ES473 Environmental Geology
Field Guide

City of Dallas, Oregon
Water Treatment Plan and Aquifer Storage Recovery (ASR) System

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City of Dallas ASR Fieldtrip **Name_______________**
Review Questions

Read the ASR Feasibility Study by Golder Associates, answer the following questions BEFORE attending the field trip.

1. Define the following terms:

    a. WTP

    b. ASR

    c. MGD

    d. SRV

    e. DEQ

    f. OAR

    g. OWRD

2. Provide a 2-sentence description of the physiographic setting of Dallas, Oregon.

3. What watershed is the Dallas treatment plant facility located in?

4. What USGS quadrangle is the WTP and ASR located on?

5. What are the dominant bedrock units located in the ASR area? List and describe the geologic units in ascending order, from bottom to top.

6. What is the primary aquifer material at the ASR study site?

7. What was the total depth drilled for the ASR test well?

8. Is this a granular aquifer for fractured? Confined or unconfined?

9. Define the following terms

    a. Downhole survey

    b. Caliper log

    c. Conductivity

    d. Fluid resistivity

    e. Observation well

    f. Test Well

    g. Pump test

    h. Step-Rate Pump Test

    i. Static Water Level (SWL)

    j. Depth to Water (DTW)

    k. Specific capacity

    l. Drawdown

    m. Well interference

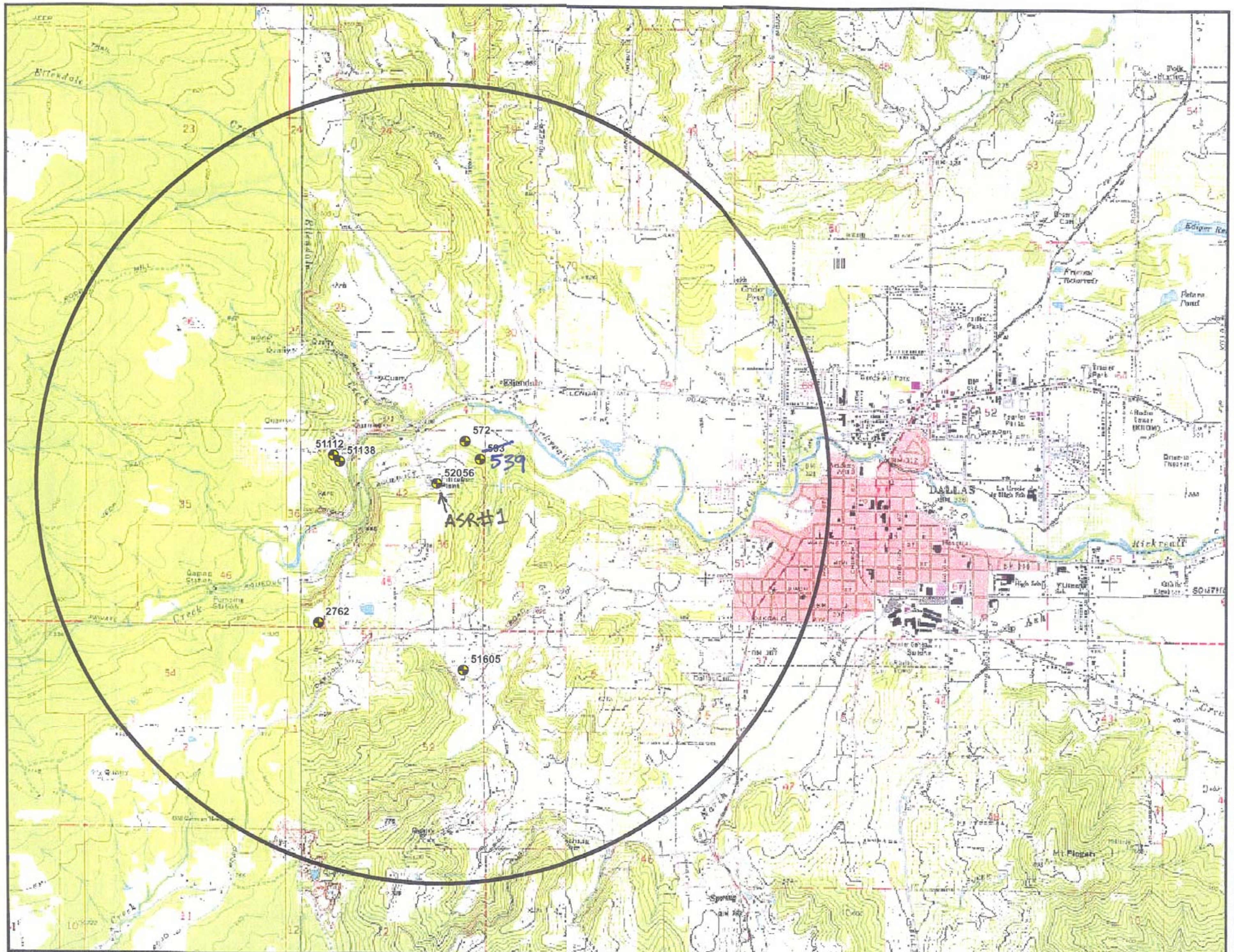

Figure 4-1
Observation Well Network

City of Dallas ASN Hydrogeologic Feasability Study 2004

Legend

- Observation Wells
- Observation Wells (2-Mile Buffer)

N W E S

0 1,250 2,500 3,750 5,000
Feet

CH2MHILL

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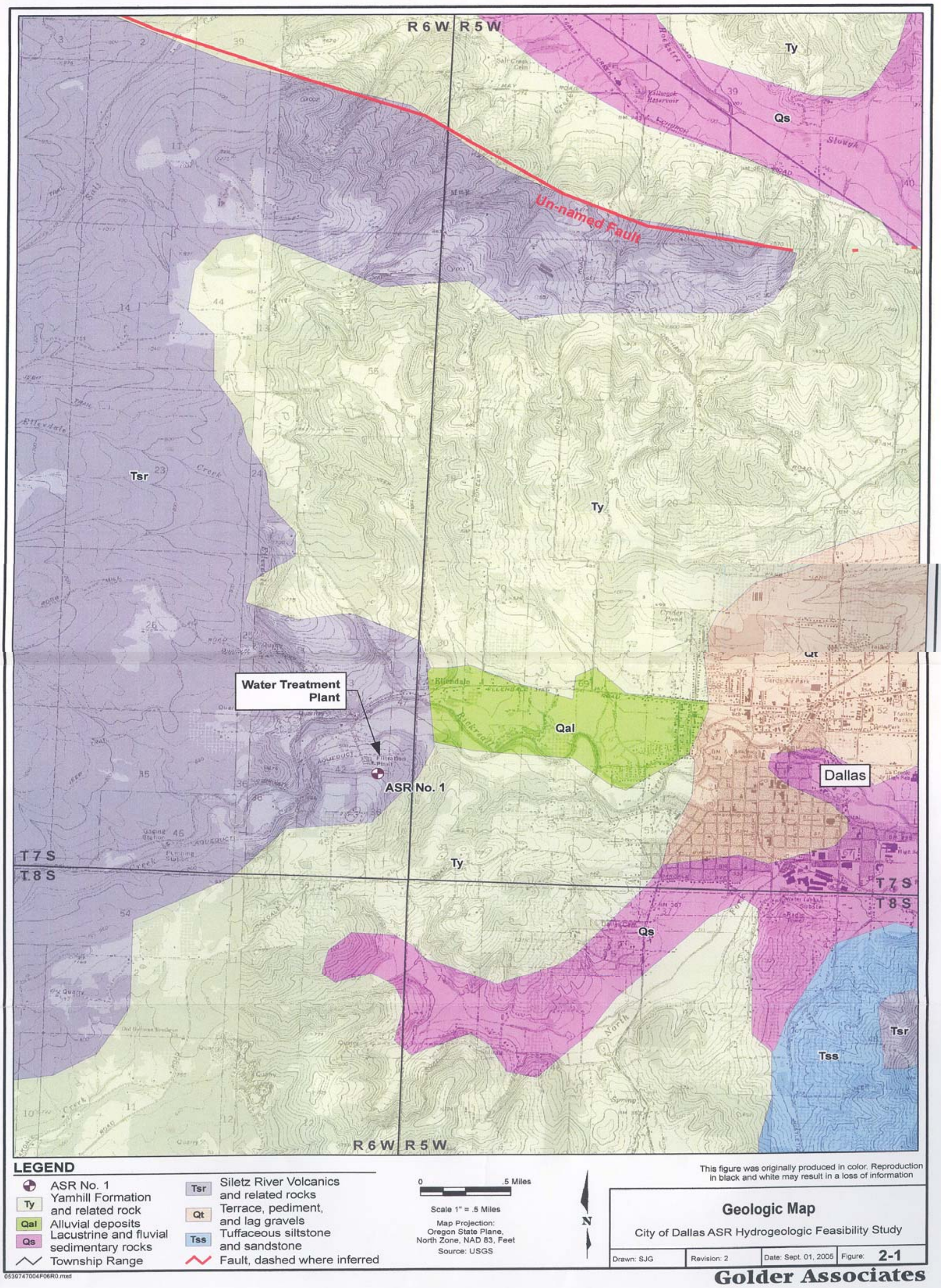
R 6 W R 5 W
Ty
Qs
Un-named Fault
Tsr
Ty
Qt
Water Treatment Plant
ASR No. 1
Qal
Dallas
T 7 S
T 8 S
Ty
Qs
Tsr
Tss
R 6 W R 5 W
LEGEND
ASR No. 1
Ty Yamhill Formation and related rock
Qal Alluvial deposits
Qs Lacustrine and fluvial sedimentary rocks
Township Range
Tsr Siletz River Volcanics and related rocks
Qt Terrace, pediment, and lag gravels
Tss Tuffaceous siltstone and sandstone
Fault, dashed where inferred
0 .5 Miles
Scale 1" = .5 Miles
Map Projection: Oregon State Plane, North Zone, NAD 83, Feet
Source: USGS
N
This figure was originally produced in color. Reproduction in black and white may result in a loss of information
Geologic Map
City of Dallas ASR Hydrogeologic Feasibility Study
Drawn: SJG
Revision: 2
Date: Sept. 01, 2005
Figure: 2-1
Golder Associates
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1.0 INTRODUCTION

1.1 Project Background

The City of Dallas (City) is interested in developing an ASR program at its Water Treatment Plant (WTP; Public Water System No. 4100248) site to respond to increased demands on its water system capacity. This program is one of the options the City is investigating to utilize all of its existing water and storage rights on Rickreall Creek and to optimize WTP capacity. ASR offers a cost-effective way to satisfy future demands by delaying or minimizing the scale of future supply expansion projects and is an alternative to constructing new above ground storage.

The City ultimately wishes to develop a 1-million-gallon-per-day (MGD) ASR system in the Siletz River Volcanics (SRV) basalt aquifer at the WTP site. Excess water from the treatment plant will be stored during the winter and spring months within the fractured basalt of the Siletz River Volcanics. The WTP site was selected on the basis of the City's existing infrastructure. Drilling and testing at that location indicated limited aquifer permeability. However, the costs of a multiple-well system offset the infrastructure costs associated with a more distant location, so the WTP site was selected for initial development.

Based on a preliminary assessment of the site, the City implemented a pilot drilling and testing program near the WTP in 2004. The drilling and testing program included the following components:

- A test well (ASR #1; OWRD well ID POLK 52056) was drilled to approximately 2,000 feet below land surface;
- An assessment of the permeability and geologic characteristics of the Siletz River Volcanics beneath the City's WTP, including physical inspection and chemical analysis of core samples collected at selected intervals;
- A step-rate test to assess well performance;
- A 72-hour constant rate pumping test to assess aquifer performance and ASR feasibility;
- A geophysical survey of the borehole ; and
- A geochemical compatibility assessment of source water with native groundwater and the aquifer matrix.

Results of the geophysical survey indicated that no significant permeability was likely in the borehole below a depth of approximately 950 feet. Due to the lack of permeability below this depth, water could stagnate in the lower portion of the borehole and affect water quality (taste & odor) during ASR operations. A packer test was performed on June 27, 2005, in order to confirm the finding that little significant permeability exists in the borehole below a depth of 950 feet. Results from the packer test indicated that no significant permeability would be lost if the well was grouted to a depth of 950 feet, as the contribution below this depth represented only 0.07 percent of the total transmissivity. Complete testing and analysis details are provided in Appendix E. ASR #1 subsequently was grouted to a depth of 925 feet bgs in July 2005 by Geo-Tech Explorations.

The information gathered from drilling and testing at ASR #1 indicate that the aquifer can support ASR operations at rates and volumes beneficial to the City. The City will apply for a license to utilize the existing modified test well (ASR #1) to begin ASR pilot testing at the WTP over a five year period with the option to expand into a three-well ASR system at the City's WTP site.

1.2 ASR Study Scope

This ASR hydrogeologic feasibility study has been prepared in support of the City's ASR limited license application under Oregon Administrative Rule [OAR] 690.350. Program review during the permitting process is conducted by the Oregon Water Resources Department (OWRD), the Oregon Department of Environmental Quality (DEQ), and the Oregon Department of Human Services (DHS). Specific feasibility components addressed in this document include:

- Physical setting of the vicinity surrounding the WTP
- Regional and local geology and hydrogeology of the ASR study area
- Drilling and testing of a test well (ASR #1) at the WTP site
- Conceptual hydrogeologic model of the ASR study area
- Storage capacity of the target aquifer
- Potential loss of stored water and well interference effects
- Source, receiving, and recovered water quality

2.0 HYDROGEOLOGIC SETTING

Hydrogeologic characterization of the ASR study area is necessary to identify target storage zones, to estimate injection and recovery rates, to identify locations where stored water may be lost (springs or wells), and to address water quality compatibility issues. The information presented here is based upon available literature review including drillers' logs and previous aquifer exploration and testing conducted in 2004 and 2005.

2.1 Physical Setting

The City of Dallas is on the western edge of the lower Willamette Basin and the eastern edge of the Coast Range (Figure 2-1). The Willamette Valley is a structural basin composed of gently dipping marine sedimentary rock and volcanic bedrock units overlain by unconsolidated fluvial deposits. The Coast Range is a North-South trending mountain range composed of sedimentary and volcanic formations.

Rickreall Creek, a tributary of the Willamette River, is the major regional drainage in the project area. Rickreall Creek flows east from the Coast Range through the City of Dallas before merging with the Willamette River. The creek lies approximately 1,500 feet north of the ASR test well drilled at the City of Dallas WTP site.

2.2 Geology

The youngest units in the region are unconsolidated fluvial sediments consisting of recent alluvial sediments (Qal) associated with Rickreall Creek, the Little Luckiamute and Mill Creek drainages and older terrace gravel deposits (Qt). Floodplain sands and silts deposited near major streams and tributaries overlie the older terrace gravel formations. Where present, the Willamette Silt forms a thin surface veneer in the Dallas area.

The unconsolidated fluvial sediments overlie Eocene marine sediments which underlie about 75 percent of the Dallas area, identified as the Yamhill Formation. The Yamhill Formation is composed of rhythmically bedded siltstone, shale, some fine grained sandstone, and tuffaceous material. The Rickreall Limestone Member, a locally occurring basal unit of calcite-cemented sandstone-siltstone, is grouped within the Yamhill Formation. The Yamhill Formation will be referred to as "marine sediments" within this report.

The Siletz River Volcanics (SRV) is a sequence of basalt, pillow basalt, tuff, volcanic materials, and sediments which underlie the Yamhill formation. The SRV also forms the topographic uplands surrounding Dallas to the west and north. Geologic logs of oil exploration wells indicate that the SRV has a thickness of 25 kilometers in the central Coast Range. Although basalt flows in the SRV can be extremely brecciated and mineralized because of rock /water interactions during submarine eruptions and post-deposition fluid movement (Caldwell, 1993), some well-defined flows are observed in the area west of Dallas.

Uplift of the Coast Range has resulted in a complex network of folds and faults. Faults can increase permeability by creating fractured zones in consolidated rocks. An unnamed normal fault trending east to west between Salt Creek and Dolph Corner is mapped north of Dallas. The SRV and marine sediments dip to the east towards the structural depression of the Willamette Valley (Figure 2-2).

2.3 Project Area Hydrogeology

Wells completed in the shallow unconsolidated fluvial deposits in the Dallas-Monmouth-Independence area can produce high yields. In most places the sediments exhibit relatively high permeability and are in connection with surface water. Wells completed in marine sediments are generally shallower than wells completed in the SRV, exhibit shallower groundwater levels, low specific capacities (in the range of 0.1 to 1 gpm/ft of drawdown), and commonly produce saline water. Although deeper portions of the aquifer have not been targeted by production wells due to the high salinity, no high-yield wells completed in marine sediments have been identified.

Deep wells west of Dallas are completed in either the SRV or marine sediments. Where massive basalts are encountered, permeability associated with fracturing yields sufficient quantities of groundwater to support domestic and limited irrigation use. Logs of wells completed in SRV rocks indicate average specific capacity values are 1 to 2 gpm/foot of drawdown. However, wells with specific capacities greater than 7 gpm/ft of drawdown are noted. The higher yielding wells in the SRV are likely completed adjacent to specific faults or fracture zones, and wells drilled away from these features are less likely to encounter significant permeability.

Surface water features are likely to be in direct hydraulic connection with shallow groundwater in the recent sediments and possibly in the marine sedimentary sequence. Where a stream flows directly over rocks of the Siletz River Volcanics (west of Dallas, higher in the watershed), there is likely to be some hydraulic connection where the surface water features encounter fracture permeability.

4.0 AQUIFER TEST DESCRIPTION

To evaluate aquifer characteristics and assess the storage capacity of the aquifer, a 72-hour constant-rate aquifer test was conducted at the test well in September 2004. Water level data were collected during baseline (pre-pumping), pumping, and recovery phases of the test. The ASR test well and six nearby domestic wells were monitored.

The test well preparation, pump installation, and operation were performed by Geo-Tech Explorations. A brief description of the aquifer test preparation is listed below.

4.1 Observation Well Network

An observation well network was developed by contacting private well owners within a 2-mile radius of the project site. Observation wells were selected on the basis of their depth and proximity to ASR #1 a. The network consisted of a total of six stations (five domestic well sites and ASR #1) (Figure 4-1). Electronic pressure transducers were installed in the test well and two domestic wells (owners Lowe and Birko). Manual water levels were measured at each of the wells using a water level indicator. The monitoring well network developed for the aquifer test is presented in Table 4-1. Available OWRD water well reports are included in Appendix C, OWRD Water Well Reports. Ground surface elevations were estimated using USGS 7.5 minute quadrangle topographic maps. The base-of -well elevations are compared to the test well in Table 4-2.

Barometric (atmospheric) pressure changes can influence water levels in wells completed in confined aquifer systems, and make interpretation difficult. The barometric pressure (Figure 4-2) was relatively stable for the duration of this test, varying approximately 0.1 psi (0.23 feet of water, or about 2.8 inches). Water level measurements were corrected to remove barometric influences by estimating a barometric efficiency (the ratio of barometric pressure change to water level change) for each well. That percentage was applied to the barometric pressure response, and the product was subtracted from the water levels to remove the barometric response and allow a clearer evaluation of the effects of nearby pumping. Manual measurements were not corrected.

4.2 Precipitation

Precipitation data were collected at the City of Dallas wastewater treatment plant poplar tree demonstration project site, located approximately 3.5 miles east of the test well. The daily precipitation totals and cumulative precipitation data for the period of August 15 through September 30, 2004, are shown in Figure 4-3. A total of 2.3 inches of rain was measured during this period, although approximately one-half of that amount (1.6 inches) fell after the test was completed.

4.3 Pumping and Discharge

A water lubricated five-stage vertical line shaft turbine 12-inch pump on 10-inch column pipe was installed with the intake set at 505 feet. The pump was powered by a 745 hp Cummins diesel with a right angle driveshaft. A foot valve was not installed on the pump intake. A dedicated 1-inch transducer access tube and ¾-inch water level tube were installed to 500 feet below ground surface.

An in-line McCrometer propeller flow meter was installed to measure discharge flow rate. A step-rate test was conducted to assess the target rate for the constant-rate discharge test. The selected target flow rate was not within the normal range of measurement for the propeller flow meter, so a digital totalizing flow meter was installed to provide more accurate discharge flow measurements for the constant rate test.

4.4 Step Rate Testing

A step rate test was performed on September 3, 2004. The test well was pumped at rates of 220, 267, and 320 gpm for approximately 1 hour each to evaluate well performance and determine the target rate for the 72-hour constant rate test. Hydraulic response in the test well is shown in Figure 4-4.

As shown in Figure 4-4, pumping levels stabilized within approximately 20 minutes of the onset of each step, declining slowly for the remainder of each step. Specific capacities are low (approximately 1.1 gpm/foot of drawdown) reflecting the large initial water level drop at the onset of pumping. Only slight decreases in specific capacity were noted for each rate increase, indicating that turbulent losses in the wellbore are minor. Overall, the test response indicates that the capacity is primarily a function of head losses in the relatively tight fracture network encountered by the well rather than a function of well efficiency.

Post-test water levels recovered to within 98 percent of the pre-test static water level (approximately 5.5 feet of residual drawdown) within 40 minutes after pumping was terminated. However, water levels did not recover to pre-pumping levels before the beginning of the constant rate test. Approximately 0.95 feet of residual drawdown remained after 87 hours of recovery. Based on fluid conductivity measurements made during the constant rate test, the residual drawdown could be a function of increasing fluid density in the well. A Hantush-Bierschenk plot of the inverse of the specific capacity for each step vs. flow rate for that step is shown in Figure 4-5. The equation of the best-fit line through these data points can be used to estimate the amount of short-term (approximately 1-hour) drawdown that would occur at any rate. A list of the drawdown associated with different discharge rates is shown in the inset on the figure.

The estimated drawdown is related to pumping water levels in Figure 4-6. This plot indicates that the well could produce approximately 350 gpm without drawing the pumping water level below the base of the production casing at 500 feet. Assuming that the pump intake is set at the base of the production casing, the following factors could limit the long-term production rate to less than 350 gpm:

- A minimum separation between the pumping water level and the pump intake should be maintained.
- Long term pumping will result in slightly lower specific capacities than those observed during the relatively brief step-rate test.
- Some well performance changes are expected as a result of ASR operations.

It appears reasonable to expect that a long term target production rate between 300 and 330 gpm is sustainable. The majority of the drawdown that occurred during the step rate test occurred at the onset of pumping, and only minor change in specific capacity was observed as the production rate increased. This observation suggests that the majority of the losses creating the drawdown in the well are associated with aquifer losses (typically described as laminar) rather than turbulent losses in the wellbore (typically described as non-linear).

The Hantush-Beirschenk (1964) method allows for the percentage of total well losses attributable to aquifer losses to be estimated from step-rate test data. The equation for laminar well losses is defined as:

$$Lp = \frac{BQ}{BQ + CQ^2}$$

Where:

Lp = Well losses attributable to aquifer (laminar) losses
B = y-axis intercept of best fit line in Figure 4-5
Q = Discharge rate
C = Slope of best fit line in Figure 4-5

At the range of discharge rates observed during the step-rate test, the aquifer losses are estimated in Table 4-3.

These values indicate that turbulent (non-laminar) well losses account for only 1 percent of the total well losses at low discharge rates, increasing to 12 percent at 350 gpm. This is consistent with the observation that initial drawdown was substantial, subsequent step-increases in drawdown relatively small, and discharge rates relatively small for a borehole of this diameter (minimizing borehole velocity and turbulent losses). The observed fracture systems (cores and video surveys) and the magnitude of the total well losses suggest that the aquifer losses are likely related to laminar losses in a tight fracture network.

The step-rate test data were used to develop a Cooper-Jacob straight-line method estimate of aquifer transmissivity in Figure 4-7. This transmissivity estimate of 11,000 gpd/ft primarily reflects short-term aquifer response and is best used as a quality assurance check of the longer term test transmissivity estimate described in Section 5.

5.0 CONSTANT RATE AQUIFER TEST RESULTS

The aquifer test was comprised of three 72-hour phases: pre-test monitoring, pumping, and recovery. Water level data collected to evaluate the aquifer response during the test are presented as hydrographs, semi-log plots, and log-log plots.

5.1 Pre-Testing Monitoring Results

Pre-test monitoring began on September 4, 2004, and continued for 72 hours prior to the start of the constant rate pumping test. Following the step rate test, pre-test water level monitoring was initiated to evaluate background trends in the aquifer system. The purpose was to identify pre-test trends in the basalt aquifer and to evaluate the barometric efficiencies of the observation and test wells.

Water level monitoring of the Parker Well began on September 6, 2004, because of a delay in obtaining an access agreement from the landowner. Pre-test water level trends for the test well and observation wells are presented in Figures 5-1 through 5-7.

5.1.1 Test Well

The test well was continuing to recover from step rate testing prior to the constant rate test, and an increasing trend is apparent (Figure 5-1). As noted in the following section, two wells in the observation network appear to be in hydraulic connection with the ASR pilot well. These wells also exhibited a rising pre-test trend, so that trend may explain at least a portion of the increase. Small diurnal variations were also observed in water levels that do not appear to have been in response to barometric pressure changes. The observed variations appear to be attributable to earth tides.

5.1.2 Observation Wells

Large fluctuations in water levels were observed at the lower Lowe Well (51112) in response to cyclic use of the pump installed in the well during the pre-test monitoring period. The upper Lowe Well (51138) appeared to exhibit a subtle response to pumping from either the lower well or another nearby well. The Parker and Presser water levels only varied slightly because of cyclic pumping at each well. Water levels in the upper and lower Birko wells did not appear to vary considerably during the pre-test period.

The two wells (Presser 51605 and Lowe 51112) that responded to pumping at the Dallas pilot well also exhibited a rising trend prior to the constant rate test. Whether the trend is antecedent in this portion of the aquifer system or recovery from the step-rate testing is unclear.

5.2 Aquifer Test Description

The 72-hour constant rate test was started at noon on September 7, 2004. Pumping continued until noon on September 10, 2004. The observed average pumping rate (calculated from the totalizer reading) was 291 gpm. Approximately 1.25 million gallons of water was discharged to onsite settling ponds during the test and discharged through an existing permitted outfall. Small adjustments were made during the initial pumping to maintain the pumping rate.

5.2.1 Test Well

Pumping water levels in the test well are shown in Figure 5-8. Water levels in the test well dropped to 270 feet below static within the first 100 minutes of pumping.

Figure 5-9 is a semi-logarithmic plot of drawdown in the test well versus elapsed time. Aquifer transmissivity was estimated using the Cooper-Jacob Method (1946). The early portion of the response exhibits significant wellbore storage effects and the influence of small adjustments made to the flow rate. Flow rate adjustments were minor, but they resulted in large displacement of the pumping levels because of the low specific capacity of the well. A straight-line analysis of the early portion of the test indicates an estimated near-well transmissivity of approximately 20,000 gpd/ft.

After approximately 1 day of pumping, a negative boundary effect (a flow-limiting boundary) was encountered. The transmissivity decreased by approximately half, to 10,000 gpd/ft. The decrease in aquifer transmissivity could be a function of a change in fracture density at some distance from the well or to a decrease in thickness of the water-bearing zone away from the well. The late-time transmissivity estimate is in close agreement with the estimate derived from the step-rate test.

The boundary condition (and corresponding transmissivity shift) may reflect the arrival of higher density water entering the wellbore over the pumping period. Figure 5-12 shows the significant shift in fluid conductivity measured during the test, indicating an increasing proportion of saline water was entering the wellbore as the overlying (less dense) fresh water was removed. The denser saline water is heavier and will cause the rate of drawdown to appear to increase as the relative proportion of saline water increases. A more detailed description of density effects is included in Section 5.3.1.

5.2.2 Observation Wells

Water levels in observation wells during the pumping test are shown in Figures 5-2 through 5-7. No apparent response was observed in the Parker, lower Lowe (51112), lower Birko, and upper Birko wells. The upper Lowe Well and the Presser Well displayed an apparent response to pumping at the test well (Figures 5-6 and 5-7).

The responses were delayed and generally small in magnitude. Drawdown observed near the end of pumping at the observation wells is compared to theoretical values calculated using the Jacob-Cooper method in Table 5-1.

Given the fact that the aquifer system is comprised of a discrete fracture network (that is, not widely distributed as is evidenced by the lack of response at other observation wells), it seems more likely that the differences between theoretical and observed drawdown are the result of an incomplete hydraulic connection rather than a transmissivity change between the observation wells and test well. The lack of hydraulic connectivity may be because all observation wells are not deep enough to fully penetrate the fracture network. The negative boundary condition observed in the test well is not apparent in either the Presser Well or the upper Lowe (51138) well response. A more detailed discussion of observation well response will be presented in Section 5-4.

5.3 Recovery Monitoring Results

The 72-hour constant rate test was terminated and recovery monitoring initiated on September 10, 2004, and continued until September 14, 2004.

5.3.1 Test Well

Recovering water levels remained 10.4 feet below the pre-test static level ninety-four hours after pumping ceased. If an aquifer is homogeneous and of infinite areal extent, the pumping well will theoretically fully recover when the length of the recovery period is equal to the duration of the pumping period (where t/t' = 2, see Figure 5-10); in this case, 72 hours into the recovery period. At t/t' = 2, approximately 11 feet of residual drawdown remained. When the recovery response is projected toward the origin, (t/t' = 1), approximately 4-feet of residual drawdown is predicted. This amount of residual drawdown suggests that the aquifer is bounded and receives limited recharge. However, the residual drawdown appears to be a function (at least in part) of increasing fluid density (as indicated by increasing conductivity) observed during the test. Figure 5-12 illustrates the increase in fluid conductivity observed during the pumping period, showing the progression from relatively fresh to saline water. As a result, lower post-test static water levels are expected because of the difference between pre- and post-test fluid density in the borehole.

The specific weight of fresh water is 62.4 lbs/ft^3, and for seawater it is 64 lbs/ft^3. The volume of the borehole is estimated to be 2,527 ft^3, and for this volume the weight of the two different fluids are:

- Freshwater (62.4 lbs/ft^3) = 157,685 lbs
- Seawater (64 lbs/ft^3) = 161,728 lbs

The difference in weight is 4,043 lbs. At a point at the base of the borehole (201 in^2), this difference translates to approximately 20 lbs/in^2 (psi), or 46.5 feet of water.

If the difference in head at a production zone were estimated assuming that the salinity of the water entering the borehole was approximately one half that of seawater and the production zone is located at approximately 1,000 feet bgs, the increased pressure resulting from the density difference is equivalent to approximately 11 feet of water, the amount residual drawdown actually observed. This observation does not rule out changes in storage as a result of the test, but does show that it is reasonable that a large portion of the residual drawdown is the result of fluid density changes.

Based on recovery response, early time (near-well) transmissivity is estimated to be approximately 14,000 gpd/ft. Late time transmissivity decreases to 8,100 gpd/ft. An estimated effective transmissivity of 11,000 gpd/ft was calculated using the Jacob's straight line method, which is in good agreement with both the step-rate test and the constant-rate pumping results.

A line projecting pumping water levels over time is presented in Figure 5-11. This plot suggests that pumping water levels will decline 294 feet after 3 months of pumping and to a little over 295 feet after 4 months of pumping. If the static water level prior to the onset of pumping is 190 feet, then the pumping water levels would be 484 and 485 feet respectively at an average rate equivalent to the test rate of 291 gpm. Although this estimate is consistent with the 300 gpm production rate estimate derived from the step-rate test results, pumping levels are likely to be higher during ASR recovery operations when fresh water is pumped, and slightly higher rates could be sustainable. In addition, pre-pumping static water levels are expected to be higher after recharge operations, further raising pumping water levels.

5.3.2 Observation Wells

Observation wells, in general, displayed a decreasing trend in the recovery period (Figures 5-1 through 5-7). The slight decreasing trend observed at the Birko upper, Birko Lower, and Parker wells is likely the seasonal trend for the shallow aquifer. The two observation wells that responded to pumping were also slow to recover. The Lowe Well exhibited 3.86 feet of residual drawdown at the end of the recovery monitoring period, and the Presser Well 1.96 feet. Though both wells continued to recover, the residual drawdown is a large percentage of the observed total drawdown (about 82 percent and 88 percent, respectively). The net change in head is either the result of a change in storage or a broad pressure response because of fluid density changes near the test well.

The observation well response indicates that the fracture network encountered by the test well is complex and generally occurs below an elevation of 200 feet bgs. Table 5-2 illustrates the relationship between the base of well elevation and response.

5.4 Discussion of Aquifer Test Results

In summary, the aquifer system is a relatively discrete fracture network encountered below an elevation of 200 feet that exhibits an effective transmissivity of approximately 10,000 gpd/ft in the test well vicinity. Some nearby wells are hydraulically connected to the fracture network encountered by the test well, and others are not. Because of the low transmissivity of the fracture system and low well efficiency, drawdown in the test well is large, and production yield will be limited to approximately 300 gpm without lowering the pump intake below the base of the casing at 500 feet.

Figure 5-11-shows that specific capacity will decline to approximately 1 gpm/ft over a 4-month operational period, thus limiting production rates to approximately 300 gpm. To boost overall ASR system capacity to 1 MGD (a preliminary target delivery rate set by the City), two additional ASR wells would be required assuming aquifer properties are uniform.

The target recharge rate is estimated using the following assumptions:

- The recharge specific capacity is equivalent to the pumping specific capacity: 1 gpm/ft
- Recharge water levels will be maintained at least 5 feet below ground surface
- The static water level is 190 feet, creating 185 feet of available head increase within the wellbore

With a recharge specific capacity equal to 1 gpm/ft and 185 feet of available buildup, the recharge rate would be limited to 185 gpm. Over a 6-month recharge period (assumed November through April) this would result in roughly 48 million gallons stored. At 300 gpm, this volume would require 3.7 months to recover, roughly the duration of the summer peak demand period. A more detailed storage analysis resulting in modified rates and target storage volumes is presented in Section 6.2.

Two of the six observation wells responded to test pumping. The two responding wells are in nearly opposite directions from the test well (one northwest, one south), and wells much closer did not respond. Based on this observation, the hydraulic response appears depth-dependent, with only wells with base elevations below 200 feet responding. The two wells at the Lowe property suggest that the hydraulic connectivity is not a function of position: the shallow Lowe Well is closer to the test well and did not respond, while the deeper well did. This is an indication that (along with the pumping response that did not indicate an additional source of recharge to the system) ASR operations are unlikely to interact with Rickreall Creek.

The relatively large magnitude of the observation well response is a function of both the low transmissivity and extremely low storage coefficient of the fracture network. Hydraulic response to the aquifer test is further complicated by the change in fluid density observed during testing.

6.0 CONCEPTUAL MODEL FOR ASR

6.1 Conceptual Storage Model

During drilling, significant fracture zones were encountered at depths of 500-600, 680-720, and at 760 feet bgs which were confirmed by drilling production/performance increases and static borehole measurements. These depths represent the target storage zone for the Dallas ASR#1 well. No significant changes in static water level were apparent during drilling, suggesting these zones are hydraulically connected. The casing and seal in ASR No.1 that is designed to limit hydraulic connections with the shallow portion of the SRV which is locally a target for domestic supply wells. Along with the lack of response in shallow wells observed during testing, there appears to be little potential for hydraulic interaction with shallow groundwater (except through wells open to a broad range of depth intervals) and surface water.

It is likely that the water contained in these fractures results from recharge at higher elevations in the Coast Range to the west. Groundwater flow directions are likely from the higher elevations to the west toward the regional discharge point of the Willamette River system to the east. It is likely that water confined in the Siletz River Volcanics is discharged to the Willamette Formation at depth along the down-warped western edge of the Willamette trough.

It is unknown whether fracture zones in the SRV exist at depths/elevations reflecting the post-emplacement structural deformation that resulted in the Willamette lowlands (i.e. down-warped on their western edge), or the fracturing is the result of post-deformation tectonic stresses. In either case, the confined water in the SRV Formation is likely in hydraulic connection with the thick sequence of Willamette Formation sediments that form the valley fill. Because the Willamette Formation in the Dallas area is generally low permeability and contains brackish or saline groundwater, few (if any) water supply wells target this unit at depth, and hydraulic interaction between the formations is not considered likely to influence groundwater users with sedimentary formation wells.

During the aquifer test, the conductivity of the discharge water increased, indicating a progressively higher proportion of saline water was drawn into the well as the test progressed. The lower post-test water level that appeared to be the result of higher density and the static fluid resistivity measurements also indicate a freshwater layer floating above more saline water at depth. Saline groundwater in the deeper portions of the aquifer are likely to represent water recharge at a more distant location (i.e., longer residence time due to the longer flow path) providing opportunity to develop a higher concentration of dissolved solids reflecting the marine depositional environment of the volcanic and adjacent sedimentary sequence.

To be considered successful, ASR operations will need to displace saline water in the fracture network and recover relatively low TDS stored water. The first year of ASR pilot testing will begin with a succession of relatively brief low-volume storage cycles to evaluate the potential to increase recovery efficiency as the storage zone is developed. Depending on the start date for pilot testing and consequently water availability, up to four brief ASR cycles will be conducted at the site. Each of these initial cycles will be approximately one week in duration, with 3 days of recharge, up to 2 days of storage, and up to 2 days of recovery pumping. After completing the initial cycles, an extended ASR cycle with recharge occurring through May 2006 will be conducted to begin development of a larger fresh water storage zone for full scale operations at the site. Additional details regarding the proposed ASR pilot testing program are presented in *Aquifer Storage and Recovery Pilot Test Work Plan: City of Dallas, Oregon* (Golder, 2005).

6.2 ASR Well Interference Analysis

A well interference analysis using the Cooper/Jacob distance-drawdown technique was conducted to evaluate the hydraulic effects resulting from ASR pilot testing at the existing well (ASR #1).

The relationship used in this analysis is defined by the following:

$$s = \frac{-528Q}{T}\left[\log(r) + 0.5\log\left(\frac{S}{0.3Tt}\right)\right]$$

Where:

s = drawdown or buildup (feet)
Q = well pumping or recharge rate (gpm)
r = distance away from the well (feet)
S = storativity (dimensionless)
T = transmissivity (gpd/ft)
t = time since pumping or recharge started (days)

Groundwater levels in a well can be affected by hydraulic impacts from other nearby wells. Separate pumping and recharge scenarios were examined to determine the following:

- Maximum sustainable pumping/recharge rates and associated volumes;
- Optimal well site location (to minimize well interference effects), and;
- The projected effects on offsite water levels resulting from ASR operations.

Table 6-1 provides information about ASR #1, including the estimated ground surface elevation and well coordinates. The interference analysis was performed based upon the following assumptions:

- Available drawdown in ASR #1 is 300 feet, based on observed conditions with 300 feet of water above the base of the surface casing.
- The initial groundwater elevation is 409 feet msl at ASR #1 based upon September 2004 static groundwater levels.
- Well efficiency is estimated at 25 percent based upon a calculated well efficiency for ASR #1 during 2004 aquifer testing.
- Aquifer properties (transmissivity and storativity) are constant across the site (11,000 gpd/ft and 1 x 10^{-4}, respectively).
- The recovery (ASR pumping) period is assumed to be 6 months.
- Saturated aquifer thickness (cumulative thickness of permeable zones) is 100 feet (based upon static flow meter survey data). The estimated porosity is 0.15.
- Drawdown or buildup effects related to variable density (salinity) and temperature are neglected.

6.2.1 Distance-Drawdown Analysis

Table 6-2 summarizes the results of a distance-drawdown analysis shown in Figure 6-1. ASR #1 will produce a minimum of 291 gpm (0.42 MGD) while maintaining the pumping water level above the base of the surface casing over a 6-month recovery period.

6.2.2 Recharge Analysis

Table 6-3 depicts the maximum recharge rate that could be applied while maintaining the recharge water level in the well below ground surface (by about 10 feet) (Figure 6-2). The results of the recharge analysis indicate that the total annual storage volume attainable at the City's WTP site, if recharge occurs for a 6-month period, is 175 gpm for 45 MG/yr.

6.2.3 Offsite Well Interference Assessment

During the September 2004 aquifer test, the Lowe well (51112) responded with 4.3 feet of observed drawdown and the Presser well (51605) with 2.5 feet. The predicted drawdown at these wells was 11.9 feet and 3.3 feet, respectively, for Lowe and Presser wells based upon Cooper-Jacob analysis of the 2004 test data. Maintaining this ratio of observed to theoretical drawdown for these wells, the expected drawdown over 180 days of pumping (summarized in Table 6-4) is 9 feet for the Lowe well and 12 feet for the Presser well.

The effects of recharge were examined for these wells to assess the potential for water levels to approach ground surface. Results are shown in Table 6-5. When recharge rates at ASR #1 are restricted to maintain groundwater levels below ground surface, the theoretical buildup in nearby wells is 14 feet for Lowe well and 10 feet for Presser well. Using test response ratios to adjust these predictions, the anticipated buildup is 5 feet in the Lowe well and 7 feet in the Presser well.

There does not appear to be a risk of groundwater levels rising above ground level at the Lowe and Presser wells. The expected buildup will remain approximately 50-feet below ground surface at the Lowe well. At the Presser well, this maximum expected water level should remain approximately 134 feet below ground surface.

6.3 Aquifer Storage Capacity

Water that is recharged into an aquifer displaces native groundwater, forming a recharge "bubble". The radius of this bubble may be estimated based upon the following relationship:

$$\text{Radius of Bubble} = \sqrt{\frac{V}{7.48 * \pi * b * n_e}}$$

Where:

V= volume of water recharged (gallons)
π = pi
b = saturated aquifer thickness (feet)
n_e = effective porosity

Based upon an assumed saturated aquifer thickness of 100 feet and an effective porosity of 0.15, a single-well system recharged for 180 days at 175 gpm would produce a bubble radius of 359 feet. These results are summarized in Table 6-6.

6.4 Stored Water Drift

Observation wells in hydraulic connection with ASR #1 are likely to be connected to shallower zones of permeability hydraulically isolated by the 500 feet of casing and seal at ASR #1. In addition, some of the wells available for monitoring are in use as domestic supply wells. Consequently, water level elevations collected at observation wells are not likely to provide a precise assessment of groundwater gradients and flow directions. Nonetheless, groundwater levels measured at ASR # 1 and the two observation wells that responded to testing (Presser 51605 and Lowe 51112) were used to calculate a hydraulic gradient of approximately 0.0077 ft/ft, with a flow direction to the east-southeast. This flow direction generally is consistent with the expected flow directions. In the absence of a network of similarly completed wells providing static water levels for a more accurate estimate, this hydraulic gradient and flow direction will be used to evaluate the drift of stored water.

Given the relatively shallow gradient in the ASR vicinity, the total amount of drift relative to the recharge induced gradient is expected to be minimal. During the storage period, the drift is governed by the hydraulic conductivity, hydraulic gradient, and effective porosity of the system and the amount of time the water is stored in the aquifer. During a maximum storage period of 120 days, water is estimated to drift about 91 feet to the southeast (Table 6-6). This distance represents about 25 percent of the total bubble radius of 359 feet from the storage of 45 MG. This amount of potential drift may result in relatively low recovery efficiencies due to migration of the mixing zone. However, because the City will likely prefer to recover stored later in the summer season, lower recovery efficiencies are acceptable in order to obtain the security of a backup water source during times that are typically characterized with the lowest water availability.

8.0 SUMMARY AND RECOMMENDATIONS

The aquifer in the vicinity of the test well (ASR #1) at the City of Dallas WTP appears capable of storing water at a rate of approximately 175 gpm and recovering that water at a rate of approximately 300 gpm for a single-well system. The fracture permeability encountered by the test well appears to reside below a depth of 550 feet bgs and above 900 feet bgs.

The native groundwater system appears stratified with both fresh and saline groundwater present. ASR systems have been successfully developed in several saline aquifer systems within the United States, including aquifers with significantly higher salinity/TDS levels. ASR systems use the stored water to develop a mixing/buffer zone between the recharge water and the saline native groundwater. The process for developing the buffer zone for storing fresh water involves repeated recharge and recovery cycles to displace the saline water. Residual fresh water not recovered in one cycle then becomes the buffer zone surrounding the stored water of the following cycle. With repeated cycles, the recovery efficiency of the ASR system should improve, where recovery efficiency is the volumetric ratio of recovered water to the volume recharged. Typically, three to six ASR cycles are necessary to develop a sufficient buffer zone (Pyne, 1994). The ultimate recovery efficiency that is attainable for any given site has to be determined through pilot testing and operations.

A geochemical compatibility assessment of WTP source water and groundwater was conducted to predict mixing effects. The results of the geochemical modeling analysis indicate the potential for small amounts of ferrihydrite precipitation. Overall, geochemical modeling identified little potential for mineral precipitation. In order to assess whether ferrihydrite precipitation will occur during ASR operations, well performance criteria and water quality data will be monitored during the first year of pilot testing.

It is recommended that pilot testing first be conducted for a single-well system (using ASR #1) to evaluate the aquifer's response to ASR operations, monitor the potential for adverse geochemical reactions to affect the feasibility of the site, and assess the progress of developing a viable storage zone within the saline aquifer. Should the results from the first year of pilot testing indicate favorable conditions for the expansion of the City's ASR system, a detailed plan for drilling and testing new wells will be developed. Additional wells constructed at the WTP site should target a depth of approximately 900 feet and be drilled with smaller diameter boreholes designed for target production rates in the vicinity of 300 gpm.

Pilot testing during Year 1 at ASR #1 will consist of several discrete recharge, storage, and recovery cycles (up to four short cycles and one extended cycle). Year 1 testing is expected to commence in January 2006. The schedule for pilot testing during Years 2 through 5 is based upon the expected available supply for recharge between the months of November through May with recovery anticipated to take place during the summer and autumn months. Ultimately, the volume of recharged water is contingent upon the time of year when testing begins, but the City anticipates that recharge will occur for at least 120 days and up to 180 days each year. Data regarding aquifer and well performance and water quality will be collected at several stages throughout cycle testing for analysis and reporting. Details of the proposed pilot test work plan are provided in the *Aquifer Storage and Recovery Pilot Test Work Plan* (Golder Associates, 2005). Included are proposed plans for pilot testing and the expansion of the ASR system should the results from the first year of testing indicate favorable conditions for additional ASR wells.

TABLE 3-1. SUMMARY OF COLLECTED CORES, ASR TEST WELL
City of Dallas ASR Hydrogeologic Feasibility Study, 2005

Core Interval	Percent Recovery	Description
725-730	100	Basalt- Black to greenish grey, moderately fractured, secondary quartz and calcite lining fractures
803-808	100	Basalt- Black to greenish grey, minor fracturing, secondary quartz and calcite lining fractures
893-898	100	Basalt- Black to greenish grey, heavily fractured, secondary quartz and calcite lining fractures
943-948	100	Volcanic Breccia, angular basalt fragments within green clay-sized matrix, matrix hard and well lithified
1116-1121	100	Basalt - grey to greenish black, minor secondary quartz and calcite infilling fractures and vesicles, heavily fractured with some fractures "healed"
1288-1293	100	Basalt, Red to green, oxidized, moderate fracturing, secondary quartz and calcite in fractures and vesicles
1704-1709	100	Amygdaloidal[1] Basalt, grey to greenish grey, amygdules filled with quartz and calcite, only minor fractures.

[1]Amygdaloidal texture is characterized by gas cavity or vesicle that has been filled by secondary minerals such as quartz or calcite

TABLE 4.1 OBSERVATION WELL NETWORK - DALLAS, OREGON
City of Dallas ASR Hydrogeologic Feasibility Study, 2005

OWRD ID	Owner Name	Depth (feet bgs)	Pump Installed?	Monitoring Method	Approx. Distance from Test Well (feet)
POLK 52056 (ASR #1)	City of Dallas	2001	Test Pump	Electronic & Manual	0
POLK 51138	Fred Lowe	182	Yes	Manual	1600
POLK 51112	Fred Lowe	291	No	Electronic & Manual	1600
POLK 572	Woody Birko	40	Yes	Manual	700
POLK 539	Woody Birko	270	No	Electronic & Manual	1000
POLK 2762	L.D. Parker	321	Yes	Manual	4600
POLK 51605	Paul Presser	459	Yes	Manual	5800

TABLE 4.2 OBSERVATION WELL NETWORK ELEVATIONS- DALLAS, OREGON
City of Dallas ASR Hydrogeologic Feasibility Study, 2005

OWRD ID	Owner Name	Depth (feet bgs)	Estimated Surface Elevation(1) (feet, msl)	Estimated Base of Well Elevation (feet, msl)	Approx. Distance from Pumping Well (feet)
POLK 52056 (ASR #1)	City of Dallas	2001	570	-1,431	0
	ASR #1 Casing/Seal	*500*	*570*	*70*	*0*
POLK 51138	Fred Lowe	182	430	248	1,600
POLK 51112	Fred Lowe	291	450	159	1,600
POLK 572	Woody Birko	40	410	370	700
POLK 593	Woody Birko	270	470	200	1,000
POLK 2762	L.D. Parker	321	720	399	4,600
POLK 51605	Paul Presser	459	490	31	5,800

(1) Surface Elevations Estimated from USGS 7.5 minute quadrangle, accurate to within +/- 10 feet.

TABLE 4.3 STEP-RATE TEST, LAMINAR LOSS ESTIMATES
City of Dallas ASR Hydrogeologic Feasibility Study, 2005

Discharge Rate (gpm)	Drawdown (ft)	Incremental Drawdown (ft)	% Laminar Well Losses
220	187.2	187	99%
267	232.4	45	91%
300	263*	31	90%
320	281.9	19	89%
350	312*	30	88%

* Calculated from Figure 4-5

TABLE 5-1. COMPARISON OF THEORETICAL DRAWDOWN TO OBSERVED DRAWDOWN AT OBSERVATION WELLS
City of Dallas ASR Hydrogeologic Feasibility Study, 2004

Location	Pumping Rate (gpm)	Aquifer Transmissivity (gpd/ft)	Distance from Test Well (feet)	Observed Drawdown (feet)	Predicted Drawdown (feet)
Lowe Well	291	10,000	1,600	4.3	11.9
Presser Well	291	10,000	5,800	2.5	3.3

Theoretical drawdown predicted using the Jacob-Cooper Equation (Driscoll, 1986)
$s = (264*Q/T)\log[(0.3Tt)/(r^2S)]$, where
s = drawdown (feet)
Q = pumping rate at Test Well (gallons per minute)
T = Transmissivity (gallons per day per foot)
t = time since pumping started (days). [value used = 3 days]
R = radius from pumping well (feet)
S = storage coefficient (dimensionless) [value used = 1.0×10^{-4}]

TABLE 5-2 OBSERVATION WELL NETWORK BASE ELEVATIONS- DALLAS, OREGON
City of Dallas ASR Hydrogeologic Feasibility Study, 2005

OWRD ID	Owner Name	Depth (feet bgs)	Estimated Surface Elevation(1) (feet msl)	Estimated Base of Well Elevation (feet)	Responded to Pumping?
POLK 52056	ASR Test Well	2001	570	-1,431	--
POLK 51605	Paul Presser	459	490	31	Yes
POLK 51112	Fred Lowe	291	450	159	Yes
-------------	-------------	-------------	-------------	200' Elevation	-------------
POLK 593	Woody Birko	270	470	200	No
POLK 51138	Fred Lowe	182	430	248	No
POLK 572	Woody Birko	40	410	370	No
POLK 2762	L.D. Parker	321	720	399	No

(1) Surface Elevations Estimated from USGS 7.5 minute quadrangle, accurate to within +/- 10 feet.

Table 6-1 Well Information

Well Summary:					
Well	Estimated Ground Surface Elevation (feet msl)	Northing	Easting	Latitude	Longitude
ASR #1	599	470845	7460965	44' 55' 17.09"	- 124' 38' 16.71"

Note: Well location is estimated based upon the "Plot Plan Water Treatment Plant" diagram and coordinates taken from the Polk County website: http://apps.co.polk.or.us

Table 6-2 Pumping Analysis

Constant Pumping Rate (gpm)	Total Available MGD Pumped[1]	Predicted Drawdown in Well (feet)[2,3]
291	0.42	295

Notes:
[1] Assumes maximum available drawdown of 300 feet and a pumping duration of 180 days with base of well casing set at 300 feet below static
[2] Assumes a 25 percent well efficiency based upon calculated well efficiency for well ASR #1 noted during the 72-hour constant rate pumping test conducted in September 2004
[3] Assumes aquifer properties transmissivity and storativity are constant across the site at 11,000 gpd/ft and 1x10-4, respectively

Table 6-3 Recharge Analysis

Constant Recharge Rate (gpm)[1]	Total Available MGD Recharged	Recharge Over 180 Days (MG/yr)	Predicted Buildup in Well (feet)[2,3]	Maximum recharged water elevation (feet msl)[4]	Difference Between Estimated Maximum Buildup and Ground Surface Elevation (feet)[5]
175	0.25	45	180.24	589.24	-9.76

Notes:
[1] Assumes recharge rate based upon anticipated buildup to avoid well construction for under pressurized conditions
[2] Assumes a 25 percent well efficiency for each well based upon calculated well efficiency for well ASR #1 noted during the 72-hour constant rate pumping test conducted in September 2004
[3] Assumes aquifer properties transmissivity and storativity are constant across the site at 11,000 gpd/ft and 1x10-4, respectively
[4] Assumes initial groundwater elevation is 409 feet msl at ASR #1 (based upon static groundwater elevation at ASR #1 prior to September 2004 testing)
[5] Ground surface elevation is considered in the recharge evaluation

Table 6-4 Offsite Well Analysis for Pumping Scenarios

	Lowe Well (51112)		Presser Well (51605)	
Pumping Rate (MGD)	Theoretical Drawdown (feet)[2,4]	Expected Drawdown (feet)[5]	Theoretical Drawdown (feet)[3,4]	Expected Drawdown (feet)[5]
0.42	23.55	8.51	15.70	11.89

Notes:
[1] Distance-drawdown calculations are based upon theoretical estimates using the Cooper-Jacob analysis and assuming constant aquifer properties (transmissivity of 11,000 gpd/ft and storativity of $1x10^{-4}$); pumping time is 180 days
[2] Well 51112 is located about 1,600 feet away from well ASR #1 from the "City of Dallas ASR Feasibility Study Drilling, Testing, and Water Quality Monitoring Program" report dated April 2005
[3] Well 51605 is located about 5,800 feet away from well ASR #1 from the "City of Dallas ASR Feasibility Study Drilling, Testing, and Water Quality Monitoring Program" report dated April 2005
[4] Assumes static groundwater elevation at Well 51112 is 394.3 feet msl and at Well 51605 is 348.6 feet msl based upon observed statics recorded in September 2004
[5] Applies ratio between observed and predicted drawdown from September 2004 testing to ASR pilot testing (0.3613 and 0.7576 times less for Lowe and Presser wells, respectively)

Table 6-5 Offsite Well Analysis for Recharge Scenarios

		Lowe Well (51112)			Presser Well (51605)		
Scenario[1]	Recharge (MGD)	Theoretical Buildup (feet)[2]	Expected Buildup (feet)[6]	Difference Between Expected Buildup and Ground Surface Elevation (feet)[4,5]	Theoretical Buildup (feet)[3]	Expected Buildup (feet)[6]	Difference Between Expected Buildup and Ground Surface Elevation (feet)[4,5]
Recharge adjusted for surface elevation effects	0.25	14.16	5.12	-50.58	9.44	7.15	-134.25

Notes:
[1] Predicted buildup calculations are based upon theoretical estimates using the Cooper-Jacob analysis and assuming constant aquifer properties (transmissivity of 11,000 gpd/ft and storativity of $1x10^{-4}$); recharge time is 180 days
[2] Well 51112 is located about 1,600 feet away from Well ASR #1 with an estimated ground surface elevation of 450 feet msl from the "City of Dallas ASR Feasibility Study Drilling, Testing, and Water Quality Monitoring Program" report dated April 2005
[3] Well 51605 is located about 5,800 feet away from Well ASR #1 with an estimated ground surface elevation of 490 feet msl from the "City of Dallas ASR Feasibility Study Drilling, Testing, and Water Quality Monitoring Program" report dated April 2005
[4] Assumes static groundwater elevation at Well 51112 is 394.3 feet msl and at Well 51605 is 348.6 feet msl based upon observed statics recorded in September 2004
[5] A negative value indicates the groundwater level during recharge conditions is estimated to be below ground level in the well
[6] Applies ratio between observed and predicted drawdown from September 2004 testing to ASR pilot testing (0.3613 and 0.7576 times less for Lowe and Presser wells, respectively)

City of Dallas ASR
Table 6-6 Recharged Water Drift Analysis

Assumptions:	
Hydraulic gradient (dh/dl)	0.0077 ft/ft
(note - gradient is based upon observed static groundwater levels recorded on 9-6-04 in existing ASR well (52056) and 2 responding observation wells, 51605 and 51112	
Transmissivity (T)	11,000 gpd/ft
Saturated aquifer thickness (b)	100 feet
(note- saturated aquifer thickness is based upon review of static flow meter survey data)	
Recharged water storage time in aquifer (t)	120 days
Effective porosity (n_e)	0.15 (-)
Hydraulic conductivity is K = T/b	14.71 K in ft/day
Specific discharge is q = (K* dh/dl)	0.11 q in ft/day
Velocity is $v = q/n_e$	0.75 v in ft/day
Amount of Drift	**91 ft**

Recharge "Bubble" Analysis for a Single Well

Parameters	
Recharge rate	175 gpm
Recharged volume over 180 day recharge period (V)	4.536E+07 gallons
Saturated aquifer thickness (b)	100 feet
Effective porosity (n_e)	0.15 (-)
Assumes a recharge duration of	180 days

"Bubble" radius (r) (ft) = $[V/((7.48)(pi)(b)(n_e))]^{0.5}$

r= 358.73 ft

Percentage drift relative to bubble radius = **25 percent**

Table 7-1
Results of Source Water and Groundwater Mixing
Dallas ASR Hydrogeologic Feasibility Study - Geochemical Assessment

Parameter	Unit	Input		Conceptual Mixtures			
		SOURCE WATER	GROUNDWATER	80% source 20% groundwater	60% source 40% groundwater	40% source 60% groundwater	20% source 80% groundwater
pH	s.u.	***7.3***	***8.7***	7.3	7.5	7.5	7.9
Alkalinity	mg/L as CaCO3	20	12	20	18	18	17
Nitrite	mg/L as N	0.10	0.39	0.10	0.16	0.16	0.22
Chloride	mg/L	8.2	2560	8	519	519	1029
Fluoride	mg/L	0	0.44	0.00	0.09	0.09	0.18
Sulfate	mg/L	5.6	12	5.6	6.9	6.9	8
Aluminum	mg/L	0.10	0.10	0.10	0.10	0.10	0.10
Arsenic	mg/L	0.002	0.002	0.002	0.002	0.002	0.002
Barium	mg/L	0.025	0.025	0.025	0.025	0.025	0.025
Beryllium	mg/L	0.040	0.040	0.040	0.040	0.040	0.040
Calcium	mg/L	8.0	793	8	165	165	322
Cadmium	mg/L	0.005	0.005	0.005	0.005	0.005	0.005
Chromium	mg/L	0.01	0.01	0.01	0.01	0.01	0.01
Copper	mg/L	0.000	0.013	0.000	0.003	0.003	0.005
Iron	mg/L	***0.005***	***0.013***	0.001	0.007	0.001	0.008
Lead	mg/L	0.003	0.003	0.003	0.003	0.003	0.003
Magnesium	mg/L	1.8	5.7	1.8	2.6	2.6	3.4
Manganese	mg/L	0.01	0.01	0.01	0.01	0.01	0.01
Mercury	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Nickel	mg/L	0.02	0.02	0.02	0.02	0.02	0.02
Potassium	mg/L	0.27	730	0	146	146	292
Selenium	mg/L	0.002	0.002	0.002	0.002	0.002	0.002
Silicon	mg/L	13	26	13	16	16	18
Silver	mg/L	0.01	0.01	0.01	0.01	0.01	0.01
Sodium	mg/L	3.9	321	4	67	67	131
Thallium	mg/L	0.002	0.002	0.002	0.002	0.002	0.002
Zinc	mg/L	0.02	0.02	0.02	0.02	0.02	0.02

Bold Italic: Reanalysed in July, 2005. All other parameters analyzed from samples collected in September, 2004.

Table 7-2
Summary of Geochemical Analyses
City of Dallas ASR

			DASR-1	DASR-2	DASR-3	DASR-4	DASR-5
		Depth	725	807	894	944	1117
		Description	Dark green, fine grained, massive basalt; fractures with slick alteration surfaces noted.	Dark green, fine grained, massive basalt; fractures with slick alteration surfaces noted; rare pillow structures noted.	Dark green, fine grained, massive basalt; fractures with slick alteration surfaces noted.	Coarse grained, green basalt, locally fractured, weakly altered with soft, dark green "clayey" alteration products.	Fine grained, fractured, oxidized basalt; appears to be fractured with occasional "healed" fractures.
CEC	meq/100g	CEC	12	24	21.8	51.1	31.5
XRF	Wt %	Na2O	2.72	2.15	2.34	1.15	2.11
XRF	Wt %	MgO	6.95	6.43	7.3	11.5	7.19
XRF	Wt %	Al2O3	17.8	14.6	15.4	10.7	13
XRF	Wt %	SiO2	51.9	46	49	38.8	46.2
XRF	Wt %	P2O5	0.24	0.23	0.25	0.17	0.39
XRF	Wt %	S	<0.05	0.07	<0.05	<0.05	<0.05
XRF	Wt %	Cl	<0.02	<0.02	<0.02	0.06	<0.02
XRF	Wt %	K2O	0.25	0.13	0.13	1.33	0.55
XRF	Wt %	CaO	13.1	12.4	11.6	7.62	9.2
XRF	Wt %	TiO2	1.97	2.02	2.08	1.33	2.35
XRF	Wt %	MnO	0.17	0.2	0.16	0.13	0.14
XRF	Wt %	Fe2O3	13.1	13.7	13.8	11.7	15.3
XRF	Wt %	BaO	<0.01	<0.01	<0.01	<0.01	<0.01
XRF	ppm	V	330	344	331	235	365
XRF	ppm	Cr	311	218	209	221	74
XRF	ppm	Co	60	63	60	54	59
XRF	ppm	Ni	93	82	83	91	59
XRF	ppm	W	<10	<10	<10	<10	<10
XRF	ppm	Cu	184	173	100	121	214
XRF	ppm	Zn	97	99	104	72	133
XRF	ppm	As	<20	<20	<20	<20	<20
XRF	ppm	Sn	119	149	139	19)	170
XRF	ppm	Pb	<10	<10	<10	<10	<10
XRF	ppm	Mo	<10	<10	<10	<10	18
XRF	ppm	Sr	292	243	233	432	229
XRF	ppm	U	24	20	12	27	15
XRF	ppm	Th	<10	10	<10	<10	<10
XRF	ppm	Nb	11	11	12	<10	19
XRF	ppm	Zr	101	105	103	74	188
XRF	ppm	Rb	<10	<10	<10	18	<10
XRF	ppm	Y	29	31	26	17	43
BULK MINERALOGY	~ wt %	Plagioclase feldspar	52	40	48	-	40
BULK MINERALOGY	~ wt %	Clinopyroxene	45	34	33	35	25
BULK MINERALOGY	~ wt %	Analcime	-	-	-	9	-
BULK MINERALOGY	~ wt %	K-feldspar	-	-	-	<5	-
BULK MINERALOGY	~ wt %	Smectite	<5?	-	12	44	27
BULK MINERALOGY	~ wt %	Vermiculite	-	20	-	-	-
BULK MINERALOGY	~ wt %	Ilmenite	-	-	<5	-	<5
BULK MINERALOGY	~ wt %	Magnetite	-	<5	-	-	-
BULK MINERALOGY	~ wt %	Calcite	-	-	-	<5	-
BULK MINERALOGY	~ wt %	"Unidentified"	<5	<5	<5	<5	<5
CLAY MINERALGOY	~ wt %	Smectite	>85	-	>90	>90	>80
CLAY MINERALGOY	~ wt %	Chlorite	<5?	25	-	-	-
CLAY MINERALGOY	~ wt %	Mica/illite	<3?	-	-	<3?	<3
CLAY MINERALGOY	~ wt %	Vermiculite	-	<20	-	-	-
CLAY MINERALGOY	~ wt %	Kaolinite	-	-	-	<5	<5
CLAY MINERALGOY	~ wt %	Plagioclase feldspar	<5	55	<5	-	<5?
CLAY MINERALGOY	~ wt %	K-feldspar	-	-	-	-	<3?
CLAY MINERALGOY	~ wt %	Analcime	-	-	-	<3	-
CLAY MINERALGOY	~ wt %	Calcite	-	-	-	<3	-
CLAY MINERALGOY	~ wt %	Quartz	-	-	-	-	<3
CLAY MINERALGOY	~ wt %	"Unidentified"	<5	<5	<5	<5	<5

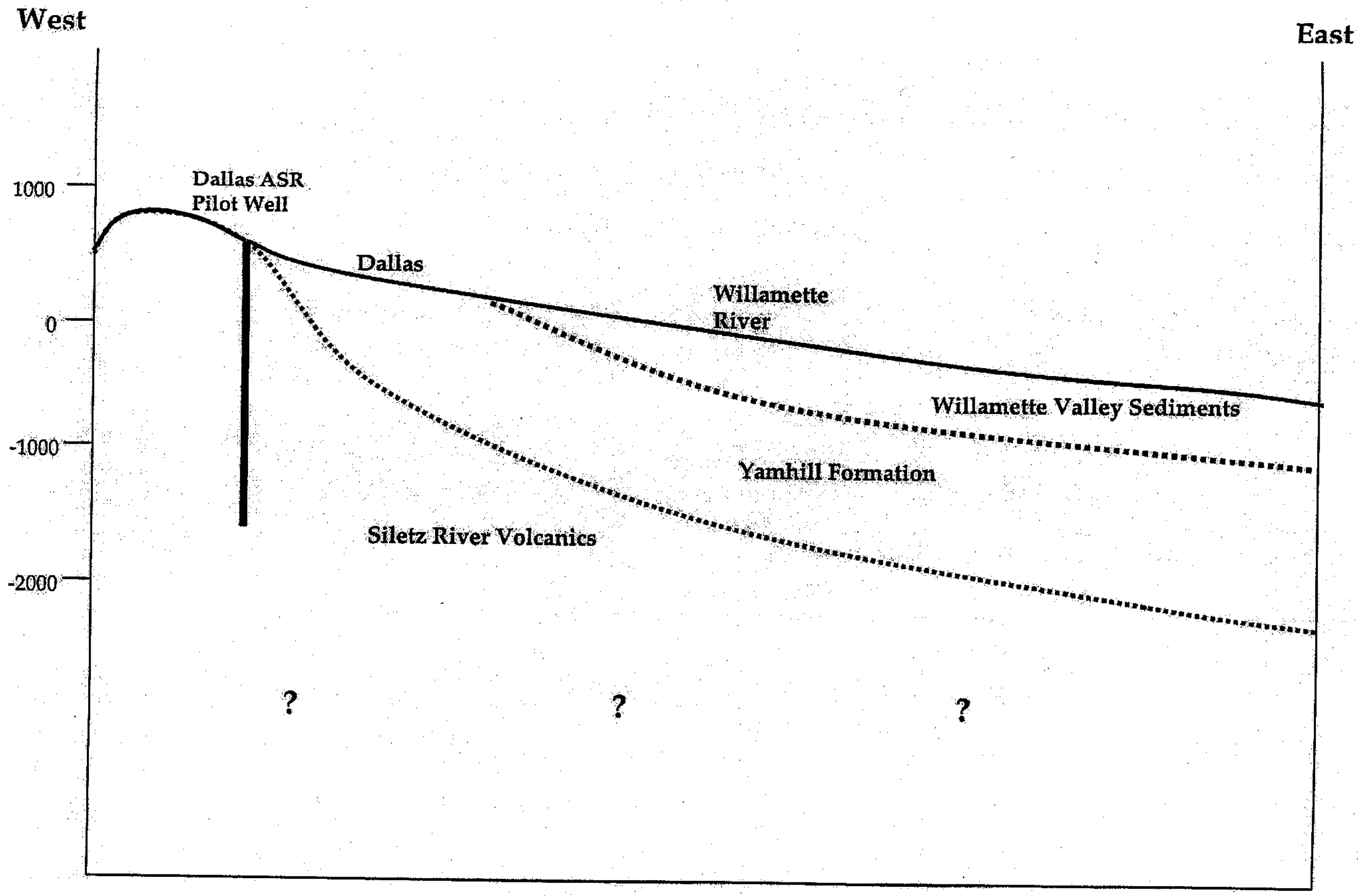


Figure 2-2. Generalized Geologic Cross Section

Figure 4-4. Dallas ASR Pilot Well Step Rate Test, 9/3/2004
City of Dallas ASR Feasibility Study, 2004

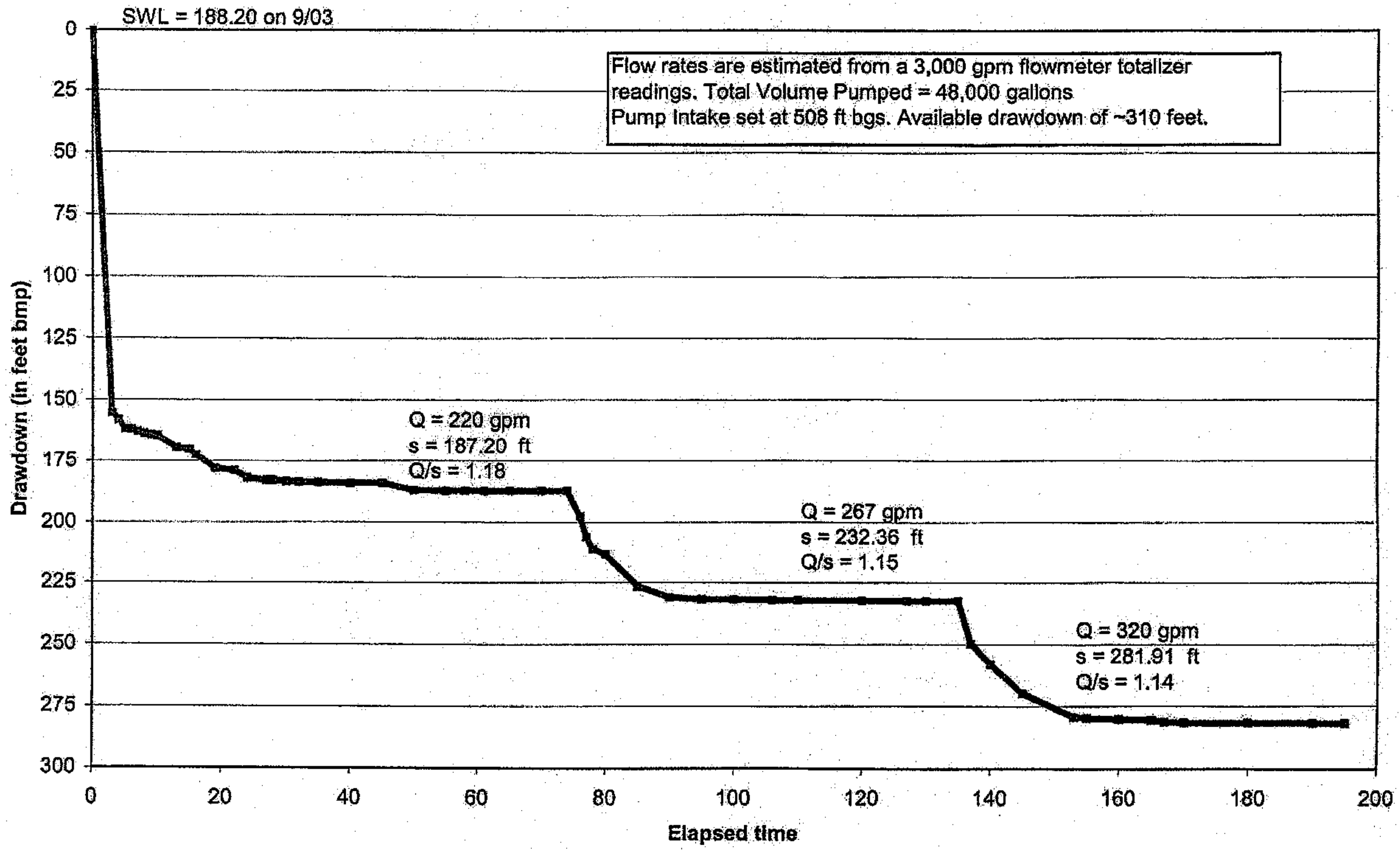


Figure 4-5. City of Dallas ASR Pilot Well Step Rate Test
Relationship Between Pumping Rate (Q) and Drawdown (s)

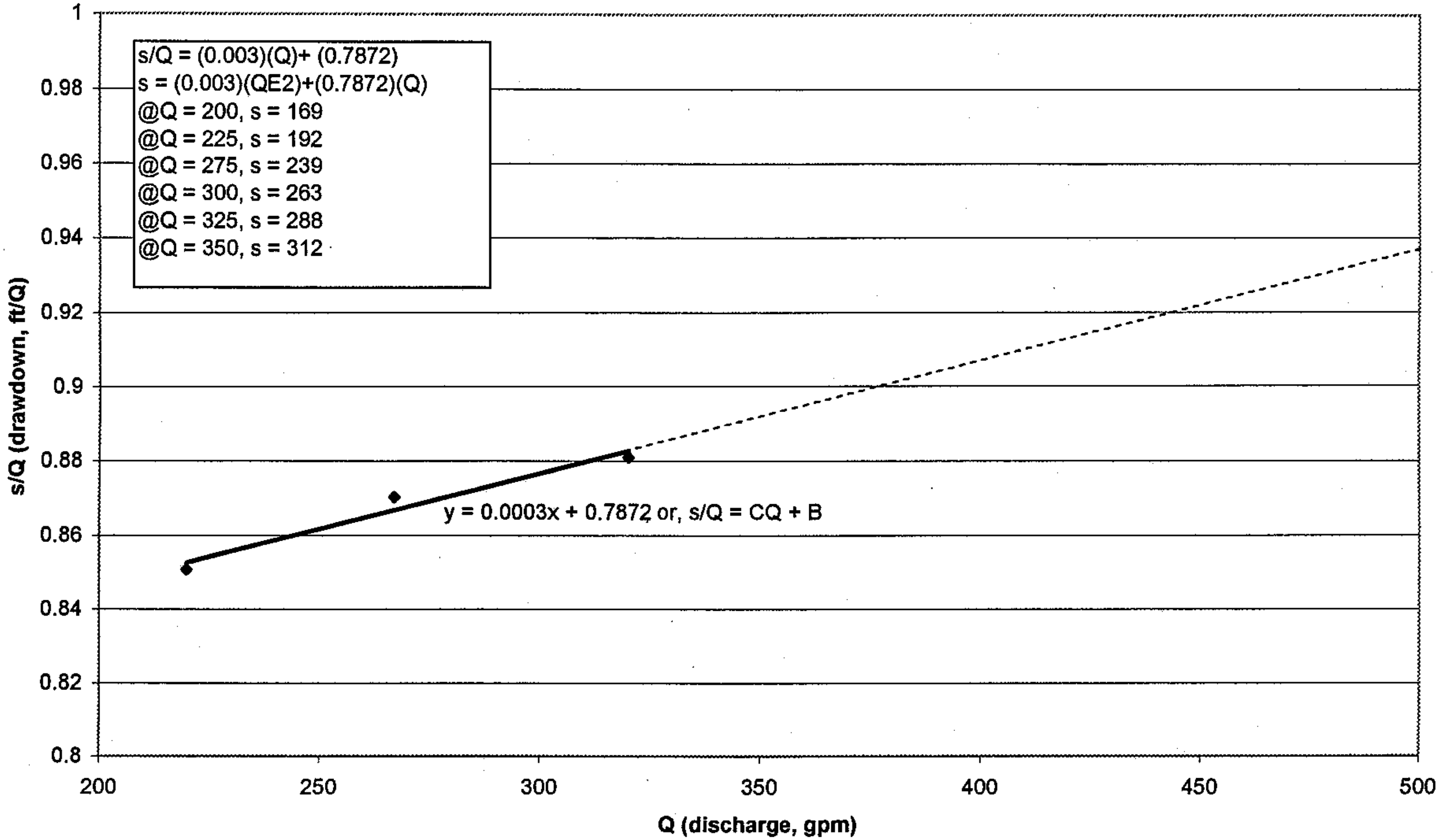
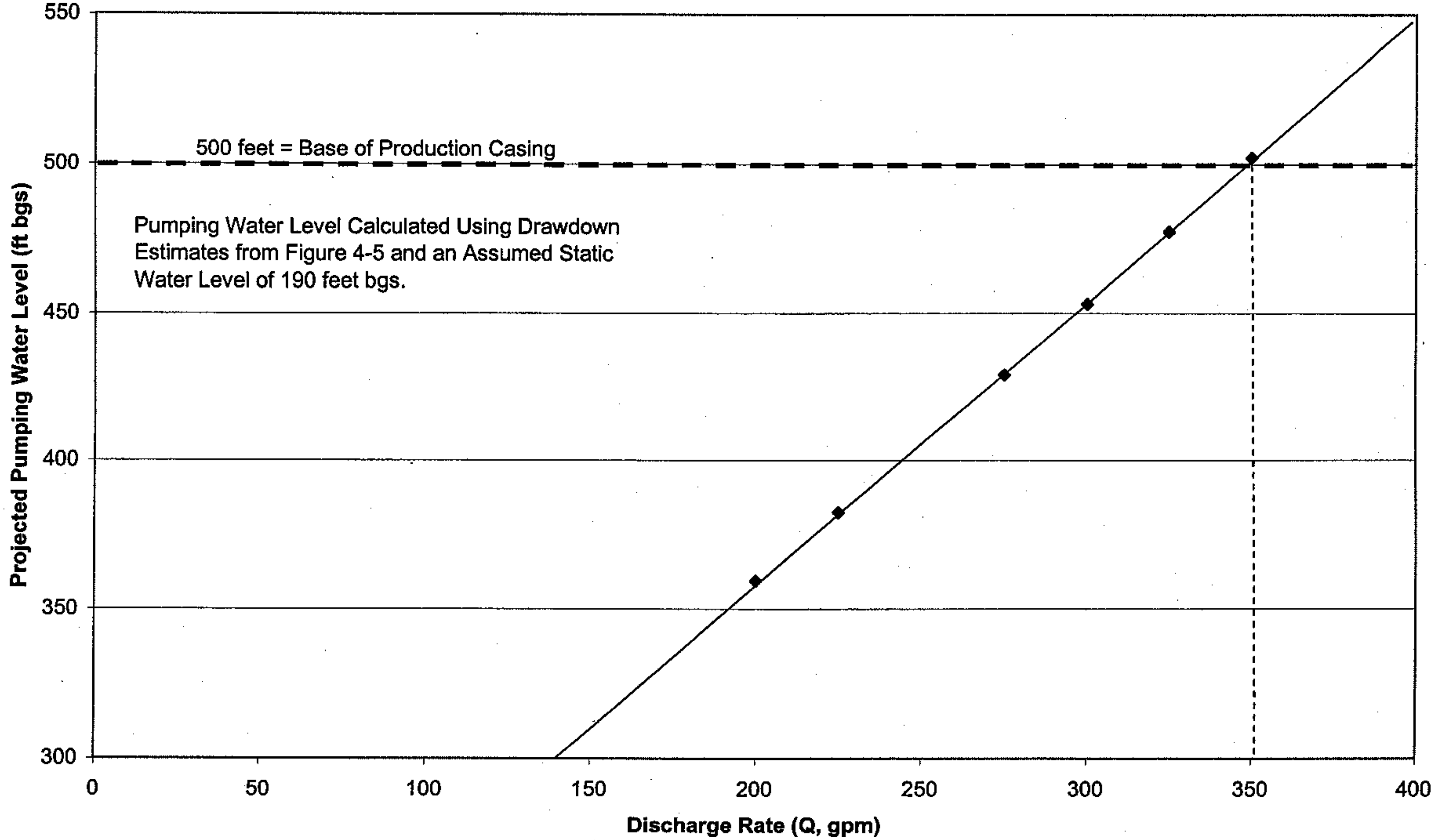


**Figure 4-6. City of Dallas ASR Pilot Well
Projected Pumping Water Level**



Well ID: Dallas ASR No. 1

CH2MHILL

Client: City of Dallas
Project: Task 40
Location: Dallas WTP
Project Number: 136343

Driller: Geo-Tech Explorations/Boart
Drilling Method: Reverse Circulation
Sampling Method: Grab samples with spot cores
Logged by: Chris Augustine
Start/Finish Date: Feb -July 2004

Depth (ft bgs)	Description	Sample Interval/No.	Graphic Log	Cored Interval	Core Description	Notes
	Ground Surface					
0	**Silty Sand** SM, Orange-brown, moist, sand med-fine					Drilling using Mud Rotary to 500 feet
10						
20						
30						
40	Some Basalt coarse sand/gravel at 50-60 feet Weathered basalt					
50						
60	Basalt, black-grey, aphanitic, dense, drill chips angular to sub angluar, magnetic Weathered at 60-70 feet zone					
70						
80						
90						
100						
110						
120						
130						
140						
150						
160						
170						
180						
190						
200						

Well ID: Dallas ASR No. 1

CH2MHILL

Client: City of Dallas
Project: Task 40
Location: Dallas WTP
Project Number: 136343

Driller: Geo-Tech Explorations/Boart
Drilling Method: Reverse Circulation
Sampling Method: Grab samples with spot cores
Logged by: Chris Augustine
Start/Finish Date: Feb -July 2004

Depth (ft bgs)	Description	Sample Interval/No.	Graphic Log	Cored Interval	Core Description	Notes
210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 310, 320, 330	Basalt, black-grey, aphanitic, dense, drill chips angular to sub angluar, magnetic Secondary mineralization: Quartz and Calcite					271-297 Loss of Drilling Mud
340, 350, 360, 370, 380	Basalt, black-grey, aphanitic, dense, drill chips angular to sub angluar, magnetic Secondary mineralization: Quartz and Calcite					
390, 400	Basalt, black-grey, aphanitic, dense, drill chips angular to sub angluar, magnetic Secondary mineralization: Quartz and Calcite					

Well ID: Dallas ASR No. 1

CH2MHILL **Sheet:** 3 of 10

Client: City of Dallas
Project: Task 40
Location: Dallas WTP
Project Number: 136343

Driller: Geo-Tech Explorations/Boart
Drilling Method: Reverse Circulation
Sampling Method: Grab samples with spot cores
Logged by: Chris Augustine
Start/Finish Date: Feb -July 2004

Depth (ft bgs)	Description	Sample Interval/No.	Graphic Log	Cored Interval	Core Description	Notes
410, 420, 430, 440, 450, 460, 470, 480, 490, 500, 510, 520, 530, 540	Basalt, black-grey, aphanitic, dense, drill chips angular to sub angluar, magnetic Secondary mineralization: Quartz and Calcite					
550, 560	Amygdaloidal Basalt, grey-green, aphanitic, magnetic Secondary mineralization in vesicles consist of pink to clear Quartz and Calcite					SWL = 188 ft. 4/23/04
570, 580	Basalt, black-grey, aphanitic, dense, drill chips angular to sub angluar, magnetic Secondary mineralization: Quartz and Calcite					
590, 600	Amygdaloidal Basalt, black-grey, aphanitic, dense, drill chips angular to sub angluar, magnetic Secondary mineralization: Quartz and Calcite					

Well ID: Dallas ASR No. 1

CH2MHILL **Sheet:** 4 of 10

Client: City of Dallas
Project: Task 40
Location: Dallas WTP
Project Number: 136343

Driller: Geo-Tech Explorations/Boart
Drilling Method: Reverse Circulation
Sampling Method: Grab samples with spot cores
Logged by: Chris Augustine
Start/Finish Date: Feb -July 2004

Depth (ft bgs)	Description	Sample Interval/No.	Graphic Log	Cored Interval	Core Description	Notes
	Basalt, black-grey, aphanitic, dense, drill chips angular to sub angluar, magnetic Secondary mineralization: Quartz and Calcite					
610						
620						
630						
640						
650						
660						SWL=188.5 ft bgs 4/26/04
670						
680						
690	Amygdaloidal Basalt, green-grey, aphanitic, dense, magnetic, Secondary mineralization: pink quartz and Calcite					
700						
710	Fractured Basalt, Porphyritic, augite and plagioclase,magnetic Secondaryminerals: manganese oxide slickensides along fracture plane					
720					725-730 Core No. 1	
730						SWL = 188 ft bgs 4/29/04
740						
750						
760	Basalt, black to greenish grey, aphanitic, magnetic, slightly fractured					
770						
780						
790						
800						

Well ID: Dallas ASR No. 1

CH2MHILL

Client: City of Dallas
Project: Task 40
Location: Dallas WTP
Project Number: 136343

Driller: Geo-Tech Explorations/Boart
Drilling Method: Reverse Circulation
Sampling Method: Grab samples with spot cores
Logged by: Chris Augustine
Start/Finish Date: Feb -July 2004

Depth (ft bgs)	Description	Sample Interval/No.	Graphic Log	Cored Interval	Core Description	Notes
					803-808 Core No. 2	
810						
20						
830						
840						
50						
860						
70						
80						
890					893-898 Core No. 3.	
00						SWL = 188 5/12/04 SWL= 188 ft bgs 5/19/04
910	Volcanic Breccia/agglomerate, green-black, green clay sized matrix with gravel sized angular basaltic clasts					
920						
30	Fault/Fracture plane?					
940					943-948 Core No. 4	
50						
60	Basalt, red-brown - black, aphanitic, oxidized, magnetic, minor secondary quartz and calcite					
970						
80						
90						
000						

Well ID: Dallas ASR No. 1

CH2MHILL

Client: City of Dallas
Project: Task 40
Location: Dallas WTP
Project Number: 136343

Driller: Geo-Tech Explorations/Boart
Drilling Method: Reverse Circulation
Sampling Method: Grab samples with spot cores
Logged by: Chris Augustine
Start/Finish Date: Feb -July 2004

Depth (ft bgs)	Description	Sample Interval/No.	Graphic Log	Cored Interval	Core Description	Notes
010						
020						
030						
040						
050						SWL = 188 ft. bgs 5/26/04
060	Basalt, black-grey, aphanitic, dense, drill chips angular to sub angluar, magnetic Secondary mineralization: Quartz and Calcite					
070						
080						
090						
100						
110					1116-1121 Core No. 5	
120						SWL = 188.5 ft bgs 5/28/04
130						
140						
150						
160	Amygdaloidal Basalt, black-grey, aphanitic, dense, magnetic Secondary mineralization: Quartz and Calcite					
170						SWL = 189.5 ft bgs 6/3/04
180	Basalt, black-grey, aphanitic, dense, magnetic Secondary mineralization: Quartz and Calcite					
190						
200						

Well ID: Dallas ASR No. 1

CH2MHILL **Sheet:** 7 of 10

Client: City of Dallas
Project: Task 40
Location: Dallas WTP
Project Number: 136343

Driller: Geo-Tech Explorations/Boart
Drilling Method: Reverse Circulation
Sampling Method: Grab samples with spot cores
Logged by: Chris Augustine
Start/Finish Date: Feb -July 2004

Depth (ft bgs)	Description	Sample Interval/No.	Graphic Log	Cored Interval	Core Description	Notes
210–240						
240–290	Basalt, black-grey, aphanitic, dense, magnetic Secondary mineralization: Quartz and Calcite					
290–330	Basalt, black-grey, aphanitic, dense, magnetic Drill chips small (med sand) and subangular to sub rounded Secondary mineralization: Quartz and Calcite				1288-1293 Core No. 6	SWL = 189.8 ft bgs 6/7/04
330–350	Basalt, black-grey, aphanitic, dense, magnetic Secondary mineralization: Quartz and Calcite					SWL = 189.7 ft bgs 6/11/04
350–360	Pumaceous Basalt, grey, porphyritic, magnetic Secondary mineralization: Quartz and Calcite					
360–380	Basalt, black-grey, aphanitic, dense, drill chips angular to sub angluar, magnetic Secondary mineralization: Quartz and Calcite					
380–390	Vesicular Basalt, red-brown to grey, porphyritic, magnetic, some oxidation Secondary mineralization: Quartz and Calcite					SWL = 189.7 ft bgs 6/16/04
390–400						

Well ID: Dallas ASR No. 1

CH2MHILL

Client: City of Dallas
Project: Task 40
Location: Dallas WTP
Project Number: 136343

Driller: Geo-Tech Explorations/Boart
Drilling Method: Reverse Circulation
Sampling Method: Grab samples with spot cores
Logged by: Chris Augustine
Start/Finish Date: Feb -July 2004

Depth (ft bgs)	Description	Sample Interval/No.	Graphic Log	Cored Interval	Core Description	Notes
	Basalt, black-grey, aphanitic, dense, magnetic					
410	Secondary mineralization: Quartz and Calcite					
420	Basalt, black-grey, aphanitic, dense, magnetic					
430	Secondary mineralization: Quartz and Calcite					
440						
450						
460						
470						
480						
490						
500						SWL = 191.3 ft bgs 6/18/04
510						
520						
530						
540						
550						
560						
570						SWL = 190.5 ft bgs 6/24/04
580						
590	Vesicular Basalt-andesite, grey - red, magnetic Pillow Basalt?					
600						

Well ID: Dallas ASR No. 1

CH2MHILL

Client: City of Dallas
Project: Task 40
Location: Dallas WTP
Project Number: 136343

Driller: Geo-Tech Explorations/Boart
Drilling Method: Reverse Circulation
Sampling Method: Grab samples with spot cores
Logged by: Chris Augustine
Start/Finish Date: Feb -July 2004

Depth (ft bgs)	Description	Sample Interval/No.	Graphic Log	Cored Interval	Core Description	Notes
	Amygdaloidal Basalt, black-grey, aphanitic, dense, magnetic Secondary mineralization: Quartz and Calcite					
610						
620						
630						
640						
650						
660						
670						SWL = 191.4 ft bgs 6/29/04
680						
690	Basalt, black-red, aphanitic, dense, magnetic Secondary mineralization: Quartz and Calcite					
700					1704-1709 Core No. 7	
710						
720						
730						
740						
750						
760						SWL = 190.7 ft bgs 7/7/04
770						
780						
790						
800						

Well ID: Dallas ASR No. 1

CH2MHILL

Client: City of Dallas
Project: Task 40
Location: Dallas WTP
Project Number: 136343

Driller: Geo-Tech Explorations/Boart
Drilling Method: Reverse Circulation
Sampling Method: Grab samples with spot cores
Logged by: Chris Augustine
Start/Finish Date: Feb -July 2004

Depth (ft bgs)	Description	Sample Interval/No.	Graphic Log	Cored Interval	Core Description	Notes
	Amygdaloidal Basalt, black-grey, aphanitic, dense, magnetic					
810	Secondary mineralization: Quartz and Calcite					
820						
830						SWL = 191 ft bgs 7/08/04
840						
850						
860						
870						
880						
890						
900						SWL = 190.8 ft bgs 7/09/04
910						
920						
930						
940						
950						
960						
970						SWL = 190.8 ft bgs 07/12/04
980						
990						
2000						SWL = 191.5 ft bgs 7/13/04

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WATER RESOURCES DEPT.
SALEM, OREGON

POLK

51099

Original 51138 Log

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765)
Instructions for completing this report are on the last page of this form.

WELL I.D. # L 27491
START CARD # 116245

(1) OWNER: Well Number 1
Name Fred + Joann Lowe
Address 16655 Martin Rd
City Dallas State Oregon Zip 97338

(2) TYPE OF WORK
☐ New Well ☑ Deepening ☐ Alteration (repair/recondition) ☐ Abandonment

(3) DRILL METHOD:
☑ Rotary Air ☐ Rotary Mud ☐ Cable ☐ Auger
☐ Other

(4) PROPOSED USE:
☑ Domestic ☐ Community ☐ Industrial ☐ Irrigation
☐ Thermal ☐ Injection ☐ Livestock ☐ Other

(5) BORE HOLE CONSTRUCTION:
Special Construction approval ☐ Yes ☑ No Depth of Completed Well 194 ft.
Explosives used ☐ Yes ☑ No Type Amount

HOLE Diameter	From	To	SEAL Material	From	To	Sacks or pounds
6"	120	343	cement		343	8

How was seal placed: Method ☐ A ☐ B ☑ C ☐ D ☐ E
☐ Other Tremie pipe
Backfill placed from 194 ft. to 343 ft. Material cement
Gravel placed from ft. to ft. Size of gravel

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:	Original		Seal		Undisturbed			
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
Liner:					☐	☐	☐	☐
					☐	☐	☐	☐

Final location of shoe(s)

(7) PERFORATIONS/SCREENS:
☐ Perforations Method
☐ Screens Type Material

From	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
						☐	☐
						☐	☐
						☐	☐
						☐	☐
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour
☐ Pump ☐ Bailer ☑ Air ☐ Flowing Artesian

Yield gal/min	Drawdown	Drill stem at	Time
1 gpm	NaCl H_2O	@ 335-343'	1 hr.
1 1/2	172	200	2 hrs

Temperature of water 54° Depth Artesian Flow Found
Was a water analysis done? ☐ Yes By whom
Did any strata contain water not suitable for intended use? ☐ Too little
☑ Salty ☐ Muddy ☐ Odor ☐ Colored ☐ Other
Depth of strata: 335-343'

(9) LOCATION OF WELL by legal description:
County Polk Latitude Longitude
Township 7 N or S Range 6 E or W WM.
Section 25 SW 1/4 SW 1/4
Tax Lot 400 Lot Block Subdivision
Street Address of Well (or nearest address) 16655 Martin Rd

(10) STATIC WATER LEVEL:
28 ft. below land surface. Date 1-27-00
Artesian pressure lb. per square inch. Date

(11) WATER BEARING ZONES:

Depth at which water was first found 170'

From	To	Estimated Flow Rate	SWL
170'	171'	< 1/2 gpm	28
335	343'	1 NaCl H_2O	—

(12) WELL LOG:
Ground Elevation

Material	From	To	SWL
Basalt, Black	120	170	28
Basalt, Grey	170	190	28
Basalt, Black	190	292	28
Sandstone, Grey - hard	292	300	28
Basalt, Black	300	320	28
Basalt, Grey - medium	320	343	28
Dickerson Well Drilling Inc			
PH # (503) 623-2664			

Date started 1-20-00 Completed 1-25-00

(unbonded) Water Well Constructor Certification:

I certify that the work I performed on the construction, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

WWC Number
Signed Date

(bonded) Water Well Constructor Certification:

I accept responsibility for the construction, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

WWC Number 1571
Signed William A [illegible] Date 1-27-00

ORIGINAL – WATER RESOURCES DEPARTMENT FIRST COPY – CONSTRUCTOR SECOND COPY – CUSTOMER

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APR 03 2000

WATER RESOURCES DEPT.
SALEM, OREGON

POLK
51112

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765)

Instructions for completing this report are on the last page of this form.

WELL I.D. # L 39719
START CARD # 116255

(1) OWNER: Well Number 2

Name Fred + Joany Lowe
Address 16655 Martin Rd
City Dallas State Ore Zip 97338

(2) TYPE OF WORK

☑ New Well ☐ Deepening ☐ Alteration (repair/recondition) ☐ Abandonment

(3) DRILL METHOD:

☑ Rotary Air ☐ Rotary Mud ☐ Cable ☐ Auger
☐ Other

(4) PROPOSED USE:

☑ Domestic ☐ Community ☐ Industrial ☐ Irrigation
☐ Thermal ☐ Injection ☐ Livestock ☐ Other

(5) BORE HOLE CONSTRUCTION:

Special Construction approval ☐ Yes ☑ No Depth of Completed Well 291 ft.
Explosives used ☐ Yes ☑ No Type ____ Amount ____

HOLE Diameter	From	To	SEAL Material	From	To	Sacks or pounds
10"	0	39	bentonite	0	39	20
6"	39	291				

How was seal placed: Method ☐A ☐B ☐C ☐D ☐E
☐ Other poured dry
Backfill placed from ____ ft. to ____ ft. Material ____
Gravel placed from ____ ft. to ____ ft. Size of gravel ____

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:	6"	+1	39	.250	☑	☐	☑	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
Liner:					☐	☐	☐	☐
					☐	☐	☐	☐

Final location of shoe(s) 39½'

(7) PERFORATIONS/SCREENS:

☐ Perforations Method ____
☐ Screens Type ____ Material ____

From	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
						☐	☐
						☐	☐
						☐	☐
						☐	☐
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour

☐ Pump ☐ Bailer ☑ Air ☐ Flowing Artesian

Yield gal/min	Drawdown	Drill stem at	Time
2	195	291	½ hr.
1½	195	291	1 hr

Temperature of water 54° Depth Artesian Flow Found ____
Was a water analysis done? ☐ Yes By whom ____
Did any strata contain water not suitable for intended use? ☐ Too little
☑ Salty ☐ Muddy ☐ Odor ☐ Colored ☐ Other
Depth of strata: 324 mg/L Na Sulfates

(9) LOCATION OF WELL by legal description:

County Polk Latitude ____ Longitude ____
Township 7 N or S Range 6 E or W WM.
Section 25 SW 1/4 SW 1/4
Tax Lot 400 Lot ____ Block ____ Subdivision ____
Street Address of Well (or nearest address) 16655 Martin Rd

(10) STATIC WATER LEVEL:

96 ft. below land surface. Date 3-17-00
Artesian pressure ____ lb. per square inch. Date ____

(11) WATER BEARING ZONES:

Depth at which water was first found 21'

From	To	Estimated Flow Rate	SWL
21	22	< ¼ gpm	—
277	290	1½ gpm	96

(12) WELL LOG:

Ground Elevation ____

Material	From	To	SWL
Topsoil	0	1	—
Clay, Brown w/ Brown Rock	1	3	—
~~Basalt~~ Clay, Brown-Sandy	3	11½	—
Basalt, Grey	11½	21	—
Basalt, Brown - Fractured	21	22	—
Basalt, black - hard	22	98	—
Coastal Basalt, Grey w/ hard Basalt Layers	98	291	96

Dickerson Well Drilling, Inc
PH# (503) 623-2664

Date started 3-13-00 Completed 3-17-00

(unbonded) Water Well Constructor Certification:

I certify that the work I performed on the construction, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

WWC Number ____
Signed ____ Date ____

(bonded) Water Well Constructor Certification:

I accept responsibility for the construction, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

WWC Number 1571
Signed William A Blair Date 3-17-00

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WATER RESOURCES DEPT
SALEM, OREGON

78/6W/36ad

STATE OF OREGON
WATER WELL REPORT
(as required by ORS 537.765)

(START CARD) # 48790

(1) OWNER: Well Number #2

Name Wolodymyr Birko
Address 1363 Plaza NW
City Salem Ore State Ore Zip 97304

(2) TYPE OF WORK:
☒ New Well ☐ Deepen ☐ Recondition ☐ Abandon

(3) DRILL METHOD:
☒ Rotary Air ☐ Rotary Mud ☐ Cable
☐ Other

(4) PROPOSED USE:
☒ Domestic ☐ Community ☐ Industrial ☐ Irrigation
☐ Thermal ☐ Injection ☐ Other

(5) BORE HOLE CONSTRUCTION:
Special Construction approval ☐ Yes ☐ No Depth of Completed Well 40 ft.
Explosives used ☐ Yes ☒ No Type Amount

HOLE Diameter	From	To	SEAL Material	From	To	Amount sacks or pounds
10"	0	20	Cement	14	16	1.5 Sak
6"	18	40	Bentonite	0	14	4 Sak

How was seal placed: Method ☐ A ☐ B ☐ C ☐ D ☐ E
☒ Other Filled with Bentonite to top
Backfill placed from ft. to ft. Material
Gravel placed from ft. to ft. Size of gravel

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:	6"	+1	19	250	☒	☐	☐	☐
Liner:	4"	0	40	160	☐	☒	☒	☐

Final location of shoe(s)

(7) PERFORATIONS/SCREENS:
☒ Perforations Method Saw Cut
☐ Screens Type Material

From	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
18	40	1/4	21	160 6" long		☐	☒

(8) WELL TESTS: Minimum testing time is 1 hour
☐ Pump ☐ Bailer ☒ Air ☐ Flowing Artesian

Yield gal/min	Drawdown	Drill stem at	Time
5 gpm		40'	1 hr.

Temperature of Water 54° Depth Artesian Flow Found
Was a water analysis done? ☐ Yes By whom
Did any strata contain water not suitable for intended use? ☐ Too little
☐ Salty ☐ Muddy ☐ Odor ☐ Colored ☐ Other
Depth of strata:

(9) LOCATION OF WELL by legal description:
County Polk Latitude Longitude
Township 7 S N or S Range 6 W E or W. WM.
Section 36 SE 1/4 NE 1/4
Tax Lot 111 Lot Block Subdivision
Street Address of Well (or nearest address) 16310 Elendale Dallas Ore. 97338

(10) STATIC WATER LEVEL:
15 ft. below land surface. Date 2/20/93
Artesian pressure lb. per square inch. Date

(11) WATER BEARING ZONES:
Depth at which water was first found 16'-18'

From	To	Estimated Flow Rate	SWL
16'	18'	5GPM	

(12) WELL LOG:
Ground elevation

Material	From	To	SWL
Soil	0	1	
Orange Clay	1	9	
Gray Clay	9	16	
Gravel	16	18	
Black Basalt	18	40	

ROBINSON DRILLING
WELLS & PUMPS
4520 Dallas-Salem Hwy.
Salem, Ore. 97304
371-1844

ROBINSON DRILLING
WELLS & PUMPS
4520 Dallas-Salem Hwy.
Salem, Ore. 97304
371-1844

Date started 2-?-93 Completed 2-19-93

(unbonded) Water Well Constructor Certification:
I certify that the work I performed on the construction, alteration, or abandonment of this well is in compliance with Oregon well construction standards. Materials used and information reported above are true to my best knowledge and belief.

WWC Number
Signed Date

(bonded) Water Well Constructor Certification:
I accept responsibility for the construction, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon well construction standards. This report is true to the best of my knowledge and belief.

WWC Number 1585
Signed [signature] Date 3-2-93

ORIGINAL & FIRST COPY - WATER RESOURCES DEPARTMENT SECOND COPY - CONSTRUCTOR THIRD COPY - CUSTOMER 9809C 10/91

STATE OF OREGON
WATER WELL REPORT
(as required by ORS 537.765)

POLK 539

7S/6W/35dd

(START CARD) # 29065

(1) OWNER: Well Number

Name Woody Binker

Address 1363 Plaza NW

City Salem State Ore Zip 97304

(2) TYPE OF WORK:

☑ New Well ☐ Deepen ☐ Recondition ☐ Abandon

(3) DRILL METHOD:

☑ Rotary Air ☐ Rotary Mud ☐ Cable

☐ Other

(4) PROPOSED USE:

☑ Domestic ☐ Community ☐ Industrial ☐ Irrigation

☐ Thermal ☐ Injection ☐ Other

(5) BORE HOLE CONSTRUCTION:

Special Construction approval ☐ Yes ☑ No Depth of Completed Well 270 ft.

Explosives used ☐ Yes ☑ No Type Amount

HOLE Diameter	From	To	SEAL Material	From	To	Amount sacks or pounds
10"	0	18	bentonite	0	18	13
6"	18	270				

How was seal placed: Method ☐ A ☐ B ☑ C ☐ D ☐ E

☐ Other poured dry.

Backfill placed from ft. to ft. Material

Gravel placed from ft. to ft. Size of gravel

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:	6"	+2	18	.250	☑	☐	☑	☐
Liner:	None				☐	☐	☐	☐

Final location of shoe(s)

(7) PERFORATIONS/SCREENS:

☐ Perforations Method None.

☐ Screens Type Material

From	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour

☐ Pump ☐ Bailer ☑ Air ☐ Flowing Artesian

Yield gal/min	Drawdown	Drill stem at	Time
½-¾ gpm	221	268	1 hr.

Temperature of Water 53° Depth Artesian Flow Found

Was a water analysis done? ☐ Yes By whom

Did any strata contain water not suitable for intended use? ☐ Too little

☐ Salty ☐ Muddy ☐ Odor ☐ Colored ☐ Other

Depth of strata:

(9) LOCATION OF WELL by legal description:

County Polk Latitude Longitude

Township 7 N or Ⓢ Range 6 E or Ⓦ WM.

Section 35 NW ¼ SE ¼

Tax Lot Lot Block Subdivision

Street Address of Well (or nearest address) 16000 Ellendale. Dallas, Ore 97338

(10) STATIC WATER LEVEL:

39' ft. below land surface. Date 10/27/92

Artesian pressure lb. per square inch. Date

(11) WATER BEARING ZONES:

Depth at which water was first found 47'

From	To	Estimated Flow Rate	SWL
47'	49'	½-¾ gpm	39

(12) WELL LOG:

Ground elevation

Material	From	To	SWL
Topsoil	0	11	—
black basalt (hard)	11	41	—
Gray basalt	41	72	39
Gray Claystone	72	96	39
black basalt w/ lavender layers	96	115	39
Gray basalt	115	147	39
lavender basalt	147	166	39
Gray basalt	166	270	39

RECEIVED
NOV 17 1992
OCT 30 1992
WATER RESOURCES DEPT
SALEM, OREGON

Date started 10/24/92 Completed 10/27/92

(unbonded) Water Well Constructor Certification:

I certify that the work I performed on the construction, alteration, or abandonment of this well is in compliance with Oregon well construction standards. Materials used and information reported above are true to my best knowledge and belief.

ph# 623-2664

WWC Number

Signed Dickerson Well Drilling, Inc Date

(bonded) Water Well Constructor Certification:

I accept responsibility for the construction, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon well construction standards. This report is true to the best of my knowledge and belief.

WWC Number 1571

Signed William J. Blair Date 10/29/92.

NOTICE TO WATER WELL CONTRACTOR
The original and first copy of this report are to be filed with the
WATER RESOURCES DEPARTMENT, SALEM, OREGON 97310 within 30 days from the date of well completion.

RECEIVED JAN 4 1978 WATER RESOURCES DEPT. SALEM, OREGON

WATER WELL REPORT
STATE OF OREGON
(Please type or print)
(Do not write above this line)

POLK 2762

State Well No. 7S/6W-35dc

State Permit No.

(1) OWNER:
Name LOWELL D. PARKER
Address RT 3 BOX 258
DALLAS OREGON

(2) TYPE OF WORK (check):
New Well [X] Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:
Rotary [X] Driven ☐
Cable ☐ Jetted ☐
Dug ☐ Bored ☐

(4) PROPOSED USE (check):
Domestic [X] Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) CASING INSTALLED: Threaded ☐ Welded [X]
6" Diam. from +1 ft. to 89 ft. Gage .250
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(6) PERFORATIONS: Perforated? ☐ Yes [X] No.
Type of perforator used
Size of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

(7) SCREENS: Well screen installed? ☐ Yes [X] No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(8) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes [X] No If yes, by whom?
Yield: 5 gal./min. with 55 ft. drawdown after 2 hrs.
" " "
" " "
Bailer test 5 gal./min. with 55 ft. drawdown after 2 hrs.
Artesian flow g.p.m.
Temperature of water 51° Depth artesian flow encountered ft.

(9) CONSTRUCTION:
Well seal—Material used CEMENT
Well sealed from land surface to 30 ft.
Diameter of well bore to bottom of seal 10 in.
Diameter of well bore below seal 8 in.
Number of sacks of cement used in well seal 7 sacks
How was cement grout placed? MIXED AND POURED

Was a drive shoe used? ☐ Yes [X] No Plugs Size: location ft.
Did any strata contain unusable water? ☐ Yes [X] No
Type of water? depth of strata
Method of sealing strata off
Was well gravel packed? ☐ Yes [X] No Size of gravel:
Gravel placed from ft. to ft.

(10) LOCATION OF WELL:
County POLK Driller's well number
SW ¼ SE ¼ Section 35 T. 7S R. 6W W.M.
Bearing and distance from section or subdivision corner

(11) WATER LEVEL: Completed well.
Depth at which water was first found 125 ft.
Static level ~~125~~ 160 ft. below land surface. Date 11/29/77
Artesian pressure lbs. per square inch. Date

(12) WELL LOG: Diameter of well below casing 6
Depth drilled 321 ft. Depth of completed well 321 ft.

Formation: Describe color, texture, grain size and structure of materials; and show thickness and nature of each stratum and aquifer penetrated, with at least one entry for each change of formation. Report each change in position of Static Water Level and indicate principal water-bearing strata.

MATERIAL	From	To	SWL
TOP SOIL RED	0	2	
CLAY RED-YELLOW LAYERED	2	80	
SHALE GRAY HARD	80	86	
BASALT BLACK HARD	86	118	
BASALT BROKEN	118	130	125
BASALT LOOSE ROCKY	130	140	
BASALT	140	146	
SHALE GRAY	146	176	
BASALT	176	201	
SHALE GRAY	201	221	
BASALT FRACTURED	221	321	160
CAVING FROM 118			
TO 140 — CEMENTED			
OFF AND DRILLED			
OUT SHUTING OFF			
FIRST WATER ABOUT			
1 GPM 20 SACKS			
CEMENT			

Work started 11/17 1977 Completed 12/9 1977
Date well drilling machine moved off of well 12/9 1977

Drilling Machine Operator's Certification:
This well was constructed under my direct supervision. Materials used and information reported above are true to my best knowledge and belief.
[Signed] Allan Harrington (Drilling Machine Operator) Date 12-15, 1977
Drilling Machine Operator's License No. 875

Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Name BELLO WELL DRILLING (Person, firm or corporation) (Type or print)
Address 4783 COLUMBIA DR SE SALEM
[Signed] Paul Bello (Water Well Contractor)
Contractor's License No. 579 Date 12/15, 1977

(USE ADDITIONAL SHEETS IF NECESSARY)

POLK 51605

RECEIVED NOV 1 2 2002 WATER RESOURCES DEPT SALEM, OREGON

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765)
Instructions for completing this report are on the last page of this form.

WELL I.D. # L 56697
START CARD # 148450

(1) LAND OWNER Well Number 1
Name Paul Presser
Address 15750 Oakdale Rd.
City Dallas State Ore Zip 97338

(2) TYPE OF WORK
[x] New Well [ ] Deepening [ ] Alteration (repair/recondition) [ ] Abandonment

(3) DRILL METHOD:
[x] Rotary Air [ ] Rotary Mud [ ] Cable [ ] Auger
[ ] Other

(4) PROPOSED USE:
[x] Domestic [ ] Community [ ] Industrial [ ] Irrigation
[ ] Thermal [ ] Injection [ ] Livestock [ ] Other

(5) BORE HOLE CONSTRUCTION:
Special Construction approval [ ] Yes [x] No Depth of Completed Well 459 ft.
Explosives used [ ] Yes [x] No Type ___ Amount ___

HOLE Diameter	From	To	SEAL Material	From	To	Sacks or pounds
10"	0	258	bentonite	0	50	38
			cement w/ 5% bentonite	50	258	37
6"	258	459				

How was seal placed: Method [ ] A [ ] B [x] C [ ] D [ ] E
[ ] Other cement tremied / bentonite poured
Backfill placed from ___ ft. to ___ ft. Material ___
Gravel placed from ___ ft. to ___ ft. Size of gravel ___

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:	6"	+2	258	.250	[x]	[ ]	[x]	[ ]
					[ ]	[ ]	[ ]	[ ]
					[ ]	[ ]	[ ]	[ ]
					[ ]	[ ]	[ ]	[ ]
Liner:	4"	5	459	160	[ ]	[x]	[x]	[ ]
					[ ]	[ ]	[ ]	[ ]

Drive Shoe used [ ] Inside [x] Outside [ ] None
Final location of shoe(s) @ 258'

(7) PERFORATIONS/SCREENS:
[x] Perforations Method skilsaw
[ ] Screens Type ___ Material pvc

From	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
220	459	6"	260	1/8"	4"	[ ]	[x]
						[ ]	[ ]
						[ ]	[ ]
						[ ]	[ ]

(8) WELL TESTS: Minimum testing time is 1 hour
[ ] Pump [ ] Bailer [x] Air [ ] Flowing Artesian

Yield gal/min	Drawdown	Drill stem at	Time
240+	318'	458	2hr.
180	230'	370	1/2
150	150'	290	1/2

Temperature of water 55° Depth Artesian Flow Found ___
Was a water analysis done? [ ] Yes By whom ___
Did any strata contain water not suitable for intended use? [ ] Too little
[ ] Salty [ ] Muddy [ ] Odor [ ] Colored [ ] Other
Depth of strata:
Conductivity is 300 us

(9) LOCATION OF WELL by legal description:
County Polk Latitude N 44°54.747 Longitude W 123°28.117
Township 7 N or S Range 5 E or W WM.
Section 31 ___ 1/4 ___ 1/4
Tax Lot 1600 Lot ___ Block ___ Subdivision ___
Street Address of Well (or nearest address) 15750 Oakdale Rd. Dallas, Or 97338

(10) STATIC WATER LEVEL:
140 ft. below land surface. Date 11-3-02
Artesian pressure ___ lb. per square inch Date ___

(11) WATER BEARING ZONES:
Depth at which water was first found 16'

From	To	Estimated Flow Rate	SWL
16	18	1 1/2	10
41	42	1	10
340	450	240+	140

(12) WELL LOG:
Ground Elevation ___

Material	From	To	SWL
Topsoil	0	3	—
Clay, brown	3	11	—
Shale, brown - Grey	11	16	—
Claystone, Grey - medium	16	20	—
hard w/ soft sandstone seams	20	205	—
Sandstone, Light Grey - hard	205	308	—
Sandstone, Grey - Green - hard	308	340	—
Sandstone, Grey - hard - fractured	340	383	140
Basalt, Black - fractured	383	406	140
Sandstone, Grey-Green - Fractured	406	414	140
Basalt, Black, Fractured	414	419	140
Sandstone, Grey - fractured	419	426	140
Basalt, Black - fractured	426	432	140
Sandstone, Grey - fractured	432	440	140
Claystone, fractured - Grey	440	450	140
Claystone, Grey - soft	450	459	140
* Further Pump Testing Needed for Accurate Flow Rate.			
Dickerson Well Drilling, Inc.			

Date started 10-29-02 Completed 11-2-02

(unbonded) Water Well Constructor Certification:
I certify that the work I performed on the construction, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.
WWC Number ___
Signed ___ Date ___

(bonded) Water Well Constructor Certification:
I accept responsibility for the construction, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.
WWC Number 1571
Signed William A. Blair Date 11-3-02