REPORT

SEGMENT 2
FIELD TESTS OF THE PROGRAMMABLE LOGIC CONTROL AND VARIABLE FREQUENCY DRIVE WELL PUMPS
GASCO SEDIMENTS SITE, PORTLAND, OREGON

Prepared for

NW Natural
Portland, Oregon

Prepared by

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Suite 333
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CERTIFICATION STATEMENT

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Anchor QEA, LLC

5/25/2011

Date

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LIST OF ACRONYMS AND ABBREVIATIONS

EPA	U.S. Environmental Protection Agency
FDR	Draft Groundwater Source Control Final Design Report
gpm	gallons per minute
Order	Administrative Settlement Agreement and Order on Consent
PLC	Programmable Logic Control
Siltronic	Siltronic Corporation
VFD	variable frequency drive
WBZ	Water Bearing Zone

1 INTRODUCTION

NW Natural and Siltronic Corporation (Siltronic) are working with the U.S. Environmental Protection Agency (EPA) under an Administrative Settlement Agreement and Order on Consent (Order) for sediments cleanup at the Gasco Sediments Site within Portland Harbor. The location of the Gasco Sediments Site is shown on Figure 1. The Segment 2 Capture Zone Field Test was conducted to provide information on offshore groundwater seepage control for the design of the in-water sediment cleanup. The *Segment 2 Capture Zone Field Test Report* (Anchor QEA 2011a) showed that pumping at a constant rate achieved a high degree of gradient reduction in the upper alluvium, and that it is expected that complete containment can be achieved by varying the extraction well pumping rate to counterbalance the effect of river stage and tidal fluctuations on groundwater gradients.

EPA provided comments on the Segment 2 Capture Zone Field Test Report on April 25, 2011. Section 2 of this report provides responses to EPA's comments.

As discussed in the *Draft Groundwater Source Control Final Design Report* (FDR) (Anchor QEA 2011b), the gradient control system is designed to use a Programmable Logic Control (PLC) to monitor the gradient differential (ΔH) between groundwater and river elevation at selected control wells. The PLC will interface with the variable frequency drive (VFD) at each extraction well to change the pump speed and thereby modify the well discharge rate concurrently with groundwater elevation changes induced by the river tides.

The purposes of the PLC and VFD testing were to assess the PLC programming and test the interface between the PLC and pump VFDs. This included an assessment of the ability of the PLC/transducer system to respond to groundwater elevation changes and the consequent response of the well pumps.

The findings presented in this Segment 2 Field Test Report were used in preparation of the FDR.

The PLC and pump VFDs were field tested during March and April 2011. Sections 3 and 4 of this report describe the work completed and analysis of the water level data.

2 RESPONSE TO EPA COMMENTS ON SEGMENT 2 CAPTURE ZONE FIELD TEST REPORT

In an email dated April 25, 2011, EPA commented on the *Segment 2 Capture Zone Field Test Report*. Several of EPA's questions can be more fully answered using the data collected during the PLC and VFD testing and are therefore provided herein. EPA's questions and comments are repeated in bold italic print below, followed by NW Natural's response.

2.1 General Comments

1. ***NW Natural should elaborate on how the results from the Segment 2 capture zone testing will be integrated into future numerical groundwater modeling studies.***

NW Natural Response: We do not anticipate using the results of the constant rate tests in the groundwater model. The upland groundwater modeling that has been completed to date was used to support the groundwater source control design, and additional modeling is not needed to support source control design. The variable rate test data from the PLC and VFD testing is more useful in the long term because the source control wells will be operated at variable rates. Additional modeling using the data from the PLC and VFD variable rate test is being planned for the purpose of supporting the development of the river sediment remedy

2. ***NW Natural should set a more definitive threshold to define potential capture in Table 3. For instance a head difference of 0.5 feet or greater is fairly definitive, but if smaller, it becomes questionable if the gradient reversal is attributable to pumping or a natural influence related to seasonal river stage and groundwater heads.***

NW Natural Response: Any reliably measurable head difference between the groundwater elevation at an offshore piezometer and the river elevation demonstrates seepage control at the piezometer location. The question of the necessary magnitude of the elevation delta is actually a question of the accuracy of the measurements. The transducer measurements are accurate to 0.01 foot. A difference of about twice this (0.02 foot or greater) documents an adequate elevation delta to demonstrate groundwater containment and seepage control. Performance monitoring of the upland source control wells is described in Section 3 of the FDR. The FDR describes how performance monitoring will determine if the elevation delta between the river elevation and the groundwater elevation is being maintained to provide

source control. At times, the elevation delta will be maintained by ambient conditions in the river that cause the river elevation to be higher than the groundwater elevation. These conditions occur during some but not all periods of high river tides.

2.2 Specific Comments

EPA had the following specific comments related to this document:

1. ***Section 1.0, page 1, paragraph 3:*** ***NW Natural states in the first sentence that studies conclude shoreline extraction wells will control groundwater discharge from the Gasco Sediments Site into the river, but the second sentence states, "Shoreline groundwater containment will also reduce groundwater discharge from the sediment mudline into the river channel within an area of the riverbed near the Gasco Sediments Site." NW Natural should explain the distinction between controlling groundwater discharge and reducing groundwater discharge within the area of riverbed near the Gasco Sediments Site.***

NW Natural Response: Some areas with contaminated sediment may be outside the zone of offshore capture by the extraction system. While the extraction system will control groundwater discharge from the site, it will not stop all groundwater flux to the river from upriver, downriver, or from the east side of the river.

2. ***Section 2.3.1, page 5, paragraph 3:*** ***NW Natural should present the specific capacities of the wells determined from the various pumping test rates (preferably in table format). It is also important that NW Natural expand on the analysis and discussion of each well's capacity to meet the range of required pumping rate discharges to meet groundwater capture at target wells. Understanding the well capacity limitations helps deal with potential problems proactively, rather than reactively, thereby limiting periods of inadvertent well shutdown due to pumping capacity problems and risk of potential recontamination of the in-water sediment cleanup areas. Furthermore, this analysis and information can be used to inform design of wells for other capture zone segment areas to provide more efficient and effective capture. If the well efficiency and sustainable capacities are not addressed up front, then a robust performance monitoring plan will be critical in managing this reactive method of monitoring and addressing well capacity issues in an effective and timely manner.***

NW Natural Response: See Table 1 for specific capacities of the pumping wells measured during the November 2010 pump test.

3. ***Section 3, pages 8 and 9, paragraphs 4-7:*** ***The Serfes method appears to be sufficient in understanding and quantifying the influence and relationship between diurnal tidal river stage flux and the groundwater heads of the fill and alluvium units during test periods. However, this analysis does not address the relationship between longer-term seasonal river stages and groundwater heads in aquifer zones. Based on a review of capture zone test data, this relationship is significant and should be evaluated by NW Natural, as it appears some of the influence being attributed to pumping, may in fact be due to a natural relationship between river stage and groundwater heads.***

   For example, EPA reviewed the results of two very similar 72-hour tests conducted by NW Natural in late April 2010 and in early November 2010. Both tests had the pumping wells (PW-7-93, PW-8-39, and PW9-92) pumping at a rate of 25 gallons per minute (gpm) and both test results were analyzed using the Serfes method. Despite these similarities, the capture assigned to the pumping was generally greater and influenced more wells during the April test than during the November test (see Table 3 in the Capture Zone Field Test Report). A key difference between the two tests was the seasonal stage of the Willamette River, which during the April test was 1.89 feet higher than during the November test.

   The significance of this seasonal variability between two similar tests indicates some quantifiable difference between river stage and groundwater heads (presented in the report as the delta) might be incorrectly assigned and attributed as capture/influence from pumping wells. Instead a portion, or the entire quantified delta may be due to seasonal changes in flux between the river and the alluvial aquifer. This means at certain times of the year, the river presents a bank recharge effect and the gradients between river stage and groundwater heads are reversed naturally. Based on a review of the 23- year U.S. Geological Survey (USGS) Willamette River stage record at Portland, the lowest stage typically occurs in September and it is an additional 2 feet lower than the typical November stage. EPA suggests that NW Natural evaluate this seasonal stage influence and relationship between river and local alluvium groundwater heads to understand and better quantify what is actual pumping influence and not seasonal bank recharge influence.

NW Natural Response: Ambient pre-test and/or post-test conditions are shown for each test on Table 3 of the *Segment 2 Capture Zone Field Test Report*. Table 3 from that report has been updated by adding the April 2011 VFD testing results and is included as Table 2 of this report. By comparing the gradient difference during the 2010 tests with the corresponding pre- or post-test ambient conditions (immediately before or after the test), the effects of pumping can be seen. For example, Table 2 shows no gradient reversals (with the exception of PZ4-12) during the ambient pre-test periods in April 2010, while a majority of the wells show a reversal during pumping. Potential "seasonal effects" can be observed by comparing ambient (non-pumping data) between periods. As stated previously in this report, it is agreed that there are periods of "natural" gradient reversals, particularly during high river tides, and during these periods groundwater does not discharge to the river. The source control extraction well system will be operated to maintain a condition of containment regardless of the tidal cycle.

4. ***Section 4.1, page 10, paragraph 2, last sentence:*** ***NW Natural should provide the analysis and the methodology, or explain how hydraulic conductivity was derived from the 2010 pumping test of Segment 2 pilot well PW8-39.***

NW Natural Response: Hydraulic conductivity was calculated using data from the September 2010 pump test in which PW-8-39 was pumped at 2 gallons per minute (gpm). A report of the of the pump test analysis is provided in Appendix A.

5. ***Section 4.1, page 10, paragraph 3, second and last sentences:*** ***NW Natural should expand on their test findings that the Segment 2 capture zone tests were inadvertently conducted in an area not representative of the upper alluvium and provide sufficient information to support this statement. Additional testing in the upper alluvium of the other segments, similar to what was conducted in Segment 2, may be necessary to provide sufficient information to support this hypothesis.***

NW Natural Response: As stated in the report, pump tests have been conducted in the Segment 1 upper alluvium at pilot wells PW-1-80 and PW-3-85. The hydraulic conductivity measured at the PW-3-85 test was about 10 feet per day and approximately 3 feet per day at PW-1-80. The hydraulic conductivity derived from the PW-8-39 test was about 0.2 foot per day (see Appendix A). The well-specific capacity measured during the PW-1-80 test was

about 1 gpm per foot of drawdown and about 0.15 gpm per foot of drawdown at PW-8-39. Based on the results of the historically conducted pump tests in Segment 1 compared to the recent analysis of the PW-8-39 pump test data in Segment 2, the upper alluvium is much more permeable in Segment 1 than in the area of Segment 2 near PW-8-39. Appendix C of the source control FDR contains the results of slug tests conducted in wells screened in the upper alluvium in Segments 1 and 2. Those results indicate that the hydraulic conductivity in the upper alluvium is variable in both segments, but is lower in general in Segment 2.

6. ***Section 4.1, page 10, paragraph 4, first sentence:*** ***NW natural should define the term "high degree" used in the context of this sentence. Based on review of the hydraulic capture data (Table 3), the quantified gradient reduction appears very small, with the exception of the pumping wells, which have significant drawdown as a result of well loss effects.***

NW Natural Response: In this case, we were trying to describe the amount of the decline in the elevation delta between the river elevation and the groundwater elevation at the offshore piezometers. For example, if the pre-pumping ambient average elevation delta at a particular piezometer was 0.2 feet and during the test an average elevation delta of 0.1 foot was measured, then a 50 percent reduction in the elevation delta was achieved compared to ambient conditions.

7. ***Section 4.1, page 10, paragraph 4:*** ***NW Natural should present additional information and analysis to support their belief that "complete containment" can be achieved by varying extraction well pumping rates to counterbalance the effect of river tidal fluctuations and seasonal river stage fluctuations. This information would evaluate, on an analytical basis, the sustainable pumping rates of each well based on their available drawdown, specific capacities, and pumping rates necessary to achieve drawdown at during seasonal extremes. This evaluation should include the month of September when groundwater heads are low resulting in less available drawdown and river stages are even lower, requiring higher pumping rates. These conditions do not appear to have been evaluated in any of the existing long-term alluvial aquifer pumping tests.***

NW Natural Response: These conditions can be evaluated using the groundwater flow model, but the reviewer's assessment that, "when groundwater heads are low resulting in less available drawdown and river stages are even lower, requiring higher pumping rates"

is not correct. When groundwater levels and river levels are low, then groundwater flow is also low; therefore, there is less groundwater that needs to be captured and pumps would operate at lower flow rates with less drawdown.

3 PLC AND VFD FIELD TESTS

3.1 Programming

The first phase of the VFD testing plan was to program the PLC, which was contracted to R&W Engineering, Inc.. Locations of the pumping wells, control wells, and monitoring wells are shown on Figure 2 in Plan View. Cross sections showing locations of the pumping wells, control wells, and monitoring wells are shown on Figures 3a and 3b.

A control well was selected to control each pumping well for the test. Monitoring well MW-22-80 was selected to control pumping well PW-9-92, monitoring well MW-23-75 was selected to control pumping well PW-8-68, and monitoring well MW-21-75 was selected to control PW-7-93. The selected control wells are approximately 100 to 150 feet away from the corresponding pumping well with a screen interval at a similar depth so that the control well would be more likely to have a strong hydraulic connection with the pumping well. The selected control wells are also identified in Table 3-4 of the FDR.

As described in the source control FDR, the PLC can be programmed to monitor the groundwater elevation at each control well, which is continuously compared in real time to the river water elevation. The difference between the river elevation and the groundwater elevation at each control well is termed the elevation delta. For the test, the PLC was programmed to maintain an elevation delta at each of the three control wells. This means that the PLC will adjust the extraction well pump speed to maintain the groundwater elevation below the river elevation at each of the control wells. The PLC was programmed to increase the pump speed as needed to maintain the groundwater elevation below river elevation. As explained in the next section, the PLC was programmed to maintain different elevation deltas for the short-term tests and the 3-day test.

3.2 Pump Test

During March 2011, several short-term pump tests were conducted to test the programming of the PLC and confirm that the pump speed responded consistent with the programming. Test durations ranged from several minutes to several hours as programming was tested and modified. During these short-term tests, all three control wells were programmed to maintain an elevation delta between 0.1 and 0.2 feet. That is, the system was programmed to maintain the groundwater elevation at each of the control wells between 0.1 and 0.2 feet below the river

elevation. The programming was successful in maintaining the target elevation delta at the control wells for the short-term tests.

A 3-day continuous pump test was next performed to provide data to assess the performance of the PLC and VFD system. The 3-day test began on April 5, 2011. For the 3-day test, all three of the control wells were assigned an elevation delta between 0.3 and 0.4 foot. The increased elevation delta was selected to determine if the system would be capable of maintaining a higher elevation delta at the control wells.

Prior to running the 3-day test, the transducer at the river and the transducers installed in the pumping wells, control wells, and monitoring wells were field calibrated. Due to the high river stage at the time of test, the PZ5 piezometer cluster located at the riverbank was inaccessible and could not be monitored. Throughout the 3-day test, the discharge rate and totaled flow volumes from each of the extraction wells were recorded, along with the water level and water temperature data from the transducers. Copies of the electronic data are provided on a CD in Appendix B to this report.

The flow from each of the pumping wells was recorded at 1-minute intervals during the test. During the 3-day test, the pumping rate ranged from 0 to 74 gpm in PW-7-93 with an average pumping rate of 12 gpm. The pumping rate ranged from 0 to 72 gpm in PW-8-68, with an average pumping rate of 50 gpm. The pumping rate ranged from 0 to 67 gpm in PW-9-92, with an average pumping rate of 34 gpm. Review of the water level data and pumping rates indicates that pumping at PW-8-68 was strongly affecting the water elevation at MW-21-75 (the control well for PW-7-93) so that a lower pumping rate was needed at PW-7-93 to maintain the elevation delta. As described in Section 3 of the FDR, when the complete source control extraction system is installed, it will be necessary during startup to adjust the elevation delta at each of the control wells to balance the pumping rates between the extraction wells.

4 WATER LEVEL DATA ANALYSIS

All transducer data were downloaded and compiled into an Excel spreadsheet. Figure 4 shows a hydrograph of all monitored wells compared to the Willamette River. As shown in the figure, before the test, most monitoring wells show the groundwater elevation above the level of the River. Once the test begins, the water level elevations in all but a few monitoring wells are quickly lowered below river level. The few wells that do not show a groundwater elevation below the river level during pumping are either upland wells that are beyond the capture zone for the three extraction wells or fill wells that are not affected by short-term pumping in the alluvium.

Figures 5, 6, and 7 are the hydrographs for offshore piezometer clusters PZ1, PZ2, and PZ4. Review of these hydrographs shows that during the 3-day test, the groundwater elevation in all of the offshore piezometers screened in the alluvium were maintained below the river elevation. The only offshore piezometers that did not achieve a groundwater elevation below the river elevation were PZ1-5 and PZ2-5, which are screened in the shallow fill sediments overlying the alluvial sediments. As described below, significant reductions in the elevation delta were achieved at PZ1-5 and PZ2-5.

As with the previous Segment 2 constant rate pump tests, the groundwater elevations were calculated from the pump test data using the method of Serfes (1991). The data and calculated elevations are shown on Table 2. Where ΔH is positive, the groundwater elevation is higher than the river elevation; where ΔH is negative, the groundwater elevation is lower than the river elevation. Negative ΔH indicates reversal of gradient (that is, no groundwater seepage into the river at that location). The river elevation data are from the permanent electric water level transducer attached to the dock.

In Table 2, the negative or downward gradients are shown in red. The Serfes method filters tidal data over a 72-hour period to obtain mean groundwater and river elevations. These mean elevations are used to determine groundwater gradients. The Serfes method is specifically designed for use at sites where groundwater levels are strongly influenced by tidal fluctuations, as with the Gasco Sediments Site.

At all well locations in the last column in Table 2, for the post pumping ambient data (the 72-hour period following the VFD pump test), the ΔH is positive, indicating groundwater discharged to the river.

A simple interpretation of the data shows that negative differences mean that the groundwater levels are below the river and therefore contained by the pumping wells. By comparing the ΔH between the post-test ambient data and the VFD pumping data, it is seen that gradient reversals and seepage control were achieved at all offshore piezometers screened in the alluvium. At offshore piezometers PZ1-5 and PZ2-5 screened in the offshore fill, significant reductions in the elevation delta were achieved as compared to the post-test ambient water elevations. It is anticipated that the Fill Water Bearing (WBZ) source control measure proposed in the FDR will achieve seepage control in the offshore fill.

The field tests of the PLC and VFD interface showed that the system is successful at controlling extraction well discharge rates concurrent with groundwater level changes to maintain a consistent condition of offshore seepage control throughout the tidal cycles.

5 REFERENCES

Anchor QEA, 2011a. *Segment 2 Capture Zone Field Test Report*, Gasco Sediments Site, Portland, Oregon. Submitted to U.S. Environmental Protection Agency and Oregon Department of Environmental Quality. March 2011.

Anchor QEA, 2011b. *Draft Groundwater Source Control Final Design Report,* NW Natural Gasco Site. Submitted to Oregon Department of Environmental Quality. May 2011.

Serfes, M. 1991. Determining the mean hydraulic gradient of ground water affected by tidal fluctuations. Ground Water, v. 29, n. 4.

TABLES

Table 1
Specific Capacity of Pumping Wells

Well ID	Pumping Rate GPM	Static Water Elevation at Start of Test ft	Water Elevation at Steady-State Pumping ft	Drawdown ft	Specific Capacity GPM/ft	Specific Capacity GPD/ft
PW-7-93	35	7.30	2.25	5.05	6.9	9980
PW-8-39	2	7.78	-5.93	13.71	0.15	210
PW-8-68	35	7.29	4.43	2.86	12.2	17622
PW-9-92	35	7.13	-4.48	11.61	3.0	4341

Well ID	Pumping Rate GPM	Water Elevation at End of Test ft	Static Water Elevation after Recovery ft	Drawdown ft	Specific Capacity GPM/ft	Specific Capacity GPD/ft
PW-7-93	35	0.70	6.93	6.23	5.6	8090
PW-8-39	2	-8.60	7.22	15.82	0.13	182
PW-8-68	35	3.87	6.93	3.06	11.4	16471
PW-9-92	35	-5.30	6.98	12.28	2.9	4104
				Average	6.3	9035
					0.14	196
					11.8	17046
					2.9	4223

Table 2
Pump Test Results Average Groundwater Elevations

	Ambient Pre-Test		Ambient Pre-test		72 hour Pump Test - 25 GPM		72 hour Pump Test - 35 GPM		Pre Test Ambient		72 hour Pump Test - 25 GPM	
	4/21/10 18:00 - 4/24/10 18:00		4/23/10 0:00 - 4/26/10 0:00		4/27/10 0:00 - 4/30/10 0:00 25 GPM		5/4/10 12:00 - 5/7/10 12:00		11/5/10 12:00 - 11/8/10 11:00		11/8/10 12:47 - 11/11/10 12:47	
	72 hour Moving Average	Δ H from River	72 hour Moving Average	Δ H from River	72 hour Moving Average	Δ H from River	72 hour Moving Average	Δ H from River	72 hour Moving Average	Δ H from River	72 hour Moving Average	Δ H from River
MW-2-32	13.13	5.60	13.11	4.97	13.27	3.92	13.08	5.21	10.14	2.61	10.22	2.76
MW-2-61	7.63	0.11	8.24	0.10	9.12	(0.23)	7.57	(0.30)	7.65	0.12	7.27	(0.19)
MW-2-104	7.64	0.11	8.25	0.11	9.11	(0.24)	7.54	(0.33)	7.69	0.16	7.30	(0.16)
MW-3-26	13.78	6.26	13.65	5.51	14.31	4.96	13.82	5.94	13.97	6.44	14.44	6.98
MW-3-56	7.76	0.24	8.33	0.19	9.34	(0.01)	7.96	0.09	7.77	0.25	7.54	0.08
MW-16-65	7.76	0.24	8.33	0.19	9.37	0.02	8.00	0.13	7.78[a]	0.25	7.58[a]	0.12
MW-18-125	NA	NA	NA	NA	NA	NA	NA	NA	7.69[b]	0.16	7.45[b]	(0.01)
MW-18-180	7.74	0.22	8.35	0.21	9.51	0.16	8.06	0.19	7.78	0.25	7.68	0.22
MW-21-12	12.73	5.20	12.72	4.58	13.16	3.81	12.85	4.98	12.23	4.70	12.48	5.02
MW-21-75	7.67	0.15	8.28	0.14	9.12	(0.23)	7.56	(0.32)	7.73	0.20	7.32	(0.14)
MW-21-115	7.73	0.20	8.33	0.19	9.23	(0.12)	7.65	(0.22)	7.78	0.25	7.40	(0.06)
MW-21-166	7.84	0.32	8.45	0.31	9.60	0.25	8.14	0.26	7.88	0.35	7.76	0.30
MW-22-80	7.53	0.00	8.14	(0.00)	9.09	(0.26)	7.63	(0.25)	7.64	0.11	7.32	(0.14)
MW-23-27	9.51	1.99	9.59	1.45	10.10	0.75	9.89	2.01	9.01	1.48	9.16	1.70
MW-23-75	7.58	0.06	8.20	0.06	9.05	(0.30)	7.51	(0.37)	7.65	0.12	7.27	(0.19)
MW-23-123	7.59	0.07	8.20	0.06	9.19	(0.16)	7.69	(0.18)	7.69	0.16	7.37	(0.09)
MW-24-70	7.73	0.21	8.30	0.16	9.32	(0.03)	7.93	0.05	7.78	0.25	7.55	0.09
MW-24-130	7.66	0.14	8.27	0.13	9.28	(0.07)	7.78	(0.09)	7.70	0.17	7.44	(0.02)
OW-7-17	11.72	4.19	11.71	3.57	12.28	2.93	11.78	3.91	11.91	4.38	12.18	4.72
OW-8-15	12.02	4.50	12.04	3.90	12.49	3.14	12.15	4.28	11.42	3.89	11.54	4.08
OW-8-28	NA	NA	NA	NA	NA	NA	NA	NA	9.24	1.71	8.21	0.75
OW-9-25	9.83	2.31	9.88	1.74	10.29	0.94	9.93	2.05	9.31	1.78	9.40	1.93
PW-7-93	7.87	0.35	8.48	0.34	3.59	(5.76)	-1.14	(9.02)	7.83	0.30	1.73	(5.73)
PW-8-39	NA	NA	NA	NA	NA	NA	NA	NA	8.24	0.71	-7.88	(15.34)
PW-8-68	7.81	0.29	8.42	0.28	6.38	(2.97)	3.60	(4.27)	7.84	0.31	4.51	(2.95)
PW-9-92	7.78	0.25	8.39	0.25	-2.83	(12.18)	-10.60	(18.47)	7.69	0.16	-4.41	(11.87)
PZ1-5	7.87	0.34	8.35	0.21	9.63	0.28	8.38	0.51	8.33	0.80	8.29	0.83
PZ1-20	7.86	0.34	8.41	0.27	9.47	0.12	8.14	0.27	7.67	0.14	7.50	0.04
PZ1-50	7.63	0.10	8.24	0.10	9.17	(0.18)	7.64	(0.23)	7.66	0.13	7.32	(0.14)
PZ2-5	7.68	0.15	8.29	0.15	9.31	(0.04)	7.80	(0.08)	7.63	0.10	7.57	0.11
PZ2-20	7.70	0.18	8.30	0.16	9.39	0.04	7.97	0.10	7.67	0.14	7.50	0.04
PZ2-43	7.60	0.08	8.21	0.07	9.30	(0.05)	7.83	(0.05)	7.65	0.12	7.46	(0.00)
PZ2-77	7.68	0.15	8.29	0.15	9.31	(0.04)	7.80	(0.08)	7.70	0.17	7.45	(0.02)
PZ4-12	7.55	0.03	8.13	(0.01)	9.28	(0.07)	7.90	0.02	7.60	0.07	7.49	0.03
PZ4-41	7.59	0.06	8.19	0.05	9.34	(0.01)	7.89	0.01	7.63	0.10	7.50	0.04
PZ5-5	9.52	2.00	9.69	1.55	10.35	1.00	9.69	1.81	9.61	2.08	9.60	2.14
PZ5-20	8.58	1.05	8.98	0.84	9.92	0.57	8.88	1.00	8.61	1.08	8.51	1.05
PZ5-55	7.69	0.17	8.30	0.16	9.21	(0.14)	7.67	(0.21)	7.71	0.18	7.35	(0.11)
PZ5-85	7.70	0.18	8.31	0.17	9.24	(0.11)	7.70	(0.17)	7.71	0.18	7.35	(0.11)
Willamette River	7.52	0.00	8.14	0.00	9.35	0.00	7.87	0.00	7.53	0.00	7.46	0.00

Notes:

Values represent average water level elevation in feet, City of Portland datum. Average values calculated using a 72 hour moving average method (Serfes, 1991).

Values in red with parentheses represent negative values (average water level in River higher than average water level in well).

a = Survey elevations corrected for MW-16-65 (was 34.65, now 33.21)

b = Survey elevations corrected for MW-18-125 (was 33.18, now 34.65)

Table 2
Pump Test Results Average Groundwater Elevations

	Post Test Ambient		72 hour Pump Test - VFD		72 hour Pump Test - VFD	
	11/12/10 8:40 - 11/15/10 8:40		4/5/11 12:30 - 4/8/11 12:30		4/8/11 14:00 - 4/11/11 14:00	
	72 hour Moving Average	Δ H from River	72 hour Moving Average	Δ H from River	72 hour Moving Average	Δ H from River
MW-2-32	9.79	4.08	17.31	0.46	16.11	2.12
MW-2-61	5.91	0.19	16.49	(0.37)	14.18	0.18
MW-2-104	5.96	0.24	16.47	(0.38)	14.19	0.19
MW-3-26	14.37	8.66	17.23	0.38	16.23	2.24
MW-3-56	6.14	0.43	16.84	(0.01)	14.40	0.40
MW-16-65	6.14[a]	0.43	16.76	(0.09)	14.27	0.27
MW-18-125	5.95[b]	0.23	16.73	(0.12)	14.19	0.19
MW-18-180	6.03	0.32	16.96	0.11	14.27	0.28
MW-21-12	12.34	6.62	17.41	0.56	16.04	2.05
MW-21-75	6.01	0.29	16.49	(0.37)	14.19	0.20
MW-21-115	6.02	0.31	16.59	(0.26)	14.24	0.25
MW-21-166	6.12	0.41	17.03	0.17	14.35	0.35
MW-22-80	5.88	0.17	16.56	(0.30)	14.14	0.15
MW-23-27	8.86	3.15	16.99	0.14	15.08	1.09
MW-23-75	5.89	0.18	16.56	(0.30)	14.23	0.24
MW-23-123	5.93	0.22	16.60	(0.26)	14.19	0.20
MW-24-70	6.14	0.42	16.79	(0.07)	14.27	0.27
MW-24-130	5.95	0.24	16.74	(0.12)	14.21	0.21
OW-7-17	11.88	6.17	16.94	0.08	14.51	0.51
OW-8-15	11.34	5.62	17.05	0.20	15.25	1.25
OW-8-28	8.38	2.66	16.86	0.01	14.59	0.60
OW-9-25	9.17	3.45	16.96	0.11	14.62	0.63
PW-7-93	6.09	0.37	14.76	(2.09)	14.39	0.39
PW-8-39	6.72	1.00	16.74	(0.11)	14.45	0.46
PW-8-68	6.09	0.37	11.01	(5.84)	14.40	0.41
PW-9-92	5.94	0.22	0.92	(15.93)	14.19	0.20
PZ1-5	7.08	1.37	16.92	0.07	14.13	0.13
PZ1-20	5.97	0.25	16.82	(0.04)	14.22	0.23
PZ1-50	5.91	0.20	16.52	(0.33)	14.15	0.15
PZ2-5	5.83	0.12	16.93	0.08	14.14	0.14
PZ2-20	5.97	0.25	16.82	(0.04)	14.22	0.23
PZ2-43	5.90	0.19	16.60	(0.25)	14.00	0.01
PZ2-77	5.94	0.23	16.65	(0.20)	14.15	0.16
PZ4-12	5.91	0.19	16.77	(0.09)	14.11	0.12
PZ4-41	5.87	0.16	16.78	(0.08)	14.10	0.10
PZ5-5	9.12	3.41	NA	NA	NA	NA
PZ5-20	7.55	1.83	NA	NA	NA	NA
PZ5-55	5.96	0.25	NA	NA	NA	NA
PZ5-85	5.96	0.24	NA	NA	NA	NA
Willamette River	5.71	0.00	16.85	0.00	13.99	0.00

Notes:

Values represent average water level elevation in feet, City of Portland datum. Average values calculated using a 72 hour moving average method (Serfes, 1991).

Values in red with parentheses represent negative values (average water level in River higher than average water level in well).

a = Survey elevations corrected for MW-16-65 (was 34.65, now 33.21)

b = Survey elevations corrected for MW-18-125 (was 33.18, now 34.65)

FIGURES

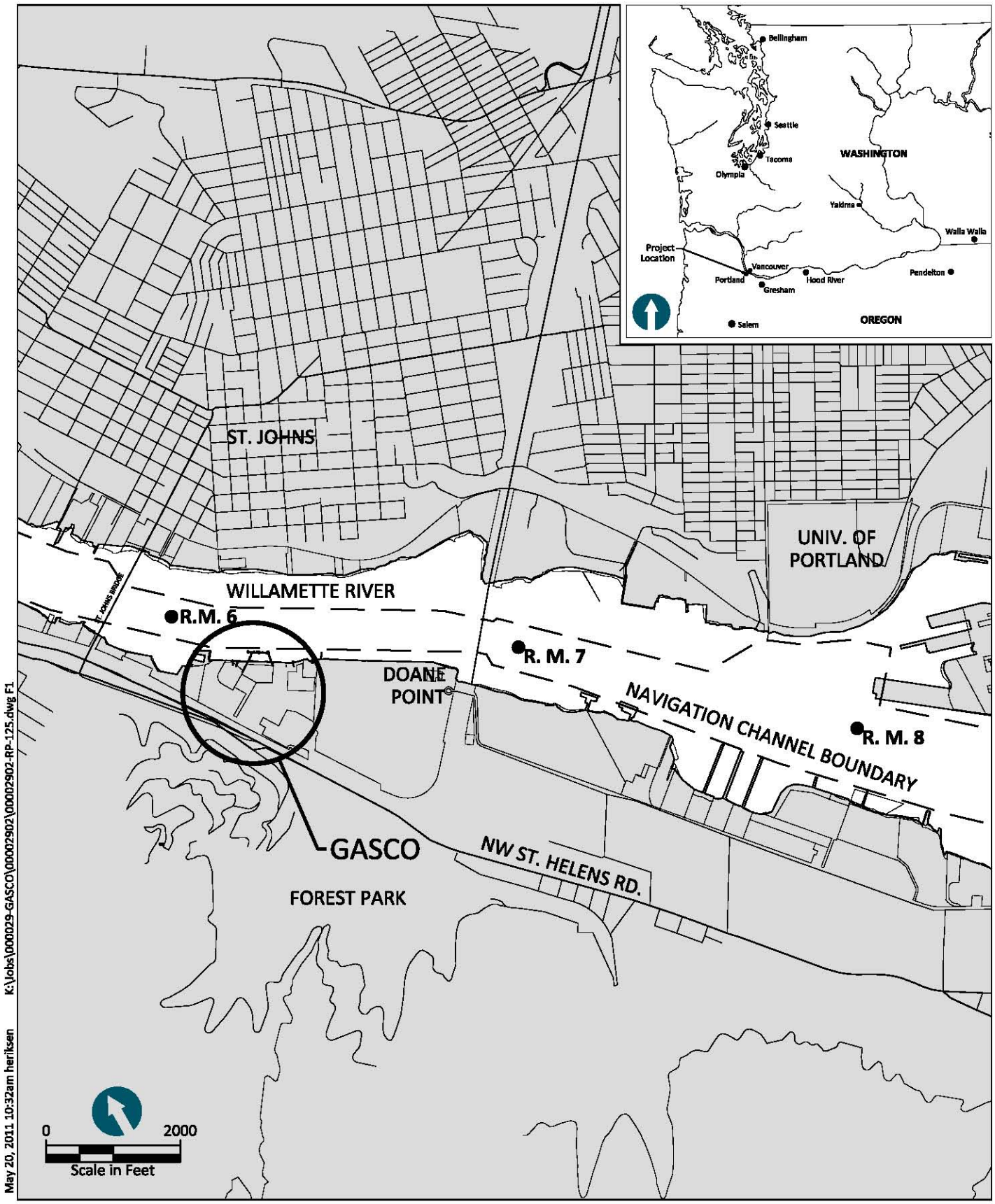

Figure 1
Site Vicinity Map
Segment 2 VFD Testing Report
Gasco

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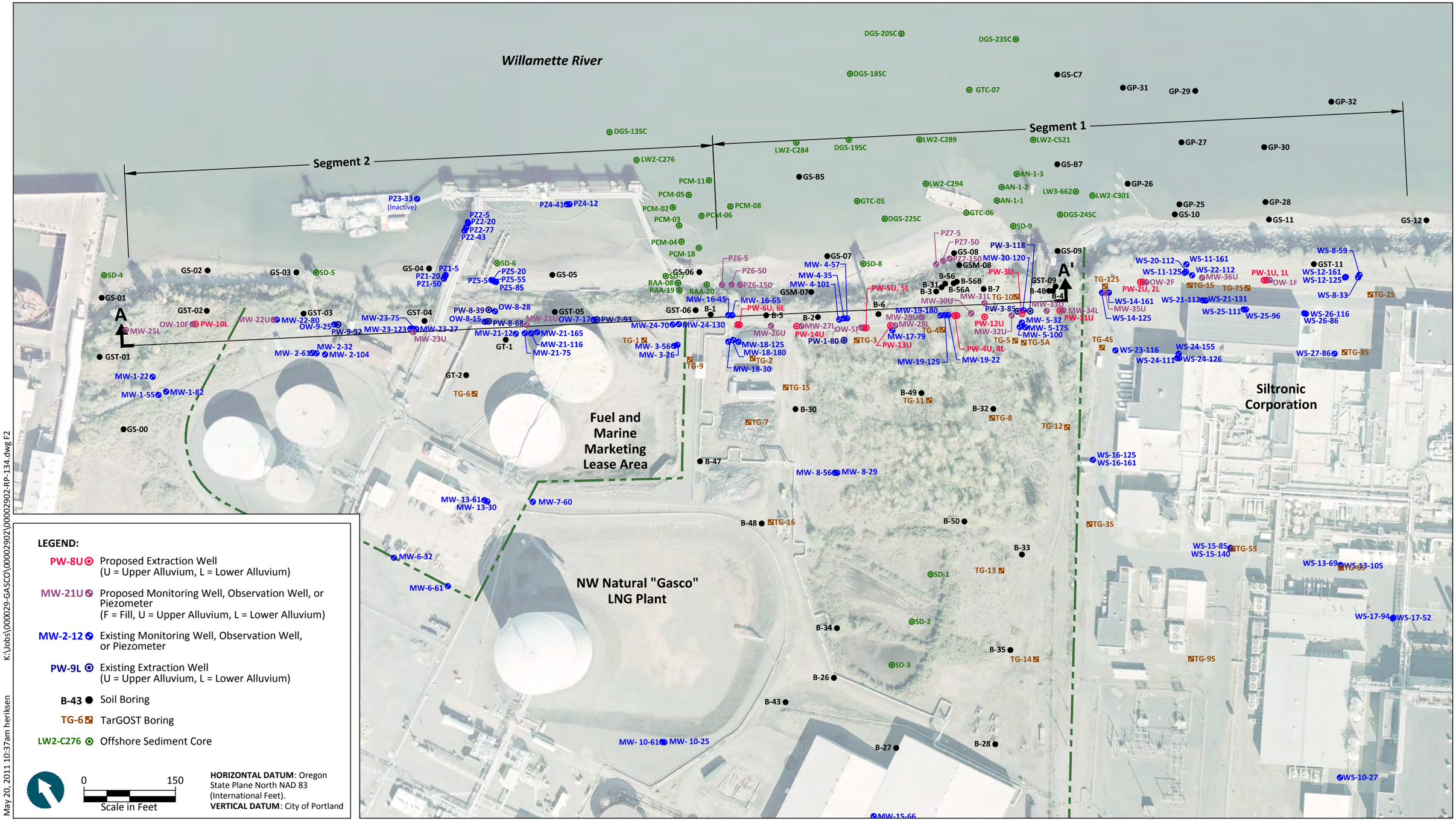

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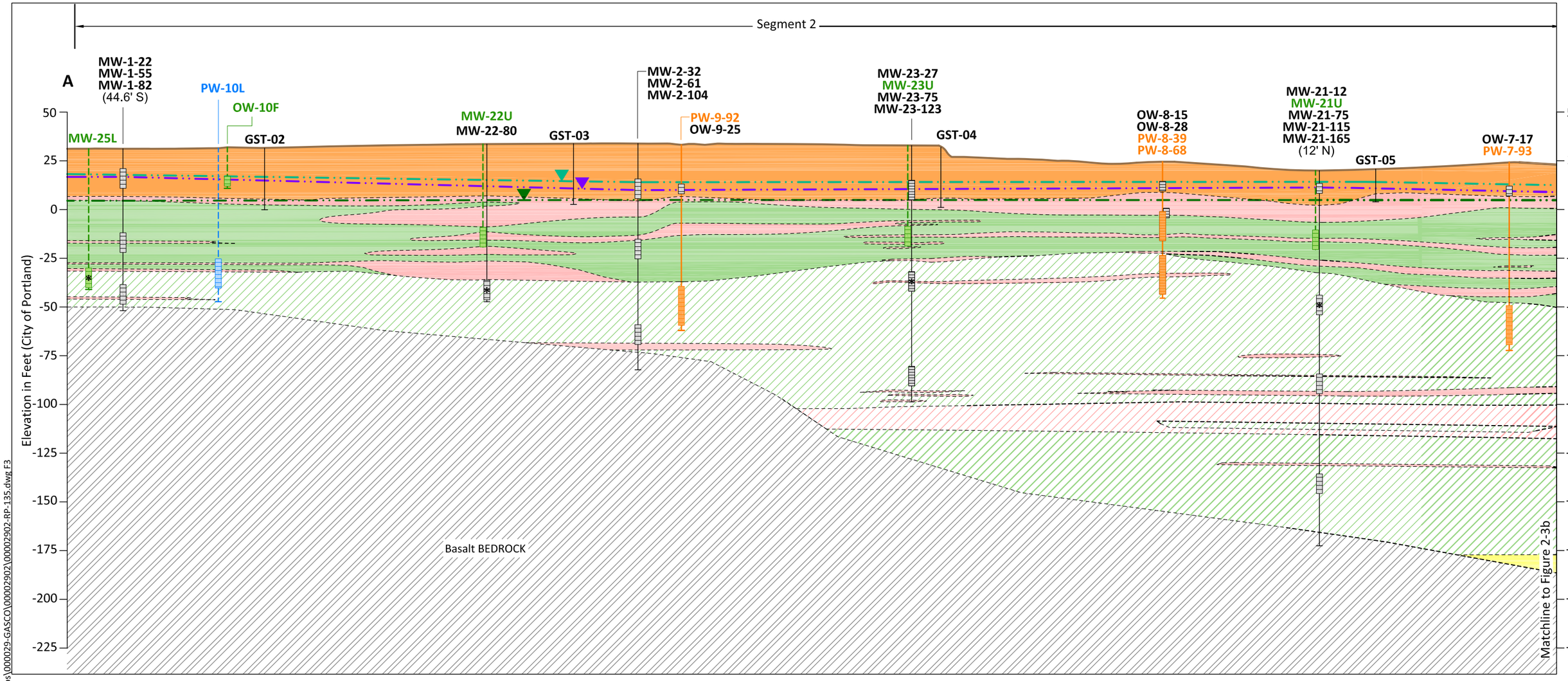
Figure 2
Monitoring Well and Cross Section Location Map
Segment 2 VFD Testing Report
Gasco



LEGEND:

- Fill composed of gravel, silt, sand, metal, brick, and concrete debris
- Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Primarily fine to medium grained SAND and SILTY-SAND interbedded with thin silt and sandy-silt layers
- Alluvial GRAVEL, sandy gravel, gravelly sand, and gravelly silt
- Aquitard; Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Primarily medium grained SAND with generally less than 15% fines.
- Basalt BEDROCK
- Potentiometric Surface of Surficial Fill (measured June 3, 2009)
- Potentiometric Surface of Surficial Fill (measured August 5, 2009)
- Potentiometric Surface of Alluvium (measured August 5, 2009)
- Existing Ground Surface

MW-21-16 — Boring ID
(57' E) — Offset Distance in Feet

Proposed Extraction Well
Existing Extraction Well
Proposed Well or Piezometer
Existing Well or Piezometer

- Tar Interval
- NAPL or Mixed NAPL and Tar Interval
- Well Screen
- * — Control Well

0 50
Scale in Feet

NOTE: Geologic contacts are inferred between borings.

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Figure 3a
Geologic Cross Section A-A'
Segment 2 VFD Testing Report
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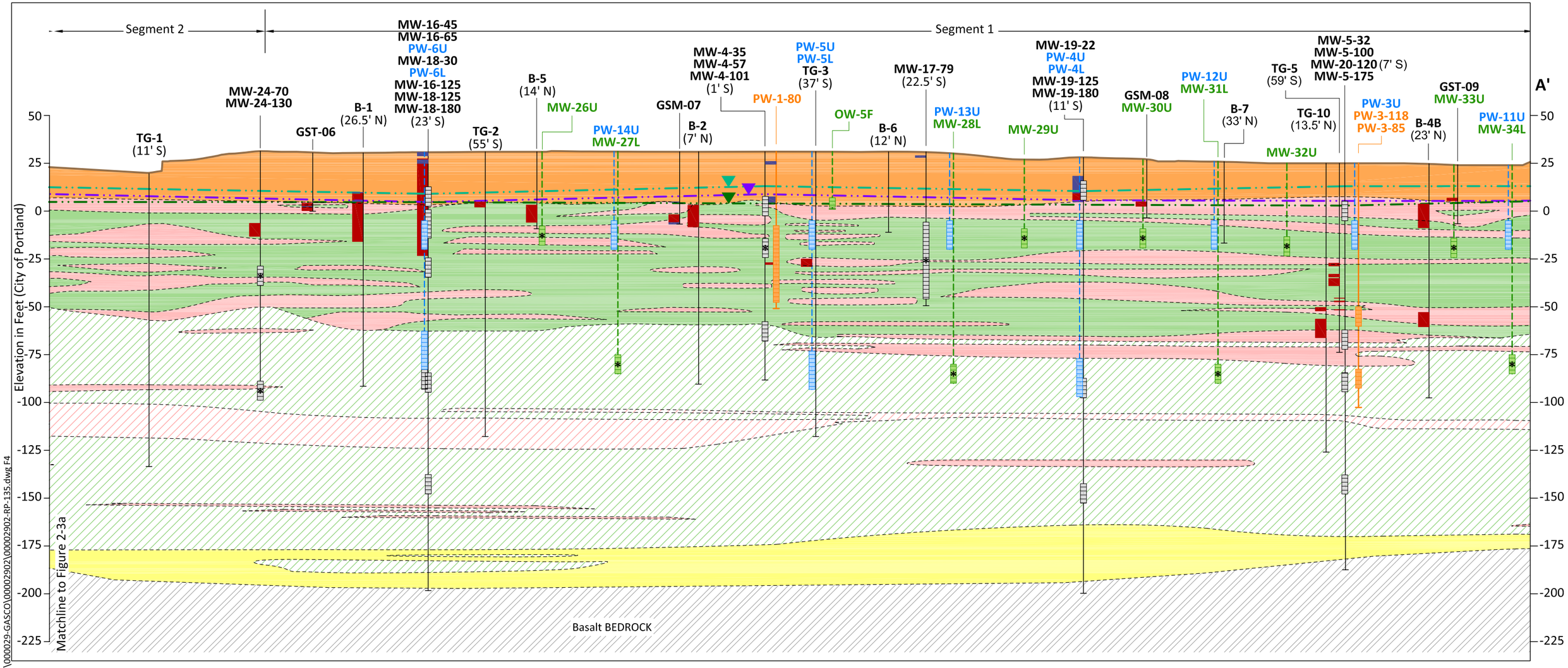

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LEGEND:

- Fill composed of gravel, silt, sand, metal, brick, and concrete debris
- Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Primarily fine to medium grained SAND and SILTY-SAND interbedded with thin silt and sandy-silt layers
- Alluvial GRAVEL, sandy gravel, gravelly sand, and gravelly silt
- Aquitard; Primarily SILT and SANDY-SILT interbedded with thin sand and silty-sand layers
- Primarily medium grained SAND with generally less than 15% fines.
- Basalt BEDROCK
- Potentiometric Surface of Surficial Fill (measured June 3, 2009)
- Potentiometric Surface of Surficial Fill (measured August 5, 2009)
- Potentiometric Surface of Alluvium (measured August 5, 2009)
- Existing Ground Surface

MW-21-16 — Boring ID
(57' E) — Offset Distance in Feet

Existing Extraction Well
Proposed Extraction Well
Proposed Well or Piezometer
Existing Well or Piezometer

- Tar Interval
- NAPL or Mixed NAPL and Tar Interval
- Well Screen
- * — Control Well

0 50
Scale in Feet

NOTE: Geologic contacts are inferred between borings.

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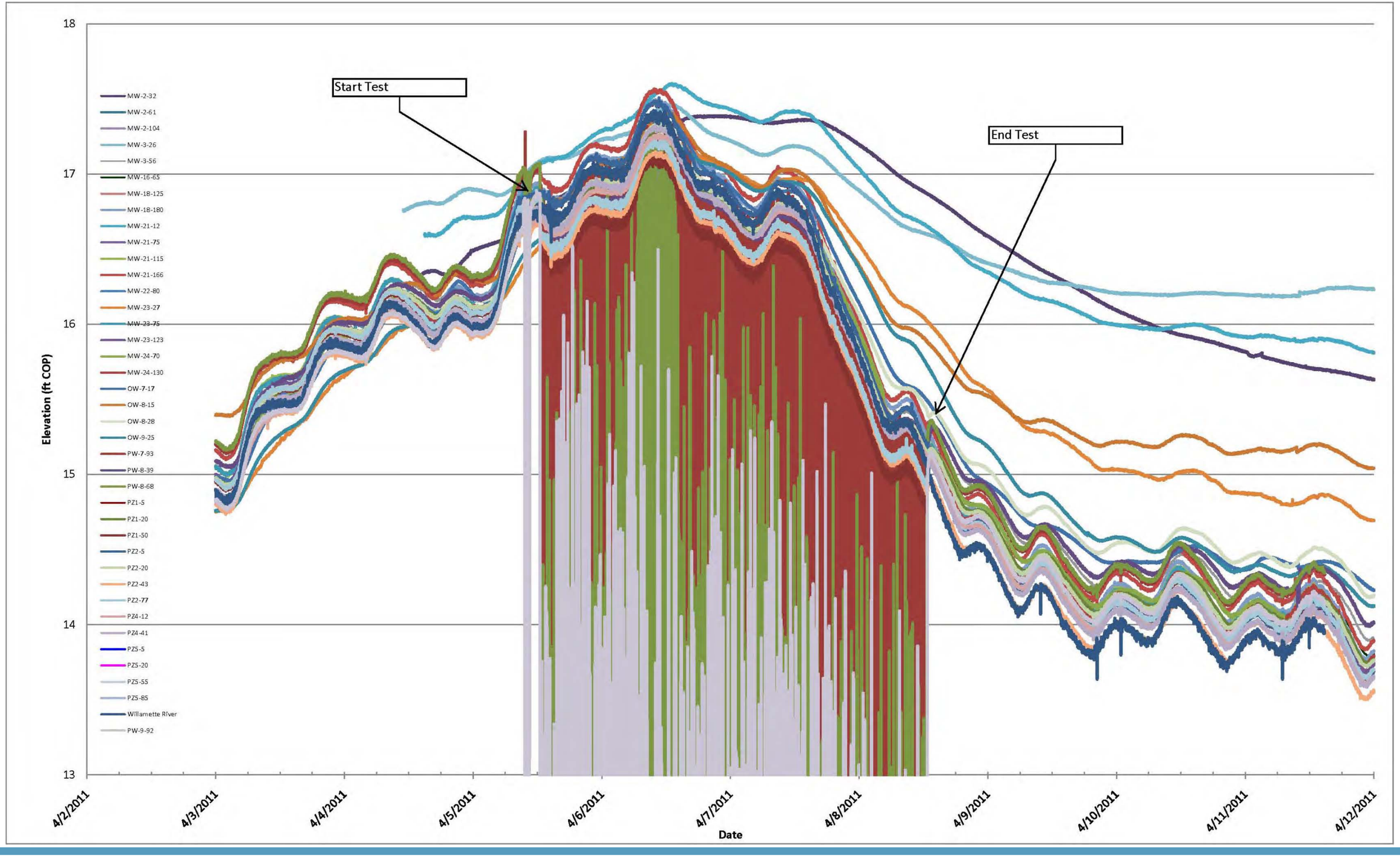
Figure 3b
Geologic Cross Section A-A'
Segment 2 VFD Testing Report
Gasco



ANCHOR QEA

Figure 4
Hydrograph – All Wells
Segment 2 VFD Testing Report
Gasco

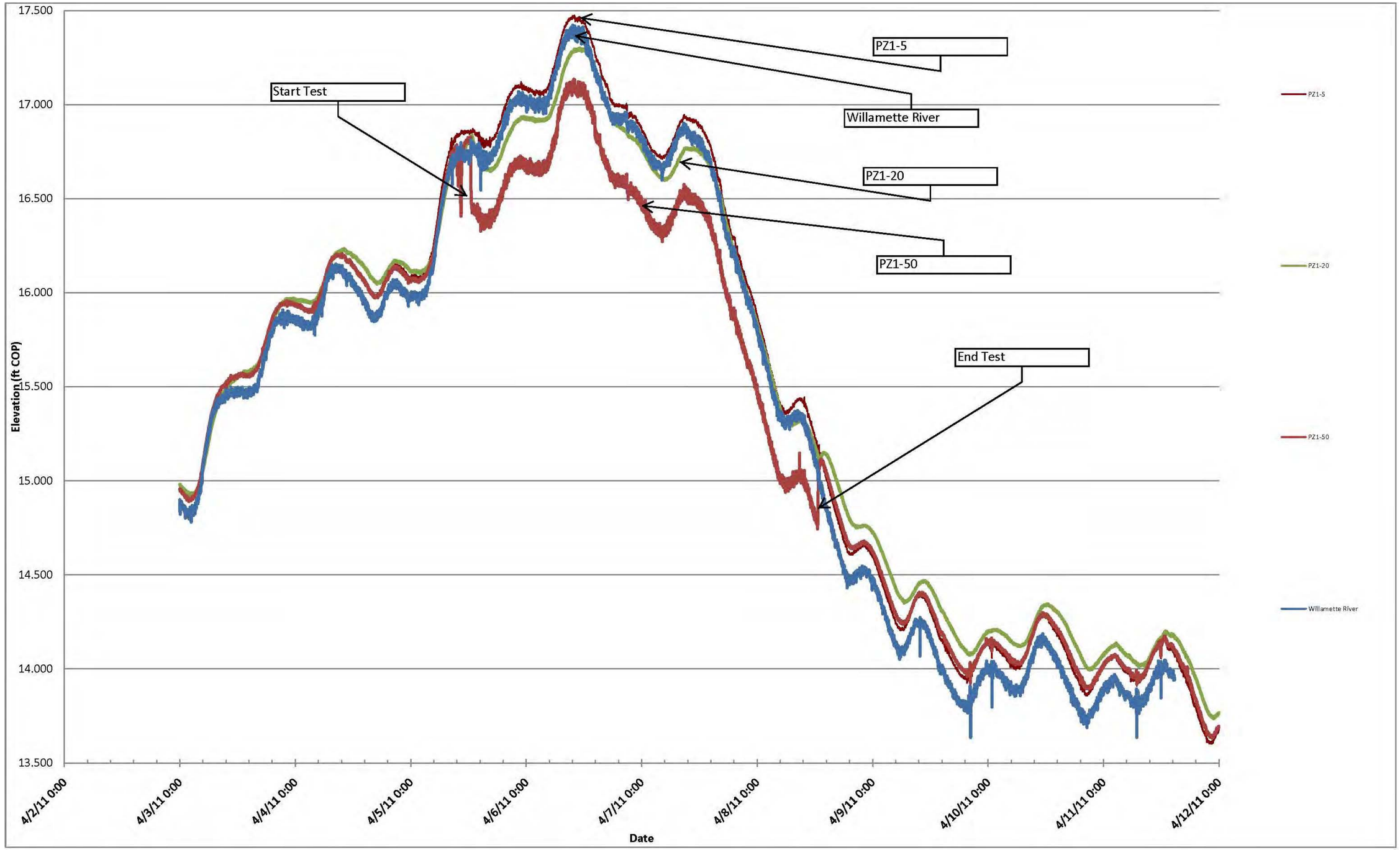


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Figure 5
Hydrograph – PZ1 Cluster
Segment 2 VFD Testing Report
Gasco

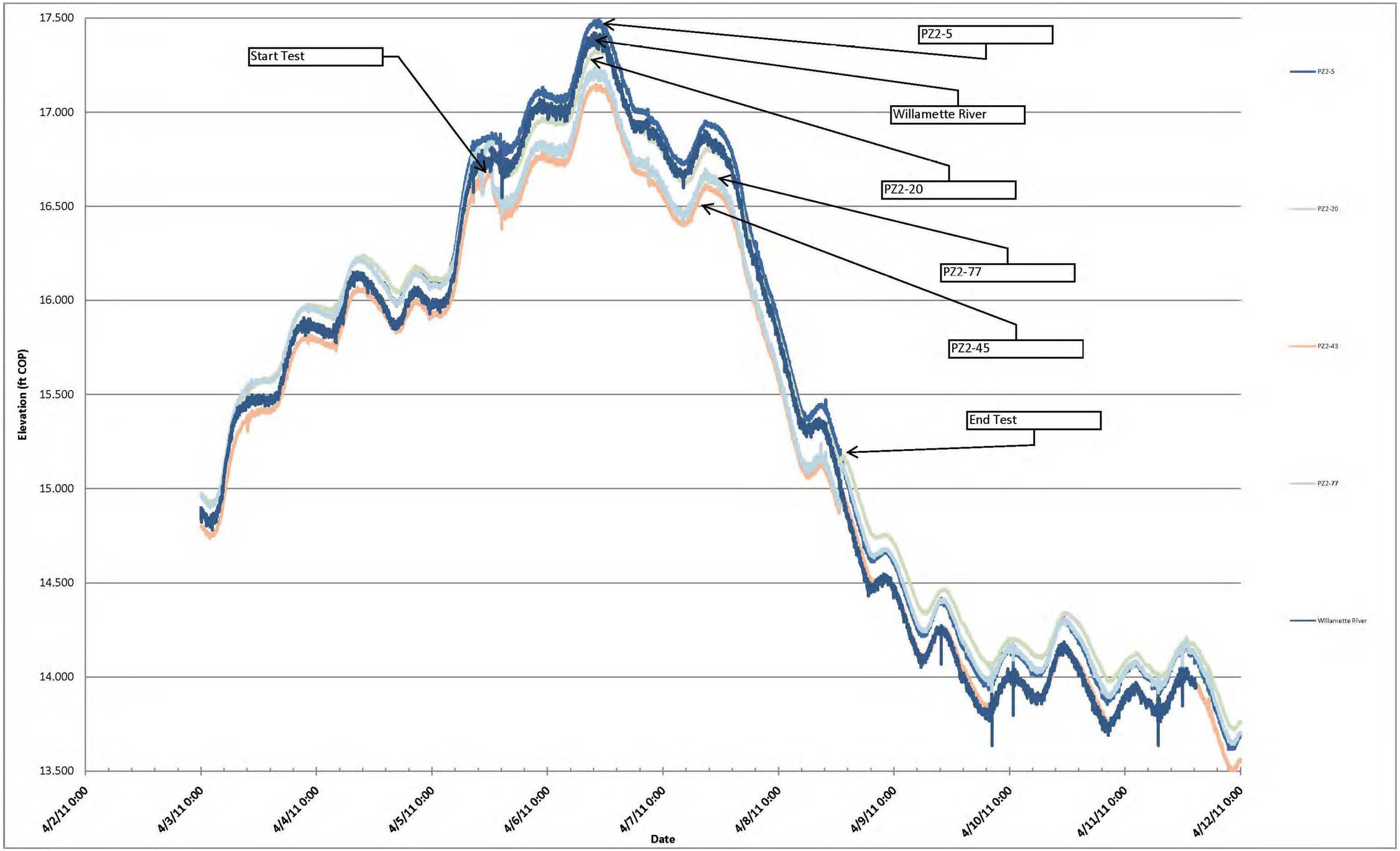

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Figure 6
Hydrograph – PZ2 Cluster
Segment 2 VFD Testing Report
Gasco

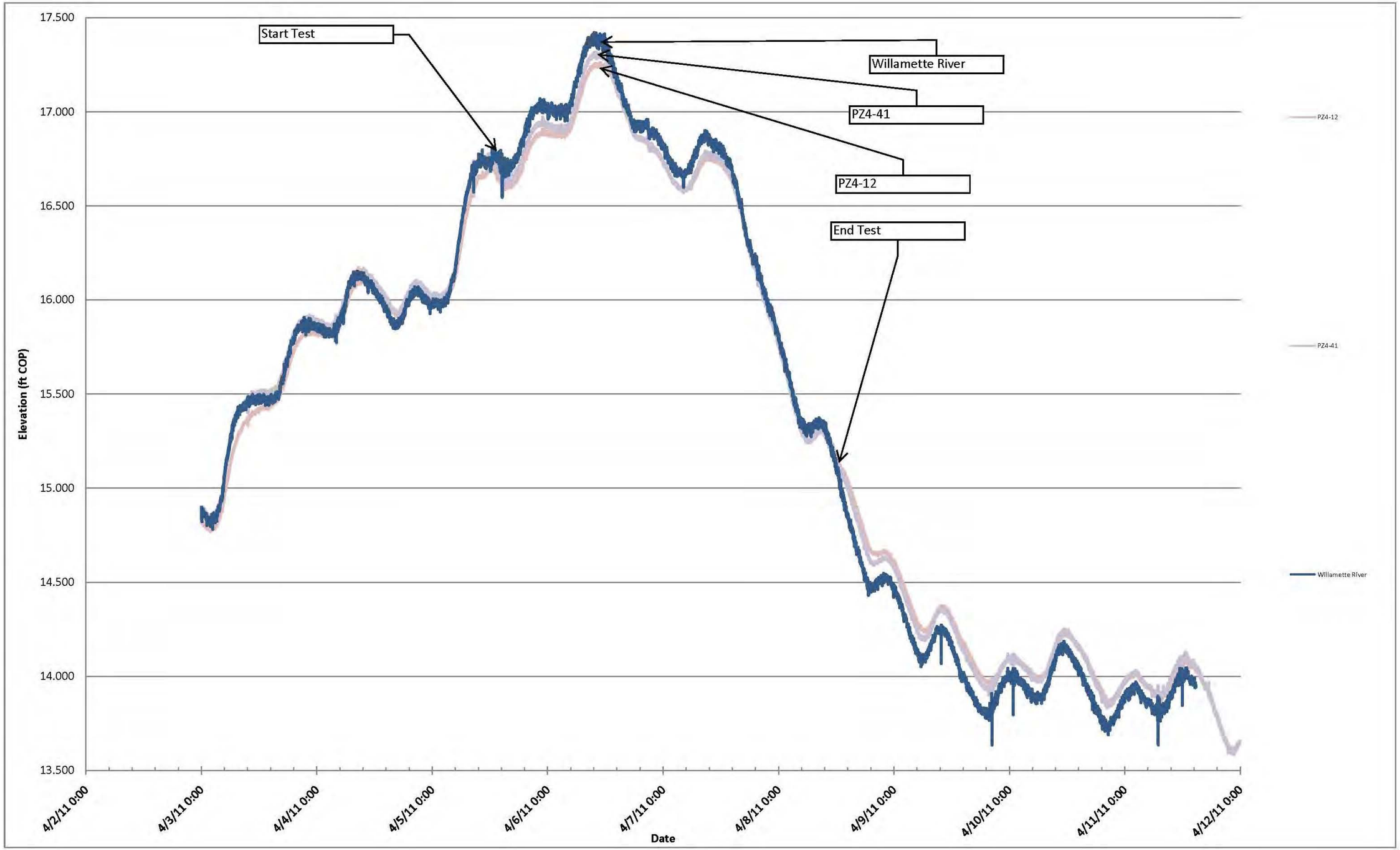

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Figure 7
Hydrograph – PZ4 Cluster
Segment 2 VFD Testing Report
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APPENDIX A
PW-8-39 PUMP TEST ANALYSIS

SSP1037

PW-8-39 Pumping Test Interpretation

Christopher J. Neville and Glenn A. Milner
S.S. Papadopulos & Associates, Inc.
Latest Update: 2011/01/24

Objective

To estimate the transmissivity from the responses to pumping PW-8-39.

Data

Data at the site include water levels for several wells and levels in the Willamette River collected between 2010/11/03 and 2010/11/21.

Methodology

The plot of water levels in the spreadsheet provided is reproduced in Figure 1. Water levels are shown for the Willamette River and all observation wells surrounding the river. The *x*-axis corresponds to the date and time the water levels were measured, and the *y*-axis corresponds to the water level above City of Portland datum, in feet.

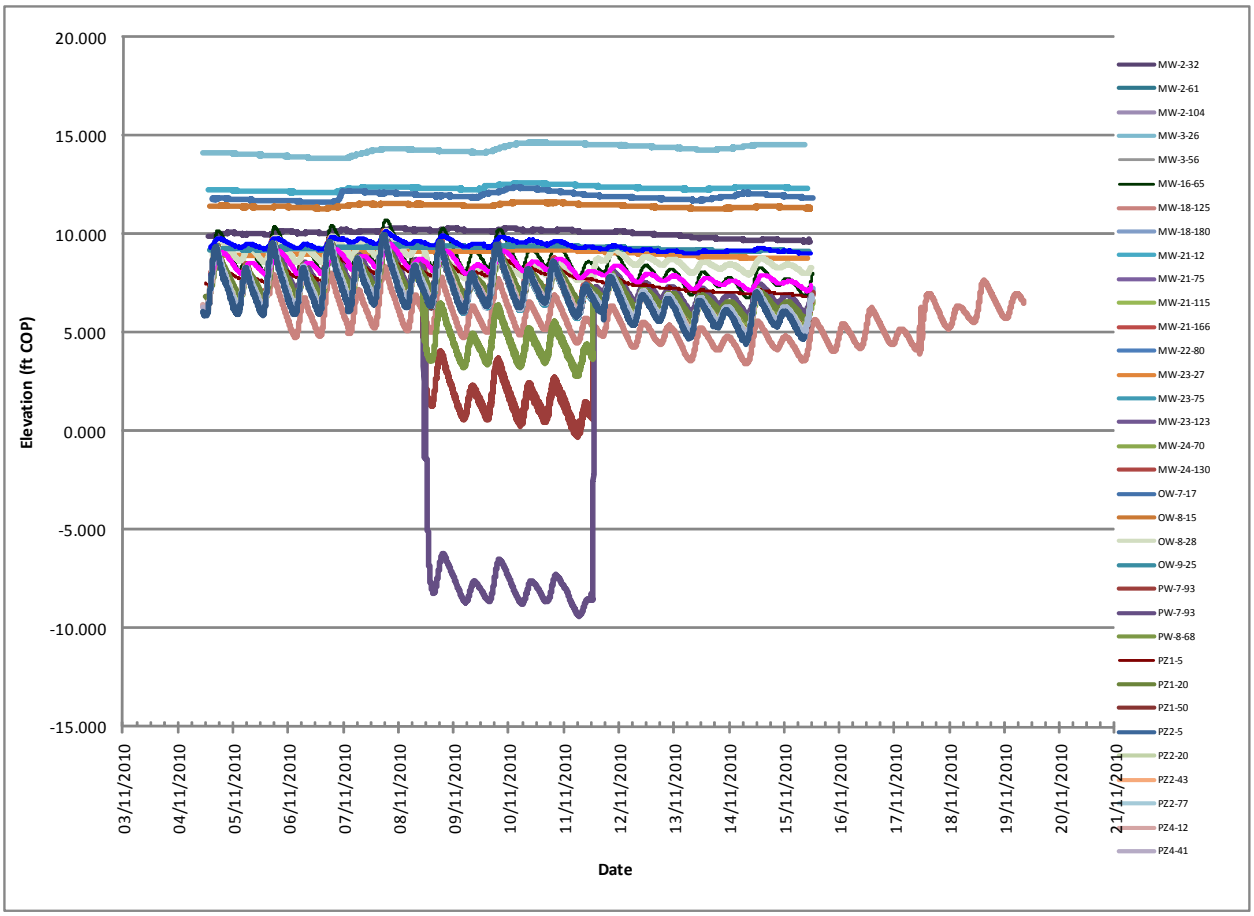

Figure 1 – Water levels in all wells and the Willamette River

Observations from the raw data records

Four features can be observed in the data shown in Figure 1. First, water levels oscillate through time, both in the Willamette River (curve shown in blue) and in several of the observation wells. Second, there is a long-term decreasing trend in the water level in the Willamette River. Third, there are abrupt changes in the water level in PW-8-39, PW-7-93 and PW-8-68 at the start and end of pumping. Finally, there appears to be declining trends in the water levels of PW-8-39, PW-7-93 and PW-8-68 reflecting the evolution of the effects of pumping.

The water levels for the three wells affected by pumping incorporate the effects of water level declines due to pumping, and of changes affected by pumping caused by fluctuations in the Willamette River. The changes in groundwater levels caused by changes in the Willamette River appear to be due to short-term cycles that are superimposed on a long-term declining trend.

For simplicity, we will assume that the long-term decline in the levels of the Willamette River can be approximated by a straight line. Using the water levels at the low points in the cycle, we estimate that the average water level declines at a rate of 0.202 ft/day. This long-term trend is shown in Figure 2.

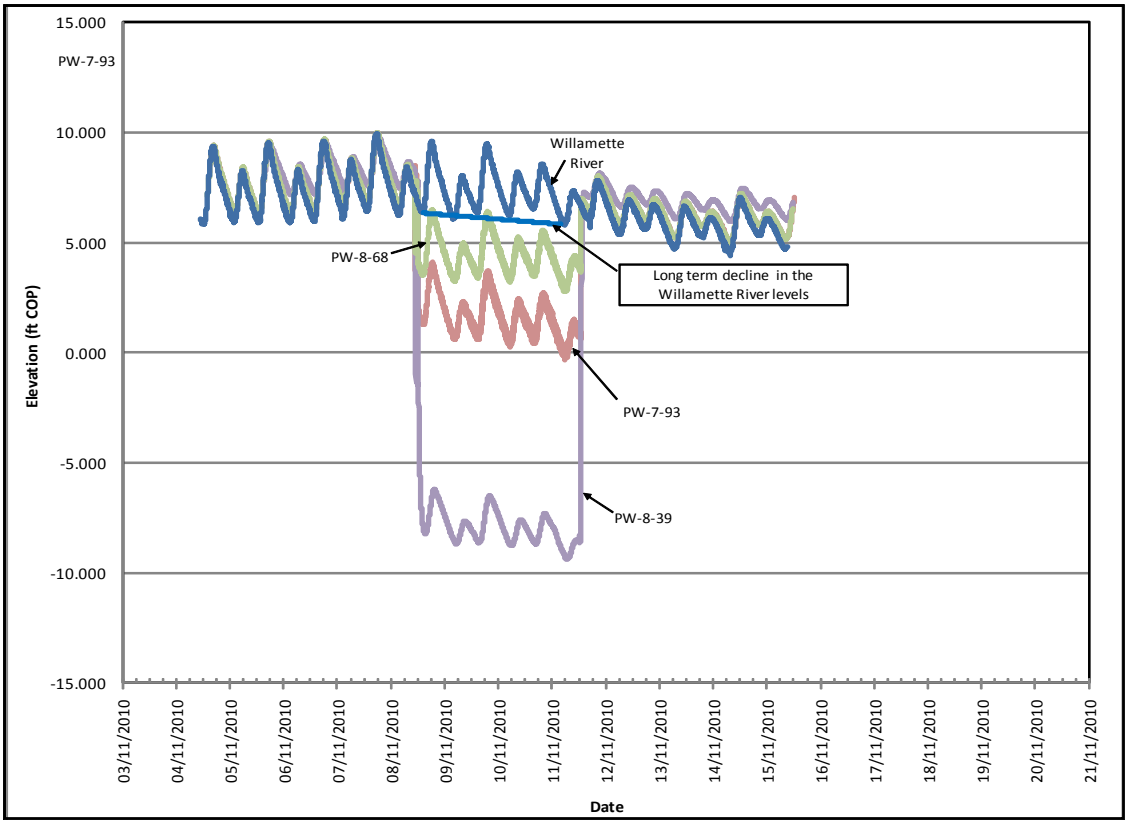

Figure 2 – Long term declining trend in the Willamette River

The long-term record of groundwater levels at PW-8-39, PW-7-93 and PW-8-68 are similar to that observed for the river, but with abrupt changes in levels at the start and end of pumping. We will assume that the changes associated with the fluctuations in the Willamette River are superimposed on the combined effects of pumping; that is, the initial abrupt decline followed by a more gradual decline, and a background declining trend. It appears that the background declining trend is similar for each of the three wells as that inferred for the Willamette River. This is shown in Figure 3.

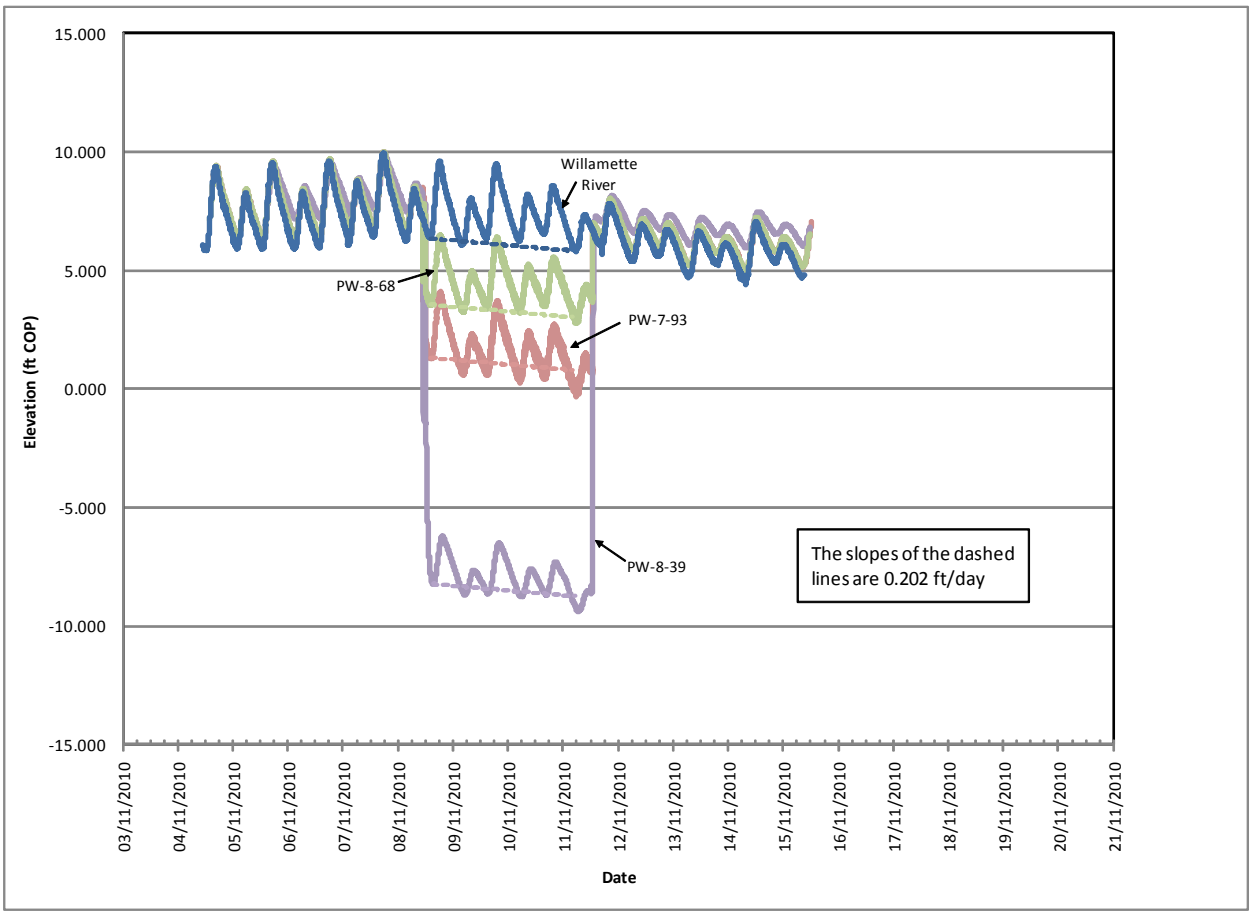

Figure 3 – Declining trends for isolating the long-term trend in the Willamette River

"Filtered" records for PW-8-39, PW-7-93 and PW-8-68 are created by removing the effects of the long-term decline in the level of the Willamette River. The adjusted water level is calculated as:

$$h(t)_{Adjusted} = h(t) + 0.202\frac{ft}{day} \times t \qquad (1)$$

Here $h(t)$ denotes observed water levels in the well at any point in time and t is the time in days since the start of pumping. Here $h(t=0)$ denotes observed water levels in a well at the start of pumping.

The drawdown at any time is defined as the difference between the observed water level and the water level at the start of pumping. The drawdown at each of the wells is estimated and adjusted for the effects of the Willamette River according to:

$$s(t) = h(t=0) - [h(t) + 0.202\frac{ft}{day} \times t] \qquad (2)$$

The filtered drawdown level records for PW-8-39, PW-7-93 and PW-8-68 are plotted as solid lines in Figure 4. The original drawdown record for each well incorporating the effects of the decline in the Willamette River is also shown in Figure 4 for comparison (shown as dashed lines above the filtered records).

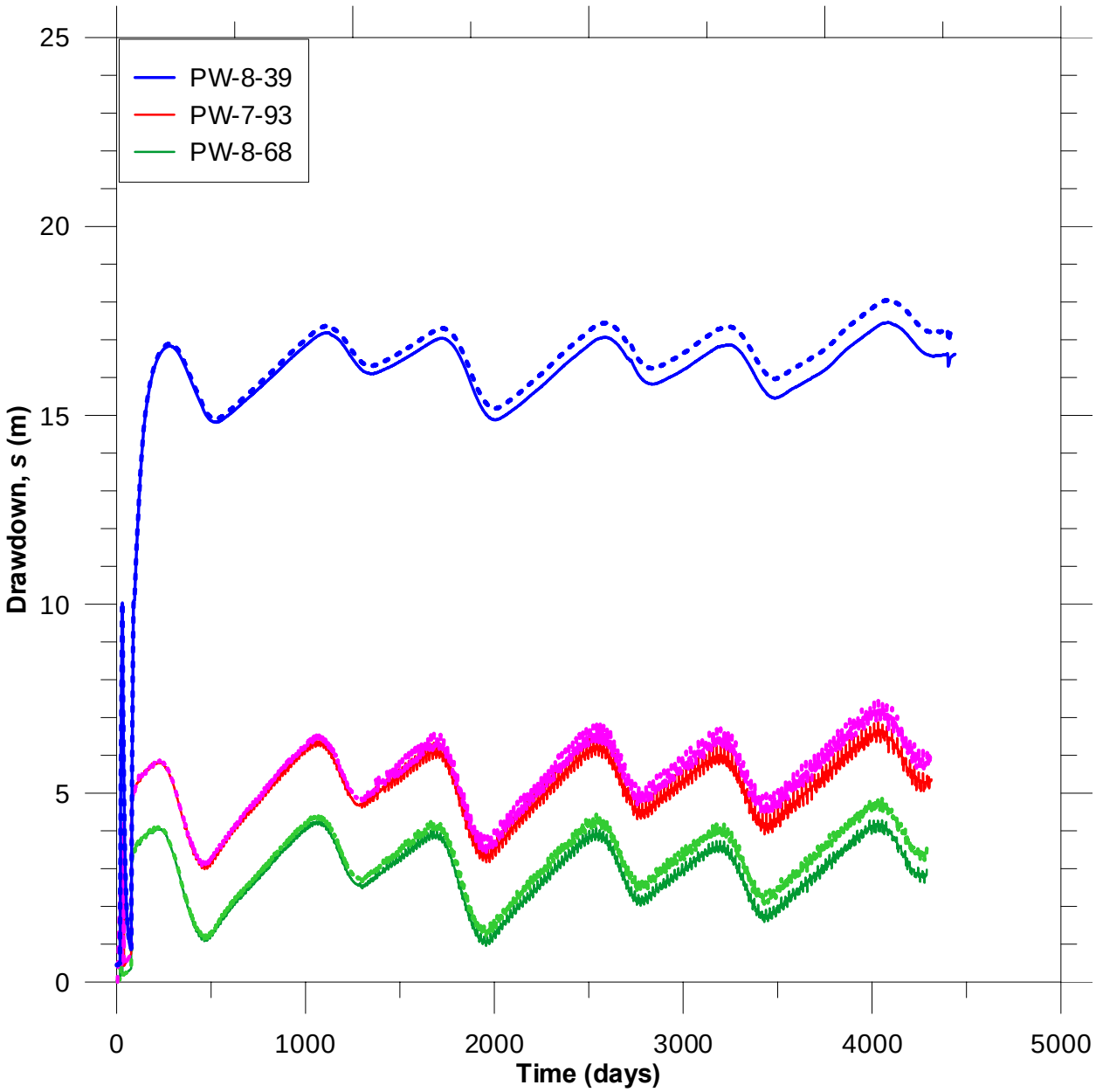

Figure 4 – Filtered changes in drawdown for PW-8-39, PW-7-93 and PW-8-68 since the start of pumping

Estimation of aquifer parameters from the PW-8-39 pumping test

Information found on wells PW-8-39, PW-7-93 and PW-8-68 are provided on Table 1.

Table 1 – Specifications of Pumping Wells

Well	Diameter(inches)	Well Depth (feet)	Ground Surface (feet COP)
PW-8-39	8	96.5	24.19
PW-7-93	8	50	23.22
PW-8-68	8	70	24.6

[1]Information for each well has been taken from the boring log files provided by the client

To estimate the transmissivity, the adjusted drawdown data from PW-8-39, PW-7-93, and PW-8-68 are matched with the Theis solution. The objective is to reproduce the general trend of the data with a consistent set of parameters (transmissivity, *T*, and storage coefficient, *S*). The effects of the connection to the river are interpreted as oscillations about the general trend. The results obtained through trial-and-error are shown in Figure 5. As shown in the figure, the estimated transmissivity is not very sensitive to the assumed value of the storage coefficient (*S*). For *S* ranging between 10^{-4} and 10^{-6}, the estimated transmissivity, *T*, varies from about 28 ft/day to 36 ft^2/day.

Evaluation

The aquifer is about 130 feet thick in the vicinity of PW-8-39. Therefore, the estimated hydraulic conductivities range from 0.2 ft/day to 0.3 ft/day. These values are in the middle of the range Freeze and Cherry (1979) suggest for silty sand.

The transmissivity estimated from pumping PW-7-93 was about 30 ft/d (SSP&A note of January 27, 2010). This matches closely the estimates derived from the PW-8-39 pump test.

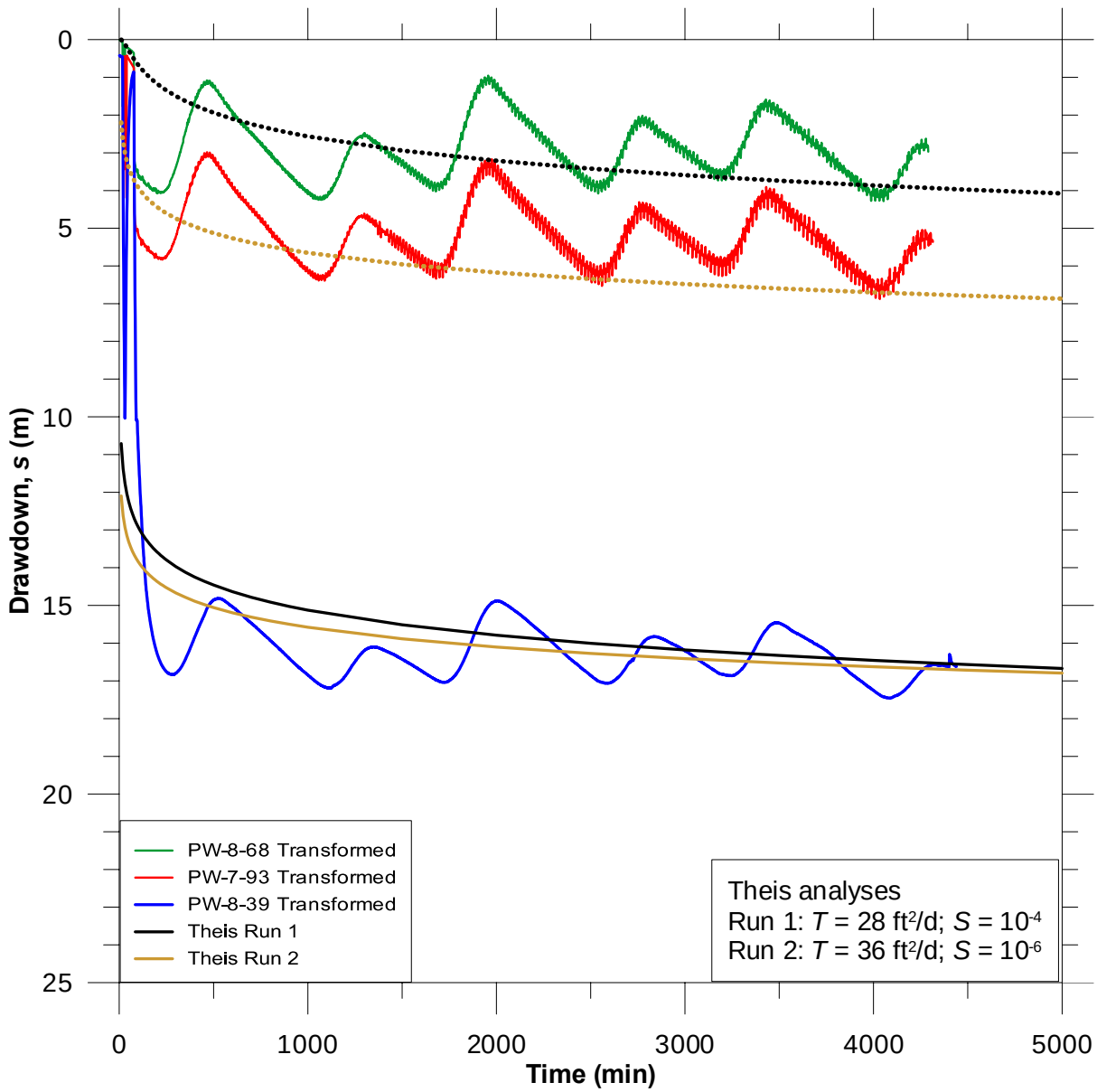

Figure 5 – Interpretation of the PW-8-39 pump test

APPENDIX B
DATA CD