ADVENTUS
Proven Soil, Sediment, and Groundwater Remediation Technologies

Field Profile
Combined use of ISCR and ISCO

Project

Confidential site, Dallas, TX
Lead Consultant – Burns & McDonnell

Summary

Groundwater at an industrial site in Texas is impacted with Chlorinated Volatile Organic Carbon's (CVOCs), primarily PCE and TCE, from historical waste disposal. The topography at the site slopes steeply towards a small channel where the groundwater discharges. Depth to groundwater ranges from approximately 20 ft bgs at the source area to 1 ft bgs close to the channel. The soil consists of silty clays. Remedial objectives are to achieve the Texas Risk Reduction Program Tier 1 Residential Protective Concentration Levels (PCLs). Remediation of groundwater at the site has entailed a combined approach employing chemical oxidation at the source area and a reductive Permeable Reactive Barrier (PRB) for passive plume control along the channel. Reductive technologies were preferred adjacent to the channel in order to protect the water body and aquatic life. Prior to in situ applications, source area soil was excavated from the vadose zone. These combined measures have resulted in > 90% reduction in total chlorinated ethenes in groundwater at the source area (from a maximum of 2,211 mg/L measured in 2002 to a maximum of 0.216 mg/L measured in January 2009). Subsequent performance monitoring at the channel has confirmed > 98% removal of total chlorinated ethenes directly downgradient from the reductive treatment zone (from a maximum of 1.815 mg/L measured in April 2005 prior to the installation of the reductive zone to a maximum of 0.028 mg/L measured in January 2009).

Summary of Remediation Activities

<u>June 2004:</u>

- Approximately 522 tons of soil removed from source area. Blended potassium permanganate ($KMnO_4$) and silica sand was added to the base of the excavation prior to backfilling. A water injection system was also installed to dissolve the emplaced $KMnO_4$ and then distribute the solution into the subsurface formation. Five large diameter injection borings (IB-1 through IB-5) was installed to a total depth of 24 to 27.5 ft bgs within the excavation zone and three water injection wells (IW-1 through IW-3) were installed to a depth of 37 ft bgs.
- A total of approximately 44,000 lbs of KMnO4 was injected as slurry into 16 locations using hydraulic fracturing – total of 44 fractures emplaced at depths of 25, 31, and 37 feet bgs of (1,000 lbs $KmnO_4$ per fracture).

<u>June 2005:</u>

- An additional 6,000 lbs of KMnO4 was injected as slurry into 2 locations at depths of 25, 31, and 37 feet bgs (1,000 lbs $KMnO_4$ per fracture).

- To address the continuing migration of the plume into the channel, a PRB was installed across the plume along the channel. A total of approximately 11,000 lbs of zero-valent iron (ZVI) was emplaced via hydraulic fracturing.

October 2007:

- A total of 28,000 gallons of 3% $NaMnO_4$ was injected into five 1,200 ft^2 areas (Area-1 through Area-5) over a 20 ft vertical injection interval. Approximately 17,700 lbs of 40% NaMnO4 was diluted on-site using specialized mixing equipment to a 3% NaMnO4 solution.
- A total of 2,600 lbs of EHC was injected into 15 injection points at Area-6.
- Injections were performed using standard direct-push equipment and conducted in a top-down fashion targeting discrete injection intervals spaced 2 ft apart vertically.

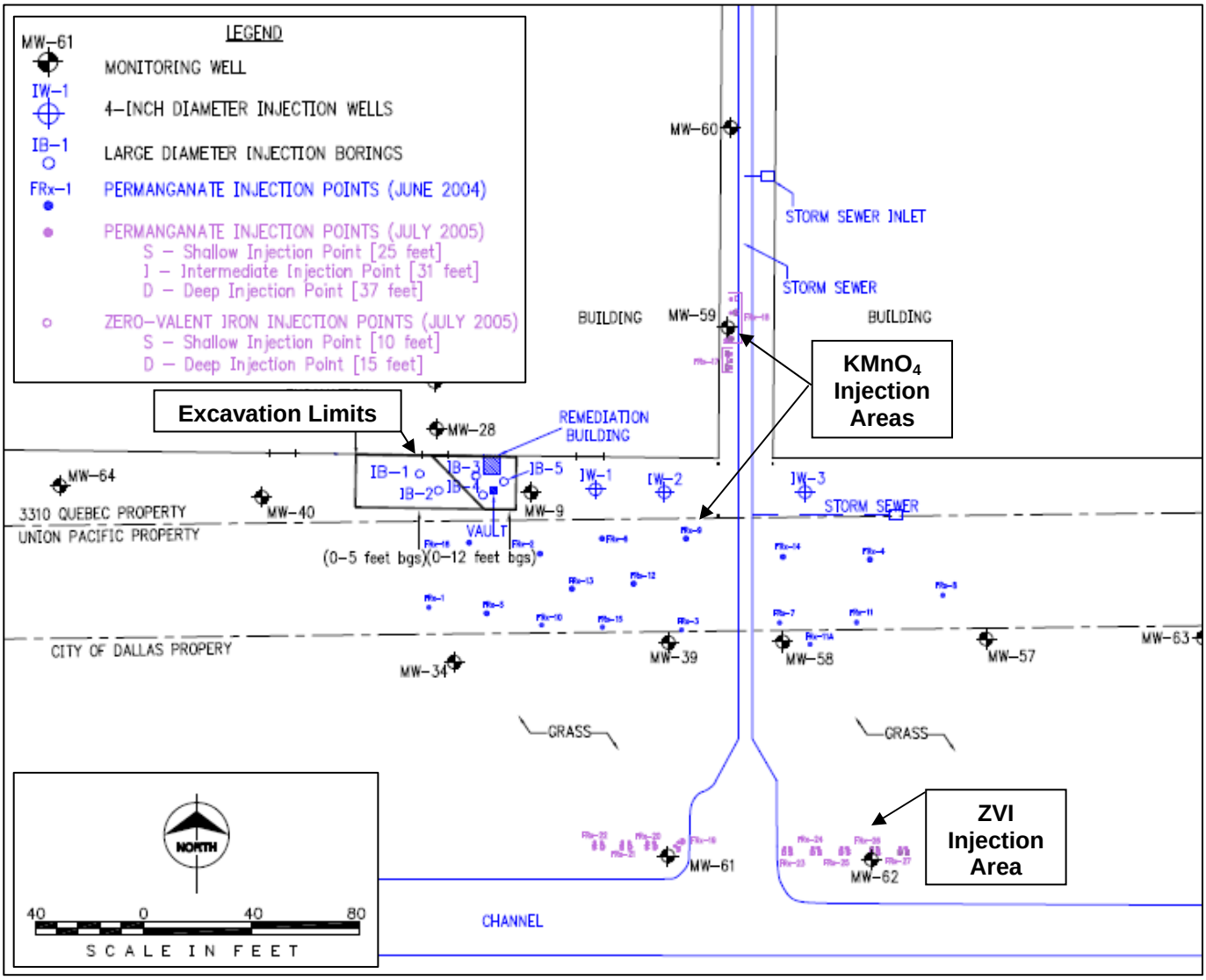

Figure 1: Areas targeted during June 2004 and June 2005 remedial activities – KmnO4 injected at caissons (IB-1 to IB-5) and fracture locations FRx-1 to FRx-18; ZVI injected at locations FRx-19 to FRx-27 along channel.

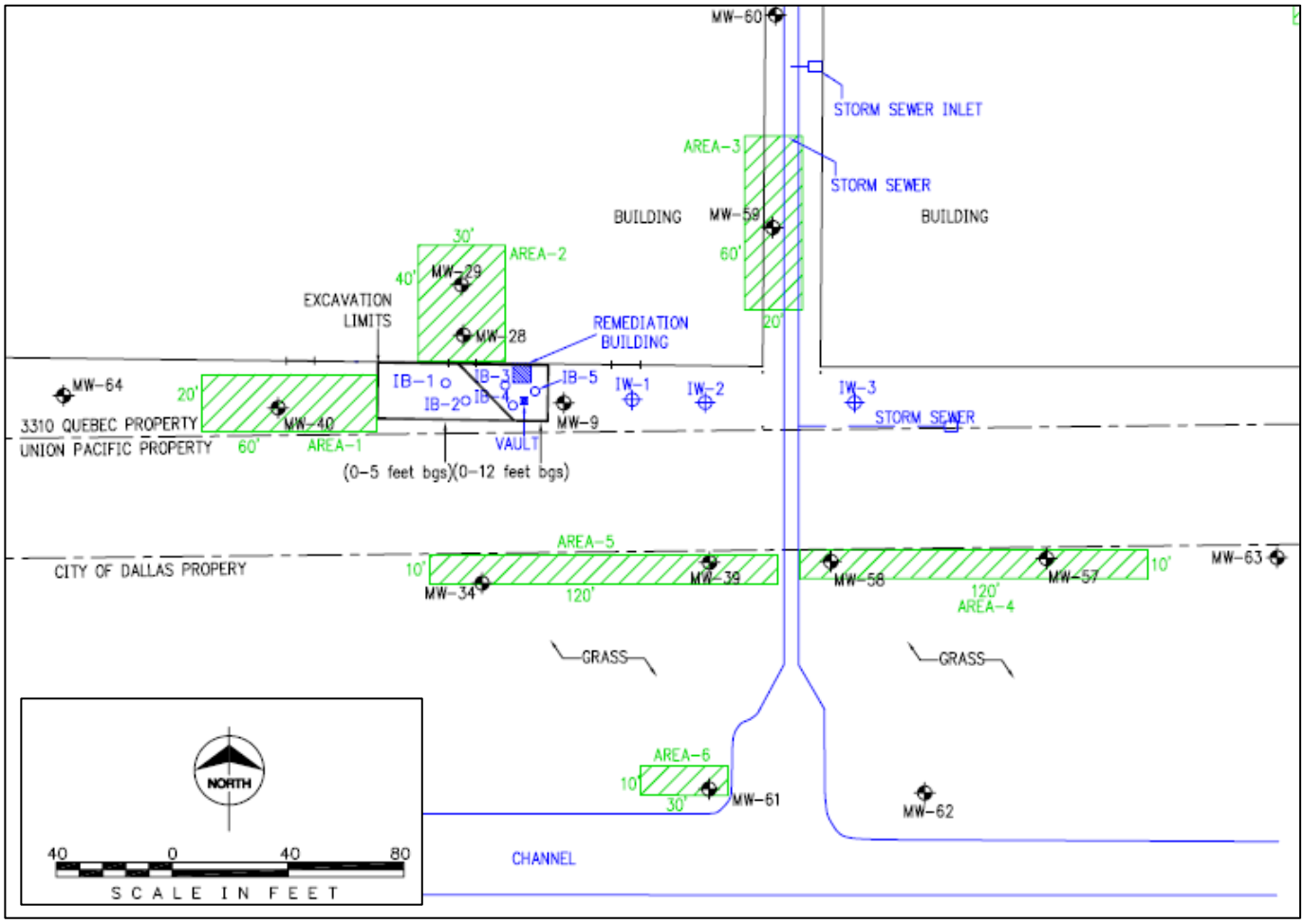

Figure 2: Injection areas October 2007 – NaMnO4 injected at Area-1 to Area-5 and EHC injected at Area-6.

Application of ISCO at source area

Source area soil was removed in 2004. At the same time blended potassium permanganate ($KMnO_4$) and silica sand was added to the excavation prior to backfilling and to the groundwater aquifer via hydraulic fracturing. A water injection system was also installed to dissolve the emplaced $KMnO_4$, and then distribute the solution into the subsurface formation (**Figure 3**). The system was shutdown in October 2005 due to the intended objectives being met, and a total of approximately 1.5 pore volumes of water was applied from start-up through system shut-down. An additional source area measure included injection of bentonite/$KMnO_4$ slurry via hydraulic fracturing in June 2005. Also, direct push injection of 3% sodium permanganate ($NaMnO_4$) solution in October 2007 was performed to address low level contamination at the margins of the plume and elevated contaminant levels in the vicinity of MW-58 and MW-59 (**Figure 4**).

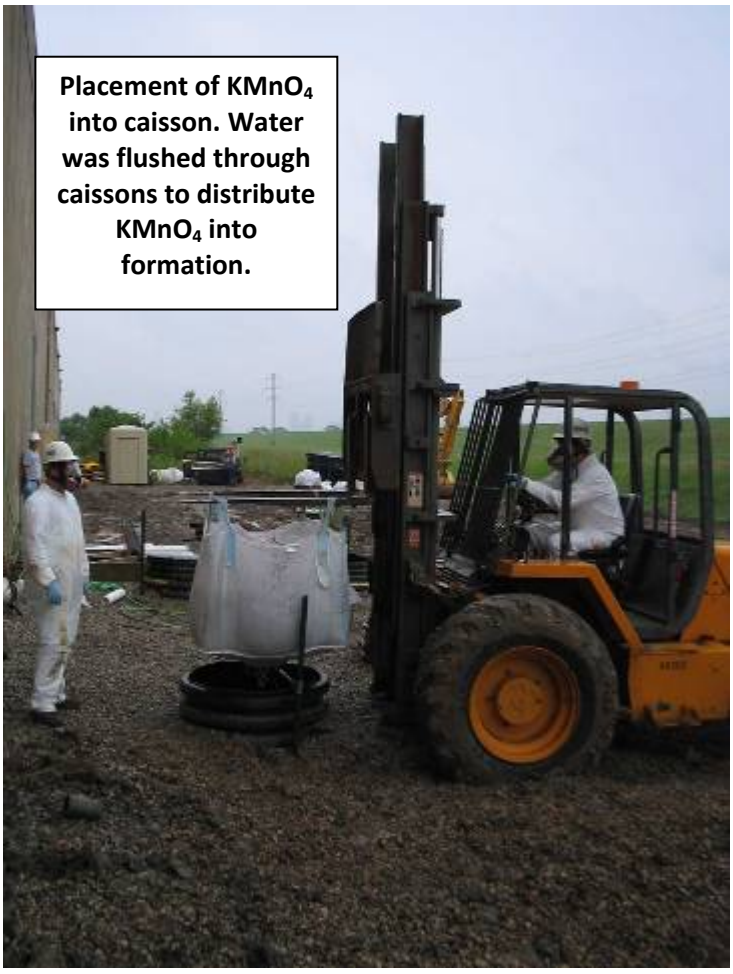

Figure 3: Source area remedial measures.

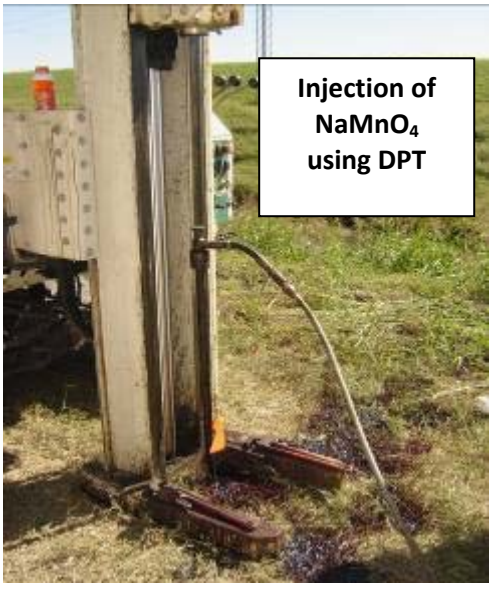

Figure 4: Direct injection of soluble $NaMnO_4$.

Installation of ZVI PRB for plume control

To address the continuing migration of the plume into the channel, a PRB was installed across the plume along the channel in June 2005. A total of approximately 11,000 lbs of zero-valent iron (ZVI) was emplaced via hydraulic fracturing (**Figure 5**).

Figure 5: ZVI injected as a guar slurry using hydraulic fracturing applied via injection wells.

Groundwater in this area is as shallow as 1 ft below ground surface (bgs) and significant issues with surfacing of slurry occurred in one area during injection. Subsequent sampling confirmed the importance of product placement; since the installation, the PRB has effectively treated CVOCs to below the treatment criteria at the eastern end where the injections were successful. However, more limited reductions were measured at the area with significant surfacing issues. This area was therefore targeted during a second application conducted in October 2007; this time a more fine-grained iron and carbon product, EHC®, was applied via direct push injections. A total of 2,600 lbs of EHC was injected into 15 injection points over an area measuring approximately 30 ft long x 15 ft wide x 12 ft deep, resulting in an application rate of approximately 0.44% EHC to soil mass within the reactive zone. Issues with surfacing were limited by injecting the EHC as thick, viscous slurry with an estimated 35% solids. More dilute slurry and test injections with water only resulted in significant surfacing. The EHC slurry was prepared using Chem Grout's CG-550 grout system with paddle mixers (**Figure 6**).

The injections were performed using conventional direct push technology at discrete intervals spaced 2 ft apart. A total of 175 lbs was added into each point with 25 lbs added per vertical lift. The depth interval

targeted was 12 ft; from the groundwater table (*ca*. 3 to 5 ft bgs) down to approximately 15 to 17 ft bgs. The injections were performed from the top-down using Geoprobe's pressure activated injection tip. The injection rate was in the range of 3 to 4 GPM. The injection rate was purposely kept low to avoid surfacing.

Figure 6: Injection of EHC at channel using DPT. Preparation of EHC slurry containing 35% solids using Chem Grout's CG-550 mixing system.

Results

A significant overall reduction in chlorinated ethenes concentrations has been observed throughout the groundwater PCL Exceedance zone:

- Source area well MW-9 confirms that any residual soil impacts in the source area are not leaching to groundwater at levels above the PCLs and therefore, the soil remediation objectives have been met.
- The combined effect from $KmnO_4$ and $NaMnO_4$ injection activities have decreased chlorinated ethene concentrations in groundwater at wells located within and directly downgradient from targeted areas (**Figure 7**).
- Injections of NaMnO4 at the margins and within the former source area have decreased total chlorinated ethenes concentrations from a maximum of 0.642 mg/L measured in April 2007 prior to the injections to a current maximum of 0.216 mg/L measured in January 2009 (**Figure 8**).

- Performance monitoring at the channel has confirmed >98% removal of total chlorinated ethenes directly downgradient from the ZVI/EHC treatment zone (from a maximum concentrations of 1.815 mg/L measured in April 2005 prior to the installation of the reductive zone to a maximum of 0.028 mg/L measured in January 2009) (**Figure 9**).

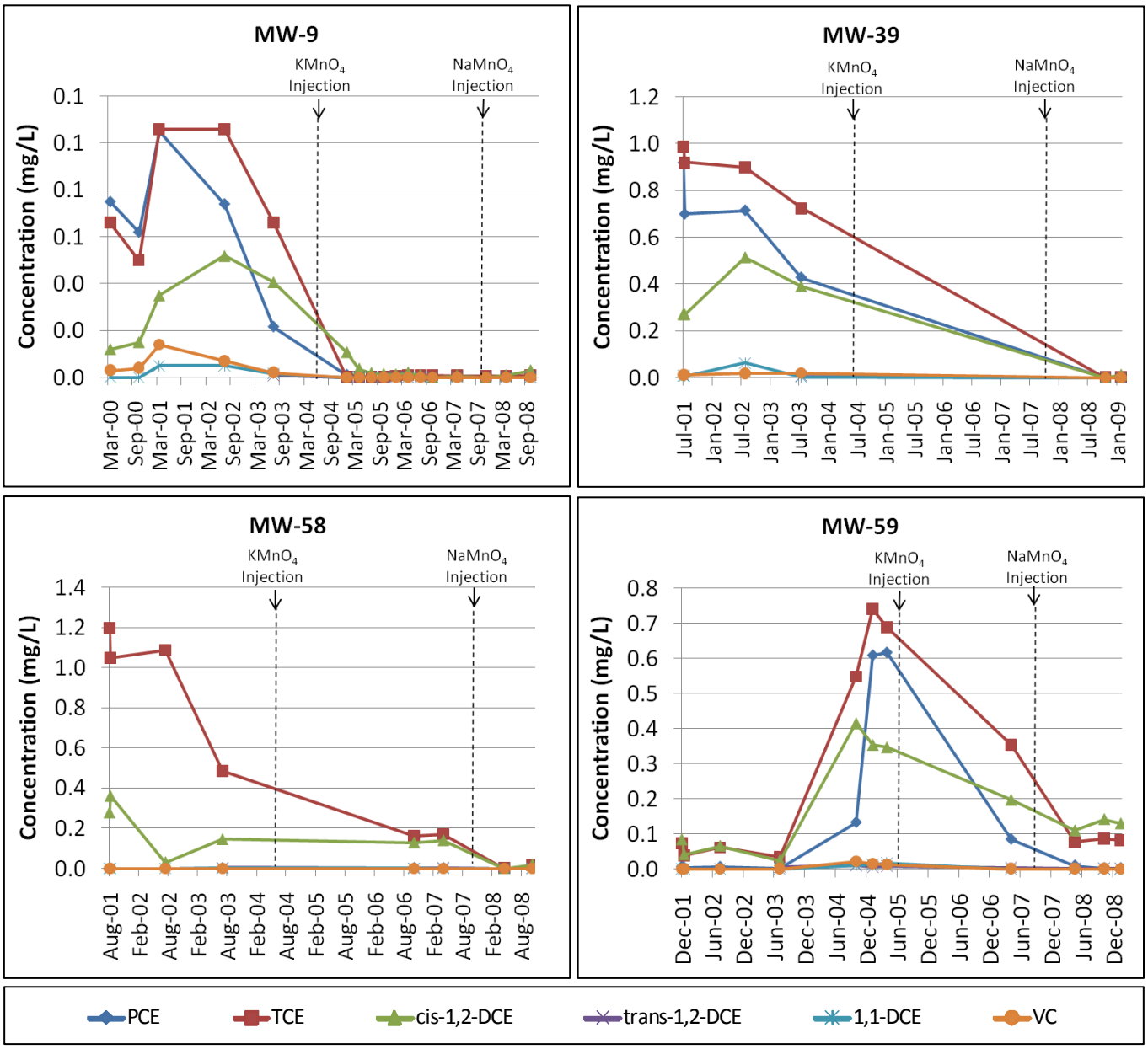

Figure 7: Effect of applications of $KMnO_4$ and $NaMnO_4$ at wells located at the source area (MW-9), directly downgradient from the source area (MW-39 and MW-58) and at isolated hot-zone (MW-59) targeted during the June 2004/2005 and October 2007 injection events.

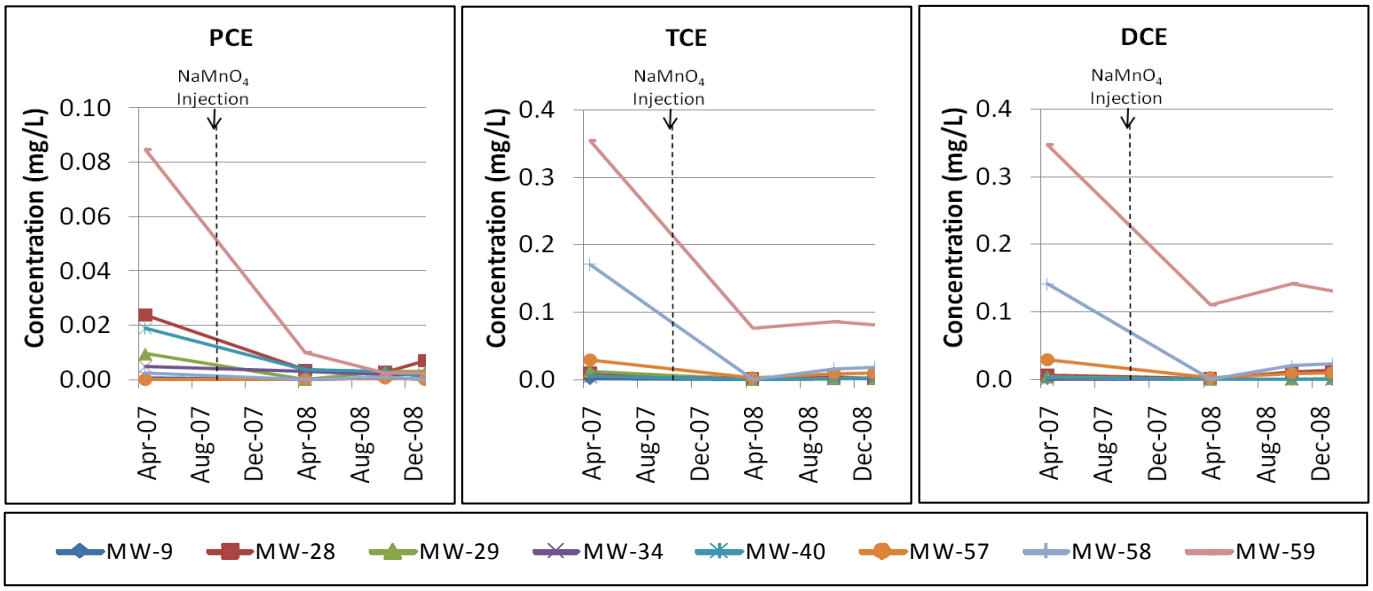

Figure 8: Effect of NaMnO4 injection conducted in October 2007.

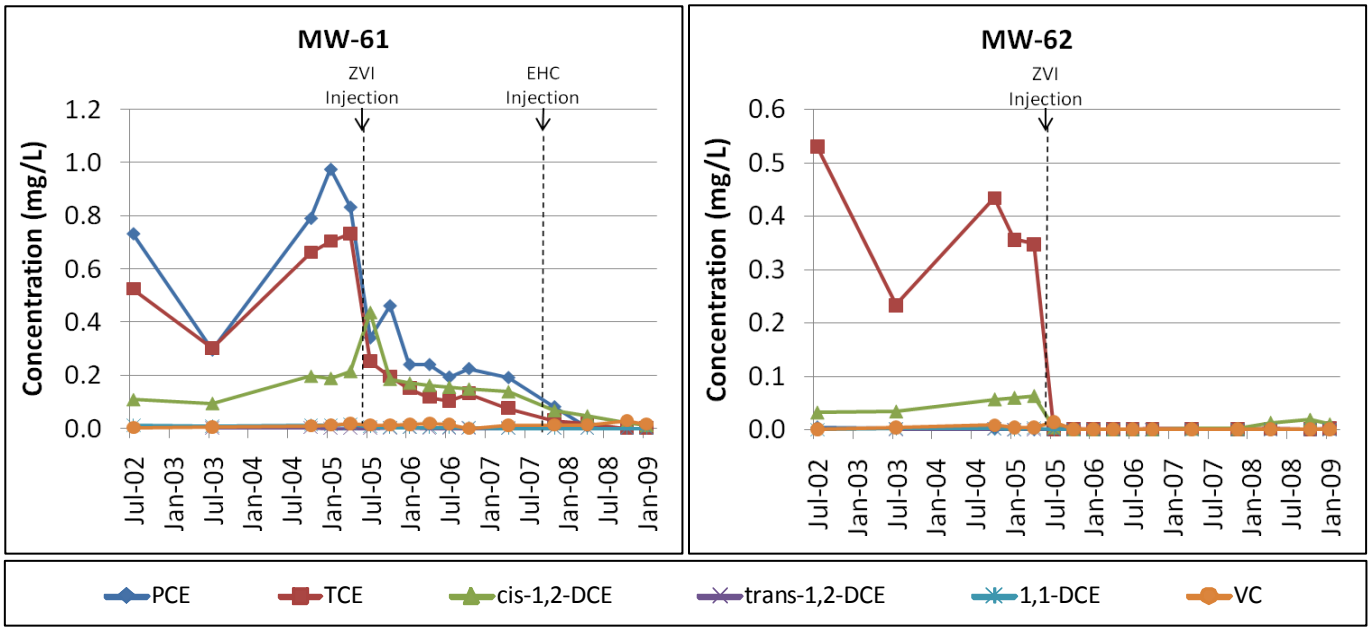

Figure 9: Concentration of chlorinated ethenes measured downgradient from ZVI/EHC PRB.

Carus® RemOx™ S ISCO Reagent:
Potassium Permanganate ($KMnO_4$) provided as crystalline solid
Carus® RemOx™ L ISCO Reagent:
Sodium Permanganate ($NaMnO_4$) provided as concentrated liquid

ADVENTUS

EHC® is a patented combination of micro-scale zero valent iron and organic carbon for ISCR of CVOCs in groundwater. EHC® is a registered trademark of Adventus Intellectual Property Inc.