PRESCO, Inc.
2006 Annual Water Sampling Report
Battlement Mesa Area, Garfield County, Colorado

Prepared for:
PRESCO, Inc.
10200 Grogan's Mill Road, Suite 520
The Woodlands, Texas 77380

Prepared by:
Cordilleran Compliance Services, Inc.
5550 Marshall Street
Arvada, Colorado 80002

April 2007

Cordilleran Project #E04243

Table of Contents

FIGURES AND TABLES

FIGURES

TABLES

APPENDICES

LIST OF ACRONYMS AND TERMS

AEC	Acronym for the Atomic Energy Commission
ALI	Annual Limit on Intake for occupational exposures to radionuclides established by the United States Nuclear Regulatory Commission. The ALI is the derived limit for the amount radioactive material taken into the body of an adult worker by inhalation or ingestion over a period of a year.
Alpha Particles (α)	Radioactive particles consisting of two protons and two neutrons, the same as a helium nucleus. These particles can be shielded by a piece of paper and cannot penetrate the outer layer of skin cells, but pose a hazard if inhaled.
Analyte	A substance or chemical constituent undergoing analysis or the substance being measured by an analytical procedure. Any chemical, parameter, or radionuclide in a water sample with a concentration or activity capable of be measured by a laboratory.
Anion	An anion is a negatively charged ion.
Aquifer	An aquifer is a body of rock that is sufficiently permeable to conduct groundwater and yield significant quantities of potable water to wells and springs.
Aquitard	A confining bed of rock that retards but does not prevent the flow of water to or from an adjacent aquifer. An aquitard does not readily yield water to wells or springs, but may serve as a storage unit for groundwater.
Background	Naturally occurring ionizing radiation from sources including cosmic radiation, terrestrial radiation (radiation from soil and rocks), internal radiation from potassium in our bodies, and indoor radon concentrations.
BART™	A patented biological activity reaction test biodetection system which can be customized to determine the aggressivity and composition of selected groups of bacteria. It is a simple and effective method for monitoring population size and activities of specific types of bacteria, including iron related, sulfate reducing, and slime forming bacteria, the three groups most commonly responsible for biofouling wells.
Becquerel (Bq)	is a unit of radioactivity measurement used by the International System of Units (SI) and equals 1 disintigration per second.

Beta Particles (β)	Beta particles are radioactive particles consisting of electrons. Beta particles can travel no more than 10 meters in air or about 1 centimeter in tissue, and can be shielded by a pad of paper. Beta particles can cause damage to skin cells in high doses outside the body and can cause damage to cells and critical organs when emitted inside the body through ingestion or inhalation.
BTEX	An acronym for the volatile organic compounds benzene, toluene, ethylbenzene, and xylenes.
Cation	A cation is a positively charged ion.
CDPHE	Acronym for the Colorado Department of Public Health and Environment
CFU	Acronym for Colony Forming Units (units for microbiological samples)
COGCC	Acronym for the Colorado Oil and Gas Conservation Commission
CO_2	Chemical formula for carbonate
Connate Water	Water that is trapped inside a sedimentary bedrock formation and was present at the time that the sediments were deposited, as opposed to meteoric water that has fallen as precipitation and percolated into the ground.
CPM	Counts per minute. A measure of radioactive disintegration
Curie (Ci)	A unit of radioactivity measurement. One curie equals 3.7×10^{10} disintegrations per second. One Becquerel (Bq) is the International System of Units (SI) unit and equals 1 disintegration per second.
DAC	Derived Air Concentrations. The DAC represents occupational exposure limits to radionuclides established by the United States Nuclear Regulatory Commission. The DAC is defined as the concentration of a radionuclide in air and the time of exposure to that radionuclide in hours.
Darcy (d)	A standard unit of permeability, equivalent to the passage of one cubic centimeter of fluid of one centipoise viscosity flowing in one second under a pressure differential of one atmosphere through a porous medium having an area of cross section of one square centimeter and a length of one centimeter.
DO	Abbreviation for dissolved oxygen, or the concentration of dissolved oxygen in a water sample.

DOE	Acronym for the United States Department of Energy (formerly known as the AEC).
EPA	Acronym for the United States Environmental Protection Agency.
EPA Method	A specific method required by the EPA for laboratory analysis of a specific parameter or analyte and is followed by the method number.
Fission Products	Radionuclides created during the detonation of a nuclear device or daughter products resulting from the nuclear fission of uranium.
Gamma (γ)	Gamma radiation is electromagnetic radiation with high energy, similar to x-rays. Gamma radiation is given off by the nucleus of radionuclides, while x-rays come from outside the nucleus, and can travel long distances and penetrate through the human body. Gamma radiation is a hazard to all organs from both inside and outside the body. Gamma radiation can be shielded by heavy materials such as lead and barium.
gpm	Acronym for gallons per minute
Half-life	The time it takes for half of the radioactive atoms present to decay. The half-life is dependent on the radionuclide, some having half lives measured in seconds, days, years, or in millions of years.
HCO_3	Chemical formula for bicarbonate
LANL	Acronym for the Los Alamos National Laboratory
LLL	Acronym for the Lawrence Livermore Laboratory
MCi	A mega curie equals one million (10^6) curies.
MCL	Maximum Contaminant Limit(s) set by the EPA as the maximum concentration or activity allowed in a municipal drinking water supply
MDA	Minimum Detectable Activity is the minimum activity emitted by a given radionuclide that the laboratory can detect. Sometimes the MDA is referred to as the minimum detectable concentration (MDC).
MDL	Method Detection Limit is the same as the laboratory reporting limit or the minimum concentration of an analyte that the laboratory can accurately quantify using a particular laboratory method.

meq/L	Milliequivalents per liter is a measure of ionic charge in an aqueous solution. Used for both cations, positively charged ions, and anions, or negatively charged ions.
Methane	A volatile organic compound composed of one carbon atom and four hydrogen atoms, chemical formula written as CH_4. Methane can form as a naturally occurring byproduct of bacterial decay of organic matter, forming "biogenic" methane caused by reduction of CO_2. Methane can also form as a result of thermal breakdown of heavier hydrocarbons, and is a large constituent of natural gas as formed by geologic processes, known as "thermogenic" methane.
mg/L	One milligram per liter equals one thousandth (10^{-3}) of a gram per liter of water, and is approximately equivalent to one part per million.
millidarcies	The customary unit of measurement of fluid permeability, equivalent to 0.001 darcy, abbreviated md.
Mean	A statistical average, or arithmetic mean, is the sum of all the observations in a random variable data set divided by the total number of observations in the data set.
Median	A statistical median is the middle value in the random variable data set list and divides the data set into two equal parts.
Mode	The most frequent value assumed by a random variable, or occurring in a sampling of a random variable. The term is applied both to probability distributions and to collections of data.
mrem	Millirem (see "rem")
MTBE	Methyl tertiary butyl ether is a volatile organic compound.
NO_2	Chemical formula for nitrites
NO_3	Chemical formula for nitrates
pH	The pH is a measure of acidic or basic conditions of water. A pH of 7.0 is "neutral" where low pH readings (4.0) are acidic, and higher pH readings (10.0) are basic. Natural pH conditions range from 6.0 standard units (su) to 9.0 su.
ppb	Parts per billion, approximately equivalent to micrograms per liter.
ppm	Parts per million, approximately equivalent to milligrams per liter.

pCi/L	Picocuries per liter is a measurement of radioactivity in water. One picocurie is one trillionth of a curie, or 10^{-12} curies per liter.
PO_4	Chemical formula for phosphate
Project Rulison	An experiment conducted by the AEC and a private oil company on September 10, 1969 involving the detonation of a nuclear device to stimulate natural gas production from low permeability sandstone at a depth of 8,426 feet.
QA/QC	Quality Assurance/Quality Control is an evaluation of the accuracy and precision of laboratory analytical results.
Radionuclide	A radioactive is an isotope of a chemical element
Radionuclides of Interest	Those fission-product radionuclides that exist in a gaseous or vapor state and which therefore theoretically could be entrained in the natural gas or encountered during drilling activities. Concentrations of radionuclides related to Project Rulison are not expected to be encountered; however, these parameters are monitored.
rem	A measurement of radioactivity dose. A radiation dose is a measure of the amount of energy absorbed by body tissues. One mrem is one thousandth (10^{-3}) of a rem.
roentgen (R)	Measure of radiation exposure, or the amount of ionizing radiation produced by gamma radiation or x-rays in the air. An exposure of one milliroentgen (mR) would result in a dose of approximately one millirem (mrem)
SAR	Sodium Adsorption Ratio (SAR) is an agricultural measurement of soils with an accumulation of exchangeable sodium, or salt impact, characterized by poor tilth and low permeability. The equation to calculate SAR is expressed as the milliequivalent concentration of sodium divided by the square root of one-half the milliequivalent concentrations of calcium and magnesium added together.
Shielding	Shielding is the use of a physical barrier, such as a lead apron, as protection from radiation.
SO_4	Chemical formula for sulfates
Solifluction	Unconsolidated, water logged deposits resulting from erosion and mass wasting of sediments derived from alluvial and colluvial debris flows

Stiff Diagrams	Stiff diagrams are graphs that display water quality by comparing ionic composition of the sample. The graph plots cations on one side of a linear scale and anions on the other resulting in a polygonal graph. Both cation and anion concentrations are presented in milli-equivalents per liter (meq/L).
TDS	Total Dissolved Solids (TDS) is a measure of the amount of dissolved minerals, principally salts, in water.
Thallium	Is a soft gray metallic element represented by the chemical symbol, Tl, and atomic number 81 on the periodic table.
Tritium	A radioactive form of hydrogen, H-3, that forms naturally by reactions in the upper atmosphere as a result of interaction with cosmic rays, and also formed in larger quantities by the detonation of nuclear devices.
TU	"Tritium Units" are an older unit of measurement, with one TU equal to 3.21 pCi/L tritium.
µd	Microdarcies are a unit of fluid permeability equal to 0.000001 darcies, (10^{-6} darcies) representative of low permeability sediments or media.
µg/L	Micrograms per liter, or one millionth (10^{-6}) of a gram per liter of water, approximately equivalent to parts per billion.
µCi/L	microcuries per liter, or one millionth (10^{-6}) of a curie per liter of water, are a measurement of radionuclide activity concentration.
Unconsolidated	A sediment that is loosely arranged, unstratified, or whose particles are not cemented together or "lithified"as a sedimentary rock, occurring either at the surface or at depth. Soil material that is in a loosely aggregated form.
USGS	Acronym for the United States Geological Survey

1.0 Introduction

PRESCO Inc. (PRESCO) retained Cordilleran Compliance Services, Inc. (Cordilleran) to conduct baseline and annual water sampling activities associated with PRESCO's development of natural gas resources in the vicinity of Battlement Mesa, Garfield County, Colorado. This report presents the data collected during the 2006 annual water sampling event.

1.1 Purpose of Monitoring

The purpose of the water quality monitoring was to document baseline water quality conditions prior to PRESCO's development of natural gas resources in the area and to assess potential water quality impacts during natural gas exploration and production (E&P) activities.

To accomplish this goal, PRESCO and Cordilleran developed a Baseline Water Sampling Work Plan in September 2004. The Work Plan also contained monitoring activities for PRESCO's gas well drilling, and was finalized in January 2005 and was revised in May 2005. The Work Plan outlined the following objectives of the water sampling activities:

1) Review available geologic and groundwater information to develop an understanding of the local hydrogeology;
2) Identify potential receptors including water supply wells and surface waters;
3) Identify baseline sample locations including water supply wells, monitoring wells, springs, and surface waters;
4) Establish protocols for collecting groundwater and surface water samples; and
5) Evaluate the data in an ongoing sampling program.

Cordilleran reviewed information from the United States Geological Survey (USGS) for water quality monitoring performed in the area in the 1960s and 1970s. Cordilleran conducted baseline water sampling at fourteen locations including private water wells, springs, and surface water locations in November 2004. PRESCO began natural gas well drilling activities in the fall of 2005. PRESCO has prepared their drilling program and natural gas well completion plans for protecting area water resources, the public, and the environment. Special consideration has been given to development of natural gas resources in proximity of the Project Rulison test site. Figure 1 presents the sample locations described in this report. Table 1 presents the sample locations and well completion information. Table 2 presents the Analyte Reference Table, or the analytes for which analysis was performed.

1.2 Project Rulison Test Site

Project Rulison, named after the nearby, rural community of Rulison, in Garfield County, Colorado, was an underground nuclear test project involving detonation of a 43-kiloton device conducted on September 10, 1969. The purpose of this test was to stimulate natural gas production from tight gas sands.

The Atomic Energy Commission (AEC), a predecessor to the United States Department of Energy (DOE), and Austral Oil Company, an independent oil company, co-sponsored the Project Rulison nuclear test under the Plowshare Program. The Plowshare Program consisted of a series of nuclear and conventional explosive tests conducted to explore peacetime uses of nuclear devices. The Project Rulison nuclear test took place at a depth of 2,568 meters (8,426 feet) and was designed to stimulate natural gas production from low-permeability sandstone of the Mesa Verde Group. The Project Rulison experiment utilized a uranium nuclear device built by Los Alamos National Laboratory (LANL) in New Mexico. The Project Rulison device was installed in the Hayward #25-95 (R-E) emplacement well located in the Northeast Quarter of the Southeast Quarter of Section 25, Township 7 South, Range 95 West of the Sixth Principal Meridian.

According to the AEC Project Rulison Manager's Report (Thalgott and Allaire, 1973), the detonation created a roughly spherical to egg-shaped cavity where the surrounding sandstone and shale were vaporized and the melted rock cooled to form a glass, lining the cavity, and collected in the bottom forming a "puddle." The Project Rulison experiment also resulted in a zone of fractured rock surrounding the cavity, and a "chimney" of rock rubble above and surrounding the shot point. The DOE calculated the chimney cavity radius at 75 feet and the outer radius fracture zone at 220 feet.

Most of the radionuclides, or residual radioactive elements from the detonation of the Project Rulison device, are trapped within the glass slag, and are immobile. Volatile and gaseous radionuclides, trapped within the glass, may also be present in connate water in the cavity, or possibly entrained in natural gas present within the cavity or in the surrounding fracture zone. These gas-phase radionuclides include tritium (^{3}H), carbon-14 (^{14}C), and krypton-85 (^{85}Kr). Table 3 presents radionuclides of interest, or those fission products that could be encountered in the development of natural gas resources.

Approximately one year after the detonation a separate re-entry well (R-EX) was directionally drilled into the chimney cavity and fracture zone created by the nuclear detonation. Natural gas production testing from the cavity began in 1970 and was completed in April 1971. The Project Rulison test produced a total of 450,000,000 cubic feet of gas, which was flared to the atmosphere at the site from 1970 to1971. Cleanup of the site was initiated in 1972, and the two wells were plugged and abandoned in 1976.

A plaque left at the Project Rulison surface location states that no excavation, drilling, and/or removal of subsurface materials is permitted below 6,000 feet inside of "Lot 11", also described as the Northeast Quarter of the Southwest Quarter of Section 25, Township 7 South, Range 95 West, of the 6th P.M., (the 40 acres of land containing the Hayward 25-95 (R-E) well), without U.S. Government permission. The DOE also entered into an agreement with the COGCC to notify the DOE of any application to drill within a three mile radius of the Project Rulison test site (Macke, 1998). Drilling and development of natural gas resources is not prohibited within the three mile radius, but allows the DOE the opportunity to conduct testing. The COGCC met with the DOE prior to 1998 to address concerns that drilling activities were encroaching on the Project Rulison site. The COGCC Order #139-43 on February 10, 2004 approved PRESCO's request for an order to amend the 640 acre drill spacing for wells in the Williams Fork Formation but required a hearing before the Commission prior to approving any permits to drill for wells located within ½ mile of the Project Rulison site.

1.3 Battlement Mesa Setting, Geology, and Hydrogeology

Battlement Mesa is located in central Garfield County, Colorado along the southern edge of the Piceance Basin. The Piceance Basin is a geologic, structural depression in the earth's crust created as a result of tectonic forces associated with the uplift of the Colorado Rocky Mountains and the Colorado Plateau. During the Cretaceous geologic period, much of the western United States was occupied by a shallow inland sea. Marine and near shore sediments containing organic materials became deeply buried and the resulting heat and pressure from the earth acting on these organic materials produced the natural gas resources contained within the Mesa Verde Group. The Mesa Verde Group in this area consists of the Williams Fork Formation, the Iles Formation, and the Ohio Creek Member. These formations are comprised primarily of interbedded siltstone, silty sandstone lenses, carbonaceous shale, and coal. The Ohio Creek Member consists of sandstone and conglomerate.

The Mesa Verde Group is overlain by impermeable sedimentary rock including the Tertiary Wasatch Formation and Green River Formation. These thick sedimentary rock strata limit the downward migration of surface water and are covered by unconsolidated sediments and boulders of basalt eroded from the top of Battlement Mesa.

A review of the information contained in the database maintained by the State Engineer's Office – Division of Water Resources confirms that water wells in the area are typically less than 250 feet deep, with water being produced from "All Unnamed Aquifers" indicating that this water is not being produced from a named bedrock aquifer. The underlying bedrock units of the Green River Formation, Wasatch Formation, and Mesa Verde Group are thousands of feet thick and are not designated as aquifers. These formations are generally considered confining units or aquitards (Robson and Banta,

1995). The Ohio Creek Member of the Mesa Verde Group is an aquifer in some places in the region; however, the Ohio Creek Member is not an aquifer on Battlement Mesa as described below.

Prior to conducting the Project Rulison test, the DOE worked with the USGS to log the emplacement well where the Rulison device was to be detonated. The USGS personnel logged the emplacement well and tested bedrock zones for the presence of groundwater. These results were summarized in USGS Open-File Report 474-68, Geohydrology – Project Rulison, Garfield County, Colorado with a section on Aquifer Response, (Voegeli, West, and Cordes, 1970). The USGS report states that:

1) *"…all zones below a depth of 6,129 feet in the Rulison exploratory hole that yielded any water during drilling, or zones interpreted from geophysical logs as being likely to contain water, were hydraulically tested. The pressures recorded during the drill-stem tests of the different zones indicated negligible or no fluid entry to the hole while the test tool was open. No fluid was recovered on any of the swab tests performed during the drill stem tests."*

2) *"Hydrologic tests on the Rulison exploratory hole indicate little or no water occurs in the Ohio Creek conglomerate and the Mesa Verde Group which are the stratigraphic units most likely to yield water to that hole."*

3) *"Studies of preshot and postshot hydrologic conditions indicate that the detonation did not significantly or permanently affect wells, springs, steams, shallow aquifers, or reservoirs in or near the Rulison site." and*

4) *"The ground-water resources in the Rulison area are confined primarily to unconsolidated surficial deposits (e.g. flood-plain deposits and terrace and fan gravel shed from the flanks of the mesa). Essentially all the wells and most of the springs in the area derive their water from these deposits. The underlying bedrock formations generally have low permeability and yield little or no water."*

The unconsolidated, eroded, surficial deposits consist of mudflows, talus accumulations, fan and pediment gravel, slump blocks, and alluvium of Battlement Creek and the Colorado River. These deposits generally range in thickness from 20 feet to 40 feet, but locally may be more than 100 feet thick. Ground water occurs in many of these deposits yielding water to area water wells and springs. According to the Geologic Map of the Rulison Quadrangle, (Yeend et al,1988), the surficial sediments in the Battlement Creek drainage consist of mudflow and fan-gravel deposits that are derived largely from the slow downward migration of waterlogged soil, known as solifluction deposits, located higher up in the drainage. These deposits are poorly sorted, with clasts ranging in size from clay and silt, pebbles, cobbles, and boulder sized clasts, consisting primarily of unweathered basalt, in a matrix of coarse sand and gravel. Figure 2 prepared by Mr. Brian Richter, U.S. Capital Energy and PRESCO's Managing Geologist for the

Battlement Mesa Project, shows the relationships between the bedrock units and overlying unconsolidated deposits.

1.4 Previous Water Quality Studies

Several water quality studies have been conducted in the vicinity of Battlement Mesa in conjunction with Project Rulison, and for other purposes. A description of some of these studies follows.

United States Geological Survey

The AEC worked with the USGS to collect water samples from area water wells, springs, and surface water resources in the vicinity of the proposed Rulison test site prior to conducting the Project Rulison test, as well as during and after the Rulison test. The water samples were analyzed for a variety of water quality parameters, elements, and compounds, as well as for radionuclides including tritium, a radioactive form of hydrogen, and gamma emitting radionuclides. The USGS water sampling activities were conducted from 1967 until 1972.

The results of these analyses indicated that concentrations of tritium were detected that represented naturally occurring concentrations or atmospheric tritium that results from world wide nuclear testing conducted in the 1950s and 1960s. The USGS report presents the tritium data in tritium units (TU), an older unit used in geology and hydrology references. The TU is an estimated ratio of tritium atoms to stable hydrogen atoms prior to nuclear weapons testing, and is set at 1×10^{18} atoms. One TU is equal to 3.231 picocuries per liter (pCi/L) of water. A copy of the USGS report is included as Appendix A.

United States Environmental Protection Agency

In 1972 the United States Environmental Protection Agency (EPA) took over the water sampling activities from the USGS. The EPA has conducted annual water sampling, as well as sampling of other environmental media in the area, for tritium and gamma emitting radionuclide analysis since 1972. A copy of the EPA Annual Water Quality Report for 2004 is included as Appendix B. Copies of the EPA reports for 2005 and 2006 calendar years have not been made available; however, copies of previous years are available from the DOE website www.doe.gov. Cordilleran has requested information for 2005 and 2006 water monitoring under the Freedom of Information Act; however no information has been received at the writing of this report.

The EPA has sampled the Grand Valley municipal supplementary drinking water springs, water supply wells for five local ranches, a surface water sample from Battlement Creek, and two surface discharge spring sites in the vicinity of the Project Rulison test site. According to the EPA Annual Report for Calendar Year 2004:

- *"Tritium has never been observed in measurable concentrations in the Grand Valley Springs. All of the remaining sampling sites show detectable concentrations of tritium, which have generally exhibited a stable or decreasing trend over the last two decades."*
- *"The detectable concentrations of tritium activities are consistent with values found in current precipitation and, perhaps, a small residual component remaining from clean-up activities at the site."*
- *"Desert Research Institute analysis, indicates that most of the sampling locations at the Rulison site are shallow, drawing water from the surficial aquifer, and therefore, unlikely to become contaminated by radionuclide migration from the Project Rulison cavity."*

All gamma-ray spectral analysis results indicated that no man-made gamma ray emitting radionuclides were present above the minimum detectable activity (MDA).

Colorado Oil and Gas Conservation Commission

The Colorado Oil and Gas Conservation Commission (COGCC) collected water samples for water quality parameters from area water wells and springs in 1997 and 1998. These samples were analyzed for a variety of parameters including volatile organic compounds, inorganic compounds, and water quality parameters. The COGCC did not analyze samples for radionuclides. Copies of analytical tables from the COGCC are presented as Appendix C.

Town of Parachute and Battlement Mesa Metro District

The Colorado Department of Public Health and Environment (CDPHE) regulates public water supply systems limiting the amount of certain contaminants in drinking water to ensure that tap water is safe to drink. The Town of Parachute and Battlement Mesa Metro District routinely monitor for contaminants in drinking water according to Federal and State laws. Some of the parameters these public water suppliers monitor are the same as those monitored by the COGCC and PRESCO; however, the town also monitors for other analytes not associated with oil and gas production. Copies of the Town of Parachute and Battlement Mesa Metro District 2006 Drinking Water Consumer Confidence Reports for Calendar Year 2005, are presented in Appendix D.

1.5 Ionizing Radiation

Radiation is a form of kinetic energy, or energy in motion. Ionizing radiation has enough kinetic energy to strip electrons from atoms. Radioactive decay is the process by which a radioactive atom releases energy in the form of radiation to become more stable. A half-life is the time that it takes for half of the radioactive atoms present to decay. The half-life is dependent on the radionuclide and may occur in a matter of seconds, days, years, or even millions of years.

Not all ionizing radiation released during the decay process has the same amount of energy, and the energy released is dependent on the radionuclide. The three types of radiation include:

- alpha particles (α) which consist of 2 protons and 2 neutrons and are the same as a helium nucleus;
- beta particles (β) which consist of an electron; and
- gamma (γ) radiation and x-rays which consist of electromagnetic radiation, are similar to visible light, ultraviolet light, and microwaves, but have more kinetic energy.

The type of radiation and energy released are dependent on the radionuclide. Ways to control radiation dose to the human body are dependent on the following factors:

1. Minimize the time of exposure to the source of radiation;
2. Maximize the distance to the source of radiation; and
3. Use shielding, or a physical barrier, to reduce the exposure to the human body.

Alpha radiation has the least amount of energy, traveling only about five centimeters in air, or 0.01 centimeters in tissue. Alpha particles can be shielded by a piece of paper and are not a hazard outside the body since they cannot penetrate the outer layer of skin cells. If inhaled, alpha particles can be a high hazard inside the body because they can cause substantial amount damage to cells in a small volume of tissue.

Beta particles, as electrons, are smaller in particle size, and will travel no more than 10 meters in air or about 1 centimeter in tissue. Beta particles have higher energy than alpha particles, but can be shielded by a pad of paper, and can cause skin damage at high dose levels from outside the body. Beta particles can also cause damage to cells and critical organs when emitted inside the body or when ingested or inhaled.

Gamma rays and x-rays are electromagnetic radiation with high energy. Gamma radiation is given off by the nucleus, whereas x-rays come from outside the nucleus. Gamma radiation can travel long distances and can penetrate through the body. Gamma radiation is a hazard to all organs from both inside and outside the body. Gamma rays can be shielded by heavy materials such as the cab of a vehicle, a lead apron, barium compounds, or thick sedimentary rock sequences.

1.6 Background Radiation

Background radiation is ionizing radiation from natural sources, including cosmic radiation and sources within the earth, and those that are incorporated in food, water, and in tissues of the human body. Natural background radiation originates from three primary sources: cosmic radiation, terrestrial sources, and radon.

Cosmic Radiation

All living things on the earth are constantly bombarded by radiation from outside our solar system. This radiation interacts in the atmosphere to create secondary radiation that "rains down." The dose rate from cosmic radiation varies in different parts of the world based largely on the geomagnetic field and land elevation. The background radiation levels on the Colorado western slope range from 50 millirem (mrem) to 100 mrem per year. Background radiation levels are lower at lower elevations.

Terrestrial Radiation

Naturally occurring radioactive material is found throughout nature in the soil, rocks, water, air, and vegetation. The primary radionuclides responsible for terrestrial radiation are potassium (K), uranium (U), and thorium (Th). These radionuclides undergo a well documented radioactive decay process which yields daughter products that are distinct from the fission products released during the detonation of a nuclear device, such as the one used for the Project Rulison experiment.

1.7 Radionuclides of Interest

Radionuclides of interest are those identified by previous water quality studies and other studies conducted by the USGS, AEC/DOE, and EPA at the Project Rulison site and other underground nuclear test sites. These agencies conducted water sampling in the area prior to the Project Rulison experiment and annually in the thirty-seven years since the experiment was conducted. The historic water quality data from these studies indicates that concentrations of tritium are consistent with background levels, and that gamma emitting radionuclides, related to Project Rulison, have not been detected in area water samples.

Tritium

The primary radionuclide analyzed by the EPA at underground nuclear test sites is tritium. As a product of underground nuclear testing, high levels of tritium are found in the test cavities and lower concentrations are found in the fractured rock surrounding the cavity through a process known as prompt injection. Some of the tritium is expected to be in the form of free water in the cavity, and also as water vapor. Since tritium may be incorporated as a hydrogen atom in water molecules, it is expected to be the first radionuclide to migrate from a test cavity. Therefore, tritium serves as an indicator of radionuclide migration. Tritium has a half-life of 12.3 years which means that half of the tritium present decays in this time to a form that is no longer radioactive.

Most hydrogen is made up of one proton and an orbital electron, but tritium has two extra neutrons in the nucleus. In nature, tritium is produced when cosmic rays interact with nitrogen (^{14}N) or oxygen (^{16}O), causing spallation from the nuclei, and forming tritium

(^{3}H) and carbon (^{12}C), or when cosmic rays interact with deuterium (^{2}H). These interactions primarily occur in the upper atmosphere and the resulting tritium falls to earth as precipitation. The USGS and EPA data indicate the presence of naturally occurring, atmospheric tritium in surface water samples and samples from shallow aquifers and springs closely connected to shallow aquifers, and possibly some residual tritium associated with fall-out from the flaring operations in the early 1970s, and perhaps a small amount of global "fallout tritium" remaining from nuclear testing in the 1950s and 1960s.

Prior to atmospheric nuclear weapons testing, the global equilibrium tritium inventory was estimated at 80 megaCuries (MCi). Surface waters such as lakes and streams are estimated to have had a concentration of 5 to 10 pCi/L. Post World War II atmospheric testing caused an increase in atmospheric input rate of about 6 to 7 MCi per megaton yield. With rapid hydrosphere mixing, a half-life of 12 years, greater than natural level concentrations of man-made tritium can now be found in surface and shallow groundwaters. These tritium levels have been declining back toward the natural background levels with the reduction in aboveground nuclear weapons testing.

The drinking water supply wells in the area produce water from shallow, unconsolidated aquifers and, consequently, do not represent groundwater from the bedrock formations, known as connate water. Connate water is trapped in the pore spaces and fractures within sedimentary rock which lacks sufficient permeability to allow this water to be produced. Connate water typically has much higher total dissolved solids (TDS).

Project Rulison was conducted at a depth of 8,425 feet, more than a mile and half below ground surface, and is below sea level. The Project Rulison test cavity is well below the depth of shallow water resources used for drinking water in the area. Connate water trapped in the Mesa Verde Group is largely immobile, and dates to the late Cretaceous when these sediments were deposited, millions of years before the present. Since tritium has a 12.3 year half-life, naturally occurring tritium is not present in the Mesa Verde Group, and tritium found within the Mesa Verde Group could only be from the Project Rulison cavity, or as atmospheric tritium introduced from some other surficial source.

One picocurie is equivalent to one trillionth of a curie (Ci), and concentrations of tritium are measured in picocuries (pCi) in a liter of water, or picocuries per liter (pCi/L). Therefore, the laboratory is capable of measuring extremely low levels of radioactivity. In the past the DOE/EPA have employed two types of tritium analysis, the conventional method and electrolytic enrichment, both using an automatic liquid scintillation counter. In the conventional method the water sample is prepared by distillation, and in the tritium enrichment method the sample is concentrated by electrolysis following distillation. The enrichment method lowers the minimum detectable concentration (MDC) from approximately 300 pCi/L down to 5 pCi/L. The EPA has decided that a maximum of 25

percent of all samples collected will be analyzed by the low-level enrichment method, based on the time required for the analysis and the past results.

The EPA has established a drinking water standard for tritium of 20,000 pCi/L, which is the concentration that is expected to result in a total body dose of 4 millirems (mrem) per year. A dose of 4 mrem/year is the EPA established maximum contaminant level (MCL) for any beta emitting radionuclide for public water supply systems. The MCL for tritium at 20,000 pCi/L is well above the MDA (300 pCi/L) for tritium using the conventional method.

Due to the time lapsed since the test in September 1969, any tritium remaining is approximately one-eighth of the original amount generated during the Project Rulison test, and the extremely low permeability of the formation inhibits migration of the tritium away from the cavity. The maximum permissible exposure whole body burden to tritium is 1 milliCurie (mCi) or 1,000,000,000 pCi. Table 3 presents the occupational exposure limits for tritium and other radionuclides of interest.

Tritium is one of the weakest beta particle emitters known. The range of the most energetic tritium beta particle is only about 5 millimeters in air or 0.005 millimeters in water or soft tissue, making it nonhazardous outside the body. However, its lack of energy presents a detection problem. Where other radionuclides can be detected by their penetrating radiation, tritium has to be introduced directly inside the detector or counter in order to be measured. Therefore, without the use of specialized equipment maintained in a clean environment, water samples must be sent to a laboratory to be able to detect the presence of tritium.

Tritium is almost always found as water, or "tritiated" water. Once tritium enters the body it disperses quickly and is uniformly distributed throughout the body. Since tritium is in the form of water and disperses through the body, there are no target organs as is the case with other radionuclides. Tritium is excreted through urine within a month or so after ingestion. Organically bound tritium can remain in the body for a longer period. While not impossible, ingesting a large enough dose of tritium to cause any significant harm to a person is unlikely.

Gamma Emitting Radionuclides

Since gamma radiation has the highest energy, and is produced in association with the release of alpha particles and beta particles during radionuclide decay, gamma emitting radionuclides are also of interest. According to the EPA reports, the first time samples are collected from a well, concentrations of strontium isotopes, plutonium isotopes, and uranium isotopes are determined, in addition to the tritium analysis. At least one, one gallon capacity sample, from each site is analyzed by gamma spectrometry.

In the EPA report for the Annual Water Sampling and Analysis, Calendar Year 2004, (Davis and Houston, 2004) all routine samples were analyzed for the presence of gamma-ray emitting radionuclides and the gamma spectrometry results were all reported as "ND" or not detected as presented in the EPA's Table 3, Analysis Results for Water Samples Collected at the Rulison Site – May 2004. In reviewing the earlier EPA reports, similar statements were made regarding the absence of gamma emitting radionuclides in reports from previous years.

Ambient gamma radiation rates differ among locations since rates vary with altitude (cosmic radiation) and with radioactivity in the soil (terrestrial radiation) and at a location due to changes in weather patterns and other environmental factors.

2.0 Annual 2006 Water Sample Collection

The following sections describe the water sample locations, field sampling techniques, field screening data and observations, and other information about the sample locations.

2.1 Water Sample Locations

The scope of work consisted of sampling a representative number of water wells, springs, and surface water locations in the vicinity of the Project Rulison test site to compare with the 2004 baseline and 2005 annual water quality results. The water sample locations requested by PRESCO include many of the same locations sampled by the USGS, EPA, and COGCC during previous water quality studies.

Access letters were sent out to well and spring owners requesting permission to sample prior to the 2006 annual sampling event. Follow up telephone calls were made to set up times to meet with the well and spring owners to sample water on October 16, and October 17, 2006.

Participation in the baseline and annual sampling events is voluntary on the part of the well or spring owner. PRESCO provided each well or spring owner a brief letter report, table comparing the results to applicable EPA drinking water standards or state water quality standards, and a copy of their water sample laboratory results in exchange for allowing Cordilleran to collect a sample for laboratory analysis. Although the COGCC recommends that oil and gas companies conduct baseline water quality monitoring prior to drilling in new areas, baseline sampling is voluntary. The list of parameters for which the water samples are analyzed consists of those suggested by the COGCC, and radiochemistry methods used by the EPA/DOE for their annual water monitoring around the Project Rulison site.

A total of 14 water samples and two duplicate samples were collected during the 2004 baseline sampling event and again during the 2005 annual sampling event from these same 14 locations. During the 2006 annual sampling event, Cordilleran personnel collected water samples from the same 14 locations, and collected two replicate samples that were sent to a different laboratory (ACZ) for analysis, rather than duplicate samples sent to the same laboratory. The water sample locations included seven water supply wells, four springs including the Grand Valley municipal springs, and three surface water sampling locations including Battlement Creek near the USGS gauging station, Hayward Creek near the Project Rulison site, and Monument Creek near the Parachute water treatment facility. Figure 1 presents the Rulison area and the 14 water sample locations.

During the 2005 sampling event a water sample, BM 36 CULV, was collected from near one of PRESCO's well pads following a bentonite drilling mud release in October 2005. The water sample was collected to evaluate water quality impacts from the drilling mud

release, but was also submitted for the same parameters as the other baseline water quality sample parameters. A separate report was prepared following the investigation of the drilling mud release and was submitted to the COGCC. This site location was not sampled during 2006 sampling event due to rain and snow melt runoff.

2.2 Field Parameter Screening Data

Field parameters were measured using a *Quanta Hydrolab* water quality meter including pH, dissolved oxygen, specific conductivity, temperature, total dissolved solids, and turbidity. Field parameter measurements are presented in Table 4. The field parameters were measured by placing the *Quanta* probe into a five gallon bucket with water purged from the well or spring hydrant and/or garden hose, or by placing the probe directly within the stream flow at the surface water sampling location where the flow was sufficient to be measured. Where possible, approximately ten gallons of water were purged, as estimated by bucket fill from the well and spring hydrants prior to sampling.

Each of the water sampling locations were screened for the presence of radioactivity using a Ludlum Model 3 survey meter and pancake probe. Levels of radioactivity were consistent with background levels. All field parameters including visual and olfactory observations were recorded in the field logbook. Samples were submitted for laboratory analysis of analytes listed in Table 2, including the COGCC recommended baseline parameters, and for tritium, and gamma emitting radionuclide analyses.

2.3 Water Sample Collection

Water samples were collected directly from the well or spring hydrant and/or garden hose at each of the private well or spring locations. Surface water samples were collected in an bottle from the stream flow which was then used to fill the other bottles in the sample suite. Each of the samples were collected in a suite of laboratory provided sample containers some of which contained preservatives for individual analytes. The samples were stored on ice in plastic coolers pending shipment to the laboratory. The following locations were sampled during the 2006 annual water sampling event. The sample identification for each of the locations is shown in parentheses.

- Juanita Satterfield, Guy Botkin's water well, (JLS-W1) from Morrisania Mesa;
- Battlement Creek surface water near the USGS gauging station (USGS-BC1);
- Cary Weldon's water well (CW-W2) near the Project Rulison site;
- Hayward Creek surface water (HC-S2) near the Project Rulison site;
- Lynn Shore's water well (LJS-W3) from Morrisania Mesa;
- Grand Valley Springs (GVS-SP1) from Morrisania Mesa;
- Ethel Gardner's spring (EG-SP2) near the Project Rulison site;
- Wesley Kent's spring (WK-SP3) near the Project Rulison site;
- Judy Hayward's 96 Ranch spring (LH96-SP4) near the Project Rulison site;

- Joan Savage and Roy Savage's (RS-W4) water well east of Doghead Mountain;
- Christy Koenke's (CK-W5) water well from Morrisania Mesa;
- Tim and Karla Jacobs'(TJ-W6) water well from Morrisania Meas;
- Randy and Pat Warren's Take a Break Ranch well (PW-W7) in the Battlement Creek drainage basin downgradient of the Project Rulison site; and
- Monument Creek surface water outside of the Parachute water treatment facility (MC-S3).

Field water quality measurements are presented in Table 4. A comprehensive table with all of the 2006 water sample laboratory results is presented as Table 5, and radionuclide analytical results are presented in Table 6.

2006 Annual Water Sampling Event

Cordilleran collected water samples from thirteen of the fourteen locations listed above on October 16 and October 17, 2006. The RS-W4 sample was collected by Cordilleran personnel from Grand Junction on Friday, October 20, 2006 due to snow and rain on October 17 making the road to the site impassible by pickup truck. The samples were submitted to Evergreen Analytical Laboratory in Wheat Ridge, Colorado for analysis of volatile organic compounds and inorganic compounds. Samples for tritium and gamma emitting radionuclides were submitted to Paragon Analytics in Fort Collins, Colorado, and the bacteria (BART™) samples were submitted to Grand Junction Laboratories, in Grand Junction, since Evergreen does not perform these analyses.

In the past Cordilleran has collected at least two duplicate samples selected at random to evaluate quality control/quality assurance (QA/QC) procedures at the laboratory by comparing the results for the duplicate with the original sample. These samples have not shown any significant differences, indicating that the laboratory results were reproducible.

This year, Cordilleran collected replicate samples which were sent to a different laboratory for the same analyses. Replicate samples were collected from Cary Weldon's well (sample id: CW-W902) and from Ethel Gardner's spring (sample id: EG-SP902), were submitted to ACZ laboratory in Steamboat Springs, Colorado for analysis. At the time of the sample analysis ACZ was not able to perform the radiochemistry analysis for tritium and gamma emitting radionuclides. ACZ subcontracted the radiochemistry analysis for these parameters to Paragon Analytics with Cordilleran's permission. ACZ assigned their own sample identification numbers to the replicate samples and filled out new chain-of-custody forms, so Paragon Analytics was not aware that Cordilleran had collected the samples.

A BART™ sample was not analyzed from Ethel Gardner's spring, either due to the sample inadvertently not being collected, or due to the sample being lost or broken in

transport to Grand Junction Laboratory. Laboratory analysis of BART™ samples collected from Ethel Gardner's spring during the previous two sampling events have indicated the presence of bacteria in similar population ranges as other water samples in the area.

Since the Savage well was sampled on a Friday and the samples were shipped to Evergreen Analytical for Saturday delivery, parameters such as nitrates, nitrites, and phosphates, that have short holding times, were analyzed outside of those holding times.

Cordilleran collected the 2005 Grand Valley Springs sample from the spring box shed since the chlorination unit had not been deactivated, and therefore the decision was made to collect the water sample from the top of the spring box "upstream" of the chlorination unit. However, Cordilleran later learned that this sample was only representative of one of the springs which was plumbed into the top of the spring box later, and that the other springs feed into the spring box from below the chlorination unit.

During the 2006 sampling event, Cordilleran collected the sample from the settling basin inlet pipe, even though the chlorination unit had not been deactivated, so the sample would be representative of all of the Grand Valley Springs. The DOE/EPA reportedly collects their Grand Valley Springs water sample from the settling basin inlet pipe and this is where Cordilleran had collected the 2004 baseline water sample. The chlorination process may affect the analytical results of some of the chemical and biological, but is not expected to affect the radionuclides. The analytical results for the BART™ test show that bacteria are absent or significantly reduced as compared with the other samples, and that the chloride and bromide suggest elevated concentrations above background levels as compared with the other samples.

2.4 Analyte List and Laboratory Parameters

In 2006 water samples were submitted to Evergreen Analtyical Laboratory (EAL) for analysis of BTEX and methane and inorganic parameters including metals, alkalinity, anions, and TDS. Water samples for radiochemistry analysis of tritium and gamma emitting radionuclides were submitted to Paragon Analytics. Water samples for BART™ analysis were submitted to Grand Junction Laboratories, Inc. Two replicate samples for all parameters except for BART™ analysis were submitted to ACZ Laboratories. ACZ Laboratories subcontracted the radiochemistry analysis to Paragon Analytics. The water samples collected from the Battlement Mesa area included analysis for the analytes listed in Table 2.

2.5 Well Completions

A review of information obtained from the Colorado Department of Natural Resources, State Engineer's Office, Division of Water Resources, indicates that the water wells in the Battlement Creek area are producing water from unconsolidated materials including

colluvium and alluvium. The water well depths range from 98 feet to 250 feet below ground surface. The well logs indicate that the wells are completed within the clays, silts, and basaltic or "volcanic rock" cobbles that comprise the mudflow and fan-gravel deposits described on the Geologic Map of the Rulison Quadrangle (Yeend, Donnell, Smith, 1988).

Two of the seven wells Cordilleran sampled were completed into bedrock. Mr. and Mrs. Weldon's well is completed to a depth of 98 feet, with a screened interval from 60 feet to 90 feet, producing water from a gravel interval at the interface with the Wasatch bedrock. The well was drilled eight feet into the Wasatch Formation to provide a sump. The well owned by Mr. and Mrs. Warren is completed to a depth of 250 feet below ground, with a screened interval from 215 feet to 240 feet, producing water from gravels at the bedrock interface, and ten feet into the Wasatch Formation, from 240 feet to 250 feet.

The remaining five wells sampled are completed entirely within the gravel-fan alluvium and colluvium, as are the springs present in the vicinity of the Project Rulison site. These water sources contain meteoric water, or relatively "young" groundwater, and may be directly or indirectly in communication with surface water from Battlement Creek and its tributary streams.

3.0 Laboratory Analytical Results

The following sections present the laboratory analytical data collected during PRESCO's 2006 annual water sampling event. Copies of the 2006 analytical results are presented in Appendix E. Stiff diagrams presenting a graphic representation of the major cations and anions are presented in Appendix F, and are plotted on Figure 3.

3.1 Radionuclides

Paragon Analytics laboratory analysis of water samples collected from the 14 locations indicated that tritium was not detected. Paragon Analytics laboratory results indicated that concentrations of gamma emitting were not detected in any of the 14 samples.

The laboratory has found a significant low bias for bismuth-214 and lead-214 or for samples where results are reported are qualified with a "J" value indicating that the activities values are estimated. Activity concentrations above the calculated MDC are reported as "tentatively identified," abbreviated "TI", in some instances where minimum nuclide identification criteria are not met.

3.2 Volatile Organic Compounds

The EAL laboratory analytical results indicated that concentrations of the volatile organic compounds benzene, toluene, ethylbenzene, and xylenes (BTEX), and methyl tertiary butyl ether (MTBE) were not detected in any of the 14 samples. Concentrations of methane were not detected in any of the samples.

3.3 Inorganic Compounds

The EAL laboratory analytical results indicated that concentrations of the metals calcium, iron, magnesium, manganese, potassium, selenium, and sodium were consistent with the results obtained during 2004 and 2005. Concentrations of boron were consistent with results obtained during 2005. The EAL laboratory analytical results for total hardness, total alkalinity, bicarbonate, nitrogen as ammonia, sulfate, and total dissolved solids (TDS) are consistent with results obtained during the 2004 and 2005 sampling events. Laboratory reporting varied for the analysis of nitrates, nitrites, and phosphates, or ortho-phosphorus so these parameters are not directly comparable to the 2004 and 2005 results but appear to be within the same general ranges. Concentrations of bromides, chlorides, and fluorides were consistent with results obtained during 2005. Concentrations of hydrogen sulfide were not detected in any of the samples.

Many natural factors can affect water quality; however, the primary factors include the water source, chemical composition of recharge water, the lithologic and hydrological properties of the source materials, and the length of time the water is in contact with these

materials. Stiff diagrams illustrate the ionic water quality data providing a visual comparison of the results for individual sample locations. Generally the water sample results indicate sodium bicarbonate type water. Surface water locations for Battlement Creek (USGS-BC1) and Hayward Creek (HC-S2) show less dissolved constituents than groundwater samples collected from area wells and springs. The stiff diagram for the sample collected from Monument Creek (MC-S3) indicates a higher concentration of dissolved solids, and is comparable to the stiff diagrams for the groundwater samples. The flow in Monument Creek has been much less than that for either Battlement Creek or Hayward Creek. The lower flow rates in Monument Creek may account for the higher ion concentrations. Springs recharged by water in contact with the upper part of the Wasatch Formation or water wells completed into the Wasatch Formation have the highest TDS and ion concentrations. The PRESCO stiff diagrams were generated using Rockworks™ v. 2004 and are plotted on Figure 3 and are included in Appendix F. A stiff diagram for sea water was generated using Zetaware 2003, trial version software downloaded from zetaware.com, and is provided for comparison, noting the difference in scale for the sea water sample as compared to the freshwater samples.

3.4 Bacteria Activity Reaction Tests

The Grand Junction Laboratory results for the BART™ analysis indicate similar population counts for individual sample locations as compared with the 2004 and 2005 results. The population counts for the three specific groups of bacteria also show similar trends as compared with the other samples collected during 2006. Populations of iron related bacteria typically range from 2,300 CFU/ml to 9,000 CFU/ml. Populations of sulfate reducing bacteria were typically low or absent in most of the groundwater samples, but were elevated to 700,000 CFU/ml in all three of the surface water samples. Populations of slime forming bacteria were reported from 12,500 CFU/ml to 350,000 CFU/ml. In general the surface water sample locations from Hayward Creek, Battlement Creek, and Monument Creek had higher bacteria population results.

4.0 Data Comparison and Evaluation

The following sections provide a narrative comparison and evaluation of the data collected during the 2006 sampling event with the 2004 baseline and the 2005 annual sampling event. This section also compares PRESCO's data (Table 5 and Table 6) with data collected during the earlier studies including data gathered by the USGS prior to and after Project Rulison, EPA data for water monitoring conducted for tritium and gamma emitting radionuclides, and data collected by the COGCC in 1998 for baseline water quality. Where possible a statistical analysis of these data sets is used for ease of comparison.

4.1 Tritium Results

From 1967 to 1971, the USGS completed an inventory and conducted hydrologic monitoring of all water wells, springs, and surface water resources within a ten mile radius of Project Rulison.

The tritium results were reported in tritium units, with only three detections out of 28 select wells, springs, and cistern sample results, and the remaining 25 samples less than 220 TU, or approximately 710 pCi/L. The maximum tritium detection was 323 TU (1037 pCi/L). Out of 31 surface water samples, ten samples had detectable activities of tritium with a maximum tritium concentration of 430 TU (1390 pCi/L), and the rest were less than 220 TU.

Hazen Research analyzed the 2004 baseline samples for tritium and reported that tritium concentrations were not detected above the detection limit. Results plus or minus the detection limit were provided as an estimate of tritium activity. Paragon indicated that tritium was not detected above the MDA in any of the water samples collected during the 2005 annual sampling event. Both laboratories analyzed the water samples by the conventional method, which has a MDA of approximately 200 pCi/L to 400 pCi/L. Although estimated results are not accurate below the MDA, a comparison is presented below

Data Set	Maximum H3 (pCi/L)	Average H3 (pCi/L)	Median H3 (pCi/L)	Total Number of Samples
PRESCO (2yr)	580 ± 460 (1,040)	438	310	30
USGS (2 yrs)	1,390	983 1017	954 890	Groundwater: 28 Surface water: 31
EPA/DOE (32 yrs)	1,310	161	97.5	432

The maximum reading was 580 pCi/L, which would be in the range of the highest results obtained by the USGS and EPA. These values are well below the EPA drinking water

standard of 20,000 pCi/L. The tritium results for samples collected during PRESCO's 2004 baseline through 2006 annual water sampling events are presented in Table 5 and Table 6.

The USGS sample results for tritium indicate higher concentrations because of the time frame during which they were collected. Global atmospheric tritium concentrations were higher because of aboveground nuclear testing and have been decreasing back toward natural, background concentrations since test ban treaties went into effect.

4.2 Alpha Radiation and Beta Radiation Screening Results

The USGS screened six of the groundwater samples for gross beta and gross alpha radiation, which indicated that the highest gross beta radiation count was 8 pCi/L, and the highest alpha radiation count was 10 pCi/L. The EPA public drinking water MCL for alpha radiation is 15 pCi/L above background, and beta radiation dose of 4 mrem annually. The concentration of a particular radionuclide resulting in a dose of 4 mrem is dependent on the radionuclide.

The DOE and EPA screened water samples for gross alpha and gross beta radiation as part of the annual sampling events from 1972 until 1978. The maximum alpha radiation recorded was 14 pCi/L. The average reading for alpha radiation was 3.77 pCi/L and the median alpha radiation was 2.8 pCi/L. The maximum beta radiation was 7 pCi/L, with an average beta radiation reading of 2.75 pCi/L, and a median beta radiation reading of 3.5 pCi/L. These activity levels are consistent with terrestrial background radiation.

PRESCO did not request laboratory analysis of gross alpha radiation or gross beta radiation; however, the samples were screened by Paragon upon arrival as a routine protocol for receiving samples for radionuclide analysis and the screening did not indicate the presence of radioactivity above background levels. The screening levels recorded on the laboratory sheets ranged from 15 pCi/L to 16 pCi/L. PRESCO did not request analysis for alpha radiation or beta radiation since it has not been performed by the EPA as part of the annual water sampling since the mid-1970s.

4.3 Gamma Spectrometry Results

The DOE and EPA have conducted gamma spectrometry analysis and have not detected levels of gamma radioactivity in any of the water samples collected annually since 1972. The 2006 analytical results from Paragon indicate that gamma emitting radionuclides were not detected in any of the 14 water samples submitted. The laboratory reported a "low bias" in the analysis for bismuth-214 (Bi-214) and lead-214 (Pb-214) for which it provided estimates below the MDC.

In two of the water samples (CW-W2 and CK-W5), low levels of thallium-208 (Tl-208), and in one sample (EG-SP2) iron-59 (Fe-59), were reported as "tentatively identified."

According to the Paragon Analytics Radiochemistry Case Narrative for the gamma spectroscopy, radionuclides are reported as tentatively identified where minimum nuclide identification criteria were not met. Thallium-208 has a half-life of 3 minutes, and iron-59 has a half-life of 44 days, which means that half the material present decays in this time. Therefore, they cannot be related to Project Rulison. Thallium-208, if present, in low activities, is a gamma emitting daughter product resulting from the decay series of naturally occurring radon, uranium, or thorium. Iron-59 is produced by a double neutron reaction with Iron-54, which is a stable isotope.

The analytical results for samples collected during PRESCO's 2004 baseline and 2005 annual sampling indicate that low, background levels of naturally occurring radionuclides, such as the daughter products of uranium or thorium decay series, were present in a few of the samples. The results for the gamma spectrometry analysis are presented in Table 6.

These radionuclides are very different from fission products that result from the detonation of a man-made nuclear device. According to the EPA 2004 Annual Report, "*most of the sampling locations at the Project Rulison site are shallow, drawing water from the surficial aquifer, and therefore, unlikely to become contaminated by radionuclide migration from the Project Rulison cavity* (Davis and Houston, 2004)." Additionally, the report states "*All routine samples were analyzed for presence of gamma-ray emitting radionuclides*" and the accompanying Table 3 in the EPA 2004 annual report indicates that none were detected (ND).

4.4 Volatile Organic Compound Results

The 2006 water quality samples were analyzed for BTEX, MTBE, and methane. Concentrations of BTEX and MTBE were not detected in any of the 14 water samples submitted to Evergreen Analytical Laboratory. Concentrations of methane were also not detected above the laboratory lower quantitation limit (LQL). Cordilleran submitted two replicate samples (CW-W902 and EG-SP902) to ACZ Laboratories. The ACZ results for BTEX and MTBE indicate that these compounds were not detected. However, ACZ Laboratories qualified the results for these samples noting that they exceeded holding time for these parameters. Methane concentrations were not detected in either of the samples analyzed by ACZ.

Concentrations of BTEX, MTBE, and methane were not detected in the majority of PRESCO's 2004 baseline and 2005 annual water quality samples. Low levels of the BTEX compounds were detected in one sample submitted to ACZ in 2004, and in a few of the samples submitted to Paragon Analytics in 2005. It should be noted that benzene was detected in the Paragon Analytics method blank associated with the October 2005

analyses. Paragon also exceeded holding times on one of the water samples and on the trip blanks accompanying the samples which were run after midnight on the fourteenth day. Subsequent samples were collected from these locations and were submitted to Evergreen Analytical Laboratory in December 2005. The Evergreen Analytical results indicated that BTEX concentrations were not detected. None of the reported BTEX concentrations exceeded maximum contaminant levels (MCLs).

The COGCC analyzed water samples for BTEX, butane, ethane, hexane, methane, pentane, and propane as part of its 1997 to 1999 sampling program. A total of 21 samples were analyzed for BTEX. With the exception of some low concentrations of toluene at or below the MCL in six of the samples, the results indicated that BTEX compounds were not detected. The COGCC analyzed a total of 20 samples for methane, and the results indicate that methane was not detected. The results also indicated that butane, ethane, hexane, pentane, and propane were not detected in any of the samples. A statistical comparison for the volatile organic compounds was not practical since most of the results were "non-detect" and because the USGS and DOE/EPA did not analyze for these compounds. The laboratory analytical results for the volatile organic compounds are presented in Table 7.

4.5 Inorganic Compound Results

The values obtained as laboratory results for PRESCO's 2006 annual sampling event and laboratory results for the 2004 baseline sampling event and 2005 annual sampling event, for inorganic parameters, total metals or cations, anions, and TDS are included in Table 8. The anion and cation balance results are presented in Table 9.

The following section presents a comparison of the 2006 sample inorganic results with PRESCO's 2004 baseline and 2005 annual sampling water results with results from the USGS, EPA, and COGCC studies. The data sets are consistent with one another with the exception of some of the data obtained from the DOE/EPA for iron and calcium which appear anomalous. These may represent a difference in analytical method that was run such as dissolved phase metal concentrations rather than total metals concentrations.

Samples may be analyzed for total metals concentrations or dissolved metals concentrations. For total metals analysis, the samples must be digested prior to analysis to ensure the elements of interest are extracted from the sample. Samples for total metals are placed into plastic bottles containing a small amount of nitric acid. For dissolved metals analysis, the sample is filtered through a 0.45 millimeter polycarbonate membrane or fluorocarbon filter. The filtrate is acidified with purified nitric acid to a pH of less than 2 for preservation of metal species. If precipitates develop after filtration and addition of acid, the filtered sample must be digested as for total metals. The samples for PRESCO were analyzed for total metals concentrations.

The statistical average and median values have been calculated for each parameter including metals/cations, anions, and water quality parameters for ease of comparison between the data sets. Typically the average and median values fall within the same range of numbers for each of the data sets, however, Cordilleran does not warrant and cannot verify the accuracy of other agency results. In most cases the data was presented in reports or as tables, and the laboratory data was not included.

Cations, Anions, and Water Quality Parameters

The following inset tables present the cations (metals) and anions results for the historic sampling that has been conducted as compared with samples collected for PRESCO since 2004. The following table presents the mean value, median value, and standard deviation for metals analysis performed on the water samples for the water quality studies.

Cations

Data Set	Boron (mg/L)	Calcium (mg/L)	Iron (mg/L)	Magnesium (mg/L)	Manganese (mg/L)	Potassium (mg/L)	Selenium (mg/L)	Sodium (mg/L)
USGS 1969	13 samples	25 sample	30 sample	24 samples	13 samples	13 samples	13 samples	13 samples
Mean	0.16	59.4	0.16	26.7	0.025	2.96	< 0.1	83.8
Median	0.07	66	0.04	29	0.02	3.4	< 0.01	25
Standard Deviation	0.2	26.7	0.52	12.0	NC	0.9	NC	200.9
DOE/EPA 1974-77	0 samples	25 samples	25 sample	25 samples	25 samples	25 samples	0 samples	25 samples
Mean	NA	28.4	103.1	26.4	75.3	2.19	NA	42.06
Median	NA	22	100	30	100	2.25	NA	47
Standard Deviation	NA	17.8	11.7	13.3	NC	0.97	NA	29.4
COGCC 1997-99	0 samples	57 samples	57 sample	57 samples	57 samples	57 samples	57 samples	57 samples
Mean	NA	51.7	0.09 (d)	36.8	0.0078 (d)	2.58	NA	65.02 (d)
Median	NA	51.4	0.02 (d)	36.4	0.007 (d)	2.35	NA	50.8 (d)
Standard Deviation	NA	23.94	0.12 (d)	16.67	NC	1.08	NA	60.8 (d)
PRESCO 2004-06	33 samples	48 samples	48 sample	48 samples	48 samples	48 samples	48 samples	48 samples
Mean	0.17	52.6	3.25	36.57	0.027	2.52	0.006	53.2
Median	0.14	47.6	0.19	30.1	0.015	1.7	0.005	45.8
Standard Deviation	0.069	24.4	9.64	27.6	NC	2.0	NC	43.4

Notes: mg/L – milligrams per liter

NA – Not Analyzed

NC – Not Calculated (The majority of results were below laboratory lower detection limit)

(d) – dissolved metals concentrations (rather than total metals concentrations)

Anions

The following table presents the mean value, median value, and standard deviation for inorganic parameter analysis performed on the water samples for the water quality studies.

Data Set	Bicarbonate (mg/L)	Carbonate (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Nitrate/Nitrite (mg/L)	Phosphate (mg/L)	Sulfate (mg/L)
USGS 1969	37 samples	37 samples	13 samples	13 samples	13 samples (NO_3)	13 samples	13 samples
Mean	380.05	0.68	11.15	0.22	10.5	< 0.01	137
Median	411	0	8.5	0.2	9	< 0.01	39
Standard Deviation	134.2	NC	9.63	0.14	8	NC	309.5
DOE/EPA 1974-77	0 samples	0 samples	25 samples	25 samples	25 samples	25 samples	25 samples
Mean	NA	NA	6.8	0.53	1.08	0.006	36.16
Median	NA	NA	5.35	0.4	0.28	0.002	29
Standard Deviation	NA	NA	5.9	0.57	1.17	0.007	32.09
COGCC 1997-99	57 samples	57 samples	57 samples	57 samples	57 samples	0 samples	57 samples
Mean	322	18.63	8.58	0.38	1.4 (d)	NA	76.09
Median	322	< 2	5	0.4	1.2 (d)	NA	30
Standard Deviation	55.98	NC	9.28	0.14	1.18	NA	173.8
PRESCO 2004-06	48 samples	15 samples	33 samples	33 samples	29 samples	29 samples	48 samples
Mean	267.8	0	6.09	0.32	0.67	0.09	113.9
Median	306	0	2.7	0.32	0.32	0.07	56
Standard Deviation	87.9	NC	10.6	0.13	0.71	NC	214

Notes: mg/L – milligrams per liter

NA – Not Analyzed

NC – Not Calculated (Majority of Results were below the laboratory lower detection limit)

NO_3 – Only nitrates were measured

(d) – dissolved concentrations measured rather than total

The results for cations and anions show similar results for each of the data sets, with the exception of iron in the DOE/EPA data set which appears to be anomalous, because most of the readings were 100 mg/l. The calcium values reported by the DOE/EPA are also lower than those reported in the other three data sets, but overall most of the parameters fall within similar ranges. The COGCC reportedly analyzed for dissolved phase metals rather than total metals; however, this does not appear to have caused a significant difference in the reported concentrations for most parameters.

Other water quality parameters, such as hardness, total dissolved solids, and pH, are also consistent between the individual data sets. The average and median values for these parameters are presented on the inset table on the following page. The data from the USGS, DOE/EPA, the COGCC, Town of Parachute and Battlement Mesa Metro District and PRESCO are presented in Appendix A, Appendix B, and Appendix C, Appendix D, and Appendix E respectively, and Stiff diagrams for the 2006 data are in Appendix F.

Water Quality Parameters

Data Set	Hardness as CaCO3 (mg/L)	Total Alkalinity (mg/L)	Nitrogen as Ammonia (mg/L)	pH (Standard Units)	Total Dissolved Solids (mg/L)	Residue, Filterable (TDS) @180 (mg/L)
USGS 1969	22 samples	0 samples	0 samples	34 samples	0 samples	26 samples
Average	274.5	NA	NA	7.86	NA	485
Median	322	NA	NA	7.75	NA	424
Standard Deviation	92.6	NA	NA	0.78	NA	440
DOE/EPA 1974-77	0 samples	25 samples	25 samples	0 samples	25 samples	0 samples
Average	NA	258.8	0.022	NA	312.3	NA
Median	NA	240	0.019	NA	330	NA
Standard Deviation	NA	137.5	NC	NA	124.4	NA
COGCC 1997-99	57 samples	57 samples	0 samples	57 samples	57 samples	57 samples
Average	18.63	323.4	NA	7.9 (l)	394.7	449.6
Median	17.5	331	NA	7.9 (l)	379.5	395
Standard Deviation	NC	58	NA	0.28	80.9	311.4
PRESCO 2004-06	15 samples	29 samples	29 samples	29 samples	0 samples	48 samples
Average	305.13	268	< 0.1	7.86 (f)	NA	462.5
Median	269	306	< 0.1	7.83 (f)	NA	396.5
Standard Deviation	165.4	94.07	NC	0.42	NA	370.5

Notes: mg/L – milligrams per liter
TDS – total dissolved solids
NA – Not Analyzed
NC – Not Calculated
(l) – laboratory measured pH
(f) – field measured pH using a HACH Quanta Water Quality Meter

4.6 Bacteria Results

The BART™ results indicate that elevated numbers of iron related and slime forming bacteria are present in the water at the sample locations. The surface water locations show the highest numbers of bacteria colonies and the springs typically had higher numbers of bacteria colonies than the wells. Sulfate reducing bacteria were generally present in low populations or were absent in the water samples. The Grand Junction Laboratories results are presented in Table 10.

Owners of wells and springs were informed that the presence of bacteria in the water samples indicate that these bacteria could cause problems with water quality and water quantities produced from the wells or springs if corrosion or clogging of equipment should occur. The owners were advised to contact a licensed water well contractor to treat the well or spring if there is a change in water quality or diminished water capacity.

Bacteria analyses data were not presented in the USGS, DOE/EPA, or COGCC water quality studies. The Town of Parachute and Battlement Mesa Metro District analyzed samples for total colliform bacteria, which is different from the BART™ analysis. The presence of high concentrations of certain bacteria may generate methane, as biogenic methane. In rare instances certain bacteria may thrive in the presence of thermogenic methane, or methane gas created as a result of geologic processes.

Due to the change in bacteria populations the chemistry of the water in the well will also change, resulting in production of hydrogen sulfide gas (H_2S) or result chemical precipitates such as iron sulfide or manganese sulfide. Sulfides were not detected, manganese was either not detected or was reported at concentrations slightly above the laboratory detection limit. Similarly, the laboratory reported low concentrations of iron.

5.0 SUMMARY

The following is a summary of the results of the 2006 water quality sampling event

- Concentrations of tritium were not detected in water samples collected during PRESCO's 2006 annual water sampling event. Concentrations of tritium at background levels are well below the laboratory MDL, or what the laboratory can accurately quantify using the conventional method of analysis. The conventional method MDL of approximately 330 pCi/L is well below the EPA drinking water standard for tritium of 20,000 pCi/L. According to the EPA 2004 Annual Report, "*tritium concentrations collected onsite and offsite are consistent with those of past studies at the Project Rulison Test Site. In general, the current level of tritium in these shallow wells cannot be distinguished from the rain-out of naturally produced tritium augmented by, perhaps, a small amount of residual global "fallout tritium" remaining from nuclear testing in the 1950s and 1960s.*"

- Concentrations of gamma emitting radionuclides related to the Project Rulison Test Site were not detected in water samples collected during the 2006 annual water sampling event. The laboratory reported a "low bias" in the analysis for bismuth-214 (Bi-214) and lead-214 (Pb-214) for which it provided estimates below the MDC.

  In two of the water samples (CW-W2 and CK-W5), low levels of thallium-208 (Tl-208), and in one sample (EG-SP2) iron-59 (Fe-59), were reported as "tentatively identified." According to the Paragon Analytics Radiochemistry Case Narrative for the gamma spectroscopy, radionuclides are reported as tentatively identified where minimum nuclide identification criteria were not met. Thallium-208 has a half-life of 3 minutes, and iron-59 has a half-life of 44 days, which means that half the material present decays in this time. Therefore, they cannot be related to Project Rulison. Thallium-208, potentially present in low activities, is a gamma emitting daughter product resulting from the decay series of naturally occurring radon, uranium, or thorium. Iron-59 is produced by a double neutron reaction with Iron-54, which is a stable isotope. These radionuclides are very different from fission products that result from the detonation of a man-made nuclear device. According to the EPA 2004 Annual Report, "*most of the sampling locations at the Project Rulison site are shallow, drawing water from the surficial aquifer, and therefore, unlikely to become contaminated by radionuclide migration from the Project Rulison cavity* (IT Corporation, 1996)." Additionally, the report states "*All routine samples were analyzed for presence of*

gamma-ray emitting radionuclides" and the accompanying Table 3 in the EPA 2004 annual report indicates that none were detected (ND).

- The Evergreen Analytical Laboratory analytical results indicate that concentrations of BTEX, MTBE, and methane were not detected in any of the water quality samples.
- The Evergreen Analytical Laboratory results indicate that inorganic parameters, such as metals, anions, and other water quality parameters, such as total dissolved solids (TDS), were consistent with results for samples collected during the 2004 baseline sampling and 2005 annual water sampling. Generally, water is of a bicarbonate type chemistry which is common in the region. Sodium bicarbonate (bicarbonate of soda or baking soda) has been mined from the Green River Formation in the Parachute Creek Valley to the north of Battlement Mesa. High TDS and sulfate concentrations are likely the result of water from the Wasatch Formation. The concentrations of sulfate are likely to be due to the presence of hydrous calcium sulfate also known as gypsum. The TDS is a measure of dissolved salts, whether they be chlorides, carbonates, sulfates, nitrates, etc.
- The Grand Junction Laboratories, Inc. results for the BART™ analysis indicate similar results for iron related bacteria, sulfate reducing bacteria, and slime forming bacteria as observed in the previous sampling events. High numbers of bacteria, reported in colony forming units per milliliter of water (CFU/ml), may affect water quality (odor or taste), corrode or clog well screen, pumps, and/or plumbing, and could potentially cause illness. Water well owners or spring owners should contact a licensed water well contractor to address these issues.

6.0 Recommendations

PRESCO and Cordilleran wish to thank all of the private water well owners, and the private and municipal spring owners who participated in PRESCO's 2006 water sampling event. With continued access to these water resources PRESCO will continue these annual sampling efforts. PRESCO intends to continue to provide well and spring owners who participate in the sampling events with a copy of the analytical results for their water source.

Additionally PRESCO will perform the following actions to further reduce the potential for impact to water resources:

- PRESCO, Inc. will set additional conductor casing to a minimum depth of 100 feet on wells drilled from the 36-23 pad (this includes current permits 36-24, 36-14, 36-22) and wells drilled from the 36-31 pad (this includes current permit 36-31.) These pads have been identified as being located on the alluvial/colluvial basaltic boulder deposit;
- A high quality cement job will be achieved on the conductor casing on all wells near the Project Rulison site or Battlement Creek drainage;
- When drilling the surface holes on these wells, fluid loss will be closely monitored and loss circulation sweeps will be used to control any seepage;
- PRESCO's annual water quality monitoring will continue; and
- Monitoring will continue to be performed during the drilling of gas wells.

PRESCO conducted monitoring activities natural gas well drilling and gas production in 2006 which will be described in a separate report. These activities included screening the drill cuttings using a Geiger Mueller meter, placing thermoluminescent dosimeter badges on the drill rig and equipment during the drilling activities, collecting samples of the produced water for tritium and gamma emitting radionuclide analysis, and collecting samples of the natural gas for analysis of tritium and carbon-14.

Cordilleran recommends that the list of analytes for water quality for the original 14 sample locations be reduced to the following list of analytes:

- Tritium;
- Gamma Emitting Radionuclides;
- BTEX;
- Methane; and
- TDS.

These analytes include the radionuclides of interest and the analytes that would indicate impacts were occurring from natural gas drilling operations in the area. Although no radionuclides or petroleum hydrocarbon impacts are expected to be encountered, these are the parameters of greatest interest and should continue to be monitored. Reducing the number of parameters will simplify the reporting.

PRESCO has performed three rounds of sampling which show that the cations and anions have not changed significantly from the 2004 baseline sampling results, and they are consistent with the results obtained during previous studies. The above list will provide data for the radionuclides of interest, and will indicate changes in water quality.

If laboratory analytical results for the above listed analytes show changes, or if new sampling locations are added, water samples will be analyzed for the full suite of analyses.

7.0 REFERENCES

Davis, Max G., and Houston, Rose (Kitty), Annual Water Sampling and Analysis, Calendar Year 2004, EPA-402 R-04-006, November 2004, Prepared for the U.S. Department of Energy, under Interagency Agreement DE-AI08-96NV1196, 22 p.

IT Corporation, Preliminary Site Characterization Report, Rulison Site, Colorado, ITLV/10972—177 UC-700, August 1996, Performed for the U.S. DOE by Contract No.: DE-AC08-96NV10972, p. 153

Johns, L.S., Sharfman, P., Shaw A. et al, The Containment of Underground Nuclear Explosions, U.S. Congress, Office of Technology Assessment, OTA-ISC-414, (Washington, D.C., U.S. Government Printing Office, October 1989), p.90

Little, Craig, Ph.D., TetraTech (MFG, Inc.) Consulting Scientists and Engineers, personal communication, 2006

Macke, Brian J., Project Rulison Study Colorado Oil and Gas Conservation Commission, May 5, 1998, 8 p.

Robson, S.G. and Banta, E.R., Groundwater Atlas of the United States, Segment 2, Arizona, Colorado, New Mexico, Utah, USGS Hydrologic Investigations Atlas 730-C, Reston, Virginia, 1995, 32 p., illus.

Scott, Cindy, COGCC Water Quality Database extracted data tables on 09/21/04 for samples collected in Townships 6 South and 7 South, Range 95 West, Sixth Prinicipal Meridian.

Thalgott, R.H. NV, Test Manager, and Allaire, W.W., Deputy Test Manager, et al, Project Rulison Manager's Report, April 1973, NVO-71, United States Atomic Energy Commission, Nevada Operations Office, Las Vegas, Nevada, p. 247

Voegeli, P.T., Sr., and West, S.W., and Cordes, E.H., Geohydrology – Project Rulison, Garfield County, Colorado with a Section on Aquifer Response, Open-file report USGS 70-353, 474-68, March 1970, 53 p., 11 figs.

Voegeli, P.T., Sr., Claassen, H.C., Radiochemical Analyses of Water from Selected Streams, Wells, Springs, and Precipitation Collected Prior to Reentry Drilling, USGS Open File Report 71-312, 1971, 15 p. illus.

Yeend, W.E.,; Donnell, J.R.; Smith, M.C., Geologic Map of the Rulison Quadrangle, Garfield County, Colorado, USGS Miscellaneous Field Studies Map MF260, 1988, scale 1:24,000