DOE/WIPP-12-3489

# Waste Isolation Pilot Plant Annual Site Environmental Report for 2011

U.S. Department of Energy

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Rev. 0

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2011 Annual Site Environmental Report

To our readers:

This Waste Isolation Pilot Plant (WIPP) Annual Site Environmental Report for 2011 presents summary environmental data to (1) characterize site environmental management performance, (2) summarize environmental occurrences and responses reported during the calendar year, (3) confirm compliance with environmental standards and requirements, and (4) highlight the WIPP Environmental Management System (EMS), significant environmental programs, and accomplishments, including progress toward U.S. Department of Energy (DOE) Environmental Sustainability Goals.

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| | |
|---|---|
| ALARA | as low as reasonably achievable |
| Am | americium |
| amsl | above mean sea level |
| ANOVA | analysis of variance |
| ANSI | American National Standards Institute |
| ARRA | *American Recovery and Reinvestment Act* |
| ASER | Annual Site Environmental Report |
| | |
| BCG | biota concentration guide |
| BLM | U.S. Department of the Interior, Bureau of Land Management |
| Bq | becquerel(s) |
| Bq/L | becquerels per liter |
| Bq/m3 | becquerels per cubic meter |
| Btu | British thermal unit |
| | |
| CAA | *Clean Air Act* |
| CAO | Carlsbad Area Office (now Carlsbad Field Office) |
| CBFO | Carlsbad Field Office |
| C&D | construction and demolition |
| cc | cubic centimeter |
| CCl4 | carbon tetrachloride |
| CEMRC | Carlsbad Environmental Monitoring and Research Center |
| CERCLA | *Comprehensive Environmental Response, Compensation, and Liability Act* |
| CFR | Code of Federal Regulations |
| CH | contact-handled |
| Ci | curie |
| cm | centimeter |
| Co | cobalt |
| Cs | cesium |
| CY | calendar year |
| | |
| d | day |
| DMP | Detection Monitoring Program |
| DER | duplicate error ratio |
| DOE | U.S. Department of Energy |
| DOELAP | DOE Laboratory Accreditation Program |
| DP | discharge permit |
| | |
| EDE | effective dose equivalent |
| EMS | Environmental Management System |
| EO | Executive Order |
| EPA | U.S. Environmental Protection Agency |
| EPCRA | *Emergency Planning and Community Right-to-Know Act* |
| | |
| FAS | fixed air sampler |

| | |
|---|---|
| ft | foot/feet |
| ft/d | feet per day |
| ft2/d | square feet per day |
| ft3 | cubic feet |
| FY | fiscal year |
| | |
| GC/MS | gas chromatography/mass spectrometry |
| GHG | greenhouse gas |
| GWQB | Ground Water Quality Bureau |
| | |
| HEAL | Hall Environmental Analysis Laboratory |
| HEPA | high-efficiency particulate air (filter) |
| HPS | Health Physics Society |
| HWDU | Hazardous Waste Disposal Unit |
| ICP-MS | inductively coupled plasma emission spectroscopy combined with mass spectrometry |
| | |
| ID | identification |
| in. | inch(es) |
| ISO | International Organization for Standardization |
| | |
| K | potassium |
| kg | kilogram(s) |
| km | kilometer(s) |
| km2 | square kilometers |
| KWh | kilowatt hour |
| | |
| L | liter(s) |
| LCS | laboratory control sample |
| LCSD | laboratory control sample duplicate |
| LEPC | Local Emergency Planning Committee |
| LMP | Land Management Plan |
| LWA | *Land Withdrawal Act* |
| LWB | Land Withdrawal Boundary |
| | |
| m | meter(s) |
| m2 | square meters |
| m2/d | square meters per day |
| m3 | cubic meters |
| m/d | meters per day |
| m/s | meters per second |
| MAPEP | Mixed Analyte Performance Evaluation Program |
| MCD | maximum concentration detected |
| MDC | minimum detectable concentration |
| MDL | method detection limit |
| MEI | maximally exposed individual |
| mg | milligram(s) |
| mg/L | milligrams per liter |

| | |
|---|---|
| mGy | milligray(s) |
| mGy/d | milligrays per day |
| mi | mile(s) |
| mi2 | square miles |
| mL | milliliter(s) |
| MOC | management and operating contractor |
| mph | miles per hour |
| mrem | millirem |
| MRL | method reporting limit |
| MS | mass spectrometry |
| MS/MSD | matrix spike / matrix spike duplicate |
| mSv | millisievert(s) |
| MW | megawatt |
| MWh | megawatt hour |
| N/A | not applicable |
| NCRP | National Council on Radiation Protection and Measurements |
| NELAC | National Environmental Laboratory Accreditation Associates Conference |
| NELAP | National Environmental Laboratory Accreditation Program |
| NEPA | *National Environmental Policy Act* |
| NESHAP | National Emission Standards for Hazardous Air Pollutants |
| NIST | National Institute of Standards and Technology |
| NMAC | New Mexico Administrative Code |
| NMED | New Mexico Environment Department |
| NMIMT | New Mexico Institute of Mining and Technology |
| NMSA | New Mexico Statutes Annotated |
| NPDES | National Pollutant Discharge Elimination System |
| NRIP | National Institute of Standards and Technology Radiochemistry Intercomparison Program |
| oz | ounce(s) |
| PCB | polychlorinated biphenyl |
| PE | performance evaluation |
| Permit | Hazardous Waste Facility Permit |
| pH | measure of the acidity or basicity of a solution |
| PIP | production-injection packer |
| ppmv | parts per million by volume |
| ppbv | parts per billion by volume |
| Pu | plutonium |
| QA | quality assurance |
| QC | quality control |
| rad | radiation absorbed dose |
| RCRA | *Resource Conservation and Recovery Act* |
| rem | roentgen equivalent man |
| RER | relative error ratio |

| | |
|---|---|
| RH | remote-handled |
| RPD | relative percent difference |
| | |
| SARA | *Superfund Amendments and Reauthorization Act of 1986* |
| SDWA | *Safe Drinking Water Act* |
| SEIS | Supplemental Environmental Impact Statement |
| SERC | State Emergency Response Commission |
| SNL | Sandia National Laboratories |
| SOP | standard operating procedure |
| SOW | statement of work |
| SPDV | site and preliminary design validation |
| Sr | strontium |
| SR/DL | Santa Rosa/Dewey Lake |
| SSP | Site Sustainability Plan |
| SSW | shallow subsurface water |
| Sv | sievert |
| SVOC | semivolatile organic compound |
| | |
| TDS | total dissolved solids |
| TOC | total organic carbon |
| TOX | total organic halogen |
| TPU | total propagated uncertainty |
| TRU | transuranic (waste) |
| TSCA | Toxic Substances Control Act |
| TSDF | treatment, storage, and disposal facility |
| TSS | total suspended solids |
| | |
| U | uranium |
| ug/L | microgram per liter |
| U.S. | United States |
| U.S.C. | United States Code |
| UNSCEAR | United Nations Scientific Committee on the Effects of Atomic Radiation |
| USFWS | U.S. Fish and Wildlife Service |
| UST | underground storage tank |
| UTLV | Upper Tolerance Limit Value |
| | |
| VOC | volatile organic compound |
| | |
| WHB | Waste Handling Building |
| WIPP | Waste Isolation Pilot Plant |

**SYMBOLS**

| | |
|---|---|
| ˚C | degrees Celsius |
| ˚F | degrees Fahrenheit |
| > | greater than |
| < | less than |
| ≤ | less than or equal to |
| μg | microgram |

| | |
|---|---|
| μmhos | micromhos |
| % | percent |
| ± | plus or minus |
| [RN] | radionuclide concentration |
| σ | sigma |

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# EXECUTIVE SUMMARY

## PURPOSE

The purpose of the Waste Isolation Pilot Plant (WIPP) Annual Site Environmental Report for 2011 (ASER) is to provide information required by U.S. Department of Energy (DOE) Order 231.1B, *Environment, Safety, and Health Reporting*. Specifically, the ASER presents summary environmental data to:

- Characterize site environmental management performance.
- Summarize environmental occurrences and responses reported during the calendar year.
- Confirm compliance with environmental standards and requirements.
- Highlight significant environmental accomplishments, including progress toward the DOE Environmental Sustainability Goals made through implementation of the WIPP Environmental Management System (EMS).

The DOE Carlsbad Field Office (CBFO) and the management and operating contractor (MOC) maintain and preserve the environmental resources at the WIPP facility. DOE Order 231.1B; DOE Order 436.1, *Departmental Sustainability*; and DOE Order 458.1, *Radiation Protection of the Public and the Environment*, require that the affected environment at and near DOE facilities be monitored to ensure the safety and health of the public and workers, and preservation of the environment.

This report was prepared in accordance with DOE Order 231.1B, which requires that DOE facilities submit an ASER to the DOE Headquarters Chief Health, Safety, and Security Officer.

## WIPP MISSION

The WIPP mission is to safely dispose of transuranic (TRU) waste generated by the production of nuclear weapons and other activities related to the national defense of the United States. In 2011, 7,232 cubic meters ($m^3$) of TRU waste were disposed of at the WIPP facility, including 7,192 $m^3$ of contact-handled (CH) TRU waste and 40 $m^3$ of remote-handled (RH) TRU waste. From the first receipt of waste in March 1999 through the end of 2011, 79,654 $m^3$ of TRU waste had been disposed of at the WIPP facility.

### WIPP Environmental Management System

The WIPP EMS is the mechanism through which the WIPP project protects human health and the environment; maintains compliance with applicable environmental laws and regulations; and implements sustainable practices for enhancing environmental, energy, and transportation management. The EMS is described in the *Waste Isolation Pilot Plant Environmental Management System Description* (DOE/WIPP-05-3318). Measuring and monitoring to assure that the project meets these objectives are key elements in the EMS.

**Monitoring for Environmental Impacts**

The DOE collects data needed to detect and quantify potential impacts that WIPP facility operations may have on the surrounding environment. *The Waste Isolation Pilot Plant Environmental Monitoring Plan* (DOE/WIPP-99-2194) outlines major environmental monitoring and surveillance activities at the WIPP facility and the WIPP facility quality assurance/quality control (QA/QC) program as it relates to environmental monitoring.

WIPP facility employees conduct both effluent monitoring (i.e., point source monitoring at release points such as the exhaust shaft) to detect radionuclides and quantify doses, and traditional pathway and receptor monitoring in the broader environment. The WIPP facility environmental monitoring program is designed to monitor pathways that radionuclides and other contaminants could take to reach the environment surrounding the WIPP facility. Pathways monitored include air, groundwater, surface water, soils, sediments, vegetation, and game animals. The goal of this monitoring is to determine if the local ecosystem has been, or is being, adversely impacted by WIPP facility operations and, if so, to evaluate the geographic extent and the effects on the environment.

The *Waste Isolation Pilot Plant Land Management Plan* (DOE/WIPP-93-004) (LMP) was created in compliance with the WIPP Land Withdrawal Act of 1992 (LWA) (Public Law 102-579, as amended by Public Law 104-201, National Defense Authorization Act for Fiscal Year 1997). This plan identifies resource values, promotes multiple-use management, and identifies long-term goals for the management of WIPP project lands. The LMP includes a land reclamation program that addresses both the short-term and long-term effects of WIPP facility operations and includes monitoring for environmental impacts. WIPP personnel also conduct surveillance in the region surrounding the site to protect the WIPP facility from trespass.

WIPP facility monitoring and surveillance programs used to determine if the local ecosystem has been impacted are listed below:

Environmental Radiological Programs

- Airborne particulates
- Biota
- Effluent
- Groundwater
- Sediments
- Soil
- Surface water

Environmental Nonradiological Programs

- Hydrogen and methane monitoring
- Land management
- Liquid effluent
- Meteorology

- Seismic activity
- Volatile organic compound (VOC) monitoring

Groundwater Protection Programs

- Groundwater levels
- Groundwater quality
- Pressure density surveys
- Shallow subsurface water (SSW) levels
- SSW quality

In 2011, results of these programs, including observations and analytical data, demonstrated that (1) compliance with applicable environmental requirements was maintained, and (2) the operations at the WIPP facility have not had a negative impact on human health or the environment.

**Environmental Compliance**

The owner and operator(s) of the WIPP facility are required to comply with applicable federal and state laws and DOE orders. In order to accomplish and document compliance with certain requirements, the following submittals, which are required on a routine basis, were among those completed in 2011:

New Mexico Submittals

- Hazardous Waste Facility Permit
    - 2010 Annual Site Environmental Report
    - Semiannual VOC, Hydrogen, and Methane Data Summary Reports
    - Mine Ventilation Rate Monitoring Report
    - Waste Minimization Statement
    - Semiannual WIPP Groundwater Detection Monitoring Reports
    - Geotechnical Analysis Report
    - Monthly Water Level Reports
- Discharge Permit (DP-831)
    - Semiannual Discharge Monitoring Reports
- Superfund Amendments and Reauthorization Act of 1986
    - Emergency and Hazardous Chemical Inventory Report
    - Toxic Chemical Release Inventory Report

U.S. Environmental Protection Agency (EPA) Submittals

- Delaware Basin Monitoring Annual Report
- 2011 Annual Polychlorinated Biphenyls Report
- WIPP Subsidence Monument Leveling Survey

- 2010/2011 Annual Change Report
- Toxic Chemical Release Inventory Report

Carlsbad Field Office Submittals

- Delaware Basin Monitoring Annual Report
- WIPP Subsidence Monument Leveling Survey

Other correspondence, regulatory submittals, monitoring reports, and the results of the EPA Annual Inspection, as well as other inspections, are described in Chapters 2 and 3 of this report.

The DOE maintains an in-depth, integrated evaluation program that consists of audits, assessments, surveillances, and inspections. In fiscal year (FY) 2011, 204 evaluations were conducted that monitored for compliance with environmental requirements. This program, coupled with the WIPP project corrective action programs, assures that potential compliance issues are identified and corrective/preventive actions are tracked formally through completion.

Overall, the data provided in the required submissions and the evaluation program results confirmed that the WIPP project maintained compliance with environmental requirements during 2011.

**Sustainable Practices**

WIPP's EMS objectives and targets support achievement of DOE's sustainability goals. Highlights of WIPP's progress for 2011 in sustainability include the following:

- Transition to renewable diesel was not successful after extensive efforts to secure fuel from a local startup renewable diesel manufacturing company failed.

- Site energy use was maintained at approximately 3.0 megawatt hours (MWh) per $m^3$ of TRU waste disposed at the WIPP facility. The WIPP facility used 1,500,000 kilowatt hours (kWh) of wind source energy, representing 7.5 percent of total energy used.

- A 13 percent reduction in energy intensity for WIPP site operations compared to the FY 2003 baseline was achieved. Energy intensity has reduced 21 percent since FY 2000 and 54 percent since FY 1999.

- The WIPP project continued to actively seek partners to enter into a Power Purchase Agreement for construction and operation of a 2 megawatt (MW) solar array project on WIPP lands. This type of facility would reduce greenhouse gas (GHG) emissions by 30 percent. However, due to WIPP's remote location and the modest cost of purchased energy, third parties found such a project to not be economically viable.

- Sustainable performance was recognized by the New Mexico Environment Department (NMED) with a Green Zia Environmental Leadership Program award and by the DOE with a 2011 Departmental Sustainability Award. The award was granted based on several innovative environmental solutions in the areas of air quality, water conservation and waste reduction including:

- Reducing carbon tetrachloride ($CCl_4$) levels in the underground repository
- Implementing a recycling method for used "slip sheets" by returning them to the product manufacturer for reprocessing
- Saving 340,000 gallons of fresh water by using on-site collected storm water and 7,800 tons of recycled asphalt for a road construction project

- WIPP continued to implement sustainable life-cycle management of electronics through the development of an Electronics Management Policy.
- Significant improvements were made to the sustainable acquisition program with the addition of a Green Catalog for purchases of environmentally preferred office products and upgrades to the procurement procedure and electronic system to improve inclusion of environmentally preferred products in purchase requisitions

**EMS Implementation**

Semiannual surveillance audits were conducted by the International Organization for Standardization (ISO) 14001 registrar during 2011 to confirm the EMS continued to be effectively implemented. No issues were identified from these audits and the EMS continued to be certified as conforming to ISO 14001:2004, Environmental Management Systems - Requirements with Guidance for Use.

Significant accomplishments of the EMS for 2011 were as follows:

- WIPP had no reportable, unauthorized contaminant releases to the environment in 2011.
- The 2011 environmental monitoring data continued to demonstrate that there has been no adverse impact to human health or the environment from WIPP facility operations.
- The NMED awarded CBFO a Green Zia Environmental Leadership Program award during 2011.

## SUMMARY OF RELEASES AND RADIOLOGICAL DOSES TO THE PUBLIC

### Doses to the Public and the Environment

The radiation dose to members of the public from WIPP facility operations has been calculated from WIPP facility effluent monitoring results and demonstrates compliance with federal regulations.

### Dose Limits

The regulatory limit for the WIPP facility is established in Title 40 *Code of Federal Regulations* (CFR) Part 191, Subpart A, "Environmental Standards for Management and Storage." This standard requires that the combined annual dose equivalent to any member of the public in the general environment resulting from discharges of radioactive material and direct radiation from such management and storage shall not exceed 25 millirem (mrem) ("rem" is roentgen equivalent man) to the whole body and 75 mrem to any critical organ. In addition, in a 1995 memorandum of understanding between the EPA and the DOE, the DOE agreed that the WIPP facility would comply with 40 CFR Part 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities," hereafter referred to as the NESHAP (National Emissions Standards for Hazardous Air Pollutants). The NESHAP standard for radionuclides requires that the emissions of radionuclides to the ambient air from DOE facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent (EDE) of 10 mrem per year.

### Background Radiation

There are several sources of naturally occurring radiation: cosmic and cosmogenic radiation (from outer space and the earth's atmosphere), terrestrial radiation (from the earth's crust), and internal radiation (naturally occurring radioactive material in our bodies). In addition to natural radioactivity, small amounts of radioactivity from aboveground nuclear weapons tests and from nuclear accidents are present in the environment. Together, natural radiation and residual fallout are called "background" radiation. Site-specific background gamma measurements on the surface, conducted by Sandia National Laboratories (SNL), showed an average dose rate of 7.65 microrem per hour (Minnema and Brewer, 1983), which would equate to the background gamma radiation dose of 0.67 millisieverts (mSv) (67.0 mrem) per year. A comprehensive radiological baseline study before WIPP facility disposal operations began was also documented in *Statistical Summary of the Radiological Baseline for the Waste Isolation Pilot Plant* (DOE/WIPP-92-037), which provides the basis for environmental background comparison after WIPP facility disposal operations commenced.

### Dose from Air Emissions

WIPP personnel have identified air emissions as the major pathway of concern for radionuclide transport during the receipt and emplacement of waste at the WIPP facility. To determine the radiation dose received by members of the public from WIPP facility operations, WIPP personnel used the EPA emission monitoring and test procedure (40 CFR §61.93, "Emission Monitoring and Test Procedure"), which requires the use of the EPA-approved CAP88-PC (computer code for calculating both dose and risk from radionuclide emissions) to calculate the EDE to members of the public. CAP88-PC dose calculations are based on the assumption that exposed people remain at home during the entire year and all vegetables, milk, and meat consumed are home-produced. Thus, this dose calculation is a maximum dose that encompasses dose from inhalation, plume immersion, deposition, and ingestion of air-emitted radionuclides.

### Total Dose from WIPP Facility Operations

The dose to an individual from the ingestion of WIPP facility-managed radionuclides transported in water is nonexistent because drinking water for communities near the WIPP site comes from groundwater sources that are too far away to be affected by WIPP facility operations.

Game animals sampled during 2011 were deer, quail, fish, and rabbit. The only radionuclide detected in any of the animal samples was naturally occurring potassium-40 ($^{40}K$), which was detected in all the samples. By extrapolation, no dose from WIPP facility-related radionuclides has been received by any individual from this pathway (i.e., the ingestion of meat from game animals) during 2011.

Based on the results of the WIPP effluent monitoring program, concentrations of radionuclides in air emissions did not exceed environmental dose standards set by 40 CFR Part 191, Subpart A, "Environmental Standards for Management and Storage," or by 40 CFR Part 61, Subpart H, "National Emission Standards for Hazardous Air Pollutants." The results indicate that the hypothetical maximally exposed individual (MEI) who resides year-round at the fence line, 350 meters (m) (1148 feet (ft)) from the exhaust shaft, receives a dose that is less than 1.29E-05 mSv (1.29E-03 mrem) per year for the whole body and less than 1.86E-05 mSv (1.86E-03 mrem) per year to the critical organ. These values are in compliance with the Subpart A standards specified in 40 CFR §191.03(b). For NESHAP (40 CFR §61.92) standards, the EDE potentially received by the MEI residing 7.5 kilometers (km) (4.66 miles (mi)) west-northwest of WIPP was calculated to be less than 1.75E-07 mSv (1.75E-05 mrem) per year for the whole body. This value is in compliance with the 40 CFR §61.92 standards.

Chapter 4 of this report presents figures and tables that provide the EDE values from calendar years (CYs) 1999 through 2011. These EDE values are below the EPA limit specified in 40 CFR Part 191, Subpart A, and 40 CFR Part 61, Subpart H.

### Dose to Nonhuman Biota

Dose limits that cause no deleterious effects on populations of aquatic and terrestrial organisms have been suggested by the National Council on Radiation Protection and Measurements (NCRPM) and the International Atomic Energy Agency. These absorbed dose limits are listed below:

- Aquatic Animals — 10 milligray/day (mGy/d) (1 radiation absorbed dose per day [rad/d])
- Terrestrial Plants — 10 mGy/d (1 rad/d)

- Terrestrial Animals 1 mGy/d (0.1 rad/d)

The DOE requires discussion of radiation doses to nonhuman biota in the ASER using the DOE Technical Standard, DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*. This standard requires an initial screening phase using conservative assumptions. This guidance was used to screen radionuclide concentrations observed around the WIPP site during 2011. The screening results indicate that radiation in the environment surrounding the WIPP site does not have a deleterious effect on populations of plants and animals.

**Release of Property Containing Residual Radioactive Material**

There was no release of radiologically contaminated materials or property in 2011.

# CHAPTER 1 – INTRODUCTION

The purpose of this report is to provide information needed by the DOE to assess WIPP facility environmental performance and to make WIPP project environmental information available to the public. This report has been prepared in accordance with DOE Order 231.1B, *Environment, Safety, and Health Reporting*. This document gives a brief overview of the WIPP facility environmental monitoring processes and reports CY 2011 results.

The WIPP facility is authorized by the DOE National Security and Military Applications of Nuclear Energy Authorization Act of 1980 (Public Law 96-164). After more than 20 years of scientific study and public input, the WIPP facility received its first shipment of waste on March 26, 1999.

Located in southeastern New Mexico, the WIPP facility is the nation's first underground repository permitted to safely and permanently dispose of TRU radioactive and mixed waste generated through defense activities and programs. TRU waste is defined in the WIPP LWA (Public Law 102-579) as radioactive waste containing more than 100 nanocuries (3,700 becquerels [Bq]) of alpha-emitting TRU isotopes per gram of waste, with half-lives greater than 20 years except for: (a) high-level waste; (b) waste that the Secretary has determined, with the concurrence of the Administrator, does not need the degree of isolation required by the disposal regulations; (c) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR Part 61. Most TRU waste is contaminated industrial trash, such as rags and tools, sludges from solidified liquids, glass, metal, and other materials. The waste must meet the criteria in *Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant* (DOE/WIPP-02-3122).

TRU waste is disposed of 655 m (2,150 ft) below the surface in excavated disposal rooms in the Salado Formation (Salado), which is a thick sequence of Permian Age evaporite salt beds. At the conclusion of the WIPP disposal phase, seals will be placed in the shafts. One of the main attributes of salt, as a rock formation in which to isolate radioactive waste, is the ability of the salt to creep, that is, to deform continuously over time. Excavations into which the waste-filled drums are placed will close eventually and the surrounding salt will flow around the drums and seal them within the Salado. A detailed description of the WIPP geology and hydrology may be found in Chapter 6.

## 1.1 WIPP Mission

The WIPP mission is to provide for the safe, environmentally sound disposal of defense TRU radioactive waste left from research, development, and production of nuclear weapons.

## 1.2 WIPP History

Government officials and scientists initiated the WIPP site selection process in the 1950s. At that time, the National Academy of Sciences undertook an evaluation of stable geological formations that could be used to contain radioactive wastes for thousands of years. In 1955, after this evaluation, salt deposits were recommended as a promising medium for the disposal of radioactive waste.

Salt deposits were selected as the host for the disposal of nuclear waste for several reasons. Most deposits of salt are found in stable geological areas with very little earthquake activity, assuring the stability of a waste repository. Salt deposits also demonstrate the absence of water that could move waste to the surface. If water had been present in the past or was currently present, it would have dissolved the salt beds. In addition, salt is relatively easy to mine. Finally, rock salt heals its own fractures because it behaves plastically under lithostatic pressure. This means salt formations will slowly and progressively move in to fill mined areas and will seal radioactive waste within the formation, safely away from the biosphere.

After a search for an appropriate site for the disposal of radioactive waste throughout the 1960s, the salt deposits in southeastern New Mexico were tested in the early 1970s. Salt and other evaporite formations at the WIPP site were deposited in thick beds during the evaporation of the Permian Sea. These geologic formations consist mainly of sodium chloride in the form of solid rock. The salt formation that serves as the host rock for the WIPP repository is approximately 610 m (2,000 ft) thick, begins 259 m (850 ft) below the earth's surface, and constitutes a stable geologic environment.

In 1979, Congress authorized the construction of the WIPP facility, and the DOE constructed the facility during the 1980s. In late 1993, the DOE created the Carlsbad Area Office (CAO), subsequently redesignated as the CBFO, to lead the TRU waste disposal effort. The CBFO coordinates the TRU program throughout the DOE complex.

On March 26, 1999, the WIPP facility received its first waste shipment from the Los Alamos National Laboratory in northern New Mexico.

## 1.3 Site Description

Located in Eddy County in the Chihuahuan Desert of southeastern New Mexico (Figure 1.1), the WIPP site encompasses 41.4 $km^2$ (16 $mi^2$). This part of New Mexico is relatively flat and is sparsely inhabited, with little surface water. The site is 42 km (26 mi) east of Carlsbad, New Mexico, in a region known as Los Medaños (the Dunes).

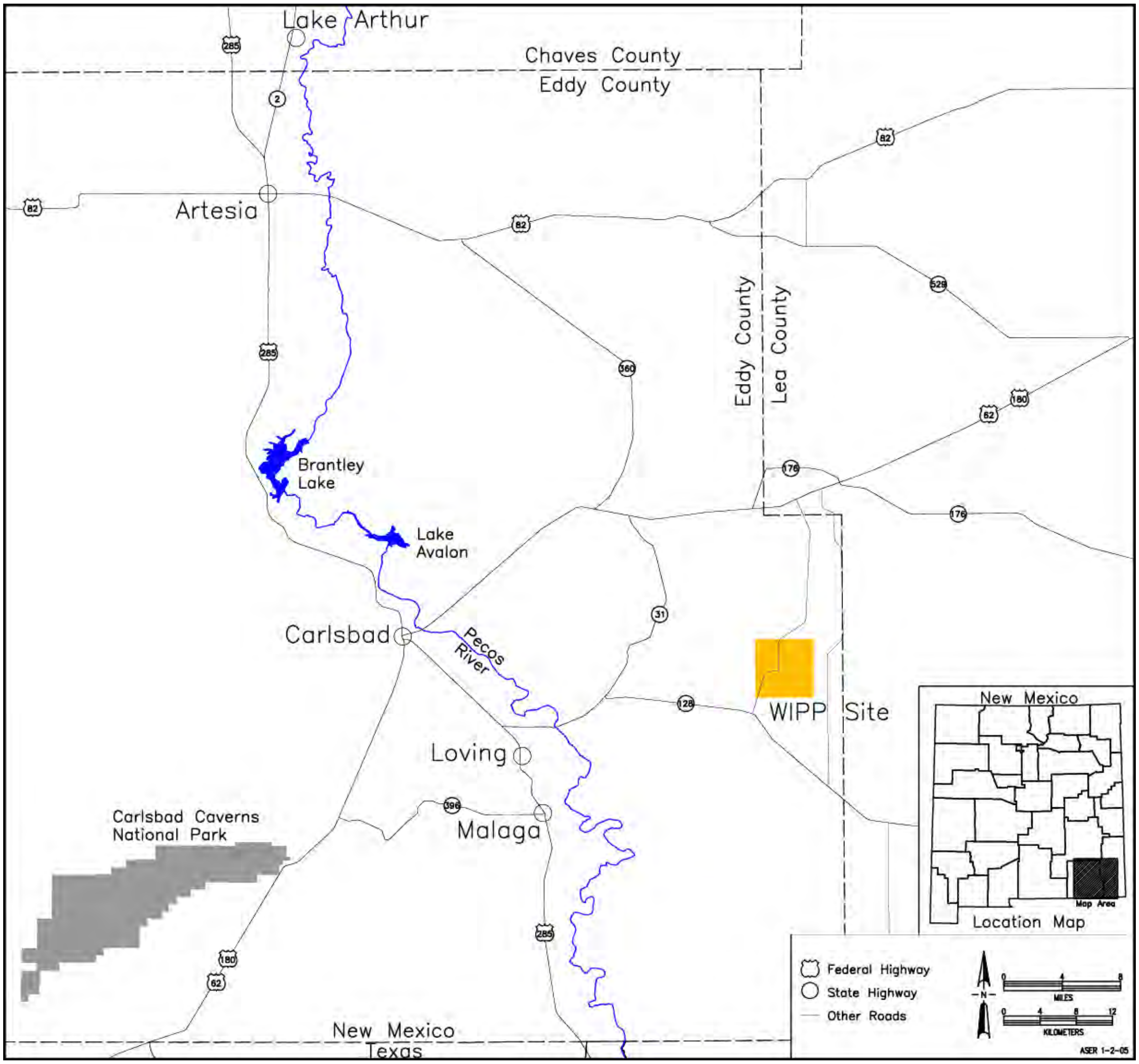


Figure 1.1 – WIPP Location

The WIPP LWA was signed into law on October 30, 1992, transferring the administration of federal land from the U.S. Department of the Interior to the DOE. With the exception of facilities within the boundaries of the posted 1.17 $km^2$ (0.45 $mi^2$) Exclusive Use Area, the surface land uses remain largely unchanged from pre-1992 uses, and are managed in accordance with accepted practices for multiple land use.

The majority of the lands in the immediate vicinity of the WIPP site are managed by the U.S. Department of the Interior Bureau of Land Management (BLM). Land uses in the surrounding area include livestock grazing, potash mining, oil and gas exploration and production, and recreational activities such as hunting, camping, hiking, and bird watching. The region is home to diverse populations of animals and plants.

### 1.3.1 WIPP Property Areas

Four property areas are defined within the WIPP site boundary (Figure 1.2).

Property Protection Area

The interior core of the facility encompasses 0.14 $km^2$ (0.05 $mi^2$) (35 acres) surrounded by a chain link fence. Security is provided for this area 24 hours a day.

Exclusive Use Area

The Exclusive Use Area is comprised of 1.17 $km^2$ (0.45 $mi^2$) (290 acres). It is surrounded by a barbed wire fence and is restricted exclusively for the use of the DOE and its contractors and subcontractors in support of the project. This area is marked by DOE warning signs (e.g., "No Trespassing") and is patrolled by WIPP facility security personnel to prevent unauthorized activities or uses.

Off Limits Area

Unauthorized entry and introduction of weapons and/or dangerous materials are prohibited in the Off-Limits Area, which encompasses 5.88 $km^2$ (2.27 $mi^2$) (1,454 acres). Pertinent prohibitions are posted along the perimeter. Grazing and public thoroughfare will continue in this area unless these activities present a threat to the security, safety, or environmental quality of the WIPP site. This area is patrolled by WIPP facility security personnel to prevent unauthorized activities or use.

WIPP Land Withdrawal Area

The WIPP site boundary delineates the perimeter of the 41.4 $km^2$ (16 $mi^2$) (10,240 acres) WIPP LWA. This tract includes the Property Protection Area, the Exclusive Use Area, and the Off-Limits Area, as well as outlying areas.

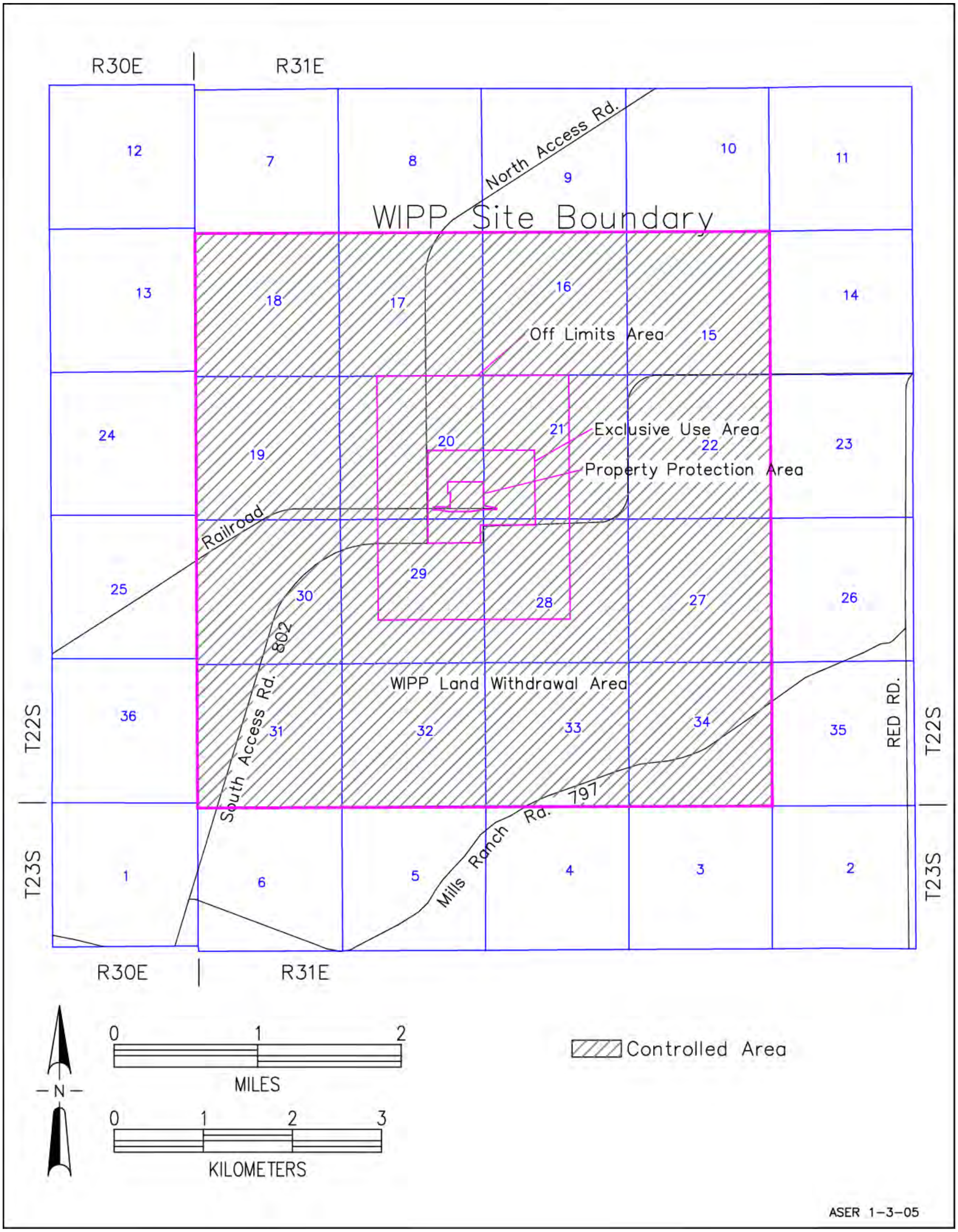


Figure 1.2 – WIPP Property Areas

Special Management Areas

Certain properties used in the execution of the WIPP project (e.g., reclamation sites, well pads, roads) are, or may be, identified as Special Management Areas in accordance with the WIPP LMP (DOE/WIPP-93-004), which is described further in Chapter 5. A Special Management Area designation is made when resources and/or other circumstances meet the criteria for protection and management under special management designations. Unique resources of value that are in danger of being lost or damaged, areas where ongoing construction is occurring, fragile plant and/or animal communities, sites of archaeological significance, locations containing safety hazards, or sectors that may receive an unanticipated elevated security status would be suitable for designation as Special Management Areas. No areas were designated as Special Management Areas in 2011.

### 1.3.2 Population

There are 11 permanent residents living within 16 km (10 mi) of the WIPP site (DOE/WIPP-93-004). This population is associated with ranching, oil and gas exploration/production, and potash mining.

The majority of the local population within 80.5 km (50 mi) of WIPP is concentrated in and around the communities of Carlsbad, Hobbs, Eunice, Loving, Jal, Lovington, and Artesia, New Mexico. According to 2010 census data, the estimated population within this radius is 88,952. The nearest community is the village of Loving (estimated population 1,413), 29 km (18 mi) west-southwest of the WIPP site. The nearest major populated area is Carlsbad, 42 km (26 mi) west of the WIPP site. The 2010 census reported the population of Carlsbad as 26,138.

## 1.4 WIPP Environmental Stewardship

The DOE policy is to conduct its operations in compliance with applicable environmental laws and regulations, and to safeguard the integrity of the southeastern New Mexico environment. The DOE conducts effluent monitoring, environmental surveillance, land management, and assessments to verify that these objectives are met. Environmental monitoring includes collecting and analyzing environmental samples from various media and evaluating whether WIPP facility operations have caused any adverse environmental impacts.

### 1.4.1 Environmental Monitoring Plan

The *Waste Isolation Pilot Plant Environmental Monitoring Plan* (DOE/WIPP-99-2194) outlines the program for monitoring the environment at and around the WIPP site, including the major environmental monitoring and surveillance activities at the WIPP facility. The plan also discusses the WIPP project QA/QC program as it relates to environmental monitoring. The purpose of the plan is to specify how the effects of WIPP facility operations on the local ecosystem are to be determined. Effluent and environmental monitoring data are necessary to demonstrate compliance with applicable environmental protection regulations. The frequency of 2011 sampling is provided in Table 1.1.

**Table 1.1 – Environmental Monitoring Sampling[a]**

| Program | Type of Sample | Number of Sampling Locations | Sampling Frequency |
|---|---|---|---|
| Radiological | Airborne effluent | 3 | Periodic/confirmatory |
| | Airborne particulate | 7 | Weekly |
| | Sewage treatment system (DP-831)[b] | 3 | Semiannual |
| | H-19 (DP-831)[b] | 1 | Semiannual |
| | Liquid effluent | 1 (WHB sump) | If needed |
| | Biotic | | |
| | Quail<br>Rabbit<br>Beef/Deer<br>Javelina<br>Fish<br>Vegetation | WIPP vicinity<br>WIPP vicinity<br>WIPP vicinity<br>WIPP vicinity<br>3<br>6 | Annual<br>As available<br>As available<br>As available<br>Annual<br>Annual |
| | Soil | 6 | Annual |
| | Surface water | Maximum of 14 | Annual |
| | Sediment | Maximum of 12 | Annual |
| | Groundwater | 7 | Semiannual |
| Nonradiological | Meteorology | 1 | Continuous |
| | Volatile organic compounds (VOCs) | | |
| | VOCs – Repository<br>VOCs – Disposal Room | 2<br># of active panel disposal rooms | Semiweekly<br>Biweekly |
| | Hydrogen and methane | 18 per filled panel | Monthly |
| | Groundwater | 7 | Semiannual |
| | Shallow subsurface water (SSW) | 11 | Semiannual |
| | Surface water (DP-831) | 9 | After a major storm event or annually, whichever is more frequent |

(a) The number of certain types of samples taken can be driven by site conditions. For example, during dry periods there may be no surface water or sediment to sample at certain locations. Likewise, the number of samples for biota will also vary. For example, the number of rabbits available as samples of opportunity will vary, as will fishing conditions that are affected by weather and algae levels in the water.

(b) Includes a nonradiological program component.

The plan describes the monitoring of naturally occurring and specific anthropogenic (human-made) radionuclides. The geographic scope of radiological sampling is based on projections of potential release pathways from the waste disposed at the WIPP facility. The plan also describes monitoring of VOCs, groundwater chemistry, and other nonradiological environmental parameters, and collection of meteorological data.

### 1.4.2 WIPP Facility Environmental Monitoring Program and Surveillance Activities

Employees of the WIPP facility monitor air, surface water, groundwater, sediments, soils, and biota (e.g., vegetation, selected mammals, quail, and fish). Environmental monitoring activities are performed in accordance with procedures that govern how samples are to be taken, preserved, and transferred. Procedures also direct the verification and validation of environmental sampling data.

The atmospheric pathway, which can lead to the inhalation of radionuclides, has been determined to be the most likely exposure pathway to the public from the WIPP facility. Therefore, airborne particulate sampling for alpha-emitting radionuclides is emphasized. Air sampling results are used to trend environmental radiological levels and determine if there has been a deviation from established baseline concentrations. The geographic scope of radiological sampling is based on projections of potential release pathways and nearby populations for the types of radionuclides in TRU wastes that are managed at the WIPP facility, and includes Carlsbad and nearby ranches.

Nonradiological environmental monitoring activities at the WIPP site consist of sampling and analyses designed to detect and quantify impacts of operational activities, and verify compliance with applicable requirements.

## 1.5 Environmental Performance

DOE Order 436.1, *Departmental Sustainability*, describes the DOE commitment to environmental protection and pledges to implement sound stewardship practices that are protective of the air, water, land, and other natural and cultural resources. The provisions of DOE Order 436.1 are implemented by WIPP environmental policy and the EMS.

In 2011, WIPP maintained compliance with applicable environmental laws, regulations, and permit conditions. Furthermore, analyses of the WIPP environmental monitoring data have demonstrated that WIPP operations have not had an adverse impact on the environment. Implementation of the *WIPP Environmental Monitoring Plan* (DOE/WIPP-99-2194) fulfills the environmental monitoring requirements of DOE Order 436.1. Detailed information on WIPP programs are contained in the remaining chapters.

# CHAPTER 2 – COMPLIANCE SUMMARY

The WIPP facility is required to comply with the applicable regulations promulgated pursuant to federal and state statutes, DOE orders, and Executive Orders (EOs). Compliance with regulatory requirements is incorporated into facility plans and implementing procedures. Methods for maintaining compliance with environmental requirements include the use of engineered controls and written procedures, routine training of facility personnel, ongoing self-assessments, and personnel accountability. The following sections list the environmental statutes/regulations applicable to WIPP, and describe significant accomplishments and ongoing compliance activities. A detailed breakdown of WIPP facility compliance with environmental laws is available in the *Waste Isolation Pilot Plant Biennial Environmental Compliance Report* (DOE/WIPP-10-2171).

A summary of WIPP facility compliance with major environmental regulations is presented below. A list of active WIPP environmental permits appears in Appendix B.

## 2.1 Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)

The *Comprehensive Environmental Response, Compensation and Liability Act* (42 U.S.C. [United States Code] §§9601, et seq.), or Superfund, establishes a comprehensive federal strategy for responding to, and establishing liability for, releases of hazardous substances from a facility to the environment. Any spills of hazardous substances that exceed a reportable quantity must be reported to the National Response Center under the provisions of CERCLA and 40 CFR Part 302, "Designation, Reportable Quantities, and Notification." Hazardous substance cleanup procedures are specified in 40 CFR Part 300, "National Oil and Hazardous Substances Pollution Contingency Plan."

### 2.1.1 Superfund Amendments and Reauthorization Act of 1986 (SARA)

The WIPP facility is required by the *Superfund Amendments and Reauthorization Act of 1986 Title III* (SARA) (42 U.S.C. §11001, also known as the *Emergency Planning and Community Right-to-Know Act* [EPCRA]), which is implemented by 40 CFR Parts 355, 370, 372, and 373, to submit (1) a list of hazardous chemicals present at the facility in excess of 10,000 pounds for which Material Safety Data Sheets are required, (2) an Emergency and Hazardous Chemical Inventory Form (Tier II Form) that identifies the inventory of hazardous chemicals present during the preceding year, and (3) notification to the State Emergency Response Commission (SERC) and the Local Emergency Planning Committee (LEPC) of any accidental releases of hazardous chemicals in excess of reportable quantities. The list of hazardous chemicals and the Tier II Form are also submitted to the regional fire departments.

The list of chemicals provides external emergency responders with information they may need when responding to a hazardous chemical emergency at WIPP. The list of hazardous chemicals is a one-time notification unless new hazardous chemicals in excess of 10,000 pounds, or new information on existing chemicals, are received.

The LEPC and the SERC are notified whenever a new hazardous chemical is received on site in excess of 10,000 pounds at any one time. The hazardous chemical is reported to the LEPC and the SERC within 30 days of receipt.

The Tier II Form, due on March 1 of each year, provides information to the public about hazardous chemicals above threshold planning quantities that a facility has on site at any time during the year. The Tier II Form is submitted annually to the LEPC and the SERC, and to each fire department with which the CBFO maintains a memorandum of understanding.

Title 40 CFR Part 372, "Toxic Chemical Release Reporting: Community Right to Know," identifies requirements for facilities to submit a toxic chemical release report to the EPA and the resident state if toxic chemicals are used at the facility in excess of established threshold amounts. The Toxic Chemical Release Report was submitted to the EPA and to the SERC prior to the July 1, 2011, reporting deadline. Table 2.1 presents the 2011 EPCRA reporting status. A response of "yes" indicates that the report was required and submitted.

**Table 2.1 – Status of Emergency Planning and Community Right-to-Know Act Reporting**

| EPCRA Regulations – 40 CFR Parts | Description of Reporting | Status |
|---|---|---|
| 355 | Planning Notification | Further Notification Not Required |
| 302 | Extremely Hazardous Substance Release Notification | Not Required |
| 355 | Material Safety Data Sheet/Chemical Inventory (Tier II Form) | Yes |
| 372 | Toxics Release Inventory Reporting | Yes |

### 2.1.2 Accidental Releases of Reportable Quantities of Hazardous Substances

There were no releases of hazardous substances exceeding the reportable quantity limits during 2011.

## 2.2 Resource Conservation and Recovery Act

The *Resource Conservation and Recovery Act* (RCRA) (42 U.S.C. §§6901, et seq.) was enacted in 1976. Implementing regulations were promulgated in May 1980. This body of regulations ensures that hazardous waste is managed and disposed of in a way that protects human health and the environment. The *Hazardous and Solid Waste Amendments of 1984* (Public Law 98-616, Stat. 3221) prohibit land disposal of hazardous waste unless treatment standards are met or specific exemptions apply. The amendments also emphasize waste minimization. Section 9(a) of the WIPP LWA exempts TRU mixed waste designated by the Secretary of Energy for disposal at the WIPP facility from treatment standards. Such waste is not subject to the land disposal prohibitions of the *Solid Waste Disposal Act* (42 U.S.C. §§6901-6992, et seq.).

The NMED is authorized by the EPA to implement the hazardous waste program in New Mexico pursuant to the New Mexico Hazardous Waste Act (New Mexico Statutes Annotated [NMSA] §§74-4-1, et seq., 1978). The technical standards for hazardous waste treatment, storage, and disposal facilities in New Mexico are outlined in 20.4.1.500 New Mexico Administrative Code (NMAC), which adopts, by reference, 40 CFR Part 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities." The hazardous waste management permitting program is administered through 20.4.1.900 NMAC, "Adoption of 40 CFR Part 270" [EPA Administered Permit Programs: The Hazardous Waste Permit Program].

### 2.2.1 Hazardous Waste Facility Permit

The Hazardous Waste Facility Permit NM4890139088-TSDF (Permit) authorizes DOE and MOC (collectively known as the Permittees) to receive, store, and dispose of CH and RH TRU mixed waste at the WIPP facility. Two storage units (the Parking Area Unit and the Waste Handling Building (WHB) Unit) are permitted for storage of TRU mixed waste. Eight underground hazardous waste disposal units are currently permitted for the disposal of CH and RH TRU mixed waste.

### 2.2.2 Modification Requests

In 2011, the Permittees submitted eight Class 1 permit modification notifications and two Class 2 permit modification requests to the NMED, as described in Table 2.2.

**Table 2.2 – Permit Modification Notifications and Requests Submitted in 2011**

| Class | Description | Date Submitted |
|---|---|---|
| 1 | Class 1 Permit Modification to Add South Access Road for Transportation of TRU Mixed Waste | March 17, 2011 |
| 1 | Class 1 Permit Modification Notification to Revise TRUPACT-III Management Language and Revise Procedure Reference for the Bolting Station in Table E-1 | May 24, 2011 |
| 1 | Class 1 Permit Modification Notification to Update Emergency Coordinator List | June 2, 2011 |
| 1 | Class 1 Permit Modification Notification to Update Emergency Coordinator List | July 5, 2011 |
| 1 | Class 1 Permit Modification Notification – Editorial Corrections to the Permit Issued April 15, 2011 | July 11, 2011 |
| 1 | Class 1 Permit Modification Notification – Revise Tables 4.1.1 and G-1 | August 8, 2011 |
| 1 | Class 1 Permit Modification Notification with eight changes | November 21, 2011 |
| 1 | Class 1 Permit Modification Notification – Continuing Training Timeframe | December 16, 2011 |
| 2 | Class 2 Permit Modification Request TRUPACT-III | January 10, 2011 |
| 2 | Class 2 Permit Modification Notification – Item 1, Update Ventilation Language; Item 2, Addition of a Shielded Container; Item 3, Revise the WIPP Groundwater Detection Monitoring Program Plan | September 29, 2011 |

In accordance with Permit Part 1, Section 1.14, *Information Repository*, all permit modification notifications and all permit modification requests, along with associated responses from the regulator, were posted on the Permittees' web page within 10 calendar days. Other Permit information of interest was also provided in the Information Repository.

### 2.2.3 Underground Storage Tanks

Title 40 CFR Part 280, "Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks (UST)," addresses USTs containing petroleum products or hazardous chemicals. Requirements for UST management pertain to the design, construction, installation, and operation of USTs, as well as notification and corrective action requirements in the event of a release and actions required for out-of-service USTs. The NMED has been authorized by the EPA to regulate USTs, and implements the EPA program through 20.5 NMAC, "Petroleum Storage Tanks."

The NMED conducted an inspection of WIPP USTs on March 23, 2011. The inspector found no inconsistencies and the USTs were found to be in compliance with NMED petroleum storage tanks standards.

### 2.2.4 Hazardous Waste Generator Compliance

Nonradioactive hazardous waste is currently generated through routine facility operations, and is managed in satellite accumulation areas, a "less-than-90-day" accumulation area on the surface, and a "less-than-90-day" accumulation area underground.

Hazardous waste generated at the WIPP facility is accumulated, characterized, packaged, labeled, and manifested to off-site treatment, storage, and disposal facilities in accordance with the requirements codified in 20.4.1.300 NMAC, which adopts, by reference, 40 CFR Part 262, "Standards Applicable to Generators of Hazardous Waste."

### 2.2.5 Program Deliverables and Schedule

WIPP is in compliance with the Permit conditions related to reporting as noted below.

- Permit Part 4, Section 4.6, Maintenance and Monitoring Requirements, requires annual reports evaluating the geomechanical monitoring program and the mine ventilation rate monitoring program. The WIPP facility continued to comply with these requirements by preparing and submitting annual reports in October 2011, representing results for July 1, 2010, through June 30, 2011.

- Permit Part 4, Section 4.6, Maintenance and Monitoring Requirements, requires semiannual reports describing the results (data and analysis) of confirmatory VOC monitoring. The WIPP facility continued to comply with this requirement by preparing and submitting semiannual reports in April 2011, representing results for July 1, 2010, through December 31, 2010, and in October 2011, representing results for January 1, 2011, through June 30, 2011. Hydrogen and methane program data were included with the semiannual reports in 2011.

- Permit Part 5, Section 5.10.2.1 requires reports of the analytical results for semiannual Detection Monitoring Program (DMP) well samples and duplicates, as well as results of the statistical analysis of the samples showing whether statistically significant evidence of contamination is present. The reports for sampling Rounds 32 and 33 were submitted to the NMED in 2011. Sampling results are summarized in appendices E and F of this ASER.

- Permit Part 5, Section 5.10.2.2 requires monthly submittal of groundwater surface elevation results calculated from field measurements and fresh-water head elevations calculated as specified in Permit Attachment L, Section L-4c(1). Twelve monthly reports were submitted to the NMED in 2011 as required.

- Permit Part 5, Section 5.10.2.3 requires that groundwater flow data be included in the Annual Culebra Groundwater Report by November 30. The first of these reports is due in 2012.

## 2.3 National Environmental Policy Act

The *National Environmental Policy Act* (NEPA) (42 U.S.C. §§4321, et seq.) requires the federal government to use all practicable means to consider potential environmental impacts of proposed projects as part of the decision-making process. The NEPA also dictates that the public shall be allowed to review and comment on proposed projects that have the potential to significantly affect the environment.

NEPA regulations and requirements are detailed in 40 CFR Parts 1500-1508, "Council on Environmental Quality." The DOE codified its requirements for implementing the council's regulations in 10 CFR Part 1021, "National Environmental Policy Act Implementing Procedures." Title 10 CFR §1021.331 requires that, following completion of each environmental impact statement and its associated record of decision, the DOE prepare a mitigation action plan that addresses mitigation commitments expressed in the record of decision. The CBFO tracks the performance of mitigation commitments in the WIPP annual mitigation report. This report was issued July 5, 2011.

Day-to-day operational compliance with the NEPA at the WIPP facility is achieved through implementation of a NEPA compliance plan and procedure. Thirty-two projects were reviewed and approved by the CBFO NEPA Compliance Officer through the NEPA screening and approval process in 2011. These projects were primarily upgrades to WIPP facilities and equipment. The approvals were in addition to routine activities which have been determined to be bounded by existing NEPA documentation and which do not require additional evaluation by the CBFO NEPA Compliance Officer. The CBFO NEPA Compliance Officer also routinely participates in the development of NEPA documents for other DOE offices and other federal agencies for proposed actions that may have environmental impacts on WIPP.

In October 2011, CBFO adopted an Environmental Assessment written by the Bureau of Land Management that examined the potential environmental impacts associated with improvements to the City of Carlsbad Double Eagle Water System. CBFO also issued a Finding of No Significant Impact for this EA.

### 2.4 Clean Air Act (CAA)

The *Clean Air Act* (CAA)(42 U.S.C. §§7401, et seq.) provides for the preservation, protection, and enhancement of air quality. Both the State of New Mexico and the EPA have authority for regulating compliance with portions of the CAA. Radiological effluent monitoring in compliance with EPA standards is discussed in Chapter 4.

Based on an initial 1993 air emissions inventory, the WIPP facility is not required to operate under CAA permits. In 1993, the DOE did obtain a New Mexico Air Quality Control (NMSA 1978 §74-2) Regulation 702 Operating Permit (recodified in 2001 as 20.2.72 NMAC, "Construction Permits") for two backup diesel generators at the WIPP facility. There have been no activities or modifications to the operating conditions of the diesel generators that would require reporting under the conditions of the Permit in 2011.

VOC emissions from containers of TRU and TRU mixed waste that are vented to prevent the buildup of gases generated by radiolysis remain less than 5 tons per year for all VOCs monitored under the Permit.

### 2.5 Clean Water Act (CWA)

The *Clean Water Act* (33 U.S.C. §§1251, et seq.) establishes provisions for the issuance of permits for discharges into waters of the United States. The regulation defining the scope of the permitting process is contained in 40 CFR §122.1(b), "Scope of the NPDES [National Pollutant Discharge Elimination System] Permit Requirement," which states that "The NPDES program requires permits for the discharge of 'pollutants' from any 'point source' into 'waters' of the United States."

The CAA established National Ambient Air Quality Standards for six "criteria" pollutants: sulfur oxides, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead. The initial 1993 WIPP air emissions inventory was developed as a baseline document to calculate maximum potential hourly and annual emissions of both hazardous and criteria pollutants. Based on the current air emissions inventory, WIPP facility operations do not exceed the 10-ton-per-year emission limit for any individual hazardous air pollutant, the 25-ton-per-year limit for any combination of hazardous air pollutant emissions, or the 10-ton-per-year emission limit for criteria pollutants except for total suspended particulate matter and particulate matter less than 10 microns in diameter. Particulate matter is produced from fugitive sources related to the management of salt tailings extracted from the underground. Consultation with the NMED Air Quality Bureau resulted in a March 2006 determination that a permit is not required for fugitive emissions of particulate matter that result from salt management at the WIPP facility. Proposed facility modifications are reviewed to determine if they will create new air emission sources and require permit applications."

The WIPP facility does not discharge wastewater or storm water runoff into waters of the United States and is not subject to regulation under the NPDES program.

Wastewaters generated at the WIPP facility are either disposed of offsite or managed in on-site, lined evaporation ponds. Storm water runoff is also collected in lined detention basins. The management of wastewater and storm water runoff is regulated under the *New Mexico Water Quality Act* (NMSA 1978, §§74-6-1, et seq.), as discussed in section 2.6.

## 2.6 New Mexico Water Quality Act

The *New Mexico Water Quality Act* created the New Mexico Water Quality Control Commission, tasked with the development of regulations to protect New Mexico ground and surface water. New Mexico water quality regulations for ground and surface water protection are contained in 20.6.2 NMAC, "Ground and Surface Water Protection." The WIPP facility does not discharge to surface water, but does have a discharge permit designed to prevent impacts to groundwater.

The DOE was issued a discharge permit (DP-831) from the NMED Ground Water Quality Bureau (GWQB) for the operation of the WIPP sewage treatment facility in January 1992. The discharge permit was renewed and modified to include the H-19 Evaporation Pond in July 1997. The H-19 Evaporation Pond is used for the treatment of wastewater generated during groundwater monitoring activities, water removed from sumps in the underground, and condensation from duct work in the mine ventilation system. The discharge permit was modified in December 2003 to incorporate infiltration controls for salt contact storm water runoff and in December 2006 to provide a more detailed closure plan. The discharge permit was renewed on September 9, 2008.

In accordance with discharge permit requirements, monthly inspections are conducted of each of the infiltration control ponds and salt storage areas to ensure they are maintained in good condition. When deficiencies are observed, such as liner tears or significant erosion, appropriate repairs are conducted. The sewage lagoons and H-19 Evaporation Pond are inspected weekly for signs of erosion or damage to the liners even though the permit only requires monthly inspections. The distance between normal water levels and the top of the sewage lagoons, the H-19 Evaporation Pond, and all infiltration control ponds (known as "freeboard") is monitored daily.

The discharge permit requires the sewage lagoons and H-19 Evaporation Pond to be sampled semiannually and analyzed for nitrate, total Kjeldahl nitrogen, total dissolved solids (TDS), sulfate, and chloride. The infiltration control ponds must be sampled annually for TDS, sulfates, and chlorides. The results of this monitoring are reported in section 5.7, Liquid Effluent Monitoring. Additionally, the permit requires annual groundwater level monitoring and semiannual groundwater monitoring for sulfate, chloride, and TDS. There are no regulatory limits associated with the analytes. Subsurface shallow water monitoring results are discussed in Chapter 6.

## 2.7 Safe Drinking Water Act (SDWA)

The *Safe Drinking Water Act* (42 U.S.C. §§300f, et seq.) provides the regulatory strategy for protecting public water supply systems and underground sources of drinking water. New Mexico's drinking water regulations are contained in 20.7.10 NMAC, "Drinking Water," which adopts, by reference, 40 CFR Part 141, "National Primary

Drinking Water Regulations," and 40 CFR Part 143, "National Secondary Drinking Water Regulations." Water is supplied to the WIPP facility by the city of Carlsbad; however, the WIPP facility is classified as a nontransient, noncommunity water system subject to New Mexico drinking water regulations.

The WIPP facility qualifies for a reduced monitoring schedule under 40 CFR §141.86(d)(4), and is required to sample for lead and copper every three years. All samples taken in August 2011 were below action levels as specified by New Mexico monitoring requirements for lead and copper in tap water. Samples will again be collected between June and September 2014.

Bacterial samples are collected and residual chlorine levels tested monthly. Chlorine levels are reported to the NMED monthly. All bacteriological analytical results have been below the SDWA regulatory limits. Disinfectant byproducts testing per 40 CFR §141.132 is conducted annually by the State of New Mexico. All results have been below regulatory limits.

## 2.8 National Historic Preservation Act

The *National Historic Preservation Act* (16 U.S.C. §§470, et seq.) was enacted to protect the nation's cultural resources and establish the National Register of Historic Places. No archaeological investigations were required at the WIPP facility in 2011.

## 2.9 Toxic Substances Control Act (TSCA)

The *Toxic Substances Control Act* (TSCA)(15 U.S.C. §§2601, et seq.) was enacted to provide information about all chemicals and to control the production of new chemicals that might present an unreasonable risk of injury to health or the environment. The TSCA authorizes the EPA to require testing of old and new chemical substances. The TSCA also provides the EPA authority to regulate the manufacturing, processing, import, use, and disposal of chemicals.

Polychlorinated biphenyls (PCBs) are one of the compounds regulated by the TSCA. The PCB storage and disposal regulations are listed in the applicable subparts of 40 CFR Part 761, "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions." On May 15, 2003, EPA Region VI approved the disposal of waste containing PCBs at the WIPP facility. The WIPP facility began receiving PCB-contaminated waste on February 5, 2005. The EPA renewed the disposal authority April 30, 2008.

The required PCB annual report, containing information on PCB waste received and disposed of at the WIPP facility during 2010, was submitted to EPA Region VI prior to the required submission date in 2011.

## 2.10 Federal Insecticide, Fungicide, And Rodenticide Act

The *Federal Insecticide, Fungicide, and Rodenticide Act* (7 U.S.C. §§136, et seq.) authorizes the EPA to regulate the registration, certification, use, storage, disposal, transportation, and recall of pesticides (40 CFR Parts 150-189).

All applications of restricted-use pesticides at the WIPP facility are conducted by commercial pesticide contractors who are required to meet federal and state standards. General-use pesticides are stored according to label instructions. Used, empty cans are managed and disposed of in accordance with federal and state regulations.

## 2.11 Endangered Species Act

The *Endangered Species Act of 1973* (16 U.S.C. §§1531, et seq.) was enacted to prevent the extinction of certain species of animals and plants. This act provides strong measures to help alleviate the loss of species and their habitats, and places restrictions on activities that may affect endangered and threatened animals and plants to help ensure their continued survival. With limited exceptions, the act prohibits activities that could impact protected species, unless a permit is granted from the U.S. Fish and Wildlife Service (USFWS). A biological assessment and "formal consultation," followed by the issuance of a "biological opinion" by the USFWS, may be required for any species that is determined to be in potential jeopardy.

There are no known species of plants or animals at the WIPP site that are protected by the *Endangered Species Act*.

## 2.12 Migratory Bird Treaty Act

The *Migratory Bird Treaty Act* (16 U.S.C. §§703, et seq.) is intended to protect birds that have common migratory flyways between the United States, Canada, Mexico, Japan, and Russia. The act makes it unlawful "at any time, by any means or in any manner, to pursue, hunt, take, capture, kill, or attempt to take, capture, or kill… any migratory bird, any part, nest, or eggs of any such bird" unless specifically authorized by the Secretary of the Interior by direction or through regulations permitting and governing these actions (50 CFR Part 20, "Migratory Bird Hunting"). In 2011, no activities involving migratory birds took place at the WIPP facility.

## 2.13 Federal Land Policy And Management Act

The objective of the Federal Land Policy and Management Act (43 U.S.C. §§1701, et seq.) is to ensure that

> *…public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use.*

Title II under the act, *Land Use Planning; Land Acquisition and Disposition*, directs the Secretary of the Interior to prepare and maintain an inventory of all public lands and to develop and maintain, with public involvement, land use plans regardless of whether subject public lands have been classified as withdrawn, set aside, or otherwise designated. The DOE developed, and operates in accordance with, the WIPP LMP, which is described in further detail in section 5.2.

Under Title V, *Rights-of-Way*, the Secretary of the Interior is authorized to grant, issue, or renew rights-of-way over, upon, under, or through public lands. To date, several right-of-way reservations and land-use permits have been granted to the DOE. Examples of right-of-way permits include those obtained for a water pipeline, an access road, a caliche borrow pit, and a sampling station. Each "facility" (road, pipeline, railroad, etc.) is maintained and operated in accordance with the stipulations provided in the respective right-of-way reservation. Areas that are the subject of a right-of-way reservation are reclaimed and revegetated consistent with the terms of the right-of-way.

## 2.14 Atomic Energy Act

The *Atomic Energy Act of 1954*, as amended (42 U.S.C. §§2011, et seq.), initiated a national program with responsibility for the development and production of nuclear weapons and a civilian program for the development and the regulation of civilian uses of nuclear materials and facilities in the United States. Amendments to the act split these functions between the DOE, which is responsible for the development and production of nuclear weapons, promotion of nuclear power, and other energy-related work, and the U.S. Nuclear Regulatory Commission, which regulates the use of nuclear energy for domestic civilian purposes.

The statutory authority for the EPA to establish and implement the regulatory standards applicable to the operation, closure, and long-term performance of the WIPP facility can also be found in the *Atomic Energy Act of 1954*, Reorganization Plan Number 3 of 1970, and in the *Nuclear Waste Policy Act of 1982* (42 U.S.C. §10101, et seq.). The EPA final rule, 40 CFR Part 191, was promulgated on December 20, 1993 (effective January 19, 1994) and consists of three subparts: Subpart A, "Environmental Standards for Management and Storage"; Subpart B, "Environmental Standards for Disposal"; and Subpart C, "Environmental Standards for Ground-Water Protection."

The results of monitoring and dose calculations have confirmed that there have been no releases of radionuclides from the WIPP that may adversely impact the public. WIPP personnel have conducted periodic confirmatory monitoring since receipt of waste began in March 1999. Results of the monitoring program demonstrate compliance with the dose limits discussed above and addressed in further detail in Chapter 4.

The WIPP is subject to EPA inspections in accordance with 40 CFR §194.21, "Inspections." During the week of May 9, 2011, the EPA conducted an inspection of WIPP waste management and storage operations, emplacement activities, and monitoring program (Docket: A-98-49, II B3-116). As a result of the inspection, the EPA determined that the activities related to emissions monitoring during waste management and storage continue to comply with the requirements of 40 CFR Part 191, Subpart A. The EPA also determined that the DOE continued to adequately monitor the 10 parameters that are important to the long-term containment of waste, as identified in the EPA's Compliance Certification.

The LWA requires the EPA to conduct recertification of continued compliance every five years after the initial receipt of TRU waste for disposal until the end of the decommissioning phase. The next Compliance Recertification Application for the WIPP facility is due to the EPA in March 2014.

## 2.15 DOE Orders

DOE orders are used to direct and guide project participants in the performance of their work and establish the standards of operations at WIPP. The DOE orders documented in this report require that emission, effluent, and environmental monitoring programs be conducted to ensure that the WIPP mission can be accomplished while protecting the public, the worker, and the environment. The list of DOE orders identified for the WIPP facility is reviewed and updated annually.

### 2.15.1 DOE Order 151.1C, Comprehensive Emergency Management System

This order establishes requirements for emergency planning hazards assessment, categorization, classification, preparedness, response, notification, coordination control, public protection, and readiness assurance activities. The applicable requirements of this order are implemented through the WIPP emergency management program, the emergency response program, the training program, the emergency readiness program, the records management program, and the RCRA Contingency Plan.

### 2.15.2 DOE Order 231.1B, Environment, Safety and Health Reporting

This order replaces cancelled DOE Order 231.1A and specifies the timely collection, reporting, analysis and dissemination of data pertaining to environment, safety, and health that are required by law or regulation, or that are essential for evaluating DOE operations and identifying opportunities for improvement needed for planning purposes within the DOE. The order specifies the reports that must be filed, the persons or organizations responsible for filing the reports, the recipients of the reports, the format in which the reports must be prepared, and the schedule for filing the reports. This order is implemented in part at the WIPP facility through ASERs, environmental protection program reports, occupational injury and illness reports, the radiation safety manual, the dosimetry program, the fire protection program, and WIPP facility procedures.

### 2.15.3 DOE Order 414.1D, Quality Assurance

This order replaces cancelled DOE Order 414.1C and provides the criteria for establishing, implementing, and maintaining programs, plans, and actions to ensure quality in DOE programs. This order is implemented at WIPP through the *CBFO Quality Assurance Program Document* (DOE/CBFO-94-1012), which establishes QA program requirements for all quality-affecting programs, projects, and activities sponsored by the CBFO. Chapter 7 of this ASER provides additional details on the WIPP QA programs.

### 2.15.4 DOE Order 435.1, Radioactive Waste Management

The objective of this order is to ensure that all DOE radioactive waste, including TRU waste that is disposed of at the WIPP site, is managed in a manner that is protective of workers and the public. In the event that a conflict exists between any requirements of this order and the WIPP LWA regarding their application to the WIPP facility, the requirements of the LWA prevail. The DOE implements the requirements of this order through the *Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant* (DOE/WIPP-02-3122), and procedures governing the management and disposal of TRU radioactive waste generated off site.

### 2.15.5 DOE Order 436.1, Departmental Sustainability

This order supersedes DOE Order 450.1A, Environmental Protection Program, and DOE Order 430.2B, *Departmental Energy, Renewable Energy and Transportation Management*. The order requires that DOE sites comply with the sustainability requirements contained in the two executive orders related to governmental sustainability (EOs 13423 and 13514). Sites must also develop, and commit to implement, an annual Site Sustainability Plan (SSP) that identifies their respective contributions toward meeting the DOE's sustainability goals. The site EMS must be used for implementing the SSP. Site EMSs must maintain conformance to ISO 14001:2004. The WIPP SSP for FY 2012 was issued on December 8, 2011. This second annual update addresses the WIPP project's contribution toward meeting the DOE sustainability goals. The SSP becomes a basis for establishing annual site environmental objectives and targets. WIPP works toward achieving the sustainability goals through the EMS. The WIPP EMS was certified to the ISO 14001:2004 standard in May 2009. During 2011, the EMS maintained certification based on semi-annual surveillance audits.

### 2.15.6 DOE Order 451.1B, Chg. 2, National Environmental Policy Act Compliance Program

This order establishes DOE requirements and responsibilities for implementing the NEPA, the Council on Environmental Quality Regulations Implementing the Procedural Provisions of NEPA (40 CFR Parts 1500-1508), and the DOE NEPA implementing procedures (10 CFR Part 1021). This order is implemented by the DOE for the WIPP facility through compliance plans and a screening procedure. These tools are used to evaluate environmental impacts associated with proposed activities and to determine if additional analyses are required.

### 2.15.7 DOE Order 458.1 Chg. 2, Radiation Protection of the Public and the Environment

This order replaces cancelled DOE Order 5400.5 Chg 2, along with portions of DOE Order 231.1B, and establishes standards and requirements for DOE and contractor operations with respect to protecting members of the public and the environment against undue risk from radiation. Activities and analyses describing compliance with the applicable requirements of the order are contained in the *Waste Isolation Pilot Plant Documented Safety Analysis* (DOE/WIPP 07-3372). Monitoring activities to document compliance with the order are described in the WIPP ALARA (as low as reasonably achievable) program manual, the records management program, and the radiation safety manual.

## 2.16 Executive Orders

Executive Orders are used by the President to direct federal agencies and officials in their execution of policies. Compliance is accomplished through the WIPP EMS as described in Chapter 3. Confirmation of compliance is through the WIPP assessment processes.

### 2.16.1 Executive Order 13423, Strengthening Federal Environmental, Energy, and Transportation Management

In January 2007, EO 13423 was issued, replacing five prior EOs that established requirements for greening the government (EOs 13101, 13123, 13134, 13148, and 13149) relative to waste prevention, recycling, federal acquisition, energy management, use of biobased products and energy, fleet and transportation efficiency and EMSs. Requirements are implemented and integrated into operations through energy management, fleet and vehicle management, affirmative procurement, and pollution prevention programs.

### 2.16.2 Executive Order 13514, Federal Leadership in Environmental, Energy, and Economic Performance

This EO was issued in October 2009, to establish an integrated strategy toward sustainability in the federal government and to make reduction of GHG emissions a priority for federal agencies. Goals for improvements in GHG emissions, energy efficiency, water use efficiency and management, pollution prevention and waste elimination, regional and local integrated planning, sustainable federal buildings, sustainable acquisition, electronics stewardship and environmental management were established for federal agencies. The WIPP project complies with the EO through its EMS. Accomplishments toward goals established in the EO are discussed in Chapter 3.

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## CHAPTER 3 – ENVIRONMENTAL MANAGEMENT SYSTEM

The CBFO and the MOC consider protection of workers, the public, and the environment to be the highest priority of all activities at the WIPP facility. This commitment is made public in the WIPP Environmental Policy and is carried out through the WIPP EMS. Effectiveness of the EMS is demonstrated by the negligible effect of WIPP facility operations on the environment, reduced environmental risk from safe disposal of generator sites' TRU and TRU mixed waste at the WIPP facility, the WIPP project's excellent compliance history, and the progress in sustainability.

The EMS continued to result in strong environmental performance in 2011. The WIPP project maintained certification of the EMS to the ISO standard 14001:2004, *Environmental Management Systems - Requirements with Guidance for Use*, and met the President's Council on Environmental Quality and DOE's requirements for full implementation of the EMS. Maintaining the ISO certification is based on semiannual surveillance audits by the ISO-accredited registrar, Advanced Waste Management Systems.

Extensive environmental monitoring conducted during 2011 demonstrates there are no significant environmental impacts (radiological or nonradiological) from operation of the WIPP facility. This is accomplished by personnel carrying out their daily responsibilities in accordance with the WIPP project conduct of operations program, which is the foundation for the operational control element of the EMS. It is also accomplished by the EMS ensuring that potential environmental impacts are identified, and appropriate controls and actions are taken to address them.

The WIPP project commitment to compliance with applicable environmental requirements is achieved through implementation of the EMS and its supporting programs, procedures, and work practices. As noted in Chapter 2, compliance performance has been excellent. Compliance highlights are listed below:

- The WIPP facility had no reportable, unauthorized contaminant releases.
- There were no external agency compliance issues.
- The WIPP Permit Community Relations Plan was developed and implemented to provide interested parties with background information about the Permit, updated information on Permit actions, and information about opportunities to participate in the Permit process.

Sustainability performance was recognized by the NMED with a Green Zia Environmental Leadership Program award. The Leadership Program is based on the Malcolm Baldrige Business Performance Excellence Criteria and the Quality New Mexico program and helps participants incorporate environmental decision-making into core business practices. The award was granted based on innovative environmental solutions in the areas of air quality, water conservation, and waste reduction. These were:

Reducing CCl4 levels in the underground.

Implementing a recycling method for used "slip sheets" by returning them to the product manufacturer for reprocessing.  Slip sheets are large sheets of plastic that are used to transfer waste containers when downloading TRU waste containers for emplacement.

Saving 340,000 gallons of fresh water by using on-site collected storm water and using 7,800 tons of recycled asphalt during a road construction project.

The CBFO and MOC encourage all employees to integrate conservation and recycling in their everyday work. A recent example was the Recycle/Reuse Day held during Earth Week, where employees at the WIPP site and the Skeen-Whitlock Building were encouraged to make unused office supplies available for use by others. The photo at right illustrates the material that was gathered to be reused or recycled at the WIPP site or in the community.


### 3.1 EMS 2011 Highlights

| | |
|---|---|
| **Environmental Aspects** | No new environmental aspects or modifications to existing aspects were necessary. |
| **Legal and Other Requirements** | There were no significant new or revised legal requirements during 2011. |

| | |
|---|---|
| **Objectives, Targets, and Program(s)** | The WIPP SSP provides the basis for WIPP's environmental objectives and targets. A significant number of the targets focused on DOE's sustainability goals. One hundred percent of the following FY 2011 environmental goals were achieved:<br>• Zero reportable, unauthorized contaminant releases<br>• Implemented the renewed Permit into WIPP operations<br>• Completed VOC Monitoring Equipment for Standard Large Box Processing Station<br>• Completed fire water distribution system repairs as scheduled (to ensure water leaks are identified and repaired)<br>• Analyzed business air travel to identify opportunities for reduction<br>• Completed awareness campaign to promote bus ridership and car pooling<br>• Developed and implemented green catalog for procurement card purchases<br>• Updated the procurement processes to ensure that 95 percent of applicable new subcontracts include DOE's new sustainability clauses and to implement changes that will improve the ability to track sustainable products used at the WIPP<br>• Developed and implemented the WIPP Electronics Management Policy<br>• Conducted site wide Recycle/Reuse Day<br>• Conducted activities to maintain employee awareness of EMS and sustainability |
| **Communication** | The WIPP Community Relations Plan was completed and implemented |
| **Competence, Awareness and Training** | Employees completed EMS online training for a second year |
| **Operational Control** | Environmental controls were integrated into procedures and implemented in accordance with the WIPP Conduct of Operations program |

| | |
|---|---|
| **Emergency Preparedness and Response** | • The Baseline Needs Assessment was updated. This addresses the WIPP emergency response capability.<br>• The Emergency Management department performed 42 exercises/drills/events. |
| **Monitoring and Measurement** | The environmental monitoring program confirmed that there has been no significant environmental impact from WIPP operations. The EMS met Council on Environmental Quality and DOE requirements. |
| **Evaluation of Compliance** | No regulatory noncompliance issues were identified from over 204 evaluations (audits/assessments) of WIPP facility operations. |
| **Nonconformity, Corrective Action, and Preventive Action** | The Issues Management and Corrective Action Request Programs continued to be effective. Ninety percent of identified corrective/preventative actions were completed by December 31, 2011, and the remaining actions are on schedule for completion. |
| **Internal Audit** | An internal audit of the WIPP EMS was completed with no findings. |
| **Management Review** | CBFO and MOC senior managers established ten FY 2012 environmental targets focusing on continual improvement of efficiency in the waste emplacement process and sustainability performance. |

As noted previously, EMS online training was completed by CBFO and MOC employees. The training covered key environmental policy commitments, EMS roles and responsibilities, objectives and targets, and sustainable performance. In addition, the training demonstrated the link between employee's everyday responsibilities and protecting the environment. Figure 3.1 shows the EMS in action at WIPP.


Figure 3.1 – EMS in WIPP Operations

## 3.2 Significant Environmental Programs

Fundamental to the EMS are programs through which environmental protection is integrated with operations. These programs, with supporting procedures, translate the environmental policy's higher order commitments into practical actions for individual employees to take to protect the environment as they work. Significant WIPP environmental programs are described below.

Affirmative Procurement

This program provides a systematic and cost-effective structure for promoting and procuring environmentally preferable (sustainable) products. These include bio-based, recycled content, energy and water efficient products, and products with fewer hazards or toxicity.

**Delaware Basin Drilling Surveillance**

This program includes conducting active surveillance of drilling activities within the Delaware Basin with specific emphasis on the nine-township area that includes the WIPP site. The surveillance of drilling activities builds on the data used to develop modeling assumptions for performance assessment for the EPA's Compliance Certification.

Environmental Monitoring

The environmental monitoring program includes radiological and nonradiological monitoring, land management monitoring, and oil and gas surveillance. Radiological constituents are monitored in airborne effluent and particulates, sewage treatment and water disposal evaporation ponds, biotics, soils, surface water, sediment, and groundwater. Non-radiological monitoring includes meteorology, VOCs, groundwater surveillance, hydrogen, methane, nearby hydrocarbon drilling activity, and SSW monitoring.

Environmental Compliance Audit

Audits and reviews of compliance are conducted via the MOC Regulatory Compliance Department environmental compliance assessments and the CBFO and MOC QA assessment programs.

**Groundwater Protection**

Groundwater, which may potentially be affected by DOE operations, is monitored to detect and document the effects of operations on groundwater quality and quantity, and to show compliance with applicable federal and state laws and regulations.

**Land Management**

The land management program provides for management and oversight of WIPP lands under the jurisdiction of the DOE and lands used for WIPP activities outside of the WIPP boundary. It provides protocols that are used for managing and oversight of wildlife practices, cultural resources, grazing, recreation, energy and mineral resources, lands/realty, reclamation, security, industrial safety, emergency management, maintenance and work control on these lands.

NEPA Compliance

This program ensures requirements of the NEPA are met prior to making decisions to implement work at or on behalf of the WIPP facility.

Sustainability

Promotes integration of energy and water efficiency, environmentally preferred purchasing, waste minimization, and recycling and reuse into the WIPP project.

Waste Stream Profile Review and Approval

This is a critical program for ensuring compliance requirements are met for wastes being disposed at the WIPP facility. Profiles for each waste stream are reviewed to verify that the generator's characterization information is complete and accurate, and that waste streams comply with the Permit and the Waste Acceptance Criteria.

Waste Confirmation

Under this program, waste containers are confirmed to have no ignitable, corrosive, or reactive waste using radiography and/or visual examination of a statistically representative subpopulation of the waste. The DOE demonstrates compliance with the Permit through this program.

Waste Management

This program ensures that site-generated hazardous, universal, special, low-level and mixed low-level radioactive wastes are properly handled, accumulated, and transported to approved disposal facilities in accordance with legal and internal requirements.

## 3.3 Environmental Performance Measurement

Extensive monitoring and measurement is conducted by the WIPP facility staff to assure that the WIPP mission is carried out in accordance with its environmental policy. This includes monitoring (1) impacts to environment, (2) EMS effectiveness, and (3) sustainability progress. Each of these is discussed in the following sections.

### 3.3.1 Environmental Impacts

There was no significant environmental impact from WIPP operations in 2011 as determined from environmental monitoring program implementation results. Detailed analyses and summaries of the results of this program are included in Chapters 4, 5, and 6.

### 3.3.2 EMS Effectiveness

System indicators demonstrate the EMS continues to be suitable and effective for carrying out the WIPP mission and meeting environmental policy commitments. Indicators confirmed that environmental protection is integrated into WIPP processes (e.g., significant aspects/impacts are current; environmental compliance is included in audits), and demonstrated strong environmental performance including zero compliance issues, zero reportable containment releases, and success in meeting annual environmental objectives and targets.

### 3.3.3 Sustainability Progress (Continuous Improvement)

As summarized below, progress in this area is measured by the WIPP project's contribution toward the DOE Sustainability Goals established under EOs 13514 and 13423.

<u>Reduce Greenhouse Gas Emissions</u>

The WIPP project comprehensive GHG inventory (Figure 3.2) demonstrates that the largest contributors to the WIPP project GHG footprint are electricity use (Scope 2) and business travel and employee commute to the WIPP site (Scope 3).

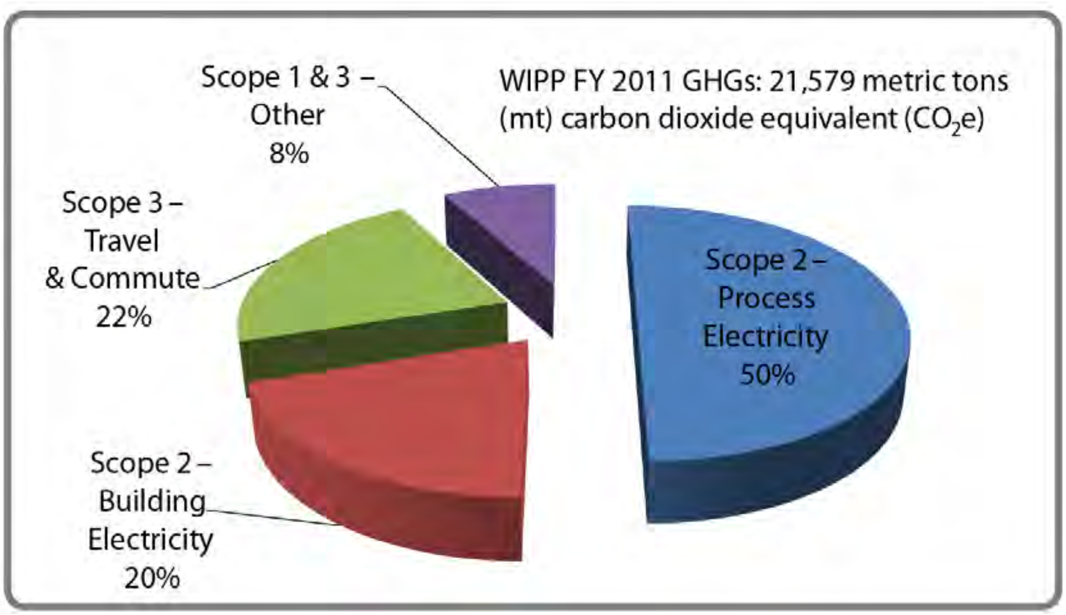



Figure 3.2 – WIPP GHG Profile - FY 2011

Given this profile, the priority for GHG reduction at the WIPP is reducing electricity use. A secondary effort is placed on business travel and petroleum fuel use reductions. Accomplishments and actions toward GHG reductions for 2011 are highlighted below.

**Renewable Energy**

- The WIPP facility used 1,500,000 kWh of energy from wind generation, representing 7.4 percent of total energy used.
- The WIPP project continued to actively seek partners to enter into a Power Purchase Agreement for construction and operation of a 2 MW solar array project on DOE lands. This type of facility would reduce GHG emissions by 30 percent. However, due to the WIPP facility's remote location and the low cost of purchased energy, third parties found such a project to not be economically viable.

**Energy Efficiency**

- Site energy use continues to be 3.0 MWh per cubic meter of TRU waste emplaced.
- WIPP site energy intensity (energy use per square foot) reduction remains at 13 percent compared to the FY 2003 baseline. Energy intensity has been reduced 21 percent since FY 2000 and 54 percent since FY 1999.

**Building Metering**

- Ninety-seven percent of process energy use is metered and 87 percent of site office space is metered by building. WIPP facility advanced metering allows detailed monitoring of significant site loads for analysis of energy use.

**Cool Roofs**

- Fourteen facilities have Cool Roofs; 233,631 sq ft of total space at the site has been enhanced with increased roof insulation and reflective surface.

**Fleet/Fuel Improvements**

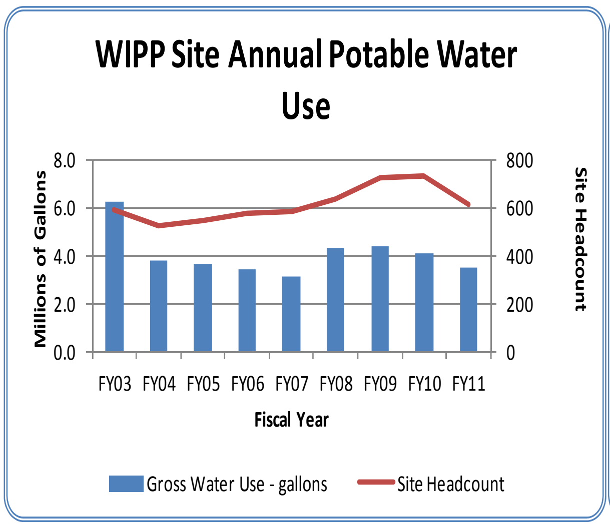
- Seventy-two percent of WIPP vehicles are alternative fuel vehicles or hybrids.
- The fleet was reduced by 8 percent compared to the FY 2005 baseline.
- Petroleum use for the project and at the site was reduced by 19 percent compared to the FY 2005 baseline due to consolidated/reduced trips and the use of more fuel efficient/hybrid vehicles.
- Extensive work with a local, startup, renewable diesel manufacturing company to test renewable diesel for use in industrial equipment was not successful.

**Business Travel**

- GHG emissions associated with business ground travel were decreased by 63 percent. Each department at the WIPP project contributed to the reduction; most departments reduced the number of trips taken by over 60 percent compared to the previous year. Personnel increased their use of technology options such as telework and ride sharing when traveling by vehicle.

Water Efficiency and Management

WIPP water use is illustrated in Figure 3.3. The graphs show that great strides have been made in reducing water use both in terms of total volume of water used (graph on left) and water used per employee per day (graph on right).



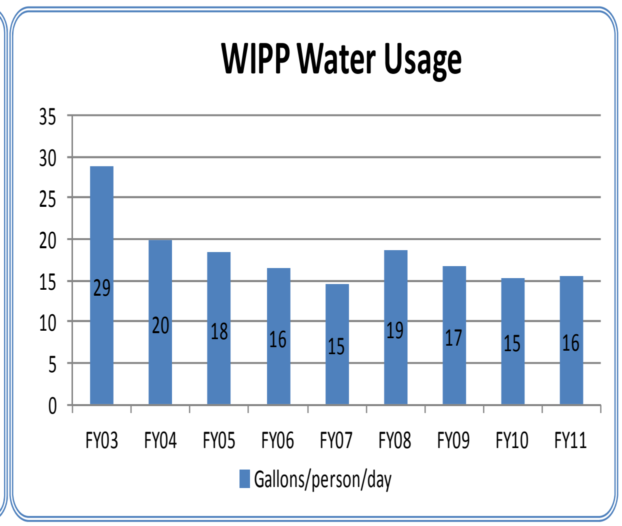




Figure 3.3 – WIPP Annual Potable Water Use

As shown in the graph on the left, between FY 2003 and FY 2007 water consumption was reduced by 49 percent. The lowest recorded water use for the site was in FY 2007. In FY 2008 and 2009, water consumption increased primarily due to a water leak in the fire protection line and an increase in site personnel from FY 2007 through FY 2010 as projects were implemented to enhance the site's ability to accomplish its mission using *American Recovery and Reinvestment Act* (ARRA) funding. Personnel increases in mining/waste-related activities during this period resulted in a greater increase in water use compared to increases that would result from additional office personnel on single shifts.

WIPP has dedicated resources to water distribution system maintenance for the past four years. As a result, water leaks have been identified and repaired, and overall water use has decreased.

The graph on the right illustrates that water use per employee is low for an industrial operation. Water use for FY 2011 averaged 16 gallons/person/day and includes all water use at the site. Average water use at a factory or other industrial facility is 25 gallons/person/day, which means that WIPP water use is almost 40 percent lower than in a standard industrial facility.

Recycling and Waste Diversion

Waste diversion and recycling are key components of the WIPP sustainability program. Waste streams that are possible to be recycled within regional infrastructure continue to be recycled. Materials that can be recycled include a narrow scope of non-hazardous and construction and demolition (C&D) materials, as well as some hazardous, universal, and New Mexico special waste streams. Materials diverted at the WIPP site are highlighted in Figure 3.4. The overall objective is to recycle or divert 50 percent of non-hazardous solid waste and C&D debris by FY 2015.

Non-hazardous & C&D
Wastes Recycled

Aluminum Cans

Cardboard

Paper

Plastic

Metals

Fencing

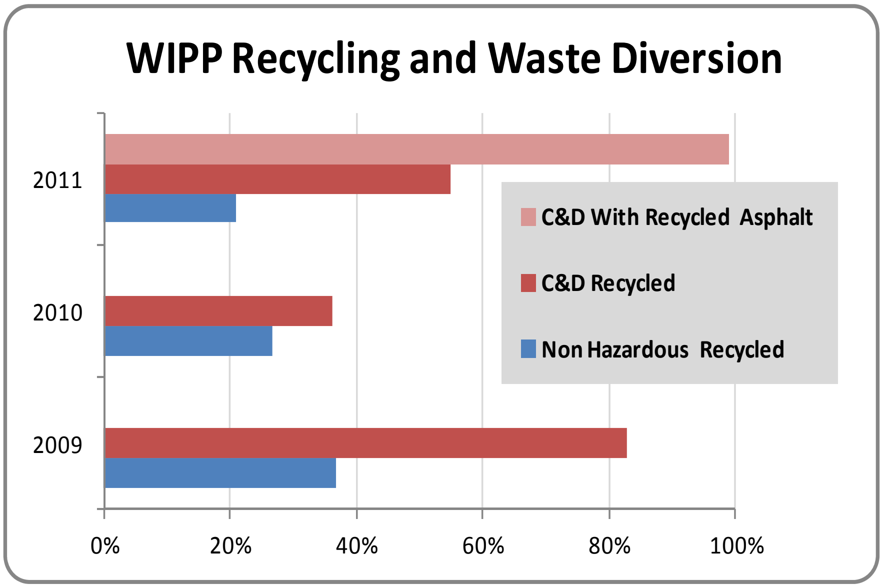



Figure 3.4 – WIPP Recycling and Waste Diversion

The WIPP also recycles toner cartridges, used motor oil and antifreeze, batteries, and electronics (ballasts, computers, circuit boards, and fluorescent tubes). These recycled materials are not included in the percentages recycled in Figure 3.4.

During FY 2011, the WIPP switched from providing bottled water to providing drinking water via installation of new reverse osmosis water fountains. This greatly reduced the use of single-serve water bottles and eliminated the handling of bulky water dispenser containers.

The 2011 Earth Day activities included an employee suggested Recycle/Reuse day for the WIPP site and town locations. Employees were encouraged to do spring cleaning of their workspaces and bring unused and gently used office supplies and equipment to central locations. The supplies were sorted and staged for shopping by other employees and departments. Remaining materials were donated to kindergarten students at the Carlsbad Early Childhood Education Center.

Sustainable Acquisition

WIPP continued to purchase 30 percent recycled content paper and use environmentally friendly products for janitorial services when they meet cost, performance, and availability requirements. WIPP established and implemented the purchase of office supplies through a green catalog in order to improve the percentage of green products used. In addition, upgrades were made to the purchase requisition procedure and its supporting software in order to ensure that applicable contracts contain the appropriate sustainable acquisition clauses.

The WIPP procurement process continues to ensure ozone depleting substances are not purchased.  The WIPP has no Class 1 ozone depleting substances onsite.

Electronics Stewardship and Data Centers

WIPP continued to use sustainable life cycle management of electronics as demonstrated in Figure 3.5. The CBFO and MOC developed and issued a joint *Waste Isolation Pilot Plant Electronics Management Policy Statement* (DOE/WIPP-11-3474) in FY 2011 to formalize the WIPP projects commitments and approach to electronics management.

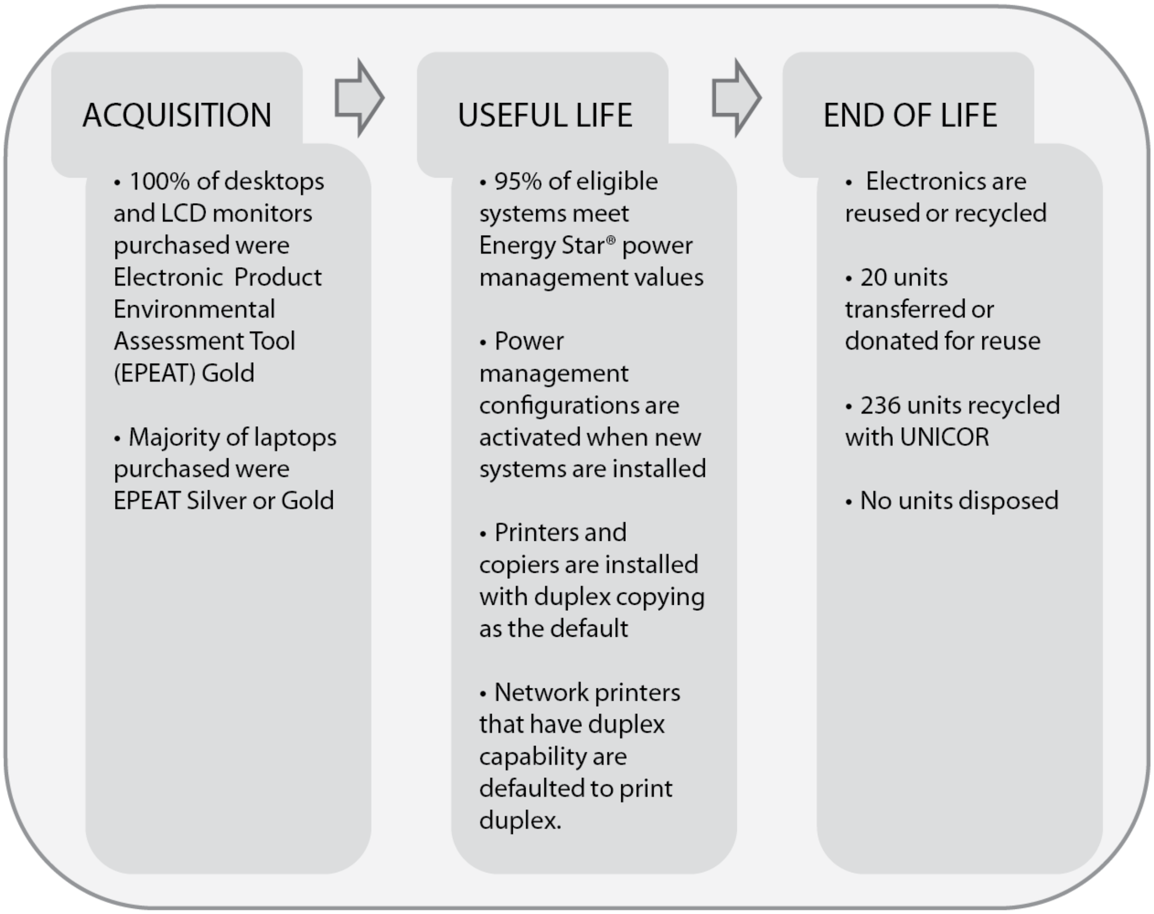



Figure 3.5 – Life Cycle Management of Electronics at WIPP

## 3.4 EMS Awards

The NMED awarded CBFO a Green Zia Environmental Leadership Program award in 2011. The award program recognizes businesses and other organizations for their commitment to environmental stewardship by implementing pollution prevention practices for excellence in environmental and economic sustainability. WIPP and four New Mexico businesses were selected for the honor.

A 2011 DOE Energy Management Award was presented to the WIPP team for incorporating sustainable practices into the construction of the South Access Road, which is used daily by employees commuting to and from the WIPP site. As a result of the team's efforts, WIPP saved $150,000 in construction costs, 9.7 billion British thermal units (Btu) of energy, 340,000 gallons of fresh water, and the equivalent of 604 million tons of carbon dioxide emissions. In addition, the project enhanced road safety and allows for a shorter delivery route for TRU waste shipments, which will result in further DOE fuel savings and reduction in GHG emissions.

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# CHAPTER 4 – ENVIRONMENTAL RADIOLOGICAL PROGRAM INFORMATION

DOE Order 458.1 states that the DOE "must" conduct DOE radiological activities so that exposure to members of the public is maintained within the dose limits established in this Order; control the radiological clearance of DOE real and personal property; ensure that potential radiation exposures to members of the public are as low as is reasonably achievable; ensure that DOE sites have the capabilities, consistent with the types of radiological activities conducted, to monitor routine and non-routine radiological releases and to assess the radiation dose to members of the public; and provide protection of the environment from the effects of radiation and radioactive material. "

Radionuclides present in the environment, whether naturally occurring or human-made, may contribute to radiation doses to humans. Therefore, environmental monitoring around nuclear facilities is imperative to characterize radiological baseline conditions, identify any releases, and determine the effects of releases should they occur.

WIPP personnel sample air, groundwater, surface water, soils, sediments, and biota to monitor the radiological environment around the facility. This monitoring is carried out in accordance with the WIPP Environmental Monitoring Plan. The radiological effluent monitoring portion of this plan meets the requirements contained in DOE/EH-0173T, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*.

The WIPP facility is regulated under 40 CFR §191.03, Subpart A, which applies to management and storage of radioactive waste at disposal facilities operated by the DOE. The standards in 40 CFR §191.03(b) state that management and storage of TRU waste at DOE facilities shall be conducted in a manner that provides reasonable assurance that the annual radiation to any member of the public in the general environment resulting from discharges of radioactive material and direct radiation from such management and storage shall not exceed specified limits. Based on analysis of WIPP facility operations, the DOE has identified air emissions as the only plausible pathway for radionuclide transport during receipt and emplacement of waste at the WIPP facility.

The regulatory limits for the WIPP effluent monitoring program can be found in 40 CFR Part 191, Subpart A. Radionuclides being released from WIPP operations, including the underground TRU waste disposal areas and the WHB, are monitored through the WIPP effluent monitoring program. The referenced standard specifies that the combined annual dose equivalent to any member of the public in the general environment resulting from discharges of radioactive material and direct radiation from such management and storage shall not exceed 25 mrem to the whole body and 75 mrem to any critical organ. In addition, in a 1995 memorandum of understanding between the EPA and the DOE, the DOE agreed that the WIPP facility would comply with 40 CFR Part 61, "National Emission Standards for Hazardous Air Pollutants" (NESHAP), Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities." The NESHAP standard (40 CFR §61.92) states that the emissions of radionuclides to the ambient air from DOE facilities shall not exceed those amounts that would cause any member of the public to receive in any year an EDE of 10 mrem per year.

The *Statistical Summary of the Radiological Baseline for the Waste Isolation Pilot Plant* (DOE/WIPP-92-037) summarizes the radiological baseline data obtained at and near the WIPP site during the period 1985 through 1989, prior to the time that the WIPP became operational. Radioisotope concentrations in environmental media sampled under the current ongoing monitoring program are compared with this baseline to gain information regarding annual fluctuations. Appendix H presents data that compare the highest concentrations of radionuclides detected from the WIPP environmental monitoring program to the baseline data.

The sampling media for the environmental monitoring program include airborne particulates, soil, surface water, groundwater, sediments, and biota (vegetation and animals). These samples are analyzed for 10 radionuclides, including natural uranium ($^{233/234}U$, $^{235}U$, and $^{238}U$); potassium-40 ($^{40}K$); transuranic actinides expected to be present in the waste (plutonium [$^{238}Pu$], $^{239/240}Pu$, and americium [$^{241}Am$]); major fission products (cesium [$^{137}Cs$] and strontium [$^{90}Sr$]); and reactor structural materials (cobalt [$^{60}Co$]). Environmental levels of these radionuclides could provide corroborating information on which to base conclusions regarding releases from WIPP facility operations.

Table 4.1 summarizes the list of target radionuclides included in the environmental monitoring program along with their type of radiation, method of detection, and reason for monitoring at the WIPP site. The WIPP airborne effluent monitoring program also monitors for these same radionuclides with the exception of $^{235}U$, $^{40}K$, and $^{60}Co$.

**Table 4.1 – Radioactive Nuclides Monitored at the WIPP Site**

| Radionuclide | Radiation | Detection Method | Reason for Monitoring |
|---|---|---|---|
| $^{233/234}U$ | Alpha | Alpha spectroscopy | Naturally occurring |
| $^{235}U$ | Alpha | Alpha spectroscopy | Naturally occurring |
| $^{238}U$ | Alpha | Alpha spectroscopy | Naturally occurring |
| $^{40}K$ | Gamma | Gamma spectroscopy | Ubiquitous in nature |
| $^{238}Pu$ | Alpha | Alpha spectroscopy | Component of waste |
| $^{239/240}Pu$ | Alpha | Alpha spectroscopy | Component of waste |
| $^{241}Am$ | Alpha | Alpha spectroscopy | Component of waste |
| $^{137}Cs$ | Gamma | Gamma spectroscopy | Fission product/potential component of waste |
| $^{60}Co$ | Gamma | Gamma spectrometry | Activation product of reactor structural materials |
| $^{90}Sr$ | Beta | Gas Proportional Counting | Fission product/potential component of waste |

Note: The radionuclides $^{243}Am$, $^{242}Pu$, and $^{232}U$ are used as tracers in the WIPP Laboratories.

Radionuclides are considered "detected" in a sample if the measured concentration or activity is greater than the total propagated uncertainty (TPU) at the 2 sigma (σ) TPU level, and greater than the minimum detectable concentration (MDC). This methodology was patterned after that described in "Hanford Decision Level for Alpha Spectrometry Bioassay Analyses Based on the Sample-Specific Total Propagated Uncertainty" (MacLellan, 1999). The MDC is determined by the analytical laboratory based on the natural background radiation, the analytical technique, and inherent characteristics of the analytical equipment. The MDC represents the minimum concentration of a radionuclide detectable in a given sample using the given equipment and techniques with a specific statistical confidence (usually 95 percent). The TPU is an estimate of the uncertainty in the measurement due to all sources, including counting error, measurement error, chemical recovery error, detector efficiency, randomness of radioactive decay, and any other sources of uncertainty.

Measurements of radioactivity are actually probabilities due to the random nature of the disintegration process. A sample is decaying as it is being measured, so no finite value can be assigned. Instead, the ranges of possible activities are reported by incorporating the TPUs of the method. For radionuclides determined by gamma spectroscopy ($^{137}$Cs, $^{60}$Co, and $^{40}$K), an additional factor considered in the determination of detectability is the identification (ID) confidence with which the peak or peaks associated with the particular radionuclide can be identified by the gamma spectroscopy software. In accordance with the statement of work (SOW) for the laboratory analyses, gamma spectroscopy samples with ID confidence less than 90 percent (<0.90) are not considered "detects," regardless of their activities compared to the TPU and MDC. Sample results are also normalized with the instrument background and/or the method blank. If either of those measurements have greater activity ranges than the actual sample, it is possible to get negative values on one end of the reported range of activities. Additional information on the equations used is provided in Appendix D.

WIPP Laboratories performed the analyses for the 10 target radionuclides in all radiological samples. Highly sensitive radiochemical analysis and detection techniques were used that resulted in very low detection limits. This allowed detection of radionuclides at concentration levels far below those of environmental and human health concern. The MDCs attained by WIPP Laboratories were below the recommended MDCs specified in American National Standards Institute (ANSI) N13.30, *Performance Criteria for Radiobioassay*.

Comparisons of radionuclide concentrations were made between years and locations using the statistical procedure ANOVA (analysis of variance) for those data sets containing sufficient "detects" to make such comparisons statistically meaningful. When this or other statistical tests were used, the p value was reported. The p value is the probability under the null hypothesis of observing a value as unlikely or more unlikely than the value of the test statistic. The p value is the significance level for ANOVA calculations. A p value >0.05 indicates no significant difference in the values from a data set, and a p value <0.05 indicates a significant difference in the values from a data set. In many cases, scientists have accepted a value of p <0.05 as indicative of a difference between samples.

Interpretation of p values requires some judgment on the part of the reader, and individual readers may choose to defend a higher or lower value for p as the cutoff value. However, for this report, a p value of 0.05 was used.

The air monitoring for radionuclides is divided between two programs: the WIPP effluent monitoring program and the environmental monitoring program. Descriptions of these two programs are provided in the following sections.

Effluent Monitoring Program

The WIPP facility has three effluent monitoring stations, Stations A, B, and C. Each station employs one or more fixed air samplers, collecting particulates from the effluent air stream using a Versapor® filter. Fixed air samplers at Station A sample the unfiltered underground exhaust air. At Station B, samples are collected from the underground exhaust air after high-efficiency particulate air (HEPA) filtration, and sometimes from nonfiltered air during ventilation fan maintenance. At Station C, samples are collected from the exhaust air from the WHB after HEPA filtration.

For each sampling event, chain-of-custody forms are initiated to track and maintain an accurate written record of filter sample handling and treatment from the time of sample collection through laboratory procedures to disposal. During 2011, filter samples from all three effluent air monitoring stations were analyzed for $^{238}$Pu, $^{239/240}$Pu, $^{241}$Am, $^{90}$Sr, $^{137}$Cs, $^{233/234}$U, and $^{238}$U.

In June 2012, the *Annual Periodic Confirmatory Measurement Compliance Repor*t for Calendar Year 2011, was submitted to the EPA as required by 40 CFR Part 61, Subpart H (NESHAP). The report described ongoing CH and RH TRU and TRU mixed waste receipt and emplacement. For CY 2011, the CAP88-PC dose assessment computer model was used to calculate the EDE value of 1.75E-05 mrem/year to the MEI.

Environmental Monitoring Program

The purpose of the radiological environmental monitoring program is to measure radionuclides in the ambient environmental media. These data allow for a comparison of sample data to results from previous years and to baseline data, to determine what impact, if any, WIPP is having on the surrounding environment. Radiological monitoring at the WIPP site includes sampling and analysis of air, groundwater, surface water, sediment, soil, and biota for the 10 target radionuclides listed in Table 4.1. For each sampling event, chain-of-custody forms were initiated to track and maintain an accurate written record of sample handling and treatment from the time of sample collection through delivery to the laboratory. Internal chain-of-custody forms are used by the laboratory to track and maintain custody while samples are being analyzed.

The radionuclides analyzed were $^{238}$Pu, $^{239/240}$Pu, $^{241}$Am, $^{233/234}$U, $^{235}$U, $^{238}$U, $^{137}$Cs, $^{60}$Co, $^{40}$K, and $^{90}$Sr. Isotopes of plutonium and americium were analyzed because they are the most significant alpha-emitting radionuclides among the constituents of TRU wastes received at the WIPP facility. Uranium isotopes were analyzed because they are prominent alpha-emitting radionuclides in the natural environment.

Strontium-90, $^{60}$Co, and $^{137}$Cs were analyzed to demonstrate the ability to quantify these beta and gamma-emitting radionulides should they appear in the TRU waste stream. Potassium-40, a natural gamma-emitting radionuclide that is ubiquitous in the earth's crust, was also monitored.

## 4.1 Effluent Monitoring

### 4.1.1 Sample Collection

Stations A, B, and C use skid-mounted fixed air samplers at each effluent air monitoring station. The volume of air sampled at each location varied depending on the sampling location and configuration. Each system is designed to provide a representative sample using a 3.0-µm, 47-mm diameter Versapor® membrane filter.

Daily (24-hour) filter samples were collected from Station A from the unfiltered underground exhaust stream. Each day at Station A, approximately 81 $m^3$ (2,875 cubic feet [$ft^3$]) of air was filtered through the Versapor® filter.

Weekly (24 hours/seven days per week) filter samples were collected at Station B. Station B samples the underground exhaust air after HEPA filtration, and sometimes the nonfiltered air during maintenance. Each week at Station B, approximately 568 $m^3$ (20,076 $ft^3$) of air were filtered through the Versapor® filter. Based on the specified sampling periods, these air volumes were within plus or minus (±) 10 percent of the volume derived using the flow rate set point of 0.057 $m^3$/min (2 $ft^3$/min) for Stations A and B.

From mid January 2011 to May 5, 2011, an instrumentation upgrade was performed at Station C. Four fixed air samplers (FASs) were used to collect the weekly filter samples in the WHB during that time. On May 6, 2011, sampling resumed at Station C (FAS 157). To date, no radioactivity has been detected in the samples from the WHB. Station C sampling results for 2011 are provided in Table 4.3.

Weekly filter samples were collected at FAS-019, FAS-021, FAS-023, FAS-256, and Station C. The four FASs sampled the air in the WHB, and Station C sampled the air from the WHB after HEPA filtration. Approximately 481 $m^3$ (16,969 $ft^3$) of air were filtered through the Versapor® filter. The air volume for Station C was within ±10 percent of the volume derived using the flow rate required for isokinetic sampling conditions and the specified sampling period. The sampling flow rate for the Station C varied according to the exhaust air flow in the WHB in order to maintain isokinetic sampling conditions.

The Station C effluent air sampling system was designed in accordance with ANSI Standard N13.1-1969. The update of the flow control system replaced obsolete instruments with their current models. The isokinetic sampling configuration did not change, thus maintaining compliance with the 1969 standard. This was necessary since ANSI/HPS N13.1-1999 does not include isokinetic sampling.

The filter samples for Stations B and C were composited each quarter. Because of the large quantity of filters from Station A, samples were composited monthly. All filter samples were radiochemically analyzed for $^{241}Am$, $^{238}Pu$, $^{239/240}Pu$, $^{90}Sr$, $^{233/234}U$, $^{238}U$, and $^{137}Cs$.

### 4.1.2 Sample Preparation

The monthly and quarterly filter samples were composited. The composites were transferred to Pyrex® beakers, spiked with appropriate tracers ($^{232}$U, $^{243}$Am, and $^{242}$Pu), and heated in a muffle furnace at 250°C (482°F) for two hours, followed by two hours of heating at 375°C (707°F) and six hours of heating at 525°C (977°F).

The filters were ashed and cooled, and then transferred into Teflon® beakers by rinsing with concentrated nitric acid, and heated with concentrated hydrofluoric acid until completely dissolved. Hydrofluoric acid was removed by evaporation to dryness.

Approximately 25 milliliters (mL) (0.845 fluid ounce [oz]) of concentrated nitric acid and 1 gram (0.0353 oz) of boric acid were added (to remove residual hydrofluoric acid) and carriers (strontium nitrate and barium nitrate), and the samples were heated and evaporated to dryness. The sample residues were dissolved in 8 molar nitric acid for gamma spectroscopy and measurement of $^{90}$Sr and the alpha-emitting radionuclides.

### 4.1.3 Determination of Individual Radionuclides

Gamma-emitting radionuclides were measured in the air filters by gamma spectroscopy. Strontium-90 and alpha-emitting radionuclides were measured by sequential separation and counting. Strontium-90 was counted on a gas proportional counter. The actinides were co-precipitated, separated on an anion exchange column, and analyzed by alpha spectroscopy.

### 4.1.4 Results and Discussion

From 29 total composite samples taken in 2011, 203 analyses were performed, as shown in Tables 4.2, 4.3 and 4.4. The analytes of interest were $^{241}$Am, $^{238}$Pu, $^{239/240}$Pu, $^{90}$Sr, $^{233/234}$U, $^{238}$U and $^{137}$Cs.

Radionuclides are considered detected in a sample if the measured activity is greater than the 2 σ TPU and MDC. The detected radionuclides that met this definition were selected as the nuclide data for the CAP88-PC dataset report, as shown in Tables 4.2, 4.3 and 4.4. Another criterion was to have the 2 σ TPU added to the activity value. The final result was compared to the MDC. The highest result of the two was also selected for the nuclide data in the CAP88-PC dataset report.

Sampling was performed in the underground and at the WHB using FASs. The April 2011 backup composite samples (Station A Skid A23 and Station D) were analyzed to confirm results obtained in the initial April 2011 analysis for $^{239/240}$Pu (see Table 4.4). The analysis showed no detection. Station D sampling system is located in the underground.

In addition, the July 2011 Station A sample result for $^{137}$Cs indicated the measured activity was greater than the 2 sigma TPU and MDC. For the gamma emitting isotopes, the Laboratory first looks at the reading for the ID confidence. For this particular sample, with the ID confidence less than 0.9, the numbers for activity (TPA or MDA) were qualified with a "U" qualifier code. The ID confidence is the instrument's measure of how likely that isotope was positively detected based on background, electrical interference and how close to the isotopes' known energy did it appear on the spectrum.

Evaluation of the filter sample results indicated that there were no detectable releases from the WIPP facility that resulted in a dose that exceeded 25 mrem to the whole body and 75 mrem to any critical organ in accordance with the provisions of 40 CFR §191.03(b). In addition, there were no detectable releases from the WIPP facility that resulted in a dose that exceeded the 10 mrem per year limit, as specified in 40 CFR §61.92, and the 0.1 mrem per year limit for periodic confirmatory sampling required by 40 CFR §61.93(b)(4)(l).

**Table 4.2 – Activity (Bq) of Quarterly Composite Air Samples from WIPP Effluent Monitoring Station B for 2011**

| Qtr. | Nuclide | Activity (Bq/Sample) | 2σTPU[a] | MDC[b] |
|---|---|---|---|---|
| 1st | $^{241}$Am | 4.88E-04 | 6.92E-04 | 8.58E-04 |
| 2nd | $^{241}$Am | 1.18E-04 | 4.44E-04 | 9.77E-04 |
| 3rd | $^{241}$Am | 7.18E-04 | 8.03E-04 | 8.44E-04 |
| 4th | $^{241}$Am | 2.27E-04 | 4.29E-04 | 7.81E-04 |

| Qtr. | Nuclide | Activity (Bq/Sample) | 2σTPU | MDC |
|---|---|---|---|---|
| 1st | $^{238}$Pu | 6.73E-04 | 6.81E-04 | 8.25E-04 |
| 2nd | $^{238}$Pu | 6.22E-04 | 7.99E-04 | 7.81E-04 |
| 3rd | $^{238}$Pu | 2.91E-04 | 5.55E-04 | 7.40E-04 |
| 4th | $^{238}$Pu | 2.29E-04 | 5.11E-04 | 7.22E-04 |

| Qtr. | Nuclide | Activity (Bq/Sample) | 2σTPU | MDC |
|---|---|---|---|---|
| 1st | $^{239/240}$Pu | 6.36E-05 | 2.84E-04 | 6.70E-04 |
| 2nd | $^{239/240}$Pu | 2.08E-04 | 4.07E-04 | 5.88E-04 |
| 3rd | $^{239/240}$Pu | -3.96E-06 | 3.34E-04 | 6.70E-04 |
| 4th | $^{239/240}$Pu | -8.92E-05 | 1.91E-04 | 6.30E-04 |

| Qtr. | Nuclide | Activity (Bq/Sample) | 2σTPU | MDC |
|---|---|---|---|---|
| 1st | $^{90}$Sr | 1.28E-03 | 3.06E-02 | 1.79E-02 |
| 2nd | $^{90}$Sr | -3.04E-03 | 4.07E-02 | 1.98E-02 |
| 3rd | $^{90}$Sr | -3.40E-06 | 5.14E-02 | 2.83E-02 |
| 4th | $^{90}$Sr | 9.07E-03 | 2.73E-02 | 2.68E-02 |

| Qtr. | Nuclide | Activity (Bq/Sample) | 2σTPU | MDC |
|---|---|---|---|---|
| 1st | $^{233/234}$U | 2.12E-03 | 9.88E-04 | 1.07E-03 |
| 2nd | $^{233/234}$U | 1.63E-03 | 9.99E-04 | 9.40E-04 |
| 3rd | $^{233/234}$U | 1.17E-03 | 8.00E-04 | 1.20E-03 |
| 4th | $^{233/234}$U | 1.69E-03 | 1.09E-03 | 9.84E-04 |

| Qtr. | Nuclide | Activity (Bq/Sample) | 2σTPU | MDC |
|---|---|---|---|---|
| 1st | $^{238}$U | 8.51E-04 | 6.18E-04 | 6.81E-04 |
| 2nd | $^{238}$U | 1.50E-03 | 9.55E-04 | 8.70E-04 |
| 3rd | $^{238}$U | 1.23E-03 | 7.81E-04 | 7.30E-04 |
| 4th | $^{238}$U | 1.10E-03 | 8.81E-04 | 8.77E-04 |

| Qtr. | Nuclide | Activity (Bq/Sample) | 2σTPU | MDC |
|---|---|---|---|---|
| 1st | $^{137}$Cs | -2.04E-02 | 1.15E+00 | 1.29E+00 |
| 2nd | $^{137}$Cs | -1.34E+00 | 1.67E+00 | 1.73E+00 |
| 3rd | $^{137}$Cs | -2.93E-01 | 9.40E-01 | 1.06E+00 |
| 4th | $^{137}$Cs | -1.33E-01 | 3.34E-01 | 3.60E-01 |

(a) Total propagated uncertainty.
(b) Minimum detectable concentration.

**Table 4.3 – Activity (Bq) of Quarterly Composite Air Samples from WIPP Effluent Monitoring Station C for 2011**

| Qtr. | FAS | Nuclide | Activity | 2σTPU[a] | MDC[b] |
|---|---|---|---|---|---|
| | | (Bq/Sample) | | | |
| 1st | 19 | $^{241}$Am | 3.88E-04 | 6.66E-04 | 9.03E-04 |
| 1st | 21 | $^{241}$Am | 4.77E-04 | 6.85E-04 | 8.73E-04 |
| 1st | 23 | $^{241}$Am | 1.25E-04 | 5.25E-04 | 9.14E-04 |
| 1st | 256 | $^{241}$Am | 2.21E-04 | 5.55E-04 | 8.73E-04 |
| 2nd | 19 | $^{241}$Am | 6.50E-04 | 6.85E-04 | 9.00E-02 |
| 2nd | 21 | $^{241}$Am | 3.41E-04 | 6.40E-04 | 9.99E-04 |
| 2nd | 23 | $^{241}$Am | 2.20E-04 | 4.70E-04 | 9.44E-04 |
| 2nd | 256 | $^{241}$Am | 4.70E-04 | 6.40E-04 | 9.40E-04 |
| 2nd | 157 | $^{241}$Am | 6.30E-04 | 6.73E-04 | 9.40E-04 |
| 3rd | 157 | $^{241}$Am | 3.05E-04 | 6.44E-04 | 8.70E-04 |
| 4th | 157 | $^{241}$Am | 7.20E-05 | 4.22E-04 | 8.00E-04 |
| | | | | | |
| 1st | 19 | $^{239/240}$Pu | 2.40E-05 | 6.40E-04 | 1.02E-03 |
| 1st | 21 | $^{239/240}$Pu | 5.00E-04 | 6.00E-04 | 7.03E-04 |
| 1st | 23 | $^{239/240}$Pu | 3.06E-04 | 6.90E-04 | 9.70E-04 |
| 1st | 256 | $^{239/240}$Pu | 4.90E-04 | 7.60E-04 | 9.30E-04 |
| 2nd | 19 | $^{239/240}$Pu | 1.22E-04 | 3.25E-04 | 5.11E-04 |
| 2nd | 21 | $^{239/240}$Pu | 4.84E-04 | 5.00E-04 | 5.33E-04 |
| 2nd | 23 | $^{239/240}$Pu | 1.63E-04 | 3.13E-04 | 5.18E-04 |
| 2nd | 256 | $^{239/240}$Pu | 3.60E-05 | 2.70E-04 | 5.30E-04 |
| 2nd | 157 | $^{239/240}$Pu | 1.50E-04 | 3.40E-04 | 5.30E-04 |
| 3rd | 157 | $^{239/240}$Pu | 5.40E-05 | 2.40E-04 | 6.18E-04 |
| 4th | 157 | $^{239/240}$Pu | 7.70E-05 | 2.32E-04 | 6.22E-04 |
| | | | | | |
| 1st | 19 | $^{233/234}$U | 1.50E-03 | 9.30E-04 | 1.13E-03 |
| 1st | 21 | $^{233/234}$U | 9.80E-04 | 7.80E-04 | 1.20E-03 |
| 1st | 23 | $^{233/234}$U | 1.61E-03 | 9.25E-04 | 1.11E-03 |
| 1st | 256 | $^{233/234}$U | 1.30E-03 | 8.03E-04 | 1.10E-03 |
| 2nd | 19 | $^{233/234}$U | 6.50E-04 | 6.10E-04 | 9.00E-04 |
| 2nd | 21 | $^{233/234}$U | 5.00E-04 | 4.90E-04 | 8.51E-04 |
| 2nd | 23 | $^{233/234}$U | 5.03E-04 | 5.40E-04 | 9.03E-04 |
| 2nd | 256 | $^{233/234}$U | 5.51E-04 | 5.00E-04 | 8.70E-04 |
| 2nd | 157 | $^{233/234}$U | 1.10E-04 | 3.50E-04 | 8.70E-04 |
| 3rd | 157 | $^{233/234}$U | 2.33E-04 | 3.80E-04 | 1.15E-03 |
| 4th | 157 | $^{233/234}$U | 3.73E-04 | 5.25E-04 | 9.73E-04 |
| | | | | | |
| 1st | 19 | $^{137}$Cs | 9.81E-02 | 1.13E+00 | 1.30E+00 |
| 1st | 21 | $^{137}$Cs | 1.02E-01 | 1.55E+00 | 1.75E+00 |
| 1st | 23 | $^{137}$Cs | 1.46E-01 | 1.52E+00 | 1.67E+00 |
| 1st | 256 | $^{137}$Cs | -2.43E-01 | 1.18E+00 | 1.28E+00 |
| 2nd | 19 | $^{137}$Cs | -6.29E-01 | 1.00E+00 | 1.11E+00 |
| 2nd | 21 | $^{137}$Cs | 1.07E+00 | 1.52E+00 | 1.80E+00 |
| 2nd | 23 | $^{137}$Cs | 8.10E-01 | 1.22E+00 | 1.50E+00 |
| 2nd | 256 | $^{137}$Cs | 1.21E+00 | 9.70E-01 | 1.21E+00 |
| 2nd | 157 | $^{137}$Cs | 4.14E-01 | 1.51E+00 | 1.73E+00 |
| 3rd | 157 | $^{137}$Cs | -6.22E-01 | 7.51E-01 | 7.70E-01 |
| 4th | 157 | $^{137}$Cs | -4.63E-01 | 4.60E-01 | 5.00E-01 |

| Qtr. | FAS | Nuclide | Activity | 2σTPU | MDC |
|---|---|---|---|---|---|
| | | (Bq/Sample) | | | |
| 1st | 19 | $^{238}$Pu | 1.10E-03 | 1.27E-03 | 1.12E-03 |
| 1st | 21 | $^{238}$Pu | 3.46E-04 | 5.37E-04 | 8.10E-04 |
| 1st | 23 | $^{238}$Pu | 1.04E-03 | 1.16E-03 | 1.08E-03 |
| 1st | 256 | $^{238}$Pu | 3.20E-04 | 8.44E-04 | 1.04E-03 |
| 2nd | 19 | $^{238}$Pu | 2.53E-04 | 4.59E-04 | 6.85E-04 |
| 2nd | 21 | $^{238}$Pu | 1.50E-04 | 3.50E-04 | 7.10E-04 |
| 2nd | 23 | $^{238}$Pu | -3.43E-05 | 3.09E-04 | 7.00E-04 |
| 2nd | 256 | $^{238}$Pu | 2.90E-04 | 4.85E-04 | 7.03E-04 |
| 2nd | 157 | $^{238}$Pu | -4.00E-05 | 3.24E-04 | 7.07E-04 |
| 3rd | 157 | $^{238}$Pu | 2.93E-04 | 4.50E-04 | 6.90E-04 |
| 4th | 157 | $^{238}$Pu | 2.18E-04 | 4.11E-04 | 7.14E-04 |
| | | | | | |
| 1st | 19 | $^{90}$Sr | -2.51E-02 | 4.85E-02 | 2.01E-02 |
| 1st | 21 | $^{90}$Sr | -2.70E-02 | 4.14E-02 | 2.00E-02 |
| 1st | 23 | $^{90}$Sr | -2.00E-02 | 4.44E-02 | 2.00E-02 |
| 1st | 256 | $^{90}$Sr | -1.20E-02 | 4.20E-02 | 1.93E-02 |
| 2nd | 19 | $^{90}$Sr | 6.70E-03 | 3.24E-02 | 2.00E-02 |
| 2nd | 21 | $^{90}$Sr | -1.44E-02 | 3.46E-02 | 2.02E-02 |
| 2nd | 23 | $^{90}$Sr | -1.38E-02 | 3.05E-02 | 2.00E-02 |
| 2nd | 256 | $^{90}$Sr | -1.52E-02 | 3.06E-02 | 2.00E-02 |
| 2nd | 157 | $^{90}$Sr | -5.00E-03 | 3.09E-02 | 2.00E-02 |
| 3rd | 157 | $^{90}$Sr | 2.05E-03 | 4.37E-02 | 2.72E-02 |
| 4th | 157 | $^{90}$Sr | 1.70E-02 | 2.70E-02 | 2.70E-02 |
| | | | | | |
| 1st | 19 | $^{238}$U | 3.00E-04 | 4.51E-04 | 8.07E-04 |
| 1st | 21 | $^{238}$U | 1.10E-03 | 8.18E-04 | 8.33E-04 |
| 1st | 23 | $^{238}$U | 1.27E-03 | 8.10E-04 | 8.00E-04 |
| 1st | 256 | $^{238}$U | 1.90E-03 | 9.70E-04 | 7.81E-04 |
| 2nd | 19 | $^{238}$U | 1.04E-03 | 7.00E-04 | 7.80E-04 |
| 2nd | 21 | $^{238}$U | 6.14E-04 | 5.14E-04 | 7.40E-04 |
| 2nd | 23 | $^{238}$U | 6.30E-04 | 5.81E-04 | 7.90E-04 |
| 2nd | 256 | $^{238}$U | 6.44E-04 | 5.40E-04 | 7.50E-04 |
| 2nd | 157 | $^{238}$U | 1.12E-04 | 3.42E-04 | 7.60E-04 |
| 3rd | 157 | $^{238}$U | 2.42E-04 | 3.70E-04 | 6.81E-04 |
| 4th | 157 | $^{238}$U | 6.85E-04 | 6.54E-04 | 8.66E-04 |

(a) Total propagated uncertainty.
(b) Minimum detectable concentration.

**Table 4.4 – Activity (Bq) of Monthly Composite Air Samples from WIPP Effluent Monitoring Station A for 2011**

| Month | Nuclide | Activity | 2σ TPU[a] | MDC[b] |
|---|---|---|---|---|
| | | Bq/sample | Bq/sample | Bq/sample |
| January | $^{241}$Am | 4.96E-06 | 5.88E-04 | 2.18E-05 |
| February | $^{241}$Am | -6.70E-05 | 6.66E-04 | 2.46E-05 |
| March | $^{241}$Am | 1.00E-04 | 5.37E-04 | 1.99E-05 |
| April | $^{241}$Am | 6.25E-04 | 1.18E-03 | 4.35E-05 |
| April Backup A23 | $^{241}$Am | 3.77E-04 | 5.51E-04 | 2.04E-05 |
| April Backup D | $^{241}$Am | 1.89E-04 | 4.63E-04 | 1.71E-05 |
| May | $^{241}$Am | 4.37E-04 | 7.18E-04 | 2.66E-05 |
| June | $^{241}$Am | 3.44E-04 | 6.36E-04 | 2.35E-05 |
| July | $^{241}$Am | 4.70E-04 | 5.99E-04 | 2.22E-05 |
| August | $^{241}$Am | 2.91E-04 | 4.96E-04 | 1.83E-05 |
| September | $^{241}$Am | 3.34E-04 | 6.29E-04 | 2.33E-05 |
| October | $^{241}$Am | 4.03E-04 | 5.74E-04 | 2.12E-05 |
| November | $^{241}$Am | 2.80E-04 | 6.33E-04 | 2.34E-05 |
| December | $^{241}$Am | 2.94E-05 | 4.81E-04 | 1.78E-05 |
| | | | | |
| January | $^{239/240}$Pu | -1.03E-04 | 3.10E-04 | 1.01E-03 |
| February | $^{239/240}$Pu | 6.66E-05 | 4.88E-04 | 6.99E-04 |
| March | $^{239/240}$Pu | 1.68E-04 | 5.11E-04 | 7.55E-04 |
| April | $^{239/240}$Pu | 6.44E-02 | 7.55E-03 | 8.10E-04 |
| April Backup A23 | $^{239/240}$Pu | 3.26E-04 | 4.88E-04 | 6.18E-04 |
| April Backup D | $^{239/240}$Pu | 6.29E-05 | 2.60E-04 | 5.59E-04 |
| May | $^{239/240}$Pu | 4.88E-04 | 5.51E-04 | 5.74E-04 |
| June | $^{239/240}$Pu | 2.97E-05 | 3.33E-04 | 6.03E-04 |
| July | $^{239/240}$Pu | 7.33E-05 | 2.65E-04 | 5.40E-04 |
| August | $^{239/240}$Pu | 9.25E-05 | 2.48E-04 | 5.37E-04 |
| September | $^{239/240}$Pu | 4.22E-05 | 2.87E-04 | 5.96E-04 |
| October | $^{239/240}$Pu | -6.18E-05 | 1.72E-04 | 6.73E-04 |
| November | $^{239/240}$Pu | -3.74E-05 | 1.27E-04 | 6.66E-04 |
| December | $^{239/240}$Pu | -8.10E-05 | 1.85E-04 | 6.36E-04 |
| | | | | |
| January | $^{233/234}$U | 6.55E-03 | 2.21E-03 | 8.16E-05 |
| February | $^{233/234}$U | 1.87E-03 | 1.15E-03 | 4.27E-05 |
| March | $^{233/234}$U | 2.41E-03 | 1.39E-03 | 5.13E-05 |
| April | $^{233/234}$U | 2.22E-03 | 1.56E-03 | 5.78E-05 |
| April Backup A23 | $^{233/234}$U | 1.72E-03 | 1.01E-03 | 3.74E-05 |
| April Backup D | $^{233/234}$U | 6.18E-04 | 6.18E-04 | 2.29E-05 |
| May | $^{233/234}$U | 1.25E-03 | 8.70E-04 | 3.22E-05 |
| June | $^{233/234}$U | 1.09E-03 | 8.21E-04 | 3.04E-05 |
| July | $^{233/234}$U | 1.11E-03 | 7.73E-04 | 2.86E-05 |
| August | $^{233/234}$U | 2.86E-04 | 4.63E-04 | 1.71E-05 |
| September | $^{233/234}$U | 2.68E-04 | 4.85E-04 | 1.79E-05 |
| October | $^{233/234}$U | 2.29E-03 | 1.17E-03 | 4.33E-05 |
| November | $^{233/234}$U | 1.74E-03 | 9.92E-04 | 3.67E-05 |
| December | $^{233/234}$U | 3.70E-04 | 5.22E-04 | 1.93E-05 |
| | | | | |
| January | $^{137}$Cs | -6.59E-01 | 1.39E+00 | 1.49E+00 |
| February | $^{137}$Cs | 3.42E-01 | 7.84E-01 | 8.55E-01 |
| March | $^{137}$Cs | 3.64E-02 | 1.05E+00 | 1.18E+00 |
| April | $^{137}$Cs | 1.74E+00 | 1.74E+00 | 2.12E+00 |
| April Backup A23 | $^{137}$Cs | -2.01E-01 | 1.01E+00 | 1.16E+00 |
| April Backup D | $^{137}$Cs | -2.21E-01 | 8.14E-01 | 8.92E-01 |
| May | $^{137}$Cs | 4.74E-01 | 9.47E-01 | 1.14E+00 |
| June | $^{137}$Cs | -1.49E+00 | 9.44E-01 | 9.18E-01 |
| July | $^{137}$Cs | 1.92E+00 | 1.19E+00 | 1.48E+00 |
| August | $^{137}$Cs | 5.14E-01 | 7.59E-01 | 8.58E-01 |
| September | $^{137}$Cs | -2.94E-03 | 6.85E-01 | 7.55E-01 |
| October | $^{137}$Cs | -8.40E-01 | 1.01E+00 | 1.08E+00 |
| November | $^{137}$Cs | 3.23E-01 | 6.85E-01 | 7.70E-01 |
| December | $^{137}$Cs | -2.98E-01 | 4.70E-01 | 5.25E-01 |

| Month | Nuclide | Activity | 2σ TPU | MDC |
|---|---|---|---|---|
| | | Bq/sample | Bq/sample | Bq/sample |
| January | $^{238}$Pu | 1.89E-04 | 1.08E-03 | 4.00E-05 |
| February | $^{238}$Pu | 4.63E-04 | 8.47E-04 | 3.14E-05 |
| March | $^{238}$Pu | 9.18E-05 | 5.51E-04 | 2.04E-05 |
| April | $^{238}$Pu | 5.59E-04 | 8.95E-04 | 3.31E-05 |
| April Backup A23 | $^{238}$Pu | 6.33E-04 | 6.99E-04 | 2.59E-05 |
| April Backup D | $^{238}$Pu | 5.92E-05 | 4.07E-04 | 1.51E-05 |
| May | $^{238}$Pu | 1.83E-04 | 4.81E-04 | 1.78E-05 |
| June | $^{238}$Pu | 1.96E-04 | 5.29E-04 | 1.96E-05 |
| July | $^{238}$Pu | 5.48E-04 | 6.14E-04 | 2.27E-05 |
| August | $^{238}$Pu | 7.07E-04 | 7.14E-04 | 2.64E-05 |
| September | $^{238}$Pu | 7.25E-05 | 5.22E-04 | 1.93E-05 |
| October | $^{238}$Pu | 3.56E-04 | 5.51E-04 | 2.04E-05 |
| November | $^{238}$Pu | 6.36E-05 | 4.07E-04 | 1.51E-05 |
| December | $^{238}$Pu | 1.11E-05 | 2.99E-04 | 1.11E-05 |
| | | | | |
| January | $^{90}$Sr | -1.44E-02 | 3.85E-02 | 2.10E-02 |
| February | $^{90}$Sr | -1.10E-02 | 3.36E-02 | 1.94E-02 |
| March | $^{90}$Sr | -1.90E-02 | 2.66E-02 | 1.90E-02 |
| April | $^{90}$Sr | -1.32E-02 | 3.81E-02 | 1.81E-02 |
| April Backup A23 | $^{90}$Sr | -4.59E-03 | 2.59E-02 | 1.86E-02 |
| April Backup D | $^{90}$Sr | -8.21E-03 | 2.43E-02 | 1.85E-02 |
| May | $^{90}$Sr | 3.77E-03 | 2.52E-02 | 1.86E-02 |
| June | $^{90}$Sr | -1.48E-02 | 2.33E-02 | 1.84E-02 |
| July | $^{90}$Sr | -9.81E-03 | 3.96E-02 | 1.97E-02 |
| August | $^{90}$Sr | -7.29E-03 | 2.12E-02 | 1.97E-02 |
| September | $^{90}$Sr | -2.96E-02 | 4.44E-02 | 2.72E-02 |
| October | $^{90}$Sr | 9.77E-03 | 4.14E-02 | 2.73E-02 |
| November | $^{90}$Sr | -2.39E-02 | 4.77E-02 | 2.95E-02 |
| December | $^{90}$Sr | -1.86E-02 | 2.84E-02 | 2.68E-02 |
| | | | | |
| January | $^{238}$U | 1.63E-04 | 2.54E-04 | 5.88E-04 |
| February | $^{238}$U | 9.99E-04 | 8.21E-04 | 8.21E-04 |
| March | $^{238}$U | 1.74E-03 | 1.16E-03 | 8.88E-04 |
| April | $^{238}$U | 1.56E-03 | 1.31E-03 | 1.04E-03 |
| April Backup A23 | $^{238}$U | 7.18E-04 | 6.48E-04 | 8.07E-04 |
| April Backup D | $^{238}$U | 1.27E-03 | 8.77E-04 | 8.21E-04 |
| May | $^{238}$U | 1.44E-03 | 8.84E-04 | 7.99E-04 |
| June | $^{238}$U | 1.37E-03 | 9.03E-04 | 8.14E-04 |
| July | $^{238}$U | 2.04E-03 | 1.05E-03 | 8.29E-04 |
| August | $^{238}$U | 1.01E-03 | 7.62E-04 | 8.21E-04 |
| September | $^{238}$U | 9.58E-04 | 7.25E-04 | 7.62E-04 |
| October | $^{238}$U | 2.44E-03 | 1.20E-03 | 7.77E-04 |
| November | $^{238}$U | 6.96E-04 | 6.36E-04 | 6.44E-04 |
| December | $^{238}$U | 9.95E-05 | 3.18E-04 | 8.62E-04 |

(a) Total propagated uncertainty.
(b) Minimum detectable concentration.
(c) Backup A23: Station A Skid A23 FAS
(d) Backup D: Station D FAS

## 4.2 Airborne Particulates

### 4.2.1 Sample Collection

Weekly airborne particulate samples were collected from seven locations on or near the WIPP site (Figure 4.1) using low-volume air samplers. Locations were selected based on the prevailing wind direction. Location codes are shown in Appendix C. Each week at each sampling location, approximately 600 $m^3$ (21,187 $ft^3$) of air were sampled through a 4.7-centimeter (cm) (1.85-inch [in.]) diameter glass microfiber filter using a continuous low-volume air sampler.

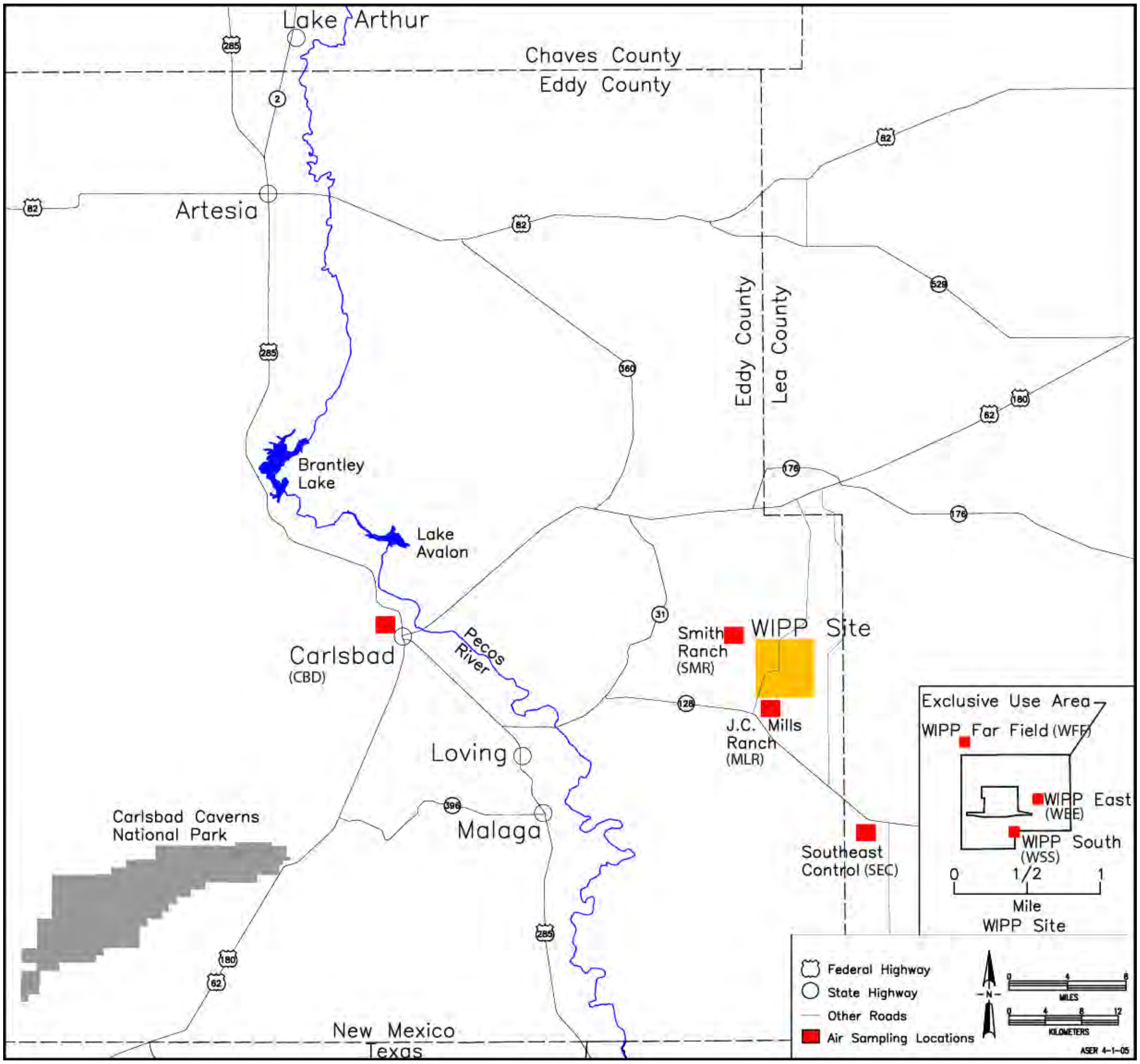



Figure 4.1 – Air Sampling Locations On and Near the WIPP Site

### 4.2.2 Sample Preparation

Weekly air particulate samples were analyzed for gross alpha and beta and then composited for each quarter. The composite samples were transferred into a Pyrex® beaker, spiked with appropriate tracers ($^{232}$U, $^{243}$Am and $^{242}$Pu), and heated in a muffle furnace at 250°C (482°F) for two hours, followed by heating for two hours at 375°C (707°F), and heating for six hours at 525°C (977°F).

The filters were wet-ashed and cooled, and then transferred into Teflon® beakers by rinsing with concentrated nitric acid. The mixture was then heated with concentrated hydrofluoric acid until completely dissolved. Hydrofluoric acid was removed by evaporation to dryness.

Approximately 25 mL of concentrated nitric acid and one gram of boric acid were added, and the samples were heated and finally evaporated to dryness. The residues were dissolved in 8 molar nitric acid for subsequent radionuclide separation and analysis.

### 4.2.3 Determination of Individual Radionuclides

The acid digestates of the filter composite samples were split into two fractions. One fraction was analyzed by gamma spectroscopy for $^{40}$K, $^{60}$Co, and $^{137}$Cs. The other fraction was analyzed for the uranium/transuranic radioisotopes and $^{90}$Sr by employing a series of chemical, physical, and ion exchange procedures to separate the radionuclides, followed by mounting the sample residues on a planchet for counting. Uranium/transuranic isotopes were counted by alpha spectroscopy and $^{90}$Sr was counted for beta emissions using gas proportional counting.

### 4.2.4 Results and Discussion

The combined mean, minimum, and maximum concentrations (becquerels per composite air filter sample [Bq/sample]) of target radionuclides for all air sampling locations are reported in Table 4.5. The location and sampling quarter for the minimum and maximum activities (radionuclide concentrations) are also reported. Detailed sample analysis data for each sampling station are reported in Appendix G (Table G.1). Whenever the word "sample" is used for air filter samples, it should be taken to mean "composite sample." Blank filter composite samples were prepared and analyzed, and the results are reported separately for each quarter.

The average concentrations are reported for those locations where duplicate samples were collected using low-volume air samples. A Qualifier column is included in all the data tables in Appendix G, to show whether the activity of the radionuclide is greater than the 2 $\sigma$ TPU and MDC and thus whether the radionuclide was detected in the sample. Table G.2 shows the Bq/sample converted to Bq/m$^3$ by dividing the sample activity in Bq by the total quarterly air volumes.

The only radionuclide detections in any of the air filter composite samples were as follows:

- Detection of $^{233/234}U$ in samples from locations MLR and SMR during the first quarter and locations SEC and CBD during the fourth quarter
- Detection of $^{238}U$ in locations WSS, MLR, and SMR during the first quarter; in WSS, MLR, CBD, and SMR during the third quarter; and in WSS during the fourth quarter
- Detection of $^{239/240}Pu$ in locations WFF and one of the WSS duplicates during the fourth quarter

However, the WAB blank filters also contained detections of $^{233/234}U$ in the first and third quarter blank filter samples and 238U in the blank filter samples from all four quarters. The activity of $^{233/234}U$ in the filter blank samples ranged from about 48 percent to 93 percent of the activity in the samples, and thus the air sample composites contained negligible concentrations of $^{233/234}U$. Likewise, the activity of $^{238}U$ in the filter blank samples ranged from about 43 percent to 170 percent of the activity in the composite samples and thus the air sample composites contained negligible, if any, concentrations of $^{238}U$. The uranium isotopes were detected at similar concentrations in the 2010 air composite samples and filter blank samples, and therefore ANOVA comparisons between years and between locations were not performed.

In contrast to 2010, $^{239/240}Pu$ was detected in two of the 2011 samples, including the fourth quarter WFF and one of the fourth quarter WSS duplicate composite samples. Since $^{239/240}Pu$ was not detected in the 2010 air filter composite samples, no ANOVA comparisons between years or between locations could be performed.

There were no measurable concentrations of $^{235}U$, $^{238}Pu$, $^{241}Am$, $^{40}K$, $^{137}Cs$, $^{60}Co$, or $^{90}Sr$ in any of the 2011 air filter composite samples. As a result, no ANOVA comparisons could be performed between years or between locations for these radionuclides.

**Table 4.5 – 2011 Mean, Minimum, and Maximum Radionuclide Concentrations (Bq/sample) in Air Filter Composite Samples from Stations Surrounding the WIPP Site**

**See Appendix G for Supporting Data**

| Radionuclide | | Location | Qtr | [RN][a] | 2 σ TPU[b] | MDC[c] |
|---|---|---|---|---|---|---|
| 233/234U | Meand | | | 4.68E-03 | 2.81E-03 | 7.72E-03 |
| | Minimum[e] | WSS | 1 | -1.44E-04 | 2.59E-03 | 8.70E-03 |
| | Maximum[e] | MLR | 1 | 1.78E-02 | 8.13E-03 | 8.93E-03 |
| 235U | Mean[d] | | | 2.30E-04 | 6.32E-04 | 1.11E-03 |
| | Minimum[e] | SEC | 1 | -6.34E-04 | 2.82E-04 | 1.41E-03 |
| | Maximum[e] | WSS | 1 | 1.14E-03 | 1.28E-03 | 1.29E-03 |
| 238U | Mean[d] | | | 4.82E-03 | 2.70E-03 | 5.44E-03 |
| | Minimum | MLR | 4 | 7.65E-04 | 1.94E-03 | 5.76E-03 |
| | Maximum[e] | MLR | 1 | 1.32E-02 | 6.42E-03 | 6.17E-03 |
| 238Pu | Mean[d] | | | -1.59E-04 | 5.41E-04 | 9.06E-04 |
| | Minimum[e] | CBD | 4 | -1.24E-03 | 5.45E-04 | 1.49E-03 |
| | Maximum[e] | SMR | 3 | 6.89E-04 | 7.21E-04 | 6.31E-04 |
| 239/240Pu | Mean[d] | | | 2.11E-04 | 4.77E-04 | 9.32E-04 |
| | Minimum[e] | SMR | 4 | -6.69E-04 | 1.63E-04 | 1.09E-03 |
| | Maximum[e] | WFF | 4 | 4.98E-03 | 1.63E-03 | 1.10E-03 |
| 241Am | Mean[d] | | | 6.29E-05 | 7.41E-04 | 9.85E-04 |
| | Minimum | MLR | 1 | -6.48E-04 | 4.85E-04 | 1.01E-03 |
| | Maximum[e] | CBD | 2 | 9.65E-04 | 1.17E-03 | 1.12E-03 |
| 40K | Mean[d] | | | 5.22E+00 | 9.31E+00 | 1.12E+01 |
| | Minimum[e] | MLR | 1 | -6.00E+00 | 1.07E+01 | 1.04E+01 |
| | Maximum[e] | SEC | 1 | 1.61E+01 | 1.12E+01 | 1.44E+01 |
| 60Co | Mean[d] | | | 4.95E-02 | 9.91E-01 | 1.13E+00 |
| | Minimum[e] | CBD | 2 | -1.28E+00 | 1.19E+00 | 1.16E+00 |
| | Maximum[e] | MLR | 2 | 9.56E-01 | 9.71E-01 | 1.26E+00 |
| 137Cs | Mean[d] | | | -3.01E-02 | 1.35E+00 | 1.18E+00 |
| | Minimum[e] | SEC | 2 | -1.06E+00 | 1.75E+00 | 1.82E+00 |
| | Maximum[e] | CBD | 3 | 1.37E+00 | 9.05E+00 | 1.13E+00 |
| 90Sr | Mean[d] | | | -6.84E-03 | 3.12E-02 | 3.57E-02 |
| | Minimum[e] | SMR | 4 | -3.82E-02 | 2.76E-02 | 3.77E-02 |
| | Maximum[e] | WSS | 3 | 3.26E-02 | 3.87E-02 | 2.72E-02 |

(a) Radionuclide Concentration. Values are for eight locations and four quarterly composites (Appendix G).

(b) Total Propagated Uncertainty at the 2 σ level.

(c) Minimum Detectable Concentration.

(d) Arithmetic average for concentration, 2 σ TPU, and MDC.

(e) Minimum and maximum reported concentrations for each radionuclide are based on the radionuclide concentration [RN], while the associated 2 σ TPU and MDC values are inherited with the specific [RN], and thus are not necessarily minimum and maximum values.

The precision of the combined sampling and analysis steps for the air monitoring samples was determined by collecting duplicate samples. During 2011, duplicate samples were taken from location SMR during the first quarter, location WFF during the second quarter, location WEE during the third quarter, and location WSS during the fourth quarter.

The only detections in any of the duplicate samples were for $^{233/234}U$, $^{238}U$, and $^{239/240}Pu$. The only samples for which radionuclides were detected in both duplicate samples were for $^{233/234}U$ and $^{238}U$ in the first quarter duplicates from location SMR and $^{238}U$ in the fourth quarter from WSS. However, the filter blank sample yielded blank activities of 93 percent and 70 percent, respectively, of the activity in the samples, and thus the samples only contained negligible amounts, if any, of the uranium isotopes. The radionuclide $^{239/240}Pu$ was detected in only one of the duplicate samples at location WSS, but the detection is more certain. The activity in the sample was 2.4 times higher than the TPU and 4.8 times higher than the activity in the corresponding filter blank sample. The Pu radionuclide could be detected in one duplicate sample and not the other if it is associated with well-dispersed particulate matter that was captured on one of the filters but not the duplicate filter.

Relative error ratios (RERs) were calculated for all the target radionuclides in all the duplicate composite air filter samples, although the radionuclides were only detected in a few of the samples as discussed above. (RERs for duplicate samples are also referred to as duplicate error ratios (DERs)). The sample activities and total propagated errors for each radionuclide were used to calculate RERs for each radionuclide whether or not it was detected in the samples. The RERs for the target radionuclides in the duplicate samples are presented in Table 4.6. The data show good precision for the duplicate samples based on nearly all RERs being less than 1. The only exceptions were for $^{137}Cs$ at location SMR during the first quarter (RER = 1.051), $^{238}Pu$ at location WSS during the fourth quarter (RER = 1.410), and $^{239/240}Pu$ at location WSS during the fourth quarter (RER = 2.802). Note that the $^{239/240}Pu$ RER is for the duplicate samples where the radionuclide was detected in one of the duplicate samples but not the other, and thus the RER was expected to be high.

There is no firmly established quality assurance objective for the precision of field duplicates, since the composition of field samples could be slightly different. One source (*Rocky Flats Annual Report of Site Surveillance and Maintenance Activities - CY2008*, Doc. No. S05247, U.S. Department of Energy, April, 2009) suggested that 85 percent of field duplicates should yield RERs (DERs) <1.96. This objective was readily met for the air particulate samples discussed above. Field duplicate RERs <1 indicate very good precision for the combined sampling and laboratory analysis procedures. Poorer precision suggests that there could be actual differences in the composition of the samples collected in the field, and this was the case with duplicate samples where $^{239/240}Pu$ was detected on just one of the duplicate filter samples.

**Table 4.6 – Results of Radionuclide Analysis of Duplicate Air Particulate Samples (Units in Bq/Sample)**

**See Figure 4.1 for Sampling Locations**

| | | | Sample 1 | | Sample 2 | | |
|---|---|---|---|---|---|---|---|
| Qtr | Location | Isotope | [RN][a] | 2 σ TPU[b] | [RN] | 2 σ TPU | RER[c] |
| 1 | SMR | $^{233/234}U$ | 9.53E-03 | 4.78E-03 | 1.10E-02 | 5.12E-03 | 0.210 |
| 1 | SMR | $^{235}U$ | 5.90E-04 | 1.17E-03 | 1.54E-04 | 9.33E-04 | 0.291 |
| 1 | SMR | $^{238}U$ | 9.07E-03 | 4.39E-03 | 9.34E-03 | 4.43E-03 | 0.043 |
| 1 | SMR | $^{238}Pu$ | 7.39E-04 | 1.01E-03 | -2.17E-04 | 6.39E-04 | 0.800 |
| 1 | SMR | $^{239/240}Pu$ | -2.34E-04 | 4.77E-04 | -1.12E-04 | 5.26E-04 | 0.172 |
| 1 | SMR | $^{241}Am$ | -1.34E-04 | 7.45E-04 | -2.03E-04 | 8.51E-04 | 0.061 |
| 1 | SMR | $^{40}K$ | 5.36E+00 | 7.46E+00 | 1.47E+01 | 1.12E+01 | 0.694 |
| 1 | SMR | $^{60}Co$ | 4.81E-01 | 7.00E-01 | -5.19E-01 | 1.28E+00 | 0.685 |
| 1 | SMR | $^{137}Cs$ | 3.85E-01 | 7.56E-01 | -1.40E+00 | 1.52E+00 | 1.051 |
| 1 | SMR | $^{90}Sr$ | -1.08E-02 | 3.81E-02 | -1.08E-02 | 3.87E-02 | 0.000 |
| | | | Sample 1 | | Sample 2 | | |
| Qtr | Location | Isotope | [RN] | 2 σ TPU | [RN] | 2 σ TPU | RER |
| 2 | WFF | $^{233/234}U$ | 3.62E-03 | 2.02E-03 | 1.92E-03 | 1.95E-03 | 0.605 |
| 2 | WFF | $^{235}U$ | -3.80E-04 | 2.82E-04 | -2.09E-04 | 4.11E-04 | 0.343 |
| 2 | WFF | $^{238}U$ | 7.53E-04 | 1.57E-03 | 1.80E-03 | 1.84E-03 | 0.433 |
| 2 | WFF | $^{238}Pu$ | 2.74E-04 | 5.48E-04 | 1.38E-04 | 5.04E-04 | 0.183 |
| 2 | WFF | $^{239/240}Pu$ | 2.96E-05 | 3.63E-04 | -1.60E-04 | 1.60E-04 | 0.478 |
| 2 | WFF | $^{241}Am$ | 1.97E-04 | 6.08E-04 | 8.01E-04 | 1.20E-03 | 0.449 |
| 2 | WFF | $^{40}K$ | 1.71E+00 | 9.61E+00 | 1.13E+00 | 1.16E+01 | 0.039 |
| 2 | WFF | $^{60}Co$ | 7.31E-01 | 9.22E-01 | 1.56E-01 | 1.17E+00 | 0.386 |
| 2 | WFF | $^{137}Cs$ | -6.77E-01 | 1.00E+00 | -9.45E-01 | 1.37E+00 | 0.158 |
| 2 | WFF | $^{90}Sr$ | 1.13E-02 | 2.95E-02 | 1.65E-02 | 2.87E-02 | 0.126 |
| | | | Sample 1 | | Sample 2 | | |
| Qtr | Location | Isotope | [RN] | 2 σ TPU | [RN] | 2 σ TPU | RER |
| 3 | WEE | $^{233/234}U$ | 2.87E-03 | 2.49E-03 | 2.76E-03 | 2.72E-03 | 0.030 |
| 3 | WEE | $^{235}U$ | 5.80E-04 | 8.20E-04 | -2.15E-05 | 5.78E-04 | 0.600 |
| 3 | WEE | $^{238}U$ | 4.55E-03 | 2.49E-03 | 4.48E-03 | 2.74E-03 | 0.019 |
| 3 | WEE | $^{238}Pu$ | 1.24E-04 | 5.80E-04 | 3.65E-04 | 6.75E-04 | 0.271 |
| 3 | WEE | $^{239/240}Pu$ | -1.08E-04 | 2.66E-04 | 3.34E-04 | 5.06E-04 | 0.773 |
| 3 | WEE | $^{241}Am$ | 1.53E-04 | 7.17E-04 | 8.88E-05 | 6.73E-04 | 0.065 |
| 3 | WEE | $^{40}K$ | 6.52E+00 | 7.28E+00 | 8.20E+00 | 7.15E+00 | 0.165 |
| 3 | WEE | $^{60}Co$ | 7.80E-03 | 7.35E-01 | 1.80E-01 | 7.61E-01 | 0.163 |
| 3 | WEE | $^{137}Cs$ | -5.69E-01 | 7.98E-01 | -1.84E-01 | 7.48E-01 | 0.352 |
| 3 | WEE | $^{90}Sr$ | 1.99E-03 | 3.08E-02 | -5.78E-03 | 3.10E-02 | 0.178 |
| | | | Sample 1 | | Sample 2 | | |
| Qtr | Location | Isotope | [RN] | 2 σ TPU | [RN] | 2 σ TPU | RER |
| 4 | WSS | $^{233/234}U$ | 3.85E-03 | 2.04E-03 | 2.77E-03 | 1.98E-03 | 0.380 |
| 4 | WSS | $^{235}U$ | 3.92E-04 | 4.79E-04 | 6.77E-04 | 6.26E-04 | 0.362 |
| 4 | WSS | $^{238}U$ | 2.19E-03 | 2.03E-03 | 4.30E-03 | 2.35E-03 | 0.679 |
| 4 | WSS | $^{238}Pu$ | -2.45E-04 | 4.05E-04 | -1.07E-03 | 4.22E-04 | 1.410 |
| 4 | WSS | $^{239/240}Pu$ | 2.91E-03 | 1.19E-03 | -5.16E-04 | 2.80E-04 | 2.802 |
| 4 | WSS | $^{241}Am$ | 3.17E-05 | 7.04E-04 | -2.64E-04 | 6.88E-04 | 0.300 |
| 4 | WSS | $^{40}K$ | 5.43E-01 | 6.88E+00 | -6.27E-01 | 7.18E+00 | 0.118 |
| 4 | WSS | $^{60}Co$ | 8.78E-02 | 6.73E-01 | 8.56E-02 | 7.19E-01 | 0.002 |
| 4 | WSS | $^{137}Cs$ | -5.86E-01 | 7.31E-01 | -2.21E-01 | 7.21E-01 | 0.355 |
| 4 | WSS | $^{90}Sr$ | -2.06E-02 | 2.64E-02 | -3.41E-02 | 2.73E-02 | 0.355 |

(a) Radionuclide activity
(b) Two σ times the Total Propagated Uncertainty.
(c) Relative error ratio

The laboratory generates and analyzes lab duplicate samples from a single field sample for matrices other than air particulate samples where enough of the sample is available for an additional analysis. In the case of laboratory duplicates, the quality assurance objective for laboratory precision is a RER (DER) of <1 for the WIPP environmental analysis program. The laboratory generates precision data for all the radionuclides in a sample whether the radionuclide was detected or not, based on the activities and 2 σ TPUs measured in the samples. The laboratory duplicate sample RERs are not provided in the ASER, but >99 percent of all the laboratory RERs from analysis of WIPP environmental samples during 2011 were <1. The laboratory's SOW indicates that "the Laboratory shall assess the need for corrective actions" if the laboratory duplicate precision yields RERs >1, but there were no situations where this was required.

The RER precision data for all the duplicate environmental samples analyzed during 2011 were calculated and are reported in this ASER. However, in the case of a deer sample of opportunity, duplicate portions of the carcass were collected from the deer and analyzed. In addition, one of two portions was analyzed in duplicate. The precision of these Analyses Is Reported In Section 4.7.4.

## 4.3 Groundwater

### 4.3.1 Sample Collection

Groundwater samples were collected twice in 2011 (Rounds 32 and 33) from six different detection monitoring wells on the WIPP site, as shown in Figure 6.3. During each of the resulting 12 sampling episodes, a primary sample and a duplicate sample were collected consecutively from continuously flowing water. These wells are completed in the Culebra, which is a water bearing geologic rock formation. Approximately three well bore volumes of water were pumped out of each well before collecting approximately 38 liters (L) (10 gallons) of water samples. The water samples were collected from depths ranging from 180 to 270 m (591 to 886 ft) from the six wells (WQSP-1 to WQSP-6). Approximately 8 L (2 gallons) of water per well were sent to the laboratory for the measurement of the target radionuclides. The remaining sample portions were used to analyze for nonradiological parameters (volatile and semivolatile organics, metals, and general chemistry indicator parameters), or were placed in storage. The radiological samples were filtered during collection and acidified to pH (the measure of the acidity or basicity of a solution) less than or equal to (≤) 2 with concentrated nitric acid.

### 4.3.2 Sample Preparation

The acidified groundwater sample containers were shaken to distribute any suspended material evenly, and sample aliquots were measured into glass beakers. The first 0.5-L portion was used directly for gamma spectroscopy analysis and the second 0.5-L portion was used for uranium and transuranic target isotopes and $^{90}$Sr. Tracers ($^{232}$U, $^{243}$Am, and $^{242}$Pu) and carriers (strontium nitrate and barium nitrate) were added to the second portion and the samples were digested using concentrated nitric acid and hydrofluoric acid. The samples were then heated to dryness and wet-ashed using concentrated nitric acid and hydrogen peroxide. Finally, the samples were heated to dryness again, and the isotopic separation process was initiated.

### 4.3.3 Determination of Individual Radionuclides

The first portion of water sample was used directly for the measurement of the gamma-emitting radionuclides $^{40}K$, $^{60}Co$, and $^{137}Cs$, by gamma spectroscopy. The second 0.5-L portion of the water sample was used for the sequential separation of the uranium isotopes, the transuranics, and $^{90}Sr$. The digested samples described in section 4.3.2 were prepared for counting by co-precipitating the target isotopes and corresponding tracers with an iron carrier, performing ion exchange and chromatographic separations of the individual radionuclides, and micro-precipitating the separated radionuclides onto planchets for counting the uranium/transuranic isotopes by alpha spectroscopy and $^{90}Sr$ by gas proportional counting.

### 4.3.4 Results and Discussion

Isotopes of naturally occurring uranium ($^{233/234}U$, $^{235}U$, and $^{238}U$) were detected in all the groundwater well samples in 2011, as shown by the data in Table 4.7. The concentrations reported in Table 4.7 are from the primary samples collected from each WQSP well. A duplicate sample from each well was also analyzed during each sampling episode. The data from the duplicate samples was used for the precision determinations, as reported later in this section and Table 4.8. The radionuclides were considered detected if the activity was greater than the 2 σ TPU and MDC.

The 2011 groundwater concentrations in the detection monitoring wells were compared with the concentrations from the same locations in 2010 using ANOVA. ANOVA calculations were performed using the mean uranium concentrations of the primary samples from the spring and fall sampling (Rounds 32 and 33). The uranium isotopes were also detected in all the groundwater samples in 2010.

The concentrations of the uranium isotopes measured in 2011 did not vary significantly from the concentrations measured in the same wells in 2010, as demonstrated by the combined ANOVA results of the wells with $^{233/234}U$ p = 0.760, $^{235}U$ p = 0.651, and $^{238}U$ p = 0.783, with all the p values well above the significance level of 0.05.

The concentrations of the uranium isotopes measured in 2011 were also compared to the 2010 concentrations by location. The variation by location between the wells sampled in 2010 and 2011 was significant, as demonstrated by the combined ANOVA results of $^{233/234}U$ p = 0.000249, $^{235}U$ p = 0.00640, and $^{238}U$ p = 0.000127. The differences in uranium isotope concentrations at the different locations are likely due to the differences in the abundance of these naturally occurring isotopes in the earth's crust and the associated variable dissolution into the groundwater.

Concentrations of uranium isotopes were also compared with baseline concentrations measured between 1985 and 1989 (baseline values: $^{233/234}U$ = 1.30 Bq/L, $^{235}U$ = 3.10E-02 Bq/L, and 238U = 3.20E-01 Bq/L). For 2011, the highest Round 32 concentration of $^{233/234}U$ was just above the baseline concentration with 1.34 Bq/L at WQSP-1. The highest Round 33 concentration was also just above the baseline concentration with 1.34 Bq/L at WQSP-1 with WQSP-2 close behind at 1.29 Bq/L.

The $^{235}U$ and $^{238}U$ concentrations were also generally highest at WQSP-1 and WQSP-2 during Rounds 32 and 33, although the WQSP-4 Round 32 $^{235}U$ concentration of 9.64E-03 Bq/L was slightly higher than WQSP-2 Round 32 concentration of 7.46E-03 Bq/L. All $^{235}U$ and $^{238}U$ concentrations were well within the 99 percent confidence interval ranges of the baseline concentrations (DOE/WIPP-92-037).

The transuranic alpha spectroscopy radionuclides, $^{238}Pu$, $^{239/240}Pu$, and $^{241}Am$, were also analyzed for in the groundwater samples (Table 4.7). These isotopes, which are related to WIPP waste disposal operations, were not detected in any of the groundwater samples, so no ANOVA comparisons between years and among locations could be performed.

The beta emitter, $^{90}Sr$, was not detected in any of the groundwater samples, thus no ANOVA comparisons between years or among locations could be performed.

The potassium isotope $^{40}K$ was detected in all of the Round 32 and Round 33 samples except for the Round 32 duplicate sample from WQSP-5, and the Round 33 primary and duplicate samples at WQSP-6.

The 2011 concentrations of $^{40}K$ did not vary significantly from the 2010 concentrations based on an ANOVA p value of 0.691. However, $^{40}K$ concentrations did vary significantly by location from well to well, yielding an ANOVA p value of 0.000149. Some differences in $^{40}K$ concentrations at the various wells (locations) would be expected due to differences in the abundance of this naturally occurring isotope at various locations in the earth's crust and the associated variable dissolution by groundwater.

The measured concentrations of $^{40}K$ in 2011 were all within the 99 percent confidence interval range of the baseline concentrations (baseline concentration: 6.30E+01 Bq/L). The nearest concentration measured in 2011 was 5.17E+01 Bq/L in the primary sample from the spring sampling (Round 32) from WQSP-3.

The isotopes $^{137}Cs$ and $^{60}Co$ were not detected in any of the 2011 groundwater samples and no ANOVA comparisons were performed.

**Table 4.7 – 2011 Radionuclide Concentrations (Bq/L) of Groundwater from Detection Monitoring Wells at the WIPP Site**

**See Figure 6.3 for Sampling Locations**

| Location | Round | [RN][a] | 2 σ TPU[b] | MDC[c] | Q[d] | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $^{233/234}U$ | | | | $^{235}U$ | | | | $^{238}U$ | | | |
| WQSP-1 | 32 | 1.34E+00 | 2.36E-01 | 1.04E-03 | + | 1.57E-02 | 4.24E-03 | 7.11E-04 | + | 2.18E-01 | 3.97E-02 | 8.21E-04 | + |
| | 33 | 1.34E+00 | 2.18E-01 | 1.18E-03 | + | 1.58E-02 | 3.90E-03 | 5.86E-04 | + | 2.27E-01 | 3.80E-02 | 7.36E-04 | + |
| WQSP-2 | 32 | 8.26E-01 | 1.25E-01 | 1.08E-03 | + | 7.46E-03 | 2.34E-03 | 6.42E-04 | + | 1.30E-01 | 2.09E-02 | 7.54E-04 | + |
| | 33 | 1.29E+00 | 1.92E-01 | 1.20E-03 | + | 1.26E-02 | 3.24E-03 | 5.93E-04 | + | 1.98E-01 | 3.07E-02 | 7.40E-04 | + |
| WQSP-3 | 32 | 2.19E-01 | 4.26E-02 | 1.18E-03 | + | 1.18E-03 | 9.65E-04 | 7.20E-04 | + | 3.76E-02 | 8.40E-03 | 8.03E-04 | + |
| | 33 | 2.53E-01 | 4.16E-02 | 1.23E-03 | + | 1.95E-03 | 1.15E-03 | 6.39E-04 | + | 3.49E-02 | 6.90E-03 | 7.73E-04 | + |
| WQSP-4 | 32 | 5.85E-01 | 1.10E-01 | 1.16E-03 | + | 9.64E-03 | 3.06E-03 | 6.59E-04 | + | 1.05E-01 | 2.09E-02 | 8.40E-04 | + |
| | 33 | 5.32E-01 | 7.96E-02 | 9.05E-04 | + | 5.63E-03 | 1.96E-03 | 6.25E-04 | + | 8.77E-02 | 1.43E-02 | 7.90E-04 | + |
| WQSP-5 | 32 | 5.60E-01 | 9.32E-02 | 1.13E-03 | + | 2.55E-03 | 1.32E-03 | 5.91E-04 | + | 7.88E-02 | 1.43E-02 | 8.08E-04 | + |
| | 33 | 5.87E-01 | 9.25E-02 | 1.22E-03 | + | 4.30E-03 | 1.74E-03 | 6.70E-04 | + | 8.02E-02 | 1.39E-02 | 8.29E-04 | + |

### Table 4.7 – 2011 Radionuclide Concentrations (Bq/L) of Groundwater from Detection Monitoring Wells at the WIPP Site

**See Figure 6.3 for Sampling Locations**

| Location | Round | [RN][a] | 2 σ TPU[b] | MDC[c] | Q[d] | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WQSP-6 | 32 | 5.12E-01 | 7.08E-02 | 9.71E-04 | + | 3.73E-03 | 1.47E-03 | 5.19E-04 | + | 6.99E-02 | 1.08E-02 | 7.72E-04 | + |
| | 33 | 5.47E-01 | 8.31E-02 | 1.22E-03 | + | 3.42E-03 | 1.50E-03 | 6.39E-04 | + | 6.80E-02 | 1.16E-02 | 7.51E-04 | + |
| | | $^{238}Pu$ | | | | $^{239/240}Pu$ | | | | $^{241}Am$ | | | |
| WQSP-1 | 32 | -5.48E-05 | 6.80E-04 | 8.02E-04 | U | -2.10E-04 | 3.33E-04 | 6.99E-04 | U | 3.30E-04 | 7.53E-04 | 9.51E-04 | U |
| | 33 | 4.18E-04 | 7.62E-04 | 8.61E-04 | U | 1.09E-04 | 3.77E-04 | 7.98E-04 | U | 6.15E-05 | 4.85E-04 | 8.13E-04 | U |
| WQSP-2 | 32 | -5.22E-05 | 6.47E-04 | 7.78E-04 | U | -6.96E-05 | 4.07E-04 | 7.13E-04 | U | -2.06E-04 | 3.79E-04 | 9.56E-04 | U |
| | 33 | 3.00E-04 | 2.04E-03 | 1.92E-03 | U | 3.59E-04 | 1.28E-03 | 1.86E-03 | U | 5.79E-05 | 6.67E-04 | 9.02E-04 | U |
| WQSP-3 | 32 | 7.39E-05 | 4.73E-04 | 8.30E-04 | U | -1.26E-04 | 2.51E-04 | 6.90E-04 | U | 3.99E-04 | 6.91E-04 | 8.93E-04 | U |
| | 33 | 6.66E-04 | 7.03E-04 | 6.89E-04 | U | 1.78E-04 | 3.42E-04 | 5.60E-04 | U | 1.95E-04 | 7.63E-04 | 9.02E-04 | U |
| WQSP-4 | 32 | -7.97E-05 | 4.67E-04 | 8.85E-04 | U | -1.35E-04 | 2.78E-04 | 7.69E-04 | U | 1.45E-04 | 8.47E-04 | 1.03E-03 | U |
| | 33 | 1.92E-04 | 5.77E-04 | 7.82E-04 | U | -1.37E-05 | 3.89E-04 | 6.08E-04 | U | 7.01E-05 | 5.53E-04 | 1.03E-03 | U |
| WQSP-5 | 32 | 3.95E-04 | 5.72E-04 | 8.44E-04 | U | -1.03E-04 | 2.12E-04 | 7.20E-04 | U | 2.98E-04 | 5.68E-04 | 8.43E-04 | U |
| | 33 | 5.00E-04 | 5.91E-04 | 6.76E-04 | U | 1.36E-04 | 3.59E-04 | 5.26E-04 | U | -2.01E-04 | 3.12E-04 | 8.97E-04 | U |
| WQSP-6 | 32 | 2.63E-04 | 4.83E-04 | 7.95E-04 | U | -5.95E-05 | 1.55E-04 | 6.40E-04 | U | 6.80E-05 | 4.66E-04 | 8.76E-04 | U |
| | 33 | 1.07E-04 | 4.46E-04 | 7.23E-04 | U | 8.09E-05 | 2.93E-04 | 6.03E-04 | U | 5.99E-04 | 6.46E-04 | 8.30E-04 | U |
| | | $^{40}K$ | | | | $^{60}Co$ | | | | $^{137}Cs$ | | | |
| WQSP-1 | 32 | 1.53E+01 | 5.72E+00 | 6.32E+00 | + | -2.01E-01 | 6.21E-01 | 6.72E-01 | U | 3.58E-01 | 5.05E-01 | 6.24E-01 | U |
| | 33 | 1.53E+01 | 5.57E+00 | 5.99E+00 | + | 1.66E-01 | 5.35E-01 | 6.79E-01 | U | 2.18E-01 | 4.70E-01 | 5.97E-01 | U |
| WQSP-2 | 32 | 1.46E+01 | 5.51E+00 | 6.41E+00 | + | 2.98E-01 | 5.03E-01 | 6.82E-01 | U | -8.91E-02 | 5.32E-01 | 5.87E-01 | U |
| | 33 | 1.68E+01 | 5.58E+00 | 5.85E+00 | + | 1.50E-01 | 5.21E-01 | 6.59E-01 | U | 2.03E-01 | 4.19E-01 | 5.46E-01 | U |
| WQSP-3 | 32 | 5.17E+01 | 1.03E+01 | 5.67E+00 | + | -8.45E-02 | 7.19E-01 | 8.09E-01 | U | 2.23E-01 | 5.23E-01 | 6.29E-01 | U |
| | 33 | 4.56E+01 | 9.68E+00 | 6.68E+00 | + | 2.47E-01 | 5.93E-01 | 7.58E-01 | U | 3.49E-01 | 4.49E-01 | 5.98E-01 | U |
| WQSP-4 | 32 | 2.27E+01 | 6.23E+00 | 5.36E+00 | + | -1.05E-01 | 6.82E-01 | 7.75E-01 | U | 4.22E-01 | 5.46E-01 | 6.69E-01 | U |
| | 33 | 2.27E+01 | 6.43E+00 | 5.95E+00 | + | -2.65E-01 | -6.96E-01 | 7.48E-01 | U | 5.25E-01 | 4.45E-01 | 6.19E-01 | U |
| WQSP-5 | 32 | 7.63E+00 | 4.08E+00 | 5.35E+00 | + | 2.64E-01 | 4.73E-01 | 6.45E-01 | U | -2.34E-01 | 5.61E-01 | 5.87E-01 | U |
| | 33 | 1.11E+01 | 4.31E+00 | 4.60E+00 | + | -3.90E-01 | 6.93E-01 | 6.94E-01 | U | 7.97E-02 | 4.41E-01 | 5.46E-01 | U |
| WQSP-6 | 32 | 5.86E+00 | 3.26E+00 | 4.13E+00 | + | -1.61E-01 | 6.41E-01 | 6.99E-01 | U | 6.20E-01 | 4.67E-01 | 6.32E-01 | U |
| | 33 | 5.23E+00 | 6.05E+00 | 8.30E+00 | U | 8.43E-02 | 6.35E-01 | 7.68E-01 | U | 2.10E-01 | 4.68E-01 | 5.98E-01 | U |
| | | $^{90}Sr$ | | | | | | | | | | | |
| WQSP-1 | 32 | -2.22E-03 | 2.74E-02 | 2.23E-02 | U | | | | | | | | |
| | 33 | 6.95E-03 | 4.19E-02 | 2.62E-02 | U | | | | | | | | |
| WQSP-2 | 32 | -4.61E-03 | 2.54E-02 | 1.96E-02 | U | | | | | | | | |
| | 33 | 5.32E-03 | 3.23E-02 | 2.67E-02 | U | | | | | | | | |
| WQSP-3 | 32 | -8.44E-03 | 2.73E-02 | 1.91E-02 | U | | | | | | | | |
| | 33 | -8.06E-03 | 5.32E-02 | 2.72E-02 | U | | | | | | | | |
| WQSP-4 | 32 | -1.18E-02 | 3.14E-02 | 1.69E-02 | U | | | | | | | | |
| | 33 | -8.28E-03 | 4.08E-02 | 2.04E-02 | U | | | | | | | | |
| WQSP-5 | 32 | -1.17E-03 | 4.75E-02 | 1.83E-02 | U | | | | | | | | |
| | 33 | -2.04E-02 | 5.23E-02 | 2.49E-02 | U | | | | | | | | |
| WQSP-6 | 32 | 5.51E-03 | 4.70E-02 | 1.78E-02 | U | | | | | | | | |
| | 33 | -6.66E-03 | 3.10E-02 | 2.19E-02 | U | | | | | | | | |

(a) Radionuclide activity of the primary sample. Only radionuclides with activities greater than 2 σ TPU and MDC are considered detections.
(b) Two σ the Total Propagated Uncertainty.
(c) Minimum Detectable Concentration.
(d) Qualifier. Indicates whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

This ASER generally reports the precision of the duplicate field sample precision as RERs only for the radionuclides that were detected during analysis of the primary and duplicate samples collected at each WQSP well. The detected radionuclides in the 2011 groundwater samples included the uranium isotopes and $^{40}K$. The analysis data and resulting RERs are shown in Table 4.8 for 2011 Sampling Round 32, and in Table 4.9 for 2011 Sampling Round 33.

The Round 32 RERs in Table 4.8 show that there was one RER greater than 1.96 and two RERs with values between 1.0 and 1.96. The Round 33 RERs in Table 4.9 show that there were no values greater than 1.96 and only one value greater than 1.0. The RER of 3.640 for $^{40}K$ in Round 32 WQSP-4 samples was due to a very large variation in the activities in the two samples, although the radionuclide was detected in both samples based on the activity being greater than the total propagated error and the MDC and the ID confidence >0.90. $^{40}K$ was not detected in the Round 32 duplicate sample of WQSP-6 and the Round 33 primary sample of WQSP-6, and thus the RERs are not presented.

The laboratory analyzed the primary groundwater sample from each well in duplicate from each sampling round. All RERs calculated from analysis of laboratory duplicates were <1.0, which indicated good laboratory precision for the radionuclide measurement process.

**Table 4.8 – 2011 Precision Results for Duplicate Groundwater Samples Analyses for Round 32 (Units in Bq/L)**

**See Figure 6.3 for Sampling Locations**

| **Location** | | **Sample** | | **Duplicate** | | |
|---|---|---|---|---|---|---|
| | | **[RN][a]** | **2 σ TPU[b]** | **[RN]** | **2 σ TPU** | **RER[c]** |
| WQSP-1 | $^{233/234}U$ | 1.34E+00 | 2.36E-01 | 1.33E+00 | 2.42E-01 | 0.010 |
| | $^{235}U$ | 1.57E-02 | 4.24E-03 | 2.48E-02 | 6.07E-03 | 1.223 |
| | $^{238}U$ | 2.18E-01 | 3.97E-02 | 2.11E-01 | 3.96E-02 | 0.126 |
| | $^{40}K$ | 1.53E+01 | 5.72E+00 | 1.71E+00 | 4.36E+00 | 1.890 |
| WQSP-2 | $^{233/234}U$ | 8.26E-01 | 1.25E-01 | 9.15E-01 | 1.61E-01 | 0.438 |
| | $^{235}U$ | 7.46E-03 | 2.34E-03 | 8.52E-03 | 2.81E-03 | 0.290 |
| | $^{238}U$ | 1.30E-01 | 2.09E-02 | 1.41E-01 | 2.61E-02 | 0.328 |
| | $^{40}K$ | 1.46E+01 | 5.51E+00 | 1.88E+01 | 4.55E+00 | 0.588 |
| WQSP-3 | $^{233/234}U$ | 2.19E-01 | 4.26E-02 | 2.35E-01 | 5.43E-02 | 0.227 |
| | $^{235}U$ | 1.18E-03 | 9.65E-04 | 2.08E-03 | 1.45E-03 | 0.520 |
| | $^{238}U$ | 3.76E-02 | 8.40E-03 | 3.76E-02 | 9.85E-03 | 0.002 |
| | $^{40}K$ | 5.17E+01 | 1.03E+01 | 4.57E+01 | 1.07E+01 | 0.404 |
| WQSP-4 | $^{233/234}U$ | 5.85E-01 | 1.10E-01 | 5.32E-01 | 8.57E-02 | 0.378 |
| | $^{235}U$ | 9.64E-03 | 3.06E-03 | 9.64E-03 | 2.82E-03 | 0.002 |
| | $^{238}U$ | 1.05E-01 | 2.09E-02 | 8.72E-02 | 1.52E-02 | 0.689 |
| | $^{40}K$ | 2.27E+01 | 6.23E+00 | 2.31E-02 | 7.34E-03 | 3.640 |
| WQSP-5 | $^{233/234}U$ | 5.60E-01 | 9.32E-02 | 6.18E-01 | 1.01E-01 | 0.424 |
| | $^{235}U$ | 2.55E-03 | 1.32E-03 | 3.38E-03 | 1.55E-03 | 0.405 |
| | $^{238}U$ | 7.88E-02 | 1.43E-02 | 8.62E-02 | 1.54E-02 | 0.351 |
| | $^{40}K$ | 7.63E+00 | 4.08E+00 | 1.07E+01 | 6.22E+00 | 0.413 |

**Table 4.8 – 2011 Precision Results for Duplicate Groundwater Samples Analyses for Round 32 (Units in Bq/L)**

**See Figure 6.3 for Sampling Locations**

| Location | | Sample | | Duplicate | | |
|---|---|---|---|---|---|---|
| | | [RN][a] | 2 σ TPU[b] | [RN] | 2 σ TPU | RER[c] |
| WQSP-6 | $^{233/234}U$ | 5.12E-01 | 7.08E-02 | 5.73E-01 | 9.30E-02 | 0.516 |
| | $^{235}U$ | 3.73E-03 | 1.47E-03 | 4.49E-03 | 1.78E-03 | 0.329 |
| | $^{238}U$ | 6.99E-02 | 1.08E-02 | 7.62E-02 | 1.36E-02 | 0.363 |

(a) Radionuclide Concentration.
(b) Total Propagated Uncertainty.
(c) Relative Error Ratio.

**Table 4.9 – 2011 Precision Results for Duplicate Groundwater Sample Analyses for Round 33 (Units in Bq/L)**

**See Figure 6.3 for Sampling Locations**

| Location | | Sample | | Duplicate | | |
|---|---|---|---|---|---|---|
| | | [RN][a] | 2 σ TPU[b] | [RN] | 2 σ TPU | RER[c] |
| WQSP-1 | $^{233/234}U$ | 1.34E+00 | 2.18E-01 | 1.22E+00 | 2.99E-01 | 0.323 |
| | $^{235}U$ | 1.58E-02 | 3.90E-03 | 9.06E-03 | 3.01E-03 | 1.374 |
| | $^{238}U$ | 2.27E-01 | 3.80E-02 | 2.10E-01 | 5.20E-02 | 0.265 |
| | $^{40}K$ | 1.53E+01 | 5.57E+00 | 1.63E+01 | 6.99E+00 | 0.112 |
| WQSP-2 | $^{233/234}U$ | 1.29E+00 | 1.92E-01 | 1.37E+00 | 2.39E-01 | 0.254 |
| | $^{235}U$ | 1.26E-02 | 3.24E-03 | 1.58E-02 | 4.14E-03 | 0.613 |
| | $^{238}U$ | 1.98E-01 | 3.07E-02 | 2.09E-01 | 3.77E-02 | 0.220 |
| | $^{40}K$ | 1.68E+01 | 5.58E+00 | 1.67E+01 | 7.23E+00 | 0.011 |
| WQSP-3 | $^{233/234}U$ | 2.53E-01 | 4.16E-02 | 2.64E-01 | 4.52E-02 | 0.184 |
| | $^{235}U$ | 1.95E-03 | 1.15E-03 | 1.82E-03 | 1.11E-03 | 0.082 |
| | $^{238}U$ | 3.49E-02 | 6.90E-03 | 3.43E-02 | 7.00E-03 | 0.061 |
| | $^{40}K$ | 4.56E+01 | 9.68E+00 | 4.49E+01 | 1.04E+01 | 0.049 |
| WQSP-4 | $^{233/234}U$ | 5.32E-01 | 7.96E-02 | 5.55E-01 | 8.12E-02 | 0.203 |
| | $^{235}U$ | 5.63E-03 | 1.96E-03 | 3.59E-03 | 1.49E-03 | 0.830 |
| | $^{238}U$ | 8.77E-02 | 1.43E-02 | 9.18E-02 | 1.46E-02 | 0.201 |
| | $^{40}K$ | 2.27E+01 | 6.43E+00 | 2.31E+01 | 5.09E+00 | 0.049 |
| WQSP-5 | $^{233/234}U$ | 5.87E-01 | 9.25E-02 | 5.61E-01 | 8.60E-02 | 0.202 |
| | $^{235}U$ | 4.30E-03 | 1.74E-03 | 4.79E-03 | 1.82E-03 | 0.193 |
| | $^{238}U$ | 8.02E-02 | 1.39E-02 | 7.30E-02 | 1.24E-02 | 0.386 |
| | $^{40}K$ | 1.11E+01 | 4.31E+00 | 7.13E+00 | 3.11E+00 | 0.747 |
| WQSP-6 | $^{233/234}U$ | 5.47E-01 | 8.31E-02 | 5.69E-01 | 8.89E-02 | 0.181 |
| | $^{235}U$ | 3.42E-03 | 1.50E-03 | 4.50E-03 | 1.75E-03 | 0.472 |
| | $^{238}U$ | 6.80E-02 | 1.16E-02 | 7.37E-02 | 1.27E-02 | 0.330 |

(a) Radionuclide Concentration.
(b) Total Propagated Uncertainty.
(c) Relative Error Ratio.

In theory, the primary and duplicate groundwater samples should have nearly identical concentrations since the sample containers are filled consecutively from continuously flowing water. The RER results show slightly higher RERs for a few of the uranium isotope and $^{40}K$ analysis results in the field duplicates compared to the laboratory duplicates, as indicated by a few RERs for $^{235}U$ and $^{40}K$ >1. The alpha spectroscopy sample preparation requires many different laboratory procedures, and all the steps combined can contribute to some lack of precision. The laboratory re-analyzed some batches of samples because of spectral interferences, and some samples contained relatively weak alpha spectra as evidenced by low tracer recoveries, although the laboratory's QA/QC criteria for tracer recovery were met.

The greater imprecision of a few field duplicates compared to lab duplicates suggests that some imprecision could be associated with actual slight differences in the composition of the samples.

## 4.4 Surface Water

### 4.4.1 Sample Collection

Surface water samples were collected from various locations around the WIPP site as shown in Figure 4.2 (see Appendix C for location codes). If a particular surface water collection location was dry, a sediment sample was collected. Sediment sample analysis results are discussed in section 4.5. Surface water samples were not collected from locations NOY and LST due to lack of water during a very dry 2011.

Water from each sampling location was used to rinse 3.78-L (1-gallon) polyethylene containers at least three times prior to taking the sample. Approximately one gallon of water was collected from each location. The samples were acidified to pH ≤ 2 immediately after collection with concentrated nitric acid. Later, the samples were transferred to WIPP Laboratories for analysis. Chain of custody was maintained throughout the process.

### 4.4.2 Sample Preparation

Surface water sample containers were shaken to distribute suspended material evenly, and sample aliquots were measured into glass beakers. One 0.5-L portion was used for gamma spectroscopy and another 0.5-L portion was used for sequential analysis of the uranium/transuranic isotopes and $^{90}Sr$. Tracers ($^{232}U$, $^{243}Am$, and $^{242}Pu$) and carriers (strontium nitrate and barium nitrate) were added to the second sample portion, and the samples were then digested using concentrated nitric acid and hydrofluoric acid. The samples were heated to dryness and wet-ashed using concentrated nitric acid and hydrogen peroxide. Finally, the samples were heated to dryness again, and the isotopic separation steps were initiated.

### 4.4.3 Determination of Individual Radionuclides

A 0.5-L portion of the acidified water sample was used directly for the gamma spectroscopy measurement of the gamma-emitting radionuclides $^{40}K$, $^{60}Co$, and $^{137}Cs$. The other 0.5-L portion of the water was prepared by co-precipitating the target isotopes and corresponding tracers with an iron carrier, performing ion exchange and chromatographic separations of the individual radionuclides, and micro-precipitating the separated radionuclides onto planchets for counting. The uranium isotopes and transuranics were counted using alpha spectroscopy, and $^{90}Sr$ was beta counted using a gas proportional detector.

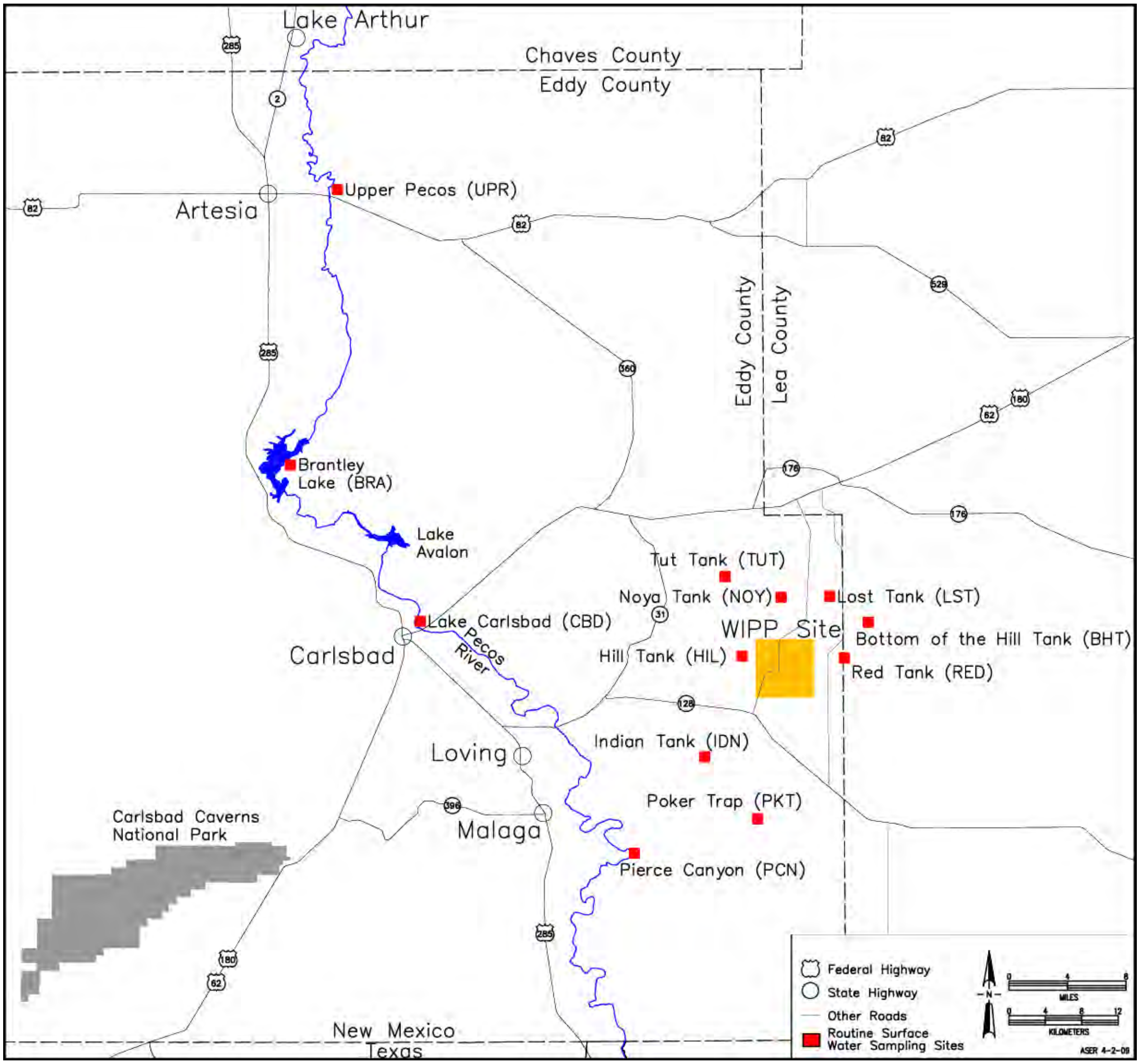



Figure 4.2 – Routine Surface Water Sampling Locations

### 4.4.4 Results and Discussion

Uranium isotopes were detected in most of the surface water samples, which included 12 separate samples, two sets of duplicate samples, and a distilled water field blank (sample location COW). The field blank sample (sample location COW) was submitted to the laboratory as a "blind" QC sample, and sample COY was submitted as a blind duplicate of sample PCN. The uranium isotope analyses resulted in detection of $^{233/234}U$ in all the surface water samples including the COW field blank; detection of $^{235}U$ in TUT, FWT, IDN, PCN and Dup, SWL, CBD, BRA, and UPR; and detection of $^{238}U$ in all the samples including the COW field blank (Table 4.10). The activities in the COW blank were lower than in the samples.

**Table 4.10 – 2011 Uranium Concentrations (Bq/L) in Surface Waters Taken near the WIPP Facility**

**See Figure 4.2 for Sampling Locations**

| Location | [RN][a] | 2 σ TPU[b] | MDC[c] | Qd | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $^{233/234}U$ | | | | $^{235}U$ | | | | $^{238}U$ | | | |
| RED | 7.11E-03 | 2.58E-03 | 1.24E-03 | + | 3.37E-04 | 5.78E-04 | 7.87E-04 | U | 5.05E-03 | 2.08E-03 | 8.58E-04 | + |
| HIL | 6.86E-03 | 2.64E-03 | 1.26E-03 | + | -8.45E-05 | 2.63E-04 | 7.85E-04 | U | 4.62E-03 | 2.06E-03 | 9.42E-04 | + |
| TUT | 6.62E-03 | 2.16E-03 | 1.07E-03 | + | 8.09E-04 | 7.43E-04 | 6.31E-04 | + | 6.19E-03 | 2.07E-03 | 8.53E-04 | + |
| FWT | 3.04E-02 | 6.42E-03 | 1.04E-03 | + | 1.60E-03 | 1.03E-03 | 5.92E-04 | + | 1.20E-02 | 3.14E-03 | 8.21E-04 | + |
| COW | 3.37E-03 | 1.32E-03 | 1.02E-03 | + | -2.80E-05 | 1.23E-04 | 5.63E-04 | U | 3.14E-03 | 1.27E-03 | 7.98E-04 | + |
| PKT | 1.85E-02 | 4.57E-03 | 1.17E-03 | + | 6.39E-04 | 7.02E-04 | 6.76E-04 | U | 8.52E-03 | 2.63E-03 | 8.54E-04 | + |
| PKT Dup | 1.66E-02 | 4.52E-03 | 1.19E-03 | + | 3.31E-04 | 5.25E-04 | 7.02E-04 | U | 7.09E-03 | 2.46E-03 | 8.75E-04 | + |
| IDN | 4.24E-02 | 7.47E-03 | 1.13E-03 | + | 1.42E-03 | 9.13E-04 | 6.47E-04 | + | 3.24E-02 | 6.00E-03 | 7.45E-04 | + |
| PCN | 1.39E-01 | 2.75E-02 | 1.11E-03 | + | 6.65E-03 | 2.50E-03 | 6.74E-04 | + | 6.61E-02 | 1.39E-02 | 8.87E-04 | + |
| COY (PCN Dup) | 1.46E-01 | 2.95E-02 | 1.09E-03 | + | 5.67E-03 | 2.24E-03 | 6.52E-04 | + | 6.54E-02 | 1.39E-02 | 8.69E-04 | + |
| SWL | 4.99E-02 | 1.16E-02 | 1.21E-03 | + | 1.21E-03 | 9.99E-04 | 7.53E-04 | + | 1.82E-02 | 4.94E-03 | 8.31E-04 | + |
| CBD | 7.50E-02 | 1.53E-02 | 1.09E-03 | + | 2.00E-03 | 1.24E-03 | 6.47E-04 | + | 3.45E-02 | 7.69E-03 | 8.66E-04 | + |
| BRA | 9.28E-02 | 3.40E-02 | 1.46E-03 | + | 3.99E-03 | 2.71E-03 | 1.10E-03 | + | 5.06E-02 | 1.92E-02 | 1.23E-03 | + |
| UPR | 6.91E-02 | 1.32E-02 | 1.04E-03 | + | 2.24E-03 | 1.22E-03 | 5.93E-04 | + | 3.21E-02 | 6.77E-03 | 8.22E-04 | + |
| BHT | 8.35E-03 | 2.60E-03 | 1.18E-03 | + | 2.86E-04 | 4.90E-04 | 7.07E-04 | U | 5.80E-03 | 2.05E-03 | 7.94E-04 | + |

(a) Radionuclide Concentration.
(b) Total Propagated Uncertainty.
(c) Minimum Detectable Concentration.
(d) Qualifier. Indicated whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

The concentrations of the uranium isotopes were compared between 2010 and 2011 and also between sampling locations using ANOVA for those locations where the uranium isotopes were detected both years. The average concentrations were used for detections at PKT and UPR in 2010, and PKT and PCN in 2011. In 2010 and 2011, $^{233/234}U$ was detected in 12 common locations, $^{235}U$ was detected in six common locations, and $^{238}U$ was detected in 12 common locations.

There was no significant variation in the concentrations of the uranium isotopes in the surface water between 2010 and 2011 (ANOVA $^{233/234}U$ $p = 0.638$, ANOVA $^{235}U$ $p = 0.335$, and ANOVA $^{238}U$ $p = 0.659$).

There was much greater variability in the concentrations of $^{233/234}U$ and $^{238}U$ between sampling locations with ANOVA $^{233/234}U$ $p = 0.000197$ and ANOVA $^{238}U$ $p = 0.0000504$. The radionuclide $^{235}U$, with lower activities and detection at six common locations between 2010 and 2011, yielded ANOVA $^{235}U$ $p = 0.501$, suggesting much less variability between locations when this isotope is detected. The significant variability in the concentrations between sampling locations likely reflects differences in soil chemistry, as well as differences in rainfall amounts and evaporation rates.

The 2011 uranium isotope surface water concentrations were also compared with the baseline concentrations measured between 1985 and 1989 (DOE/WIPP-92-037).

None of the concentrations detected for $^{233/234}U$, $^{235}U$, and $^{238}U$ in the Pecos River and associated bodies of water, which include locations PCN, CBD, BRA, and UPR, were higher than the 99 percent confidence interval ranges of the measured baseline concentrations (baseline levels: $^{233/234}U$ = 3.30E-01 Bq/L, $^{235}U$ = 1.40E-02 Bq/L, and $^{238}U$ = 1.10E-01 Bq/L).

The highest concentrations of the three uranium isotopes in the surface water samples taken from tanks and tank-like structures (RED, HIL, TUT, FWT, PKT, IDN, BHT) were within the 99 percent confidence interval ranges of baseline concentrations (baseline levels: $^{233/234}U$ = 1.00E-01 Bq/L, $^{235}U$ = 5.20E-03 Bq/L, and $^{238}U$ = 3.20E-02 Bq/L).

The surface water samples were also analyzed for $^{238}Pu$, $^{239/240}Pu$, and $^{241}Am$ (Table 4.11). None of these radionuclides were detected in the surface water samples in 2011. Thus, no ANOVA comparisons between years and among locations could be performed.

**Table 4.11 – 2011 Plutonium and Americium Concentrations (Bq/L) in Surface Waters Taken near the WIPP Facility**

**See Figure 4.2 for Sampling Locations**

| Location | [RN][a] | 2 σ TPU[b] | MDC[c] | Q[d] | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $^{238}Pu$ | | | | $^{239/240}Pu$ | | | | $^{241}Am$ | | | |
| RED | 7.12E-05 | 3.82E-04 | 6.64E-04 | U | 1.67E-04 | 3.26E-04 | 5.51E-04 | U | 8.82E-05 | 3.87E-04 | 8.38E-04 | U |
| HIL | 1.89E-04 | 5.25E-04 | 8.19E-04 | U | 1.01E-04 | 2.70E-04 | 7.13E-04 | U | 4.65E-04 | 1.11E-03 | 1.01E-03 | U |
| TUT | -4.44E-05 | 7.29E-04 | 9.26E-04 | U | 2.17E-04 | 4.62E-04 | 7.61E-04 | U | 5.83E-05 | 7.88E-04 | 9.26E-04 | U |
| FWT | -5.13E-05 | 3.38E-04 | 7.95E-04 | U | 1.43E-04 | 3.53E-04 | 6.65E-04 | U | 3.11E-04 | 5.74E-04 | 8.68E-04 | U |
| COW | 7.80E-04 | 7.93E-04 | 8.48E-04 | U | 2.94E-04 | 4.40E-04 | 6.83E-04 | U | 2.40E-04 | 7.22E-04 | 9.95E-04 | U |
| PKT | 5.47E-05 | 4.67E-04 | 8.20E-04 | U | 2.52E-05 | 3.31E-04 | 7.13E-04 | U | 3.77E-04 | 6.95E-04 | 9.25E-04 | U |
| PKT Dup | 5.48E-04 | 7.64E-04 | 8.94E-04 | U | -1.89E-04 | 3.34E-04 | 7.88E-04 | U | 4.25E-04 | 7.97E-04 | 9.83E-04 | U |
| IDN | 2.13E-04 | 4.87E-04 | 7.02E-04 | U | 4.47E-04 | 4.91E-04 | 5.89E-04 | U | 2.34E-04 | 5.49E-04 | 9.06E-04 | U |
| PCN | 4.89E-04 | 6.43E-04 | 8.42E-04 | U | 9.77E-05 | 2.48E-04 | 6.78E-04 | U | 2.29E-04 | 5.37E-04 | 8.90E-04 | U |
| COY (PCN Dup) | -1.07E-04 | 3.98E-04 | 8.47E-04 | U | 1.87E-04 | 3.65E-04 | 6.83E-04 | U | 5.45E-04 | 7.83E-04 | 9.53E-04 | U |
| SWL | -1.29E-04 | 2.62E-04 | 7.49E-04 | U | 1.01E-04 | 3.05E-04 | 6.36E-04 | U | 2.61E-04 | 5.47E-04 | 9.12E-04 | U |
| CBD | 2.78E-04 | 7.72E-04 | 9.51E-04 | U | -1.15E-04 | 2.65E-04 | 7.87E-04 | U | 2.85E-04 | 5.76E-04 | 9.26E-04 | U |
| BRA | 1.76E-04 | 8.26E-04 | 9.59E-04 | U | 3.10E-04 | 6.34E-04 | 7.95E-04 | U | 1.32E-04 | 3.94E-04 | 8.51E-04 | U |
| UPR | -9.02E-05 | 6.54E-04 | 8.74E-04 | U | 8.59E-05 | 4.61E-04 | 7.09E-04 | U | 5.14E-04 | 9.20E-04 | 1.07E-03 | U |
| BHT | 7.99E-05 | 3.86E-04 | 6.70E-04 | U | 2.51E-04 | 4.11E-04 | 5.57E-04 | U | 4.27E-04 | 5.64E-04 | 8.49E-04 | U |

(a) Radionuclide Concentration.
(b) Total Propagated Uncertainty.
(c) Minimum Detectable Concentration.
(d) Qualifier. Indicated whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

The analysis data for the gamma isotopes and $^{90}Sr$ are presented in Table 4.12. As shown in the table, $^{40}K$ was detected in only one of the surface water samples, SWL. SWL was also the only location where $^{40}K$ was detected in 2009 and 2010, thus, there were not enough data to perform ANOVA comparisons. The activities for $^{40}K$ were greater than the 2 σ TPU and MDC for the PKT duplicate and UPR samples, but the ID Confidence was zero for these two samples, and thus $^{40}K$ was not detected.

**Table 4.12 – 2011 Gamma Radionuclides and 90Sr Concentrations (Bq/L) in Surface Waters Taken near the WIPP Facility**

**See Figure 4.2 for Sampling Location Codes**

| Location | [RN][a] | 2 σ TPU[b] | MDC[c] | Q[d] | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $^{40}$K | | | | $^{60}$Co | | | | $^{137}$Cs | | | |
| RED | 1.59E+00 | 3.24E+00 | 4.12E+00 | U | -1.31E-01 | 3.43E-01 | 3.63E-01 | U | 1.96E-02 | 2.82E-01 | 3.23E-01 | U |
| HIL | 2.21E+00 | 5.11E+00 | 6.58E+00 | U | 6.74E-02 | 5.67E-01 | 6.85E-01 | U | 4.70E-02 | 4.92E-01 | 5.68E-01 | U |
| TUT | 3.62E+00 | 6.03E+00 | 7.79E+00 | U | 1.17E-01 | 5.61E-01 | 6.96E-01 | U | 1.70E-01 | 4.76E-01 | 5.73E-01 | U |
| FWT | 7.47E+00 | 9.05E+00 | 1.15E+01 | U | 3.18E-01 | 9.13E-01 | 1.07E+00 | U | -9.31E-01 | 1.13E+00 | 1.13E+00 | U |
| COW | 3.56E+00 | 3.06E+00 | 4.33E+00 | U | 3.58E-01 | 2.74E-01 | 4.07E-01 | U | -2.63E-01 | 3.68E-01 | 3.58E-01 | U |
| PKT | 3.43E+00 | 9.22E+00 | 1.13E+01 | U | 3.73E-01 | 6.98E-01 | 9.31E-01 | U | -4.41E-01 | 7.60E-01 | 7.90E-01 | U |
| PKT Dup | 1.10E+01 | 5.25E+00 | 8.60E+00 | U | -1.79E-01 | 5.57E-01 | 5.93E-01 | U | 1.87E-01 | 5.22E-01 | 6.17E-01 | U |
| IDN | 3.38E+00 | 3.31E+00 | 4.48E+00 | U | 1.40E-01 | 3.18E-01 | 4.00E-01 | U | 1.00E-01 | 2.84E-01 | 3.36E-01 | U |
| PCN | 1.77E+00 | 3.66E+00 | 4.62E+00 | U | 9.85E-02 | 2.98E-01 | 3.79E-01 | U | -5.67E-03 | 3.10E-01 | 3.42E-01 | U |
| COY (PCN Dup) | -3.33E-01 | 8.66E+00 | 9.61E+00 | U | -2.62E-01 | 7.76E-01 | 8.36E-01 | U | -1.49E-01 | 6.82E-01 | 7.58E-01 | U |
| SWL | 2.35E+02 | 3.57E+01 | 7.46E+00 | + | 4.08E-01 | 9.45E-01 | 1.21E+00 | U | -3.75E-02 | 8.44E-01 | 9.61E-01 | U |
| CBD | 6.39E+00 | 6.87E+00 | 9.70E+00 | U | -4.09E-01 | 7.86E-01 | 8.16E-01 | U | -5.25E-01 | 7.79E-01 | 7.90E-01 | U |
| BRA | 2.23E+00 | 5.29E+00 | 6.80E+00 | U | 3.21E-01 | 5.25E-01 | 7.02E-01 | U | -1.79E-01 | 4.80E-01 | 5.10E-01 | U |
| UPR | 1.61E+01 | 8.31E+00 | 1.17E+01 | U | 2.61E-01 | 9.62E-01 | 1.11E+00 | U | -1.35E+00 | 1.15E+00 | 1.10E+00 | U |
| BHT | -2.44E+00 | 6.04E+00 | 6.31E+00 | U | 3.38E-02 | 5.74E-01 | 6.89E-01 | U | 1.91E-01 | 4.12E-01 | 5.35E-01 | U |
| | $^{90}$Sr | | | | | | | | | | | |
| RED | -1.52E-02 | 2.46E-02 | 2.15E-02 | U | | | | | | | | |
| HIL | 5.00E-03 | 3.51E-02 | 1.71E-02 | U | | | | | | | | |
| TUT | -1.24E-02 | 2.62E-02 | 1.77E-02 | U | | | | | | | | |
| FWT | -1.53E-02 | 2.89E-02 | 1.80E-02 | U | | | | | | | | |
| COW | 7.36E-03 | 2.72E-02 | 1.77E-02 | U | | | | | | | | |
| PKT | -2.02E-02 | 3.28E-02 | 1.69E-02 | U | | | | | | | | |
| PKT Dup | -1.45E-02 | 3.22E-02 | 1.68E-02 | U | | | | | | | | |
| IDN | -4.63E-04 | 2.51E-02 | 2.16E-02 | U | | | | | | | | |
| PCN | 1.82E-03 | 2.54E-02 | 1.76E-02 | U | | | | | | | | |
| COY (PCN Dup) | -7.03E-03 | 2.50E-02 | 1.76E-02 | U | | | | | | | | |
| SWL | -6.90E-03 | 2.87E-02 | 2.22E-02 | U | | | | | | | | |
| CBD | -5.53E-03 | 2.58E-02 | 1.77E-02 | U | | | | | | | | |
| BRA | -2.46E-02 | 2.46E-02 | 1.76E-02 | U | | | | | | | | |
| UPR | -2.14E-02 | 2.72E-02 | 1.78E-02 | U | | | | | | | | |
| BHT | -1.12E-03 | 2.70E-02 | 2.19E-02 | U | | | | | | | | |

(a) Radionuclide Concentration.
(b) Total Propagated Uncertainty.
(c) Minimum Detectable Concentration.
(d) Qualifier. Indicated whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

Comparison of the detected $^{40}$K (2.35E+02 Bq/L) in the SWL sample with the baseline data (baseline value: 7.60E+01 Bq/L) shows that in 2011, as in 2010 and 2009, the concentration was higher than the 99 percent confidence interval range of the baseline concentration (DOE/WIPP-92-037). Since $^{40}$K was not detected in any other surface water sample, sewage is the likely source. Sewage contains significant potassium from human excretions and $^{40}$K makes up 0.012 percent of all naturally occurring potassium.

Cesium-137, $^{60}$Co, and $^{90}$Sr, were not detected in any of the surface water samples (Table 4.12). Since these isotopes were not detected, no ANOVA comparisons between years or among locations were performed.

The reproducibility of the sampling and analysis procedures was assessed by collecting and analyzing duplicate samples from two locations (PKT, PCN). The PKT duplicate was a blind sample labeled "COY." The RERs were calculated for the isotopes with measurable concentrations of the target radionuclides in both the primary and duplicate samples. The RERs for the analysis results are presented in Table 4.13.

**Table 4.13 – 2011 Precision Results for Duplicate Surface Water Sampling and Analysis (Units in Bq/L)**
**See Figure 4.2 for Sampling Locations**

| Location | | Sample | | Duplicate | | |
|---|---|---|---|---|---|---|
| | | [RN][a] | 2 σ TPU[b] | [RN] | 2 σ TPU | RER[c] |
| PKT | $^{233/234}U$ | 1.85E-02 | 4.57E-03 | 1.66E-02 | 4.52E-03 | 0.296 |
| | $^{238}U$ | 8.52E-03 | 2.63E-03 | 7.09E-03 | 2.46E-03 | 0.397 |
| | | | | | | |
| PCN | $^{233/234}U$ | 1.39E-01 | 2.75E-02 | 1.46E-01 | 2.95E-02 | 0.174 |
| | $^{235}U$ | 6.65E-03 | 2.50E-03 | 5.67E-03 | 2.24E-03 | 0.292 |
| | $^{238}U$ | 6.61E-02 | 1.39E-02 | 6.54E-02 | 1.39E-02 | 0.036 |

(a) Radionuclide Concentration.
(b) Total Propagated Uncertainty.
(c) Relative Error Ratio.

The RERs for $^{233/234}U$ and $^{238}U$ were <1 in the PKT duplicates. The RERs for $^{233/234}U$, $^{235}U$, and $^{238}U$ were all <1 for the PCN duplicates. The analysis data demonstrate good reproducibility for the combined sampling and analysis procedures.

## 4.5 Sediments

### 4.5.1 Sample Collection

Sediment samples were collected from 12 locations around the WIPP site, with duplicate samples collected from two sites (14 samples total). The sites included all the same sites as for surface water, but with the addition of locations NOY and LST and deletion of locations FWT and SWL. Neither of the duplicate samples was blind and there was no COW field blank (see Figure 4.3; see Appendix C for location codes). The samples were collected in 1-L plastic containers from the top 15 cm (6 in.) of the sediments of the water bodies and transferred to WIPP Laboratories for determination of individual radionuclides.

### 4.5.2 Sample Preparation

Sediment samples were dried at 110°C (230°F) for several hours and homogenized by grinding into smaller particle sizes. Tracers and carriers were added to a 2-gram aliquot of each of the dried and homogenized sediment samples, which were subsequently dissolved by heating with a mixture of nitric, hydrochloric, and hydrofluoric acids. The sample residues were heated with nitric and boric acids to remove hydrofluoric acid. Finally, the residues were dissolved in hydrochloric acid in preparation for separation of the radionuclides.

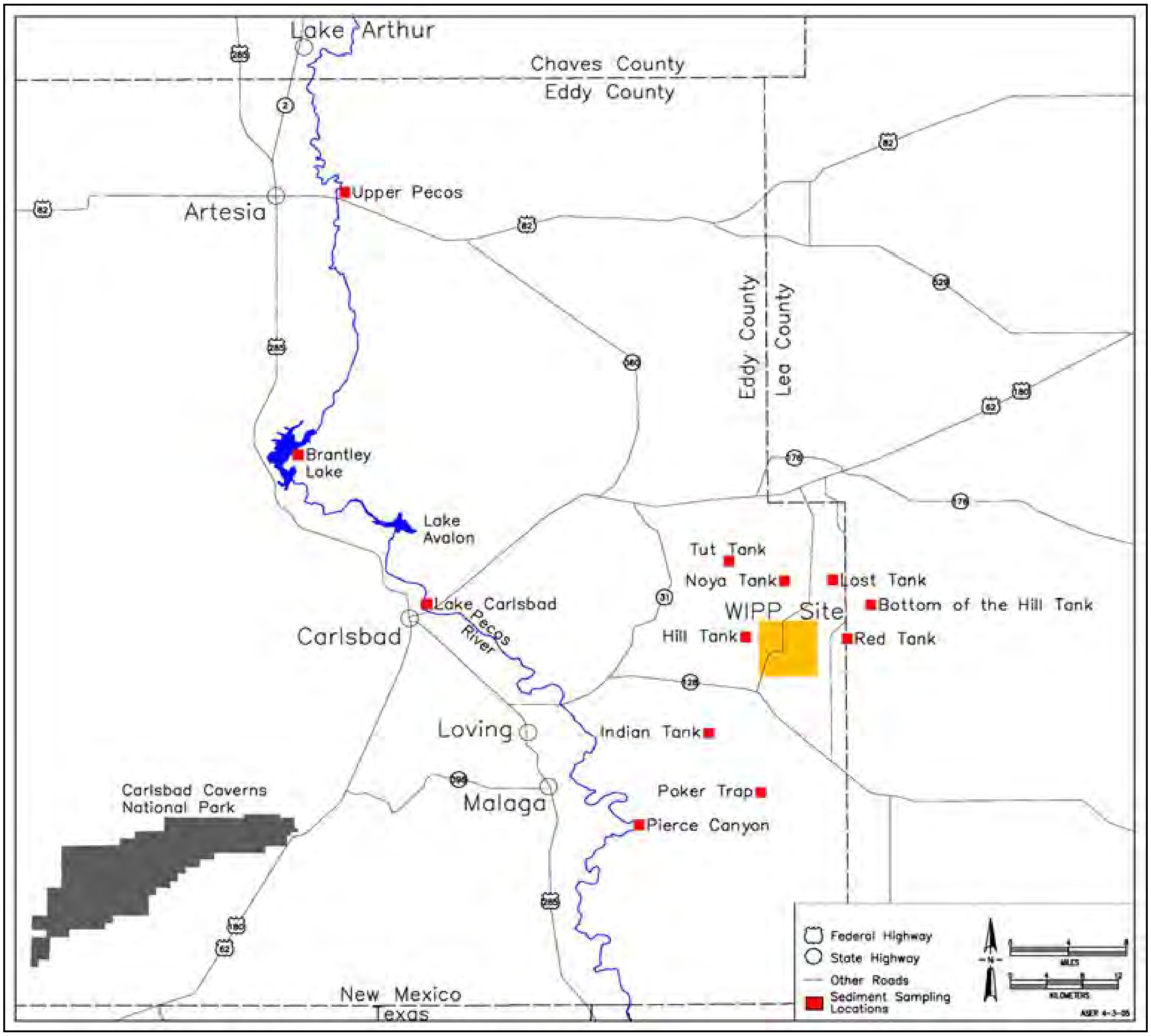



Figure 4.3 – Sediment Sampling Sites

### 4.5.3 Determination of Individual Radionuclides

The hydrochloric acid digestates of the sediment samples were split into two fractions. One fraction was analyzed by gamma spectroscopy for $^{40}K$, $^{60}Co$, and $^{137}Cs$. The other was analyzed sequentially for the uranium/transuranic radioisotopes and $^{90}Sr$ by employing a series of chemical, physical, and ion exchange separations, followed by mounting the sample residues on planchets for counting. The uranium/transuranic isotopes were measured by alpha spectroscopy and the $^{90}Sr$ by gas proportional counting.

### 4.5.4 Results and Discussion

Uranium-233/234 and $^{238}U$ were detected in all the sediment samples. Uranium-235 was detected in all the sediment samples except RED and the primary PKT sample, as shown in Table 4.14.

**Table 4.14 – 2011 Uranium Concentrations (Bq/g) in Sediment Samples Taken near the WIPP Facility**

**See Figure 4.3 for Sampling Location Codes**

| Location | [RN][a] | 2 σ TPU[b] | MDC[c] | Qd | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $^{233/234}U$ | | | | $^{235}U$ | | | | $^{238}U$ | | | |
| RED | 7.99E-03 | 1.76E-03 | 8.76E-04 | + | 1.53E-04 | 1.62E-04 | 2.82E-04 | U | 7.77E-03 | 1.72E-03 | 5.93E-04 | + |
| NOY | 9.53E-03 | 1.75E-03 | 8.67E-04 | + | 3.82E-04 | 2.43E-04 | 2.70E-04 | + | 1.05E-02 | 1.90E-03 | 5.84E-04 | + |
| HIL | 1.05E-02 | 2.11E-03 | 8.78E-04 | + | 3.46E-04 | 2.53E-04 | 2.83E-04 | + | 1.08E-02 | 2.18E-03 | 5.95E-04 | + |
| TUT | 2.75E-02 | 5.20E-03 | 8.05E-04 | + | 1.55E-03 | 5.77E-04 | 2.98E-04 | + | 2.98E-02 | 5.60E-03 | 5.84E-04 | + |
| PKT | 5.26E-03 | 1.02E-03 | 8.61E-04 | + | 2.60E-04 | 1.88E-04 | 2.63E-04 | U | 5.56E-03 | 1.06E-03 | 5.78E-04 | + |
| PKT Dup | 1.02E-02 | 1.87E-03 | 8.62E-04 | + | 3.90E-04 | 2.38E-04 | 2.64E-04 | + | 9.29E-03 | 1.73E-03 | 5.79E-04 | + |
| IDN | 1.31E-02 | 2.20E-03 | 8.62E-04 | + | 3.96E-04 | 2.36E-04 | 2.64E-04 | + | 1.12E-02 | 1.92E-03 | 5.79E-04 | + |
| PCN | 2.96E-02 | 5.78E-03 | 8.00E-04 | + | 8.00E-04 | 3.86E-04 | 2.93E-04 | + | 2.26E-02 | 4.50E-03 | 5.80E-04 | + |
| PCN Dup | 3.14E-02 | 5.76E-03 | 8.06E-04 | + | 1.07E-03 | 4.59E-04 | 2.99E-04 | + | 2.56E-02 | 4.76E-03 | 5.85E-04 | + |
| CBD | 1.77E-02 | 3.84E-03 | 8.17E-04 | + | 6.09E-04 | 3.65E-04 | 3.14E-04 | + | 1.54E-02 | 3.38E-03 | 5.96E-04 | + |
| BRA | 2.60E-02 | 4.45E-03 | 7.88E-04 | + | 1.11E-03 | 4.27E-04 | 2.78E-04 | + | 2.81E-02 | 4.77E-03 | 5.68E-04 | + |
| UPR | 2.19E-02 | 5.15E-03 | 8.22E-04 | + | 1.10E-03 | 5.24E-04 | 3.20E-04 | + | 2.29E-02 | 5.36E-03 | 6.01E-04 | + |
| LST | 5.64E-03 | 1.09E-03 | 8.57E-04 | + | 2.14E-04 | 1.68E-04 | 2.58E-04 | + | 5.60E-03 | 1.08E-03 | 5.74E-04 | + |
| BHT | 8.69E-03 | 1.63E-03 | 8.65E-04 | + | 5.47E-04 | 2.86E-04 | 2.67E-04 | + | 8.07E-03 | 1.53E-03 | 5.82E-04 | + |

(a) Radionuclide Concentration.
(b) Total Propagated Uncertainty.
(c) Minimum Detectable Concentration.
(d) Qualifier. Indicated whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

Using ANOVA, the concentrations of the uranium isotopes were compared between 2010 and 2011, and between sampling locations. Average concentrations were used for PKT and UPR in 2010, and PKT and PCN in 2011 except that the 2011 PKT Dup concentration was used for $^{235}U$. There were 12 common locations for $^{233/234}U$ and $^{238}U$ with detections in both 2010 and 2011, and seven common locations where $^{235}U$ was detected in 2010 and 2011 (NOY, HIL, PKT, IDN, PCN, LST, and BHT).

The ANOVA calculations showed that the concentrations of $^{233/234}U$ and $^{238}U$ did not vary significantly between 2010 and 2011 (ANOVA $^{233/234}U$ $p = 0.933$, and ANOVA $^{238}U$ $p = 0.840$) based on 12 common locations. In contrast to $^{233/234}U$ and $^{238}U$, $^{235}U$ showed more of a variation between 2010 and 2011 with ANOVA $^{235}U$ $p = 0.0836$, just above the significance level of 0.05.

The ANOVA calculations showed that the concentrations of all three of the uranium isotopes did not vary significantly between sediment locations (ANOVA $^{233/234}U$ $p = 0.982$, ANOVA $^{235}U$ $p = 0.885$, and ANOVA $^{238}U$ $p = 0.956$).

The uranium isotope composition of the sediments may not have been impacted as much as in recent years due to much less rainfall to wash away and deposit sediments.

Concentrations of all three uranium isotopes fell within the 99 percent confidence interval ranges of the baseline data ($^{233/234}U$: 1.10E-01 Bq/g; $^{235}U$: 3.20E-03 Bq/g; $^{238}U$: 5.00E-02 Bq/g).

Sediment samples were also analyzed for $^{238}Pu$, $^{239/240}Pu$, and $^{241}Am$, by alpha spectroscopy, with the results reported in Table 4.15. In contrast to previous years, there were no detections for any of the three radionuclides in the sediment samples.

**Table 4.15 – 2011 Plutonium and Americium Concentrations (Bq/g) in Sediment Samples Taken near the WIPP Facility**

**See Figure 4.3 for Sampling Locations**

| Location | [RN][a] | 2 σ TPU[b] | MDC[c] | Q[d] | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $^{238}$Pu | | | | $^{239/240}$Pu | | | | $^{241}$Am | | | |
| RED | 2.50E-05 | 1.21E-04 | 6.32E-04 | U | -1.93E-05 | 5.03E-05 | 5.04E-04 | U | 8.78E-05 | 1.73E-04 | 6.61E-04 | U |
| NOY | -3.41E-05 | 5.79E-05 | 6.09E-04 | U | 1.48E-04 | 1.25E-04 | 4.81E-04 | U | 2.06E-04 | 1.94E-04 | 6.36E-04 | U |
| HIL | 8.85E-05 | 1.26E-04 | 6.08E-04 | U | 1.62E-04 | 1.36E-04 | 4.80E-04 | U | 2.79E-04 | 2.31E-04 | 6.40E-04 | U |
| TUT | 4.28E-05 | 1.07E-04 | 5.89E-04 | U | 1.14E-04 | 1.22E-04 | 4.38E-04 | U | 9.07E-05 | 2.69E-04 | 6.78E-04 | U |
| PKT | -9.93E-06 | 7.54E-05 | 6.07E-04 | U | 1.24E-05 | 5.96E-05 | 4.79E-04 | U | 4.82E-05 | 1.16E-04 | 6.40E-04 | U |
| PKT Dup | 1.05E-04 | 1.55E-04 | 6.23E-04 | U | 2.06E-04 | 1.63E-04 | 4.95E-04 | U | 2.14E-05 | 1.29E-04 | 6.39E-04 | U |
| IDN | -9.46E-06 | 7.77E-05 | 6.09E-04 | U | 1.37E-04 | 1.30E-04 | 4.82E-04 | U | 1.73E-04 | 2.44E-04 | 6.93E-04 | U |
| PCN | 2.99E-05 | 1.19E-04 | 6.11E-04 | U | 5.74E-05 | 1.03E-04 | 4.60E-04 | U | 2.04E-04 | 2.01E-04 | 6.27E-04 | U |
| PCN Dup | 5.18E-05 | 1.44E-04 | 6.11E-04 | U | 1.41E-04 | 1.64E-04 | 4.60E-04 | U | 1.43E-04 | 1.75E-04 | 6.29E-04 | U |
| CBD | -2.92E-05 | 1.71E-04 | 6.66E-04 | U | -6.39E-05 | 1.16E-04 | 5.15E-04 | U | 1.67E-04 | 3.14E-04 | 6.64E-04 | U |
| BRA | -6.01E-06 | 7.55E-05 | 5.88E-04 | U | -7.73E-06 | 2.77E-05 | 4.36E-04 | U | 1.17E-04 | 2.17E-04 | 6.58E-04 | U |
| UPR | -4.17E-05 | 8.31E-05 | 6.35E-04 | U | -1.00E-05 | 4.08E-05 | 4.83E-04 | U | 1.04E-04 | 2.03E-04 | 6.49E-04 | U |
| LST | -3.15E-05 | 1.07E-04 | 6.25E-04 | U | -3.50E-06 | 2.06E-05 | 4.97E-04 | U | 2.91E-04 | 2.27E-04 | 6.40E-04 | U |
| BHT | 4.90E-05 | 1.26E-04 | 6.23E-04 | U | 1.92E-04 | 1.67E-04 | 4.95E-04 | U | 4.64E-05 | 1.41E-04 | 6.57E-04 | U |

(a) Radionuclide Concentration.
(b) Total Propagated Uncertainty.
(c) Minimum Detectable Concentration.
(d) Qualifier. Indicates whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

The sediment analysis results for the gamma radionuclides and $^{90}$Sr are shown in Table 4.16. The gamma radionuclide $^{40}$K was detected in all the sediment samples, and $^{137}$Cs was detected in most of the sediment samples. $^{137}$Cs was not detected in the samples TUT, PCN, CBD, BRA, UPR and BHT. Cobalt-60 and $^{90}$Sr were not detected in any of the sediment samples.

**Table 4.16 – 2011 Gamma Radionuclides and 90Sr Concentrations (Bq/g) in Sediment Samples Taken near the WIPP Facility**

**See Figure 4.3 for Sampling Locations**

| Location | [RN][a] | 2 σ TPU[b] | MDC[c] | Q[d] | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $^{40}$K | | | | $^{60}$Co | | | | $^{137}$Cs | | | |
| RED | 3.95E-01 | 6.36E-02 | 1.69E-02 | + | -7.24E-04 | 1.88E-03 | 2.05E-03 | U | 1.75E-03 | 9.78E-04 | 1.40E-03 | + |
| NOY | 8.97E-01 | 1.28E-01 | 1.30E-02 | + | 3.59E-04 | 1.11E-03 | 1.24E-03 | U | 2.16E-03 | 7.29E-04 | 9.67E-04 | + |
| HIL | 9.98E-01 | 1.59E-01 | 1.57E-02 | + | 2.42E-05 | 1.91E-03 | 2.21E-03 | U | 6.28E-03 | 1.76E-03 | 2.04E-03 | + |
| TUT | 8.54E-01 | 1.38E-01 | 1.64E-02 | + | 7.25E-05 | 1.99E-03 | 2.30E-03 | U | 1.20E-03 | 1.07E-03 | 1.67E-03 | U |
| PKT | 5.82E-01 | 9.50E-02 | 1.81E-02 | + | 1.19E-03 | 1.43E-03 | 1.84E-03 | U | 5.97E-03 | 1.53E-03 | 1.66E-03 | + |
| PKT Dup | 6.55E-01 | 9.38E-02 | 1.32E-02 | + | -1.50E-04 | 1.10E-03 | 1.20E-03 | U | 6.13E-03 | 1.14E-03 | 9.69E-04 | + |
| IDN | 6.48E-01 | 9.52E-02 | 1.19E-02 | + | 6.71E-05 | 1.16E-03 | 1.38E-03 | U | 4.61E-03 | 1.03E-03 | 1.01E-03 | + |
| PCN | 3.94E-01 | 6.55E-02 | 1.17E-02 | + | 1.04E-04 | 1.26E-03 | 1.48E-03 | U | 1.42E-03 | 1.23E-03 | 1.92E-03 | U |
| PCN Dup | 4.45E-01 | 6.43E-02 | 9.28E-03 | + | -5.15E-04 | 1.00E-03 | 1.04E-03 | U | 1.37E-03 | 4.18E-04 | 6.25E-04 | + |
| CBD | 2.12E-01 | 3.63E-02 | 9.88E-03 | + | 4.30E-04 | 8.97E-04 | 1.11E-03 | U | 7.85E-05 | 9.68E-04 | 1.09E-03 | U |
| BRA | 6.10E-01 | 8.72E-02 | 9.32E-03 | + | 2.60E-04 | 9.87E-04 | 1.11E-03 | U | 2.11E-04 | 1.02E-03 | 1.12E-03 | U |
| UPR | 2.54E-01 | 3.82E-02 | 7.13E-03 | + | 2.89E-05 | 7.28E-04 | 8.54E-04 | U | 2.89E-04 | 1.68E-04 | 3.80E-04 | U |
| LST | 4.42E-01 | 6.95E-02 | 6.94E-03 | + | 2.23E-04 | 8.15E-04 | 9.82E-04 | U | 1.61E-03 | 7.19E-04 | 1.00E-03 | + |
| BHT | 2.83E-01 | 4.86E-02 | 1.36E-02 | + | 1.78E-04 | 1.40E-03 | 1.65E-03 | U | 1.28E-03 | 1.45E-03 | 1.74E-03 | U |
| | $^{90}$Sr | | | | | | | | | | | |
| RED | -1.16E-03 | 6.38E-03 | 1.50E-02 | U | | | | | | | | |

**Table 4.16 – 2011 Gamma Radionuclides and 90Sr Concentrations (Bq/g) in Sediment Samples Taken near the WIPP Facility**

**See Figure 4.3 for Sampling Locations**

| Location | [RN][a] | 2 σ TPU[b] | MDC[c] | Q[d] | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NOY | -3.38E-03 | 6.62E-03 | 1.50E-02 | U | | | | | | | | |
| HIL | 4.13E-03 | 7.07E-03 | 1.51E-02 | U | | | | | | | | |
| TUT | -2.45E-03 | 1.26E-02 | 1.69E-02 | U | | | | | | | | |
| PKT | -1.99E-03 | 6.70E-03 | 1.50E-02 | U | | | | | | | | |
| PKT Dup | -3.08E-03 | 6.42E-03 | 1.50E-02 | U | | | | | | | | |
| IDN | 3.41E-04 | 6.63E-03 | 1.50E-02 | U | | | | | | | | |
| PCN | 5.65E-03 | 1.34E-02 | 1.70E-02 | U | | | | | | | | |
| PCN Dup | 8.86E-04 | 1.26E-02 | 1.69E-02 | U | | | | | | | | |
| CBD | 2.32E-04 | 1.25E-02 | 1.69E-02 | U | | | | | | | | |
| BRA | -1.02E-03 | 1.21E-02 | 1.69E-02 | U | | | | | | | | |
| UPR | 1.13E-02 | 1.23E-02 | 1.68E-02 | U | | | | | | | | |
| LST | 1.61E-03 | 6.99E-03 | 1.50E-02 | U | | | | | | | | |
| BHT | -3.58E-03 | 6.30E-03 | 1.50E-02 | U | | | | | | | | |

(a) Radionuclide Concentration.
(b) Total Propagated Uncertainty.
(c) Minimum Detectable Concentration.
(d) Qualifier. Indicates whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

All detected concentrations of $^{40}$K observed in the sediment samples associated with the tanks and tank-like structures (BHT, HIL, RED, IDN, LST, NOY, and TUT) were within the 99 percent confidence interval range of baseline concentrations (baseline concentration: 1.20E+00 Bq/g).

The sediment locations associated with the Pecos River and associated bodies of water (PCN, CBD, BRA, and UPR) have a $^{40}$K baseline concentration of 4.00E-01 Bq/g. The 2011 average $^{40}$K concentration at PCN and the BRA concentration exceeded the baseline concentration for sediments, with concentrations of 4.20E-01 Bq/g and 6.10E-01 Bq/g, respectively. Potassium is ubiquitous throughout the earth's crust, with variable concentrations in rocks, soil, and water, and therefore would be expected to be present at variable concentrations in the sediment samples.

The ANOVA calculations showed that the sediment concentrations of $^{40}$K varied significantly between years (ANOVA $^{40}$K p = 0.00693). However, the $^{40}$K concentrations did not vary significantly by location (ANOVA $^{40}$K p = 0.933). These p values show the opposite trend from 2010, with lower concentrations of $^{40}$K in 2011 in the sediments associated with tanks and tank-like structures, but with more similar concentrations from location to location.

In comparing the 2010 data with the 2011 data, $^{137}$Cs was detected in six common locations, RED, NOY, HIL, PKT, IDN, and LST, all which are tanks and tank-like structures.

For $^{137}$Cs, there was no significant difference in the concentrations between 2010 and 2011 (ANOVA $^{137}$Cs p = 0.242). There was more variability in the concentrations by location with ANOVA $^{137}$Cs p = 0.0524, just above the 0.05 significance point.

All the measured $^{137}$Cs concentrations in the sediments associated with tanks and tank-like structures (RED, NOY, HIL, PKT, IDN, and LST) were within the 99 percent confidence interval range of the baseline concentration (3.50E-02 Bq/g). Cesium-137 is a fission product and is consistently found in sediment and soil because of global fallout from atmospheric nuclear weapons testing (Beck and Bennett, 2002; UNSCEAR [United Nations Scientific Committee on the Effects of Atomic Radiation], 2000). Thus, it is not being added to sediments in the same manner as $^{40}$K, which is abundant in rocks and soils.

Because $^{90}$Sr and $^{60}$Co were not detected in any of the sediment samples (see Table 4.16), no ANOVA among sampling locations or between years could be calculated.

Duplicate analyses were performed for all the target radionuclides in sediment samples from sampling locations PKT and PCN. Precision calculations were performed for the uranium isotopes $^{40}$K and $^{137}$Cs, as shown in Table 4.17. Relative error ratios are reported for the isotopes with measurable concentrations in both the primary and the duplicate samples.

All but two of the RERs in Table 4.17 were <1.0. The RER for $^{233/234}$U in the PKT duplicates was >1.96 at 2.32 due to significant differences in the activities of the two samples. The RER for $^{238}$U was >1, but <1.96 at 1.84 in the PKT duplicates.

**Table 4.17 – 2011 Precision Results for Duplicate Sediment Sampling and Analysis (Units in Bq/g)**

**See Figure 4.3 for Sampling Locations**

| Location | Isotope | Sample | | Duplicate | | |
|---|---|---|---|---|---|---|
| | | [RN][a] | 2 σ TPU[b] | [RN] | 2 σ TPU | RER[c] |
| PKT | 233/234U | 5.26E-03 | 1.02E-03 | 1.02E-02 | 1.87E-03 | 2.319 |
| | 235U | 2.60E-04 | 1.88E-04 | 3.90E-04 | 2.38E-04 | 0.429 |
| | 238U | 5.56E-03 | 1.06E-03 | 9.29E-03 | 1.73E-03 | 1.838 |
| | 40K | 5.82E-01 | 9.50E-02 | 6.55E-01 | 9.38E-02 | 0.547 |
| | 137Cs | 5.97E-03 | 1.53E-03 | 6.13E-03 | 1.14E-03 | 0.084 |
| PCN | 233/234U | 2.96E-02 | 5.78E-03 | 3.14E-02 | 5.76E-03 | 0.221 |
| | 235U | 8.00E-04 | 3.86E-04 | 1.07E-03 | 4.59E-04 | 0.450 |
| | 238U | 2.26E-02 | 4.50E-03 | 2.56E-02 | 4.76E-03 | 0.458 |
| | 40K | 3.94E-01 | 6.55E-02 | 4.45E-01 | 6.43E-02 | 0.556 |
| | 137Cs | 1.42E-03 | 1.23E-03 | 1.37E-03 | 4.18E-04 | 0.038 |

(a) Radionuclide Concentration.
(b) Total Propagated Uncertainty.
(c) Relative Error Ratio.

## 4.6 Soil Samples

### 4.6.1 Sample Collection

Soil samples were collected from the six locations where the low-volume air samplers are stationed around the WIPP site: WFF, WEE, WSS, MLR, SEC, and SMR (Figure 4.4). Samples were collected from each location in three incremental profiles: surface soil (0-2 cm [0-0.8 in.]), intermediate soil (2-5 cm [0.8-2 in.]), and deep soil

(5-10 cm [2-4 in.]). Measurements of radionuclides in depth profiles may provide information about their vertical movements in the soil systems.

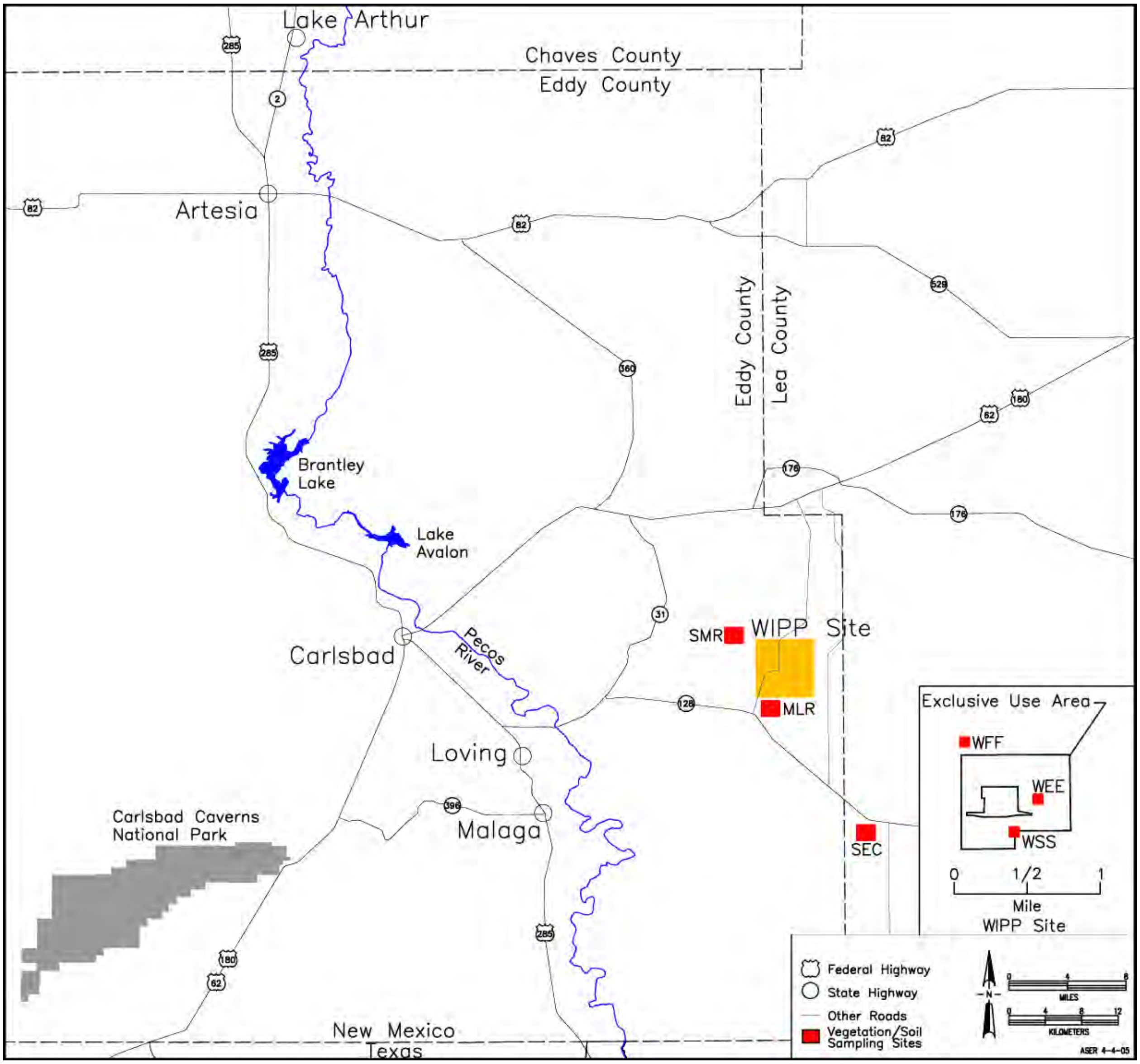



Figure 4.4 – Routine Soil and Vegetation Sampling Areas

### 4.6.2 Sample Preparation

Soil samples were dried at 110°C (230°F) for several hours and homogenized by grinding to small particles. Tracers and carriers were added to a 2-g aliquot of each of the dried and homogenized soil samples, which were subsequently dissolved by heating with a mixture of nitric, hydrochloric, and hydrofluoric acids. The sample residues were heated with nitric and boric acids to remove hydrofluoric acid. Finally, the residues were dissolved in nitric acid for the measurement of the individual radionuclide concentrations.

### 4.6.3 Determination of Individual Radionuclides

The nitric acid digestates of the soil samples were split into two fractions. One fraction was analyzed by gamma spectroscopy for $^{40}$K, $^{60}$Co, and $^{137}$Cs. The other was analyzed sequentially for the uranium/transuranic radioisotopes and $^{90}$Sr by employing a series of chemical, physical, and ion exchange separations, then mounting the sample residues on a planchet for counting. The uranium/transuranic isotopes were measured by alpha spectroscopy and the $^{90}$Sr by gas proportional counting.

### 4.6.4 Results and Discussion

As shown in Table 4.18, $^{233/234}$U and $^{238}$U were detected in all soil samples, and $^{235}$U was detected in about half of the samples. Uranium-235 was detected in all the SMR samples, which were collected and analyzed in duplicate. In 2010, $^{235}$U was detected in the shallow sample at SMR, but not in the intermediate and deep samples.

In comparing the 2010 and 2011 uranium data, the average of the primary and duplicate samples was used for sample locations where duplicate samples were taken, and the uranium isotopes were detected in both samples. There were only four common locations where $^{235}$U was detected in both 2010 and 2011: the 2-5 cm depth at WFF, the 2-5 cm depth at WEE, the 5-10 cm depth at WEE, and the 0-2 cm depth at SMR. All locations and all depths were common for $^{233/234}$U and $^{238}$U in 2010 and 2011.

The general trend for these samples was no significant difference in concentrations between years for $^{233/234}$U and $^{238}$U (ANOVA $^{233/234}$U $p = 0.911$ and ANOVA $^{238}$U $p = 0.987$), but a significant difference by year for $^{235}$U (ANOVA $^{235}$U $p = 0.020$). The 2011 concentrations were lower than the 2010 concentrations; however, this was based on only the four data points. The concentrations between locations were not significantly different for the three uranium isotopes (ANOVA $^{233/234}$U $p = 0.993$, ANOVA $^{235}$U $p = 0.852$, and ANOVA $^{238}$U $p = 0.991$).

The highest concentrations of $^{233/234}$U measured in 2011 (1.40 E-02 Bq/g at the 0-2 cm depth of the primary SMR sample) fell within the 99 percent confidence interval range of the baseline concentration (baseline = 2.20E-02 Bq/g). The highest concentration of $^{235}$U at 7.00E-04 Bq/g (0-2 cm in the primary SMR sample) fell within the 99 percent confidence interval of 1.70E-03 Bq/g. The highest concentration of $^{238}$U at 1.42E-02 Bq/g (0-2 cm at the primary SMR sample) was slightly higher than the $^{238}$U baseline concentration of 1.30E-02 Bq/g (DOE/WIPP-92-037).

**Table 4.18 – 2011 Uranium Concentrations (Bq/g) in Soil Samples Taken near the WIPP Facility**

**See Figure 4.4 for Sampling Locations**

| Location | Depth (cm) | [RN][a] | 2 σ TPU[b] | MDC[c] | Q[d] | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $^{233/234}U$ | | | | $^{235}U$ | | | | $^{238}U$ | | | |
| WFF | 0-2 | 5.66E-03 | 1.37E-03 | 8.41E-04 | + | 1.60E-04 | 1.70E-04 | 3.56E-04 | U | 5.95E-03 | 1.43E-03 | 5.33E-04 | + |
| WFF | 2-5 | 5.57E-03 | 1.17E-03 | 8.31E-04 | + | 4.01E-04 | 2.50E-04 | 3.43E-04 | + | 5.43E-03 | 1.14E-03 | 5.23E-04 | + |
| WFF | 5-10 | 6.10E-03 | 1.35E-03 | 8.31E-04 | + | 2.16E-04 | 1.84E-04 | 3.43E-04 | U | 5.87E-03 | 1.31E-03 | 5.23E-04 | + |
| WEE | 0-2 | 7.21E-03 | 1.48E-03 | 8.32E-04 | + | 2.03E-04 | 1.91E-04 | 3.44E-04 | U | 6.86E-03 | 1.42E-03 | 5.24E-04 | + |
| WEE | 2-5 | 8.72E-03 | 2.07E-03 | 8.50E-04 | + | 5.37E-04 | 3.32E-04 | 3.67E-04 | + | 7.83E-03 | 1.89E-03 | 5.42E-04 | + |
| WEE | 5-10 | 6.52E-03 | 1.35E-03 | 8.36E-04 | + | 3.50E-04 | 2.40E-04 | 3.50E-04 | + | 6.05E-03 | 1.28E-03 | 5.28E-04 | + |
| WSS | 0-2 | 2.40E-03 | 6.36E-04 | 8.87E-04 | + | 5.99E-05 | 1.08E-04 | 3.38E-04 | U | 2.60E-03 | 6.69E-04 | 5.60E-04 | + |
| WSS | 2-5 | 2.31E-03 | 6.44E-04 | 8.90E-04 | + | 2.24E-05 | 8.67E-05 | 3.41E-04 | U | 2.21E-03 | 6.24E-04 | 5.63E-04 | + |
| WSS | 5-10 | 2.43E-03 | 6.86E-04 | 8.94E-04 | + | 1.05E-04 | 1.39E-04 | 3.45E-04 | U | 2.27E-03 | 6.53E-04 | 5.66E-04 | + |
| MLR | 0-2 | 3.45E-03 | 9.09E-04 | 9.01E-04 | + | 1.15E-04 | 1.52E-04 | 3.55E-04 | U | 3.26E-03 | 8.73E-04 | 5.74E-04 | + |
| MLR | 2-5 | 4.48E-03 | 1.21E-03 | 9.08E-04 | + | 1.62E-04 | 1.90E-04 | 3.63E-04 | U | 3.27E-03 | 9.48E-04 | 5.80E-04 | + |
| MLR | 5-10 | 3.88E-03 | 9.13E-04 | 8.91E-04 | + | 1.76E-04 | 1.73E-04 | 3.42E-04 | U | 4.03E-03 | 9.35E-04 | 5.64E-04 | + |
| SEC | 0-2 | 6.33E-03 | 1.32E-03 | 8.74E-04 | + | 3.54E-04 | 2.46E-04 | 3.43E-04 | + | 6.71E-03 | 1.38E-03 | 5.76E-04 | + |
| SEC | 2-5 | 8.96E-03 | 1.88E-03 | 8.84E-04 | + | 1.94E-04 | 1.93E-04 | 3.55E-04 | U | 8.06E-03 | 1.72E-03 | 5.85E-04 | + |
| SEC | 5-10 | 6.58E-03 | 1.49E-03 | 8.81E-04 | + | 3.16E-04 | 2.35E-04 | 3.51E-04 | U | 6.40E-03 | 1.45E-03 | 5.82E-04 | + |
| SMR | 0-2 | 1.40E-02 | 2.59E-03 | 8.74E-04 | + | 7.00E-04 | 3.41E-04 | 3.43E-04 | + | 1.42E-02 | 2.63E-03 | 5.76E-04 | + |
| SMR | 2-5 | 9.30E-03 | 1.84E-03 | 8.70E-04 | + | 4.94E-04 | 2.76E-04 | 3.38E-04 | + | 9.93E-03 | 1.94E-03 | 5.72E-04 | + |
| SMR | 5-10 | 1.02E-02 | 1.85E-03 | 8.72E-04 | + | 4.34E-04 | 2.58E-04 | 3.40E-04 | + | 9.91E-03 | 1.81E-03 | 5.74E-04 | + |
| SMR Dup | 0-2 | 1.19E-02 | 2.17E-03 | 8.67E-04 | + | 3.97E-04 | 2.44E-04 | 3.34E-04 | + | 1.32E-02 | 2.37E-03 | 5.69E-04 | + |
| SMR Dup | 2-5 | 1.31E-02 | 2.19E-03 | 8.65E-04 | + | 6.92E-04 | 3.16E-04 | 3.32E-04 | + | 1.30E-02 | 2.16E-03 | 5.67E-04 | + |
| SMR Dup | 5-10 | 1.14E-02 | 1.98E-03 | 8.64E-04 | + | 5.50E-04 | 2.81E-04 | 3.31E-04 | + | 1.13E-02 | 1.97E-03 | 5.66E-04 | + |

(a) Radionuclide Concentration.

(b) Total Propagated Uncertainty.

(c) Minimum Detectable Concentration.

(d) Qualifier. Indicates whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

The 2011 $^{238}$U isotope concentrations were lower than the range of natural concentrations of uranium found in soils throughout the world. The average concentration of $^{238}$U in the earth's soil (upper crust) is 3.60E-02 Bq/g (National Council on Radiation Protection & Measurements [NCRP] Report No. 94, 1987). The distribution of uranium isotopes in the WIPP samples in 2011 agrees with natural uranium isotope distributions in soils throughout the world, and none of the radioisotopes in the TRU waste material that would be expected to be released were detected in concentrations in excess of baseline quantities. These two facts suggest that soil concentrations follow a pattern of variability consistent with the existence of natural uranium.

All the soil samples shown in Table 4.19 were analyzed for $^{238}$Pu, $^{239/240}$Pu, and $^{241}$Am; none was detected. Plutonium-239/240 was detected in one soil sample in 2010 and seven soil samples in 2009. There were not enough data to perform ANOVA calculations for $^{239/240}$Pu.

Table 4.20 presents the soil sample analysis data for the gamma radionuclides and 90Sr. The sample data in Table 4.20 show that $^{40}$K was detected in all the samples; $^{137}$Cs was detected in all but four of the samples; and $^{60}$Co and $^{90}$Sr were not detected in any of the samples in 2011. In 2010 $^{40}$K and $^{137}$Cs were detected in all samples.

There were 18 common locations where 40K was detected between 2010 and 2011 for ANOVA comparisons. The average concentrations were used for the duplicate samples at SEC in 2010 and SMR in 2011. There were no significant variations in the $^{40}$K concentrations between 2010 and 2011 (ANOVA $^{40}$K p = 0.355). There was significant variation in the concentrations between locations, including the various soil depths (ANOVA $^{40}$K p = 2.29E-05). This value represents significantly more variation between the locations from 2010 and 2011 than from 2009 and 2010. Potassium-40 is a naturally occurring gamma-emitting radionuclide that is ubiquitous in soils with various concentrations, depending on source rock and movement through the environment.

The highest $^{40}$K concentration of 5.43E-01 Bq/g occurred at the 0-2 cm depth at location SMR (same as in 2009 and 2010). A total of three 2011 individual MLR and two average SMR $^{40}$K concentrations were higher than the 99 percent confidence interval range of baseline levels (3.40E-01 Bq/g) (DOE/WIPP-92-037).

Statistical analyses for $^{137}$Cs were performed for 15 common locations using the average concentrations for the 2010 SEC duplicate samples and the average concentrations for the 2011 SMR duplicate samples at 0-2 cm and 5-10 cm. The ANOVA calculations showed that there was no significant difference between the concentrations in 2010 and 2011 (ANOVA $^{137}$Cs p = 0.560). However, there was a significant difference in the concentrations between the sampling locations (ANOVA $^{137}$Cs p = 1.47E-07).

**Table 4.19 – 2011 Plutonium and Americium Concentrations (Bq/g) in Soil Samples Taken near the WIPP Facility**

**See Figure 4.4 for Sampling Locations**

| Location | Depth (cm) | [RN][a] | 2 σ TPU[b] | MDC[c] | Q[d] | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $^{238}$Pu | | | | $^{239/240}$Pu | | | | $^{241}$Am | | | |
| WFF | 0-2 | 2.27E-05 | 1.46E-04 | 5.84E-04 | U | 2.54E-05 | 9.18E-05 | 4.67E-04 | U | 2.45E-04 | 2.37E-04 | 5.77E-04 | U |
| WFF | 2-5 | 7.58E-05 | 1.81E-04 | 5.96E-04 | U | 1.34E-05 | 1.14E-04 | 4.79E-04 | U | 4.05E-05 | 1.33E-04 | 5.69E-04 | U |
| WFF | 5-10 | 8.82E-05 | 1.57E-04 | 5.68E-04 | U | 8.00E-06 | 8.95E-05 | 4.51E-04 | U | 1.48E-04 | 1.72E-04 | 5.61E-04 | U |
| WEE | 0-2 | -1.26E-05 | 1.13E-04 | 5.78E-04 | U | 2.39E-05 | 8.65E-05 | 4.60E-04 | U | 9.26E-05 | 1.78E-04 | 5.86E-04 | U |
| WEE | 2-5 | 1.68E-04 | 2.36E-04 | 6.22E-04 | U | 9.40E-05 | 1.60E-04 | 5.05E-04 | U | 9.82E-05 | 1.48E-04 | 5.54E-04 | U |
| WEE | 5-10 | 4.06E-05 | 1.56E-04 | 5.98E-04 | U | 2.56E-04 | 2.23E-04 | 4.80E-04 | U | 2.57E-04 | 2.25E-04 | 5.74E-04 | U |
| WSS | 0-2 | 3.60E-05 | 4.15E-04 | 1.35E-03 | U | -1.57E-05 | 9.75E-05 | 4.59E-04 | U | 7.04E-05 | 1.90E-04 | 5.89E-04 | U |
| WSS | 2-5 | 1.38E-05 | 3.17E-04 | 1.37E-03 | U | 9.67E-05 | 1.17E-04 | 4.65E-04 | U | -1.56E-05 | 1.24E-04 | 5.76E-04 | U |
| WSS | 5-10 | -7.79E-05 | 2.89E-04 | 1.38E-03 | U | 2.00E-05 | 8.28E-05 | 4.69E-04 | U | -1.62E-05 | 1.23E-04 | 5.71E-04 | U |
| MLR | 0-2 | -1.98E-05 | 2.44E-04 | 1.37E-03 | U | 4.61E-04 | 2.54E-04 | 4.66E-04 | U | 2.28E-04 | 2.41E-04 | 5.90E-04 | U |
| MLR | 2-5 | 5.91E-05 | 3.63E-04 | 1.36E-03 | U | 8.32E-05 | 1.21E-04 | 4.63E-04 | U | -6.88E-05 | 1.01E-04 | 5.70E-04 | U |
| MLR | 5-10 | -3.51E-05 | 2.48E-04 | 1.36E-03 | U | 1.00E-04 | 1.45E-04 | 4.63E-04 | U | 1.10E-04 | 1.94E-04 | 5.80E-04 | U |
| SEC | 0-2 | 4.88E-05 | 1.14E-04 | 5.09E-04 | U | 3.10E-05 | 9.40E-05 | 4.46E-04 | U | -2.51E-05 | 2.06E-04 | 4.79E-03 | U |
| SEC | 2-5 | 2.10E-05 | 1.13E-04 | 5.18E-04 | U | 1.05E-04 | 1.33E-04 | 4.55E-04 | U | -1.09E-05 | 2.35E-04 | 4.83E-03 | U |
| SEC | 5-10 | 6.63E-05 | 1.30E-04 | 5.22E-04 | U | -3.20E-05 | 6.39E-05 | 4.59E-04 | U | -1.95E-06 | 2.32E-04 | 4.76E-03 | U |
| SMR | 0-2 | 6.17E-05 | 1.21E-04 | 5.16E-04 | U | 1.02E-06 | 8.48E-05 | 4.53E-04 | U | -3.18E-05 | 2.09E-04 | 4.79E-03 | U |
| SMR | 2-5 | -1.09E-05 | 8.97E-05 | 5.13E-04 | U | 7.23E-05 | 1.10E-04 | 4.50E-04 | U | 4.69E-05 | 2.05E-04 | 4.76E-03 | U |
| SMR | 5-10 | 4.04E-05 | 9.71E-05 | 5.15E-04 | U | 7.48E-05 | 1.12E-04 | 4.51E-04 | U | 7.47E-06 | 1.50E-04 | 4.76E-03 | U |
| SMR Dup | 0-2 | 1.70E-05 | 1.03E-04 | 5.09E-04 | U | 1.04E-05 | 7.10E-05 | 4.46E-04 | U | 5.80E-05 | 1.82E-04 | 4.75E-03 | U |
| SMR Dup | 2-5 | 1.66E-04 | 1.64E-04 | 5.11E-04 | U | 4.97E-05 | 8.59E-05 | 4.48E-04 | U | -2.54E-05 | 2.09E-04 | 4.79E-03 | U |
| SMR Dup | 5-10 | 0.00E+00 | 1.57E-04 | 5.41E-04 | U | 1.95E-04 | 1.78E-04 | 4.78E-04 | U | 1.73E-04 | 2.84E-04 | 4.77E-03 | U |

(a) Radionuclide Concentration.

(b) Total Propagated Uncertainty.

(c) Minimum Detectable Concentration.

(d) Qualifier. Indicates whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

**Table 4.20 – 2011 Gamma and Beta Radionuclide Concentrations (Bq/g) in Soil Samples Taken near the WIPP Facility**

**See Appendix C for Sampling Location Codes**

| Location | Depth (cm) | [RN][a] | 2 σ TPU[b] | MDC[c] | Q[d] | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $^{40}$K | | | | $^{60}$Co | | | | $^{137}$Cs | | | |
| WFF | 0-2 | 1.62E-01 | 2.40E-02 | 5.01E-03 | + | 3.85E-04 | 4.64E-04 | 5.52E-04 | U | 7.22E-04 | 3.03E-04 | 4.23E-04 | + |
| WFF | 2-5 | 1.58E-01 | 2.42E-02 | 5.04E-03 | + | 9.53E-05 | 4.89E-04 | 5.89E-04 | U | 1.01E-03 | 3.52E-04 | 4.51E-04 | + |
| WFF | 5-10 | 1.47E-01 | 2.61E-02 | 1.14E-02 | + | -1.80E-04 | 1.10E-03 | 1.26E-03 | U | 1.20E-03 | 6.43E-04 | 9.12E-04 | + |
| WEE | 0-2 | 2.01E-01 | 2.94E-02 | 5.28E-03 | + | 3.40E-04 | 5.23E-04 | 6.06E-04 | U | 2.20E-03 | 4.45E-04 | 3.97E-04 | + |
| WEE | 2-5 | 2.08E-01 | 3.04E-02 | 5.25E-03 | + | -1.09E-04 | 5.09E-04 | 5.47E-04 | U | 2.34E-03 | 4.61E-04 | 3.98E-04 | + |
| WEE | 5-10 | 2.08E-01 | 3.37E-02 | 6.01E-03 | + | -4.90E-05 | 5.98E-04 | 6.98E-04 | U | 1.73E-03 | 5.17E-04 | 5.96E-04 | + |
| WSS | 0-2 | 1.79E-01 | 2.71E-02 | 4.64E-03 | + | 1.70E-04 | 5.13E-04 | 6.27E-04 | U | 1.32E-03 | 4.16E-04 | 5.20E-04 | + |
| WSS | 2-5 | 1.93E-01 | 2.93E-02 | 5.72E-03 | + | -5.24E-06 | 5.49E-04 | 6.46E-04 | U | 1.74E-03 | 4.94E-04 | 5.91E-04 | + |
| WSS | 5-10 | 1.71E-01 | 2.89E-02 | 8.48E-03 | + | 9.08E-05 | 1.09E-03 | 1.30E-03 | U | 8.39E-04 | 6.34E-04 | 9.67E-04 | U |
| MLR | 0-2 | 3.94E-01 | 5.67E-02 | 7.29E-03 | + | -3.60E-04 | 7.75E-04 | 8.07E-04 | U | 8.20E-03 | 1.29E-03 | 6.89E-04 | + |
| MLR | 2-5 | 3.49E-01 | 5.54E-02 | 1.32E-02 | + | 1.07E-03 | 1.53E-03 | 1.94E-03 | U | 2.17E-03 | 1.04E-03 | 1.48E-03 | + |
| MLR | 5-10 | 3.50E-01 | 5.59E-02 | 1.51E-03 | + | 3.47E-05 | 1.66E-03 | 1.95E-03 | U | 1.11E-03 | 1.62E-03 | 1.93E-03 | U |
| SEC | 0-2 | 1.83E-01 | 3.18E-02 | 1.42E-02 | + | -1.53E-04 | 1.21E-03 | 1.39E-03 | U | 2.30E-03 | 8.46E-04 | 1.08E-03 | + |
| SEC | 2-5 | 2.16E-01 | 3.62E+02 | 5.28E-03 | + | 1.51E-04 | 5.75E-04 | 6.97E-04 | U | 1.73E-03 | 4.55E-04 | 5.03E-04 | + |
| SEC | 5-10 | 2.19E-01 | 3.46E-02 | 8.21E-03 | + | -5.37E-04 | 9.07E-04 | 9.29E-04 | U | 1.38E-03 | 6.14E-04 | 8.47E-04 | + |
| SMR | 0-2 | 5.43E-01 | 8.26E-02 | 8.14E-03 | + | -6.44E-04 | 7.92E-04 | 7.85E-04 | U | 1.16E-03 | 3.86E-04 | 4.78E-04 | + |
| SMR | 2-5 | 4.05E-01 | 6.32E-02 | 1.56E-02 | + | 2.55E-04 | 1.47E-03 | 1.75E-03 | U | 6.30E-04 | 7.40E-04 | 1.19E-03 | U |
| SMR | 5-10 | 3.91E-01 | 5.74E-02 | 6.99E-03 | + | 6.35E-04 | 6.61E-04 | 8.39E-04 | U | 1.90E-03 | 4.10E-04 | 4.80E-04 | + |
| SMR Dup | 0-2 | 2.94E-01 | 4.29E-02 | 4.34E-03 | + | 1.76E-04 | 4.33E-04 | 5.23E-04 | U | 7.40E-04 | 2.59E-04 | 3.35E-04 | + |
| SMR Dup | 2-5 | 2.20E-01 | 3.43E-02 | 7.92E-03 | + | 8.48E-05 | 8.44E-04 | 9.99E-04 | U | 4.47E-04 | 3.96E-04 | 6.17E-04 | U |
| SMR Dup | 5-10 | 4.19E-01 | 6.15E-02 | 7.33E-03 | + | -4.42E-04 | 8.35E-04 | 9.13E-04 | U | 1.76E-03 | 5.82E-04 | 7.55E-04 | + |

**Table 4.20 – 2011 Gamma and Beta Radionuclide Concentrations (Bq/g) in Soil Samples Taken near the WIPP Facility**

**See Figure 4.4 for Sampling Location Codes**

| Location | Depth (cm) | [RN][a] | 2 σ TPU[b] | MDC[c] | Q[d] | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $^{90}$Sr | | | | | | | | | | | |
| WFF | 0-2 | 4.53E-04 | 6.91E-03 | 1.80E-02 | U | | | | | | | | |
| WFF | 2-5 | -3.66E-03 | 6.48E-03 | 1.80E-02 | U | | | | | | | | |
| WFF | 5-10 | -1.19E-03 | 6.48E-03 | 1.80E-02 | U | | | | | | | | |
| WEE | 0-2 | 1.70E-05 | 7.02E-03 | 1.80E-02 | U | | | | | | | | |
| WEE | 2-5 | -1.66E-03 | 6.54E-03 | 1.80E-02 | U | | | | | | | | |
| WEE | 5-10 | -4.49E-03 | 6.48E-03 | 1.80E-02 | U | | | | | | | | |
| WSS | 0-2 | 1.41E-03 | 6.37E-03 | 1.83E-02 | U | | | | | | | | |
| WSS | 2-5 | 1.45E-03 | 6.22E-03 | 1.83E-02 | U | | | | | | | | |
| WSS | 5-10 | 1.15E-04 | 6.08E-03 | 1.80E-02 | U | | | | | | | | |
| MLR | 0-2 | -1.23E-03 | 6.52E-03 | 1.84E-02 | U | | | | | | | | |
| MLR | 2-5 | -3.84E-03 | 6.66E-03 | 1.84E-02 | U | | | | | | | | |
| MLR | 5-10 | -6.51E-03 | 6.50E-03 | 1.84E-02 | U | | | | | | | | |
| SEC | 0-2 | -6.34E-03 | 9.99E-03 | 1.87E-02 | U | | | | | | | | |
| SEC | 2-5 | -6.35E-03 | 1.00E-02 | 1.87E-02 | U | | | | | | | | |
| SEC | 5-10 | 2.39E-04 | 1.04E-02 | 1.87E-02 | U | | | | | | | | |
| SMR | 0-2 | -2.60E-03 | 9.67E-03 | 1.86E-02 | U | | | | | | | | |
| SMR | 2-5 | -7.52E-04 | 9.94E-03 | 1.86E-02 | U | | | | | | | | |
| SMR | 5-10 | -1.62E-03 | 9.62E-03 | 1.86E-02 | U | | | | | | | | |
| SMR Dup | 0-2 | 1.30E-03 | 1.07E-02 | 1.87E-02 | U | | | | | | | | |
| SMR Dup | 2-5 | -1.23E-03 | 1.01E-02 | 1.87E-02 | U | | | | | | | | |
| SMR Dup | 5-10 | 5.88E-04 | 1.08E-02 | 1.87E-02 | U | | | | | | | | |

(a) Radionuclide Concentration.
(b) Total Propagated Uncertainty.
(c) Minimum Detectable Concentration.
(d) Qualifier. Indicates whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

Cesium-137 concentrations in 2011 were all within the 99 percent confidence interval range of the baseline concentration (4.00E-02 Bq/g). Cesium-137 is a fission product and is ubiquitous in soils because of global fallout from atmospheric nuclear weapons testing (Beck and Bennett, 2002; UNSCEAR, 2000). Additional $^{137}$Cs is not being added to the environment, and the data appear to show a gradual decrease in the concentrations over time.

Since $^{90}$Sr and $^{60}$Co were not detected at any sampling locations (Table 4.20), there were insufficient data to permit any kind of variance analysis between years or among sampling locations.

Precision data were calculated for the duplicate soil samples collected from all three depths at location SMR. The analysis results are shown in Table 4.21. The RERs were calculated for $^{233/234}$U, $^{235}$U, $^{238}$U, $^{40}$K, and $^{137}$Cs. The activities and total propagated errors were used for the radionuclides in the primary and duplicate samples, although $^{137}$Cs was not detected at the 2-5 cm depth in the SMR primary sample where the 2 σ TPU and MDC were greater than the activity.

**Table 4.21 – Results of 2011 Duplicate Soil Sampling and Analysis (Units in Bq/g)**

**See Figure 4.4 for Sampling Locations**

| Location | Depth (cm) | Isotope | Sample | | Duplicate | | |
|---|---|---|---|---|---|---|---|
| | | | [RN][a] | 2 σ TPU[b] | [RN] | 2 σ TPU | RER[c] |
| SMR | 0-2 | $^{233/234}$U | 1.40E-02 | 2.59E-03 | 1.19E-02 | 2.17E-03 | 0.622 |
| SMR | 2-5 | $^{233/234}$U | 9.30E-03 | 1.84E-03 | 1.31E-02 | 2.19E-03 | 1.329 |
| SMR | 5-10 | $^{233/234}$U | 1.02E-02 | 1.85E-03 | 1.14E-02 | 1.98E-03 | 0.443 |
| SMR | 0-2 | $^{235}$U | 7.00E-04 | 3.41E-04 | 3.97E-04 | 2.44E-04 | 0.723 |
| SMR | 2-5 | $^{235}$U | 4.94E-04 | 2.76E-04 | 6.92E-04 | 3.16E-04 | 0.472 |
| SMR | 5-10 | $^{235}$U | 4.34E-04 | 2.58E-04 | 5.50E-04 | 2.81E-04 | 0.304 |
| SMR | 0-2 | $^{238}$U | 1.42E-02 | 2.63E-03 | 1.32E-02 | 2.37E-03 | 0.282 |
| SMR | 2-5 | $^{238}$U | 9.93E-03 | 1.94E-03 | 1.30E-02 | 2.16E-03 | 1.057 |
| SMR | 5-10 | $^{238}$U | 9.91E-03 | 1.81E-03 | 1.13E-02 | 1.97E-03 | 0.520 |
| SMR | 0-2 | $^{40}$K | 5.43E-01 | 8.26E-02 | 2.94E-01 | 4.29E-02 | 2.675 |
| SMR | 2-5 | $^{40}$K | 4.05E-01 | 6.32E-02 | 2.20E-01 | 3.43E-02 | 2.573 |
| SMR | 5-10 | $^{40}$K | 3.91E-01 | 5.74E-02 | 4.19E-01 | 6.15E-02 | 0.333 |
| SMR | 0-2 | $^{137}$Cs | 1.16E-03 | 3.86E-04 | 7.40E-04 | 2.59E-04 | 0.904 |
| SMR | 2-5 | $^{137}$Cs | 6.30E-04 | 7.40E-04 | 4.47E-04 | 3.96E-04 | 0.218 |
| SMR | 5-10 | $^{137}$Cs | 1.90E-03 | 4.10E-04 | 1.76E-03 | 5.82E-04 | 0.197 |

(a) Radionuclide Concentration.
(b) Total Propagated Uncertainty.
(c) Relative Error Ratio.

Eleven of the radionuclide RERs were <1, two RERs were between 1.00 and 1.96, and two RERs were greater than 1.96, with the RERs at 2.675 and 2.573 for $^{40}$K in the 0-2 cm and 2-5 cm depths, respectively, at location SMR. Review of the $^{40}$K data showed significantly higher activity in the primary samples compared to the duplicate samples at the 0-2 cm and 2-5 cm depths.

## 4.7 Biota

### 4.7.1 Sample Collection

Rangeland vegetation samples were collected from the same six locations from which the soil samples were collected (Figure 4.4). Fauna (animal) samples were also collected when available. All biota samples were analyzed for the target radionuclides.

### 4.7.2 Sample Preparation

#### 4.7.2.1 Vegetation

The vegetation samples were chopped into 2.5- to 5-cm (1- to 2-in.) pieces, mixed together well, and air dried at room temperature. Weighed aliquots were spiked with tracers and carriers and heated in a muffle furnace to burn off organic matter.
The samples were digested with concentrated nitric acid, hydrochloric acid, hydrofluoric acid, and hydrogen peroxide. The samples were dried and heated in a muffle furnace. The remaining residue was repetitively wet-ashed with concentrated acids until only a white or pale yellow residue remained. The residue was dissolved in nitric acid for separation of the individual radionuclides.

#### 4.7.2.2 Fauna

The tissue samples were spiked with tracers and carriers and dried in a muffle furnace. The samples were then digested with concentrated acids and hydrogen peroxide in the same manner as the vegetation samples and dissolved in nitric acid for the separation of the individual radionuclides.

### 4.7.3 Determination of Individual Radionuclides

The nitric acid digestates of the biota samples were split into two fractions. One fraction was analyzed by gamma spectroscopy for $^{40}$K, $^{60}$Co, and $^{137}$Cs. The other fraction was analyzed sequentially for the uranium/transuranic radionuclides and $^{90}$Sr by employing a series of chemical, physical, and ion exchange separations, then mounting the sample residues on a planchet for counting. The uranium/transuranics were counted by alpha spectroscopy and the $^{90}$Sr by gas proportional counting.

### 4.7.4 Results and Discussion

#### 4.7.4.1 Vegetation

Table 4.22 shows that the only detection of uranium isotopes was for $^{233/234}$U and $^{238}$U in the vegetation sample from location SEC, and $^{238}$U in the duplicate vegetation samples from SMR. In 2010, the only uranium detections were for $^{233/234}$U and $^{238}$U in the sample from SMR. The measured $^{233/234}$U concentrations of 1.03E-03 Bq/g were higher than the 99 percent confidence range of the baseline concentration of 6.00E-05 Bq/g. Since there was only one common location for U$^{238}$ between 2010 and 2011, ANOVA calculations could not be completed.

**Table 4.22 – 2011 Radionuclide Concentrations (Bq/g Wet Mass) in Vegetation Samples Taken near the WIPP Facility**

**See Figure 4.4 for Sampling Locations**

| Location | [RN][a] | 2 σ TPU[b] | MDC[c] | Qd | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $^{233/234}$U | | | | $^{235}$U | | | | $^{238}$U | | | |
| WFF | 1.60E-04 | 1.19E-04 | 6.33E-04 | U | 5.97E-06 | 3.80E-05 | 2.87E-04 | U | 1.53E-04 | 1.11E-04 | 5.15E-04 | U |
| WSS | 2.61E-04 | 1.52E-04 | 8.71E-04 | U | -2.22E-06 | 1.38E-05 | 3.22E-04 | U | 3.87E-04 | 1.90E-04 | 4.80E-04 | U |
| MLR | 2.92E-04 | 1.39E-04 | 8.59E-04 | U | 1.35E-05 | 3.64E-05 | 3.07E-04 | U | 2.66E-04 | 1.31E-04 | 4.68E-04 | U |
| SEC | 1.03E-03 | 2.99E-04 | 8.60E-04 | + | 3.06E-05 | 5.11E-05 | 3.08E-04 | U | 7.25E-04 | 2.36E-04 | 4.69E-04 | + |
| SMR | 3.91E-04 | 1.72E-04 | 6.32E-04 | U | 4.01E-05 | 5.81E-05 | 2.85E-04 | U | 5.58E-04 | 2.05E-04 | 5.13E-04 | + |
| SMR Dup | 3.76E-04 | 1.79E-04 | 6.36E-04 | U | -1.15E-05 | 1.86E-05 | 2.90E-04 | U | 5.57E-04 | 2.18E-04 | 5.17E-04 | + |
| | $^{238}$Pu | | | | $^{239/240}$Pu | | | | $^{241}$Am | | | |
| WFF | -2.17E-06 | 3.15E-05 | 4.23E-04 | U | -5.77E-06 | 1.55E-05 | 2.61E-04 | U | 4.10E-05 | 6.21E-05 | 6.45E-04 | U |
| WSS | -9.07E-06 | 6.04E-05 | 4.17E-04 | U | 5.26E-06 | 3.59E-05 | 2.98E-04 | U | -1.65E-05 | 3.00E-05 | 5.69E-04 | U |
| MLR | 3.99E-05 | 6.62E-05 | 4.13E-04 | U | 3.60E-05 | 4.51E-05 | 2.94E-04 | U | -3.26E-06 | 3.60E-05 | 5.64E-04 | U |
| SEC | 8.25E-05 | 9.83E-05 | 4.15E-04 | U | 5.06E-05 | 6.58E-05 | 2.95E-04 | U | 4.85E-06 | 4.51E-05 | 5.64E-04 | U |
| SMR | 5.27E-05 | 6.60E-05 | 4.26E-04 | U | 5.19E-05 | 5.71E-05 | 2.65E-04 | U | 4.75E-06 | 6.41E-05 | 6.47E-04 | U |
| SMR Dup | 5.14E-06 | 4.40E-05 | 4.25E-04 | U | 4.36E-06 | 2.97E-05 | 2.64E-04 | U | 2.61E-05 | 6.51E-05 | 6.47E-04 | U |
| | $^{40}$K | | | | $^{60}$Co | | | | $^{137}$Cs | | | |
| WFF | 2.66E-01 | 7.00E-02 | 5.42E-02 | + | 3.36E-03 | 5.41E-03 | 7.45E-03 | U | 2.72E-03 | 4.12E-03 | 5.59E-03 | U |
| WSS | 3.14E-01 | 6.20E-02 | 4.00E-02 | + | 1.85E-03 | 3.34E-03 | 4.35E-03 | U | 2.10E-03 | 3.41E-03 | 4.13E-03 | U |
| MLR | 8.30E-01 | 1.31E-01 | 3.87E-02 | + | 1.22E-03 | 3.94E-03 | 4.41E-03 | U | -1.23E-03 | 3.47E-03 | 3.64E-03 | U |
| SEC | 4.67E-01 | 1.06E-01 | 7.09E-02 | + | 4.66E-03 | 5.90E-03 | 8.18E-03 | U | 3.43E-03 | 4.75E-03 | 6.25E-03 | U |
| SMR | 1.43E+00 | 2.01E-01 | 4.28E-02 | + | 2.56E-03 | 4.22E-03 | 4.83E-03 | U | 1.42E-03 | 3.46E-03 | 3.93E-03 | U |
| SMR Dup | 1.37E+00 | 1.96E-01 | 3.41E-02 | + | -1.97E-03 | 3.87E-03 | 3.99E-03 | U | -3.22E-03 | 3.49E-03 | 3.38E-03 | U |
| | $^{90}$Sr | | | | | | | | | | | |
| WFF | 2.08E-03 | 4.97E-03 | 1.81E-02 | U | | | | | | | | |
| WSS | 2.48E-03 | 4.86E-03 | 1.93E-02 | U | | | | | | | | |
| MLR | 2.32E-03 | 4.55E-03 | 1.92E-02 | U | | | | | | | | |
| SEC | 1.07E-03 | 4.95E-03 | 1.93E-02 | U | | | | | | | | |
| SMR | 2.35E-03 | 5.21E-03 | 1.81E-02 | U | | | | | | | | |
| SMR Dup | 2.10E-03 | 5.01E-03 | 1.80E-02 | U | | | | | | | | |

(a) Radionuclide Concentration.
(b) Total Propagated Uncertainty.
(c) Minimum Detectable Concentration.
(d) Qualifier. Indicates whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

Potassium-40 was detected in all the vegetation samples analyzed in 2011 (Table 4.22), as it was in 2009 and 2010. The average concentrations of $^{40}$K were used for ANOVA calculations at WSS in 2010, and SMR in 2011. The ANOVA calculations included five common locations. The sixth location, WEE, was not sampled in 2011 since there was no vegetation present due to drought.

The ANOVA calculations showed no statistical difference in $^{40}$K vegetation concentrations between 2010 and 2011 (ANOVA 40K $p = 0.596$). There was more variation in the concentrations between locations, but the p value was still just above the significance factor of 0.05, ANOVA $^{40}$K $p = 0.0561$. The natural variability of this naturally occurring radionuclide in the soil would be expected to yield some variation in the vegetation concentrations between locations. The concentrations of $^{40}$K were within the 99 percent ID confidence range of the average baseline concentration of 3.2E+00 Bq/g.

Table 4.23 shows the precision results for the analysis of $^{40}$K, the only radionuclide detected in the duplicate samples from location SMR. The RER calculated for $^{40}$K was much less than 1, indicating good precision for the duplicate sampling and analysis procedures.

**Table 4.23 – 2011 Results for Duplicate Analysis of Vegetation Samples (Units in Bq/g)**

**See Figure 4.4 for Sampling Locations**

| Location | Isotope | Sample | | Duplicate | | |
|---|---|---|---|---|---|---|
| | | [RN][a] | 2 σ TPU[b] | [RN] | 2 σ TPU | RER[c] |
| SMR | $^{40}$K | 1.43E+00 | 2.01E-01 | 1.37E+00 | 1.96E-01 | 0.214 |

(a) Radionuclide Concentration.

(b) Total Propagated Uncertainty.

(c) Relative Error Ratio.

Since there were no detections of $^{241}$Am, $^{60}$Co, $^{137}$Cs and $^{90}$Sr, no statistical comparisons between years or locations could be performed.

### 4.7.4.2 Fauna

Table 4.24 shows that the only radionuclide detected in any of the animal samples was $^{40}$K, and that it was detected in all the samples. Uranium-233/234, $^{235}$U, $^{238}$U, $^{241}$Am, $^{238}$Pu, $^{239/240}$Pu, $^{137}$Cs, $^{60}$Co, and $^{90}$Sr, were not detected in any of the animal samples. No statistical comparisons between locations or years could be performed for any of the undetected radionuclides.

The $^{40}$K detections occurred in a quail, three fish, a rabbit, and a deer. There were too few samples to allow statistical comparison between years. The detected $^{40}$K concentrations were within the baseline analysis results, including 3.9E-01 Bq/g for rabbit (dry), 4.1E-01Bq/g for quail (dry), and 6.1E-01Bq/g for fish (dry) (DOE/WIPP-92-037). Baseline concentrations were not available for the other animals.

**Table 4.24 – 2011 Radionuclide Concentrations (Bq/g Wet Mass) in Quail, Rabbit, Deer, and Fish Samples Taken near the WIPP Facility**

**See Appendix C for Sampling Location Codes**

| Biota (Location) | [RN][a] | 2 σ TPU[b] | MDC[c] | Q[d] | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $^{233/234}U$ | | | | $^{235}U$ | | | | $^{238}U$ | | | |
| Quail (WEE) | 1.41E-04 | 2.76E-05 | 6.63E-04 | U | 4.36E-06 | 2.74E-06 | 2.46E-04 | U | 1.52E-04 | 2.95E-05 | 4.33E-04 | U |
| Rabbit (SOO) | 6.96E-05 | 1.53E-05 | 8.04E-04 | U | 1.91E-06 | 1.77E-06 | 2.30E-04 | U | 5.37E-05 | 1.24E-05 | 4.74E-04 | U |
| Deer (SOO) | 1.51E-06 | 1.18E-06 | 6.71E-04 | U | -1.00E-07 | 3.11E-07 | 2.51E-04 | U | 1.49E-06 | 1.18E-06 | 4.58E-04 | U |
| Fish (PCN) | 4.30E-04 | 6.18E-05 | 5.57E-04 | U | 1.10E-05 | 3.87E-06 | 2.45E-04 | U | 1.89E-04 | 2.88E-05 | 4.66E-04 | U |
| Fish (BRA) | 1.50E-04 | 3.24E-05 | 5.57E-04 | U | 4.18E-06 | 3.00E-06 | 2.46E-04 | U | 6.95E-05 | 1.67E-05 | 4.67E-04 | U |
| Fish (CBD) | 1.11E-04 | 2.13E-05 | 5.80E-04 | U | 4.06E-06 | 2.92E-06 | 2.46E-04 | U | 5.49E-05 | 1.23E-05 | 5.09E-04 | U |
| | $^{238}Pu$ | | | | $^{239/240}Pu$ | | | | $^{241}Am$ | | | |
| Quail (WEE) | 1.77E-07 | 1.40E-06 | 4.56E-04 | U | 1.79E-06 | 2.00E-06 | 3.31E-04 | U | 2.56E-07 | 1.88E-06 | 4.19E-04 | U |
| Rabbit (SOO) | 8.12E-07 | 1.73E-06 | 5.05E-04 | U | 7.24E-07 | 1.30E-06 | 3.63E-04 | U | 1.09E-06 | 2.33E-06 | 5.00E-04 | U |
| Deer (SOO) | 4.63E-07 | 1.06E-06 | 5.84E-05 | U | -2.01E-07 | 4.50E-07 | 2.88E-04 | U | 4.09E-07 | 1.16E-06 | 4.58E-04 | U |
| Fish (PCN) | -1.15E-06 | 1.89E-06 | 4.75E-04 | U | 1.34E-07 | 2.14E-06 | 3.10E-04 | U | 2.88E-07 | 1.84E-06 | 5.24E-04 | U |
| Fish (BRA) | 2.25E-07 | 1.77E-06 | 4.64E-04 | U | -4.00E-07 | 8.60E-07 | 3.19E-04 | U | 1.78E-06 | 3.74E-06 | 5.25E-04 | U |
| Fish (CBD) | 1.21E-06 | 2.22E-06 | 4.22E-04 | U | 5.63E-07 | 1.59E-06 | 2.43E-04 | U | -5.17E-07 | 3.92E-06 | 6.16E-04 | U |
| | $^{40}K$ | | | | $^{60}Co$ | | | | $^{137}Cs$ | | | |
| Quail (WEE) | 1.16E-01 | 2.73E-02 | 2.31E-02 | + | -1.07E-03 | 2.70E-03 | 2.85E-03 | U | 1.56E-04 | 2.83E-03 | 3.24E-03 | U |
| Rabbit (SOO) | 1.15E-01 | 1.84E-02 | 1.30E-02 | + | -2.95E-04 | 1.42E-03 | 1.61E-03 | U | -6.64E-04 | 1.43E-03 | 1.47E-03 | U |
| Deer (SOO) | 1.46E-01 | 3.10E-02 | 1.58E-02 | + | 2.61E-03 | 2.45E-03 | 2.96E-03 | U | -4.58E-03 | 3.55E-03 | 3.38E-03 | U |
| Fish (PCN) | 9.46E-02 | 2.67E-02 | 2.76E-02 | + | 2.00E-03 | 2.80E-03 | 3.32E-03 | U | -6.06E-04 | 3.63E-03 | 3.92E-03 | U |
| Fish (BRA) | 8.01E-02 | 2.13E-02 | 2.09E-02 | + | -3.98E-04 | 2.43E-03 | 2.68E-03 | U | -4.41E-04 | 2.35E-03 | 2.72E-03 | U |
| Fish (CBD) | 1.02E-01 | 2.50E-02 | 2.41E-02 | + | 1.89E-03 | 2.97E-03 | 3.69E-03 | U | 6.87E-04 | 2.99E-03 | 3.57E-03 | U |
| | $^{90}Sr$ | | | | | | | | | | | |
| Quail (WEE) | 1.09E-04 | 9.23E-05 | 2.07E-02 | U | | | | | | | | |
| Rabbit (SOO) | 7.91E-05 | 1.08E-04 | 1.68E-02 | U | | | | | | | | |
| Deer (SOO) | 6.75E-06 | 4.96E-05 | 2.10E-02 | U | | | | | | | | |
| Fish (PCN) | 2.99E-05 | 7.83E-05 | 1.58E-02 | U | | | | | | | | |
| Fish (BRA) | 2.56E-05 | 8.63E-05 | 1.58E-02 | U | | | | | | | | |
| Fish (CBD) | -1.29E-04 | 1.52E-04 | 1.67E-02 | U | | | | | | | | |

(a) Radionuclide Concentration.
(b) Total Propagated Uncertainty.
(c) Minimum Detectable Concentration.
(d) Qualifier. Indicates whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

These results can only be used as a gross indication of uptake by the animals, since the sample sizes are too small to provide a detailed analysis. Within this limitation, the data suggest that no animal uptake of radionuclides from the WIPP facility has occurred.

Precision data for animal samples were limited to laboratory duplicates from the same sample since duplicate animal samples were not collected. However, duplicate field portions of the deer carcass were taken and submitted for analysis. WIPP Laboratories analyzed the duplicate field portions and also analyzed one of the portions in duplicate as the laboratory duplicate sample. The precision data reported in Table 4.25 are based on the measured activities and total propagated error, whether or not the radionuclides were actually detected in the samples. The duplicate field sample RERs were all <1 for the selected radionuclides shown in the table, demonstrating good precision for the complex analysis procedures.  Laboratory duplicate RERs for the deer carcass samples were also <1 for the radionuclides listed in Table 4.25.

**Table 4.25 – Results of 2011 Animal Biota Field Duplicate Analysis Precision (Units in Bq/g)**

**See Appendix C for Sampling Location Codes**

| Animal | Location | Isotope | Sample | | Duplicate | | |
|---|---|---|---|---|---|---|---|
| | | | [RN][a] | 2 σ TPU[b] | [RN] | 2 σ TPU | RER[c] |
| Deer | SOO | $^{233/234}U$ | 1.51E-06 | 1.18E-06 | 1.87E-06 | 1.36E-06 | 0.200 |
| Deer | SOO | $^{235}U$ | -1.00E-07 | 3.11E-07 | 2.27E-07 | 5.78E-07 | 0.498 |
| Deer | SOO | $^{238}U$ | 1.49E-06 | 1.18E-06 | 1.39E-06 | 1.21E-06 | 0.059 |
| Deer | SOO | $^{40}K$ | 1.46E-01 | 3.10E-02 | 1.38E-01 | 3.07E-02 | 0.183 |

(a) Radionuclide Concentration.
(b) Total Propagated Uncertainty.
(c) Relative Error Ratio.

## 4.8 Potential Dose From WIPP Operations

### 4.8.1 Dose Limits

Compliance with the regulatory standards is determined by comparing annual radiation doses to the regulatory standards. The regulatory standards can be found in 40 CFR Part 191, Subpart A. The referenced standard specifies that the combined annual dose equivalent to any member of the public in the general environment resulting from discharges of radioactive material and direct radiation from such management and storage shall not exceed 25 mrem to the whole body and 75 mrem to any critical organ. In addition, in a 1995 memorandum of understanding between the EPA and the DOE, the DOE agreed that the WIPP facility would comply with the applicable NESHAP for radionuclides. The NESHAP standard states that the emissions of radionuclides to the ambient air from DOE facilities shall not exceed those amounts that would cause any member of the public to receive in any year an EDE of 10 mrem per year. The EDE is the weighted sum of the doses to the individual organs of the body. The dose to each organ is weighted according to the risk that dose represents. These organ doses are then added together, and that total is the EDE. In this manner, the risk from different sources of radiation can be controlled by a single standard.

Compliance with applicable regulatory requirements is determined by monitoring, extracting, and calculating the EDE. Calculating the EDE to members of the public requires the use of CAP88-PC or other EPA-approved computer models and procedures. The WIPP effluent monitoring program generally uses CAP88-PC, which is a set of computer programs, datasets and associated utility programs for estimating dose and risk from radionuclide air emissions. CAP88-PC uses a Gaussian Plume dispersion model, which calculates deposition rates, concentrations in food, and intake rates for people. CAP88-PC estimates dose and risk to individuals and populations from multiple pathways. Dose and risk is calculated for ingestion, inhalation, ground-level air immersion, and ground-surface irradiation exposure pathways.

The SDWA (40 CFR §141.66, "Maximum Contaminant Levels for Radionuclides") states that average annual concentrations for beta- and gamma-emitting human-made radionuclides in drinking water shall not result in an annual dose equivalent >0.04 mSv (4 mrem). It is important to note that all of these dose equivalent limits are set for radionuclides released to the environment from DOE operations. They do not include, but are limits in addition to, doses from natural background radiation or from medical procedures.

### 4.8.2 Background Radiation

There are several sources of natural radiation: cosmic and cosmogenic radiation (from outer space and the earth's atmosphere), terrestrial radiation (from the earth's crust), and internal radiation (naturally occurring radiation in our bodies, such as $^{40}$K). The most common sources of terrestrial radiation are uranium, and thorium, and their decay products. Another source of terrestrial radiation is $^{40}$K. While not a major radiation source, $^{40}$K in the southeastern New Mexico environment may be due to the deposition of tailings from local potash mining. Radon gas, a decay product of uranium, is a widely known naturally occurring terrestrial radionuclide. In addition to natural radioactivity, small amounts of radioactivity from aboveground nuclear weapons tests that occurred from 1945 through 1980, and the 1986 Chernobyl nuclear accident are also present in the environment. Together, these sources of radiation are called "background" radiation.

Naturally occurring radiation in the environment can deliver both internal and external doses. Internal dose is received as a result of the intake of radionuclides through ingestion (consuming food or drink containing radionuclides) and inhalation (breathing radioactive particulates). External dose can occur from immersion in contaminated air or deposition of contaminants on surfaces. The average annual dose received by a member of the public from naturally occurring radionuclides is approximately 3 mSv (300 mrem).

### 4.8.3 Dose From Air Emissions

The standard 40 CFR Part 191, Subpart A, limits radiation doses to members of the public and the general environment. The DOE has identified air emissions as the major pathway of concern for the WIPP facility.

Compliance with Subpart A (40 CFR §191.03[b]) and the NESHAP standard (40 CFR §61.92) is determined by comparing annual radiation doses to the MEI to the regulatory standards. As recommended by the EPA, the DOE uses computer modeling to calculate radiation doses for compliance with the Subpart A and NESHAP standards. Compliance procedures for DOE facilities (40 CFR §61.93[a]) require the use of CAP88-PC or AIRDOS-PC computer models, or equivalent, to calculate dose to members of the public. Source term input for CAP88-PC was determined by radiochemical analyses of filter air samples taken from Stations A, B, and C. Air filter samples were analyzed for $^{241}$Am, $^{239/240}$Pu, $^{238}$Pu, $^{90}$Sr, $^{233/234}$U, $^{238}$U, and $^{137}$Cs because these radionuclides constitute over 98 percent of the dose potential from CH and RH waste. A combination of measured concentration or activity results, the 2 σ TPU and MDC, were used as input nuclide data in the CAP88-PC computer model to calculate the EDEs to members of the public. See section 4.1.4 for more information on the results and discussion of the effluent monitoring data.

CAP88-PC dose calculations are based on the assumption that exposed persons remain at home during the entire year and all vegetables, milk, and meat consumed are home-produced. Thus, this dose calculation is a maximum potential dose, which encompasses dose from inhalation, submersion, deposition, and ingestion of radionuclides emitted via the air pathway from the WIPP facility.

### 4.8.4 Total Potential Dose From WIPP Operations

The radiation dose equivalent received by members of the public as a result of the management and storage of TRU radioactive wastes at any disposal facility operated by the DOE is regulated under 40 CFR Part 191, Subpart A. Specific standards state that the combined annual dose equivalent to any member of the public in the general environment resulting from the discharges of radioactive material and direct radiation from management and storage shall not exceed 0.25 mSv (25 mrem) to the whole body and 0.75 mSv (75 mrem) to any critical organ. Section 4.8.4.3 discusses the potential dose equivalent received from radionuclides released to the air from WIPP. The following sections discuss the potential dose equivalent through other pathways and the total potential dose equivalent a member of the public may have received from the WIPP facility during 2011.

#### 4.8.4.1 Potential Dose From Water Ingestion Pathway

The potential dose to individuals from the ingestion of WIPP facility-related radionuclides transported in water is determined to be zero for several reasons. Drinking water for communities near the WIPP facility comes from groundwater sources that are not expected to be affected by WIPP facility contaminants based on current radionuclide transport scenarios summarized in the *Waste Isolation Pilot Plant Documented Safety Analysis* (DOE/WIPP-07-3372). The only credible pathway for contaminants from the WIPP facility to accessible groundwater is through the Culebra as stated in *Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant* (DOE/CAO-96-2184). Water from the Culebra is naturally not potable due to high levels of TDS. Water from the Dewey Lake is suitable for livestock consumption, having TDS values below 10,000 milligrams per liter (mg/L). Groundwater samples collected from the Culebra around the WIPP facility during 2011 did not contain radionuclide concentrations discernible from those in samples collected prior to the WIPP facility receiving waste.

#### 4.8.4.2 Potential Dose from Wild Game Ingestion

Game animals sampled during 2011 were deer, rabbit, fish and quail. The only radionuclide detected in any of the animal samples was $^{40}$K, which was detected in all the samples. Therefore, no dose from WIPP facility-related radionuclides could have been received by any individual from this pathway during 2011.

#### 4.8.4.3 Total Potential Dose from All Pathways

The only credible pathway from the WIPP facility to humans is through air emissions; therefore, this is the only pathway for which a dose is calculated. The total radiological dose and atmospheric release at WIPP in 2011 is summarized in Table 4.26 for the regulations in both 40 CFR §61.92 and 40 CFR §191.03(b).

In compliance with 40 CFR Part 191, Subpart A, the receptor selected is assumed to reside year-round at the fence line in the northwest sector. For 2011, the dose to this receptor was estimated to be <1.29E-05 mSv (1.29E-03 mrem) per year for the whole body and <1.86E-05 mSv (1.86E-03 mrem) per year to the critical organ. These values are in compliance with the requirements specified in 40 CFR §191.03(b).

For the NESHAP standard (40 CFR §61.92), the EDE potentially received by the MEI in 2011 assumed to be residing 7.5 km (4.66 mi) west-northwest of WIPP is calculated to be <1.75E-07 mSv (1.75E-05 mrem) per year for the whole body. This value is in compliance with 40 CFR §61.92 requirements.

As required by DOE Order 458.1, the collective dose to the public within 80 km (50 mi) of the WIPP facility has been evaluated, and is 2.67E-07 sieverts (Sv) (2.67E-05 person-rem/year) in 2011.

**Table 4.26 – WIPP Radiological Dose and Release Summary**

| **WIPP Radiological Atmospheric Releases[a] During 2011** | | | |
|---|---|---|---|
| **$^{238}$Pu** | **$^{239/240}$Pu** | **$^{241}$Am** | **$^{90}$Sr** |
| 9.35E-08 Ci | 4.34E-07 Ci | 9.46E-08 Ci | 2.45E-06 Ci |
| 3,460 Bq | 16,058 Bq | 3,500 Bq | 90,650 Bq |
| 233/234U | 238U | 137Cs | |
| 1.70E-07 Ci | 1.19E-07 Ci | 1.29E-04 Ci | |
| 6,290 Bq | 4,403 Bq | 4.77E+06Bq | |

| **WIPP Radiological Dose Reporting Table in 2011** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Pathway** | **EDE to the MEI at 7,500 Meters WNW** | | **Percent of EPA 10 mrem/Year Limit to Member of the Public** | **Estimated Population Dose Within 50 Miles** | | **Population Within 50 Miles[b]** | **Estimated Natural Radiation Population Dose[c]** |
| | (mrem/year) | (mSv/year) | | (person-rem/year) | (person-Sv/year) | | (person-rem) |
| Air | 1.75E-05 | 1.75E-07 | 1.75E-04 | 2.67E-05 | 2.67E-07 | 92,599 | 27,780 |
| Water | N/Ad | N/A | N/A | N/A | N/A | N/A | N/A |
| Other Pathways | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

| WIPP Radiological Dose Reporting Table in 2011 | | | | | | |
|---|---|---|---|---|---|---|
| Pathway | Dose equivalent to the whole body of the receptor who resides year-round at WIPP fence line 350 meters NW | | Percent of EPA 25 mrem/Year Whole Body Limit | Dose equivalent to the critical organ of the receptor who resides year-round at WIPP fence line 350 meters NW | | Percent of EPA 75-mrem/Year Critical Organ Limit |
| | (mrem/year) | (mSv/year) | | (mrem/year) | (mSv/year) | |
| Air | 1.29E-03 | 1.29E-05 | 5.16E-03 | 1.86E-03 | 1.86E-05 | 2.48E-03 |
| Water | N/A | N/A | N/A | N/A | N/A | N/A |
| Other Pathways | N/A | N/A | N/A | N/A | N/A | N/A |

(a) Total releases from combination of Stations A, B, and C. Values are calculated from detected activities plus 2 σ TPU or the MDC, whichever is greater and multiplied by the ratio of flow to stack flow volumes.

(b) Source: United States Census Bureau (2010 Census Data).

(c) Estimated natural radiation population dose = (population within 50 mi) x (300 mrem/year).

(d) Not applicable at WIPP.

### 4.8.5 Dose to Nonhuman Biota

Dose limits for populations of aquatic and terrestrial organisms are discussed in NCRP Report No. 109, Effects of Ionizing Radiation on Aquatic Organisms (NCRP, 1991), and the International Atomic Energy Agency Technical Report Series No. 332, *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards*. Those dose limits are:

- Aquatic animals - 10 mGy/d (1 rad/d)
- Terrestrial plants - 10 mGy/d (1 rad/d)
- Terrestrial animals - 1 mGy/d (0.1 rad/d)

The DOE has considered establishing these dose standards for aquatic and terrestrial biota in proposed rule 10 CFR Part 834, "Radiation Protection of the Public and the Environment," but has delayed finalizing this rule until guidance for demonstrating compliance is developed. *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE-STD-1153-2002) was developed to meet this need.

The DOE requires reporting of radiation doses to nonhuman biota in the ASER using DOE-STD-1153-2002, which requires an initial general screening using conservative assumptions. In the initial screen, biota concentration guides (BCGs) are derived using conservative assumptions for a variety of generic organisms. Maximum concentrations of radionuclides detected in soil, sediment, and water during environmental monitoring are divided by the BCGs and the results are summed for each organism. If the sum of these fractions is <1.0, the site is deemed to have passed the screen and no further action is required. This screening evaluation is intended to provide a very conservative evaluation of the site in relation to the recommended limits. This guidance was used to screen radionuclide concentrations observed around WIPP during 2011 using the maximum radionuclide concentrations listed in Table 4.27, and the sum of fractions was

<1.0 for all media. The element $^{40}K$ is not included in Table 4.27 since it is a natural component of the earth's crust and is not part of WIPP-related radionuclides

**Table 4.27 – General Screening Results for Potential Radiation Dose to Nonhuman Biota From Radionuclide Concentrations in Surface Water (Bq/L), Sediment (Bq/g), and Soil (Bq/g) near the WIPP Facility in 2011**

| Medium | Radionuclide | Maximum Detected Concentration | BCG[a] | Concentration/BCG |
|---|---|---|---|---|
| **Aquatic System Evaluation** | | | | |
| Sediment (Bq/g) | $^{60}Co$ | ND[c] | 5.00E+01 | NA[d] |
| | $^{90}Sr$ | ND | 2.00E+01 | NA |
| | $^{137}Cs$ | 6.28E-03 | 1.00E+02 | 6.28E-05 |
| | $^{233/234}U$ | 3.05E-02 | 2.00E+02 | 1.53E-04 |
| | $^{235}U$ | 1.55E-03 | 1.00E+02 | 1.55E-05 |
| | $^{238}U$ | 2.98E-02 | 9.00E+01 | 3.31E-04 |
| | $^{238}Pu$ | ND | 2.00E+02 | NA |
| | $^{239/240}Pu$ | ND | 2.00E+02 | NA |
| | $^{241}Am$ | ND | 2.00E+02 | NA |
| Water[b] (Bq/L) | $^{60}Co$ | ND | 1.00E+02 | NA |
| Surface | $^{90}Sr$ | ND | 1.00E+01 | NA |
| | $^{137}Cs$ | ND | 2.00E+00 | NA |
| | $^{233/234}U$ | 1.43E-01 | 7.00E+00 | 2.04E-02 |
| | $^{235}U$ | 6.16E-03 | 8.00E+00 | 7.70E-04 |
| | $^{238}U$ | 6.58E-02 | 8.00E+00 | 8.23E-03 |
| | $^{238}Pu$ | ND | 7.00E+00 | NA |
| | $^{239/240}Pu$ | ND | 7.00E+00 | NA |
| | $^{241}Am$ | ND | 2.00E+01 | NA |
| | | | Sum of Fractions | 3.00E-02 |
| **Terrestrial System Evaluation** | | | | |
| Soil (Bq/g) | $^{60}Co$ | ND | 3.00E+01 | NA |
| | $^{90}Sr$ | ND | 8.00E-01 | NA |
| | $^{137}Cs$ | 8.23E-03 | 8.00E-01 | 1.03E-02 |
| | $^{233/234}U$ | 1.30E-02 | 2.00E+02 | 6.50E-05 |
| | $^{235}U$ | 5.93E-04 | 1.00E+02 | 5.93E-06 |
| | $^{238}U$ | 1.37E-02 | 6.00E+01 | 2.28E-04 |
| | $^{238}Pu$ | ND | 2.00E+02 | NA |
| | $^{239/240}Pu$ | ND | 2.00E+02 | NA |
| | $^{241}Am$ | ND | 1.00E+02 | NA |
| Water (Bq/L) | $^{60}Co$ | ND | 4.00E+04 | NA |
| Surface | $^{90}Sr$ | ND | 2.00E+04 | NA |
| | $^{137}Cs$ | ND | 2.00E+04 | NA |
| | $^{233/234}U$ | 1.43E-01 | 1.00E+04 | 1.43E-05 |
| | $^{235}U$ | 6.16E-03 | 2.00E+04 | 3.08E-07 |
| | $^{238}U$ | 6.58E-02 | 2.00E+04 | 3.29E-06 |

**Table 4.27 – General Screening Results for Potential Radiation Dose to Nonhuman Biota From Radionuclide Concentrations in Surface Water (Bq/L), Sediment (Bq/g), and Soil (Bq/g) near the WIPP Facility in 2011**

| Medium | Radionuclide | Maximum Detected Concentration | BCG[a] | Concentration/BCG |
|---|---|---|---|---|
| | $^{238}$Pu | ND | 7.00E+03 | NA |
| | $^{239/240}$Pu | ND | 7.00E+03 | NA |
| | $^{241}$Am | ND | 7.00E+03 | NA |
| | | | Sum of Fractions | 1.06E-02 |

(a) The radionuclide concentration in the medium that would produce a radiation dose in the organism equal to the dose limit under the conservative assumptions in the model.

(b) Sediment and surface water sample were assumed to be co-located.

(c) Not detected in all sampling locations for a given medium.

(d) Not available for calculation.

Note: Maximum detected concentrations were compared with BCG values to assess potential dose to biota. As long as the sum of the ratios between detected maximum concentrations and the associated BCG is below 1.0, no adverse effects on plant or animal populations are expected (DOE-STD-1153-2002).

### 4.8.6 Release of Property Containing Residual Radioactive Material

There was no release of radiologically contaminated materials or property from the WIPP facility in 2011. The criteria used for release of potentially radioactive materials are specified in DOE Order 458.1, *Radiation Protection of the Public and the Environment*, Figure IV-1, Allowable Total Residual Surface Contamination. The values in DOE Order 458.1 for transuranics are <20 percent of the values in ANSI/HPS N13.12-1999, *Surface and Volume Radioactivity Standards for Clearance*.

## 4.9 Radiological Program Conclusions

### 4.9.1 Effluent Monitoring

For 2011, the EDE to the receptor (hypothetical MEI) who resides year-round at the fence line is <1.29E-05 mSv (1.29E-03 mrem) per year for the whole body, and is <1.86E-05 mSv (1.86E-03 mrem) per year for the critical organ. For the WIPP effluent monitoring program, Figure 4.5 and Table 4.28 show the dose to the whole body for the hypothetical MEI for CY 1999 to CY 2011. Figure 4.6 and Table 4.29 show the dose to the critical organ for the hypothetical MEI for CY 1999 to CY 2011. These dose equivalent values are below the 25 mrem to the whole body and 75 mrem to any critical organ, in accordance with the provisions of 40 CFR §191.03(b).

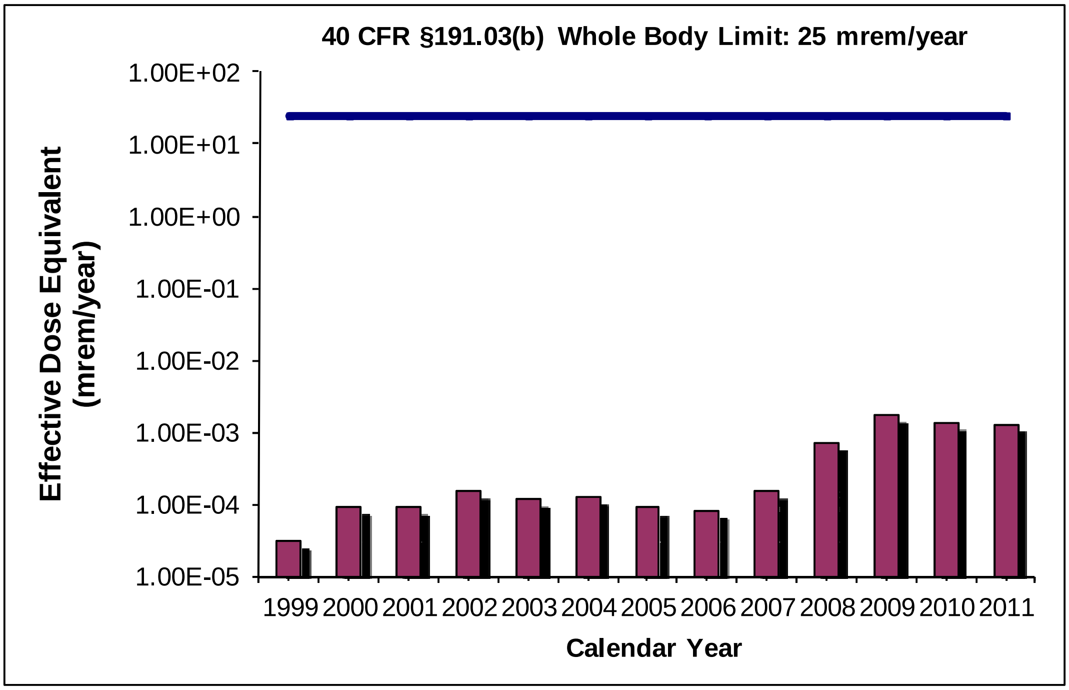



Figure 4.5 – Dose to the Whole Body for the Hypothetical Maximally Exposed Individual at the WIPP Fence Line (Figure 4.5 and Table 4.28 update data reported in the 2010 ASER

**Table 4.28 – Comparison of Dose to the Whole Body to EPA Limit of 25 mrem/year per 40 CFR § 191.03(b)**

| Year | Annual Dose (mrem/yr) | Percent of EPA Limit |
|---|---|---|
| 1999 | 3.10E-05 | 0.00012 |
| 2000 | 9.35E-05 | 0.00037 |
| 2001 | 8.99E-05 | 0.00036 |
| 2002 | 1.51E-04 | 0.00060 |
| 2003 | 1.15E-04 | 0.00046 |
| 2004 | 1.27E-04 | 0.00051 |
| 2005 | 8.86E-05 | 0.00035 |
| 2006 | 8.16E-05 | 0.00033 |
| 2007 | 1.52E-04 | 0.00061 |
| 2008 | 7.14E-04 | 0.00290 |
| 2009 | 1.71E-03 | 0.00684 |
| 2010 | 1.31E-03 | 0.00524 |
| 2011 | 1.29E-03 | 0.00516 |
| 40 CFR §191.03(b) Whole Body Limit | 25 | |

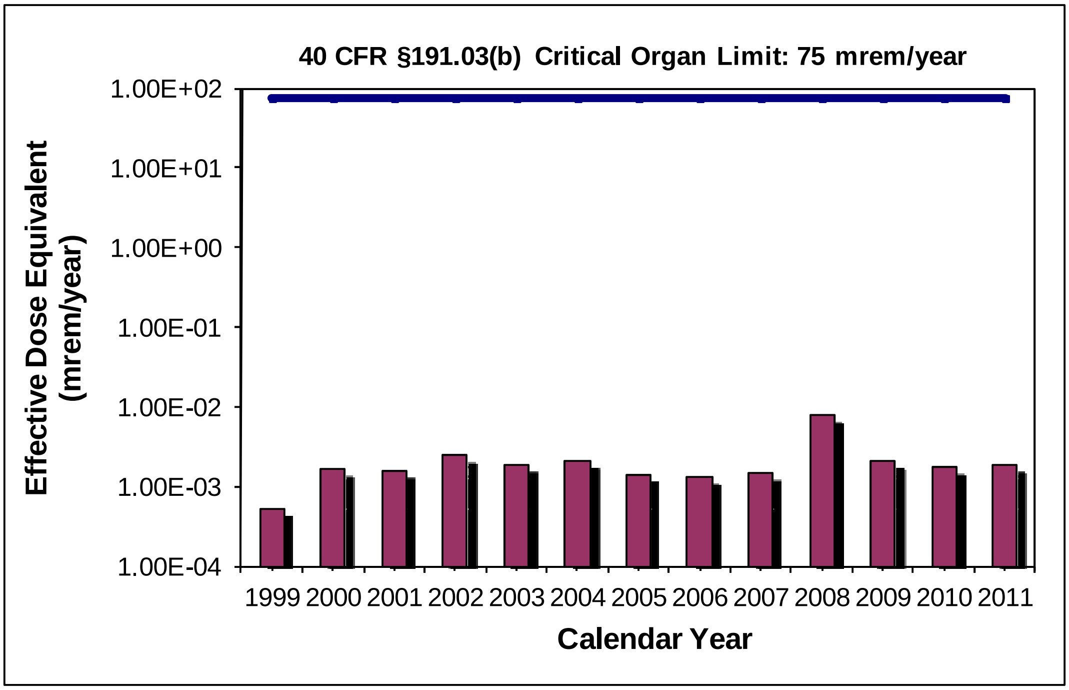



Figure 4.6 – Dose to the Critical Organ for Hypothetical Maximally Exposed Individual at the WIPP Fence Line

**Table 4.29 – Comparison of Dose to the Critical Organ to EPA Limit of 75 mrem/year per 40 CFR §191.03(b)**

| Year | Annual Dose (mrem/yr) | Percent of EPA Limit |
|---|---|---|
| 1999 | 5.30E-04 | 0.00071 |
| 2000 | 1.63E-03 | 0.0022 |
| 2001 | 1.56E-03 | 0.0021 |
| 2002 | 2.46E-03 | 0.0033 |
| 2003 | 1.85E-03 | 0.0025 |
| 2004 | 2.11E-03 | 0.0028 |
| 2005 | 1.41E-03 | 0.0019 |
| 2006 | 1.30E-03 | 0.0017 |
| 2007 | 1.46E-03 | 0.0019 |
| 2008 | 7.81E-03 | 0.0014 |
| 2009 | 2.10E-03 | 0.0028 |
| 2010 | 1.73E-03 | 0.0023 |
| 2011 | 1.86E-03 | 0.0025 |
| 40 CFR §191.03(b) Critical Organ Limit | 75 | |

For 2011, the EDE to the MEI from normal operations conducted at the WIPP facility is <1.75E-03 mSv (1.75E-05 mrem). For the WIPP effluent monitoring program, Figure 4.7 and Table 4.30 show the EDE to the MEI for CY 1999 to CY 2011. These EDE values are more than six orders of magnitude below the EPA NESHAP standard of 10 mrem per year, as specified in 40 CFR §61.92.

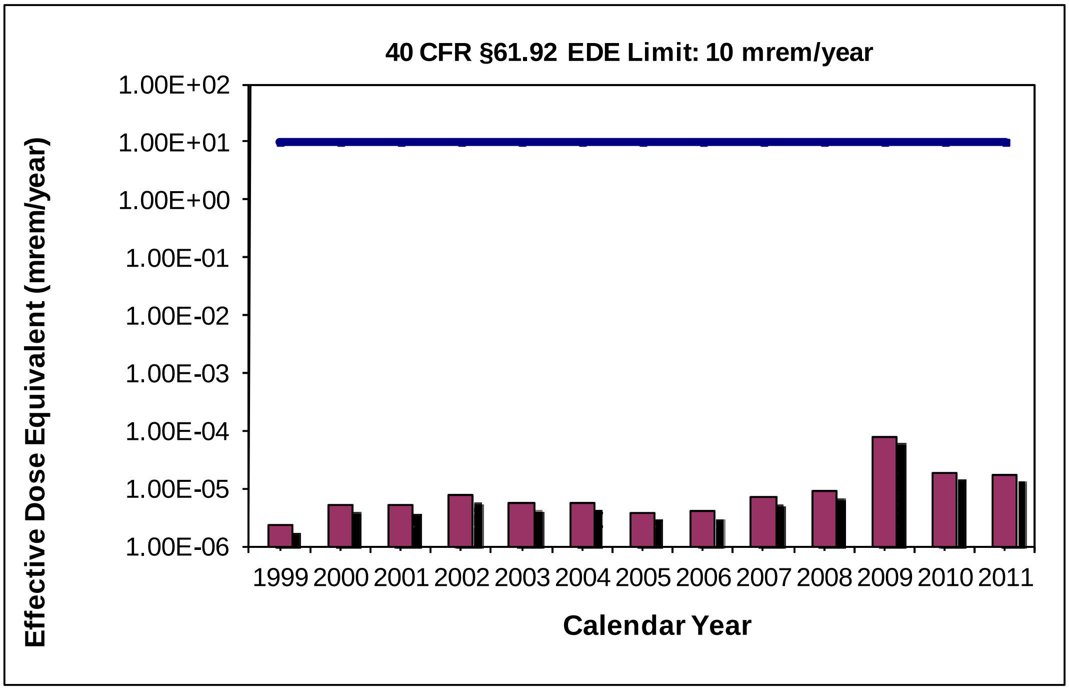



Figure 4.7 – WIPP Effective Dose Equivalent to the Off-Site Maximally Exposed Individual

**Table 4.30 – Comparison of EDEs to EPA Limit of 10 mrem/year per 40 CFR §61.92**

| Year | Annual Dose (mrem/yr) | Percent of EPA Limit |
|---|---|---|
| 1999 | 2.23E-06 | 0.000022 |
| 2000 | 5.18E-06 | 0.000051 |
| 2001 | 4.96E-06 | 0.000050 |
| 2002 | 7.61E-06 | 0.000076 |
| 2003 | 5.43E-06 | 0.000054 |
| 2004 | 5.69E-06 | 0.000057 |
| 2005 | 3.85E-06 | 0.000039 |
| 2006 | 3.93E-06 | 0.000039 |
| 2007 | 7.01E-06 | 0.000070 |
| 2008 | 9.05E-06 | 0.000091 |
| 2009 | 7.80E-05 | 0.000780 |
| 2010 | 1.91E-05 | 0.000191 |
| 2011 | 1.75E-05 | 0.000175 |
| NESHAP Limit | 10 | |

### 4.9.2 Environmental Monitoring

Radionuclide concentrations observed in environmental monitoring were extremely small and comparable to radiological baseline levels. Appendix H contains graphs comparing detected radionuclide concentrations to their respective baseline values. In cases where the radionuclide concentrations slightly exceeded baseline levels (uranium isotopes and $^{40}K$ in some samples), these differences are most likely due to natural spatial variability, and they are so far below the regulatory limit as to be nonimpactive.

# CHAPTER 5 – ENVIRONMENTAL NONRADIOLOGICAL PROGRAM INFORMATION

Nonradiological programs at the WIPP facility include land management, meteorological monitoring, VOC monitoring, hydrogen and methane monitoring, seismic monitoring, certain aspects of liquid effluent, and surface water and groundwater monitoring. The monitoring is performed to comply with the provisions of the WIPP authorization documents. Radiological and nonradiological groundwater monitoring is discussed in Chapters 4 and 6, respectively.

## 5.1 Principal Functions Of Nonradiological Sampling

The principal functions of the nonradiological environmental surveillance program are to:

- Assess the impacts of WIPP facility operations on the surrounding ecosystem.
- Monitor ecological conditions in the Los Medaños region.
- Provide environmental data that has not or will not be acquired by other programs, but are important to the mission of the WIPP project.
- Comply with applicable commitments (e.g., BLM/DOE Memorandum of Understanding and interagency agreements).

## 5.2 Land Management Programs

On October 30, 1992, the WIPP LWA was signed by the President. This law transfers the responsibility for the management of the 16 sections of land that comprises the WIPP site to the Secretary of Energy.

The DOE developed a LMP as required to identify resource values, promote multiple-use management, and identify long-term goals for the management of WIPP lands. The LMP was developed in consultation with the BLM and the State of New Mexico.

The LMP sets forth cooperative arrangements and protocols for addressing WIPP-related land management actions. Commitments contained in current permits, agreements, or concurrent memoranda of understanding with other agencies will be respected when addressing and evaluating land use management activities and future amendments that affect the management of WIPP lands.

In November 2010 the DOE, with concurrence from the U.S. Department of Interior and New Mexico State agencies, issued an update to the LMP as provided in Chapter 8 of the LMP. The update includes reference to the January 2010 formal transfer of the WIPP South Access Road right-of-way, formerly Eddy County Road 802, to the DOE for a 40-year term.

### 5.2.1 Land Use Requests

Parties who wish to conduct activities that may impact lands under the jurisdiction of the DOE, but outside the Property Protection Area, are required by the LMP to prepare a land use request. A land use request consists of a narrative description of the project, a completed environmental review, and a map depicting the location of the proposed activity. This documentation is used to determine if applicable regulatory requirements have been met prior to the approval of a proposed project. A land use request is submitted to the Land Use Coordinator by organizations wishing to complete construction on owned right-of-ways, pipeline easement, or similar action within the WIPP LWA or on lands used in the operation of the WIPP facility, under the jurisdiction of the DOE. In 2011, 10 land use requests were submitted to, and approved by, the Land Use Coordinator.

### 5.2.2 Wildlife Population Monitoring

In 1995, the USFWS provided an updated list of threatened and endangered species for Eddy and Lea Counties, New Mexico. Included were 18 species that may be present on DOE lands. A comprehensive evaluation in support of the SEIS-II (Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement, DOE/EIS 0026-S-2) was conducted in 1996 to determine the presence or absence of threatened or endangered species in the vicinity of the WIPP site and the effect of WIPP facility operations on these species. Results indicated that activities associated with the operation of the WIPP facility have no impact on any threatened or endangered species.

Employees of the WIPP facility continue to consider resident species when planning activities that may impact their habitat, in accordance with the DOE/BLM memorandum of understanding, the Joint Powers Agreement with the State of New Mexico (Appendices C and G of the LMP, respectively), and 50 CFR Part 17, "Endangered and Threatened Wildlife and Plants." An example of this is protection of the Lesser Prairie Chicken (a candidate for listing under the Endangered Species Act) and its habitat in accordance with BLM guidance.

### 5.2.3 Reclamation of Disturbed Lands

Reclamation serves to mitigate the effects of WIPP-related activities on affected plant and animal communities. The objective of the reclamation program is to restore lands used in the operation of the WIPP facility that are no longer needed for those activities. Reclamation is intended to reduce soil erosion, increase the rate of plant colonization and succession, and provide habitat for wildlife in disturbed areas.

The DOE follows a reclamation program and a long-range reclamation plan in accordance with the LMP and specified permit conditions. As locations are identified for reclamation, WIPP personnel reclaim these areas by using the best acceptable reclamation practices. Seed mixes used reflect those species indigenous to the area, with priority given to those plant species that are conducive to soil stabilization, wildlife, and livestock needs.

#### 5.2.4 Oil and Gas Surveillance

Oil and gas activities within 1.6 km (1 mi) of the WIPP site boundary are routinely monitored in accordance with the LMP to identify new activities associated with oil and gas exploration and production, including the following:

- Survey staking
- Geophysical exploration
- Drilling
- Pipeline construction
- Work-overs
- Changes in well status
- Anomalous occurrences (e.g., leaks, spills, accidents)

During 2011, WIPP surveillance teams conducted monthly surveillances and field inspections.

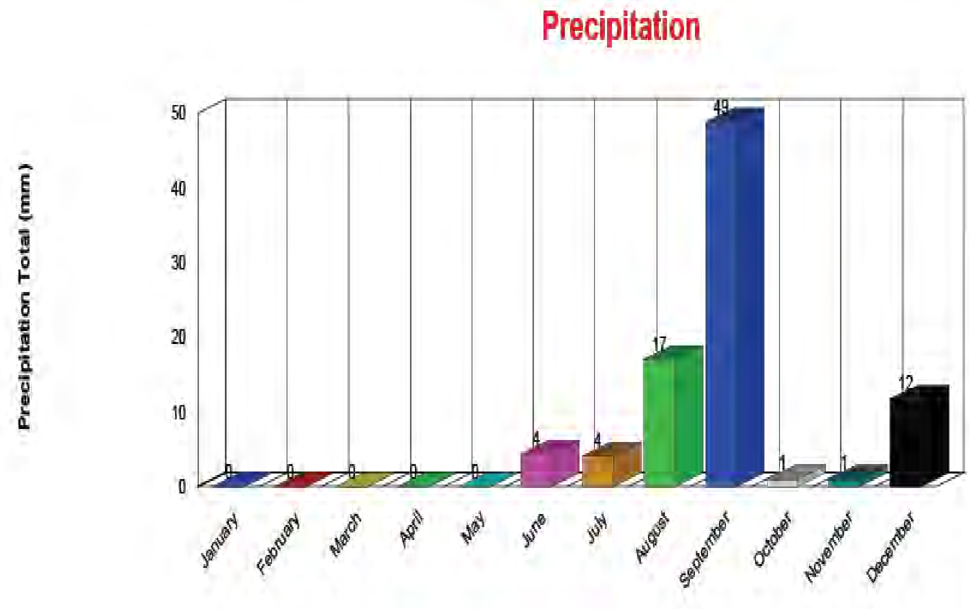
Proposed new well locations staked within one mile of the WIPP site are field-verified. This ensures that the proposed location is of sufficient distance from the WIPP boundary to protect the WIPP site from potential trespass. Six new wells were drilled and completed in 2011 within one mile of the WIPP site boundary. If a well is within 330 feet of the WIPP site boundary, the driller is required to submit daily deviation surveys to the WIPP Land Use Coordinator to assess the horizontal drift of the well bore during drilling. Of the six new wells, four were drilled within 330 ft of the WIPP site boundary. Deviation calculations showed that there were no trespass conditions.

### 5.3 Meteorological Monitoring

The WIPP facility meteorological station is located 600 m (1,970 ft) northeast of the WHB. The main function of the station is to provide data for atmospheric dispersion modeling. The station measures and records wind speed, wind direction, and temperature at elevations of 2, 10, and 50 m (6.5, 33, and 165 ft). Measurements taken at 10 m (33 ft) are provided in this report. The station also records ground-level measurements of barometric pressure, relative humidity, precipitation, and solar radiation.

#### 5.3.1 Weather Data

The precipitation at the WIPP site for 2011 was 87.89 mm (3.46 in.). Figure 5.1 displays the monthly precipitation at the WIPP site.




| Month | Total (mm) |
|---|---|
| January | 0.00 |
| February | 0.00 |
| March | 0.00 |
| April | 0.00 |
| May | 0.00 |
| June | 4.32 |
| July | 4.06 |
| August | 17.02 |
| September | 48.77 |
| October | 1.02 |
| November | 1.02 |
| December | 11.68 |

Figure 5.1 – WIPP Precipitation Report for 2011

The maximum recorded surface temperature (2-m level) at the WIPP site in 2011 was 42.67°C (108.81°F) in June, while the lowest recorded was -19.75°C (-3.55°F) in February. Monthly temperatures are illustrated in Figures 5.2, 5.3, and 5.4. The mean temperature at the WIPP site in 2011 was 18.46°C (65.23°F). The average monthly temperatures for the WIPP area ranged from 30.73°C (87.314°F) during August to 3.78°C (38.80°F) in December (Figure 5.3).

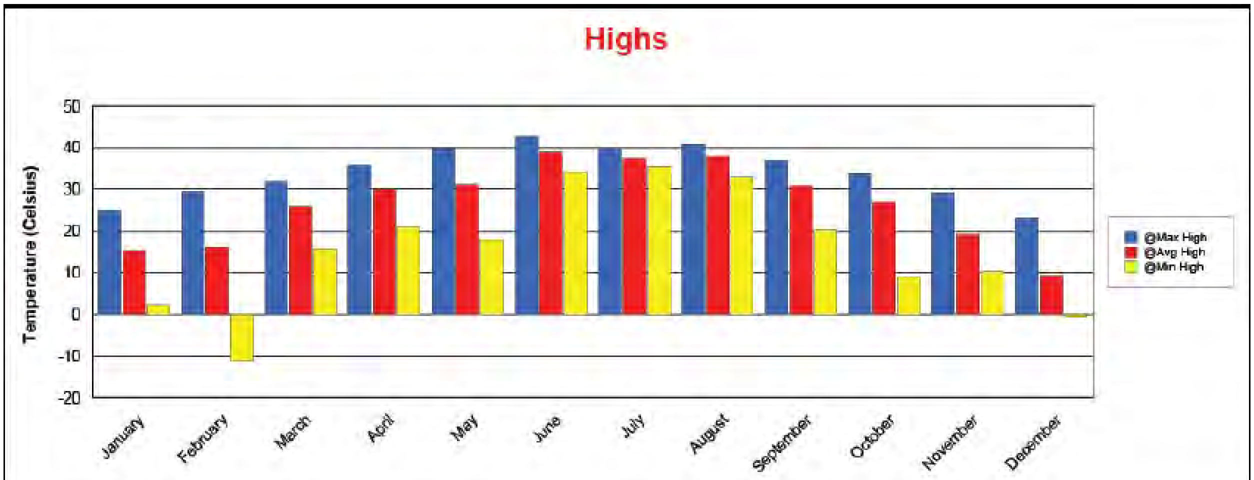
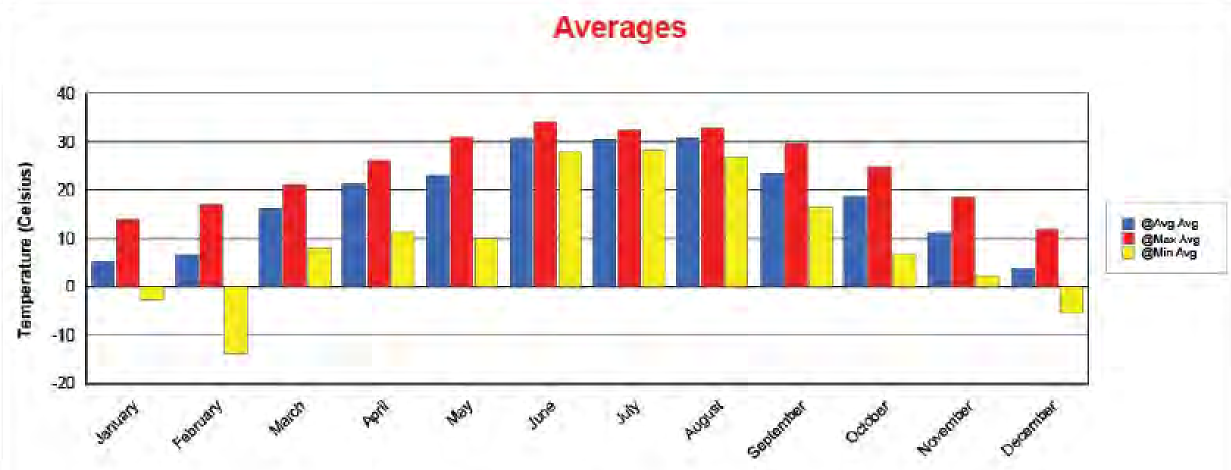



Figure 5.2 – WIPP High Temperatures for 2011




Average Monthly Temperatures

| | | | |
|---|---|---|---|
| January | 5.36 | July | 30.48 |
| February | 6.60 | August | 30.73 |
| March | 16.30 | September | 23.62 |
| April | 21.25 | October | 18.70 |
| May | 22.97 | November | 11.16 |
| June | 30.58 | December | 3.78 |

Figure 5.3 – WIPP Average Temperatures for 2011

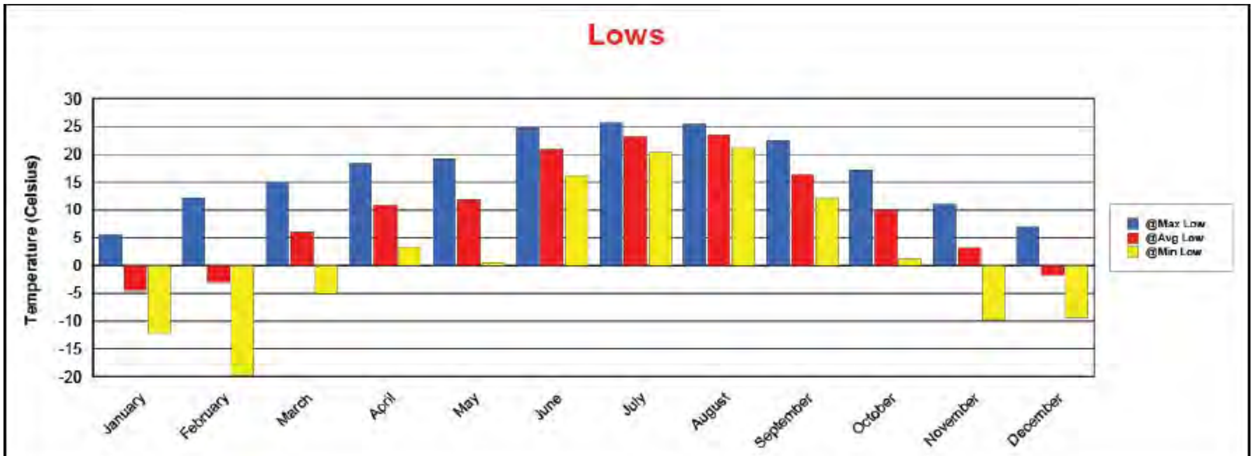
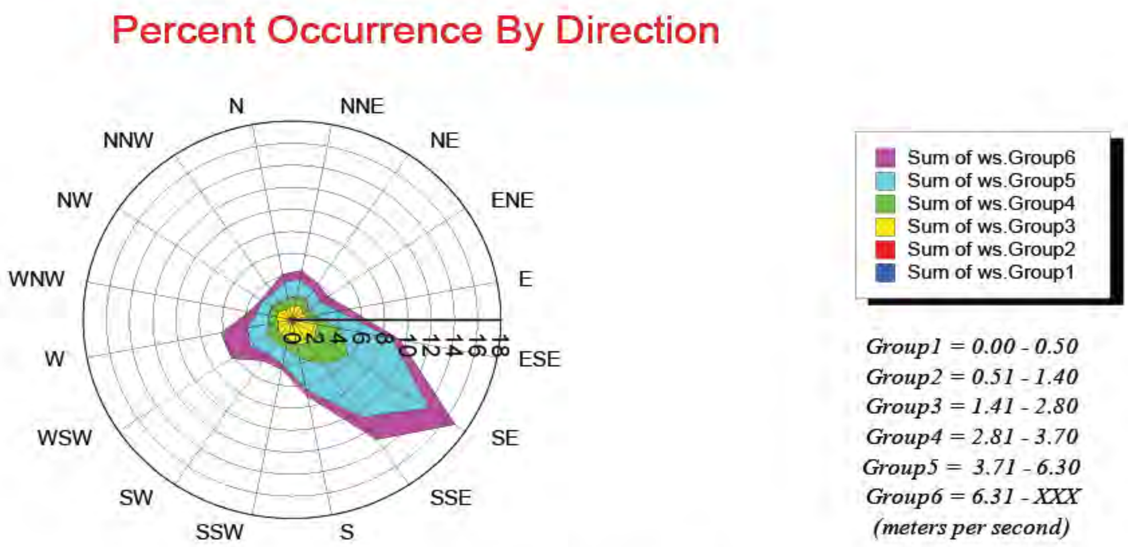



Figure 5.4 – WIPP Average Low Temperatures for 2011

### 5.3.2 Wind Direction and Wind Speed

Winds in the WIPP area are predominantly from the southeast. In 2011, winds of 3.71 to 6.30 meters per second [m/s] (8.30 to 14.09 miles per hour [mph]) were the most prevalent over 2011, occurring approximately 39 percent of the time (measured at the 10-m level). There were no tornadoes at the WIPP site in 2011. Figure 5.5 displays the annual wind data at WIPP for 2011.




| Wind Direction | *Wind Speeds in meters per second* 0.0 - 0.50 | 0.51 - 1.40 | 1.41 - 2.80 | 2.81 - 3.70 | 3.71 - 6.30 | >6.30 | Total Percent Occurrence by Direction |
|---|---|---|---|---|---|---|---|
| **E** | 0.03 | 0.31 | 1.00 | 0.69 | 2.11 | 0.92 | **5.06** |
| **ENE** | 0.03 | 0.29 | 0.77 | 0.63 | 1.23 | 0.80 | **3.75** |
| **NE** | 0.06 | 0.32 | 1.04 | 0.89 | 1.00 | 0.62 | **3.93** |
| **NNE** | 0.03 | 0.28 | 1.03 | 0.89 | 1.53 | 0.78 | **4.54** |
| **N** | 0.02 | 0.21 | 0.93 | 0.73 | 1.62 | 0.72 | **4.23** |
| **NNW** | 0.04 | 0.19 | 0.83 | 0.79 | 1.07 | 0.45 | **3.36** |
| **NW** | 0.02 | 0.27 | 1.08 | 0.77 | 0.95 | 0.11 | **3.20** |
| **WNW** | 0.03 | 0.35 | 0.98 | 0.70 | 1.07 | 0.64 | **3.76** |
| **W** | 0.03 | 0.30 | 0.91 | 0.74 | 1.96 | 2.29 | **6.24** |
| **WSW** | 0.03 | 0.25 | 1.24 | 1.12 | 1.73 | 1.92 | **6.28** |
| **SW** | 0.02 | 0.30 | 1.34 | 0.85 | 1.21 | 0.74 | **4.46** |
| **SSW** | 0.02 | 0.34 | 1.39 | 0.92 | 1.50 | 0.45 | **4.62** |
| **S** | 0.03 | 0.43 | 1.83 | 1.32 | 2.89 | 0.58 | **7.07** |
| **SSE** | 0.04 | 0.41 | 2.09 | 2.36 | 5.77 | 2.42 | **13.08** |
| **SE** | 0.02 | 0.38 | 2.10 | 3.36 | 8.45 | 2.66 | **16.97** |
| **ESE** | 0.02 | 0.38 | 1.74 | 2.08 | 4.59 | 0.65 | **9.45** |
| | **0.48%** | **4.99%** | **20.27%** | **18.84%** | **38.68%** | **16.75%** | **100.00%** |

Figure 5.5 – Wind Speed (at 10-m level) Report for 2011

## 5.4 Volatile Organic Compound Monitoring

VOC monitoring was implemented on April 21, 1997, in accordance with WP 12-VC.01, Confirmatory Volatile Organic Compound Monitoring Program. This program is a requirement of the Permit. VOC monitoring is performed to verify that VOCs emitted by the waste are within the concentration limits specified by the Permit.

Nine target compounds, which contribute approximately 99 percent of the calculated human health risks from RCRA constituents, were chosen for monitoring. These target compounds are shown in Table 5.1.

**Table 5.1 – Concentrations of Concern for Volatile Organic Compounds, from Part 4 of the Permit (No. NM4890139088-TSDF)**

| Compound | Concentration of Concern ppbv[a] | Room-Based Limits ppmv[b] |
|---|---|---|
| 1,1,1-Trichloroethane | 590 | 33,700 |
| 1,1,2,2-Tetrachloroethane | 50 | 2,960 |
| 1,1-Dichloroethylene | 100 | 5,490 |
| 1,2-Dichloroethane | 45 | 2,400 |
| Carbon tetrachloride | 960 | 9,625 |
| Chlorobenzene | 220 | 13,000 |
| Chloroform | 180 | 9,930 |
| Methylene chloride | 1,930 | 100,000 |
| Toluene | 190 | 11,000 |

(a) Parts per billion by volume

(b) Parts per million by volume

On November 16, 2006, additional Permit conditions were implemented, requiring the addition of disposal room VOC monitoring to the program. This new requirement included the addition of sampling locations within active underground hazardous waste disposal units (HWDUs). Within each active underground HWDU, two sampling locations are required for each filled room, one at the exhaust side of the room and one at the inlet side of the room. In addition, each room actively receiving waste is required to be sampled at the exhaust side of the room. The sampling frequency for disposal rooms is once every two weeks. Typical disposal room VOC sampling locations are shown in Figure 5.6. For 2011, Sampling in panel 5 included two locations in rooms 7, 6, 5, 4, 3, and 2, while room 1 had one location at the exhaust side. Sampling in panel 6 included two locations in room 7, while rooms 6 and 5 had one location at the exhaust side.

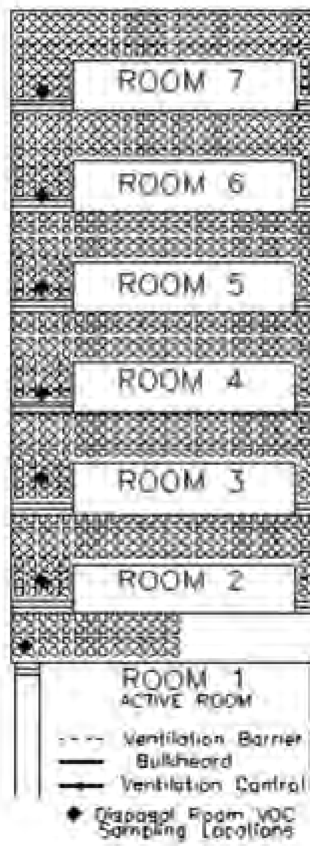



Figure 5.6 – Typical Disposal Room Volatile Organic Compound Sampling Locations

On March 25, 2008, new permit conditions were added, requiring ongoing disposal room VOC monitoring in "filled" panels (panels in which waste emplacement is complete). This included continued VOC monitoring in room 1 of the filled panel. The sampling frequency for ongoing disposal room monitoring is once per month. For 2011, ongoing disposal room monitoring was conducted in panels 3 and 4. Panel 5 was not subject to ongoing disposal room monitoring since block walls were installed in the intake and exhaust sides of the panel upon completion of waste disposal activities.

Repository VOC sampling for target compounds is performed semiweekly at two ambient air monitoring stations, VOC-A, located downstream from HWDU panel 1 in Drift E300, and VOC-B, located upstream from the active panel. As waste is placed in new panels, VOC-B will be relocated to ensure that it samples underground air before it passes the waste panels. The location of VOC-A is not anticipated to change.

Target compounds found in VOC-B are not attributable to open or closed panels. The VOC concentrations measured at this location are VOCs entering the mine through the air intake shaft and VOCs contributed by facility operations upstream of the waste panels. Differences measured between the two stations represent any VOC contributions from the waste panels. Any positive concentration differences in the annual averages between the two stations must be less than the concentrations of concern listed in the Permit (Table 5.1).

As a basis, VOC sampling reported in this section was performed using guidance included in Compendium Method TO-15, *Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially-Prepared Canisters and Analysis By Gas Chromatography/Mass Spectrometry* (GC/MS) (EPA, 1999). The samples were analyzed using gas chromatography/mass spectrometry under an established QA/QC program. Laboratory analytical procedures were developed based on the concepts contained in both TO-15 and the draft EPA Contract Laboratory Program Volatile Organics Analysis of Ambient Air in Canisters (EPA, 1994).

For repository VOC sampling, the routine method reporting limits (MRLs) and maximum concentrations detected (MCDs) are shown in Table 5.2. It should be noted that the MRLs are between 20 times and 386 times lower than the respective concentrations of concern for the nine target compounds.

The results of 2011 VOC monitoring are reported in the *Semiannual VOC, Hydrogen, and Methane Data Summary Report* [DOE/WIPP-11-3443]. For the repository VOC monitoring, the results in 2011, compared to 2010 (DOE/WIPP-10-3443), indicated a slight increase in annual average for 1,1,1-tricholoroethaneand CCl4, as well as slight increases in the maximum detected concentrations for CCl4 and chloroform in air downstream of panel 1. The running maximum values for annual average concentration differences are found in Table 5.2. This shows that at no time during 2011 did the running annual average exceed the concentrations of concern (Table 5.1). Table 5.2 also shows that none of the individual sample sets (VOC-A and VOC-B) exceeded the concentrations of concern (Table 5.1) as an annual average or as individual sample sets.

**Table 5.2 – Repository Air Volatile Organic Compound Method Reporting Limits and Maximum Concentrations Detected**

| Compound | Method Reporting Limit (ppbv)* | Running Annual Average Concentration Max. Value (ppbv) | MCD (ppbv)* |
|---|---|---|---|
| 1,1,1-Trichloroethane | 5 | 25.7 | 82.11 |
| 1,1,2,2-Tetrachloroethane | 2 | <MRL | ND |
| 1,1-Dichloroethylene | 5 | <MRL | ND |
| 1,2-Dichloroethane | 2 | <MRL | ND |
| Carbon Tetrachloride | 2 | 182.4 | 641.1 |
| Chlorobenzene | 2 | <MRL | ND |
| Chloroform | 2 | 16.9 | 56.3 |
| Methylene chloride | 5 | <MRL | 16.89 |
| Toluene | 5 | <MRL | ND |

* ppbv = parts per billion by volume
ND = Non-Detect

For disposal room VOC monitoring, routine MRLs and MCDs are shown in Table 5.3. Six of the nine target compounds were detected above the MRL. The sample results indicated an increase in MCDs in disposal rooms for 1,1,1-trichloroethane, 1,1-dichloroethylene, CCl4, chloroform, methylene chloride, and toluene. During 2011, disposal room samples in panel 5 yielded 32 samples that exceeded the 50 percent action level for CCl4. None of the samples exceeded the 95 percent action level. Upon completion of waste disposal activities in panel 5, block walls were constructed in the intake and exhaust of the panel.

**Table 5.3 – Disposal Room Volatile Organic Compound Method Reporting Limits and Maximum Concentrations Detected**

| Compound | MRL (ppmv) | MCD (ppmv) |
|---|---|---|
| 1,1,1-Trichloroethane | 0.5 | 313 |
| 1,1,2,2-Tetrachloroethane | 0.5 | <MDL |
| 1,1-Dichloroethylene | 0.5 | 4.7 |
| 1,2-Dichloroethane | 0.5 | <MDL |
| Carbon tetrachloride | 0.5 | 8,935 |
| Chlorobenzene | 0.5 | <MDL |
| Chloroform | 0.5 | 896 |
| Methylene chloride | 0.5 | 86 |
| Toluene | 0.5 | 9.4 |

ppmv = parts per million by volume

Ongoing disposal room VOC monitoring was conducted in panels 3 and 4 during 2011. None of the samples yielded concentrations exceeding the action levels. Ongoing disposal room VOC monitoring results are listed in Table 5.4.

**Table 5.4 – Ongoing Disposal Room Volatile Organic Compound Method Reporting Limits and Maximum Concentrations Detected**

| Compound | MRL (ppmv) | MCD (ppmv) |
|---|---|---|
| 1,1,1-Trichloroethane | 0.5 | 156 |
| 1,1,2,2-Tetrachloroethane | 0.5 | <MDL |
| 1,1-Dichloroethylene | 0.5 | 1 |
| 1,2-Dichloroethane | 0.5 | <MDL |
| Carbon tetrachloride | 0.5 | 798 |
| Chlorobenzene | 0.5 | <MDL |
| Chloroform | 0.5 | 68.1 |
| Methylene chloride | 0.5 | 40.6 |
| Toluene | 0.5 | 2 |

ppmv = parts per million by volume

## 5.5 Hydrogen And Methane Monitoring

Hydrogen and methane monitoring in "filled" panels 3 through 7 was included as a new Permit condition on March 25, 2008. Hydrogen and methane are required to be monitored at two locations in each room and at four additional bulkhead locations in the panel area upon the completion of waste emplacement in each panel unless an explosion isolation wall is constructed in the panel. Monitoring is required monthly at each location. In April 2008, this Permit condition was implemented. In 2011, hydrogen and methane monitoring was conducted in panels 3 and 4.

Hydrogen and methane samples are analyzed using gas chromatography with thermal conductivity detection under an established QA/QC program. Specialized laboratory analytical procedures were developed based on standard laboratory techniques and approved through established QA processes.

For samples collected between January 1, 2011, and December 31, 2011, the maximum detected value for hydrogen, 947 ppmv, was considerably lower than the action levels (less than 24 percent of Action Level 1 and less than 12 percent of Action Level 2, as shown in Table 5.5). None of the samples contained methane.

**Table 5.5 – Hydrogen and Methane Method Reporting Limits Action Levels and Maximum Concentrations Detected**

| Compound | MRL (ppmv) | Action Level 1 | Action Level 2 | MCD (ppmv) |
|---|---|---|---|---|
| Hydrogen | 0.5 | 4,000 | 8,000 | 947 |
| Methane | 0.5 | 5,000 | 10,000 | N/A |

ppmv = parts per million by volume

## 5.6 Seismic Activity

Currently, seismicity within 300 km (186 mi) of the WIPP site is being monitored by the New Mexico Institute of Mining and Technology (NMIMT) using data from a nine-station network approximately centered on the site (Figure 5.7). Station signals are transmitted to the NMIMT Seismological Observatory in Socorro, New Mexico. When appropriate, readings from the WIPP network stations are combined with readings from an additional NMIMT network in the central Rio Grande Rift. Occasionally, data are also exchanged with the University of Texas at El Paso and Texas Tech University in Lubbock, both of which operate monitoring stations in west Texas.

The mean operational efficiency of the WIPP seismic monitoring stations during 2011 was approximately 89.3 percent. From January 1 through December 31, 2011, locations for 185 seismic events were recorded within 300 km (186 mi) of the WIPP site. Recorded data included origin times, epicenter coordinates, and magnitudes. The strongest recorded event (magnitude 3.9) occurred on September 11, 2011, and was located approximately 288 km (179 mi) northeast of the site. The closest event to the site was located approximately 14 km (9 mi) southwest and had a magnitude of 1.6. These events had no effect on WIPP structures.

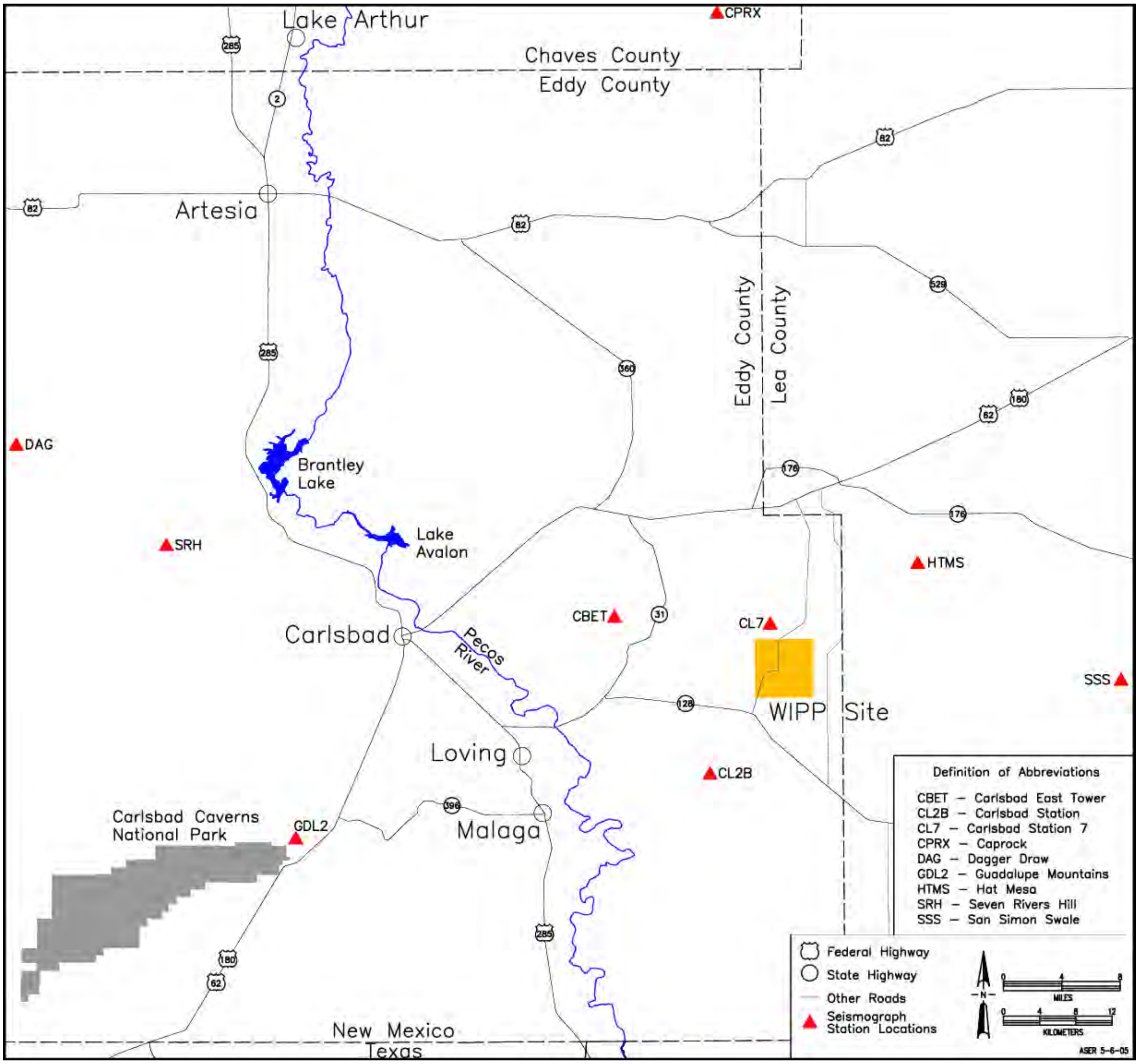



Figure 5.7 – Seismograph Station Locations in the Vicinity of the WIPP Site

## 5.7 Liquid Effluent Monitoring

The NMED Ground and Surface Water Protection regulations set forth in 20.6.2 NMAC regulate discharges that could impact surface water or groundwater. DOE compliance with the Ground and Surface Water Protection Regulations is discussed in Chapter 2. The discharge permit was renewed on September 9, 2008. A modification to the discharge permit was submitted on November 15, 2009, to incorporate a new pond into the permit (the Salt Storage Extension Basin II) that was built to provide additional holding and evaporation capacity for runoff from the active Salt Storage Area. Analytical data from the discharge monitoring reports are summarized in Table 5.6 and Table 5.7, respectively.

**Table 5.6 – Sewage Lagoon and H-19 Analytical Results for January through June 2011**

| Analyte | Influent Pond 2A | Evaporation Pond B | Evaporation Pond C | H-19 Evaporation Pond |
|---|---|---|---|---|
| Nitrate (mg/L) | ND | N/A | N/A | N/A |
| TKN (mg/L) | 92 | N/A | N/A | N/A |
| TDS (mg/L) | 490 | 609,000 | NS | NS |
| Sulfate (mg/L) | 60 | 63,000 | NS | NS |
| Chloride (mg/L) | 540 | 280,000 | NS | NS |

N/A – The analytical parameter not required.

ND – Non-Detect

NS – Not Sampled

TKN –Total Kjeldahl Nitrogen (as N)

TDS – Total dissolved solids

**Table 5.7 – Sewage Lagoon, H-19, and Infiltration Control Pond Analytical Results for July through December 2011**

| Location | Nitrate (mg/L) | TKN (mg/L) | TDS (mg/L) | Sulfate (mg/L) | Chloride (mg/L) |
|---|---|---|---|---|---|
| Influent Pond 2A | ND | ND | 478 | 54 | 96 |
| Evaporation Pond B | N/A | N/A | 400,000 | 63,000 | 310,000 |
| Evaporation Pond C | N/A | N/A | NS | NS | NS |
| H-19 Evaporation Pond | N/A | N/A | NS | NS | NS |
| Salt Pile Evaporation Pond | N/A | N/A | NS | NS | NS |
| Salt Storage Extension Evaporation Basin I | N/A | N/A | 359,000 | 19,000 | 230,000 |
| Salt Storage Extension Evaporation Basin II | N/A | N/A | 423,000 | 110,000 | 430,000 |
| Pond 1 | N/A | N/A | NS | NS | NS |
| Pond 2 | N/A | N/A | 14,200 | 270 | 8,100 |
| Pond A | N/A | N/A | 3,090 | 330 | 1,800 |

N/A – The analytical parameter not required.

ND – Non-Detect

NS – Not Sampled

TKN –Total Kjeldahl Nitrogen (as N)

TDS – Total dissolved solids

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# CHAPTER 6 – SITE HYDROLOGY, GROUNDWATER MONITORING, AND PUBLIC DRINKING WATER PROTECTION

Current groundwater monitoring activities for the WIPP facility are outlined in the *WIPP Groundwater Monitoring Program Plan* (WP 02-1). In addition, the WIPP facility has detailed procedures for performing specific activities, such as pumping system installations, field parameter analyses and documentation, and QA records management. Groundwater monitoring activities are also included in the *Waste Isolation Pilot Plant Environmental Monitoring Plan* (DOE/WIPP-99-2194).

## 6.1 Site Hydrology

The hydrology at and surrounding the WIPP site has been studied extensively over the last 30 years. A summary of the hydrology in this area is contained in the following sections. Figure 6.1 shows the stratigraphy at the site.

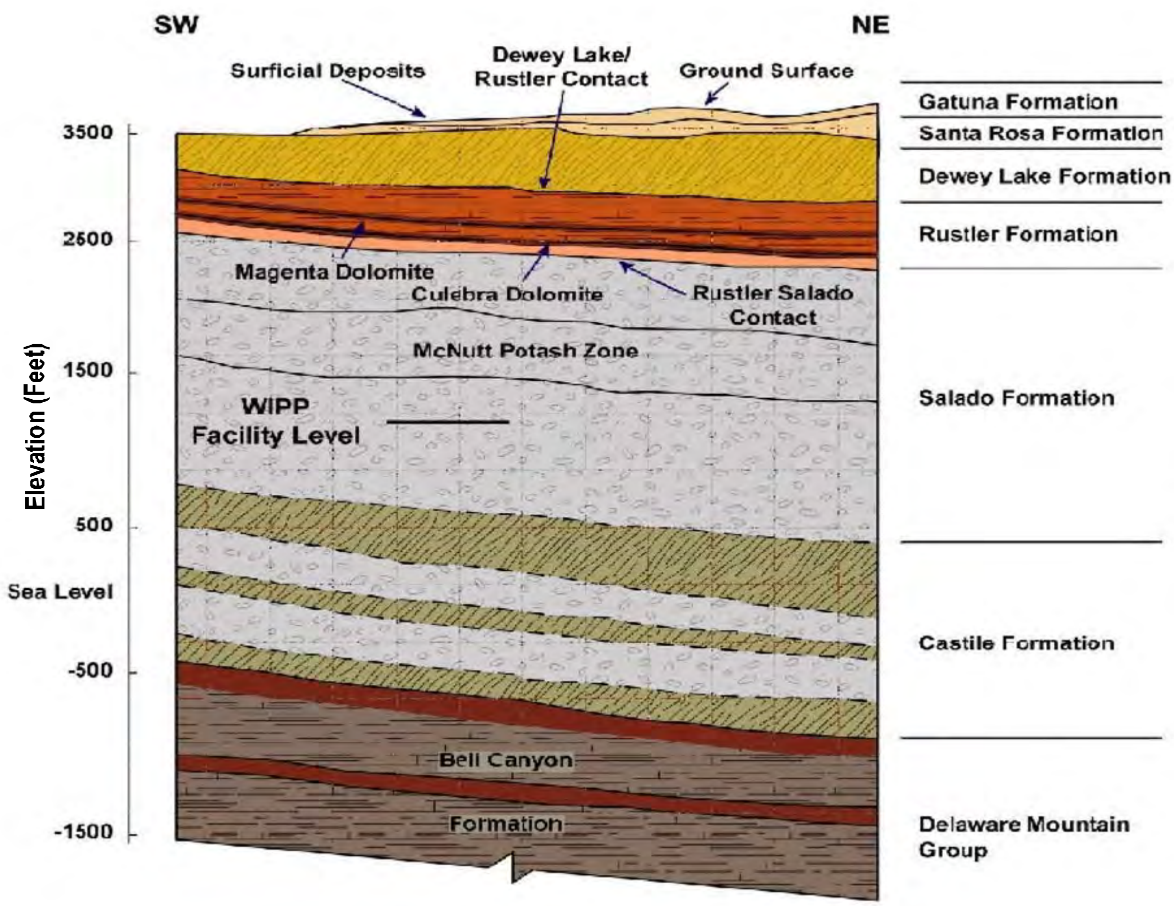


Figure 6.1 – WIPP Stratigraphy

### 6.1.1 Surface Hydrology

Surface water is absent at the WIPP site. The nearest significant surface water body, Laguna Grande de la Sal, is 13 km (8 mi) west-southwest of the center of the WIPP site in Nash Draw, where shallow brine ponds occur. Small, manmade livestock watering holes ("tanks") occur several km from the WIPP site, but are not hydrologically connected to the formations overlying the WIPP repository.

### 6.1.2 Subsurface Hydrology

Several water-bearing zones have been identified and extensively studied at and near the WIPP site. Limited amounts of potable water are found in the middle Dewey Lake and the overlying Triassic Dockum group in the southern part of the WIPP LWA. Two water-bearing units, the Culebra and Magenta Dolomite Member (Magenta), occur in the Rustler Formation (Rustler) and produce brackish to saline water at and in the vicinity of the site. Another very low transmissivity, saline water-bearing zone is the Rustler-Salado contact.

#### 6.1.2.1 Hydrology of the Castile Formation

The Castile Formation (Castile) is composed of a sequence of three thick anhydrite beds separated by two thick halite beds. This formation acts as an aquitard, separating the Salado from the underlying water-bearing sandstones of the Bell Canyon Formation. In the halite zones, the occurrence of circulating groundwater is restricted because halite at these depths does not readily maintain secondary porosity, open fractures, or solution channels.

No regional groundwater flow system has been found in the Castile in the vicinity of the WIPP site. The only significant water present in the formation occurs in isolated brine reservoirs in fractured anhydrite. Wells have encountered pressurized brine reservoirs in the upper anhydrite unit of the Castile in the vicinity of the WIPP site. Two such encounters have been made by boreholes drilled for the WIPP project: (1) ERDA 6, northeast of the WIPP site, encountered a pressurized brine reservoir in 1975; and (2) borehole WIPP-12, one mile north of the center of the WIPP site, encountered a brine reservoir in 1981. Both encounters were hydrologically and chemically tested in 1981 and determined to be unconnected (Popielak et al., 1983).

#### 6.1.2.2 Hydrology of the Salado Formation

The massive halite beds within the Salado host the WIPP facility horizon. The Salado represents a regional aquiclude due to the hydraulic properties of the bedded halite that forms most of the formation. In the halites, the presence of circulating groundwater is restricted because halites do not readily maintain primary porosity, solution channels, or open fractures.

The results of permeability testing, both within the facility and from the surface, are generally consistent with a hydraulic conductivity of the undisturbed salt mass of less than 6.5E-09 meters per day (m/d) (2.1E-08 feet per day (ft/d)), with the more pure (less argillaceous) halites having even lower permeability. Anhydrite interbeds typically have hydraulic conductivities ranging from 6.5E-09 m/d to 6.5E-07 m/d (2.1E-08 to 2.1E-06 ft/d) (Beauheim and Roberts, 2002). The only significant variation to these extremely low permeabilities occurs in the immediate vicinity of the underground workings (Stormont et al., 1991). This increase is believed to be a result of near-field fracturing due to the excavation.

Small quantities of brine have been observed to collect in boreholes drilled into Marker Bed 139 a few ft below the floor of the WIPP underground repository rooms and have also been observed to seep out of the excavated walls. The long-term performance assessment for the WIPP disposal system assumes that small quantities of brine will be present in the WIPP repository.

#### 6.1.2.3 Hydrology of the Rustler-Salado Contact

In Nash Draw and areas immediately west of the site, the Rustler-Salado contact exists as a dissolution residue capable of transmitting water. Eastward from Nash Draw toward the WIPP site, the amount of dissolution decreases and the transmissivity of this interval decreases (Mercer, 1983). Small quantities of brine were found in the test holes in this zone at the WIPP site (Mercer and Orr, 1977).

#### 6.1.2.4 Hydrology of the Culebra Member

The Culebra is the most transmissive hydrologic unit in the WIPP site area and is considered the most significant potential hydrologic pathway for a radiologic release to the accessible environment.

Tests show that the Culebra is a fractured, heterogeneous system with varying local anisotropic characteristics (Mercer and Orr, 1977; Mercer, 1983; Beauheim, 1986, 1987; Beauheim and Ruskauff, 1998). Calculated transmissivities for the Culebra within the WIPP site boundary have a wide range, with values between 1.2E-08 square meters per day ($m^2$/d) to approximately 112 $m^2$/d (1.29E-07 $ft^2$/d to 1.20E03 $ft^2$/d); the majority of the values are less than 9.3E-02 $m^2$/d (1 $ft^2$/d) (DOE/WIPP-09-3424; *Compliance Recertification Application, Appendix HYDRO*, 2009). Transmissivities generally decrease from west to east across the site area, with a relatively high transmissivity zone trending southeast from the center of the WIPP site to the site boundary. The regional flow direction of groundwater in the Culebra is generally south.

#### 6.1.2.5 Hydrology of the Magenta Member

The Magenta is situated above the Culebra and, though not the water-bearing zone of interest for monitoring of a facility release, it is of interest in understanding water-level changes that occur in the Culebra. The Magenta has been tested in 18 cased and open holes at and around the WIPP site. Magenta transmissivities within the WIPP site range from 2.0E-04 to 3.5E-02 $m^2$/d (2.1E-03 to 3.8E-01 $ft^2$/d) (Beauheim et al., 1991; Beauheim and Ruskauff, 1998; SNL, 2003; Bowman and Roberts, 2009).

#### 6.1.2.6 Hydrology of the Dewey Lake Redbeds Formation

The Dewey Lake at the WIPP site is approximately 152 m (500 ft) thick and consists of alternating thin beds of siltstone and fine-grained sandstone. The upper Dewey Lake consists of a thick, generally unsaturated section. The middle Dewey Lake is the interval immediately above a cementation change, from carbonate (above) to sulfate (below), where saturated conditions and a natural water table have been identified in limited areas. An anthropogenic saturated zone has been observed in the overlying Santa Rosa Formation (Santa Rosa) and in the upper part of the Dewey Lake since 1995. This is described in section 6.6. The lower Dewey Lake is below the sulfate cementation change, with much lower permeabilities.

WIPP monitoring well WQSP-6A (see Figure 6.2) intersects natural water in the Dewey Lake. At this location, the saturated horizon is within the middle portion of the formation. The saturated zone at well WQSP-6A is both vertically and laterally distinct from the water at C-2811 (see section 6.6 for a full discussion of SSW). Well C-2811 is located approximately one mile (1.61 km) to the northeast of WQSP-6A on the C-2737 well pad (see Figure 6.2). Approximately one mile south of the WIPP site, domestic and stock supply wells produce water from the middle Dewey Lake.

#### 6.1.2.7 Hydrology of the Santa Rosa and Gatuña Formations

Within the WIPP site boundary, the Santa Rosa is relatively thin to absent. At the Air Intake Shaft, 0.6 m (2 ft) of rock is classified as the Santa Rosa. The Santa Rosa is a maximum of 78 m (255 ft) thick in exploratory potash holes drilled for WIPP, east of the site boundary. The Santa Rosa is thicker to the east. The geologic data from design studies have been incorporated with data from drilling to investigate SSW in the Santa Rosa to provide structure and thickness maps of the Santa Rosa in the vicinity of the WIPP surface structures area. These results are consistent with the broader regional distribution of the Santa Rosa (Compliance Recertification Application, DOE/WIPP-04-3231).

Water in the Santa Rosa has been found in the center part of the WIPP site since 1995, and because no water was found in this zone during the mapping of the shafts in 1980s, this water is deemed to be caused by human activity (Daniel B. Stephens & Associates, Inc., 2003). To assess the quantity and quality of this water, piezometers PZ-1 to PZ-12 were installed in the area between the WIPP shafts. Also, wells C-2505, C-2506, and C-2507 were drilled and tested in 1996 and 1997 (*Exhaust Shaft Hydraulic Assessment Data Report*, DOE/WIPP-97-2219). These wells are shown in Figure 6.15. During October 2007, three additional piezometers (PZ-13, PZ-14, and PZ-15) were installed around the site and preliminary design validation (SPDV) tailings pile to evaluate the nature and extent of SSW around this area.

The Gatuña Formation (Gatuña) unconformably overlies the Santa Rosa at the WIPP site. This formation ranges in thickness from approximately 6 to 9 m (19 to 31 ft) at the WIPP site and consists of silt, sand, and clay, with deposits formed in localized depressions during the Pleistocene period.

The Gatuña is water-bearing in some areas, with saturation occurring in discontinuous perched zones. However, because of its erratic distribution, the Gatuña has no known continuous saturation zone. Drilling at the WIPP site, including 30 exploration borings drilled between 1978 and 1979, did not identify any saturated zones in the Gatuña (Daniel B. Stephens & Associates, Inc., 2003).

## 6.2 Groundwater Monitoring

### 6.2.1 Program Objectives

The objectives of the groundwater monitoring program are to:

- Monitor the physical and chemical characteristics of groundwater;
- Maintain surveillance of groundwater levels surrounding the WIPP facility throughout the operational lifetime of the facility; and
- Document and identify effects, if any, of WIPP operations on groundwater parameters throughout the operational lifetime (including closure) and post-closure of the facility.

Data obtained by the WIPP groundwater monitoring program support two major regulatory programs: (1) the RCRA DMP supporting the Permit in compliance with 20.4.1.500 NMAC (incorporating 40 CFR Part 264, Subpart F, "Releases From Solid Waste Management Units;" and 40 CFR Part 264 Subpart X, "Miscellaneous Units"), and (2) performance assessment supporting the *Compliance Certification Application for the Waste Isolation Pilot Plant* (DOE/CAO-96-2184) and five-year recertification applications.

Baseline water chemistry data were collected from 1995 through 1997 and reported in the *Waste Isolation Pilot Plant RCRA Background Groundwater Quality Baseline Report* (DOE/WIPP-98-2285). The baseline data were expanded in 2000 to include 10 Rounds of sampling instead of five. The data were published in Addendum 1, *Waste Isolation Pilot Plant RCRA Background Groundwater Quality Baseline Update Report* (IT Corporation, 2000). These baseline data are compared to water quality data collected semiannually.

### 6.2.2 Summary of 2011 Activities

Routine groundwater monitoring activities include groundwater quality sampling, groundwater level monitoring, and the pressure density survey, as described in this section. These annual programs are required by the Permit. Activities supported during 2011 included hydraulic testing and non-Permit groundwater quality sampling (section 6.4), and well maintenance (section 6.5). Table 6.1 presents a summary of WIPP DMP groundwater monitoring well analyses for organic and metal constituents in 2011. In addition to the constituent analyses shown in Table 6.1, the DMP groundwater samples were analyzed for general chemistry parameters including alkalinity, anions (nitrate, chloride, and sulfate), pH, specific gravity, specific conductance, total dissolved solids, total suspended solids, total organic carbon, and the cation metals (Ca, Mg, K, and Na).

Wells are classified as environmental surveillance wells. The WIPP facility does not have wells required for remediation, waste management, or other requirements. Appendix F, Table F.8, lists active groundwater monitoring wells used by the DOE for the WIPP facility at the end of 2011.

Radiological data for 2011 from the DMP are summarized in Chapter 4. The remaining data from the DMP are contained in this chapter.

**Table 6.1 – Summary of 2011 DOE WIPP Region Groundwater Monitoring Program**

| | **Environmental Surveillance** |
|---|---|
| Number of Active Wells | 84 |
| Number of Samples Taken | 24[a] |
| Number of Water Level Measurements | 785 |
| Number of Analyses Performed for Constituents | 104[b] |
| Total Number of Individual Constituent Sample Measurements | 1568[c] |
| % of Individual Constituent Analyses that were Non-Detects | 94%[d] |
| Total Number of Individual General Chemistry Parameter Sample Measurements | 360 |
| Percent of Individual General Chemistry Parameters that Were Non-Detects | 6.7[e] |

(a) Primary and duplicate samples taken from six wells during two rounds in 2011, with 43 constituents analyzed per sample.

(b) Includes volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), trace metals, and mercury. VOCs were analyzed in field blanks and trip blanks at each well, and trace metals and mercury were analyzed in preserved and unpreserved field blanks at four wells.

(c) Constituent analyses included 19 VOCs by gas chromatography/mass spectrometry (GC/MS),10 SVOCs by GC/MS, 13 trace metals by inductively coupled plasma emission spectroscopy (ICP), and mercury by cold vapor atomic absorption spectroscopy (CVAAS).

(d) Nearly all of the constituent detects were at trace concentrations near the method detection limit (MDL) of the analytical methods.

(e) The only non-detects for the general chemistry parameters were for the anion nitrate.

Regular monthly groundwater level data were gathered from 58 wells across the WIPP region (Figure 6.2), one of which is equipped with a production-injection packer (PIP) to allow groundwater level surveillance of more than one hydrologic zone in the same well. The six redundant wells on the H-19 pad, the 19 shallow water wells, and H-3D, which was dry (for "SR/DL" [Santa Rosa/Dewey Lake contact] listed in Appendix F, Table F.8), were measured quarterly. Table F.9 shows the water level data. Water level data were not taken where access was poor, or in certain wells when testing equipment was present.

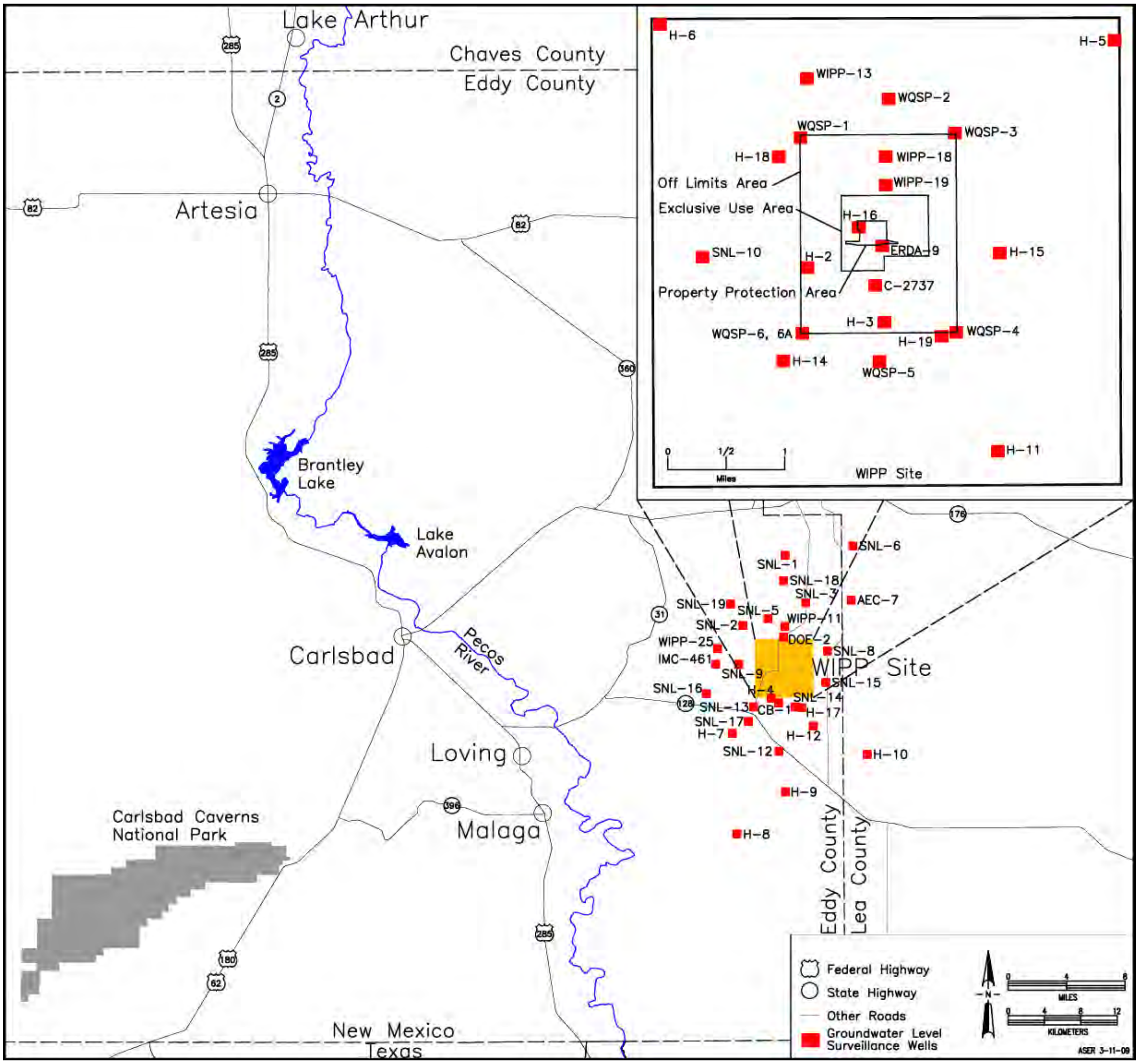


Figure 6.2 – Groundwater Level Surveillance Wells (Inset Represents the Groundwater Surveillance Wells in the WIPP Land Withdrawal Area)

### 6.2.3 Groundwater Quality Sampling

The Permit required groundwater quality sampling twice a year, from March through May (Round 32 for 2011), and again from September through November (Round 33 for 2011). Sampling for groundwater quality was performed at six well sites (Figure 6.3). Field analyses for oxygen-reduction potential, pH, specific gravity, specific conductance, temperature, acidity or alkalinity, chloride, divalent cations, and total iron were performed periodically during the sampling.

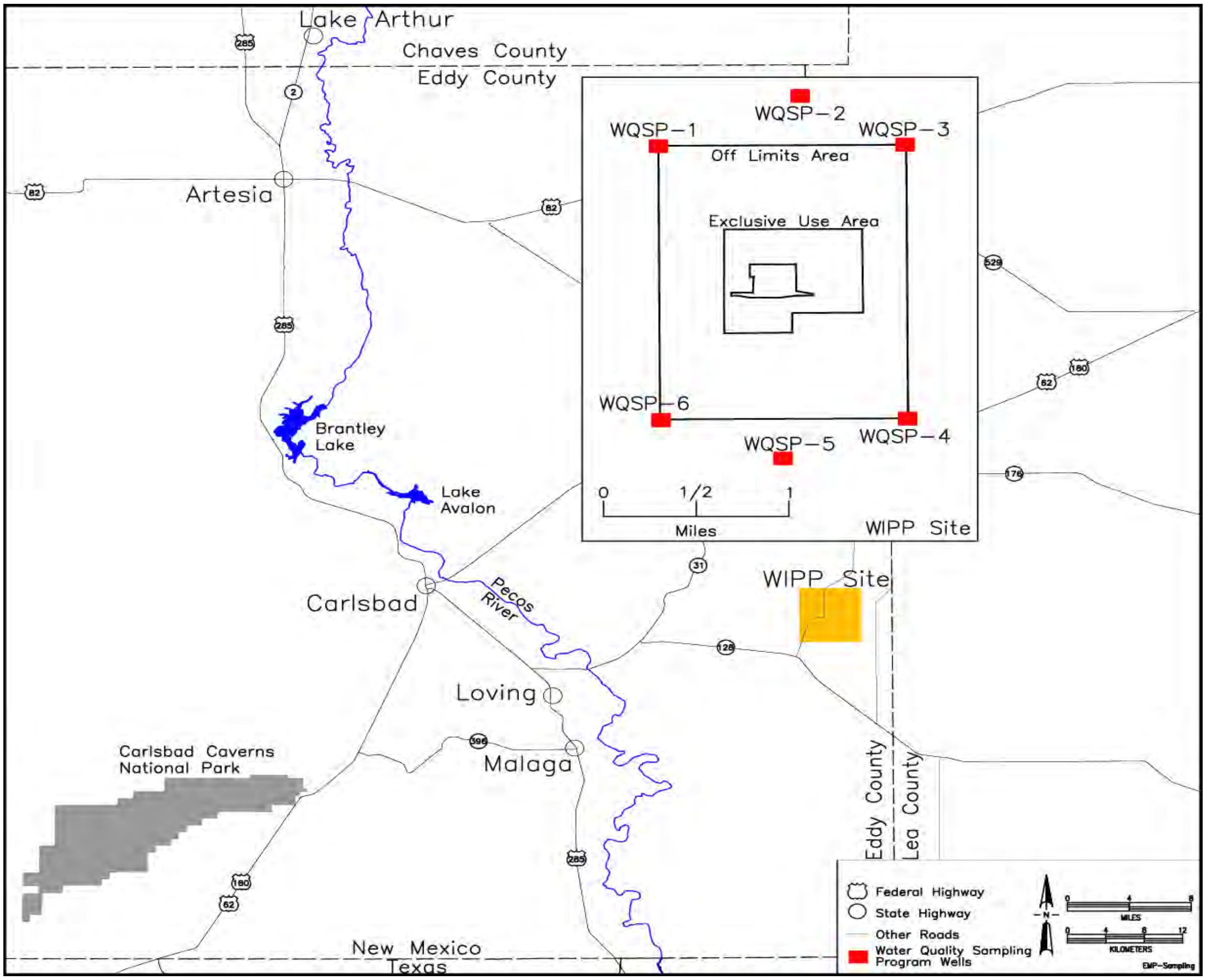


Figure 6.3 – Detection Monitoring Program Wells

Primary and duplicate samples for groundwater quality were taken from each of the six wells completed in the Culebra (WQSP-1 through WQSP-6), for a total of 12 samples analyzed per sampling Round.

Wells WQSP-1, WQSP-2, and WQSP-3 are located upgradient of the WIPP shaft. The locations of the wells were selected to be representative of the groundwater moving downgradient onto the WIPP site. Wells WQSP-4, WQSP-5, and WQSP-6 are located downgradient of the WIPP shaft. WQSP-4 was also specifically located to monitor a zone of higher transmissivity.

The difference between the depth of the WIPP repository and the depth of the WQSP wells completed in the Culebra varies from 387 m to 587 m (1,271 ft to 1,925 ft). The DOE does not anticipate finding WIPP-related contamination in the groundwater because a release from the repository to the Culebra is highly unlikely. In order for contaminated liquid to move from the repository to the Culebra, three conditions would have to be met. First, sufficient brine would have to accumulate in the waste disposal areas to leach contaminants from the disposed waste. Second, sufficient pressure would have to build up in the disposal area to overcome the hydrostatic head between the repository and the Culebra. Third, a pathway would have to exist and remain open for contaminated brine to flow from the repository to the Culebra. Since the times required for the brine accumulation and repository pressurization are on the order of thousands of years, and current plans call for the sealing of the shafts and boreholes that could potentially become such pathways upon closure of the facility, WIPP-related contamination of the groundwater is highly unlikely.

Table 6.2 lists the analytical parameters included in the 2011 groundwater sampling program.

### 6.2.4 Evaluation of Culebra Groundwater Quality

The quality of the Culebra groundwater sampled at the WIPP site is naturally poor and not suitable for human consumption or for agricultural purposes, because the TDS concentrations are generally above 10,000 mg/L. In 2011, average TDS concentrations in the Culebra (as measured in WQSP wells) varied from a low of 15,325 mg/L (WQSP-6) to a high of 216,000 mg/L (WQSP-3). The groundwater of the Culebra is considered to be Class III water (non-potable) by EPA guidelines.

For comparison, water quality measurements performed in the Dewey Lake indicate that the water is considerably better quality than that in the Culebra. In 2011, the TDS concentrations in water from the well WQSP-6A, obtained from the Dewey Lake, averaged 3,465 mg/L. This water is suitable for livestock consumption, and is classified as Class II water by EPA guidelines. Saturation of the Dewey Lake in the area of the WIPP facility is discontinuous. In addition to this naturally occurring groundwater, anthropogenic SSW has been encountered in the upper Dewey Lake at the Santa Rosa contact (see section 6.6).

Because of the highly variable TDS concentrations within the Culebra, baseline groundwater quality was defined for each individual well. The 2011 analytical results showing the concentrations of detectable constituents are displayed as time trend plots compared to the baseline concentrations (Appendix E). The analysis results for each parameter or constituent for the two sampling sessions in 2011 (Rounds 32 and 33) are summarized in Appendix F, Tables F.1 through F.7.

**Table 6.2 – Analytical Parameters for Which Groundwater Was Analyzed**

| CAS No.[a] | Parameter | EPA Method Number | CAS No. | Parameter | Method Number[b] |
|---|---|---|---|---|---|
| 71-55-6 | 1,1,1-Trichloroethane | 8260B | 7782-50-5 | Chloride | EPA 300.0 |
| 79-34-5 | 1,1,2,2-Tetrachloroethane | 8260B | | Specific Gravity | SM2710F |
| 79-00-5 | 1,1,2-Trichloroethane | 8260B | 7727-37-9 | Nitrate (as N) | EPA 300.0 |
| 75-34-3 | 1,1-Dichloroethane | 8260B | | pH | SM 4500-H+B |
| 75-35-4 | 1,1-Dichloroethylene | 8260B | | Specific conductance | EPA 120.1 |
| 107-06-2 | 1,2-Dichloroethane | 8260B | | Sulfate | EPA 300.0 |
| 56-23-5 | Carbon tetrachloride | 8260B | | Total dissolved solids | SM2540C |
| 108-90-7 | Chlorobenzene | 8260B | | Total organic carbon | SM5310B |
| 67-66-3 | Chloroform | 8260B | | Total organic halogen | EPA 9020B |

**Table 6.2 – Analytical Parameters for Which Groundwater Was Analyzed**

| CAS No.[a] | Parameter | EPA Method Number | CAS No. | Parameter | Method Number[b] |
|---|---|---|---|---|---|
| | | | | Total suspended solids | SM2540D |
| 540-59-0 | *trans*-1, 2-Dichloroethylene | 8260B | 7440-36-0 | Alkalinity | SM2320B |
| 78-93-3 | Methyl ethyl ketone (2-butanone) | 8260B | 7440-38-2 | Antimony | 6020 |
| 75-09-2 | Methylene chloride | 8260B | 7440-39-3 | Arsenic | 6020 |
| 127-18-4 | Tetrachloroethylene | 8260B | 7440-41-7 | Barium | 6010B |
| 108-88-3 | Toluene | 8260B | 7440-43-9 | Beryllium | 6010B |
| 79-01-6 | Trichloroethylene | 8260B | 7440-70-2 | Cadmium | 6010B |
| 75-69-4 | Trichlorofluoromethane | 8260B | 7440-47-3 | Calcium | 6010B |
| 75-01-4 | Vinyl chloride | 8260B | 7439-89-6 | Chromium | 6010B |
| 1330-20-7 | Xylene | 8260B | 7439-92-1 | Iron | 6010B |
| 95-50-1 | 1,2-Dichlorobenzene | 8270C | 7439-95-4 | Lead | 6010B |
| 106-46-7 | 1,4-Dichlorobenzene | 8270C | 7439-97-6 | Magnesium | 6010B |
| 51-28-5 | 2,4-Dinitrophenol | 8270C | 7439-97-6 | Mercury | 7470A |
| 121-14-2 | 2,4-Dinitrotoluene | 8270C | 7440-02-0 | Nickel | 6010B |
| 95-48-7 | 2-Methylphenol | 8270C | 7782-49-2 | Potassium | 6010B |
| 108-39-4/ 106-44-5 | 3-Methylphenol/ 4-Methylphenol | 8270C | 7440-22-4 | Selenium | 6020 |
| 118-74-1 | Hexachlorobenzene | 8270C | 7440-23-5 | Silver | 6010B |
| 67-72-1 | Hexachloroethane | 8270C | 7440-28-0 | Sodium | 6010B |
| 98-95-3 | Nitrobenzene | 8270C | 7440-62-2 | Thallium | 6020 |
| 87-86-5 | Pentachlorophenol | 8270C | 7440-66-6 | Vanadium | 6010B |
| 110-86-1 | Pyridine | 8270C | | | |
| 78-83-1 | Isobutanol (isobutyl alcohol) | 8260B | | | |

(a) Chemical Abstract Service Registry Number

(b) Methods are EPA methods except those designated SM, which are from Standard Methods.

The tables display either the 95$^{th}$ Upper Tolerance Limit Value (UTLV) or the 95$^{th}$ percentile value (as calculated for the background sampling Rounds) for each parameter depending on the type of distribution exhibited by the particular parameter or constituent. Both values represent the concentrations below which 95 percent of the concentrations in a population are expected to occur. The UTLVs were calculated for data that exhibited a normal or a lognormal distribution. The 95$^{th}$ percentile was applied to data that were considered nonparametric (i.e., having neither a normal nor a lognormal distribution with 16-95 percent non-detects). Due to the large number of nondetectable concentrations of organic compounds, the limits for organic compounds were considered nonparametric and based on the contract-required method reporting limit for the contract laboratory. These values were recomputed after the baseline sampling was completed in 2000, and were applied to sampling Rounds 32 and 33 to evaluate potential contamination of the local groundwater. None of the constituents of interest (organics and trace metals) exceeded the baseline concentrations.

### 6.2.5 Groundwater Level Surveillance

Wells were used to perform surveillance of the groundwater surface elevation of five water-bearing zones in the vicinity of the WIPP facility:

- SSW (SR/DL contact)
- Dewey Lake
- Magenta (MAG)
- Culebra (CUL)
- Bell Canyon (B/C)

The two zones of most interest are the Culebra and Magenta (see Figure 6.1). Throughout 2011, water levels in up to 50 Culebra wells were measured (including the Culebra zone of a dual completion well) and 13 wells in the Magenta (including the Magenta zone of a dual completion well). One Dewey Lake well and two Bell Canyon wells were monitored. Nineteen wells in the shallow zone of the SR/DL contact were monitored. Groundwater level measurements were taken monthly in at least one accessible well bore at each well site for each available formation (Figure 6.2). Water levels in redundant well bores (well bores located on well pads with multiple wells completed in the same formation) at each well site were measured on a quarterly basis (Appendix F, Table F.9). Water levels at SSW wells and piezometers were also measured on a quarterly basis.

A breakdown of the groundwater zones intercepted by each well measured at least once in 2011 is given in Appendix F, Table F.8. Note that one existing well (Culebra/Magenta C-2737) is completed at multiple depths. By using a PIP, this well monitors more than one formation.

Water elevation trend analysis was performed for 47 of 50 wells completed or isolated in the Culebra. The subset of wells analyzed were those which had a sufficient period of record to analyze through CY 2011, did not display anomalous levels or trends, and were representative of more than one well at a given well pad (Appendix F, Table F.8). Excluded from trend analysis were SNL-6 and SNL-15 because they both were in long-term water level recovery. SNL-13 was also excluded due to a sudden rise and then stabilization following the drilling of a new oil or gas well nearby. Well H-11b4R was excluded because it was new in November 2011.

The dominant trend through 2011 was a spatially uniform, decreasing freshwater equivalent level in the Culebra monitoring wells at the WIPP site. The term "dominant" means that (1) water levels fell in 42 of 47 wells from January through December (or shorter periods in wells that still had a discernible trend), (2) the average water-level decrease was 1.32 feet (0.34 m), and (3) the general water-level drop is best indicated by 30 measured water levels decreasing in the zero (neutral) to 2-foot range, and 12 were more than 2 feet.

Water levels in Culebra wells to the northwest of the WIPP site (for example see figures 6.4 and 6.5 below) showed a larger decrease compared to the southern and eastern wells (for example see figures 6.6-6.9) in 2011.

Water levels in the Culebra, and to a lesser extent in the Magenta, have generally been rising since the completion of site characterization activities in 1989. The rise was not recognized as having a regional extent for many years because well drilling and testing, shaft sinking, and other human activities disturbed water levels. Since these activities were completed, a rise in water levels over the monitored area has become evident. However, recent trends indicated a regional decrease in water levels, possibly showing that the Culebra system has reached an equilibrium state following completion of human activities.

The historical water-level rise is not monotonic, but shows variations related to factors both known and hypothesized. Water levels in the Culebra in Nash Draw, west of the WIPP site, respond to major rainfall events within a few days (Hillesheim et al., 2006). It is hypothesized that the change in head in Nash Draw then propagates under Livingston Ridge to the WIPP site in the succeeding weeks or months. It is also hypothesized that the Culebra may be receiving leakage through poorly plugged and abandoned drillholes, or through fractures in Nash Draw, from higher hydrologic units and/or potash tailings piles north of the WIPP site. For example, the observed long-term rise in water levels might be caused by the leakage into the Culebra of approximately 74 acre-ft/yr of brine discharged onto the Intrepid East tailings pile north of the WIPP site, and/or by the leakage of a similar volume through 26 potash exploration holes north, west, and south of the WIPP site that may not have been properly plugged through the Culebra (Lowry and Beauheim, 2004; 2005). Likewise, a number of plugged and abandoned oil or gas wells have been identified, mostly to the east and south of the WIPP site, that may not have been plugged through the Culebra with cement and could, hypothetically, be sources of leakage that affects the head in the Culebra (Powers, 2004).

Because of the wide area distribution of the rise, it does not result in significant changes in the hydraulic gradient in the Culebra, which controls the rate and direction of groundwater flow. The DOE uses updated heads in calculating potential radionuclide releases through the Culebra in the 10,000-year performance assessments that are part of each Compliance Recertification Application that is submitted to the EPA every five years.

Figures 6.4 through 6.9 provide hydrographs of wells WQSP-1 to WQSP-6 for CY 2011. The six Culebra wells (Figure 6.4 through 6.9) are typical of the hydrographs of the 40 wells analyzed for Culebra water-level trends. Temporary declines from spring and fall water quality sampling are evident in some wells, such as WQSP-3 and WQSP-5. In 2011, the Permit required that the NMED be notified if a cumulative groundwater surface elevation change of more than 2 feet is detected in wells WQSP-1 to WQSP-6 over the course of one year that is not attributable to site tests or natural stabilization of the site hydrologic system. There was no abnormal or unexplained change in the DMP wells outside the regional trend. Wells WQSP-1 and WQSP-2 had cumulative decreases in water level in excess of 2 feet during the course of the year from January to December. The changes in these wells are typical of the wells in the northern section of the monitoring network.

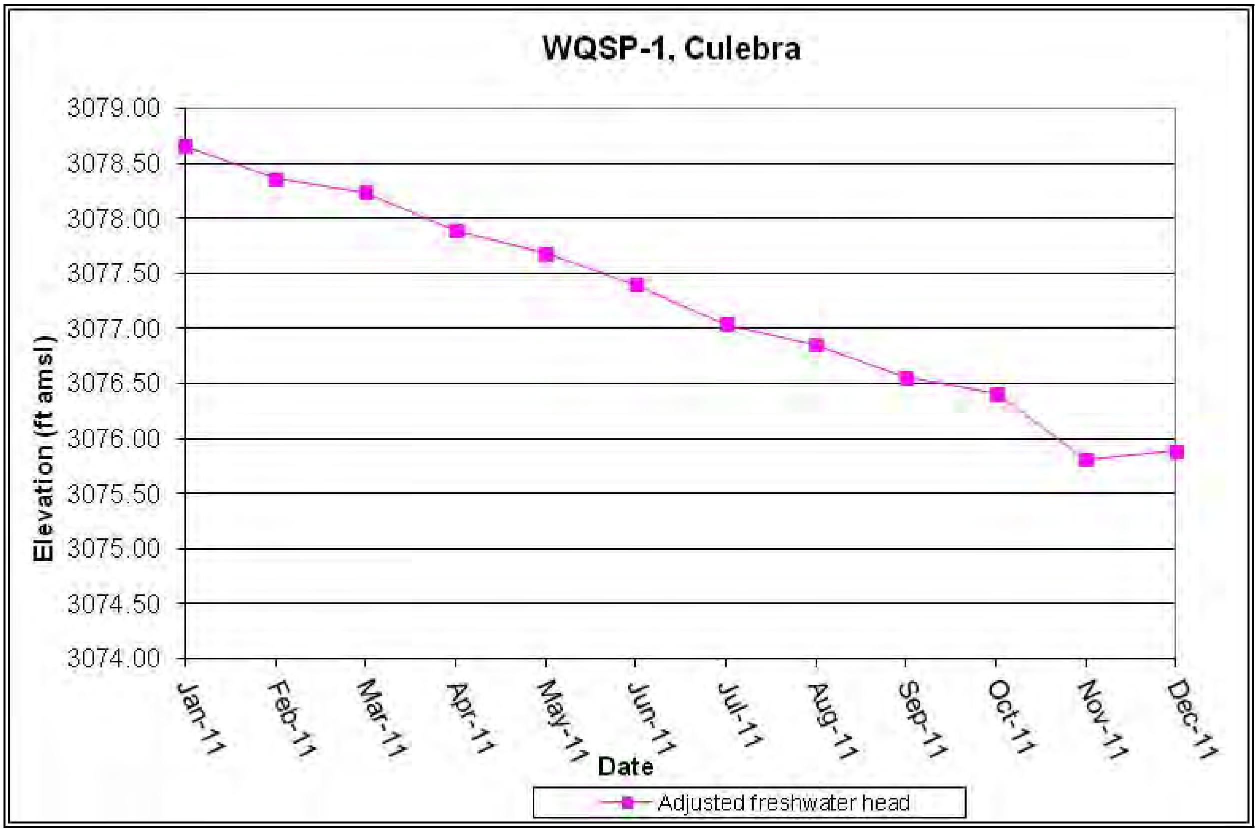


Figure 6.4 – Hydrograph of WQSP-1

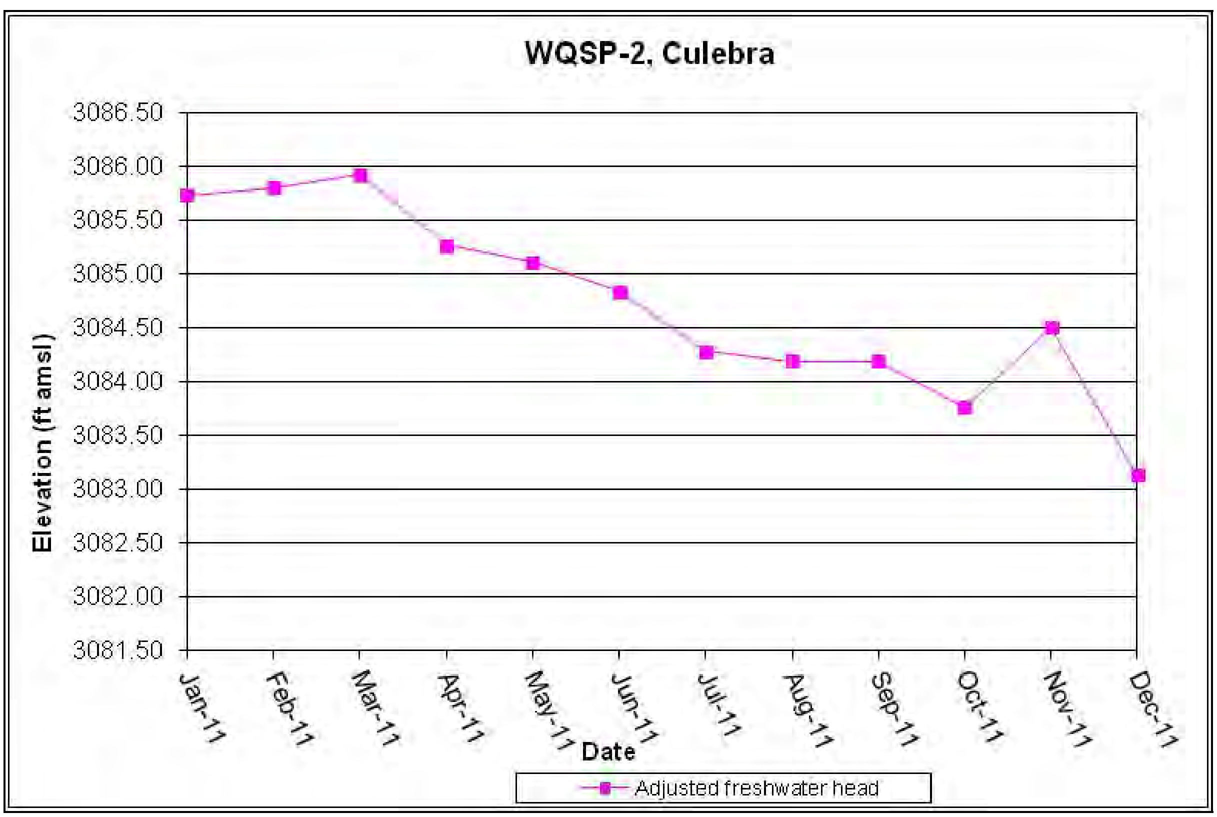


Figure 6.5 – Hydrograph of WQSP-2

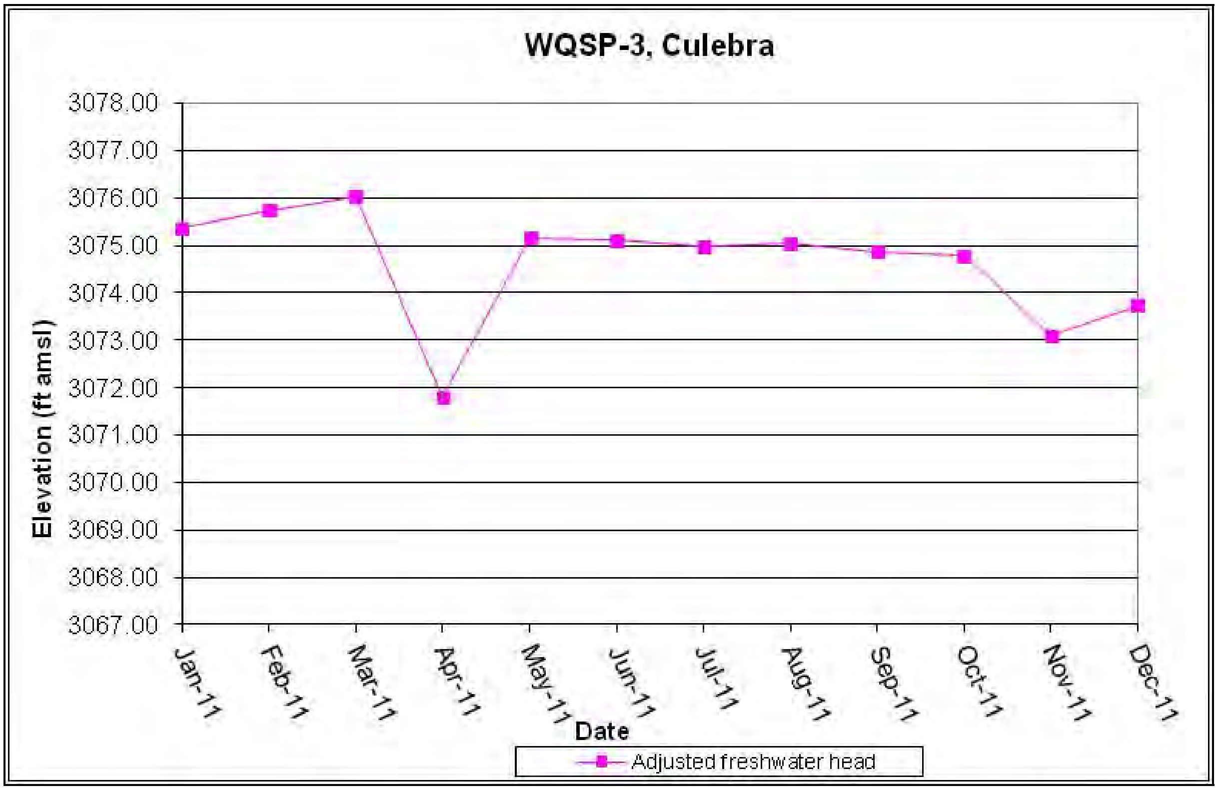


Figure 6.6 – Hydrograph of WQSP-3

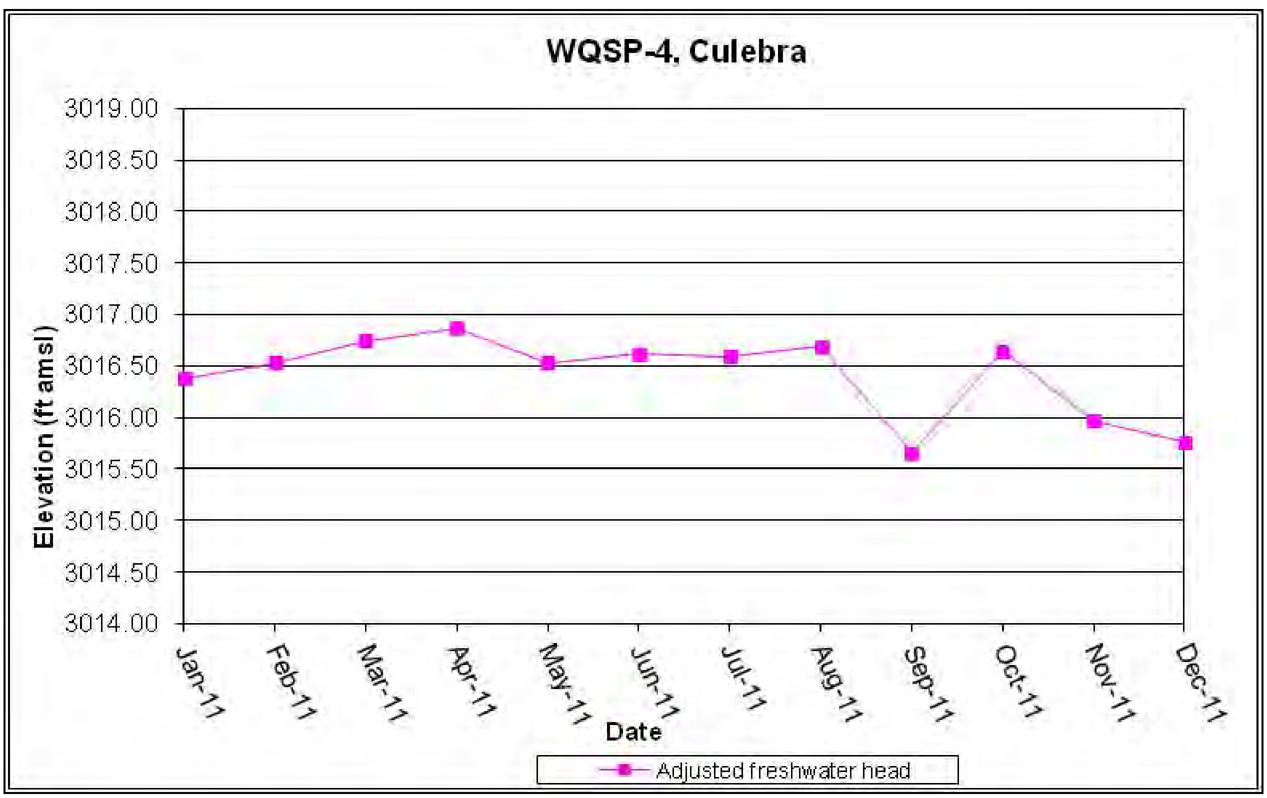


Figure 6.7 – Hydrograph of WQSP-4

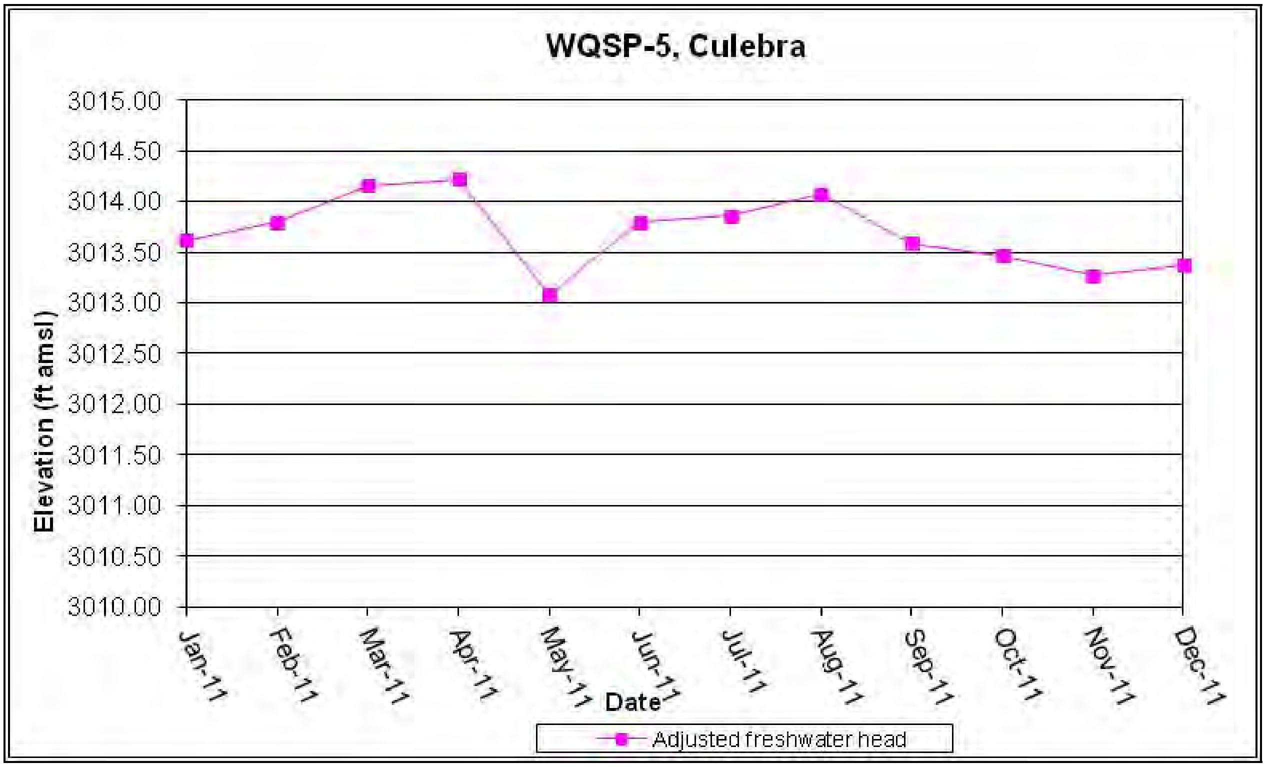


Figure 6.8 – Hydrograph of WQSP-5

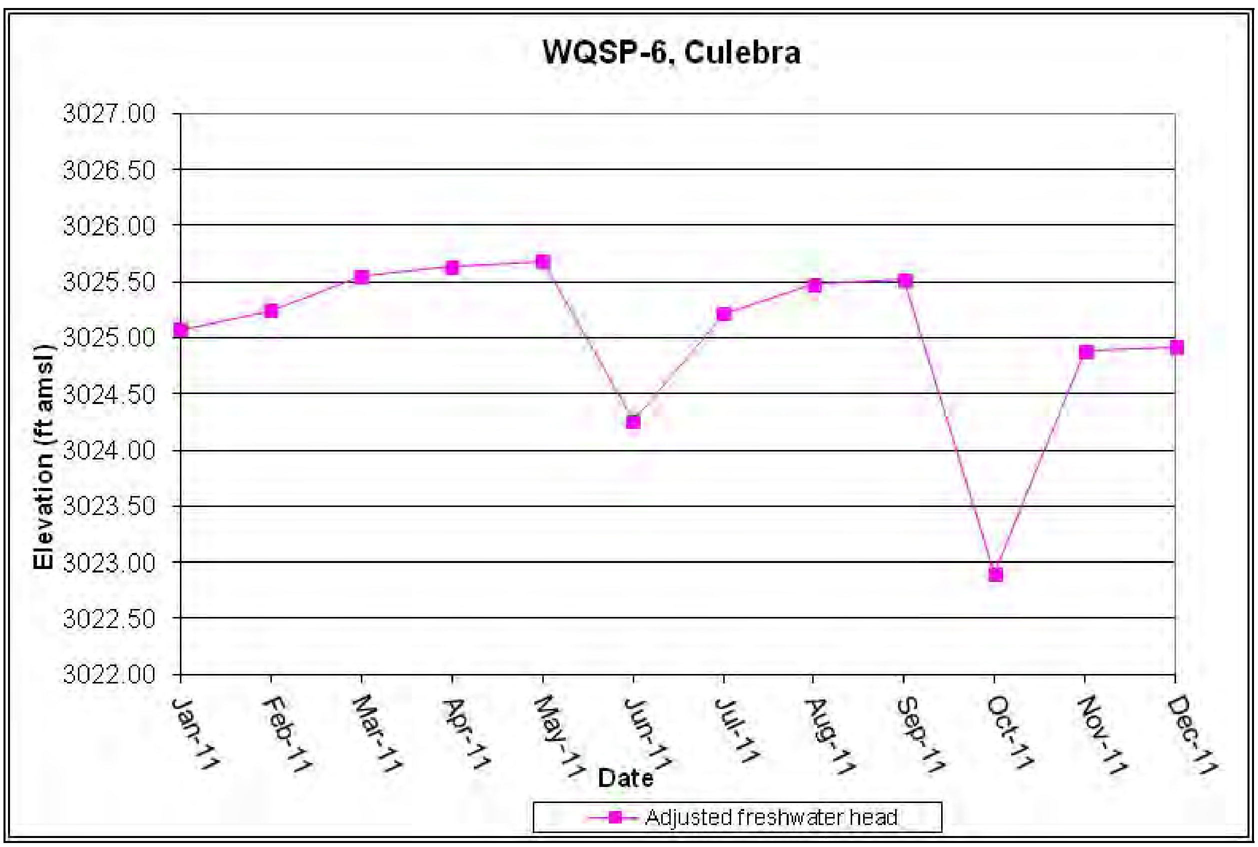


Figure 6.9 – Hydrograph of WQSP-6

Groundwater-level data were transmitted on a monthly basis to the NMED, SNL and the CBFO.

For the Culebra wells in the vicinity of the WIPP site, equivalent freshwater heads for August 2011 were used to calibrate a groundwater flow model, which was used by SNL to compute a potentiometric surface using SNL procedure SP 9-9. This month was judged to have a large number of Culebra water levels available, few wells affected by pumping events, and all wells in quasi-steady state, with few individual wells contrary to the general water-level trend. Table 6.3 shows the water-level data set. Wells SNL-6 and SNL-15 were not included in the mapping because the elevations do not represent static conditions. These wells are located in the low transmissivity zone of the Culebra and after drilling and testing, are still in recovery to reach equilibrium. Well SNL-13 was excluded this year due to oil/gas drilling nearby that caused fluctuations to the water level as the Culebra was penetrated by the drill, and subsequent re-stabilization. Adjusted freshwater heads are typically accurate to ± 1.5 feet, given the density measurement error. Density measurement error is less than 0.019 specific gravity units (WP 02-1).

**Table 6.3 – Water Level Elevations for the 2011 Potentiometric Surface Calibration, Culebra Hydraulic Unit**

| Well ID | Date of Measurement | Adjusted Freshwater Head (ft, amsl) | Density Used (grams/cc) [from 2010 survey] | Notes |
|---|---|---|---|---|
| AEC-7 | 08/09/11 | 3064.76 | 1.078 | |
| C-2737 (PIP) | 08/10/11 | 3022.32 | 1.027 | |
| ERDA-9 | 08/10/11 | 3035.03 | 1.072 | |
| H-02b2 | 08/10/11 | 3046.60 | 1.013 | |
| H-03b2 | 08/10/11 | 3015.04 | 1.043 | |
| H-04bR | 08/09/11 | 3007.29 | 1.018 | |
| H-05b | 08/09/11 | 3082.15 | 1.093 | |
| H-06bR | 08/09/11 | 3071.11 | 1.037 | |
| H-07b1 | 08/08/11 | 2998.38 | 1.006 | |
| H-09bR | 08/08/11 | 2995.19 | 1.000 | 2011 density used, not measured in 2010 |
| H-10c | 08/09/11 | 3028.02 | 1.091 | |
| H-11b4 | 08/09/11 | 3003.43 | 1.051 | |
| H-12 | 08/09/11 | 3011.54 | 1.107 | |
| H-15R | 08/10/11 | 3018.45 | 1.119 | |
| H-16 | 08/10/11 | 3049.24 | 1.037 | |
| H-17 | 08/09/11 | 3008.39 | 1.136 | |
| H-19b0 | 08/10/11 | 3015.20 | 1.068 | |
| I-461 | 08/08/11 | 3043.44 | 1.005 | |
| SNL-01 | 08/08/11 | 3083.87 | 1.028 | |
| SNL-02 | 08/08/11 | 3071.50 | 1.009 | |
| SNL-03 | 08/09/11 | 3081.47 | 1.028 | |
| SNL-05 | 08/08/11 | 3074.44 | 1.008 | |

**Table 6.3 – Water Level Elevations for the 2011 Potentiometric Surface Calibration, Culebra Hydraulic Unit**

| Well ID | Date of Measurement | Adjusted Freshwater Head (ft, amsl) | Density Used (grams/cc) [from 2010 survey] | Notes |
|---|---|---|---|---|
| SNL-06 | 08/09/11 | 3129.35 | 1.233 | Exclude from mapping |
| SNL-08 | 08/09/11 | 3052.62 | 1.094 | |
| SNL-09 | 08/09/11 | 3053.98 | 1.018 | |
| SNL-10 | 08/08/11 | 3053.89 | 1.009 | |
| SNL-12 | 08/08/11 | 3002.57 | 1.005 | |
| SNL-13 | 08/08/11 | 3018.66 | 1.023 | Exclude from mapping |
| SNL-14 | 08/09/11 | 3004.67 | 1.046 | |
| SNL-15 | 08/09/11 | 2993.00 | 1.228 | Exclude from mapping |
| SNL-16 | 08/08/11 | 3008.44 | 1.009 | |
| SNL-17 | 08/08/11 | 3005.67 | 1.004 | |
| SNL-18 | 08/08/11 | 3074.73 | 1.006 | |
| SNL-19 | 08/08/11 | 3071.57 | 1.006 | |
| WIPP-11 | 08/09/11 | 3082.46 | 1.037 | |
| WIPP-13 | 08/10/11 | 3078.35 | 1.044 | |
| WIPP-19 | 08/10/11 | 3064.57 | 1.051 | |
| WQSP-1 | 08/10/11 | 3076.85 | 1.049 | |
| WQSP-2 | 08/10/11 | 3084.18 | 1.047 | |
| WQSP-3 | 08/10/11 | 3075.04 | 1.147 | |
| WQSP-4 | 08/10/11 | 3016.69 | 1.078 | |
| WQSP-5 | 08/10/11 | 3014.07 | 1.028 | |
| WQSP-6 | 08/10/11 | 3025.48 | 1.016 | |

amsl above mean sea level
cc cubic centimeter

Modeled freshwater head contours for August 2011 for the model domain are shown in Figure 6.10. These contours were generated using the results of the Culebra MODFLOW 2K (Harbaugh et al., 2000) run utilizing ensemble average distributed aquifer parameters from the SNL Culebra flow model, which was calibrated as part of the performance assessment baseline calculation for the 2009 *Compliance Recertification Application* (DOE/WIPP-09-3424). Because that model was calibrated to both a snapshot of assumed steady-state water levels (May 2007) and to transient multi-well responses observed during large-scale pumping tests throughout the domain, the boundary conditions were adjusted to improve the match between the model and the observed August 2011 Culebra freshwater heads presented in this report. The portion of the flow domain of interest to the site is extracted as shown on Figure 6.11. The freshwater head values for August 2011 were computed using 2010 densities.

The base transmissivity fields-and the 100 calibrated model realizations derived from them for the performance assessment baseline calculation-embody the hydrologic and geologic understanding of the Culebra behavior in the vicinity of the WIPP site (Kuhlman, 2012). Using the ensemble average of these 100 realizations, therefore, captures the mean flow behavior of the system, and allows straightforward contouring of results from a single-flow model.

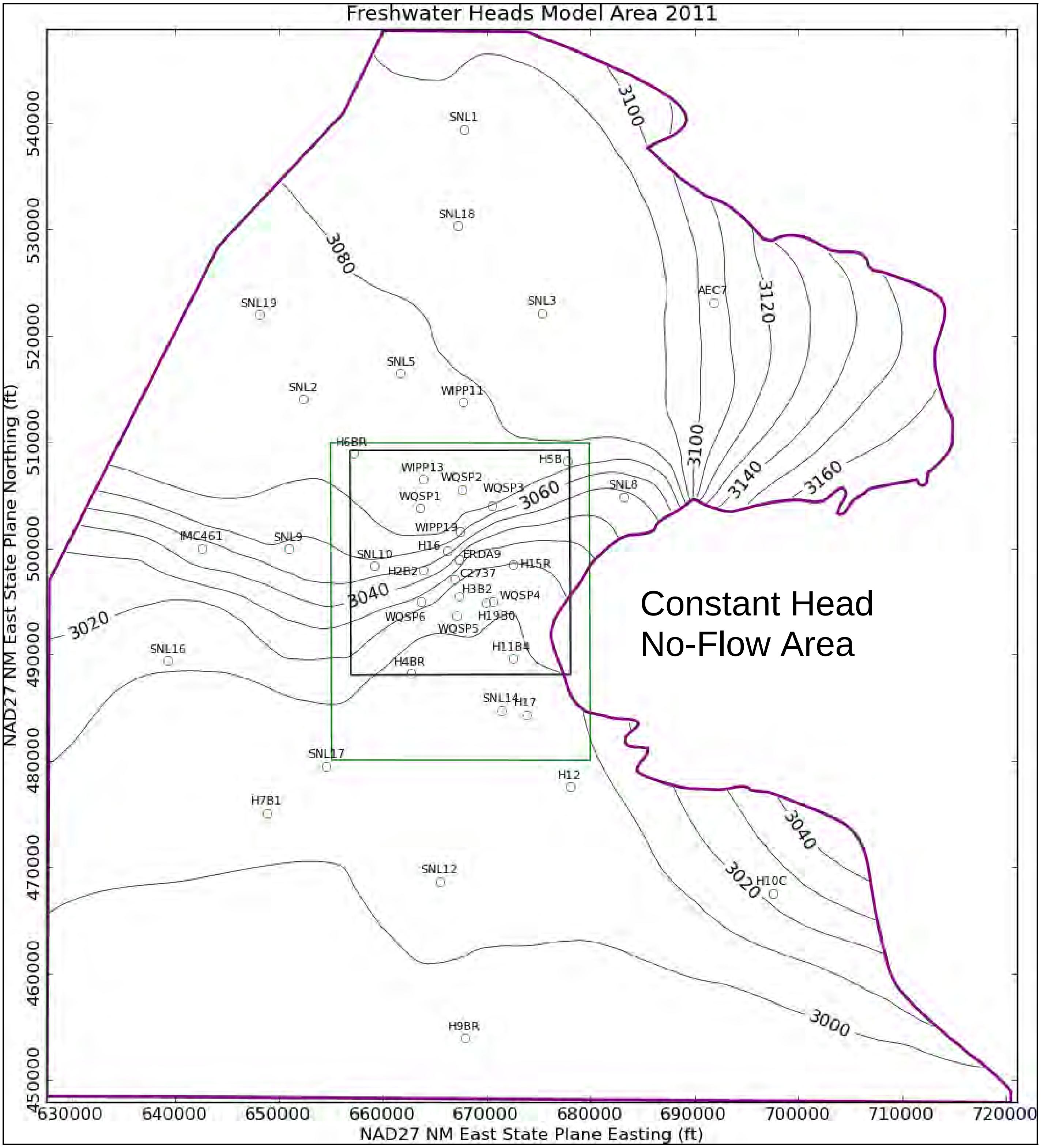


Figure 6.10 – Model Generated August 2011 Freshwater Head Contours in the Model Domain (contour interval in ft amsl)

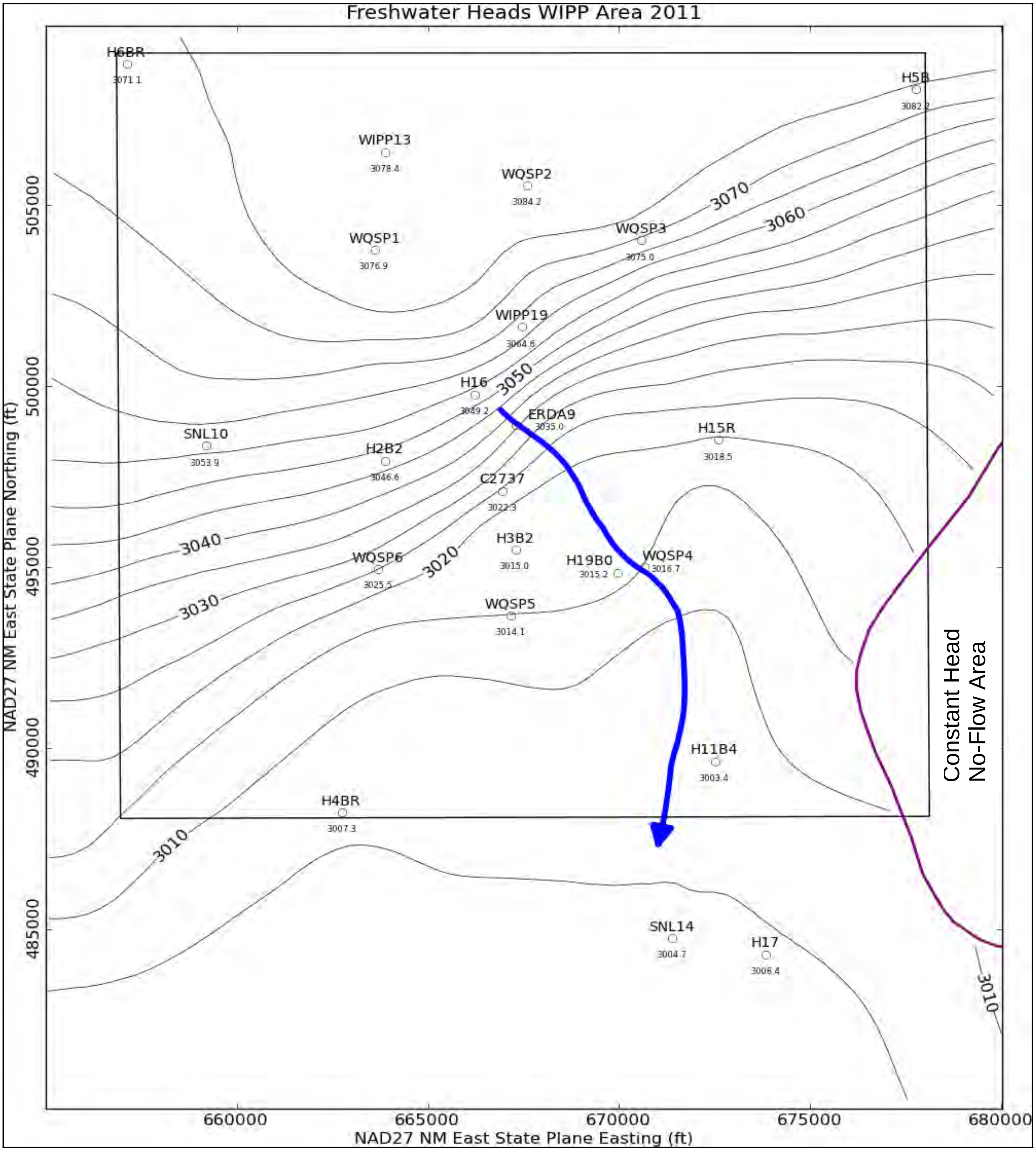


Figure 6.11 – Model-generated August 2011 Freshwater Head Contours (5-foot Contour Interval) in the WIPP Vicinity with Blue Water Particle Track from Waste Handling Shaft to WIPP Land Withdrawal Boundary (contour interval in ft amsl)

The Culebra flow model is a single-layer groundwater flow model. The boundary conditions of the flow model are of two types. First are the geologic- or hydrologic-type boundary conditions, which include the specified head along the eastern boundary and the no-flow boundary along the northwestern boundary of the domain. The second type of boundary condition is specified head. The northern and southern boundaries are of this type, along with the southern portion of the west boundary. The no-flow constant head boundary defined in Figure 6.11 is due to the low transmissivity for this area defined by such wells as SNL-8 and SNL-15 (Figure 6.2).

The second type of boundary condition was determined using the parameter estimation code PEST (Doherty, 2002) to systematically adjust and optimize the boundary conditions to maximize the fit between modeled and observed heads at wells.

The illustrated particle in Figure 6.11 (heavy blue line) shows the DTRKMF-predicted path a water particle would take through the Culebra from the coordinates corresponding to the WIPP waste handling shaft to the land withdrawal boundary (LWB) (a computed path length of 4.092 km). Assuming a thickness of 4 m for the transmissive portion of the Culebra and a constant porosity of 16 percent, the travel time to the WIPP LWB is 5,826 years (output from DTRKMF is adjusted from a 7.75-m Culebra thickness), for an average velocity of 0.70 m/yr. Since the flow model has the ensemble hydraulic conductivity and anisotropy fields as inputs, the freshwater head contours and particle tracks take into account the variability of known aquifer conditions across the site.

The scatter plot in Figure 6.12 shows measured and modeled freshwater heads at the observation locations used in the PEST calibration. The observations are divided into three groups based on proximity to the WIPP site. Wells within the LWB are represented by red crosses, wells outside but within 3 km of the LWB are represented with green "x"s, and other wells within the MODFLOW model domain but distant from the WIPP site are shown by blue asterisks. These groupings were used in the PEST calibration; higher weights (2.5) were given to wells inside the LWB, lower weights (0.4) were given to wells distant to the WIPP site, and wells in the middle received an intermediate weight (1.0). Additional observations representing the average heads north of the LWB and south of the LWB were used to help prevent over-smoothing of the estimated results across the LWB. This allowed PEST to improve the fit of the model to observed heads inside the area contoured in Figure 6.11, at the expense of fitting wells closer to the boundary conditions (i.e., wells shown in Figure 6.10).

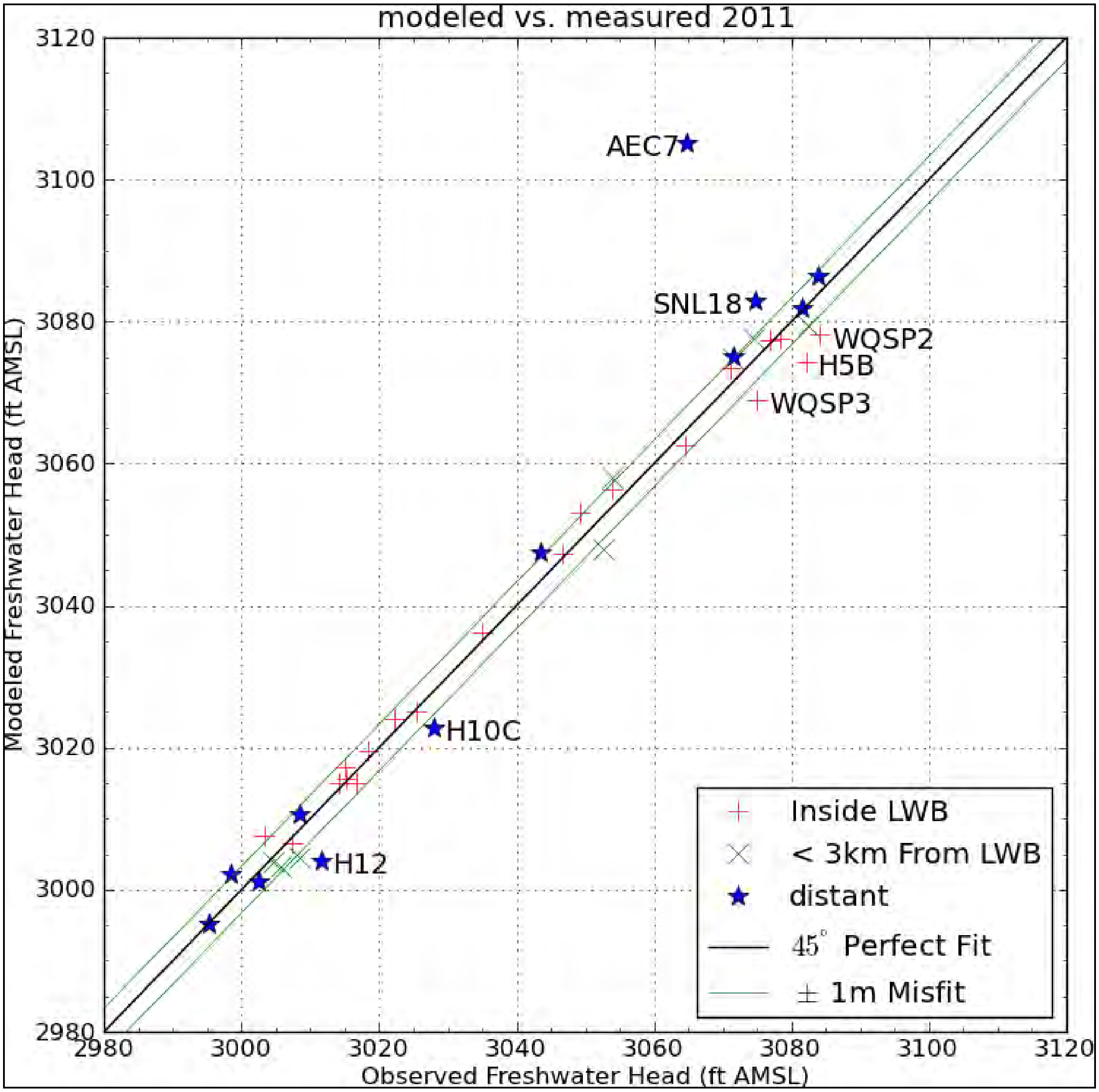


Figure 6.12 – Measured Versus Modeled Scatter Plot for PEST-calibrated MODFLOW 2000 Generated Heads and August 2011 Observed Freshwater Heads

The central diagonal line in Figure 6.12 represents a perfect model fit (1:1 or 45-degree slope). The two lines on either side of the central line represent a 1-m misfit above or below the perfect fit. Wells more than 1.5 m from the 1:1 line are labeled. AEC-7 has a large misfit for two reasons. First, this well has historically had an anomalously low freshwater head elevation, lower than all wells surrounding it. Second, this well was undergoing well reconfiguration activities during May 2007 and was not measured. Therefore, AEC-7 was not included as a calibration target in the SNL Performance Assessment MODFLOW model calibration. The ensemble-average transmissivity, anisotropy, and recharge fields used here were not calibrated to accommodate this observation. This well is situated in a low-transmissivity region, and near the constant-head boundary associated with the halite margin; therefore, PEST will not be able to improve this fit solely through adjustment of the second type boundary conditions along the edges of the domain (Figure 6.10).

Figure 6.13 and Figure 6.14 show the distribution of errors resulting from the PEST-adjusted fit to observed data. The distribution in Figure 6.13 is roughly symmetric, indicating there is not a strong bias. Aside from AEC-7, and to a lesser degree some other distant wells whose modeled values do not greatly impact the contours shown in Figure 6.11, the model fit to the August 2011 observations is very good. The ensemble average model captures the average Culebra behavior, while the PEST calibration improved the model fit to the specific August 2011 observations.

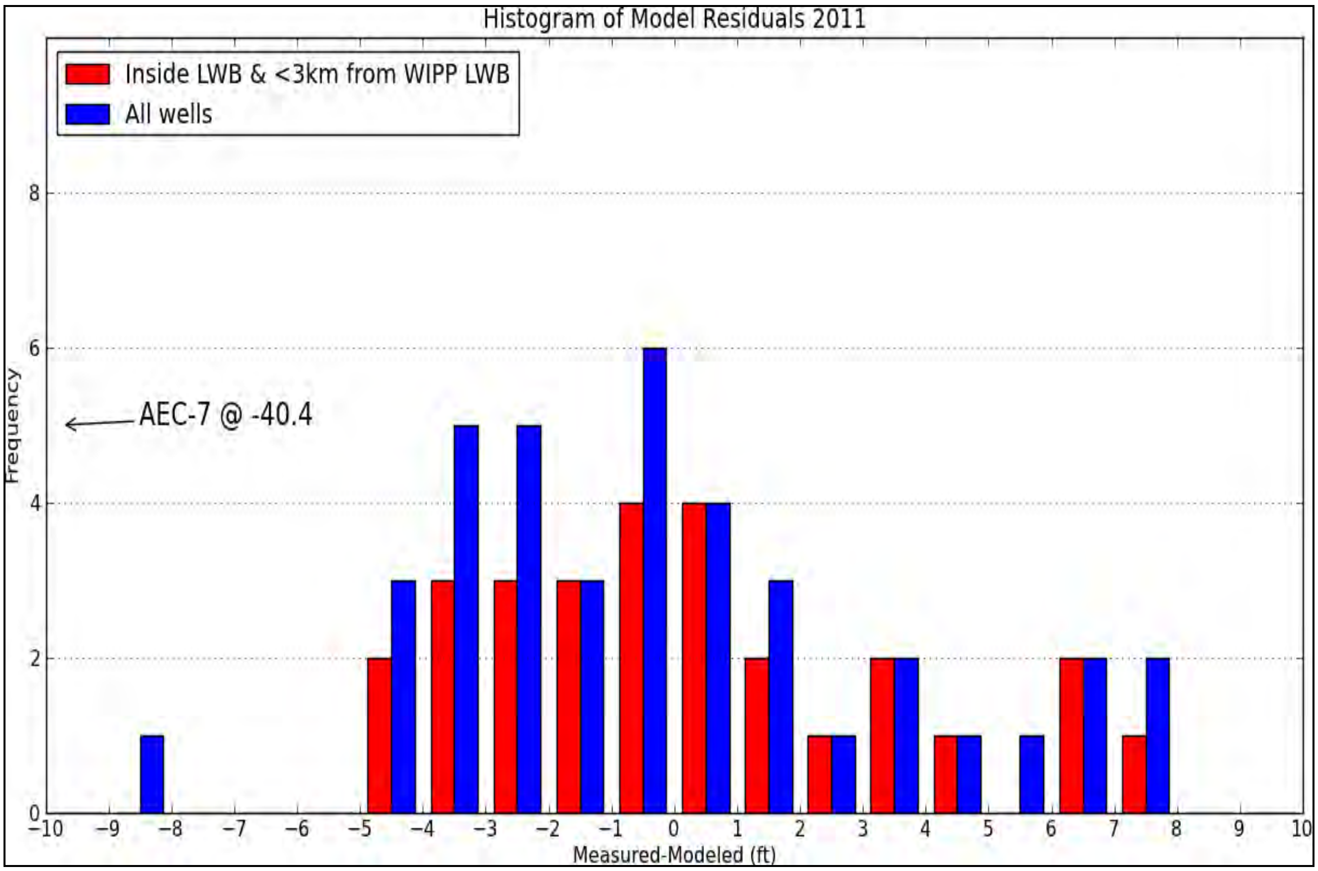


Figure 6.13 – Frequency of Modeled Freshwater Head Residuals

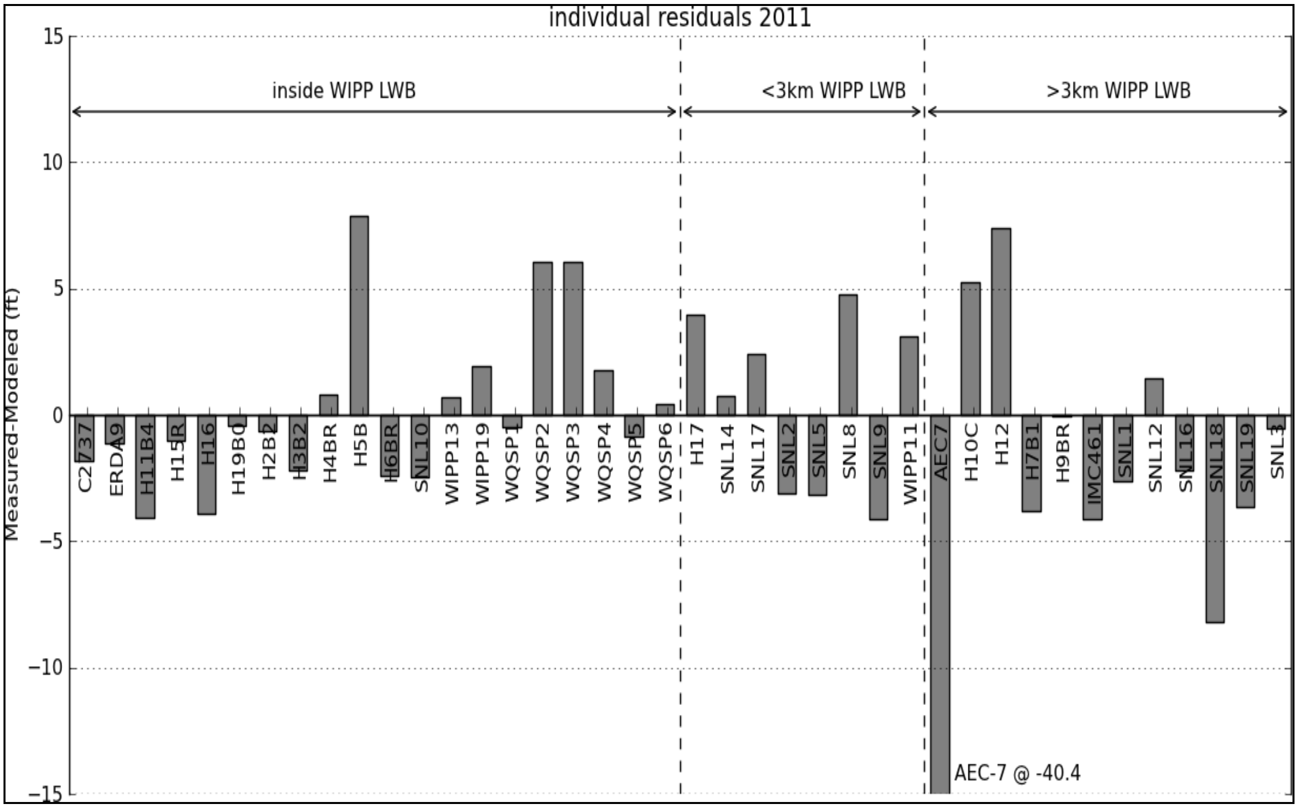


Figure 6.14 – Modeled Residual Freshwater Head at Each Well

### 6.2.6 Pressure Density Surveys

At the WIPP site, variable TDS concentrations result in variability in groundwater density (WP 02-1). WIPP measures the density of well-bore fluids in water-level monitoring wells to adjust water levels to their equivalent freshwater head values. This allows more accurate determination of relative heads between wells. Pressure density surveys have been performed by two different methods during past years. In 2006 (and prior years), pressure density was obtained by a mobile trailer-mounted system that obtained data at each well. In 2007, SNL installed a dedicated pressure transducer in each well. In 2011, densities were derived from 37 wells from Mini-Trolls installed by SNL (see Table 6.4), six from hydrometers as part of the WQSP sampling program, and six from the redundant H-19 wells. This approach employed several calibrated pressure-measuring transducers dedicated to given wells at varying times during the year. For the WQSP wells, field hydrometer measurements are always used. For comparison, 2009 and 2010 density data are shown. All year-to-year density differences are within the error as described in WP 02-1.

**Table 6.4 – Pressure Density Survey for 2011**

| Well I.D. | 2009 Fluid Density Survey Result Density (grams/cc) | 2009 Conversion to Specific Gravity at 70° F Density (grams/cc) | 2010 Fluid Density Survey Result Density (grams/cc) | 2010 Conversion to Specific Gravity at 70° F Density (grams/cc) | 2011 Fluid Density Survey Result Density (grams/cc) | 2011 Conversion to Specific Gravity at 70° F Density (grams/cc) | Notes for 2009-2011 Fluid Density Survey |
|---|---|---|---|---|---|---|---|
| AEC-7 | 1.078 | 1.080 | 1.076 | 1.078 | 1.069 | 1.071 | |
| C-2737 | 1.025 | 1.027 | 1.025 | 1.027 | 1.025 | 1.027 | |
| ERDA-9 | 1.068 | 1.070 | 1.070 | 1.072 | 1.071 | 1.073 | |
| H-02b2 | 1.009 | 1.011 | 1.011 | 1.013 | 1.010 | 1.012 | |
| H-03b2 | 1.040 | 1.042 | 1.041 | 1.043 | 1.039 | 1.041 | |
| H-04bR | 1.016 | 1.018 | 1.016 | 1.018 | 1.015 | 1.017 | Replacement for well H-04b drilled in July 2009 |
| H-05b | 1.094 | 1.096 | 1.091 | 1.093 | 1.095 | 1.097 | |
| H-06bR | 1.035 | 1.037 | 1.035 | 1.037 | 1.036 | 1.038 | |
| H-07b1 | 1.004 | 1.006 | 1.004 | 1.006 | 1.004 | 1.006 | |
| H-09c | 1.004 | 1.006 | 1.004 | 1.006 | NA | NA | Plugged back to Magenta only in October 2010 |
| H-9bR | NA | NA | NA | NA | 1.000* | 1.000* | Replacement well for H-09c-Culebra, drilled in 2010, * Rounded up to 1.000 for 2011 |
| H-10c | 1.005 | 1.007 | NA | NA | NA | NA | Use up to July 2009, Bailed in July 2009 to restore fluid density |
| H-10c | 1.089 | 1.091 | 1.089 | 1.091 | 1.092 | 1.094 | Use for July 2009 forward |
| H-11b4 | 1.058 | 1.060 | 1.049 | 1.051 | 1.039 | 1.041 | Plugged in Nov. 2011, data generated Jan-Oct. |
| H-11b4R | NA | NA | NA | NA | NA | NA | New replacement well to H-11b4 drilled in 2011 |
| H-12 | 1.095 | 1.097 | 1.105 | 1.107 | 1.105 | 1.107 | |
| H-15R | 1.118 | 1.120 | 1.117 | 1.119 | 1.117 | 1.119 | |
| H-16 | 1.037 | 1.039 | 1.035 | 1.037 | 1.035 | 1.037 | |
| H-17 | 1.133 | 1.135 | 1.134 | 1.136 | 1.134 | 1.136 | |
| H-19b0 | 1.065 | 1.067 | 1.066 | 1.068 | 1.064 | 1.066 | |
| I-461 | 1.005 | 1.007 | 1.003 | 1.005 | 1.000* | 1.000* | * Rounded up to 1.000 for 2011 |
| SNL-01 | 1.028 | 1.030 | 1.026 | 1.028 | 1.029 | 1.031 | |
| SNL-02 | 1.006 | 1.008 | 1.007 | 1.009 | 1.007 | 1.009 | |
| SNL-03 | 1.030 | 1.032 | 1.026 | 1.028 | 1.026 | 1.028 | |
| SNL-05 | 1.007 | 1.009 | 1.006 | 1.008 | 1.007 | 1.009 | |
| SNL-06 | 1.230 | 1.232 | 1.231 | 1.233 | 1.239 | 1.241 | |
| SNL-08 | 1.091 | 1.093 | 1.092 | 1.094 | 1.092 | 1.094 | |
| SNL-09 | 1.016 | 1.018 | 1.016 | 1.018 | 1.016 | 1.018 | |
| SNL-10 | 1.007 | 1.009 | 1.007 | 1.009 | 1.007 | 1.009 | |
| SNL-12 | 1.002 | 1.004 | 1.003 | 1.005 | 1.003 | 1.005 | |
| SNL-13 | 1.023 | 1.025 | 1.021 | 1.023 | 1.023 | 1.025 | |
| SNL-14 | 1.044 | 1.046 | 1.044 | 1.046 | 1.045 | 1.047 | |
| SNL-15 | 1.223 | 1.225 | 1.226 | 1.228 | 1.230 | 1.232 | |
| SNL-16 | 1.013 | 1.015 | 1.007 | 1.009 | 1.006 | 1.008 | |
| SNL-17 | 1.003 | 1.005 | 1.002 | 1.004 | 1.004 | 1.006 | |
| SNL-18 | 1.003 | 1.005 | 1.004 | 1.006 | 1.005 | 1.007 | |
| SNL-19 | 1.005 | 1.007 | 1.004 | 1.006 | 1.004 | 1.006 | |
| WIPP-11 | 1.035 | 1.037 | 1.035 | 1.037 | 1.036 | 1.038 | |
| WIPP-13 | 1.043 | 1.045 | 1.042 | 1.044 | 1.041 | 1.043 | |
| WIPP-19 | 1.049 | 1.051 | 1.049 | 1.051 | 1.050 | 1.052 | |
| WIPP-25 | 1.000* | 1.000* | NA | NA | NA | NA | *March-May, not reliable, Plugged in 2009 |
| WQSP-1 | 1.046 | 1.048 | 1.047 | 1.049 | 1.047 | 1.049 | Average Rounds 32 and 33, field hydrometer |
| WQSP-2 | 1.045 | 1.047 | 1.045 | 1.047 | 1.046 | 1.048 | Average Rounds 32 and 33, field hydrometer |
| WQSP-3 | 1.144 | 1.146 | 1.144 | 1.146 | 1.143 | 1.146 | Average Rounds 32 and 33, field hydrometer |
| WQSP-4 | 1.074 | 1.076 | 1.076 | 1.078 | 1.074 | 1.076 | Average Rounds 32 and 33, field hydrometer |
| WQSP-5 | 1.025 | 1.027 | 1.026 | 1.028 | 1.025 | 1.027 | Average Rounds 32 and 33, field hydrometer |
| WQSP-6 | 1.014 | 1.016 | 1.014 | 1.016 | 1.015 | 1.017 | Average Rounds 32 and 33, field hydrometer |

NA: no available measurement

## 6.3 Drilling Activities

Well H-11b4R was drilled as a replacement for Culebra well H-11b4, which was plugged and abandoned in November 2011. The new well was drilled to a total depth of 755 feet below ground surface, with the screened interval at 720 to 746 feet below ground surface.

## 6.4 Hydraulic Testing And Other Water Quality Sampling

In addition to the chemical testing in the six WQSP wells as required by the Permit, WIPP personnel also conducted basic water chemistry tests in four other wells as listed in Table 6.5.

**Table 6.5 – 2011 Well and Water Quality Sampling Testing Activities**

| Well Location | Dates | Activity* |
|---|---|---|
| H-2b1, Magenta | February 2011 | Water quality sampling |
| H-9bR, Culebra | March and June 2011 | Water quality sampling |
| H-9c, Magenta | April 2011 | Pumping test |
| H-4c, Magenta | Feb-March 2011 | Water quality sampling |
| *Water chemistry obtained by SNL. General chemical parameters (anions/cations). | | |

## 6.5 Well Maintenance

Well maintenance for 2011 included plugging and abandonment of H-11b4. The open hole portion of this well had filled in with sediment over time and was selected for replacement in 2011. The well was plugged to the surface with cement and a monument was erected per BLM requirements.

## 6.6 Shallow Subsurface Water Monitoring Program

Shallow subsurface water occurs beneath the WIPP site at a depth of less than 100 feet below ground level at the contact between the Santa Rosa and the Dewey Lake (Figure 6.15). Water yields are generally less than one gallon per minute in monitoring wells and piezometers, and the water contains varying concentrations of TDS (1,640 mg/L to 259,000 mg/L) and chloride (370 mg/L to 170,000 mg/L). To the south, yields are greater and TDS and chloride concentrations lower. The origin of the high TDS and chlorides in this water is believed to be primarily from anthropogenic sources, with some contribution from natural sources. The SSW occurs not only under the WIPP site surface facilities but also to the south, as indicated by shallow water in drill hole C-2811, about one-half mile south of the WIPP property protection fence.

In order to investigate the SSW, 15 piezometers (PZ-1 to PZ-15) and four wells (C-2505, C-2506, C-2507, and C-2811) have been drilled as part of a monitoring program to measure spatial and temporal changes in SSW levels and water quality. Monitoring activities during 2011 included SSW level surveillance at these 19 locations (Figure 6.15).

Additionally, drilling in 2007 around the SPDV salt pile tailings revealed shallow water in three piezometers (PZ-13, PZ-14, and PZ-15, shown in Figure 6.15). Natural shallow groundwater occurs in the middle part of the Dewey Lake at the southern portion of the WIPP site (WQSP-6A; see Figure 6.2) and to the south of the WIPP site (J. C. Mills Ranch). To date, there is no indication that the anthropogenic SSW has affected the naturally occurring groundwater in the Dewey Lake.

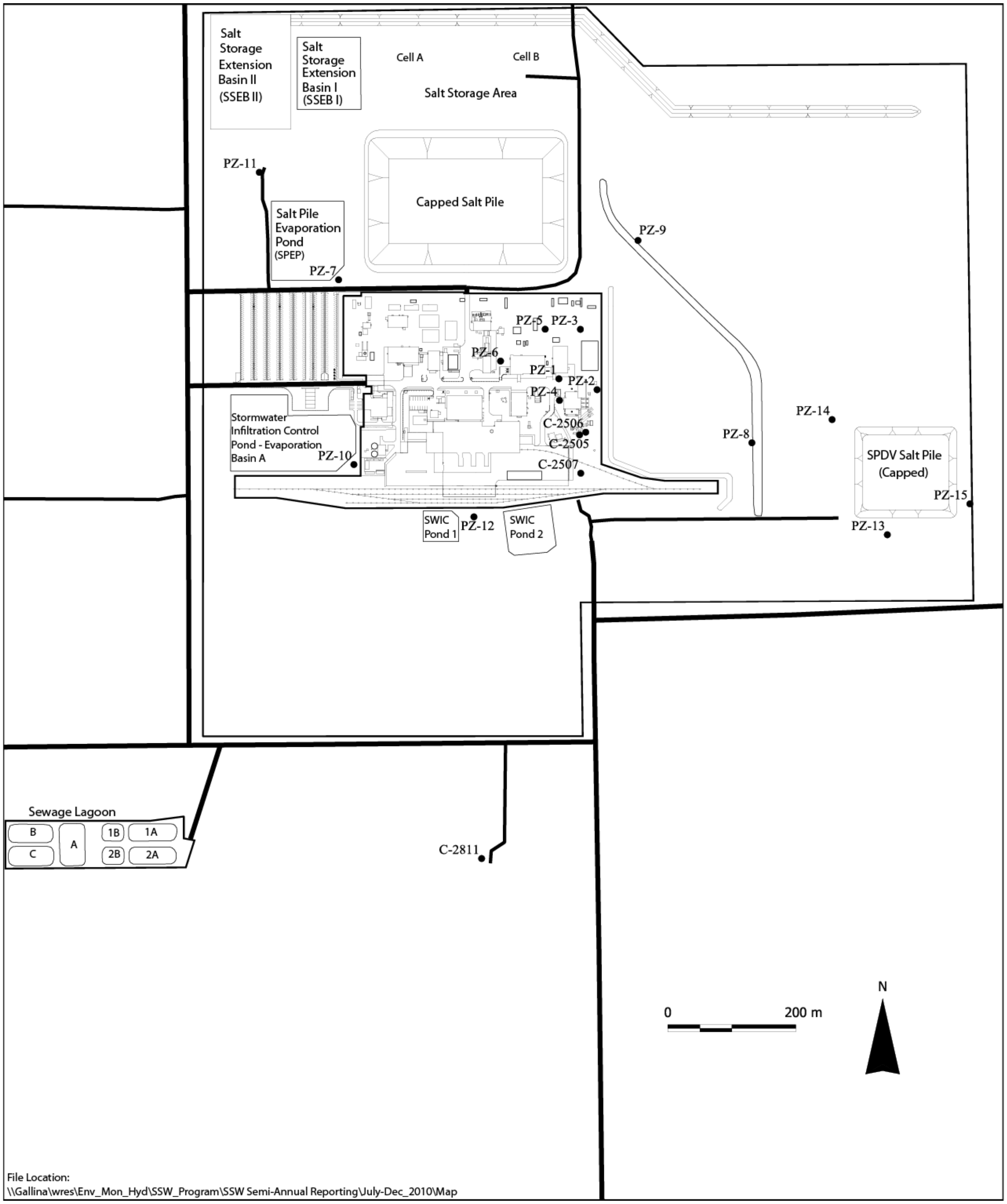


Figure 6.15 – Location of Shallow Subsurface Water Wells (piezometers PZ-1 through 15, C-2811, C-2505, C-2506, C-2507

### 6.6.1 Shallow Subsurface Water Quality Sampling

The discharge permit (DP-831), as modified, requires 11 SSW wells and WQSP-6A to be sampled on a semiannual basis. Wells C-2507, C-2811, PZ-1, PZ-5, PZ-6, PZ-7, PZ-9, PZ-10, PZ-11, PZ-12 and PZ-13 are sampled for this program. These wells were sampled in May and October 2011 and the parameters shown in Table 6.6 were analyzed.

**Table 6.6 – 2011 Shallow Subsurface Water Quality Sampling Results**

| Well | Sample Date | Sulfate (mg/L) | Chloride (mg/L) | TDS (mg/L) | Nitrate (mg/L) | TKN (mg/L) |
|---|---|---|---|---|---|---|
| PZ-1 | 5/24/2011 | 2,000 | 51,000 | 85,200 | NA | NA |
| PZ-1 | 10/5/2011 | 2,000 | 50,000 | 84,600 | NA | NA |
| PZ-5 | 5/24/2011 | 1,200 | 10,000 | 18,400 | NA | NA |
| PZ-5 | 10/4/2011 | 1,300 | 13,000 | 19,800 | NA | NA |
| PZ-6 | 5/24/2011 | 1,700 | 37,000 | 67,700 | NA | NA |
| PZ-6 | 10/5/2011 | 1,900 | 41,000 | 69,800 | NA | NA |
| PZ-7 | 5/23/2011 | 2,700 | 60,000 | 101,000 | NA | NA |
| PZ-7 | 10/4/2011 | 3,100 | 81,000 | 116,000 | NA | NA |
| PZ-9 | 5/24/2011 | 4,300 | 83,000 | 147,000 | NA | NA |
| PZ-9 | 10/4/2011 | 4,600 | 99,000 | 153,000 | NA | NA |
| PZ-10 | 5/23/2011 | 400 | 310 | 1,620 | NA | NA |
| PZ-10 | 10/4/2011 | 440 | 370 | 1,640 | NA | NA |
| PZ-11 | 5/23/2011 | 2,000 | 45,000 | 80,500 | NA | NA |
| PZ-11 | 10/3/2011 | 2,300 | 65,000 | 92,200 | NA | NA |
| PZ-12 | 5/23/2011 | 900 | 5,600 | 10,900 | NA | NA |
| PZ-12 | 10/3/2011 | 900 | 6,800 | 13,100 | NA | NA |
| PZ-13 | 5/24/2011 | 2,700 | 150,000 | 248,000 | NA | NA |
| PZ-13 | 10/4/2011 | 3,000 | 170,000 | 259,000 | NA | NA |
| C-2811 | 5/23/2011 | 350 | 960 | 2,370 | NA | NA |
| C-2811 | 10/3/2011 | 340 | 910 | 2,330 | NA | NA |
| C-2507 | 5/24/2011 | 790 | 3,200 | 6,190 | NA | NA |
| C-2507 | 10/5/2011 | 810 | 3,400 | 6,660 | NA | NA |
| WQSP-6A | 5/26/2011 | 2,100 | 270 | 3,480 | 6.5 | <1.0 |
| WQSP-6A | 10/6/2011 | 2,100 | 280 | 3,450 | 5.9 | <1.0 |
| NA: Not analyzed, not required per permit conditions | | | | | | |

### 6.6.2 Shallow Subsurface Water Level Surveillance

Nineteen wells were used for surveillance of the SSW-bearing horizon in the Santa Rosa and the upper portion of the Dewey Lake. Water levels were measured quarterly at all the piezometers and wells shown in Figure 6.15.

The potentiometric surface for the SSW using December 2011 data is presented in Figure 6.16. The contours were generated using SURFER version 9 surface mapping software by Golden Software. Sixteen data points were used in the contour development, whereas the contours around the SPDV salt pile were estimated by hand.

Groundwater elevation measurements in the SSW indicate that flow is to the east and south away from a potentiometric high located near PZ-7 adjacent to the Salt Pile Evaporation Pond (Figure 6.16). At this time, it appears that the water identified in PZ 13 and PZ-14 is separate and distinct from the SSW in the other wells at the WIPP facilities area (DOE/WIPP-08-3375, *Basic Data Report for Piezometers PZ-13, PZ-14, PZ-15 and SSW)*. PZ-13 and PZ-14 were completed at the contact of the Santa Rosa and Dewey Lake. PZ-15 was completed at a much more shallow level in the Gatuña, where it appears rainwater has accumulated from a localized recharge source. Geochemically, the piezometer wells around the SPDV salt pile are distinct from the SSW wells located in the WIPP facilities area. Because of the recharge influence from a localized depression near PZ-15, this is geochemically distinct from the areas around the SPDV salt pile and the WIPP facilities.

In 2004, storm water evaporation ponds were lined with high-density polyethylene in accordance with DP-831 requirements. Since the installation of the liners, there has been a decrease in SSW elevations, which indicates that the liners have minimized the potential for groundwater to be impacted.

## 6.7 Public Drinking Water Protection

The water wells nearest the WIPP site that use the natural shallow groundwater for domestic use are the Barn Well and Ranch Well located on the J. C. Mills Ranch. These wells are located approximately 3 miles south-southwest of the WIPP surface facilities, and about 1.75 miles south of WQSP-6A (see Figure 6.2). TDS concentrations in the Barn Well have ranged from 630 to 720 mg/L, and TDS concentrations in the Ranch Well have ranged from 2,800 to 3,300 mg/L (CCA, DOE/CAO-96-2184).

A water budget analysis in 2003 indicated that seepage from five primary sources (salt pile and four surface water detention basins) provided sufficient recharge to account for the observed SSW saturated lens, and that the lens was expected to spread.

The potential extent for long-term SSW migration was examined by expanding the saturated flow model domain to include the 16-square-mile WIPP LWA. The long-term migration model simulations indicated that the engineered seepage controls that are now in place will substantially reduce the extent of migration.

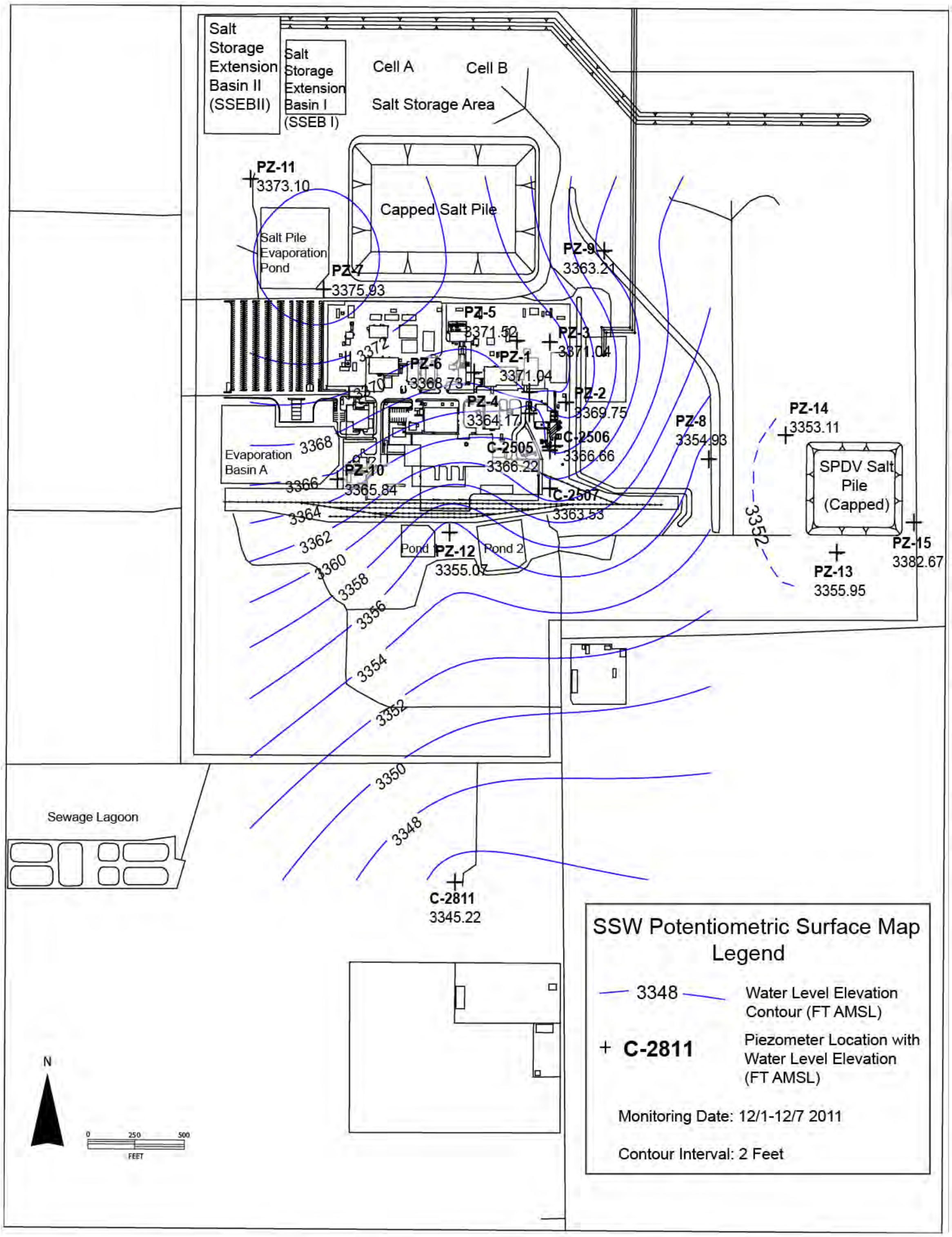


Figure 6.16 – Shallow Subsurface Water Potentiometric Surface

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## CHAPTER 7 – QUALITY ASSURANCE

The fundamental objective of the environmental QA program is to obtain accurate and precise analytical data that are technically and legally defensible. Quality data are generated through a series of activities that plan, implement, review, assess, and correct as necessary. Samples are collected and analyzed in sample delivery groups along with the requisite QA samples using standardized and proven methods. The sample analysis results and associated QC data are reviewed, verified, validated, and incorporated into succinct and informative reports, which describe how well the lab met its QA objectives.

In 2011, WIPP Laboratories performed the radiological analyses of environmental samples from the WIPP site. Carlsbad Environmental Monitoring and Research Center (CEMRC) in Carlsbad, New Mexico, performed the non-radiological VOC analyses, and Hall Environmental Analysis Laboratory (HEAL) in Albuquerque, New Mexico, performed the non-radiological groundwater analyses. In addition, HEAL subcontracted groundwater analyses to Columbia Analytical Systems to perform the specialty total organic halogen analyses, and to Anatek Laboratories to perform trace metal analyses. Both of these subcontracted laboratories have documented QA programs, including an established QA plan, and laboratory-specific standard operating procedures (SOPs) based on published standard methods to perform the work.

All the laboratories except CEMRC demonstrated the quality of their analytical data through participation in reputable, interlaboratory comparison programs such as the National Institute of Standards and Technology Radiochemistry Intercomparison Program (NRIP), Mixed Analyte Performance Evaluation Program (MAPEP), and National Environmental Laboratory Accreditation Conference (NELAC) Proficiency Testing studies. Laboratories used by the WIPP program are also required to meet the applicable requirements of the CBFO *Quality Assurance Program Document* (DOE/CBFO-94-1012), as flowed down through the Washington TRU Solutions, LLC, *Quality Assurance Program Description* (WP 13-1). CEMRC was not required to participate in intercomparison programs during 2011.

The WIPP sampling program and the subcontracted analytical laboratories operate in accordance with QA plans and QA project plans that incorporate QA requirements from the MOC *Quality Assurance Program Description*. These plans contain such elements as the following:

- Management and organization
- Quality system and description
- Personnel qualification and training
- Procurement of products and services
- Documents and records
- Computer hardware and software
- Planning
- Management of work process (SOPs)
- Assessment and response
- Quality improvement

To ensure that the quality of systems, processes, and deliverables are maintained or improved, three layers of assessments and audits are performed:

- DOE/CBFO performs assessments and audits of the MOC QA program.
- MOC performs internal assessments and audits of its own QA program.
- MOC performs assessments and audits of subcontractor QA programs as applied to MOC contract work.

The QA objectives for the sampling and analysis program are completeness, precision, accuracy, comparability, and representativeness. Sections 7.1, 7.2, and 7.3 discuss the QC results for the WIPP Laboratories, CEMRC, and HEAL, in terms of how well they met the QA objectives.

## 7.1 WIPP Laboratories

Samples for analysis of radionuclides were collected using approved WIPP procedures. The procedures are based on generally accepted methodologies for environmental sampling, ensuring that the samples were representative of the media sampled. The samples were analyzed for natural radioactivity, fallout radioactivity from nuclear weapons tests, and anthropogenic radionuclides contained in the transuranic waste buried at the WIPP site. The reported concentrations at various locations in 2011 were representative of the baseline concentrations for radionuclides of interest at the WIPP facility.

### 7.1.1 Completeness

The SOW for analyses performed by WIPP Laboratories states that "analytical completeness, as measured by the amount of valid data collected versus the amount of data expected or needed, shall be greater than 90 percent for MOC sampling programs." For radiological sampling and analysis programs, this contract requirement translates into the following quantitative definition.

*Completeness is expressed as the number of samples analyzed with valid results as a percent of the total number of samples submitted for analysis, or*

$$\%C = \frac{V}{n} \times 100$$

*Where:*

*%C = Percent Completeness*

*V = Number of Samples with Valid Results*

*n = Number of Samples Submitted for Analysis*

Samples and measurements for all environmental media (air particulate composites, groundwater, surface water, soil, sediment, plant, and animal) were 100 percent complete for 2011.

### 7.1.2 Precision

The SOW states that analytical precision (as evaluated through replicate measurements) will meet or surpass control criteria or guidelines established in the industry-standard methods used for sample analysis. To ensure overall quality of analysis of environmental samples, precision was evaluated for both sample collection and sample analysis procedures combined, as well as the sample analysis procedures alone. At least one pair of field duplicates was collected and analyzed for each matrix type. (Field duplicates would not necessarily apply to all sample types, such as small animals.) The precision of laboratory duplicates was reported by WIPP Laboratories and reviewed by the data validator, and the precision of field duplicates was calculated and reviewed by the validator.

The measure of precision for radionuclide sample analyses is the RER, which is expressed as:

$$RER = \frac{(MeanActivity)ori - (MeanActivity)dup}{\sqrt{(2\sigma TPU)^2 ori + (2\sigma TPU)^2 dup}}$$

Where:

| | | |
|---|---|---|
| *(Mean Activity)$_{ori}$* | = | Mean Activity of the Original or Primary Sample |
| *(Mean Activity)$_{dup}$* | = | Mean Activity of the Duplicate Sample |
| 2 σ TPU | = | Total Propagated errors at the 2 σ level |

The laboratory performed duplicate analyses on separate portions of the same homogenized sample on at least one sample from each batch for each type of sample matrix in order to generate analysis precision data. The duplicate analyses of separate aliquots of the same sample evaluated the precision of sub-sampling in the laboratory, the heterogeneity of the media being sampled, and the precision of the analytical method. These laboratory precision data, as RERs, are reviewed and evaluated during verification and validation of the data, but are not included in this report. The verification and validation review showed that all the RERs met the WIPP quality assurance objective of <1 for the sample batches analyzed in 2011, demonstrating good precision for the analysis procedures.

The RERs for field duplicate samples were also calculated by the data reviewer as an indicator of the overall precision, reflecting the combination of both sample collection and laboratory analysis. Duplicate samples were collected at the same time, same place, and under similar conditions as the primary samples. In the case of fauna (animals), field duplicates (separate animals) are not generally collected; however, separate portions of a deer were taken in the field and submitted for analysis. WIPP Laboratories analyzed both portions of the deer sample (precision data are provided in

Chapter 4, Table 4.23). The lab also analyzed one portion of the deer in duplicate as part of its normal procedure.

The WIPP environmental monitoring program has not defined a quality assurance objective for field duplicate samples. Nonetheless, precision for field duplicate measurements is tracked. For the purposes of this report, precision data are evaluated using the guidance for a similar monitoring project as cited in the reference document "*Rocky Flats Annual Report of Site Surveillance and Maintenance Activities-CY2008*," (Doc. No. S05247, U.S. Department of Energy, April, 2009). This source suggests that 85 percent of field duplicates should yield RERs (DERs) <1.96. Thus, 15 percent of the precision values would be allowed to be >1.96. Even so, a summary of the field duplicate samples with precision RERs >1 was compiled:

1. $^{137}$Cs yielded a RER of 1.051 in the duplicate air particulate composite samples at SMR during the first quarter ($^{137}$Cs not detected).

2. $^{239/240}$Pu yielded a RER of 2.802 in the duplicate air particulate composite samples at WSS during the fourth quarter ($^{239/240}$Pu detected in one duplicate and not the other).

3. $^{238}$Pu yielded a RER of 1.410 in the duplicate air particulate composite samples at WSS during the fourth quarter ($^{238}$Pu not detected).

4. $^{40}$K yielded a RER of 1.890 in the duplicate Round 32 groundwater samples from WQSP-1.

5. $^{40}$K yielded a RER of 3.640 in the duplicate Round 32 groundwater samples from WQSP-4.

6. $^{238}$U yielded a RER of 1.223 in the duplicate Round 32 groundwater samples from WQSP-1.

7. $^{235}$U yielded a RER of 1.374 in the duplicate Round 33 groundwater samples from WQSP-1.

8. $^{233/234}$U yielded a RER of 2.319 in the duplicate sediment samples from PKT.

9. $^{238}$U yielded a RER of 1.838 in the duplicate sediment samples from PKT.

10. $^{40}$K yielded a RER of 2.675 in the duplicate Smith Ranch soil samples at 0-2 cm.

11. $^{40}$K yielded a RER of 2.573 in the duplicate Smith Ranch soil samples at 2-5 cm.

12. $^{238}$U yielded a RER of 1.057 in the duplicate Smith Ranch soil samples at 2-5 cm.

13. $^{233/234}$U yielded a RER of 1.329 in the duplicate Smith Ranch soil samples at 2-5 cm.

The precision data show that only five precision values exceeded the 1.96 value and that three of these were for $^{40}K$. Overall, the precision of the field duplicates was very good and demonstrated that the sampling and analysis procedures were performed consistently.

The percentage of field duplicates that yielded RERs>1 was very small. Based on the total number of radionuclides and duplicate field samples collected in 2011, the percentage of radionuclide field duplicates that yielded RERs >1 was approximately 7.5% for air samples 3.3% for groundwater samples, 1.4% for sediment samples, 1.9% for soil samples, 0% surface water samples and 0% vegetation samples.

The number of field duplicates with RERs greater than 1.96 (Rocky Flats Criterion) was only 2.5% for air particulate samples, 0.83% for groundwater samples, 0.71% for sediment samples, 0.95% for soil samples, and 0% for surface water, vegetation and biota (0.69% total our of 720 field duplicate radioculide measurements).

### 7.1.3 Accuracy

The accuracy of the radiochemical analyses was checked by analyzing initial and continuing calibration standards, method blanks, and laboratory control samples (blank spikes) as specified in the standard methods and in the corresponding lab SOPs. The daily calibration standards were used to confirm that the response in the daily standard closely matched the corresponding response during the initial calibration. Instrument accuracy was assured by using National Institute of Standards and Technology (NIST)-traceable radiochemistry standards for instrument calibration. The method blanks were used to confirm that the accuracy of the radiological sample analysis was not adversely affected by the presence of any of the target analytes as background contaminants that may have been introduced during sample preparation and analysis. The laboratory control sample (LCS) was analyzed to check that the analytical method was in control by measuring the percent recoveries of the target analytes spiked into clean water. Duplicate LCS samples were prepared and analyzed for some of the radiochemical batches.

The radiochemical SOW requires the measured accuracy to meet or surpass control criteria or guidelines established in the industry-standard methods used for sample analysis. However, the SOW does not require the analysis of matrix spike samples.

NIST-traceable standards were spiked into clean water or a clean solid matrix to prepare LCS samples. Analysis of LCSs containing the isotopes of interest was performed on a minimum 10 percent basis (one per batch of 10 or fewer samples). The QA objective for the analysis results was for the measured concentration to be within ± 20 percent of the known expected concentration. If this criterion was not met, the entire batch of samples was re-analyzed. LCS results for each isotope were tracked on a running basis using control charts. The data validator checked that all the control chart points matched those reported by the laboratory. The review showed that all the radiological LCS results fell within the established recovery range, indicating good accuracy.

Accuracy was also ensured through the participation of WIPP Laboratories in the DOE MAPEP, the DOE Laboratory Accreditation Program (DOELAP), and the NRIP interlaboratory comparison program (through NIST), as discussed in more detail in section 7.1.4. Under these programs, WIPP Laboratories analyzed blind check samples, and the analysis results were compared with the official results measured by the DOELAP, MAPEP, and NRIP agency laboratories. Performance was established by percent bias, calculated as:

$$\%Bias = \frac{(A_m - A_k)}{A_k} \times 100$$

Where:

| | | |
|---|---|---|
| *% Bias* | = | Percent Bias |
| $A_m$ | = | Measured Sample Activity |
| $A_k$ | = | Known Sample Activity |

The DOELAP and NRIP programs primarily include the analyses of bioassay samples (urine and feces). Bioassay samples are not analyzed as part of the WIPP environmental program, and NRIP and DOELAP program performance evaluation (PE) bioassay analysis results are not specifically discussed in this report. The NRIP bioassay samples are part of an emergency preparedness exercise where the accuracy has a relatively wide acceptance range, but a fast turnaround time for reporting the results is very important. The analysis results for the WIPP target radionuclides in the samples ($^{241}$Am, $^{238}$Pu, $^{240}$Pu, $^{90}$Sr, and $^{137}$Cs) all met the accuracy criteria in a feces and urine sample.

WIPP Laboratories analyzed eight MAPEP environmental samples consisting of two each of soil, water, air filter, and vegetation samples. In addition, the laboratory analyzed one environmental soil sample from NRIP (NIST). The analysis results are presented in section 7.1.4.

Based on the number of acceptable (A) ratings earned by WIPP Laboratories for the analysis of PE samples, the laboratory provided accurate and reliable radionuclide analysis data for the WIPP environmental samples.

### 7.1.4 Comparability

The mission of WIPP Laboratories is to produce high-quality and defensible analytical data in support of the WIPP operations. The SOW requires WIPP Laboratories to ensure consistency through the use of standard analytical methods coupled with specific procedures that govern the handling of samples and the reporting of analytical results.

A key element in the WIPP Laboratories QA program is analysis of PE samples distributed as part of interlaboratory comparison programs by reputable agencies. The DOELAP, MAPEP, and the NIST NRIP programs involve preparing QC samples containing various alpha-, beta-, and gamma-emitting radionuclides in synthetic urine, synthetic feces, air filter, water, soil, and vegetation media, and distributing the samples to the participating laboratories.

The programs are interlaboratory comparisons in that the analysis results generated by the laboratory participants are compared with the analysis results experimentally measured by the administering agencies. The programs assess each laboratory's analysis results as acceptable (passing) or not acceptable (failing), based on the accuracy of the analyses. A warning (W) may be issued for a result near the borderline of acceptability.

Table 7.1 presents the analysis results for the first set of MAPEP soil, water, air filter, and vegetation PE (performance evaluation) samples (Series 24) analyzed in 2011. The acceptable range for the MAPEP samples is a bias ≤20 percent; the Acceptable range with a Warning (W) is a bias >20 percent but <30 percent, and the Not Acceptable (N) results are those with a bias >30 percent. The WIPP Laboratories analysis results for the MAPEP-11 MaS24 soil samples showed that the results were acceptable except for $^{90}$Sr, where WIPP Laboratories reported 234 Bq/kg and the acceptable range (including warning range) was 112-208 Bq/kg. The radionuclide was not detected in any of the WIPP samples.

The WIPP Laboratories analysis results were all acceptable for the WIPP target radionuclides in the aqueous sample (MaW24). The WIPP Laboratories analysis results were also acceptable for the radiological air filter samples (RdF24). The gross alpha acceptable range is ≤ +/-70 percent, and the gross beta acceptance range is ≤ +/-50 percent.

WIPP Laboratories reported slightly high results for $^{233/234}$U and $^{238}$U in vegetation samples (RdV24) as shown in Table 7.1. The reported value for $^{233/234}$U was 0.217 Bq/sample, just above the acceptable range (including warning range) of 0.114-0.212 Bq/sample and reference concentration of 0.163 Bq/sample. The reported value for $^{238}$U was 0.219 Bq/sample, just above the acceptable range (with warning range) of 0.118-0.218 Bq/sample and reference concentration of 0.168 Bq/sample.

Table 7.2 presents the results for the second set of MAPEP soil, water, air filter, and vegetation PE samples (Series 25) analyzed in 2011. WIPP Laboratories results for the MAPEP Series 25 samples showed all acceptable results for the target radionuclides in soil samples (MaS25). The water sample (MaW25) results were acceptable except for 90Sr, where the lab reported 142 Bq/L, which was significantly outside the acceptable range of 9.9-18.5 Bq/L. The radionuclide has not been detected in any aqueous samples from the WIPP site.

All acceptance ranges were met for the target radionuclides in the radiological air filters (RdF25). All WIPP Laboratories results were acceptable for the vegetation sample (RdV25).

**Table 7.1 – Mixed Analyte Performance Evaluation Program Review for WIPP Laboratories, 2011, First Set (Series 24)**

| | MATRIX: Air Filter (Bq/Filter) MAPEP-11-RdF24 | | | | MATRIX: Water (Bq/L) MAPEP- 11-MaW24 | | | |
|---|---|---|---|---|---|---|---|---|
| [RN][a] | Reported Value | MAPEP[b] Value | E[c] | % Bias | Reported Value | MAPEP Value | E | % Bias |
| $^{241}$Am | 0.000438 | ND | A | False Positive Test | 0.553 | 0.529 | A | 4.5 |
| $^{60}$Co | 0.0908 | ND | A | False Positive Test | 24.6 | 24.6 | A | 0.0 |
| $^{137}$Cs | 2.31 | 2.28 | A | 1.3 | 28.6 | 29.4 | A | -2.7 |
| $^{238}$Pu | 0.115 | 0.096 | A | 19.8 | 1.15 | 1.064 | A | 8.1 |
| $^{239/240}$Pu | 0.0850 | 0.0765 | A | 11.1 | 0.807 | 0.809 | A | -0.2 |
| $^{90}$Sr | 1.59 | 1.36 | A | 10.3 | 9.41 | 8.72 | A | 7.9 |
| $^{233/234}$U | 0.179 | 0.178 | A | 0.6 | 1.64 | 1.50 | A | 9.3 |
| $^{238}$U | 0.182 | 0.185 | A | -1.6 | 1.59 | 1.54 | A | 3.2 |
| | MATRIX: Soil (Bq/kg) MAPEP-11-MaS24 | | | | MATRIX: Vegetation (Bq/Sample) MAPEP-11-RdV24 | | | |
| [RN] | Reported Value | MAPEP Value | E | % Bias | Reported Value | MAPEP Value | E | % Bias |
| $^{241}$Am | 54.0 | 61.1 | A | -11.6 | 0.00117 | ND | A | False Positive Test |
| $^{60}$Co | 501 | 482 | A | 3.9 | 5.09 | 4.91 | A | 3.7 |
| $^{137}$Cs | 741 | 758 | A | -2.2 | 10.8 | 9.94 | A | 8.7 |
| $^{238}$Pu | 0.845 | 0.48 | A | (d) | 0.121 | 0.102 | A | 18.6 |
| $^{239/240}$Pu | 93.1 | 98.0 | A | -5.0 | 0.156 | 0.141 | A | 10.6 |
| $^{90}$Sr | 234 | 160 | N | 46.3 | 2.63 | 2.46 | A | 6.9 |
| $^{233/234}$U | 180 | 176 | A | 2.3 | 0.217 | 0.163 | N | 33.1 |
| $^{238}$U | 181 | 184 | A | -1.6 | 0.219 | 0.168 | N | 30.4 |

(a) Radionuclide
(b) Mixed Analyte Performance Evaluation Program
(c) Evaluation Rating (A = Acceptable, W = Acceptable with warning, N = Not acceptable)
(d) Not detected. Reported a statistically zero result for sensitivity evaluation

**Table 7.2 – Mixed Analyte Performance Evaluation Program Review for WIPP Laboratories, 2011 Second Set (Series 25)**

| | MATRIX: Air Filter (Bq/Filter) MAPEP-11-RdF25 | | | | MATRIX: Water (Bq/L) MAPEP-11-MaW25 | | | |
|---|---|---|---|---|---|---|---|---|
| [RN][a] | Reported Value | MAPEP[b] Value | E[c] | % Bias | Reported Value | MAPEP Value | E | % Bias |
| $^{241}$Am | 0.130 | 0.147 | A | -11.6 | 2.62 | 3.18 | A | -17.6 |
| $^{60}$Co | 3.89 | 3.20 | A | 21.6 | 28.3 | 29.3 | A | -3.4 |
| $^{137}$Cs | 3.05 | 2.60 | A | 17.3 | 60.1 | 60.6 | A | -0.8 |
| $^{238}$Pu | 0.119 | 0.1183 | A | 0.6 | 0.0186 | 0.016 | A | Sensitivity Evaluation |
| $^{239/240}$Pu | 0.131 | 0.135 | A | -3.0 | 2.34 | 2.40 | A | -2.5 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $^{90}$Sr | 1.72 | 1.67 | A | 3.0 | 142 | 14.2 | N | 900 |
| $^{233/234}$U | 0.175 | 0.162 | A | 8.0 | 3.04 | 2.78 | A | 9.4 |
| $^{238}$U | 0.174 | 0.168 | A | 3.6 | 3.07 | 2.89 | A | 6.2 |
| | **MATRIX: Soil (Bq/kg) MAPEP-11-MaS25** | | | | **MATRIX: Vegetation (Bq/Sample) MAPEP-11-RdV25** | | | |
| **[RN]** | **Reported Value** | **MAPEP Value** | **E** | **% Bias** | **Reported Value** | **MAPEP Value** | **E** | **% Bias** |
| $^{241}$Am | 0.376 | 0.259 | A | (d) | 0.206 | 0.222 | A | -7.2 |
| $^{60}$Co | 643 | 644 | A | -0.2 | 3.52 | 3.38 | A | 4.1 |
| $^{137}$Cs | 927 | 979 | A | -5.3 | 4.69 | 4.71 | A | -0.4 |
| $^{238}$Pu | 101 | 93.6 | A | 7.9 | 0.134 | 0.124 | A | 8.1 |
| $^{239/240}$Pu | 81.6 | 77.4 | A | 5.4 | 0.000699 | 0.0008 | A | d |
| $^{90}$Sr | 332 | 320 | A | 3.8 | 1.40 | 1.26 | A | 11.1 |
| $^{233/234}$U | 287 | 263 | A | 9.1 | 0.364 | 0.357 | A | 2.0 |
| $^{238}$U | 292 | 274 | A | 6.6 | 0.371 | 0.370 | A | 0.3 |

(a) Radionuclide

(b) Mixed Analyte Performance Evaluation Program

(c) Evaluation Rating (A = Acceptable, W = Acceptable with warning, N = Not acceptable)

(d) Not detected. Reported a statistically zero result for sensitivity evaluation

Table 7.3 presents the results for the NIST soil sample analysis. NIST did not report results as acceptable or not acceptable, but all the results for the WIPP site target radionuclides were close to the NIST values with the bias ranging from -6.6 percent to one value at 14.4 percent, and the next highest value at 2.9 percent.

**Table 7.3 – NIST Report of Traceability, Soil**

| [RN] | Reported Value | NIST Value | % Bias |
|---|---|---|---|
| $^{241}$Am | 4.04 | 4.29 | -5.9 |
| $^{60}$Co | 730 | 638.1 | 14.4 |
| $^{137}$Cs | 724 | 774.9 | -6.6 |
| $^{238}$Pu | 1.48 | 1.439 | 2.9 |
| $^{239/240}$Pu | 1.77 | 1.833 | -3.4 |
| $^{90}$Sr | 37.1 | 37.6 | -1.3 |
| $^{233/234}$U | 4.83 | 4.69 | 2.9 |
| $^{238}$U | 4.86 | 4.87 | -0.2 |

### 7.1.5 Representativeness

Representativeness is the extent to which measurements actually represent the true environmental condition or population at the time a sample was collected. The primary objective of the EMS is to protect the health and safety of the population surrounding the WIPP facility. According to the SOW, analytical representativeness is assured through the use of technically sound and accepted approaches for environmental investigations, including industry-standard procedures for sample collection and monitoring for potential sample cross-contamination through the analysis of field and laboratory method blank samples. These conditions were satisfied during the sample collection and analysis practices of the WIPP environmental monitoring program.

The environmental media samples (air, groundwater, surface water, soil, sediment, and biota) were collected from areas representative of potential pathways for intake of radionuclides. The samples were collected using generally accepted methodologies for environmental sampling, ensuring that they would be representative of the media sampled. Both sample collection blanks and laboratory method blanks were used to check for cross-contamination and to ensure sample integrity.

## 7.2 Carlsbad Environmental Monitoring And Research Center

CEMRC performed the analyses of VOC and hydrogen/methane samples collected in the WIPP underground during 2011.

### 7.2.1 Completeness

Completeness is defined in WP 12-VC.01, *Confirmatory Volatile Organic Compound Monitoring Plan*, and WP 12-VC.04, *Quality Assurance Project Plan for Hydrogen and Methane Monitoring*, as being "the percentage of the ratio of the number of valid sample results received versus the total number of samples collected." The quality assurance objective for completeness in the VOC monitoring program is 95 percent.

For 2011, 537 VOC samples (including field duplicates) were submitted to CEMRC for analysis; 535 of these produced valid data. For repository, disposal room, and ongoing VOC monitoring, the program completion percentage was 99.6 percent.

For 2011, 398 hydrogen and methane samples (including field duplicates) were submitted to CEMRC for analysis; 397 of these produced valid data. For hydrogen and methane monitoring, the program completion percentage was 99.7 percent.

### 7.2.2 Precision

Precision is demonstrated in both the VOC monitoring and hydrogen and methane programs by evaluating results from both laboratory duplicate analysis and field duplicate samples. The laboratory duplicate samples consist of an LCS and laboratory control sample duplicate (LCSD). The field duplicate is a duplicate sample that is collected parallel with the original sample. Both of these duplicate samples are evaluated using the relative percent difference (RPD), as defined in WP 12-VC.01 and WP 12-VC.04. The RPD is calculated using the following equation.

$$RPD = \frac{(A - B)}{(|A + B|)/2} \times 100$$

Where:

A = Original Sample Result

B = Duplicate Sample Result

A LCS and a LCSD (for applicable instrumental methods) were generated and evaluated for all data packages discussed in section 7.2.1. All the LCS/LCSD data generated during Round 32 and Round 33 in 2011 yielded RPDs ≤20.

Field duplicate samples are also collected and compared for precision. The acceptable range for the RPD between measured concentrations is ± 35 percent. For each value reported over the MRL in 2011, each field duplicate met the acceptance criteria with the exception of one disposal room VOC sample and two ongoing disposal room VOC samples.

### 7.2.3 Accuracy

The VOC monitoring program evaluates both quantitative and qualitative accuracy and recovery of internal standards. Qualitative evaluation consists of the evaluation of standard ion abundance for the instrument tune; that is, a mass calibration check performed prior to analyses of calibration curves and samples.

The hydrogen and methane monitoring program evaluates quantitative accuracy. The quantitative evaluation includes performance verification for instrument calibrations and LCS recoveries.

#### 7.2.3.1 Quantitative Accuracy

Instrument Calibrations

Instrument calibrations are required to have a relative standard deviation percentage of less than or equal to 30 percent for each analyte of the calibration. This is calculated by first calculating the relative response factor as indicated below:

$$\text{Relative Response Factor} = \frac{\text{(Analyte Response)(Internal Standard Concentration)}}{\text{(Internal Standard Response)(Analyte Concentration)}}$$

$$\text{Relative Standard Deviation} = \frac{\text{Standard Deviation of Relative Response Factor}}{\text{Average Relative Response Factor of Analyte}} \times 100$$

During 2011, 100 percent of instrument calibrations met the ≤30 percent criteria.

LCS Recoveries

LCS recoveries are required to have a percent recovery of ± 40 (60-140%R) percent. LCS recoveries are calculated as:

$$PercentRecovery = \frac{X}{T} \times 100$$

X = Experimentally determined value of the analyte recovered from the standard

T = True reference value of the analyte being measured

During 2011, 100 percent of the LCS recoveries met the ± 40 percent criterion.

Internal Standard Area

For VOC analyses, internal standard areas are compared to a calibrated standard to evaluate accuracy. The acceptance criteria is ± 40 percent.

During 2011, 100 percent of all standards met this criterion.

Sensitivity

To meet sensitivity requirements, the method detection limit for each of the nine target compounds must be evaluated before sampling begins. The initial and annual method detection limit evaluation is performed in accordance with 40 CFR Part 136, "Guidelines Establishing Test Procedures for the Analysis of Pollutants," and with EPA/530-SW-90-021, Q*uality Assurance and Quality Control* (Chapter 1 of EPA SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*) (1996). For 2011, CEMRC completed method detection limit studies for VOC analyses in October and for hydrogen methane analysis in August.

#### 7.2.3.2 Qualitative Accuracy

For VOC analyses, the standard ion abundance criteria for bromofluorobenzene is used to evaluate the performance of the analytical system in the identification of target analytes as well as unknown contaminants (qualitative accuracy). This ensures that the instrumentation is correctly identifying individual compounds during the analysis of air samples.

During 2011, all ion abundance criteria were within tolerance.

### 7.2.4 Comparability

There is no Permit requirement for comparability in the VOC monitoring program and the hydrogen and methane monitoring program. However, comparability is maintained through the use of consistent, approved SOPs for sample collection and analyses.

### 7.2.5 Representativeness

Representativeness is ensured by use of programmatic plans and procedures implementing EPA guidance designed to collect and analyze samples in a consistent manner.

## 7.3 Hall Environmental Analysis Laboratory

HEAL was awarded the groundwater analysis contract in February 2008 and performed the chemical analyses for the spring and fall sampling in 2011 (Rounds 32 and 33). HEAL followed SOPs based on standard analytical methods from EPA and from *Standard Methods for the Examination of Water and Wastewater* (Eaton et al., 2005).

### 7.3.1 Completeness

Six WQSP monitoring wells were sampled twice during 2011, March through May, and September through November, for the WIPP groundwater DMP. The completeness objective was met as analytical results were received for all the samples submitted (100 percent completeness).

### 7.3.2 Precision

The groundwater samples generally contained detectable concentrations of the major cations including calcium, magnesium, potassium, and sodium. Measurements were made for chloride, sulfate, total organic carbon (TOC), density, TDS, total suspended solids (TSS), pH, conductivity, total organic halogen (TOX), and alkalinity. TOC was detected in many of the groundwater samples at concentrations between the method detection limit (MDL) and MRL. HEAL subcontracted the specialty TOX analyses to Columbia Analytical Services and subcontracted the trace metals analysis for antimony (Sb), arsenic (As), selenium (Se), and thallium (Tl) by inductively coupled plasma emission spectroscopy combined with mass spectrometry (ICP-MS) to Anatek Laboratories in order to achieve the requisite detection limits.

Precision was based on the analysis results of duplicate samples from a single well sample for some general chemistry parameter methods, as well as the precision of the recoveries of LCS/LCSD and matrix spike/matrix spike duplicate (MS/MSD) pairs. Duplicate samples were collected at each of the WQSP wells, and the samples are termed the "primary" sample and the "duplicate" sample. Since they are separate samples, there are no particular precision requirements for the analysis results. The precision of duplicate field samples was discussed in section 7.1.2. The duplicate groundwater samples were collected consecutively from continuously flowing water. The composition of the samples is expected to be consistent, and the precision of the analysis results should meet the same requirements as duplicate analysis of the primary groundwater sample. LCS and LCSD samples were prepared by spiking the target constituent (VOCs, SVOCs, and trace metals) or general chemistry parameter analytes into clean water and preparing and analyzing the samples. (LCSD samples were only prepared for analytical methods involving an instrumental analysis step and simply required the reanalysis of the LCS sample.) The precision objective of LCS/LCSD pairs was a RPD ≤20 for all constituents and general chemistry parameters.

MS and MSD samples were generated by spiking the target constituents and general chemistry indicator parameter analytes into separate portions of the primary groundwater samples. The samples were analyzed, and the recoveries of the VOCs, SVOCs, and metals and general chemistry indicator parameters were measured and reported. The quality assurance objective for the precision of the MS and MSD concentrations was also generally ≤20 RPD for all constituents and general chemistry parameters.

Another precision quality assurance objective for VOC and SVOC analyses included agreement of daily GC/MS calibration standard concentrations with 20 percent difference (bias) from the initial calibration curve.

Table 7.4 shows the groundwater samples for which the analysis of the primary and duplicate groundwater sample yielded RPDs >20. These data are provided for information only since the precision objective does not necessarily apply to duplicate field samples. The precision objective was most often not met during the analyses for analytes for which the analytical methods are challenged by the high-brine groundwater samples including TSS and TOX. Other cases where the duplicate groundwater sample RPD was >20 was for analytes, especially the trace metals, that were detected at low concentrations between the MDL and the MRL where the concentrations were J-flagged as estimated. With respect to QA samples, only the four SVOC compounds pentachlorophenol, pyridine, 2, 4-dinitrophenol and nitrobenzene did not meet the precision objective in seven MS and MSD samples with the exception that none of the SVOC compounds met the precision objective in one MS/MSD pair during analysis of the WQSP-1 samples in Round 32.

Table 7.4 also shows those instances where the precision objective was not met for the MS/MSD analyses. All LCS/LCSD measurements met the precision objective.

**Table 7.4 – Individual Cases Where the Groundwater RPDs were >20 for Duplicate Field Samples and the MS/MSD Precision Objective Was Not Met (RPD>20) for QA/QC Samples**

| Well | Round | Parameter | Primary Sample, mg/L | Duplicate Sample, mg/L | RPD |
|---|---|---|---|---|---|
| WQSP-1 | 32 | TOX | 0.42 | 0.29 | 37 |
| WQSP-1 | 32 | Fe | 0.15 J[a] | 0.12 J | 22 |
| WQSP-2 | 32 | TOX | 0.57 | 0.90 | 45 |
| WQSP-3 | 32 | TOX | 1.24 | 2.65 | 72 |
| WQSP-4 | 32 | TOX | 0.33 | 0.67 | 68 |
| WQSP-4 | 32 | Ba | 0.038 J | 0.025 J | 41 |
| WQSP-5 | 32 | TOX | 0.17 | 0.29 | 52 |
| WQSP-5 | 32 | TSS | 15 | 19 | 24 |
| WQSP-5 | 32 | Hg | 0.0027 J | 0.00096 J | 95 |
| WQSP-5 | 32 | Fe | 0.54 J | 0.84 J | 43 |
| WQSP-1 | 32 | All 11 SVOCs[b] | 14.3–68.3 ug/L (MS) | 9.00–50.2 ug/L (MSD) | 23–45 |
| WQSP-3 | 32 | Pentachlorophenol | 55.7 ug/L (MS) | 41.1 ug/L (MSD) | 30 |
| WQSP-3 | 32 | Pyridine | 26.3 ug/L (MS) | 35.0 ug/L (MSD) | 28 |
| WQSP-4 | 32 | 2,4-Dinitrophenol | 32.3 ug/L (MS) | 25.2 ug/L (MSD) | 25 |
| WQSP-4 | 32 | Pentachlorophenol | 24.1 ug/L (MS) | 17.6 ug/L (MSD) | 31 |
| WQSP-5 | 32 | 2,4-Dinitrophenol | 27.8 ug/L (MS) | 34.0 ug/L (MSD) | 20 |
| WQSP-5 | 32 | Nitrobenzene | 53.6 ug/L (MS) | 66.3 ug/L (MSD) | 21 |
| WQSP-1 | 33 | TOC | 0.60 J | 0.75 J | 22 |
| WQSP-1 | 33 | TOX | 0.57 | 0.26 | 75 |
| WQSP-1 | 33 | Be | 0.0032 J | 0.0040 J | 22 |
| WQSP-1 | 33 | Fe | 0.17 J | 0.11 J | 43 |
| WQSP-2 | 33 | Be | 0.0043 J | 0.0071 J | 49 |
| WQSP-2 | 33 | V | 0.037 J | 0.051 J | 32 |
| WQSP-2 | 33 | Se | 0.012 J | 0.021 J | 55 |

**Table 7.4 – Individual Cases Where the Groundwater RPDs were >20 for Duplicate Field Samples and the MS/MSD Precision Objective Was Not Met (RPD>20) for QA/QC Samples**

| Well | Round | Parameter | Primary Sample, mg/L | Duplicate Sample, mg/L | RPD |
|---|---|---|---|---|---|
| WQSP-3 | 33 | TOC | 0.36 J | 1.0 | 94 |
| WQSP-3 | 33 | TOX | 1.52 | 0.89 | 52 |
| WQSP-3 | 33 | Be | 0.017 J | 0.0097 J | 55 |
| WQSP-3 | 33 | V | 0.13 J | 0.082 J | 45 |
| WQSP-4 | 33 | TOC | 0.73 J | 0.35 J | 70 |
| WQSP-4 | 33 | TOX | 0.31 | 0.64 | 69 |
| WQSP-5 | 33 | TOX | 0.14 | 0.21 | 40 |
| WQSP-5 | 33 | TSS | 13 | 7.0 | 60 |
| WQSP-5 | 33 | Fe | 0.21 J | 0.27 J | 25 |
| WQSP-6 | 33 | TOX | 0.14 | 0.21 | 40 |
| WQSP-6 | 33 | Hg | 0.000056 J | 0.000041 J | 31 |
| WQSP-1 | 33 | 2,4-Dinitrophenol | 43.2 ug/L (MS) | 61.7 ug/L (MSD) | 35 |
| WQSP-1 | 33 | Pentachlorophenol | 38.3 ug/L (MS) | 63.5 ug/L (MSD) | 35 |
| WQSP-2 | 33 | 7 SVOC compounds[c] | 48.1–75.1 ug/L (MS) | 29.5–60.0 ug/L (MSD) | 21–63 |
| WQSP-3 | 33 | 11 VOC compounds[d] | 13.5 ug/L-22.7 ug/L (MS) | 17.5–30.3 ug/L (MSD) | 20–30 |
| WQSP-4 | 33 | Pentachlorophenol | 11.9 ug/L (MS) | 7.9 ug/L (MSD) | 29 |

(a) Concentrations are between the MDL and MRL and are J-flagged as estimated.

(b) 11 SVOCs as follows: 1,2-dichlorobenzene, 1,4-dichlorobenzene, 2,4-dinitrophenol, 2,4-dinitrotoluene, hexachlorobenzene, hexachloroethane, 2-methylphenol, 3- + 4-methylphenol, nitrobenzene, pentachlorophenol, and pyridine.

(c) 7 SVOCs as follows: 1,2-dichlorobenzene, 1,4-dichlorobenzene, 2,4-dinitrophenol, hexachloroethane, 2-methylphenol, 3- + 4-methylphenol, and pentachlorophenol

(d) 11 VOCs as follows: toluene, 1,2-dichloroethane, 2-butanone, chlorobenzene, chloroform, 1,1-dichloroethane, methylene chloride, 1,1,2,2 tetrachloroethane, 1,1,1-trichloroethane, 1,1,2-trichloroethane, and total xylenes

Considering the hundreds of groundwater sample data points and QA/QC sample data points that were generated during Rounds 32 and 33, the number of duplicate groundwater samples and MS/MSD QA samples that did not meet the precision quality assurance objective was very low, at about 3 percent. There was a consistent pattern of certain analytes appearing on the list in Table 7.4. TOX appeared most frequently in Table 7.4 for poor agreement of the analysis results for the primary and duplicate groundwater samples.

TOX analyses are affected by the high chloride concentrations in the DMP samples. The quality assurance objectives for precision have not always been met. In addition, the QC objective of retaining 90 percent of the measured TOX in the groundwater samples on the front granular activated carbon is generally not met, likely resulting in false positive measurements for TOX. The search for halogenated compounds is primarily performed using the more sensitive GC/MS analyses for target and non-target VOCs and SVOCs that may be in the samples. As a result, TOX analyses will be discontinued in future Rounds.

The primary and duplicate groundwater TSS measurements appeared twice in the table and can be affected by how long a sample is allowed to settle before an aliquot is taken for analysis. In addition, the small particle size of the solids if close to the pore size of the filters contributing to poorer precision.

A total of 13 primary and duplicate groundwater trace metal concentrations appeared in Table 7.4. Most of the trace metal concentrations were between the MDL and MRL and are thus J-flagged as estimated. The precision would not be expected to be as good for analytes with concentrations lower than the lowest calibration standard. The same applies to the TOC analysis results with most concentrations less than the MRL.

MS and MSD samples were generated by spiking the target constituents and general chemistry indicator parameter analytes into separate portions of the primary groundwater samples. The samples were analyzed, and the recoveries of the VOCs, SVOCs, and metals and general chemistry indicator parameters measured and reported. The quality assurance objective for the precision of the MS and MSD concentrations was generally ≤20 RPD, just as for the LCS/LCSD pairs.

No SVOC compounds were detected in the groundwater samples, but some data packets contained data for one or more SVOC compounds spiked into the MS and MSD samples that did not meet the precision quality assurance objective for recovery. The variable recoveries between the two samples were generally due to consistently better recoveries from one of the samples than the other. The same situation applied to one set of VOC compounds in the MS and MSD samples.

### 7.3.3 Accuracy

The accuracy of the analyses was checked by analyzing initial calibration verification standards, continuing calibration verification standards, method blanks, LCS and LCSD samples, and MS and MSD samples as specified in the standard methods and in the corresponding lab SOPs. The daily calibration standards were used to confirm that the response in the daily standard closely matched the corresponding response during the initial calibration. The method blanks were used to confirm that the accuracy of the groundwater sample analyses was not adversely affected by the presence of any of the target analytes as background contaminants that may have been introduced during sample preparation and analysis. The LCS and LCSD, where applicable, were analyzed to check that the analytical method was in control by measuring the percent recoveries of the target analytes spiked into clean water. MS and MSD samples were prepared and analyzed to check the effect of the groundwater sample matrix on the accuracy of the analytical measurements as percent recovery.

Table 7.5 summarizes the QC samples for which the accuracy QA objective, as measured by percent recovery, was not met during the Round 32 and 33 sampling and analysis in 2011. None of the target analytes were detected in method blank samples as contaminants, and thus accuracy was not adversely affected by contamination. The recoveries of analytes that contained native sample concentrations greater than four times the matrix spike concentration, such as the major cations, chloride, and sulfate, are not included in Table 7.5 since MS/MSD recovery data are not applicable per EPA guidance for samples with high native concentrations of a given analyte.

Organics

The accuracy quality assurance objectives for the organic constituents included recoveries of 70-130 percent recovery for VOCs from LCS/LCSD samples and MS/MSD samples and recoveries determined by the lab's historical control chart limits or EPA guidance for SVOCs in LCS/LCSD and MS/MSD samples. The recovery objectives for the SVOCs were generally wider than for VOCs. Other quality assurance objectives include agreement of daily calibration standard concentrations to within 20 percent difference (bias) from the initial calibration curve and method blanks with any detected analytes at concentrations less than the MRL and preferably not detected at all.

**Table 7.5 – Individual Cases where the Accuracy Quality Assurance Objective was not Met in 2011 for Groundwater QA Sample Analyses**

| Well | Round | Parameter | Sample | % Rec | Sample | % Rec |
|---|---|---|---|---|---|---|
| WQSP-1 | 32 | Isobutanol (70-130) | MS | 151 | MSD | 149 |
| WQSP-1 | 32 | 2-butanone (70-130) | MS | 144 | MSD | 147 |
| WQSP-1 | 32 | TOX (82-121) | MS | 62 | MSD | 92 (ok) |
| WQSP-2 | 32 | Mercury (75-125) | MS | 70.5 | MSD | 74.0 |
| WQSP-2 | 32 | Isobutanol (70-130) | MS | 143 | MSD | 157 |
| WQSP-2 | 32 | 2-butanone (70-130) | MS | 148 | MSD | 151 |
| WQSP-2 | 32 | 1,1,2,2-tetrachloroethane (70-130) | MS | 131 | MSD | 133 |
| WQSP-3 | 32 | Mercury (75-125) | MS | 70.0 | MSD | 71.2 |
| WQSP-3 | 32 | Isobutanol (70-130) | MS | 415 | MSD | 424 |
| WQSP-3 | 32 | 2-butanone (70-130) | MS | 235 | MSD | 239 |
| WQSP-3 | 32 | 1,1,2,2-tetrachloroethane (70-130) | MS | 135 | MSD | 142 |
| WQSP-3 | 32 | Tetrachloroethylene (70-130) | MS | 65.4 | MSD | 61.9 |
| WQSP-3 | 32 | Xylenes (70-130) | MS | 65.4 | MSD | 62.7 |
| WQSP-4 | 32 | TOX (82-121) | MS | 127 | MSD | 111 (ok) |
| WQSP-4 | 32 | TDS (80-120) | MS | 126 | MSD | 105 (ok) |
| WQSP-4 | 32 | Isobutanol (70-130) | MS | 178 | MSD | 184 |
| WQSP-4 | 32 | 2-butanone (70-130) | MS | 166 | MSD | 167 |
| WQSP-4 | 32 | 1,1,2,2-tetrachloroethane (70-130) | MS | 150 | MSD | 145 |
| WQSP-5 | 32 | Isobutanol (70-130) | MS | 134 | MSD | 132 |
| WQSP-1 | 33 | Isobutanol (70-130) | MS | 143 | MSD | 146 |
| WQSP-1 | 33 | 2-Butanone (70-130) | MS | 240 | MSD | 237 |
| WQSP-1 | 33 | TOX (82-121) | MS | 88 (a) | MSD | 38 |
| WQSP-2 | 33 | Isobutanol (70-130) | MS | 132 | MSD | 156 |
| WQSP-2 | 33 | 2-Butanone (70-130) | MS | 162 | MSD | 191 |
| WQSP-3 | 33 | Isobutanol (70-130) | MS | 234 | MSD | 234 |
| WQSP-3 | 33 | 2-Butanone (70-130) | MS | 353 | MSD | 369 |
| WQSP-3 | 33 | 1,1,2,2-tetrachloroethane (70-130) | MS | 152 | MSD | 161 |
| WQSP-3 | 33 | Mercury (75-125) | MS | 63.8 | MSD | 59.4 |
| WQSP-3 | 33 | TOX (82-121) | MS | 110 (ok) | MSD | 130 |

**Table 7.5 – Individual Cases where the Accuracy Quality Assurance Objective was not Met in 2011 for Groundwater QA Sample Analyses**

| Well | Round | Parameter | Sample | % Rec | Sample | % Rec |
|---|---|---|---|---|---|---|
| WQSP-4 | 33 | Isobutanol (70-130) | MS | 183 | MSD | 183 |
| WQSP-4 | 33 | 2-Butanone (70-130) | MS | 196 | MSD | 190 |
| WQSP-4 | 33 | 1,1,2,2-tetrachloroethane (70-130) | MS | 146 | MSD | 142 |
| WQSP-5 | 33 | Isobutanol (70-130) | MS | 136 | MSD | 140 |
| WQSP-5 | 33 | 2-butanone (70-130) | MS | 281 | MSD | 284 |
| WQSP-6 | 33 | 2-butanone (70-130) | MS | 220 | MSD | 223 |

Every calibration standard, groundwater sample, and quality control sample analyzed by GC/MS served as a surrogate spike sample in that the surrogate recovery compounds were spiked into the samples prior to analysis, and their recoveries were reported as a measure of accuracy of the analyses.

As shown in Table 7.5, most of the cases of organics not meeting the quality assurance objective for recovery was due to high recoveries for three particular compounds including isobutanol (isobutyl alcohol), 2-butanone (methylethyl ketone), and 1,1,2,2, tetrachloroethane. Table 7.5 is nearly identical to the same table for the 2009 and 2010 ASERs.

The reason for the high recoveries of isobutanol and 2-butanone is likely due to the higher purging efficiencies from brine solution than from the relatively clean calibration standards. The 1,1,2,2-tetrachloroethane recoveries are also higher than the quality assurance objective in a few MS/MSD samples, probably due to degradation and conversion of other chlorinated organic compounds such as the dichloroethylenes and trichloroethylene to 1,1,2,2-tetrachloroethane in the spiked brine samples. These compounds yielded slightly lower MS/MSD recoveries than the other VOCs.

With respect to SVOCs some MS/MSD recoveries were out of the range suggested by EPA guidance of 40 to 140 percent for base/neutral compounds and 30 to 130 percent for acidic compounds.  However, the recoveries were within the lab's historical control chart range and are not included in Table 7.5.

Since all the LCS/LCSD recoveries readily met the recovery objectives, it was possible to determine which compounds were adversely affected by the high-TDS groundwater matrix based on the MS/MSD recoveries. The compounds that appeared to be most affected included 2,4-dinitrophenol and pentachlorophenol. However, these compounds were not detected in the groundwater samples.

Metals

The accuracy quality assurance objectives for the metals included recoveries of 80-120 percent for metals and mercury in LCS/LCSD samples and 75-125 percent recovery in MS/MSD samples with any detected analytes in the method blanks at concentrations less than the MRL and preferably not detected at all.

The only metal that did not meet the quality assurance recovery objective in all the spiked samples was mercury, as shown in Table 7.5. The mercury MS and MSD recoveries were low for WQSP-2 and WQSP-3 during Round 32 and WQSP-3 from Round 33. Thus, the mercury recoveries appear to be reduced by the high TDS content of these wells. Mercury was detected at extremely low concentrations in the groundwater samples from WQSP-5 in Round 32 and WQSP-6 in Round 33. The MS/SD recoveries for mercury suggest that reported concentrations could be biased low. However, the TDS is the highest in WQSP-2 and WQSP-3 where the mercury spike recoveries were low but mercury was not detected. The TDS is lowest in WQSP-5 and WQSP-6 where mercury was detected and the MS/MSD recovery objectives were met.

General Chemistry Indicator Parameters

The accuracy quality assurance objectives for the general chemistry indicator parameters are generally tighter than for the constituent organics and metals, with recoveries of 80-120 percent with any detected analytes in the method blanks at concentrations less than the MRL and preferably not detected at all.

Table 7.5 contains four total individual TOX MS or MSD recoveries that did not meet the objective. Three recoveries were low and one was high, and one TDS MS recovery was slightly high.

TOX, TSS (for which MS/MSD analyses are not performed) and nitrate analyses are the three general chemistry indicator parameter analytes whose analytical methods are the most challenged by the high-TDS samples. TOX analyses are adversely affected by the high chloride concentrations in the DMP groundwater samples, since the method relies on washing all the chloride off the front and backup collection columns prior to analysis. The lab's quality assurance objective for recovery of TOX from spiked MS and MSD samples is 82-121 percent recovery. The method QC objective of retaining 90 percent of the measured TOX in the groundwater samples on the front granular activated carbon column has not been met for high-brine groundwater samples; however, eight of the 12 TOX MS/MSD analyses did meet the quality assurance objective for recovery. As stated above, TOX analyses will be discontinued in future Rounds.

The recovery results for nitrate in all the MS/MSD pairs met the quality assurance objective for accuracy; however, high concentrations of chloride in the groundwater samples raise the method reporting limit. Nitrate has not been detected in the relatively deep Culebra groundwater wells, and it is unlikely that it is present.

Overall, the quality of the accuracy QC data was excellent, with nearly all the spiked LCS/LCSD and MS/MSD data meeting the quality assurance objectives.

### 7.3.4 Comparability

The Permit requires that groundwater analytical results be comparable by reporting data in consistent units and collecting and analyzing samples using consistent methodology. These comparability requirements were met through the use of consistent, approved SOPs for sample collection and analyses. The normal reporting units for metals and general chemistry parameters were mg/L, and the normal reporting limits for organics were micrograms per liter (ug/L).

HEAL and its subcontract laboratories are certified by several states and by the National Environmental Laboratory Accreditation Program (NELAP) through Oregon for HEAL and Anatek and through Florida for Columbia Analytical Services.

HEAL's state certifications include Oregon, Utah, Texas, New Mexico, and Arizona. As such, the labs participate in interlaboratory evaluation programs, including on-site NELAC QA audits. The labs also regularly analyze performance evaluation samples provided by a NELAC accredited Proficiency Standard Vendor such as Wibby Environmental. HEAL also analyzed MAPEP performance evaluation samples as part of the DOE performance evaluation program. The Wibby Water Supply performance evaluation samples included chloride, nitrate, sulfate, trace metals, mercury, pH, TOC, regulated VOCs, unregulated VOCs, and the Wibby Water Pollution performance evaluation samples included chloride, sulfate, TDS, TSS, nitrate, TKN, alkalinity, trace metals, mercury, specific conductance, pH, VOCs, SVOCs (acids and base-neutrals), and the MAPEP performance evaluation samples included SVOCs.

In 2011, HEAL analyzed two sets of Wibby Water Supply Proficiency Testing Studies and one set of MAPEP PE samples that were analyzed for SVOCs in water. The Wibby samples covered nearly the entire WIPP target VOC, SVOC, metal, and general chemistry parameters list. The only WIPP target parameter not present in any of the PE samples was the VOC compound isobutyl alcohol. Of the dozens of individual parameter measurements made by HEAL in the three sets of PE samples, all the results were acceptable. HEAL correctly reported 101 out of 101 results for the Water Supply PE samples and 260 out of 260 results for the Water Pollution PE samples. Some of the values were for analytes not measured in the WIPP groundwater samples. The MAPEP results were also all acceptable for the target DMP SVOC analytes.

For the analytes that HEAL subcontracted to other analytical laboratories, Columbia Analytical Services obtained acceptable analysis results for TOX in various performance evaluation samples, and Anatek Laboratory obtained acceptable results for trace metals by ICP/MS in various performance evaluation samples.

### 7.3.5 Representativeness

The groundwater DMP is designed so that representative groundwater samples are collected from specific monitoring well locations. Prior to collecting the final samples from each well, serial samples were collected and analyzed in an on-site mobile laboratory to help determine whether the water being pumped from the monitoring wells was stable and representative of the natural groundwater at each well. The parameters analyzed in the mobile laboratory included temperature, pH, specific gravity, alkalinity, specific conductance, chlorides, divalent cations, and total iron. The final samples for analysis of VOCs, SVOCs, metals and general chemistry parameters were collected only when it had been determined from serial sampling and analysis that the water being pumped was representative of the natural groundwater at each location.

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# APPENDIX B – Environmental Permits

APPENDIX B – Environmental Permits

**Table B.1 – Major Active Environmental Permits for the Waste Isolation Pilot Plant as of December 31, 2011**

| Granting Agency | Type of Permit | Permit Number | Granted/ Submitted | Expiration | Current Permit Status |
|---|---|---|---|---|---|
| New Mexico Environment Department | Hazardous Waste Facility Permit | NM48901390 88-TSDF | 12/30/10 | 12/30/15 | Active |
| New Mexico Environment Department Groundwater Quality Bureau | Discharge Permit | DP-831 | 09/09/08 | 09/09/13 | Active |
| New Mexico Environment Department Air Quality Bureau | Operating Permit for Two Backup Diesel Generators | 310-M-2 | 12/07/93 | None | Active |
| New Mexico Environment Department Petroleum Storage Tank Bureau | Storage Tank Registration Certificate | Registration Number 2033<br><br>Facility Number 31539 | 07/01/11 | 06/30/12 | Active |
| U.S. Environmental Protection Agency Region 6 | Conditions of Approval for Disposal of PCB/TRU and PCB/TRU Mixed Waste at the US Department of Energy (DOE) Waste Isolation Pilot Plant (WIPP) Carlsbad, New Mexico | N/A | 04/30/08 | 04/30/13 | Active |
| U.S. Fish and Wildlife Service | Special Purpose – Relocate | MB155189-0 | 06/01/10 | 05/31/12 | Active |
| New Mexico Department of Game and Fish | Biotic Collection Permit | Authorization # 3293 | 01/26/11 | 12/31/13 | Active |

N/A Not Applicable

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# APPENDIX C – Location Codes

APPENDIX C – Location Codes

**Table C.1 – Codes Used to Identify the Sites from which Samples were Collected**

| Code | Location | Code | Location |
|---|---|---|---|
| BHT | Bottom of the Hill Tank | PD2 | SWIC Pond 2 (DP-831) |
| BLK | Blank | PEC | Pecos River |
| BRA | Brantley Lake | PKT | Poker Trap |
| CBD | Carlsbad | PP1 | Polishing Pond 1A (DP-831) |
| COW | Coyote Well (deionized water blank) | PP2 | Polishing Pond 2B (DP-831) |
| COY | Coyote (surface water duplicate) | RED | Red Tank |
| EBA | SWIC Evaporation Basin A (DP-831) | SEC | Southeast Control |
| EB1 | Salt Storage Extension Basin I (DP-831) | SMR | Smith Ranch |
| EB2 | Salt Storage Extension Basin II (DP-831) | SOO | Sample Of Opportunity* |
| EPA | Evaporation Pond A (DP-831) | SP1 | Settling Pond 1A (DP-831) |
| EPB | Evaporation Pond B (DP-831) | SP2 | Settling Pond 2A (DP-831) |
| EPC | Evaporation Pond C (DP-831) | SPE | Salt Pile Evaporation Pond (DP-831) |
| FWT | Fresh Water Tank | SWL | Sewage Lagoons (DP-831) |
| HIL | Hill Tank | TUT | Tut Tank |
| H19 | H-19 Evaporation Pond (DP-831) | UPR | Upper Pecos River |
| IDN | Indian Tank | WAB | WIPP Air Blank |
| LST | Lost Tank | WEE | WIPP East |
| MLR | Mills Ranch | WFF | WIPP Far Field |
| NOY | Noya Tank | WIP | WIPP 16 Sections |
| PCN | Pierce Canyon | WSS | WIPP South |
| PD1 | SWIC Pond 1 (DP-831) | | |

* Sample taken where found.

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# APPENDIX D – Radiochemical Equations

APPENDIX D – Radiochemical Equations

## Detection

All radionuclides with the exception of the gamma spectroscopy targets (137Cs, 60Co, and 40K) are considered "detected" if the radionuclide activity or concentration [RN] is greater than the minimum detectable concentration and greater than the total propagated uncertainty at the 2 σ level. The gamma radionuclides are considered detected when the above criteria are met and the gamma spectroscopy software used to identify the peak generates an associated identification confidence of 90 percent or greater (ID Confidence ≥0.90).

## Minimum Detectable Concentration (MDC)

The MDC is the smallest amount (activity or mass) of a radionuclide in a sample that will be detected with a 5 percent probability of nondetection while accepting a 5 percent probability of erroneously deciding that a positive quantity of a radionuclide is present in an appropriate blank sample. This method assures that any claimed MDC has at least a 95 percent chance of being detected. It is possible to achieve a very low level of detection by analyzing a large sample size and counting for a very long time.
The WIPP Laboratories use the following equation for calculating the MDCs for each radionuclide in various sample matrices:

$$MDC = \frac{4.66\sqrt{S}}{KT} + \frac{3.00}{KT}$$

Where:

S = Net method blank counts; when method blank counts = 0, average of the last 30 blanks analyzed are substituted

K = A correction factor that includes items such as unit conversions, sample volume/weight, decay correction, detector efficiency, chemical recovery, abundance correction, etc.

T = Counting time where the background and sample counting time are identical

For further evaluation of the MDC, refer to ANSI N13.30, *Performance Criteria for Radiobioassay*.

## Total Propagated Uncertainty (TPU)

The TPU is an estimate of the uncertainty in the measurement due to all sources, including counting error, measurement error, chemical recovery error, detector efficiency, randomness of radioactive decay, and any other sources of uncertainty.
The TPU for each data point must be reported at the 2 σ level (2 σ TPU). For further discussion of TPU, refer to ANSI N13.30.

# APPENDIX D – Radiochemical Equations

## Relative Error Ratio (RER)

The RER is a method, similar to a t-test, with which to compare duplicate results (see Chapters 4 and 7, and WP 02-EM3004, *Radiological Data Verification and Validation*).

$$RER = \frac{(MeanActivity)ori - (MeanActivity)dup}{\sqrt{(2\sigma TPU)^2 ori + (2\sigma TPU)^2 dup}}$$

Where:

| | | |
|---|---|---|
| *(Mean Activity)$^{ori}$* | = | Mean activity of the original or primary sample |
| *(Mean Activity)$^{dup}$* | = | Mean activity of the duplicate sample |
| *2σTPU* | = | Total propagated errors at the 2 σ level |

## Percent Bias (% Bias)

The percent bias is a measure of the accuracy of radiochemical separation methods and counting instruments; that is, a measure of how reliable the results of analyses are when compared to the actual values.

$$\%Bias = \frac{(A_m - A_k)}{A_k} \times 100$$

Where:

| | | |
|---|---|---|
| % BIAS | = | Percent bias |
| Am | = | Measured sample activity |
| Ak | = | Known sample activity |

# APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater

APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater

The six WQSP Culebra wells had been sampled 31 times prior to the two sampling Rounds performed in 2011. The first 10 sampling Rounds were conducted from 1995 through 2000 (prior to receiving mixed waste at the WIPP site), and were used to establish the original baseline for groundwater chemistry at each sampling location. The baseline sample sets are used to determine whether statistically significant changes have occurred at any well. Selected time trend charts with the data from Rounds 32 and 33 added to all previous Rounds, including the baseline Rounds, are presented below.

The baseline was established incorporating data from three different laboratories. The wide ranges of target analyte concentrations measured during the baseline resulted from past difficulties in analyzing the high-brine groundwater from the WIPP site. The contract laboratories used variable dilution factors when analyzing the samples resulting in variable detection limits for some analytes.

The target analyte constituents are 20 volatile organic compounds, 12 semivolatile organic compounds, and 14 trace metals. Time trend plots are not included for these constituents. The other target analytes selected are general chemistry indicator parameters including the common cation metals, calcium, magnesium, potassium, and sodium, the anions chloride and sulfate, specific gravity, pH, specific conductance, TDS, total suspended solids, TOC, and total organic halogens. Time trend plots are provided below for the following general chemistry indicator parameters: dissolved calcium, chloride, dissolved magnesium, pH, dissolved potassium, sulfate and TDS. The dissolved concentrations are measured in filtered samples. These plots show the concentrations in the primary sample and the duplicate sample for all sampling Rounds.

The 2011 laboratory analytical results were verified and validated in accordance with WIPP procedures and U.S. Environmental Protection Agency technical guidance. Sampling Round 32 samples were taken March through May 2011 and sampling Round 33 samples were taken September through November 2011. See Appendix F for the concentrations of all the target analytes in the WQSP groundwater wells.

Techniques were established to compare the current detection monitoring data to data generated during the baseline study. A 95th UTLV or a 95th percentile was determined from those data sets where analytical parameters were measured at concentrations above the method reporting limits. A 95th percentile was established for those parameters that were detected in less than 15 percent of the samples, while the 95th UTLV is for analytes with greater than 15 percent detects. It is expected that 5 percent of the measured concentrations would be higher than the baseline 95th UTLV or 95th percentile.

An external outlier test was performed on all the current WIPP facility groundwater monitoring data. In the external test, a newly obtained sample result for a selected groundwater target analyte, such as TDS, is simply compared with the established 10 Rounds of baseline (background) data to determine whether the analytical result is greater than or less than the 95th UTLV or 95th percentile.

# APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater

The groundwater analysis results from year 2011 Round 32 were compared with the baseline water quality statistics to determine whether any measurable or statistically significant changes in water quality have occurred or are occurring.

Review of the Round 32 chemical analysis data demonstrated that all Permit-required target constituent (volatile and semivolatile organics and trace metal) concentrations were lower than the 95$^{th}$ UTLV or 95$^{th}$ percentile concentrations except that for the WQSP-5 groundwater samples. The concentration of mercury in the primary sample of 0.0027 mg/L was higher than the 95$^{th}$ percentile concentration of 0.0020 mg/L, and the concentration of iron in the duplicate sample of 0.84 mg/L was higher than the 95$^{th}$ percentile concentration of 0.795 mg/L. Both of these concentrations were J-flagged as estimated since they were lower than the method reporting limit but higher than the method detection limit.

The sampling Round 32 data showed that the six WQSP wells contained 18 individual measurements that were higher than the 95$^{th}$ UTLV or 95$^{th}$ percentile, including the following:

- WQSP-1: Contained a primary sample chloride concentration of 41,000 mg/L compared to the 95$^{th}$ UTLV concentration of 40,472 mg/L. (The duplicate sample chloride concentration was 40,000 mg/L.) The TSS concentrations were 73 mg/L in the primary sample and 68 mg/L in the duplicate sample; these concentrations were higher than the 95$^{th}$ percentile concentration of 33.3 mg/L.

- WQSP-2: The TSS concentrations of 96 mg/L in the primary sample and 88 mg/L in the duplicate sample were higher than the 95$^{th}$ percentile concentration of 43.0 mg/L.

- WQSP-3: The chloride concentrations of 158,000 mg/L in the primary sample and 153,000 mg/L in the duplicate sample were higher than the 95$^{th}$ UTLV concentration of 149,100 mg/L. The sulfate concentrations of 8,490 mg/L in the primary sample and 8,880 mg/L in the duplicate sample were higher than the 95$^{th}$ UTLV concentration of 8,015 mg/L.

- WQSP-4: The chloride concentrations of 68,300 mg/L in the primary sample and 66,000 mg/L in the duplicate sample were higher than the 95$^{th}$ UTLV concentration of 63,960 mg/L. The TSS concentration of 63 mg/L in the primary sample was higher than the 95$^{th}$ percentile concentration of 57 mg/L. The duplicate sample concentration was 55 mg/L, yielding an average concentration of 59 mg/L, just above the 95$^{th}$ percentile concentration of 57 mg/L.

- WQSP-5: The TSS concentrations of 15 mg/L in the primary sample and 19 mg/L in the duplicate sample were both higher than the 95$^{th}$ percentile concentration of <10 mg/L. The estimated (J-flagged) iron concentration of 0.84 mg/L in the duplicate sample was higher than the 95$^{th}$ percentile concentration of 0.795 mg/L. The estimated (J-flagged) mercury

APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater

concentration of 0.0027 mg/L in the primary sample was higher than the 95th percentile concentration and Permit background value of 0.002 mg/L.

- WQSP-6: The specific conductance of 29,900 micromhos per centimeter ( mhos/cm) in the primary sample and 29,800 mhos/cm in the duplicate sample were both higher than the 95th UTLV of 27,660 mhos/cm.

Review of the Round 33 chemical analysis data demonstrated that all Permit-required target constituent (volatile and semivolatile organics and trace metal) concentrations were lower than the 95th UTLV or 95th percentile concentrations.

The chemical analysis data from Round 33 showed that the six WQSP wells contained only seven individual measurements for general chemistry indicator parameters that were higher than the 95th UTLV or 95th percentile, including the following:

- WQSP-1: Contained a duplicate sample TSS concentration of 36 mg/L compared to the 95th percentile concentration of 33.3 mg/L. The primary sample concentration was 33 mg/L and the average concentration was 35 mg/L.

- WQSP-2: No concentrations exceeded the 95th UTLV or 95th percentile.

- WQSP-3: The chloride concentration of 151,000 mg/L in the primary sample was higher than the 95th UTLV concentration of 149,100 mg/L. The duplicate sample concentration was 146,000 mg/L. The sulfate concentration of 8,170 mg/L in the primary sample was higher than the 95th UTLV concentration of 8,015 mg/L. The duplicate sample concentration was 7,920 mg/L.

- WQSP-4: The TSS concentration of 64 mg/L in the primary sample was higher than the 95th percentile concentration of 57.0 mg/L. The duplicate sample concentration was 55 mg/L, yielding an average concentration of 60 mg/L, just above the 95th percentile concentration of 57.0 mg/L.

- WQSP-5: The TSS concentrations of 13 mg/L in the primary sample was higher than the 95th percentile concentration of <10 mg/L. The duplicate sample concentration was 7.0 mg/L and the average concentration was 10 mg/L.

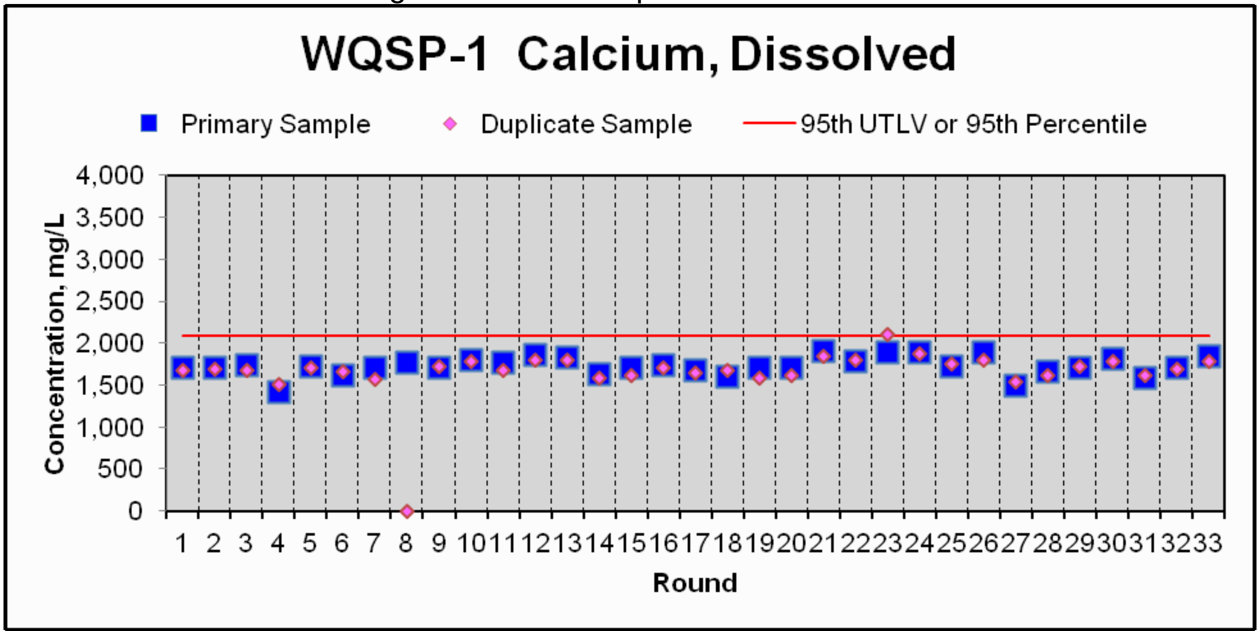
- WQSP-6: The specific conductance of 29,000 mhos/cm in the primary sample and 28,000 mhos/cm in the duplicate sample were both higher than the 95th UTLV of 27,660 mhos/cm.

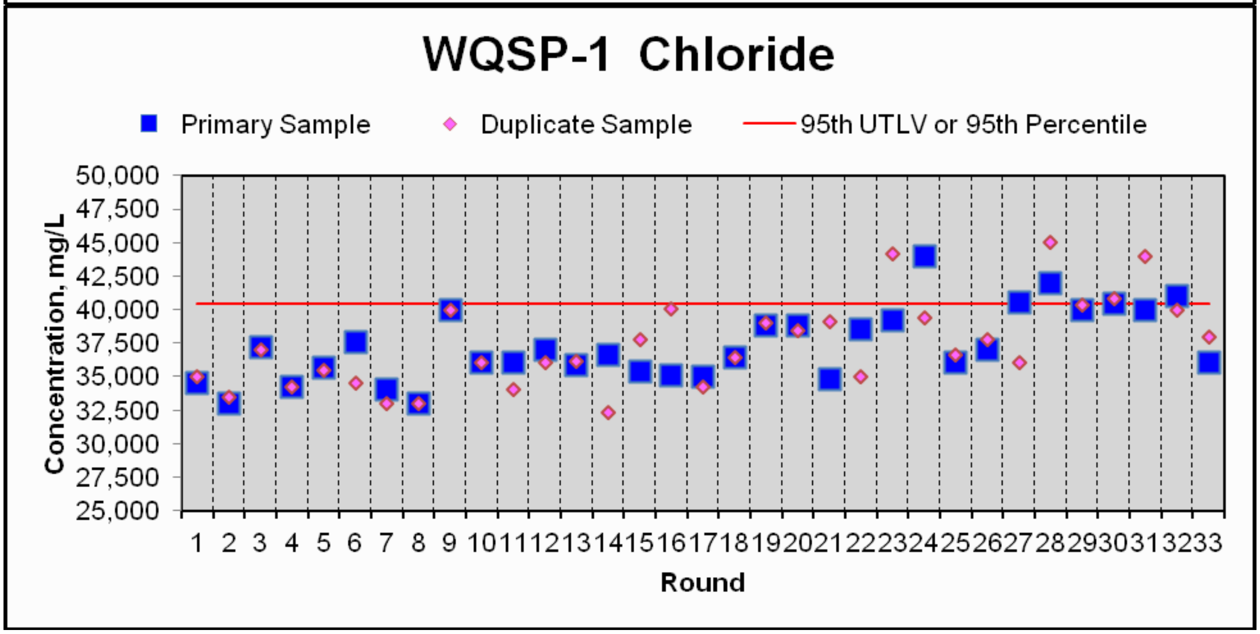
Although it is expected that 5 percent of the measured concentrations would be higher than the baseline 95th UTLV or 95th percentile; data results from sampling Rounds 32 and 33 showed that only one primary sample concentration and one duplicate sample concentration were higher than the baseline and Permit-required target constituent concentrations. In addition, data results showed that fewer primary sample or duplicate

APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater

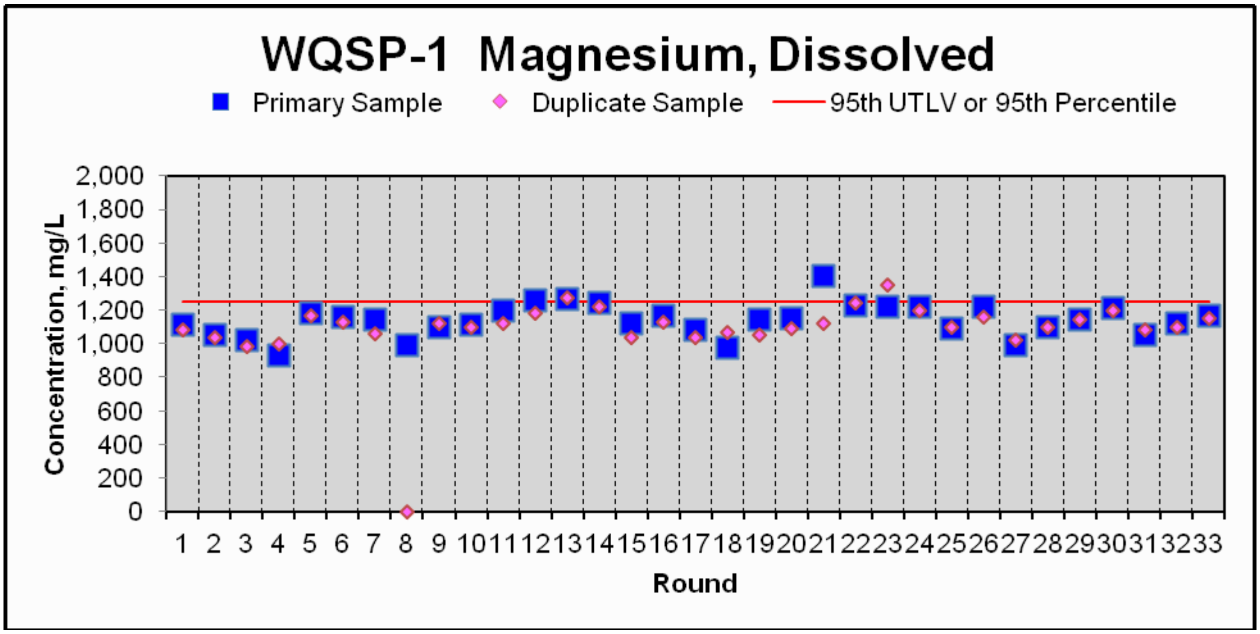
sample concentrations were above the baseline 95th UTLV or 95th percentile than in recent sampling Rounds.

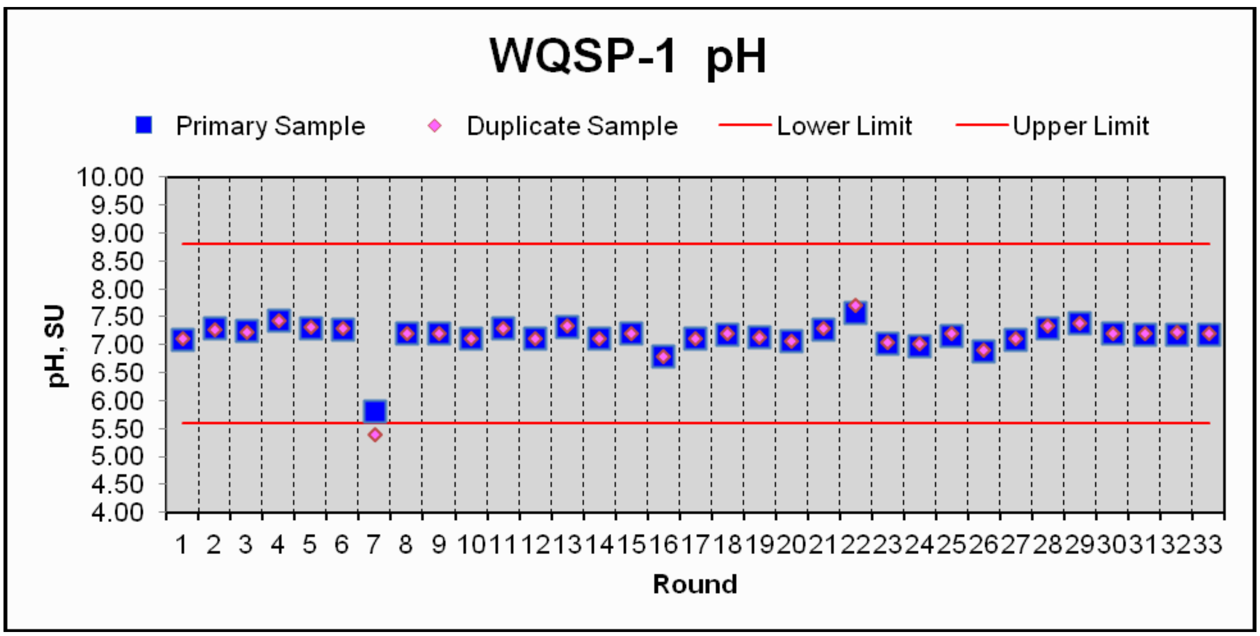
Evaluation of the chemical analysis data for the hazardous waste constituents and general chemistry indicator parameters indicates that no evidence of any external contamination exists in the groundwater samples.



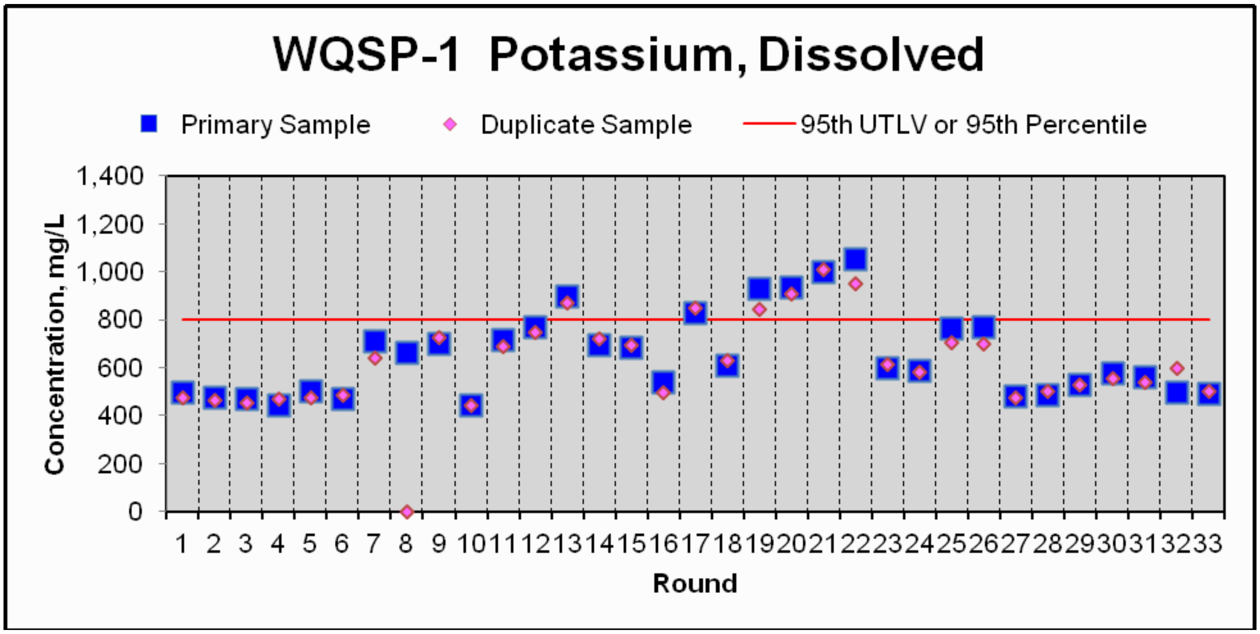



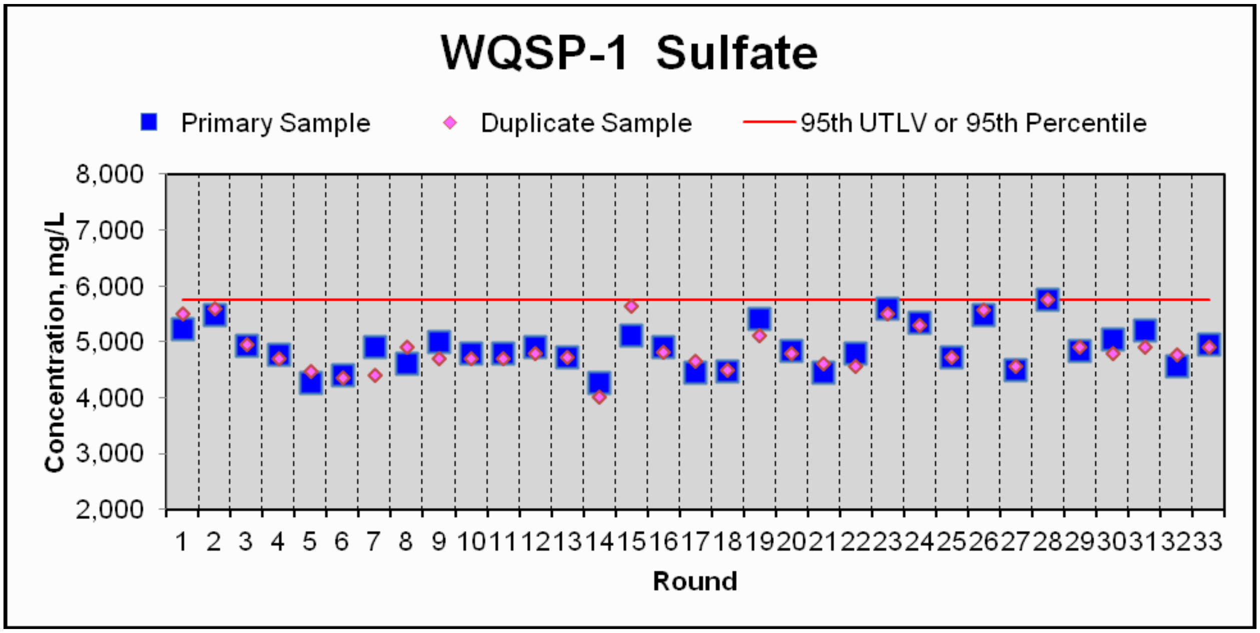
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



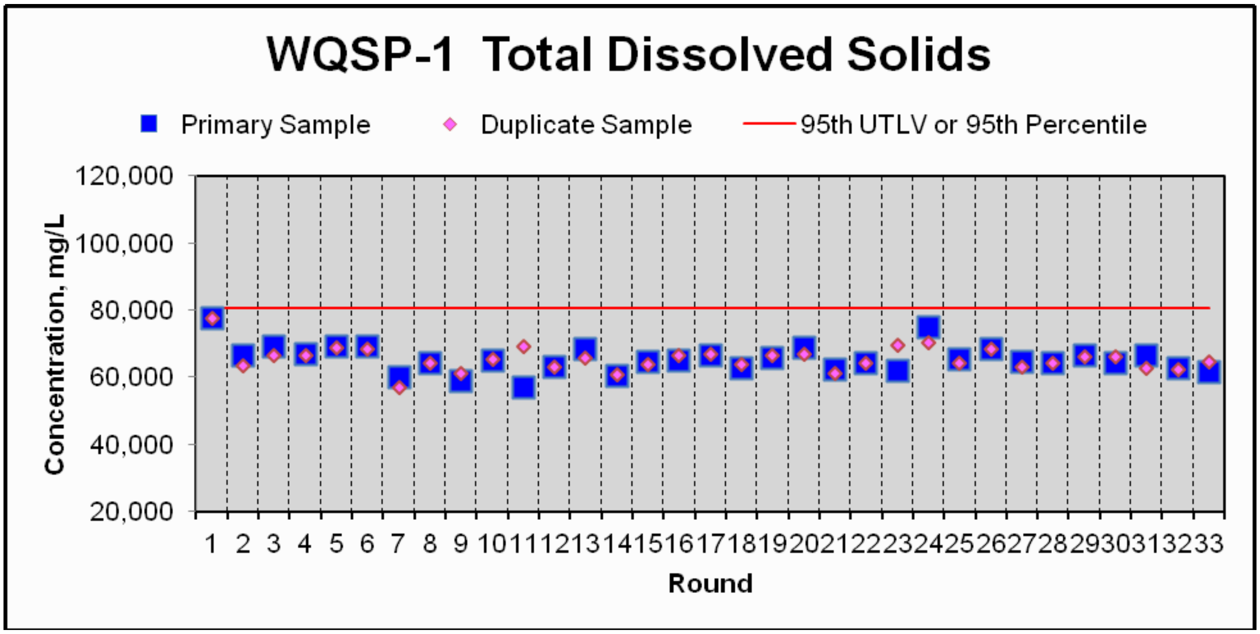



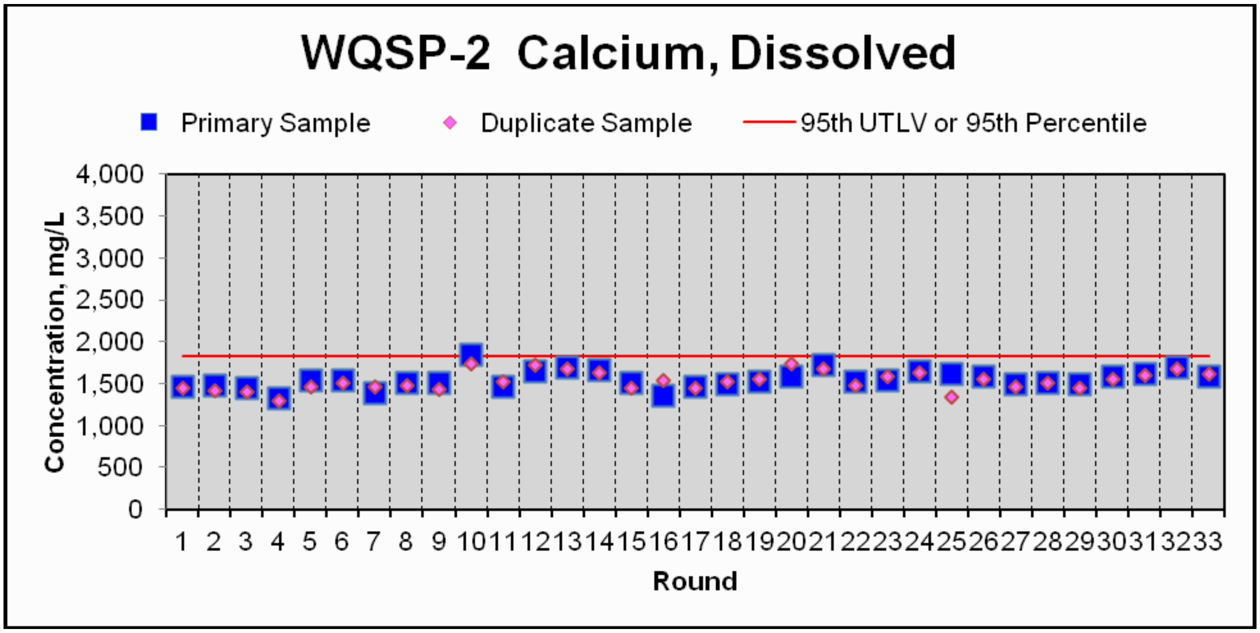
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



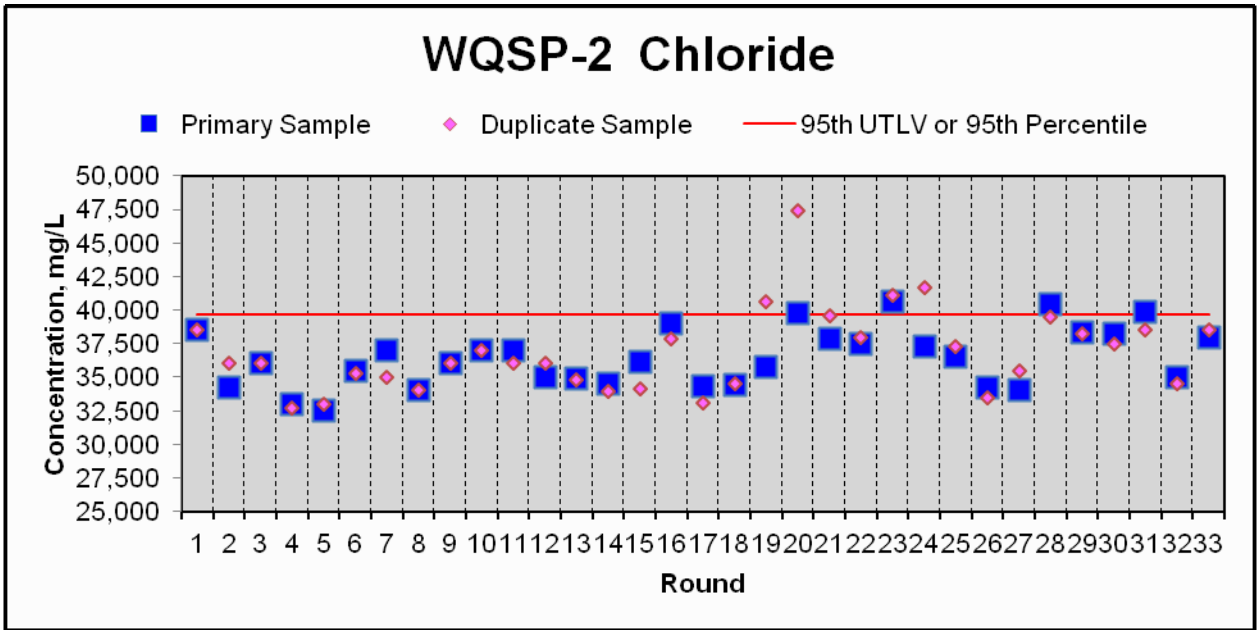



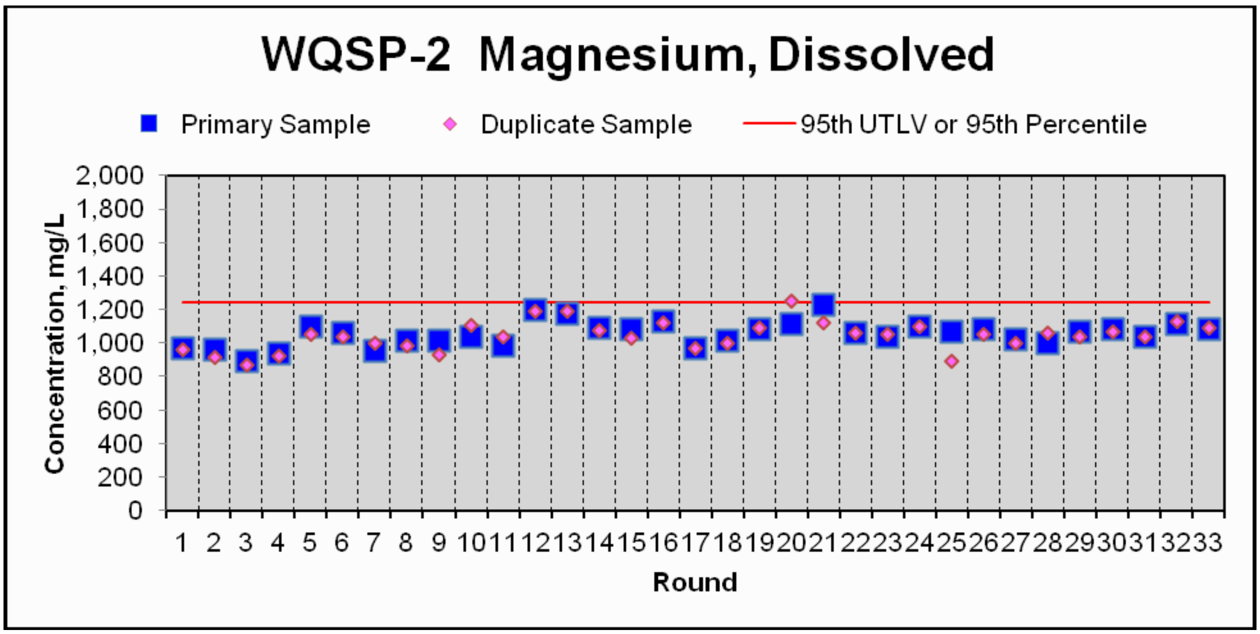
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



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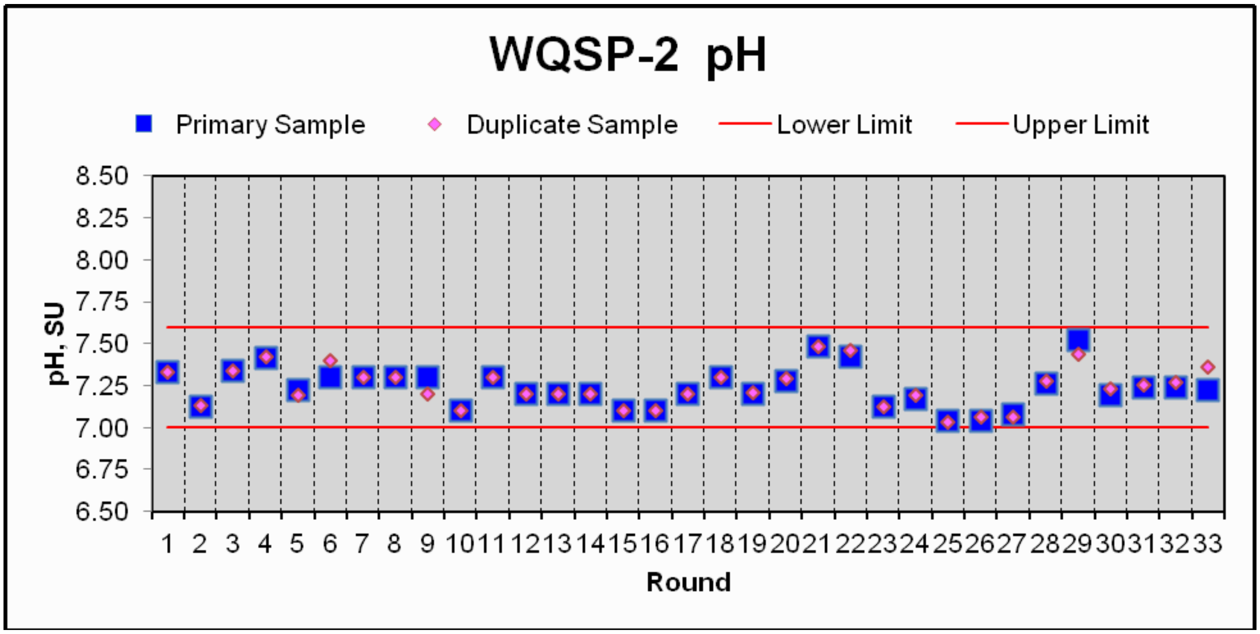


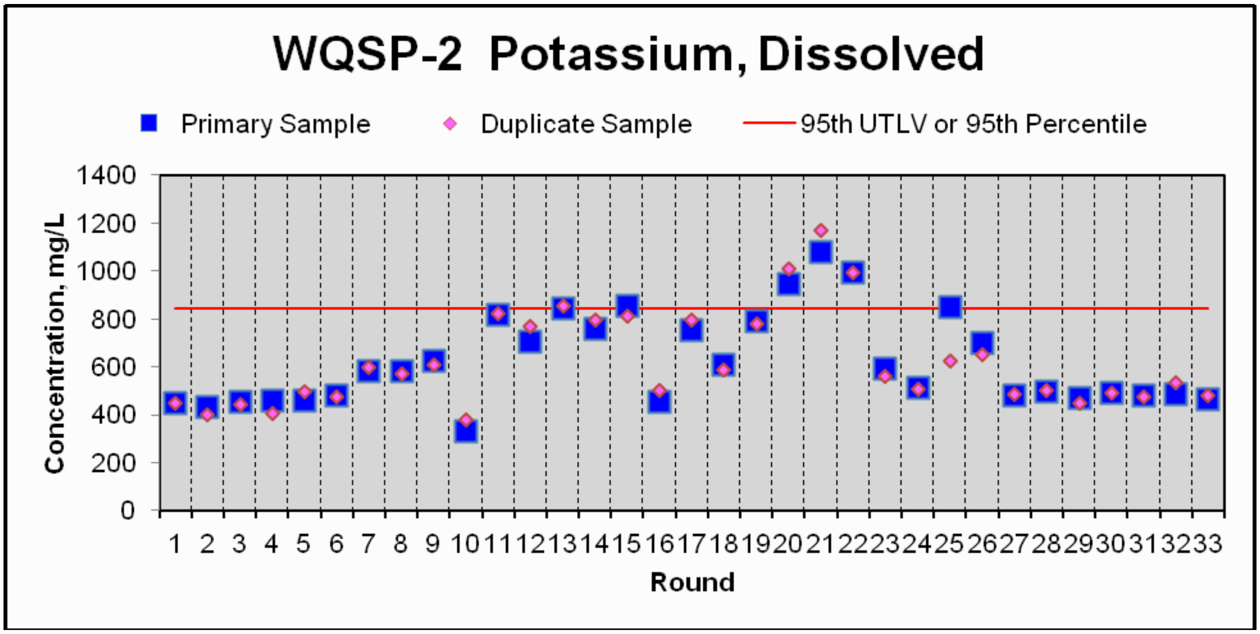

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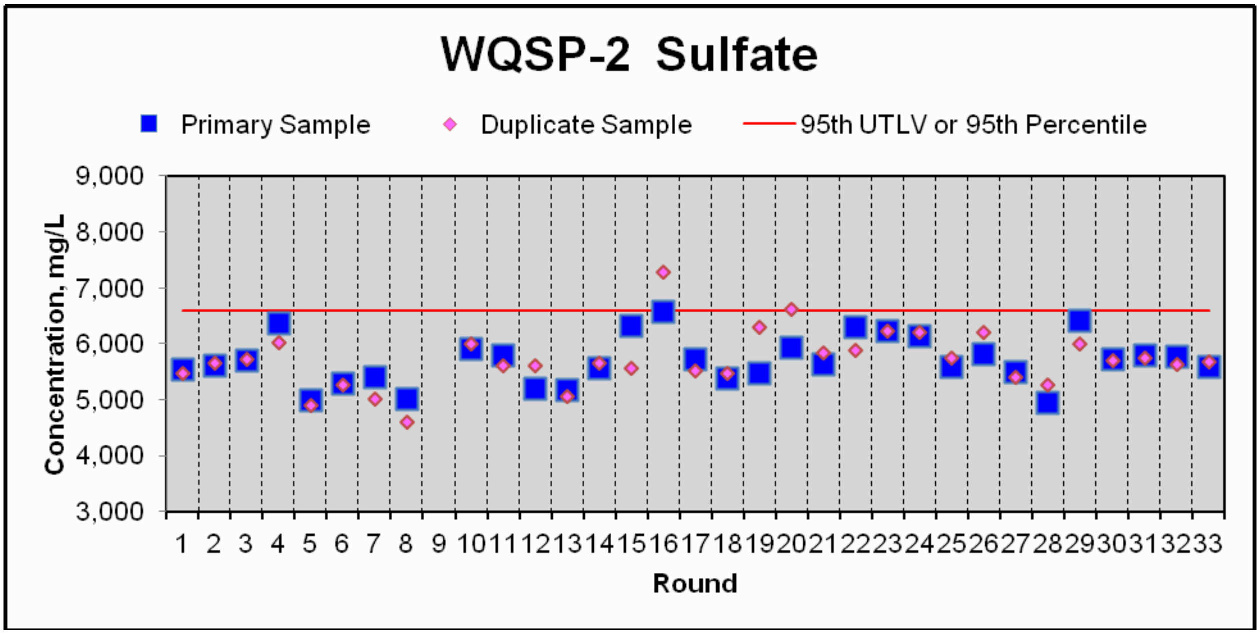
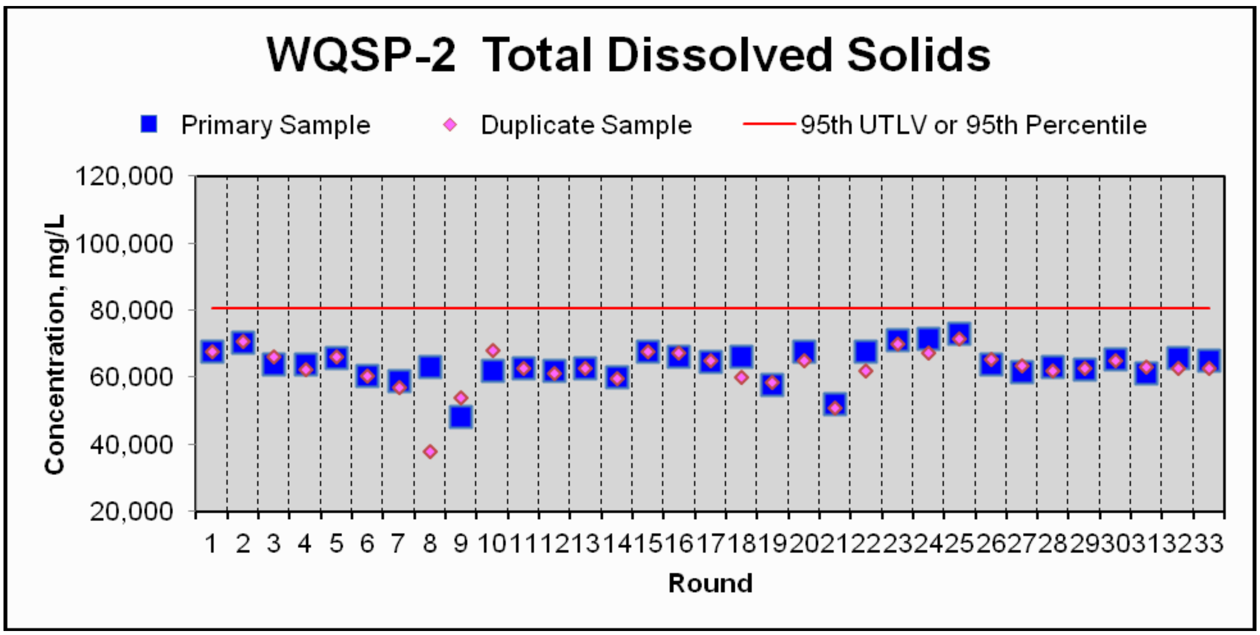
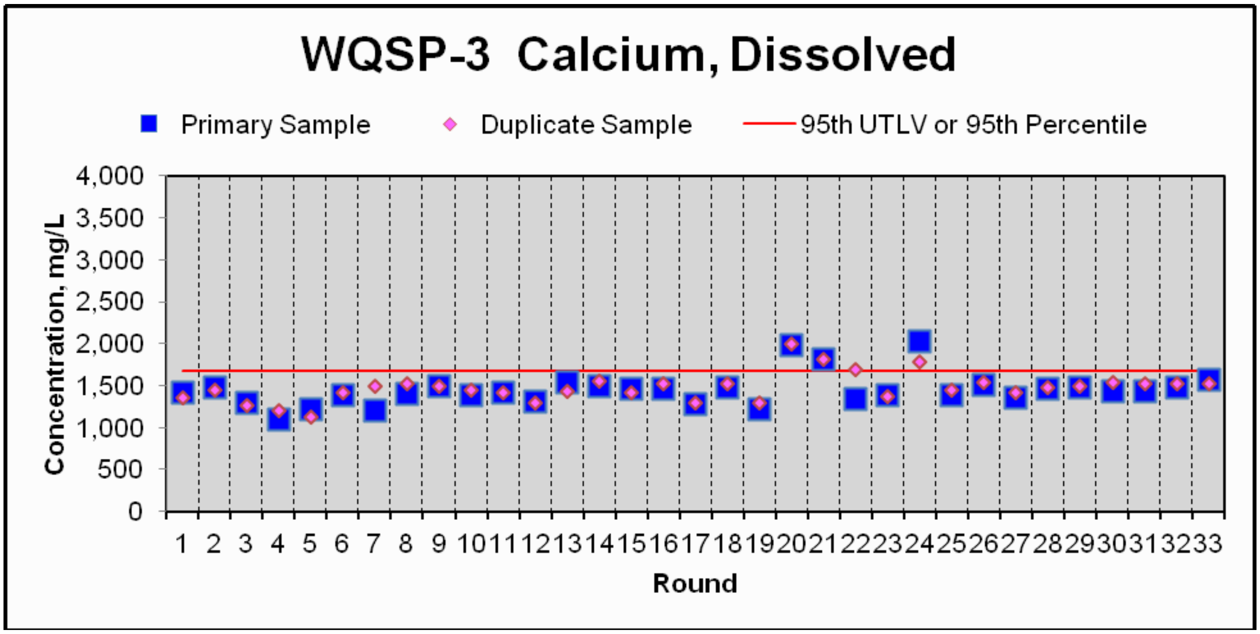
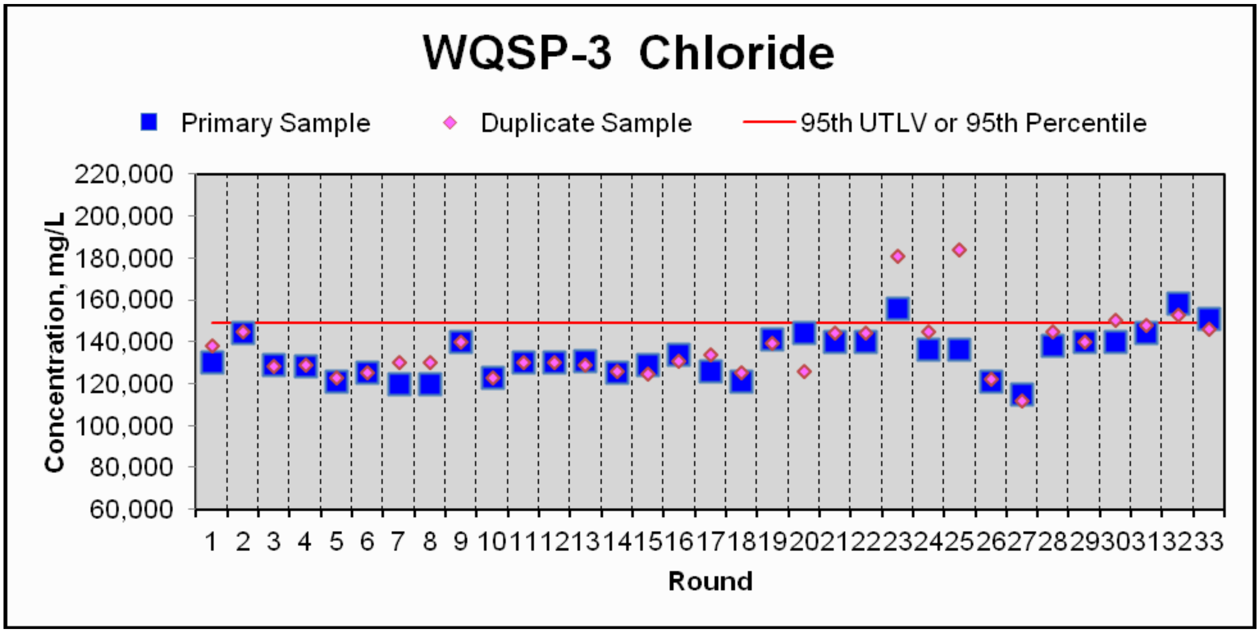


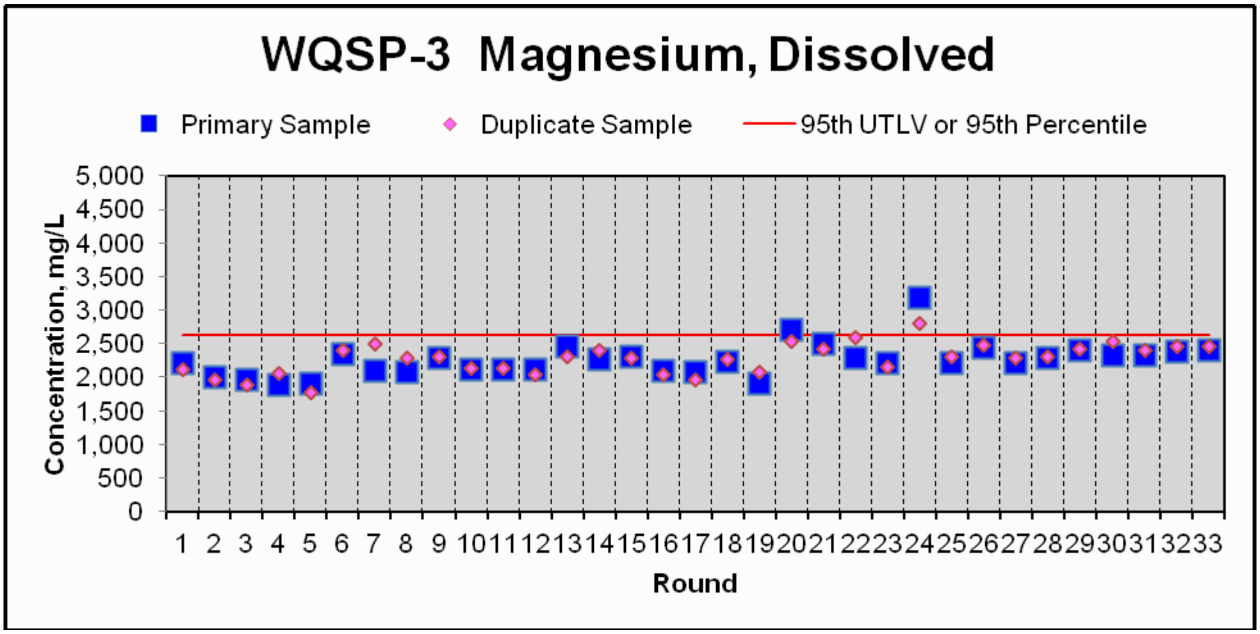



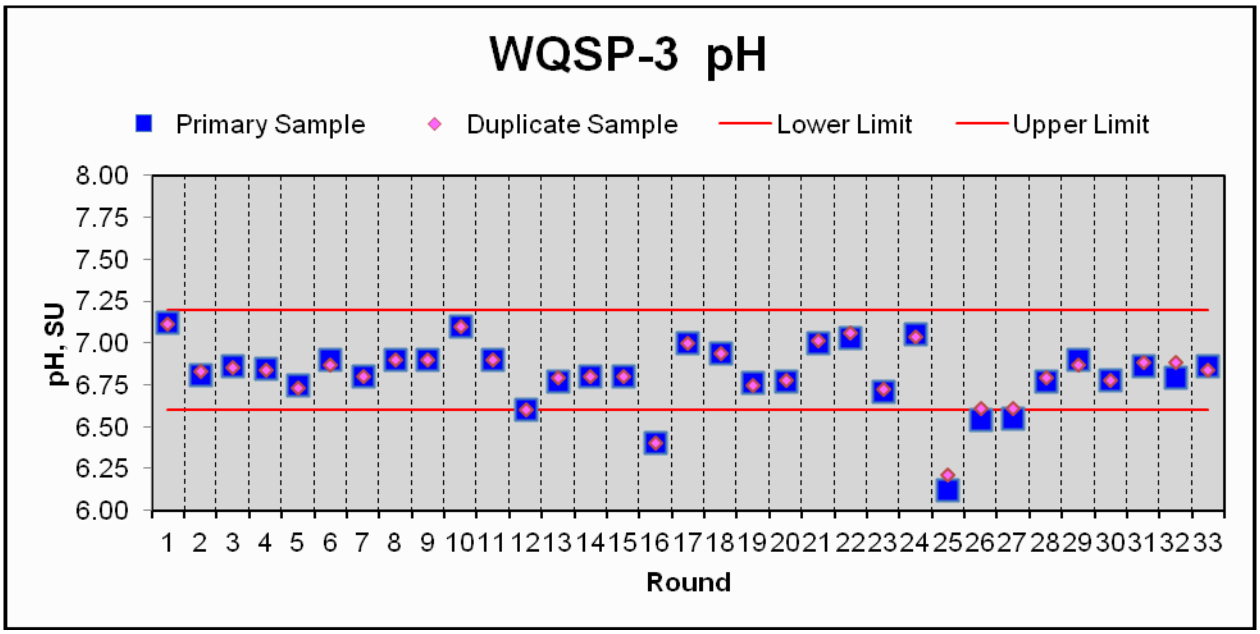
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



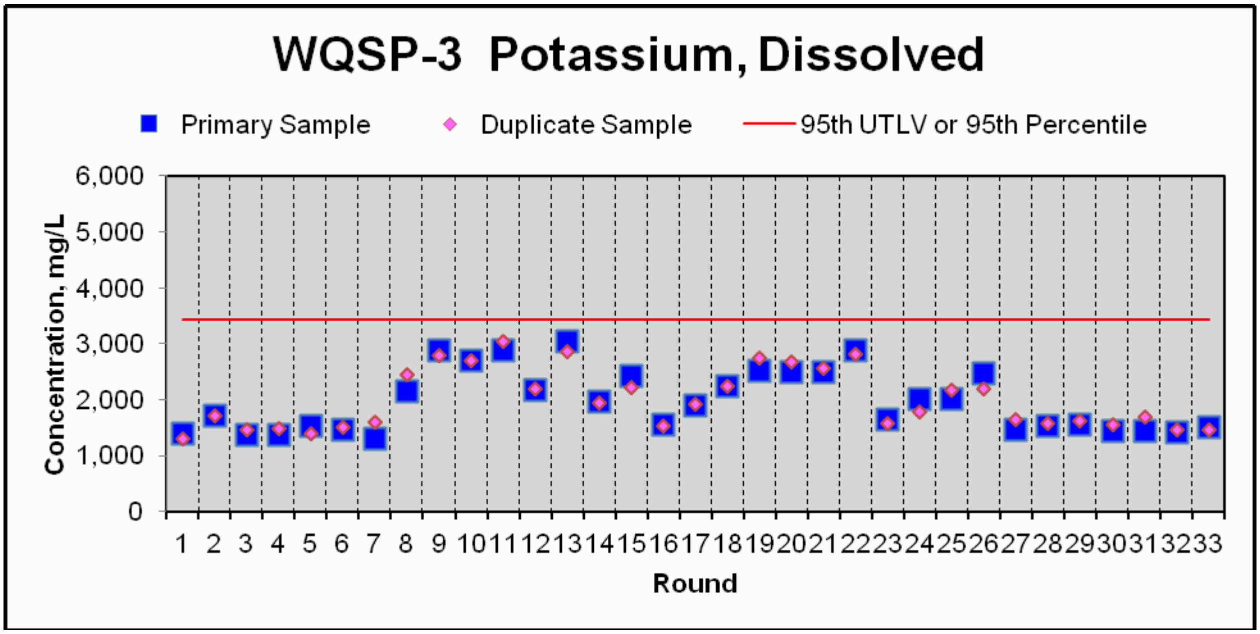



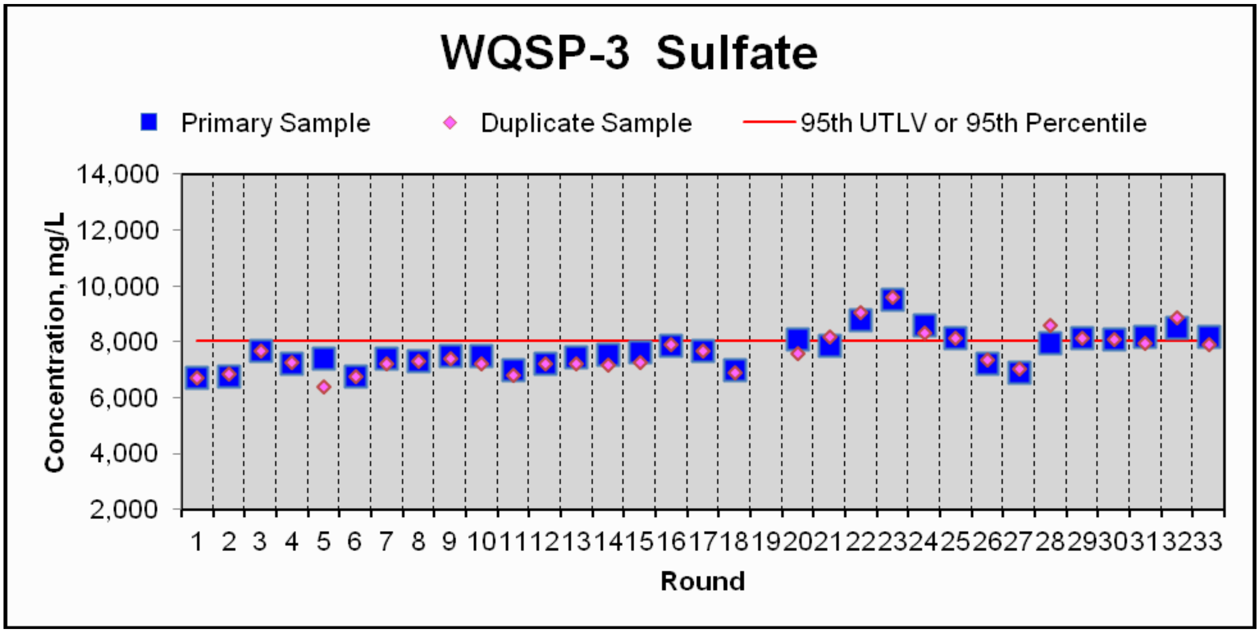
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



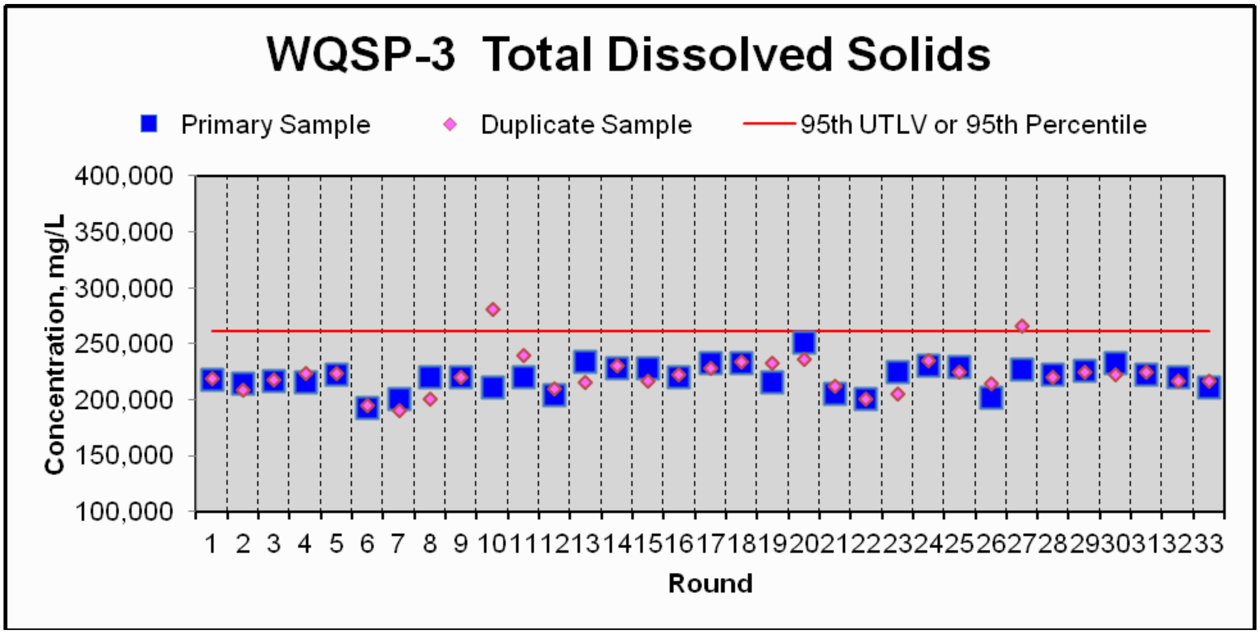



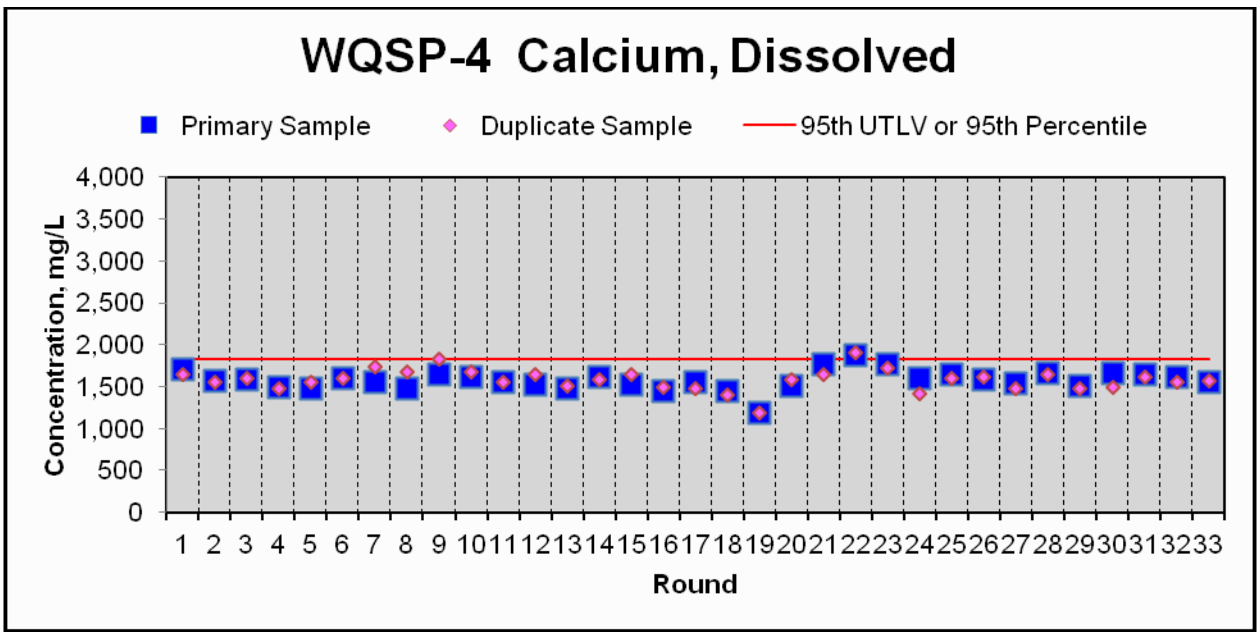
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



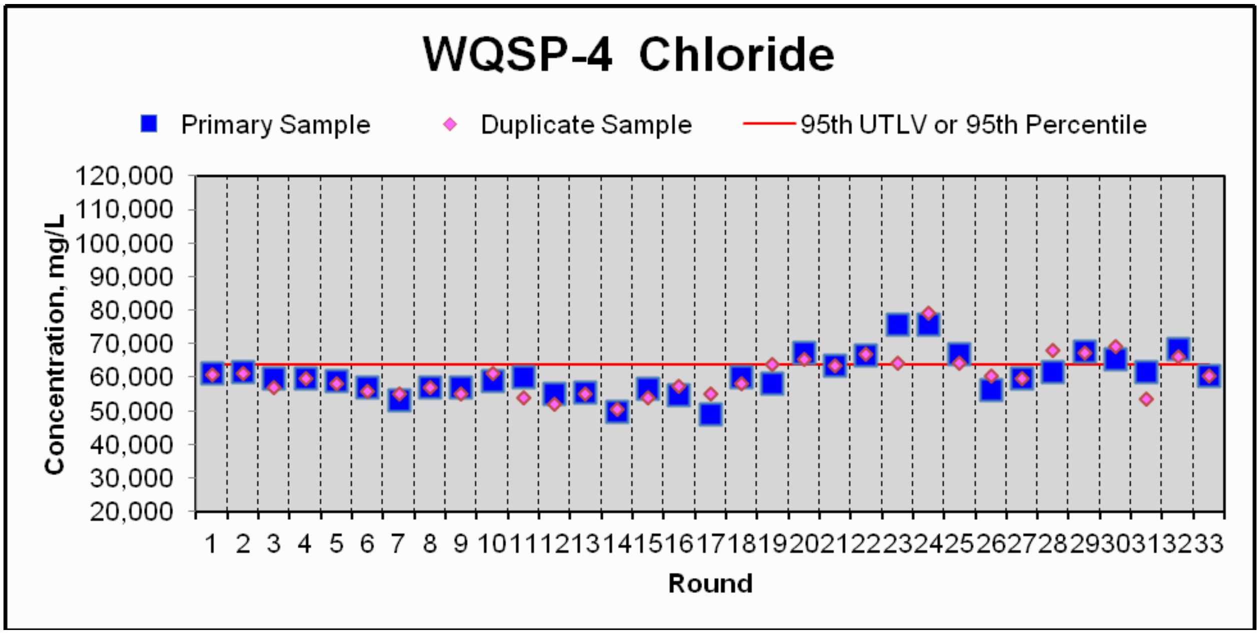



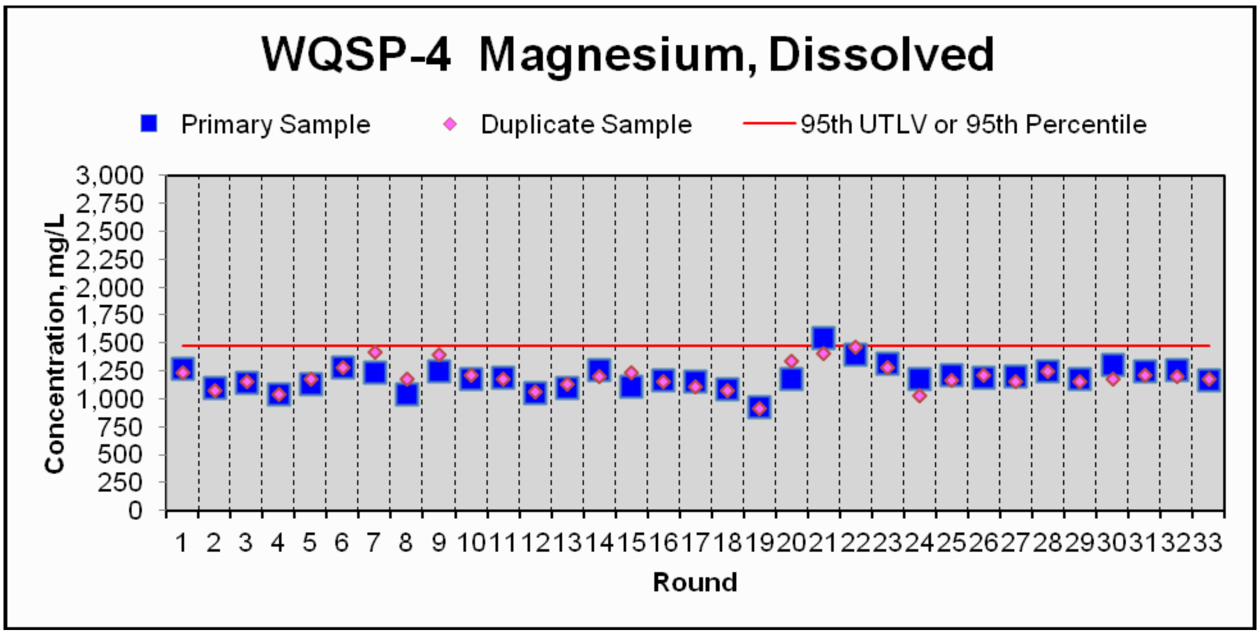
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



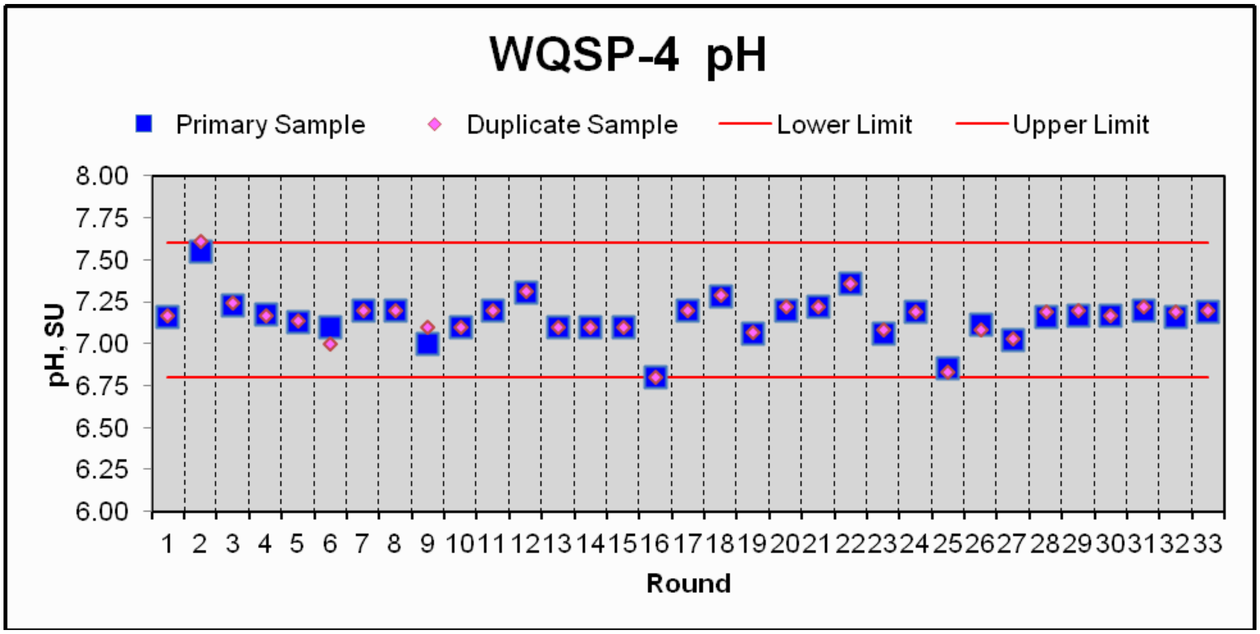



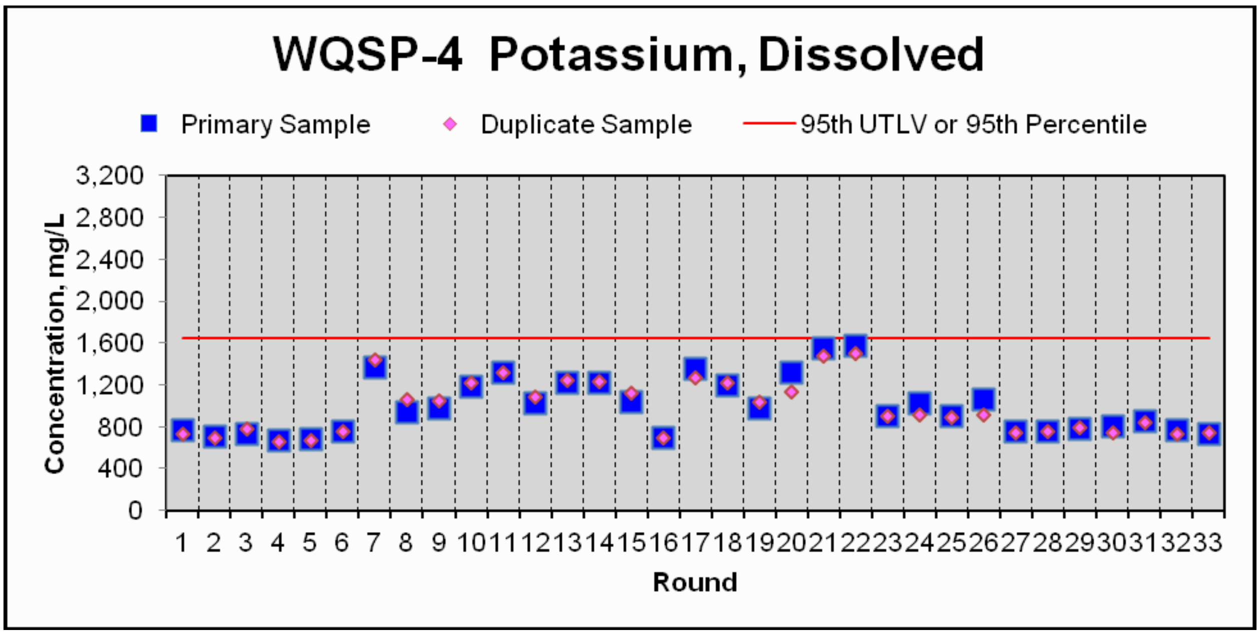
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



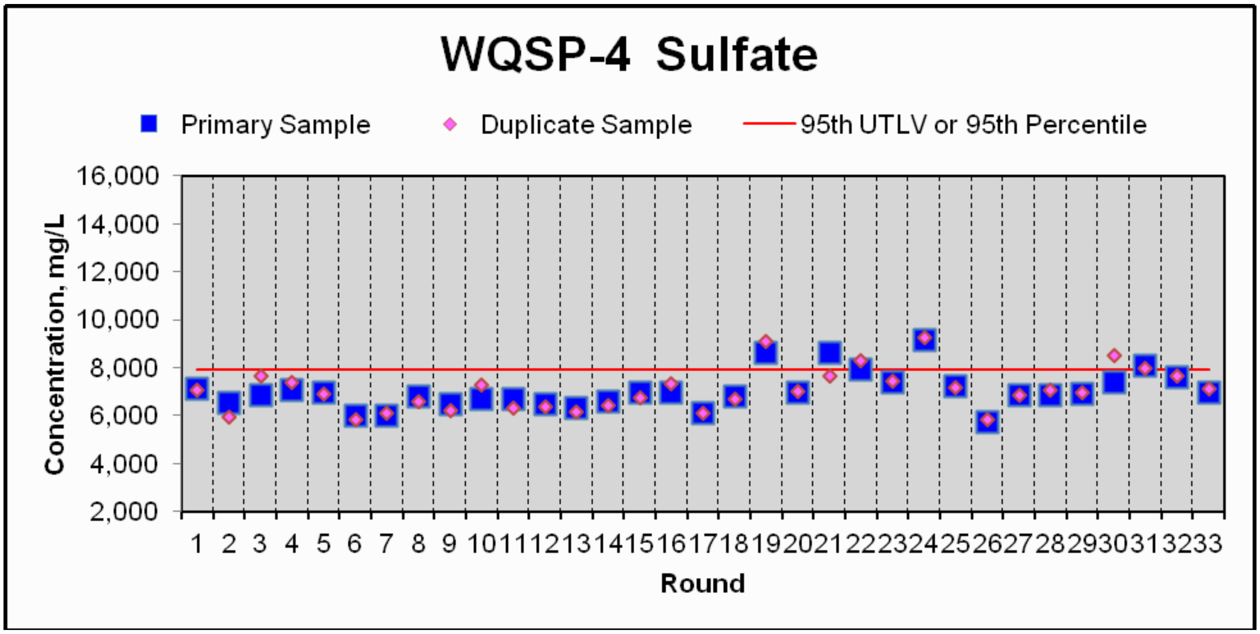



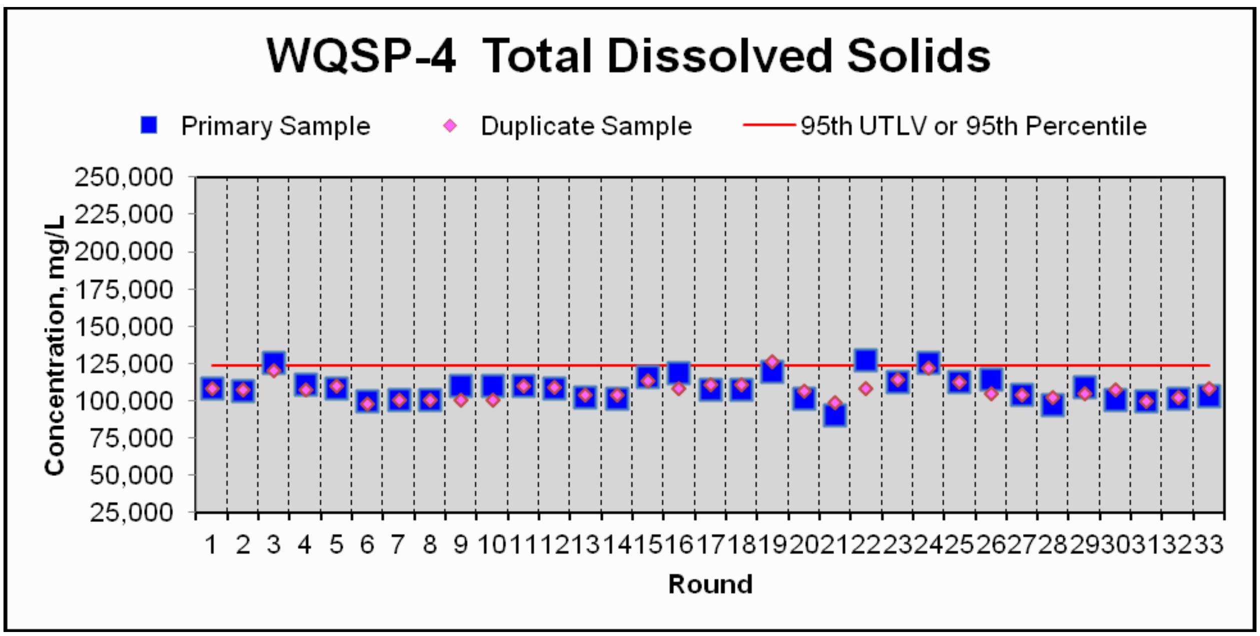
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



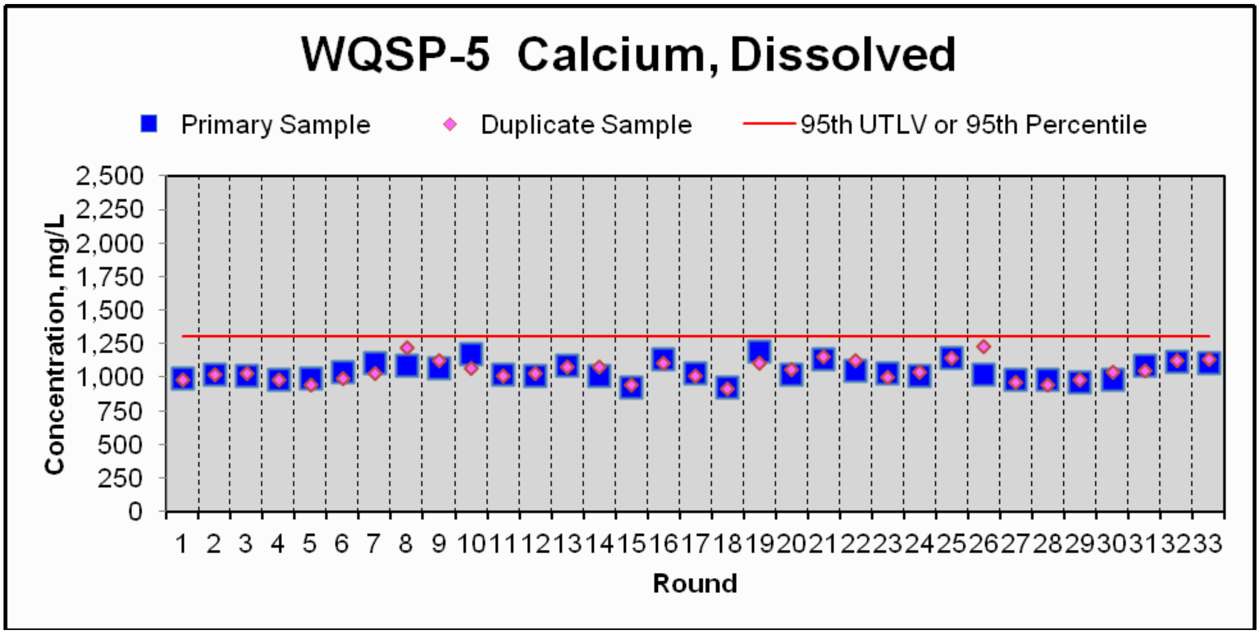



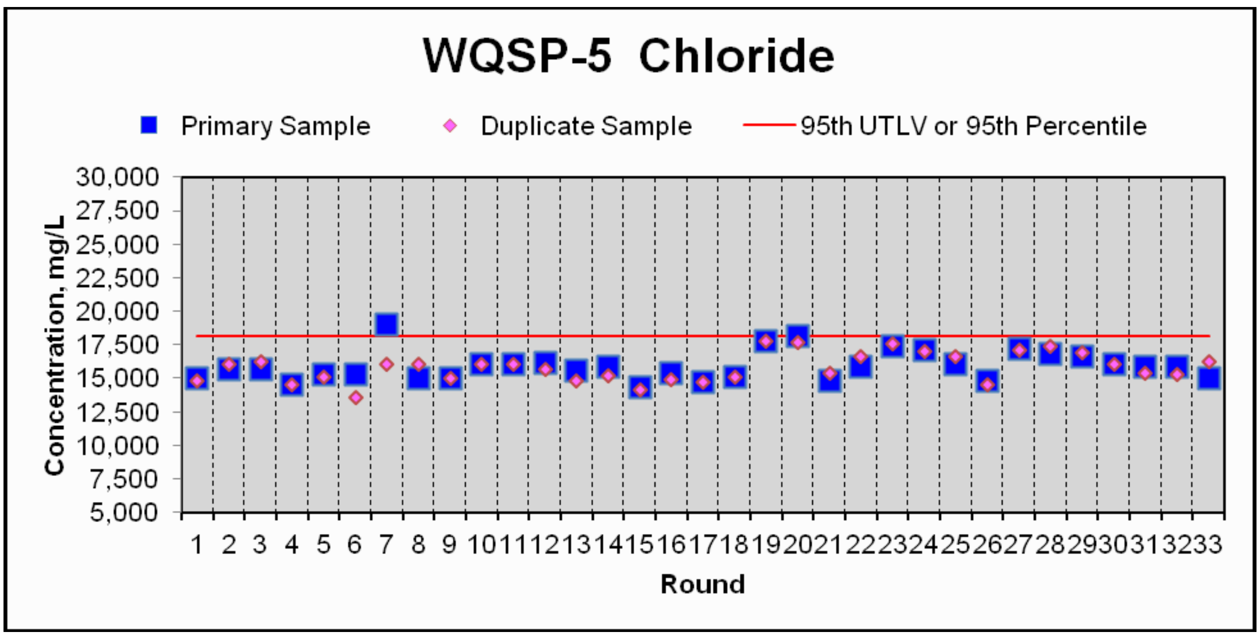
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



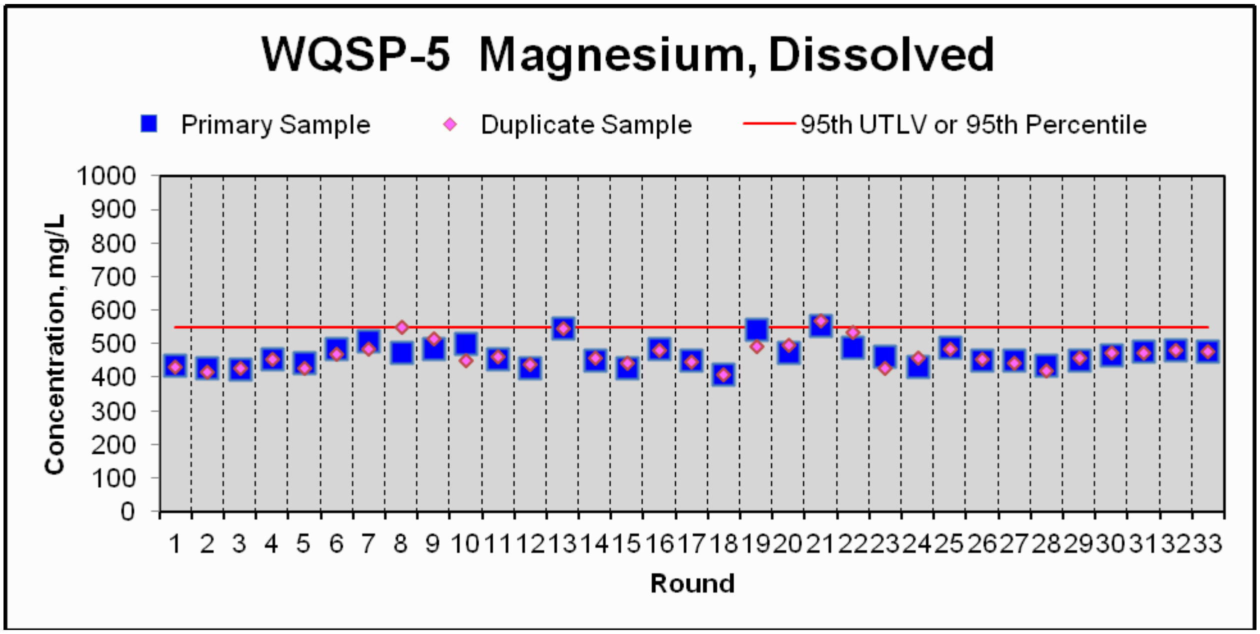



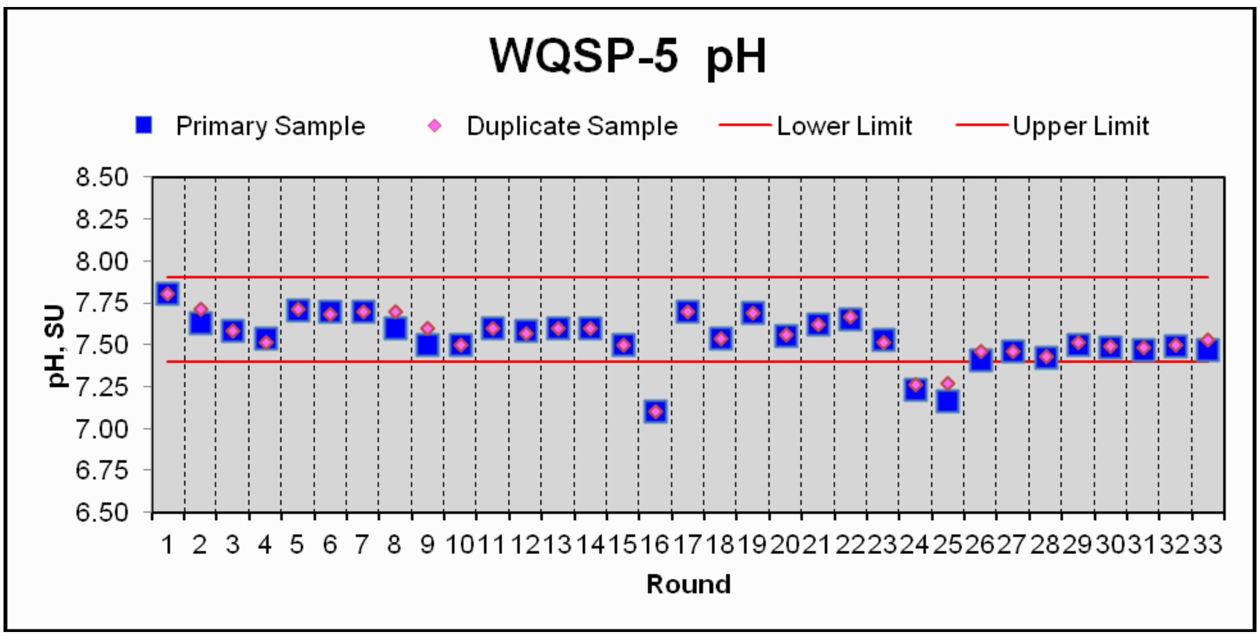
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



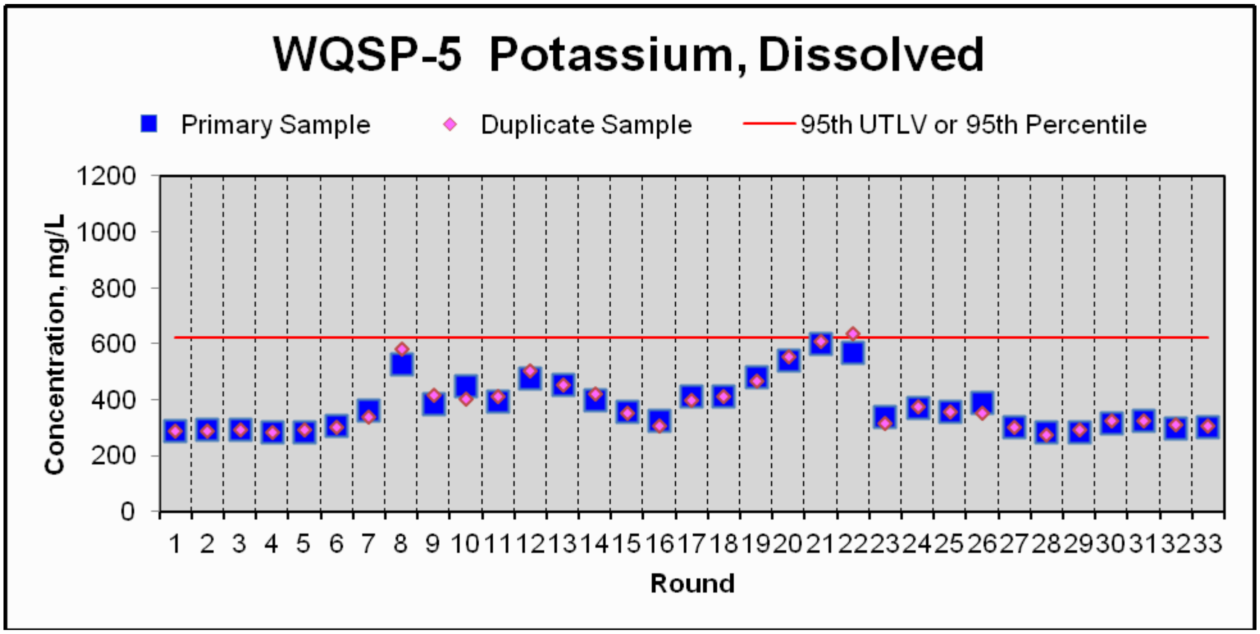



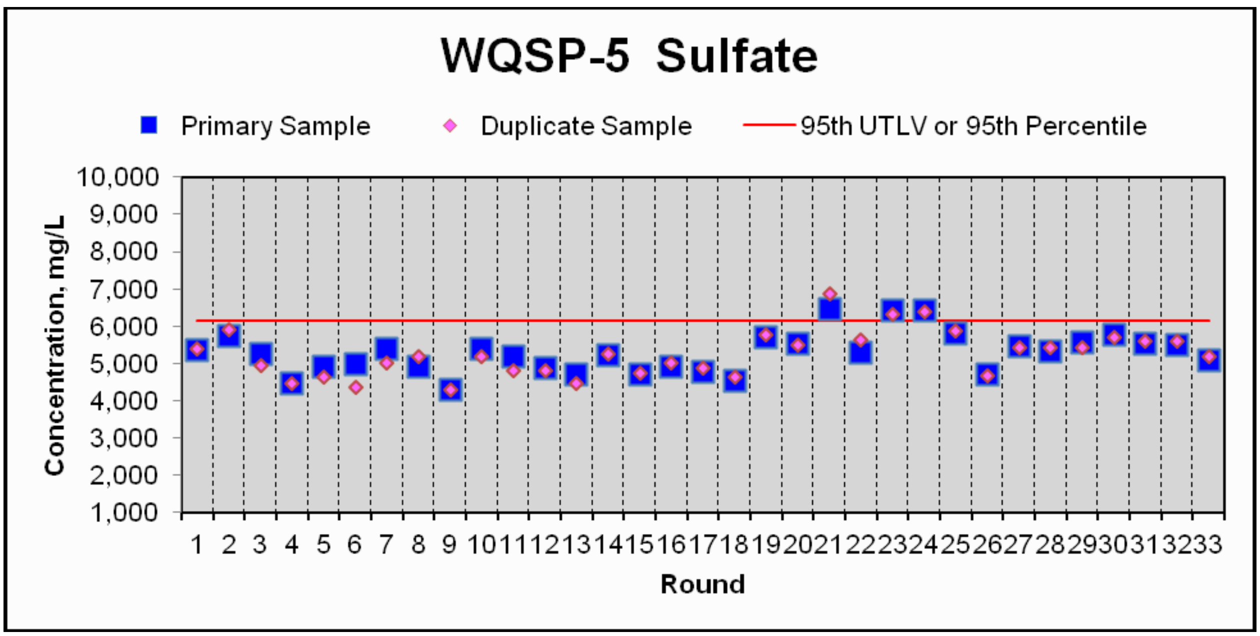
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



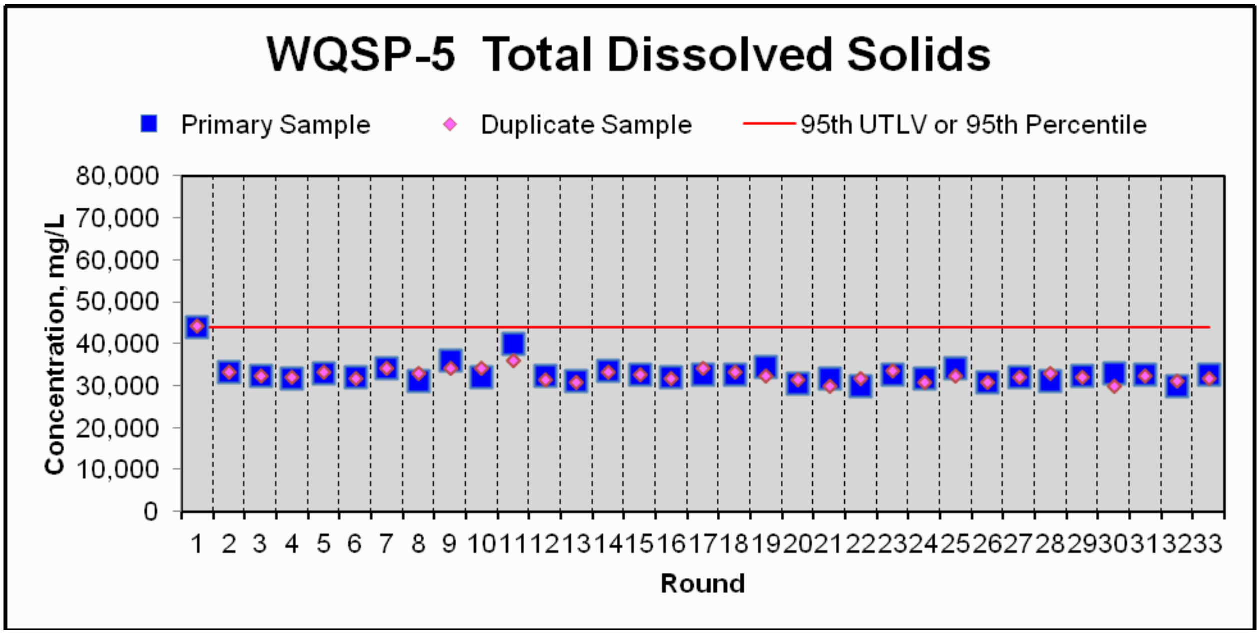



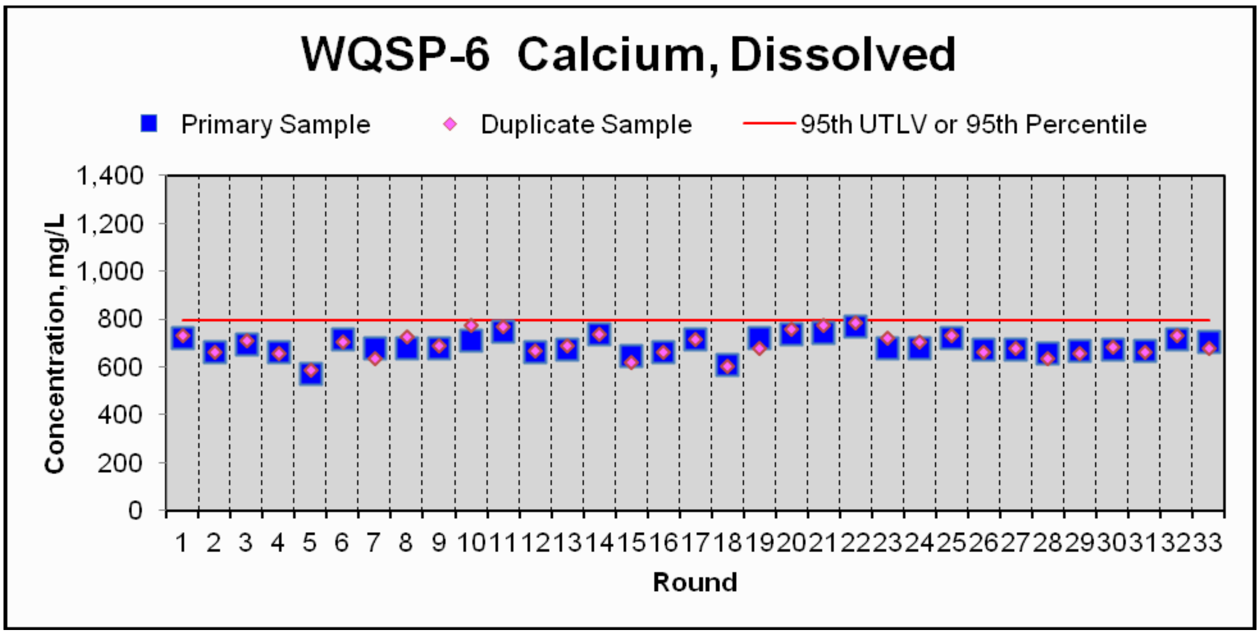
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



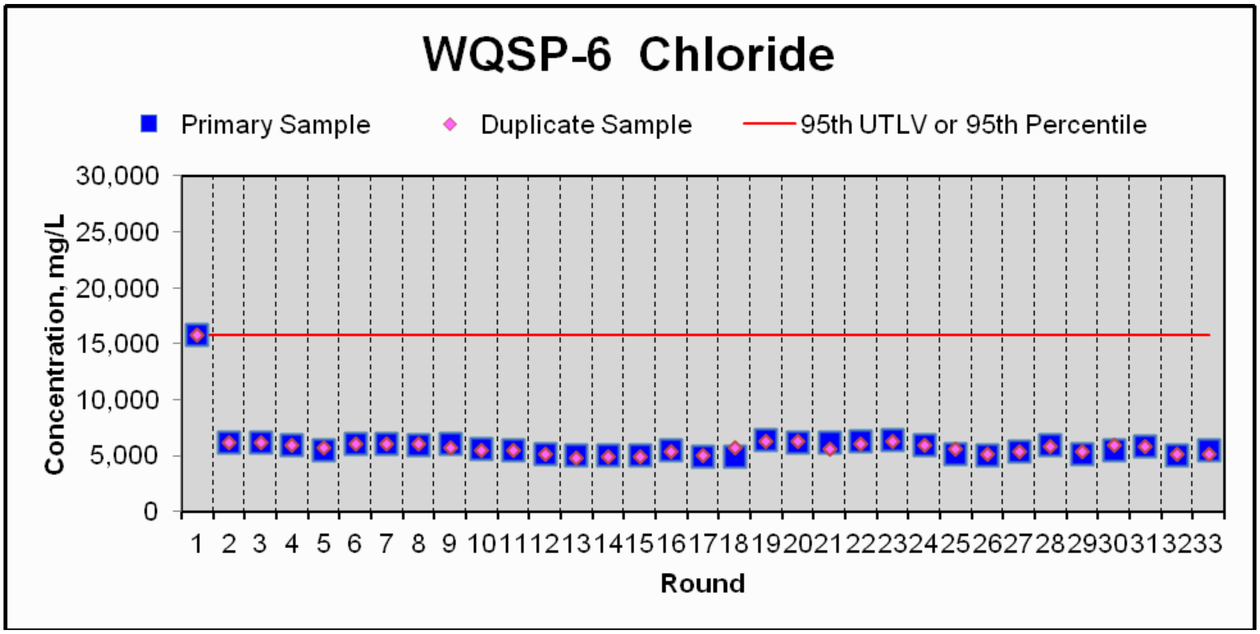



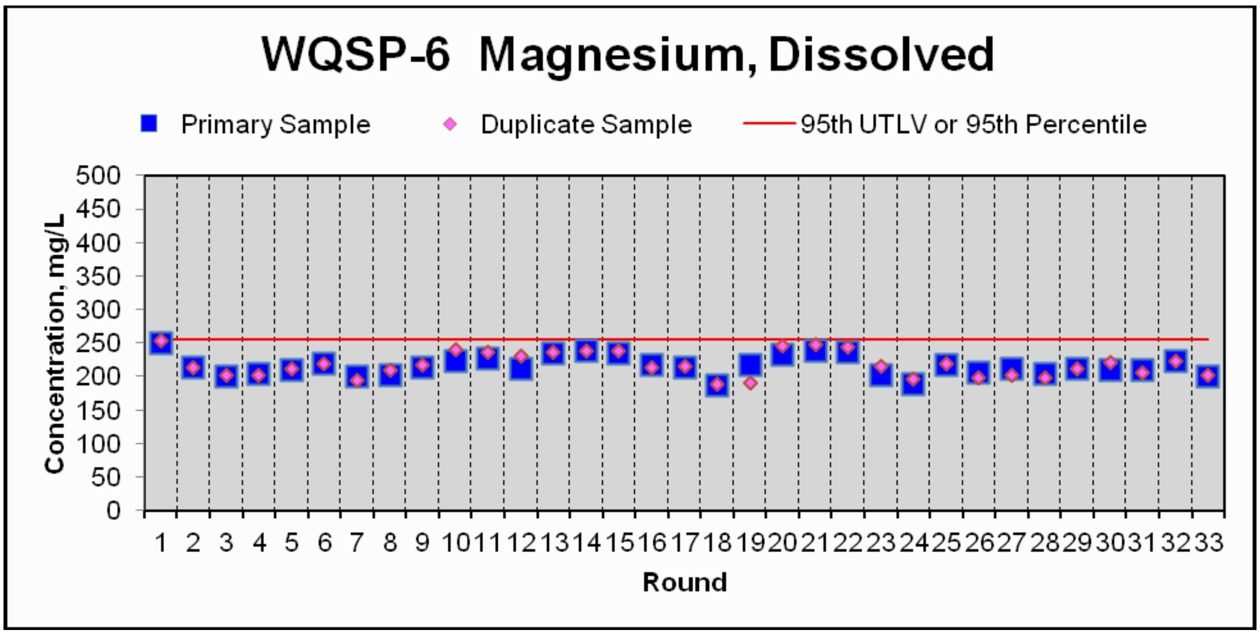
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



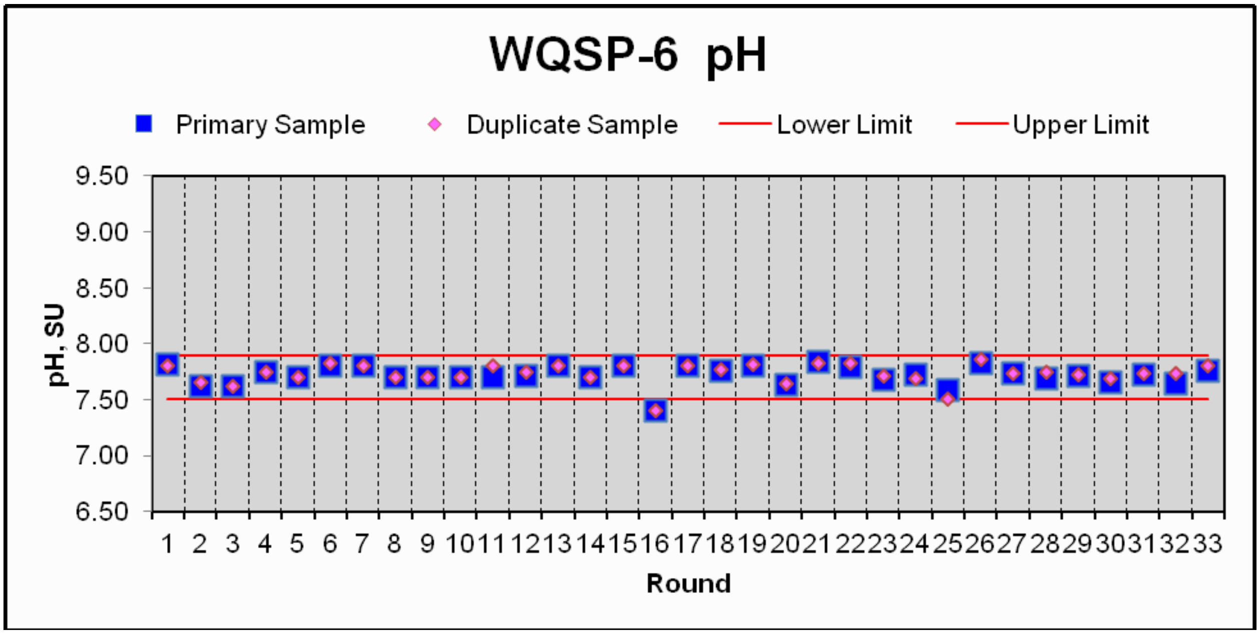



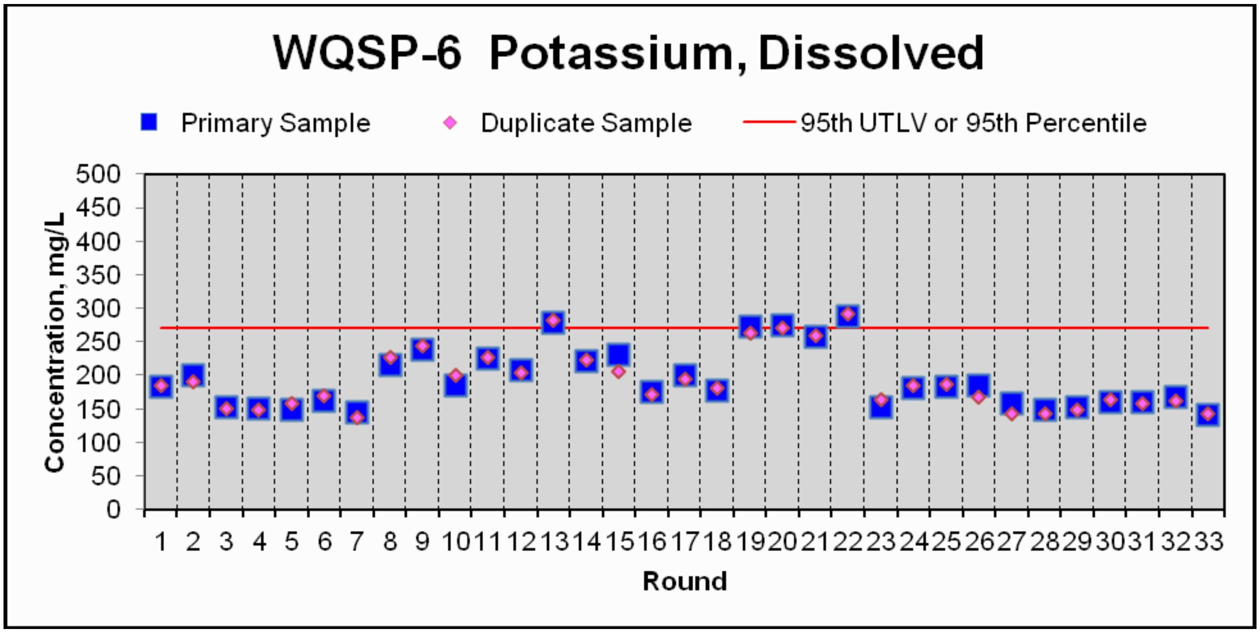
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



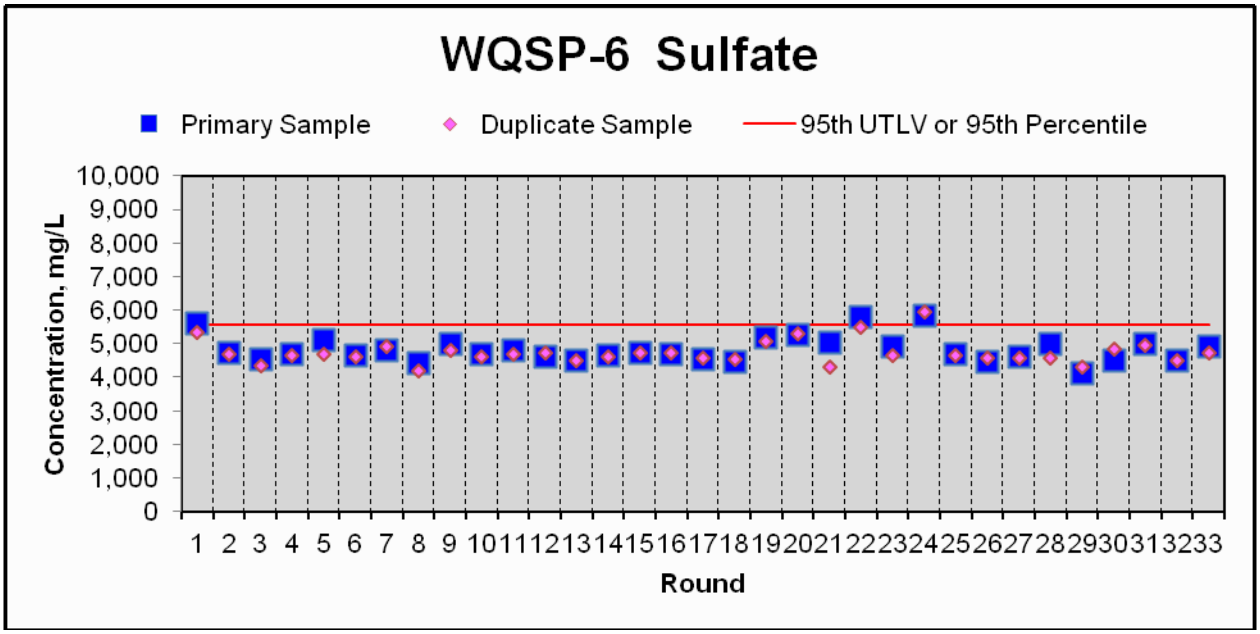



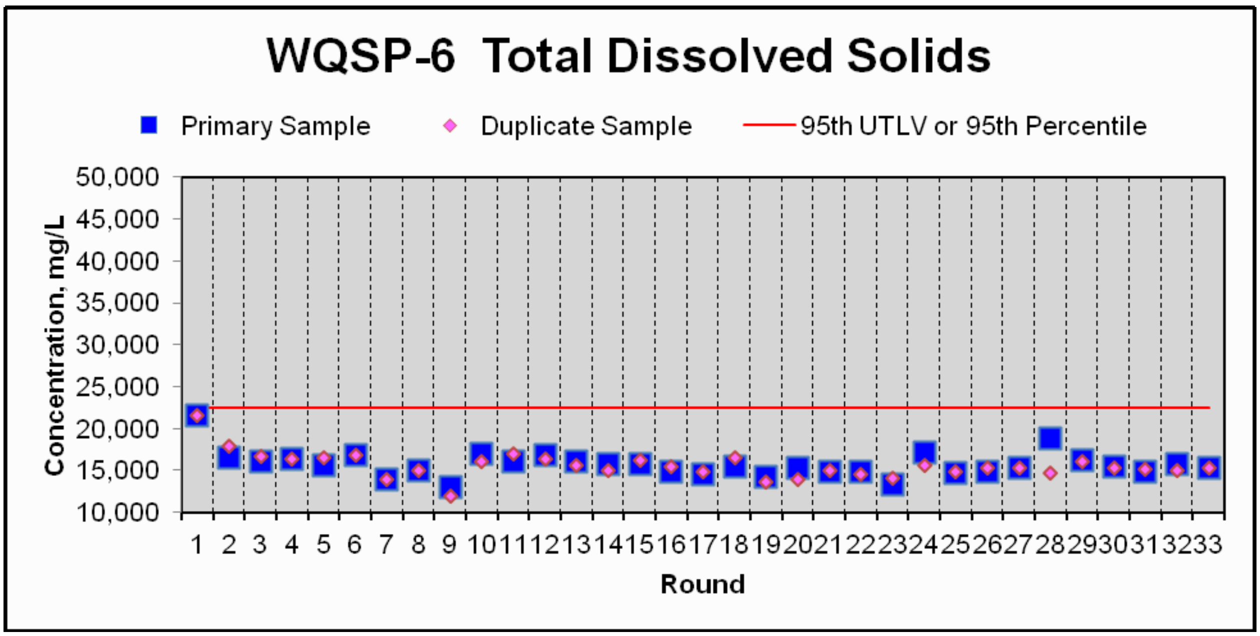
APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



APPENDIX E – Time Trend Plots for Detectable Constituents in Groundwater



# APPENDIX F – Groundwater Data Tables

APPENDIX F – Groundwater Data Tables

The following notes apply to Tables F.1- F.7:

(a) $95^{th}$ UTLV, equivalent to 95 percent confidence limit. $95^{th}$ percentile for nitrate, TOC, TOX, TSS, and trace metals.

(b) (<RL)> Reporting Limit.  Value corresponds to MRL.

(J) Analyte detected at an estimated concentration less than the MRL but higher than the MDL.  Less than (<) concentrations correspond the MRL.

(ICP/MS): Inductively Couple Plasma/Mass Spectrometry

N/A : Not Applicable

Primary Sample and Duplicate results in **Bold** type were above the $95^{th}$ UTLV or $95^{th}$ Percentile.

# APPENDIX F – Groundwater Data Tables

**Table F.1 – VOC and SVOC results of all DMP wells in 2011. All wells were reported below the Method Reporting Limit for each parameter.**

| Parameter | Round 32 | | Round 33 | | Units | Method Reporting Limit | | 95th |
|---|---|---|---|---|---|---|---|---|
| | Sample | Duplicate | Sample | Duplicate | | Round 32 | Round 33 | UTLV[a] |
| 1,1,1-Trichloroethane | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL[b] |
| 1,1,2,2-Tetrachloroethane | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL |
| 1,1,2-Trichloroethane | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL |
| 1,1-Dichloroethane | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL |
| 1,1-Dichloroethylene | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL |
| 1,2-Dichloroethane | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL |
| Carbon tetrachloride | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL |
| Chlorobenzene | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL |
| Chloroform | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL |
| trans-1,2-Dichloroethylene | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL |
| 2-butanone | <5 | <5 | <5 | <5 | µg/L | 5 | 5 | <RL |
| Isobutanol | <5 | <5 | <5 | <5 | µg/L | 5 | 5 | <RL |
| Methylene chloride | <5 | <5 | <5 | <5 | µg/L | 5 | 5 | <RL |
| Tetrachloroethylene | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL |
| Toluene | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL |
| Trichloroethylene | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL |
| Trichlorofluoromethane | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL |
| Vinyl chloride | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL |
| Xylene | <1 | <1 | <1 | <1 | µg/L | 1 | 1 | <RL |
| 1,2-Dichlorobenzene | <5 | <5 | <5 | <5 | µg/L | 5 | 5 | <RL |
| 1,4-Dichlorobenzene | <5 | < 5 | <5 | <5 | µg/L | 5 | 5 | <RL |
| 2,4-Dinitrophenol | <5 | <5 | <5 | <5 | µg/L | 5 | 5 | <RL |
| 2,4-Dinitrotoluene | <5 | <5 | <5 | <5 | µg/L | 5 | 5 | <RL |
| 2-Methylphenol | <5 | <5 | <5 | <5 | µg/L | 5 | 5 | <RL |
| 3-Methylphenol/4-Methylphenol | <5 | <5 | <5 | <5 | µg/L | 5 | 5 | <RL |
| Hexachlorobenzene | <5 | <5 | <5 | <5 | µg/L | 5 | 5 | <RL |
| Hexachloroethane | <5 | <5 | <5 | <5 | µg/L | 5 | 5 | <RL |
| Nitrobenzene | <5 | <5 | <5 | <5 | µg/L | 5 | 5 | <RL |
| Pentachlorophenol | <5 | <5 | <5 | <5 | µg/L | 5 | 5 | <RL |
| Pyridine | <5 | <5 | <5 | <5 | µg/L | 5 | 5 | <RL |

# APPENDIX F – Groundwater Data Tables

**Table F.2 WQSP-1 Analytical Data in 2011**

| Chemical | Round 32 Primary Sample | Round 32 Duplicate | Round 33 Primary Sample | Round 33 Duplicate | Distribution Type | 95th UTLVor 95th Percentile | Permit Table 5.6 |
|---|---|---|---|---|---|---|---|
| | Concentration (mg/L) | | Concentration (mg/L) | | | | |
| **General Chemistry** | | | | | | | |
| Specific Gravity | 1.043 | 1.046 | 1.043 | 1.045 | Normal | 1.070 | N/A |
| pH (SU) | 7.17 | 7.22 | 7.17 | 7.19 | Lognormal | 5.6 – 8.8 | N/A |
| Specific Conductance (μmhos/cm) | 125,000 | 126,000 | 122,000 | 124,000 | Lognormal | 175,000 | N/A |
| Total Dissolved Solids | 62,700 | 62,400 | 61,400 | 64,700 | Lognormal | 80,700 | N/A |
| Total Organic Carbon | 0.84 J | 0.86 J | 0.60 J | 0.75 J | Nonparametric | <5.0 | N/A |
| Total Organic Halogens | 0.42 | 0.29 | 0.57 | 0.26 | Nonparametric | 14.6 | N/A |
| Total Suspended Solids | **73** | **68** | 33 | **36** | Nonparametric | 33.3 | N/A |
| **Total Trace Metals** | | | | | | | |
| Antimony | ND | ND | ND | ND | Nonparametric | 0.33 | 0.33 |
| Arsenic | 0.011 | 0.01 | ND | ND | Nonparametric | <0.1 | 0.1 |
| Barium | 0.034 J | 0.031 J | 0.033 J | 0.031 J | Nonparametric | <1.0 | 1 |
| Beryllium | ND | 0.0026 J | 0.0032 J | 0.004 J | Nonparametric | <0.02 | 0.02 |
| Cadmium | ND | ND | ND | ND | Nonparametric | <0.2 | 0.2 |
| Chromium | ND | ND | ND | ND | Nonparametric | <0.5 | 0.5 |
| Iron | 0.15 J | 0.12 J | 0.17 J | 0.11 J | Nonparametric | 0.91 | N/A |
| Lead | ND | ND | ND | ND | Nonparametric | 0.105 | 0.11 |
| Mercury | ND | ND | ND | ND | Nonparametric | <0.002 | 0.002 |
| Nickel | ND | ND | ND | ND | Nonparametric | 0.49 | 0.5 |
| Selenium | ND | ND | ND | ND | Nonparametric | 0.15 | 0.15 |
| Silver | ND | ND | ND | ND | Nonparametric | <0.5 | 0.5 |
| Thallium | ND | ND | ND | ND | Nonparametric | 0.98 | 1 |
| Vanadium | 0.026 J | 0.028 J | 0.040 J | 0.041 J | Nonparametric | <0.1 | 0.1 |
| **Major Cations, Dissolved** | | | | | | | |
| Calcium | 1,710 | 1,690 | 1,850 | 1,790 | Normal | 2,087 | N/A |
| Magnesium | 1,120 | 1,100 | 1,170 | 1,150 | Normal | 1,247 | N/A |
| Potassium | 498 | 596 | 489 | 499 | Lognormal | 799 | N/A |
| Sodium | 20,100 | 19,900 | 20,500 | 20,900 | Lognormal | 22,090 | N/A |
| **Major Anions** | | | | | | | |
| Alkalinity | 51.3 | 51.5 | 52.8 | 50.8 | Lognormal | 55.8 | N/A |
| Chloride | **41,000** | 40,000 | 36,000 | 38,000 | Normal | **40,472** | N/A |
| Nitrate, $NO_3^-$ (As N) | ND | ND | ND | ND | Nonparametric | <10.0 | N/A |
| Sulfate | 4,570 | 4,770 | 4,950 | 4,900 | Normal | 5,757 | N/A |

# APPENDIX F – Groundwater Data Tables

**Table F.3 WQSP-2 Analytical Data in 2011**

| Chemical | Round 32 Primary Sample | Round 32 Duplicate | Round 33 Primary Sample | Round 33 Duplicate | Distribution Type | 95th UTLV or 95th Percentile | Permit Table 5.6 |
|---|---|---|---|---|---|---|---|
| | Concentration (mg/L) | | Concentration (mg/L) | | | | |
| **General Chemistry** | | | | | | | |
| Specific Gravity | 1.041 | 1.044 | 1.040 | 1.044 | Lognormal | 1.060 | N/A |
| pH (SU) | 7.24 | 7.27 | 7.22 | 7.36 | Normal | 7.0–7.6 | N/A |
| Specific Conductance (μmhos/cm) | 121,000 | 121,000 | 118,000 | 118,000 | Lognormal | 124,000 | N/A |
| Total Dissolved Solids | 65,700 | 62,800 | 65,100 | 62,600 | Normal | 80,500 | N/A |
| Total Organic Carbon | 0.46 J | 0.45 J | 0.32 J | 0.39 J | Nonparametric | 7.97 | N/A |
| Total Organic Halogens | 0.57 | 0.90 | 0.74 | 0.72 | Lognormal | 202 | N/A |
| Total Suspended Solids | **96** | **88** | 34 | 34 | Nonparametric | **43.0** | N/A |
| **Total Trace Metals** | | | | | | | |
| Antimony | ND | ND | ND | ND | Nonparametric | <0.5 | 0.5 |
| Arsenic | 0.01 | 0.011 | ND | ND | Nonparametric | 0.062 | 0.06 |
| Barium | 0.023 | 0.022 | ND | 0.034 J | Nonparametric | <1.0 | 1 |
| Beryllium | ND | ND | 0.0043 J | 0.0071 J | Nonparametric | <1.0 | 1 |
| Cadmium | ND | ND | ND | ND | Nonparametric | <0.5 | 0.5 |
| Chromium | ND | ND | ND | ND | Nonparametric | <0.50 | 0.5 |
| Iron | ND | ND | ND | ND | Nonparametric | 0.91 | N/A |
| Lead | ND | ND | ND | ND | Nonparametric | 0.163 | 0.17 |
| Mercury | ND | ND | ND | ND | Nonparametric | <0.002 | 0.002 |
| Nickel | ND | ND | ND | ND | Nonparametric | 0.37 | 0.5 |
| Selenium | ND | ND | 0.012 | 0.021 | Nonparametric | 0.15 | 0.15 |
| Silver | ND | ND | ND | ND | Nonparametric | <0.5 | 0.5 |
| Thallium | ND | ND | ND | ND | Nonparametric | 0.98 | 1 |
| Vanadium | ND | ND | 0.037 J | 0.051 J | Nonparametric | <0.1 | 0.1 |
| **Major Cations, Dissolved** | | | | | | | |
| Calcium | 1,690 | 1,670 | 1,580 | 1,610 | Lognormal | 1,827 | N/A |
| Magnesium | 1,110 | 1,130 | 1,080 | 1,090 | Normal | 1,244 | N/A |
| Potassium | 484 | 533 | 465 | 483 | Lognormal | 845 | N/A |
| Sodium | 21,500 | 20,000 | 21,700 | 20,100 | Normal | 21,900 | N/A |
| **Major Anions** | | | | | | | |
| Alkalinity | 47.8 | 48.0 | 50.7 | 49.1 | Normal | 70.3 | N/A |
| Chloride | 35,000 | 34,500 | 38,000 | 38,500 | Normal | 39,670 | N/A |
| Nitrate, $NO_3^-$ (As N) | ND | ND | ND | ND | Nonparametric | <10.0 | N/A |
| Sulfate | 5,760 | 5,620 | 5,580 | 5,680 | Normal | 6,590 | N/A |

# APPENDIX F – Groundwater Data Tables

**Table F.4 WQSP-3 Analytical Data in 2011**

| Chemical | Round 32 Primary Sample | Round 32 Duplicate | Round 33 Primary Sample | Round 33 Duplicate | Distribution Type | 95th UTLV or 95th Percentile | Permit Table 5.6 |
|---|---|---|---|---|---|---|---|
| | Concentration (mg/L) | | Concentration (mg/L) | | | | |
| **General Chemistry** | | | | | | | |
| Specific Gravity | 1.138 | 1.139 | 1.140 | 1.143 | Normal | 1.170 | N/A |
| pH (SU) | 6.79 | 6.88 | 6.86 | 6.84 | Lognormal | 6.6 – 7.2 | N/A |
| Specific Conductance (µmhos/cm) | 426,000 | 416,000 | 381,000 | 383,000 | Normal | 517,000 | N/A |
| Total Dissolved Solids | 220,000 | 216,000 | 211,000 | 217,000 | Lognormal | 261,000 | N/A |
| Total Organic Carbon | 0.30 J | 0.32 J | 0.36 J | 1.0 | Nonparametric | <5.0 | N/A |
| Total Organic Halogens | 1.24 | 2.65 | 1.52 | 0.89 | Nonparametric | 55 | N/A |
| Total Suspended Solids | 85 | 79 | 97 | 91 | Nonparametric | 107 | N/A |
| **Total Trace Metals** | | | | | | | |
| Antimony | ND | ND | ND | ND | Nonparametric | <1.0 | 1 |
| Arsenic | ND | ND | ND | ND | Nonparametric | <1.0 | 0.21 |
| Barium (ICP/MS) | 0.034 | 0.037 | 0.037 J | 0.040 J | Nonparametric | <1.0 | 1 |
| Beryllium | ND | ND | 0.017 J | 0.0097 J | Nonparametric | <0.1 | 0.1 |
| Cadmium | ND | ND | ND | ND | Nonparametric | <0.5 | 0.5 |
| Chromium | ND | ND | ND | ND | Nonparametric | <2.0 | 2 |
| Iron | ND | ND | 0.32 J | 0.39 J | Nonparametric | <4.0 | N/A |
| Lead | ND | ND | ND | ND | Nonparametric | 0.8 | 0.8 |
| Mercury | ND | ND | ND | ND | Nonparametric | <0.002 | 0.002 |
| Nickel | ND | ND | ND | ND | Nonparametric | <5.0 | 5 |
| Selenium | ND | ND | ND | 0.027 | Nonparametric | <2.0 | 2 |
| Silver | ND | ND | ND | ND | Nonparametric | 0.31 | 0.31 |
| Thallium | ND | ND | ND | ND | Nonparametric | 5.8 | 5.8 |
| Vanadium | ND | ND | 0.13 J | 0.082 J | Nonparametric | <5.0 | 5 |
| **Major Cations, Dissolved** | | | | | | | |
| Calcium | 1,470 | 1,520 | 1,570 | 1,520 | Normal | 1,680 | N/A |
| Magnesium | 2,390 | 2,460 | 2,400 | 2,460 | Lognormal | 2,625 | N/A |
| Potassium | 1,420 | 1,470 | 1,500 | 1,470 | Lognormal | 3,438 | N/A |
| Sodium | 76,000 | 71,000 | 80,000 | 71,000 | Nonparametric | 140,400 | N/A |
| **Major Anions** | | | | | | | |
| Alkalinity | 32.6 | 33.2 | 33.4 | 33.5 | Lognormal | 54.5 | N/A |
| Chloride | **158,000** | **153,000** | **151,000** | 146,000 | Lognormal | **149,100** | N/A |
| Nitrate, $NO_3^-$ (As N) | ND | ND | ND | ND | Nonparametric | <12.0 | N/A |
| Sulfate | **8,490** | **8,880** | **8,170** | 7,920 | Normal | **8,015** | N/A |

# APPENDIX F – Groundwater Data Tables

**Table F.5 WQSP-4 Analytical Data in 2011**

| Chemical | Round 32 Primary Sample | Round 32 Duplicate | Round 33 Primary Sample | Round 33 Duplicate | Distribution Type | 95th UTLV or 95th Percentile | Permit Table 5.6 |
|---|---|---|---|---|---|---|---|
| | Concentration (mg/L) | | Concentration (mg/L) | | | | |
| **General Chemistry** | | | | | | | |
| Specific Gravity | 1.066 | 1.070 | 1.070 | 1.068 | Lognormal | 1.090 | N/A |
| pH (SU) | 7.16 | 7.19 | 7.19 | 7.20 | Lognormal | 6.8 – 7.6 | N/A |
| Specific Conductance (μmhos/cm) | 204,000 | 205,000 | 191,000 | 189,000 | Lognormal | 319,800 | N/A |
| Total Dissolved Solids | 101,000 | 102,000 | 103,000 | 108,000 | Normal | 123,500 | N/A |
| Total Organic Carbon | 0.56 J | 0.52 J | 0.73 J | 0.35 J | Nonparametric | <5.0 | N/A |
| Total Organic Halogens | 0.33 | 0.67 | 0.31 | 0.64 | Lognormal | 84.1 | N/A |
| Total Suspended Solids | **63** | 55 | **64** | 55 | Nonparametric | **57** | N/A |
| **Total Trace Metals** | | | | | | | |
| Antimony | ND | ND | ND | ND | Nonparametric | <10.0 | 0.8 |
| Arsenic | ND | ND | ND | ND | Nonparametric | <0.5 | 0.5 |
| Barium | 0.029 | 0.027 | 0.035 J | 0.038 J | Nonparametric | 1 | 1 |
| Beryllium | 0.021 J | 0.018 J | 0.0076 J | 0.0087 J | Nonparametric | 0.25 | 0.25 |
| Cadmium | ND | ND | ND | ND | Nonparametric | <0.5 | 0.5 |
| Chromium | ND | ND | ND | ND | Nonparametric | <2.0 | 2 |
| Iron | ND | ND | ND | 0.18 J | Nonparametric | 2.245 | N/A |
| Lead | ND | ND | ND | ND | Nonparametric | 0.525 | 0.53 |
| Mercury | ND | ND | ND | ND | Nonparametric | <0.002 | 0.002 |
| Nickel | ND | ND | ND | ND | Nonparametric | <5.0 | 5 |
| Selenium | ND | ND | ND | ND | Nonparametric | 2.009 | 2 |
| Silver | ND | ND | ND | ND | Nonparametric | 0.519 | 0.52 |
| Thallium | ND | ND | ND | ND | Nonparametric | 1 | 1 |
| Vanadium | 0.089 J | 0.094 J | 0.14 J | 0.15 J | Nonparametric | <5.0 | 5 |
| **Major Cations, Dissolved** | | | | | | | |
| Calcium | 1,620 | 1,550 | 1,560 | 1,570 | Lognormal | 1,834 | N/A |
| Magnesium | 1,260 | 1,200 | 1,170 | 1,180 | Lognormal | 1,472 | N/A |
| Potassium | 763 | 731 | 734 | 743 | Lognormal | 1,648 | N/A |
| Sodium | 36,500 | 33,700 | 36,800 | 35,100 | Normal | 38,790 | N/A |
| **Major Anions** | | | | | | | |
| Alkalinity | 39.8 | 39.8 | 39.9 | 39.8 | Normal | 47.1 | N/A |
| Chloride | **68,300** | **66,000** | 60,400 | 60,300 | Normal | **63,960** | N/A |
| Nitrate, $NO_3^-$ (As N) | ND | ND | ND | ND | Nonparametric | <10.0 | N/A |
| Sulfate | 7,610 | 7,650 | 6,950 | 7,120 | Normal | 7,927 | N/A |

# APPENDIX F – Groundwater Data Tables

Table F.6 WQSP-5 Analytical Data in 2011

| Chemical | Round 32 | | Round 33 | | | | |
|---|---|---|---|---|---|---|---|
| | Primary Sample | Duplicate | Primary Sample | Duplicate | Distribution Type | 95th UTLV or 95th Percentile | Permit Table 5.6 |
| | Concentration (mg/L) | | Concentration (mg/L) | | | | |
| **General Chemistry** | | | | | | | |
| Specific Gravity | 1.017 | 1.016 | 1.022 | 1.021 | Normal | 1.040 | N/A |
| pH (SU) | 7.49 | 7.50 | 7.47 | 7.53 | Normal | 7.4 – 7.9 | N/A |
| Specific Conductance (μmhos/cm) | 51,700 | 46,500 | 60,100 | 60,200 | Lognormal | 67,700 | N/A |
| Total Dissolved Solids | 29,700 | 31,000 | 32,700 | 31,600 | Nonparametric | 43,950 | N/A |
| Total Organic Carbon | 0.66 J | 0.62 J | 0.60 J | 0.53 J | Nonparametric | <5.0 | N/A |
| Total Organic Halogens | 0.17 | 0.29 | 0.14 | 0.21 | Lognormal | 8.37 | N/A |
| Total Suspended Solids | **15** | **19** | **13** | 7.0 | Nonparametric | <10.0 | N/A |
| **Total Trace Metals** | | | | | | | |
| Antimony | ND | ND | ND | ND | Nonparametric | 0.073 | 0.07 |
| Arsenic | ND | ND | ND | ND | Nonparametric | <0.5 | 0.5 |
| Barium | ND | ND | ND | ND | Nonparametric | <1.0 | 1 |
| Beryllium | ND | ND | ND | ND | Nonparametric | <0.02 | 0.02 |
| Cadmium | ND | ND | ND | ND | Nonparametric | <0.05 | 0.05 |
| Chromium | ND | ND | ND | ND | Nonparametric | <0.5 | 0.5 |
| Iron | 0.54 J | **0.84 J** | 0.21 J | 0.27 J | Nonparametric | **0.795** | N/A |
| Lead | ND | ND | ND | ND | Nonparametric | <0.05 | 0.05 |
| Mercury | **0.0027 J** | 0.00096 J | ND | ND | Nonparametric | **<0.002** | 0.002 |
| Nickel | ND | ND | ND | ND | Nonparametric | <0.1 | 0.1 |
| Selenium | ND | ND | ND | ND | Nonparametric | <0.1 | 0.1 |
| Silver | ND | ND | ND | ND | Nonparametric | <0.5 | 0.5 |
| Thallium | ND | ND | ND | ND | Nonparametric | 0.209 | 0.21 |
| Vanadium | ND | ND | 0.024 J | 0.024 J | Nonparametric | 2.7 | 2.7 |
| **Major Cations, Dissolved** | | | | | | | |
| Calcium | 1,110 | 1,120 | 1,100 | 1,130 | Lognormal | 1,303 | N/A |
| Magnesium | 480 | 480 | 478 | 478 | Nonparametric | 547 | N/A |
| Potassium | 297 | 312 | 300 | 306 | Lognormal | 622 | N/A |
| Sodium | 9,310 | 9,330 | 10,500 | 9,970 | Normal | 11,190 | N/A |
| **Major Anions** | | | | | | | |
| Alkalinity | 48.0 | 48.1 | 47.4 | 47.6 | Lognormal | 56 | N/A |
| Chloride | 15,900 | 15,300 | 15,000 | 16,200 | Lognormal | 18,100 | N/A |
| Nitrate, $NO_3^-$ (As N) | ND | ND | ND | ND | Nonparametric | <10.0 | N/A |
| Sulfate | 5,480 | 5,580 | 5,090 | 5,200 | Normal | 6,129 | N/A |

# APPENDIX F – Groundwater Data Tables

**Table F.7 WQSP-6 Analytical Data in 2011**

| Chemical | Round 32 Primary Sample | Round 32 Duplicate | Round 33 Primary Sample | Round 33 Duplicate | Distribution Type | 95th UTLV or 95th Percentile | Permit Table 5.6 |
|---|---|---|---|---|---|---|---|
| | Concentration (mg/L) | | Concentration (mg/L) | | | | |
| **General Chemistry** | | | | | | | |
| Specific Gravity | 1.009 | 1.008 | 1.007 | 1.008 | Normal | 1.020 | N/A |
| pH (SU) | 7.64 | 7.73 | 7.76 | 7.80 | Normal | 7.5 – 7.9 | N/A |
| Specific Conductance (μmhos/cm) | **29,900** | **29,800** | **29,000** | **28,000** | Lognormal | **27,660** | N/A |
| Total Dissolved Solids | 15,700 | 15,000 | 15,300 | 15,300 | Lognormal | 22,500 | N/A |
| Total Organic Carbon | 0.43 J | 0.45 J | 0.88 J | 0.78 J | Nonparametric | 10.14 | N/A |
| Total Organic Halogens | 0.052 | 0.059 | 0.14 | 0.21 | Lognormal | 1.54 | N/A |
| Total Suspended Solids | 5.0 | 6.0 | 7.0 | 7.0 | Nonparametric | 14.8 | N/A |
| **Total Trace Metals** | | | | | | | |
| Antimony | ND | ND | ND | ND | Nonparametric | 0.14 | 0.14 |
| Arsenic | ND | ND | ND | ND | Nonparametric | <0.5 | 0.5 |
| Barium | ND | ND | ND | ND | Nonparametric | <1.0 | 1 |
| Beryllium | ND | ND | 0.0053 J | 0.0061 J | Nonparametric | <0.02 | 0.02 |
| Cadmium | ND | ND | ND | ND | Nonparametric | <0.05 | 0.05 |
| Chromium | ND | ND | ND | ND | Nonparametric | <0.5 | 0.5 |
| Iron | ND | ND | 0.17 J | 0.20 J | Nonparametric | 3.105 | N/A |
| Lead | ND | ND | ND | ND | Nonparametric | 0.15 | 0.15 |
| Mercury | ND | ND | 0.000056 J | 0.000041 J | Nonparametric | <0.002 | 0.002 |
| Nickel | ND | ND | ND | ND | Nonparametric | <0.5 | 0.5 |
| Selenium | ND | ND | ND | ND | Nonparametric | 0.1 | 0.1 |
| Silver | ND | ND | ND | ND | Nonparametric | <0.5 | 0.5 |
| Thallium | ND | ND | ND | ND | Nonparametric | 0.56 | 0.56 |
| Vanadium | ND | ND | 0.027 J | 0.032 J | Nonparametric | 0.07 | 0.1 |
| **Major Cations, Dissolved** | | | | | | | |
| Calcium | 714 | 730 | 706 | 680 | Normal | 796 | N/A |
| Magnesium | 222 | 223 | 200 | 202 | Lognormal | 255 | N/A |
| Potassium | 167 | 162 | 141 | 143 | Lognormal | 270 | N/A |
| Sodium | 4,290 | 4,280 | 4,410 | 4,420 | Lognormal | 6,290 | N/A |
| **Major Anions** | | | | | | | |
| Alkalinity | 48.2 | 46.8 | 49.3 | 48.5 | Normal | 55.8 | N/A |
| Chloride | 5,060 | 5,080 | 5,500 | 5,120 | Nonparametric | 15,800 | N/A |
| Nitrate, $NO_3^-$ (As N) | ND | ND | ND | ND | Nonparametric | 7.45 | N/A |
| Sulfate | 4,490 | 4,510 | 4,900 | 4,740 | Lognormal | 5,557 | N/A |

# APPENDIX F – Groundwater Data Tables

**Table F.8 – WIPP Well Inventory for 2011**

| Sorted by Active Wells at Year-End | | | | Sorted by Formation for Wells Measured at Least Once in 2011 | | | |
|---|---|---|---|---|---|---|---|
| **Count** | **Well Number** | **Zone** | **Comments** | **Count** | **Well Number** | **Zone** | **Reason Not Assessed for Long-Term Water Level Trend in Culebra** |
| 1 | AEC-7 | CUL | | 1 | CB-1(PIP) | B/C | |
| 2 | C-2505 | SR/D | | 2 | DOE-2 | B/C | |
| 3 | C-2506 | SR/D | | 3 | AEC-7 | CUL | |
| 4 | C-2507 | SR/D | | 4 | ERDA-9 | CUL | |
| 5 | C-2737 | MAG/CUL | | 5 | H-02b2 | CUL | |
| 6 | C-2811 | SR/D | | 6 | H-03b2 | CUL | |
| 7 | CB-1(PIP) | B/C | | 7 | H-04bR | CUL | |
| 8 | DOE-2 | B/C | | 8 | H-05b | CUL | |
| 9 | ERDA-9 | CUL | | 9 | H-06bR | CUL | |
| 10 | H-02b1 | MAG | | 10 | H-07b1 | CUL | |
| 11 | H-02b2 | CUL | | 11 | H-09bR | CUL | |
| 12 | H-03b1 | MAG | | 12 | H-10c | CUL | |
| 13 | H-03b2 | CUL | | 13 | H-11b4 | CUL | |
| 14 | H-03D | SR/D | dry; not measured in 2011 | 14 | H-11b4R | CUL | New in November 2011 |
| 15 | H-04bR | CUL | | 15 | H-12 | CUL | |
| 16 | H-04c | MAG | | 16 | H-17 | CUL | |
| 17 | H-05b | CUL | | 17 | H-19b0 | CUL | |
| 18 | H-06bR | CUL | | 18 | H-19b2 | CUL | Redundant to H19b0 |
| 19 | H-06c | MAG | | 19 | H-19b3 | CUL | Redundant to H19b0 |
| 20 | H-07b1 | CUL | | 20 | H-19b4 | CUL | Redundant to H19b0 |
| 21 | H-08a | MAG | | 21 | H-19b5 | CUL | Redundant to H19b0 |
| 22 | H-09c | MAG | | 22 | H-19b6 | CUL | Redundant to H19b0 |
| 23 | H-09bR | CUL | | 23 | H-19b7 | CUL | Redundant to H19b0 |
| 24 | H-10a | MAG | | 24 | I-461 | CUL | |
| 25 | H-10c | CUL | | 25 | SNL-01 | CUL | |
| 26 | H-11b2 | MAG | | 26 | SNL-02 | CUL | |
| 27 | H-11b4R | CUL | New in November 2011 | 27 | SNL-03 | CUL | |
| 28 | H-12 | CUL | | 28 | SNL-05 | CUL | |
| 29 | H-14 | MAG | | 29 | SNL-6 | CUL | Depressed from projected equilibrium |
| 30 | H-15R | CUL | | 30 | SNL-08 | CUL | |
| 31 | H-15 | MAG | | 31 | SNL-09 | CUL | |
| 32 | H-16 | CUL | | 32 | H-15R | CUL | |
| 33 | H-17 | CUL | | 33 | SNL-10 | CUL | |
| 34 | H-18 | MAG | | 34 | H-16 | CUL | |

# APPENDIX F – Groundwater Data Tables

**Table F.8 – WIPP Well Inventory for 2011**

| Sorted by Active Wells at Year-End | | | | Sorted by Formation for Wells Measured at Least Once in 2011 | | | |
|---|---|---|---|---|---|---|---|
| **Count** | **Well Number** | **Zone** | **Comments** | **Count** | **Well Number** | **Zone** | **Reason Not Assessed for Long-Term Water Level Trend in Culebra** |
| 35 | H-19b0 | CUL | | 35 | SNL-12 | CUL | |
| 36 | H-19b2 | CUL | | 36 | SNL-13 | CUL | Rise from oil field activities |
| 37 | H-19b3 | CUL | | 37 | SNL-14 | CUL | |
| 38 | H-19b4 | CUL | | 38 | SNL-15 | CUL | Depressed from projected equilibrium |
| 39 | H-19b5 | CUL | | 39 | SNL-16 | CUL | |
| 40 | H-19b6 | CUL | | 40 | SNL-17 | CUL | |
| 41 | H-19b7 | CUL | | 41 | SNL-18 | CUL | |
| 42 | I-461 | CUL | | 42 | SNL-19 | CUL | |
| 43 | SNL-01 | CUL | | 43 | WIPP-11 | CUL | |
| 44 | SNL-02 | CUL | | 44 | WIPP-13 | CUL | |
| 45 | SNL-03 | CUL | | 45 | WIPP-19 | CUL | |
| 46 | SNL-05 | CUL | | 46 | WQSP-1 | CUL | |
| 47 | SNL-06 | CUL | | 47 | WQSP-2 | CUL | |
| 48 | SNL-08 | CUL | | 48 | WQSP-3 | CUL | |
| 49 | SNL-09 | CUL | | 49 | WQSP-4 | CUL | |
| 50 | SNL-10 | CUL | | 50 | WQSP-5 | CUL | |
| 51 | SNL-12 | CUL | | 51 | WQSP-6 | CUL | |
| 52 | SNL-13 | CUL | | 52 | WQSP-6A | DL | |
| 53 | SNL-14 | CUL | | 53 | H-02b1 | MAG | |
| 54 | SNL-15 | CUL | | 54 | H-03b1 | MAG | |
| 55 | SNL-16 | CUL | | 55 | H-04c | MAG | |
| 56 | SNL-17 | CUL | | 56 | H-06c | MAG | |
| 57 | SNL-18 | CUL | | 57 | H-08a | MAG | |
| 58 | SNL-19 | CUL | | 58 | H-10a | MAG | |
| 59 | PZ-01 | SR/D | | 59 | H-11b2 | MAG | |
| 60 | PZ-02 | SR/D | | 60 | H-14 | MAG | |
| 61 | PZ-03 | SR/D | | 61 | H-18 | MAG | |
| 62 | PZ-04 | SR/D | | 62 | WIPP-18 | MAG | |
| 63 | PZ-05 | SR/D | | 63 | H-15 | MAG | |
| 64 | PZ-06 | SR/D | | 64 | H-09c | MAG | |
| 65 | PZ-07 | SR/D | | 65 | C-2737 | MAG / CUL | |
| 66 | PZ-08 | SR/D | | 66 | C-2505 | SR/D | |
| 67 | PZ-09 | SR/D | | 67 | C-2506 | SR/D | |
| 68 | PZ-10 | SR/D | | 68 | C-2507 | SR/D | |
| 69 | PZ-11 | SR/D | | 69 | C-2811 | SR/D | |

# APPENDIX F – Groundwater Data Tables

**Table F.8 – WIPP Well Inventory for 2011**

| Sorted by Active Wells at Year-End | | | | Sorted by Formation for Wells Measured at Least Once in 2011 | | | |
|---|---|---|---|---|---|---|---|
| **Count** | **Well Number** | **Zone** | **Comments** | **Count** | **Well Number** | **Zone** | **Reason Not Assessed for Long-Term Water Level Trend in Culebra** |
| 70 | PZ-12 | SR/D | | 70 | PZ-01 | SR/D | |
| 71 | PZ-13 | SR/D | | 71 | PZ-02 | SR/D | |
| 72 | PZ-14 | SR/D | | 72 | PZ-03 | SR/D | |
| 73 | PZ-15 | SR/D | | 73 | PZ-04 | SR/D | |
| 74 | WIPP-11 | CUL | | 74 | PZ-05 | SR/D | |
| 75 | WIPP-13 | CUL | | 75 | PZ-06 | SR/D | |
| 76 | WIPP-18 | MAG | | 76 | PZ-07 | SR/D | |
| 77 | WIPP-19 | CUL | | 77 | PZ-08 | SR/D | |
| 78 | WQSP-1 | CUL | | 78 | PZ-09 | SR/D | |
| 79 | WQSP-2 | CUL | | 79 | PZ-10 | SR/D | |
| 80 | WQSP-3 | CUL | | 80 | PZ-11 | SR/D | |
| 81 | WQSP-4 | CUL | | 81 | PZ-12 | SR/D | |
| 82 | WQSP-5 | CUL | | 82 | PZ-13 | SR/D | |
| 83 | WQSP-6 | CUL | | 83 | PZ-14 | SR/D | |
| 84 | WQSP-6A | DL | | 84 | PZ-15 | SR/D | |
| | | | | 85 | H-03D | SR/D | Dry; not measured in 2011 |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| AEC-7 | CUL | 01/10/11 | 612.63 | 186.73 | 3044.43 | 927.94 | 3064.70 |
| AEC-7 | CUL | 02/08/11 | 612.65 | 186.74 | 3044.41 | 927.94 | 3064.68 |
| AEC-7 | CUL | 03/01/11 | 612.56 | 186.71 | 3044.50 | 927.96 | 3064.77 |
| AEC-7 | CUL | 04/12/11 | 612.48 | 186.68 | 3044.58 | 927.99 | 3064.86 |
| AEC-7 | CUL | 05/16/11 | 612.57 | 186.71 | 3044.49 | 927.96 | 3064.76 |
| AEC-7 | CUL | 06/07/11 | 612.43 | 186.67 | 3044.63 | 928.00 | 3064.91 |
| AEC-7 | CUL | 07/12/11 | 612.18 | 186.59 | 3044.88 | 928.08 | 3065.18 |
| AEC-7 | CUL | 08/09/11 | 612.57 | 186.71 | 3044.49 | 927.96 | 3064.76 |
| AEC-7 | CUL | 09/13/11 | 612.48 | 186.68 | 3044.58 | 927.99 | 3064.86 |
| AEC-7 | CUL | 10/10/11 | 612.52 | 186.70 | 3044.54 | 927.98 | 3064.82 |
| AEC-7 | CUL | 11/08/11 | 612.39 | 186.66 | 3044.67 | 928.02 | 3064.96 |
| AEC-7 | CUL | 12/02/11 | 612.67 | 186.74 | 3044.39 | 927.93 | 3064.65 |
| C-2737 (PIP) | CUL | 01/12/11 | 387.06 | 117.98 | 3013.70 | 918.58 | 3021.91 |
| C-2737 (PIP) | CUL | 02/09/11 | 386.91 | 117.93 | 3013.85 | 918.62 | 3022.06 |
| C-2737 (PIP) | CUL | 03/03/11 | 386.74 | 117.88 | 3014.02 | 918.67 | 3022.24 |
| C-2737 (PIP) | CUL | 04/13/11 | 386.68 | 117.86 | 3014.08 | 918.69 | 3022.30 |
| C-2737 (PIP) | CUL | 05/19/11 | 386.64 | 117.85 | 3014.12 | 918.70 | 3022.34 |
| C-2737 (PIP) | CUL | 06/08/11 | 386.76 | 117.88 | 3014.00 | 918.67 | 3022.22 |
| C-2737 (PIP) | CUL | 07/13/11 | 386.70 | 117.87 | 3014.06 | 918.69 | 3022.28 |
| C-2737 (PIP) | CUL | 08/10/11 | 386.66 | 117.85 | 3014.10 | 918.70 | 3022.32 |
| C-2737 (PIP) | CUL | 09/15/11 | 386.92 | 117.93 | 3013.84 | 918.62 | 3022.05 |
| C-2737 (PIP) | CUL | 10/12/11 | 387.05 | 117.97 | 3013.71 | 918.58 | 3021.92 |
| C-2737 (PIP) | CUL | 11/09/11 | 387.36 | 118.07 | 3013.40 | 918.48 | 3021.60 |
| C-2737 (PIP) | CUL | 12/06/11 | 387.18 | 118.01 | 3013.58 | 918.54 | 3021.78 |
| ERDA-9 | CUL | 01/12/11 | 398.46 | 121.45 | 3011.71 | 917.97 | 3034.66 |
| ERDA-9 | CUL | 02/09/11 | 398.68 | 121.52 | 3011.49 | 917.90 | 3034.42 |
| ERDA-9 | CUL | 03/02/11 | 398.91 | 121.59 | 3011.26 | 917.83 | 3034.17 |
| ERDA-9 | CUL | 04/13/11 | 398.42 | 121.44 | 3011.75 | 917.98 | 3034.70 |
| ERDA-9 | CUL | 05/19/11 | 398.20 | 121.37 | 3011.97 | 918.05 | 3034.94 |
| ERDA-9 | CUL | 06/08/11 | 398.27 | 121.39 | 3011.90 | 918.03 | 3034.86 |
| ERDA-9 | CUL | 07/13/11 | 398.07 | 121.33 | 3012.10 | 918.09 | 3035.08 |
| ERDA-9 | CUL | 08/10/11 | 398.11 | 121.34 | 3012.06 | 918.08 | 3035.03 |
| ERDA-9 | CUL | 09/14/11 | 398.34 | 121.41 | 3011.83 | 918.01 | 3034.79 |
| ERDA-9 | CUL | 10/12/11 | 398.52 | 121.47 | 3011.65 | 917.95 | 3034.59 |
| ERDA-9 | CUL | 11/09/11 | 398.70 | 121.52 | 3011.47 | 917.90 | 3034.40 |
| ERDA-9 | CUL | 12/07/11 | 398.94 | 121.60 | 3011.23 | 917.82 | 3034.14 |
| H-02b2 | CUL | 01/11/11 | 335.75 | 102.34 | 3042.61 | 927.39 | 3046.51 |
| H-02b2 | CUL | 02/09/11 | 335.65 | 102.31 | 3042.71 | 927.42 | 3046.61 |
| H-02b2 | CUL | 03/03/11 | 335.38 | 102.22 | 3042.98 | 927.50 | 3046.88 |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| H-02b2 | CUL | 04/13/11 | 335.42 | 102.24 | 3042.94 | 927.49 | 3046.84 |
| H-02b2 | CUL | 05/17/11 | 335.40 | 102.23 | 3042.96 | 927.49 | 3046.86 |
| H-02b2 | CUL | 06/08/11 | 335.54 | 102.27 | 3042.82 | 927.45 | 3046.72 |
| H-02b2 | CUL | 07/12/11 | 335.70 | 102.32 | 3042.66 | 927.40 | 3046.56 |
| H-02b2 | CUL | 08/10/11 | 335.66 | 102.31 | 3042.70 | 927.41 | 3046.60 |
| H-02b2 | CUL | 09/15/11 | 335.83 | 102.36 | 3042.53 | 927.36 | 3046.43 |
| H-02b2 | CUL | 10/12/11 | 335.72 | 102.33 | 3042.64 | 927.40 | 3046.54 |
| H-02b2 | CUL | 11/09/11 | 335.91 | 102.39 | 3042.45 | 927.34 | 3046.35 |
| H-02b2 | CUL | 12/06/11 | 336.31 | 102.51 | 3042.05 | 927.22 | 3045.94 |
| H-03b2 | CUL | 01/12/11 | 388.14 | 118.31 | 3001.77 | 914.94 | 3014.65 |
| H-03b2 | CUL | 02/09/11 | 387.98 | 118.26 | 3001.93 | 914.99 | 3014.82 |
| H-03b2 | CUL | 03/03/11 | 387.70 | 118.17 | 3002.21 | 915.07 | 3015.11 |
| H-03b2 | CUL | 04/13/11 | 387.64 | 118.15 | 3002.27 | 915.09 | 3015.17 |
| H-03b2 | CUL | 05/19/11 | 388.06 | 118.28 | 3001.85 | 914.96 | 3014.73 |
| H-03b2 | CUL | 06/08/11 | 387.89 | 118.23 | 3002.02 | 915.02 | 3014.91 |
| H-03b2 | CUL | 07/13/11 | 387.91 | 118.23 | 3002.00 | 915.01 | 3014.89 |
| H-03b2 | CUL | 08/10/11 | 387.77 | 118.19 | 3002.14 | 915.05 | 3015.04 |
| H-03b2 | CUL | 09/15/11 | 388.62 | 118.45 | 3001.29 | 914.79 | 3014.15 |
| H-03b2 | CUL | 10/12/11 | 388.36 | 118.37 | 3001.55 | 914.87 | 3014.42 |
| H-03b2 | CUL | 11/09/11 | 388.43 | 118.39 | 3001.48 | 914.85 | 3014.35 |
| H-03b2 | CUL | 12/06/11 | 388.68 | 118.47 | 3001.23 | 914.77 | 3014.09 |
| H-04bR | CUL | 01/12/11 | 330.81 | 100.83 | 3003.83 | 915.57 | 3007.02 |
| H-04bR | CUL | 02/08/11 | 330.09 | 100.61 | 3004.55 | 915.79 | 3007.75 |
| H-04bR | CUL | 03/01/11 | 330.40 | 100.71 | 3004.24 | 915.69 | 3007.43 |
| H-04bR | CUL | 04/13/11 | 330.27 | 100.67 | 3004.37 | 915.73 | 3007.57 |
| H-04bR | CUL | 05/16/11 | 331.37 | 101.00 | 3003.27 | 915.40 | 3006.45 |
| H-04bR | CUL | 06/07/11 | 330.28 | 100.67 | 3004.36 | 915.73 | 3007.56 |
| H-04bR | CUL | 07/12/11 | 330.54 | 100.75 | 3004.10 | 915.65 | 3007.29 |
| H-04bR | CUL | 08/09/11 | 330.54 | 100.75 | 3004.10 | 915.65 | 3007.29 |
| H-04bR | CUL | 09/14/11 | 330.66 | 100.79 | 3003.98 | 915.61 | 3007.17 |
| H-04bR | CUL | 10/11/11 | 330.44 | 100.72 | 3004.20 | 915.68 | 3007.39 |
| H-04bR | CUL | 11/07/11 | 330.32 | 100.68 | 3004.32 | 915.72 | 3007.52 |
| H-04bR | CUL | 12/05/11 | 330.76 | 100.82 | 3003.88 | 915.58 | 3007.07 |
| H-05b | CUL | 01/10/11 | 467.21 | 142.41 | 3039.57 | 926.46 | 3080.78 |
| H-05b | CUL | 02/08/11 | 467.12 | 142.38 | 3039.66 | 926.49 | 3080.87 |
| H-05b | CUL | 03/01/11 | 467.09 | 142.37 | 3039.69 | 926.50 | 3080.91 |
| H-05b | CUL | 04/12/11 | 466.85 | 142.30 | 3039.93 | 926.57 | 3081.17 |
| H-05b | CUL | 05/16/11 | 466.59 | 142.22 | 3040.19 | 926.65 | 3081.45 |
| H-05b | CUL | 06/07/11 | 466.43 | 142.17 | 3040.35 | 926.70 | 3081.63 |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| H-05b | CUL | 07/12/11 | 466.14 | 142.08 | 3040.64 | 926.79 | 3081.95 |
| H-05b | CUL | 08/09/11 | 465.95 | 142.02 | 3040.83 | 926.84 | 3082.15 |
| H-05b | CUL | 09/13/11 | 465.96 | 142.02 | 3040.82 | 926.84 | 3082.14 |
| H-05b | CUL | 10/10/11 | 465.73 | 141.95 | 3041.05 | 926.91 | 3082.39 |
| H-05b | CUL | 11/08/11 | 465.60 | 141.91 | 3041.18 | 926.95 | 3082.54 |
| H-05b | CUL | 12/02/11 | 465.74 | 141.96 | 3041.04 | 926.91 | 3082.38 |
| H-06bR | CUL | 01/11/11 | 289.05 | 88.10 | 3060.17 | 932.74 | 3072.32 |
| H-06bR | CUL | 02/07/11 | 289.03 | 88.10 | 3060.19 | 932.75 | 3072.34 |
| H-06bR | CUL | 03/02/11 | 289.12 | 88.12 | 3060.10 | 932.72 | 3072.24 |
| H-06bR | CUL | 04/12/11 | 289.35 | 88.19 | 3059.87 | 932.65 | 3072.00 |
| H-06bR | CUL | 05/17/11 | 289.53 | 88.25 | 3059.69 | 932.59 | 3071.82 |
| H-06bR | CUL | 06/06/11 | 289.81 | 88.33 | 3059.41 | 932.51 | 3071.53 |
| H-06bR | CUL | 07/12/11 | 290.15 | 88.44 | 3059.07 | 932.40 | 3071.18 |
| H-06bR | CUL | 08/09/11 | 290.21 | 88.46 | 3059.01 | 932.39 | 3071.11 |
| H-06bR | CUL | 09/14/11 | 290.45 | 88.53 | 3058.77 | 932.31 | 3070.86 |
| H-06bR | CUL | 10/10/11 | 290.65 | 88.59 | 3058.57 | 932.25 | 3070.66 |
| H-06bR | CUL | 11/08/11 | 290.81 | 88.64 | 3058.41 | 932.20 | 3070.49 |
| H-06bR | CUL | 12/07/11 | 291.02 | 88.70 | 3058.20 | 932.14 | 3070.27 |
| H-07b1 | CUL | 01/11/11 | 165.72 | 50.51 | 2998.00 | 913.79 | 2998.63 |
| H-07b1 | CUL | 02/07/11 | 165.80 | 50.54 | 2997.92 | 913.77 | 2998.54 |
| H-07b1 | CUL | 03/02/11 | 165.89 | 50.56 | 2997.83 | 913.74 | 2998.45 |
| H-07b1 | CUL | 04/11/11 | 165.99 | 50.59 | 2997.73 | 913.71 | 2998.35 |
| H-07b1 | CUL | 05/16/11 | 165.89 | 50.56 | 2997.83 | 913.74 | 2998.45 |
| H-07b1 | CUL | 06/06/11 | 165.85 | 50.55 | 2997.87 | 913.75 | 2998.49 |
| H-07b1 | CUL | 07/11/11 | 165.96 | 50.58 | 2997.76 | 913.72 | 2998.38 |
| H-07b1 | CUL | 08/08/11 | 165.96 | 50.58 | 2997.76 | 913.72 | 2998.38 |
| H-07b1 | CUL | 09/13/11 | 168.27 | 51.29 | 2995.45 | 913.01 | 2996.06 |
| H-07b1 | CUL | 10/10/11 | 166.50 | 50.75 | 2997.22 | 913.55 | 2997.84 |
| H-07b1 | CUL | 11/07/11 | 166.50 | 50.75 | 2997.22 | 913.55 | 2997.84 |
| H-07b1 | CUL | 12/02/11 | 166.52 | 50.76 | 2997.20 | 913.55 | 2997.82 |
| H-09bR | CUL | 08/08/11 | 413.15 | 125.93 | 2995.19 | 912.93 | 2995.19 |
| H-09bR | CUL | 09/12/11 | 413.10 | 125.91 | 2995.24 | 912.95 | 2995.24 |
| H-09bR | CUL | 10/11/11 | 412.85 | 125.84 | 2995.49 | 913.03 | 2995.49 |
| H-09bR | CUL | 11/08/11 | 412.71 | 125.79 | 2995.63 | 913.07 | 2995.63 |
| H-09bR | CUL | 12/05/11 | 413.01 | 125.89 | 2995.33 | 912.98 | 2995.33 |
| H-10c | CUL | 01/10/11 | 719.65 | 219.35 | 2968.75 | 904.88 | 3028.12 |
| H-10c | CUL | 02/08/11 | 719.75 | 219.38 | 2968.65 | 904.84 | 3028.01 |
| H-10c | CUL | 03/01/11 | 719.89 | 219.42 | 2968.51 | 904.80 | 3027.86 |
| H-10c | CUL | 04/11/11 | 719.81 | 219.40 | 2968.59 | 904.83 | 3027.95 |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| H-10c | CUL | 05/16/11 | 719.85 | 219.41 | 2968.55 | 904.81 | 3027.90 |
| H-10c | CUL | 06/07/11 | 719.81 | 219.40 | 2968.59 | 904.83 | 3027.95 |
| H-10c | CUL | 07/13/11 | 719.85 | 219.41 | 2968.55 | 904.81 | 3027.90 |
| H-10c | CUL | 08/09/11 | 719.74 | 219.38 | 2968.66 | 904.85 | 3028.02 |
| H-10c | CUL | 09/13/11 | 719.54 | 219.32 | 2968.86 | 904.91 | 3028.24 |
| H-10c | CUL | 10/11/11 | 719.66 | 219.35 | 2968.74 | 904.87 | 3028.11 |
| H-10c | CUL | 11/09/11 | 719.39 | 219.27 | 2969.01 | 904.95 | 3028.41 |
| H-10c | CUL | 12/05/11 | 719.69 | 219.36 | 2968.71 | 904.86 | 3028.08 |
| H-11b4 | CUL | 01/11/11 | 423.42 | 129.06 | 2987.37 | 910.55 | 3003.32 |
| H-11b4 | CUL | 02/09/11 | 423.15 | 128.98 | 2987.64 | 910.63 | 3003.61 |
| H-11b4 | CUL | 03/01/11 | 422.98 | 128.92 | 2987.81 | 910.68 | 3003.78 |
| H-11b4 | CUL | 04/12/11 | 423.09 | 128.96 | 2987.70 | 910.65 | 3003.67 |
| H-11b4 | CUL | 05/17/11 | 423.01 | 128.93 | 2987.78 | 910.68 | 3003.75 |
| H-11b4 | CUL | 06/07/11 | 423.05 | 128.95 | 2987.74 | 910.66 | 3003.71 |
| H-11b4 | CUL | 07/13/11 | 423.22 | 129.00 | 2987.57 | 910.61 | 3003.53 |
| H-11b4 | CUL | 08/09/11 | 423.32 | 129.03 | 2987.47 | 910.58 | 3003.43 |
| H-11b4 | CUL | 09/12/11 | 425.11 | 129.57 | 2985.68 | 910.04 | 3001.55 |
| H-11b4 | CUL | 10/11/11 | 424.06 | 129.25 | 2986.73 | 910.36 | 3002.65 |
| H-11b4R | CUL | 12/05/11 | 428.98 | 130.75 | ND | ND | ND |
| H-12 | CUL | 01/11/11 | 456.65 | 139.19 | 2970.68 | 905.46 | 3011.53 |
| H-12 | CUL | 02/08/11 | 456.64 | 139.18 | 2970.69 | 905.47 | 3011.54 |
| H-12 | CUL | 03/01/11 | 456.60 | 139.17 | 2970.73 | 905.48 | 3011.59 |
| H-12 | CUL | 04/12/11 | 456.61 | 139.17 | 2970.72 | 905.48 | 3011.57 |
| H-12 | CUL | 05/17/11 | 456.56 | 139.16 | 2970.77 | 905.49 | 3011.63 |
| H-12 | CUL | 06/06/11 | 456.62 | 139.18 | 2970.71 | 905.47 | 3011.56 |
| H-12 | CUL | 07/13/11 | 456.54 | 139.15 | 2970.79 | 905.50 | 3011.65 |
| H-12 | CUL | 08/09/11 | 456.64 | 139.18 | 2970.69 | 905.47 | 3011.54 |
| H-12 | CUL | 09/13/11 | 456.86 | 139.25 | 2970.47 | 905.40 | 3011.30 |
| H-12 | CUL | 10/11/11 | 456.75 | 139.22 | 2970.58 | 905.43 | 3011.42 |
| H-12 | CUL | 11/09/11 | 456.76 | 139.22 | 2970.57 | 905.43 | 3011.41 |
| H-12 | CUL | 12/05/11 | 456.84 | 139.24 | 2970.49 | 905.41 | 3011.32 |
| H-15R | CUL | 01/11/11 | 507.33 | 154.63 | 2974.69 | 906.69 | 3018.17 |
| H-15R | CUL | 02/09/11 | 507.23 | 154.60 | 2974.79 | 906.72 | 3018.28 |
| H-15R | CUL | 03/02/11 | 507.11 | 154.57 | 2974.91 | 906.75 | 3018.42 |
| H-15R | CUL | 04/13/11 | 507.01 | 154.54 | 2975.01 | 906.78 | 3018.53 |
| H-15R | CUL | 05/19/11 | 506.84 | 154.48 | 2975.18 | 906.83 | 3018.72 |
| H-15R | CUL | 06/08/11 | 507.06 | 154.55 | 2974.96 | 906.77 | 3018.47 |
| H-15R | CUL | 07/13/11 | 507.10 | 154.56 | 2974.92 | 906.76 | 3018.43 |
| H-15R | CUL | 08/10/11 | 507.08 | 154.56 | 2974.94 | 906.76 | 3018.45 |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| H-15R | CUL | 09/14/11 | 507.66 | 154.73 | 2974.36 | 906.58 | 3017.80 |
| H-15R | CUL | 10/12/11 | 507.39 | 154.65 | 2974.63 | 906.67 | 3018.10 |
| H-15R | CUL | 11/09/11 | 507.53 | 154.70 | 2974.49 | 906.62 | 3017.95 |
| H-15R | CUL | 12/07/11 | 508.13 | 154.88 | 2973.89 | 906.44 | 3017.28 |
| H-16 | CUL | 01/12/11 | 374.50 | 114.15 | 3035.56 | 925.24 | 3048.14 |
| H-16 | CUL | 02/09/11 | 379.49 | 115.67 | 3030.57 | 923.72 | 3042.96 |
| H-16 | CUL | 03/03/11 | 375.77 | 114.53 | 3034.29 | 924.85 | 3046.82 |
| H-16 | CUL | 04/13/11 | 374.17 | 114.05 | 3035.89 | 925.34 | 3048.48 |
| H-16 | CUL | 05/19/11 | 373.55 | 113.86 | 3036.51 | 925.53 | 3049.12 |
| H-16 | CUL | 06/08/11 | 373.44 | 113.82 | 3036.62 | 925.56 | 3049.24 |
| H-16 | CUL | 07/14/11 | 373.43 | 113.82 | 3036.63 | 925.56 | 3049.25 |
| H-16 | CUL | 08/10/11 | 373.44 | 113.82 | 3036.62 | 925.56 | 3049.24 |
| H-16 | CUL | 09/15/11 | 373.74 | 113.92 | 3036.32 | 925.47 | 3048.93 |
| H-16 | CUL | 10/12/11 | 373.83 | 113.94 | 3036.23 | 925.44 | 3048.83 |
| H-16 | CUL | 11/09/11 | 374.56 | 114.17 | 3035.50 | 925.22 | 3048.08 |
| H-16 | CUL | 12/07/11 | 375.94 | 114.59 | 3034.12 | 924.80 | 3046.64 |
| H-17 | CUL | 01/11/11 | 418.12 | 127.44 | 2967.12 | 904.38 | 3008.24 |
| H-17 | CUL | 02/09/11 | 418.06 | 127.42 | 2967.18 | 904.40 | 3008.30 |
| H-17 | CUL | 03/01/11 | 417.98 | 127.40 | 2967.26 | 904.42 | 3008.39 |
| H-17 | CUL | 04/12/11 | 417.96 | 127.39 | 2967.28 | 904.43 | 3008.42 |
| H-17 | CUL | 05/17/11 | 417.85 | 127.36 | 2967.39 | 904.46 | 3008.54 |
| H-17 | CUL | 06/07/11 | 417.92 | 127.38 | 2967.32 | 904.44 | 3008.46 |
| H-17 | CUL | 07/13/11 | 417.99 | 127.40 | 2967.25 | 904.42 | 3008.38 |
| H-17 | CUL | 08/09/11 | 417.98 | 127.40 | 2967.26 | 904.42 | 3008.39 |
| H-17 | CUL | 09/12/11 | 418.46 | 127.55 | 2966.78 | 904.27 | 3007.85 |
| H-17 | CUL | 10/11/11 | 417.91 | 127.38 | 2967.33 | 904.44 | 3008.47 |
| H-17 | CUL | 11/07/11 | 417.56 | 127.27 | 2967.68 | 904.55 | 3008.87 |
| H-17 | CUL | 12/05/11 | 418.01 | 127.41 | 2967.23 | 904.41 | 3008.36 |
| H-19b0 | CUL | 01/12/11 | 425.79 | 129.78 | 2992.54 | 912.13 | 3014.85 |
| H-19b0 | CUL | 02/08/11 | 425.21 | 129.60 | 2993.12 | 912.30 | 3015.47 |
| H-19b0 | CUL | 03/02/11 | 425.41 | 129.66 | 2992.92 | 912.24 | 3015.26 |
| H-19b0 | CUL | 04/13/11 | 425.29 | 129.63 | 2993.04 | 912.28 | 3015.39 |
| H-19b0 | CUL | 05/17/11 | 425.66 | 129.74 | 2992.67 | 912.17 | 3014.99 |
| H-19b0 | CUL | 06/08/11 | 425.58 | 129.72 | 2992.75 | 912.19 | 3015.08 |
| H-19b0 | CUL | 07/13/11 | 425.59 | 129.72 | 2992.74 | 912.19 | 3015.07 |
| H-19b0 | CUL | 08/10/11 | 425.47 | 129.68 | 2992.86 | 912.22 | 3015.20 |
| H-19b0 | CUL | 09/14/11 | 426.49 | 129.99 | 2991.84 | 911.91 | 3014.11 |
| H-19b0 | CUL | 10/12/11 | 425.98 | 129.84 | 2992.35 | 912.07 | 3014.65 |
| H-19b0 | CUL | 11/09/11 | 426.12 | 129.88 | 2992.21 | 912.03 | 3014.50 |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| H-19b0 | CUL | 12/01/11 | 426.45 | 129.98 | 2991.88 | 911.93 | 3014.15 |
| H-19b2 | CUL | 03/01/11 | 426.71 | 130.06 | 2992.22 | 912.03 | 3015.22 |
| H-19b2 | CUL | 06/08/11 | 426.95 | 130.13 | 2991.98 | 911.96 | 3014.97 |
| H-19b2 | CUL | 09/14/11 | 427.90 | 130.42 | 2991.03 | 911.67 | 3013.95 |
| H-19b2 | CUL | 12/01/11 | 427.83 | 130.40 | 2991.10 | 911.69 | 3014.03 |
| H-19b3 | CUL | 03/02/11 | 427.00 | 130.15 | 2992.02 | 911.97 | 3015.41 |
| H-19b3 | CUL | 06/08/11 | 427.19 | 130.21 | 2991.83 | 911.91 | 3015.21 |
| H-19b3 | CUL | 09/14/11 | 428.06 | 130.47 | 2990.96 | 911.64 | 3014.27 |
| H-19b3 | CUL | 12/01/11 | 428.03 | 130.46 | 2990.99 | 911.65 | 3014.31 |
| H-19b4 | CUL | 03/02/11 | 426.25 | 129.92 | 2992.73 | 912.18 | 3013.99 |
| H-19b4 | CUL | 06/08/11 | 426.44 | 129.98 | 2992.54 | 912.13 | 3013.79 |
| H-19b4 | CUL | 09/14/11 | 427.32 | 130.25 | 2991.66 | 911.86 | 3012.85 |
| H-19b4 | CUL | 12/06/11 | 427.39 | 130.27 | 2991.59 | 911.84 | 3012.77 |
| H-19b5 | CUL | 03/01/11 | 426.27 | 129.93 | 2992.31 | 912.06 | 3014.68 |
| H-19b5 | CUL | 06/08/11 | 426.41 | 129.97 | 2992.17 | 912.01 | 3014.53 |
| H-19b5 | CUL | 09/14/11 | 427.27 | 130.23 | 2991.31 | 911.75 | 3013.62 |
| H-19b5 | CUL | 12/01/11 | 427.30 | 130.24 | 2991.28 | 911.74 | 3013.58 |
| H-19b6 | CUL | 03/02/11 | 426.91 | 130.12 | 2992.11 | 912.00 | 3016.71 |
| H-19b6 | CUL | 06/08/11 | 427.08 | 130.17 | 2991.94 | 911.94 | 3016.52 |
| H-19b6 | CUL | 09/14/11 | 427.99 | 130.45 | 2991.03 | 911.67 | 3015.54 |
| H-19b6 | CUL | 12/01/11 | 427.97 | 130.45 | 2991.05 | 911.67 | 3015.57 |
| H-19b7 | CUL | 03/01/11 | 426.94 | 130.13 | 2992.00 | 911.96 | 3015.83 |
| H-19b7 | CUL | 06/08/11 | 427.11 | 130.18 | 2991.83 | 911.91 | 3015.65 |
| H-19b7 | CUL | 09/14/11 | 427.98 | 130.45 | 2990.96 | 911.64 | 3014.72 |
| H-19b7 | CUL | 12/01/11 | 427.99 | 130.45 | 2990.95 | 911.64 | 3014.71 |
| I-461 | CUL | 01/10/11 | 238.79 | 72.78 | 3044.82 | 928.06 | 3045.51 |
| I-461 | CUL | 02/07/11 | 239.13 | 72.89 | 3044.48 | 927.96 | 3045.17 |
| I-461 | CUL | 03/03/11 | 239.19 | 72.91 | 3044.42 | 927.94 | 3045.11 |
| I-461 | CUL | 04/11/11 | 239.81 | 73.09 | 3043.80 | 927.75 | 3044.48 |
| I-461 | CUL | 05/16/11 | 240.02 | 73.16 | 3043.59 | 927.69 | 3044.27 |
| I-461 | CUL | 06/06/11 | 240.22 | 73.22 | 3043.39 | 927.63 | 3044.07 |
| I-461 | CUL | 07/11/11 | 240.72 | 73.37 | 3042.89 | 927.47 | 3043.57 |
| I-461 | CUL | 08/08/11 | 240.85 | 73.41 | 3042.76 | 927.43 | 3043.44 |
| I-461 | CUL | 09/13/11 | 240.93 | 73.44 | 3042.68 | 927.41 | 3043.36 |
| I-461 | CUL | 10/10/11 | 240.81 | 73.40 | 3042.80 | 927.45 | 3043.48 |
| I-461 | CUL | 11/07/11 | 240.61 | 73.34 | 3043.00 | 927.51 | 3043.68 |
| I-461 | CUL | 12/02/11 | 240.91 | 73.43 | 3042.70 | 927.41 | 3043.38 |
| SNL-01 | CUL | 01/11/11 | 432.03 | 131.68 | 3080.81 | 939.03 | 3085.87 |
| SNL-01 | CUL | 02/07/11 | 431.93 | 131.65 | 3080.91 | 939.06 | 3085.98 |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| SNL-01 | CUL | 03/03/11 | 431.95 | 131.66 | 3080.89 | 939.06 | 3085.95 |
| SNL-01 | CUL | 04/11/11 | 432.51 | 131.83 | 3080.33 | 938.88 | 3085.38 |
| SNL-01 | CUL | 05/17/11 | 432.56 | 131.84 | 3080.28 | 938.87 | 3085.33 |
| SNL-01 | CUL | 06/06/11 | 433.09 | 132.01 | 3079.75 | 938.71 | 3084.78 |
| SNL-01 | CUL | 07/11/11 | 433.71 | 132.19 | 3079.13 | 938.52 | 3084.15 |
| SNL-01 | CUL | 08/08/11 | 433.98 | 132.28 | 3078.86 | 938.44 | 3083.87 |
| SNL-01 | CUL | 09/13/11 | 434.51 | 132.44 | 3078.33 | 938.27 | 3083.32 |
| SNL-01 | CUL | 10/10/11 | 434.73 | 132.51 | 3078.11 | 938.21 | 3083.10 |
| SNL-01 | CUL | 11/07/11 | 434.75 | 132.51 | 3078.09 | 938.20 | 3083.08 |
| SNL-01 | CUL | 12/02/11 | 435.18 | 132.64 | 3077.66 | 938.07 | 3082.63 |
| SNL-02 | CUL | 01/10/11 | 251.83 | 76.76 | 3071.23 | 936.11 | 3073.20 |
| SNL-02 | CUL | 02/07/11 | 252.12 | 76.85 | 3070.94 | 936.02 | 3072.91 |
| SNL-02 | CUL | 03/03/11 | 252.18 | 76.86 | 3070.88 | 936.00 | 3072.85 |
| SNL-02 | CUL | 04/11/11 | 252.72 | 77.03 | 3070.34 | 935.84 | 3072.30 |
| SNL-02 | CUL | 05/16/11 | 252.92 | 77.09 | 3070.14 | 935.78 | 3072.10 |
| SNL-02 | CUL | 06/06/11 | 253.10 | 77.14 | 3069.96 | 935.72 | 3071.92 |
| SNL-02 | CUL | 07/11/11 | 253.57 | 77.29 | 3069.49 | 935.58 | 3071.44 |
| SNL-02 | CUL | 08/08/11 | 253.52 | 77.27 | 3069.54 | 935.60 | 3071.50 |
| SNL-02 | CUL | 09/13/11 | 253.87 | 77.38 | 3069.19 | 935.49 | 3071.14 |
| SNL-02 | CUL | 10/10/11 | 254.03 | 77.43 | 3069.03 | 935.44 | 3070.98 |
| SNL-02 | CUL | 11/07/11 | 254.15 | 77.46 | 3068.91 | 935.40 | 3070.86 |
| SNL-02 | CUL | 12/02/11 | 254.36 | 77.53 | 3068.70 | 935.34 | 3070.65 |
| SNL-03 | CUL | 01/11/11 | 417.16 | 127.15 | 3073.19 | 936.71 | 3082.97 |
| SNL-03 | CUL | 02/07/11 | 416.94 | 127.08 | 3073.41 | 936.78 | 3083.20 |
| SNL-03 | CUL | 03/03/11 | 417.02 | 127.11 | 3073.33 | 936.75 | 3083.12 |
| SNL-03 | CUL | 04/12/11 | 417.47 | 127.24 | 3072.88 | 936.61 | 3082.65 |
| SNL-03 | CUL | 05/17/11 | 417.60 | 127.28 | 3072.75 | 936.57 | 3082.52 |
| SNL-03 | CUL | 06/06/11 | 418.10 | 127.44 | 3072.25 | 936.42 | 3082.01 |
| SNL-03 | CUL | 07/12/11 | 418.46 | 127.55 | 3071.89 | 936.31 | 3081.64 |
| SNL-03 | CUL | 08/09/11 | 418.62 | 127.60 | 3071.73 | 936.26 | 3081.47 |
| SNL-03 | CUL | 09/13/11 | 418.98 | 127.71 | 3071.37 | 936.15 | 3081.10 |
| SNL-03 | CUL | 10/10/11 | 419.31 | 127.81 | 3071.04 | 936.05 | 3080.76 |
| SNL-03 | CUL | 11/08/11 | 419.31 | 127.81 | 3071.04 | 936.05 | 3080.76 |
| SNL-03 | CUL | 12/06/11 | 419.71 | 127.93 | 3070.64 | 935.93 | 3080.35 |
| SNL-05 | CUL | 01/10/11 | 305.66 | 93.17 | 3074.32 | 937.05 | 3077.07 |
| SNL-05 | CUL | 02/07/11 | 306.09 | 93.30 | 3073.89 | 936.92 | 3076.63 |
| SNL-05 | CUL | 03/03/11 | 306.40 | 93.39 | 3073.58 | 936.83 | 3076.32 |
| SNL-05 | CUL | 04/11/11 | 307.17 | 93.63 | 3072.81 | 936.59 | 3075.54 |
| SNL-05 | CUL | 05/16/11 | 307.41 | 93.70 | 3072.57 | 936.52 | 3075.30 |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| SNL-05 | CUL | 06/07/11 | 307.71 | 93.79 | 3072.27 | 936.43 | 3075.00 |
| SNL-05 | CUL | 07/11/11 | 308.07 | 93.90 | 3071.91 | 936.32 | 3074.64 |
| SNL-05 | CUL | 08/08/11 | 308.27 | 93.96 | 3071.71 | 936.26 | 3074.44 |
| SNL-05 | CUL | 09/13/11 | 308.64 | 94.07 | 3071.34 | 936.14 | 3074.06 |
| SNL-05 | CUL | 10/10/11 | 308.77 | 94.11 | 3071.21 | 936.10 | 3073.93 |
| SNL-05 | CUL | 11/07/11 | 308.78 | 94.12 | 3071.20 | 936.10 | 3073.92 |
| SNL-05 | CUL | 12/02/11 | 309.19 | 94.24 | 3070.79 | 935.98 | 3073.51 |
| SNL-06 | CUL | 01/10/11 | 703.48 | 214.42 | 2942.63 | 896.91 | 3090.52 |
| SNL-06 | CUL | 02/08/11 | 698.92 | 213.03 | 2947.19 | 898.30 | 3096.14 |
| SNL-06 | CUL | 03/01/11 | 695.74 | 212.06 | 2950.37 | 899.27 | 3100.07 |
| SNL-06 | CUL | 04/12/11 | 689.32 | 210.10 | 2956.79 | 901.23 | 3107.98 |
| SNL-06 | CUL | 05/16/11 | 684.15 | 208.53 | 2961.96 | 902.81 | 3114.36 |
| SNL-06 | CUL | 06/07/11 | 681.08 | 207.59 | 2965.03 | 903.74 | 3118.14 |
| SNL-06 | CUL | 07/12/11 | 675.97 | 206.04 | 2970.14 | 905.30 | 3124.44 |
| SNL-06 | CUL | 08/09/11 | 671.99 | 204.82 | 2974.12 | 906.51 | 3129.35 |
| SNL-06 | CUL | 09/14/11 | 666.89 | 203.27 | 2979.22 | 908.07 | 3135.64 |
| SNL-06 | CUL | 10/10/11 | 663.35 | 202.19 | 2982.76 | 909.15 | 3140.00 |
| SNL-06 | CUL | 11/08/11 | 659.28 | 200.95 | 2986.83 | 910.39 | 3145.02 |
| SNL-06 | CUL | 12/02/11 | 656.06 | 199.97 | 2990.05 | 911.37 | 3148.99 |
| SNL-08 | CUL | 01/10/11 | 543.39 | 165.63 | 3012.34 | 918.16 | 3052.42 |
| SNL-08 | CUL | 02/08/11 | 543.41 | 165.63 | 3012.32 | 918.16 | 3052.39 |
| SNL-08 | CUL | 03/01/11 | 543.62 | 165.70 | 3012.11 | 918.09 | 3052.16 |
| SNL-08 | CUL | 04/12/11 | 543.54 | 165.67 | 3012.19 | 918.12 | 3052.25 |
| SNL-08 | CUL | 05/16/11 | 543.48 | 165.65 | 3012.25 | 918.13 | 3052.32 |
| SNL-08 | CUL | 06/07/11 | 543.39 | 165.63 | 3012.34 | 918.16 | 3052.42 |
| SNL-08 | CUL | 07/13/11 | 543.31 | 165.60 | 3012.42 | 918.19 | 3052.50 |
| SNL-08 | CUL | 08/09/11 | 543.20 | 165.57 | 3012.53 | 918.22 | 3052.62 |
| SNL-08 | CUL | 09/13/11 | 543.34 | 165.61 | 3012.39 | 918.18 | 3052.47 |
| SNL-08 | CUL | 10/11/11 | 543.07 | 165.53 | 3012.66 | 918.26 | 3052.77 |
| SNL-08 | CUL | 11/08/11 | 543.04 | 165.52 | 3012.69 | 918.27 | 3052.80 |
| SNL-08 | CUL | 12/05/11 | 543.15 | 165.55 | 3012.58 | 918.23 | 3052.68 |
| SNL-09 | CUL | 01/11/11 | 310.65 | 94.69 | 3050.31 | 929.73 | 3054.93 |
| SNL-09 | CUL | 02/07/11 | 310.65 | 94.69 | 3050.31 | 929.73 | 3054.93 |
| SNL-09 | CUL | 03/03/11 | 310.56 | 94.66 | 3050.40 | 929.76 | 3055.02 |
| SNL-09 | CUL | 04/11/11 | 311.00 | 94.79 | 3049.96 | 929.63 | 3054.57 |
| SNL-09 | CUL | 05/17/11 | 310.95 | 94.78 | 3050.01 | 929.64 | 3054.62 |
| SNL-09 | CUL | 06/06/11 | 311.18 | 94.85 | 3049.78 | 929.57 | 3054.39 |
| SNL-09 | CUL | 07/12/11 | 311.49 | 94.94 | 3049.47 | 929.48 | 3054.07 |
| SNL-09 | CUL | 08/09/11 | 311.58 | 94.97 | 3049.38 | 929.45 | 3053.98 |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| SNL-09 | CUL | 09/14/11 | 311.73 | 95.02 | 3049.23 | 929.41 | 3053.83 |
| SNL-09 | CUL | 10/10/11 | 311.90 | 95.07 | 3049.06 | 929.35 | 3053.65 |
| SNL-09 | CUL | 11/08/11 | 311.94 | 95.08 | 3049.02 | 929.34 | 3053.61 |
| SNL-09 | CUL | 12/05/11 | 312.10 | 95.13 | 3048.86 | 929.29 | 3053.45 |
| SNL-10 | CUL | 01/11/11 | 325.68 | 99.27 | 3051.91 | 930.22 | 3054.50 |
| SNL-10 | CUL | 02/07/11 | 325.62 | 99.25 | 3051.97 | 930.24 | 3054.56 |
| SNL-10 | CUL | 03/02/11 | 325.58 | 99.24 | 3052.01 | 930.25 | 3054.60 |
| SNL-10 | CUL | 04/12/11 | 325.75 | 99.29 | 3051.84 | 930.20 | 3054.43 |
| SNL-10 | CUL | 05/17/11 | 325.77 | 99.29 | 3051.82 | 930.19 | 3054.41 |
| SNL-10 | CUL | 06/07/11 | 325.91 | 99.34 | 3051.68 | 930.15 | 3054.27 |
| SNL-10 | CUL | 07/11/11 | 326.16 | 99.41 | 3051.43 | 930.08 | 3054.02 |
| SNL-10 | CUL | 08/08/11 | 326.28 | 99.45 | 3051.31 | 930.04 | 3053.89 |
| SNL-10 | CUL | 09/15/11 | 326.55 | 99.53 | 3051.04 | 929.96 | 3053.62 |
| SNL-10 | CUL | 10/10/11 | 326.60 | 99.55 | 3050.99 | 929.94 | 3053.57 |
| SNL-10 | CUL | 11/08/11 | 326.62 | 99.55 | 3050.97 | 929.94 | 3053.55 |
| SNL-10 | CUL | 12/06/11 | 327.00 | 99.67 | 3050.59 | 929.82 | 3053.17 |
| SNL-12 | CUL | 01/10/11 | 337.88 | 102.99 | 3001.58 | 914.88 | 3002.74 |
| SNL-12 | CUL | 02/09/11 | 338.03 | 103.03 | 3001.43 | 914.84 | 3002.59 |
| SNL-12 | CUL | 03/01/11 | 337.90 | 102.99 | 3001.56 | 914.88 | 3002.72 |
| SNL-12 | CUL | 04/11/11 | 337.89 | 102.99 | 3001.57 | 914.88 | 3002.73 |
| SNL-12 | CUL | 05/17/11 | 337.64 | 102.91 | 3001.82 | 914.95 | 3002.99 |
| SNL-12 | CUL | 06/06/11 | 337.87 | 102.98 | 3001.59 | 914.88 | 3002.75 |
| SNL-12 | CUL | 07/11/11 | 338.04 | 103.03 | 3001.42 | 914.83 | 3002.58 |
| SNL-12 | CUL | 08/08/11 | 338.05 | 103.04 | 3001.41 | 914.83 | 3002.57 |
| SNL-12 | CUL | 09/12/11 | 338.26 | 103.10 | 3001.20 | 914.77 | 3002.36 |
| SNL-12 | CUL | 10/11/11 | 337.95 | 103.01 | 3001.51 | 914.86 | 3002.67 |
| SNL-12 | CUL | 11/07/11 | 337.68 | 102.92 | 3001.78 | 914.94 | 3002.95 |
| SNL-12 | CUL | 12/05/11 | 338.18 | 103.08 | 3001.28 | 914.79 | 3002.44 |
| SNL-13 | CUL | 01/11/11 | 280.41 | 85.47 | 3013.81 | 918.61 | 3016.59 |
| SNL-13 | CUL | 02/07/11 | 280.35 | 85.45 | 3013.87 | 918.63 | 3016.65 |
| SNL-13 | CUL | 03/02/11 | 280.30 | 85.44 | 3013.92 | 918.64 | 3016.70 |
| SNL-13 | CUL | 04/12/11 | 280.38 | 85.46 | 3013.84 | 918.62 | 3016.62 |
| SNL-13 | CUL | 05/16/11 | 269.45 | 82.13 | 3024.77 | 921.95 | 3027.80 |
| SNL-13 | CUL | 06/06/11 | 275.62 | 84.01 | 3018.60 | 920.07 | 3021.49 |
| SNL-13 | CUL | 07/11/11 | 277.49 | 84.58 | 3016.73 | 919.50 | 3019.57 |
| SNL-13 | CUL | 08/08/11 | 278.38 | 84.85 | 3015.84 | 919.23 | 3018.66 |
| SNL-13 | CUL | 09/12/11 | 277.07 | 84.45 | 3017.15 | 919.63 | 3020.00 |
| SNL-13 | CUL | 10/11/11 | 279.16 | 85.09 | 3015.06 | 918.99 | 3017.87 |
| SNL-13 | CUL | 11/08/11 | 280.04 | 85.36 | 3014.18 | 918.72 | 3016.96 |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| SNL-13 | CUL | 12/05/11 | 280.69 | 85.55 | 3013.53 | 918.52 | 3016.30 |
| SNL-14 | CUL | 01/11/11 | 377.28 | 114.99 | 2991.13 | 911.70 | 3004.57 |
| SNL-14 | CUL | 02/09/11 | 377.05 | 114.92 | 2991.36 | 911.77 | 3004.81 |
| SNL-14 | CUL | 03/01/11 | 376.82 | 114.85 | 2991.59 | 911.84 | 3005.05 |
| SNL-14 | CUL | 04/12/11 | 376.84 | 114.86 | 2991.57 | 911.83 | 3005.03 |
| SNL-14 | CUL | 05/17/11 | 376.75 | 114.83 | 2991.66 | 911.86 | 3005.13 |
| SNL-14 | CUL | 06/07/11 | 376.83 | 114.86 | 2991.58 | 911.83 | 3005.04 |
| SNL-14 | CUL | 07/13/11 | 377.10 | 114.94 | 2991.31 | 911.75 | 3004.76 |
| SNL-14 | CUL | 08/09/11 | 377.19 | 114.97 | 2991.22 | 911.72 | 3004.67 |
| SNL-14 | CUL | 09/12/11 | 377.59 | 115.09 | 2990.82 | 911.60 | 3004.25 |
| SNL-14 | CUL | 10/18/11 | 377.25 | 114.99 | 2991.16 | 911.71 | 3004.60 |
| SNL-14 | CUL | 11/07/11 | 376.94 | 114.89 | 2991.47 | 911.80 | 3004.93 |
| SNL-14 | CUL | 12/05/11 | 377.61 | 115.10 | 2990.80 | 911.60 | 3004.23 |
| SNL-15 | CUL | 01/10/11 | 578.41 | 176.30 | 2901.52 | 884.38 | 2980.05 |
| SNL-15 | CUL | 02/09/11 | 576.98 | 175.86 | 2902.95 | 884.82 | 2981.80 |
| SNL-15 | CUL | 03/01/11 | 575.82 | 175.51 | 2904.11 | 885.17 | 2983.23 |
| SNL-15 | CUL | 04/12/11 | 573.69 | 174.86 | 2906.24 | 885.82 | 2985.84 |
| SNL-15 | CUL | 05/16/11 | 571.94 | 174.33 | 2907.99 | 886.36 | 2987.99 |
| SNL-15 | CUL | 06/07/11 | 570.87 | 174.00 | 2909.06 | 886.68 | 2989.31 |
| SNL-15 | CUL | 07/13/11 | 569.17 | 173.48 | 2910.76 | 887.20 | 2991.39 |
| SNL-15 | CUL | 08/09/11 | 567.86 | 173.08 | 2912.07 | 887.60 | 2993.00 |
| SNL-15 | CUL | 09/13/11 | 566.33 | 172.62 | 2913.60 | 888.07 | 2994.88 |
| SNL-15 | CUL | 10/11/11 | 565.04 | 172.22 | 2914.89 | 888.46 | 2996.47 |
| SNL-15 | CUL | 11/08/11 | 563.75 | 171.83 | 2916.18 | 888.85 | 2998.05 |
| SNL-15 | CUL | 12/05/11 | 562.57 | 171.47 | 2917.36 | 889.21 | 2999.50 |
| SNL-16 | CUL | 01/10/11 | 123.92 | 37.77 | 3009.08 | 917.17 | 3009.82 |
| SNL-16 | CUL | 02/07/11 | 124.08 | 37.82 | 3008.92 | 917.12 | 3009.66 |
| SNL-16 | CUL | 03/02/11 | 124.21 | 37.86 | 3008.79 | 917.08 | 3009.53 |
| SNL-16 | CUL | 04/11/11 | 124.65 | 37.99 | 3008.35 | 916.95 | 3009.08 |
| SNL-16 | CUL | 05/16/11 | 124.78 | 38.03 | 3008.22 | 916.91 | 3008.95 |
| SNL-16 | CUL | 06/06/11 | 124.89 | 38.07 | 3008.11 | 916.87 | 3008.84 |
| SNL-16 | CUL | 07/11/11 | 125.18 | 38.15 | 3007.82 | 916.78 | 3008.55 |
| SNL-16 | CUL | 08/08/11 | 125.29 | 38.19 | 3007.71 | 916.75 | 3008.44 |
| SNL-16 | CUL | 09/13/11 | 125.40 | 38.22 | 3007.60 | 916.72 | 3008.33 |
| SNL-16 | CUL | 10/10/11 | 125.21 | 38.16 | 3007.79 | 916.77 | 3008.52 |
| SNL-16 | CUL | 11/07/11 | 124.95 | 38.08 | 3008.05 | 916.85 | 3008.78 |
| SNL-16 | CUL | 12/02/11 | 125.18 | 38.15 | 3007.82 | 916.78 | 3008.55 |
| SNL-17 | CUL | 01/11/11 | 232.98 | 71.01 | 3005.08 | 915.95 | 3005.55 |
| SNL-17 | CUL | 02/07/11 | 232.67 | 70.92 | 3005.39 | 916.04 | 3005.86 |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| SNL-17 | CUL | 03/01/11 | 232.71 | 70.93 | 3005.35 | 916.03 | 3005.82 |
| SNL-17 | CUL | 04/12/11 | 232.61 | 70.90 | 3005.45 | 916.06 | 3005.92 |
| SNL-17 | CUL | 05/17/11 | 232.61 | 70.90 | 3005.45 | 916.06 | 3005.92 |
| SNL-17 | CUL | 06/06/11 | 232.73 | 70.94 | 3005.33 | 916.02 | 3005.80 |
| SNL-17 | CUL | 07/11/11 | 232.82 | 70.96 | 3005.24 | 916.00 | 3005.71 |
| SNL-17 | CUL | 08/08/11 | 232.86 | 70.98 | 3005.20 | 915.98 | 3005.67 |
| SNL-17 | CUL | 09/13/11 | 233.22 | 71.09 | 3004.84 | 915.88 | 3005.31 |
| SNL-17 | CUL | 10/11/11 | 233.02 | 71.02 | 3005.04 | 915.94 | 3005.51 |
| SNL-17 | CUL | 11/07/11 | 232.89 | 70.98 | 3005.17 | 915.98 | 3005.64 |
| SNL-17 | CUL | 12/05/11 | 233.24 | 71.09 | 3004.82 | 915.87 | 3005.29 |
| SNL-18 | CUL | 01/11/11 | 299.81 | 91.38 | 3075.63 | 937.45 | 3077.14 |
| SNL-18 | CUL | 02/07/11 | 300.03 | 91.45 | 3075.41 | 937.38 | 3076.92 |
| SNL-18 | CUL | 03/03/11 | 300.50 | 91.59 | 3074.94 | 937.24 | 3076.44 |
| SNL-18 | CUL | 04/11/11 | 301.13 | 91.78 | 3074.31 | 937.05 | 3075.81 |
| SNL-18 | CUL | 05/17/11 | 301.26 | 91.82 | 3074.18 | 937.01 | 3075.68 |
| SNL-18 | CUL | 06/06/11 | 301.87 | 92.01 | 3073.57 | 936.82 | 3075.07 |
| SNL-18 | CUL | 07/11/11 | 301.90 | 92.02 | 3073.54 | 936.81 | 3075.04 |
| SNL-18 | CUL | 08/08/11 | 302.20 | 92.11 | 3073.24 | 936.72 | 3074.73 |
| SNL-18 | CUL | 09/13/11 | 302.65 | 92.25 | 3072.79 | 936.59 | 3074.28 |
| SNL-18 | CUL | 10/10/11 | 302.74 | 92.28 | 3072.70 | 936.56 | 3074.19 |
| SNL-18 | CUL | 11/07/11 | 302.78 | 92.29 | 3072.66 | 936.55 | 3074.15 |
| SNL-18 | CUL | 12/02/11 | 303.17 | 92.41 | 3072.27 | 936.43 | 3073.76 |
| SNL-19 | CUL | 01/10/11 | 150.31 | 45.81 | 3072.34 | 936.45 | 3073.57 |
| SNL-19 | CUL | 02/07/11 | 150.65 | 45.92 | 3072.00 | 936.35 | 3073.23 |
| SNL-19 | CUL | 03/03/11 | 150.81 | 45.97 | 3071.84 | 936.30 | 3073.07 |
| SNL-19 | CUL | 04/11/11 | 151.31 | 46.12 | 3071.34 | 936.14 | 3072.56 |
| SNL-19 | CUL | 05/16/11 | 151.63 | 46.22 | 3071.02 | 936.05 | 3072.24 |
| SNL-19 | CUL | 06/06/11 | 151.98 | 46.32 | 3070.67 | 935.94 | 3071.89 |
| SNL-19 | CUL | 07/11/11 | 152.27 | 46.41 | 3070.38 | 935.85 | 3071.60 |
| SNL-19 | CUL | 08/08/11 | 152.30 | 46.42 | 3070.35 | 935.84 | 3071.57 |
| SNL-19 | CUL | 09/13/11 | 152.61 | 46.52 | 3070.04 | 935.75 | 3071.25 |
| SNL-19 | CUL | 10/10/11 | 152.73 | 46.55 | 3069.92 | 935.71 | 3071.13 |
| SNL-19 | CUL | 11/07/11 | 152.81 | 46.58 | 3069.84 | 935.69 | 3071.05 |
| SNL-19 | CUL | 12/02/11 | 153.00 | 46.63 | 3069.65 | 935.63 | 3070.86 |
| WIPP-11 | CUL | 01/10/11 | 361.69 | 110.24 | 3066.09 | 934.54 | 3084.45 |
| WIPP-11 | CUL | 02/07/11 | 361.80 | 110.28 | 3065.98 | 934.51 | 3084.33 |
| WIPP-11 | CUL | 03/03/11 | 362.04 | 110.35 | 3065.74 | 934.44 | 3084.08 |
| WIPP-11 | CUL | 04/12/11 | 362.53 | 110.50 | 3065.25 | 934.29 | 3083.57 |
| WIPP-11 | CUL | 05/17/11 | 362.62 | 110.53 | 3065.16 | 934.26 | 3083.48 |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| WIPP-11 | CUL | 06/07/11 | 362.97 | 110.63 | 3064.81 | 934.15 | 3083.12 |
| WIPP-11 | CUL | 07/12/11 | 363.58 | 110.82 | 3064.20 | 933.97 | 3082.49 |
| WIPP-11 | CUL | 08/09/11 | 363.60 | 110.83 | 3064.18 | 933.96 | 3082.46 |
| WIPP-11 | CUL | 09/15/11 | 363.99 | 110.94 | 3063.79 | 933.84 | 3082.06 |
| WIPP-11 | CUL | 10/10/11 | 364.06 | 110.97 | 3063.72 | 933.82 | 3081.99 |
| WIPP-11 | CUL | 11/08/11 | 364.24 | 111.02 | 3063.54 | 933.77 | 3081.80 |
| WIPP-11 | CUL | 12/06/11 | 364.64 | 111.14 | 3063.14 | 933.65 | 3081.39 |
| WIPP-13 | CUL | 01/10/11 | 342.35 | 104.35 | 3063.32 | 933.70 | 3079.73 |
| WIPP-13 | CUL | 02/09/11 | 342.60 | 104.42 | 3063.07 | 933.62 | 3079.47 |
| WIPP-13 | CUL | 03/02/11 | 342.51 | 104.40 | 3063.16 | 933.65 | 3079.57 |
| WIPP-13 | CUL | 04/12/11 | 342.90 | 104.52 | 3062.77 | 933.53 | 3079.16 |
| WIPP-13 | CUL | 05/17/11 | 343.00 | 104.55 | 3062.67 | 933.50 | 3079.05 |
| WIPP-13 | CUL | 06/07/11 | 343.21 | 104.61 | 3062.46 | 933.44 | 3078.84 |
| WIPP-13 | CUL | 07/12/11 | 343.65 | 104.74 | 3062.02 | 933.30 | 3078.38 |
| WIPP-13 | CUL | 08/10/11 | 343.67 | 104.75 | 3062.00 | 933.30 | 3078.35 |
| WIPP-13 | CUL | 09/15/11 | 344.01 | 104.85 | 3061.66 | 933.19 | 3078.00 |
| WIPP-13 | CUL | 10/10/11 | 344.19 | 104.91 | 3061.48 | 933.14 | 3077.81 |
| WIPP-13 | CUL | 11/08/11 | 344.16 | 104.90 | 3061.51 | 933.15 | 3077.84 |
| WIPP-13 | CUL | 12/06/11 | 344.45 | 104.99 | 3061.22 | 933.06 | 3077.54 |
| WIPP-19 | CUL | 01/12/11 | 389.61 | 118.75 | 3045.50 | 928.27 | 3064.91 |
| WIPP-19 | CUL | 02/09/11 | 389.50 | 118.72 | 3045.61 | 928.30 | 3065.02 |
| WIPP-19 | CUL | 03/03/11 | 389.45 | 118.70 | 3045.66 | 928.32 | 3065.07 |
| WIPP-19 | CUL | 04/13/11 | 389.54 | 118.73 | 3045.57 | 928.29 | 3064.98 |
| WIPP-19 | CUL | 05/19/11 | 389.46 | 118.71 | 3045.65 | 928.31 | 3065.06 |
| WIPP-19 | CUL | 06/08/11 | 389.71 | 118.78 | 3045.40 | 928.24 | 3064.80 |
| WIPP-19 | CUL | 07/12/11 | 389.95 | 118.86 | 3045.16 | 928.16 | 3064.55 |
| WIPP-19 | CUL | 08/10/11 | 389.93 | 118.85 | 3045.18 | 928.17 | 3064.57 |
| WIPP-19 | CUL | 09/14/11 | 390.11 | 118.91 | 3045.00 | 928.12 | 3064.38 |
| WIPP-19 | CUL | 10/11/11 | 390.22 | 118.94 | 3044.89 | 928.08 | 3064.26 |
| WIPP-19 | CUL | 11/09/11 | 390.74 | 119.10 | 3044.37 | 927.92 | 3063.72 |
| WIPP-19 | CUL | 12/07/11 | 390.78 | 119.11 | 3044.33 | 927.91 | 3063.68 |
| WQSP-1 | CUL | 01/10/11 | 358.02 | 109.12 | 3061.23 | 933.06 | 3078.66 |
| WQSP-1 | CUL | 02/07/11 | 358.30 | 109.21 | 3060.95 | 932.98 | 3078.36 |
| WQSP-1 | CUL | 03/02/11 | 358.42 | 109.25 | 3060.83 | 932.94 | 3078.24 |
| WQSP-1 | CUL | 04/13/11 | 358.75 | 109.35 | 3060.50 | 932.84 | 3077.89 |
| WQSP-1 | CUL | 05/17/11 | 358.95 | 109.41 | 3060.30 | 932.78 | 3077.68 |
| WQSP-1 | CUL | 06/08/11 | 359.22 | 109.49 | 3060.03 | 932.70 | 3077.40 |
| WQSP-1 | CUL | 07/13/11 | 359.56 | 109.59 | 3059.69 | 932.59 | 3077.04 |
| WQSP-1 | CUL | 08/10/11 | 359.74 | 109.65 | 3059.51 | 932.54 | 3076.85 |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| WQSP-1 | CUL | 09/14/11 | 360.02 | 109.73 | 3059.23 | 932.45 | 3076.56 |
| WQSP-1 | CUL | 10/12/11 | 360.16 | 109.78 | 3059.09 | 932.41 | 3076.41 |
| WQSP-1 | CUL | 11/09/11 | 360.73 | 109.95 | 3058.52 | 932.24 | 3075.81 |
| WQSP-1 | CUL | 12/06/11 | 360.66 | 109.93 | 3058.59 | 932.26 | 3075.89 |
| WQSP-2 | CUL | 01/12/11 | 398.21 | 121.37 | 3065.66 | 934.41 | 3085.72 |
| WQSP-2 | CUL | 02/09/11 | 398.14 | 121.35 | 3065.73 | 934.43 | 3085.80 |
| WQSP-2 | CUL | 03/03/11 | 398.02 | 121.32 | 3065.85 | 934.47 | 3085.92 |
| WQSP-2 | CUL | 04/13/11 | 398.65 | 121.51 | 3065.22 | 934.28 | 3085.26 |
| WQSP-2 | CUL | 05/19/11 | 398.80 | 121.55 | 3065.07 | 934.23 | 3085.10 |
| WQSP-2 | CUL | 06/08/11 | 399.06 | 121.63 | 3064.81 | 934.15 | 3084.83 |
| WQSP-2 | CUL | 07/12/11 | 399.59 | 121.80 | 3064.28 | 933.99 | 3084.28 |
| WQSP-2 | CUL | 08/10/11 | 399.68 | 121.82 | 3064.19 | 933.97 | 3084.18 |
| WQSP-2 | CUL | 09/14/11 | 399.68 | 121.82 | 3064.19 | 933.97 | 3084.18 |
| WQSP-2 | CUL | 10/11/11 | 400.09 | 121.95 | 3063.78 | 933.84 | 3083.75 |
| WQSP-2 | CUL | 11/08/11 | 399.38 | 121.73 | 3064.49 | 934.06 | 3084.50 |
| WQSP-2 | CUL | 12/07/11 | 400.69 | 122.13 | 3063.18 | 933.66 | 3083.13 |
| WQSP-3 | CUL | 01/12/11 | 463.09 | 141.15 | 3017.05 | 919.60 | 3075.37 |
| WQSP-3 | CUL | 02/09/11 | 462.77 | 141.05 | 3017.37 | 919.69 | 3075.74 |
| WQSP-3 | CUL | 03/03/11 | 462.51 | 140.97 | 3017.63 | 919.77 | 3076.04 |
| WQSP-3 | CUL | 04/13/11 | 466.20 | 142.10 | 3013.94 | 918.65 | 3071.81 |
| WQSP-3 | CUL | 05/19/11 | 463.28 | 141.21 | 3016.86 | 919.54 | 3075.15 |
| WQSP-3 | CUL | 06/08/11 | 463.32 | 141.22 | 3016.82 | 919.53 | 3075.11 |
| WQSP-3 | CUL | 07/12/11 | 463.44 | 141.26 | 3016.70 | 919.49 | 3074.97 |
| WQSP-3 | CUL | 08/10/11 | 463.38 | 141.24 | 3016.76 | 919.51 | 3075.04 |
| WQSP-3 | CUL | 09/14/11 | 463.54 | 141.29 | 3016.60 | 919.46 | 3074.86 |
| WQSP-3 | CUL | 10/11/11 | 463.61 | 141.31 | 3016.53 | 919.44 | 3074.78 |
| WQSP-3 | CUL | 11/08/11 | 465.07 | 141.75 | 3015.07 | 918.99 | 3073.10 |
| WQSP-3 | CUL | 12/01/11 | 464.52 | 141.59 | 3015.62 | 919.16 | 3073.73 |
| WQSP-4 | CUL | 01/12/11 | 443.06 | 135.04 | 2990.03 | 911.36 | 3016.38 |
| WQSP-4 | CUL | 02/09/11 | 442.92 | 135.00 | 2990.17 | 911.40 | 3016.53 |
| WQSP-4 | CUL | 03/02/11 | 442.72 | 134.94 | 2990.37 | 911.46 | 3016.75 |
| WQSP-4 | CUL | 04/13/11 | 442.61 | 134.91 | 2990.48 | 911.50 | 3016.87 |
| WQSP-4 | CUL | 05/17/11 | 442.92 | 135.00 | 2990.17 | 911.40 | 3016.53 |
| WQSP-4 | CUL | 06/08/11 | 442.84 | 134.98 | 2990.25 | 911.43 | 3016.62 |
| WQSP-4 | CUL | 07/13/11 | 442.86 | 134.98 | 2990.23 | 911.42 | 3016.60 |
| WQSP-4 | CUL | 08/10/11 | 442.77 | 134.96 | 2990.32 | 911.45 | 3016.69 |
| WQSP-4 | CUL | 09/14/11 | 443.73 | 135.25 | 2989.36 | 911.16 | 3015.66 |
| WQSP-4 | CUL | 10/12/11 | 442.81 | 134.97 | 2990.28 | 911.44 | 3016.65 |
| WQSP-4 | CUL | 11/09/11 | 443.44 | 135.16 | 2989.65 | 911.25 | 3015.97 |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| WQSP-4 | CUL | 12/06/11 | 443.63 | 135.22 | 2989.46 | 911.19 | 3015.77 |
| WQSP-5 | CUL | 01/12/11 | 378.60 | 115.40 | 3005.78 | 916.16 | 3013.62 |
| WQSP-5 | CUL | 02/09/11 | 378.43 | 115.35 | 3005.95 | 916.21 | 3013.80 |
| WQSP-5 | CUL | 03/03/11 | 378.08 | 115.24 | 3006.30 | 916.32 | 3014.16 |
| WQSP-5 | CUL | 04/13/11 | 378.02 | 115.22 | 3006.36 | 916.34 | 3014.22 |
| WQSP-5 | CUL | 05/17/11 | 379.13 | 115.56 | 3005.25 | 916.00 | 3013.08 |
| WQSP-5 | CUL | 06/08/11 | 378.43 | 115.35 | 3005.95 | 916.21 | 3013.80 |
| WQSP-5 | CUL | 07/13/11 | 378.37 | 115.33 | 3006.01 | 916.23 | 3013.86 |
| WQSP-5 | CUL | 08/10/11 | 378.16 | 115.26 | 3006.22 | 916.30 | 3014.07 |
| WQSP-5 | CUL | 09/14/11 | 378.63 | 115.41 | 3005.75 | 916.15 | 3013.59 |
| WQSP-5 | CUL | 10/12/11 | 378.75 | 115.44 | 3005.63 | 916.12 | 3013.47 |
| WQSP-5 | CUL | 11/09/11 | 378.94 | 115.50 | 3005.44 | 916.06 | 3013.27 |
| WQSP-5 | CUL | 12/06/11 | 378.84 | 115.47 | 3005.54 | 916.09 | 3013.38 |
| WQSP-6 | CUL | 01/12/11 | 343.70 | 104.76 | 3021.02 | 920.81 | 3025.07 |
| WQSP-6 | CUL | 02/09/11 | 343.53 | 104.71 | 3021.19 | 920.86 | 3025.25 |
| WQSP-6 | CUL | 03/03/11 | 343.23 | 104.62 | 3021.49 | 920.95 | 3025.55 |
| WQSP-6 | CUL | 04/13/11 | 343.15 | 104.59 | 3021.57 | 920.97 | 3025.63 |
| WQSP-6 | CUL | 05/17/11 | 343.10 | 104.58 | 3021.62 | 920.99 | 3025.68 |
| WQSP-6 | CUL | 06/07/11 | 344.50 | 105.00 | 3020.22 | 920.56 | 3024.26 |
| WQSP-6 | CUL | 07/13/11 | 343.56 | 104.72 | 3021.16 | 920.85 | 3025.22 |
| WQSP-6 | CUL | 08/10/11 | 343.30 | 104.64 | 3021.42 | 920.93 | 3025.48 |
| WQSP-6 | CUL | 09/14/11 | 343.26 | 104.63 | 3021.46 | 920.94 | 3025.52 |
| WQSP-6 | CUL | 10/12/11 | 345.84 | 105.41 | 3018.88 | 920.15 | 3022.90 |
| WQSP-6 | CUL | 11/08/11 | 343.89 | 104.82 | 3020.83 | 920.75 | 3024.88 |
| WQSP-6 | CUL | 12/06/11 | 343.85 | 104.81 | 3020.87 | 920.76 | 3024.92 |
| C-2737 (ANNULUS) | MAG | 01/12/11 | 256.96 | 78.32 | 3143.80 | 958.23 | NA |
| C-2737 (ANNULUS) | MAG | 02/09/11 | 256.77 | 78.26 | 3143.99 | 958.29 | NA |
| C-2737 (ANNULUS) | MAG | 03/03/11 | 256.58 | 78.21 | 3144.18 | 958.35 | NA |
| C-2737 (ANNULUS) | MAG | 04/13/11 | 256.60 | 78.21 | 3144.16 | 958.34 | NA |
| C-2737 (ANNULUS) | MAG | 05/19/11 | 256.43 | 78.16 | 3144.33 | 958.39 | NA |
| C-2737 (ANNULUS) | MAG | 06/08/11 | 256.58 | 78.21 | 3144.18 | 958.35 | NA |
| C-2737 (ANNULUS) | MAG | 07/13/11 | 256.64 | 78.22 | 3144.12 | 958.33 | NA |
| C-2737 (ANNULUS) | MAG | 08/10/11 | 256.58 | 78.21 | 3144.18 | 958.35 | NA |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| C-2737 (ANNULUS) | MAG | 09/15/11 | 256.66 | 78.23 | 3144.10 | 958.32 | NA |
| C-2737 (ANNULUS) | MAG | 10/12/11 | 256.53 | 78.19 | 3144.23 | 958.36 | NA |
| C-2737 (ANNULUS) | MAG | 11/09/11 | 256.66 | 78.23 | 3144.10 | 958.32 | NA |
| C-2737 (ANNULUS) | MAG | 12/06/11 | 256.59 | 78.21 | 3144.17 | 958.34 | NA |
| H-02b1 | MAG | 05/17/11 | 314.41 | 95.83 | 3064.08 | 933.93 | NA |
| H-02b1 | MAG | 06/08/11 | 296.74 | 90.45 | 3081.75 | 939.32 | NA |
| H-02b1 | MAG | 07/12/11 | 278.66 | 84.94 | 3099.83 | 944.83 | NA |
| H-02b1 | MAG | 08/10/11 | 268.19 | 81.74 | 3110.30 | 948.02 | NA |
| H-02b1 | MAG | 09/15/11 | 259.11 | 78.98 | 3119.38 | 950.79 | NA |
| H-02b1 | MAG | 10/12/11 | 254.16 | 77.47 | 3124.33 | 952.30 | NA |
| H-02b1 | MAG | 11/09/11 | 250.29 | 76.29 | 3128.20 | 953.48 | NA |
| H-02b1 | MAG | 12/06/11 | 247.42 | 75.41 | 3131.07 | 954.35 | NA |
| H-03b1 | MAG | 01/12/11 | 244.57 | 74.54 | 3146.15 | 958.95 | NA |
| H-03b1 | MAG | 02/09/11 | 244.44 | 74.51 | 3146.28 | 958.99 | NA |
| H-03b1 | MAG | 03/03/11 | 244.33 | 74.47 | 3146.39 | 959.02 | NA |
| H-03b1 | MAG | 04/13/11 | 244.24 | 74.44 | 3146.48 | 959.05 | NA |
| H-03b1 | MAG | 05/19/11 | 244.00 | 74.37 | 3146.72 | 959.12 | NA |
| H-03b1 | MAG | 06/08/11 | 244.13 | 74.41 | 3146.59 | 959.08 | NA |
| H-03b1 | MAG | 07/13/11 | 244.13 | 74.41 | 3146.59 | 959.08 | NA |
| H-03b1 | MAG | 08/10/11 | 244.01 | 74.37 | 3146.71 | 959.12 | NA |
| H-03b1 | MAG | 09/15/11 | 244.07 | 74.39 | 3146.65 | 959.10 | NA |
| H-03b1 | MAG | 10/12/11 | 243.90 | 74.34 | 3146.82 | 959.15 | NA |
| H-03b1 | MAG | 11/09/11 | 243.99 | 74.37 | 3146.73 | 959.12 | NA |
| H-03b1 | MAG | 12/06/11 | 243.99 | 74.37 | 3146.73 | 959.12 | NA |
| H-04c | MAG | 05/19/11 | 212.52 | 64.78 | 3121.76 | 951.51 | NA |
| H-04c | MAG | 06/07/11 | 191.28 | 58.30 | 3143.00 | 957.99 | NA |
| H-04c | MAG | 07/12/11 | 189.02 | 57.61 | 3145.26 | 958.68 | NA |
| H-04c | MAG | 08/09/11 | 188.68 | 57.51 | 3145.60 | 958.78 | NA |
| H-04c | MAG | 09/14/11 | 188.51 | 57.46 | 3145.77 | 958.83 | NA |
| H-04c | MAG | 10/11/11 | 188.20 | 57.36 | 3146.08 | 958.93 | NA |
| H-04c | MAG | 11/07/11 | 188.21 | 57.37 | 3146.07 | 958.92 | NA |
| H-04c | MAG | 12/05/11 | 188.17 | 57.35 | 3146.11 | 958.93 | NA |
| H-06c | MAG | 01/11/11 | 278.32 | 84.83 | 3070.37 | 935.85 | NA |
| H-06c | MAG | 02/07/11 | 278.20 | 84.80 | 3070.49 | 935.89 | NA |
| H-06c | MAG | 03/02/11 | 278.00 | 84.73 | 3070.69 | 935.95 | NA |
| H-06c | MAG | 04/12/11 | 277.97 | 84.73 | 3070.72 | 935.96 | NA |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| H-06c | MAG | 05/17/11 | 277.78 | 84.67 | 3070.91 | 936.01 | NA |
| H-06c | MAG | 06/06/11 | 278.83 | 84.99 | 3069.86 | 935.69 | NA |
| H-06c | MAG | 07/12/11 | 277.75 | 84.66 | 3070.94 | 936.02 | NA |
| H-06c | MAG | 08/09/11 | 277.60 | 84.61 | 3071.09 | 936.07 | NA |
| H-06c | MAG | 09/14/11 | 277.64 | 84.62 | 3071.05 | 936.06 | NA |
| H-06c | MAG | 09/14/11 | 277.64 | 84.62 | 3071.05 | 936.06 | NA |
| H-06c | MAG | 10/10/11 | 277.62 | 84.62 | 3071.07 | 936.06 | NA |
| H-06c | MAG | 11/08/11 | 277.56 | 84.60 | 3071.13 | 936.08 | NA |
| H-08a | MAG | 01/10/11 | 412.02 | 125.58 | 3021.26 | 920.88 | NA |
| H-08a | MAG | 02/08/11 | 410.95 | 125.26 | 3022.33 | 921.21 | NA |
| H-08a | MAG | 03/01/11 | 410.39 | 125.09 | 3022.89 | 921.38 | NA |
| H-08a | MAG | 04/11/11 | 409.56 | 124.83 | 3023.72 | 921.63 | NA |
| H-08a | MAG | 05/17/11 | 409.04 | 124.68 | 3024.24 | 921.79 | NA |
| H-08a | MAG | 06/06/11 | 408.82 | 124.61 | 3024.46 | 921.86 | NA |
| H-08a | MAG | 07/11/11 | 408.46 | 124.50 | 3024.82 | 921.97 | NA |
| H-08a | MAG | 08/08/11 | 408.02 | 124.36 | 3025.26 | 922.10 | NA |
| H-08a | MAG | 09/12/11 | 407.76 | 124.29 | 3025.52 | 922.18 | NA |
| H-08a | MAG | 10/11/11 | 407.49 | 124.20 | 3025.79 | 922.26 | NA |
| H-08a | MAG | 11/07/11 | 407.30 | 124.15 | 3025.98 | 922.32 | NA |
| H-08a | MAG | 12/05/11 | 407.12 | 124.09 | 3026.16 | 922.37 | NA |
| H-09c | MAG | 08/08/11 | 269.30 | 82.08 | 3137.75 | 956.39 | NA |
| H-09c | MAG | 09/12/11 | 269.26 | 82.07 | 3137.79 | 956.40 | NA |
| H-09c | MAG | 10/11/11 | 269.18 | 82.05 | 3137.87 | 956.42 | NA |
| H-09c | MAG | 11/07/11 | 269.33 | 82.09 | 3137.72 | 956.38 | NA |
| H-09c | MAG | 12/05/11 | 269.75 | 82.22 | 3137.30 | 956.25 | NA |
| H-10a | MAG | 01/10/11 | 576.04 | 175.58 | 3112.41 | 948.66 | NA |
| H-10a | MAG | 02/08/11 | 576.06 | 175.58 | 3112.39 | 948.66 | NA |
| H-10a | MAG | 03/01/11 | 575.95 | 175.55 | 3112.50 | 948.69 | NA |
| H-10a | MAG | 04/11/11 | 575.84 | 175.52 | 3112.61 | 948.72 | NA |
| H-10a | MAG | 05/16/11 | 575.87 | 175.53 | 3112.58 | 948.71 | NA |
| H-10a | MAG | 06/07/11 | 575.42 | 175.39 | 3113.03 | 948.85 | NA |
| H-10a | MAG | 07/13/11 | 575.88 | 175.53 | 3112.57 | 948.71 | NA |
| H-10a | MAG | 08/09/11 | 575.89 | 175.53 | 3112.56 | 948.71 | NA |
| H-10a | MAG | 09/13/11 | 575.93 | 175.54 | 3112.52 | 948.70 | NA |
| H-10a | MAG | 10/11/11 | 575.84 | 175.52 | 3112.61 | 948.72 | NA |
| H-10a | MAG | 11/09/11 | 575.85 | 175.52 | 3112.60 | 948.72 | NA |
| H-10a | MAG | 12/05/11 | 575.91 | 175.54 | 3112.54 | 948.70 | NA |
| H-11b2 | MAG | 01/11/11 | 272.20 | 82.97 | 3139.66 | 956.97 | NA |
| H-11b2 | MAG | 02/09/11 | 272.20 | 82.97 | 3139.66 | 956.97 | NA |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| H-11b2 | MAG | 03/01/11 | 272.18 | 82.96 | 3139.68 | 956.97 | NA |
| H-11b2 | MAG | 04/12/11 | 272.22 | 82.97 | 3139.64 | 956.96 | NA |
| H-11b2 | MAG | 05/17/11 | 272.22 | 82.97 | 3139.64 | 956.96 | NA |
| H-11b2 | MAG | 06/07/11 | 272.20 | 82.97 | 3139.66 | 956.97 | NA |
| H-11b2 | MAG | 07/13/11 | 272.22 | 82.97 | 3139.64 | 956.96 | NA |
| H-11b2 | MAG | 08/09/11 | 272.18 | 82.96 | 3139.68 | 956.97 | NA |
| H-11b2 | MAG | 09/12/11 | 276.10 | 84.16 | 3135.76 | 955.78 | NA |
| H-11b2 | MAG | 10/11/11 | 273.03 | 83.22 | 3138.83 | 956.72 | NA |
| H-11b2 | MAG | 12/05/11 | 276.86 | 84.39 | 3135.00 | 955.55 | NA |
| H-14 | MAG | 01/11/11 | 212.90 | 64.89 | 3134.18 | 955.30 | NA |
| H-14 | MAG | 02/08/11 | 212.37 | 64.73 | 3134.71 | 955.46 | NA |
| H-14 | MAG | 03/02/11 | 211.99 | 64.61 | 3135.09 | 955.58 | NA |
| H-14 | MAG | 04/13/11 | 211.45 | 64.45 | 3135.63 | 955.74 | NA |
| H-14 | MAG | 05/17/11 | 210.97 | 64.30 | 3136.11 | 955.89 | NA |
| H-14 | MAG | 06/07/11 | 211.38 | 64.43 | 3135.70 | 955.76 | NA |
| H-14 | MAG | 07/12/11 | 210.36 | 64.12 | 3136.72 | 956.07 | NA |
| H-14 | MAG | 08/09/11 | 210.08 | 64.03 | 3137.00 | 956.16 | NA |
| H-14 | MAG | 09/12/11 | 209.78 | 63.94 | 3137.30 | 956.25 | NA |
| H-14 | MAG | 10/10/11 | 209.51 | 63.86 | 3137.57 | 956.33 | NA |
| H-14 | MAG | 11/08/11 | 209.31 | 63.80 | 3137.77 | 956.39 | NA |
| H-14 | MAG | 12/06/11 | 209.22 | 63.77 | 3137.86 | 956.42 | NA |
| H-15 | MAG | 01/11/11 | 347.34 | 105.87 | 3136.16 | 955.90 | NA |
| H-15 | MAG | 02/09/11 | 343.29 | 104.63 | 3140.21 | 957.14 | NA |
| H-15 | MAG | 03/02/11 | 343.03 | 104.56 | 3140.47 | 957.22 | NA |
| H-15 | MAG | 04/13/11 | 342.66 | 104.44 | 3140.84 | 957.33 | NA |
| H-15 | MAG | 05/19/11 | 342.00 | 104.24 | 3141.50 | 957.53 | NA |
| H-15 | MAG | 06/08/11 | 341.84 | 104.19 | 3141.66 | 957.58 | NA |
| H-15 | MAG | 07/13/11 | 341.56 | 104.11 | 3141.94 | 957.66 | NA |
| H-15 | MAG | 08/10/11 | 340.45 | 103.77 | 3143.05 | 958.00 | NA |
| H-15 | MAG | 09/14/11 | 340.14 | 103.67 | 3143.36 | 958.10 | NA |
| H-15 | MAG | 10/12/11 | 339.91 | 103.60 | 3143.59 | 958.17 | NA |
| H-15 | MAG | 11/09/11 | 340.10 | 103.66 | 3143.40 | 958.11 | NA |
| H-15 | MAG | 12/07/11 | 339.84 | 103.58 | 3143.66 | 958.19 | NA |
| H-18 | MAG | 01/10/11 | 260.91 | 79.53 | 3153.30 | 961.13 | NA |
| H-18 | MAG | 02/07/11 | 260.97 | 79.54 | 3153.24 | 961.11 | NA |
| H-18 | MAG | 03/02/11 | 260.71 | 79.46 | 3153.50 | 961.19 | NA |
| H-18 | MAG | 04/13/11 | 260.39 | 79.37 | 3153.82 | 961.28 | NA |
| H-18 | MAG | 05/17/11 | 260.16 | 79.30 | 3154.05 | 961.35 | NA |
| H-18 | MAG | 06/06/11 | 260.19 | 79.31 | 3154.02 | 961.35 | NA |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| H-18 | MAG | 07/12/11 | 260.01 | 79.25 | 3154.20 | 961.40 | NA |
| H-18 | MAG | 08/09/11 | 259.82 | 79.19 | 3154.39 | 961.46 | NA |
| H-18 | MAG | 09/14/11 | 259.68 | 79.15 | 3154.53 | 961.50 | NA |
| H-18 | MAG | 10/12/11 | 259.48 | 79.09 | 3154.73 | 961.56 | NA |
| H-18 | MAG | 11/09/11 | 259.62 | 79.13 | 3154.59 | 961.52 | NA |
| H-18 | MAG | 12/06/11 | 259.45 | 79.08 | 3154.76 | 961.57 | NA |
| WIPP-18 | MAG | 01/12/11 | 308.26 | 93.96 | 3149.31 | 959.91 | NA |
| WIPP-18 | MAG | 02/09/11 | 308.15 | 93.92 | 3149.42 | 959.94 | NA |
| WIPP-18 | MAG | 03/03/11 | 308.08 | 93.90 | 3149.49 | 959.96 | NA |
| WIPP-18 | MAG | 04/13/11 | 307.89 | 93.84 | 3149.68 | 960.02 | NA |
| WIPP-18 | MAG | 05/19/11 | 307.72 | 93.79 | 3149.85 | 960.07 | NA |
| WIPP-18 | MAG | 06/08/11 | 307.76 | 93.81 | 3149.81 | 960.06 | NA |
| WIPP-18 | MAG | 07/12/11 | 307.72 | 93.79 | 3149.85 | 960.07 | NA |
| WIPP-18 | MAG | 08/10/11 | 307.64 | 93.77 | 3149.93 | 960.10 | NA |
| WIPP-18 | MAG | 09/14/11 | 307.64 | 93.77 | 3149.93 | 960.10 | NA |
| WIPP-18 | MAG | 10/10/11 | 307.51 | 93.73 | 3150.06 | 960.14 | NA |
| WIPP-18 | MAG | 11/09/11 | 307.52 | 93.73 | 3150.05 | 960.14 | NA |
| WIPP-18 | MAG | 12/07/11 | 307.51 | 93.73 | 3150.06 | 960.14 | NA |
| WQSP-6a | DL | 01/12/11 | 167.73 | 51.12 | 3196.32 | 974.24 | NA |
| WQSP-6a | DL | 02/09/11 | 167.60 | 51.08 | 3196.45 | 974.28 | NA |
| WQSP-6a | DL | 03/03/11 | 167.24 | 50.97 | 3196.81 | 974.39 | NA |
| WQSP-6a | DL | 04/13/11 | 167.28 | 50.99 | 3196.77 | 974.38 | NA |
| WQSP-6a | DL | 05/17/11 | 167.14 | 50.94 | 3196.91 | 974.42 | NA |
| WQSP-6a | DL | 06/07/11 | 167.06 | 50.92 | 3196.99 | 974.44 | NA |
| WQSP-6a | DL | 07/13/11 | 167.37 | 51.01 | 3196.68 | 974.35 | NA |
| WQSP-6a | DL | 08/10/11 | 167.31 | 51.00 | 3196.74 | 974.37 | NA |
| WQSP-6a | DL | 09/14/11 | 167.34 | 51.01 | 3196.71 | 974.36 | NA |
| WQSP-6a | DL | 10/12/11 | 167.26 | 50.98 | 3196.79 | 974.38 | NA |
| WQSP-6a | DL | 11/08/11 | 167.40 | 51.02 | 3196.65 | 974.34 | NA |
| WQSP-6a | DL | 12/06/11 | 167.55 | 51.07 | 3196.50 | 974.29 | NA |
| CB-1 | B/C | 01/11/11 | 315.76 | 96.24 | 3013.36 | 918.47 | NA |
| CB-1 | B/C | 02/09/11 | 315.39 | 96.13 | 3013.73 | 918.58 | NA |
| CB-1 | B/C | 03/01/11 | 315.07 | 96.03 | 3014.05 | 918.68 | NA |
| CB-1 | B/C | 04/12/11 | 314.43 | 95.84 | 3014.69 | 918.88 | NA |
| CB-1 | B/C | 05/17/11 | 313.83 | 95.66 | 3015.29 | 919.06 | NA |
| CB-1 | B/C | 06/07/11 | 313.63 | 95.59 | 3015.49 | 919.12 | NA |
| CB-1 | B/C | 07/13/11 | 313.25 | 95.48 | 3015.87 | 919.24 | NA |
| CB-1 | B/C | 08/09/11 | 312.76 | 95.33 | 3016.36 | 919.39 | NA |
| CB-1 | B/C | 09/12/11 | 312.41 | 95.22 | 3016.71 | 919.49 | NA |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| CB-1 | B/C | 10/11/11 | 311.79 | 95.03 | 3017.33 | 919.68 | NA |
| CB-1 | B/C | 11/07/11 | 311.45 | 94.93 | 3017.67 | 919.79 | NA |
| CB-1 | B/C | 12/05/11 | 311.23 | 94.86 | 3017.89 | 919.85 | NA |
| DOE-2 | B/C | 01/10/11 | 352.34 | 107.39 | 3066.84 | 934.77 | NA |
| DOE-2 | B/C | 02/08/11 | 352.35 | 107.40 | 3066.83 | 934.77 | NA |
| DOE-2 | B/C | 03/03/11 | 352.35 | 107.40 | 3066.83 | 934.77 | NA |
| DOE-2 | B/C | 04/12/11 | 352.23 | 107.36 | 3066.95 | 934.81 | NA |
| DOE-2 | B/C | 05/17/11 | 352.17 | 107.34 | 3067.01 | 934.82 | NA |
| DOE-2 | B/C | 06/07/11 | 352.19 | 107.35 | 3066.99 | 934.82 | NA |
| DOE-2 | B/C | 07/12/11 | 352.02 | 107.30 | 3067.16 | 934.87 | NA |
| DOE-2 | B/C | 08/09/11 | 351.99 | 107.29 | 3067.19 | 934.88 | NA |
| DOE-2 | B/C | 09/15/11 | 352.07 | 107.31 | 3067.11 | 934.86 | NA |
| DOE-2 | B/C | 10/12/11 | 351.90 | 107.26 | 3067.28 | 934.91 | NA |
| DOE-2 | B/C | 11/08/11 | 351.90 | 107.26 | 3067.28 | 934.91 | NA |
| DOE-2 | B/C | 12/06/11 | 352.02 | 107.30 | 3067.16 | 934.87 | NA |
| C-2505 | SR/D | 03/02/11 | 45.30 | 13.81 | 3367.63 | 1026.45 | NA |
| C-2505 | SR/D | 06/08/11 | 45.85 | 13.98 | 3367.08 | 1026.29 | NA |
| C-2505 | SR/D | 09/15/11 | 46.59 | 14.20 | 3366.34 | 1026.06 | NA |
| C-2505 | SR/D | 12/01/11 | 46.71 | 14.24 | 3366.22 | 1026.02 | NA |
| C-2506 | SR/D | 03/02/11 | 44.66 | 13.61 | 3368.18 | 1026.62 | NA |
| C-2506 | SR/D | 06/08/11 | 45.22 | 13.78 | 3367.62 | 1026.45 | NA |
| C-2506 | SR/D | 09/15/11 | 45.97 | 14.01 | 3366.87 | 1026.22 | NA |
| C-2506 | SR/D | 12/01/11 | 46.18 | 14.08 | 3366.66 | 1026.16 | NA |
| C-2507 | SR/D | 03/02/11 | 45.18 | 13.77 | 3364.73 | 1025.57 | NA |
| C-2507 | SR/D | 06/08/11 | 45.57 | 13.89 | 3364.34 | 1025.45 | NA |
| C-2507 | SR/D | 09/15/11 | 46.20 | 14.08 | 3363.71 | 1025.26 | NA |
| C-2507 | SR/D | 12/01/11 | 46.38 | 14.14 | 3363.53 | 1025.20 | NA |
| C-2811 | SR/D | 03/03/11 | 51.99 | 15.85 | 3346.85 | 1020.12 | NA |
| C-2811 | SR/D | 06/08/11 | 52.32 | 15.95 | 3346.52 | 1020.02 | NA |
| C-2811 | SR/D | 09/15/11 | 53.40 | 16.28 | 3345.44 | 1019.69 | NA |
| C-2811 | SR/D | 12/06/11 | 53.62 | 16.34 | 3345.22 | 1019.62 | NA |
| PZ-01 | SR/D | 03/02/11 | 41.68 | 12.70 | 3371.60 | 1027.66 | NA |
| PZ-01 | SR/D | 06/08/11 | 42.06 | 12.82 | 3371.22 | 1027.55 | NA |
| PZ-01 | SR/D | 09/15/11 | 42.60 | 12.98 | 3370.68 | 1027.38 | NA |
| PZ-01 | SR/D | 12/07/11 | 42.87 | 13.07 | 3370.41 | 1027.30 | NA |
| PZ-02 | SR/D | 03/02/11 | 42.32 | 12.90 | 3371.04 | 1027.49 | NA |
| PZ-02 | SR/D | 06/08/11 | 42.69 | 13.01 | 3370.67 | 1027.38 | NA |
| PZ-02 | SR/D | 09/15/11 | 44.43 | 13.54 | 3368.93 | 1026.85 | NA |
| PZ-02 | SR/D | 12/01/11 | 43.61 | 13.29 | 3369.75 | 1027.10 | NA |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| PZ-03 | SR/D | 03/03/11 | 43.83 | 13.36 | 3372.29 | 1027.87 | NA |
| PZ-03 | SR/D | 06/08/11 | 44.13 | 13.45 | 3371.99 | 1027.78 | NA |
| PZ-03 | SR/D | 09/15/11 | 44.69 | 13.62 | 3371.43 | 1027.61 | NA |
| PZ-03 | SR/D | 12/07/11 | 45.08 | 13.74 | 3371.04 | 1027.49 | NA |
| PZ-04 | SR/D | 03/02/11 | 45.95 | 14.01 | 3366.06 | 1025.98 | NA |
| PZ-04 | SR/D | 06/08/11 | 46.59 | 14.20 | 3365.42 | 1025.78 | NA |
| PZ-04 | SR/D | 09/15/11 | 47.40 | 14.45 | 3364.61 | 1025.53 | NA |
| PZ-04 | SR/D | 12/07/11 | 47.84 | 14.58 | 3364.17 | 1025.40 | NA |
| PZ-05 | SR/D | 03/03/11 | 42.45 | 12.94 | 3372.79 | 1028.03 | NA |
| PZ-05 | SR/D | 06/08/11 | 42.86 | 13.06 | 3372.38 | 1027.90 | NA |
| PZ-05 | SR/D | 09/15/11 | 43.44 | 13.24 | 3371.80 | 1027.72 | NA |
| PZ-05 | SR/D | 12/07/11 | 43.72 | 13.33 | 3371.52 | 1027.64 | NA |
| PZ-06 | SR/D | 03/03/11 | 43.10 | 13.14 | 3370.23 | 1027.25 | NA |
| PZ-06 | SR/D | 06/08/11 | 43.61 | 13.29 | 3369.72 | 1027.09 | NA |
| PZ-06 | SR/D | 09/15/11 | 44.28 | 13.50 | 3369.05 | 1026.89 | NA |
| PZ-06 | SR/D | 12/07/11 | 44.60 | 13.59 | 3368.73 | 1026.79 | NA |
| PZ-07 | SR/D | 03/02/11 | 36.93 | 11.26 | 3376.91 | 1029.28 | NA |
| PZ-07 | SR/D | 06/08/11 | 37.13 | 11.32 | 3376.71 | 1029.22 | NA |
| PZ-07 | SR/D | 09/12/11 | 37.70 | 11.49 | 3376.14 | 1029.05 | NA |
| PZ-07 | SR/D | 12/01/11 | 37.91 | 11.55 | 3375.93 | 1028.98 | NA |
| PZ-08 | SR/D | 03/03/11 | 62.58 | 19.07 | 3355.61 | 1022.79 | NA |
| PZ-08 | SR/D | 06/08/11 | 62.62 | 19.09 | 3355.57 | 1022.78 | NA |
| PZ-08 | SR/D | 09/14/11 | 62.92 | 19.18 | 3355.27 | 1022.69 | NA |
| PZ-08 | SR/D | 12/01/11 | 63.26 | 19.28 | 3354.93 | 1022.58 | NA |
| PZ-09 | SR/D | 03/03/11 | 57.35 | 17.48 | 3363.74 | 1025.27 | NA |
| PZ-09 | SR/D | 06/08/11 | 57.49 | 17.52 | 3363.60 | 1025.22 | NA |
| PZ-09 | SR/D | 09/14/11 | 57.71 | 17.59 | 3363.38 | 1025.16 | NA |
| PZ-09 | SR/D | 12/01/11 | 57.88 | 17.64 | 3363.21 | 1025.11 | NA |
| PZ-10 | SR/D | 03/02/11 | 38.11 | 11.62 | 3367.62 | 1026.45 | NA |
| PZ-10 | SR/D | 06/08/11 | 38.83 | 11.84 | 3366.90 | 1026.23 | NA |
| PZ-10 | SR/D | 09/15/11 | 38.60 | 11.77 | 3367.13 | 1026.30 | NA |
| PZ-10 | SR/D | 12/06/11 | 39.89 | 12.16 | 3365.84 | 1025.91 | NA |
| PZ-11 | SR/D | 03/02/11 | 44.30 | 13.50 | 3374.48 | 1028.54 | NA |
| PZ-11 | SR/D | 06/08/11 | 44.45 | 13.55 | 3374.33 | 1028.50 | NA |
| PZ-11 | SR/D | 09/15/11 | 45.36 | 13.83 | 3373.42 | 1028.22 | NA |
| PZ-11 | SR/D | 12/01/11 | 45.68 | 13.92 | 3373.10 | 1028.12 | NA |
| PZ-12 | SR/D | 03/02/11 | 51.65 | 15.74 | 3357.27 | 1023.29 | NA |
| PZ-12 | SR/D | 06/08/11 | 52.33 | 15.95 | 3356.59 | 1023.09 | NA |
| PZ-12 | SR/D | 09/15/11 | 53.25 | 16.23 | 3355.67 | 1022.81 | NA |

# APPENDIX F – Groundwater Data Tables

**Table F.9 – Water Levels**

| Well Number | Zone | Date | Adjusted Depth Top of Casing (ft) | Adjusted Depth (meters) | Water Level Elevation (ft amsl) | Elevation in Meters (amsl) | Adjusted Freshwater Head (ft amsl) |
|---|---|---|---|---|---|---|---|
| PZ-12 | SR/D | 12/06/11 | 53.85 | 16.41 | 3355.07 | 1022.62 | NA |
| PZ-13 | SR/D | 03/02/11 | 65.96 | 20.10 | 3356.28 | 1022.99 | NA |
| PZ-13 | SR/D | 06/08/11 | 66.08 | 20.14 | 3356.16 | 1022.96 | NA |
| PZ-13 | SR/D | 09/14/11 | 66.21 | 20.18 | 3356.03 | 1022.92 | NA |
| PZ-13 | SR/D | 12/01/11 | 66.29 | 20.21 | 3355.95 | 1022.89 | NA |
| PZ-14 | SR/D | 03/02/11 | 67.36 | 20.53 | 3353.22 | 1022.06 | NA |
| PZ-14 | SR/D | 06/08/11 | 67.41 | 20.55 | 3353.17 | 1022.05 | NA |
| PZ-14 | SR/D | 09/14/11 | 67.47 | 20.56 | 3353.11 | 1022.03 | NA |
| PZ-14 | SR/D | 12/01/11 | 67.47 | 20.56 | 3353.11 | 1022.03 | NA |
| PZ-15 | SR/D | 03/02/11 | 47.53 | 14.49 | 3383.33 | 1031.24 | NA |
| PZ-15 | SR/D | 06/08/11 | 47.87 | 14.59 | 3382.99 | 1031.14 | NA |
| PZ-15 | SR/D | 09/14/11 | 48.01 | 14.63 | 3382.85 | 1031.09 | NA |
| PZ-15 | SR/D | 12/01/11 | 48.19 | 14.69 | 3382.67 | 1031.04 | NA |

NA: Freshwater head calculations not performed for non-Culebra wells.

ND: AMSL reference elevations not determined for new well H-11b4R at time of report generation.

# APPENDIX G – Air Sampling Data: Concentrations of Radionuclides in Air Filter Composites

APPENDIX G – Air Sampling Data: Concentrations of Radionuclides in Air Filter Composites

**Updated Table G.1 – 2011 Radionuclide Concentrations (Bq/sample) in Quarterly Composite Air Filters Collected from Locations Surrounding the WIPP Facility**

**See Appendix C for sampling location codes**

| | | $^{233/234}U$ | | | | $^{235}U$ | | | | $^{238}U$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Location** | **Quarter** | **[RN][(a)]** | **2 σ TPU[(b)]** | **MDC[(c)]** | **Q[(d)]** | **[RN]** | **2 σ TPU** | **MDC** | **Q** | **[RN]** | **2 σ TPU** | **MDC** | **Q** |
| WFF | 1 | 5.75E-03 | 3.29E-03 | 8.64E-03 | U | 6.79E-04 | 1.06E-03 | 1.22E-03 | U | 4.79E-03 | 2.80E-03 | 5.89E-03 | U |
| | 2(Avg) | 2.77E-03 | 1.99E-03 | 7.57E-03 | U | -2.95E-04 | 3.46E-04 | 9.83E-04 | U | 1.28E-03 | 1.70E-03 | 5.10E-03 | U |
| | 3 | 2.46E-04 | 2.13E-03 | 7.66E-03 | U | 3.89E-04 | 7.39E-04 | 1.01E-03 | U | 4.35E-03 | 2.42E-03 | 4.74E-03 | U |
| | 4 | 4.25E-03 | 2.16E-03 | 6.99E-03 | U | 7.87E-04 | 6.77E-04 | 1.07E-03 | U | 1.44E-03 | 2.01E-03 | 5.76E-03 | U |
| WEE | 1 | 3.61E-03 | 3.00E-03 | 8.66E-03 | U | 3.55E-04 | 9.22E-04 | 1.24E-03 | U | 5.73E-03 | 3.02E-03 | 5.90E-03 | U |
| | 2 | 1.27E-03 | 1.84E-03 | 7.57E-03 | U | 5.52E-05 | 5.35E-04 | 9.91E-04 | U | 1.85E-03 | 1.81E-03 | 5.11E-03 | U |
| | 3(Avg) | 2.82E-03 | 2.61E-03 | 7.7E-03 | U | 2.79E-04 | 6.99E-04 | 1.06E-03 | U | 4.51E-03 | 2.62E-03 | 4.78E-03 | U |
| | 4 | 4.01E-03 | 2.45E-03 | 6.68E-03 | U | -8.19E-05 | 3.21E-04 | 1.11E-03 | U | 1.79E-03 | 2.29E-03 | 6.24E-03 | U |
| WSS | 1 | -1.44E-04 | 2.59E-03 | 8.70E-03 | U | 1.14E-03 | 1.28E-03 | 1.29E-03 | U | 7.80E-03 | 3.68E-03 | 5.95E-03 | + |
| | 2 | 6.71E-04 | 1.87E-03 | 7.62E-03 | U | 1.01E-04 | 6.21E-04 | 1.04E-03 | U | 3.28E-03 | 2.15E-03 | 5.15E-03 | U |
| | 3 | 1.73E-03 | 2.17E-03 | 7.61E-03 | U | 4.44E-04 | 7.05E-04 | 9.55E-04 | U | 6.03E-03 | 2.51E-03 | 4.70E-03 | + |
| | 4(Avg) | 3.31E-03 | 2.01E-03 | 6.98E-03 | U | 5.35E-04 | 5.53E-04 | 1.06E-03 | U | 3.25E-03 | 2.19E-03 | 5.76E-03 | + |
| MLR | 1 | 1.78E-02 | 8.13E-03 | 8.93E-03 | + | 3.09E-04 | 1.15E-03 | 1.57E-03 | U | 1.32E-02 | 6.42E-03 | 6.17E-03 | + |
| | 2 | 1.00E-03 | 1.85E-03 | 7.59E-03 | U | -5.27E-04 | 2.10E-04 | 1.01E-03 | U | 1.09E-03 | 1.76E-03 | 5.12E-03 | U |
| | 3 | 3.34E-03 | 2.42E-03 | 7.62E-03 | U | -4.09E-04 | 1.65E-04 | 9.70E-04 | U | 5.07E-03 | 2.43E-03 | 4.71E-03 | + |
| | 4 | 4.53E-03 | 2.20E-03 | 6.99E-03 | U | 5.50E-04 | 5.67E-04 | 1.07E-03 | U | 7.65E-04 | 1.94E-03 | 5.76E-03 | U |
| SEC | 1 | 4.47E-03 | 3.67E-03 | 8.79E-03 | U | -6.34E-04 | 2.82E-04 | 1.41E-03 | U | 5.65E-03 | 3.58E-03 | 6.04E-03 | U |
| | 2 | 2.05E-03 | 1.93E-03 | 7.58E-03 | U | 5.90E-04 | 7.62E-04 | 9.94E-04 | U | 1.52E-03 | 1.76E-03 | 5.11E-03 | U |
| | 3 | 4.41E-03 | 2.44E-03 | 7.60E-03 | U | -1.06E-04 | 3.94E-04 | 9.44E-04 | U | 4.57E-03 | 2.25E-03 | 4.69E-03 | U |
| | 4 | 1.03E-02 | 3.69E-03 | 6.73E-03 | + | 2.85E-04 | 6.16E-04 | 1.16E-03 | U | 3.83E-03 | 2.73E-03 | 6.29E-03 | U |
| CBD | 1 | 4.01E-03 | 3.20E-03 | 8.70E-03 | U | 7.00E-04 | 1.08E-03 | 1.28E-03 | U | 5.15E-03 | 3.05E-03 | 5.94E-03 | U |
| | 2 | 7.12E-03 | 2.68E-03 | 7.58E-03 | U | 7.92E-05 | 5.46E-04 | 1.00E-03 | U | 6.09E-03 | 2.45E-03 | 5.12E-03 | U |
| | 3 | 4.78E-03 | 2.80E-03 | 7.67E-03 | U | -9.04E-05 | 5.02E-04 | 1.02E-03 | U | 8.31E-03 | 3.17E-03 | 4.75E-03 | + |
| | 4 | 8.07E-03 | 2.74E-03 | 7.00E-03 | + | -8.60E-05 | 1.41E-04 | 1.08E-03 | U | 4.74E-03 | 2.46E-03 | 5.77E-03 | U |
| SMR | 1 (Avg) | 1.03E-02 | 4.95E-03 | 8.78E-03 | + | 3.72E-04 | 1.05E-03 | 1.39E-03 | U | 9.21E-03 | 4.41E-03 | 6.03E-03 | + |

# APPENDIX G – Air Sampling Data: Concentrations of Radionuclides in Air Filter Composites

**Updated Table G.1 – 2011 Radionuclide Concentrations (Bq/sample) in Quarterly Composite Air Filters Collected from Locations Surrounding the WIPP Facility**

**See Appendix C for sampling location codes**

| | | $^{233/234}U$ | | | | $^{235}U$ | | | | $^{238}U$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Location** | **Quarter** | **[RN][(a)]** | **2 σ TPU[(b)]** | **MDC[(c)]** | **Q[(d)]** | **[RN]** | **2 σ TPU** | **MDC** | **Q** | **[RN]** | **2 σ TPU** | **MDC** | **Q** |
| | 2 | 5.37E-03 | 2.28E-03 | 7.56E-03 | U | 2.70E-04 | 6.17E-04 | 9.71E-04 | U | 6.95E-03 | 2.40E-03 | 5.09E-03 | + |
| | 3 | 7.49E-03 | 3.10E-03 | 7.65E-03 | U | 4.11E-04 | 7.09E-04 | 1.00E-03 | U | 8.52E-03 | 3.07E-03 | 4.73E-03 | + |
| | 4 | 5.93E-03 | 2.44E-03 | 7.00E-03 | U | 3.32E-04 | 4.61E-04 | 1.08E-03 | U | 4.31E-03 | 2.40E-03 | 5.78E-03 | U |
| | **Mean** | 4.68E-03 | 2.81E-03 | 7.72E-03 | | 2.30E-04 | 6.32E-04 | 1.11E-03 | | 4.82E-03 | 2.70E-03 | 5.44E-03 | |
| | **Minimum[(e)]** | -1.44E-04 | 2.59E-03 | 8.70E-03 | | -6.34E-04 | 2.82E-04 | 1.41E-03 | | 7.65E-04 | 1.94E-03 | 5.76E-03 | |
| | **Maximum[(e)]** | 1.78E-02 | 8.13E-03 | 8.93E-03 | | 1.14E-03 | 1.28E-03 | 1.29E-03 | | 1.32E-02 | 6.42E-03 | 6.17E-03 | |
| WAB | 1 | 9.60E-03 | 3.42E-03 | 8.70E-03 | + | 5.90E-04 | 8.03E-04 | 1.29E-03 | U | 6.48E-03 | 2.63E-03 | 5.94E-03 | + |
| (Blank)[(f)] | 2 | 6.52E-03 | 2.20E-03 | 7.64E-03 | U | 4.57E-04 | 5.78E-04 | 1.07E-03 | U | 5.73E-03 | 2.02E-03 | 5.17E-03 | + |
| | 3 | 8.47E-03 | 2.94E-03 | 7.61E-03 | + | 3.70E-04 | 5.23E-04 | 9.54E-04 | U | 6.11E-03 | 2.30E-03 | 4.70E-03 | + |
| | 4 | 6.67E-03 | 2.17E-03 | 6.99E-03 | U | -4.69E-05 | 1.52E-04 | 1.07E-03 | U | 8.79E-03 | 2.65E-03 | 5.77E-03 | + |

(a) Radionuclide activity of the primary sample. Only radionuclides with activities greater than 2 σ TPU and MDC are considered detections.

(b) 2 times the Total Propagated Uncertainty.

(c) Minimum Detectable Concentration.

(d) Qualifier. Indicates whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

(e) Minimum and maximum reported concentrations for each radionuclide are based on the sample's activity, [RN], while the associated 2 σ TPU and MDC are inherited with the specific [RN].

# APPENDIX G – Air Sampling Data: Concentrations of Radionuclides in Air Filter Composites

### Updated Table G.1 – 2011 Radionuclide Concentrations (Bq/sample) in Quarterly Composite Air Filters Collected from Locations Surrounding the WIPP Facility

See Appendix C for sampling location codes

| | | $^{238}Pu$ | | | | $^{239/240}Pu$ | | | | $^{241}Am$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Quarter | [RN][(a)] | 2 σ TPU[(b)] | MDC[(c)] | Q[(d)] | [RN] | 2 σ TPU | MDC | Q | [RN] | 2 σ TPU | MDC | Q |
| WFF | 1 | -2.40E-04 | 5.57E-04 | 7.81E-04 | U | 4.43E-04 | 6.90E-04 | 9.47E-04 | U | 3.28E-04 | 9.40E-04 | 9.88E-04 | U |
| | 2(Avg) | 2.06E-04 | 5.26E-04 | 6.67E-04 | U | -6.52E-05 | 2.61E-04 | 8.10E-04 | U | 4.99E-04 | 9.02E-04 | 1.09E-03 | U |
| | 3 | -4.74E-04 | 4.12E-04 | 6.26E-04 | U | 4.42E-04 | 5.40E-04 | 7.69E-04 | U | 1.93E-04 | 7.49E-04 | 8.16E-04 | U |
| | 4 | -1.76E-04 | 4.09E-04 | 1.46E-03 | U | 4.98E-03 | 1.63E-03 | 1.10E-03 | + | -7.66E-07 | 8.10E-04 | 9.55E-04 | U |
| WEE | 1 | 3.62E-04 | 8.21E-04 | 8.52E-04 | U | -2.94E-04 | 4.42E-04 | 1.02E-03 | U | -1.99E-04 | 6.79E-04 | 1.00E-03 | U |
| | 2 | -1.52E-04 | 3.03E-04 | 6.45E-04 | U | 2.23E-05 | 3.31E-04 | 7.88E-04 | U | 8.77E-04 | 1.03E-03 | 1.11E-03 | U |
| | 3(Avg) | 2.44E-04 | 6.28E-04 | 6.2E-04 | U | 1.13E-04 | 3.86E-04 | 7.7E-04 | U | 1.21E-04 | 6.95E-04 | 8.3E-04 | U |
| | 4 | -1.21E-03 | 3.81E-04 | 1.48E-03 | U | -4.83E-05 | 5.55E-04 | 1.14E-03 | U | 3.09E-04 | 8.05E-04 | 9.20E-04 | U |
| WSS | 1 | 3.07E-04 | 7.33E-04 | 8.06E-04 | U | -1.94E-04 | 3.14E-04 | 9.72E-04 | U | -4.68E-04 | 7.10E-04 | 1.09E-03 | U |
| | 2 | 1.01E-04 | 4.40E-04 | 6.74E-04 | U | -1.92E-04 | 2.00E-04 | 8.17E-04 | U | -2.93E-04 | 4.92E-04 | 1.12E-03 | U |
| | 3 | 2.81E-04 | 7.00E-04 | 6.29E-04 | U | 2.69E-04 | 5.32E-04 | 7.73E-04 | U | -2.47E-04 | 6.74E-04 | 8.52E-04 | U |
| | 4(Avg) | -6.59E-04 | 4.14E-04 | 1.46E-03 | U | 1.20E-03 | 7.34E-04 | 1.10E-03 | +/U | -1.16E-04 | 6.96E-04 | 9.45E-04 | U |
| MLR | 1 | 5.90E-05 | 7.75E-04 | 9.10E-04 | U | 9.52E-05 | 7.05E-04 | 1.08E-03 | U | -6.48E-04 | 4.85E-04 | 1.01E-03 | U |
| | 2 | -2.33E-05 | 4.85E-04 | 7.40E-04 | U | 3.73E-04 | 5.68E-04 | 8.83E-04 | U | 8.04E-04 | 1.09E-03 | 1.13E-03 | U |
| | 3 | 2.53E-05 | 4.69E-04 | 6.21E-04 | U | -1.64E-04 | 1.07E-04 | 7.65E-04 | U | 7.82E-05 | 6.10E-04 | 8.36E-04 | U |
| | 4 | -8.55E-04 | 5.08E-04 | 1.46E-03 | U | -4.05E-04 | 3.38E-04 | 1.12E-03 | U | -3.87E-04 | 8.32E-04 | 1.01E-03 | U |
| SEC | 1 | 3.90E-04 | 8.30E-04 | 8.61E-04 | U | -5.16E-04 | 3.63E-04 | 1.03E-03 | U | 4.91E-04 | 1.09E-03 | 1.08E-03 | U |
| | 2 | -7.45E-05 | 2.74E-04 | 6.70E-04 | U | 6.66E-05 | 3.42E-04 | 8.14E-04 | U | 6.15E-04 | 8.92E-04 | 1.01E-03 | U |
| | 3 | -2.87E-04 | 3.16E-04 | 6.55E-04 | U | -5.33E-05 | 2.63E-04 | 7.98E-04 | U | -2.55E-04 | 4.62E-04 | 8.50E-04 | U |
| | 4 | -8.68E-04 | 6.99E-04 | 1.47E-03 | U | -1.63E-04 | 5.72E-04 | 1.12E-03 | U | -4.18E-04 | 4.81E-04 | 9.30E-04 | U |
| CBD | 1 | -1.21E-04 | 5.82E-04 | 8.41E-04 | U | 3.84E-04 | 7.40E-04 | 1.01E-03 | U | -3.39E-04 | 6.13E-04 | 1.08E-03 | U |
| | 2 | -1.82E-04 | 3.68E-04 | 6.91E-04 | U | 7.80E-05 | 3.65E-04 | 8.34E-04 | U | 9.65E-04 | 1.17E-03 | 1.12E-03 | U |
| | 3 | 9.48E-05 | 4.41E-04 | 6.23E-04 | U | 3.96E-05 | 3.18E-04 | 7.66E-04 | U | -6.05E-05 | 5.42E-04 | 8.80E-04 | U |

# APPENDIX G – Air Sampling Data: Concentrations of Radionuclides in Air Filter Composites

**Updated Table G.1 – 2011 Radionuclide Concentrations (Bq/sample) in Quarterly Composite Air Filters Collected from Locations Surrounding the WIPP Facility**

**See Appendix C for sampling location codes**

| | | $^{238}$Pu | | | | $^{239/240}$Pu | | | | $^{241}$Am | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Location** | **Quarter** | **[RN][(a)]** | **2 σ TPU[(b)]** | **MDC[(c)]** | **Q[(d)]** | **[RN]** | **2 σ TPU** | **MDC** | **Q** | **[RN]** | **2 σ TPU** | **MDC** | **Q** |
| | 4 | -1.24E-03 | 5.45E-04 | 1.49E-03 | U | -2.07E-04 | 5.41E-04 | 1.15E-03 | U | -3.72E-04 | 5.46E-04 | 9.77E-04 | U |
| SMR | 1 (Avg) | 2.61E-04 | 8.23E-04 | 8.89E-04 | U | -1.73E-04 | 5.01E-04 | 1.05E-03 | U | -1.68E-04 | 7.98E-04 | 1.09E-03 | U |
| | 2 | 6.59E-05 | 4.62E-04 | 6.77E-04 | U | -2.71E-05 | 2.58E-04 | 8.20E-04 | U | 7.45E-04 | 9.61E-04 | 1.06E-03 | U |
| | 3 | 6.89E-04 | 7.21E-04 | 6.31E-04 | U | 5.85E-04 | 5.88E-04 | 7.75E-04 | U | -4.85E-05 | 4.93E-04 | 8.56E-04 | U |
| | 4 | -9.77E-04 | 5.18E-04 | 1.44E-03 | U | -6.69E-04 | 1.63E-04 | 1.09E-03 | U | -2.47E-04 | 4.99E-04 | 9.27E-04 | U |
| | **Mean** | -1.59E-04 | 5.41E-04 | 9.06E-04 | | 2.11E-04 | 4.77E-04 | 9.32E-04 | | 6.29E-05 | 7.41E-04 | 9.85E-04 | |
| | **Minimum[(e)]** | -1.24E-03 | 5.45E-04 | 1.49E-03 | | -6.69E-04 | 1.63E-04 | 1.09E-03 | | -6.48E-04 | 4.85E-04 | 1.01E-03 | |
| | **Maximum[(e)]** | 6.89E-04 | 7.21E-04 | 6.31E-04 | | 4.98E-03 | 1.63E-03 | 1.10E-03 | | 9.65E-04 | 1.17E-03 | 1.12E-03 | |
| WAB | 1 | 2.06E-04 | 5.71E-04 | 7.81E-04 | U | 3.11E-04 | 5.19E-04 | 9.47E-04 | U | 3.61E-04 | 8.68E-04 | 1.05E-03 | U |
| (Blank) | 2 | 1.19E-04 | 4.73E-04 | 6.66E-04 | U | 9.87E-05 | 2.22E-04 | 8.09E-04 | U | -4.96E-06 | 4.20E-04 | 9.41E-04 | U |
| | 3 | 6.63E-05 | 3.77E-04 | 6.19E-04 | U | 1.36E-04 | 3.36E-04 | 7.62E-04 | U | 3.14E-04 | 5.02E-04 | 8.15E-04 | U |
| | 4 | 9.66E-04 | 1.03E-03 | 1.54E-03 | U | 6.09E-04 | 6.77E-04 | 1.20E-03 | U | 5.68E-04 | 5.80E-04 | 9.24E-04 | U |

(a) Radionuclide activity of the primary sample. Only radionuclides with activities greater than 2 σ TPU and MDC are considered detections.

(b) 2 times the Total Propagated Uncertainty.

(c) Minimum Detectable Concentration.

(d) Qualifier. Indicates whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

(e) Minimum and maximum reported concentrations for each radionuclide are based on the sample's activity, [RN], while the associated 2 σ TPU and MDC are inherited with the specific [RN].

U/+: Radionuclide detected in one of the duplicates but not the other.

# APPENDIX G – Air Sampling Data: Concentrations of Radionuclides in Air Filter Composites

**Updated Table G.1 – 2011 Radionuclide Concentrations (Bq/sample) in Quarterly Composite Air Filters Collected from Locations Surrounding the WIPP Facility**

**See Appendix C for sampling location codes**

| | | $^{40}K$ | | | | $^{60}Co$ | | | | $^{137}Cs$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Location** | **Quarter** | **[RN][(a)]** | **2 σ TPU[(b)]** | **MDC[(c)]** | **Q[(d)]** | **[RN]** | **2 σ TPU** | **MDC** | **Q[(d)]** | **[RN]** | **2 σ TPU** | **MDC** | **Q[(d)]** |
| WFF | 1 | 7.50E+00 | 1.10E+01 | 1.36E+01 | U | 5.83E-01 | 1.06E+00 | 1.34E+00 | U | 3.73E-01 | 1.35E+00 | 1.56E+00 | U |
| | 2(Avg) | 6.49E+00 | 1.06E+01 | 1.29E+01 | U | 4.43E-01 | 1.05E+00 | 1.27E+00 | U | -8.11E-01 | 1.19E+00 | 1.31E+00 | U |
| | 3 | 7.40E+00 | 6.79E+00 | 8.30E+00 | U | -2.13E-01 | 7.64E-01 | 8.37E-01 | U | -3.20E-01 | 7.62E-01 | 8.14E-01 | U |
| | 4 | 3.05E+00 | 8.47E+00 | 1.03E+01 | U | -1.13E-01 | 9.31E-01 | 1.05E+00 | U | -3.03E-01 | 8.89E-01 | 1.00E+00 | U |
| WEE | 1 | 7.06E+00 | 8.13E+00 | 1.04E+01 | U | 5.08E-01 | 8.64E-01 | 1.08E+00 | U | -1.37E-02 | 1.05E+00 | 1.16E+00 | U |
| | 2 | 6.12E+00 | 1.40E+01 | 1.66E+01 | U | -6.01E-02 | 1.42E+00 | 1.57E+00 | U | 5.32E-01 | 1.59E+00 | 1.78E+00 | U |
| | 3(Avg) | 7.36E+00 | 7.21E+00 | 8.6E+00 | U | 9.41E-02 | 7.48E-01 | 8.5E-01 | U | -3.76E-01 | 7.73E-01 | 8.2E-01 | U |
| | 4 | 7.49E+00 | 1.08E+01 | 1.30E+01 | U | 1.12E-01 | 1.10E+00 | 1.28E+00 | U | -1.03E+00 | 1.36E+00 | 1.34E+00 | U |
| WSS | 1 | 2.22E+00 | 1.11E+01 | 1.31E+01 | U | 2.47E-01 | 1.13E+00 | 1.29E+00 | U | 3.42E-01 | 1.40E+00 | 1.55E+00 | U |
| | 2 | 1.04E+00 | 9.94E+00 | 1.17E+01 | U | -3.42E-01 | 1.08E+00 | 1.18E+00 | U | 6.90E-02 | 1.01E+00 | 1.20E+00 | U |
| | 3 | 5.39E+00 | 7.33E+00 | 8.65E+00 | U | 4.16E-01 | 7.40E-01 | 8.64E-01 | U | 3.36E-01 | 7.12E-01 | 7.99E-01 | U |
| | 4(Avg) | -4.19E-02 | 7.03E+00 | 7.97E+00 | U | 8.67E-02 | 6.96E-01 | 7.99E-01 | U | -4.04E-01 | 7.26E-01 | 7.66E-01 | U |
| MLR | 1 | -6.00E+00 | 1.07E+01 | 1.04E+01 | U | 5.20E-02 | 9.45E-01 | 1.10E+00 | U | 3.88E-01 | 9.88E-01 | 1.13E+00 | U |
| | 2 | 6.80E+00 | 9.23E+00 | 1.17E+01 | U | 9.56E-01 | 9.71E-01 | 1.26E+00 | U | 7.92E-02 | 9.95E-01 | 1.18E+00 | U |
| | 3 | -1.68E+00 | 8.95E+00 | 1.00E+01 | U | -3.77E-02 | 9.97E-01 | 1.14E+00 | U | -3.53E-01 | 9.52E-01 | 1.07E+00 | U |
| | 4 | 1.17E+01 | 7.08E+00 | 1.03E+01 | U | -4.90E-01 | 9.77E-01 | 1.03E+00 | U | -3.12E-01 | 9.41E-01 | 1.07E+00 | U |
| SEC | 1 | 1.61E+01 | 1.12E+01 | 1.44E+01 | U | 3.66E-01 | 1.15E+00 | 1.32E+00 | U | 6.03E-01 | 1.15E+00 | 1.68E+00 | U |
| | 2 | 3.57E+00 | 1.31E+01 | 1.53E+01 | U | 1.10E-01 | 1.54E+00 | 1.75E+00 | U | -1.06E+00 | 1.75E+00 | 1.82E+00 | U |
| | 3 | 4.82E+00 | 7.10E+00 | 8.40E+00 | U | -5.14E-01 | 7.85E-01 | 8.22E-01 | U | -1.54E-01 | 7.23E-01 | 7.85E-01 | U |
| | 4 | 1.03E+01 | 1.01E+01 | 1.26E+01 | U | 4.04E-01 | 1.06E+00 | 1.27E+00 | U | -5.22E-01 | 1.31E+00 | 1.34E+00 | U |
| CBD | 1 | 8.11E-01 | 1.19E+01 | 1.38E+01 | U | 4.51E-01 | 1.17E+00 | 1.35E+00 | U | 6.55E-01 | 1.38E+00 | 1.56E+00 | U |
| | 2 | 9.57E+00 | 9.12E+00 | 1.20E+01 | U | -1.28E+00 | 1.19E+00 | 1.16E+00 | U | 7.64E-01 | 9.67E-01 | 1.20E+00 | U |
| | 3 | 3.08E+00 | 8.28E+00 | 1.01E+01 | U | -3.59E-01 | 9.90E-01 | 1.05E+00 | U | 1.37E+00 | 9.05E+00 | 1.13E+00 | U |

# APPENDIX G – Air Sampling Data: Concentrations of Radionuclides in Air Filter Composites

**Updated Table G.1 – 2011 Radionuclide Concentrations (Bq/sample) in Quarterly Composite Air Filters Collected from Locations Surrounding the WIPP Facility**

**See Appendix C for sampling location codes**

| | | $^{40}$K | | | | $^{60}$Co | | | | $^{137}$Cs | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Location** | **Quarter** | **[RN][a]** | **2 σ TPU[b]** | **MDC[c]** | **Q[d]** | **[RN]** | **2 σ TPU** | **MDC** | **Q[d]** | **[RN]** | **2 σ TPU** | **MDC** | **Q[d]** |
| | 4 | 5.52E+00 | 6.24E+00 | 7.62E+00 | U | -4.87E-01 | 7.27E-01 | 7.61E-01 | U | -5.82E-01 | 7.38E-01 | 7.65E-01 | U |
| SMR | 1 (Avg) | 1.00E+01 | 9.33E+00 | 1.15E+01 | U | -1.90E-02 | 9.90E-01 | 1.10E+00 | U | -5.08E-01 | 1.14E+00 | 1.17E+00 | U |
| | 2 | 8.13E+00 | 1.22E+01 | 1.47E+01 | U | -3.69E-01 | 1.31E+00 | 1.46E+00 | U | 1.28E+00 | 1.31E+00 | 1.60E+00 | U |
| | 3 | -5.94E+00 | 7.27E+00 | 7.38E+00 | U | 4.87E-01 | 7.03E-01 | 8.34E-01 | U | -2.09E-01 | 6.94E-01 | 7.46E-01 | U |
| | 4 | 8.33E+00 | 6.55E+00 | 8.13E+00 | U | 3.55E-01 | 6.70E-01 | 7.94E-01 | U | -6.74E-01 | 7.70E-01 | 7.89E-01 | U |
| | **Mean** | 5.22E+00 | 9.31E+00 | 1.12E+01 | | 4.95E-02 | 9.91E-01 | 1.13E+00 | | -3.01E-02 | 1.35E+00 | 1.18E+00 | |
| | **Minimum[e]** | -6.00E+00 | 1.07E+01 | 1.04E+01 | | -1.28E+00 | 1.19E+00 | 1.16E+00 | | -1.06E+00 | 1.75E+00 | 1.82E+00 | |
| | **Maximum[e]** | 1.61E+01 | 1.12E+01 | 1.44E+01 | | 9.56E-01 | 9.71E-01 | 1.26E+00 | | 1.37E+00 | 9.05E+00 | 1.13E+00 | |
| WAB | 1 | -5.57E-01 | 8.72E+00 | 9.93E+00 | U | 3.53E-01 | 7.58E-01 | 9.06E-01 | U | -3.43E-01 | 8.68E-01 | 9.08E-01 | U |
| (Blank) | 2 | 4.64E+00 | 1.40E+01 | 1.65E+01 | U | -9.30E-01 | 1.62E+00 | 1.67E+00 | U | 2.61E-01 | 1.58E+00 | 1.77E+00 | U |
| | 3 | -7.06E-01 | 7.12E+00 | 7.96E+00 | U | -1.66E-01 | 7.33E-01 | 8.08E-01 | U | 7.33E-01 | 6.78E-01 | 7.75E-01 | U |
| | 4 | -3.56E+00 | 8.86E+00 | 9.49E+00 | U | 1.13E-01 | 8.85E-01 | 1.04E+00 | U | -1.65E-01 | 8.93E-01 | 1.02E+00 | U |

(a) Radionuclide activity of the primary sample. Only radionuclides with activities greater than 2 σ TPU and MDC are considered detections.

(b) 2 times the Total Propagated Uncertainty.

(c) Minimum Detectable Concentration.

(d) Qualifier. Indicates whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

(e) Minimum and maximum reported concentrations for each radionuclide are based on the sample's activity, [RN], while the associated 2 σ TPU and MDC are inherited with the specific [RN].

# APPENDIX G – Air Sampling Data: Concentrations of Radionuclides in Air Filter Composites

**Updated Table G.1 – 2011 Radionuclide Concentrations (Bq/sample) in Quarterly Composite Air Filters Collected from Locations Surrounding the WIPP Facility**

**See Appendix C for sampling location codes**

| | | $^{90}$Sr | | | |
|---|---|---|---|---|---|
| **Location** | **Quarter** | **[RN][(a)]** | **2 σ TPU[(b)]** | **MDC[(c)]** | **Q[(d)]** |
| WFF | 1 | -8.34E-03 | 3.60E-02 | 4.24E-02 | U |
| | 2(Avg) | 1.39E-02 | 2.91E-02 | 3.59E-02 | U |
| | 3 | -4.22E-03 | 3.11E-02 | 2.65E-02 | U |
| | 4 | -1.78E-03 | 2.74E-02 | 3.78E-02 | U |
| WEE | 1 | -2.06E-02 | 3.78E-02 | 4.27E-02 | U |
| | 2 | -1.18E-02 | 2.81E-02 | 3.59E-02 | U |
| | 3(Avg) | -1.90E-03 | 3.09E-02 | 2.65E-02 | U |
| | 4 | -1.60E-02 | 2.77E-02 | 3.78E-02 | U |
| WSS | 1 | -2.58E-02 | 3.78E-02 | 4.27E-02 | U |
| | 2 | -6.70E-03 | 2.84E-02 | 3.59E-02 | U |
| | 3 | 3.26E-02 | 3.87E-02 | 2.72E-02 | U |
| | 4(Avg) | -2.74E-02 | 2.68E-02 | 3.77E-02 | U |
| MLR | 1 | -2.24E-02 | 3.60E-02 | 4.25E-02 | U |
| | 2 | -1.31E-02 | 2.77E-02 | 3.59E-02 | U |
| | 3 | 2.31E-02 | 3.07E-02 | 2.65E-02 | U |
| | 4 | -3.96E-04 | 2.59E-02 | 3.76E-02 | U |
| SEC | 1 | -9.18E-03 | 3.67E-02 | 4.24E-02 | U |
| | 2 | -2.10E-02 | 2.85E-02 | 3.60E-02 | U |
| | 3 | 9.52E-03 | 3.17E-02 | 2.65E-02 | U |
| | 4 | -6.97E-03 | 2.71E-02 | 3.77E-02 | U |
| CBD | 1 | -7.27E-03 | 3.81E-02 | 4.26E-02 | U |
| | 2 | -2.05E-03 | 2.85E-02 | 3.60E-02 | U |
| | 3 | -1.64E-02 | 2.95E-02 | 2.64E-02 | U |

# APPENDIX G – Air Sampling Data: Concentrations of Radionuclides in Air Filter Composites

**Updated Table G.1 – 2011 Radionuclide Concentrations (Bq/sample) in Quarterly Composite Air Filters Collected from Locations Surrounding the WIPP Facility**

**See Appendix C for sampling location codes**

| | | $^{90}$Sr | | | |
|---|---|---|---|---|---|
| **Location** | **Quarter** | **[RN][(a)]** | **2 σ TPU[(b)]** | **MDC[(c)]** | **Q[(d)]** |
| | 4 | -4.88E-03 | 2.72E-02 | 3.78E-02 | U |
| SMR | 1 (Avg) | -1.08E-02 | 3.84E-02 | 4.27E-02 | U |
| | 2 | -5.39E-03 | 2.83E-02 | 3.60E-02 | U |
| | 3 | 1.19E-02 | 3.14E-02 | 2.65E-02 | U |
| | 4 | -3.82E-02 | 2.76E-02 | 3.77E-02 | U |
| | **Mean** | -6.84E-03 | 3.12E-02 | 3.57E-02 | |
| | **Minimum[(e)]** | -3.82E-02 | 2.76E-02 | 3.77E-02 | |
| | **Maximum[(e)]** | 3.26E-02 | 3.87E-02 | 2.72E-02 | |
| WAB | 1 | -1.04E-02 | 2.63E-02 | 4.26E-02 | U |
| (Blank) | 2 | 2.05E-03 | 2.05E-02 | 3.60E-02 | U |
| | 3 | 0.00E+00 | 2.26E-02 | 2.66E-02 | U |
| | 4 | 2.12E-02 | 1.84E-02 | 3.77E-02 | U |

(a) Radionuclide activity of the primary sample. Only radionuclides with activities greater than 2 σ TPU and MDC are considered detections.

(b) 2 times the Total Propagated Uncertainty.

(c) Minimum Detectable Concentration.

(d) Qualifier. Indicates whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

(e) Minimum and maximum reported concentrations for each radionuclide are based on the sample's activity, [RN], while the associated 2 σ TPU and MDC are inherited with the specific [RN].

# APPENDIX G – Air Sampling Data: Concentrations of Radionuclides in Air Filter Composites

**Updated Table G.2 – 2011 Radionuclide Concentrations (Bq/m$^3$) in Quarterly Composite Air Filters Collected from Locations Surrounding the WIPP Facility**

**See Appendix C for sampling location codes**

| | | | $^{233/234}$U | | $^{235}$U | | $^{238}$U | | $^{238}$Pu | | $^{239/240}$Pu | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Location** | **Quarter** | **Vol, m$^3$** | **Bq/sample** | **Bq/m$^3$** | **Bq/sample** | **Bq/m$^3$** | **Bq/sample** | **Bq/m$^3$** | **Bq/sample** | **Bq/m$^3$** | **Bq/sample** | **Bq/m$^3$** |
| WFF | 1 | 6966.016 | 5.75E-03 | 8.26E-07 | 1.06E-03 | 1.52E-07 | 4.79E-03 | 6.87E-07 | -2.40E-04 | -3.45E-08 | 4.43E-04 | 6.36E-08 |
| | 2(Avg) | 7090.234 | 2.77E-03 | 3.91E-07 | 3.46E-04 | 4.89E-08 | 1.28E-03 | 1.80E-07 | 2.06E-04 | 2.90E-08 | -6.52E-05 | -9.19E-09 |
| | 3 | 7486.137 | 2.46E-04 | 3.28E-08 | 7.39E-04 | 9.87E-08 | 4.35E-03 | 5.81E-07 | -4.74E-04 | -6.33E-08 | 4.42E-04 | 5.90E-08 |
| | 4 | 7396.919 | 4.25E-03 | 5.74E-07 | 6.77E-04 | 9.15E-08 | 1.44E-03 | 1.94E-07 | -1.76E-04 | -2.38E-08 | 4.98E-03 | 6.73E-07 |
| WEE | 1 | 7362.723 | 3.61E-03 | 4.91E-07 | 9.22E-04 | 1.25E-07 | 5.73E-03 | 7.78E-07 | 3.62E-04 | 4.91E-08 | -2.94E-04 | -4.00E-08 |
| | 2 | 7346.379 | 1.27E-03 | 1.73E-07 | 5.35E-04 | 7.28E-08 | 1.85E-03 | 2.52E-07 | -1.52E-04 | -2.07E-08 | 2.23E-05 | 3.04E-09 |
| | 3(Avg) | 7469.495 | 2.82E-03 | 3.77E-07 | 6.99E-04 | 9.35E-08 | 4.51E-03 | 6.04E-07 | 2.44E-04 | 3.27E-08 | 1.13E-04 | 1.51E-08 |
| | 4 | 7417.72 | 4.01E-03 | 5.40E-07 | 3.21E-04 | 4.32E-08 | 1.79E-03 | 2.41E-07 | -1.21E-03 | -1.63E-07 | -4.83E-05 | -6.51E-09 |
| WSS | 1 | 7380.306 | -1.44E-04 | -1.95E-08 | 1.28E-03 | 1.73E-07 | 7.80E-03 | 1.06E-06 | 3.07E-04 | 4.16E-08 | -1.94E-04 | -2.62E-08 |
| | 2 | 6951.249 | 6.71E-04 | 9.65E-08 | 6.21E-04 | 8.93E-08 | 3.28E-03 | 4.71E-07 | 1.01E-04 | 1.45E-08 | -1.92E-04 | -2.75E-08 |
| | 3 | 7541.744 | 1.73E-03 | 2.29E-07 | 7.05E-04 | 9.35E-08 | 6.03E-03 | 8.00E-07 | 2.81E-04 | 3.73E-08 | 2.69E-04 | 3.56E-08 |
| | 4(Avg) | 7385.407 | 3.31E-03 | 4.48E-07 | 5.53E-04 | 7.48E-08 | 3.25E-03 | 4.40E-07 | -6.59E-04 | -8.92E-08 | 1.20E-03 | 1.62E-07 |
| MLR | 1 | 7375.414 | 1.78E-02 | 2.41E-06 | 1.15E-03 | 1.56E-07 | 1.32E-02 | 1.79E-06 | 5.90E-05 | 8.00E-09 | 9.52E-05 | 1.29E-08 |
| | 2 | 6947.436 | 1.00E-03 | 1.45E-07 | 2.10E-04 | 3.02E-08 | 1.09E-03 | 1.57E-07 | -2.33E-05 | -3.35E-09 | 3.73E-04 | 5.37E-08 |
| | 3 | 7483.615 | 3.34E-03 | 4.46E-07 | 1.65E-04 | 2.20E-08 | 5.07E-03 | 6.77E-07 | 2.53E-05 | 3.38E-09 | -1.64E-04 | -2.19E-08 |
| | 4 | 7393.431 | 4.53E-03 | 6.13E-07 | 5.67E-04 | 7.67E-08 | 7.65E-04 | 1.04E-07 | -8.55E-04 | -1.16E-07 | -4.05E-04 | -5.48E-08 |
| SEC | 1 | 7400.121 | 4.47E-03 | 6.04E-07 | 2.82E-04 | 3.82E-08 | 5.65E-03 | 7.63E-07 | 3.90E-04 | 5.26E-08 | -5.16E-04 | -6.97E-08 |
| | 2 | 7292.853 | 2.05E-03 | 2.82E-07 | 7.62E-04 | 1.05E-07 | 1.52E-03 | 2.09E-07 | -7.45E-05 | -1.02E-08 | 6.66E-05 | 9.14E-09 |
| | 3 | 7407.089 | 4.41E-03 | 5.95E-07 | 3.94E-04 | 5.32E-08 | 4.57E-03 | 6.17E-07 | -2.87E-04 | -3.87E-08 | -5.33E-05 | -7.19E-09 |
| | 4 | 7388.857 | 1.03E-02 | 1.39E-06 | 6.16E-04 | 8.34E-08 | 3.83E-03 | 5.18E-07 | -8.68E-04 | -1.18E-07 | -1.63E-04 | -2.21E-08 |
| CBD | 1 | 7428.103 | 4.01E-03 | 5.39E-07 | 1.08E-03 | 1.45E-07 | 5.15E-03 | 6.93E-07 | -1.21E-04 | -1.63E-08 | 3.84E-04 | 5.17E-08 |
| | 2 | 7275.10 | 7.12E-03 | 9.78E-07 | 5.46E-04 | 7.50E-08 | 6.09E-03 | 8.37E-07 | -1.82E-04 | -2.50E-08 | 7.80E-05 | 1.07E-08 |

# APPENDIX G – Air Sampling Data: Concentrations of Radionuclides in Air Filter Composites

### Updated Table G.2 – 2011 Radionuclide Concentrations ($Bq/m^3$) in Quarterly Composite Air Filters Collected from Locations Surrounding the WIPP Facility

**See Appendix C for sampling location codes**

| | | | $^{233/234}U$ | | $^{235}U$ | | $^{238}U$ | | $^{238}Pu$ | | $^{239/240}Pu$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Location** | **Quarter** | **Vol, $m^3$** | **Bq/sample** | **$Bq/m^3$** | **Bq/sample** | **$Bq/m^3$** | **Bq/sample** | **$Bq/m^3$** | **Bq/sample** | **$Bq/m^3$** | **Bq/sample** | **$Bq/m^3$** |
| | 3 | 7470.519 | 4.78E-03 | 6.40E-07 | 5.02E-04 | 6.72E-08 | 8.31E-03 | 1.11E-06 | 9.48E-05 | 1.27E-08 | 3.96E-05 | 5.30E-09 |
| | 4 | 7441.539 | 8.07E-03 | 1.08E-06 | 1.41E-04 | 1.89E-08 | 4.74E-03 | 6.37E-07 | -1.24E-03 | -1.67E-07 | -2.07E-04 | -2.78E-08 |
| SMR | 1 (Avg) | 7298.868 | 1.03E-02 | 1.41E-06 | 1.05E-03 | 1.44E-07 | 9.21E-03 | 1.26E-06 | 2.61E-04 | 3.57E-08 | -1.73E-04 | -2.37E-08 |
| | 2 | 7211.162 | 5.37E-03 | 7.45E-07 | 6.17E-04 | 8.56E-08 | 6.95E-03 | 9.64E-07 | 6.59E-05 | 9.14E-09 | -2.71E-05 | -3.75E-09 |
| | 3 | 7407.778 | 7.49E-03 | 1.01E-06 | 7.09E-04 | 9.57E-08 | 8.52E-03 | 1.15E-06 | 6.89E-04 | 9.31E-08 | 5.85E-04 | 7.89E-08 |
| | 4 | 7231.398 | 5.93E-03 | 8.20E-07 | 4.61E-04 | 6.37E-08 | 4.31E-03 | 5.96E-07 | -9.77E-04 | -1.35E-07 | -6.69E-04 | -9.25E-08 |
| **Mean** | | 7330.272 | 4.68E-03 | 6.38E-07 | 6.32E-04 | 8.63E-08 | 4.82E-03 | 6.56E-07 | -1.59E-04 | -2.16E-08 | 2.11E-04 | 2.86E-08 |
| **Minimum** | | 6947.436 | -1.44E-04 | -1.95E-08 | 1.41E-04 | 1.89E-08 | 7.65E-04 | 1.04E-07 | -1.24E-03 | -1.67E-07 | -6.69E-04 | -9.25E-08 |
| **Maximum** | | 7541.744 | 1.78E-02 | 2.41E-06 | 1.28E-03 | 1.73E-07 | 1.32E-02 | 1.79E-06 | 6.89E-04 | 9.31E-08 | 4.98E-03 | 6.73E-07 |

# APPENDIX G – Air Sampling Data: Concentrations of Radionuclides in Air Filter Composites

**Updated Table G.2, continued – 2011 Radionuclide Concentrations (Bq/m3) in Quarterly Composite Air Filters Collected from Locations Surrounding the WIPP Facility**

**See Appendix C for sampling location codes**

| | | | $^{241}$Am | | $^{90}$Sr | | $^{40}$K | | $^{60}$Co | | $^{137}$Cs | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Location** | **Quarter** | **Vol, m$^3$** | **Bq/sample** | **Bq/m$^3$** | **Bq/sample** | **Bq/m$^3$** | **Bq/sample** | **Bq/m$^3$** | **Bq/sample** | **Bq/m$^3$** | **Bq/sample** | **Bq/m$^3$** |
| WFF | 1 | 6966.016 | 3.28E-04 | 4.70E-08 | -8.34E-03 | -1.20E-06 | 7.50E+00 | 1.08E-03 | 5.83E-01 | 8.36E-05 | 3.73E-01 | 5.35E-05 |
| | 2(Avg) | 7090.234 | 4.99E-04 | 7.04E-08 | 1.39E-02 | 1.96E-06 | 6.49E+00 | 9.16E-04 | 4.43E-01 | 6.25E-05 | -8.11E-01 | -1.14E-04 |
| | 3 | 7486.137 | 1.93E-04 | 2.58E-08 | -4.22E-03 | -5.63E-07 | 7.40E+00 | 9.89E-04 | -2.13E-01 | -2.84E-05 | -3.20E-01 | -4.28E-05 |
| | 4 | 7396.919 | -7.66E-07 | -1.04E-10 | -1.78E-03 | -2.41E-07 | 3.05E+00 | 4.13E-04 | -1.13E-01 | -1.53E-05 | -3.03E-01 | -4.10E-05 |
| WEE | 1 | 7362.723 | -1.99E-04 | -2.71E-08 | -2.06E-02 | -2.80E-06 | 7.06E+00 | 9.59E-04 | 5.08E-01 | 6.91E-05 | -1.37E-02 | -1.86E-06 |
| | 2 | 7346.379 | 8.77E-04 | 1.19E-07 | -1.18E-02 | -1.61E-06 | 6.12E+00 | 8.32E-04 | -6.01E-02 | -8.18E-06 | 5.32E-01 | 7.24E-05 |
| | 3(Avg) | 7469.495 | 1.21E-04 | 1.62E-08 | -1.90E-03 | -2.54E-07 | 7.36E+00 | 9.85E-04 | 9.41E-02 | 1.26E-05 | -3.76E-01 | -5.04E-05 |
| | 4 | 7417.72 | 3.09E-04 | 4.17E-08 | -1.60E-02 | -2.16E-06 | 7.49E+00 | 1.01E-03 | 1.12E-01 | 1.51E-05 | -1.03E+00 | -1.39E-04 |
| WSS | 1 | 7380.306 | -4.68E-04 | -6.34E-08 | -2.58E-02 | -3.50E-06 | 2.22E+00 | 3.01E-04 | 2.47E-01 | 3.35E-05 | 3.42E-01 | 4.63E-05 |
| | 2 | 6951.249 | -2.93E-04 | -4.21E-08 | -6.70E-03 | -9.64E-07 | 1.04E+00 | 1.49E-04 | -3.42E-01 | -4.92E-05 | 6.90E-02 | 9.93E-06 |
| | 3 | 7541.744 | -2.47E-04 | -3.27E-08 | 3.26E-02 | 4.33E-06 | 5.39E+00 | 7.15E-04 | 4.16E-01 | 5.51E-05 | 3.36E-01 | 4.46E-05 |
| | 4(Avg) | 7385.407 | -1.16E-04 | -1.57E-08 | -2.74E-02 | -3.70E-06 | -4.19E-02 | -5.68E-06 | 8.67E-02 | 1.17E-05 | -4.04E-01 | -5.47E-05 |
| MLR | 1 | 7375.414 | -6.48E-04 | -8.78E-08 | -2.24E-02 | -3.04E-06 | -6.00E+00 | -8.14E-04 | 5.20E-02 | 7.05E-06 | 3.88E-01 | 5.26E-05 |
| | 2 | 6947.436 | 8.04E-04 | 1.16E-07 | -1.31E-02 | -1.89E-06 | 6.80E+00 | 9.79E-04 | 9.56E-01 | 1.38E-04 | 7.92E-02 | 1.14E-05 |
| | 3 | 7483.615 | 7.82E-05 | 1.04E-08 | 2.31E-02 | 3.09E-06 | -1.68E+00 | -2.24E-04 | -3.77E-02 | -5.04E-06 | -3.53E-01 | -4.71E-05 |
| | 4 | 7393.431 | -3.87E-04 | -5.23E-08 | -3.96E-04 | -5.36E-08 | 1.17E+01 | 1.58E-03 | -4.90E-01 | -6.62E-05 | -3.12E-01 | -4.22E-05 |
| SEC | 1 | 7400.121 | 4.91E-04 | 6.63E-08 | -9.18E-03 | -1.24E-06 | 1.61E+01 | 2.18E-03 | 3.66E-01 | 4.95E-05 | 6.03E-01 | 8.15E-05 |
| | 2 | 7292.853 | 6.15E-04 | 8.44E-08 | -2.10E-02 | -2.88E-06 | 3.57E+00 | 4.90E-04 | 1.10E-01 | 1.51E-05 | -1.06E+00 | -1.46E-04 |
| | 3 | 7407.089 | -2.55E-04 | -3.45E-08 | 9.52E-03 | 1.29E-06 | 4.82E+00 | 6.51E-04 | -5.14E-01 | -6.94E-05 | -1.54E-01 | -2.07E-05 |
| | 4 | 7388.857 | -4.18E-04 | -5.65E-08 | -6.97E-03 | -9.43E-07 | 1.03E+01 | 1.40E-03 | 4.04E-01 | 5.47E-05 | -5.22E-01 | -7.06E-05 |
| CBD | 1 | 7428.103 | -3.39E-04 | -4.56E-08 | -7.27E-03 | -9.79E-07 | 8.11E-01 | 1.09E-04 | 4.51E-01 | 6.07E-05 | 6.55E-01 | 8.82E-05 |
| | 2 | 7275.10 | 9.65E-04 | 1.33E-07 | -2.05E-03 | -2.82E-07 | 9.57E+00 | 1.32E-03 | -1.28E+00 | -1.76E-04 | 7.64E-01 | 1.05E-04 |
| | 3 | 7470.519 | -6.05E-05 | -8.10E-09 | -1.64E-02 | -2.20E-06 | 3.08E+00 | 4.13E-04 | -3.59E-01 | -4.81E-05 | 1.37E+00 | 1.84E-04 |
| | 4 | 7441.539 | -3.72E-04 | -5.00E-08 | -4.88E-03 | -6.56E-07 | 5.52E+00 | 7.42E-04 | -4.87E-01 | -6.54E-05 | -5.82E-01 | -7.82E-05 |
| SMR | 1 (Avg) | 7298.868 | -1.68E-04 | -2.31E-08 | -1.08E-02 | -1.47E-06 | 1.00E+01 | 1.37E-03 | -1.90E-02 | -2.60E-06 | -5.08E-01 | -6.95E-05 |
| | 2 | 7211.162 | 7.45E-04 | 1.03E-07 | -5.39E-03 | -7.48E-07 | 8.13E+00 | 1.13E-03 | -3.69E-01 | -5.12E-05 | 1.28E+00 | 1.77E-04 |

# APPENDIX G – Air Sampling Data: Concentrations of Radionuclides in Air Filter Composites

**Updated Table G.2, continued – 2011 Radionuclide Concentrations (Bq/m3) in Quarterly Composite Air Filters Collected from Locations Surrounding the WIPP Facility**

**See Appendix C for sampling location codes**

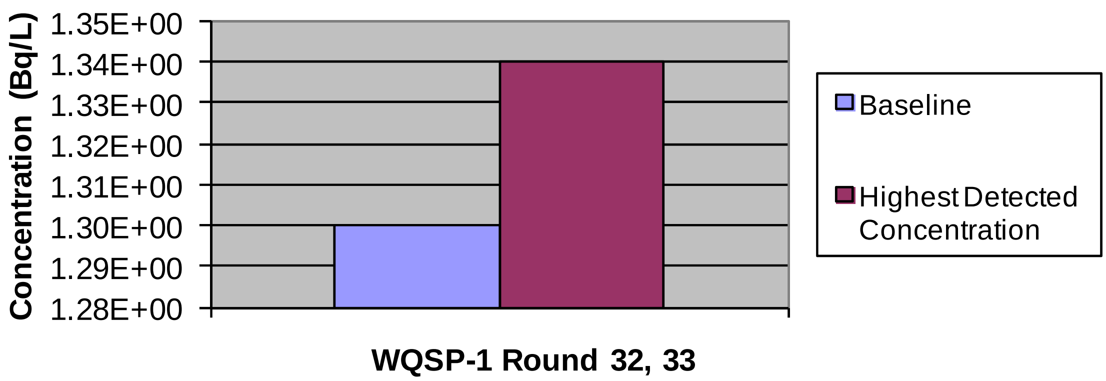
| | | | $^{241}$Am | | $^{90}$Sr | | $^{40}$K | | $^{60}$Co | | $^{137}$Cs | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Location** | **Quarter** | **Vol, $m^3$** | **Bq/sample** | **Bq/$m^3$** | **Bq/sample** | **Bq/$m^3$** | **Bq/sample** | **Bq/$m^3$** | **Bq/sample** | **Bq/$m^3$** | **Bq/sample** | **Bq/$m^3$** |
| | 3 | 7407.778 | -4.85E-05 | -6.55E-09 | 1.19E-02 | 1.61E-06 | -5.94E+00 | -8.02E-04 | 4.87E-01 | 6.57E-05 | -2.09E-01 | -2.83E-05 |
| | 4 | 7231.398 | -2.47E-04 | -3.41E-08 | -3.82E-02 | -5.28E-06 | 8.33E+00 | 1.15E-03 | 3.55E-01 | 4.91E-05 | -6.74E-01 | -9.31E-05 |
| **Mean** | | 7330.272 | 6.29E-05 | 9.06E-09 | -6.84E-03 | -9.42E-07 | 5.22E+00 | 7.15E-04 | 4.95E-02 | 7.05E-06 | -3.01E-02 | -4.05E-06 |
| **Minimum** | | 6947.436 | -6.48E-04 | -8.78E-08 | -3.82E-02 | -5.28E-06 | -6.00E+00 | -8.14E-04 | -1.28E+00 | -1.76E-04 | -1.06E+00 | -1.46E-04 |
| **Maximum** | | 7541.744 | 9.65E-04 | 1.33E-07 | 3.26E-02 | 4.33E-06 | 1.61E+01 | 2.18E-03 | 9.56E-01 | 1.38E-04 | 1.37E+00 | 1.84E-04 |

# APPENDIX H – Comparison of Detected Radionuclides to the Radiological Baseline

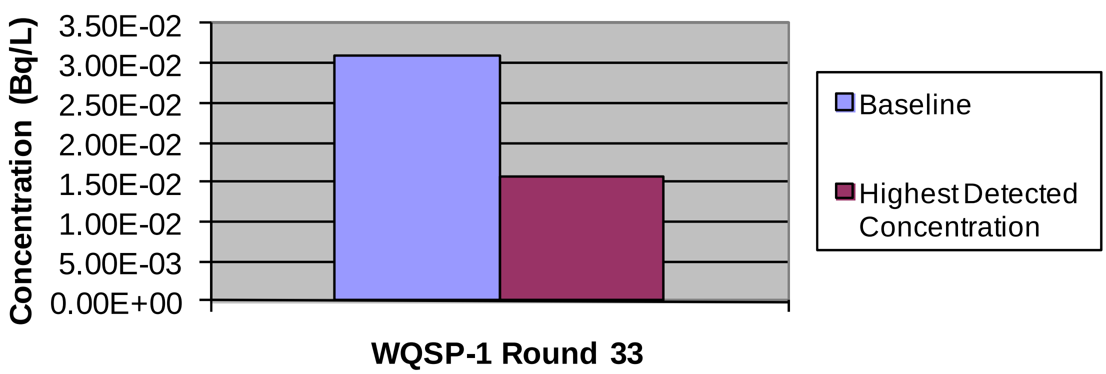
APPENDIX H – Comparison of Detected Radionuclides to the Radiological Baseline

The figures in this appendix show the highest detected radionuclides from 2011 environmental monitoring sample analysis results compared to the 99 percent confidence interval radiological baseline values established for these isotopes (DOE/WIPP-92-037). Figures address groundwater, surface water, sediment, soil, and vegetation results. Note: all results with the exception of vegetation were compared to the baseline upper 99 percentile probability value. The baseline did not include probability distributions for vegetation; therefore, vegetation sample results are compared to the baseline mean values. A detailed discussion of environmental monitoring radionuclide sample results is presented in Chapter 4.

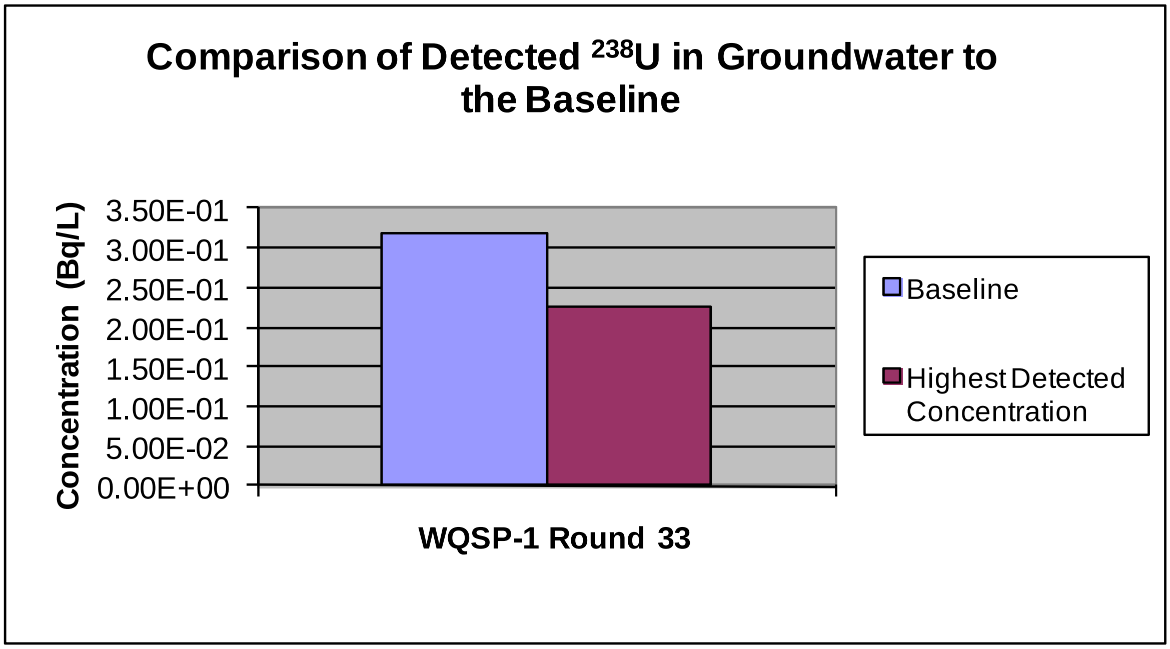
**Comparison of Detected $^{233/234}U$ in Groundwater to the Baseline**

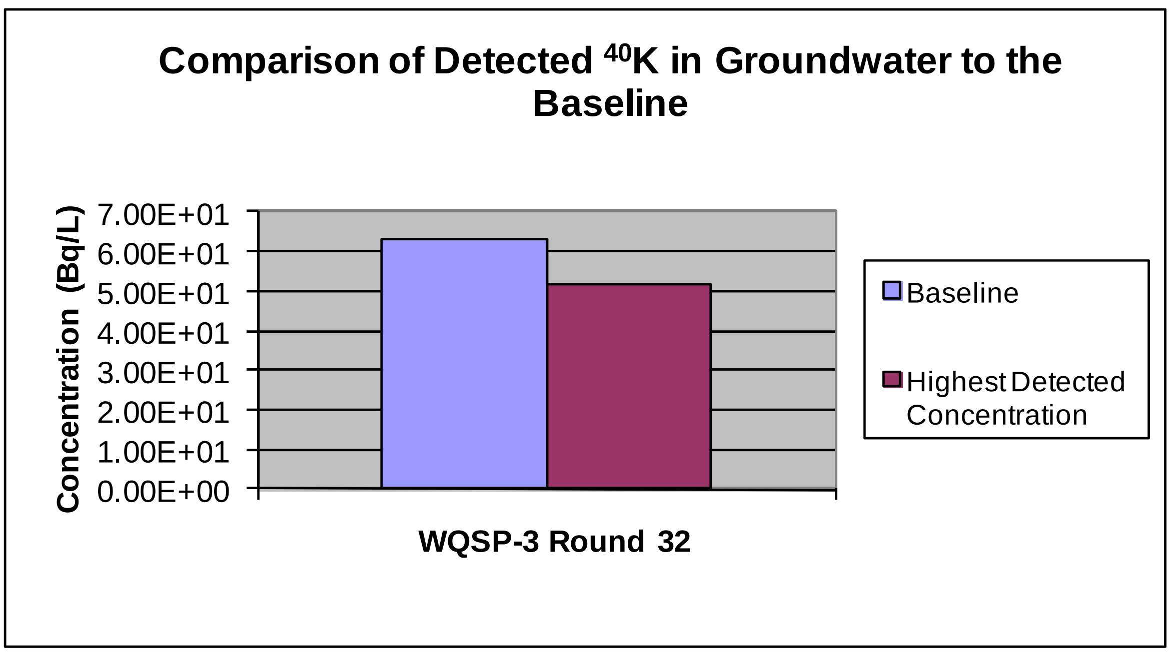



**Comparison of Detected $^{235}U$ in Groundwater to the Baseline**



APPENDIX H – Comparison of Detected Radionuclides to the Radiological Baseline



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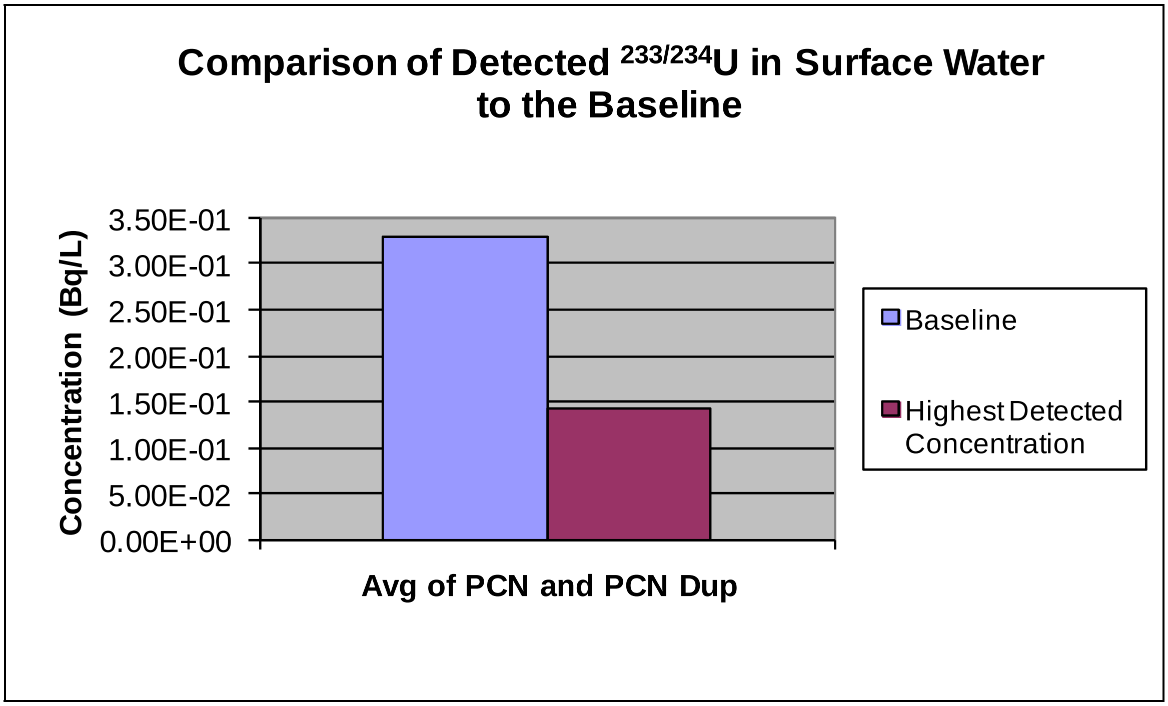


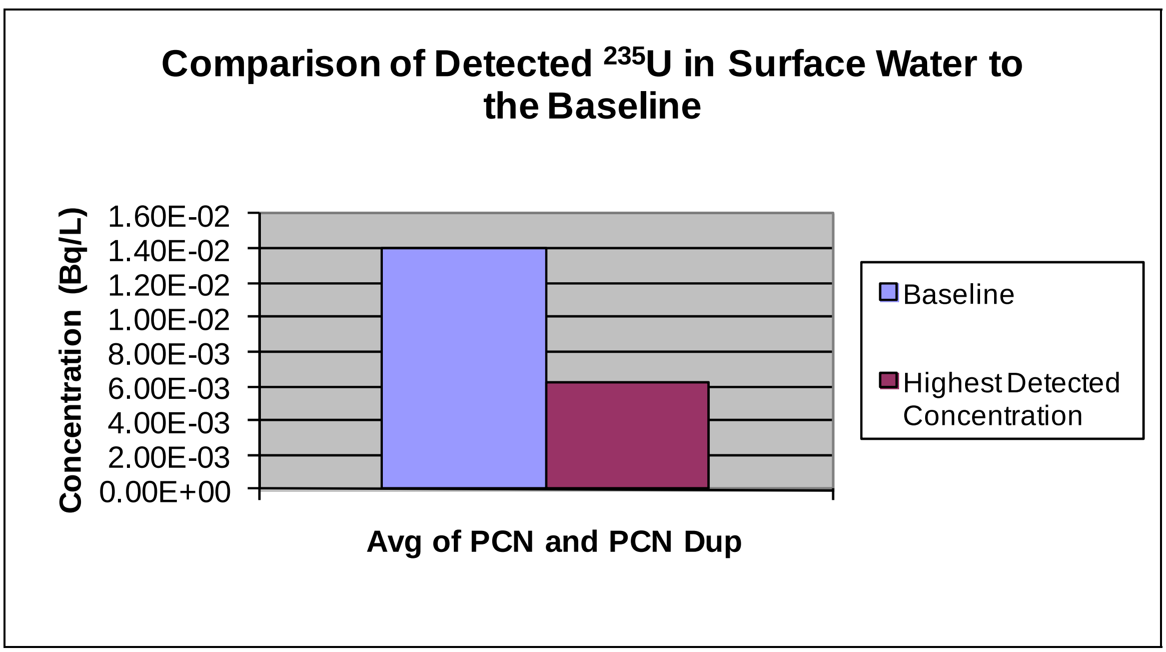

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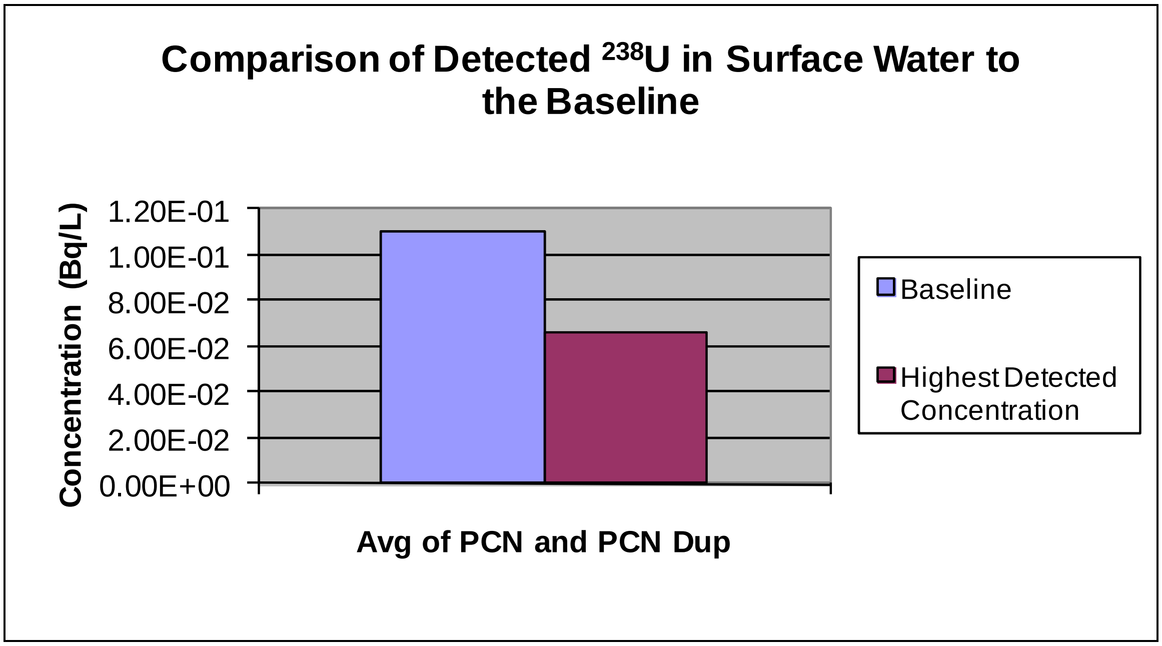


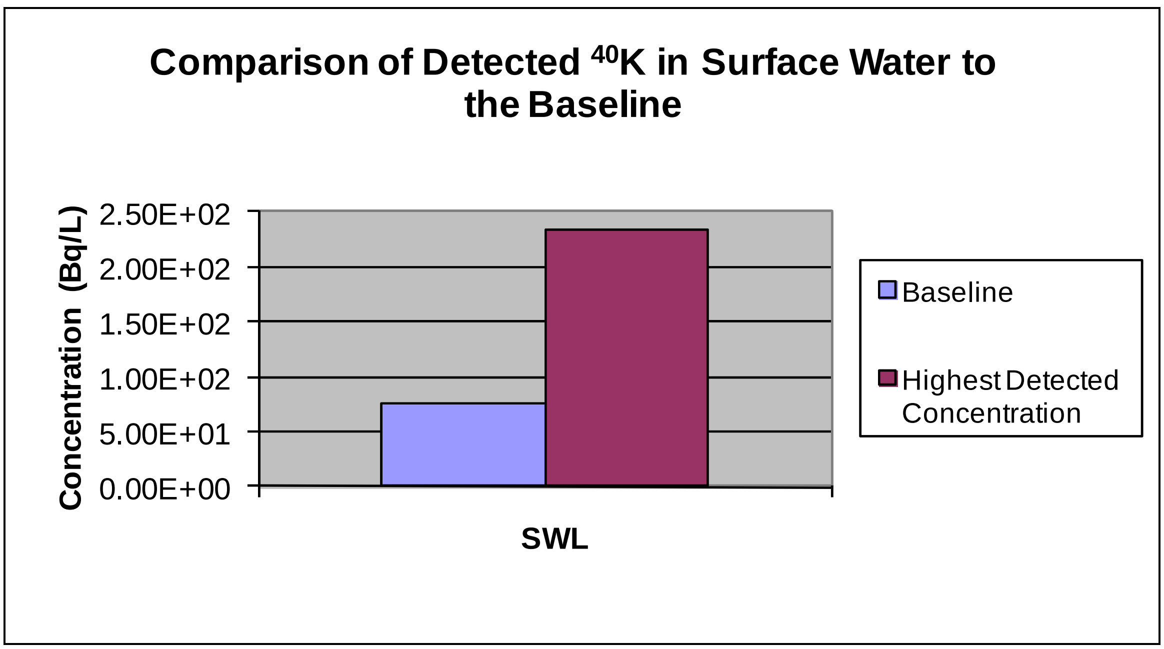

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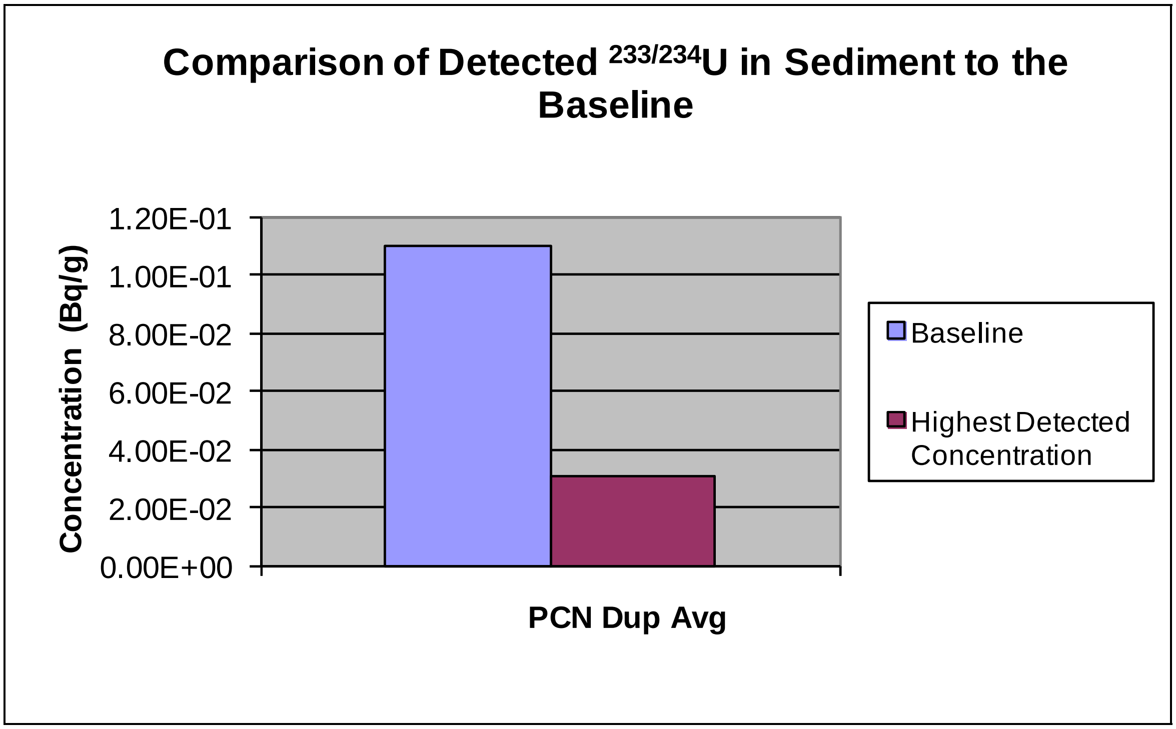


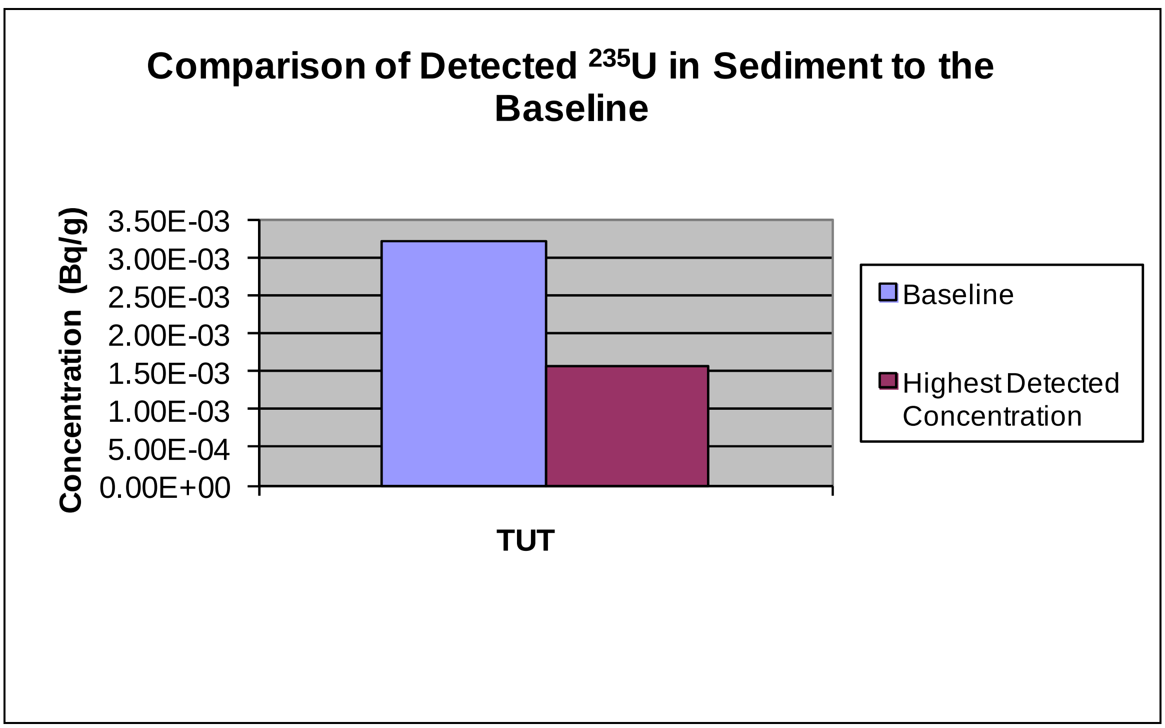

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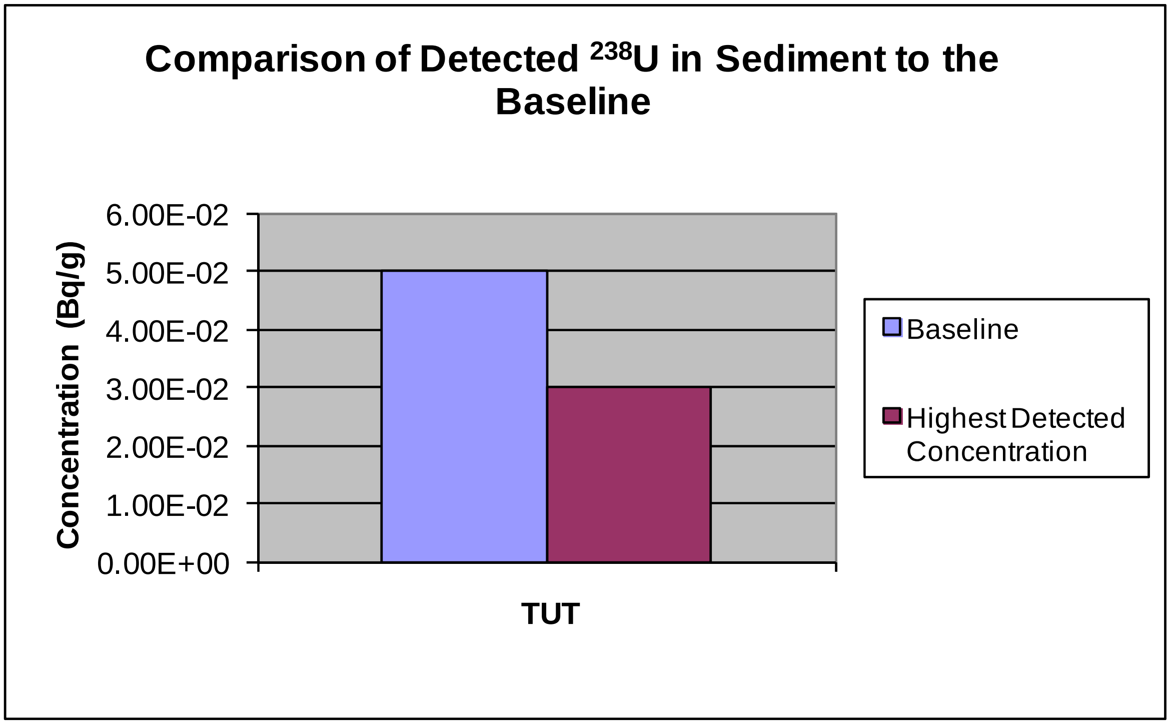


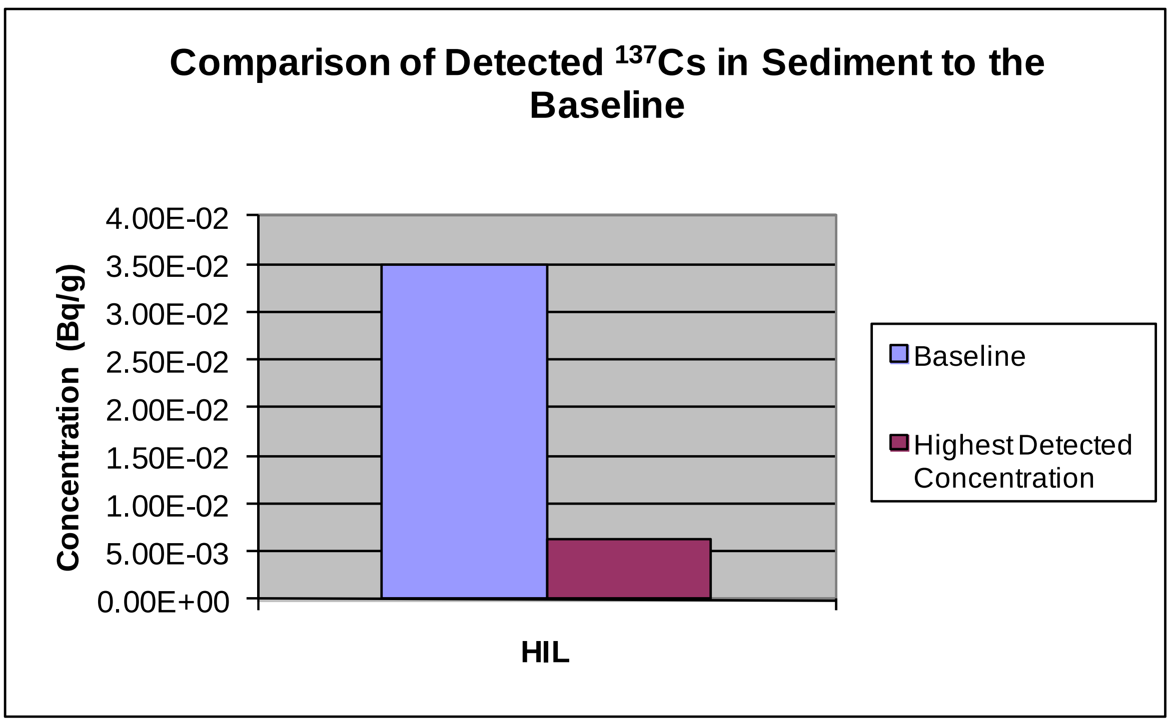

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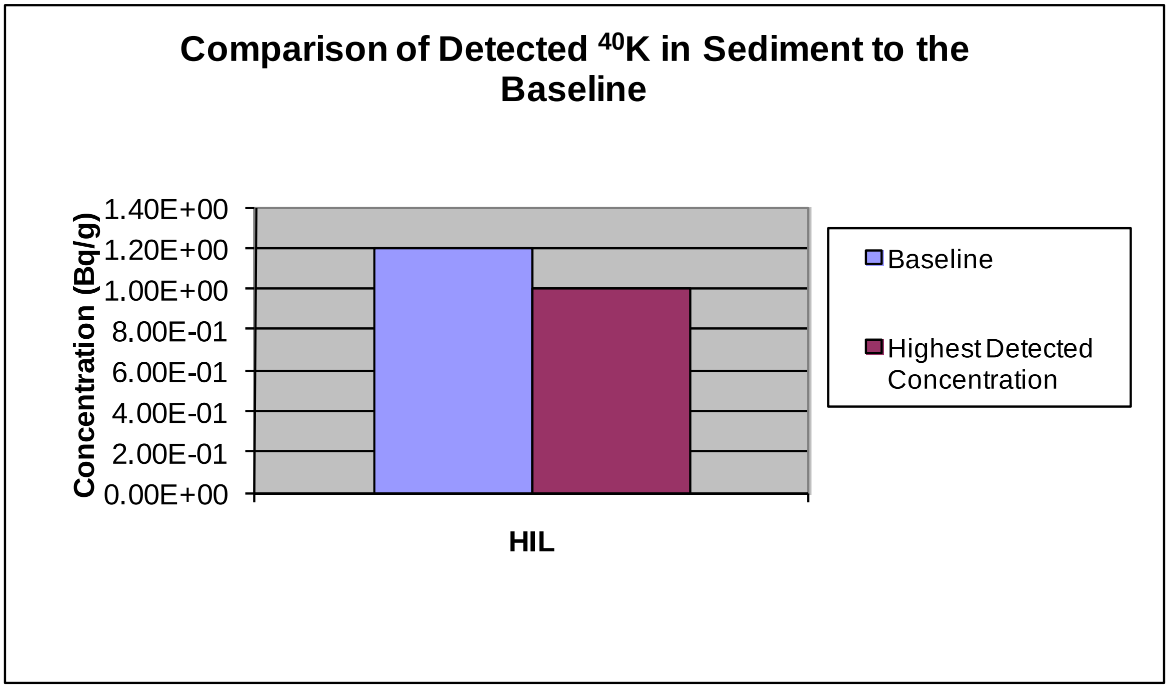


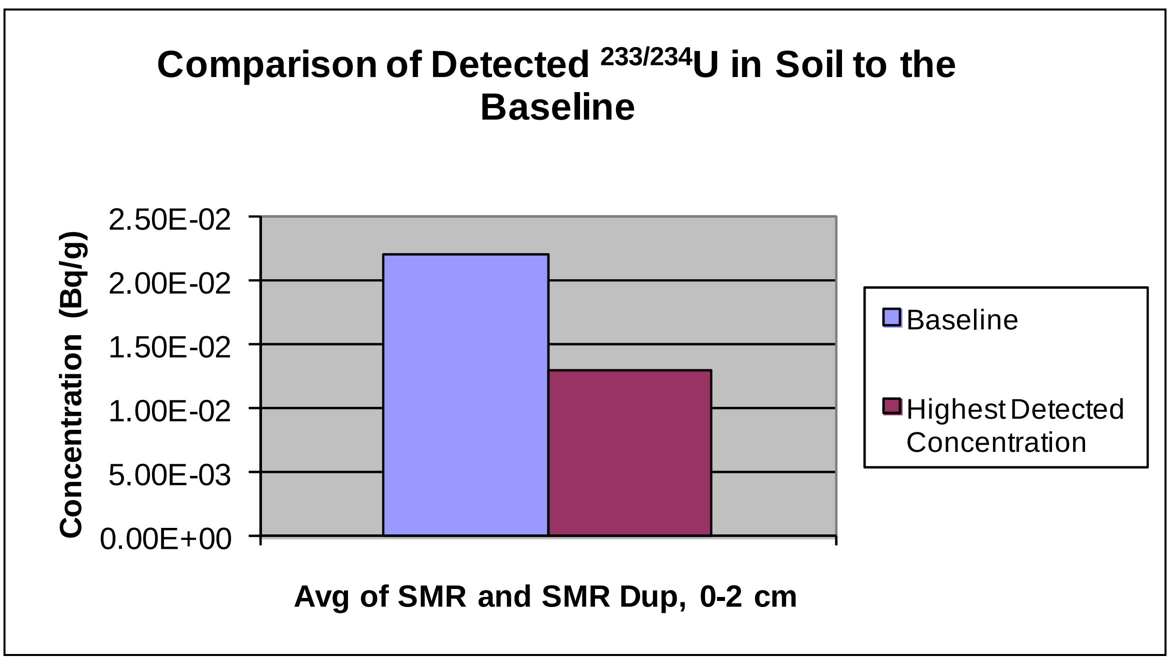

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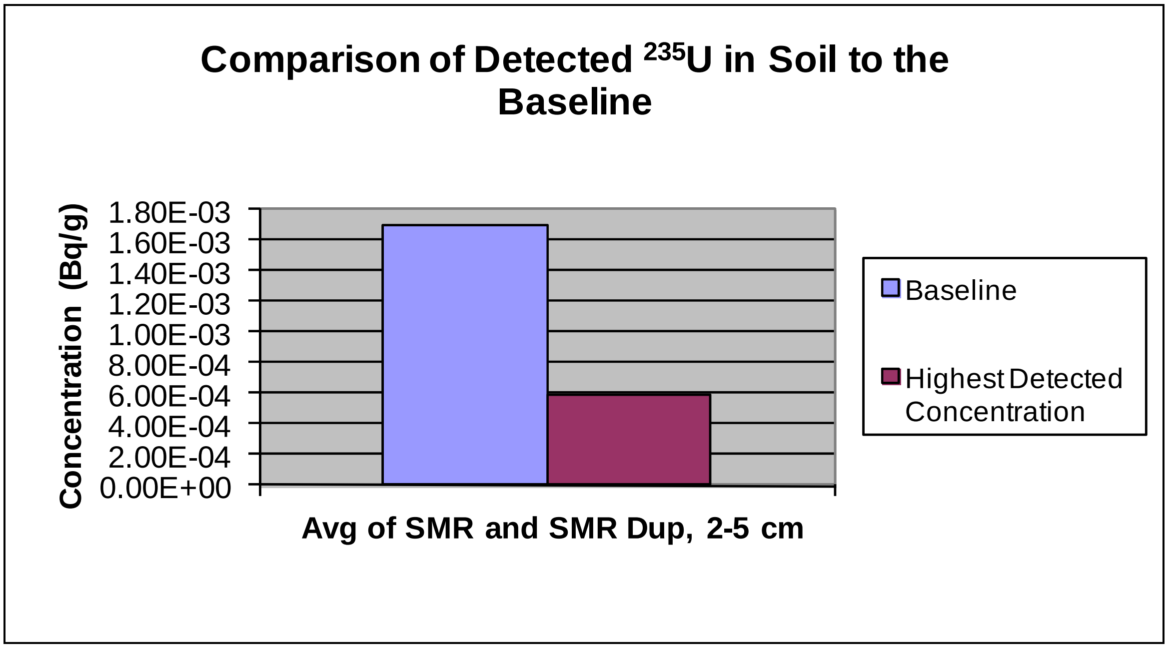


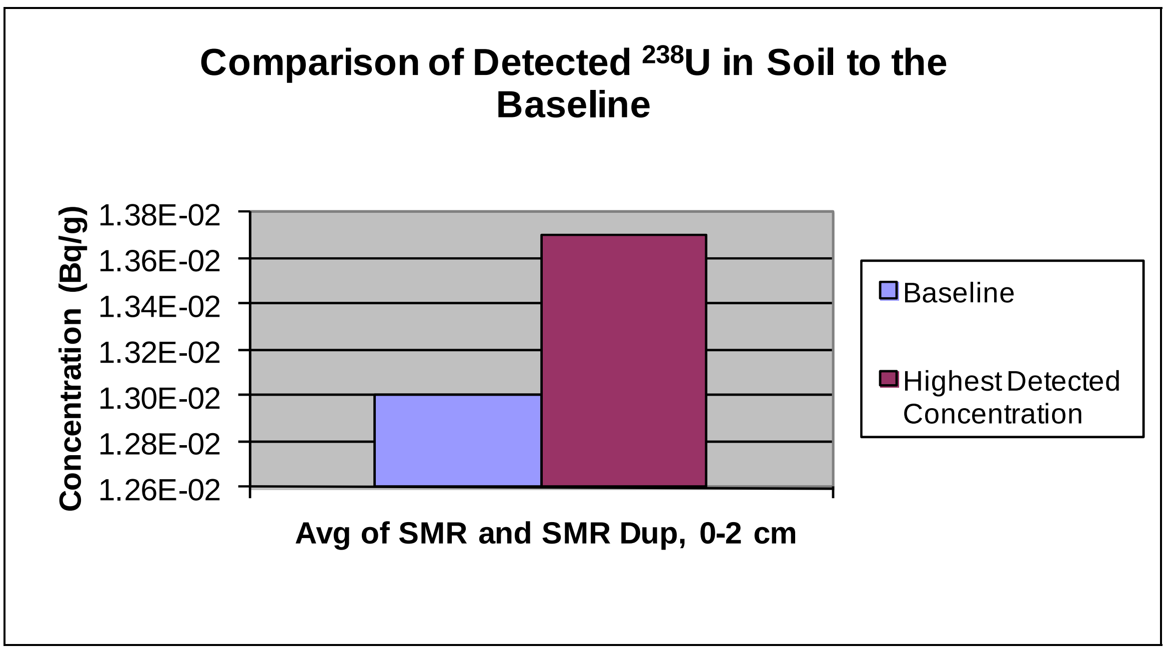

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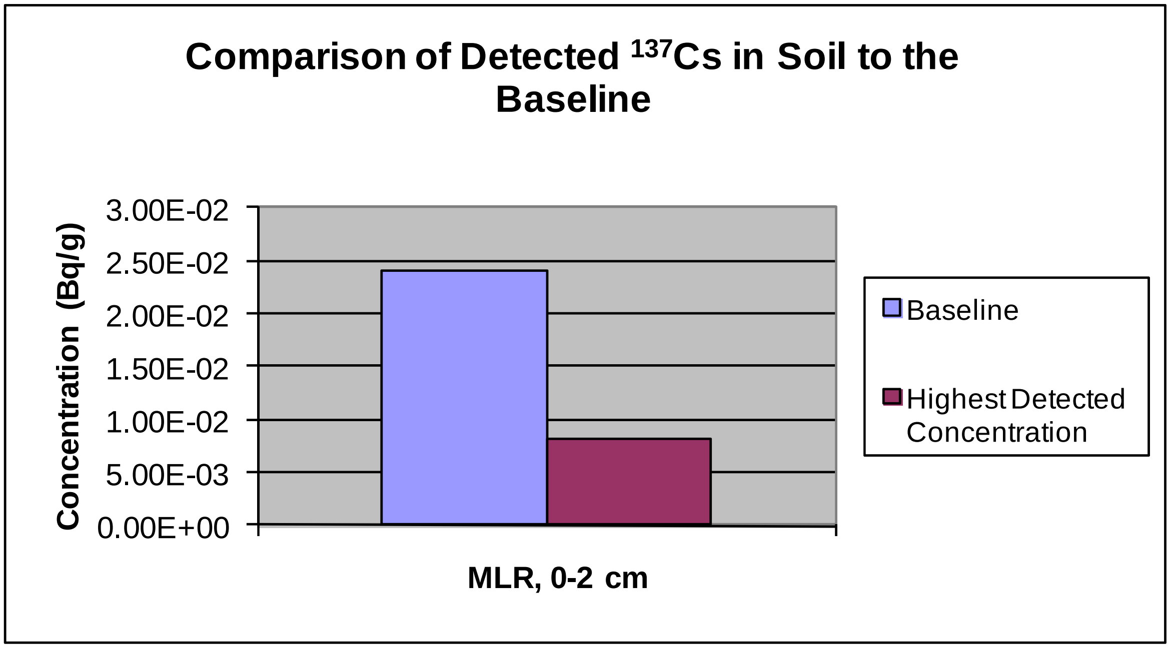


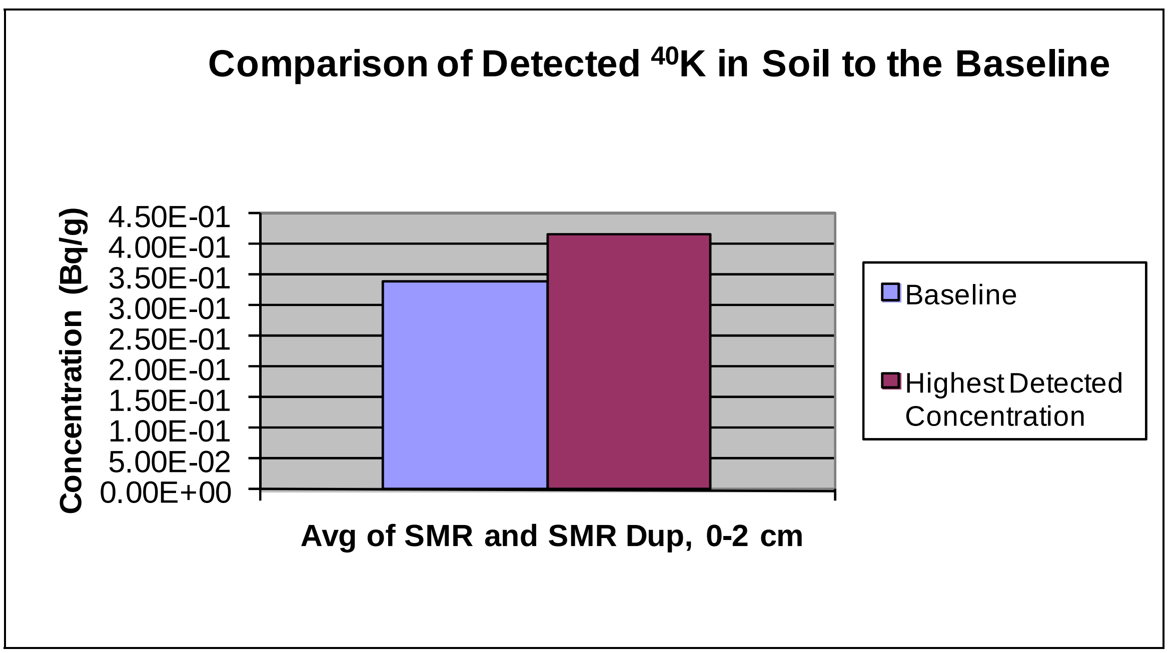

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