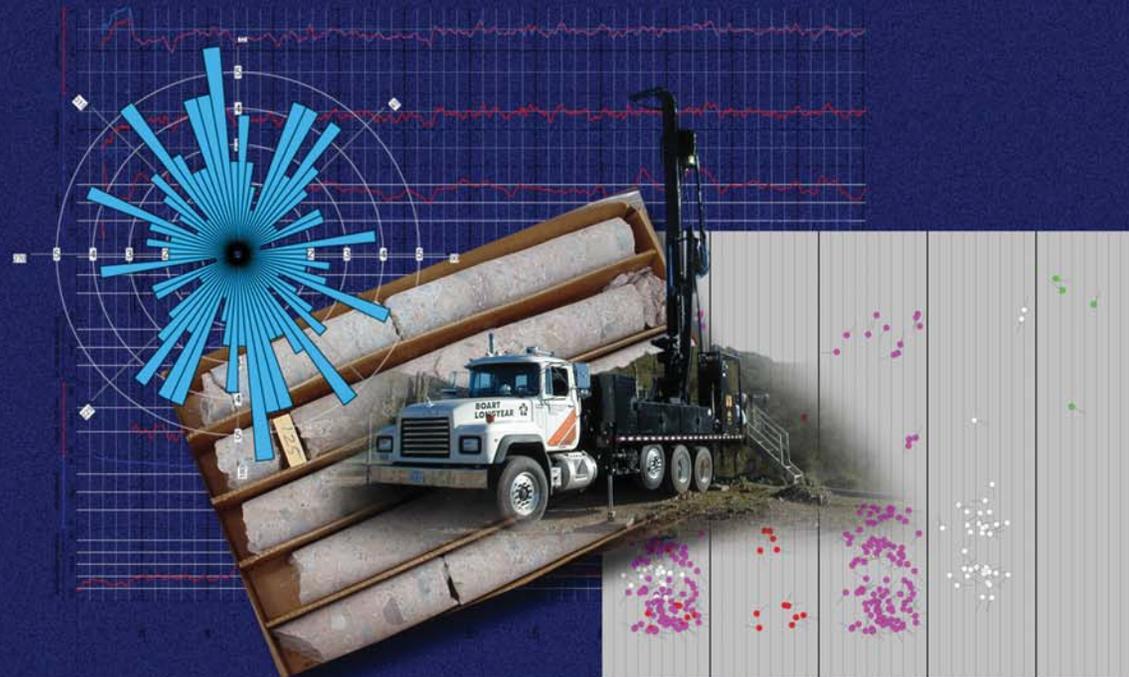


# Final Remedial Investigation Report

Universal Propulsion Co. Inc.



June 2011



**Universal Propulsion Company, Inc.**

25401 N. Central Avenue • Phoenix, AZ 85085-2837

# Final Remedial Investigation Report

June 2011



EXPIRES 12/31/12



Expires: 6/30/2014

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**LIST OF ACRONYMS**


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ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
ADOT	Arizona Department of Transportation
ADWR	Arizona Department of Water Resources
AFC	Ambient Flow Characterization
AOC	Area of Concern
API	American Petroleum Institute
APP	Aquifer Protection Permit
ASLD	Arizona State Land Department
ASTM	American Society for Testing and Materials
AWQS	Aquifer Water Quality Standards
bgs	Below Ground Surface
BTLM	Batch Test Leaching Method
°C	degrees Celsius
C&D	Construction and Demolition
CAD	Cartridge Actuated Device
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
cfm	Cubic Feet per Minute
cm/day	Centimeters per day
CMS	Corrective Measures Study
CSM	Conceptual Site Model
COPC	Contaminant of Potential Concern
DAF	Dilution-Attenuation Factors
DCA	Dichloroethane
DCE	Dichloroethylene
DI	De-ionized
EED	Electronic Explosive Device
EPA	United States Environmental Protection Agency
FEC	Fluid Electrical Conductivity
GPL	Groundwater Protection Level
gpm	Gallon Per Minute
gpm/ft	Gallon Per Minute Per Feet
HBGL	Health Based Guidance Level

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HC	Hydraulic Characterization
HPL	Hydrophysical Logging
IDW	Investigative Derived Waste
IPA	Isopropyl Alcohol
J&E	Johnson and Ettinger
K	Hydraulic Conductivity
Kd	Soil-Water Partition Coefficient
LAU	Lower Alluvial Unit
LES	Liquid Environmental Solutions
m	meter
MAU	Middle Alluvial Unit
MEK	Methyl Ethyl Ketone
mg/kg	Milligram per Kilogram
mg/L	Milligram per Liter
mL	Milliliter
µg/L	Microgram per Liter
µS	Microsiemens
MIBK	Methyl Isobutyl Ketone
msl	Mean Sea Level
NAD 83	North American Datum 1983
NGVD 29	Arizona State Plane Coordinate System
NTU	Nephelometric Turbidity Unit
OBD	Open Burning Devices
OBI	Optical Borehole Imaging
OBU	Open Burn Unit
PAD	Propellant Actuated Device
PDI	Pumping During Injection
POE	Point of entry
ppbv	Parts Per Billion per Volume
PRG	Preliminary Remediation Goal
PVC	Polyvinyl Chloride
PW	Production well
QA/QC	Quality Assurance/ Quality Control
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act

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RFA	RCRA Facility Assessment
RFI	Remedial Feasibility Investigation
RI	Remedial Investigation
RQD	Rock Quality Designation
S	Storativity
SA+B	Scott, Allard & Bohannon, Inc.
SAIC	Science Applications International Corporation
SMA	Storage Magazine Area
SP	Spontaneous Potential
SPLP	Synthetic Precipitation Leaching Procedure
SRL	Soil Remediation Level
SU	Standard Units
SVOC	Semi-Volatile Organic Compound
SWMU	Solid Waste Management Unit
T	Transmissivity
TCA	Trichloroethane
TCLP	Toxicity Characteristic Leaching Procedure
TNT	Trinitrotoluene
TTU	Thermal Treatment Unit
UAU	Upper Alluvial Unit
UPCO	Universal Propulsion Company
USCS	Unified Soil Classification System
USGS	United States Geologic Survey
VOC	Volatile Organic Compound

# 1. Introduction

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This Final Remedial Investigation (RI) Report (report) summarizes the soil, soil vapor, and groundwater investigation activities conducted at the former Universal Propulsion Company, Inc. (UPCO) facility (site) in Phoenix, Arizona. The work has been conducted under Consent Order No. P-136-04 (Appendix A) between UPCO and the Arizona Department of Environmental Quality (ADEQ). The purpose of the RI activities was to identify and delineate contaminants of potential concern (COPCs) that may have been released into the soil and/or groundwater as a result of past operational activities. This report is a revision to the Interim RI Summary Report submitted in February 2009 (Malcolm Pirnie, 2009b) and includes additional information and RI data obtained between January 2009 and May 2011. As such, previous submittals such as the draft RI Summary Report and related Technical Memorandums and the Interim RI Summary Report should be considered superseded by this Final RI Report.

## 1.1. Site Description

The former UPCO facility is located at 25401 North Central Avenue in Phoenix, Arizona, near the intersection of Central Avenue and Happy Valley Road (Figure 1). The site is within the southeast quarter, Section 5, Township 4 North, Range 3 East of the Union Hills 7.5' United States Geologic Survey (USGS) quadrangle. The former UPCO facility was situated on approximately 160 acres of land leased from the State of Arizona and was initially constructed in 1972. The western, southern, and eastern boundaries of the property are undeveloped land owned by the State of Arizona. Residential properties are to the north along Yearling Road. The former operational areas of the facility are surrounded by a security fence and primary access is limited to a gate along Happy Valley Road.

The facility consisted of various manufacturing, storage, and administrative buildings/structures which were separated into seven operational areas. These areas of the site are illustrated on Figure 2 and include:

- A-Complex;
- B-Complex;
- C-Complex;
- D-Complex;

- E-Complex (Storage Magazine Area);
- F-Complex; and
- Open Burn Unit (New Burn Area).

## 1.2. Site History

UPCO, a Delaware corporation, is the successor to the original Universal Propulsion Co., a California Corporation, incorporated in 1959. UPCO began operations at its current Arizona facility in 1972. UPCO became part of Goodrich Corporation in 1998. A more detailed corporate history can be found in the draft Remedial Investigation Work Plans (Hargis+Associates, Inc. (H+A), 2004a and 2004b).

The UPCO operations were transferred to a facility in Fairfield, California in the fourth quarter of 2009. Demolition of the UPCO facility occurred throughout 2009 and was completed in January 2010.

## 1.3. Facility Operations

The former UPCO facility primarily produced components for crew escape systems for military aircraft. Component products such as gas generators, rocket motors, cartridge actuated devices (CADs), propellant actuated devices (PADs), and electronic explosive devices (EEDs) were also developed and manufactured at the facility.

The facility included several separate operational areas for manufacturing, assembling, testing and storing energetic materials. Sections 1.3.1 through 1.3.7 provide an explanation of the operational practices within each area.

Utilities available at the facility at the time of operation included electrical power and communications; however, municipal services were not available in the area; therefore, the facility relied on a production well and septic systems.

### 1.3.1. A-Complex

The A-Complex Area (Figure 3) consisted of buildings associated with the administrative and management functions. It consisted of four buildings (A-1 through A-4). RI field sampling activities were not conducted in the A-Complex Area as there were no historical operations activities identified which could have released COPCs to the environment.

### 1.3.2. B-Complex

The B-Complex Area (Figure 3) consisted of various buildings/structures used primarily for ejection seat, EED, CAD, and PAD assemblies. Examples of EED and CAD products assembled in the B-Complex included squibs, explosive bolts, explosive cutters, initiators, and cartridges. Examples of PAD products included solid propellant rocket motors and gas generators. The assembly process involved the manual loading of small quantities of delay powders or energetic material powder blends (milligram or gram quantities) into the device hardware. These devices were then further assembled into gas generator or rocket motor assemblies.

Additional activities performed in the B-Complex to support assembly operations included surface coating operations, x-ray inspection, shipping, receiving, and facilities maintenance. Small quantities of solvents, solvent-based sealants, and adhesives were used in the assembly process within the B-Complex.

Surface coating activities occurred in Building B-11. Chemicals used in the process have included a variety of military-specification solvent-based primers, coatings and thinners that may have included, but were not limited to, chromates, methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), toluene, and historically trichloroethane (TCA).

The x-ray inspection facilities were located on the west side of the B-Complex. Building B-9 housed a large x-ray tube for the inspection of rocket motors. Building B-1 housed three x-ray machines as well as the x-ray film developing equipment. X-ray wastewater discharge from the Building B-1 operations had historically been pretreated and discharged to a septic tank and leach field under an Aquifer Protection Permit (APP). The x-ray wastewater discharge to the septic tank/leach field was ceased on February 5, 2007 and a clean closure application was filed with ADEQ. The clean closure application was approved by ADEQ on August 23, 2010 (see Appendix B).

A more detailed description of the B-Complex Area operations is provided in the Site Investigation Work Plan for the B-Complex (Malcolm Pirnie, 2005e).

### 1.3.3. C-Complex

The C-Complex Area (Figure 3) consisted of various buildings/structures used for the manufacturing of castable propellants including material weigh-out, oxidizer grinding, propellant mixing and casting. The C-Complex also served as a research and development area to improve and refine products and performance. The research and development activities included development of new castable propellants and energetic powders. Historically, Buildings C-2, C-9, and C-11 were used for the quality

assurance/quality control laboratory activities. These activities were later relocated to the F-Complex Building F-10 QC Laboratory. Oxidizers, binders, and metallic powders were also stored in the C-Complex Area.

During the manufacturing process, dry oxidizer materials were mechanically ground to the desired particle size distribution, sieved to break up agglomerates, and weighed out for a particular batch size. Polymeric binders consisting of polyurethane or polybutadiene and carbon black were then evenly applied to the interior of the motor tubes. Solvents were used to fluidize the binder for ease of application during the lining process. These solvents included methylene chloride and historically TCA. After the lining cured, the tubes were placed into the casting fixture. Tooling was inserted into the tubes to form the appropriate annulus space that was filled with the propellant mixture. Polymeric binders and fuels (magnesium or aluminum powders) were added to the oxidizer to form a raw propellant blend. The propellant was then vacuum-cast into the lined tubes and cured in ovens. After curing, the tooling was removed and the propellant tubes were prepared for further assembly.

During research and development activities, new castable propellants and powders were generated in smaller quantities using the same techniques described for the manufacturing process.

The chemicals predominantly used in the C-Complex included ammonium perchlorate, potassium perchlorate, lead nitrate, ammonium nitrate, potassium nitrate, iron oxide, polymeric binders (e.g. polyurethane or polybutadiene-based materials), magnesium or aluminum-based powders, methylene chloride, acetone, and isopropyl alcohol (IPA).

A more detailed description of the C-Complex Area operations is provided in the Site Investigation Work Plan for the C-Complex Area (Malcolm Pirnie, 2004c).

#### **1.3.4. D-Complex**

The D-Complex Area was located in the northwest portion of the facility (Figure 3) and consisted of various buildings/structures used primarily for device testing, as well as the waterbore process. There were three specific areas of focus within the D-Complex which included the Old Burn Area, the Thermal Treatment Unit (TTU), and Waterbore Area. The activities conducted at each of these focus areas within the D-Complex are discussed below.

#### **1.3.4.1. Old Burn Area**

The Old Burn Area was located in the northern portion of the D-Complex and used to burn off-specification energetic materials and devices. Open burning of waste materials occurred in the Old Burn Area during the 1970s and early 1980s, until open burn operations were moved to the Open Burn Unit (OBU) in the New Burn Area. Activities consisted of open burning of primarily high density propellants by various methods including placing the materials in a metal cage on the ground, placing the materials in concrete culvert pipes (oriented vertically and embedded in the ground), and/or spreading materials along the bottom of an ephemeral wash. The concrete culverts were approximately six feet in diameter and extended approximately four feet above grade. Open burn operations in the ephemeral wash occurred in an area approximately 5 to 10 feet wide and 10 to 20 feet long.

A more detailed description of the Old Burn Area operations is provided in the Site Investigation Work Plan for the Old Burn Area and Thermal Treatment Unit (Malcolm Pirnie, 2005b).

#### **1.3.4.2. Thermal Treatment Unit**

The TTU was located south of the D-Complex fence line (Figure 3) and was used to burn off-specification solid propellant materials. The TTU was not used for the treatment of energetic powders, devices or energetic material contaminated trash and debris.

The TTU was installed in 1992 and operated from December 1992 to May 2004. The TTU was approximately 100 feet long and 18 feet wide and consisted of a conveyor, a combustion chamber, a series of expansion/cooling chambers, a blower, and a dust collector (baghouse). The baghouse exhaust stack rose approximately 38 feet above ground level. Concrete secondary containment structures were located beneath each section of the TTU. The unit was used to perform self-sustaining thermal treatment of waste propellant and did not meet the Resource Conservation and Recovery Act (RCRA) definition of an incinerator.

During TTU operation, waste propellant was transported from the Storage Magazine Area (SMA) in the E-Complex to Building D-7 where the material was weighed and cut into approximately two-pound sections. These quantities of waste propellant were then fed into the combustion chamber by a conveyor belt running from a control booth located approximately 25 feet northwest of the TTU. Maximum feed rate of the TTU was 90 pounds of propellant per hour. The rate was determined through stack testing as the maximum allowable burn rate to ensure that hydrogen chloride emissions from the operation remained below the facility's air permit limits. The first quantity of waste

introduced into the TTU was ignited by a propane pilot flame. Each successive quantity of propellant fed into the TTU was ignited by the previously burning quantity. Emissions from the burning propellant cooled as they were pulled through a series of expansion chambers by a blower operating at approximately 13,000 cubic feet per minute (cfm). The blower directed the emissions through a baghouse that filtered the particulate emissions using polyester cloth bags.

Temperatures in the combustion and expansion chambers were monitored at the control booth so that an appropriate propellant feed rate was maintained for flame propagation in the combustion chamber. Pressure drop across the baghouse was also periodically monitored to verify the filter media was not blocked. As necessary, the residue collected on the filter media was dislodged by a manually controlled shaker and collected in drums and/or cubic yard boxes.

RCRA Closure of the TTU was conducted in December 2007 and January 2008 in accordance with the RCRA Closure Workplan, Attachment G of the facility Part B permit (see Section 1.4.10). Closure activities included decontamination, demolition, and disposal. Decontamination activities included removal of solid residue and paint from the interior of the expansion/cooling chamber and pressure washing the interior of the chambers and the baghouse. The TTU, support equipment, and concrete pad were demolished using various equipment (cutting torches, track mounted excavator, front-end loader, and forklift). Waste materials were separated and characterized for disposal. Metal debris was recycled, concrete debris was sent to a construction and demolition (C&D) landfill, other solid debris was sent to a non-hazardous landfill, and the collected rinsate and sediment from the pressure washing activities were transported off-site either as hazardous waste or non-hazardous waste based on characterization sampling and analysis. See the RCRA Closure Report (Malcolm Pirnie, 2008j), submitted to ADEQ on December 19, 2008, for more details.

A more detailed description of the TTU operations is provided in the Site Investigation Work Plan for the Old Burn Area and Thermal Treatment Unit (Malcolm Pirnie, 2005b).

#### **1.3.4.3. Waterbore Area**

Since at least 1983, a high-pressure water spray wand operation had been used to remove solid propellant and binders from rocket motor tubes so that the tubes could be reused. This process was referred to as the waterbore operation. The Waterbore Area (Figure 3), where waterbore operation was performed, was located at the southern end of the D-Complex within the fence line.

The Waterbore Area consisted of the waterbore water wand station, fiberglass and polyethylene above ground waterbore wastewater evaporation tanks, and two fiberglass evaporation tanks used for the evaporation of non-hazardous mop/rinse water generated throughout the facility.

The original (former) water wand was located approximately 30 feet north of the current water wand. The former water wand was located in a fiberglass containment tank and in November 2002, the wand was shielded with plastic sheeting to limit horizontal water spray. In mid 2003, the former wand was decommissioned and replaced with a fully-contained water wand station.

The wastewater generated by the waterbore operation contained suspended solids and dissolved oxidizers. The wastewater was filtered to remove the solids and the remaining solution containing the oxidizers was piped to the open-top evaporation tanks.

Prior to 1988, waterbore wastewater was collected and diverted into two earthen containment ponds lined with plastic. The former ponds covered a surface area of approximately 2,000 square feet and were located adjacent to the water wand station. The wastewater in the ponds was allowed to evaporate and the remaining solids removed for treatment or disposal. The ponds were excavated and removed from service in the fall of 1988 and replaced with fiberglass open-top tanks. In 2003, inner open-top polyethylene tanks were added so that the fiberglass tanks function as secondary containment. Additional containment was also provided by a 40 mil polyethylene liner which was beneath the tanks and a six-inch sand layer.

The non-hazardous mop/rinse-water evaporation tanks were utilized for the evaporation of non-hazardous process rinse water and mop water generated throughout the facility. The resulting solution/solids were transported off-site for disposal.

In January 2008, concurrent with the RCRA closure activities conducted at the Open Burn Unit and the TTU, the former water wand and associated containment basis were removed from the Waterbore Area in accordance with the RCRA Closure Workplan, Attachment G of the facility's RCRA Part B Permit. Closure activities included decontamination, demolition, and disposal. Decontamination activities included pressure washing the wand and the fiberglass collection basin. The wand, basin, and concrete pad were then demolished and the waste materials were separated and characterized for disposal. Metal debris was recycled, concrete debris was sent to a C&D landfill, other solid debris was sent to a non-hazardous landfill, and the rinsate was transported off-site as non-hazardous waste based on characterization sampling and analysis. See the RCRA

Closure Report (Malcolm Pirnie, 2008j), submitted to ADEQ on December 19, 2008, for more details.

A more detailed description of the Waterbore Area operations is provided in the Site Investigation Work Plan for the Waterbore Area (Malcolm Pirnie, 2004a).

### **1.3.5. E-Complex (Storage Magazine Area)**

The E-Complex (Figure 3), also referred to as the SMA, consisted of portable prefabricated metal (Conex-type) containers used for the storage of energetic materials and devices used at the facility. Waste materials and devices were also stored at the SMA while awaiting off-site disposal and historically while awaiting on-site treatment. The stored materials included propellants, energetic powders and devices containing oxidizers such as lead nitrate, ammonium nitrate, ammonium perchlorate, and potassium perchlorate and fuel/additive compounds containing aluminum, barium, chromium, iron, potassium, cobalt, titanium, boron, magnesium, and zirconium.

A more detailed description of the SMA area operations is provided in the Soil Characterization Work Plan for the Storage Magazine Area (H+A, 2004d).

### **1.3.6. F-Complex**

The F-Complex Area (Figure 3) consisted of various buildings/structures used for manufacturing of powder-based energetic formulations, assembly operations and quality assurance/quality control (QA/QC) testing. Historically it was also used for the manufacturing of castable and extruded propellants. The F-Complex operations included powder processing, stun grenade assembly and QA/QC testing.

The powder processing area consisted of Buildings F-1 through F-4. Dry oxidizer materials were mechanically ground to the desired particle size distribution, sieved to break up agglomerates, and weighed to a particular batch size. The oxidizers were then mixed with fuel materials, binders, and solvent materials in remote operating areas to produce the powder formulations. The powder formulations were dried in ovens and either sent to storage magazines or assembly operations.

Oxidizers used in powder processing included ammonium perchlorate, potassium perchlorate, and chromate-based materials. The fuel materials included zirconium, tungsten, barium, boron, aluminum, and magnesium. Other materials including small quantities of lead azide, lead styphnate, and tetracene were also processed in this area. Solvents were used to decrease the sensitivity of the powder-based formulations during

the processing steps and included water, hexane, heptane, MEK, ethanol, isopropyl alcohol, acetone, and methylene chloride.

The stun grenade assembly area was located in Building F-10, South. The units were assembled using energetic powder-based formulations. The assembled devices were packaged for transportation off-site.

The QA/QC laboratory activities that historically occurred in the C-Complex were relocated to Building F-10, North in December 2003. The laboratory activities performed in this area included wet chemistry and bench-top testing of physical parameters such as pH, density, material assays, moisture content, heat of reaction, burn rate, particle size, conductivity, products of combustion, product compatibility, and product sensitivity. The sample sizes typically ranged from approximately 10 to 100 grams.

Historical processes in the F-Complex included manufacturing of castable and extruded propellant, manufacturing of large rocket motors, lining of rocket motor tubes, liner drying, tool pull, propellant mixing, propellant casting, and propellant curing, and weigh-out of oxidizers, binders, and fuel powders.

The extruded propellant manufacturing area in the F-Complex was located in Buildings F-5 through F-9. Oxidizer materials for the extruder operations were initially ground and weighed out to a particular batch size in the C-Complex. The ground oxidizer was then transferred to the F-Complex and loaded into hoppers along with polymeric binders, plasticizers, fuel materials, and burn rate modifiers. Once the propellant was extruded, it was cut into specified lengths and packaged for off-site shipment.

The oxidizers used in the extruder operations included potassium perchlorate, ammonium perchlorate, potassium chlorate, iron oxide, and sodium nitrate. Other ingredients included polymeric compounds and burn rate modifiers. Solvents were not used in the propellant mixing or extrusion process but were used in small amounts for equipment cleaning.

A more detailed description of the F-Complex Area operations is provided in the Site Investigation Work Plan for the F-Complex (Malcolm Pirnie, 2005c).

### **1.3.7. Open Burn Unit (New Burn Area)**

The OBU was operated in the New Burn Area, located south of the C-Complex near the south central property boundary (Figure 3). Open burning of waste/off-specification solid propellant materials were performed in this area since 1980. Originally, wastes were

burned on bare soil. In 1986, a burn pad consisting of 25 feet by 75 feet of four-inch steel-reinforced concrete covered with six inches of sand was installed. In 1989, a 10-foot wide outer concrete apron, sloped towards the center, was constructed around the perimeter of the burn pad. Open burning activities were discontinued in December 2004.

RCRA Closure of the OBU and associated open burning devices (OBDS) was conducted in December 2007 and January 2008 in accordance with the RCRA Closure Workplan, Attachment G of the facility's RCRA Part B Permit (see Section 1.4.10). Closure activities included decontamination, demolition, and disposal. Decontamination activities included removal of rainwater from the burn pad and pressure washing the OBDS. The OBDS, concrete burn pad, and the concrete apron around the burn pad were demolished using various equipment (cutting torches, track mounted excavator, front-end loader, and forklift). Waste materials were separated and characterized for disposal. The metal OBDS were recycled, concrete debris from the apron was sent to a C&D landfill, concrete from the burn pad was transported off site as hazardous waste, and the collected rainwater/rinsate were transported off-site as non-hazardous waste.

Limited removal of impacted soil was conducted in September 2008. Surface soils from three areas where lead, arsenic, and perchlorate concentrations in soil were above the Arizona non-residential Soil Remediation Levels (SRLs) were excavated. Confirmation samples were collected to verify that the extent of the impacted soil in each area was removed. The excavated soil was transported off site for disposal as non-hazardous waste. See the RCRA Closure Report (Malcolm Pirnie, 2008j), submitted to ADEQ on December 19, 2008, for more details.

A more detailed description of the New Burn Area operations is provided in the Soil Characterization Work Plan for the New Burn Area (H+A, 2004c) and Site Investigation Work Plan for the New Burn Area (Malcolm Pirnie, 2005d).

## **1.4. Previous Investigations**

Summaries of previous site inspections, assessments, and investigations performed prior to the RI activities described in this report are summarized below.

### **1.4.1. RCRA Part B Permit Application (UPCO, 1988-2008)**

Due to the on-site thermal treatment of hazardous wastes, the UPCO facility maintained a RCRA Hazardous Waste Facility, Part B Permit. The permit application and subsequent revisions have presented descriptions of the open burn and TTU operations, as well as, listing the types and characteristics of wastes treated in the Old Burn Area, New Burn

Area, and at the TTU. Thermal decomposition products and air emission modeling were also evaluated during the application process.

The permit application/revisions identified that aluminum, copper, iron, lead, and magnesium were present in significant quantities in waste materials historically burned at the Old Burn Area and the New Burn Area. In addition, barium, boron, chromium, titanium, tungsten, and zirconium were present in lesser amounts in the waste materials. Metals present in waste materials historically treated in the TTU include significant quantities of aluminum and lead and smaller quantities of copper, iron, magnesium and tin. Perchlorate was present in waste materials treated at the Old Burn Area, New Burn Area, and the TTU. Appendix D-1 of the Part B Permit provides information on the composition and quantity of waste propellants and oxidizers burned at the Open Burn Unit or treated at the TTU.

Emissions from the Old Burn Area and New Burn Area included typical combustion by-products (carbon dioxide, carbon monoxide, oxides of nitrogen, sulfur dioxide, and water), hydrogen chloride, and particulate matter (metallic oxides and metallic chlorides). Open burning was authorized to occur when the wind direction was to the north-northeast or northeast. Appendix D-2 of the Part B Permit presents the combustion products and estimated emissions and emission rates from the historic open burn operations. Although all permitted operations are undergoing closure, a Part B Permit Renewal Application was submitted to ADEQ in January 2009 for corrective actions and is currently being reviewed by ADEQ. RCRA Closure activities were conducted at the permitted treatment units (OBU and TTU) in late 2007 and 2008 (Malcolm Pirnie, 2008j). The UPCO facility submitted the RCRA Closure Report and Closure Certification to ADEQ on December 19, 2008, and ADEQ approved the Closure Certification on February 23, 2009 (Appendix C).

#### **1.4.2. Waterbore Surface Impoundment Excavation (EarthTech, 1988)**

The former waterbore containment pond was decommissioned in the fall of 1988. The pond liner was removed and the surface soil excavated to approximately one foot below ground surface (bgs). Earth Technology, Inc. (EarthTech) collected soil samples from the bottom of the excavation that were analyzed for lead by EP Toxicity and Synthetic Precipitation Leach methods. The analyses indicated that the leachable extract from two of the soil samples contained elevated lead concentrations. Additional soil was excavated to a depth of approximately two feet below grade from the areas where these two soil samples were collected. Additional soil sampling in these areas indicated that the leachable extracts did not contain lead at concentrations above the regulatory threshold.

The samples were not analyzed for perchlorate during the containment pond removal because that constituent was not considered a COPC at that time.

#### **1.4.3. Facility Inspection (ADEQ, 1989)**

A facility inspection was performed by ADEQ in March 1989 (ADEQ, 1989). The inspection report identified two areas in the C-Complex where releases to the ground surface had occurred. One release was observed at the particulate collection tank/drum on the north side of Building C-1. The other release was observed on the east side of Building C-2 where the propellant tube rinsing operation was performed. The propellant tank spill was subsequently cleaned up, the tank repaired, and the operation moved indoors. The propellant tube washing operation is currently performed in a sink that drains to a holding tank. The non-hazardous wastewater in the holding tank is ultimately transferred to an evaporation tank at the Waterbore Area.

#### **1.4.4. TTU Stack Testing (SA&B, 1992 and 1993)**

In December 1992 and March 1993, Scott, Allard & Bohannon, Inc. (SA&B) conducted two compliance stack emission tests for the TTU. During each test, particulate and hydrogen chloride emissions were monitored. The testing demonstrated that the particulate removal efficiency of the TTU baghouse was greater than 98 percent. In addition, the testing determined that a propellant treatment rate of 90 pounds per hour emitted less than 20 pounds per hour of hydrogen chloride, which was the emissions limitation for hydrogen chloride in the facility's air quality permit. This treatment rate was subsequently set as the maximum allowable feed rate for the TTU.

#### **1.4.5. RCRA Facility Assessment (SAIC, 1993)**

In December 1993, the U.S. Environmental Protection Agency (EPA) contracted with Science Applications International Corporation (SAIC) to conduct a RCRA Facility Assessment (RFA) as part of the Part B permitting process. The RFA report identified and assessed 22 Solid Waste Management Units (SWMUs) and other Areas of Concern (AOCs) at the UPCO facility. The SWMUs and AOCs are located within the operational areas discussed above. A SWMU includes any part of an area which has been used for the treatment, storage, or disposal of solid waste. Appendix D provides a summary of the SWMUs identified during the RFA, as well as additional SWMUs identified by UPCO after the 1993 assessment. Figure 3 shows the SWMUs relative to facility buildings/structures. The RFA report identified six SWMUs (5, 10, 11, 19, 20, and 22) and eight AOCs (1 through 8) as potential sources of releases to the environment and recommended further investigation of these areas. The remaining SWMUs were not considered potential threats to the environment and were not recommended for further investigation.

#### **1.4.6. RCRA Facility Investigation Report (SA&B, 1999 & 2001)**

Between 1999 and 2001, SA&B conducted a Remedial Feasibility Investigation (RFI) of several SWMUs for UPCO, as recommended in the RFA report. Surface and subsurface soil samples were collected from SWMUs 5, 10, 11, 19, 20, and 22 (Figure 3). The samples were analyzed for selected organic and inorganic constituents based on the chemicals of potential concern associated with operations conducted at or near each SWMU (SA&B, 1999 and 2001).

##### *SWMU 5 (B-Complex)*

Six borings were drilled in the vicinity of former Building B-5 (SWMU 5) during the RFI. SWMU 5 was a former solvent storage building. The soil samples collected from the borings were analyzed for priority pollutant metals and volatile organic compounds (VOCs) by the EPA Methods 6010/7471 and 8260B, respectively. Metals were not detected at concentrations that exceeded the respective Arizona residential SRLs. VOCs were detected in two of the samples. The detected VOC concentrations were below the respective residential SRLs. Based on the analytical results, the report concluded that a potential solvent release at SWMU 5 had not adversely impacted subsurface soil.

##### *SWMU 10 / SWMU 11 (D-Complex)*

The investigation of the Waterbore Area SWMUs 10 and 11 (current waterbore evaporation tanks and former waterbore evaporation ponds) during the RFI was conducted in four phases from August 1999 to March 2001 (SA&B, 1999 and 2001). A summary of the perchlorate results from previous investigations is provided in Appendix E.

The first phase of the investigation consisted of sampling surface soils in the vicinity of the waterbore operations. The investigation included the collection of soil in the immediate vicinity of the waterbore operations, as well as along a 175-foot section of the adjacent wash located to the southeast. Perchlorate was not detected in the surface soil samples collected along the wash at concentrations above the laboratory reporting limit of 2 milligrams per kilogram (mg/kg) except for one location approximately 30 feet downstream of the Waterbore Area where the perchlorate concentration was 2.4 mg/kg (SA&B, 1999 and 2001). Within the Waterbore Area, the highest concentrations were found in surface soil located in the vicinity of the former water wand, the former containment ponds, and topographically downgradient from the former pond (sample locations D, E and F in Appendix E). Concentrations of perchlorate in the surface soil ranged from not detected (< 2 mg/kg) to 1,800 mg/kg (SA&B, 1999 and 2001).

The next three phases of investigation involved the collection of a series of progressively deeper soil samples, analyzed for perchlorate, in areas that had the highest observed impact to surface soil. The deepest borehole, D1, completed to 67 bgs, was drilled a few feet outside the northwest edge of the former containment pond. Concentrations of perchlorate in the subsurface soil ranged from not detected (< 2 mg/kg) to 369 mg/kg (SA&B, 1999 and 2001).

#### *SWMU 19 (B-Complex)*

Three borings were drilled in the vicinity of SWMU 19 (septic tank/leach field associated with Building B-1 x-ray inspection activities) during the RFI to assess if there had been a release of VOCs and/or silver to soil. Historic sampling of x-ray wastewater indicated detections of acetate, TCA, lead, silver, and chromium in the wastewater that had been discharged to the septic leach field.

Soil samples were analyzed for total silver and VOCs by EPA Methods 6010 and 8260B, respectively. Analytical results indicated that silver was detected at concentrations less than 2 mg/kg in each sample and VOCs were not detected above the laboratory reporting limits. Based on the analytical results, SA&B concluded that potential historical releases of silver and VOCs to the Building B-1 leach field (SWMU 19) did not adversely impact subsurface soil and additional investigation of the leach field was not recommended.

#### *SWMU 20 (C-Complex)*

During the RFI, five borings were attempted within SWMU 20 (leach field associated with the former C-Complex laboratory) using a hollow stem auger drill rig. Auger refusal occurred at less than five feet in three locations and no soil samples were collected. At one location, auger refusal occurred between five and 10 feet bgs and at another location, auger refusal occurred between 10 and 15 feet bgs. Samples were collected in these two borings at 5 and 10 feet bgs. COPCs identified at that time, VOCs and metals, were either not detected or were detected in concentrations below their respective residential SRL (SA&B, 1999 and 2001). The samples were not analyzed for perchlorate during the RFI.

#### *SWMU 22 (B-Complex)*

Five surface soil samples were collected along the bottom of a 150 foot stretch of ephemeral wash west of Building B-9 (SWMU 22) to assess the concentration of silver that may have impacted soil due to discharge of x-ray film processing wastewater from 1983 to 1986. Five soil samples were analyzed for total silver by using EPA Method 6010. Analytical results indicated that silver was not detected above the laboratory reporting limit in these samples. Based on the analytical results, SA&B concluded that historical releases of x-ray film processing wastewater did not adversely impact surface

soil within the ephemeral wash behind Building B-1. Additional investigation of the ephemeral wash adjacent to Building B-9 was not recommended.

#### **1.4.7. SMA Soil Sampling (UPCO, 2002)**

In response to a 2002 incident involving the deflagration of energetic materials and the release of debris within the SMA (E-Complex), UPCO collected surface soil samples at 12 locations within the observed debris field to evaluate potential impacts to the surrounding soil (Appendix E). The surface soil samples were analyzed for perchlorate, RCRA metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver) by Toxicity Characteristic Leaching Procedure (TCLP), aluminum, copper, iron, and magnesium (total recoverable), chloride, potassium, sulfur, nitrate, nitrite, nitrogen, total Kjeldahl nitrogen, and pH.

The surface soil samples collected approximately 90 feet east of Magazine E-1D contained perchlorate concentrations that ranged from 0.02 mg/kg to 124 mg/kg. Analytical results from the October 2002 SMA sampling event are presented in Appendix E.

#### **1.4.8. Mop Water Investigation (UPCO, 2002)**

In 2002, UPCO had an accidental release of approximately 100 gallons of mop water to the soil in the C-Complex Area. The mop water contained perchlorate and lead generated by housekeeping activities in the C-Complex process areas. The spill area (Mop Water Area) is bounded by a sidewalk that allows access to Buildings C-1, C-2, C-3, and C-7. The topography of the Mop Water Area slopes downhill generally from east to west. A visible drainage feature trends roughly through the center of the Mop Water Area and exits the C-Complex Area to the west into an ephemeral wash.

Following the mop water spill incident, 11 soil samples were collected by UPCO to assess the extent of impacted soil. Based on the analytical data, approximately 56 cubic yards of soil was excavated to a depth of approximately five feet bgs and transported off site for disposal. Soil with a perchlorate concentration greater than 610 mg/kg, the Arizona Department of Health Services (ADHS) Health Based Guidance Level (HBGL), or lead concentrations greater than the non-residential SRL of 1,200 mg/kg was removed. Three confirmation samples were collected to evaluate if enough soil had been removed to the specified levels. The concentration of perchlorate in the confirmation samples ranged from 13.7 mg/kg to 197 mg/kg. A polyethylene liner was placed at the bottom of the excavation and the excavation was backfilled to grade with import material.

#### **1.4.9. Initial Groundwater Investigation (H+A and ADEQ, 2003 and 2004)**

Two monitor wells, MW-1 and MW-2, were installed at the UPCO facility in December 2003 (H+A, 2004e). An exploratory boring, SH-1, was also drilled in the Waterbore Area, northwest of the current water wand, as part of this investigation. The purpose of the well installation and borehole activities was to investigate the hydrogeologic conditions and groundwater quality at the facility. The results of the investigation are summarized below.

- The total depth drilled at MW-1, MW-2, and SH-1 was 243, 253, and 278 feet, respectively. Each boring intersected the groundwater surface. Table 1 provides a description of the well construction details for MW-1 and MW-2 and Figure 4 presents well locations.
- Two separate subsurface geologic units were observed in the three borings which included an overlying sedimentary unit and a bedrock unit. The interpreted depth to the bedrock unit for MW-1, MW-2, and SH-1 was 100, 95, and 167 feet bgs respectively.
- Subsurface soil samples were collected at each boring at 10 foot intervals to a total depth of 50 feet bgs. The samples were analyzed for perchlorate. The analytical results at MW-1 and MW-2 indicated perchlorate was not present above laboratory reporting limits for each depth interval. The soil results at SH-1 had detectable concentrations of perchlorate ranging from 0.10 to 2.6 mg/kg.
- Groundwater levels collected from the monitor wells MW-1 and MW-2 were initially interpreted to show a general flow direction to the west-southwest. The groundwater flow direction was considered approximate and additional monitor well installation was recommended.
- Perchlorate was detected in groundwater samples collected from MW-1 and MW-2. Water quality samples were not collected from SH-1. Perchlorate concentrations in MW-1 ranged in concentration from 88 to 130 micrograms per liter ( $\mu\text{g/L}$ ) over three initial monthly sampling events. Perchlorate concentrations in MW-2 ranged in concentration from 39 to 47  $\mu\text{g/L}$  over the same time period. Perchlorate and 1,1-dichloroethene (DCE) were also detected in the facility production well, PW-1.

During March 2004, ADEQ sampled private domestic wells in the neighborhood areas located north and west of the facility, and production wells at the Arizona Department of Transportation (ADOT) facility located at 24251 North 7<sup>th</sup> Avenue. Perchlorate was not detected above the laboratory reporting limit in groundwater samples collected from the private wells or at the ADOT facility.

#### **1.4.10. RCRA Closure (Malcolm Pirnie, 2008)**

The RCRA permitted hazardous waste treatment units at the UPCO facility (OBU and TTU), ceased operations in December 2004 and May 2004, respectively. The treatment units were decontaminated and demolished in December 2007 and January 2008 following the ADEQ-approved Closure Plan (Attachment G of the facility's RCRA Part B Permit). The closure of the OBU also included limited excavation and disposal of impacted soil adjacent to the burn pad. The soil removal was conducted on September 20, 2008. A summary of the closure activities is included in the RCRA Closure Report submitted to ADEQ on December 19, 2008 (Malcolm Pirnie, 2008j).

### **1.5. Regional Setting**

#### **1.5.1. Regional Geology**

The Site is located within the Basin and Range physiographic province of Arizona. The Basin and Range is characterized by northwest trending bedrock mountain ranges separated by gently sloping alluvial valleys (basins). The UPCO facility is located between and within the southern flanks of the Union Hills, a northwest trending bedrock mountain range, and the northern margin of the West Salt River Valley within the Union Hills USGS 7.5' Quadrangle (Figure 5). Topographic relief near the facility ranges up to 800 feet, and generally slopes in a south-southwest direction from the Union Hill towards the West Salt River Valley. The geology of the Union Hills and West Salt River Valley are described below.

##### **1.5.1.1. Bedrock Geology of the Union Hills**

Near the former UPCO facility, the Union Hills are comprised of Early to Middle Proterozoic (1740 to 1335 Ma) metavolcanic, metasedimentary, and plutonic bedrock. The bedrock is described as comprising part of a Proterozoic terrane that contains rocks of similar metamorphic grade and deformational fabrics largely correlative with the Tonto Basin Supergroup, Diamond Rim Intrusive Suite, and a younger intrusive suite (Holloway and Leighty, 1998). The bedrock is often covered by a thin veneer of regolith, but it may locally outcrop in the dry washes or road cuts in the Union Hills. Figure 6 shows the surface distribution of the bedrock at and surrounding the facility.

Descriptions of the individual bedrock units are provided below and are based on geologic mapping by Holloway and Leighty (1998) and Wilson et al. (1957).

### *Metavolcanic Units*

The metavolcanic bedrock units (Xva, Xvat, Xvd, Xvf, and Xvft on Figure 6) are highly foliated, predominantly intermediate to mafic in composition, and are of greenschist or lower metamorphic grade. The geochemical composition of the meta-volcanic rocks vary from rhyolitic to basaltic, with textures ranging from aphanitic to porphyritic. The different volcanic units are locally interbedded and are collectively referred to as the greenstone throughout this report. The greenstone forms one of the predominant bedrock types mapped near the facility, and is observed to weather red, brown, orange, and green at the surface. Hydrothermally altered zones of the more felsic rocks within the unit are described as rich in hematite, limonite, goethite, and ilmenite (Holloway and Leighty, 1998). The rocks within the greenstone unit were deposited in the proximal and distal portions of a submarine volcanic system (Anderson, 1989b).

### *Metasedimentary Unit*

The metasedimentary bedrock unit (Xs and Xfc on Figure 6) is comprised of indurated, slightly foliated meta-greywacke with lesser amounts of stretched pebble conglomerate, breccia, and ferruginous chert. This unit is interbedded with the metavolcanic sequence, forming only a minor component of the mapped bedrock in the Union Hills (Holloway and Leighty, 1998).

### *Plutonic Units*

The plutonic bedrock units (YXd, YXg, YXgd, Xd, Xg, Xgp, and Xgd on Figure 6) are predominantly granitic to granodioritic in composition. Two intrusive bodies are present near the UPCO facility, a foliated suite (Xd, Xg, Xgp, and Xgd) and a relatively unfoliated suite (YXd, YXg, and YXgd). The foliated suite is geochemically similar to the meta-volcanic bedrock discussed above, and may be related to its parent magma (Anderson, 1989b). The relatively unfoliated plutonic rocks cross-cut the metavolcanic bedrock; and most likely belong to a younger group (1485–1380 Ma) of granitic batholiths extending from the mid-continent region to the Mojave Desert (Anderson, 1989a).

### *Bedrock Structure*

As reported by Holloway and Leighty, 1998, a foliated structural fabric is present in the Early to Middle Proterozoic bedrock units of the Union Hills; and has a preferred strike to the north and/or northeast and is steeply dipping to northwest. The foliation is defined by alignment of mica grains, segregation of felsic and mafic minerals, and cleavage. The foliation is most pronounced in the greenstone bedrock unit. A secondary horizontal foliation is also reported within the greenstone unit near the site. Tight, northeast-trending isoclinal folds and large megascopic folds of the metavolcanic and co-eval plutonic rocks

are reported in the central portions of the Union Hills; however, faulting is not reported or mapped. The deformational fabric (i.e. foliation and folds) likely developed during the Yavapai Orogeny (1700 to 1690 Ma), which predates the emplacement of the unfoliated granitic suite. The entire Proterozoic bedrock basement sequence of the Union Hills has been dissected by detachment and normal faulting during extensional events which occurred from 25 to 8 Ma. Faulting associated with the extensional tectonics is not mapped near the Site, and is likely obscured by recent (Holocene) sedimentation (Holloway and Leighty, 1998).

The interpreted geologic history of the bedrock is summarized below:

- Compositionally diverse volcanism (basalt, andesite, dacite, and rhyolite) and related sediments were erupted/deposited during the Early Proterozoic (1740 to 1710) as part of a submarine volcanic complex. Co-eval, and potential co-genetic granitic to dioritic plutons were emplaced during this period.
- The volcanic and plutonic suite was deformed during the Yavapai Orogeny (1700 to 1690 Ma). The deformational event resulted in the dominant north to northeast striking sub-vertical foliation.
- Middle Proterozoic (1485 to 1380 Ma) granitic to dioritic plutons were emplaced into the older Proterozoic terrane.
- Two periods of extensional tectonics dissect the Proterozoic basement. The first is related to the low angle detachment faulting associated with the South Mountain-White Tank Metamorphic core complex (Spencer and Reynolds, 1989). The second is related to high-angle rotational block faulting of Basin and Range tectonics which resulted in the northeast trending mountain ranges and valleys that we see today (Menges and Pearthree, 1989).

#### **1.5.1.2. Geology of the West Salt River Valley**

The West Salt River Valley in the Union Hills quadrangle, also referred to as Deer Valley, is comprised of Cenozoic (Late Oligocene to Pleistocene) basin fill sedimentary deposits and basaltic flows which overlie and/or are deposited on top of the down-dropped, tilted bedrock units described previously. Descriptions of the West Salt River Valley units are provided below and are based on geologic mapping by Holloway and Leighty (1998) and Wilson et al. (1957).

##### *Tertiary Basalts*

Tertiary basaltic flows are not observed near the Site; however, they are mapped as isolated mesa-capping units within the Union Hills quadrangle. The basalts post-date low-angle extensional tectonics, but predate rotational block faulting. Basaltic clasts

derived from the erosion of the Tertiary basalts are preserved in the sedimentary deposits described below.

### *Sedimentary Units*

A thin veneer of unconsolidated to well cemented alluvial/colluvial sediments (Undifferentiated Quaternary on Figure 6) comprise the majority of the surface area within the Union Hills quadrangle. Near the Site, the surface deposits are described as middle Pleistocene alluvial fan and terrace deposits that are comprised of sandy to loamy, tan sandstones and conglomerates. The conglomerates have abundant granitic and metamorphic gravel clasts in a tan to brown sandy/silty matrix. The alluvial/colluvial sediments are locally eroded or are covered by small active dry-washes, low terraces, and broad alluvial fans.

The Undifferentiated Quaternary deposits cover older (Tertiary) Basin Fill deposits throughout most of the Union Hills; however, the older Basin Fill deposits locally outcrop to the southwest of the Site (Tsy on Figure 6). The Basin Fill deposits, where observed at the surface, are described as clast-supported, poorly sorted, conglomerate. The clast compositions include Proterozoic granite, granodiorite, and diorite; and Tertiary basalts. The matrix of the conglomerate is calcareous and sandy with variable amounts of hematite. The sedimentary deposits within Deer Valley near the Site are likely derived from the surrounding Union Hills (Holloway and Leighty, 1998).

The young colluvial/alluvial cover, and the older Basin Fill deposits are collectively referred to as the Sedimentary Unit throughout this report. Previous research suggests that the sedimentary strata within Deer Valley does not form a significant basin. The thickness of the Sedimentary Unit near the Site is generally mapped as less than 500 feet in thickness (Corkhill et al., 1993; Brown and Pool, 1989).

### *Sedimentary Unit Structure*

Surface expressions of normal faults, such as fault scarps in the sediment or bedrock, are not reported in recent geologic investigation of the Union Hills (Holloway and Leighty, 1998). However, Quaternary faulting within nearby sedimentary deposits is reported by Pearthree and Scarborough (1984). The surface contact between the Sedimentary Unit and the Precambrian basement near the site is mapped as a nonconformity.

## **1.5.2. Regional Hydrogeology**

The regional hydrogeology encompasses two significant hydrogeologic units. They include the Sedimentary Unit within the West Salt River Valley Basin, and the Proterozoic bedrock which comprises the Union Hills and underlies the alluvial deposits.

The West Salt River Valley Basin is comprised of a heterogeneous interbedded mixture of valley-fill deposits generally surrounded by bedrock outcrops. The basin is bounded on its eastern margin by the Union Hills, the Phoenix Mountains, and the Papago Buttes. The southern boundary includes South Mountain, the Sierra Estrella Mountains and the Buckeye Hills. The western boundary consists of the White Tank Mountains and the northern boundary consists of the Hieroglyphic Mountains (Reeter and Remick, 1986; Hammett and Herther, 1995).

The water-bearing units within the valley-fill deposits are traditionally divided based on lithologic characteristics. In descending order from the land surface, the water-bearing units include the upper alluvial unit (UAU), the middle fine-grained unit (MAU), and the lower alluvial unit (LAU). The primary water bearing unit in the West Salt River Valley Sub-basin is the UAU. The UAU ranges in thickness from zero feet near the mountain fronts to more than 1,000 feet in the interior of the sub-basin (Reeter and Remick, 1986). A direct correlation between the typical hydrogeologic units of the Salt River Valley (e.g. UAU, MAU, and LAU) and those underlying the UPCO facility has not been made.

Depths to groundwater vary within the UAU temporally and with location. On a regional scale, the groundwater flow direction near the UPCO facility appears to be from the northeast to the southwest away from the Union Hills (Rascona, 2003). Generally, groundwater levels are shallowest near the primary surface water courses including the Agua Fria, Salt, and Gila Rivers, and increase in depth as distance from the main water courses increases. Groundwater levels are also affected by centers of groundwater pumpage and recharge. A Regional Groundwater Elevation Map is provided as Figure 7.

Groundwater in the UAU generally occurs under unconfined conditions and ranges from a sodium/calcium-bicarbonate water type to a sodium-chloride type (Reeter and Remick, 1986). Confined or leaky-confined conditions may locally occur where substantial fine grained units overly the main water-bearing unit, or where fine-grained and coarse-grained units interfinger (Anderson, 1995). Total dissolved solids concentrations in upper alluvial groundwater range from as low as 200 milligrams per liter (mg/L) in the northern portion of the sub-basin to approximately 2,400 mg/L generally along the western extent of the Salt River (Reeter and Remick, 1986). Chemical quality of groundwater in the basins varies spatially and with depth and is closely related to mineralogy, structure, and drainage patterns with the basin (Anderson, 1995).

The bedrock units, which underlie the basin sediments and comprises the Union Hills, may contain usable amounts of groundwater where they are significantly fractured or faulted (Anderson, 1995).

## 1.6. Report Organization

This report has been organized to follow the guidelines for remedial investigation reporting outlined in the EPA's Guidance for Conducting Remedial Investigations and Feasibility Studies under Comprehensive Environmental Response Compensation and Liability Act (CERCLA) (EPA, 1988) and the American Society for Testing and Materials (ASTM) E1689-95 Standard Guide for Developing Conceptual Site Models for Contaminated Sites (ASTM, 1995). It consists of the following main sections:

- Introduction – overview of the facility operations, previous investigations, and regional geology / hydrogeology;
- Study Area Investigation – a summary of field activities performed during the soil, soil gas and groundwater investigations conducted as part of the RI
- Nature and Extent of Contamination – a summary of the analytical results of the RI investigations
- Physical Characteristics of Study Area – a summary of the geologic and hydrogeologic properties of the site
- Conceptual Site Model (CSM) – a summary of current site conditions and the predicted fate, transport, and potential exposure; and
- Summary and Conclusions

## 2. Study Area Investigation

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### 2.1. Soil Investigation Summary

Initial RI soil characterization activities were conducted between July 2004 and August 2005 and supplemental soil characterization was performed between February and March 2008. The soil investigation activities included the sampling and analysis of soil samples at each of the following operational areas:

- B-Complex;
- C-Complex;
- D-Complex
  - Waterbore Area
  - Thermal Treatment Unit
  - Old Burn Area;
- E-Complex
  - Storage Magazine Area;
- F-Complex; and
- Open Burn Unit (New Burn Area).

The area by area investigations were focused on the suspected or known releases of COPCs. The soil boring and sampling activities were intended to provide sufficient data to vertically and horizontally characterize surface and subsurface soils that may contain COPCs above the applicable screening levels.

The results of each area by area investigation were originally presented to ADEQ in separate draft site investigation reports organized by operational area. ADEQ reviewed and commented on these draft area reports, as well as the draft RI Summary Report (Malcolm Pirnie, 2006e), and the Interim RI Summary Report (Malcolm Pirnie, 2009b). In response, additional information and revisions were incorporated into this Final RI Report, where applicable. The detailed rationale for sample methodology, sample location, sample depth, and sample analysis are described in the site investigation work plans for each of the operational areas which include:

- Soil Characterization Work Plan, Storage Magazine Area (H+A, 2004d), (E-Complex);
- Site Investigation Work Plan, Waterbore Area (Malcolm Pirnie, 2004a), (D-Complex);
- Site Investigation Work Plan, C-Complex Area (Malcolm Pirnie, 2004c);
- Site Investigation Work Plan, F-Complex (Malcolm Pirnie, 2005c);
- Site Investigation Work Plan, Old Burn Area and Thermal Treatment Unit (Malcolm Pirnie, 2005b), (D-Complex);
- Site Investigation Work Plan, New Burn Area (Open Burn Unit) (Malcolm Pirnie, 2005d);
- Site Investigation Work Plan, B-Complex (Malcolm Pirnie, 2005e); and
- Supplemental Soil and Soil Gas Investigation Work Plan (Malcolm Pirnie, 2008a).

A summary of the initial RI soil characterization activities in 2004 and 2005 and supplemental RI soil characterization in 2008 are presented in the following sections.

#### *Contaminants of Potential Concern and Characterization Targets*

The COPCs were identified for each operational area from a detailed review of operational history at the facility. To ensure soil samples were representative, the facility operations, chemicals used, and location information associated with processes and disposal were considered and incorporated into the characterization approach and sampling methodology. Following consultation with ADEQ, vertical and horizontal site characterization targets for COPCs were identified. The vertical characterization target for perchlorate in soil was identified as the project laboratory reporting limit of 0.04 mg/kg. The horizontal characterization target was identified as the EPA residential Preliminary Remediation Goal (PRG) of 7.8 mg/kg. The vertical and horizontal characterization targets for COPCs, other than perchlorate, were identified as the Arizona residential SRLs, if established. It should be noted that vertical characterization targets were superseded in instances where bedrock was encountered in the subsurface and soil sampling could not be accomplished. Site-specific clean-up objectives have not been established.

Surface and subsurface borings advanced during the 2004 and 2005 investigation activities provided initial sample results to characterize the nature, magnitude, and extent

of COPCs in soil. Supplemental surface and subsurface borings advanced in 2004, 2005 and 2008 provided additional characterization data for the horizontal and vertical delineation of COPCs in soil relative to horizontal and vertical characterization targets, respectively.

### **2.1.1. Soil Sampling Methodology**

The general soil sampling methodology followed during the soil investigations is summarized in the following sections.

#### **2.1.1.1. Surface Soil Sampling**

Surface soil samples were collected using a disposable and/or decontaminated stainless steel scoop. The surface soil samples were defined between the depths of 0 feet (ground surface) and 1-foot below ground. Soil was scooped into a disposable plastic bowl (or decontaminated stainless steel bowl), homogenized, and transferred into laboratory-provided sample containers. The stainless steel sampling equipment was decontaminated with an Alconox® solution followed by a distilled water rinse prior to and between sample collection.

#### **2.1.1.2. Sub-Surface Soil Sampling**

An ultrasonic rig was used to drill soil borings and collect soil cuttings at investigative locations. At some of the locations, drilling with the ultrasonic method was not effective due to highly cemented alluvium. At these locations an air rotary setup was used to advance the boring to within five feet of the desired sample depth to facilitate sample collection. The rig was then converted back to ultrasonic operation to drill the final five feet for sample collection in each of the investigation areas. Upon retrieving the core barrel to the surface, the soil core was placed into clear plastic bags. The cores produced ranged from one to three feet in length and were approximately six inches in diameter. The plastic wrapped soil cores were used to facilitate lithologic logging of the borehole and collection of soil samples. The samples were collected by opening the plastic core wrapping at the desired depth interval and transferring soil using disposable and/or decontaminated stainless steel scoops into laboratory-provided sample containers.

The soil cores from each boring were retained in their original plastic wrapping and placed in cardboard boxes, which were stacked on pallets for future sampling and/or observation, if necessary. After drilling and sampling to the specified total depth, each borehole was abandoned using cement grout in accordance with Arizona Department of Water Resources (ADWR) guidelines. In areas that were inaccessible to the drill rig (i.e., in the ephemeral washes), soil borings were advanced manually with a decontaminated hand auger.

### **2.1.1.3. Quality Assurance**

Sample jars containing soil were preserved on ice in a cooler at approximately 4 degrees Celsius (°C) under chain of custody protocol before transferring the samples to the laboratory. Procedures regarding sample collection, handling, and analysis were in accordance with the Quality Assurance Project Plan (QAPP) (H+A, 2004b).

Duplicate samples, matrix spike, and matrix spike duplicate samples were collected at a frequency of 10 percent for QA/QC purposes, as described in the QAPP (H+A, 2004b). Appendix F provides documentation of the quality assurance procedures.

### **2.1.2. Background and Fence Line Sampling**

Background surface soil samples were collected at one location within the undeveloped portion of the UPCO property, northwest of UPCO's operations, during the SMA investigation (see Figure 8). The samples were collected to establish background concentrations of COPCs in soil. In addition, soil samples were collected, at the request of nearby homeowners, from nine primary surface soil borings within the UPCO facility lease boundary along the north and west fence line. The objective of the fence line sampling was to assess if surface soil that was representative of nearby residential properties had detectable concentrations of COPCs associated with historic open burning and testing activities at the UPCO facility. The COPCs investigated include perchlorate, RCRA metals, explosives, and dioxins.

### **2.1.3. B-Complex**

A total of 117 soil samples were collected from 39 surface or subsurface soil boring locations within the B-Complex Area (see Figure 9). The sample locations, depths, and analyses were identified based on area operations, potential or known historic releases, and data gaps from previous assessments/investigations. The COPCs in soil include perchlorate, RCRA metals, nitrate, and acetate. A more detailed discussion regarding sampling locations and depths can be found in the Site Investigation Work Plan for the B-Complex Area (Malcolm Pirnie, 2005e), the draft Site Investigation Report for the B-Complex Area (Malcolm Pirnie, 2005h) and the Supplemental Soil and Soil Gas Investigation Work Plan (Malcolm Pirnie, 2008a).

### **2.1.4. C-Complex**

A total of 98 soil samples were collected from 22 surface or subsurface soil boring locations within the C-Complex Area (see Figure 10). The sample locations, depths, and analyses were identified based on area operations, potential or known historic releases, and data gaps from previous assessments/investigations. The COPCs in soil include

perchlorate, RCRA metals, nitrate, cyanide, semi volatile organic compounds (SVOCs), and sodium azide. A more detailed discussion regarding sampling locations and depths can be found in the Site Investigation Work Plan for the C-Complex Area (Malcolm Pirnie, 2004e), the draft Site Investigation Report for the C-Complex Area (Malcolm Pirnie, 2005f) and the Supplemental Soil and Soil Gas Investigation Work Plan (Malcolm Pirnie, 2008a)

### **2.1.5. D-Complex**

There were three specific sub-areas of focus within the D-Complex during the soil investigation. These areas include the Old Burn Area, TTU, and the Waterbore Area.

#### **2.1.5.1. Old Burn Area**

A total of 112 soil samples were collected from 51 surface or subsurface soil boring locations within the Old Burn Area (see Figures 11 and 12). The sample locations, depths, and analyses were identified based on area operations, potential or known historic releases, and data gaps from previous assessments/investigations. The COPCs in soil include perchlorate, RCRA metals plus aluminum and copper, nitrate, explosives, and dioxins. A more detailed discussion regarding sampling locations and depths can be found in the Old Burn and Thermal Treatment Unit Site Investigation Work Plan (Malcolm Pirnie, 2005b), the draft Old Burn and Thermal Treatment Unit Site Investigation Report (Malcolm Pirnie, 2005i) and the Supplemental Soil and Soil Gas Investigation Work Plan (Malcolm Pirnie, 2008a).

#### **2.1.5.2. Thermal Treatment Unit**

A total of 104 soil samples were collected from 30 surface or subsurface soil boring locations within the TTU Area (see Figure 13). The sample locations, depths, and analyses were identified based on area operations, potential or known historic releases, and data gaps from previous assessments/investigations. The COPCs in soil include perchlorate, RCRA metals plus aluminum and copper, nitrate, and pH. A more detailed discussion regarding sampling locations and depths can be found in the Site Investigation Work Plan for the Old Burn and Thermal Treatment Unit (Malcolm Pirnie, 2005b), the draft Site Investigation Report for the Old Burn and Thermal Treatment Unit (Malcolm Pirnie, 2005i) and the Supplemental Soil and Soil Gas Investigation Work Plan (Malcolm Pirnie, 2008a).

#### **2.1.5.3. Waterbore Area**

A total of 155 soil samples were collected from 15 surface or subsurface soil boring locations within the Waterbore Area (see Figure 14). The sample locations, depths, and analyses were identified based on area operations, potential or known historic releases,

and data gaps from previous assessments/investigations. The COPCs in soil include perchlorate, nitrate, and lead. A more detailed discussion regarding sample locations and depths can be found in the Site Investigation Work Plan for the Waterbore Area (Malcolm Pirnie, 2004a), the draft Site Investigation Report for the Waterbore Area (Malcolm Pirnie, 2004e) and the Supplemental Soil and Soil Gas Investigation Work Plan (Malcolm Pirnie, 2008a).

#### **2.1.6. E-Complex (Storage Magazine Area)**

A total of 61 soil samples were collected from 27 surface or subsurface soil boring locations within the SMA (see Figure 15). The sample locations, depths, and analyses were identified based on area operations, potential or known historic releases, and data gaps from previous assessments/investigations. The COPCs in soil include perchlorate, nitrate, and lead. A more detailed discussion regarding sampling locations and depths can be found in the Soil Characterization Work Plan for the Storage Magazine Area (H+A, 2004d) and draft Site Investigation Report for the Storage Magazine Area (Malcolm Pirnie, 2004b).

#### **2.1.7. F-Complex**

A total of 71 soil samples were collected from 22 surface or subsurface soil boring locations within the F-Complex Area (see Figure 16). The sample locations, depths, and analyses were identified based on area operations, potential or known historic releases, and data gaps from previous assessments/investigations. The COPCs in soil include perchlorate, RCRA metals, and nitrate. A more detailed discussion regarding sampling locations and depths can be found in the Site Investigation Work Plan for the F-Complex (Malcolm Pirnie, 2005c), the Proposed Supplemental F-Complex Soil Investigation letter to ADEQ (Malcolm Pirnie, 2006a), the draft Site Investigation Report for the F-Complex Area (Malcolm Pirnie, 2005g) and the Supplemental Soil and Soil Gas Investigation Work Plan (Malcolm Pirnie, 2008a).

#### **2.1.8. Open Burn Unit (New Burn Area)**

A total of 147 soil samples were collected from 47 surface or subsurface soil boring locations within the New Burn Area (see Figures 17 and 18). The sample locations, depths, and analyses were identified based on area operations, potential or known historic releases, and data gaps from previous assessments/investigations. The COPCs in soil include perchlorate, RCRA metals plus aluminum and copper, nitrate, explosives, and dioxins. A more detailed discussion regarding sampling location and depths can be found in the Site Investigation Work Plan for the New Burn Area (Malcolm Pirnie, 2005d) and the draft Site Investigation Report for the New Burn Area (Malcolm Pirnie, 2005j).

## 2.2. Soil Gas Investigation Summary

Initial soil gas investigation activities were conducted between July 2004 and August 2005 and supplemental soil gas characterization was performed between February and March 2008. The soil gas investigation activities included the sampling and analysis of soil gas samples at each of the following operational areas:

- B-Complex;
- C-Complex;
- D-Complex
  - Waterbore Area
  - Old Burn Area;
- F-Complex; and
- Open Burn Unit (New Burn Area).

The area investigations were focused on locations where solvents were managed, stored, or used and/or potentially released to the surrounding soil (e.g., septic leach fields). The soil boring and soil gas sampling activities were intended to provide sufficient data to assess for the presence or absence of VOCs in soil vapor and identify primary COPCs.

The results of each area investigation were originally presented to ADEQ in separate draft site investigation reports organized by operational area. ADEQ reviewed and commented on these draft area reports, and supplemental soil gas data was obtained to address ADEQ's comments. The detailed rationale for sample methodology, sample location sample depth, and sample analysis are described in the site investigation work plans for each of the operational areas including:

- Site Investigation Work Plan, C-Complex Area (Malcolm Pirnie, 2004c);
- Site Investigation Work Plan, F-Complex (Malcolm Pirnie, 2005c);
- Site Investigation Work Plan, Old Burn Area and Thermal Treatment Unit (Malcolm Pirnie, 2005b);
- Site Investigation Work Plan, New Burn Area (Malcolm Pirnie, 2005d);
- Site Investigation Work Plan, B-Complex (Malcolm Pirnie, 2005e); and
- Supplemental Soil and Soil Gas Investigation Work Plan (Malcolm Pirnie, 2008a).

Sampling methodology and the initial RI soil gas investigation activities in 2004 and 2005 and supplemental RI soil gas investigation in 2008 are summarized in the following sections.

### **2.2.1. Soil Gas Sampling Methodology**

Soil gas samples were collected during the 2004 and 2005 investigations using direct push and/or packer assemblies, and during the 2008 supplemental investigation using a packer assembly. Both soil gas investigations utilized one-liter Summa canisters for sample collection. The total depth and number of samples varied for each location and area assessed during the investigations. Soil gas sampling performed beneath the septic leach fields started at a depth of 30 feet bgs so that samples were collected beneath the potential release areas.

#### **2.2.1.1. Direct Push Soil Gas Sampling**

Direct push soil gas sampling included the use of a discrete sampling probe that was advanced at borehole locations to the desired interval by the drill rig. The outer casing of the probe was then retracted a few inches as the drive point was held in place, exposing an air intake screen. Soil vapor was purged using a vacuum pump and disposable tubing connected to the probe's screened chamber. After purging the appropriate number of well volumes, a soil gas sample was collected. The soil gas sample was collected by connecting a one-liter stainless-steel Summa canister (under vacuum) to the disposable tubing using a stainless steel manifold system. The manifold valve was then opened allowing soil gas to flow into the canister under vacuum pressure. A flow control valve regulated the sample collection rate at approximately one liter per minute. Direct push sampling was not used during the 2008 supplemental investigation.

#### **2.2.1.2. Packer Assembly Soil Gas Sampling**

At locations where advancement of the direct-push sampling probe was unsuccessful, a packer assembly was used to collect soil gas samples. After the ultrasonic core rig advanced a borehole to the desired soil gas sampling depth, an inflatable packer was lowered to the bottom of the borehole. The packer was inflated so that a seal was created against the wall of the borehole. If a proper seal could not be achieved within the open borehole, a temporary casing was driven along the walls of the borehole to approximately one foot above the total borehole depth and the packer was inflated to create a seal against the casing. A flexible tube, which passed through the packer into the open borehole beneath the packer, was connected to a vacuum pump and the bottom of the borehole purged and sampled in the same manner described in the direct push method. The air pressure of the packer was monitored to ensure a seal was maintained during sample collection.

At locations where refusal occurred during sonic drilling, an air rotary drilling setup was used to drill within five feet of the desired sampling depth. The rig was then converted to the sonic drill setup and advanced an additional five feet to the desired sampling depth. The packer assembly was then utilized to collect the soil gas sample as described above.

### **2.2.1.3. Quality Assurance**

Duplicate samples, matrix spike, and matrix spike duplicate samples were collected at a frequency of 10 percent for QA/QC purposes, as described in the QAPP (H+A, 2004b). Appendix F provides documentation of the quality assurance procedures.

## **2.2.2. B-Complex**

A total of 80 soil gas samples were collected from 41 subsurface soil borings within the B-Complex Area (see Figures 19, 20 and 21). The sample location, sample depth, and COPCs were identified based on B-Complex Area operations, potential historic releases, and data gaps from previous assessments/investigations. A detailed discussion on B-Complex Area operations, potential historic releases, previous site investigations, and the rationale for sampling locations and depths can be found in the Site Investigation Work Plan for the B-Complex Area (Malcolm Pirnie, 2005e) and the Supplemental Soil and Soil Gas Investigation Work Plan (Malcolm Pirnie, 2008a).

### **2.2.2.1. Soil Vapor Monitoring Well Installation**

One of the boring locations, BC-SG41, was completed as a nested soil vapor monitoring well (SVMW-1) in October and November 2008 to allow for monitoring of the vertical distribution of COPCs in soil gas beneath the suspected source area in B-Complex (see Figures 19-21). The pilot borehole that was advanced during the soil gas investigation was reamed using a conventional air-rotary method. A 20-foot section of low carbon steel conductor casing was grouted in place to provide a surface seal and prevent collapse of the borehole during reaming. The boring had a nominal 10-inch diameter that was initially advanced approximately 20 feet below the water table to facilitate the collection of a grab sample near the surface of the groundwater table (see Section 3.3.3). Grab samples of the soil cuttings were collected at regular intervals while reaming and logged using the Unified Soil Classification System (USCS) method. If bedrock was encountered in the borehole, it was logged using USGS rock descriptions. The lithologic log for this borehole is provided in Appendix G.

The borehole was then grouted and a series of four nested soil gas monitoring screens, each ten feet in length, were installed at 190-200 feet bgs, 140-150 feet bgs, 90-100 feet bgs, and 30-40 feet bgs, respectively. The soil vapor monitor well was constructed with

one 0.5-inch diameter schedule 80 polyvinyl chloride (PVC) casing and 0.04-inch slot screen (installed at 190 to 200 feet bgs) and three 2-inch diameter schedule 80 PVC casing with 0.02-inch slot screens. Annular construction materials included #8-12 silica sand, 3/8"-inch washed pea gravel, bentonite pellets, and neat cement grout. Annular materials were delivered to the subsurface using a tremie pipe. An as-built well construction diagram is provided in Appendix G.

### **2.2.3. C-Complex**

A total of 13 soil vapor samples were collected from 8 subsurface soil borings within the C-Complex Area (see Figure 22). The sample location, sample depth, and COPCs were identified based on C-Complex Area operations, potential historic releases, and data gaps from previous assessments/investigations. A more detailed discussion on C-Complex Area operations, potential historic releases, previous site investigations, and rationale for sampling locations and depths can be found in the Site Investigation Work Plan for the C-Complex Area (Malcolm Pirnie, 2004c) and the Supplemental Soil and Soil Gas Investigation Work Plan (Malcolm Pirnie, 2008a).

### **2.2.4. D-Complex**

There were two sub-areas of focus within the D-Complex during the soil gas investigations: the Old Burn Area and the Waterbore Area. VOCs were not identified as COPCs at the TTU; therefore, a soil gas investigation was not conducted in that area. The following paragraphs describe soil gas sampling efforts in each area.

#### **2.2.4.1. Old Burn Area**

A total of four soil vapor samples were collected from three subsurface soil borings within the Old Burn Area (see Figure 23). The sample location, sample depth, and COPCs were identified based on Old Burn Area operations, potential historic releases, and data gaps from previous assessment/investigations. A detailed discussion on Old Burn Area operations, potential historic releases, previous site investigations, and rationale for sampling locations and depths can be found in the Site Investigation Work Plan for the Old Burn Area and Thermal Treatment Unit (Malcolm Pirnie, 2005b) and the Supplemental Soil and Soil Gas Investigation Work Plan (Malcolm Pirnie, 2008a).

#### **2.2.4.2. Waterbore Area**

A total of two soil gas samples were collected from one boring within the Waterbore Area during the supplemental soil gas investigation (see Figure 23). The sample location, sample depths, and COPCs were identified based on Waterbore Area operations, potential historic releases, and data gaps from previous assessment/investigations. A detailed discussion on Waterbore Area operations, potential historic releases, previous

site investigations, and rationale for sampling locations and depths can be found in the Site Investigation Work Plan for the Waterbore Area (Malcolm Pirnie, 2004a) and the Supplemental Soil and Soil Gas Investigation Work Plan (Malcolm Pirnie, 2008a).

### **2.2.5. F-Complex**

A total of 34 soil vapor samples were collected from 13 subsurface soil borings within the F-Complex Area (see Figure 24). The sample location, sample depth, and COPCs were identified based on F-Complex Area operations, potential historic releases, and data gaps from previous assessments/investigations. A detailed discussion on F-Complex Area operations, potential historic releases, previous site investigations, and rationale for sampling locations and depths can be found in the Site Investigation Work Plan for the F-Complex (Malcolm Pirnie, 2005c) and the Supplemental Soil and Soil Gas Investigation Work Plan (Malcolm Pirnie, 2008a).

A fifth boring, identified in the work plan as FC-27, was not drilled during the supplemental investigation. The proposed boring was located in the vicinity of a compromised data line that was critical to operations at the F-Complex and D-Complex. UPCO was concerned that ground vibrations and heavy equipment travel associated with drilling at this location could permanently damage the data line, resulting in ceased operations and extensive repairs. ADEQ reviewed the previous soil gas data in this area and concurred that additional data obtained during the supplemental investigation would not provide enough value to warrant the risk of permanent damage to the data line.

After UPCO's operations were removed from the site, the necessity to collect a sample from location FC-27 was re-evaluated. Based on the data collected to date at the F-Complex, and knowledge of historical operations in the vicinity of proposed boring FC-27, the collection of additional data from FC-27 was not expected to identify a new contamination source or change the site conceptual model. Therefore, additional soil characterization in the F-Complex was not considered necessary to complete the RI and a sample from FC-27 was not collected.

### **2.2.6. Open Burn Unit (New Burn Area)**

A total of nine soil vapor samples were collected from three subsurface soil borings within the New Burn Area (see Figure 25). The sample location, sample depth, and COPCs were identified based on New Burn Area operations, potential historic releases, and data gaps from previous assessments/investigations. A detailed discussion on New Burn Area operations, potential historic releases, previous site investigations, and rationale for sampling locations and depths can be found in the Site Investigation Work Plan for the New Burn Area (Malcolm Pirnie, 2005d).

### 2.3. Hydrogeologic Investigation

A hydrogeologic investigation was conducted between December 2003 and April 2011 at and near the UPCO facility. The hydrogeologic investigation included:

- The installation of monitor wells (MW-1 through MW-19) to assess the prevailing hydrogeologic conditions in the vicinity of the UPCO facility.
- Collection of core samples from four monitor well locations (MW-5, MW-6, MW-9, and MW-13) to assess the subsurface geology.
- Collection of geophysical logs from the open boreholes at most of the monitor well locations to assess the subsurface geology.
- Recording of groundwater elevations from the monitor wells, using a combination of manual depth to water measurement and pressure data downloaded from dedicated transducers installed in select wells to assess groundwater conditions.
- Collection of quarterly groundwater samples from monitor wells to assess groundwater quality beneath the facility.
- Analysis of the surface drainage pattern in the vicinity of the site.
- Collection of semi-annual samples from private off-site domestic wells north of the UPCO facility along Yearling Road.

The rationale for monitor well locations, groundwater monitoring, and groundwater sampling and analysis are described in multiple work plans including:

- Monitor Well Construction Work Plan (H+A, 2004e);
- Quality Assurance Project Plan (H+A, 2004b);
- Groundwater Monitoring Plan (Malcolm Pirnie, 2004d);
- Updated Groundwater Monitoring Plan (Malcolm Pirnie, 2008c); and
- Supplemental Groundwater Investigation Work Plan (Malcolm Pirnie, 2008a).

The groundwater monitor wells were installed in phases. The results for each phase activities are described in the well installation reports which include:

- Monitor Well Construction Summary Report (MW-1 and MW-2) (H+A, 2004f).
- Phase II Monitor Well Installation Report (MW-3 through MW-8)

(Malcolm Pirnie, 2005a).

- Phase III Monitor Well Installation Report (MW-9 through MW-12) (Malcolm Pirnie, 2006b).

Phase IV Monitor Well Installation (MW-13 through MW-15) and Phase V Monitor Well Installation (MW-16 through MW-19) results are included in this report. The results of the hydrogeologic investigation activities are summarized in the following sections.

### **2.3.1. Monitor Well Installation**

Between 2004 and 2011, nineteen groundwater monitor wells were installed at on-site and off-site locations to assess groundwater quality, groundwater flow direction, and subsurface geology in the vicinity of the UPCO facility. The locations of the UPCO facility on site and off site monitor wells are shown in Figure 4. A summary of monitor well installation activities is presented in the following subsections.

#### **2.3.1.1. Pilot Borehole Drilling (Core Drilling)**

Pilot core holes were drilled at four monitor well locations (MW-5, MW-6, MW-9, and MW-13) to provide representative sections of the subsurface geology at the site (see Figure 4). An HQ core rig drilled a 3-inch diameter pilot borehole to a total depth of at least 50 feet below the first observed occurrence of groundwater, except MW-13 which was drilled to 500 feet bgs. A core barrel was utilized to collect lithologic samples. Continuous core was collected from the core barrel to the total depth drilled. The core barrel was advanced in up to five foot sections. The core samples were logged using the USCS visual manual method outlined in ASTM D2488 in unconsolidated layers. Consolidated units (i.e. bedrock) were logged using USGS rock descriptions. The lithologic logs for each borehole are provided in Appendix G. The recovered core was placed in labeled and indexed boxes which are currently stored on-site.

The total depth of the pilot boreholes for MW-5, MW-6, MW-9, and MW-13 are 285, 300, 240, and 500 feet bgs, respectively. Bedrock was encountered in the boring for MW-5 at a depth of 185 feet bgs, a depth of 48 feet bgs for MW-9, a depth of 195 feet bgs for MW-13, and not encountered in the boring for MW-6. Subsequent to pilot hole drilling and geophysics, the diameter of the pilot borehole was increased by reaming with an air rotary drill rig.

#### **2.3.1.2. Air Rotary Drilling and Reaming**

The boreholes for monitoring wells MW-1 through MW-19 were drilled, or reamed, using a conventional air-rotary method. The Phase I through Phase III borings (MW-1 through MW-11) were nominal 8-inch diameter with a total depth objective of

approximately 50 feet below the first observed occurrence of groundwater. The pilot borehole total depth was extended at MW-9 during reaming to achieve 50 feet of submergence below first observed occurrence of groundwater. The Phase IV and Phase V borings (MW-12 through MW-19) were nominal 10-inch diameter, to accommodate a larger well casing, with total depth objectives exceeding 300 feet below ground surface. At each location, a 20-foot section of low carbon steel conductor casing was grouted in place to provide a surface seal and prevent collapse of the borehole. Table 1 provides a description of the total depth drilled at each of the wells. Grab samples of the cuttings were collected at regular intervals from each boring and logged using USCS visual manual method outlined in ASTM D2488 in unconsolidated layers. If bedrock was encountered in the borehole, it was logged using USGS rock descriptions. The lithologic logs for each borehole are provided in Appendix G.

### **2.3.1.3. Borehole Geophysics**

Geophysical surveys were performed in boreholes MW-3 through MW-14, and MW-16 through MW-18, and the private well installed at 18 E. Yearling. MW-15 and MW-19 were not logged because they were located within 50 feet of boreholes (MW-14 and MW-13, respectively) that were logged to at least 500 feet bgs. The geophysical techniques performed included:

- natural gamma ray;
- neutron;
- caliper;
- dual inductive resistance;
- density;
- spontaneous potential (SP);
- fluid temperature and fluid resistivity;
- normal, guard, and single point resistivity; and
- acoustic and optical borehole televiewer.

The type of geophysical methods employed at each location depended upon the stability of the borehole, type and level of fluid in the borehole, and potential of the borehole to retain fluid. Table 2 provides a summary of the geophysical surveys for each borehole. The geophysical data was collected by a variety of source and receivers. The processed data are provided in Appendix I. A description of each geophysical technique is provided below.

**Acoustic Televiwer:** The acoustic televiwer log produces a 360° oriented image of the fluid filled portions of a borehole using transmitted sound waves. The acoustic televiwer log is useful for indicating fractures and or bedding orientation, sedimentological characteristics, and unit contacts. The log is affected by borehole conditions, such as the roughness of the borehole wall and diameter, and centralization of the tool.

**Caliper:** The caliper log measures the borehole diameter in an open or fluid filled borehole. The caliper log is useful for assessing borehole integrity, zones of washout, or zones of borehole narrowing typically associated with swelling clays or blocks of fractured rock. The borehole diameter recorded by the caliper log critical to the interpretation for each of the other geophysical log types.

**Density:** The density log measures the electron density of the formation. Porosity can be interpreted from the density log in conjunction with lithologic identification. The log is affected by borehole diameter, decentralization of the tool, and quality of drill core.

**Inductive Resistivity:** The inductive resistivity log measures conductivity form alternating electrical currents that are induced into the formation in an open borehole. The inductive resistivity log is useful for stratigraphic comparisons between boreholes and determining porosity when the formation does not contain clay.

**Normal Resistivity:** The normal resistivity logs measures the resistivity of the surrounding formation in fluid filled boreholes. The resistivity logs is a useful tool for measuring pore fluid or interconnected pore spaces, and for stratigraphic comparisons with other boreholes.

**Natural Gamma Ray:** The natural gamma ray log measures the natural radioactivity of formations as the tool is lowered into an open or fluid filled borehole. The gamma ray log usually serves as an indicator of the shale or clay content of a formation due to the higher concentrations of radioactive isotopes, such as Potassium 40, which are found in these sedimentary units. The logs are useful for stratigraphic correlation between boreholes. The gamma ray log is affected by the centralization of the probe within the borehole, width of the borehole, presence of arkosic sands derived from granitic rocks, and the presence of caliche.

**Neutron:** The neutron log measures the results of the bombardment of the formation with neutrons emitted from a source on the tool as it is lowered into an open or fluid filled borehole. The neutrons commonly interact with hydrogen atoms as they are emitted, and

as a result the tool is a good indicator of moisture content above the water table, and saturated porosity below the water table. In conjunction with the gamma density log, the tool can be used to identify potential perched aquifers.

**Optical Televiwer:** The optical televiwer log produces a 360° oriented optical image of the fluid filled portions of a borehole. This technique is useful in clear fluid only. The optical televiwer log is useful for indicating fractures and or bedding orientation, sedimentological characteristics, and unit contacts. The log is affected by borehole conditions, such as the roughness of the borehole wall and diameter, and centralization of the tool.

**Spontaneous Potential:** The spontaneous potential log is a measure of electric potential, or voltage, measured between an electrode lowered into a fluid filled borehole and a second stationary electrode at the ground surface. The spontaneous potential log can be useful for correlating geologic units, determining bed thickness, delineating relative permeabilities, and determining the presence of shale.

#### **2.3.1.4. Geophysical Fracture Analyses**

Fracture analyses were performed in the Phase II through Phase V borings where bedrock was observed, which includes monitor wells MW-3, MW-4, MW-5, MW-8, MW-9, MW-11, MW-12, MW-13, MW-14, MW-16 and MW-18. Fracture analyses of MW-15 and MW-19 were not conducted due to analyses performed in deeper boreholes, located in proximity. MW-14 is considered representative of MW-14 and MW-13 is considered representative of. In addition, MW-12 is considered representative of MW-1. The analyses were performed to provide a quantitative assessment of the orientation and intensity of fractures. Acoustical and optical televiwer geophysical tools collected fracture data from bedrock sections with the boreholes. The data was reduced and digitized to conduct the fracture analyses. The orientation and depth interval were recorded for each fracture observed. Appendix I provides a summary of the fracture analyses.

#### **2.3.1.5. Rock Quality Designation**

Rock Quality Designation (RQD) analysis was performed on the bedrock core recovered from the pilot boreholes for MW-5, MW-9, and MW-13. RQD evaluates the relative degree of fracturing of the bedrock unit and provides a systematic method of identifying the location and extent of fracture zones. Appendix J provides the RQD data per core run for MW-5, MW-9, and MW-13.

### 2.3.1.6. Zonal Groundwater Sampling

Zonal groundwater sampling was conducted at select intervals in borings MW-12, MW-13, MW-14, MW-18 and SVMW-1, prior to well construction, to provide vertical characterization of perchlorate in groundwater. Some of the zonal samples were collected with a packer assembly which was lowered into the pilot borehole (approximately four inches in diameter) to the targeted sampling depth and then the packers were inflated to create a seal with the walls of the borehole, isolating a 20-foot section of the borehole for sample collection. A bladder pump supplied with nitrogen gas was used to purge the sampling interval and then collect the sample. Due to an obstruction in the MW-14 borehole at approximately 420 feet bgs, the deepest sample from this borehole was collected with a modified packer assembly. The bottom packer was removed and the top packer was set at approximately 413.5 feet bgs. The sample was collected from the open borehole between the packer seal at 413.5 feet and the bottom of the borehole, approximately 500 feet bgs. Additional water was purged prior to sample collection due to the larger sampling interval at this location.

Due to borehole instability, some of the zonal samples were collected using a temporary well set. As the borehole was reamed out to full diameter for well installation, the drilling was advanced to the targeted sampling depth and then the temporary well set was installed. The temporary well set consisted of a bentonite seal at the bottom of the sampling interval, a 10-foot or 20-foot screen, sand pack around the temporary screen, then another bentonite seal at the top of the sampling interval. A submersible pump was lowered into the temporary well screen for purging and sample collection within the targeted interval. At the completion of sample collection, the well screen was removed and the bentonite and sand pack were reamed out for well completion.

Zonal samples were collected from the MW-12, MW-13, MW-14, and SVMW-1 boreholes as follows:

- At MW-12, zonal samples were collected at 280 to 305 feet bgs and 370 to 380 feet bgs with temporary well sets.
- At MW-13, zonal samples were collected at 247 to 269 feet bgs with a temporary well set and at 480 to 502 feet bgs with a packer assembly.
- At MW-14, zonal samples were collected at 285 to 305 feet bgs and 413.5 to 500 feet bgs with a packer assembly and at 360 to 380 feet bgs with a temporary well set.
- At MW-18, zonal samples were collected at 175 feet to 195 feet bgs; 275 feet to 295 feet bgs and 369.5 feet to 389.5 feet bgs with temporary wells sets.

- At SVMW-1, a zonal sample was collected at 218 to 238 feet bgs (at the upper surface of groundwater) with a temporary well set.

### 2.3.1.7. Borehole Hydrophysics

Hydrogeophysical logging (HPL) activities were conducted in the borehole for monitor well MW-14 between June 23, 2008 and June 25, 2008. The tests were discrete in nature, and performed to identify water bearing zones, and quantify the flow rates under ambient and dynamic (pumping) conditions. Hydrophysical analyses consisted of an ambient flow characterization (AFC) test, a hydraulic characterization (HC) test using a prescribed draw down to assess well productivity, and a pumping during injection (PDI) test to monitor changes in fluid electrical conductivity (FEC). HPL testing planned at the MW-13 borehole location was not conducted due to borehole instability.

The HPL tool calibration was completed with prepared solutions of 3 micro Siemens ( $\mu\text{s}$ ) and 547  $\mu\text{s}$ . On the initial run down the borehole to conduct an ambient log, the HPL tool would not pass at approximately 422 feet bgs. Therefore, to avoid damaging the HPL tool, subsequent hydrophysical logging runs were made from a depth of 420 feet bgs to the water surface. Prior to conducting AFC testing, 450 gallons of deionized (DI) water were injected at 420 feet bgs and emplaced groundwater between 420 feet bgs to the water surface. This process lasted approximately 2 hours. An electronic water level meter was used to record the ambient water level in the borehole during emplacement.

HC testing consisted of three and nine feet slug tests (rising head) and a constant pumping test at 7.7 gallons per minute (gpm). Water levels were logged during each test and evaluated to estimate hydraulic conductivity (K) and transmissivity (T) using the Hvorslev equation (for the slug test data) and the Theim equation (for the pumping test data). Based on results from the slug tests and pumping test, an optimum ratio of 5 to 2 gpm (pumping of formation water to injection of DI water) was determined for the PDI test.

During the PDI test, the average extraction pumping rate was 8.5 gpm while the average DI water injection rate was 2.9 gpm. This resulted in a net formation production rate of 5.6 gpm during the test with a maximum drawdown of 9.9 feet. Flow and drawdown data was recorded throughout the test.

A post test HPL tool calibration was performed after the testing. Hydrophysical testing results are summarized in Section 4.2.2.

#### **2.3.1.8. Well Construction**

Monitor wells were installed in each borehole at the completion of drilling activities. Most of the monitor wells were constructed with four-inch diameter schedule 40 PVC casing and 0.02-inch slot screen. At MW-12, MW-13, MW-14, and MW-16, five-inch diameter schedule 80 PVC casing was used to provide additional structural integrity due to the deeper construction. MW-19 was also constructed with five-inch diameter schedule 80 PVC casing to facilitate potential future pilot testing at the well during the corrective measures study. Annular construction materials included #10-20 or #8-12 silica sand, #60 sand, bentonite pellets, and neat cement grout. The well screen for MW-19 was constructed with larger 0.05-inch slot screen, since this well may be used pilot testing/aquifer testing during the corrective measures study. Annular materials were delivered to the subsurface using a tremie pipe. A summary of the well information for the UPCO facility monitor wells is provided in Table 1. As-built well construction diagrams are provided in Appendix G.

#### **2.3.1.9. Well Development**

Monitor wells MW-3 through MW-19 were typically developed within one week of installation. The monitor wells were developed by swabbing, surging, bailing and pumping. Development activities were conducted for two to eight hours at each well. The well screen was surged in 10-foot sections from the top of the interval to the bottom for between 30 and 45 minutes. A bailer was used to remove settled solids that had entered the casing during surging for between two to five hours. A submersible Grundfos pump was used for 1 to 2 hours to dislodge the finer grained materials from the filter pack and clarify the water.

Wells MW-3, MW-4, MW-6, MW-8, MW-10, MW-17, and MW-18 were purged dry during development pumping. Development was considered complete when turbidity in the effluent averaged one nephelometric turbidity unit (NTU) or after eight hours of pumping. Well development and pump installation occurred concurrently at monitoring wells MW-14, MW-15, MW-16, MW-17, and MW-19. MW-18 was not initially equipped with a dedicated sampling pump until it was determined (after a couple of monitoring events) that the well would yield a sufficient volume of water for purging, prior to sampling.

#### **2.3.1.10. Well Head Completion and Pump Installation**

Following construction and development activities, dedicated submersible pump assemblies were installed and surface completions added. Dedicated stainless steel Grundfos submersible pumps were installed approximately three feet above the bottom of the well screen. The drop pipe for the pump was constructed with one-inch diameter

coupled PVC pipe. A sounding pipe for water level measurement was installed to the top of the pump. The sounding pipe was constructed with one-inch diameter flush thread PVC pipe and 0.01-inch slot screen. A water tight well seal with ports for the drop pipe, electrical cable from the pump, and sounding pipe was installed at the top of each well. Surface completions were either 12-inch diameter traffic rated flush mounted vaults or above grade monuments. Each surface completion was surrounded by a three-foot square concrete pad. Each of the flush mounted vaults were removed and converted to above grade monuments following decommissioning of the UPCO facility in 2009. A stamped steep plate with the monitor well identification and ADWR registration number is attached to the top of each monument. As-built well construction diagrams are provided in Appendix G.

#### **2.3.1.11. Well Survey**

A state registered land surveyor established horizontal and vertical control at each of the UPCO facility monitor wells and private wells located at 18, 218 and 520 East Yearling Road. The vertical coordinate of the sounding port, top of casing, and ground surface was surveyed in the Arizona State Plane Coordinate System (NGVD 29) with units of international feet above mean sea level. The measuring point elevation of the PVC sounding port contained in the well seal was measured to the nearest 0.01 foot. The measuring point was marked on the north side of the port. The horizontal coordinate of the well was surveyed in the Arizona State Plane Coordinate System, Central Zone, North American Datum 1983 (NAD 83) with units of international feet. Survey information is provided in Table 1.

#### **2.3.2. Groundwater Monitoring**

The groundwater quality at the site was assessed through sampling on-site and off-site monitor wells, the UPCO production well (PW-1), the facility's former potable water system point of entry (POE), and private residential wells located along Yearling Road. The groundwater quality assessment included analyzing groundwater samples for COPCs and general chemistry typing. Sampling locations, sampling frequency and analytical methods for historic and current groundwater monitoring efforts are outlined in the Groundwater Monitoring Plan (Malcolm Pirnie, 2004a), and the Updated Groundwater Monitoring Plan (Malcolm Pirnie, 2008c). Groundwater monitoring locations are presented in Figure 26.

##### **2.3.2.1. On-Site Wells**

Groundwater samples were collected at each well (monitor wells MW-1 through MW-19) using permanent submersible pump assemblies and a dedicated decontaminated galvanized sample tee's with brass fittings. The sample tee for each site wide well is

equipped with a dedicated discharge line for well purging and a dedicated sampling port. The first two samples collected from MW-18 utilized a bailer and a temporary submersible pump, respectively, before a permanent pump was installed in April 2011. A more detailed discussion on groundwater sampling methodology can be found in the Updated Groundwater Monitoring Plan (Malcolm Pirnie, 2008c).

### 2.3.2.2. Private Domestic Wells

Private residential wells have been sampled on a semi-annual basis from November 2004 to the present. The private wells are located along Yearling Road, north of the former UPCO facility, as shown on Figure 26. Private wells that have been sampled as part of this RI investigation included the following addresses:

- 8 W. Yearling;
- 16 E. Yearling;
- 18 E. Yearling;
- 104 E. Yearling;
- 106 W. Yearling;
- 122 W. Yearling;
- 204 E. Yearling;
- 218 E. Yearling;
- 412 E. Yearling;
- 424 E. Yearling;
- 520 E. Yearling;
- 604-616 E. Yearling;
- 25825 N. 1<sup>st</sup> Place; and
- 25903 N. 2<sup>nd</sup> Street.

Private wells were sampled using existing dedicated submersible pumps, when available. Groundwater samples were collected from the closest available port to the well head prior to filtration or treatment systems (i.e. reverse osmosis, carbon filters, water softeners).

Approximately five gallons of water were flushed through the sampling port prior to collecting samples from the private wells. Field parameters measurements including pH, temperature and specific conductance were collected during private well sampling but the data was not used to establish parameter stabilization. It was assumed that if an owner granted access to their well, that the well was being used on a regular basis for domestic purposes and that the water in the line was representative of potable water that the owner was using.

Groundwater samples from private wells for laboratory analysis were collected and handled in accordance with the procedures described for the UPCO facility wells and in the QAPP (H+A, 2004b).

### 2.3.2.3. Quality Assurance

Sample bottles were preserved at approximately 4 degrees Celsius (°C) under chain of custody protocol before transferring the samples to the laboratory. A detailed description

of sample storage and preservation techniques, and laboratory protocol is included in the QAPP (H+A, 2004b) and QAPP Addendum (Malcolm Pirnie, 2009).

Duplicate samples, matrix spike, and matrix spike duplicate samples were collected at a frequency of 10 percent for QA/QC purposes, as described in the QAPP (H+A, 2004b). Appendix F provides documentation of the quality assurance procedures.

### **2.3.3. Groundwater Elevations**

Groundwater elevations have been monitored at and near the former UPCO facility to evaluate potential gradients. These measurements have been collected at UPCO site wide monitor wells and private wells located near the north property boundary at 18 East Yearling, 218 East Yearling and 520 East Yearling Road using electronic water level equipment and dedicated pressure transducers. Figure 26 shows the location of the UPCO facility monitor wells and private residences where groundwater elevations have been monitored.

#### **2.3.3.1. Manual Groundwater Measurements**

Groundwater level measurements were collected from January 2005 through December 2007 in accordance with the Groundwater Monitoring Plan (Malcolm Pirnie, 2004d), and from January 2008 through May 2011 in accordance with the Updated Groundwater Monitoring Plan (Malcolm Pirnie, 2008c). Groundwater elevations were not measured between February 2010 and May 2010 or between July 2010 and January 2011 while a post-lease access agreement with the Arizona State Land Department for site access was under negotiation.

Differences between the 2004 and 2008 groundwater monitoring plans include additional groundwater measurements from:

- the addition of wells MW-9, MW-10, MW-11 and MW-12, described in Phase III well installation report (Malcolm Pirnie, 2006b);
- addition of wells MW-13, MW-14 and MW-15; and
- availability to obtain depth to water measurements from private residences at 18 East Yearling, 218 East Yearling and 520 East Yearling.

Measurements were collected to the nearest 0.01 foot. Groundwater elevation was calculated based on the depth to water from a marked surveyed measuring point. The electronic water level probe was decontaminated prior to and between well measurements using an Alconox® solution followed by a distilled water rinse.

### 2.3.3.2. Transducers

Groundwater elevation data has also been collected since November 2006 with data logging pressure transducers at select on-site wells, off-site wells and private residence wells. Transducer data was retrieved approximately every month, reduced for groundwater elevation, and plotted over time.

Transducer installation consisted of:

- setting the transducer sensor to a depth within the pressure rating of the transducer;
- using the static water level as a reference point prior to starting the test; and
- logging the transducer data as depth to water.

Water level changes from collected transducer data is plotted over time and is provided in Figures 27, 28, and 29. Location and duration of transducer installation is provided in Table 3.

Hydrographs for each monitor well are provided on Figure 30. Monthly groundwater elevation maps for 2005 through 2010 are provided in the 2005 through 2010 Annual Groundwater Reports (Malcolm Pirnie, 2006c, 2007b, 2008e, 2009c, 2010, 2011), respectively. Groundwater elevation maps for 2011 are provided in the First Quarter 2011 monitoring report (Malcolm Pirnie, 2011). Groundwater elevation maps for Second Quarter 2011 are provided on Figures 31 through 34.

### 2.3.4. Aquifer Test

In September 2008, a short duration aquifer testing was conducted at monitor well MW-14 to estimate hydraulic parameters. As part of the aquifer testing, a single well pumping test followed by a recovery test of the same duration was performed in the test well (MW-14) while water levels were monitored in site monitor wells (MW-3, MW-4, MW-12, MW-13, and MW-15), production well PW-1, and three private wells located along E. Yearling Road (18 E. Yearling, 218 E. Yearling, and 520 E. Yearling). The locations of the wells are shown on Figure 26. Table 4 lists the location and completion details for the test well and observation wells.

Prior to conducting the aquifer test, three half-hour step drawdown tests were conducted to assess the optimum pumping rate for the constant rate test. The step drawdown tests were conducted at pumping rates of 2, 4 and 5 gpm. These rates were selected based on drawdown observed during well development activities. Results from the step drawdown test are presented in Appendix L. Specific capacity during the tests ranged from 0.01 to

0.03 gallon per minute per foot (gpm/ft). Analysis of the step drawdown results indicated a maximum sustainable rate of approximately 1.5 gpm for the proposed 10-hour duration without drawing water below the well screened interval.

Two days following the completion of the step drawdown tests, the aquifer and recovery tests were conducted by pumping from well MW-14 using the installed dedicated submersible pump at flow rate of 1.5 gpm. During the aquifer tests, electronic data logging transducers were used to collect automatic water level data from the pumping and observation wells. Water levels in the site monitor wells were also manually measured during the tests using an electronic water level probe. The water level measurement frequency was conducted in accordance with the Addendum to the Supplemental Groundwater Investigation Work Plan-Proposed Aquifer Test at Monitor Well MW-14, submitted to ADEQ. The water level measurement data were used to assess drawdown in the wells during the tests. The aquifer test findings are discussed in Section 4.2. The manual water level measurement for the test and observations wells, drawdown data, and the automated water level measurements for the test well and observation wells are provided in Appendix L.

### **2.3.5. Surface Drainage Analysis**

An analysis of the surface drainage pattern for the area around the site was completed using the following methodology:

- a study area was chosen that included the UPCO facility monitor wells (MW-1 through MW-19) at or surrounding the UPCO Facility;
- the surface drainage network within the study area was traced using the USGS 1:24,000 scale topographic maps and digital aerial photography;
- the drainage network was divided into 100 foot sections (reaches);
- the orientation for each 100 foot section was measured from north; and
- the orientation information for the stream reaches was plotted on a rose diagram to determine the primary drainage orientation.

The findings of the surface drainage analysis are presented in Section 4.3. The surface drainage network and orientation are presented in Figure 35.

### **2.3.6. Surface Geophysics**

In March 2008, a Subsurface Imaging Technical Memorandum and Work Plan was prepared to attempt to identify the nature and location of the geologic structure presumed to be in the vicinity of the wash on the western side of the site. Due to safety concerns

while the facility was in operation, the survey was postponed. After UPCO's operations were removed from the site, the benefit of conducting the surface geophysics survey was re-evaluated. The data collected from well installation activities, the soil and soil gas investigation, groundwater monitoring, and aquifer testing has provided enough information to develop a site conceptual model that can be used to proceed with the corrective measures study. UPCO determined that, while information obtained from a surface geophysics survey could add value, it was not considered necessary to complete the remedial investigation. If during the course of the corrective measures study the nature and location of the geologic structure is needed to evaluate remedial strategies, then the surface geophysics work plan will be re-visited with ADEQ.

## 2.4. GPL Determination Sampling

ADEQ has established SRLs for perchlorate of 55 mg/kg for residential land use and 720 mg/kg for non-residential land use (AAC, 2007). The SRL for a residential land use scenario is based on child exposure via ingestion of soil in a residential setting. The SRL for non-residential sites is based upon adult exposure via ingestion of soil in an occupational setting. The SRL does not address the potential for perchlorate to leach into groundwater from impacted soil and be exposed to receptors via ingestion of groundwater.

ADEQ has developed a model for deriving groundwater protection levels (GPLs) for inorganic contaminants in soil; however, the target application of this model is for use with metals by using an empirical relationship between the total concentration in soil, and a concentration in soil leachate, coupled with a basic mixing cell to calculate the concentration in the groundwater. Since the ADEQ GPL model was developed for metal compounds, it is not applicable to water soluble chemicals such as perchlorate. Therefore, a method for the development of a site-specific GPL for perchlorate was proposed by ADEQ in 2006 (ADEQ, 2006) and a subsequent proposal of an alternative method was presented by UPCO in 2008 (Malcolm Pirnie, 2008g).

UPCO proposed using the batch test leaching method (BTLM) model for perchlorate GPL development since it is similar to the approach outlined in ADEQ's 2006 GPL approach in that it is essentially composed of three parameters: a maximum allowable concentration in soil to protect groundwater, a source zone dilution factor, and an equilibrium assumption using a soil-water partition coefficient. The primary difference between the two methods is in the calculation of the soil-water partition coefficient ( $K_d$ ). The method proposed by ADEQ in 2006 used a  $K_d$  equation intended for organic compounds and estimated input parameter values for perchlorate that were inappropriate for an inorganic compound. With the BTLM model, the calculation of  $K_d$  includes a

comparison of the mass of contaminant that remains sorbed to the soil, after a synthetic precipitation leaching procedure (SPLP) test, to the mass of contaminant leached into solution.

Since the  $K_d$  for perchlorate may vary due to soil type and perchlorate concentration, sampling locations were selected to be representative of the soil found at different operating areas, varying depths, and the range of perchlorate concentrations that have been observed in the site soil. In September 2008, 15 soil samples were collected from soil cores that were generated during previous soil investigation activities (see Table 5). The samples were analyzed for total perchlorate concentration. The samples were selected to represent the range of perchlorate concentrations observed in site soil during previous investigations (<1 mg/kg to 100 mg/kg). An attempt was made to obtain at least one data point to represent each of the following perchlorate concentration intervals: <1 mg/kg, 1 to 25 mg/kg, 25 to 50 mg/kg, 50 to 75 mg/kg, 75 to 100 mg/kg, and >100 mg/kg as well as at least one data point for each operational area where perchlorate was detected (Waterbore Area, C-Complex and F-Complex). Based on the results of these initial analyses, the 10 samples that represented the greatest range of perchlorate concentrations were submitted for SPLP perchlorate analyses to develop the site-specific  $K_d$  curve for GPL determination.

Soil samples were collected by opening the plastic sonic core wrapping (or the appropriate core box) at the desired depth interval and removing enough soil to fill a 16-ounce sample jar using a trowel. The soil was placed in a stainless steel mixing bowl, broken into fragments no larger than one centimeter, and thoroughly homogenized. Soil samples collected from different operational areas were not mixed together. The well-mixed soil was then transferred into a certified-clean 16-ounce glass jar provided by the laboratory. Sample jars were labeled and placed on ice until they were submitted to the laboratory for analysis. The mixing bowl (and trowel, if disposable scoops were not used) were decontaminated with a detergent solution and thoroughly rinsed with distilled water after the collection of each sample.

Section 5.4.1.1 and Appendix M provide a summary of the results of the total perchlorate and SPLP perchlorate analyses as well as the development of the site-specific GPL for perchlorate in soil at the UPCO facility.

## 2.5. Investigative Derived Waste

Investigation derived waste (IDW) materials generated from the soil, soil gas, and groundwater investigation phases of the RI have included soil cuttings from soil borings;

excavated soil; development and purge water generated during well installation, sampling and aquifer testing; and residual liquid from decontamination activities.

Solid IDW was managed in roll-off bins during investigation activities. When the bins were filled to capacity, composite soil samples were collected and analyzed for TCLP metals and perchlorate. The wastes were transported off-site by Romic Environmental (Romic) or MP Environmental for disposal. Soil bins removed from the facility as part of these investigations were disposed at either the Waste Management Butterfield Landfill in Mobile, Arizona or the Waste Management Northwest Regional Landfill in Phoenix, Arizona.

Monitor well development water, purge water from sampling activities, and residual decontamination liquid was transferred into poly tanks for temporary storage. When the tanks were filled to capacity, water samples are collected from the tanks and analyzed for metals and perchlorate. Water containing perchlorate at concentrations below 100 µg/L was transported off-site by Romic or MP Environmental to the Liquid Environmental Solutions (LES) facility in Phoenix, AZ for treatment/disposal. IDW water containing perchlorate at concentrations above 100 µg/L were transported off site by MP Environmental to the Veolia facility in Azusa, CA for treatment/disposal.

Waste summary tables and disposal documentation are provided in Appendix N.

## 3. Nature and Extent of Contamination

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### 3.1. Soil Results

Soil samples collected during the RI investigations were submitted to an Arizona state-certified laboratory and analyzed for one or more of the following constituents:

- perchlorate by EPA Method 314;
- total RCRA metals, aluminum, boron, cobalt, copper, and iron by EPA Method 6010B (mercury by Method 7471);
- nitrate by EPA Method 300;
- cyanide by EPA Method 335;
- SVOCs by EPA Method 8270;
- dioxins by EPA Method 1613 and/or 8290;
- high explosives by EPA Method 8330 and 8332; and
- pH by EPA Method 150.1.

The following sections summarize the results of the RI soil investigation analyses.

#### 3.1.1. Fence Line Sampling

The COPCs identified for investigation in soil at the UPCO facility include perchlorate, RCRA metals, explosives, and dioxins. Fence line sampling was conducted to assess potential impacts to surface soil from historic burning operations. Table 6 and Figure 8 summarize the analytical results and locations for fence line sampling conducted at the site.

##### *Perchlorate*

Perchlorate was not detected at concentrations above the vertical characterization target of 0.04 mg/kg or the horizontal characterization target of 7.8 mg/kg. All perchlorate concentrations were <0.04 mg/kg.

##### *Metals*

The following metals (with their respective maximum concentrations) were not detected above their respective vertical and horizontal characterization targets: Arsenic (9.7

mg/kg), barium (140 mg/kg), cadmium (<0.5 mg/kg), chromium (48 mg/kg), lead (12 mg/kg), mercury (0.061 mg/kg), selenium (<5 mg/kg), and silver (<0.5 mg/kg).

#### *Explosives*

The explosives analyzed include 16 constituents. Explosive constituents were not detected above their respective vertical and horizontal characterization targets. 2,4,6-Trinitrotoluene (TNT) was detected at the highest concentration at 2.6 mg/kg.

#### *Dioxins*

The dioxins analyzed include 18 constituents. Dioxin constituents were not detected above their respective vertical and horizontal characterization targets. The highest constituent detected was OCDD at a concentration of 120 mg/kg.

### **3.1.2. B-Complex**

Table 7 presents the analytical results for soil samples collected at B-Complex. The following summarizes the soil characterization in the B-Complex.

#### *Perchlorate*

Perchlorate concentrations ranged from <0.04 mg/kg to 0.39 mg/kg in the soil samples collected within the B-Complex. Perchlorate was not detected above the vertical characterization target of 0.04 mg/kg in soil borings at total depth and was not detected above the horizontal characterization target of 7.8 mg/kg.

Horizontal and vertical characterization of perchlorate in soil at the B-Complex is considered complete. Figure 9 summarizes the sample locations and analytical results for perchlorate at B-Complex.

#### *Metals*

Arsenic was detected above the vertical and horizontal characterization target of 10 mg/kg in two samples (BC-SB32-0 and BC-SB32-1) at concentrations ranging from 11 mg/kg to 12 mg/kg. Supplemental hand auger sampling was conducted to the southwest (BC-SB45-0 and BC-SB45-1) and to the northeast (BC-SB46-0 and BC-SB46-1) of BC-SB32, within the wash, to delineate the extent of elevated arsenic concentrations observed at BC-SB32. Arsenic was not detected above the characterization target of 10 mg/kg in the supplemental soil samples.

The following metals (with their respective maximum concentrations) were not detected above their respective vertical and horizontal characterization targets: barium (690 mg/kg), cadmium (1.1 mg/kg), chromium (33 mg/kg), lead (17 mg/kg), mercury (<0.1

mg/kg), selenium (<5.1 mg/kg), and silver (0.52 mg/kg). Horizontal and vertical characterization of metals in soil at the B-Complex is considered complete.

#### *Nitrate*

The highest concentration of nitrate was detected at 82 mg/kg and was not detected at concentrations above the vertical and horizontal characterization target of 100,000 mg/kg. Horizontal and vertical characterization of nitrate in soil at the B-Complex is considered complete.

#### *Acetate*

Only soil samples collected from boring BC-SB21 were analyzed for acetate due to its proximity to the Building B-1 leach field. Acetate was detected in soil sample leachate at concentrations ranging between 3.8 mg/L and 14.8 mg/L. An SRL has not been established for acetate; therefore, there were no vertical and horizontal characterization targets for soil. Horizontal and vertical characterization of acetate in soil at the B-Complex is considered complete.

### **3.1.3. C-Complex**

Table 8 presents the results of inorganic analyses and Table 9 presents the analytical results for SVOCs in soil samples collected at C-Complex. The following summarizes soil characterization in the C-Complex.

#### *Perchlorate*

Perchlorate concentrations ranged from <0.04 mg/kg to 330 mg/kg in the C-Complex soil. The horizontal characterization target of 7.8 mg/kg was exceeded in four of the borings (CC-SB08, CC-SB10, CC-SB14, and CC-SB15). Supplemental soil samples were collected at CC-SB16, CC-SB17, CC-SB18, CC-SB19, CC-SB20, CC-SB21 and CC-SB25 to delineate the horizontal extent of the elevated perchlorate concentrations detected in the C-Complex. Perchlorate was not detected above the horizontal characterization target of 7.8 mg/kg in the supplemental soil samples.

The vertical characterization target of 0.04 mg/kg was exceeded in seven of the borings (CC-SB06, CC-SB08, CC-SB09, CC-SB10, CC-SB16, CC-SB20, and CC-SB21) at total depth. Bedrock was encountered in borings CC-SB06, CC-SB08, CC-SB09, and CC-SB10 superseding the vertical characterization target at those locations. The highest perchlorate concentration at the bottom of these four borings was 0.25 mg/kg. Additional deeper sampling for perchlorate was not conducted at borings CC-SB16, CC-SB20, and CC-SB21 because these locations were sampled for the purpose of horizontal characterization around borings CC-SB15 and CC-SB10, respectively. Borings CC-SB15

and CC-SB20 were drilled deeper than borings CC-SB16, CC-SB20, and CC-SB21 and vertical characterization was achieved at those potential source areas.

Horizontal and vertical characterization of perchlorate in soil at the C-Complex is considered complete. Figure 10 summarizes the sample locations and analytical results for perchlorate at C-Complex.

#### *Metals*

Arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver were not detected above their respective vertical and horizontal characterization targets. The following metals (with their respective maximum concentrations) were not detected above their respective vertical and horizontal characterization targets: arsenic (8.3 mg/kg), barium (1400 mg/kg), cadmium (1.5 mg/kg), chromium (37 mg/kg), lead (61 mg/kg), mercury (0.022 mg/kg), selenium (<10 mg/kg), and silver (52 mg/kg). Horizontal and vertical characterization of metals in soil at the C-Complex is considered complete.

#### *Nitrate*

The highest concentration of nitrate was detected at 140 mg/kg and was not detected at concentrations above the vertical and horizontal characterization target of 100,000 mg/kg. Horizontal and vertical characterization of nitrate in soil at the C-Complex is considered complete.

#### *Cyanide*

Cyanide was not detected at concentrations above the vertical and horizontal characterization target of 1,300 mg/kg. Horizontal and vertical characterization of cyanide in soil at the C-Complex is considered complete.

#### *SVOC*

SVOCs were not detected at concentrations above their respective vertical and horizontal characterization targets. 3,3-Dichlorobenzidine and pentachlorophenol were not detected; however, the laboratory detection limit resulting from sample recovery of the surface soil sample was greater than the SRLs of 1.2 mg/kg and 3.2 mg/kg, respectively. Horizontal and vertical characterization of SVOCs in soil at the C-Complex is considered complete.

#### *Sodium Azide*

Sodium azide was not detected at concentrations above the laboratory reporting limit of 0.155 mg/kg. Therefore, sodium azide was not detected at concentrations above the

vertical and horizontal characterization target of 310 mg/kg. Horizontal and vertical characterization of sodium azide in soil at the C-Complex is considered complete.

### **3.1.4. D-Complex**

#### **3.1.4.1. Old Burn Area**

Table 10 shows the results for inorganic analyses and Table 11 shows the analytical results for explosives and dioxins in soil samples collected at the Old Burn Area in the D-Complex. The following summarizes soil characterization in the Old Burn Area.

##### *Perchlorate*

Perchlorate concentrations ranged from <0.04 mg/kg to 0.8 mg/kg in the soil samples collected in the vicinity of the Old Burn Area. Perchlorate was not detected at concentrations above the horizontal characterization target of 7.8 mg/kg. The vertical characterization target of 0.04 mg/kg was exceeded in one boring (OB-SB01) at total depth. The perchlorate concentration at the bottom of this boring was 0.061 mg/kg. Additional deeper sampling for perchlorate was not conducted at OB-SB01 because samples collected at the same depth interval from borings OB-SB02 and OB-SB04, immediately adjacent to OB-SB01, did not contain perchlorate above the vertical characterization target of 0.04 mg/kg.

Horizontal and vertical characterization of perchlorate in soil at the Old Burn Area is considered complete. Figure 11 summarizes the sample locations and analytical results for perchlorate at the Old Burn Area.

##### *Metals*

Arsenic was detected above the vertical and horizontal characterization target of 10 mg/kg in one sample (OB-SB14-1) at a concentration of 11 mg/kg. Supplemental samples were collected at OB-SB50, OB-SB51 and OB-SB52 to delineate the horizontal extent of the elevated arsenic at OB-SB14. Arsenic was not detected at concentrations above the characterization target of 10 mg/kg in the supplemental samples.

Lead was detected above the vertical and horizontal characterization target of 400 mg/kg in seven samples (OB-SB08-0, OB-SB20-0, OB-SB40-0, OB-SB40-1, OB-SB41-0, OB-SB45-0, and OB-SB46-0) at concentrations ranging from 420 mg/kg to 4,800 mg/kg. Vertical and horizontal characterization targets for lead were achieved with additional sampling at OB-SB47, OB-SB48 and OB-SB49. Figure 12 summarizes the sample locations and analytical results for lead at the Old Burn Area.

The following metals (with their respective maximum concentrations) were not detected above their respective vertical and horizontal characterization targets: aluminum (31,000 mg/kg), barium (240 mg/kg), cadmium (1.8 mg/kg), copper (130 mg/kg), chromium (45 mg/kg), mercury (0.068 mg/kg), selenium (<5 mg/kg), and silver (<0.5 mg/kg). Horizontal and vertical characterization of metals in soil at the Old Burn Area is considered complete.

#### *Nitrate*

The highest concentration of nitrate was detected at 78 mg/kg and was not detected at concentrations above the vertical and horizontal characterization target of 100,000 mg/kg. Horizontal and vertical characterization of nitrate in soil at the Old Burn Area is considered complete.

#### *Explosives*

The explosives analyzed include 16 constituents. Explosive constituents were not detected above their respective vertical and horizontal characterization targets. The highest constituent detected was 4-Nitrotoluene at a concentration of 9.1 mg/kg. Horizontal and vertical characterization of explosives in soil at the Old Burn Area is considered complete.

#### *Dioxins*

The dioxins analyzed include 18 constituents. Dioxin constituents were not detected above their respective vertical and horizontal characterization targets. OCDD was detected at the highest concentration of 32 mg/kg. Horizontal and vertical characterization of dioxins in soil at the Old Burn Area is considered complete.

#### **3.1.4.2. Thermal Treatment Unit**

Table 12 shows the analytical results for soil samples collected at the TTU in the D-Complex. The following summarizes soil characterization in the vicinity of the TTU.

#### *Perchlorate*

Perchlorate concentrations ranged from <0.04 mg/kg to 16 mg/kg in the samples collected at the TTU. Perchlorate was detected at concentrations above the horizontal characterization target of 7.8 mg/kg in two samples (TT-SB24-10 and TT-SB25-5) at concentrations of 16 mg/kg, and 11 mg/kg, respectively. Supplemental sampling was conducted at borings TT-SB27, TT-SB28, TT-SB29, and TT-SB30 to complete horizontal delineation of elevated perchlorate concentrations in the vicinity of the TTU. Perchlorate was not detected above the horizontal characterization limit of 7.8 mg/kg in the supplemental soil samples.

The vertical characterization target of 0.04 mg/kg was exceeded in two borings (TT-SB24 and TT-SB30) at total depth. The perchlorate concentrations at the bottom of these borings were 1.2 mg/kg and 0.21 mg/kg, respectively. Additional deeper sampling for perchlorate was not conducted at boring TT-SB24 because vertical characterization was achieved at boring WB-SB08 (to 175 feet bgs), which was drilled adjacent to the TT-SB24 location during the investigation of the Waterbore Area (see next section). Boring TT-SB30 was not drilled deeper because this location was sampled for the purpose of horizontal characterization around boring TT-SB24B.

Horizontal and vertical characterization of perchlorate in soil at the TTU is considered complete. Figure 13 summarizes the sample locations and analytical results for perchlorate in soil at the TTU.

#### *Metals*

The following metals (with their respective maximum concentrations) were not detected above their respective vertical and horizontal characterization targets: aluminum (30,000 mg/kg), arsenic (9.7 mg/kg), barium (280 mg/kg), cadmium (0.86 mg/kg), copper (34 mg/kg), chromium (49 mg/kg), lead (22 mg/kg), mercury (0.038 mg/kg), selenium (<5 mg/kg), and silver (<0.5 mg/kg). Horizontal and vertical characterization of metals in soil at the TTU is considered complete.

#### *Nitrate*

The highest concentration of nitrate was detected at 100 mg/kg and was not detected at concentrations above the vertical and horizontal characterization target of 100,000 mg/kg. Horizontal and vertical characterization of nitrate in soil at the TTU is considered complete.

#### *pH*

The pH levels in soil ranged between 7.0 and 9.0 standard units (SU). There is currently no SRL established for pH; therefore, there were no vertical and horizontal characterization targets in soil.

### **3.1.4.3. Waterbore Area**

Tables 13 and 14 show the analytical results for soil samples collected at the Waterbore Area in the D-Complex. The following summarizes soil characterization in the vicinity of the Waterbore Area.

#### *Perchlorate*

Perchlorate concentrations ranged from <0.04 mg/kg to 130 mg/kg in the soil samples collected at the Waterbore Area. The horizontal characterization target of 7.8 mg/kg was exceeded in borings WB-SB06, WB-SB07, and WB-SB11 at multiple depths (highest concentration of 130 mg/kg). Lateral delineation was accomplished around each boring except to the east of WB-SB11. Additional sampling was not conducted east of WB-SB11 due to drill rig access limitations to the east and southeast due to hill side sloping.

The vertical characterization target of 0.04 mg/kg was exceeded in five of the borings (WB-SB05, WB-SB06, WB-SB07, WB-SB10, and WB-SB11) at total depth. Bedrock was encountered at or near the bottom in each of these borings superseding the vertical characterization target at those locations. The highest perchlorate concentration at the bottom of these five borings was 32 mg/kg in the soil sample collected from soil boring WB-SB06 at a depth of 175 feet bgs.

Horizontal and vertical characterization of perchlorate in soil at the Waterbore Area is considered complete. Figure 14 summarizes the sample locations and analytical results for perchlorate at the Waterbore Area.

#### *Metals*

The following metals (with their respective maximum concentrations) were not detected above their respective vertical and horizontal characterization targets: arsenic (7.8 mg/kg), barium (180 mg/kg), cadmium (0.88 mg/kg), chromium (17 mg/kg), lead (57 mg/kg), mercury (<0.10 mg/kg), selenium (<5 mg/kg), and silver (<0.5 mg/kg). Horizontal and vertical characterization of metals in soil at the Waterbore Area is considered complete.

#### *Nitrate*

The highest concentration of nitrate was detected at 86 mg/kg and was not detected at concentrations above the vertical and horizontal characterization target of 100,000 mg/kg. Horizontal and vertical characterization of nitrate in soil at the Waterbore Area is considered complete.

### **3.1.5. E-Complex (Storage Magazine Area)**

Table 15 shows the analytical results for soil samples collected at the SMA in the E-Complex. The following summarizes soil characterization within the SMA.

#### *Perchlorate*

Perchlorate concentrations ranged from <0.04 mg/kg to 6.2 mg/kg in the soil samples collected at the SMA. Perchlorate was not detected at concentrations above the horizontal

characterization target of 7.8 mg/kg. The vertical characterization target of 0.04 mg/kg was exceeded at 13 of the surface locations. Based on the relatively low, but distributed shallow concentrations of perchlorate, three locations were chosen for additional deeper sampling to 10 feet following preliminary data review with ADEQ (Malcolm Pirnie, 2004b). The highest concentration at the bottom of these supplemental borings was 0.64 mg/kg (SMA-SB05) at 20 feet bgs. Additional sampling was not conducted due to drill rig access limitations.

Horizontal and vertical characterization of perchlorate in soil at the SMA is considered complete. Figure 15 summarizes the sample locations and analytical results for perchlorate at SMA.

#### *Metals*

The following metals (with their respective maximum concentrations) were not detected above their respective vertical and horizontal characterization targets: barium (160 mg/kg), cadmium (<0.50 mg/kg), chromium (31 mg/kg), lead (100 mg/kg). Horizontal and vertical characterization of metals in soil at the SMA is considered complete.

#### **3.1.6. F-Complex**

Table 16 shows the analytical results for soil samples collected at F-Complex. The following summarizes soil characterization results for the F-Complex.

#### *Perchlorate*

Perchlorate concentrations ranged from <0.04 mg/kg to 6.5 mg/kg in the soil samples collected within the F-Complex. Perchlorate was not detected at concentrations above the horizontal characterization target of 7.8 mg/kg in the F-Complex soil samples.

The vertical characterization target of 0.04 mg/kg was exceeded in four of the borings (FC-SB03, FC-SB05, FC-SB08, and FC-SB11) at total depth. Borings FC-SB03, FC-SB05, and FC-SB11 were drilled using a smaller “mini” rig due to physical access limitations at those locations and could not be advanced deeper. The highest perchlorate concentration at the bottom of these three borings was 0.97 mg/kg. Perchlorate was detected at a concentration of 1.8 mg/kg at the bottom of boring FC-SB08. Access to this boring location was restricted following initial sample collection due to production schedules. The vertical characterization target was also exceeded at total depth at borings FC-SB-16, FC-SB17, FC-SB18, and FC-SB20; however, these samples were collected to delineate potential surface soil impacts associated with an incident at Building F-5. The highest perchlorate concentration at the bottom of these three borings was 6.5 mg/kg in the soil sample collected from soil boring FC-SB17 at a depth of one foot bgs. Additional

deeper sampling for perchlorate was not conducted at these borings because vertical characterization was achieved at adjacent soil boring FC-SB08 and FC-SB08, or the borings were located in a wash, and drill rig access was not possible (Borings FC-SB18 and FC-SB20).

Supplemental soil samples were collected at FC-SB24 and FC-SB25 to delineate the vertical extent of the perchlorate concentrations detected at the bottom of borings FC-SB03 and FC-SB05, respectively. Boring FC-SB11 could not be accessed by the sonic core rig. Perchlorate was not detected in boring FC-SB25 at depth and was detected in boring FC-SB24 at depth (60 feet bgs) at a concentration of 0.47 mg/kg. Further vertical delineation at FC-SB24 was not considered necessary, as discussed with ADEQ.

Horizontal and vertical characterization of perchlorate in soil at the F-Complex is considered complete. Figure 16 summarizes the sample locations and analytical results for perchlorate in soil at the F-Complex.

#### *Metals*

Arsenic was detected above the vertical and horizontal characterization target of 10 mg/kg in two samples (FC-SB02-20 and FC-SB06-20) at concentrations ranging from 11 mg/kg to 12 mg/kg. Additional sampling for arsenic was not conducted because, at 20 feet bgs, the observed concentrations are considered consistent with naturally occurring conditions. The following metals (with their respective maximum concentrations) were not detected above their respective vertical and horizontal characterization targets: barium (690 mg/kg), cadmium (0.59 mg/kg), chromium (50 mg/kg), lead (54 mg/kg), mercury (0.04 mg/kg), selenium (<5 mg/kg) and silver (16 mg/kg). Horizontal and vertical characterization of metals in soil at the F-Complex is considered complete.

#### *Nitrate*

The highest concentration of nitrate was detected at 43 mg/kg and was not detected at concentrations above the vertical and horizontal characterization target of 100,000 mg/kg. Horizontal and vertical characterization of nitrate in soil at the F-Complex is considered complete.

### **3.1.7. Open Burn Unit (New Burn Area)**

Table 17 shows the analytical results for inorganics and Table 18 shows the analytical results for explosives and dioxins in soil samples collected at the New Burn Area. The following summarizes soil characterization.

#### *Perchlorate*

Perchlorate concentrations ranged from <0.04 mg/kg to 150 mg/kg in the soil samples collected at the New Burn Area. Perchlorate was detected at concentrations above the horizontal characterization target of 7.8 mg/kg at borings NB-SB01, NB-SB02, NB-SB03, NB-SB04, NB-SB06, NB-SB08, NB-SB10, NB-SB12, NB-SB39, NB-SB43 and NB-SB44. Additional supplemental sampling was not conducted based on the perchlorate concentrations of soil samples collected laterally around these borings (borings NB-SB04, NB-SB09, NB-SB10, NB-SB17, NB-SB18, NB-SB19, NB-SB20, NB-SB25, NB-SB27, NB-SB28, NB-SB29, NB-SB34, NB-SB36, NB-SB37, NB-SB42, NB-SB45, and CC-SB12, collected during the C-Complex investigation) confirming that the horizontal characterization target of 7.8 mg/kg was achieved.

The vertical characterization target of 0.04 mg/kg was exceeded in fourteen of the borings (NB-SB01, NB-SB03, NB-SB05, NB-SB06, NB-SB07, NB-SB11, NB-SB13, NB-SB16, NB-SB39, NB-SB40, NB-SB43, NB-SB44, NB-SB46, and NB-SB47) at total depth. Bedrock was encountered in borings NB-SB01, NB-SB03, NB-SB06, NB-SB16, and NB-SB40 superseding the vertical characterization target at those locations. The highest perchlorate concentration at the bottom of these five borings was 4 mg/kg. Additional deeper sampling for perchlorate was not conducted at borings NB-SB05, NB-SB07, NB-SB11, and NB-SB13 because depth representative samples for that immediate area were observed from adjacent borings NB-SB01, NB-SB04, NB-SB08, NB-SB10, NB-SB12 drilled at the same depth or deeper. Additional deeper sampling for perchlorate was not conducted at borings NB-SB39, NB-SB43, NB-SB44, NB-SB46, and NB-SB47 because these locations were drilled for the purpose of further horizontal characterization around the former burn pad and depth representative samples were obtained at the borings in the immediate vicinity of the burn pad (NB-SB01, NB-SB04, NB-SB08, NB-SB10, NB-SB12).

Figure 17 summarizes the sample locations and analytical results for perchlorate at the New Burn Area.

### *Metals*

Arsenic was detected above the vertical and horizontal characterization target of 10 mg/kg in one sample (NB-SB01-0) at a concentration of 15 mg/kg. Additional sampling for arsenic was not conducted because the observed concentrations are considered consistent with naturally occurring conditions. Lead was detected above the vertical and horizontal characterization target of 400 mg/kg in one sample (NB-SS09-0) at a concentration of 650 mg/kg in the soil sample collected at the surface from soil boring NB-SB09. Vertical and horizontal characterization targets for lead were achieved with additional sampling. Figure 18 summarizes the sample locations and analytical results for

lead at the New Burn Area. Aluminum, barium, cadmium, copper, chromium, mercury, selenium, and silver were not detected above their respective vertical and horizontal characterization targets. The following metals (with their respective maximum concentrations) were not detected above their respective vertical and horizontal characterization targets: aluminum (39,000 mg/kg), barium (570 mg/kg), cadmium (7.9 mg/kg), copper (53 mg/kg), chromium (35 mg/kg), mercury (0.078 mg/kg), selenium (8.4 mg/kg) and silver (4.8 mg/kg).

#### *Nitrate*

The highest concentration of nitrate was detected at 27 mg/kg and was not detected at concentrations above the vertical and horizontal characterization target of 100,000 mg/kg.

#### *Explosives*

The explosives analyzed include 16 constituents. Explosive constituents were not detected above their respective vertical and horizontal characterization target. All concentrations of explosives were <2.0 mg/kg.

#### *Dioxins*

The dioxins analyzed include 18 constituents. Dioxin constituents were not detected above their respective vertical and horizontal characterization targets. The constituent with the highest detection was total HpCDF at a concentration of 60 mg/kg.

## **3.2. Soil Gas Results**

Soil gas samples collected during the RI investigations were submitted to an Arizona-certified laboratory and analyzed for VOCs by EPA Method TO-15. Soil gas samples were only collected in areas where solvents and/or adhesives were historically managed. Therefore, some of the areas investigated for potential soil impacts were not investigated for soil gas impacts (e.g., the TTU area). The following sections summarize the results of the RI soil gas investigation analyses.

### **3.2.1. B-Complex**

Of the 62 VOCs listed on the EPA TO-15 analyte list, 27 were detected in at least one of the soil gas samples collected at the B-Complex Area. The VOCs detected with the greatest frequency included 1,1-DCE, MEK, MIBK, acetone, and propene (propylene). The presence of propylene may be attributed to the use of polypropylene tubing for sample collection. Other VOCs detected with less frequency included 1,1-dichloroethane (1,1-DCA), 2,2,4-trimethylpentane, 2-hexanone, 2-propanol, dichlorodifluoromethane (F-12), benzene, and hexane. Table 19 summarizes the analytical results for soil vapor samples collected at the B-Complex. A subset of three VOC analytes (1,1-DCE, MEK,

and acetone) were selected to show area-wide distribution of VOCs in soil vapor on Figures 19 through 21. This subset of analytes was selected based on a cross reference of four main criteria that included: consistent detections in multiple areas, elevated concentrations (above 1,000 parts per billion per volume (ppbv) (0.26 micrograms per liter ( $\mu\text{g/L}$ ))), common use at the facility, and constituents with established AWQSSs.

Supplemental borings BC-SG36 through BC-SG44 were advanced and sampled to provide additional vertical delineation of VOCs detected in soil gas at depth in borings BC-SG24, BC-SG27, BC-SG22, BC-SG19, BC-SG34, BC-SG15, BC-SG33, BC-SG09, and BC-SG10, respectively. Significantly increasing VOC concentrations were detected at depth in soil gas samples collected at three supplemental locations in the B-Complex: BC-SG39, BC-SG41, and BC-SG44. Per the supplemental soil and soil gas investigation work plan, a significant increase in soil gas concentration at depth was defined as an increase in concentration of a COPC greater than 25% between the two deepest successive samples at a sampling location, provided that the concentrations are greater than 1,000 ppbv (0.26  $\mu\text{g/L}$ ).

Two locations (BC-SG39 and BC-SG44) had significantly increasing concentrations of acetone with depth: < 25 to 1,800 ppbv (0.081 to <0.30  $\mu\text{g/L}$ ) at 80 feet bgs and 470 to 3,000 ppbv (<0.060 to 0.28  $\mu\text{g/L}$ ) at 60 feet bgs, respectively. One location (BC-SG41) had significantly increasing concentrations of 1,1-DCE with depth: 740 to 6,900 ppbv (3.0 to 28  $\mu\text{g/L}$ ) at 80 feet bgs. A fourth boring (BC-SG42) had increasing 1,1-DCE concentrations with depth: 30 to 840 ppbv (0.12 to 3.4  $\mu\text{g/L}$ ) at 60 feet; however, this does not meet the “significantly increasing” criteria outlined in the work plan. Borings BC-SG36 and BC-SG38 had elevated concentrations of 1,1-DCE with depth: 960 ppbv (3.9  $\mu\text{g/L}$ ) at 80 feet bgs and 960 ppbv (3.9  $\mu\text{g/L}$ ) at 60 feet bgs, respectively. However 1,1-DCE concentrations appear to have stabilized and were decreasing at these locations.

Vertical delineation of VOCs in soil gas at BC-SG41 was accomplished after the nested soil vapor monitoring well, SVMW-1, was installed (see next section). Horizontal and vertical delineation of VOCs in soil gas in the B-Complex is considered complete.

#### **3.2.1.1. SVMW-1**

After the installation of SVMW-1, soil gas samples were collected from each nested interval (30-40 feet bgs, 90-100 feet bgs, 140-150 feet bgs, and 190-200 feet bgs). The soil gas analyses indicate 1,1-DCE concentrations peak at 11,000 ppbv (44  $\mu\text{g/L}$ ) at 90-100 feet bgs before decreasing to 180 ppbv (0.73  $\mu\text{g/L}$ ) at 190-200 feet bgs, just above the water table. Peak concentrations of other VOCs in soil gas were observed at either the 90-100 foot bgs interval or the 140-150 foot bgs interval. VOC concentrations decreased

in the 190-200 foot bgs interval. Table 19 summarizes the soil gas sampling results for SVMW-1. There has been no significant vertical migration of VOCs at SVMW-1 observed during eight rounds of quarterly soil gas monitoring. See Section 3.3.3 for a summary of the grab sample collected from the groundwater beneath the B-Complex during SVMW-1 installation.

### **3.2.2. C-Complex**

Of the 62 VOCs listed on the EPA TO-15 analyte list, 28 were detected in at least one of the soil gas samples collected at the C-Complex Area. The VOCs detected with greatest frequency included 1,1-DCE, MEK, 2-propanol, acetone, benzene, carbon disulfide, methylene chloride, propylene, and toluene. The presence of propylene may be attributed to the use of polypropylene tubing for sample collection. Other VOCs detected with less frequency included, 2-hexanone, dichlorodifluoromethane (F-12), ethylbenzene, hexane, m- & p-xylene, and o-xylene. Table 20 summarizes the analytical results for soil vapor samples collected at the C-Complex Area. A subset of three VOC analytes (1,1-DCE, MEK, and acetone) were selected to show area-wide distribution of VOCs in soil vapor on Figure 22. This subset of analytes was selected based on a cross reference of four main criteria that included: consistent detections in multiple areas, elevated concentrations (above 1,000 ppbv (0.26 µg/L)), common use at the facility, and constituents with established Arizona Water Quality Standards (AWQS).

Supplemental borings CC-SG22, CC-SG23, and CC-SG24 were advanced and sampled to provide additional vertical delineation of VOCs detected in soil gas at depth in borings CC-SG01, CC-SG05, and CC-SG06, respectively. The soil gas samples collected in C-Complex indicated that most VOC concentrations (notably MEK) decreased with depth. VOCs that increased with depth were detected at concentrations less than 1,000 ppbv and did not meet the “significantly increasing” criteria outlined in the work plan; therefore, further vertical delineation was not required. Acetone was detected at significantly increasing concentrations (as defined in the work plan) at the bottom of borings CC-SG23 and CC-SG24; however, these borings were drilled a few feet beneath the bedrock interface; therefore, further vertical delineation was not pursued at those locations. Horizontal and vertical delineation of VOCs in soil gas in the C-Complex is considered complete.

### **3.2.3. D-Complex**

#### **3.2.3.1. Old Burn Area**

Seventeen VOCs were detected in at least one of the three soil gas samples collected at the Old Burn Area. The VOCs detected with greatest frequency included 1,3-butadiene, MEK, acetone, benzene, chloromethane, propylene, and toluene. The presence of

propylene may be attributed to the use of polypropylene tubing for sample collection. Other VOCs detected with less frequency included 1,1-DCE, 2,2,4-trimethylpentane, 2-propanol, heptane, and tetrahydrofuran. Table 21 summarizes the analytical results for soil vapor samples collected at the Old Burn Area. A subset of three VOC analytes (1,1-DCE, MEK, and acetone) were selected to show area-wide distribution of VOCs in soil vapor on Figure 23. This subset of analytes was selected based on a cross reference of four main criteria that included: consistent detections in multiple areas, elevated concentrations (above 1,000 ppbv (0.26 µg/L)), common use at the facility, and constituents with established AWQs.

Supplemental boring OB-SG49 was advanced and sampled to provide additional vertical delineation of VOCs detected in soil gas at depth in borings OB-SG01 and OB-SG02. The soil gas sample collected at OB-SG49 indicated that VOC concentrations (notably MEK and toluene) decreased with depth (see Table 21). Horizontal and vertical delineation of VOCs in soil gas in the Old Burn Area is considered complete.

#### **3.2.3.2. Waterbore Area**

One boring (WB-SG13) was drilled at the Waterbore Area to assess potential VOC impacts to soil and soil gas related to historic evaporation pond operations. The previous Waterbore Area investigation did not include the collection of soil gas samples for VOC analysis. Six VOCs were detected in the soil gas samples including MEK, benzene, chloromethane, heptanes, propylene and toluene. The presence of propylene may be attributed to the use of polypropylene tubing for sample collection. The soil gas samples collected at WB-SG13 did not indicate VOC impacts at the Waterbore Area requiring further investigation (see Table 22). Horizontal and vertical delineation of VOCs in soil gas in the Waterbore Area is considered complete.

#### **3.2.4. F-Complex**

Twenty eight VOCs were detected in at least one of the 34 soil gas samples collected at the F-Complex Area. The VOCs detected with greatest frequency included MEK, 2-hexanone, 2-propanol, acetone, benzene, carbon disulfide, hexane, propylene, and toluene. The presence of propylene may be attributed to the use of polypropylene tubing for sample collection. Other VOCs detected with less frequency included 4-methyl 2-pentanone. Table 23 summarizes the analytical results for soil vapor samples collected at the F-Complex Area. A subset of three VOC analytes (1,1-DCE, MEK, and acetone) were selected to show area-wide distribution of VOCs in soil vapor on Figure 24. This subset of analytes was selected based on a cross reference of four main criteria that

included: consistent detections in multiple areas, elevated concentrations (above 1,000 ppbv), common use at the facility, and constituents with established AWQSSs.

Supplemental borings FC-SG21, FC-SG22, FC-SG23, and FC-SG26 were advanced and sampled to provide additional vertical delineation of VOCs detected in soil gas at depth in borings FC-SG09, FC-SG08, FC-SG02, and FC-SG01, respectively. The soil gas samples collected in F-Complex indicated that VOC concentrations (notably MEK and acetone) decreased with depth (see Table 23). Horizontal and vertical delineation of VOCs in soil gas in the F-Complex is considered complete.

### **3.2.5. Open Burn Unit (New Burn Area)**

Seventeen VOCs were detected in at least one of the soil vapor samples collected at the New Burn Area. The VOCs detected with greatest frequency included 1,1-DCE, 2,2,4-trimethylpentane, MEK, acetone, benzene, carbon disulfide, hexane, propylene, and toluene. The presence of propylene may be attributed to the use of polypropylene tubing for sample collection. Other VOCs detected with less frequency included, 2-proponal, cyclohexane, and methylene chloride. Table 24 summarizes the analytical results for soil vapor samples collected at the New Burn Area. A subset of three VOC analytes (1,1-DCE, MEK, and acetone) were selected to show area-wide distribution of VOCs in soil vapor on Figure 25. This subset of analytes was selected based on a cross reference of four main criteria that included: consistent detections in multiple areas, elevated concentrations (above 1,000 ppbv (0.26 µg/L)), common use at the facility, and constituents with established AWQSSs.

VOCs were not detected above 1,000 ppbv at any depth interval and concentrations of 1,1-DCE, MEK, and acetone were not detected above 150 ppbv at total depth (30 feet bgs); therefore, further vertical delineation sampling was not conducted during the supplemental investigation. Horizontal and vertical delineation of VOCs in soil gas in the New Burn Area is considered complete.

## **3.3. Groundwater Quality**

### **3.3.1. Site Wells**

Groundwater samples have been collected from 19 monitor wells and production well PW-1, on a quarterly basis since August 2004, with the exclusion of the Third and Fourth Quarters of 2010 due to site access negotiations between UPCO and the Arizona State Land Department. Zonal grab samples from groundwater have also been collected during

drilling of MW-12, MW-13, MW-14, MW-18, and SVMW-1. Analytical data are summarized in the following paragraphs.

The COPCs identified in groundwater included perchlorate, VOCs, RCRA metals, and nitrate. Groundwater sampling activities were intended to provide sufficient data to vertically and horizontally characterize groundwater that may contain COPCs above the applicable groundwater screening levels. Following consultation with ADEQ, a site characterization target for vertical and horizontal characterization of perchlorate in groundwater was identified as the EPA Method 314 laboratory reporting limit of 2 µg/L. The vertical and horizontal characterization targets for VOCs, metals and nitrate were the AWQSs for these constituents. The following discusses characterization of the COPCs.

#### *Perchlorate*

Table 25 summarizes the perchlorate analysis results for groundwater samples collected from site wells. Perchlorate has been detected at concentrations above the characterization target in six of the UPCO monitor wells (MW-1, MW-2, MW-5, MW-6, MW-13, and MW-19). These wells are located centrally to the UPCO facility. In the shallow monitor wells, perchlorate was detected with the highest concentration at MW-19 at 55,000 µg/L. Perchlorate was detected in lower concentrations at MW-5 and MW-6, ranging from 6.4 to 25 µg/L at MW-5 and 15 to 20 µg/L at MW-6.

Perchlorate concentrations in samples collected from the completed deeper well at MW-13 have ranged between 6 and 330 µg/L and have exhibited lower concentrations with additional development and purging. The deepest zonal sample collected from the open borehole, prior to well construction, had a perchlorate concentration of 3.6 µg/L. This suggests that the elevated perchlorate concentrations initially detected in MW-13 were temporarily related to well installation activities and not representative of the overall aquifer water quality at that location. Perchlorate was detected at 120,000 µg/L in shallow zonal sample collected during drilling for MW-13. Zonal sampling results are discussed in Section 3.3.3.

Intermittent detections above the characterization target have been observed at PW-1. Perchlorate was detected at concentrations ranging from <2 to 4.8 µg/L in PW-1. Perchlorate was detected at concentrations ranging from <2 to 5 µg/L at the POE. In April 2008, the location for POE sampling was changed to a sink in the Building A-1 lunch room. The POE was changed due to the installation of an arsenic treatment system at this sink. RI related sampling at the POE then ceased.

A historic trend graph of perchlorate detections for each monitor well is provided on Figure 36. A perchlorate concentration map for the second quarter 2011 groundwater sampling event is provided on Figure 37. Quarterly perchlorate concentration maps for 2005 through 2010 are provided in the 2005 through 2010 Annual Groundwater Reports (Malcolm Pirnie, 2006c, 2007b, 2008e, 2009a, 2010a, 2011a).

#### *VOC*

VOCs were generally not detected at concentrations above their respective vertical and horizontal characterization targets in groundwater samples collected. Nine VOCs were detected above the laboratory reporting limit including 1,1-DCA, 1,1-DCE, 1,4-dioxane, dibromochloromethane, bromodichloromethane, bromoform, chloroform, toluene, and trihalomethanes. 1,1-DCE had been periodically detected above the characterization target in PW-1 prior to initiating RI activities. During the remedial investigation, detections of 1,1-DCE were observed at PW-1 and the initial POE location, with concentrations ranging from 2.0 to 6.0 µg/L. Three detections of 1,1-DCA were observed at PW-1 and the initial POE with concentrations ranging from 0.51 to 0.62 µg/L. Detections of 1,4-dioxane were observed at MW-1, MW-2, PW-1, and both POE locations, with concentrations ranging from 1 to 3.7 µg/L. Dibromochloromethane has been detected four times at the initial POE and MW-5 at concentrations ranging from 0.99 to 2.3 µg/L. Bromodichloromethane was detected once at the initial POE location at a concentration of 1.1 µg/L. Detections of bromoform were observed at the initial POE location with concentrations ranging from 1.4 to 5.2 µg/L, and five detections of chloroform were observed at MW-8, PW-1 and the initial POE at concentrations ranging from 1.1 to 14 µg/L. Toluene was detected once at MW-13 and MW-15 in the first samples collected after well installation. Trihalomethanes were only detected in samples collected at the initial POE location, most likely a byproduct of chlorination. Only 1,4-dioxane had been detected in samples collected from the second POE location.

Tables 26 through 41 summarize the VOC analytical results for groundwater samples collected from site wells.

#### *Metals*

Arsenic was detected at concentrations above the vertical and horizontal characterization target of 10 µg/L at five wells, MW-1, MW-5, MW-7, MW-8, MW-10, MW-18 and MW-19. Lead, barium, cadmium, chromium, mercury, selenium, and silver have not been detected above their respective vertical and horizontal characterization targets. Tables 42 through 57 summarize the inorganic analyses of groundwater samples collected from the site wells.

### *Nitrate*

Nitrate has not been detected at concentrations above the vertical and horizontal characterization target of 10 mg/L. The highest nitrate concentration of 7.8 mg/L was detected in a groundwater sample collected from MW-19.

### **3.3.2. Private Wells**

Groundwater samples have been collected from residential private wells along Yearling Road, north of the facility, and analyzed for perchlorate since November 2004. Fifteen residents have participated in one or more of the groundwater monitoring events allowing UPCO to sample their well. Samples were originally analyzed for perchlorate by EPA Method 314. Perchlorate was not detected in the samples collected between November 2004 and May 2006 above the detection limit of 2 µg/L. Beginning in November 2006, samples collected from the private wells were analyzed for perchlorate by both EPA Method 314 and EPA Method 332. Since November 2006, perchlorate has been detected in two samples analyzed by EPA Method 314, 2.2 µg/L and 2.4 µg/L. Perchlorate has been detected at concentrations ranging from 0.00089 µg/L to 3.1 µg/L in samples analyzed by EPA Method 332. Table 58 summarizes the private well analytical data.

### **3.3.3. Zonal Sampling**

Zonal sampling was conducted prior to well construction within the boreholes of the deeper monitor wells MW-12, MW-13, MW-14 and MW-18 that were advanced to approximately 400 to 500 ft bgs. Shallower zonal sampling was also conducted from the bottom of the soil vapor monitor well SVMW-1 borehole, prior to installing the soil vapor monitor well. The zonal samples were analyzed for perchlorate by EPA Method 314. The groundwater sample collected at SVMW-1 was also analyzed for VOCs by EPA Method 8260.

At MW-12, the sample collected from the interval 280 to 305 feet bgs contained perchlorate at a concentration of 67 µg/L. This concentration is lower than the perchlorate concentrations that have been detected in samples collected from adjacent monitor well MW-1; which is screened from 190 to 240 feet bgs. The samples collected from MW-1 have shown perchlorate concentrations between 47 µg/L to 130 µg/L. The sample collected at the deeper interval, 370 to 380 feet bgs, did not contain perchlorate concentrations above the laboratory detection limit of 2 µg/L for EPA Method 314

The zonal sample collected from 247 to 269 feet bgs at MW-13, near the surface of the water table directly beneath the former Waterbore Area ponds, contained perchlorate at a concentration of 120,000 µg/L. The zonal sample collected at the bottom of the borehole (480 to 502 feet bgs) contained perchlorate at a concentration of 3.6 µg/L prior to

reaming the borehole and completing well construction. As noted in Section 3.3.1, the perchlorate concentrations in groundwater samples collected from the completed well were initially elevated (330 µg/L); however, the concentrations have been decreasing with additional development and purging. This observed decrease in concentration with additional purging, along with the initial zonal sample collected at the bottom of the open borehole support the observation that the elevated perchlorate concentrations were temporarily related to well installation activities and not representative of the deeper aquifer water quality at MW-13.

The zonal samples collected at MW-14 from 285 to 305 feet bgs, 360 to 380 feet bgs, and 413.5 to 500 feet bgs, did not contain perchlorate at concentrations above the laboratory detection limit of 2 µg/L for EPA Method 314.

The shallow zonal sample collected at MW-18 from 175 to 195 feet bgs contained a perchlorate concentration of 2.8 µg/L. The zonal samples collected at MW-18 from 275 feet to 295 feet bgs and 369.5 feet to 389.5 feet bgs did not contain perchlorate at concentrations above the laboratory reporting limit of 2.0 µg/L. The perchlorate detection in the shallow zonal sample collected at MW-18 may have been influenced by water added during vadose zone drilling for cuttings management and dust control. The source of the water added during drilling of MW-18 was the production well (PW-1) which has historically contained low concentrations of perchlorate. A sample collected from the water stored in the driller's support truck contained perchlorate at a concentration of 3.2 µg/L, similar to the shallow zonal sample. Water from PW-1 was not added during the installation of the temporary wells between 275 feet to 295 feet bgs and 369.5 feet to 389.5 feet bgs. Perchlorate has not been detected in the completed well MW-18 above the Method 314 laboratory reporting limit of 2.0 µg/L.

The zonal sample collected from the boring at SVMW-1, between 218 to 238 feet bgs, contained perchlorate at a concentration of 7.8 µg/L. Acetone and MEK were detected in the groundwater sample at concentrations of 45 µg/L and 4.6 µg/L, respectively. Acetone was also detected in the trip blank sample that was concurrently submitted to the laboratory with the zonal sample.

Table 59 summarizes the zonal sampling analytical data for perchlorate. The VOC analysis for the zonal sample collected at SVMW-1 is included in Table 38.

### 3.3.4. General Water Chemistry

Samples and water quality parameter measurements were collected from site and private wells to analyze cation and anion balances. Piper and Stiff diagrams were generated for

the site wells to give a characterization of the general water chemistry at the site (Appendix H). The Stiff plots show that the dominant cations include co-equal amounts of sodium and potassium, and calcium except in a few wells. Likewise, the dominant anion in a majority of the site wells is bicarbonate. General water chemistry from the private wells show similar composition.

## 4. Physical Characteristics of Study Area

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The following section provides a summary of the physical characteristics (geologic and hydrogeologic) observed during the installation of on-site monitor wells, collection of geophysical survey data, collection of soil samples, analysis of the surface drainage patterns, collection of depth to groundwater measurements, and aquifer testing. The physical descriptions are restricted to data results and observations collected during the remedial investigation activities. Interpretations are provided in the Conceptual Site Model.

### 4.1. Geologic Evaluation

#### 4.1.1. Surface Geology – Geologic Mapping

The surface geology of the site was most recently mapped by Holloway and Leighty in 1998. The geology can be grouped into two categories, Tertiary/Quaternary sedimentary strata (Sedimentary Unit), and Precambrian basement rock of various lithologies (see Figure 6). A detailed description of the surface geologic units is provided in Section 1.5.1 and is therefore not repeated; however, the following additional observations were made during the remedial investigation activities:

- The surface deposits (upper two feet) of the Sedimentary Unit are generally poorly consolidated and poorly sorted, with particle sizes ranging from clay to boulder. Locally, desert pavement is observed in undisturbed areas of the site and caliche is found in the upper few feet of the soil horizon as observed at bank cuts of entrenched washes in the area.
- As mapped by Holloway and Leighty, 1998, surface bedrock surrounds the leased property on the north, east, and south boundaries in somewhat of a crescent shape. The recent mapping of the bedrock is consistent with site observations, with the exception of the bedrock outcrop mapped along the southern property boundary (see YXgd on Figure 6). Visual inspection of this area, as well as a road cut along Happy Valley Road, indicates that at least the upper five feet are comprised of the Sedimentary Unit and not Precambrian bedrock.

#### 4.1.2. Subsurface Geology - Borehole Logs

Twenty borehole logs within the study area were collected or reviewed as part of the RI of the UPCO facility. The logs were collected from onsite monitoring wells MW-1

through MW-19, and soil vapor extraction well SVMW-1. The lithologic logs from various work phases referenced in Section 2.3 were collectively re-evaluated during preparation of this Final RI Report. The review was conducted to consider the current understanding of subsurface geology based on additional information and observation obtained throughout the RI process and ADEQ comments on previous submittals. Finalized borehole logs are provided in Appendix G. Similar to the surface geology, two major geologic units are observed in the borehole logs, a Sedimentary Unit and a Bedrock Unit.

#### **4.1.2.1. Sedimentary Unit**

The Sedimentary Unit is observed in each of the 20 boreholes, overlies the Bedrock Unit, and ranges in thickness from a few feet (i.e. MW-4) to greater than 300 feet (i.e. MW-6 and MW-10). The Sedimentary Unit is comprised predominantly of angular to sub-rounded gravel and sand, with lesser amounts of interbedded fine sand, silt, and clay. The gravel size component found throughout the study area is composed of metavolcanics (greenstone), basalt, granite, and granodiorite; with lesser amounts of tuff. The finer grained fraction consists of clay to coarse sand. The unit as a whole is moderately to well-cemented with calcium carbonate; however, unconsolidated non-cemented layers are observed within the core samples at MW-5, MW-6, MW-9, and MW-13; and near the surface. Comparison of borehole logs within the Sedimentary Unit shows that the local geology is fairly uniform (e.g., sand and gravel); however, distinct stratigraphic horizons, such as a clay layer, have not been correlated from one borehole to the next.

The observed characteristics of the Sedimentary Unit are consistent with the unconsolidated Quaternary deposits (Undifferentiated Quaternary on Figure 6) and cemented basin fill deposits (Tsy on Figure 6) as described by Holloway and Leighty, 1998.

#### **4.1.2.2. Bedrock Unit**

The Bedrock Unit is observed in 17 of the 20 boreholes, is covered by the Sedimentary Unit, and ranges in depth across the site. The well installed in one of the boreholes where bedrock was observed, MW-7, was not screened within the bedrock. Figure 43 provides a summary of the depth to bedrock as recorded in the borehole logs. The bedrock surface is irregular; however, depth to bedrock generally increases to the southwest. Geophysical data used to constrain the depth to bedrock is described further in Section 4.1.3. The unit consists of highly fractured and weathered metamorphic rock as well as fractured granitic rock (e.g. granite, grano-diorite, and diorite). Analysis of the fractures is discussed in Section 4.1.4.

The weathered metamorphic lithology is generally aphanitic or fine grained in crystalline texture; however, coarser grained intervals are observed to contain crystals of feldspar, calcite, and quartz. The drill cuttings from this lithology are gray-green and may weather to a rust brown to orange color. Thin veins of calcite are observed in the cuttings. This rock type is observed at borings MW-4 and MW-9. Based on the texture, mineralogic assemblage, and its proximity to the Union Hills, this bedrock is likely the subsurface equivalent of the Precambrian metavolcanic Greenstone mapped by Wilson et al., 1957, and Holloway and Leighty, 1998.

The granitic rock is phaneritic with visible feldspar, quartz, amphibole, and mica; and appears to be the dominant bedrock lithology observed in the subsurface beneath the Site. Intact core samples and drill cuttings are generally salt and pepper colored (i.e. white and black) with minor amounts of pink alkali-feldspar. The unit weathers to a rust brown or orange color, similar to the greenstone, and is found in borings MW-3, MW-5, MW-7, MW-8, MW-9, MW-10, MW-11, MW-12, MW-13, MW-14, MW-15, MW-16, MW-18 and MW-19 and SVMW-1. At MW-3, a significant interval of the bedrock unit (200 to 240 feet bgs) appears to be significantly weathered to silt and clay. It is difficult to distinguish between highly weathered granite and highly weather greenstone. In such instances, the bedrock is noted as undifferentiated in the borehole logs. The granitic component of the Bedrock Unit is likely the subsurface equivalent of the Precambrian granites and granodiorites mapped by Holloway and Leighty, 1998; however, a differentiation between the slightly foliated younger granitic rocks, and the older foliated granitic sequence could not be made based on the drill cuttings.

#### **4.1.2.3. Structure**

As described previously, the surface contact between the Sedimentary Unit and the Bedrock unit is a nonconformity. Surface expressions of faulting, such as fault scarps, are not observed within the leased property boundary and may be covered by recent regolith development. A northeasterly trending structural fabric (foliation) has been mapped at the surface within Precambrian Greenstone and granitic bedrock.

Visual observation of the drill cuttings, especially well preserved core cuttings, indicate that the Bedrock Unit and well cemented sections of the Sedimentary Unit are fractured. The fractures are often filled with calcite, but are also observed to be devoid of any filling. Displacement along some of these fractures, within both the sedimentary unit and bedrock unit, is evidenced by slicken-sided surfaces at cores collected at MW-6, MW-5, MW-9, and MW-13. Extensive zones of fractures with displacement surfaces may represent significant faults within the study area. Other evidence for faulting in the subsurface includes the following:

- Joints with slickenside surfaces observed at monitor wells MW-6, MW-9, and MW-13.
- Truncated gravel clast observed at MW-6.
- Gravel sized clasts with their long axis oriented vertically which is uncharacteristic of an alluvial depositional environment.
- An extensive weathered clay layer observed between 75 to 85 feet bgs at MW-3 separating the overlying Sedimentary Unit and the Bedrock Unit.
- General location of the facility between a bedrock high and alluvial valley low, which are commonly separated by normal faults in the Basin and Range geologic provenance.

#### **4.1.3. Borehole Geophysical Survey Results**

Table 2 provides a description of the geophysical analyses performed on each of the monitoring well boreholes as part of the RI activities. Summary logs of the geophysical survey results for the monitor wells, as well as the private well at 18 E. Yearling, are provided in Appendix I. The significant observations made from the geophysical survey results are summarized below.

- The data from the optical and acoustic televiewer logs were used to evaluate the orientation (strike and dip) and intensity of fractures within the bedrock. Section 4.1.4 provides the result of fracture analysis.
- The data from the optical and acoustic televiewer logs were used to refine and/or support the observations made from the drill cuttings in the borehole logs. These refinements included:
  - A more thorough description of the sedimentary unit such as the angularity of rock clasts, presence of open pore space, presence and thickness of finer grained units, and an undisturbed view of the sedimentary structures which were discussed previously;
  - A visual confirmation of the depth to bedrock in boreholes where bedrock was encountered; and
  - A more thorough description of the bedrock unit such as the type of bedrock (greenstone vs. granitic).
- Neutron logs were used to help identify groundwater elevation as observed by a decrease in API units. This information was used to determine the placement of

the well screen. These groundwater elevations were later confirmed by taking measurements with a water level probe inside the monitor well casing.

- Natural gamma and neutron logs were used in conjunction with other geophysical data (i.e. optical and acoustic logs) to help constrain the depth to bedrock. The natural gamma logs often show a decreasing trend near the contact as observed at MW-3, MW-5, MW-9, and MW-12 (see Appendix H).
- A lack of a recognizable correlation between borehole geophysical logs within the Sedimentary Unit, including neutron, gamma, SP, and acoustical/OBI logs, suggests that bedding is discontinuous over a distance of several hundred feet. An exception to this may be a large spike in induction resistivity observed at MW-7 (25-60 feet bgs) and MW-8 (55- 70 feet bgs) along the southern portions of the property. However, this observation is not substantiated by correlations of other geophysical logs, such as neutron or gamma. As requested by ADEQ, it should be noted that correlations of certain geophysical logs within the vadose zone, such as the normal resistivity logs, cannot be made as these logs were only conducted in sections of the borehole containing fluid.

#### **4.1.4. Geophysical Bedrock Fracture Analyses**

Bedrock fractures orientations (strike and dip) for monitoring wells MW-4, MW-5, MW-8, MW-9, MW-11, MW-12, MW-13, MW-14, MW-16, MW-18 and 18 E. Yearling were evaluated using the optical and acoustical geophysical logs (see Appendix I). Rose diagrams (directional fracture plots) of the data are plotted on Figure 45 and 46. A discussion of the results and observations are provided below.

- Fracture orientations for individual wells are provided in Table 60 and summarized below.
  - The data from MW-4 show a weak preferred orientation of the fractures in an east-northeast to west-southwest direction within the greenstone unit. The fractures dip both in northerly and southerly direction and have an average dip angle of 55 degrees.
  - The data from MW-5 show a weak orientation of the fractures in a north-northwest to south-southeast direction within the granitic unit. The fractures along this orientation dip both easterly and westerly, with a higher percentage dipping to the east. The average dip angle of the fractures at MW-5 is 51 degrees.
  - The limited data set (n=17) from MW-8 shows a weak bimodal orientation of the fractures in a northwest to southeast and northeast to southwest

direction within the granitic unit. The fractures dip predominantly to the southeast or southwest with an average dip angle of 41 degrees.

- The data from MW-9 show a weak orientation of the fractures in a west-northwest to east-southeast direction within both the granitic and greenstone units. The fractures dip in a northerly and southerly direction, with a higher percentage dipping to the south in the granitic and to the north in the greenstone. The fractures have an average dip of 50 degrees for both units.
- The data from MW-11 show a weak orientation of the fractures in a northwest to southeast direction, with a preferred dip to the southwest in the greenstone unit. Data reported within the granitic unit show a general fracture orientation from west to east with a preferred dip direction to the south. The fractures are within the greenstone unit and have an average dip of 57 degrees and the granitic unit have an average dip of 54 degrees.
- The data from MW-12 show a weak orientation to the west-northwest to east-southeast, dipping to the north and south. The fractures are within the granitic unit and have an average dip of 50 degrees.
- The data from MW-13 show a preferred orientation north-northwest to south-southeast direction within the granitic unit. The fractures dip to both the east and west and have an average dip of 47 degrees.
- The data from MW-14 show a weak orientation to the northeast to southwest within the granitic unit. The fractures dip predominantly to the southeast with an average dip of 52 degrees. The reported data set within the greenstone unit shows a weak bimodal orientation of the fractures in a west to east and northwest to southeast direction. The fractures within the greenstone dip predominantly to the south an average dip angle of 64 degrees.
- The data from MW-16 show a weak orientation from the northeast to the southwest within the granitic unit. The fractures dip predominantly to the southeast and have an average dip of 62 degrees.
- The data from MW-18 show a weak orientation from the west-northwest to east-southeast within the granitic unit. The fractures dip to both the north and south and have an average dip of 46 degrees.
- The data from 18 E. Yearling show a weak orientation of the fractures in a northeast to southwest direction within the granitic unit. The fractures dip

both in northerly and southerly direction with a preferred dip to the southeast. The fractures have an average dip of 68 degrees.

- As illustrated on Figure 45 and 46, the fractures do not appear to have a site wide preferential orientation. Locally, the fractures do exhibit weakly preferred orientations and show the following characteristics:
  - MW-4, MW-16, and 18 E. Yearling, located in the northern third of the study area, show a preferred fracture orientation in a northeast-southwest direction. MW-4 is located within the greenstone; while 18 E. Yearling and MW-16 are within the granitic rock. MW-14 also shows a northeast-southwest orientation within the granitic unit; however, the fractures within the greenstone unit of this well show no preferred orientation.
  - MW-13 and MW-5 show preferred orientations in a roughly north south direction. These wells are located near each other along a lineament separating the Bedrock Unit and the Sedimentary Unit as seen on Figure 45 and 46. These are the only two locations to show a north-south trend in their dominant fracture orientation. The fracture data from the borings are collected within granitic bedrock.
  - The monitoring wells in the southern portions of the study area (MW-9, MW-18, MW-11, and MW-12) show weakly preferred orientations in a west-northwest to east-southeast direction. MW-8 is not included due to the sparse data set at this location.
- The fracture orientation does not appear to be dependent on the type of bedrock (greenstone vs. granitic). For example, MW-9 has fractures in both units which are oriented in the same direction. The dip direction for both units shows a north and south affinity; however, the greenstone unit appears to dip more consistently to the north, and the granitic units tend to dip more consistently to the south.

#### 4.1.5. Rock Quality Designation (RQD)

RQD data was collected from borings MW-5, MW-9, and MW-13. Based on the classification system developed by Deere (1963) the quality of the rock can be grouped as follows:

<u>RQD Range</u>	<u>Rock Quality</u>
90 – 100%	Excellent
75 – 90 %	Good
50 – 75 %	Fair
25 – 50 %	Poor
0 – 25 %	Very Poor

The RQD results for each well are provided in Appendix J, and indicate the following:

- RQD data collected at MW-5 indicates the fracture intensity at this location is heterogeneous with depth from 185 to 267 feet below ground surface. Different competency zones range from less than a foot to ten feet in length. The entire length of the core is within the “poor” to “very poor” RQD range, with the exception of an interval near 200 feet below ground surface.
- RQD data collected at MW-9 indicates that fracture intensity of the bedrock at this location decreases with depth from 50 to 235 feet below ground surface. The zone from 48 to 100 feet bgs is less competent (i.e. more fractured) than the deeper bedrock section from 100 to 239 feet bgs. The majority of the rock core falls within the “poor” to “very poor” RQD range. However, competent zones within the “fair” and “good” range are observed near 120, 140, and 210 feet below ground surface.
- RQD data collected at MW-13 indicates that fracture intensity at this location is heterogeneous with depth from 197 to 492 feet below ground surface. Similar to the other boreholes, the majority of the rock core is within the “poor” to “very poor” RQD range; however, there are zones of “fair” and “good” RQD throughout the borehole.

In general, most of the RQD data from the three boreholes falls within the “poor” to “very poor” rock quality range. This is consistent with the interpretation of the bedrock as fractured to highly fractured.

## 4.2. Hydrogeologic Evaluation

### 4.2.1. Groundwater Elevation

Figures 31 through 34 present groundwater elevation maps for the second quarter of 2011. Quarterly groundwater elevation maps from second quarter 2007 to first quarter 2011 are presented in Appendix K. Historic depth to groundwater measurements and groundwater elevations for site and private wells are summarized in Table 61. Historic hydrographs and graphs of transducer data are presented in Figures 27 through 30.

Although, each site well does not have similar length of water level record, the highest recorded water elevations were observed in late 2004 to early 2005, and the lowest elevations were observed in 2011. Most of the monitoring wells showed a mainly declining water level trend since 2004.

The addition of pressure transducers in selected wells and access to private wells to the north of UPCO has enhanced the understanding of current groundwater gradients. A review of groundwater level data collected to date from transducers and manual measurements indicate that the groundwater elevation in the private wells are currently lower than at the nearest site wells, MW-3, MW-4, MW-14 and MW-15. These wells are completed in bedrock units and show an overall declining water level trend. More recently, some of the private well owners have also resorted to drilling deeper wells as water levels have continued to decline in the area. Hydrographs for the private wells show pumping level drawdowns ranging from 10 to 50 feet below static levels, especially during the on-cycles which may correlate with cumulative peak periods of use (Figure 29). However, this drawdown has not been observed in nearest site wells, showing at a minimum that the short term pumping related drawdown does not extend very far. Although, as noted above, wells MW-3, MW-4, MW-14 and MW-15 show steeper water level declines when compared to other onsite wells suggesting that the overall lowered water table to the north is propagating south toward the site.

#### **4.2.1.1. Geologic Structure**

Based on analysis of site geology and available hydrogeologic information, groundwater underlying the site occurs within two distinct zones, separated by one or possibly several associated subsurface geologic structures. Monitor wells completed in bedrock at the Site (MW-1, MW-2, MW-3, MW-4, MW-5, MW-8, MW-9, MW-11, MW-12, MW-13, MW-14, MW-15, MW-16, MW-18 and MW-19) exhibit groundwater elevations 30 to 40 feet lower than wells (MW-6, MW-7, MW-10, and MW-17) completed in the consolidated Sedimentary Unit west of the Site. The difference in groundwater elevation and depth to bedrock between the two zones is potentially an additional line of evidence for faulting along the western side of the Site. MW-6 is thought to be located near or within the influence of this subsurface geologic structure and has shown response in groundwater elevation due to significant precipitation events. A series of hydrogeologic cross sections are shown on Figure 39 through Figure 43. A base map showing the cross section lines is provided on Figure 38.

Numerous detailed studies in unconsolidated and consolidated sediments, as well as in fractured rock, show that faults may have significant impact on groundwater regime. For example, Mozley et al. (1996) discuss reduction in hydraulic conductivity associated with high-angle normal faults that cut poorly consolidated sediments. Such fault zones are commonly cemented by calcite, and their cemented thickness ranges from a few centimeters to several meters, as a function of the sediment grain size on either side of the fault. Cement is typically thickest where the host sediment is coarse grained and thinnest where it is fine grained.

#### 4.2.2. Borehole Hydrophysical Survey Results

Analysis of the ambient flow tests in the borehole for MW-14 suggest interval specific volumetric flow rates ranging from less than 0.001 to 0.008 gpm, with the highest ambient flow rates were observed at intervals 287-302, 310-325, and 390-405 feet bgs. A summary of the results is provided in Table 62. Due to borehole diameter irregularities, the HPL testing tool could not be advanced below 412 feet bgs. However, results and data analysis of pumping tests conducted during the HPL testing suggest that minimal groundwater flow occurs below this depth.

K and T values were estimated from the HPL slug and pumping tests. The slug test results were analyzed by the Hvorslev (1951) method while the ambient/pumping test data were analyzed using Theim (1906) method. Results from the slug tests estimated Ks ranging from 6-11.8 ft/day, and T ranged from 900-1900 ft<sup>2</sup>/day for the borehole interval from 287-420 feet bgs. Results from the pumping tests estimated Ks ranging from 0.64 - 0.79 ft/day, and Ts ranged from 90-119 ft<sup>2</sup>/day for the same interval. The results also estimate interval specific flow rates that ranged from 0.01 to 1.39 gpm.

The K values from the slug and pumping tests are within the range of published literature values for fractured rock although results from the pumping tests are two to three orders of magnitude different from the slug tests. Conversely, results of the aquifer test described in Section 4.2.3 estimated Ks to be much lower, ranging from  $6.6 \times 10^{-3}$  to  $7.7 \times 10^{-3}$  ft/day. The range of estimated Ks from the aquifer test is also within the literature values, but for unfractured rock. The results of both hydrophysical and aquifer testing methods conducted at MW-14 correlates with borehole geophysical data (fracture analysis) presented in Appendix I. The borehole geophysical data suggest that the interval from 260-420 feet bgs (hydrophysical testing interval), has a higher fracture frequency/density than the interval from 420-495 feet bgs (aquifer testing interval).

#### 4.2.3. Aquifer Test Results

Before the aquifer test data analysis, site hydrogeological conditions and well response (*i.e.*, drawdown versus time) were evaluated to determine an appropriate analytical methodology. Well response curves for the observation wells were prepared from data collected during the pumping tests. The well response curves are presented in Appendix L.

As discussed in Kruseman and de Ridder (2000), the shape of the well response curves is diagnostic of aquifer type (*i.e.*, confined, leaky confined, or unconfined), well geometry (*i.e.*, borehole storage or partial penetration), and aquifer geometry (*i.e.*, barrier or

recharge boundaries). Data collected during drilling for the observation wells located near the test wells indicate that the aquifer is semi-consolidated to consolidated fractured aquifer.

The shapes of the response curves of the nearest observation well MW-15, as well as the other site and private wells monitored during the tests indicate the observation wells were not influenced by the pumping of well MW-14. Consequently, a determination of the type of aquifer (unconfined, confined, or leaky confined) near the test well cannot be made using diagnostic type curves.

Therefore, based on the above observations, analytical methods appropriate for analysis of single well tests were used to analyze the data. More emphasis was placed on analyzing the late-time data due to the apparent effects of borehole storage. Data from the single-well pumping test were analyzed by the Theis (Theis, 1935) recovery method (for recovery analysis), and the Cooper and Jacob (1946) method (for drawdown analysis), which are semilog, straight-line analysis methods.

The pumping test data analysis results for the pumping test are summarized in Appendix L. The Theis recovery and the Jacob time-drawdown method linear regression plots for the pumping well are also included in Appendix L.

#### **4.2.3.1. Pumping Test Analysis Results**

Of the three primary parameters used to assess an aquifer's ability to transmit groundwater, T, K, and storativity (S), only two parameters (T and K) can be somewhat reliably determined based on the aquifer responses observed during this test. As shown in Appendix L, T was estimated to range from 0.30 to 0.39 ft<sup>2</sup>/day; and K was estimated to range from  $6.6 \times 10^{-3}$  to  $7.7 \times 10^{-3}$  ft/day, assuming an aquifer thickness of 50 feet (screened interval of pumping well).

There is general agreement in the aquifer parameter estimates from the pumping test conducted on well MW-14 and literature values for aquifers in unfractured to fractured igneous and metamorphic rocks (Driscoll, 1986). Additionally, the range of the hydraulic conductivity compares to the zone specific discharge and hydraulic conductivity values observed during the hydrophysical testing of well MW-14. In general, the pumping test results indicate that the aquifer has a low hydraulic conductivity (*i.e.*, K ranged from  $6.6 \times 10^{-3}$  to  $7.7 \times 10^{-3}$  ft/day) and low transmissivity (*i.e.*, T ranged from  $3.3 \times 10^{-1}$  to  $3.9 \times 10^{-1}$  ft<sup>2</sup>/day).

#### 4.2.4. Groundwater Flow

The static groundwater levels at some of the monitor wells are declining more rapidly than other wells which may exhibit more stable groundwater levels (refer to Appendix D for monitor well hydrographs). As a result, interpreted groundwater flow conditions may be varying over time. Previously presented groundwater flow interpretations in documents such as annual groundwater reports and the Interim RI Summary Report have been superseded as more information became available. As an example, the addition of pressure transducers in selected wells, access to private wells to the north of UPCO, and installation of additional monitor wells have enhanced the understanding of current conditions and trends. Hence, the iterative approach taken to develop the CSM presented in this report.

Historically, groundwater generally was expected to flow to the south - south west out of the CSM study area away from the mountain front. For that reason, MW-1, MW-2, and MW-5 were placed at locations on the site that were thought to be “downgradient” from the suspected primary perchlorate source area at the Waterbore Area. In addition, MW- 7 through MW-10 were placed with that understanding to monitor for potential off site migration. It is believed that up until the mid to late 1980s or early 1990s, groundwater flow was generally to the south-southwest. This opinion is based on the following observations:

- Groundwater levels identified during drilling of some private wells to the north of the site in the mid 1980s through mid 1990s appear to have been between approximately 50 and 100 feet higher than current conditions. This is based on a cursory review of drilling logs filed with ADWR and discussions with well owners and drillers in the area.
- The majority of perchlorate mass in groundwater appears to be at the Waterbore Area (MW-19) and extends to wells MW-1 and MW-2 which are south and west of the main operational complexes at the site.

Currently, groundwater in the central and southeast portion of the site still appears to follow a generally south and southwest flow pattern (Figure 31). The horizontal groundwater gradient in the vicinity of this group of wells (MW-1, MW-2, MW-5, MW-8, MW-9, MW-11, and MW-19) is relatively flat and flow directions may vary on a smaller scale when comparing groundwater elevations between individual wells. More recently, groundwater flow direction in the northern portion of the CSM study area has been observed to be more north-northwest between monitor wells, MW-3, MW-4, MW-14, and MW-15, and the private wells along Yearling. This is based on data obtained from the private wells and observed steeper rates of water level decline in wells MW-3,

MW-4, MW-14, and MW-15. This condition is likely the result of an induced gradient due to the combined effective pumping of the multiple private wells in the lower yielding bedrock unit to the north. Horizontal groundwater gradients are steeper between the central and northern portions of the site and appear to be increasing over time due to the higher rates of water level decline, observed in well MW-3, MW-4, MW-14 and MW-15. The general groundwater flow direction between monitor wells MW-6, MW-7 and MW-10 constructed in the Sedimentary Unit appears to be south to south easterly and between monitor wells MW-6 and MW-17 appears to be northerly based on current groundwater elevations (Figure 32).

Vertical groundwater gradients have been observed at shallow/deep bedrock monitor well sets, including MW-1/MW-12, MW-15/MW-14, MW-19/MW-13 and MW-3/MW-16. A downward vertical gradient has been observed between shallow and deep bedrock wells, MW-1 and MW-12, located in the south central portion of the site. Groundwater elevations observed in MW-1 have been 0.77 feet to 1.18 feet higher than in MW-12. An upward vertical gradient has been observed between shallow and deep bedrock wells, MW-15 and MW-14, located in the north central portion of the site. Groundwater elevations in MW-15 have been 0.02 feet to 0.94 feet lower than in MW-14. A downward vertical gradient has been observed between shallow and deep bedrock wells, MW-3 and MW-16, located in the northwest portion of the site. The groundwater elevation in MW-3 is approximately 11.5 feet higher than at well MW-16, based on May 2011 data. An upward vertical gradient has been observed between shallow and deep bedrock wells, MW-19 and MW-13, located in the east central side of the site. The groundwater elevation in MW-19 is approximately 0.59 feet lower than at well MW-13, based on May 2011 data.

As stated in Section 4.3, pressure transducers were installed in selected site and private wells to better understand site hydrogeological conditions. A review of groundwater level data collected from the transducers indicate that the groundwater elevation in the private wells are generally lower today than at the nearest site wells, MW-14 and MW-15. Wells MW-14 and MW-15 are completed in bedrock and both show an overall declining water level trend. Based on anecdotal evidence, a similar general declining water level trend has been observed in the private wells over a period of the last 15 to 20 years. It is important to note that the number of residents living in this area increased significantly in the last ten years and this declining water level trend is likely the result of cumulative pumping from the low yield bedrock unit in which most of the wells were installed. At the time of construction of these private wells, the water level elevations were reported to be much higher in most cases. More recently, some of the private well owners have also resorted to drilling deeper wells as water levels have continued to decline. Hydrographs

for the private wells show steep pumping level drawdowns ranging from 10 to 50 plus feet below static levels, especially during the on-cycles which may correlate with cumulative peak periods of use. However, this steep drawdown has not been observed in nearest site wells, showing at a minimum that the short term pumping related drawdown does not extend very far. Although, as noted above, wells MW-14 and MW-15 show steeper water level declines when compared to other onsite wells suggesting that the overall lowered water table to the north is propagating south onto the site.

Most of the groundwater pumpage in the vicinity of the site has been from private residential wells and UPCO's former site production well, PW-1. Approximately 95 private residential wells are located to the north, west and southwest of the site. A list of these wells is provided in Table 63. There are no formal requirements for reporting pumpage from residential wells, however, flow monitoring of three private residential wells located north of the site (18 E, 218 E and 530 E Yearling Rd) between June, 2007 and January 2010 indicated that average pumping rates ranged from 277 gallons/day to 516 gallons/day. UPCO's production well, PW-1, was in operation since the facility was constructed in 1972 until decommissioned in 2010. The average pumping rate at PW-1, between June 2007 and December 2009 was 4,129 gallons per day.

Groundwater velocities are generally expected to be low in the central portion of the site where horizontal groundwater gradients are relatively low. However, groundwater velocities are expected to be higher and possibly increasing in the northern portion of the site where horizontal gradients are steeper and have been increasing over time.

### **4.3. Surface Drainage Analysis**

Analysis of the surface drainage network was conducted as described in Section 2.3.5, the results of which are provided on Figure 35. The data indicate that the primary drainage orientation is in a northeast to southwest direction away from the Union Hills.

#### **4.3.1. Recharge**

The dominant recharge mechanism for the aquifer system beneath the site is considered to be mountain-front recharge. This is supported by the analysis of site surface drainage, which shows a pattern of focused flow along the washes. Traditionally, mountain front recharge considers only focused stream channel recharge at the mountain front, and assumes that the bedrock underlying the mountain block is essentially impermeable, suggesting negligible groundwater movement through the mountain block. Faults may play an important role in regulating flow paths in mountain blocks and are believed to act as both hydraulic conduits and barriers (Wilson and Guan, 2004). Faults that develop in brittle crystalline and lithified sedimentary rocks have a damaged zone and a core zone,

where the saturated permeability of the damaged zone is several orders of magnitude higher than the core zone.

As shown on Figure 30, MW-6 reacted most significantly to a period of heavy precipitation at the end of 2004 and beginning of 2005. The other monitoring wells at the site, regardless of where they are screened (in the sedimentary unit, bedrock or both), did not react as sharply to the increased precipitation. Prior to this recharge period, MW-6 had similar water elevation as MW-7 and MW-10. While wells MW-7 and MW-10 did appear to respond slightly to this longer duration precipitation event the difference is attributed to lower saturated permeabilities and their distances from the wash and inferred related structure. The water level at MW-6 stayed elevated for a period of time since 2005 and has since been slowly declining. None of the monitoring wells, including MW-6, MW-7, and MW-10 appear to have reacted in a similar manner to several subsequent rainfall events, some of which had higher intensity but shorter duration than the 2004-2005 rainfall.

## 5. Conceptual Site Model

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### 5.1. Contaminants of Potential Concern

Analyses of samples collected from various media at each operational area within the UPCO facility have indicated that COPCs are present at concentrations above the characterization targets. The following sections summarize the COPCs identified in environmental media at the site.

#### 5.1.1. Soil

Soil samples collected during the RI activities indicated that perchlorate and select metals (arsenic and lead) were detected at concentrations above the characterization targets. The elevated arsenic and lead concentrations detected in soil were limited to surface and near surface samples collected at the Old Burn Area, the New Burn Area, and one location along the wash behind the B-Complex. The highest arsenic concentration detected in soil was 15 mg/kg at the New Burn Area and the highest lead concentration detected in soil was 4,800 mg/kg at the Old Burn Area.

During the initial and supplemental soil investigations, perchlorate was detected above the characterization targets within each operational area investigated. The highest concentrations were detected in the Waterbore Area, C-Complex and the New Burn Area. The highest concentration detected in soil at the C-Complex was 330 mg/kg, in a surface soil sample (at boring CC-SB08). The highest perchlorate concentration detected in a subsurface soil sample at the C-Complex is 83 mg/kg at 20 feet bgs.

The highest perchlorate concentration detected in soil at the New Burn Area was 150 mg/kg. This was detected in surface soil at the former burn pad, which was subsequently removed. After the limited soil removal activities, performed as part of the RCRA closure of the OBU, the highest perchlorate concentration remaining in soil at the New Burn Area is 61 mg/kg, at 5 feet bgs.

The highest perchlorate concentration detected in soil at the Waterbore Area was 369 mg/kg, at 20 feet bgs during RFI activities (Appendix E3). At two borings drilled beneath the former evaporation ponds during RI activities, perchlorate was detected at elevated concentrations in each soil sample collected at WB-SB06, to a depth of 175 feet bgs, and in 7 of 13 samples collected at WB-SB07, to a depth of 70 feet bgs.

### 5.1.2. Soil Vapor

Soil gas sampling identified several VOCs that are present at low concentrations in the soil vapor beneath operational areas where solvent usage and/or management has occurred, namely B-Complex, C-Complex, F-Complex, and the Old Burn Area. Based on frequency of detection, magnitude of concentration, historic usage, and detection in groundwater samples, 1,1-DCE, acetone and MEK were identified as the COPCs in soil vapor that warranted evaluation.

### 5.1.3. Groundwater

Routine groundwater monitoring at the UPCO facility indicated two COPCs in groundwater that have historically been detected at concentrations above the characterization targets: perchlorate and 1,1-DCE.

During the most recent groundwater sampling event in April 2011, perchlorate was detected in groundwater collected at five monitor wells (MW-1, MW-2, MW-5, MW-6, and MW-19) at concentrations above the site-specific HBGL of 14 µg/L.

Only samples collected from production well PW-1 have contained concentrations of 1,1-DCE near or above the AWQS of 7 µg/L. The highest 1,1-DCE concentration detected at PW-1 was 7.5 µg/L in September 2004. 1,1 DCE has not been detected in PW-1 above the AWQS since 2004 and was detected at a concentration of 5 µg/L in the most recent sample collected during Second Quarter 2011.

## 5.2. Source Identification

### 5.2.1. Perchlorate

The remedial investigation activities conducted at the facility indicate that perchlorate has been released to the environment from past operations. The refurbishing of rocket motor tubes at the Waterbore Area is considered the source that has contributed the majority of the perchlorate mass observed in the soil and groundwater. This conclusion is based on the elevated concentrations of perchlorate detected in soil at the Waterbore Area, a historical hydraulic driver (infiltration of hundreds to thousands of gallons of wastewater, potentially containing perchlorate from historical waterbore operations) and the apparent direction of historical groundwater flow (southwest).

Perchlorate concentrations detected in monitor wells MW-1 and MW-2, downgradient of C-Complex and the New Burn Area, suggest former propellant production activities in C-Complex and former open burning of waste energetic materials in the New Burn Area

have also contributed some perchlorate mass to the groundwater beneath the site. These areas are considered smaller sources of perchlorate mass contribution to groundwater in comparison to the Waterbore Area operations. This is based on lower perchlorate concentrations detected in soil in these areas and lower hydraulic drivers (infiltration driven only by minor spills of mop water and/or precipitation).

While perchlorate was detected in four C-Complex borings at the bedrock interface, three of these samples were collected at 30 feet bgs and one sample was collected at 60 feet bgs. The highest perchlorate concentration detected in soil above the bedrock in C-Complex was 0.25 mg/kg. The deepest detection of perchlorate in soil at the C-Complex, from borings where bedrock was not encountered, was 40 feet bgs. Perchlorate was detected in five New Burn Area borings at the bedrock interface, at depths ranging from 7 feet bgs to 56 feet bgs. The highest perchlorate concentration detected in soil above the bedrock in the New Burn Area was 4 mg/kg. The deepest detection of perchlorate in soil at the New Burn Area, from borings where bedrock was not encountered, was 40 feet bgs.

An additional minor source of perchlorate detected in groundwater may possibly be attributed to recharge of impacted surface water from historic F-Complex, D-Complex, and/or Old Burn Area operations in the wash along the west side of the site. This potential source may explain the lower level perchlorate concentrations (15 to 20 µg/L) observed in groundwater at MW-6. The source areas for the primary COPC, perchlorate, are shown on Figure 48.

### **5.2.2. Metals**

Lead detections in soil have been limited to the areas where historic open burning of lead-containing waste propellants occurred (Old Burn Area and New Burn Area). Impacts to soil are limited to surface and near surface soils in the vicinity where the former open burning activities were conducted. The lead detections were not observed to be widespread.

Arsenic was also detected in soil in the vicinity of the former waste treatment units in the Old Burn Area and the New Burn Area. Arsenic is naturally occurring in soils within the vicinity of the UPCO facility.

### **5.2.3. VOCs**

The VOCs detected in soil gas samples collected at B-Complex, C-Complex, D-Complex and F-Complex appear to be the result of historic solvent and adhesive usage in these areas. Historic management of waste solvents at SWMU 5 in the B-Complex, appears to

have resulted in release of solvents to the soil which caused migration of VOCs into soil vapor.

Widespread VOC impacts to groundwater have not been observed in site monitoring wells including the grab sample collected during installation of SVMU-1 within the B-Complex. Limited VOCs have been detected in groundwater (see Section 3.3) with 1,1-DCE historically detected above the characterization target in 2004 at PW-1. The 1,1-DCE concentration in PW-1 is currently below the characterization target. The 1,1-DCE detected in PW-1 appears to be from historical solvent management activities in the B-Complex, most likely due to releases at SWMU 5.

### **5.3. Remedial Goals**

The results of the RI activities have lead to the identification of COPCs in soil, soil gas, and groundwater, as discussed in the previous section. In order to determine if COPC concentrations in these media pose potential threats to human health or the environment, requiring further evaluation and potential remediation, remedial goals need to be established.

A remedial goal is a concentration of a COPC in a media (e.g., soil, groundwater) that is identified as a regulatory or site-specific calculated threshold for remedial evaluation. COPC concentrations identified above the remedial goals will be evaluated as part of the Corrective Measure Study (CMS) process.

The following sections discuss the remedial goals established for COPCs in soil, soil gas, and groundwater at the Site.

#### **5.3.1. Metals in Soil**

Arsenic and lead were the only two metals detected in soil that were identified as COPCs. Arizona Residential SRLs have been established for arsenic and lead concentrations in soil that are protective of direct contact with potential human receptors in a residential scenario. The residential SRL for arsenic is 10 mg/kg and the residential SRL for lead is 400 mg/kg. ADEQ has also developed minimum GPLs for arsenic and lead to be protective of migration to groundwater, and potential exposure to human receptors via drinking water ingestion. The minimum GPL for arsenic and lead is 290 mg/kg, which is less stringent for arsenic but more stringent than the SRL for lead. Therefore, the SRL of 10 mg/kg for arsenic and the minimum GPL of 290 mg/kg for lead have been identified as remedial goals in soil at the Site.

### 5.3.2. Perchlorate in Soil

Arizona has established a Residential SRL for the perchlorate concentration in soil that is protective of direct contact with potential human receptors in a residential scenario. The residential SRL for perchlorate is 55 mg/kg. Due to perchlorate's solubility and potential mobility for migration to groundwater, a site-specific GPL was developed for perchlorate to determine remedial goals for perchlorate in soil. The following sections discuss the development of a minimum GPL for perchlorate in soil.

#### 5.3.2.1. Perchlorate GPL Development

A site-specific GPL for perchlorate was developed for the Site since the current ADEQ Inorganic GPL Model was not directly applicable. The site-specific GPL development for perchlorate at the Site followed a modified BTLM method (see Section 4.2) which included development of soil-water partition coefficients, determination of dilution factors, and graphical determination of the GPL.

##### *Modified BTLM Approach*

The modified BTLM approach (Equation 5-1) was used for the development of a GPL for perchlorate at the UPCO facility. The BTLM method is an equilibrium partitioning model.

#### Equation 5-1. Modified BTLM

$$C_s = C_w \times \left( K_d + \left( \frac{\theta_w}{\rho_b} \right) \right) \times DF_1 \times DF_2$$

where:

$C_s$  = contaminant concentration in soil (mg/kg)

$C_w$  = groundwater concentration (mg/l)

$K_d$  = soil-water partition coefficient (l/kg)

$\theta_w$  = water filled porosity (volume water/volume soil) (%)

$\rho_b$  = soil bulk density (kg/l)

$DF_1$  = dilution factor in source zone (unitless)

$DF_2$  = dilution factor due to dispersion and vertical mixing (unitless)

The modified BTLM approach utilized site-specific soil leaching data to estimate the soil-water partitioning coefficient. Since the partition coefficient does not always follow a constant or linear relationship with regards to soil type or varying contaminant concentrations in soil, the use of a constant partition coefficient for perchlorate was not appropriate for the site. Site-specific data was used to develop a  $K_d$  model as a function of contaminant concentration and representative of the vadose zone soil type at the site.

The following sections discuss how the modified BLTM approach was used to develop a site-specific GPL for perchlorate.

*Soil-Water Partition Coefficient (Kd) Determination*

As discussed in Section 2.4, 15 soil samples collected from various investigation areas and at various depths below grade were submitted for total perchlorate analysis. Ten of the samples that represented the greatest range of perchlorate concentrations were selected for SPLP analysis. The total perchlorate concentrations for these samples were 0.82 mg/kg, 3 mg/kg, 5 mg/kg, 14 mg/kg, 29 mg/kg, 40 mg/kg, 63 mg/kg, 84 mg/kg, and 91 mg/kg, respectively. For the estimation of the soil-water partition coefficient, Kd, the mass of contaminant that remained sorbed to the soil, derived from total perchlorate and SPLP data, was compared to the mass of contaminant that leached into solution. The Kd values were then plotted and a regression analysis was performed (linear and non-linear) to determine a best-fit quantitative predictor equation with Kd as a function of contaminant concentration in soil (i.e.,  $K_d = f(C_s)$ ). Appendix M provides a summary of the Kd regression analysis.

*Dilution Factor Determination*

The modified BTLM approach utilizes two dilution factors. The first dilution factor,  $DF_1$ , accounts for dilution in the source zone and is a function of monitoring well screen length, effective porosity, groundwater velocity, infiltration rate through the contaminated vadose zone, and length of contaminant release parallel to the direction of groundwater flow. This dilution factor is the same as the dilution factor used in ADEQ’s Inorganic GPL Model (see Equation 5-2).

**Equation 5-2. Source Zone Dilution Factor**

$$DF_1 = \left( \frac{z \times n \times v}{I \times L} \right)$$

where:

$DF_1$  = dilution factor in source zone (unitless)

$z$  = perforated length of monitoring well (m)

$n$  = effective porosity (unit less)

$v$  = fluid velocity in groundwater (cm/day)

$I$  = infiltration rate through contaminated soil zone (cm/day)

$L$  = length of contaminant release parallel to direction of groundwater flow (m)

The Inorganic GPL Model does not account for additional dilution that would occur if a compliance point was located some distance from the edge of the source. Therefore a

second dilution factor,  $DF_2$ , due to dispersion and vertical mixing between the source zone and the compliance point, was added to the modified BTLM approach. The compliance point dilution factor was estimated following the methodology presented in the *Graphical Approach For Determining Site-Specific Dilution-Attenuation Factors (DAF)* published by the American Petroleum Institute (API 1998).

The dilution factors were estimated based on a series of plume dimension assumptions, vadose zone characteristics, and aquifer characteristics. Some of these parameters were derived from site-specific data while default values were utilized for other parameters. Appendix M provides a summary of the parameter values used for the site-specific dilution factor calculations. Where default values were used in lieu of site-specific data, a rationale is provided.

*GPL Determination*

Re-arranging the modified BTLM equation, Equation 5-1, and replacing  $K_d$  with the predictor equation  $f(C_s)$  obtained from regression analysis, estimated perchlorate concentrations in groundwater were plotted as a function of perchlorate soil concentration (see Equation 5-3).

**Equation 5-3. Estimated Groundwater Concentration  
as a Function of Contaminant Concentration in Soil**

$$C_w = \frac{C_s}{\left( f(C_s) + \left( \frac{\theta_w}{\rho_b} \right) \right) \times DF_1 \times DF_2}$$

where:

$C_w$  = estimated groundwater concentration (mg/l)

$C_s$  = contaminant concentration in soil (mg/kg)

$f(C_s)$  = soil-water partition coefficient as a function of contaminant concentration in soil; predictor equation from regression analysis of site-specific  $K_d$  values (l/kg)

$\theta_w$  = water filled porosity (volume water/volume soil) (%)

$\rho_b$  = soil bulk density (kg/l)

$DF_1$  = dilution factor in source zone (unitless)

$DF_2$  = dilution factor at compliance point due to dispersion and vertical mixing (unitless)

The GPL was calculated by setting the target groundwater concentration at 14  $\mu\text{g/L}$  and selecting the associated contaminant concentration in soil from the graph. Appendix K provides the graphical approach used to determine the site-specific GPL.

#### **5.3.2.2. Perchlorate Remedial Goal in Soil**

The site-specific GPL calculated for the UPCO facility using the BTLM approach for perchlorate in soil is 16 mg/kg. ADEQ has questioned the use of the two dilution factors for the site-specific GPL development. However, when ADEQ calculated a site-specific GPL using the default parameters for the source zone dilution factor (from ADEQ's Inorganic GPL Model), the result was similar to the GPL calculated by this study. ADEQ approved the use of a site-specific GPL of 16 mg/kg in a letter dated October 22, 2009. This concentration is more stringent than the Arizona residential SRL of 55 mg/kg. Therefore, the remedial goal for perchlorate in soil at the Site is the GPL of 16 mg/kg.

#### **5.3.3. Perchlorate in Groundwater**

At the time the Consent Order was executed, the ADHS HBGL of 14 µg/L for perchlorate in groundwater was specified as the perchlorate concentration in groundwater that would be protective of ingestion in a residential exposure scenario. Therefore, 14 µg/L has subsequently been established as the remedial goal for perchlorate in groundwater at the Site.

#### **5.3.4. VOCs in Groundwater**

The remedial goal established for 1,1-DCE in groundwater at the Site is the AWQS of 7 µg/L.

#### **5.3.5. VOCs in Soil Gas**

There are two potential migration pathways for the VOCs in soil gas that may pose an exposure risk to human receptors. One pathway involves vertical migration downward, dissolution in groundwater, and ingestion; while the other involves vertical migration upward, vapor intrusion into buildings (current or future) and inhalation. Based on the vertical profile of VOC concentrations in soil gas at the suspected source area in B-Complex (collected at SVMW-1), the majority of the VOC mass is approximately 100 feet bgs and has not impacted the groundwater which is located approximately 210 feet bgs. The collection of a grab sample from the groundwater during drilling/installation of SVMW-1 beneath where SWMU 5 had been located, confirmed that VOC migration to groundwater is not a pathway of concern at this time since the COPC with the highest concentrations in soil gas (1,1,DCE) was not detected in the grab groundwater sample.

Potential indoor air exposure risks due to VOCs in soil gas at the Site can be evaluated using the Johnson & Ettinger (J&E) Vapor Intrusion Model. The EPA has established an On-Line Screening Level Implementation of the Johnson and Ettinger Vapor Intrusion Model (EPA, 2009) that executes a Reverse Calculation of Target Media Concentrations to determine soil gas concentrations that are protective of indoor air quality. Using this

on-line tool, target concentrations for VOCs of concern in soil gas at the Site were calculated. As discussed in Section 3.2, the three VOCs of concern in soil gas, 1,1-DCE, acetone and MEK, were identified based on a combination of the following criteria: consistent detections in soil gas collected in multiple areas, elevated concentrations (above 1,000 ppbv), common use at the facility, and constituents with established AWQSS. Using the EPA's on-line screening tool, soil gas concentrations protective of indoor air were calculated to be 26,900 ppbv for 1,1-DCE, 65,440 ppbv for acetone, and 194,200 ppbv for MEK, assuming a depth to contamination of 10 feet bgs (see Appendix O) and using default parameters for building design. These concentrations have been established as the remedial goals for 1,1-DCE, acetone, and MEK in soil gas.

## 5.4. Source Delineation

### 5.4.1. Soil

#### 5.4.1.1. Perchlorate

Perchlorate has been detected at concentrations above the remedial goal of 16 mg/kg in the Waterbore Area, C-Complex, and New Burn Area. The elevated perchlorate concentrations in soil at the Waterbore Area are limited to the soil beneath the former evaporation ponds where wastewater from the water wand operation was discharged. Perchlorate was detected above the remedial goal of 16 mg/kg in 18 subsurface soil samples collected from three borings in the vicinity of the former evaporation ponds (see Figures 14 and 49). In the boring drilled directly beneath the former ponds, perchlorate detections above 16 mg/kg extend vertically to 175 feet bgs, at bedrock.

Perchlorate detections above the remedial goal of 16 mg/kg in the C-Complex are limited to five samples collected from five different locations: two surface soil locations and three subsurface soil locations at depths ranging from 10 to 20 feet bgs. These elevated perchlorate concentrations include one subsurface sample, 20 feet bgs, to the north of Building C-1, one surface sample to the south of Building C-1, one subsurface soil location, 20 feet bgs, located between Buildings C-1 and C-2, one subsurface soil sample, 10 feet bgs, east of Building C-2, and one surface soil location outside of Building C-4 (see Figures 10 and 50).

The impacted surface soil at the New Burn Area, beneath the former burn pad, was removed during RCRA closure activities. The remaining elevated perchlorate concentrations observed in the New Burn Area were limited to 11 subsurface soil samples collected from eight locations beneath and adjacent to the former OBU burn pad, at depths ranging from 5 to 20 feet bgs (see Figures 17 and 51).

#### 5.4.1.2. Metals

Elevated lead concentrations above the remedial goal of 290 mg/kg were detected in the Old Burn Area and the New Burn Area. The elevated lead concentration detected in the New Burn Area was limited to one surface soil sample located in the vicinity of the former OBU burn pad. The impacted soil in the New Burn Area was removed during RCRA closure activities; therefore, lead is not a contaminant of concern at the New Burn Area. The only area with elevated lead concentrations in soil is the Old Burn Area at nine surface to near surface (one foot bgs) locations in the vicinity of the former treatment unit (see Figures 12 and 52).

Arsenic was detected above the remedial goal of 10 mg/kg in soil at a few locations within the Old Burn Area, F-Complex, B-Complex and the New Burn Area. The elevated arsenic concentration detected in the New Burn Area was limited to one surface soil sample located beneath the former OBU burn pad. The impacted soil was removed during RCRA closure activities. The arsenic impacted soil in the B-Complex is limited to one surface location in the wash that borders the west and north side of the operational area. The arsenic impacted soil in the F-Complex is limited to one location, 20 feet bgs, off the southwest corner of Building F-1. The arsenic impact at the Old Burn Area is limited to one near surface location (one foot bgs) to the northwest of the former burn area.

#### 5.4.2. Soil Gas

VOCs present in soil vapor appear to be limited primarily to the B-Complex, C-Complex and F-Complex, which are also the operational areas historically with the highest solvent usage. 1,1-DCE and acetone are the primary VOC impacts to the B-Complex soil vapor. VOCs were detected in soil gas samples collected throughout the B-Complex at various depths; however, the highest concentrations were detected beneath SWMU 5, which was a former solvent storage shed. VOC impacts to soil vapor extend to the water table at SWMU 5 based on soil gas sampling during the B-Complex site investigation and the installation of a nested soil vapor monitoring well. The highest 1,1-DCE and acetone concentrations were measured in a sample collected approximately 100 feet bgs. These concentrations are below the remedial goals for 1,1-DCE and acetone in soil vapor.

The VOC impacts in the C-Complex appear to be limited to acetone which was detected in soil vapor beneath Building C-2 and the former laboratory trailer, Building C-11. Vertical migration beneath Building C-2 appears to be limited to approximately 40 feet bgs. Vertical migration of VOCs in soil vapor beneath the former laboratory trailer appears to extend at least 80 feet bgs. VOC concentrations in soil vapor beneath the C-Complex were below the remedial goals.

The VOC impacts in the F-Complex appear to be limited to MEK and acetone which were detected in soil vapor beneath Building F-1 and F-10. Vertical migration beneath Building F-1 appears to extend at least 100 feet bgs. Vertical migration of VOCs in soil vapor beneath Building F-10 appears to extend at least 60 feet bgs. Further vertical delineation of VOC impacts at Buildings F-1 and F-10 were not completed due to access issues for the drill rig and the lack of an aquifer water quality standard for acetone. VOC concentrations in soil vapor beneath the F-Complex were below the remedial goals.

### **5.4.3. Groundwater**

#### **5.4.3.1. Perchlorate**

During the remedial investigation activities conducted since 2004, perchlorate has been detected in groundwater at concentrations above the remedial goal of 14 µg/L in samples collected at monitor wells MW-1, MW-2, MW-5, MW-6, MW-13, and MW-19. The elevated perchlorate concentrations observed in MW-19 and MW-5 appear to be attributed to impacts from historical waterbore operations. The elevated concentrations initially detected at MW-13 were related to well installation activities since the zonal sample (3.6 µg/L) collected from the borehole, prior to well installation, did not contain perchlorate at concentrations above the remedial goal. Perchlorate concentrations in this well have dropped below the remedial goal of 14 µg/L during subsequent sampling events. Elevated perchlorate concentrations at MW-1 and MW-2 may be attributed to historical waterbore operations, propellant production in the C-Complex, waste propellant burning in the New Burn Area, and/or a combination of these sources. The elevated perchlorate concentrations in MW-6 are considered to be potentially attributed to historic release(s) at F-Complex via surface drainage and infiltration from a wash on the west side of the facility.

Figure 53 shows the inferred extent of perchlorate concentrations in groundwater above the remedial goal.

#### **5.4.3.2. 1,1-DCE**

Groundwater collected from the facility production well, PW-1, has historically contained low concentrations of 1,1-DCE, potentially attributed to historic solvent release in the B-Complex. The 1,1-DCE concentration has not exceeded the remedial goal of 7 µg/L since 2004.

## 5.5. Contaminant Fate and Transport

### 5.5.1. Soil

Perchlorate is a soluble salt that can migrate through the vadose zone to the groundwater via water infiltrating in soil pores and/or fractures in bedrock. During historic rocket motor tube refurbishing activities, the wastewater discharge from the waterbore operations provided the driving force for perchlorate migration from the soil to the groundwater. Once the waterbore operations were contained, the driving force for perchlorate mobilization in vadose zone soil was limited to rainfall infiltration. Natural decay and/or degradation of perchlorate in soil are not considered to be significant fate and transport mechanisms and perchlorate concentrations in the soil are considered stable in the absence of water.

Arsenic and lead are metals with fairly low solubility and moderate mobility in soil. In addition, biological decay and/or degradation of arsenic or lead in soil are not considered to be significant fate and transport mechanisms.

### 5.5.2. Soil Gas

VOCs can adsorb onto soil particles, partition into water within the soil pore space, or migrate through soil pores as soil vapor. VOCs that migrate vertically downward may reach the water table and dissolve into the groundwater. Alternatively, impacted water in soil pores may infiltrate vertically and mix with groundwater. Vertical migration of VOCs to the groundwater appears to have occurred to some degree beneath the B-Complex based on historic groundwater monitoring data collected from the production well PW-1 and the grab sample collected from the boring completed as soil vapor monitoring well SVMW-1. VOCs may also migrate vertically upward and be released to ambient air or may migrate into on-site buildings via vapor intrusion mechanisms. Sampling of SVMW-1 indicates that the bulk of the VOC mass appears to be located approximately 90 to 100 feet bgs. Quarterly monitoring of SVMW-1 suggest little vertical migration of VOCs is currently occurring in the soil vapor beneath the B-Complex.

### 5.5.3. Surface Water

Surface water impacts would be associated with seasonal precipitation contacting surface soil with COPCs. The COPCs could potentially be transported as a dissolved constituent in water or attached to sediment traveling with the water.

#### **5.5.4. Groundwater**

Perchlorate is a soluble salt that can migrate through the vadose zone to the groundwater via water infiltrating in soil pores and/or fractures in bedrock. COPCs in contact with groundwater could be dissolved and transported with groundwater movement in fractures or pore spaces. Natural groundwater flow rates in fractured bedrock at the site are considered low in the absence of induced gradients.

Natural decay and/or degradation of perchlorate in groundwater are not considered to be significant fate and transport mechanisms. The current monitoring network indicates a relatively flat groundwater table at the wells where perchlorate is detected and low fluctuations in perchlorate concentrations at these wells, suggesting a currently stable plume with low mobility.

### **5.6. Future Land and Water Use**

#### **5.6.1. On-Site Land Use**

The UPCO facility is located on property owned by the Arizona State Land Department (ASLD). The land is currently zoned as S-1. The September 2008 City of Phoenix General Plan shows the future planned use for the property as a commerce / business park. Since UPCO's operations have been removed from the Site, ASLD may lease or sell the property to another commercial operation, sell the property for residential property development, or take no action and leave it as a vacant land. ASLD's specific plans for future use of the Site are not known at this time but could involve either residential or commercial uses.

#### **5.6.2. Off-Site Land Use**

The properties to the north of the Site have been developed for residential use. It is anticipated that the area to the north of the Site will remain residential use properties. The properties immediately west, south, and east of the Site are owned by ASLD. The property to the east is part of the Sonoran Desert Preserve and the Phoenix General Plan shows that the area is planned to be a park/open space. The property to the south is planned as commerce/business park. ASLD's plans for future use of the properties to the west, south, and east of the Site are not known at this time but future use of the land west and south of the former UPCO facility could include either residential or commercial development. At this time it appears unlikely that the hills to the east of the site would be developed.

### 5.6.3. On-Site Water Use

The UPCO facility utilized the groundwater beneath the site as the potable water and process water source for operations. There is no water service currently available from the City of Phoenix. If ASLD leases or sells the property for commercial use in the near future, it is likely that groundwater will be utilized for potable and/or process water purposes, unless the water demand proves to be unsustainable for the aquifer beneath the site. It is possible that a future commercial operation or residential development may receive water from the City of Phoenix, if the City's service is extended west along Happy Valley Road.

### 5.6.4. Off-Site Water Use

Currently the residences to the north of the Site utilize groundwater as a potable water source. It is possible that land to the west and south of the facility could also be converted to residential development, or commercial development, in the future. It is anticipated that the current usage of the groundwater north of the site as well as any future developments west and south of the site, will continue until the groundwater supply is depleted to a point it is no longer sustainable or economic, or the City of Phoenix extends water services to these areas. Water levels collected at the site, and at residences north of the site, indicate that the groundwater supply is being depleted within the residential development at a potentially unsustainable rate (multiple residences have had to drill deeper wells or have their potable water delivered). It is assumed that additional future development north, west or south of the site would accelerate the depletion of the groundwater supply in the vicinity of the site.

## 5.7. Risk Assessment Framework

The discussion below and Figure 54 represents the conceptual understanding of on-site sources of chemical contaminants, the means by which these chemicals could be transported within and among environmental media (e.g., soil, groundwater, and air), and the potential exposure pathways and routes by which there may be contact with human receptors.

Exposure pathways are considered potentially complete where each of the following is present:

- A source and mechanism of chemical release to the environment;
- Retention or transport media for the released chemical;
- A point of potential contact with an impacted medium; and
- An exposure route at the contact point.

The extent to which a potential pathway is actually complete and/or the associated potential exposure risk will be evaluated.

### **5.7.1. Fate and Transport Mechanisms**

As discussed in Section 5.5, the concentration and distribution of chemicals at the Site may be affected by one or more fate and transport mechanisms. The primary release and transport mechanisms of chemicals in soil are leaching to groundwater, surface water runoff of chemicals attached to soil particles, dust generation, and volatilization. Secondary media of potential consideration are groundwater, surface water, and sediment. The primary release and transport mechanisms of chemicals in groundwater and surface water are off-site migration of dissolved chemicals and volatilization. The release and transport mechanisms of chemicals in sediment (when the washes are dry) are the same as for soil. An additional medium of consideration is air, both ambient air due to potential release of dust from soil and/or volatile chemicals from soil or groundwater, and indoor air from potential vapor intrusion of volatile chemicals released from soil or groundwater. Therefore, soil, groundwater, surface water, sediment, and air are considered potential exposure pathways.

### **5.7.2. Potential Human Receptors**

Four categories of current and future potentially exposed human receptor populations are identified in the vicinity of the Site, including:

- Current off-site residents - Adults and children currently living off site in the vicinity of the Site.
- Future on-site workers – adults who will work on and around the grounds or in future on-site buildings.
- Future on-site residents – Adults and children who will live on site in the future.
- Future off-site residents – Adults and children who will live off site in the vicinity of the Site.

The potential exposure pathways and routes of exposure for each human receptor population are presented in Figure 54. Depending on the type of human receptor population, potential exposure routes include ingestion, dermal contact, and inhalation.

### **5.7.3. Exposure Pathways**

#### **5.7.3.1. Soil Exposure Pathway**

Soil is a potentially complete exposure pathway for current off-site residents, future on-site industrial workers, future on-site residents, and future off-site residents. Potential exposure routes are:

- ingestion of, and dermal contact with, chemicals in soil, and
- inhalation of chemicals released from soil to outdoor air (on dust or as chemical vapors).

#### **5.7.3.2. Groundwater Exposure Pathway**

Groundwater is a potentially complete exposure pathway for each of the receptor populations. Ingestion and dermal contact with the groundwater are potential exposure routes for each receptor. Inhalation of volatile chemicals released from impacted groundwater to indoor air (vapor intrusion) and outdoor air is a potential exposure route for future on-site workers and future on-site residents.

#### **5.7.3.3. Surface Water/Sediment Exposure Pathways**

A series of washes traverse the Site which are dry most of the year. However, some surface water flow intermittently occurs during storm events. During periods when the washes at the Site are dry, sediment is essentially soil and, as such, presents a potentially complete exposure pathway for current on-site workers and future on-site residents. Ingestion of, and dermal contact with, sediment/soil are potential exposure routes.

During or immediately after a storm event, flowing or ponded surface water may present potentially complete exposure pathways for future on-site workers and future on-site residents due to the potential for chemical leaching from soil to surface water. Dermal contact is the potential exposure route in these cases.

#### **5.7.3.4. Air Exposure Pathway**

As discussed in the previous sections, the potential release of dust and volatile chemicals from soil to outdoor air, the potential release of volatile chemicals from groundwater to outdoor air, and the potential release of volatile chemicals from soil or groundwater causing vapor intrusion to indoor air, present potentially complete exposure pathways for some of the potential receptor populations. Inhalation is the potential exposure route in these cases.

#### **5.7.4. Human Health Risk Assessment**

Soil remediation standards noted in A.A.C. R18-7-203(A)(3) and subsequently referenced A.A.C. R18-7-206 (A) indicate site specific remediation standards can be developed for sites by completing a human health risk assessment which uses reasonable maximum exposures for future use scenarios. The site specific risk assessment would follow the deterministic risk assessment guidance provided by EPA (1989) which is the basis of the guidance drafted by the ADHS (2003).

## 6. Summary and Conclusions

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### 6.1. Summary

UPCO has conducted a comprehensive series of soil, soil gas and groundwater investigations to assess the nature, magnitude, and extent of potential releases associated with historical operations at the Site. Contaminants were detected in soil, soil gas and groundwater at concentrations above characterization targets, requiring further evaluation and establishment of remedial goals.

Three COPCs have been identified in soil at concentrations above the remedial goals: perchlorate, lead and arsenic. The highest concentrations of perchlorate in soil at the former UPCO facility, and the deepest vertical extent of elevated perchlorate concentrations in soil (to 175 feet bgs), were observed in the Waterbore Area. There were also some elevated perchlorate concentrations in soil detected in the C-Complex and the New Burn Area, at depths ranging from 0 to 20 feet bgs. Lead concentrations in soil appear to be attributed to historic burning of waste propellants in the former open burning areas: Old Burn Area and New Burn Area. The elevated lead detected in surface soil at the New Burn Area was removed during the OBU closure activities. Observed arsenic concentrations in soil are considered consistent with naturally occurring conditions.

VOCs were detected in soil gas samples collected in B-Complex, C-Complex, F-Complex, and Old Burn Area. The suspected source of the VOC detections is historic solvent and adhesive use in these areas. 1,1-DCE, acetone and MEK have been identified as the COPCs in soil vapor based on frequency of detection, magnitude of concentration, historic usage, and detection in groundwater samples. The largest VOC impacts to soil vapor were observed in the B-Complex. The VOC concentrations detected in B-Complex do not appear to be impacting groundwater above characterization targets, based on groundwater monitoring data obtained at wells in the vicinity of the B-Complex (MW-1, MW-2, MW-6, MW-7, MW-10, MW-12, and PW-1) as well as the grab groundwater sample collected beneath the suspected source area in B-Complex, SWMU 5. Screening level J&E modeling also suggests that vapor intrusion is not of concern.

Perchlorate and 1,1-DCE are the two COPCs identified in groundwater. Historic groundwater sampling detected 1,1-DCE in the production well, PW-1, at a concentrations above the remedial goal of 7 µg/L in 2004. 1,1-DCE has not been detected

above the laboratory reporting limit in the other site monitoring wells. The concentration of 1,1-DCE in PW-1 has declined below the remedial goal since 2004.

## 6.2. Conclusions

Perchlorate is currently detected in five site monitor wells, MW-1, MW-2, MW-5, MW-6 and MW-19, at concentrations above the remedial goal. Detections of perchlorate in monitor wells MW-5 and MW-19 appear to be attributed to historic waterbore operations. The detections in MW-1 and MW-2 are thought to be attributed either to historic waterbore operations, propellant production in the C-Complex and/or burning of waste propellant at the New Burn Area.

As discussed in Section 5.2, the Waterbore Area is suspected to have contributed the most perchlorate mass to the groundwater beneath the site. Perchlorate mass contributions to groundwater from the C-Complex and New Burn Area are considered to be smaller in comparison to the Waterbore Area since the elevated perchlorate concentrations in soil at these areas are lower and the hydraulic driver to transport perchlorate to the groundwater is limited to infiltration from precipitation.

The perchlorate detections in MW-6, which is installed in Sedimentary Unit to the west of an apparent subsurface geologic structure, may be attributed to recharge of impacted surface water (from historic F-Complex operations) in the wash along the west side of the Site.

The results of the investigations suggest that the characterization of soil, soil gas, and groundwater at the Site are complete. Soil with COPC concentrations above the remedial goals will be evaluated during the Corrective Measures Study to determine the appropriate actions needed to address potential risks to human health. VOC concentrations in soil gas are below the remedial goals for the Site.

The concentrations of 1,1-DCE in PW-1 have declined below the remedial goal since 2004.

Perchlorate concentrations detected in groundwater during the remedial investigation period (2004 to 2011) have remained relatively stable and current perchlorate detections are limited to four shallow bedrock wells and one shallow sedimentary unit well. The current monitoring network is designed to monitor potential perchlorate migration in each direction as described in the following paragraphs.

Elevated perchlorate concentrations in the shallow bedrock wells MW-1, MW-2, MW-5, and MW-19 are delineated by MW-3, MW-15, and MW-4 to the north, the grab sample collected during drilling at SVMW-1 and the inferred subsurface geologic structure to the west, MW-11 to the east, and MW-8, MW-9, and MW-18 to the south. Potential vertical migration of perchlorate impacts in monitor wells MW-1 and MW-2 are currently delineated by MW-12 and PW-1.

Potential vertical migration of perchlorate impacts at the Waterbore Area are delineated by MW-13 at the Waterbore Area, MW-12 to the south, MW-14 and MW-16 to the north, and PW-1 to the west. The elevated perchlorate concentration initially observed at MW-13 was attributed to well installation activities. This is supported by the zonal sample collected at the bottom of the borehole, prior to well installation, and the current perchlorate concentration of 7 ug/L, which are both below the remedial goal of 14 µg/L.

Elevated perchlorate concentrations in the shallow Sedimentary Unit at MW-6 are delineated by the inferred subsurface geologic structure to the east and monitor wells MW-7, MW-10, and MW-17 to the south, southwest, and northwest, respectively.

## 7. References

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