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ANNUAL GROUNDWATER TREATMENT PERFORMANCE MONITORING REPORT Q3 2010 MOSS-AMERICAN SITE MILWAUKEE, WISCONSIN

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1. INTRODUCTION

In accordance with paragraph 4a of the Remedial Design/Remedial Action Statement of Work (RD/RA SOW), Tronox LLC (TRONOX), formerly known as Kerr-McGee Chemical, LLC, is required to implement a groundwater monitoring program capable of detecting changes in chemical concentrations in the groundwater. TRONOX has directed Weston Solutions, Inc. (WESTON®) to perform this work. This report presents the findings for the sampling conducted in Q3 of 2010.

The current monitoring network includes four shallow groundwater monitoring wells (MW-5S, MW-7S, MW-9S, and MW-27S), nine containment performance monitoring wells (MW-30S, MW-31S, MW-32S, MW-33S, MW-34S, MW-35S, MW-37S, MW-38S, and MW-39S), and nine piezometers (PZ-01 through PZ-07, PZ-09, and PZ-10). Each of the monitoring wells and piezometers is screened in the shallow groundwater-bearing zone underlying the site. These monitoring locations are indicated on Figure 1-1.

A treatment performance monitoring network has also been installed per the Quality Assurance Project Plan for Installation of Groundwater Remedial System (QAPP) (WESTON, October 1999). This network includes six groundwater treatment gates (TG1 through TG6) with three treatment performance monitoring wells located at each groundwater treatment gate. At each treatment gate, monitoring wells 1, 2, and 3 are located upgradient, within, and downgradient of the treatment gate, respectively (e.g., TG1-1, TG1-2, and TG1-3). The locations of the treatment performance monitoring wells are indicated on Figure 1-1.

In addition to the on-site groundwater monitoring wells, 11 shallow groundwater monitoring wells (MW-A through MW-K) monitor the groundwater conditions between the old and new river channels in Reaches 1 through 3. The locations of the river reach wells are indicated in Figures 1-2 through 1-4.

A number of modifications have been made to the sampling program. A complete discussion of these modifications is presented in the Quarterly Groundwater Treatment Performance Monitoring Report, Q1 2007, (WESTON, May 2007). In March and September of each year, four monitoring wells (MW-7S, MW-34S, MW-38S, and MW-39S) are sampled to monitor

plume conditions within the containment area. In September of each year, the shallow monitoring wells, performance monitoring wells, treatment performance monitoring wells, and river reach wells are sampled. Only the upgradient and downgradient treatment performance monitoring wells are sampled. A complete round of groundwater levels is also measured in September of each year.

In accordance with paragraph 4a (i) of the RD/RA SOW, the field measurement and analysis of groundwater samples collected from the shallow and containment performance groundwater monitoring wells include groundwater elevation, pH, temperature, turbidity, specific conductance, oxidation-reduction (redox) potential, and dissolved oxygen (DO). Required laboratory analyses include benzene, toluene, ethylbenzene, and xylene (BTEX collectively) and the following polynuclear aromatic hydrocarbon (PAH) compounds: acenaphthylene, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluorene, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene.

In accordance with Addendum No. 1 to the QAPP (WESTON, May 2001), the field measurements for samples collected from the treatment performance monitoring wells include groundwater elevation, pH, temperature, turbidity, specific conductance, redox potential, and DO. Laboratory analyses required for the treatment performance wells include microbial enumeration, nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), total kjeldahl nitrogen (TKN), ammonia-nitrogen (NH_3-N), total phosphate-phosphorous (PO_4-P), orthophosphate (ORP), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), BTEX, and the PAHs indicated in the above paragraph.

2. ON-SITE GROUNDWATER MONITORING RESULTS

The Q3 2010 groundwater-monitoring event at the Moss-American site was completed on 23 September and between 27 and 30 September 2010. Tasks completed during the field effort for this event included the collection of groundwater elevation and DO measurements from the shallow groundwater monitoring, containment performance monitoring, and treatment performance monitoring wells referenced in Section 1. Groundwater elevation and DO measurements were also collected from the 11 monitoring wells located along Reaches 1 through 3. Following groundwater elevation and DO measurements, groundwater samples were collected from the shallow, containment performance, treatment performance, and river reach groundwater monitoring wells. The results of the Q3 2010 groundwater sampling event are described in the following subsections.

2.1 GROUNDWATER ELEVATION MEASUREMENTS

2.1.1 Q3 2010

Depth to water measurements in each of the shallow groundwater monitoring wells, containment performance monitoring wells, treatment performance monitoring wells, additional monitoring wells, and piezometers were made on 23 September 2010. These measurements were used to determine the elevation of the potentiometric surface within the shallow groundwater-bearing zone underlying the site. The water level measurements of the shallow groundwater monitoring and containment performance monitoring wells and calculated groundwater elevations are presented in Table 2-1. The groundwater level measurements and corresponding groundwater elevations, calculated hydraulic gradients across the treatment gates, and estimated groundwater flow velocities through the treatment gates are presented in Table 2-2. The groundwater levels for the piezometers are presented in Table 2-3. Figure 2-1 presents a potentiometric surface map of the shallow groundwater-bearing zone, based on the September 2010 (Q3) data. An evaluation of the Q3 2010 potentiometric surface map is presented below.

As shown in Figure 2-1, the groundwater within the shallow groundwater-bearing zone generally flows northeastward toward the Little Menominee River (LMR). In the topographically higher (western) portion of the site, the horizontal hydraulic gradient is relatively steep, at approximately 0.033 feet per foot (ft/ft) to the northeast, as measured from the vicinity of PZ-07

to TG2-1. The topography of the site levels out near the river, as does the potentiometric surface with a northerly hydraulic gradient of approximately 0.017 ft/ft, as measured from the vicinity of PZ-05 to the vicinity of MW-9S. The estimated hydraulic gradients within the treatment gates ranged from 0.0007 to 0.0094 ft/ft (Table 2-2). The hydraulic gradient is relatively flat within the treatment gate area with an overall hydraulic gradient from TG1 to TG5 of approximately 0.0025 ft/ft in an easterly direction.

The average velocity of groundwater flow within the shallow water-bearing zone can be calculated using the following equation:

$$v = Ki/n$$

where:

v = groundwater velocity
K = hydraulic conductivity (also referred to as the coefficient of permeability)
i = hydraulic gradient
n = porosity

Based on slug tests performed on wells installed during the remedial investigation (RI), the hydraulic conductivity of the deposits located on the topographically higher, western portion of the site were in the range of 1×10^{-5} to 1×10^{-6} centimeters per second (cm/s) (0.03 to 0.003 feet per day [ft/day]). Based on laboratory-performed hydraulic conductivity analyses conducted on material used to backfill areas of the site located along the LMR, the hydraulic conductivity of soils located in the topographically lower portion of the site within the funnel-and-gate remedial system is approximately 1×10^{-3} cm/s (3 ft/day). Using a hydraulic gradient of 0.033 ft/ft, an assumed effective porosity of 0.3, and a hydraulic conductivity of 0.03 ft/day, the groundwater flow velocity in the western portion of the site is calculated to be approximately 0.0033 ft/day. Near the river, using a hydraulic gradient of 0.017 ft/ft, a porosity of 0.3, and a hydraulic conductivity of 3 ft/day, the velocity of groundwater flow is calculated to be approximately 0.17 ft/day. The groundwater flow velocities within the treatment gates are estimated to range from 0.0066 to 0.0888 ft/day. The groundwater flow velocity through each treatment gate is presented in Table 2-2.

2.2 GROUNDWATER SAMPLE ANALYTICAL RESULTS

Groundwater samples, in Q3 2010, were collected from a total of 25 shallow monitoring wells screened within the shallow groundwater-bearing zone. The shallow wells sampled include four shallow groundwater monitoring wells (MW-5S, MW-7S, MW-9S, and MW-27S); nine containment performance monitoring wells (MW-30S, MW-31S, MW-32S, MW-33S, MW-34S, MW-35S, MW-37S, MW-38S, and MW-39S); and twelve treatment performance monitoring wells (TG1-1, TG1-3, TG2-1, TG2-3, TG3-1, TG3-3, TG4-1, TG4-3, TG5-1, TG5-3, TG6-1, and TG6-3).

In addition to the investigative groundwater samples collected in Q3 2010, two field sample duplicates, two matrix spike/matrix spike duplicates (MS/MSD), and two field blanks (identified by an FB prefix) samples were collected for QA/QC purposes. Trip blanks accompanied each cooler of sample containers from the laboratory to the site and were shipped back to the laboratory within each cooler containing volatile organic compound (VOC) samples.

All groundwater samples were field screened and laboratory analyzed for the parameters indicated in Section 1.

2.2.1 Field-Measured Parameters

The groundwater samples for the sampling event, Q3 2010, were measured in the field for pH, specific conductance, temperature, and turbidity. The field parameters were collected using a YSI 556 portable water quality meter and a Hanna HI98703 turbidimeter. Also, in Q3 2010 downhole DO and redox potential readings were collected from monitoring wells after sampling at a given well was completed. The groundwater pH, redox potential, specific conductance, temperature, and turbidity were monitored during well purging prior to sampling. The final (stabilized) values for these measurements prior to sample collection are presented in Table 2-4. Water quality parameter measurements were not collected from wells MW-34S and TG1-1 due to the presence of product measured in the water.

2.2.1.1 pH

The pH of the groundwater samples collected during Q3 2010 ranged from 6.34 to 7.16 pH standard units (S.U.). pH is an important factor in determining the feasibility of bioremediation of contaminants in the site groundwater because biological systems typically function only in narrow pH ranges (typically 6.5 to 8.5 S.U.), and because microbial growth rates are pH dependent.

2.2.1.2 Redox Potential

The redox potentials of the groundwater samples collected at the site during Q3 2010 ranged from -124.0 to 81 millivolts (mV). Redox potential indicates the capability of the groundwater to promote chemical oxidation-reduction processes that consume organic matter and ultimately oxidize organic compounds. Microorganisms typically act as catalysts in oxidation reactions, and as such, the redox potential indicates the potential for the groundwater to oxidize the contaminants present.

Since environmental systems are typically not in equilibrium, the redox potential is used as a gross indicator of the state of oxidation-reduction in the system. Oxidation-reduction rates in the system are greater as the redox potential increases in magnitude. A positive redox potential typically indicates conditions where oxidized ionic species (i.e., NO_3^-, SO_4^{2-}, and Fe^{3+}) predominate in comparison to their reduced counterparts (NH_4^+, S^{2-}, and Fe^{2+}, respectively). Once DO is removed from water (i.e., via biodegradation of organics), oxidized ionic species become electron acceptors in redox processes. As the processes continues under anaerobic conditions, the reduced ionic species concentration increases, resulting in an overall decrease of the water's oxidation potential.

2.2.1.3 Dissolved Oxygen

DO levels for the groundwater samples collected during Q3 2010 ranged from 0.4 to 5.63 milligrams per liter (mg/L). Overall, the DO readings indicate the presence of intermediate levels of oxygen in the water, and the system as a whole is considered to be generally under oxic conditions. DO promotes the growth of aerobic and facultative bacteria and the production of

readily assimilated nutrients. All of these factors are required to facilitate the oxidation reaction responsible for removing the contaminants from the groundwater under aerobic conditions.

2.2.1.4 Specific Conductance

The specific conductance of the groundwater samples collected during Q3 2010 ranged from 0.966 to 1.695 millimhos per centimeter (mmho/cm). Conductivity of water is a measure of the ability of the solution to carry an electrical current that is transported by ions in the solution; therefore, conductivity is used as an indicator of the total dissolved solids (TDS) present in a water sample. As the dissolved solids content of a solution increases, the capacity for the water to transmit electrical current increases. Although conductivity is a measure of the aggregate dissolved solids in the water it may be correlated to the readily available nutrient levels in the water, since TDS includes nitrate, nitrite, ammonium, and phosphate ions.

2.2.1.5 Temperature

Groundwater temperatures ranged from 12.15 to 16.79 degrees Celsius (°C) during Q3 2010. Temperature is an extremely important factor in bioremediation because microbial growth rates are greatly dependent upon temperature.

2.2.1.6 Turbidity

Turbidity ranged from 0.43 to 4.84 NTU during Q3 2010. Turbidity is a measure of the clarity of water and is used as an indicator of the solids present in a water sample and overall water quality.

2.2.2 Laboratory Analyses

The results of the laboratory analyses performed on the groundwater samples collected during September (Q3) 2010 are provided in Appendix A. A discussion of the results of the laboratory analyses performed on the groundwater samples are presented in the following subsections.

2.2.2.1 Laboratory Analyses for BTEX and PAH

Each groundwater sample collected during the September (Q3) 2010 sampling events were analyzed for BTEX and PAH compounds. The results of these analyses are presented and

compared to WDNR Preventive Action Limits (PALs) and Enforcement Standards (ESs) in Table 2-5 for the Q3 2010 data. Table 2-5 identifies parameters detected at concentrations exceeding their respective PALs (shown as bolded values). Parameters with concentrations exceeding both PALs and ESs are presented as shaded and bolded values in Table 2-5. Exceedances are summarized in the following paragraphs.

Groundwater Sample Results

As shown in Table 2-5, anthracene, benzene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, fluoranthene, fluorene, naphthalene, and pyrene were detected at concentrations exceeding their respective PALs and/or ESs in the groundwater samples collected from the shallow monitoring well network. The results are as follows:

WDNR PAL Exceedances – Q3 2010

- Anthracene was detected at concentrations exceeding the PAL of 600 µg/L in the groundwater sample collected from well TG1-1.
- Benzene was detected at concentrations exceeding the PAL of 0.5 µg/L in the groundwater samples collected from wells MW-7S, MW-34S, and MW-38S.
- Benzo(a)pyrene was detected at concentrations exceeding the PAL of 0.02 µg/L in the groundwater samples collected from wells MW-34S, MW-37S, and TG1-1.
- Benzo(b)fluoranthene was detected at concentrations exceeding the PAL of 0.02 µg/L in the groundwater samples collected from wells MW-34S and TG1-1.
- Chrysene was detected at concentrations exceeding the PAL of 0.02 µg/L in the groundwater samples collected from wells MW-34S and TG1-1.
- Fluoranthene was detected at concentrations exceeding the PAL of 80 µg/L in the groundwater sample collected from wells MW-34S and TG1-1.
- Fluorene was detected at concentrations exceeding the PAL of 80 µg/L in the groundwater samples collected from wells MW-34S and TG1-1.
- Naphthalene was detected at concentrations exceeding the PAL of 8 µg/L in the groundwater samples from wells MW-33S, MW-34S, MW-38S, and TG1-1.
- Pyrene was detected at concentrations exceeding the PAL of 50 µg/L in the groundwater sample collected from wells MW-34S and TG1-1.

WDNR ES Exceedances – Q3 2010

- Anthracene was detected at concentrations exceeding the ES of 3000 µg/L in the groundwater sample collected from well TG1-1.
- Benzene was detected at a concentration exceeding the ES of 5 µg/L in the groundwater sample collected from well MW-34S.
- Benzo(a)pyrene was detected at concentrations exceeding the ES of 0.2 µg/L in the groundwater samples collected from wells MW-34S and TG1-1.
- Benzo(b)fluoranthene was detected at concentrations exceeding the ES of 0.2 µg/L in the groundwater samples collected from wells MW-34S and TG1-1.
- Chrysene was detected at concentrations exceeding the ES of 0.2 µg/L in the groundwater samples collected from wells MW-34S and TG1-1.
- Fluoranthene was detected at concentrations exceeding the ES of 400 µg/L in the groundwater samples collected from wells MW-34S and TG1-1.
- Fluorene was detected at concentrations exceeding the ES of 400 µg/L in the groundwater samples collected from wells MW-34S and TG1-1.
- Naphthalene was detected at concentrations exceeding the ES of 40 µg/L in the groundwater samples collected from wells MW-33S, MW-34S, MW-38S, and TG1-1.
- Pyrene was detected at concentrations exceeding the ES of 250 µg/L in the groundwater samples collected from wells MW-34S and TG1-1.

Based on the Q3 2010 data, the plume boundary is primarily in an area encompassing four shallow monitoring wells (MW-7S, MW-33S, MW-34S, and MW-38S). As shown on Figure 2-1, a plume boundary has also been included at containment well MW-37S and treatment gate well TG1-1 where minor PAL exceedances were found. No other wells during this sampling event had exceedances above WDNR PALs or WDNR ES.

The majority of PAL and ES exceedances, as well as detections of BTEX and PAH constituents below PAL and ES levels, are associated with wells MW-34S and TG1-1 in which free product has historically been observed. In general, PAH concentrations measured in groundwater samples collected from the rest of the site were at relatively low levels with only sporadic detections. Based on the detected concentrations, the contaminant plume generally demonstrates a northeasterly trend, as indicated in Figure 2-1, similar to the previous groundwater sampling events. Low to very low (estimated) concentrations of BTEX compounds, including acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(b)flouranthene,

benzo(g,h,i)perylene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, fluoranthene, flourene, ideno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and/or pyrene were detected during the Q3 2010 round in monitoring wells MW-27S, MW-30S, MW-35S, and MW-39S and in treatment gate wells TG1-3, TG2-3, TG3-1, TG3-3, TG5-3, TG6-1, and TG6-3, where exceedances of PALs/ESs did not occur.

A summary of the concentrations of contaminants at wells that have regularly exceeded PALs and/or ESs during the last 19 quarters (7 years) is presented in Table 2-6. Levels of benzene, naphthalene, fluorene, and benzo(a)pyrene fluctuate over wide ranges in some of these wells. However, several constituents have shown an overall decreasing trend in monitoring wells MW-32S, MW-33S and MW-35S, as follows. Concentrations of benzene, naphthalene, and fluorene have not exceeded PALs and/or ESs in MW-32S and MW-35S over the past seven or more years. Benzo(a)pyrene in MW-35S has been detected at estimated concentrations, but above the PAL sporadically over the past seven years. Benzene concentrations in MW-33S have shown a decreasing trend. Fluorene concentrations, below PALs, and naphthalene concentrations, above PALs and ESs, continue to fluctuate in MW-33S.

Benzene and benzo(a)pyrene concentrations have remained relatively constant in MW-7S; however, fluorene and naphthalene concentrations show an overall decreasing trend in MW-7S. Well MW-34S has shown overall fluctuating levels in naphthalene, fluorene, and benzo(a)pyrene; however, benzene concentrations have remained relatively consistent in MW-34S. Varying levels of free product have been found in MW-34S in the recent past. This correlates with the elevated levels of constituents found in MW-34S. Well TG1-1 has shown fluctuating naphthalene, fluorene, and benzo(a)pyrene concentrations since it was first sampled in Q3 2000. These fluctuating concentrations could be due to the presence of free product which has historically been observed in well TG1-1. Benzene concentrations have remained relatively consistent in TG1-1.

2.2.2.2 Laboratory Analyses for Treatment Performance Monitoring

The groundwater samples collected from the treatment performance monitoring wells were analyzed for microbial enumeration, NO_3-N, NO_2-N, TKN, NH_3-N, PO_4-P, ORP, BOD, COD, TOC, BTEX, and PAHs. The analytical results for microbial enumeration, NO_3-N, NO_2-N, TKN, NH_3-N, PO_4-P, ORP, BOD, COD, and TOC are presented in Table 2-7. The analytical

results for the treatment performance monitoring well groundwater samples are summarized below. The laboratory reports of nutrient and microbial analyses are also included in Appendix A.

Nitrogen and Phosphorous Compounds

Nitrite (NO_2-N) and Nitrate (NO_3-N) were not detected in any of the treatment performance wells. Total Kjeldahl Nitrogen (TKN) results include ten detections with concentrations ranging from 0.51 to 3.0 mg/L. Ammonia (NH_3-N) results include nine detections ranging from 0.25 to 2.2 mg/L. Overall, nitrogen compound concentrations are at relatively low levels; however, previous sample results have indicated that NH_3-N concentrations are typically an order of magnitude greater than NO_3-N concentrations and approximately two orders of magnitude greater than NO_2-N.

Total phosphorous (PO_4-P) was detected in treatment performance gates TG3-1 and TG6-1 at concentrations of 0.28, and 0.34 mg/L, respectively. Orthophosphate (ORP) was detected in treatment performance wells TG4-1 and TG5-1 at concentrations of 0.072 and 0.1 mg/L respectively.

BOD, COD, and TOC

BOD was detected in two of the twelve treatment wells sampled, TG1-1 and TG3-3 at concentrations of 29.2 and 8.3 mg/L respectively. COD concentrations for the samples collected throughout the treatment system ranged from 7.1 to 415 mg/L. TOC concentrations for the samples collected throughout the treatment system ranged from 2.3 to 11.7 mg/L. As expected, the treatment gate wells indicate less BOD compared to COD. COD indicates the presence of constituents that exert an oxygen demand, including carbon compounds such as the site contaminants in the groundwater; other constituents such as ammonia, sulfurous compounds; and biological material such as humic acids and detritus. A significant portion of oxygen demand exerted by the constituents measured in the COD test may not be readily biodegradable and would typically exert the oxygen demand over an extended time period. The oxygen demand exerted by the constituents the COD analysis detected is catalyzed chemically and thermally. The low BOD indicates low concentrations of material that is readily biodegradable and/or quickly oxidized.

Microbial Enumeration

The total microbial populations for TG1 and TG2 included detections ranging from 1.6×10^2 to 6.3×10^3 colony forming units per milliliter (CFU/mL) during Q3 2010. The total microbial population for TG3 and TG4 ranged from 4.0×10^1 to 8.1×10^2 CFU/mL during Q3 2010. The total microbial populations for TG5 and TG6 ranged from non-detect to 1.68×10^3 CFU/mL during Q3 2010.

The result of degrader microbial population analysis for TG1 and TG2 included detections ranging from 1.0×10^2 to 1.85×10^3 CFU/mL during Q3 2010. The degrader microbial populations for TG3 and TG4 included detections ranging from 2.0×10^1 to 4.3×10^2 CFU/mL during Q3 2010. The degrader microbial populations for TG5 and TG6 included three non-detect results and one detection of 6.0×10^1 CFU/mL in TG6-1 during Q3 2010.

3. EVALUATION OF PILOT SCALE OPERATIONS

Augmentation of the groundwater treatment system was initiated in October 2000 by injecting air at the treatment gates. In late June 2001, nutrient addition was initiated at TG1 using a solution containing Potassium Nitrate (KNO_3) and Potassium Phosphate ($KHPO_4$). System modifications were proposed in the Q2 2002 Quarterly Groundwater Treatment Performance Monitoring Report.

3.1 DISSOLVED OXYGEN

During Q3 2010, the DO concentrations were found to range from 0.72 to 5.63 mg/L in the treatment performance monitoring wells. DO measurements in the downgradient treatment performance monitoring wells ranged from 1.04 to 5.63 mg/L.

Well packers were installed in the TG5 injection wells in June 2000; however, no discernable change in the DO levels were observed in the TG5 wells until Q1 and Q2 2003. TRONOX/WESTON attempted to install inflatable bladder packers in the TG1 and TG2 injection wells in August 2001. However, the packers could not be properly installed due to the injection well configuration.

TRONOX/WESTON will continue to evaluate alternatives for air introduction into the treatment gates.

3.2 NUTRIENTS AND PH

Nutrient injection was discontinued at gate area TG1 as a part of the site modifications recommended in the Q2 2002 Monitoring Report. This took place at the end of October 2002, after the Agencies granted approval. However, nutrient and contaminant levels will continue to be monitored.

Recommended guidelines for bioremediation of contaminants in site groundwater include a pH range of 6.5 to 8.5 S.U. and a minimum carbon-nitrogen-phosphorous (C:N:P) ratio of 100:14:1. The range of pH values measured in the treatment performance monitoring wells (6.58 to 7.16 S.U.) is sufficient to facilitate biological activity.

Table 3-1 contains calculated C:N:P ratios for each of the treatment performance monitoring wells. During Q3 2010, of all of the treatment performance monitoring wells, only well TG6-1 approximately exhibited the desired C:N:P ration of 100:14:1. The remaining treatment performance monitoring wells did not exhibit this desired ratio. Nitrogen and phosphorous appear to be the limiting nutrients at the site.

3.3 BACTERIAL POPULATIONS

Total bacterial counts were found, in general, to have decreased in TG1-1, TG1-3, TG2-3, TG3-1, TG3-3, TG4-1 and TG6-3 from Q3 2009. Total bacterial counts increased in TG2-1, TG4-3, TG5-1, and TG5-3 from Q3 2009 levels. There was no change in total bacterial counts for TG6-3 from Q3 2009. Degrader bacterial counts in each of the treatment gate monitoring wells were found to generally decrease or remain steady from Q3 2008. Figure 3-1 compares the degrader populations in TG1 and TG2 since Q1 2001. As indicated in Figure 3-1, there was a trend of general decrease in the degrader bacterial population levels in TG1 and TG2 from Q1 2001 to Q2 2004. It is uncertain what the cause of this bacterial decrease at the site was. However, the overall degrader populations appear to be increasing since Q3 2006.

3.4 HYDROGEOLOGY

TRONOX/WESTON identified a potential concern associated with the site hydrogeology in the Q2 2001 Monitoring Report. This concern is primarily based on the premise that low flow conditions may cause anoxic conditions and may inhibit TRONOX/WESTON's ability to introduce nutrients and other additives at an optimum level due to poor dispersion from the injection point. Low flow conditions are apparent based on the hydraulic gradient and flow velocities derived. A low flow velocity may be indirectly beneficial as a longer residence time in the treatment gate may allow for more effective biodegradation. No significant change was observed in relation to site hydrogeology during Q3 2010.

4. REACH 1, 2 AND 3 GROUNDWATER MONITORING RESULTS

The September 2010 groundwater-monitoring event included the annual sampling event of the Reach 1, 2, and 3 monitoring well network at the Moss-American site. These monitoring wells include MW-A through MW-K and are shown in Figures 1-2 through 1-4. Monitoring wells MW-A through MW-D were first sampled in September 2003 during the on-site Q3 2003 groundwater sampling event. The September 2005 Q3 sampling event was the first time monitoring wells MW-E through MW-K were sampled. Similar to the on-site wells, groundwater elevation measurements were collected from the Reach 1, 2, and 3 monitoring wells prior to sampling each monitoring well and groundwater elevations are presented on Table 4-1. DO measurements were also collected following the purging and sampling of each well.

The results of the annual Reach 1, 2, and 3 groundwater sampling event are described in the following subsections.

4.1 GROUNDWATER SAMPLE ANALYTICAL RESULTS

Groundwater samples were collected from a total of 11 Reach 1, 2, and 3 monitoring wells: MW-A through MW-K. Two duplicate samples were collected from the Reach 1, 2, and 3 monitoring wells for quality control purposes. The QA/QC samples were collected in conjunction with the on-site groundwater monitoring network sampling effort.

4.1.1 Field-Measured Parameters

The groundwater samples were measured in the field for pH, specific conductance, temperature, redox potential, DO, and turbidity. The field parameters were collected using a YSI 556 portable water quality meter and a Hanna HI98703 turbidimeter. Downhole DO readings were collected from each monitoring well subsequent to purging and sampling the well. The groundwater pH, redox potential, specific conductance, temperature, and turbidity were monitored during well purging prior to sampling. The final (stabilized) values for these measurements prior to sample collection are presented in Table 4-2.

4.1.2 Laboratory Analyses

Each groundwater sample collected from the Reach 1, 2, and 3 monitoring well network during the September 2010 sampling event was analyzed for BTEX and PAH compounds. PAHs were detected in monitoring wells MW-E and MW-K. Benzo(a)pyrene and benzo(g,h,i)perylene, were detected at low, estimated concentrations in MW-E. Anthracene was detected at a low, estimated concentration in MW-K. Only sporadic detections of BTEX and PAH constituents have been documented from the 2004 through the 2010 sampling events of the Reach 1, 2, and 3 monitoring wells. Based on the above observations, the Reach 1, 2, and 3 monitoring wells continue to demonstrate an overall effectiveness of the remedy. Future annual sampling event data will be evaluated to determine any changes or trends in the data. The results of the laboratory analyses performed on the Reach 1, 2, and 3 groundwater samples collected during September 2010 are provided in Appendix A.

Table 2-1
Groundwater Elevation Measurements
Shallow and Containment Performance Monitoring Wells
Moss-American Site
Milwaukee, Wisconsin
Third Quarter 2010

Well ID	Ground Elevation	TOC Elevation	Depth to Water	Groundwater Elevation	Product Thickness
MW-5S	723.41	724.63	6.19	718.44	None Detected
MW-7S	719.47	721.59	5.49	716.10	Sheen on GW
MW-9S	719.15	721.66	5.46	716.20	None Detected
MW-27S	720.57	723.10	5.78	717.32	
MW-30S	725.35	727.34	4.22	723.12	
MW-31S	725.29	725.31	2.88	722.43	
MW-32S	719.68	722.79	6.66	716.13	
MW-33S	719.25	721.81	6.28	715.53	
MW-34S	718.97	721.52	5.51	716.01	0.38
MW-35S	718.14	721.75	5.60	716.15	None Detected
MW-37S	721.33	723.30	6.26	717.04	
MW-38S	NS	NS	5.40	---	
MW-39S	NS	NS	4.57	---	

Notes:
All values in feet.
All elevation measurements are with respect to Mean Sea Level (MSL).
TOC - Top of well casing.
GW - Groundwater.
NS - Not Surveyed.
Depth to groundwater was measured on 23 September 2010.

Table 2-2
Groundwater Elevation Measurements
Treatment Performance Monitoring Wells
Moss-American Site
Milwaukee, Wisconsin
Third Quarter 2010

Well ID	Ground Elevation	TOC Elevation	Depth to Water	GW Elevation	Hydraulic Gradient (ft/ft)	Groundwater Velocity (ft/day)	Product Thickness
TG1-1	719.77	723.32	6.50	716.82	-0.0015	-0.0142	0.45
TG1-2	720.06	722.81	6.14	716.67			None Detected
TG1-3	719.56	722.53	5.56	716.97			
TG2-1	720.67	723.80	6.30	717.50	0.0094	0.0888	
TG2-2	720.62	723.05	6.01	717.04			
TG2-3	720.06	722.61	6.05	716.56			
TG3-1	719.14	721.05	4.74	716.31	-0.0008	-0.0076	
TG3-2	718.87	720.92	4.42	716.50			
TG3-3	718.35	720.60	4.21	716.39			
TG4-1	718.06	721.14	5.04	716.10	-0.0041	-0.0387	
TG4-2	718.26	720.75	4.44	716.31			
TG4-3	718.01	720.04	3.53	716.51			
TG5-1	717.60	721.12	5.18	715.94	0.0007	0.0066	
TG5-2	718.18	720.63	4.87	715.76			
TG5-3	718.17	719.99	4.12	715.87			
TG6-1	719.47	721.96	5.33	716.63	0.0013	0.0123	
TG6-2	719.70	722.05	5.62	716.43			
TG6-3	719.58	722.47	5.97	716.50			

Notes:
All values in feet.
All elevation measurements are with respect to Mean Sea Level (MSL).
Porosity of soil is assumed to be 0.3.
Hydraulic conductivity of treatment gate material is assumed to be 1E-3 cm/s = 3.0 ft/day.
TOC - Top of well casing.
GW - Groundwater.
ft/day - feet per day.
ft/ft - feet per foot.
NM - Not Measured.
A negative value in the groundwater velocity column indicates that the groundwater flow was opposite to the general direction of groundwater flow at the site.
Depth to groundwater was measured on 23 September 2010.

Table 2-3
Groundwater Elevation Measurements
Piezometers
Moss-American Site
Milwaukee, Wisconsin
Third Quarter 2010

Well ID	Ground Elevation	TOC Elevation	Depth to Water	Groundwater Elevation	Product Thickness
Groundwater					
PZ-01	718.04	721.05	4.70	716.35	None Detected
PZ-02	718.89	721.84	7.12	714.72	
PZ-03	719.00	722.09	5.94	716.15	
PZ-04	717.30	720.22	4.59	715.63	
PZ-05	724.34	727.43	6.13	721.30	
PZ-06	724.62	727.79	4.94	722.85	
PZ-07	725.78	728.72	4.49	724.23	
PZ-09	721.12	724.08	4.08	720.00	
PZ-10	722.04	725.05	5.88	719.17	

Notes:
All values in feet.
All elevation measurements are with respect to Mean Sea Level (MSL).
TOC - Top of well casing.
GW - Groundwater.
NM - Not measured

Depth to groundwater was measured on 23 September 2010.

Table 2-4
Field-Measured Parameters
Shallow Groundwater and Containment Performance Monitoring Wells
Moss-American Site
Milwaukee, Wisconsin
Third Quarter 2010

Well ID	Dissolved Oxygen (mg/L)	Redox Potential (mV)	pH (Standard Units)	Specific Conductance (mmho/cm)	Temperature (Deg C)	Turbidity (NTU)
MW-5S	11.2 *	36.1	6.57	1.695	12.15	0.72
MW-7S	0.8	-70	6.89	1.244	13.12	4.16
MW-9S	1.7	-21.3	6.69	0.980	13.75	2.06
MW-27S	0.8	-70.1	6.47	1.471	14.51	1.44
MW-30S	0.8	45.5	6.72	1.370	13.87	0.46
MW-31S	0.8	-16.1	6.90	1.116	13.37	4.51
MW-32S	2.4	-57.6	6.40	1.136	16.49	2.08
MW-33S	3.7	-18.2	6.34	1.236	14.60	1.55
MW-34S	NM	NM	NM	NM	NM	NM
MW-35S	0.8	-38.9	6.46	1.527	16.26	0.91
MW-37S	3.0	-18.6	6.71	1.115	15.58	0.43
MW-38S	1.0	-43.3	6.87	1.221	14.32	4.75
MW-39S	0.4	-48.3	6.75	1.255	16.04	4.84

Notes:
S - Shallow well.
TG - Treatment gate performance monitoring well.
NM - Not measured due to presence of a sheen or free product in well.
mmho/cm - millimhos per centimeter.
Deg C - Degrees Celcius
mV - millivolt
mg/L - milligram per liter
NTU - Nephelometric Turbidity unit
* - The DO reading from MW-5S is elevated and likely due to an erroneous field reading.

Table 2-4 (Continued)
Field-Measured Parameters
Shallow Groundwater and Containment Performance Monitoring Wells
Moss-American Site
Milwaukee, Wisconsin
Third Quarter 2010

Well ID	Dissolved Oxygen (mg/L)	Redox Potential (mV)	pH (Standard Units)	Specific Conductance (mmho/cm)	Temperature (Deg C)	Turbidity (NTU)
TG1-1	NM	NM	NM	NM	NM	NM
TG1-3	1.68	-124.0	6.97	1.196	16.08	3.81
TG2-1	0.76	-2.5	6.77	1.089	14.23	3.53
TG2-3	1.12	-113.6	6.88	0.966	16.63	3.62
TG3-1	3.04	-67.1	6.81	1.196	16.75	3.69
TG3-3	1.19	-81.5	6.79	1.106	16.79	4.0
TG4-1	5.16	70.4	6.97	1.119	15.83	1.60
TG4-3	5.63	-6.3	7.16	1.118	15.96	0.85
TG5-1	5.37	81.0	6.89	1.249	15.68	1.00
TG5-3	1.04	-36.5	7.08	1.051	15.31	4.5
TG6-1	0.72	-110.7	6.86	1.359	16.71	2.06
TG6-3	1.33	-46.4	6.58	1.330	15.76	1.15

Notes:
S - Shallow well.
TG - Treatment gate performance monitoring well.
NM - Not measured due to presence of a sheen or free product in well.
NA - DO reading not avalible in mg/L.
mmho/cm - millimhos per centimeter.
Deg C - Degrees Celcius
mV - millivolt
mg/L - milligram per liter
NTU - Nephelometric Turbidity unit