Technical Memorandum
on the
Step-Rate Injection Testing of Well IW-1 at the
Cemetery Road Wastewater Treatment Facility

Prepared for

Okeechobee Utility Authority

Prepared by:

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March 2019

Executive Summary

Step-rate injection testing was performed on Class I deep injection well IW-1 at the Okeechobee Utility Authority (OUA) Cemetery Road Wastewater Treatment Plant (WWTP) from February 23, 2019 to March 2, 2019. The purpose of the testing was 1) to demonstrate whether IW-1 is capable of accepting an injection rate of not less than 12,942 gallons per minute (gpm) or 18.64 million gallons per day (mgd) of wastewater, (equivalent to an injection velocity of 10 feet per second), 2) to obtain information related to well performance, and 3) to demonstrate the absence of a hydraulic connection between the injection zone and overlying intervals monitored by the dual-zone monitor well DZMW-1. Injection testing was performed in accordance with testing procedures and information submitted to the Florida Department of Environmental Protection (FDEP) on October 11, 2018.

The injection test consisted of a background data collection phase, a pumping phase, and a recovery data collection phase. The background phase involved collection of IW-1 wellhead pressure, IW-1 downhole pressure, upper and lower monitor zone pressure from DZMW-1 and barometric pressure for a 48-hour period before beginning the pumping phase. The pumping phase consisted of pumping treated fresh wastewater from a lined pond down injection well IW-1 at four progressively higher injection “steps” for a period of five hours per injection rate. The injection steps consisted of rates of approximately 3,500 gpm, 7,000 gpm, 10,500 gpm and the highest injection rate averaged 13,577 gpm, which is equivalent to an injection velocity of 10.48 feet per second based on an inside casing diameter of 23-inches. The static injection wellhead pressure was 14.38 pounds per square inch (psi) just prior to beginning to pump into IW-1 at the highest injection rate. The average injection wellhead pressure was 69.77 psi while pumping at the highest injection rate. The 55.39 psi difference in wellhead pressure results in a calculated specific injectivity index of 245 gpm/psi. Recorded downhole pressure was 1,217.35 psi just prior to beginning to pump into IW-1. While pumping into IW-1 at the highest injection rate the downhole pressure averaged 1,219.73 psi. The observed downhole pressure of 1,219.73 psi is considerably below the calculated formation fracturing pressure of 1,769.6 psi, this demonstrates that IW-1 can

reasonably be expected to operate at an injection rate of 13,577 gpm without exceeding the formation fracture pressure.

Monitor well pressure data collected from the upper (1,820 to 1,847 feet below pad level [ft bpl]) and lower (1,970 to 2,005 ft bpl) monitor zones of DZMW-1 during injection testing did not indicate any appreciable pressure increases which demonstrates the absence of a direct hydraulic connection between the injection zone and monitoring intervals.

Introduction

The OUA Cemetery Road WWTP is located at 1335 NE 39th Boulevard (Cemetery Road) in Okeechobee, Florida. Figure 1 provides a map for the WWTP and shows the location of the lined pond that served as the wastewater source for testing. The WWTP uses a Class I deep injection well system as a backup for treated effluent disposal. The injection system was originally constructed in 2008 and has been in operation since then.

The injection well system consists of one deep injection well (IW-1) and a dual-zone monitor well (DZMW-1). The deep injection well was completed with a 24-inch diameter steel casing installed to a depth of 2,765 feet below pad level (bpl) and a total depth of 3,200 feet bpl. DZMW-1 was constructed with an upper monitor zone of 1,820 to 1,847 feet bpl, and a lower monitor zone of 1,970 to 2,005 feet bpl. Figures 2 and 3 present completion diagrams of the injection well and the dual-zone monitor well, respectively.

The current permitted maximum injection rate for IW-1 is 4.4 million gallons per day (MGD), which is far less than the maximum permittable injection rate of 18.6 MGD based on an injection velocity of 10 feet per second inside the 24-inch outside diameter final casing and 23-inch inside diameter final casing. OUA conducted a short-term injection test on IW-1 to demonstrate the ability of the well to accept up to 18.6 MGD. The purpose of demonstrating the well's ability to accept up to 18.6 MGD was to support a request by the utility to modify the existing operating permit to increase the maximum permitted injection rate to 12,942 gallons per minute (gpm), or 18.6 MGD. In doing so it assists the South Florida Water Management District (SFWMD) in demonstrating the ability of proposed Estuary Protection Wells to operate as an alternative water management technology. Prior to conducting the test, McNabb Hydrogeologic Consulting, Inc. submitted a testing plan to the

Florida Department of Environmental Protection (FDEP) for review and approval. A copy of the text portion of the short-term injection testing plan and the November 14, 2018, FDEP approval of the plan is provided in Attachment A. Data collected during the step-rate injection test were reviewed and tabulated March 4, 2019 through March 8, 2019. A draft of the Technical Memorandum on the Step-Rate Injection Testing of Well IW-1 at the Cemetery Road Wastewater Treatment Facility was submitted to the OUA on March 8, 2019 and review comments from the OUA were received and incorporated into the draft Technical Memorandum on March 8, 2019.

Step-Rate Injection Test

Procedures

Prior to conducting the test, the pumping contractor (All-Webbs Enterprises, Inc.) mobilized to the site constructed a temporary pipeline to allow pumping of wastewater treated to reuse standards from a lined storage pond to injection well IW-1. Five high-capacity pumps were installed near the lined pond to pump the wastewater to the injection well. The pumping contractor mobilization and set up of equipment for the test took place February 4, 2019 through February 7, 2019. The pump intakes were equipped with screens to ensure large solids were not pumped down the injection well. The pumps used for the test proved to be very sensitive to throttle position, which limited fine tuning of the pumping rate during each step. Photographs showing the temporary pipeline and pumps used for the test are provided in Attachment B. Additional photographs showing the equipment setup are also provided in Attachment B.

Prior to performing the pumping portion of the test, a one-hour “shake-down” injection test was performed to ensure that the target injection rates could be achieved and identify any leaks in the temporary pipeline. This implementation phase took place from February 8, 2019 through February 23, 2019. The pumping contractor demobilized from the site after completion of the step-rate injection test over the period from March 4, 2019 through March 11, 2019.

The injection well was shut-in, and no pumping took place for 24 hours prior to beginning the background data collection phase of the short-term injection test. Equipment calibration certificates were checked to verify each monitoring device was within calibration standards corresponding to the test equipment. A General Electric TransPort PT900 ultrasonic flowmeter was installed on the pipeline for recording pumping rate measurements.

All monitoring equipment was installed prior to beginning the background data collection phase of the test. One primary and one back-up In-Situ Level Troll 700 pressure transducer with a range of 7 to 300 psi was installed on IW-1 on a port located approximately one-half foot above the injection well pad. One primary and one back-up In-Situ Level Troll 700 pressure transducer with a range of 7 to 30 psi was installed in the upper monitor zone to a depth of eight feet below pad level. One primary and one back-up In-Situ Level Troll 700 pressure transducer with a range of 7 to 30 psi was installed in the lower monitor zone to a depth of 20 feet below pad level. One primary and one back-up In-Situ Baro Troll 500 pressure transducer with a range of 7 to 30 psi was used to collect barometric pressure throughout the short-term injection test. One primary and one back-up McDonald Specialist Piezo III memory gauge was installed to a depth of 2,750 feet bpl near the base of the final casing of IW-1 to collect downhole pressure data. Calibration documentation for the pressure transducers, memory gauges, and barometric pressure measuring and recording equipment is provided in Attachment C.

Short-term injection testing consisted of three data collection phases: background, pumping (i.e., injection), and recovery, all of which took place between February 23, 2019 and March 2, 2019. The background phase involved the collection of 48-hours of background data. The injection phase included 20 hours of pumping and data collection. The recovery phase consisted of 48-hours of recovery data collection. The pumping phase of the test included four different injection rates that included target pumping rates of approximately 3,500 gpm, 7,000 gpm, 10,500 gpm, and approximately 13,000 gpm. Each of the pumping rates was conducted for a duration of five hours, except the fourth (13,000 gpm) step, which was temporarily interrupted by a pump failure.

A pump failure occurred approximately 90 minutes after beginning the highest interval of approximately 13,000 gpm, resulting in the pumping phase of the test being temporarily shutdown. An attempt to re-establish the 13,000 gpm pumping portion of the test occurred approximately two hours and 45 minutes after shutting the pumps down, however, this second attempt failed. After replacing one of the pumps, the approximately 13,000 gpm pumping portion of the test was performed two days later. The recovery data collection phase of the short-term injection test began after completing the five-hour long-approximately 13,000 gpm pumping phase of the test (which occurred 2 days after the initial testing) and had a duration of 48 hours.

In addition to data collected from the injection well and monitoring well and on-site barometric pressure, tidal water level data from the Lake Worth Pier, Florida were obtained from the National Oceanic and Atmospheric Administration (NOAA) website and graphed to investigate the influence of tidal water level [height in feet relative to North American Vertical Datum of 1988 (NAVD 88)] on the observed injection zone and monitoring zone pressure fluctuations. Lake Worth Pier is the nearest primary NOAA tide monitoring station to the injection well system. An outline of the as-performed testing procedure is provided below.

Background Data Collection Phase – For a period of 48 hours (February 23, 2019 9:00 PM to February 25, 2019 9:00 PM), prior to beginning the pumping phase of the short-term injection test, IW-1 wellhead pressure, IW-1 downhole pressure, pressure at both monitor zones of DZMW-1, and barometric pressure were recorded to establish background (pre-pumping) phase conditions.

Pumping Phase – The pumping phase consisted of pumping treated wastewater into IW-1. The pumping phase of the injection test commenced immediately after completing the background data collection phase. The pumping phase was performed in two separate portions due to a pump failure as previously discussed. The first pumping portion started on February 25, 2019 at 9:00 PM and lasted 16.5 hours prior to being shut down due to pump failure. The pumping rate was not electronically recorded during the first one hour and 40 minutes of pumping portion of the test due to improper data recording setup by the testing contractor. Therefore, pumping rate data that was manually recorded during the first one hour and 40 minutes of the pumping phase of the test were used to fill in the missing data.

The second portion of the pumping phase of the test was performed two days later on February 28, 2019 at 10:20 AM and lasted five hours and was completed on February 28, 2019 at 3:20 PM. IW-1 wellhead pressure and flowrate, IW-1 downhole pressure, pressure at both monitor zones of DZMW-1, and barometric pressure were electronically recorded throughout the pumping data collection phase.

Recovery Data Collection Phase – Upon completion of the pumping data collection phase, the recovery data collection phase began. Recovery phase data were recorded for 48 hours and was completed on March 2, 2019 at 3:20 PM. Data collection included IW-1 wellhead pressure, IW-1 downhole pressure, pressure at both monitor zones of DZMW-1 and barometric pressure.

Results

The data collected during the step-rate injection test are presented in Figure 4. Table 1 provides a summary of IW-1 average pumping rate, wellhead pressure, downhole pressure, upper and lower zone DZMW-1 pressure and barometric pressure for each phase of the injection test.

Table 1. Average IW-1 Pressure and Pumping Data and DZMW-1 Pressure Data Summary

Test Phase	Average Pumping rate (gpm)	Average Injection Velocity (feet per second)	Average IW-1 Wellhead Pressure (psi)	Average IW-1 Downhole Pressure (psi)	Average DZMW-1 Upper Zone Pressure (psi)	Average DZMW-1 Lower Zone Pressure (psi)	Average Barometric Pressure (inches of Mercury)
Background	0	0	13.50	1,217.09	1.67	1.17	30.11
1st Pumping Rate	3,626	2.80	18.55	1,217.85	1.69	1.13	30.24
2nd Pumping Rate	7,244	5.60	30.55	1,218.50	1.68	1.16	30.20
3rd Pumping Rate	10,648	8.23	49.31	1,219.21	1.70	1.17	30.23
4th Pumping Rate	13,577	10.49	69.77	1,219.73	1.65	1.24	30.02
Recovery	0		14.64	1,217.49	1.66	1.17	30.06

Note: The inside diameter of the final casing is 23-inches.

Review of Figure 4 shows that each of the injection rates influenced IW-1 wellhead pressure but did not appear to have a significant effect on monitor zone pressure. Additionally, other factors such as tidal water level and barometric pressure did not appear to significantly affect IW-1 wellhead pressure.

Figure 5 provides the same information as Figure 4 with most of the background and recovery data eliminated to allow a focus on the pumping portion of the test (from 2,800 to 7,000 minutes). Again, the data shows that injection into IW-1 affected IW-1 wellhead pressure but did not appear to significantly affect monitor zones pressure or IW-1 downhole pressure.

Figures 6 and 7 provide IW-1 wellhead pressure and pumping rate data for the entire test and with a focus on the pumping phase of the short-term injection test, respectively. The other sources of data have been removed from Figures 6 and 7 to provide a less cluttered view of the pumping and wellhead pressure data. The IW-1 wellhead pressure at the end of the background phase was 12.75 psi. There was an immediate increase in wellhead pressure when pumping into IW-1 began at an average rate of 3,626 gpm. Wellhead pressure averaged 18.55 psi while pumping at this rate, representing a 5.80 psi increase over static pressure just prior to beginning injection. The IW-1 wellhead pressure then increased to an average of 30.55 psi when the pumping rate was increased to an average of 7,244 gpm, representing a 17.80 psi increase over the static pressure just before beginning the pumping phase of the test. When the pumping rate was increased to an average rate of 10,648 gpm, the IW-1 wellhead pressure increased to an average of 49.31 psi, representing a 36.56 psi pressure increase over that of the static wellhead pressure just prior to beginning the pumping phase of the test. The final pumping stage took place two days after completing the third pumping stage. The static IW-1 wellhead pressure was 14.38 psi just prior to beginning the final pumping stage. IW-1 wellhead pressure averaged 69.77 psi while pumping into IW-1 at an average rate of 13,577 gpm, representing a wellhead pressure increase of 55.39 psi over static pressure just prior to beginning the final pumping step of the test. Wellhead pressure decreased to 14.91 psi almost immediately after pumping ceased and decreased to 14.42 psi by the end of the 48-hour recovery data collection phase of the test. The average deviation between the primary wellhead pressure transducer and the back-up wellhead transducer was 0.03 psi and the standard deviation between the primary and back-up wellhead transducers was 0.41 psi. The maximum deviation between the primary and the back-up wellhead transducers was 11.53 psi and occurred then the pumping rate was increased following the approximately 10,500 gpm. The reason for the relatively large difference in the recorded pressure at that time is because it appears that the primary transducer collected a data point a few seconds before increasing the pumping rate and the back-up transducer collected a corresponding data point a few seconds after the increase in pumping rate (i.e., the transducers were out of sync by a few seconds).

Figures 8 and 9 present IW-1 downhole hydrostatic pressure data collected by the memory gauge that had been installed to a depth of 2,750 feet bpl and pumping rate data for the entire test and with a focus on the pumping phase of the short-term injection test, respectively. A very slight trend of decreasing downhole hydrostatic pressure was observed near the beginning of the background phase of the test. This trend is due to the dissipation of wastewater that had been injected into the injection zone during the preliminary injection test that took place 24 hours prior to beginning the background data collection phase of the test.

IW-1 downhole pressure response to pumping into IW-1 was small but observable when reviewing Figures 8 and 9. Downhole hydrostatic pressure was 1,217.11 psi at the conclusion of the background phase of the test and responded immediately to pumping into IW-1. The downhole pressure had increased to 1,217.26 psi within three minutes of beginning the first pumping stage of the test and had increased to 1,217.92 psi at the end of the first pumping stage of the test. Downhole hydrostatic pressure had increased to 1,218.92 psi at the end of the third pumping stage. An instantaneous response to the cessation of pumping on the first day of the pumping phase of the test was followed by a trend of decreasing downhole hydrostatic pressure due to dissipation of the injected wastewater.

Downhole hydrostatic pressure had decreased to 1,217.35 psi just prior to beginning the last pumping stage of the test. Downhole hydrostatic pressure averaged 1,219.73 psi while pumping at an average rate of 13,577 gpm during the final pumping stage of the short-term injection test. An instantaneous response to the cessation of the final pumping rate of the test was followed by a trend of decreasing downhole hydrostatic pressure due to dissipation of the injected wastewater. The increase of only 2.38 psi that took place in response to pumping into IW-1 at an average rate of 13,577 gpm is an indication that the Boulder Zone at the IW-1 location is extremely transmissive and capable of accepting extremely high flowrates.

Pressure data for both monitoring zones and pumping rate for the entire test are presented in Figure 10. Figure 11 provides the same information as Figure 10 but focuses on the pumping phase of the short-term injection test (from 2,800 to 7,000 minutes). Review of the monitor zone pressure and pumping rate data indicates there is no correlation between monitor zone pressure and pumping into deep injection well IW-1, during the first three pumping stages. A one-tenth of a psi increase was observed in the lower monitor zone during the final pumping stage when injection rates averaged 13,577 gpm. While it is apparent that the one-tenth of a psi increase and subsequent decrease in monitor zone pressure appear to coincide with the pump being started up and shut down during the high-rate portion of the test, the one-tenth psi change is within the range of natural fluctuations observed during the background, pumping, and recovery periods. The lack of a significant pressure response in the monitor zones from pumping into IW-1 appears to demonstrate the absence of a direct hydraulic connection between the injection zone and the intervals monitored by DZMW-1.

Figure 12 presents pressure data for both monitoring zones, tidal water level, and recorded barometric pressure. Review of the data suggests that barometric pressure does not appear to have any influence on monitor zones pressure. It appears that tidal water level has a very minor influence on the upper monitor zone pressure and a more muted influence on the lower monitor zone pressure.

Analysis

Injection wellhead pressure, pumping rate and downhole pressure data can be used to calculate specific injectivity index, increases in wellhead pressure due to friction losses inside the IW-1 casing and a formation fracturing pressure.

Pumping Rate and IW-1 Wellhead Pressure Comparison

Figure 13 presents a graph of pumping rate versus IW-1 wellhead pressure. Review of the graph indicates the data is not linear, reflecting a decrease in well efficiency at higher pumping rates. Greater head losses due to friction as pumping rates increase are the cause of the decreased well efficiency.

Specific Injectivity Index

Test pumping rate and wellhead pressure data were used to calculate a specific injectivity index (SII) for IW-1. Specific injectivity index is a measure of a well's ability to accept fluids and is calculated using the following formula:

Specific Injectivity Index = $Q/(P_P-P_S)$, where

Q = pumping rate in gpm

P_P = wellhead pressure in psi while pumping into the well, and

P_S = static wellhead pressure in psi

The specific injectivity index is calculated below for each of the four pumping rates.

SII at 3,626 gpm = 3,626 gpm/(18.55 psi – 13.50 psi) = 718 gpm/psi

SII at 7,244 gpm = 7,244 gpm/(30.55 psi – 13.50 psi) = 426 gpm/psi

SII at 10,648 gpm = 10,648 gpm/(49.31 psi – 13.50 psi) = 297 gpm/psi

SII at 13,577 gpm = 13,577 gpm/(69.77 psi – 14.38 psi) = 245 gpm/psi

The trend of decreasing SII with increasing pumping rate is apparent and is due primarily to increased pipe friction losses as injection rates increase.

For comparison, the calculated SII from the short-term injection test performed following construction of IW-1 was 1,788 gpm/psi while injecting at a rate of 3,040 gpm. The SII for IW-1 during the most recent step-rate injection test are lower than most deep injection wells in south Florida. The decrease in SII that has occurred since the well was constructed is due an increase in friction losses due to a large change in the roughness of the inside casing wall.

Wellhead Pressure Increases Due to Friction

Theoretically, the difference between the wellhead pressure and the downhole pressure while pumping into the injection well at a steady rate is due to friction losses created as the wastewater being pumped down the well flows along the inside wall of the casing. The observed increase in downhole pressure while pumping into IW-1 at an average rate of 13,577 gpm was 2.38 psi (1,219.73 psi – 1,217.35 psi). The observed increase in average wellhead pressure above static wellhead pressure while pumping at an average rate of 13,577 gpm was 55.39 psi (69.77 psi – 14.38 psi). This suggests that 53.01 psi (55.39 psi – 2.38 psi) of the observed wellhead pressure increase is due to friction losses inside the well casing. It should be noted that during a video survey of the inside wall of the injection well final casing performed on August 31, 2018, the inside wall of the final casing was observed to be very rough due to mineral deposits.

The Hazen-Williams equation is an empirical formula used to model the friction head loss of water flowing through pipe and is defined as follows:

$h_f = 0.002028 \times L \times (100 \div C)^{1.85} \times (Q^{1.85} \div d^{4.8655})$, where:

h_f = head loss due to friction in feet of water

L = length of pipe in feet

C = Hazen-Williams friction factor (internal casing "roughness")

Q = pumping rate in gpm

d = inside pipe diameter in inches

Using a length of pipe of 2,750 feet (the depth of the downhole pressure gauges) a pumping rate of 13,577 gpm and an inside pipe diameter of 23 inches (the inside diameter of the final casing of IW-1), requires a Hazen-Williams friction factor of 70 to calculate the approximate pressure increases observed while pumping into IW-1 at a rate of 13,577 gpm. The calculation is presented below.

$h_f = 0.002028 \times 2{,}220 \text{ feet} \times (100 \div 70)^{1.85} \times (13{,}577^{1.85} \div 23^{4.8655})$

h_f = 118.4 feet of head loss due to friction

To convert h_f from feet to psi, a conversion factor of 2.31 feet per psi is used to yield the following results:

h_f = 118.4 feet ÷ 2.31 feet per psi = 51.3 psi

The calculated head loss due to friction of 51.3 psi using a Hazen-Williams friction factor of 70 is fairly close to the observed difference in observed wellhead pressure and downhole pressure of 53.01 psi. A video survey of IW-1 performed on August 31, 2018 indicated the inside wall of the IW-1 final casing was very rough and irregular (but mechanically sound) due to buildup of material on the inside wall of the casing. Therefore, the calculated Hazen-Williams friction factor of 70 is reasonable. It should be noted that a Hazen-Williams friction factor of 140 was assumed for the short-term injection test that was performed on IW-1 following well construction.

Formation Fracturing Calculation

As part of the evaluation of the injection test results, a comparison of the observed downhole pressure to the minimum fracture initiation pressure for the formation is conducted. Potential damage to the injection zone and confining unit can occur when injection zone hydrostatic pressures surpass the mechanical strength of the formation. The equation developed by Hubbert and Willis (1972) to predict the minimum bottom hole pressure that could potentially propagate hydraulic fracturing of the formation is used for this calculation:

$$pi = \frac{Sz + 2Po}{3}$$ where

pi = hydraulic fracturing gradient in psi/foot

Sz = total lithostatic stress in psi/foot

Po = formation fluid pressure in psi/foot

Utilizing values of 1.0 and 0.46 psi/foot for Sz and Po (representing the theoretical vertical lithostatic and hydrostatic gradients derived from the respective densities of rock and water), a minimum fracture initiation gradient of 0.64 psi/foot is calculated using the following equation (Hubbert and Willis, 1972):

pi = (1.0 psi/foot + (2 × 0.46 psi/foot))/3

pi = 0.64 psi/foot

This representation conservatively assumes minimal lateral earth stress. At a depth of 2,765 feet bpl (the base of the final casing) and the calculated fracture initiation gradient of 0.64 psi/foot, the calculated minimum bottom-hole pressure that may initiate hydraulic fracturing is:

Bottom-hole fracture initiation pressure = 0.64 psi/foot × 2,765 feet = 1,769.6 psi.

The observed average downhole pressure of 1219.73 psi while pumping into IW-1 at an average rate of 13,577 gpm is considerably less than the calculated minimum fracture initiation pressure of 1,769.6 psi. Therefore, hydraulic fracturing initiated by anticipated injection operations is not considered likely.

Conclusion

During the final pumping phase of the injection test, IW-1 was operated at an average pumping rate of 13,577 gpm (equivalent to 19.55 mgd) with an average wellhead operating pressure of 69.77 psi. Additionally, the observed average downhole pressure of 1,219.73 psi while pumping into IW-1 at an average rate of 13,577 gpm is considerably less than the calculated formation fracture pressure of 1,769.6 psi. These results demonstrate IW-1 and the Boulder Zone at this location can accept an average pumping rate of 13,577 gpm with a low operating well head pressure without resulting in fracturing of the formation. While the effects of the step pumping rates were observed as increases in IW-1 wellhead pressure, injection into IW-1 did not appreciably affect the intervals monitored by DZMW-1, appears to demonstrate an absence of a hydraulic connection between the injection zone and the intervals monitored by DZMW-1, even at higher injection rates than the permit currently allows.

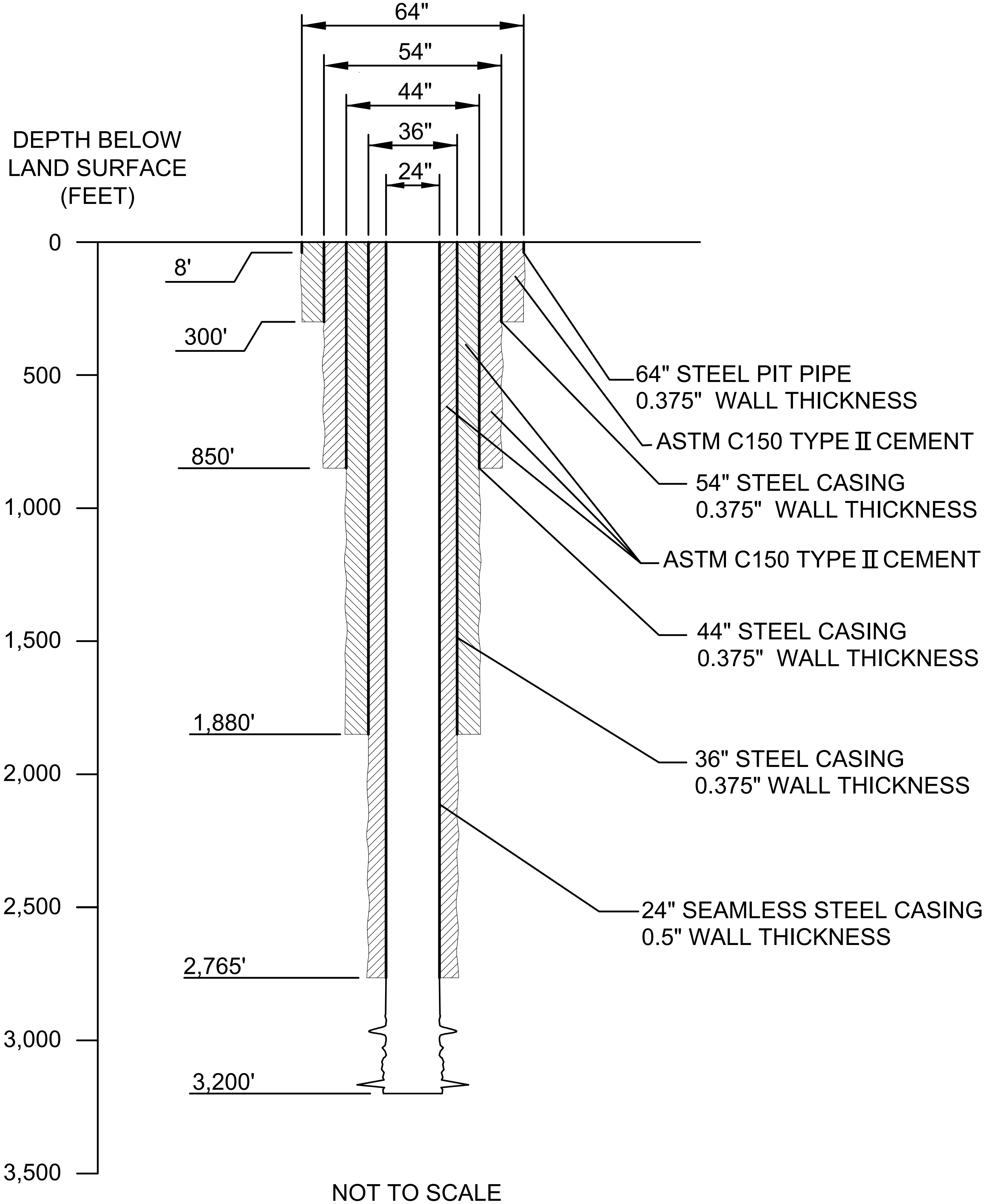
Figures

REFERENCE: U.S.G.S. "TAYLOR CREEK SE. FLORIDA" QUADRANGLE MAP
SECTION: 27 AND 34
TOWNSHIP: 36 SOUTH
RANGE: 25 EAST

ISSUED: 1953
PHOTO REVISED: 1972

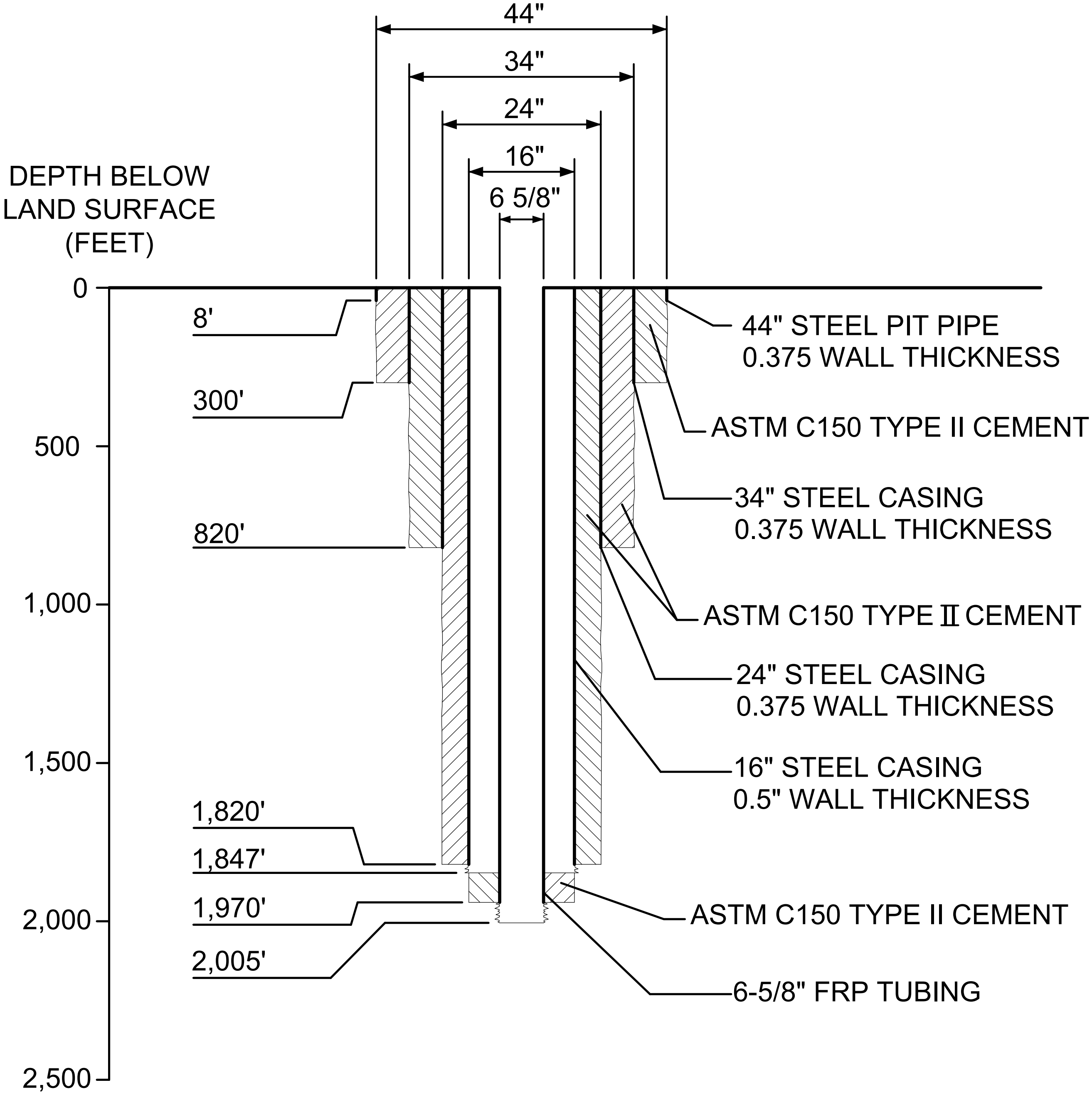
NOT TO SCALE

MHC McNabb Hydrogeologic Consulting, Inc. 4600 MILITARY TRAIL, SUITE 116 Jupiter, Florida 33458 Phone 561.891.0763	OKEECHOBEE UTILITY AUTHORITY CEMETERY ROAD WWTF	LOCATION MAP	FIGURE 1



MHC McNabb Hydrogeologic Consulting, Inc. 4600 MILITARY TRAIL, SUITE 116 Jupiter, Florida 33458 Phone 561.891.0763	OKEECHOBEE UTILITY AUTHORITY CEMETERY ROAD WWTF	INJECTION WELL IW-1 COMPLETION DIAGRAM	Figure 2

DUAL-ZONE MONITOR WELL



NOT TO SCALE

MHC McNabb Hydrogeologic Consulting, Inc. 4600 MILITARY TRAIL, SUITE 116 Jupiter, Florida 33458 Phone 561.891.0763	OKEECHOBEE UTILITY AUTHORITY CEMETERY ROAD WWTF	DUAL ZONE MONITOR WELL DZMW-1 COMPLETION DIAGRAM	Figure 3

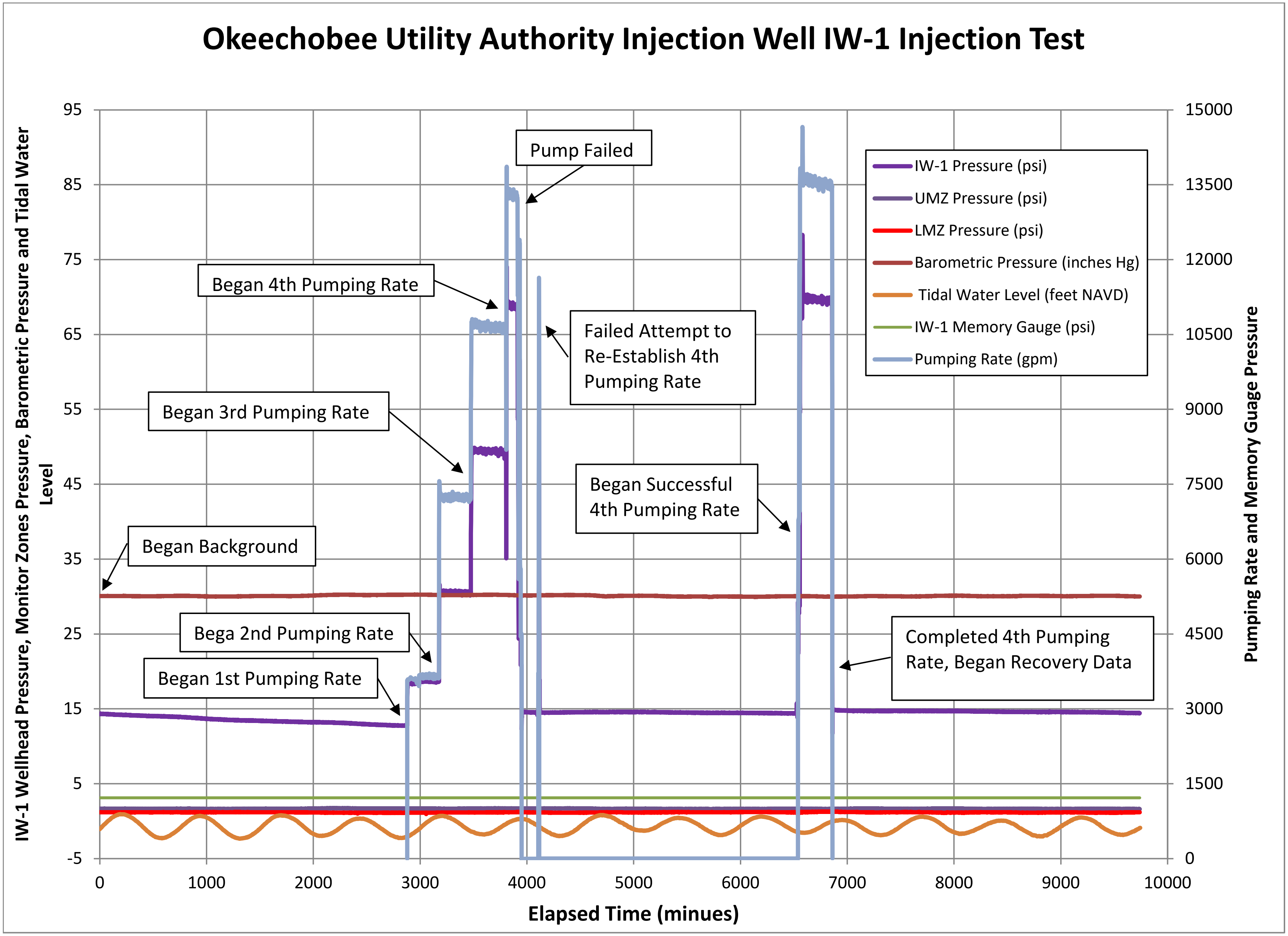


Figure 4. All injection test data.

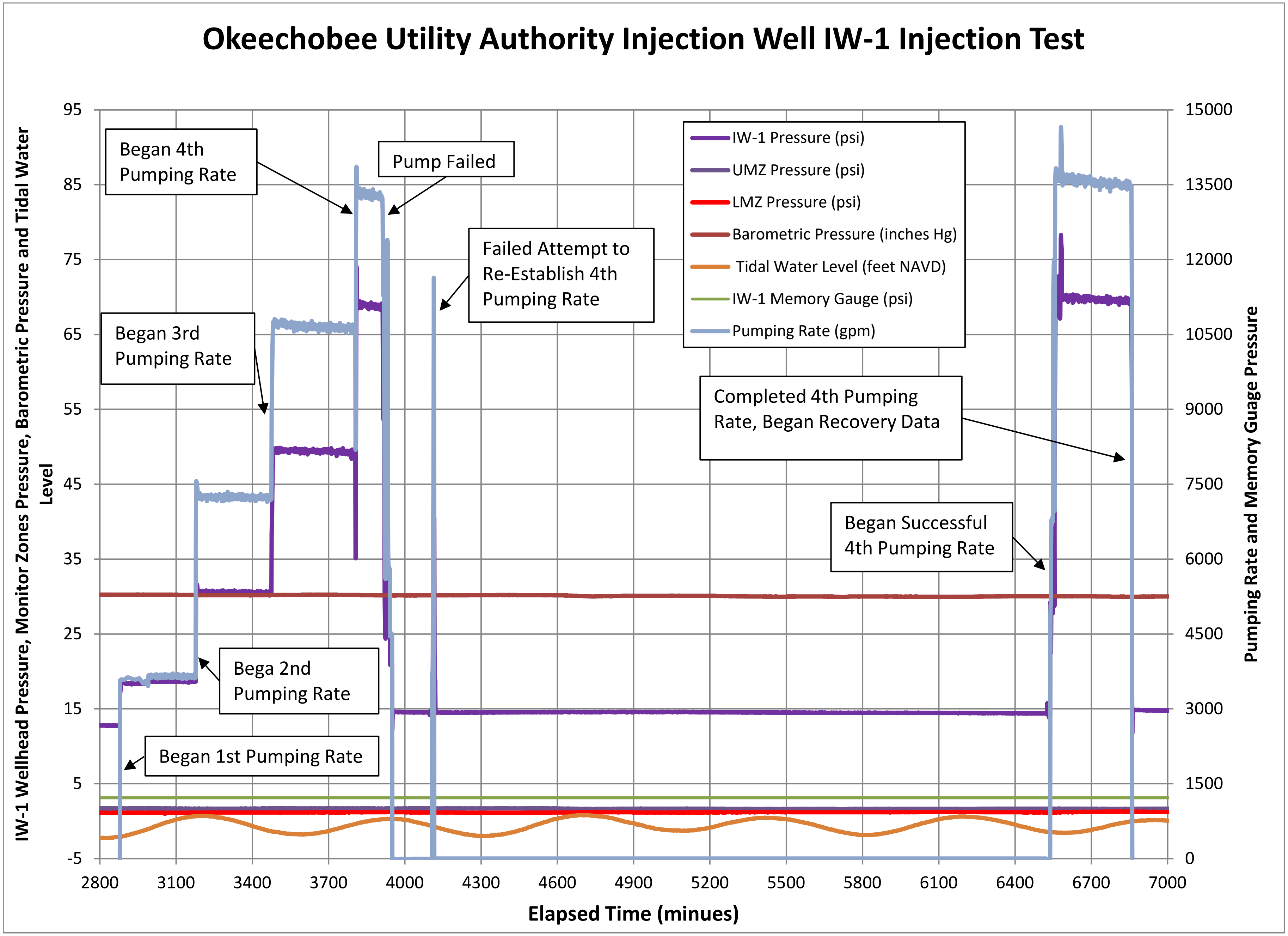


Figure 5. All injection test data with focus on the pumping phase.

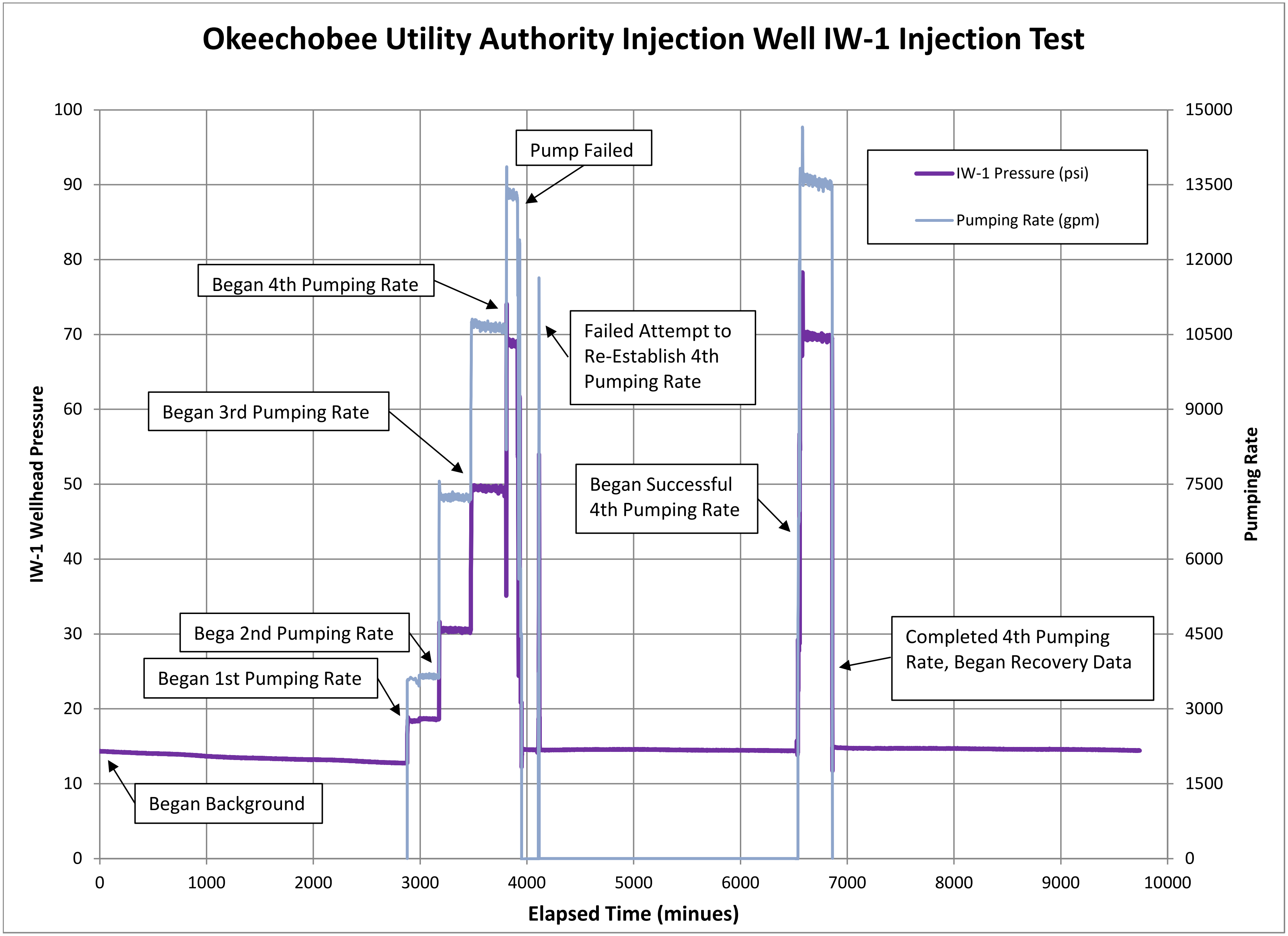


Figure 6. Injection rate and wellhead pressure data.

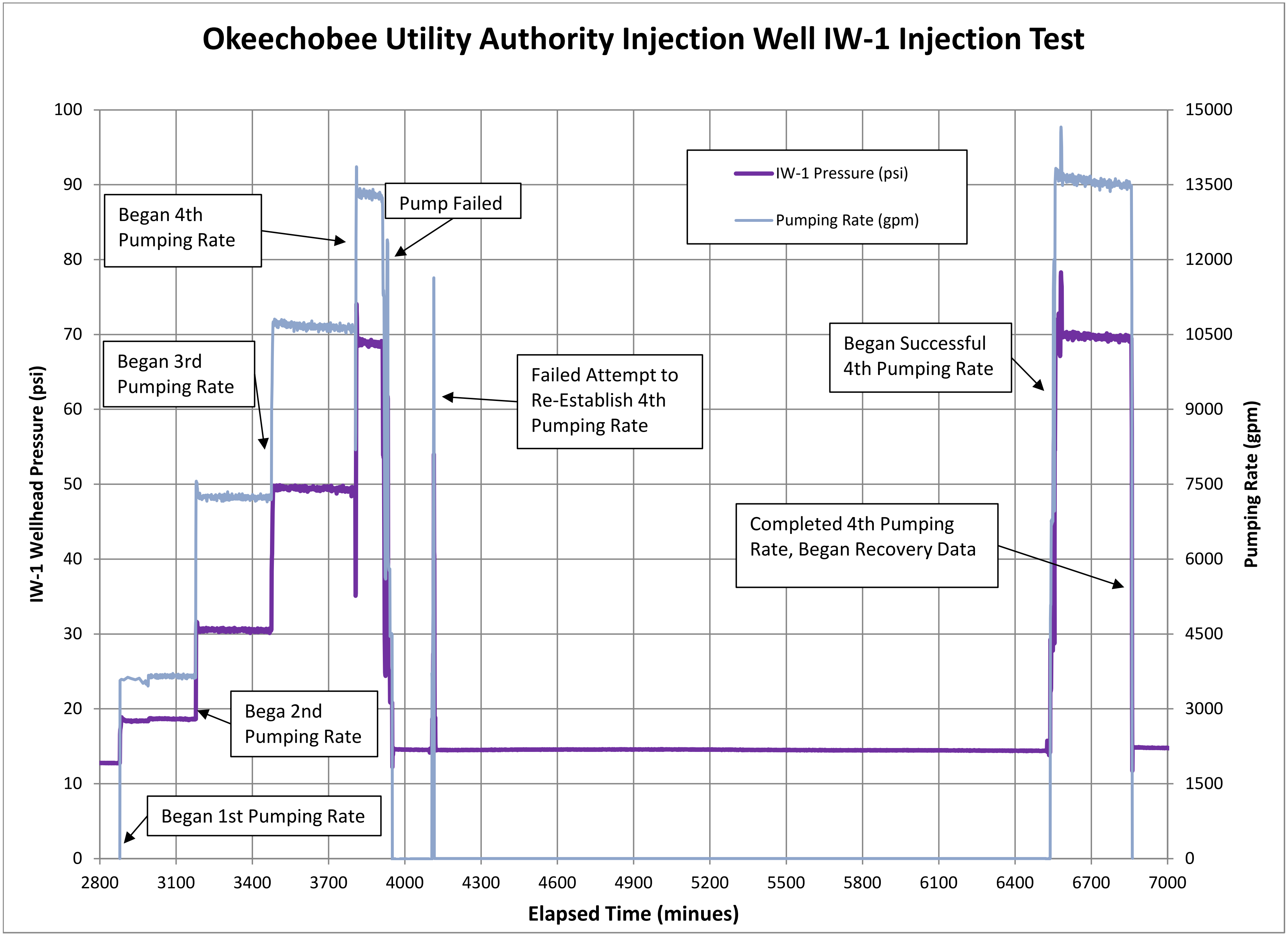


Figure 7. Injection rate and wellhead pressure data with focus on the pumping phase.

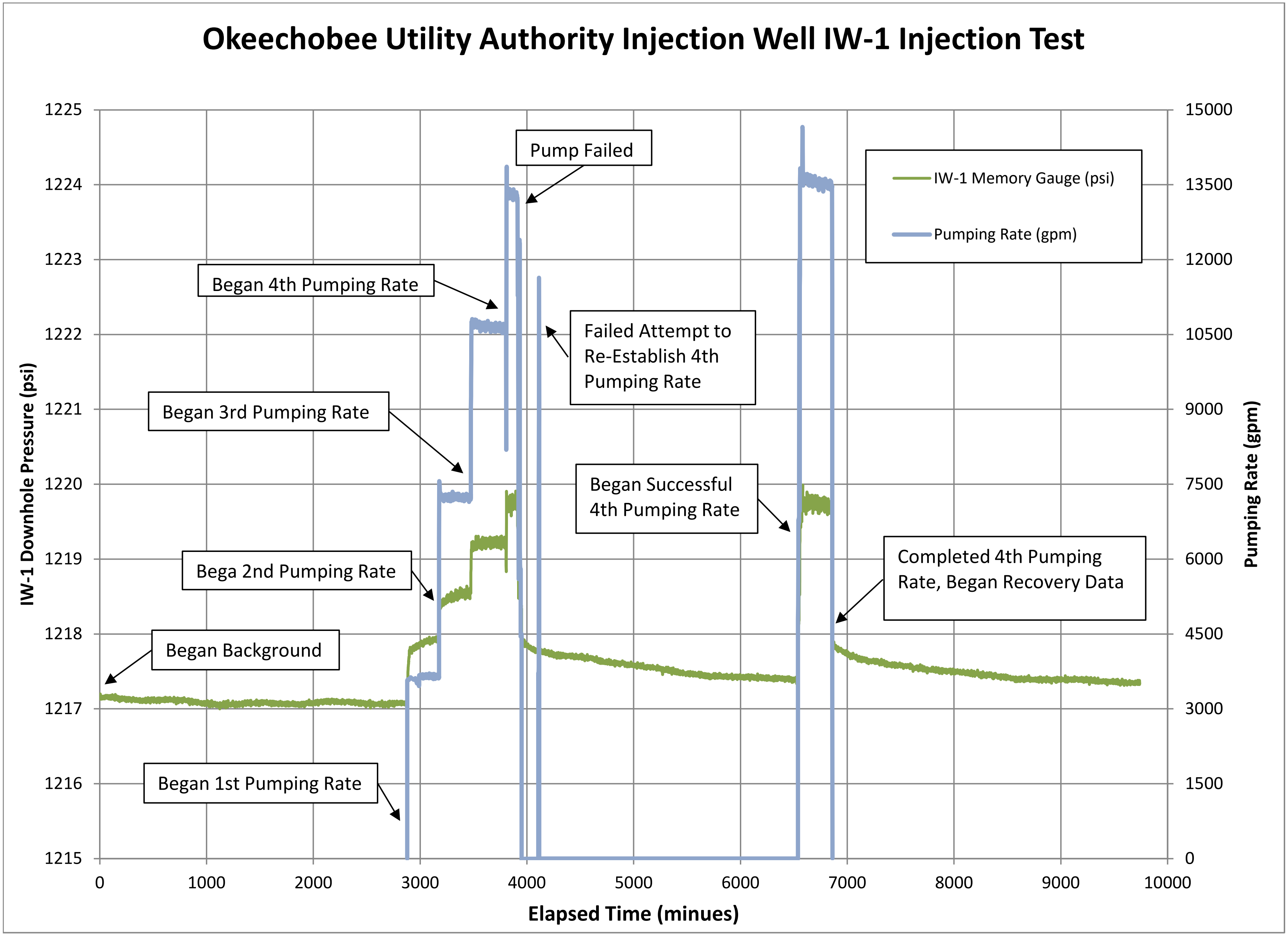


Figure 8. Pumping rate and IW-1 downhole pressure data.

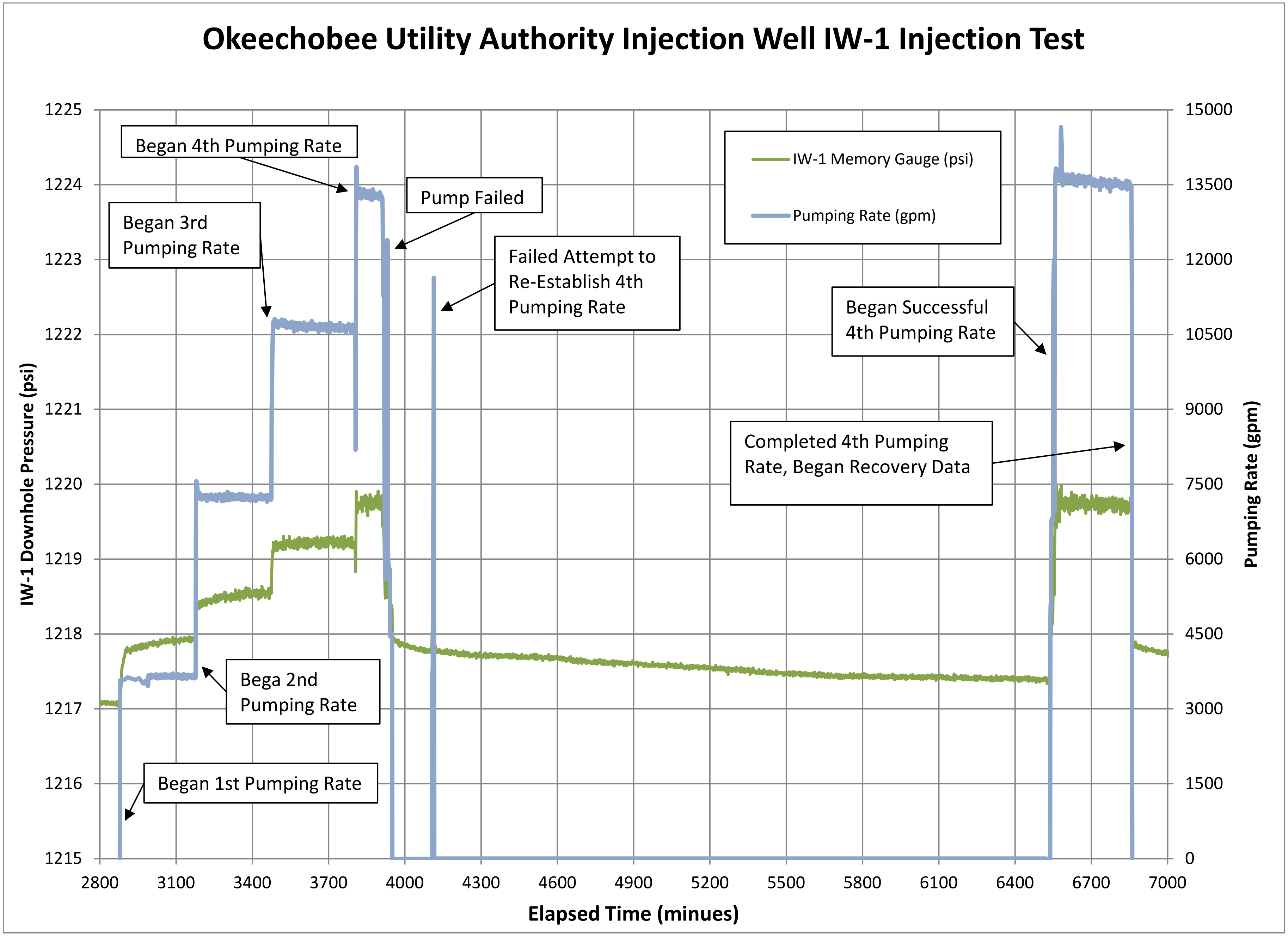


Figure 9. Pumping rate and IW-1 downhole pressure data with focus on the pumping phase.

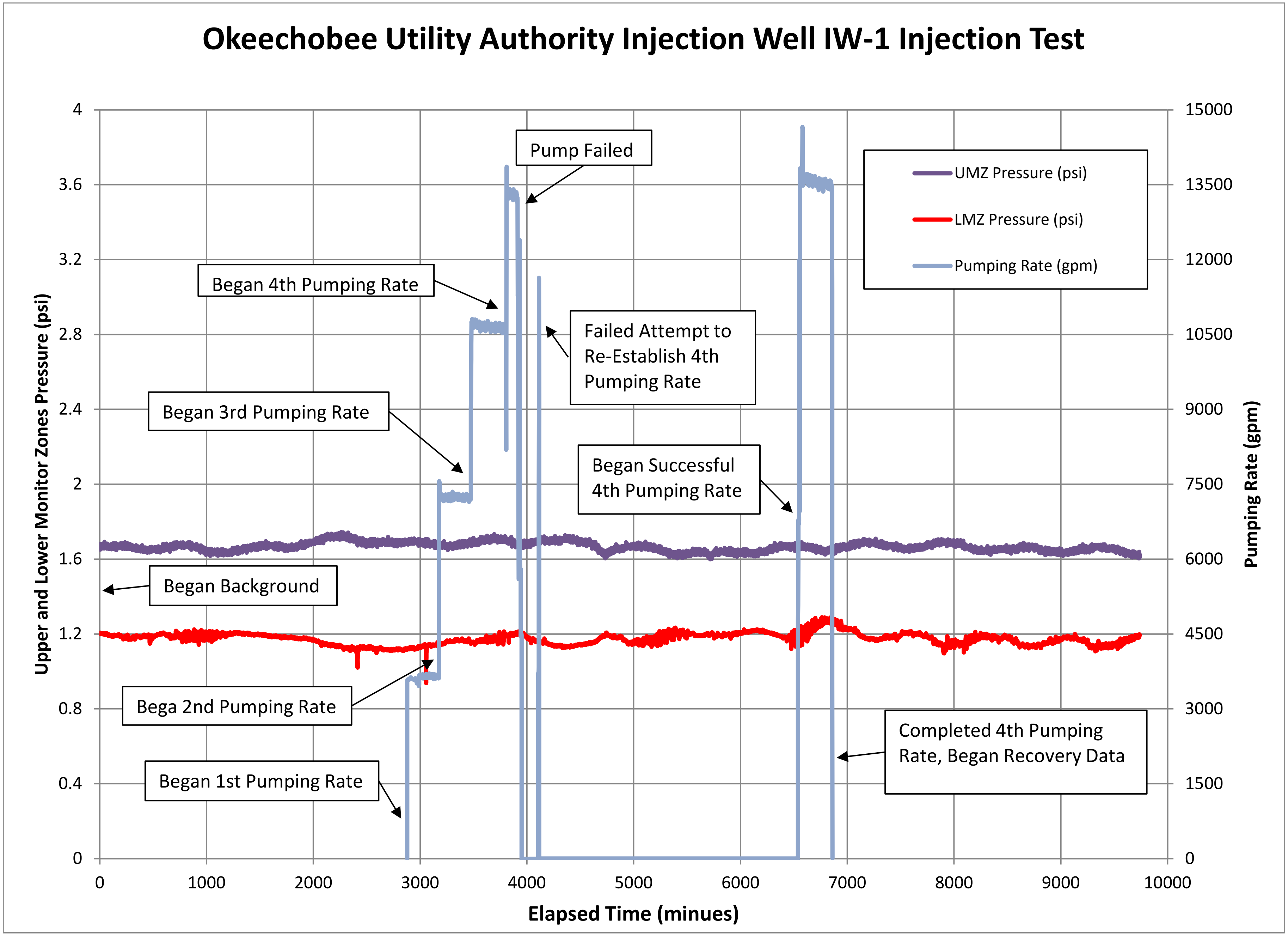


Figure 10. Pumping rate and upper and lower monitor zones data.

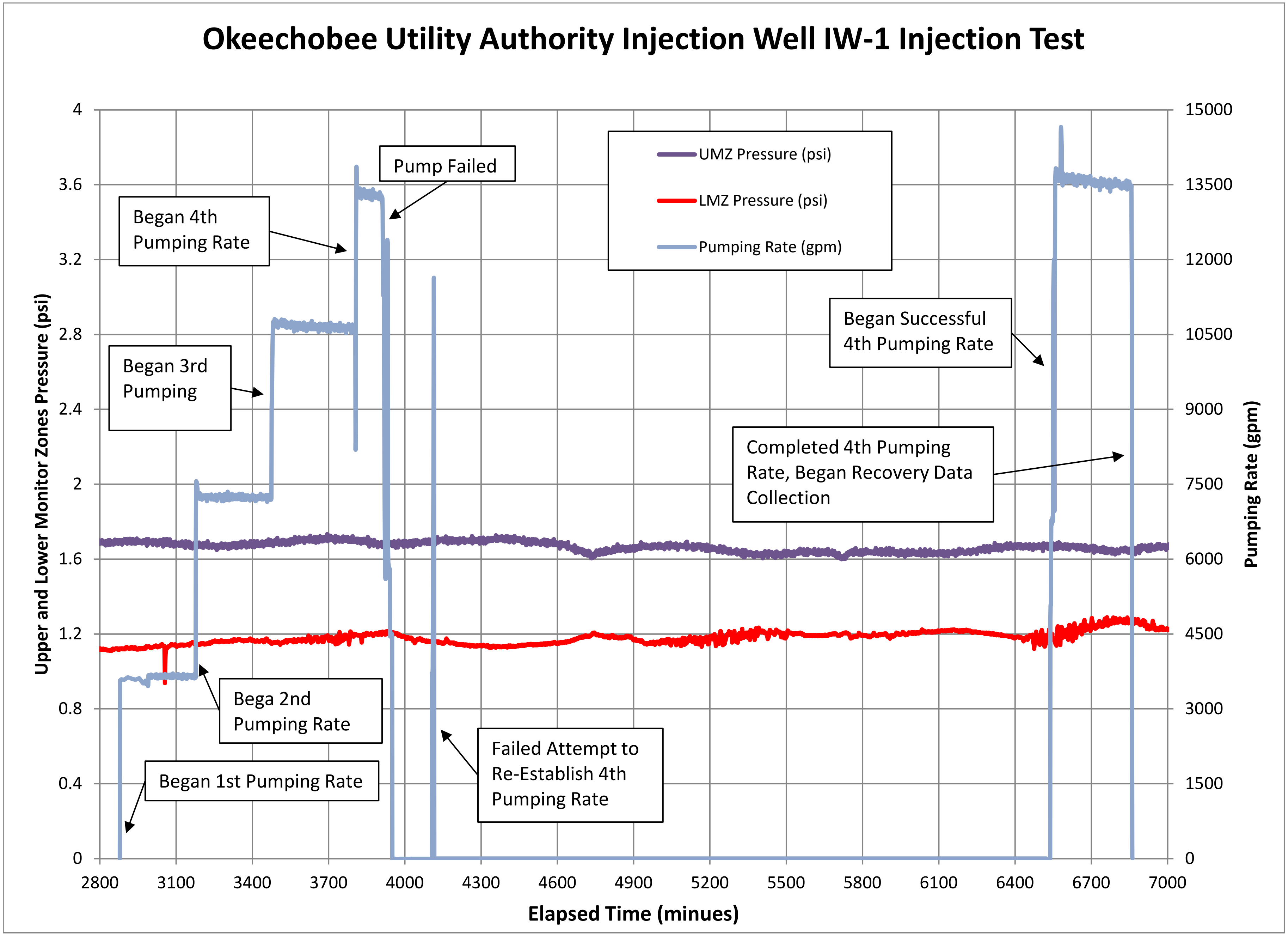


Figure 11. Pumping rate and upper and lower monitor zones data with focus on the pumping phase.

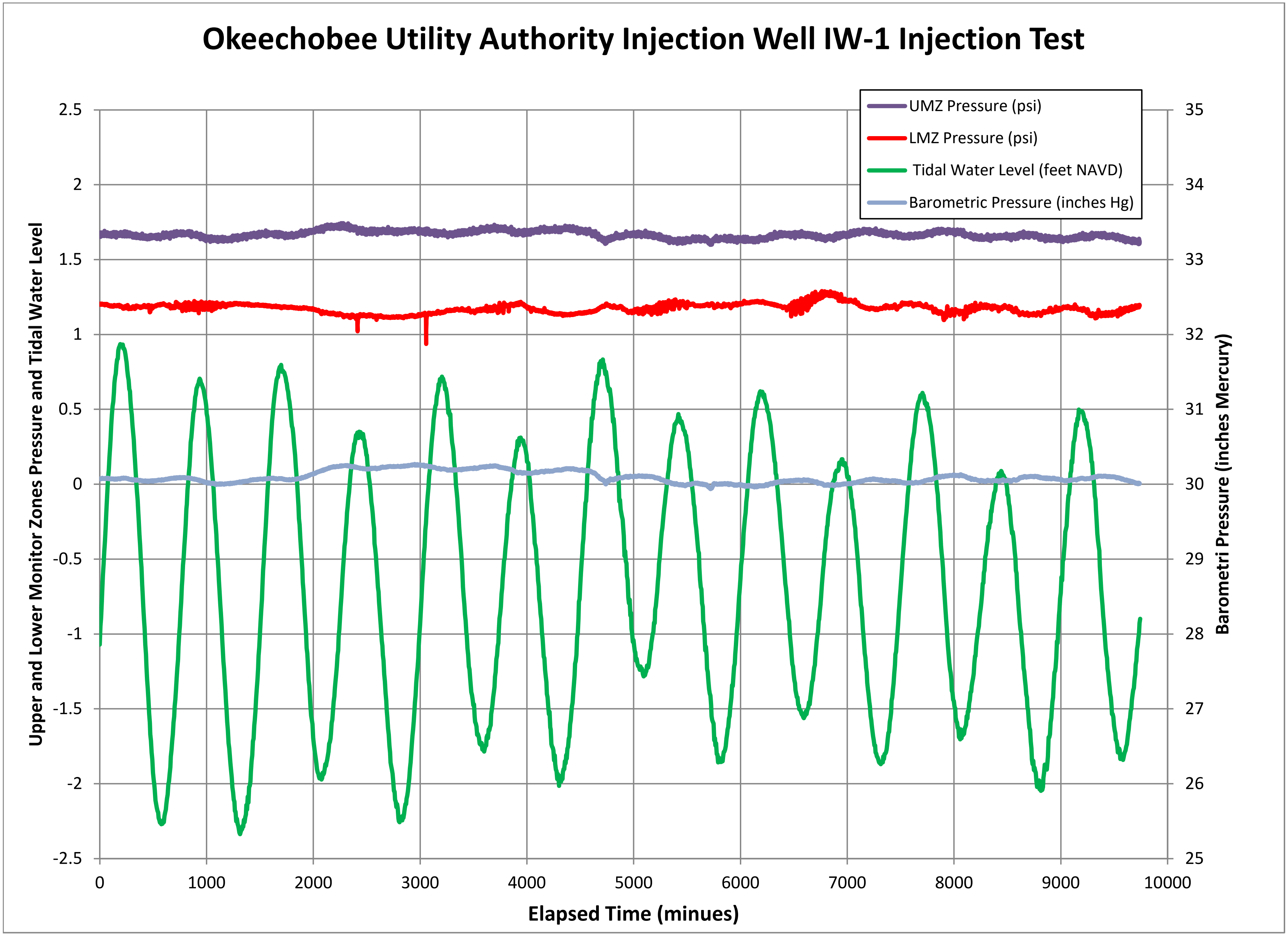


Figure 12. Barometric pressure, tidal water level and upper and lower monitor zones data.

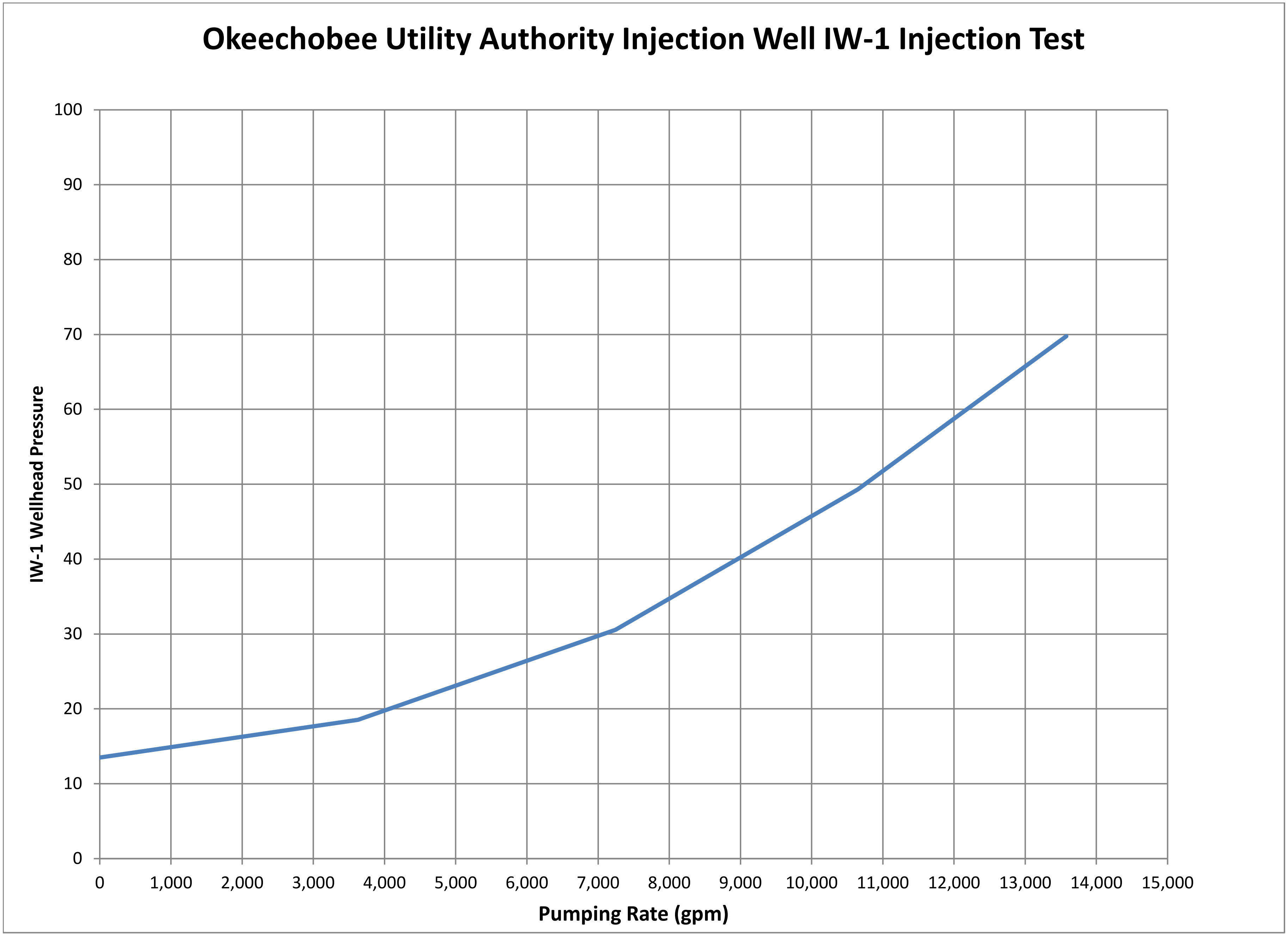


Figure 13. Pumping rate versus IW-1 wellhead pressure.

Attachment A

Short-Term Injection Testing Plan and FDEP Plan Approval

Revised Short-Term Injection Testing Plan for Okeechobee Utility Authority Deep Injection Well

The Okeechobee Utility Authority (OUA) Cemetery Road Wastewater Treatment Plant (WWTP) is located at 1335 NE 39th Boulevard (Cemetery Road) in Okeechobee, Florida. Figure 1 provides a location map for the WWTP. The WWTP uses a Class I deep injection well system as its backup treated effluent disposal system when the primary disposal system (re-use) is not able to meet the disposal needs of the WWTP.

The deep injection well (IW-1) was constructed with a total depth of 3,200 feet below pad level (bpl) and a 24-inch diameter final casing installed to a depth of 2,765 feet bpl. Figure 2 provides a completion diagram of IW-1. The current permitted maximum injection rate for IW-1 is 4.4 million gallons per day (MGD), which is far less than the maximum permittable injection rate of 18.6 MGD based on an injection velocity of 10 feet per second inside the 24-inch diameter final casing.

OUA is proposing to conduct a short-term injection test on IW-1 to demonstrate the ability of the well to safely accept up to 18.6 MGD. The purpose of demonstrating the well's ability to accept up to 18.6 MGD is to assist the South Florida Water Management District (SFWMD) with the evaluation the ability of Estuary Protection Wells to operate as alternative discharge locations in lieu of making damaging flow control discharges to the Northern Estuaries.

This testing protocol sets forth the means for conducting the proposed short-term injection test.

Injection testing of IW-1will consist of a 48-hour background data collection period, a 20-hour pumping period, and a 48-hour recovery data collection period.

The water source for the injection test will be wastewater treated to reuse standards from an on-site lined storage pond. A temporary pipeline will installed to convey the water from the on-site storage pond to IW-1. A strainer will be used to ensure large solids are not pumped down the well.

Monitoring and Recording Equipment

The table below lists the monitoring and recording equipment that will be installed for the short-term injection test.

Equipment	Purpose
Redundant Upper Monitor Zone Level Transducers with a range of 0 – 30 psi	Measure upper monitor zone pressure
Redundant Lower Monitor Zone Level Transducer with a range of 0 – 30 psi.	Measure lower monitor zone pressure
Redundant Injection Wellhead Pressure Transducers with a range of 0 – 300 psi	Measure IW-1 wellhead pressure
Redundant Formation Pressure Memory Gauge	Measure IW-1 formation pressure near the injection zone
Injection Well Flow meter	Measure IW-1 injection rate
Barometric Pressure Recorder	Measure barometric pressure
Data Recorder	Record upper and lower monitor zone pressure, IW-1 wellhead pressure, flowrate and barometric pressure

IW-1 Short-Term Injection Test Protocol

Introduction

The short-term injection test will consist of a background, pumping, and recovery phase, each of which are discussed below. Barometric pressure will be collected throughout each phase of the short-term injection test. Tidal data from the Port of Palm Beach for the testing period will be retrieved from the National Oceanic and Atmospheric Association (NOAA) and included with the test results. The Port of Palm Beach is the nearest NOAA tide monitoring station to the OUA site. A data recorder will be used to collect the monitor well pressure, injection wellhead pressure, flowrate and barometric data throughout each phase of the short-term injection test. Additionally, a memory gauge and backup memory gauge will be installed to a depth of approximately 2,755 feet below pad level (10 feet above the base of the 24-inch diameter final casing) to measure pressure near the base of the final casing of IW-1 throughout each phase of the short-term injection test.

Prior to beginning the short-term injection test, temporary piping, pumps and all data recording instrumentation must be installed. Following installation of the piping, pumps and instrumentation a Preliminary Test will be performed as described below.

Preliminary Test – A minimum of 6-hours prior to beginning the 48 hour background data collection phase of the test, a preliminary test, will be performed to ensure that piping and pumping system is operating correctly and is free from leaks, the data recording equipment is working properly, and the target pumping rate and delivery pressure can be achieved. This will also confirm that the piping system is filled with water and free of air and the injection well casing is filled with water that will be used for the short-term injection test and background water level data collection.

Prior to beginning the Preliminary Test, the following should be completed to ensure all equipment is ready for the Preliminary Test:

1. Ensure that the temporary pipeline between the injection well and the storage pond is completed, is free of leaks, and all connections to temporary pumps are completed.

2. Ensure that all temporary pumps have adequate quantity of fuel to run the pumps for a minimum of three hours.

3. Ensure that all monitoring equipment have been installed in the proper locations. Two 30 psi Level Troll transducers shall be installed in both the lower and upper monitor zones. Two 300 psi Level Troll transducers shall be installed on the injection wellhead. The flowmeter must be in place on the piping between the injection wellhead and the temporary pumps. Each of the transducers and the flowmeter shall be connected to the data recorder to allow data recording of the pumping rate, injection wellhead pressure, and the pressure of the upper and lower monitor zones of the dual-zone monitor well.

4. Ensure that all monitoring equipment matches the calibration certificates that have been provided by the Contractor.

5. Prior to turning on the temporary pumps, ensure that all valves on the temporary pipeline between the injection well and storage pond are in the open position. Ensure that the 24-inch diameter gate valve on the injection wellhead is in the open position.

6. Record the injection well pressure and upper and lower monitoring zone pressures prior to turning on the temporary pumps.

7. Record flowmeter totalizer reading prior to any pumping.

The Preliminary Test shall be performed in the following manner:

1. Contractor will begin recording monitor zone pressure, injection wellhead pressure, barometric pressure, and pumping rate using the data recorder prior to beginning pumping water into the temporary pipeline. Contractor will turn on and operate temporary pumps to fill the pipeline with water from the storage pond.

2. Upon filling the temporary pipeline with water, the Contractor will increase the pumping rate to approximately 3,500 gpm. The pumping rate should be maintained for 10 minutes. The throttle position of the pump(s) should be noted by the Contractor. The pumping rate should then be increased to approximately 7,000 gpm and the throttle position of the pump(s) should be noted by the Contractor. The pumping rate should be maintained for 10 minutes. The pumping rate should then be increased to 10,500 gpm and once again the throttle position on the pump(s) should be noted by the Contractor. The pumping rate should be maintained for 10 minutes. The pumping rate should then be increased to approximately 13,000 gpm and the throttle position of the pump(s) should be noted by the Contractor.

3. Pumping will take place at a rate of approximately 13,000 gpm for approximately 20 minutes. The temporary pipeline shall be checked for leaks throughout the preliminary test.

4. Check the data recorder to ensure that all monitoring devises are working and the data is being recorded.

5. Cease pumping after the Consultant notifies the Contractor that the intent of the Preliminary Test has been achieved.

6. Contractor shall close the valve on the temporary pipeline between the injection wellhead and the nearest pump(s).

Background Data Collection Phase – A minimum of 48-hours of background water level data will be collected following completion of the preliminary test and prior to the short term injection test. The memory gauges (if not already installed) shall be installed to a depth of 2,755 feet below land surface prior be beginning the Background Data Collection Phase of the test. The well shall not be disturbed during this phase of the test. During this time, pressure in both monitor zones, pressure at the injection wellhead and barometric pressure will be recorded using a data recorder. Pressure near the base of the injection tubing will also be recorded by the memory gauges.

Prior to beginning the Background Data Collection Phase, the following should be completed to ensure all equipment is ready for the test:

1. Any equipment found to be malfunctioning during the preliminary test shall have been replaced or repaired and demonstrated to be in working order (documentation and/or calibrations shall be available for inspection prior to the test).

2. Ensure that the temporary pipeline between the injection well and the storage pond is completed, is free of leaks and all connections to temporary pumps and road crossings are completed. Leaks in the temporary pipeline that were identified during the preliminary test shall have been repaired.

3. Ensure that all monitoring equipment (including the downhole memory gauges) have been installed in the proper locations. The downhole memory gauges shall be installed to a depth of 2,755 feet below land surface. Two of the 30 psi Level Troll transducers shall be installed at the lower and upper monitor zone ports on the dual-zone monitor. Two of the 300 psi Level Troll transducers shall be installed on the injection wellhead on the well-side of the final temporary pumps near the wellhead. The flowmeter must be in place on the piping between the injection wellhead and the temporary pumps near the well. Each of the transducers and the flowmeter shall be connected to the data recorder to allow data recording of the pumping rate, injection wellhead pressure, and the pressure of the upper and lower monitor zones of the dual-zone monitor well.

4. Ensure that all monitoring equipment matches the calibration certificates that have been provided by the Contractor.

Pumping Phase – Prior to beginning the pumping phase of the test, the background data should be checked to ensure there are no data gaps and all recording equipment is working properly. The pipeline should be checked for leaks and any leaks must be repaired prior to beginning the pumping portion of the test.

The pumping phase of the short-term injection test will take place following completion of background data collection and will last for approximately 24 hours. The pumping phase will consist of injecting from the water source into IW-1 at rates of approximately 3,500 gpm, 7,000 gpm, 10,500 gpm and finally 13,000 gpm for approximately 5 hours at each rate. In the case that any of the electronic data recording temporarily fails, the pumping period shall be extended by the amount of time the data recording failed. If electronic data recording fails to result in wellhead injection pressure, monitor zone pressure or flowrate data recording, the test must be re-run, beginning at the Background Data Collection phase.

Pressure in both monitor zones and pressure at the injection wellhead and barometric pressure will be recorded using a data recorder. Pressure near the base of the injection tubing will also be recorded by the memory gauges. Flowrate data shall be collected and recorded at no greater than 5 minute intervals during the pumping portion of the short-term injection test.

The pumping phase of the test shall be performed in the following manner:

1. Record injection wellhead pressure and monitor well zones pressure and totalizer reading just prior to turning on the pumps. Establish in injection rate of approximately 3,500 gpm.

2. Maintain an injection rate of approximately 3,500 gpm for approximately 5 hours prior to increasing the pumping rate of approximately 7,000 gpm.

3. Maintain an injection rate of approximately 7,000 gpm for approximately 5 hours prior to increasing the pumping rate of approximately 10,500 gpm.

4. Maintain an injection rate of approximately 10,500 gpm for approximately 5 hours prior to increasing the pumping rate of approximately 13,000 gpm.
5.

6. After maintaining an injection rate of 13,000 gpm for 5 hours, shut down the pumps and close the valve located between the pumps and the injection wellhead.
7. Record totalizer reading, injection wellhead pressure and upper and lower monitor zones pressure.

Recovery Data Collection Phase – Upon completion of pumping test, the recovery data collection phase will begin. Recovery phase pressure monitoring and recording will continue for a minimum of 48 hours for the injection well and both monitor zones of dual zone monitoring well. Barometric data will also be collected during this period. A data recorder will be used to collect injection wellhead pressure and monitor zone pressure data during the recovery phase of the short-term injection test. Pressure near the base of the injection tubing will also be recorded by the memory gauges. The well shall not be disturbed during this phase of the test.

At the end of the recovery data collection phase, Contractor shall download all data from the test and provide the data to OUA in Excel format.

david@mcnabbhydroconsult.com

From:	Haberfeld, Joe <Joe.Haberfeld@FloridaDEP.gov>
Sent:	Wednesday, November 14, 2018 3:50 PM
To:	david@mcnabbhydroconsult.com
Cc:	Woods, Tracy; jhayford@ouafl.com; McCarty, Cathleen
Subject:	RE: Okeechobee Utility Authority IW-1 Short-Term Injection Testing Plan
Attachments:	OUA injection testing plan_Revised.pdf

David,

The Department has no objection to running the short-term injection test as proposed.

Joe Haberfeld, P.G.
Aquifer Protection Program
Florida Department of Environmental Protection
2600 Blair Stone Road
Mail Station 3530
Tallahassee, Florida 32399-2400
Phone 850-245-8655
joe.haberfeld@dep.state.fl.us

From: david@mcnabbhydroconsult.com <david@mcnabbhydroconsult.com>
Sent: Wednesday, November 14, 2018 10:35 AM
To: Haberfeld, Joe <Joe.Haberfeld@FloridaDEP.gov>
Cc: Woods, Tracy <Tracy.Woods@dep.state.fl.us>; jhayford@ouafl.com
Subject: RE: Okeechobee Utility Authority IW-1 Short-Term Injection Testing Plan

Joe,
The path forward will be related to the test results. I anticipate positive results, so it is likely that OUA would apply for a minor modification if the results are positive.

From: Haberfeld, Joe <Joe.Haberfeld@FloridaDEP.gov>
Sent: Wednesday, November 14, 2018 10:25 AM
To: David McNabb <david@mcnabbhydroconsult.com>

Cc: Woods, Tracy <Tracy.Woods@dep.state.fl.us>
Subject: RE: Okeechobee Utility Authority IW-1 Short-Term Injection Testing Plan

If approved and the test is run, will the Utility be applying for a minor modification to re-rate the well?

From: David McNabb <david@mcnabbhydroconsult.com>
Sent: Tuesday, November 13, 2018 1:57 PM
To: Haberfeld, Joe <Joe.Haberfeld@FloridaDEP.gov>
Cc: Woods, Tracy <Tracy.Woods@dep.state.fl.us>; John Hayford <jhayford@ouafl.com>
Subject: Okeechobee Utility Authority IW-1 Short-Term Injection Testing Plan

Joe,
The Okeechobee Utility Authority is preparing to contract with a well testing firm for the performance of short-term injection testing of IW-1 at their Cemetery Road WWTP. The revised short-term injection testing plan for the proposed testing was submitted to the Department on 10/11/18. Can you let us know of the status of the review of the testing plan?

Thank you,

David McNabb
McNabb Hydrogeologic Consulting, Inc.
4600 Military Trail, Suite 116
Jupiter, Florida 33458
561-891-0763

Attachment B

Photographs

Photo 1. Photo showing the temporary pipeline leading from the lined temporary pumps (next to the lined pond) to the injection well in the foreground. The crane was used to hold the standpipe in place on top of the injection wellhead to allow the memory gauges to be installed to a depth of 2,750 feet bpl using the geophysical logging truck (white truck in the right foreground) logging wireline. Note: The photo shows 4 temporary pumps near the lined pond. One additional pump was brought to the site prior to beginning the test.

Photo 2. Photo showing the 5 temporary test pumps and pump intakes. Floats were used to keep the pumping intakes off the bottom of the lined pond.

Photo 3. Photo of the primary and back-up In-Situ Level Troll 700 transducers (located in approximately the center of the photo) used to record injection wellhead pressures. The large 24-inch diameter gate valve remained open throughout the test so that the memory gauges could remain the well throughout the entire test. A temporary 18-inch diameter butterfly valve installed at the pipeline-wellhead connection was used to shut-in the well.

Photo 4. Photo showing primary and back-up In-Situ Level Troll 700 transducers installed in the upper and lower monitor zones of the dual-zone monitor well.

Attachment C

Monitoring Equipment Calibration Certificates

Calibration Report

In-Situ Inc.

Report Number: 20190123165852-585984
221 East Lincoln Avenue, Fort Collins, CO 80524 USA
1-970-498-1500, 1-800-446-7488, FAX: 1-970-498-1598
Visit us at www.in-situ.com

Instrument Details:

Instrument Model:	**Level TROLL 700**
Full Scale Pressure Range	**300 PSI non-vented**
Serial Number:	**585984**

Calibration Details:

Calibration Result:	**PASS**
Calibration Date:	2019-01-23 16:58:52 (UTC)
Nominal Range of Applied Temperature:	-5 C to +50 C
Temperature Accuracy Specification:	+/- 0.1 C From -5 C to +50 C
Nominal Range of Applied Pressure:	7.0 PSI to 300.0 PSI
Pressure Accuracy Specification:	+/- 0.1 %FS from -5 C to +50 C, +/- 0.05 %FS at +15 C

Post-Calibration Check:

Parameter	Applied	Reported	Deviation
Pressure	300.0010	300.0212	0.0067
Pressure	130.0590	130.0574	-0.0005
Pressure	6.9989	7.0069	0.0027
Temperature	24.7100	24.7185	0.0085

Calibration Procedures and Equipment Used:

Automated calibration procedures used.
Manu Agilent Model 34980A SerialNo MY44001931
Manu Instrulab Model 4312A-15 SerialNo 30117
Manu Instrulab Model 832-151-01 SerialNo 12078
Manu Mensor Model CPC6000 SerialNo 410009W9

Notes:

1. Standards used in this calibration are traceable to the National Institute of Standards and Technology.
2. This calibration report shall not be reproduced, except in full, without the written approval of In-Situ, Inc.
3. A calibration interval of 12 to 18 months is recommended.

Performed By: FM

In-Situ Inc.

Calibration Report

Report Number: 20190123165852-582958

221 East Lincoln Avenue, Fort Collins, CO 80524 USA
1-970-498-1500, 1-800-446-7488, FAX: 1-970-498-1598
Visit us at www.in-situ.com

Instrument Details:

Instrument Model:	**Level TROLL 700**
Full Scale Pressure Range	**300 PSI non-vented**
Serial Number:	**582958**

Calibration Details:

Calibration Result:	**PASS**
Calibration Date:	2019-01-23 16:58:52 (UTC)
Nominal Range of Applied Temperature:	-5 C to +50 C
Temperature Accuracy Specification:	+/- 0.1 C From -5 C to +50 C
Nominal Range of Applied Pressure:	7.0 PSI to 300.0 PSI
Pressure Accuracy Specification:	+/- 0.1 %FS from -5 C to +50 C, +/- 0.05 %FS at +15 C

Post-Calibration Check:

Parameter	Applied	Reported	Deviation
Pressure	300.0010	300.0133	0.0041
Pressure	130.0600	130.0651	0.0017
Pressure	6.9991	7.0020	0.0009
Temperature	24.7100	24.7149	0.0049

Calibration Procedures and Equipment Used:

Automated calibration procedures used.
Manu Agilent Model 34980A SerialNo MY44001931
Manu Instrulab Model 4312A-15 SerialNo 30117
Manu Instrulab Model 832-151-01 SerialNo 12078
Manu Mensor Model CPC6000 SerialNo 410009W9

Notes:

1. Standards used in this calibration are traceable to the National Institute of Standards and Technology.
2. This calibration report shall not be reproduced, except in full, without the written approval of In-Situ, Inc.
3. A calibration interval of 12 to 18 months is recommended.

Performed By: FM

In-Situ Inc.

Calibration Report

Report Number: 20180406163018-579123

221 East Lincoln Avenue, Fort Collins, CO 80524 USA
1-970-498-1500, 1-800-446-7488, FAX: 1-970-498-1598
Visit us at www.in-situ.com

Instrument Details:

Instrument Model:	**Level TROLL 700**
Full Scale Pressure Range	**100 PSI / 60 m / 197 ft / non-vented**
Serial Number:	**579123**

Calibration Details:

Calibration Result:	**PASS**
Calibration Date:	2018-04-06 16:30:18 (UTC)
Nominal Range of Applied Temperature:	-5 C to +50 C
Temperature Accuracy Specification:	+/- 0.1 C From -5 C to +50 C
Nominal Range of Applied Pressure:	7.0 PSI to 100.0 PSI
Pressure Accuracy Specification:	+/- 0.1 %FS from -5 C to +50 C, +/- 0.05 %FS at +15 C

Post-Calibration Check:

Parameter	Applied	Reported	Deviation
Pressure	100.0000	99.9970	-0.0030
Pressure	44.2000	44.2052	0.0052
Pressure	6.9998	7.0021	0.0023
Temperature	38.8730	38.8767	0.0037

Calibration Procedures and Equipment Used:

Automated calibration procedures used.
Manu Agilent Model 34970A SerialNo MY44201907
Manu Mensor Model CPC6000 SerialNo 41000617
Manu Instrulab Model 3312A-14-15-24 SerialNo 31154
Manu Instrulab Model 406X-0031-01 SerialNo 2-31134
Manu Agilent Model 53131A-010 SerialNo MY47002678
Manu MENSOR Model 600 SerialNo 622742

Notes:

1. Standards used in this calibration are traceable to the National Institute of Standards and Technology.
2. This calibration report shall not be reproduced, except in full, without the written approval of In-Situ, Inc.
3. A calibration interval of 12 to 18 months is recommended.

Performed By: LY

Upper Monitor Zone Back-Up

Calibration Report

In-Situ Inc.

Report Number: 2018040702169-581212
221 East Lincoln Avenue, Fort Collins, CO 80524 USA
1-970-498-1500, 1-800-446-7488, FAX: 1-970-498-1598
Visit us at www.in-situ.com

Instrument Details:

Instrument Model:	**Level TROLL 700**
Full Scale Pressure Range	**100 PSI / 60 m / 197 ft / non-vented**
Serial Number:	**581212**

Calibration Details:

Calibration Result:	**PASS**
Calibration Date:	2018-04-07 02:16:9 (UTC)
Nominal Range of Applied Temperature:	-5 C to +50 C
Temperature Accuracy Specification:	+/- 0.1 C From -5 C to +50 C
Nominal Range of Applied Pressure:	7.0 PSI to 100.0 PSI
Pressure Accuracy Specification:	+/- 0.1 %FS from -5 C to +50 C, +/- 0.05 %FS at +15 C

Post-Calibration Check:

Parameter	Applied	Reported	Deviation
Pressure	100.0010	99.9735	-0.0275
Pressure	44.2002	44.2148	0.0146
Pressure	6.9991	7.0058	0.0067
Temperature	39.1300	39.1300	0.0000

Calibration Procedures and Equipment Used:

Automated calibration procedures used.
Manu Agilent Model 34970A SerialNo MY44000742
Manu Mensor Model CPC6000 SerialNo 610915
Manu Instrulab Model 3312A-14-15-24 SerialNo 31102-(41037)
Manu Instrulab Model 406X-0031-01 SerialNo 31099-2
Manu Agilent Model 53131A-010 SerialNo MY47002678
Manu MENSOR Model 600 SerialNo 622742

Notes:

1. Standards used in this calibration are traceable to the National Institute of Standards and Technology.
2. This calibration report shall not be reproduced, except in full, without the written approval of In-Situ, Inc.
3. A calibration interval of 12 to 18 months is recommended.

Performed By: KK

Calibration Report

In-Situ Inc.
Report Number: 20170816042514-540138
221 East Lincoln Avenue, Fort Collins, CO 80524 USA
1-970-498-1500, 1-800-446-7488, FAX: 1-970-498-1598
Visit us at www.in-situ.com

Instrument Details:

Instrument Model:	**Level TROLL 700**
Full Scale Pressure Range	**30 PSI / 21 m / 69 ft / vented**
Serial Number:	**540138**

Calibration Details:

Calibration Result:	**PASS**
Calibration Date:	2017-08-16 04:25:14 (UTC)
Nominal Range of Applied Temperature:	-5 C to +50 C
Temperature Accuracy Specification:	+/- 0.1 C From -5 C to +50 C
Nominal Range of Applied Pressure:	0.0 PSI to 30.0 PSI
Pressure Accuracy Specification:	+/- 0.1 %FS from -5 C to +50 C, +/- 0.05 %FS at +15 C

Post-Calibration Check:

Parameter	Applied	Reported	Deviation
Pressure	30.0001	30.0023	0.0073
Pressure	12.0000	11.9979	-0.0069
Pressure	0.0000	-0.0009	-0.0030
Temperature	38.8660	38.8711	0.0051

Calibration Procedures and Equipment Used:

Automated calibration procedures used.
Manu Agilent Model 34970A SerialNo MY4402330
Manu Mensor Model CPC6000 SerialNo 41000617
Manu Instrulab Model 3312A-14-15-24 SerialNo 31154
Manu Instrulab Model 406X-0031-01 SerialNo 1-31103
Manu Agilent Model 53131A-010 SerialNo MY47002282
Manu MENSOR Model 600 SerialNo 622742

Notes:

1. Standards used in this calibration are traceable to the National Institute of Standards and Technology.
2. This calibration report shall not be reproduced, except in full, without the written approval of In-Situ, Inc.
3. A calibration interval of 12 to 18 months is recommended.

Performed By: KK

Lower Monitor Zone Back-Up

Calibration Report

Report Number: 20170914202049-544887

221 East Lincoln Avenue, Fort Collins, CO 80524 USA
1-970-498-1500, 1-800-446-7488, FAX: 1-970-498-1598
Visit us at www.in-situ.com

Instrument Details:

Instrument Model:	**Level TROLL 700**
Full Scale Pressure Range	**30 PSI / 21 m / 69 ft / vented**
Serial Number:	**544887**

Calibration Details:

Calibration Result:	**PASS**
Calibration Date:	2017-09-14 20:20:49 (UTC)
Nominal Range of Applied Temperature:	-5 C to +50 C
Temperature Accuracy Specification:	+/- 0.1 C From -5 C to +50 C
Nominal Range of Applied Pressure:	0.0 PSI to 30.0 PSI
Pressure Accuracy Specification:	+/- 0.1 %FS from -5 C to +50 C, +/- 0.05 %FS at +15 C

Post-Calibration Check:

Parameter	Applied	Reported	Deviation
Pressure	30.0002	30.0021	0.0063
Pressure	12.0000	11.9971	-0.0097
Pressure	0.0001	0.0003	0.0005
Temperature	38.9460	38.9502	0.0042

Calibration Procedures and Equipment Used:

Automated calibration procedures used.
Manu Agilent Model 34970A SerialNo MY44038788
Manu Mensor Model CPC6000 SerialNo 610294
Manu Instrulab Model 3312A-14-15-24 SerialNo 31103
Manu Instrulab Model 406X-0031-01 SerialNo 31128-1
Manu Agilent Model 53131A-010 SerialNo MY47002282
Manu MENSOR Model 600 SerialNo 622742

Notes:

1. Standards used in this calibration are traceable to the National Institute of Standards and Technology.
2. This calibration report shall not be reproduced, except in full, without the written approval of In-Situ, Inc.
3. A calibration interval of 12 to 18 months is recommended.

Performed By: LY

In-Situ Inc.

Calibration Report

Report Number: 20190125081810-637935

221 East Lincoln Avenue, Fort Collins, CO 80524 USA
1-970-498-1500, 1-800-446-7488, FAX: 1-970-498-1598
Visit us at www.in-situ.com

Instrument Details:

Instrument Model:	**Baro TROLL 500**
Full Scale Pressure Range	**30 PSI / 1 m / 15 ft /**
Serial Number:	**637935**

Calibration Details:

Calibration Result:	**PASS**
Calibration Date:	2019-01-25 08:18:10 (UTC)
Nominal Range of Applied Temperature:	-5 C to +50 C
Temperature Accuracy Specification:	+/- 0.1 C From -5 C to +50 C
Nominal Range of Applied Pressure:	7.0 PSI to 30.0 PSI
Pressure Accuracy Specification:	+/- 0.2 %FS from -5 C to +50 C, +/- 0.1 %FS at +15 C

Post-Calibration Check:

Parameter	Applied	Reported	Deviation
Pressure	30.0000	29.9970	-0.0100
Pressure	16.1996	16.2007	0.0038
Pressure	6.9998	6.9992	-0.0022
Temperature	39.2920	39.2955	0.0035

Calibration Procedures and Equipment Used:

Automated calibration procedures used.
Manu Agilent Model 34970A SerialNo MY41015886
Manu Mensor Model CPC6000 SerialNo 41000617
Manu Instrulab Model 3312A-14-15-24 SerialNo 31154
Manu Instrulab Model 406X-0031-01 SerialNo 1-31140
Manu Agilent Model 53131A-010 SerialNo MY47002678
Manu MENSOR Model 600 SerialNo 622743

Notes:

1. Standards used in this calibration are traceable to the National Institute of Standards and Technology.
2. This calibration report shall not be reproduced, except in full, without the written approval of In-Situ, Inc.
3. A calibration interval of 12 to 18 months is recommended.

Performed By: SR

In-Situ Inc.

Calibration Report

Report Number: 2018061100277-427741

221 East Lincoln Avenue, Fort Collins, CO 80524 USA
1-970-498-1500, 1-800-446-7488, FAX: 1-970-498-1598
Visit us at www.in-situ.com

Instrument Details:

Instrument Model:	**Baro TROLL 500**
Full Scale Pressure Range	**30 PSI**
Serial Number:	**427741**

Calibration Details:

Calibration Result:	**PASS**
Calibration Date:	2018-06-11 00:27:7 (UTC)
Nominal Range of Applied Temperature:	-5 C to +50 C
Temperature Accuracy Specification:	+/- 0.1 C From -5 C to +50 C
Nominal Range of Applied Pressure:	7.0 PSI to 30.0 PSI
Pressure Accuracy Specification:	+/- 0.2 %FS from -5 C to +50 C, +/- 0.1 %FS at +15 C

Post-Calibration Check:

Parameter	Applied	Reported	Deviation
Pressure	30.0001	30.0020	0.0064
Pressure	16.6604	16.6619	0.0050
Pressure	6.9985	6.9999	0.0047
Temperature	25.0540	25.0396	-0.0144

Calibration Procedures and Equipment Used:

Automated calibration procedures used.
Manu Agilent Model 34980A SerialNo MY44001931
Manu Instrulab Model 4312A-15 SerialNo 41014
Manu Instrulab Model 832-151-01 SerialNo 808
Manu Mensor Model CPC6000 SerialNo 410008J4

Notes:

1. Standards used in this calibration are traceable to the National Institute of Standards and Technology.
2. This calibration report shall not be reproduced, except in full, without the written approval of In-Situ, Inc.
3. A calibration interval of 12 to 18 months is recommended.

Performed By: WR

Report generated: 2019-02-11 10:42:38 UTC

IW-1 Downhole Memory Gauge

DataCan

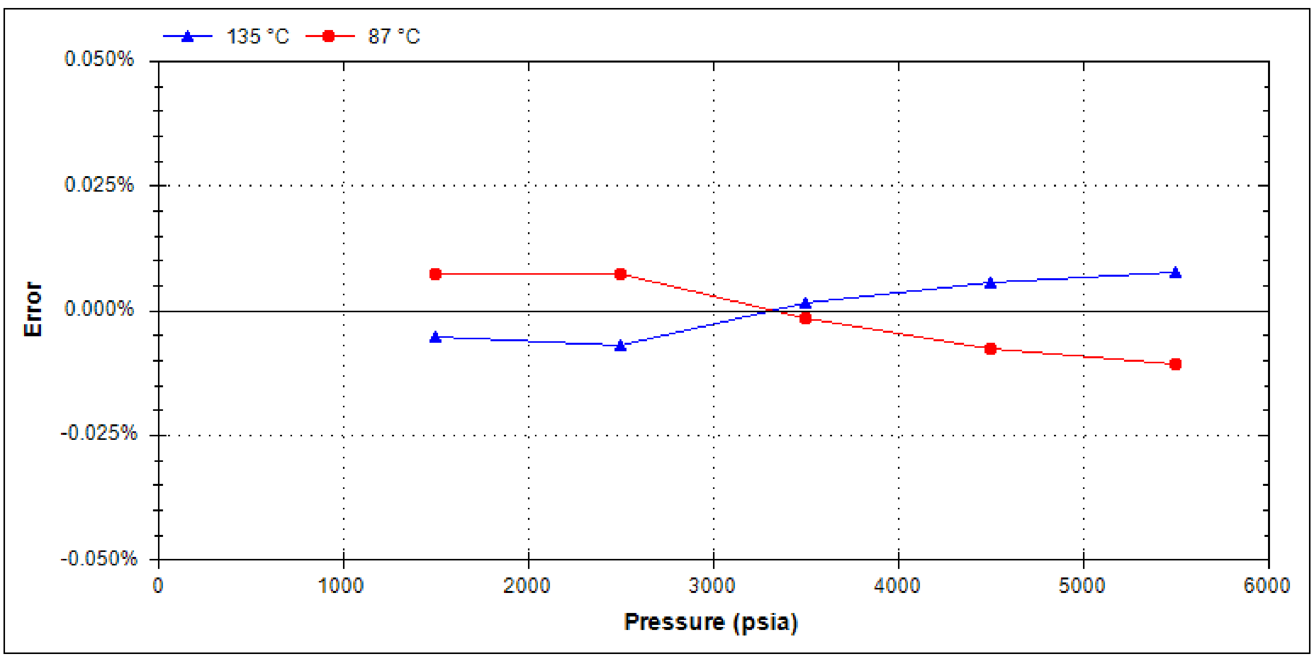
"The Next Generation of Down Hole Tools"

Calibration Date: 26-Nov-18
Max Pressure Error: 0.022% F.S.
Max Temperature Error: 0.157 °C
Part Number: 100657
Serial Number: P1210

Calibration System: CALIBRATION02
Batch Number: 20181122.152942

1.25 OD Piezo I Calibrated Assy I-718			
Max Pressure		Max Temperature	
psi	kPa	ºF	ºC
6,000	41,369	302	150

Accuracy: As shown in the graph below, this DataCan Pressure gauge conforms to within +/- 0.030% F.S. of the pressure standard used in calibration, which is accurate to within +/- 0.01% of reading.



Working Standards

Sun Electronic Systems Environmental Chamber, Model: EC127, Serial: EC0063
DHI Instruments Pressure Controller, Model: PPCH-200M (30,000psi Reference), Serial: 1894

Traceability Statement

All working standards are traceable to nationally or internationally recognized standards.

Approved By:
DataCan Services Corp.

Calibrated By:
Angelo Pulido

DataCan

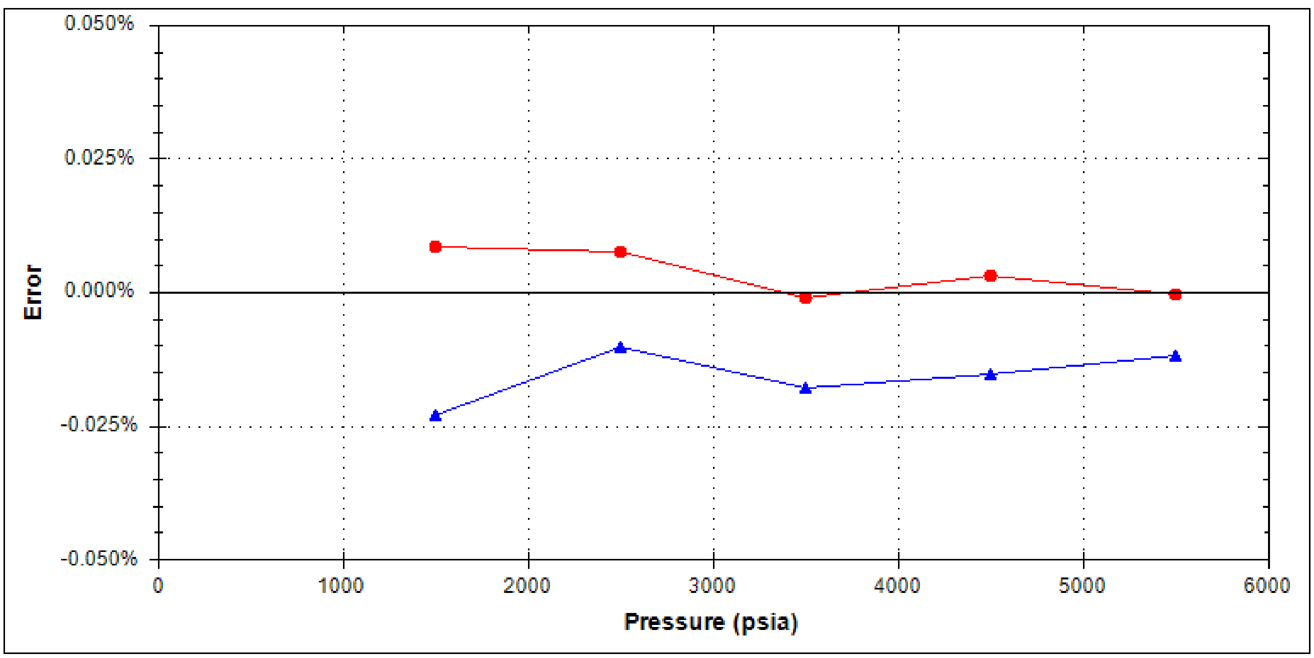
"The Next Generation of Down Hole Tools"

Calibration Date: 30-Jan-19
Max Pressure Error: 0.023% F.S.
Max Temperature Error: 0.213 °C
Part Number: 100657
Serial Number: P1232

Calibration System: CALIBRATION02
Batch Number: 20190128.104724

1.25 OD Piezo I Calibrated Assy I-718			
Max Pressure		Max Temperature	
psi	kPa	ºF	ºC
6,000	41,369	302	150

Accuracy: As shown in the graph below, this DataCan Pressure gauge conforms to within +/- 0.030% F.S. of the pressure standard used in calibration, which is accurate to within +/- 0.01% of reading.



Working Standards

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All working standards are traceable to nationally or internationally recognized standards.

Approved By:
DataCan Services Corp.

Calibrated By:
Angelo Pulido