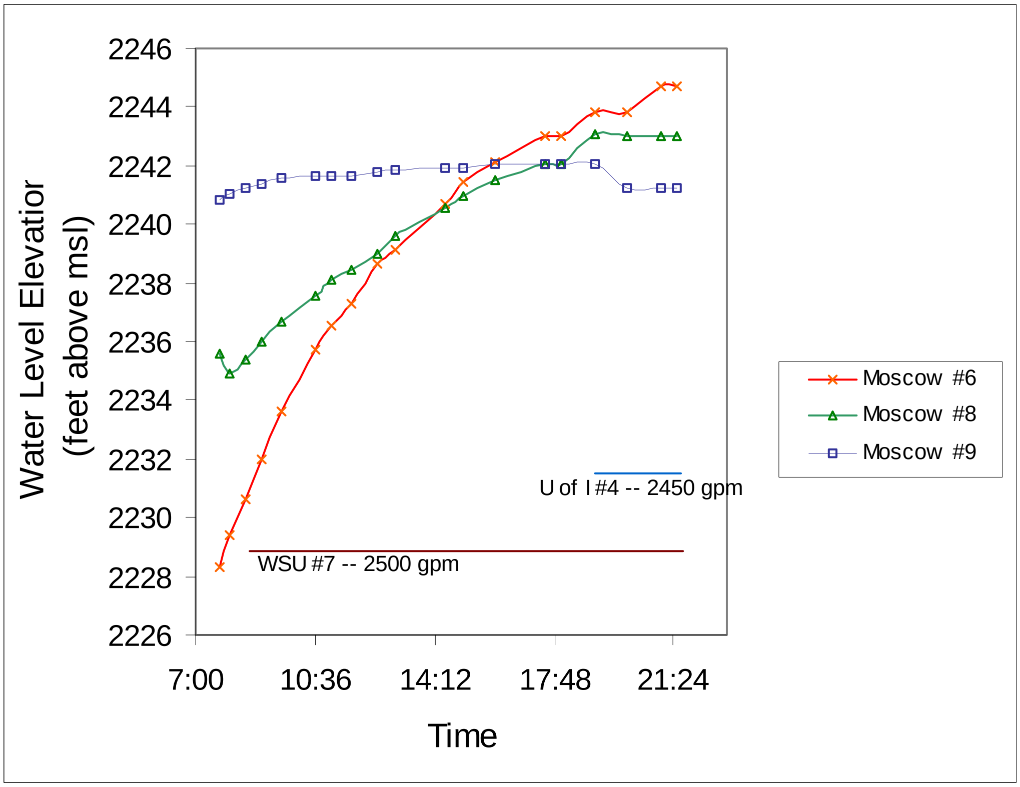

Figure 12. Arithmetic plot of water levels for Moscow city wells during WSU #7 aquifer test.

U of I #4 Aquifer Test

The purpose of this test was to confirm the potential connection between the WDOE test well and the U of I well #4 seen in the results from the WSU #7 aquifer test. To confirm this connection, another constant discharge aquifer test was designed. The pumping well for this test was the U of I well #4. The WDOE test well, city of Palouse well #2, and city of Moscow wells #6, #8, and #9 were used as observation wells (Figure 8).

The aquifer test began at 8:00 am (t=0 min) on June 30, 2002, with a constant pumping rate of 2323 gpm for about 500 minutes (t=500 min). City of

Moscow well #6 and well #8 were shut down 12 hours (t=-620 min to t=0 min) prior to the test to allow the water levels to recover.

WDOE Test Well

Water levels in the WDOE test well were monitored with a submersible, Solinst™ pressure transducer, data logger measuring every five minutes. Drawdown was measured in the WDOE test well in response to pumping of the U of I well #4, (Figure 13). These drawdown data were corrected for the pre-test trend that existed before the test. However, the unexplained stepping of the pre-test water levels complicated the trend correction for this test. The water levels continued to step through time during the pumping period. Therefore, the corrected drawdown also appears to step through time. The unexplained stepping water levels appear to be a characteristic of the WDOE test well and also complicated analysis of the WSU #7 test. If it can be assumed the effects of the stepping water levels can be ignored, the corrected drawdown data can be used to estimate transmissivity and storativity for the aquifer. Using the Theis (1935) solution, the corrected drawdown data were plotted on log-log graph paper as drawdown versus time (Figure 14) with the software program AQTESOLV (HydroSOLVE, 1996). This matching technique provided the values needed to solve the following equations:

$$s = [Q/4\pi T]\, W(u)$$

where s = drawdown (ft)
Q = pumping rate (ft^3/min)
T = transmissivity (ft^2/min)
$W(u)$ = well function of u and $u = r^2S/4Tt$

r = distance to pumping well (ft)
S = aquifer storativity (dimensionless)
t = time (minutes)

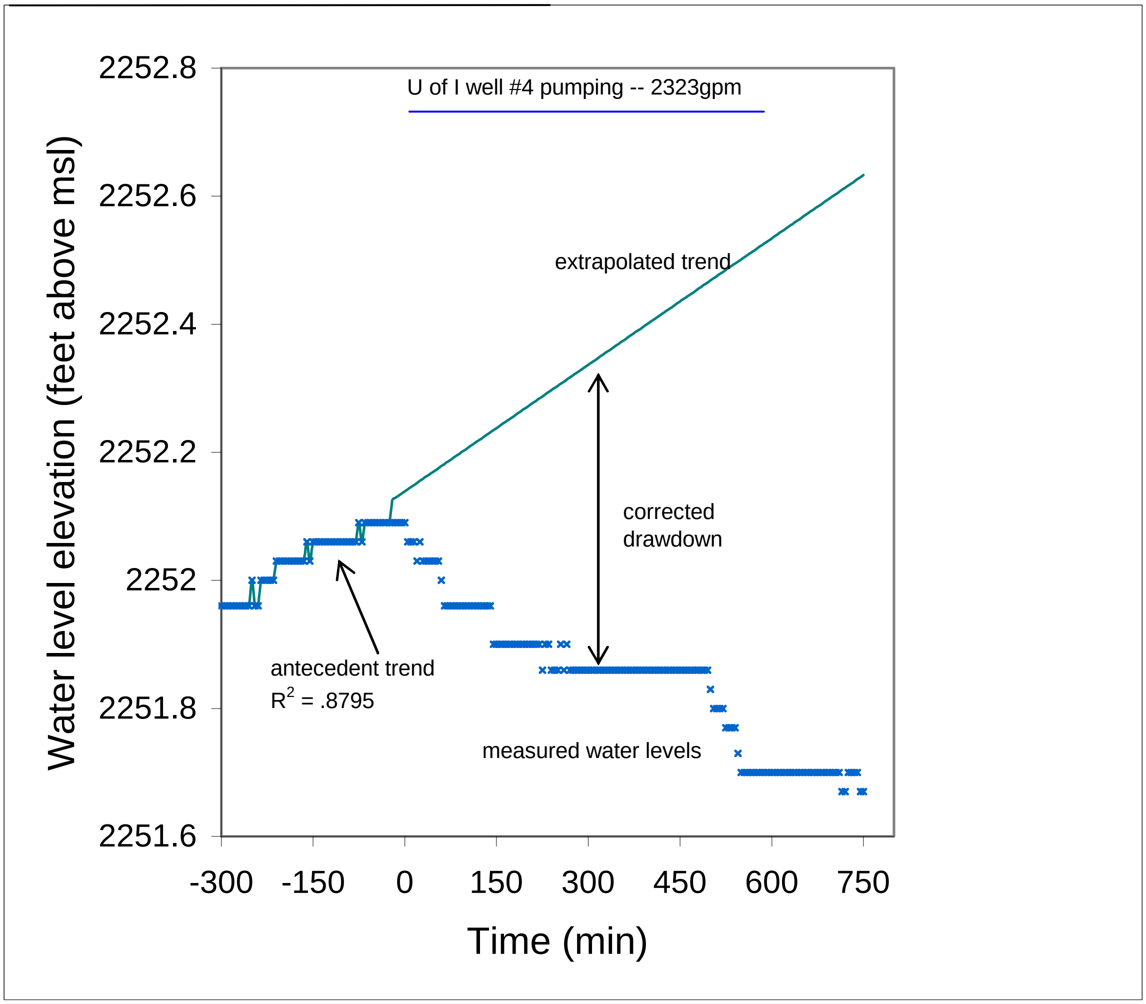

Figure 13. Arithmetic plot of water levels in the WDOE test well for the U of I #4 aquifer test.

The corrected drawdown data deviate from the predicted type curve with somewhat regular steps, and what appears to be a late time departure above the type curve due to negative boundaries (Figure 14). Steps in the drawdown data are common to the WDOE test well and Palouse city well #2, but are not fully understood. It is possible the stepping water levels in the WDOE test well are due to the problems encountered during construction of the well (Appendix F).

With the questionable match to the Theis type curve (Figure 14), caution must be used when estimating aquifer properties based on these data. The basic assumptions for the equations used are violated in this particular situation, so the calculated values must be considered rough estimates.

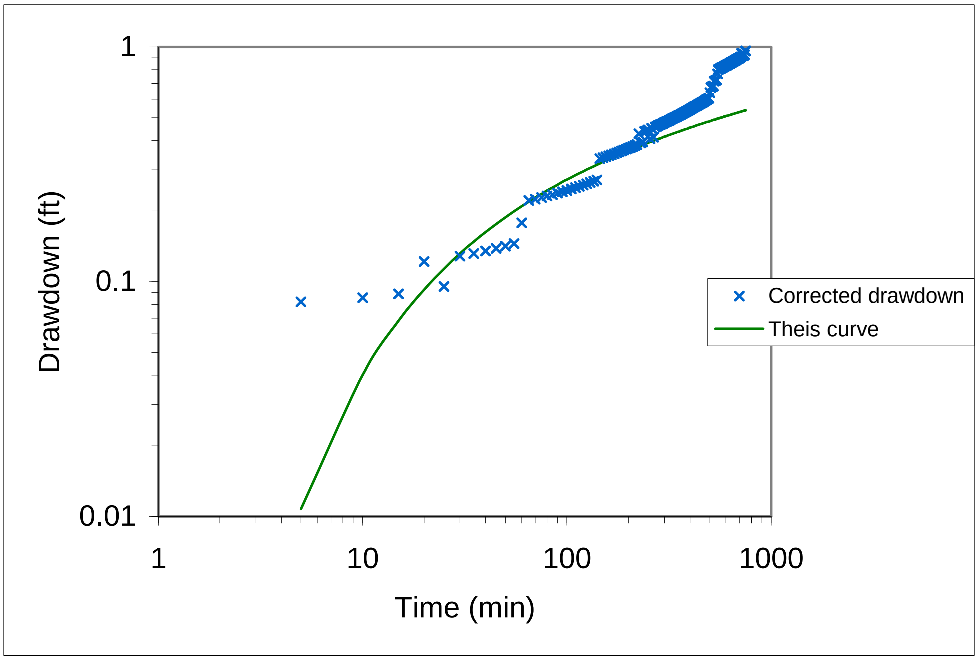

Figure 14. Log-log plot of time versus corrected drawdown for the WDOE test well during the U of I #4 aquifer test.

City of Moscow Wells

Water levels in the city of Moscow wells were monitored by city personnel with the air lines installed in the well heads. City of Moscow well #6 and #8 did not respond to the pumping of the U of I well #4, suggesting a hydraulic discontinuity between these wells from the pumping well. The lack of response corresponds to the geology of these wells shown in the well logs (Appendix F). Moscow city well #9 did respond predictably to pumping (Figure 15).

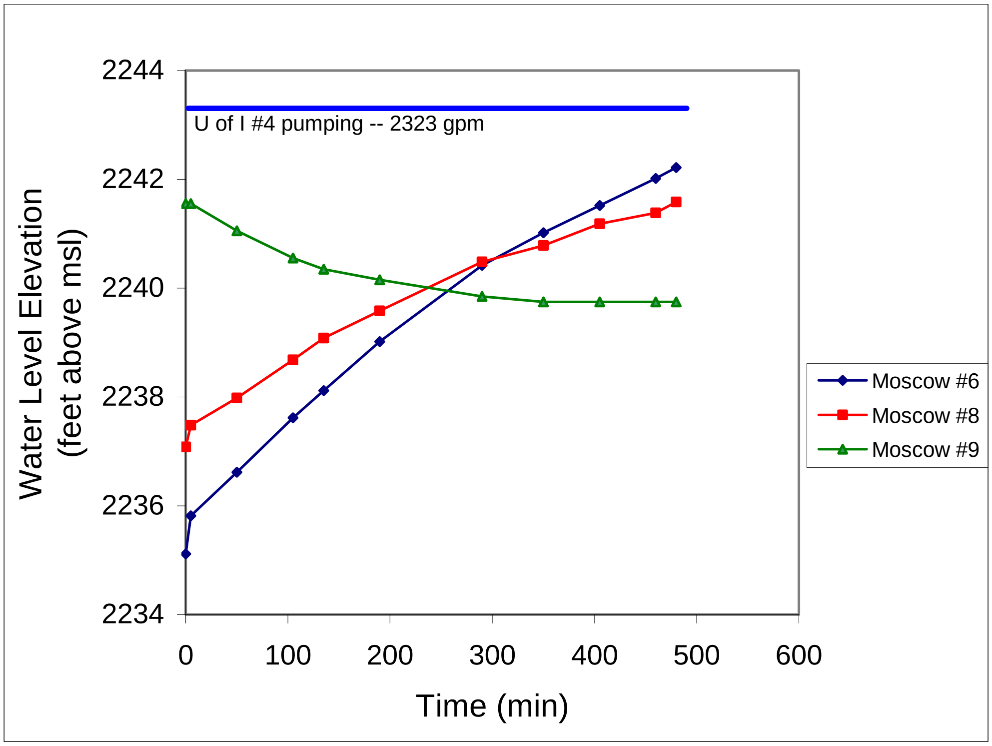

Figure 15. Arithmetic plot of water level elevations for Moscow city wells during U of I #4 aquifer test.

Figure 16 presents a logarithmic plot of drawdown data versus time for the city of Moscow well #9. The drawdown data match the Theis type curve very well; however, pre-test water level measurements were not recorded, and only eleven measurements were taken during the test by city personnel. Caution still must be taken with the estimated values as pre-test data and early time data were not available.

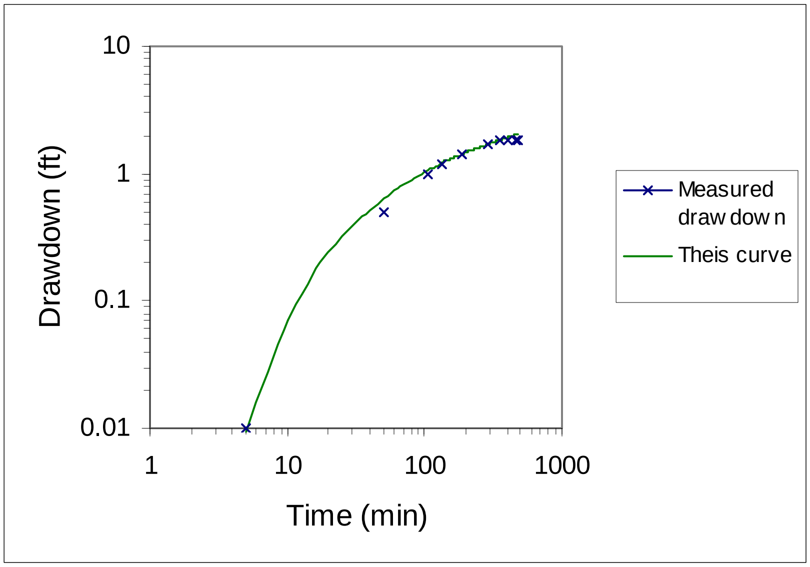

Figure 16. Log-log plot of measured drawdown versus time for the city of Moscow well #9 during the U of I #4 aquifer test.

City of Palouse well #2

Water level measurements were recorded by a down hole pressure transducer, owned by the city, on five minute intervals for 50 minutes prior to the test and throughout the pumping period. However, the existence of only 50 minutes of data is very limiting when trying to address any pre-test trends. The well is located in a locked, city pump house, and access was limited to the time during which a city official was available to open it.

A sudden drop in water level of about 0.30 feet was measured at the start of the test as shown in Figure 17. This response suggests the possibility of a direct hydraulic connection between the city of Palouse well #2 and U of I well #4.

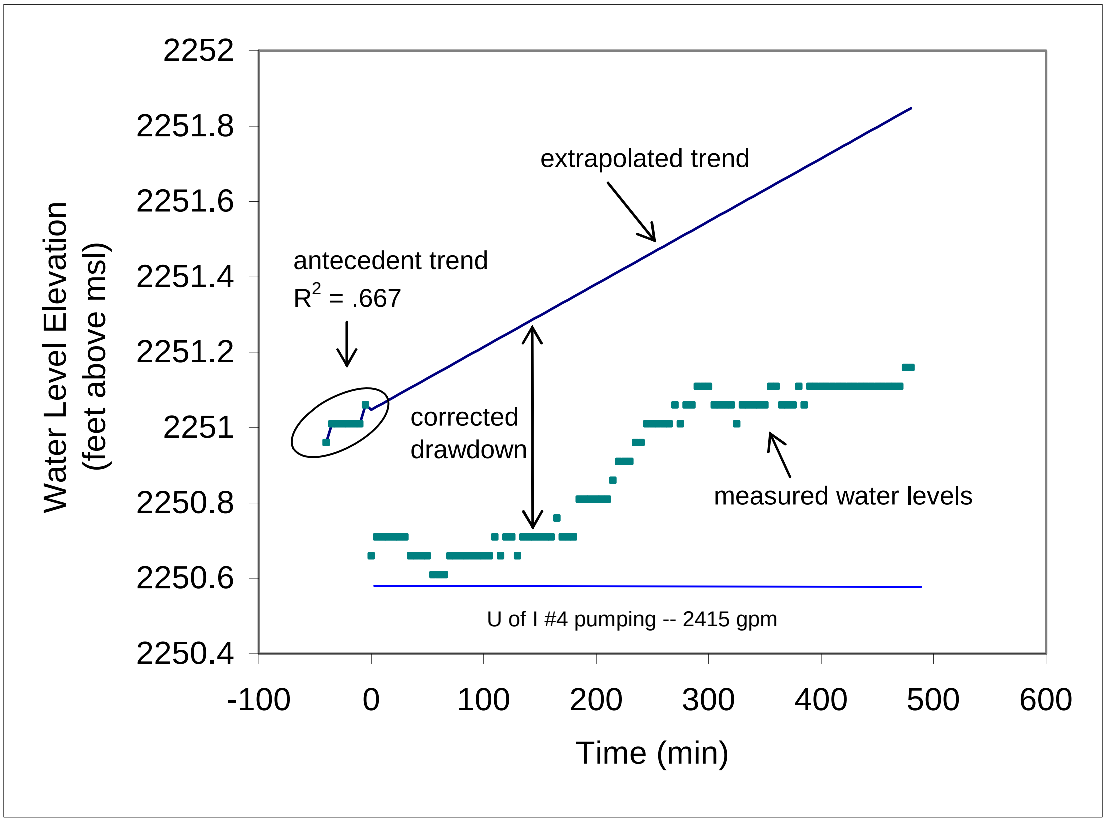

Figure 17. Arithmetic plot of water levels for city of Palouse well #2 during the U of I #4 aquifer test.

The decreasing water levels at the beginning of the aquifer test suggest a direct hydraulic connection between the U of I well #4 and the city of Palouse well #2, based on the extrapolated trend (Figure 17). The extrapolated trend was used to determine the corrected drawdown that is plotted in Figure 18. Figure 18 shows the corrected drawdown deviating from the Theis solution at late times. This deviation is similar to the negative boundary effects seen in drawdown data for this well during the WSU #7 and Moscow #9 aquifer tests.

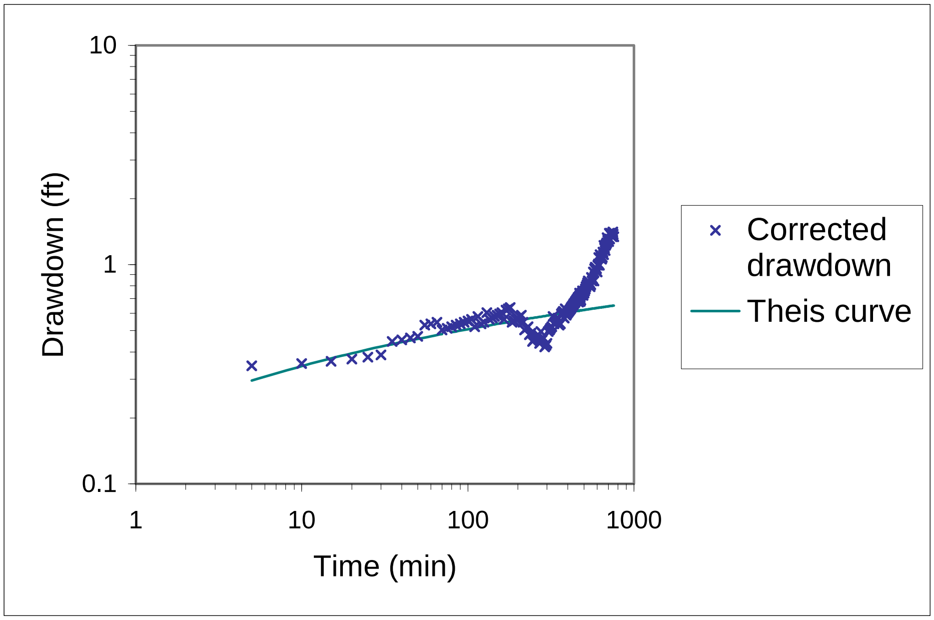

Figure 18. Logarithmic plot of corrected drawdown versus time for the city of Palouse well #2 during the U of I #4 aquifer test.

The “fit” of the Theis solution to the corrected drawdown data is marginal at best. The non-theoretical response suggests hydraulic connection. However, aquifer coefficients cannot be derived from these data.

Moscow #9 Test

A constant discharge aquifer test was designed to evaluate the hydraulic connection between the city of Palouse well #2 and the U of I well #4 – city of Moscow well #9 pair. City of Palouse well #2 was the observation well of interest. Because of the significance associated with understanding the apparent, direct hydraulic connection between the Moscow and Palouse pumping centers, City of Moscow well #9 and the U of I well #4 were pumped concurrently to maximize the stress placed on the aquifer. Water levels in the city of Palouse well #2 were recorded every five minutes for the duration of the test by the down hole, pressure transducer owned by the city.

The city of Palouse well #2 was shut down for over 48 hours prior to the test. City of Moscow well #9 and U of I well #4 were both shut down 18 hours prior to the start of the test.

The test was completed on February 20, 2003. City of Moscow well #9 began pumping at 8:00 am (t=0 min) and pumped at a constant rate of 2416 gpm for eight hours (t=480 min). U of I well #4 began pumping at 8:32 am (t=32 min) and pumped at a constant rate of 2310 gpm for four hours and 34 minutes (until t=274 min). Water levels were measured in the city of Palouse well #2 on five minute intervals for one hour prior to the test on five minute intervals. Pre-test measurements in city of Palouse well #2 were limited to one hour because of access limitations imposed by the city personnel.

<u>City of Palouse well #2</u>

The water level data for the city of Palouse well #2 were analyzed and corrected for a pre-test trend (Figure 19). The corrected data were plotted to show the adjusted drawdown response to the combined stress of concurrent pumping of U of I well #4 and city of Moscow well #9.

Figure 19 shows a distinct flattening of the rising water level trend at time t=10 min. The change in slope clearly indicates direct hydraulic connection between Palouse and Moscow. The extrapolated trend is based on a linear regression of 60 minutes of pre-test measurements as described in Appendix A. It is also assumed that the trend continued for the duration of the aquifer test.

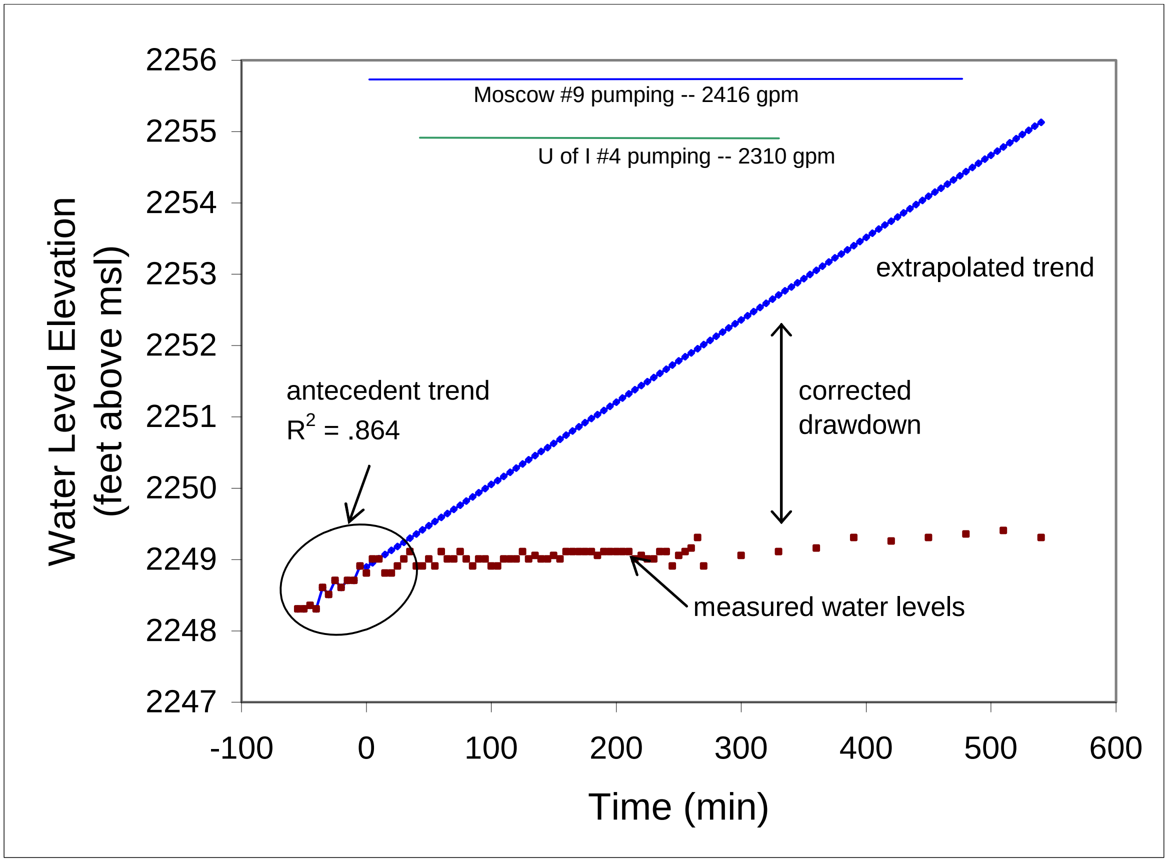

Figure 19. Arithmetic plot of water level elevation versus time for city of Palouse well #2 during the Moscow #9 aquifer test.

Figure 20 shows departure of the corrected drawdown above the Theis type curve during late time. This departure is believed to reflect the effects of negative boundaries at basalt/crystalline rock contacts as mentioned previously for the WSU #7 test. The late time departure from the Theis type curve is very similar to the response measured for this well during the U of I #4 aquifer test (Figure 14).

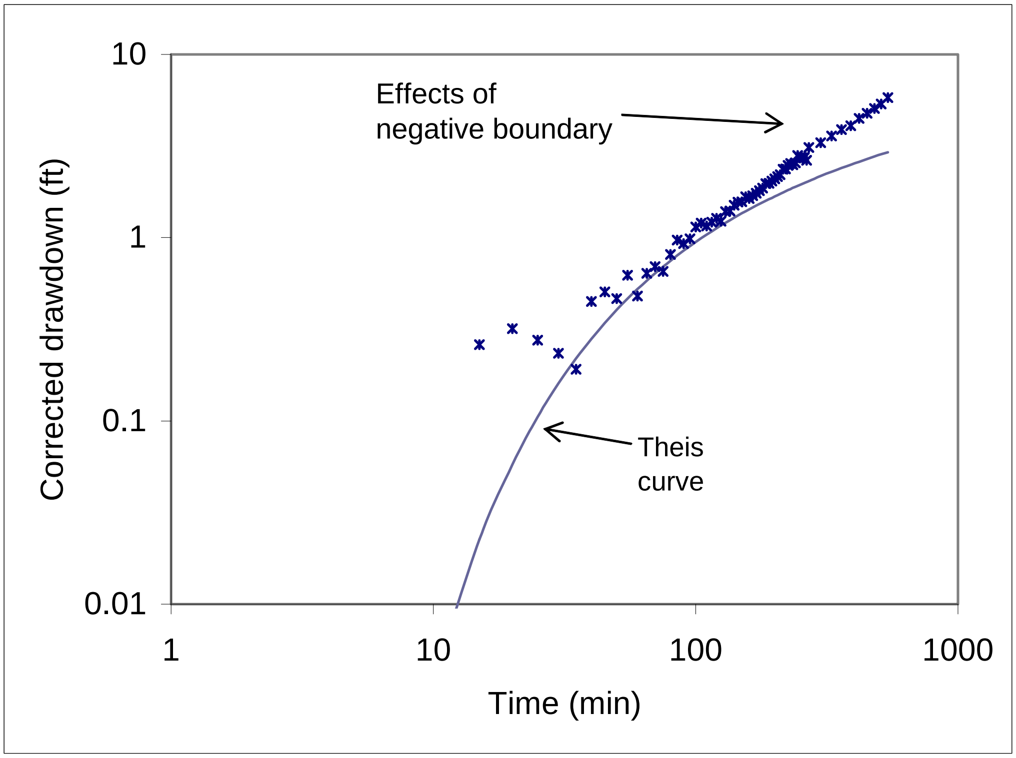

Figure 20. Logarithmic plot of corrected drawdown versus time for city of Palouse well #2 during the Moscow #9 aquifer test.

WDOE Test Well

Water levels in the WDOE test well were recorded by a submersible, Solinst™ pressure transducer, data logger. The water levels were measured every five minutes and the data were corrected for a pre-test trend. The extrapolated trend is based on a linear regression of 60 minutes of pre-test measurements as described in Appendix A. It is also assumed that the trend continued for the duration of the aquifer test. The water levels in the WDOE test well responded to the concurrent pumping of U of I well #4 and the city of Moscow well #9 (Figure 21). The response to pumping was seen within minutes of the beginning of pumping of the two wells. It was not possible to differentiate the effects of the U of I well #4 pumping from the effects of city of Moscow well #9 pumping. However, cessation of pumping in the two wells clearly is visible as two distinct steps of recovery.

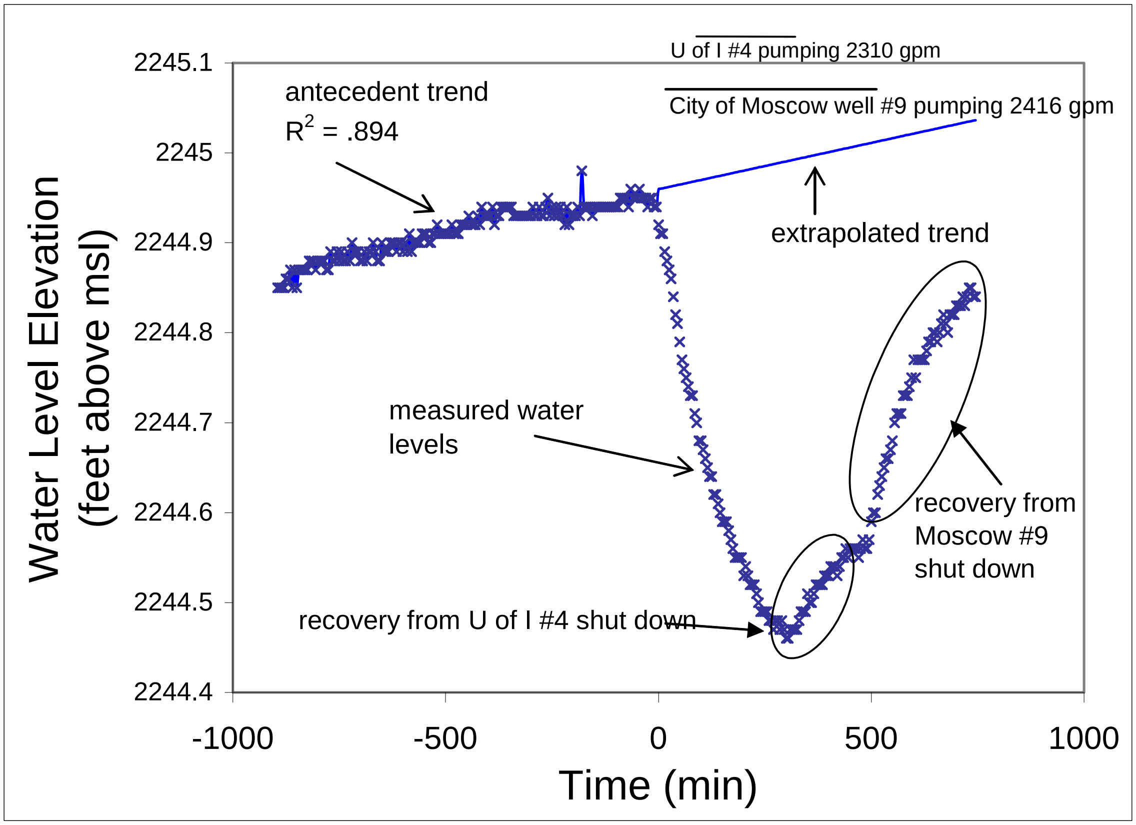

Figure 21. Arithmetic plot of water levels in the WDOE test well during the Moscow #9 Test.

Figure 22 shows a logarithmic plot of the corrected drawdown versus time for the WDOE test well. A Theis curve was matched to the corrected drawdown and fit reasonably well. The corrected drawdown departs from the Theis curve at early time (t<30 min). This departure may be due well construction problems of the observation well, or the possibly the pre-test trend was not linear. Another departure from the Theis curve occurs in the late time data (beginning at t=400 min), where the drawdown begins to decrease (Figure 22). This is attributed to the U of I well #4 shutting off, decreasing the stress on the system, and allowing the water levels to begin to recover.

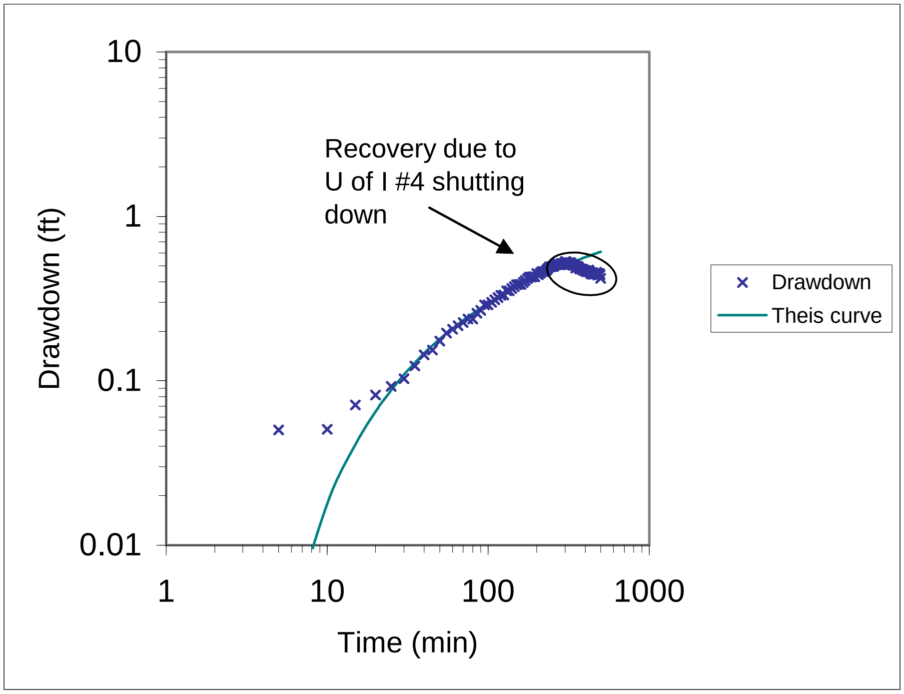

Figure 22. Logarithmic plot of corrected drawdown versus time for the WDOE test well during the Moscow #9 aquifer test.

Moscow #8 Test

Water level monitoring in Moscow wells #6 and #8 has suggested that these wells do not respond directly to pumping of other city of Moscow wells or the U of I well #4. A constant discharge test was designed to provide sufficient data to estimate transmissivity and storativity for the aquifer(s) penetrated by these two wells.

City of Moscow well #8 was the designated pumping well, and city of Moscow well #6 was the observation well of greatest interest. The WDOE test well and city of Palouse wells #1 and #2 also served as observation wells throughout the test (Figure 8).

Wells used in this test were allowed sufficient time to fully recover to eliminate potential recovery trends induced by pumping. The city of Moscow well #8 was shut down 19 hours prior to the start of the test. City of Moscow well #6 was idle for 21 hours prior to the test startup. The city of Palouse wells #1 and #2 were both idle for at least 24 hours prior to the test.

The test was completed on March 11, 2003, with the city of Moscow well #8 began pumping at 8:10 am (t=0 min) at a constant rate of 1100 gpm for 410 minutes. The remaining city wells and U of I well #4 were shut down for the duration of the test.

City of Moscow well #6

The city of Moscow well #6 responded to the pumping of city of Moscow well #8. Water levels were measured every five minutes for the first three hours and then every 15 minutes for the remainder of the test. Figure 23 shows that drawdown followed the Theis curve for about 80 minutes. Departure from the type curve suggests a negative boundary was reached by the cone of depression. This bounded drawdown response suggests that the aquifer is of limited area, as suggested in Figure 6. Transmissivity and storativity estimates are about 8630 ft^2/day and 1.9 X 10^{-5}, respectively, based on an AQTESOLV (HydroSOLVE, 1996) manual curve match.

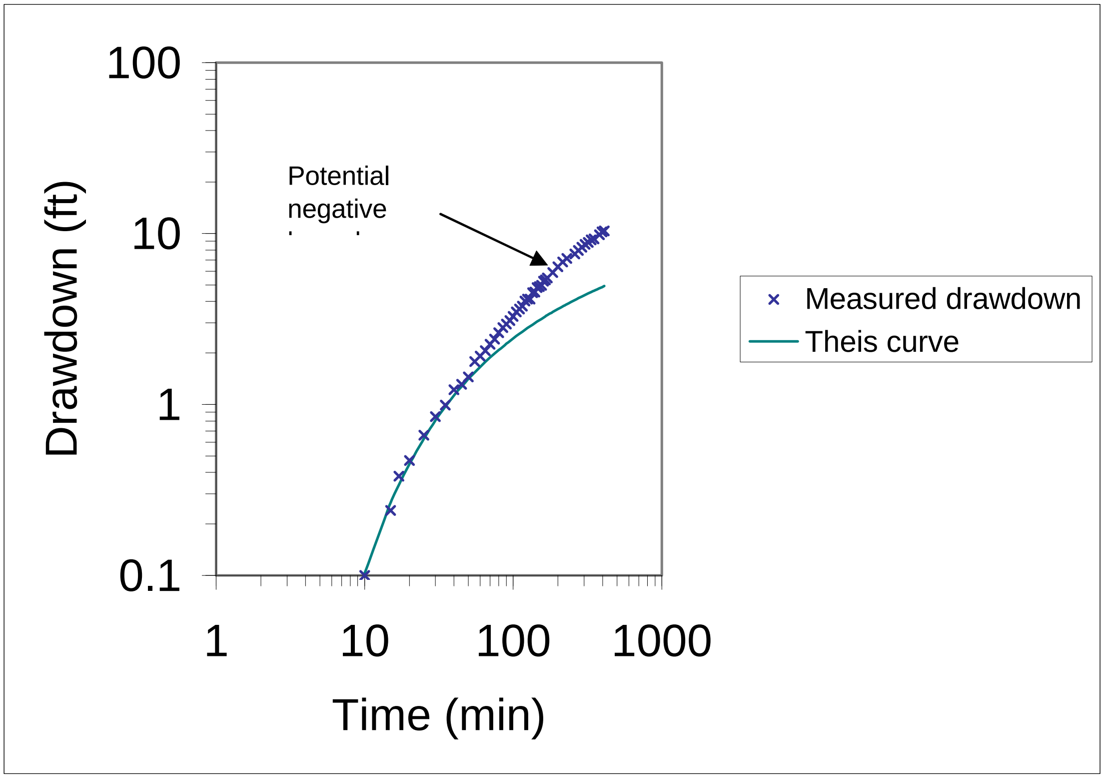

Figure 23. Logarithmic plot of drawdown versus time for city of Moscow well #6
T = 8630 ft^2/day, and S = 1.9 X 10^{-5}.

Figure 24 is a semi-logarithmic plot of drawdown versus time for the pumping well, city of Moscow well #8. The Cooper-Jacob (1946) method was used to estimate transmissivity. Based on Figure 24, transmissivity was estimated to be 9900 ft^2/day. It is not possible to estimate storativity because the effective radius of the well is not known. The transmissivity value matches the estimated value for the city of Moscow well #6 very well.

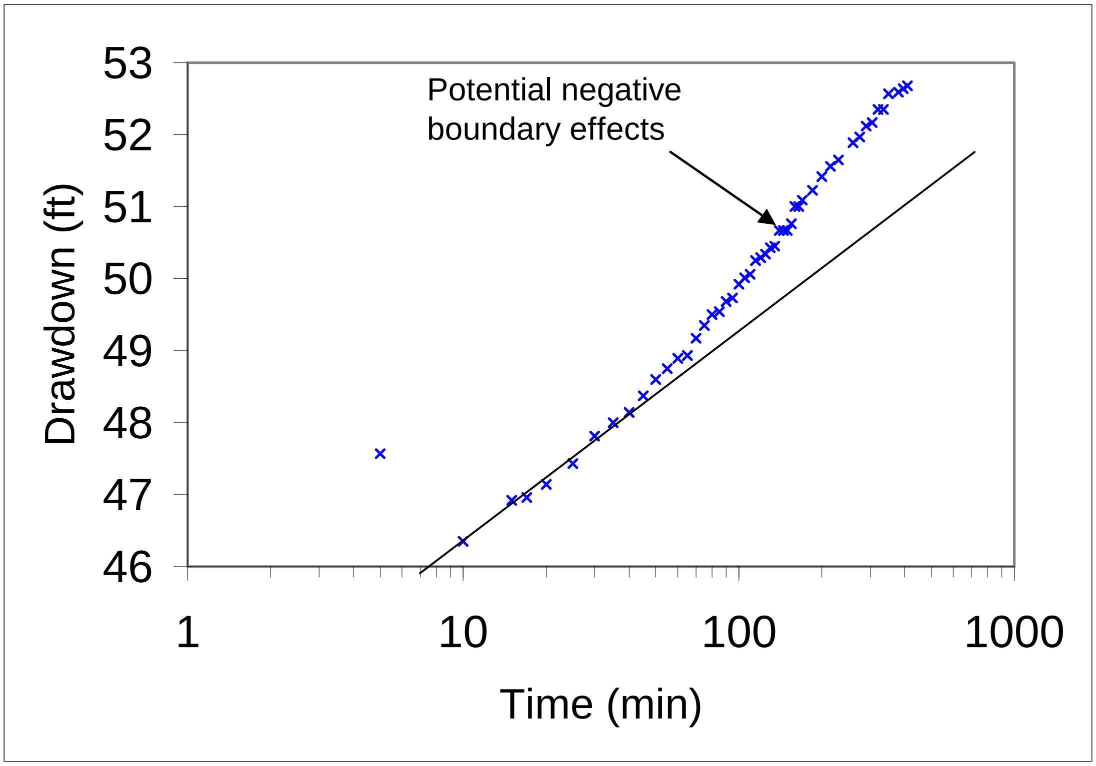

Figure 24. Semi-logarithmic plot of drawdown versus time for the city of Moscow well #8 (pumping well) during the Moscow #8 test.

WDOE Test Well

Water levels in the WDOE test well were recorded every five minutes for about 1500 minutes prior to the beginning of the test, and throughout the pumping period by a submersible, Solinst™ pressure transducer, data logger.. Figure 25 shows that the WDOE test well responded to pumping of city of Moscow well #8. This response was unexpected because it was believed that city of Moscow wells #6 and #8 are located in a hydraulically isolated portion of the stratigraphic section. However, it is possible that the hydraulic connection between the wells occurred through the Wanapum aquifer. According to Brown (1976), construction problems were encountered during the placement of the well casing in the WDOE test well. In addition, rumors exist that the upper portions of the well casings in the city of Moscow well #8 and well #6 were “slotted” with a down hole ripper at some time in the past in an effort to increase productivity.

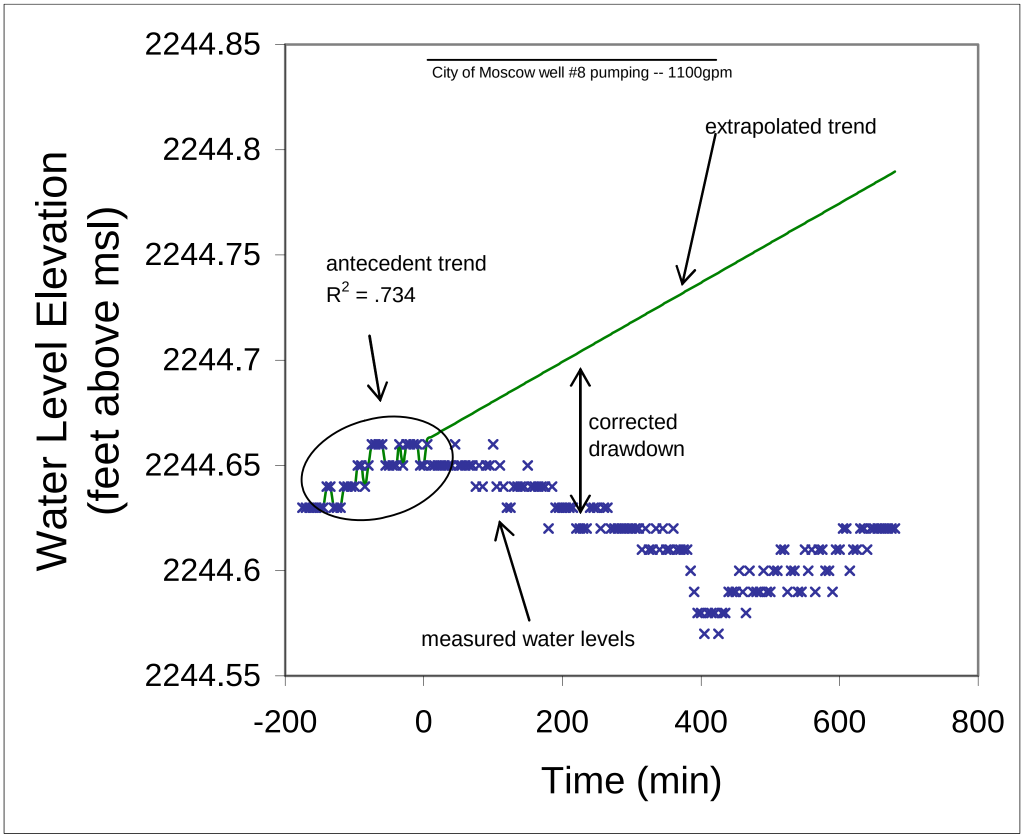

Figure 25. Arithmetic plot of water level elevation versus time for the WDOE test well during the Moscow #8 test.

The water level data for the WDOE test well were corrected for a rising antecedent trend. The extrapolated trend is based on a linear regression of 210 minutes of pre-test measurements as described in Appendix A. It is also assumed that the trend continued for the duration of the aquifer test. Figure 26 presents a Theis type curve match of corrected drawdown versus time. Early time (t<80 minutes) deviation above the type curve likely is due to the small amount of drawdown relative to the slope of the trend line produced by linear regression. In other words, the corrected, early time, data (<0.03 feet) are inaccurate due to scatter (noise) of the actual water level measurements relative to the simplified, predicted, straight line trend used to correct the drawdown.

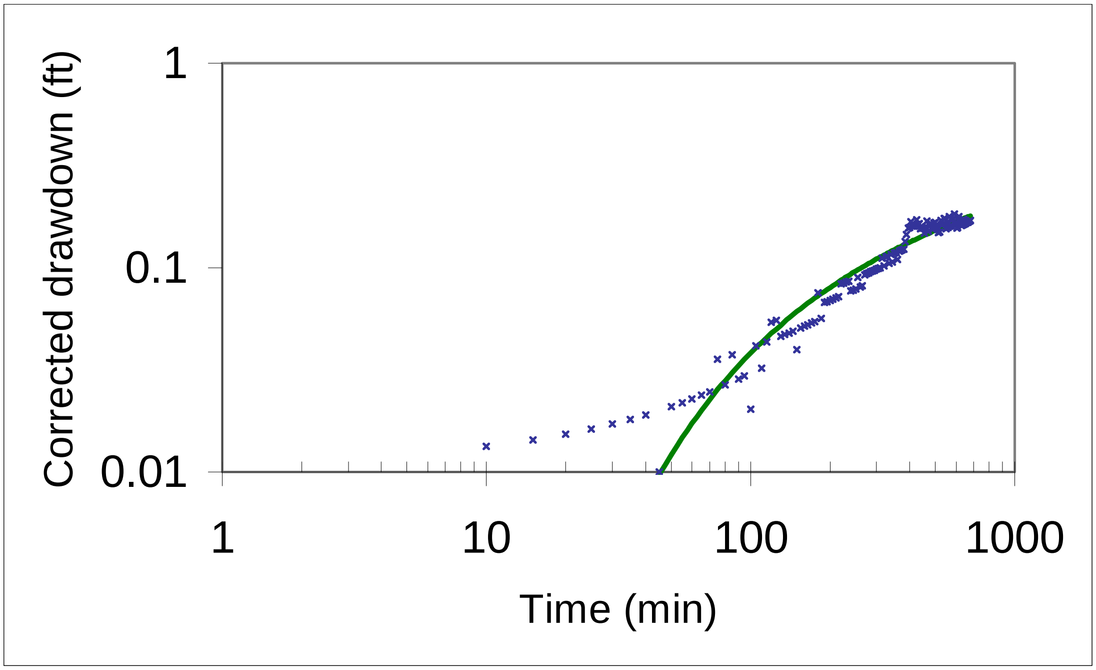

Figure 26. Logarithmic plot of corrected drawdown versus time for the WDOE test well during the Moscow #8 test. T = 173000 ft^2/day, S = 9 x 10^{-5}.

The transmissivity value estimated from this plot is orders of magnitude larger than the estimates derived from the city of Moscow #6 and #8 results. The meaning of this transmissivity value must be considered with caution because the aquifer system is known to be strongly heterogeneous and possibly anisotropic. Ground water flow appears to be compartmentalized within the basalts by a combination of basalt/crystalline rock contacts, basalt/sediment interfaces and/or merged basalt lobes or geologic structures. Based on the spatially variable hydraulic responses measured in the observation wells, the cone of depression has a long and narrow shape, and is strongly affected by heterogeneities and boundaries. Thus, the value for transmissivity derived for the WDOE test well by the Theis type curve match probably is overestimated. However, the aquifer transmissivity in the vicinity of city of Moscow wells #6 and #8 is expected to be lower due to the presence of numerous sediment interbeds in that area compared to relatively few interbeds near the WDOE test well.

Chapter 4 -- CONCLUSIONS

General conclusions pertaining to the Grande Ronde aquifer system were reached after analyzing the aquifer test data and interpreting the geology through well logs. The general conclusions are:

1. The Grande Ronde aquifer system is very heterogeneous due to the irregular nature of interflow zones, basalt/sediment interfaces, merged basalt lobes, and complex basalt/crystalline rock contacts.
2. The Grande Ronde aquifer system is composed of multiple, hydraulically compartmentalized aquifers that appear to be hydraulically separated on the short term (e.g., aquifer tests).
3. Pumping Grande Ronde wells in the Moscow pumping center does not affect the water levels in Grande Ronde wells in the Pullman pumping center during short-term aquifer tests.
4. Hydraulic connections exist between the city of Palouse well #2 and the Moscow and Pullman pumping centers through the Angel Butte/Kamiak Butte gap during separate, short term, aquifer tests.
5. Effects of negative boundaries are seen in drawdown data for the city of Palouse well #2 and the WDOE test well during aquifer tests WSU #7, U of I #4, and Moscow #9
6. Pre-test water level trends are very common in the Grande Ronde basalt aquifers. Pre-test water level measurements are needed to

delineate specific, antecedent trends so individual drawdown responses can be "corrected" and analyzed appropriately.

7. The WDOE test well showed an inverse water level rise coinciding with the pumping of WSU well #7. This potential affect could be significant in terms of the extent of the aquifer penetrated by the WSU well #7.

Specific conclusions:

WSU #7 Test

1. <u>City of Palouse well #2</u>. The water levels in the city of Palouse well #2 are affected by trends presumably caused by pumping in the basin. When drawdown data are "corrected" for these trends, the city of Palouse well #2 can be shown to respond to pumping of WSU well #7 within a time period of 20 minutes. This response to a controlled hydraulic stress confirms a hydraulic connection through the Angle Butte and Kamiak Butte gap. The drawdown data also show the effects of the negative boundaries formed by the basalt/crystalline rock contacts (i.e., basin boundaries).
2. <u>WDOE test well</u>. The WDOE test well did not respond predictably to the pumping of the WSU well #7. The most notable response measured in this well was due to the inadvertent pumping of the U of I well #4. This lack of response in the WDOE test well suggests that a potential hydraulic barrier exists between the WDOE test well and WSU well #7. Though no drawdown was measured in this well, an inverse water level fluctuation coincided with the start of the pumping of WSU well #7. This affect is

commonly known as the Noordbergum affect, and could be significant in the extent of the aquifer PGR1.

3. City of Moscow wells. None of the city of Moscow wells responded predictably to the pumping of the WSU well #7. Water levels in Moscow increased throughout the duration of the test, until the inadvertent pumping of the U of I well #4 caused drawdown in the city of Moscow well #9. City of Moscow wells #6 and #8 did not respond to this pumping.

U of I #4 Test

1. WDOE test well. The WDOE test well responded predictably to the pumping of the U of I well #4. Though drawdown was measured, reliable aquifer coefficients were not derivable from this drawdown data. The complexity of the aquifer pumped for this test creates too much error in any aquifer values estimated.
2. City of Moscow wells. The city of Moscow wells #6 and #8 did not respond to the pumping of the U of I well #4. City of Moscow well #9 responded to the pumping, and the drawdown data were analyzed to estimate aquifer properties
3. City of Palouse well #2. The city of Palouse well #2 responded to pumping of the U of I well #4 confirming the hydraulic interference between the two wells through the Angel Butte / Kamiak Butte gap.

4. Total corrected drawdown of about 1.1 feet was calculated for the city of Palouse well #2 after eight hours of pumping, and the pre-test trends were removed.

Moscow #9 Test

1. City of Palouse well #2. The city of Palouse well #2 responded to the combined pumping of the city of Moscow well #9 and the U of I well #4. This is the third confirmation of the hydraulic connection between the Angel Butte and Kamiak Butte gap.
2. The WDOE test well. The WDOE test well responded to the combined pumping of the U of I well #4 and the city of Moscow well #9.
3. Moscow city wells. The city of Moscow wells #6 and #8 did not respond to the combined pumping of the U of I #4 and city of Moscow #9 over the eight hour aquifer test.

Moscow #8 Test

1. City of Moscow wells. The city of Moscow well #9 did not respond to the pumping of the city of Moscow well #8 during the eight hour aquifer test. The city of Moscow well #6 did respond to the pumping stress.
2. City of Palouse well #2. The city of Palouse well #2 did not respond to the pumping of the city of Moscow well #8 over the eight hour aquifer test.
3. WDOE test well. The WDOE test well did respond predictably to the pumping of the city of Moscow well #8. Transmissivity was estimated to be 86,000 ft^2/day and storativity was estimated to be 9×10^{-5}. These values

were derived based on the Theis (1935) solution after a pre-test trend was removed. However, several of the Theis assumptions are not satisfied leading to potential inaccuracies in the calculated aquifer coefficients.

4. Based on drawdown data for city of Moscow wells #6 and #8, the estimated average transmissivity and storativity values for this aquifer are 3960 ft^2/day and 3.9×10^{-5}.

Recommendations

Specific recommendations based on this study are:

1. Additional Grande Ronde wells should be drilled for municipal supply, and for long term monitoring based on stratigraphic and hydraulic data.
2. Well interference and hydraulic connections throughout the Palouse should be evaluated on a well by well basis, because the system is extremely heterogeneous. Before pumping of any well can be considered to have an effect on another well, an aquifer test needs to be conducted to confirm the influence. Wells located within close proximity (500 ft) and completed to similar depths, may have no influence on one another. However, wells located over four miles apart might show well interference effects.
3. Future aquifer tests should be conducted with longer recovery periods both prior to and following the test to minimize uncertainties in the data. Pre-test data should be collected for longer periods to help reduce the uncertainty of potential hydraulic connections.

4. Future aquifer tests should incorporate U of I well #3, which was not available during this study.
5. A detailed water level monitoring program should be implemented for all municipal wells. This monitoring program should be designed so that the data for all of the regional municipal wells are on the same time scale and measured using the same techniques/equipment. The details of water level fluctuations could give insight to the aquifers in this system.
6. Geophysical investigations throughout the basin should be completed to investigate several factors. The southwestern boundary is currently unknown, and is speculated to exist just to the southwest of Pullman. A geophysical study could examine the potential for a geologic anomaly that could produce such a boundary. The hydraulic barrier hypothesized to exist between the WDOE test well and the Pullman pumping center could also be investigated with the use of geophysics.
7. The basement complex topography should be delineated to specifically locate the edges of the aquifers. The spatial extent of these aquifers should be defined before any predictions are made about future water supplies. The spatial extent of these aquifers is greatly dependent on the subsurface topography and locations of the crystalline basement rocks.

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APPENDIX A
TREND CORRECTION PROCEDURES

Trend analysis procedures

Pretest data were measured and are presented in the table below.

An XY scatter-plot of water level elevation versus time is created.

From that plot, a linear regression trend line is fit.

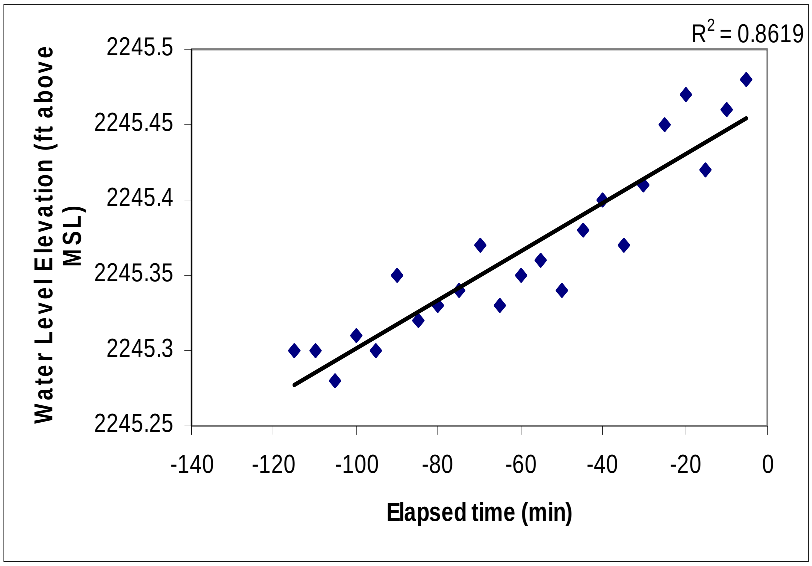
An R-squared value is displayed to show the goodness of the fit of the trend line to the plotted data.

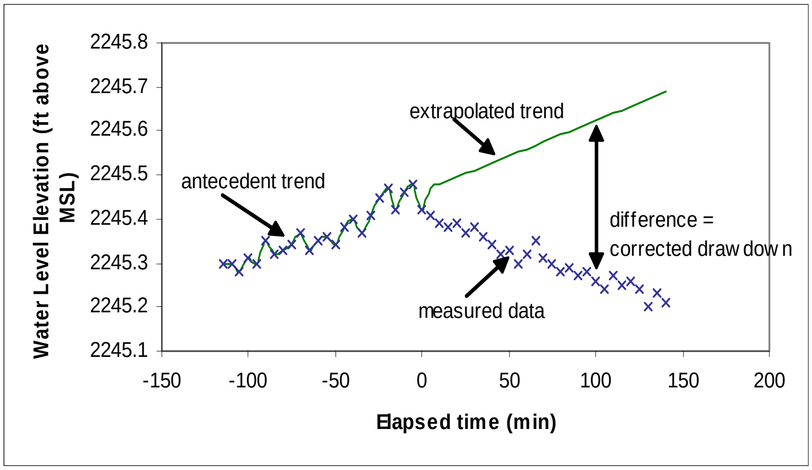
The linear line is extrapolated throughout the duration of the aquifer test.

This line is then used to "correct" the data and estimate drawdown.

EXAMPLE:

Elapsed Time (min)	Water level elevation (ft above msl)
-115	2245.3
-110	2245.3
-105	2245.28
-100	2245.31
-95	2245.3
-90	2245.35
-85	2245.32
-80	2245.33
-75	2245.34
-70	2245.37
-65	2245.33
-60	2245.35
-55	2245.36
-50	2245.34
-45	2245.38
-40	2245.4
-35	2245.37
-30	2245.41
-25	2245.45
-20	2245.47
-15	2245.42
-10	2245.46
-5	2245.48





Drawdown estimates

Subtract extrapolated trend from measured values to obtain corrected drawdown

Elapsed time (min)	Water level elevation (feet above mean sea level)	Extrapolated water level in feet above mean sea level	Corrected drawdown (ft)
-115	2245.3	2245.30	0.00
-110	2245.3	2245.30	0.00
-105	2245.28	2245.28	0.00
-100	2245.31	2245.31	0.00
-95	2245.3	2245.30	0.00
-90	2245.35	2245.35	0.00
-85	2245.32	2245.32	0.00
-80	2245.33	2245.33	0.00
-75	2245.34	2245.34	0.00
-70	2245.37	2245.37	0.00
-65	2245.33	2245.33	0.00
-60	2245.35	2245.35	0.00
-55	2245.36	2245.36	0.00
-50	2245.34	2245.34	0.00
-45	2245.38	2245.38	0.00
-40	2245.4	2245.40	0.00
-35	2245.37	2245.37	0.00
-30	2245.41	2245.41	0.00
-25	2245.45	2245.45	0.00
-20	2245.47	2245.47	0.00
-15	2245.42	2245.42	0.00
-10	2245.46	2245.46	0.00
-5	2245.48	2245.48	0.00
0	2245.42	2245.42	0.00
5	2245.41	2245.47	0.06
10	2245.39	2245.48	0.09
15	2245.38	2245.49	0.11
20	2245.39	2245.49	0.10
25	2245.37	2245.50	0.13
30	2245.38	2245.51	0.13
35	2245.36	2245.52	0.16
40	2245.34	2245.53	0.19
45	2245.32	2245.54	0.22
50	2245.33	2245.54	0.21
55	2245.3	2245.55	0.25
60	2245.321	2245.56	0.24
65	2245.35	2245.57	0.22

70	2245.31	2245.58	0.27
75	2245.3	2245.58	0.28
80	2245.28	2245.59	0.31
85	2245.29	2245.60	0.31
90	2245.27	2245.61	0.34
95	2245.28	2245.62	0.34
100	2245.26	2245.62	0.36
105	2245.24	2245.63	0.39
110	2245.27	2245.64	0.37
115	2245.25	2245.65	0.40
120	2245.26	2245.66	0.40
125	2245.24	2245.66	0.42
130	2245.2	2245.67	0.47
135	2245.23	2245.68	0.45
140	2245.21	2245.69	0.48

APPENDIX B

WATER LEVEL MEASUREMENTS FOR WSU #7 TEST

WDOE testwell -- WSU #7 test
Retrieved with Solinst pressure transduced data logger
Pumping well -- WSU #7
Radial distance to pumping well -- 20279 ft

Elapsed Time (min)	Water level elevation (feet above mean sea level)	Extrapolated trend in feet above mean sea level	Corrected drawdown (feet)
-210	2244.49	2244.49	0.00
-205	2244.49	2244.49	0.00
-200	2244.49	2244.49	0.00
-195	2244.49	2244.49	0.00
-190	2244.49	2244.49	0.00
-185	2244.46	2244.46	0.00
-180	2244.46	2244.46	0.00
-175	2244.42	2244.42	0.00
-170	2244.46	2244.46	0.00
-165	2244.42	2244.42	0.00
-160	2244.42	2244.42	0.00
-155	2244.42	2244.42	0.00
-150	2244.42	2244.42	0.00
-145	2244.42	2244.42	0.00
-140	2244.42	2244.42	0.00
-135	2244.42	2244.42	0.00
-130	2244.42	2244.42	0.00
-125	2244.42	2244.42	0.00
-120	2244.42	2244.42	0.00
-115	2244.42	2244.42	0.00
-110	2244.42	2244.42	0.00
-105	2244.42	2244.42	0.00
-100	2244.42	2244.42	0.00
-95	2244.42	2244.42	0.00
-90	2244.42	2244.42	0.00
-85	2244.42	2244.42	0.00
-80	2244.42	2244.42	0.00
-75	2244.42	2244.42	0.00
-70	2244.42	2244.42	0.00
-65	2244.42	2244.42	0.00
-60	2244.42	2244.42	0.00
-55	2244.42	2244.42	0.00
-50	2244.42	2244.42	0.00
-45	2244.42	2244.42	0.00
-40	2244.42	2244.42	0.00
-35	2244.42	2244.42	0.00
-30	2244.42	2244.42	0.00
-25	2244.46	2244.46	0.00
-20	2244.49	2244.49	0.00

-15	2244.46	2244.46	0.00
-10	2244.46	2244.46	0.00
-5	2244.49	2244.49	0.00
0	2244.49	2244.49	0.00
5	2244.49	2244.46	-0.04
10	2244.49	2244.46	-0.04
15	2244.49	2244.46	-0.04
20	2244.52	2244.47	-0.04
25	2244.52	2244.47	-0.07
30	2244.52	2244.47	-0.06
35	2244.52	2244.47	-0.06
40	2244.52	2244.48	-0.06
45	2244.55	2244.48	-0.06
50	2244.52	2244.48	-0.09
55	2244.55	2244.48	-0.06
60	2244.59	2244.48	-0.09
65	2244.59	2244.49	-0.12
70	2244.55	2244.49	-0.12
75	2244.59	2244.49	-0.08
80	2244.59	2244.49	-0.12
85	2244.59	2244.49	-0.12
90	2244.59	2244.50	-0.12
95	2244.59	2244.50	-0.12
100	2244.59	2244.50	-0.12
105	2244.59	2244.50	-0.11
110	2244.59	2244.51	-0.11
115	2244.62	2244.51	-0.11
120	2244.62	2244.51	-0.14
125	2244.62	2244.51	-0.14
130	2244.62	2244.51	-0.14
135	2244.62	2244.52	-0.14
140	2244.62	2244.52	-0.14
145	2244.62	2244.52	-0.13
150	2244.62	2244.52	-0.13
155	2244.62	2244.53	-0.13
160	2244.62	2244.53	-0.13
165	2244.65	2244.53	-0.13
170	2244.62	2244.53	-0.16
175	2244.65	2244.53	-0.13
180	2244.62	2244.54	-0.16
185	2244.65	2244.54	-0.12
190	2244.62	2244.54	-0.15
195	2244.65	2244.54	-0.12
200	2244.69	2244.54	-0.15
205	2244.65	2244.55	-0.19
210	2244.69	2244.55	-0.15
215	2244.65	2244.55	-0.19
220	2244.69	2244.55	-0.14
225	2244.69	2244.56	-0.18
230	2244.69	2244.56	-0.18

235	2244.69	2244.56	-0.18
240	2244.69	2244.56	-0.18
245	2244.69	2244.56	-0.18
250	2244.69	2244.57	-0.18
255	2244.69	2244.57	-0.18
260	2244.69	2244.57	-0.17
265	2244.72	2244.57	-0.17
270	2244.69	2244.58	-0.20
275	2244.69	2244.58	-0.17
280	2244.69	2244.58	-0.17
285	2244.72	2244.58	-0.17
290	2244.72	2244.58	-0.20
295	2244.69	2244.59	-0.20
300	2244.69	2244.59	-0.16
305	2244.72	2244.59	-0.16
310	2244.69	2244.59	-0.19
315	2244.75	2244.59	-0.16
320	2244.72	2244.60	-0.22
325	2244.72	2244.60	-0.19
330	2244.72	2244.60	-0.19
335	2244.75	2244.60	-0.18
340	2244.75	2244.61	-0.21
345	2244.75	2244.61	-0.21
350	2244.75	2244.61	-0.21
355	2244.75	2244.61	-0.21
360	2244.72	2244.61	-0.21
365	2244.75	2244.62	-0.18
370	2244.75	2244.62	-0.21
375	2244.75	2244.62	-0.20
380	2244.75	2244.62	-0.20
385	2244.75	2244.63	-0.20
390	2244.75	2244.63	-0.20
395	2244.75	2244.63	-0.20
400	2244.75	2244.63	-0.20
405	2244.75	2244.63	-0.20
410	2244.75	2244.64	-0.20
415	2244.75	2244.64	-0.19
420	2244.75	2244.64	-0.19
425	2244.75	2244.64	-0.19
430	2244.75	2244.64	-0.19
435	2244.75	2244.65	-0.19
440	2244.75	2244.65	-0.19
445	2244.75	2244.65	-0.19
450	2244.78	2244.65	-0.18
455	2244.75	2244.66	-0.21
460	2244.75	2244.66	-0.18
465	2244.78	2244.66	-0.18
470	2244.78	2244.66	-0.21
475	2244.78	2244.66	-0.21
480	2244.78	2244.67	-0.21

485	2244.78	2244.67	-0.21
490	2244.78	2244.67	-0.20
495	2244.78	2244.67	-0.20
500	2244.78	2244.68	-0.20
505	2244.78	2244.68	-0.20
510	2244.78	2244.68	-0.20
515	2244.78	2244.68	-0.20
520	2244.78	2244.68	-0.20
525	2244.78	2244.69	-0.20
530	2244.78	2244.69	-0.19
535	2244.82	2244.69	-0.19
540	2244.78	2244.69	-0.23
545	2244.78	2244.69	-0.19
550	2244.78	2244.70	-0.19
555	2244.82	2244.70	-0.19
560	2244.78	2244.70	-0.23
565	2244.78	2244.70	-0.19
570	2244.85	2244.71	-0.18
575	2244.82	2244.71	-0.25
580	2244.78	2244.71	-0.22
585	2244.82	2244.71	-0.18
590	2244.82	2244.71	-0.22
595	2244.82	2244.72	-0.22
600	2244.82	2244.72	-0.22
605	2244.85	2244.72	-0.21
610	2244.85	2244.72	-0.24
615	2244.85	2244.73	-0.24
620	2244.85	2244.73	-0.24
625	2244.85	2244.73	-0.24
630	2244.85	2244.73	-0.24
635	2244.85	2244.73	-0.24
640	2244.85	2244.74	-0.24
645	2244.85	2244.74	-0.23
650	2244.85	2244.74	-0.23
655	2244.85	2244.74	-0.23
660	2244.85	2244.74	-0.23
665	2244.82	2244.75	-0.23
670	2244.82	2244.75	-0.20
675	2244.78	2244.75	-0.20
680	2244.78	2244.75	-0.16
685	2244.78	2244.76	-0.15
690	2244.75	2244.76	-0.15
695	2244.75	2244.76	-0.12
700	2244.75	2244.76	-0.12
705	2244.75	2244.76	-0.12
710	2244.75	2244.77	-0.12
715	2244.75	2244.77	-0.12
720	2244.75	2244.77	-0.11
725	2244.72	2244.77	-0.11
730	2244.69	2244.78	-0.08

735	2244.72	2244.78	-0.05
740	2244.69	2244.78	-0.08
745	2244.69	2244.78	-0.05
750	2244.69	2244.78	-0.05
755	2244.69	2244.79	-0.05
760	2244.69	2244.79	-0.04
765	2244.69	2244.79	-0.04
770	2244.69	2244.79	-0.04
775	2244.69	2244.79	-0.04
780	2244.65	2244.80	-0.04
785	2244.65	2244.80	0.00
790	2244.62	2244.80	0.00
795	2244.65	2244.80	0.03
800	2244.62	2244.81	0.01
805	2244.65	2244.81	0.04
810	2244.62	2244.81	0.01
815	2244.62	2244.81	0.04
820	2244.62	2244.81	0.04
825	2244.62	2244.82	0.04
830	2244.62	2244.82	0.04
835	2244.62	2244.82	0.04
840	2244.62	2244.82	0.05

Palouse city well #2 -- WSU #7 test
Pumping well -- WSU #7
Radial distance to pumping well -- 68093 ft
Manually retrieved measurements using city instrumentation

Elapsed time (min)	Water level elevation (feet above mean sea level)	Extrapolated trend in feet above mean sea level	Corrected drawdown (feet)
-40.00	2250.50	2250.50	0.00
-35.00	2250.50	2250.50	0.00
-30.00	2250.50	2250.50	0.00
-25.00	2250.60	2250.60	0.00
-20.00	2250.50	2250.50	0.00
-15.00	2250.60	2250.60	0.00
-10.00	2250.60	2250.60	0.00
-5.00	2250.60	2250.60	0.00
0.00	2250.63	2250.60	0.03
5.00	2250.64	2250.60	0.04
10.00	2250.66	2250.65	0.01
15.00	2250.68	2250.65	0.03
20.00	2250.69	2250.70	-0.01
25.00	2250.71	2250.60	0.11
30.00	2250.73	2250.60	0.13
35.00	2250.74	2250.60	0.14
40.00	2250.76	2250.65	0.11
45.00	2250.78	2250.60	0.18
50.00	2250.79	2250.70	0.09
55.00	2250.81	2250.70	0.11
60.00	2250.83	2250.70	0.13
65.00	2250.84	2250.70	0.14
70.00	2250.86	2250.70	0.16
75.00	2250.88	2250.70	0.18
80.00	2250.89	2250.70	0.19
85.00	2250.91	2250.70	0.21
90.00	2250.92	2250.80	0.12
95.00	2250.94	2250.80	0.14
100.00	2250.96	2250.80	0.16
105.00	2250.97	2250.75	0.22
110.00	2250.99	2250.80	0.19
115.00	2251.01	2250.85	0.16
120.00	2251.02	2250.80	0.22
125.00	2251.04	2250.80	0.24
130.00	2251.06	2250.85	0.21
135.00	2251.07	2250.80	0.27

140.00	2251.09	2250.85	0.24
145.00	2251.11	2250.85	0.26
150.00	2251.12	2250.80	0.32
155.00	2251.14	2251.10	0.04
160.00	2251.16	2250.90	0.26
165.00	2251.17	2250.90	0.27
170.00	2251.19	2250.80	0.39
175.00	2251.21	2250.90	0.31
180.00	2251.22	2250.90	0.32
185.00	2251.24	2250.90	0.34
190.00	2251.26	2250.90	0.36
195.00	2251.27	2250.90	0.37
200.00	2251.29	2251.00	0.29
205.00	2251.31	2251.20	0.11
210.00	2251.32	2251.10	0.22
215.00	2251.34	2251.00	0.34
220.00	2251.36	2251.10	0.26
225.00	2251.37	2251.20	0.17
230.00	2251.39	2251.10	0.29
235.00	2251.41	2251.10	0.31
240.00	2251.42	2251.10	0.32
245.00	2251.44	2251.10	0.34
250.00	2251.46	2251.16	0.30
255.00	2251.47	2251.15	0.32
260.00	2251.49	2251.10	0.39
265.00	2251.51	2251.20	0.31
270.00	2251.52	2251.15	0.37
275.00	2251.54	2251.20	0.34
280.00	2251.56	2251.20	0.36
285.00	2251.57	2251.15	0.42
290.00	2251.59	2251.20	0.39
295.00	2251.61	2251.20	0.41
300.00	2251.62	2251.20	0.42
305.00	2251.64	2251.30	0.34
310.00	2251.66	2251.30	0.36
315.00	2251.67	2251.30	0.37
320.00	2251.69	2251.30	0.39
325.00	2251.71	2251.30	0.41
330.00	2251.72	2251.40	0.32
335.00	2251.74	2251.30	0.44
340.00	2251.76	2251.40	0.36
345.00	2251.77	2251.30	0.47
350.00	2251.79	2251.40	0.39
355.00	2251.81	2251.40	0.41
360.00	2251.82	2251.40	0.42
365.00	2251.84	2251.40	0.44
370.00	2251.86	2251.40	0.46
375.00	2251.87	2251.50	0.37
380.00	2251.89	2251.60	0.29
385.00	2251.91	2251.40	0.51

390.00	2251.92	2251.45	0.47
395.00	2251.94	2251.40	0.54
400.00	2251.96	2251.40	0.56
405.00	2251.97	2251.40	0.57
410.00	2251.99	2251.40	0.59
415.00	2252.01	2251.40	0.61
420.00	2252.02	2251.40	0.62
425.00	2252.04	2251.45	0.59
430.00	2252.06	2251.45	0.61
435.00	2252.07	2251.45	0.62
440.00	2252.09	2251.45	0.64
445.00	2252.11	2251.45	0.66
450.00	2252.12	2251.45	0.67
455.00	2252.14	2251.45	0.69
460.00	2252.16	2251.45	0.71
465.00	2252.17	2251.50	0.67
470.00	2252.19	2251.45	0.74
475.00	2252.21	2251.50	0.71
480.00	2252.22	2251.50	0.72
485.00	2252.24	2251.50	0.74
490.00	2252.26	2251.50	0.76
495.00	2252.27	2251.55	0.72
500.00	2252.29	2251.55	0.74
505.00	2252.31	2251.55	0.76
510.00	2252.32	2251.55	0.77
515.00	2252.34	2251.55	0.79
520.00	2252.36	2251.55	0.81
525.00	2252.37	2251.55	0.82
530.00	2252.39	2251.55	0.84
535.00	2252.41	2251.60	0.81
540.00	2252.42	2251.60	0.82
545.00	2252.44	2251.65	0.79
550.00	2252.46	2251.65	0.81
555.00	2252.47	2251.60	0.87
560.00	2252.49	2251.65	0.84
565.00	2252.51	2251.65	0.86
570.00	2252.52	2251.60	0.92
575.00	2252.54	2251.70	0.84
580.00	2252.56	2251.60	0.96
585.00	2252.57	2251.60	0.97
590.00	2252.59	2251.65	0.94
595.00	2252.61	2251.65	0.96
600.00	2252.62	2251.70	0.92
605.00	2252.64	2251.65	0.99
610.00	2252.66	2251.65	1.01
615.00	2252.67	2251.60	1.07
620.00	2252.69	2251.70	0.99
625.00	2252.71	2251.60	1.11
630.00	2252.72	2251.65	1.07
635.00	2252.74	2251.65	1.09

640.00	2252.76	2251.70	1.06
645.00	2252.77	2251.70	1.07
650.00	2252.79	2251.65	1.14
655.00	2252.81	2251.70	1.11
660.00	2252.82	2251.60	1.22
665.00	2252.84	2251.65	1.19
670.00	2252.86	2251.70	1.16
675.00	2252.87	2251.65	1.22
680.00	2252.89	2251.65	1.24
685.00	2252.91	2251.65	1.26
690.00	2252.92	2251.60	1.32
695.00	2252.94	2251.65	1.29
700.00	2252.96	2251.65	1.31
705.00	2252.97	2251.70	1.27
710.00	2252.99	2251.60	1.39
715.00	2253.01	2251.70	1.31
720.00	2253.02	2251.65	1.37
725.00	2253.04	2251.65	1.39
730.00	2253.06	2251.70	1.36
735.00	2253.07	2251.70	1.37
740.00	2253.09	2251.75	1.34
745.00	2253.11	2251.70	1.41
750.00	2253.12	2251.75	1.37
755.00	2253.14	2251.80	1.34

Moscow #9 – WSU #7 Test
Manually retrieved
Pumping well -- WSU #7
Radial distance to pumping well -- 34469 ft

Elapsed time (min)	Water level elevation (feet above mean sea level)
-15	2240.85
0	2241.05
30	2241.25
60	2241.35
95	2241.55
155	2241.65
185	2241.65
220	2241.65
270	2241.75
300	2241.85
390	2241.95
425	2241.95
480	2242.05
570	2242.05
600	2242.05
660	2242.05
720	2241.25
780	2241.25
840	2241.25

Moscow #8 – WSU #7 Test
Pumping well -- WSU #7
Manually retrieved measurements
Radial distance to pumping well -- 39405 ft

Elapsed time (min)	Water level elevation (feet above mean sea level)
-15	2235.58
0	2234.88
30	2235.38
60	2235.98
95	2236.68
155	2237.58
185	2238.08
220	2238.48
270	2238.98
300	2239.58
390	2240.58
425	2240.98
480	2241.48
570	2242.08
600	2242.08
660	2243.08
720	2242.98
780	2242.98
840	2242.98

Moscow #6 -- WSU # 7 Test
Pumping well -- WSU #7
Manually retrieved from well pressure transducer
Radial distance to pumping well -- 43962 ft

Elapsed time (min)	Water level elevation (feet above mean sea level)
-15	2228.32
0	2229.42
30	2230.62
60	2232.02
95	2233.62
155	2235.72
185	2236.52
220	2237.32
270	2238.62
300	2239.12
390	2240.72
425	2241.42
480	2242.12
570	2243.02
600	2243.02
660	2243.82
720	2243.82
780	2244.72
840	2244.72

APPENDIX C
WATER LEVEL MEASUREMENTS FOR U OF I #4 AQUIFER TEST

WDOE test well -- U of I #4 aquifer test
Pumping well -- U of I #4
Retrieved with Solinst pressure transduced data logger
Radial distance to pumping well -- 16079 ft

Elapsed Time (min)	Water level elevation (feet above mean sea level)	Extrapolated trend in feet above mean sea level	Corrected drawdown (feet)
-270	2251.96	2251.96	0.00
-265	2251.96	2251.96	0.00
-260	2251.96	2251.96	0.00
-255	2251.96	2251.96	0.00
-250	2252.00	2252.00	0.00
-245	2251.96	2251.96	0.00
-240	2251.96	2251.96	0.00
-235	2252.00	2252.00	0.00
-230	2252.00	2252.00	0.00
-225	2252.00	2252.00	0.00
-220	2252.00	2252.00	0.00
-215	2252.00	2252.00	0.00
-210	2252.03	2252.03	0.00
-205	2252.03	2252.03	0.00
-200	2252.03	2252.03	0.00
-195	2252.03	2252.03	0.00
-190	2252.03	2252.03	0.00
-185	2252.03	2252.03	0.00
-180	2252.03	2252.03	0.00
-175	2252.03	2252.03	0.00
-170	2252.03	2252.03	0.00
-165	2252.03	2252.03	0.00
-160	2252.06	2252.06	0.00
-155	2252.03	2252.03	0.00
-150	2252.06	2252.06	0.00
-145	2252.06	2252.06	0.00
-140	2252.06	2252.06	0.00
-135	2252.06	2252.06	0.00
-130	2252.06	2252.06	0.00
-125	2252.06	2252.06	0.00
-120	2252.06	2252.06	0.00
-115	2252.06	2252.06	0.00
-110	2252.06	2252.06	0.00
-105	2252.06	2252.06	0.00
-100	2252.06	2252.06	0.00
-95	2252.06	2252.06	0.00
-90	2252.06	2252.06	0.00
-85	2252.06	2252.06	0.00
-80	2252.06	2252.06	0.00
-75	2252.09	2252.09	0.00

-70	2252.06	2252.06	0.00
-65	2252.09	2252.09	0.00
-60	2252.09	2252.09	0.00
-55	2252.09	2252.09	0.00
-50	2252.09	2252.09	0.00
-45	2252.09	2252.09	0.00
-40	2252.09	2252.09	0.00
-35	2252.09	2252.09	0.00
-30	2252.09	2252.09	0.00
-25	2252.09	2252.09	0.00
-20	2252.09	2252.09	0.00
-15	2252.09	2252.09	0.00
-10	2252.09	2252.09	0.00
-5	2252.09	2252.09	0.00
0	2252.09	2252.09	0.00
5	2252.06	2252.14	0.08
10	2252.06	2252.15	0.09
15	2252.06	2252.15	0.09
20	2252.03	2252.15	0.12
25	2252.06	2252.16	0.10
30	2252.03	2252.16	0.13
35	2252.03	2252.16	0.13
40	2252.03	2252.17	0.14
45	2252.03	2252.17	0.14
50	2252.03	2252.17	0.14
55	2252.03	2252.18	0.15
60	2252.00	2252.18	0.18
65	2251.96	2252.18	0.22
70	2251.96	2252.18	0.22
75	2251.96	2252.19	0.23
80	2251.96	2252.19	0.23
85	2251.96	2252.19	0.23
90	2251.96	2252.20	0.24
95	2251.96	2252.20	0.24
100	2251.96	2252.20	0.24
105	2251.96	2252.21	0.25
110	2251.96	2252.21	0.25
115	2251.96	2252.21	0.25
120	2251.96	2252.22	0.26
125	2251.96	2252.22	0.26
130	2251.96	2252.22	0.26
135	2251.96	2252.23	0.27
140	2251.96	2252.23	0.27
145	2251.90	2252.23	0.33
150	2251.90	2252.24	0.34
155	2251.90	2252.24	0.34
160	2251.90	2252.24	0.34
165	2251.90	2252.25	0.35
170	2251.90	2252.25	0.35
175	2251.90	2252.25	0.35

180	2251.90	2252.26	0.36
185	2251.90	2252.26	0.36
190	2251.90	2252.26	0.36
195	2251.90	2252.27	0.37
200	2251.90	2252.27	0.37
205	2251.90	2252.27	0.37
210	2251.90	2252.28	0.38
215	2251.90	2252.28	0.38
220	2251.90	2252.28	0.38
225	2251.86	2252.29	0.43
230	2251.90	2252.29	0.39
235	2251.90	2252.29	0.39
240	2251.86	2252.30	0.44
245	2251.86	2252.30	0.44
250	2251.86	2252.30	0.44
255	2251.90	2252.31	0.41
260	2251.86	2252.31	0.45
265	2251.90	2252.31	0.41
270	2251.86	2252.32	0.46
275	2251.86	2252.32	0.46
280	2251.86	2252.32	0.46
285	2251.86	2252.33	0.47
290	2251.86	2252.33	0.47
295	2251.86	2252.33	0.47
300	2251.86	2252.34	0.48
305	2251.86	2252.34	0.48
310	2251.86	2252.34	0.48
315	2251.86	2252.35	0.49
320	2251.86	2252.35	0.49
325	2251.86	2252.35	0.49
330	2251.86	2252.36	0.50
335	2251.86	2252.36	0.50
340	2251.86	2252.36	0.50
345	2251.86	2252.37	0.51
350	2251.86	2252.37	0.51
355	2251.86	2252.37	0.51
360	2251.86	2252.38	0.52
365	2251.86	2252.38	0.52
370	2251.86	2252.38	0.52
375	2251.86	2252.39	0.53
380	2251.86	2252.39	0.53
385	2251.86	2252.39	0.53
390	2251.86	2252.40	0.54
395	2251.86	2252.40	0.54
400	2251.86	2252.40	0.54
405	2251.86	2252.41	0.55
410	2251.86	2252.41	0.55
415	2251.86	2252.41	0.55
420	2251.86	2252.42	0.56
425	2251.86	2252.42	0.56

430	2251.86	2252.42	0.56
435	2251.86	2252.43	0.57
440	2251.86	2252.43	0.57
445	2251.86	2252.43	0.57
450	2251.86	2252.44	0.58
455	2251.86	2252.44	0.58
460	2251.86	2252.44	0.58
465	2251.86	2252.45	0.59
470	2251.86	2252.45	0.59
475	2251.86	2252.45	0.59
480	2251.86	2252.46	0.60
485	2251.86	2252.46	0.60
490	2251.86	2252.46	0.60
495	2251.86	2252.47	0.61
500	2251.83	2252.47	0.64
505	2251.80	2252.47	0.67
510	2251.80	2252.47	0.67
515	2251.80	2252.48	0.68
520	2251.80	2252.48	0.68
525	2251.77	2252.48	0.71
530	2251.77	2252.49	0.72
535	2251.77	2252.49	0.72
540	2251.77	2252.49	0.72
545	2251.73	2252.50	0.77
550	2251.70	2252.50	0.80
555	2251.70	2252.50	0.80
560	2251.70	2252.51	0.81
565	2251.70	2252.51	0.81
570	2251.70	2252.51	0.81
575	2251.70	2252.52	0.82
580	2251.70	2252.52	0.82
585	2251.70	2252.52	0.82
590	2251.70	2252.53	0.83
595	2251.70	2252.53	0.83
600	2251.70	2252.53	0.83
605	2251.70	2252.54	0.84
610	2251.70	2252.54	0.84
615	2251.70	2252.54	0.84
620	2251.70	2252.55	0.85
625	2251.70	2252.55	0.85
630	2251.70	2252.55	0.85
635	2251.70	2252.56	0.86
640	2251.70	2252.56	0.86
645	2251.70	2252.56	0.86
650	2251.70	2252.57	0.87
655	2251.70	2252.57	0.87
660	2251.70	2252.57	0.87
665	2251.70	2252.58	0.88
670	2251.70	2252.58	0.88
675	2251.70	2252.58	0.88

680	2251.70	2252.59	0.89
685	2251.70	2252.59	0.89
690	2251.70	2252.59	0.89
695	2251.70	2252.60	0.90
700	2251.70	2252.60	0.90
705	2251.70	2252.60	0.90
710	2251.70	2252.61	0.91
715	2251.67	2252.61	0.94
720	2251.67	2252.61	0.94
725	2251.70	2252.62	0.92
730	2251.70	2252.62	0.92
735	2251.70	2252.62	0.92
740	2251.70	2252.63	0.93
745	2251.67	2252.63	0.96
750	2251.67	2252.63	0.96

Palouse city well #2 -- U of I #4 aquifer test
Pumping well -- U of I #4
Manually retrieved data
Radial distance to pumping well -- 64018 ft

Elapsed Time (min)	Water level elevation (feet above mean sea level)	Extrapolated trend in feet above mean sea level	Corrected drawdown (feet)
-40	2250.96	2250.96	0.00
-35	2251.01	2251.01	0.00
-30	2251.01	2251.01	0.00
-25	2251.01	2251.01	0.00
-20	2251.01	2251.01	0.00
-15	2251.01	2251.01	0.00
-10	2251.01	2251.01	0.00
-5	2251.06	2251.06	0.00
0	2250.66	2250.66	0.00
5	2250.71	2251.06	0.35
10	2250.71	2251.06	0.35
15	2250.71	2251.07	0.36
20	2250.71	2251.08	0.37
25	2250.71	2251.09	0.38
30	2250.71	2251.10	0.39
35	2250.66	2251.11	0.45
40	2250.66	2251.11	0.45
45	2250.66	2251.12	0.46
50	2250.66	2251.13	0.47
55	2250.61	2251.14	0.53
60	2250.61	2251.15	0.54
65	2250.61	2251.16	0.55
70	2250.66	2251.16	0.50
75	2250.66	2251.17	0.51
80	2250.66	2251.18	0.52
85	2250.66	2251.19	0.53
90	2250.66	2251.20	0.54
95	2250.66	2251.21	0.55
100	2250.66	2251.21	0.55
105	2250.66	2251.22	0.56
110	2250.71	2251.23	0.52
115	2250.66	2251.24	0.58
120	2250.71	2251.25	0.54
125	2250.71	2251.26	0.55
130	2250.66	2251.26	0.60
135	2250.71	2251.27	0.56
140	2250.71	2251.28	0.57
145	2250.71	2251.29	0.58
150	2250.71	2251.30	0.59

155	2250.71	2251.31	0.60
160	2250.71	2251.31	0.60
165	2250.76	2251.32	0.56
170	2250.71	2251.33	0.62
175	2250.71	2251.34	0.63
180	2250.71	2251.35	0.64
185	2250.81	2251.36	0.55
190	2250.81	2251.36	0.55
195	2250.81	2251.37	0.56
200	2250.81	2251.38	0.57
205	2250.81	2251.39	0.58
210	2250.81	2251.40	0.59
215	2250.86	2251.41	0.55
220	2250.91	2251.41	0.50
225	2250.91	2251.42	0.51
230	2250.91	2251.43	0.52
235	2250.96	2251.44	0.48
240	2250.96	2251.45	0.49
245	2251.01	2251.46	0.45
250	2251.01	2251.46	0.45
255	2251.01	2251.47	0.46
260	2251.01	2251.48	0.47
265	2251.01	2251.49	0.48
270	2251.06	2251.50	0.44
275	2251.01	2251.51	0.50
280	2251.06	2251.51	0.45
285	2251.06	2251.52	0.46
290	2251.11	2251.53	0.42
295	2251.11	2251.54	0.43
300	2251.11	2251.55	0.44
305	2251.06	2251.56	0.50
310	2251.06	2251.56	0.50
315	2251.06	2251.57	0.51
320	2251.06	2251.58	0.52
325	2251.01	2251.59	0.58
330	2251.06	2251.60	0.54
335	2251.06	2251.61	0.55
340	2251.06	2251.61	0.55
345	2251.06	2251.62	0.56
350	2251.06	2251.63	0.57
355	2251.11	2251.64	0.53
360	2251.11	2251.65	0.54
365	2251.06	2251.66	0.60
370	2251.06	2251.66	0.60
375	2251.06	2251.67	0.61
380	2251.11	2251.68	0.57
385	2251.06	2251.69	0.63
390	2251.11	2251.70	0.59
395	2251.11	2251.71	0.60
400	2251.11	2251.71	0.60

405	2251.11	2251.72	0.61
410	2251.11	2251.73	0.62
415	2251.11	2251.74	0.63
420	2251.11	2251.75	0.64
425	2251.11	2251.76	0.65
430	2251.11	2251.76	0.65
435	2251.11	2251.77	0.66
440	2251.11	2251.78	0.67
445	2251.11	2251.79	0.68
450	2251.11	2251.80	0.69
455	2251.11	2251.81	0.70
460	2251.11	2251.81	0.70
465	2251.11	2251.82	0.71
470	2251.11	2251.83	0.72
475	2251.16	2251.84	0.68
480	2251.16	2251.85	0.69

Moscow City Wells -- U of I #4 aquifer test
Pumping well -- U of I #4
Manually retrieved data
Radial distance to pumping well --

Moscow #6	7688.32 ft
Moscow #8	3507.63 ft
Moscow #9	1860.74 ft

Elapsed Time (min)	Moscow #6 water level elevation (feet above mean sea level)	Moscow #8 water level elevation (feet above mean sea level)	Moscow #9 water level elevation (feet above mean sea level)
0	2235.12	2237.08	2241.55
5	2235.82	2237.48	2241.55
50	2236.62	2237.98	2241.05
105	2237.62	2238.68	2240.55
135	2238.12	2239.08	2240.35
190	2239.02	2239.58	2240.15
290	2240.42	2240.48	2239.85
350	2241.02	2240.78	2239.75
405	2241.52	2241.18	2239.75
460	2242.02	2241.38	2239.75
480	2242.22	2241.58	2239.75

APPENDIX D
WATER LEVEL MEASUREMENTS FOR MOSCOW #9 AQUIFER TEST

Palouse city well #2 -- Moscow #9 Test
Pumping wells -- Moscow #9 and U of I #4
Radial distance to pumping wells
Moscow #9 -- 63237 ft
U of I #4 -- 64018 ft

Elapsed Time (min)	Water level elevation (feet above mean sea level)	Extrapolated trend in feet above mean sea level	Corrected drawdown (feet)
-55	2248.31	2248.31	0.00
-50	2248.31	2248.31	0.00
-45	2248.36	2248.36	0.00
-40	2248.31	2248.31	0.00
-35	2248.61	2248.61	0.00
-30	2248.51	2248.51	0.00
-25	2248.71	2248.71	0.00
-20	2248.61	2248.61	0.00
-15	2248.71	2248.71	0.00
-10	2248.71	2248.71	0.00
-5	2248.91	2248.91	0.00
0	2248.81	2248.90	0.09
5	2249.01	2248.96	-0.06
10	2249.01	2249.01	0.00
15	2248.81	2249.07	0.26
20	2248.81	2249.13	0.32
25	2248.91	2249.19	0.28
30	2249.01	2249.24	0.23
35	2249.11	2249.30	0.19
40	2248.91	2249.36	0.45
45	2248.91	2249.42	0.51
50	2249.01	2249.47	0.46
55	2248.91	2249.53	0.62
60	2249.11	2249.59	0.48
65	2249.01	2249.65	0.64
70	2249.01	2249.71	0.70
75	2249.11	2249.76	0.65
80	2249.01	2249.82	0.81
85	2248.91	2249.88	0.97
90	2249.01	2249.94	0.93
95	2249.01	2249.99	0.98
100	2248.91	2250.05	1.14
105	2248.91	2250.11	1.20
110	2249.01	2250.17	1.16
115	2249.01	2250.23	1.22
120	2249.01	2250.28	1.27

125	2249.11	2250.34	1.23
130	2249.01	2250.40	1.39
135	2249.06	2250.46	1.40
140	2249.01	2250.51	1.50
145	2249.01	2250.57	1.56
150	2249.06	2250.63	1.57
155	2249.01	2250.69	1.68
160	2249.11	2250.74	1.63
165	2249.11	2250.80	1.69
170	2249.11	2250.86	1.75
175	2249.11	2250.92	1.81
180	2249.11	2250.98	1.87
185	2249.06	2251.03	1.97
190	2249.11	2251.09	1.98
195	2249.11	2251.15	2.04
200	2249.11	2251.21	2.10
205	2249.11	2251.26	2.15
210	2249.11	2251.32	2.21
215	2249.01	2251.38	2.37
220	2249.06	2251.44	2.38
225	2249.01	2251.50	2.49
230	2249.01	2251.55	2.54
235	2249.11	2251.61	2.50
240	2249.11	2251.67	2.56
270	2248.91	2251.73	2.82
300	2249.06	2251.78	2.72
330	2249.11	2251.84	2.73
360	2249.16	2251.90	2.74
390	2249.31	2251.96	2.65
420	2249.26	2252.01	2.75
450	2249.31	2252.07	2.76
480	2249.36	2252.13	2.77
510	2249.41	2252.19	2.78
540	2249.31	2252.25	2.94

WDOE Test well -- Moscow #9 Test
Radial distance to pumping wells
Moscow #9 -- 14044 ft
U of I #4 -- 15883 ft

Elapsed Time (min)	Water level elevation (feet above mean sea level)
-2330	2245.04
-2325	2245.05
-2320	2245.04
-2315	2245.04
-2310	2245.05
-2305	2245.05
-2300	2245.04
-2295	2245.05
-2290	2245.05
-2285	2245.05
-2280	2245.06
-2275	2245.06
-2270	2245.06
-2265	2245.06
-2260	2245.05
-2255	2245.06
-2250	2245.06
-2245	2245.06
-2240	2245.06
-2235	2245.06
-2230	2245.07
-2225	2245.06
-2220	2245.07
-2215	2245.07
-2210	2245.06
-2205	2245.07
-2200	2245.08
-2195	2245.07
-2190	2245.07
-2185	2245.08
-2180	2245.07
-2175	2245.08
-2170	2245.08

-2165	2245.09
-2160	2245.09
-2155	2245.08
-2150	2245.08
-2145	2245.09
-2140	2245.09
-2135	2245.08
-2130	2245.09
-2125	2245.09
-2120	2245.09
-2115	2245.09
-2110	2245.09
-2105	2245.08
-2100	2245.07
-2095	2245.06
-2090	2245.05
-2085	2245.03
-2080	2245.02
-2075	2245.02
-2070	2245.01
-2065	2245
-2060	2244.99
-2055	2244.99
-2050	2244.98
-2045	2244.97
-2040	2244.96
-2035	2244.95
-2030	2244.97
-2025	2244.97
-2020	2244.96
-2015	2244.97
-2010	2244.98
-2005	2244.99
-2000	2244.99
-1995	2244.98
-1990	2245
-1985	2245
-1980	2245
-1975	2245.01
-1970	2245.01
-1965	2245.01
-1960	2245.02
-1955	2245.01
-1950	2245.02
-1945	2245.03
-1940	2245.02
-1935	2245.02
-1930	2245.02

-1925	2245.03
-1920	2245.02
-1915	2245.02
-1910	2245.02
-1905	2245.03
-1900	2245.04
-1895	2245.04
-1890	2245.04
-1885	2245.04
-1880	2245.05
-1875	2245.05
-1870	2245.06
-1865	2245.05
-1860	2245.05
-1855	2245.05
-1850	2245.05
-1845	2245.06
-1840	2245.06
-1835	2245.06
-1830	2245.06
-1825	2245.06
-1820	2245.07
-1815	2245.06
-1810	2245.06
-1805	2245.07
-1800	2245.06
-1795	2245.06
-1790	2245.05
-1785	2245.03
-1780	2245.03
-1775	2245.02
-1770	2245.01
-1765	2245
-1760	2245
-1755	2244.98
-1750	2244.98
-1745	2244.98
-1740	2244.98
-1735	2244.95
-1730	2244.96
-1725	2244.97
-1720	2244.98
-1715	2244.98
-1710	2244.99
-1705	2244.99
-1700	2245
-1695	2245
-1690	2245.01

-1685	2245.01
-1680	2245.02
-1675	2245.02
-1670	2245.02
-1665	2245.02
-1660	2245.02
-1655	2245.04
-1650	2245.03
-1645	2245.02
-1640	2245.04
-1635	2245.05
-1630	2245.04
-1625	2245.05
-1620	2245.05
-1615	2245.05
-1610	2245.05
-1605	2245.06
-1600	2245.06
-1595	2245.06
-1590	2245.06
-1585	2245.06
-1580	2245.06
-1575	2245.06
-1570	2245.07
-1565	2245.06
-1560	2245.07
-1555	2245.06
-1550	2245.07
-1545	2245.07
-1540	2245.08
-1535	2245.07
-1530	2245.07
-1525	2245.09
-1520	2245.09
-1515	2245.09
-1510	2245.09
-1505	2245.09
-1500	2245.09
-1495	2245.08
-1490	2245.1
-1485	2245.09
-1480	2245.1
-1475	2245.09
-1470	2245.1
-1465	2245.09
-1460	2245.09
-1455	2245.1
-1450	2245.1

-1445	2245.1
-1440	2245.09
-1435	2245.09
-1430	2245.09
-1425	2245.11
-1420	2245.11
-1415	2245.12
-1410	2245.11
-1405	2245.11
-1400	2245.13
-1395	2245.11
-1390	2245.11
-1385	2245.1
-1380	2245.12
-1375	2245.12
-1370	2245.12
-1365	2245.11
-1360	2245.11
-1355	2245.11
-1350	2245.12
-1345	2245.12
-1340	2245.11
-1335	2245.12
-1330	2245.12
-1325	2245.11
-1320	2245.1
-1315	2245.09
-1310	2245.09
-1305	2245.08
-1300	2245.07
-1295	2245.06
-1290	2245.05
-1285	2245.03
-1280	2245.03
-1275	2245.02
-1270	2245
-1265	2245
-1260	2245
-1255	2244.99
-1250	2244.99
-1245	2244.98
-1240	2244.98
-1235	2244.97
-1230	2244.97
-1225	2244.96
-1220	2244.96
-1215	2244.95
-1210	2244.94

-1205	2244.94
-1200	2244.93
-1195	2244.92
-1190	2244.92
-1185	2244.92
-1180	2244.91
-1175	2244.9
-1170	2244.9
-1165	2244.9
-1160	2244.89
-1155	2244.89
-1150	2244.88
-1145	2244.88
-1140	2244.88
-1135	2244.88
-1130	2244.88
-1125	2244.87
-1120	2244.87
-1115	2244.87
-1110	2244.87
-1105	2244.87
-1100	2244.87
-1095	2244.86
-1090	2244.85
-1085	2244.86
-1080	2244.86
-1075	2244.87
-1070	2244.86
-1065	2244.88
-1060	2244.87
-1055	2244.88
-1050	2244.88
-1045	2244.89
-1040	2244.9
-1035	2244.9
-1030	2244.9
-1025	2244.9
-1020	2244.91
-1015	2244.92
-1010	2244.92
-1005	2244.93
-1000	2244.92
-995	2244.94
-990	2244.95
-985	2244.93
-980	2244.94
-975	2244.94
-970	2244.95

-965	2244.95
-960	2244.95
-955	2244.95
-950	2244.95
-945	2244.97
-940	2244.97
-935	2244.96
-930	2244.98
-925	2244.98
-920	2244.98
-915	2244.99
-910	2244.99
-905	2244.98
-900	2244.99
-895	2245
-890	2244.99
-885	2245
-880	2245
-875	2245
-870	2245
-865	2245.01
-860	2245.01
-855	2245.02
-850	2245
-845	2245.02
-840	2245
-835	2245.02
-830	2245.02
-825	2245.02
-820	2245.02
-815	2245.02
-810	2245.03
-805	2245.03
-800	2245.03
-795	2245.02
-790	2245.03
-785	2245.03
-780	2245.03
-775	2245.03
-770	2245.02
-765	2245.02
-760	2245.04
-755	2245.03
-750	2245.03
-745	2245.04
-740	2245.03
-735	2245.04
-730	2245.03

-725	2245.03
-720	2245.04
-715	2245.03
-710	2245.05
-705	2245.04
-700	2245.04
-695	2245.04
-690	2245.03
-685	2245.03
-680	2245.04
-675	2245.03
-670	2245.04
-665	2245.04
-660	2245.05
-655	2245.04
-650	2245.03
-645	2245.03
-640	2245.05
-635	2245.04
-630	2245.04
-625	2245.04
-620	2245.05
-615	2245.05
-610	2245.05
-605	2245.04
-600	2245.05
-595	2245.05
-590	2245.04
-585	2245.05
-580	2245.04
-575	2245.06
-570	2245.04
-565	2245.05
-560	2245.05
-555	2245.05
-550	2245.05
-545	2245.06
-540	2245.06
-535	2245.06
-530	2245.05
-525	2245.05
-520	2245.06
-515	2245.06
-510	2245.07
-505	2245.06
-500	2245.06
-495	2245.06
-490	2245.06

-485	2245.06
-480	2245.06
-475	2245.07
-470	2245.06
-465	2245.06
-460	2245.06
-455	2245.07
-450	2245.07
-445	2245.07
-440	2245.07
-435	2245.08
-430	2245.07
-425	2245.07
-420	2245.07
-415	2245.08
-410	2245.07
-405	2245.09
-400	2245.08
-395	2245.08
-390	2245.08
-385	2245.08
-380	2245.09
-375	2245.07
-370	2245.08
-365	2245.08
-360	2245.09
-355	2245.09
-350	2245.09
-345	2245.09
-340	2245.09
-335	2245.09
-330	2245.08
-325	2245.08
-320	2245.08
-315	2245.08
-310	2245.08
-305	2245.08
-300	2245.08
-295	2245.08
-290	2245.08
-285	2245.09
-280	2245.08
-275	2245.08
-270	2245.09
-265	2245.08
-260	2245.08
-255	2245.09
-250	2245.1

-245	2245.08
-240	2245.09
-235	2245.08
-230	2245.09
-225	2245.08
-220	2245.09
-215	2245.08
-210	2245.07
-205	2245.09
-200	2245.07
-195	2245.08
-190	2245.08
-185	2245.08
-180	2245.09
-175	2245.08
-170	2245.13
-165	2245.09
-160	2245.09
-155	2245.09
-150	2245.09
-145	2245.08
-140	2245.09
-135	2245.09
-130	2245.09
-125	2245.09
-120	2245.09
-115	2245.09
-110	2245.09
-105	2245.09
-100	2245.09
-95	2245.09
-90	2245.09
-85	2245.09
-80	2245.1
-75	2245.1
-70	2245.1
-65	2245.1
-60	2245.09
-55	2245.11
-50	2245.1
-45	2245.1
-40	2245.1
-35	2245.11
-30	2245.1
-25	2245.1
-20	2245.1
-15	2245.09
-10	2245.1

-5	2245.1
0	2245.09
5	2245.09
10	2245.07
15	2245.06
20	2245.06
25	2245.04
30	2245.03
35	2245.02
40	2245.01
45	2244.99
50	2244.97
55	2244.96
60	2244.94
65	2244.92
70	2244.91
75	2244.9
80	2244.89
85	2244.88
90	2244.88
95	2244.86
100	2244.85
105	2244.83
110	2244.83
115	2244.82
120	2244.81
125	2244.8
130	2244.79
135	2244.79
140	2244.77
145	2244.77
150	2244.76
155	2244.75
160	2244.74
165	2244.74
170	2244.74
175	2244.73
180	2244.72
185	2244.71
190	2244.7
195	2244.7
200	2244.7
205	2244.7
210	2244.68
215	2244.69
220	2244.68
225	2244.67
230	2244.67

235	2244.67
240	2244.66
245	2244.65
250	2244.64
255	2244.64
260	2244.64
265	2244.64
270	2244.63
275	2244.63
280	2244.62
285	2244.63
290	2244.63
295	2244.62
300	2244.63
305	2244.62
310	2244.61
315	2244.61
320	2244.62
325	2244.62
330	2244.62
335	2244.62
340	2244.63
345	2244.64
350	2244.64
355	2244.64
360	2244.66
365	2244.65
370	2244.65
375	2244.66
380	2244.67
385	2244.67
390	2244.67
395	2244.67
400	2244.68
405	2244.68
410	2244.68
415	2244.69
420	2244.69
425	2244.69
430	2244.68
435	2244.69
440	2244.7
445	2244.7
450	2244.71
455	2244.7
460	2244.71
465	2244.71
470	2244.71

475	2244.71
480	2244.7
485	2244.71
490	2244.72
495	2244.71
500	2244.71
505	2244.72
510	2244.74
515	2244.75
520	2244.75
525	2244.77
530	2244.78
535	2244.79
540	2244.8
545	2244.81
550	2244.81
555	2244.82
560	2244.83
565	2244.85
570	2244.86
575	2244.86
580	2244.86
585	2244.88
590	2244.88
595	2244.88
600	2244.89
605	2244.9
610	2244.92
615	2244.9
620	2244.92
625	2244.92
630	2244.92
635	2244.92
640	2244.93
645	2244.94
650	2244.94
655	2244.95
660	2244.95
665	2244.94
670	2244.95
675	2244.96
680	2244.97
685	2244.96
690	2244.95
695	2244.97
700	2244.97
705	2244.97
710	2244.98

715	2244.98
720	2244.98
725	2244.99
730	2244.98
735	2244.99
740	2245
745	2245
750	2244.99
755	2244.99
760	2245
765	2245.01
770	2245
775	2245.01
780	2245.01
785	2245.01
790	2245.03
795	2245.01
800	2245.01
805	2245.02
810	2245.03
815	2245.03
820	2245.03
825	2245.04
830	2245.03
835	2245.05
840	2245.04
845	2245.05
850	2245.05
855	2245.05
860	2245.06
865	2245.05
870	2245.06
875	2245.05
880	2245.06
885	2245.05
890	2245.06
895	2245.06
900	2245.06
905	2245.06
910	2245.06
915	2245.05
920	2245.04
925	2245.04
930	2245.02
935	2245.02
940	2245.01
945	2245
950	2244.99

955	2244.99
960	2244.97
965	2244.97
970	2244.96
975	2244.95
980	2244.94
985	2244.96
990	2244.95
995	2244.95
1000	2244.95
1005	2244.97
1010	2244.97
1015	2244.98
1020	2244.98
1025	2244.98
1030	2244.97
1035	2244.99
1040	2244.99
1045	2244.99
1050	2244.99
1055	2245
1060	2245
1065	2245
1070	2245
1075	2245.01
1080	2245.01
1085	2245.01
1090	2245.01
1095	2245.02
1100	2245.03
1105	2245.02
1110	2245.03
1115	2245.03
1120	2245.02
1125	2245.03
1130	2245.04
1135	2245.03
1140	2245.02
1145	2245.04
1150	2245.03
1155	2245.05
1160	2245.04
1165	2245.05
1170	2245.04
1175	2245.05
1180	2245.06
1185	2245.05
1190	2245.06

1195	2245.05
1200	2245.06
1205	2245.05
1210	2245.05
1215	2245.06
1220	2245.05
1225	2245.06
1230	2245.05
1235	2245.06
1240	2245.06
1245	2245.07
1250	2245.07
1255	2245.07
1260	2245.06
1265	2245.08
1270	2245.06
1275	2245.07
1280	2245.07
1285	2245.07
1290	2245.08
1295	2245.09
1300	2245.09
1305	2245.09
1310	2245.09
1315	2245.08
1320	2245.09
1325	2245.09
1330	2245.09
1335	2245.09
1340	2245.1
1345	2245.09
1350	2245.09
1355	2245.09
1360	2245.1
1365	2245.1
1370	2245.09
1375	2245.1
1380	2245.1
1385	2245.11
1390	2245.11
1395	2245.1
1400	2245.1
1405	2245.11
1410	2245.11
1415	2245.1
1420	2245.09
1425	2245.08
1430	2245.07

1435	2245.06
1440	2245.05
1445	2245.04
1450	2245.04
1455	2245.02
1460	2245.01
1465	2245.01
1470	2244.99
1475	2244.99
1480	2244.98
1485	2244.98
1490	2244.98
1495	2244.97
1500	2244.98
1505	2244.98

APPENDIX E
WATER LEVEL MEASUREMENTS FOR MOSCOW #8 TEST

Moscow wells -- Moscow #8 aquifer test
Moscow #8 pumping well
Radial distances to pumping well
Moscow #6 -- 4404 ft
Moscow #9 -- 3788 ft

	Water Level Elevation (feet above mean sea level)		
Elapsed Time (min)	#6	#8	#9
-10	2242.97	2245.83	2242.97
0	2242.97	2245.83	2242.97
5	2242.97	2198.26	2242.97
10	2242.87	2199.48	2243.02
15	2242.73	2198.91	2242.91
17	2242.59	2198.87	2242.97
20	2242.5	2198.69	2242.91
25	2242.31	2198.4	2242.91
30	2242.12	2198.02	2242.91
35	2241.98	2197.83	2242.91
40	2241.75	2197.69	2242.91
45	2241.66	2197.46	2242.97
50	2241.52	2197.23	2242.91
55	2241.19	2197.08	2243.02
60	2241.05	2196.94	2242.97
65	2240.91	2196.9	2242.91
70	2240.72	2196.66	2242.97
75	2240.56	2196.48	2242.91
80	2240.34	2196.33	2242.91
85	2240.16	2196.29	2242.97
90	2240.02	2196.15	2242.91
95	2239.87	2196.1	2242.91
100	2239.69	2195.91	2242.97
105	2239.5	2195.82	2242.91
110	2239.36	2195.77	2242.91
115	2239.22	2195.58	2242.91
120	2238.94	2195.54	2242.91
125	2238.84	2195.49	2242.91
130	2238.84	2195.4	2242.97
135	2238.47	2195.38	2242.91
140	2238.42	2195.16	2242.97
145	2238.14	2195.16	2242.97
150	2238.09	2195.16	2242.97
155	2238	2195.07	2242.97

160	2237.72	2194.83	2243.02
165	2237.62	2194.83	2243.02
170	2237.48	2194.74	2242.91
185	2237.06	2194.6	2242.91
200	2236.59	2194.41	2243.02
215	2236.17	2194.27	2243.02
230	2235.84	2194.18	2243.02
260	2235.37	2193.94	2243.02
275	2235	2193.86	2242.91
290	2234.67	2193.71	2243.02
305	2234.34	2193.66	2243.02
320	2234.11	2193.48	2243.02
335	2233.78	2193.48	2243.02
350	2233.69	2193.26	2243.13
380	2233.12	2193.24	2242.91
395	2232.75	2193.19	2243.08
410	2232.61	2193.15	2243.02

WDOE Test well -- Moscow #8 Test
Radial distance to pumping well -- 19012 ft

Elapsed Time (min)	Water level elevation (feet above mean sea level)
-545	2244.31
-540	2244.32
-535	2244.33
-530	2244.33
-525	2244.34
-520	2244.36
-515	2244.38
-510	2244.38
-505	2244.38
-500	2244.4
-495	2244.4
-490	2244.41
-485	2244.42
-480	2244.44
-475	2244.44
-470	2244.44
-465	2244.45
-460	2244.45
-455	2244.46
-450	2244.46
-445	2244.48
-440	2244.47
-435	2244.48
-430	2244.49
-425	2244.49
-420	2244.51
-415	2244.5
-410	2244.52
-405	2244.52
-400	2244.53
-395	2244.52
-390	2244.53
-385	2244.54
-380	2244.53
-375	2244.53
-370	2244.53

-365	2244.55
-360	2244.54
-355	2244.55
-350	2244.55
-345	2244.55
-340	2244.55
-335	2244.55
-330	2244.56
-325	2244.56
-320	2244.57
-315	2244.58
-310	2244.58
-305	2244.57
-300	2244.58
-295	2244.59
-290	2244.58
-285	2244.59
-280	2244.59
-275	2244.59
-270	2244.59
-265	2244.6
-260	2244.59
-255	2244.61
-250	2244.6
-245	2244.61
-240	2244.61
-235	2244.61
-230	2244.61
-225	2244.6
-220	2244.59
-215	2244.62
-210	2244.62
-205	2244.61
-200	2244.62
-195	2244.61
-190	2244.62
-185	2244.62
-180	2244.62
-175	2244.63
-170	2244.63
-165	2244.63
-160	2244.63
-155	2244.63
-150	2244.63
-145	2244.63
-140	2244.64
-135	2244.64
-130	2244.63
-125	2244.63
-120	2244.63

-115	2244.64
-110	2244.64
-105	2244.64
-100	2244.64
-95	2244.65
-90	2244.65
-85	2244.64
-80	2244.65
-75	2244.66
-70	2244.66
-65	2244.66
-60	2244.66
-55	2244.65
-50	2244.65
-45	2244.65
-40	2244.65
-35	2244.66
-30	2244.65
-25	2244.66
-20	2244.66
-15	2244.66
-10	2244.66
-5	2244.65
0	2244.65
5	2244.66
10	2244.65
15	2244.65
20	2244.65
25	2244.65
30	2244.65
35	2244.65
40	2244.65
45	2244.66
50	2244.65
55	2244.65
60	2244.65
65	2244.65
70	2244.65
75	2244.64
80	2244.65
85	2244.64
90	2244.65
95	2244.65
100	2244.66
105	2244.64
110	2244.65
115	2244.64
120	2244.63
125	2244.63
130	2244.64

135	2244.64
140	2244.64
145	2244.64
150	2244.65
155	2244.64
160	2244.64
165	2244.64
170	2244.64
175	2244.64
180	2244.62
185	2244.64
190	2244.63
195	2244.63
200	2244.63
205	2244.63
210	2244.63
215	2244.63
220	2244.62
225	2244.62
230	2244.62
235	2244.62
240	2244.63
245	2244.63
250	2244.63
255	2244.62
260	2244.63
265	2244.63
270	2244.62
275	2244.62
280	2244.62
285	2244.62
290	2244.62
295	2244.62
300	2244.62
305	2244.62
310	2244.62
315	2244.61
320	2244.62
325	2244.61
330	2244.61
335	2244.62
340	2244.61
345	2244.62
350	2244.61
355	2244.61
360	2244.62
365	2244.61
370	2244.61
375	2244.61
380	2244.61

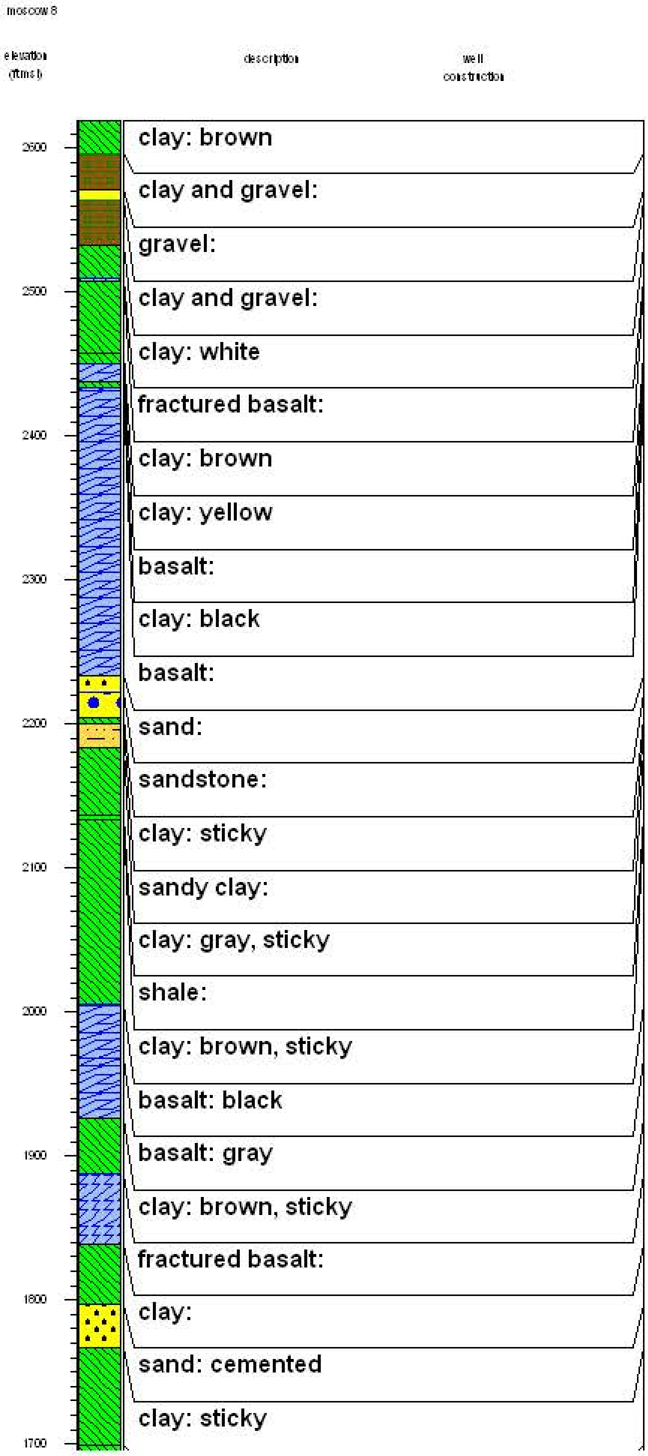
385	2244.6
390	2244.59
395	2244.58
400	2244.58
405	2244.57
410	2244.58
415	2244.58
420	2244.58
425	2244.57
430	2244.58
435	2244.58
440	2244.59
445	2244.59
450	2244.59
455	2244.6
460	2244.59
465	2244.58
470	2244.6
475	2244.59
480	2244.59
485	2244.59
490	2244.6
495	2244.59
500	2244.59
505	2244.6
510	2244.6
515	2244.61
520	2244.61
525	2244.59
530	2244.6
535	2244.6
540	2244.59
545	2244.59
550	2244.61
555	2244.6
560	2244.61
565	2244.59
570	2244.61
575	2244.61
580	2244.6
585	2244.6
590	2244.59
595	2244.61
600	2244.61
605	2244.62
610	2244.62
615	2244.6
620	2244.61
625	2244.61
630	2244.62

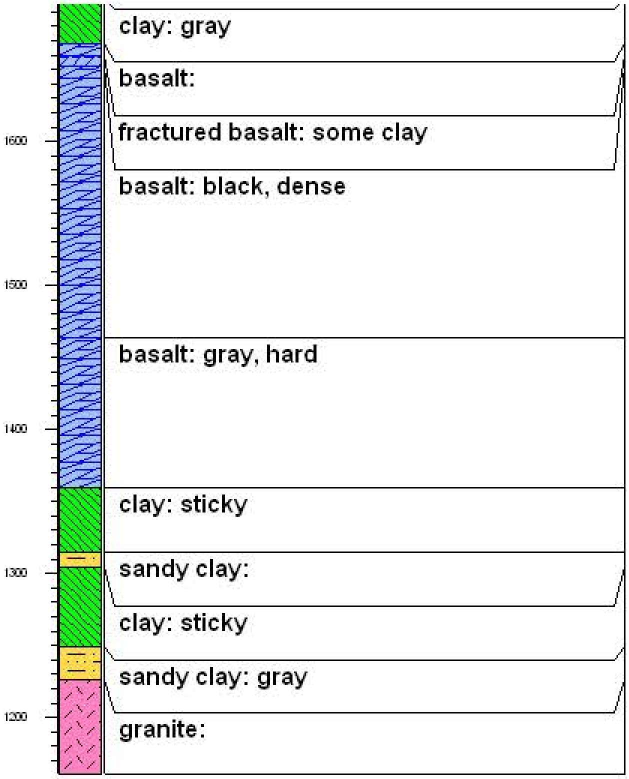
635	2244.62
640	2244.61
645	2244.62
650	2244.62
655	2244.62
660	2244.62
665	2244.62
670	2244.62
675	2244.62
680	2244.62

APPENDIX F

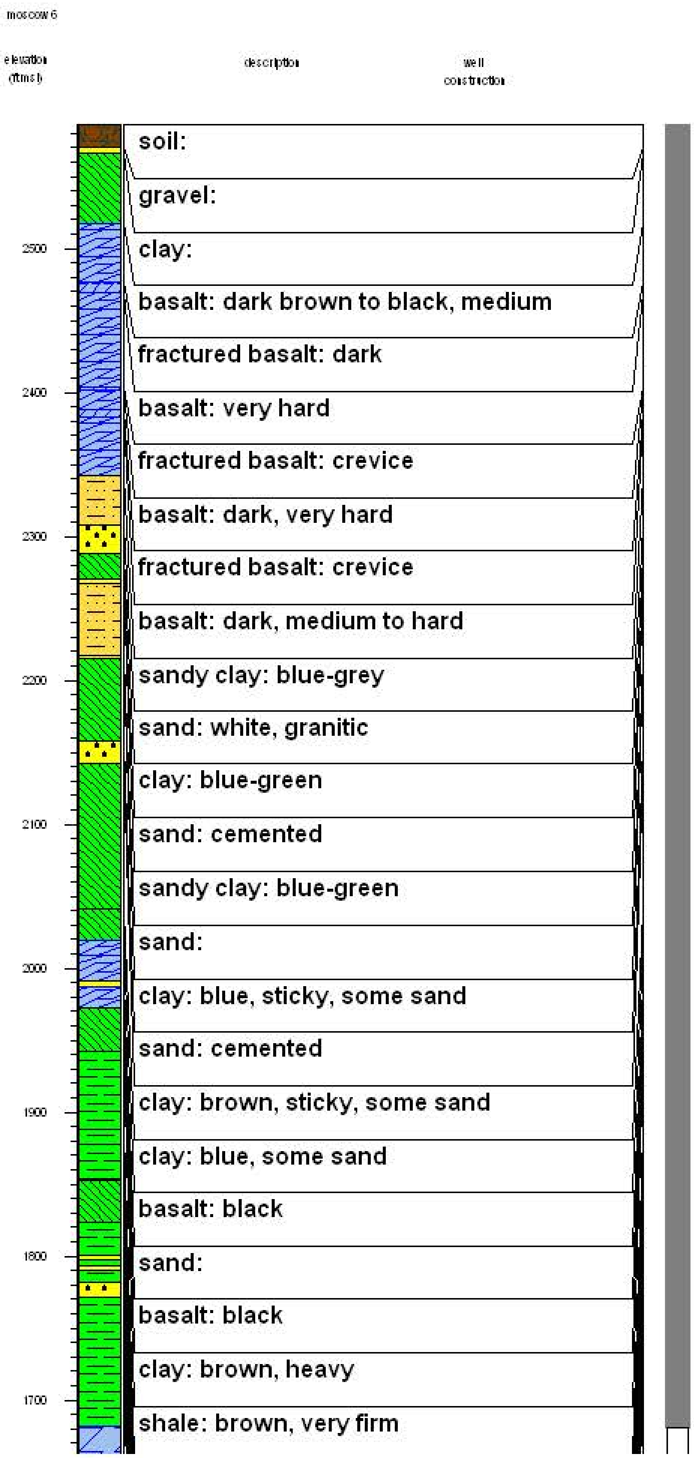
WELL LOGS FOR PUMPING AND OBSERVATION WELLS

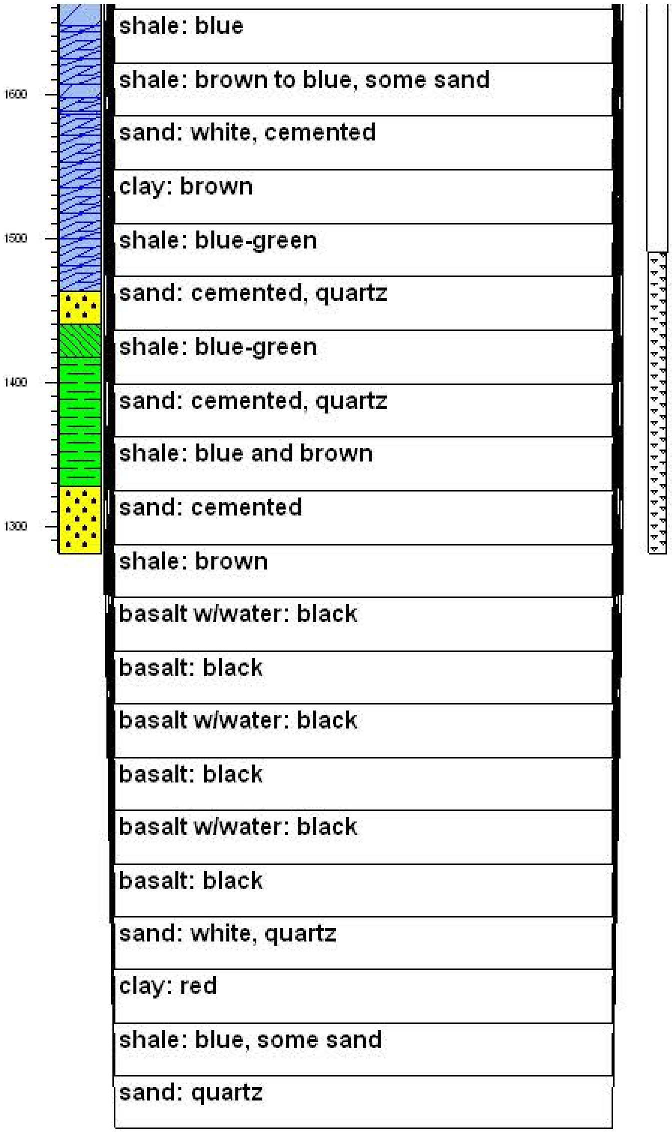
Moscow #8


moscow 8
elevation (ft msl)
description
well construction
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
clay: brown
clay and gravel:
gravel:
clay and gravel:
clay: white
fractured basalt:
clay: brown
clay: yellow
basalt:
clay: black
basalt:
sand:
sandstone:
clay: sticky
sandy clay:
clay: gray, sticky
shale:
clay: brown, sticky
basalt: black
basalt: gray
clay: brown, sticky
fractured basalt:
clay:
sand: cemented
clay: sticky

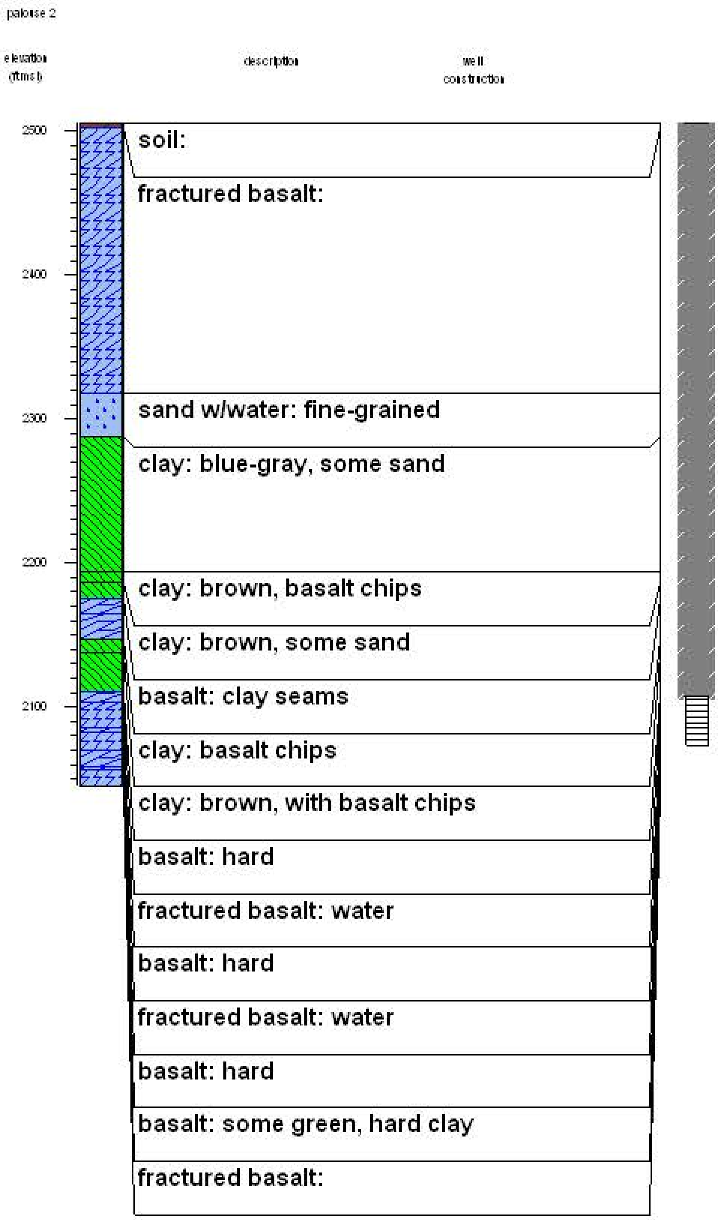

1600
1500
1400
1300
1200
clay: gray
basalt:
fractured basalt: some clay
basalt: black, dense
basalt: gray, hard
clay: sticky
sandy clay:
clay: sticky
sandy clay: gray
granite:

Moscow #6

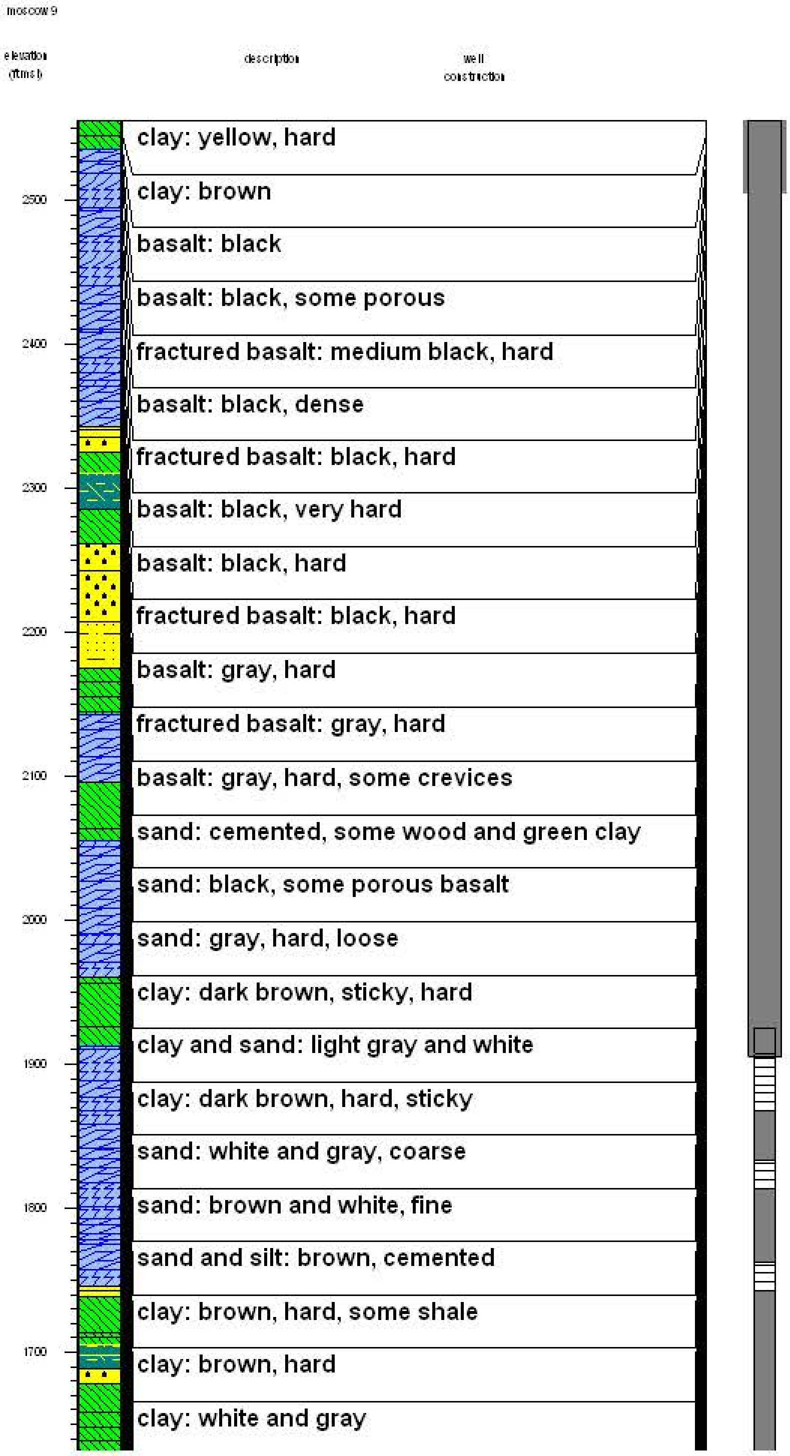

moscow 6
elevation (ft msl)
description
well construction
2500
2400
2300
2200
2100
2000
1900
1800
1700
soil:
gravel:
clay:
basalt: dark brown to black, medium
fractured basalt: dark
basalt: very hard
fractured basalt: crevice
basalt: dark, very hard
fractured basalt: crevice
basalt: dark, medium to hard
sandy clay: blue-grey
sand: white, granitic
clay: blue-green
sand: cemented
sandy clay: blue-green
sand:
clay: blue, sticky, some sand
sand: cemented
clay: brown, sticky, some sand
clay: blue, some sand
basalt: black
sand:
basalt: black
clay: brown, heavy
shale: brown, very firm

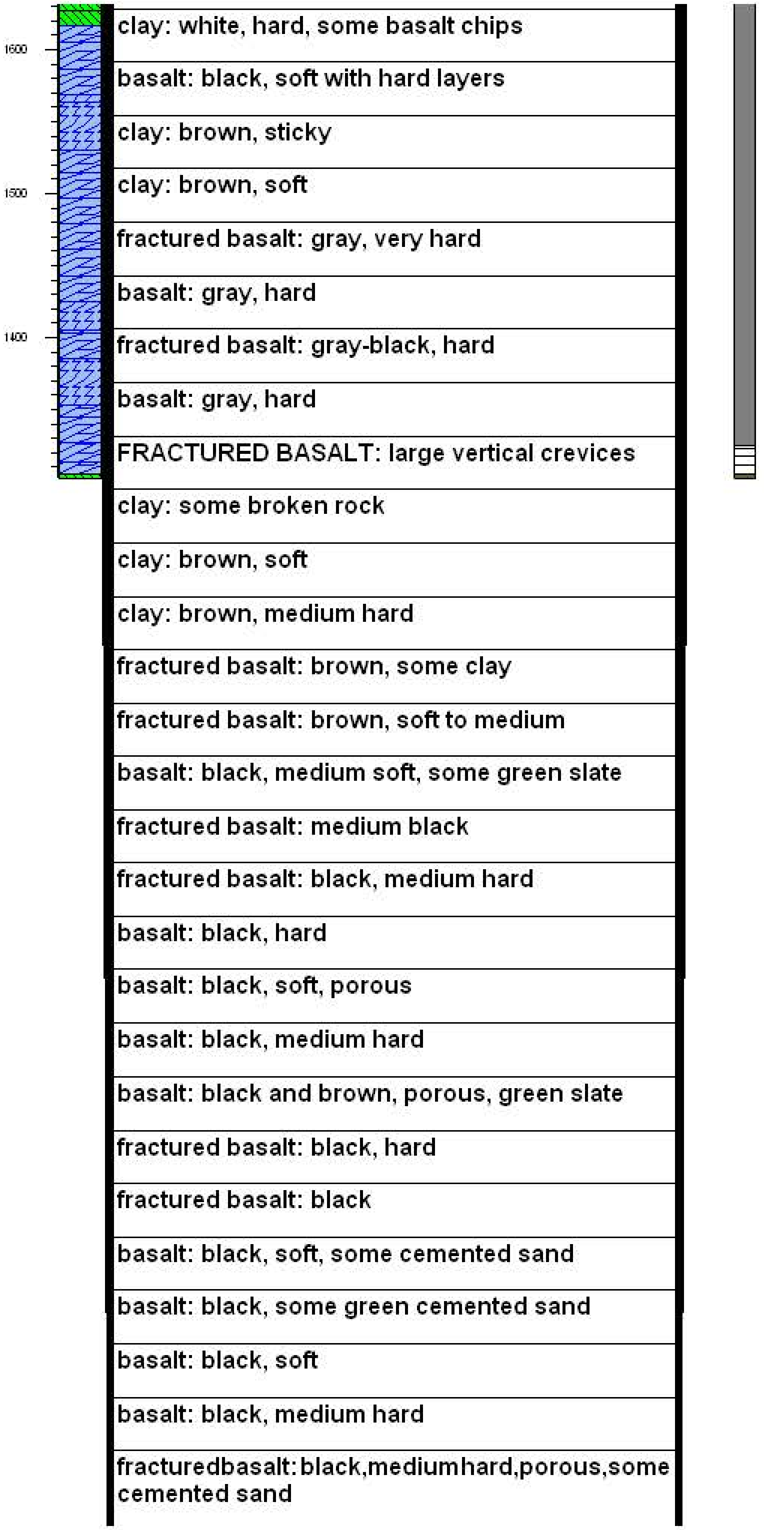

1600
1500
1400
1300
shale: blue
shale: brown to blue, some sand
sand: white, cemented
clay: brown
shale: blue-green
sand: cemented, quartz
shale: blue-green
sand: cemented, quartz
shale: blue and brown
sand: cemented
shale: brown
basalt w/water: black
basalt: black
basalt w/water: black
basalt: black
basalt w/water: black
basalt: black
sand: white, quartz
clay: red
shale: blue, some sand
sand: quartz

Palouse #2


palouse 2
elevation (ft msl)
description
well construction
2500
2400
2300
2200
2100
soil:
fractured basalt:
sand w/water: fine-grained
clay: blue-gray, some sand
clay: brown, basalt chips
clay: brown, some sand
basalt: clay seams
clay: basalt chips
clay: brown, with basalt chips
basalt: hard
fractured basalt: water
basalt: hard
fractured basalt: water
basalt: hard
basalt: some green, hard clay
fractured basalt:

Moscow #9


moscow 9
elevation (ft msl)
description
well construction
2500
2400
2300
2200
2100
2000
1900
1800
1700
clay: yellow, hard
clay: brown
basalt: black
basalt: black, some porous
fractured basalt: medium black, hard
basalt: black, dense
fractured basalt: black, hard
basalt: black, very hard
basalt: black, hard
fractured basalt: black, hard
basalt: gray, hard
fractured basalt: gray, hard
basalt: gray, hard, some crevices
sand: cemented, some wood and green clay
sand: black, some porous basalt
sand: gray, hard, loose
clay: dark brown, sticky, hard
clay and sand: light gray and white
clay: dark brown, hard, sticky
sand: white and gray, coarse
sand: brown and white, fine
sand and silt: brown, cemented
clay: brown, hard, some shale
clay: brown, hard
clay: white and gray



clay: white, hard, some basalt chips

basalt: black, soft with hard layers

clay: brown, sticky

clay: brown, soft

fractured basalt: gray, very hard

basalt: gray, hard

fractured basalt: gray-black, hard

basalt: gray, hard

FRACTURED BASALT: large vertical crevices

clay: some broken rock

clay: brown, soft

clay: brown, medium hard

fractured basalt: brown, some clay

fractured basalt: brown, soft to medium

basalt: black, medium soft, some green slate

fractured basalt: medium black

fractured basalt: black, medium hard

basalt: black, hard

basalt: black, soft, porous

basalt: black, medium hard

basalt: black and brown, porous, green slate

fractured basalt: black, hard

fractured basalt: black

basalt: black, soft, some cemented sand

basalt: black, some green cemented sand

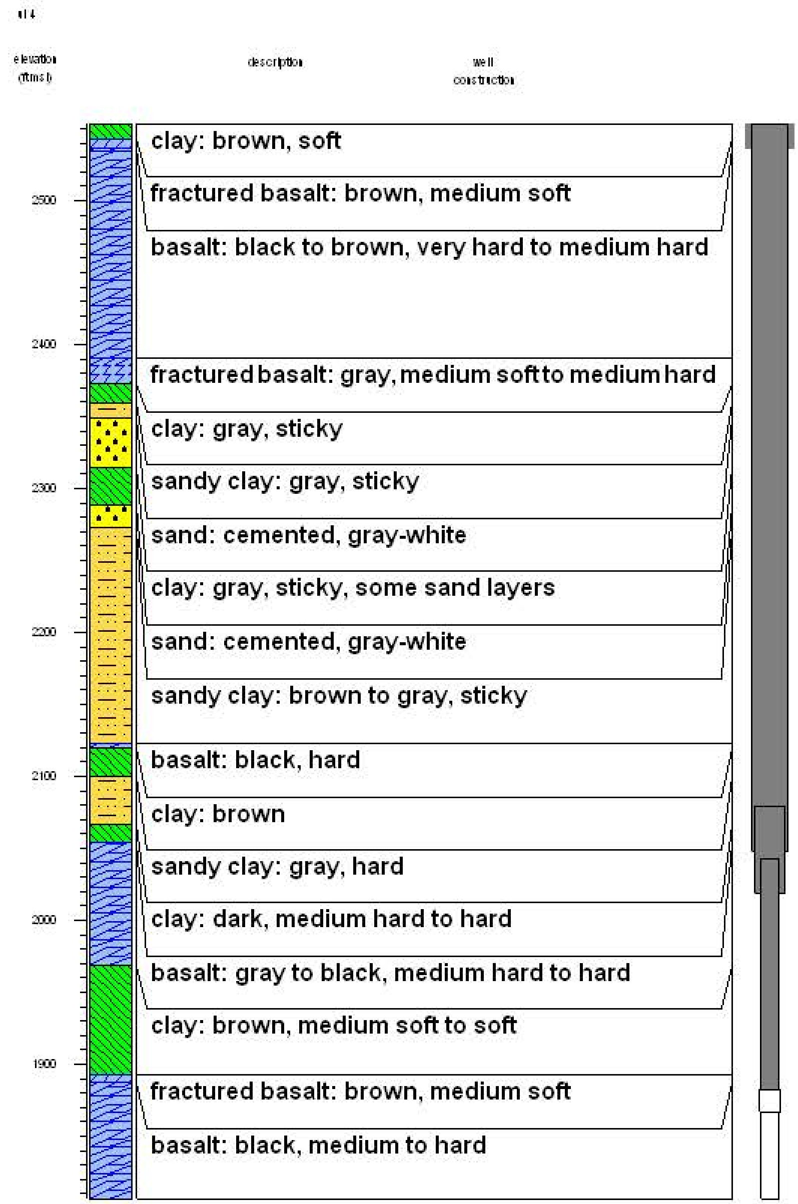
basalt: black, soft

basalt: black, medium hard

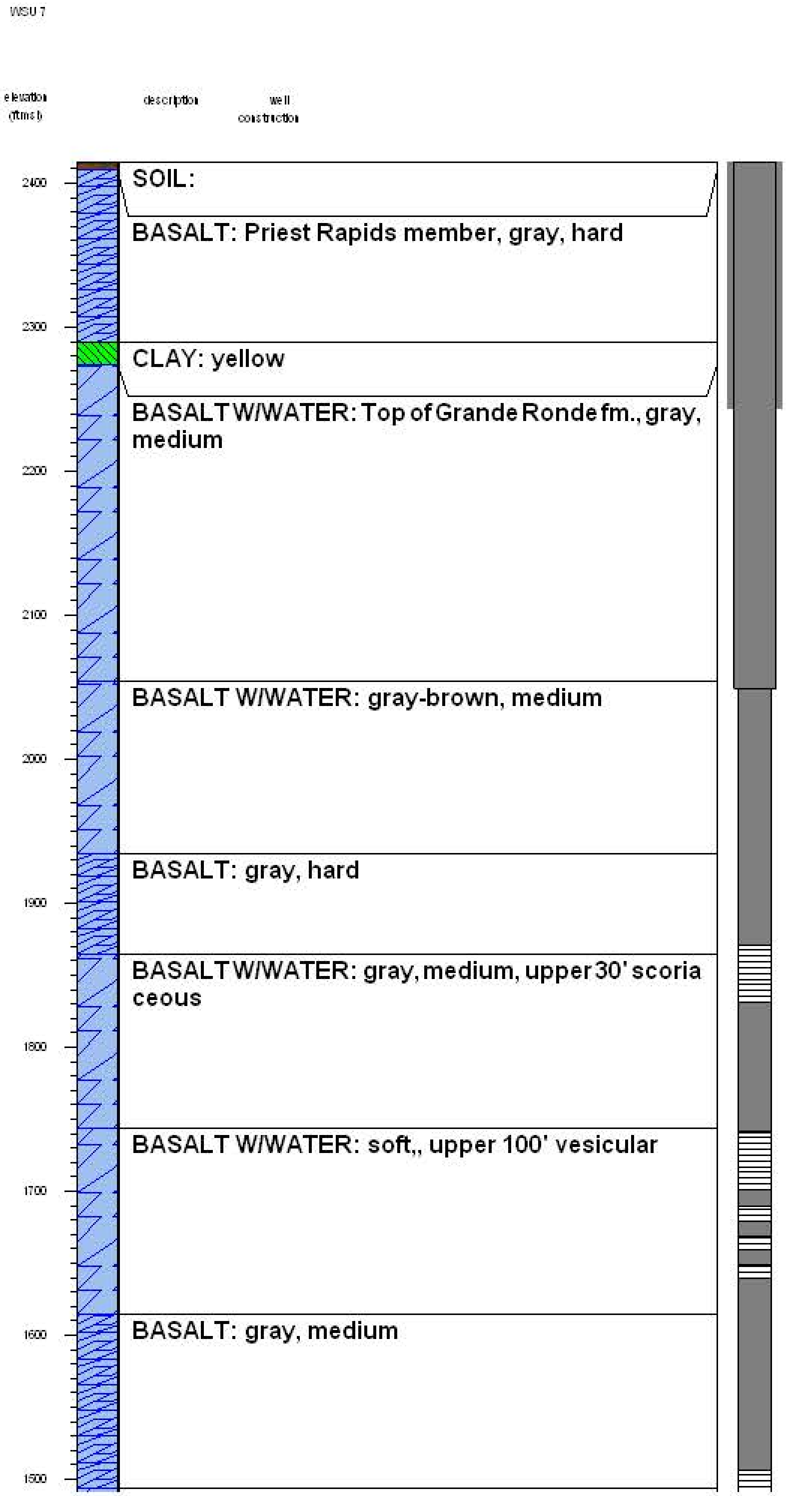
fractured basalt: black, medium hard, porous, some cemented sand

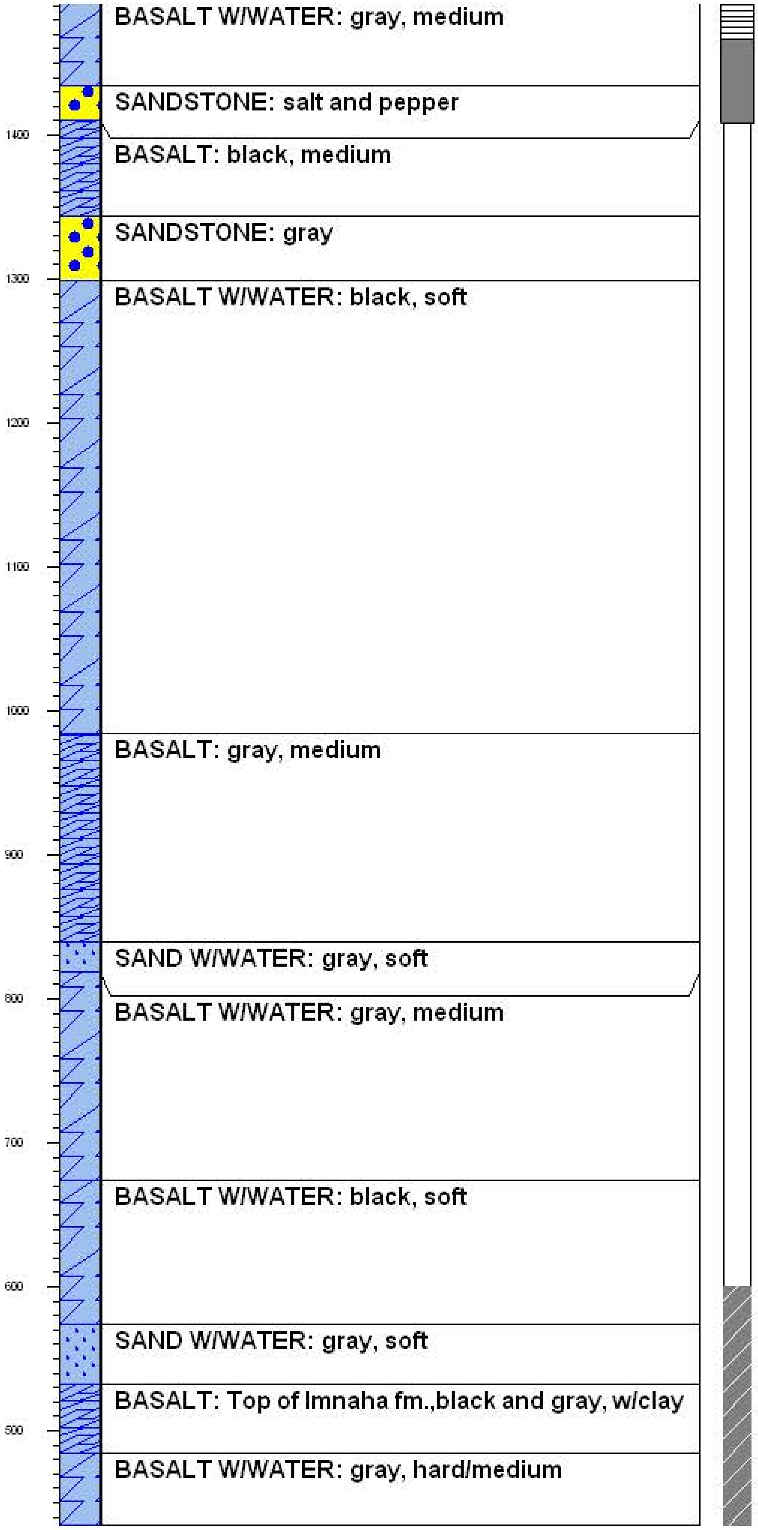
sand: dark, some cemented
sand: cemented, almost clay
clay: dark brown, hard, slatey
clay: brown and gray, some basalt
clay: gray, wood chips
clay and sand: gray, green, some cemented
clay and sand: gray, cemented
sand: gray, cemented
clay: dark brown, hard
clay: dark brown, very hard
clay: light brown, hard
clay: dark brown, hard
clay: black, hard, some basalt
basalt: black, hard
fractured basalt: black, hard
fractured basalt: black, hard, rough drilling
basalt: black, hard
fractured basalt: black, softer
basalt: black, hard
fractured basalt: black, medium hard
basalt: black, hard
basalt: black, medium hard
basalt: black, soft, some clay
clay: light brown, soft

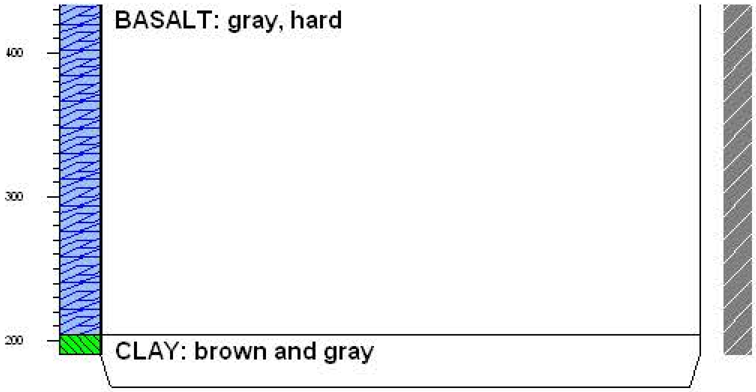
U of I #4


ui 4
elevation (ft msl)
description
well construction
2500
2400
2300
2200
2100
2000
1900
clay: brown, soft
fractured basalt: brown, medium soft
basalt: black to brown, very hard to medium hard
fractured basalt: gray, medium soft to medium hard
clay: gray, sticky
sandy clay: gray, sticky
sand: cemented, gray-white
clay: gray, sticky, some sand layers
sand: cemented, gray-white
sandy clay: brown to gray, sticky
basalt: black, hard
clay: brown
sandy clay: gray, hard
clay: dark, medium hard to hard
basalt: gray to black, medium hard to hard
clay: brown, medium soft to soft
fractured basalt: brown, medium soft
basalt: black, medium to hard

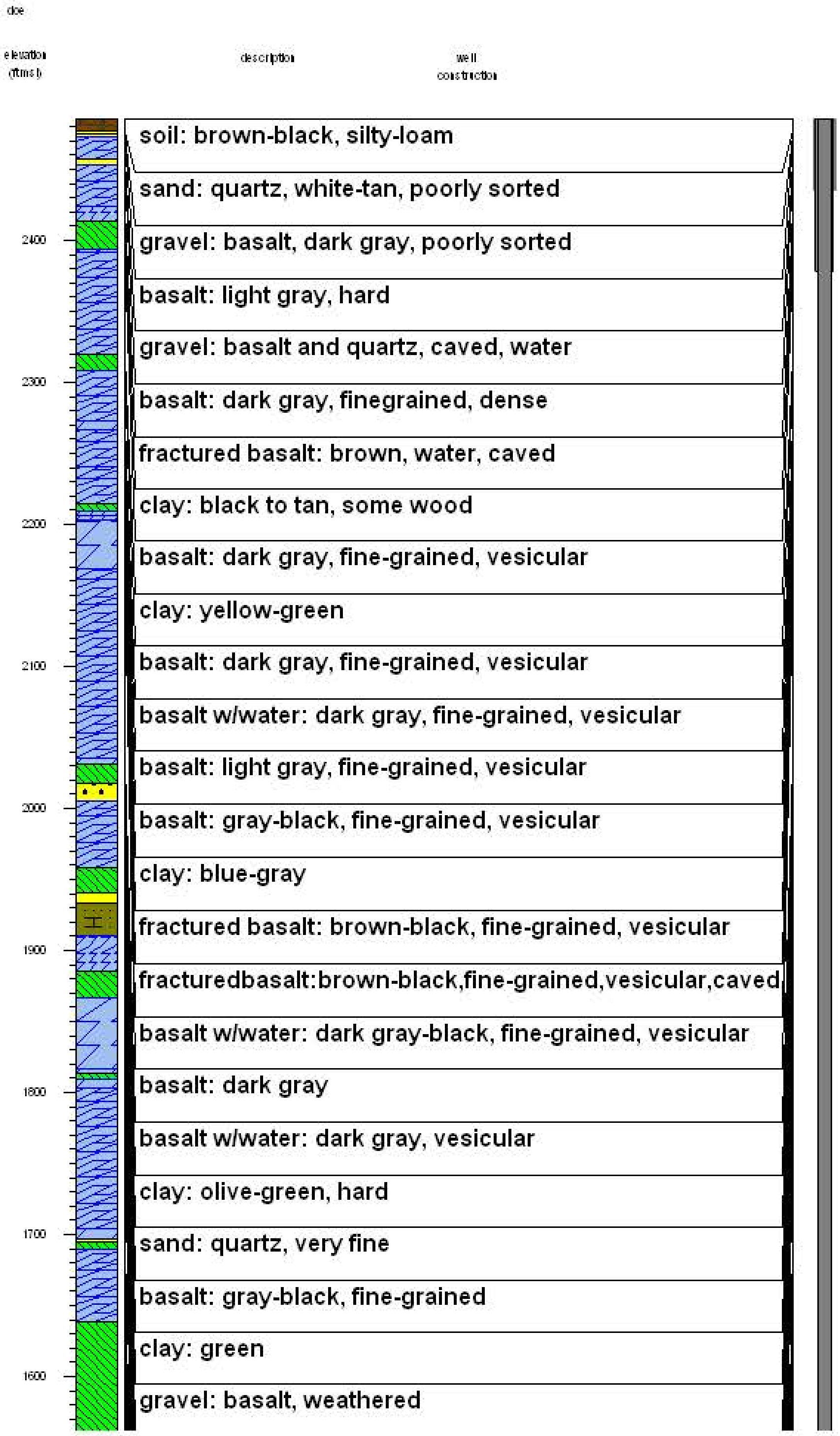
WSU #7

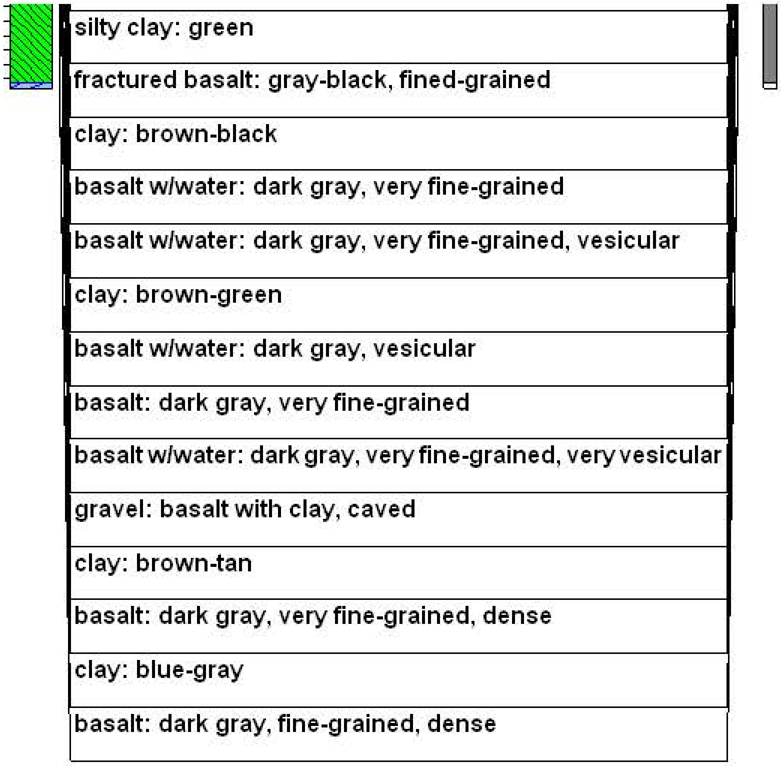

WSU 7
elevation (ft msl)
description
well construction
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
SOIL:
BASALT: Priest Rapids member, gray, hard
CLAY: yellow
BASALT W/WATER: Top of Grande Ronde fm., gray, medium
BASALT W/WATER: gray-brown, medium
BASALT: gray, hard
BASALT W/WATER: gray, medium, upper 30' scoriaceous
BASALT W/WATER: soft,, upper 100' vesicular
BASALT: gray, medium


BASALT W/WATER: gray, medium
SANDSTONE: salt and pepper
1400
BASALT: black, medium
SANDSTONE: gray
1300
BASALT W/WATER: black, soft
1200
1100
1000
BASALT: gray, medium
900
SAND W/WATER: gray, soft
800
BASALT W/WATER: gray, medium
700
BASALT W/WATER: black, soft
600
SAND W/WATER: gray, soft
BASALT: Top of Imnaha fm.,black and gray, w/clay
500
BASALT W/WATER: gray, hard/medium


BASALT: gray, hard
400
300
200
CLAY: brown and gray

WDOE Test Well





silty clay: green

fractured basalt: gray-black, fined-grained

clay: brown-black

basalt w/water: dark gray, very fine-grained

basalt w/water: dark gray, very fine-grained, vesicular

clay: brown-green

basalt w/water: dark gray, vesicular

basalt: dark gray, very fine-grained

basalt w/water: dark gray, very fine-grained, very vesicular

gravel: basalt with clay, caved

clay: brown-tan

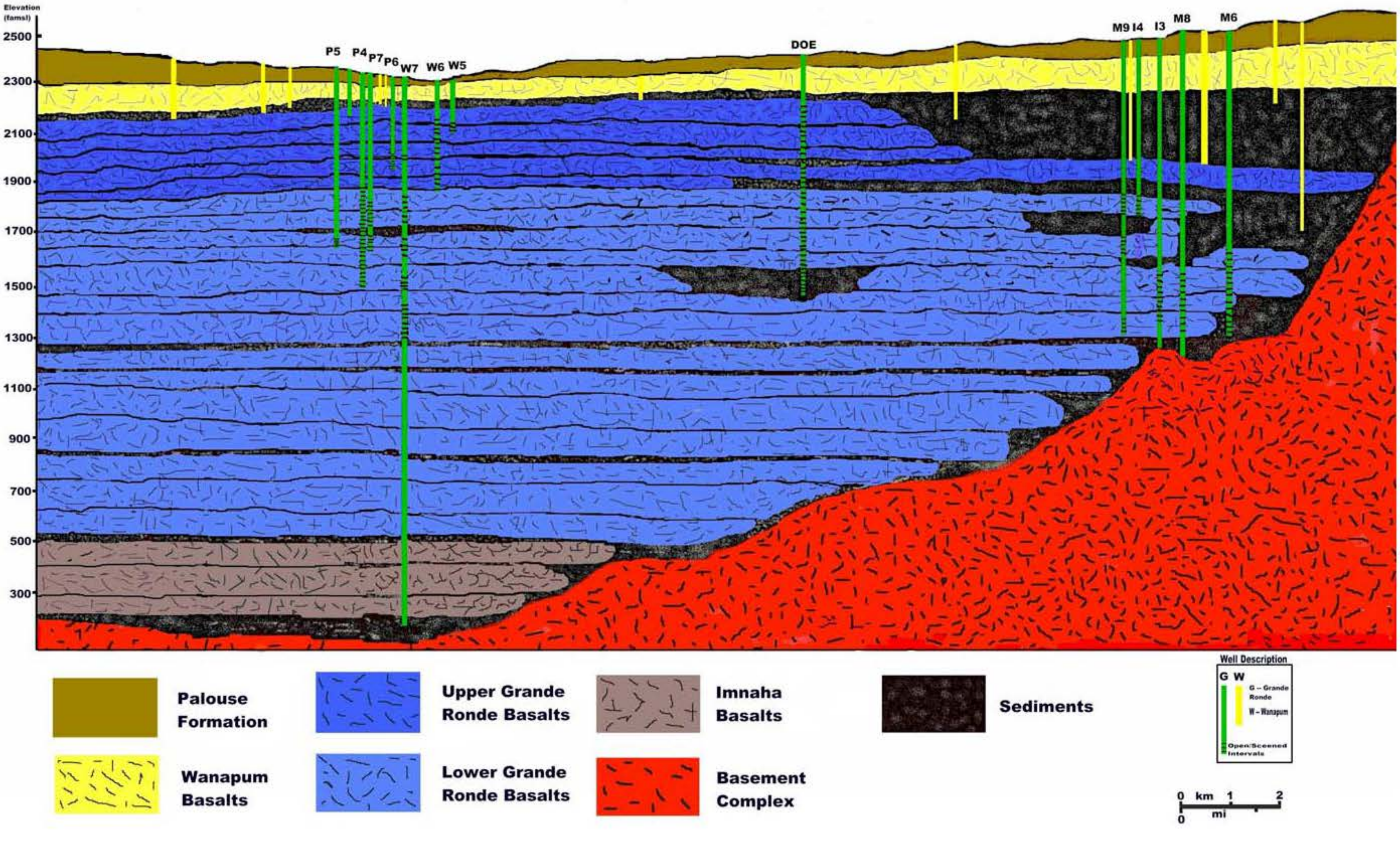
basalt: dark gray, very fine-grained, dense

clay: blue-gray

basalt: dark gray, fine-grained, dense

APPENDIX G
SCHEMATIC EAST WEST CROSS-SECTION

The schematic geologic cross-section presented in this study was constructed based on the well log information provided from the well logs of the various city, private, and university well owners. Shallow wells were used to constrain shallow marker beds, topography, and the upper-most basalt flows. The deeper sections of the cross-section were interpreted based on my pre-existing knowledge of the local geology, and information taken from the well logs. Assumptions were needed to determine rock unit descriptions from the well logs. Quality checks were also done on the well logs, verifying the integrity of the information provided. To minimize details, units were generalized and lumped together, based on a five foot minimal unit thickness to be included in the cross-section. Extrapolation and continuity of marker beds, basalt flows, and interbeds are assumed to be relatively horizontal and continuous. The extent and location of basement complex is also speculated, based on the provided information.


Elevation (famsl)
2500
2300
2100
1900
1700
1500
1300
1100
900
700
500
300
P5
P4
P7
P6
W7
W6
W5
DOE
M9
I4
I3
M8
M6
Palouse Formation
Wanapum Basalts
Upper Grande Ronde Basalts
Lower Grande Ronde Basalts
Imnaha Basalts
Basement Complex
Sediments
Well Description
G
W
G -- Grande Ronde
W – Wanapum
Open/Sceened Intervals
0
km
1
2
mi
0