Memorandum

Environmental Resources Management

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To: Catherine Brown, Remedial Project Manager
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Date: 23 April 2010

Subject: Draft Technical Memorandum #7 - Month One Post-Injection Results, Discussion, and Conclusions
Phase III Nano-scale Zero-Valent Iron Injection Field Testing Program
Phoenix-Goodyear Airport-North Superfund Site
Goodyear, Arizona

This memorandum transmits the month one results and conclusions of the Phase III Nano-scale Zero-valent Iron (NZVI) Pilot Test (PT) on behalf of Crane Co. The Phase III NZVI Pilot Test injections were completed by ERM on 2 through 5 February 2010 in accordance with the PT Work Plan, Response to Comments, and Response to Comments Addendum, dated 31 August 2009, 16 November 2009, and 20 November 2009, respectively. EPA approval for the revised PT Work Plan was received via electronic mail on 18 December 2009. This data and results summary is based on field observations and groundwater monitoring data collected during:

- The baseline groundwater sampling event conducted on 17 through 19 January 2010;
- The NZVI injection activities completed between 2 through 5 February 2010; and
- The post-injection groundwater monitoring events that occurred:
    - One week after completion of injection activities, on 10 and 11 February 2010;
    - Two weeks after completion of injection activities on 17 through 19 February 2010; and
    - One month after completion of injection activities on 3 and 4 March 2010.

The data are provided in both tables and trend plots. Groundwater monitoring data are presented in a format that will be updated as the remaining data become available from the analytical laboratory.

The remaining two groundwater monitoring events are presently scheduled for:

- 5 – 7 May 2010 (month 3); and
- 4 – 6 August 2010 (month 6).

Summary Description of Injection Activities

The jet-assisted injection process involved the installation of two blank-cased wells IRZ-BW-01 and IRZ-BW-02. The locations of the injections wells are indicated on Figure 1. The injection wells were installed using a Becker drilling rig and were constructed within 9-inch boreholes, similar to the injection wells currently on-site, but without a screen or filter pack. The well casing was sealed to the formation with Sikagrout, a cement-based grout tremied into the annulus of the well. The 4-inch diameter polyvinyl chloride (PVC) casing extended 10-ft past the deepest injection depth, to provide a sump. IRZ-BW-01 and IRZ-BW-02 were constructed on 12 and 13 January 2010 to total depths of 135.25- and 136.08-ft bgs. Boring logs for these injection wells are provided in Attachment A. Stainless steel spacers were used to ensure that the casing would stay centered in the borehole during well construction. The injection field work was performed approximately 2 weeks after well construction to allow the grout to cure and ensure a contiguous seal between the well casing and the formation.

The NZVI injection was conducted using combination of a jet lance injection tool and pressurized packer isolation of the target injection zone. The jet-injection lance is comprised of a set of packers straddling an array of ten high-pressure water nozzles. Five sets of opposing jets were located at six-inch intervals and oriented at 90 degrees to balance injection pressure and provide radial coverage on the injection lance. Separate nitrogen, water jet, and injectate feed lines were passed through the top packer. The packers and jet-injection lance was lowered into the well by a well development rig. The lower 5-ft injection interval was completed first, and then the packers were deflated and moved to the upper injection interval at each injection well.

The jet-assisted injection of anaerobic water using a 10,000-pounds per square inch (psi) tri-plex pump was alternated with injection of NZVI using a piston pump. The 10,000- psi jetted water was applied to the lance

to carve approximately 1/16- to 1/8-inch diameter holes through the PVC and through the grout to create ten jetted conduits into the formation. The injectate piston pump then pressurized the casing between the packers to 100- to 160-psi forcing the NZVI into the jetted conduit, and creating fractures as the injectate pressure exceeded the overburden pressure. These stresses are hypothesized to result in nucleation of hydraulic fractures, increasing the distribution of the NZVI into the surrounding soils. Periodic application of the water jets was used to create high pressure turbulence to further mix the NZVI with soil in the vicinity of the jetted conduit and clear the casing of NZVI particles.

After completion of the lower injection interval, the packers were pulled up to the next injection interval and the process was repeated. Two intervals, 113- to 118-ft bgs and 108- to 113-ft bgs, were completed at each injection well. The wells were finished with a standard flush-mount well casing and both remain in place for potential reuse in future remediation activities.

A total of 7,421-gallons of highly reducing (-500 to -800 mV) NZVI particles were injected into a deep alluvial water-bearing zone within the source area. PolyMetallix™ NZVI was provided by Polyflon, a Crane Co. Company, as a 35.2 gram per liter aqueous solution contained in eighteen 275-gallon totes. Each tote of NZVI was batch-mixed with anaerobic water prior to subsurface injection. The injectate contained a total of 1,400 pounds of NZVI.

Monitoring Program

Prior to start of injections, TempHion™ probes and pressure transducers were installed in six downgradient monitoring locations. The TempHions™ and pressure transducers were programmed to collect a measurement every 15 minutes. This interval was shortened to every 5 minutes after the injection of the first batch of NZVI particles at IRZ-BW-2 due to the observed speed of the change in oxidation-reduction potential (ORP) during injection. The TempHions™ are equipped to measure pH, temperature, and ORP. The paired down-hole probes were placed at mid-screen, approximately 115-ft bgs at IRZ-MW-B, IRZ-MW-C, IRZ-MW-D, IRZ-IW-02, IRZ-IW-04, and IRZ-IW-05.

Pilot test groundwater monitoring includes a baseline round, conducted prior to the injection of the NZVI particles, and groundwater sampling rounds performed at week one, two and 4, and month one, three, and six after injection. The baseline sampling round was conducted a week and a

half prior to the injection field work. The monitoring schedule is provided in the introduction to this memorandum.

Groundwater samples were analyzed for VOCs, perchlorate, chlorate, chlorite, and hydrogen during every sampling event. During select monitoring rounds periodic samples were taken to monitor changes in total and dissolved iron, manganese, chloride, sulfate, nitrate, alkalinity, sodium, phosphate, and total organic carbon in groundwater during the monitoring period.

In accordance with the Response to Comments on the Work Plan, passive diffusion bags (PDBs) were placed in pilot test monitoring wells IRZ-MW-C and IRZ-MW-D at two depths, 115 ft and 125 ft two weeks prior to the month one sampling event. The PDBs were analyzed for volatile organic compounds via Method 8260C. PDBs were placed at these wells due to the longer length of well screen present at these locations. PDBs were not placed at IRZ-MW-B due to the presence of NZVI within the well screen. PDBs will be deployed at the same locations and depths for the month three and month six groundwater monitoring events.

Results and Discussion

Tables 1 through 3, attached to this memorandum, contain data from groundwater samples analyzed by TestAmerica Laboratories, located in Phoenix, Arizona. Data validation was performed in accordance with the an addendum to the Site-wide Quality Assurance Project Plan, titled, "*Quality Assurance Project Plan Addendum – In Situ Reactive Zone Treatability Study, Phoenix-Goodyear Airport-North Superfund Site*", dated 19 May 2004. Table 4 shows field parameter measurements collected during each of the groundwater sampling events. Attachment B contains the laboratory data packages for each sampling event as portable data format files.

Real-time monitoring results. The ORP, pH, temperature, and water level data changed in direct response to the injections conducted at IRZ-BW-01 and IRZ-BW-02 (Figure 2). A decrease in ORP to less than -800 milliVolts (mV) at IRZ-IW-02, located approximately 12.5-ft from the injection point, was observed within a few minutes of the start of injection at IRZ-BW-02. Measurements taken by a hand-held field instrument at IRZ-MW-B, which was 19-ft from IRZ-BW-02 also showed a drop in conductivity within a similar timeframe.

The ORP at IRZ-IW-04 significantly and rapidly decreased in response to injection at IRZ-BW-01, but no response was measured to injection at IRZ-BW-02. IRZ-IW-04 is located 29-ft from IRZ-BW-01. Data from the probes at IRZ-IW-04 showed a similar decrease in ORP, and increases in

pH, temperature, and water level elevation, to those seen at IRZ-BW-02, with these changes also occurring within minutes of the start of injection. Increased water levels were observed at injection well IRZ-BW-02 during the injection into IRZ-BW-01. IRZ-BW-02 is located 15-ft from IRZ-BW-01.

Finally, a definite and brief increase in water level elevation was recorded at IRZ-IW-05 in response to injection at IRZ-BW-01. These two locations are 22-ft apart.

TCE and perchlorate. Figures 3 and 4 provide time series plots for TCE and perchlorate, respectively, including data from the baseline through month one groundwater sampling events. TCE concentrations in groundwater samples from IRZ-MW-B, IRZ-IW-02, and IRZ-IW-04 decreased between 82% and 96% between the baseline and week two sampling events. TCE concentrations at IRZ-MW-B decreased from 46 µg/L to 1.7 µg/L. TCE concentrations at IRZ-IW-2 and IRZ-IW-4 decreased from 510 µg/L to 93 µg/L, and 2,300 µg/L to 280 µg/L, respectively. Between week two and month one, TCE concentrations in NZVI treated monitoring wells began to recover, with the exception of IRZ-MW-B, where the TCE concentration has remained at 1.7 µg/L (Table 1).

At IRZ-IW-03, the month one data shows TCE concentrations to be fluctuating significantly, likely due to immediate impacts of NZVI, and migration of both mobilized TCE and treated groundwater through this area.

TCE concentrations temporarily increased at groundwater monitoring locations outside of the radius of influence of the NZVI indicating that the injections may have facilitated the release of TCE within the injection area. Former injection well IRZ-IW-5 was the injection well for the Phase II pilot test, and due to the loss of permeability in the vicinity of this well, it is suspected that the Phase III injectate may have bypassed this location, and that the low permeability of the soil may have prevented access to the area near IRZ-IW-01. The continued low permeability conditions in the vicinity of IRZ-IW-05 is evidenced by the ORP, which has remained below -300 mV since the Phase II pilot injection performed in April of 2008 (Arcadis 2009).

Perchlorate concentrations decreased significantly at IRZ-MW-B, and then began to rebound between week one and week two. Perchlorate concentrations remained relatively unaffected at IRZ-IW-01, IRZ-IW-03, and IRZ-IW-04. At IRZ-MW-C and IRZ-MW-D, the perchlorate concentrations increased and then returned to baseline levels at month

one. At IRZ-IW-02 and
IRZ-IW-05, perchlorate concentrations increased, possibly as a result of pilot test injection activities (Table 1).

PDB data. The TCE concentrations measured in the PDB groundwater samples are 62%- to 75%-lower than the concentrations detected in the groundwater samples collected by the low-flow sampling method at these locations. The results of the PDB samples and the low flow samples are compared in Table 2. At both locations, IRZ-MW-C and IRZ-MW-D, the TCE concentrations were higher in the PDB samples collected at the lower, 125-ft depth.

Hydrogen and total and dissolved iron. Significantly elevated concentrations of hydrogen (Figure 5 and Table 3) were detected in the week one and week two post-injection sampling events at all groundwater monitoring locations. Hydrogen concentrations began to decline after week one in monitoring wells located within the injection radius of influence, but groundwater from wells outside the injection area showed increasing trends in hydrogen after the second week groundwater monitoring event, indicating the downgradient migration of NZVI treated groundwater. Hydrogen concentrations have almost returned to baseline concentrations one month after the injections were completed, with the exception of IRZ-MW-C, where the hydrogen concentration has increased from 11- to 5,900-nanomoles per liter between week two and month one.

Sodium and total iron concentrations followed patterns similar to hydrogen. Elevated concentrations of dissolved iron were detected in all of the monitoring wells except IRZ-MW-D and IRZ-IW-02. IRZ-IW-02 was not sampled for iron because the well exhibited limited recovery and the required sample volume could not be met.

Other analytes. No significant changes in sodium, alkalinity, phosphate, total phosphorus, and TOC, was observed in the data from the baseline and month one sampling events (Table 3). Chloride concentrations rose slightly in the monitoring wells IRZ-IW-04 and IRZ-MW-B. Chloride concentrations fluctuated within a statistically insignificant range at IRZ-IW-03, IRZ-MW-C, and IRZ-MW-D. At IRZ-MW-B, the chloride concentration increased significantly from a baseline of 740 mg/L to 1,700 mg/L, indicating that on a stoichiometric equivalent basis, potentially 3.5 grams of TCE per liter of groundwater was degraded by NZVI in the vicinity of this monitoring well.

Field Parameters – ORP, DO, and pH. These parameters allow monitoring wells to be grouped by presence or absence of NZVI. A decrease in ORP and increase in pH is evident in groundwater at

IRZ-IW-02, IRZ-MW-B, IRZ-IW-04, and IRZ-IW-05. NZVI was also observed in groundwater purged from these wells during post-injection groundwater sampling activities. NZVI was observed in groundwater at IRZ-IW-5, and ORP decreased slightly at week one, but then rebounded to baseline levels at week two. The ORP at IRZ-IW-05 was already negative during the baseline sampling event, due to use of this well as the primary injection point during the Phase II pilot test.

The ORP, IRZ-IW-01, IRZ-IW-03, IRZ-MW-C, and IRZ-MW-D all decreased slightly between the baseline round and the month one sampling event, distinguishing groundwater in the vicinity of these wells from untreated groundwater. A significant increase in pH was measured at monitoring wells IRZ-IW-02, IRZ-MW-B, IRZ-IW-04, and IRZ-IW-05, again confirming the presence of NZVI from the pilot test injections at these locations. Finally, a decrease in dissolved oxygen concentration was measured at all monitoring points, except the two locations furthest from the injection points, IRZ-MW-C and IRZ-MW-D, indicating that anaerobic water, or water treated by NZVI was present at those locations.

Conclusions

Jet-assisted injection was effective in delivering a significant mass of NZVI to a distance of at least 29-ft from the injection points. Treatment efficiencies for TCE of up to 96% were observed during early post-injection monitoring at locations where NZVI was observed in groundwater. Post-injection data also indicate that groundwater containing higher concentrations of TCE was released, likely from non-connected porespace within the saturated zone soils, increasing accessibility of the released mass to future remediation efforts.

The month one data show an increase in hydrogen at IRZ-MW-C, but no corresponding increase in iron concentration. At IRZ-IW-03, a significant increase in iron was detected, also at month one, together with a 47% decrease in TCE concentration. These data support a hypothesis that groundwater containing suspended NZVI particles migrated through this area one month after injection. Additionally, these data indicate that treated groundwater may be migrating downgradient and through monitoring wells, with hydrogen preceding iron. Future data to be collected in May and August 2010 will provide further information regarding this hypothesis.

The data and field observations collected during this pilot test by ERM will be used as the basis for future applications of in situ chemical reduction using PolyMetallix™ NZVI to treat TCE at this site. During future field activities, further investigation into the distribution of the

injected iron is recommended in order to optimize contact between target compounds and the iron during future deployment of this technology. ERM anticipates that judicious use of jet-assisted injection to treat groundwater and soil containing high concentrations of TCE will likely reduce the cost, magnitude, and longevity of ongoing groundwater extraction and aboveground treatment activities.

Attachments

Attachment A: Injection Well Construction Logs
Attachment B: Laboratory Data Packages

Figures

Figure 1 – Source Area Map
Figure 2 – Real-Time Temperature, Oxidation Reduction Potential, pH and Transducer Data Trend Plots
Figure 3 – Trichoroethene Trend Plot
Figure 4 – Perchlorate Trend Plot
Figure 5 – Molecular Hydrogen Trend Plot
Figure 6 – Oxidation Reduction Potential, Dissolved Oxygen, and pH Trend Plots

Tables

Table 1 – VOC and Perchlorate Data
Table 2 – VOC Data from Multiple Sampling Methods
Table 3 – Metals and Ion Data
Table 4 – Field Parameter Data

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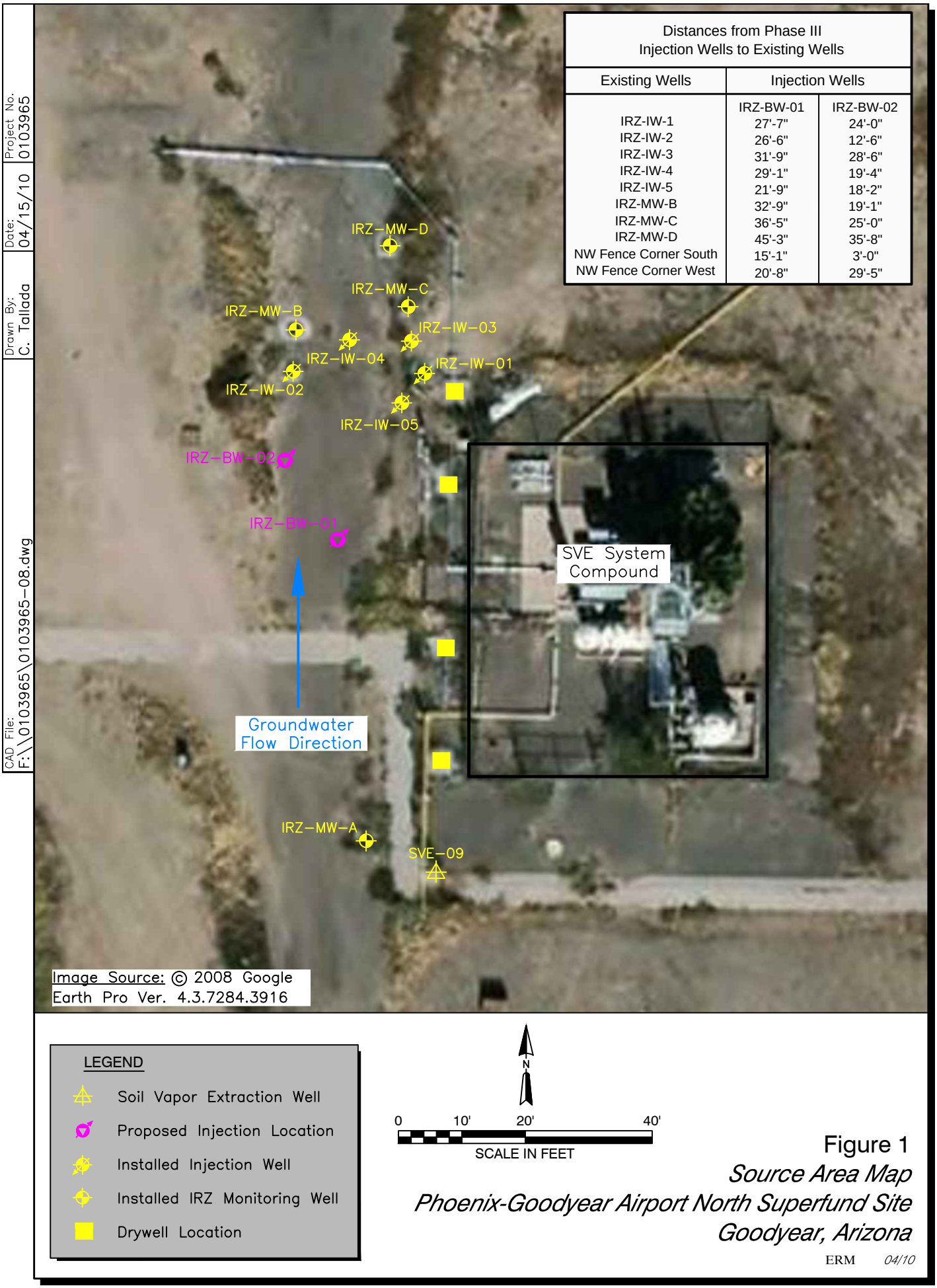

Figure 1

Source Area Map

Phoenix-Goodyear Airport North Superfund Site

Goodyear, Arizona

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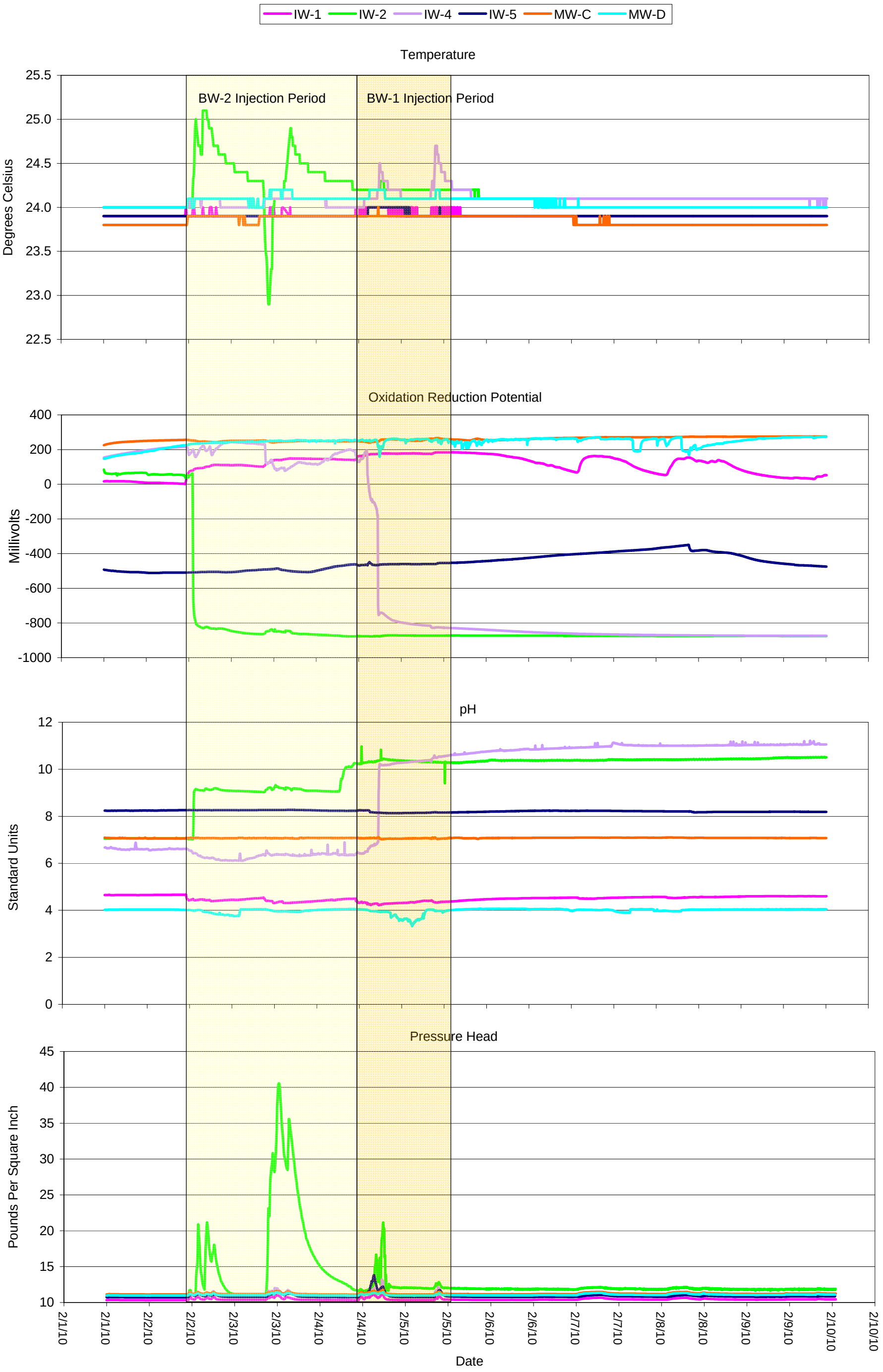

Figure 2

Real-time Temperature, Oxidation Reduction Potential, pH and Transducer Trend Plots
Phase III NZVI Pilot Test
Phoenix-Goodyear Airport-North Superfund Site
Goodyear, Arizona

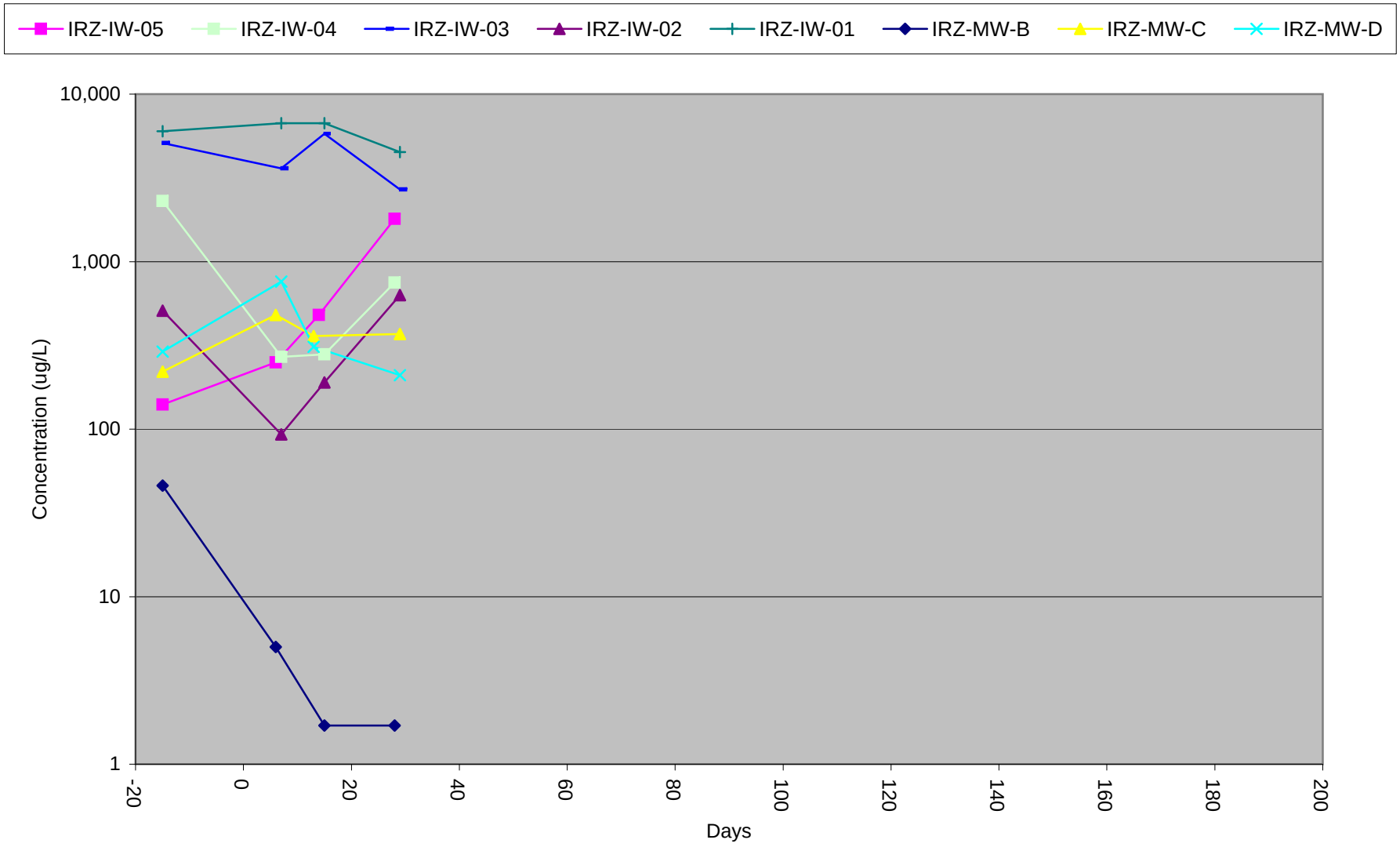

Figure 3

Trichloroethene Trend Plot
Phase III NZVI Pilot Test
Phoenix-Goodyear Airport-North Superfund Site
Goodyear, Arizona

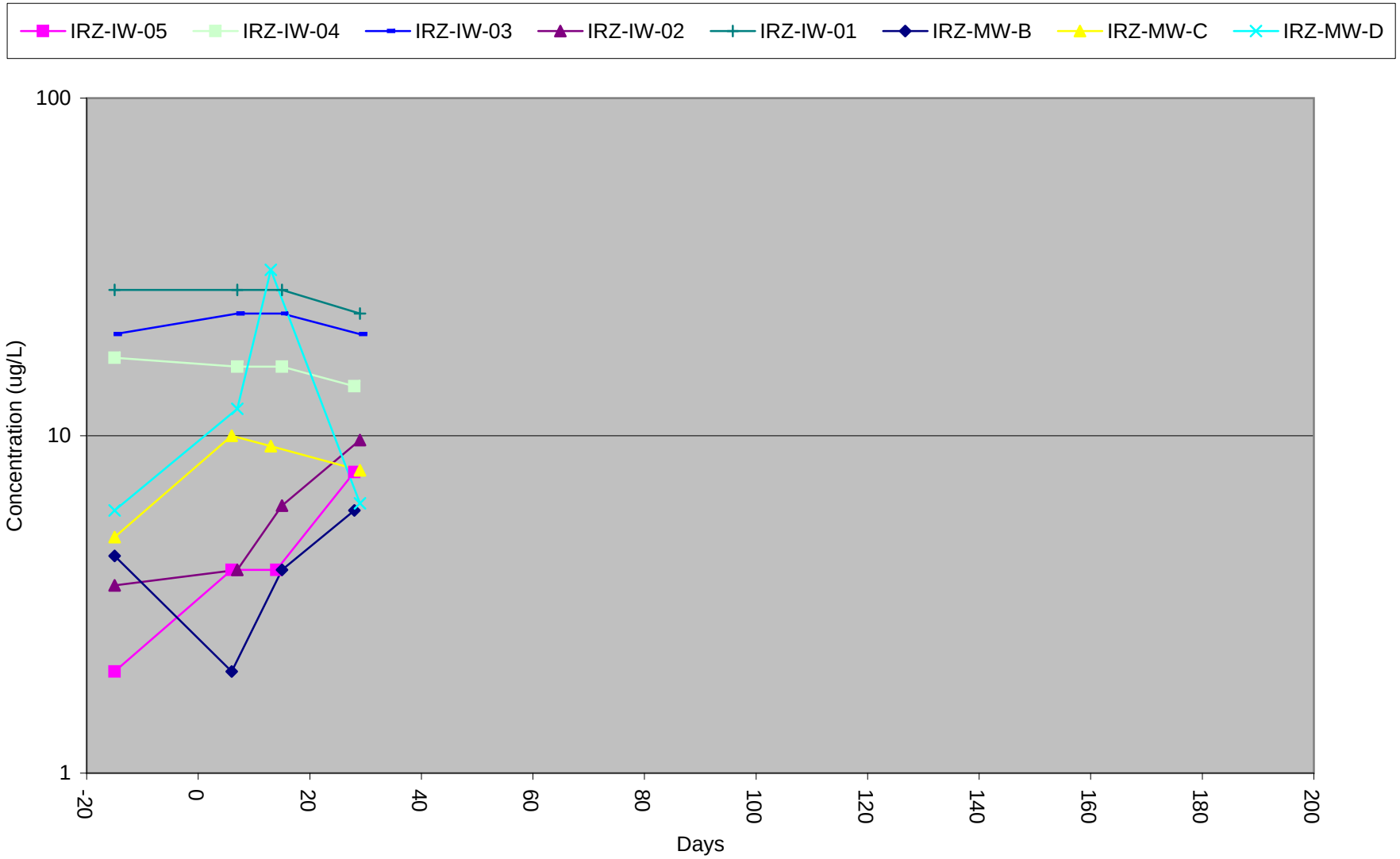

Figure 4

Perchlorate Trend Plot
Phase III NZVI Pilot Test
Phoenix-Goodyear Airport-North Superfund Site
Goodyear, Arizona

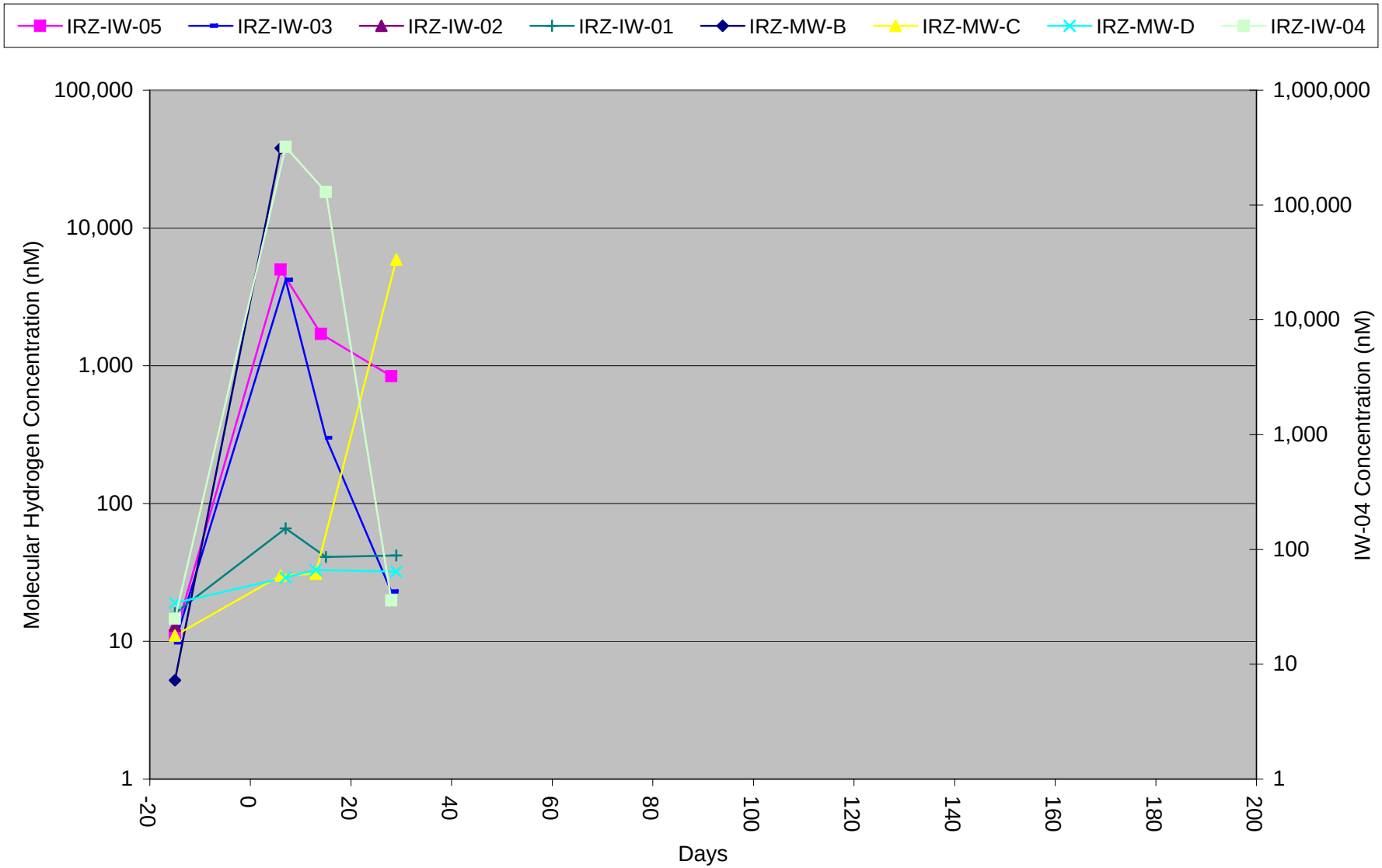

Figure 5

Molecular Hydrogen Trend Plot
PGA-North Superfund Site
Goodyear, Arizona

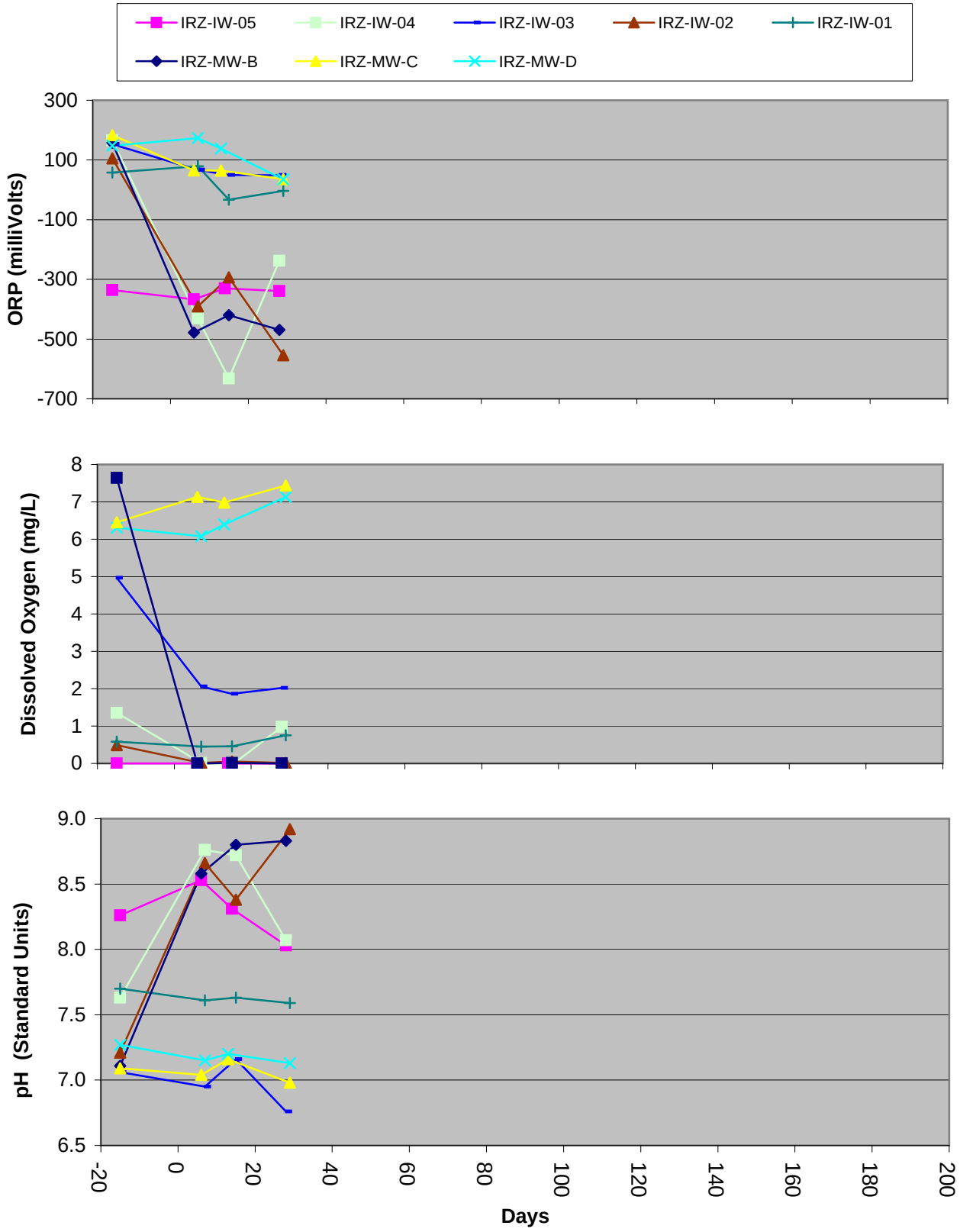

Figure 6

Oxidation Reduction Potential, Dissolved Oxygen and pH Trend Plots
Phase III NZVI Pilot Test
Phoenix-Goodyear Airport-North Superfund Site
Goodyear, Arizona

TABLE 1
VOCs and Perchlorate Data
Phase III NZVI Pilot Test
Phoenix-Goodyear Airport-North Superfund Site
Goodyear, Arizona

Location	Event	Sample Date	Day	Screen Interval (ft bgs)	PCE (µg/L)	TCE (µg/L)	cis-1,2-DCE (µg/L)	Vinyl Chloride (µg/L)	Perchlorate (µg/L)	Chlorate (µg/L)	Chlorite (µg/L)	Other Detected VOCs (µg/L)
IRZ-IW-05	Baseline	1/18/10	-15	109 - 118.5	< 0.5	140	1.6	< 0.5	< 2	< 100	< 100	
IRZ-IW-05	1 week	2/10/10	6	109 - 118.5	< 5	250	6.3	< 5	< 4	22	< 100	
IRZ-IW-05	2 week	2/18/10	14	109 - 117.48	< 5	480	3.8	< 0.5	< 4	< 200	< 200	carbon disulfide = 0.8, 1,1-dichloroethene = 1.2
IRZ-IW-05	1 month	3/3/10	28	109 - 117.59	0.68	1800	3.2	< 0.5	7.8	< 40	< 200	benzene = 0.51, carbon disulfide = 0.71, chloroform = 0.82, 1,1-dichloroethene = 1.6
IRZ-IW-05	3 months	5/5/10	92									
IRZ-IW-05	6 months	7/4/10	183									
IRZ-IW-04	Baseline	1/18/10	-15	110 - 120	0.98	2,300	< 0.5	< 0.5	14	93	< 200	chloroform = 0.80
IRZ-IW-04	1 week	2/11/10	7	110 - ?	< 5	270	7.5	< 5	16	< 100	< 400	
IRZ-IW-04	2 week	2/19/10	15	110 - 117.55	< 2.5	280	7.7	< 2.5	16	< 40	< 200	1,1-dichloroethene = 4.1
IRZ-IW-04	1 month	3/3/10	28	110 - 117.54	< 0.5	750	2.3	< 0.5	14	< 40	< 200	1,1-dichloroethene = 1.1
IRZ-IW-04	3 months	5/5/10	92									
IRZ-IW-04	6 months	7/4/10	183									
IRZ-IW-03	Baseline	1/19/10	-15	108 - 118	2.3	5,100	< 0.5	< 0.5	20	100	< 200	carbon disulfide = 0.77 ug/L, chloroform 1.6 ug/L
IRZ-IW-03	1 week	2/11/10	7	108 - 118	< 50	3,600	< 50	< 50	23	84	< 40	duplicate TCE = 3,800 ug/L, duplicate perchlorate = 18 ug/L
IRZ-IW-03	2 week	2/19/10	15	108 - 118	2.3	5,800	< 0.5	< 0.5	23	93	< 200	benzene = 0.72, chloroform = 1.7, 1,1,dichloroethene = 3.7,
IRZ-IW-03	1 month	3/4/10	29	108 - 118	< 10	2,700	< 10	< 10	20	89	< 200	
IRZ-IW-03	3 months	5/5/10	92									
IRZ-IW-03	6 months	7/4/10	183									
IRZ-IW-02	Baseline	1/20/10	-15	110 - 120	< 0.5	510	2.0	< 0.5	3.6	< 40	< 200	1,1-dichloroethene = 1.2, MTBE = 67
IRZ-IW-02	1 week	2/11/10	7	-1	< 0.5	93	2.3	< 0.5	< 4	< 100	< 400	acetone = 57, benzene = 0.72, bromodichloromethane = 0.90, 2-butanone (MEK) = 9.4, 1,1-dichloroethene = 0.67, methylene chloride = 1.8, and toluene = 1.8
IRZ-IW-02	2 week	2/19/10	15	-1	< 0.5	190	3.2	< 0.5	6.2	< 100	< 400	duplicate trichloroethene = 190, acetone = 32/30, benzene = 0.81/0.66, 2-butanone (MEK) = 4.4/4.0, chlorobenzene = 0.98/0.96, 1,1-dichloroethene = 0.93/0.75, and toluene = 1.0/0.87, duplicate perchlorate = 5.8
IRZ-IW-02	1 month	3/4/10	29	-1	< 2.5	630	< 2.5	< 2.5	9.7	#N/A	#N/A	
IRZ-IW-01	Baseline	1/18/10	-15	110 - 120	3.0	6,300	1.4	< 0.5	27	68	1,300	benzene = 0.91, chloroform = 2.1, and 1,1-dichloroethene = 10
IRZ-IW-01	1 week	2/11/10	7	110 - 120	1.9	6,700	1.6	< 0.5	27	< 100	930	benzene = 0.82, chloroform = 2.0, and 1,1-dichloroethene = 8.4
IRZ-IW-01	2 week	2/19/10	15	110 - 120	2.4	6,700	1.4	< 0.5	27	74	830	benzene = 0.85, chloroform = 1.9, and 1,1-dichloroethene = 8.8

TABLE 1
VOCs and Perchlorate Data
Phase III NZVI Pilot Test
Phoenix-Goodyear Airport-North Superfund Site
Goodyear, Arizona

Location	Event	Sample Date	Day	Screen Interval (ft bgs)	PCE (µg/L)	TCE (µg/L)	cis-1,2-DCE (µg/L)	Vinyl Chloride (µg/L)	Perchlorate (µg/L)	Chlorate (µg/L)	Chlorite (µg/L)	Other Detected VOCs (µg/L)
IRZ-IW-01	1 month	3/4/10	29	110 - 120	< 50	4,500	< 50	< 50	23	77	900	
IRZ-IW-01	3 months	5/5/10	92									
IRZ-IW-01	6 months	7/4/10	183									
IRZ-MW-B	Baseline	1/19/10	-15	110 - 130	< 0.5	46	< 0.5	< 0.5	4.4	85	< 200	
IRZ-MW-B	1 week	2/10/10	6	110 - 112.15	< 5	< 5	< 5	< 5	< 2	< 100	< 100	
IRZ-MW-B	2 week	2/19/10	15	110 - 112.15	< 0.5	1.7	< 0.5	< 0.5	< 4	< 100	< 400	acetone = 46, 2-butanone = 7.4 (MEK), toluene = 1.3
IRZ-MW-B	1 month	3/3/10	28	110 - 112	< 0.5	1.7	< 0.5	< 0.5	< 6	180	< 400	acetone = 30, 2-butanone (MEK) = 9.9, toluene = 1.7
IRZ-MW-B	3 months	5/5/10	92									
IRZ-MW-B	6 months	7/4/10	183									
IRZ-MW-C	Baseline	1/19/10	-15	110 - 130	< 0.5	220	< 0.5	< 0.5	5.0	89	< 200	
IRZ-MW-C	1 week	2/10/10	6	110 - 130	< 0.5	480	< 0.5	< 0.5	10	86	< 100	
IRZ-MW-C	2 week	2/17/10	13	110 - 130	< 0.5	360	< 0.5	< 0.5	9.3	87	< 200	
IRZ-MW-C	1 month	3/4/10	29	110 - 130	< 2.5	370	< 2.5	< 2.5	7.9	85	< 200	duplicate TCE = 470
IRZ-MW-C	3 months	5/5/10	92									
IRZ-MW-C	6 months	7/4/10	183									
IRZ-MW-D	Baseline	1/19/10	-15	111 - 131	< 0.5	290	< 0.5	< 0.5	6.0	90	< 200	1,1-dichloroethene = 0.82
IRZ-MW-D	1 week	2/11/10	7	111 - 131	< 0.5	760	< 0.5	< 0.5	12	89	< 100	1,1-dichloroethene = 0.96, toluene = 0.54
IRZ-MW-D	2 week	2/17/10	13	111 - 131	< 0.5	310	< 0.5	< 0.5	31	87	< 200	
IRZ-MW-D	1 month	3/4/10	29	111 - 131	< 2.5	210	< 2.5	< 2.5	6.3	85	< 200	
IRZ-MW-D	3 months	5/5/10	92									
IRZ-MW-D	6 months	7/4/10	183									

µg/L - micrograms per liter
mg/L - milligram per liter
#N/A - Parameter not measured, no data available for this date.

TABLE 2

VOC Data from Multiple Sampling Methods
Phase III NZVI Pilot Test
Phoenix-Goodyear Airport-North Superfund Site
Goodyear, Arizona

Location	*Event*	*Sample Date*	*Day*	*Screen Interval* (ft bgs)	*PCE* (µg/L)	*TCE* (µg/L)	*cis-1,2-DCE* (µg/L)	*Vinyl Chloride* (µg/L)	*Other Detected VOCs* (µg/L)
IRZ-MW-C	***Baseline***	1/19/10	-15	110 - 130	< 0.5	220	< 0.5	< 0.5	
IRZ-MW-C	***1 week***	2/10/10	6	110 - 130	< 0.5	480	< 0.5	< 0.5	
IRZ-MW-C	***2 week***	2/17/10	13	110 - 130	< 0.5	360	< 0.5	< 0.5	
IRZ-MW-C	***1 month***	3/4/10	29	110 - 130	< 2.5	370	< 2.5	< 2.5	duplicate TCE = 470
IRZ-MW-C-115	***1 month***	3/3/10	28	110 - 130	< 0.5	99	< 0.5	< 0.5	acetone = 22, benzene = 73
IRZ-MW-C-125	***1 month***	3/3/10	28	110 - 130	< 0.5	140	< 0.5	< 0.5	acetone = 17, benzene = 41, bromoform = 1.0
IRZ-MW-C	***3 months***	5/5/10	92						
IRZ-MW-C-115	***3 months***	5/5/10	92						
IRZ-MW-C-125	***3 months***	5/5/10	92						
IRZ-MW-C	***6 months***	7/4/10	183						
IRZ-MW-C-115	***6 months***	7/4/10	183						
IRZ-MW-C-125	***6 months***	7/4/10	183						
IRZ-MW-D	***Baseline***	1/19/10	-15	111 - 131	< 0.5	290	< 0.5	< 0.5	1,1-dichloroethene = 0.82
IRZ-MW-D	***1 week***	2/11/10	7	111 - 131	< 0.5	760	< 0.5	< 0.5	1,1-dichloroethene = 0.96, toluene = 0.54
IRZ-MW-D	***2 week***	2/17/10	13	111 - 131	< 0.5	310	< 0.5	< 0.5	
IRZ-MW-D	***1 month***	3/4/10	29	111 - 131	< 2.5	210	< 2.5	< 2.5	
IRZ-MW-D-115	***1 month***	3/3/10	28	111 - 131	< 0.5	53	< 0.5	< 0.5	acetone = 17, benzene = 4.4
IRZ-MW-D-125	***1 month***	3/3/10	28	111 - 131	< 0.5	68	< 0.5	< 0.5	acetone = 18, benzene = 3.7
IRZ-MW-D	***3 months***	5/5/10	92	111 - 131					
IRZ-MW-D-115	***3 months***	5/5/10	92	111 - 131					
IRZ-MW-D-125	***3 months***	5/5/10	92	111 - 131					
IRZ-MW-D	***6 months***	7/4/10	183	111 - 131					
IRZ-MW-D-115	***6 months***	7/4/10	183	111 - 131					
IRZ-MW-D-125	***6 months***	7/4/10	183	111 - 131					

µg/L - micrograms per liter

mg/L - milligram per liter

#N/A - Parameter not measured, no data available for this date.

Depth of passive diffusion bag indicated in location identification - for example, the "-115" in IRZ-MW-C-115 indicates that the passive diffusion bag was stationed at 115 feet below the top of the well casing.

TABLE 3
Metals and Ion Data
Phase III NZVI Pilot Test
Phoenix-Goodyear Airport-North Superfund Site
Goodyear, Arizona

Location	Event	Sample Date	Day	Screen Interval	Hydrogen	Total Iron	Dissolved Iron	Total Manganese	Total Sodium	Total Phosphorus	Phosphate	Sulfate	Nitrate as N	Bicarbonate Alkalinity as CaCO3	Chloride	TOC
				(ft bgs)	(nM)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Tank	Pre-Injection	1/20/10	-13	#N/A	#N/A	< 0.05	#N/A	< 0.05	220	#N/A	#N/A	770	16	140	660	#N/A
IRZ-IW-05	*Baseline*	1/18/10	-15	109 - 118.5	11	1,300	6.6	5.3	320	140	430	800	3.3	160	750	1.4
IRZ-IW-05	*1 week*	2/10/10	6	109 - 117.48	5,000	6,900	4,200	32	460	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
IRZ-IW-05	*2 week*	2/18/10	14	109 - 117.48	1,700	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
IRZ-IW-05	*1 month*	3/3/10	28	109 - 117.59	840	500	3.3	3.3	420	52	160	1000	12	190	800	1.4
IRZ-IW-05	*3 months*	5/5/10	92													
IRZ-IW-05	*6 months*	7/4/10	183													
IRZ-IW-04	*Baseline*	1/18/10	-15	110 - 117.44	25	14	< 0.05	0.16	410	< 0.1	< 0.3	1,100	21	220	770	< 1.0
IRZ-IW-04	*1 week*	2/11/10	7	110 - ?	320,000	6,200	2,100	25	1,300	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
IRZ-IW-04	*2 week*	2/19/10	15	110 - 117.55	130,000	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
IRZ-IW-04	*1 month*	3/3/10	28	110 - 117.54	36	100	1.6	0.67	460	5.1	16	1,100	7.7	220	810	1.2
IRZ-IW-04	*3 months*	5/5/10	92													
IRZ-IW-04	*6 months*	7/4/10	183													
IRZ-IW-03	*Baseline*	1/19/10	-15	108 - 118	9.8	68	1.8	0.49	470	1	3.1	1,100	20	210	820	1.3
IRZ-IW-03	*1 week*	2/11/10	7	108 - 118	4,200	910	100	9.5	470	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
IRZ-IW-03	*2 week*	2/19/10	15	108 - 118	300	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
IRZ-IW-03	*1 month*	3/3/10	28	108 - 118	23	91,000	2.4	11	380	6.5	20	1100	19	220	790	4.9
IRZ-IW-03	*3 months*	5/5/10	92													
IRZ-IW-03	*6 months*	7/4/10	183													
IRZ-IW-02	*Baseline*	1/20/10	-15	110 - 120	13	1.40	< 0.05	0.09	430	< 0.1	< 0.3	980	9.8	200	730	< 1.0
IRZ-IW-02	*1 week*	2/11/10	7	-1	#N/A	79	#N/A	0.22	1900	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
IRZ-IW-02	*3 months*	5/5/10	92													
IRZ-IW-02	*6 months*	7/4/10	183													
IRZ-IW-01	*Baseline*	1/18/10	-15	110 - 120	16	0.11	< 0.05	0.019	420	< 0.1	< 0.3	1,100	15	91	800	1.0
IRZ-IW-01	*1 week*	2/11/10	7	110 - 120	66	0.15	< 0.05	0.018	450	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
IRZ-IW-01	*2 week*	2/19/10	15	110 - 120	41	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
IRZ-IW-01	*1 month*	3/4/10	29	110 - 120	42	14	< 0.05	0.046	430	< 0.1	< 0.3	1100	16	110	810	< 1.0
IRZ-IW-01	*3 months*	5/5/10	92													
IRZ-IW-01	*6 months*	7/4/10	183													

TABLE 3
Metals and Ion Data
Phase III NZVI Pilot Test
Phoenix-Goodyear Airport-North Superfund Site
Goodyear, Arizona

Location	*Event*	*Sample Date*	*Day*	*Screen Interval*	*Hydrogen*	*Total Iron*	*Dissolved Iron*	*Total Manganese*	*Total Sodium*	*Total Phosphorus*	*Phosphate*	*Sulfate*	*Nitrate as N*	*Bicarbonate Alkalinity as CaCO3*	*Chloride*	*TOC*
				(ft bgs)	*(nM)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*
IRZ-MW-B	***Baseline***	1/19/10	-15	110 - 130	5.2	< 0.05	< 0.05	< 0.01	510	< 0.1	< 0.3	950	20	180	740	< 1.0
IRZ-MW-B	***1 week***	2/10/10	6	110 - 112.15	38,000	4,000	150	9.7	390	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
IRZ-MW-B	***1 month***	3/3/10	28	110 - 112	#N/A	26	< 0.05	0.075	1700	1.9	5.8	500	< 0.2	< 6*	1,700	10
IRZ-MW-B	***3 months***	5/5/10	92													
IRZ-MW-B	***6 months***	7/4/10	183													
IRZ-MW-C	***Baseline***	1/19/10	-15	110 - 130	11	130	< 0.05	0.31	490	0.61	1.9	980	21	180	750	1.1
IRZ-MW-C	***1 week***	2/10/10	6	110 - 130	30	30	< 0.05	0.058	460	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
IRZ-MW-C	***2 week***	2/17/10	13	110 - 130	31	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
IRZ-MW-C	***1 month***	3/4/10	29	110 - 130	5,900	11	0.45	0.021	450	< 0.3	< 0.3	940	20	180	730	< 1.0
IRZ-MW-C	***3 months***	5/5/10	92													
IRZ-MW-C	***6 months***	7/4/10	183													
IRZ-MW-D	***Baseline***	1/19/10	-15	111 - 131	19	1.90	< 0.05	0.014	490	< 0.1	< 0.3	990	20	180	750	1.0
IRZ-MW-D	***1 week***	2/11/10	7	111 - 131	29	2.80	< 0.05	0.031	480	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
IRZ-MW-D	***2 week***	2/17/10	13	111 - 131	33	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
IRZ-MW-D	***1 month***	3/4/10	29	111 - 131	32	2.30	< 0.05	0.026	470	< 0.1	< 0.3	940	20	180	730	< 1.0
IRZ-MW-D	***3 months***	5/5/10	92													
IRZ-MW-D	***6 months***	7/4/10	183													

µg/L - micrograms per liter
mg/L - milligram per liter
ft bgs = feet below groundwater surface
*Alkalinity as CaCO3 was measured at 1,500 mg/L, Carbonate Alkalinity = 1,000, Hydroxide Alkalinity = 450 mg/L, and Alkalinity via Phenolphthalein = 960 mg/L

TABLE 4

Field Parameter Data
Phase III NZVI Pilot Test
Phoenix-Goodyear Airport-North Superfund Site
Goodyear, Arizona

Location	Event	Sample Date	Day	Depth to Water** (ft bgs)	Screen Interval (ft bgs)	pH (SU)	Specific Conductance (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Oxidation Reduction Potential (mV)
IRZ-IW-05	Baseline	1/18/10	-15	91.49	109 - 118.5	8.26	3851	7.601	0	25.25	-336
IRZ-IW-05	1 week	2/10/10	6	90.88	109-117.48	8.53	3289	0	0	19.16	-367
IRZ-IW-05	2 week	2/18/10	14	90.66	109-117.48	8.31	3758	19.77	0	24.96	-330
IRZ-IW-05	1 month	3/3/10	28	90.35	109-117.59	8.03	4483	30.12	0	25.12	-339
IRZ-IW-05	3 month	5/5/10	92								
IRZ-IW-05	6 month	7/4/10	183								
IRZ-IW-04	Baseline	1/18/10	-15	91.29	110 - 120	7.63	3963	198.1	1.35	22.27	166
IRZ-IW-04	1 week	2/11/10	7	90.98	110 - ?	8.76	6278	5	0.01	24.31	-431
IRZ-IW-04	2 week	2/19/10	15	90.78	110 - 117.55	8.72	3865	1.4	-.04*	23.11	-632
IRZ-IW-04	1 month	3/3/10	28	90.44	110 - 117.54	8.07	4197	59.14	0.98	25.12	-238
IRZ-IW-04	3 month	5/5/10	92								
IRZ-IW-04	6 month	7/4/10	183								
IRZ-IW-03	Baseline	1/19/10	-15	91.67	108 - 118	7.06	4234	731.1	4.97	23.91	153
IRZ-IW-03	1 week	2/11/10	7	91.24	108 - 118	6.95	4361	2926	2.06	24.9	67
IRZ-IW-03	2 week	2/19/10	15	91.04	108 - 118	7.16	4232	1219	1.86	26.32	50
IRZ-IW-03	1 month	3/3/10	28	90.80	108 - 118	6.76	4553	457	2.02	26.65	49
IRZ-IW-03	3 month	5/5/10	92								
IRZ-IW-03	6 month	7/4/10	183								
IRZ-IW-02	Baseline	1/20/10	-15	91.92	110 - 120	7.21	3685	1514	0.49	21.16	105
IRZ-IW-02	1 week	2/11/10	7	68.45	-1	8.66	4464	167	0.01	24.91	-391
IRZ-IW-02	2 week	2/19/10	15	75.36	-1	8.38	1155	176.4	0.05	25.13	-293
IRZ-IW-02	1 month	3/4/10	29	90.46	-1	8.92	5630	177.5	0.01	25.84	-554

TABLE 4

Field Parameter Data
Phase III NZVI Pilot Test
Phoenix-Goodyear Airport-North Superfund Site
Goodyear, Arizona

Location	Event	Sample Date	Day	Depth to Water** (ft bgs)	Screen Interval (ft bgs)	pH (SU)	Specific Conductance (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Oxidation Reduction Potential (mV)
IRZ-IW-01	Baseline	1/18/10	-15	91.63	110 - 120	7.70	4233	1.828	0.58	25.22	58
IRZ-IW-01	1 week	2/11/10	7	91.13	110 - 120	7.61	4242	6.295	0.45	24.79	79
IRZ-IW-01	2 week	2/19/10	15	90.93	110 - 120	7.63	4200	15.13	0.46	26.33	-33
IRZ-IW-01	1 month	3/4/10	29	90.62	110 - 120	7.59	4328	24.01	0.75	26.17	-4
IRZ-IW-01	3 month	5/5/10	92								
IRZ-IW-01	6 month	7/4/10	183								
IRZ-MW-B	Baseline	1/19/10	-15	91.36	110 - 130	7.11	3662	91.36	7.64	21.5	158
IRZ-MW-B	1 week	2/10/10	6	90.63	110 - 112.15	8.58	3318	1.556	0	22.25	-478
IRZ-MW-B	2 week	2/19/10	15	90.98	110 - 112.15	8.80	4009	35.14	0.01	24.11	-420
IRZ-MW-B	1 month	3/3/10	28	90.67	110 - 112	8.83	5858	35.15	0	25.87	-469
IRZ-MW-B	3 month	5/5/10	92								
IRZ-MW-B	6 month	7/4/10	183								
IRZ-MW-C	Baseline	1/19/10	-15	90.55	110 - 130	7.09	3892	1197	6.45	25.36	183
IRZ-MW-C	1 week	2/10/10	6	90.71	110 - 130	7.04	3794	369.9	7.13	22.31	65
IRZ-MW-C	2 week	2/17/10	13	90.54	110 - 130	7.16	3987	303.5	6.98*	24.94	64
IRZ-MW-C	1 month	3/4/10	29	90.23	110 - 130	6.98	3776	130.1	7.44	21.2	36
IRZ-MW-C	3 month	5/5/10	92								
IRZ-MW-C	6 month	7/4/10	183								
IRZ-MW-D	Baseline	1/19/10	-15	90.88	111 - 131	7.27	3928	32.77	6.31	24.06	148
IRZ-MW-D	1 week	2/11/10	7	90.90	111 - 131	7.15	3901	85.46	6.08	23.58	173
IRZ-MW-D	2 week	2/17/10	13	90.73	111 - 131	7.20	4018	15.58	6.39*	25.24	138
IRZ-MW-D	1 month	3/4/10	29	90.44	111 - 131	7.13	3589	31	7.13	19.4	35
IRZ-MW-D	3 month	5/5/10	92								
IRZ-MW-D	6 month	7/4/10	183								

TABLE 4

Field Parameter Data
Phase III NZVI Pilot Test
Phoenix-Goodyear Airport-North Superfund Site
Goodyear, Arizona

Location	*Event*	*Sample Date*	*Day*	*Depth to Water*** *(ft bgs)*	*Screen Interval* *(ft bgs)*	*pH* *(SU)*	*Specific Conductance* *(mS/cm)*	*Turbidity* *(NTU)*	*Dissolved Oxygen* *(mg/L)*	*Temperature* *(°C)*	*Oxidation Reduction Potential* *(mV)*
Average	***Baseline***	1/19/10	-15			7.42	3931	471.72	3.47	23.59	79.38
Average	***1 week***	2/11/10	7			7.91	4206	445.15	1.97	23.28	-160.38
Average	***2 week***	2/17/10	13			7.92	3653	223.24	1.96	25.02	-182.00
Average	***1 month***	3/3/10	28			7.79	4552	118.00	2.29	24.42	-185.50

µS/cm - microSiemen per centimeter
mg/L - milligram per liter
mV - millivolt
SU - standard unit
°C - degrees Celsius
PDB - passive diffusion bag
NTU - Nephelometric turbidity units
#N/A - Parameter not measured, no data available for this date.
* Data considered anomalous and was not used to compute average.
**Depth to water measured before start of purging.