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S.S. PAPADOPULOS & ASSOCIATES, INC.
ENVIRONMENTAL & WATER-RESOURCE CONSULTANTS

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Hazardous Waste Bureau

June 30, 2015

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Subject: **Sparton Technology, Inc: Former Coors Road Plant Remedial Program 2014 Annual Report**

Gentlemen:

On behalf of Sparton Technology, Inc. (Sparton), S.S. Papadopulos & Associates, Inc. (SSP&A) is pleased to submit the subject report. The report presents data collected at Sparton's former Coors Road Plant during the operation of the remedial systems in 2014, and evaluations of these data to assess the performance of the systems.

We certify under penalty of law that this document and all attachments were prepared under our direction and supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based upon our inquiry of either the person or persons who manage the system and/or the person or persons directly responsible for gathering the information, the information submitted is, to the best of our knowledge and belief, true, accurate, and complete. We further certify, to the best of our knowledge and belief, that this document is consistent with the applicable requirements of the Consent Decree entered among the New Mexico Environment Department, the U.S. Environmental Protection Agency, Sparton Technology, Inc., and others in connection with Civil Action No. CIV 97 0206 LH/JHG, United States District Court for the District of New Mexico. We are aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

If you have any questions concerning the report, please contact us.

Sincerely,

S.S. PAPADOPULOS & ASSOCIATES, INC.

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Founder & Senior Principal

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Sparton Technology, Inc. Former Coors Road Plant Remedial Program

2014 Annual Report

Prepared for:

Sparton Technology, Inc.
Schaumburg, Illinois

Prepared by:

S.S. PAPADOPULOS & ASSOCIATES, INC.
Environmental & Water-Resource Consultants

June 30, 2015

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μg/L	Microgram per liter
COA	City of Albuquerque
Cr	Chromium
DCE	1,1-Dichloroethene
DFZ	Deep Flow Zone below the 4800-foot clay
Fe	Iron
ft	foot or feet
ft MSL	feet above Mean Sea Level
ft/d	feet per day
ft/year	feet per year
ft^3	cubic feet
gal	gallons
gpm	gallons per minute
hrs	hours
in	inch or inches
kg	Kilogram
lb	Pounds
LLFZ	Lower Lower Flow Zone
MCL	Maximum Contaminant Level
Metric	Metric Corporation
mg/L	Milligrams per liter
min	minutes
Mn	Manganese
MNW	Multi-Node Well
MSL	Mean Sea Level
NMED	New Mexico Environment Department
NMWQCC	New Mexico Water Quality Control Commission
NS	Not Sampled
PCE	Tetrachloroethene
Sparton	Sparton Technology, Inc.
SSP&A	S.S. Papadopulos and Associates, Inc.
SVE	Soil Vapor Extraction
TCA	1,1,1-Trichloroethane
TCE	Trichloroethene
UFZ	Upper Flow Zone
ULFZ	Upper Lower Flow Zone
USEPA	United States Environmental Protection Agency

USGS	United States Geological Survey
VOC	Volatile Organic Compound

Section 1
Introduction

The former Coors Road Plant of Sparton Technology, Inc. (Sparton) is located at 9621 Coors Boulevard NW (on the west side of the boulevard), Albuquerque, New Mexico, north of Paseo del Norte and south of the Arroyo de las Calabacillas (see Figure 1.1). Investigations conducted between 1983 and 1987 at and around the plant revealed that on-site soils and groundwater were contaminated by volatile organic compounds (VOCs), primarily trichloroethene (TCE), 1,1,1-trichloroethane (TCA) and 1,1-dichloroethene (DCE), and by chromium, and that contaminated groundwater had migrated beyond the boundaries of the facility to downgradient, off-site areas.

These investigations also indicated that groundwater contamination was primarily within a sandy unit that lies above a 2-4 feet (ft) thick clay unit referred to as the 4,800-ft clay unit. This unit was encountered in every deep well installed during site investigations and in the U.S. Geological Survey (USGS) Hunter Ridge Park 1 Boring about 0.5 mile north of the site. The saturated thickness of the sands above the clay unit is about 160 ft. Beneath the facility, and in an approximately 1,500 ft wide band trending north from the facility, a silty clay unit has been mapped between an elevation of about 4,965 ft above mean sea level (ft MSL) and 4,975 ft MSL. This unit is referred to as the 4,970-ft silt/clay unit. Depending on the depth of their screened interval, wells installed at the site and its vicinity during site investigations, or later, have been referred to as Upper Flow Zone (UFZ) wells if screened across, or within 15 ft of, the water table, Upper Lower Flow Zone (ULFZ) wells if screened 15-45 ft below the water table, Lower Lower Flow Zone (LLFZ) wells if screened more than 45 ft below the water table, and Deep Flow Zone (DFZ) wells if screened below the 4,800-ft clay. The USGS boring also indicates a 15-ft thick clay unit below the DFZ between elevations of 4,705 and 4,720 ft MSL. At the onsite area, the 4,970-ft silt/clay unit separates the UFZ from the ULFZ. Well locations are shown in Figure Figure 1.2 and their screened interval in relation to these flow zones is shown in Figure 1.3.

The predominant contaminants at the off-site areas are VOCs, primarily TCE followed by DCE and TCA. The horizontal extent of these three contaminants prior to the implementation of the remedial measures discussed below, based on data collected in November 1998 from monitoring wells that existed at that time, is shown in Figures 1.4, 1.5, and 1.6.

On March 3, 2000, the United States Environmental Protection Agency (USEPA), the State of New Mexico Environment Department (NMED), the County of San Bernalillo, the City of Albuquerque (COA) and Sparton entered into a Consent Decree that set the terms for addressing soil and groundwater contamination. Under the terms of this Consent Decree, Sparton is currently operating an off-site and a source containment system to address groundwater contamination[1]. The off-site containment system consists of a containment well, CW-1, that fully penetrates the saturated portion of the sand unit above the 4,800-ft clay, a treatment building with an air stripper to treat the pumped water, a pipeline to the nearby Arroyo de las Calabacillas, and an infiltration gallery in the arroyo for returning the treated water to the aquifer (see Figure 1.7). The source containment system also consists of a containment well, CW-2, with a 50-ft screen across the upper part of the sand unit, an on-site treatment building with an air stripper and

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[1] Under the terms of the Consent Decree, Sparton also operated a Soil Vapor Extraction (SVE) system to address on-site soil contamination; this system was operated for a total of about 372 days between April 10, 2000 and June 15, 2001 and was dismantled in May 2002 after data indicated that the requirements and performance goals of the Consent Decree were met.

a chromium removal unit[2] to treat the pumped water, and pipelines to two on-site ponds [3] for returning the treated water to the aquifer (see Figure 1.8).

Based on the horizontal (see Figure 1.4) and the vertical extent of the 1998 TCE plume [see Appendix B to both the 1999 and the 2000 Annual Reports (S.S. Papadopulos & Associates, Inc. [SSP&A], 2001a; 2001b)] and a porosity of 0.3, the initial pore volume of the plume was estimated to be approximately 150 million cubic ft (ft^3), or 1.13 billion gallons, or 3,450 acre-ft. The initial dissolved TCE mass within this pore volume was estimated through the development of the numerical groundwater flow and transport model of the hydrogeologic system underlying the Site. Based on the calibration of this model against 1999 through 2014 water-quality data, the current estimate of the initial TCE mass is about 7,100 kilograms (kg) or 15,700 pounds (lbs). Using this estimate, and ratios of the removed TCE mass to the removed DCE and TCA mass, the initial masses of dissolved DCE and TCA are estimated to be approximately 510 kg (1,120 lbs) and 21 kg (46 lbs), respectively. Thus, the total initial mass of dissolved contaminants is currently estimated to be about 7,630 kg (16,820 lbs).

The off-site containment well began operating on December 31, 1998 and is currently operating at an average pumping rate of about 300 gallons per minute (gpm). The year 2014 constitutes the 16th year of operation of the off-site containment system. The source containment system began operating at an average rate of about 50 gpm on January 3, 2002. Thus, the year 2014 constitutes the 13th year of operation of this system. As discussed in the 2013 Annual Report (SSP&A, 2014), the source containment system was shut down on November 15, 2013 to implement corrective measures for addressing increased chromium concentrations in the pumped water. These corrective measures, which consisted of the addition of a chromium removal unit to the treatment system and of modifications to the plumbing to accommodate this unit, were implemented in early 2014, and the source containment system resumed operations on April 23, 2014.

Between the beginning of the current remedial operations in December 1998 and the end of May 2011, Metric Corporation of Albuquerque (Metric) and then of Los Lunas, New Mexico was responsible for the operation of the remedial systems, the collection of monitoring and system performance data, and for other field activities. After the passing away of Gary Richardson of Metric in May of 2011, SSP&A took over the responsibility for these activities effective June 1, 2011; however, during 2014 these activities were subcontracted by SSP&A to Easterling Consultants, LLC of Albuquerque, New Mexico effective August 1, 2014.

The objectives of the containment systems are:

- To contain and capture contaminated groundwater in the off-site area;
- To contain and capture most of the contaminated groundwater leaving the on-site area;
- To treat the captured water and return it to the aquifer; and
- Achieve ground water standards to the extent required by the terms of the Consent Decree (2000).

The purpose of this 2014 Annual Report is to:

- Discuss problems encountered during the 2014 operation of the systems;

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[2] The original treatment system consisted only of the air stripper; a chromium removal unit was added in early 2014 to address increased chromium concentrations in the influent.

[3] The original design consisted of six infiltration ponds. Based on performance data from these ponds, two ponds were backfilled in late 2005 and another two in early 2014 with the approval of the regulatory agencies.

- Present the data collected during 2014 from operating and monitoring systems; and
- Evaluate the performance of the systems with respect to meeting the above cited objectives, and the requirements of the site's permits.

This report was prepared by SSP&A on behalf of Sparton. In accordance with the June 3, 2013 agreement[4] between the regulatory agencies and Sparton, this 2014 Annual Report also includes an update of the site's numerical groundwater flow and contaminant transport model. Issues related to the year-2014 operation of the off-site and source containment systems are discussed in Section 2. Data collected to evaluate system performance and to satisfy permit or other requirements are presented in Section 3. Section 4 presents evaluations of the data with respect to the performance and the goals of the remedial systems. Information on the update and recalibration of the site's numerical flow and transport model and the results of evaluations made with the model are presented in Section 5. A summary and conclusions of the report and a discussion of future plans are presented in Section 6. Section 7 lists previous reports and documents pertinent to site investigations and activities, including references cited in this report.

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[4] Second Agreement to Modify Schedules for the Completion of the Work under the March 3, 2000 Consent Decree.

Section 2
Systems Operations

2.1 Monitoring Well System

During 2014, water levels were measured in and samples were collected from all monitoring wells that were not dry and had sufficient water during the measurement or sampling event. Water levels were measured quarterly and samples were collected from each well at the frequency specified either in the Groundwater Monitoring Program Plan[5] (Monitoring Plan) and the State of New Mexico Groundwater Discharge Permit DP-1184 (Discharge Permit).

The completion flow zone, location coordinates, and measuring point elevation of all existing wells are presented on Table 2.1; their diameters and screened intervals are summarized on Table 2.2.

2.2 Containment Systems

2.2.1 Off-Site Containment System

The total hours of operation and the downtime for the Off-Site Containment System during the year are summarized on Table 2.3.

2.2.2 Source Containment System

The totals hours of operation and downtime for the Source Containment System during the year are summarized on Table 2.4. As discussed earlier and as shown on Table 2.4, this system was shut down during the early months of 2014 while modifications were being made to the treatment system for the installation of a chromium removal unit. The installation of the chromium removal unit was completed in April 2014 and the system resumed operations on April 23, 2014.

2.3 Problems and Responses

The chromium removal unit installed at the source containment system consists of two resin filled ion exchange tanks assembled in series. Portion of the pumped water is routed through these tanks and then blended with the remainder of the pumped water before going through the air stripper. After the first tank has reached its capacity to exchange with chromium and other ions present in the pumped water, it is replaced with the second tank and a new tank is installed as the second tank. A calibration period followed the installation of the chromium removal unit for determining (a) the percentage of the pumped water that should be routed through the tanks so that the blended water going into the air stripper meets

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[5] Attachment A to the Consent Decree

the New Mexico Water Quality Control Commission (NMWQCC) standard for chromium in groundwater (50 micrograms per liter [μg/L]), and (b) the frequency at which the tank replacement should occur.

During this calibration period adjustments were made to the percentage of the water treated for chromium, and samples were obtained for chromium analyses from the influent to the tanks, between the tanks, the effluent from the second tank, and the effluent from the air stripper that discharges into the ponds. Because of changes in the chromium concentrations of the pumped water, this calibration process took a long time, until September 15, 2014, when chromium concentrations in the influent somewhat stabilized at about 110 μg/L (see Figure 4.23). Several exceedances in the effluent chromium concentrations occurred during this period (see Table 3.7). Based on the data collected, the percentage of the pumped water that must be treated for chromium was established to be 70%, or about 35 gpm, with tank replacement frequency of three week.

With two exceptions on November 3 and 17, 2014 (see Figure 4.23 and Table 3.7), chromium exceedances in the effluent from the air stripper did not occur during the remainder of the year. These November exceedances were attributed to the accumulation of chromium containing sediment in the air stripper, and plans were made for the implementation of additional measures to prevent its recurrence[6].

Chromium exceedances were also observed in pond monitoring wells MW-17 and MW-78. Well MW-17 had been put on a monthly sampling schedule since the observed exceedances in 2013. During 2014, the well could not be sampled until June, because of low water levels caused by the cessation of pond discharge. Monthly sampling since that date indicated that total chromium concentrations in the well continued to exceed the NMWQCC standard throughout the remainder of the year. Dissolved chromium concentrations in these samples, however, were below the NMWQCC standard: this strongly suggests that chromium containing sediments accumulated in the well are the cause of the higher total chromium concentrations[7]. Total chromium exceedances were also observed at well MW-78 in May 2014 and the well was put in monthly sampling effective July 2014. Chromium concentrations in the well, however, declined below the NMWQCC standard in September 2014 and remained below the standard for the remainder of the year.

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[6] This additional measure, consisting of a bag filter installed on the discharge line from the air stripper, was implemented on April 1, 2015.

[7] Experiments with sampling methodology conducted between February and May 2015 indicated that the higher total chromium concentrations in samples from the well were indeed due to the accumulation of chromium containing sediments in the well which were agitated during the purging that preceded the sampling of the well.

Section 3
Monitoring Results - 2014

The following data were collected in 2014 to evaluate the performance of the operating remedial systems and to meet the requirements of the Consent Decree and of the permits for the site:

- Water-level and water-quality data from monitoring wells;
- Data on containment well flow rates; and
- Data on the quality of the influent to and effluent from the water-treatment systems.

3.1 Monitoring Wells

3.1.1 Water Levels

Water levels during 2014 were measured quarterly, in February, May, August and November. During each round of measurements, the depth to water was measured in all monitoring wells that were not dry during the measurement round, the off-site and source containment wells, the two observation wells near CW-1 (see Figure 1.2), and the piezometer installed in the infiltration gallery. The corresponding elevations of the water levels during each of the four measurement rounds, calculated from these data, are summarized on Table 3.1. Selected monitoring well hydrographs are presented in Figure 3.1. As these hydrographs indicate, until the last several years, regional water-levels have been declining due to groundwater production from deeper aquifers and a reduction in the extent of irrigated lands in the vicinity of the Site. During the last several years, however, water-levels appear to have somewhat stabilized and even reversed in trend.

3.1.2 Water Quality

Monitoring wells within and in the vicinity of the plume were sampled at the frequency specified in the Monitoring Plan and the Discharge Permit. The samples were analyzed for VOCs and for total chromium (unfiltered, and occasionally filtered, samples). The results of the analysis of the samples collected from the groundwater monitoring program wells during all sampling events conducted in 2014, and for all of the analyzed constituents, are presented in Table 3.2. The results of the analysis of the samples collected from the infiltration gallery and pond monitoring wells during all sampling events conducted in 2014, are presented in Table 3.3. Concentrations of TCE, DCE, TCA and of chromium that exceed the more stringent of their Maximum Contaminant Levels (MCLs) for drinking water or their maximum allowable concentrations in groundwater set by NMWQCC are highlighted on Tables 3.2 and 3.3.

3.2 Containment Systems

3.2.1 Flow Rates

The volumes of groundwater pumped by the off-site and source containment wells during 2014 and the corresponding flow rates are summarized on Table 3.4.

3.2.2 Influent and Effluent Quality

Concentrations of TCE, DCE, TCA, and of total chromium, iron, and manganese in monthly influent and effluent samples collected from the off-site containment system during 2014 are summarized on Table 3.5. The concentrations of the same constituents in monthly influent and effluent samples collected from the source containment system during 2014 are summarized on Table 3.6. Concentrations of TCE, DCE, TCA and of chromium that exceed the more stringent of their MCLs for drinking water or their maximum allowable concentrations in groundwater set by NMWQCC are highlighted on Tables 3.5 and 3.6.

As discussed earlier, samples for chromium analysis were collected from the influent to the tanks, between the tanks, the effluent from the second tank, and the effluent from the air stripper that discharges into the ponds. Sampling was conducted at different frequencies, initially semi-weekly and then weekly. The chromium concentrations in these samples and in the monthly influent and effluent samples collected from the source containment system during 2014, the flow rates and other data from the treatment plant since installation of the chromium removal unit are summarized on Table 3.7. Chromium concentrations that exceed the NMWQCC of 50 μg/L are highlighted on Table 3.7.

Section 4
Evaluation of Operations - 2014

As stated in the Introduction (Section 1), the objectives of the off-site and source containment systems are:

- To contain and capture contaminated groundwater in the off-site area;
- To contain and capture most of the contaminated groundwater leaving the on-site area;
- To treat the captured water and return it to the aquifer; and
- Achieve ground water standards to the extent required by the terms of the Consent Decree (2000).

This section presents evaluations of the performance of the off-site and source containment systems, based on data collected during 2014, with respect to their meeting the above-stated objectives.

4.1 Hydraulic Containment

4.1.1 Water Levels and Capture Zones

The water-level elevation data presented in Table 3.1 were used to evaluate the performance of both the off-site and source containment wells with respect to providing hydraulic containment for the plume and potential on-site source areas. Maps of the elevation of the on-site water table and of the water levels in the UFZ/ULFZ and the LLFZ during each quarterly round of water-level measurements in 2014 are shown in Figures 4.1 through 4.12. Note that unlike previous years, this year's UFZ/ULFZ and LLFZ water-level maps include the effects of the infiltration gallery on water-levels. Also shown on these water-level maps are: (1) the limit of the capture zones of the containment wells in the UFZ/ULFZ or the LLFZ, as determined from the configuration of the water levels; and (2) the extent of the TCE plume. The extent of the TCE plume shown in Figures 4.1 through 4.9 is based on last year's (November 2013) water-quality data from monitoring wells, and that shown on the water-level maps for November 2014 (Figures 4.10 through 4.12) is based on the November 2014 water-quality data.

The quarterly water levels and the capture zones of the off-site and source containment wells within the UFZ/ULFZ are shown in Figures 4.2, 4.5, 4.8, and 4.11; those within the LLFZ are shown in Figures 4.3, 4.6, 4.9, and 4.12. As shown in these figures, at a pumping rate that averaged about 290 gpm during 2014, the capture zone of the off-site containment well CW-1 extends well beyond the November 2013 or November 2014 extent of the TCE plume and provides an ample safety margin to the hydraulic containment of the off-site plume. The figures also indicate that, despite its lower average pumping rate of 35 gpm for the year, which is due to its shutdown during the first part of 2014, the source containment well CW-2, when operating, contained and captured most of the contaminated groundwater leaving the on-site area.

The direction of groundwater flow and the hydraulic gradient in the DFZ during each quarterly round of the 2014 water-level measurements in the three DFZ wells, MW-67, MW-71R, and MW-79, and for the average water level in these wells are shown in Figure 4.13. During 2014 the direction of groundwater flow in the DFZ ranged from W 5.8° N in November to W 26.1° N in February, and the hydraulic gradient from 0.00219 in May to 0.00279 in February. The average direction of groundwater flow in the DFZ during 2014 was W 19.9° N with an average hydraulic gradient of 0.00238.

4.1.2 Effects of Containment Well Shutdown on Capture

The containment systems are occasionally shut down for maintenance and repairs, and sometimes due to power or equipment failures. For example, during 2014 the off-site containment system was shut down numerous times for relatively short periods due to power outages, repairs and maintenance problems, and included a shutdown of almost a day due to a blown fuse (see Table 2.3). The source containment system did not operate until April, 23, 2014 during the period when modifications were made to the treatment system and the chromium removal unit was installed.

The capture zone of the source containment well lies within the capture zone of the off-site containment well, and its downgradient limit is within the plume area. Any shutdown of this well would cause some contaminants to escape beyond its capture zone, but these contaminants will remain within the capture zone of the off-site containment well and eventually be captured by this well.

Given the distance between the leading edge of the off-site plume and the limits of the capture zone of the off-site containment well, it is highly unlikely that any contaminants would escape beyond the capture zone of the well during a shutdown of limited duration. Under non-pumping conditions, the hydraulic gradient near the leading edge of the plume is about 0.003. The aquifer above the 4800-ft clay has a hydraulic conductivity of 25 feet per day (ft/d) and a porosity of about 0.3. Thus, the rate at which groundwater, and hence contaminants, would move under non-pumping conditions is 0.25 ft/d or about 90 feet per year (ft/yr). The downgradient distance between the limit of the capture zone of the off-site containment well and the leading edge of the plume is more than several hundred feet (see Figures 4.1 through 4.12). Thus, shutdowns of the length that have been experienced in the past, and of even much longer periods, could not cause any contaminants to escape beyond the capture zone of the well. Hydraulic containment of the plume has been, therefore, maintained during any past shutdowns of the off-site containment system, and will continue to be maintained during any future shutdowns of reasonable duration.

4.2 Groundwater Quality in Monitoring Wells

4.2.1 Concentration Trends

Plots showing temporal changes in the concentrations of TCE, DCE, and TCA were prepared for a number of on-site and off-site wells to evaluate long-term water-quality changes at the Sparton site. Plots for on-site wells are shown in Figure 4.14 and plots for off-site wells in Figure 4.15.

The VOC concentrations in the on-site wells (Figure 4.14) indicate a general decreasing trend. In fact, the data from wells MW-9 and MW-16, which have the longest record, suggest that this decreasing trend started before 1983. A significant decrease in concentrations occurred in well MW-16 during 1999 through 2001 when a soil vapor extraction (SVE) system was operating at its vicinity. Since the termination of the SVE operations in 2001, low concentrations have been observed not only in this well but also in all other onsite wells completed above the 4,970-ft silt/clay unit. The lower VOC concentrations measured in these onsite wells indicate that the cleanup of the unsaturated zone beneath the former Sparton plant area by the SVE system, and the flushing provided by the water infiltrating from the infiltration ponds of the source containment system has been very effective in reducing VOC concentrations in the saturated sediments overlying the 4,970-ft silt clay. The higher water levels and steeper horizontal and vertical gradients that have developed at the on-site area due to infiltration from the ponds, however, have apparently mobilized chromium that may have been present in the unsaturated zone and/or within the 4,970-ft silt/clay unit resulting in the higher chromium concentrations that have been observed at some on-site wells and the source containment system influent during the last two years.

The VOC concentration plots of the six off-site monitoring wells shown in Figure 4.15 indicate that concentrations in most wells have declined and are much lower than their pre-remediation levels. The 2014 VOC concentrations in well MW-60 continued to be the highest observed in an off-site well, as it has been the case since the beginning of remedial operations. Note, however, that concentrations in this well have been declining since the mid-2000s; TCE concentrations in the well have declined from 18,000 micrograms per liter (μg/L) in November 2004 to 450 μg/L in November 2014.

Of the three monitoring wells completed in the DFZ, wells MW-67 and MW-79 have been clean since their installation in 1996 and 2006, respectively. The third DFZ well, MW-71R, located about 30 ft south of the MW-60/61 cluster, was installed in February 2002 as a replacement for DFZ well MW-71 which was plugged and abandoned in October 2001 because of contamination[8]. The first sample from MW-71R, obtained in February 2002, had a TCE concentration of 130 μg/L and the well has remained contaminated since then. Concentrations of TCE in the well during quarterly sampling events in 2014 ranged from 54 μg/L to 67 μg/L.

4.2.2 Concentration Distribution and Plume Extent

The Fourth Quarter 2014 TCE and DCE data presented in Tables 3.2 and 3.3 and the average concentrations of these compounds in the CW-1 and CW-2 influent samples from November 3 and November 5 sampling events (see Tables 3.5 and 3.6) were used to prepare concentration distribution maps showing conditions near the end of 2014. The horizontal extent of the TCE and DCE plumes and the concentration distribution within these plumes in November 2014 are shown on Figures 4.16 and 4.17, respectively[9]. Concentrations of TCA in all monitoring and both containment wells have been below regulatory standards since 2003; in November 2014 only the off-site containment well and 2 of the 55 sampled monitoring wells contained TCA above the detection limit of 1 μg/L. The highest TCA concentrations were measured in well MW-52R (1.8 μg/L); the concentrations in the other wells where TCA was detected were less than 1.7 μg/L. Based on the low concentrations of TCA that have been observed since 2003 and with the approval of the agencies, inclusion of a concentration distribution map for TCA and of other evaluations of TCA data in the Annual Reports has been discontinued since the 2011 Annual Report; however, TCA concentrations in the off-site containment well continue to be used in calculations of mass removal by this well.

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[8] See 1999 Annual Report (SSP&A, 2001a) for a detailed discussion of the history of well MW-71, and SSP&A and Metric (2002) for actions taken prior to its plugging and abandonment.

[9] At well cluster locations, the concentrations shown in Figures 4.16 and 4.17 are those for the well with the highest concentration.

4.2.2.1 Changes in Concentrations

A total of 55 monitoring wells and the influent from the two containment wells were sampled in November 2014. Of these 57 wells, 36 are wells that existed in November 1998 (prior to the implementation of the current remedial activities), 7 are replacement or deepened version of wells that existed in November 1998, and the remaining 14 are wells that were installed in later years. Changes between the TCE and DCE concentrations measured in these wells in November 2014 and those measured in November 1998, or during the first sampling event after their installation, are summarized on Table 4.1. Twenty-one of the 57 wells listed on Table 4.1 are wells, or their replacements/deepened versions, that were used for defining both the November 1998 and the November 2014 plume; another 15 are wells that were used to define either the November 1998 or the November 2014 plume. Concentration changes in these 36 wells are presented in Figures 4.18, and 4.19 to show the distribution of concentration changes that occurred since the implementation of the off-site and source containment systems.

As this table and figures indicate, considerable progress has been made towards aquifer restoration. Current concentrations in most, if not all, wells are much lower than those that existed prior to the start of the current remedial operations. The only wells where a significant increase in concentrations occurred are the off-site containment well CW-1, on-site monitoring well MW-19, and off-site monitoring well MW-52R. Increases in CW-1 were to be expected since this well has been drawing water from the entire plume area where higher concentrations existed and continue to exist. The increase in MW-19 is attributed to increased downward leakage through the 4,970-ft silt/clay unit caused by the pond discharge and the resulting increased vertical gradients across this unit where residual contaminants may persist.

4.3 Containment Systems

4.3.1 Flow Rates

A total of about 172.4 million gallons of water, corresponding to an average pumping rate of about 328 gpm, were pumped during 2014 from the off-site and source containment wells (see Table 3.4). The volume of water pumped during each year of the operation of the containment wells is summarized on Table 4.2. The total volume pumped from both wells since the beginning of remedial pumping in December 1998 is about 2.3 billion gallons, and corresponds to an average rate of 276 gpm over the 16 years of operation. This volume represents approximately 205 percent of the initial plume pore volume.

The volume of water pumped from the off-site containment well during 2014 was approximately 154 million gallons and that pumped from the source containment well was 19 million gallons. The corresponding average annual pumping rates were 293 gpm and 35 gpm, respectively, and the average pumping rates during operating hours were about 295 gpm and 52 gpm, respectively.

The total volume of water pumped by the off-site containment well since the beginning of its operation is 2.02 billion gallons, or 179 percent of the plume pore volume; the corresponding numbers for the source containment well are 0.3 billion gallons and 27 percent.

A plot of the volume of water pumped by each well during each month of 2014 and of the total monthly volume is presented in Figure 4.20; a plot of the cumulative volume pumped by the wells since the beginning of their operation is presented in Figure 4.21.

4.3.2 Influent and Effluent Quality

The concentrations of TCE, DCE, TCA, and of total chromium, iron, and manganese in the monthly samples of influent to and effluent from the off-site treatment system during 2014 were presented on Table 3.5; the corresponding concentrations in the monthly samples of influent to and effluent from the source treatment system were presented on Table 3.6. Plots of the TCE, DCE, and total chromium concentrations in the influent to both systems, prepared from these data, are presented in Figure 4.22.

As discussed earlier, the chromium removal system started operation on April 23, 2014. Samples for chromium analysis were collected from the influent to the tanks, between the tanks, the effluent from the second tank, and the effluent from the air stripper that discharges into the ponds. Sampling was conducted at different frequencies, initially semi-weekly and then weekly. The chromium concentrations in these samples and in the monthly influent and effluent samples collected from the source containment system during 2014 are summarized on Table 3.7. Plots of the total chromium concentration in the source containment influent and effluent, prepared from these data, are presented in Figure 4.23.

4.3.3 Contaminant Mass Removal

The monthly and total mass of VOCs removed by the Off-Site Containment System (TCE, DCE and TCA) and the Source Containment System (TCE and DCE) during 2014, calculated from the monthly flow volumes reported on Table 3.4 and the influent concentrations reported on Table 3.5 and 3.6, are summarized on Table 4.3; also shown on this table is the total mass of contaminants removed by both systems.

A total of about 235 kg (519 lbs) of contaminants, consisting of about 210 kg (463 lbs) of TCE, 25.3 kg (55.8 lbs) of DCE, and 0.34 kg (0.75 lbs) of TCA, were removed by the two containment wells during 2014. A plot of the TCE, DCE and total mass removed by the two containment wells during each month of 2014 is presented in Figure 4.24. The total mass of contaminants removed by the two containment wells during each year of their operation is summarized on Table 4.4, and a plot of the cumulative TCE, DCE, and total mass removed by the wells is presented in Figure 4.25. As shown on Table 4.4, the total mass removed by the containment wells, since the beginning of the current remedial operations in December 1998, is about 7,410 kg (16,300 lbs), consisting of about 6,890 kg (15,200 lbs) of TCE, 495 kg (1,090 lbs) of DCE, and 20.4 kg (44.9 lbs) of TCA. This represents about 97 percent of the total dissolved contaminant mass currently estimated to have been present in the aquifer prior to the testing and operation of the off-site containment system.

4.4 Site Permits

The infiltration gallery associated with the off-site containment system and the rapid infiltration ponds associated with the source containment system are operated under a State of New Mexico Groundwater Discharge Permit (DP-1184). This Discharge Permit was originally issued by the Groundwater Bureau of the NMED for a five-year period on June 23, 1998 and renewed for two more five-year periods on December 29, 2006 and on October 18, 2012.

The air stripper associated with the off-site containment system is operated under Air Quality Source Registration No. NM/001/00462/967, issued by the Air Quality Services Section, Air Pollution Control Division, Environmental Health Department, City of Albuquerque, and the source containment system air stripper is operated under Albuquerque/Bernalillo County Authority-to-Construct Permit No. 1203.

The performance of the off-site and source containment systems with respect to the requirements of these permits is discussed below.

4.4.1 Off-Site Containment System

Discharge Permit DP-1184 requires monthly sampling of the treatment system effluent, and the quarterly sampling of the infiltration gallery monitoring wells MW-74, MW-75 and MW-76. The results of these sampling events during 2014 (see Tables 3.3, 3.5,and 3.6) were reported to the NMED Groundwater Bureau in the 2014 Annual Monitoring Report for the permit submitted to the Bureau on February 6, 2013[10].

Calculations of VOC emissions made in June 1999 indicated that the off-site air stripper was in in full compliance with the limits (0.32 pound per hour [lb/hr] or 1.37 tons/yr) specified in Registration No. NM/001/00462/967. Under the terms of the registration, further monitoring and/or reporting of the emissions from the air stripper was not required, and has not been carried out since that time.

No violation notices were received during 2014 for activities associated with the operation of the off-site containment system.

4.4.2 Source Containment System

The rapid infiltration ponds associated with the source containment system are also subject to the above-stated requirements of Discharge Permit DP-1184. The monitoring wells for this system are MW-17, MW-77 and MW-78; the data collected from these wells (see Tables 3.3) were included in the 2014 Annual Monitoring Report for the permit.

As discussed in Section 2.3, a calibration period followed the installation of the chromium removal unit for determining (a) the percentage of the pumped water that should be routed through the tanks so that the blended water going into the air stripper meets the NMWQCC standard for chromium in groundwater, and (b) the frequency at which the tank replacement should occur. During this calibration period adjustments were made to the percentage of the water treated for chromium, and the calibration process was deemed completed on September 15, 2014, when chromium concentrations in the influent somewhat stabilized at about 110 μg/L. Effluent concentrations since calibration have met the NMWQCC standard with the exception of two exceedances which were attributed to the accumulation of chromium containing sediment in the air stripper. Evaluations for additional measures are planned as discussed in Section 2.3.

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[10] Letter to Ms. Naomi Davidson of the Groundwater Bureau, NMED from Stavros S. Papadopulos of SSP&A on the subject "2013 Annual Monitoring Report for Discharge Permit DP-1184."

Chromium concentrations in well MW-78 have been below the New Mexico standard since September 2014, and therefore monthly sampling at that well was discontinued in November 2014, resuming quarterly sampling frequency.

Emissions of VOCs from the source containment system air stripper during 2014 (0.00062 lb/hr or 0.00188 ton/yr) met the requirements of The Authority-to-Construct Permit No. 1203 and were reported to the Albuquerque Environmental Health Department, Air Quality Division in the 2014 Annual Report on Air Emissions which was submitted on February 24, 2015[11].

4.5 Contacts

Under the terms of the Consent Decree[12], Sparton is required to prepare an annual Fact Sheet summarizing the status of the remedial actions, and after approval by USEPA/NMED, distribute this Fact Sheet to property owners located above the plume and adjacent to the off-site treatment plant water discharge pipeline. After the approval of the 2013 Annual Report on September 19, 2014[13] Sparton prepared a 2014 Fact Sheet and submitted it to the USEPA/NMED for approval on October 29, 2014[14]. An approval from the agencies has not received as of the date of this report.

During 2014, the agencies requested from Sparton to split samples of the monthly influent and effluent and of well MW-80 for the purpose of determining dioxane content in the water. This sampling was conducted on November 3rd with the participation of agency personnel. The dioxane concentrations in these samples, as determined by the laboratories used by the regulatory agencies and by Sparton, are summarized on Table 4.5.

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[11] Letter to Regan Eyerman, Health Scientist, Air Quality Division, Environmental Health Department, City of Albuquerque, from Stavros S. Papadopulos of SSP&A on the subject"Authority-to-Construct Permit #1203 - 2014 Annual Report on Air Emissions"

[12] Public Involvement Plan for Corrective Measure Activities. Attachment B to the Consent Decree in Albuquerque v. Sparton Technology, Inc., No. CV 07 0206 (D.N.M.).

[13] Letter from Mr. John E. Kieling of NMED and Mr. Chuck Hendrickson of USEPA to Mr. Ernesto Martinez of Sparton, Re: Approval, 201 Annual Report, Sparton Technology, Inc., EPA ID NO. NMD083212332.

[14] Email from Stavros S. Papadopulos of SSP&A to Chuck Hendrickson of USEPA and Dave Cobrain and Brian Salem of NMED , on the subject of "Sparton Technology Remedial Program - Draft 2013 Fact Sheet".

Section 5
Groundwater Flow and Transport Model

This section describes a numerical groundwater flow and contaminant transport model of the aquifer system underlying the Sparton site and its vicinity that has been used to evaluate water levels and TCE concentrations. This model was developed following the general outline described in Task 3 of the "Work Plan for the Assessment of Aquifer Restoration" (SSP&A, 2000b), which is incorporated as Attachment D in the Consent Decree. The development of the current version of the model is described in detail in the 2008 Annual Report (SSP&A, 2009a). The initial version of the model was described in the 1999 Annual Report (SSP&A, 2001) and the model has been updated and recalibrated several times since then as described in the 2008 Annual Report (SSP&A, 2009a) and in the 2009 report on the Evaluation of Alternative Systems for Aquifer Restoration (SSP&A, 2009b), hereafter "Alternatives Report." In 2013, Sparton proposed to USEPA and NMED that model simulations be performed once every three years, rather than annually, to provide a larger data base for assessing model reliability. The agencies agreed to this proposed change and the parties entered into a formal agreement, which was signed by all three parties by June 3, 2013[15]. The model was recalibrated for the 2014 simulations to represent recent changes in regional groundwater flow conditions, as indicated in upward water-level trends observed at long-term hydrographs of monitoring wells, and observed concentration trends at the recovery wells in recent years.

The groundwater flow model is based on MODFLOW-2000 (Harbaugh and others, 2000). The flow model is coupled with the solute transport simulation code MT3D (Zheng and SSP&A, 1999; Zheng, 2008) for the simulation of the movement of constituents of concern in the aquifer underlying the site, and the particle tracking codes PATH3D (Zheng, 1991) and MODPATH (Pollock, 1994; 2008) for the calculation of capture zones and of areas of origin, respectively. Flow and transport model simulations were performed using updated versions of these codes as developed by SSP&A to enhance their capabilities and address dry-cell issues in particular (Bedekar et al, 2011). The models have been used to simulate groundwater levels and TCE concentrations in the aquifer from start-up of the off-site containment well in December 1998 through December 2014, and to predict water levels and TCE concentrations through December 2015.

5.1 Groundwater Flow Model

5.1.1 Structure of Model

The model area and model grid are presented in Figure 5.1. The overall model dimensions are 15,000 ft by 9,500 ft. The model consists of 88 rows and 133 columns. The central part of the model covers a finely gridded area of 4,900 ft by 2,800 ft which includes the Site and the off-site plume; the grid spacing in this area is uniform at 50 ft. Outward from this central area, the grid spacing is gradually increased to as much as 1,000 feet at the limits of the model domain. The column axis of the model grid is aligned with the approximate direction of regional groundwater flow (W 25° N).

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[15] Second Agreement to Modify Schedules for the completion of the Work under the March 3, 2000 Consent Decree, Agreement signed by John E. Kieling for NMED and by Chuck Hendrickson for USEPA on June 3, 2013, and by Tony Hurst for Sparton on May 24, 2013, in the United States Court for the District of New Mexico, The City of Albuquerque and the Board of County Commissioners of the County of Bernalillo, Plaintiffs v. Sparton Technology, Inc., Defendant, Civil Action No: CIV 97 0206 LH/JHG consolidated with CIV 97 0208 JC/RLP, CIV 97 0210 M/DJS, and CIV 97 0981 LH/JHG.

The model consists of 15 layers. The vertical discretization used in the model is shown in Figure 5.2. Layers 1 through 11 correspond to the surficial aquifer. Layer 1 is 15 ft thick, layer 2 is 5 ft thick, layers 3 through 7 are 10 ft thick each, layers 8 and 9 are 20 ft thick each, and layers 10 and 11 are 40 ft thick each. Layer 12 is a 4-foot-thick unit that represents the 4800-foot clay unit. Layer 13 represents the 76-foot thick deep flow zone, layer 14 represents the 15-foot thick 4705 foot clay unit, and layer 15 represents the upper 165 ft of the deeper aquifer units[16]. The vertical discretization was selected to minimize vertical numerical dispersion.

5.1.1.1 Boundary Conditions

The eastern boundary of the model is a no-flow boundary located just east of the Rio Grande and oriented approximately parallel to the river. The northern and southern boundaries of the model are specified as no-flow boundaries along the eastern portion of these boundaries and as constant head boundaries along the western portion of these boundaries (see Figure 5.1). In the eastern portion of the model area, regional groundwater flow is away from the Rio Grande and approximately parallel to the northern and southern boundaries of the model and thus it is appropriate to specify these portions of the model boundaries as no-flow boundaries. In the western portion of the model area, however, regional groundwater pumping creates a divergence in groundwater flow directions. As a result, in the western portion of the model area the direction of regional groundwater flow is not parallel to the northern and southern model boundaries, and groundwater could flow in or out of the model boundaries; therefore, the western 5,000-foot portions of these boundaries were specified as constant-head boundaries to allow groundwater flow across these boundaries to be simulated (in or out of the model area). The western boundary of the model area is also simulated as a constant-head boundary.

The water levels at the constant head boundaries were estimated during model calibration detailed in the 2011 Annual Report (SSP&A, 2012). As part of that calibration process the water-levels at the constant head boundaries were specified on the basis of five parameters. The five parameters were water levels in 1998 at the following locations: (1) in layer 1 at the eastern end of the constant-head segment of the northern boundary (4,959.47 ft MSL); (2) in layer 1 at the eastern end of the constant head segment of the southern boundary (4,950.63 ft MSL), (3) in layer 1 in the northwest corner of the model grid (4,954.37 ft MSL); (4) in layer 1 in the southwest corner of the model grid (4,948.04 ft MSL); and (5) in layer 1 in the center of the western model boundary (4,951.05 ft MSL). The locations of these constant-head boundary parameters are shown on Figure 5.1. Based on these five water levels, water levels were estimated at all constant-head boundary cells using the following algorithm:

1. The starting 1998 water levels along the constant-head boundaries in layer 1 were calculated by linear interpolation from the 5 water levels described above. Long-term hydrographs of monitoring wells (see Figure 5.3) indicate that water levels near the site were declining due to regional pumping effects until 2011. However, rising trends are observed in recent years. Therefore, the water levels along the model constant-head boundaries were simulated as declining between 1998 and 2011, and as rising after 2011; the rates of decline and rise were determined during model calibration. These calibrated decline rates were 0.4 foot per year for 1998 through 2007, and 1.5 feet per year for 2008 through 2010; the calibrated rise rate was 1.0 foot per year for 2011 through 2015.

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[16] The units represented by Layers 13, 14, and 15 were identified from the log of the USGS Hunter Ridge Park 1 Boring (Johnson and others, 1996).

2. Water levels in constant-head boundary cells in layers 2 through 11 were calculated based on the water levels estimated in layer 1 and a specified vertical hydraulic gradient of 0.002 ft/ft. This vertical hydraulic gradient was assumed to be constant through time.
3. Water levels in constant head cells in layers 12 and 13 were calculated based on the water levels estimated in layer 11 and a specified water-level change of 2.34 across the 4800-foot clay. This water-level change was determined in the model calibration process.
4. Water levels in constant head cells in layers 14 and 15 were calculated based on water levels estimated in layer 13 and a specified water-level change of 2.0 feet across the clay unit represented by layer 14. This water-level change was based on water-level data from the USGS monitoring well cluster at Hunter Ridge adjacent to Arroyo de las Calabacillas.

5.1.1.2 Hydraulic Properties

Five hydrogeologic zones are specified within the model domain:

1. Holocene-aged channel and flood plain deposits, also referred to as Recent Rio Grande deposits;
2. The 4970-foot silt/clay unit, which represents Late-Pleistocene-aged overbank deposits;
3. Sands of the Upper Santa Fe Group, Late-Pleistocene-aged channel and flood plain deposits, and Late-Pleistocene-aged and Holocene-aged arroyo fan and terrace deposits, collectively referred to as the sand unit;
4. The 4800-foot clay unit; and
5. The 4705-foot clay unit.

The sand unit, which is primarily classified as USF2 facies assemblages 2 and 3 (Hawley, 1996), was subdivided into six subzones for purposes of model calibration:

1. Sand unit above the 4970-foot silt/clay unit, except near the far southeastern of the silt/clay unit, which represents Late-Pleistocene-aged arroyo fan and terrace deposits (this zone was defined north of the simulated discontinuity shown on Figure 5.1);
2. Sand unit above the 4970-foot silt/clay unit near the far southeastern extent of this unit (this zone was defined south of the simulated discontinuity shown on Figure 5.1);
3. Sand unit in the region between the western extent of the Rio Grande deposits and the eastern extent of the 4970-foot silt/clay unit (this zone is shown as the "Upper Sand Unit" on Figure 5.1);
4. Sand unit above the 4800-foot clay unit except above and in vicinity of 4970-foot silt/clay unit;
5. Sand unit between the 4800-foot clay unit and the 4705-foot clay unit (model layer 13);
6. Sand unit below the 4705-foot clay unit (model layer 15).

The spatial extent of the Recent Rio Grande deposits, the 4970-foot silt/clay unit, and the Upper Sand Unit are shown in Figure 5.1. Also shown on Figure 5.1 is the location of a discontinuity in the sand unit above the 4970-silt/clay unit. This discontinuity was simulated with the MODFLOW horizontal flow barrier package. The horizontal conductance of the barrier was specified as 10^{-6} per day.

The hydraulic conductivity, specific yield and specific storage in each of the hydrogeologic zones in the calibrated groundwater model are listed on the table below.

Hydrolgeologic Zone		Hydraulic Conductivity, ft/d		Specific Yield	Specific Storage, ft^{-1}	Model Layers in which zone is present
		Horizontal	Vertical			
Recent Rio Grande deposits		150	0.025	0.2	2 x 10^{-5}	1-6
4970-foot silt/clay unit		0.0041	0.00003		2 x 10^{-5}	3
Sand Unit	above 4970-foot silt/clay unit	40	0.2	0.2	2 x 10^{-5}	1
	above 4970-foot silt/clay unit near SE extent	40	0.3	0.2	2 x 10^{-5}	1,2
	between Recent Rio Grande deposits and eastern extent of 4970-foot silt/clay unit (Upper Sand Unit)	120	0.05	0.2	2 x 10^{-5}	1,2
	above the 4800-foot clay unit	25	0.2	0.2	2 x 10^{-5}	3-11
	in Layer 13	23	0.068		2 x 10^{-5}	13
	in Layer 15	22	0.1		2 x 10^{-5}	15
4800-foot clay unit		0.0042	0.00053		2 x 10^{-5}	12
4705-foot clay unit		0.2	0.058		2 x 10^{-5}	14

5.1.1.3 Sources and Sinks

The groundwater sinks in the model domain are the off-site containment well CW-1, the source containment well CW-2, and eight on-site shallow wells (PW-1, MW-18, and MW-23 through MW-28) that were extraction wells for an IM that was implemented in 1988 and operated until November 1999. The off-site containment well has been in operation since December 31, 1998 with a brief shut down in April 1999. The pumping capacity of CW-1 was 225 gpm prior to November 3, 2010 at which time the pumping capacity was increased to 300 gpm. The average annual pumping rate is less than the pumping capacity due to downtime related to system maintenance. Also, the annual-average pumping rate used in the model represents the total pumped volume during the year divided by the number of days in the year, and not the average operating pumping rate. Since 2011, when modeling last was implemented for assessing water levels and TCE concentrations, the average pumping rate was 287 gpm in 2012, 281 gpm in 2013 and 293 gpm in 2014. The pumping at CW-1 is distributed across model layers 6 through 11 and is apportioned based on layer transmissivities[17]. The discharge from well CW-1 to the infiltration gallery is simulated using wells injecting into layer 2. The discharge is distributed across the area of the gallery and is specified at the same rate as the CW-1 pumping rate.

The source containment well, CW-2, began operation in January 2002. The well has operated at an average annual pumping rate of between 31 gpm and 52 gpm. The average pumping rate in 2012 was

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[17] The production wells CW-1 and CW-2 are simulated in MODFLOW with the Multi-Node Well (MNW) package which dynamically allocates production to model layers based on water levels, hydraulic conductivity and layer thickness.

42 gpm, 31 gpm in 2013, and in 35 gpm in 2014. The pumping at CW-2 is distributed across model layers 3 through 8. Ninety-nine percent of the treated water from this well is assumed to infiltrate back to the aquifer from the on-site infiltration ponds based on consumptive use calculations. Only some of the ponds are used for infiltration at any given time; during 2002 the treated discharge from the well was rotated among the six original ponds, in 2003 and 2004 only ponds 1 and 4 were used, and from 2004 to 2013 the discharge was rotated among ponds 1 through 4. In 2014, ponds 1 and 4 were abandoned and only pond 3 was used (see Figure 1.8 for pond locations). In the model, the amount of water directed to each of the ponds was based upon operation records.

The effects of the shallow extraction wells, which were shut down in November 1999, were considered only for the first thirteen months of the simulation period which started in December 1998. The average pumping rate was of the wells during this thirteen-month period 0.24 gpm. Since discharge from the shallow extraction wells was to the city sewer, infiltration of this water was not simulated in the model. Infiltration of precipitation is considered to be negligible due to high evapotranspiration and low precipitation.

Infiltration from the Rio Grande was simulated with the MODFLOW river package. The water level in the Rio Grande was estimated from the USGS 7.5 minute topographic map for the Los Griegos, New Mexico quadrangle and the river-bed conductance was determined as part of the model calibration process. Recharge along the Arroyo de las Calabacillas was simulated with the MODFLOW recharge package. This recharge rate was determined during the model calibration process to be 0.2 ft/year.

5.1.2 Model Simulated Water Levels from 1999 through 2014

The groundwater model was used to simulate groundwater levels in the aquifer system underlying the former Sparton site and its vicinity from December 1998, just prior to the startup of containment well CW-1, until December 2014 for purposes of evaluating correspondence between model calculated and observed water levels. An initial steady-state stress period was used to simulate conditions prior to startup, and this was followed by a month-long stress period for December 1998, and annual stress periods for the years 1999 through 2014. The average annual pumping rates specified for the containment wells CW-1 and CW-2 are based on the pumped volumes presented on Table 4.2.

A total of 1235 water-level targets were used to evaluate the correspondence between model calculated and observed water levels. These targets were developed from average annual water levels for each year from 1998 to 2014 calculated from available water-level data for seventy-six monitoring wells at the Sparton site and four piezometers maintained by the USGS at the Hunters Ridge site located near the infiltration basin on the north side of the Arroyo de las Calabacillas.

The calculated water levels in December 2014 with the calibrated groundwater model for the water table (UFZ), ULFZ, and LLFZ [18] are shown in Figures 5.4, 5.5, and 5.6, respectively. These calculated water levels are similar to observed water levels. The correspondence between observed and model-calculated water levels was evaluated using both qualitative and quantitative measures. The qualitative measures included: (1) the preparation of scatter plots of observed versus calculated water levels to provide a visual comparison of the fit of model to the observed water level data; (2) plots of observed and calculated water levels for the period 1998 through 2014 for each of the monitoring wells and piezometers used for model calibration; (3) maps of the difference between observed and calculated water levels for each of the major aquifer units; and (4) evaluation of model water balance.

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[18] The ULFZ water levels shown on Figure 5.5 are based on model calculated water levels in model Layer 5 and the LLFZ water levels shown on Figure 5.6 are based on model calculated water levels in model Layer 9.

Scatter plots of observed water levels versus calculated water levels between 1998 and 2014 for all monitoring wells in the UFZ above the 4970-foot silt/clay unit (on-site UFZ wells), for all wells in the UFZ, ULFZ and LLFZ, except for those above the 4970-foot silt/clay unit, and for all wells in the DFZ are shown on Figure 5.7. In a model with good correspondence between calculated and observed water levels, the points on the scatter plot are random and closely distributed about the straight line that represents an exact match between the calculated and observed groundwater levels. The scatter plots shown in Figure 5.7 plot the average observed water level in each monitoring well during each year of the simulation against the average water level calculated for each well during each year of the simulation[19]. These scatter plots visually illustrate the excellent comparison between model calculated water levels and observed water levels in the UFZ/ULFZ/LLFZ and DFZ zones. In the on-site UFZ the correspondence between observed and calculated water levels is not as good as in the other zones. This is the result of significant heterogeneity in the sands above the 4970-foot silt/clay unit.

Plots of observed versus calculated water levels at all monitoring wells and piezometers used are shown in Appendix A on Figures A-1, A-2, and A-3. These plots indicate that the water-level trends in the observed and calculated water levels are very similar at almost all monitoring wells illustrating the close correspondence between observed and calculated water levels. The areal distribution of residuals in the on-site UFZ, the UFZ/ULFZ/LLFZ and the DFZ in 2014 are shown in Appendix A on Figures A-4, A-5 and A-6, respectively. An evaluation of these figures indicates that the spatial distribution of residuals is relatively random.

The model water balance was compiled for 1998, 2001, 2011, and 2014 to evaluate the reasonableness of groundwater flows within the model domain. The water balance consists of water inflows into the model domain, groundwater outflow from the model domain, and changes in groundwater storage within the model area. Water inflows consist of infiltration from the Rio Grande, recharge along the Arroyo de las Calabacillas, and infiltration from the infiltration gallery and the on-site infiltration ponds. Groundwater outflows consist of groundwater pumping from containment wells CW-1 and CW-2 and groundwater flow out of the model domain across the constant-head boundaries. The average annual water balances for 1998, 2001, 2011 and 2014 are summarized below[20]:

	Component	1998	2001	2011	2014
Inflows, in gpm	Change in Storage (net)	0	80	9	-162
	Infiltration from Gallery and Ponds	0	216	335	328
	River Infiltration	1181	1232	1404	1358
	Recharge	7	7	7	7
	Total Inflows	**1188**	**1535**	**1755**	**1693**
Outflows, in gpm	Containment Wells	0	216	335	328
	Constant Head (net)	1188	1319	1420	1203
	Total Outflows	**1188**	**1535**	**1755**	**1693**

Total water inflows and outflows from the model area are perfectly balanced. The changes through time in inflows from storage and the river and outflows from constant heads are the result of changes in regional pumping.

The quantitative evaluation of the model simulation consisted of examining the difference between the 1235 average annual water levels observed in the monitoring wells and piezometers at the former

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[19] Observed water levels were compared to calculated water levels in the model layer corresponding to the location of the screened interval of the monitoring well. When the screened interval of a monitoring well spanned more than one model layer, the observed water levels were compared to the transmissivity weighted average of the calculated water levels in the layers penetrated by the well.

[20] The calculated inflows and outflows in 1998 and 2001 are slightly different than those reported in the 2009 Annual Report. These differences are the result of using a new version of MODFLOW that handles dry cells more efficiently (Bedekar and others 2012).

Sparton site and its vicinity and the corresponding calculated water levels for these monitoring wells. The difference between an observed and a measured water level is called a residual. Three statistics were calculated for the residuals to quantitatively describe the model calibration: the mean of the residuals, the mean of the absolute value of the residuals, and the root mean-squared error[21]. The mean of all the residuals is -0.39 ft, the mean of the absolute value of the residuals is 1.16 ft, and the root mean-squared error is 1.6. The minimum residual is -9.2 ft and the maximum residual is 6.0 ft, both for on-site monitoring wells. The absolute mean residual of 1.16 ft is considered acceptable since the observed water-level measurements applied as calibration targets have a total range of about 39.7 ft, and seasonal fluctuations of water levels are on the order of several feet. The quantitative statistics based on the monitoring wells in the major flow zones are listed below:

Flow Zone	Count	Mean Residuals	Absolute Mean Residual	Root-Mean Squared Error	Minimum Residual	Maximum Residual
On-Site UFZ	282	-0.24	1.96	2.69	-9.19	5.99
UFZ/ULFZ/LLFZ	879	-0.48	0.95	1.3	-8.42	3.64
DFZ	74	0.24	0.54	0.69	-1.02	2.06

The qualitative and quantitative evaluations of the comparisons between observed and model calculated water levels indicate that the groundwater model is a reliable simulator of existing conditions.

5.1.3 Capture Zone Analysis

The capture zones of containment wells CW-1 and CW-2 at the water table (UFZ), and in the ULFZ and LLFZ were calculated by applying particle tracking to the calculated average 2014 water levels in these horizons of the aquifer (Figures 5.4, 5.5, and 5.6), assuming that these water levels represented a steady-state condition. The particle tracking was carried out using the PATH3D computer code (Zheng, 1991), and by releasing particles at one-foot intervals along a line upgradient from both containment wells, and near and parallel to Rio Grande (along column 129 of the model grid shown in Figure 5.1). The calculated capture zones of containment wells CW-1 and CW-2 in the UFZ (water table), the ULFZ, and the LLFZ are presented in Figures 5.4, 5.5, and 5.6, respectively. Also shown in these figures is the extent of the TCE plume in November 2014.

Particle tracking analysis was also used to determine the aquifer area where the water extracted at CW-1 between 1999 and 2014 was located at the start of extraction in 1998 and where the water extracted at CW-2 between 2002 and 2014 was located at the start of extraction in January 2002 (the "areas of origin"). This particle tracking analysis was carried out using the MODPATH computer code (Pollock 1994, 2008); particles were released on a twenty foot grid at the top of each model layer throughout the model domain, and keeping track of those particles that discharged at CW-1 and CW-2. The results of this analysis are shown on Figure 5.8 in both map [Figure 5.8 (a)] and cross-section view [Figure 5.8 (b)]. The outlines of the areas of origin of the water pumped during different time periods [Figure 5.8 (a)] represent the outer boundary of the envelope of particle traces that discharged at each of the wells during that period.

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[21] The root mean-squared error is defined as

$$RSME = \left[\frac{1}{N}\sum_{i=1}^{N} R_i^2\right]^{1/2}$$

where N is the number of calibration targets, and R is the residual. The root mean-squared error is close to the standard deviation when the mean error is small and the number of targets is large.

The travel time from the center of the Sparton property (a point near monitoring well MW-26) to the source containment well CW-2, and the travel time from a point downgradient from and outside the capture zone of CW-2 to the off-site containment well CW-1 were estimated using the particle-tracking method. These travel times were calculated as 1.4 and 13 years, respectively[22]. This calculation assumed that both the off-site and the source containment wells are operating continuously at their current pumping rates (293 gpm at CW-1 and 35 gpm at CW-2) and that 2014 water level conditions exist throughout a 15-year period. The calculated travel time to the off-site containment well CW-1 was longer than the travel time reported in 2011, despite having a larger pumping rate compared to 2011 (284 gpm) as a result of implementing the increasing trend in regional and water levels, observed in recent years, in the downgradient constant-head boundary condition.

5.2 Solute Transport Model

A solute transport model is linked to the groundwater flow model to simulate the concentration of TCE in groundwater at the site. The three-dimensional contaminant transport simulation code MT3D (Zheng, 2008; Zheng and SSP&A, 1999) was applied for this study. The model was used to simulate TCE concentrations in the aquifer from December 1998 through December 2015.

Model input parameters were specified based on available data. The TCE concentrations in the model domain at the start of the simulation period were estimated from the maximum measured concentration data in 1998. The model was used only to predict TCE concentrations in the aquifer and no attempt was made to simulate DCE and TCA. Generally, DCE is detected at monitoring wells where TCE is detected, but DCE concentrations are much lower than TCE concentrations. During 2014, DCE was about 11 percent of the total mass of chlorinated volatile organic compounds extracted by CW-1 and less than 1 percent of that extracted by CW-2.

The other constituent of concern, TCA, had been historically detected at concentrations greater than the 60 μg/L maximum allowable concentration in groundwater set by the NMWQCC, primarily in monitoring wells at the facility; prior to 2003 TCA had been detected at levels above 60 μg/L in only one off-site well, MW-46. The concentrations of TCA have been below 60 μg/L since 2003; the maximum TCA concentration reported this year was 1.8 μg/L at MW-52R. The limited distribution of TCA and the reduction in its concentrations are the result of the abiotic transformation of TCA to acetic acid and DCE; a transformation that occurs relatively rapidly when TCA is dissolved in water. Only about 20 percent of TCA degrades to DCE, the rest degrades to acetic acid (Vogel and McCarty, 1987). The current concentrations of TCA and DCE in monitoring wells indicate that the amount of TCA available for degradation has been greatly reduced and that, therefore, significant increases in DCE would not be expected to occur in the future as the result of TCA degradation.

5.2.1 Transport Parameters

A number of aquifer and chemical properties are required as input parameters for the contaminant transport simulation. The required aquifer properties are porosity, bulk density, and dispersivity. The required chemical property is the retardation coefficient, which is a function of the fraction organic carbon, the organic-carbon partition coefficient for the organic compound being simulated, and the effective diffusion coefficient. The effective porosity was 0.3 in all geologic units and dispersivity was set to zero. The retardation coefficient for TCE was specified as unity in all geologic units. In previous years,

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[22] This travel time is the travel time for ground water, and should not be construed as the time at which contaminants will migrate over the same distance; travel time for contaminants would be different due to dispersion and other factors that affect contaminant migration.

a retardation coefficient of 4.3 was specified for the 4970-foot silt/clay unit. In the model calibration conducted in 2011, it was determined that the model with a retardation coefficient of unity provided just as good a calibration as with a retardation coefficient of 4.3; therefore, for simplicity a retardation coefficient of unity was also specified for this unit.

5.2.2 Initial Concentration Distribution and Model Calibration

The transport model has been calibrated for each annual report since 1999, except for the 2006 annual report, by adjusting the TCE concentrations in the aquifer in 1998 prior to startup of the groundwater remediation systems; these concentrations are referred to as the model's initial concentration distribution. The calibration process consisted of adjusting the initial TCE concentration distribution in the aquifer in a manner consistent with available data until a reasonable match was obtained between the calculated and measured TCE concentrations at containment wells CW-1 and CW-2, and the calculated and measured TCE mass removal by these two wells throughout their respective period of operation. The approach used in determining the initial concentration distribution has varied through time. In the last major recalibration of the transport model, which is described in the Alternatives Report, the initial concentration distribution was interpolated based on the November 1998 measured concentration data and a number of the pilot points along the center line of the plume using three-dimensional kriging. The parameter estimation program PEST (Doherty, 2006) was used to estimate TCE concentrations at the pilot points, the containment wells and especially well CW-2.

The initial TCE concentration distribution was redeveloped this year to provide a better representation of observed concentrations at the containment wells. The initial concentration distribution was interpolated considering maximum measured concentration data in 1998. Mass loading in Model Layer 2 above the 4970-ft clay, starting in 2002 and decreasing after that, was implemented to represent potential mobilization of residual free product due to discharge of the effluent water from the source containment system into the ponds. This calibration process resulted in excellent agreement between observed and calculated TCE mass removal from containment wells CW-1 and CW-2, and between observed and calculated TCE concentrations at these two wells, as shown in Figure 5.9.

The initial TCE mass in the aquifer, estimated from the initial TCE concentration distribution in the recalibrated model, is 7,100 kg (15,656 lbs). This estimated initial mass has changed little since the 2009 recalibration of the model described in the Alternatives Report[23]. The distribution of this mass among the model layers, and the corresponding maximum TCE concentrations within each layer are summarized on Table 5.1.

5.2.3 Model Calculated TCE Mass Removal Rates and Concentration

The measured cumulative amount of TCE removed by operation of the on-site and off-site containment systems through the end of each year since 1999 and the model calculated amount of TCE removed are tabulated below:

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[23] Initial mass estimates during nine previous model calibrations increased from 2,180 kg (4,810 lbs) in 1999 to 7,340 kg (16,780 lbs) in 2003 and it has fluctuated within a relatively narrow margin since then.

	Cumulative TCE Mass Removed (kg)					
	CW-1		CW-2		Total	
Year	Measured	Calculated	Measured	Calculated	Measured	Calculated
1999	359	326			359	326
2000	821	761			821	761
2001	1,340	1,298			1,340	1,298
2002	1,884	1,871	60	60	1,944	1,931
2003	2,452	2,459	108	109	2,560	2,568
2004	3,018	3,031	137	138	3,155	3,169
2005	3,558	3,591	155	156	3,713	3,747
2006	4,057	4,089	169	170	4,226	4,259
2007	4,513	4,557	181	181	4,694	4,738
2008	4,938	4,975	189	190	5,127	5,165
2009	5,310	5,348	195	196	5,505	5,544
2010	5,615	5,681	199	200	5,814	5,881
2011	5,963	6,017	203	204	6,166	6,221
2012	6,245	6,282	205	206	6,450	6,488
2013	6,476	6,482	207	207	6,683	6,689
2014	6,684	6,635	208	208	6,892	6,843

The total TCE removed through the end of 2014 is 6,892 kg; this amount is about 97 percent of the amount of TCE estimated to have been in the aquifer in 1998. The model calculated total TCE removal is about the same, 6,843 kg.

The average annual measured and model calculated concentrations in the water pumped from CW-1 and CW-2 through the end of each year since 1999 are tabulated below:

	Average Annual TCE Concentration (μg/L)			
	CW-1		CW-2	
Year	Measured	Calculated	Measured	Calculated
1999	829	750		
2000	1,055	1,008		
2001	1,205	1,250		
2002	1,225	1,300	723	624
2003	1,275	1,316	473	477
2004	1,317	1,331	301	297
2005	1,217	1,257	191	180
2006	1,166	1,174	152	157
2007	1,050	1,057	130	119
2008	982	962	90	93
2009	869	863	64	67
2010	703	766	52	49
2011	615	598	35	37
2012	506	464	31	26
2013	418	357	25	18
2014	356	263	23	15

As these tables and Figure 5.9 indicate, there is very good agreement between the observed and the model calculated amounts of TCE mass removed by each containment well, and between the observed and model calculated TCE concentrations in the water pumped by these wells.

A comparison of calculated to observed concentrations of TCE at all monitoring wells for all samples analyzed between November 1998 and November 2014 is presented in Figure 5.10. Also presented in Figure 5.10 is a comparison of calculated to observed concentrations of TCE for only those samples analyzed in November 2014 on which the individual data points are labeled with the well number. The general agreement between observed and computed concentrations is reasonable given the uncertainty of the initial contaminant distribution. Plots of calculated and observed TCE concentrations at selected monitoring wells during the period 1998 through 2014 are shown in Appendix A on Figure A-7. The calibrated initial TCE plume (November 1998), and model calculated TCE plumes for November 2003, 2008, 2011, and 2014 are presented in Figure 5.11; the concentration contours shown on this figure are based on the maximum TCE concentration simulated in any layer.

5.3 Simulation of TCE Concentrations in 2015

The groundwater model was used to forecast TCE concentrations in the aquifer and the mass extracted from CW-1 and CW-2 from January through December 2015. The predicted TCE concentration distribution in December 2015, based on the maximum TCE concentration simulated in any layer, is presented in Figure 5.12. The predicted December 2015 TCE concentration at CW-1 is 187 μg/L, and that at CW-2 is 12 μg/L.

Section 6
Conclusions and Future Plans

6.1 Summary and Conclusions

During 2014, considerable progress was made towards achieving the goals of the remedial measures:

- The off-site containment well operated 99.3 percent of the time available in 2014 at an average rate of 295 gpm and maintained hydraulic containment of the off-site plume.
- The concentrations of constituents of concern in the water treated at the off-site containment system met all the requirements of the Discharge Permit for the site.
- The source containment well operated only 68.6 percent of the time available in 2014. During its operating hours the average pumping rate of the well was about 52 gpm, and the well contained most of contaminated groundwater leaving the on-site area.
- The treated water from both systems was returned to the aquifer through the infiltration gallery in the Arroyo de las Calabacillas and the on-site infiltration ponds.
- Groundwater monitoring was conducted as specified in the Monitoring Plan and the Discharge Permit.
- Water levels in all accessible wells and/or piezometers were measured quarterly. Samples were collected for water-quality analyses from monitoring wells at the frequency specified in the Monitoring Plan and analyzed for VOCs and total chromium.
- Samples were obtained from the influent and effluent of the treatment plants for the off-site and source containment systems, and the infiltration gallery and infiltration pond monitoring wells at the frequency specified in the Discharge Permit. All samples were analyzed for VOCs, total chromium, iron, and manganese.
- Changes in concentrations observed in monitoring wells since the implementation of the current remedial measures indicate that VOC concentrations decreased significantly both in the on-site and off-site area.
- A total of about 172.4 million gallons of water were pumped from the wells. The total volume of water pumped since the beginning of the current remedial operations on December 1998 is about 2.3 billion gallons and represents 205 percent of the initial volume of contaminated groundwater (pore volume).
- A total of about 235 kg (519 lbs) of VOCs were removed from the aquifer by the two containment wells during 2014. The total VOC mass that was removed since the beginning of the of the current remedial operations through the end of 2014 is about 7,410 kg (16,300 lbs), and represents about 97 percent of the total dissolved VOC mass estimated to have been initially present in groundwater.
- The groundwater flow and solute transport model was recalibrated including data from the last three years since it was last updated, to represent recent changes in regional groundwater flow conditions and observed concentration trends at the recovery wells in recent years. Implementation of an updated initial concentration distribution and solute migration patterns in the aquifer resulted in excellent agreement between measured and calculated concentrations at both recovery wells.

6.2 Future Plans

The containment systems will continue to operate during 2015 at a pumping rate as close as possible to their current design pumping rates of 300 and 50 gpm for the off-site and source containment system, respectively.

Evaluations of chromium data will continue to determine whether elevated influent concentrations to the source containment system are a long term problem and whether an alternative treatment system is required.

Chromium exceedances in the source containment effluent will be addressed by installing a bag filter at the air stripper discharge line to eliminate occasional sediment-related chromium exceedances in the effluent discharged into the pond[24].

Potential alternatives to the discharge ponds will be evaluated to determine whether mobilization of chromium due to discharge of the effluent water from the source containment system into the ponds can be reduced by implementing an alternative discharge method.

Evaluation of chromium containing sediment as the cause of chromium exceedance in well MW-17 will be performed by (a) investigating whether well development would reduce or eliminate the effects of sediment in the well on total chromium concentrations, and (b) sampling conducted under different conditions using double check valve bailers, with samples collected prior to purging the well, after purging the well, and a day after the purging of the well[25].

Data collection will continue in accordance with the Monitoring Plan and the Discharge Permit, and as necessary for the evaluation of the performance of the remedial systems. Monitoring wells MW-7 and MW-9, which did not provide reliable water-level measurements in 2014 and did not contain sufficient water for sampling, will be abandoned and will be replaced with a two-well cluster near the MW-7 location with one well open to the aquifer above the 4970-ft clay and the other well open below the clay, upon approval of this report by the agencies.

The groundwater flow and solute transport model will be updated in three years using a larger data base for assessing model reliability and evaluating contaminant migration patterns and mass recovery.

The USEPA and the NMED will continue to be kept informed of any significant milestones or changes in remedial system operations. The goal of the systems will continue to be the return of the contaminated groundwater to beneficial use.

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[24] The bag filter was installed on April 1, 2015.

[25] These evaluations were conducted between February and May 2015. The results indicated that the higher total chromium concentrations in the well were due to chromium containing sediments which were agitated by the purging that precedes normal sampling procedures. Samples collected prior to purging or one or more days after purging had lower total chromium concentrations. Dissolved chromium concentrations in all samples, regardless of whether they were collected prior to, immediately after or one or more days after purging, were essentially the same, about 40 μg/L.

Section 7
List of Reports and Documents

Black & Veatch. 1997. Report on Soil Gas Characterization and Vapor Extraction System Pilot Testing. Report prepared for Sparton Technology, Inc. June.

Bedekar, V., Niswonger, R. G., Kipp, K., Panday, S. and Tonkin, M. 2012. Approaches to the Simulation of Unconfined Flow and Perched Groundwater Flow in MODFLOW. Ground Water, 50 (2), pp. 187-198.

Bexfield, L.M., and S. K. Anderholm. 2002. Estimated Water-Level Declines in the Santa Fe Group Aquifer System in the Albuquerque Area, Central New Mexico, Predevelopment to 2002: U.S. Geological Survey Water-Resources Investigations Report 02-4233.

Chandler, P.L., Jr. 2000. Vadose Zone Investigation and Implementation Workplan. Attachment E to the Consent Decree. City of Albuquerque and The Board of County Commissioners of the County of Bernalillo v. Sparton Technology, Inc. U.S. District Court for the District of New Mexico. Civil Action No. CIV 97 0206. March 3.

Chandler, P.L., Jr. and Metric Corporation. 2001. Sparton Technology, Inc., Coors Road Plant Remedial Program, Final Report on the On-Site Soil Vapor Extraction System. Report prepared for Sparton Technology, Inc. in association with S.S. Papadopulos & Associates, Inc. November 29.

Consent Decree. 2000. City of Albuquerque and the Board of County Commissioners of the County of Bernalillo v. Sparton Technology, Inc. U.S. District Court for the District of New Mexico. CIV 97 0206. March 3.

Doherty, J. 2006. PEST: Model Independent Parameter Estimation. Version 11.8. Queensland, Australia: Watermark Numerical Computing.

Harbaugh, A.W., E. Banta, M. Hill, and M. McDonald. 2000. MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model-User Guide to Modularization Concepts and the Ground-Water Flow Process. U.S. Geological Survey Open-File Report 00-92. Reston, Virginia.

Harding Lawson Associates. 1983. Groundwater Monitoring Program, Sparton Southwest, Inc. Report prepared for Sparton Corporation. June 29.

Harding Lawson Associates. 1985. Hydrogeologic Characterization and Remedial Investigation, Sparton Technology, Inc. 9261 Coors Road Northwest, Albuquerque, New Mexico. Report prepared for Sparton Technology. March 13.

Harding Lawson Associates. 1992. RCRA Facility Investigation. Report revised by HDR Engineering, Inc. in conjunction with Metric Corporation. Report prepared for Sparton Technology, Inc. May 1.

Hawley, J.W. 1996. Hydrogeologic Framework of Potential Recharge Areas in the Albuquerque Basin, Central New Mexico. New Mexico Bureau of Mines and Mineral Resources, Open-File Report 402D, Chapter 1.

HDR Engineering Inc. 1997. Revised Final Corrective Measure Study. Report revised by Black & Veatch. Report prepared for Sparton Technology, Inc. March 14.

Johnson, P.S., S.D. Connell, B. Allred, and B.D. Allen. 1996. Field Boring Log Reports, City of Albuequerque Piezometer Nests (Sister City Park, Del Sol Dividers, Hunters Ridge Park 1, West Bluff Park, Garfield Park. New Mexico Bureau of Mines and Mineral Resources, Open-File Report 426, 126 p.

Metric Corporation, 2005, Sparton Technology, Inc., Former Coors Road Plant Remedial Program, Request to Modify Approved Source Containment System Workplan, April 22.

Pollock, D. W. 2008. MODPATH Version 5.0: A Particle Tracking Post-Processing for MODFLOW 2000 and MODFLOW 2005. USGS Website. Water.usgs.gov/nrp/gwsoftware/modpath5.

Pollock, D.W. 1994. UserâĂŹs Guide for MODPATH/PODPATH-Plot, Version 3: A Particle Tracking Program for MODFLOW. USGS Open-file Report 94-464.

S.S. Papadopulos & Associates Inc. 1998. Interim Report on Off-Site Containment Well Pumping Rate. Report prepared for Sparton Technology, Inc. December 28.

S.S. Papadopulos & Associates Inc. 1999a. Report on the Installation of On-Site Monitoring Wells MW-72 and MW-73. Report prepared for Sparton Technology, Inc. April 2.

S.S. Papadopulos & Associates Inc. 1999b. Groundwater Investigation Report: Performance Assessment of the Off-Site Containment Well, Sparton Technology, Inc. Report prepared for Sparton Technology, Inc. August 6.

S.S. Papadopulos & Associates Inc. 2000a. Work Plan for the Off-Site Containment System. Attachment C to the Consent Decree. City of Albuquerque and The Board of County Commissioners of the County of Bernalillo v. Sparton Technology, Inc. U.S. District Court for the District of New Mexico. CIV 97 0206. March 3.

S.S. Papadopulos & Associates Inc. 2000b. Work Plan for the Assessment of Aquifer Restoration. Attachment D to the Consent Decree. City of Albuquerque and The Board of County Commissioners of the County of Bernalillo v. Sparton Technology, Inc. U.S. District Court for the District of New Mexico. CIV 97 0206. March 3.

S.S. Papadopulos & Associates Inc. 2000c. Work Plan for the Installation of a Source Containment System. Attachment F to the Consent Decree. City of Albuquerque and The Board of County Commissioners of the County of Bernalillo v. Sparton Technology, Inc. U.S. District Court for the District of New Mexico. CIV 97 0206. March 3.

S.S. Papadopulos & Associates Inc. 2001a. Sparton Technology, Inc., Coors Road Plant Remedial Program, 1999 Annual Report. Report prepared for Sparton Technology, Inc. in association with Metric Corporation and Pierce L. Chandler, Jr. Original issue: June 1, 2000; Modified issue: February 9.

S.S. Papadopulos & Associates Inc. 2001b. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, 2000 Annual Report. Report prepared for Sparton Technology, Inc. in association with Metric Corporation. May 17.

S.S. Papadopulos & Associates Inc. 2002. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, 2001 Annual Report. Report prepared for Sparton Technology, Inc. in association with Metric Corporation. May 7.

S.S. Papadopulos & Associates Inc. 2003. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, 2002 Annual Report. Report prepared for Sparton Technology, Inc. in association with Metric Corporation. May 16.

S.S. Papadopulos & Associates Inc. 2004. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, 2003 Annual Report. Report prepared for Sparton Technology, Inc. in association with Metric Corporation. May 28.

S.S. Papadopulos & Associates Inc. 2005. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, 2004 Annual Report. Report prepared for Sparton Technology, Inc. in association with Metric Corporation. May 31.

S.S. Papadopulos & Associates Inc. 2006. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, 2005 Annual Report. Report prepared for Sparton Technology, Inc. in association with Metric Corporation. May 31.

S.S. Papadopulos & Associates Inc. 2007. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, 2006 Annual Report. Report prepared for Sparton Technology, Inc. in association with Metric Corporation. May 30.

S.S. Papadopulos & Associates Inc. 2008. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, 2007 Annual Report. Report prepared for Sparton Technology, Inc. in association with Metric Corporation. May 29.

S.S. Papadopulos & Associates Inc. 2009a. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, 2008 Annual Report. Report prepared for Sparton Technology, Inc. in association with Metric Corporation. June 11.

S.S. Papadopulos & Associates Inc. 2009b. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, Evaluation of Alternative Systems and Technologies for Aquifer Restoration. Report prepared for Sparton Technology, Inc. November 25, corrected December 3.

S.S. Papadopulos & Associates Inc. 2010. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, 2009 Annual Report. Report prepared for Sparton Technology, Inc. in association with Metric Corporation. June 11.

S.S. Papadopulos & Associates Inc. 2011a. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, 2010 Annual Report. Report prepared for Sparton Technology, Inc. in association with Metric Corporation. June 20.

S.S. Papadopulos & Associates Inc. 2011b. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, Work Plan for Plugging and Abandoning Three Monitoring Wells and for Installing a Replacement Well. Report prepared for Sparton Technology, Inc., and transmitted to USEPA and NMED on November 22.

S.S. Papadopulos & Associates Inc. 2012. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, 2011 Annual Report. Report prepared for Sparton Technology, Inc. June 29.

S.S. Papadopulos & Associates Inc. 2013. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, 2012 Annual Report. Report prepared for Sparton Technology, Inc. June 28.

S.S. Papadopulos & Associates Inc. 2014. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, 2013 Annual Report. Report prepared for Sparton Technology, Inc. May 20, 2014.

S.S. Papadopulos & Associates Inc., and Metric Corporation. 2002. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, Results of Investigation Conducted in Monitoring Well MW-71. Report prepared for Sparton Technology, Inc. January 9.

S.S. Papadopulos & Associates Inc., and Metric Corporation. 2004a. Sparton Technology, Inc., Former Coors Road Plant Remedial Program Work Plan for the Proposed MW-71R Pump-and-Treat System. Report prepared for Sparton Technology, Inc., and transmitted to USEPA and NMED on January 14.

S.S. Papadopulos & Associates Inc., and Metric Corporation. 2004b. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, Work Plan for Installing a Monitoring/Standby-Extraction Well in the Deep Flow Zone. Report prepared for Sparton Technology, Inc., and transmitted to USEPA and NMED on December 6.

S.S. Papadopulos & Associates Inc., and Metric Corporation. 2010. Sparton Technology, Inc., Former Coors Road Plant Remedial Program, Work Plan for Installing Monitoring Well MW-80. Report prepared for Sparton Technology, Inc., and transmitted to USEPA and NMED, original issue May 4, revised issue May 25.

Vogel, T.M., and P.L. McCarty. 1987. Abiotic and Biotic Transformations of 1,1,1-Trichloroethane under Methanogenic Conditions: Environmental Science & Technology 21: 1208-1213.

Zheng, C. 1991. PATH3D, A Groundwater and Travel-Time Simulator. Version 3.2. Bethesda, Maryland: S.S. Papadopulos & Associates, Inc.

Zheng, C. 2008. MT3DMSU5.2, A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion and Chemical Reactions, Supplemental Users Guide. Prepared for U.S. Army Corps. of Engineers.

Zheng, C., and S.S. Papadopulos & Associates Inc. 1999. MT3D99, A Modular, Three-Dimensional Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems. Bethesda, Maryland: S.S. Papadopulos & Associates, Inc.