Annual Remedial Performance Report for Chromium and Perchlorate

Tronox LLC, Henderson, Nevada
July 2008 – June 2009

Submitted in Accordance with 1986 Chromium Consent Order and 2001 Perchlorate Administrative Order on Consent

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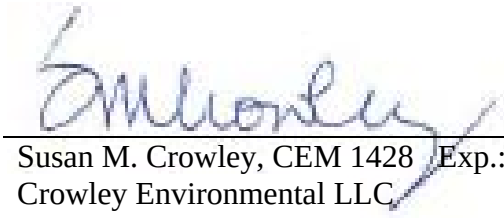
Tronox LLC
Henderson, Nevada

Responsible CEM for this project

I hereby certify that all laboratory analytical data was generated by a laboratory certified by the NDEP for each constituent and media presented herein.

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all applicable federal, state and local statutes, regulations and ordinances.



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1.0 INTRODUCTION

In accordance with the Consent Order for remediation of chromium-impacted groundwater at the Henderson facility, finalized September 9, 1986, and the Administrative Order on Consent (AOC) for remediation of perchlorate-impacted groundwater in the Henderson area, finalized October 8, 2001, Tronox LLC (Tronox) submits this remedial performance report to the Nevada Division of Environmental Protection (NDEP).

This report, covering the period July 2008 through June 2009, summarizes performance data for both the chromium and perchlorate remediation programs. Specifically, this report describes:

- Regional groundwater conditions based on April-June 2009 groundwater levels and constituent loading (TDS, chlorate, nitrate);
- The hexavalent chromium remediation system and evaluates the effectiveness of the groundwater capture and treatment system installed to carry out the chromium remediation program; and
- The perchlorate remediation system (consisting of the on-site Interceptor well field, the off-site Athens Road well field, the off-site Seep well field, and the off-site Seep surface-flow capture sump) and evaluates the effectiveness of the groundwater treatment system installed to carry out the perchlorate remediation program.

Other activities that occurred during the reporting period included:

- Refurbishing the injection trenches.

The annual groundwater sampling (completed in the second calendar quarter) is a robust sampling event, in which data from groundwater samples collected by neighboring companies are incorporated into the Tronox potentiometric, total chromium, and perchlorate maps. Additionally, annually we have mapped the total dissolved solids (TDS), chlorate, and nitrate concentrations combining the available data provided by the other companies. Tronox received information from American Pacific Corporation (AMPAC) and Southern Nevada Water Authority (SNWA) and their data were integrated into Tronox's to develop these maps.

This report is provided in both hard copy and electronic forms. Where electronic files are referenced or information is stated as provided on CD, this information is contained on the CD inserted at the front of the hard copy report. Appendix A contains two tables: Table A-1, which has five quarters of analytical data, and Table A-2, which has April through June 2009 data from AMPAC and SNWA used to supplement the Plates in the report. An Access © compatible data file (on the report CD) contains a full up-to-date database. Appendix B contains the laboratory

reports and field sheets from January 2009 (on the report CD). Appendix C contains correspondence with NDEP, including responses to comments on previous Tronox reports, and Appendix D contains the data validation summary report.

Figure 1, a location map covering the area between the Tronox facility and Las Vegas Wash, shows the components of the remedial systems with an index for accompanying cross sections. The performance of each component will be discussed separately, starting with the on-site Interceptor well field and proceeding to the successively northward components. Plate 1 shows the locations of all wells and borings in the mapped area.

2.0 AREA GROUNDWATER CONDITIONS

Plate 2, the *Potentiometric Surface Map: Shallow Water-Bearing Zone*, is based on groundwater elevation measurements taken in April-June 2009 by Tronox and AMPAC, and shows a generally north-northeast groundwater flow direction, with an average gradient of 0.02 feet per foot south of the Athens Road well field, flattening to 0.007 feet per foot north of the well field.

On the map's southern end, beneath the Tronox facility, the flow direction is generally north-northwesterly, whereas north of the facility the direction changes slightly to the north-northeast. This generally uniform flow pattern has been modified locally by subsurface alluvial channels cut into the underlying Upper Muddy Creek formation surface (UMCf), the on-site bentonite-slurry groundwater barrier wall (barrier wall), on- and off-site artificial groundwater highs or "mounds" created around the recharge trenches and City of Henderson Water Reclamation Facility (COH WRF) Rapid Infiltration Basins (RIBs), and by depressions or "low areas" created by the groundwater recovery wells at the three groundwater recovery well fields.

2.1 Interceptor Well Field Area

The Interceptor well field area is shown on Figure 1 and Plate 2. Plate 2 shows that the potentiometric surface upgradient of the 1695-foot above mean sea level (amsl) contour is in both the alluvium (in localized alluvial channels) and the UMCf. On the plate, a well with the groundwater surface in the shallow Muddy Creek formation is indicated by an orange highlight over the well identifier.

North of the well field and barrier wall, the groundwater is artificially recharged with clean (less than 5 ppb perchlorate) Lake Mead water that is introduced into gravel-filled trenches to balance the loss of groundwater removed from the alluvium and Muddy Creek formations by the Interceptor well field. The groundwater mound that had been redeveloping in the vicinity of wells M-70, M-80 and M-83 from the recharge trenches dissipated in late summer 2008. The mound reduction was due to a reduction in recharge flow until a method for Quagga mussel prevention was in place for the fresh lake water being introduced into the refurbished north recharge trench. The process for Quagga mussel prevention is now in place and Tronox will follow the effect of the north trench reactivation on area water levels. In June 2009, the monthly average water introduced to the south trench and the open area was 26.5 gallons per minute (gpm). With the reactivation of the north trench, the combined flow being introduced to both trenches is currently 55 gpm, and is expected to rise over the coming weeks to match the volume of water extracted from the Interceptor well field.

North (downgradient) of the barrier wall water, elevations in wells M-69 through M-74 range between three to seven feet lower than water elevations south (upgradient) of the barrier wall. Figure 2, *Hydrograph Pairs across the Barrier Wall*, shows the redevelopment of the mound after trench refurbishment (about February 2008) and its dissipation starting in July-August 2008. The hydrographs show that the relatively instantaneous rise and fall of the water levels in the below-barrier wells (M-69 through M-72) was due solely to the quantity of water being recharged in the trenches. In contrast, the above-barrier wells, I-Y, and M-55, -56 and -58, show only minor water elevation changes due to pumping rate changes.

The fact that the water elevation in M-70 spiked above the water elevation of M-55 while the water elevation of M-55 remained flat shows that there is negligible leakage through the barrier wall and that the increase in water elevation was due to recharge mounding. If the barrier had been leaking between March 2007 and February 2008, then the shutdown of the recharge trenches would have had little or no effect on the water levels seen in the wells downgradient from the barrier wall; that is, the hydrographs would have shown gently changing water levels mirroring the levels in the wells upgradient from the barrier wall rather than the measured four- to six-foot declines.

Plate 3, the *West-East Hydrogeologic Cross Section - Interceptor Well Field*, shows the current water levels in the pumping Interceptor wells, adjacent monitor wells, and the relationships between the pre-pumping and current groundwater level. The cross section also shows the series of narrow subparallel alluvial channels separated by Muddy Creek ridges, many of which are above the current groundwater level. Recent installation of new wells on both ends of the barrier wall has affirmed the presence of inter-channel Muddy Creek ridges at both ends of the barrier wall. The tops of these bounding ridges are shown in the section to be above the adjacent potentiometric surface – separating the saturated alluvium at Timet well CLD2-R from Interceptor well I-K on the east.

On the west, a new channel, discovered west of abandoned well I-A, is separated from I-B by the remnants of a Muddy Creek ridge. The contact between the alluvium and the Muddy Creek at the bottom of this newly discovered channel is present about five feet below the contact in adjacent well M-57A. In general, water elevations in the well field in May 2009 are about one foot lower than in May 2008. Up to two borings are planned to be drilled to determine the width of this new channel and one new recovery well is planned to be completed between I-B and I-AA. The goal of the Interceptor well system is not necessarily to dewater the alluvium at each well, but to control and influence groundwater in the saturated intervals between the Interceptor wells, and remove contaminant mass.

The monthly average discharge rate for each Interceptor well during June 2009 is shown on Table 1. This table compares the June discharge data to the same time period each year back to June 2004. These discharge data illustrate the gradual increase in groundwater capture after the barrier wall was installed in October 2001. The June 2009 total discharge was a record 69.3 gpm.

2.2 Athens Road Field Area

The Athens Road well field was completed in March 2002 and groundwater collection in this area began shortly thereafter. Continuous pumping from this well field began in mid-October 2002. More recently, in early September 2006, an additional recovery well (ART-9) began full-time pumping. Figure 1 and Plate 2 show the location of the Athens Road well field. Recent mapping of the May 2009 groundwater elevations is shown on Plate 2, the *Potentiometric Surface Map: Shallow Water-Bearing Zone*. In this well field area, the map shows the Main alluvial channel trending generally north-northeast toward the Wash. Inset A on Plate 2 shows the interpreted groundwater inflow in the western part of the well field (closed 1588' contour) and in the eastern part of the well field (closed 1583' contour). Continuing construction activity by the City of Henderson has made access to some of the monitor wells impossible.

North of this well field, in the east-central portion of Section 36, large intermittent surface-water infiltration from the RIBs periodically forms large groundwater mounds in the potentiometric surface. In this area the groundwater gradient decreases from an average of 0.020 feet per foot to less than 0.007 feet per foot. An event such as this has the effect of reducing the downgradient flow of groundwater from the well field area and dissolving perchlorate trapped in the vadose zone.

Plate 4, the *West-East Hydrogeologic Cross Section - Athens Road Well Field*, shows hydrologic conditions at the time of groundwater sampling in May 2009 versus April 2002. Groundwater levels are currently as much as 12.0 feet lower than they were in 2002 before pumping began. This figure also shows the extent of erosion of the Muddy Creek formation and the subsurface channels filled with the alluvium. In this area, the Main Channel splits into two subchannels separated by a Muddy Creek basement ridge above which the alluvium is unsaturated. In general, the water elevations in the western subchannel are about one foot higher than in May 2008, whereas they are one foot lower in the eastern subchannel. Figure 3, *Athens Road Well Field Drawdown*, shows that these higher water levels are now decreasing and that drawdown has progressed to the point that ART-5 and PC-12 are currently dry. Monitor wells PC-17, -134, -135, -136, -137 and ARP-2 and -3 are currently buried by construction debris.

Recent recovery well discharge rates are shown on Table 2. This table shows that the June 2009 average discharge from the pumping Athens Road recovery wells – ART-2, 3A, 4A, 7, 8 and 9 – was about 259 gpm. Discharge rate comparisons back to June 2004 are also provided.

2.3 Seep Well Field Area

The Seep well field and the Seep stream pumping station are shown on Figure 1 and Plate 2. In July 2002 when pumping began, the Seep well field consisted of three recovery wells situated over the deepest part of the subsurface alluvial channel in the UMCf. In February 2003, five additional wells (PC-117 to PC-121) and in December 2004 one additional well (PC-133) were completed in the Seep well field area. Plate 2 shows that north of the Athens Road well field the gradient of the north-northeast sloping potentiometric surface decreases to about 0.007 feet per foot due to constant water infiltration from the COH Birding Ponds, periodic mounding events from the COH WRF, and underflow from Las Vegas Wash. Recent depth to water measurements north of the COH WRF show that water elevations are up to 17 feet lower now than they were in May 2008. This water elevation decrease is thought to be due to cessation of the discharge of treated effluent to the Pabco Road RIBs since the completion of the COH WRF in 2008.

Figure 4, the *West-East Hydrogeologic Cross Section Seep Well Field*, shows that the alluvial channel is much less incised into the underlying UMCf than at Athens Road, and that the configuration of the alluvial channel is a broad shallow feature about 800 feet wide and averaging about 45 feet thick. In May 2001, before pumping began, the groundwater level in the area was very shallow and would daylight every winter. The figure shows that in May 2002, the depth to water averaged about 1 foot below ground level in the Seep well field area whereas in May 2009, drawdown due to pumping was up to 8.3 feet below pre-pumping levels (in monitor well PC-90). Wells along the eastern side of the cross section (PC-91, -92, -93 and -94) have lower water elevations than last year (by up to 3.2 feet) due to the suspension of discharge to the Pabco Road RIBs.

Recent recovery well discharge rates are presented in Table 3. This table shows that the average discharge rate for June 2009 was a total of about 578 gpm. Discharge rate comparisons back to June 2004 are also provided. As shown in the table, the minor decrease in the discharge rate over the last four years is due to well field optimization efforts whereby discharge rates in wells and well fields with lower contaminant mass loading are preferentially decreased over wells and well fields with higher contaminant mass loading. The Seep stream has not flowed since mid-April 2007.

3.0 CHROMIUM MITIGATION PROGRAM

Figure 1 shows the four components of the chromium mitigation program, consisting of the on-site Interceptor well field, groundwater barrier wall and groundwater recharge trenches, and the off-site Athens Road well field. For the last 12 months – July 2008 to June 2009 – a total of about 4,265 pounds of chromium was captured, hexavalent chromium reduced to trivalent chromium and removed, and residual solids disposed of in a permitted landfill. For the discussion below, total chromium is conservatively considered to be entirely hexavalent chromium. A diagram of the groundwater chromium system is presented on Figure 4, *Tronox Henderson Groundwater Treatment Flow Diagram*.

3.1 Chromium Plume Configuration

Plate 6, the *Total Chromium in Groundwater Map: Shallow Water-Bearing Zone*, shows the contoured total chromium groundwater plume from its on-site source northward to the point where the plume reaches non-detect levels south of Las Vegas Wash. South of the Interceptor well field, the highest total chromium concentration occurred in M-50 (38 mg/L), whereas north of the recharge trenches the highest total chromium concentration found was 3.0 mg/L in well M-87, which is south of Warm Springs Road.

3.1.1 On-Site Interceptor Well Field Area

Plate 3, *West-East Hydrogeologic Cross Section A – A' Interceptor Well Field*, shows the current total chromium concentration in each well; whereas Figure 5, the Interceptor Well Field Total Chromium Section Graph, shows the concentrations of total chromium across the well field over the last five quarters. The figure shows that the chromium concentrations are little changed on either end of the well line whereas relatively large but short-lived changes have occurred in the central part. Appendix A contains total chromium data for the last five quarters along with groundwater elevations for these wells.

Chromium concentration data from the five Consent Order Appendix J wells (M-11, -23, -36, -72, and -86) are presented in graph form in Figure 6, *Consent Order Appendix J Wells Total Chromium Concentration Trend Graph*. Monitor well M-11, immediately downgradient from the former primary source area (Units 4 and 5), has increased slightly from 2.8 to 3.9 mg/L total chromium between May 2008 and May 2009. Well M-36, upgradient of the Interceptor well field and barrier wall, began declining in late 2004 and has remained relatively steady in chromium concentration since 2006. This "steady state" condition may indicate that the main portion of the upgradient chromium plume has reached the area of M-36. Plate 6 shows that the southern end of

the highest total chromium contour (30 mg/L) has moved north of the Chemstar property. Since 2006, the chromium concentration in M-86 has been increasing slightly due to the fouling of the recharge trenches and concomitant dispersion of the dead zone groundwater mound. M-86 and nearby wells M-85 and M-83, were damaged or destroyed during the recharge trench refurbishment activities and Tronox hopes to replace the wells later this year. Well M-23, 1600 feet downgradient from the barrier wall, is also continuing to show declining total chromium concentrations. M-23 total chromium value was 0.73 mg/L in May 2009, which represents the third lowest total chromium value noted in this well since sampling was initiated in January 1987.

Total chromium concentrations downgradient of the barrier wall and recharge trenches continue to decline, indicating that the groundwater recovery / barrier system is functioning as an effective barrier to migration of the main portion of the chromium plume. Besides the example of the total chromium decline in M-23, well M-100, 700 feet north of the recharge trenches, has gone from 9.2 mg/L total chromium in January 2002 to 0.15 mg/L in May 2009.

3.1.2 Athens Road / Seep Well Fields Area

The groundwater recovery system at Athens Road (now renamed Galleria Drive, although the Athens Road designation has been retained for well field for consistency with past reports) has a positive effect on the total chromium concentrations north of the well field. In this area, groundwater flows around both sides of a Muddy Creek formation basement ridge. The total chromium plume on both sides of the ridge is captured and stopped by the groundwater recovery wells

Plate 4, *West-East Hydrogeologic Cross Section B - B' Athens Road Well Field*, shows the current total chromium concentration in each well. Figure 7, the *Athens Road Well Field Total Chromium Concentration Section Graph* shows that chromium concentrations in the western subchannel over the last year have been low relative to those in the eastern subchannel. Another recovery well, ART-9, was installed in this area in 2006 to capture a narrow channel of high chromium-impacted groundwater that was moving through the recovery well field. Consequently, a dramatic decline in chromium concentration occurred in well PC-122 that went from 1.5 to 0.10 mg/L between November 2006 and February 2007 and contained 0.08 mg/L in May 2009. The chromium concentration in ART-9 has increased slightly from 1.4 mg/L in August 2008 to the current 1.7 mg/L. Tronox had intended to put well ART-6 back online in the first half of 2009 but the well has been inaccessible due to ongoing City of Henderson construction work. As soon as the well is accessible, hopefully in the fourth quarter, ART-6 will be put back on-line. Total chromium present in groundwater collected in this area continues to be treated at Lift Station #3 with metered

ferrous sulfate additions to reduce the hexavalent chromium to insoluble trivalent chromium before the water is sent to the on-site perchlorate treatment system.

Further north, as shown on Plate 6, no total chromium section graph was prepared for the Seep well field because wells in this well field closest to Las Vegas Wash continue to contain < 0.01 mg/L total chromium. However an anomalous situation is developing east of the well field where total chromium concentrations in nested well pair PC-93/ PC-94 are now 0.061 and 0.065 mg/L, respectively (see Plate 5, the *West-East Hydrogeologic Cross Section C - C' Seep Well Field*). This is the first time these wells have contained chromium above the detection limit. As mapped on Plate 6, chromium-impacted groundwater is flowing from the Upper BMI Ponds east of Pabco Road and has finally reached these wells. As discussed under area groundwater conditions, water elevations have dropped in this area between three and 17 feet over the last year due to cessation of discharge of treated effluent in the Pabco Road RIBs. It may also be possible that past infiltration acted to dilute a previously existing chromium plume, and without this dilution, it is finally being observed. Tronox will continue to monitor the situation.

3.2 On-Site Chromium Treatment System

The operation and maintenance of the total chromium reduction process was contracted to Veolia Water North America (formerly US Filter Operating Services) on August 1, 2003. Tronox retains responsibility for compliance with the terms of the 1986 Consent Order and the subsequent Underground Injection Control (UIC) Permit NEV94218. Table 4 contains the July 2008 to June 2009 process treatment data from the on-site Groundwater Treatment Plant (GWTP). The treated groundwater from the GWTP, which includes about 25 gpm from GW-11 was pumped to two 150,000 gallon tanks (BT-40 and BT-45 in series), then to the equalization tanks where it combined with water from the off-site recovery systems. From the equalization tanks, most of the blended water flows through activated carbon beds before being filtered and pumped to the Fluidized Bed Reactors (FBRs) for treatment to destroy perchlorate, chlorate, and nitrate. A small portion of the blended GWTP flow (1-3 gpm) is not pumped to the FBRs but instead is returned to the GW-11 pond in order to avoid running the underflow pump dry.

As shown in Table 4, since July 2008 the total chromium inflow concentration from the Interceptor wells to the GWTP is holding fairly steady in the range of 13 to 14 mg/L. The reduction of hexavalent chromium during the reporting period has been consistently effective. Total chromium outflow concentrations for the last 12 months ranged from 0.131 to 0.492 mg/L – well below the required level of 1.7 mg/L established in the 1986 Consent Order. The hexavalent chromium outflow concentration during the reporting period ranged from 0.003 to

0.012 mg/L – well below the required level of 0.05 mg/L, established in the 1986 Consent Order. For the period between July 2008 and December 2008, about 3,966 pounds of chromium have been removed from the groundwater.

Results of total chromium analysis from weekly FBR influent and effluent samples are presented in Table 5. These data, between July 2008 and June 2009, show that the FBR's influent total chromium concentrations varied from <0.01 to 0.11 mg/L. Based on an average concentration of about 0.082 mg/L total chromium with an average flow rate of 941 gpm, the FBRs were receiving about 0.9 pounds of chromium per day from the equalization tanks.

Treated water from the FBRs discharges to Las Vegas Wash just upgradient of the Pabco Road erosion control structure under authority of NPDES Permit NV0023060. Analyses of this water performed between July 2008 and June 2009 appear in Table 5. The table shows that all hexavalent chromium analyses, except one, have been non-detect at <0.0001 mg/L and that all total chromium analyses, except 13, have been non-detect at <0.01 mg/L. At an influent concentration of approximately 0.9 pounds per day the FBR system removed an additional 299 pounds of chromium over the 12 month period. The sum of the chromium removed from the groundwater between July 2008 and June 2009 by the chromium recovery and treatment system and by the FBRs totals 4,265 pounds.

A diagram of the groundwater chromium system is presented on Figure 4. This block diagram is a life cycle presentation of chromium-impacted groundwater from the four primary groundwater collection areas, through the various treatment stages, and then to ultimate discharge as clean effluent to Las Vegas Wash.

4.0 PERCHLORATE RECOVERY PROGRAM

The four components of the perchlorate recovery system, consisting of the on-site Interceptor well field and barrier wall, the off-site Athens Road well field, the off-site Seep well field, and the off-site Seep surface-flow capture sump, are shown on Figure 1. In the last 12 months, since July 2008, a total of about 570,132 pounds of perchlorate (1,562 pounds per day) have been captured, removed, and destroyed in the biological treatment system. Of this total, about 312,445 pounds (856 pounds per day) came from the on-site Interceptor well field, about 241,210 pounds (661 pounds per day) came from the Athens Road well field, about 16,477 pounds (45 pounds per day) came from the Seep well field and zero pounds came from the Seep surface-flow capture sump. Figure 8 shows the July 2008 – June 2009 monthly perchlorate recovery totals and the relative significance of each of the four components, whereas Table 7 shows the average pounds of perchlorate per day removed by each component. Note also on Table 7 that the June 2009 recovery is an estimate that will be recalculated next month.

4.1 Perchlorate Plume Configuration

Plate 7, the *Perchlorate in Groundwater Map: Shallow Water-Bearing Zone*, shows the contoured perchlorate plume from the Tronox plant site to Las Vegas Wash based on data collected in May 2009. Based on this sampling, the highest perchlorate concentration south of the Interceptor well field occurred in well I-A-R (2570 mg/L) whereas north of the recharge trenches the highest perchlorate concentration found was 683 mg/L in well M-44 along the north boundary of the Tronox property.

Comparing Plate 7 with Plate 7A, the *Perchlorate in Groundwater Map: Shallow Water-Bearing Zone – Second Quarter 2002*, it is obvious that significant changes in plume concentrations have occurred over seven years. For example, south of the barrier wall, the highest perchlorate concentration was from well M-37, which contained 5300 mg/L in 2002; whereas in 2009 the same well contains only 1690 mg/L. In contrast to 2002, no wells south of the barrier wall contained more than 2570 mg/L in 2009. In 2002, a large area of concentrations greater than 1000 mg/L was mapped between the barrier wall and the Athens Road well field. This has been reduced to a much smaller area of concentrations greater than 500 mg/L today. In 2002, a perchlorate plume located north of Athens Road greater than 100 mg/L existed all the way to Las Vegas Wash. Today, that plume has been reduced to less than 10 mg/L.

4.1.1 Interceptor Well Field Area

The three components of this well field area, the recovery well line, the barrier wall and the groundwater recharge trenches, significantly reduce the amount of perchlorate in the downgradient groundwater.

Plate 3, *West-East Hydrogeologic Cross Section A – A' Interceptor Well Field*, shows the current perchlorate concentration in each well whereas Figure 9, the *Interceptor Well Field Perchlorate Concentration Section Graph*, shows the perchlorate concentrations for the Interceptor wells in May 2002 and over the last four quarters. The most recent data from May 2009 show that the perchlorate concentrations in many of the Interceptor wells are significantly lower than in May 2002 and many wells are at or near their historic lows. As with the chromium data, perchlorate concentrations are little changed on either end of the well line; whereas relatively large but short-lived changes have occurred in the central part.

Based on this graph (Figure 9) and Figures 10 and 10A, the *Interceptor Well Field Perchlorate Concentration Trend Graph*, since at least May 2002 there have been two sub-plumes impacting the well field – a major plume east of well I-M and a minor plume west of I-M – and the overall perchlorate loading is declining over time. On the west end of the barrier wall, Interceptor well I-B has continued to decrease from 3000 mg/L in May 2006 to 755 mg/L in May 2009 and monitor well M-69, directly downgradient from I-B, has now begun to dramatically decrease (1350 mg/L in November 2006 to 371 mg/L in May 2009). The reason for this decline is probably the increased pumping in upgradient well I-AR. In January 2008, Tronox installed additional monitoring wells and one recovery well west of I-B, which will be connected to the well field in late 2009.

Since high perchlorate concentrations are often associated with high total dissolved solids (TDS) concentrations, a TDS section graph was constructed across the well field. A comparison of Figure 9 and Figure 11, the *Interceptor Well Field Total Dissolved Solids Section Graph*, shows that the broad zone of high TDS in the central part of the well field continues in the most recent sampling without a concomitant increase in perchlorate concentrations. It is also noteworthy that the high perchlorate plume on the west side of the well field is not associated with high TDS. It is thought that a groundwater pulse containing a high concentration of perchlorate, with few other salts present, is responsible for this anomaly.

The monthly average perchlorate concentration collected at the well field has been decreasing, with short-lived minor reversals, from a high of about 1,900 mg/L in 2002 to about 1,063 mg/L in June 2009 (see Figure 12, *Interceptor Well Field Average Perchlorate Concentration and*

Mass Removed). This figure also shows the monthly average perchlorate removed from the groundwater which is estimated to be 26,922 pounds in June 2009; reflecting the decreasing perchlorate mass available for capture. Data shown on Figure 13, *Well M-100 Perchlorate Concentration vs. Water Elevation Trend*, from well M-100, seven hundred feet north of the recharge trenches, demonstrate that the recharge trenches were effective up until about May 2007 when their slow clogging started to choke off the water supply to M-100. As shown, the historically low perchlorate concentration in this well (13 mg/L) occurred in May 2007 and was 99 percent less than the January 2002 concentration of 1000 mg/L. Currently, M-100 contains 32.3 mg/L perchlorate.

The decrease of recharge water to the trenches is seen in the graph as a decrease in water elevation since about December 2008. However, the recharge decrease has been reversed and Tronox will now follow water levels for the effect of the refurbished north trench reactivation.

4.1.2 Athens Road Well Field Area

The Athens Road well field was completed in March 2002 and groundwater collection in this area began shortly thereafter. Continuous pumping from this well field began in mid-October 2002. In September 2006, an additional recovery well (ART-9) began full-time pumping. Figure 1 and Plate 7 shows the location of the Athens Road well field. As of May 13, 2009, the pumping Athens Road wells were ART-2, -3A, -4A, -7, -8 and -9, and the June 2009 recovery well discharge rate was about 259 gpm (Table 2). Appendix A presents groundwater elevations and analytical data from the wells in this area.

The perchlorate concentrations of the ART-series wells are shown in Figures 14 and 14A, *Athens Road Well Field Perchlorate Concentration Trend Graph*. The trend lines on Figure 14 show that between January 2003 and September 2006 the perchlorate concentrations were basically stable with only minor variations and that after September 2006 perchlorate concentrations in nearly all wells began to accelerate their decline. Figure 14A, an expanded view of the last five quarters of Figure 14, shows that in late 2008-early 2009, ART-3, -4 and -8 began a short-lived increase and are now back to mid-2008 concentrations. ART-6, currently containing 84 mg/L, continues to swing between 75 and 340 mg/L. Tronox is working to put ART-6 back on-line by the fourth quarter and recover groundwater from the well, but these efforts have been delayed due to City of Henderson development work in the immediate vicinity. Groundwater from well ART-9, currently pumping at about 44 gpm, contains 346 mg/L of perchlorate, down slightly from 385 mg/L at the commencement of pumping in September 2006. Since mid-2008, ART-9 is exhibiting a slight increase in concentration.

Plate 4, *West-East Hydrogeologic Cross Section B - B' Athens Road Well Field*, shows the current total perchlorate concentration in each well whereas Figure 15, the *Athens Road Well Field Perchlorate Concentration Section Graph*, shows that over the last four quarters concentration changes have occurred in a narrow range – with the exception of ART-6 – and that most of the present concentrations are below those from May 2002. Note that the perchlorate concentrations on the western (PC-55 and ART-1) and the eastern sides of the well field (PC-122) continue to remain very low. Currently, PC-17, -134, -135, -136 and -137 are buried due to construction activities, and ART-5 and PC-12 are dry. The monthly perchlorate concentration in ART-8, as shown on Figure 16, the *Athens Road Well Field Average Perchlorate Concentration in ART-8 and Mass Removed*, is currently 256 mg/L – near the low end of its range. Also shown on this graph is the monthly average perchlorate mass removed from the well field which was estimated to be 18,330 pounds in June, reflecting the declining perchlorate mass available for capture.

Starting in August 2006, TDS data have been collected from the well field. A section graph, Figure 17, *Athens Road Well Field Total Dissolved Solids Section Graph*, shows that two zones of higher TDS exist at the well field, centered on ART-2 on the west (12,100 mg/L) and ART-7 on the east (11,800 mg/L).

About 250 feet north of the Athens Road well field, seven ARP-series, and one MW-K series wells make up the Athens Road piezometer well line. The perchlorate concentrations of these wells are shown in Figures 18 and 18A, *Athens Road Piezometer Well Field Perchlorate Concentration Trend Graph*. The western two wells, ARP-1 and -2, and the eastern well, ARP-7, continue to contain perchlorate concentrations below 5.7 mg/L. Well MW-K4, east of ARP-3, which had declined significantly in 2008, is rising again and contained 192 mg/L in June 2009. A comparison of Figures 14 and 18 shows that the perchlorate concentrations in ART-3, -4 and -8 began to rise in November 2008, but have now declined to pre-November levels and it is therefore expected that MW-K4 will soon begin to decline as well. Figure 18 shows that short-lived increases have happened in the past and will likely happen in the future. Tronox will continue to monitor this situation. Figure 19, the *Athens Road Piezometer Well Field Perchlorate Concentration Section Graph*, shows the sharp decline in perchlorate concentrations since May 2002 in the western sub-channel. It is expected to take longer to clean the piezometer line wells because pumping at the Athens Road well field and periodic discharge by COH WRF has flattened the hydraulic gradient in the area of the piezometers.

The Athens Road well field area, extending north to the piezometer line, is undergoing extensive construction activities. As a result, wells are periodically buried or damaged. Currently, ARP-2

and -3 are buried. As the COH clears an area, Tronox is working to repair or replace damaged wells and will attempt to minimize future damage as City of Henderson construction continues.

Intermediate between the Athens Road area and the Seep area are the COH WRF and the Lower Ponds monitor well lines. Figures 20 and 20A, *City of Henderson Well Line Perchlorate Concentration Trend Graph*, show the perchlorate concentrations in the COH WRF wells from January 2001 to June 2009. As shown, wells PC-98R and MW-K5, in which concentrations have previously been erratic prior to April 2004, have varied in a narrow range of 8.8 to 25.0 and 2.3 to 17.7 mg/L, respectively, since May 2007. As of June 2009, PC-98R and MW-K5 contain 18.6 and 14.7 mg/L perchlorate, respectively. Figure 21, *City of Henderson Well Line Perchlorate Concentration Section Graph*, shows that for the last four quarterly reporting periods the perchlorate concentrations in the well line have declined to historic lows due to a large infiltration event in November 2008 only to rebound slightly in February 2009. Figure 22, the *PC-98R Perchlorate vs. Water Elevation Trend Graph*, shows that since February 2003 the groundwater level has continued to generally decline, but significant groundwater "mounding events", due to increased COH WRF surface water infiltration, continue to occur sporadically. It is significant to note on this graph that since December 2003, a spike in perchlorate concentration occurred during each spike in groundwater elevation. This suggests that during higher water levels additional perchlorate from the vadose zone was put into solution and that the historic higher-than-normal perchlorate concentrations in this well line are more a function of COH WRF discharge than presumed perchlorate leakage past the Athens Road well field. However, during the latest seven mounding events occurring since May 2007, this has not been the case. This suggests that much of the perchlorate in the vadose zone in this area has been removed and that during these last events infiltration water has diluted the perchlorate (and chromium) concentrations in the adjacent groundwater.

Tronox has proposed to pilot test an in-situ technology along the COH WRF well transect. If approved, an edible oil substrate will be injected below the water table to form a permeable reactive barrier. Perchlorate entering the barrier would be destroyed biologically, similar to the process used in the biological treatment plant.

The Lower Ponds well line is 2,200 feet north of the COH WRF well line. Figures 23 and 23A, the *Lower Ponds Well Line Perchlorate Concentrations Trend Graph*, show that perchlorate concentrations have not shown much variation since about February 2004. The last five quarters of data shown on Figure 23A are essentially flat with minor variations in PC-56 and a step-up in concentrations starting in November 2008 in PC-58. As of June 2009, PC-58 contains the highest concentration at 9.6 mg/L. Figure 24, the *Lower Ponds Perchlorate Concentration*

Section Graph, shows that over the last four quarters the perchlorate concentrations show little change and that PC-56 shows the most variability. In May 2009, PC-58 contained the highest perchlorate concentration (10.3 mg/L) along the well line.

4.1.3 Seep Well Field Area

The original three recovery wells in the Seep well field went on-line in August 2002. In February 2003, five additional wells (PC117 to PC121), and in December 2004, one additional well (PC133), were completed in the Seep well field (see Figure 1). At present, the Seep well field consists of ten wells – two of which (PC-99R2 and 99R3) are connected and operate as one – positioned over the deepest part of the alluvium channel that contains the highest concentrations of perchlorate. The well field is located about 600 feet upgradient of the seep surface-flow capture sump. Three monitor wells are planned to be installed in the well field as soon as an access agreement has been obtained. Plate 5, the *West-East Hydrogeologic Cross Section C - C' Seep Well Field*, shows the perchlorate concentrations in the wells as of May 2009; whereas Figure 25, the *Seep Well Field Perchlorate Concentration Trend Graph*, shows the historic perchlorate content of the wells. Figure 25A, an expanded part of Figure 25, shows that over the last five quarters the two wells with the highest perchlorate concentrations – PC-99R2/R3 and adjacent well PC-115R – have decreased from December 2008 levels, but are slowly increasing again. Currently, PC-115R contains the highest concentration at 8.2 mg/L perchlorate.

As mapped on Plates 5 and 7, a tongue of greater than 10 mg/L perchlorate occurs east of the well field in well pair PC-91/PC-92. The cross section shows that the deeper part of the aquifer (screened in PC-91) contains 30.2 mg/L perchlorate whereas the upper part (screened in PC-92) contains only 2.6 mg/L. Coincidentally, the TDS concentrations are 7,510 mg/L in the lower part compared to 3,410 mg/L in the upper part. This density stratification does not occur in any other sampled well pair. The perchlorate concentration in recovery well PC-133, located 200 feet north (downgradient) and screened throughout the entire saturated zone, contains only 0.97 mg/L perchlorate and 2,640 mg/L TDS. The relatively higher perchlorate-impacted groundwater in PC-91 appears to be limited in lateral and vertical extent, based on the lower concentrations in other nearby wells. Once the planned monitor well is installed north of PC-133, a three-point solution for flow direction can be determined. Tronox will continue to monitor this situation.

Table 3 contains the June 2009 discharge rates from the individual wells and the total for the well field (578 gpm total). Figure 26, *Well PC-97 Perchlorate Concentration vs. Water*

Elevation Trend Graph, shows perchlorate concentrations in the well continue to remain low (1.1 mg/L in June 2009) and that in the past when the groundwater level increased in the winter there was a concomitant bump in perchlorate concentration; however, this has not occurred for the last two winters, suggesting vadose zone perchlorate has been mostly removed.

Figure 27, the *Seep Well Field Perchlorate Section Graph*, shows that the concentrations from May 2009 are little different from concentrations over the last four quarters with the highest concentrations in wells PC-99R3/R3 and PC-115R. Data from May 2002 are shown for comparison. TDS concentrations for the last four quarters are plotted on Figure 28, the *Seep Well Field Total Dissolved Solids Section Graph*. This figure shows that the highest TDS concentration (4,360 mg/L) is currently in PC-116R.

The monthly perchlorate concentration, as shown on Figure 29, *Seep Area Average Perchlorate Concentration and Mass Removed*, currently averages about 4.9 mg/L. Also shown on this graph is the monthly average perchlorate mass removed which was estimated to be 1,066 pounds in June 2009. This graph shows that decreasing perchlorate concentration is responsible for decreasing perchlorate pounds removed. The seep stream has not flowed since mid-April 2007.

The May 2009 SNWA sampling of five vegetation irrigation wells (plotted on Plate 7) completed in Las Vegas Wash show that these wells all contain less than 3.1 mg/L perchlorate. Well WMW6.15S which contained 45.6 mg/L in June 2002 contained 1.2 mg/L in May 2009; these decreases provide evidence that the in-place recovery systems are functioning well to reduce concentrations of perchlorate in the Las Vegas Wash. As plotted on Plate 7, the 1 mg/L groundwater perchlorate contour is only about 700 feet downgradient of the Pabco structure.

4.2 On-Site Perchlorate Groundwater Treatment System and Remediation

Throughout the reporting period, groundwater was collected and treated in both the Groundwater Treatment Plant (GWTP, for on-site water containing hexavalent chromium) and the biological treatment plant (FBRs, for onsite, Athens Road, and Seep Area collection systems, to remove nitrate, chlorate and perchlorate). Effluent from the biological treatment process was discharged into Las Vegas Wash and stayed within the limits specified in the NPDES NV0023060 discharge permit. With very few exceptions, the effluent has met discharge permit limits. As shown on Table 6, since July 2008 the perchlorate influent to the FBRs has ranged from 118 to 352 mg/L; whereas the effluent discharged to Las Vegas Wash was mostly non-detect at < 0.004 mg/L perchlorate. Routine maintenance is completed as needed at the GWTP and FBRs.

Transfers of perchlorate from the AP-5 pond continued throughout the period. A total of 1,014 tons of perchlorate have been removed from AP-5, which matches the original estimate of about 1,000 tons. Tronox plans to remove the remaining insoluble pond solids and close the AP-5 pond in 2010.

5.0 OTHER MAPPED ANALYTES

5.1 Total Dissolved Solids (TDS)

Plate 8, the *Total Dissolved Solids (TDS) in Groundwater Map: Shallow Water-Bearing Zone*, shows the contoured TDS configuration from the Tronox plant site area to Las Vegas Wash based on data collected in April through June 2009 by Tronox, AMPAC, and SNWA. Prior mapping shows that the Tronox facility is sandwiched between two high TDS zones originating from off-site sources. High TDS on the Tronox site occurs up to 21,100 mg/L in Interceptor well I-T. Between the barrier wall and the Wash there are no TDS concentrations above 12,100 mg/L (ART-2). Figures 11, 17, and 28 show, in section graph format, the distribution of TDS across the Interceptor, Athens Road and Seep well fields, respectively.

5.2 Chlorate

Plate 9, the *Chlorate in Groundwater Map: Shallow Water-Bearing Zone*, shows the contoured chlorate configuration from the Tronox plant site to Las Vegas Wash based on data collected in April through June 2009 by Tronox and AMPAC. The map shows that upgradient of the barrier wall, well M-36 contains the highest chlorate concentration at 7,040 mg/L. Between the barrier wall and the Wash, the chlorate concentration is 741 mg/L (PC-50) along Sunset Road. Concentrations continue to decrease northward toward the Wash. North of the City of Henderson, WRF PC-4 contains 107 mg/L chlorate, suggesting a separate source in the BMI Upper Ponds. The biological treatment plant also destroys chlorate from water treated for perchlorate removal.

5.3 Nitrate

Plate 10, the *Nitrate in Groundwater Map: Shallow Water-Bearing Zone*, shows the contoured nitrate configuration from the Tronox plant site to Las Vegas Wash, based on data collected in April through June 2009 by Tronox, AMPAC, and SNWA. The map shows that upgradient of the barrier wall, well M-37 contains the highest nitrate concentration at 130 mg/L. The two closest downgradient wells north of the barrier wall, M-23 and PC-21A, contain 62 and 34 mg/L, respectively. Concentrations continue to decrease northward toward the Wash. North of the City of Henderson, WRF PC-4 contains 24 mg/L nitrate, suggesting a separate source in the BMI Upper Ponds. The biological treatment plant also destroys nitrate from water treated for perchlorate removal.

6.0 CONCLUSIONS

Chromium concentrations in monitor wells immediately downgradient of the on-site groundwater barrier wall show a marked decline in concentration due to a combination of groundwater capture in the Interceptor well field and dilution by Lake Mead water in the recharge trenches. The north trench has been refurbished and has recently been returned to service. For the 12-month period ending in June 2009, using an average of 13.7 mg/L total chromium and an average groundwater recovery rate of 66.1 gpm, the chromium recovery and treatment system captured about 10.9 pounds of chromium per day for a total of about 3,966 pounds. Adding the 299 pounds of chromium removed by the FBRs for the 12 month period, a total of 4,265 pounds of chromium were removed from the groundwater between July 2008 and June 2009. Ongoing assessment and monitoring will continue during 2009 to monitor capture of the chromium- and perchlorate-impacted groundwater upgradient of the groundwater barrier.

Chromium capture at the Athens Road well field improved with the addition of recovery well ART-9 in the eastern portion of the plume and is expected to show further improvement with the planned re-initiation of pumping from the ART-6 well. Overall recovery of chromium-impacted groundwater in this area has aided in reducing the plume to non-detect levels prior to reaching Las Vegas Wash.

Perchlorate continues to be captured by the four components of the remediation program. The on-site Interceptor well field, coupled with the groundwater barrier wall, provides capture in this on-site area. Since October 2002 the Athens Road area well field has been in continuous operation and is maturing into an efficient interception line. The Seep well field and the seep surface capture make up the remaining portions of the perchlorate recovery system. The Seep well field is advantageously located over the main part of the alluvium channel and is in close proximity to Las Vegas Wash. Capture in this area makes the most immediate impact on Wash perchlorate concentrations. The perchlorate concentration in seep area groundwater is continuing to decrease with minor reversals partly due to periodic groundwater mounding events from the COH WRF. It is anticipated that the impact of continued pumping at the Athens Road well field – especially with ART-9 online – will continue to be observed in the seep area concentrations, modified by discharge activities at COH WRF.

As the ultimate measure of the effectiveness of the combined systems over the last 10 years, one need look no further than the decrease in perchlorate loading in Las Vegas Wash since 1999. In May 1999 the perchlorate loading in the wash was 1,104 pounds per day compared to 61 pounds per day in April 2009, a 94.5 percent drop.

7.0 PROPOSED FUTURE ACTIVITIES

Tronox is committed to utilize the new recovery well in the Interceptor well field as well as "mining" groundwater from the three dead zone wells. In order to capture more groundwater at the Athens Road well field, Tronox will determine how to reactivate recovery well ART-6. Three monitor wells remain to be installed in the Seep well field as part of the Groundwater Capture Work Plan. This work will begin soon after an access agreement is finalized. At the west end of the on-site Interceptor well line borings will be drilled to determine the extent of the recently discovered subsurface alluvial channel, and one additional recovery well will be installed between wells I-B and I-AA.

Tronox will continue to record water levels in the Consent Order and AOC areas. Potentiometric surface maps will be developed as well as chromium and perchlorate in groundwater maps. The effect of changing the pumping rates of the recovery wells will be monitored, and responses (i.e. pump rate adjustments) will be made to ensure optimal drawdown and plume interception at the well fields. Pumping wells will be rehabilitated as necessary. The monitoring plan in current use will be modified, as necessary, to facilitate collection of pertinent data to track the progress of chromium and perchlorate capture at the well fields and the seep.