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1. Introduction

This report prepared by Daniel B. Stephens & Associates, Inc. (DBS&A) presents the field methods and results of the 2009 groundwater monitoring event conducted for Basic Remediation Company (BRC) at the BMI Eastside Common Areas in Henderson, Nevada. **BRC's groundwater monitoring program has evolved since the first sampling event was conducted in 2004 (Appendix A). A work plan for groundwater sampling, dated April 28, 2009, was prepared to present the program for the 2009 event. Comments to the work plan received from the Nevada Division of Environmental Protection (NDEP), dated April 30, 2009, were addressed in the revised work plan (BRC, 2009) dated June 26, 2009 (Appendix B).**

This revised report addresses comments received from the NDEP, dated March 25, 2010, to the 2009 event monitoring report dated February 25, 2010 (Appendix B).

1.1 Project History

The BMI Eastside Common Areas (the "Site") is located on approximately 2,320 acres of land in Clark County, Nevada, approximately 13 miles southeast of Las Vegas, Nevada (Figure 1). The Site consists of former used and unused wastewater effluent ponds (now removed), into which various wastewaters from the BMI Industrial Complex were discharged from the early 1940s through 1976, and portions of the system of former conveyance ditches that were used to transport those wastewaters to the effluent ponds. The Eastside also formerly included municipal rapid infiltration basins (RIBs) and lined ponds in the southwestern portion of the Upper Ponds that were constructed over the original ponds (also known as the TIMET ponds or the Pabco Road ponds).

In addition to the former effluent ponds and conveyance ditch segments, the Eastside includes adjoining lands northeast of Boulder Highway, northwest of Lake Mead Boulevard, and south of Las Vegas Wash. With the exception of a short segment that traverses Parcel 9 South, former conveyance ditch segments to the west of Boulder Highway are not part of the Eastside Site.



The transport and disposal of industrial and sewage effluent is understood to be the primary source of chemicals in the former ponds and ditch areas. No industrial or manufacturing activities have taken place on the Eastside. In addition to the on-site sources of chemicals, potential off-site sources have also been identified. Elevated concentrations of perchlorate, arsenic, and hexavalent chromium in groundwater have been well documented in groundwater samples collected from upgradient and off-site wells located west and southwest of the Site, indicating that contaminants are currently flowing beneath a portion of the Eastside.

Potential off-site sources include nearby facilities such as the City of Henderson (COH) Water Reclamation Facility/Bird Preserve, the facilities currently operating within the BMI Industrial Complex (e.g., Tronox LLC [formerly Kerr-McGee Chemical, LLC], Titanium Metals Corporation [TIMET], Olin Chlor Alkali [formerly known as Pioneer Americas LLC, which includes former Stauffer and Montrose sites], two former COH RIBs, and the inactive facility owned by American Pacific Corporation [AMPAC, former PEPCON plant] located west of the BMI Complex).

Since 2004 BRC has conducted several investigations at the Site to evaluate geologic and hydrogeologic conditions and groundwater quality. After a comprehensive program of drilling, soil sampling, geophysical surveying, well installation, and groundwater sampling was completed in 2004, groundwater monitoring has been conducted and reported over five additional events or “rounds:”

- The first round was conducted between April and June 2006 (MWH, 2006b).
- The second round was conducted between July and August 2006 (MWH, 2006c).
- The third round was conducted between October and November 2006 (MWH, 2007a).
- The fourth round was conducted between January and March 2007 (MWH, 2007b).
- The fifth round was conducted between April and July 2008 (MWH, 2008).

This report summarizes the field sampling and analytical results of the 2009 sampling event completed between August and October 2009.



1.2 Geology and Hydrogeology

The depositional environment of the various strata encountered beneath the Site has been characterized through drilling and sampling of numerous borings installed during previous investigations. The Site is located on alluvial fan sediments, with a surface that slopes to the north-northeast, toward Las Vegas Wash, at a topographic gradient of approximately 0.02. The uppermost two geologic formations encountered at the Site are the focus of this report:

- The uppermost unit is composed of relatively coarse-grained Quaternary alluvial sediments.
- These alluvial sediments are underlain by lacustrine sediments known as the Tertiary Muddy Creek Formation (TMCf). For the most part, the lacustrine TMCf is comprised of silts and clays, although a coarser facies was noted in the southwest portion of the site (Section 1.2.2).

1.2.1 Quaternary Alluvium

The uppermost strata beneath the Site consist primarily of alluvial sands and gravels of Quaternary age (Carlsen et al., 1991) and are mapped and referred to as Quaternary alluvium (Qal). The alluvial fan deposits are composed of volcanic materials that were shed from various nearby mountains and then coalesced in the Las Vegas Valley. The Qal is typically on the order of 50 feet thick at the Site, with a maximum thickness of 65 feet noted to the southwest of the Southern RIBs. The variations in the thickness of the Qal are, in part, a result of the non-uniform contact between the Qal and the underlying TMCf. The Qal is not present in localized areas of the northernmost portion of the Site, where it was removed as a result of previous gravel mining. Areas where excavation has occurred previously (such as Tuscany Village or the Weston Hills development) have since been backfilled to allow for residential development.

Whereas the original surface of the Qal prior to development was a nominally planar surface that, as a whole, dipped gently to the north, the contact between the Qal and the underlying TMCf is not a planar surface. The unconformity between these two geologic units is a result of



erosion of the TMCf prior to the deposition of the alluvial sediments that comprise the Qal. As the TMCf was eroded, broad channels were incised into its surface and were subsequently filled with the alluvium, resulting in the development of several paleochannels of varying depths and width. BRC et al. (2006) have interpreted that two paleochannels originating to the east and west of the Southern RIBs join at the southern end of the former location of the historical spray wheel to form one paleochannel that runs north beneath the Northern RIBs and then northeast to Las Vegas Wash.

As indicated by borelog data, the structural surface of the TMCf also exhibits a topographic gradient to the north-northeast. However, the TMCf topography does not appear to be so deeply incised that the flow of groundwater is controlled by paleochannel features at all groundwater elevations. The flow of groundwater may be controlled by paleochannels to a greater degree at low groundwater elevations than under high groundwater elevations.

1.2.2 Tertiary Muddy Creek Formation

The TMCf underlies much of the Las Vegas Valley and is more than 2,000 feet thick in places. At the Site, this unit is encountered beneath the Qal, where an unconformity separates the two geologic units. The depth to the top of the TMCf ranges from approximately 27 feet below ground surface (ft bgs) at well MCF-11 to approximately 65 ft bgs southwest of the Southern RIBs. At the Site, the TMCf was encountered to the maximum explored depth of 430 ft bgs. The TMCf is typically fine-grained (sandy silt and clayey silt), although thin layers (interbeds or “stringers”) with increased sand content are encountered sporadically.

A coarser-grained facies of the TMCf occurs off-site and in the southwest portion of the study area (at well MCF-27, for example). The proportion of coarser-grained sediments in the upper portion of the TMCf decreases to the north beneath the Site. This more permeable TMCf facies is interpreted as being caused by an influx of slightly coarser alluvial deposits into the older lacustrine depositional environment. One possible ramification of the presence of these coarser TMCf sediments near the southwestern border of the Site is that they may serve as a potential pathway for chemicals to migrate into the TMCf.



1.2.3 Water-Bearing Zones

A January 2009 NDEP-produced document entitled *Hydrogeologic and Lithologic Nomenclature Unification* defines NDEP's rationale behind the definitions of three water-bearing zones at the Site and at adjacent properties: the Shallow, Middle, and Deep Zones (NDEP, 2009a):

- The uppermost water-bearing zone (referred to as the Shallow Zone) is unconfined and present primarily in the Qal, although at some locations on the Site, Shallow Zone groundwater is first encountered in the uppermost portion of the TMCf (referred to as the Upper Muddy Creek Formation [UMCf]). This unconfined Shallow Zone groundwater generally flows in a northerly direction toward Las Vegas Wash. The Shallow Zone groundwater is generally continuous across the Site, but there are areas where Shallow Zone wells are dry. The Shallow Zone is designated to be between the surface and approximately 90 ft bgs (NDEP, 2009a). **To distinguish between unconfined groundwater occurring in the two lithologies, the Shallow Zone is further divided into Layer 1 (Qal only) and Layer 2 (TMCf only).**
- Below the Shallow Zone, deeper groundwater occurs in sporadically encountered lenses in the Middle Zone, designated by NDEP to be between approximately 90 and 270 ft bgs.
- Deep Zone groundwater is generally continuous across the Site and is characterized with wells screened below 270 ft bgs to a maximum nominal depth of 400 feet bgs. Groundwater elevation data from the last several rounds of groundwater monitoring (2006, 2007, 2008, 2009) show that Deep Zone groundwater is confined and the potentiometric surface of Deep Zone groundwater is oriented generally north toward Las Vegas Wash (MWH, 2008).

1.2.4 Vertical Gradients

Vertical gradients, as measured in the five recent Eastside monitoring events, have been generally upward (DBS&A, 2009), consistent with the position of the Site at the relatively distal



end of two coalescing alluvial deposits from the River Mountains and McCullough Range. In general, high-energy alluvial sediments are deposited near their source, resulting in a geologic profile dominated by coarser-textured soils that are conducive to downward recharge of precipitation and mountain runoff. At more distal locations, it is common to encounter lower-energy alluvial sediments that result in a geologic profile dominated by finer-textured soils. The distal portions of alluvial deposits often comprise pressure zones where confining or semiconfining zones exist. Water in these zones is often laterally recharged at depth, resulting in pressure buildup that is sustained by the head of water created in the upslope vertical recharge zones.

As discussed in by DBS&A (2009), downward gradients exist in some isolated locations. For example:

- The 2009 monitoring event elevation data (MWH, 2008) indicate a small downward gradient (0.011) between the Shallow Zone and the Middle Zone at Location 12; the gradient between the Shallow Zone and Deep Zone at Location 12 is upward (0.060).
- A downward gradient was also calculated between the Middle Zone and the Deep Zone at Location 28 (0.217); well elevation data for the Shallow Zone at this location were not available to make a comparison.
- A slight downward gradient (0.007) was also calculated between the Shallow Zone and the Deep Zone at Location 7; the direction of gradient has alternated between up and down at this location in previous monitoring events.
- Historically, downward vertical gradients have been measured at Location 6 (groundwater elevation was not measured in 2009; previous 2007 vertical gradient was 0.043).



1.2.5 Zone Connectivity

As discussed by DBS&A (2009), evaluation of existing analytical and isotopic data indicates that only limited or incidental connectivity exists between the three water-bearing zones at the Site, and the Shallow Zone and the Deep Zone are believed to be largely isolated from one another at the Site. However, there could be limited and incidental connection between the Shallow Zone and the Deep Zone via the Middle Zone. The large depth interval and generally low permeability of the Middle Zone together serve to greatly modulate and buffer hydraulic variation and chemical transport between the Shallow and the Deep Zones. Though it is possible that greater connectivity between water-bearing zones exists upgradient of the Site, limited data exist upon which to base an evaluation.

1.3 Purpose and Scope

The 2009 groundwater monitoring event was performed to collect groundwater data to further characterize Site geochemistry and hydrogeology. Sampling was also completed to provide additional data to improve the understanding of the Site-wide conceptual site model (CSM), to evaluate groundwater conditions to ensure that public health and the environment are protected, and to establish baseline conditions in areas where these conditions have not been established. The following activities were performed during the groundwater monitoring event:

- Inspected wellheads, including surface completion and well security
- Measured depth to groundwater in wells relative to top of casing (TOC)
- Measured total depth of well relative to TOC in wells without dedicated pumps in place
- Collected photoionization detector (PID) readings at wellheads
- Collected groundwater samples for laboratory chemical analysis using both micro-purge and net-purge sampling techniques
- Evaluated hydrogeology and chemical analytical results for water quality
- Evaluated data for trends based on previous data and project-specific screening levels



2. Groundwater Monitoring Program

Groundwater monitoring and sampling procedures were performed as specified in the *Revised Periodic Groundwater Monitoring Plan for Groundwater Sampling and Analysis – BMI Common Areas (Eastside), Henderson, Nevada* (MWH, 2006a), *BMI Common Areas (Eastside) Fifth Round Groundwater Monitoring Work Plan, BMI Complex, Henderson, Nevada (Revision 0)* (BRC, 2008) and associated NDEP letter dated March 21, 2008, associated revised Site-specific *Field Sampling and Standard Operating Procedures (FSSOPs)* (BRC et al., 2007), and revised BRC *Quality Assurance Project Plan (QAPP)* (BRC and ERM, 2008). Additionally, with the approval of the NDEP transmittal dated March 31, 2006, BRC modified the groundwater sampling procedures to include the micro-purge and sampling methodology for the program. The 2009 event also followed the procedures outlined in the *Technical Memorandum – Work Plan for Groundwater Sampling, BMI Common Areas (Eastside) Site, Clark County, Nevada (rev 2)* dated June 26, 2009 (BRC, 2009) and associated NDEP comments dated June 29, 2009.

Chemicals known or suspected to be associated with historical operations and potential impacted groundwater in the vicinity of the Site, referred to as site-related chemicals (SRCs), are presented in Table 1. The current groundwater monitoring analytical program implemented during the 2009 sampling event, including analytical laboratories, analytical methods, sample containers, preservation, and holding times, is summarized in Table 2. Wells used for water level measurements only are presented in Table 3.

Prior to implementing the second round of 2009 sampling, BRC requested and NDEP approved a reduction in the required analyses. These changes include discontinuing analyses of groundwater samples for polynuclear aromatic hydrocarbons (PAH) by U.S. Environmental Protection Agency (EPA) method SW8310, polychlorinated biphenyls (PCB) by EPA method SW8082, herbicides by EPA method SW8151A, dioxin and furans by EPA method SW8290, cyanide by EPA method 9010, sulfite by EPA method 377.1, sulfide by EPA method 376.1/376.2, total petroleum hydrocarbons (TPH) by EPA method SW8015B, and methyl mercury by EPA method 1630. These analyses have been excluded from the current sampling program as listed in Table 2 and Appendix A.



Prior to implementing the fourth round monitoring event (2007), BRC requested and NDEP approved an additional reduction in the required analyses. These changes include discontinuing analyses of groundwater samples for glycols and alcohols by EPA method SW8015B and flashpoint by EPA method 1010. These analyses have been excluded from the current sampling program listed in Table 2 and Appendix A.

Prior to implementing the fifth round monitoring event (2008), BRC requested and NDEP approved additional reduction in required groundwater analyses for individual wells in which concentrations have been consistently below detection limits for the following analyses: aldehydes by EPA method 8315A, organic acids by HPLC, organochlorine pesticides (OCPs) by EPA method 8081A, and semivolatile organic compounds (SVOCs) by EPA method 8270C. Analyses for dichlorobenzil by EPA method 8270C, organophosphate pesticides (OPPs) by EPA method 8141A, and dissolved gases by RSK 175 were also removed from the program. The changes to the analytical program are presented in Appendix A.

For the 2009 sampling event, groundwater samples were analyzed for:

- Volatile organic compounds (VOCs)
- Organochlorine pesticides (OCPs)
- Total metals
- Anions
- General chemistry and water quality parameters (including perchlorate and total dissolved solids [TDS])
- Radionuclides
- Stable isotopes

Cation-anion balance (CAB) calculations completed with prior monitoring event data exceed the acceptable criteria detailed in NDEP guidance (NDEP, 2009c) and Section 1030 E of the *Standard Methods for the Examination of Water and Wastewater* (APHA, 1999). As discussed in the 2009 Work Plan (BRC, 2009), a selected set of wells were to be filtered in the field for



anions and metals for dissolved analyses to help evaluate CAB calculations. The filtered data set would supplement the unfiltered total analyses that will also be conducted for samples from each well. It was suspected that field-filtering may help achieve a better CAB. During field sampling, however, BRC elected to field-filter groundwater samples from all wells sampled in the 2009 event (in addition to collecting unfiltered samples) so that a complete filtered and unfiltered dataset for anions and metals would be collected for analysis and evaluation.

In addition, alkalinity was measured in the field to help determine if this parameter is a CAB factor. Further, a set of well samples were collected and packaged separately for metals and anion analyses (both total and dissolved). The samples were isolated from other Site samples (separate coolers, separate chain-of-custody forms, separate delivery) so that distinct laboratory reports for each group would be generated and available for detailed review if needed.

2.1 Well Inspection and Measurements

Well construction data are included in Table 4. Every monitoring well scheduled for water level measurement or sampling was inspected for deficiencies and problems. An inspection log was completed, noting all deficiencies and problems (Table 5). The following general information was documented during the inspections:

- Date and well identification
- Condition of security posts, well pad, security casing, and dedicated sampling components, if applicable
- Condition of gasket, lock, well casing, wellhead, and flange bolt tightness
- Straightness of the wellhead.

In addition to the routine well inspection, total depth was measured in each well that has no dedicated pump to determine if formation material surrounding the well has migrated into and accumulated inside the well casing. Wells that contained an accumulation of material exceeding 20 percent of the screened interval were noted and will be considered for redevelopment. During the fifth round event, excessive sedimentation was measured at the



bottom of one well (PC-24) used for chemical analyses. PC-24 had a measured total well depth variance of -3.71 feet or approximately 24.7 percent of the screen interval filled with sediment. This well is owned by Tronox. Well PC-24 was sampled in the 2009 event.

Several wells were not sampled during the 2009 event:

- During the 2009 well inspection and measurement activities, the following wells could not be located: AA-24, HMWWT-8, DM-9, PC-12, PC-84, PC-106, PC-107, and PZ-13. AA-24 and DM-9 may be buried by recent construction activities and PC-12 may be paved over.
- Well PC-40 was inaccessible during sampling as the lock has been changed since the Fourth Round event.
- Well PC-89 appeared caved in and no casing or cover was evident.
- Similarly, the cover of well PC-95 has been crushed into the well casing and could not be removed for sampling. The wells casing at COH-1A also appeared to have caved in.
- The following wells were dry during 2009 well inspection and measurement activities: AA-19, DBMW-6, DM-4, DM-5, DM-7B, DM-8, HMWWT-4, and PC-1.
- Two wells were artesian during the 2009 event: MCF-10A and MCF-17A.
- ~~The following TIMET wells could not be accessed: TPMZ 105 through TPMZ 110, TPMX 112, and CMT 307.~~

2.2 Water Level Measurements

Water level measurements provide a measure of water potential (hydraulic head) at specific geographic locations and depths beneath the Site. The primary purpose for measuring water levels in monitoring wells is to determine horizontal and vertical groundwater flow directions and



gradients. These measurements, when converted to elevations relative to mean sea level and posted on a map, can be contoured to prepare potentiometric surface maps and used to determine where and at what rate groundwater is moving.

Horizontal gradients are calculated as the difference in groundwater elevations between wells screened in the same monitoring zone divided by the horizontal distance between the wells. The horizontal gradients indicate the direction of groundwater flow, from higher to lower elevations.

During the 2009 event water levels were measured in all available wells across the Site and adjacent areas, as shown in Figure 2, to provide data for a “snapshot” of water levels, gradients, and flow directions. All of the water level measurements were conducted between August 3 and 7, 2009) except for well MCF-06A-R (originally inaccessible due to Site construction), which was measured on August 21, 2009.

All groundwater level measurements were performed to coincide with the similar measurements being conducted by other BMI Complex companies, whenever possible. Measurements within geographic areas were collected in the shortest possible time, so that local hydraulic gradients in each zone and between zones can be assumed to have been made under comparable conditions.

A total of 173 wells were proposed for groundwater measurements. Of these wells, 63 are screened solely in the Qal, 29 are screened in the Qal with some portion of the screen in the UMCf, and 73 are screened solely in the UMCf (specific screen information for 8 shallow wells [HMW-16, MW-13, MW-15, POU3, PZ-13, W02, WMW5.58SD and WMW5.58SI] is not available).

In accordance with NDEP guidance (2009), the wells are also classified by water-bearing zone: 127 wells are in the Shallow Zone, 19 wells are in the Middle Zone, and 27 wells are in the Deep Zone. Some wells may be better classified in a different zone, and some may have characteristics of more than one zone. These issues, as they impact the accuracy of site characterization and potential remedial decision-making, will be further evaluated as the



Eastside CSM is further developed. (Note: If a Qal well is screened less than 1 foot into the UMCf, the well is considered solely a Qal well for classification purposes).

The 2009 groundwater potentiometric surface data for the Shallow, Middle, and Deep Zone wells are presented in Figures 3, 4, and 5, respectively. Water levels were measured in accordance with procedures described in the project-specific FSSOP 5 (Water Sampling and Field Measurements). Where available, contemporaneous Shallow Zone data from upgradient well locations are also presented (no Middle or Deep Zone data were available for the upgradient locations).

2.3 Sample Collection

BRC used the NDEP-approved low-flow purge and sampling technique when feasible during field sampling. BRC sampling guidance (FSSOP 5) specifies a maximum allowable drawdown in a well while using approved low-flow purge techniques. If drawdown exceeds the maximum allowed, a “net-purge” procedure approved by the U.S. EPA is used instead. During purging, water levels should be monitored to ensure that drawdown does not exceed 0.1 meter (0.3 foot). If the water level drop exceeds this, the flow rate should be decreased until the water level stabilizes. If water levels in low yield wells do not stabilize at flow rates near 0.1 liters per minute (L/min), the well should be purged to dryness once and then sampled (U.S. EPA, 1986). Samples should be collected when the well has recovered to 80 percent of its original capacity or at 24 hours from being purged to dryness, whichever comes first. At no time should the well be pumped to dryness if the recharge rate causes the formation water to vigorously cascade down the sides of the screen. In this case, samples should be collected at a rate slow enough to maintain the water level at or above the top of the screen to prevent cascading.

BRC-owned wells are equipped with QED Well Wizard (A-system and L-system) dedicated bladder pumps for monitoring and sampling where possible. QED MP10H high pressure micro-purge controllers are used during sampling. The Well Wizard A-system is installed in AA wells (or shallow MCF wells) due to their relative shallow well design (less than 100 feet deep). The L-system pumps are used in many of the MCF wells due to the depth of the wells. The L-system uses a drop-tube that attaches to the base of the pump and extends down to a



specified intake depth within the well screen interval. This allows the pump to be located closer to the top of the well and still collect groundwater samples from across a screen interval located as deep as 400 feet below the top of the casing (ft btc). Generally, pump (sample) intakes were installed across the middle of the well screen intervals for saturated well screens (typically identified as MCF wells [confined aquifer]) and approximately 1 to 3 feet from the bottom of the wells for non-saturated well screens (typically identified as AA wells [unconfined aquifer]).

BRC and non-BRC-owned wells without dedicated pumps are monitored and sampled using a QED brand SamplePro portable bladder pump system. QED MP10H high pressure micro-purge controllers are used during sampling. The portable pump (sample) intakes are generally placed in the middle of the saturated well screen interval for groundwater monitoring and sampling collection. Well purging and sampling summary data are presented in Table 6.

Standard sampling and documentation procedures presented in the groundwater monitoring program (Table 2) and the BRC FSSOPs were developed for field water level measurements, monitoring well sampling, well maintenance, general field operations, and instrument calibration. Adherence to these procedures promotes consistency in field procedures and ensures comparability of data collected over time.

Field quality control (QC) measures implemented during groundwater sampling are detailed in the BRC QAPP and FSSOPs. Specific wells or locations where QC samples were collected were identified at the beginning of the event by BRC and its field consultant. The required QC sample frequencies and field QC measures include but are not limited to:

- Collection of 10 percent field duplicates, 5 percent equipment blanks, and 10 percent matrix spike/matrix spike duplicate (MS/MSD) samples
- Providing accurate, detailed field documentation
- Proper sample packaging and shipment under chain of custody procedures



2.4 Decontamination Procedures

Decontamination all non-dedicated, non-disposable equipment was performed to minimize the potential for cross contamination between wells or investigation and sampling locations. BRC FSSOPs were followed to ensure proper decontamination of sampling equipment.

Decontamination equipment was prepared at each well location for cleaning sampling equipment. Supplies included 5-gallon buckets, bottle brushes, potable water, distilled water, and non-phosphate cleaning solution (Liquinox or Alconox). Prior to and after use at each location, all groundwater sampling equipment was washed in the non-phosphate solution, rinsed with potable water, and then rinsed twice with distilled water. Submersible pumps and downhole equipment at each location were also cleaned in the same manner prior to and after use.

Decontamination water was transferred into secured and properly labeled Department of Transportation-approved 55-gallon steel drums located on-site at a centralized staging area for short-term storage before proper disposal.

2.5 Analytical Program

Analytical procedures for the fifth round sampling event were implemented according to the BRC QAPP. Analytical specifications include methods, target analytes, detection and quantitation limits, calibration and calibration verification, and QC procedures and specifications. These specifications also require that analyses be performed according to the method-specific SOPs, which have also been revised to be site-specific stand-alone documents.

The current list of chemicals known to be associated with historical area operations, or site-related chemicals (SRCs), is presented in the revised 2008 BRC QAPP and provided herein as Table 1. This table also includes the groundwater sampling parameters of interest, analytical methods, and specific compounds. The 2009 groundwater monitoring analytical program is presented in Table 2. Additional details about the analytical program are provided in the 2009



Work Plan (BRC, 2009), and in NDEP comments dated April 30, 2009, June 23, 2009, and June 29, 2009 (Appendix B).

Analytical methods used during the program were selected to provide data to evaluate impacts to groundwater and surface water quality and were based on data requirements for investigating Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites and for conducting human health and ecological risk assessment. The analytical methods used are primarily referenced U.S. EPA-approved testing procedures.

Table 2 summarizes the analytical laboratories, methods, containers, preservation, and holding times used during the sampling event for the collection and analysis of groundwater samples. Analytical laboratories performing analyses for the Site have Nevada State certification for the methods performed. Samples were packaged and shipped with proper chain-of-custody documentation to the analytical laboratories as described in the BRC FSSOPs and QAPP.

2.6 Groundwater Analyses

Groundwater samples from 127 monitoring wells were analyzed in the 2009 event for a broad spectrum of chemical analytes and chemical classes based on previous detections, as presented in Table 2. As noted in Section 2, groundwater samples collected during the 2009 event were analyzed for VOCs, OCPs, total metals, anions, general chemistry and water quality parameters (including perchlorate and TDS), radionuclides, and stable isotopes. Analytical results are discussed in Section 3.2.

Because a subset of the past groundwater sample analyses resulted in some relatively high detection limits, perchlorate was analyzed in the 2009 event using EPA method LC/MS SW846 6850 to achieve lower detection limits. Similarly, arsenic was analyzed using ICP/MS (collision cell), and hexavalent chromium was analyzed using EPA method 7196A to achieve reduced detection limits.



2.7 Analytical Laboratories

Several laboratories were used during the 2009 event (Table 2). TestAmerica Laboratories (TA), located in Earth City, Missouri (TA-St. Louis), was the primary laboratory used for the majority of the chemical analyses. TA-St. Louis was not equipped to perform some of the selected chemical analyses and therefore enlisted other TA facilities to conduct those analyses, including TA-Irvine (California) for the anion analyses.

Advanced Tech Laboratories, located in Las Vegas, Nevada, was subcontracted to analyze for hexavalent chromium in groundwater samples. General Engineering Laboratories, located in Charleston, South Carolina, performed the radionuclide analyses, and Isotech Laboratories, Inc. (Champaign, Illinois) performed the isotope analyses. Lancaster Laboratories analyzed the samples for arsenic and chromium.

All of the laboratories are certified by the State of Nevada with the exception of Isotech Laboratories, Inc., which performed the isotope analyses. BRC could not locate a Nevada-certified laboratory that could perform the isotope analyses.

2.8 Quality Assurance/Quality Control

Measurement data for the Eastside groundwater monitoring program are consistently assessed and documented to determine whether objectives were met. The review assesses data quality and identifies potential limitations on data use, thereby providing information on overall method performance and data usability. Section A7 of the BRC QAPP defines the basis for assessing the elements of data quality. Laboratory data and data quality review reporting procedures and formats are also addressed in Section A7 of the BRC QAPP.

Quality assurance (QA) activities include performing technical system audits, performance audits, and data validation at the frequency recommended in the BRC QAPP. Field audits are not required, but may be performed in the event that significant discrepancies are identified that warrant evaluation of field practices. No field audits were performed during the 2009 event.



Various types of QC samples were collected to aid in evaluating the analytical data quality:

- Field duplicate groundwater samples were collected at a rate of 10 percent, or 1 duplicate sample for every 10 groundwater samples.
- Trip blanks were prepared by the laboratory and were included in each shipment containing groundwater samples for analysis of VOCs.
- Equipment decontamination blanks were collected (using non-dedicated or non-disposable equipment) at a rate of 5 percent of all groundwater samples collected, or 1 blank for every 20 groundwater samples collected, and were analyzed for all applicable target analytes.
- Additional sample volume was collected for 1 of every 10 groundwater samples in order to conduct laboratory MS/MSD analyses.

2.9 Data Review and Validation

The guidance for data review and validation is provided in U.S. EPA National Functional Guidelines for data review of organic and inorganic constituents (U.S. EPA, 1999, 2001, 2004 and 2005) and *U.S. EPA Test Methods for Evaluating Solid Waste Physical/Chemical Methods (SW-846), Third Edition* (U.S. EPA, 2008). These guidance manuals provided direction for the data review and validation activities conducted for data collected during this event.

Additionally, the NDEP guidance letters dated May 3, 2006 and February 23, 2007 (Data Validation Summary Report [DVSR]), and the *American Public Health Association (APHA) 1999 Twentieth Edition of Standard Methods for the Examination of Water and Wastewater* (Standard Methods) were also referenced. The Standard Methods were used for CAB evaluation along with the NDEP CAB guidance dated September 28, 2009 (NDEP, 2009c).

All of the data were subjected to a Level 3 review, which consists of a manual review of all parameters related to sample analysis, including holding times, instrument performance check



(as applicable), initial calibration, continuing calibration, blank contamination, laboratory control sample (LCS), MS/MSD, surrogates and internal standards (as applicable), and compound identification. In addition to the Level 3 review, 20 percent of all data collected during the course of the investigation were subject to full Level 4 data validation, which consists of review of all parameters included in the Level 3 review with additional review of the raw data including chromatograms, log books, quantitation reports, and spectra. Laboratory Data Consultants, Inc. (LDC) was subcontracted to conduct all the data validation. A DVSR for all data collected during this event (DVSR #58) was submitted separately to the NDEP as a stand-alone report (BRC and ERM, 2010) and was approved by NDEP on January 16, 2010.

Data for Deep Zone well MCF-07A were rejected for the 2009 event. The initially reported 2009 perchlorate concentration in well MCF-07A (93 J+ [see Table 7 for explanations of data qualifiers] micrograms per liter [$\mu\text{g/L}$]) was recognized to be the highest reported for this well. Although detection limits were relatively high in some past analyses (up to 67.8 $\mu\text{g/L}$), perchlorate had not been reported in well MCF-07A before the 2009 event. Consequently, a review of field sampling procedures was conducted and identified several issues that demonstrated that field sampling was not conducted according to BRC SOPs (DBS&A, 2010b). Issues out of compliance include purging method, rate, and parameter stability, elapsed sampling time after purging, drawdown during purging, and well sampling sequence (sampling impacted wells before unimpacted wells).

The field methods review and data rejection are discussed in detail in a DBS&A memorandum to BRC dated January 13, 2010 (DBS&A, 2010b). BRC has agreed to resample this well and the field activity is currently underway.



3. Groundwater Monitoring Data

This section summarizes general groundwater conditions and analytical results for the 2009 event. Measured groundwater elevations at the Site are summarized in Table 8. Potentiometric surface maps from two identified water-bearing zones (Shallow and Deep) are presented as Figures 3 and 5, respectively. Groundwater elevation data are presented for Middle Zone wells in Figure 4; these data were not contoured because current data suggest that the Middle Zone is discontinuous.

Overall groundwater analytical summary results for the 2009 event are presented in Table 9; summary results by water-bearing zone (Shallow, Middle, Deep) are presented in Tables 10, 11, and 12, respectively. Groundwater analytical summary results by chemical class for all events are presented in Appendix C. The isotope analyses results collected from selected Deep Zone wells are presented in Table 13. Concentration figures (contour maps) for analytes of interest for the 2009 event are presented in Figures 6 through [3244](#).

3.1 Groundwater Conditions

Groundwater level measurements were attempted at 173 wells and successfully collected from 140 wells across the Site (Table 8). The remaining 33 wells could not be monitored due to the field conditions discussed in Section 2.1.

Depth to groundwater measurements ranged from artesian conditions at wells MCF-10A and MCF-17A to a maximum measured depth to groundwater of 109.30 ft btoc in well MCF-06A-R. The highest groundwater elevation was 1781.50 **feet above mean sea level (ft msl)** in well MCF-02A, screened within the Deep Zone and located in the southernmost portion of the Site. The lowest measured groundwater elevation was 1405.53 ft msl in well W02, screened in the Shallow Zone and located just west of the COH Landfill. Well hydrographs are presented in Appendix D.

In the monitoring report for the fourth round of sampling (MWH, 2007b), well MW-15 was mislabeled as MW-08 based on mislabeling on the well itself and the current well information at



that time. Based on new information provided by COH Landfill personnel during the fifth round of monitoring, BRC has changed the identification of well MW-08 to MW-15.

~~The following wells had significant changes in groundwater elevation (greater than 50 feet) between the fifth round water level measurement event completed in 2008 and the 2009 event (Table 8):~~

- ~~• Shallow Zone well AA-13: Decline of 56.66 feet~~
- ~~• Deep Zone well MCF-19A: Increase of 77.64 feet~~
- ~~• Deep Zone well MCF-06A-R: Increase of 118.95 feet~~
- ~~• Deep Zone well MCF-20A: Increase of 119.47 feet~~
- ~~• Deep Zone well MCF-18A: Increase of 146.64 feet~~
- ~~• Deep Zone well MCF-24A: Increase of 163.13 feet~~

~~The decline in groundwater elevation in Shallow Zone well AA-13 is likely due to the deactivation in 2007 of the former Southern RIBs just upgradient from this well. The Deep Zone wells listed above were all installed at the Site in 2008, and the 2009 event was only the second time water levels were recorded in these wells.~~ The yield of the **Deep Zone se-UMCf** wells is low, although Deep Zone groundwater is confined and water levels commonly rise several hundred feet above the screen interval. For example, the depth to water in well MCF-18A was 26.30 ft btoc in 2009 and two Deep Zone wells were artesian during the 2009 event (MCF-10A and MCF-17A). The **relatively large increases** in groundwater elevation measured in the **se** Deep Zone wells between 2008 and 2009 is likely due to the stabilization of Deep Zone groundwater in the area of these wells after the hydraulic stress of drilling, well installation, and well development in 2008 had dissipated. **Smaller changes in Deep Zone head can be attributable to barometric pressure changes.**

The potentiometric surface of Shallow Zone and Deep Zone groundwater is depicted as Figures 3 and 5. Middle Zone groundwater elevations are posted on Figure 4. Shallow Zone groundwater flow is oriented generally to the northwest at an average gradient of 0.02 foot per



foot (ft/ft). Deep Zone groundwater flow is also oriented generally to the northeast with an average gradient of 0.02 ft/ft. The potentiometric surface and flow direction for both the Shallow Zone and the Deep Zone are broadly consistent with data from prior monitoring events.

3.2 Analytical Results and Summary of Findings

This section presents groundwater analytical results for the 2009 event. Data validation qualifiers and reason codes are presented in Table 7. Statistical summaries of the 2009 analytical results are presented in Tables 9 through 12. Results by chemical class (for all events) are presented in Appendix C. The results of isotope sampling (2008 and 2009) are presented in Table 13.

The 2009 data were evaluated by number and frequency of detections, maximum and minimum concentrations, and number of detections exceeding U.S. EPA maximum contaminant levels (MCLs) or **NDEP** basic comparison levels (BCLs). Based on detection frequency and detected concentrations over MCLs or BCLs, the following analytes of interest (AOIs) from the various chemical classes were selected for further evaluation:

- Tetrachloroethylene (PCE)
- **Chloroform** **Total trihalomethanes (TTHMs)**
- Carbon tetrachloride
- Alpha BHC and beta BHC
- Arsenic
- Hexavalent chromium
- Magnesium
- Radium-226+228
- Perchlorate
- Total dissolved solids (TDS)



Concentration trend graphs for ~~the~~ AOIs are presented in Appendix E. Consistent with prior BRC monitoring reports, the ten wells in the 2009 dataset with the highest detected concentrations for each parameter are plotted in the Appendix E graphs. Data from the 2009 event were screened against MCLs and BCLs as a preliminary analysis, and the screening results are discussed in Sections 3.2.1 through 3.2.11.

3.2.1 Volatile Organic Compounds

Of the 33 VOCs detected in Shallow Zone wells, 17 have a detection frequency of 5 percent or more. Of these VOCs with a detection frequency of at least 5 percent, only 2 exceed an MCL: carbon tetrachloride and PCE. ~~Four~~ **Only two** VOCs with a detection frequency of at least 5 percent in Shallow Zone wells exceed NDEP BCLs: PCE **and** ~~carbon tetrachloride~~, **each of which** ~~chloroform, and bromodichloromethane. Bromodichloromethane has only one detection over its BCL (26 µg/L in well POU3), while cCarbon tetrachloride and PCE each have~~ **has** 6 detections over BCLs (the MCL and the BCL for carbon tetrachloride and PCE are both 5 µg/L):

- PCE was detected over its MCL/BCL of 5 µg/L in Shallow Zone wells AA-01, AA-UW1, MCF-01B, MW-15, PC-67, and POU3 (Figure 6). The maximum Shallow Zone PCE detections are 73 J µg/L in well AA-01 and 53 J µg/L in well AA-UW1.
- Carbon tetrachloride was detected over its MCL/BCL of 5 µg/L in Shallow Zone wells BEC-6, DBMW-11, DBMW-7, DBMW-8, PC-67, and POU3 (Figure 9). The maximum Shallow Zone carbon tetrachloride detection is 25 µg/L in well POU3.

In addition to the VOCs cited above, TTHMs (sum of detected chloroform, bromodichloromethane, dibromochloromethane, and bromoform) were detected over the associated MCL of 80 µg/L in 21 Shallow Zone wells sampled in 2009, including wells installed along the northeastern Site boundary, in the former ponds area, and north of the plants area (Figure 13 and 14).



~~In 2009, chloroform exceeded its BCL of 1.6 µg/L in 54 of 82 Shallow Zone wells (there is no chloroform MCL) (Figure 12), but was the only VOC detected above MCLs or BCLs in Middle Zone and Deep Zone wells. It was detected in Middle Zone wells MCF-24B and MCF-29B at 7.2 µg/L and 1.9 µg/L, respectively, and in Deep Zone wells MCF-10A (0.069 µg/L), MCF-02A (0.44 µg/L), and MCF-29A (0.93 µg/L).~~

Detected PCE, carbon tetrachloride, **and TTHM**, ~~and chloroform~~ concentrations in Shallow Zone wells are plotted and contoured to show the distribution of these ~~VOCs analytes~~ in Site groundwater (Figures 6, 9, **10, and 132, and 14**). Middle Zone data ~~for these three VOCs, mostly showing non-detects, are posted without contours~~ (Figures 7, ~~110, and 153~~), and ~~except for chloroform, where isolated low concentrations are detected,~~ Deep Zone data (**Figure 8, 12, and 16**) for these ~~three VOCs analytes~~ are ~~also~~ posted without contours (~~Figure 8, 141, and 164~~). Concentration trend graphs for these parameters (wells with the 10 highest detections in 2009) are included in Appendix E.

The carbon tetrachloride and TTHM data are further divided into Shallow Zone Layer 1 (Qal-only wells) and Shallow Zone Layer 2 (TMCf-only wells). In addition, available data for the plants area and AMPAC are included to further illustrate the regional trend in carbon tetrachloride and TTHM data.

As shown in Figure 6, the maximum detected PCE concentrations (up to 73 µg/L) in the Site area are located along the upgradient Eastside property boundary at Shallow Zone wells AA-01, MCF-01B, and AA-UW1. PCE impacts extend further downgradient to on-site well POU3 (9 µg/L) and off-site well PC-67 (13 µg/L). Lower PCE detections between 1 and 4 µg/L extend further north-northeast to well HMW-09 (1.2 µg/L) near Las Vegas Wash. Detected PCE concentrations that exceed those cited above have been documented upgradient and off-site to the southwest of the Eastside area (Broadbent, 2010).

~~As shown in Figure 12, the highest detected chloroform concentrations in on-site Shallow Zone groundwater were detected in wells DBMW-11 (900 µg/L) and DBMW-12 (590 µg/L). Comparable concentrations were detected in off-site wells PC-67 (650 µg/L) and PC-24 (570 µg/L). The highest detected off-site chloroform concentrations broadly trend east-~~



~~northeast from the PC-67 area. On-site, the highest concentrations trend roughly northerly from the well BEC-6 area where 420 µg/L of chloroform was detected. In between these two areas, where the former spray wheel, the Northern RIBs, and the Southern RIBs have been active (BRC et al., 2006), chloroform concentrations are lower than those cited above and less than 100 µg/L.~~

As shown in Figure 9 and 10, the highest detected carbon tetrachloride concentrations in Shallow Zone groundwater are broadly comparable to ~~both PCE. and chloroform. Chloroform is a daughter product of the anaerobic degradation of carbon tetrachloride, so these two analytes are typically co-located as a result of this process.~~

Like PCE the highest carbon tetrachloride detections are near the southwest portion of the Eastside area. Carbon tetrachloride was detected in on-site well POU3 at 25 µg/L and in off-site wells PC-67 (7.8 µg/L), PC-24 (4.6 µg/L), and PC-28 (4.3 µg/L). ~~Like chloroform, r~~Relatively high carbon tetrachloride concentrations were detected at the northeast property boundary at wells DBMW-11 (10 µg/L) and DBMW-8 (9.3 µg/L), and south of the northeast property boundary in well BEC-6 (9.5 µg/L).

Between these two areas, where the former spray wheel, the Northern RIBs, and the Southern RIBs have been active, carbon tetrachloride concentrations ~~, like chloroform,~~ are lower than those cited above, less than 1 µg/L. Infiltration from the ~~former spray wheel and~~ RIBs may have served to reduce VOC concentrations in the central portion of Shallow Zone in this area.

Detected carbon tetrachloride ~~and chloroform~~ concentrations that exceed those cited above have been documented upgradient and off-site to the southwest of the Eastside area (Broadbent, 2010). **As shown in Figure 9, the highest carbon tetrachloride concentrations in Shallow Zone Layer 1 were detected in the plants area and in the southwestern portion of the Site. A concentration of 12 µg/L was reported in plants area Layer 1 well TMPZ-106, and 25 µg/L was detected in BRC Layer 1 well POU3. In Shallow Zone Layer 2, carbon tetrachloride was detected up to 2,900 µg/L in plants area well MC-MW-09. The highest carbon tetrachloride concentration in the BRC Layer 2 wells was 10 µg/L in well DBMW-11.**



Low-concentration VOC detections below the Shallow Zone may be the result of these higher-concentration upgradient impacts migrating into Middle Zone and Deep Zone wells through coarse-grained lenses within the UMCf.

As shown in Figures 13 and 14, the highest detected TTHMs are located in the plants area southwest of the Site. The maximum reported concentration in a Shallow Zone Layer 1 well is 21,001 $\mu\text{g/L}$ in well AA-MW-07, located in the plants area. The maximum reported concentration in a Shallow Zone Layer 2 well is 65,220 $\mu\text{g/L}$ in well MC-MW-10, also located in the plants area. Reported values in Middle and Deep Zone wells are much lower both on-site and off-site. The distribution of TTHMs in regional Shallow Zone groundwater trends basically north and northeast with groundwater flow.

3.2.2 Organochlorine Pesticides

Of the detected OCPs, only two (alpha-BHC and beta-BHC) were detected above BCLs (these two OCPs have no MCLs). **No OCP compounds were detected above MCLs.** Alpha-BHC was detected above its BCL of 0.011 $\mu\text{g/L}$ in 24 of 82 Shallow Zone well analyses, with a maximum concentration (0.35 $\mu\text{g/L}$) detected in well PC-88 near the Las Vegas Wash. The maximum beta-BHC detection was 0.88 $\mu\text{g/L}$ in well AA-08, located to the west of PC-88. In the 2009 event, no OCPs were detected above MCLs or BCLs in Middle Zone or Deep Zone wells.

3.2.3 Metals

Concentrations above MCLs were detected in Shallow Zone wells for the following metals: arsenic, total chromium, hexavalent chromium, lead, selenium, and uranium. The MCLs for these compounds are the same as the BCL. Concentrations over the applicable MCL/BCL were detected in 80 of 82 analyses for arsenic, 7 analyses for total chromium, 6 analyses for hexavalent chromium, 1 analysis for lead, 10 analyses for selenium, and 29 of 82 analyses for uranium.



For metals that have no MCLs, concentrations above BCLs were detected in Shallow Zone wells for the following: iron (1 detection), lithium (65 detections), magnesium (42 detections), manganese (9 detections), molybdenum (11 detections), and strontium (1 detection).

Arsenic was detected over its MCL of 10 $\mu\text{g/L}$ in 14 Middle Zone well analyses in the 2009 event. Selenium, the only other metal detected over its MCL in Middle Zone well analyses, was detected in 3 Middle Zone well samples over its MCL of 50 $\mu\text{g/L}$.

The 2009 Deep Zone well analyses detected concentrations above BCLs for the following metals: arsenic (22 detections), boron (8 detections), lithium (17 detections), magnesium (11 detections), manganese (10 detections), molybdenum (9 detections), selenium (3 detections), and strontium (1 detection).

The detected concentrations of arsenic, hexavalent chromium, and magnesium were plotted and contoured to show the distribution of these metals in Site groundwater (Figures 175 through 253). **Maps for manganese and selenium, including Shallow Zone maps split by Layer 1 and Layer 2, are also included for review (Figures 26 through 33).** Concentration trend graphs for these parameters (wells with the 10 highest detections in 2009) are included in Appendix E.

3.2.3.1 *Arsenic*

In Shallow Zone wells sampled in 2009, the highest arsenic concentration (235 $\mu\text{g/L}$) was detected in off-site cross-gradient well PC-28. Adjacent off-site well PC-67 had the next highest detected concentration at 165 $\mu\text{g/L}$. On-site, the nine highest arsenic concentrations ranged from 102 to 161 $\mu\text{g/L}$. Arsenic concentrations over and approximating 100 $\mu\text{g/L}$ trend north-northeast from the PC-28/PC-67 area toward Las Vegas Wash. To the east at well AA-UW6, arsenic was detected at 161 $\mu\text{g/L}$ and concentrations over 100 $\mu\text{g/L}$ extend to the north of AA-UW6 to wells DBMW-14 (103 $\mu\text{g/L}$) and DBMW-15 (155 $\mu\text{g/L}$). Arsenic concentrations in the Shallow Zone are less than 100 $\mu\text{g/L}$ in the central portion of the Eastside near the former Southern RIBs and spray wheel.



As discussed by DBS&A (2010a), higher arsenic concentrations, up to 1,000 $\mu\text{g/L}$, have been detected in Shallow Zone groundwater off-site and upgradient to the southwest. In the Middle Zone, the highest arsenic concentration (100 $\mu\text{g/L}$) was detected in well MCF-12C. The highest Deep Zone arsenic concentration in 2009 was detected in well MCF-08A at 54 $\mu\text{g/L}$.

3.2.3.2 *Hexavalent Chromium*

The distribution of hexavalent chromium in Shallow Zone groundwater is roughly comparable to the isoconcentration maps of PCE and arsenic in the Shallow Zone. Like PCE, the highest hexavalent chromium detections in the 2009 data are located off-site to the southwest, and similarly to PCE and arsenic, hexavalent chromium concentrations were detected in an area that extends from the southwest to the north-northeast across the Site toward Las Vegas Wash. The maximum hexavalent chromium was detected in off-site upgradient well PC-28 at 1,400 $\mu\text{g/L}$. The next highest detected concentration (780 $\mu\text{g/L}$) was detected in adjacent off-site well PC-67. On-site, the highest hexavalent chromium concentration (420 $\mu\text{g/L}$) was detected in well POU3, located southeast of PC-67. Hexavalent chromium concentrations are relatively lower immediately downgradient of the former RIBs and spray wheel areas.

In the Middle Zone, hexavalent chromium was detected only in wells MCF-02B (4.71 J $\mu\text{g/L}$) and MCF-12C (5.21 J $\mu\text{g/L}$). Both of these detections are less than the hexavalent chromium BCL of 110 $\mu\text{g/L}$. In the Deep Zone, hexavalent chromium was detected only in wells MCF-27 (34 $\mu\text{g/L}$) and MCF-03A (38 $\mu\text{g/L}$). Like VOCs, the relatively low-concentration hexavalent chromium detections below the Shallow Zone may be the result of higher-concentration upgradient impacts migrating into Middle Zone and Deep Zone wells through coarse-grained lenses within the UMCf.

3.2.3.3 *Magnesium*

In the Shallow Zone, the highest detected magnesium concentration (11,600,000 $\mu\text{g/L}$) in the 2009 event was measured in well WMW5.58SD, installed in Las Vegas Wash. On-site, the highest concentration was measured in well MCF-06B at 3,760,000 J-TDS $\mu\text{g/L}$. The highest magnesium concentrations are located in an area between wells MCF-16C (600,000 J-CAB&TDS $\mu\text{g/L}$) and MW-4 (974,000 J-CAB&TDS $\mu\text{g/L}$).



The distribution of magnesium in Shallow Zone groundwater is roughly comparable to the isoconcentration maps of PCE, arsenic, and hexavalent chromium in the Shallow Zone, with the highest magnesium concentrations detected in an area that extends broadly from the southwest to the north-northeast across the Site toward Las Vegas Wash.

In Middle Zone wells sampled in 2009, the highest magnesium concentration was detected in well MCF-05 at 15,300,000 J-TDS $\mu\text{g/L}$. The minimum Middle Zone detection was 9,010 J-TDS $\mu\text{g/L}$ in well MCF-02B at the southern property boundary.

The highest magnesium concentrations in Deep Zone wells sampled in 2009 are located in an area trending southwest to northeast from well MCF-19A (10,300,000 J-TDS $\mu\text{g/L}$) to well MCF-31A (14,000,000 J-TDS $\mu\text{g/L}$). The maximum Deep Zone magnesium concentration was detected in well MCF-06A-R at 15,800,000 J-TDS $\mu\text{g/L}$. The minimum Deep Zone detection was 6,490 J-TDS $\mu\text{g/L}$ in well MCF-02A, at the southern property boundary.

3.2.3.4 Manganese

Manganese was detected above its BCL of 510 $\mu\text{g/L}$ in 9 samples collected from Shallow Zone wells in the 2009 event (no MCL has been set for manganese). The maximum Shallow Zone concentration (1,770 $\mu\text{g/L}$) was detected in well PC-108, located in the Western Hook subarea. Manganese was detected above its BCL in 10 Middle Zone samples. The maximum Middle Zone concentration (4,530 $\mu\text{g/L}$) was detected in well MCF-05 (south of the northern RIBs). In the Deep Zone, 17 samples exceeded the BCL for manganese. The maximum Deep Zone concentration was 5,720 $\mu\text{g/L}$ in well MCF-24A in the Spray Wheel Area.

The regional distribution of manganese is shown in Figures 26 through 29. Data from the plants area show that manganese concentrations up to 20,000 $\mu\text{g/L}$ (well EC-09) have been detected in Shallow Zone Layer 1 off-site. In Shallow Zone Layer 2, values as high as 3,400 $\mu\text{g/L}$ have been detected in the plants area (well MC-MW-10). Detected shallow zone concentrations trend basically north and northeast from the plants area, with groundwater flow.



In Middle Zone off-site wells, manganese has been detected up to 8,800 µg/L (well IW-1).

In Deep Zone off-site wells, manganese has been detected up to 340 µg/L (MW-08).

3.2.3.5 Selenium

Selenium was detected above its MCL/BCL of 50 µg/L in 10 samples collected from Shallow Zone wells during the 2009 event. The maximum Shallow Zone concentration (169 µg/L) was detected in well DBMW-2. Selenium was detected above its MCL/BCL in 3 Middle Zone samples. The maximum Middle Zone concentration detected was 167 µg/L in well MCF-05. In the Deep Zone, 3 samples exceeded the MCL/BCL for selenium. The maximum Deep Zone concentration was 127 µg/L in well MCF-30A.

The regional distribution of selenium is shown in Figures 30 through 33. Data from the plants area show that only relatively low concentrations of selenium are detected in off-site groundwater (Shallow, Middle and Deep Zone). The maximum reported off-site concentration in the Shallow Zone is 26 µg/L in well EC-01. Detected shallow zone concentrations trend basically north and northeast, with groundwater flow.

3.2.4 Radionuclides

For the 2009 event, radium 226+228 (the sum of detected radium 226 and radium 228 activities) was the only radionuclide detected above its MCL of 5 picocuries per liter (pCi/L). NDEP has not assigned a BCL for this analyte. Radium 226+228 activities above 5 pCi/L were detected in 12 of 82 Shallow Zone well samples, 3 Middle Zone samples, and 10 Deep Zone well samples.

The distribution of radium 226+228 was plotted and contoured to show the distribution of this analyte in Site groundwater (Figures 324 through 326). Concentration trend graphs for this parameter (wells with the 10 highest detections in 2009) are included in Appendix E.

Similar to the isoconcentration maps for Shallow Zone VOCs and metals discussed above, the radium 226+228 map of 2009 Shallow Zone groundwater data (Figure 324) shows a trend with the highest detections extending across the Site from the southwest to the northeast. The



highest radium 226+228 activity was measured in well DBMW-12 (19.4 pCi/L in a field duplicate).

The maximum detection in the Shallow Zone was 19.4 pCi/L in well DBMW-12 (field duplicate). The maximum detection in the Middle Zone was 12.9 pCi/L in well MCF-30B, and the maximum detection in the Deep Zone was 40.4 pCi/L in well MCF-28A. The highest Deep Zone radium 226+28 detections are located in the northern portion of the Site and trend roughly east-west.

3.2.5 Perchlorate

In Shallow Zone wells sampled during the 2009 event, perchlorate was detected in 76 of 82 samples above its BCL of 18 µg/L (perchlorate currently has no MCL). The maximum detection (in an unfiltered sample) was 500,000 µg/L in Shallow Zone well PC-28. In Middle Zone wells, perchlorate was detected in 7 wells, 2 of which had concentrations above the BCL: MCF-12C (430 µg/L) and MCF-32B (19 µg/L). In Deep Zone wells sampled in 2009, perchlorate was detected in 10 samples, at a maximum of 17 µg/L (MCF-28A), but no detections exceeded the perchlorate BCL.

The distribution of perchlorate was plotted and contoured to show the distribution of this analyte in Site groundwater (Figures 327 through 329). Concentration trend graphs for this parameter (wells with the 10 highest detections in 2009) are included in Appendix E.

Similar to the isoconcentration maps for Shallow Zone VOCs, metals and radium 226+228 discussed above, the perchlorate map of 2009 Shallow Zone groundwater data (Figure 327) shows a trend with the highest perchlorate detections extending across the Site from the southwest to the northeast. The highest Shallow Zone perchlorate concentration was measured in off-site well PC-28 at 500,000 µg/L. Perchlorate concentrations exceeding 10,000 µg/L extend from the PC-28 area northeast on either side of the former spray wheel area up to the northeast property boundary. Shallow Zone perchlorate concentrations that exceed those detected at the Site in 2009 have been documented upgradient and off-site to the southwest of the Eastside area (TRONOX, 2006).



3.2.6 Total Dissolved Solids

In Shallow Zone wells sampled during the 2009 event, TDS was detected in 80 of 82 samples, and all 80 of these detections exceed the TDS MCL (secondary) of 500 mg/L. NDEP has not assigned a BCL to TDS. The maximum Shallow Zone TDS detection was 142,000 mg/L in well WMW5.58SD, installed in Las Vegas Wash. On-site, the highest TDS detection in a Shallow Zone well is 14,400 mg/L in well MW-04.

In Middle Zone wells, TDS was detected in all 18 samples, and each detected value exceeded 500 mg/L. The maximum detection in a Middle Zone well was 180,000 mg/L in well MCF-05. In Deep Zone wells sampled in 2009, TDS was detected over 500 mg/L in all 27 wells sampled. The maximum detected concentration in a Deep Zone well was 188,000 mg/L in well MCF-28A.

The distribution of TDS was plotted and contoured to show the distribution of this analyte in Site groundwater (Figures 430 through 432). Concentration trend graphs for this parameter (wells with the 10 highest detections in 2009) are included in Appendix E. Similar to the isoconcentration maps for Shallow Zone VOCs, metals, radium 226+228, and perchlorate discussed above, the TDS map of 2009 Shallow Zone groundwater data shows a trend with the highest TDS detections extending across the Site from the southwest to the northeast. Relatively low TDS concentrations were detected in wells downgradient of the former RIBs. Similar to the Deep Zone radium 226+228 map (Figure 326), the map of 2009 Deep Zone TDS (Figure 432) shows that the wells with the highest TDS detections are located in the northern portion of the Site. As discussed by DBS&A (2009), the Deep Zone TDS detections are consistent with the presence of a paleoevaporite deposit in this area of the Site.

3.2.7 Anions

As discussed in Section 2, CAB calculations completed with prior monitoring event data exceed acceptable criteria detailed in NDEP guidance (NDEP, 2009c) and Section 1030 E of the *Standard Methods for the Examination of Water and Wastewater* (APHA, 1999). Specific field procedures were therefore followed with the 2009 samples (field filtering, field alkalinity, separate shipping) to help develop a better CAB. In addition, BRC discussed the fifth round



CAB failures with the metals and anions laboratory (TestAmerica) prior to the 2009 sampling event, and the laboratory agreed to closely monitor their 2009 results for metals and anions and re-analyze samples, where possible and within protocol, to develop a better overall CAB.

Using the 2009 dataset, a revised CAB calculation table (Appendix F) was developed for both filtered and unfiltered metals and anions. As shown in this table, 96.93% of the 116-125 unfiltered samples (80.76 percent) in the 2009 dataset pass the CAB test with an acceptable variance of less than 5 percent. This percentage is a significant improvement from the CAB prepared with the fifth round data, where 64 of 106 samples (60 percent) passed the CAB criteria.

The percentage of unfiltered samples passing the TDS evaluation criteria in the 2009 dataset was less than the percentage passing in the fifth round dataset; 26.3% of the 116-125 samples (21.0 percent) passed the TDS criteria for comparison of anion/cation sum to the laboratory measured TDS value, and 18 of the samples (14.5 percent) passed the criteria for laboratory-measured TDS versus electrical conductivity. The low percentage of samples passing in the TDS checks appears related to the relatively high TDS concentrations measured in the groundwater samples.

Field filtering resulted in 12.9% more samples passing the CAB for 2009: 86.7 percent (108.2 of 126.17 samples) of the filtered samples passed the CAB criteria (Appendix F) compared to 76.80 percent (96.3 of 125.16 samples) of the unfiltered samples (TDS checks were not evaluated for filtered versus unfiltered samples because all samples were filtered by the laboratory before the TDS analysis).

Field-measured alkalinity does not appear to have a significant effect on the results of the CAB or the TDS criteria checks. The same samples pass and fail the analysis for both field- and laboratory-measured alkalinity (Appendix F).

3.2.8 Tritium and Stable Isotopes

A comprehensive summary and analysis of tritium and stable isotope data is presented in the separate BRC report entitled *Evaluation of Hydrogeologic Zone Connectivity Through Tritium*



and Stable Isotope Sampling and Analysis, BMI Common Areas (Eastside) (Isotope Report) prepared by DBS&A and dated December 29, 2009 (DBS&A, 2009) (NDEP has reviewed and provided comments to this document, dated February 11, 2010, that BRC is currently in the process of addressing). A summary of this report is included in this section because the data were collected as part of the 2009 sampling event and the prior fifth round event.

The presence of an event marker, such as bomb tritium (radioactive isotope of hydrogen), in groundwater can provide evidence that a component of sampled groundwater has recharged during a particular time period. Because of tritium's short half-life (12.32 years), the use of bomb tritium as a hydrologic tracer is relatively temporary. Before significant amounts of tritium were injected into the atmosphere through nuclear activities in the 1950s and 1960s, precipitation had an estimated natural background of approximately 5 to 10 tritium units (TU) (Illinois Environmental Protection Agency, 1997). Radioactive decay of the tritium in any water recharged before the 1950s would therefore leave no detectable tritium today. Tritium content in precipitation in North America since the advent of atmospheric nuclear bomb testing in 1952 reached an atmospheric high in approximately 1963 and has diminished significantly since that time to the present atmospheric levels. In the southern hemisphere, the bomb pulse has already decayed to within 15 TU of natural background. More than 20 years ago, Bentley et al. (1986) reported that bomb tritium will be difficult to detect in 10 to 20 years.

The actual tritium content varies widely with location (Illinois Environmental Protection Agency, 1997). The Santa Maria, California and the Albuquerque, New Mexico stations have tritium monitoring stations with some of the longest monitoring records in the U.S. At Santa Maria, peak atmospheric tritium concentrations of about 1,300 TU were recorded from 1962 through early 1964, but by late 1964, tritium concentrations had diminished to less than 400 TU. Today, atmospheric background levels in the northern hemisphere are between about 5 and 30 TU (IAEA/WMO, 2006).

For 1976, the last year of record at Santa Maria, the average tritium atmospheric content from nine Santa Maria reporting stations was 15.33 TU (IAEA, 2009). Albuquerque, New Mexico reported a mean atmospheric tritium content of 7.3 TU from 12 reporting stations in 2001. These data are in agreement with the statement by the IAEA (2009) that, "Atmospheric tritium



concentrations have been decreasing over the last 30 years and are currently almost at their low, natural levels, making tritium less useful as a hydrological tracer.”

While tritium was chemically analyzed and evaluated for the Site monitoring wells sampled, the evaluation is qualitative and based on the absence or presence of tritium. Nonetheless, it provides an additional useful line of evidence in the interpretation of the source and fate and transport of chemicals at the Site.

Stable isotopes of hydrogen (H) and oxygen (O) were sampled to evaluate the connectivity between the three water-bearing zones and to potentially gain insight as to the origin of the water in the individual zones (DBS&A, 2009).

Laboratory analyses can determine the ratio of isotopes in a water sample. For the Site sample analyses, the isotopic ratios of $^{18}\text{O}/^{16}\text{O}$ and $^2\text{H}/^1\text{H}$ (D/H) were analyzed and interpreted. The laboratory analyses for stable isotopes of hydrogen and oxygen were conducted by Isotech Laboratories, Inc., in Champaign, Illinois.

The isotope ratio from Site samples was compared to the isotopic ratio of a reference material called Vienna Standard Mean Ocean Water (VSMOW). The comparison is made by means of the parameter δ , defined by Fetter (1988) for isotope ratios of oxygen and hydrogen (expressed in parts per thousand [‰]) as:

$$\delta^{18}\text{O} (\text{‰}) = \left[\frac{\left(\frac{^{18}\text{O}}{^{16}\text{O}} \right)_{\text{sample}}}{\left(\frac{^{18}\text{O}}{^{16}\text{O}} \right)_{\text{VSMOW}}} - 1 \right] 10^3$$

$$\delta^2\text{H} (\text{‰}) = \left[\frac{\left(\frac{^2\text{H}}{^1\text{H}} \right)_{\text{sample}}}{\left(\frac{^2\text{H}}{^1\text{H}} \right)_{\text{VSMOW}}} - 1 \right] 10^3$$

It is well established that the isotopic composition of precipitation at a particular location will vary seasonally and with individual storms (Mook, 2006). The isotopic composition of precipitation will also vary among locations depending upon climate and elevation. Nevertheless, the



composition of all precipitation generally falls on a straight line plot of $\delta^2\text{H}$ versus $\delta^{18}\text{O}$. This line is called the Global Meteoric Water Line (GMWL).

After liquid water is formed from vapor (as in precipitation), the isotopic ratios of ^{18}O and ^2H do not change and are locked into the water molecule except when a body of water is exposed to either (1) geothermal heating or (2) evaporation, such as from ponds or lakes in dry climates. The stable isotope concentration of the precipitation can be modified subsequent to precipitation; this modified signature of the soil water can be used to reveal the origin of the water.

Evaporation of soil water or evaporation from a free water surface leads to an increase in the concentration of the stable isotopes ^2H and ^{18}O in the residual water, since the lighter isotopes ^1H and ^{16}O are preferentially lost during evaporation as vapor. This physical process is known as fractionation.

Another process that can change the stable isotope signature of a parcel of water is a rock-water interaction such as exchange with water in hydrated minerals. For example, evaporites such as gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) are hydrated by the highly fractionated water from which they precipitated, and dissolution of the mineral or exchange of water with the mineral will release this fractionated water into more recently recharged water and shift its isotopic signature in proportion to the mixing.

In geothermal systems, significant isotope exchange of hydrogen and oxygen occurs between rock and water, due to membrane filtration through layers of semipermeable clays as well as hydration or dehydration of secondary minerals. Water that is heated geothermally becomes relatively enriched in ^{18}O due to the water coming into equilibrium with elevated concentrations of that isotope in minerals. Hydrogen is not similarly affected (Mook, 2006).

3.2.8.1 Groundwater Sampling for Tritium and Stable Isotopes

During the fifth round of sampling in 2008, groundwater samples for tritium and stable isotopes were collected from the three water-bearing zones at the Site (DBS&A, 2009). During the 2009 event, additional stable isotope samples were collected from the Deep Zone. No additional



samples were collected for tritium analysis during this event. The results of the laboratory analyses were used to determine if the isotopic character of the water in the three water-bearing zones could be differentiated on the basis of their isotopic signature and to assess the connectivity between the three site water-bearing zones. During the fifth round event in 2008, the following wells were sampled:

- *Northern Site Area (near Las Vegas Wash):* Wells AA-08 (Shallow Zone), MCF-08B-R (Middle Zone), and MCF-17A (Deep Zone)
- *Northern Site Area (upgradient of Northern RIBs):* Wells MCF-05 (Middle Zone) and MCF-20A (Deep Zone) (Shallow Zone Well DM-5 was proposed but not sampled due to lack of water.)
- *Middle Site Area (near high perchlorate and TDS detections):* Wells MCF-16C (Shallow Zone), MCF-16B (Middle Zone), and MCF-16A (Deep Zone)
- *Southern Site Area (near plants sites):* Wells AA-01 (Shallow Zone), MCF-02B (Middle Zone), and MCF-01A (Deep Zone)

Between August 21 and September 29, 2009, additional groundwater samples were collected by Converse Consultants, Inc. (Converse) and analyzed for stable isotopes. The samples from the 2009 monitoring event were collected from the following monitoring wells:

- *MCF-02A:* Located at the southern end of the Site, approximately 1,830 feet north-northwest of the intersection of Boulder Highway and Lake Mead Drive
- *MCF-06A-R:* Located at the north-central edge of the Site, on the boundary with the Weston Hill property
- *MCF-18A:* Located approximately 390 feet west-northwest of the northwest corner of the COH Northern RIBs



- *MCF-18A (FD)*: Field duplicate collected from monitoring well MCF-18A
- *MCF-29A*: Located at the northwestern corner of the Weston Hills property, immediately south of Las Vegas Wash
- *MCF-31A*: Located adjacent to the north-central boundary of the Tuscany Village property
- *MCF-30A*: Located approximately 460 feet east of the northwest corner of the Tuscany Village property, south of the C channel

3.2.8.2 Tritium Results

Two tritium samples (AA-08 and AA-01) collected from wells screened in the Qal contained tritium above the detection limit (1 TU) with activities of 5.18 and 9.88 TU, respectively. These samples represent water that has recharged relatively recently (DBS&A, 2009). Theoretically, this water could have recharged any time since the 1950s or 1960s, when atmospheric levels of tritium were much higher, and the tritium concentrations in the subsurface were then subsequently reduced to present levels by radioactive decay and possibly mixing with older groundwater. However, Site data from aquifer testing indicates that water travel velocities within the Qal are relatively fast. Thus, analysis of tritium samples indicates that the water in the Shallow Zone (Qal) is younger than water in the Middle or Deep Zones.

The remaining samples, collected from wells having various screened interval depths within the UMCf, were below the tritium detection limit. These data suggest that groundwater is on the order of at least 37 years old (assuming that three tritium decay half-lives are required to reduce atmospheric [assumed for this calculation to average 7.5 TU] background concentrations of tritium to below the detection limit of 1 TU) (DBS&A, 2009).

3.2.8.3 Stable Isotope Results

The range of $\delta^2\text{H}$ values measured in the Site samples generally fell within the range of expected $\delta^2\text{H}$ VSMOW values for temperate zone precipitation: -60 to -95 ‰ (Mook, 2006). Likewise, the range of $\delta^{18}\text{O}$ values measured in the Site samples generally fell within the range



of expected $\delta^{18}\text{O}$ VSMOW values for temperate zone precipitation: -2 to -15 ‰ (Mook, 2006). The stable isotope concentrations in most of the Deep Zone wells are relatively high and indicate a source of water that has been strongly fractionated (DBS&A, 2009).

The 2008 samples collected from monitoring wells MCF-05 and MCF-20A are isotopically heavier than, and distinct from, the other samples collected in 2008. Well MCF-20A is a Deep Zone well that has a screened interval from 360 to 380 ft bgs. Well MCF-05 is screened at a relatively deep depth interval within the Middle Zone at 221 to 231 ft bgs. These two wells are located in the vicinity of relatively high TDS concentrations that were reported for samples from the Deep Zone and the Middle Zone. The data represent one line of evidence that the elevated TDS in this area of the Deep and Middle Zones is the result of groundwater that is in contact with a paleoevaporite deposit.

As noted above, six additional Deep Zone wells were sampled in 2009. The data for all of these samples except for MCF-02A indicate that groundwater has undergone isotopic fractionation and is enriched in the heavier isotopes ^{18}O and ^2H . The data lend further support to the interpretation that the elevated TDS in this area of the Deep and Middle Zones is the result of groundwater that is in contact with a paleoevaporitic deposit (DBS&A, 2009).

As depicted in Figure 432, the area of elevated TDS in the Deep Zone is focused at and north of the northern boundary of the Site. Isoconcentration plots of the distribution of groundwater with enriched ^{18}O and ^2H are presented in Figures 433 and 434. Elevated TDS impacts appear coincident with the area of enriched ^2H and ^{18}O .

These figures show a focused region of heavy isotope enrichment in the same area that is characterized by elevated TDS. This coincident occurrence is consistent with and indicative of an area of evaporite deposits (DBS&A, 2009).



4. Path Forward

BRC has completed six rounds of sitewide groundwater sampling and analysis. In discussion with NDEP, BRC has developed a list of AOIs that consists of:

- Alpha BHC
- Arsenic
- Carbon tetrachloride
- Manganese
- Magnesium
- PCE
- Perchlorate
- Radium 226+228
- Selenium
- TDS
- Total and hexavalent chromium
- TTHMs

For any future monitoring events, BRC will conduct laboratory analysis for those analytical parameters listed above or an appropriate subset approved by the NDEP. Annual water level monitoring will be conducted for wells where water levels are relatively stable. Semiannual water level monitoring will be conducted where water levels appear to be relatively unstable or fluctuating (where change is greater than 10 percent of the well water column height compared to the prior round).



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