Geochemical and Isotopic Analysis of Groundwater at the Burn Site Area of Concern, Sandia National Laboratories/New Mexico

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This report summarizes results for a groundwater-sampling event conducted at the Burn Site during October and November 2015. Ten (10) monitoring wells at the site were sampled for various inorganic and organic constituents during the groundwater-sampling event. Analytical data collected as part of this investigation are used to determine or refine the source(s) of nitrate plus nitrite detected in groundwater at the site. Analytical suites consisted of major cations and anions, total organic carbon, diesel range organic compounds, gasoline range organics, perchlorate, low-detection level tritium, ammonia, stable isotopes of hydrogen, nitrogen and oxygen, and cations/trace elements. Detectable activities of tritium measured at several monitoring wells verify that recent recharge has taken place since the early 1950s. Stable isotopes of nitrogen and oxygen in nitrate are useful tracers to determine if residual nitrogen in the form of nitrate-nitrite is or is not produced from incomplete combustion of high explosive compounds and/or dissociation of ammonium nitrate. Concentrations of dissolved nitrate plus nitrite (as N) in groundwater range from 0.2 to 34 milligrams per liter (mg/L) at the Burn Site during fall of 2015.

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Executive Summary

The Burn Site Groundwater (BSG) Area of Concern (AOC), located in Lurance Canyon within the Manzanita Mountains, New Mexico, is within the eastern boundaries of both the Department of Energy (DOE) Sandia National Laboratories/New Mexico (SNL/NM) and U.S. Air Force (USAF) Kirtland Air Force Base (KAFB). Research conducted at the BSG AOC consisted of testing fire survivability of transportation containers, weapons components, simulated weapons, and satellite components. Groundwater samples were collected from the BSG AOC during October to November 2015 and analyzed for nitrate plus nitrite, ammonium-ammonia, Total Kjeldahl nitrogen (TKN), cations and anions, perchlorate, gasoline range organic (GRO) compounds, diesel range organic (DRO) compounds, low-detection level tritium, and stable isotopes of hydrogen, nitrogen, and oxygen.

Concentrations of nitrate plus nitrite (as N) above local background (<5 milligrams/liter, mg/L) occur with the source area at the Burn Site. Concentrations of nitrate plus nitrite (as N) in groundwater range from 0.2 to 34 mg/L. Sources of nitrate plus nitrite include components of both a natural origin (soil nitrogen in the vadose zone) and an anthropogenic origin possibly resulting from nitrification processes with explosive compounds. Nitrogen isotope composition of groundwater ($\delta^{15}N$ ranging from +2.22 to +11.20 permil) suggest that nitrification processes have taken place and that denitrification only occurs to a limited extent under aerobic conditions with dissolved oxygen (DO) concentrations typically greater than 4 mg/L. Excess N_2 gas concentrations in Burn Site groundwater were generally low to non-detect in noble gas studies conducted by Madrid et al. (2016), indicating that denitrification is not widely occurring.

Downward vertical flow paths through the fractured and faulted vadose zone to the bedrock aquifer(s) are collocated with a nitrogen source resulting in a nitrate plus nitrite plume. Concentrations of total organic carbon (TOC) above background (>0.3 milligrams carbon/liter, mgC/L) occur within the source area along with elevated concentrations of nitrate plus nitrite. The chemical composition, structure, and reactivity of TOC in groundwater are not known.

Activities of tritium are less than analytical detection (<0.29 picocuries/liter, pCi/L) and concentrations of nitrate plus nitrite (as N) are less than 5 mg/L at background and noncontaminated, downgradient sampling stations. Nondetect activity of tritium in submodern groundwater confirms that recent recharge (post early 1950s) has not taken place outside of the source area. Groundwater with detectable activity of tritium have both mixed and/or modern ages, and recent recharge has taken place in the source area since the early 1950s. Sources of modern recharge water most likely include precipitation and water used for fire suppression at the Burn Site. Active or present day recharge occurs at the site based on long-term monitoring data collected by SNL/NM and New Mexico Environment Department (NMED).

## 1. *Site Conditions and Scope of Investigation*

The BSG Area of Concern (AOC) is located in Lurance Canyon within the Manzanita Mountains, north-central New Mexico (SNL 2016). Figure 1 shows the location of the BSG AOC and surrounding area southeast of Albuquerque, New Mexico. This site is located within the eastern boundaries of both SNL/NM and KAFB. Research conducted at the BSG AOC consisted of testing fire survivability of transportation containers, weapons components, simulated weapons, and satellite components (SNL 2016). Open detonation of high explosive (HE) compounds and open burning of HE compounds, liquid propellants, and solid propellants were conducted at the BSG AOC mostly between 1967 and 1975. High explosive compounds combusted at this site included hexahydro-1,3,5-trinitro-1,3,5-triazine or RDX (Research Department Explosive), 2,4,6-trinitrotoluene (TNT), and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocene or HMX (High Melting Explosive). High explosive testing was completely eliminated by the mid- to late-1980s at the Burn Site. Groundwater at the BSG AOC is characterized by elevated concentrations of nitrate plus nitrite (as N) that exceed local background within a fractured bedrock aquifer(s), consisting of Precambrian metasediments and granitic gneiss (SNL 2016).

Initial burn testing of explosive materials was conducted in unlined pits excavated several feet into unconsolidated soil and sediments at the BSG AOC. Portable steel burn pans were used for open burning by 1975, mainly using jet propellant, fuel grade 4 (JP-4). Several engineered structures, including the Light Air Transport Accident Resistant Container Unit, were constructed and used at the Burn Site (SNL 2016). The structures mostly used JP-4. Occasionally diesel fuel and gasoline were added to produce high temperatures representing automobile-truck transportation accidents. Jet propellant, fuel grade 8 (JP-8) replaced JP-4 in the mid-1980s as the petroleum fuel used for burn tests. Most test structures have been dismantled and the only test cell is the Fire Laboratory for Accreditation of Modeling by Experiment. Portable burn pans up to 25 feet in diameter are occasionally used (SNL 2016).

This report summarizes results for a groundwater-sampling event conducted at the BSG AOC, starting on October 19, 2015 and ending on November 9, 2015, by the NMED DOE Oversight Bureau (DOE-OB) in coordination with SNL/NM. Ten (10) monitoring wells (designated CYN-MW) at the site were sampled for various inorganic and organic constituents during the groundwater-sampling event. This included one background (up/crossgradient) station (CYN-MW4), six source area stations (CYN-MW9, CYN-MW10, CYN-MW11, CYN-MW12, CYN-MW14A, and CYN-MW15), and three downgradient stations (CYN-MW7, CYN-MW8, and CYN-MW13). Analytical data collected as part of this investigation are used to determine or refine the source(s) of nitrate plus nitrite detected in groundwater at the site. Analytical suites consisted of major cations/trace elements and anions, ammonia, total organic carbon (TOC), DRO compounds, GRO compounds, perchlorate, low-detection level tritium, and stable isotopes of hydrogen, nitrogen and oxygen to

help determine the source(s) of nitrate plus nitrite (as N) measured in groundwater at the BSG AOC. Detectable activities of tritium measured at several monitoring wells in the BSG AOC verify that recent recharge has taken place since the early 1950s. Stable isotopes of nitrogen and oxygen in nitrate are useful tracers to determine if residual nitrogen in the form of nitrate-nitrite is or is not produced from incomplete combustion of HE compounds and/or dissociation of ammonium nitrate. Concentrations of dissolved nitrate plus nitrite (as N) in groundwater range from 0.2 to 34 mg/L at the BSG AOC during fall of 2015.

Figure 1. Location Map of the Burn Site Groundwater Area of Concern, Sandia National Laboratories/NM and Kirtland Air Force Base, New Mexico (SNL 2016).
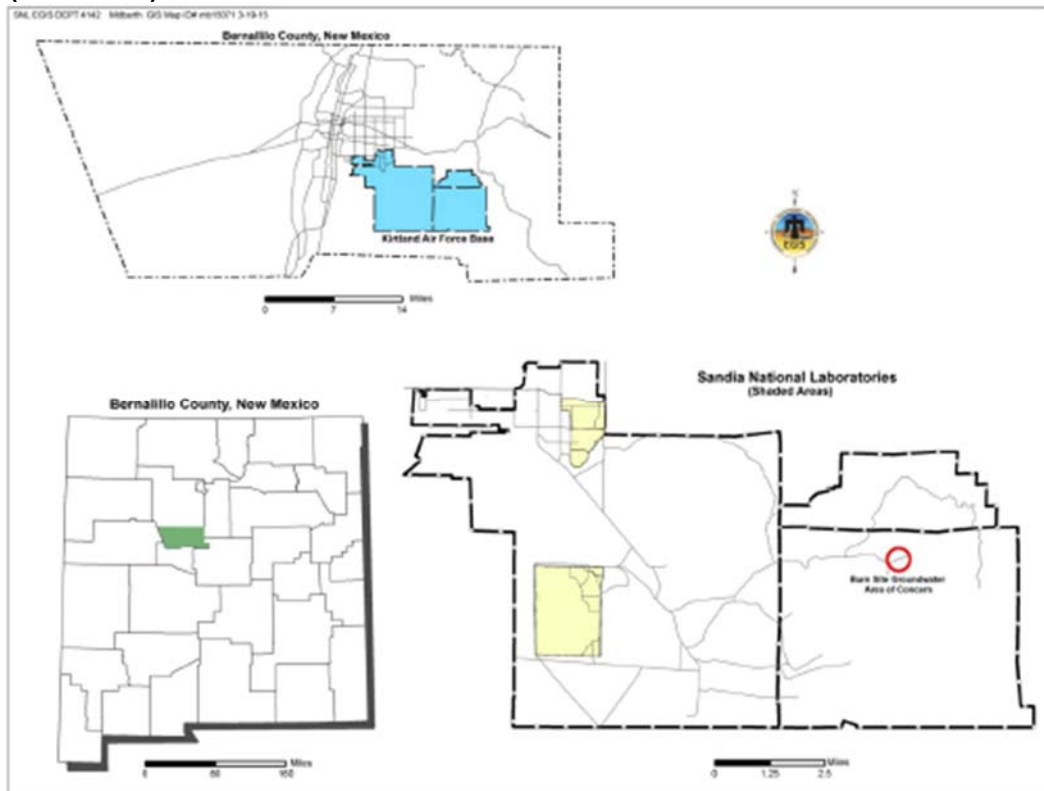
2. *Field Procedures, Analytes, and Analytical Methods*

This section presents a discussion on field procedures, inorganic and organic analytes, and Environmental Protection Agency (EPA)-approved well purging and sampling protocols and analytical methods for groundwater sampling the BSG AOC by NMED and SNL/NM. Groundwater samples (filtered, 0.45 μm, and non-filtered) were submitted to different external NMED laboratories for chemical and isotope analyses on groundwater samples collected from ten monitoring wells located at the Burn Site. Analyte suites, analytical methods, and quality control samples collected at the BSG AOC were evaluated by SNL/NM and the DOE-OB prior to sampling conducted during October to November 2015. Splits of

groundwater samples were collected from the monitoring wells by NMED and SNL/NM for chemical analyses for various inorganic and organic constituents.

All wastewater produced from pumping monitoring wells installed at the BSG AOC was placed into 55-gallon open head poly-drums (OHPD) and stored at SNL/NM, Building 9925 accumulation area. Waste management practices routinely implemented by SNL/NM typically require that purge groundwater extracted from monitoring wells and pumped decontaminated water are containerized into separate drums and managed as "Non-Hazardous Waste."

2.1 Field Methods and Measurements

Field measurements recorded during sample collection and preservation prior to performing laboratory analyses were conducted in complete conformance with updated field operating procedures written by the SNL/NM and NMED staff.

2.11 Equipment Decontamination

A portable Bennett pump provided by SNL/NM was used to extract groundwater from monitoring wells at the BSG AOC. The Bennett sampling pump and tubing bundle are decontaminated prior to installation at each monitoring well, according to procedures stated in "Groundwater Monitoring Equipment Decontamination" developed and implemented by SNL/NM (SNL/NM FOP 05-03).

2.12 Monitoring Well Purging

The Bennett pump intake was set near or at the bottom of the screen interval in each monitoring well. Monitoring well CYN-MW11 has a large water column, and due to buoyancy issues additional weight (stainless steel slug) was attached to the sampling system when lowering the pump to the sample depth. A minimum flow rate, given limitations of equipment and well characteristics, was required for all purging and sampling activities.

In accordance with procedures described in "Groundwater Monitoring Well Sampling and Field Analytical Measurements" (SNL/NM FOP 05-01), each monitoring well is purged for a minimum of one saturated casing volume, which is defined as the volume of one length of the saturated screen plus the borehole annulus around the saturated screen interval. Stability of groundwater quality parameters was maintained prior to collecting groundwater samples. Purging of each monitoring well continues until four stable measurements are recorded for turbidity, pH, temperature, and specific conductance (SC) prior to collecting, filtering, and preserving the samples. Groundwater stability is considered acceptable and representative when turbidity measurements are less than 5 nephelometric turbidity units (NTU), or within 10 percent for elevated turbidity values greater than 5 NTU, 0.1 pH units, 1.0 degree Celsius, and SC is within 5 percent. Additional field parameters collected at all monitoring wells included oxidation-reduction potential (ORP) and DO. Dissolved oxygen is reported by SNL/NM in both percent saturation and in concentration units of mg/L. In addition, groundwater level measurements are collected during purging and recorded on

the field measurement log by SNL/NM. During October to November 2015, the depths to groundwater varied from 89 to 326 feet below ground surface (SNL 2016) at the site. Monitoring wells CYN-MW3 and CYN-MW6 were not sampled in October to November 2015 based on poor recovery and low volumetric discharge observed from previous pumping and sampling events. These two monitoring wells are screened in low transmissive saturated zones within Precambrian metasediments (SNL 2016).

2.13 Groundwater Sample Collection and Handling

Groundwater sampling conducted by NMED and SNL/NM during October to November 2015 was performed in strict accordance with "Groundwater Monitoring Well Sampling and Field Analytical Measurements" (SNL/NM FOP 05-01), SNL/NM Sample Management Office (SMO) procedures and protocols implemented by SNL/NM, and NMED sample management procedures. Sample container materials depend on specific inorganic and organic analytes. The analytical method, sample preservation, sample containers, sample volumes, preservatives, and maximum holding times for analytical parameters were verified with selected laboratories or SMO personnel prior to conducting this field investigation. The NMED collected duplicate groundwater samples for chemical and/or isotope analyses from monitoring wells CYN-MW11, CYN-MW13, and/or CYN-MW14.

2.14 Analytical Methods

Dissolved anions, including bromide, chloride, fluoride, and sulfate, were analyzed by ALS-Fort Collins CO with ion chromatography (IC) (EPA Method 300.0); Nitrate-nitrite-N using EPA Method 353.2; and ammonia-N using EPA Method 350.1. Total Kjeldahl nitrogen (TKN) was analyzed using EPA method 351.2 (semi-automated colorimetry). General Engineering Laboratories (GEL) analyzed total carbonate alkalinity for SNL/NM during the June 2015 sampling conducted at the Burn Site (SNL/NM 2016). Groundwater samples analyzed for nitrogen species were preserved with concentrated sulfuric acid (H_2SO_4) in the field prior to IC and specific ion electrode analyses. ALS analyzed total organic carbon (TOC) in nonfiltered and acidified (H_2SO_4) groundwater samples by EPA Method SW-846-9060 using a TOC analyzer. Groundwater samples analyzed for dissolved cations were preserved with concentrated nitric acid (HNO_3) in the field and analyzed using EPA Method SW-846-6020 (inductively coupled plasma-mass spectrometry). Groundwater samples, which were nonfiltered and acidified with hydrochloric acid (HCl), were analyzed for semivolatile diesel range organic compounds and volatile gasoline range organic compounds with EPA Method SW846-8015A/B. One nonfiltered groundwater sample collected from monitoring well CYN-MW15 was analyzed for perchlorate using EPA Method SW-846-6850 consisting of liquid chromatography-mass spectrometry (LC-MS).

Pace Analytics analyzed groundwater samples for dual stable isotopes (nitrogen and oxygen) in nitrate, using isotope ratio mass spectrometry (IRMS). Groundwater samples were filtered and nonacidified prior to IRMS analysis. The

University of Arizona analyzed groundwater samples for stable isotopes of hydrogen and oxygen in water, which were nonfiltered and nonacidified using IRMS. The University of Miami, Rosenstiel School of Marine & Atmospheric Science, analyzed activities of tritium in nonfiltered and nonacidified groundwater samples using electrolytic enrichment that provides an analytical detection limit of 0.29 picocuries/liter (pCi/L). Appendix A contains all analytical results for groundwater samples collected during this investigation.

3. *Burn Site Hydrogeology*

An informative discussion on local hydrogeological conditions at the BSG AOC is presented in the Sandia Annual Groundwater Report (SNL 2016). The Burn Site is located in the Manzanita Mountains consisting of a complex sequence of uplifted Precambrian metamorphic and granitic rocks that have undergone multiple episodes of deformation. Paleozoic sandstones, shales, and limestones of the Sandia Formation and Madera Group cap or overlay Precambrian rocks at the Burn Site.

Groundwater flow in the Manzanita Mountains occurs in fractured metamorphic and intrusive rocks consisting of metavolcanics, quartzite, metasediments (schists and phyllites), and the Manzanita Granite (SNL 2016). The Burn Site Spring was the only perennial spring discharging upgradient and upslope from BSG AOC (SNL 2016). This spring has been dry since 2007. Groundwater discharges to several ephemeral springs along the Manzanita Mountain block- front located approximately three miles west of the Burn Site.

The Burn Site is bisected by a north-south trending system consisting of several high angle normal faults, which are downfaulted to the east (SNL 2016). Reactive minerals, including calcium carbonate (calcite), precipitate within fractures based on examination of core hole data. Reactive minerals can impede the rate and direction of groundwater flow within the complex fracture matrix. The potentiometric surface for the BSG AOC during October 2015 is provided in Figure 2 (SNL 2016). Groundwater generally flows to the west-southwest beneath the BSG AOC, based on a decreasing elevation of the potentiometric surface expressed in Figure 2. Sandia National Laboratories (2016) estimate that horizontal hydraulic gradients vary from 0.08 to 0.18 feet per foot (ft/ft), which is based on groundwater elevations measured at BSG monitoring wells, with an average horizontal gradient of approximately 0.1 ft/ft (Figure 2). The range of horizontal hydraulic gradients is most likely controlled by hydraulic properties in fault zones identified in the bedrock units exposed at the BSG AOC (SNL 2016). A minimum contaminant transport rate of 160 feet per year (ft/yr), for soluble petroleum hydrocarbons released from Solid Waste Management Unit (SWMU) 94F and arriving at monitoring well (MW) CYN-MW1D, is reported by SNL/NM (SNL 2016). Sandia National Laboratories, however, acknowledge that fracture

connectivity could be limited, which can influence this apparent movement or velocity of organic contaminants of concern (COC) at the Burn Site (SNL 2016). Figure 2 shows locations of the monitoring wells installed by SNL/NM at the Burn Site. Monitoring wells CYN-MW3 and CYN-MW4 are completed in Precambrian quartzite; CYN-MW6, CYN-MW9, CYN-MW10, CYN-MW11, CYN-MW12, CYN-MW14, and CYN-MW15 are completed in Precambrian metasediments; and CYN-MW7, CYN-MW8, and CYN-MW13 are completed in Precambrian granitic gneiss (SNL 2016). Wells CYN-MW3 and CYN-MW6 are not shown in Figure 2.

Figure 2. Burn Site Groundwater Area of Concern Potentiometric Surface for October 2015, Sandia National Laboratories/NM (SNL 2016).
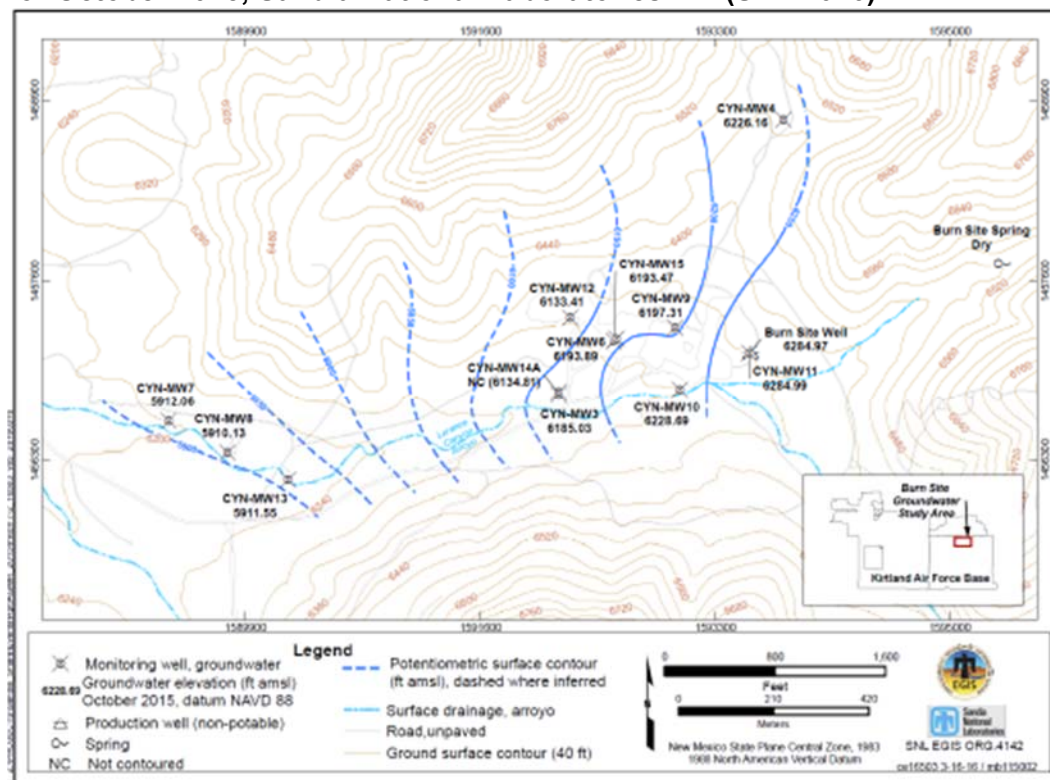
4. *Groundwater Geochemistry*

This section provides a detailed discussion of groundwater geochemistry at the BSG AOC, including major ions and trace elements, low-detection level tritium, organic compounds, and stable isotopes of hydrogen, oxygen, and nitrogen. A detailed understanding of diverse hydrogeochemical processes taking place at the site is essential for critically evaluating both natural and anthropogenic sources of nitrate plus nitrite (as N) observed in groundwater at BSG AOC. Appendix A provides results of analytical data for groundwater samples collected by NMED at the BSG AOC during October 2015 and November 2015.

4.1 Field Parameters and Major Ion Chemistry

Groundwater at the Burn Site is relatively oxidizing based on field ORP values ranging from +176 to +387 millivolts (mV) and DO concentrations varying from 1.04 to 7.65 mg/L (SNL 2016). Groundwater is characterized by a mixed calcium-sodium-sulfate-bicarbonate composition and circumneutral pH values ranging from 7.0 to 7.34. Specific conductance varies from 630 to 1122 microSiemens/centimeter (μS/cm) in groundwater at the Burn Site (SNL 2016).

Figure 3 shows a bivariate plot of sodium versus chloride, which suggests that monitoring wells CYN-MW11, CYN-MW12, CYN-MW14A, and CYN-MW15, completed in the Precambrian metasediments, are geochemically distinct from CYN-MW4 (background), CYN-MW7, CYN-MW8, CYN-MW9, CYN-MW10, and CYN-MW13, which are completed in Precambrian quartzite, granitic gneiss, and metasediments. The sodium/chloride line shown in units of milliequivalents/liter (meq/L) provides a separation of sodium-enriched groundwater from chloride-enriched groundwater at the Burn Site. This line also represents dissolution of sodium chloride (NaCl, halite), a constituent of brine aquifers. Precipitation of halite, however, is unlikely to be occurring at the Burn Site based on relatively low concentrations of sodium and chloride present in the bedrock aquifer(s). Monitoring wells plotting above the Na-Cl line contain excess sodium to chloride, including background well CYN-MW4. Increasing concentrations of chloride are most likely indicative of longer groundwater-solute residence time characteristic of low permeable quartzite, granitic gneiss, and fine-grained metasediments. Over long periods of time (1000 yr), chloride leaches from the vadose zone and chlorine-bearing minerals and accumulates along groundwater-flow paths.

Ratios of sodium versus calcium/magnesium in groundwater at the Burn Site shown in Figure 4 suggest that background (CYN-MW4, Precambrian quartzite) has a lower calcium/magnesium (Ca/Mg) ratio compared to source area and downgradient monitoring wells. Variations in calcium/magnesium ratios could be due to cation exchange involving clay minerals and dissolution of calcium carbonate. Concentrations of sodium range from approximately 23 to 49 mg/L and calcium/magnesium ratios range from 2.2 to 5.2 at the Burn Site. Monitoring wells CYN-MW7, CYN-MW8, and CYN-MW13, which are completed in Precambrian granitic gneiss, have slightly higher calcium/magnesium ratios compared to monitoring wells completed in Precambrian metasediments (CYN-MW9, CYN-MW10, CYN-MW11, CYN-MW12, CYN-MW14A, and CYN-MW15).

Figure 3. Concentrations of Sodium Versus Chloride at the Burn Site Groundwater Area of Concern, Sandia National Laboratories/NM.
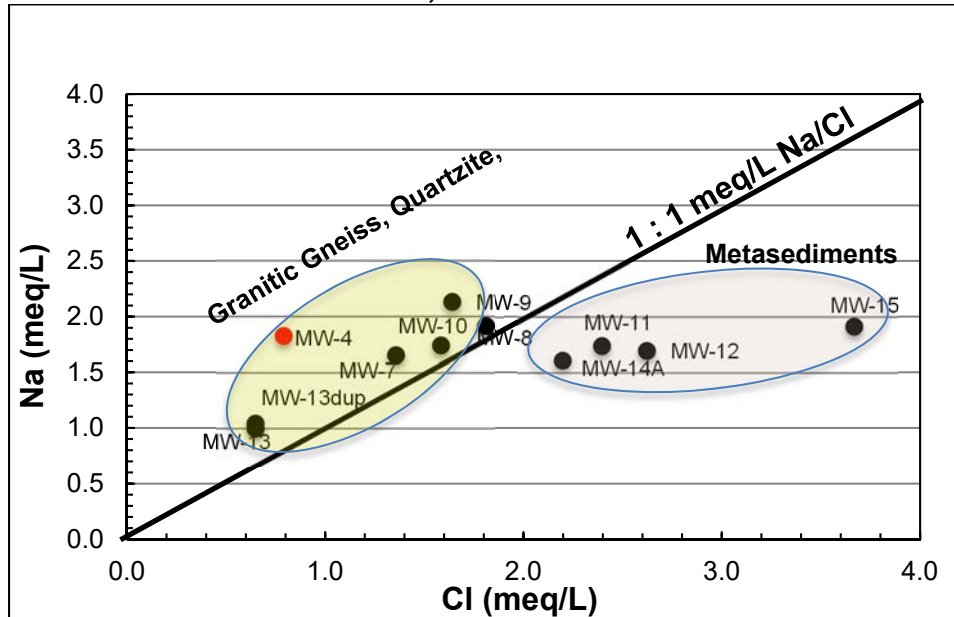
Figure 4. Concentrations of Sodium Versus Calcium/Magnesium in Groundwater at the Burn Site Groundwater Area of Concern, Sandia National Laboratories/NM.
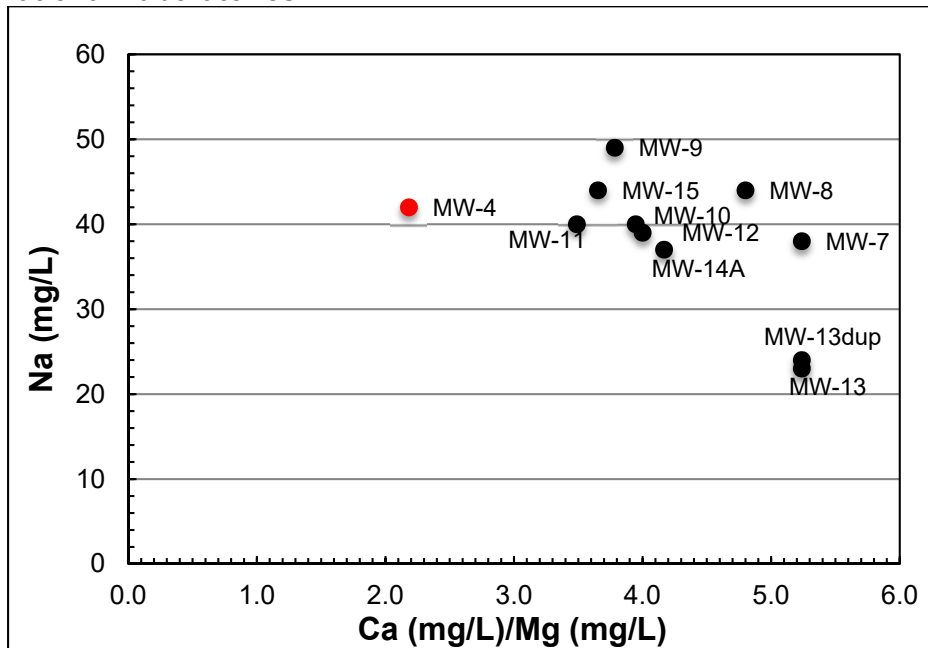
Monitoring wells located in the source area show a smaller variation in sodium concentrations compared to monitoring wells completed in granitic gneiss. This suggests that more mixing has taken place along groundwater-flow paths in the Precambrian metasediments than in granitic gneiss controlled by fracture flow.

A bivariate plot of chloride (Cl) versus bromide (Br), representing two groundwater tracers, is presented as Figure 5. These two anions have very similar chemical properties and are easily transported in aquifer systems under circumneutral pH conditions. Concentrations of chloride and bromide are the lowest at background monitoring well CYN-MW4 and downgradient well CYN-MW13 compared to other monitoring wells located in the source area. Bromide and chloride may have leached to a greater extent from bromine- and chlorine-bearing minerals present in the Precambrian metasediments having silicate minerals with a larger reactive surface area, compared to fractured granitic gneiss. Large volumes of water pumped from the Burn Site well and potable water brought to the site by tanker trucks were used for fire suppression and could have enhanced leaching of bromide and chloride from unconsolidated alluvium and the underlying vadose zone to the bedrock aquifer. Monitoring well CYN-MW9 deviates from the other monitoring wells located at the Burn Site by having excess chloride relative to bromide. This monitoring well has 10.7 pCi/L of tritium and contains a component of modern water postdating the early-1950s (see discussion in Section 4.3).

Figure 5. Concentrations of Chloride Versus Bromide at the Burn Site Groundwater Area of Concern, Sandia National Laboratories/NM.
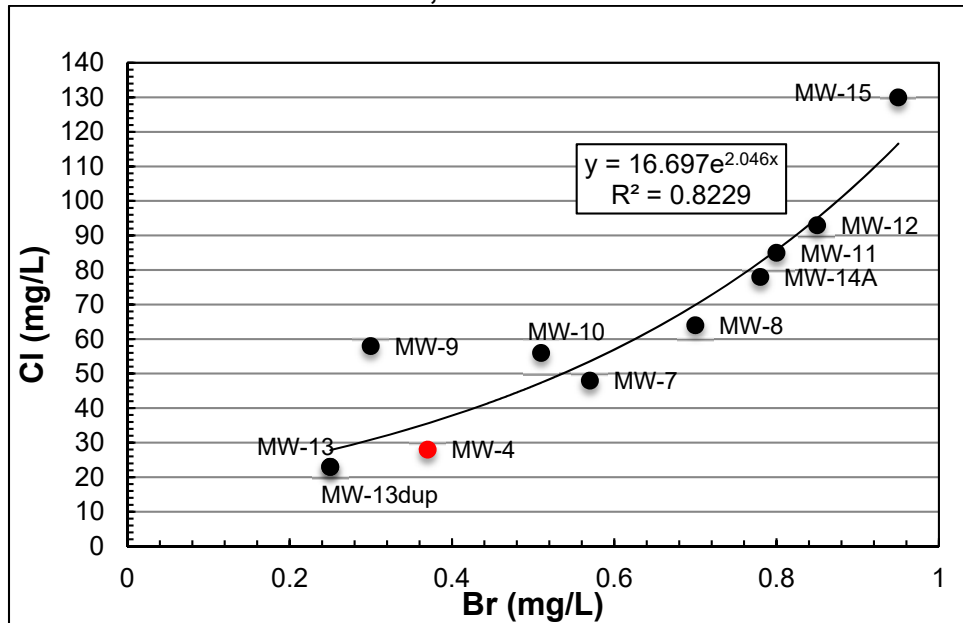

4.2 Stable Isotopes of Hydrogen and Oxygen

Stable isotopes of hydrogen (H) and oxygen (O) in water provide critical information on identifying the presence and source of meteoric water (rain and/or snow melt) that comprise initial recharge to aquifer systems worldwide, including bedrock aquifer(s) at the Burn Site. Figure 6 presents the isotopic composition of δ^2H versus δ^{18}O, in units of permil or parts per thousand, for groundwater samples collected from the Burn Site and analyzed by the University of Arizona using IRMS.

All groundwater samples collected from monitoring wells at the Burn Site fall on or close to the Global Meteoric Water Line (GMWL) defined by Craig (1961). Groundwater samples do not show any significant evaporation under warm semiarid conditions typical of climatic conditions in north-central New Mexico. Groundwater sampled at background monitoring well CYN-MW4 is most likely is recharged by meteoric water characterized by a cooler temperature and/or higher elevation, and has isotopically lighter δ^2H and $\delta^{18}O$ values compared to other monitoring wells located at the site. Isotope composition of monitoring wells located in the source area cluster together and most likely have the same or a very similar source of recharge water that is isotopically different from background and monitoring wells CYN-MW-9 and CYN-MW13. Meteoric water originating at a lower elevation, under warmer climatic conditions, is consistent with modern recharge and most likely recharges these two monitoring wells. Monitoring wells CYN-MW-9 and CYN-MW13 may contain a fraction of water that was initially used during fire suppression sourced from other supply wells at SNL/NM that have a lower elevation of recharge and warmer temperature.

Figure 6. δ^2H Versus $\delta^{18}O$ in Groundwater with the Global Meteoric Water Line (GMWL) at the Burn Site Groundwater Area of Concern, Sandia National Laboratories/NM (VSMOW means Vienna Standard Mean Ocean Water).
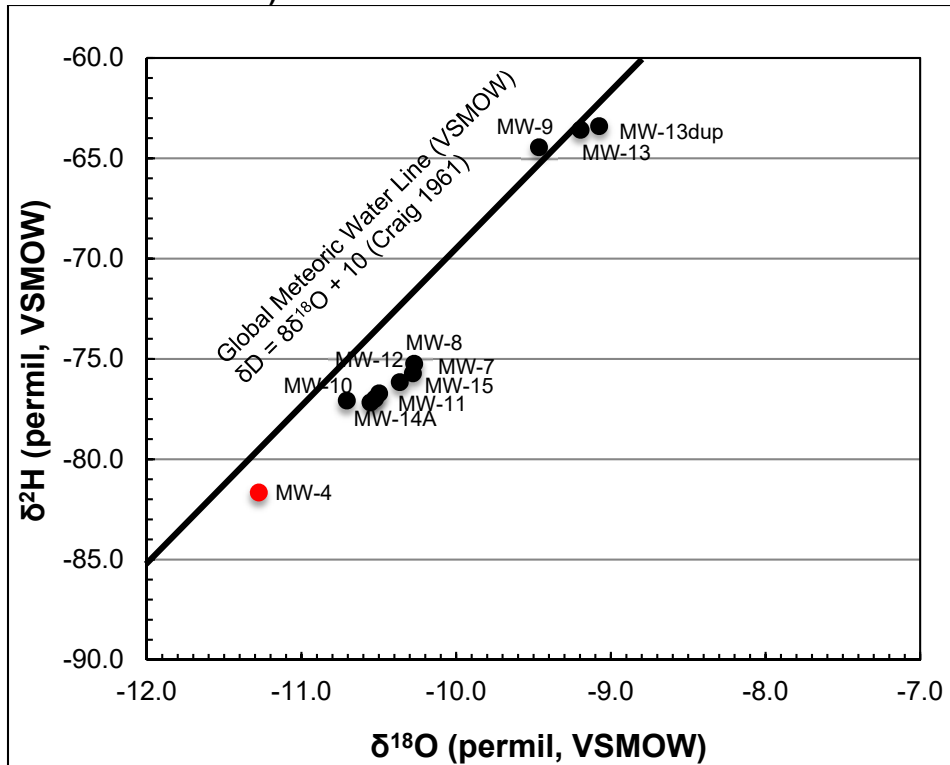
4.3 Nitrate, Tritium, Nitrogen Stable Isotopes, and Other Analytes

This section provides a discussion on different analytical suites evaluated as part of this investigation to help identifying source(s) of nitrate plus nitrite present in groundwater at the Burn Site. A nitrate plus nitrite (as N) plume shown in Figure 7 has been identified by SNL/NM at the BSG AOC (SNL 2016). Groundwater samples have been collected and analyzed during the past years for a variety of inorganic and organic constituents, as part of SNL's routine monitoring program conducted at the site. This plume has two high centers of nitrate plus nitrite in excess of 30 mg/L located at monitoring wells CYN-MW9 and CYN-MW13. Background and source area concentrations of nitrate plus nitrite (as N) and isotopic composition of nitrogen and oxygen in nitrate are useful parameters for quantification and identification of sources of nitrate plus nitrite at the Burn Site. The origin of nitrate plus nitrite at the Burn Site may include both natural and/or anthropogenic sources. Nitrate originates from nitrogen gas present in the atmosphere reacting with water and oxygen gas. Natural nitrate accumulates in the vadose zone over long periods of time and eventually migrates to groundwater during multiple recharge events. Nitrate is also produced from incomplete combustion and dissociation of ammonium nitrate and perhaps oxidation of HE compounds, in which nitro (R-N-NO_2) functional groups present in RDX, TNT, HMX, and other HE compounds oxidize to nitrate under extreme energetic conditions.

Figure 7. Nitrate Plume in Groundwater at the Burn Site Groundwater Area of Concern, Sandia National Laboratories/NM (SNL 2016).
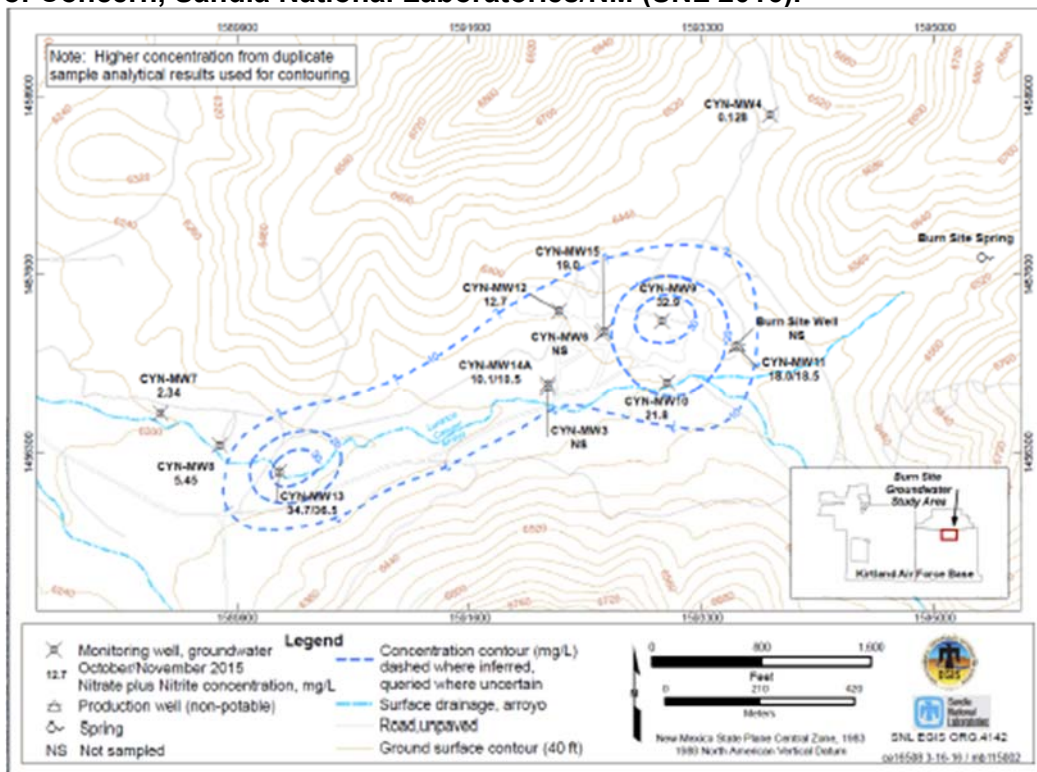
Figure 8 presents a plot of nitrate plus nitrite (as N) versus Cl in groundwater at the Burn Site. Nitrate is the dominant contaminant of concern at the Burn Site, as concentrations of this anion exceed both the EPA drinking water standard and the New Mexico Water Control Commission (WQCC) groundwater standard of 10 mg/L for nitrate (as N). Nitrate in groundwater commonly dominates over nitrite under strongly to moderately oxidizing and circumneutral pH conditions (Langmuir 1997, Clark 2015). During October 2015, the concentration of nitrate plus nitrite (as N) at background well CYN-MW4 (completed in Precambrian quartzite) was less than 0.2 mg/L. Concentrations of nitrate plus nitrite (as N) and chloride increase and vary in groundwater in the source area, whereas the downgradient and contaminated monitoring well CYN-MW13 (completed in Precambrian granitic gneiss) contains the highest concentration of nitrate plus nitrite (as N), but relatively low concentrations of chloride (Figure 8). Monitoring well CYN-MW15, completed in Precambrian metasediments and located in the source area contains the highest concentrations of chloride and nitrate plus nitrite (as N), which are 130 and 33 mg/L, respectively.

Figure 8. Concentrations of Nitrate Plus Nitrite (as N) Versus Chloride at the Burn Site Groundwater Area of Concern, Sandia National Laboratories/NM.
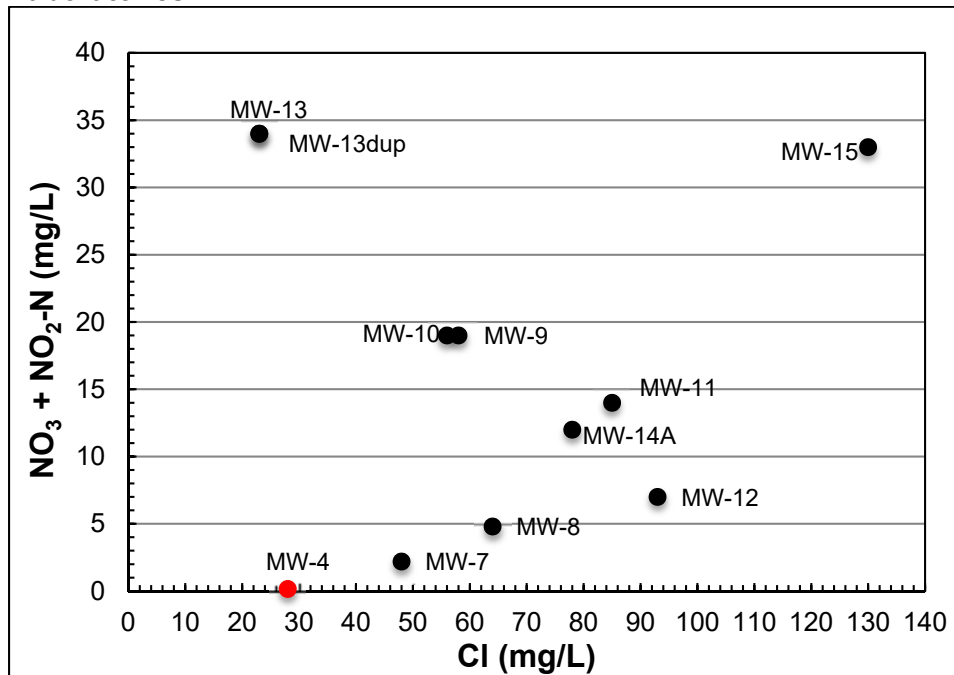
Concentrations of nitrate plus nitrite (as N) versus activities of tritium measured in groundwater at the Burn Site are shown in Figure 9. The University of Miami conducted tritium analyses using electrolytic enrichment having an analytical detection limit of 0.29 pCi/L or 0.09 tritium units (TU) (1 TU = 3.222 pCi/L tritium). Detectable activities of tritium measured in groundwater samples collected at the site confirm the presence of a component of recent or modern recharge, which is

younger than the early 1950s when thermonuclear atmospheric testing took place. Significant amounts of tritium, known as "bomb pulse tritium" were present in the atmosphere in excess of several thousand pCi/L of tritium (Clark and Fritz 1997). Since the 1950s, the International Atomic Energy Agency (IAEA) and other organizations have monitored precipitation worldwide for tritium. Groundwater age at the Burn Site falls into three different categories: (1) submodern (pre-1952 recharge with no detectable activity of tritium, <0.29 pCi/L); (2) mixed (contains both submodern and modern components with detectable tritium ranging between 0.30 and 12.89 pCi/L); and modern (entirely post-1952 with detectable tritium between 16.11 and 48.33 pCi/L) (modified from Clark and Fritz 1997). Madrid et al. (2016) provide an informative discussion on the distribution of submodern, mixed, and modern groundwater at the Burn Site by utilizing tritium-helium dating. Madrid et al. (2016) also evaluate the presence or absence of excess dissolved nitrogen gas produced during denitrification. Monitoring wells CYN-MW4 (background), CYN-MW7, and CYN-MW8 do not contain any detectable tritium (<0.29 pCi/L) and consist entirely of submodern groundwater and have not experienced any recent recharge occurring since the early 1950s. Concentrations of nitrate plus nitrite (as N) in groundwater samples collected from monitoring wells CYN-MW4, CYN-MW7, and CYN-MW8 are above analytical detection limit (0.02 mg/L), and most likely represent local background with concentrations of nitrate plus nitrite (as N) up to 5 mg/L in the absence of measureable tritium.
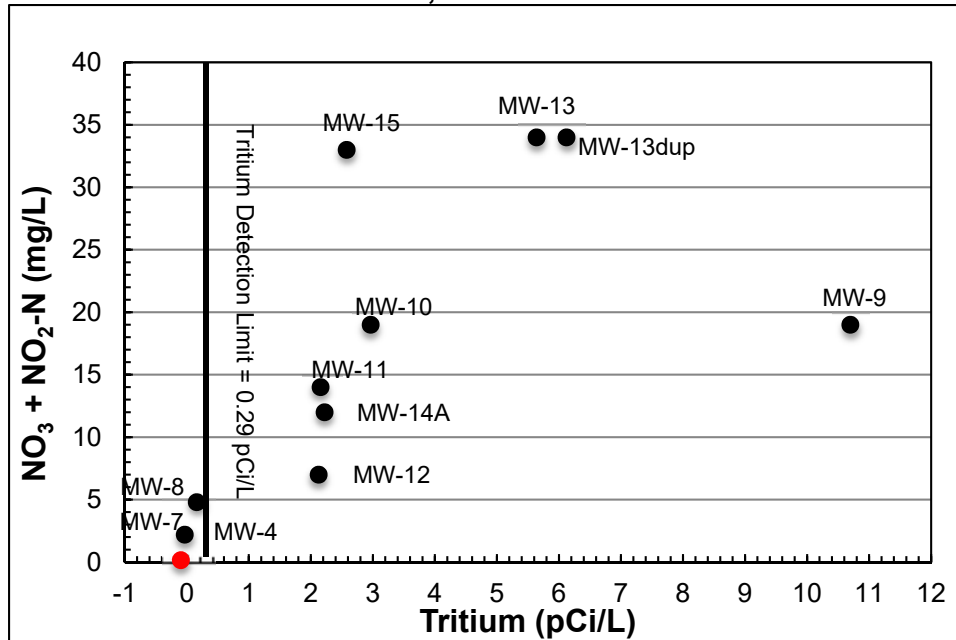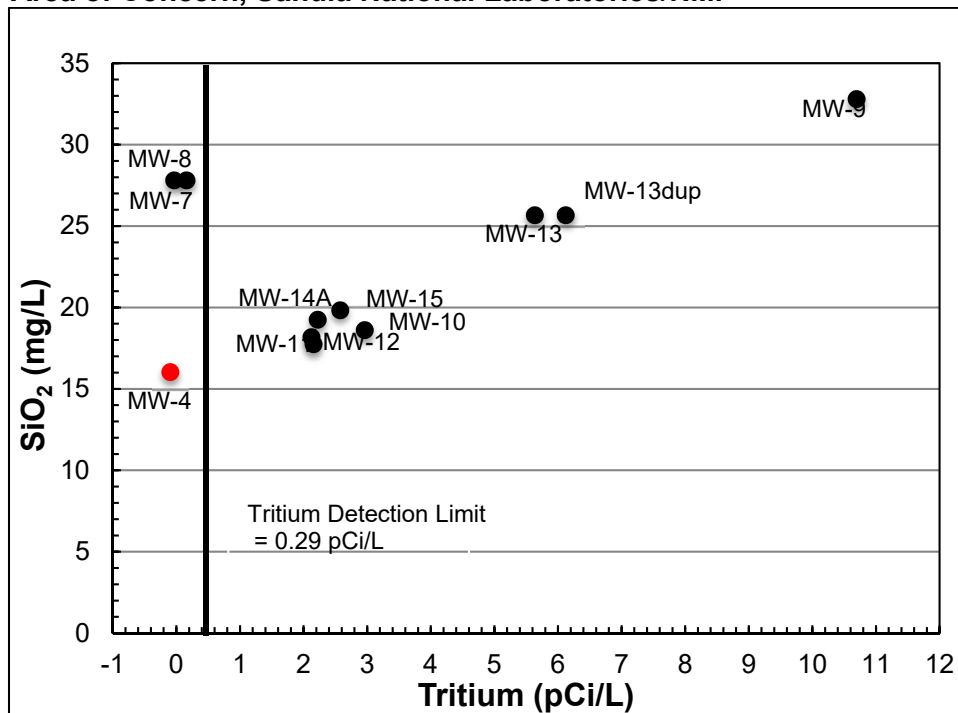
Figure 9. Nitrate Plus Nitrite (as N) Versus Tritium at the Burn Site Groundwater Area of Concern, Sandia National Laboratories/NM.

A bivariate plot of dissolved silica versus tritium measured in groundwater samples collected at the Burn Site is provided as Figure 10. Concentrations of dissolved silica, calculated from dissolved silicon values provided in Appendix A, increase

with increasing activities of tritium, suggesting that silica behaves as a conservative solute at the site. Volcanic ash, possibly consisting of a mixture of amorphous and poorly crystalline silica phases, is present within Precambrian metasediments/volcanics at the Burn Site (SNL 2016). Amorphous silica has a high aqueous solubility and dissolved silica is stable as silicic acid ($Si(OH_4^0)$) (Langmuir 1997). This dissolution process could be associated with preferred groundwater-flow paths characterized by a higher hydraulic conductivity under fracture flow conditions. Monitoring wells CYN-MW7 and CYN-MW8, however, deviate from this correlation possibly due to the presence of separate or isolated groundwater-flow paths that have not experienced any recent recharge since the early 1950s. Complexities of fracture flow within Precambrian granitic gneiss contribute to nonisotropic properties of the aquifer system(s) present at the Burn Site. Monitoring well CYN-MW9 contains the highest activity of tritium (10.70 pCi/L) and dissolved silica (32.8 mg/L) along with a concentration of nitrate-nitrite (as N) of 19 mg/L. Monitoring wells CYN-MW10, CYN-MW11, CYN-MW12, CYN-MW14A, and CYN-MW-15 cluster closely together, suggesting that similar groundwater-flow paths occur at their locations (Figure 10).

Figure 10. Dissolved Silica Versus Tritium at the Burn Site Groundwater Area of Concern, Sandia National Laboratories/NM.

Concentrations of nitrate plus nitrite (as N) versus TOC in groundwater at the Burn Site are shown in Figure 11. Concentrations of TOC generally increase with increasing nitrate plus nitrite (as N) at monitoring wells located in the source area. Background concentrations of TOC are below 0.4 mgC/L, as measured in a groundwater sample collected from CYN-MW4. Similar concentrations of TOC

occurring at downgradient wells CYN-MW7 and CYN-MW8 may also represent background. Total Organic Carbon of unknown composition is most likely derived from natural and anthropogenic sources, including oxidized residual carbon from petroleum hydrocarbons (JP-4 and JP-8) used at the Burn Site. If TOC occurs as soluble oxidized dissociated organic acids stable as anions, these hydrophilic compounds are mobile in groundwater at the site and would easily transport along with nitrate under oxidizing and circumneutral pH conditions. Concentrations of TOC should decrease through oxidation processes forming bicarbonate during denitrification as nitrate plus nitrite undergo reduction to nitrogen gas. Colocation of elevated above background concentrations of TOC with anthropogenic nitrate plus nitrite (as N) in groundwater strongly implies a common source for both analytes that is likely linked to detonation and open burning operations that took place in the past at the Burn Site.

Figure 11. Nitrate Plus Nitrite (as N) Versus Total Organic Carbon (TOC) at the Burn Site Groundwater Area of Concern, Sandia National Laboratories/NM.
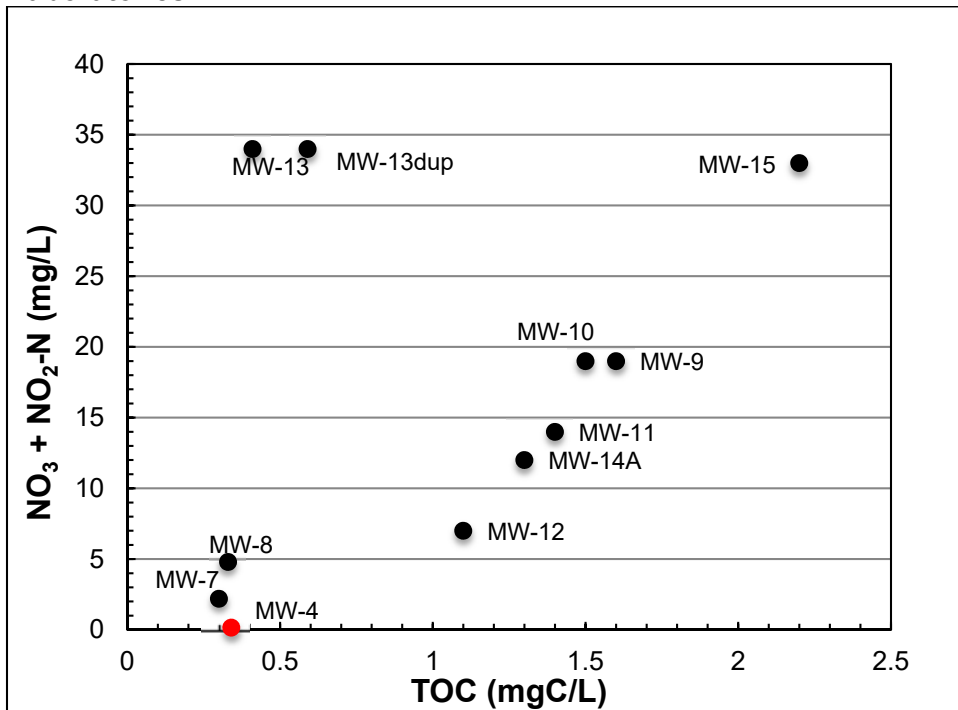
Concentrations of TOC versus tritium measured in groundwater at the Burn Site are shown in Figure 12. Background well CYN-MW4 and downgradient wells CYN-MW7 and CYN-MW8 plot closely together in the lower left side of the figure. These wells have not experienced recharge since the early 1950s and express nondetectable activities of tritium (<0.29 pCi/L). Concentrations of TOC are less than 0.4 mgC/L in groundwater samples collected from the three monitoring wells and likely represent background concentrations. Several monitoring wells located in the source area, including CYN-MW9, CYN-MW10, CYN-MW11, CYN-MW12,

CYN-MW14A, and CYN-MW-15, contain measurable activities of tritium ranging from 2.13 to 10.70 pCi/L. Groundwater sampled from these monitoring wells contain a mixture of submodern and modern water with a component of recharge taking place since the early 1950s. Monitoring well CYN-MW13 contains tritium activities of 5.64 and 6.12 pCi/L and concentrations of TOC less than 0.65 mgC/L. Groundwater sampled from this monitoring well has a mixed age with a fraction of a submodern component but dominated by a modern component of recent recharge.

Figure 12. Total Organic Carbon (TOC) Versus Tritium at the Burn Site Groundwater Area of Concern, Sandia National Laboratories/NM.
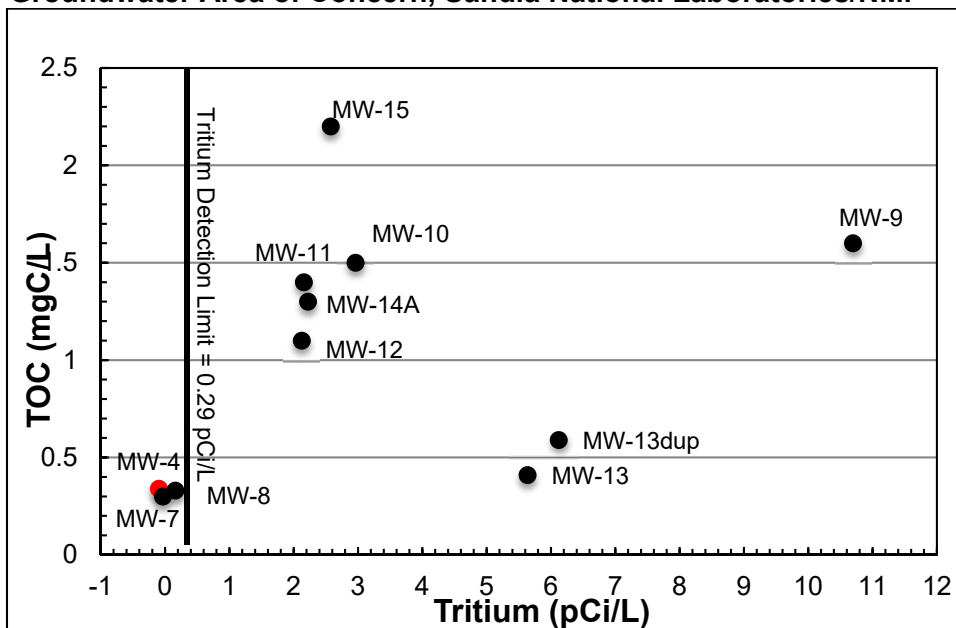
Stable isotopes of nitrogen (^{15}N and ^{14}N) and oxygen (^{18}O and ^{16}O) in nitrate provide quantification of diverse biogeochemical reactions taking place during oxidation and reduction reactions of nitrogen species in aquifer systems (Clark and Fritz 1997 and Clark 2015). Reduction of nitrate ultimately to nitrogen gas is denitrification. This (bio)geochemical process involves several intermediate aqueous compounds and gases, including nitrite (NO_2^-), nitric oxide (NO), and nitrous oxide (N_2O), that takes place under anaerobic conditions (Clark and Fritz 1997, Clark 2015). Denitrification is shown by the following overall oxidation-reduction (redox) reaction, which is thermodynamically favored with a positive $\log_{10}K$ (Clark 2015):

$$4NO_3^- + 5CH_2O + 4H^+ \rightarrow 2N_2(g) + 5CO_2(g) + 7H_2O \qquad \text{Eq. 1}$$
$$\log_{10}K = 44.28 \text{ at } 25°C.$$
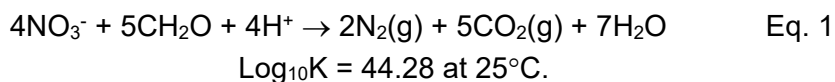
During denitrification, the heavy isotope of nitrogen (^{15}N) accumulates in residual nitrate and the lighter isotope (^{14}N) is reactive and partitions or accumulates in

reduced nitrogen species. Concentrations of nitrate decrease as denitrification proceeds and residual nitrate contain ^{15}N to a greater extent over ^{14}N producing isotopically heavy nitrogen in nitrate with positive $\delta^{15}N$ values typically greater than 15 permil (Clark and Fritz 1997, Clark 2015). Nitrification involves oxidation of ammonium to nitrate, in which nitrate concentrates the lighter isotope ^{14}N and has lighter $\delta^{15}N$-nitrate values relative to $\delta^{15}N$-ammonium. Nitrification is shown by the following overall redox reaction, which is thermodynamically favored with a positive $\log_{10}K$ (Clark 2015):

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + H_2O + 2H^+ \qquad\qquad \text{Eq. 2}$$
$$\text{Log}_{10}K = 46.74 \text{ at } 25°C.$$
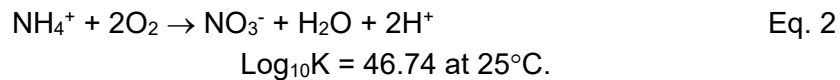
Nitrification of slurries of ammonium nitrate occurring under aerobic conditions in groundwater at the Burn Site could account for elevated concentrations of nitrate plus nitrite (as N) measured in the source area.

Figure 13 represents a plot of nitrate plus nitrite (as N) versus $\delta^{15}N$-nitrate in units of permil or parts per thousand. The standard for measuring nitrogen isotopes in nitrate is $N_2(g)$ in air (Clark and Fritz 1997, Clark 2015). Groundwater at the Burn Site source area has undergone a limited extent of denitrification, based on both slightly positive $\delta^{15}N$-nitrate values and absence of excess dissolved nitrogen gas (Madrid et al. 2016). Monitoring well CYN-MW4 shows the highest $\delta^{15}N$-nitrate value of +11.20 permil, which suggests denitrification is occurring to a greater extent at this background location. Other monitoring wells located in the source area and downgradient also exhibit an inverse relationship with increasing nitrate plus nitrite (as N) concentrations with decreasing $\delta^{15}N$-nitrate values. Monitoring wells CYN-MW13 and CYN-MW15 deviate from the other monitoring wells by having much higher concentrations of nitrate plus nitrite (N) (as N) exceeding 30 mg/L and values of $\delta^{15}N$-nitrate ranging from +4.42 to +5.68 permil.

Figure 14 shows a strong inverse relationship between $\delta^{15}N$-nitrate and tritium in groundwater at the Burn Site. Monitoring wells located in the source area have higher activities of tritium and lower $\delta^{15}N$-nitrate values compared to background. Groundwater sampled from background well CYN-MW4 has the highest $\delta^{15}N$-nitrate value of +11.20 permil and nondetectable tritium (<0.29 pCi/L). Monitoring wells CYN-MW7 and CYN-MW8 also have nondetectable tritium and $\delta^{15}N$-nitrate values less than +7 permil. Figure 14 implies that the extent and rate of limited denitrification depends on a time scale of decades with submodern groundwater. Monitoring well CYN-MW9 has the highest activity of tritium (10.70 pCi/L), with the largest component of post early-1950s modern water, and the lowest $\delta^{15}N$-nitrate value (+2.77 permil). Groundwater sampled from monitoring well CYN-MW9 may be representative of slightly fractionated nitrogen originally present in explosive compounds, including ammonium nitrate, tested at the Burn Site.

Figure 13. Nitrate Plus Nitrite Versus δ¹⁵N in Nitrate at the Burn Site Groundwater Area of Concern, Sandia National Laboratories/NM.

**Figure 14. δ¹⁵N in Nitrate Versus Tritium at the Burn Site Groundwater Area of Concern, Sandia National Laboratories/NM.**
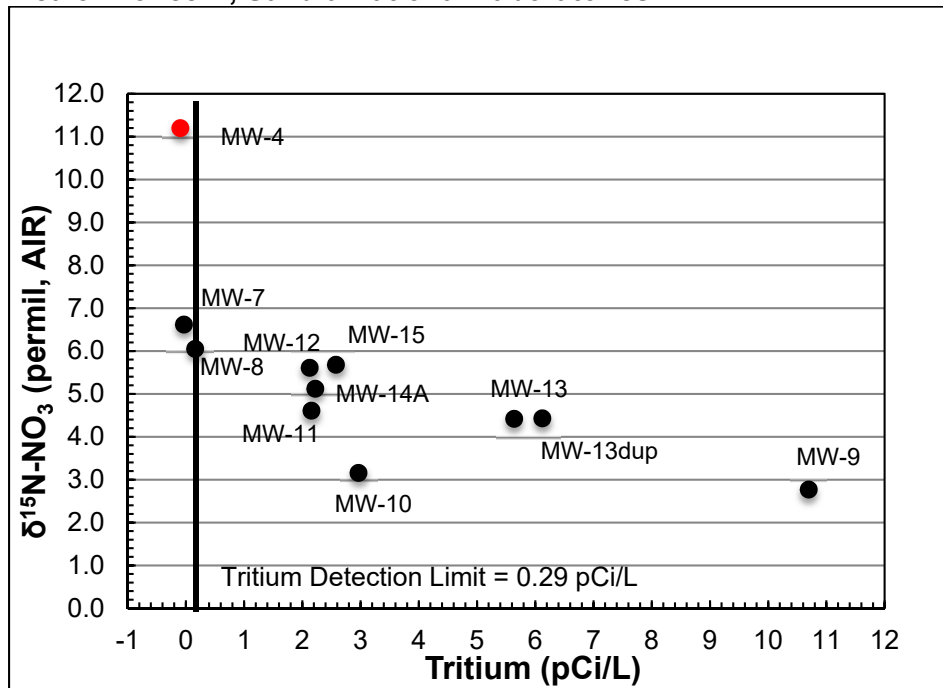
Figure 15 shows the isotopic relationship between $\delta^{18}O$-nitrate and $\delta^{15}N$-nitrate in groundwater. Madrid et al. (2016) present the same plot and there is an excellent agreement with isotope composition of nitrate provided by both NMED and

Lawrence Livermore National Laboratory (LLNL). Stability fields for the isotopic composition for "nitrified ammonia" and "soil nitrogen" (Kendall 1998) and "nitrification" (Durka et al., 1994) are shown in Figure 15, showing that most groundwater samples collected from the Burn Site fall within the three nitrogen fields. CYN-MW4 falls in the "denitrification" field (field not shown in Figure 15). Monitoring wells CYN-MW9, CYN-MW10, CYN-MW11, and CYN-MW13 fall within the "nitrified ammonia" field and the other monitoring wells including CYN-MW7, CYN-MW8, CYN-MW11, CYN-MW12, CYN-MW14A, and CYN-MW15 fall within the "soil nitrogen" field. Several source area monitoring wells falling within the "nitrified ammonia" and "nitrification" fields suggest that nitrate is derived from oxidation of ammonium-ammonia, likely sourced from ammonium nitrate.

Figure 15. $\delta^{18}O$ Versus $\delta^{15}N$ in Nitrate at the Burn Site Groundwater Area of Concern, Sandia National Laboratories.
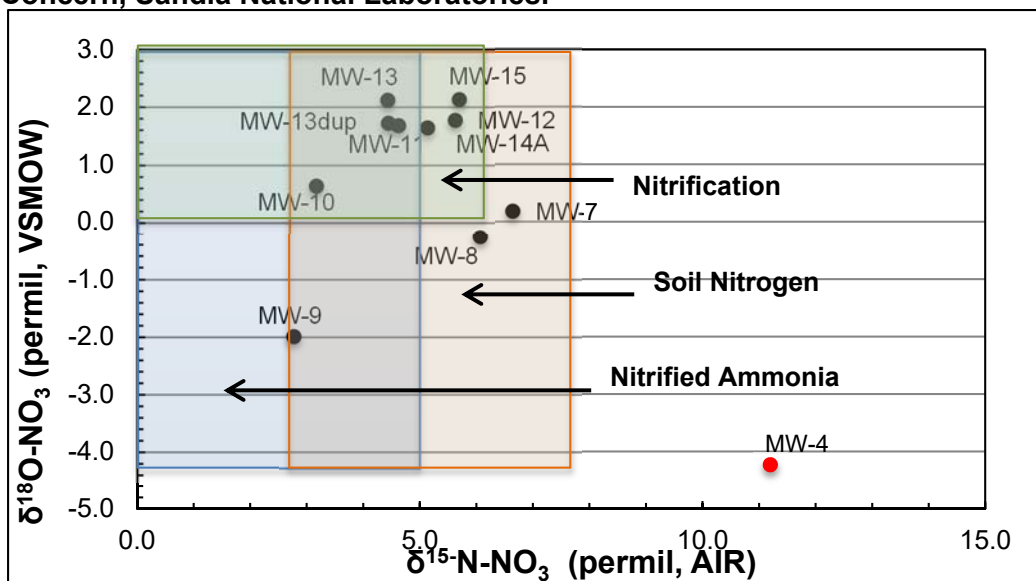
Naturally occurring ammonium is very unlikely to occur at the Burn Site based on redox chemistry and the mineralogical and chemical composition of the bedrock aquifer material, consisting of Precambrian metasediments and granitic gneiss. Very small amounts of natural solid organic matter (<0.1 weight percent) are considered to be present at the Burn Site. The "soil nitrogen" field includes different forms of organic and inorganic nitrogen. Ammonium nitrate and pristine HE compounds, including nitro functional groups ($R-N-NO_2$) potentially fall within the "soil nitrogen" field. More detailed spectroscopic characterization of organic carbon and nitrogen is required to understand TOC structure and composition.

Monitoring wells located in the source area have higher $\delta^{18}O$-nitrate values compared to background monitoring well CYN-MW4 (-4.23 permil). These monitoring wells cluster closely together with respect to $\delta^{18}O$-nitrate values ranging from +1.64 to +2.13 permil (Figure 15). Groundwater background, however, has a

heavier or more positive $\delta^{15}N$-nitrate value compared to the isotopic signature of the source area suggestive of early-stage denitrification.

Figure 16 shows the isotopic relationship between $\delta^{18}O$-nitrate and $\delta^{18}O$-water at the Burn Site. A local nitrification line (Madrid et al. 2016), representing oxidation of ammonium to nitrate, at the Burn Site is shown in this figure. Nitrate produced by nitrification processes commonly derives two oxygen atoms from groundwater and one oxygen atom from oxygen gas (Clark and Fritz 1997, Clark 2015). Atmospheric oxygen is strongly enriched with ^{18}O, which produces a very heavy or positive $\delta^{18}O$ value (+23.5 permil) (Amberger and Schmidt 1987). The isotopic signature of atmospheric-derived ^{18}O produces heavier $\delta^{18}O$-nitrate during nitrification compared to ^{18}O in groundwater, resulting in significantly lighter $\delta^{18}O$-water compositions. ^{18}Oxygen fractionation does not significantly occur during nitrification (Clark and Fritz 1997, Clark 2015). The oxygen isotopic composition of groundwater does vary and is site-specific depending mainly on atmospheric temperature prevailing during precipitation and elevation of recharge. At the Burn Site, $\delta^{18}O$-nitrate values produced from nitrification are expected to range from approximately +0.60 to +2.50 permil, based on the unique isotopic composition of atmospheric oxygen ($\delta^{18}O$ = +23.5 permil) (Amberger and Schmidt 1987) and that of contaminated groundwater ($\delta^{18}O$ = -10.7 to -9.1 permil) at the Burn Site (Figure 16). It is evident that nitrate plus nitrite (as N) measured in groundwater at the Burn Site is most likely derived from nitrification processes, as $\delta^{18}O$-nitrate falls on or close to the local nitrification line (Madrid et al. 2016) shown in Figure 16. Monitoring wells CYN-MW4, consisting of background and submodern water, and CYN-MW9, consisting entirely of modern water, fall below the empirical nitrification line (Madrid et al. 2016).

Figure 16. $\delta^{18}O$-Nitrate Versus $\delta^{18}O$ in Groundwater at the Burn Site Groundwater Area of Concern, Sandia National Laboratories.
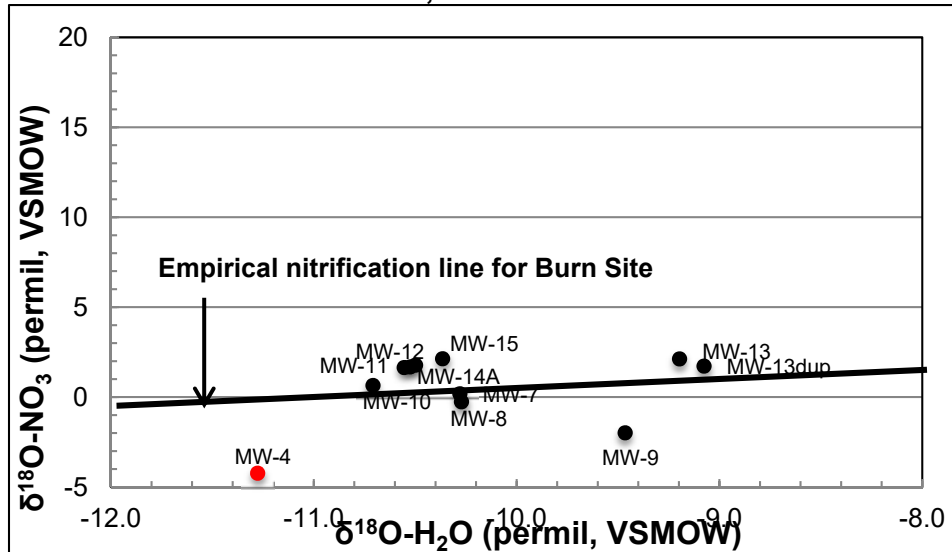
Figure 17 shows the relationship between TOC and δ^{15}N-nitrate at the Burn Site. Background (CYN-MW4) is isolated with respect to these two analytes from the other sampling stations at the site. Monitoring wells located in the source area (CYN-MW9, CYN-MW10, CYN-MW11, CYN-MW12, and CYN-MW14A) show an inverse relationship between decreasing δ^{15}N-nitrate values and increasing concentrations of TOC. This implies that TOC is not reactive and does serve as a viable electron donor for enhancing potential denitrification at the Burn Site. Downgradient monitoring wells CYN-MW7, CYN-MW8, and CYN-MW13 group together and fall below TOC concentrations measured at source area monitoring wells. The narrow range of δ^{15}N-nitrate values (+2.27 to +6.62 permil) does not support significant denitrification occurring in groundwater at the Burn Site.

Figure 17. TOC Versus δ^{15}N-Nitrate in Groundwater at the Burn Site Groundwater Area of Concern, Sandia National Laboratories.
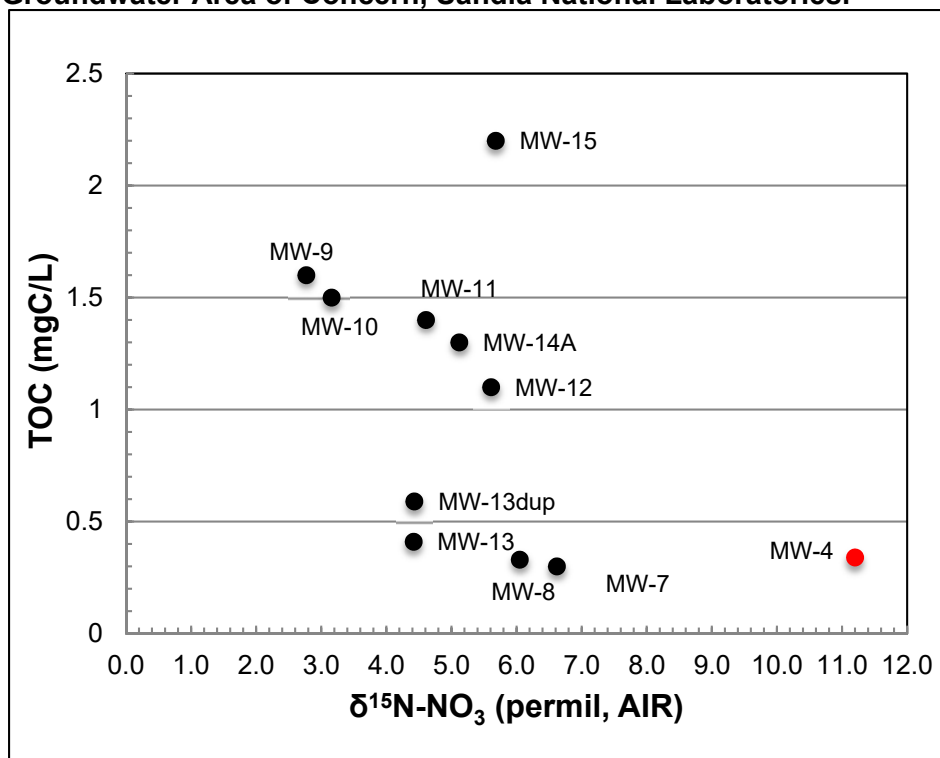
4.4 Petroleum Hydrocarbon Fuels, Reduced Nitrogen, and Perchlorate

Gasoline range organic compounds and diesel range organic compounds were not detected in groundwater at the Burn Site during October to November 2015. Perchlorate was detected at a concentration of 1.8 μg/L at monitoring well CYN-MW15, and this was the only sampling station analyzed for perchlorate. The origin of perchlorate at the Burn Site is unknown, but could be derived from both natural and anthropogenic sources. Concentrations of TKN were less than analytical detection (0.34 mg/L) in groundwater samples collected at the Burn Site monitoring wells. Ammonia-N was not detected (<0.03 mg/L) in groundwater samples collected at the Burn Site. Nondetection of TKN and ammonium-ammonia supports

the concept that nitrification processes are complete and effective in aerobic groundwater at the Burn Site.

5. *Summary and Conclusions*

Groundwater samples were collected from the Burn Site AOC and analyzed for a variety of isotopes and inorganic and organic chemicals, including nitrate plus nitrite (as N), ammonia, TKN, TOC, low-detection level tritium, stable isotopes of hydrogen, nitrogen, and oxygen, perchlorate, major cations and anions, gasoline range organic compounds, and diesel range organic compounds. Gasoline range organic compounds, diesel range organic compounds, TKN, and ammonia (as N) were not detected in any of the Burn Site groundwater samples.

Activities of tritium are less than analytical detection (<0.29 pCi/L) using electrolytic enrichment (University of Miami) and concentrations of nitrate plus nitrite (as N) are less than 5 mg/L, at background monitoring well CYN-MW4 and downgradient wells CYN-MW7 and CYN-MW8. Absence of tritium at these three locations confirms that groundwater is submodern in age and that recharge has not taken place since the early 1950s outside of the source area.

Concentrations of nitrate plus nitrite (as N) above local background (<5 mg/L) were measured in groundwater samples collected from source area monitoring wells CYN-MW9, CYN-MW10, CYN-MW11, CYN-MW12, CYN-MW13, CYN-MW14A, and CYN-MW15. These monitoring wells also have detectable activities of tritium confirming that recent recharge has taken place since the early 1950s and are either mixed or modern in groundwater age. The sources of modern recharge water most likely include a minor component of precipitation, in the form of rain and snowmelt, and water used for fire suppression at the Burn Site.

Nitrate plus nitrite (as N) are mobile anions that easily transport without retardation in the bedrock aquifer(s) characterized by oxidizing-aerobic and circumneutral pH conditions at the Burn Site. Sources of nitrate plus nitrite (as N) at the Burn Site include components of both a natural origin (soil nitrogen present in the vadose zone) and an anthropogenic origin most likely resulting from nitrification processes and dissociation of ammonium nitrate. Downward vertical flow paths through the fractured and faulted vadose zone to the bedrock aquifer(s) are collocated with the nitrate source resulting in a nitrate plus nitrite (as N) plume. Active or present-day recharge probably occurs at the Burn Site, based on groundwater age and long-term monitoring data collected by SNL/NM and NMED.

Concentrations of TOC above background (<0.3 mgC/L) occur within the source area, which is also characterized by elevated concentrations of nitrate-nitrite (as N) above site-specific background (> 5 mg/L). The source, reactivity, chemical composition, and structure of TOC in groundwater, however, are not known. Relationships between TOC and nitrate plus nitrite (as N) concentrations and TOC

and δ^{15}N-nitrate values do not support active denitrification, but do support nitrification.

Nitrogen isotope compositions for groundwater at the Burn Site suggest that nitrification processes have taken place and that denitrification only occurs to a limited extent under aerobic conditions with DO concentrations typically greater than 4 mg/L. Excess N_2 gas concentrations in Burn Site groundwater were generally low to non-detect in noble gas studies conducted by Madrid et al. (2016), indicating that denitrification is not widely occurring.

6. *Acknowledgements*

7. *References*

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Appendix A: Groundwater Chemistry

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Appendix A: Burn Site Groundwater Quality Results: Nitrate-Nitrite as Nitrogen
New Mexico Environment Department DOE Oversight Bureau
October/November 2015

SNL/NM Monitoring Well	Sample Date	Analyte	Result (mg/L)	Method Detection Limit (mg/L)	Laboratory Detection Limit (mg/L)	Laboratory Qualifier	Analytical Method
CYN-MW4	10/19/2015	Nitrate-Nitrite as Nitrogen	0.16	0.003	0.01		EPA:353.2
CYN-MW7	10/27/2015	Nitrate-Nitrite as Nitrogen	2.2	0.015	0.05		EPA:353.2
CYN-MW8	10/26/2015	Nitrate-Nitrite as Nitrogen	4.8	0.06	0.2		EPA:353.2
CYN-MW9	11/11/2015	Nitrate-Nitrite as Nitrogen	19	0.06	0.2		EPA:353.2
CYN-MW10	11/2/2015	Nitrate-Nitrite as Nitrogen	19	0.06	0.2		EPA:353.2
CYN-MW11	11/4/2015	Nitrate-Nitrite as Nitrogen	14	0.06	0.2		EPA:353.2
CYN-MW11-DUP	11/4/2015	Nitrate-Nitrite as Nitrogen	14	0.06	0.2		EPA:353.2
CYN-MW12	10/20/2015	Nitrate-Nitrite as Nitrogen	7	0.15	0.5		EPA:353.2
CYN-MW13	10/28/2015	Nitrate-Nitrite as Nitrogen	34	0.06	0.2		EPA:353.2
CYN-MW13-DUP	10/28/2015	Nitrate-Nitrite as Nitrogen	34	0.06	0.2		EPA:353.2
CYN-MW14A	10/21/2015	Nitrate-Nitrite as Nitrogen	12	0.15	0.5		EPA:353.2
CYN-MW14A-DUP	10/21/2015	Nitrate-Nitrite as Nitrogen	12	0.15	0.5		EPA:353.2
CYN-MW15	11/10/2015	Nitrate-Nitrite as Nitrogen	33	0.06	0.2		EPA:353.2

Appendix A: Burn Site Groundwater Quality Results: Ammonia as Nitrogen
New Mexico Environment Department DOE Oversight Bureau
October/November 2015

SNL/NM Monitoring Well	Sample Date	Analyte	Result (mg/L)	Method Detection Limit (mg/L)	Laboratory Detection Limit (mg/L)	Laboratory Qualifier	Analytical Method
CYN-MW4	10/19/2015	Ammonia as Nitrogen	0.03	0.03	0.1	U	EPA:350.1
CYN-MW7	10/27/2015	Ammonia as Nitrogen	0.03	0.03	0.1	U	EPA:350.1
CYN-MW8	10/26/2015	Ammonia as Nitrogen	0.03	0.03	0.1	U	EPA:350.1
CYN-MW9	11/11/2015	Ammonia as Nitrogen	0.03	0.03	0.1	U	EPA:350.1
CYN-MW10	11/2/2015	Ammonia as Nitrogen	0.03	0.03	0.1	U	EPA:350.1
CYN-MW11	11/4/2015	Ammonia as Nitrogen	0.03	0.03	0.1	U	EPA:350.1
CYN-MW11-DUP	11/4/2015	Ammonia as Nitrogen	0.03	0.03	0.1	U	EPA:350.1
CYN-MW12	10/20/2015	Ammonia as Nitrogen	0.03	0.03	0.1	U	EPA:350.1
CYN-MW13	10/28/2015	Ammonia as Nitrogen	0.03	0.03	0.1	U	EPA:350.1
CYN-MW13-DUP	10/28/2015	Ammonia as Nitrogen	0.03	0.03	0.1	U	EPA:350.1
CYN-MW14A	10/21/2015	Ammonia as Nitrogen	0.03	0.03	0.1	U	EPA:350.1
CYN-MW14A-DUP	10/21/2015	Ammonia as Nitrogen	0.03	0.03	0.1	U	EPA:350.1
CYN-MW15	11/10/2015	Ammonia as Nitrogen	0.03	0.03	0.1	U	EPA:350.1

U = Qualifier indicates that the analyte was not detected above the Method Detection Limit (MDL).

Appendix A: Burn Site Groundwater Quality Results: Total Kjeldahl Nitrogen (TKN)
New Mexico Environment Department DOE Oversight Bureau
October/November 2015

SNL/NM Monitoring Well	Sample Date	Analyte	Result (mg/L)	Method Detection Limit (mg/L)	Laboratory Detection Limit (mg/L)	Laboratory Qualifier	Analytical Method
CYN-MW4	10/19/15	Total Kjeldahl Nitrogen	0.34	0.34	1	U	EPA:351.2
CYN-MW7	10/27/15	Total Kjeldahl Nitrogen	0.34	0.34	1	U	EPA:351.2
CYN-MW8	10/26/15	Total Kjeldahl Nitrogen	0.34	0.34	1	U	EPA:351.2
CYN-MW9	11/11/15	Total Kjeldahl Nitrogen	0.34	0.34	1	U	EPA:351.2
CYN-MW10	11/2/15	Total Kjeldahl Nitrogen	0.34	0.34	1	U	EPA:351.2
CYN-MW11	11/4/15	Total Kjeldahl Nitrogen	0.34	0.34	1	U	EPA:351.2
CYN-MW11-DUP	11/4/15	Total Kjeldahl Nitrogen	0.34	0.34	1	U	EPA:351.2
CYN-MW12	10/20/15	Total Kjeldahl Nitrogen	0.34	0.34	1	U	EPA:351.2
CYN-MW13	10/28/15	Total Kjeldahl Nitrogen	0.34	0.34	1	U	EPA:351.2
CYN-MW13-DUP	10/28/15	Total Kjeldahl Nitrogen	0.34	0.34	1	U	EPA:351.2
CYN-MW14A	10/21/15	Total Kjeldahl Nitrogen	0.34	0.34	1	U	EPA:351.2
CYN-MW14A-DUP	10/21/15	Total Kjeldahl Nitrogen	0.34	0.34	1	U	EPA:351.2
CYN-MW15	11/10/15	Total Kjeldahl Nitrogen	0.34	0.34	1	U	EPA:351.2

U = Qualifier indicates that the analyte was not detected above the Method Detection Limit (MDL).

Appendix A: Burn Site Groundwater Quality Results: Major Anions
New Mexico Environment Department DOE Oversight Bureau
October/November 2015

SNL/NM Monitoring Well	Sample Date	Analyte	Result (mg/L)	Method Detection Limit (mg/L)	Laboratory Detection Limit (mg/L)	Laboratory Qualifier	Analytical Method
CYN-MW4	10/19/2015	Bromide	0.37	0.06	0.2		EPA:300.0
CYN-MW4	10/19/2015	Chloride	28	0.6	2		EPA:300.0
CYN-MW4	10/19/2015	Fluoride	0.8	0.03	0.1		EPA:300.0
CYN-MW4	10/19/2015	Sulfate	130	3	10		EPA:300.0
CYN-MW7	10/27/2015	Bromide	0.57	0.06	0.2		EPA:300.0
CYN-MW7	10/27/2015	Chloride	48	0.6	2		EPA:300.0
CYN-MW7	10/27/2015	Fluoride	1.4	0.03	0.1		EPA:300.0
CYN-MW7	10/27/2015	Sulfate	91	0.3	1		EPA:300.0
CYN-MW8	10/26/2015	Bromide	0.7	0.06	0.2		EPA:300.0
CYN-MW8	10/26/2015	Chloride	64	0.6	2		EPA:300.0
CYN-MW8	10/26/2015	Fluoride	1.5	0.03	0.1		EPA:300.0
CYN-MW8	10/26/2015	Sulfate	120	3	10		EPA:300.0
CYN-MW9	11/11/2015	Bromide	0.3	0.06	0.2		EPA:300.0
CYN-MW9	11/11/2015	Chloride	58	0.3	1		EPA:300.0
CYN-MW9	11/11/2015	Fluoride	0.43	0.03	0.1		EPA:300.0
CYN-MW9	11/11/2015	Sulfate	130	1.5	5		EPA:300.0
CYN-MW10	11/2/2015	Bromide	0.51	0.06	0.2		EPA:300.0
CYN-MW10	11/2/2015	Chloride	56	0.6	2		EPA:300.0
CYN-MW10	11/2/2015	Fluoride	0.54	0.03	0.1		EPA:300.0
CYN-MW10	11/2/2015	Sulfate	160	3	10		EPA:300.0
CYN-MW11	11/4/2015	Bromide	0.8	0.06	0.2		EPA:300.0
CYN-MW11	11/4/2015	Chloride	85	0.6	2		EPA:300.0
CYN-MW11	11/4/2015	Fluoride	0.61	0.03	0.1		EPA:300.0
CYN-MW11	11/4/2015	Sulfate	180	3	10		EPA:300.0

Appendix A: Burn Site Groundwater Quality Results: Major Anions
New Mexico Environment Department DOE Oversight Bureau
October/November 2015

SNL/NM Monitoring Well	Sample Date	Analyte	Result (mg/L)	Method Detection Limit (mg/L)	Laboratory Detection Limit (mg/L)	Laboratory Qualifier	Analytical Method
CYN-MW12	10/20/2015	Bromide	0.85	0.06	0.2		EPA:300.0
CYN-MW12	10/20/2015	Chloride	93	0.6	2		EPA:300.0
CYN-MW12	10/20/2015	Fluoride	1.1	0.03	0.1		EPA:300.0
CYN-MW12	10/20/2015	Sulfate	210	3	10		EPA:300.0
CYN-MW13	10/28/2015	Bromide	0.25	0.06	0.2		EPA:300.0
CYN-MW13	10/28/2015	Chloride	23	0.6	2		EPA:300.0
CYN-MW13	10/28/2015	Fluoride	1.8	0.03	0.1		EPA:300.0
CYN-MW13	10/28/2015	Sulfate	77	3	10		EPA:300.0
CYN-MW13-DUP	10/28/2015	Bromide	0.25	0.06	0.2		EPA:300.0
CYN-MW13-DUP	10/28/2015	Chloride	23	0.6	2		EPA:300.0
CYN-MW13-DUP	10/28/2015	Fluoride	1.7	0.03	0.1		EPA:300.0
CYN-MW13-DUP	10/28/2015	Sulfate	79	3	10		EPA:300.0
CYN-MW14A	10/21/2015	Bromide	0.78	0.06	0.2		EPA:300.0
CYN-MW14A	10/21/2015	Chloride	78	0.6	2		EPA:300.0
CYN-MW14A	10/21/2015	Fluoride	1.1	0.03	0.1		EPA:300.0
CYN-MW14A	10/21/2015	Sulfate	190	3	10		EPA:300.0
CYN-MW15	11/10/2015	Bromide	0.95	0.06	0.2		EPA:300.0
CYN-MW15	11/10/2015	Chloride	130	0.6	2		EPA:300.0
CYN-MW15	11/10/2015	Fluoride	0.39	0.03	0.1		EPA:300.0
CYN-MW15	11/10/2015	Sulfate	220	3	10		EPA:300.0

Appendix A: Burn Site Groundwater Quality Results: Major Cations
New Mexico Environment Department DOE Oversight Bureau
October/November 2015

SNL/NM Monitoring Well	Sample Date	Analyte	Result (mg/L)	Method Detection Limit (mg/L)	Laboratory Detection Limit (mg/L)	Laboratory Qualifier	Analytical Method
CYN-MW4	10/19/2015	Calcium	72	0.018	1	B	SW-846:6010B
CYN-MW4	10/19/2015	Lithium	0.068	0.0012	0.01	B	SW-846:6010B
CYN-MW4	10/19/2015	Magnesium	33	0.022	1		SW-846:6010B
CYN-MW4	10/19/2015	Potassium	7.2	0.19	1		SW-846:6010B
CYN-MW4	10/19/2015	Silicon	7.5	0.017	0.05	B	SW-846:6010B
CYN-MW4	10/19/2015	Sodium	42	0.049	1	B	SW-846:6010B
CYN-MW4	10/19/2015	Strontium	0.77	0.0018	0.01		SW-846:6010B
CYN-MW7	10/27/2015	Calcium	110	0.018	1		SW-846:6010B
CYN-MW7	10/27/2015	Lithium	0.039	0.0012	0.01	B	SW-846:6010B
CYN-MW7	10/27/2015	Magnesium	21	0.022	1		SW-846:6010B
CYN-MW7	10/27/2015	Potassium	2.8	0.19	1		SW-846:6010B
CYN-MW7	10/27/2015	Silicon	13	0.017	0.05		SW-846:6010B
CYN-MW7	10/27/2015	Sodium	38	0.049	1	B	SW-846:6010B
CYN-MW7	10/27/2015	Strontium	0.62	0.0018	0.01		SW-846:6010B
CYN-MW8	10/26/2015	Calcium	120	0.018	1		SW-846:6010B
CYN-MW8	10/26/2015	Lithium	0.042	0.0012	0.01	B	SW-846:6010B
CYN-MW8	10/26/2015	Magnesium	25	0.022	1		SW-846:6010B
CYN-MW8	10/26/2015	Potassium	2.7	0.19	1		SW-846:6010B
CYN-MW8	10/26/2015	Silicon	13	0.017	0.05		SW-846:6010B
CYN-MW8	10/26/2015	Sodium	44	0.049	1	B	SW-846:6010B
CYN-MW8	10/26/2015	Strontium	0.64	0.0018	0.01		SW-846:6010B
CYN-MW9	11/11/2015	Calcium	140	0.018	1	B	SW-846:6010B
CYN-MW9	11/11/2015	Lithium	0.055	0.0012	0.01	B	SW-846:6010B
CYN-MW9	11/11/2015	Magnesium	37	0.022	1		SW-846:6010B
CYN-MW9	11/11/2015	Potassium	2.8	0.19	1		SW-846:6010B
CYN-MW9	11/11/2015	Silicon	15	0.017	0.05		SW-846:6010B
CYN-MW9	11/11/2015	Sodium	49	0.049	1	B	SW-846:6010B
CYN-MW9	11/11/2015	Strontium	1.1	0.0018	0.01		SW-846:6010B

B = Qualifier indicates that the analyte was detected in the blank.

Appendix A: Burn Site Groundwater Quality Results: Major Cations
New Mexico Environment Department DOE Oversight Bureau
October/November 2015

SNL/NM Monitoring Well	Sample Date	Analyte	Result (mg/L)	Method Detection Limit (mg/L)	Laboratory Detection Limit (mg/L)	Laboratory Qualifier	Analytical Method
CYN-MW10	11/2/2015	Calcium	150	0.018	1		SW-846:6010B
CYN-MW10	11/2/2015	Lithium	0.051	0.0012	0.01	B	SW-846:6010B
CYN-MW10	11/2/2015	Magnesium	38	0.022	1		SW-846:6010B
CYN-MW10	11/2/2015	Potassium	2.4	0.19	1		SW-846:6010B
CYN-MW10	11/2/2015	Silicon	8.7	0.017	0.05		SW-846:6010B
CYN-MW10	11/2/2015	Sodium	40	0.049	1	B	SW-846:6010B
CYN-MW10	11/2/2015	Strontium	1	0.0018	0.01		SW-846:6010B
CYN-MW11	11/4/2015	Calcium	150	0.018	1		SW-846:6010B
CYN-MW11	11/4/2015	Lithium	0.062	0.0012	0.01	B	SW-846:6010B
CYN-MW11	11/4/2015	Magnesium	43	0.022	1		SW-846:6010B
CYN-MW11	11/4/2015	Potassium	3.4	0.19	1		SW-846:6010B
CYN-MW11	11/4/2015	Silicon	8.3	0.017	0.05		SW-846:6010B
CYN-MW11	11/4/2015	Sodium	40	0.049	1	B	SW-846:6010B
CYN-MW11	11/4/2015	Strontium	1.1	0.0018	0.01		SW-846:6010B
CYN-MW12	10/20/2015	Calcium	160	0.018	1	B	SW-846:6010B
CYN-MW12	10/20/2015	Lithium	0.057	0.0012	0.01	B	SW-846:6010B
CYN-MW12	10/20/2015	Magnesium	40	0.022	1		SW-846:6010B
CYN-MW12	10/20/2015	Potassium	3.2	0.19	1		SW-846:6010B
CYN-MW12	10/20/2015	Silicon	8.5	0.017	0.05	B	SW-846:6010B
CYN-MW12	10/20/2015	Sodium	39	0.049	1	B	SW-846:6010B
CYN-MW12	10/20/2015	Strontium	1.1	0.0018	0.01		SW-846:6010B
CYN-MW13	10/28/2015	Calcium	110	0.018	1		SW-846:6010B
CYN-MW13	10/28/2015	Lithium	0.034	0.0012	0.01	B	SW-846:6010B
CYN-MW13	10/28/2015	Magnesium	21	0.022	1		SW-846:6010B
CYN-MW13	10/28/2015	Potassium	2.3	0.19	1		SW-846:6010B
CYN-MW13	10/28/2015	Silicon	12	0.017	0.05		SW-846:6010B
CYN-MW13	10/28/2015	Sodium	23	0.049	1	B	SW-846:6010B
CYN-MW13	10/28/2015	Strontium	0.65	0.0018	0.01		SW-846:6010B

B = Qualifier indicates that the analyte was detected in the blank.

Appendix A: Burn Site Groundwater Quality Results: Major Cations
New Mexico Environment Department DOE Oversight Bureau
October/November 2015

SNL/NM Monitoring Well	Sample Date	Analyte	Result (mg/L)	Method Detection Limit (mg/L)	Laboratory Detection Limit (mg/L)	Laboratory Qualifier	Analytical Method
CYN-MW13-DUP	10/28/2015	Calcium	110	0.018	1		SW-846:6010B
CYN-MW13-DUP	10/28/2015	Lithium	0.035	0.0012	0.01	B	SW-846:6010B
CYN-MW13-DUP	10/28/2015	Magnesium	21	0.022	1		SW-846:6010B
CYN-MW13-DUP	10/28/2015	Potassium	2.3	0.19	1		SW-846:6010B
CYN-MW13-DUP	10/28/2015	Silicon	12	0.017	0.05		SW-846:6010B
CYN-MW13-DUP	10/28/2015	Sodium	24	0.049	1	B	SW-846:6010B
CYN-MW13-DUP	10/28/2015	Strontium	0.65	0.0018	0.01		SW-846:6010B
CYN-MW14A	10/21/2015	Calcium	150	0.018	1	B	SW-846:6010B
CYN-MW14A	10/21/2015	Lithium	0.047	0.0012	0.01	B	SW-846:6010B
CYN-MW14A	10/21/2015	Magnesium	36	0.022	1		SW-846:6010B
CYN-MW14A	10/21/2015	Potassium	3.2	0.19	1		SW-846:6010B
CYN-MW14A	10/21/2015	Silicon	9	0.017	0.05	B	SW-846:6010B
CYN-MW14A	10/21/2015	Sodium	37	0.049	1	B	SW-846:6010B
CYN-MW14A	10/21/2015	Strontium	1	0.0018	0.01		SW-846:6010B
CYN-MW15	11/10/2015	Calcium	180	0.018	1	B	SW-846:6010B
CYN-MW15	11/10/2015	Lithium	0.064	0.0012	0.01	B	SW-846:6010B
CYN-MW15	11/10/2015	Magnesium	49	0.022	1		SW-846:6010B
CYN-MW15	11/10/2015	Potassium	3.5	0.19	1		SW-846:6010B
CYN-MW15	11/10/2015	Silicon	9.5	0.017	0.05		SW-846:6010B
CYN-MW15	11/10/2015	Sodium	44	0.049	1	B	SW-846:6010B
CYN-MW15	11/10/2015	Strontium	1.3	0.0018	0.01		SW-846:6010B

B = Qualifier indicates that the analyte was detected in the blank.

Appendix A: Burn Site Groundwater Quality Results: Total Organic Carbon
New Mexico Environment Department DOE Oversight Bureau
October/November 2015

SNL/NM Monitoring Well	Sample Date	Analyte	Result (mg/L)	Method Detection Limit (mg/L)	Laboratory Detection Limit (mg/L)	Laboratory Qualifier	Analytical Method
CYN-MW4	10/19/2015	Total Organic Carbon	0.34	0.3	1	J	EPA:415.1
CYN-MW7	10/27/2015	Total Organic Carbon	0.3	0.3	1	U	EPA:415.1
CYN-MW8	10/26/2015	Total Organic Carbon	0.33	0.3	1	J	EPA:415.1
CYN-MW9	11/11/2015	Total Organic Carbon	1.6	0.3	1		EPA:415.1
CYN-MW10	11/2/2015	Total Organic Carbon	1.5	0.3	1		EPA:415.1
CYN-MW11	11/4/2015	Total Organic Carbon	1.4	0.3	1		EPA:415.1
CYN-MW12	10/20/2015	Total Organic Carbon	1.1	0.3	1		EPA:415.1
CYN-MW13	10/28/2015	Total Organic Carbon	0.41	0.3	1	J	EPA:415.1
CYN-MW13-DUP	10/28/2015	Total Organic Carbon	0.59	0.3	1	J	EPA:415.1
CYN-MW14A	10/21/2015	Total Organic Carbon	1.3	0.3	1		EPA:415.1
CYN-MW15	11/10/2015	Total Organic Carbon	2.2	0.3	1		EPA:415.1

J = The reported value was obtained from the reading that was less than the Reporting Limit but greater than or equal to the Method Detection Limit (MDL).

U = Qualifier indicates that the analyte was not detected above the Method Detection Limit (MDL).

Appendix A: Burn Site Groundwater Quality Results: Diesel and Gasoline Range Organics
New Mexico Environment Department DOE Oversight Bureau
October/November 2015

SNL/NM Monitoring Well	Sample Date	Analyte	Result (mg/L)	Method Detection Limit (mg/L)	Laboratory Detection Limit (mg/L)	Laboratory Qualifier	Analytical Method
CYN-MW4	10/19/2015	Diesel Range Organics	0.18	0.18	0.59	U	SW-846:8015M
CYN-MW4	10/19/2015	Gasoline Range Organics	0.011	0.01	0.1	JB	SW-846:8015
CYN-MW7	10/27/2015	Diesel Range Organics	0.17	0.17	0.58	U	SW-846:8015M
CYN-MW7	10/27/2015	Gasoline Range Organics	0.01	0.01	0.1	U	SW-846:8015
CYN-MW8	10/26/2015	Diesel Range Organics	0.17	0.17	0.57	U	SW-846:8015M
CYN-MW8	10/26/2015	Gasoline Range Organics	0.01	0.01	0.1	U	SW-846:8015
CYN-MW9	11/11/2015	Diesel Range Organics	0.18	0.18	0.59	U	SW-846:8015M
CYN-MW9	11/11/2015	Gasoline Range Organics	0.01	0.01	0.1	U	SW-846:8015
CYN-MW10	11/2/2015	Diesel Range Organics	0.18	0.18	0.58	U	SW-846:8015M
CYN-MW10	11/2/2015	Gasoline Range Organics	0.01	0.01	0.1	U	SW-846:8015
CYN-MW11	11/4/2015	Diesel Range Organics	0.17	0.17	0.57	U	SW-846:8015M
CYN-MW11	11/4/2015	Gasoline Range Organics	0.01	0.01	0.1	U	SW-846:8015
CYN-MW11-DUP	11/4/2015	Diesel Range Organics	0.18	0.18	0.59	U	SW-846:8015M
CYN-MW11-DUP	11/4/2015	Gasoline Range Organics	0.01	0.01	0.1	U	SW-846:8015
CYN-MW12	10/20/2015	Diesel Range Organics	0.17	0.17	0.58	U	SW-846:8015M
CYN-MW12	10/20/2015	Gasoline Range Organics	0.01	0.01	0.1	U	SW-846:8015
CYN-MW13	10/28/2015	Diesel Range Organics	0.17	0.17	0.57	U	SW-846:8015M
CYN-MW13	10/28/2015	Gasoline Range Organics	0.01	0.01	0.1	U	SW-846:8015
CYN-MW13-DUP	10/28/2015	Diesel Range Organics	0.17	0.17	0.58	U	SW-846:8015M
CYN-MW13-DUP	10/28/2015	Gasoline Range Organics	0.01	0.01	0.1	U	SW-846:8015
CYN-MW14A	10/21/2015	Diesel Range Organics	0.17	0.17	0.57	U	SW-846:8015M
CYN-MW14A	10/21/2015	Gasoline Range Organics	0.01	0.01	0.1	U	SW-846:8015
CYN-MW14A-DUP	10/21/2015	Diesel Range Organics	0.17	0.17	0.58	U	SW-846:8015M
CYN-MW14A-DUP	10/21/2015	Gasoline Range Organics	0.01	0.01	0.1	U	SW-846:8015
CYN-MW15	11/10/2015	Diesel Range Organics	0.18	0.18	0.59	U	SW-846:8015M
CYN-MW15	11/10/2015	Gasoline Range Organics	0.01	0.01	0.1	U	SW-846:8015

B = Qualifier indicates that the analyte was detected in the blank.

J = The reported value was obtained from the reading that was less than the Reporting Limit but greater than or equal to the Method Detection Limit (MDL).

U = Qualifier indicates that the analyte was not detected above the Method Detection Limit (MDL).

Appendix A: Burn Site Groundwater Quality Results: Perchlorate
New Mexico Environment Department DOE Oversight Bureau
October/November 2015

SNL/NM Monitoring Well	Sample Date	Analyte	Result (µg/L)	Method Detection Limit (µg/L)	Laboratory Detection Limit (µg/L)	Laboratory Qualifier	Analytical Method
CYN-MW15	11/10/2015	Perchlorate	1.8	0.4	1		EPA:314.0

Appendix A: Burn Site Groundwater Quality Results: Oxygen and Hydrogen Isotopes
New Mexico Environment Department DOE Oversight Bureau
October/November 2015

SNL/NM Monitoring Well	Sample Date	δ18O ‰	δD ‰
CYN-MW4	10/19/2015	-11.3	-81.7
CYN-MW7	10/27/2015	-10.3	-75.7
CYN-MW8	10/26/2015	-10.3	-75.2
CYN-MW9	11/11/2015	-9.5	-64.5
CYN-MW10	11/2/2015	-10.7	-77.1
CYN-MW11	11/4/2015	-10.5	-77.0
CYN-MW12	10/20/2015	-10.5	-76.7
CYN-MW13	10/28/2015	-9.2	-63.6
CYN-MW13-DUP	10/28/2015	-9.1	-63.4
CYN-MW14A	10/21/2015	-10.6	-77.2
CYN-MW15	11/10/2015	-10.4	-76.2

Appendix A: Burn Site Groundwater Quality Results: Stable Isotopes of Nitrate
New Mexico Environment Department DOE Oversight Bureau
October/November 2015

SNL/NM Monitoring Well	Sample Date	$\delta^{15}N$ NO_3^-	$\delta^{18}O$ NO_3^-
CYN-MW4	10/19/2015	11.20	-4.23
CYN-MW7	10/27/2015	6.62	0.18
CYN-MW8	10/26/2015	6.05	-0.26
CYN-MW9	11/11/2015	2.77	-1.99
CYN-MW10	11/2/2015	3.16	0.64
CYN-MW11	11/4/2015	4.61	1.68
CYN-MW12	10/20/2015	5.61	1.77
CYN-MW13	10/28/2015	4.42	2.12
CYN-MW13-DUP	10/28/2015	4.43	1.72
CYN-MW14A	10/21/2015	5.12	1.64
CYN-MW15	11/10/2015	5.68	2.13

Appendix A: Burn Site Groundwater Quality Results: Low-Level Tritium
New Mexico Environment Department DOE Oversight Bureau
October/November 2015

SNL/NM Monitoring Well	Sample Date	Analyte	Result (pCi/L)	Uncertainty (pCi/L)	Minimum Detectable Activity (pCi/L)	Laboratory Qualifier
CYN-MW4	10/19/2015	Low Level Tritium	-0.10	0.29	0.29	
CYN-MW7	10/27/2015	Low Level Tritium	-0.03	0.29	0.29	
CYN-MW8	10/26/2015	Low Level Tritium	0.16	0.29	0.29	
CYN-MW9	11/11/2015	Low Level Tritium	10.70	0.35	0.29	
CYN-MW10	11/2/2015	Low Level Tritium	2.96	0.29	0.29	
CYN-MW11	11/4/2015	Low Level Tritium	2.16	0.29	0.29	
CYN-MW12	10/20/2015	Low Level Tritium	2.13	0.29	0.29	
CYN-MW13	10/28/2015	Low Level Tritium	5.64	0.29	0.29	
CYN-MW13-DUP	10/28/2015	Low Level Tritium	6.12	0.29	0.29	
CYN-MW14A	10/21/2015	Low Level Tritium	2.22	0.29	0.29	
CYN-MW15	11/10/2015	Low Level Tritium	2.58	0.29	0.29	