



PHASE I SITE INVESTIGATION PROGRESS REPORT

Prather Spring Phase I Site Investigation

Fall 2008

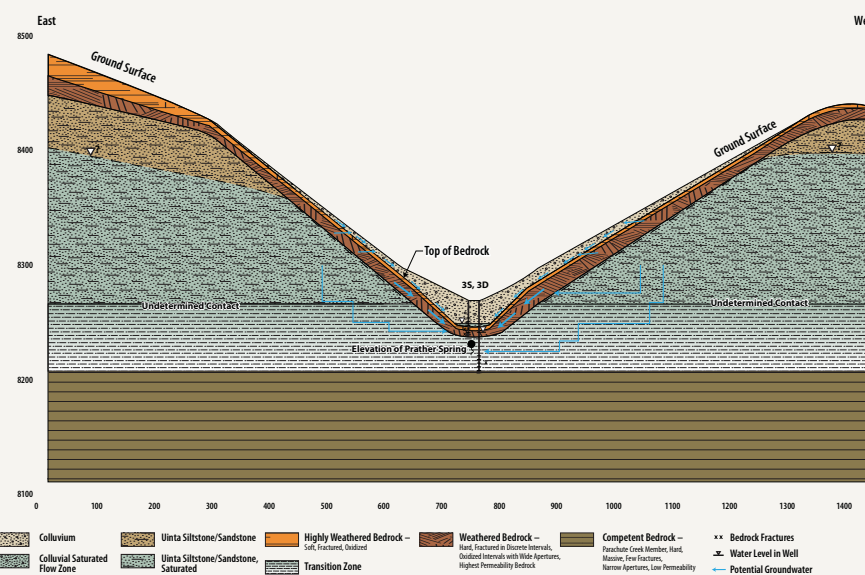
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URS



Phase I Site Investigation Progress Report

Fall 2008

Prather Spring Investigation

Garfield County, Colorado

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Prepared by
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for
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Petroleum Development Corporation
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1.0 Introduction

1.1 Project Background

This progress report was prepared on behalf of Williams Production RMT Company (Williams), Petroleum Development Corporation (PDC), Marathon Oil Company (Marathon), and Nonsuch Natural Gas (Nonsuch) (collectively, “the Companies”), to summarize the Phase I site investigation activities conducted to date. The objective of the Phase I site investigation was to locate the source(s) of contamination that have impacted a private drinking water supply in the form of a spring located in the vicinity of active natural gas development. The contaminated water is present at Prather Spring.

This spring was previously developed by the landowner with the addition of a spring box and 500-gallon cistern. The water source was permitted as a well under Permit 233234 with the State Engineers Office (SEO), located in Section 14 (SE quarter of the SW quarter) of Township 6 south, Range 97 west and is referred to herein as “Prather Spring.” The description of the well in the SEO records is enigmatic. From its origin, water from Prather Spring is piped approximately 0.25 miles down-slope to a hunting cabin (the Prather Cabin), where it is used seasonally as the main potable water supply. The overflow from this water delivery system flows down-gradient through additional piping and is eventually discharged into a perennial stream known as McKay Gulch. Figure 1 shows the locations of pertinent surface features and surface water and groundwater sample locations.

Contaminated water was discovered in Prather Spring on or around May 31, 2008, when one of the cabin owners (Mr. Ned Prather) turned on the cabin tap while opening up the hunting cabin for the summer season. Benzene, toluene, xylenes, 1,2,4-trimethylbenzene (1,2,4-TMB) and 1,3,5-TMB have been reported in samples from the spring and cabin tap, with benzene, toluene, and xylene concentrations above their respective drinking water standard at both the spring and cabin tap.

In response to the contaminant release, on June 19, 2008, the Colorado Oil and Gas Conservation Commission (COGCC) issued a Notice of Alleged Violation (NOAV) to each of the Companies and directed them to provide an alternate drinking water supply for the cabin. The NOAV also included a requirement to provide a suitable alternate water supply for livestock consumption. The Companies have since complied with these directives, and have initiated the Phase I site hydrogeologic investigation to delineate the contamination source(s).

On June 23, 2008, the Companies formed a joint group to facilitate investigation in the valley areas and URS Corporation (URS) was retained to lead, conduct, and oversee the joint investigation in the vicinity of the spring on behalf of the Companies. In addition to this proposed study, other operators have responded to the NOAV by performing their own internal pad-specific investigations.

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As part of the Companies' interim response, routine surface water monitoring commenced in early July 2008 at 10 locations (Addendum #1 to the *Phase I Site Investigation Work Plan [Joint Work Plan]*). A significant increase in chloride concentration and the presence of low concentrations of several petroleum hydrocarbon (PHC) constituents (benzene and xylenes) were detected in a sample collected from Spring 2 during routine sampling on July 17, 2008. Since this time, identifying the source or sources of PHC and chloride to Spring 2 has been added to the site investigation objectives.

1.2 Phased Investigation Approach

The project scope involved a phased investigation approach. The objective of the Phase I site investigation was to identify the probable source(s) of contamination for the springs. The Phase I site investigation conducted to date is described in this progress report and involved three rounds of drilling, monitoring well installation, and sampling, as described in the initial *Joint Work Plan* (URS 2008a) and related Work Plan addenda (Golder 2008; URS 2008b, c, d, e), which are described further in Section 2.0. Table 1 provides an overview of the Phase I field activities. (This phase also included numerous surface water sampling events conducted weekly/biweekly).

Any future Phase 2 investigation activities would be those designed to verify and delineate the extent of source(s) identified during Phase I activities. Phase 2 activities would also characterize the potential impact that documented contamination may have to human health or the environment. Phase 3 activities would be designed to remediate the source(s) of the groundwater contamination identified from the Phase 2 results, and address remediation of soils, if necessary. The Phase 2 and Phase 3 Investigation activities are beyond the scope of this investigation.

2.0 Investigation Scope and Objectives

The project scope is described in the *Joint Work Plan* (URS 2008a) and all five associated *Joint Work Plan* addenda. These documents, and pertinent correspondence, are included as Attachment 1 and summarized below. In addition, Table 1 provides an overview of the field activities conducted in 2008 in support of the Phase I site investigation.

2.1 Recap of Initial Field Activities in Interim Report

The initial draft *Joint Work Plan* was completed on July 7, 2008. The *Joint Work Plan* was revised per comments received by COGCC, and the Revised Work Plan was submitted to the COGCC on July 31, 2008. The initial field activities were conducted between July 15 and 17, 2008 and consisted of drilling six boreholes and installing monitoring wells to characterize groundwater. Five of these wells were installed within the shallow, unconfined groundwater encountered along the colluvial/bedrock interface. One well, PSMW-11D, was installed within the bedrock with a screened interval at the approximate elevation of Prather Spring. Laboratory analytical data of a groundwater sample collected from well PSMW-11D contained PHCs (benzene, toluene, xylenes, and gasoline range constituents [PHCG]). PHCs were not detected in samples collected from shallow wells within the saturated colluvial flow zone. The results of the initial field effort were presented in the *Interim Prather Spring Phase I Site Investigation Drilling Report* (URS 2008f), dated August 7, 2008, which is included in Attachment 2 to this report.

The initial investigation phase was designed to collect subsurface soil and groundwater samples from saturated portions of the colluvium and/or shallow bedrock at the site in an attempt to find and characterize a potential shallow contaminant source. The results of this initial investigation were considered insufficient to determine the origin of the impacts to groundwater in the area, and additional drilling into weathered bedrock and bedrock was planned for the purposes of: 1) characterizing a potential fluid source from a deeper confined to semi-confined aquifer, and 2) conducting further sampling and analysis.

2.2 Overview of Work Plan Addenda and Additional Field Activities

Five addenda to the *Joint Work Plan* outlining a variety of field activities were prepared. The purpose and scope of each *Joint Work Plan* addendum are summarized in the subsections below. Several addenda were prepared and other field activities conducted in response to the COGCC letter dated July 10, 2008 which provided comments on the initial draft of the *Joint Work Plan*.

2.2.1 Joint Work Plan Addendum #1 - Golder Memorandum

The first addendum to the *Joint Work Plan* was a memorandum prepared by Golder Associates dated July 10, 2008 that outlined a twice-weekly sampling regime at 10 surface water locations for a minimum of 4 weeks or until the source of contamination is determined. The sample analysis specified in this addendum is volatile organic compounds (VOCs) using U.S. Environmental Protection Agency (USEPA) Method 8260. The intent of this surface water sampling program was “to allow evaluation of water quality trends, with the ultimate objective of protecting human health.” The addendum references several sections of the *Joint Work Plan* for quality assurance/quality control (QA/QC) procedures, decontamination procedures, data deliverables, and data validation and database management procedures.

2.2.2 Joint Work Plan Addendum #2 - Modifications to Surface Water Monitoring and Groundwater Monitoring Program

This addendum to the *Joint Work Plan* describes groundwater, surface water, and seep/spring sample collection activities that were being conducted in support of the Phase I Site Investigation – Prather Spring. The intent of this supplemental sampling program was to allow evaluation of water quality trends to assist in the objectives of the Phase I site investigation.

This addendum specified modifications to the surface water monitoring program and additional parameters for groundwater analysis. The additional parameters included dissolved trace and other metals, dissolved major cations, major anions, and other inorganics. Tables 2, 3, and 4 display the number of analyses for each sampling location for each analytical method type for surface water, groundwater, and drinking water respectively. The drinking water samples were collected from the potable water tank which was installed to supply the cabin with potable water throughout the summer. Table 5 shows the analogous information for the few soil samples that were collected.

2.2.3 Joint Work Plan Addendum #3 - Deep Bedrock Well Installation

This addendum to the *Joint Work Plan* described the activities associated with the advancement of additional boreholes and installation of groundwater monitoring wells in bedrock underlying the colluvial deposits at the Prather Spring site. The intent of this program was to continue the investigation of soil and groundwater sampling and analysis to meet the objectives of the Phase I investigation.

In August and September 2008, additional borings (including bedrock coring) and well installations were performed to further characterize subsurface geology and hydrostratigraphy in the Ned Prather Spring drainage, as well as to begin subsurface characterization within the Spring 2 drainage. In the Ned Prather Spring drainage, three additional wells were installed within the shallow flow zone, and five additional wells were installed within deeper bedrock flow zones. In the Spring 2 drainage, four shallow flow zone

wells and three deeper flow zone wells were installed. Continuous coring was conducted at most holes and the cores are currently in storage. Attachment 2, which contains all previous project deliverables, includes the boring logs and core photos in the folder containing the September 29, 2008 COGCC Meeting deliverables.

Laboratory analytical data for groundwater samples collected from the wells installed during these addenda activities did not contain PHCs at concentrations of the same magnitude as observed in either Ned Prather Spring or Spring 2. However, laboratory analytical data for major ions, coupled with groundwater potentiometric levels, review of rock cores, and other site data, have led to the development of a refined conceptual hydrogeologic site model. This model suggests that shallow groundwater may flow preferentially within relatively narrow, discrete zones of higher transmissivity, potentially related to fractures within the upper bedrock (URS 2008c).

2.2.4 Joint Work Plan Addendum #4 - Cistern Excavation Evaluation

This addendum to the *Joint Work Plan* describes the cistern excavation activities near Ned Prather Spring and sample collection activities that were planned in support of the Phase I site investigation of Prather Spring. Excavation of the cistern was requested by the COGCC in a letter from Mr. Chris Canfield, addressed to the Companies, and dated July 10, 2008, "The cistern associated with the spring box must be removed and replaced. Samples of any sediment or other solid materials within the cistern will be collected and submitted for laboratory analysis."

The actual field activities conducted consisted of collecting representative aqueous samples (primary sample, field duplicate sample and split sample) through the access port on the top of the cistern and submitting the sample for analysis for an extended list of analytes. Minimal solid material was found in the cistern; therefore, there was adequate volume for the VOC analysis only. In addition, the condition and contents of the cistern were documented (written and photo). The cistern was not removed or replaced, nor was associated piping disturbed.

2.2.5 Joint Work Plan Addendum #5

This addendum to the *Joint Work Plan* describes the activities associated with conducting a geophysical survey, a soil gas survey, and installation of additional groundwater monitoring wells within the colluvial deposits and fractured bedrock at the Prather Spring site.

The addendum specified a combination of shallow geophysical surveys and soil gas surveys to be used to identify potential areas with greater fracture density, and the location(s) of elevated PHC concentrations and/or chloride concentrations in shallow groundwater flow zones. Immediately following these surveys, the addendum specified that monitoring wells will be placed in areas where shallow groundwater is

inferred to be impacted, based upon the preliminary results of the geophysical and soil gas surveys.

Finally, the addendum specified that, if preliminary results from the two surveys are inconclusive as to the location of groundwater impacts, the additional monitoring wells will be installed in cross-valley transects and in select areas to “bracket” potential flow paths into the drainages from potential uphill sources.

2.2.6 Vegetation Survey

In response to a request from COGCC contained in a letter dated July 10, 2008 and subsequent verbal communication from Chris Canfield of COGCC, URS personnel conducted a field evaluation for stressed vegetation at the Prather stock pond, the creek connecting Prather spring to the Prather stock pond, and aspen groves between the spring and a gas production wellpad (well nos. 14D-14D and 41A-22D). The field visit was made on July 30, 2008. The purpose of the visit was to evaluate reports of stressed vegetation at the stock pond and Prather Spring.

No evidence of unusual vegetation stress was observed. The results of the field evaluation were presented to COGCC in a memorandum dated October 3, 2008 (contained in Attachment 2). The report describes the study methods and the conditions present at the site during the field visit and numerous photos are included.

On a separate issue, in June and July there were two reports of “animal mortalities” discovered, and the subsequent analysis of an elk calf carcass discovered inside the stock fencing around Spring 2. The results of necropsy conducted by the State Veterinarian concluded that the elk calf died from other natural causes and was not attributed to ingesting PHC-impacted water related to Spring 2.

3.0 Summary of Field Data

This section summarizes field data collected during the Phase I site investigation. Field sampling locations are shown on Figures 2 through 5. Figure 2 presents the surface water sampling locations. Figures 3 and 4 contain sampling locations for the Prather and Spring 2 drainages, respectively. The soil gas sampling locations near two condensate tanks located on the ridge south of the springs are shown on Figure 5.

3.1 EM-34 Survey Results

An electromagnetic (EM) geophysical survey was conducted during October 8 to 10, 2008 by Cordilleran Compliance Services (Cordilleran). The objective of the survey was to delineate geologic/hydrogeologic features located in the shallow subsurface in the Prather Spring and Spring 2 drainages. More specifically, the objectives of the surveys were to differentiate between saturated colluvium and unsaturated shallow bedrock and also to determine if any plume of elevated concentrations of salinity could be delineated in the shallow groundwater.

The Geonics EM34-3 system was used to acquire apparent terrain conductivity of the subsurface stratigraphy in both drainages. The EM34-3 consists of two coils, one used as a transmitter and the other used as a receiver. The primary magnetic field is generated from the transmitter which induces current into the subsurface. This current generates a secondary magnetic field which is detected along with the primary field by the receiver coil.

During the survey, a total of 13 transects with a total line length of 1,625 meters were surveyed in the two drainages. A conductivity measurement was recorded every 10 meters (approximately 30 feet) along each transect with an effective penetration depth of approximately 25 feet below ground surface (bgs).

The survey conductivity data was calibrated to site subsurface conditions using well logs from existing monitoring wells in the areas. The conductivity of the subsurface (colluvium and weathered bedrock) is influenced by the presence of water. Water levels from existing wells were used to check the conductivity contrast between saturated and unsaturated materials. Saturated colluvium/bedrock was found to have a higher conductivity (generally greater than 10 milliSiemens per meter [mS/m]) than of unsaturated colluvium or bedrock (generally less than 10 mS/m).

Cordilleran prepared a contour map of the observed terrain conductivity values for both areas, which is shown in Appendix A, Figure 1. The conductivity values found in the Prather Spring area varied from 4 mS/m to 18 mS/m. The conductivity values in the Spring 2 area varied from 4 mS/m to 150 mS/m. The high conductivity values (greater than 20 mS/m) that were found in the Spring 2 valley were located

along the road and are not shown on the map due to the presence of a buried metallic pipeline, which was unknown at the time of the survey.

Cordilleran provided an interpretation of the EM survey data, which is presented in Appendix A. Cordilleran concluded that a significant conductivity difference between colluvium and bedrock was observed during the survey. In both the Prather Spring and Spring 2 drainages, higher conductivity values occur where shallow groundwater is encountered, which generally corresponds with thicker colluvium deposits. Additionally, the valley sides did not contain colluvial deposits and the depth to groundwater was greater than 25 feet. The survey could not differentiate between fractured and unfractured bedrock in either drainage.

3.2 Soil Gas Survey Results

A soil gas survey was conducted during the third drilling event (October 13 to 24, 2008). Soil gas probe locations were selected based on the preliminary results of the EM survey. In both the Prather and Spring 2 drainages, soil gas probes were located in areas of significant colluvial thickness upgradient of the spring. In the Spring 2 drainage, additional locations were placed along cross-valley transects to evaluate potential discrete flow paths (e.g., fractures) within the drainage. Additionally, shallow soil gas probes were installed near two pipeline collection or “drip” tanks located near the top of the two drainages (Figure 5). The installation of shallow soil gas probes near a third drip tank was not possible due to denial of access by the property owner and/or the facility operator.

To install soil gas probes, a borehole was advanced with a 4-inch nominal solid-stem auger. Boreholes were advanced to either the competent bedrock interface or approximately to the water table, as determined from the water level in nearby monitoring wells. Soil gas probes were installed in each borehole. The probes were constructed of 0.625-inch nominal PVC, which contained approximately 4 feet of slotted pipe at the base of the probe. Probes were installed in the open borehole and contained a retaining device (grout basket) approximately 3 feet bgs. Plastic was placed on top of the grout basket, and 3 to 6 inches of bentonite chips were placed on top of the plastic and hydrated to provide a seal, preventing ambient air from entering the borehole. Drill cuttings were then placed on top of the bentonite chips as additional sealant.

Soil gas probes were purged using a photoionization detector (PID) and/or a peristaltic pump. Purged soil gas was monitored for the presence of organic vapors using a PID. The highest PID measurement during the purging period was recorded in the field notebook. PID readings in the Prather drainage ranged from 2.7 to 14.6 PID units. PID readings in the Spring 2 drainage were all below 0.1 PID units. A summary of PID readings from soil gas purging are presented in Table 6.

After purging, soil probes were allowed to equilibrate for a minimum of six hours. Samples were then collected by purging a volume equal to the standing air in the soil probe, then collecting soil gas in a Tedlar bag. Soil gas samples were labeled and submitted to the mobile laboratory for analysis.

A total of 12 soil gas probes were installed in the Prather drainage, which ranged in depths from approximately 15 to 20 feet bgs. A total 15 soil gas probes were installed in the Spring 2 drainage, which ranged in depths from approximately 8 to 14 feet bgs. Five soil gas probes were installed at both of the drip tank locations for a total of ten, which ranged in depths from approximately 8 to 9 feet bgs. A summary of soil gas probe completion information is included in Table 6.

3.3 Monitoring Well Installation Results

Monitoring wells were installed at the site in three separate events. A summary of well construction details is included in Table 7. The first drilling event occurred from July 15 to July 18, 2008. During the first event, a total of seven wells were installed in the Prather drainage. Boreholes were advanced using 3.75-inch inside diameter hollow-stem augers (7-inch nominal outside diameter). Split-spoon samples were collected for lithologic logging and analytical sample collection purposes. The boreholes for wells PS-MW05S, PS-MW06, and PS-MW11S were advanced to the bedrock interface (split-spoon refusal). Wells PS-MW04 and PS-MW03 were advanced into weathered bedrock until auger refusal. The borehole for PS-MW11D was advanced into competent bedrock using four-inch nominal solid-stem augers and the well set in the open borehole. Six of the seven wells were installed in the shallow flow zone (colluvium and weathered bedrock), and one well, PS-MW11D was installed in a deeper bedrock flow zone. Wells were completed with above-grade surface protective covers and well pads.

During the second drilling event (August 28 through September 10, 2008), a total of 15 wells were installed in the Prather and Spring 2 drainages. In the Prather drainage, five deep wells, two intermediate wells, and one shallow well were installed for a total of eight. In the Spring 2 drainage, four shallow and three deep wells were installed, for a total of seven (Table 7).

The second drilling event included auger and air coring methods. Air core drilling was used to characterize competent bedrock lithologies in both drainages. Shallow wells in the Spring 2 drainage were installed using hollow-stem augers. Split-spoon samples were collected for lithologic logging and analytical sample collection. Wells were completed with above-grade surface protective covers and well pads.

The third drilling event (October 13 through 24, 2008) included the installation of 21 temporary monitoring wells in both the Prather and Spring 2 drainages. Seventeen monitoring wells were installed in the Prather drainage and five monitoring wells were installed in the Spring 2 drainage. Wells in both

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drainages were screened within the shallow flow zone, including the lower colluvium and weathered bedrock lithologies (Table 8).

Selected monitoring well locations for the October drilling event were based on the preliminary results of the EM survey and soil gas survey. In the Prather drainage, monitoring wells were installed near soil gas probes with elevated PID readings, as well as in cross-valley transects to evaluate potential discrete flow paths within the drainage. In the Spring 2 drainage, wells were placed in a cross-valley transect, as well as along the east and south sides of the drainage to evaluate discrete flow paths beneath this side of the drainage.

Boreholes were advanced using 6-inch nominal solid-stem augers to a depth corresponding to the respective spring elevation, or 10 feet below bedrock, whichever was encountered first. A temporary monitoring well was installed in each borehole, which were constructed of either 1.5-inch or 2-inch nominal PVC. Wells were grouted above the filter pack with bentonite chips, but surface protective casing or well pads were not installed.

After installation, a grab sample was collected from the temporary wells and submitted to the mobile laboratory for analysis. Wells were developed in accordance with the Work Plan. During development, water quality parameters were recorded, which are summarized in Table 9. After wells were developed, a second groundwater sample was collected and submitted to the mobile laboratory for analysis. A summary of organic analytes detected by the mobile laboratory are also summarized in Table 9.

4.0 Hydrologic Conceptual Model

Although a number of monitoring wells have been installed during the 2008 field season, the location of impacted groundwater above the Prather spring and the origin of the PHCs have not been specifically identified. The following discussion of the geologic and hydrogeologic conditions is presented to provide a framework for better understanding groundwater flow conditions in the area. This understanding may provide better capabilities to locate additional monitoring wells in the future, if necessary, as well as assist in predicting where and when impacted groundwater may occur in the future. The hydrogeologic framework also provides a lens to view the surface water and groundwater quality data (both organic and inorganic), and evaluate water quality relative to the location in the watershed.

4.1 Geology

The geology for the Circle Dot Gulch quadrangle was mapped by the U.S. Geological Survey (USGS) in 1982 (Hail 1982). The principal rock units in the Prather spring area include the Tertiary (Eocene age) Unit D of the lower Uinta Formation (Uinta D) and Parachute Creek Member of the upper Green River Formation. Colluvial deposits are present in the valley drainages.

The Crystal Creek Anticline is mapped to the south of the Prather and Spring 2 drainages, and generally follows the ridgeline (Hail 1982; Hail, et al. 1989). Based upon the depth and elevation of the Mahogany Zone (termed the Mahogany Ledge in outcrop), a marker horizon encountered in oil shale exploration holes drilled in the area, the axis of the anticline is oriented in a northwest to southeast direction (north 44 degrees west), and plunges gently to the northwest (Hail 1982; Hail, et al. 1989). The Mahogany Zone is a laterally extensive oil shale unit within the Parachute Creek Member. Structural contours drawn on top of the Mahogany Zone indicate that beneath the site, the bedrock dips gently (about one-half to one degree) to the northeast, or approximately a one foot drop per 50 feet. Although rock outcrop is scarce in the area, a small exposure of Uinta sandstone is present on the north side of the access road leading down to the Marathon-PDC well pad. The bedding observed at this location appears to dip gently to the north-northeast. Resistant shale beds observed in the valley bottom below the Ned Prather cabin also dip gently to the northeast.

Review of topographic maps and aerial photography of the area reveals the presence of numerous linear geographic features, termed lineaments. In the project area, a prominent linear feature is Garden Gulch, which is oriented in a northeast-southwest direction. This trend extends southwest above Garden Gulch, up McKay Gulch. The northeast-southwest orientation of linear features is clearly evident in the area.

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The Uinta D unit is present on the ridge tops and extends down into the upland drainages. The Uinta consists primarily of fine grained sandstone and siltstone. Field observations agree with descriptions by Hail, who notes that the Uinta Unit D is, “relatively nonresistant; and weathers to rounded slopes.”

Underlying the Uinta are marly siltstone, silty marlstone, dolomitic marlstones, and oil shales of the Parachute Creek Member of the Green River Formation. Regionally, the precise contact between the two units is difficult to identify because marlstones and sandstones are interbedded or intertongued over large distances. However, interbeds are less common in the southern half of the Circle Dot Gulch quadrangle (Hail 1992). The Parachute Creek Member is resistant to weathering and is described as, “resistant, forms high precipitous cliffs on canyon walls” (Hail 1982).

The mapped contact between the Uinta D and Green River Formation is located in the valley just below Ned Prather’s cabin (Hail 1982; Hail, et al. 1989). However, during the three rounds of drilling associated with the Phase I site investigation the contact was encountered at higher elevations. Soil borings drilled up-valley of both Prather Spring and Spring 2 encountered marlstones of the Parachute Creek Member beneath colluvium deposits. There was little Uinta Formation (sandstone) encountered in any of the soil borings that were subsequently completed as monitoring wells in the Prather valley. Sandstone was encountered at shallow depths in several borings completed on the slope above the east side of Prather valley, suggesting that the Uinta-Green River Formation contact is present at an elevation just higher than the elevation of Prather Spring.

URS has interpreted the presence of two important geologic contacts that affect the occurrence of springs in the study area. The upper contact serves as the primary contact between the higher permeability Uinta sandstone units and the underlying relatively low permeability marly siltstones and dolomitic marlstones. These marly siltstones and silty marlstones represent a transitional unit separating Uinta sandstones and Parachute Creek Member dolomitic marlstones. The second geologic contact is the mapped contact of Hail (1982, 1989) that marks the contact with Parachute Creek Member dolomitic marlstones. This contact forms the valley bottom below the Ned Prather cabin. Figure 6 is a schematic cross-section that extends east-west across the Prather Valley above the spring. The cross-section shows the inferred contacts between the Uinta sandstone, the underlying transitional unit (silty marlstones), and the shale-dominant Parachute Creek Member of the Green River Formation in this area. Geologically, the transitional unit identified in this area could be considered either the basal section of the Uinta Formation or the upper portion of the Parachute Creek Member. This study interprets the transitional unit as belonging to the upper Parachute Creek Member because of the presence of marlstone interbeds and significant contrast in permeability to groundwater and resulting occurrence of springs. The hydrologic significance of these contacts is described in the next section.

Colluvium is present in both drainages, and consists of angular clasts of sandstone and claystone in a clayey matrix. The thickness of the colluvium ranges from six feet on the hillslope above the Prather valley (PSMW-13D), to 22 feet in the valley (PSMW-03S/D). In two of the original soil borings (MW-05 and -06) the field geologist observed that near the base of the colluvium the core was visually wet, however, monitoring wells installed in these locations were dry, and remained dry for the duration of the 2008 field season. Subsequent monitoring wells completed in the Prather drainage were installed at a greater depth, and completed into deeper fractured bedrock materials. All of the wells that extended into the bedrock contained groundwater upon completion.

The second round of drilling, completed in both drainages during late August and early September (Addendum #3, URS 2008c), was completed using a larger drilling rig, and wells were generally installed to deeper completion depths. These wells were also continuously cored to provide geologic information and evaluation of the occurrence and density of the fractures. (Boring logs and photos of the rock core are presented in the September 29 technical presentation materials [Attachment 2].) Evaluation of the core identified a zone of softer weathered bedrock present beneath the colluvium, which transitioned with depth to more competent but fractured bedrock. A schematic profile illustrating this sequence is shown in Figure 7.

The thickness of the fractured bedrock interval observed in the core was generally in the range of two to five feet. Fracture orientations in this interval were typically at angles of 30 to 40 degrees from horizontal. Fracture apertures displayed rust-colored (oxidized) faces. Although observed fracture aperture widths were typically thin (one to several millimeters), at several locations the fracture widths were much wider (up to a centimeter), and were “filled” with reddish-brown mud and gravel clasts. As is typical when drilling in shallow fractured bedrock, groundwater was rarely observed in soil cores while drilling, but the wells all yield groundwater.

Hard and competent bedrock consisting of marly siltstones and dolomitic marlstones of the Parachute Creek Member were encountered beneath the upper weathered and fractured bedrock interval at all of the monitoring well locations where borings were cored. The upper portion of the Parachute Creek Member bedrock, especially at boring locations in the Prather valley, was relatively silty, and displayed high angle and contorted (disturbed) bedding, interpreted to represent slump features formed shortly following sediment deposition.

Few fractures were observed in the deeper bedrock intervals, and no fracture zones (discrete intervals with multiple fractures) were identified. At a depth of 56.5 feet bgs in well PSMW-03D, a 4-inch interval of rust-colored (oxidized) marlstone was identified containing several bedding parallel (horizontal) fractures. A thin (approximately 0.5 inches) seam of black hard carbonaceous material was present

immediately beneath this fractured horizon. A similar carbonaceous interval was identified in core from well PSMW- 10D in the Spring 2 drainage at a depth of 28 feet bgs. Correlation of the elevations of the carbonaceous seam at both locations (approximately 8,212 feet above mean sea level [msl]) yields a bedding strike¹ orientation of north 28 degrees west. Comparison of lithologic units in core of the Parachute Creek Member bedrock between the two drainages suggests that the upper approximately 20 to 30 feet of silty marlstones in the Prather valley borings are not present in the borings completed in the Spring 2 valley. This agrees with the fact that Spring 2 is located at a ground surface elevation of approximately 30 below the Prather spring elevation (8,209 compared to 8,239 feet msl, respectively).

Monitoring wells completed during the second round of drilling were completed in the upper portion of the fractured bedrock, and deeper bedrock intervals. Monitoring well designations utilized at the site are as follows:

- “S” refers to “shallow” and was initially used for wells completed in the colluvial flow zone. However, to install wells that would yield groundwater, the well screen needed to extend below the base of the colluvium, down into fractured bedrock material. “S” wells are screened within the lower colluvium and upper bedrock.
- “M” refers to “middle” and was generally used for wells completed only in the upper portions of the bedrock, beneath the colluvium.
- “D” refers to “deep” and was generally used for wells completed in deeper competent bedrock intervals.

Figures 8 and 9 are schematic cross-sections oriented down the Prather and Spring 2 valleys, respectively. The cross-sections show the completion intervals of several monitoring wells, lithologic variations with depth, and the spring discharge elevations. Boring logs show that the spring discharge elevations are coincident with the contact between the base of the colluvium and upper fractured bedrock. This would be the likely horizon for groundwater discharge.

4.2 Hydrogeology

The primary objective of the Phase I site investigation was to identify potential source(s) of PHC impacts to Prather Spring. However, there are several other springs in the area, and the Joint Companies were directed by COGCC to collect water samples from several springs and streams in the local area (Figures 1 and 2). Additionally, in mid-July, approximately one month following issuance of the NOAVs to the four

¹ The *strike* of a stratum or planar feature is a line representing the intersection of that feature with the horizontal. http://en.wikipedia.org/wiki/Strike_and_dip.

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companies, PHC and elevated chloride concentrations were detected in one of these other springs, Spring 2. This increased concerns regarding the origin of groundwater in the separate springs, and the possibility of hydraulic interconnection of the springs.

There are five springs identified in the area, four of which have been sampled multiple times as part of this joint investigation:

- **Prather Spring** (developed), located in the unnamed tributary above the Ned Prather cabin.
- **Spring 2** (undeveloped), located up McKay Gulch
- **Donna's Spring** (developed), located in an unnamed tributary north of McKay Gulch
- **Dick's Cabin Spring** (developed), located on the south side of McKay Gulch above the Dick Prather cabin
- **Spring below Dick's Cabin** (undeveloped), located east of Dick's Cabin, sampled once by COGCC and not included in the scope of this investigation

The project site is located in the upper reaches of the Garden Gulch watershed, which discharges to Parachute Creek. All five springs discharge water into McKay Gulch or tributaries to McKay Gulch. Three of the springs are similar from a geomorphic perspective. At Prather Spring, Spring 2, and Donna's Spring, each of these springs discharges from the base of thick colluvial deposits, which are located immediately up-valley of the spring. These thick colluvial deposits form the valley floor, and underlie a meadow up the valley from each of these three spring locations. There is no visual evidence of a gully or drainage in the valleys, i.e., no evidence of surface runoff or an ephemeral stream. There is no evidence of surface water runoff (e.g., eroded gullies) in any of the side tributaries that connect the ridgelines to the valley. The absence of surface runoff features indicates there is a relatively high rate of water infiltration and low runoff, probably attributable to highly permeable surface soils in the valley bottoms. In the valley below each spring, the drainage contains a perennial stream.

The flow rate of Prather Spring was measured on several occasions using a stopwatch and 5-gallon bucket. The flow rate was approximately 20 gallons per minute (gpm) in early June, during the initial response effort. Flow was measured on July 16 (14 gpm), August 27 (8 gpm), September 16 (6.3 gpm), and October 21 (4.5 gpm).

When viewed on a map, three springs appear to be aligned in a trend, which is oriented north-northwest (north 20 degrees west). This trend is similar to the strike of the Parachute Creek Member identified from the similar elevations of a carbonaceous seam in borings in the Prather and Spring 2 drainages (north 28 degrees west).

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The apparent linear trend of these three spring locations and coincidence of the orientation to the strike of the marlstone bedrock, suggests that the springs are located along an unmapped geologic contact that is inferred herein to separate two units with different hydrologic properties. Specifically, the springs appear to discharge at the contact between overlying permeable Uinta Formation sandstones and the underlying low permeability marly siltstones and silty marlstones of the Parachute Creek Member of the Green River Formation encountered at drilling locations for this investigation. An additional piece of evidence suggesting the presence of an unmapped geologic contact influencing the presence of the three springs is the observation that each spring occurs at the base of a relatively sharp boundary between thick colluvial valley fill above each spring, and an absence of such valley fill below each spring. The colluvial fill is interpreted to thin considerably in each valley at a location below the contact with the overlying and less resistant (more erosive) Uinta sandstones.

The presence of highly weathered Uinta sandstone situated at the top of the watershed and permeable colluvium in the upper portion of the valleys results in high rates of infiltration during storm and snowmelt periods, which creates a shallow groundwater reservoir to supply the springs. The absence of visual evidence of erosional features associated with surface runoff (i.e., gullies) indicates that surface soils have sufficient permeability to absorb precipitation and resulting runoff each spring. The “reservoir” (aquifer) drains from the base, at the lowest elevation in each valley where the low permeability “floor” (aquitard) is intersected, resulting in groundwater discharge at a spring. Figure 6 is a schematic cross-section across the Prather drainage valley, illustrating this hypothesis.

Technical consultants on the project were informed by the Prather’s that prior to development of the Prather spring the majority of seeps were visible on the east side of the valley bottom. Spring 2 is undeveloped, and the seeps are still visible in the spring area on the hillside on the east side of the drainage. One hypothesis to explain why seeps forming the spring at each location are on the east side of the valley bottom is that this is due to the strike and dip direction of the bedrock. Springs occur (daylight) at the lowest point along the geologic contact with the underlying lower permeability horizon and the ground surface. Because the bedrock dips gently downwards to the east-northeast, the speculated geologic contact is at a lower elevation on the east side of each valley bottom, and therefore, the spring in each drainage occurs on the east side of the drainage.

The strike and dip of the bedding within the Parachute Creek Member bedrock unit may also result in a subtle variation in groundwater flow direction in each valley. For groundwater flow occurring along bedding plane fractures, the east-northeast dip direction of the bedrock could potentially skew the direction of groundwater flow towards the east and north in Prather valley. Although this concept is speculative, a better understanding of potential groundwater flow paths in each valley may eventually

allow delineation of impacted groundwater flow paths and assist in understanding potential remediation alternatives.

This conceptual model for Prather Spring, Spring 2, and Donna's Spring implies a similar origin of the groundwater for each spring (surface water infiltration into the Uinta sandstone at the top of each watershed). The conceptual model does not imply that the three springs are hydraulically interconnected to each other, or share a common geographic origin of the groundwater. In fact, the origin of groundwater for the spring in each valley is inferred to be the approximate areal extent of the watershed for each valley.

The origin of groundwater discharging from Dick's Cabin Spring is less certain, but a hypothesis or conceptual model is presented here, as COGCC staff have inquired as to the likelihood of this spring becoming impacted in the future. The spring is developed, and the geology of the spring discharge is therefore covered underground. However, the discharge location is in an area located immediately below the mapped contact between the Uinta Unit D and Parachute Creek Member (Hail 1982; Hail, et al. 1989). URS has walked the rock outcrop in the area of the spring above Dick's Cabin, and observed the presence of white-weathering paper shale underlain by highly resistive (competent) dolomitic marlstones in this area that are likely the basis for Hail's mapped contact. This spring location is likely caused by the permeability contrast between the "transitional" upper Parachute Creek Member slightly more permeable silty marlstones and the underlying low permeability shales and dolomitic marlstones of the Parachute Creek Member. Dick's Cabin Spring is located in the low point (valley bottom, east side) of McKay Gulch where this geologic contact daylights at the ground surface. The spring is located in McKay Gulch below the confluence of the other three spring drainages (Prather, Spring 2, and Donna's), and may discharge groundwater originating from all three drainages. However, the discharge point for the spring is a deeper stratigraphic horizon, and therefore is from a deeper flow zone than the other three upland springs.

Shallow and Deep Flow Zones in Each Drainage

The depth to groundwater ranges from 16 to 50 feet in wells installed in the Prather drainage and from 13 to 32 feet bgs in wells completed in the Spring 2 drainage. At least during the months of this investigation, there was little groundwater present in the colluvial deposits. The saturated thickness of the colluvium ranges from 0 to 2 feet. Generally, the colluvium is dry on the hillsides and has the greatest saturated thickness in the floor of the valley.

The second round of drilling (Addendum #3, URS 2008c) was designed to collect rock core of the bedrock and complete monitoring wells in the upper and lower portions of the bedrock. Well pairs were installed in the shallow and deeper intervals. Water levels in the shallow wells were generally at

elevations corresponding to the base of the colluvium or upper portion of the bedrock surface, suggesting that groundwater in the upper portion of the bedrock was hydraulically connected to what little groundwater was found in the overlying colluvium. The deeper bedrock wells generally had greater depths to water than adjacent shallow well completions, although the water levels were relatively close in many locations. The lower water levels in the deeper monitoring wells indicate a downward hydraulic gradient from the shallow to deeper bedrock zones. A downward hydraulic gradient is anticipated in groundwater recharge (upland) areas. The deeper monitoring wells are generally completed at an elevation below the elevation of the Prather and Spring 2 discharge elevations.

Based upon the water chemistry in the monitoring wells and springs (see next section), the groundwater in Prather Spring is quite similar to groundwater in shallow monitoring wells located hydraulically upgradient of the spring. The similarity in water chemistry suggests that groundwater discharging from the springs is derived from groundwater present in the shallow colluvial and fractured bedrock flow zone.

The depth to water in groundwater monitoring wells was measured on a (typically) weekly frequency. Groundwater elevations were calculated by subtracting the depth to water from the measuring point elevation, which is typically the top of the well casing. Accurate mapping of the potentiometric surface was hindered by several factors. The low water yield from many of the monitoring wells caused a delay in the water level equilibration to static conditions following well installation and/or sample collection. There were also issues obtaining accurate survey elevations due to variations in the topography at the site and poor access to GPS satellites due to well locations in valleys and in forested areas.

Figures 10 and 11 are potentiometric surface maps for the shallow groundwater flow zone in the Prather and Spring 2 valleys, respectively. As expected, groundwater flow directions in both valleys generally follow the surface topography and flows downhill. Figure 12 is a map showing groundwater elevations for wells completed in the deep flow zone in both Prather and Spring 2 valleys.

In the Prather Valley, the axis of the valley bottom (valley center) differs slightly from the axis of the potentiometric surface contours. The water level elevation is slightly lower in wells on the east side of the valley, which is most pronounced at wells PSMW-16, -17, and -28. The water level elevation in well PSMW-28 is apparently lower than the discharge point for Prather Spring (assuming the survey elevation for this well is correct). One explanation for the slight decrease in water level elevations along the east portion of the Prather Valley is the east–northeast dip to the bedrock surface.

There is an additional geologic feature in the area of Prather Spring that may influence the flow direction of groundwater. A lineament oriented east-west extends from both directions of Prather Spring. This lineament is visible on the aerial photo basemap and is reflected by ground surface contour patterns on a

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topographic map. The linear feature extends west from the western bend in the Prather driveway, across a low area bisecting the north–south trending ridgeline, down to the Prather Spring, up the drainage west of Prather Spring to a point on the ridgeline just south of the Nonsuch well pad, then parallel to topographic contours along the south side of the Spring 2 drainage (south of the two switchbacks in the dirt road). It extends due west up a tributary drainage of the Spring 2 drainage to Trail Ridge Road.

Well hydrographs for select shallow and deep monitoring wells in both drainages were presented in the September 29 technical presentation to the COGCC (Attachment 2). Water level data from October measurements have been added to these hydrographs. The water level measurements and calculated elevations are presented in a table in Attachment 3 and well hydrographs for shallow and deep wells in both valleys are shown in Figures 13 through 16. Overall, water level trends in both valleys generally show a slight downward to flat trend in both shallow and deep wells in both valleys. Overall, water levels in the Prather valley have declined up to 2.45 feet (PSMW-03S and -04S), and increased up to 1.2 feet (PSMW-6R) over the course of the investigation period. In the Spring 2 valley monitoring wells, water levels have increased up to 1.6 feet in two deep wells (PSMW-07D and -10D) and declined up to 0.4 feet in other wells. The variation in water level elevations observed in Spring 2 monitoring wells is generally less than variations observed in monitoring wells installed in the Prather Valley. However, the duration of the observation period has been shorter for the Spring 2 drainage.

5.0 Summary of Analytical Data

A substantial set of analytical data was compiled over the 2008 investigation season. As shown in Table 10, a total of 69 data packages with Phase I data were received. Table 10 also summarizes who collected the field samples, which laboratory analyzed the samples, the number and types of samples in each package, the sample analyses, and which project work plan the samples were collected to support. The following subsections summarize overall data quality (Section 5.1) and the results obtained (Section 5.2).

5.1 Analytical Data Quality and Data Management

Overall, the data validation program indicated that acceptable levels of accuracy, precision, completeness, comparability, and representativeness were attained for the samples collected during the Phase I site investigation. The following subsections provide an overview of the data quality. Section 5.1.1 discusses the data sources including analytical methods and laboratories used; Section 5.1.2 summarizes the data validation procedure, Section 5.1.3 provides an overview of the resultant data qualification issued, Section 5.1.4 summarizes the split sample evaluation, and Section 5.1.5 provides an overview of the database structure.

5.1.1 Sample Analysis

All analytical methods used for sample analysis are USEPA-approved, industry-standard analysis methods used for site characterization. The samples were analyzed for one or more of the following parameters:

- VOCs by Method SW8260B
- Gasoline range organics (GRO) by Method SW8015M
- Diesel range organics (DRO) by Method SW8015M
- Motor oil range organics (MRO) by Method SW8015M
- Semivolatile organic compounds (SVOCs) by Method SW8270C)
- Select dissolved metals by Methods SW6010B and SW6020
- Glycols by Method SW8015M
- General chemistry parameters
 - Chloride, sulfate, sulfide, fluoride, bromide, nitrate, nitrite by Method SM4500B, F, H
 - Alkalinity by Method SM2320
 - Methane by RSK175

The SW846 series methods are specified in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, 3rd Edition, including all updates, prepared by USEPA's Office of Solid Waste. The 100 and

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300 series methods are specified in *Methods for Chemical Analysis of Water and Wastes* (USEPA 1983). The “SM” methods are found in *Standard Methods for the Examination of Water and Wastewater*, 18th Edition, prepared jointly by the American Public Health Organization, American Water Works Association, and the Water Pollution Control Federation.

The primary laboratory used for this investigation is Evergreen Analytical, Inc. (EAL) in Wheat Ridge, Colorado. EAL is certified by the Colorado Department of Public Health and Environment (CDPHE) for Phase I/II/V organic and inorganic drinking water tests and the Disinfection By-Product analytes. EAL is certified by the State of Utah and the National Environmental Laboratory Accreditation Program (NELAP) to analyze samples under the Resource Conservation and Recovery Act (RCRA).

The secondary laboratory used for this investigation when the primary lab could not guarantee fast turn around and for the cistern samples is Paragon Analytics, Inc. (Paragon) in Fort Collins, Colorado. Paragon was selected for this program due to its qualifications (which are summarized below), the laboratory’s ability to meet fast turn around requirements and analyze an extended list of analytes for the cistern samples, and URS’s successful working relationship with Paragon. Paragon holds the following programmatic certifications and/or validations:

- U.S. Department of Energy (USDOE)
- U.S. Army Corps of Engineers (USACE), self declaration
- U.S. Navy Naval Facilities Engineering Service Center (NFESC)
- U.S. Air Force Center for Environmental Excellence (AFCEE)
- Radioactive Materials Handling License – State of Colorado No. 847-02
- NELAP – Primary NELAP Certification through the State of Utah

Split samples were collected by LT Environmental Inc. (LTE), and these samples were submitted to either Test America in Nashville, Tennessee, or to Paragon for analysis.

Analytical data generated for the project were provided in both an electronic format and hardcopy format. The majority of hardcopy data packages were Level IV data packages that could be fully validated. For sample collected very early in the investigation and toward the end of the 2008 field season, the hard copy deliverables were Level II (i.e., QC summary packages). The Adobe Acrobat files (PDFs) of the QC summary portion of the data packages are included in Attachment 5.

5.1.2 Data Validation

To determine if the analytical data are of sufficient quality for their intended use, all data were validated by qualified URS chemists. The validation consisted of an evaluation of sample-specific parameters for

100 percent of the dataset as well as a review of laboratory performance parameters for a selected subset of the dataset. Problems identified during the laboratory performance parameter review as potentially being systematic laboratory performance issues were then also evaluated for all data packages. The sample-specific and laboratory-performance review parameters are summarized below. The Data Validation SOP was provided as Attachment B to the *Joint Work Plan* (URS 2008a) and includes the detailed data validation procedures. The resultant data validation reports and qualified data reporting forms are included in Attachment 5.

The review of sample-specific parameters included evaluating parameters that are field sample-related. These include: case narrative comments, chain-of-custody and sample condition upon receipt, holding times, method blank results, surrogate recoveries, matrix spike recoveries, laboratory duplicate analyses, post-digestion spike recoveries, serial dilution analysis agreement (metals only), internal standard performance, and results for field QC samples (e.g., field duplicates).

The review of laboratory performance parameters included evaluating operations that are in the control of the laboratory, but are independent of the field samples being analyzed. These include: initial calibration, initial and continuing calibration verification, laboratory control sample analysis, compound identification, result calculation (i.e., quantitation), data transcription (i.e., verification), and method-specific QC requirements (e.g., thermal stability, tuning, resolution, mass calibration, interference check sample analysis). Evaluation of these parameters provides an assessment of overall system performance.

5.1.3 Data Qualification and Usability

Results qualified as estimated (J or UJ) or nondetect (U) are considered usable for meeting project objectives. With the exception of 111 results for 2-chloroethylvinyl ether (2-CEVE), 9 chloroform results, and a single 1,2,4-TMB result, project data were found to be usable for meeting project objectives.

Nearly 40 percent of the 2-CEVE results were qualified as unusable because 2-CEVE was not recovered in any of the matrix spike/matrix spike duplicate samples. Another 23 percent of 2-CEVE results were qualified as estimated on the basis of low matrix spike recoveries. This is a known problem caused by the acidic preservation of the samples for VOCs analysis. The loss of 2-CEVE is not considered to affect the overall project objectives because this is not an indicator parameter for this investigation.

Approximately 2 percent of the chloroform results (all reported in a single data package) were qualified as unusable due to a low matrix spike recovery. A single 1,2,4-TMB result for a soil sample was rejected.

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Some results were qualified as nondetect on the basis of blank contamination and some results were qualified as estimated on the basis of matrix spike recoveries, duplicate precision, surrogate recoveries, and split sample agreement. The tables below summarize the data qualification issued by sample matrix.

Summary of Quantity of Qualified Data by Matrix

Groundwater	Number	Percentage
Total # Results ¹	9713	100%
# Results qualified as unusable (R)	8	0.08%
# Results qualified as estimated (J or UJ)	744	7.66%
# Results qualified as nondetect (U)	73	0.75%
Surface Water	Number	Percentage
Total # Results ¹	16677	100%
# Results qualified as unusable (R)	112	0.67%
# Results qualified as estimated (J or UJ)	528	3.17%
# Results qualified as nondetect (U)	90	0.54%
SoilSediment	Number	Percentage
Total # Results ¹	2106	100%
# Results qualified as unusable (R)	1	0.05%
# Results qualified as estimated (J or UJ)	182	8.64%
# Results qualified as nondetect (U)	2	0.09%
Drinking Water ²	Number	Percentage
Total # Results ¹	1752	100%
# Results qualified as unusable (R)	0	0.00%
# Results qualified as estimated (J or UJ)	54	2.56%
# Results qualified as nondetect (U)	3	0.14%
¹ Primary field samples only (excludes field duplicates, splits, and other field QC samples).		
² Includes Ned's Cabin when cabin was supplied by potable water tank.		

The data validation reports and qualified data reporting forms for all data packages are included in Attachment 5. These are organized by laboratory. Table 10 provides a cross-reference summary to the data reported by each laboratory.

5.1.4 Split Sample Evaluation

A total of 27 split samples (18 groundwater, 1 surface water, and 8 soil split samples) were collected for the Prather Spring sampling event, meeting the evaluation criterion specified in the *Joint Work Plan*. The split samples were collected by LTE and the samples were sent to Test America, Paragon, or EAL for analysis. The split samples were never sent to the same laboratory as the primary samples. When EAL received split samples (i.e., the cistern samples collected under *Joint Work Plan Addendum #4*), the primary samples were analyzed by Paragon.

Because split sample evaluation criteria were not included in the Work Plan, the following concentration-dependent criteria were used:

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- If one or both results were less than 5xRL, then the absolute difference between the results was compared to a criterion of plus/minus 2xRL for aqueous samples and plus/minus 3.5xRL for solid samples.
- If both results were greater than or equal to 5xRL, then the relative percent difference (RPD) between the two results was compared to an evaluation criterion of less than or equal to 30 percent for aqueous samples and less than or equal to 50 percent for solid samples.

With the exception of the few target analytes presented in the table below, all the split sample results were in agreement with the evaluation criteria used for data validation. These 17 split sample results, identified as not meeting the split sample evaluation criteria, account for only 1 percent of the total split sample results, indicating acceptable precision.

Summary of Split Sample Results Not Meeting Acceptance Criteria

Site ID	Collection Date	Analyte
PS-BH08S 10-12	03-Sep-08	ACETONE
PS-MW03D	08-Sep-08	SELENIUM
PS-MW04D	08-Sep-08	MANGANESE
PS-MW04D	08-Sep-08	ALKALINITY, BICARBONATE (as CaCO ₃)
PS-MW04D	08-Sep-08	ALKALINITY, TOTAL (as CaCO ₃)
PS-MW04D	08-Sep-08	METHANE
PS-MW06R	08-Sep-08	2-BUTANONE (MEK)
PS-MW07S	09-Sep-08	ALKALINITY, TOTAL (as CaCO ₃)
PS-MW07S	09-Sep-08	METHANE
PS-MW08D	08-Sep-08	SULFATE (AS SO ₄)
PS-MW08S	08-Sep-08	MANGANESE
PS-MW08S	08-Sep-08	FLUORIDE
PS-MW10S	09-Sep-08	MANGANESE
PS-MW11D	21-Jul-08	1,2,4-TRICHLOROBENZENE
PS-MW11D	21-Jul-08	BROMOMETHANE
PS-MW12M	09-Sep-08	ALKALINITY, TOTAL (as CaCO ₃)
PS-MW13D	09-Sep-08	METHANE

5.1.5 Chemical Database

All project data summarized in Table 9 are included in the electronic database. Prior to loading the electronic data into the project database, the electronic data files were verified against the hard copy data

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package (10-percent frequency). Field data such as sample data, water levels, and field parameters were entered using the templates included in the database management system (DBMS). The Phase I site investigation database is contained on a CD included as Attachment 3 to this report.

The database is an Access 2000 file format based on an ERPIMS structure. This data structure features referential integrity between tables and a significant number of lookup tables which ensures consistency in the data entry. The general content of some of the main database tables is summarized below.

LDI – This table contains sampling and measurement point location along with the associated GIS coordinates, elevations, source of GIS coordinates, and COGCC ID (if available at the time of reporting).

SAMPLES – This table contains sample collection information for field and laboratory analyses. Included are field sample IDs, sampling dates, company collecting the samples, whether the sample fraction is total or dissolved (filtered), and what type of sample was collected (e.g., primary sample, field duplicate, blank, etc).

TESTS – This table contains analytical method information for field and laboratory samples. This includes data on the analytical method, laboratory, laboratory receipt date, analysis date, and laboratory sample ID.

RESULTS – The results table contains the data for the analytical and field tests, including the analyte name (PARLABEL), the analyte concentration (PARVAL), and data qualifies (PARVQ, QAPPFLAGS, and LAB_FLAG).

WCI – General information for a well including well completion date measuring point elevation, and total depth at completion.

WINT – Describes each screen interval of a well.

GWD – This table contains depth to water and measuring point elevation for each sampling event.

Some of the main Lookup Tables include:

LOOKUP_ANMCODE – Descriptions of analytical method.

LOOKUP_MARTIX – Description of sample matrix: surface water (WS), groundwater (WG), drinking water (WP), QC water (WQ), etc.

LOOKUP_PARLABEL – Chemical name for analyte.

LOOKUP_PARVQ – Code describing if analyte was detected (=), not detected (ND), detected at a trace concentrations (TR), a tentatively identified compound (TIC), etc.

LOOKUP_SACODE - Code describing type of sample: normal (N), equipment blank (EB), field duplicate (FD), matrix spike (MS), trip blank (TB), etc.

5.2 Summary of Analytical Results by Matrix

To facilitate discussion of results, summary tables of detections have been prepared for major analyte classes (organics, metals, and inorganics) and sample matrix (surface water, groundwater, drinking water, and soil). A detects summary table was not prepared for the soil vapor matrix because all soil vapor data were nondetect. It is important to note that due to the long VOC analyte list, the organics tables are limited to only the organic analytes that were detected in at least one sample. Additionally, only the detected values are shown in the table. An empty cell does not necessarily mean the analyte was nondetect; any empty cell could also mean that the sample was not analyzed for that analyte. As noted earlier, Tables 2, 3, 4, and 5 present the analysis frequency for each sample location and method number by sample matrix. Also, Table 9 summarizes the analytical data reported in each data package. The complete database is included as Attachment 3, and Attachment 5 contains all of the data validation reports, qualified data reporting forms, and QC summary data packages.

5.2.1 Surface Water

Tables 11, 12, and 13 are detects-only summary tables for surface water samples for Organic Parameters, Dissolved Metals, and Inorganic Parameters, respectively. The tables are sorted by sampling location and then sampling date. Although field duplicates and split samples are included in the data tables, the discussion is based on results for primary field samples.

Prather Spring Drainage

Since early June 2008, water quality at Prather Spring has been monitored for VOCs and various other parameters. The presence of hydrocarbon constituents in Ned Prather Spring has been persistent since early June 2008. Benzene and total xylenes were detected in every sample collected from Ned Prather Spring after June 23, 2008. Between June 23 and November 4, benzene concentrations ranged from 190 to 320 micrograms per liter ($\mu\text{g/L}$) and total xylenes concentration ranged from 710 to 3,000 $\mu\text{g/L}$. The maximum benzene concentration of 320 $\mu\text{g/L}$ was detected in the September 4, 2008 sample; the second highest benzene concentration of 310 $\mu\text{g/L}$ was detected in the July 17, 2008 sample. The maximum total xylene concentrations of 3,000 $\mu\text{g/L}$ were detected in the October 8 and October 16 samples.

Figure 17 is a chart of BTEX and chloride concentrations in water samples from Ned Prather Spring over the course of the 2008 field season. Concentrations of ethylbenzene are significantly lower than for the other three constituents and are plotted on the right-hand Y-axis. An increase in all constituents is evident during the summer. However, the concentrations of benzene and toluene begin to decrease in early

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September, while the concentrations of ethylbenzene and xylenes continue to increase. The toluene concentration evidently varies to a larger degree than the benzene concentration. Ethylbenzene may have been present at lower concentrations earlier in the summer but was not detected due to dilution of the samples because of the presence of higher concentrations of other constituents (i.e., xylenes). Chloride concentrations display a slow but steady increase in concentration over the field season.

Ethylbenzene was detected in samples collected from Ned Prather Spring between August 21, 2008 and October 29, 2008. The ethylbenzene concentration ranged from 5.0 to 12 µg/L. The maximum ethylbenzene concentrations were detected in samples collected in October 2008.

Toluene was consistently detected in samples collected from Ned Prather Spring since June of 2008. Toluene concentrations have ranged from 180 µg/L to 1,300 µg/L with the highest detection occurring in the July 17, 2008 sample.

TMBs were detected consistently in samples collected between August 24 and October 29, 2008, with 1,2,4-TMB and 1,3,5-TMB reaching their maximum observed values of 220 and 230 µg/L respectively in the October 29, 2008 sample (the last sample collected on November 4, 2008 was only analyzed for benzene, toluene, ethylbenzene, and total xylenes [BTEX] parameters).

Of the BTEX and TMB analytes, maximum detections were not observed in the same sample. The highest benzene concentration (320 µg/L) and highest naphthalene concentration (12 µg/L) were observed in the September 4, 2008 sample. The second highest benzene detection (310 µg/L) and highest toluene detection (1,300 µg/L) were observed in the July 17, 2008 sample. The highest ethylbenzene results were detected in the October samples (11 and 12 µg/L). The highest toluene concentrations (3,000 µg/L) were detected in samples collected in early October 2008. The highest TMB concentrations were detected in late October samples. The benzene concentration for the last sample collected on November 4, 2008 sample was 170 µg/L. The total PHC as gasoline (PHCG) for this sample was 7,200 µg/L. PHCG was an analysis parameter for June samples and later samples, but was not analyzed for consistently throughout the summer. Thus, it is difficult to know when PHCG concentrations reached their maximum values.

The chloride dataset for the Prather Spring spans from late June 2008 to October 29, 2008. The dataset for other parameters such as alkalinity, bromide, fluoride, sulfate, and TDS is more limited, spanning late August to mid-September, 2008. There were no discernable trends in this latter extended dataset. However, chloride concentrations ranged from 54.5 mg/L in the June 23, 2008 sample to 118 mg/L in the October 23, 2008 sample, showing a steady increase throughout the summer months.

The dissolved metals dataset for Prather Spring is more limited than for the organic parameters and chloride, consisting of four data points for major cations and barium collected between the end of August

and middle of September. In general, the barium and major cation concentrations in Ned Prather Spring remained constant between the August 29, 2008 and the September 17, 2008 sample.

Spring 2 Drainage

Low levels of TMBs were detected in a sample collected from Spring 2 on June 6, 2008 which prompted routine monitoring at Spring 2 beginning in mid-July. Additional PHCs were first observed in Spring 2 from the sample collected on July 17, 2008, in which benzene and total xylenes were detected at the respective concentrations of 11 and 5.5 µg/L. The concentration of benzene and total xylenes increased throughout the summer to maximum values of 71 and 53 µg/L, respectively, in the September 4, 2008 sample. After September, benzene and total xylenes concentrations decreased and these analytes were present in the last sample collected on October 29, 2008 at concentrations of 20 and 13 µg/L respectively.

1,2,4-TMB and 1,3,5-TMB were consistently detected in Spring 2 samples from August 14 through October 29, 2008, with maximum concentrations also being detected in the September 4, 2008 sample (13 and 11 µg/L, respectively for 1,2,4-TMB and 1,3,5-TMB). The 1,2,4-TMB and 1,3,5-TMB concentrations for the October 29, 2008 sample collected at Spring 2 were 2.6 and 1.3 µg/L, respectively.

Ethylbenzene was first detected in Spring 2 on July 22, 2008 and its presence remained consistent in samples collected from July 29, 2008 through October 29, 2008. The maximum ethylbenzene concentration detected in Spring 2 was 5.4 µg/L for the sample collected on September 4, 2008.

Ethylbenzene was reported as detected in the last sample collected on October 29, 2008 at a concentration of 0.33 µg/L.

Figure 18 is a chart of BTEX and chloride concentrations in water samples from Spring 2 over the course of the 2008 field season. Concentrations of benzene, ethylbenzene, xylene, and chloride all tend to follow a similar trend, although the timing of the trend of the organic constituents lag slightly behind the chloride concentration trend. An increase in chloride is evident until mid-August, and organic constituents increase until about early September. However, the concentration of chloride begins to decrease in later August, while the concentrations of benzene, ethylbenzene, and xylenes do not begin a declining trend until early September.

The chloride dataset for Spring 2 spans from July 15, 2008 to October 29, 2008. The chloride concentration in Spring 2 was 286 mg/L for the July 15, 2008 sample and showed a sharp increase to 568 mg/L for the July 17, 2008 sample. The chloride concentration in Spring 2 increased from July to August with a maximum concentration of 795 mg/L observed for the August 14, 2008 sample. The chloride concentration at Spring 2 showed a sharp decrease between August 25, 2008 (787 mg/L) and August 29, 2008 (428 mg/L). After this decrease, the chloride concentration in Spring 2 began to increase

again, showing a second peak concentration of 728 mg/L for the October 1, 2008 sample after which the chloride concentration in Spring 2 showed a slightly decreasing trend throughout October. The chloride concentration for the last sample collected on October 29, 2008 was 645 mg/L.

The dissolved metals dataset for Spring 2 is more limited than for the organic parameters and chloride, consisting of four data points for major cations and barium collected between the end of August and middle of September. In general, the major cation concentrations in Spring 2 increased from the August 29, 2008 sample to the September 17, 2008 sample. The barium, potassium and sodium concentration double in this time frame, the manganese concentration tripled, and the calcium and magnesium concentrations showed more modest increases.

The benzene to total xylene ratios for samples collected at Prather Spring and Spring 2 suggest that the sources for the two springs may be different. For samples collected from Ned Prather Spring, the total xylenes concentrations are typically 8 to 10 times higher than the benzene concentrations. For samples collected from Spring 2, the benzene and total xylenes concentrations are generally more equal.

Ned Prather Cistern

On October 3, 2008, a water sample, field duplicate, and split sample were collected from Ned Prather's Cistern. The primary field sample and field duplicate were submitted to Paragon for and extended list of analytes as described in *Joint Work Plan Addendum #4* (URS 2008d). A trace level of benzene (0.08 µg/L) was detected in the split sample and trace levels of xylenes all below 1 µg/L were detected in the primary sample, the field duplicate, and the split sample. Also detected in all three samples was trace levels of 1,3,5-TMB, all less than 0.50 µg/L. 2,4-Dimethylphenol was reported as detected in the split sample at 2.0 µg/L, but was not found in either the primary sample or field duplicate. Ethylene glycol was found in the primary sample at an estimated concentration of 3.1 mg/L, but was not detected in the field duplicate or split samples. Lastly, oil and grease was detected in the split sample at 7.25 mg/L, but was not found in the primary or field duplicate sample.

Dissolved barium concentrations for the sample collected from the cistern ranged from 0.068 to 0.71 mg/L. These concentrations are comparable to the range found from Ned Prather Spring which ranged from 0.069 to 0.078 mg/L. These dissolved barium concentrations for Prather Spring and cistern are the lowest of all sites within both drainages.

Sulfate concentrations for the cistern samples ranged from 44.5 to 51 mg/L, which is lower than the sulfate range observed for samples collected from Ned Prather Spring, 79.4 to 82.2 mg/L. Similarly, chloride concentrations for the cistern samples were lower than those observed for Ned Prather Spring,

19.9 to 24 mg/L vs. 54.5 to 117 mg/L. Because the cistern is fed by Ned Prather Spring, one might expect the results to be more similar to the spring.

The difference observed is considered likely due to the fact that the water content of the cistern has been stagnant since the potable water tank was plumbed into the line supplying Ned Prather's cabin on June 26, 2008. This hypothesis is supported by the fact that the dissolved metals and inorganic concentrations observed for the cistern samples more closely resemble the concentrations found in the June 4, 2008 sample collected by the COGCC. Biodegradation and volatilization processes may have caused the concentrations of PHC constituents to decrease in the cistern during the roughly 3-month period the cistern water flow was cut off from Prather Spring.

5.2.2 Groundwater

This section describes water quality results for groundwater samples collected from shallow bedrock and deeper bedrock monitoring well completions in the Prather (30 wells total) and Spring 2 (12 wells total) drainages, and compares the water quality results to samples obtained from Prather Spring and Spring 2. Discussion of water quality results in this report for samples obtained from springs is provided in both the groundwater and surface water sections. Results for the third (last) round of monitoring wells completed in the two drainages during October are from analyses completed by ChemSolutions mobile laboratory.

Ned Prather Spring Drainage

The primary constituents of concern (COCs) in groundwater for wells completed in the Prather drainage are petroleum hydrocarbons detected in Prather Spring samples, and to a lesser degree, chloride. The COCs include: benzene, toluene, ethylbenzene, xylenes, 1,2,4-TMB, 1,3,5-TMB, and chloride.

Organics

PHC COCs have been detected at low concentrations in several groundwater monitoring wells in the Prather drainage, and at relatively high concentrations similar to concentrations in the spring discharge at one location (PSMW-28). Figure 19 is a map showing monitoring well locations that are color-coded to identify four classifications of BTEX detections:

- Green – All BTEX constituents are Not Detected
- Blue – One or more BTEX constituents detected at concentrations below 1 µg/L.
- Yellow – One or more BTEX constituents detected at concentrations above 1 µg/L.
- Orange – One or more BTEX constituents detected at concentrations above the maximum contaminant level (MCL).

Well PSMW-28 is the only monitoring well, in either drainage and completed at any depth, where groundwater concentrations of any constituent exceed the drinking water standard or MCL (orange color code on Figure 19). This well is located approximately 30 feet southeast of Prather Spring, has a total depth of 25 feet bgs, and is completed in the colluvium and upper fractured bedrock. The well was completed on October 21, 2008, the next-to-last day of the third and final round of drilling activities. Concentrations of BTEX constituents were 150, 21, 3.6J, and 1,200 µg/L, respectively. Figure 20 is a bar chart that compares concentrations of BTEX constituents at well PSMW-28 and Prather Spring (October data). Additionally, only well, PSMW-28, contained detectable concentrations of all five PHCs in one groundwater sample, BTEX and 1,2,4-TMB. The concentration levels for all the BTEX constituents are lower in the monitoring well sample as compared to the spring sample but are of a similar magnitude, suggesting that well PSMW-28 is located within the same groundwater flow path as the plume of impacted groundwater which discharges from the Prather Spring. The extent and origin of the plume is unknown.

Three well locations are color-coded yellow on Figure 19, wells PSMW-3S, -11D, and -30. A total xylene concentration of 4.2J µg/L was detected at well PSMW-3S in a sample collected on September 3, 2008. No other BTEX constituents were detected in this sample, and a confirmation sample collected two weeks later was nondetect for all BTEX constituents.

At well PSMW-11D, both benzene and toluene were detected at concentrations of 0.97 and 1.1J µg/L in the initial sample from July 21, 2008. Both ethylbenzene and xylenes were nondetect. A second sample collected on August 15, 2008 detected low concentrations of benzene, toluene, and xylenes (0.5J, 0.77J, and 0.35J µg/L, respectively). Well PSMW-11S, located next to well PSMW-11D, had concentrations of benzene (0.21 µg/L) and toluene (0.27 µg/L) in one sample collected on October 16, 2008. A soil sample obtained from the bottom of the borehole for well PSMW-11D, at a depth of 49 feet bgs, also contained BTEX constituents and PHC-diesel range organics.

Well PSMW-30 was completed on October 22, 2008, to a depth of 47 feet bgs, and is located approximately 80 feet southeast of Prather Spring. Concentrations of benzene, toluene, and total xylenes in groundwater were 1.3J, 1.4J, and 1.6J µg/L, respectively. Similar concentration levels of these three constituents were also detected in the groundwater grab sample prior to well development.

Other monitoring wells in the Prather drainage where groundwater concentrations of BTEX constituents were detected, but at concentrations of less than 1 µg/L (blue color-code on Figure 19), include PSMW-4D, -5D, -6R(S), -11S, and -13D. The low concentration levels of BTEX constituents at these well locations, and with the exception of well PSMW-11S, absence of benzene, may indicate that the constituent detections are not associated with the groundwater impacts at the Prather Spring.

Inorganics

Evaluation of the concentrations of the major ions, specifically the major cations and anions, is useful data for describing the geochemistry of the groundwater, and can be used to differentiate varying water types and mixtures of groundwater types in an area.

Figure 21 is a map showing surface and groundwater monitoring locations that are color-coded to identify two classifications of chloride concentrations. Orange labels indicate monitoring locations where chloride concentrations were reported above 250 mg/L in one or more samples. Green labels indicate locations where chloride concentrations were at or below 250 mg/L in sample results. Figure 22 presents time-series graphs of chloride at surface and groundwater sampling locations.

Stiff diagrams were prepared to illustrate the major ion distributions for groundwater and surface water samples (Attachment 2). Groundwater in shallow and deep monitoring wells in the Prather drainage have a low total dissolved solids content (ranging from 300 to 550 mg/L) and are a calcium-bicarbonate water type. The sodium content increases slightly in the deeper groundwater, potentially due a slightly longer residence time in the subsurface (deeper/longer flowpath). The sodium content could also be slightly higher because the groundwater in the deeper bedrock has likely spent a longer time in contact with silty marlstones and dolomitic marlstones of the Parachute Creek Member, than shallower groundwater. Other constituents that support the hypothesis that groundwater in the deeper monitoring wells represents a slightly different water chemistry than the shallow wells in the Prather drainage are potassium, sulfate, arsenic, chromium, fluoride, boron, and selenium.

The major ion content of groundwater in the Prather drainage closely resembles samples collected by the USGS from “upland springs” in this area and reported in 1985 (Butler 1985). This comparison is shown in Stiff diagrams and Piper plots in the September 29 technical presentation to the COGCC (Attachment 2). However, the water chemistry in well PS-MW05D is different than the other water samples in this drainage, in that there is a higher concentration of sodium and chloride relative to other water samples.

Although no samples were collected from the newly installed monitoring wells (October drilling event) for analysis of major ions, the specific conductance measurements obtained during well development may provide some basis for interpretation of groundwater quality (Table 10). The four new wells with the highest measurements of specific conductance, in decreasing order, are wells PS-MW28, MW30, MW31, and MW29. Measurements at these well locations ranged from 1.10 to 0.54 milliSiemens per centimeter (mS/cm). Specific conductance measurements at the remaining newly installed wells were relatively low, likely representing background readings (less than 0.54 mS/cm).

Spring 2

The primary COCs in groundwater for wells completed in the Spring 2 drainage are chloride and petroleum hydrocarbons detected in Spring 2 samples. The COCs include: chloride, benzene, ethylbenzene, xylenes, 1,2,4-TMB, and 1,3,5-TMB. Toluene has not been detected in water samples collected from Spring 2, concentrations of ethylbenzene have not exceeded 5.4 µg/L, and concentrations of the two TMB constituents have not exceeded 13 µg/L. The chloride concentration at Spring 2 has increased from 160 mg/L (COGCC June 4, 2008 sample), to a maximum value of 795 mg/L on August 14, 2008. For comparison, the maximum observed chloride concentration at the Ned Prather Spring was 118 mg/L (October 23, 2008), and concentrations were initially lower (41 mg/L) earlier in the summer.

Organics

Figure 23 is a map showing monitoring well locations that are color-coded to identify three classifications of BTEX detections in the Spring 2 drainage. There are no groundwater samples with concentrations of BTEX constituents exceeding drinking water standards in the Spring 2 drainage (orange color on the map).

Groundwater samples from four monitoring well locations had detections of one or more BTEX constituents at concentrations above 1 µg/L (yellow color-code on Figure 23). These well locations are PS-MW07S (benzene, toluene, and xylenes), PS-MW08D (benzene), PS-MW10S (toluene), and PS-MW27 (xylenes). Well PS-MW07S and 07D are located on the north side of the Spring 2 drainage bottom. Groundwater present in these wells appears to exceed the interpreted background concentrations of major ions and petroleum hydrocarbons in the area, but groundwater at this location is interpreted to originate from the north side of the Spring 2 drainage. The well pads identified in the NOAVs issued to the joint Companies for groundwater impacts at Prather Spring and Spring 2 are located on the south side of the Spring 2 drainage. Occidental Petroleum operates a facility west of Spring 2, at the top of the watershed but on the north side of the Spring 2 drainage, and (in addition to the joint Companies) was issued a NOAV for the Spring 2 impact. URS speculates that groundwater originating from infiltration occurring on the south side of the Spring 2 drainage and Spring 2 drainage watershed would most likely result in flow beneath the south side of the valley bottom or valley center.

Well PS-MW27(S) is located approximately 30 feet southwest of Spring 2. Low concentrations of xylenes were detected in the pre- and post-development groundwater samples (12 and 4.8J µg/L, respectively) obtained in late October. No benzene was detected in these samples.

Stiff diagrams were prepared to illustrate the major ion distributions for groundwater and surface water samples in the Spring 2 drainage (Figure 24; Attachment 2). Only one well, PS-MW09S, showed a water chemistry signature similar to the interpreted background pattern displayed by many of the wells in the

Prather drainage. Groundwater in the other shallow and deep monitoring wells that was analyzed for major ions in the Spring 2 drainage have elevated total dissolved solids content (ranging from 580 to 1,130 mg/L) and are a calcium-chloride to calcium-sodium-chloride water type. The concentrations of calcium, magnesium, fluoride, and bromide are generally higher in these monitoring wells than anticipated for background conditions. Sulfate concentrations are notably higher in wells PS-MW07D and MW08D.

Although no samples were collected from the newly installed monitoring wells (October drilling event) for analysis of major ions, the specific conductance measurements obtained during well development may provide some basis for interpretation of groundwater quality (Table 10). The three new wells with the highest measurements of specific conductance, in decreasing order, are wells PS-MW25, MW26, and MW23. Measurements at these well locations ranged from 1.40 mS/cm to 0.81 mS/cm. Specific conductance measurements at newly installed well MW24 was relatively low, likely representing background readings (less than 0.54 mS/cm). Insufficient recharge volume into well PS-MW27 during development and sampling did not allow for measurement of field water quality parameters.

5.2.3 Drinking Water

A summary of analytes detected above laboratory reporting limits (RLs) from samples of potable (drinking) water are presented in Tables 15, 16, and 17, which present organic parameters, dissolved metals, and inorganic parameters, respectively.

The most common organic analytes detected in drinking water samples were bromodichloromethane, bromoform, chloroform, and dibromochloromethane, which are common by-products of potable water treatment. Trace level concentrations of benzene, toluene, and methylene chloride were detected in one or more samples, but not all samples were obtained from Ned Prather's cabin faucet, which is supplied by a dedicated potable water tank located on the Nonsuch well pad. Water in this tank is trucked to the site from Parachute by Toby's Water Supply Service, a licensed drinking water transporter and supplier. Additionally, 2-butanone and acetone were detected above the laboratory RL in samples from Ned Prather's cabin, and methane was detected above laboratory RLs in a sample from the potable water hydrant used to supply the potable water tank (Toby's water supply hydrant), located in Parachute, Colorado.

5.2.4 Soil

Subsurface soil samples were collected from boreholes advanced during the first and second well installation events. Table 18 summarizes organic compounds detected in soil samples. A majority of the detected analytes are estimated trace-level concentrations (benzene, toluene, xylenes, gasoline-range

organics, acetone, carbon disulfide, and methylene chloride). Diesel-range organics were detected above laboratory RLs in PS-BH11D at 49 feet bgs and in a split sample of PS-BH06R at 17 to 21 feet bgs. Carbon disulfide was detected above laboratory RLs in a split sample of PS-BH08S at 10 to 12 feet bgs.

5.2.5 Soil Gas

Soil gas analytical results are limited to volatile organics from the mobile laboratory. Preliminary analytical results from soil gas samples taken on October 15 from the Prather drainage contained trace level detections of ethylbenzene, toluene, and xylenes. These trace level concentrations were also found in field and ambient blanks taken at the site, and therefore were interpreted as not being indicative of soil vapor conditions. Samples collected on or after October 16 were nondetect for reported analytes. A summary of PID field-screening results from the soil gas probes is included in Table 6.

6.0 Summary

Contaminated water was discovered in Prather Spring on or around May 31, 2008, when one of the cabin owners (Mr. Ned Prather) reportedly turned on the cabin tap while opening up the hunting cabin for the summer season. Benzene, toluene, xylenes, 1,2,4-TMB and 1,3,5-TMB have been reported in samples from the spring and cabin tap, with benzene, toluene, and xylene concentrations above the respective drinking water standard at both the spring and cabin tap. Subsequent water samples from springs in adjacent drainages were nondetect for these constituents, suggesting a localized source or sources of contaminants.

In response to the contaminant release, on June 19, 2008, the COGCC issued each of the Companies a NOAV, and directed the Companies to provide an alternate drinking water supply for the cabin. The NOAV also included a requirement to provide a suitable alternate water supply for livestock consumption. The Companies have since complied with these directives, and have initiated a hydrogeologic investigation to delineate the contamination source(s).

As part of the Companies interim response, routine surface water monitoring was instigated in early July at 10 locations (Addendum #1 to the *Joint Work Plan*). A significant increase in chloride concentration and the presence of low concentrations of several petroleum hydrocarbon constituents were detected in a sample collected from Spring 2 during routine sampling on July 17, 2008. Since this time, identifying the source of petroleum hydrocarbons and chloride to Spring 2 has been added to the site investigation objectives.

6.1 Scope and Objectives

The project scope involved a phased investigation approach. The objective of the Phase I Investigation is to identify the probable contamination source(s) to the springs. Phase I field activities completed on behalf of the Companies have consisted of surface water sample collection and analysis, completion of soil borings with soil and rock coring, installation of groundwater monitoring wells and soil vapor probes, surveying, utility locates, and electromagnetic resistivity surveys. A mobile field laboratory was utilized during two rounds of drilling to facilitate field decisions in the selection of boring and well locations.

The Phase I investigation conducted to date involved three rounds or iterations of drilling, monitoring well installation, and sampling as described in the initial *Joint Work Plan*. A total of 42 groundwater monitoring wells (total depth ranged from 14 to 62 feet bgs) were installed, and 37 soil vapor probes (total depth ranged from 5 to 20 feet bgs) were completed and sampled.

6.2 Sample Collection, Analysis, and Data Validation

Over 700 sample analyses have been performed, validated, and input electronically to a Microsoft Access database. Sample matrices consisted of soil, surface water, drinking (potable) water, soil vapor, and groundwater. Laboratory analyses included BTEX, inorganics (cations and anions), dissolved metals (cations, mercury, and trace metals), PHCG, PHCD, SVOCs, and VOC analytes.

All analytical methods used for sample analysis are USEPA-approved, industry-standard analysis methods used for site characterization. To determine if the analytical data generated are sufficient quality for their intended use, all data were validated by qualified URS chemists. The validation consisted of an evaluation of sample-specific parameters for 100 percent of the dataset, as well as a review of laboratory performance parameters for a select subset of the dataset. Overall, the data validation program indicated that acceptable levels of accuracy, precision, completeness, comparability, and representativeness were attained for the samples collected during the Phase I site investigation. With the exception of 111 results for 2-CEVE, 9 chloroform results, and a single 1,2,4-TMB result, project data were found to be usable for meeting project objectives. Results qualified as estimated (J or UJ) or nondetect (U) are considered usable for meeting project objectives.

Laboratory analytical data for groundwater samples collected from the wells have not contained PHCs at concentrations of the same magnitude as observed in either Ned Prather Spring or Spring 2. However, laboratory analytical data for major ions, coupled with groundwater potentiometric levels, review of rock cores, and other site data, have led to the development of a refined conceptual hydrogeologic site model. This model suggests that shallow groundwater may flow preferentially within relatively narrow, discrete zones that are potentially related to fractures within the upper bedrock (URS 2008c).

6.3 Cistern Sampling

At the request of the landowner and COGCC, water samples from the cistern that was plumbed to the Ned Prather Spring were collected following excavation and exposure of the cistern fill port by the landowner. The water in the cistern was analyzed for a comprehensive list of analytes, including constituents reportedly used during drilling and completion operations. Although several PHC constituents were detected in the cistern water samples, concentrations were relatively low and well below the concentrations found in the Prather Spring. Concentrations of PHCs were below drinking water standards; however, ethylene glycol was detected at a concentration of 3.1 mg/L. There was very little sediment present in the bottom of the cistern, so only one sediment sample (a single 2-ounce jar) was submitted for analysis of VOCs. According to on-site observations, the sediment present in the bottom of

the cistern appeared to be fine-grained mineral silt. The sediment sample contained no detectable VOC constituents.

6.4 Vegetation Survey

At the request of the COGCC, URS conducted a reconnaissance of the area to evaluate the presence or absence of distressed vegetation that may have been related to the presence of petroleum hydrocarbon constituents in the subsurface. The resulting memorandum was submitted to the COGCC, and is not included in this report. However, distressed vegetation associated with petroleum hydrocarbons in soils and/or groundwater was not encountered in the Prather drainage.

6.5 Geology

The principal rock units in the Prather spring area include the Tertiary (Eocene age) Uinta “Unit D” Formation and the Parachute Creek Member of the Green River Formation. Colluvial deposits are present in the valley drainages. Review of topographic maps or aerial photography of the area reveals the presence of numerous linear geographic features, termed lineaments. In the project area, a prominent linear feature is Garden Gulch, which is oriented in a northeast-southwest direction. This trend extends southwest into the drainage above Garden Gulch, up McKay Gulch.

The Uinta D Unit is present on the ridge tops and extends down into the upland drainages. The Uinta consists primarily of fine grained sandstone and siltstone. Field observations agree with descriptions by Hail, who notes that the Uinta Unit D is, “relatively nonresistant; and weathers to rounded slopes.” Underlying the Uinta are marly siltstone, silty marlstone, dolomitic marlstones, and oil shales of the Parachute Creek Member of the Green River Formation. The Parachute Creek Member is resistant to weathering and is described as, “resistant, forms high precipitous cliffs on canyon walls” (Hail 1982).

6.6 Hydrogeology

At Prather Spring, Spring 2, and Donna’s Spring, each of these springs discharges from the base of thick colluvial deposits, which are located immediately up-valley of the spring. These thick colluvial deposits form the valley floor, and underlie a meadow up the valley from each of these three spring locations. There is no visual evidence of a gully or drainage in the valleys upgradient to the springs, i.e., no evidence of surface runoff or an ephemeral stream. There is no evidence of surface water runoff (e.g., eroded gullies) in any of the side tributaries that connect the ridgelines to the valley. The absence of surface runoff features indicates there is a relatively high rate of water infiltration and low runoff, probably attributable to highly permeable surface soils in the valley bottoms. In the valley below each spring, the drainage contains a perennial stream.

The conceptual model for groundwater discharge from the Prather Spring, Spring 2, and Donna's Spring in this report is speculative. The model implies a similar origin of the groundwater for each spring (surface water infiltration into the Uinta sandstone at the top of each watershed). The conceptual model does not imply that the three springs are hydraulically interconnected to each other, or share a common geographic origin of the groundwater. In fact, the origin of groundwater for the spring in each valley is inferred to be the approximate areal extent of the watershed above each valley.

The depth to groundwater ranges from 16 to 50 feet in wells installed in the Prather drainage and from 13 to 32 feet bgs in wells completed in the Spring 2 drainage. At least during the months of this investigation, there was little groundwater present in the colluvial deposits. The saturated thickness of the colluvium ranges from 0 to 2 feet

During the second round of drilling well pairs were installed in the shallow and deeper bedrock intervals. Water levels in the shallow wells were generally at elevations corresponding to the base of the colluvium or upper portion of the bedrock surface, suggesting that groundwater in the upper portion of the bedrock was hydraulically connected to what little groundwater was found in the overlying colluvium. The deeper bedrock wells generally had greater depths to water than adjacent shallow well completions, although the water levels were relatively close in many locations. The lower water levels in the deeper monitoring wells indicate a downward hydraulic gradient from the shallow to deeper bedrock zones. A downward hydraulic gradient is anticipated in groundwater recharge (upland) areas.

As expected for the shallow zone, and based on the limited survey and water level depths at many of the more recently installed monitoring wells, groundwater flow directions in both valleys generally follow the surface topography and flows downhill.

Based upon well hydrographs, water level trends in both valleys generally show a slight downward to flat trend in both shallow and deep wells in both valleys. Overall, water levels in the Prather valley have declined up to 2.45 feet (PSMW-03S and -04S), and increased up to 1.2 feet (PSMW-6R) over the course of the investigation period. In the Spring 2 valley monitoring wells, water levels have increased up to 1.6 feet in two deep wells (PSMW-07D and -10D) and declined up to 0.4 feet in other wells. The variation in water level elevations observed in Spring 2 monitoring wells is generally less than variations observed in monitoring wells installed in the Prather Valley. However, the duration of the observation period has been shorter for the Spring 2 drainage.

6.7 Soil Gas

Soil gas analytical results are limited to volatile organics analyzed by the mobile laboratory. Preliminary analytical results from soil gas samples obtained from temporary soil vapor probes in the Prather drainage

contained trace level detections of ethylbenzene, toluene, and xylenes. These trace level concentrations were also found in field and ambient blanks taken at the site, and therefore were interpreted as not being indicative of subsurface soil vapor conditions. A second round of soil gas samples were collected using different tubing, and results were all nondetect for reported PHC analytes.

Soil gas monitoring probes were installed adjacent to two separate pipeline liquid collection or “drip” tanks located on the ridge above the Prather drainage. Soil gas samples were collected and analyzed by the field mobile laboratory. Results for these samples were all nondetect for reported petroleum hydrocarbon analytes.

6.8 Groundwater Quality

The COCs in groundwater for wells completed in the Prather drainage are petroleum hydrocarbons detected in Prather Spring samples, and to a lesser degree, chloride. The COCs include: benzene, toluene, ethylbenzene, xylenes, 1,2,4-TMB, 1,3,5-TMB, and chloride.

Groundwater in shallow and deep monitoring wells in the Prather drainage have a low total dissolved solids content (ranging from 300 to 550 mg/L) and are a calcium-bicarbonate water type. Major ion concentrations present in groundwater in the majority of monitoring wells appears to resemble background concentrations as published by USGS for upland springs in this region.

Three monitoring wells in the Prather spring drainage appeared to have petroleum hydrocarbons that *could* be related to the source of impacted groundwater observed at the Prather spring. Well PSMW-28 is the only monitoring well, in either drainage and completed at any depth, where groundwater concentrations of any constituent exceed the drinking water standard or MCL. This well is located approximately 30 feet southeast of Prather Spring, has a total depth of 25 feet bgs, and is completed in the colluvium and upper fractured bedrock. Concentrations of BTEX constituents are 150, 21, 3.6J, and 1,200 µg/L, respectively.

The primary COC in groundwater for wells completed in the Spring 2 drainage are chloride and petroleum hydrocarbons detected in Spring 2 samples. The COCs include: chloride, benzene, ethylbenzene, xylenes, 1,2,4-TMB, and 1,3,5-TMB. Toluene has not been detected in water samples collected from Spring 2, concentrations of ethylbenzene have not exceeded 5.4 µg/L, and concentrations of the two TMB constituents have not exceeded 13 µg/L. The chloride concentration at Spring 2 has increased from 160 mg/L to a maximum value of 795 mg/L.

Groundwater sampled in wells within the Spring 2 drainage have elevated total dissolved solids content (ranging from 580 to 1,130 mg/L) and are a calcium-chloride to calcium-sodium-chloride water type.

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Only one well, PS-MW09S, showed a water chemistry signature similar to the interpreted background pattern displayed by most of the wells in the Prather drainage.

Groundwater samples from four monitoring well locations in the Spring 2 drainage had detections of one or more BTEX constituents at concentrations above 1 µg/L. PS-MW08D (benzene), PS-MW10S (toluene), and PS-MW27 (xylenes). Well PS-MW07S and 07D are located on the north side of the Spring 2 drainage bottom. Groundwater present in these wells appears to exceed the interpreted background concentrations of major ions and petroleum hydrocarbons in the area, but groundwater at this location is interpreted to originate from the north side of the Spring 2 drainage. The well pads identified in the NOAVs issued to the Joint Companies for groundwater impacts at Prather Spring and Spring 2 are located on the south side of the Spring 2 drainage.

7.0 Limitations

Interpretations presented in this report apply to the conditions that existed at the time of our investigation. Site conditions may be affected by natural processes or by the works of man. Samples collected for observations and analysis are believed to be representative of the site conditions for the project area, however geologic and groundwater conditions can vary between borings, wells, and surface outcrops.

While the chemistry dataset is robust for some matrices like surface water, the dataset for groundwater is more limited, especially for the newest wells. The limited dataset is a constraining factor for the current data interpretation. Additionally, the reader should recognize that any interpretation based primarily on J-flagged data (results above the maximum detection level but below the laboratory RL) will necessitate further refinement.

Much of the data presented in this report was collected by parties not contracted directly to or managed by URS. The survey data were supplied by William H. Smith Surveyors. The vast majority of the surface water samples and many groundwater samples were collected by HRL Compliance Solutions. In addition, HRL was responsible for several rounds of water level and stream flow measurements. Lastly, Cordilleran conducted the EM-34 survey and supplied URS with the associated survey maps. URS can not certify the accuracy or quality of data supplied by other parties.

All parties involved in the Phase I site investigation strived to meet industry standards for the performance of work activities. During each period of intrusive field activity, one or more of the companies had an independent contractor performing oversight activities.

The scope of this investigation intended to provide selected information in accordance with the contractual work statement for this project. Opinions, judgments, and recommendations expressed herein that are based on URS' understanding and interpretation of current regulatory standards should not be construed as legal opinions.

8.0 References

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