Technical Memorandum
on the
Short-Term Injection Testing of Deep Injection Well IW-1 at the Cemetery Road Wastewater Treatment Facility

Prepared for

Okeechobee Utility Authority

Prepared by:

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Executive Summary

Short-term injection testing was performed on Class I deep injection well IW-1 at the Okeechobee Utility Authority Cemetery Water Treatment Facility beginning on July 13, 2010 through July 16, 2010. The purpose of performing the short-term injection test was to demonstrate deep injection well IW-1 is capable of accepting the desired injection rate, gain hydraulic information related to well performance, and demonstrate the absence of a direct hydraulic connection between the injection zone and the intervals monitored by dual-zone monitor well DZMW-1. Injection testing was performed in accordance with testing procedures submitted to the Department on June 8, 2010.

The injection well was operated at an injection rate as high as 3,050 gallons per minute (gpm) during testing with a maximum wellhead operating pressure of approximately 17.5 pounds per square inch (psi). These results demonstrate Class I deep injection well IW-1 is capable of safely accepting flows in excess of 3,000 gpm, which is equivalent to an injection velocity of less than 2.5 feet per second. Monitor well pressure data collected during injection testing demonstrates the absence of a direct hydraulic connection between the injection zone and monitoring intervals.

Introduction

Class I deep injection well IW-1 was constructed with a 24-inch diameter final casing installed to a depth of 2,765 feet bpl and a total depth of 3,200 feet bpl. The short-term injection test was performed by Youngquist Brothers, Inc. following FDEP approval. McNabb Hydrogeologic Consulting, Inc. (MHC) provided on consulting services during the injection testing.

Short-Term Injection Test

Procedures

Injection testing consisted of background, injection, and recovery steps. The injection test consisted of a 24-hour background data collection period, a 24-hour step-injection period, and a 24-hour recovery data collection period. Wellhead pressure at IW-1, pressure at both monitoring intervals at DZMW-1, and barometric data were collected during all steps of injection testing. A Hermit 3000 datalogger was used to record data throughout injection testing. Injection rate measurements were recorded by MHC and test contractor staff during the injection step of testing. Tidal data for the Port of Palm Beach for the period of injection testing were obtained from the National Oceanic and Atmospheric Administration (NOAA) website. An outline of the testing procedure is provided below.

Background Data Collection Step – For a period of 24-hours prior to beginning injection, background pressure data for both monitor zones and IW-1, and barometric pressure were recorded to establish pre-injection background conditions.

Injection Step – The injection step consisted of pumping reclaimed water into IW-1 at an average rate of 3,040 gpm for 8 hours, followed by injection at a rate of 2,000 gpm for 8 hours, and finally, injection at a rate of 1,050 gpm for 8 hours. The injection rate of 3,040 gpm (4.38 mgd) represents an injection velocity of less than 2.5 feet per second (fps).

Pressure at both monitor zones and the injection wellhead, and barometric pressure were electronically recorded throughout the injection step. Injection rate measurements were taken using a 12-inch in-line flowmeter and recorded manually.

Recovery Data Collection Step – Upon completion of the injection step, the recovery data collection step began. Recovery step pressure data were recorded for 24 hours for both monitor zones of DZMW-1 and the IW-1 wellhead. Barometric data was also collected during this period.

Results

The data for the entire injection test are presented in Figure 1. An interpretation of each of the injection phases of the injection test is provided below.

Figure 2 provides IW-1 wellhead pressure and injection rate data for the background, injection, and recovery steps of injection testing. Injection wellhead shut-in pressure was approximately 16.0 psi during the background data collection step. Wellhead pressure momentarily increased to a maximum of 30.2 psi when the injection pumps were initially turned on. Wellhead pressure then almost immediately decreased to approximately 17.5 to

18.0 psi (averaged 17.7 psi) after the pumping rate had stabilized to approximately 3,040 gpm. The wellhead pressure then decreased to approximately 17.0 and 16.8 psi, when the injection rate was decreased to 2,000 and 1,000 gpm, respectively. Wellhead shut-in pressure was 16.8 psi at the beginning of the recovery step and had decreased to 16.2 psi by the end of the recovery step. The 1.7 psi difference between wellhead pressure when injecting at 3,000 gpm and pre-injection shut-in pressure represents a specific capacity of 774 gpm/foot. However, pipe friction losses account for more than half of the wellhead pressure increase during injection. Using a pipe roughness factor of 140 (appropriate for new steel casing), the adjusted wellhead pressure (minus pipe friction losses) becomes 0.8 psi, resulting in an adjusted specific capacity of 1,645 gpm/foot.

Pressure data for both monitor zones, injection rate data and tidal data are presented in Figure 3. Review of the monitor zone pressure and injection rate data suggests there is no correlation between monitor zone pressure and injection at deep injection well IW-1. Pressure at the upper monitor zone remained between 6.40 and 6.64 psi throughout the entire testing period. Pressure at the lower monitor zone fluctuated between 4.46 and 4.57 psi through injection testing. Tide level readings fluctuated between -0.5 and 3.6 feet relative to low tidal water level. Tidal level does not appear to have a large affect on water level at the monitoring zones.

Figure 4 presents monitor zones pressure, injection rate, and barometric pressure data for the entire test. Review of the data indicates barometric pressure did not have a significant influence on monitor zone pressure.

Formation Fracturing Calculation

Potential damage to the injection zone and confining unit can occur when formation injection pressures surpass the mechanical strength of the formation. An equation developed by Hubbert and Willis (1972) is used to predict the minimum bottom hole pressure that could potentially propagate hydraulic fracturing of the formation. The equation is:

$$pi = \frac{Sz + 2Po}{3}$$ 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. This scenario assumes minimal lateral earth stress. At a depth of 2,765 feet bpl (the base of the final casing), using the calculated fracture initiation gradient of 0.64 psi/foot, a pressure of 1,770 psi is the calculated minimum bottom-hole pressure that may create hydraulic fracturing.

The calculated specific capacity of the injection zone is 1,645 gpm/foot. Therefore, while injecting at the maximum permitted injection rate of 3,040 gpm (4.38 mgd), the calculated bottom-hole pressure is 1.8 feet or 0.8 psi at the base of casing. This pressure is considerably less than the previously calculated minimum fracture initiation pressure of 1,770 psi.

Conclusion

During injection testing, the injection well was operated at an injection rate as high as 3,040 gpm with a wellhead operating pressure of approximately 17.7 psi. These results demonstrate Class I deep injection well IW-1 is capable of safely accepting flows in excess of 3,040 gpm. Injection well operating pressure data indicates the well can safely operate at the maximum permitted injection rate without fracturing the injection formation or overlying confining intervals. Data collected during injection testing demonstrates the absence of a direct hydraulic connection between the injection zone and monitoring intervals.

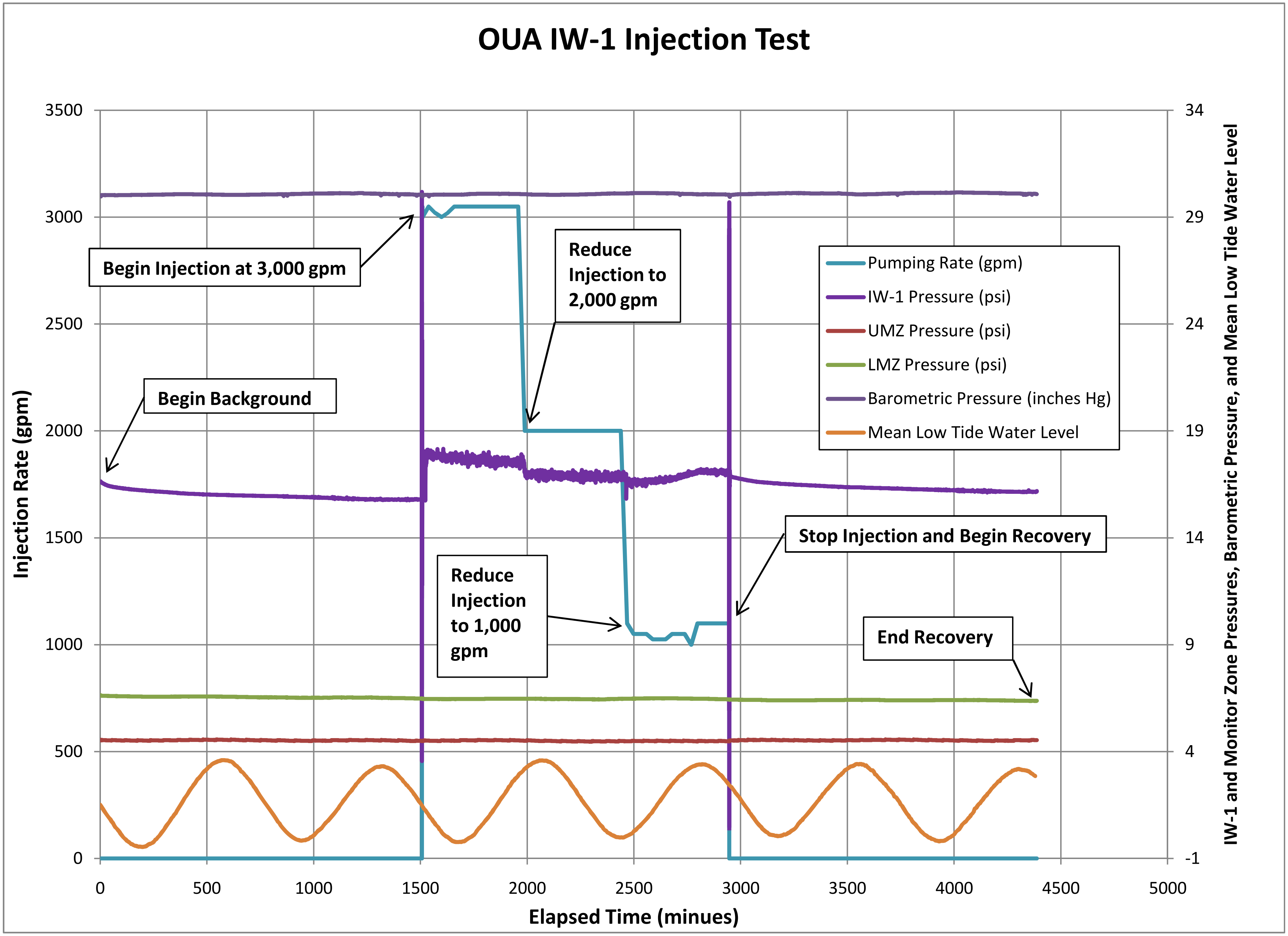

Figure 1. All injection test data.

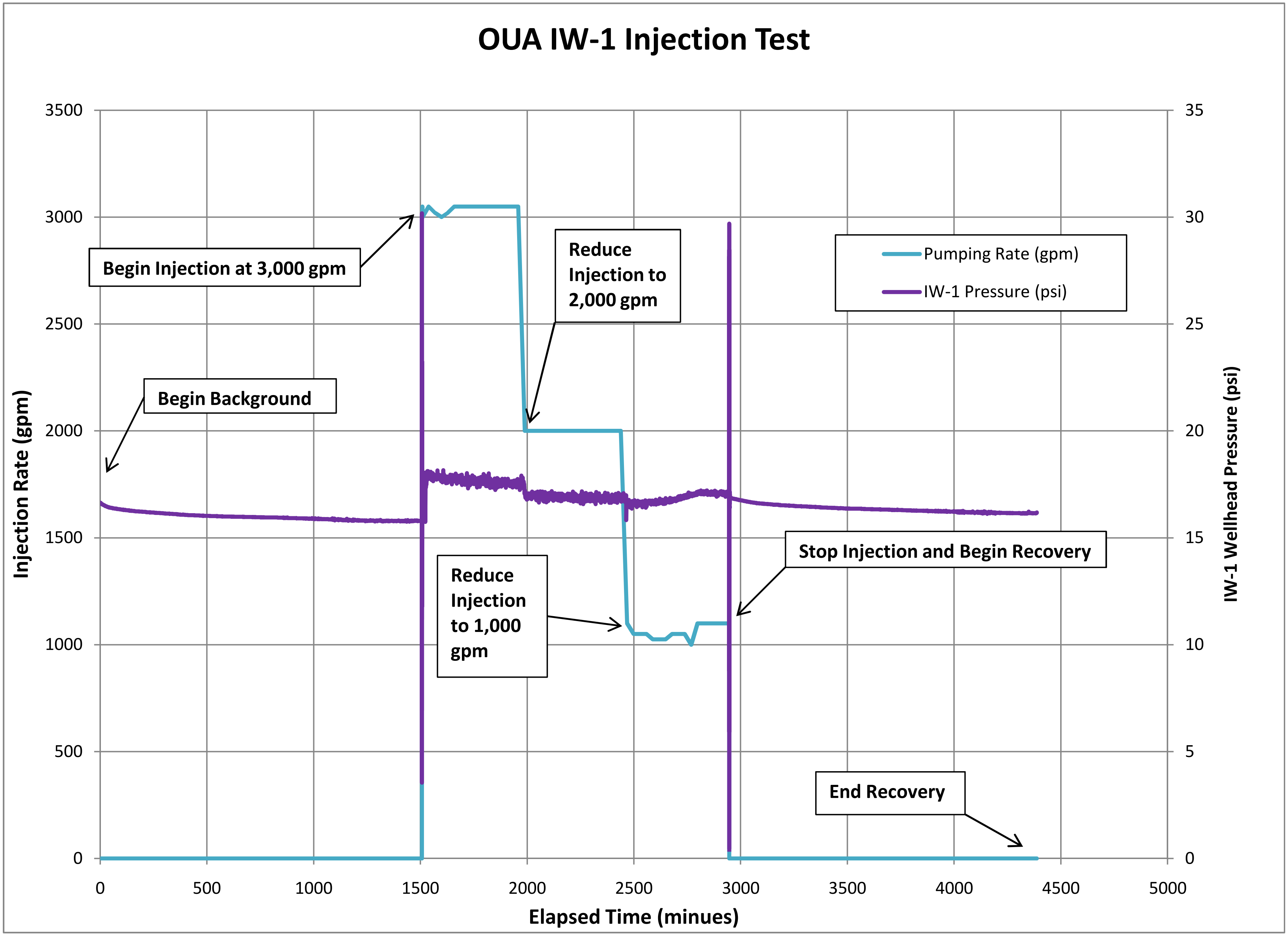

Figure 2. Injection Wellhead Pressure and Injection Rate data.

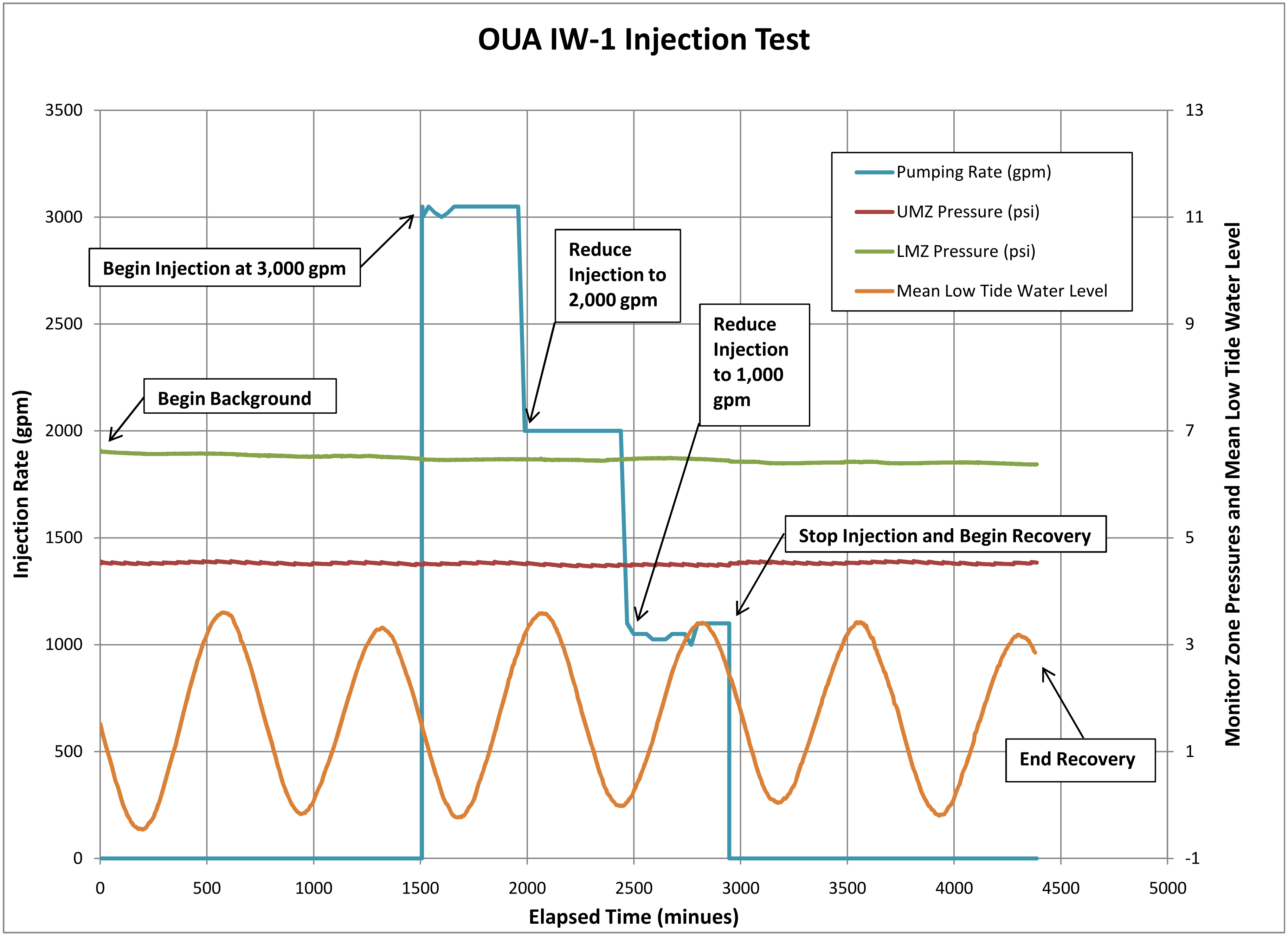

Figure 3. Injection Rate, Monitor Zones Pressure, and Tidal data.

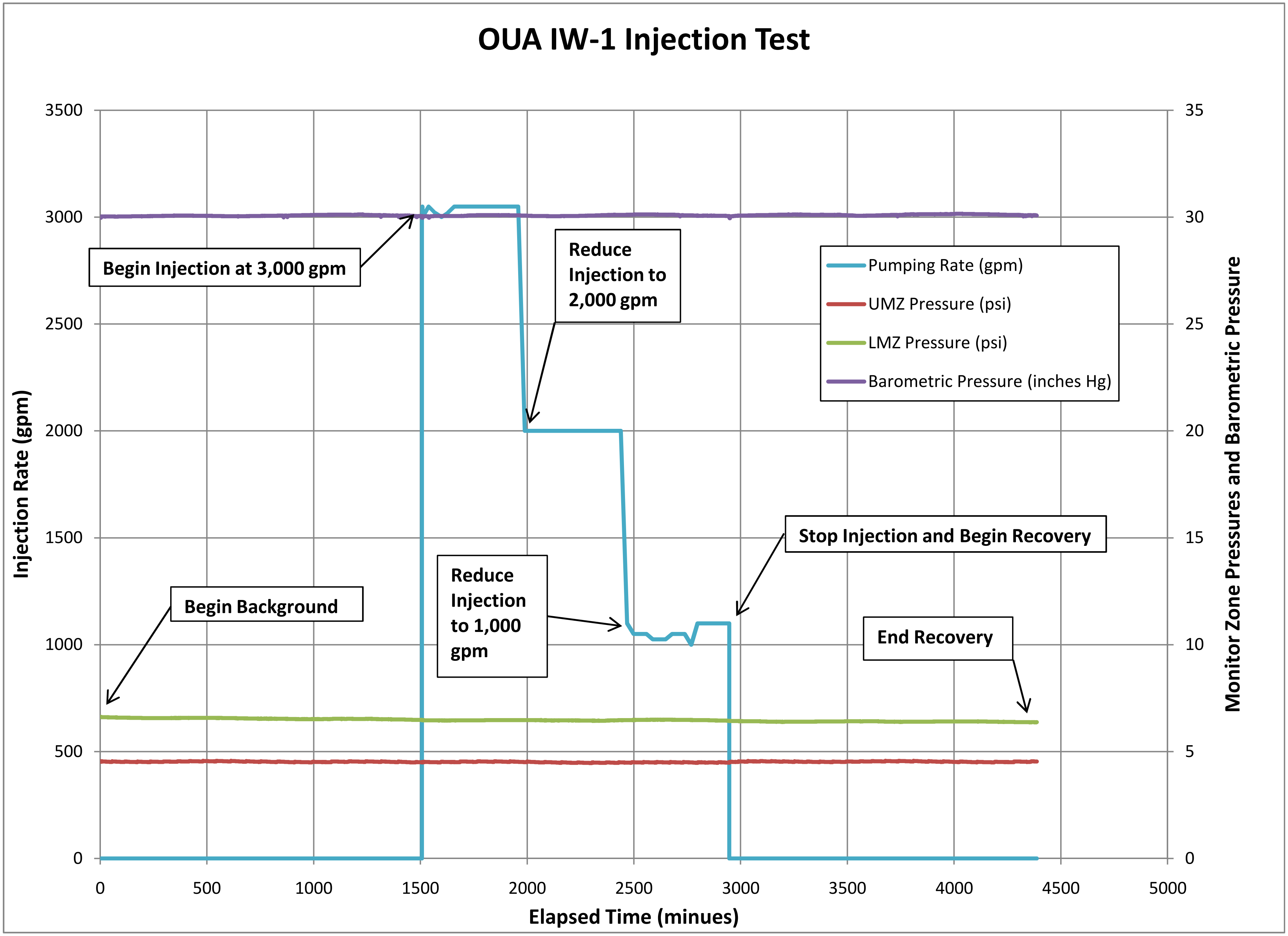

Figure 4. Injection Rate, Monitor Zones Pressure, and Barometric Pressure data.